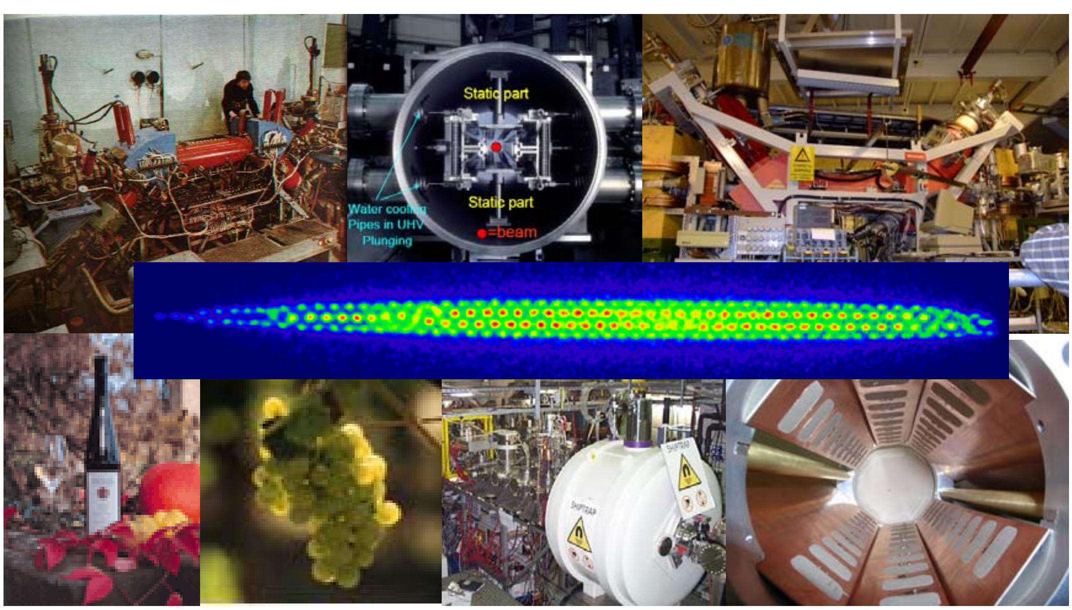
Workshop on Beam Cooling and Related Topics

COOL 07



Organized by GSI, Darmstadt

COOL 07

Bad Kreuznach, Germany
September 10-14, 2007

Workshop on Beam Cooling and Related Topics

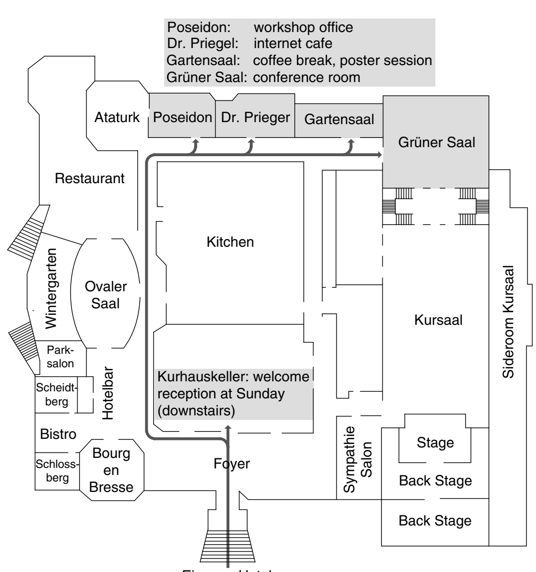
The workshop on beam cooling and related topics COOL 07 is hosted by GSI Darmstadt. It succeeds to previous beam cooling conferences the most recent of which was hosted by Fermi National Accelerator Laboratory (COOL 05).

The workshop focuses on beam cooling methods, such as stochastic and electron cooling. More advanced techniques like laser cooling and ionization cooling are covered as well. The program includes applications of beam cooling to traps, antiproton and heavy ion beams. Presentations of new developments in existing and future facilities are invited.

Workshop Venue

The workshop location is the DOMINA PARK Hotel in Bad Kreuznach:
DOMINA PARK Hotel
Kurhausstrasse 28
D-55543 Bad Kreuznach
Germany

phone +49 671 8020 714 (from Germany 0671 8020 714)
email parkhotelkurhaus@domina.it



The complimentary use of the nearby CRUZENIA thermal baths is included in the hotel room rate.

The city with the adjacent spa gardens has a long history and is in the heart of the wine growing Nahe area. The city center is within walking distance to the hotel. Shops which cover all kinds of needs and restaurants can be conveniently reached.

Registration and Information Desk

Registration fee applies to all participants, including invited speakers and chair persons. Payment should be made by bank transfer in advance (reduced fee of 520 €, compared to 600 € at the workshop). Credit card payment will be organized on the first day of the workshop (Monday), afterwards only cash payment can be accepted.

The registration fee includes the welcome reception (Sunday), the excursion and conference dinner (Wednesday), coffee breaks, a lunch buffet (Monday to Thursday), the book of abstracts and a CD-ROM of the proceedings.

Registration will take place at the conference venue during the following opening hours of the registration and information desk:

Sunday, 9 September 2007	16.00 to 19.00
Monday, 10 September 2007	8.00 to 18.00
Tuesday, 11 September 2007	8.30 to 18.00
Wednesday, 12 September 2007	8.30 to 13.00
Thursday, 13 September 2007	8.30 to 18.00
Friday, 14 September 2007	8.30 to 13.00

The office will be available under the phone number:
+49 671 802 714 (from Germany 0671 802 714)

Meals

The price of the hotel room includes breakfast. For workshop participants the lunch buffet offered from Monday to Thursday is included in the registration fee. The fee also includes the morning and afternoon coffee breaks. On Friday, lunch at the hotel can be arranged and must be paid extra. Meals at dinner time, except the conference dinner on Wednesday, are not included in the workshop fee.

Companions

Accompanying persons can take the lunch buffet at a price of 25.-€ per day and person. The workshop dinner (including the excursion in the afternoon) on Wednesday is offered at 70.- € per person for accompanying persons.

Workshop Program

The workshop starts Monday morning, 10 September 2007, at 9 a.m. and is organized as follows. There are two morning and two afternoon sessions on Monday and Tuesday. There are two morning sessions on Wednesday, Thursday and Friday. The afternoon session on Thursday is a poster session, followed by a general talk (Teatime talk) given by F. Bosch from GSI on the use of cooled beams for physics experiments. The workshop ends on Friday, 14 September 2007, at about 12.30.

Oral Presentations

Oral contributions will be organized in sessions with three talks. The time for oral contributions (invited and contributed) is 25+5 minutes. In order to provide enough time for discussion the time limit for the talk should not be exceeded.

A personal computer operating under Windows XP will be available for the electronic presentations. The following software will be installed on the PC: PowerPoint 2002, OpenOffice 2.2.1, Acrobat Reader 8.1. An overhead projector for transparencies will also be available.

Posters

The poster session takes place on Thursday afternoon. Posters should be mounted after the morning session, they should be manned from 14.00 to 16.30 and taken down immediately after the session. Poster boards are 2 m high and 1 m wide. Mounting material will be provided.

Workshop Proceedings

The conference proceeding will be published with JACoW. The proceedings will be available on the JACoW website. Participants will get a free copy in CD-ROM format. For those who have indicated their interest and paid the additional fee of 45 € a printed copy will be provided.

The proceedings will be prepared electronically. The deadline for submission of papers is Friday, 7 September 2007. The page limit is 5 pages for invited speakers and 4 pages for contributed papers. Instructions for the preparation of proceedings can be found on the JACoW website, where templates for WORD and LaTeX can be downloaded.

The electronic files of contributions to the proceeding will be processed during the workshop. The editing will be performed in cooperation with the authors and should be finished by the end of the workshop. No editing after the conferences is planned. Authors should submit all source files needed to prepare the paper and a postscript version. They should bring a hard copy of the paper to the workshop. We kindly ask all authors to respect the deadline for paper submission before the conference, which is crucial for immediate publication of the proceedings.

Internet Café

An Internet café is located next to the registration room in front of the auditorium. A few personal computers with internet access as well as wireless connections will be available free of charge in this area. Wireless access in the rooms can be provided by the hotel at extra cost.

Insurance

Attendants of the workshop are expected to have a proper health and personal liability insurance. No responsibility can be taken by the organizers.

Travel

Bad Kreuznach is at a distance of about 70 km from Frankfurt international airport. It can be conveniently reached by car or trains within approximately one hour.

There are frequent trains from the Frankfurt Rhein-Main airport train station to Bad Kreuznach.
There are two kinds of trains.
Local trains go directly from the airport to Bad Kreuznach, the trip takes 47 minutes.
Local trains depart (on Sunday) at: 7.38, 8.38, 10.38, 12.38, 14.38, 16.37, 18.38, 20.38.
A fast train goes from the airport to Mainz main train station where you have to change to a local train to Bad Kreuznach, this trip takes 63 minutes.
The fast trains depart every hour: 6.29, 8.59, 9.29, 9.58, 10.59, 11.58, 12.59, 13.59, 14.59, 15.58, 16.59, 17.58, 18.59, 19.58, 21.29, 22.29.
(Times are from the present timetable, but are subject to changes. More info on trains can be found on the webpage of German railway http://www.db.de.)

The hotel is facing the spa gardens (Kurpark), the distance to the Bad Kreuznach train station is less than 2 km.

