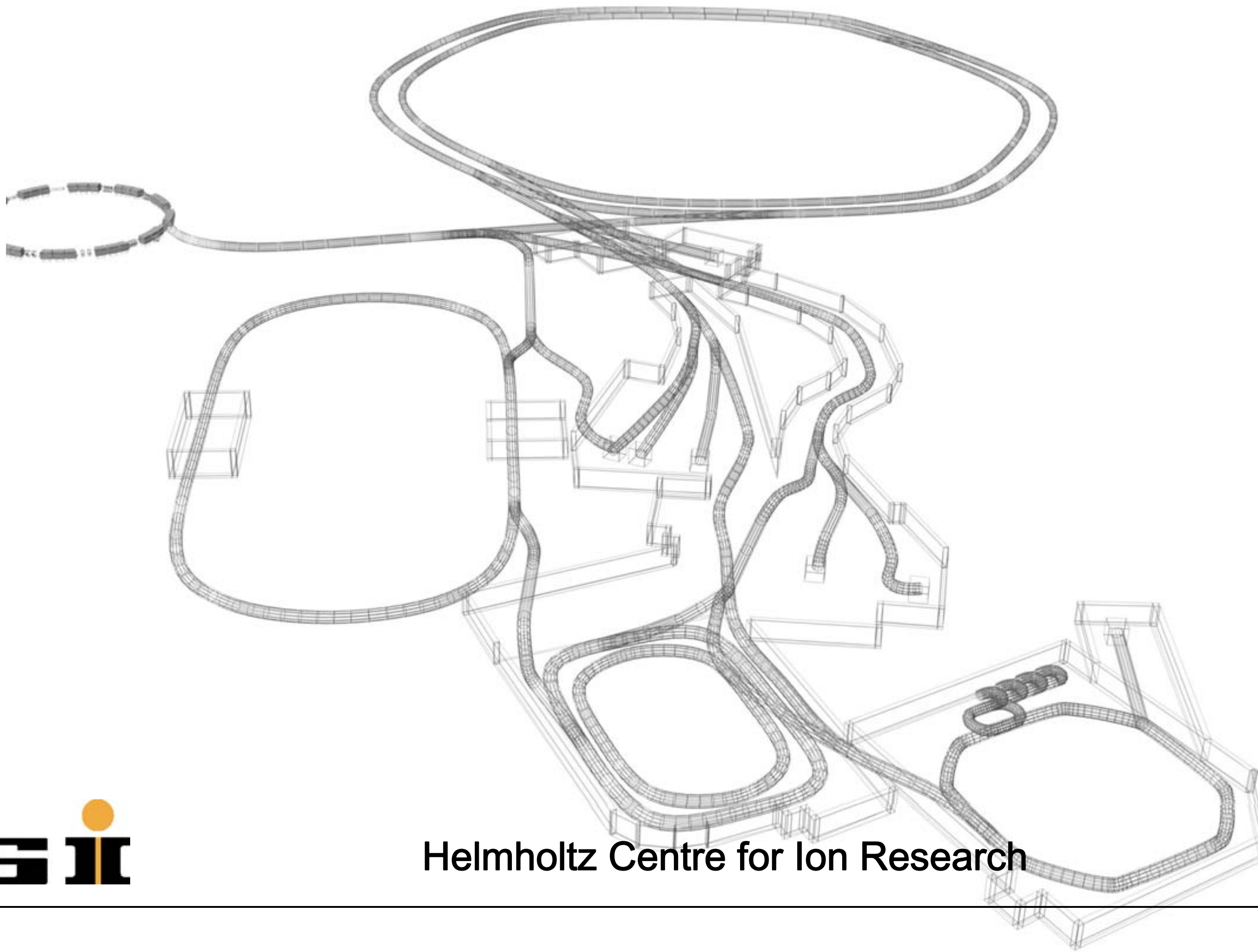
Current Status of the FAIR Project



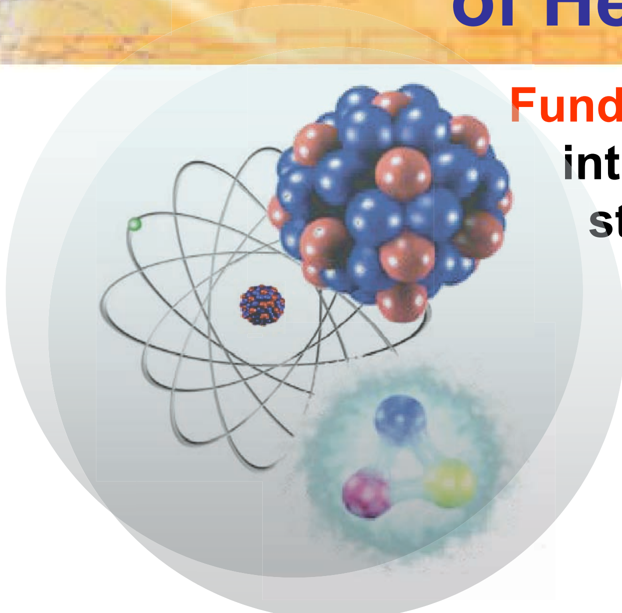
Helmholtz Centre for Ion Research

D. Krämer for the FAIR Design Team, PAC, Albuquerque, June 2007

FAIR: Motives and Objectives

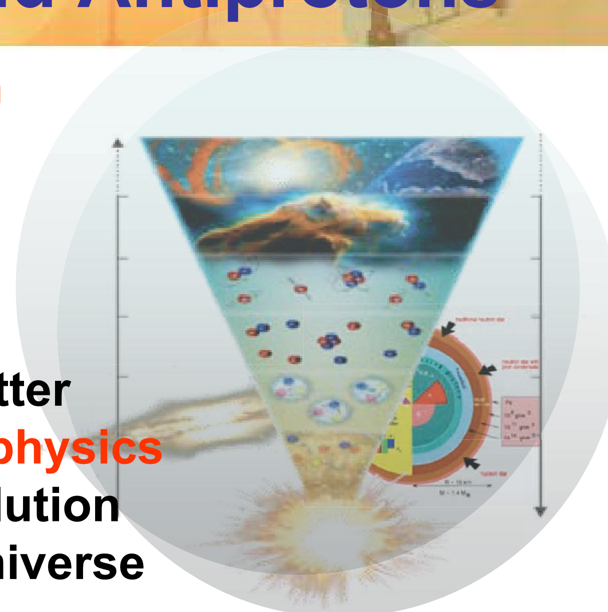
- Provide the European research area with a world-leading scientific infrastructure for nuclear and hadron research
- Build on the experience of GSI, the German competence center for hadron and nuclear physics
- Realize FAIR in an international cooperation

