HALO COLLIMATION FOR SIS100

I.Strasik, O.Boine-Frankenheim

MULTI-TURN INJECTION OPTIMIZATION USING GENETIC ALGORITHMS

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HALO BUILD-UP DUE TO SPACE-CHARGE AND COHERENT OSCILLATIONS

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HALO COLLIMATION FOR SIS100

I.Strasik, I.Prokhorov, O.Boine-Frankenheim, PRSTAB **18**, 081001 (2015)

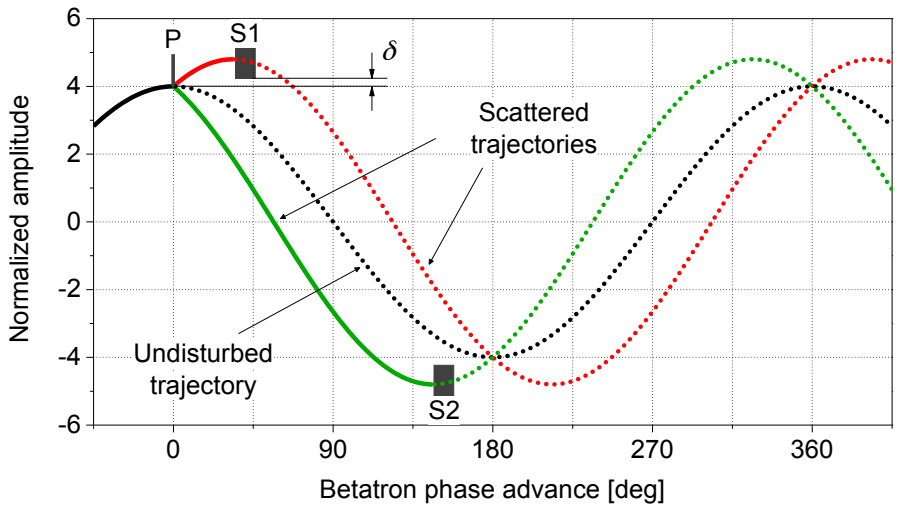
https://doi.org/10.1103/PhysRevSTAB.18.081001

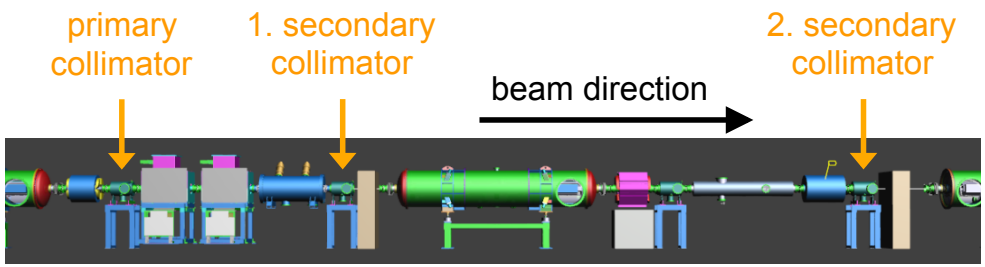
Protons and fully stripped ions

primary collimator is the scattering foil,
two bulky secondary collimators.
Single-pass and multi-pass collimation.

Two stage collimation system

- Intended for proton and fully stripped ion collimation in SIS100
- Primary collimator (thin foil) – scattering of the halo particles
- Secondary collimators (bulky blocks) – absorption of the scattered particles
- Multiple transition through the collimation system (multipass efficiency)





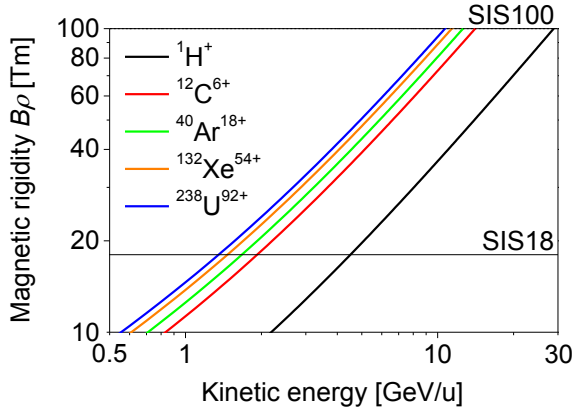
[Ref] J.B. Jeanneret, Phys. Rev. ST Accel. Beams 1, 081001 (1998)
[Ref] M. Seidel, DESY Report (Dissertation), 94-103, (1994)

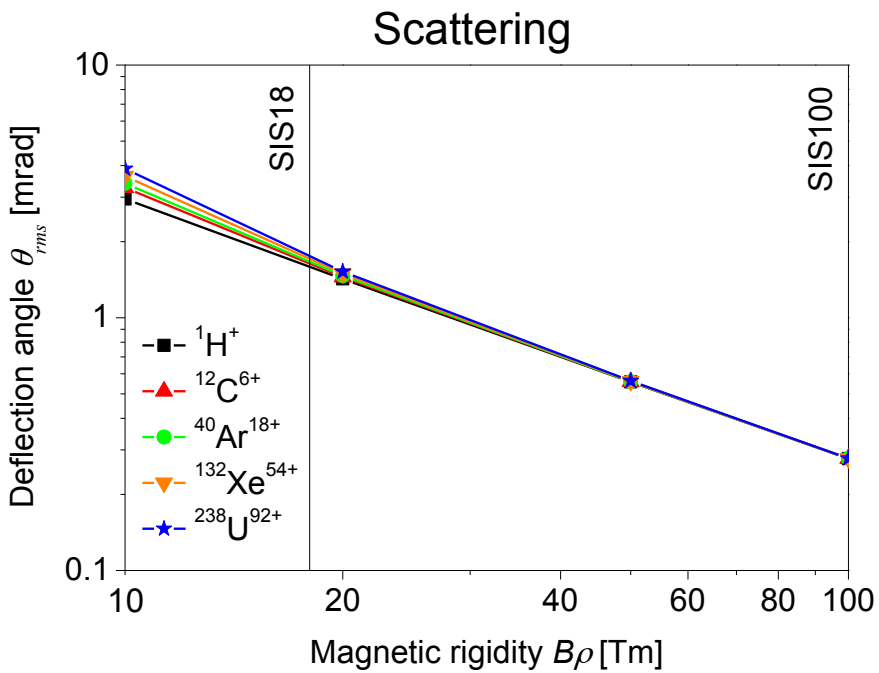
- Very robust concept applied in many machines

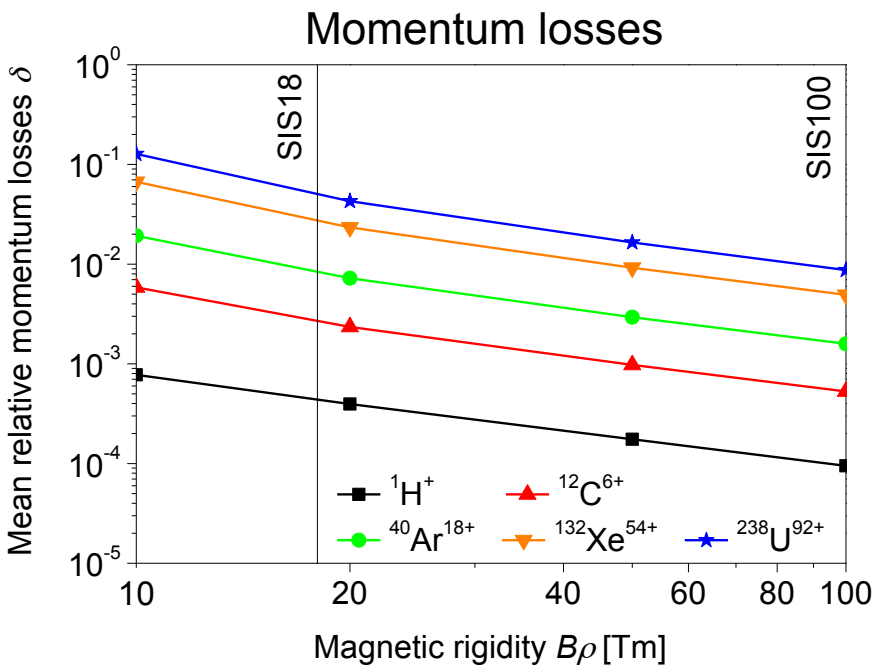
Interaction of ions with the primary collimator

