Status SIS100/300

Peter Spiller

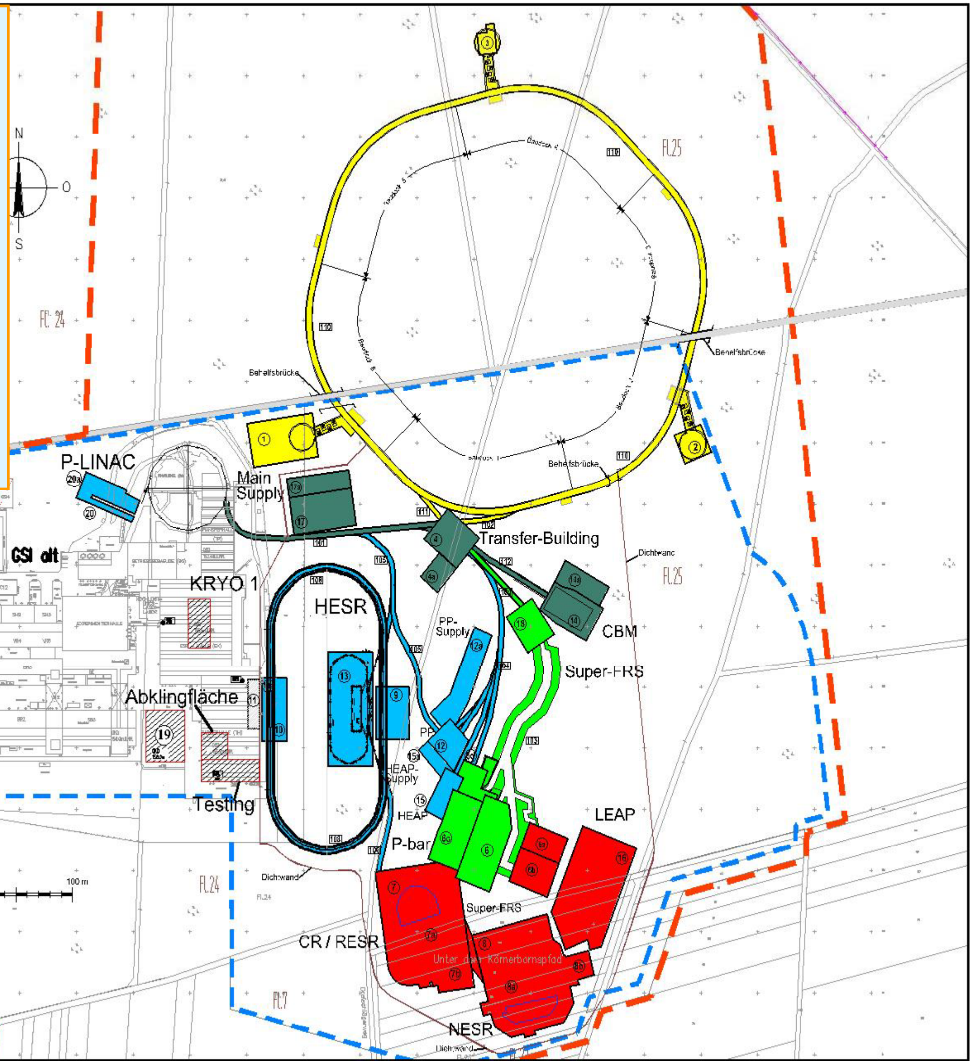
CARE-HHH Workshop

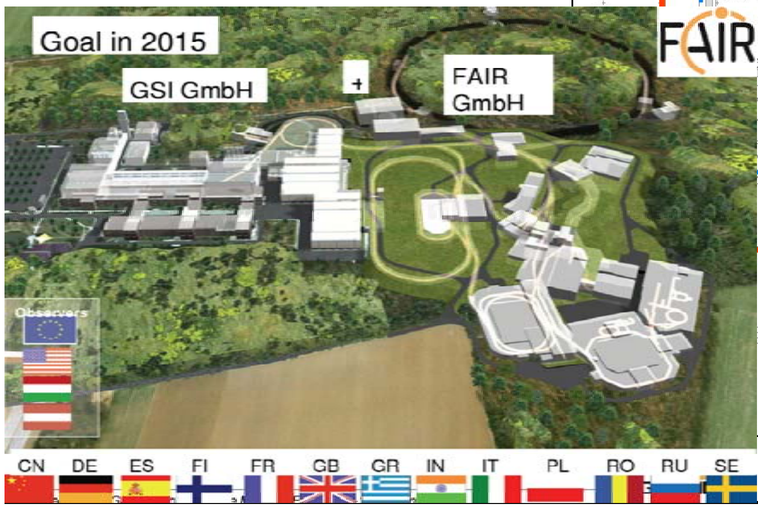
24.11.2008

GSI/FAIR Accelerator Facility

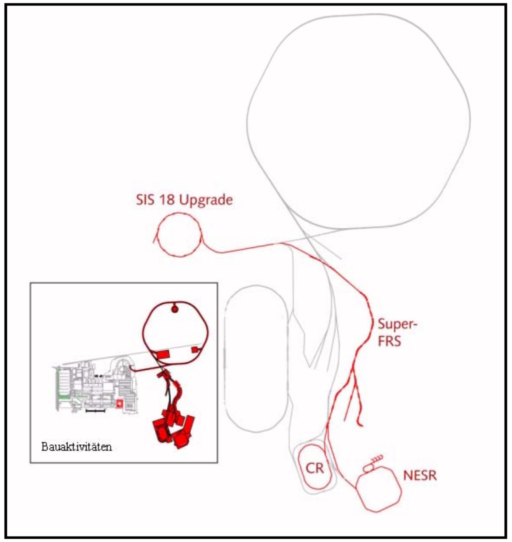
Primary Beam Intensity	x 100-1000
Secondary Beam Intensity	x 10 000
Heavy Ion Beam Energy	x 30

- New: Cooled pbar Beams (15 GeV)
- Intense Cooled Radioactive Beams
- Parallel Operation

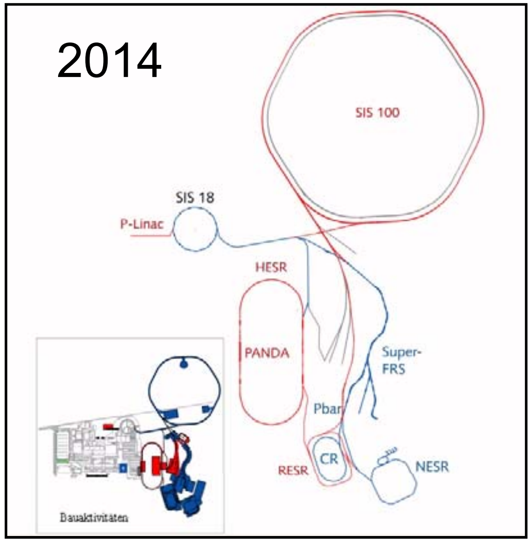




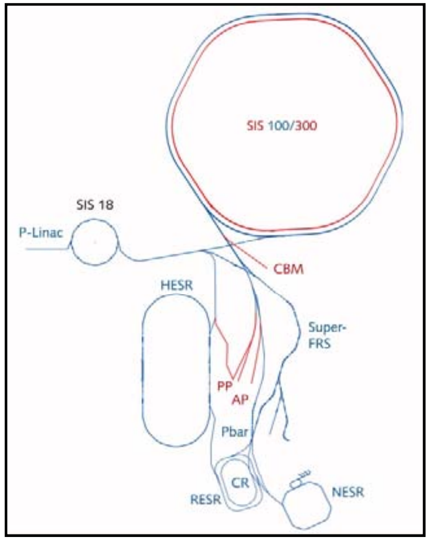
FAIR Uranium Intensity (staged realization)



Stage 1



Stage 2



Stage 3

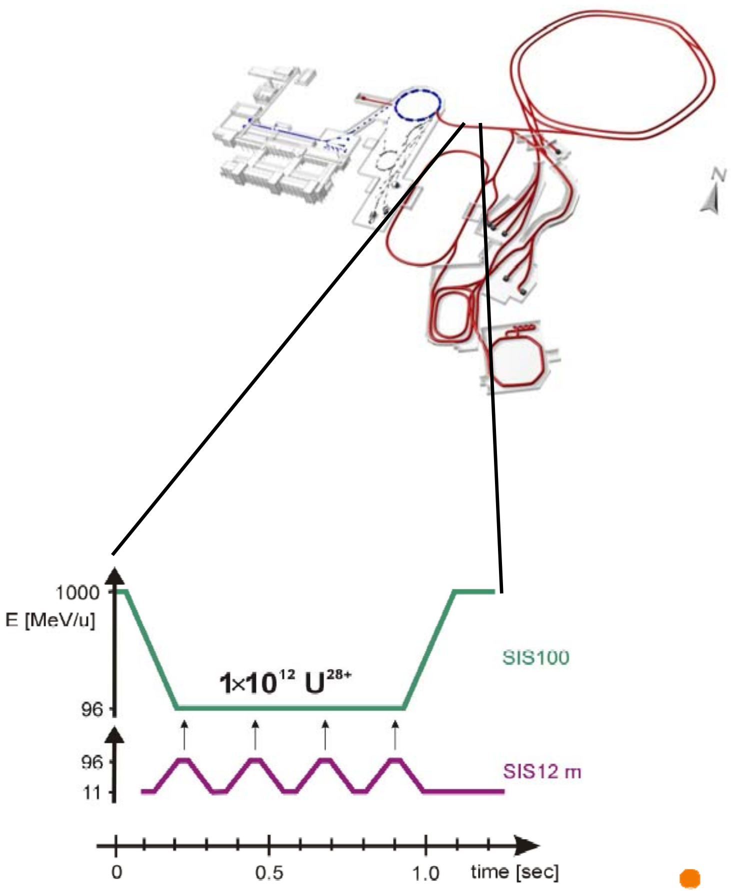
Uranium Beam Intensities		
SIS18 (U^{73+})	SIS100 (U^{28+})	SIS100/300 (U^{28+})
2×10^{10} /cycle	5×10^{11} /cycle	5×10^{11} /cycle
Slow Extraction at 1 GeV/u and 1.4 s Spill		
1.1×10^{10} /s	1.5×10^{11} /s	3.5×10^{11} /s
Fast Extraction at 1 GeV/u		
5.4×10^{10} /s	3.5×10^{11} /s	not foreseen

Beam Parameters SIS18/SIS100

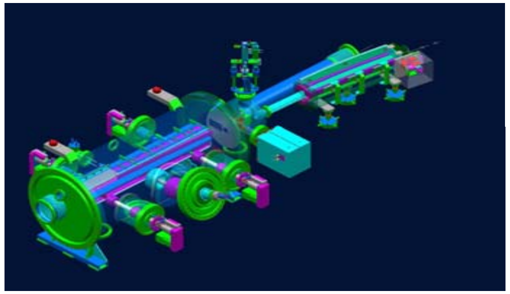
SIS18	Protons	Uranium
Number of ions per cycle	5 x 10^{12}	1.5 x 10^{11}
Initial beam energy	70 MeV	11 MeV/u
Ramp rate	10 T/s	10 T/s
Final beam energy	4.5 GeV	200 MeV/u
Repetition frequency	2.7 Hz	2.7 Hz

SIS100	Protons	Uranium
Number of injections	4	4
Number of ions per cycle	2.5x 10^{13} ppp	5 x 10^{11}
Maximum Energy	29 GeV	2.7 GeV/u
Ramp rate	4 T/s	4 T/s
Beam pulse length after compression	50 ns	90 - 30 ns
Extraction mode	Fast and slow	Fast and slow
Repetition frequency	0.7 Hz	0.7 Hz