Program Committee

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Y. Derbenev (JLab)
D. Kaplan (IIT)
K.J. Kim (ANL)
I. Meshkov (JINR)
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A. Noda (Kyoto Univ.)
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A. Sessler (LBNL)
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Program

Sunday, September 09, 2007

16:00 – 19:00 **Registration**

18:00 – 20:00 **Reception**

Monday, September 10, 2007

09:00 – 09:30 **Introduction**

09:30 – 10:30 **MOM1 — Monday Morning Session 1**
Session Chair: I. N. Meshkov, JINR (Dubna, Moscow Region)

MOM1I01 Status of the Recycler Ring
P. Derwent (Fermilab)
MOM1I02 Status of the Antiproton Decelerator and of the ELENA Project at CERN
P. Belochitskii (CERN)

10:30 – 11:00 **Coffee Break**

11:00 – 12:30 **MOM2 — Monday Morning Session 2**
Session Chair: S. Nagaitsev, Fermilab (Batavia, Illinois)

MOM2I03 Progress of High-energy Electron Cooling for RHIC
A. V. Fedotov (BNL)
MOM2C04 Cooling Experiments at COSY
D. Prasuhn (FZJ)
MOM2C05 Longitudinal Accumulation of Ion Beams in the Experimental Storage Ring Supported by Electron Cooling
C. Dimopoulou (GSI)

12:30 – 14:00 **Lunch Buffet**

14:00 – 15:30 **MOA1 — Monday Afternoon Session 1**
Session Chair: R. J. Pasquinelli, Fermilab (Batavia, Illinois)

MOA1I01 Bunched Beam Stochastic Cooling at RHIC
J. M. Brennan (BNL)
MOA1C02 Stochastic Cooling for the HESR at FAIR
H. Stockhorst (FZJ)
MOA1C03 Stochastic Cooling for the FAIR Project
F. Nolden (GSI)

15:30 – 16:00 **Coffee Break**

16:00 – 17:30 **MOA2 — Monday Afternoon Session 2**
Session Chair: I. Ben-Zvi, BNL (Upton, Long Island, New York)

MOA2I04 Antiproton Production and Accumulation
V. A. Lebedev (Fermilab)
MOA2C05 Calculations on High-energy Electron Cooling in the HESR
D. Reistad (TSL)
MOA2I06 Electron Cooling Status and Characterization at Fermilab's Recycler
L. R. Prost (Fermilab)

Tuesday, September 11, 2007

09:00 – 10:30 **TUM1 — Tuesday Morning Session 1**
Session Chair: H. Danared, MSL (Stockholm)

TUM1I01 Cooling Results from LEIR
G. Tranquille (CERN)
TUM1I02 Commissioning of Electron Cooling in CSRm
X. D. Yang (IMP)
TUM1I03 Comparison of Hollow Electron Device and Electron Heating
V. V. Parkhomchuk (BINP SB RAS)

10:30 – 11:00 **Coffee Break**

11:00 – 12:30 **TUM2 — Tuesday Morning Session 2**
Session Chair: A. Sessler, LBNL (Berkeley, California)

TUM2I04 Ionization Cooling
R. P. Johnson (Muons, Inc)
TUM2I05 MICE, the international Muon Ionization Cooling Experiment
A. P. Blondel (DPNC)
TUM2I06 Cooling Scheme for a Muon Collider
R. B. Palmer (BNL)

12:30 – 14:00 **Lunch Buffet**

14:00 – 16:00 **TUA1 — Tuesday Afternoon Session 1**
Session Chair: A. Noda, Kyoto ICR (Uji, Kyoto)

TUA1I01 Cooling Simulations with the BETACOOL Code
A. O. Sidorin (JINR)
TUA1I02 Theoretical Study of Emittance Transfer
H. Okamoto (Hiroshima University)

TUA1C03	Necessary Condition for Beam Ordering A. V. Smirnov (JINR)
TUA1I04	Recent Theoretical Investigations of Beam Crystallization J. Wei (BNL)
16:00 – 16:30	**Coffee Break**
16:30 – 18:00	TUA2 — Tuesday Afternoon Session 2 Session Chair: D. Möhl, CERN (Geneva)
TUA2C05	Introduction to the Session on Lattice Optimization for Stochastic Cooling D. Möhl (CERN)
TUA2C06	Lattices for Secondary Beam Collection and Cooling J. Wei (BNL)
TUA2C07	Lattice Modifications for Optimized Stochastic Cooling in COSY and HESR D. Prasuhn (FZJ)
TUA2C08	Lattice Considerations for Collector and Accumulator Rings of the FAIR A. Dolinskii (GSI)
TUA2C09	Lattice Optimization for the Stochastic Cooling in the Accumulator Ring at Fermilab V. P. Nagaslaev (Fermilab)

Wednesday, September 12, 2007

09:00 – 10:30	**WEM1 — Wednesday Morning Session 1** Session Chair: D. Prasuhn, FZJ (Jülich)
WEM1C01	Status of the LEPTA Project A. G. Kobets (JINR)
WEM1C02	Optical Stochastic Cooling Experiment at the MIT-Bates South Hall Ring W. A. Franklin (MIT)
WEM1C03	Resonance Analysis for the Electron Cooler of SIS-18 Using MAD-X S. Sorge (GSI)
10:30 – 11:00	**Coffee Break**
11:00 – 12:30	**WEM2 — Wednesday Morning Session 2** Session Chair: Y. S. Derbenev, Jefferson Lab (Newport News, Virginia)
WEM2C04	Status of VORPAL Friction Force Simulations for the RHIC II Cooler D. L. Bruhwiler (Tech-X)
WEM2I05	Bunched Beam Stochastic Cooling Simulations and Comparison with Data M. Blaskiewicz
WEM2C06	Simulation of Cooling Mechanisms of Highly-charged Ions in the HITRAP Cooler Trap G. Maero (GSI)

12:30 – 13:40 **Lunch Buffet**

13:40 – 19:30 **Excursion**

19:30 – 21:30 **Workshop Dinner**

23:00 **back at Hotel**

Thursday, September 13, 2007

09:00 – 10:30 **THM1 — Thursday Morning Session 1**
Session Chair: G. Tranquille, CERN (Geneva)

THM1I01 Commissioning and Performance of LEIR
C. Carli (CERN)
THM1I02 Electron Cooling Experiments at S-LSR
T. Shirai (Kyoto ICR)
THM1I03 Status of the FAIR Project
D. Krämer (GSI)

10:30 – 11:00 **Coffee Break**

11:00 – 13:00 **THM2 — Thursday Morning Session 2**
Session Chair: V. V. Parkhomchuk, BINP SB RAS (Novosibirsk)

THM2I04 Progress with Tevatron Electron Lenses
V. Kamerdzhiev (Fermilab)
THM2I05 Use of an Electron Beam for Stochastic Cooling
Y. S. Derbenev (Jefferson Lab)
THM2I06 Electron Beams as Stochastic 3D Kickers
V. B. Reva (BINP SB RAS)

12:30 – 13:40 **Lunch Buffet**

14:30 – 16:30	THA — Thursday Afternoon Poster Session
THAP01	Electron Cooling for Arbitrary Distribution of Electrons A. O. Sidorin (JINR)
THAP02	Implementation of synchrotron motion in barrier buckets in the BETACOOL program A. V. Smirnov (JINR)
THAP03	An Ultracold Cryogenic Photoelectron Source for the TSR Electron Target C. Krantz (MPI-K)
THAP04	Optimization of the Magnet System for Low Energy Coolers A. V. Bubley (BINP SB RAS)
THAP05	Prototype of the High Voltage Section for the 2 MeV Electron Cooler at COSY J. Dietrich (FZJ)
THAP06	Cooling in Compound Buckets A. V. Shemyakin (Fermilab)
THAP07	Image Charges in the Cooling Section of the Recycler Cooler A. V. Shemyakin (Fermilab)
THAP08	Electron Cooling Measurements in the Recycler Cooler A. V. Shemyakin (Fermilab)
THAP09	Beam-based Field Alignment of the Cooling Solenoids for Fermilab's Electron Cooler L. R. Prost (Fermilab)
THAP10	Status of the Design Work Towards an Electron Cooler for HESR B. Gålnander (TSL)
THAP12	Electron Cooling Design for ELIC - a High Luminosity Electron-Ion Collider Y. S. Derbenev (Jefferson Lab)
THAP13	Recent Developments for the HESR Stochastic Cooling System R. Stassen (FZJ)
THAP14	Pick-Up Electrode System for the CR Stochastic Cooling System C. Peschke (GSI)
THAP15	Beam Based Measurements Stochastic Cooling Systems in Fermilab V. A. Lebedev (Fermilab)
THAP16	Development and Design of Equalizers for Stochastic Cooling in Fermilab V. A. Lebedev (Fermilab)
THAP17	The 6D Intra-beam Scattering Formulation S. Nagaitsev (Fermilab)
THAP18	Theoretical and Numerical Studies of the Magnetized Friction Force G. Zwicknagel (Institut für Theoretische Physik, Erlangen)
THAP19	Influences of Space Charge Effect during Ion Accumulation using Moving Barrier Bucket Cooperated with Beam Cooling T. Kikuchi (Utsunomiya University)
THAP20	Internal Target Effects in the ESR Storage Ring with Cooling V. Gostishchev (GSI)
THAP21	Longitudinal Schottky Signals of Cold Systems with Low Number of Particles R. W. Hasse (GSI)
THAP22	Limitations of the Observation of Beam Ordering M. Steck (GSI)

16:30 – 17:00	**Coffee Break**
17:00 – 18:00	**THA2 — Thursday Afternoon Teatime Talk** Session Chair: F. Nolden, GSI (Darmstadt)
THA2I01	Exciting New Physics with Stored and Cooled Single Ions F. G. Bosch (GSI)

Friday, September 14, 2007

09:00 – 10:30	**FRM1 — Friday Morning Session 1** Session Chair: H. W. Zhao, IMP (Lanzhou)
FRM1I01	Present Status and Recent Activity on Laser Cooling at S-LSR A. Noda (Kyoto ICR)
FRM1C02	Laser Cooling of Relativistic Ion Beams: Summary of Experimental Results and Prospects for FAIR experiments. M. H. Bussmann (LMU)
FRM1C03	Electron Cooling with Photocathode Electron Beams D. Orlov (MPI-K)
10:30 – 11:00	**Coffee Break**
11:00 – 12:30	**FRM2 — Friday Morning Session 2** Session Chair: M. Steck, GSI (Darmstadt)
FRM2C04	Beam Studies at CRYRING for FLAIR H. Danared (MSL)
FRM2C05	Simulation Study of Ion Beam Accumulation with Moving Barrier Bucket assisted with Electron Cooling T. Katayama (GSI)
FRM2C06	Electron Cooling Simulations for Low-energy RHIC Operation A. V. Fedotov (BNL)

MOM1 — Monday Morning Session 1

Status of the Recycler Ring

MOM1I01

P. Derwent (Fermilab)

I will present the current operational status of the Fermilab Recycler Ring. Using a mix of stochastic and electron cooling, we prepare antiproton beams for the Fermilab Tevatron Collider program.

