SIS100 beam loss mechanisms and corresponding machine protection

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SIS100 beam parameters & lattice

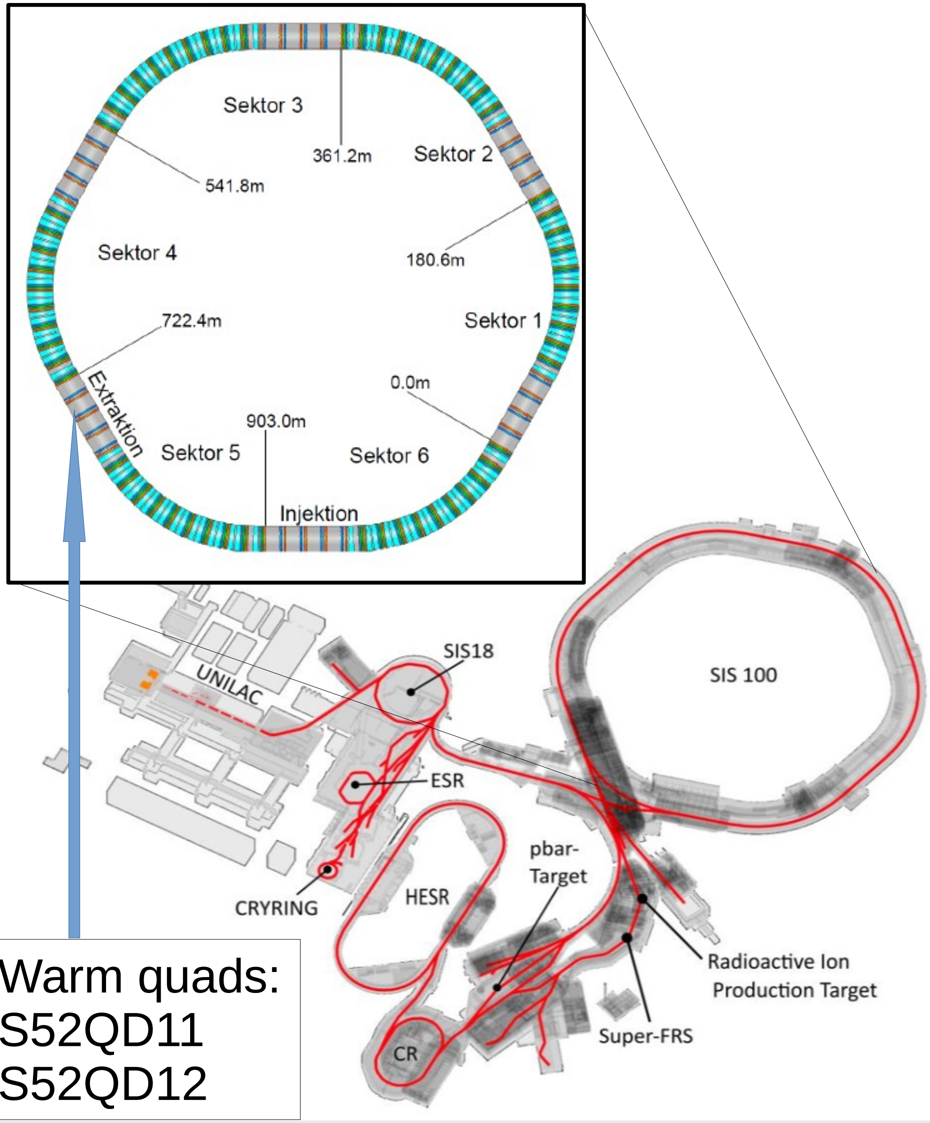
INJECTION

	Protons	U28+
Energy, MeV/u	4000	200
Ions per cycle	2.5e13	5.0e11
RMS_Emittance_x	3e-6	9e-6
RMS_Emittance_y	1e-6	4e-6
delp_rms	1.5e-3	0.5e-3
Stored energy, kJ	16	3.8

EXTRACTION

	Protons	U28+
Energy, GeV/u	29	1.5
RMS_Emittance_x	0.5e-6	2.6e-6
RMS_Emittance_y	0.2e-6	1.1e-6
Stored energy, kJ	116	28.6

