CYCLOTRONS'2010

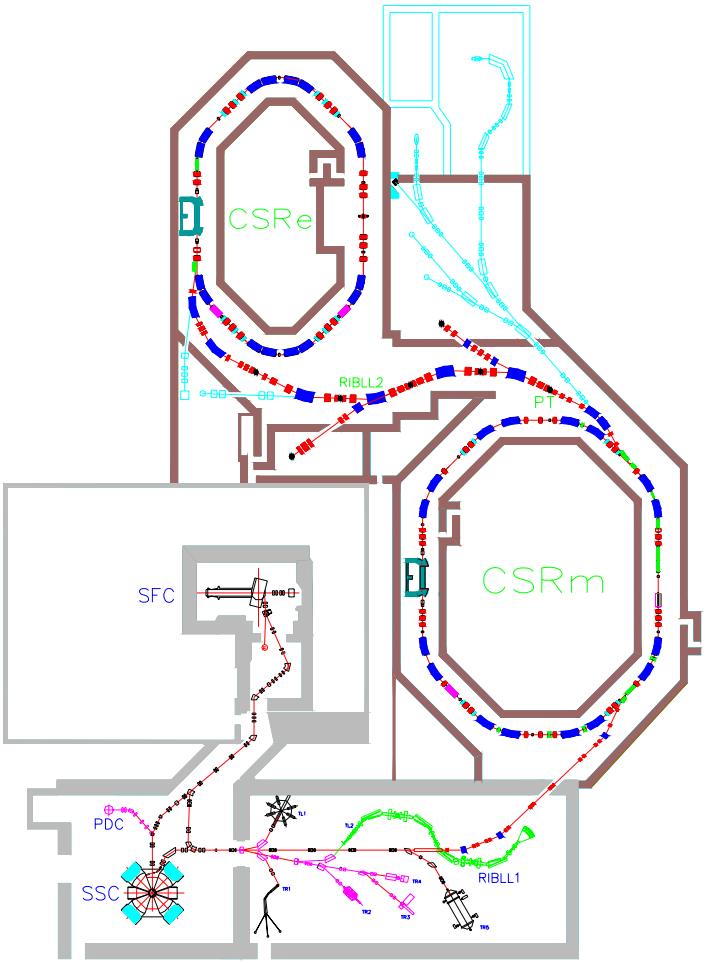
The 19-th International Conference on Cyclotrons and Their Applications

Lanzhou, China
6 to 10, September, 2010

Institute of Modern Physics
Chinese Academy of Sciences

http://cyclotrons10.impcas.ac.cn

Overview of IMP



Layout of HIRFL

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Organized by

Chinese Academy of Sciences,
Institute of Modern Physics, CAS

Sponsored by

Advanced Applied Physics Solutions

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G. Dutto, TRIUMF
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F.Marti, NSCL/MSU
M.Seidel, PSI
T.J. Zhang, CIAE

Local Organizing Committee

X.H. Cai H.L Chen H.F. Hao Y. He Z.G. Hu
Q. Liang (Secretary) Y. Liu M.T. Song
L.J. Mao (Scientific secretary) B. Wang J.W. Xia M. Xie
Z. Xu H.W. Zhao X.D. Yang Y.J. Yuan (Chairman)

Organization Office and Contact Information

The CYCLOTRONS'2010 conference desk is located at the lobby of building No.2 in Ning-Wo-Zhuang hotel. The conference desk is opened from 14:00 on September 5th and keeps opened during the conference on each day 8:00-17:00.

Mr. Q. Liang
Institute of Modern Physics (IMP), Chinese Academy of Sciences
509 Nanchang Road,
Lanzhou, 730000
P.R. China
Tel: 86-931-4969221
Fax: 86-931-8272100
Email: cyclotrons@impcas.ac.cn
Conference Website: http://cyclotrons10.impcas.ac.cn

In any case, you may reach the following members in local organizing committee through their cell phone:

Hongwei Zhao (co-chair) 13893616458
Youjin Yuan (chair of local committee) 18919189125
Qiang Liang (Conference secretary) 18919189103
Lijun Mao (Scientific secretary) 13359466279

Index

Welcome to CYCLOTRONS'2010

It is our great pleasure to host the 19-th International Conference on Cyclotrons and their Applications (CYCLOTRONS'2010) in Lanzhou. We would like to express our hearty welcome to all the participants and also thanks for your coming to the conference.

Let us enjoy the conference by all the presentations and all those fruitful discussions. We wish you enjoy your visit and have a pleasant stay in Lanzhou. Let us wish the conference success!

Chair of CYCLOTRONS'2010: **Wenlong Zhan**
Co-Chair of CYCLOTRONS'2010: **Hongwei Zhao**

CYCLOTRONS'2010

The 19-th International Conference on
Cyclotrons and their applications, Lanzhou, China
6 to 10, September, 2010

INTRODUCTION

The 19-th international conference on cyclotrons and their applications (CYCLOTRONS'2010) will be held **at the conference hall in building No.2 at Ning-Wo-Zhuang hotel** in Lanzhou. The conference will start with a **get-together reception at 19:30 in the evening of Sunday September 5th at the second floor of building No.2 in Ning-Wo-Zhuang hotel**, and will continue with oral-presentation sessions, poster sessions, a conference banquet, a half day excursion and a technical tour to IMP facilities until the afternoon of Friday September 10th, 2010.

The conference will be the same as the previous ones. The scientific program will include the following topics:

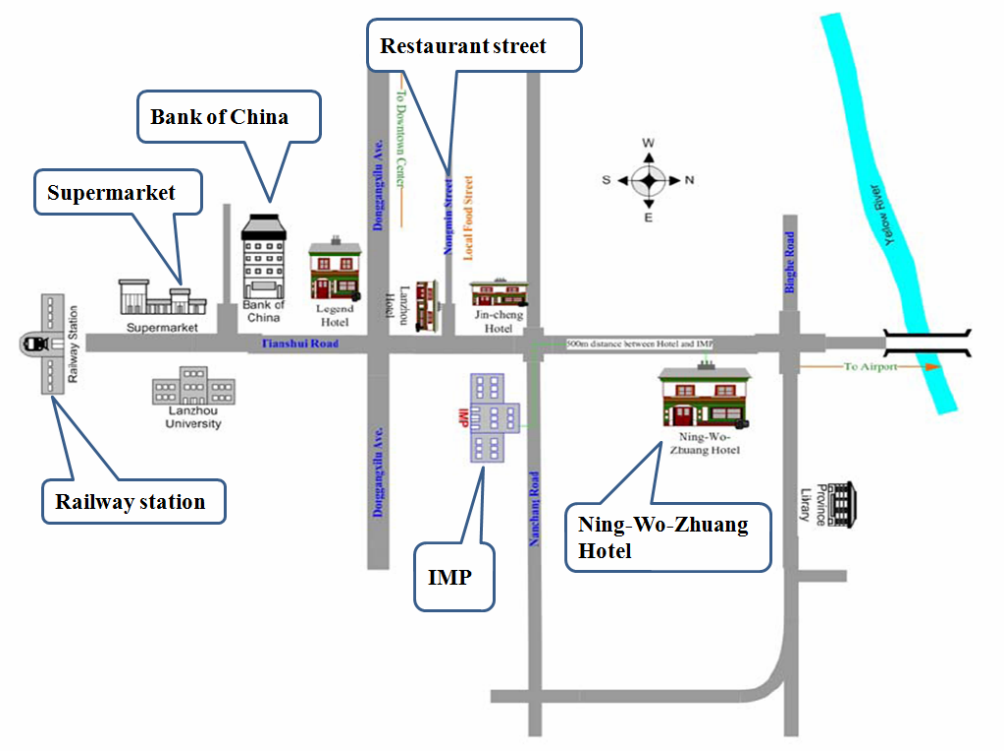
- Cyclotron applications
- Newly operating cyclotrons
- Operational cyclotrons: developments and status
- Facilities under construction
- Projects and proposals
- FFAG accelerators
- High beam intensity operation
- Radioactive beams
- Beam dynamics
- Ion sources, strippers and targets
- Radio frequency systems
- Magnet and vacuum
- Beam transport, diagnostics and control system

CONFERENCE VENUE

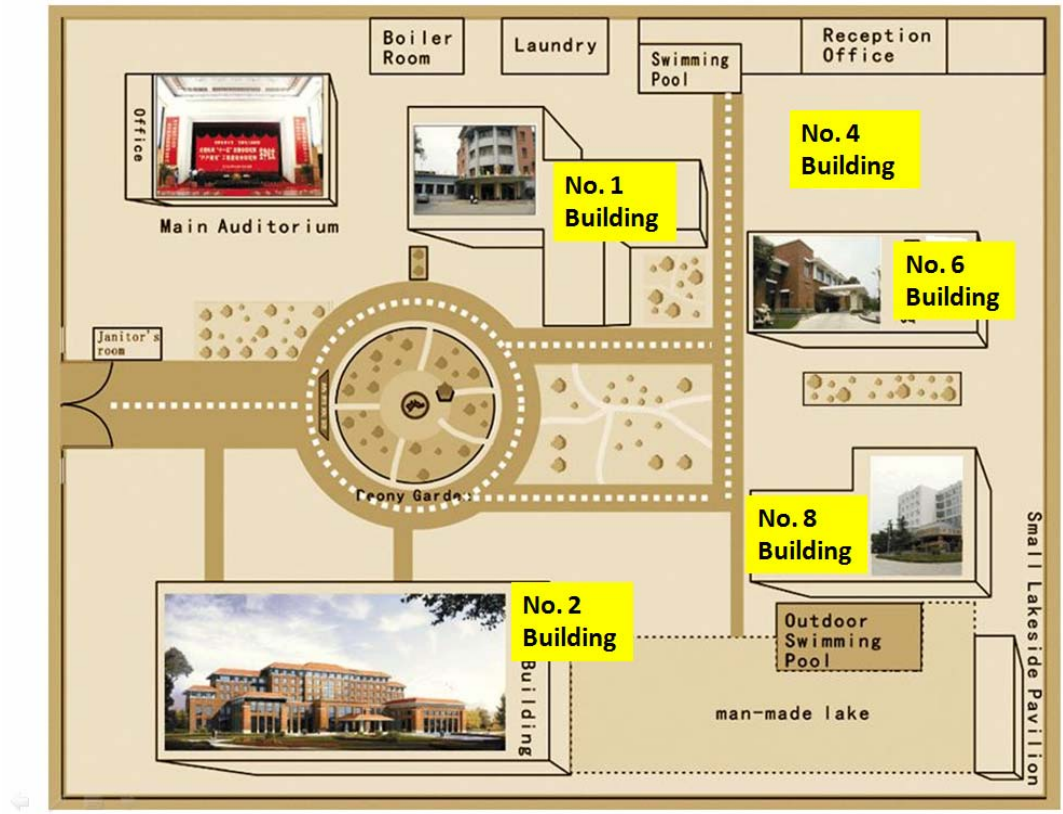
The CYCLOTRONS'2010 will be held at the conference hall in building No.2 in Ning-Wo-Zhuang hotel in Lanzhou with advanced equipments, elegant decorations and satisfying environment. Ning-Wo-Zhuang hotel is located in the centre of Lanzhou city, nearby the IMP Campus. In the plot below, you can find the geometrical location of the Ning-Wo-Zhuang Hotel and the hotel map. Details of the venue are available on the following web site:

http://www.gsnwzhotels.com/English/index.asp
Ning-Wo-Zhuang Hotel
No.20 Tianshui Zhong Lu Rd,
Lanzhou 730000, P.R.China

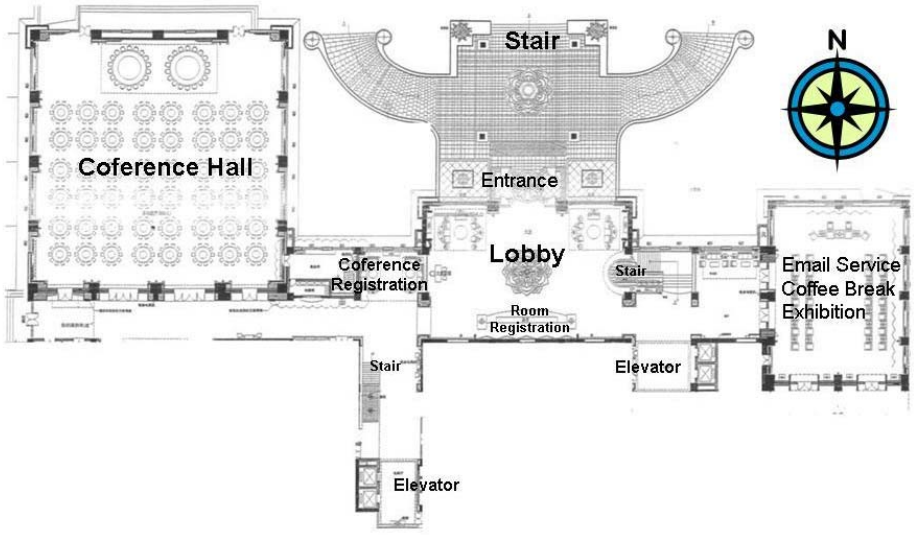
Location of Ning-Wo-Zhuang Hotel



Ning-Wo-Zhuang Hotel Map



Conference Hall Layout at No.2 Building



TRAVEL AND ARRIVAL

It is 70 km away from Lanzhou Zhongchuan Airport to Ning-Wo-Zhuang Hotel. We will pick up all attendees at the airport and drive you to the hotel. Additionally, there is also airport shuttle bus that drives you to the downtown of Lanzhou (the last stop is near to Lanzhou University, which is only about 700 meters away from Ning-Wo-Zhuang Hotel). If you come to Lanzhou by train, please go to Ning-Wo-Zhuang Hotel by TAXI or the bus No. 16 (the Train Station is about 2km away from hotel).

Lanzhou, the capital of Gansu province, is a major stop on the ancient "Silk Road", located at the upper reaches of the Yellow River. It's an amazing city with a long history, offers many historic spots and interest places. Today, Lanzhou is an important heavy industrial base in the western China. In Lanzhou, everyone will be interesting in her unique charm. You can find the interesting information on the web site:

http://www.chinats.com/lanzhou/index.htm

INTERNET ACCESS

Wireless internet is available free of charge in the conference hall (SSID: Cyclotrons10). The Internet service with 5 computers is also available at the poster-session hall which is located nearby the conference hall. Password for connections is not necessary at all of the access points.

REGISTRATION DESK

Registration fees are due for all participants except invited speakers. The late registrants should pay at the conference registration desk by cash or credit card (such as Visa, MasterCard). Cheques can not be accepted.

The registration desk for registration fee payment will be opened as follows:

Sunday, 05 September, 14:00-20:00

Monday to Tuesday, 06-07 September 8:30-18:00

The reduced conference fee is EUR €550.00 (five hundred fifty EUROS) for payments which are received on or before August 6th 2010. After that date the registration fee will increase to EUR € 600.00 (or USD 760$). A special reduced registration fee EUR €300.00 (or USD 380$) is offered to students and retiree. The registration fee for each accompanying person is EUR €200.00(or USD 250$). The conference registration fee includes:

- Materials of conference including the abstract book and the proceedings
- Coffee breaks and lunch buffet
- Conference excursion and technical tour
- Reception and banquet
- Transportation between Lanzhou airport and the hotel

EXCURSION

The conference excursion will be arranged on the afternoon of Wednesday, September 8th. We will visit two sight spots in Lanzhou during 4 hours excursion: one is Gansu Provincial Museum and the other one is the Waterwheel Exhibition Park. The conference banquet will be held after the excursion at 19:00 in the evening. Gansu Provincial Museum，the largest comprehensive museum in Gansu province, was built in 1956 and there are collections of more than 100,000 cultural relics including painted pottery, bamboo ships in Han Dynasty (206 BC-220BC), silk and hemp products, gold and silver sarira reliquaries and Buddhism art treasures. Among them the top treasures include bronze galloping horse which is the symbol of China tourism. All these cultural relics provide important historic evidence for the study of cultural and trade exchanges between China and the west in ancient times. The Waterwheel Exhibition Park is located at the bank of the Yellow River, the second largest river in China. The park is a popular sightseeing site in Lanzhou which was originated in the Ming Dynasty (1368-1644). The waterwheel is the earliest tool of pumping water for irrigation along the Yellow River in Lanzhou. Before 1952, across the Yellow River in Lanzhou City there once stood more than 200 waterwheels, which earned Lanzhou the title “The capital of waterwheels”. Now waterwheels have been replaced by machinery, and a small number of waterwheels were left or rebuild as a witness to the history.

TECHNICAL TOUR

A technical tour at Institute of Modern Physics (IMP) will be arranged on the afternoon of Thursday, September 9th. This technical tour will focus on HIRFL(Heavy Ion Research Facility in Lanzhou) facility including the ion sources, two cyclotrons (SFC and SSC), the radioactive ion beam line (RIBLL1), the two cooling storage rings (CSRm and CSRe), the experimental setups at HIRFL including the ion therapy terminal as well as 320kV ECRIS high voltage atomic physics research terminals.

WEATHER

Lanzhou stretches along the Yellow River as it snakes its way through the valley. The city is located on the loess plateau with an average elevation of 1520 meters. The weather is comparatively nice. The weather at the beginning of September should be still pleasantly warm, typical temperature could be 17-27 ℃, but you should be prepared for cold and rainy days.

MEALS

The price of the hotel includes breakfast. The lunch buffet is offered from Monday to Friday by the

conference at the second floor in building No.2 in Ning-Wo-Zhuang hotel. The conference banquet will be scheduled at 19:00 on Wednesday at a restaurant near Yellow River which is included in the registration fee. Dinners on Monday and Thursday are provided which are supported by the sponsors and IMP. You may have your supper on Tuesday and Friday in the hotel restaurant or some restaurants nearby the hotel. You can find a lot of restaurants in Nong-Ming-Xiang Street, which is located at the south of Ning-Wo-Zhuang Hotel.

CURRENCY

The official currency in China is Ren-Min-Bi (RMB). Typically, 1 Euro=8.7 Yuan RMB, 1$ USD = 6.8 Yuan RMB. Visit http://www.x-rates.com/ for updated currency rate. You may exchange RMB in the banks nearby.

SCIENTIFIC PROGRAM

The scientific program has been organized with 14 oral sessions and one poster sessions.

14 oral sessions:

1. Cyclotron Status and high intensity beam *I*
2. Cyclotron Status and high intensity beam *II*
3. Cyclotron Status, upgrade and development
4. Cyclotron Status and high intensity beam *III*
5. Newly operating cyclotrons and new cyclotrons under commissioning
6. New projects and new ideas
7. Cyclotrons under construction
8. Ion sources
9. RF system and beam diagnostics
10. Radioactive beam facility
11. Beam dynamic and beam stripper
12. FFAG accelerator
13. Cyclotron application I
14. Cyclotron application II

Oral Presentations

The program includes two kinds of oral presentations, the 30 minutes invited talk (including 5 minutes discussion) and the 20 minutes contributed talk (also including 5 minutes discussion). The International Organizing Committee has recommended and selected the invited speakers. The Scientific Program Committee has selected the contributed-oral presentations from the abstracts submitted. The following presentation devices will be available at the oral presentation sessions during the conference: LCD screen projector displaying your presentations, a laptop computer for uploading your presentation from CD or memory stick and a laser pointer. The laptop computer operating under Windows Vista (English version) will be available for the electronic presentations. The following softwares will be installed in the computer:

PowerPoint 2007/2003, Word 2007/2003, Acrobat Reader 9.0

We encourage the speakers to upload your presentations via CYCLOTRONS10 Author Accounts. You can also upload your presentations into the conference laptops during the conference, but all the

speakers are requested to upload your presentations at the very latest one session before your scheduled presentation time. Session chairmen please coordinate with the speakers and the assigned working staff of IMP who will help you with your presentation. Please contact them just before the session with your talk starts. Slides of all presentations will be published on web version of the conference proceedings without any further notification.

If you are selected as the speakers at the Monday morning session, please upload your presentation before Sunday, September 5th (preferred) or, at the latest, upload your presentation into the conference laptop computer during the get-together welcome reception on Sept. 5th evening.

Posters

Poster boards with a size of 2m height and 1m width will be provided. All the posters should be mounted before the poster session scheduled in Monday afternoon and Tuesday afternoon. The authors presenting the posters are invited to stand nearby their poster boards for discussions during the poster session in Monday and Tuesday afternoon. **All posters are requested to be kept on the poster boards until Friday morning**. Mounting material will be provided.

Manuscript Preparation and Submission

The style of the manuscript is the one generally used at JACoW accelerator conference. Authors are advised to use the Templates which are available at the conference web site, more complete guidelines are provided in the text of the templates, available at the JACoW Site. The page limit is 6 pages for invited talks and 3 pages for the others. Authors should bring a printed copy of the paper to the conference.

Paper submission has started. The papers will be published with JACOW and also will be published in CYCLOTRONS 2010 proceedings. The papers must be submitted before the conference, **the deadline is Sept. 4th, 2010**. Only papers which are presented at the conference can be published. The papers will be edited during the conference and the proceedings should be available in a few weeks after the conference.

All contributions properly presented at the conference are eligible for publication in the conference proceedings at the JACoW site. Upload of contributions is via CYCLOTRONS10 Author Accounts. Please name the file of your paper with your paper code which is available at the conference website.

The deadline for submission of the contributions to the proceeding office is 4 September 2010. The submission deadline is ahead of the conference so that the papers can be processed by the JACoW technical editors in Lanzhou. In this way any problems can be analyzed and discussed with authors upon their arrival at the conference, prior to moving on to a quality check of all successfully processed papers. The aim is to publish all contributions on the last day of the conference via the SPMS, with final publication at the JACoW site.

The successful processing of all contributions during the conference relies heavily on the collaboration of all authors. Since the JACoW editorial team is only available during the conference, any delay in receiving contributions will cause a delay in processing them, and will ultimately jeopardize swift publication on JACoW.

PROCEEDINGS

The conference proceedings will be prepared electronically and published at the JACoW site. A separate electronic version will also be available for download at conference homepage. T**he**

proceedings office is located in a meeting room at the third floor in Building No.2 in Ning-Wo-Zhuang Hotel (the confeece hall and the poster-seesion hall are located at the first floor).

INDUSTRIAL EXHIBITION

During the conference, the industrial exhibition will be held at the same hall as the poster-session from Monday September 6th to Friday September 10th. The list of exhibition is the following:

1. Advanced Applied Physics Solutions
   Dr.Cynthia Reis (office@aapsinc.com)
2. Beijing Changfeng Broadcasting and Communications Equipment Corporation Limited
   Mr.Wang Bin (davidwb@vip.sohu.net)
3. Kyocera Corporation
   Dr.Hiroyuki Shoda (Hiroyuki.shouda.hs@kyocera.jp)
4. Lanzhou Kejin Taiji Coporation, LTD.
   Dr.Yuan Ping (yuanp@impcas.ac.cn)
5. Shenyang Huiyu Vacuum Tech.Co, LTD
   Mr.Dong Liang (syhuiyu@vip.163.com)
6. Siemens Healthcare
   Dr.Rick Ryba (Rick.ryba@siemens.com)
7. Sigmaphi
   Dr.William Beeckmann (wbeeckman@sigmaphi.fr)
8. Sumitomo Heavy Industries Ltd
   Dr.Yuji Matsubara (Yji_matsubara@shi.co.jp)
9. Thamway Co. Ltd
   Mr.Junichi Ohashi (ohashi@thamway.co.jp)
10. ZAG Zyklotron AG
    Dr.H.Schweickert (Hermann.Schweickert@zyklotron-ag.de)

IOC MEETING

17:30-18:30, Tuesday, 7 September 2010, in a meeting room at the fourth floor in Building No.2 in Ning-Wo-Zhuang Hotel.

All members of IOC (International Organizing Committee) are invited to attend the IOC meeting to discuss all the issues related to the cyclotron conference.

SATELLITE MEETING: PRE-MEETING OF JAAWS2010

14:00 – 16:00, Friday, 10 September 2010, in a meeting room at the fourth floor in Building No.2 in Ning-Wo-Zhuang Hotel.

Organized by Professor Ken Takayama, with topics on (1) Example of possible applications such as BNCT, RI medicine, Cancer therapy, heavy ion mutation of plants; (2) Example of collaborations between academic institute and industry; (3) Expected urgent domestic collaboration, which is specific in Asia; (4) Promotion by government; (5) Individuals who are expected to attend the 2nd JAAWS.

