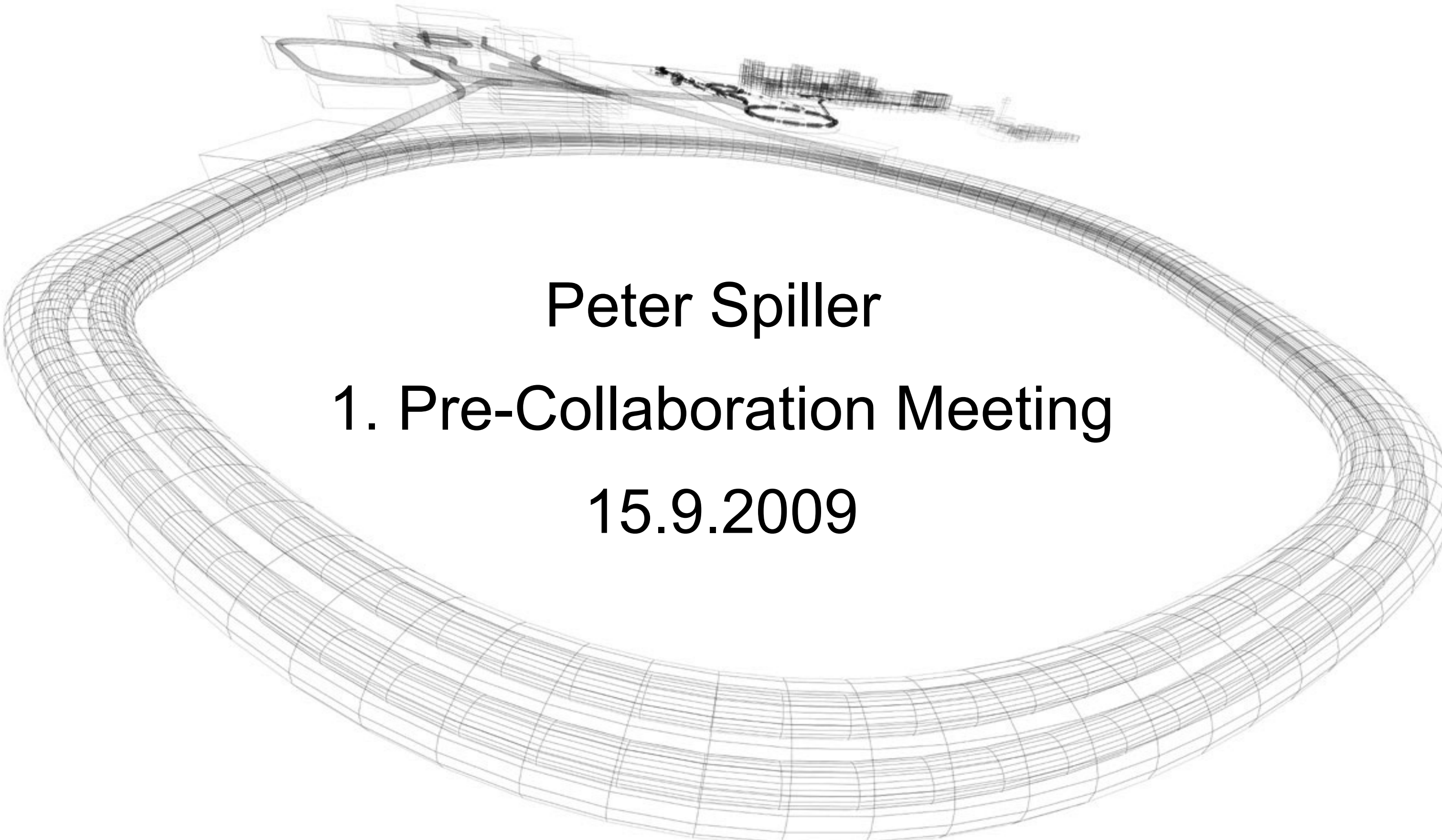
Status SIS100



Peter Spiller

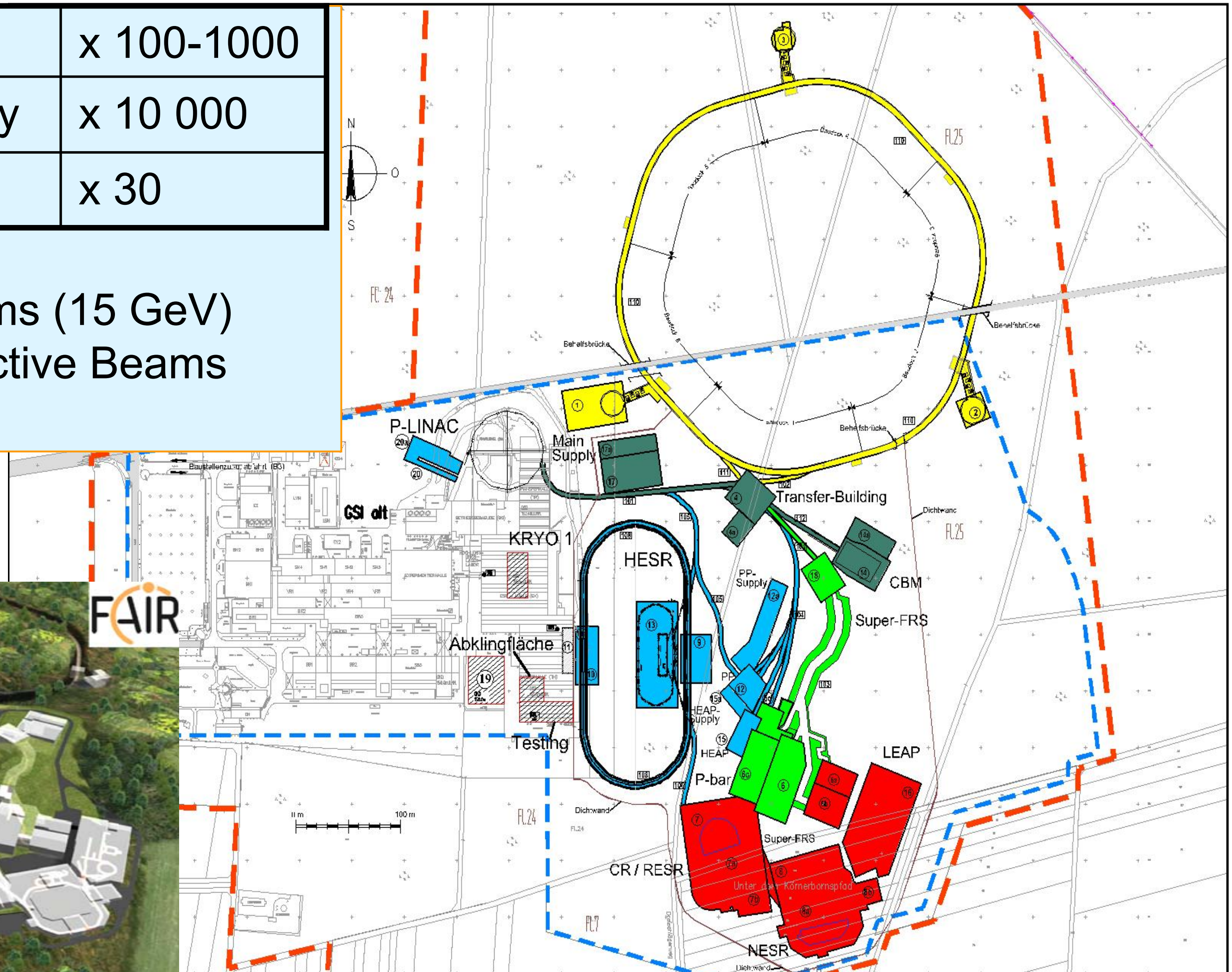
1. Pre-Collaboration Meeting

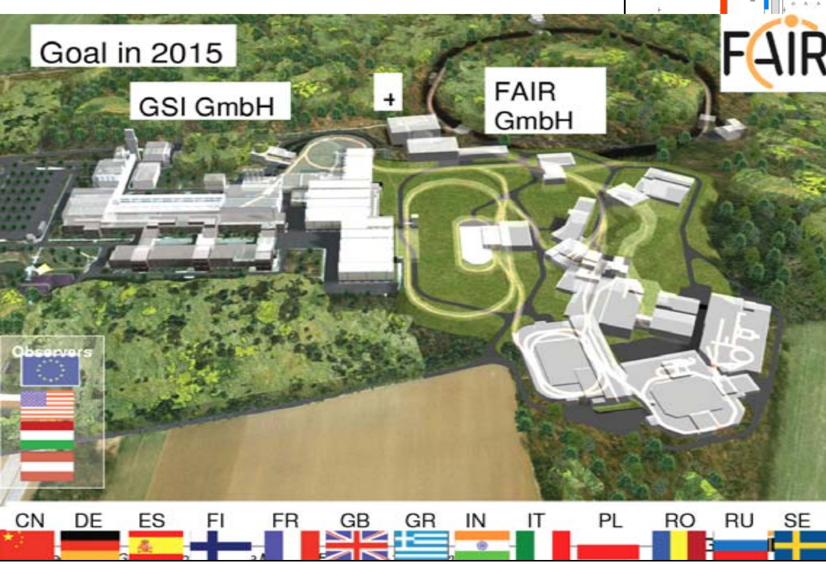
15.9.2009

GSI/FAIR Accelerator Facility

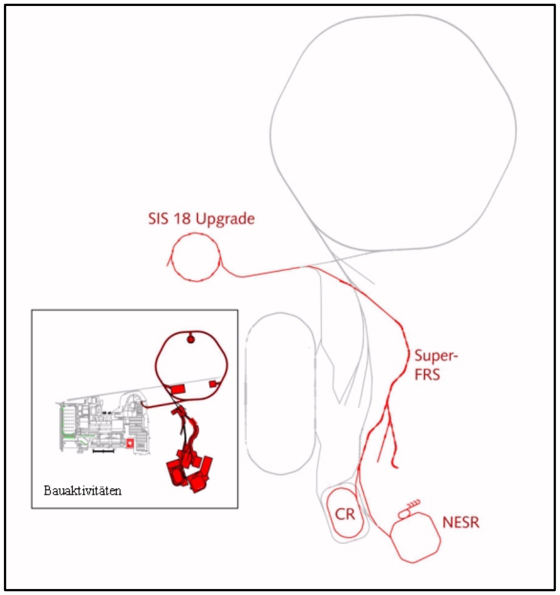
Primary Beam Intensity	x 100-1000
Secondary Beam Intensity	x 10 000
Heavy Ion Beam Energy	x 30

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

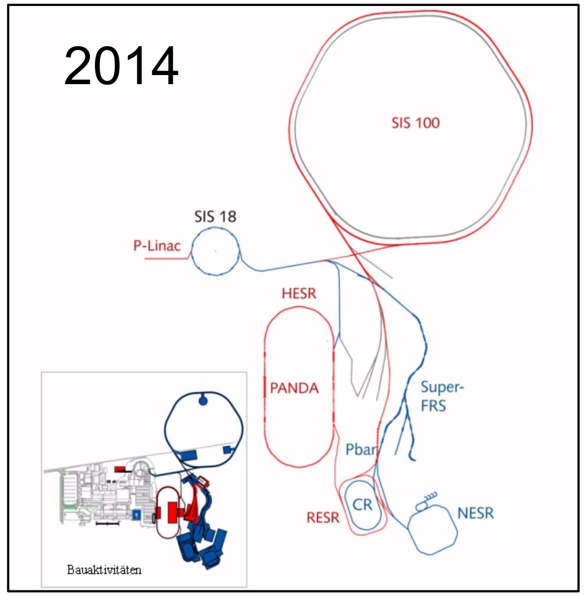




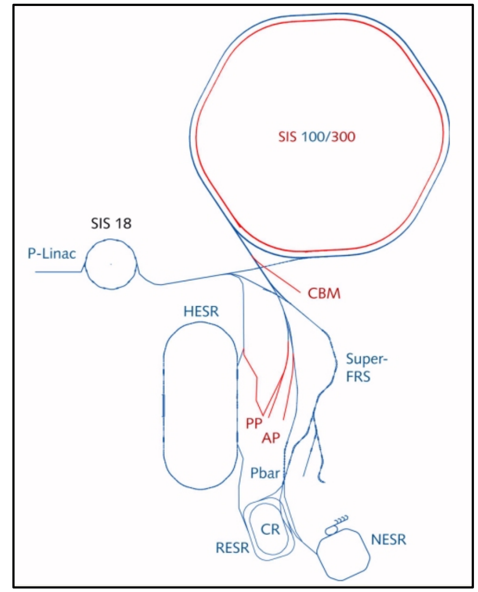
FAIR Uranium Intensity (staged realization)



Stage 1



Stage 2



Stage 3

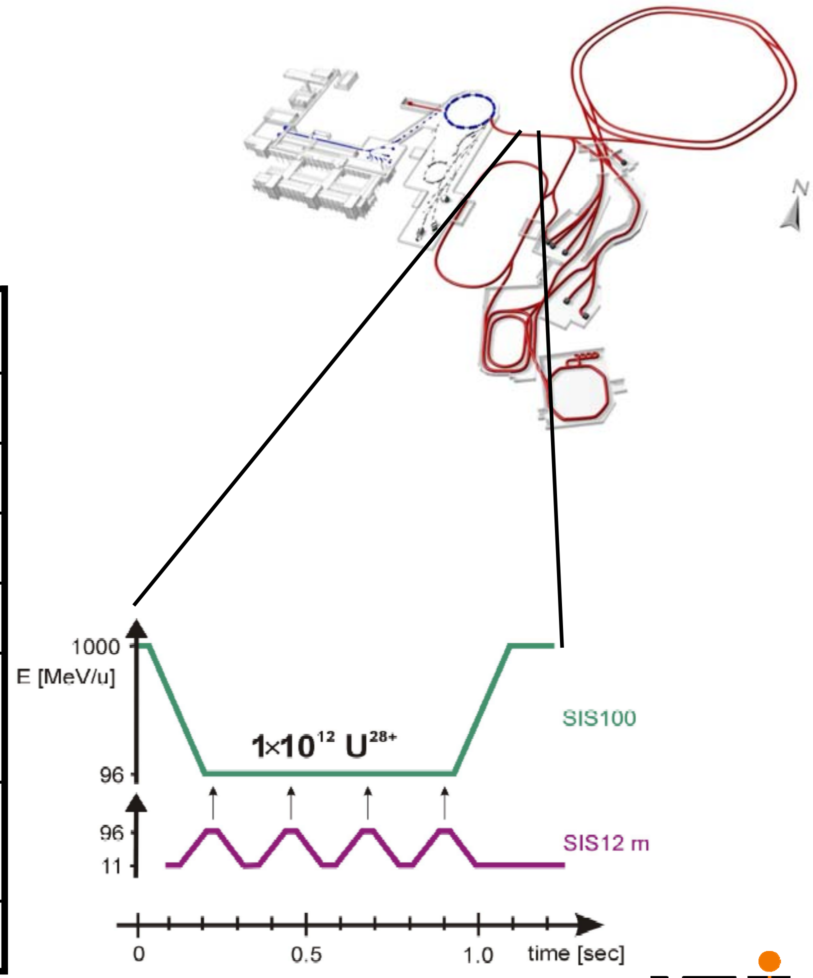
Uranium Beam Intensities		
SIS18	SIS100	SIS100/300
2 x 10^{10} /cycle	5 x 10^{11} /cycle	5 x 10^{11} /cycle
Slow Extraction at 1 GeV/u and 1.4 s Spill		
1.1 x 10^{10} /s	1.5 x 10^{11} /s	3.5 x 10^{11} /s
Fast Extraction at 1 GeV/u		
5.4 x 10^{10} /s	3.5 x 10^{11} /s	not foreseen