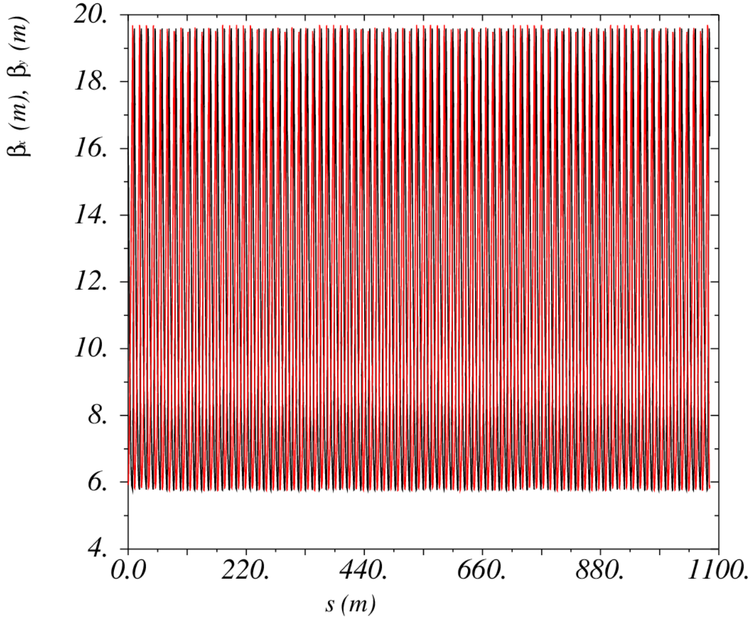
Momentum acceptance 5e-3



Warm quads:
S52QD11
S52QD12

SIS100 beta functions (Qx=18.84, Qy=18.73)

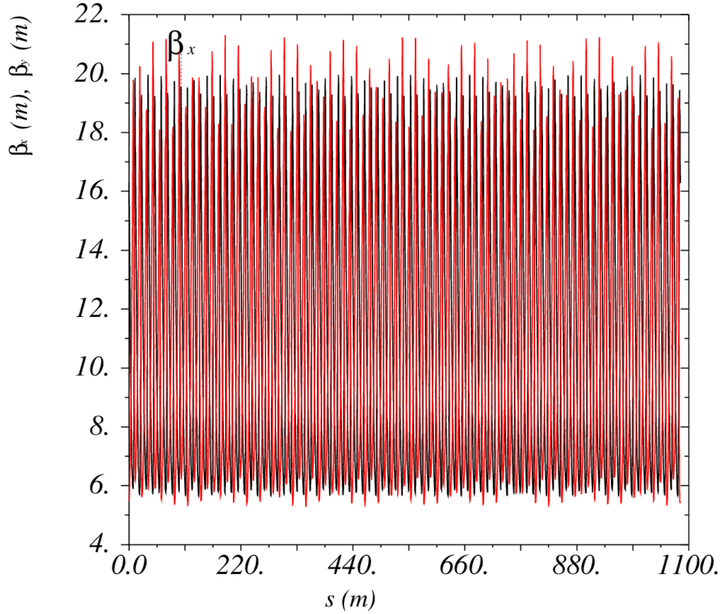
If SIS100 had only cold quadrupoles:



Horizontal aperture bottleneck: 3.8*σ_{xRMS}

Vertical aperture bottleneck: 2.9*σ_{yRMS}

2 warm quads (F & D) in sector 5:



Horizontal aperture bottleneck: 4.5*σ_{xRMS}

Vertical aperture bottleneck: 3.2*σ_{yRMS}

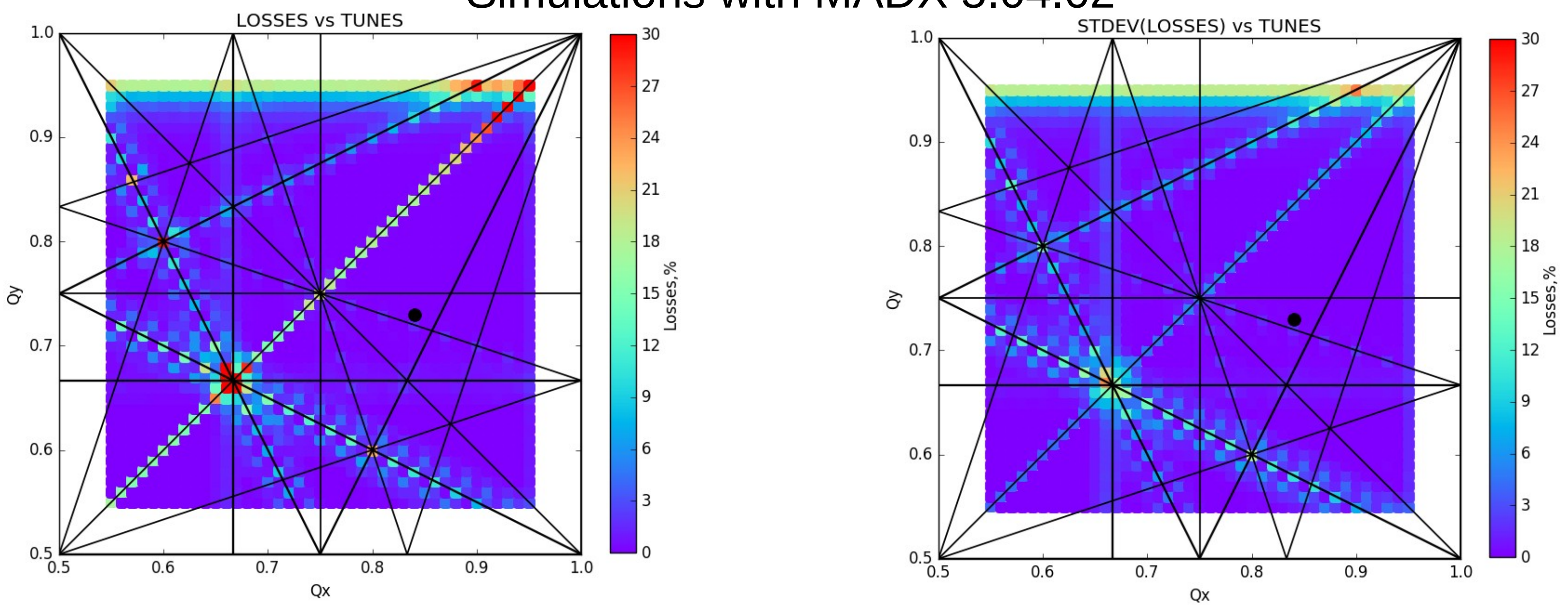
- „Beta-beating“ between all-cold and actual lattice depends on the settings of the warm quadrupoles

SIS100 with magnet errors (no space charge)

- Dipole errors are taken from the magnet measurements
- Quadrupole errors are taken from the model assumptions
- Several error ensembles are considered

Tune scan for the Working Point region 18.55 – 18.95

Simulations with MADX 5.04.02



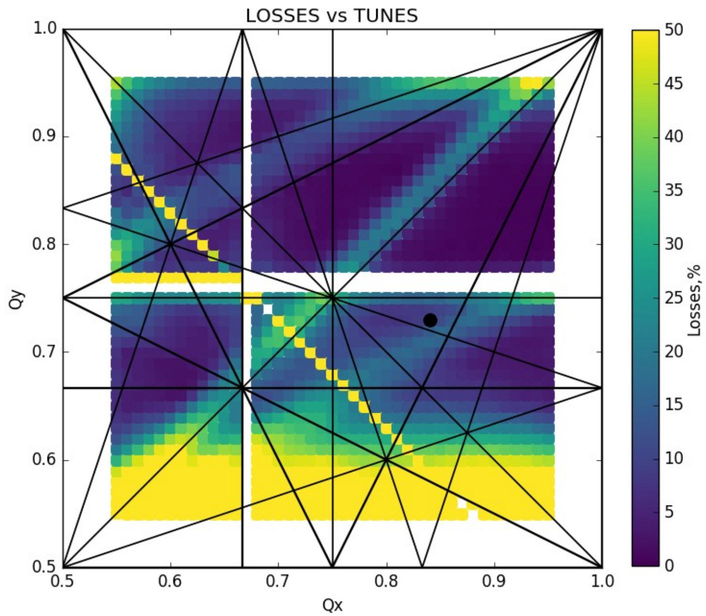
No Space Charge: Beam losses for (18.84, 18.73) working point: 0.1±0.1%