Scientific Program

September 6th, Monday

Opening session: MOM1. Chairman: H. W. Zhao, IMP			
Time	Code	Speaker	Title
8:30		Hongwei Zhao, IMP	Welcome address on behalf of organizing committee and IMP
8:40		Zhanting Yuan	Welcome address from mayor of Lanzhou city
8:55	MOM1CIO01	Isao Tanihata, RCNP & Beihang Univ	How nuclear physics has changed in these 20 years --a role and hope for cyclotrons
9:35	MOM1CIO02	Michael Craddock, UBC&TRIUMF	Eighty years of cyclotrons
10:15 10:55	Photo and Coffee Break		
Session: MOM2. Cyclotron Status and high intensity beam I Chairman: Andrew Sessler, LBNL			
10:55	MOM2CIO01	Akira Goto, RIKEN	Review of high power cyclotrons for heavy ion beams
11:25	MOM2CIO02	Frederic Chautard, GANIL	Intense beam operation at GANIL
11:55	MOM2CCO03	Sytze Brandenburg , KVI	Progress towards high intensity heavy ion beams at the agor-facility
12:15	MOM2CCO04	Donald May, Texas A&M University	Recent progress on the facility upgrade for accelerated radioactive beams at Texas A&M
12:35 14:00	Lunch break		
Session: MOA1. Cyclotron Status and high intensity beam II Chairman: M. Seidel, PSI			
14:00	MOA1CIO01	Jeff Stetson, MSU	Intense beam operation of MSU cyclotrons
14:30	MOA1CIO02	Georgy Gulbekian, JINR	High intensity cyclotrons for superheavy element research of FLNR JINR
15:00	MOA1CIO03	Hongwei Zhao, IMP	IMP cyclotron status and development
15:30 15:55	Coffee break		
Session: MOA2. Cyclotron Status, upgrade and development Chairman: L. Calabretta, LNS-INFN			
15:55	MOA2CIO01	Youjin Yuan, IMP	HIRFL-CSR facility status and development
16:25	MOA2CCO02	Jacobus Conradie, iThemba LABS	Current Status Of The Cyclotron Facilities And Future Projects At iThemba Labs
16:45	MOA2CCO03	Ken Yoshiki Franzen, LBNL	Status Of The LBNL 88-Inch Cyclotron High-Voltage Injection Upgrade Project
17:05 18:30	Poster session and coffee		
19:00	Dinner supported by sponsors and IMP		

September 7th, Tuesday

Session: TUM1. Cyclotron Status and high intensity beam *III* Chairman: A. Goto, RIKEN			
Time	Code	Speaker	Title
8:30	TUMCIO01	Mike Seidel, PSI	Towards the 2 MW proton cyclotron and latest development
9:00	TUMCIO02	Yuri Bylinski, TRIUMF	Latest performance of the 500 MeV H- cyclotron and recent progress towards three simultaneous RIB ion beams at TRIUMF.
9:30	TUMCCO03	Gerardo Dutto, TRIUMF	Reliable Production Of Multiple High Intensity Beams With The 500 Mev TRIUMF Cyclotron
9:50	TUMCCO04	Heinrich Röcken, VMS-PT	The VARIAN 250 MeV Superconducting Compact Proton Cyclotron: Medical Operation of the 2nd Machine, Production and Commissioning Status of Machines No. 3 to 7
10:10 10:35	Coffee Break		
Session: TUM2. Newly operating cyclotrons and new cyclotrons under commissioning Chairman: T. Zhang, CIAE			

10:35	TUM2CIO01	Osamu Kamigaito, RIKEN	Status of RIBF accelerators at RIKEN
11:05	TUM2CCO02	Chaturanan Mallik, VECC	First Beam Acceleration In Kolkata Superconducting Cyclotron And Its Present Status
11:25	TUM2CCO03	Pauli Heikkinen, JYFL	Commissioning Of The JYFL MCC30/15 Cyclotron
11:45	TUM2CCO04	Luis Medeiros-Romao, IBA	Cyclone 70 Arronax Cyclotron - Commissioning Progress Report
12:05 14:00	Lunch break		
Session: TUA1. New projects and new ideas Chairman: M. Craddock, TRIUMF			
14:00	TUA1CIO01	Luciano Calabretta, LNS-INFN	A multi Mega Watt cyclotron complex to search for CP violation in neutrino sector
14:30	TUA1CIO02	Tim Antaya, MIT	Energetic Cyclotrons as devices- Pushing beyond 6 Tesla
15:00	TUA1CCO03	Jose Alonso, LBNL and MIT	High Power, High Energy Cyclotrons For Muon Antineutrino Production: The Daedalus Project
15:20	TUA1CCO04	Hyun Wook Kim, SKKU	Developement of 70 MeV Separate Sector Cyclotron for KoRIA project
15:40 16:05	Coffee break		
Session: TUA2. Cyclotrons under construction Chairman: P. Bertrand, GANIL			
16:05	TUA2CIO01	Tianjue Zhang, CIAE	CIAE cyclotron progress
16:35	TUA2CCO02	Ken Takayama, KEK	Induction Sector Cyclotron For Cluster Ions
16:55	TUA2CCO03	Bing Wang, IMP	Design and Construction progress of a 7MeV/u cyclotron
17:15 18:30	Poster session and coffee		

September 8th, Wednesday

Session: WEM1. Ion sources Chairman: Y. Jongen, IBA			
Time	Code	Speaker	Title
8:30	WEM1CIO01	Claude Lyneis, LBNL	4th generation ECRIS and application in cyclotron
9:00	WEM1CIO02	Takahide Nakagawa, RIKEN	28 GHz SC-ECRIS at RIBF
9:30	WEM1CIO03	Luigi Celona, LNS-INFN	Novel Tools to increase highly charged ion's current in ECR sources
10:00	WEM1CIO04	Guillaume Machicoane, MSU	Transverse collimation with the Superconducting ECR ion source SuSI at the Coupled Cyclotron Facility
10:30 10:55	Coffee Break		
Session: WEM2. RF system and beam diagnostics Chairman: F. Marti, NSCL			
10:55	WEM2CIO01	Lukas Stingelin, PSI	High Power RF Systems and Resonators for Sector Cyclotrons
11:25	WEM2CCO02	Naruhiko Sakamoto, RIKEN	Operating Experience With The RF System For Superconducting Ring Cyclotron Of RIBF
11:45	WEM2CCO03	Martin Humbel, PSI	Disturbance effects caused by rf power leaking out from cavities in the psi ring cyclotron
12:05	WEM2CIO04	Rudolf Doelling, PSI	Beam Diagnostics for Cyclotrons
12:35	WEM2CCO05	Tamaki Watanabe, RIKEN	Beam Diagnostics For RIBF In RIKEN
12:55 14:15	Lunch break		
14:15-18:00	Excursion : Gansu Provincial Museum and Waterwheel Exhibition Park		
19:00	Conference Banquet		

September 9th, Thursday

Session: THM1. Radioactive beam facility Chairman: O.Kamigaito, RIKEN			
Time	Code	Speaker	Title
8:30	THM1CIO01	Patrick Bertrand,	Post-acceleration of high intensity RIB through the

		A. Savalle, GANIL	CIME cyclotron in the frame of the SPIRAL2 project at GANIL
9:00	THM1CIO02	Bob Laxdal, TRIUMF	The achievement of the ISAC goal of 6.5 MeV/u with a superconducting Linac
9:30	THM1CIO03	Xiaoyu Wu, MSU	The Accelerator System for ReA3 – the New Re-accelerated Rare Isotope Beam Facility at MSU
10:00	THM1CIO04	Yinong Rao, TRIUMF	Progress towards new RI and higher RIB intensities at TRIUMF.
10:30 10:55	Coffee Break		
Session: THM2. Beam dynamic and beam stripper Chairman: L.Onischenko, JINR			
10:55	THM2CIO01	Andreas Adelmann ,PSI	Precise Simulations of High Power Cyclotrons: how does it work?
11:25	THM2CCO02		
11:45	THM2CCO03	Felix Marti, NSCL	Stripper foil developments at NSCL/MSU
12:05 14:00	Lunch break		
Session: THA1. FFAG accelerator Chairman: D.May, Texas A&M Univ.			
14:00	THA1CIO01	Yoshiharu Mori, Kyoto University	FFAG developments in Japan
14:30	THA1CIO02	Susan Smith, STFC Daresbury Lab	EMMA commissioning and first results
15:00	THA1CIO03	Carol Johnstone, Fermilab	Non-scaling FFAG designs for ion therapy
15:30	THA1CCO04	Michael Craddock, TRIUMF	Cyclotron And FFAG Studies Using Cyclotron Codes
15:50 17:30	IMP facility Visit		
19:00	Dinner supported by IMP		

September 10th, Friday

Session: FRM1. Cyclotron application I Chairman: G.Dutto, TRIUMF			
Time	Code	Speaker	Title
8:30	FRM1CIO01	Yves Jongen, IBA	Review on cyclotrons for cancer therapy
9:00	FRM1CIO02	Andrew Sessler, LBNL	Introduction to Ion Beam Cancer Therapy
9:30	FRM1CIO03	Nikolay Morozov, JINR	IBA-JINR 400 MeV/u superconducting cyclotron for hadron therapy
10:00	FRM1CIO04	Marco Schippers, PSI	Fast scanning techniques for cancer therapy with hadrons - a domain of cyclotrons
10:30	FRM1CCO05	Andrea Denker, HZB	Advocacy For A Dedicated 70 Mev Proton Therapy Facility
10:50 11:15	Coffee Break		
Session: FRM2. Cyclotron application II Chairman: C.Lyneis, LBNL			
11:15	FRM2CIO01	Paul Schmor, TRIUMF	Review of Isotope-producing cyclotrons for medical applications
11:45	FRM2CIO02	Mingwu Fan, HUST	Virtual Prototyping for Design of Compact Medical Cyclotron
12:15	FRM2CCO03	Yuan Ping, IMP	Magnets technologies and development at IMP
12:35	FRM2CCO04	Hiroshi Tsutsui, SHI	BNCT System Using 30 MeV H-Cyclotron
Closing session Chairman: P. Schmor, TRIUMF			
12:55 13:20	FRCC	Sytze Brandenburg, KVI	Conference summary
13:20	Lunch		

Abstracts

MOM1CIO01 How Nuclear Physics Has Changed In These 20 Years --A Role and Hope for Cyclotrons

Invited Oral

01 Cyclotron applications

Isao Tanihata (RCNP & Beihang Univ.)

RCNP

To be finished.

MOM1CIO02 Eighty Years of Cyclotrons

Invited Oral

03 Operational cyclotrons: developments and status

Michael Craddock (UBC & TRIUMF, Vancouver, British Columbia)

UBC & TRIUMF

Lawrence's invention of the cyclotron in 1930 not only revolutionized nuclear physics, but proved the starting point for a whole variety of recirculating accelerators, from microtrons to FFAGs to synchrotrons, that have had an enormous impact in almost every branch of science and several areas of medicine and industry. Cyclotrons (i.e. fixed-field accelerators) themselves have proved remarkably adaptable, incorporating a variety of new ideas and technologies over the years: frequency modulation, edge focusing, AG focusing, axial and azimuthal injection, ring geometries, stripping extraction, superconducting magnets and rf... Long may they flourish!

MOM2CIO01 Review of High Power Cyclotrons for Heavy Ion Beams

Invited Oral

03 Operational cyclotrons: developments and status

Akira Goto (RIKEN Nishina Center, Wako)

RIKEN Nishina Center

Since heavy ion cyclotrons for use in radioactive beam sciences were built in laboratories worldwide in 1980's, a lot of efforts on the upgrade of many such cyclotrons have been made in terms of beam intensity as well as beam energy. This talk describes an overview of such cyclotrons that provide heavy ion beams with the power in kW range or higher. Some technological issues related to high-power heavy ion beams are also discussed based on the experiences of those cyclotrons.

MOM2CIO02 Intense Beam Operation at GANIL

Invited Oral

03 Operational cyclotrons: developments and status

Frédéric Chautard (GANIL, Caen)

GANIL

The GANIL (Grand Accélérateur National d'Ions Lourds) produces and accelerates stable ions beams since 1982. The first radioactive beam post-accelerated with the CIME cyclotron happened in 2001. In 2013, stable beams with higher intensities and new energy range will be available from the new superconducting linear accelerator SPIRAL2. In 2015, new exotic beams will be accelerated with the existing cyclotron CIME. This paper will show how GANIL manages the SPIRAL2 machine arrival by continuing the delivery of high intensity and exotic beams. But also by pursuing the developments of the machine capabilities in a project structure in order to keep equipments running with a high reliability yield and still responding to physics demands. The progress in ion source production will be exposed. Finally, it will be presented the foreseen calendar of the exploitation for the existing machine together with SPIRAL2.

MOM2CCO03 Progress Towards High Intensity Heavy Ion Beams at the AGOR-Facility

Contributed Oral

03 Operational cyclotrons: developments and status

Sytze Brandenburg, Johannes P.M. Beijers, Michel Hevinga, Mariet Anna Hofstee, Herman R. Kremers, Vladimir Mironov, Jan Mulder, Suresh Saminathan, Ayanangsha Sen (KVI, Groningen)

KVI

The on-going upgrade program of the AGOR-facility aiming at intensities beyond 10^{12} pps for heavy ion beams up to Pb will be discussed. The progress in the main elements of the program (further development of the ECR-source; improvement of the transmission into and through the cyclotron and protection of equipment agains excessive beam loss) will be reported. Further improvement of the ECR ion source is facilitated by the installation of a second source. Redesign of the LEBT to compensate aberrations is in progress; simulations predict a significant increase in transmission. A new, cooled electrostatic extractor is being commissioned and the beam loss control system has been completed. The main remaining issue is vacuum degradation induced by beam loss caused by charge exchange on the residual gas. Experiments at GSI* have shown that scrapers and surface coatings can strongly reduce this effect. Tracking calculations of the distribution of the beam losses over the vacuum chamber to determine the optimum location of scrapers and application of a gold coating to relevant parts of the vacuum chamber are underway.

* Ion catcher system for the stabilisation of the dynamic pressure in SIS18; C. Omet, H. Kollmus, H. Reich-Sprenger, P. Spiller;
http://cern.ch/AccelConf/e08/papers/mopc099.pdf

This work is supported by the European Union through EURONS, contract 506065 and the "Stichting voor Fundamenteel Onderzoek der Materie" (FOM).

MOM2CCO04 Recent Progress on the Facility Upgrade for Accelerated Radioactive Beams at Texas A&M

Contributed Oral

08 Radioactive beams

Donald Philip May, Robert Tribble (Texas A&M University Cyclotron Institute, College Station, Texas), Fred Abegglen, Greg Chubaryan, Gregory Derrig, George J. Kim, Gabriel Tabacaru (Texas A&M University, College Station)

Texas A&M University Cyclotron Institute

The Cyclotron Institute at Texas A&M University is involved in an upgrade, one goal of which is to provide radioactive ion beams accelerated to intermediate energies by the K500 superconducting cyclotron. The old 88-inch cyclotron, now the K150, has been refurbished to be used as a driver and also to provide higher intensity, low-energy, primary beams for experiments. Two external ion sources, an electron-cyclotron-resonance ion source (ECRIS) and a multi-cusp negative ion source, have been installed on a new axial line to inject beams into a modified K150 central region. Acceleration of negative ions of protons and deuterons with stripping for extraction will be used in order to mitigate activation of the K150. Beams from the K150 will be used to create radioactive species via a light-ion guide and a heavy-ion guide. Singly charged ions from either ion guide will be transported to an ECRIS that is configured to capture these ions and further ionize them. One charge-state from this second ECRIS will be selected for subsequent acceleration by the K500. Progress on the upgrade, including the acceleration and extraction of both negative and positive beams by the K150, is presented.

Supported by U. S. Dept. of Energy Grant DE-FG02-93ER40773

MOA1CIO01 Intense Beam Operation of the NSCL/MSU Cyclotrons

Invited Oral

07 High beam intensity operation

Jeffry W. Stetson, Guillaume Machicoane, Felix Marti, David Poe (NSCL, East Lansing, Michigan)

NSCL

Intense heavy ion beam acceleration by superconducting compact cyclotrons presents significant challenges since surfaces impacted by lost beam are subject to high thermal loads and consequent damage. High transmission efficiencies allow 0.7-1.0 kW beams to be routinely delivered for experiment at the NSCL, with minimal negative impact on reliability. Net beam transmission measured from just before the K500 to extracted beam from the K1200 can be about 30% depending on the ion used (factoring out the unavoidable loss due to the charge stripping foil in the K1200). Techniques and examples are discussed.

Supported under National Science Foundation under grant No. PHY06-06007

MOA1CIO02 High Intensity Cyclotrons for Super Heavy Elements Research of FLNR JINR
Invited Oral
07 High beam intensity operation
Georgy Gerasimovich Gulbekyan (JINR, Dubna, Moscow Region)
JINR

Main team of FLNR JINR is super heavy elements research. From 2000 up to 2010 there was synthesized elements 112, 113, 114, 115, 116, 117, 118 and more the 40 isotopes of super heavy elements in the Lab. As a target we used 243Am, 242Pu, 248Cm, 249Bk, 249Cf et al. Full flux 48Ca ion beam through the targets on the level $5 \cdot 10^{20}$ ion with 48Ca matter consumption 0.4 mg/hour, and average beam intensity 1pμA. According plan after U400 cyclotron modernization (2012) 48Ca beam intensity will be up to 3pμA on the target and 48Ca beam intensity from new cyclotron DC200 will be 10 pμA (2014).

MOA1CIO03 IMP Cyclotron Status and Developments
Invited Oral
05 Projects and proposals
Hongwei Zhao, Bin Wang, Mingtao Song, Youjin Yuan, Yiping Yang, Huanfeng Hao and HIRFL team (IMP, Lanzhou)
IMP
HIRFL (Heavy Ion Research Facility in Lanzhou) is a heavy ion accelerator complex which consists of two cyclotrons and two cooling storage rings. The two cyclotrons SFC (Sector Focus Cyclotron) and SSC (Seperated Sector Cyclotron) have been operated for more than 20 years. Great efforts have been made to improve the operation efficiency, the facility reliability and increasing beam intensity in the last couple of years. A series of upgrading programs have been accomplished which have resulted in a dramatic enhancement of the HIRFL performance. This paper will review the latest status and development of IMP cyclotrons including SFC, SSC and a compact cyclotron for 7MeV/u 12C5+ beam being built as an injector of an ion therapy synchrotron. Meanwhile, some latest developments of highly charged ECR ion sources installed at the SFC axial beam line will be also presented.

MOA2CIO01 HIRFL-CSR Facility Status and Development

Invited Oral

05 Projects and proposals

Y.J. Yuan, H.W. Zhao, J.W. Xia, X.D. Yang, J.C. Yang, H.S. Xu, Y. He, X.W. Ma, X.H. Cai, X.L. Tu, D.Q. Gao, W. Zhang, Z. Xu, X.T. Yang, Y.W. Su, R.S. Mao, L.Z. Ma, Y.P. Yang (IMP, Lanzhou)

IMP

The HIRFL-CSR facility come into operation by the end of 2007. During operation in recent years, CSR supplied beam for experiments at several terminals and inside both CSRm and CSRe rings. The experiments covers high resolution mass measurement, cancer therapy research, neutron wall, atomic physics using electron target and internal gas target, using injection beam mainly from the SFC of cyclotron injector. New methods and further developments are required to improve the performance of CSR system including multi-gradients measurement method for beam spot commissioning and beam transfer, nonlinear effect correction and stabilization of isochronous mode of CSRe. For suppling of heverier ion beam with proper ernergy, the cyclotron complex should be enhanced and new injector is proposed to replace SFC as injector of SSC. To be finished

MOA2CCO02 Current Status of the Cyclotron Facilities and Future Projects at Ithemba Labs

Contributed Oral

03 Operational cyclotrons: developments and status

Jacobus Conradie, Lyndon Anthony, Adriaan Botha, Mogamad Amien Crombie, Deon de Villiers, John Garrett De Villiers, Johannes Delsink, William Duckitt, Dirk Theunis Fourie, Mike Hogan, Ivan Kohler, Chris Lussi, Rob McAlister, Hendrik Mostert, Sifiso Ntshangase, John V. Pilcher, Peter Rohwer, Muneer Sakildien, Nieldane Stodart, Rainer Wolfgang Thomae, Martin Johannes Van Niekerk, Pieter van Schalkwyk (iThemba LABS, Somerset West), Zoltán Kormány (ATOMKI, Debrecen), Juergen Dietrich (FZJ, Jülich), Christian Boehme (UniDo/IBS, Dortmund)

iThemba LABS

For nearly 25 years the cyclotron facilities at iThemba LABS have been utilized for radioisotope production, nuclear physics research, and proton and neutron therapy. The aging systems require continual upgrading and replacement to limit interruptions to the scheduled beam delivery. The distributed computer control system is being migrated to a system running on the EPICS platform. The analogue low-level RF control systems will be replaced with digital systems. The Minimafios ECR ion source has been replaced with an ECR source from the former Hahn Meitner Institute and a second source, based on the design of the Grenoble test source, will be commissioned later this year. To increase the production of radio-isotopes, the 66 MeV proton beam is split to deliver beam simultaneously to two production targets. The first result with the beam splitter will be reported. A beam phase measurement system comprising 21 fixed probes has been installed in the separated sector cyclotron. Progress with these projects and the status of the facilities will be presented. Proposals for new facilities for proton therapy and for acceleration of radioactive beams will also be discussed.

MOA2CCO03 Status of the LBNL 88-Inch Cyclotron High-Voltage Injection Upgrade Project
Contributed Oral
03 Operational cyclotrons: developments and status
Ken Yoshiki Franzen (LBNL, Berkeley, California)
LBNL
The goal of the project includes design of a new center region that allows external beam injection at injection voltages between 20 and 30 kV for high intensity beams. This new center region will make use of a spiral inflector to eliminate the use of a gridded mirror for high intensity beams. At the same time the mechanical design of the new center region must be flexible enough to allow use of the current center region for less intense beams. The use of two or more different center regions is necessary to cover the wide range of operation parameter space utilized by the 88-Inch Cyclotron Nuclear Science and Applied research program. The project also includes HV upgrades of the external injection lines and HV insulation of the AECR and VENUS source with the goal to provide focusing for beams up to 25 kV or if feasible up to 30 kV. The current spiral inflector design is based on extensive 3D FEM simulations which results will be presented. In addition results from ongoing efforts to improve on the transport efficiency from the AECR ion source to the current mirror inflector will be discussed.

TUM1CIO01 Towards the 2MW Cyclotron and Latest Developments at PSI

Invited Oral

03 Operational cyclotrons: developments and status

Mike Seidel (PSI, Villigen)

PSI

PSI operates a cyclotron based high intensity proton accelerator routinely at an average beam power of 1.3MW. With this power the facility is at the worldwide forefront of high intensity proton accelerators. An upgrade program is under way to ensure high operational reliability and push the intensity to even higher levels. The beam current is practically limited by losses at extraction and the resulting activation of accelerator components. Further intensity upgrades are only possible if the relative losses can be lowered in proportion, thus keeping absolute losses at a constant level. The basic upgrade path involves the reduction of space charge induced extraction losses by implementing improved RF systems and resonators in both cyclotrons. The paper describes the ongoing upgrade program, achievements that were realized since the last cyclotron conference and several operational experiences and difficulties that were observed during routine operation.

TUM1CIO02 Latest Performance of the 500 MeV H^- Cyclotron and Recent Progress towards Three Simultaneous RIB's at TRIUMF

Invited Oral

03 Operational cyclotrons: developments and status

Iouri Bylinskii (TRIUMF, Vancouver)

TRIUMF

The TRIUMF cyclotron has been operating over the last 35 years with total H^- beam intensity increasing gradually from 100 to 300 μA cw. Simultaneous extraction of three proton beams at different energies up to 500 MeV has been provided routinely with ~90% reliability. One of the beams is sent to ISOL facility to drive the ISAC RIB program. This year the Laboratory has commenced a new development plan funded through a 5-year fiscal cycle. The plan calls for an additional source of RIB generated through photo-fission by a 50 MeV electron beam from a 500 kW cw superconducting linac. In the following phase a second high intensity proton beam will be extracted from the cyclotron and directed with the electron beam towards a new ISAC target complex geared to handle actinide targets. A versatile system of mass spectrometers and an expanded ion linac accelerator structure, to be completed during 2014-2018, would then deliver simultaneously three different RIB's to the existing experimental areas, enhancing scientific productivity of the Laboratory. At the same time the cyclotron will be upgraded to accelerate beams up to 400 μA, with more than 300 μA reaching 500 MeV.

TUM1CCO03 Reliable Production of Multiple High Intensity Beams with the 500 MeV TRIUMF Cyclotron

Contributed Oral

03 Operational cyclotrons: developments and status

Richard Baartman, Frederick William Bach, Iouri Bylinskii, James Frederick Cessford, Gerardo Dutto, Daniel Gray, Andy Hurst, Keerthi Jayamanna, Michael Mouat, Yi-Nong Rao, William Reginald Rawnsley, Laurence Root, Roman Ruegg, Victor Alexandrovich Verzilov (TRIUMF, Vancouver)

TRIUMF

In 2001, after 25 years of smooth cyclotron operation with up to ~200μA H^- acceleration, developments towards higher intensities became compelling because of the ISAC expansion. Recently average current of 300μA, within a nominal ~90% duty cycle, was routinely achieved. Beam availability was 90-94% over the last five years. Development highlights are discussed in the paper. These include: ion source and beam transport re-optimized for this cyclotron acceptance; the 12 m long vertical injection line section was redesigned to accommodate higher space charge. In the centre region, a water cooled beam scraper was installed to absorb unwanted phases; other electrodes were realigned. Other activities were aimed at beam stability enhancement for ISAC. This included: reducing υr = 3/2 resonance effects at 420 MeV, stabilizing the intensity of the primary beam through pulser feedback regulation and improving beam quality at the target through beam optics optimization and target position stability feedback, etc. Extraction was also improved, using special stripping foils.
Gerardo Dutto, TRIUMF Emeritus

TUM1CCO04 The VARIAN 250 MeV Superconducting Compact Proton Cyclotron: Medical Operation of the 2nd Machine, Production and Commissioning Status of Machines No. 3 to 7

Contributed Oral

02 Newly operating cyclotrons

Heinrich Röcken, Mamdouh Abdel-Bary, Ender Akcoeltekin, Peter Budz, Thomas Stephani, Jürgen Christian Wittschen (VMS-PT, Bergisch Gladbach)

VMS-PT

Varian Medical Systems Particle Therapy (the former ACCEL) has successfully finalized in 2008 the commissioning of its 2nd superconducting compact proton cyclotron for use in proton therapy. The 250 MeV machine serves as proton source for treatments at the first clinical proton therapy center in Germany which opened in early 2009. Furthermore, Varian is currently commissioning and factory testing its 3rd machine. We report on the operation and performance of the 2nd machine as well as on the successful cool-down, quench testing, and magnetic shimming of the 3rd machine. In addition we present RF commissioning plans using a newly developed solid state amplifier, and plans for the upcoming factory beam commissioning in the new Varian cyclotron test cell, scheduled for October 2010. Finally we provide a brief status and outlook on machines no. 4 to 7.

