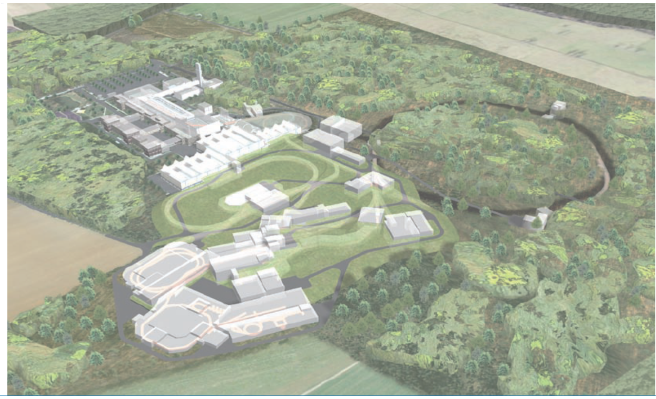
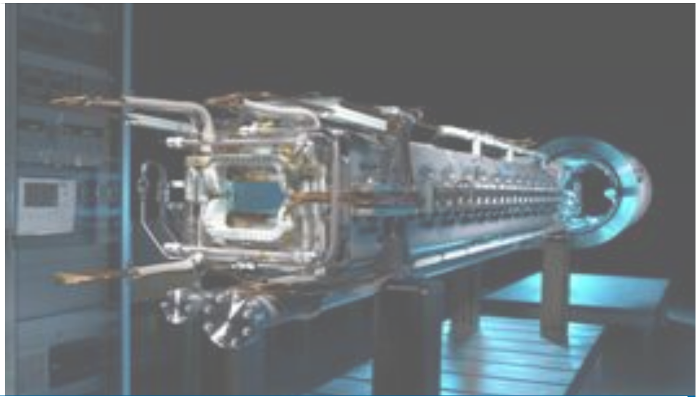




Beam Loss Simulations during acceleration

Giuliano Franchetti

MAC 5

9-10 May 2011

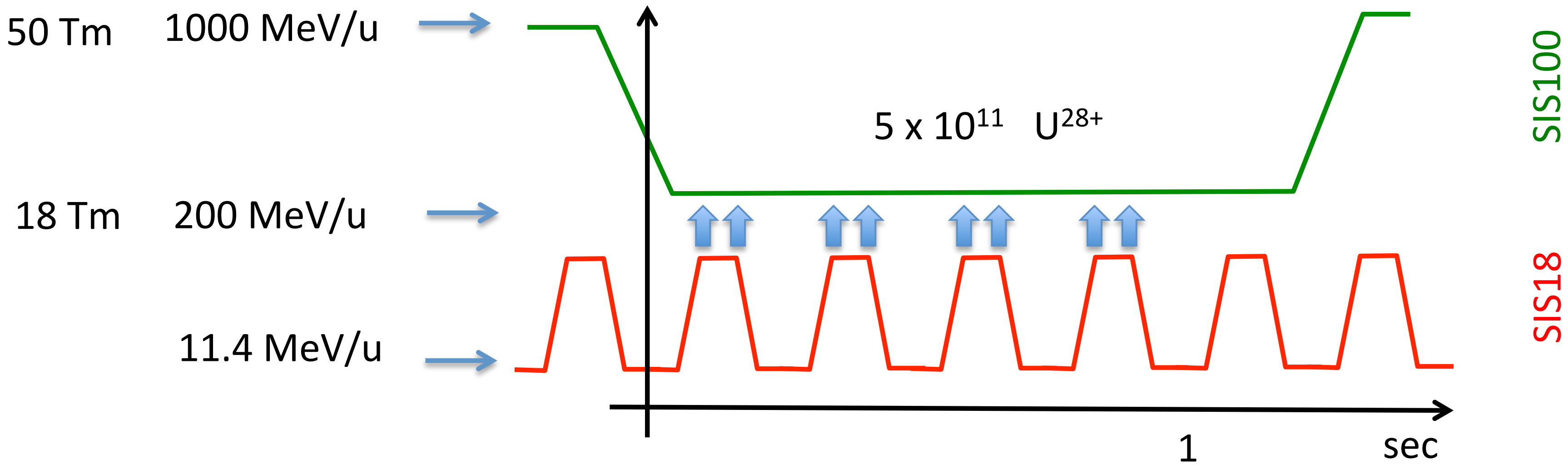
Austria China Finland France Germany Greece India Italy Poland Romania Russia Slovakia Slovenia Spain Sweden U K

FAIR

Overview

- **From injection plateau to acceleration ramp**
- **Beam Loss Mechanism during acceleration**
- **Beam Loss Prediction during acceleration**
- **Conclusion and Remarks**

SIS100 injection plateau scenario



First bunch @ 200 MeV/u

Nominal N_{ions} = 6.25 x 10^{10}/bunch
Beam1: $\varepsilon_{x/y}$ = 35/15 mm-mrad (2σ) $\Delta Q_{x/y}$= -0.21/-033
Turns = 1.57 x 10^5 (1 sec.)

Problem of control of beam loss for the bunched beams in SIS100 during 1 second

SIS100 Modeling

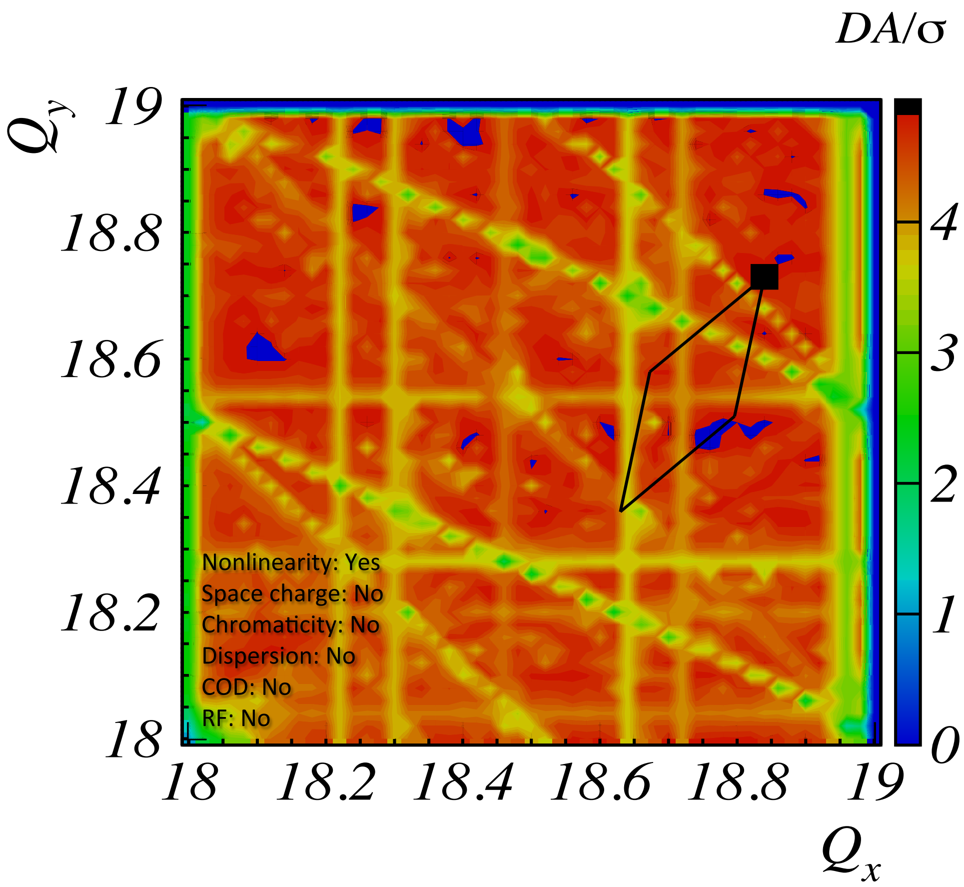
1) Linear Lattice
2) All insertions (i.e. each element sizes + all septums, NO Collimators)
3) Each magnet has nonlinear field modeled via 3 localized nonlinear kicks of the systematic errors
4) Displacement of quadrupoles is modeled by insertion of a dipolar kick in center of quadrupole
5) Inclusion of all magnet correctors: steerers and sextupole for chromatic correction and resonance corrector sextupoles (in addition with quadrupoles and octupoles)

Magnet design: CSLD *Pavel Akishin, Anna Mierau, Pierre Schnizer, Egbert Fischer 3. June 2010*

Magnet multipoles: V.Kapin, P. Schnizer, A. Mierau
Kapin, V.; Franchetti, G. ACC-note-2010-004