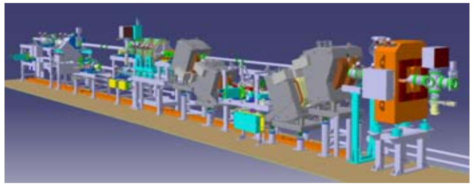
... and all other ion species



SIS18upgrade Program

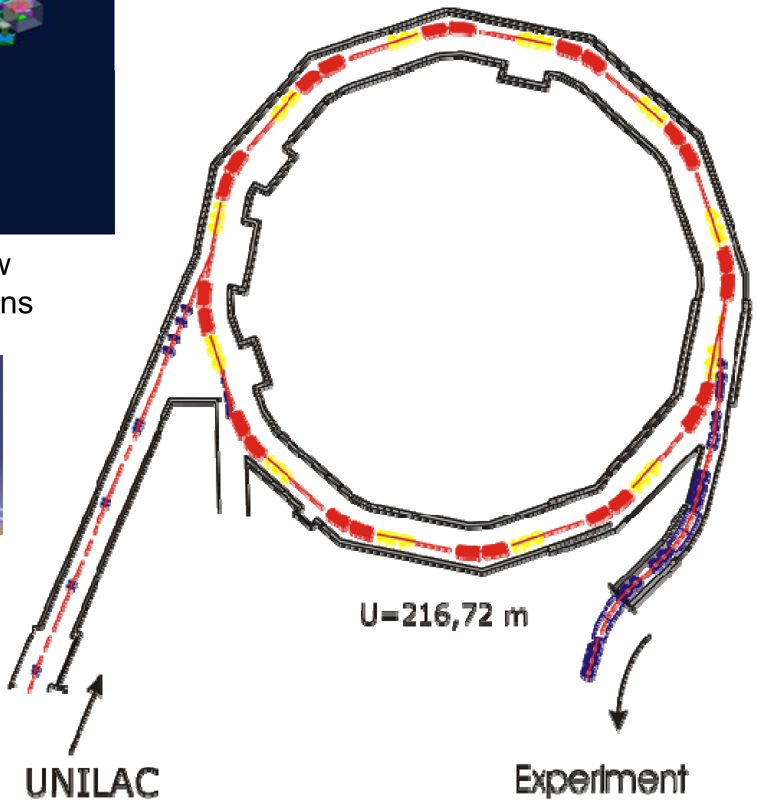


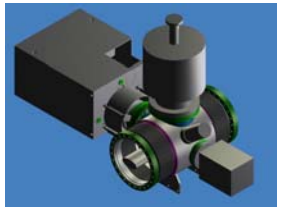
Injection system for low charged state heavy ions



Charge separator for higher intensity and high quality beams

Power grid connection



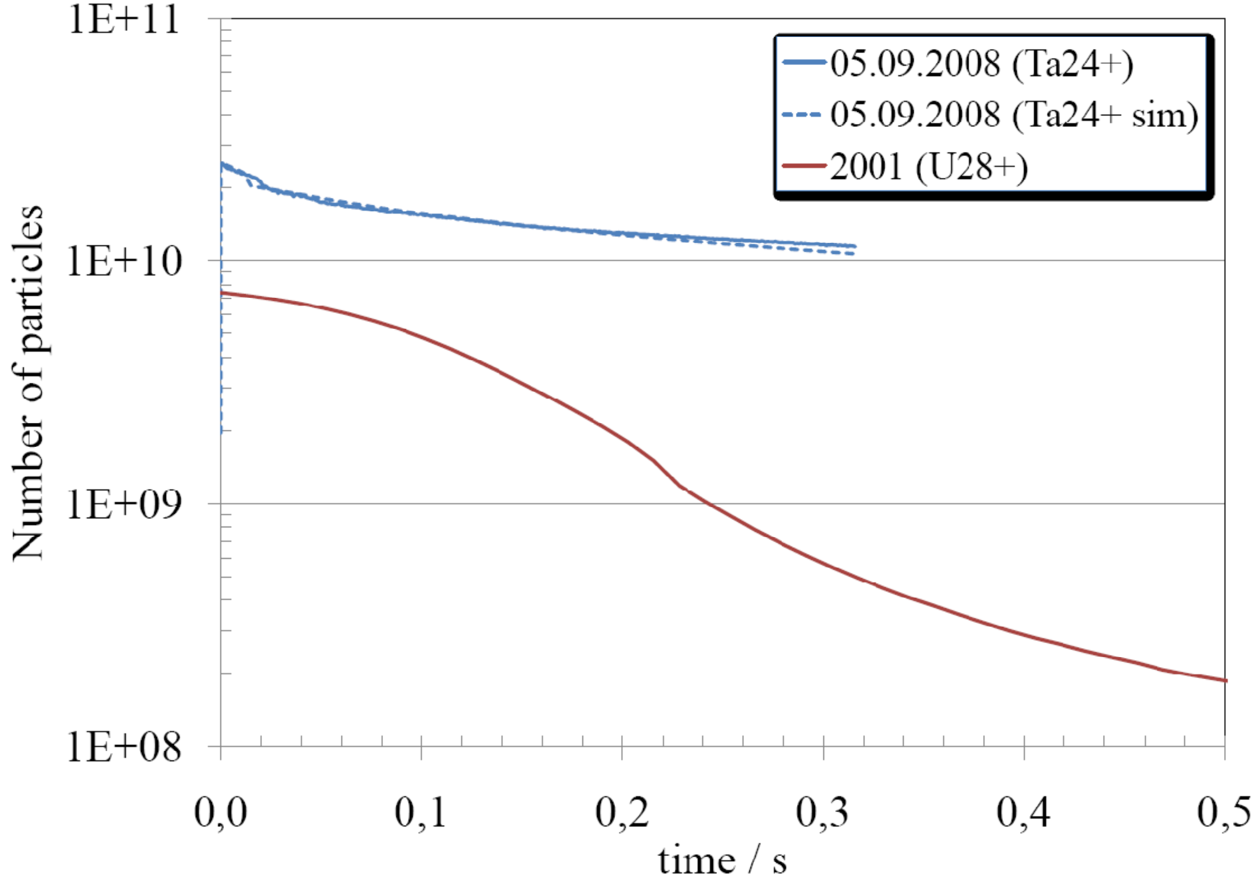


Scrapers and NEG coating for pressure stabilization

h=2 acceleration cavity for faster ramping

The SIS18upgrade program: Booster operation with low charge state heavy ions

SIS18 – Low Charge State Heavy Ion Acceleration

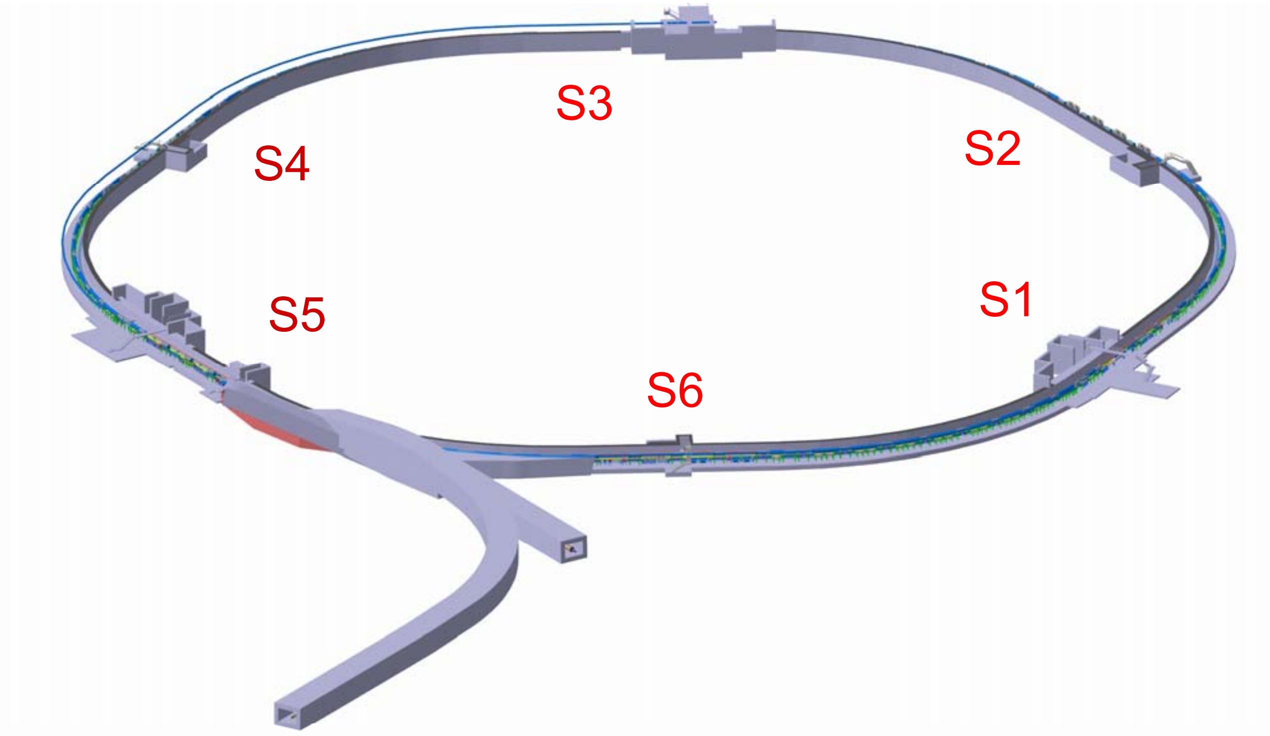


Major progress achieved resulting from the SIS18 upgrade program and careful machine setting

Technical Subsystems

Sixfold Symmetry

- Sufficiently long and number of straight sections
- Reasonable line density in resonance diagram
- Good geometrical matching to the overall topology

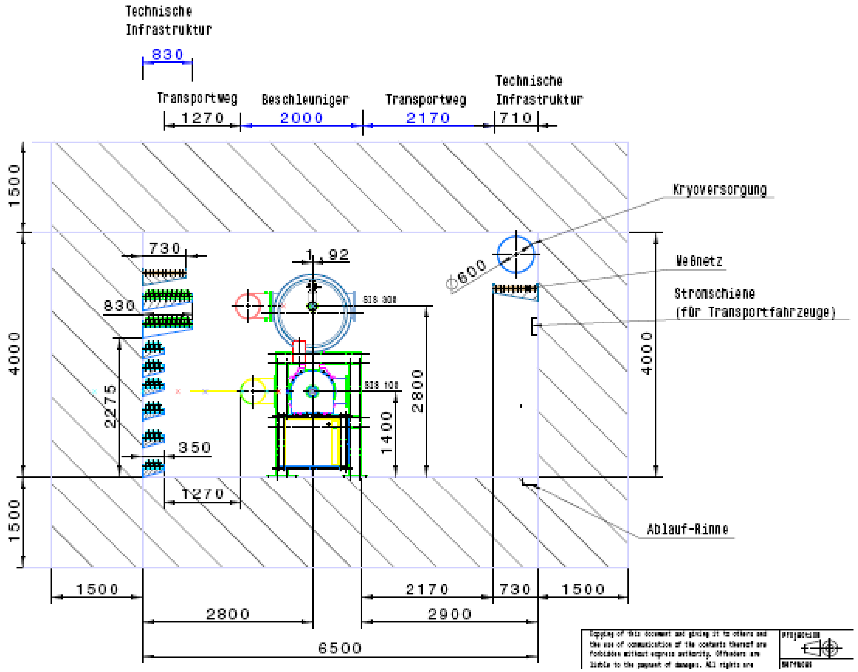


S1: Transfer to SIS300
S2: Rf Acceleration (Ferrite loaded)
S3: Rf Acceleration (Ferrite loaded)
S4: Rf Compression (MA loaded)
S5: Extraction Systems (slow and fast)
S6: Injection System plus RF Acceleration and Barrier Bucket