High Intensity Precision Beams of Heavy Ions and Antiprotons

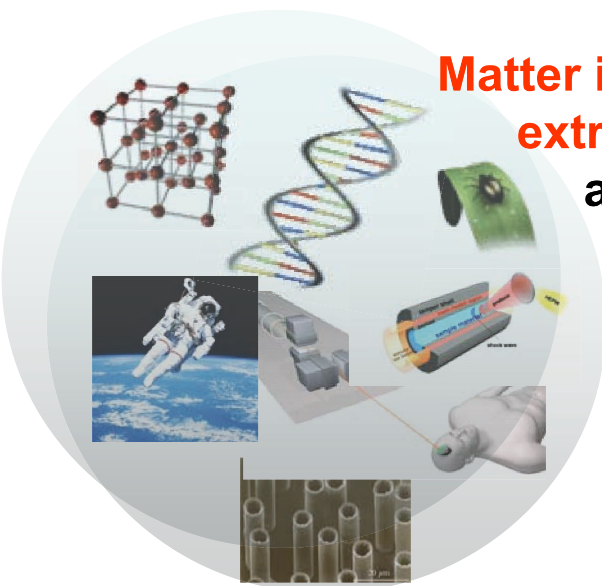


Fundamental Research
into the microscopic
structure of matter

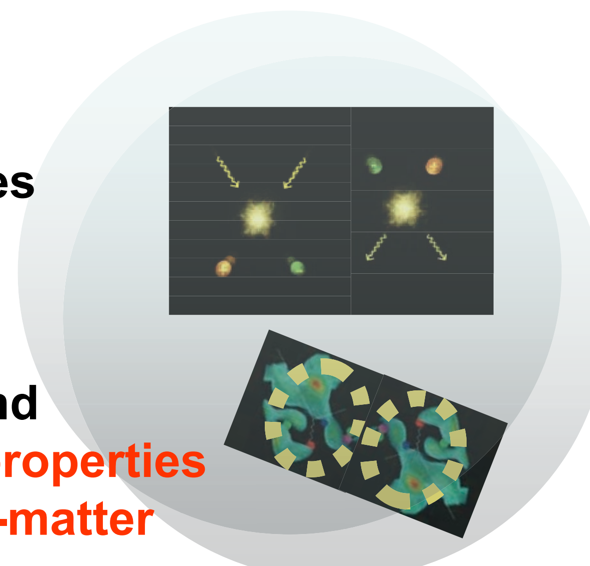
&



Creation of matter
nuclear astrophysics
and the evolution
of the universe

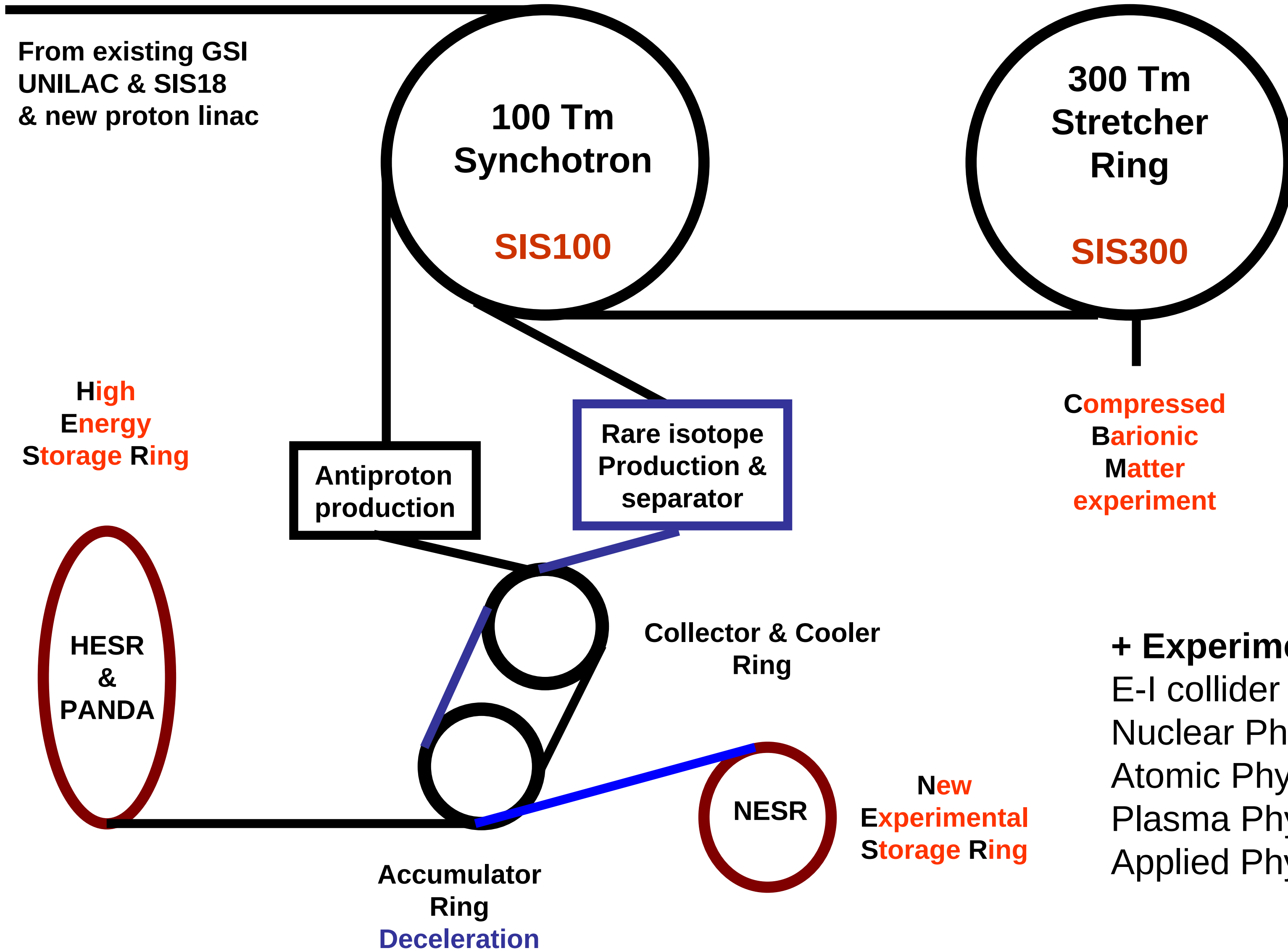


Matter in
extreme states
and material studies
& applications



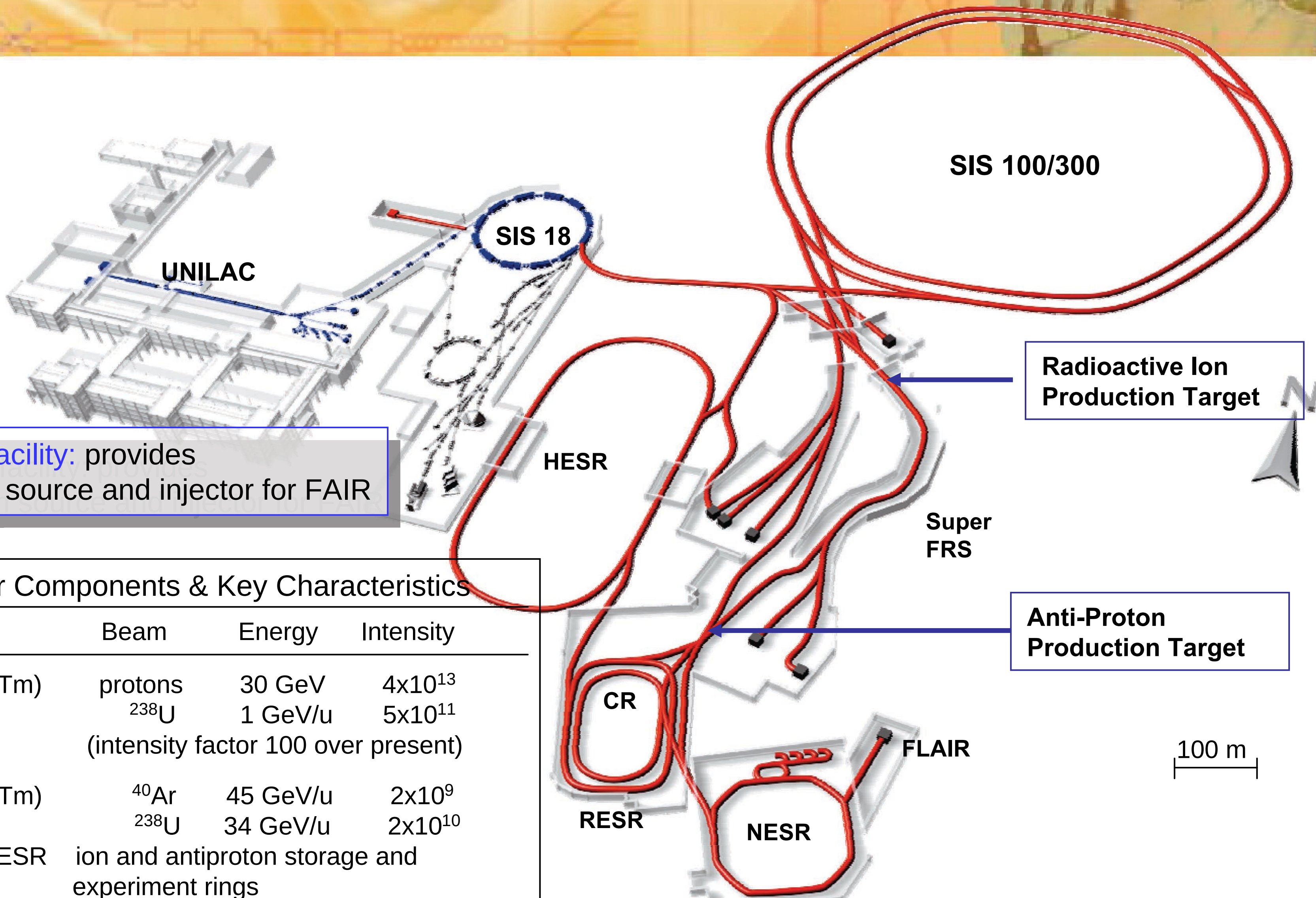
Structure and
fundamental properties
of anti-matter

The Pillars of the FAIR Complex



+ Experiments:
E-I collider
Nuclear Physics
Atomic Physics
Plasma Physics
Applied Physics

Technical Realization of FAIR

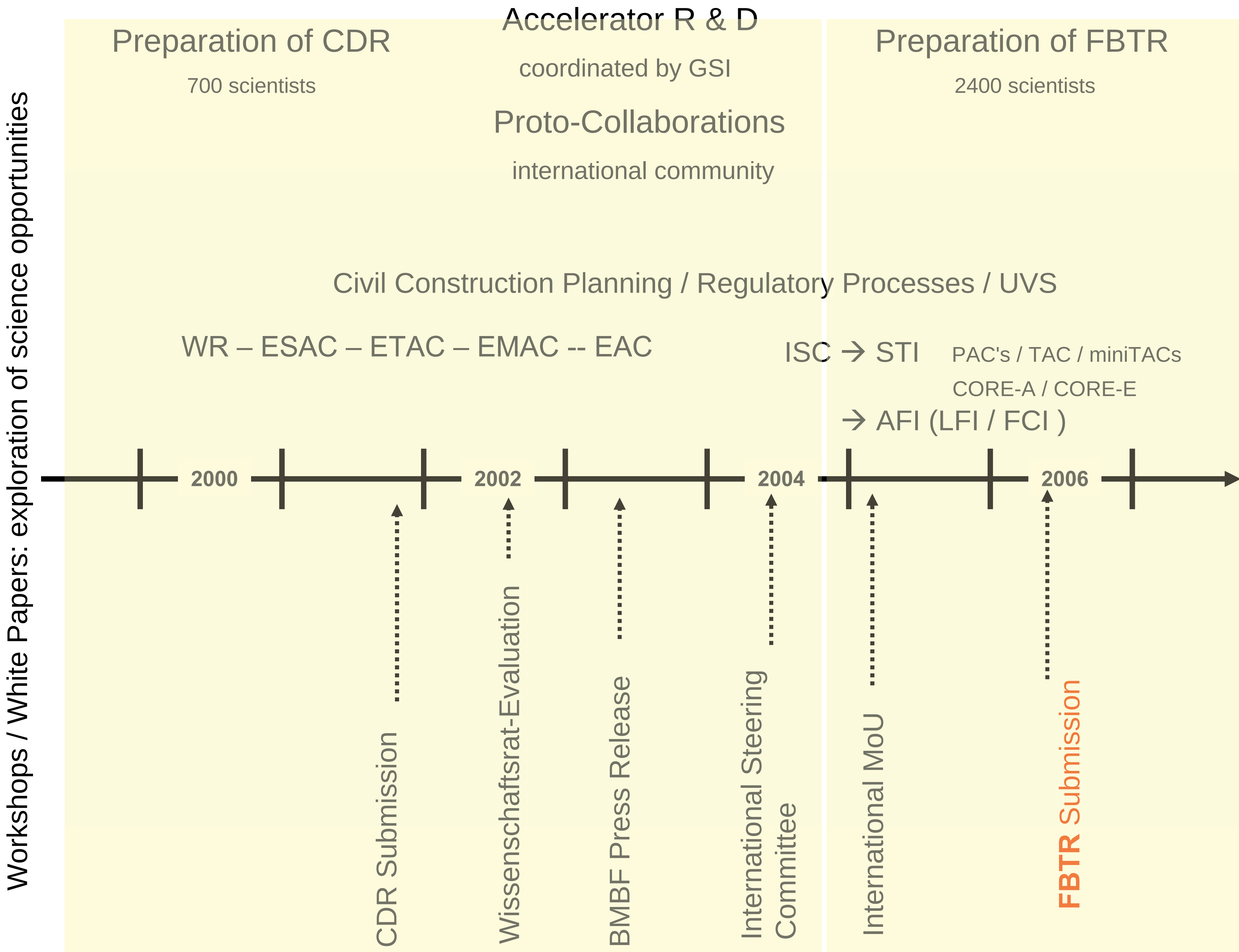


Existing facility: provides
ion-beam source and injector for FAIR

New future facility: provides ion and anti-matter
beams of highest-intensity and up to high energies

Accelerator Components & Key Characteristics

Ring/Device	Beam	Energy	Intensity
SIS100 (100Tm)	protons	30 GeV	4×10^{13}
	^{238}U	1 GeV/u	5×10^{11}
	(intensity factor 100 over present)		
SIS300 (300Tm)	^{40}Ar	45 GeV/u	2×10^{9}
	^{238}U	34 GeV/u	2×10^{10}
CR/RESR/NESR	ion and antiproton storage and experiment rings		
HESR	antiprotons	14 GeV	$\sim10^{11}$
Super-FRS	rare-isotope beams	1 GeV/u	$<10^{9}$


Accelerator R & D
Preparation of CDR
700 scientists
coordinated by GSI
Preparation of FBTR
2400 scientists
Proto-Collaborations
international community
Civil Construction Planning / Regulatory Processes / UVS
WR – ESAC – ETAC – EMAC -- EAC
ISC → STI
PAC's / TAC / miniTACs
CORE-A / CORE-E
→ AFI (LFI / FCI)
Workshops / White Papers: exploration of science opportunities
2000
2002
2004
2006
CDR Submission
Wissenschaftsrat-Evaluation
BMBF Press Release
International Steering Committee
International MoU
FBTR Submission

The International Committee Structure

(for XFEL & FAIR)

Austria | China | Finland | France | Germany | Greece | India | Italy | Poland | Spain | Sweden | Russia | Great Britain | Romania

ISC
International Steering Committee

Delegates from partner states

STI Working Group

- Baseline Technical Report
  - accelerator TR's
  - experiment proposals
  - civil construction plans

  (~ 3500 pages)
- PAC & TAC Review Reports
- Cost Book
- Cost Review Reports
  - accelerator & civil construction (CORE-A)
  - experiments (CORE-E)

FAIR Project

AFI Working Group

- Convention
- Articles of Association
- By-Laws
- Final Act Document
- Legal Framework Report (LFI)
- ll Cost Structure Report (FCI)

All documents are ready

Observes:

The FAIR Baseline Technical Report

Handed to ISC in April 2006

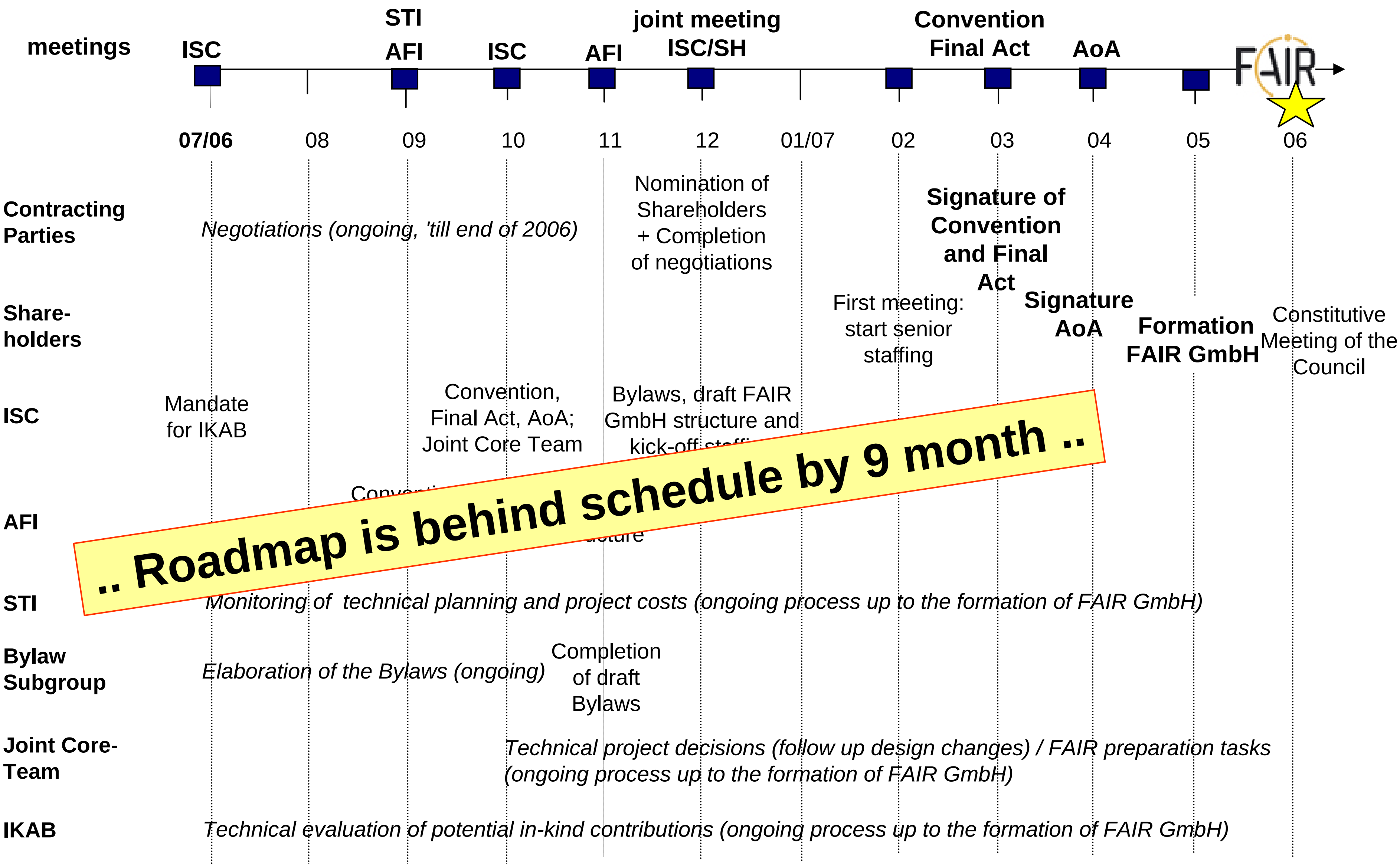
accepted as „The Project“

http://www.gsi.de/fair/reports/btr.html

FAIR Baseline Technical Report

Volume 1: Executive Summary
Volume 2: Technical Report Accelerators and Scientific Infrastructure
Volume 3: Techn. Experiment Proposals on QCD physics
Volume 4: Techn. Experiment Proposals on Nuclear Structure and Astrophysics
Volume 5: Techn. Experiment Proposals on Atomic Physics, Plasma Physics and Applied Physics
Volume 6: Techn. Report Civil Constructions

ISC FAIR – Roadmap: Establishment of FAIR GmbH as Project Owner



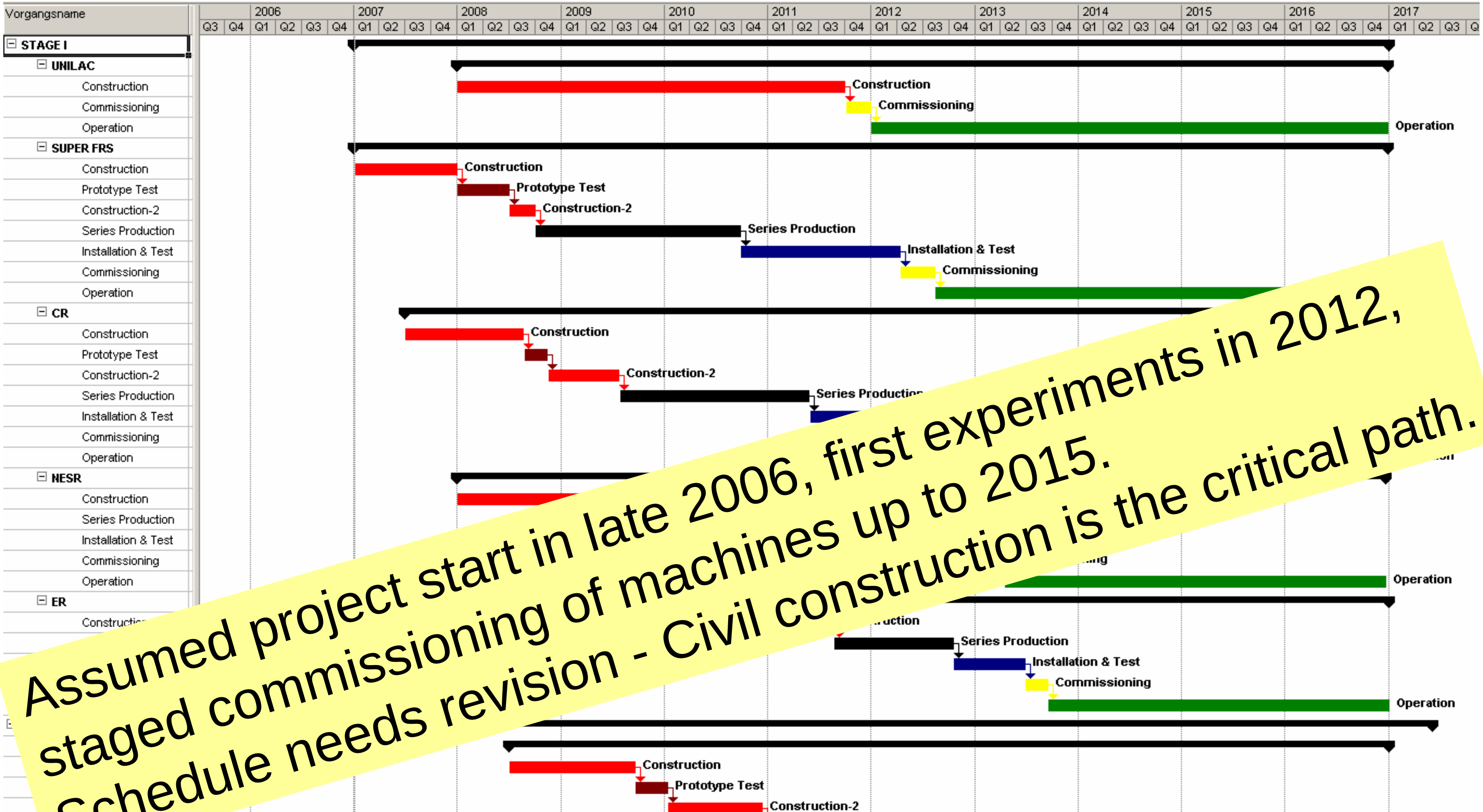
Recent decision by German Minister Ms. Schavan:

Start of the International FAIR Project

on November 7, 2007

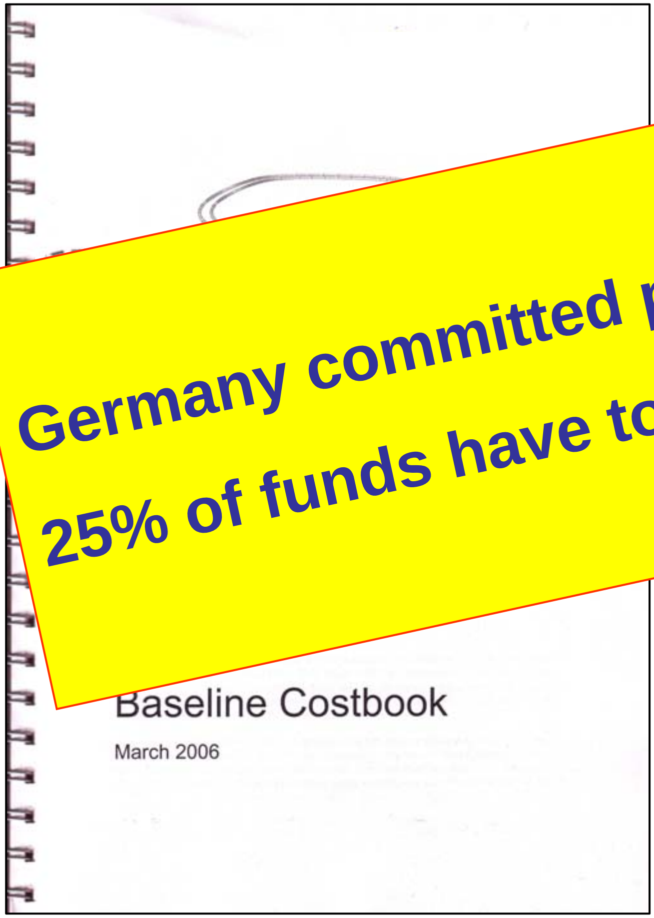
together with all partners that have expressed their commitment on FAIR.

Master Schedule - Accelerators



Assumed project start in late 2006, first experiments in 2012, staged commissioning of machines up to 2015. Schedule needs revision - Civil construction is the critical path.

Project Costs



Scrutinized by CORE, TAC, STI …

Germany committed part of funding

25% of funds have to come from non-German partners

	185 M€
Construction Costs	**1187 M€**
Commissioning Costs	**28 M€**
Operation Costs up to 2025	**1485 M€**
Sum	**2700 M€**

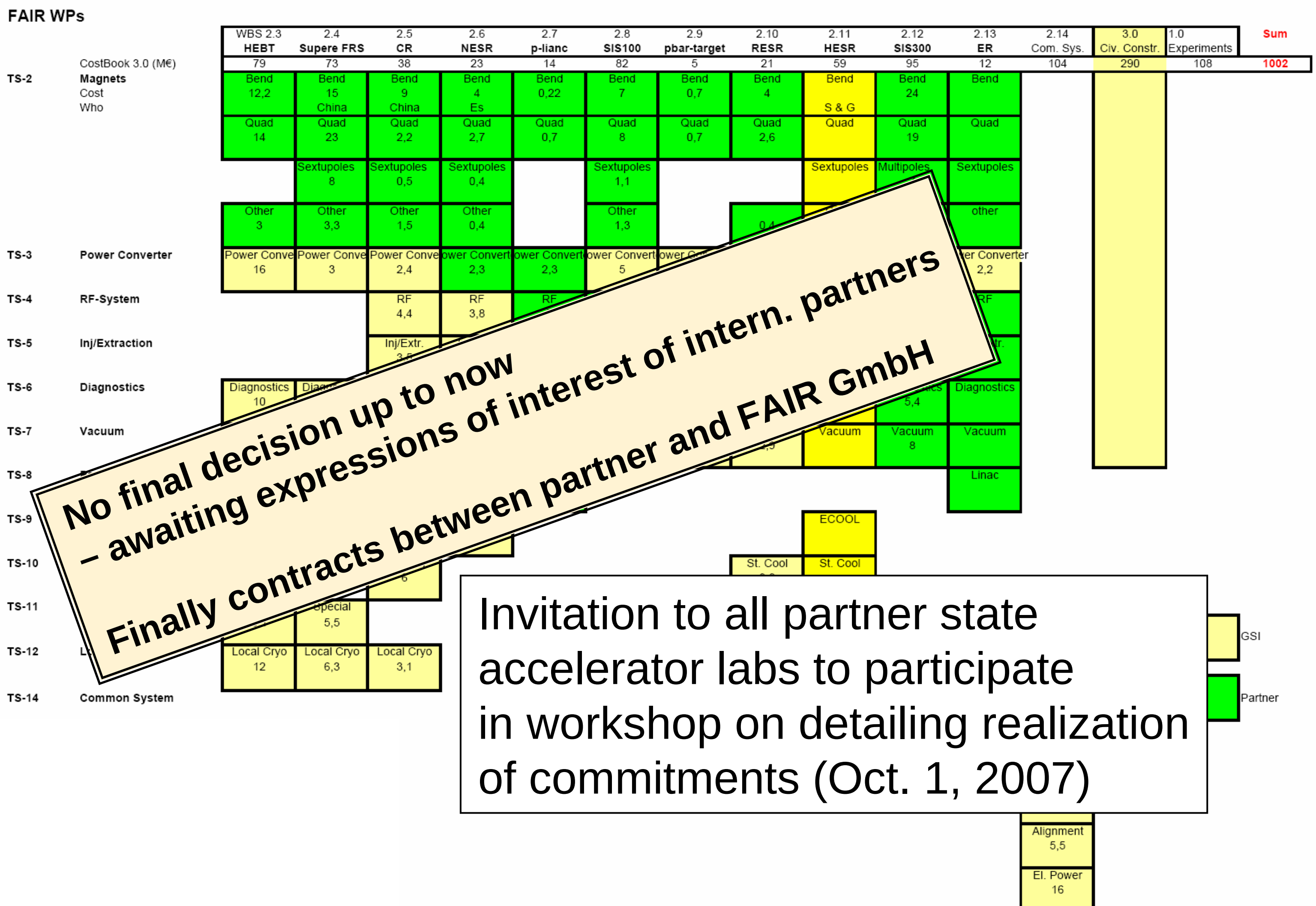
As of today: commitment by India (3%) and Rumania (1%) AND positive bilateral negotiations

