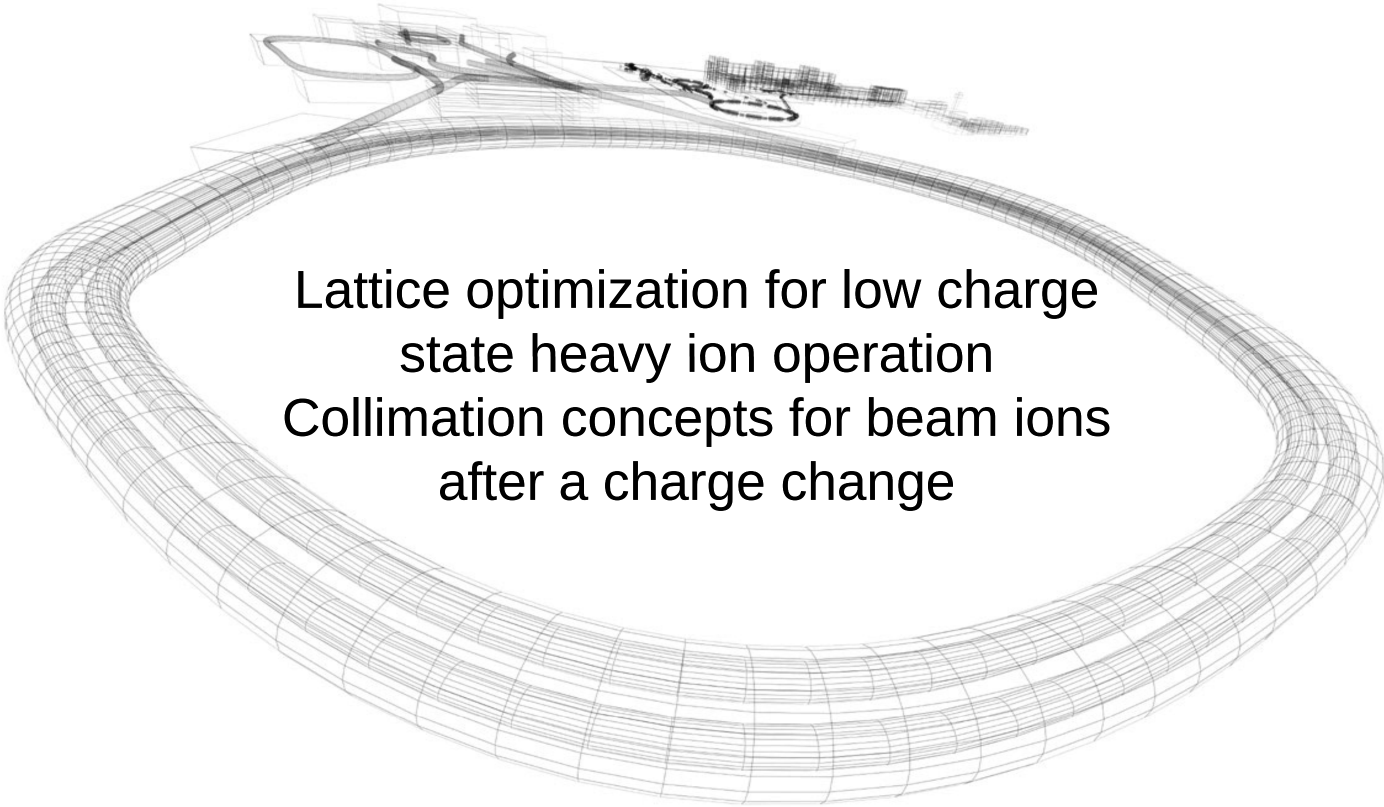

Lattice optimization for low charge state heavy ion operation
Collimation concepts for beam ions after a charge change

CERN Collimator Workshop 3rd-5th Sep. 2007

Jens Stadlmann, FAIR Synchrotrons

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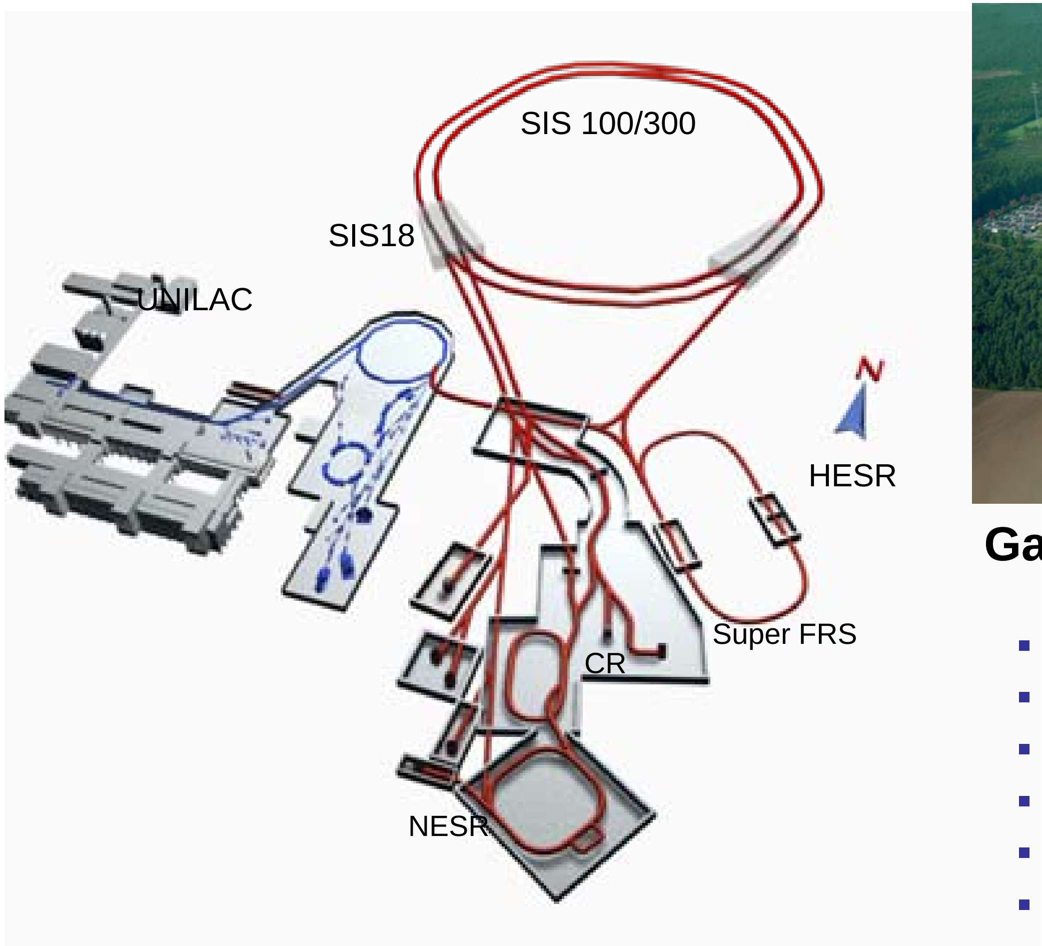
- Benchmarking of different lattice concepts for SIS100
- Conclusion