- The same collimation system for protons and fully stripped ions in SIS100

- Interaction of the fully stripped ions with the primary collimator - FLUKA code

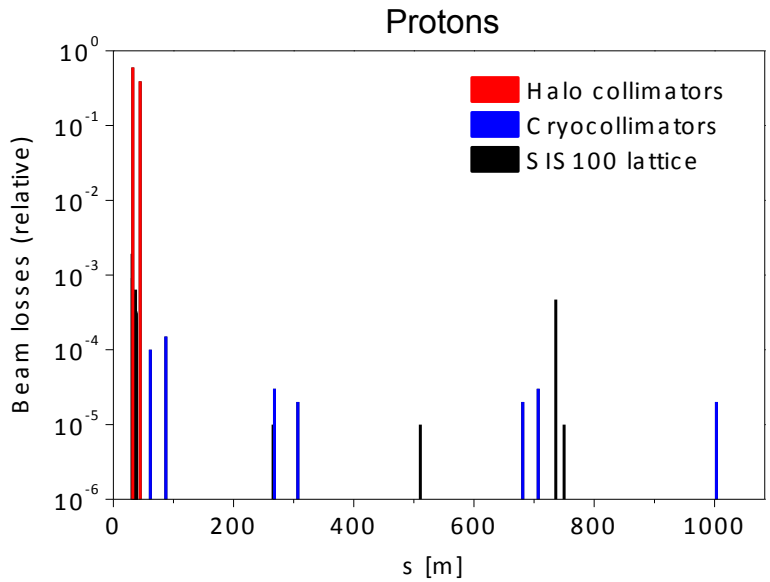


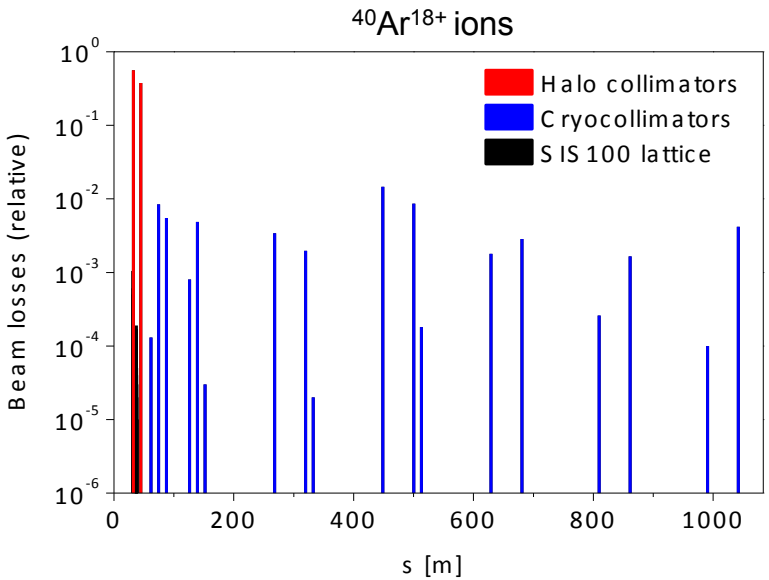


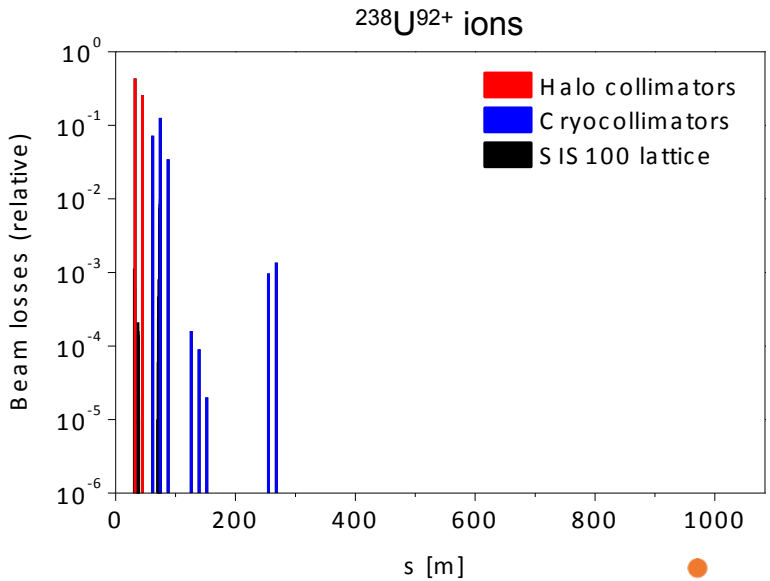


Beam loss maps of the fully stripped ion beams

- Simulation tools
  - Beam – material interaction: FLUKA code
  - Particle tracking : MAD-X code
  - Statistics: 10^5 primary particles

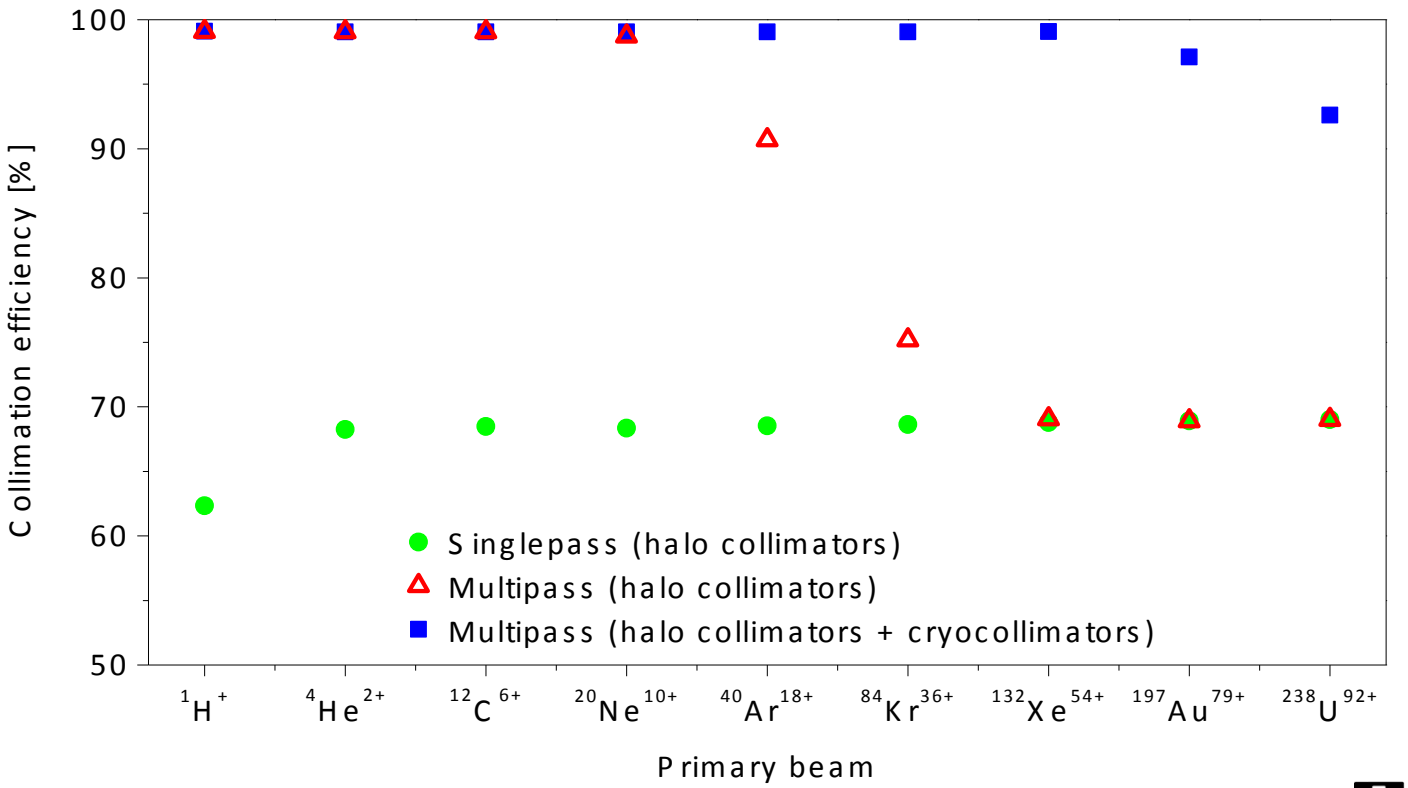






Collimation efficiency of the fully stripped ions

- Collimation efficiency of the fully stripped ions in SIS100 from proton up to uranium
- Decrease of the multipass efficiency starting from $^{40}Ar^{18+}$ is due to high momentum losses of heavy ions in the primary collimator.
- The multipass efficiency is significantly improved with the help of the cryocollimators