The SIS100 technical subsystems define the length of the straight sections of both synchrotrons

System and Ion Optical Design

Realisation of two-stage SIS100 and SIS300 concept in one tunnel is challenging:



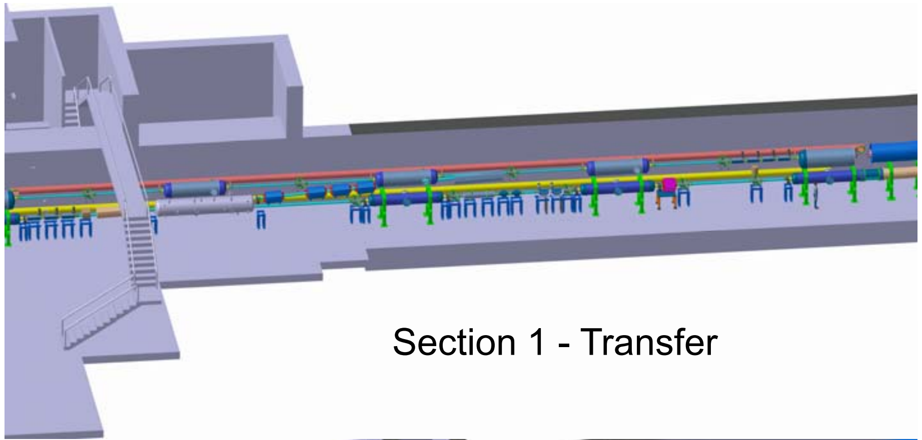
- Geometrical matching of both synchrotrons with different lattice structures (Doublet and FODO) and different magnet technologies (superferric and cosθ)

- Ratio between straight section length and arc length with fixed circumference defined by the warm straight section requirements of SIS100

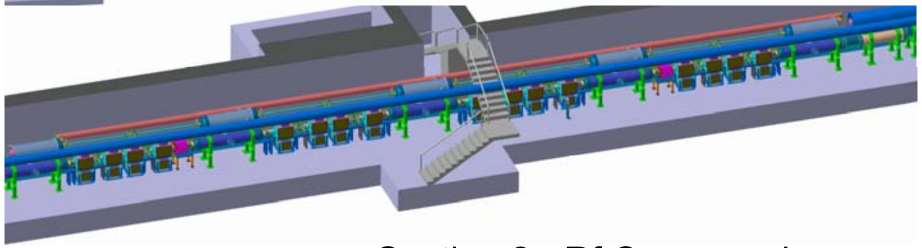
- Fast, slow and emergency extraction in one short straight and precisely at the same position, with the same angle and fixed distance between the SIS100 and SIS300 extraction channel

- Vertical extraction of SIS100 bypassing SIS300 (on top of SIS100)
- Transfer between SIS100 and SIS300, 1.4 m difference, many geometrical constraints

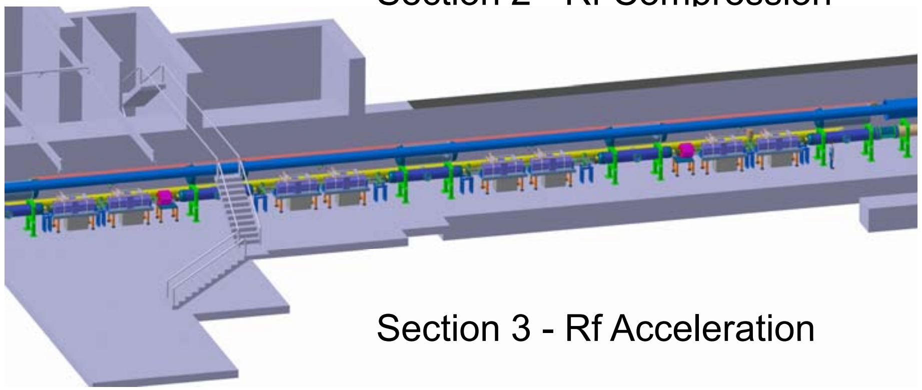
SIS100/300 Synchrotron Sections



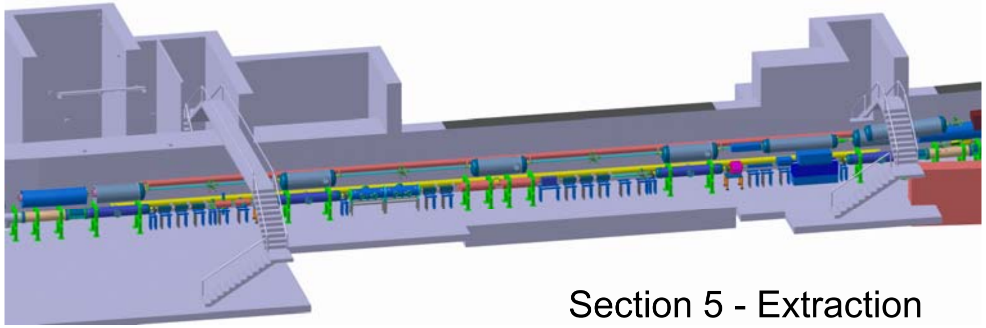
Section 1 - Transfer



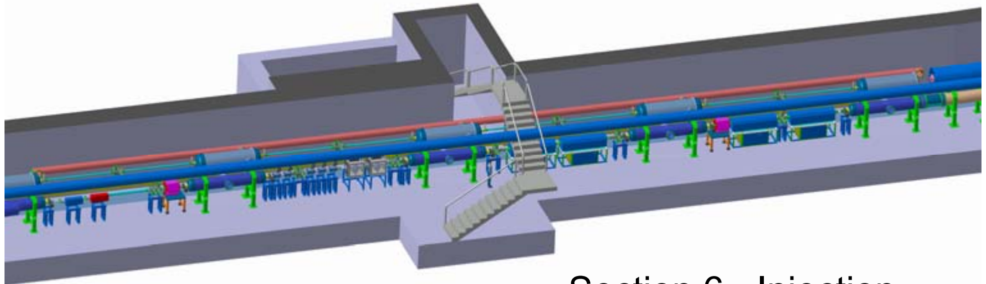
Section 2 - Rf Compression



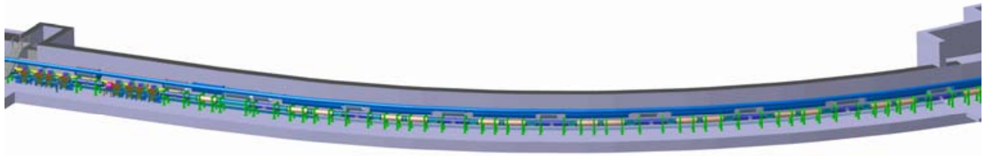
Section 3 - Rf Acceleration



Section 5 - Extraction



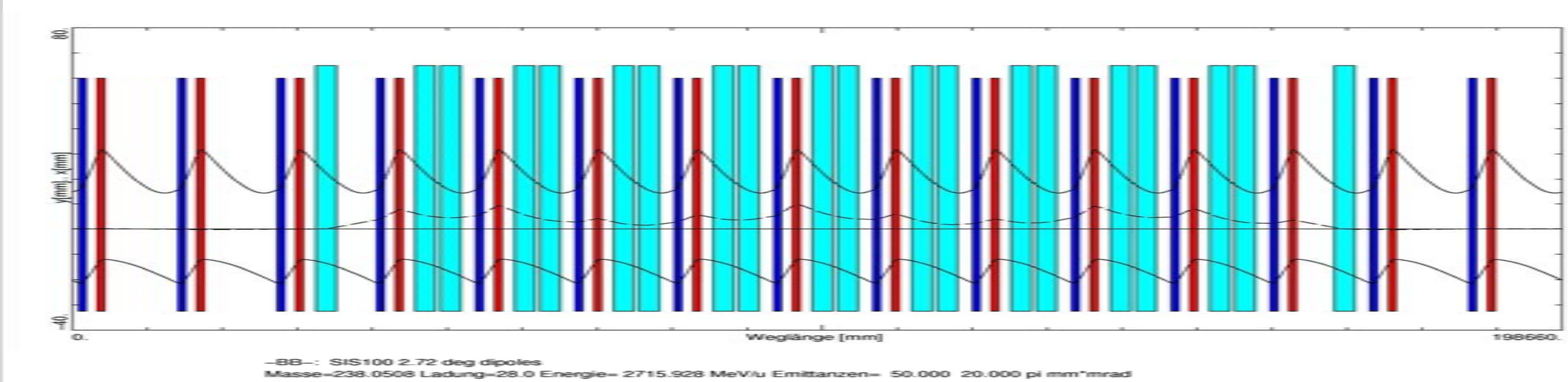
Section 6 - Injection



Arc

SIS100 Lattice Characteristics

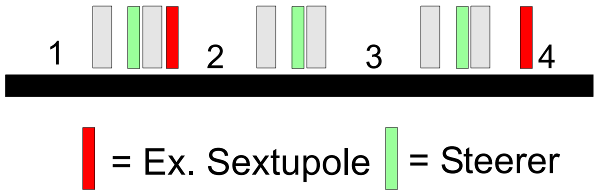
- Maximum transverse acceptance (minimum 3x emittance at injection)
  at limited magnet apertures (problems: pulse power, AC loss etc.)
- Vanishing dispersion in the straight sections for high dp/p during compression
- Low dispersion in the arcs for high dp/p during compression
- Sufficient dispersion in the straight section for slow extraction with Hardt condition
- Shiftable transition energy (three quadrupole power busses) for p operation
- Sufficient space for all components and efficient use of space
- Enabling slow, fast and emergency extraction and transfer within one straight.
- Peaked distribution and highly efficient collimation system for ionization beam loss



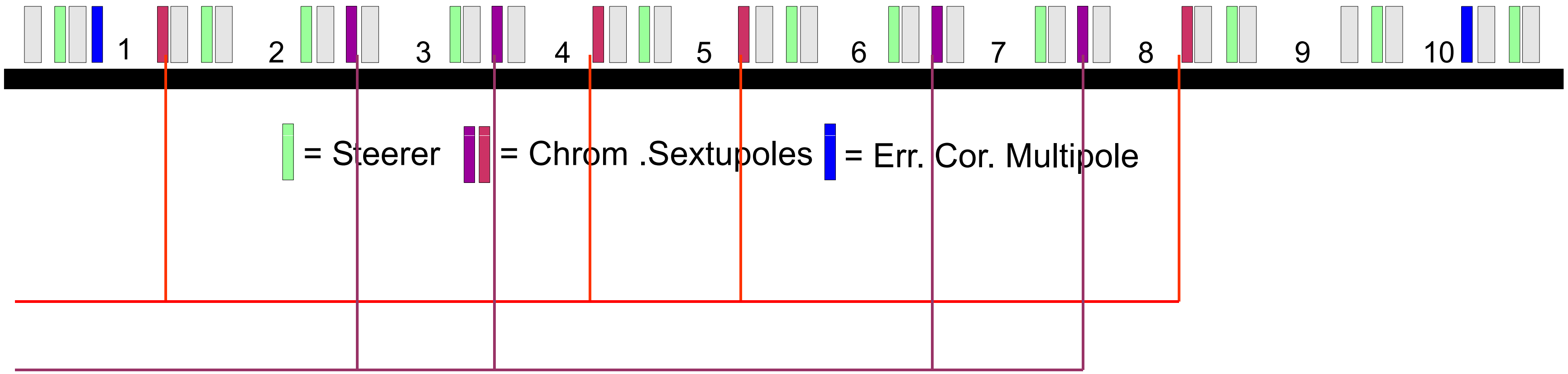
Correction System

Individual supply:
Steerers (green)
Correction Multipoles (blue)
Resonance Sextupoles (bright red)

