Advanced Concepts and Technologies for Heavy Ion Synchrotrons

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Subproject SIS100/SIS18

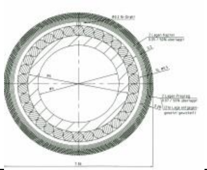
IPAC21

Fast Ramped S.C. Magnets

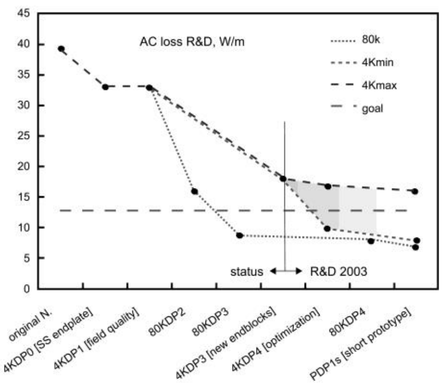
GSI has a world wide leadership in fast ramped superconducting magnets

1. R&D on fast ramped superconducting, window-frame magnets for SIS100
4 T/s up to 1.9 T

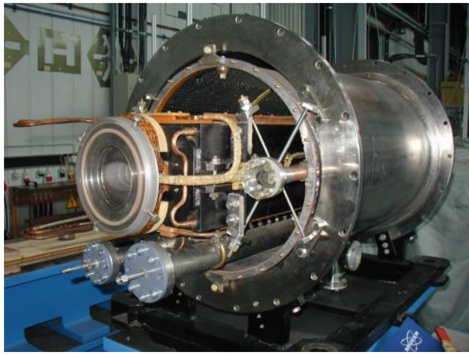
R&D goals:
1. Reduction of eddy/persistant current effects at 4 K (at most in iron yoke)
2. Optimization of field quality
3. Long term mechanical stability for (>2·10^8 cycles)



Optimization of Nuclotron Cable:
- Insulation concepts
- Winding technologies
- ANSYS models etc.



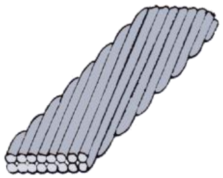
AC loss reduction 40 W>15W

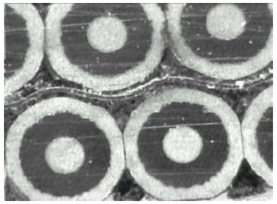


SIS100 Prototype Dipole

2. R&D on fast ramped, superconducting costheta magnets for SIS300 and others
1 T/s up to 4.5 T (world record ramp rate)

R&D goals:
1. Reduction of AC loss by improved cable and coil design
2. Optimizec conductor cooling (e.g.laser cutted cable)





Optimization of Rutherford Cable:
- Reduced filament twist pitch
- Strand coating
- Stainless steel core

Fast ramped SIS300 Dipole in Cryostat

Fast Ramped S.C. Magnets

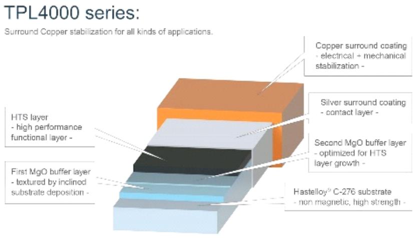
Cold test of fast ramped cosθ dipole magnet

Set-up of full size SIS300 dipole magnet at test stand t ILK

GSI continues with developing world wide unique expertise in fast ramped superconducting magnets.
A full size SIS300 dipole magnet has been developed. The main goal was minimizing the AC loss in the coil by means of a special low loss Rutherford cable. The cold mass of the full size SIS300 dipole magnet has been cold tested in a vertical bath cryostat at INFN Milano. A ramp rate of 1 T/s could be reached, which compares to 50 mT/s of usual s.c. magnets with standard Rutherford cable.
In 2020 the assembled magnet has been send to ILK for preparing a cold test of the full magnet (picture left).

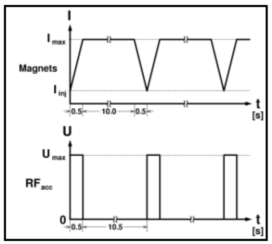
HTS Nuclotron Cable

- So far, fast ramped s.c. accelerator magnets have been build based on two types of cable: a) Nuclotron cable or b) low-loss Rutherford cable.
- GSI is going to further develop the Nuclotron cable by replacing the NbTi strands by an HTS tape.

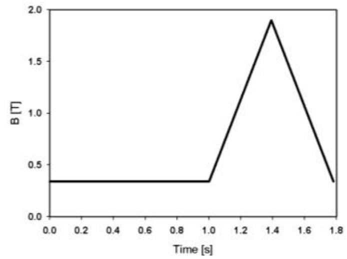


- In preparation of the EU funded program IFAST, GSI has set-up a collaboration between IEE Bratislava, ILK Dresden and University Twente on the development of an high current, wide temperature range, energy efficient ReBCO-HTS based Nuclotron cable and prototyping of a fast ramped magnet. Potential applications for energy technologies, e.g. s.c. energy storage will be studied.
- Recent progress in advanved manfacturing techniques (higher cirtical currents, advanced doping) of commercial HTS tapes may enable higher field magnets.