Partially stripped ions

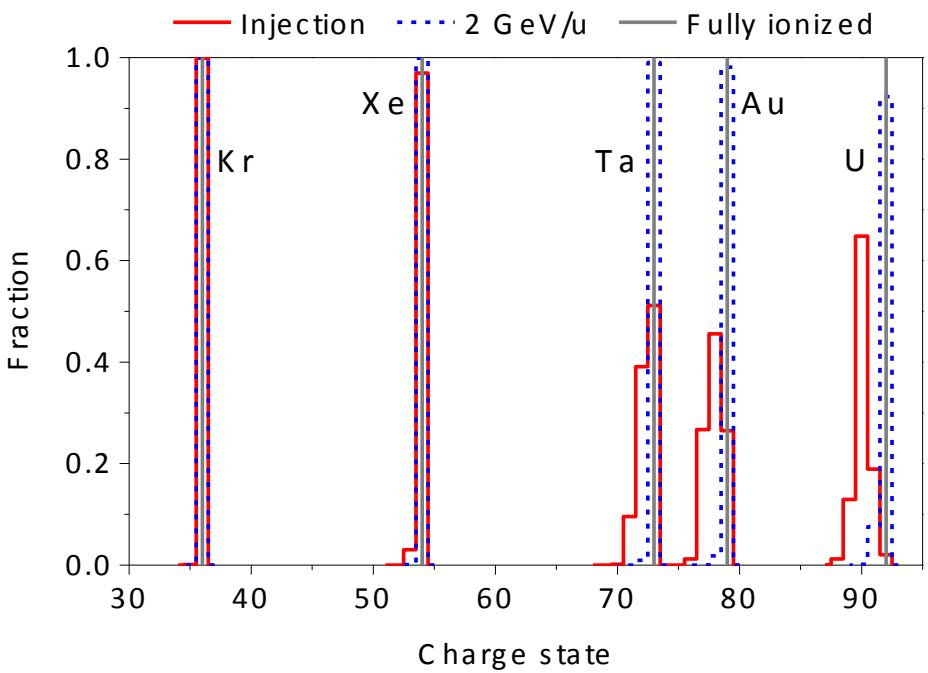
primary collimator is the stripping foil,
one bulky secondary collimator.
Single-pass collimation.

Charge state distribution after stripping

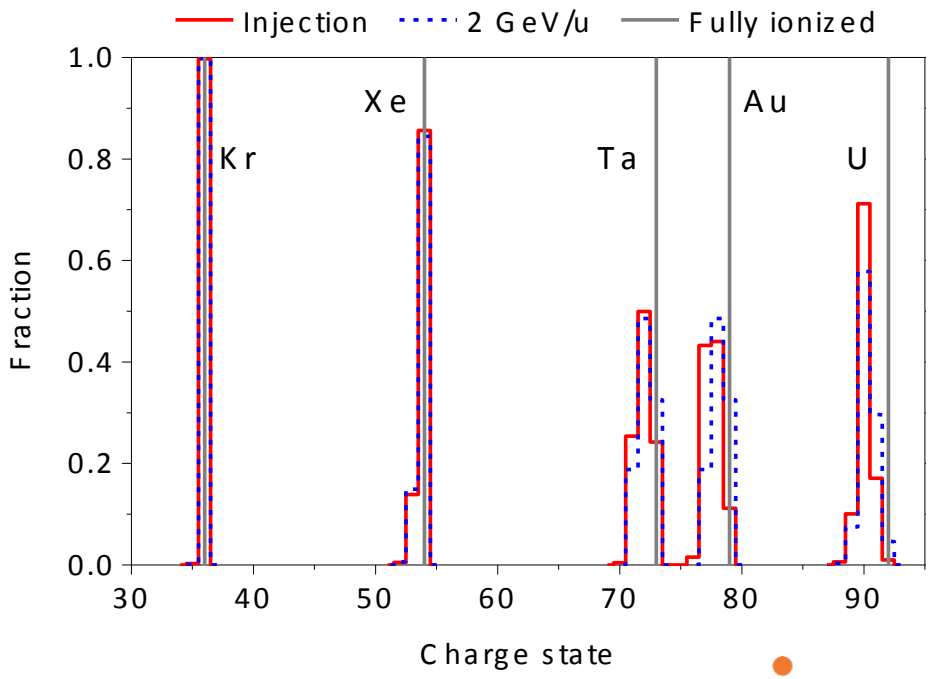
- Electron capture and electron loss → equilibrium charge-state distribution
  - code GLOBAL (implemented also in LISE++) *[Ref] C. Scheidenberger et al.,* NIMB *142 (1998) 441*
  - Medium-Z materials (Al – Cu) → suitable for efficient stripping for wide range of primary ions and beam energies (0.5 mm thick titanium foil is optimal for SIS100 beams)
  - Thermomechanical calculation for fast beam losses → titanium can be melted