Lattice: J. Stadlmann, A. Parfenova, S.Sorge

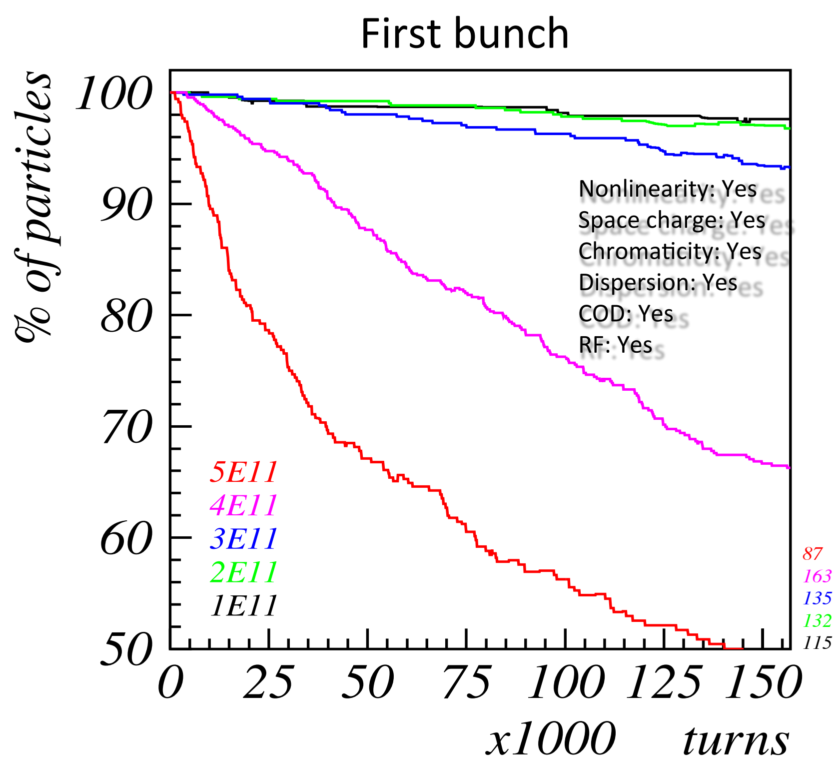
Resonances excited by the "standard seed"



Resonances crossing the space charge tune-spread

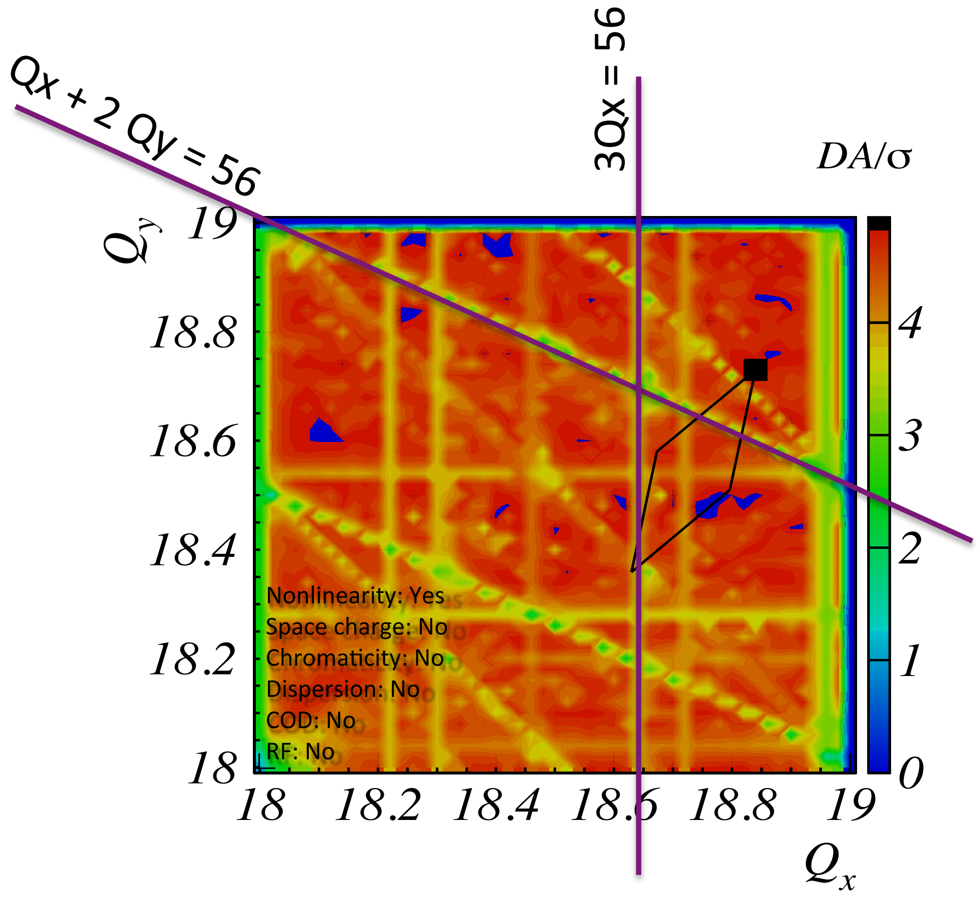
2 Qy = 37
Qx + 2 Qy = 56
3 Qx = 56
2 Qx + 2 Qy = 75
4 Qx = 75

Beam loss versus beam intensity



Beam intensity is relevant for beam survival

The 3rd order resonance was responsible of the periodic resonance crossing



Proof obtained by

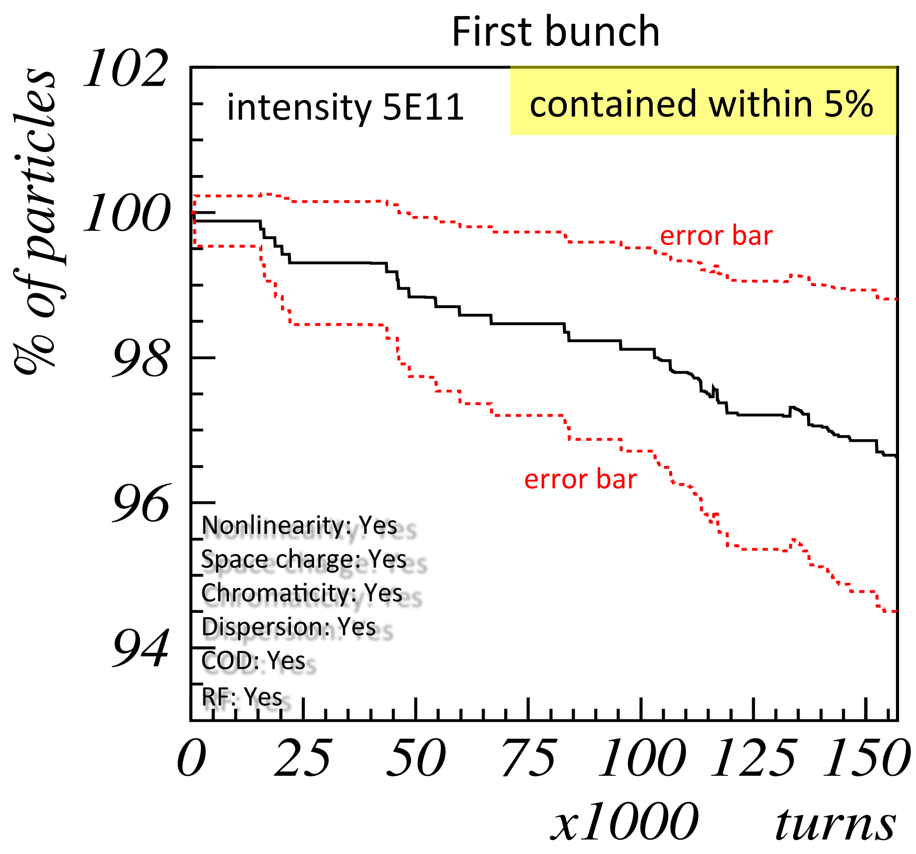
Compensating the resonance
Qx + 2 Qy = 56
without exciting the resonance
3 Qx = 56

