BINP – FAIR Collaboration

P.Yu.Shatunov

IWAPT FAIR Novosibirsk
16-19 November 2015

Budker Institute of Nuclear Physics
Novosibirsk

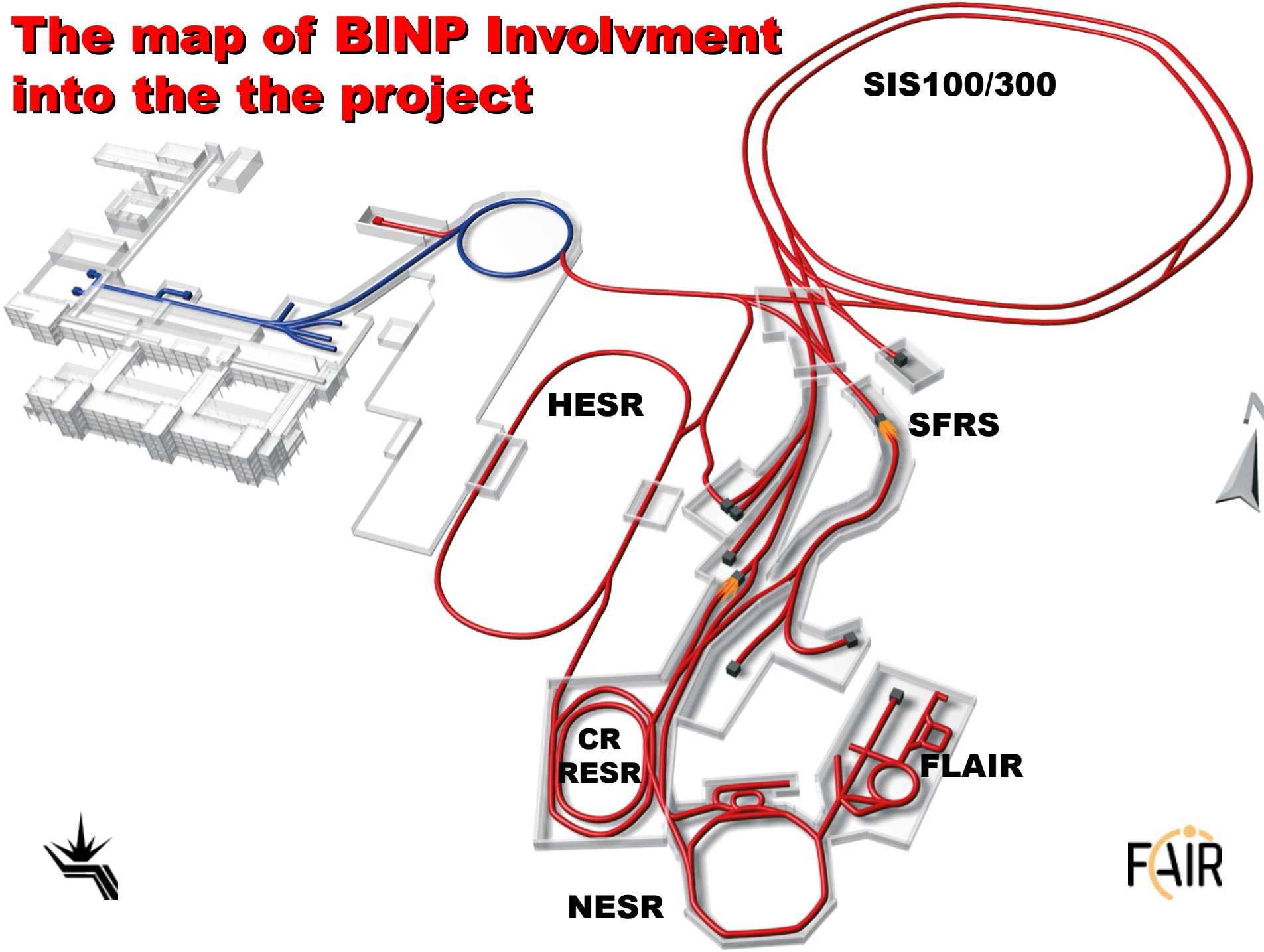
Since 1958

BINP basic research activities

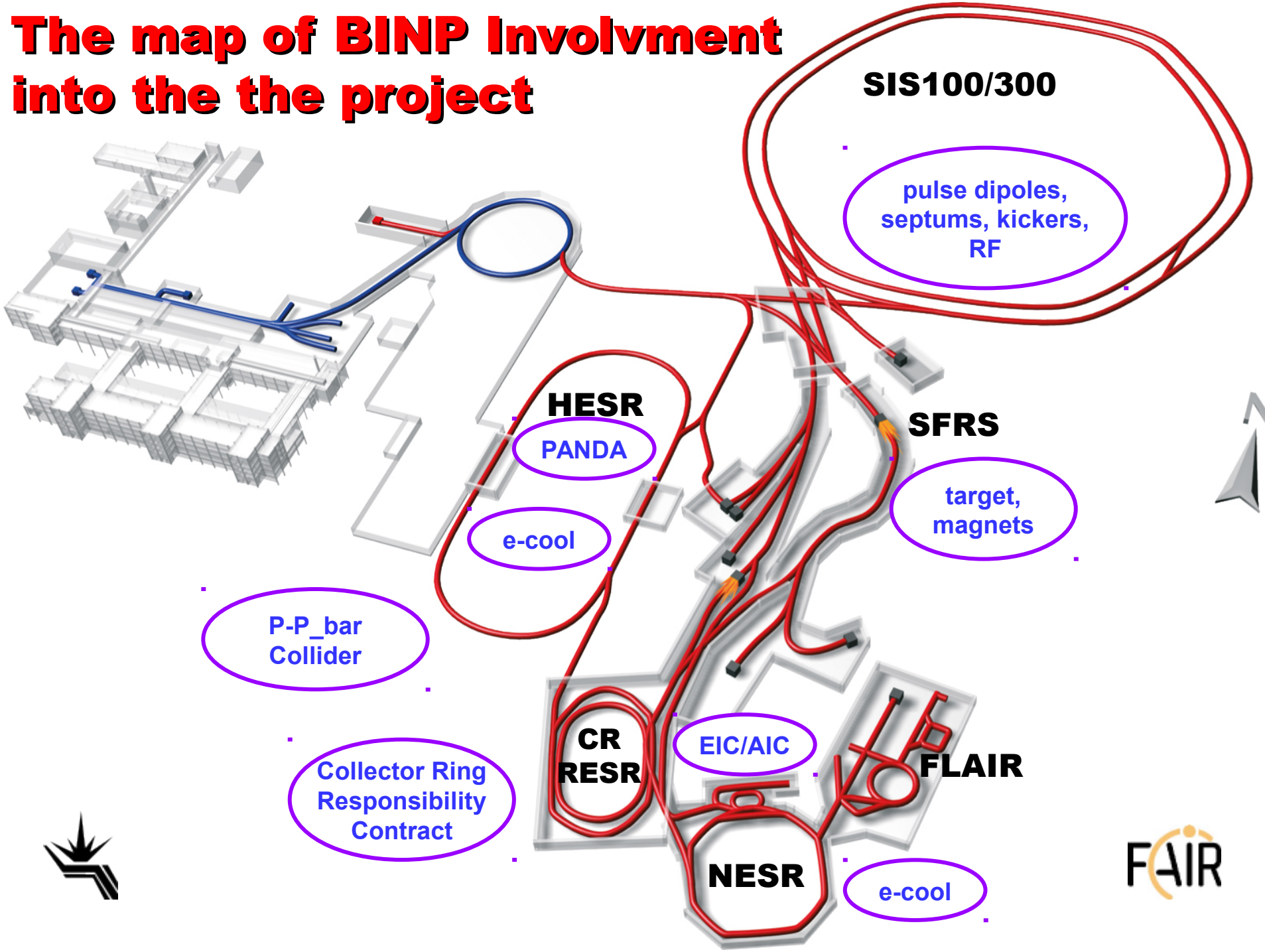
- Electron-positron colliding beams
- High energy physics
- Theoretical physics
- Physics of accelerators
- Synchrotron radiation and Free electron lasers
- Physics of High Temperature Plasma
- Industrial electron accelerators applications
- International collaborations

FAIR

The map of BINP Involvment into the the project



The map of BINP Involvment into the the project



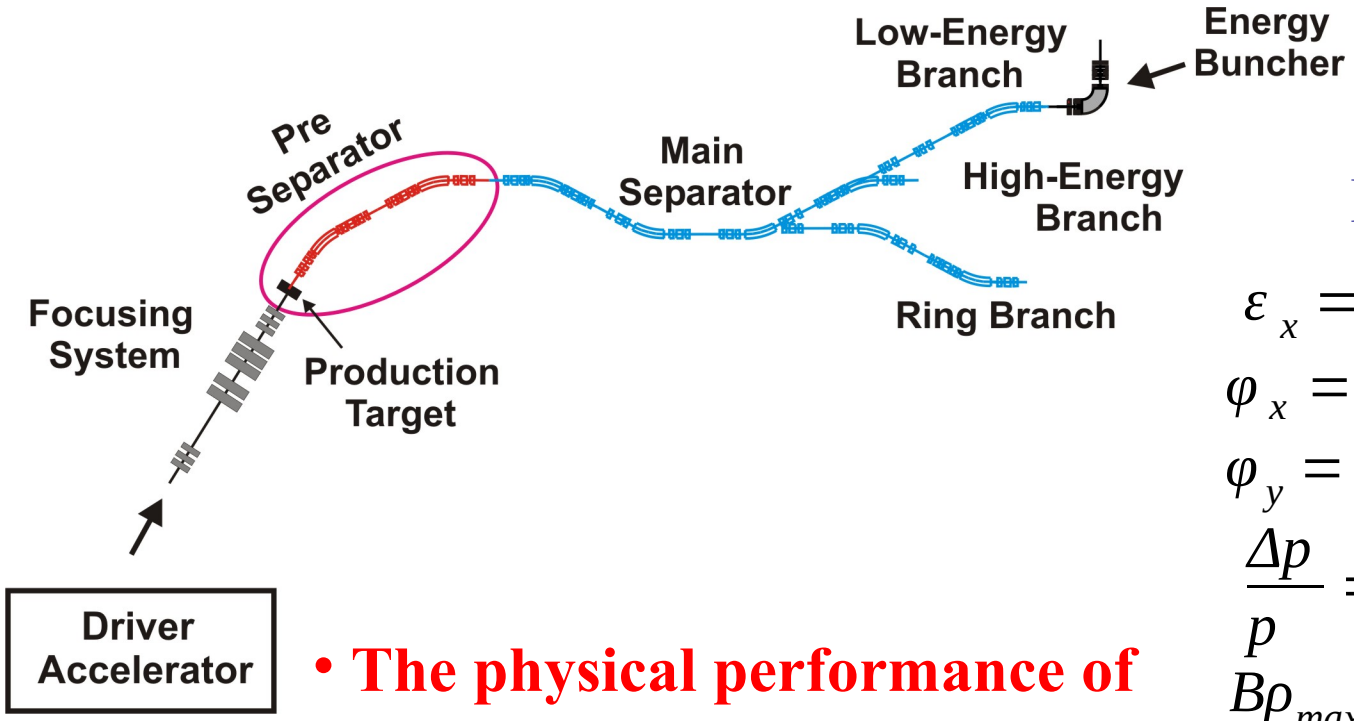
Research and Development Contract
between GSI and BINP

Skrinsky - Henning

Subject and Objectives of the Contract

1. Kickers for synchrotrons and storage rings
2. Septum magnets for synchrotrons and storage rings
3. Technical design of ER and interaction region for collider mode including modification for AIC/NUSTAR
4. Luminosity monitor and electron spectrometer for ELISE/NUSTAR
5. Pbar-Target and Collection
6. Ultra Cold Electron Target for NESR
7. Prototype High Voltage Section for the NESR Electron Cooler
8. Resistive coil magnets for FAIR
9. Production of vacuum chambers for SIS18 quadrupoles (addressed in EU-FP 6 Construction contract No. 515876)
10. Study for High radiation resistant magnets for Super-FRS (R&D contract No. RU/03533872/SE-05007 is already placed)
11. Prototype Design for the RF-Cavities at SIS100 /300 (Continuation of the study with purchase order No. 4500054244)

Layout and Design Parameters of the Super-FRS



Design Parameters

$$\varepsilon_x = \varepsilon_y = 40\ \pi mmmrad$$

$$\varphi_x = \pm 40\ mrad,$$

$$\varphi_y = \pm 20\ mrad$$

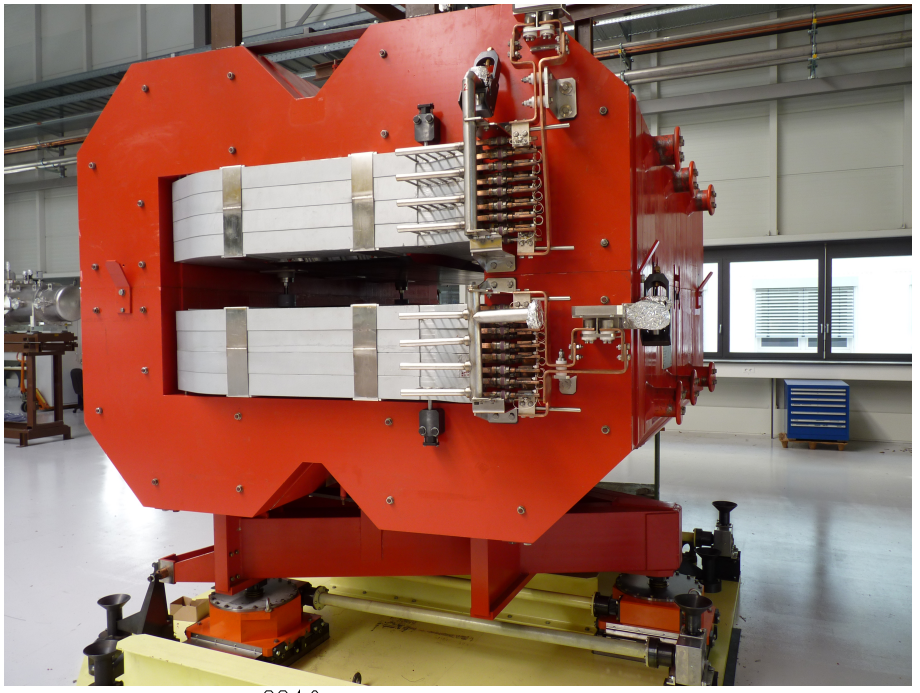
$$\frac{\Delta p}{p} = \pm\ 0.025$$

$$B\rho_{max} = 20\ Tm$$

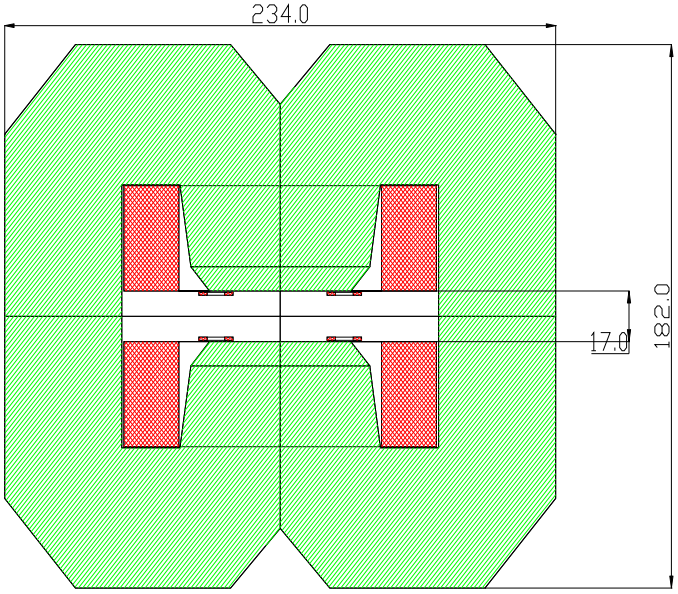
$$R_{ion} = 12\ m$$

- The physical performance of the new facility can be directly deduced from the experience with the FRS
- The main technical challenges are at the Pre-Separator