Funding: US Department of Energy

Status of the Antiproton Decelerator and of the ELENA Project at CERN

MOM1I02

P. Belochitskii (CERN)

The Antiproton Decelerator (AD) at CERN operates for physics since 2000. It delivers low energy antiprotons for production and study of antihydrogen, for atomic physics and for medical research. The 3.57 GeV/c antiprotons are produced by a 26 GeV/c proton beam coming from the CERN PS and hitting a target and then transported to the AD. There the beam is decelerated down to the extraction momentum of 100 MeV/c. Four intermediate stops in the cycle are used to cool the beam, which experiences significant emittance blow up during deceleration. Two beam cooling systems, stochastic and electron are used in AD. The first one operates at higher energies, and the second works at low energies. Machine performance is reviewed, along with plans for the future. Significant improvement of intensity and emittances of the beam delivered to theexperiments could be achieved with the addition of a small ring suitable for further deceleration and cooling. The details of this new extra low energy antiproton ring (ELENA) and its status are presented.

MOM2 — Monday Morning Session 2

MOM2I03

Progress of High-energy Electron Cooling for RHIC

A. V. Fedotov (BNL)

The fundamental questions about QCD which can be directly answered at Relativistic Heavy Ion Collider (RHIC) call for large integrated luminosities. The major goal of RHIC-II upgrade is to achieve 10 fold increase in luminosity of Au ions at the top energy of 100 GeV/n. A significant increase in luminosity for polarized protons is also expected, as well as for other ion species and for various collision energies. Such a boost in luminosity for RHIC-II is achievable with implementation of high-energy electron cooling. The design of the higher-energy cooler for RHIC recently adopted a non-magnetized approach which requires a low temperature electron beam. Such high-intensity high-brightness electron beams will be produced with superconducting Energy Recovery Linac (ERL). Detailed simulations of the electron cooling process and numerical simulations of the electron beam transport including the cooling section were performed. An intensive R&D of various elements of the design is presently underway. Here, we summarize progress in these electron cooling efforts.
Funding: Work supported by the U. S. Department of Energy.

MOM2C04

Cooling Experiments at COSY

D. Prasuhn, J. Dietrich, R. Stassen, H.-J. Stein, H. Stockhorst (FZJ) T. Katayama (CNS) I. N. Meshkov, A. O. Sidorin, A. V. Smirnov (JINR)

The Cooler Synchrotron COSY in Juelich is well suitable for cooling experiments both for electron cooling in the low energy regime and for stochastic cooling at proton energies above 800 MeV. Several experiments have already been carried out to benchmark modell predictions for beam conditions in the presence of internal targets and cooling. Further tests are planned for the near future to test diferent model predictions in view of the advanced cooling requirements for the HESR at the FAIR facility. The results of past experiments as well as future cooling experiments, especially the interplay between cooling and a Pellet-target will be presented.

MOM2C05

Longitudinal Accumulation of Ion Beams in the Experimental Storage Ring Supported by Electron Cooling

C. Dimopoulou, B. Franzke, T. Katayama, G. Schreiber, M. Steck (GSI) D. Möhl (CERN)

Recently,two longitudinal beam compression schemes have been successfully tested in the Experimental Storage Ring (ESR) at GSI with a beam of bare Ar ions at 65 MeV/u injected from the synchrotron SIS18. The first employs Barrier Bucket pulses, the second makes use of multiple injections around the unstable fixed point of a sinusoidal RF bucket at h=1. In both cases continuous application of electron cooling maintains the stack and merges it with the freshly injected beam. These experiments provide the proof of principle for the planned fast stacking of Rare Isotope Beams in the New Experimental Storage Ring (NESR) of the FAIR project.

MOA1 — Monday Afternoon Session 1

Bunched Beam Stochastic Cooling at RHIC

MOA1I01

J. M. Brennan, M. Blaskiewicz (BNL)

Stochastic cooling of ions in RHIC has been implemtneted to counteract Intra-Beam Scattering and prevent debunching during stores for luminosity production. The two main challenges in cooling bunched beam at 100 GeV/n are the coherent components in the Schottky spectra and producing the high voltage for the kicker in the 5 - 8 GHz band required for optimal cooling. The technical solutions to these challenges are described. Results of cooling proton beam in a test run and cooling gold ions in the FY07 production run are presented.

Stochastic Cooling for the HESR at FAIR

MOA1C02

H. Stockhorst, R. Maier, D. Prasuhn, R. Stassen (FZJ) T. Katayama (CNS) L. Thorndahl (CERN)

The High-Energy Storage Ring (HESR) of the future International Facility for Antiproton and Ion Research (FAIR) at the GSI in Darmstadt is planned as an anti-proton cooler ring in the momentum range from 1.5 to 15 GeV/c. An important and challenging feature of the new facility is the combination of phase space cooled beams with internal targets. The required beam parameters and intensities are prepared in two operation modes: the high luminosity mode with beam intensities up to 10^{11} and the high resolution mode with 10^{10} anti-protons cooled down to a relative momentum spread of only a few 10^{-5}. In addition to electron cooling transverse and longitudinal stochastic cooling are envisaged to accomplish these goals. A detailed numerical and analytical approach to the Fokker- Planck equation for momentum cooling including an internal target has been carried out to demonstrate the stochastic cooling capability. Cooling model predictions are compared with the stochastic cooling performance of the operational cooling system in the cooler synchrotron COSY.

Stochastic Cooling for the FAIR Project

MOA1C03

F. Nolden, A. Dolinskii, I. Nesmiyan, C. Peschke, M. Steck (GSI)

Stochastic cooling is used in the framework of the FAIR project at GSI for the first stage of phase space compression for both rare isotope and antiproton rings. The collector ring CR serves for the precooling of rare isotope and antiproton beams. Stochastic accumulation will be used for the preparation of high intensity beams for experiments in the HESR or for the low-energy FLAIR facility. The technical and beam parameters of these systems are presented. Stochastic cooling in the HESR is treated in a different contribution.

MOA2 — Monday Afternoon Session 2

MOA2I04

Antiproton Production and Accumulation

V. A. Lebedev (Fermilab)

In the course of Tevatron Run II (2001-2007) improvements of antiproton production have been one of major contributors into the collider luminosity growth. Commissioning of Recycler ring in 2004 and making electron cooling operational in 2005 freed Antiproton source from a necessity to keep large stack in Accumulator and allowed us to boost antiproton production. That resulted in doubling average antiproton production during last two years. The paper discusses improvements and upgrades of the Antiproton source during last two years and future developments aimed on further stacking improvements.

Funding: Work supported by the Fermi Research Alliance, under contract DE-AC02-76CH03000 with the U. S. Dept. of Energy.

MOA2C05

Calculations on High-energy Electron Cooling in the HESR

D. Reistad, B. Gålnander, K. Rathsman (TSL) A. O. Sidorin (JINR)

The HESR will work in a high-resolution mode with $1{\cdot}10^{10}$ stored antiprotons and a high-luminosity mode with $1{\cdot}10^{11}$ stored antiprotons. It will be equipped with both stochastic cooling and electron cooling systems. The main purpose of the electron-cooling system is to provide relative momentum spread in the antiproton beam of a few $1{\cdot}10^{-5}$ (90 %) during experiments with an internal hydrogen pellet target and with luminosity $2{\cdot}10^{31}$ – $2{\cdot}10^{32}$ $cm^{-2}s^{-1}$. The hydrogen pellet target is expected to produce a stream of frozen hydrogen pellets with diameter 30 μm, which move with 60 m/s and at a rate of 20,000 s^{-1}. The pellet stream is expected to have a diameter of 2–3 mm. Therefore, in order to avoid excessive fluctuations in the count rate, the antiproton beam size at the target must not be too small. This is solved by slightly tilting the electron beam with respect to the antiproton beam, thus making use of a so-called Hopf bifurcation. In order to get a high duty factor on another time scale, while not sacrificing momentum acceptance, a barrier-bucket rf. system will be employed. The electron-cooling system will initially be built for an antiproton energy range from 800 MeV to 9 GeV, but will be built so that its energy can be extended to the full energy of the HESR (14 GeV) at a later stage. The paper discusses the choice of parameters for the electron cooling system and presents simulations.

Funding: This work is supported by Uppsala University through The Svedberg Laboratory and by the European Community under Contract Number 515873, DIRACsecondary-Beams

Electron Cooling Status and Characterization at Fermilab's Recycler

L. R. Prost, A. V. Burov, K. Carlson, A. V. Shemyakin, M. Sutherland, A. Warner (Fermilab)

FNAL's electron cooler (4.3 MV, 0.1 A DC) has been integrated to the collider operation for almost two years, improving the storage and cooling capability of the Recycler ring (8 GeV antiprotons). In parallel, efforts are carried out to characterize the cooler and its cooling performance. This paper discusses various aspects of the cooler performance and operational functionality: high voltage stability of the accelerator (Pelletron), quality of the electron beam generated, operational procedures (off-axis cooling, electron beam energy measurements and calibration) and cooling properties (in the longitudinal and transverse directions). In particular, we show measurements of the friction force and cooling rates, which we compare to a non-magnetized model and conclude that the effective electron beam radius is smaller than expected.

Funding: Operated by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the United States Department of Energy

TUM1 — Tuesday Morning Session 1

TUM1I01

Cooling Results from LEIR

G. Tranquille (CERN)

The LEIR electron cooler has been successfully commissioned for the cooling and stacking of Pb^{54+} ions in LEIR during 2006. The emphasis of the three short commissioning runs was to produce the so-called “early” beam needed for the first LHC ion run. In addition some time was spent investigating the difficulties that one might encounter in producing the nominal LHC ion beam. Cooling studies were also made whenever the machine operational mode made it possible, and we report on the preliminary results of the different measurements (cooling-down time, lifetime etc.) performed on the LEIR cooler. Our investigations also included a study of the influence of variable electron density distributions on the cooling performance.

TUM1I02

Commissioning of Electron Cooling in CSRm

X. D. Yang (IMP)

A new generation cooler was commissioned in CSRm, $^{12}C^{6+}$ beam with energy 7MeV/u was delivered by a small cyclotron SFC, then injected into CSRm by stripping mode, the average pulse particle number is about 6.8×-10-^{8} in one injection, with the help of electron cooling of partial hollow electron beam, 3×10^9 particle were accumulated in the ring after 10 times injection in 10 seconds, and 2×10^9 particle were accelerated to final energy 1GeV/u, the momentum spread and the lifetime of ion beam were measured roughly. The work point of ring was monitored during the process of acceleration. The close-orbit correction was done initially. The momentum cooling time was about 0.3sec. About 1.6×10^{10} particle was stored in the ring after longer time accumulation.