TUM2CIO01 Status of RIBF Accelerators at RIKEN

Invited Oral

03 Operational cyclotrons: developments and status

Osamu Kamigaito, Shigeaki Arai, Tomoyuki Dantsuka, Masaki Fujimaki, Tadashi Fujinawa, Nobuhisa Fukunishi, Akira Goto, Hiroo Hasebe, Yoshihide Higurashi, Kumio Ikegami, Eiji Ikezawa, Hiroshi Imao, Tadashi Kageyama, Masayuki Kase, Masanori Kidera, Misaki Komiyama, Hironori Kuboki, Keiko Kumagai, Takeshi Maie, Makoto Nagase, Takahide Nakagawa, Makoto Nakamura, Jun-ichi Ohnishi, Hiroki Okuno, Naruhiko Sakamoto, Kenji Suda, Hiroshi Watanabe, Tamaki Watanabe, Yutaka Watanabe, Kazunari Yamada, Yasushige Yano, Shigeru Yokouchi (RIKEN Nishina Center, Wako)

RIKEN Nishina Center

Recent developments and upgrade program in the near future at RIKEN RI-Beam Factory (RIBF) are presented. The beam intensity and available ion species are increasing at RIBF, owing to the continuous efforts that have been paid since the first beam in 2006. So far, we accelerated deuteron, helium, nitrogen, oxygen, aluminum, calcium, krypton, and uranium beams with the superconducting ring cyclotron, SRC. The extracted beam intensities reached 1,000 pnA for helium and oxygen beams. From the operational point of view, however, the intensity of the uranium beam should be much increased. We are, therefore, constructing a new injector linac for the RIBF, consisting of a superconducting ECR ion source, RFQ, and DTL, which will be commissioned in this fiscal year. By using this injector, we also aim at independent operation of the RIBF and GARIS facility for super-heavy element synthesis.

TUM2CCO02 First Beam Acceleration in Kolkata Superconducting Cyclotron and Its Present Status

Contributed Oral

02 Newly operating cyclotrons

Chaturanan Mallik, Rakesh Kumar Bhandari (DAE/VECC, Calcutta)

DAE/VECC

Major systems of the superconducting cyclotron at Variable Energy Cyclotron Centre (VECC), Kolkata were functional and integrated by May 2009. After achieving the required acceleration condition internal beam trials were started in July 2009. First internal beam was observed on borescope viewer on August 14th. Ne3+ beam at 14 MHz was accelerated to full extraction radius and nuclear reaction observed on August 25th. The trials were not without difficulty and several problems did crop up during the initial phase. Major problems encountered were related to obtaining sufficient dee voltages primarily due to ceramic insulator degradation leading to vacuum breakdown. Earlier the 14 GHz ECR ion source was connected with injection line without much difficulty. The cyclotron magnet with the cryostat has been running smoothly and quite a valuable experience has been gained over the years. An analogue beam was also accelerated before taking a shutdown for installation of extraction system and augmentation of cryogenic plant. Very soon beam extraction and transportation to the experimental area will be started.

TUM2CCO03 Commissioning of the JYFL MCC30/15 Cyclotron

Contributed Oral

02 Newly operating cyclotrons

Pauli Heikkinen (JYFL, Jyvaskyla)

JYFL

The new MCC30/15 cyclotron from NIIEFA, St. Petersburg, Russia, arrived at Jyväskylä on 10th of August 2009, as a partial compensation of the Former Soviet Union debt to Finland. The cyclotron required an extension for the old experimental hall. The building of the extension started in late August, 2008. Both the cyclotron and the building projects took a little more time than planned. However, the delay of both projects was less than two months, and so the building was ready to host the cyclotron by the beginning of August, 2009. The installation of the cyclotron was done by the manufacturer's (NIIEFA) specialists. Before the end of November 2009 the maximum extracted proton intensity (in pulses) was twice the guaranteed value and 24 % over the guaranteed value for deuterons. The final acceptance protocol was signed on 30th of April, 2010. In addition to the scientific work (IGISOL), the new MCC30/15 cyclotron is planned to be used for medical radioisotope production, mainly 123-I and 18-F. Negotiations on the isotope production are underway.

TUM2CCO04 Cyclone 70 Arronax Cyclotron - Commissioning Progress Report

Contributed Oral

02 Newly operating cyclotrons

Luis Medeiros-Romao, Michel Abs, Jean-Luc Delvaux, Sebastien Deprez, Yves Jongen, Willem Kleeven, Vincent Nuttens, François Peeters, Marc Pinchart, Thierry Vanderlinden, Simon Zaremba (IBA, Louvain-la-Neuve)

IBA

The development of the Cyclone® 70, started at the end of 2005. The installation began in March of 2008 and the testing in July of the same year. The injection phase was a rapid success leading to beam acceleration and extraction. The latter presented major hurdles that were overcome with success, notwithstanding an impact on the foreseen schedule. On one side, the alpha and proton acceleration faced a harmonic one field component primarily considered negligible during the mapping. This was resolved by shimming of the iron and the introduction of harmonic coils. Moreover, the extraction of the full alpha intensity required a redesign of the deflector which was limited by its power dissipation capabilities. On the other hand, the proton beam extraction, 750μA at 70MeV, was the last major hurdle, given the vacuum and outgassing levels with high intensity beams. After an important diagnostics phase and vacuum calculations, modifications were implemented aiming the full performances. Meanwhile, the ARRONAX team started their activities and produced the first radioisotopes using this unique and powerful tool set for a wide horizon of present and future nuclear medicine applications.

TUA1CIO01 A Multi Megawatt Cyclotron Complex to Search for CP Violation in the Neutrino Sector

Invited Oral

05 Projects and proposals

Luciano Calabretta, Mario Maggiore, Leandro Amos Cristiano Piazza, Danilo Rifuggiato (INFN/LNS, Catania)

INFN/LNS

Scientists of Massachusetts Institute of Technology (MIT) proposed a new approach to search for CP violation in the neutrino sector *. They proposed to use high-power proton accelerators able to deliver a proton beam whit energy 800 MeV, 1.5 MW power and duty cycle of 20% (100 usec beam on, 400 usec beam off). In the past, a layout for a similar accelerator complex to get a proton beam with 10MW of power was proposed by the LNS Accelerator Team **. This previous machines' proposal is now updated to meet the MIT requirements. It consists in a two cascade cyclotron complex. The injector cyclotron, is a four sector machine, which accelerates a beam of H2+ up to energy of 35 MeV/n. The extraction radius is set around 130 cm and the energy gain is fixed at 1.1 MeV/turn, to obtain a turn separation of about 11 mm and then to make very efficient the extraction by the electrostatic deflector. The beam is then injected inside a 8 sectors Superconducting Cyclotron Ring. The energy gain is set at about 3 MeV/turn to reduce the number of turns inside the Ring cyclotron. The beam is extracted by the stripper method. The main characteristics and features of the machines will be presented.

* J. M. Conrad and M. H. Shaevitz,"Multiple Cyclotron Method to Search for CP violation in the Neutrino Sector",Phys.Rev.Lett.104:141802,2010

** L. Calabretta et Al., EPAC(2000),pp.918 I.N.F.N., Laboratorio Nazionale del Sud, Catania, Italy

TUA1CIO02 Tnergetic Cyclotrons as Devices – Pushing beyond 6 Tesla
Invited Oral
05 Projects and proposals
Tim Antaya (MIT)
MIT
To be finished

TUA1CCO03 High Power, High Energy Cyclotrons for Muon Antineutrino Production: the DAEdALUS Project

Contributed Oral

05 Projects and proposals

Jose Alonso (LBNL, Berkeley, California; MIT, Cambridge, Massachusetts)

MIT

Neutrino physics focuses on huge detectors deep underground. The Sanford Lab in South Dakota will build a 300 kiloton water-Cherenkov detector 1500 meters deep, for the Long Baseline experiment (LBNE) detecting GeV neutrinos from Fermilab, 1300 km away, studying muon-neutrino oscillation for neutrino mass hierarchy and CP-violation. The DAEdALUS Collaboration plans several neutrino-production sites at closer distances up to 20 km from the 300 kT detector, producing muon antineutrinos from stopped pions. The complementarity with LBNE greatly enhances results, and enthusiasm is mounting to do both experiments. DAEdALUS needs 0.8-1 GeV accelerators with mA proton beams. Three sites at 1.5, 8 and 20 km from the 300 kT detector require several accelerators. The cost per machine must be below 1/10 of existing megawatt-class proton machines. Beyond high power and energy, beam parameters are modest. Challenges are reliability, control of beam loss and minimizing activation. Options being studied are: a compact superconducting cyclotron; a ring cyclotron accelerating (H2)+ (with stripping extraction); and a stacked cyclotron with up to 9 planes sharing the same magnet yoke and rf systems. Author presenting on behalf of the DAEdALUS Collaboration

TUA1CCO04 Developement of 70 MeV Separate Sector Cyclotron for KORIA project

Contributed Oral

05 Projects and proposals

Khaled Mohamed Gad, Jong-Seo Chai, Hyun Wook Kim, Byeong-No Lee, Jin Hwan Oh, Jina Park, HoSeung Song (SKKU, Suwon)

SKKU

Starting from April 2010, KoRIA was launched in the republic of Korea; the main objects of this project are fundamental and applied researches, e.g. production of radioisotope beam for the basic science research, nuclear structure, material and life sciences and medical isotope production, A K=100 separated sector cyclotron will be used as a driving accelerator For ISOL, It will provide a 70-100 MeV, ~1 mA of proton beam and 35-50 MeV, ~1mA of deuteron ion beam, the SSC cyclotron will be injected by 8 MeV proton beam from 2 sector focused cyclotrons. In this paper we will describe briefly the conceptual design of the cyclotron including the design of separated sector magnet, beam dynamics and RF system, etc. cyclotrons, magnet design,RF systems,etc., Ministry of Education, Science and Technology, Republic of Korea Department of Energy Science and School of Information and Communication Engineering of SungKyunKwan University

TUA2CIO01 Progress on Construction of CYCIAE-100

Invited Oral

04 Facilities under construction

Tianjue Zhang, Zhenguo Li, Yinlong Lu (CIAE, Beijing)

CIAE

As a driving accelerator for RIB production, CYCIAE-100 will provide proton beam of 75MeV～100MeV with an intensity of 200μA～500μA. The design for each system has been accomplished and about 50% of fabricating work has been finished. The main magnet manufacture has entered the fine machining stage. Two main magnet coils have been completed, two 100kW RF power supplies and transmission lines are tested with full output power, and the main vacuum chamber and main magnet elevating system will be completed soon. The construction designs and market surveys for other systems are finished and ready for purchase. Some key design and technology experiments are in process and significant results have been achieved in verifications. The Comprehensive Test Stand (CRM) has successfully passed the authoritative certification, and an important progress has been made for a full scale experimental RF cavity and its frequency and Q value measured agree well with the numerical data. The certification test of vacuum cryo-panel structure has been finished with valuable information to cryo-panel design. Key technical problems related to CYCIAE-100 are being solved along with the progress.

TUA2CCO02 Induction Sector Cyclotron for Cluster Ions

Contributed Oral

05 Projects and proposals

Ken Takayama, Toshikazu Adachi (KEK, Ibaraki), Weihua Jiang (Nagaoka University of Technology, Nagaoka, Niigata), Hiroshi Tsutsui (SHI, Tokyo), Yoshiyuki Oguri (TIT, Tokyo)
KEK

A novel scheme of a sector cyclotron to accelerate extremely heavy cluster ions, called “Induction Sector Cyclotron (ISC)”, is described [*]. Its key feature is fast induction acceleration, which has been already demonstrated using the KEK 12 GeV proton synchrotron [**]. An ion bunch is accelerated and captured with pulse voltages generated by transformers. The acceleration and confinement in the longitudinal direction can be independently handled. The transformers are energized by the corresponding switching power supply, in which power solid-state devices are employed as switching elements and their turning on/off is maneuvered by gate signals digitally manipulated from the circulating beam signal of an ion bunch. Consequently the acceleration synchronizing with the revolution of any ion beam is always guaranteed. A cluster ion beam such as C-60, which so far there has been no way to repeatedly accelerate, can be accelerated from an extremely low velocity to a nearly light velocity. Its fundamental concept, beam dynamics, required key devices, and life time of a cluster ion beam will be discussed. A typical example of ISC is proposed at the conference. * K.Takayama et al., submitted to Phys. Rev. Lett. (2010). ** K.Takayama et al., Phys. Rev. Lett. 98, 054801 (2007), K.Takayama and R.Briggs (Eds.), “Induction Accelerators” (Springer, 2010). supported by Grant-in-Aid for Exploratory Research (KAKENHI 22265403)

TUA2CCO03 Design and Construction Progress of A 7mev/U Cyclotron

Contributed Oral

04 Facilities under construction

Bing Wang, Daqing Gao, Huan Feng Hao, Lizhen Ma, Kai Di Man, Mingtao Song, Xianwu Wang, Xiaotian Yang, Qinggao Yao, Zhiming You, Jing Quan Zhang, Sheng Hu Zhang, Xiao Qi Zhang, Hongwei Zhao (IMP, Lanzhou)

IMP

The 7MeV/u cyclotron accelerates carbon ions with mass number 12,5+ charges, the extraction energy of carbon ions is 7MeV/u, and the beam current density is designed to be 10eμA. It designed as injector for the HITEL(Heavy Ions Therapy Facility for LanZhou) synchrotron, which accelerates carbon ions to the energy 300MeV/u for tumors treatment. Computer modeling results on the axial injection, magnetic, accelerating and extraction systems of the cyclotron are given. Design of the main systems of the cyclotron and the results of beam dynamic simulations are introduced. The construction progress including the ECR ion source, the axial injection beam line, the magnet, the RF system, the vacuum system etc. will be described respectively.

WEM1CIO01 4th Generation ECRIS and Applications to Cyclotrons

Invited Oral

10 Ion sources, strippers and targets

Claude M Lyneis, Paolo Ferracin, Daniela Leitner, Soren Prestemon, GianLuca Sabbi, Damon Todd (LBNL, Berkeley, California)

LBNL

Progress made on high field Nb3Sn magnets for particle accelerators makes possible the development of 4th Generation ECR ion sources capable of operating at a frequency between 40 and 60 GHz with axial magnetic fields up to 8 T. A number of 3rd Generation sources are in operation or development and these sources use NbTi superconducting wire for the magnets, have solenoid fields up to 4 T and operate up to 28 GHz. Based on scaling arguments, the beam intensities for ECR ion sources increase as the square of the operating frequency and going beyond 28 GHz holds great promise for increasing the beam power of driver accelerators used in radioactive beam accelerators such as RIBF in RIKEN, FRIB in Michigan State University and FAIR at GSI. At LBNL, the concepts for the magnet structure using Nb3Sn have been developed and analyzed including methods to assemble and clamp the coils. This is new technology and a research and development phase focused on magnet construction would be the next step towards realizing a 4th Generation ECR ion source.

Work was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Nuclear Physics Division of the U.S. Department of Energy under Contract DE AC03-76SF00098

WEM1CIO02 28 GHz SC-ECRIS at RIBF

Invited Oral

10 Ion sources, strippers and targets

Takahide Nakagawa (RIKEN Nishina Center, Wako)

RIKEN Nishina Center

The next generation heavy ion accelerator facility (RIBF) for production of intense RI beam requires great variety of high charged heavy ions with higher beam intensity than currently available. In the last decade, performance of the ECR ion sources has been dramatically improved with increasing the magnetic field and RF frequency to enhance the density, confinement time of plasma and electron temperature. Furthermore, the effects of the key components (magnetic field configuration, gas pressure etc) of the ion source on the ECR plasma have been revealed. Such basic studies give us how to optimize the ion source structure. Based on these studies and superconducting technology, several SC-ECRISs with higher microwave frequency (>20GHz) were constructed. In this contribution, I present status of SC-ECRIS for RIBF, how to increase the beam intensity to meet the requirements, and the technology of the SC-ECRIS with 28GHz microwave.

WEM1CIO03 New Tools For the Improvement of Beam Brightness In ECR Ion Sources

Invited Oral

10 Ion sources, strippers and targets

Santo Gammino, Luigi Celona, Giovanni Ciavola (INFN/LNS, Catania), David Mascali (INFN/LNS, Catania; CSFNSM, Catania)

INFN/LNS

According to the model that has driven the development of ECRIS in the last years, a large variation of the pumping microwave frequency (order of GHz) along with the proportional increase of the magnetic field boosts the extracted current for each charge state because of a larger plasma density. Recent experiments have demonstrated that even slight frequency's changes (of the order of MHz) considerably influence the output current, and what's more important, even the extracted beam properties (beam shape, brightness and emittance) are affected. A number of tests have been carried out in the last few years and they will be reviewed along with the results of numerical simulations which are able to explain the observed phenomena. The frequency has been systematically changed and the beam output has been recorded either in terms of charge state distributions and beam emittance. The detected bremsstrahlung X-rays are additionally analysed: they give insights about the electron energy distribution function (EEDF). An overview about the possible future improvements of ECR ion source will be given.

WEM1CIO04 Transverse Collimation with the Superconducting ECR Ion Source Susi at the Coupled Cyclotron Facility

Invited Oral

10 Ion sources, strippers and targets

Guillaume Machicoane, Dallas Gene Cole, Marc Doleans, Tommi Ropponen, Jeffry W. Stetson, Liangting Sun, Xiaoyu Wu (NSCL, East Lansing, Michigan)

NSCL

The Coupled Cyclotron Facility (CCF) at Michigan State University has replaced the old 6.4 GHz Superconducting ECR ion source SCECR with SuSI, a fully Superconducting ECR ion source operating at 18GHz. The installation of SUSI was completed in September 2009 and since that time the ion source has been routinely used for CCF operation. Prior to the ion source installation to the cyclotron, the initial period of commissioning of SuSI had shown very solid performances for medium charge state ion beams. For example more than 300euA of Xe20+ and 400euA of Kr13+ have been obtained.However large increase in extracted ion beam current from the ECR ion source will not necessary translate into higher primary beam power on the production target. To optimize the brightness of the beam injected into the K500, a beam collimation scheme has been developed that limit the beam transverse emittance and includes several apertures and solenoids to implement successive cuts to the beam phase space distribution. In this contribution, an overview of the ion source SuSI will be presented.Experimental results from the collimation channel will also be presented and will be compared to simulations.

WEM2CIO01 High Power RF Systems and Resonators for Sector Cyclotrons

Invited Oral

11 Radio frequency systems

Lukas Stingelin, Markus Bopp, Manuel Broennimann, Jacques Cherix, Hansruedi Fitze, Markus Schneider, Wolfgang Tron (PSI, Villigen)

PSI

In the framework of the high intensity upgrade of the PSI proton accelerator facility, it is planned to replace two existing 150MHz resonators of the injector II cyclotron by two new 50MHz resonators. The first prototype resonator has been manufactured by SDMS and first vacuum- and LLRF-tests were carried out. Tuners, coupler and pickups were mounted and high power RF tests are in progress at the teststand. A new building for the rf-installation has been built and is ready to house the power amplifiers and LLRF-systems.

WEM2CCO02 Operating Experience with the RF System for Superconducting Ring Cyclotron of RIBF

Contributed Oral

11 Radio frequency systems

Naruhiko Sakamoto, Masaki Fujimaki, Akira Goto, Osamu Kamigaito, Masayuki Kase, Ryo Koyama, Kenji Suda, Kazunari Yamada, Shigeru Yokouchi (RIKEN Nishina Center, Wako)

RIKEN Nishina Center

Since December 2006, Superconducting Ring Cyclotron (SRC) has been operational. Up to now, the beams of 238U, 48Ca, pol-d, N, 4He have been provided for nuclear physics experiments. The SRC consists of 6 superconducting sector magnets, 4 accelerating cavities and one flattop cavity. Designed value of the acceleration voltage is 2 MV/turn. The gap voltage of 600 kV is excited with 130 kW rf power in the accelerating cavity. The cavities have been installed at four valley regions of 6 sector magnets and are exposed to a strong stray field of superconducting magnets. The strength of the magnetic field is as large as a few kilogauss. It is found that the condition of multipactor depends drastically on the strength of the stray field. How to treat the multipactor is one of the most important issues for stable operation of the SRC. This paper will discuss on our efforts to settle the problem concerning the cavities. By improving the vacuum, cooling, surface treatment and so on, we finally succeeded to minimize the break time due to the rf break down of the SRC cavities during experiments.

WEM2CCO03 Disturbance Effects Caused by RF Power Leaking out from Cavities in the PSI Ringcyclotron

Contributed Oral

07 High beam intensity operation

Martin Humbel (PSI-LRF, Villigen, PSI), Hui Zhang (PSI, Villigen)

PSI-LRF

While commissioning the PSI high intensity proton beam facility after the shutdown 2010 direct and indirect phenomena of interaction between the electrostatic septa of the injection and extraction region and the RF power, leaking out from the cavities occurred in the Ringcyclotron. As an indirect influence RF fields outside the cavities generate plasma clouds at the edge of magnet poles. Accelerated plasma ions sputtered metallic atoms form the vacuum chamber wall, which then covered the insulator surface with an electrically conductive layer. The septum therefore had to be replaced. Directly RF power, dissipated from the third harmonic cavity was redirected by a beam stopper in such a way, that a linear correlation between the RF pick up signal monitored at the extraction septum EEC and the leak current across the septum insulator could be observed. As an instant mending action the beam stopper, which is not permanently used, has been removed. The leaking out of RF power from a cavity is known to depend on vertical asymmetry. With asymmetrical settings of the hydraulic tuning system we will try to minimize this disturbing effect.

WEM2CIO04 Beam Diagnostics for Cyclotrons

Invited Oral

13 Beam transport, diagnostics and control

Rudolf Dölling (PSI, Villigen)

PSI

An overview is given on beam diagnostics used at cyclotrons. The focus is set to devices installed inside the cyclotron with its special "environmental" conditions and limitations and on techniques which cover specific needs of the commissioning and operation of cyclotrons.

WEM2CCO05 Beam Diagnostics for RIBF in RIKEN

Contributed Oral

13 Beam transport, diagnostics and control

Tamaki Watanabe, Masaki Fujimaki, Nobuhisa Fukunishi, Osamu Kamigaito, Masayuki Kase, Misaki Komiyama, Ryo Koyama, Hiroshi Watanabe (RIKEN Nishina Center, Wako)

RIKEN Nishina Center

In the present work, many varieties of beam diagnostics have been played a tremendous role for the RIBF (RI Beam Factory) in RIKEN. During beam user's experiments, it is essential to keep the beam transmission efficiency as high as possible, because the production of RI beams requires an intense primary beam, and the activation of the beam transport chambers induced by beam loss should be avoided. This presentation will include the overview of the Faraday cups, the transverse beam profile monitors, radial probes and phase probes to tune the accelerators and the beam transport line. To realize the stable operation of the accelerator complex, the nondestructive monitoring system of RF fields and beam-phase by using lock-in amplifies are used. Plastic scintillation monitors have been fabricated to evaluate the energy and longitudinal profiles of heavy-ion beams. Furthermore, a highly sensitive beam current (position) monitor with a high Tc (Critical Temperature) SQUID (Superconducting QUantum Interference Device) monitor, has been developed. We will report the present status of the facility, the details of the beam diagnostics and the results of the beam measurement.

THM1CIO01 Post-Acceleration of High Intensity RIB through the CIME Cyclotron in the Frame of the SPIRAL2 Project at GANIL

Invited Oral

08 Radioactive beams

Patrick Bertrand, Alain Savalle (GANIL, Caen)

GANIL

The cyclotron CIME is presently used at GANIL for the acceleration of SPIRAL1 radioactive beams. One of the goals of the SPIRAL2 project is to produce, post-accelerate and use in the existing experimental areas much higher intensity secondary beams induced by uranium fission like neutron-rich krypton, xenon, tin isotopes, and many others. Intensity may reach 10^{10} pps. Specific developments are needed for secondary beam diagnostics. Improvement of mass separation is also necessary, and the Vertical Mass Separator (VMS) is specially developed for this purpose. However, the main concern is related to the high radioactivity linked to RIB high intensity. Safety and radioprotection issues will require modifications of the installation with special care for the maintenance of the cyclotron. The experience of the SPIRAL1 beams, in terms of beam losses and equipment contamination, is especially useful to define the necessary modifications.

THM1CIO02 Acceleration above the Coulomb Barrier - Completion of the ISAC-II Project at TRIUMF

Invited Oral

08 Radioactive beams

Robert Edward Laxdal (TRIUMF, Vancouver)

TRIUMF

The ISAC-II project at TRIUMF was proposed to boost the final energy of the radioactive ion beams of the TRIUMF ISAC facility above the Coulomb barrier. The nominal goal of 6.5MeV/u for ions with A/q=6 was recently achieved. The ISAC-II post-accelerator consists of 40MV of installed heavy ion superconducting linac to broaden the energy reach and a charge state booster to broaden the mass reach. Details of the project and the ISAC-II commissioning and operation will be presented.

THM1CIO03 The Accelerator System for ReA3 - the New Re-accelerated Rare Isotope Beam Facility at MSU*

Invited Oral

08 Radioactive beams

Xiaoyu Wu (NSCL, East Lansing, Michigan)

NSCL

A new Re-accelerated Rare Isotope Beam Facility: ReA3 is currently being constructed at the Michigan State University (MSU). ReA3 is a novel system proposed to first stop the high energy Rare Isotope Beams (RIBs) created using Coupled Cyclotron Facility (CCF) by the in-flight particle fragmentation method in a helium filled gas system, then increase their charge state with an Electron Beam Ion Trap (EBIT) charge breeder, and finally re-accelerate them to a final energy of ~3 MeV/u. ReA3 will provide opportunities for an experimental program ranging from low-energy Coulomb excitation to transfer reaction studies of astrophysical reactions. The ReA3 accelerator system consists of a Low Energy Beam Transport (LEBT) with an external multi-harmonic buncher, a radio frequency quadrupole (RFQ), a superconducting linac, and a beam distribution system. The superconducting linac will use quarter-wave resonators with optimum beta of 0.041 and 0.085 for acceleration and superconducting solenoid magnets for transverse focusing. Future energy upgrade to ~ 6 MeV/u or higher is also possible. The paper will discuss the status and recent progress of R&D of the accelerator system for ReA3. *This work is supported by the U.S. Department of Energy and National Science Foundation

THM1CIO04 Progress towards New RI and Higher RIB Intensities at TRIUMF

Invited Oral

08 Radioactive beams

Pierre Gerard Bricault (TRIUMF, Vancouver)

TRIUMF

Over the past five years TRIUMF has operated routinely the ISAC facility at proton beam intensity around and above 70 μA. Contrary to other ISOL facilities ISAC utilizes a modular assembly for the target station. This is mainly to provide enough radiation shielding for operation at high proton beam intensity. So far ISAC was licensed to operate target material Z < 82. Two actinide target (UO2) tests have been performed during the past two years to assess the ISAC systems (vacuum, nuclear ventilation, personnel safety) for actinide operation. The uranium oxide target is limited to 2 μA only because of the low operating temperature. We are now developing a uranium carbide target using similar techniques as for our other carbide targets (SiC, TiC, ZrC) operating up to 70 μA. Among the recent upgrade, the mass range, which was so far limited to mass lower than 30 has been increased to 150 with the installation of a charge state booster. TRIUMF is owned and operated as a joint venture by a consortium of Canadian Universities via a contribution through the National Research Council of Canada.