0.5 mm thick stripping foil

titanium



graphite



Particle tracking of the stripped ions

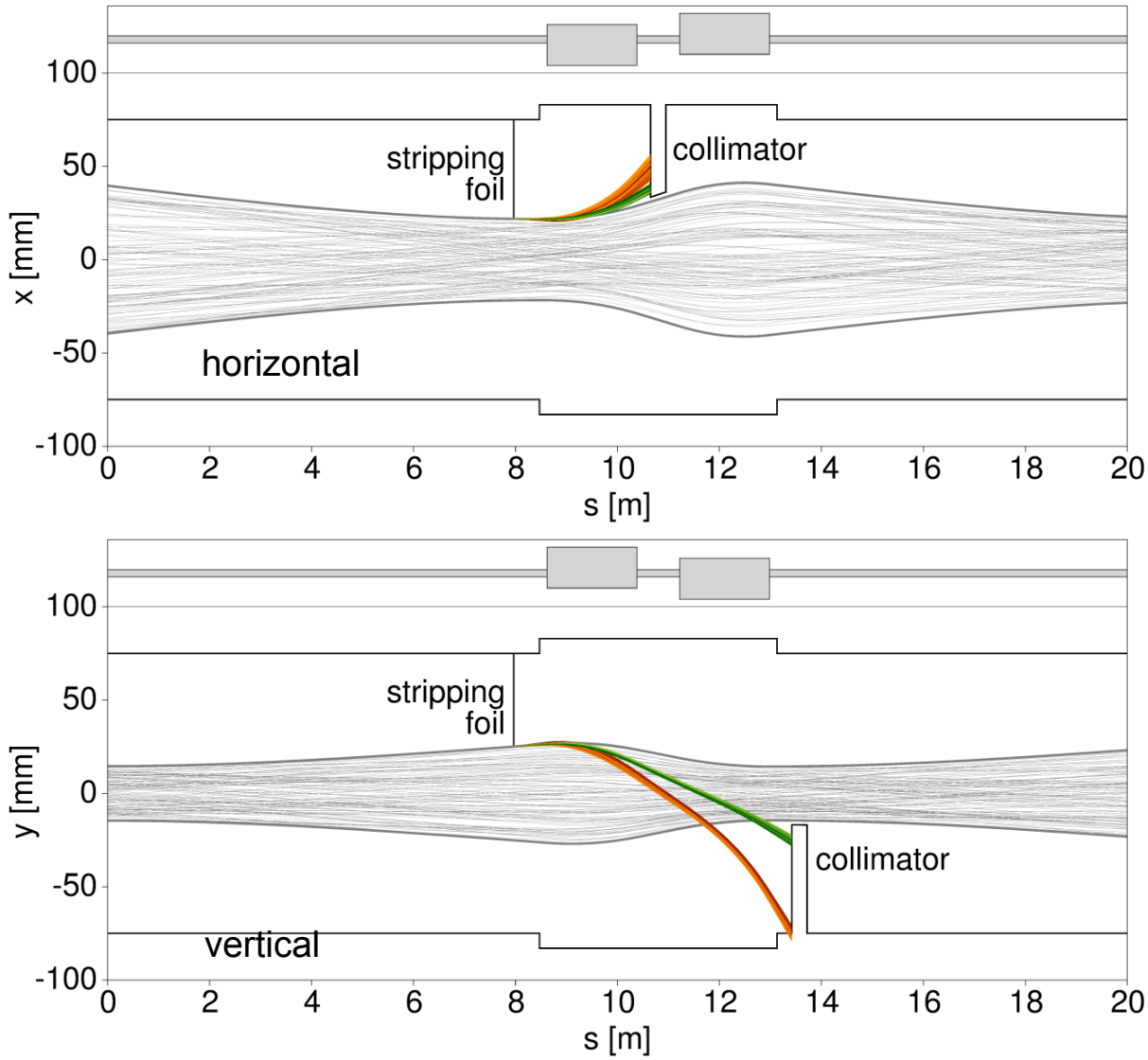
Orange tracks

$^{238}_{92}U^{28+} \rightarrow {}^{238}_{92}U^{92+}$

Green tracks

$^{84}_{36}Kr^{17+} \rightarrow {}^{84}_{36}Kr^{36+}$

The ions are deflected by the quadrupole towards the collimators

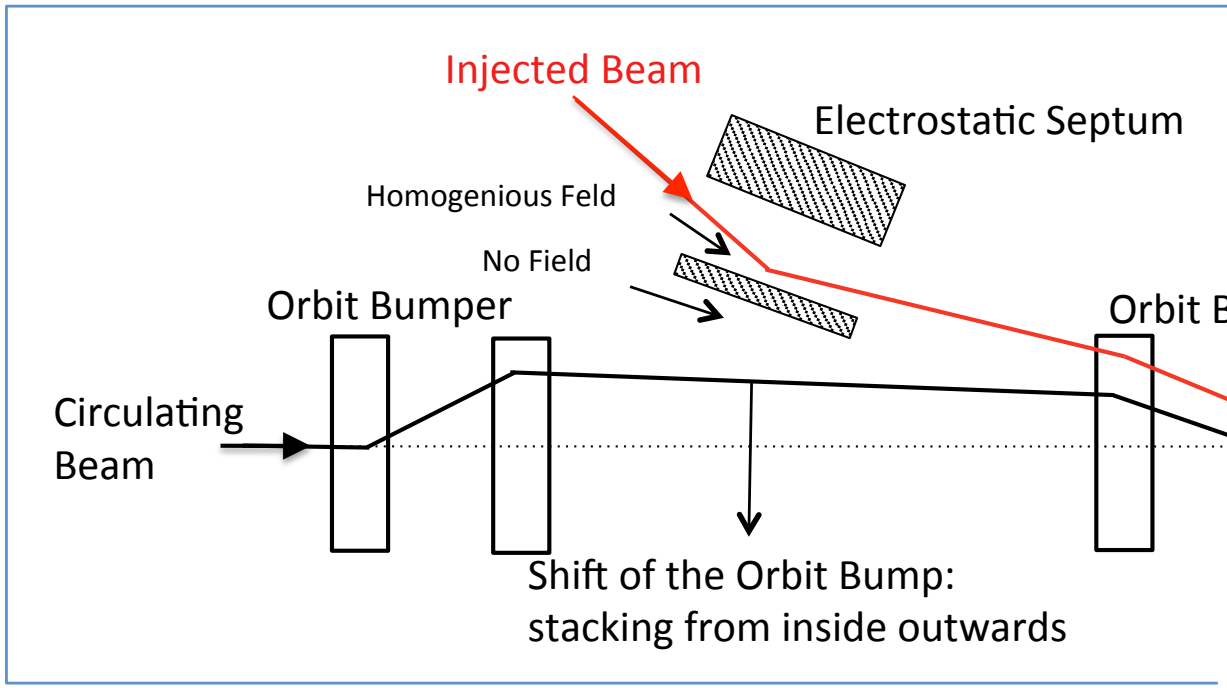


MULTI-TURN INJECTION OPTIMIZATION USING GENETIC ALGORITHMS

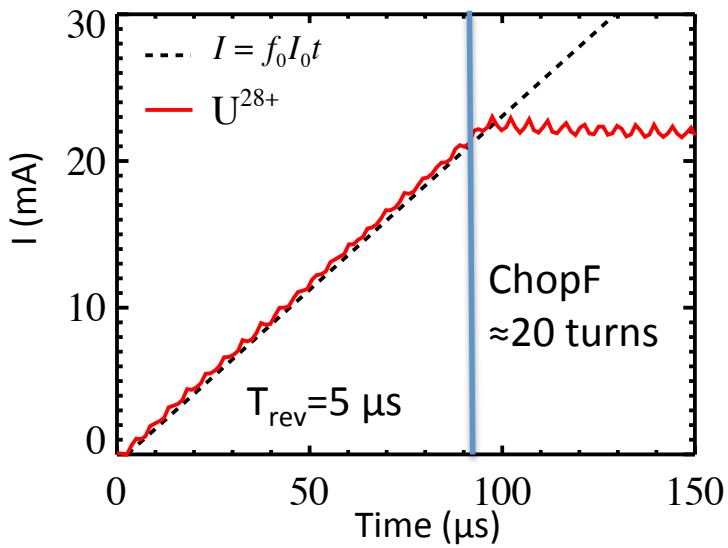
S.Appel, O.Boine-Frankenheim, NIM A (2016)