TUM1I03

Comparison of Hollow Electron Device and Electron Heating

V. V. Parkhomchuk (BINP SB RAS)

The first results of the electron cooling with hollow electron beam are present. The electron coolers with varable electron beam profiles was commissioned at CERN and IMP (China). Accumulation of the ion beam was demonstrated.

TUM2 — Tuesday Morning Session 2

Ionization Cooling

TUM2I04

R. P. Johnson (Muons, Inc)

All three components of a particle's momentum are reduced as a particle passes through and ionizes some energy absorbing material. If the longitudinal momentum is regenerated by RF cavities, the angular divergence of the particle is reduced. This is the basic concept of ionization cooling. What can be done for a muon beam with this simple idea is almost amazing, especially considering that the muon lifetime is only 2.2 μs in its rest frame. In this lecture we will discuss the evolution and present status of this idea, where we are now ready to design muon colliders, neutrino factories, and intense muon beams with very effective cooling in all six phase space dimensions. The discussion will include the heating effects and absorber Z-dependence of multiple scattering, numerical simulation programs, the accuracy of scattering models, emittance exchange, helical cooling channels, parametric-resonance ionization cooling, reverse emittance exchange, and the ionization cooling demonstration experiments, MICE and MANX.

Funding: Supported by DOE SBIR/STTR grants DE-FG02-04ER84016, 04ER86191, 05ER86252, and 05ER886253

MICE, the international Muon Ionization Cooling Experiment

TUM2I05

A. P. Blondel (DPNC)

An international experiment to demonstrate muon ionization cooling is scheduled for beam at Rutherford Appleton Laboratory (RAL) in 2007. The experiment comprises one cell of the neutrino factory cooling channel, along with upstream and downstream detectors to identify individual muons and measure their initial and final 6D phase-space parameters to a precision of 0.1%. Magnetic design of the beam line and cooling channel are complete and portions are under construction. The experiment will be described, including cooling channel hardware designs, fabrication status, and running plans. Phase 1 of the experiment will prepare the beam line and provide detector systems, including time-of-flight, Cherenkov, scintillating-fiber trackers and their spectrometer solenoids, and an electromagnetic calorimeter. The Phase 2 system will add the cooling channel components, including liquid-hydrogen absorbers embedded in superconducting Focus Coil solenoids, 201-MHz normalconducting RF cavities, and their surrounding Coupling Coil solenoids. The MICE Collaboration goal is to complete the experiment by 2010.

Cooling Scheme for a Muon Collider

TUM2I06

R. B. Palmer (BNL)

Abstract text to be submitted by the author

TUA1 — Tuesday Afternoon Session 1

TUA1I01

Cooling Simulations with the BETACOOL Code

A. O. Sidorin (JINR)

BETACOOL program developed by JINR electron cooling group is a kit of algorithms based on common format of input and output files. General goal of the program is to simulate long term processes (in comparison with the ion revolution period) leading to variation of the ion distribution function in 6 dimensional phase space. The BETACOOL program includes three algorithms for beam dynamics simulation and takes into account the following processes: electron cooling, intrabeam scattering, ion scattering on residual gas atoms, interaction of the ion beam with internal target and some others.

TUA1I02

Theoretical Study of Emittance Transfer

H. Okamoto (Hiroshima University) K. Kaneta (HU/AdSM) A. Sessler (LBNL)

Liouville's theorem implies that the six-dimensional phase-space volume occupied by a charged-particle beam is an approximate invariant unless the beam is subjected to dissipative interactions (such as in cooling). Symplectic conditions, in a Hamiltonian system (once again, no dissipation), put constraints upon emittance transfer between the various degrees of freedom. [1] We can, however, even in non-dissipative Hamiltonian systems arrange for partial emittance transfers. This process results in phase space correlations and change in the emittance projections on to various phase planes; namely, the projected emittances in three degrees of freedom are controllable while the direction and amount of a possible emittance flow are not very flexible because of the symplectic nature of Hamiltonian system. In some applications, it is clearly advantageous to optimize the ratios of projected emittances despite the effect of correlations. Since the three emittances are not always equally important, we may consider reducing the emittance of one direction at the sacrifice of the other emittance(s). As a possible scheme to achieve such emittance control, we study a compact storage ring operating near resonance. The basic features of linear and nonlinear emittance flow are briefly discussed with numerical examples. A general discussion touching on some of these matters has been previously presented. [2]

[1] E. D. Courant, Perspectives in Modern Physics, edit R. E. Marshak (1966).

[2] H. Okamoto, K. Kaneta and A. M. Sessler, to be published in J. Phys. Soc. Jpn.

Funding: Work supported in part by the U. S. Department of Energy, Office of Basic Energy Sciences, under Contract No. DE-AC02-05CH11231.

TUA1C03

Necessary Condition for Beam Ordering

A. V. Smirnov, I. N. Meshkov, A. O. Sidorin (JINR) J. Dietrich (FZJ) A. Noda, T. Shirai, H. Souda, H. Tongu (Kyoto ICR) K. Noda (NIRS)

The very low momentum spread for small number of particle was reached on different storage rings. When the sudden reduction of the momentum spread ("phase transition") was observed during decreasing of the particle number it was interpreted as ordered state of ion beams. The most extensive study of ordered ion beams was done on storage rings ESR (GSI, Darmstadt) and CRYRING (MSL, Stockholm). Recently, for the first time, the ordered proton beam has been observed on S-LSR (Kyoto University). From analysis of the ESR experimental results we assumed that the ordered state can be observed if the dependence of momentum spread on the particle number can be approximated as $\Delta P/P \sim N^k$ for $k < 0.3$. In pioneering experiments at NAP-M (INP, Novosibirsk) and, in recent years, at COSY (FZJ, Juelich) the phase transition was not observed and the coefficient was found equal $k > 0.5$. This report presents the experimental investigations of low intensity proton beams on COSY and S-LSR which have the aim to formulate the necessary conditions for the achievement of the ordered state. The experimental studies on S-LSR and numerical simulations with the BETACOOL code were done for the dependence of the momentum spread and transverse emittances on particle number with different misalignments of the magnetic field at the cooler section. As result of both experimental and numerical studies one can conclude that the necessary condition for the phase transition appearance is $k < 0.3$.

TUA1I04

Recent Theoretical Investigations of Beam Crystallization

J. Wei (BNL) H. Okamoto (Hiroshima University) A. Sessler (LBNL) Y. Yuri (HU/AdSM)

Recent theoretical investigations of beam crystallization mainly use computer modeling based on the method of molecular dynamics (MD) and analytical study based on phonon theory [1]. Topics of investigation include crystal stability in various accelerator lattices under different beam conditions, colliding crystalline beams [2], and crystalline beam formation in shear-free ring lattices with both magnets and electrodes [3]. In this paper, we review the above mentioned theoretical studies and, in particular, discuss the development of the phonon theory in a time-dependent Hamiltonian system representing a storage ring of AG focusing. Analytical study of crystalline beam stability in an AG-focusing ring was previously limited to the smooth approximation. In a typical ring, analytical results obtained under such approximation largely agrees with the results obtained with the molecular dynamics (MD) simulation method. However, as we explore ring lattices appropriate for beam crystallization at high energies (Lorentz factor gamma much higher than the betatron tunes) [2,4], this approximation fails. Here, we present a newly developed formalism to exactly predict the stability of a 1-dimensional crystalline beam in an AG focusing ring lattice.

[1] X.-P. Li, et al, PR ST-AB, 9, 034201 (2006).

[2] J. Wei, A. M. Sessler, EPAC, 862 (1998)

[3] M. Ikegami, et al, PR ST-AB 7, 120-10-1 (2004).

[4] J. Wei, H. Okamoto, et al, EPAC 2006.

Funding: * Work performed under the auspices of the U. S. Department of Energy.

TUA2 — Tuesday Afternoon Session 2

TUA2C05

Introduction to the Session on Lattice Optimization for Stochastic Cooling

D. Möhl (CERN)

Lattices that circumvent the ‘mixing dilemma’ for stochastic cooling have repeatedly been considered but were not adopted in the original design of existing cooling rings. Recently new interest has arisen to modify existing machines and to design future ‘optimum mixing rings’. This talk is meant to summarize the pros and cons with the aim to introduce the discussion.

TUA2C06

Lattices for Secondary Beam Collection and Cooling

J. Wei (BNL) S. Wang (IHEP Beijing)

During the EPAC 2006 we reported the lattice design for rapid-cycling synchrotrons used to accelerate high-intensity proton beams to energy of tens of GeV for secondary beam production. After primary beam collision with a target, the secondary beam can be collected, cooled, accelerated or decelerated by ancillary synchrotrons for various applications. For the main synchrotron, the lattice has:

a. flexible momentum compaction to avoid transition and to facilitate RF gymnastics
b. long straight sections for low-loss injection, extraction, and high-efficiency collimation
c. dispersion-free straights to avoid longitudinal-transverse coupling, and
d. momentum cleaning at locations of large dispersion with missing dipoles.

Then, we present a lattice for a cooler ring for the secondary beam. The momentum compaction across half of this ring is near zero, while for the other half it is normal. Thus, bad mixing is minimized while good mixing is maintained for stochastic beam cooling.

Funding: * Work performed under the auspices of the US Department of Energy.

TUA2C07

Lattice Modifications for Optimized Stochastic Cooling in COSY and HESR

D. Prasuhn, Y. Senichev, H. Stockhorst (FZJ) T. Katayama (CNS)

optimized stochastic cooling requires special ion optical conditions in a storage ring. The frequency slip factor strongly influences the mixing factor, and strong requirements have to be fulfilled by the unwanted mixing of the path from pickup to kicker and the wanted mixing on the way from kicker to pickup. Several ideas for a lattice with "irregular" momentum compaction factor have been investigated. The influence of possible lattice modifications to the stochastic cooling performance for COSY will be discussed. Investigations of a lattice optimized for the stochastic cooling in HESR will be summarized.

Lattice Considerations for Collector and Accumulator Rings of the FAIR

TUA2C08

A. Dolinskii, F. Nolden, M. Steck (GSI)

Two storage rings (Collector Ring (CR) and Recycled Experimental Storage Ring (RESR)) have been designed for efficient cooling, accumulation and deceleration of antiproton and rare isotopes beams. The large acceptance CR must provide efficient stochastic cooling of hot radioactive ions as well as antiproton beams. The RESR will be used as an accumulator of high intensity antiproton beams and a decelerator of rare isotopes. Different lattice structures have been considered in order to achieve good properties for the stochastic cooling and at the same time the maximum dynamic aperture. The structure of the ring lattices and its ion optical properties are described in this contribution. The beam dynamics stability and flexibility for operation in different modes are discussed.