THM2CIO01 Precise Simulations of High Power Cyclotrons: How Does It Work?

Invited Oral

09 Beam dynamics

Andreas Adelmann (PSI, Villigen)

PSI

In space charge dominated regimes non-linear forces acting over large spatial and temporal scales render precise beam dynamics simulation a challenging task. Other possibly important physics processes to be considered are: collimation including secondary effects and interaction from neighboring turns. For accurate field solutions and the precise calculation of quantities such as emittance, controlled and uncontrolled losses, sufficient particle statistics together with corresponding spatial and temporal resolution is required. These requirements call for state-of-the-art numerical algorithms and efficient parallel implementation. Many of the above mentioned challenges are met by the beam dynamics program OPAL (Object Oriented Parallel Accelerator Library). I will touch on physics and numerical modeling questions with particular emphasis on the implementation on high performance computing architectures. A short overview of the program and its unique features will be presented. Examples of OPAL simulations include space charge studies on high-intensity proton cyclotrons.

THM2CCO03 Stripper Foil Developments at NSCL/MSU

Contributed Oral

10 Ion sources, strippers and targets

Felix Marti, Scott Hitchcock, Peter Miller, Jeffry W. Stetson, John Yurkon (NSCL, East Lansing, Michigan)

NSCL

The Coupled Cyclotrons Facility (CCF) at NSCL/MSU includes an injector cyclotron (K500) and a booster cyclotron (K1200). The beam from the K500 is injected radially into the K1200 and stripped at approximately one third of the radius at energies of approximately 10 MeV/u. Stripping is done with a carbon foil. The lifetime of the foil is very short when stripping heavy ions and does not agree with the estimates from formulas that work quite well for light ions. We will present in this paper the studies performed to understand the limitations and improve the lifetime of the foils. A foil test chamber with an electron gun has been built as part of the R&D for the Facility for Rare Isotope Beams (FRIB) project. It has been used to study different ways of supporting the carbon foils and effects of high temperature operation. Different foil materials (diamond-like carbon, graphene, etc) have been tested in the cyclotron.

Work supported by DOE Cooperative Agreement DE-SC0000661 and National Science Foundation under grant No. PHY06-06007

THA1CIO01 FFAG Developments in Japan

Invited Oral

06 FFAG accelerators

Yoshiharu Mori (KURRI, Osaka)

KURRI

Recent activities of the research and development works on FFAG accelerators in Japan are reviewed in this talk.

THA1CIO02 First Commissioning Results from the Non-Scaling FFAG accelerator, EMMA
Invited Oral
06 FFAG accelerators
Susan Louise Smith (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire)
STFC/DL/ASTeC
The first results from commissioning EMMA - the Electron Model of Many Applications- are summarised in this paper. EMMA is a 10 to 20 MeV electron ring designed to test our understanding of beam dynamics in a relativistic linear non-scaling fixed field alternating gradient accelerator (FFAG). EMMA will be the world's first non-scaling FFAG and the paper will outline the characteristics of the beam injected in to the accelerator as well as summarising the results of the 4 sector "gantry-type" commissioning which took place at Daresbury Laboratory. The paper will report on recent progress made with the full EMMA ring commissioning, giving details of tune and orbit measurements as well as their correction to the desired lattice.

THA1CIO03 Innovations in Fixed-Field Accelerators: Design and Simulation

Invited Oral

06 FFAG accelerators

Carol Johnstone (Fermilab, Batavia), Martin Berz, Kyoko Makino (MSU, East Lansing, Michigan), Shane Rupert Koscielniak (TRIUMF, Vancouver), Pavel Snopok (UCR, Riverside, California)

Fermilab

The drive for high beam power, high duty cycle, and reliable beams has focused world interest on fixed field accelerators, notably Fixed-field Alternating Gradient accelerators (FFAGs) with cyclotrons representing a specific class of fixed-field accelerators. Recently, the concept of isochronous orbits has been developed for nonscaling FFAGs using new methodologies in FFAG design. The property of isochronous orbits enables the simplicity of fixed RF and, by tailoring a nonlinear radial field profile, the FFAG is isochronous well into the relativistic regime. The machine proposed here has the high current advantage and duty cycle of the cyclotron in combination with the strong focusing, smaller losses, and energy variability that are more typical of the synchrotron. Further, compact high-performance devices are often are operated in a regime where space charge effects become significant, but are complicated to analyze in fixed-field accelerators because of the cross talk between beams at different nearby radii. A new space charge simulation approach is under development in the code COSY INFINITY. This presentation reports on advances in FFAG accelerator design and simulation.

THA1CCO04 Cyclotron and FFAG studies using cyclotron codes

Contributed Oral

06 FFAG accelerators

Michael Craddock (UBC & TRIUMF, Vancouver, British Columbia), Yi-Nong Rao (TRIUMF, Vancouver)

UBC & TRIUMF

This paper describes the use of cyclotron codes to study the beam dynamics of both high-energy isochronous cyclotrons using AG focusing and non-scaling (NS) FFAGs. The equilibrium orbit code CYCLOPS determines orbits, tunes and period at fixed energies, while the general orbit code GOBLIN tracks a representative bunch of particles through the acceleration process. The results for radial-sector cyclotrons show that the use of negative valley fields allows axial focusing to be maintained, and hence intense cw beams to be accelerated, to energies $\approx$10 GeV. The results for FFAGs confirm those obtained with lumped-element codes, and suggest that cyclotron codes will prove to be important tools for evaluating the measured fields of FFAG magnets.

FRM1CIO01 Review on Cyclotrons for Cancer Therapy
Invited Oral
01 Cyclotron applications
Yves Jongen (IBA)
IBA
To be finished

FRM1CIO02 Introduction to Ion Beam Cancer Therapy
Invited Oral
01 Cyclotron applications
Andrew Sessler (LBNL)
LBNL
To be finished

FRM1CIO03 IBA-JINR 400 Mev/U Superconducting Cyclotron for Hadron Therapy

Invited Oral

04 Facilities under construction

Nikolay Morozov, Vladimir Aleksandrov, Semion Gurskiy, Galina Karamysheva, Nikolay Kazarinov, Sergey Kostromin, Eugene Samsonov, Vladimir Shevtsov, Grigori Shirkov, Evgeny Syresin, Alexey Tuzikov (JINR, Dubna, Moscow Region), Michel Abs, Albert Blondin, Yves Jongen, Willem Kleeven, Dirk Vandeplassche, Simon Zaremba (IBA, Louvain-la-Neuve), Oleg Karamyshev (JINR/DLNP, Dubna, Moscow region)

JINR

The compact superconducting isochronous cyclotron C400 [*] has been designed by the IBA-JINR collaboration. It will be the first cyclotron in the world capable of delivering protons, carbon and helium ions for cancer treatment. The cyclotron construction is started this year within the framework of the ARCHADE project [**] (Caen, France). 12C6+ and 4He2+ ions will be accelerated to 400MeV/u energy and extracted by the electrostatic deflector, H2+ ions will be accelerated to the energy of 265MeV/u and extracted by stripping. The magnet yoke has a diameter of 6.6 m, the total weight of the magnet is about 700 t. The designed magnetic field corresponds to 4.5 T in the hills and 2.45 T in the valleys. Superconducting coils will be enclosed in a cryostat; all other parts of the cyclotron will be warm. Three external ion sources will be mounted on the switching magnet on the injection line located below the cyclotron. The main parameters of the cyclotron, its design, the current status of the development work on the cyclotron systems are presented. [*] Y.Jongen et al, “IBA C400 Cyclotron Project for Hadron Therapy”, The 18th International Conference on Cyclotrons and their Applications Cyclotrons 2007, Italy 2007. [**] http://archade.fr/

FRM1CIO04 Fast Scanning Techniques for Cancer Therapy with Hadrons - A Domain of Cyclotrons

Invited Oral

01 Cyclotrons applications

Jacobus Maarten Schippers (PSI, Villigen)

PSI

In protontherapy fast 3D pencil beam scanning is regarded as the most optimal dose delivery method. The two transverse directions are covered by magnetic scanning and fast depth variations are achieved by changing beam energy with a degrader in the beam line. During the transversal scan the beam intensity is varied with kHz speed. This performance has a big impact on the accelerator concept. Routinely a very stable, reproducible and accurate beam intensity is needed, which is adjustable within a ms. Quick changes of the maximum intensity from the cyclotron are also needed when changing treatment room. The eye treatment room at PSI, for example, needs a 5-7 times higher intensity as the Gantry. Dedicated tools and setup procedures are used to switch area within a few seconds. Typical energy variations must be performed within 50-80 ms. In order to compensate the energy dependent variation (factor 100) of the transmission through the degrader it is convenient to compensate this, e.g. with an adjustable beam transport transmission or with Dee voltage. It will be shown that a cyclotron offers the most advantageous possibilities to achieve this ambitious performance.

FRM1CCO05 Advocacy for a Dedicated 70 MeV Proton Therapy Facility

Contributed Oral

05 Projects and proposals

Andrea Denker, Christoph Rethfeldt, Joerg Roehrich (HZB, Berlin), Dino Cordini, Jens Heufelder, Roland Stark, Andreas Weber (Charite, Berlin)

HZB

Since 1998 we treated more then 1500 patients with eye tumors at the HZB cyclotron with a 68 MeV proton beam. The 5 years follow up shows a tumor control rate of more then 96%. The combination of a CT/MRT based planning and excellent physical beam conditions like 2 nA in the scattered proton beam, a 0.94 mm distal dose fall-off and a dose penumbra of 2.1 mm offers the opportunity to keep side effects on a lowest level. However all new medical proton facilities are equipped with accelerators delivering beams of 230 MeV and more. While this is needed for deep seated tumors, a lot of physical and medical compromises have to be accepted for the treatment of shallow seated tumors like eye melanomas. Hence, we suggest a 70 MeV proton therapy facility. It should be equipped with a horizontal beam line and can have optionally a vertical line for more complicated cases under anesthetics or for biological experiments. By the use of PBO Lab and MCNPX beam line concepts and a radio-protecting architecture are designed. In Germany we see a definite need for a single low energy facility which guarantees the excellence of proton therapy for the need of 80 million people.

FRM2CIO02 Medical Cyclotron and Development in China

Invited Oral

01 Cyclotrons applications

Mingwu Fan (HUST, Wuhan)

HUST

The first medical cyclotron CYCIAE-30 in China was designed and constructed by China Institute of Atomic Energy (CIAE), and its construction was finished in 1994. Since then on, medical cyclotron got developed in China, several cyclotrons had been constructed, and some medical experiments and practice had been done with those cyclotrons. Now medical cyclotron develops even quickly in china, several medical cyclotrons are under design and construction. In the meantime, a compact cyclotron virtual prototyping was developed to help the cyclotron design and reduce cyclotron R & D cost.

FRM2CCO03 Magnets Technologies and Development at IMP

Contributed Oral

01 Cyclotrons applications

P.Yuan, L.Z.Ma, B.Zhang, Y.He, X.Q.Zhang, G.P.Sun, S.F.Han, Q.G.Yao, W.J.Wang, F.Wang, C.A.Xie, D.Y.Xu, X.Wu, B.L. Guo, S.L. Zhang

IMP

Many normal conducting magnets were used in Heavy Ion Research Facility in Lanzhou (HIRFL) accelerator complex's magnet system at IMP (Institute of Modern Physics, CAS, Lanzhou, China), The magnet design, fabrication and measurement of the experimental ring of CSR (Cooling Storage Ring) are presented. All magnets will be laminated and welded with an armour-coated surface between two big endplates made of sticking glue 0.5mm-thick sheets. The dipole of CSRm was chosen an H type with an air circle on the pole to improve the field homogeneity, which was agreed between magnets measurement and OPERA code calculation. The dipole of CSRe was chosen the C type with an air circle and two air slots on the pole to improve the field homogeneity. Its reproducibility of magnet to magnet was adjusted with inserting small laminating pieces before remounted pole ends to reach less than 2×10^{-4} at lower field. CSRm quadrupoles diameter is 170mm and has two different length and its endplates were made with punching pieces after coating epoxy glue, there is chamfered directly on the pole ends to reduce 12th order contribution of field and without the remounted pole end. CSRe main quadrupoles diameter is 240mm and has two different length and its endplates were also made with punching pieces after coating epoxy glue, there is also chamfered directly on the pole ends to reduce 12th order contribution of field and without the remounted pole end.

Some superconducting magnets research at IMP will be reported too. A super-ferric dipole prototype of FAIR Super-FRS is being built by FCG (FAIR China Group) in cooperation with GSI. Its superconducting coils and cryostat is made and tested in the Institute of Plasma Physics (IPP, Hefei), and it more 50 tons laminated yoke was made in IMP. This super-ferric dipole static and ramping magnetic field was measured in IMP; it reaches to the design requirement. A 3 T superconducting homogenous magnetic field solenoid with a 70 mm warm bore has been developed to calibrate Hall sensor, some testing results is reported. And a penning trap system called LPT (Lanzhou Penning Trap) is now being developed for precise mass measurements.

Other magnets and its design at IMP will be discussed in this paper.

FRM2CCO04 BNCT System Using 30 Mev H- Cyclotron

Contributed Oral

01 Cyclotrons applications

Toshinori Mitsumoto, Kazuhiro Fujita, Tsuyoshi Ogasawara, Hiroshi Tsutsui, Satoru Yajima (SHI, Tokyo), Akira Maruhashi, Yoshinori Sakurai, Hiroki Tanaka (KURRI, Osaka)

SHI

Kyoto University and Sumitomo Heavy Industries, Ltd. have developed an accelerator-based neutron source for Boron Neutron Capture Therapy (BNCT) at the Kyoto University Research Reactor Institute (KURRI). In order to obtain 10^9 n/cm2/sec epithermal neutron for cancer treatment, a newly designed 30 MeV H- AVF cyclotron named HM-30 was constructed and is being operated. With newly developed spiral inflector, the beam current in the central region can exceed 2 mA. The cyclotron is operated stably at 1 mA owing to the limit of the facility. Extracted proton beam is expanded by two scanner magnets in order to moderate heat concentration on the beryllium target, which is directly cooled by water to endure 30 kW heat load. Mainly fast neutrons are emitted from the target, and moderated to epithermal region by a moderator which consists of lead, iron, polyethylene, etc. Thermal neutron flux in a water phantom is measured by gold wire, which is consistent with the calculation using MCNPX. Preclinical studies have been continued with 10B-p-Borono- phenylalanine.

MOPCP001 Progress on the Design Study for a Compact Cyclotron Mass Spectrometry

Poster

01 Cyclotrons applications

Do Gyun Kim, Hyoung Chan Bhang, Joon Yeon Kim (SNU, Seoul), Jong-Won Kim (NCC, Korea, Kyonggi)

NCC, Korea

The design of an accelerator mass spectrometer (AMS) using compact cyclotron has been studied. We expect that the system can be much more compact than usual Tandem AMS systems if the design is fully optimized. The crucial design consideration is to make transmission efficiency high throughout the system. The current design includes a sawtooth buncher and a flat-topping cyclotron rf to enlarge the acceptance of longitudinal phase space. A prototype injection system is under construction, and the beam test will be performed soon. The injection line consists of an Einzel lens, a bending magnet, quadrupole triplet, and the buncher. The buncher is placed in the upstream of the beam line to reduce the rf voltage. The beam optics for the injection line was studied using the codes such as TRANSPORT and TRACE-3D. The beam optics and test results for the prototype beam line will be presented as well as the beam tracking study for the AMS cyclotron.

MOPCP002 The Isochronous Magnetic Field Optimization of HITEL Cyclotron

Poster 01

Cyclotrons applications

Qinggao Yao (IMP, Lanzhou)

IMP

This paper introduces the isochronous magnetic field optimization of cyclotron which accelerates two ions at HITEL（Heavy Ion Tumors Therapy Facility in Lanzhou） project. To satisfy two different isochronous field distributions, an effective method is adopted. In this method, the field distribution is adjusted by chamfering pole plate of sector and digging air trim slot. After a series of optimization procedures, the results show that the deviations between calculation values and theory are smaller than 5Gs for C125+; in addition, by putting some suitable trim coils, the isochronous field of H2+ is also obtained.

MOPCP003 Application of Cyclotrons in Brachytherapy

Poster

01 Cyclotrons applications

Pooneh Saidi Bidokhti (PPRC, Tehran), Mahdi Sadeghi (Agricultural, Medical & Industrial Research School, Gohadasht), Alireza Shirazi (Tehran University, Tehran)

PPRC

Cyclotrons are particle accelerator machines which have many applications in industry, technology and medicine. Cyclotrons play an important role in medicine and about 50% of the all particle accelerators running in the world are used in medicine for radiation therapy, medical radioisotopes production, and biomedical research. In this short review the use of cyclotrons for a radiation therapy method, brachytherapy, is discussed. Brachytherapy is a form of radiotherapy where a radioactive source placed on or in the tissue to be irradiated. For a long period the production of radioactive isotopes for medical applications was essentially done in nuclear reactors but due to some advantages of radioisotopes production with cyclotron over a nuclear reactor, in the last two decades several types

of cyclotrons have been developed to meet the specific demands of radionuclide production. This talk will briefly explain the technical design, beam transfer and beam delivery systems of cyclotron for brachytherapy radioisotope production; and also will shortly describe some detail of 103Pd production in the following: production, targetry, radiochemical separation and seed fabrication.

MOPCP004 Compromise-Optimum Carbon Beam Energyfor Therapy

Poster

01 Cyclotrons applications

Mohammad Anwar Chaudhri (University of Erlangen-Nuernberg, Erlangen)

University of Erlangen-Nuernberg

During therapy with C-ions neutrons, which have the potential to induce new cancers, are produced in patients' tissues. The only way to reduce the neutron doses is to adjust the C-ion energy to have adequate penetration with minimum neutron production. There is no reliable data on neutron production from tissue with C-ions, especially at the "production site". The measurements at some distance away from the source of neutron production are going to give wrong results due to the absorption and scattering of the neutrons. By making use of the measured neutron fluence and energy distributions from different materials constituting tissue, we have estimated the fluence and energies of the neutrons produced by the interaction of C-ions of 100-400 MeV/u energies with patients' tissues .Our results show that, for a physical treatment dose of 20 Gy in the Brag- Peak, the total fluence of neutrons produced in patients are 1.6 x 10^{9} / cm^2; 7.3 x 10^{8} / cm^2 ; 2.5 x 10^{8} / cm^2 and 4,1 x 10^{7} /cm^2 respectively at carbon-ions energies of 400, 300,200 and 100 MeV / u. Our graphical data would help the users of C-ions therapy to select their own "Compromise Optimum" energy.

MOPCP005 Kharkov Compact Cyclotron CV-28: Present and Future Status

Poster

01 Cyclotrons applications

Yuri Petrusenko, Dmitro Barankov, Denys Irzhevskyi, Sergii Myhailovych Shkyryda (NSC/KIPT, Kharkov), Rainer Hoelzle (FZJ, Jülich)

NSC/KIPT

Reported are the present and future statuses of the Kharkov Compact Cyclotron CV-28 donated to the National Science Center - Kharkov Institute of Physics & Technology (NSC KIPT) by the Forschungszentrum Juelich (Germany). The cyclotron configuration and special features of new installation at the NSC KIPT are presented. Consideration is given to the problems of promising cyclotron-beam use for investigation and development of materials for fusion reactors and generation-IV nuclear reactors, investigation and production of medical radionuclides, possible applications of a high-energy neutron source based on a deuteron beam and a thick beryllium target.

MOPCP006 Radionuclide Technique in Mechanical Engineering, actual status at ZAG

Poster

01 Cyclotrons applications

Achim Kleinrahm (ZAG, Eggenstein-Leopoldshafen)

ZAG

Since many years the Radionuclide Technique in Mechanical Engineering RTM is a powerful and sensitive tool for engineers, mainly in the automotive industry, to measure online the wear at a

running engine. The activation technique and the measurement methods are explained. Actual trends of problems and their solutions are demonstrated by means of examples. The installations for machine part activations at the TCC CP42 and at the new TR19/9 cyclotron of the ZAG Zyklotron AG are shown. Examples of special developed activations and the status of implantations of radioactive ions are discussed.

MOPCP007 62Zn/62Cu Generator

Poster

01 Cyclotrons applications

Mitra Ghergherehchi, Hossein Afarideh (AUT, Tehran), Behrooz Fateh (Nuclear Science & Technology Research Institute,)

AUT

62Cu is one of the commonly used radiopharmaceuticals in nuclear medicine which has several uses like blood flow delection in human brain & heart. As it was impossible to deposit and dissolve the suitable thickness of copper on targets. First they had been coated by a thin layer of Gold or Nickel then the natural copper was deposited. The next step was the calculation of target thickness which was performed by SRIM code. And the optimum target thickness was determined to be 118 μm after irradiation.62Zn was separated through a chemical process. The isotopic purity and activity of the product were investigated by gamma-spectrometry and its chemical purity was tested by chromatography. After that the obtained 62Zn is passed through the column which has been load with 2 N HCl. A radiolabaling process was performed using 62ZnCl2 and antitumor compound, bleomycin as a possible tumor imaging. Finally it was found that the best proton current, the optimum bombardment energy for targets and production yield would be 100 μA, 30 MeV and 5.9 mci/μAh, respectively. The comparison showed good agreement between theoretical method (ALICE code) and experimental method

MOPCP008 Control System of Cryogenic Plant for Superconducting Cyclotron at Vecc

Poster

02 Newly operating cyclotrons

Umashankar Panda, Tanushyam Bhattacharjee, Ranadhir Dey, Aditya Mandal, Sandip Pal (DAE/VECC, Calcutta)

DAE/VECC

Cryogenic Plant of Variable Energy Cyclotron Centre consists of two Helium refrigerators (250W and 415W @ 4.5K), valve box with sub-cooler and associated sub systems like pure gas storage, helium purifier and impure gas recovery etc. The system also consists of 31000 litres liquid Nitrogen storage and delivery system. This total system is running round the clock basis to cater the cryogenic requirements of Superconducting Cyclotron. This system is fully automatic and does not require human intervention after starting the operations. Three nos of Programmable Logic Controller taking care of approximately 624 field inputs/ outputs for total process automation. Supervisory control and data acquisition (SCADA) part is taken care by EPICS (Experimental Physics and Industrial Control System). The EPICS IOC is running in one computer which communicate to three PLCs over control Ethernet LAN. The system has a flexibility of control, monitoring and historical data access through any computer over the same control LAN. There is a 400 KVA UPS with 10 minutes back up time to keep the cryogenic system running with one 160KW cycle compressor during utility power

interruptions.

MOPCP009 Development of Power Supplies for 3-Φ, 240 KW RF System with Crowbar protection for Superconducting Cyclotron at VECC

Poster

02 Newly operating cyclotrons

Sajjan Kumar Thakur, Rakesh Kumar Bhandari, Anirban De, Yashwant Kumar, Jai Sanker Prasad, Subimal Saha, Sumit Som, Triyugi Prasad Tiwari (DAE/VECC, Calcutta)

DAE/VECC

RF system of K-500 super conducting cyclotron at VECC is a complex three phase system operating in the frequency range of 9 MHz to 27 MHz with maximum acceleration potential of around 100KV feeding to each of three Dee cavities placed in median plane of cyclotron 120º apart through coupling capacitors. Each phase consists of chain of amplifiers and resonator operating in synchronization and at final stage of each phase, a high power water cooled Tetrode Tube (Eimac 4CW 150,000 E) as an RF high power amplifier each capable of delivering 80 KW of RF power. Individual power supplies for biasing Anode (20kV, 22 Amp), Filament (16V, 225 Amp), Screen (1600V, 1 Amp) and grid (-500V, 0.1 Amp) each for all three high power Tetrode Tubes are designed, developed and commissioned indigenously in VECC Cyclotron building and have been in operation from last few months successfully. Anode supply is common to all three tubes, rated at 20KV, 22 Amp, 450 kW along with fast acting crowbar protection using Ignitron. This paper describes about the technical challenges in the development of the power supplies and special features of protection systems.

MOPCP010 Activities at the COSY/Jülich Injector Cyclotron JULIC

Poster

03 Operational cyclotrons: developments and status

Ralf Gebel, Ronald Brings, Olaf Felden, Rudolf Maier (FZJ, Jülich)

FZJ

The institute for nuclear physics at the Forschungszentrum Jülich is dedicated to fundamental research in the field of hadron, particle, and nuclear physics. Main activities are the development of the HESR synchrotron, part of the GSI FAIR project, the 3.7 GeV/c Cooler Synchrotron COSY-Jülich with the injector cyclotron JULIC, as well as the design, preparation, and operation of experimental facilities at this large scale facility, and theoretical investigations accompanying the scientific research program. The operation and development of the accelerator facility COSY is based upon the availability and performance of the isochronous cyclotron JULIC as the pre-accelerator. The cyclotron is commissioned in 1968 and exceeded 240 000 hours of operation. In parallel to the operation of COSY the cyclotron beam is also used for irradiation and nuclide production. A brief overview of activities, performance, new and improved installations will be presented.

MOPCP011 25 Years of Continuous Operation of the Seattle Clinical Cyclotron Facility

Poster

03 Operational cyclotrons: developments and status

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University of Washington Medical Center

The clinical cyclotron facility at the University of Washington Medical Center has now been in continuous operation for over 25 years. It is highly reliable, and its primary use is still for fast neutron therapy, mostly for salivary gland tumors. Neutron therapy accounts for about 85% of the facility use time. In cases where the tumor involves the base of the skull, significant improvements of patient outcome have been achieved by combining the neutron treatment with a gamma knife boost to areas where the neutron dose is limited by adjacent healthy tissue. Production of 211-At and 117m-Sn with alpha particles at 29.0 and 47.3 MeV and currents between 50 and 70 μA have become routine. These isotopes are used in medical applications presently under development. The introduction of a new control system using EPICS (Experimental Physics and Industrial Control System) is progressing systematically. All the user interfaces are up and running, and several accelerator subsystems have been migrated to the new controls. No interruption of therapy or isotope production operation is planned for the conversion to the new control system.