http://dx.doi.org/10.1016/j.nima.2016.11.069

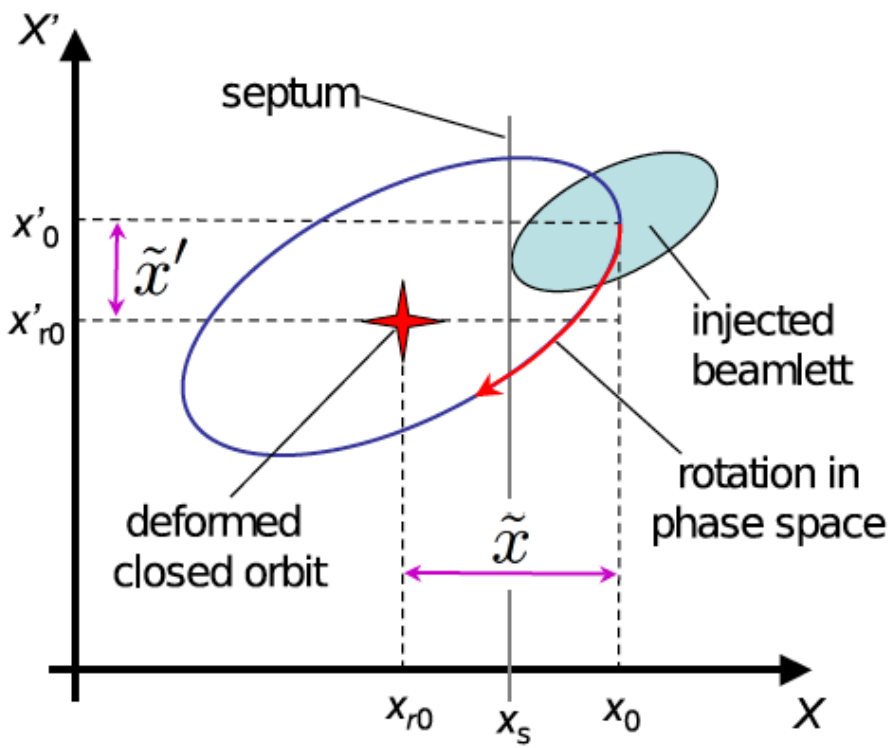
Multi-Turn Injection in SIS18

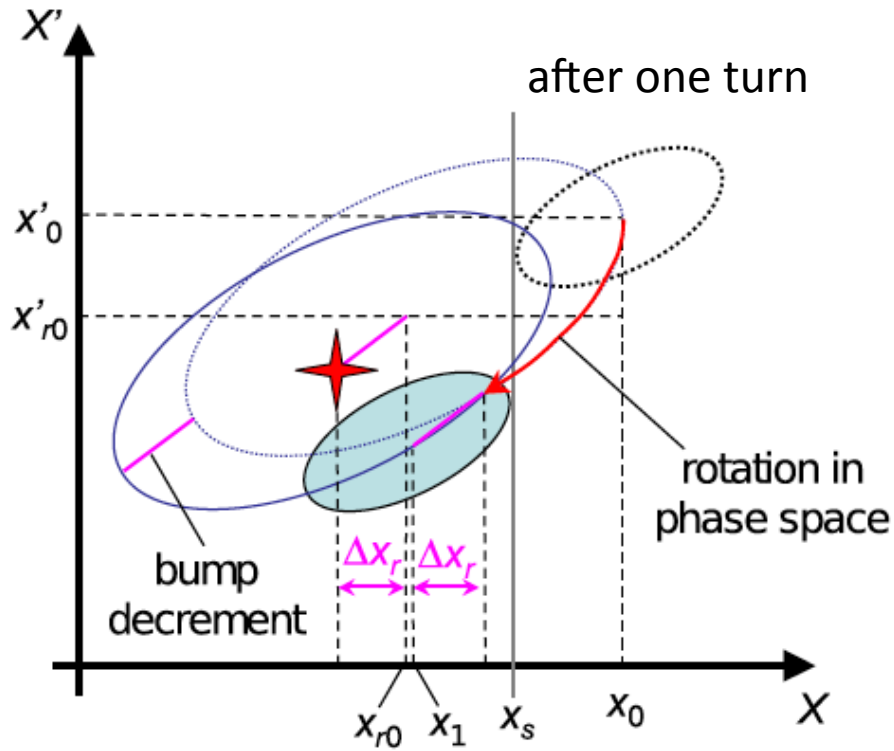


- Liouvilian injection in SIS18
  due to different ions and charge states
- Horizontal Stacking
- SIS18 performance constrain: Dynamic Vacuum
  (previous talks Omet, Bender): Low-Loss Challenge



Multi-Turn Injection





S.Paret, O.Boine-Frankenheim, HB2010, Morschach, Switzerland, 2010

Multi-Turn Injection Optimization

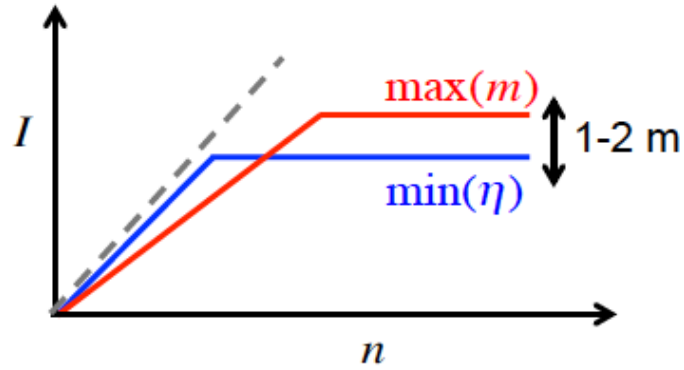
S.Appel, Miniworkshop Jülich, Nov 18, 2016

Multi-objectives

- Gain factor (maximize) $m = I/I_0$
- Beam loss (minimize) $\eta = \frac{I_{loss}}{nI_0}$
- Inj. emittance (maximize) ε_x

output

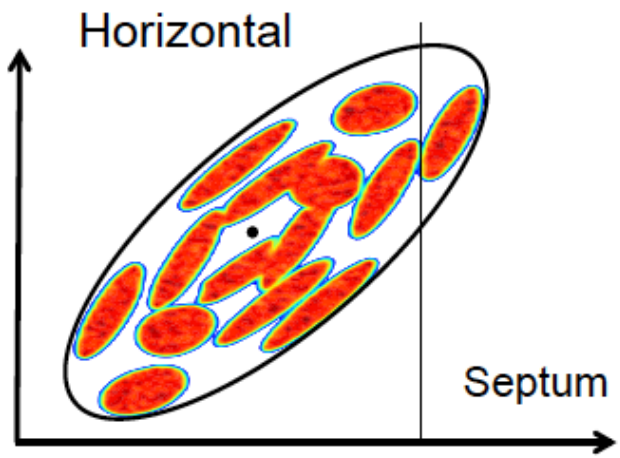
$m = (1-\eta)n$



Optimization parameters

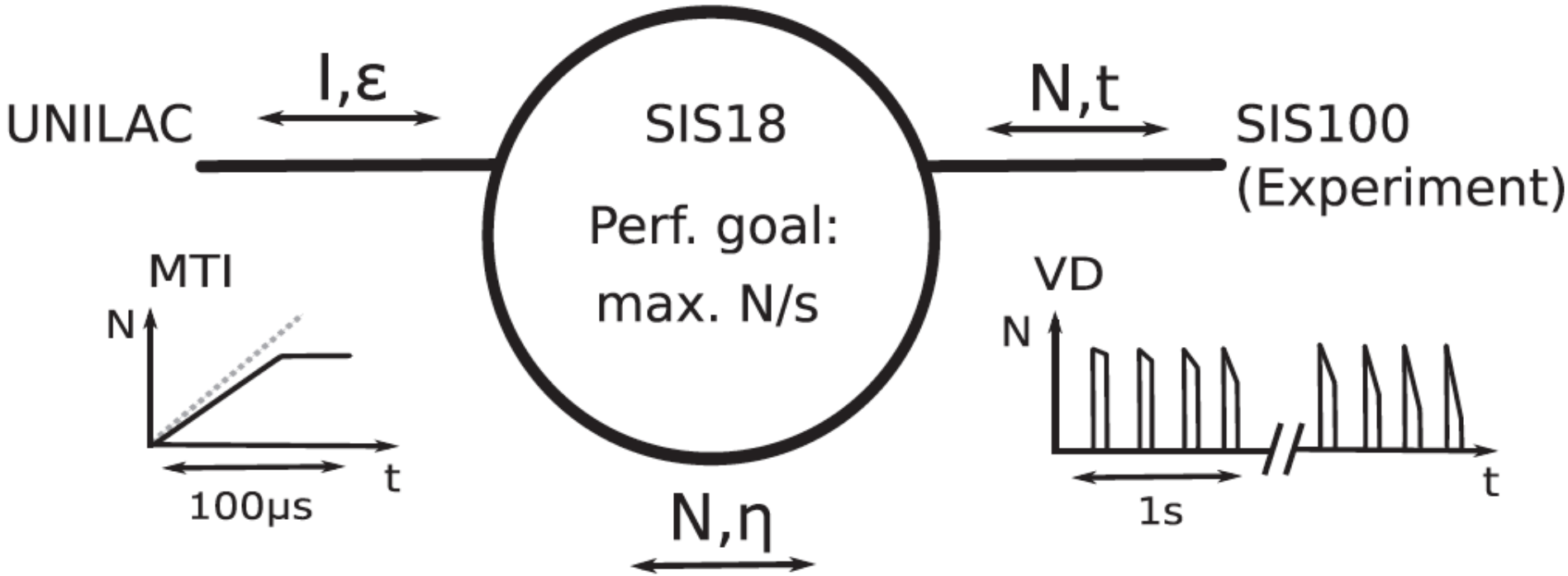
- Incoming beam x_c, x_c', M
- Orbit bump x_0, x_0', τ
- Injected turns n
- Horizontal tune Q_x
- Horizontal emittance ε_x

Model in simulation code



Particle Tracking Code pyORBIT (ORNL, Oak Ridge, USA)
http://dx.doi.org/10.1016/j.procs.2015.05.312

