The International Accelerator Project at GSI

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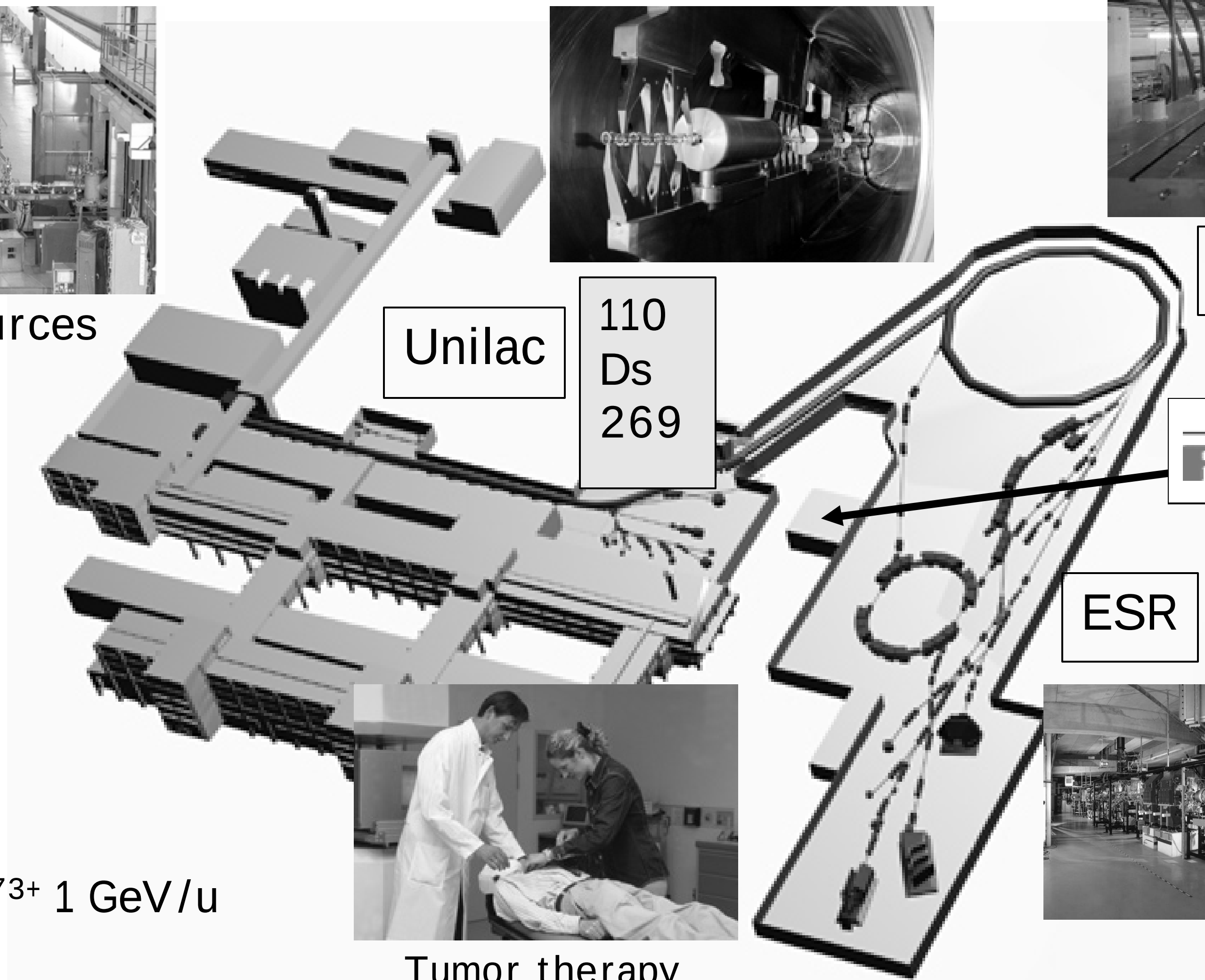
Inter'l Accelerator Project

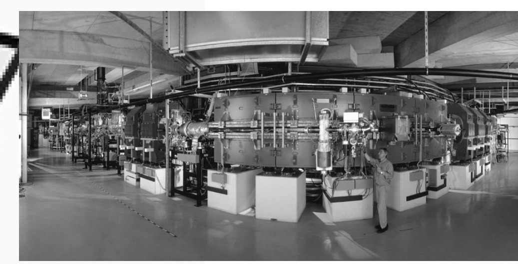
Accelerator Facility for Energetic
Ion Beams of High Intensity and Quality

The GSI Accelerator Facility

Ion sources



Tumor therapy



2004:

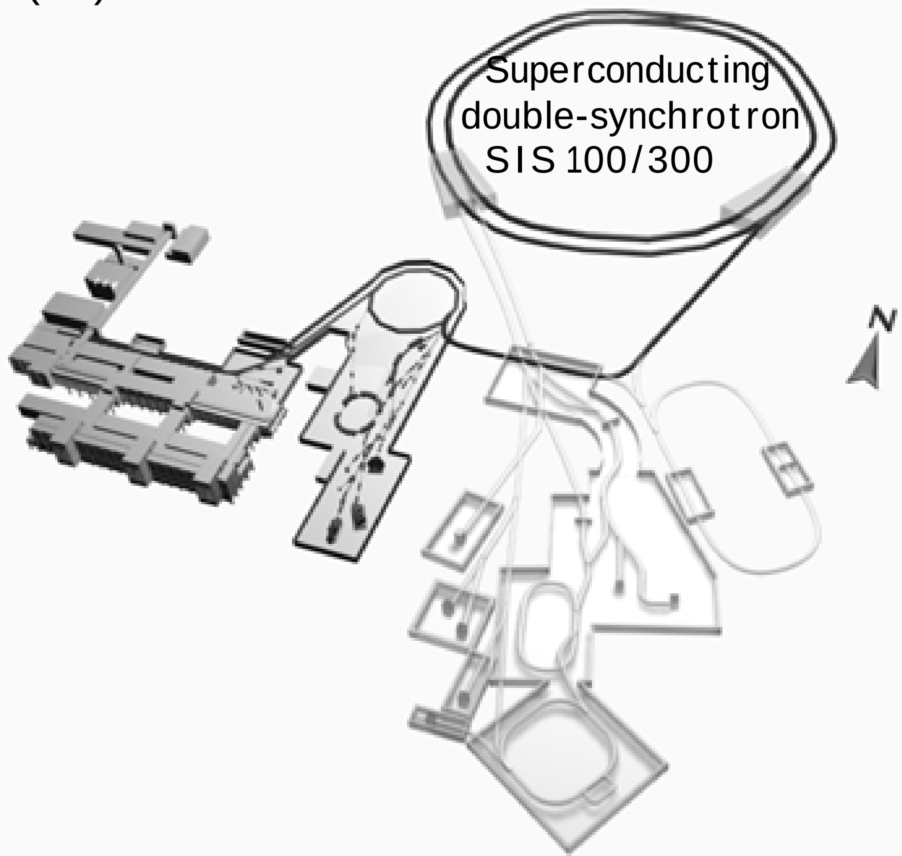
10^{10}/s U^{73+} 1 GeV/u

Scheme of the New Accelerator Facility

1.5 GeV/u U^{28+} 10^{12} /s

29 GeV p 10^{13} /s

22 (35) GeV/u U^{92+} 10^{9} /s



- Gain compared to the existing facility / new and special beam propoerties:
  - Primary beam intensities: Factor 100 – 1000
  - Ion energy: Factor 15 (25)