Lattice Optimization for the Stochastic Cooling in the Accumulator Ring at Fermilab

TUA2C09

V. P. Nagaslaev, V. A. Lebedev, S. J. Werkema (Fermilab)

New efforts are under way at Fermilab to increase the rate of the antiproton production. This program includes the machine optics optimization in order to improve mixing and help stochastic cooling. The new lattice has been implemented in May of this year. Results will be discussed, as well as some aspects of model development and lattice measurements.

WEM1 — Wednesday Morning Session 1

WEM1C01

Status of the LEPTA Project

A. G. Kobets, E. V. Ahmanova, V. Bykovsky, I. I. Korotaev, V. I. Lokhmatov, V. N. Malakhov, I. N. Meshkov, R. Pivin, A. Yu. Rudakov, A. O. Sidorin, A. V. Smirnov, G. V. Trubnikov (JINR)

The Low Energy Positron Toroidal Accumulator (LEPTA) is under commissioning at JINR. The LEPTA facility is a small positron storage ring equipped with the electron cooling system. The project positron energy is of 4-10 keV. The main goal of the facility is to generate an intense flow of positronium atoms–the bound state of electron and positron. The focusing system of the LEPTA ring after solenoidal magnetic field remeasurement and correction has been tested with pulsed electron beam by elements. Some resonant effects of beam focusing have been observed. The experiments aiming to increase the life time of the circulating electron beam and test the electron cooling elector beam are in progress. Construction of the pulsed injector of the low energy positrons is close to the completion (CPS). The injector is based on ^{22}Na radioactive isotope and consists of the cryogenic positron source, the positron trap and the acceleration section. In the CPS positrons from the ^{22}Na tablet are moderated in the solid neon and transported into the trap, where they are accumulated during about 80 seconds. Then accumulated positrons are extracted by the pulsed electric field and accelerated in electrostatic field up to required energy (the injector as a whole is suspended at a positive potential that corresponds to required positron energy in the range of 4-10 keV). In injection pulse duration is about 300 nsec. The CPS has been tested at the low activity of isotope ^{22}Na tablet (100 MBq). The continuous positron beam with average energy of 1.2 eV and spectrum width of 1 eV has been obtained. The achieved moderation efficiency is about 1 %, that exceeds the level known from literature. The accumulation process in the positron trap was studied with electron flux. The life time of the electrons in the trap is 80 s and capture efficiency is about 0.4. The maximum number of the accumulated particles is $2{\cdot}10^{+8}$ at the initial flux of $5{\cdot}10^{+6}$ electrons per second.

WEM1C02

Optical Stochastic Cooling Experiment at the MIT-Bates South Hall Ring

W. A. Franklin, K. A. Dow, J. P. Hays-Wehle, F. X. Kaertner, R. Milner, R. P. Redwine, A. M. Siddiqui, C. Tschalaer, D. Wang, F. Wang, J. van der Laan (MIT) M. Bai, M. Blaskiewicz, W. Fischer, V. Yakimenko (BNL) W. A. Barletta, A. Zholents, M. S. Zolotorev (LBNL) S.-Y. Lee (IUCF)

An experiment to demonstrate for the first time the principle of optical stochastic cooling* has been proposed using electrons at 300 MeV in the MIT-Bates South Hall Ring. The experiment will operate the Ring in a dedicated mode using a lattice tailored for transverse and longitudinal cooling. The experimental apparatus, including a magnetic chicane, undulator system, and ultrafast optical amplifier, has been designed to be compatible with existing technology. The experiment will study OSC physics to evaluate its prospects for future application at the high energy high brightness frontier and to develop deterministic diagnostics needed to achieve it. Details of the experiment design will be presented along with results from an initial beam feasibility study.
*M. Zolotorev and A. Zholents, Phys. Rev. E 50, 3087 (1994)

Resonance Analysis for the Electron Cooler of SIS-18 Using MAD-X

S. Sorge (GSI)

Due to the requirements concerning the quality of the particle beams in the FAIR project, i.e. a small momentum uncertainty together with high currents and, in the case of the storage rings, particle target interaction, there will be a strong need of electron cooling. On the other hand, an electron cooler acts as a non-linear optical element besides electron cooling. This may lead to the excitation of resonances possibly resulting in an increase of the emittance. The aim of this work is the calculation of resonances driven by the electron cooler in the Schwerionensynchrotron (SIS) 18 being a present device at GSI Darmstadt having an electron cooler. So, we get the opportunity to prove our results experimentally. For our calculations, we used a model system consisting of a rotation matrix representing the lattice and giving the according phase advance, and a non-linear transverse momentum kick representing the electron cooler in thin lens approximation. Proceeding in this way, we got only the resonances driven by the cooler. Furthermore, we used the MAD-X code to perform our calculations.

WEM2 — Wednesday Morning Session 2

WEM2C04

Status of VORPAL Friction Force Simulations for the RHIC II Cooler

D. L. Bruhwiler, G. I. Bell, A. V. Sobol (Tech-X) I. Ben-Zvi, A. V. Fedotov, V. Litvinenko (BNL)

Novel electron-hadron collider concepts are a high priority for the long-term plans of the international nuclear physics community. Orders of magnitude higher luminosity will be required for the relativistic ion beams in such particle accelerators. Electron cooling of highly relativistic ions is under consideration for the proposed RHIC II luminosity upgrade. The parallel VORPAL code is being used for molecular dynamics simulations of the friction force on individual ions, given expected parameters of the RHIC II cooling system, including the effects of an idealized helical undulator magnet and of estimated magnetic field errors. The well-known analytical formula for the field-free case is the basis for physical intuition regarding dynamical friction, but this is derived under the assumption of very long interaction times and symmetric ion/electron collisions. For RHIC II parameters, the interaction time is short compared to the electron plasma frequency, so there is essentially no shielding of the ion charge and one must consider finite time effects and asymmetric collisions. We present the current status of this work.

Funding: This work is supported by the US DOE Office of Science, Office of Nuclear Physics.

WEM2I05

Bunched Beam Stochastic Cooling Simulations and Comparison with Data

M. Blaskiewicz, J. M. Brennan (BNL)

With the experimental success of longitudinal, bunched beam stochastic cooling in RHIC it is natural to ask whether the system works as well as it might and whether upgrades or new systems are warranted. A computer code, very similar to those used for multi-particle coherent instability simulations, has been written and is being used to address these questions.

Funding: Work performed under the auspices of the United States Department of Energy.

WEM2C06

Simulation of Cooling Mechanisms of Highly-charged Ions in the HITRAP Cooler Trap

G. Maero, F. Herfurth, O. K. Kester, H. J. Kluge, S. Koszudowski, W. Quint (GSI) S. Schwarz (NSCL) S. K. Stahl (Stahl-Electronics) G. Zwicknagel (Institut für Theoretische Physik, Erlangen)

The use of heavy and highly-charged ions gives access to unprecedented investigations in the field of atomic physics. The HITRAP facility at GSI will be able to slow down and cool ion species up to bare uranium to the temperature of 4 K. The Cooler Trap, a confinement device for large numbers of particles, is designed to store and cool bunches of 10^5 highly-charged ions. Electron cooling with 10^{10} simultaneously trapped electrons and successive resistive cooling lead to extraction in both pulsed and quasi-continuous mode with a duty cycle of 10 s. After an introduction to HITRAP and overview of the setup, the dynamics of the processes investigated via a Particle-In-Cell (PIC) code are shown, with emphasis on the peculiarities of our case, namely the space charge effects and the modelling of the cooling techniques.

THM1 — Thursday Morning Session 1

Commissioning and Performance of LEIR

THM1I01

C. Carli (CERN)

The Low Energy Ion Ring (LEIR) is a key element of the LHC ion injector chain. Under fast electron cooling, several long pulses from the ion Linac 3 are accumulated and cooled, and transformed into short bunches with a density sufficient for the needs of the LHC. Experience from LEIR commissioning and the first runs in autumn 2006 and summer 2007 to provide the so-called "early LHC ion beam" for setting-up in the PS and the SPS will be reported. Studies in view of the beam needed for nominal LHC ion operation are carried out in parallel to operation with lower priority.

Electron Cooling Experiments at S-LSR

THM1I02

T. Shirai, S. Fujimoto, M. Ikegami, A. Noda, H. Souda, M. Tanabe, H. Tongu (Kyoto ICR) H. Fadil, M. Grieser (MPI-K) T. Fujimoto, S. I. Iwata, S. Shibuya (AEC) I. N. Meshkov, A. V. Smirnov, E. Syresin (JINR) K. Noda (NIRS)

The ion storage ring, S-LSR in Kyoto University has an electron beam cooler and a laser cooling system. The electron cooler for S-LSR was designed to maximize the cooling length in the limited drift space of the ring. The effective cooling length is 0.44 m, while the total length of the cooler is 1.8 m. The commissioning of the electron cooling was started from October 2005. The 7 MeV proton beam from the linac was used and the first cooling was observed on October 31. The momentum spread became 2×10^{-4} and the beam diameter was 1.2 mm with the particle number of 2×10^{8} and the electron current of 60 mA. The various experiments have been carried out using the electron cooling at S-LSR. The one-dimensional ordering of protons is one of the important subjects. The momentum spread and the beam size were observed while reducing the particle number. They were measured by the Schottky noise spectrum and the scraper. The particle number was measured by the ionization residual gas monitor. Abrupt jumps in the momentum spread and the Schottky noise power were observed for protons at a particle number of around 2000. The beam temperature was 0.17 meV and 1 meV in the longitudinal and transverse directions at the transition particle number, respectively. The normalized transition temperature of protons is close to those of heavy ions at ESR. The lowest momentum spread below the transition was 1.4×10^{-6}, which corresponded to the longitudinal beam temperature of 0.026 meV (0.3 K). It is close to the longitudinal electron temperature. The transverse temperature of the proton beam was much below that of electrons (34 meV). It is the effect of the magnetized electron.

Funding: The present work has been supported from Advanced Compact Accelerator Development Project by MEXT of Japan and 21 COE at Kyoto University-Center for Diversity and Universality in Physics.

Status of the FAIR Project

THM1I03

D. Krämer (GSI)

The international Facility for Antiproton and Ion Research (FAIR) is a multi-purpose accelerator project. The main task is production of secondary beams. Therefore the production of high intensity primary beams and the application of beam cooling to the secondary beams are the prominent features of this facility. The most recent design aspects of the accelerator complex will be described. The status of negotiations towards an international facility will be given.