MOPCP012 Operational Experience and Improvements of PSI's Protontherapy Facility and its SC Cyclotron

Poster

03 Operational cyclotrons: developments and status

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PSI

The protontherapy facility PROSCAN at PSI's Center for Proton Therapy is treating patients since February 2007. The superconducting cyclotron (Varian) delivers a 250 MeV proton beam to Gantry-1 for daily treatments of 16-18 patients, to OPTIS2 for treatments of eye tumors, and to Gantry-2, for fast scanning tests and commissioning. Service is performed during 6 scheduled shutdowns of 3 days per year. The typical availability of the facility is 97%. Based on tracking calculations, optimizations of the central region (source, puller, slits) have increased the life time of the ion source to 4 weeks, enable a very stable beam (important for line scanning) and allow quick intensity changes, adapted to the treatment area (150 nA at Gantry-1, 850 nA at OPTIS2). A beam switch between any two areas is done within 30 seconds. The home-built PSI control system has been replaced recently by a system based on EPICS. This change has been performed without major interruptions of the treatments. For Gantry-2 changes of beam energy are performed routinely (within 80 ms) by means of the fast degrader and the beam line. Currently investigations are performed for an eventual third gantry.

MOPCP013 Magnetic Field Calculation and Magnet Shimming Simulation for the Cychu-10 Cyclotron

Poster

03 Operational cyclotrons: developments and status

Zihao Chen, DeZhi Chen, Bin Qin (HUST, Wuhan)

HUST

The compact internal ion source cyclotron CYCHU-10 developed in Huazhong University of Science and Technology (HUST) is in magnet machining, and will be assembled soon later. Difference between the ideal computation and practical measurement of the magnetic field is an important reference for magnet shimming. So in this paper, a further study on magnet field computation using FEM is implemented. By giving diverse boundaries and grid meshes, a quarter and a half models are

both calculated to make sure correctness of the ideal model. Besides, the research on magnet shimming is also carried out. A new shim tool based on an improved matrix method combining the multiple linear regression is developed to simulate the practical shimming process. With the aid of 3D finite element code and beam dynamics code, an iterative shimming process has been accomplished successfully. The results verify the feasibility and effectiveness of the shim tool.

MOPCP014 Activation of a 250 MeV SC-cyclotron for Protontherapy

Poster

03 Operational cyclotrons: developments and status

Jacobus Maarten Schippers, Daniela Candida Kiselev, Roland Luescher, Otmar Morath, Michael Wohlmuther (PSI, Villigen), Beat Amrein, Peter Frey, Markus Kostezer, Andre Schmidt, Gerwin Steen (PSI-LRF, Villigen, PSI)

PSI

Dedicated Cyclotrons of 230-250 MeV are used at protontherapy facilities since ~12 years. Beam losses at acceleration and extraction cause buildup of radioactivity in the cyclotron, having consequences for accessibility, service and decommissioning. At PSI a dedicated 250 MeV SC-cyclotron is used for proton therapy since 2007. The machine has been optimized to obtain a high extraction efficiency of over 80%. Apart from these losses, most other losses occur at a pair of phase slits at 21 cm radius. Here we report on a systematic study of the radioactivity at selected locations in the pole, the RF system and of some screws located near the median plane. The spectra of gamma rays emitted from iron plugs in the pole, copper disks in the liner and several screws have been measured with HPGe detectors. From these spectra the isotopic compositions have been derived and compared with activities calculated with the Monte Carlo transport code MCNPX. Dose rate measurements have been made as a function of time. The data and beam history of the cyclotron allow us predictions of the dose rate during service activities shortly after beam interruption as well as after a specified life time.

MOPCP015 Status of the HZB# Cyclotron: Eye Tumour Therapy in Berlin

Poster

03 Operational cyclotrons: developments and status

Andrea Denker, Christoph Rethfeldt, Joerg Roehrich (HZB, Berlin), Dino Cordini, Jens Heufelder, Roland Stark, Andreas Weber (Charite, Berlin)

HZB

The ion beam laboratory ISL at the Hahn-Meitner-Institut Berlin supplied light to heavy ions for solid state physics and medicine. Since 1998, eye tumours are treated with protons together with the University Hospital Benjamin Franklin, Charité. In 12/2006, ISL was closed and a Charité - HMI agreement was signed to continue the tumour therapy, to this day the only facility in Germany for eye treatments. We have now experienced the first three years under the new terms; treating more than 600 patients in that time. The main challenge is to supply protons for therapy with less man-power but keeping the same high reliability as before. A new injector for protons has been installed and commissioned. The conversion process is not yet finished. In general, the operation of the machine went smoothly. Only in spring last year, we had for the first time an interruption of the therapy due to a water leak in the RF system. In spite of major structural changes we could keep a high quality standard and even increased the number of treated patients per year. In addition to the routine

treatment, we established proton therapy of ocular tumours for very young children under general anaesthesia. # The new Helmholtz-Zentrum Berlin für Materialien und Energie has been formed by the merger of the former Hahn-Meitner-Institut Berlin (HMI) and the Berlin electron synchrotron BESSY

MOPCP016 Present Status of the RCNP Cyclotron Facility

Poster

03 Operational cyclotrons: developments and status

Kichiji Hatanaka, Mitsuhiro Fukuda, Mitsuru Kibayashi, Shunpei Morinobu, Keiichi Nagayama, Takane Saito, Hitoshi Tamura, Tetsuhiko Yorita (RCNP, Osaka)

RCNP

The Research Center for Nuclear Physics (RCNP) cyclotron cascade system has been operated to provide high quality beams for various experiments. In order to increase the physics research opportunities, the Azimuthally Varying Field (AVF) cyclotron facility was upgraded recently. A flat-topping system and an 18-GHz superconducting Electron Cyclotron Resonance (ECR) ion source were introduced to improve the beam's quality and intensity. A new beam line was installed to diagnose the characteristics of the beam to be injected into the ring cyclotron and to bypass the ring cyclotron and directly transport low energy beams from the AVF cyclotron to experimental halls. A separator is equipped to provide RI beams produced by fusion reactions at low energy and by projectile fragmentations at high energy. Developments have been continued to increase secondary beams as white neutrons, ultra cold neutrons, muons and unstable nucleri.

MOPCP017 New High Intensity Compact Negative Hydrogen Ion Cyclotrons

Poster

03 Operational cyclotrons: developments and status

Richard R. Johnson, David Du, William Gyles, Vasile Sabaiduc, Krishnan Suthanthiran (BCSI, Vancouver, BC), William Z. Gelbart (ASD, Garden Bay), Milo P. Conard (PAC sprl, Dion Valmont)

BCSI

Best Cyclotron Systems Inc (BCSI) has been established in Springfield, Virginia, US, for the design and production of commercial cyclotrons. The company is a subsidiary of Best Medical International renowned in the field of medical instrumentation and radiation therapy. Cyclotrons are manufactured and tested at Best Theratronics, Ottawa. BCSI is initially focusing on three different energy cyclotrons. All have four radial sectors with two dees in opposite valleys and simultaneous beam extraction on opposite lines. The BEST14p is designed for fixed 14MeV extraction 100μA internal upgradable to 400μA external ion source for PET isotopes and 99mTc production. The BEST35p is designed for variable energy extraction up to 35MeV and combined current in excess of 1.5mA. The BEST70p is designed for variable energy extraction up to 70MeV with a combined current of 800μA. It may be used as injector to a post-accelerator simultaneously with isotope production. BEST70p is most challenging given its present state of the art design. Design goals are total H^- vacuum or e.m. losses $\leqslant$2%; dee voltage increasing with radius from 60kV to 81kV; extracted beam emittance $<4\pi$ mm mrad.

MOPCP018 Experience of Cyclotron Operation with Beam Sharing At TSL, Uppsala

Poster

03 Operational cyclotrons: developments and status

Daniel van Rooyen, Konrad Gajewski, Björn Gålnander, Bengt LundstrÃ¶m, Mikael Pettersson, Alexander V. Prokofiev (TSL, Uppsala)

TSL

TSL (The Svedberg Laboratory) has a long history of producing beams of accelerated particles. Originally it was conceptualized as an accelerator for radioisotope production and nuclear chemistry by The(odor) Svedberg, and later used for nuclear physics, biological radiation effects and medical therapy with protons. A major upgrade during the 1980's with the extension of new experimental areas and a storage ring, the CELSIUS-ring, enabled the facility to get involved in new areas of nuclear physics, and neutron physics. The laboratory was restructured in 2005/2006 and the focus of activities was shifted towards, mainly, proton therapy and, in addition, radiation effects testing using protons and neutrons in a beam sharing mode. Specific attention will be given to a discussion of the development of a range of software utilities, for example switching of the beam between users by the principal user instead of being controlled via a cyclotron operator which naturally enables a much more effective use of beam time. A range of features were developed that enables the end user to easily and effectively evaluate the beam quality as well as some further specific beam characteristics.

MOPCP019 Present status of JAEA AVF cyclotron facility

Poster

03 Operational cyclotrons: developments and status

Takahiro Yuyama, Ikuo Ishibori, Tomohisa Ishizaka, Hirotsugu Kashiwagi, Satoshi Kurashima, Nobumasa Miyawaki, Takayuki Nara, Susumu Okumura, Watalu Yokota, Kenichi Yoshida, Yosuke Yuri (JAEA/TARRI, Gunma-ken)

JAEA/TARRI

The JAEA AVF cyclotron provides various ion beams mainly for research in materials science and biotechnology such as estimation of radiation hardness of space-use devices, and plant breeding by ion beams. We have been developing ion sources, the cyclotron, and beam irradiation techniques to meet requirements from users. In order to stabilize the beam intensity, power supplies for magnets were improved by installing a digital-to-analog converter (DAC) unit with a Peltier device for coil current control. As a result, coil current stability of main magnet of $\pm 5\times10^{-6}$ has been obtained by the renewed DAC unit which guarantees temperature control within 1°C at 30°C. Initially, it took about eight hours to form a heavy-ion microbeam, so it was impractical to change the microbeam ion species in an experiment. However, the microbeam of a 520 MeV 40Ar14+ has been successfully changed to the one of a 260 MeV 20Ne7+ within 30 minutes using a cocktail beam acceleration technique. A beam profile uniformization system using multipole magnets are being developed to enable uniform irradiation of a large sample at a constant particle fluence rate.

MOPCP020 Beam Extraction of the Heavy Ions from the U-400M cyclotron

Poster

03 Operational cyclotrons: developments and status

Oleg Borisov (JINR, Dubna, Moscow Region)

JINR

U400M is an isochronous cyclotron with pole diameter 4.0 m and 4 spiral sectors (maximal angle is equal 40 degrees). The parameters of the cyclotron: A/Z=2-10; W=6-100 MeV/amu. A new physical channel for heavy ions beam extraction with low energies (W=5.0-9.0 MeV/amu) is constracted. Numerical simulation results of the beam extraction by stripping from the cyclotron are presented. Calculation of the transport line parameters were carried out. Borisov O.N. et al.

MOPCP021 Automated Operation and Optimization of the VARIAN 250 MeV Superconducting Compact Proton Cyclotron

Poster

03 Operational cyclotrons: developments and status

Thomas Stephani, Uwe Behrens, Heinrich Röcken (VMS-PT, Bergisch Gladbach), Christian Baumgarten (PSI, Villigen)

VMS-PT

The 250 MeV superconducting compact proton cyclotron of Varian Medical Systems Particle Therapy (the former ACCEL) is specially designed for the use in proton therapy systems. During medical operation typically no operator is required. Furthermore, several automated control system procedures guarantee a fast, simple, and reliable startup and beam optimization after overnight shutdown or regular service actions. We report on the automated startup procedures, automated beam centering, and automated optimization of extraction efficiency. Furthermore we present an automated beam current setting as used during medical operation by means of an electrostatic deflector located at the cyclotron center at low beam energies.

MOPCP022 Present Operational Status Of NIRS Cyclotrons (AVF930,HM18)

Poster

03 Operational cyclotrons: developments and status

Mitsutaka Kanazawa, Satoru Hojo, Toshihiro Honma, Akinori Sugiura, Katsuto Tashiro (NIRS, Chiba-shi), Takashi Kamiya, Takanori Okada, Yuichi Takahashi (AEC, Chiba)

NIRS

Since Japanese government launched a new program of the “Molecular Imaging Research Program” in 2005, NIRS AVF930 cyclotron has been mainly operated to produce radio-isotopes together with a small cyclotron (HM18) for PET diagnosis. There is also machine operation of AVF930 for physical experiments and tests of radiation damage on electric devices. To carry out the cyclotron operations for these purposes, some improvements have been done in the facility. In this report, we will present recent operational status of NIRS cyclotron facility (AVF930, HM18).

MOPCP023 Status of KIRAMS-30 Commissioning

Poster

04 Facilities under construction

Kun Uk Kang, Dong Hyun An, Hong Suk Chang, Ga Ram Hahn, Bong Hwan Hong, Seong Seok Hong, Won Taek Hwang, In Su Jung, Joonsun Kang, Geun-Beom Kim, Min Yong Lee, Yeun-Soo Park, Tae-Keun Yang, Heejoong Yim (KIRAMS, Seoul)

KIRAMS

KIRAMS-30 cyclotron developed for radioisotope production and the fundamental material research was tested at a temporal building from 2007 to 2008. The beam current of 600 uA at a RF duty factor

of 55 % was measured at a internal beam stop. During the same period, sub systems which are composed of Ion Source, Low Energy Beam Transport line, RF system, and Main magnet were optimized and examined. The Cyclotron Application & Research facility (ARTI/KAERI, Korea) was completed in March 2009. KIRAMS-30 was reinstalled and then the beam commissioning progress has been made since November 2009. The first proton beams with energies from 15 to 30 MeV were extracted in June 2010. In this paper, we report the results obtained during commissioning.

MOPCP024 Development of RF Cavity for 8 MeV Sector Focused Cyclotron

Poster

04 Facilities under construction

Jin Hwan Oh, Jong-Seo Chai, Khaled Mohamed Gad, Hyun Wook Kim, Byeong-No Lee, Jin-Ah. Park., HoSeung Song (SKKU, Suwon)

SKKU

RF system is one of the most important part for producing good and efficient accelerator system. The national project which is named KoRIA(Korea Rare Isotopes Accelerator) is on progress. The KoRIA is mainly focusing on the production of radioactive heavy ion. The ion beam will be derived by a K100 SSC cyclotron. 8 MeV SF cyclotron which produces 8 MeV proton beam is used as injectorof K100 SSC cyclotron. In this paper, we designed RF system including RF cavity. The total specification of system is on the following. The frequency of this RF system is 70 MHz. Also we applied 4th harmonic, dee voltage of 50KV. We simulated the RF system using commercially available simulator, CST Microwave studio and Particle studio KEYWORDS : Cyclotron, , RF system

MOPCP025 Construction of New Injector LINAC at RIBF

Poster

04 Facilities under construction

Kazunari Yamada, Shigeaki Arai, Masaki Fujimaki, Tadashi Fujinawa, Nobuhisa Fukunishi, Akira Goto, Yoshihide Higurashi, Eiji Ikezawa, Osamu Kamigaito, Masayuki Kase, Misaki Komiyama, Keiko Kumagai, Takeshi Maie, Takahide Nakagawa, Jun-ichi Ohnishi, Hiroki Okuno, Naruhiko Sakamoto, Kenji Suda, Hiroshi Watanabe, Yutaka Watanabe, Yasushige Yano, Shigeru Yokouchi (RIKEN Nishina Center, Wako), Yoichi Sato (KEK, Ibaraki), Hiroshi Fujisawa (Kyoto ICR, Uji, Kyoto)

RIKEN Nishina Center

A new additional linac injector called RILAC2 has been constructed at the RIKEN Nishina Center so that RIBF experiments and synthesis of super-heavy element can be carried out independently. The RILAC2 consists of a 28-GHz superconducting ECR ion source (SC-ECRIS), a low-energy beam transport with a prebuncher, a four-rod RFQ linac, three drift-tube linac tanks (DTL1-3), a rebuncher between the RFQ and DTL1, and strong quadrupole magnets that were placed between the rf resonators for the transverse focusing. Very heavy ions with mass-to-charge ratio of 7, such as 136Xe20+ and 238U35+, are accelerated up to an energy of 680 keV/u in the cw mode and injected into the RRC without charge stripping. The rf resonators excluding the pre-buncher are operated at a fixed rf frequency of 36.5 MHz, whereas the pre-buncher is operated at 18.25 MHz. The basic design of the RILAC2 was finished in 2006 and the construction has started since the budget was approved at the end of FY2008. The SC-ECRIS is installed in a new room, and other equipments are placed in the

existing AVF-cyclotron vault. This contribution mainly presents the details of the construction of linac part.

MOPCP026 Beam Extraction System for CYCIAE-14

Poster

04 Facilities under construction

Sumin Wei, Shizhong An, Weiping Hu, Ming Li, Yinlong Lu, Lipeng Wen, Huaidong Xie, Jiansheng Xing, Zhiguo Yin, Tianjue Zhang (CIAE, Beijing)

CIAE

A 14MeV medical cyclotron is under design and construction at CIAE, and H- ion will be accelerated and extracted by carbon stripper in dual opposite direction. Two stripping points are chosen in each extracting direction to extract proton beams to different targets or beam lines to extend the use of the machine. Two modes have been considered for the extraction system. One is designed to be installed on the wall of the vacuum cavity, and the other is designed to be inserted vertically from the sector poles. The final choice depends on the agility, simplicity and results of the experimentation. The angle between the stripper and the beam orbit is optimized to improve the extracted beam quality. The results of numerical simulation show the two stripping points at each extraction direction, the beam orbit and the beam characteristic at each extraction direction. The comparison of the beam envelope of different stripper azimuth is also presented in this paper to show the influence of the stripper azimuth. Based on the concept design, the mechanical design and the experimentation of the DC motor in magnetic field have been conducted, with the results shown in the paper as well.

MOPCP027 Preliminary Study on a Compact High Field Superconducting Isochronous Cyclotron K250-42

Poster

04 Facilities under construction

Jiexi Zhang, Timothy A. Antaya (MIT/PSFC, Cambridge, Massachusetts)

MIT/PSFC

A preliminary study has been carried out for a compact high field superconducting isochronous cyclotron, K250-42, designed as a proof-of-principle for a single stage high power proton accelerator. This cyclotron is to accelerate proton to a final energy of 250 MeV with two 45 degree dees within a radius of 40 cm. By employing a 40 mA external ECR proton source, the injected proton beam currents at high brightness are foreseen. Using phase selection in the center, a fully magnetized elliptical pole, a low energy gain per turn, a precise relation between momentum and radius at large radius are expected. It is the goal of this experiment to use this relationship to develop multi-turn extraction with passive elements only, to achieve a high external proton beam intensity (~1 mA). It is an additional goal to see if it is possible to achieve a high extraction efficiency ($\geqslant$ 99.9%), with an energy spread |E/E| $\leqslant$ 0.1%. The RF acceleration is on the first harmonic with $\omega rf = \omega 0$ = 84.5 MHz. Superconductor coils will provide a central field of B0 = 5.5 T and a peak hill field of 7 T. The present status of the beam dynamics design of the K250-42 will be presented. US Defense Threat Reduction Agency

MOPCP028 Facility for Modification and Analysis of Materials with Ion Beams (FAMA)

Poster

04 Facilities under construction

Aleksandar Slobodan Dobrosavljević, Petar Beličev, Viktor Jocic, Nebojsa Neskovic, Ivan Milos Trajić, Velibor Vujović, Ljubisa T Vukosavljevic (VINCA, Belgrade)

VINCA

The facility for modification and analysis of materials with ion beams (FAMA) is the low energy part of the TESLA Accelerator Installation, in the Vinča Institute of Nuclear Sciences, Belgrade, Serbia. It presently comprises two machines: a heavy ion source (M1) and a light ion source (M2), and two experimental channels: a channel for analysis of ion beams (C1) and a channel for surface modification of materials (C2). In April 2009 the Vinča Institute signed a contract with the Joint Institute for Nuclear Research, Dubna, Russia, on the upgrading of FAMA. The contract comprises: (i) the refurbishment of the M1 and M2 machines and the C1 and C2 channels, (ii) the construction of a channel for ion implantation (C3) and a channel for deeper modification of materials (C4), (iii) the construction of a small isochronous cyclotron (M3), and (iv) the construction of a channel for analysis of materials in vacuum (C5) and a channel for analysis of materials in air (C6). This presentation is devoted to the upgraded FAMA and its research program.

MOPCP029 The Physics Design of Magnet in CYCIAE-14

Poster

04 Facilities under construction

Junqing Zhong, Tao Cui, Ming Li, Yinlong Lu, Jiansheng Xing, Tianjue Zhang (CIAE, Beijing)

CIAE

Based on the successful experience achieved on the design and construction of the Central Region Model (CRM) cyclotron, another cyclotron has been designed and being built to produce 18F and 99m Tc etc. The 14MeV compact cyclotron, CYCIAE-14, has been chosen considering the relationship between proton energy and the reaction sector of production in radioactivity nuclide. The design of main magnet and result of beam dynamics in CYCIAE-14 will be described in this paper. The distribution of magnetic field in median plane is simulated by FEM, and the effect of parts in magnet on the magnetic field will be analyzed to optimize the magnet construction.

MOPCP030 The Injection Line and Central Region Design of CYCIAE-70

Poster

05 Projects and proposals

Ming Li, Xianlu Jia, Yinlong Lu, Chuan Wang, Jianjun Yang, Hongjuan Yao, Tianjue Zhang (CIAE, Beijing)

CIAE

A compact cyclotron CYCIAE-70 is under design at CIAE capable of providing both 70MeV, 700μA H^- beam and 35MeV, 40μA D^- beam. Both beams are produced by a single external multicusp ion source, injected axially with a transport line and bent onto the median plane through a spiral inflector. The injection line utilizes two solenoids and a quadruple triplet for transverse focusing and a buncher to increase the injection efficiency. The beam optics design is performed using TRANSOPTR, taking into account space charge effects and neutralization. The inflector is capable of bending both H^- and D^- beams with a transmission efficiency of over 80%. The central particles are tracked backwards to

obtain the initial reference orbit of the first several turns. The electrode structures and the shape of Dee tips are then optimized to achieve matching at the inflector exit and to maximize the acceptance of central region. The central region is capable to accept both beams without component replacement. The preliminary design results of the injection line, spiral inflector and center region are elaborated, and the beam matching from the ion source to the central region is presented.

MOPCP031 Physics Design and Calculation of CYCIAE-70 Extraction System

Poster

05 Projects and proposals

Shizhong An, Fengping Guan, Ming Li, Guofang Song, Chuan Wang, Sumin Wei, Fang Yang, Tianjue Zhang, Junqing Zhong (CIAE, Beijing)

CIAE

A cyclotron functioning as a driver with beam power of 50kW (70 MeV, 0.75 mA) based on compact H- cyclotron, CYCIAE-70, has been designed at CIAE in Beijing for the RIB production and application in the field of nuclear medicine recently. CYCIAE-70 is designed to be a dual particle cyclotron capable of delivering proton with energy in the range 35~70 MeV and deuteron beam with energy in a range of about 18~33 MeV. About 700 A for H+ and 40 A for D+ will be extracted in dual opposite directions by charge exchange stripping devices and the extraction beam energy is continuously adjustable. The physics design of CYCIAE-70 stripping system has been done and the optics calculations for the extraction proton and deuteron beam have been finished. The dispersion effects for the extracted beam are analyzed and the beam parameters after extraction are calculated with multi-particle tracking code COMA.

MOPCP032 Design Study of 8 MeV Cyclotron as injector for K100 SSC

Poster

05 Projects and proposals

Byeong-No Lee, Jong-Seo Chai, Khaled Mohamed Gad, Hyun Wook Kim, Jin Hwan Oh, Jin-Ah. Park., HoSeung Song (SKKU, Suwon)

SKKU

The 8MeV cyclotron was designed for injection of K=100 Separated Sector Cyclotron(SSC). It has four magnet sectors with pancake type and maximum magnetic fields is 1.9 T. The magnet adopting 4 harmonics has three kind of holes for beam injection, vacuum pumps and RF systems. The pole diameter was chosen about 70 cm with 50kV dee-voltage and 35° dee-angle. The ion-source of this accelerator consists of a double gap buncher, Solenoid Qaudrupole Qaudrupole(SQQ) and a spiral inflector. It will provide a 4~8 MeV, ~1 mA of proton beams and 2~4 MeV, ~1mA of deuteron ion beam. In this paper we will describe the conceptual design of this machine including the design of magnet, beam dynamics and RF system, etc. KEYWORDS : Cyclotron, Magnet, RF system, SSC, SQQ Ministry of Education, Science and Technology, Republic of Korea Department of Energy Science and School of Information and Communication Engineering of SungKyunKwan University

MOPCP033 Magnet Design of 70 MeV Separate Sector Cyclotron (KoRIA)

Poster

05 Projects and proposals

Khaled Mohamed Gad, Jong-Seo Chai, Hyun Wook Kim, Byeong-No Lee, Jin Hwan Oh, Jina Park,

HoSeung Song (SKKU, Suwon)
SKKU

A k=100 separated sector cyclotron is being designed in SKKU university, South Korea, this cyclotron is considered the main drive for ISOL to produce ~ 70-100 MeV proton beam and ~35-50 MeV deuteron beam for production of radioactive material as a basic nuclear research, in this paper we will describe Opera 3D (Tosca) numerical simulation for determining the basic magnet parameters, magnet material, deformation , imperfection fields and preliminary ion beam dynamics study for verifying the focusing properties of the designed magnet "Cyclotron","Magnet Design","FEM simulation",etc., Ministry of Education, Science and Technology, Republic of Korea Department of Energy Science and School of Information and Communication Engineering of SungKyunKwan University

MOPCP034 Beam Optics Study of a Fragment Separator for the Planned Rare Isotope Beam Facility in Korea

Poster

09 Beam dynamics Weishi Wan (LBNL, Berkeley, California), Youngho Park (NCC, Goyang, Kyeonggi), Jong-Won Kim (NCC, Korea, Kyonggi)
NCC, Korea

A heavy-ion accelerator facility based on linear accelerator is planned in Korea. The facility is designed to provide high-current radioisotope beams with various users. The primary beam energy is in the range of a few hundreds of MeV/u. The major mechanism to produce isotope beams is in-flight fragment separation. The rare isotope beams are to be utilized in the fields of nuclear, material and biomedical sciences. The separator system should have high mass resolution to identify and separate rare isotopes of interest, and also large momentum and angular acceptances for maximal utilization of produced isotopes. We are considering improved beam optics design to realize such a system, where all second order aberrations are corrected. The study has been performed mainly using COSY Infinity, and the results will be presented.