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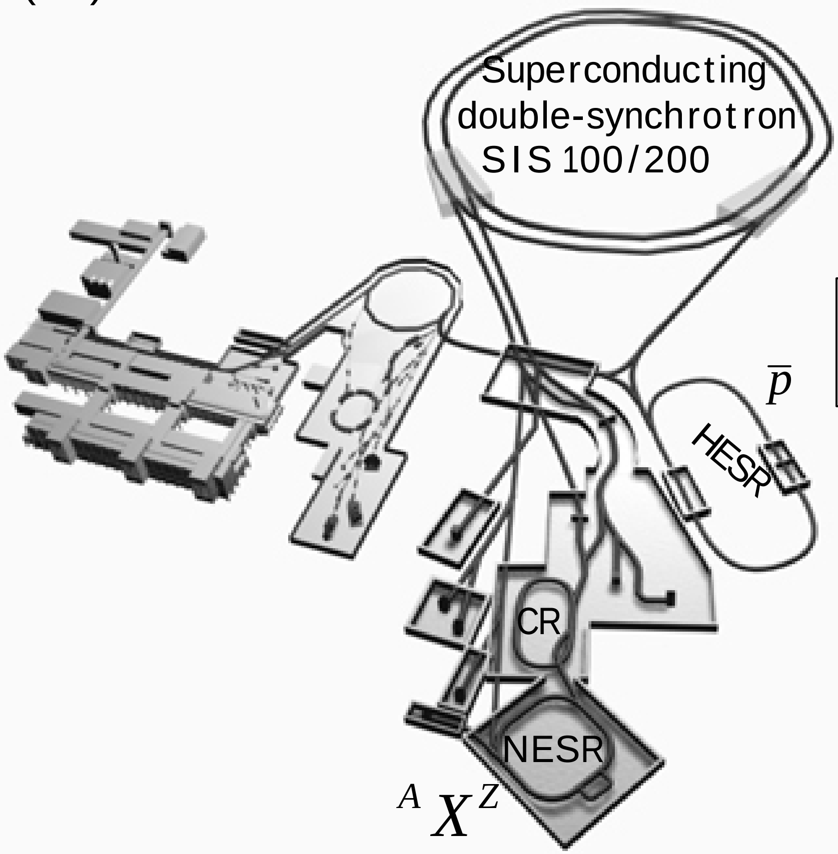


- Gain compared to the existing facility / new and special beam propoerties:
  - Primary beam intensities: Factor 100 – 1000
  - Ion energy: Factor 15 (25)
  - Secondary beam intensities for radioactive Ions: up to a factor 10000
  - New: cooled antiproton beams up to 15 GeV
  - Special: intense cooled radioactive ion beams
  - efficient parallel operation of several experiments

Bird‘s Eye View on the New Facility

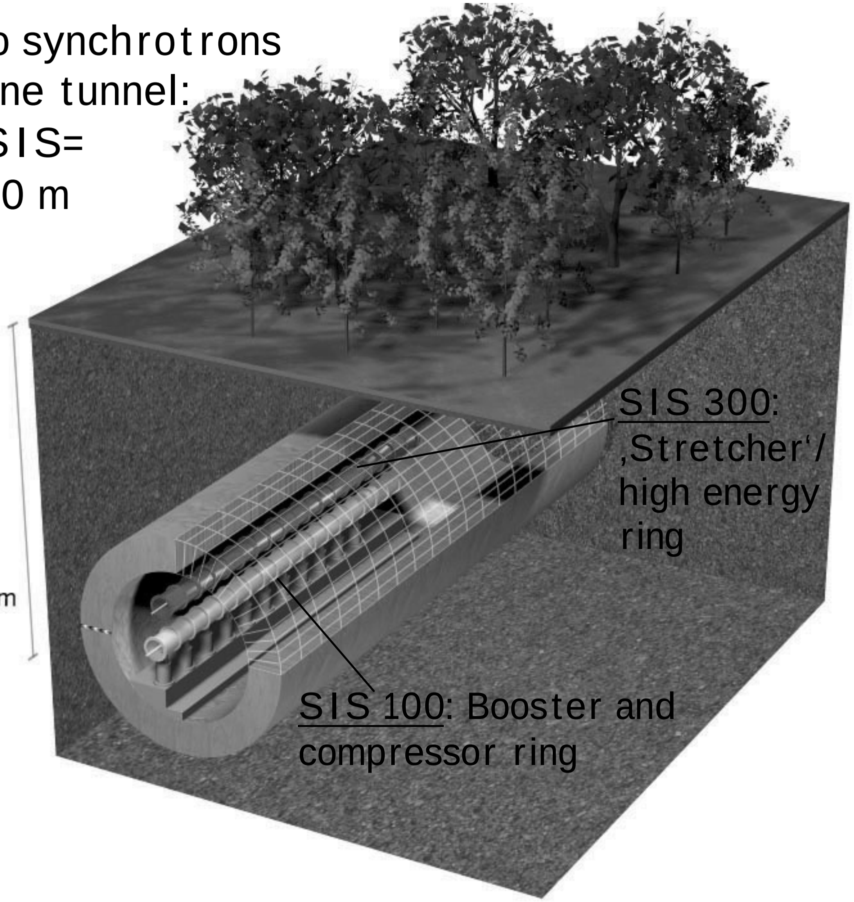
Zur Anzeige wird der QuickTime™ Dekompressor „MPEG-4 Video“ benötigt.