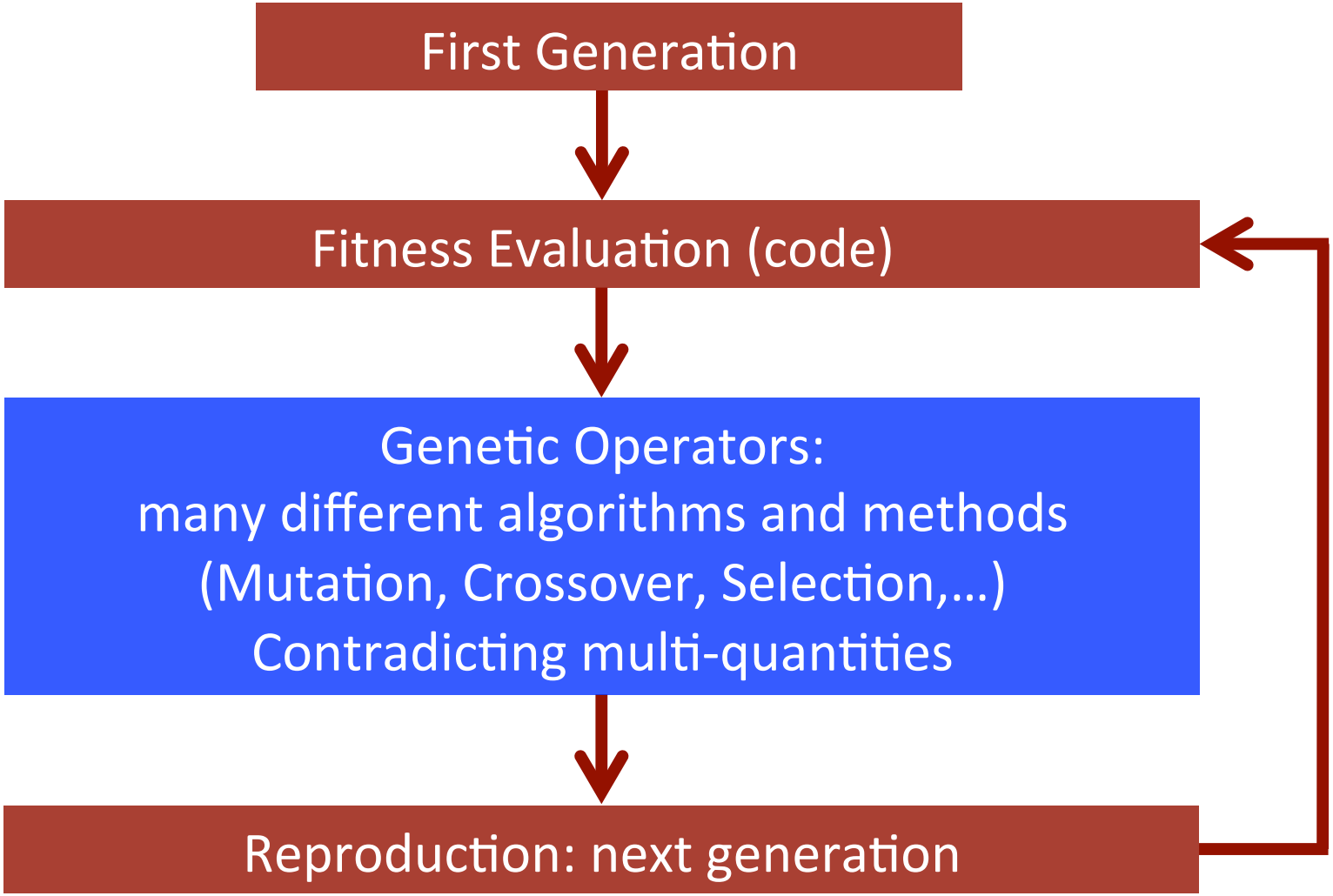
Multi-Turn Injection Optimization



$$\begin{cases} \text{minimize } \eta(n, \epsilon_x, I_0, x_c, x'_c, M, x, x', \tau, Q_x) \\ \text{maximize } m(n, \epsilon_x, I_0, x_c, x'_c, M, x, x', \tau, Q_x) \\ \text{maximize } \epsilon_x(n, \epsilon_x, I_0, x_c, x'_c, M, x, x', \tau, Q_x). \end{cases}$$

S.Appel, O.Boine-Frankenheim, NIM A (2016)

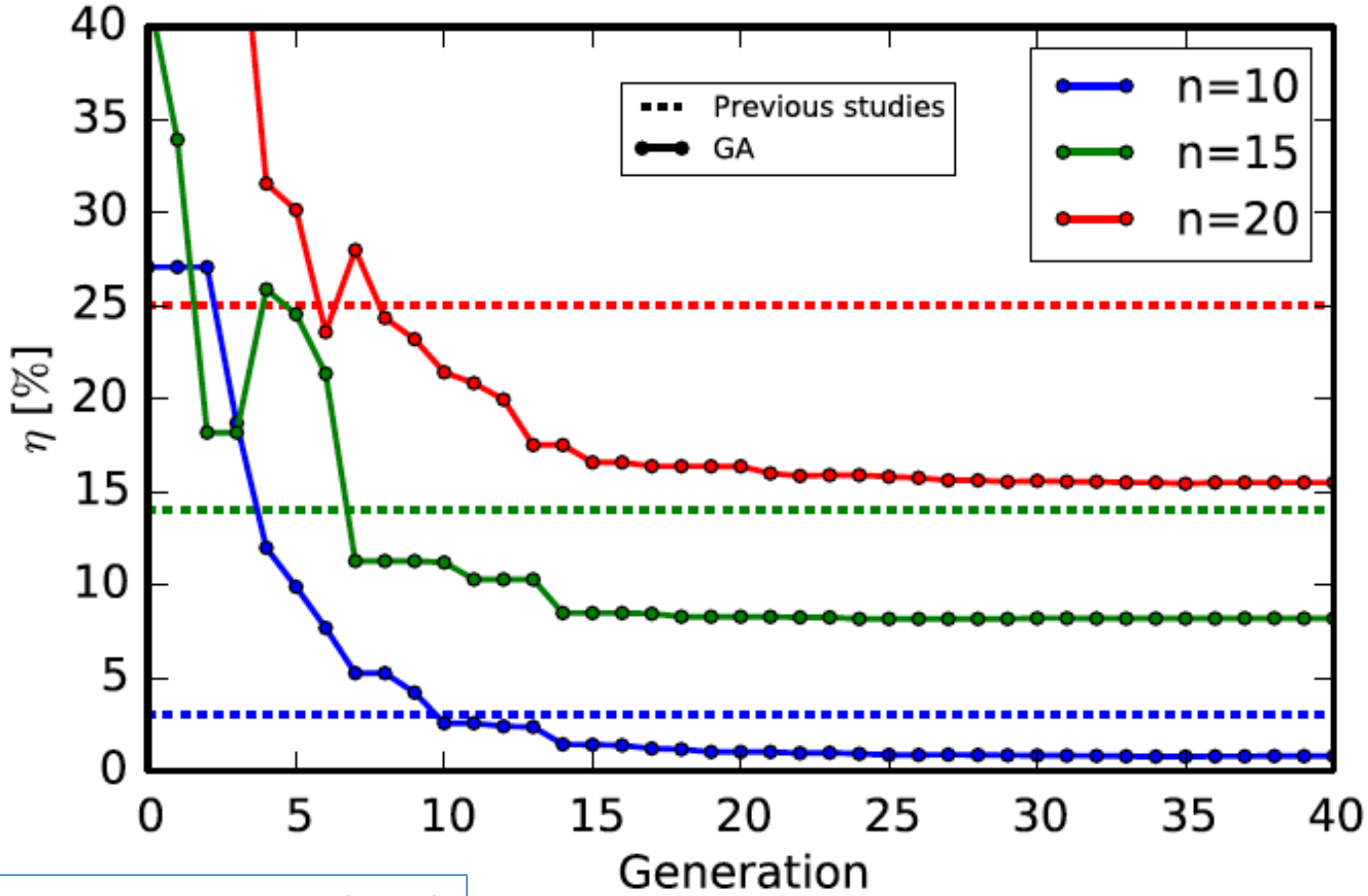
Genetic Algorithms



References in S.Appel, O.Boine-Frankenheim, NIM A (2016)