MOPCP035 Simulation of Injection System of the KIRAMS-430 Superconducting Cyclotron

Poster

09 Beam dynamics

Dong Hyun An, Bong Hwan Hong, In Su Jung, Joonsun Kang, Kun Uk Kang (KIRAMS, Seoul)
KIRAMS

The KIRAMS-430 cyclotron for a particle therapy is K=1720 superconducting cyclotron with the pole radius of 2.0 m and now under design at KIRAMS, Korea. The cyclotron accelerates ions with the charge-to-mass ratio of 0.5 to 430 MeV/u. The magnetic field at the center of the cyclotron is about 2.3 Tesla. Ion beams generated from the ECR ion source are transported to the bottom of the cyclotron with the low energy beam transport line and then axially injected through the hole of cyclotron yoke in the center. The spiral inflector makes the beam bend into the median plane of the cyclotron. After passing through the spiral inflector, ion beams are accelerated and focused in center region. This paper presents the design parameters of the low energy beam transport line, the spiral inflector and the central region of the KIRAMS-430 superconducting cyclotron and also the results of the beam simulations. This work is supported by the Ministry of Education, Science and Technology, Korean government, through its National Nuclear Technology Program (2010-0003339).

MOPCP036 Radiation in the Scheme of Cyclotron with Gap

Poster

09 Beam dynamics

Zhandos Berikkaliuly Seksembayev (ENU, Astana)

ENU

The model of the cyclic accelerator with constant radius is supposed. The strong magnet serves for focusing and keeping on the orbit of particles. That is at the slightest deviation it should return particles into an orbit. If now just before a swing zone (which we allocate) we have a gap of small sizes at which particles don't test action of fields, particles that pass the gap have a deviation from an orbit. In the gap particles move on a straight line of a tangent being continuation to an orbit at the moment when they enter gap. Having passed the gap particles again will enter into an operative range of focusing magnets. Because of they are originally rejected from a trajectory, the action of magnets will cause oscillations in a cross direction. Oscillations will have quickly fading character with the subsequent brake radiation. Thus, the shake-up of particles turns out. Energy of radiation depending on parameters of system and size of a gap from the point of view of classical electrodynamics is calculated. Also oscillations of particles in a cross direction are viewed.

MOPCP037 Central Region Design of a Baby Cyclotron

Poster

09 Beam dynamics

Xiaozhong He (TUB, Beijing), Kaizhi Zhang (CAEP/IFP, Mainyang, Sichuan)

TUB

Baby cyclotrons are widely used in short lived beta+ radioactive isotope production for PET. Central region design is one of the most important part of the design work of the cyclotron. Central region design, including design process and design results is presentd in this paper.

MOPCP038 Design Optimization of the Spiral Inflector for a High Current Compact Cyclotron

Poster

09 Beam dynamics

Animesh Goswami, Vijay Shanker Pandit, Paritosh Sing Babu (DAE/VECC, Calcutta)

DAE/VECC

VECC is developing a 10MeV, 5 mA compact proton cyclotron. 80 keV protons from a 2.45 GHz microwave ion source will be injected axially in the central region by a spiral inflector. Because of the high injection energy, the inflector will be comparatively large in size. In order to avoid the beam blow up due to space charge effect and to accommodate the inflector in the small available space in the central region, the design and optimization of the inflector parameters require special attention. This paper describes the design of the spiral inflector and studies its optical properties in the presence of space charge. The beam trajectory calculation from the entrance of the spiral inflector to the central region of the cyclotron have been carried out using the magnetic field data obtained from a 3D code and the electric field data from RELAX3D. We have also checked the orbit centering of the injected beam using a central region code. We have evaluated the effect of linear space charge and carried out optimization of the input beam parameters to minimize the coupling effects between two transverse planes at the inflector exit and to match the acceptance of the central region.

MOPCP039 Transverse Phase Space Tomography in TRIUMF Injection Beamline

Poster

09 Beam dynamics

Yi-Nong Rao, Richard Baartman (TRIUMF, Vancouver)

TRIUMF

By tomography is meant the reconstruction of a 2-dimensional distribution from a number of 1-dimensional projections. In the case of transverse phase space, one records many profiles while varying a focusing device such as a quadrupole. Our aim was to investigate the two transverse phase space distributions in our 300keV H-minus beamline. We performed a series of measurements of beam profiles as a function of the voltage of an electrostatic quadrupole and used these along with the corresponding calculated transfer matrices in an iterative program based upon the Maximum Entropy algorithm, to find the phase space distributions. As well, we made measurements using an Allison-type emittance scanner to scan both planes. In this paper we present the details of these measurements, calculations, and we compare the two techniques. TRIUMF receives funding via a contribution agreement through the National Research Council of Canada.

MOPCP040 A Mathematical Model and New Improvement for Cyclotrons

Poster

09 Beam dynamics

Richard Kriske (University of Minnesota, Minneapolis, Minnesota)

University of Minnesota

The author believes that a slight change to the modeling of Cyclotrons could yield some improvement in the beam dynamics and further the capacity of the Cyclotron.

MOPCP041 Beam Tuning in Kolkata Superconducting Cyclotron

Poster

09 Beam dynamics

Malay Kanti Dey, Rakesh Kumar Bhandari, Uttam Bhunia, Jayanta Debnath, Atanu Dutta, Chaturanan Mallik, Md. Zamal Abdul Naser, Santanu Paul, Jedidiah Pradhan (DAE/VECC, Calcutta)

DAE/VECC

The Superconducting cyclotron at VECC, Kolkata, has accelerated ion beams up to extraction radius successfully confirmed by the neutrons produced by the nuclear reactions. The internal beam tuning process started with beam parameters calculated using the measured magnetic field data. Due to some mechanical and electrical problems we were forced to tune the beam with three major trim coils off. Accurate positioning of central region Dee-extensions ensuring the proper acceleration gaps in the first turn was required for successful acceleration of beam through the compact central region clearing the posts in the median plane. Here we present different aspects and results of initial beam tuning.

MOPCP042 Determination of Isochronous Field Using Magnetic Field Map

Poster

09 Beam dynamics

Nikolay Kazarinov, Oleg Borisov, Vladimir Kazacha (JINR, Dubna, Moscow Region)

JINR

In this work a new scheme for calculation of a cyclotron isochronous field using the previously calculated or measured map of the cyclotron magnetic field in its median plane is adduced. The calculating map of the cyclotron magnetic field was set by the matrix having the dimensions 201x181. The flutter part of the magnetic field obtained by subtraction of the zero azimuth harmonic from the magnetic field values were calculated in all net nodes. The magnetic rigidity value in the equation for the particle radius versus the angle was replaced by product of the mean radius and mean along the closed orbit magnetic field. The flutter function was interpolated with the help of the third order Lagrange's polynomials using 16 nodes of the net. At every given radius with the help of the nonlinear simplex method of optimization one can find such value of the isochronous field when the particle path is enclosed with accuracy of 10-9. The results of the fulfilled calculations for the cyclotron DC-110 and their comparison with results of other calculations are given.

MOPCP043 Modification of the Center Region in the RIKEN AVF Cyclotron for Acceleration at the H=1 RF Harmonics

Poster

09 Beam dynamics

Sergey Vorozhtsov (JINR, Dubna, Moscow Region), Victor Smirnov (JINR/DLNP, Dubna, Moscow region), Akira Goto (RIKEN Nishina Center, Wako)

JINR

A highly advanced upgrade plan of the RIKEN AVF cyclotron is under way. The study is focused on the formulation of the new acceleration regimes in the AVF cyclotron by detailed orbit simulations. The expansion of the acceleration energy region of light ions towards higher energies in the existing RF harmonics equal to 2, and the modification of the center geometry for the RF harmonics equal to 1 to make it possible an acceleration of protons at several tens of MeV are considered. The substantial redesign of the center electrode structure is needed to accelerate protons with reasonable values of the dee voltages. The new inflector geometry and the optimized center electrode structure have been formulated for the upgrade. JINR/DLNP, Dubna, Russia, and RIKEN, Wako, Japan

MOPCP044 New Magnetic Einzel Lens and its Beam Optical Features

Poster

09 Beam dynamics

Md Haroon Rashid, Rakesh Kumar Bhandari, Chaturanan Mallik (DAE/VECC, Calcutta)

DAE/VECC

Magnetic cylindrical lens is used mostly in beam lines to focus and transport low energy beam. It is well known that focusing power of a magnetic solenoid lens depends on the ratio of particle momentum and electric charge. A solenoid rotates also an ion beam while focusing it and the phase space areas of the beam in x- and y-plane get entangled and increased. The paper reported here describes an effort to design a new magnetic Einzel lens using a pair of Glaser lens in anti-solenoid mode for the first time to get zero rotation of the exit beam. Analytical formulae have been generated to deduce the scalar magnetic potential and field along the central axis of the lens. Thereafter, beam optics and particle tracking is done using the combined field of a pair of Glaser Lenses constituting the magnetic Einzel lens. The required focusing power of the designed lens is achieved for a beam of given rigidity.

MOPCP045 Towards Quantitative Predictions of High Power Cyclotrons

Poster

09 Beam dynamics

Yuanjie Bi (CIAE, Beijing; PSI, Villigen; Tsinghua University, Beijing), Jianjun Yang, Tianjue Zhang (CIAE, Beijing), Andreas Adelmann, Rudolf Dölling, Martin Humbel, Werner Joho, Mike Seidel (PSI, Villigen), Chuanxiang Tang (TUB, Beijing)

CIAE

The large and complex structure of cyclotrons poses great challenges in the precise simulation of high power beams. However, such simulation capabilities are mandatory in the design and operation of the next generation high power proton drivers. The powerful tool OPAL enables us to do large scale simulations including 3D space charge and particle matter interactions. A large scale simulation effort is presented in the paper, which leads to a better quantitative understanding of the existing PSI high power proton cyclotron facility and predicts the beam behavior of CYCIAE-100 under construction at CIAE. The beam power of 1.3 MW delivered by the PSI 590 MeV Ring Cyclotron together with stringent requirements regarding the controlled and uncontrolled beam losses poses great challenges to predictive simulations. The comparisons with measurements show that OPAL can precisely predict the radial beam pattern at extraction with large dynamic range (3-4 orders of magnitude). The new particle matter interaction model is used to obtain necessary beam loss statistics during the acceleration. This data is indispensable in the design of an efficient collimation system in CYCIAE-100.

MOPCP046 Status Report of the On-Line Ion Source at IMP- LECR3

Poster

10 Ion sources, strippers and targets

Yucheng Feng, Yun Cao, Xiaohong Guo, Jinyu Li, Xixia Li, Shuhao Lin, Wang Lu, Baohua Ma, Hongyi Ma, Shan Sha, Yong Shang, Hui Wang, Wenhui Zhang, Xuezhen Zhang, Hongwei Zhao, Huanyu Zhao (IMP, Lanzhou), Liangting Sun (IMP, Lanzhou; NSCL, East Lansing, Michigan)

IMP

LECR3 (Lanzhou Electron Cyclotron Resonance ion source No. 3) source was designed and built at Institute of Modern Physics to produce intense heavy-ion beams with middle and high charge states. The axial mirror and radial sextupole magnetic fields of the source are produced by solenoid coils and NdFeB permanent magnets, respectively. The typical technical parameters are shown in Table 1. Typical results of 235 eμA O7+, 30 eμA Ar14+, 160 eμA 129Xe20+ and 6 eμA 129Xe30+ had been obtained. Since June 2005, LECR3 has been run to provide intense multiply charged ion beams for HIRFL (Heavy Ion Research Facility in Lanzhou) for 33,000 hours. The ion beam species delivered by LECR3 includes H, C, N, O, F, Ne, S, Ar, Kr and Xe, and metallic ion beams of Be, Mg, Ca, Ni, Pb and U as well. The typical results of 3-10eμA of 9Be4+, 60 eμA 24Mg7+, 34 eμA 58Ni15+ and 5.5 eμA 238U26+ had been delivered with oven technique. Since 2009, LECR3 has been upgraded, which included the replacement of the sextupole magnets, the improvement of the interlock, control and alarm systems of the source. With the upgrade, the source could be operated with long-term stability.

MOPCP047 Analysis of Beam Quality Optimization of Bucket Ion Source

Poster

10 Ion sources, strippers and targets Yahong Xie, Chundong Hu, Caichao Jiang, Lizhen Liang, Sheng Liu, Yuanlai Xie (ASIPP, Hefei)

ASIPP

The bucket ion source is widely used as the high energy beam source on the high power neutral beam injector system. A hot cathode bucket ion source is studied for the diagnostic neutral beam injector. The main parameters which influence the performance of bucket ion source are arc voltage, filament voltage, gas inlet rate and extracted voltage. In the experiment, only one parameter setting is varied when other parameter settings are fixed. The characteristics of ion source are got and the parameters setting valve are as follows: four filaments current from 500 A to 550 A, arc voltage from 120 V to 200 V, and ion source pressure during discharge is from 2.0 mTorr to 4.5 mTorr, extracted voltage from 40kV to 50kV. The arc current is higher than 100 A, and extracted beam current can reaches 6 A. Based on this, the arc efficiency, beam power deposition and beam proton ratio of ion source are analyzed and optimized. The proton ratio of extracted beam increased from 28 % to 40 %. It is very useful for the experimental operation and study about the bucket ion source. The National Nature Science Foundation of China (contract number: 10875146)

MOPCP048 Status Report of the Superconducting Electron Cyclotron Resonance Ion Source SECRAL

Poster

10 Ion sources, strippers and targets

Wang Lu, Yun Cao, Yucheng Feng, Xiaohong Guo, Jinyu Li, Xixia Li, Shuhao Lin, Baohua Ma, Hongyi Ma, Shan Sha, Yong Shang, Hui Wang, Wenhui Zhang, Hongwei Zhao, Huanyu Zhao (IMP, Lanzhou), Liangting Sun (IMP, Lanzhou; NSCL, East Lansing, Michigan)

IMP

SECRAL (Superconducting Electron Cyclotron Resonance with Advanced design in Lanzhou) is a fully superconducting ECR ion source designed for the production of intense highly charged heavy ion beams to meet the requirement of HIRFL (Heavy Ion Research Facility in Lanzhou). SECRAL, with a novel superconducting magnet structure of solenoid inside sextupole, was established in 2005 and has been put into routine operation at 18GHz or 18GHz+14.5GHz double frequency for HIRFL since May 2007. The total operation time of SECRAL served as the injector of HIRFL amounted to over 2000 hours and 129Xe27+, 78Kr19+, 209Bi31+, 58Ni17+ were delivered. To further enhance the performance of SECRAL, a 24GHz/7kW gyrotron microwave generator was installed and the first plasma of 24GHz with an aluminum chamber was acquired in July 2009. After a few weeks' commissioning, some exciting results were produced, such as 455euA of 129Xe27+ and 45euA of 129Xe35+. In order to enhance the operation efficiency of SECRAL, a liquid helium closed-cycle system has been designed and constructed by the end of 2009, the preliminary test has been carried out and further improvements are in process.

MOPCP049 Ion Source Related Research Work at JYFL

Poster

10 Ion sources, strippers and targets

Hannu Koivisto, Vesa Aho, Juha Eerik Arje, Taneli Kalvas, Janne Aleksi Kauppinen, Jani Kommpula,

Olli Tarvainen, Ville Aleksi Toivanen (JYFL, Jyvaskyla), Alessio Galatà (INFN/LNL, Legnaro (PD)), Luigi Celona, Santo Gammino, David Mascali (INFN/LNS, Catania), Tommi Ropponen (JYFL, Jyvaskyla; NSCL, East Lansing, Michigan)
JYFL

In this article the work of the JYFL ion source group will be presented. New bremsstrahlung measurements were carried out in order to compare the results with different electron heating models, especially defining the endpoint energy of the bremsstrahlung spectra. A project to obtain new information about the ion temperatures and their time evolution has been initiated. The study will be performed using spectroscopic techniques measuring the ion temperature through the Doppler broadening of emission lines. The objective is to reveal accurate information about the time evolution of highly charged ions in the ECRIS plasma. The work also includes frequency tuning experiments, beam quality experiments and tests with a so-called collar structure. The beneficial effect of collar was first tested and noticed with the ECR ion sources by the KVI ion source group and has been shortly confirmed at JYFL in collaboration with the KVI research group. The JYFL ion source group is also developing a low energy electron gun for the spacecraft applications. The results of the development work can possibly be applied also with the ion sources in order to increase the density of cold electrons.

MOPCP050 Studies of ECRIS Ion Beam Formation and Quality at the Department of Physics, University of Jyväskylä

Poster

10 Ion sources, strippers and targets

Ville Aleksi Toivanen, Vesa Aho, Juha Eerik Arje, Janne Aleksi Kauppinen, Hannu Koivisto, Olli Tarvainen (JYFL, Jyvaskyla), David Mascali (CSFNSM, Catania; INFN/LNS, Catania), Alessio Galatà (INFN/LNL, Legnaro (PD)), Luigi Celona, Giovanni Ciavola, Santo Gammino (INFN/LNS, Catania), Tommi Ropponen (NSCL, East Lansing, Michigan)
JYFL

During the last couple of years a lot of effort has been put into studies concerning the ion beam formation and beam quality of electron cyclotron resonance ion sources (ECRISs) at the Department of Physics, University of Jyväskylä (JYFL). The effects of microwave frequency fine tuning on the performance of JYFL 14 GHz ECRIS have been studied with multiple experiments in collaboration with INFN-LNS (Instituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud). Also, a number of measurements have been carried out to study the effects of space charge compensation of ion beams on the beam quality. In order to proceed further with these studies, a modified version of the beam potential measurement device developed at LBNL (Lawrence Berkeley National Laboratory) is under development. Simulations are used to study the possibility to improve the beam quality by biasing the beginning of the beam line upstream from m/q separation. With high voltage biasing the beam energy could be increased temporarily over the limit of the injection system of the accelerator. Latest results and current status of these projects will be presented and discussed.

MOPCP051 Ion Sources and Their Transport Line at RCNP

Poster

10 Ion sources, strippers and targets

Tetsuhiko Yorita, Mitsuhiro Fukuda, Kichiji Hatanaka, Mitsuru Kibayashi, Shunpei Morinobu,

Atsushi Tamii, Hitoshi Tamura (RCNP, Osaka)
RCNP

The upgrade program of the AVF cyclotron is in progress at Research Center for Nuclear Physics (RCNP), Osaka Univ., for improving the quality, stability and intensity of accelerated beams. An 18 GHz superconducting ECRIS has been installed to increase beam currents and to extend the variety of ions, especially for highly charged heavy ions which can be accelerated by RCNP cyclotrons. The production development of several ion like B, C - Xe by gas mixing or MIVOC has been done. In order to extend the variety of ions more, metal viper or spatter system has also been installed to 10GHz NEOMAFIOS with minimum modifications. The modification for transport line for injection to AVF is in prograss to improve the beam intensity and quality. The details of these recent developments will be presented.

MOPCP052 Metal Ion Production with Oven Method at IMP

Poster
10 Ion sources, strippers and targets
Yun Cao (IMP, Lanzhou)
IMP

The production of metal ion beams is one of key issues for Electron Cyclotron Resonance Ion Sources due to the growing demand of accelerators for metal ion beams. During the most common methods to produce the ion beams from solid materials, i.e. oven, sputtering and MOVIC methods, we prefer the oven technique in order to maximize the production of metallic ions with high charge states and minimize the contamination in the ion source at the same time. Various ovens were designed aiming at the production of different metal ion beams. With these ovens, the ion beams of Ca, Be, Mg, Bi and Ni et al have been produced and delivered to the accelerator successfully. An oven with a demonstrated operating temperature up to 2000℃ is being developed specially for the introduction of metals with very high melting points, the goal of which is the reliable operation at 2000℃ for several days. The up-to-date status of this work will be presented in this paper.

MOPCP053 ECR Ion Source Development at the AGOR Facility

Poster
10 Ion sources, strippers and targets
Vladimir Mironov, Johannes P.M. Beijers, Sytze Brandenburg, Herman R. Kremers, Jan Mulder, Suresh Saminathan (KVI, Groningen)
KVI

This paper reports on recent work to improve the performance of the 14 GHz KVI-AECR ion source, which is used as an injector for the AGOR cyclotron. We have installed stainless-steel screens at the injection and extraction sides and an additional collar around the extraction aperture resulting in better plasma stability and an increase of extracted ion currents. Stability and output are also improved by the use of additional RF power at 12 GHz. Source tuning is aided by continuously observing the visible light output of the plasma through the extraction aperture with a ccd camera. We now routinely extract 700 microAmp of O6+ and 50 microAmp of Pb27+ ions. Source optimization is supported by extensive computational modeling of the ion transport in the low-energy beam line and measuring the transverse emittance of the extracted ion beam with a pepperpot emittance meter. These efforts have shown that second-order aberrations in the analyzing magnet lead to a significant increase of the

effective beam emittance. Work to compensate these aberrations is underway This work is supported by the European Union through EURONS, contract 506065 and the "Stichting voor Fundamenteel Onderzoek der Materie" (FOM).

MOPCP054 RF System Design of the K1720 Superconducting Cyclotron for a Particle Therapy

Poster

11 Radio frequency systems

In Su Jung, Dong Hyun An, Ga Ram Hahn, Bong Hwan Hong, Joonsun Kang, Kun Uk Kang, Geun-Beom Kim, Tae-Keun Yang (KIRAMS, Seoul)

KIRAMS

KIRAMS (Korea Institute of Radiological & Medical Sciences) has designed the K1720 superconducting cyclotron for a particle therapy. This cyclotron will be able to accelerate carbon and proton with a charge to mass ratio of 1/2. It is designed to use two normal conduct RF cavities. The resonant frequency of the ions is 17.755MHz through magnet design and beam dynamics. The resonant frequency is 71.02MHz because of 4th harmonic mode. By computer simulation codes the principle design parameters of the RF system were estimated and the electric and the magnetic field distribution were simulated.

MOPCP055 Development of RF Cavity for 70 MeV Separated Sector Cyclotron

Poster

11 Radio frequency systems

HoSeung Song, Jong-Seo Chai, Khaled Mohamed Gad, Hyun Wook Kim, Byeong-No Lee, Jin Hwan Oh, Jina Park (SKKU, Suwon)

SKKU

RF system is one of the most important key for producing good and efficient acceleration system. The national project which is named KoRIA (Korea Rare Isotopes Accelerator) is on progress. The KoRIA is mainly focusing on the production of radioactive heavy element. The ion beam will be derived by a K100 SSC cyclotron for production of 70-100 MeV proton beam and 35-50 MeV deuteron beam. In this paper, we designed RF system including RF cavity. The overall specification of system is on the following. The frequency of this RF system is 70 MHz. Also we applied 4th harmonic number, dee voltage of 150 KeV. We simulated the RF system with CST Microwave Studio, and CST Particle Studio. "RF system", "Cyclotron", "Cavity", "CST Microwave Studio"

MOPCP056 Development of Flat-top Accelerated Beam and Analysis of Harmonic Voltages for the RCNP AVF Cyclotron

Poster

11 Radio frequency systems

Mitsuhiro Fukuda, Kichiji Hatanaka, Takane Saito, Hitoshi Tamura, Tetsuhiko Yorita (RCNP, Osaka), Satoshi Kurashima (JAEA/TARRI, Gunma-ken)

RCNP

An upgrade program of the RCNP cyclotron facility is in progress for increase of beam intensity and improvement of beam quality. The effects of the flat-top(FT) acceleration using the seventh-harmonic voltage were confirmed for a 44 MeV deuteron beam. The energy spread was improved from 42 to 32 keV FWHM by the FT acceleration. The beam emittance was reduced from 15 mm*mr to 9

mm*mr for a beam current of 2 A, resulting in improvement of beam transmission from the K140 AVF cyclotron to the K400 ring cyclotron. Transversal resonant mode of a dee electrode with a span angle of 180 degrees was investigated to evaluate the interference for the fifth harmonic voltage production and the feasibility of the fourth-harmonic voltage use for the FT acceleration in the frequency region from 50 to 60 MHz. Transversal asymmetry of the harmonic voltage amplitude was observed by pickup electrodes placed near both sides of the acceleration gap. Dependence of the fundamental and harmonic voltage distributions on the frequency was analyzed by a simulation code.

MOPCP057 A Compact Solution for Dds-Generator, Turn-On and Protections in RF Accelerator Systems

Poster

11 Radio frequency systems

Antonio Caruso, Fabrizio Consoli, Antonino Spartà (INFN/LNS, Catania), Alberto Longhitano (ALTEK, San Gregorio (CATANIA))

INFN/LNS

A single compact rack that includes a Direct Digital Synthesizer generator, a turn-on and protection system provides the smart solution in RF accelerator systems. It synthesizes a high stable RF signal up to 120 MHz, turns the power on into the RF cavities through a step-ramp modulator, protects the RF system against mismatching, sparks and multipactoring. A preliminary prototype has been designed, assembled and tested on the RF system of the k-800 superconducting cyclotron at Infn-Lns. This solution is part of the new computer-based RF control system. The hardware, software, and first test results will be shown in this paper.

MOPCP058 Commissioning Experience of the Rf System Of K500 Superconducting Cyclotron At VECC

Poster

11 Radio frequency systems

Sumit Som, Rakesh Kumar Bhandari, Probal Gangopadhyay, Aditya Mandal, Saikat Pal, P. R. Raj, Subimal Saha, Sudeshna Seth (DAE/VECC, Calcutta)

DAE/VECC

Radio frequency system of Superconducting cyclotron at VECC, has been developed to achieve accelerating voltage of 100 kV max. with frequency, amplitude and phase stability of 0.1 ppm, 100 ppm and +/-0.5 degree respectively within 9 - 27 MHz frequency. Each of the three half-wave coaxial cavity is fed with rf power (80kW max.) from a high power final rf amplifier based on Eimac 4CW150,000E tetrodes. Initially, the whole three-phase RF system has been tuned for operation with RF power to the cavities at 19.1994 MHz and thereafter commissioned the cyclotron with neon 3+ beam at external radius at 14.0 MHz. In this paper, we present brief description of the rf system and behaviour observed during initial conditioning of the cavities with rf power and the way to get out of multipacting zone together with discussion on our operational experience. We have so far achieved dee voltage up to 52 kV at 14 MHz with 20 kW of RF power fed at each of the three dees and achieved vacuum level of 4.5 x 10e-07 mbar inside the beam chamber. We also present discussion on the problems and failures of some RF components during commissioning stage and rectifications done to solve the same.