The Future Accelerator Facility - FAIR

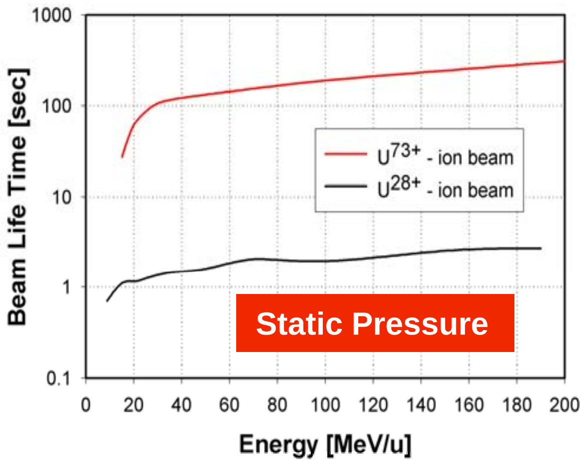


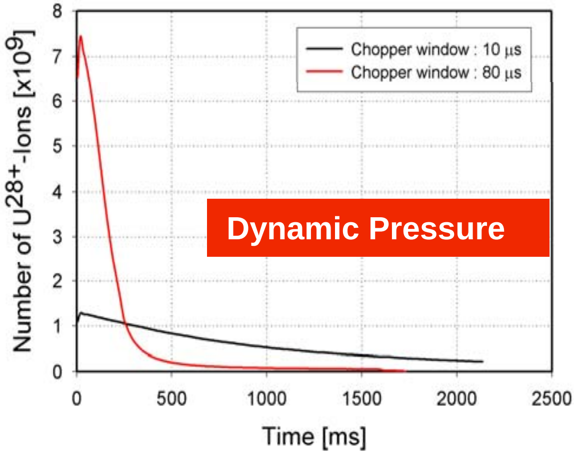
Gain Factors

- Primary beam intensiy : x 100 – 1000
- Secondary beam intensiy : x 10000
- Ion energy : x 15
- New: cooled pbar beams (15 GeV)
- Special : intense cooled RIBs
- Parallel operation and time sharing

Motivation: Beam Life Time in FAIR Synchrotrons

High intensity, heavy ion beams require intermediate charge states



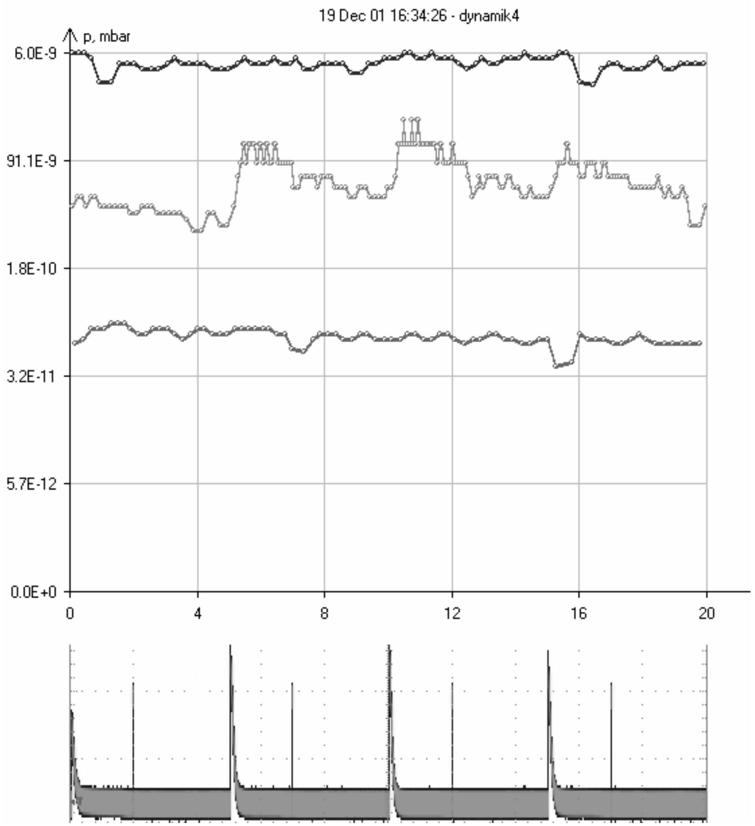


- **Life Time of U^{28+} is significantly shorter than of U^{73+}**
- **Life Time of U^{28+} depends strongly on the residual gas pressure and gas components**

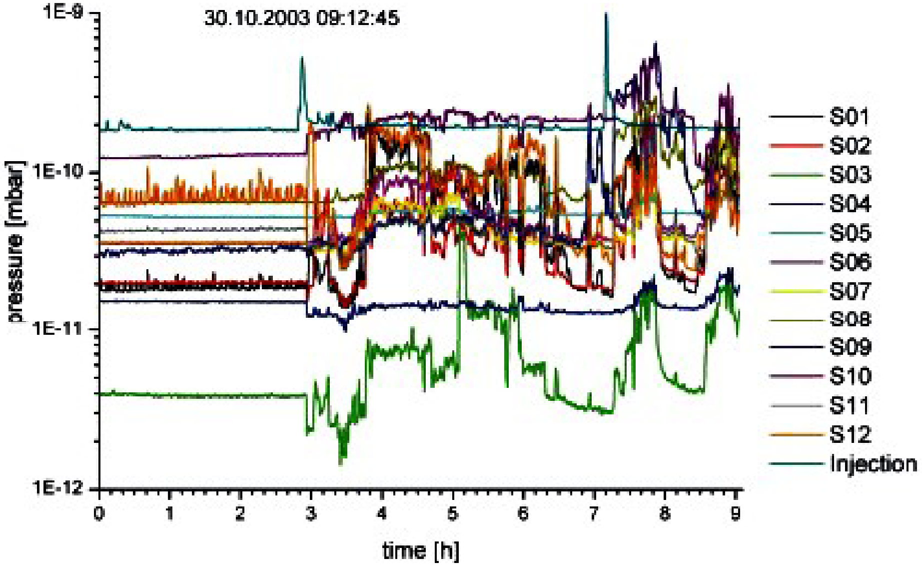
- **Desorption Processes degenerate the residual gas pressure**
- **Beam losses increase with number of injected ions (vacuum instability)**

Residual Gas Pressure Dynamics

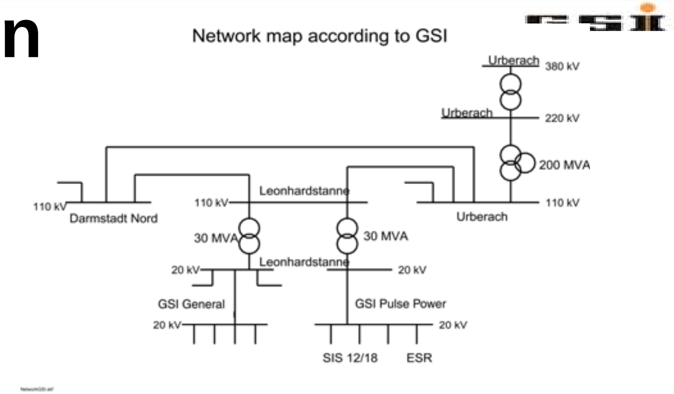
Fast variations (time scale ms)
up to two orders of magnitude



Slow variations (time scale s - h)



Main Issue: Vacuum Stabilization



- **Short cycle time and short sequences**

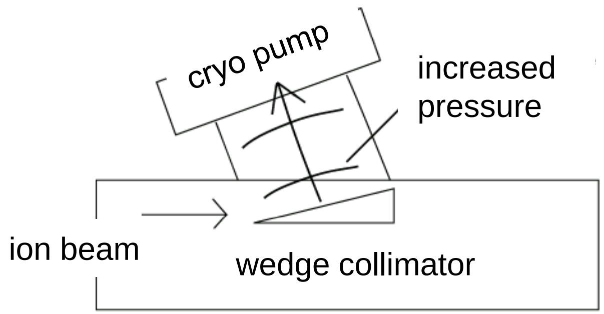
  SIS18: 10 T/s - SIS100: 4 T/s

  (high pulse power > new network connection)

- **High pumping power, optimized XHV spectrum**

  SIS18: NEG coating (local and distributed)

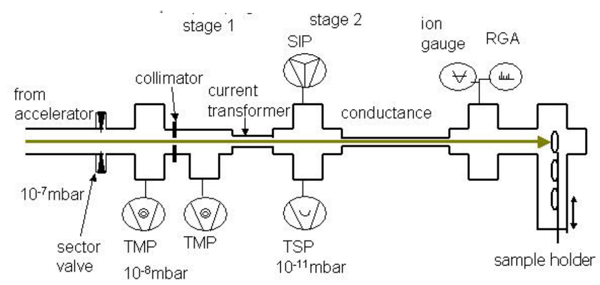
  SIS100: Actively cooled magnet chambers 4.5 K