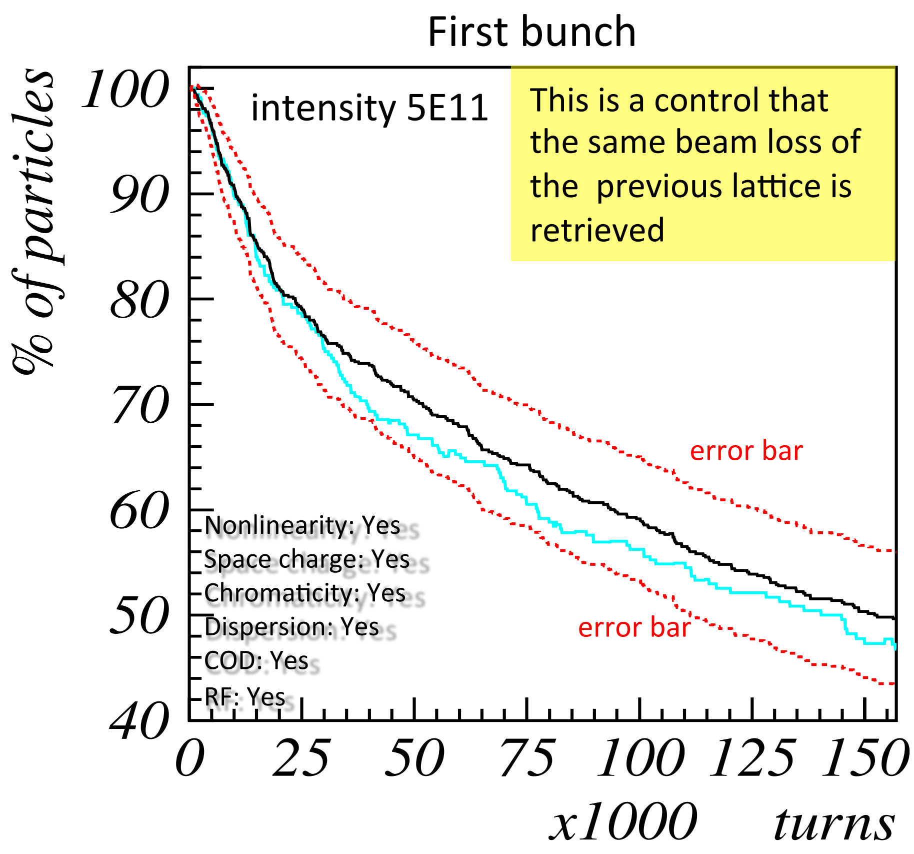
Compensating the relevant resonance mitigates beam loss

Compensated

Standard seed

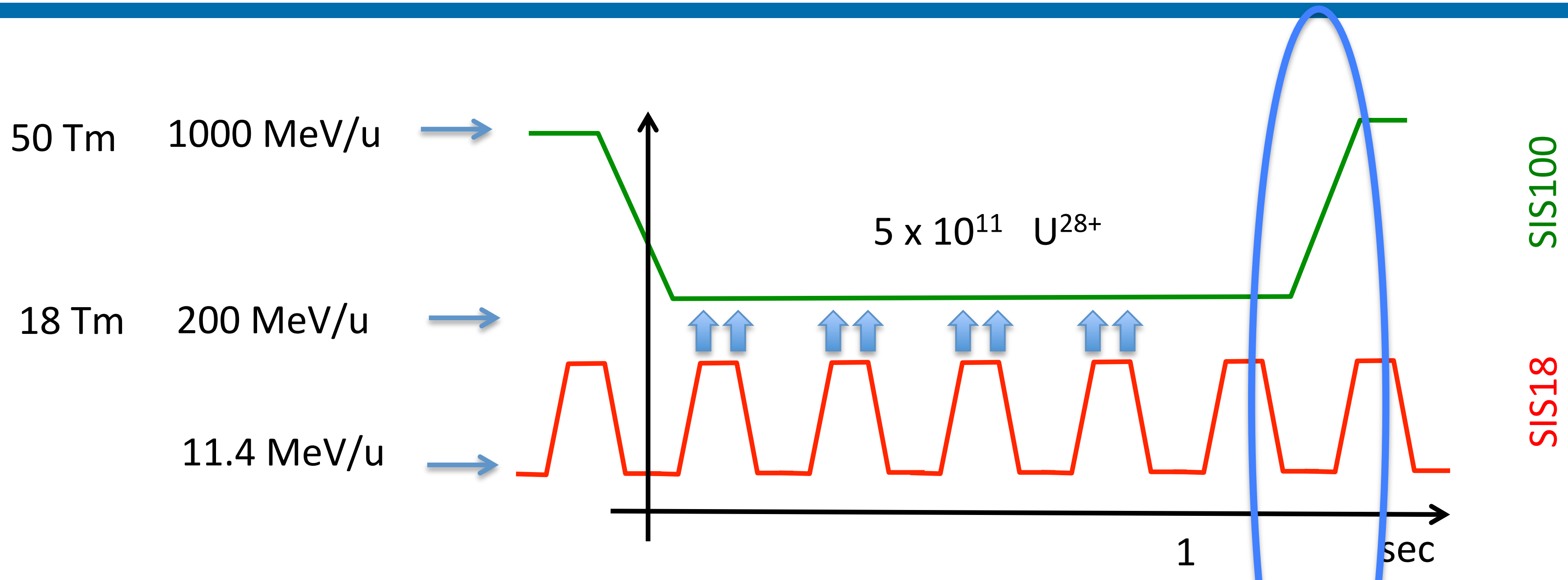
Un-Compensated





Dynamics during acceleration

SIS100 acceleration



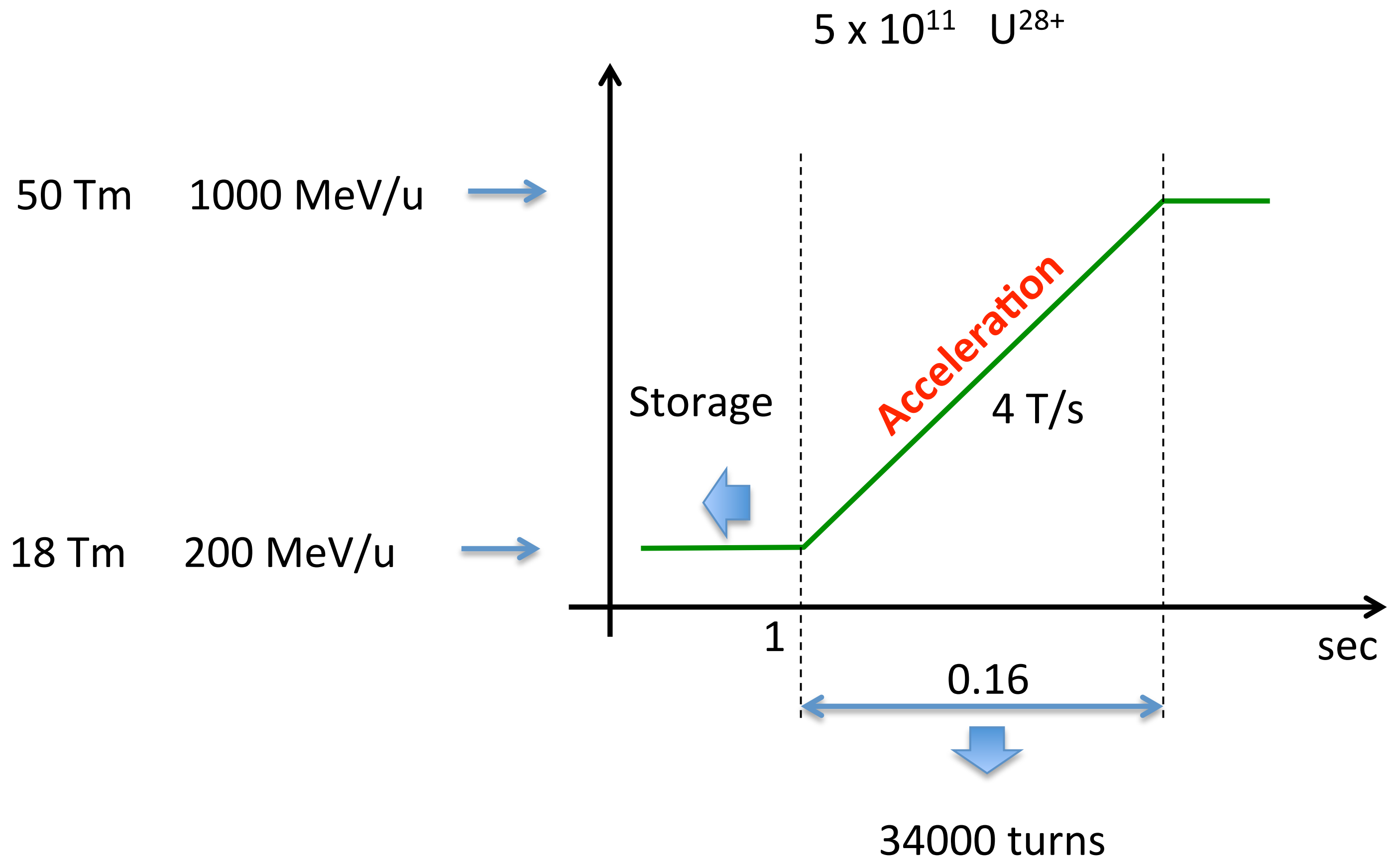
Bucket of storage

First bunch @ 200 MeV/u

Nominal N_{ions} = 6.25 x 10^{10}/bunch
Beam1: $\varepsilon_{x/y}$ = 35/15 mm-mrad (2σ) $\Delta Q_{x/y}$= -0.21/-033
Turns = 1.57 x 10^5 (1 sec.)