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

... and all other ion species

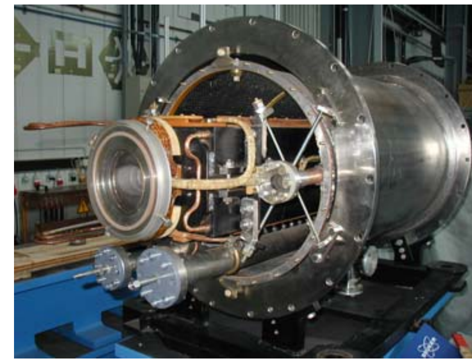
SIS100	Protons	Uranium
Number of injections	4	4
Number of ions per cycle	2.5x 10^{13} ppp	5 x 10^{11}
Maximum Energy	29 GeV	2.7 GeV/u
Ramp rate	4 T/s	4 T/s
Beam pulse length after compression	50 ns	90 - 30 ns
Extraction mode	Fast and slow	Fast and slow
Repetition frequency	0.7 Hz	0.7 Hz



Two Stage Synchrotron SIS100/300

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

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

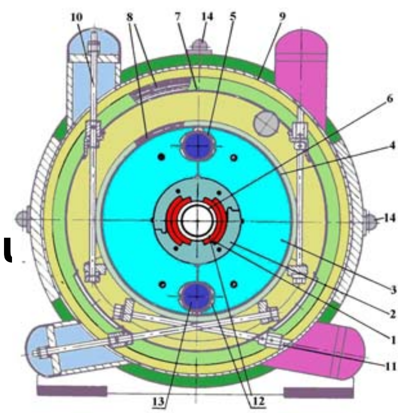


Intermediate charge state ions e.g. U^{28+}-ions up to 2.7 GeV/u
Protons up to 30 GeV

$B\rho$= 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.



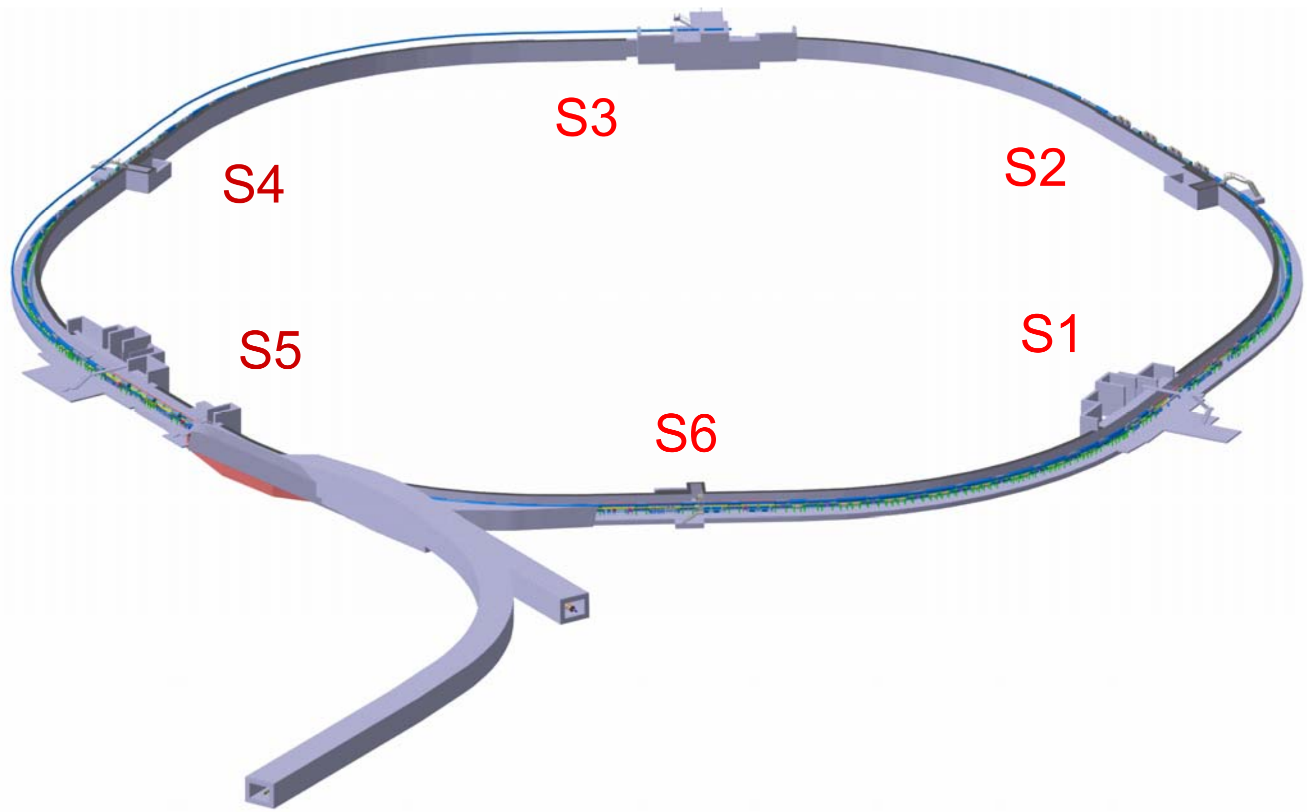
Highly charges ions e.g. U^{92+}-ions up to 34 GeV/u
Intermediate charge state ions U^{28+}- ions at 1.5 to 2.7 GeV/u with 100% du

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

Technical Subsystems

Sixfold Symmetry

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

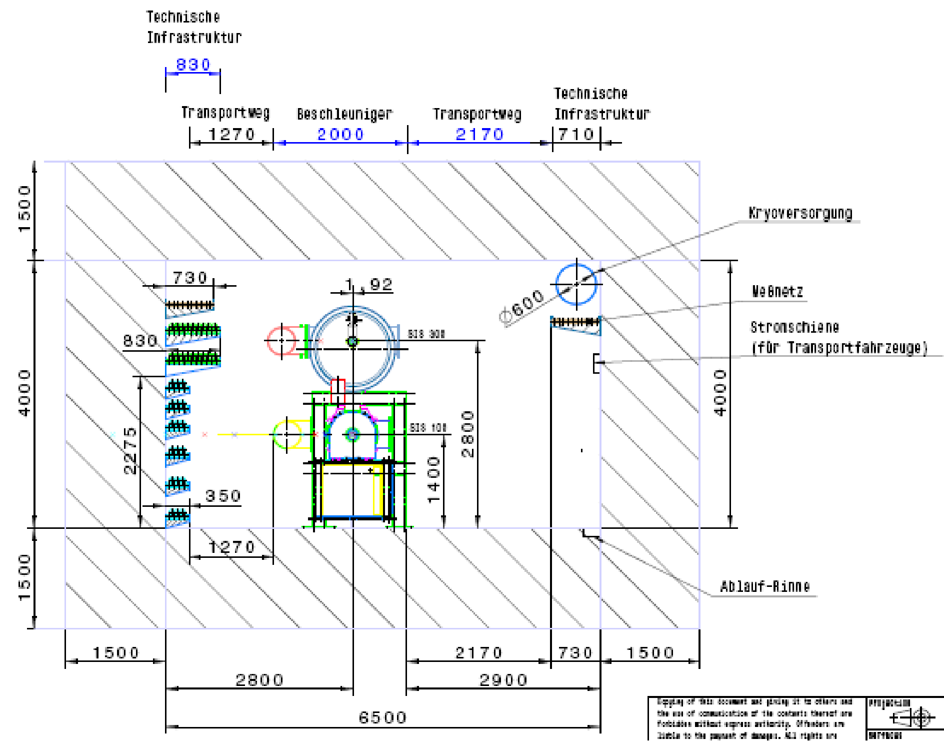


S1: Transfer to SIS300
S2: Rf Compression (MA loaded)
S3: Rf Acceleration (Ferrite loaded)
S4: Rf Acceleration (Ferrite loaded)
S5: Extraction Systems (slow and fast)
S6: Injection System plus RF Acceleration and Barrier Bucket

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:



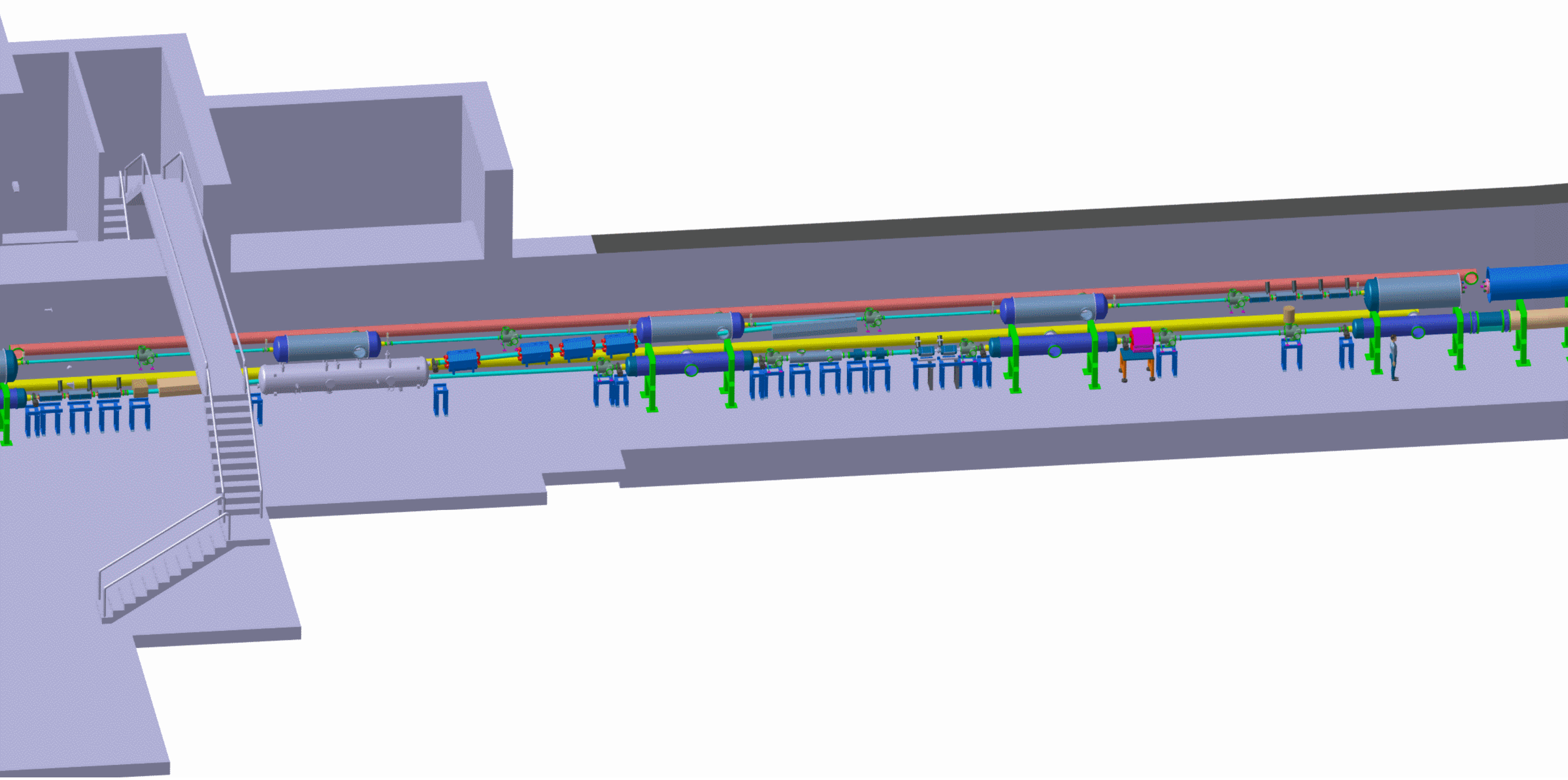
- Geometrical matching of both synchrotrons with different lattice structures (Doublet and FODO) and different magnet technologies (superferric and cosθ)

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

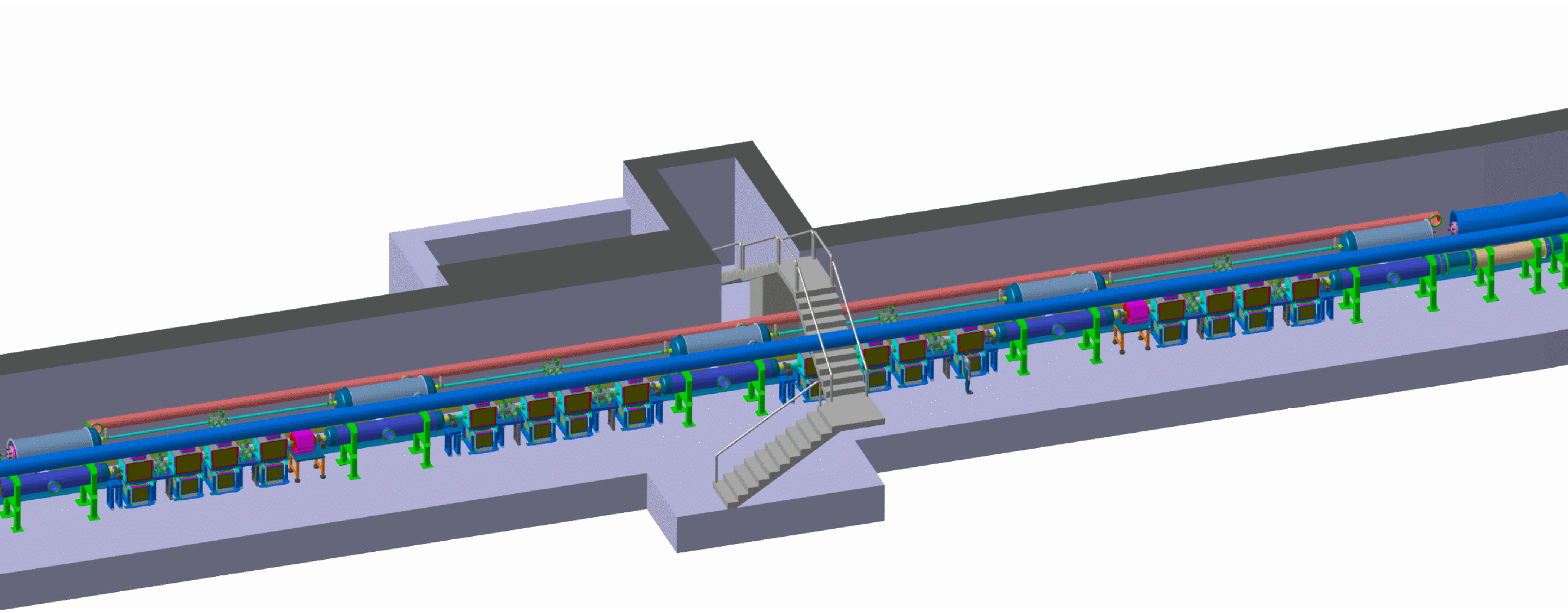
- Fast, slow and emergency extraction in one short straight and precisely at the same position, with the same angle and fixed distance between the SIS100 and SIS300 extraction channel