THM2 — Thursday Morning Session 2

THM2I04

Progress with Tevatron Electron Lenses

V. Kamerdzhiev, Y. Alexahin, G. F. Kuznetsov, V. D. Shiltsev, X. Zhang (Fermilab)

The Tevatron Electron Lenses (TELs) were initially proposed for compensation of long-range and head-on beam-beam effects of the antiproton beam at 980 GeV. Recent advances in antiproton production and electron cooling led to a significant increase of antiproton beam brightness. It is now the proton beam that suffers most from the beam-beam effects. Discussed are the concept of Electron Lenses and commissioning of the second TEL in 2006-2007. The latest experimental results obtained during numerous studies with high energy proton beam are presented.

Funding: Work supported by the U. S. Department of Energy under contract No. DE-AC02-07CH11359

THM2I05

Use of an Electron Beam for Stochastic Cooling*

Y. S. Derbenev (Jefferson Lab)

Microwave instability of an electron beam can be used for a multiple increase in the collective response for the perturbation caused by a particle of a co-moving ion beam, i.e. for enhancement of friction force in electron cooling method. The low scale (hundreds GHz and larger frequency range) space charge or FEL type instabilities can be produced (depending on conditions) by introducing an alternating magnetic fields along the electron beam path. Beams' optics and noise conditioning for obtaining a maximal cooling effect and related limitations will be discussed. The method promises to increase by a few orders of magnitude the cooling rate for heavy particle beams with a large emittance for a wide energy range with respect to either electron and conventional stochastic cooling [1,2].

[1] Ya. S.Derbenev, Coherent Electron Cooling, UM HE 91-28, August 7, 1991

[2] Ya. S.Derbenev, AIP Conf. Proc., No 253, p. 103. AIP 1992

Funding: *Authored by Jefferson Science Associate under U. S. DoE Contract No. DE-AC05-06OR23177

THM2I06

Electron Beams as Stochastic 3D Kickers

V. B. Reva, A. V. Ivanov, V. V. Parkhomchuk (BINP SB RAS)

The stochastic cooling was proposed by Van-Der-Mayer in 60-x. The active feedback system interacting with the beam damped the thermal motion of the particles. One particle displacement from the equilibrium position induces the signal on pick-up electrodes. This signal is amplified and applied to the kicker system acting on the beam. The rest particles produce the noise signal limiting the decrement rate. The electron cooling uses another physics principle. The ions and electrons move together on the straight section with equal velocities. The electrons have a small momentum spread so the cooling process of the "hot" gas of the ions is happened. These two methods are complementary methods. The stochastic cooling works well at the large momentum spread of the ions beam but the electron cooling works well at the intensive ion beam with small momentum spread. This article describes an idea combining both methods in one device. The electron cooler may work as stochastic cooler at the same time. The signal about displacements of the ion from pick-up electrode applied to electrode of electron gun after amplification. Thus, a wave of the space charge in the electron beam is induced. This wave propagates with the electron beam to the cooling section. The space charge of the electron beam acts on the ions beam producing a kick. The effectiveness of the amplification can be improved with using structure similar to a travelling-wave tube.

THA — Thursday Afternoon Poster Session

Electron Cooling for Arbitrary Distribution of Electrons

THAP01

A. O. Sidorin, A. V. Smirnov (JINR) I. Ben-Zvi, A. V. Fedotov, D. Kayran (BNL)

Typically, several approximations are being used in simulation of electron cooling process, for example, density distribution of electrons is calculated using an analytical expression and distribution in the velocity space is assumed to be Maxwellian in all degrees of freedom. However, in many applications, accurate description of the cooling process based on realistic distribution of electrons is very useful. This is especially true for a high-energy electron cooling system which requires bunched electron beam produced by an Energy Recovery Linac (ERL). Such systems are proposed, for instance, for RHIC and electron – ion collider. To address unique features of the RHIC-II cooler, new algorithms were introduced in BETACOOL code which allow us to take into account local properties of electron distribution as well as calculate friction force for an arbitrary velocity distribution. Here, we describe these new numerical models. Results based on these numerical models are compared with typical approximations using electron distribution produced by simulations of electron bunch through ERL of RHIC-II cooler.

Implementation of synchrotron motion in barrier buckets in the BETACOOL program

THAP02

A. V. Smirnov, A. O. Sidorin, G. V. Trubnikov (JINR) O. Boine-Frankenheim (GSI)

In the case of the internal pellet target the electron cooling and the stochastic cooling systems cannot compensate the mean energy losses of the ion beam. In bunched ion beams the space charge limit is reduced and the influence of intrabeam scattering is enhanced, which causes a decrease of the luminosity in comparison with a coasting beam. To resolve these problems barrier buckets are proposed for experiments with the pellet target. In the barrier bucket the long ion bunch fills nearly the whole circumference of the storage ring and a rf pulse is applied at the head and at the tail of the bunch. The general goal of the BETACOOL program is to simulate long term processes (in comparison with the ion revolution period) leading to the variation of the ion distribution function in six dimensional phase space. The investigation of the beam dynamics for arbitrary distribution functions is performed using multi particle simulation in the frame of the Model Beam algorithm. In this algorithm the ion beam is represented by an array of macro particles. The heating and cooling processes involved in the simulations lead to a change of the particle momentum components and particle number, which are calculated each time step. The barrier bucket model was developed in the Model Beam algorithm of the BETACOOL program. The trajectory of each model particle is solved analytically for a given barrier bucket voltage amplitude. An invariant of motion is calculated from the current position of the model particle and from the barrier bucket voltage amplitude. Then the phase of the invariant is calculated in accordance with the integration step and the particle gets a new coordinates. The heating and cooling effects are applied in usual procedure of the Model Beam algorithm. First simulation results for the FAIR storage rings are presented.

THAP03

An Ultracold Cryogenic Photoelectron Source for the TSR Electron Target

C. Krantz, J. Hoffmann, D. Orlov, A. Wolf (MPI-K) A. S. Jaroshevich, A. S. Terekhov (ISP)

We present a cryogenic GaAs photocathode electron source developed for the target section of the Heidelberg Test Storage Ring (TSR) [*], capable of delivering electron currents of 1 mA in continuous operation. While the initial electron kinetic energy spread is of 10 meV [*], adiabatic expansion (magnetic field ratio: 20…40) and acceleration (typically to energies of 0.05…5 keV) reduce the energy spreads transverse and longitudinal to the beam direction down to 0.5…1 meV and 0.02…0.04 meV respectively [**]. Recently, the performance and stability of the photocathode source has been significantly improved. This was achieved by controlling several quantum yield degradation effects, including cryosorbtion at the sample surface, vacuum degrading desorbtion induced by loss electron currents, and backstreaming of ionised restgas particles through the beam optics. Presently, we obtain electron currents of up to 1 mA at photocathode temperatures of about 100 K and sample lifetimes of at least 24 h. Degraded samples can be quickly replaced by freshly activated ones using a magnetic manipulator. The replacement procedure, including cooling of the new sample to cryogenic temperature takes only 30 min, allowing a practically continuous operation of the electron gun. The instrumental setup ensures an in-vacuum closed operation cycle of the photocathode samples. The preparation chamber of the setup can contain up to four cathode samples and provides facilities for heat-cleaning and cesium/oxygen-activation of the latter. After several duty cycles, the photocathodes can additionally undergo atomic hydrogen cleaning, which fully restores their emission properties. Further work in order to improve current intensity, lifetime, and energy spread of electron beams from GaAs photocathode sources is in progress. Additionnally, different types of wider-band semiconductor photocathodes, believed to be less sensitive to degradation effects, are being studied.

[*] D. A. Orlov et al., NIM A 532, 298 (2004)

[**] D. A. Orlov et al., J. Phys.: Conf. Ser. 4, 290 (2005)

THAP04

Optimization of the Magnet System for Low Energy Coolers

A. V. Bubley, V. M. Panasyuk, V. V. Parkhomchuk (BINP SB RAS)

Aspects of magnet design and field measurements are discussed in the view of low energy coolers construction. The paper describes some engineering solutions for the magnetic field improvement which provides appropriate conditions for the cooling process as well as electron and ion beams motion.

THAP05

Prototype of the High Voltage Section for the 2 MeV Electron Cooler at COSY

J. Dietrich (FZJ) A. D. Goncharov, Ya. G. Kruchkov, V. V. Parkhomchuk, V. B. Reva, D. N. Skorobogatov (BINP SB RAS)

The design, construction and installation of a 2 MeV electron cooling system for COSY-Juelich is proposed to further boost the luminosity even with strong heating effects of high-density internal targets. In addition the 2 MeV electron cooler for COSY is intended to test some new features of the high energy electron cooler for HESR at FAIR/GSI. The design of the 2 MeV electron cooler will be accomplished in cooperation with the Budker Institute of Nuclear Physics in Novosibirsk, Russia. The design and first experiments of a new developed prototyp of the high voltage section, consisting of a gas turbine, magnetic coils and high voltage generator with electronics is reported.

Cooling in Compound Buckets

THAP06

A. V. Shemyakin, C. M. Bhat, D. R. Broemmelsiek, A. V. Burov, M. Hu (Fermilab)

Presently antiprotons in Fermilab's Recycler ring are stored between rectangular RF barriers and are cooled both by a stochastic cooling system in full duty-cycle mode and by a DC electron beam. Electron cooling creates correlation between longitudinal and transverse tails of the antiproton distribution because particles with large transverse actions are cooled much more slowly than the core ones. Introducing additional RF barriers of lower amplitude allows separating spatially (along the bunch) the core and the tail. In this scenario, stochastic cooling can be "gated" to the tail, i.e. applied with a high gain to the low-density region and turned off for the core portion of the beam. This significantly increases the cooling rate of the tail particles, while the temperature of the core is preserved by electron cooling. In this paper, we will describe the procedure and first experimental results in detail.

Image Charges in the Cooling Section of the Recycler Cooler

THAP07

A. V. Shemyakin, L. R. Prost (Fermilab)

Electron cooling rate of the antiprotons in the Recycler is regulated by a parallel shift of the 4.3 MeV, 0.1 A DC electron beam in the cooling section. Image charges induced by the beam on the vacuum chamber significantly affect the off-axis electron trajectory. The paper will present the measurement results of the effect, compare them with a model, and give estimation for a possible ion compensation of the electron beam charge.