- **Localization of losses and control of desorption gases**

  SIS18/SIS100: Desoprtion Scrapers

  SIS100: Optimized lattice structure

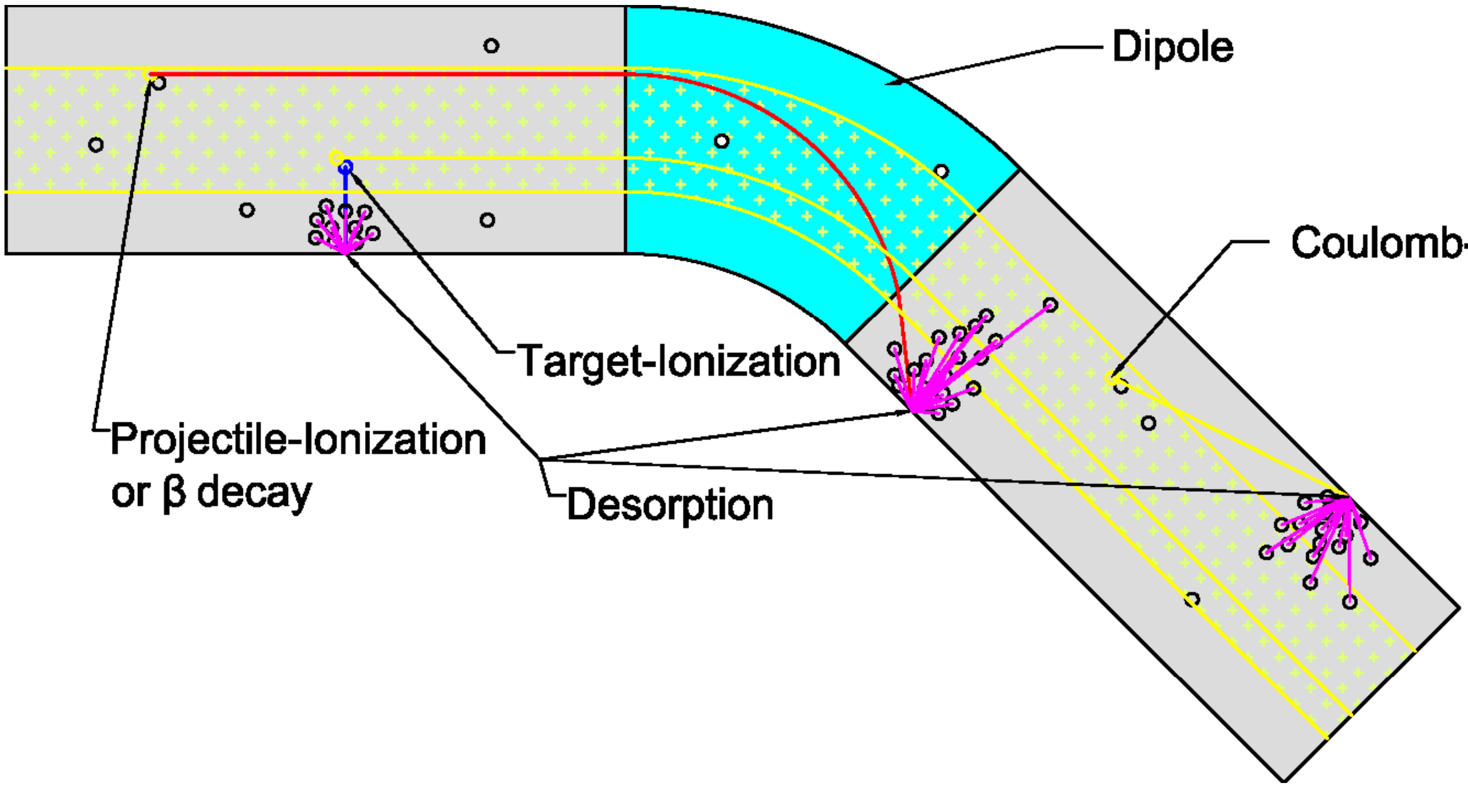


- **Low-desorption rate materials**

  Desorption rate and ERDA measurements

- **Minimization of systematic (inital) losses**

Initial loss mechanisms



Special lattice layout to control the dynamic vaccum

Basic principles

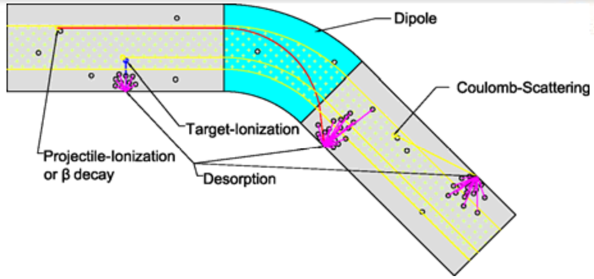
- The ions should not be lost at arbitrary positions.
- The losses should be peaked in sections with sufficient space for a dedicated scraper system
- The scrapers should not reduce the acceptance.
- The circulating beam and the contaminants should be clearly separated at the positions of the scrapers which requires a waist in the beam envelope and dispersive elements upstream.
- Ideally all unwanted ions which are produced in the downstream section after one scraper should be able to be transported at least to the next collimator. (High tune or increased aperture)

Peaked!

Separated!

Acceptance!

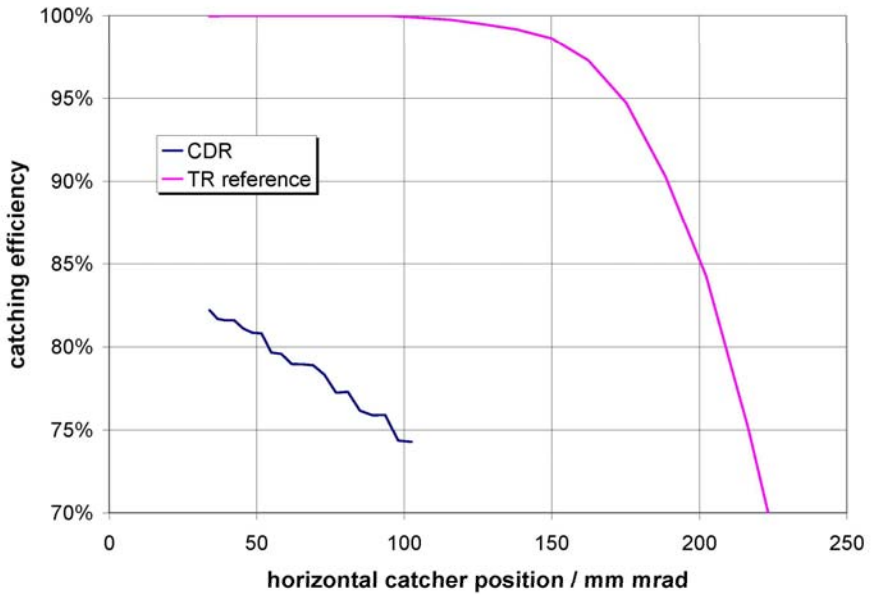
FAIR New Lattice Design Concept for U^{28+}



1. **From all loss mechanisms, only charge change by collisions with the residual gas atoms leads to loss within one lattice cell !**
2. **Each lattice cell is designed as a charge separator. The „stripped“ beam ions (U^{29+}) are well separated from the reference beam. (The low dispersion function in the SIS100 arcs complicate this issue.)**
3. **The main lattice structure optimization criteria is the catching efficiency for U^{29+}-ions.**
4. **The catching efficiency for U^{29}- ions must be close to 100%.**
5. **The 100 % catching efficiency must be achieved with scrapers at maximum distance from the beam edge. No acceptance reduction is caused by the catcher system.**
6. **The ionization beam losses on cold and NEG coated surfaces shall be minimized.**

Minimum additional load for the UHV and the cryogenic system.