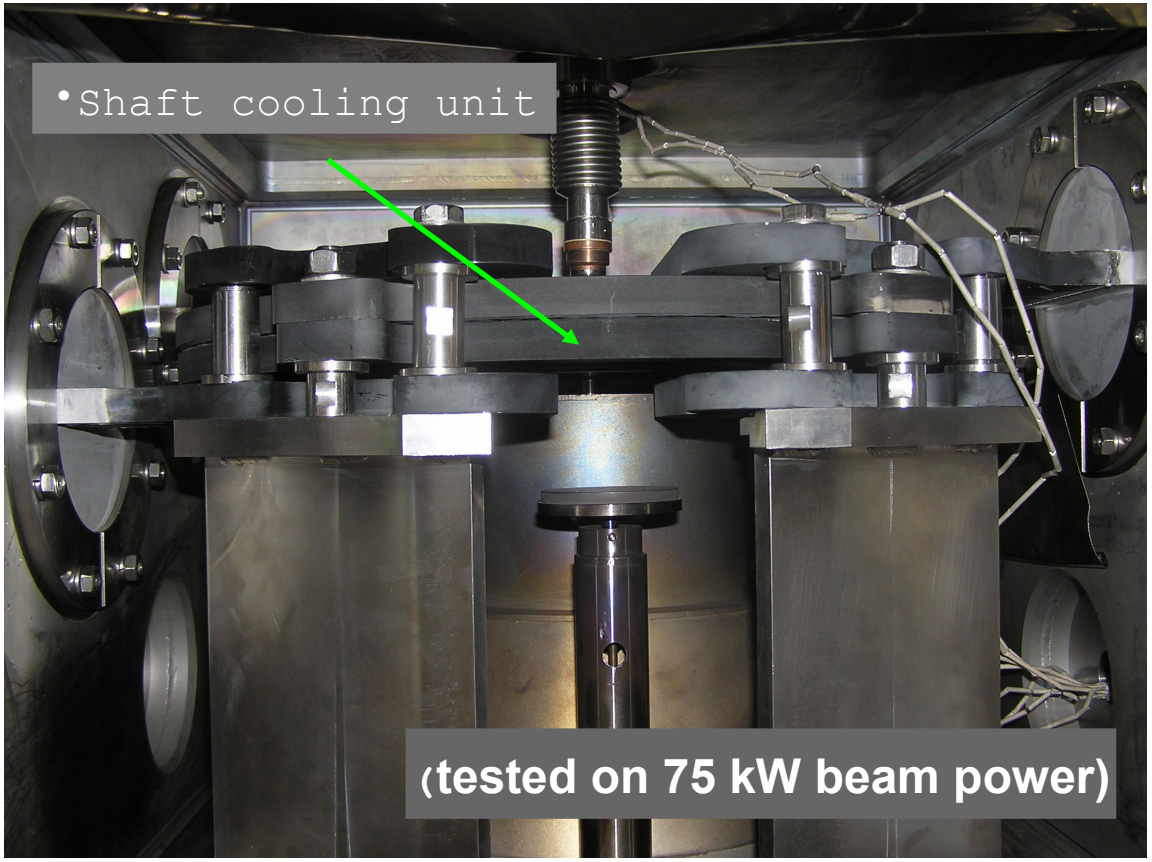
High radiation resistant dipole magnet

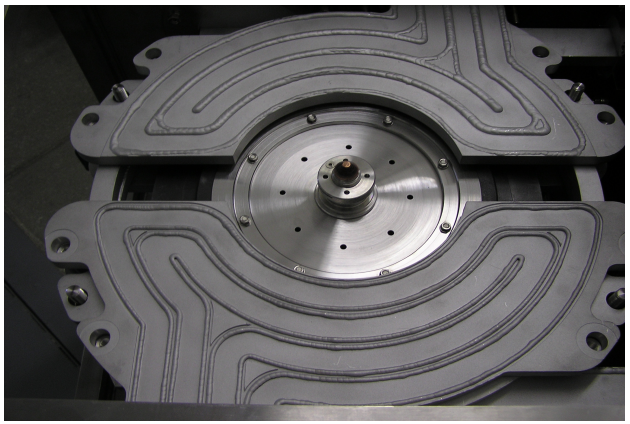


Pavel Vobly team
Power: ~ 120 kW
Weight: ~ 90 t



High power target based on liquid lead alloy technology



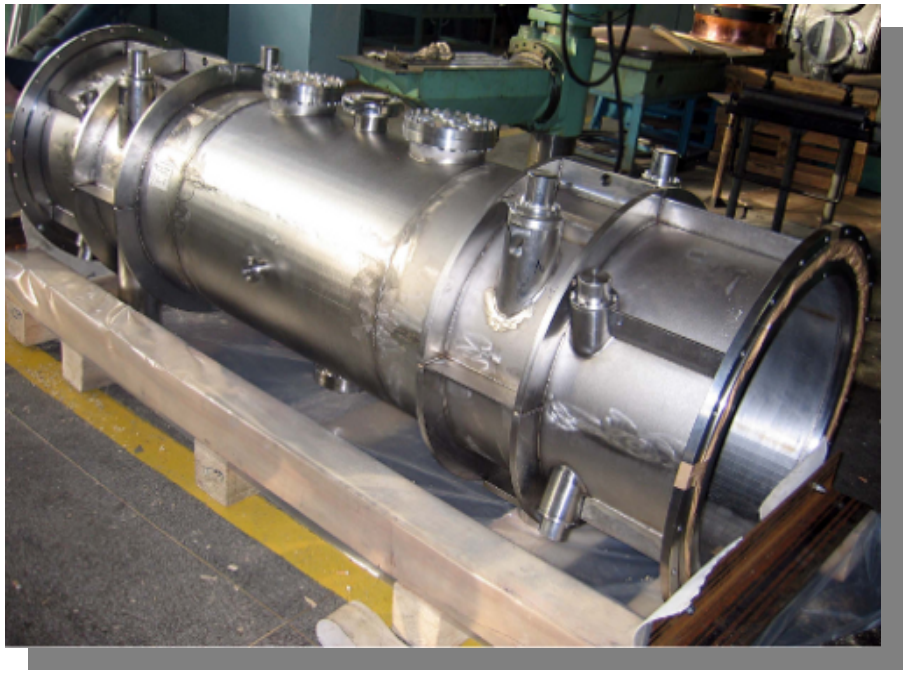


Pavel Logatchev team

- Operating temperature range (300-400°C) provides annealing of radiation damages in all corresponding subsystems.
- It provides cheap and reliable solution for bearings and rotation feed-through in high radiation area.

Superconducting dipole for SIS-100

Prototype of the dipole at BINP plant

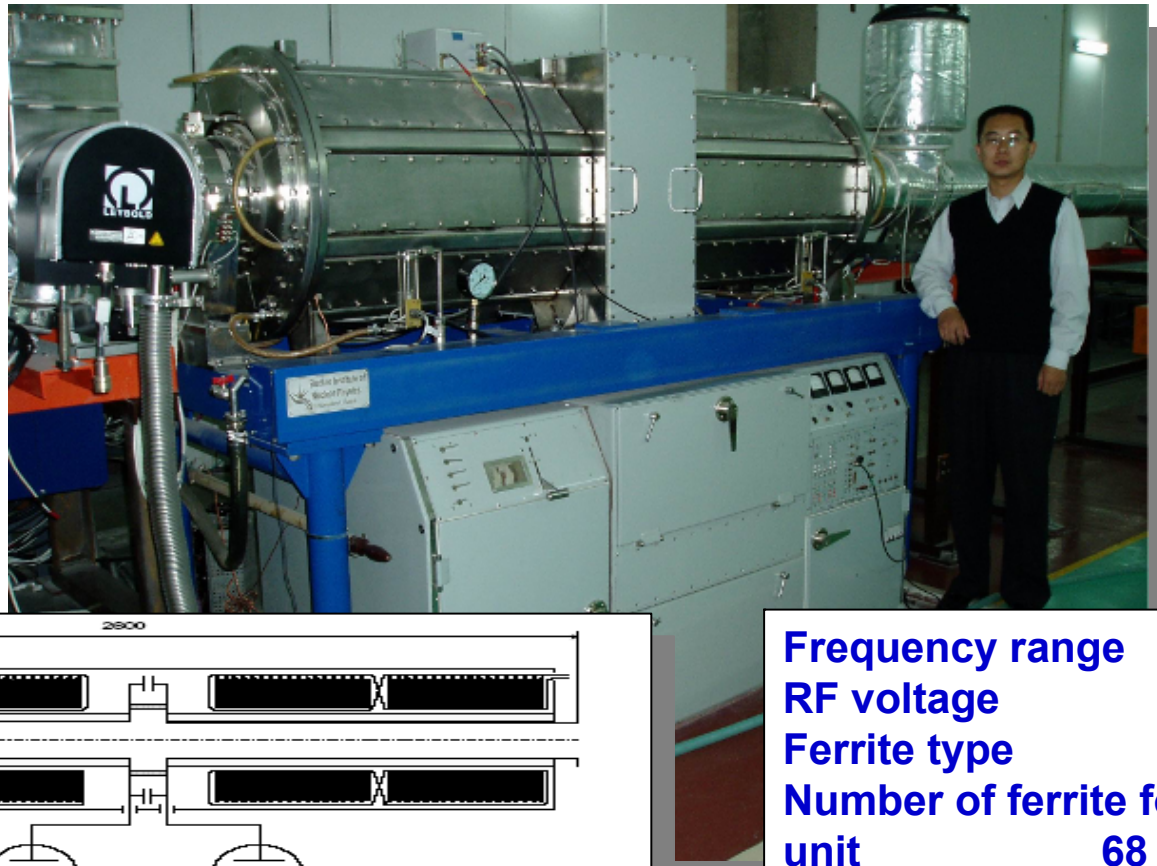


Cryostat for the SIS100

B_{max}	T	1.9 $(\pm 6\times10^{-4})$
L_{eff}	m	3.062
Ramp dB/dt	T/c	4
Bend	degtee.	3 ⅓
R_0	m	52.632

Nikolay Mezentsev team

Design of RF-station for SIS-100



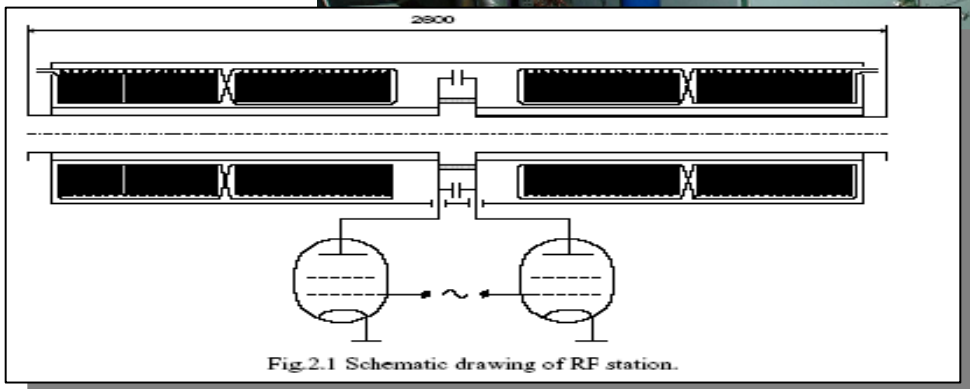


Fig.2.1 Schematic drawing of RF station.

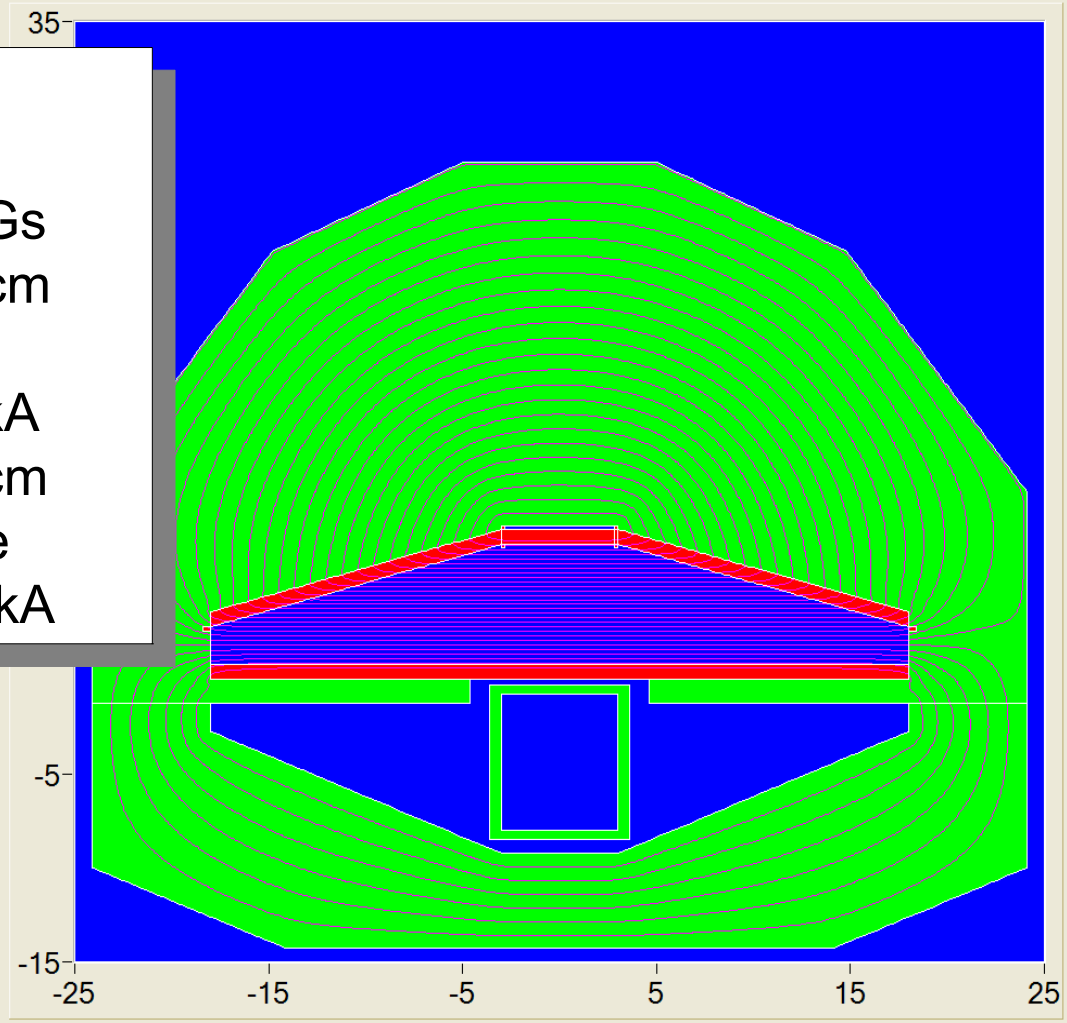
Frequency range	1.1- 2.7 MH
RF voltage	19 kV
Ferrite type	400 NN-2
Number of ferrite for unit	68
Number of unit	29
Cost per unit	0.5 Euro