FAIR Work Packages

94 WPs defined, following WBS, FBTR and Cost Book schematics

13 subprojects

15 technical systems



No final decision up to now
– awaiting expressions of interest of intern. partners

Finally contracts between partner and FAIR GmbH

Invitation to all partner state accelerator labs to participate in workshop on detailing realization of commitments (Oct. 1, 2007)

R&D on Key-Components during Preparatory Phase
by GSI & Partner Institutes since 2001

INFN
Istituto Nazionale di Fisica Nucleare

BROOKHAVEN NATIONAL LABORATORY

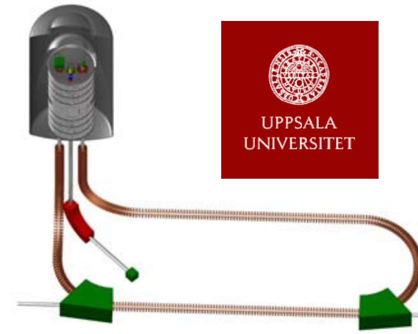
IHEP
Protvino

CEA

BINP Novosibirsk

SIS300 sc magnets

NESR Electron Cooling



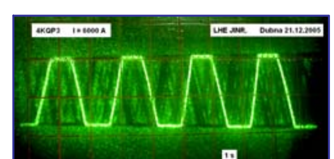
UPPSALA UNIVERSITET

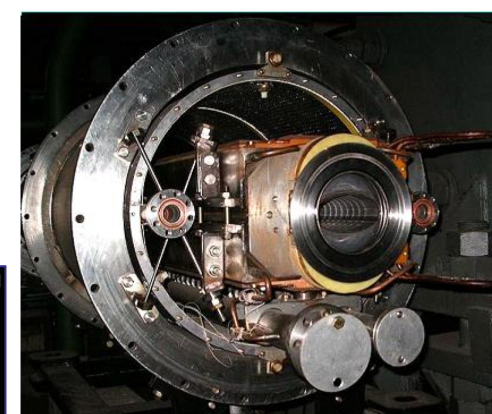
Forschungszentrum Jülich
in der Helmholtz-Gemeinschaft

Variable frequency
MA&ferrite loaded cavities

SIS100 rapidly cycling sc magnets

Joint Institute for Nuclear Research





Posters and Talks on FAIR

G.Moritz, FRYKI01,talk

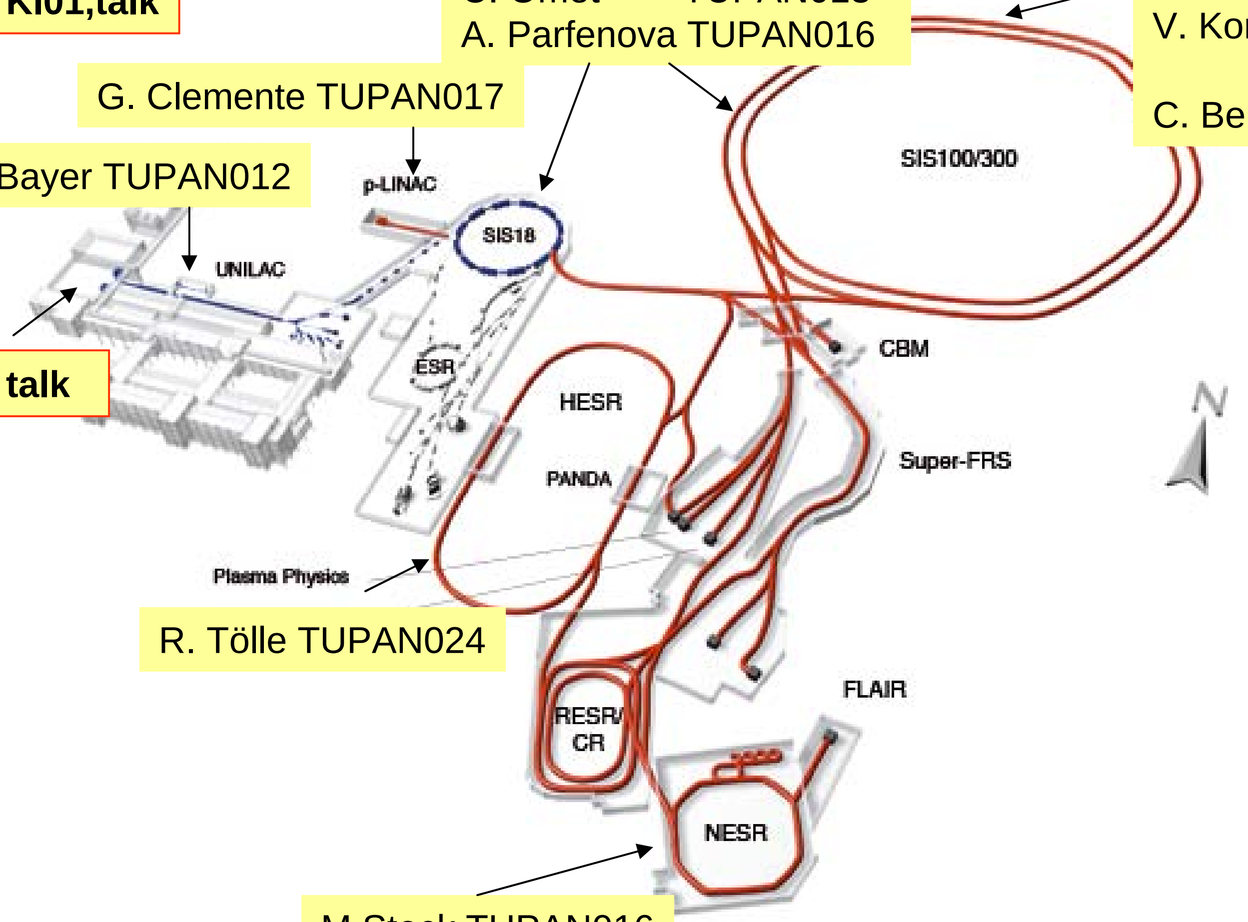
U. Blell MOPAN012
C. Omet TUPAN013
A. Parfenova TUPAN016

P. Spiller TUPAN014
J. Stadlmann TUPAN015
V. Kornilov TUPAN018 FRPMN014
C. Benedetti THPAN030

G. Clemente TUPAN017

W. Bayer TUPAN012

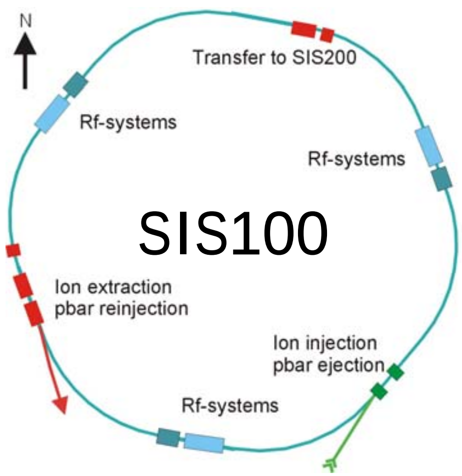
J. W. Stetson, talk

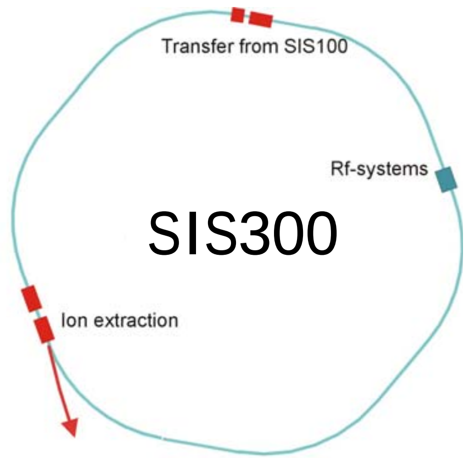


R. Tölle TUPAN024

M.Steck TUPAN016

SIS100/300 Design Parameters





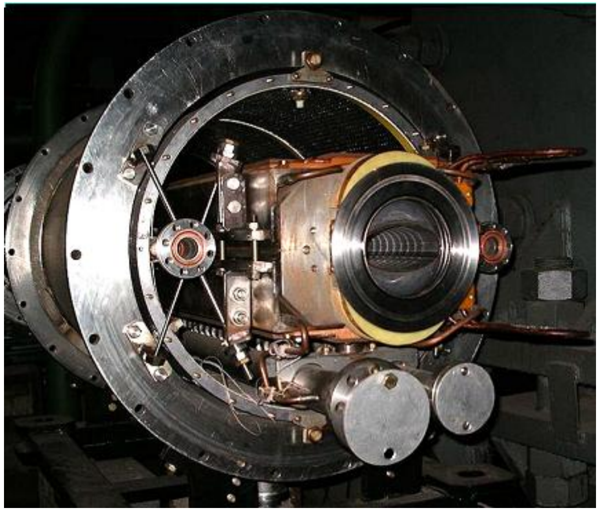
First Stage:	Second Stage:
Acceleration +	Acceleration +
Compression	Stretching

	SIS100	SIS300
Reference Ions	U^{28+} p	U^{28+} U^{92+}
Magnet. rigidity	100 Tm	300 Tm
Circumference	1083 m	1083 m
Number of Particles	$5 \cdot 10^{11}$ $5 \cdot 10^{13}$	$3 \cdot 10^{11}$ /s $1 \cdot 10^{10}$ /s
Energy	2.7 GeV/u 29 GeV	2.7 GeV/u 34 GeV/u
Beam time structure	25 – 90ns 50 ns	d.c. slow ext.
Dipole flux density	2 T	4.5 T
Ramp Rate	4 T/s	1 T/s