BMBF Pressemitteilung vom 5.2.2003:

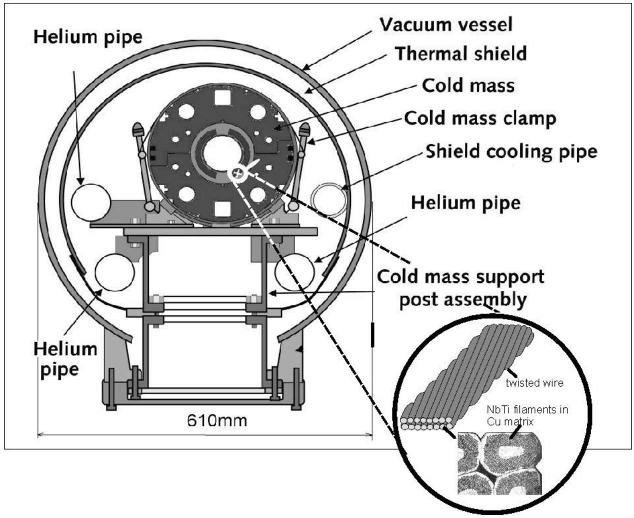
Die GSI soll gemeinsam mit europäischen Partnern ihre Anlagen stufenweise ausbauen und zu einem führenden europäischen Physikzentrum werden. Mindestens ein Viertel der Kosten in Höhe von 675 Millionen Euro soll von ausländischen Partnern aufgebracht werden.

The SIS 100/300 Double-Synchrotron

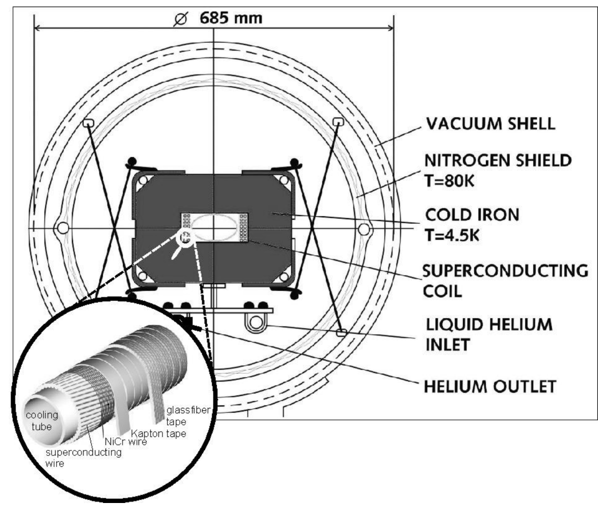
Two synchrotrons in one tunnel:
5xSIS=
1080 m



RHIC-typ dipole magnet:
B=4T (6T),
dB/dt=1T/s



Nuclotron-type dipole magnet:
B=2T,
dB/dt=4T/s

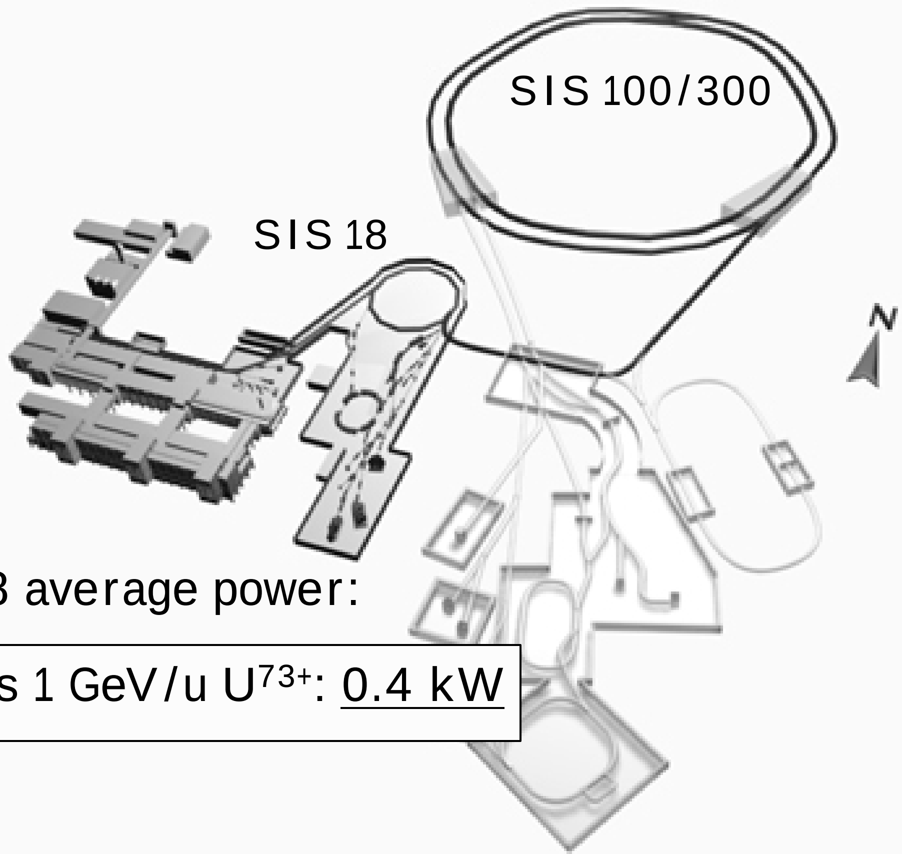


2x120 superconducting (SC) dipole magnets
132+162 SC quadrupole magnets

SIS 100/300: Low Loss Design

SIS 100/300 average (peak) power:

10^{12}/s 2.5 GeV/u U^{28+}: <u>100 kW (1 TW)</u>



SIS 18 average power:

10^{10}/s 1 GeV/u U^{73+}: <u>0.4 kW</u>

Quenching/Lifetime of SC magnets:

tolerable beam loss in the SC coils: < 1 %

Structure activation:

Hands-on maintenance requires losses < 1 %

Beam loss induced outgassing

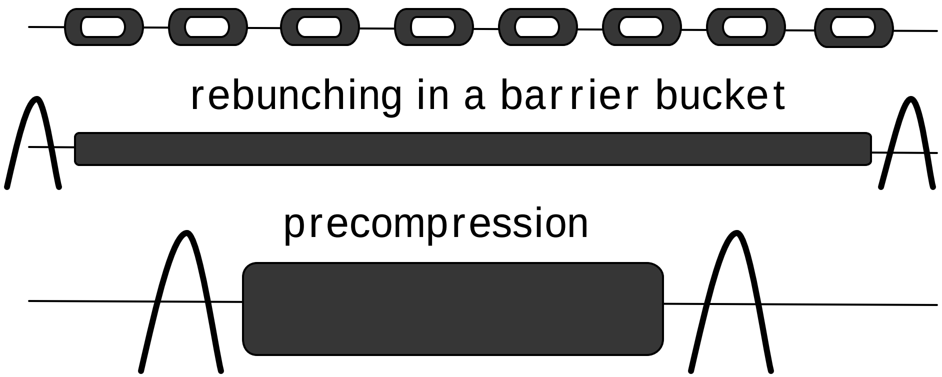
Dynamic pressure below $5x10^{12}$ mbar requires < 1 %