Multi-Turn Injection Optimization

Development of the Beam Loss during the optimization.
500 individuals, Tournament selection, n is N of injected turns



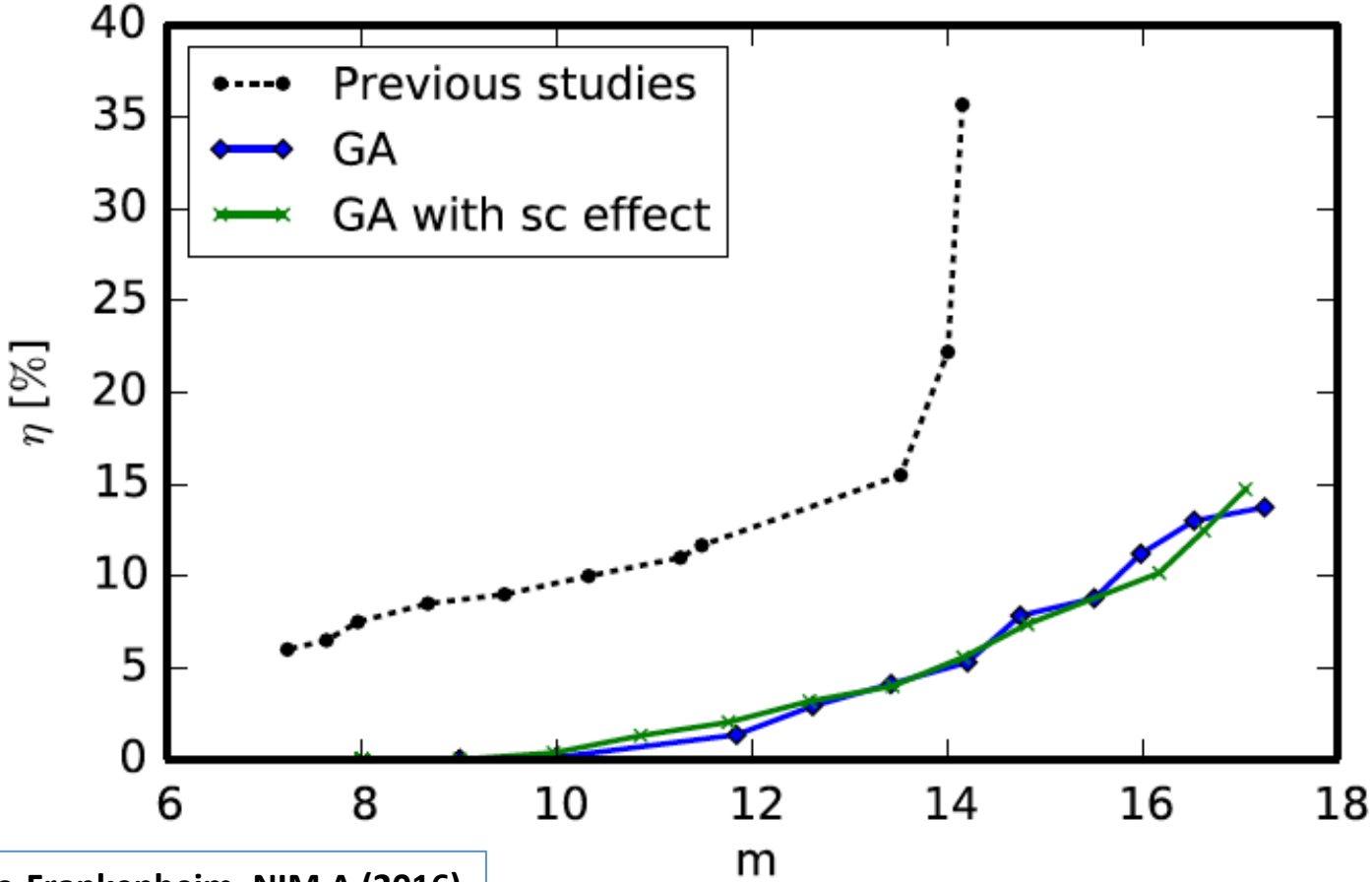
S.Appel, O.Boine-Frankenheim, NIM A (2016)

Multi-Turn Injection Optimization

Two-Quantity Optimization

The Gain Factor **m=n(1−η)**, the Beam Loss **η**

2D Pareto front **(m,η)**



S.Appel, O.Boine-Frankenheim, NIM A (2016)

HALO BUILD-UP DUE TO SPACE-CHARGE AND COHERENT OSCILLATIONS

I.Karpov, V.Kornilov, O.Boine-Frankenheom, PRAB **19**, 124201 (2016)

https://doi.org/10.1103/PhysRevAccelBeams.19.124201

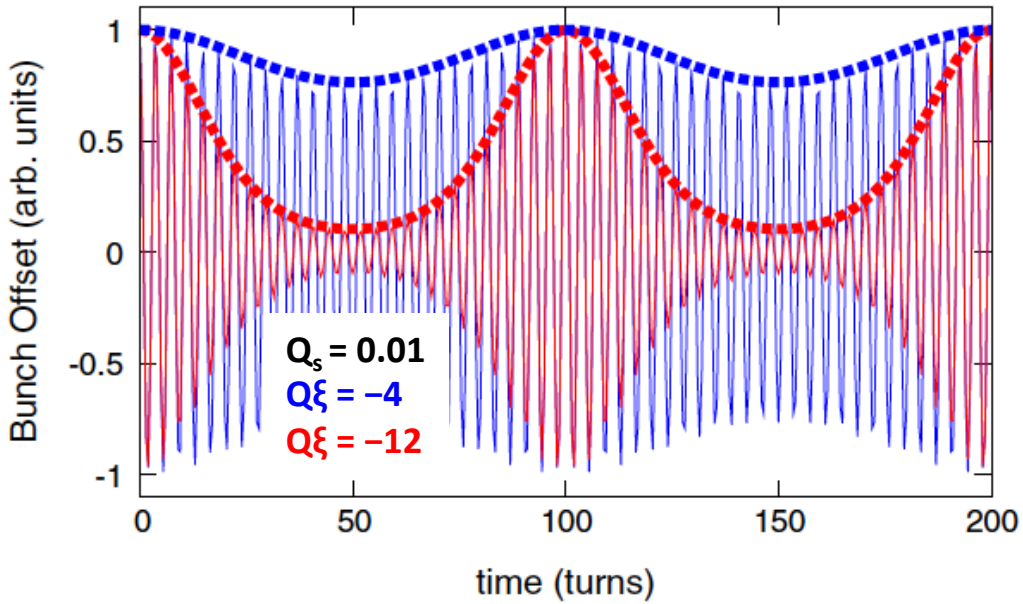
Beam Halo & Coherent Oscillations

- Halo formation due to nonlinear space-charge forces, nonlinearities, etc.
- Incoherent effects
- Usually, a slow diffusive process

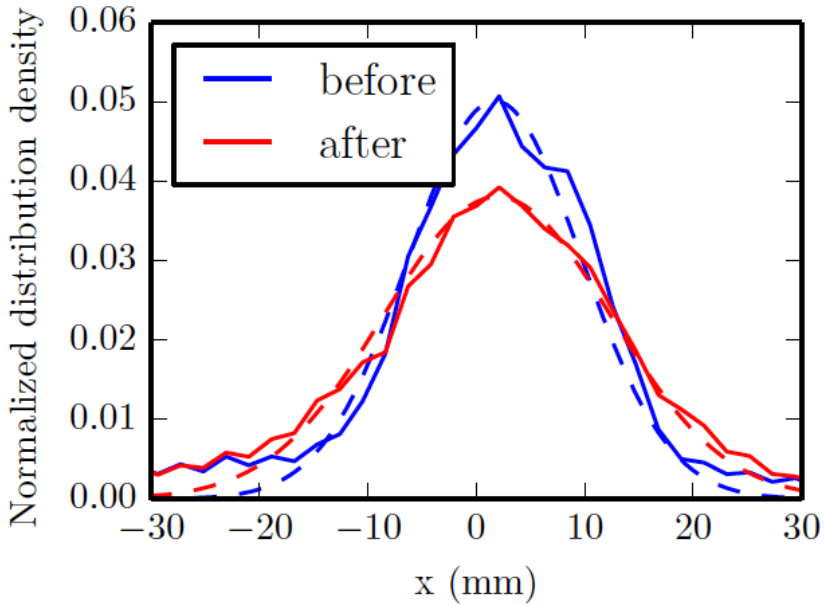
- Coherent oscillations cause emittance blow-up
- Fast Feedback systems (dampers) for injection errors

Transverse Decoherence

Linear transverse bunch oscillations
after a kick or after an injection offset.