MOPCP059 Theoritical analysis and Fabrication of Coupling capacitor for K500 Superconducting Cyclotron at Kolkata

Poster

11 Radio frequency systems

Manir Ahammed, Rakesh Kumar Bhandari, Pranab Bhattacharyya, Jayanta Chaudhuri, Anjan Dutta Gupta, Bidhan Chandra Mandal, Biswanath Manna, Subrata Saha (DAE/VECC, Calcutta)

DAE/VECC

K500 SC cyclotron has already been constructed and commissioned after spiraling Ne+3 internal beam with 70 nA upto extraction radius(670 mm) at Variable Energy Cyclotron Centre at Kolkata, India. Several problems have been experienced related to the coupling capacitor of the radio frequency system including it's sever burning during commissioning of the cyclotron. Making of the dissimilar joints between alumina ceramic and copper of the coupling capacitor demands the usage of vacuum furnace to avoid the cracking of the ceramic. Therefore exhaustive analysis has been carried out to facilitate the in-house fabrication of the coupling capacitor without using the vacuum furnace in case of emergency. The maximum allowable rate of temperature rise for the ceramic and the optimum thickness ration of the copper to ceramic has been estimated. Finally fabrication of the coupling capacitor has been carried out in-house without employing vacuum furnace. At present the coupling capacitor is performing well as maximum 57 KV DEE voltages were been achieved the till date. This paper presents the details of the analysis and experiences gain during the fabrication of the coupling capacitor.

MOPCP060 Design, Construction and Commissioning of the 100kW RF Amplifier for CYCIAE-100

Poster

11 Radio frequency systems

Zhiguo Yin, Bin Ji, Zhenguo Li, Tianjue Zhang, Zhenlu Zhao (CIAE, Beijing), Shidong Wei, Haichao Xiao, Yong Xie (CASIC, Beijing)

CIAE

As a major part of the BRIF project, the 100MeV high intensity cyclotron being constructed at CIAE, CYCIAE-100, will provide 200uA proton beam ranging from 75MeV to 100MeV for RIB production. Two identical 100kW RF amplifiers will be used to drive two cavities independently to accelerate H- beam up to 100 MeV. The detail technical specification has been investigated, fixed, and initial design has been finished by CIAE. Then, the construction design and manufacture is implemented by China Academy of Aero and Space, and the on site commissioning is successful by mutual efforts. The final commissioning is under way with a full scale prototype cavity at CIAE. A general description of the CYCIAE-100 RF system design will be given, as well as the review of 100kW amplifier design. In the commissioning of the amplifier with dummy load, different high order resonances are found when operated at different frequencies between 42MHz to 46MHz. An equivalent circuit model is carried out to hunt down the problems. The model and related analysis will be reported together with the process and results of high power test with the cavity load through ~35 meters six inch rigid transmission line.

MOPCP061 RF Cavity Simulations for Superconducting C400 Cyclotron

Poster

11 Radio frequency systems

Galina Karamysheva, Alim Glazov, Semion Gurskiy, Nikolay Morozov (JINR, Dubna, Moscow Region), Michel Abs, Yves Jongen, Willem Kleeven, Simon Zaremba (IBA, Louvain-la-Neuve), Oleg Karamyshev (JINR/DLNP, Dubna, Moscow region)

JINR

Compact superconducting isochronous cyclotron C400 has designed at IBA (Belgium) in collaboration with the JINR (Dubna). This cyclotron will be the first cyclotron in the world capable of delivering protons, carbon and helium ions for therapeutic use. 12C6+ and 4He2+ ions will be accelerated to 400 MeV/u energy and extracted by electrostatic deflector, H2+ ions will be accelerated to the energy 265MeV/u and extracted by stripping. It is planed to use two normal conducting RF cavities for ion beam acceleration in cyclotron C400. Computer model of the double gap delta RF cavity with 4 stems was developed in is a general-purpose simulation software CST STUDIO SUITE. Necessary resonant frequency and increase of the voltage along the gaps were achieved. Optimization of the RF cavity parameters leads us to the cavity with quality factor about 14000, RF power dissipation is equal to about 50 kW per cavity.

MOPCP062 TRIUMF Cyclotron Booster Frequency Tuning System

Poster

11 Radio frequency systems

Qiwen Zheng, Ken Fong, Michael Laverty (TRIUMF, Vancouver)

TRIUMF

For auto frequency tuning of TRIUMF cyclotron booster, a new control module based upon VXI Bus has been designed, tested and put into commission. This new auto tuning control module, which replaced the old analogue control box, has more features including the implementation of PIC16C71 microprocessor to generate Pulse Width Modulation (PWM) pulse, the utilization of digital RF phase detector and the most important aspect of computer control capability. Thus, the resonant frequency of cyclotron booster RF cavity is tuned automatically by this control module and the reflected RF power is kept at the minimum level in the operation.

MOPCP063 Commissioning of Buncher NB2

Poster

11 Radio frequency systems

Aimin Shi, Xianwu Wang (IMP, Lanzhou)

IMP

When the Lanzhou heavy ion Cooler Storage Ring (CSR) was put into use, higher requirements for the HIRFL, for example, extraction beam type, energy, intensity, quality, and operating efficiency were to be put forward. The purpose of this project, the development of NB2 is to increase the beam intensity of HIRFL, to realize NB1 and NB2 work together, to solve the phase space match problem, and to achieve ideal bunching effect. The key technique and innovation are as follow aspects: higher bunch voltage, rational design of buncher cavity structure, advanced mechanical technology to improving the quality factor of the cavity, adequate efficient HIRFL accelerator RF power source, and reliable control system.

MOPCP064 Amplifier Test Stand for the CRM Cyclotron

Poster

11 Radio frequency systems

Zhiguo Yin, Kai Fei, Bin Ji, Pengzhan Li, Gengshou Liu, Guofang Song, Tianjue Zhang (CIAE, Beijing), Caijun Yu (CASIC, Beijing)

CIAE

The final stage amplifier stability proves to be an important issue in the process of commissioning CRM cyclotron at CIAE. An air cooled 4CX15,000 tube final stage has been designed to evaluate the anode circuit and neutralization, both of which are weak points of the CRM cyclotron amplifier. Instead of strip line, the design of the new anode structure adopts coaxial form, resulting in less chance of parasitic resonance in the circuits. A tunable neutralization circuits is also included in the design, giving an opportunity to better stability in high power operations. First, the instability in CRM RF system will be analyzed in this paper followed with the new amplifier designs including the tube working line calculations, input/output circuit calculations and finite integral simulations. The mechanical design for tube socket and the anode tank have been successfully carried out using the data provided in this paper. The final stage amplifier is then fabricated, assembled and commissioned. In the power test with dummy load, more than 9.2kW RF fundamental power is provided at the frequency of 44MHz.

MOPCP065 Closed Loop RF Tuning For Superconducitng Cyclotron At VECC

Poster

11 Radio frequency systems

Aditya Mandal, Rakesh Kumar Bhandari, Saikat Pal, Subimal Saha, Sudeshna Seth, Sumit Som (DAE/VECC, Calcutta)

DAE/VECC

The RF system of Superconducting cyclotron has been operational within 9 - 27 MHz frequency.It has three tunable half-wave coaxial cavities as main resonators and three tunable RF amplifier cavities. A PC-based system takes care of stepper motor driven coarse tuning of cavities with positional accuracy ~20um and hydraulically driven three couplers and three trimmers. The couplers,in open loop, match the cavity impedance to 50 Ohm in order to feed power from RF amplifier. Trimmers operate in closed loop for fine tuning the cavity, if detuned thermally at high RF power. The control logic has been simulated and finally implemented with Programmable Logic Controller (PLC). Precision control of trimmer (~20um)is essential to achieve the accelerating (Dee) voltage stability better than 100 ppm. and also minimizing the RF power to maintain it. Phase difference between Dee-in and Dee-pick-off signals and the reflected power signals (from cavity) together act in closed loop for fine tuning of the cavity. The close loop PID control determines the final positioning of the trimmer in each power level and achieved the required voltage stability.

MOPCP066 Introduction of HIRFL RF system

Poster

11 Radio frequency systems

Zhe Xu, Aimin Shi, Xianwu Wang (IMP, Lanzhou)

IMP

The RF system of HIRFL-CSR consists of 5 facilities: B02 (Buncher 02) for Injection line, SFC (Sector Focus Cyclotron), NB1 (New Buncher 1) for pre-beam line, NB2 (New Buncher 2) for pre-beam line, and SSC (Separated Sector Cyclotron). The structure and feature of the subsystems are described in following related subject.

MOPCP067 Design and Primary Test of Full Scale Cavity of CYCIAE-100

Poster

11 Radio frequency systems

Bin Ji, Pengzhan Li, Jun Lin, Gengshou Liu, Gaofeng Pan, Zhenhui Wang, Jiansheng Xing, Zhiguo Yin, Suping Zhang, Tianjue Zhang, Zhenlu Zhao (CIAE, Beijing)

CIAE

The engineering of the RF cavity for cyclotron concerns several aspects of the system including vacuum, cooling, mechanical support etc, Sometime it is even more complex than the RF design itself. With limit space in a compact cyclotron, in order to achieve a voltage distribution of 60kV in central orbit and 120kV for outer orbit, a double stem double gap lambda by 2 cavities has been designed for CYCIAE-100[1]. The RF resonance of the cavity is simulated [1] by finite integral codes, while the thermal analysis and mechanical tolerance are studied using other approaches [2] [3]. The mechanical design and fabrications is then carried out under these directions, resulting in a full scale cavity model. The simulations and the mechanical design will be reported in this paper, followed with low level measurement results of quality factor, shunt impedance curve along accelerating gap etc. After surface polishing, the measurement yields an unloaded Q value of 9300, which matches well with the simulation with a neglectable difference of several hundreds. The high power test of the cavity will be carried out later, and will be given in separate paper presented at this conference.

MOPCP068 Stable Operation of RF Systems for RIBF

Poster

11 Radio frequency systems

Kenji Suda, Masaki Fujimaki, Nobuhisa Fukunishi, Masatake Hemmi, Osamu Kamigaito, Masayuki Kase, Ryo Koyama, Keiko Kumagai, Naruhiko Sakamoto, Tamaki Watanabe, Kazunari Yamada (RIKEN Nishina Center, Wako)

RIKEN Nishina Center

At RIKEN RI-Beam Factory (RIBF), heavy ion beams are accelerated up to 345 MeV/u by using the RIKEN heavy ion linac (RILAC) and four ring cyclotrons. In order to provide high intensity beams up to 1puA, all the RF systems must be stable enough for a long term (a few weeks), within +-0.1% in voltages and +-0.1 degrees in phases. For a stable operation of RIBF, we have started to monitor for the RF voltages and phases for all the RF systems, and beam intensity and phases using lock-in amplifiers. We have investigated a degree of stability of the RF systems. Then, we have performed several improvements. The Automatic Gain Control units for RILAC were replaced for a better stability. It was found that the stability of RF systems was considerably affected by the fluctuation of

reference signals. The fluctuation was mainly caused by the temperature dependence of power dividers used for a reference signal distribution. Therefore, we have changed the distribution method. The reference signal is first amplified to 40 dBm and divided by directional couplers, and they are delivered to low level circuits. The present degree of stability of the RF systems will be presented.

MOPCP069 Feasibility Study of a Superconducting Magnet for a Sector Cyclotron for Carbon-Ion Therapy

Poster

12 Magnet and vacuum

Stephane Sanfilippo, Alexander Louis Gabard, Vjeran Vrankovic (PSI-LRF, Villigen, PSI), Marco Calvi, Marco Negrazus, Jacobus Maarten Schippers (PSI, Villigen)

PSI

A system of two coupled cyclotrons is developed for carbon ions therapy. The first cyclotron accelerates protons, helium ions and carbon ions of 250 MeV/nucl. For treatments at deep tumour sites with carbon ions, these are boosted subsequently up to 450 MeV/nucl in a cyclotron consisting of six sector magnets with superconducting coils. We will report on results of a feasibility study of these sector magnets. Such a window-frame shaped magnet of about 125 tons should create a field of 3.5 T in a good field region of approximately 1 m2 and has a stored energy of 6.4 MJ. In order to prevent concave magnet pole edges and to achieve symmetry in the design of the magnet, a radial gradient has been introduced in the sector with a field strength varying from 2.7 T to 3.5 T over 0.8 m. The gradient has been obtained by tilted coils. Preliminary particle tracking calculations show that the fields are well matched to the injection and extraction energies. Stresses are evaluated using a 3D finite element analysis. The main features of the superconducting coil based on an internally cooled conductor cabled with Nb-Ti strands, the coil winding and cryogenics will be reported.

MOPCP070 Design of IBA Cyclone 30xp Cyclotron Magnet

Poster

12 Magnet and vacuum

Eric Forton, Michel Abs, Willem Kleeven, Benoit Nactergal, Damien Neuveglise, Simon Zaremba (IBA, Louvain-la-Neuve)

IBA

IBA is developing an evolution of its famous Cyclone 30 cyclotron. The Cyclone 30xp will be a multi-particle, multiport cyclotron capable of accelerating alpha particles up to 30 MeV, deuteron (D-) beams between 7.5 and 15 MeV and proton (H-) beams between 15 and 30 MeV. The magnet system has been improved with IBA Cyclone 18/9 and Cyclone 70 features. Coil dimensions have been updated in order to raise the free space in the median plane. This allows the mounting of a retractable electrostatic deflector system for the extraction of the alpha particle beam. Gradient corrector pole extensions have been added to ease the alpha beam extraction. Finally, compensation for relativistic effects between H- (q/m=1/1) and D-/alpha (q/m=1/2) beams is made by movable iron inserts located in two valleys, as in IBA Cyclone 18/9 cyclotrons. These modifications could have an adverse effect on the flutter. In addition, the second harmonic induced by the movable iron inserts drives the machine in the 2.νr=2 resonance close to the extraction. As a consequence, modifications on the pole sectors and chamfers have been made in order to improve the flutter and eliminate the harmful resonance.

MOPCP071 The RF System Design of 7MeV Cyclotron

Poster

11 Radio frequency systems

Sheng Hu Zhang, Yun Ma, Xianwu Wang, Zhe Xu (IMP, Lanzhou)

IMP

RF system of 7Mev cyclotron includes two major parts; RF resonant cavity, RF power amplifier and others Operates frequency is 31.02 MHz. The RF cavities are cooled by the water. The transmitter feed the power to Dee of the resonator through a 50 ohm transmission line and variable coupling capacitor on the Dee.

MOPCP072 Design of IBA Cyclone 11 Cyclotron Magnet

Poster

12 Magnet and vacuum

Vincent Nuttens, Michel Abs, Willem Kleeven, Benoit Nactergal, Damien Neuveglise, Simon Zaremba (IBA, Louvain-la-Neuve)

IBA

To extend customer choice in the low energy range, IBA is developing the Cyclone 11. It is a fixed energy 11 MeV H- cyclotron for the production of PET isotopes. The cyclotron magnet is based on the well known Cyclone 10/5, with the same yoke dimensions, which is compatible with the IBA self-shielding design. The higher proton energy compared to the 10 MeV machine takes the benefit of the higher PET isotope production yield. This poster presents the Cyclone 10 magnet modifications required to reach 11MeV. At first, the magnetic field has been raised by a small reduction of the valley depth. Additionally, the main coil current has been increased. The pole edge milling has been used to obtain the isochronous magnetic field shape. Beam optics in the magnet is excellent. Extraction is ensured by means of stripper foils mounted on carousels located at different azimuths allowing for up to eight targets.

MOPCP073 The Vacuum System Of HIRFL Cyclotrons

Poster

12 Magnet and vacuum

Xiaotian Yang, Jun Meng, Junhui Zhang (IMP, Lanzhou)

IMP

HIRFL has 2 cyclotrons: a sector focus cyclotron (SFC) and a separate sector cyclotron (SSC). SFC was built in 1957. In the past 50 years, the vacuum system of SFC has been upgraded for three times. The vacuum chamber was redesigned to double-deck at the third upgrade. The working pressure in beam chamber was improved from 10-6mbar to 10-8mbar. SFC has delivered Pb, Bi and U beams in the past few years since the last upgrading of its vacuum chamber. SSC began to operate in 1987. The vacuum chamber of SSC has a volume of 100m3. 8 cryopumps keep the pressure from 4E-7mbar to 8E-8mbar depending on the used pump numbers (2~8). In the past 20 years, because of the contamination of oil vapour and leaks occurred in some components inside the SSC vacuum chamber, the vacuum condition has worsened than the beginning. It is a big problem to accelerate the heavier ions. The upgrade for the SSC vacuum system will be an urgent task for us. The rough pumping system of both SFC and SSC will be rebuilt recently. The oil pump units will be changed by large dry

mechanical pumps. As a result, the oil vapour in two cyclotrons will be eliminated and the vacuum condition of them will be improved.

MOPCP074 Upgrade of the IBA Cyclone 3D Cyclotron

Poster

12 Magnet and vacuum

Willem Kleeven, Michel Abs, Benoit Nactergal, Damien Neuveglise, Thomas Servais, Simon Zaremba (IBA, Louvain-la-Neuve)

IBA

There is a need for 15O generator producing a continuous flow of PET tracer without disrupting the schedule of the hospital main cyclotron (usually used for 18F and 11C production) and to promote new emergency room evaluation of brain stroke and ischemic heart attack in PET centers without access to cyclotron short-lived isotopes. To answer, IBA improves the Cyclone 3D, originally developed for this purpose and accelerating D+ ions to more than 3 MeV. In the previous magnet design, vertical focusing is obtained by four straight pole-sectors. The new design has three spiralled pole-sectors. This improves the vertical focusing properties of the machine. Also the main coil and the return yoke are slightly modified. This will increase the extraction energy by about 10 % from 3.3 MeV to 3.6 MeV. This new design will improve the transmission in the cyclotron and the extraction efficiency above 80%, using an electrostatic deflector. The goal is to obtain an extracted current of 50 μA with the prototype, then 70 μA for subsequent machines. This represents a doubling of the previous model performance. Results of magnetic field optimization and extraction calculations are presented.

MOPCP075 Cyclotron Vacuum Model and H- Gas Stripping Losses

Poster

12 Magnet and vacuum

Vincent Nuttens, Michel Abs, Jean-Luc Delvaux, Yves Jongen, Willem Kleeven, Luis Medeiros-Romao, Marc Mehaudens, Thomas Servais, Thierry Vanderlinden, Patrick Verbruggen (IBA, Louvain-la-Neuve)

IBA

Many proton cyclotrons take the advantage of stripping for the extraction, by accelerating H- ions. However, before extraction, the negative ion beam can suffer losses from stripping by the residual gas. The higher is the pressure, the higher the losses. Moreover, the stripped beam will be stopped on the inner wall of the cyclotron, inducing an additional degassing and increasing the pressure and hence losses in the cyclotron. For high beam current, degassing can be too large compared to the pumping capacity and the beam transmission can drop down to zero. The pressure inside the cyclotron has therefore a large impact on the current that can be extracted from the cyclotron. A simple model has been set up at IBA to determine the vacuum pressure in the hills and in the valleys of the Cyclone 70 cyclotron. The transmission is then computed by integration of the gas stripping cross-section along the ion orbits in the cyclotron. Pressure and transmission provided by the model are in good agreement with experimental data in the ARRONAX Cyclone 70 cyclotron installed in Nantes.

MOPCP076 Operational Experience of Superconducting Cyclotron Magnet at VECC, Kolkata

Poster

12 Magnet and vacuum

Uttam Bhunia, Rakesh Kumar Bhandari, Pranab Bhattacharyya, Tamal Kumar Bhattacharyya, Jayanta Chaudhuri, Malay Kanti Dey, Ranadhir Dey, Anjan Dutta Gupta, Chaturanan Mallik, Chinmay Nandi, Md. Zamal Abdul Naser, Gautam Pal, Umashankar Panda, Jedidiah Pradhan, Subimal Saha (DAE/VECC, Calcutta)

DAE/VECC

The Kolkata Superconducting cyclotron magnet has been operational in the center since last few years and enabled us to extensively map magnetic fields over a year covering the operating range of the machine and successful commissioning of internal beam. The magnet cryostat coupled with the liquid helium refrigerator performs satisfactorily with moderate currents (<550A) in both the coils. The superconducting coil did not undergo any training and over the years has not suffered from any quench. Author would share the experience and difficulties of enhanced overall heat load to the liquid helium refrigerator at higher excitations of coils. This creates instability in the operation of liquid helium refrigerator and finally leads to slow dump. Rigorous study has been carried out in this regard to understand the problems and operational logic of liquid helium refrigerator has been modified accordingly to alleviate from. Some other measures have also been taken from cryostat and cryogenic distribution point of view in order to reduce the heat load at higher excitations.

MOPCP077 Median Plane Effects and Measurement Method for Radial Component of Magnetic Field in AVF Cyclotrons

Poster

12 Magnet and vacuum

Nikolay Morozov, Galina Karamysheva (JINR, Dubna, Moscow Region), Pavel Shishlyannikov (JINR/DLNP, Dubna, Moscow region)

JINR

The median plane of the magnetic field in AVF cyclotrons rather often does not coincide with the mid-plane of their magnetic system. The idea of an effective median plane formulated by J.I.M.Botman and H.L.Hagedorn [*] for the central region of the cyclotron is extended to the entire working region and tolerances for the horizontal components of the magnetic field are estimated. Equipment based on the search coils is proposed and used for measurement of the radial component of the magnetic field and for correction of the magnetic field median plane.

[*] J.I.M.Botman, H.L.Hagedorn, ‘Median Plane Effects in the Eindhoven AVF Cyclotron’, IEEE Trans. On Nucl. Science, Vol. NS-28, No.3, p.2128.

MOPCP078 Study of Magnetic Field Imperfections of Kolkata Superconducting Cyclotron

Poster

12 Magnet and vacuum

Jedidiah Pradhan, Rakesh Kumar Bhandari, Uttam Bhunia, Jayanta Debnath, Malay Kanti Dey, Chaturanan Mallik, Santanu Paul (DAE/VECC, Calcutta)

DAE/VECC

Analysis of the magnetic data obtained during the magnetic field mapping of Kolkata superconducting cyclotron showed imperfections in the main magnetic field. Since the main magnet of superconducting cyclotron is three fold rotationally symmetric, any deviation from this symmetry

creates imperfections in the magnetic field. Generally, 1st and 2nd harmonic components are inherently present in the field due to assembly errors in iron/coil. A major portion of these imperfections is attributed due to the misplacement/tilting of the iron pole tip with respect to coil. The error in positioning of main superconducting coil adds another imperfection. Rise of temperature in the pole tip region produce field imperfection due to un-even thermal expansion and change of iron-magnetization. This paper reports the various possible sources of imperfection and their estimation. The calculation is compared with measured data and find out the actual cause of imperfections and necessary corrections have been carried out.

MOPCP079 Optimization Of Sector Geometry Of A Compact Cyclotron By Random Search Method

Poster

12 Magnet and vacuum

Paritosh Sing Babu, Animesh Goswami, Vijay Shanker Pandit, Pranab Rudra Sarma (DAE/VECC, Calcutta)

DAE/VECC

A compact four sector 10 MeV, 5 mA proton cyclotron is being developed at VECC, Kolkata. Proton beam at 80keV from a 2.45 GHz ion source (under testing) will be first collimated and bunched and will be injected axially in the central region where a spiral inflector will place the beam on the orbit. This paper describes the procedure of optimizing the sector geometry of the magnet to obtain the desired isochronous field. Due to fringe field effect, analytical formulae do not predict the correct sector shape particularly at the lower radii in the cases of compact cyclotrons, where hill gap is very small and valley gap is large. Hence a 3D code becomes necessary to obtain the correct shape and size of the magnet sectors. This involves a lengthy iterative procedure of determining the hill angle at a large number of radii. In our procedure magnet sector is described in terms of a small number of parameters which are iteratively determined by random search technique geared to minimize the frequency error. 3D magnetic field data and results of equilibrium orbit code are used as input to the code developed for the optimization.

MOPCP080 Magnet Design for the KIRAMS-430 Superconducting Cyclotron

Poster

12 Magnet and vacuum

Joonsun Kang, Dong Hyun An, Bong Hwan Hong, In Su Jung, Kun Uk Kang, Geun-Beom Kim (KIRAMS, Seoul)

KIRAMS

Korea Institute of Radiological & Medical Sciences (KIRAMS) has started development of the superconducting cyclotron for a particle therapy. The superconducting magnet system is necessary to accelerate the C6+ ion to 430 MeV/u. The magnet system is composed of one set of superconducting coils and four-fold spiral sectors with a return yoke. The diameter of the magnetic pole is 3.98 m. The hill angular widths, hill gaps and spiral angles with the radius have been designed for the isochronous field. The designed results of the superconducting magnet system are listed on this paper. This work was supported by Ministry of Education, Science and Technology through the Korea Nuclear Forte Technology Initiative program.

MOPCP081 Design Study of Magnetic Channel at NIRS-AVF930

Poster

12 Magnet and vacuum

Satoru Hojo, Toshihiro Honma, Mitsutaka Kanazawa, Nobuyuki Miyahara, Masayuki Muramatsu, Koji Noda, Yukio Sakamoto, Akinori Sugiura, Katsuto Tashiro (NIRS, Chiba-shi), Takashi Kamiya, Takanori Okada, Yuichi Takahashi (AEC, Chiba)

NIRS

In the NIRS(National Institute of Radiological Sciences) -AVF930 cyclotron, a current magnetic channel has been used for ten years, and the flowing rate of cooling water at longest coil is gradually decreasing. Therefore, the high energy operation such as 70 MeV proton became difficult recently. As the design specification of this magnetic channel is very severe, the flow velocity of cooling water is very fast. The sectional area of the longest coil is expanded in the new design of magnetic channel. Details of the new design and results of calculated magnetic fields are discussed.