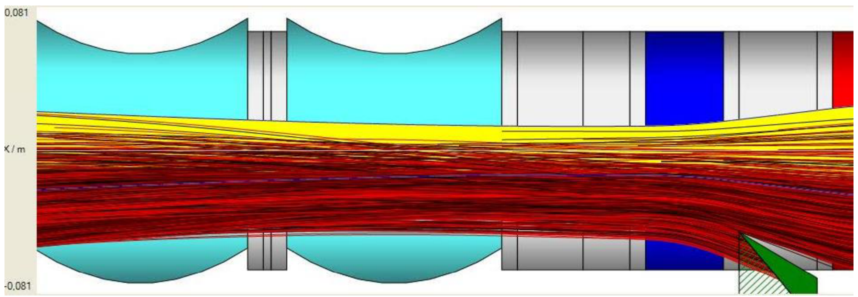
Comparison of Scraper Efficiency



$\eta_{coll} = N_{coll}/N_{total}$

at injection energy

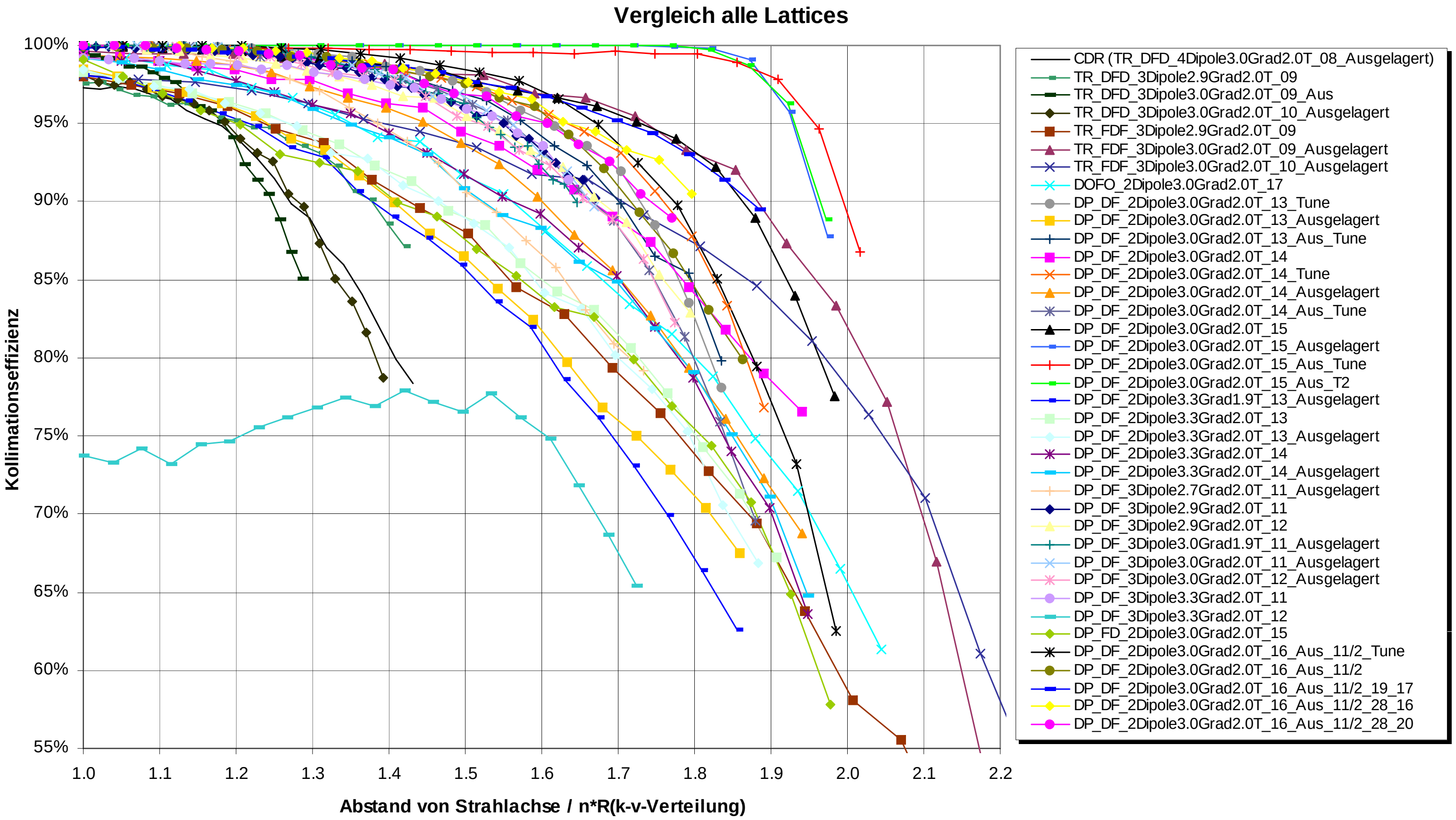
High charge scraping effciency was reached by lattice (cell) optimization. Many lattice structures have been compared.



Strahlsim -> Talk by C. Omet

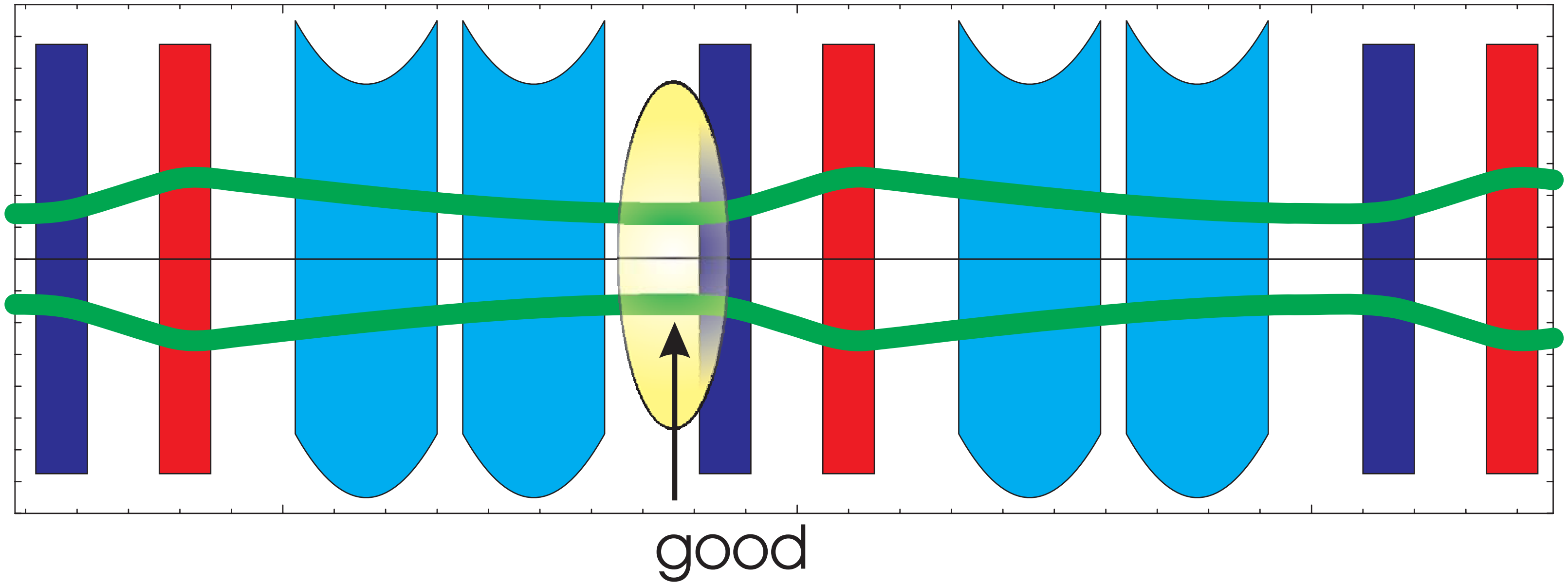
SIS 100 Design I: Lattice Choice and Optimization