U^{28+} RF Bunch Gymnastics in SIS 100

Injection and acceleration of (hollow) bunches

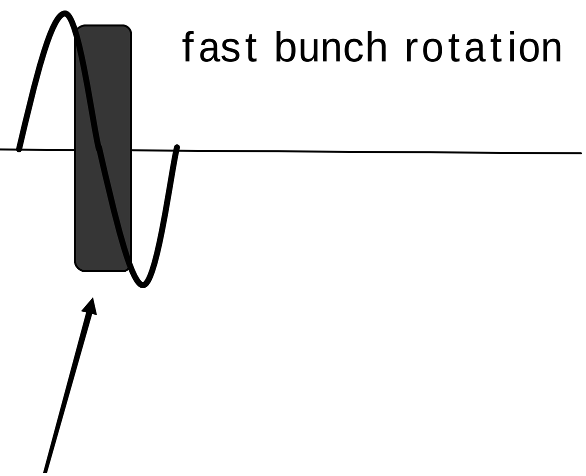
rebunching in a barrier bucket

precompression



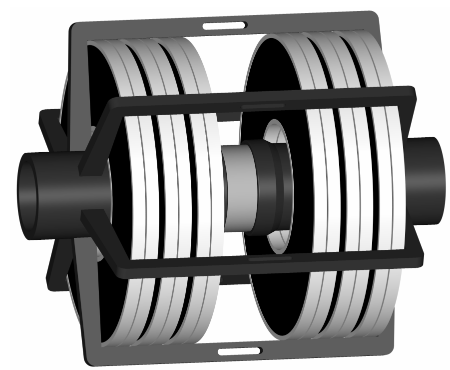
fast bunch rotation

$\Delta Q_{RL} \approx -1.0$



Key Issues:
Losses < 1% and
Dilution Factor < 2 !

26 compressor cavities (20 m) filled with high-μ cores:



40 kV/m
500 kHz

+ about 20 'normal' acceleration cavities

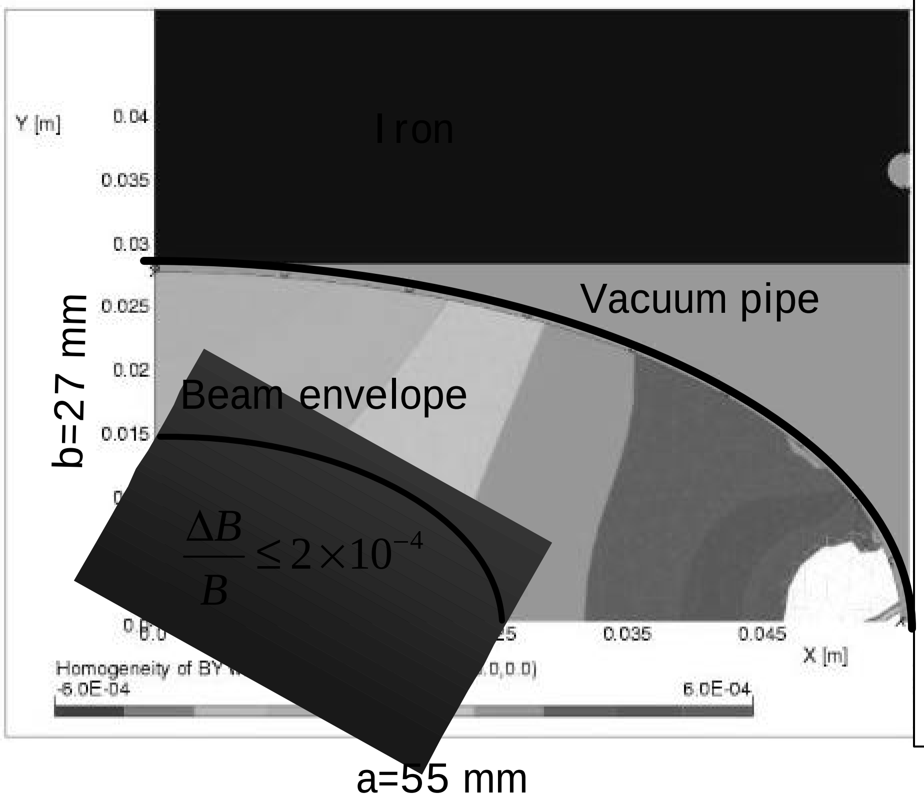
= 1 MV total !

10^{12} U^{28+} 1 GeV/u 50 ns ⟹ $P_{max} \approx 1$ TW ⟹

Beam loss budget:
- Projectil range in steel ≈ 1 cm

Nonlinear Magnet Fields and Beam Loss

SIS 100 dipole field errors + aperture:



(Horizontal) betatron equation of motion:

$$x'' + k_x(s)x = \frac{\Delta B_y}{RB_0} + \frac{F_x^{sc}}{\gamma m \beta^2 c^2}$$

linear betatron motion — nonlinear magnet errors — nonlinear space charge force

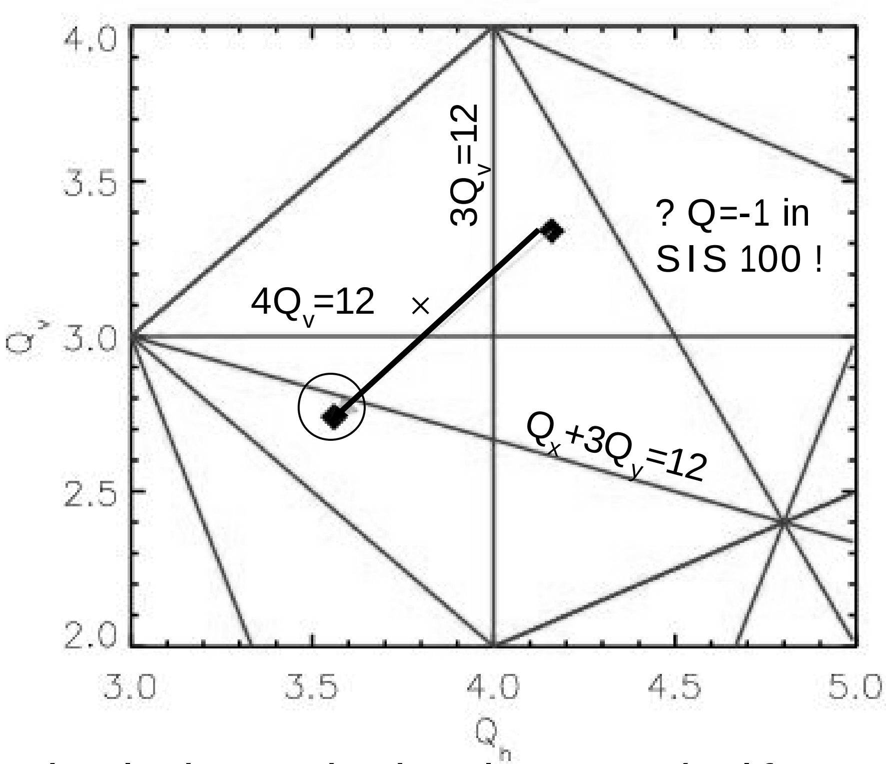
Long term stability (T=1 s):