SIS 100 Straight



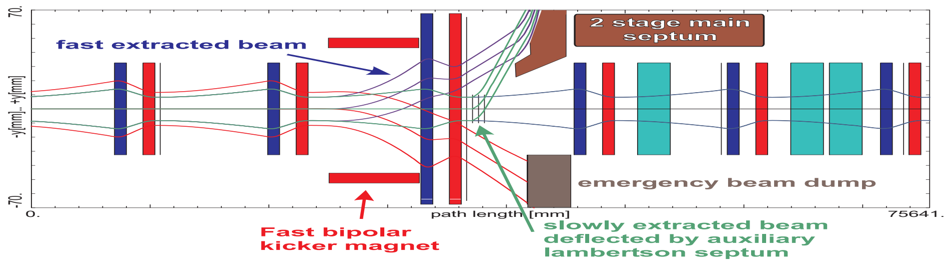
SIS 100 Arc



Chromaticity Sextupoles (red / pink):
2 x 4 sextupoles per arc in series connection
2 arcs in series connection

Extraction Systems

SIS100
- Fast extraction towards experiments
- Slow extraction towards experiments
- Fast extraction toward emergency dump
- Fast (vertical) extraction (transfer) towards SIS300

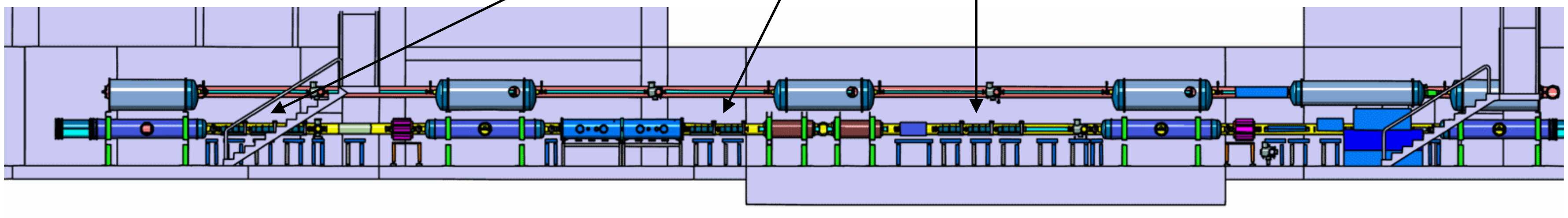


- Cooling test of high power extraction septum in preparation at GSI
- Wire heating of electrostatic septa due to beam load under investigation
- Design study for pulse power generator for bipolar, ramped kicker magnets started
- Prototype for a two stage pseudospark switch under development.

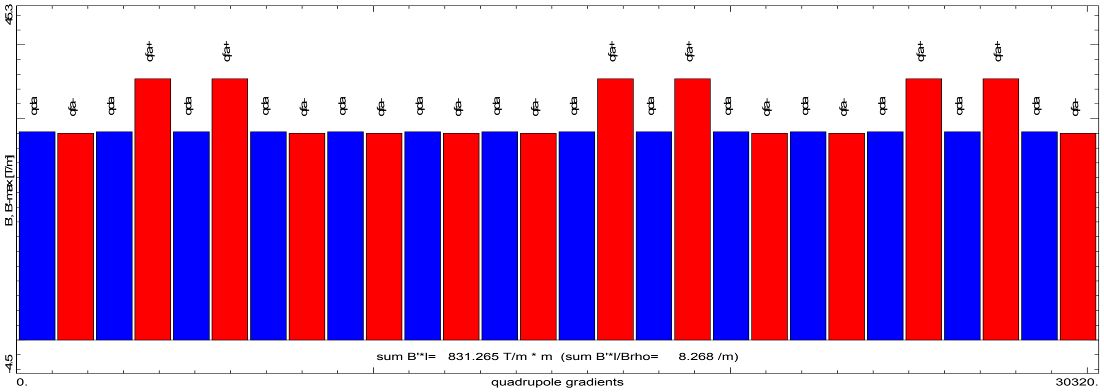
Distributed Bipolar Kicker System

KO Exciter Electrostatic Septa Lambertson Septum

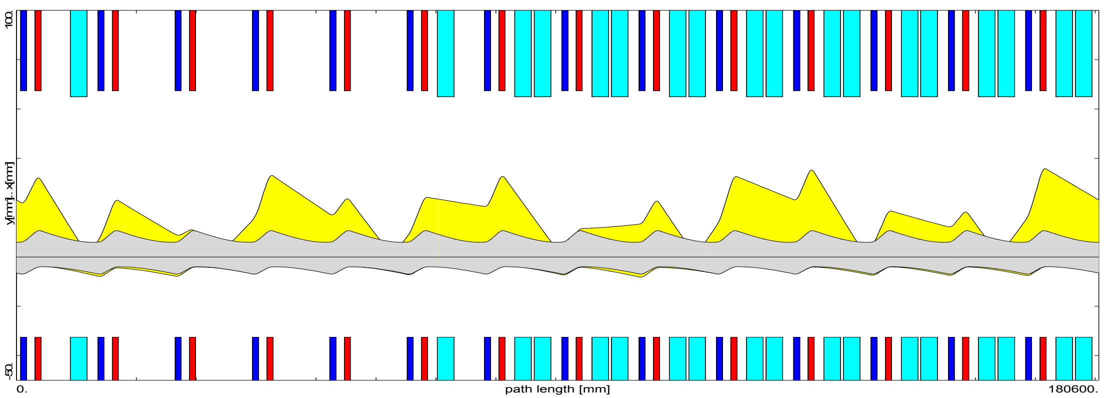
Magnetic Septa and Emergency Dump



Transverse Setting for Proton Operation



Quadrupole setting with three circuits
(two F and one D quadrupole)



Envelops with standard setting (grey)
and shifted transition energy (yellow)

Beam:

γ_{min} = 3,36 (2.2 GeV)

γ_{max} = 32 (29 GeV)

Lattice:

Symmetric: γ_T=17

Proton: γ_T = 44

No crossing of transition energy γ_T and danger of beam loss

Longitudinal Rf Manipulations for p-Operation

Synchrotron frequency for Rf manipulations at high gamma to low > Rf manipulations take to long

Standard scheme for single bunch generation and compression not applicable

	Bunch pattern	Harmonic numbers	Duration (approx.)
Injection from SIS-18	**4 bunches / 6 empty**	**10**	**1.1 s**
Merging	**2 bunches / 3 empty**	**10→5**	**0.1 s**
Batch compression	**2 bunches / 8 empty**	**5→6→7→8→9→10**	**0.3 s**
Merging	**1 bunch / 4 empty**	**10→5**	**0.1 s**
Acceleration	**1 bunch / 4 empty**	**5**	**0.4 s**

proposed scheme by OBF

Dynamic Vacuum – STRAHLSIM Code

Linear beam optics

Loss pattern due to charge change

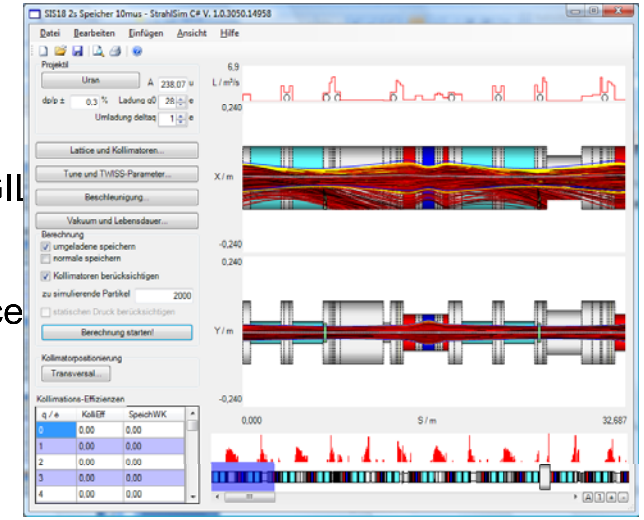
Collimation efficiency

Reads and writes many formats (AML, MIRKO, MAD-X, WinAGIL

Static Vacuum

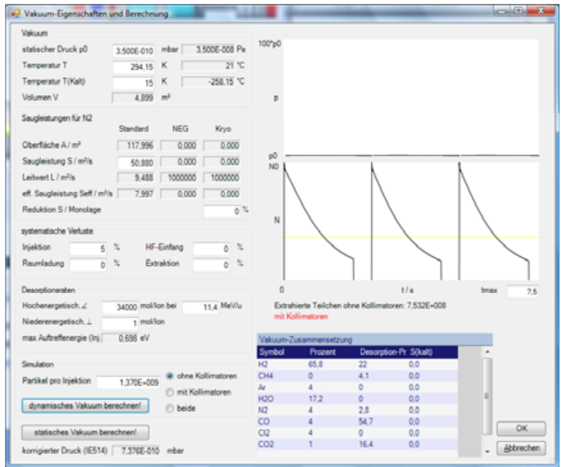
p_0, S_{eff}, Vacuum-conductances, NEG coating, cryogenic surface

Static residual gas components



Dynamic (Source of beam losses)

- Synchrotron cycle
- $S_{eff,cold}(p, T)$: analytic model, incl. saturation
- $S_{eff,NEG}(p, t)$: Saturation
- Systematic losses (injection, RF capture)
- Projectile ionisation $s_{pi}(E, Dq)$ from Shevelko, Olson, work in conjunction with AP
- Coulomb scattering
- Target ionisation
- Intra beam scattering



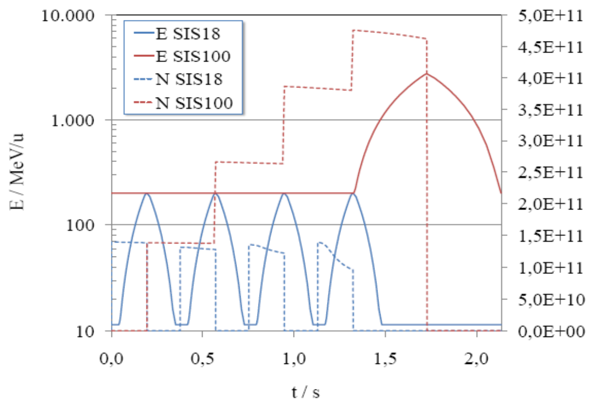
Ion stimulated desorption

(Desorption rate η scaled with $(dE/dx)^2$, beam scrubbing included) couples beam losses to pressure rises

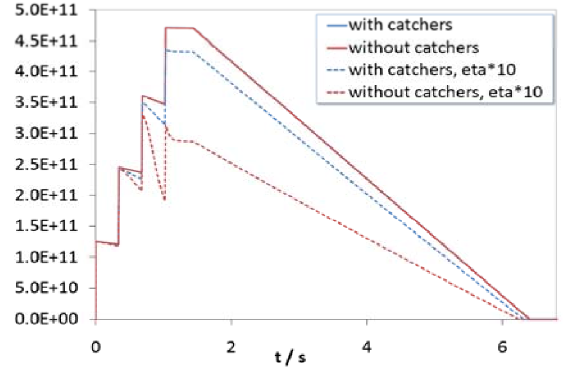
Benchmarked with many machine experiments (and at other accelerators)