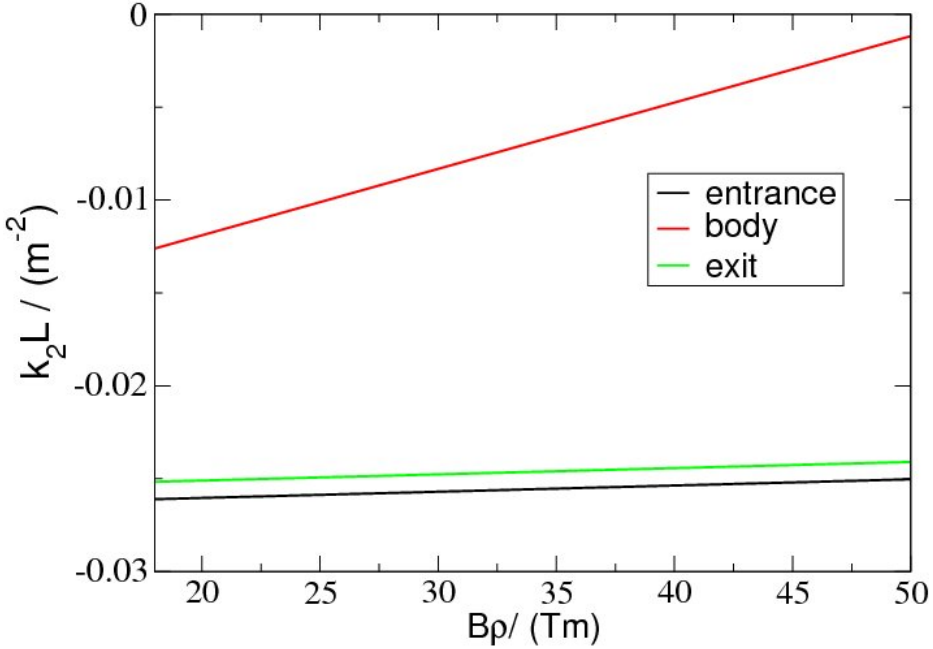
Acceleration

The acceleration Ramp

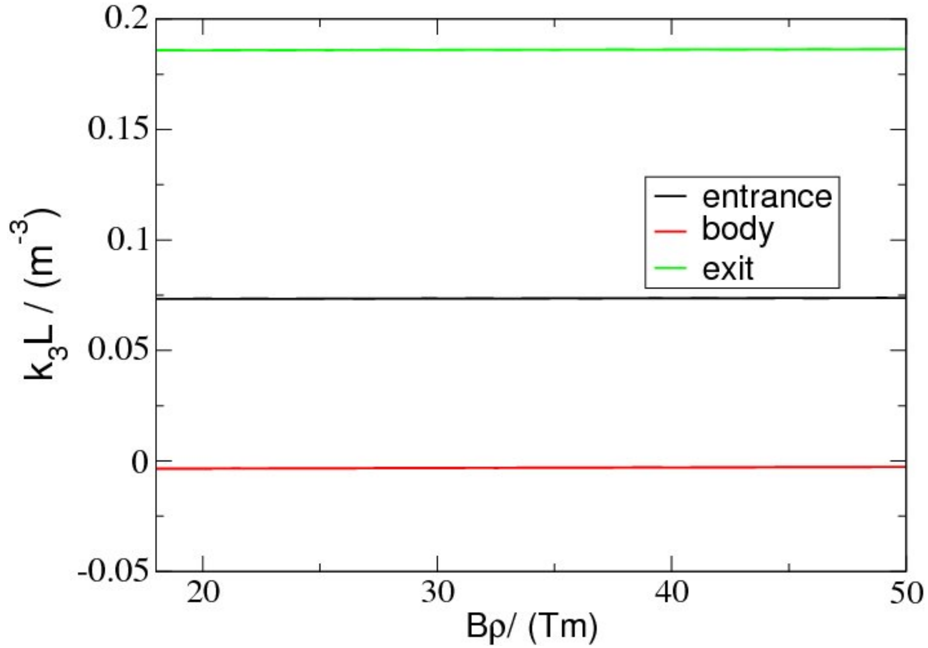


Magnet modeling during acceleration

Sextupolar component (without eddy current)



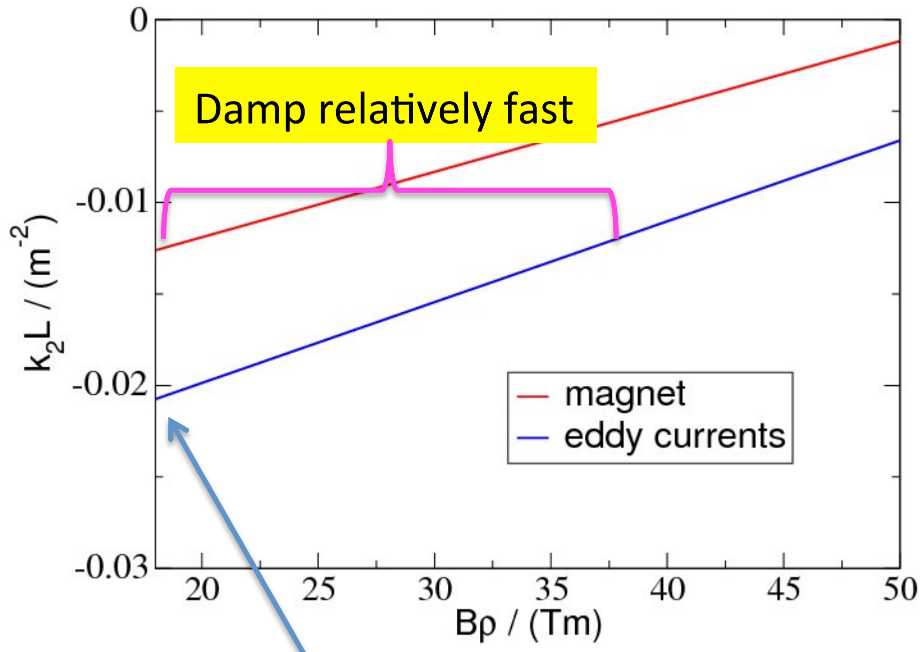
Octupolar component (without eddy current)