Electron Cooling Measurements in the Recycler Cooler

THAP08

A. V. Shemyakin, L. R. Prost (Fermilab) A. V. Fedotov (BNL) A. O. Sidorin (JINR)

A 0.1-0.5 A, 4.3 MeV DC electron beam provides cooling of 8 GeV antiprotons in Fermilab's Recycler storage ring. Properties of electron cooling have been characterized in measurements of the drag force, cooling rates, and equilibrium distributions. The paper will report experimental results and compare them with modeling by BETACOOL code.

Beam-based Field Alignment of the Cooling Solenoids for Fermilab's Electron Cooler

THAP09

L. R. Prost, A. V. Shemyakin (Fermilab)

The cooling section of FNAL's electron cooler is composed of ten (10) 2 m-long, 105 G solenoids. When FNAL's electron cooler (4.3 MeV, 0.1 A DC) was first install at the Recycler ring, the magnetic field of the cooling solenoid was carefully measured and compensated to attain the field quality necessary for effective cooling [V. Tupikov et al. COOL'05]. However, the tunnel ground motion deteriorates the field quality perceived by the beam over time. We have developed a technique which uses the cooling strength as an indication of the relative field quality and allowing us to re-align the longitudinal magnetic field in the successive solenoids of the cooling section assuming that the transverse component of the field in each solenoid has not varied.

THAP10

Status of the Design Work Towards an Electron Cooler for HESR

B. Gålnander, T. Bergmark, O. Byström, S. Johnson, T. Johnson, T. Lofnes, G. Norman, T. Peterson, K. Rathsman, D. Reistad (TSL) H. Danared (MSL)

The HESR-ring of the future FAIR-facility at GSI will include both electron cooling and stochastic cooling in order to achieve the demanding beam parameters required by the PANDA experiment. The high-energy electron cooler will cool antiprotons in the energy range 0.8 GeV to 8 GeV. The design is based on an electrostatic accelerator and shall not exclude a further upgrade to the full energy of HESR, 14.1 GeV. The beam is transported in a longitudinal magnetic field of 0.2 T and the requirement on the straightness of the magnetic field is as demanding as 10^{-5} radians rms at the interaction section. Furthermore, care must be taken in order to achieve an electron beam with sufficiently small coherent cyclotron motion and envelope scalloping. This puts demanding requirements on the electron beam diagnostics as well as the magnetic field measuring equipment. Prototype tests of certain components for these tasks are being performed. The paper will discuss these tests and recent development in the design including the high-voltage tank, electron gun and collector, magnet system, electron beam diagnostics and the magnetic field measuring system.

THAP12

Electron Cooling Design for ELIC - a High Luminosity Electron-Ion Collider *

Y. S. Derbenev (Jefferson Lab)

An electron-ion collider (EIC) of center mass energy 90 GeV (9 GeV of electron beam x 225 GeV of proton beam) at luminosity level up to $10^{35}/cm^2s$ is envisioned by high energy Nuclear Physics community as a facility adequate for studying of the fundamental properties of quark-gluon structure of nucleons and strong interactions. In response to this quest, a high luminosity ring-ring EIC design (ELIC) is developed at Jefferson Laboratory utilizing 12 GeV upgrade CEBAF accelerator as a full energy injector for electron storage ring . An inevitable component of EIC is high energy electron cooling (EC) for ion beam. The EC facility concept for ELIC is based on use of 30 mA, 125 MeV energy recovery linac (ERL) and 3A circulator-cooler ring (CCR) operated at 15 and 1500 MHz bunch repetition rate, respectively. To switch electron bunches between ERL and CCR, fast kickers of a frequency bandwidth above 2 GHz are designed. The design parameters of EC facility and preliminary results of study of electron beam transports, stability and emittance maintenance in ERL and CCR, together with scenario of forming and cooling of ion beam will be presented.

THAP13

Recent Developments for the HESR Stochastic Cooling System

R. Stassen, H. Singer, H. Stockhorst (FZJ) L. Thorndahl (CERN)

Two cooling systems will be installed in the High-Energy Storage Ring (HESR) of the future international Facility for Antiproton and Ion Research (FAIR) at the GSI in Darmstadt: an electron cooler (1.5-8 GeV/c) and a stochastic cooling system from 3.8 GeV/c up to the highest momentum of the HESR (15 GeV/c). Both cooler are mandatory for the operation of the HESR with the PANDA pellet target. The relative low aperture (89mm) of the HESR suggests fixed structures without a plunging system. An octagonal layout was chosen to increase the sensitivity of the electrodes. Two different types of electrodes were built and tested. We will report on the comparison of printed lambda/4 loops and new broadband slot couplers.

Pick-Up Electrode System for the CR Stochastic Cooling System

C. Peschke, F. Nolden (GSI)

The collector ring (CR) of the FAIR project will include a fast stochastic cooling system for exotic nuclei with a β of 0.83 and antiprotons with a β of 0.97. To reach a good signal to noise ratio of the pick-up even with a low number of particles, a cryogenic movable pick-up electrode system based on slotlines is under development. The sensitivity and noise properties of an electrode array has been calculated using field-simulation and equivalent circuits. For three-dimensional field measurements, an E-near-field probe moved by a computer controlled mapper has been used.

Beam Based Measurements Stochastic Cooling Systems in Fermilab

V. A. Lebedev, R. J. Pasquinelli, S. J. Werkema (Fermilab)

Maximizing performance of stochastic cooling would not be possible without beam based measurements. In this paper we discuss experience with beam based measurements of Antiproton source stochastic cooling; and how the measurement results are used in building of the cooling system model.

Work supported by the Fermi Research Alliance, under contract DE-AC02-76CH03000 with the U. S. Dept. of Energy.

Development and Design of Equalizers for Stochastic Cooling in Fermilab

V. A. Lebedev, R. J. Pasquinelli, D. Sun (Fermilab)

To maximize performance of Antiproton source stochastic cooling we developed and built equalizers correcting both phase and amplitude of the system gain. Design requirements have been based on the beam measurements of the system gain. Paper presents principles of the design and details of engineering, manufacturing and tuning of the equalizers.

Work supported by the Fermi Research Alliance, under contract DE-AC02-76CH03000 with the U. S. Dept. of Energy.

The 6D Intra-beam Scattering Formulation

S. Nagaitsev, V. A. Lebedev (Fermilab)

In this paper we will present the extension of the Bjorken-Mtingwa IBS theory to a coupled 6D beam phase-space case. This IBS formulation will be presented for a particular coupled optics functions description, developed by Lebedev and Bogacz and employed in a beam optics modeling program, OptiM.

THAP18

Theoretical and Numerical Studies of the Magnetized Friction Force

G. Zwicknagel (Institut für Theoretische Physik, Erlangen)

An accurate description of the electron cooling process requires a detailed knowledge of the underlying cooling force. Therefore comprehensive theoretical and numerical studies of the magnetized friction force have been performed within the binary collision model in second order perturbation theory and by classical-trajectory-Monte-Carlo simulations and within the dielectric description by the linear response treatment and by particle-in-cellsimulations of the nonlinear Vlasov-Poisson equations. Recently obtained analytical expressions are discussed and compared to the results of the numerical simulations as well as to available formulas for the magnetized friction force. In addition some comparison of the predictions of our theoretical treatments with experimental results is presented.

THAP19

Influences of Space Charge Effect during Ion Accumulation using Moving Barrier Bucket Cooperated with Beam Cooling

T. Kikuchi, S. Kawata (Utsunomiya University) T. Katayama (GSI)

Space charge effect is important role for stacking of antiprotons and ions in an accumulation ring. The Coulomb force displaces the beam orbits from the designed correct motion. The beam particles kicked out from the ring acceptance by the space charge force are lost. The space charge effect interfere the beam stacking, and the number of the accumulated beam decreases and the emittance is increased. The longitudinal ion storage method by using a moving barrier bucket system with a beam cooling can accumulate the large number of secondary generated beams*. After the multicycle injections of the beam bunch, the stored particles are kicked by the space charge effect of the accumulated beam. Using numerical simulations, we employ the longitudinal particle tracking, which takes into account the barrier bucket voltage, the beam cooling and the space charge effect, for the study of the beam dynamics during the accumulation operations.

*T. Katayama, P. Beller, B. Franzke, I. Nesmiyan, F. Nolden, M. Steck, D. Mohl and T. Kikuchi, AIP Conference Proc. 821 (2005) 196.

THAP20

Internal Target Effects in the ESR Storage Ring with Cooling

V. Gostishchev, C. Dimopoulou, A. Dolinskii, F. Nolden, M. Steck (GSI)

The accurate description of the internal target effects is important for the prediction of operation conditions which are required for the performance of experiments in the storage rings of the FAIR facility at GSI. A number of codes such as PTARGET, MOCAC, PETAG01 and BETACOOL have been developed to evaluate the beam dynamics in the storage ring, where an internal target in the combination with an electron cooling is applied. The systematic benchmarking experiments were carried out at the ESR storage ring at GSI. The 'zero' dispersion mode (dispersion at target position is about 0 m) was applied to evaluate the influence of the dispersion function on the beam parameters when the internal target is ON. The influence of the internal target on the beam parameters is demonstrated. Comparison of the experimental results with the Bethe-Bloch formula describing the energy loss of the beam particles in the target as well as with simulations with the BETACOOL code will be given.

Longitudinal Schottky Signals of Cold Systems with Low Number of Particles

R. W. Hasse (GSI)

Very cold systems of ions with sufficiently low number of particles arrange in an ordered string-like fashion. The determination of the longitudinal momentum spread and of the transverse temperature then is no longer possible by normal Schottky diagnosis. In this paper we simulate such systems in an infinitely long beam pipe with periodic boundary conditions under the influence of all long-range Coulomb interactions by Ewald summation. Then we derive the behaviour of the longitudinal Schottky signals for cold string-like systems as well as for the transition to warmer systems when the strings break, up to hot gas-like systems. Here effects from the finite number of particles, of higher harmonics and of temperature agree with those derived analytically in the limits of very low and very high temperatures.

Limitations of the Observation of Beam Ordering

M. Steck, K. Beckert, P. Beller, C. Dimopoulou, F. Nolden (GSI)

One dimensional beam ordering of electron cooled low intensity heavy ion beams has been evidenced at the ESR storage ring as a discontinuous reduction of the momentum spread. Depending on the beam parameters, technical imperfections or any sources of heating can hamper or even prevent the observation of the momentum spread reduction. Limitations for the detection of the ordered beam will be described and illustrated by experimental results.