Ionization Beam Loss and Dynamics of Pressure

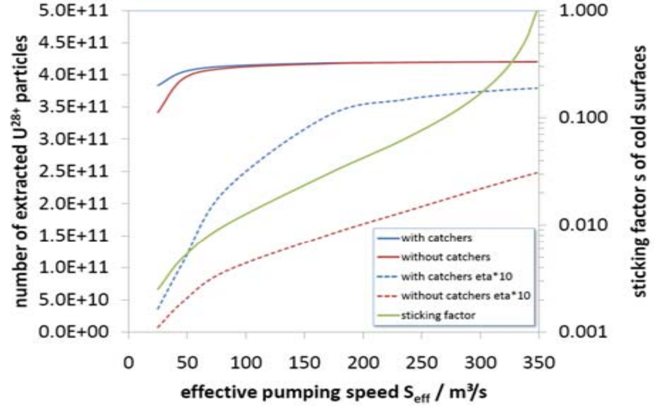
Short Term Studies (Cycles)



Ionization loss during stacking and acceleration in SIS18 and SIS100

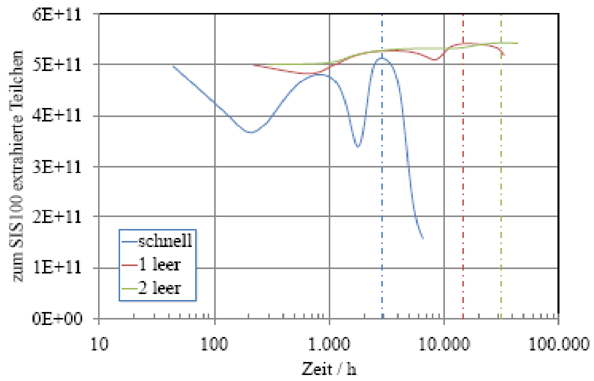


Safety studies for beam survival in SIS100

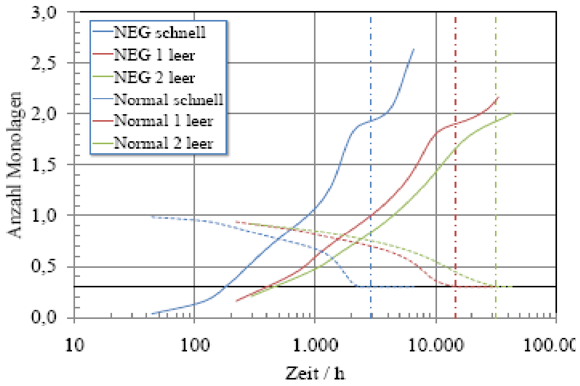


Extracted ions versus pumping speed of cryogenic surfaces

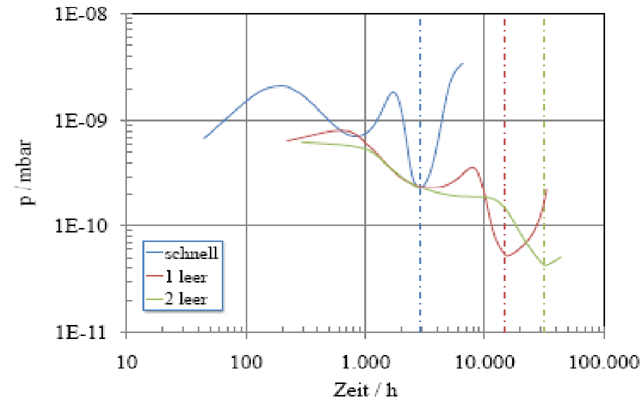
Long Term Studies



Extracted ions over months



Number of monolayers over months



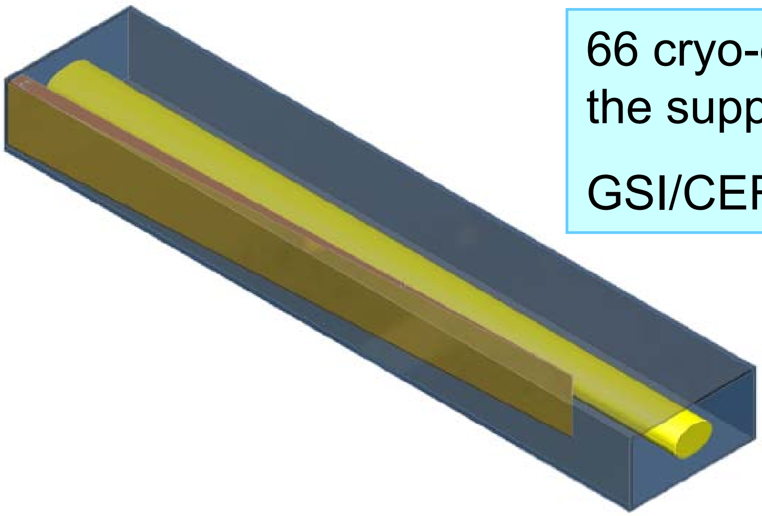
Pressure over months

STRAHLSIM Development

Recently added Features:

- Decrease of Pumping Speed of NEG Surfaces
- Decrease of Desorption Yield (Scrubbing)
- Decrease of Pumping Speed of Cryogenics Surfaces

EU FP7- ColMat Cryo-Collimator Task

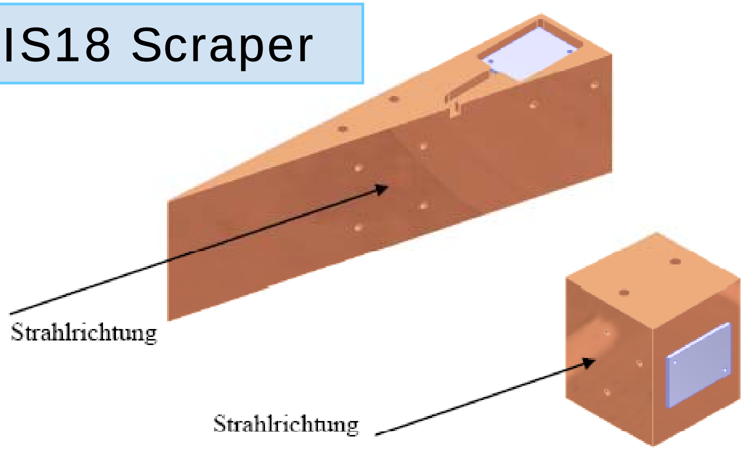


66 cryo-collimators foreseen in the SIS100 arcs for the suppression and control of desorption gases

GSI/CERN Collaboration - GSI: Work package leader

- Different geometries
- Different temperatur levels
- Test with beam at GSI facility
- Effective desorption yield
- Pumping properties for the different residual gas components

SIS18 Scraper



Two Stage Synchrotron SIS100/300

- **1. High Intensity- and Compressor Stage**

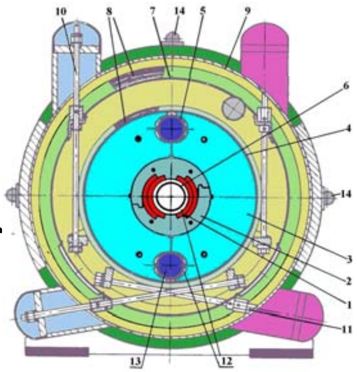
SIS100 with fast-ramped superconducting magnets and a strong bunch compression system.

Intermediate charge state ions e.g. U^{28+}-ions up to 2.7 GeV/u
Protons up to 30 GeV

$B\rho$= 100 Tm - B_{max}= 1.9 T - dB/dt= 4 T/s (curved)

- **2. High Energy- and Stretcher Stage**

SIS300 with superconducting high-field magnets and stretcher function.

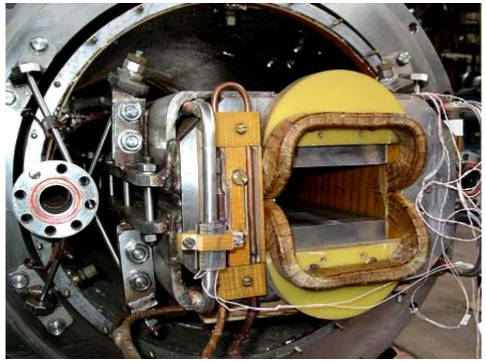


Highly charges ions e.g. U^{92+}-ions up to 34 GeV/u
Intermediate charge state ions U^{28+}- ions at 1.5 to 2.7 GeV/u with 100% du

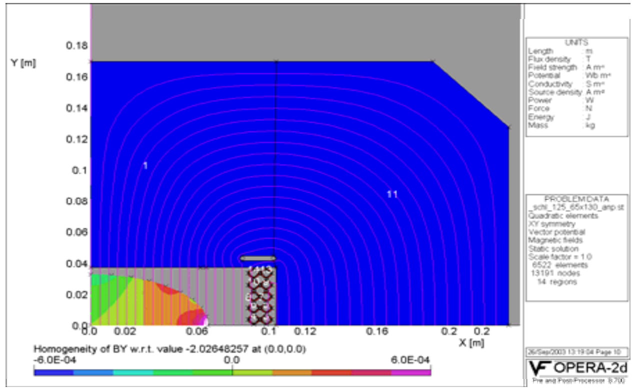
$B\rho$= 300 Tm - B_{max}= 4.5 T - dB/dt= 1 T/s (curved)

SIS100 Fast Ramped S.C. Magnets

R&D Goals



- **Reduction of eddy / persistent current effects at 4K (3D field, AC loss)**
- **Improvement of DC/AC-field quality**
- **Guarantee of long term mechanical stability** (≥ $2 \cdot 10^8$ cycles)