SIS100 Working Points and Lattice Parameters

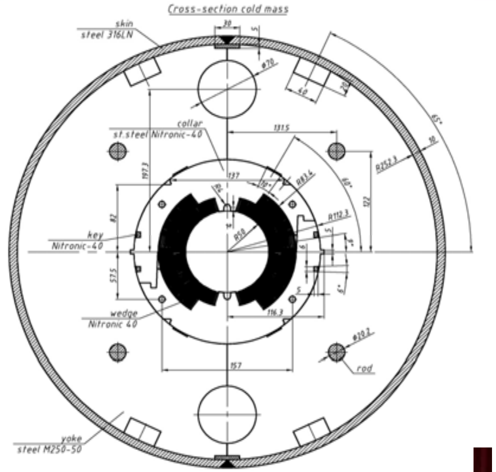
Tunes (h/v)		WP2 17.30 / 17.42	WP1 18.84 / 18.73	WP3 20.84 / 20.73
Mode of SIS100 operation		Ions, slow extraction	Ions, fast extraction	Protons, high energy
Amplitude function beta maximum	(h/v) m	19.8 / 19.6	19.6 / 19.6	20.4 / 19.9
Dispersion function alpha-p maximum alpha-p minimum	m m	1.44 -1.11	1.73 -0.12	1.30 -0.33
Phase advance per lattice cell	deg	74 / 75	81 / 80	89 / 89
Transition energy		14.29	15.58	17.48
Natural chromaticity ξ_{nat} /Q	(h/v)	-1.16 / -1.16	-1.19 / -1.2	-1.25 / -1.26
Transverse acceptance	(h/v) mm· mrad	201 / 54	206 / 54	203 / 53

Progress in SIS Magnet R&D



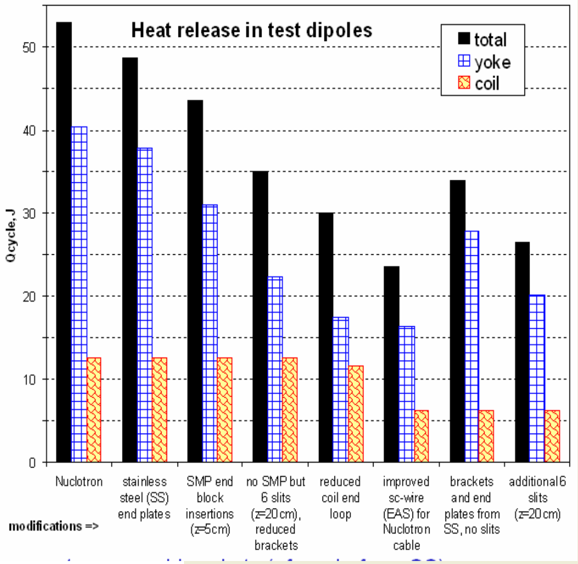
Straight mark I full scale dipole magnet under fabrication at BNG / Würzburg
Curved mark I full scale dipole magnet under fabrication at BINP / Novosibirsk
R&D continued at JINP / Dubna incl. **Quadrupole** prototype

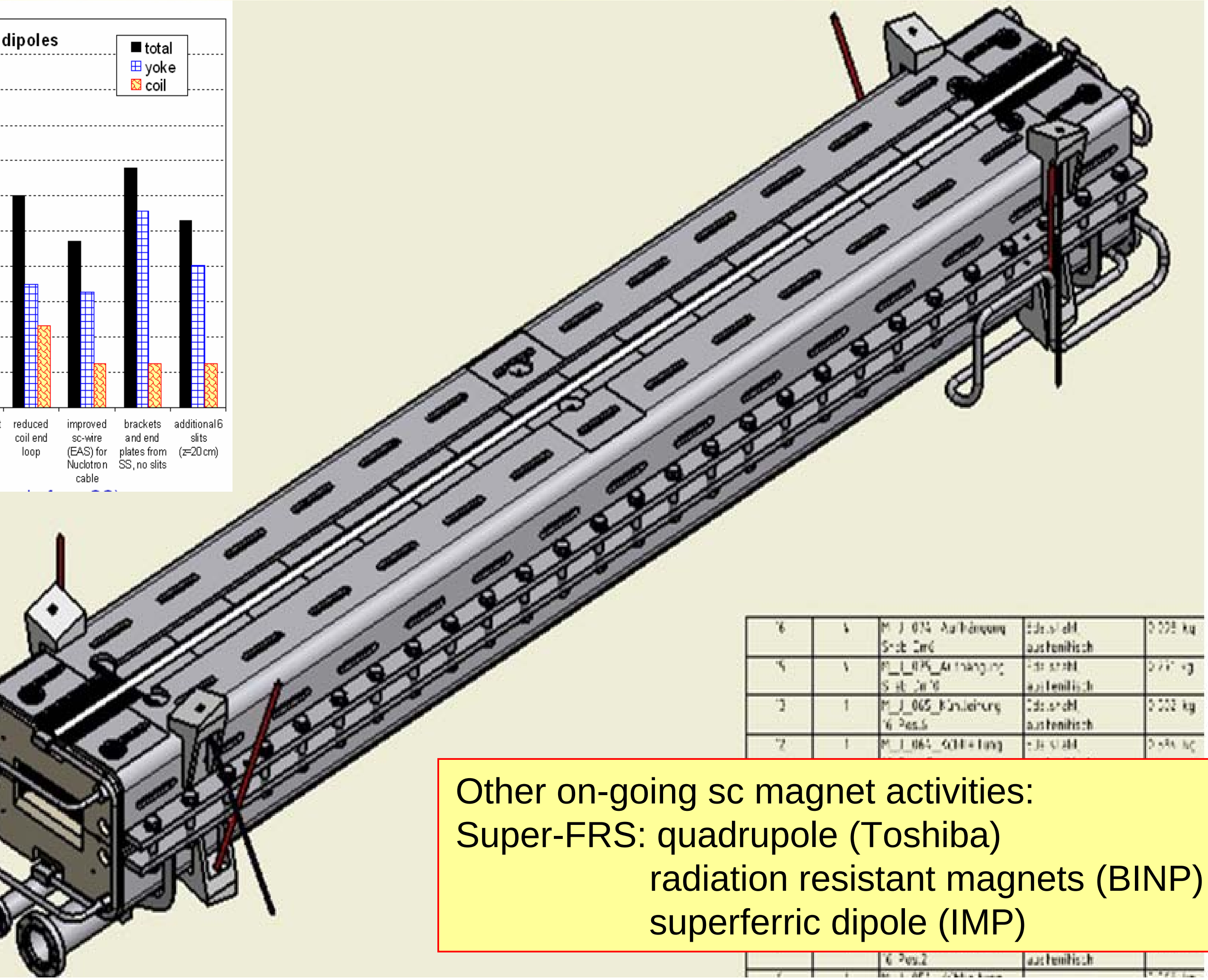
MoU on prototype R&D SIS300 bending magnet



GSI001, first 4 T prototype by BNL
6 T protoype under construction at Dubna
Curved 4.5 T dipole magnet under fabrication at INFN

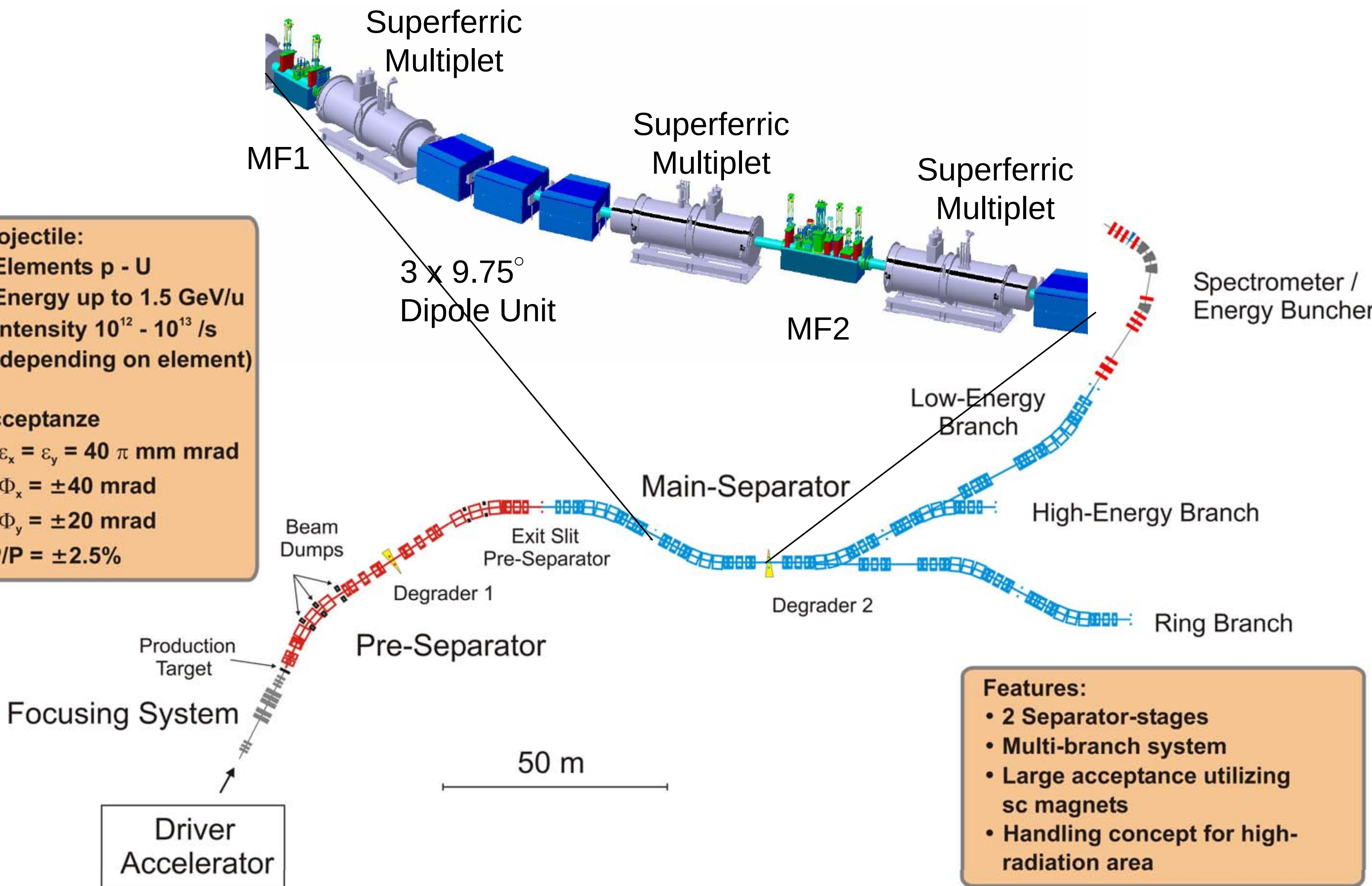
SIS 100 Dipole under Construction





Other on-going sc magnet activities:
Super-FRS: quadrupole (Toshiba)
radiation resistant magnets (BINP)
superferric dipole (IMP)

Layout of Super-FRS



Projectile:
- **Elements p - U**
- **Energy up to 1.5 GeV/u**
- **Intensity 10^{12} - 10^{13} /s (depending on element)**