Gregory Kurkin team

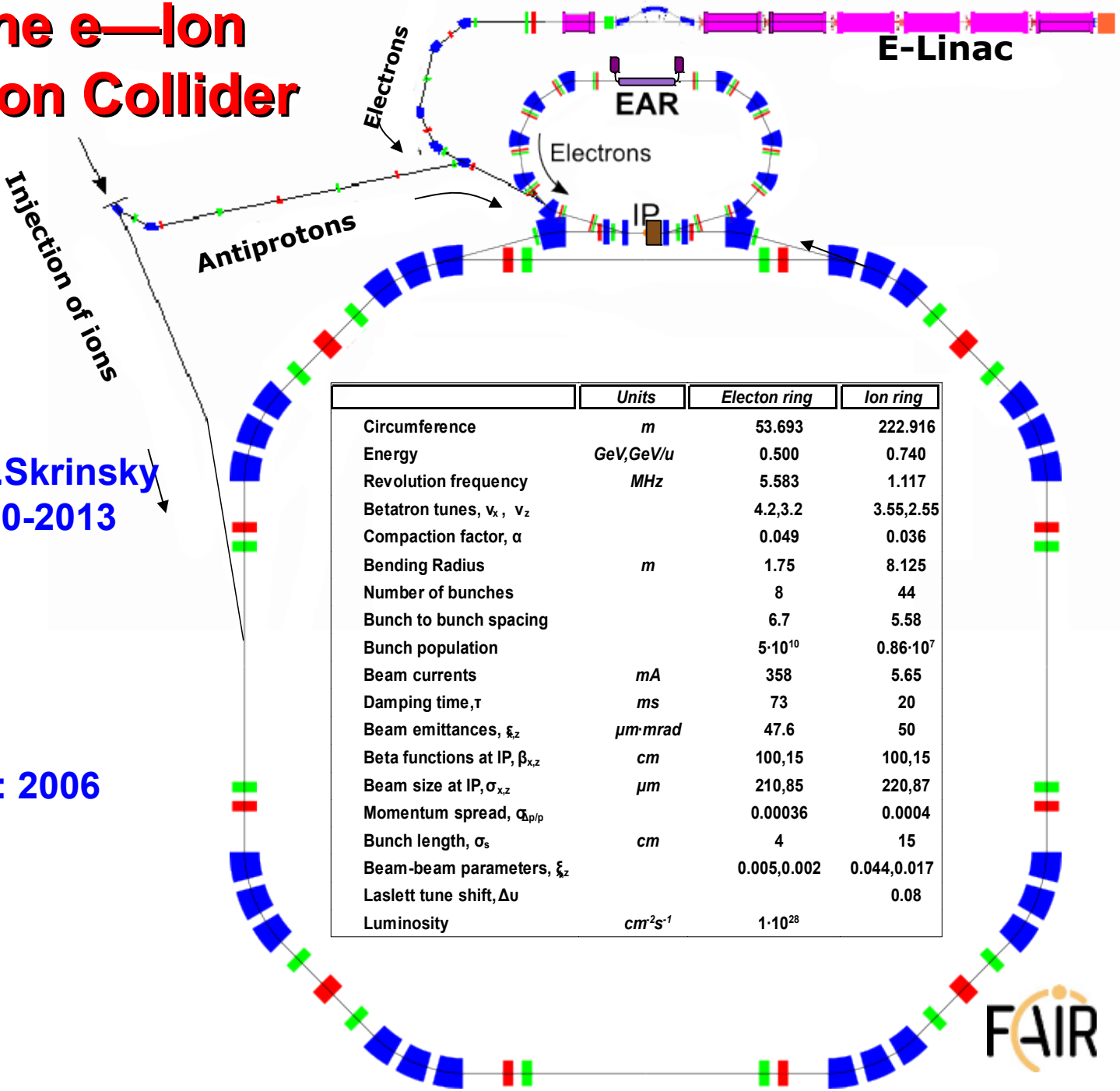
Superconducting septum for SIS-300

Magnetic parameters:

1. Magnetic field amplitude - 35 kGs
2. Magnetic length - 340 cm
3. Maximum current in SC cable ~ 2.7 kA
4. Blade thickness - 2.5 cm
5. Maximum current in one strand ($d=0.85$ mm) - 0.45 kA



Project of the e—Ion and p_bar-Ion Collider



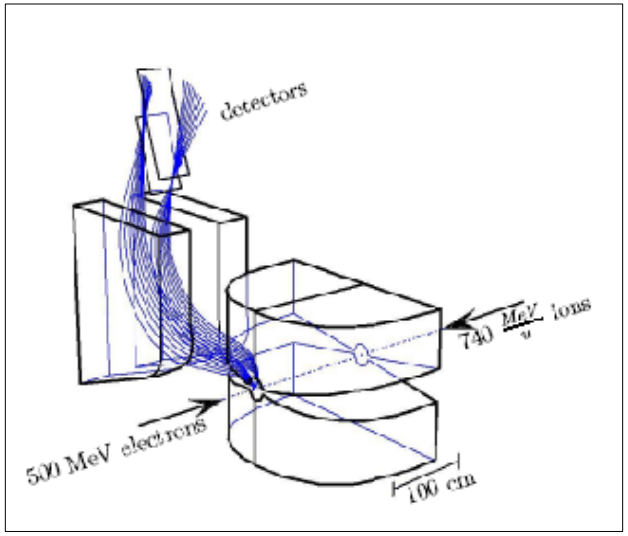
Electron-Ion:
Original idea: A.N.Skrinsky
Development: 2000-2013
CDR: 2001
TDR: 2006, 2008

Antiproton-Ion:
Idea: R. Kruecken
Preliminary study: 2006

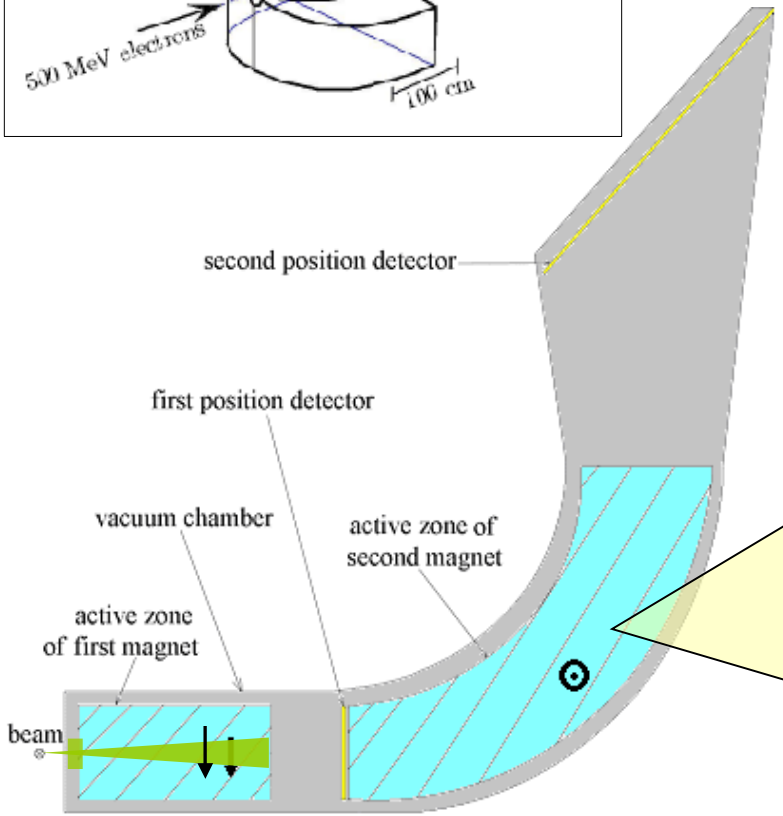
	Units	Electon ring	Ion ring
Circumference	*m*	53.693	222.916
Energy	*GeV,GeV/u*	0.500	0.740
Revolution frequency	*MHz*	5.583	1.117
Betatron tunes, ν_x , ν_z		4.2,3.2	3.55,2.55
Compaction factor, α		0.049	0.036
Bending Radius	*m*	1.75	8.125
Number of bunches		8	44
Bunch to bunch spacing		6.7	5.58
Bunch population		$5 \cdot 10^{10}$	$0.86 \cdot 10^{7}$
Beam currents	*mA*	358	5.65
Damping time,τ	*ms*	73	20
Beam emittances, $\xi_{x,z}$	*μm·mrad*	47.6	50
Beta functions at IP, $\beta_{x,z}$	*cm*	100,15	100,15
Beam size at IP, $\sigma_{x,z}$	*μm*	210,85	220,87
Momentum spread, $\sigma_{\Delta p/p}$		0.00036	0.0004
Bunch length, σ_s	*cm*	4	15
Beam-beam parameters, ξ_z		0.005,0.002	0.044,0.017
Laslett tune shift, Δu			0.08
Luminosity	$cm^{-2}s^{-1}$	$1 \cdot 10^{28}$	