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

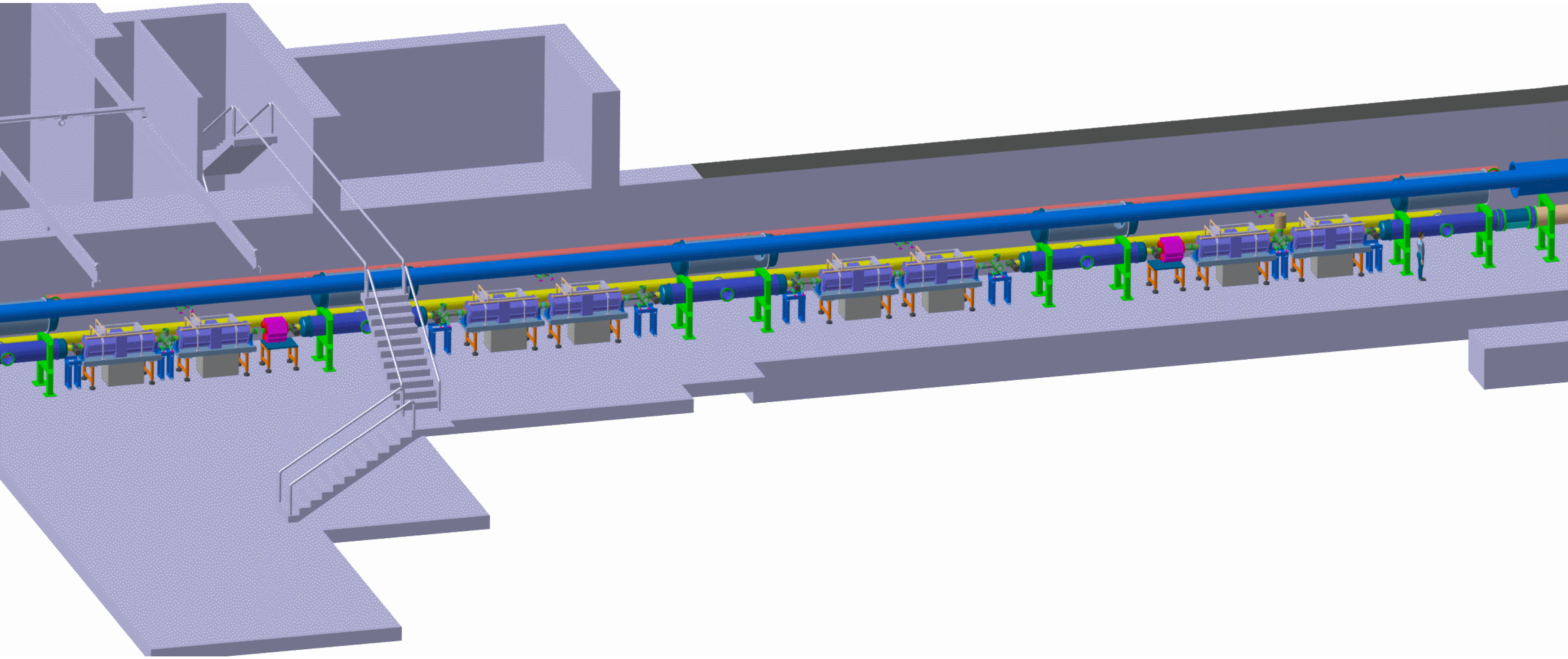
S1 - Transfer Section



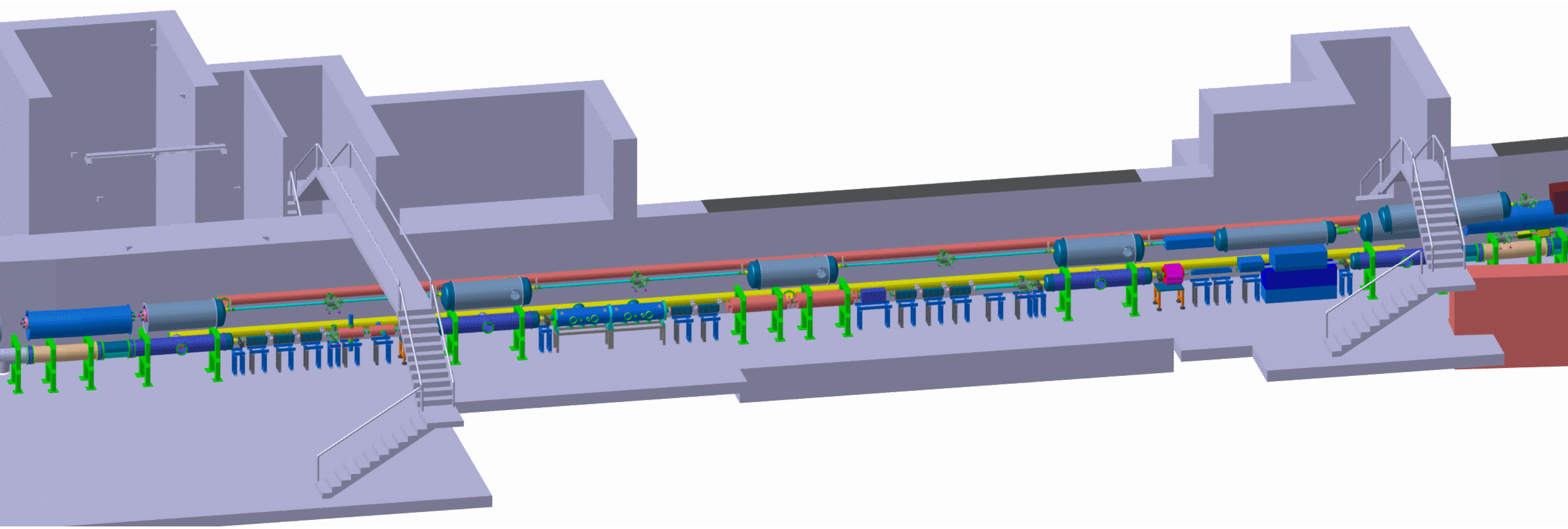
S2 - Compression Section



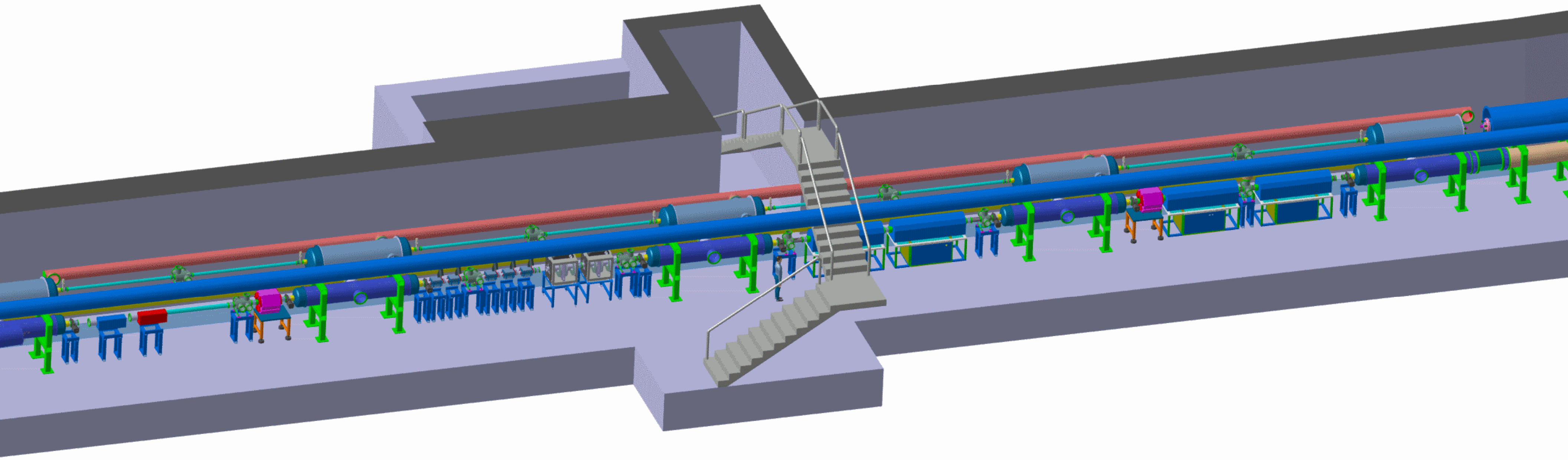
S3 - Acceleration Section



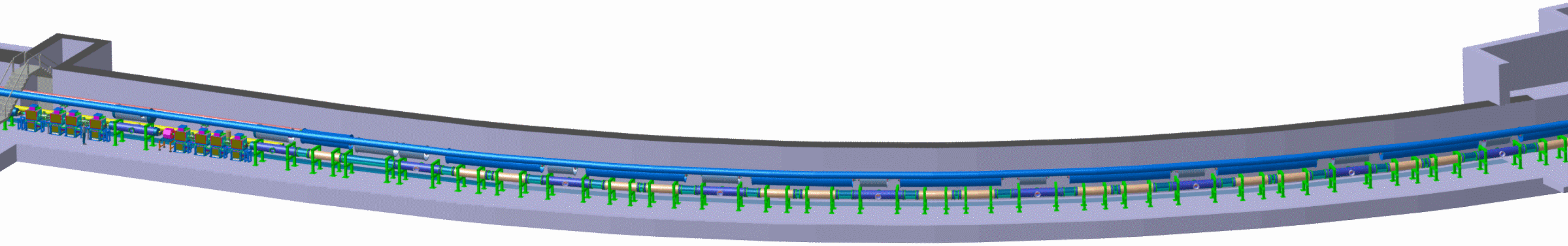
S5 - Extraction Section



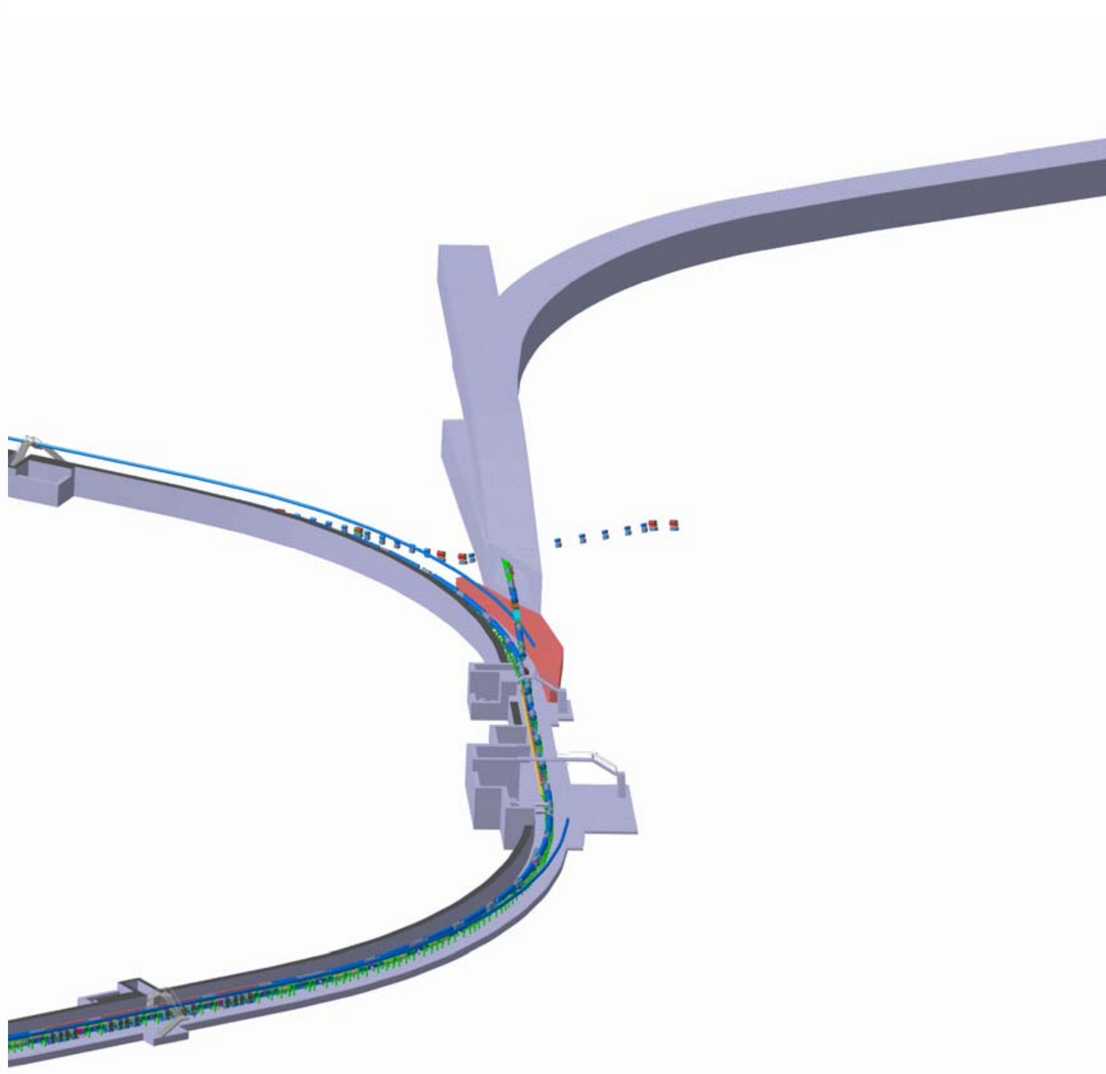
S6 - Injection Section



Cold Arc



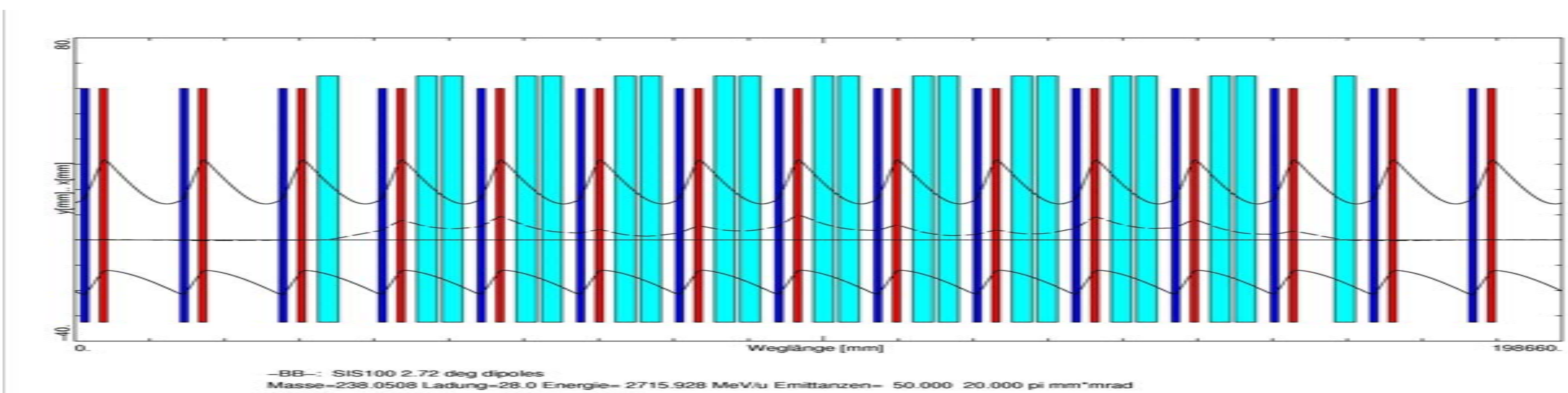
Modified BUNG Buildings and Tunnels



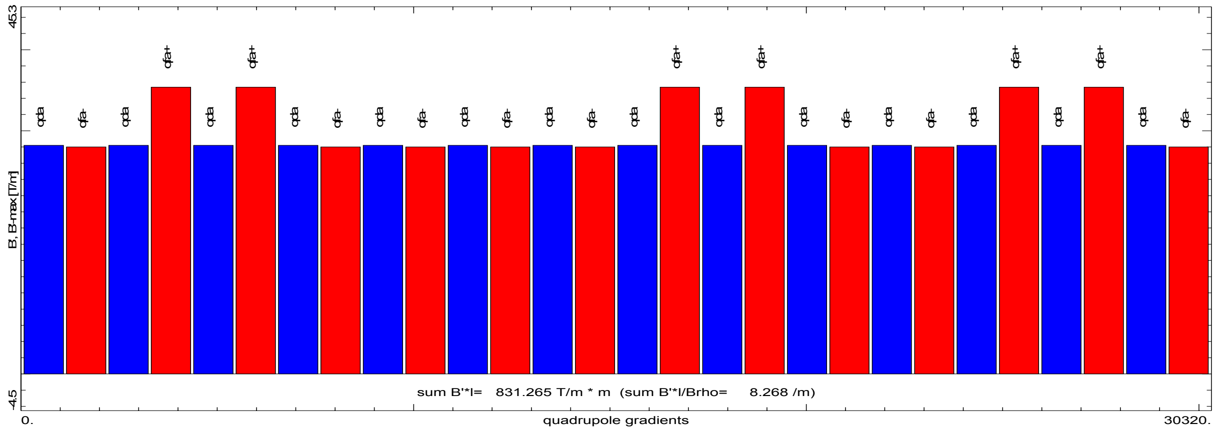
SIS100 Lattice Characteristics

- Maximum transverse acceptance (minimum 3x emittance at injection)

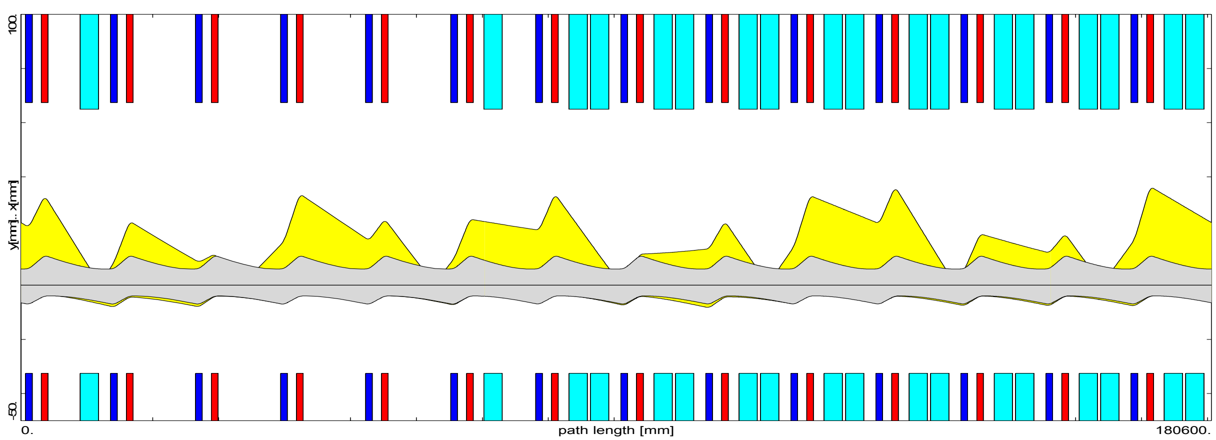
  at limited magnet apertures (problems: pulse power, AC loss etc.)
- Vanishing dispersion in the straight sections for high dp/p during compression
- Low dispersion in the arcs for high dp/p during compression
- Sufficient dispersion in the straight section for slow extraction with Hardt condition