Acceptanze

$\varepsilon_x = \varepsilon_y = 40\ \pi$ **mm mrad**

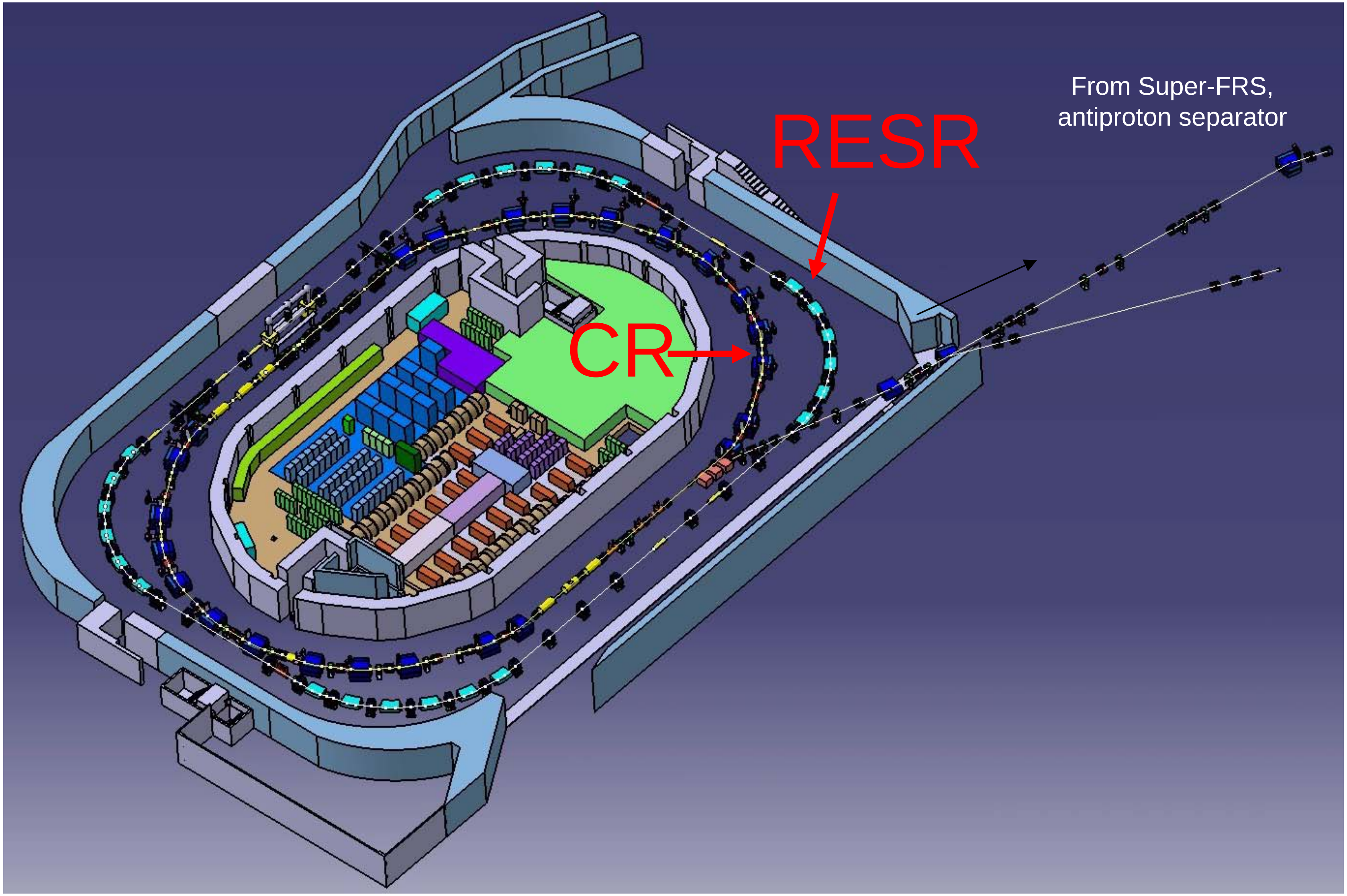
$\Phi_x = \pm 40$ **mrad**

$\Phi_y = \pm 20$ **mrad**

$\Delta P/P = \pm 2.5\%$

Features:
- **2 Separator-stages**
- **Multi-branch system**
- **Large acceptance utilizing sc magnets**
- **Handling concept for high-radiation area**

CR-RESR Complex



Tasks of the CR

1. Cooling of secondary beams of radioactive ions (RI)

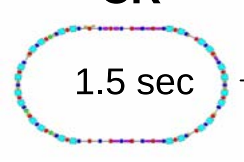
Initial RI beam

$\varepsilon_\perp$=200 mm mrad

$\Delta p/p$=3 %

From Super-FRS

CR



to the NESR

Final RI beam

$\varepsilon_\perp \lesssim$ 0.5 mm mrad

$\Delta p/p \lesssim$ 0.05 %

- 2. Cooling of antiproton beams (Pbar)

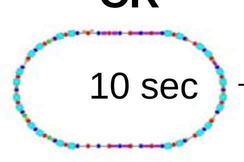
Initial antiproton beam

$\varepsilon_\perp$ =240 mm mrad

$\Delta p/p$=6 %

From antiproton separator

CR



to the RESR

Final Pbar parameters

$\varepsilon_\perp \lesssim$ 5 mm mrad

$\Delta p/p \lesssim$ 0.1 %

- 3. Mass spectrometer of radioactive ions RI (TOF)

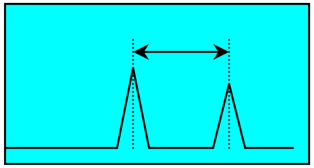
RI beam

$\varepsilon_\perp$ =100 mm mrad

$\Delta p/p$=1 %

From Super-FRS

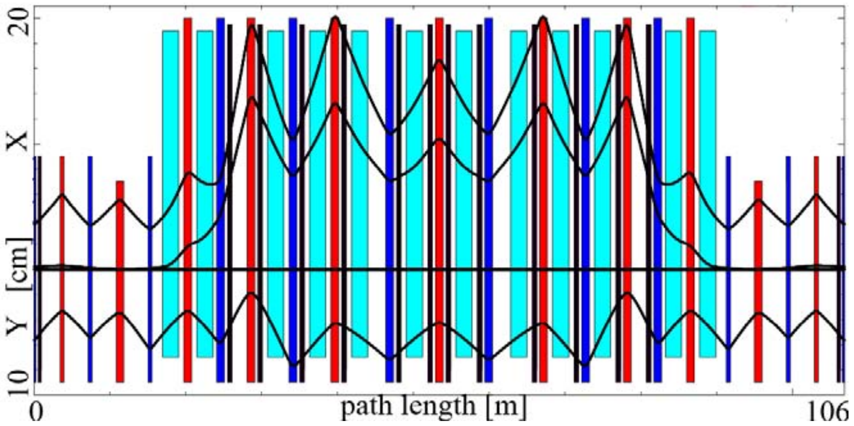
CR



$$\boxed{\frac{\Delta m}{m} = \gamma_{tr}^2 \frac{\Delta f}{f}}$$

CR Beam Envelopes

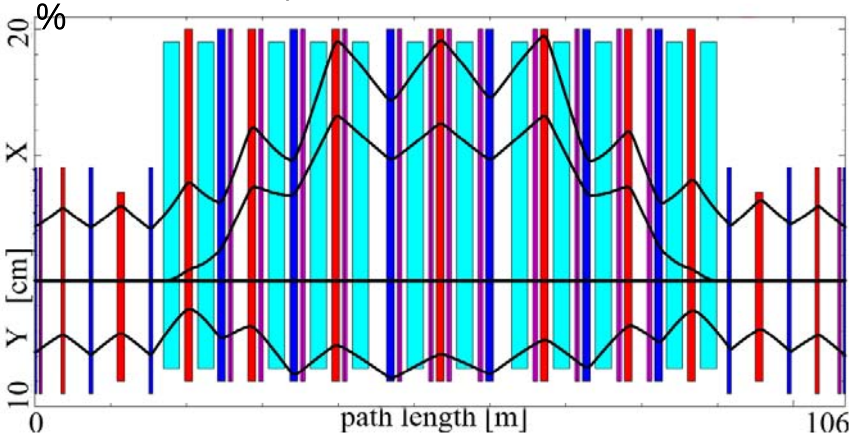
Pbar mode: $\varepsilon_{x,y}$=240 mm mrad, $\Delta p/p$=+3.0 %



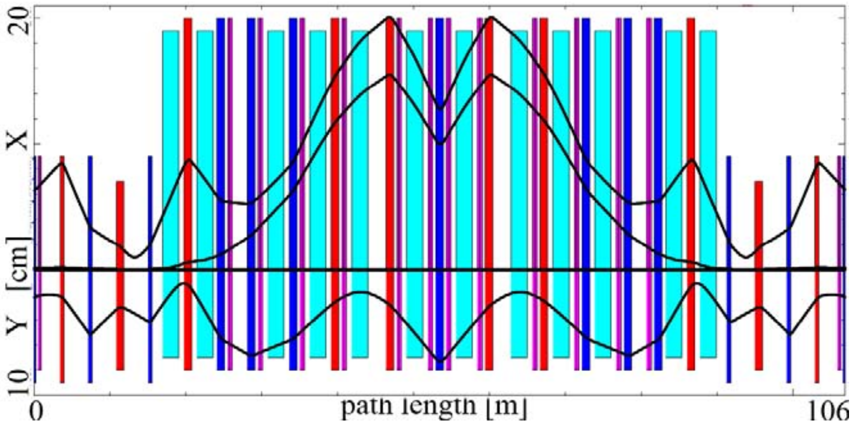
Large Acceptance Machine:

Hor. aperture A = 400 mm
Ver. aperture A = 180 mm

RIB mode: $\varepsilon_{x,y}$=200 mm mrad; $\Delta p/p$=+1.5 %



Isochronous mode:
$\varepsilon_{x,y}$=100 mm mrad; $\Delta p/p$=+0.5 %



CR Dipole Prototype Development in China

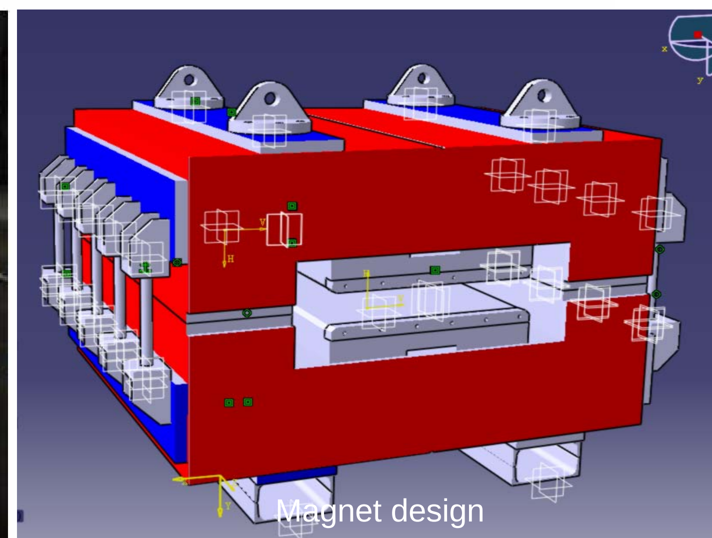
IMP Lanzhou
IPP Hefei
IEE Beijing

CAS


The assembly of die


First lamination punched


Coil fabrication


Magnet design

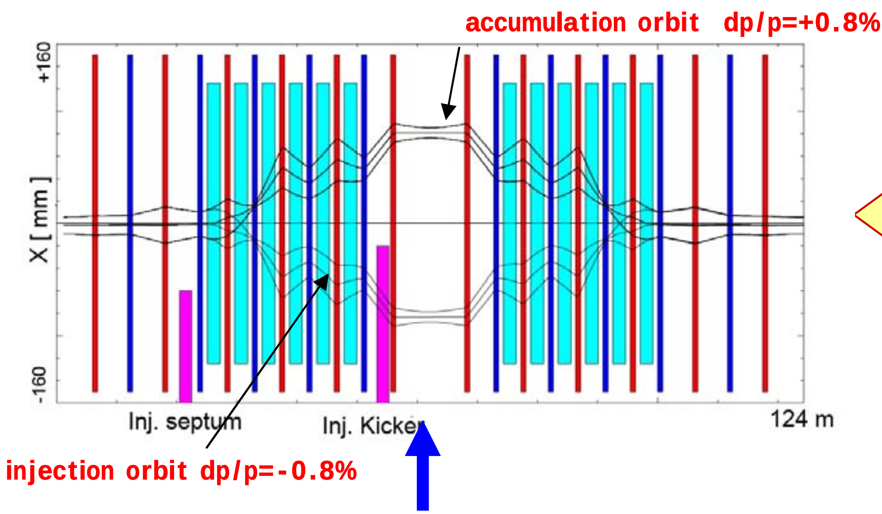
RESR: Stochastic Cooling & Accumulation Scheme