MOPCP082 Design Study of 8 Mev Injector Cyclotron Magnet for KoRIA

Poster

12 Magnet and vacuum

Hyun Wook Kim, Jong-Seo Chai, Khaled Mohamed Gad, Byeong-No Lee, Jina Park (SKKU, Suwon)

SKKU

The Korea Rare Isotope Accelerator (KoRIA) project was started on April, 2010. The main purpose of the Korean national project is producing rare isotope beam for basic science research. In KoRIA facilities, two 8MeV sector focused cyclotrons will be used as an injector cyclotron for main cyclotron that is K=100 separated sector cyclotron. In this paper, for the 8MeV injector cyclotron, the cylindrical Azimuthally Varying Field (AVF) magnet is designed to produce 8MeV proton beam and 4MeV deuteron beam. All field simulations have been performed by SUPERFISH-POSSION for 2D simulation and OPERA-3D (TOSCA) for 3D simulation. The assignments of these injector cyclotrons are generating 8MeV, 1mA proton beam and 4MeV deuteron beam that inject to the main cyclotron.

MOPCP083 Vacuum Simulation for Heavy Ion Beams in the AGOR-Cyclotron

Poster

12 Magnet and vacuum

Ayanangsha Sen, Sytze Brandenburg, Mariet Anna Hofstee (KVI, Groningen)

KVI

The vacuum in the AGOR cyclotron and thereby the beam transmission is beam intensity dependent for heavy ions. The onset of significant vacuum and transmission degradation is dependent on the ion species and final energy. For 20Ne6+ @ 23 MeV/A no significant effects are observed for intensities up to at least 2 x 10^{12} pps, while for 206Pb27+ @ 8.5 MeV/A degradation sets in at around 10^{11} pps. This process is driven by the loss of particles through charge exchange with the residual gas and subsequent desorption from the chamber walls induced by the lost particles. We are developing a model based on particle tracking simulations of beam particles after charge exchange and 3D vacuum simulation including the experimentally determined 'regular' out gassing and induced desorption. An experimental setup to measure beam induced desorption was built and tested. It will be used to evaluate the mitigation measures such as surface treatment and stimulated out gassing. Improvement of the vacuum in the injection line, which is limiting the overall transmission, is also presented. This

work is supported by the European Union through EURONS, contract 506065 and the "Stichting voor Fundamenteel Onderzoek der Materie" (FOM).

MOPCP084 Magnetic Field Mapping System for a 10MeV Compact Cyclotron

Poster

12 Magnet and vacuum

Jun Yang, Dong Li, Kaifeng Liu, Bin Qin, Yongqian Xiong, Tiaoqin Yu (HUST, Wuhan)

HUST

A 10MeV H- compact cyclotron is under construction in Huazhong University of Science and Technology (HUST). A magnetic field mapping system for the cyclotron magnet has been developed. The system bases on a Hall probe and a granite x-y stage. Unlike the traditional polar system, Cartesian mapping will be adopted. The motion control and data acquisition system for the magnetic field measurement consists of Group3 DTM151 Teslameter and MPT141 Hall probe, Panasonic servomotors, a motion control card, Renishaw optical linear encoder systems and an industrial PC. The magnetic field will be automatically scanned by this apparatus.

MOPCP085 Application of HTS Wire to Magnets

Poster

12 Magnet and vacuum

Kichiji Hatanaka, Mitsuhiro Fukuda, Tetsuhiko Yorita (RCNP, Osaka), Yasuhiro Sakemi (CYRIC, Sendai), Takeo Kawaguchi (KT Science Ltd., Akashi), Koji Noda (NIRS, Chiba-shi)

RCNP

We are developing magnets with High Temperature Superconducting (HTS) wire. A scanning magnet was designed, fabricated, and tested for its suitability as beam scanner. After successful cooling tests, the magnet performance was studied using DC and AC currents. In AC mode, the magnet was operated at frequencies of 30-59 Hz and a temperature of 77 K as well as 10-20 Hz and 20K. The power loss dissipated in the coils was measured and compared with the model calculations. The observed loss per cycle was independent of the frequency and the scaling law of the excitation current was consistent with theoretical predictions for hysteretic losses in HTS wires. A 3T dipole maget is under fablication now.

MOPCP086 New Type of Electrostatic Sensor for Beam Profile Measurement

Poster

13 Beam transport, diagnostics and control

Sandip Pal (DAE/VECC, Calcutta)

DAE/VECC

Beam profile measurement is a significant diagnostic tool for beam tuning and guiding in any kind of accelerator. It is required to develop an on-line, non-intrusive and vacuum compatible sensor for beam parameter measurements. Segmented electrostatic pick-ups can be used for beam profile measurement. All the electrical pick-up currents/voltages are dependent on the intensity distribution of the charges in the beam. Beam profiles, i.e. its intensity distribution can be monitored by reconstruction technique from the electrostatic pick-ups on different electrodes surrounding the beam line. The beam intensity distribution along the beam axis can also be determined by placing pick-up electrodes at multiple cross-sections along the beam axis. Using finite element analysis software the charge accumulation on

the electrodes can be evaluated as a forward problem for the different beam distribution, homogeneous or Gaussian or other. The accumulated charge in each electrode will be used to evaluate the beam distribution as an inverese problem. Simulation results for different charge distribution will be presented in this paper.

MOPCP087 Beamloss Monitoring and Control for high intensity Beams at the AGOR-Facility

Poster

13 Beam transport, diagnostics and control

Michel Hevinga, Sytze Brandenburg, Tjalling Nijboer, Johannes Vorenholt (KVI, Groningen)

KVI

The experiments at the AGOR facility require intense heavy ion beams with a beam power up to 500 W. Examples are 6 x 10^{12} pps of 20Ne at 23 MeV/A and 10^{12} pps 206Pb at 8.5 MeV/A. To prevent damage to components by the beam (power density >100 W/mm^3 in unfavorable cases) a modular beam loss monitoring and control system has been developed for the cyclotron and high energy beam lines. The architecture of the system will be described and the considerations for the major design choices discussed. The system uses the CAN-bus for communication and verification of system integrity. The injected beam is chopped at 1kHz with a variable duty factor up to 90 %. The beam intensity at injection and a number of locations in the high energy beam line is measured by inductive pick-ups. Furthermore localized beam losses on slits and diaphragms are directly measured. When beam loss in any section exceeds the predefined maximum value the duty factor of the beam is automatically reduced. Beam diagnostics are protected by switching off the beam when they are inserted at too high intensity. This work is supported by the European Union through EURONS, contract 506065 and the "Stichting voor Fundamenteel Onderzoek der Materie" (FOM).

MOPCP088 The Simulation on Beam Interaction with Background Particles

Poster

13 Beam transport, diagnostics and control

Chundong Hu, Lizhen Liang, Jianglong Wei (ASIPP, Hefei)

ASIPP

A particle simulation with Monte Carlo was developed to study beam interaction with background particles in neutral beam injector. The collision processes associated with charge state change and reaction cross-section were analyzed for neutralization and re-ionization. Take the neutralization processes as a reference, for the positive arc discharge ion source, there are three different original ion species in the energetic ion beam. In evolution, a fast particle will suffer kinds of collisions decided by the collision cross-section or no impact within the target gas. Classify those collisions and their cross-sections according the change of charge state and momentum. Discretize the distribution of target gas density along the neutralizer properly. As a result, the neutralizer is divided into many extremely short segments averagely. So the gas density quantity at middle point can be regarded as that of each segment. According to the collision cross-section, select a random number to determine the evolution of particle states in each segments. With that particle simulation, the neutralization efficiency is estimated. Supported by the National Nature Science Foundation of China (10875146) and the Knowledge Innovation Program of the Chinese Academy of Sciences (Y05FCQ0128)

MOPCP089 Recent Developements on the Beam Diagnostics for the Radioactive Ion Beams at INFN-LNS

Poster

13 Beam transport, diagnostics and control

Luigi Cosentino (INFN/LNS, Catania)

INFN/LNS

At Laboratori Nazionali del Sud (LNS), INFN, in last years we have developed two facilities to produce radioactive ion beams, by exploiting the techniques known as ISOL (EXCYT) and In-Flight (FRIB). Because of the low beam intensities that are produced (down to some hundreds of particle per second), it has been necessary to adopt a high sensitivity beam diagnostics, in order to measure the crucial parameters for the beam tuning operations (2 dimensional beam profiles and intensity) and to recognize the radioisotopes present in the beam. Particle detectors have been adopted in order to guarantee enough sensitivity, robustness and easily to use. More than 30 devices have been installed at all, distributed along the whole beam pipe, from the target of production until to the experimental hall. An easy to use Graphical User Interface, allows to the accelerators crew the management of such devices without any particular experties.

MOPCP090 Progress In Formation of Single-Pulse Beams by a Chopping System at the JAEA/TIARA facility

Poster

13 Beam transport, diagnostics and control

Satoshi Kurashima, Ikuo Ishibori, Takayuki Nara, Watalu Yokota (JAEA/TARRI, Gunma-ken), Mitsumasa Taguchi (JAEA/QuBS, Takasaki)

JAEA/TARRI

The intervals of beam pulses from a cyclotron is generally tens of ns and they are too short for pulse radiolysis experiments which require beam pulses at intervals ranging from 1 us to 1 ms (single-pulse beam). A chopping system, consisting of two types of high voltage kickers, is used at the JAEA AVF cyclotron to form single-pulse beam. The first kicker installed in the injection line generates beam pulses with repetition period of 1 us to 1 ms. The pulse width is about a cycle length of the acceleration frequency. The other kicker in the transport line thins out needless beam pulses caused by multi-turn extraction. We could not provide single-pulse beam stably over 30 min since the magnetic field of the cyclotron gradually decreased by 0.01% and the number of multi-turn extraction increased. The magnetic field was stabilized within 0.001% by keeping temperature of the cyclotron magnet constant. In addition, a new technique to measure and control an acceleration phase has enabled us to reduce the number of multi-turn extraction easier than before. We have succeeded to provide single-pulse beam of a 320 MeV carbon without retuning of the cyclotron over 4 h, as a result.

MOPCP091 Status of Beam Diagnostic Components for Superconducting Cyclotron at Kolkata

Poster

13 Beam transport, diagnostics and control

Suvadeep Roy (DAE/VECC, Calcutta)

DAE/VECC

VEC Centre Kolkata has constructed a K500 superconducting cyclotron (SCC). Several beam diagnostic components have been designed, fabricated and installed in SCC. In the low energy beam

line, uncooled slits, faraday cup, beam viewers, and collimators are used. The inflector is also operated in a faraday cup mode to measure the beam inside SCC. The radial probe and viewer probe are respectively used to measure beam current and to observe the beam size and shape inside SCC. The magnetic channels, electro-static deflectors and M9 slit are also used to measure beam current at the extraction radius. Water cooled faraday cup and beam viewers are used in the external beam line. The radius of curvature of the radial probe track was reduced to align the internal and external track during its assembly. It was observed that the probe did not functioning properly during beam trials. Different modifications were incorporated. But, problem with the probe persisted. The paper describes the beam diagnostic components used in the cyclotron, discusses the problems faced in operating the radial probe, modifications tried and outlines the future steps planned to operate the beam diagnostic components.

MOPCP092 Study on PXI and PAC-Based HIL Simulation Control System of CYCHU-10 Cyclotron

Poster

13 Beam transport, diagnostics and control

Xiao Hu, Dong Li, Yongqian Xiong, Jun Yang, Tiaoqin Yu (HUST, Wuhan)

HUST

Using the technology of hardware in loop (HIL), control system simulation model of the CYCHU-10 cyclotron is developed with real-time, simulation and statechart module under the LabVIEW environment. A prototyping design method based on NI PXI operation condition virtual platform and PAC controller is presented. The result indicates that the platform is feasible and effective in completing control system test under hardware virtual environment and shortening development time.

MOPCP093 Beam Extraction System and External Beam Line of Kolkata Superconducting Cyclotron

Poster

13 Beam transport, diagnostics and control

Jayanta Debnath, Sumantra Bhattacharya, Tamal Kumar Bhattacharyya, Uttam Bhunia, Pradyut Sankar Chakraborty, Malay Kanti Dey, Chaturanan Mallik, Md. Zamal Abdul Naser, Gautam Pal, Santanu Paul, Jedidiah Pradhan, Md Haroon Rashid (DAE/VECC, Calcutta)

DAE/VECC

All the major components of the extraction system of the Kolkata superconducting cyclotron are installed and functional. It includes the Electrostatic deflectors, magnetic channels, M9 slit etc. Internal beam acceleration has already been done successfully and now we are on the verge of extracting and transporting the beam to the cave. The external beam transport system has been designed comprising of quadrupole magnets, steering magnets, switching magnets, beam diagnostics etc. One of the four beam lines has been installed, which extends 20 meters up to the experimental cave-1. Control and monitoring system for all these components have been developed and tested. All the beam dynamical and technical aspects of the beam extraction and beam transportation have been discussed in this paper.

MOPCP094 Consistency in Measurement of Beam Phase and Beam Intensity Using Lock-In Amplifier and Oscilloscope Systems

Poster

13 Beam transport, diagnostics and control

Ryo Koyama, Masaki Fujimaki, Nobuhisa Fukunishi, Akira Goto, Masatake Hemmi, Osamu Kamigaito, Masayuki Kase, Naruhiko Sakamoto, Kenji Suda, Tamaki Watanabe, Kazunari Yamada (RIKEN Nishina Center, Wako)

RIKEN Nishina Center

The RIKEN RI beam factory (RIBF) consists of four ring cyclotrons (RRC, fRC, IRC, and SRC) and two injectors (RILAC and AVF) which are all connected in cascade. RILAC, AVF, and RRC began operation in the 1980s, and fRC, IRC, and SRC were installed in 2006. Phase probes (PPs) are installed in all cyclotrons and beam transport lines of RIBF, and the beam-bunch signals that are detected nondestructively by these PPs are used for tuning of isochronous magnetic field of cyclotrons and for monitoring the beam phase and beam intensity. We mainly use a newly developed system that incorporates a lock-in amplifier (LIA; SR844, SRS) for those tuning and monitoring; however, in AVF and RRC, a conventional measurement method using an oscilloscope system (OSC; DSO6052A, Agilent) is used. In this study, we investigated the consistency in the measurements carried out using LIA and OSC systems by Fourier analyzing the observed data. Additionally, we investigated the resolution and measurement uncertainty of LIA and OSC.

MOPCP095 Experiment and Analysis: Partial Loss of Insulation Vacuum in K-500 Superconducting Cyclotron during Energization

Poster

12 Magnet and vacuum

Pranab Bhattacharyya, Manir Ahammed, Samit Bandyopadhyay, Rakesh Kumar Bhandari, Uttam Bhunia, Jayanta Chaudhuri, Anirban De, Anjan Dutta Gupta, Chaturanan Mallik, Abani Mukherjee, Chinmay Nandi, Umashankar Panda, Subimal Saha (DAE/VECC, Calcutta)

DAE/VECC

At higher currents in superconducting coil of K-500 Superconducting cyclotron, it was found that the insulation vacuum surrounding the LHe vessel gets worsen with increased current in the coil,finally leading to slow dump of power of the coil .This is a limitation for further increasing current value in the superconducting magnet coil. But once the current value returned to zero, vacuum reading reaches its initial value. Experiment & analysis have been done to quantify the contribution of molecular gas conduction on heat load because of this partial loss of insulation vacuum. Experiment was done to quantify how much betterment in terms of heat load is possible by incorporating additional vacuum pump. The cryostat safety analysis because of loss of insulation vacuum has become very important at this new scenario.Analysis has been done to know what could be the maximum pressure rise with time in case of loss of vacuum. This data has been used to know what should be the relieving mass flow rate to avoid any pressure burst accident. Finally this data has been compared with the existing relief valve. It is found that the existing relief valve can take care of such incident.

MOPCP096 Flux-Coupled Isochronous Cycotron Stack as an Ultimate-Power Proton Source

Poster

01 Cyclotrons applications

Peter M. McIntyre, Akhdiyor Sattarov (Texas A&M University, College Station, Texas)

Texas A&M University

We are developing the conceptual design for a flux-coupled stack of isochronous cyclotrons as an optimum basis for delivering high-current beam of ~600-800 MeV protons. Two applications motivate this work: a 15 MW driver for a GW thorium-cycle fission core; and a beam dump source of antineutrinos for a next-generation experiment to measure the CP-violating parameter in neutrino oscillations.

MOPCP097 Superconducting RF Cavity for Stacked Flux-Coupled Cyclotrons

Poster

11 Radio frequency systems

Peter M. McIntyre, Akhdiyor Sattarov (Texas A&M University, College Station, Texas)

Texas A&M University

We are developing a conceptual design for a dielectric-loaded superconducting cavity for use in the confined space between sectors of a flux-coupled stack of cyclotrons. Details of the design will be presented.

MOPCP098 Influence of RF Magnetic Field on Ion Dynamics in IBA C400 Cyclotron

Poster

09 Beam dynamics

Eugene Samsonov, Galina Karamysheva, Sergey Kostromin (JINR, Dubna, Moscow Region), Yves Jongen (IBA, Louvain-la-Neuve)

JINR

Magnetic components of RF field in C400 cyclotron being under development by IBA makes noticeable influence on ion dynamics. In particular, increase in the dees voltage along radius leads to corresponding phase compression of a bunch. Influence of the RF magnetic field on the bunch center phase deviation during acceleration and on radial ion axial motions have been also estimated numerically. RF magnetic field changes a central ion phase by only 2 degreeRF. Calculations have also shown that RF magnetic field makes visible but pretty small influence on the radial motion of the ions ensuring some decrease in the radial amplitudes. No visible impact of the RF magnetic field on the axial motion has been detected. The results are compared for the two RF magnetic field maps: (i) obtained by Microwave Studio and, (ii) computed from RF electric field map by means of Maxwell's equations.

MOPCP099 Axial Injection Beam Line of a Compact Cyclotron

Poster

01 Cyclotrons applications

Jing Quan Zhang, Yun Cao, Lizhen Ma, Aimin Shi, Mingtao Song, Liepeng Sun, Xiaotian Yang, Qinggao Yao, Zhiming You, Xiao Qi Zhang, Xuezhen Zhang, Hongwei Zhao, Jian Hua Zheng (IMP, Lanzhou)

IMP

Axial injection beam line of the therapy cyclotron is presented. It is intended for transportation of the C5+ ion beam obtained in the permanent magnet ion source. The beam line is only 3.486m from the ion source to the entrance of spiral inflector, it consists of two sets glasser lens, one set double 90-degree bend magnet, one quadrupole lens and two solenoid lens. A big vacuum chamber is installed in the vertical part of the beam line, the sinusoidal buncher, the Faraday cap, the slit collimator and chopper are located in the vacuum chamber. The sinusoidal buncher is used for increasing of the seizing efficiency. The Faraday cap is used for the beam diagnostics. The bend magnet with the slit collimator is used for choice of C5+ ion beam. The chopper is used for choice of the beam utilizing time.

MOPCP100 Beam Extraction System of Compact Cyclotron

Poster

09 Beam dynamics

Huan Feng Hao, Kai Di Man, Mingtao Song, yalong su, Bing Wang, Qinggao Yao, Hongwei Zhao (IMP, Lanzhou)

IMP

Introduced of the designing of the beam extraction of the compact cyclotron which under designing at IMP,also introduced the beam qualities of the extracted beam.

MOPCP101 Transmission Efficiency Study of SSC

Poster

09 Beam dynamics

Huan Feng Hao, junfeng gao, qiuxian guo, guohua huan, anping li, xueming su, aijun wang, shixian wang, chunlei xie, jingjun yang, weiqing yang, yiping yang, Hongwei Zhao (IMP, Lanzhou)

IMP

HIRFL-SSC cycclotron has a lower transmission efficiency,the present paper studied the transmission efficiency of SSC by beam dynamics simulation under theoretical and real magnetic fields,and found the main reasons which caused the lower transmission efficiency of SSC.

MOPCP102 Compact Cyclotron as a Proton Source for the Detection of Explosives Based on Nuclear Resonance Absorption in Nitrogen

Poster

01 Cyclotrons applications

Leonid Onischenko, Yury Alenitsky, Alim Glazov, Evgeny Perepelkin, Alexey Vorozhtsov, Sergey Vorozhtsov (JINR, Dubna, Moscow Region), Thomas Kwan, Richard Earl Morgado, Tai-Sen Wang (LANL, Los Alamos, New Mexico)

JINR

In the proposed operational implementation of the Nuclear Resonance Absorption (NRA) method for explosives detection, the inspected object is scanned by a beam of 9.17-MeV gamma rays of a precise energy to determine the fraction of the beam resonantly absorbed in the nitrogen nuclei of the explosive in the reaction, 14N (gamma, p) 13C. The 9.17-MeV gamma rays are most readily generated in the inverse reaction, 13C (p, gamma)14N, in which a 1.747-MeV proton is resonantly captured by C13, followed by the emission of gamma rays from the recoiling N14 nucleus. To achieve the stringent requirements of a 1.747-MeV proton beam with an intensity of several milliampere and

with as small as possible energy spread and angular divergence, a compact isochronous cyclotron with internal H^- ion source and current of ~2mA was considered as a stand-alone source or as an injector (with a current of ~200 microA) into a storage ring. JINR/DLNP, Dubna, Russia and LANL, Los Alamos, NM, USA

MOPCP103 HIRFL Power Supply System

Poster

04 Facilities under construction

Zhongzu Zhou, Youxin Chen, Xiuming Feng, Daqing Gao, Yalin Gao, Jingbin Shangguan, Yong Tang, Junye Xin, Hongbin Yan, Huaihai Yan, Zhendong Yuan, Xianlai Zhang (IMP, Lanzhou)

IMP

In resent years,HIRFL DC power supply system upgrading is concentrated on middle power and low power output conertors.

MOPCP104 Research on Acceptance and Efficiency of SSC

Poster

09 Beam dynamics

Xiaoni Li, Yuan He, Youjin Yuan (IMP, Lanzhou)

IMP

The injection, acceleration and extraction of SSC is analyzed and simulated to get the transverse and longitudinal acceptance, using two typical ions 238U36+ and 70Zn10+ with energy 9.7 Mev/u and 5.62 Mev/u respectively. In order to study the actual acceptance of SSC, the isochronous magnetic field model in coincidence with the real one is established by Kr-Kb and Lagrange methods on the base of the actual measurement. The transverse and longitudinal acceptance is calculated under the above isochronous magnetic field model, and finding the main reason of low efficiency and acceptance of SSC is the defaults in the design of Msi3 and Mse3. The results show that the actual efficiency and acceptance of SSC can be improved by redesign the curvature of Msi3 and Mse3 or shim in Msi3 and Mse3 to change the distribution of inner field.

MOPCP105 Beam-Phase Measurement System for HIRFL

Poster

13 Beam transport, diagnostics and control

Jian Hua Zheng, Wei Liu, Weinian MA, Yanmou Wang, Junxia Wu, Yan Yin (IMP, Lanzhou)

IMP

The beam phase measurement system in the HIRFL is introduced. The system had been improved using rf-signal mixing and filtering techniques and noise cancellation method. Therefore,the influence of strongly RF field disturbing signal was eliminated and the signal to noise rate was increased, and a stable and sensitive phase measurement system was developed. The phase history of the ion beam was detected by using 15 set of capacitive pick-up probes installed in the SSC cyclotron. The phase information of the measurement was necessary for tuning purposes to obtain a optimized isochronous magnetic field, which the beam intensity was increased and the beam quality was optimized. The measuremnet result before and after isochronous magnetic field for ion and ion in SSC was given. The phase measurement system was reliable by optimizing isochronous magnetic field test,and the precision reached ±0.5°,the sensitivity of the phase measurement was about 10nA as well.

MOPCP106 A Design of Switch Magnet Power Supply

Poster

04 Facilities under construction

Huaihai Yan, Youxin Chen, Xiuming Feng, Daqing Gao, Yalin Gao, Jingbin Shangguan, Yong Tang, Junye Xin, Hongbin Yan, Zhendong Yuan, Xianlai Zhang, Zhongzu Zhou (IMP, Lanzhou)

IMP

The paper introduces a design of power supply for switch magnet in HIRFL. The main circuit topology used Buck chopper regulator, full-bridge inverter output and power units in parallel in the power supply is introduced. The operation principle and control strategy is analyzed in this article. The power supply can be operated in DC and pulse mode, has the very good output current long-term stability, high reliability and dynamic response characteristics. Finally, some experimental data and waveforms of the power supply are shown to demonstrate the performance of the design.

MOPCP107 Design Of High Energy Hadron FFAGS for ADSR and Other Applications

Poster

06 FFAG accelerators

Bin Qin, Yoshiharu Mori (KURRI, Osaka)

KURRI

Design study of high energy proton FFAG accelerator has been carried out at Kyoto University Research Reactor for the next generation ADSR experiment where the proton beam energy covers up to 700 MeV. The scaling type of FFAG with spiral sectors was employed. Details of the design, especially on the operational working points and dynamic apertures are described in this paper. Also, some possibility to apply this design to hadron therapy accelerators is presented.

MOPCP108 The Design of Transverse Emittance Measurement at HIRFL-CSR

Poster

13 Beam transport, diagnostics and control

Peng Li, J.X Wu, Y.Q, Yang, S.L Yang, Y.J Yuan (IMP, Lanzhou)

IMP

HIRFL-CSR is a multi-purpose heavy ion storage ring in Lanzhou. In order to measure the transverse emittance of the injected beam on the transfer channel to the HIRFL-CSR, two methods which included pepper pot and gird-slit was proposed. The pepper pot is unique in providing an instantaneous measurement of the 4 dimensional emittance of a beam. The data acquired of this method is only an image. The silt-grid is a one dimensional emittance measurement device. During the measurement, the slit, mounted with the stepper motor is moved stepwise across the beam, and then the signal induced on the grid will be stored in the computer to analyze. Because slit-grid is one dimensional device, two sets of this device are needed for transverse measurement. In this paper, we introduce the design, parameters, data acquisition and analysis process of these two methods. Especially the software integration is given in this paper. Main interest is directed on the software development for emittance front-end control and data analysis such as evaluation algorithms.

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