- Shiftable 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



Optical 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

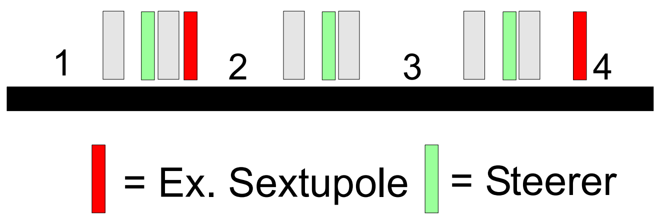
Proton: γ_T = 44

No crossing of transition energy γ_T and danger of beam loss

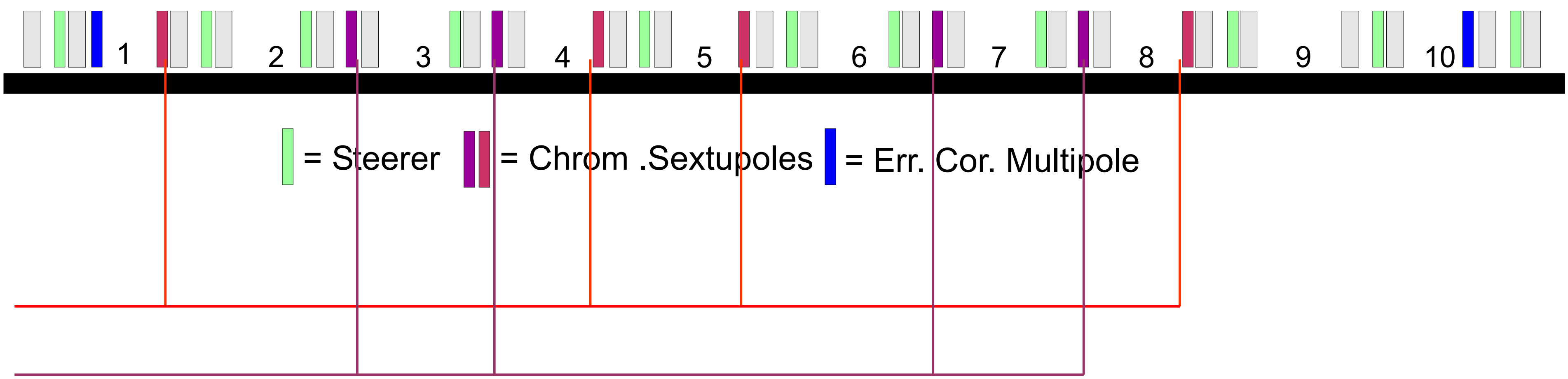
Correction System

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

SIS 100 Straight

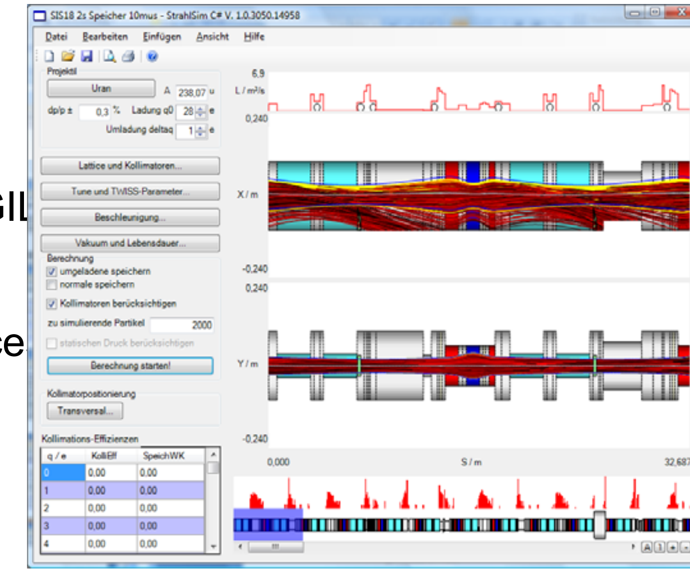


SIS 100 Arc



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

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

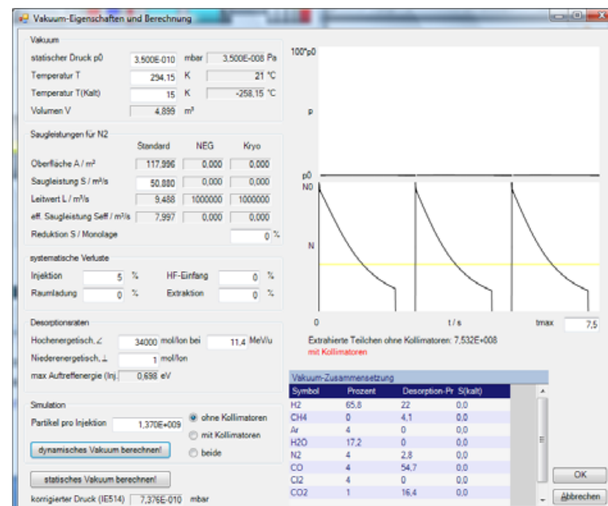
Static Vacuum

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



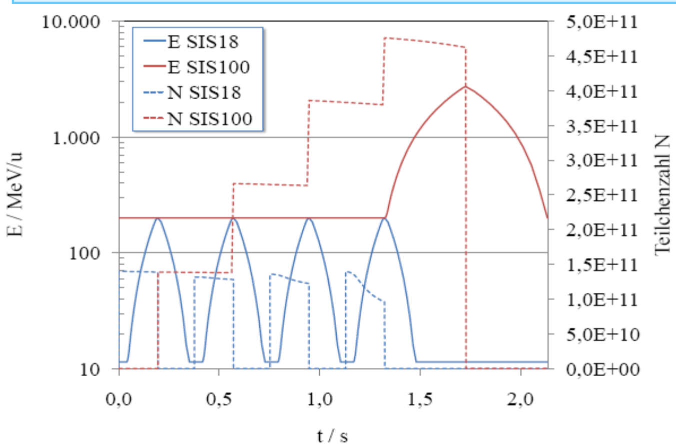
Ion stimulated desorption

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

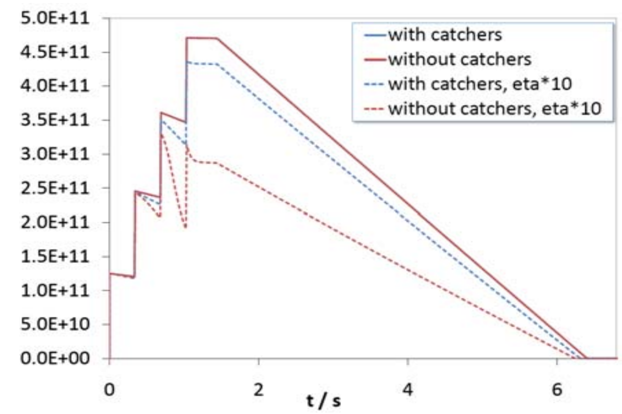
Benchmarked with many machine experiments (and at other accelerators)

Ionization Beam Loss and Dynamics of Pressure

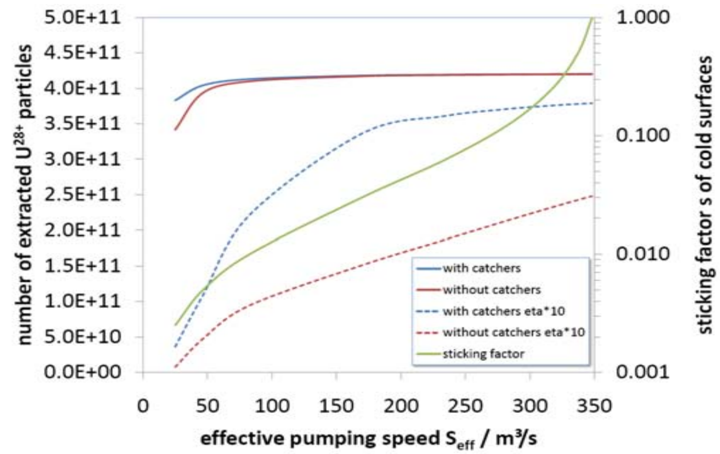
Short Term Studies (Cycles)