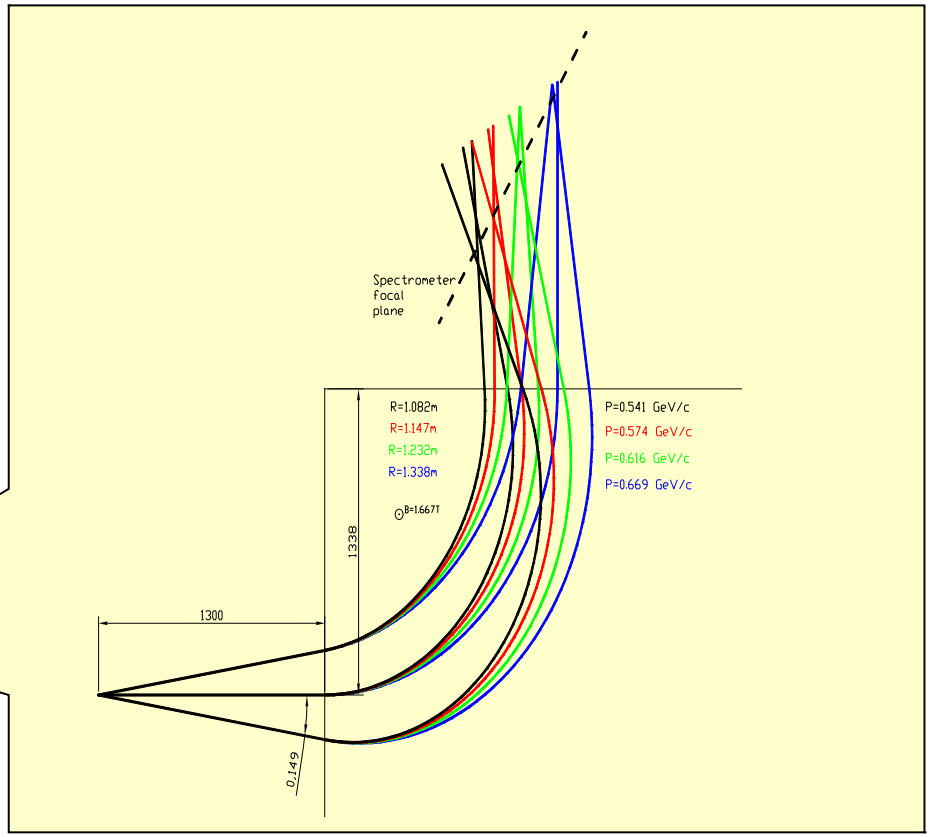
FAIR

Electron Spectrometer



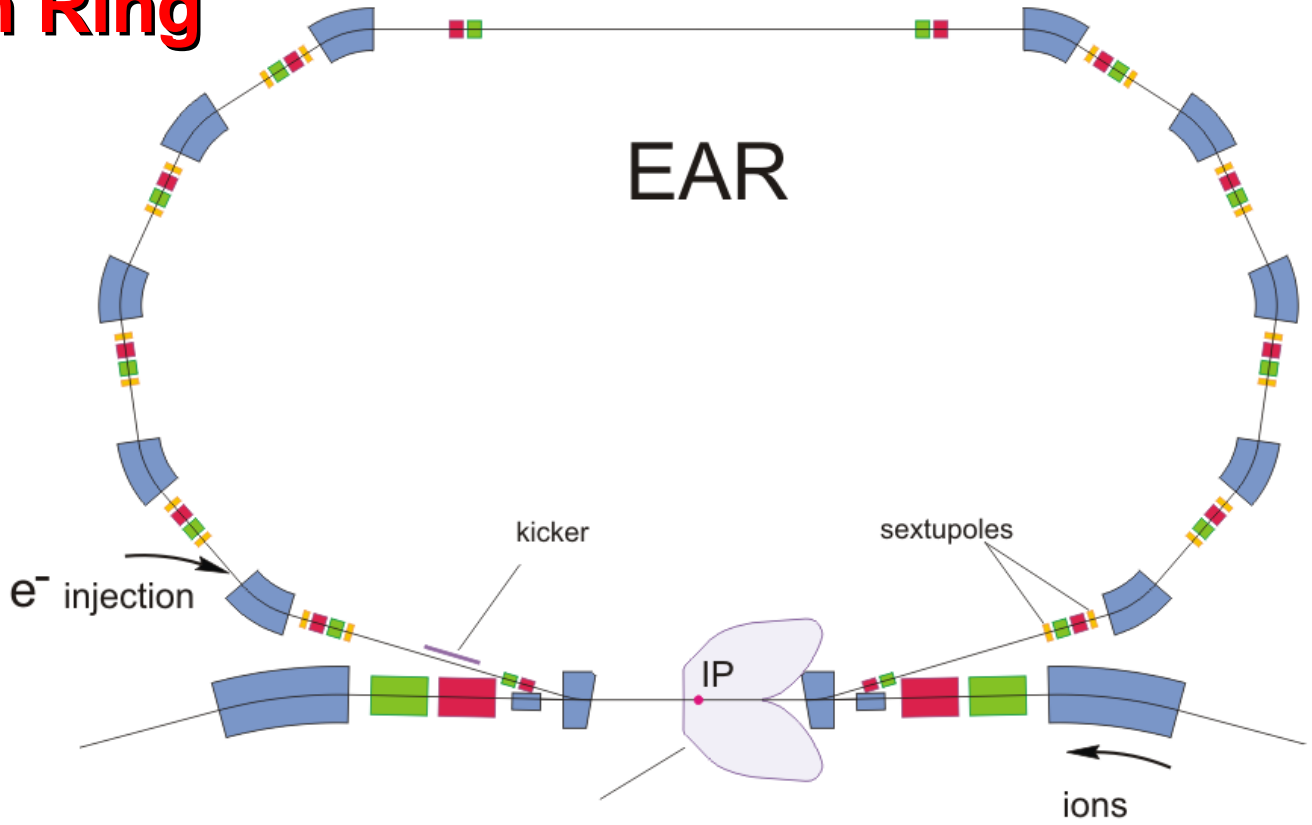
Georg Berg

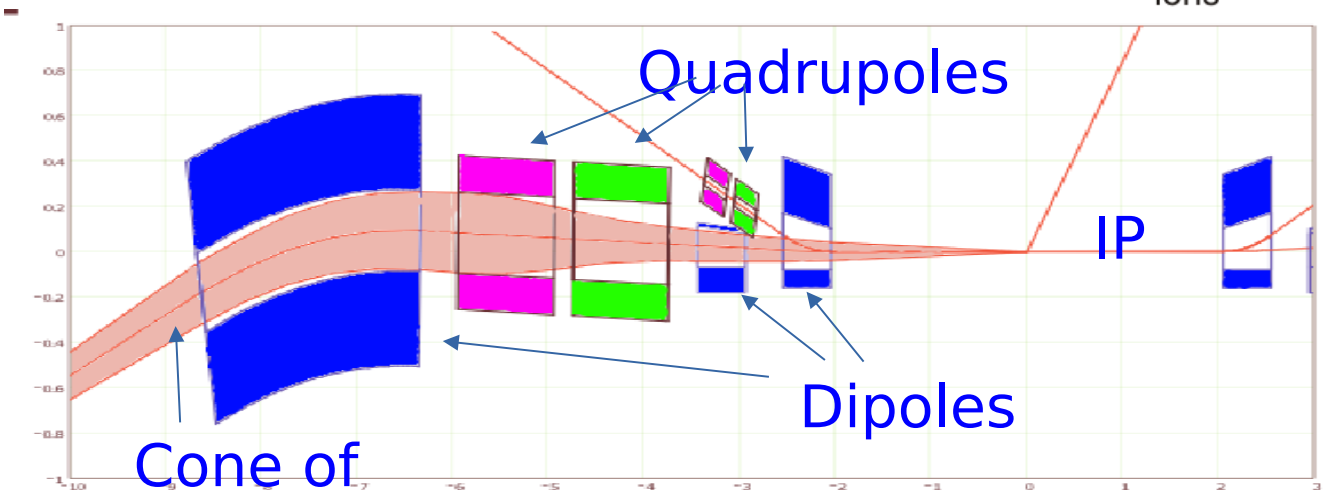




$dp/p = 2 \times 10^{-4}$

Electron Ring

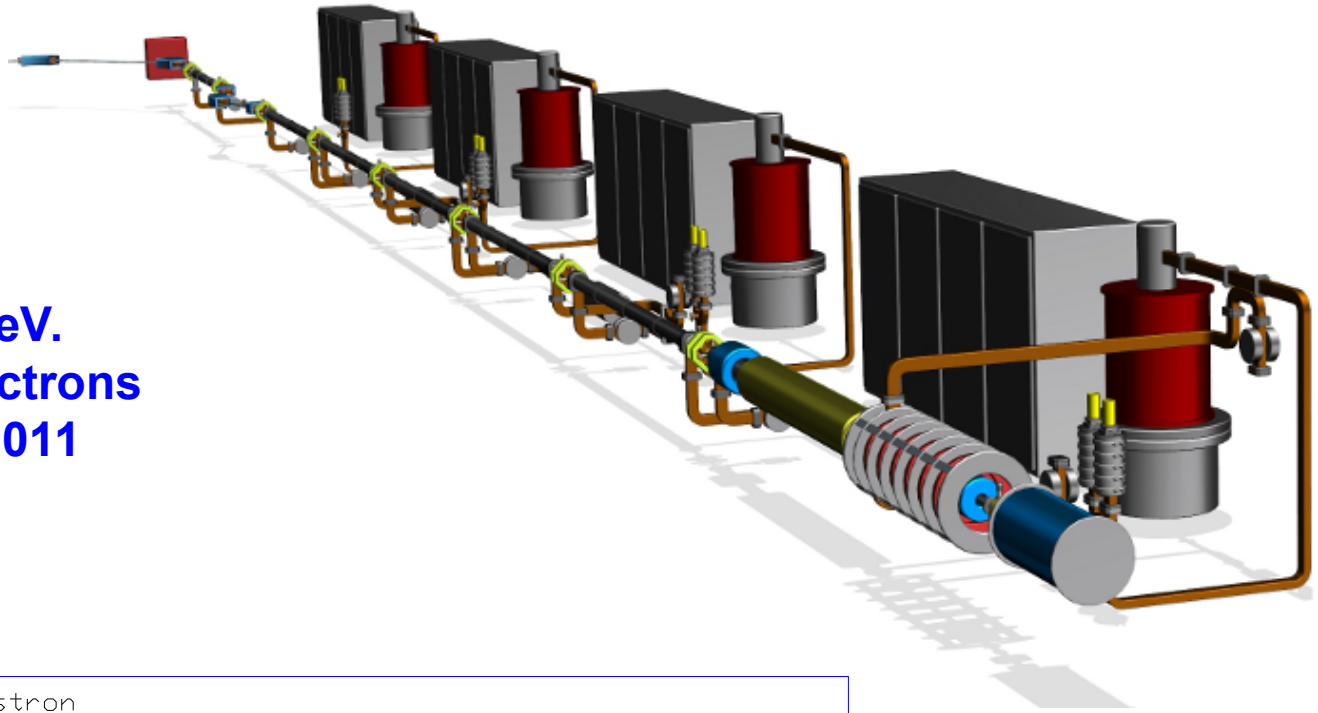


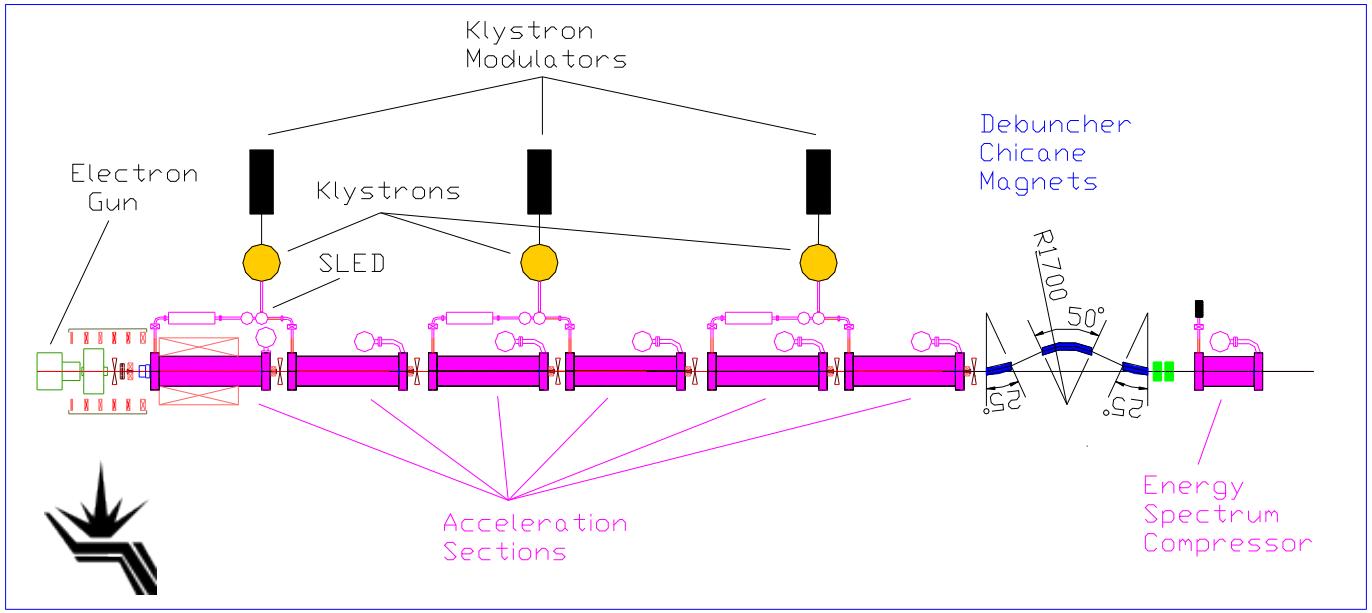


Electron Linac

Team:
Pavel Logatchev,
Alexey Levichev,
Vyacheslav Pavlov

Energy: 200 — 500 MeV.
Production: $5 \cdot 10^{10}$ electrons
Final design report: 2011



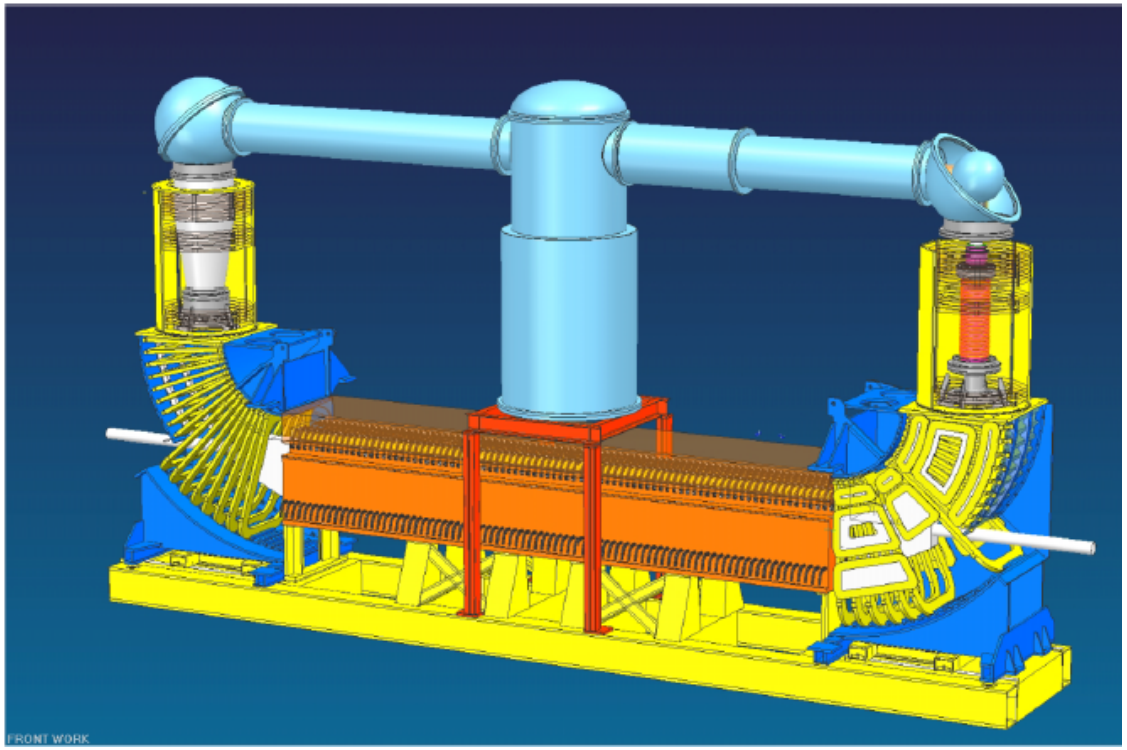


NESR Cooler

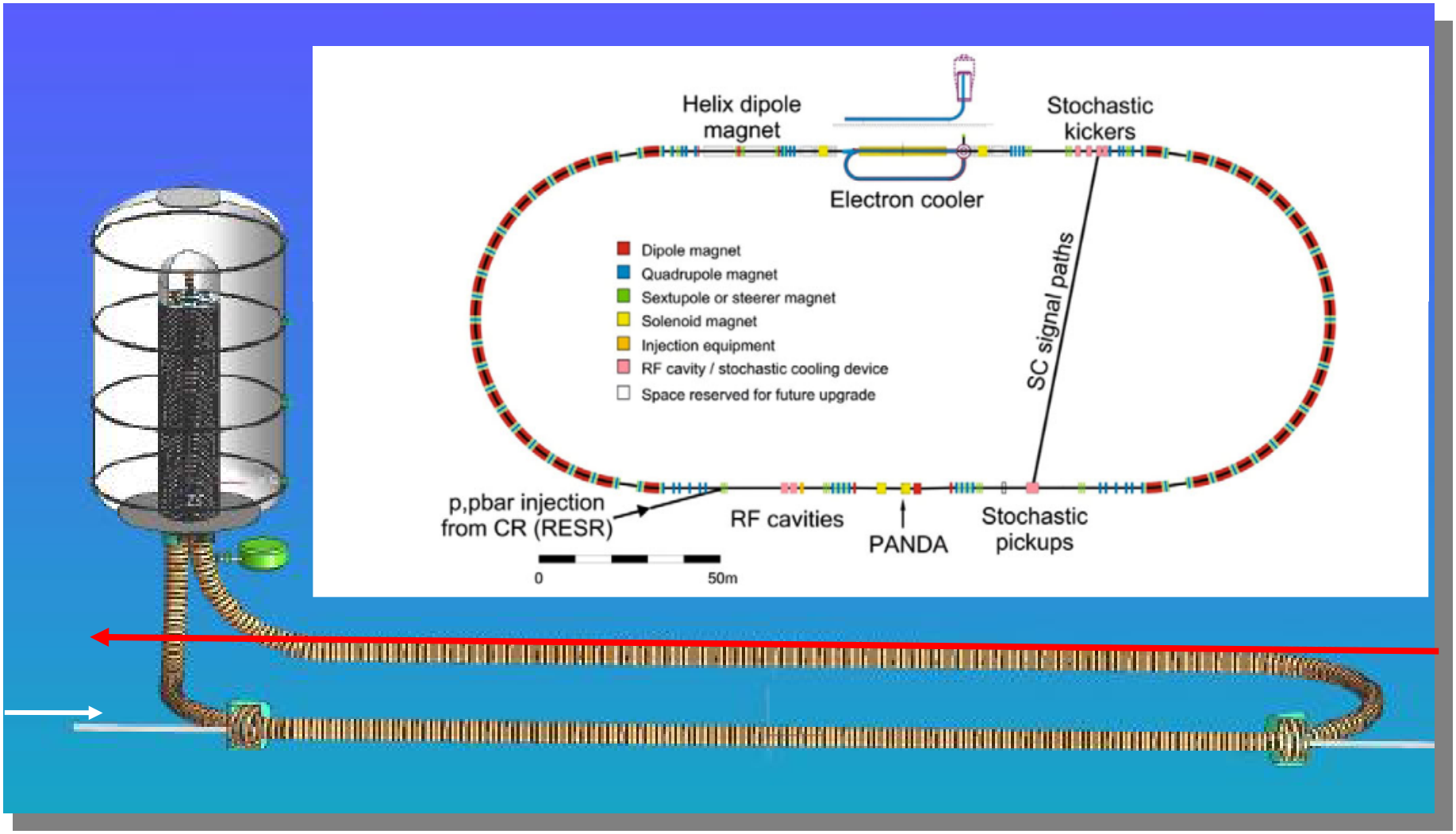
NESR main cooler
500 kV with fast ramping voltage

Team: V.V. Parhomchuk
V.B. Reva

Maximum accelerating voltage	500 kV
Maximum electron energy	450 keV
Maximum ramp rate of the accelerating voltage	250 kV/s
Maximum electron current	2 A
Cathode diameter	2 cm
Electron beam diameter in cooling section	0.5 – 2.8 cm
Inefficiency of electron beam recovery	$\leq 1 \times 10^{-4}$
Maximum power deposition in collector	15 kW
Maximum magnetic field strength in cooling section	0.2 T
in gun section	0.4 T
in collector section	0.23 T
in toroid section	0.2 T
Magnetic field straightness in cooling section	better 2×10^{-5}
Maximum electric bending field strength in toroids	10.5 kV/cm
Basic vacuum	$< 10^{-11}$ mbar