Comparison of scraper efficiency of all studied lattices



SIS100 design II, the chosen structure

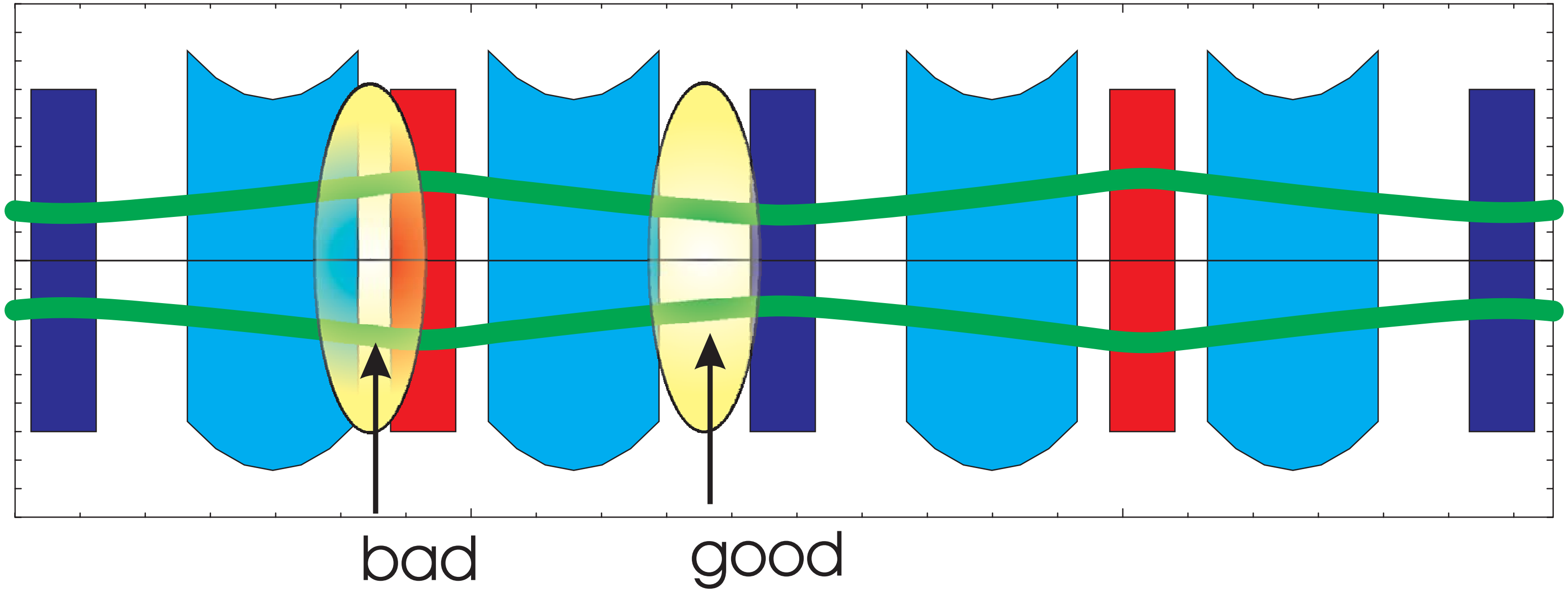
DF doublet lattice



A waist after the dispersive elements.

SIS100 design III

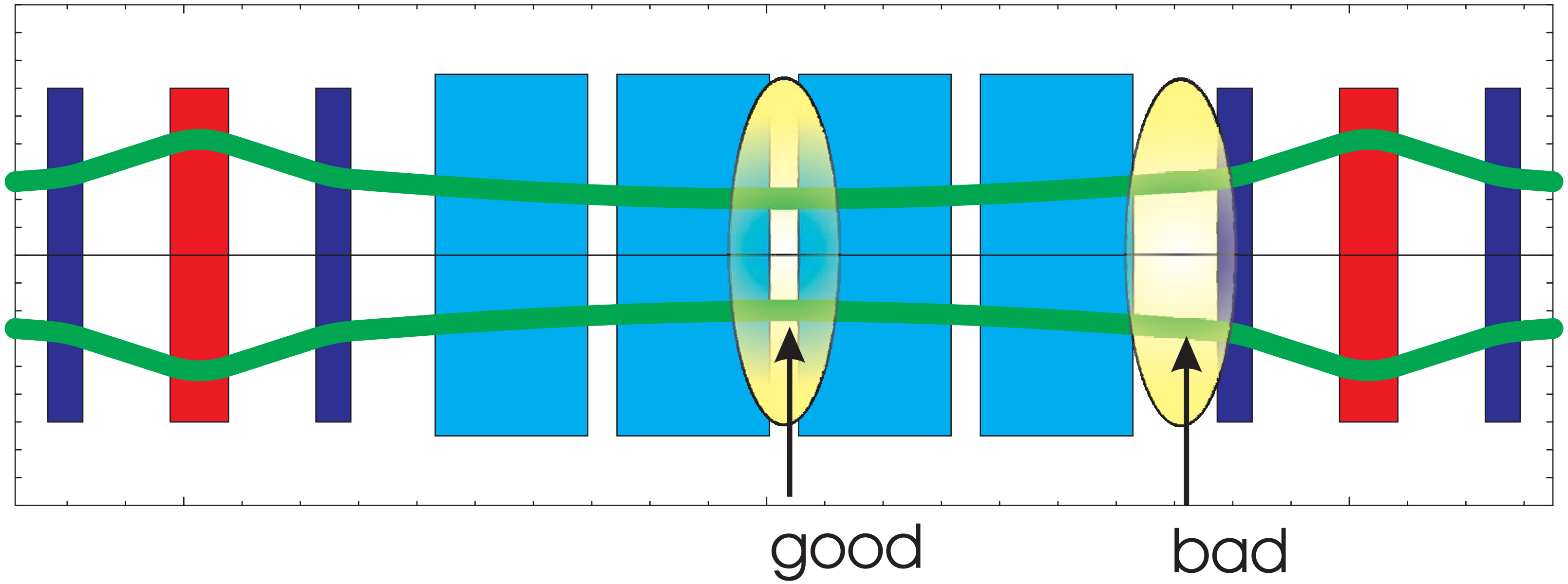
Problematic: FODO structure



One half cell is ok, next one is bad.