THA2 — Thursday Afternoon Teatime Talk

THA2I01

Exciting New Physics with Stored and Cooled Single Ions

F. G. Bosch (GSI)

Experiments addressing the beta decay of stored and cooled highly-charged ions will be presented and discussed. They have been conducted during the last decade at the facilities of GSI. There, the combination of a fragment separator (FRS) and of an ion storage-cooler ring (ESR) provided the very first opportunity to produce beta-unstable ions in-flight, to store and cool them over many hours in the ion ring by preserving their atomic charge state, and, finally, to observe time-resolved their beta decay. The astrophysical impact of those experiments is obvious: Stellar nucleosynthesis proceeds beyond iron via the interplay of neutron- or proton-capture and beta decay, at typical temperatures of 30–100 keV and, thus, at high atomic charge states. In particular, in this talk experiments concerning two-body beta decay (bound-state beta decay sc. orbital electron capture) of stored and cooled single ions at well-defined atomic charge states will be addressed, where for the first time the decay characteristics could be precisely investigated.

FRM1 — Friday Morning Session 1

Present Status and Recent Activity on Laser Cooling at S-LSR

FRM1I01

A. Noda, T. Ishikawa, M. Nakao, T. Shirai, H. Souda, M. Tanabe, H. Tongu (Kyoto ICR) M. Grieser (MPI-K) I. N. Meshkov, A. V. Smirnov (JINR) K. Noda (NIRS)

Ion storage and cooler ring, S-LSR, has been designed to enable the investigation of coldest possible ion beams with use of various beam cooling schemes such as an electron beam cooling and the laser cooling. Electron beam cooling of 7 MeV protons and laser cooling of 40 keV Mg ions have been applied up to now. The first laser cooling applied to ~10^8 Mg ions with the induction accelerator voltage of ~6 mV reduced the momentum spread (1 sigma) from 1.7×10^{-3} to 2.9×10^{-4}, which is considered to be saturated by the momentum transfer from transverse degree of freedom to the longitudinal one due to intra-beam scattering. The laser cooling force has been improved from the above one more than one order of magnitude owing to the precise alignment between the laser and Mg ion beam. Recent measurement with frequency shift of the laser showed the enhancement of the coherent signals in odd harmonics of the revolution frequency picked up with an electrostatic beam monitor and detailed measurements of various harmonics have been performed with changing the resolution bandwidth of the spectrum analyzer, although the origin of such coherency is not yet identified up to now. For the purpose of measurement of lowest possible temperature attainable by the laser cooling, measurement with reducing the ion numbers of Mg is needed, which has been blocked by the difficulty of observing the Schotty signal of such a low intensity beam. So as to cope with this situation, development of observing system of emitted light by the transition from the upper level to the ground state with the use of photomultiplier has been performed, which recently succeeded in detection of clear signals coming from the oriented process. Activities above mentioned will be presented together with the forth coming experimental results on laser cooling.
Funding: The present work has been supported from Advanced Compact Accelerator Development Project by MEXT of Japan and 21 COE at Kyoto University-Center for Diversity and Universality in Physics.

Laser Cooling of Relativistic Ion Beams: Summary of Experimental Results and Prospects for FAIR experiments.

FRM1C02

M. H. Bussmann, D. Habs (LMU) K. Beckert, P. Beller, B. Franzke, C. Kozhuharov, T. Kuehl, W. Noertershaeuser, F. Nolden, M. Steck (GSI) Ch. Geppert, S. Karpuk (Johannes Gutenberg University Mainz) C. Novotny (Johannes Gutenberg University Mainz, Institut für Physik) S. Reinhardt, G. Saathoff (MPI-K) U. Schramm (FZD)

We report on the first laser cooling of a bunched beam of C^{3+} ions at the ESR (GSI) at a beam energy of E = 1.47 GeV. Combining laser cooling of the 2S1/2-2P3/2 transition with moderate bunching of the beam lead to a reduction of the longitudinal momentum spread by one order of magnitude if compared to pure electron cooling. If additional electron cooling was applied, thus increasing the coupling between the longitudinal and transverse degree of freedom, three-dimensional cold beams with a plasma parameter of unity could be attained. In a second measurement campaign, a combination of a sweeping-frequency and a fixed-frequency laser beam was succesfully implemented to increase the momentum acceptance of the narrow band laser force. This cooling scheme improved the match of acceptance of the laser force to the momentum spread of the beam and reduced heating due to intra beam scattering. In addition to the interesting beam dynamics observed at low momentum spreads of

$\Delta p / p < 10^{-6}$ precision spectroscopy of 2S1/2-2P1/2 and 2S1/2-2P3/2 transition was performed, both absolute and relative, at a precision challenging the best theoretical models available. The laser cooling schemes used at the ESR can be directly extended to the regime of ultra-relativistic ion energies at the new FAIR facility. There, it becomes possible to cool a large number of ion species using a single laser beam source, exploiting the relativistic Doppler shift of the laser frequency. Finally, the fluorescence photons emitted by these ultra-relativistic laser cooled ion beams can be directly used for precision X-ray spectroscopy of the cooling transitions. The resolution of such measurements would essentially be only limited by the resolution of the X-ray spectrometers available.

Electron Cooling with Photocathode Electron Beams

D. Orlov, H. Fadil, M. Grieser, J. Hoffmann, C. Krantz, A. Wolf (MPI-K)

We report electron cooling experiments using a cold electron beam of 55 eV produced by a cryogenic GaAs photocathode. With this device the beam of singly charged ions with a mass of 31 amu, specifically the CF^+ ion, was cooled at an energy of 3 MeV (about 90 keV/u). Transverse cooling within 2-3 seconds to a very small equilibrium beam size was observed with an electron current of 0.3 mA (electron density of 3×10^6 cm^{-3}, magnetic guiding field of 0.04 T). A beam size of about 0.1 mm was deduced from imaging of recombination products. The short cooling times are mostly due to the low electron temperatures of 1 meV in transverse and 0.03 meV in longitudinal direction. An electrostatic Cryogenic Storage Ring (CSR) for slow ion beams, including protons, highly charged ions, and polyatomic molecules is under construction at the MPI-K. It will apply electron cooling at electron beam energies from 165 eV for 300 keV protons down to a few eV for polyatomic singly charged ions. Photoelectrons from the GaAs photocathode with laboratory energy spreads of about 10 meV [1] will be applied for generating such electron beams. In a storage ring of this type, even low electron-ion merging magnetic fields of toroids cause a strong coupling between the horizontal and vertical motions of the stored ions, reducing the ring acceptance to an intolerably low level. We present a new merging scheme of eV-electrons with stored ions, based on the idea of bringing electrons to the ion axis in a uniform dipole magnetic field superimposed to a straight solenoid field. The new magnetic field arrangement strongly improves the ring acceptance and allows to use guiding magnetic fields as high as required to provide high-quality electron beams of eV-energies for the cooling of ions and for merged beam studies in storage rings.

[1] D. A. Orlov et al., Appl. Phys. Letters 78, 2721 (2001)

FRM2 — Friday Morning Session 2

Beam Studies at CRYRING for FLAIR

FRM2C04

H. Danared, A. Källberg, A. Simonsson (MSL)

It is planned that the CRYRING synchrotron and storage ring will be moved to the future FAIR facility at GSI. There it will be used as the Low-energy Storage Ring LSR at FLAIR (Facility for Low-energy Antiproton and Ion Research). LSR will mainly be used for deceleration of antiprotons from 30 MeV down to minimum 300 keV and for deceleration of highly charged ions in the same range of magnetic rigidities. As a preparation for the transfer of CRYRING to FAIR, studies have been made in order to evaluate the performance of CRYRING for deceleration of particles relevant to FLAIR and to set specifications for beams in and out of LSR. Deceleration of protons have been studied by first accelerating the particles to 30 MeV, then decelerating back to 300 keV again. Up to $3{\cdot}10^8$ protons have been decelerated in 1.8 s without intermediate cooling, and requirements on longitudinal and transverse emittances at 30 MeV for successful deceleration have been estimated. Other studies have included investigations of the space-charge limit for protons at 300 keV and measurements of transverse cooling times for H^- ions, simulating antiprotons. Also an attempt to compare longitudinal cooling forces between protons and H^- ions has been made.

Simulation Study of Ion Beam Accumulation with Moving Barrier Bucket assisted with Electron Cooling

FRM2C05

T. Katayama, C. Dimopoulou, B. Franzke, M. Steck (GSI) T. Kikuchi (Utsunomiya University) D. Möhl (CERN)

An effective ion beam accumulation method in NESR at FAIR project, is investigated with numerical way. The princile of accumulation method is as follows: Ion beam bunch from the collector ring or synchrotron is injected in the longitudinal gap space prepared by moving barrier voltage in NESR. Injected beam becomes instantly coasting beam after switching off the barrier voltage and is migrated with the previously stacked beam. After the momentum spread is well cooled by electron cooling, the barrier voltage is switched on and moved to prepare the empty gap space for the next injection. This process is repeated say 20 times to attain the required intensity. We have investigated this stacking process numerically, including the Intra Beam Scattering effect which might limit the stacking current in the ring. Detailed simulated results will be presented for the NESR case as well as the ESR experimental parameters.

FRM2C06

Electron Cooling Simulations for Low-energy RHIC Operation

A. V. Fedotov, I. Ben-Zvi, X. Chang, D. Kayran, T. Satogata (BNL)

Recently, a strong interest emerged in running RHIC at low energies in the range of 2.5-25 GeV/n total energy of a single beam. Providing collisions in this energy range, which in RHIC case is termed "low-energy" operation, will help to answer one of the key questions in the field of QCD about existence and location of critical point on the QCD phase diagram. Applying electron cooling directly at these low energies in RHIC would result in dramatic luminosity increase, small vertex distribution and long stores. On the other hand, even without direct cooling in RHIC at these energies, significant luminosity gain can be achieved by decreasing the longitudinal emittance of the ion beam before its injection into RHIC from the AGS. This will provide good RF capture efficiency in RHIC. Such an improvement in longitudinal emittance of the ion beam can be provided at by a simple electron cooling system at injection energy of AGS. Simulations of electron cooling both for direct cooling at low-energies in RHIC and for pre-cooling in AGS were performed, and are summarized in this report.

Funding: Work supported by the U. S. Department of Energy

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