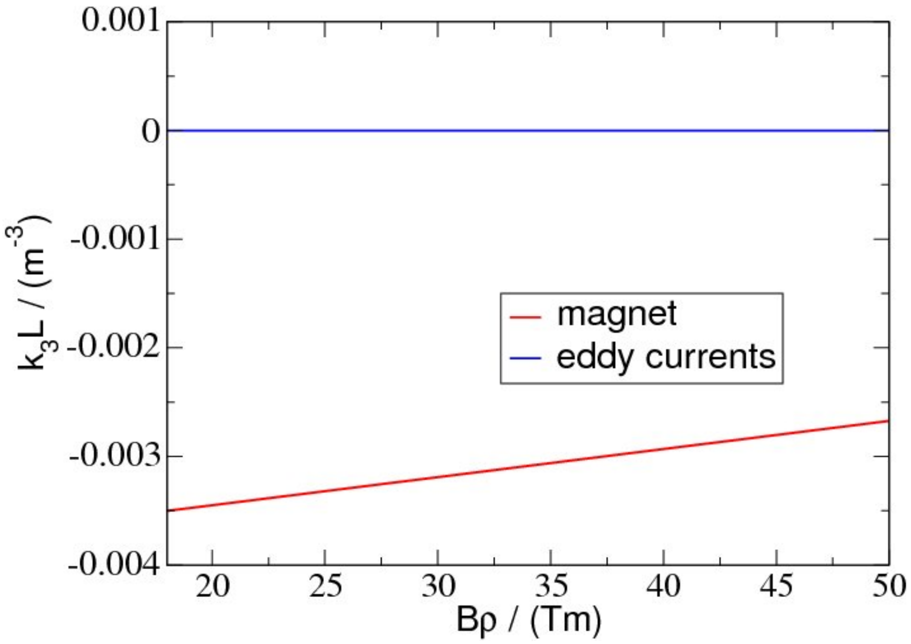
S.Sorge

Effect of the eddy current

Sextupolar component
and eddy current



Octupolar component
and eddy current



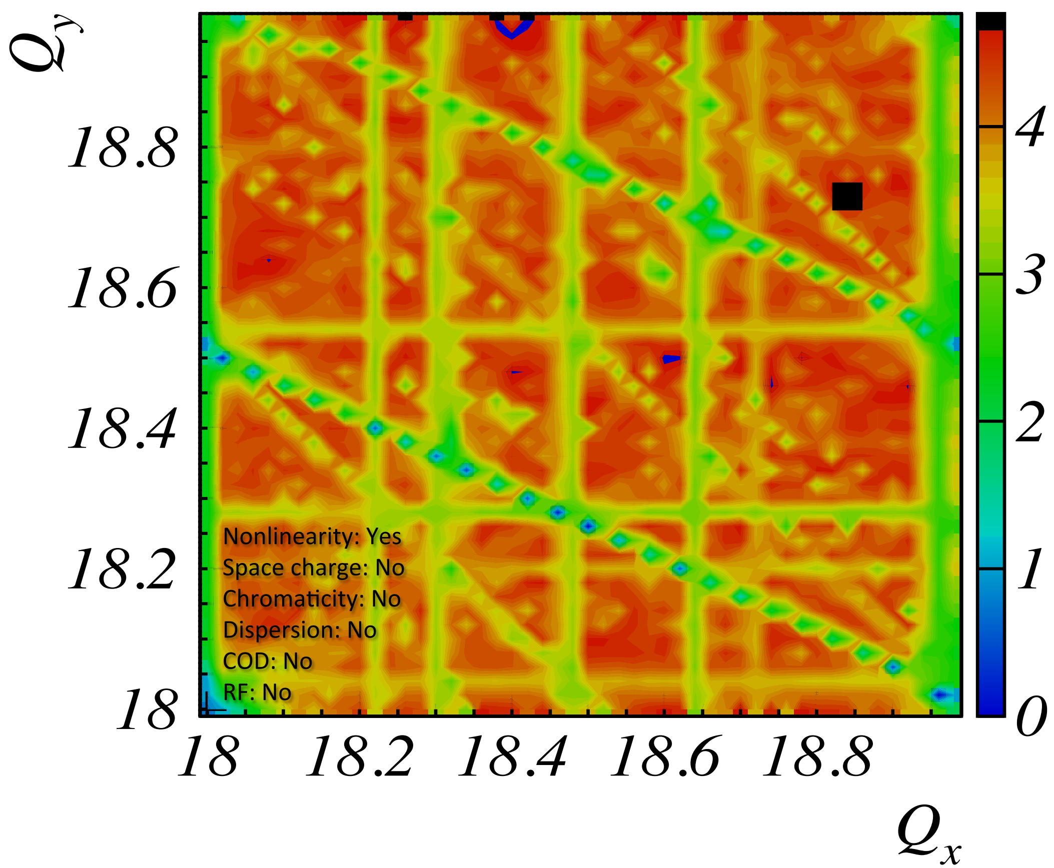
S.Sorge

Created at the beginning of the acceleration ramp of 4 T/s enhances the systematic sextupolar strength

Consequence: alteration of lattice resonances

Statistical view of the possible resonances

$$[\langle DA \rangle - 3\ \text{st.dev.}(DA)]/\sigma$$



Short term DA (1000 turns)

Statistics on 30 error seeds of random errors and quadrupoles displacement

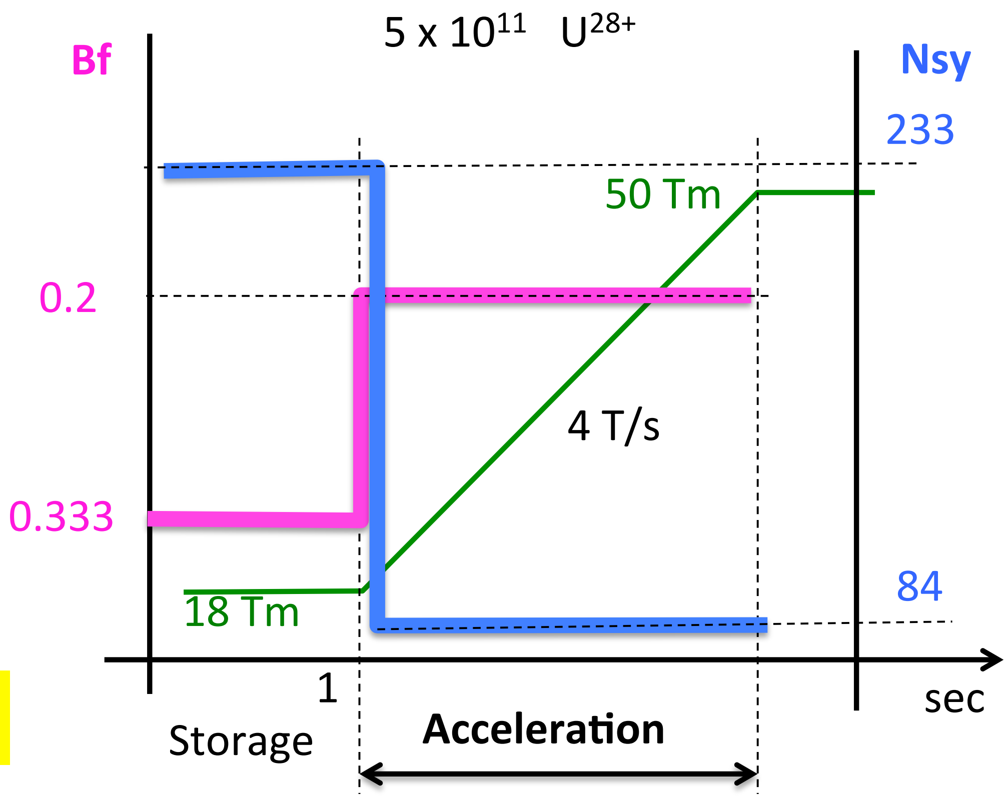
Something similar will happen during the ramp, but due to the change of multipolar components

Change of RF bucket

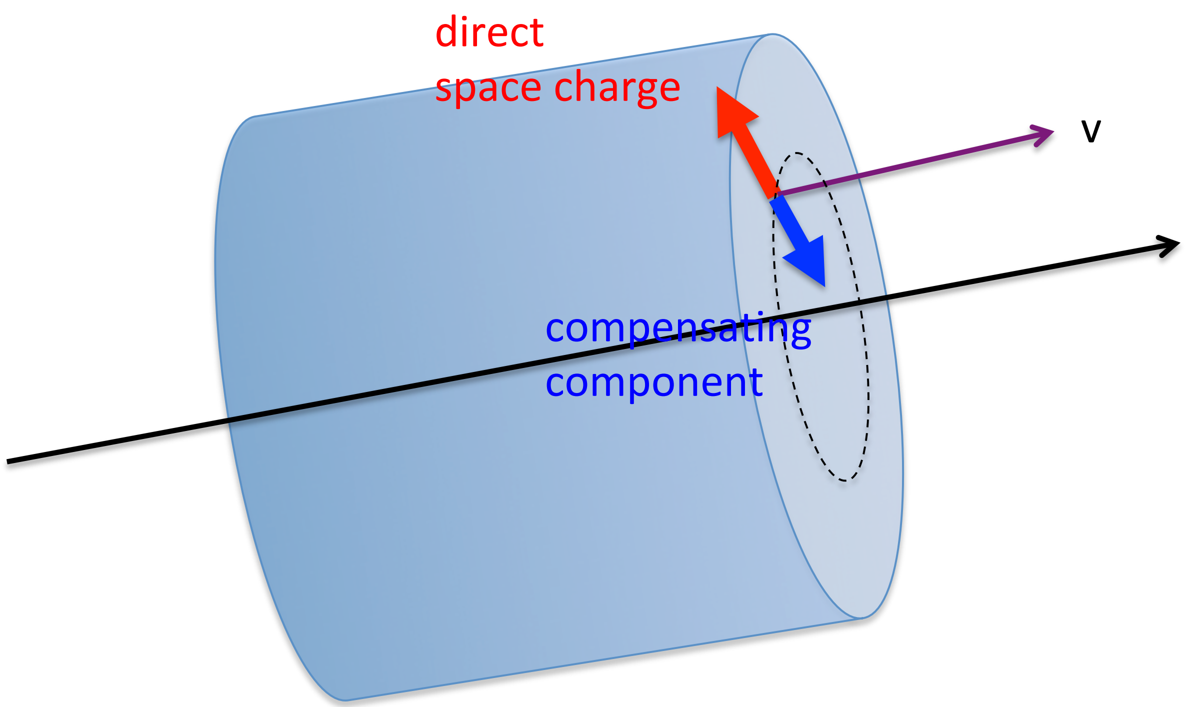
1) The bunch length is kept constant
2) The longitudinal emittance is preserved