SIS100 design IV

Not optimal: triplet structure

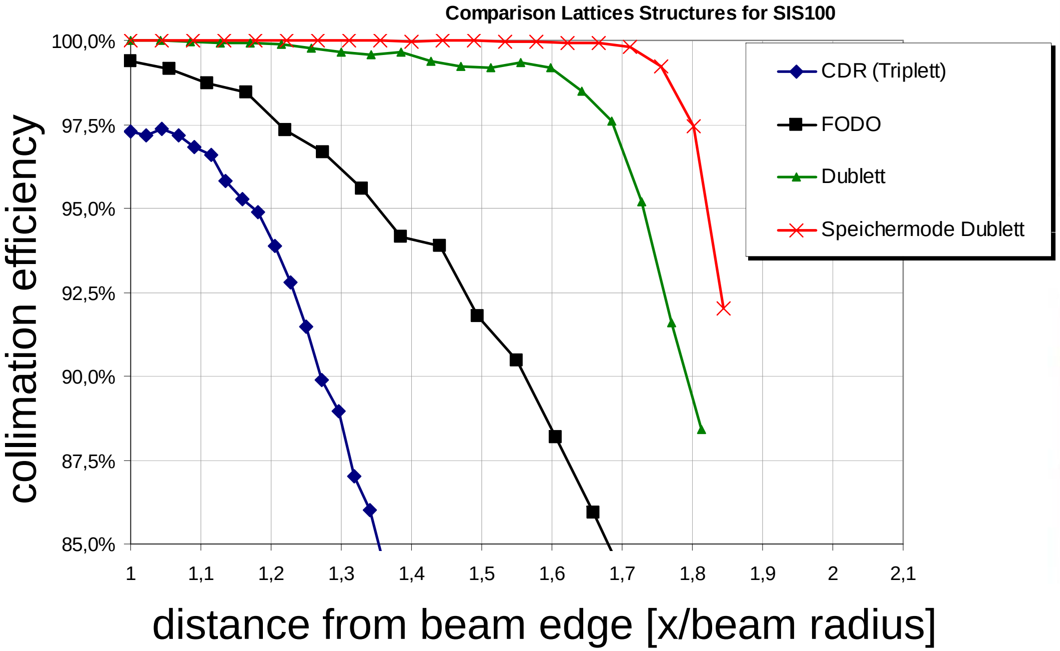


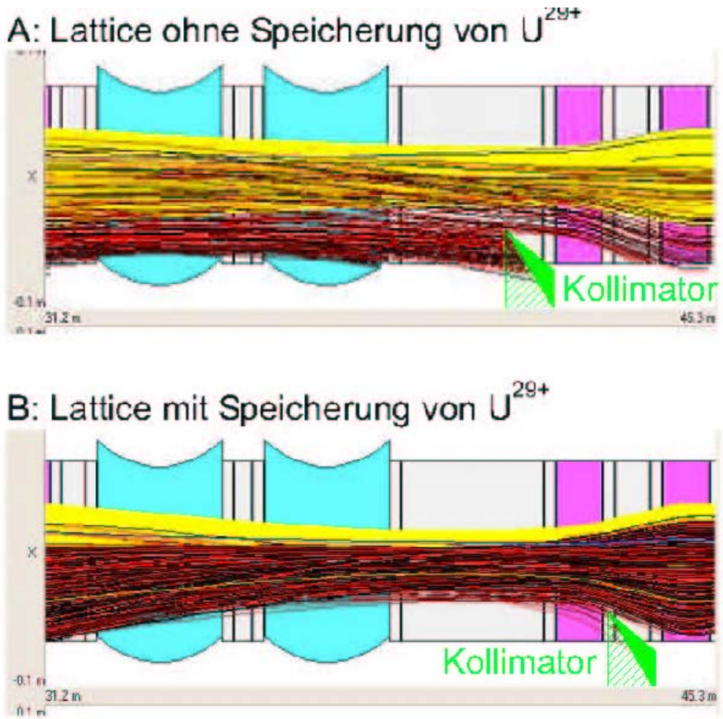
Would work, if all dispersive elements are in the first half of the cell.

FAIR SIS100 design V: Special lattice

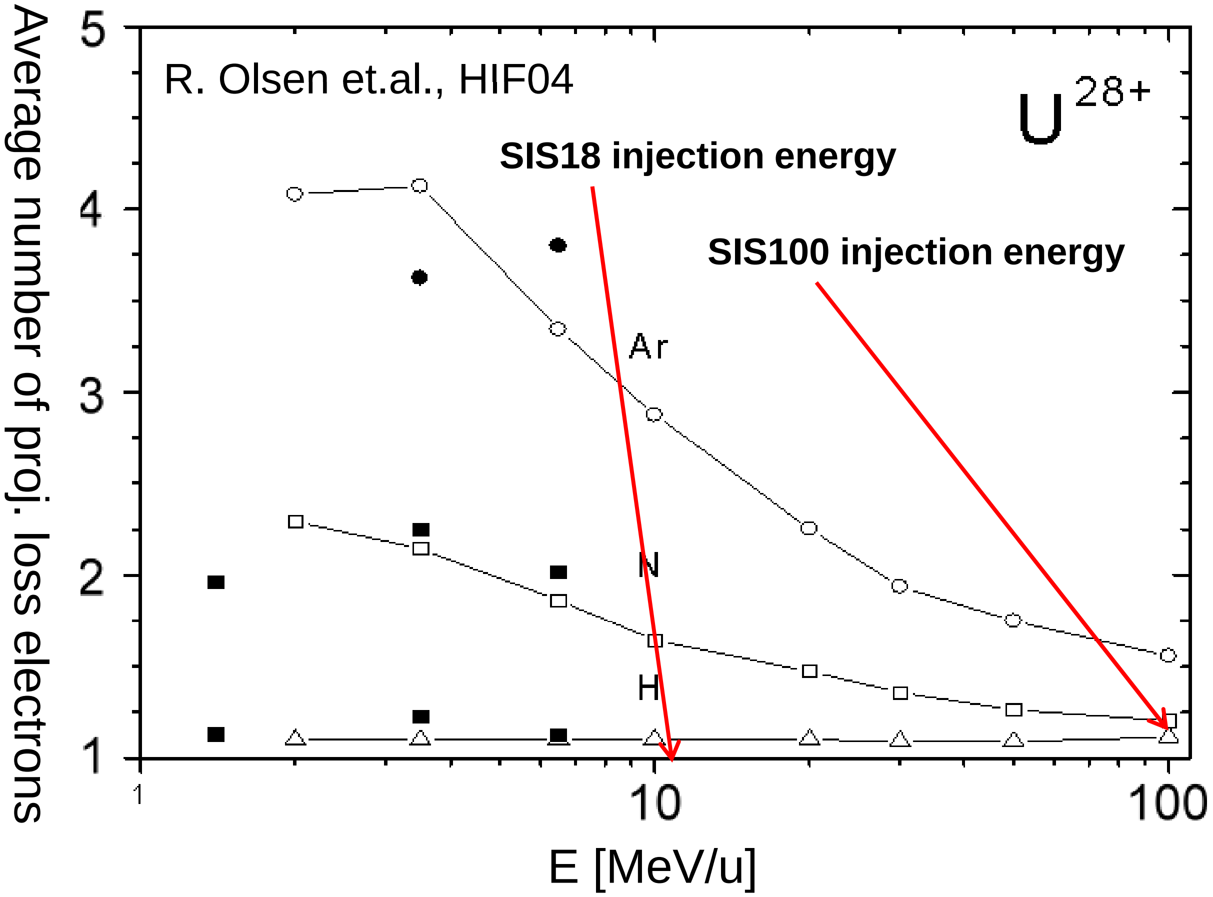
Results and influence of better transmission

The doublet structure with high momentum acceptance delivers best results. An unwanted particle just missing one collimator is "stored" and can be collimated later.

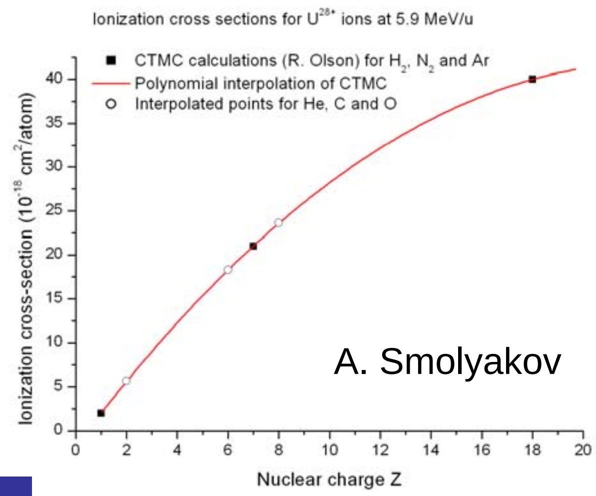




FAIR Problem 1: Multiple Ionisation



SIS18 experimental	LEAR
P = 3.67x10^{-11}	*P* = 2.87x10^{-11}
H_2 – 81.87 % CH_4 – 11.86 % CO – 3.02 % Ar – 3.25 %	H_2 – 83.18 % He – 2.36 % CH_4 – 10.38 % CO – 1.73 % N_2 – 1.38 % Ar – 0.97 %