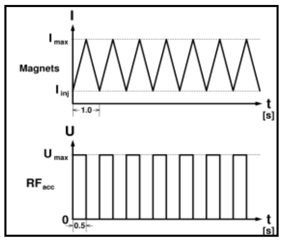
Dynamic Heat Load and Flexible Operation



quasi static heat load at long extraction (DC 3.5 kW)



Reference cycle 2c



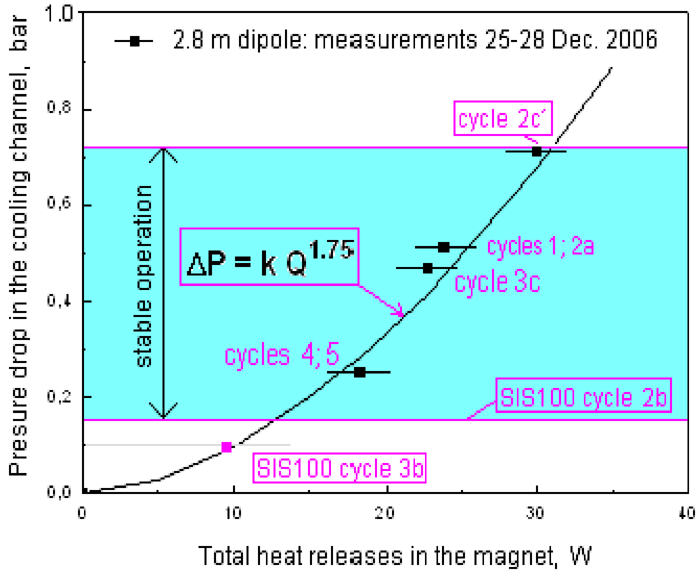
Triangular cycling with fast extraction (AC+DC 14.5 kW)

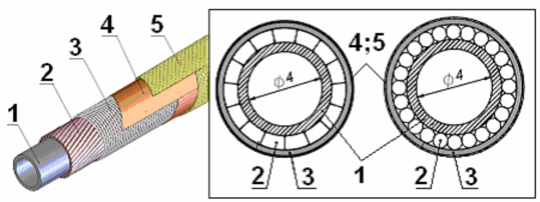
TABLE II OPERATION CYCLES AND EXPECTED LOSSES

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

Control of Magnet Cooling:

- Single layer magnet coil with low hydraulic resistance
- High current Nuclotron cable
- Hydraulically adjusted magnet cooling circuits
- Active heaters to stabilize the crogenic load
- Variable supply LHe supply pressure
- LHe pumps





Alternative coil design and high current cable

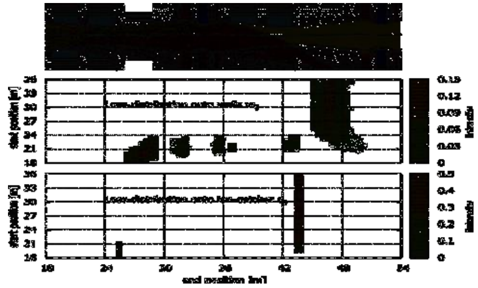
Ultimate Heavy Ion Intensities and Dynamic Vacuum

StrahlSIM Code

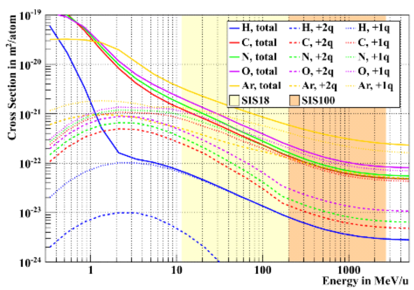
Developed by GSI for simulations on the FAIR synchrotron operation with low charge state heavy ions

„Self-consistent“ simulations for spatial and temporal pressure and loss evolution:

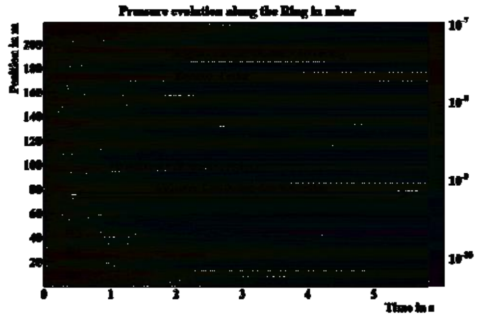
- Ion optic layout (linear)
- Cross sections for prejectile-target combinations (e-capture, e-loss, multiple)
- Maschine cycle and energy dependence of cross sections
- Ion induced desorption yields considering low desorption surfaces
- Conventional UHV system (incl. outgasing, conduction and pumping)
- Special UHV systems, e.g. NEG surfaces including saturation
- Cryopumping and transitions from room temperature