Synchrotron frequency changes
Bunching factor changes

peak tuneshift increases of ~60%

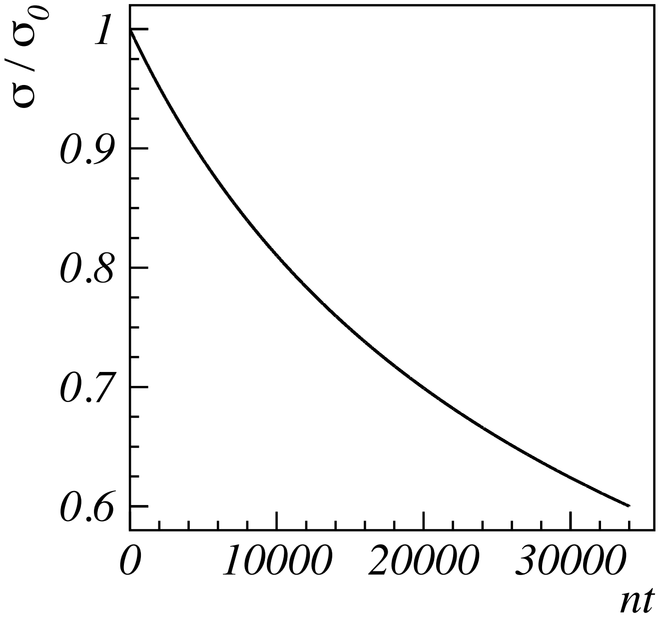


Space charge damping



Increasing beam velocity space charge damps with $\propto \frac{1}{\gamma^2}$ ⇒ **Reduction of space charge with energy**

Beam size shrinking



Beam size scaling with energy

$$\frac{\sigma_x}{\sigma_{x0}} = \sqrt{\frac{\gamma_0\beta_0}{\gamma\beta}}$$

At the beginning of the ramp

$$\frac{d}{dn}\frac{\sigma_x}{\sigma_{x0}} = -\frac{1}{2N}\left[\frac{(B\rho)_1}{(B\rho)_0} - 1\right]$$