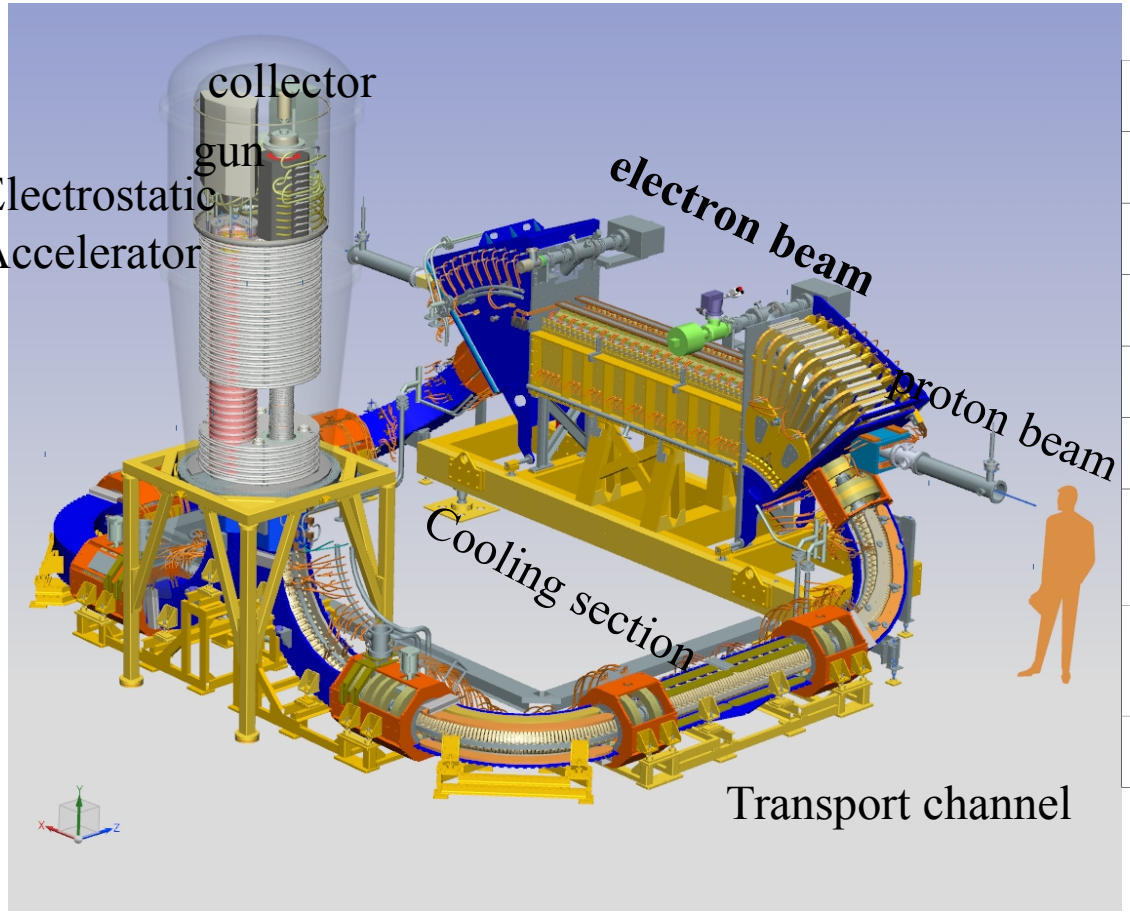


HESR electron Cooler, 8MeV!



Talk by Vladimir Reva — Wednesday.

High energy COSY cooler

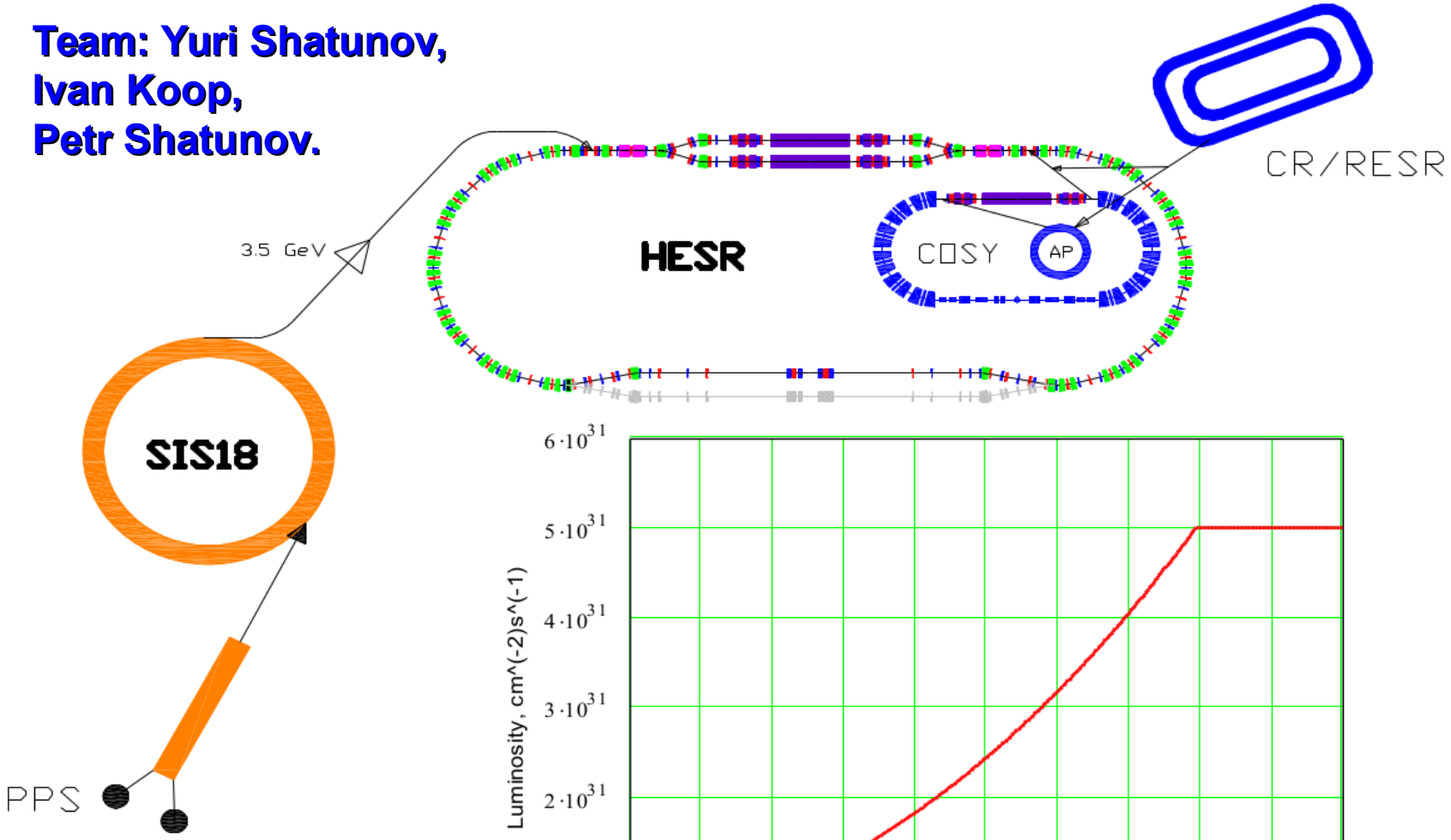


2 MeV Electron Cooler	Parameter
Energy Range	0.025 ... 2 MeV
Maximum Electron Current	1-3 A
Cathode Diameter	30 mm
Cooling section length	2.69 m
Toroid Radius	1.00 m
Magnetic field in the cooling section	0.5 ... 2 kG
Vacuum at Cooler	10^{-9} ... 10^{-10} mbar
Available Overall Length	6.39 m

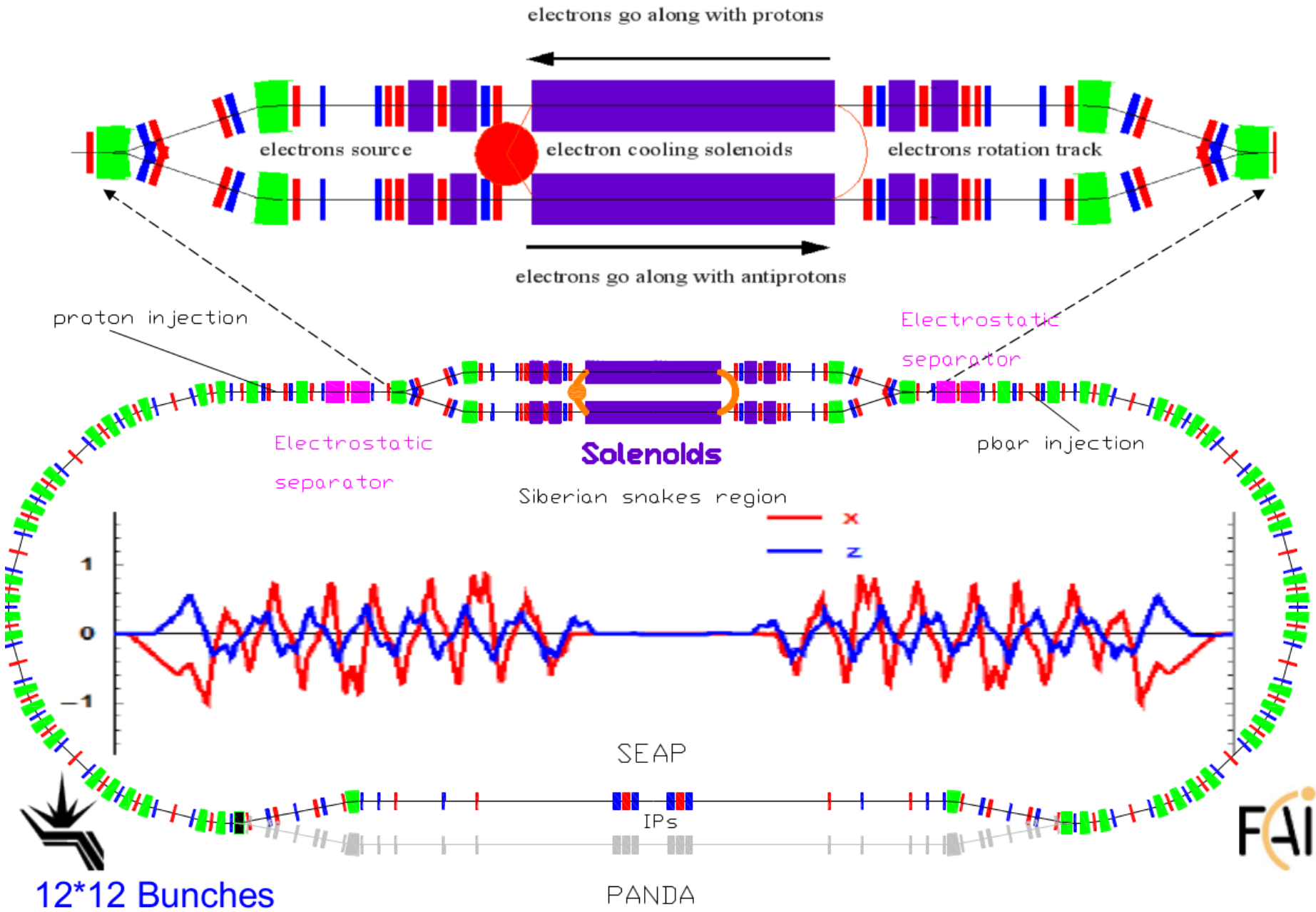
Started operation in Julich at 2013

Preliminary study of Polarized Proton-Antiproton Collider Facility at HESR

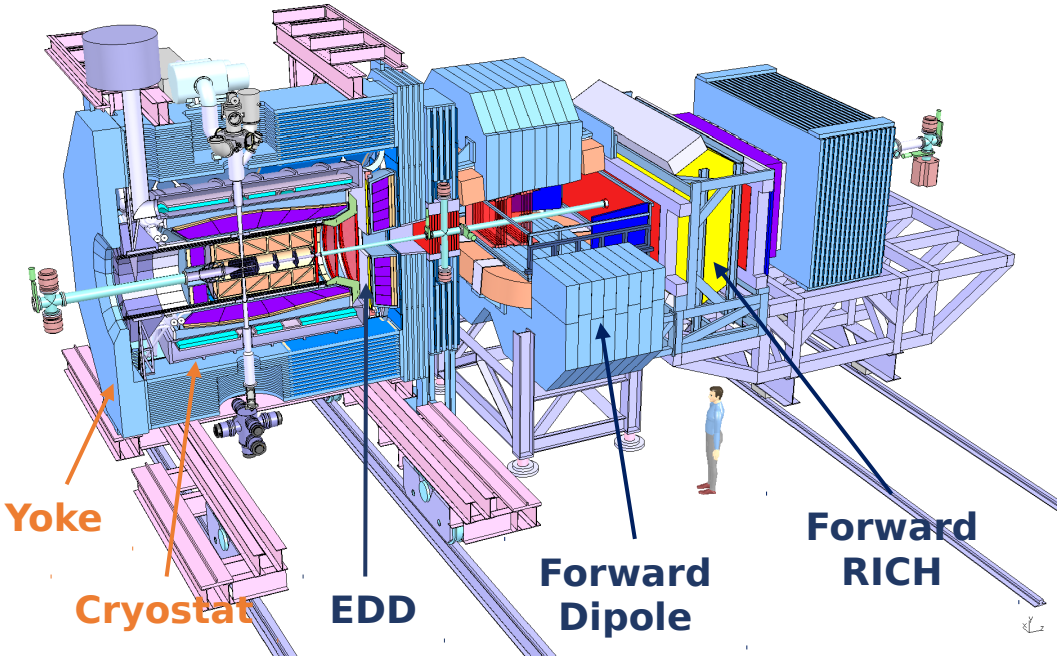
Team: Yuri Shatunov,
Ivan Koop,
Petr Shatunov.