Beam loss distribution by charge exchange

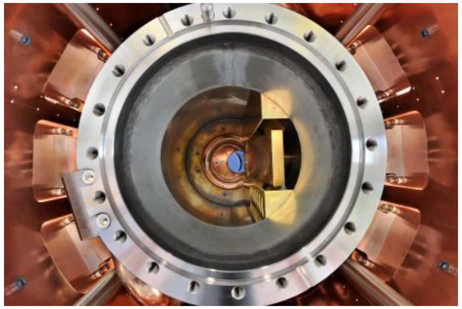


Cross section sfor charge exchange



Residual gas pressure as a function of time and space

SIS100 Technologies for Suppression of Dynamic Vacuum

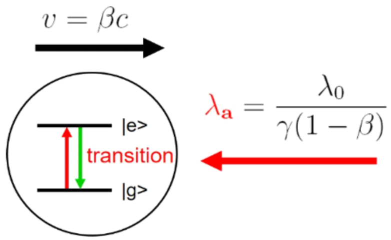
Cryogenic ion catchers with low desoprtion surface

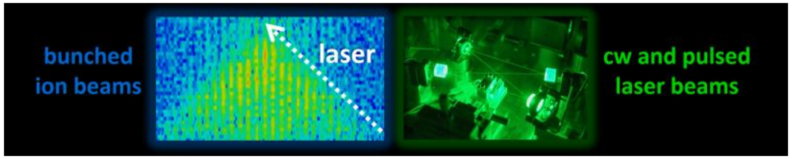
Actively LHe cooled, thin wall magnet chambers

Cryogenic adsorption pumps

Laser Cooling of Relativistic Heavy Ions

SIS100 will be the first user synchrotron equiped with a „laser cooler“ world wide.
Laser-cooled relativistic heavy-ion beams (γ up to 13 for Z = 10 - 60)
Only cooling method at relativistic energies (dp/p<10^{-7})
Extraction of very cold and very short ultra-relativistic ion bunches





Net cooling force in the direction of the laser light (longitudinal).

Major highlights:

- Installation of the laser beamline in SIS100 tunnel

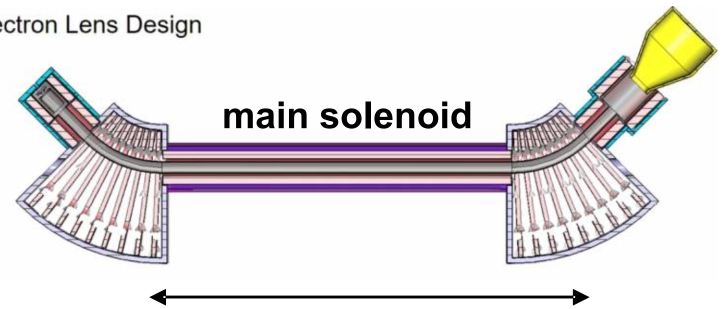
- Visiting Scientist Fellowship for Associated Professors of Chinese Academy of Science for D. Winters
- Laser and Particle Beams Young Scientist Award for S. Klammes

Electron Lens for Space Charge Compensation

Goals:

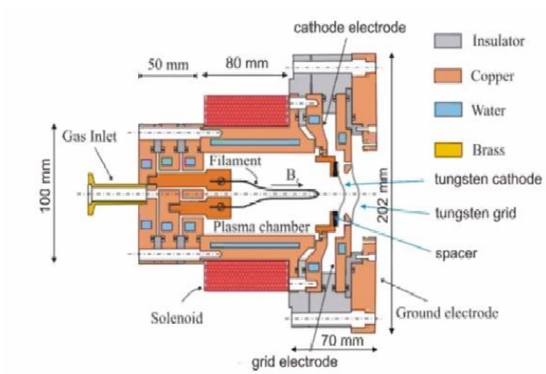
- Upgrade of SIS18/SIS100 to overcome enable further intensity enhancement
- Partial compensation of space charge tune spread
- Bunched ion beams require longitudinal e-beam modulation
- Flat transverse e-beam profile Modulation follows acceleration of ions
- Electron currents about 10 A
- Modulation bandwidth about 5 MHz

Layout of SCC lens and electron beam dynamics



Gun prototyping and simulations on electron beam propagation.

Prototype pulsed electron gun



Peak electron current	10 A
Extraction voltage	30 kV
Interaction length	3.36 m
Magnetic field	0.6 T
Horizontal beam radius	35 mm
Vertical beam radius	20 mm
Min. modulation frequency	0.4 MHz
Max. modulation frequency	1.0 MHz
Modulation bandwidth	10 MHz

EU ARIES collaboration on the development of a pulsed electron gun:

- GSI
- IAP Frankfurt
- University of Riga
- Cern