Deceleration of pre-cooled RIB to 100 MeV/u

&

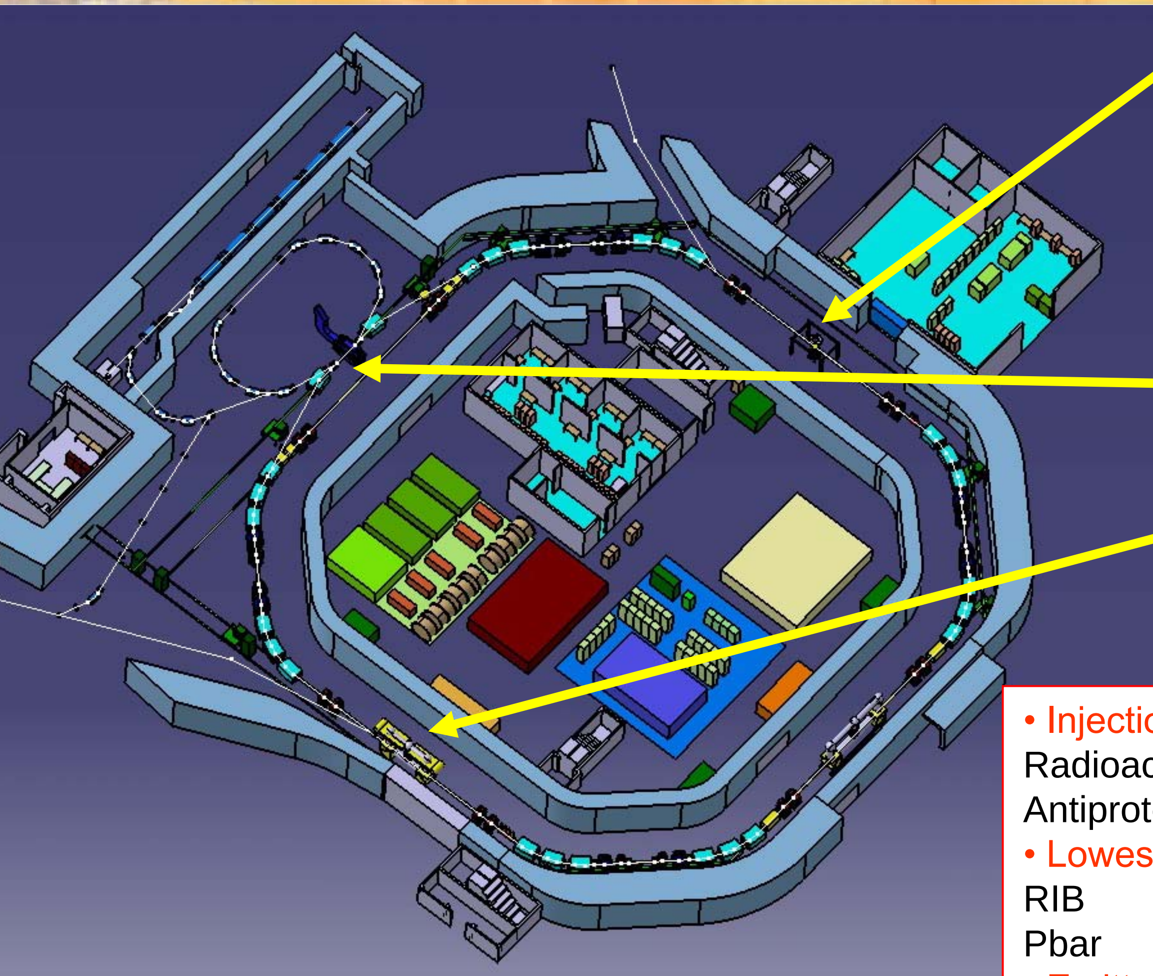
Accumulation and cooling of 10^{11} antiprotons

- **Two transverse cooling systems (horizontal, vertical)**
- **Three longitudinal systems (hand-over system, stack-tail system, stack-core system)**



Accumulation rate 1.5 x 10^{7} s^{-1}
Accumulation time 3.5 h
Number of particles 10^{11}

The New Experimental Storage Ring



Experiments with radioactive and stable ions at gas-jet or pellet target

Preparation of the low energy antiproton beams

Electron scattering on radio-active nuclei (collider mode)

Ion-electron interaction studies

• Injection energy:

Radioactive Ion Beams	(RIB)	100 – 740	Mev/u
Antiproton beams	(Pbar)	3	GeV

• Lowest extraction energy:

RIB	4	MeV/u
Pbar	30	MeV

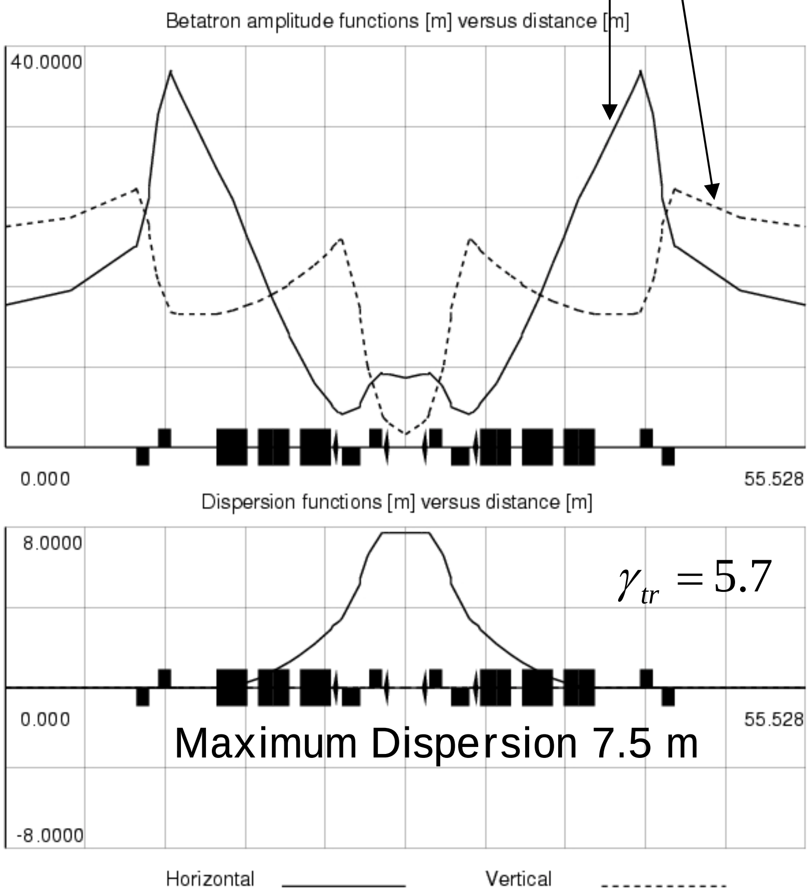
• Emittance:

RIB	0.1 – 1	mm mrad
Pbar	1	mm mrad

• Momentum spread: $< 10^{-4}$

NESR Lattice functions

betatron functions β_x β_y



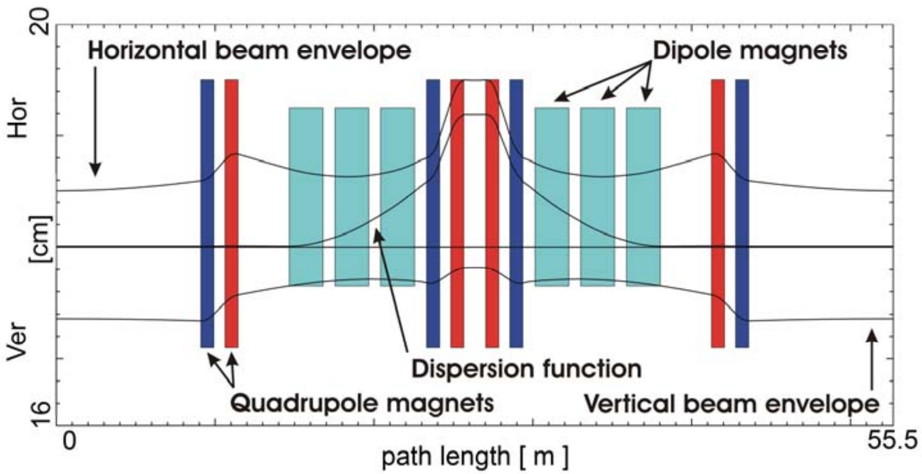
$\gamma_{tr} = 5.7$

Maximum Dispersion 7.5 m

Q_h=3.37
Q_v=3.18

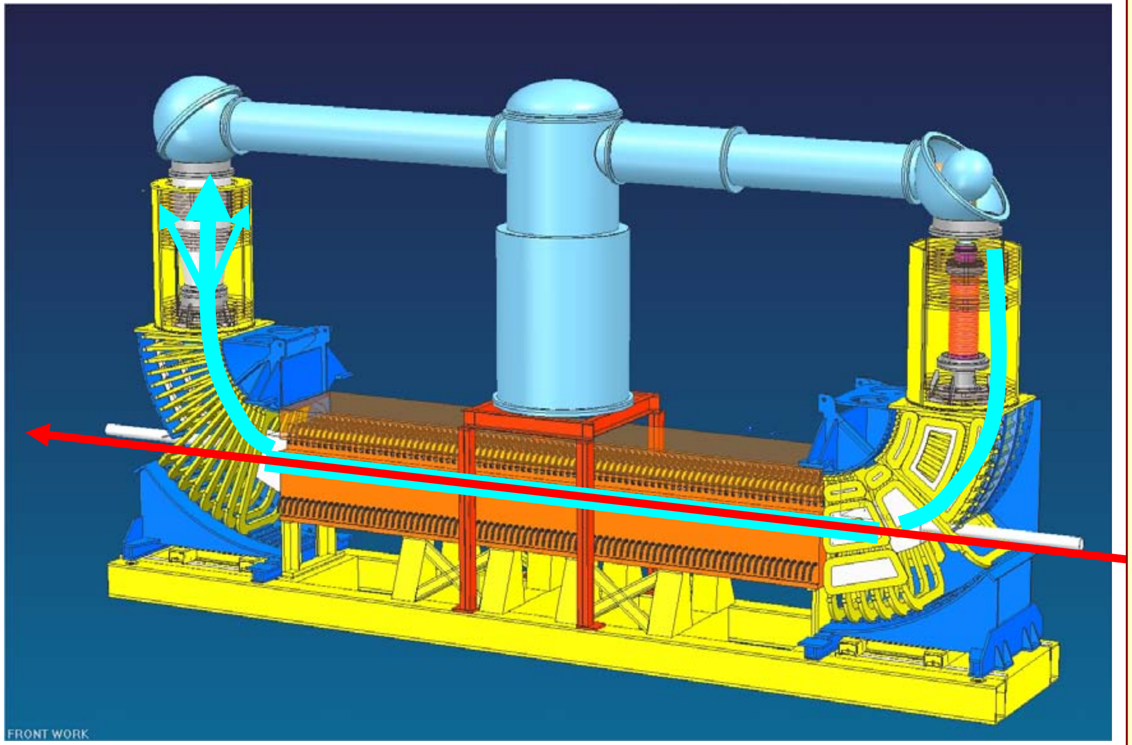
ε_x = 160 mm mrad,
ε_y = 35 mm mrad,
$\Delta p/p = \pm 1.5$ %

Hor. Aperture up to A=300 mm



The NESR Electron Cooler

design by BINP, Novosibirsk



Cooler Parameters

energy	2 - 450 keV
max. current	2 A
cathode radius	1 cm
beam radius	0.5-1.4 cm
hollow cathode option	
magnetic field	
gun	up to 0.4 T
cool. sect.	up to 0.2 T
straightness	$\leq 5 \times 10^{-5}$
adiabatic expansion option	
cool. section length	5 m
max. power in collector	15 kW
vacuum	$\leq 10^{-11}$ mbar