Ionization loss during stacking and acceleration in SIS18 and SIS100

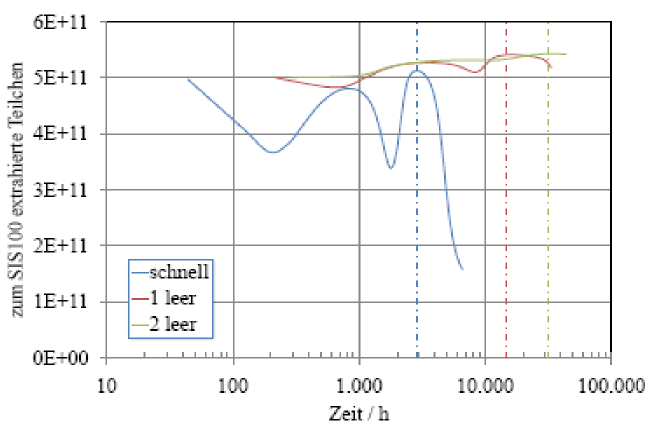


Safety studies for beam survival in SIS100

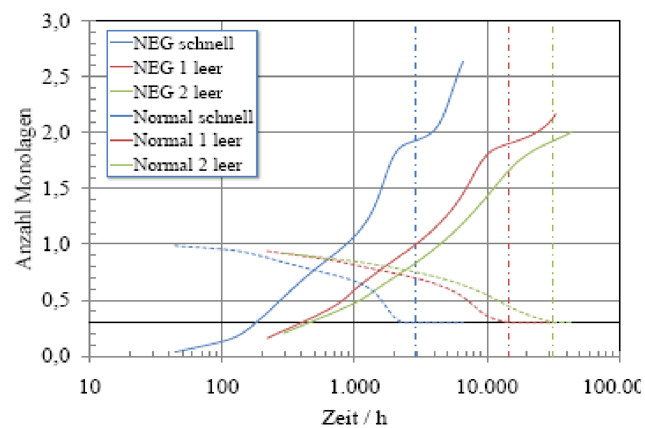


Extracted ions versus pumping speed of cryogenic surfaces

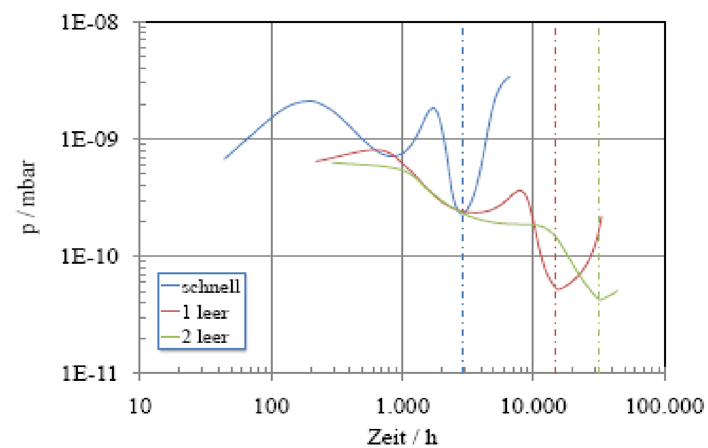
Long Term Studies



Extracted ions over months



Number of monolayers over months

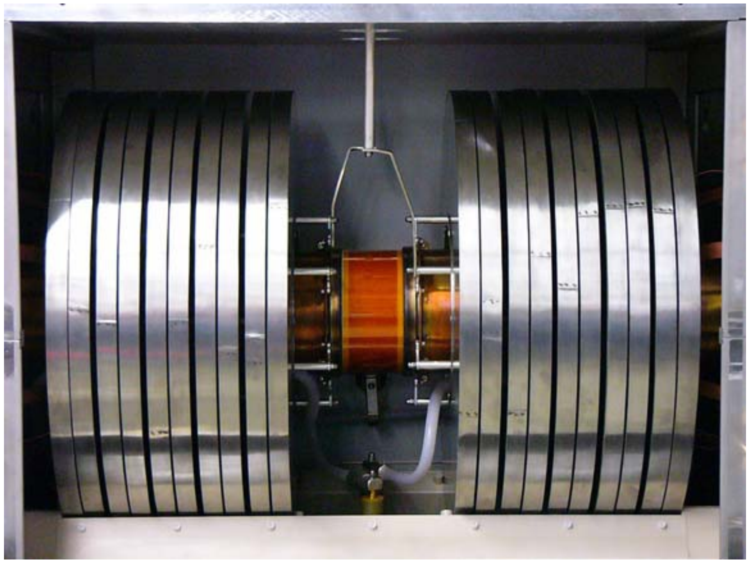


Pressure over months

SIS100 Radiofrequency: Overview

	FBTR	f [MHz]	#	Technical Concept
Acceleration System	h=10 400 kV	1.1–2.7	20 (SIS100) 8 (SIS300)	Ferrit ring core, "narrow" band cavities
Compression System	h=2 640 kV	0.395- 0.485	16	Magnetic alloy ring core, broad band (low duty cycle) cavities
Barrier Bucket System	15kV	2	2	Magnetic alloy ring core, broad band (low duty cycle) cavities

SIS18 ferrit loaded accel. cavity

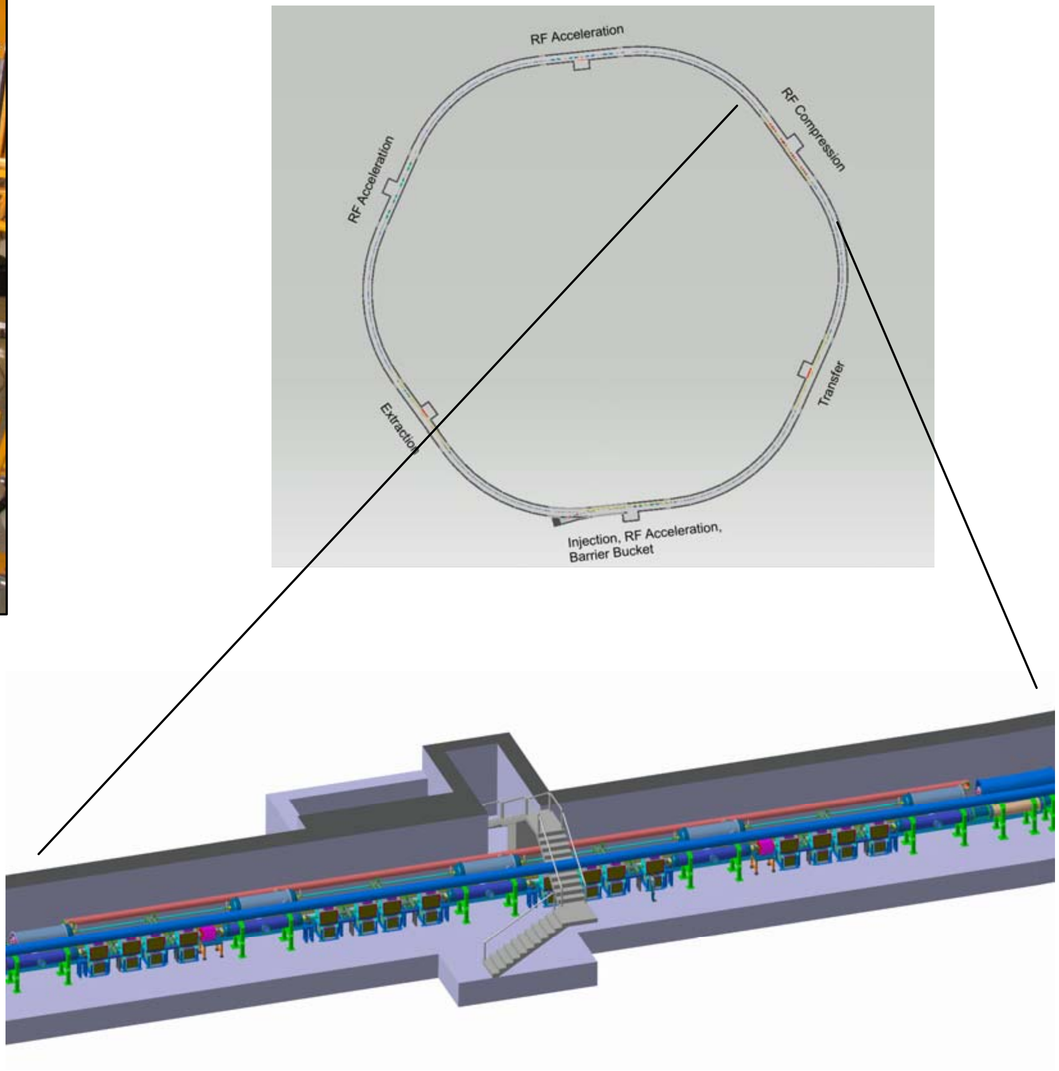


SIS18 MA loaded bunch compression cavity

Bunch Compression Systems

Short pulse (500 μs), high power bunch compressor developed at GSI

World wide MA core material survey

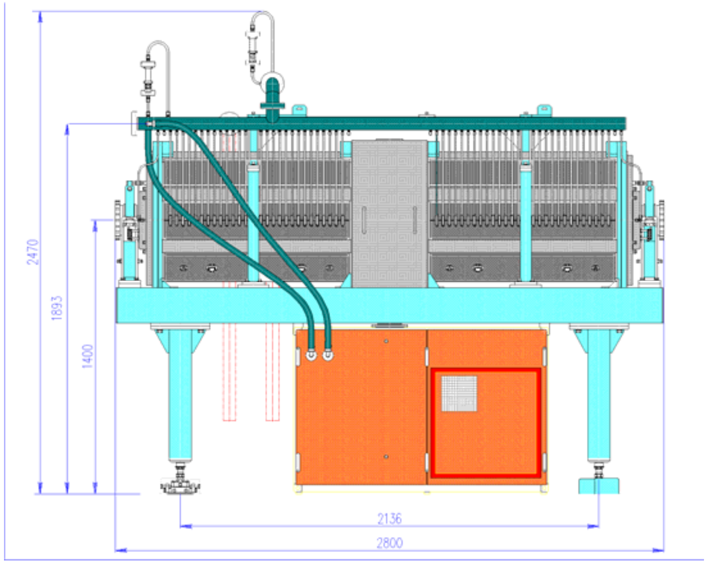


16 MA compression cavities in section S2

Rf: Acceleration Sections

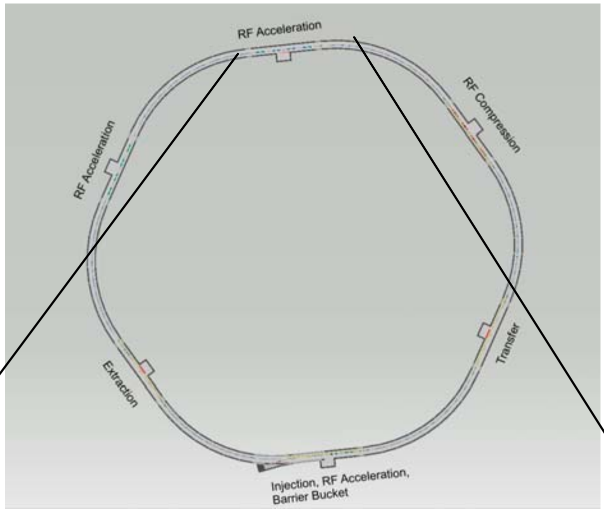
Acceleration Cavities:

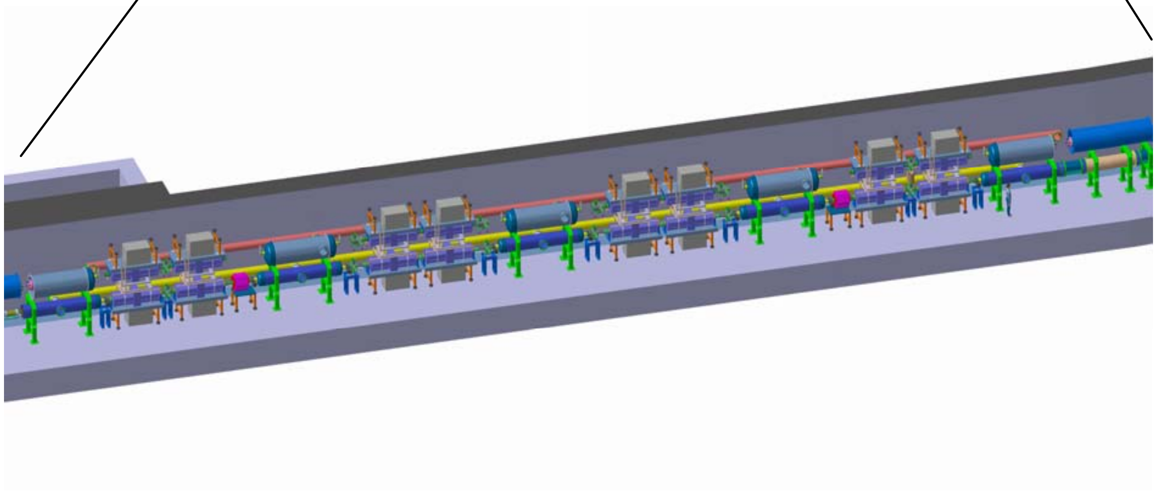
- Design study completed (BINP)



Minimization of shunt impedance:

Fast semi-conductor gap switch R&D





Rf Manipulations

- Stacking at 2.2 GeV

(4 bunches - 10 Rf buckets)

- Acceleration to 4 GeV

(4 bunches – 10 Rf buckets)

- Single bunch generation by batch compression

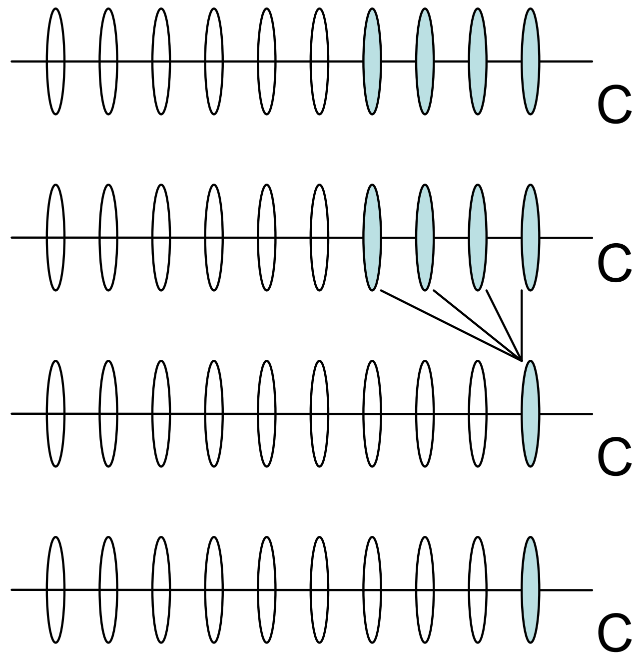
(1 bunch – 10 Rf buckets)

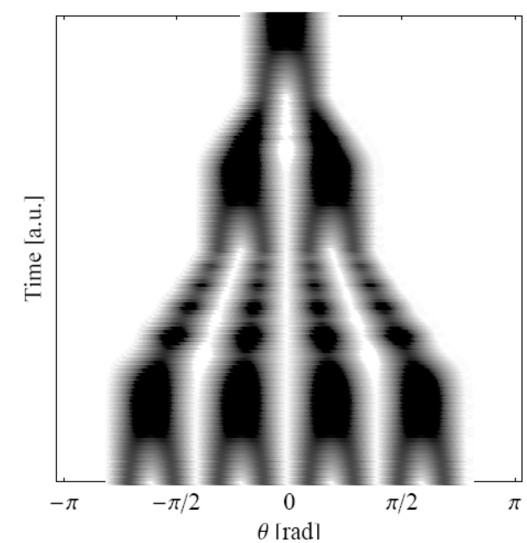
- Acceleration to 29 GeV and extraction

(1 bunch – 10 Rf buckets

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

Standard scheme for single bunch generation and compression not applicable - evtl. imag. Υ_T

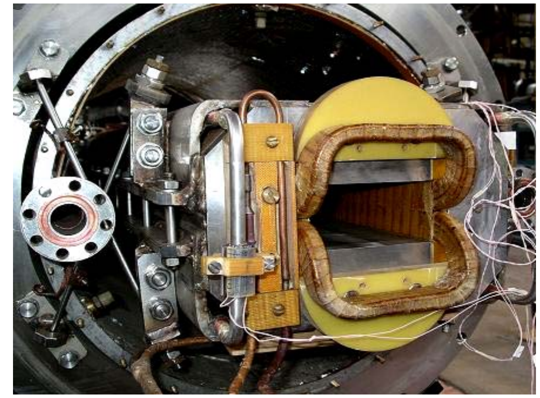


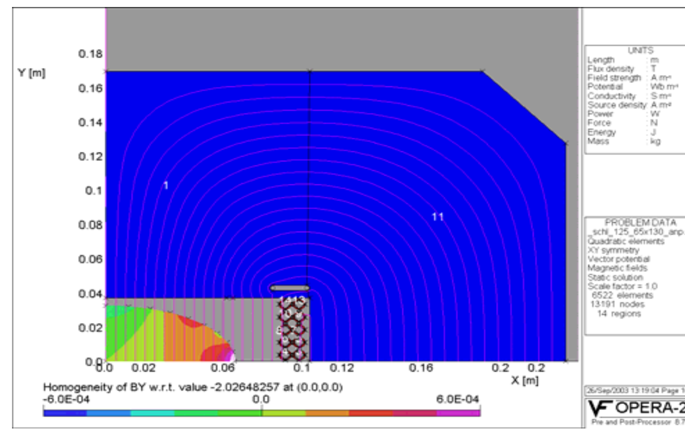


SIS100 Fast Ramped S.C. Magnets

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** ($\geq 2{\cdot}10^{8}$ cycles)