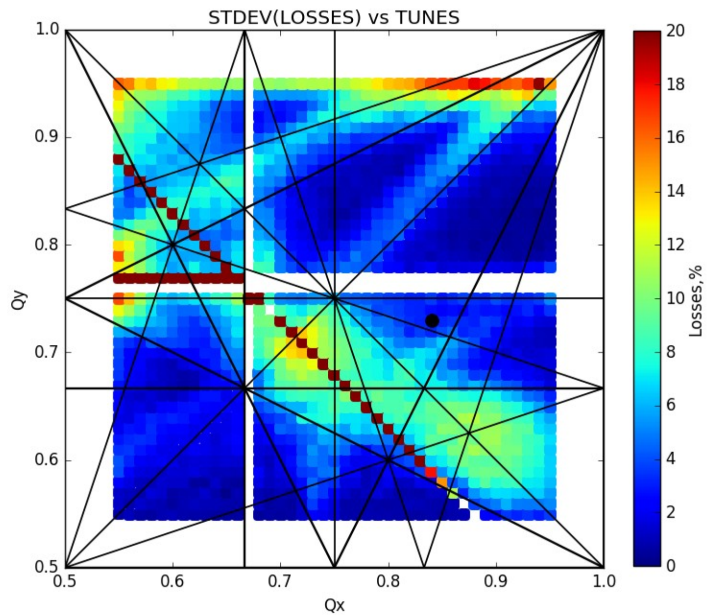
SIS100 with errors and with space charge

- U28+ at 200 MeV/u
- Particles per bunch 6.25e10

Tune scan for the Working Point region 18.55 – 18.95

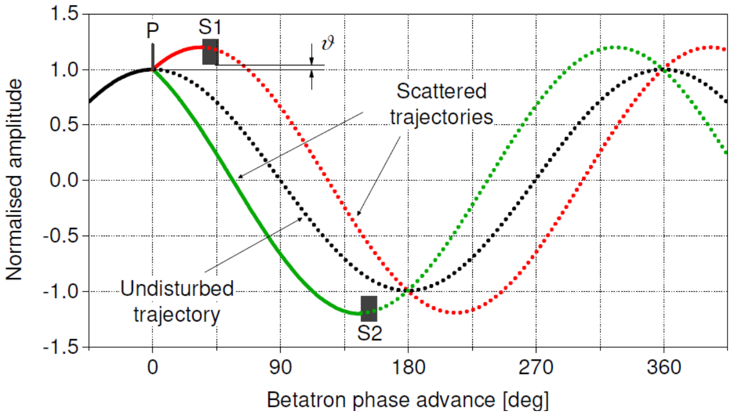
Preliminary results of simulations with MADX 5.04.02