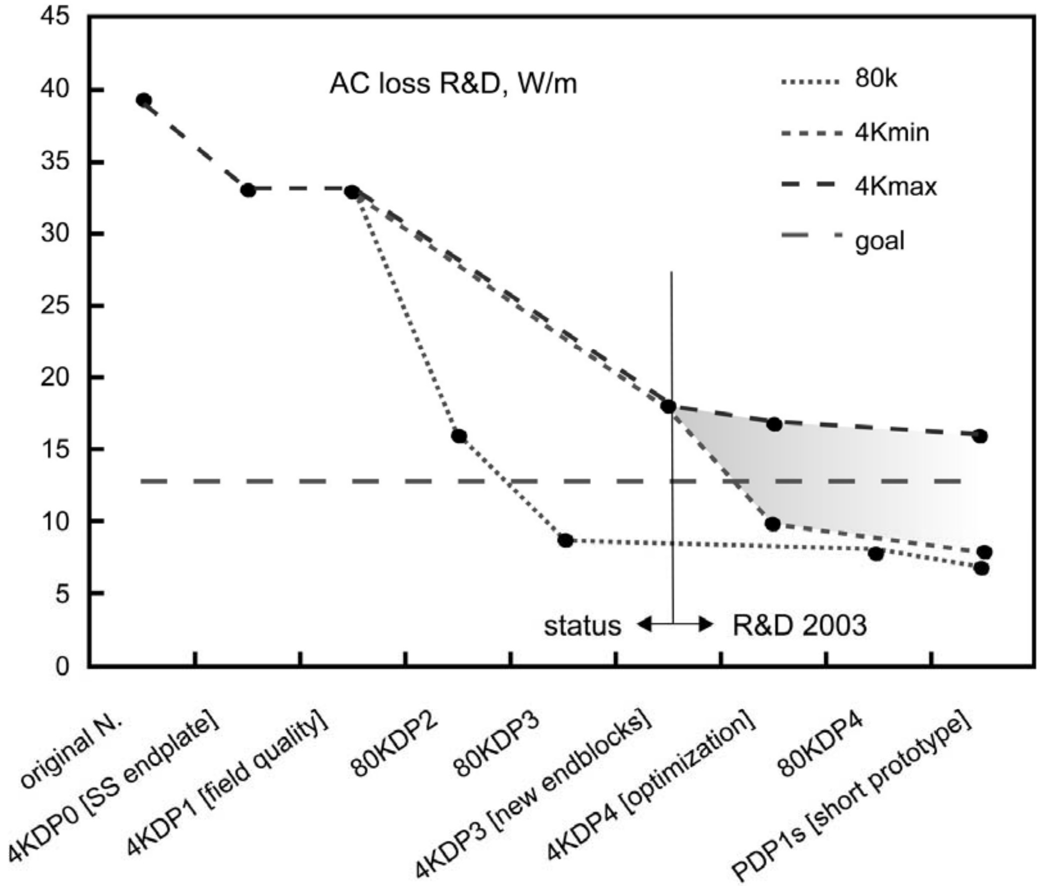
Activities

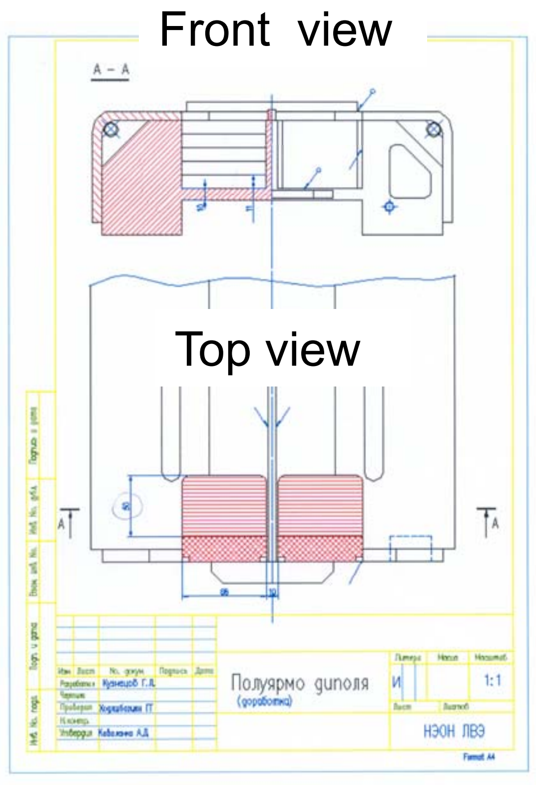
- AC Loss Reduction (exp. tests, FEM)
- 2D/3D Magnetic Field Calculations (OPERA, ANSYS, etc.)
- Mechanical Analysis and Coil Restraint (design, ANSYS) (>Fatigue of the conductor and precise positioning)

Experimental studies with modified Nuklotron magnets in JINR

SIS 100 Fast Ramped S.C. Magnets

R&D goal: AC loss reduction to 13 W/m @ 2T, 4 T/s, 1 Hz

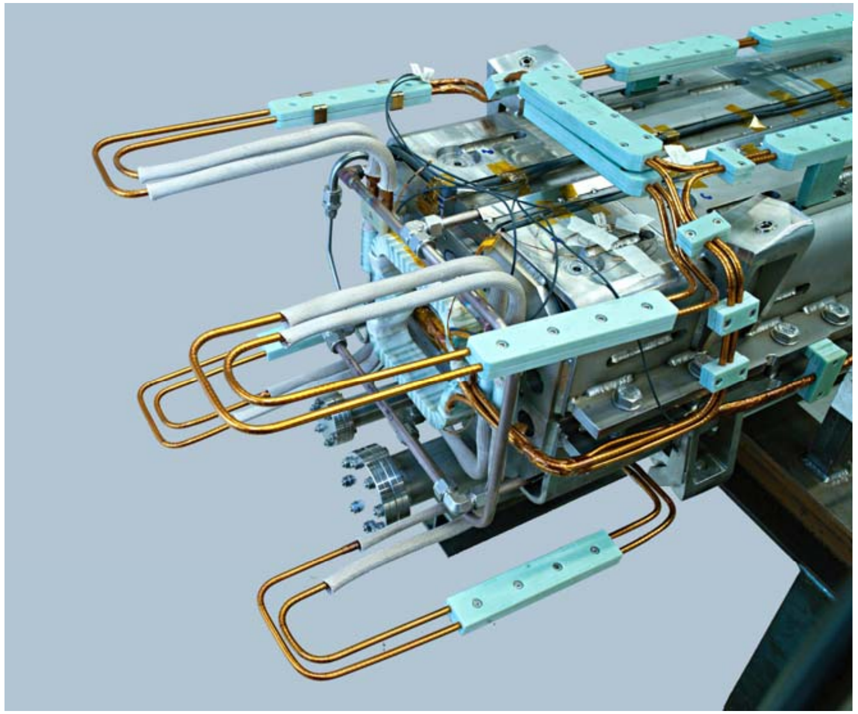


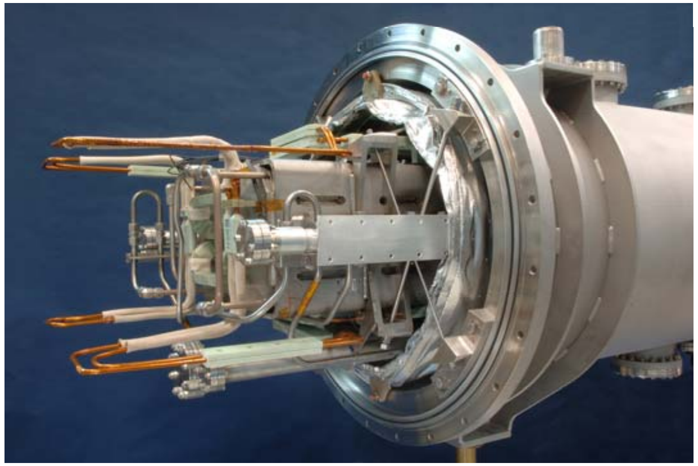


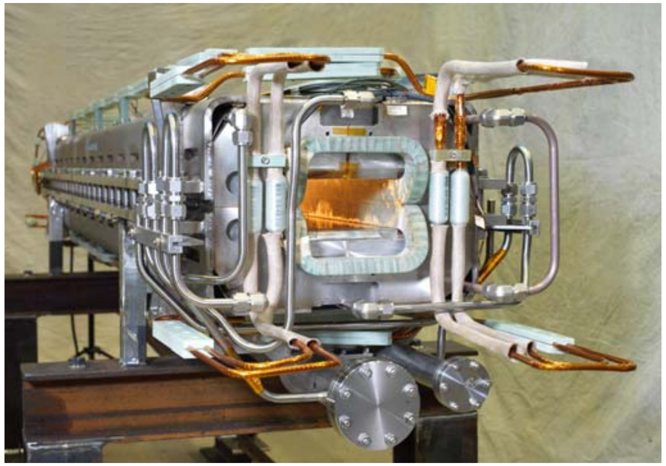
New endblock design

SIS100 Prototype Dipole – BNG

Manufactured by BNG (Würzburg)

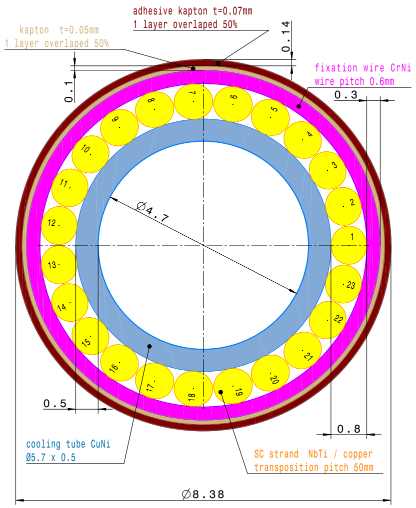


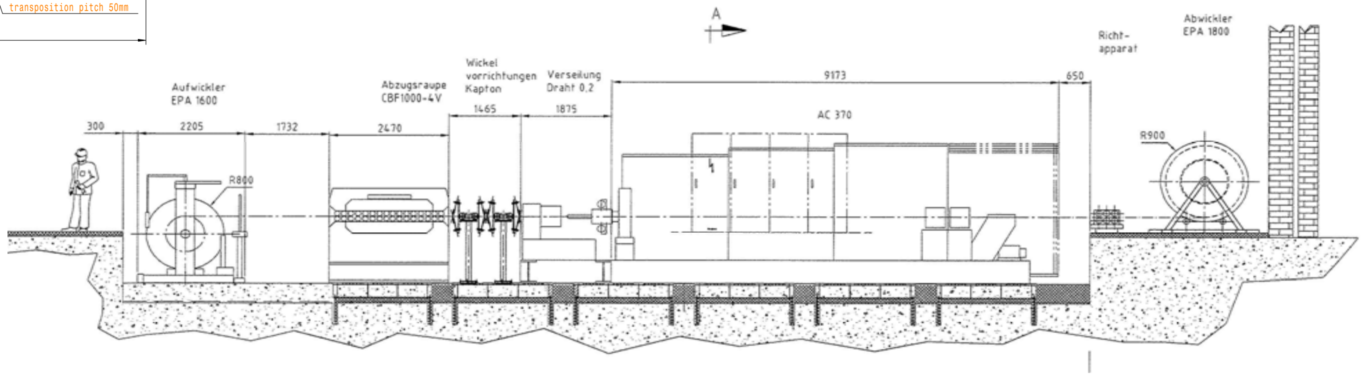




Nuklotron Cable Production at BNG

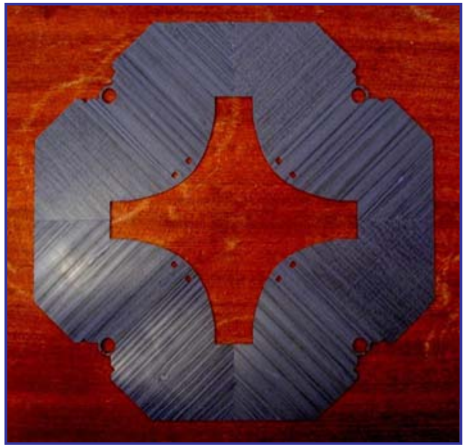
Second Nuklotron type cable production capability set-up at BNG in Würzburg





Prototype Dipole and Quadrupole - JINR

Assembly of the quadrupole prototype



Curved SIS100 Prototype Dipole - BINP

Figure 17 SIS100 curved magnet assembled without vacuum chamber.

Figure 16 Top view of SIS100 curved magnet coil inserted into lower part of iron yoke.

Figure 29 Vacuum chamber of SIS100 curved magnet.