$$x(t \rightarrow T) < a, \quad y(t \rightarrow T) < b$$

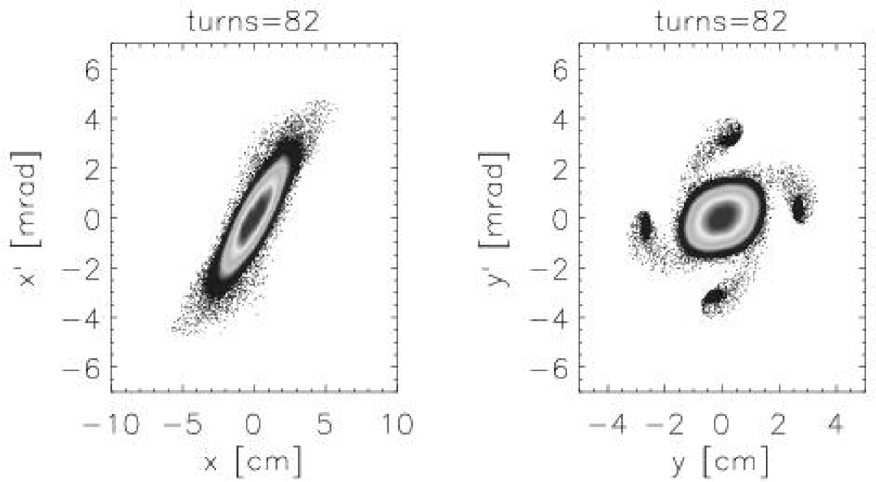
Key issue: Can we store a (thick) beam for 1 s (10^5 turns) in a nonlinear machine with space charge ?

Bunch compression in SIS 18/100

Space charge induced crossing of structure resonances in SIS during fast (100 turns) bunch compression:



2D (!) Simulation of fast bunch compression.



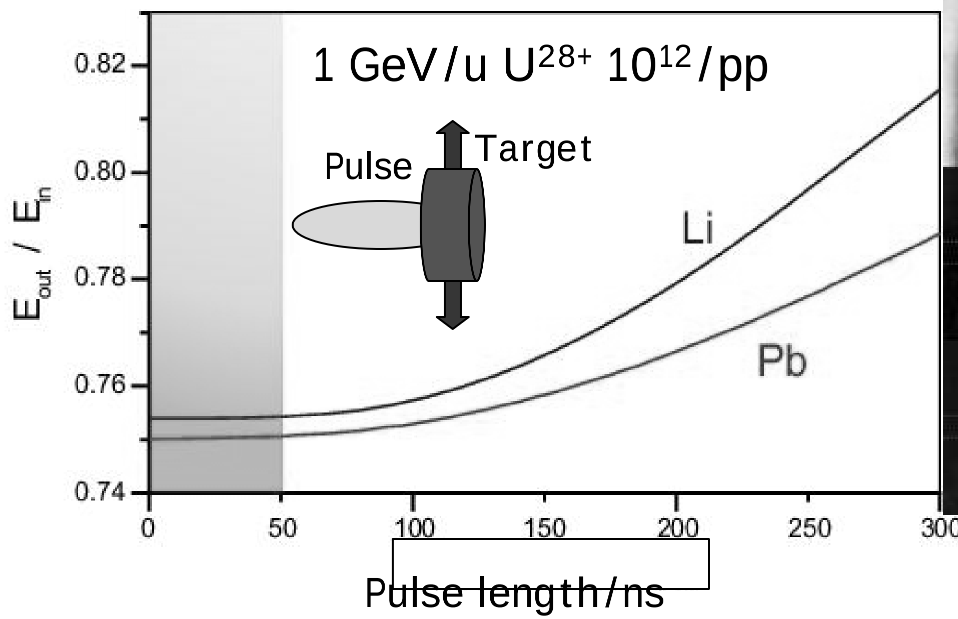
Key question:
bunch compression with losses < 1%

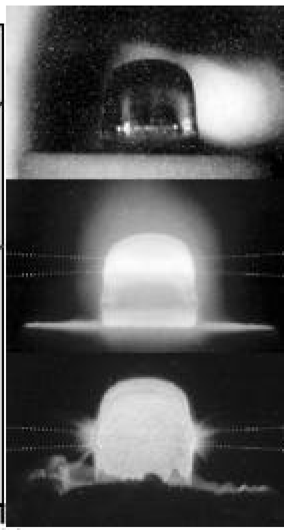
3D Simulation code development (self-consistent space charge) has been started !

High-Power (TW) Exotic Ion Production Target

Injection of secondary beams into the collector ring (CR) requires primary beam puls length $\tau < 1\mu s$ and $d \sim 1$ mm on the target !

Problem:
Hydrodynamic expansion of the target





Plasma physics targets

Solution (?):
✓Pulse length shorter <u>50 ns</u>
✓Target recovery with 1 Hz (liquid Lithium)

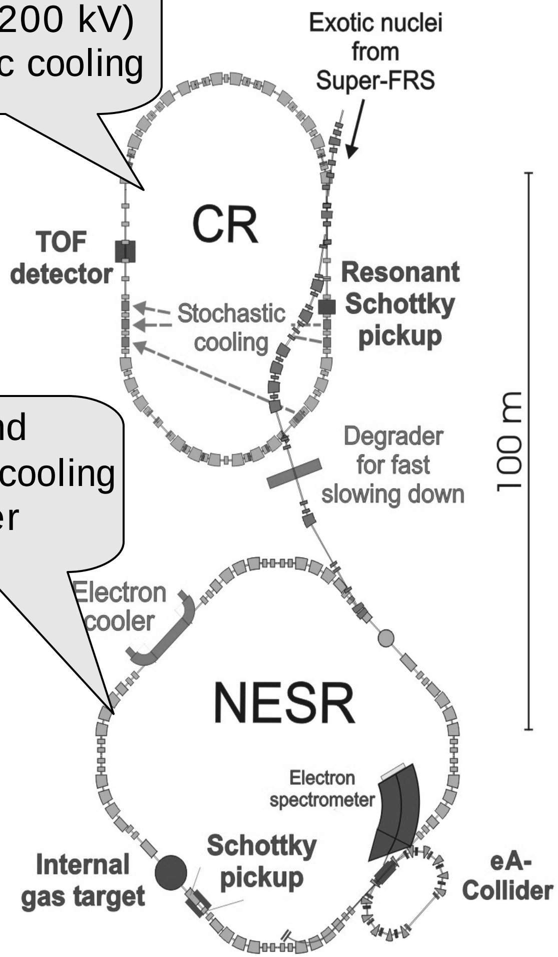
Collector and Accumulator Rings for Exotic Ions