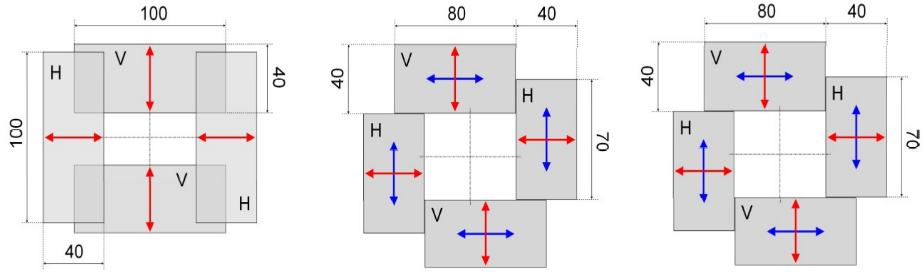


Space Charge: Beam losses for (18.84, 18.73) working point: 9±3%

Halo collimation

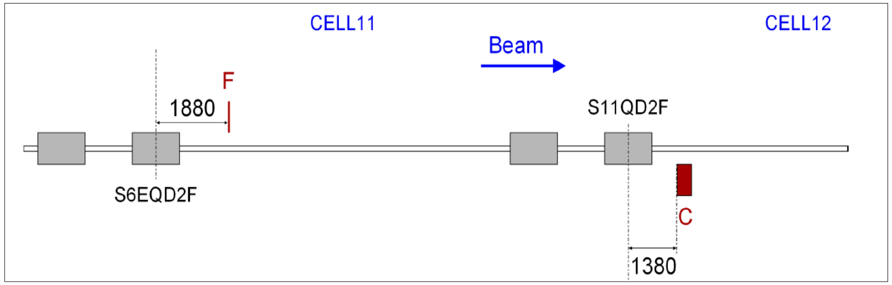


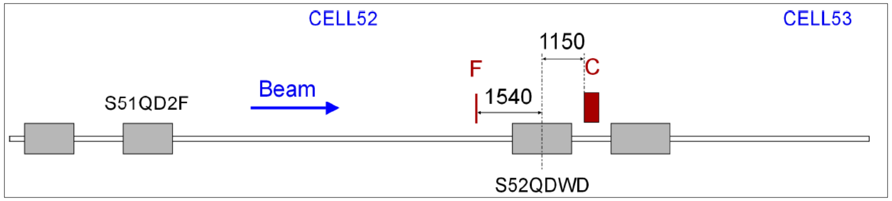
Foil | 1. absorber | 2. absorber



- Red arrows - the movement direction using stepping motors.
- Blue arrows - the movement direction for a manual adjustment of the collimator jaws. All dimensions are in mm.

Locations of halo-collimators in SIS100

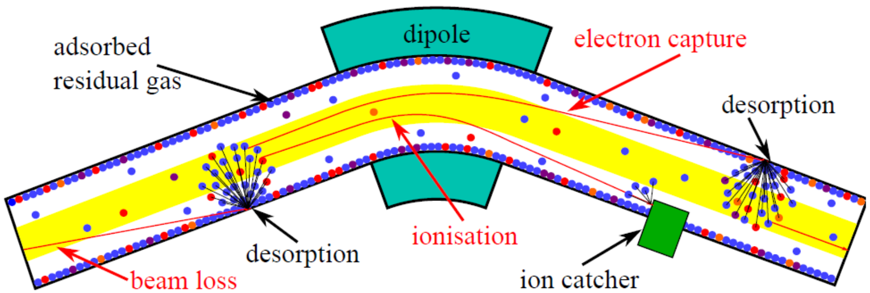




- Foil parameters:
  Thickness <1 mm
  Material: Tungsten
- Absorbers:
  Dimensions: 50cm x ~8 cm x ~3 cm
  Material: Tungsten /Densimet

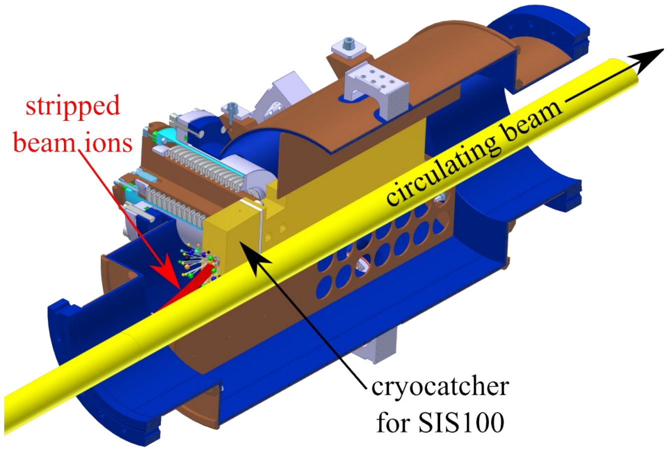
[I.Strasik, Halo collimation report, 2017]
[L.Bozyk, *Parameter der verschiedenen Halo-Kollimations Systeme im SIS100*]

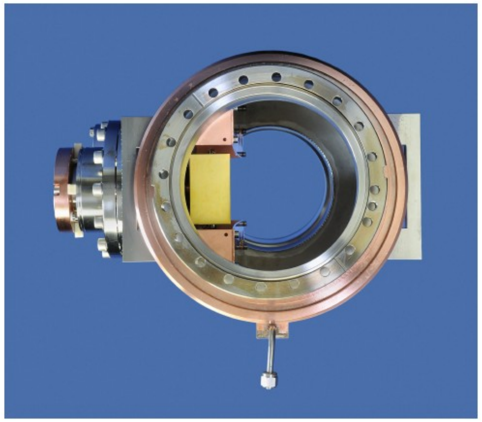
Ionization beam losses and mitigation



Principle of ionization loss and dynamic vacuum

- High electron-loss cross section (with residual gas)
- Lost particles create avalanche due to desorption
- SIS100 lattice is designed to have the loss distribution localized between the quadrupoles where the ion catcher will be installed