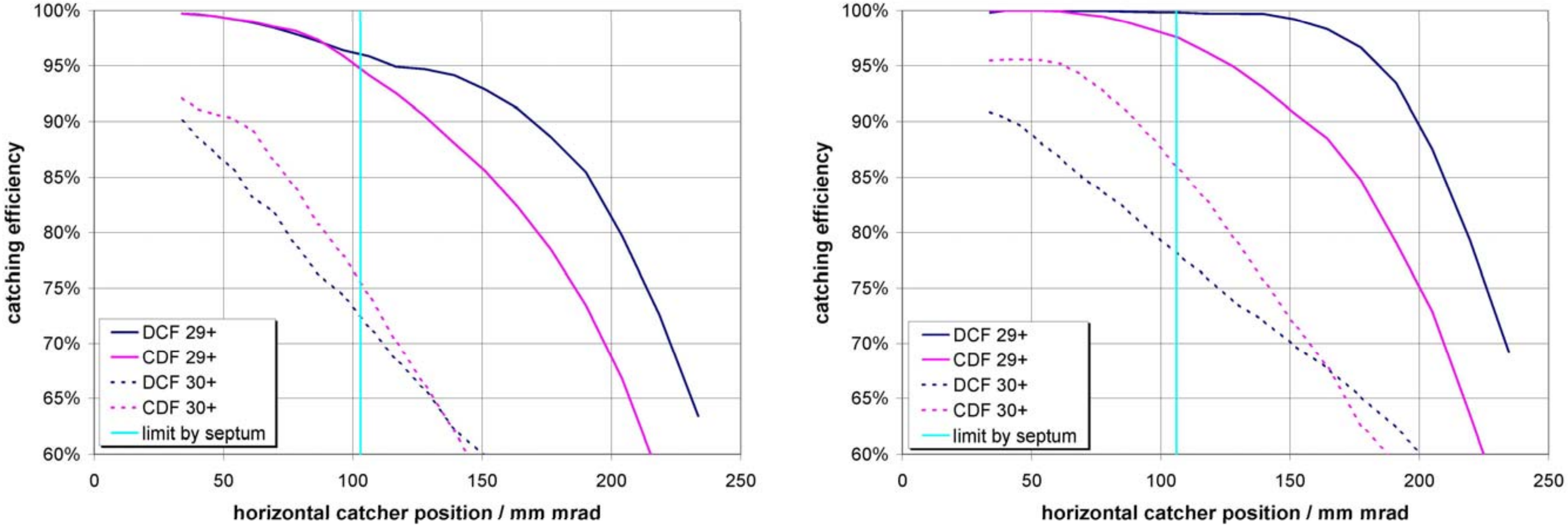


Cross section interpolation

Multiple ionization reduces the scraping efficiency

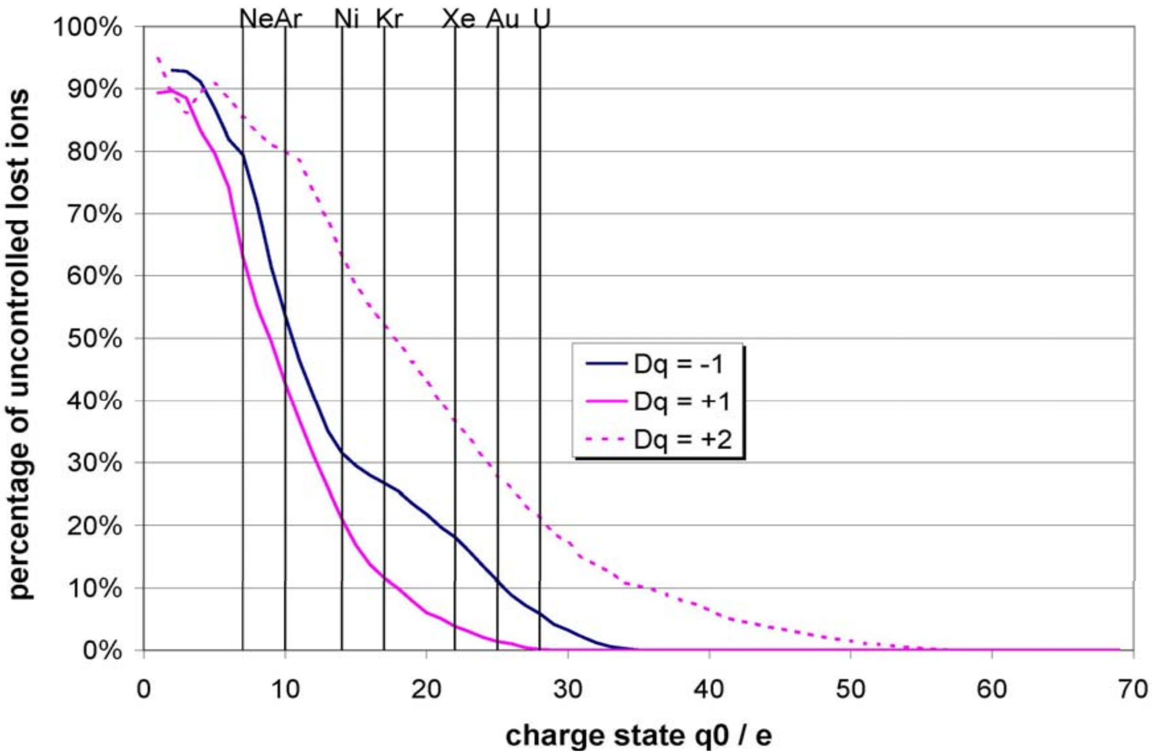
The total number of multiple ionized particles is low

Problem 2: Different working points



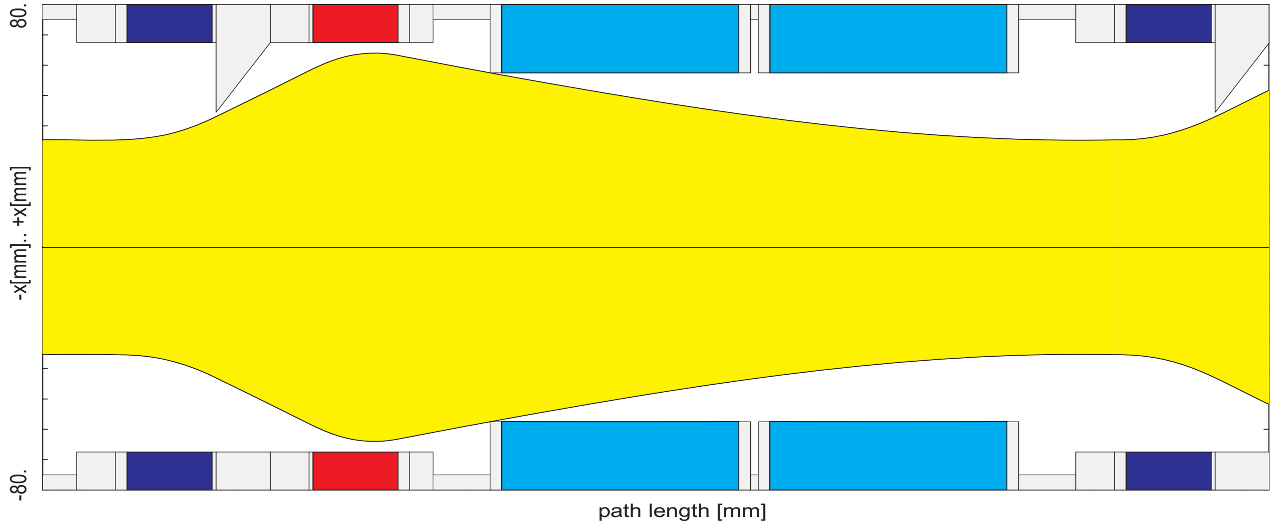
The scraping efficiency depends slightly on the tune.

Problem 3: Behaviour of lighter ions

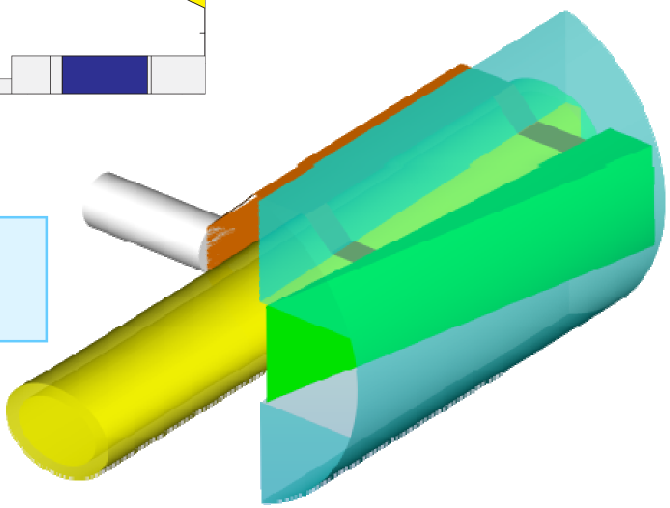


- The scraper system is optimized for heavy ions.
- Lighter ions miss the scraper and are dumped in the beam pipe.
- The loss rate of light ions is low, since the cross sections are lower (will be calculated).