In 1000 turns

size damping

$$\Delta\left[\frac{\sigma_x}{\sigma_{x0}}\right]_{1000} = -2.6\%$$

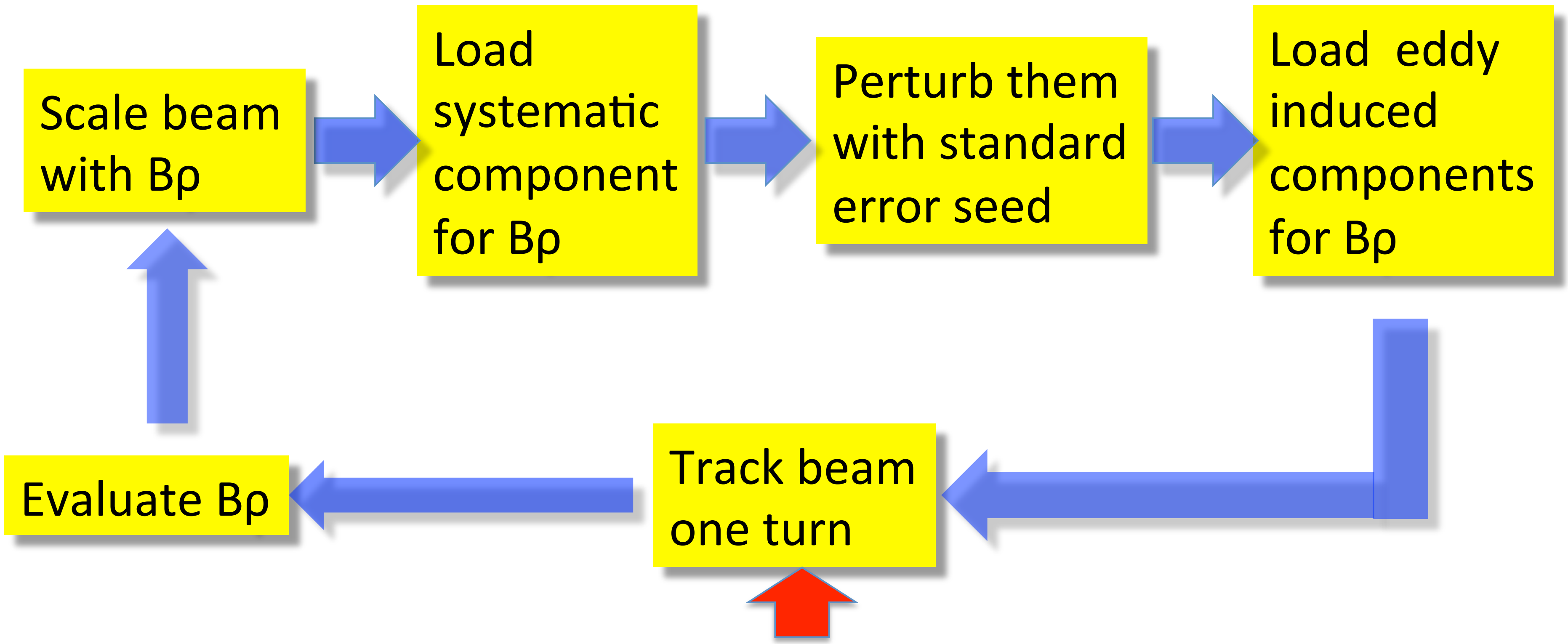
periodic crossing amplitude increasing

3 sigma → 4.7 sigma   growth of 1.7 sigma

Therefore in 1000 turns the growth is 1.7 sigma

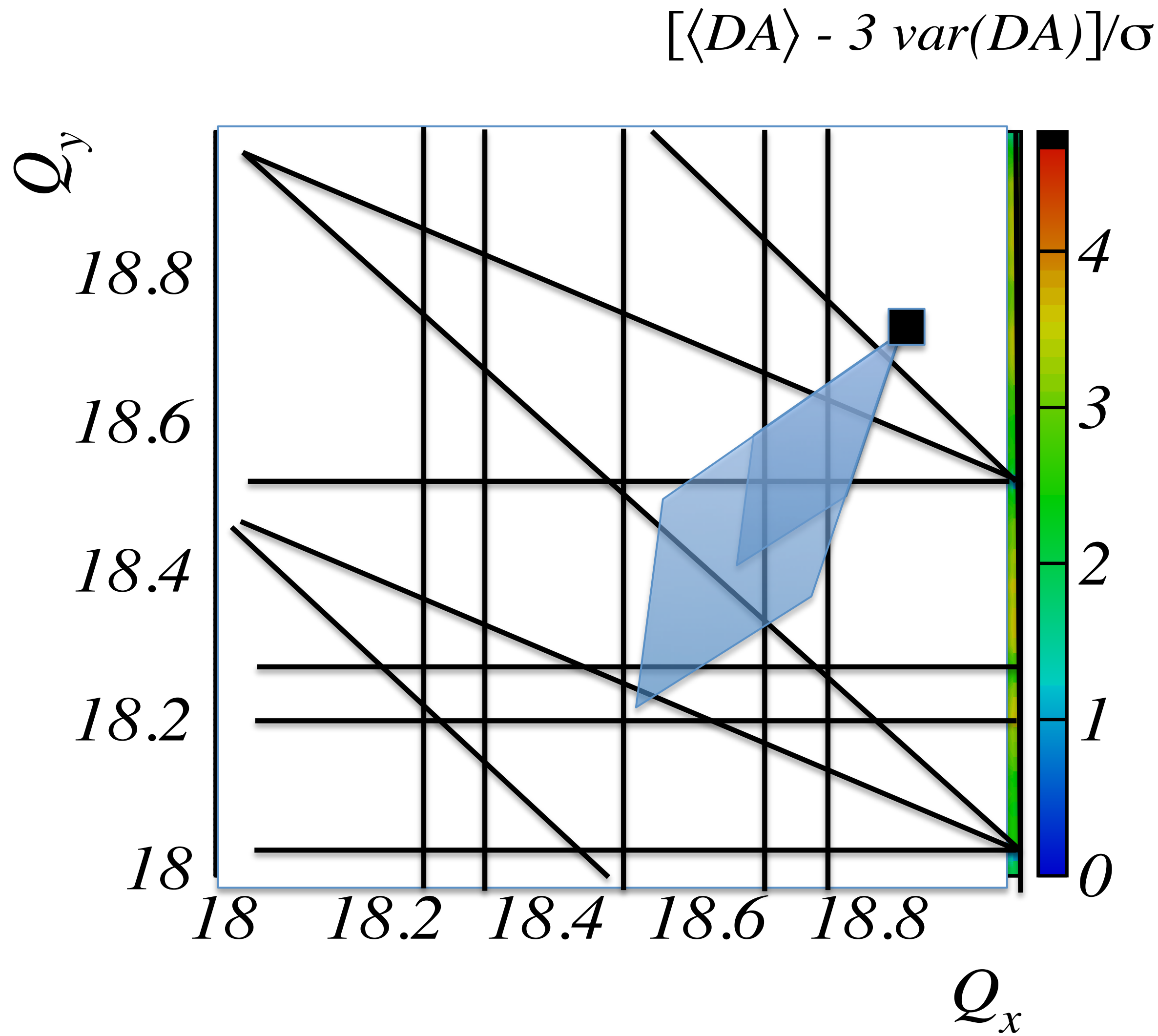
Acceleration: Code Modeling

The beam dynamics modeling is inconsistent

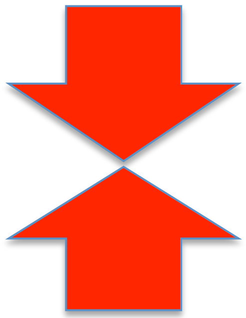


Space charge is scaled properly with Bρ

The beam dynamic issues



Increase of energy damp beam size and space charge



periodic resonances crossing push beam out

Relevance of resonances varies during the ramp

Very complex process

Study Strategy

<u>We keep conservative:</u>

Keep the error seed of the storage also during the ramp

↓

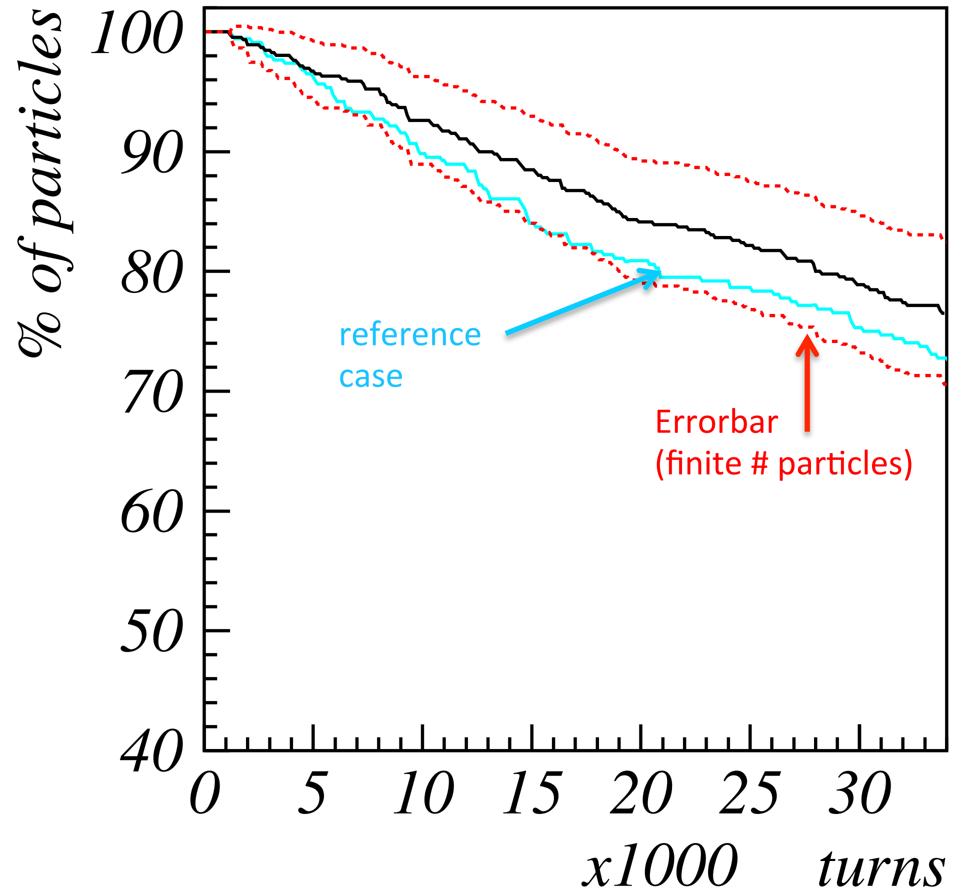
Closed orbit distortion remains during ramp
of the order of storage

Do not compensate any resonance

We study the higher intensity case $I = 5\text{x}10^{11}$ ions

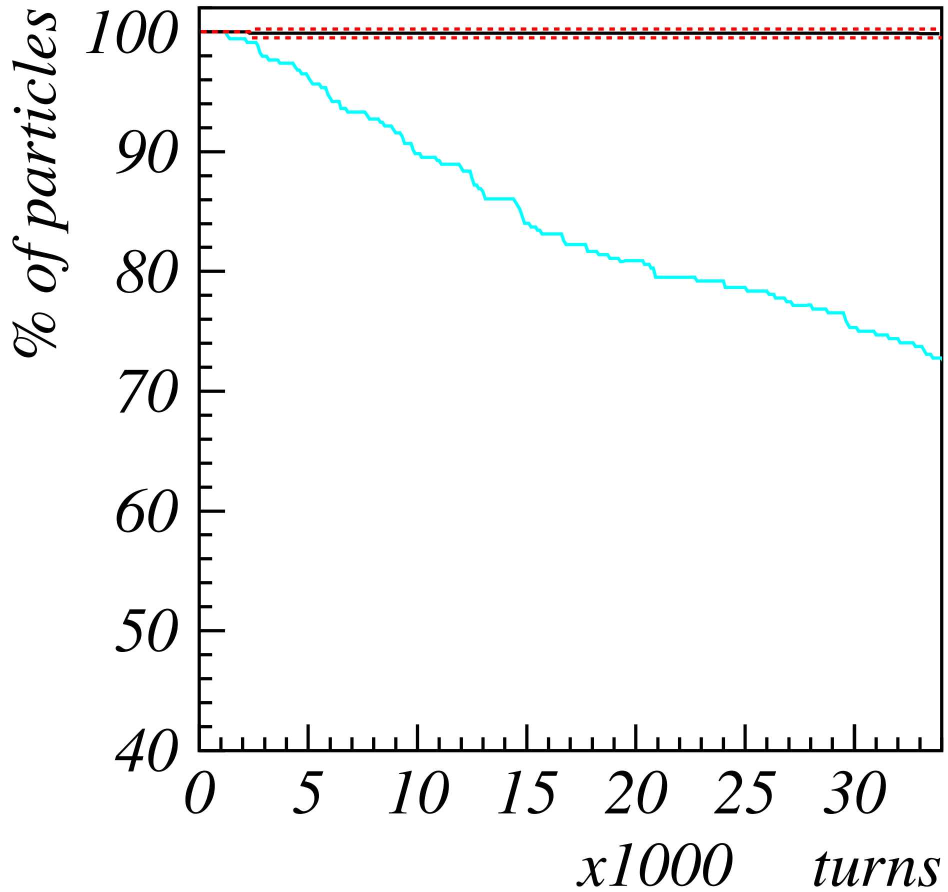
Verification of old results

emittances: 35x15
dp/p: yes
Intensity: 5E11
Resonance: uncompensated
Ramp: 18Tm → 18Tm
random seed → yes
eddy currrent → no
bucket → Storage



Acceleration keeping the "storage bucket"

emittances: 35x15
dp/p: yes
Intensity: 5E11
Resonance: uncompensated
Ramp: 18Tm → 50Tm
random seed → yes
eddy currrent → no
bucket → Storage