Layout of the P-P_bar collider



BINP contribution to $\overline{\text{PANDA}}$



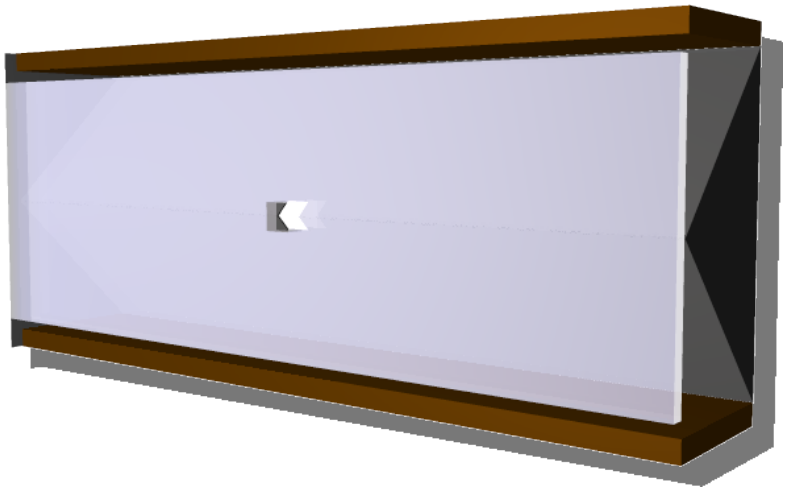
Status

- Forward RICH – EoI signed (Labs 3-1, 3-2)
- Dipole – EoI signed (Sec. 8-21)
- EDD – EoI signed (Lab 3-1 in part with Giessen Univ.)
- Solenoid cryostat & yoke in negotiations

- PANDA – one of the four pillar experiments at FAIR (see Julian Rieke talk today)
- HESR provides beams with $p=1.5\text{-}15$ GeV/c, $\sigma_p/p = 10^{-5} \div 10^{-4}$
- Hydrogen, deuterium or nuclear target
- Luminosity up to $2 \cdot 10^{32}$ cm^{-2} s^{-1} (p p_bar)
- PANDA physics: Charmonium spectroscopy, Search for Gluonic Excitations (glueballs and hybrids), Study of Hadrons in Nuclear Matter, Open Charm Spectroscopy, Hypernuclear Physics, Electromagnetic Processes

Forward RICH

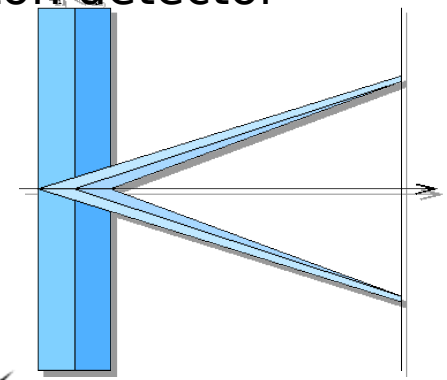
Talk by Sergey Kononov on Wednesday

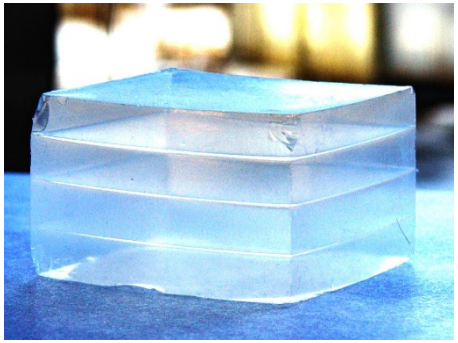


- PID in the Forward Spectrometer
- $|\theta x| < 10°$, $|\theta y| < 5°$
- ~3 x 1 m transverse active size
- Working momentum range for 3σ separation
  - π /K: 3÷10 GeV/c
  - μ/π: 0.5÷2 GeV/c possible

Focusing aerogel RICH concept

Use layered or gradient density aerogel to focus Cherenkov cone onto the photon detector

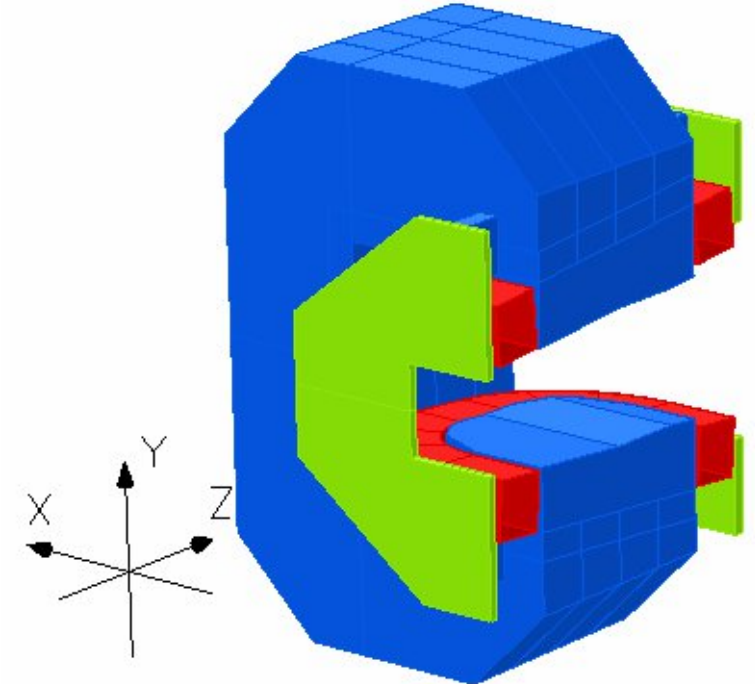


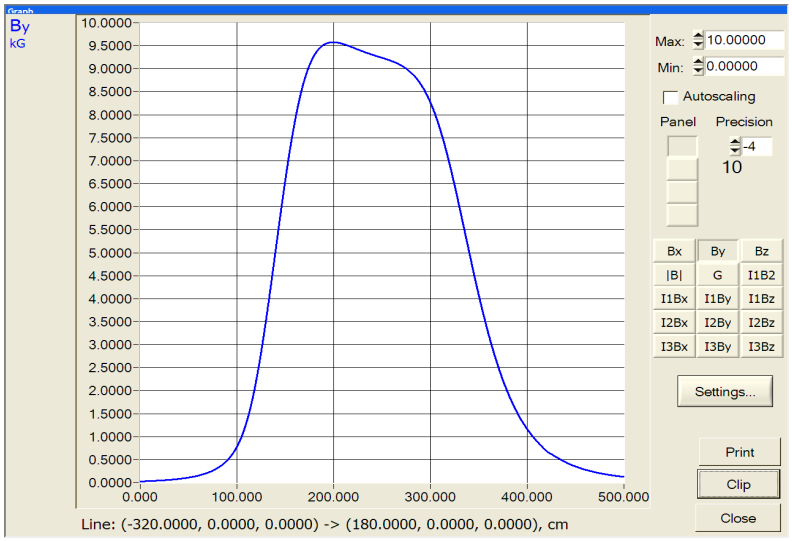


Aerogel of several layers with different refractive indices was first produced by the Boreskov Institute of Catalysis in 2004

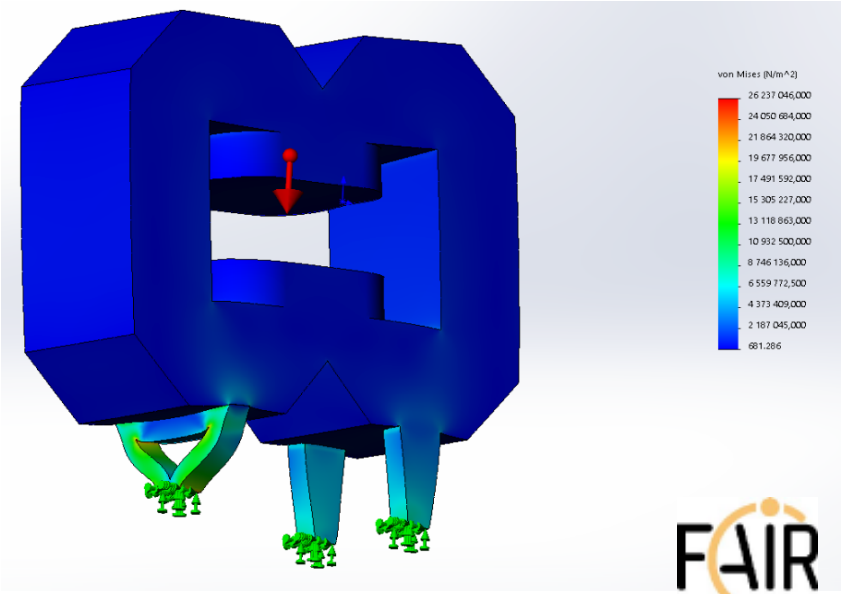
PANDA Forward Dipole Magnet

Talk by Evgeny Antokhin on Thursday





Magnetic field	1 T
Field Integral	2 T×m
Gap	0.8 m => 1.1 m
Hight×Width×Length	5.3 × 4.2 × 1.6 m
Weight	235 tons
Power	400 kW



Collector Ring

Team: Ivan Koop, Dmitry Berkaev, Dmitry Shwartz, Petr Shatunov, Vyacheslav Kolmogorov, Alexandr Krasnov, Yuri Rogovsky

MOU: November 2013

Memorandum of Understanding (MoU) No.3 *between* BINP *and* GSI *and* FAIR *on* CR

Memorandum of Understanding (MoU) No.3
between
Budker Institute of Nuclear Physics (BINP, Novosibirsk)
and
Gesellschaft für Schwerionenforschung mbH (GSI, Darmstadt)
and
Facility of Antiproton and Ion Research in Europe GmbH (FAIR, Darmstadt)
on the
Realization of the FAIR Collector Ring (CR)

1. Introduction

The Collector Ring (CR) is a dedicated storage ring for fast precooling of secondary particles, rare isotopes or antiprotons. The CR is hereinafter referred to as the "CR project", which means to design, construct, deliver, install, and commission all CR components in frame of the FAIR project.

2. Purpose

The purpose of this MoU is to specify, review, and agree on the obligations what the parties (BINP, GSI, FAIR) intend with respect to planning, constructing, installation, and commissioning of the CR. The intention is to provide the necessary equipment for the CR, as well as capital and human resources to carry out this project successfully. The items forming the CR project are divided into eleven "work packages" (WP), which are specified in Table 1 (Annex A).

Contract: July 2014

Collaboration Contract

between

Facility for Antiproton and Ion Research in Europe GmbH

and

Budker Institute for Nuclear Physics BINP SB RAS

for

Technical Coordination of the Construction of the Collector Ring

to the Construction of the FAIR Facility FAIR

Contract No.: CC CR.HOAI

As defined in detail below

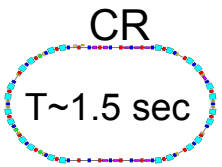
Tasks of the CR

1. Cooling of secondary beams of radioactive ion beam (RIB)

Injection RI beams from the Super-FRS E=740 MeV/u

$\varepsilon_{\perp}$=200 mm mrad

$\Delta p/p$=3 %



$\varepsilon_{\perp} \leq$ 0.5 mm mrad

$\Delta p/p \leq$ 0.05 %

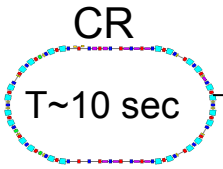
extraction RI beams to the HESR

2. Cooling of antiproton beams (Pbar)

Injection from antiproton separator E=3 GeV

$\varepsilon_{\perp}$ =240 mm mrad

$\Delta p/p$=6 %



$\varepsilon_{\perp} \leq$ 5 mm mrad

$\Delta p/p \leq$ 0.1 %

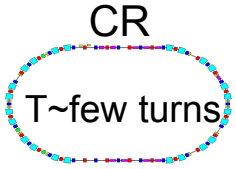
extraction Pbar to the HESR

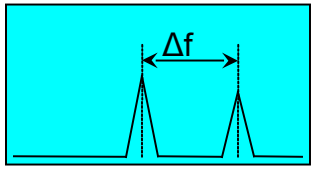
3. Mass spectrometer of radioactive ions RI (TOF)

Injection RI beams from the Super-FRS E=400 – 800 MeV/u

$\varepsilon_{\perp}$ =100 mm mrad

$\Delta p/p$=1 %

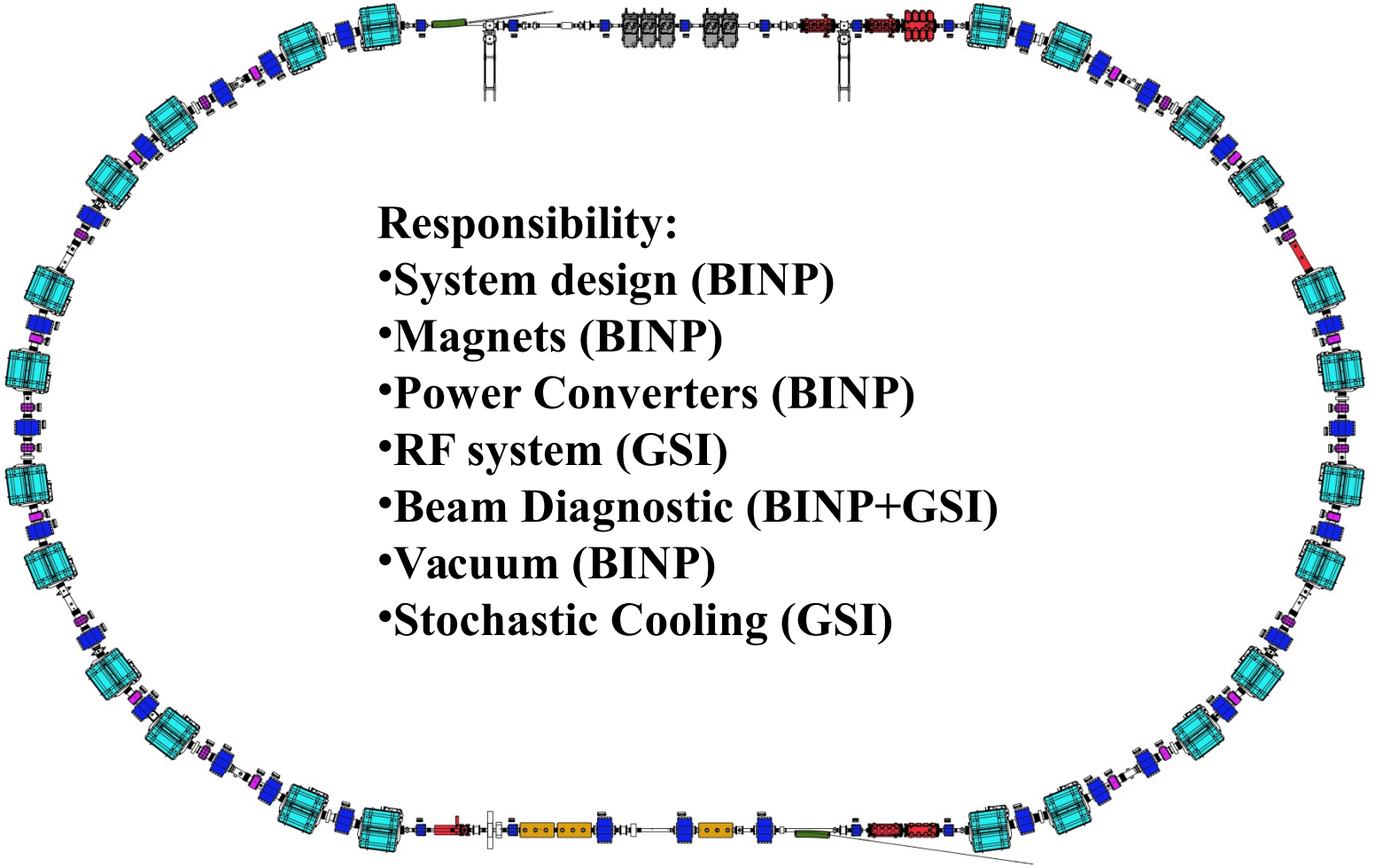




$$\frac{\Delta m}{m} = \gamma_{tr}^{2} \frac{\Delta f}{f}$$

CR Layout

C=221.45 m BR=13 Tm

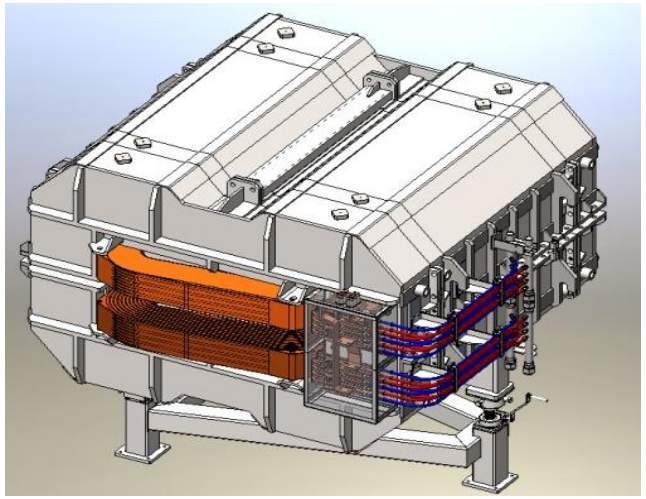


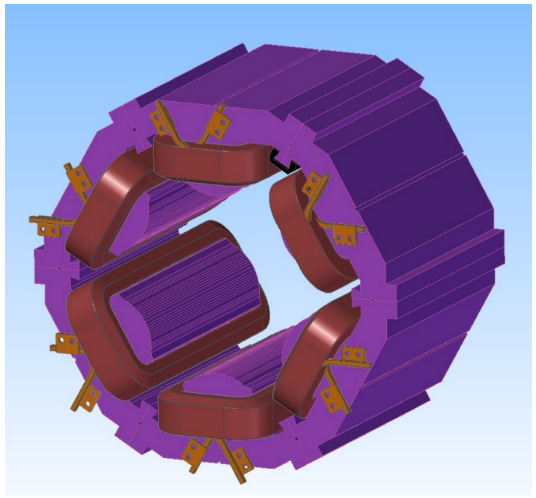
Responsibility:

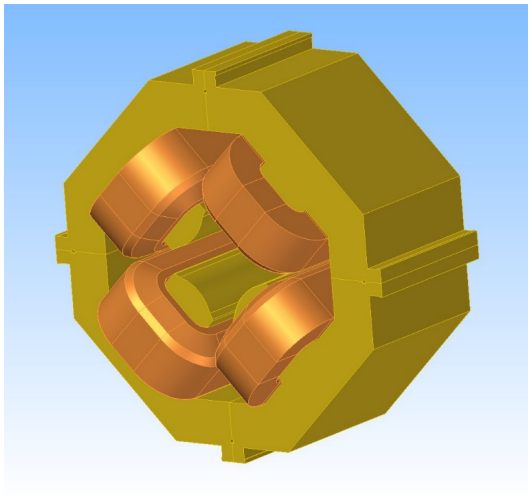
- **System design (BINP)**
- **Magnets (BINP)**
- **Power Converters (BINP)**
- **RF system (GSI)**
- **Beam Diagnostic (BINP+GSI)**
- **Vacuum (BINP)**
- **Stochastic Cooling (GSI)**

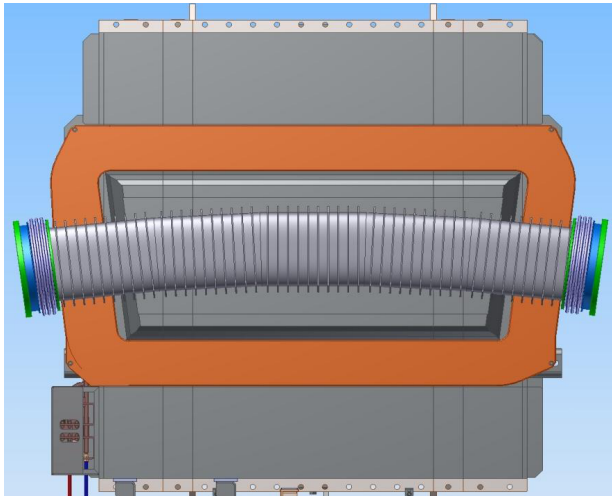
CR Dedicated session: Tuesday.

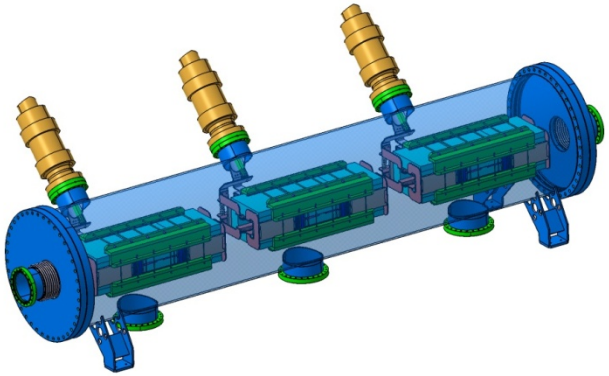
CR Work in Progress

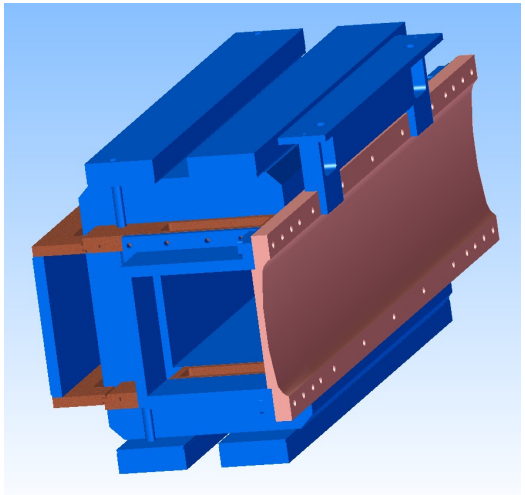












CR Dedicated session: Tuesday.

Vacuum chambers for HEBT dipoles

Team: Alexandr Krasnov, Alexey Semenov
Quantity: 53
Dates: 2011-2016

Collaboration Contract

between

Facility for Antiproton and Ion Research GmbH

and

Budker Institute for Nuclear Physics BINP SB RAS

for

design, production and delivery of vacuum chambers for dipole magnets for

Work Package PSP 2.3.7.1.2.2

for the FAIR High Energy Beam Transport (HEBT) System

The Facility for Antiproton and Ion Research GmbH

hereafter referred to as "FAIR GmbH"
limited liability company subject to the German law
having its registered office at:
Planckstrasse 1, 64291 Darmstadt, Germany
represented by:

Prof. B. Sharkov, Scientific Director and Chair of the FAIR Management Board,
Prof. Dr. G. Rosner, Administrative Director
and Dr. Krämer, Technical Director

and

Budker Institute for Nuclear Physics "BINP SB RAS" a public body organized under the laws of the Russian Federation,

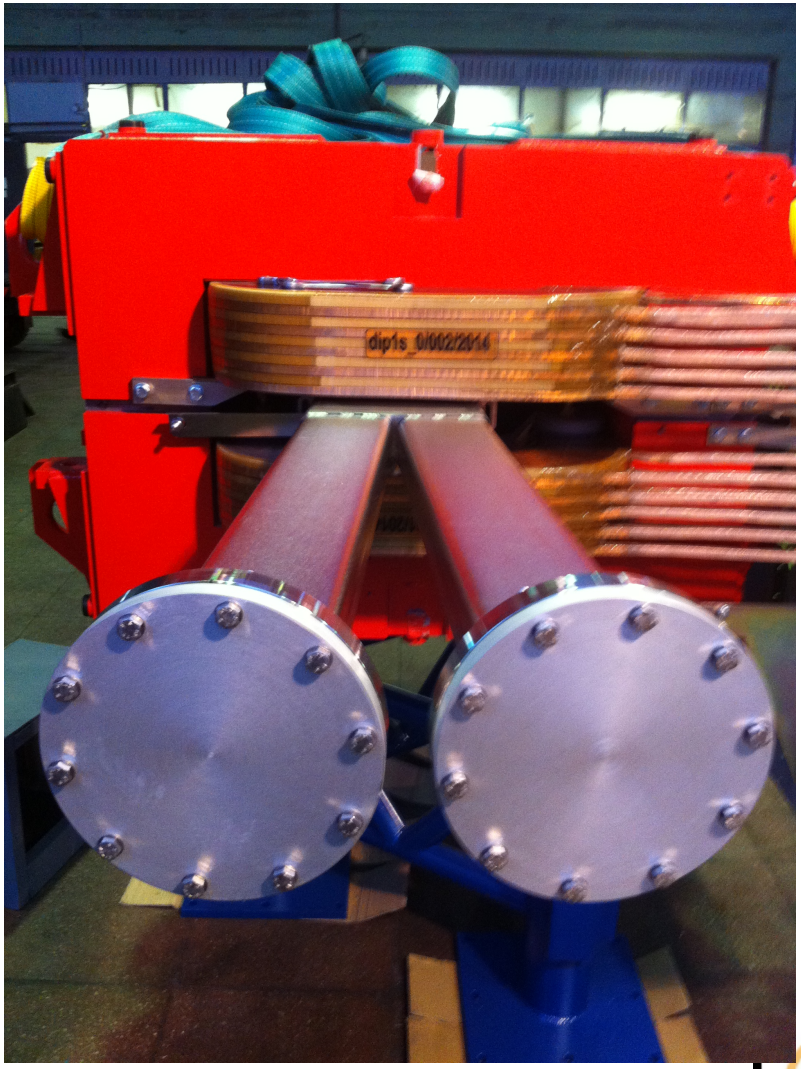
hereafter referred to as the "BINP",
having its registered office at:
11 Lavrentiev Prospect,
630090, Novosibirsk, Russia
represented by

A. N. Skrinsky, Director

V. V. Anashin, Deputy Director

hereafter collectively referred to as the Parties

HAVE AGREED UPON THE FOLLOWING PROVISIONS:



Recent agreements between BINP and FAIR

- The High Energy Beam Transport line magnetic system production.
- The Collector Ring bending magnets production.

FAIR

Thank you!

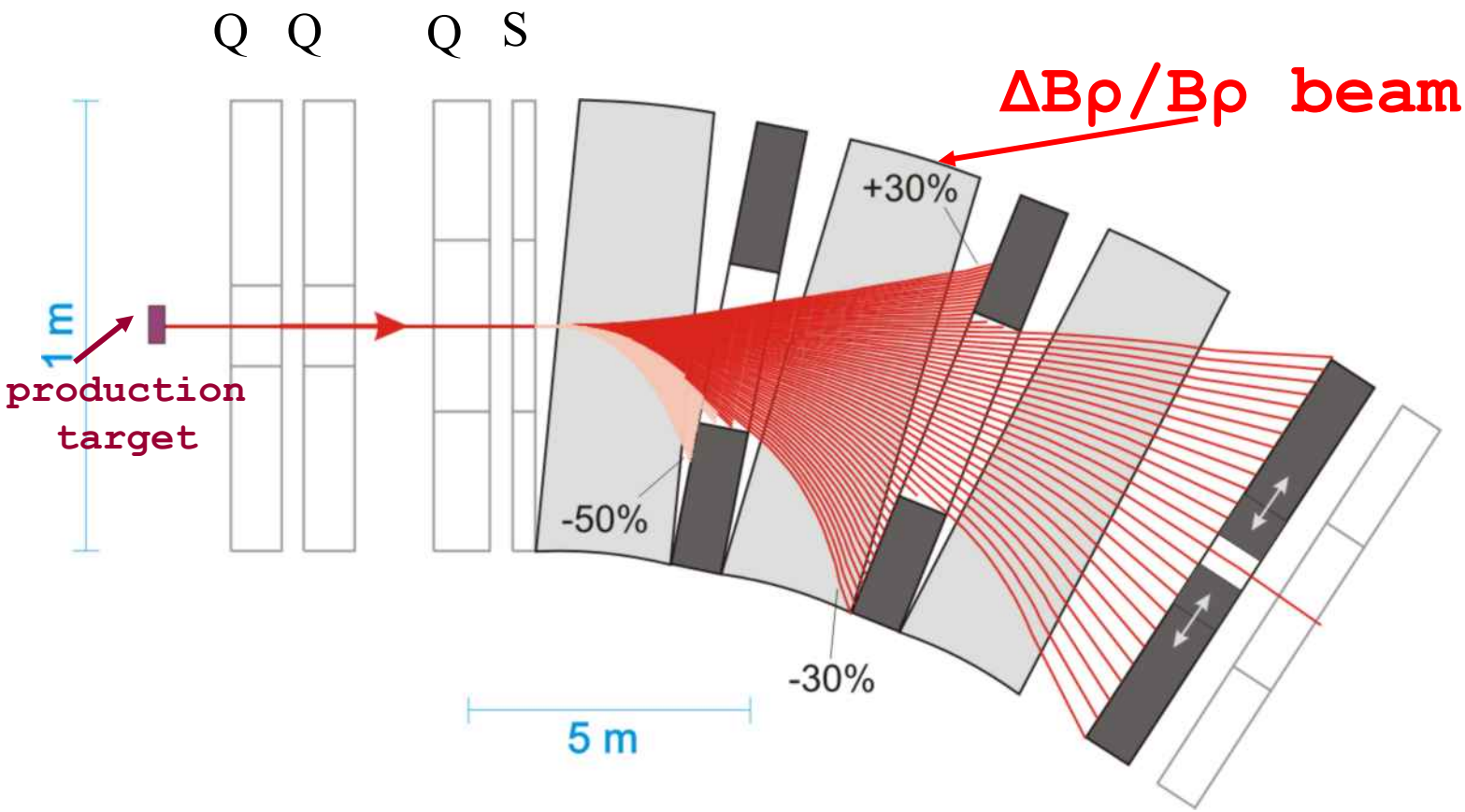
BINP — Germany reserach collaborations

- DESY: Colliding beams and polarized beams, synchrotron radiation (Doris, Petra, HERA)
- BESSY: Synchrotron radiation, polarized beam.
- KFC: Synchrotron radiation (ANKA)
- KFA: Ions source for plasma heating, Siberian snake and electron cooling for COSY.
- GSI: Electron cooling (SIS-18, ESR)
- Heidelberg university: Polarized target (TSR).

List of BINP activities in FAIR project

- Super-FRS
  - target
  - high radiation resistant magnets
- Electron-ions collider (eA)
  - e-linac
  - electron spectrometer
  - P_bar-ions collisions
- Electron colling:
  - NESR (e-coller, e-target);
  - e-cooler for P_bar – A collider,
  - HESR e-cooler
- Kickers for synchrotrons and storage rings
- Septum for synchrotrons and storage rings
- Quads for CR
- Dipole prototype and RF system for SIS-100
- Polarized P-P_bar collider at HESR

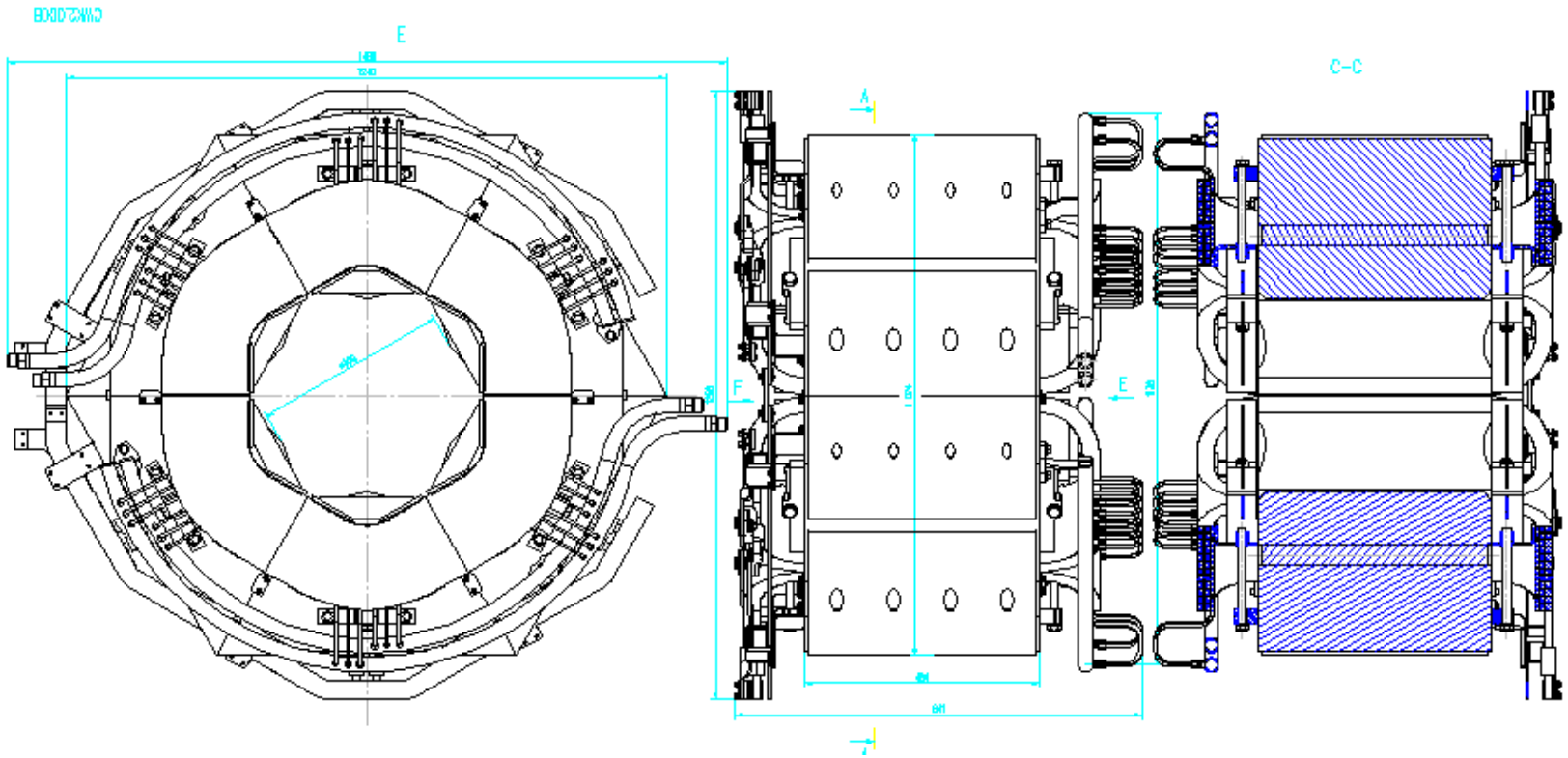
First stage of Super-FRS



High radiation resistant dipole magnet.