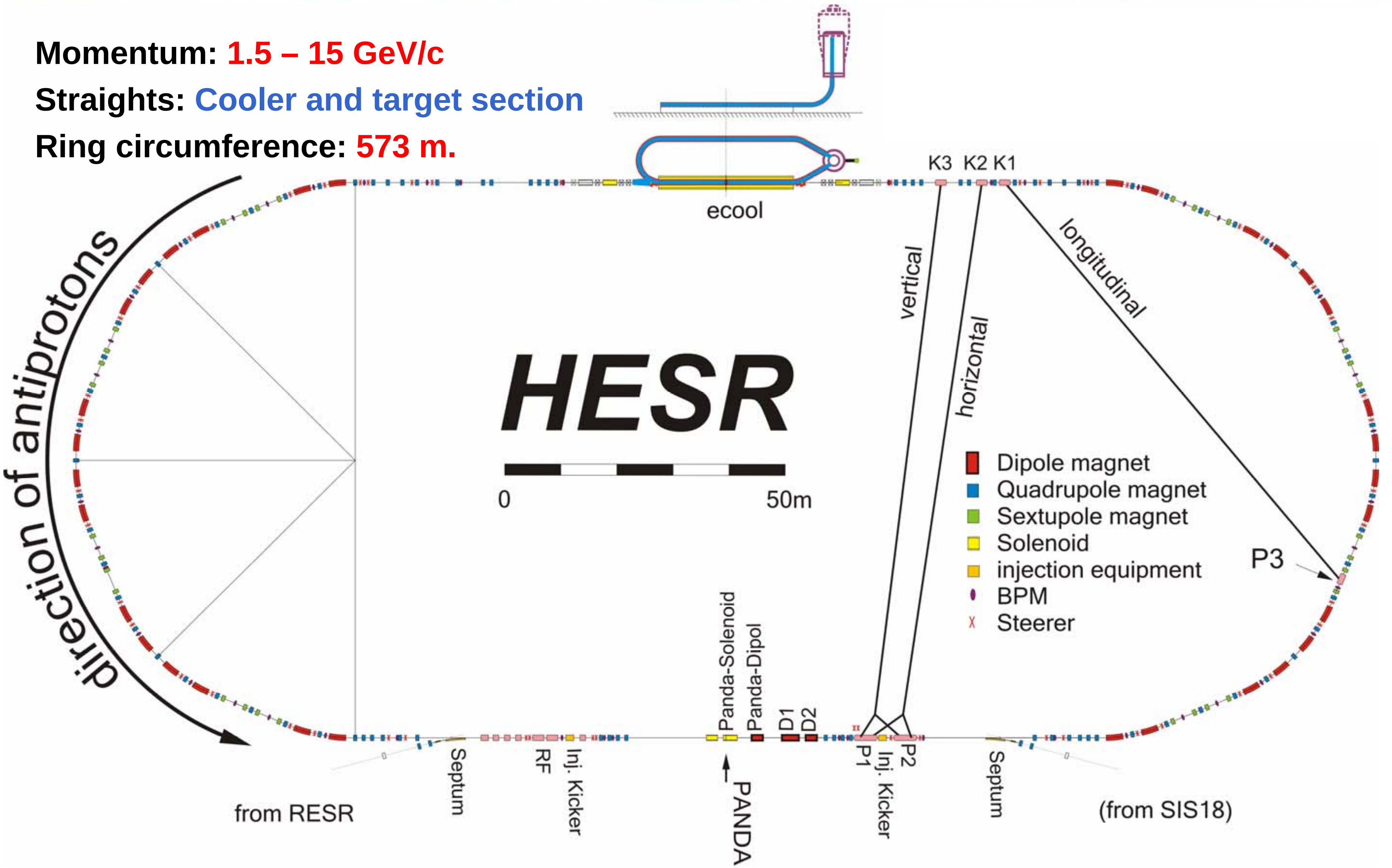
Issues:

- high voltage up to 500 kV
- fast ramping, up to 250 kV/s
- magnetic field quality

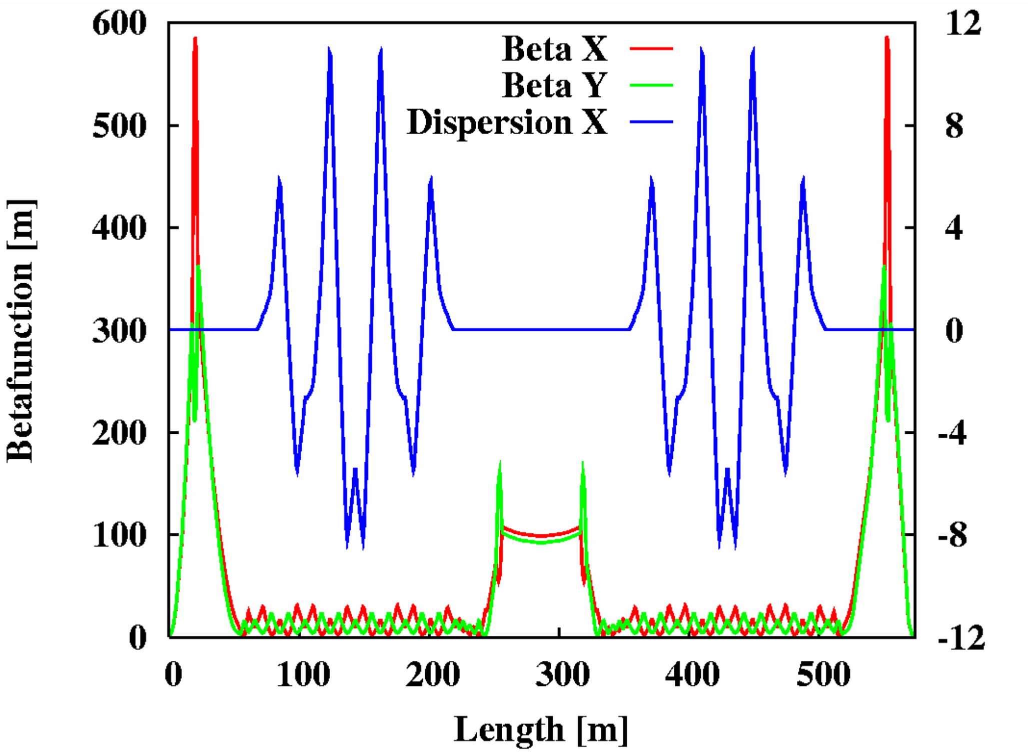
High Energy Storage Ring

for antiprotons

- **Momentum: 1.5 – 15 GeV/c**
- **Straights: Cooler and target section**
- **Ring circumference: 573 m.**



HESR Ion Optics and Lattice Parameters

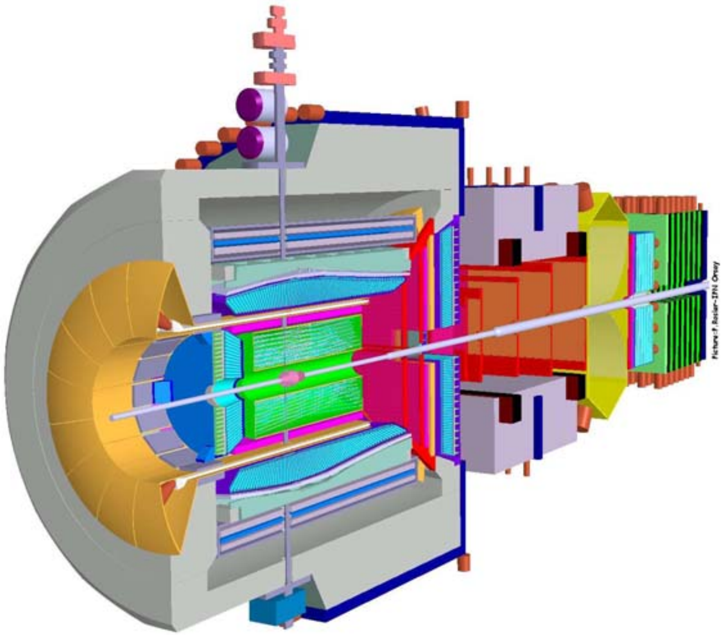


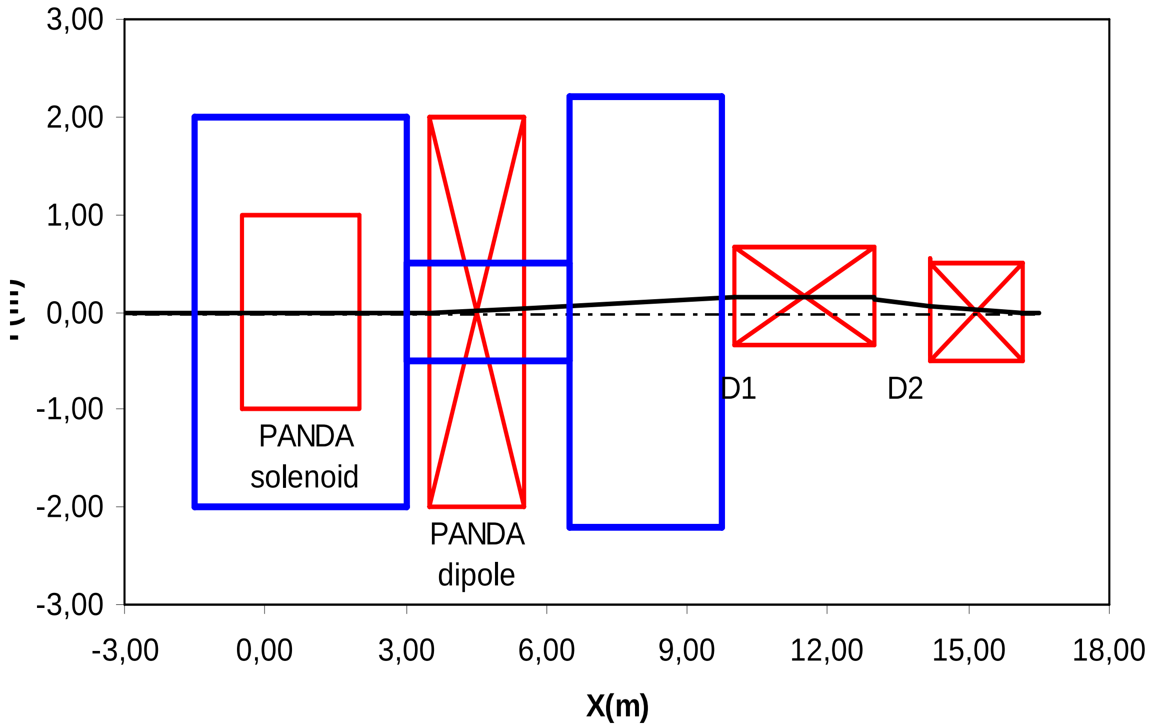
Total length	573.11 m
Tune Q_x ,Q_y Phase advance per arc	9.16, 9.18 $3 \cdot 2\,\pi$
$\beta_{x,y}^{Target}$ $\beta_{x,y}^{ElectronCooler}$ $\beta_{x,y}^{max}$ Straights $\beta_{x,y}^{max}$ Arcs	1 m - 15 m 25 m - 200 m 590 m - 130 m 30 m
D_x^{max} Arcs	12 m
Nat. Chromaticity $Q'_{x,y}$	-28 to -16
γ_{tr}	6.0i, flexible
Dipole field, max. Quadrupole gradient Arcs, Straights Sextupole strength	3.6 T, curved 23, 43 T/m 460 T/m²

Arcs: 4-fold symmetry,
with dispersion suppression
and imaginary gamma transition

Forschungszentrum Jülich
in der Helmholtz-Gemeinschaft

PANDA Detector





- ±17 m **free space between quadrupoles around the target**
- **10 m free space behind the target**
- **Compensation dipoles between quadrupoles**
- **Orbit deviation: 50 mrad, 400 mm (max)**

Summary

- Project „GO“ this year!
- Designs have been frozen.
- R&D on key components is well advanced,
- sc magnet-prototypes are under construction.
- Technical designs of conventional components has started.
- Civil Construction planning has started – execution work expected to start in early 2009.
- Detailed negotiations on partners’ contributions ongoing.

Acknowledgements

GSI FAIR Technical Division

P. Spiller, M. Steck, I. Hofmann, G. Moritz et. al.

GSI Accelerator Division

H. Eickkhoff et. al.

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