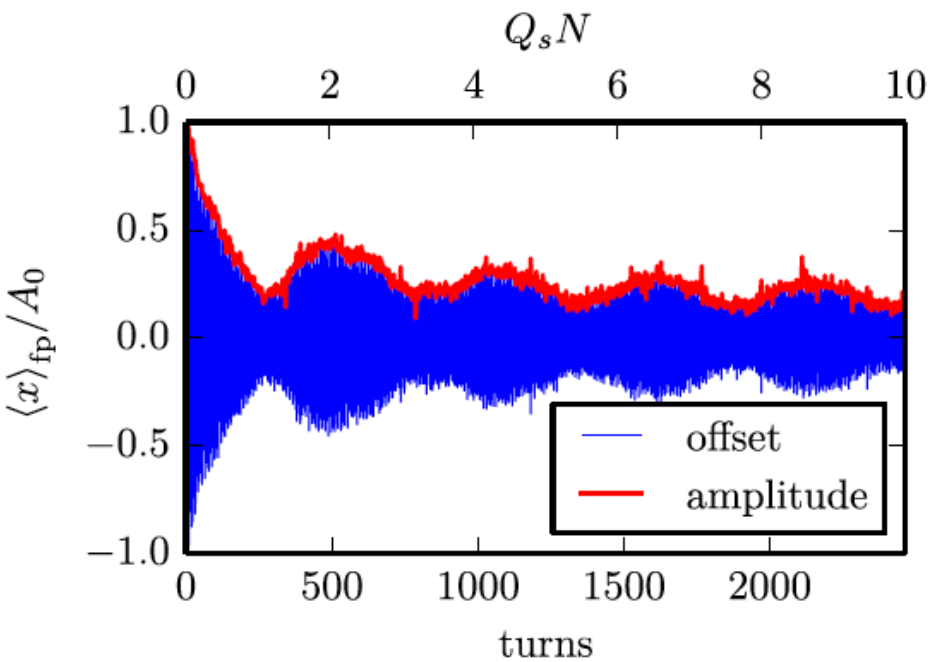
In reality: causes
a transverse emittance blow-up.
Measurements in SIS18



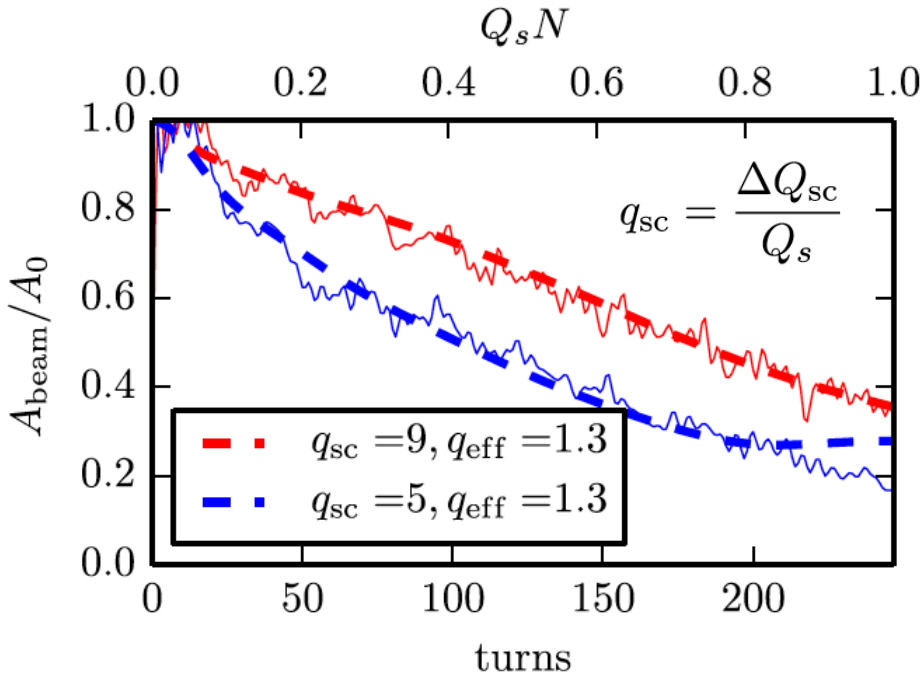
Long-term decoherence with space-charge:
V.Kornilov, O.Boine-Frankenheim, PRSTAB **15**, 114201 (2012)

Transverse Decoherence with Space-Charge

The role of space-charge in the early stage of the transverse decoherence:
Measurements in SIS18, GSI Darmstadt,
and self-consistent particle tracking simulations



Pickup signal in SIS18



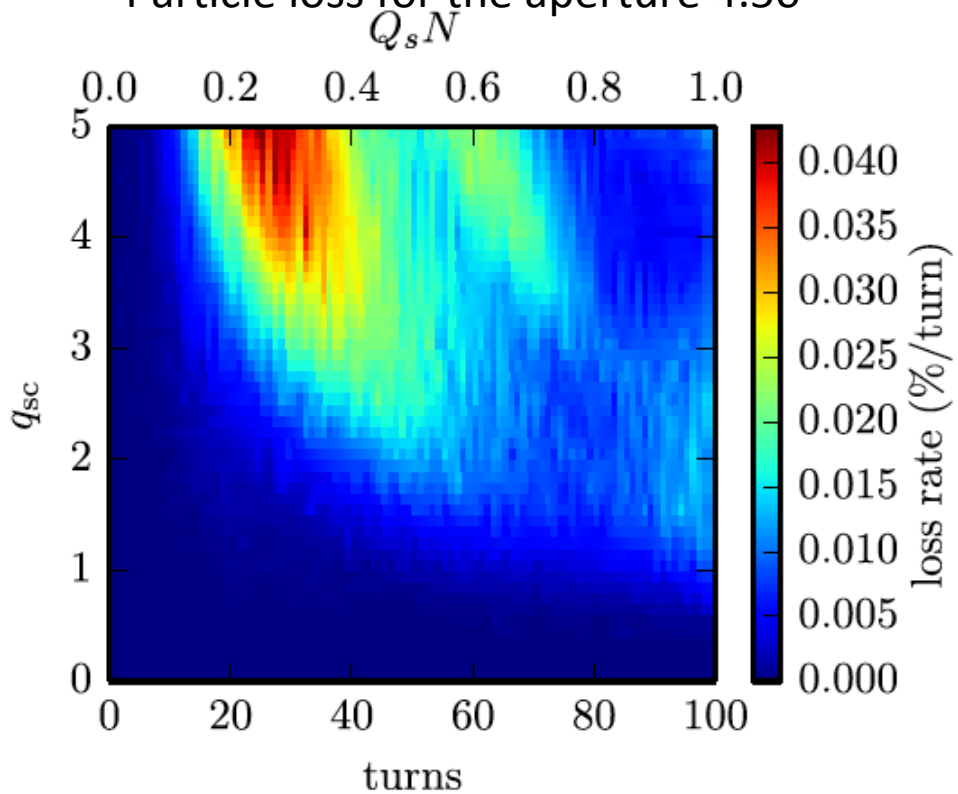
Dashed lines: simulations

I.Karpov, V.Kornilov, O.Boine-Frankenheom, PRAB **19**, 124201 (2016)

Halo Build-up

- Particles are excites (large amplitudes) by space-charge
- The resonant particles (incoherent=coherent) are excited
- Space-charge: the driving force and the incoherent tune shift
- Fast process

Particle loss for the aperture 4.5σ



Self-consistent particle tracking simulations for bunches with space-charge

I.Karpov, V.Kornilov, O.Boine-Frankenheom, PRAB **19**, 124201 (2016)

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