Yoke and Coil production at BINP plant

High radiation resistant sextupole magnet



Magnetic Field Gradient 15T/m²
Magnetic Length 600 mm

CR injection - extraction

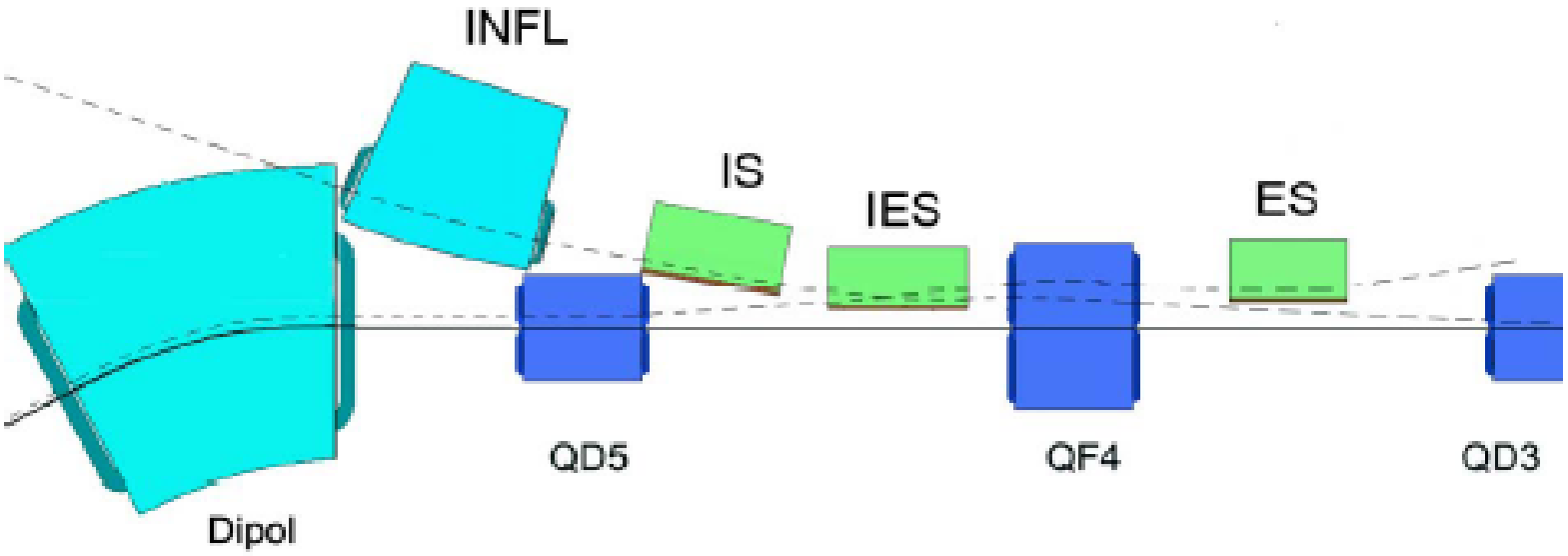
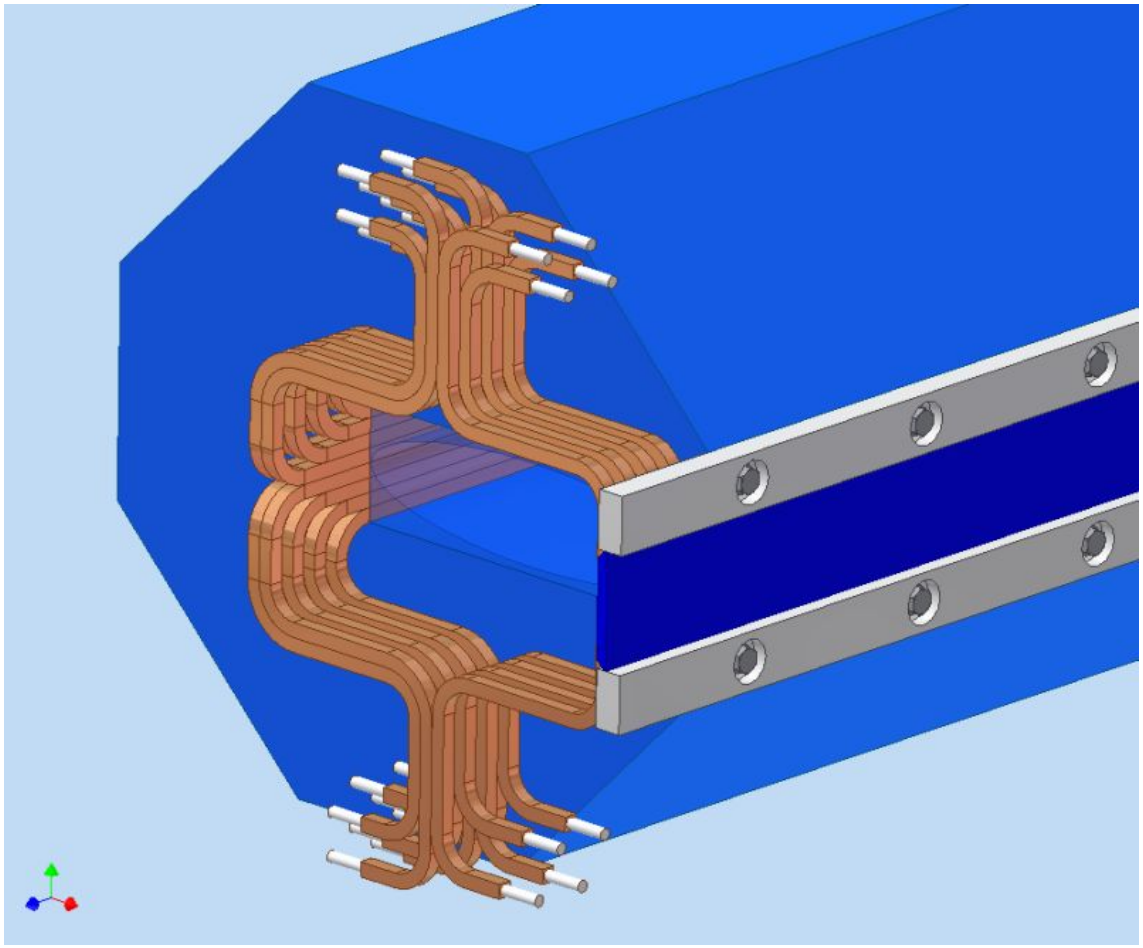
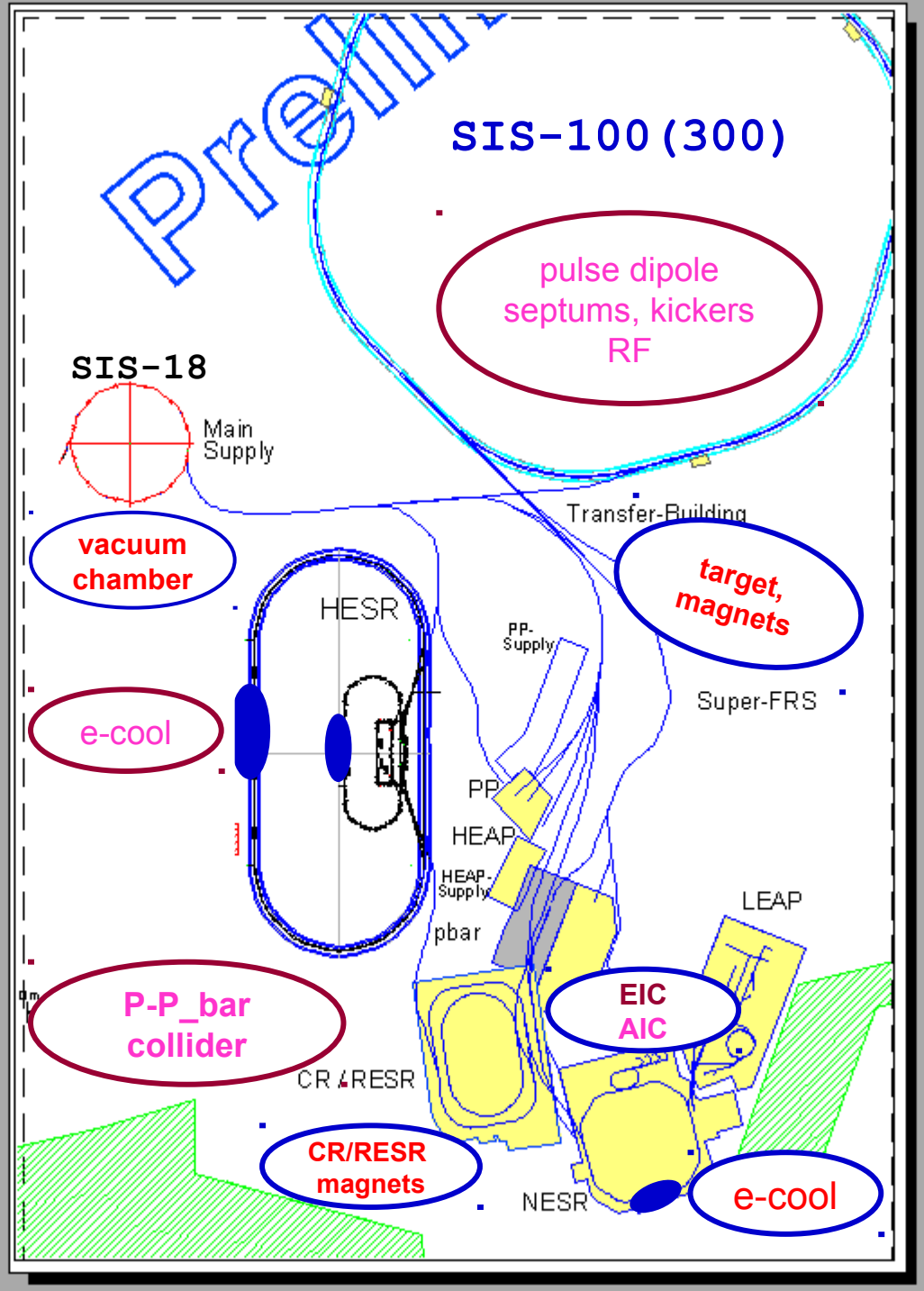


Figure 2.5.15: Injection and extraction septum magnets in the CR ring. Components labelled I are used for injection, extraction components are labelled E.

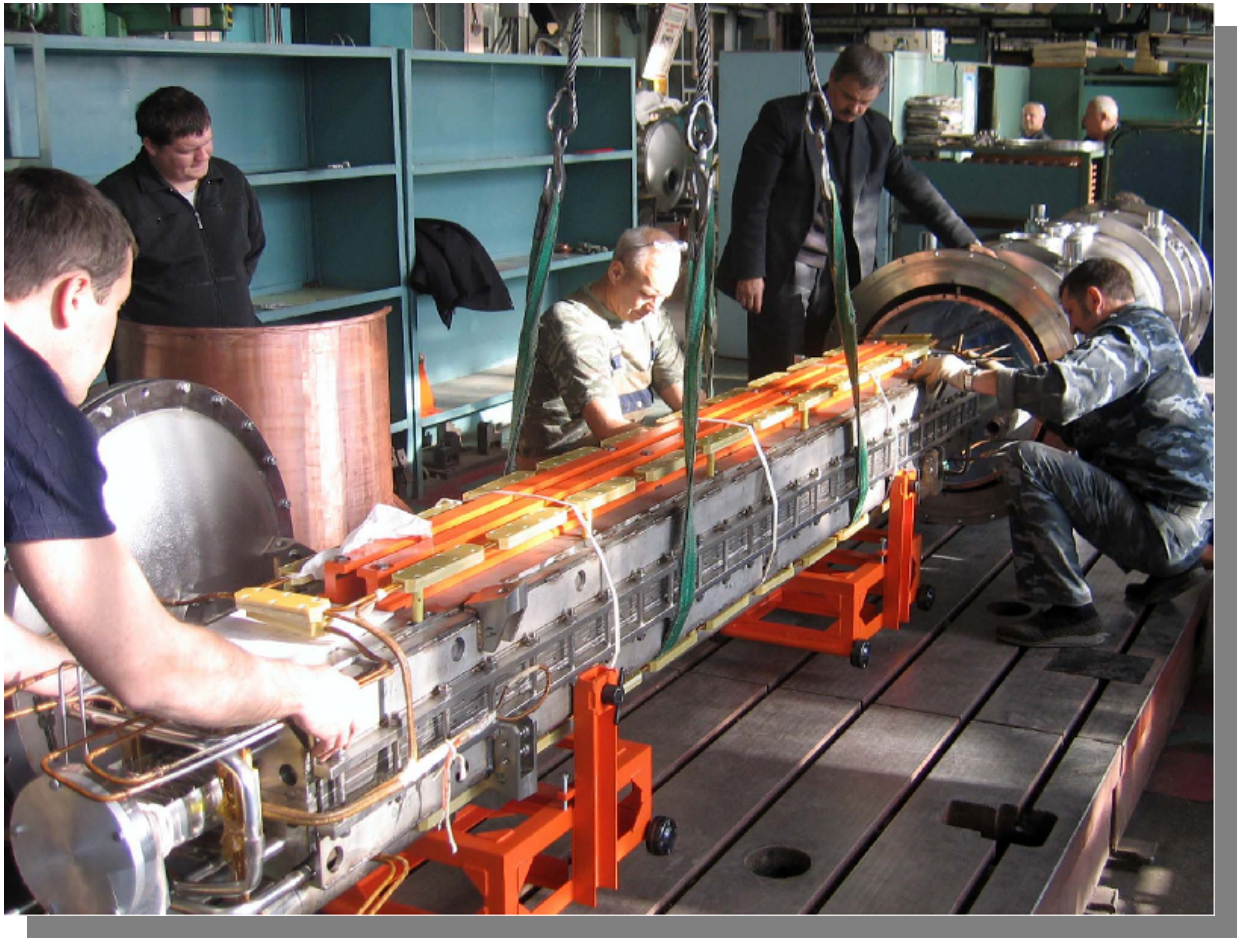
Septum-magnet for CR (1T)



BINP presence at the map of the project.



Superconducting dipole for SIS-100



Assembling process

NESR electron target

cooler 40 kV