from Target/SFRS

5 ‘decompressor’ cavities (200 kV) + stochastic cooling

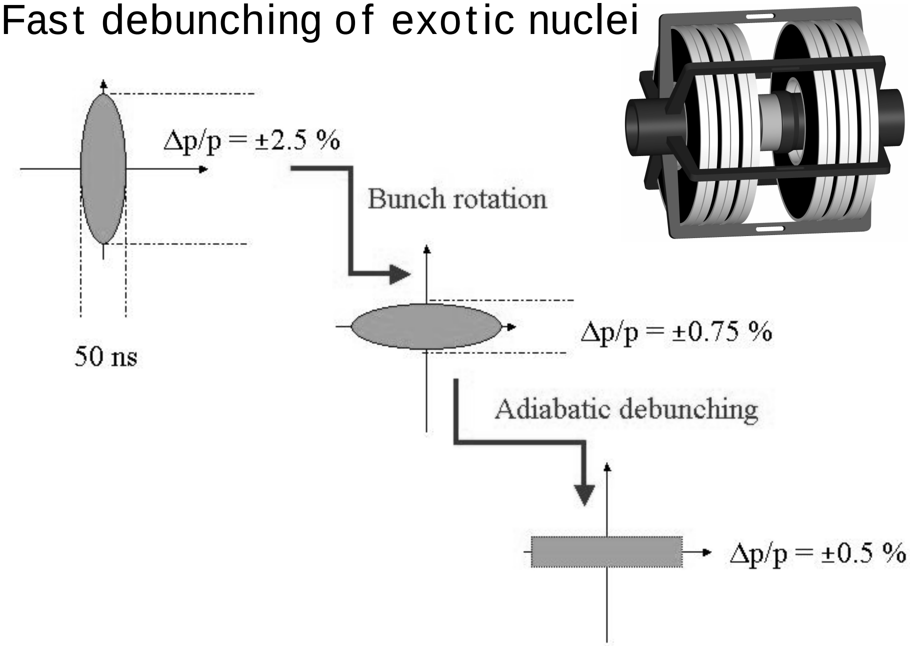
180 m circumference

Electron and stochastic cooling + eA collider



210 m circumference (approx. 2xESR)

Fast debunching of exotic nuclei

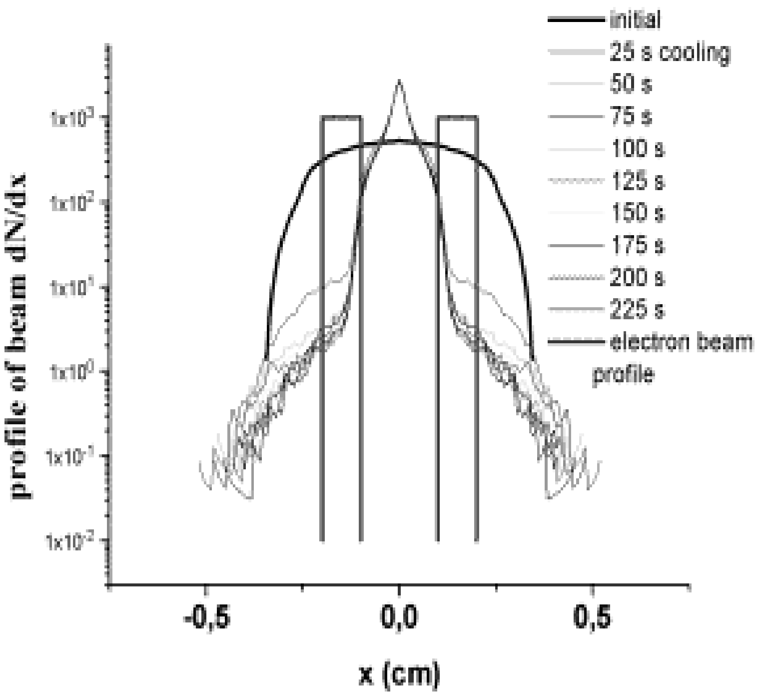


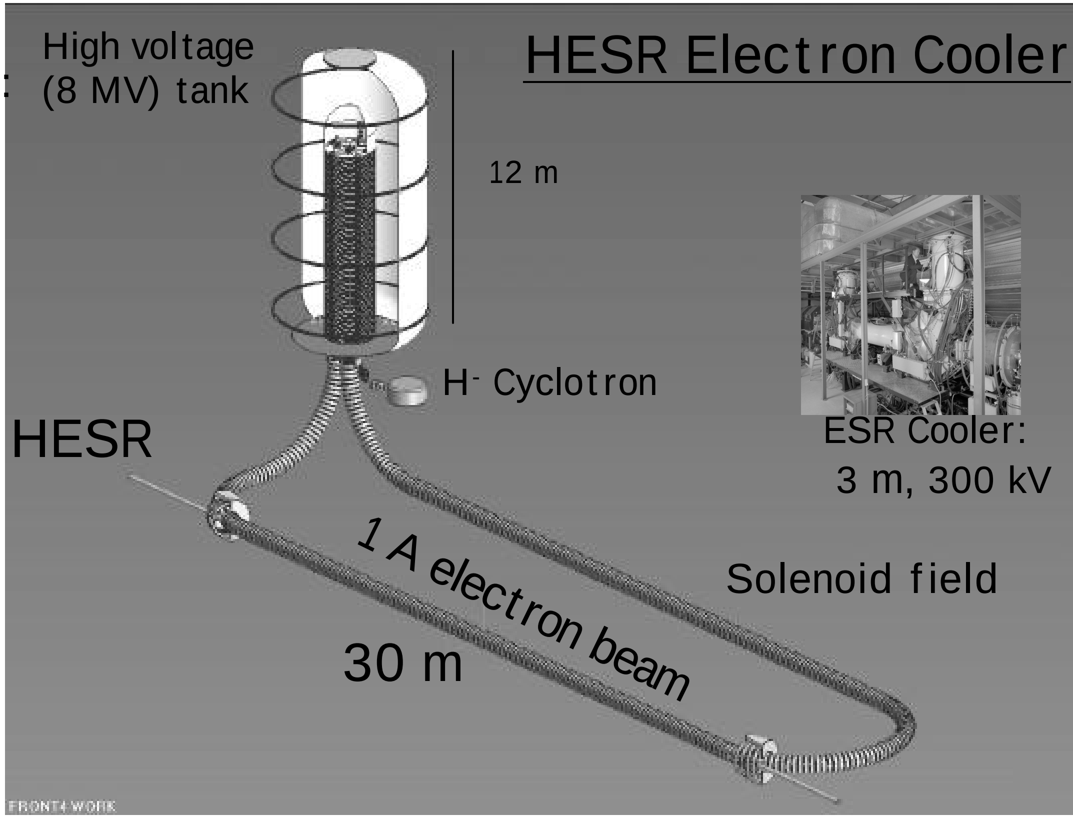
CR+NESR: 2x24 large aperture (±180 mm) superferric (1.6 T) dipole magnets