SIS100 scraper position



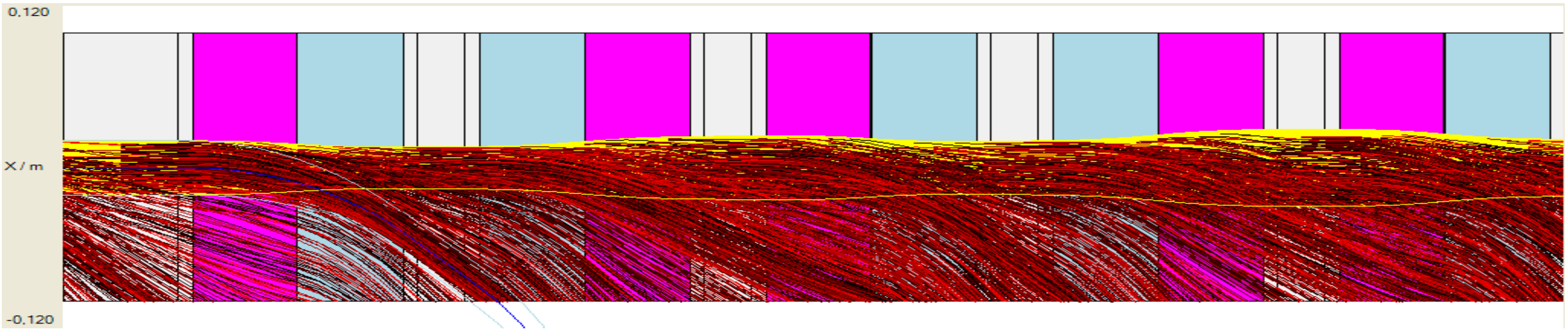
Envelopes at maximum acceptance show the position of the cathersnot interacting with the stored beam.



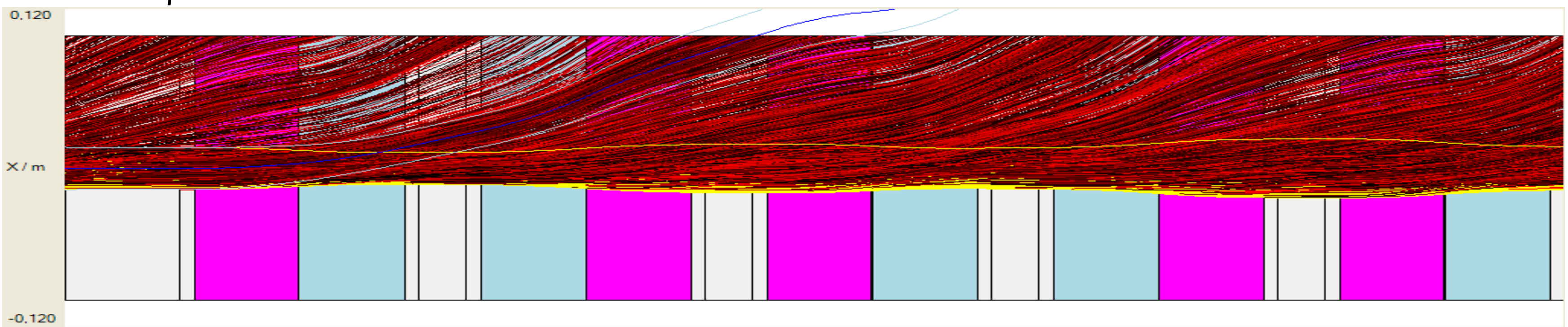
FAIR Beta Beam loss in existing PS

GSI

He_{β} beam

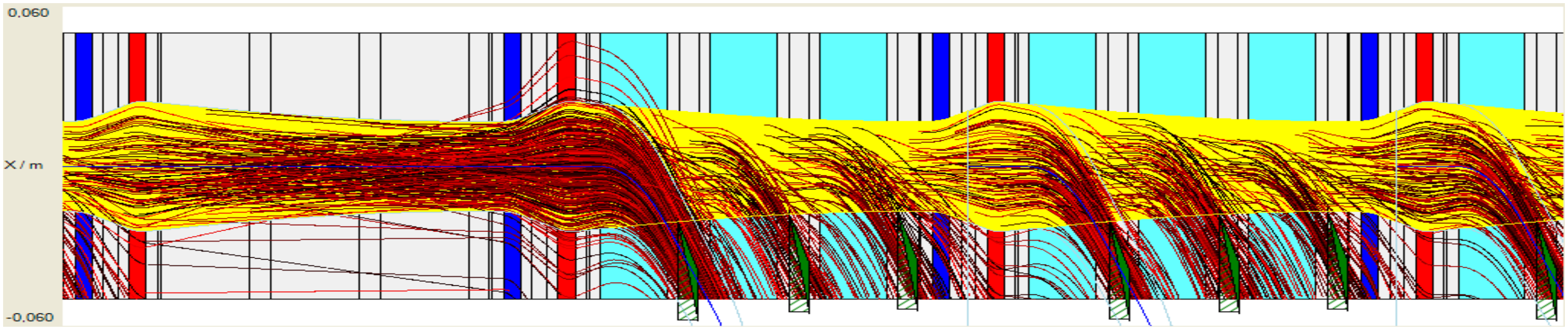


Ne_{β} beam

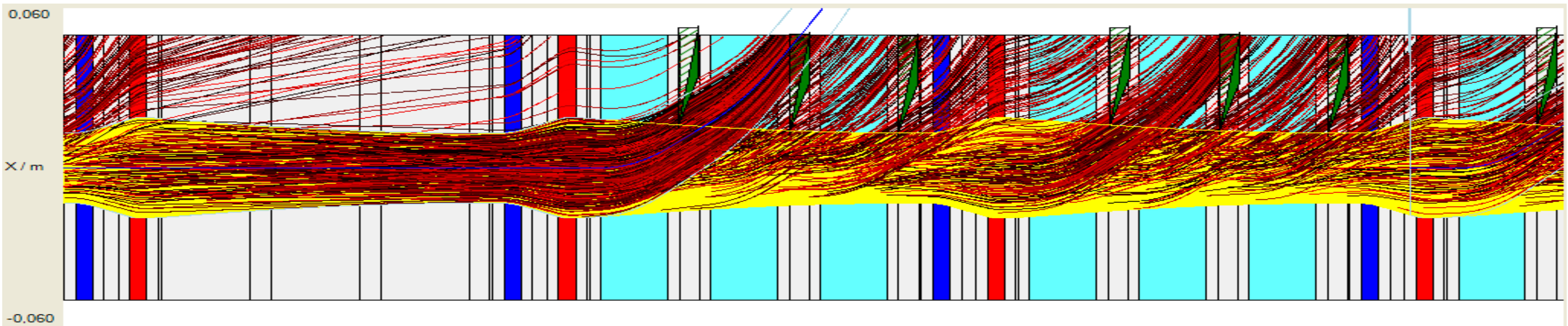


Beta beam loss in an possible new PS

He_β beam



Ne_β beam



Conclusion and Outlook

- We found a SIS100 lattice concept for FAIR heavy ion operation which limits the charge exchange induced losses to a dedicated scraper system
- No ions are lost on cold surfaces during U^{28+} Operation
- The scraper system does not limit the machine's acceptance
- Basic principles of peaked loss distribution can be applied to other problems (Beta beams at CERN)

- Studies for light ions and fragments passing the scrapers have to be done