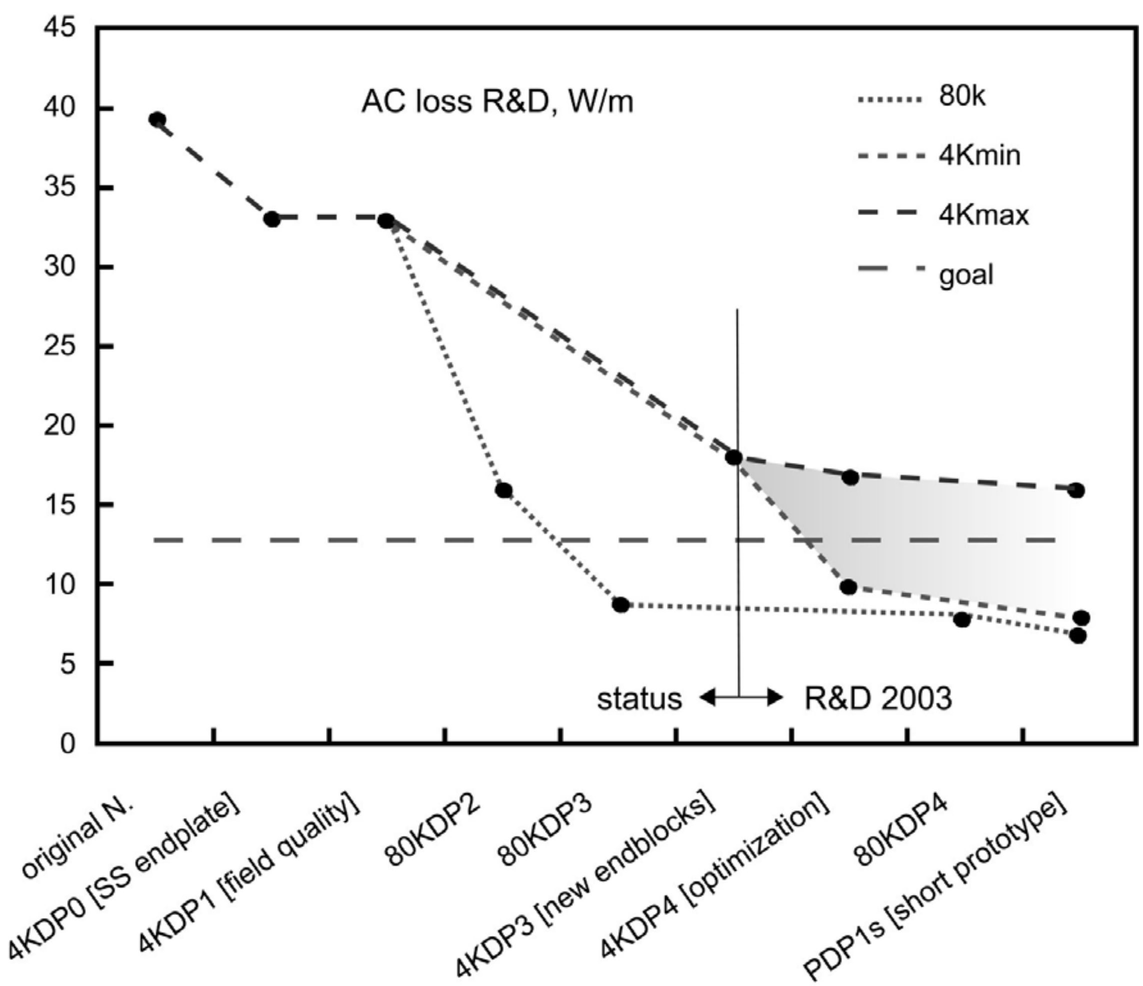
Activities

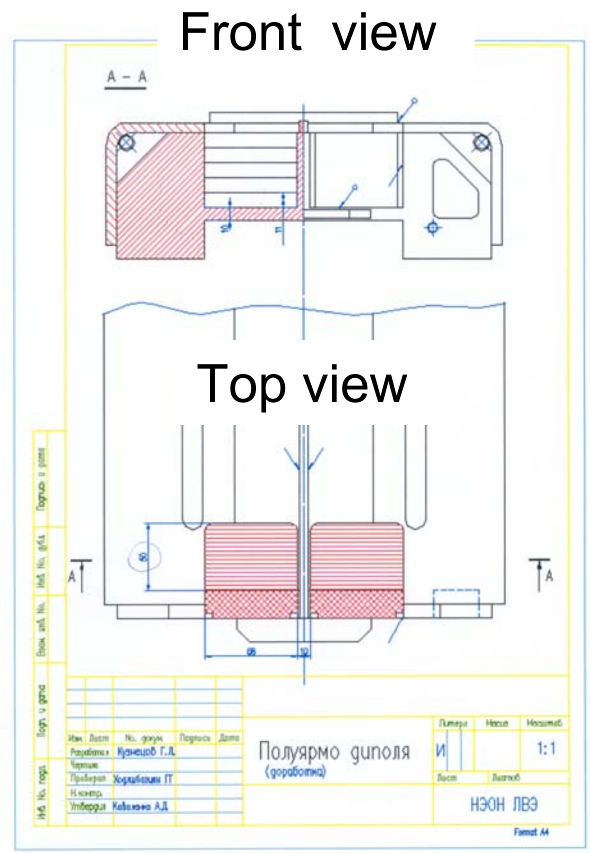
- AC Loss Reduction (exp. tests, FEM)
- 2D/3D Magnetic Field Calculations (OPERA, ANSYS, etc.)
- Mechanical Analysis and Coil Restraint (design, ANSYS) (>Fatigue of the conductor and precise positioning)

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

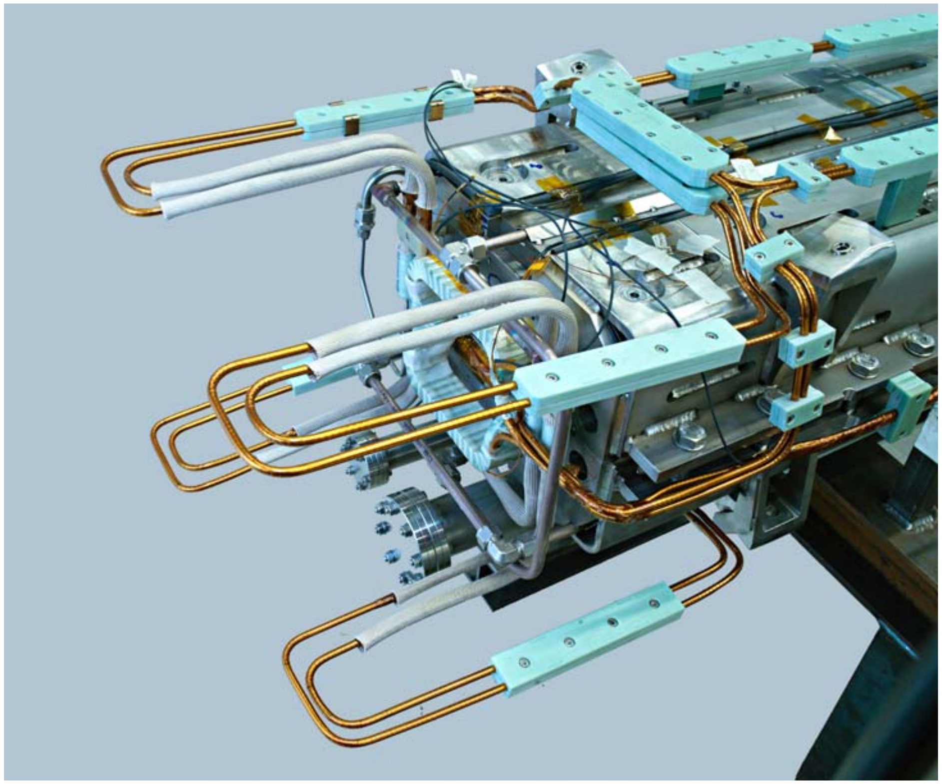


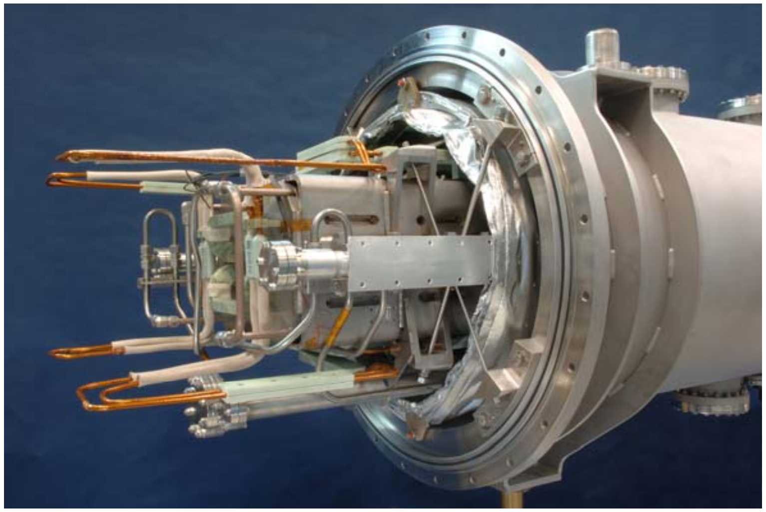


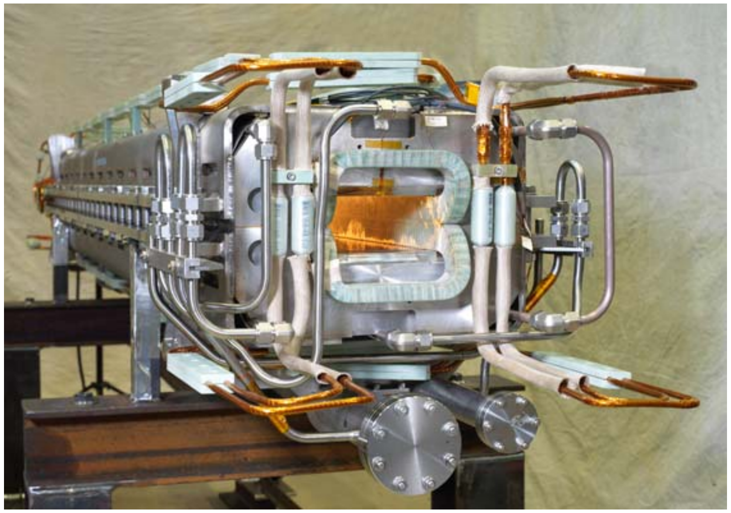
New endblock design

Full Length SIS100 Prototype Dipole

Manufactured by BNG (Würzburg)



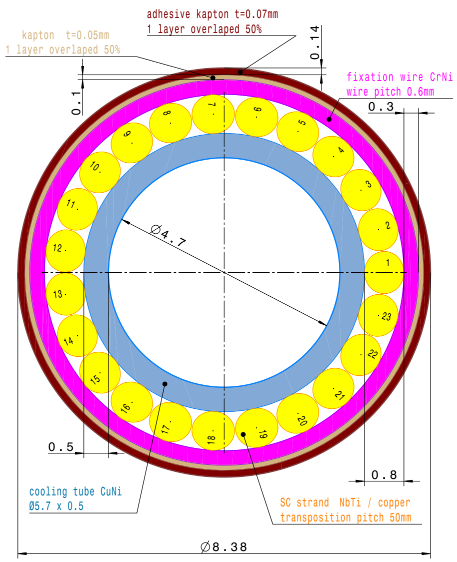


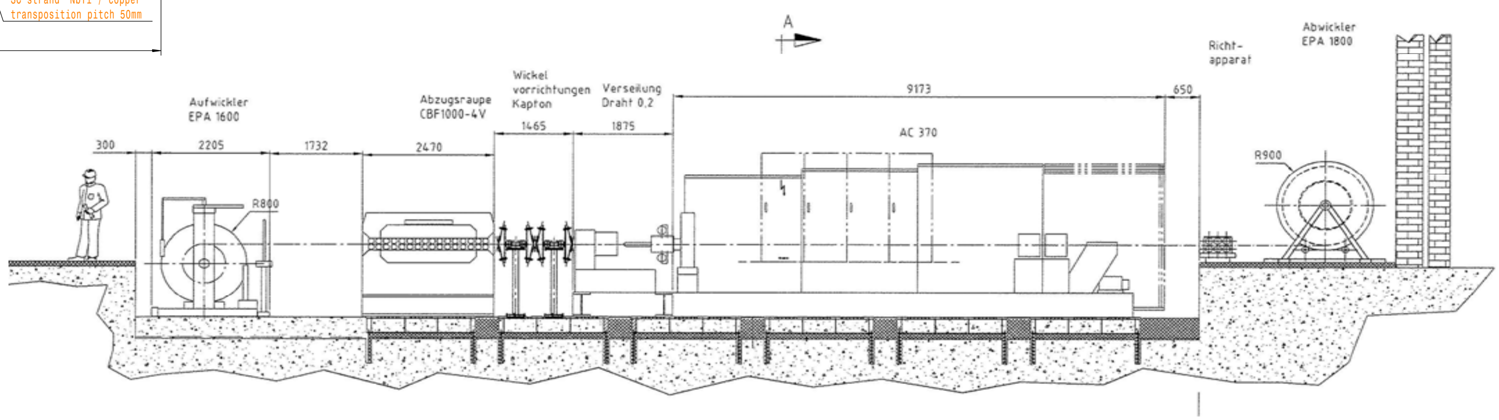


- Second straight dipole and quadrupole under manufacturing at JINR
- Curved dipole under manufacturing at BINP