Curved two layer coil with Nuclotron cable

Curved thin wall (0.3 mm) chamber

Operation Cycles and Magnet Cooling Limits

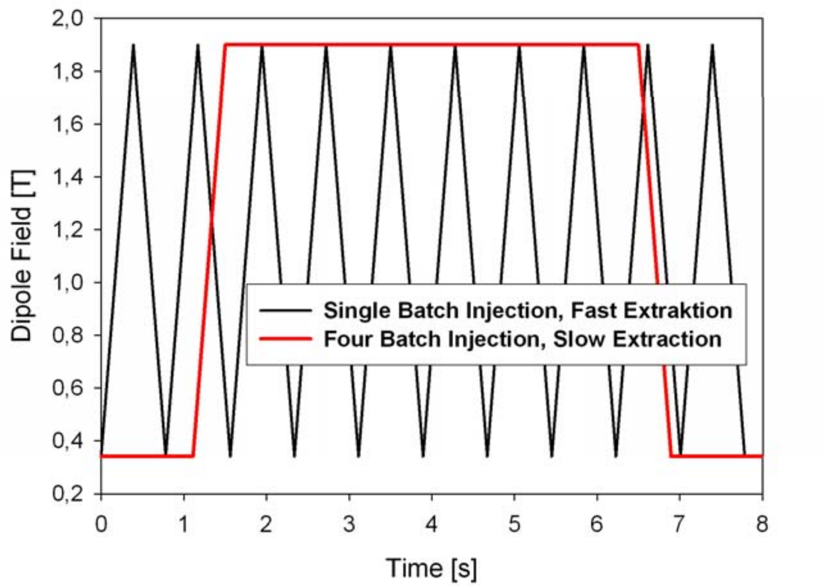
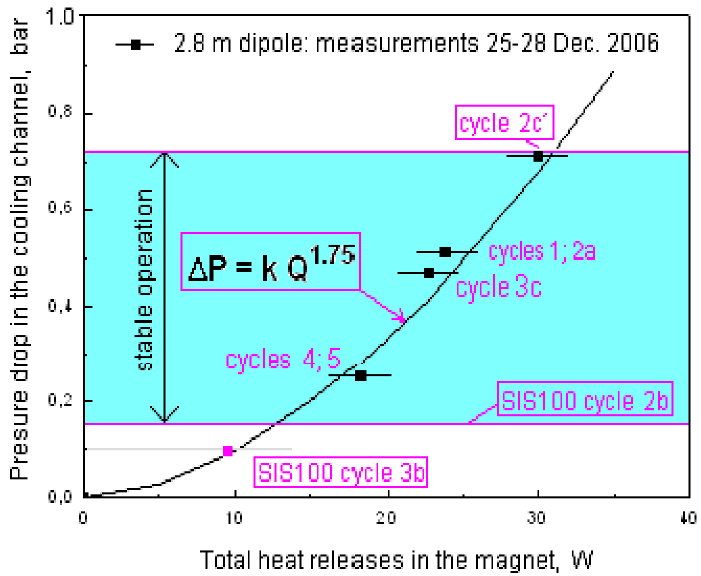
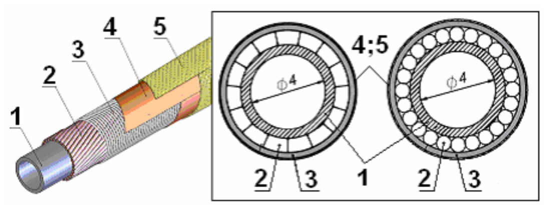


TABLE II OPERATION CYCLES AND EXPECTED LOSSES

cycle	B_{max} (T)	t_r (s)	cycle period (s)	Q_d (J/cycle)	P_d(W)	Q_q (J/cycle)	P_q(W)
1	1.2	0.1	1.4	35.2	25.2	13.1	9.4
2a	1.2	0.1	1.4	35.2	25.2	13.1	9.4
2b	0.5	0.1	1.0	8.8	8.8	3.3	3.3
2c	2.0	0.1	1.82	89	48.9	24.4	18.9
3a	1.2	1.3	2.6	35.2	13.5	13.1	5.0
3b	0.5	1.0	1.9	8.8	4.6	3.3	1.8
3c	2.0	1.7	3.4	89	26.2	34.4	10.1
4	2.0	0.1	5.0	89	17.8	34.4	6.9
5	2.0	0.1	5.0	89	17.8	34.4	6.9



- Singel layer coil with low hydraulic resistance
- High current cable
- Active heaters to stabilize the crogenic load



Alternative coil design and high current cable

Development contract planned for 2009

SIS300 Dipole Prototype at INFN/ANSALDO

Nominal field (T) :	4.5
Ramp rate (T/s)	1
Radius of magnet geometrical curvature (m)	66 2/3
Magnetic length (m)	3.879
Bending angle (deg)	3 1/3
Coil aperture (mm)	100
Max temperature of supercritical He (K)	4.7

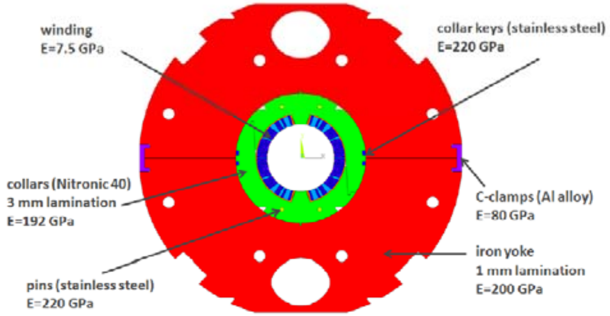


FIG.3: Cross section of the cold mass. The 5 blocks winding is in blue, the collars are in green and the iron yoke lamination in red. The two halves of the iron are clamped together using Al alloy clamps.

FIG.5: The 36 strand Rutherford cable. In between the strands one can see the thin stainless steel core used for depressing the inter-strand coupling currents.

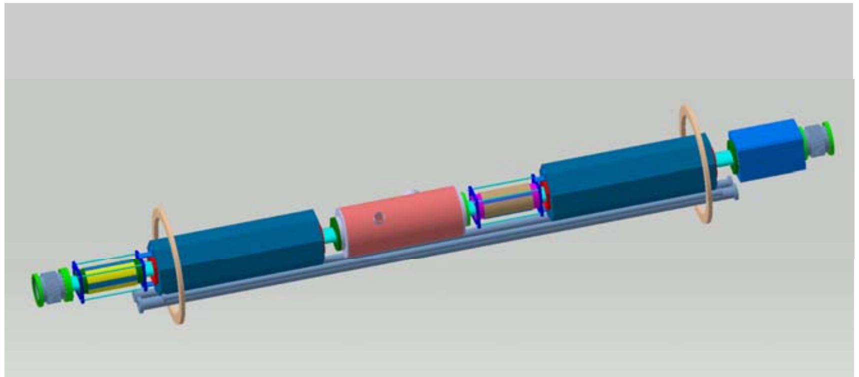
> talk:

P. Fabbricatore

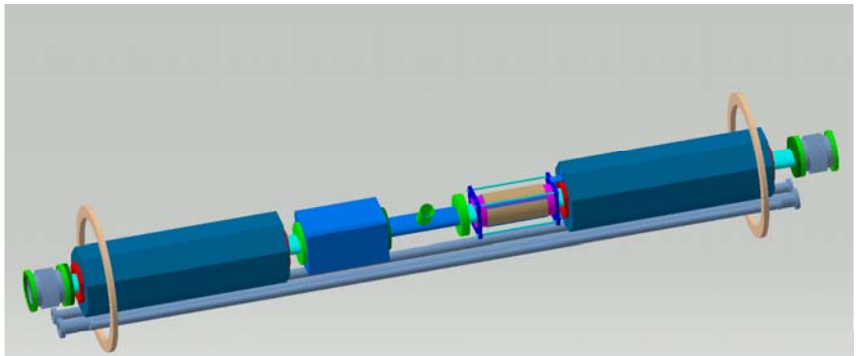
Focusing Modules

Two standard quadrupole units, but many exceptions !

Big engineering effort for pre-planning of cryomagnetic modules.

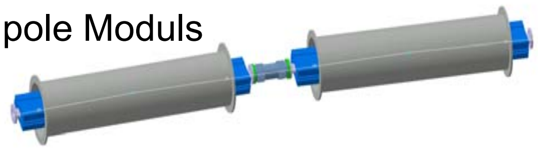


- Quadrupol unit of the arc includes sextupole, BPM and collimator (used also for pumping)



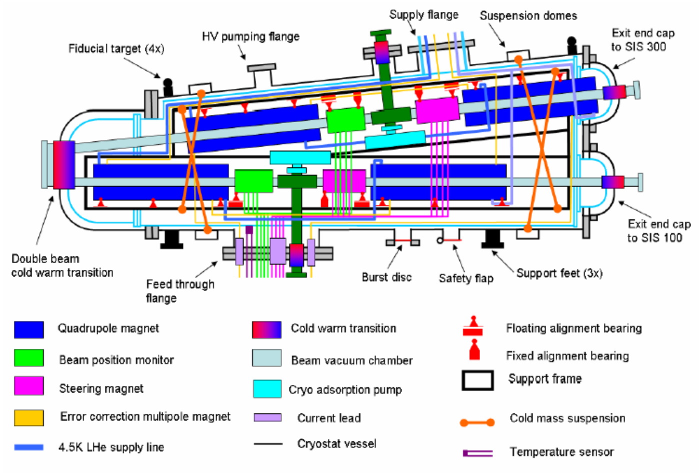
- Quadrupole unit of the straights includes BPM, sextupole and pumping chamber

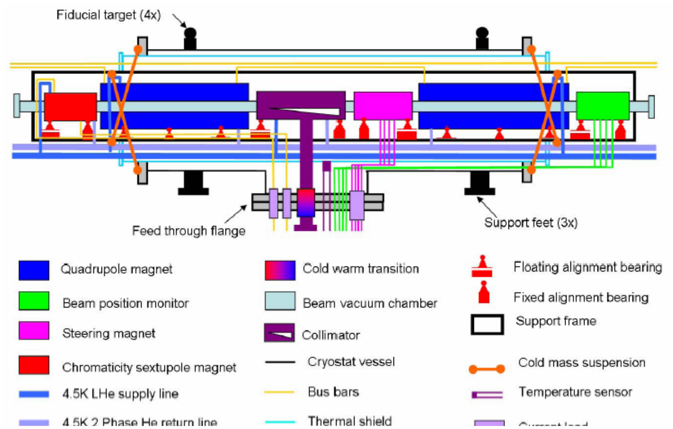
Dipole Moduls

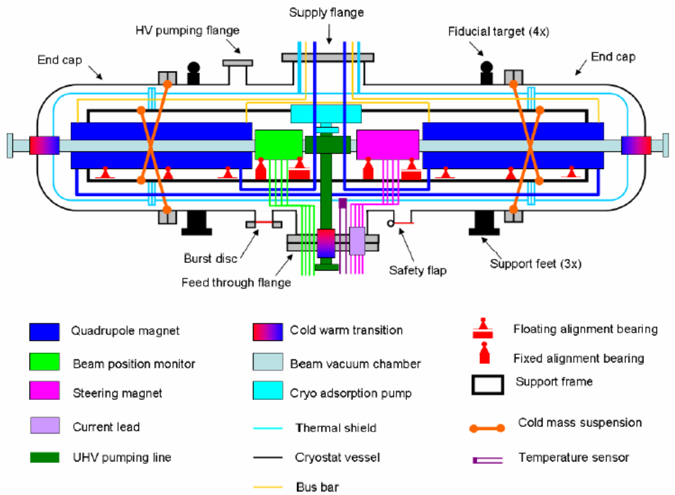


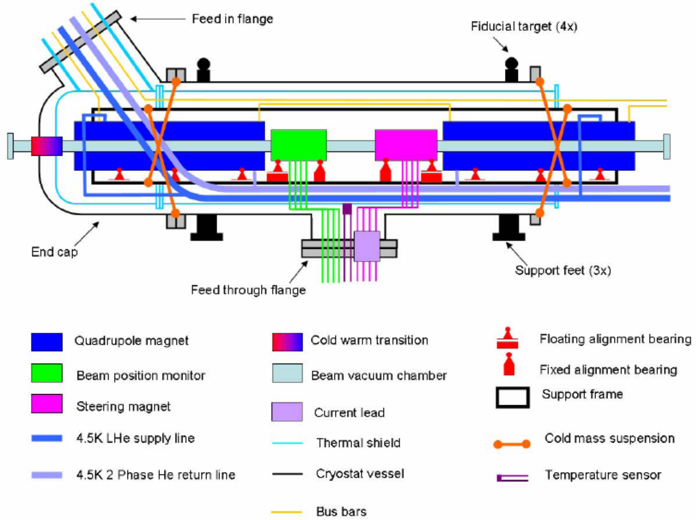
Cryomagnetic Units

Large number of different modules, examples:

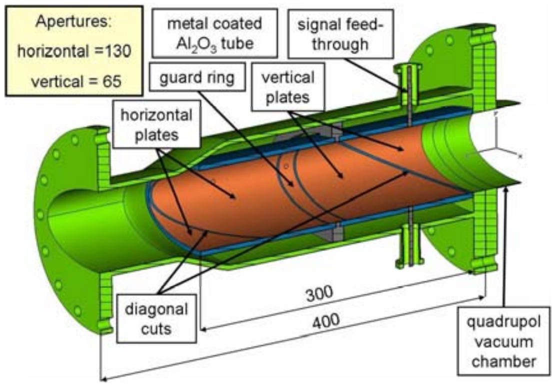




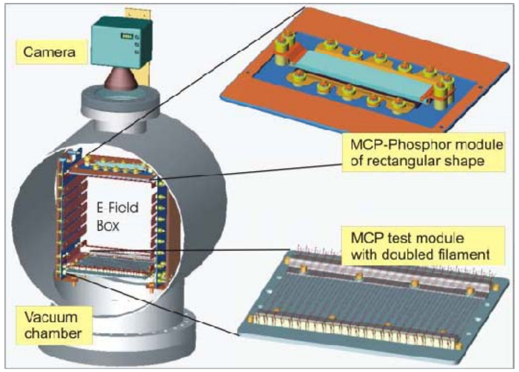




Beam Instrumentation



BPM FEM studies on cross talk and resonances



Ionization Beam Profile Monitor similar to the present SIS18/ESR development

Device Measurement Application

DCCT dc-current stored current, lifetime

GMR-DCCT dc-current for high currents

CCC dc-current for low currents

ACCT Pulsed current injection efficiency

BPM center-of-mass closed orbit & feedback turn-by-turn lattice functions

Exciter+BPM center-of-mass tune, BFT, PLL

Quad. BPM quad. moment BTF, matching

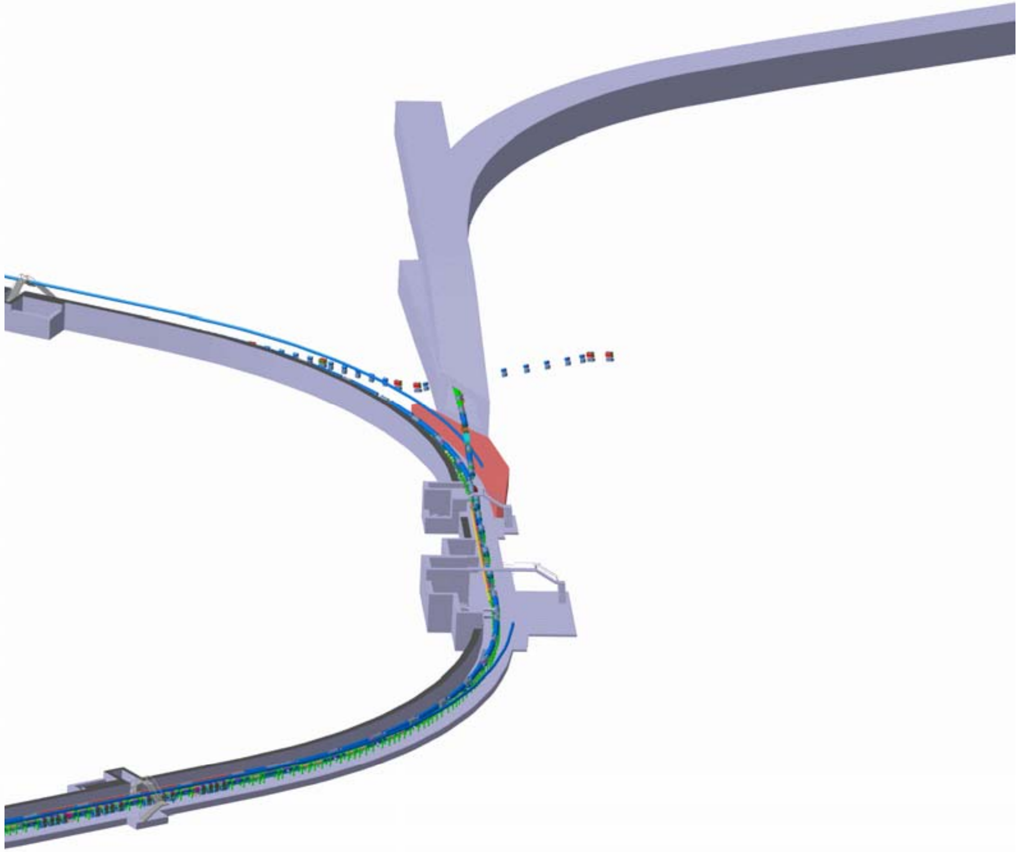
Schottky longitudinal: $\Delta p/p$, cooling transverse: tune, chromaticity

WCM or FCT bunch structure matching, bunch gymnastics

IPM beam profile cooling, matching

BLM beam loss matching, halo, scraper, losses

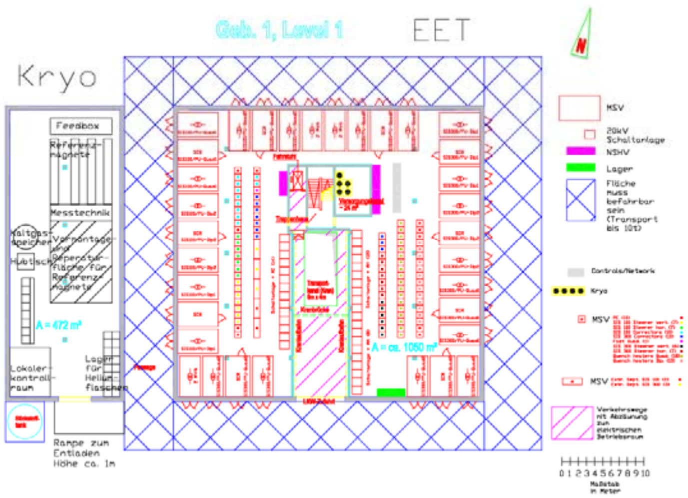
Grid/Screen beam profile first turn

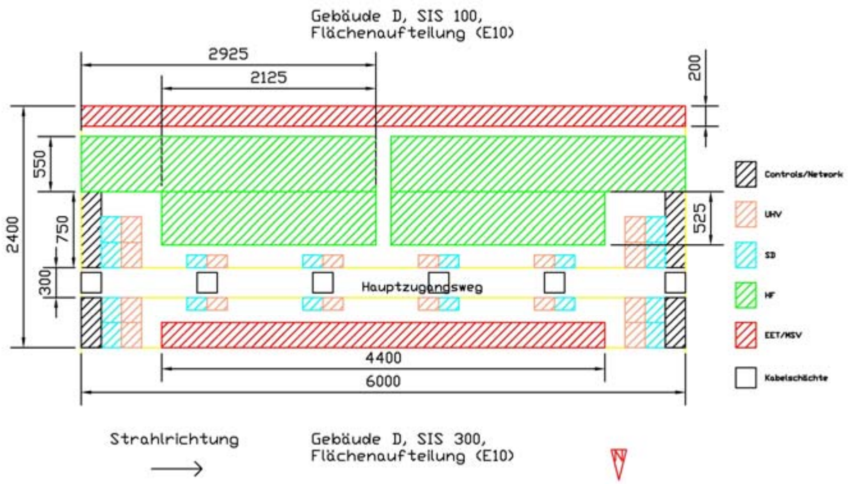


Modified BUNG Buildings and Tunnels

Civil Engineering Process

Three main supply building versus six main supply buildings





Cross section of one of the three main buildings	Cross section of one of the six main buildings

New supply buildings concept:

- Six instead of three main buildings situated on top of the SIS100/300 straight sections
- Six connections per building to the underground tunnel (shorter cables)
- Symmetric arrangement of SIS100 and SIS300 supply units

Events in 2008

Events in 2008 (beside committee meetings)

- November 2007

FAIR kick-off event

March 2008

Draft Technical Design Report (380 pages)

- April 2008

International EOI Meeting

July 2008

FAIR CC kick-off meeting – signing of architect and planner contract

- September 2008

First meeting and formation of international pre-collaboration board aiming for the finalization of the technical design

SIS100/300 – Expression of Interests

SIS100 2.8	Expressions of interest	
Dipoles 2.8.2.1	9 JINR (~50 %) 12 VNIINM (wires) / 13 GSI	
Quadrupoles 2.8.2.2	9 JINR (~50%)	
Sextupoles 2.8.2.3	9 JINR (~50%)	
other 2.8.2.4/5/6	9 JINR (~50%)	
Power Supplies 2.8.3	13 GSI (Interfaces)	4 Finland
RF Systems 2.8.4	13 GSI, partly	
Injection/Ejection 2.8.5	9 JINR (~50 %)	
Beam Diagnostics 2.8.6	9 JINR (~50 %); with 8 ITEP (partly) / 13 GSI (partly)	
Vacuum 2.8.7	9 JINR (~50 %) /18 ICSI (pumps) 7 CUT / 13 GSI V,G,Boc,NEGch	
Collimators 2.8.11	9 JINR (~50 %)	
Cryogenics 2.8.12	15 Wroclaw Univ Technol.	

SIS300 2.12	Expressions of interest	
Dipoles 2.12.2.1	19 Italy, so far R&D only 12 VNIINM (wires)	
Quadrupoles 2.12.2.2	3 IHEP / 12 VNIINM (wires)	
Sextupoles 2.12.2.3	12 VNIINM (wires)	
other 2.12.2.4/5/6/7	12 VNIINM (wires)	
Power Supplies 2.12.3		4 Finland
RF Systems 2.12.4		
Injection/Ejection 2.12.5		
Beam Diagnostics 2.12.6	8 ITEP (partly)	
Vacuum 2.12.7	21 Soltan (?)	7 Cracow UT
Cryogenics 2.12.12		

full

< 50 %

< 10 %

SIS100 – Expression of Interests

Magnets

- The total EOI amount (Germany + Russia) covers the full cryomagnetic systems without warm sextupols and septa
- The distribution of the offered amount on technical components (e.g. Germany provides dipoles coils) has to be discussed and fixed
- No EOI for the warm magnets

Power Converter

- Dipole power converter (power part) and all ACUs covered by German EOI
- No EOI for all other power converters

Rf Systems

- EOI for MA compression cavities and Rf electronics equipment by German EOI
- No EOI for acceleration cavities and Barrier-Bucket Cavities

Injection/Extraction

-Possible Russian contribution (JINR) may cover electrostatic septa and transverse damper

Beam Diagnostics

- Possible Russian contribution (JINR) covers part of cold BPMs (Rest covered by German EOI ?)
- Amount given in Jacoby-proposal for German EOI covering Data Aquisition is by far to high – how to distribute the "rest"
- IPM covered by Russian EOI (ITEP) ?

SIS100 – Expression of Interests

UHV System

- EOI cover almost 100 % of full system
- EOI Germany could cover all valves
- EOI Russia could cover all vacuum chambers and other components (which ?)
- EOI Rumania turbo pumps ?

Insertions

- EOI Russia covers almost the full amount for cryocollimators
- No EOI for other collimator systems

Local Cryogenics

- The Polish EOI covers the full cryomagnetic system ?

Is there really interest in building all technical subsystems ?

Common Systems belonging to SIS100

- Quench Protection is listed under Common Systems and therefore covered by German EOI

Road Map for SIS100

2008 Conceptual design, design studies and R&D completed

2009 - 2012 Finalization of the engineering design

2011 - 2013 Manufacturing of components

2013 - 2014 Installation and commissioning

SIS300 is not part of the FAIR start version and
at least by about 3 years delayed because of
more demanding technical developments