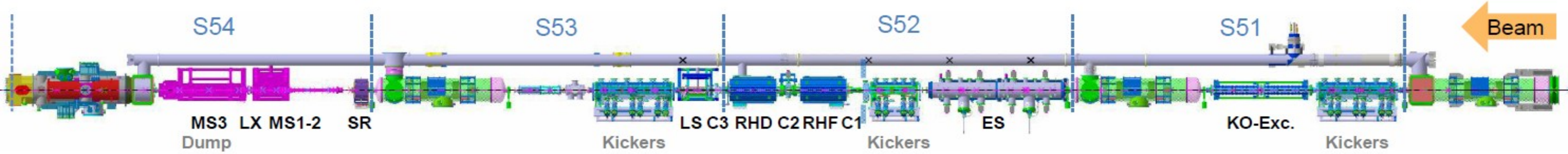


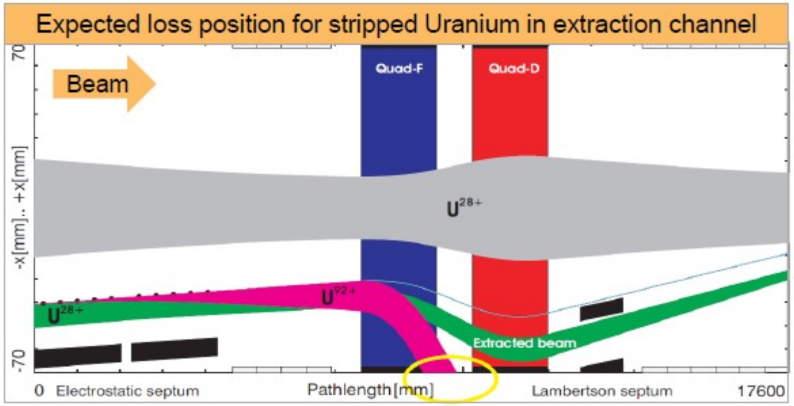
FoS cryocatcher

Low desorption surface is coated with gold and nickel diffusion barrier

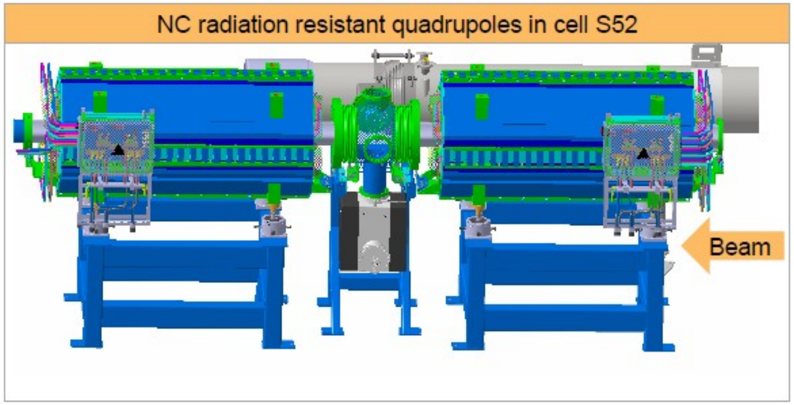
[L.Bozyk et al., Laser and Particle Beams, doi:10.1017/S0263034616000240]
[L.Bozyk, in Proc. of IPAC 2017 and IPAC 2018]