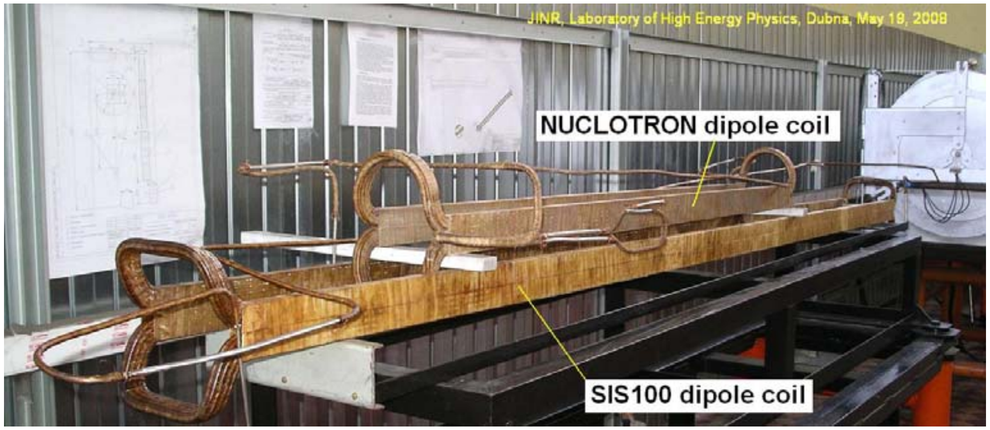
Nuklotron Cable Production at BNG

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





Full Length SIS100 Prototype Dipole



Prototype Production in JINR

Operation Cycles and Magnet Cooling Limits

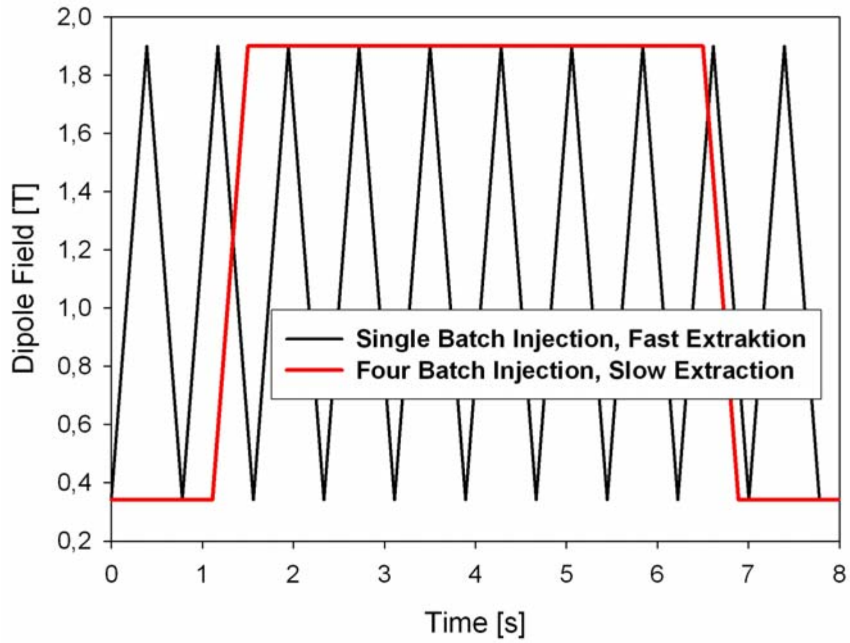
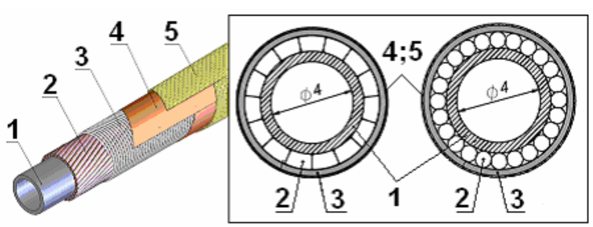


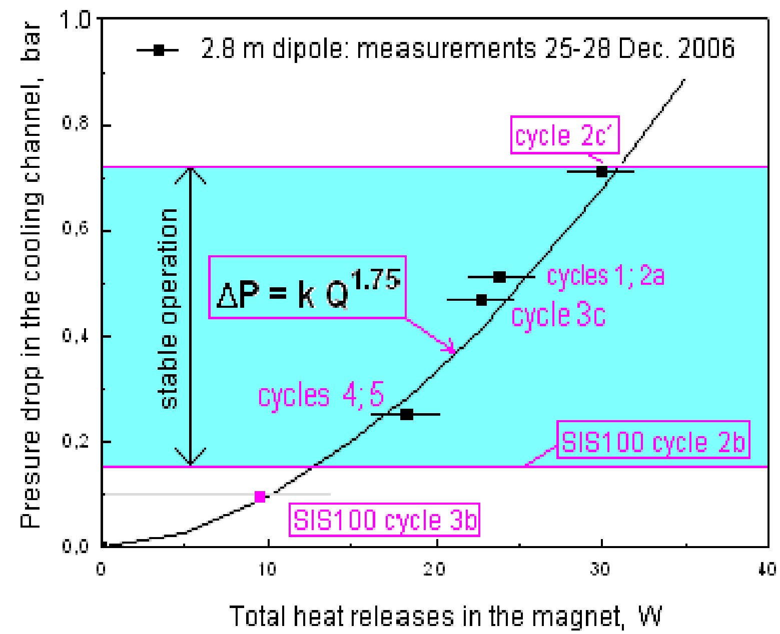
TABLE II OPERATION CYCLES AND EXPECTED LOSSES

cycle	B_{max} (T)	t_f (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

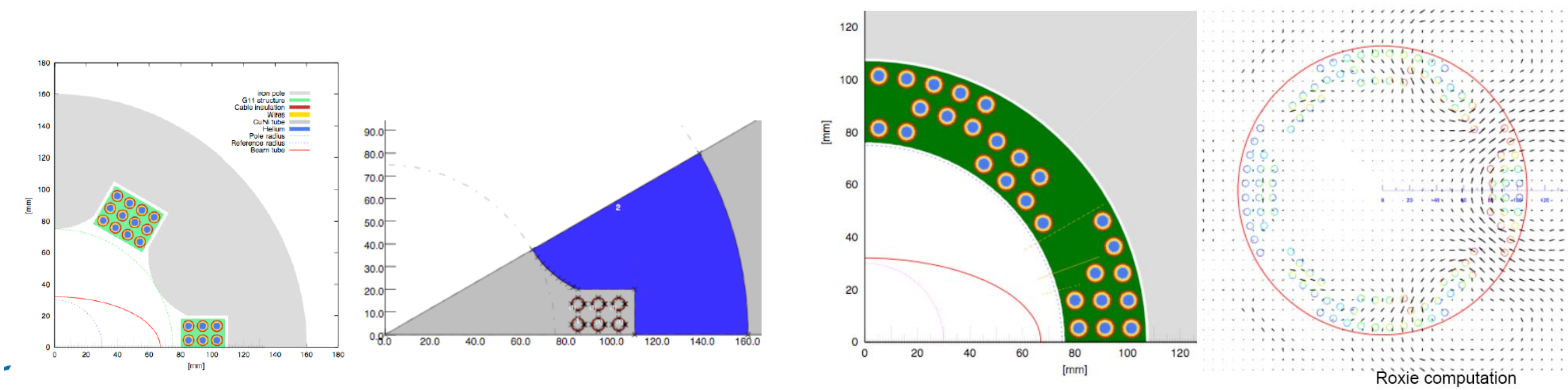


Alternative coil design and high current cable



Correction System

- Revision of all correction system parameters
- Technical layout of the correction magnets has been started.
  Technical options under investigation.
- Fast ramping of (short, high field) magnets for slow extraction (risetime 0.2 s)
  requires high power

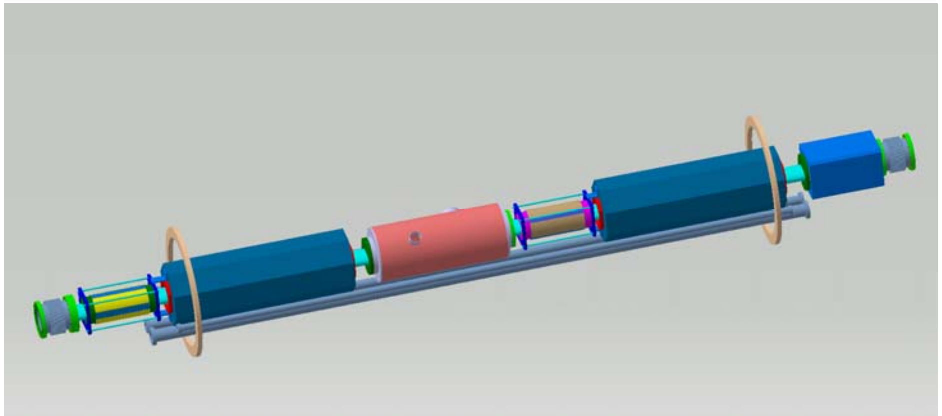


SIS100 correction magnet design studies

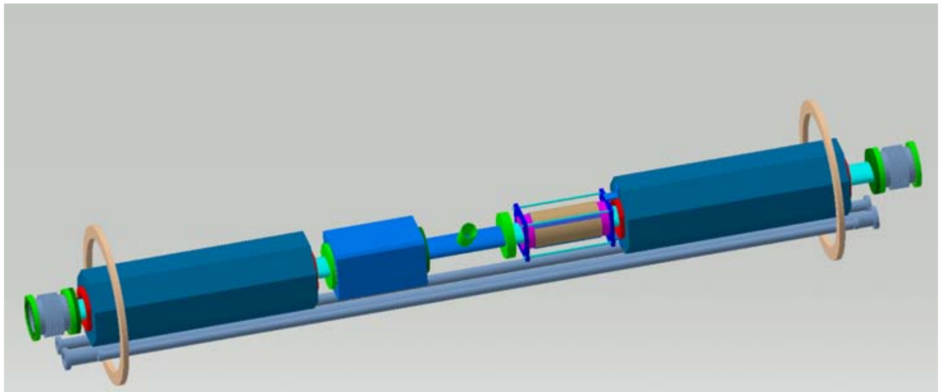
Focusing Modules

Two standard quadrupole units, but many exceptions !

Big engineering effort for pre-planning of cryomagnetic modules.

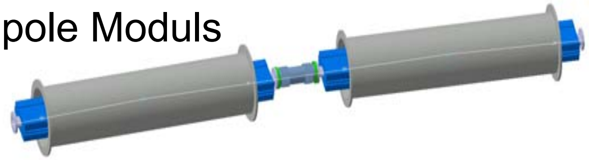


- Quadrupol unit of the arc includes sextupole, BPM and collimator (used also for pumping)



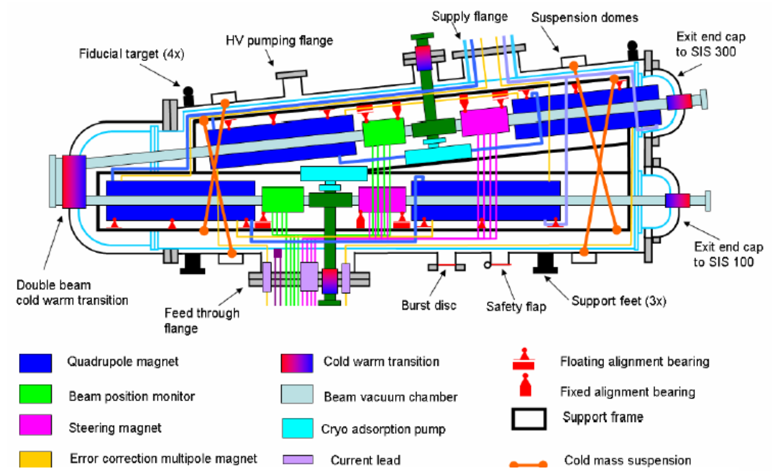
- Quadrupole unit of the straights includes BPM, sextupole and pumping chamber

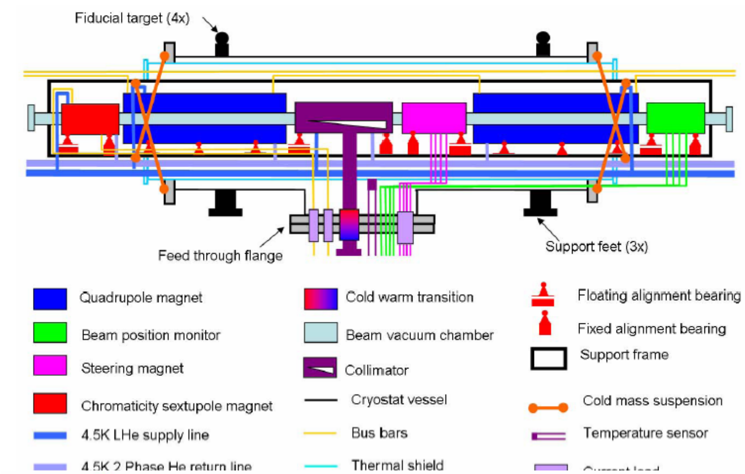
Dipole Moduls

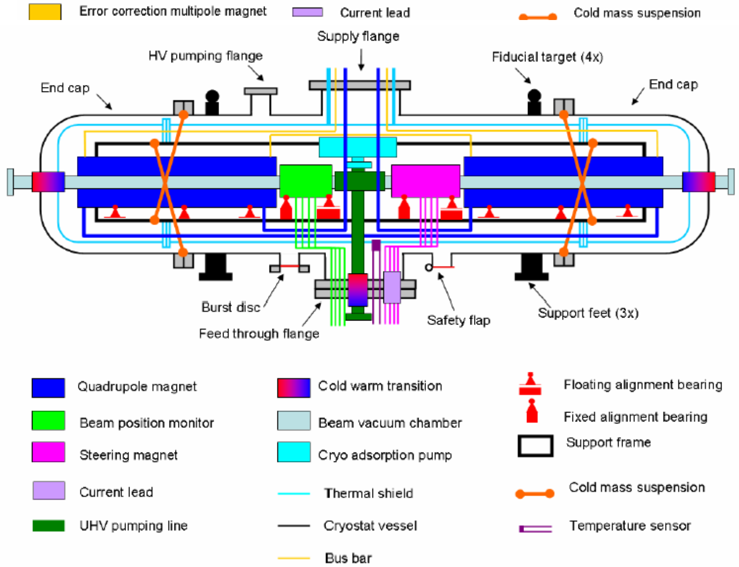


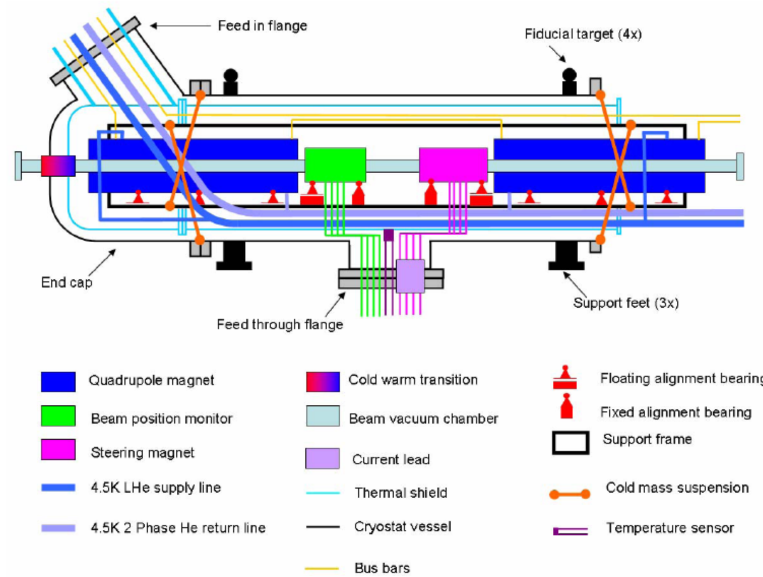
Cryomagnetic Units

Large number of different modules, examples:





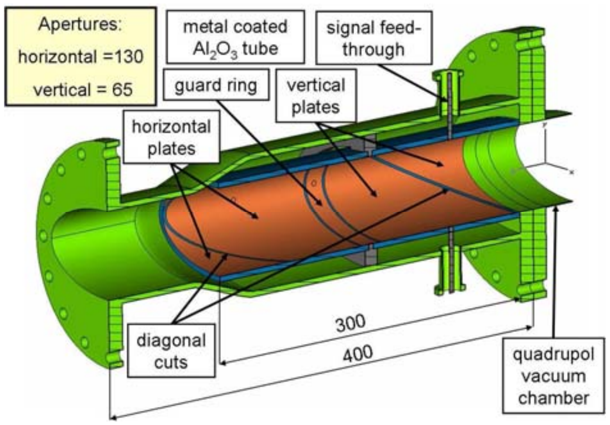




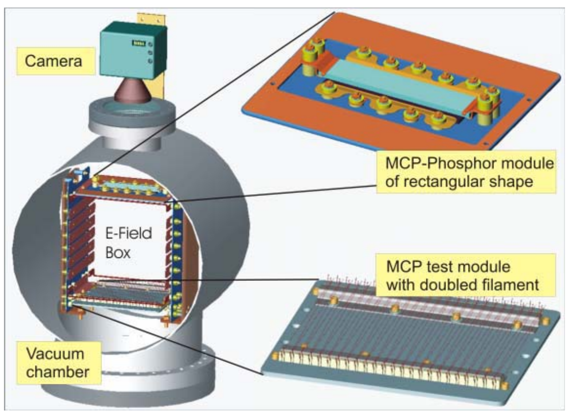
Local Cryogenics

- Feed Boxes
- Feed-in Cryostat
- Current Lead Boxes
- Cold Links
- Cryogenic Bypass Lines
- End Caps
- Measurement Technique
- Special Cryostats ?