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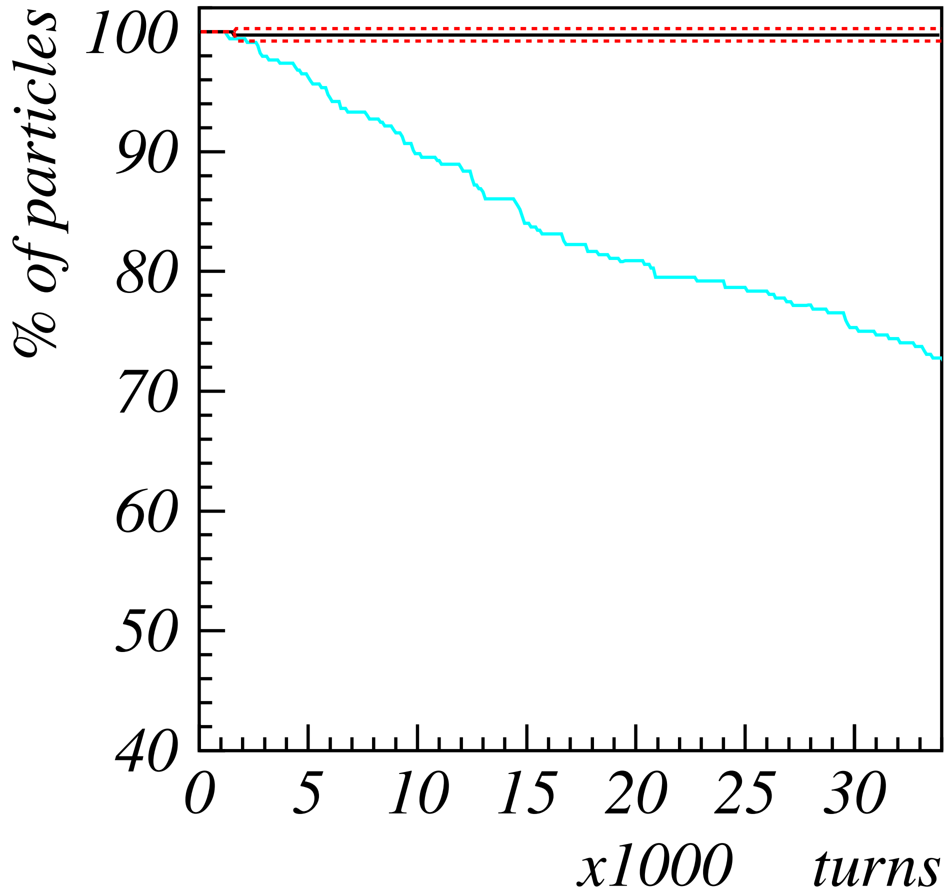
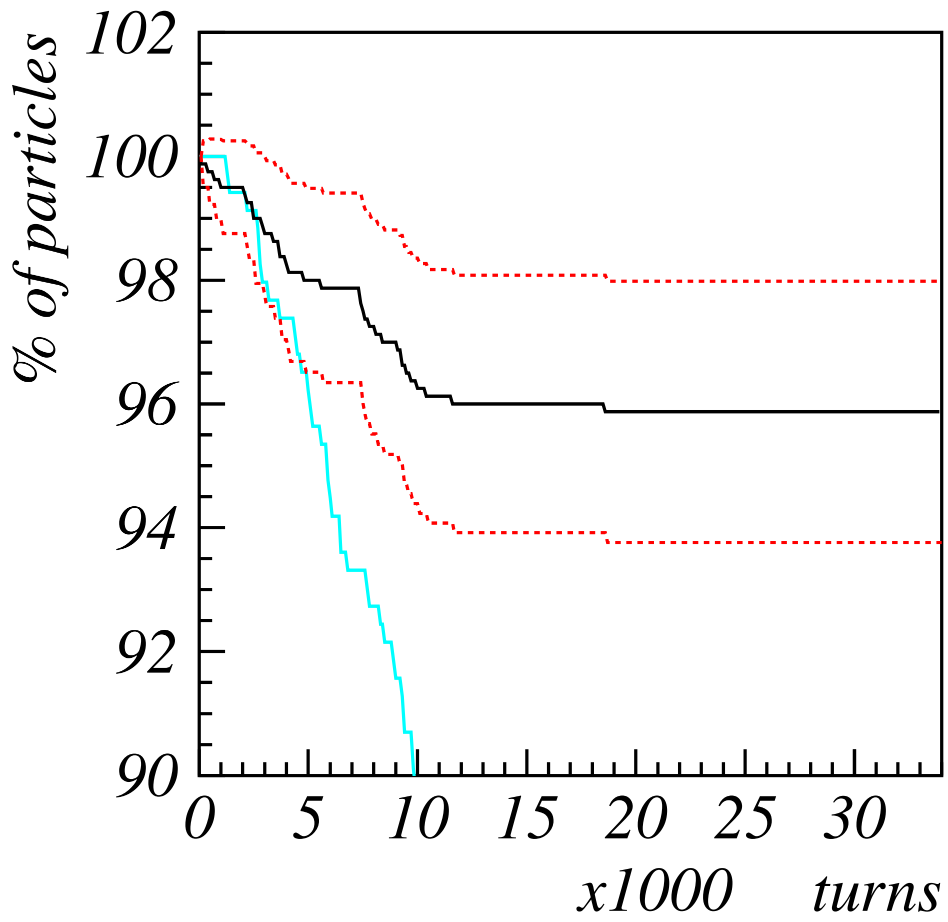


Acceleration with “realistic” bucket

emittances: 35x15
dp/p: yes
Intensity: 5E11
Resonance: uncompensated
Ramp: 18Tm → 50Tm
random seed → yes
eddy currrent → no
bucket → Ramp



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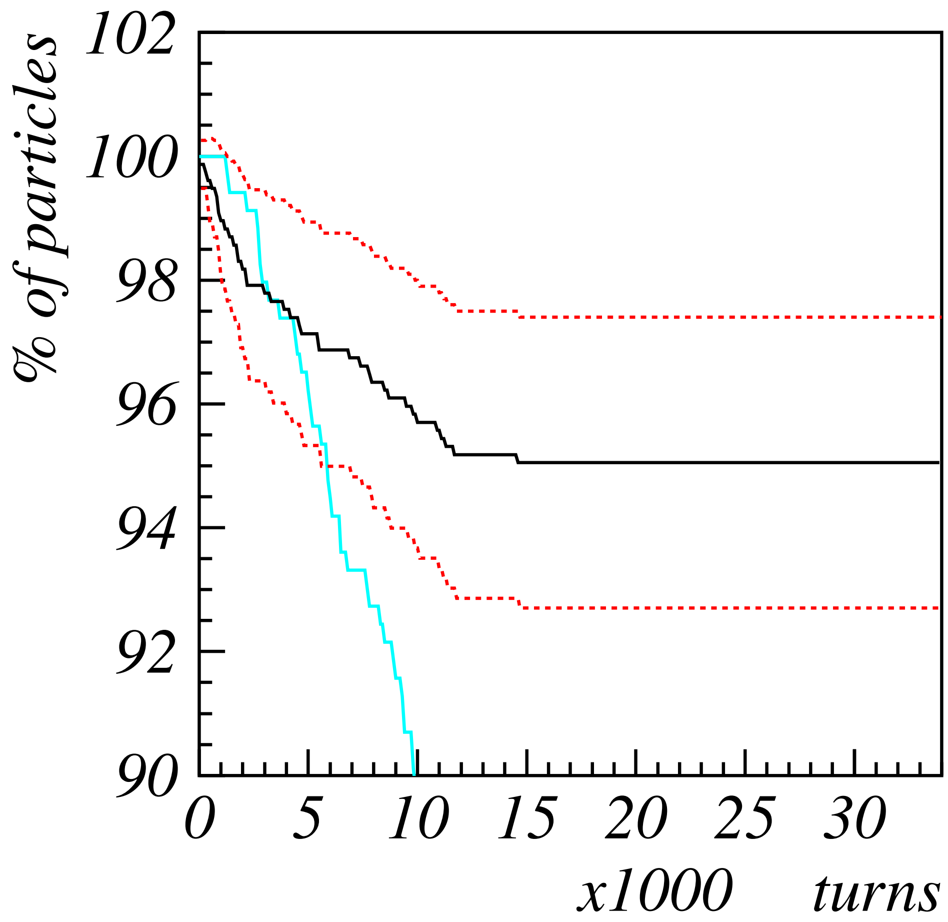

Conclusions and Remarks

For the **standard error seed** we find that during acceleration the bunches stored experiences **~ 7%** beam loss distributed over half acceleration ramp

This prediction is **conservative** as it is based on an uncompensated machine

As for the result of MAC4, this prediction is affected by the error seed taken, which is here the **standard error seed: no result is claimed for other errors seeds**

The modeling of the acceleration is inconsistent and its validity should be reconfirmed (although beam damp during acceleration fits very well with theoretical prediction)

Experimental verification in SIS18 should be foreseen to benchmark code predictions (very difficult)