Warm quadrupoles in extraction section





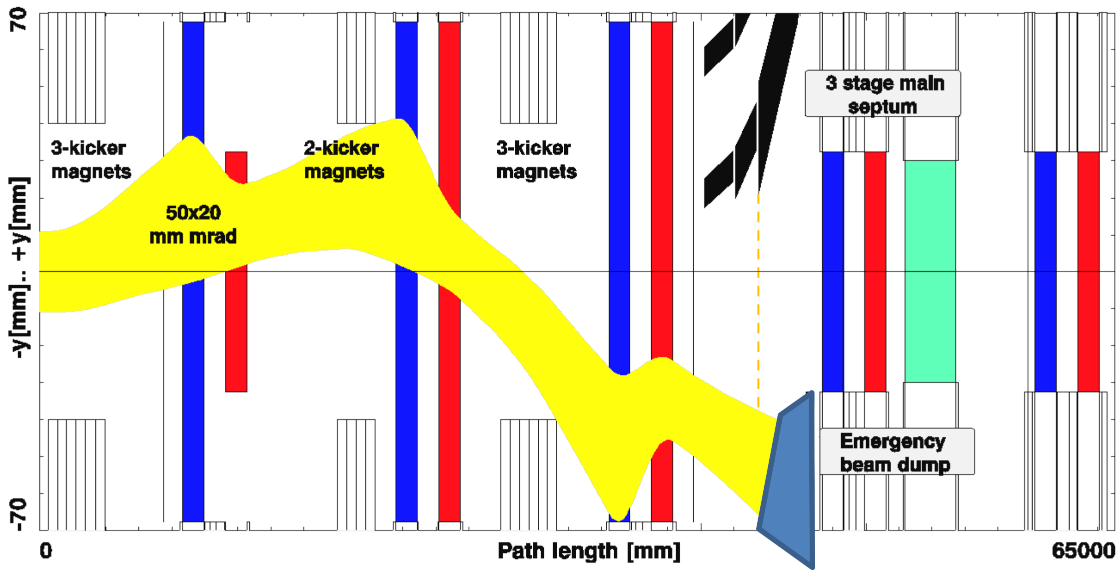
- Energy deposition in the quads of S52 is too high to keep them superconducting
- Control of activation hot spots
- Replacement by two separately powered normal conducting quadrupoles
- Increased aperture for slow and fast extracted beam
- Collimation of losses necessary

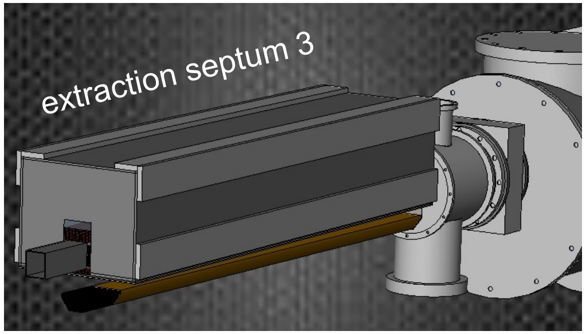


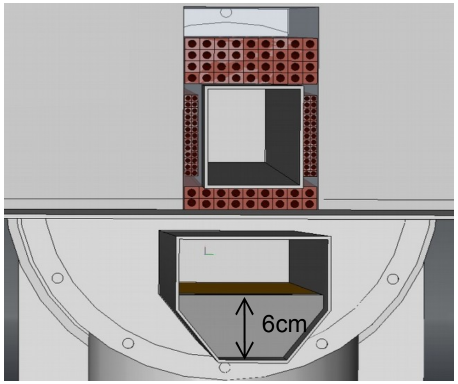
[SE WS / SE at GSI and FAIR / D. Ondreka 09.Dec.17]

Internal emergency dump

- Fast kicker magnets can extract the full synchrotron load within one turn
- Target: internal beam dump at the end of the extraction straight section
- Up to E = 51.5 kJ may be deposited within 3 μs
- Emergency dump with length of ~ 2 450 mm
  - use special chamber of lower part of magnetic septum #3
  - 20 cm graphite in front
  - 225 cm absorber (W, Ta, ...)







[F.Hagenbuch, MAC8, 2012]
[C.Omet, MAC10, 2013]

Summary & conclusions

- SIS100 working point studies are still being continued, taking into account measurements of the magnet field errors. Data on qudrupoles is still missing.
- Various loss mechanisms and respective mitigation techniques are considered:

Loss mechanisms:

- ✓ Magnet errors and misalignments
- ✓ Space charge effects
- ✓ Ionization beam losses

Mitigation techniques:

- ➢ NC quads at extraction section
- ➢ Halo collimation system
- ➢ Internal beam dump
- ➢ Cryocatchers

Acknowledgements

This talk included studies of many people from Accelerator Beam Physics and SIS18/SIS100 System Planning departments:

- Ionization beam losses + Cryocatchers: L.Bozyk, P.Puppel
- Halo collimation: I.Strasik, L.Bozyk, D.Ondreka
- Internal beam dump: D.Ondreka, C.Omet, F.Hagenbuck, N.Pyka
- Slow extraction: S.Sorge, D.Ondreka