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

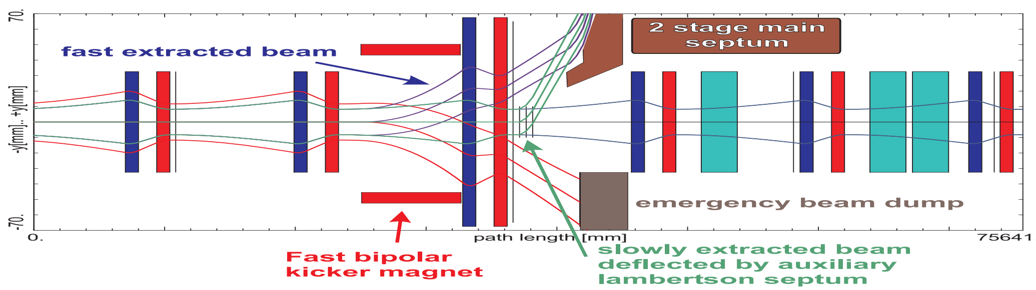
IPM beam profile cooling, matching

BLM beam loss matching, halo, scraper, losses

Grid/Screen beam profile first turn

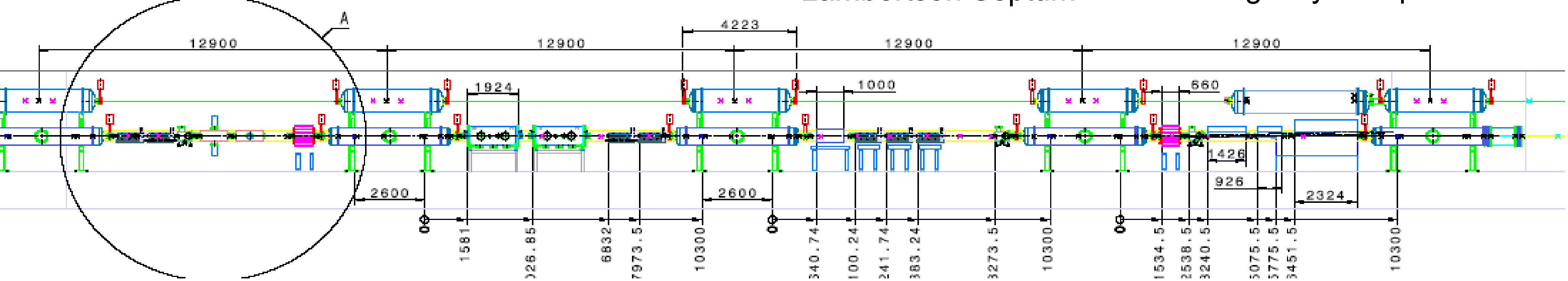
Extraction System

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

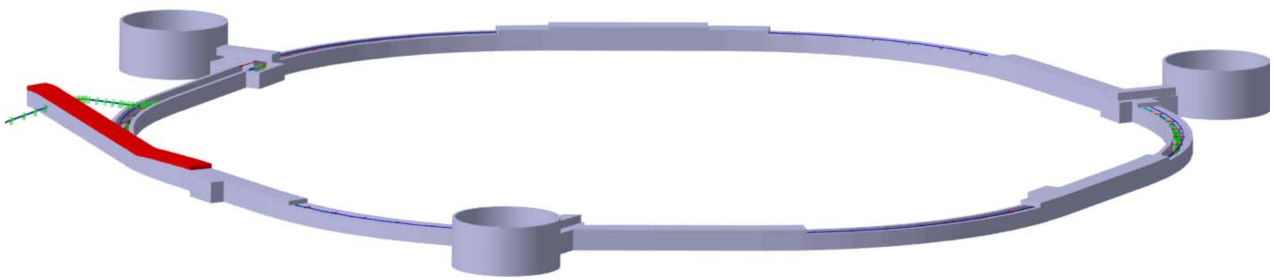


- Cooling test of high power extraction septum in preparation at GSI
- Wire heating of electrostatic septa due to beam load under investigation
- Design study for pulse power generator for bipolar, ramped kicker magnets started
- Prototype for a two stage pseudospark switch under development.

Halo Scraper | Electrostatic Septa | Bipolar Kicker System | Lambertson Septum | Magnetic Septa and Emergency Dump

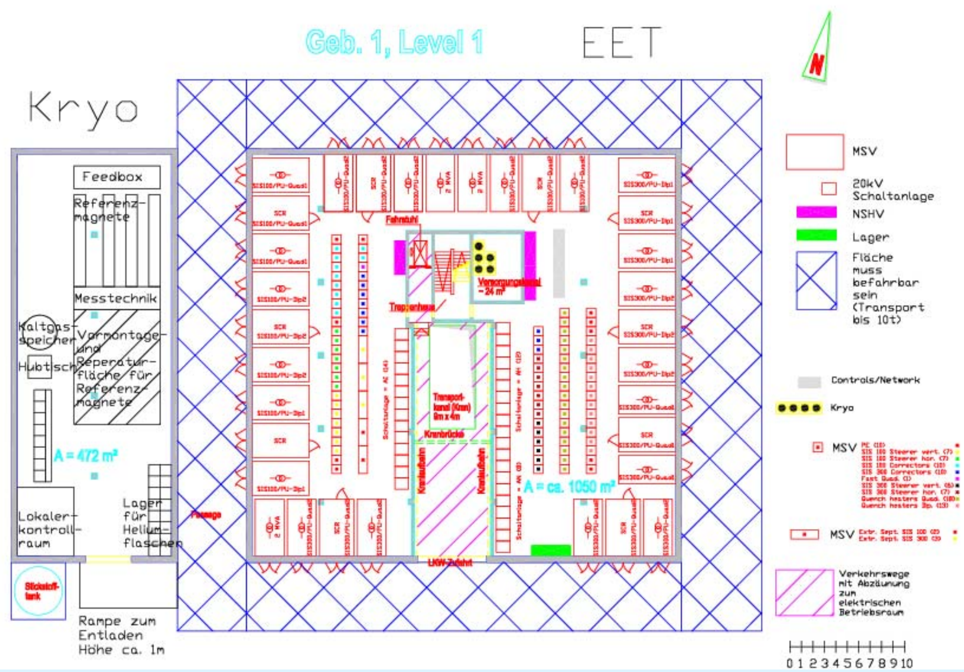


Synchrotron Main Supply Buildings



Document „Specifications for Synchrotron Buildings“ includes main accelerator aspects

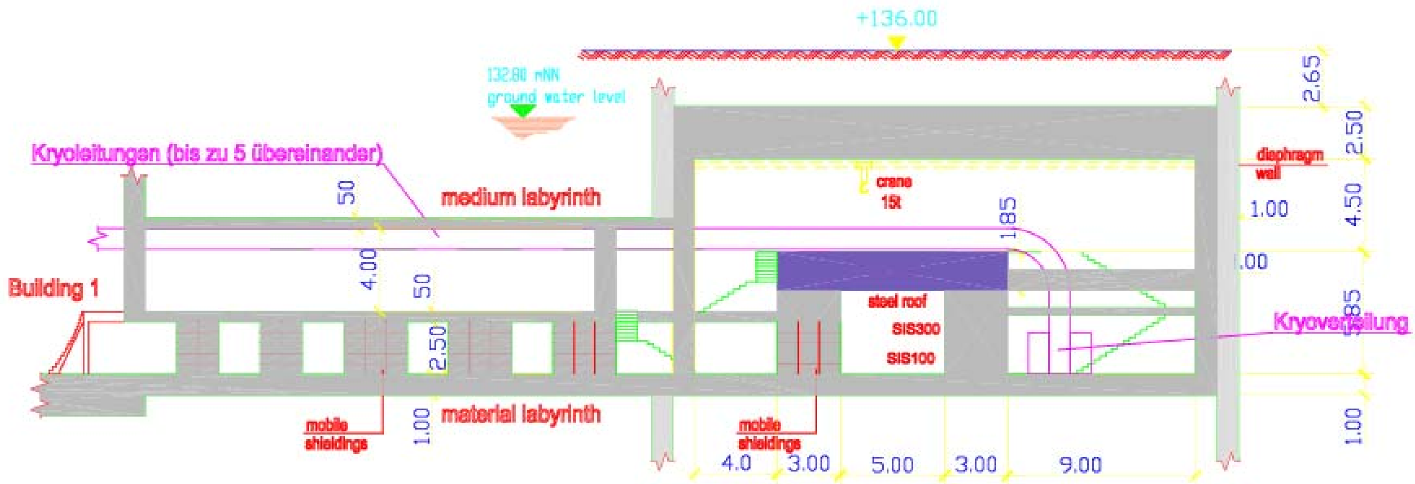
- Table of floor space requirements
- Tables for cranes and double floor
- Distribution of supply units for all buildings and floors
- Cable planning started
- General specifications

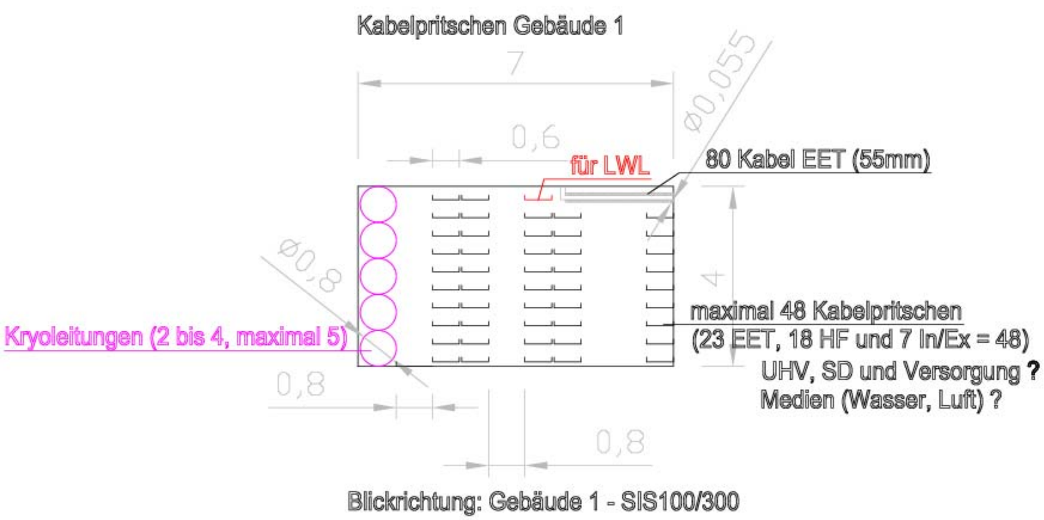


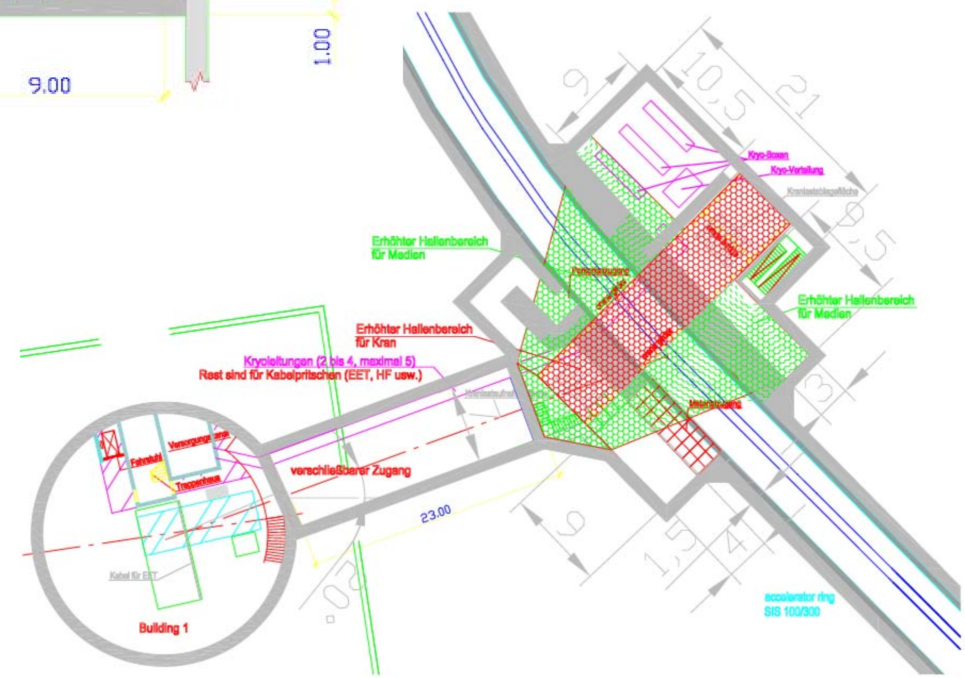
plus Load List

Evaluation of six distributed buildings as proposed by FAIR CC

Civil Construction: Supply Tunnel







Expression of Interest for SIS100 Components

Component	Expression of Interest	
SIS100 2.8		
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.	

Events in 2008 (beside committee meetings)

- November 2007

FAIR kick-off event

March 2008

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

Frame for Road Map

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

Issue for the EOI Discussion

1. Which technical systems in detail does your EOI cover ?

   Do these work packages fit into your available EOI budget ?

2. Road Map involving all technical systems with EOI expressions dedicated to

   SIS100, including those items listed in the cost book under local cryogenics

(Don't mix local cryogenics (e.g. bypass lines) with cryogenics supply

(e.g. transfer lines) (not part of SIS100 !)

Schedule for the Discussion:

1. Presentation and discussion of a possible EOI interpretation on component level

2. Presentations of the EOI representatives

   Discussion and correction of the EOI interpretation (1.)

   Discussion of road map and preconditions/comments