Control of Antiproton Beam Quality at High Energies

Feasibility study of fast electron cooling for the HESR, Budker Institute, Novosibirsk, RUS

Monte-Carlo-Simulation of pbar cooling:



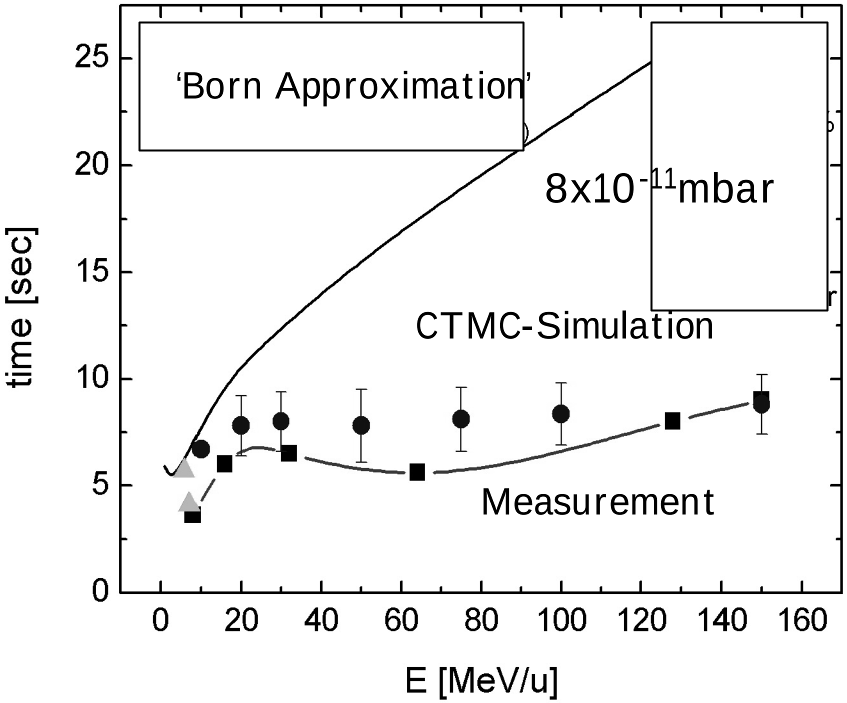


U^{28+} Lifetime and UHV Requirements

Projectile-Stripping in the residual gas:

$$U^{28+} + X \rightarrow U^{(28+j)+} + X^{m+} + (m+j)e$$

U^{28+} Beam lifetime measurements in SIS:



Scaling of the stripping cross section:

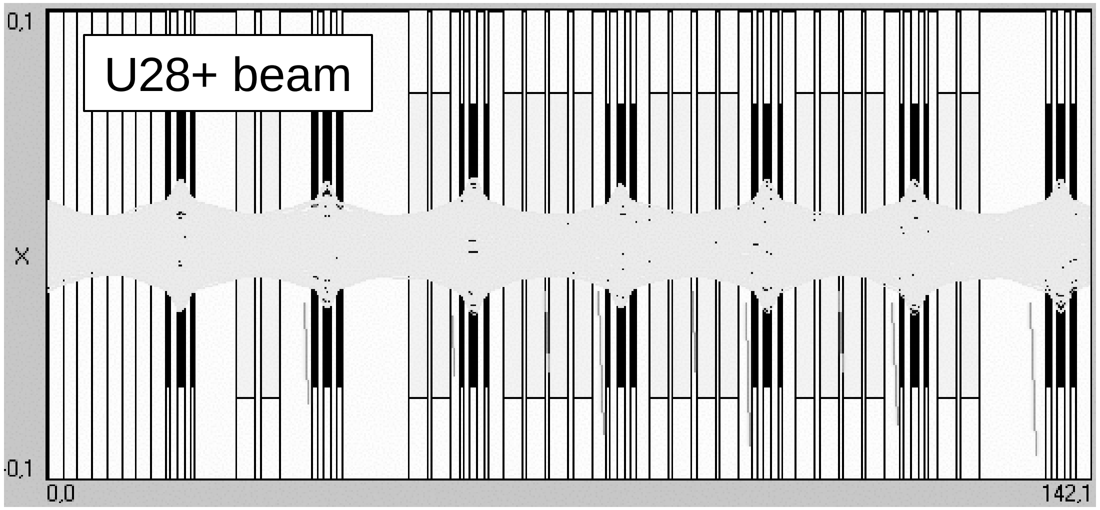
$$s \propto \frac{n_X}{Z_p^{1.4} E_p^{1/2}}$$

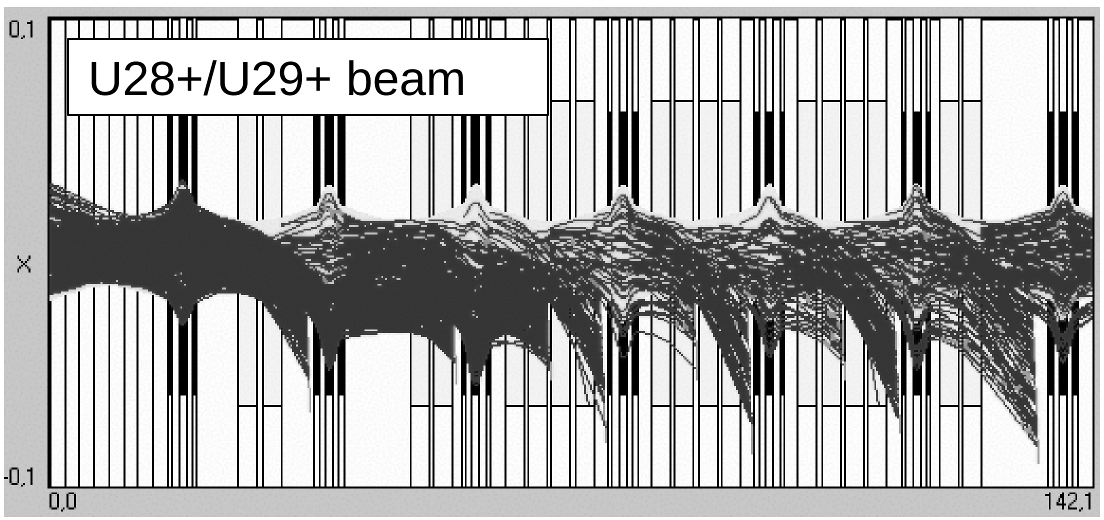
U^{28+} operation with 1 % stripping loss means:

10 s lifetime in SIS (4 Hz) or $P=5\times10^{-11}$ mbar

100 s lifetime in SIS 100/300 (T= 1 s)
or $P=5\times10^{-12}$ mbar

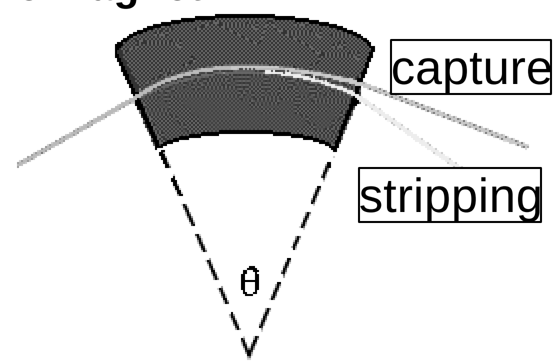
Beam Loss Distribution in SIS 100





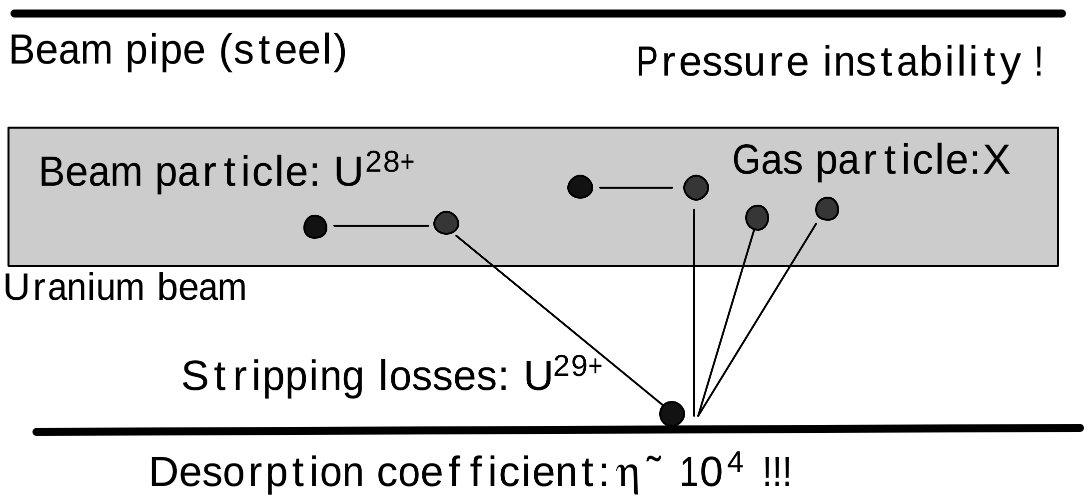
P. Spiller (2003)

Dipole magnet



U^{29+} corresponds to a momentum offset of dp/p=-3.5 %

Dynamic-UHV in SIS 18/100/300



Threshold for pressure instability in SIS 18:

$$\eta I < \frac{S}{L}\frac{q}{s} \Rightarrow N < 1-2\cdot 10^9$$

Mustafin, et al. (NIM A, 2003)

Dynamic pressure limit in SIS 100/300:

$$\eta \dot{N} < S\frac{\Delta P}{k_B T} \Rightarrow \dot{N} \leq 10^{10} \Rightarrow 1\%$$

($\eta=10^3$, S/L=100 l s^{-1} m^{-1}, $\Delta P=5\times10^{-12}$ mbar)

talk (canceled) by Edil Mustafin: Modeling

Control of dynamic UHV in SIS 18/100/300

- Short cycle time and short sequences

  SIS12 :10 T/s - SIS100 : 4 T/s

- Enhanced pumping power (talk by H. Reich)

  Cryo pumps/panels, NEG coating/stripes

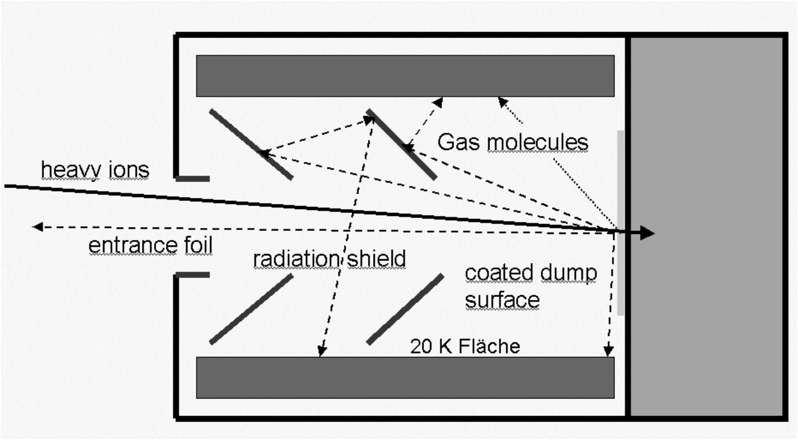
- Localization of losses and controle of desorption gases

  Prototype desorption collimator installed

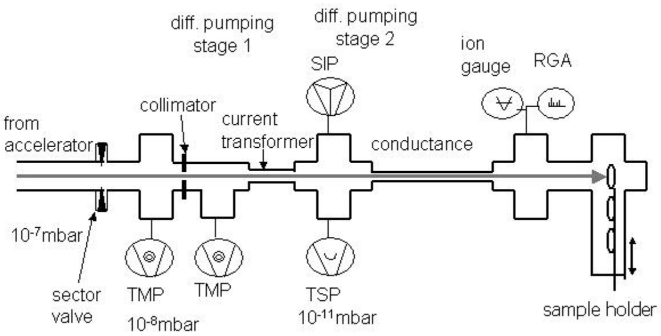
- Low-η materials (talk by A. Krämer)

  Desorption rate test stand comissioned

Novel collimators



Desorption test-stand



‚R&D Challenges'

Fast ramping SC magnets:
extremly demanding

RF systems:
at the limit of technical feasibility

Control of dynamic vacuum (UHV):
at (or presently even beyond) the limit

Control of beam loss/collective effects:
extremly demanding, many open questions

Fast stochastic/electron cooling:
at the limit of technical feasibility

Talks during the workshop:

Andreas Krämer
(SIS 18 measurements+
desorption teststand)

Hartmut Reich
(UHV design)

Edil Mustafin
(Dynamic vacuum modeling)