Space Charge Issues and EC Issues

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Lumi-06, Valencia

Overview

Space charge issues

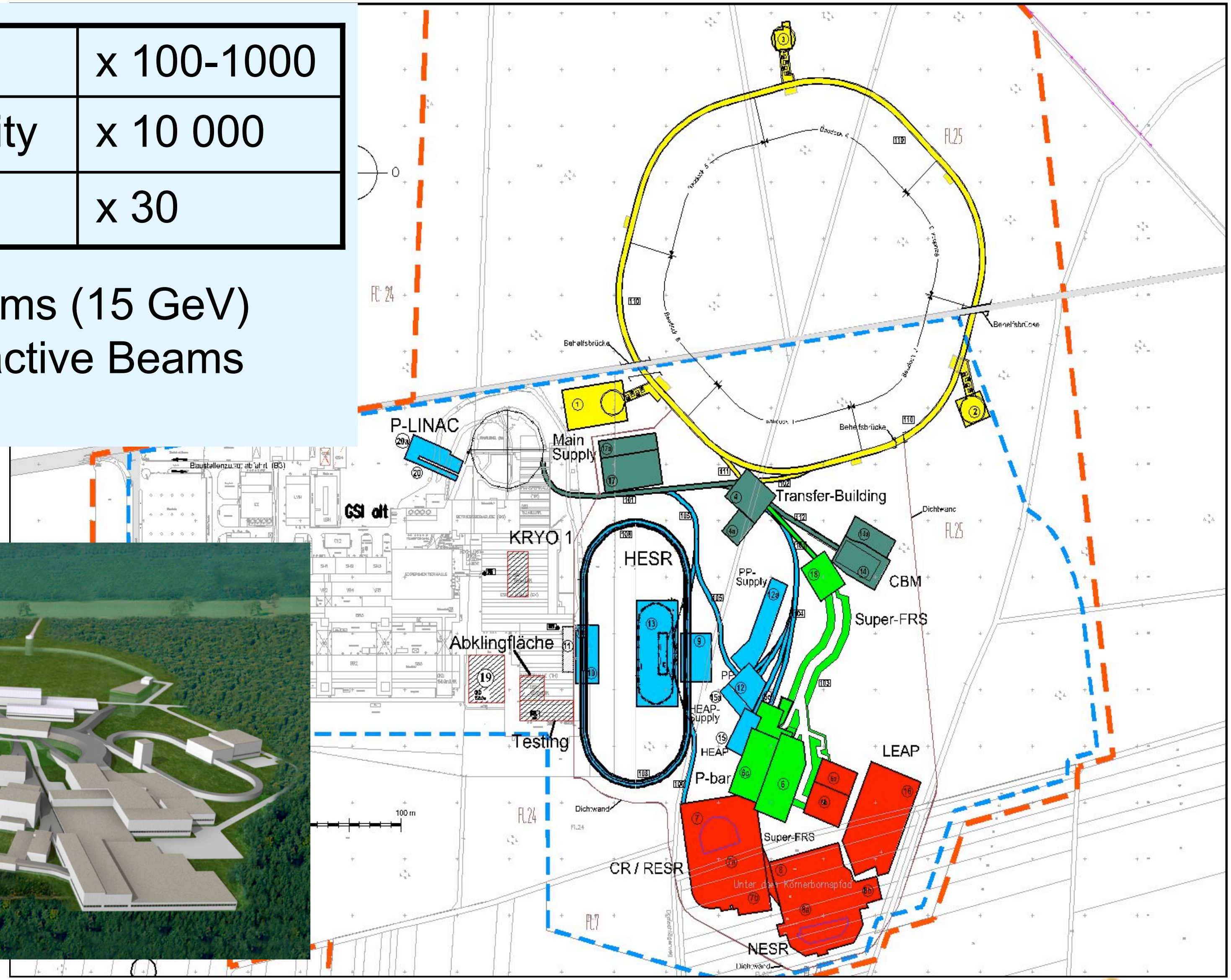
Impact on SIS100

EC incoherent effects

The next generation of computational challenges at FAIR

Primary Beam Intensity	x 100-1000
Secondary Beam Intensity	x 10 000
Heavy Ion Beam Energy	x 30

- New: Cooled pbar Beams (15 GeV)
- Intense Cooled Radioactive Beams
- Parallel Operation



SIS100 critical scenario

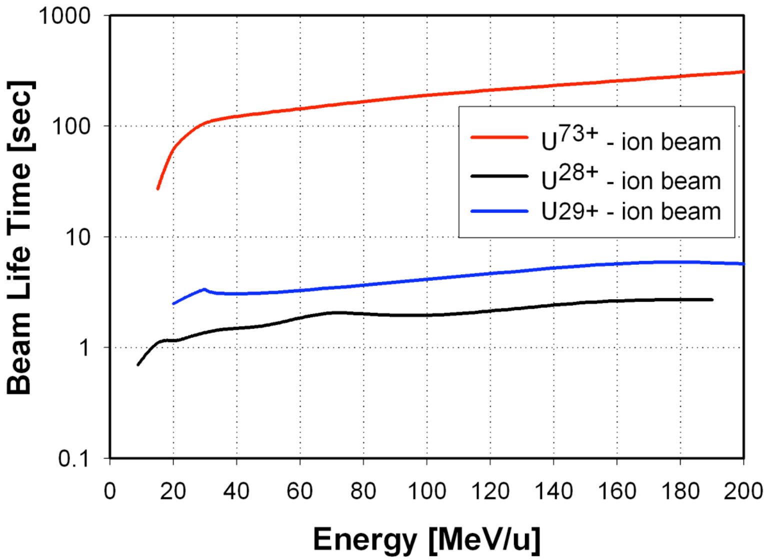
Required Intensity in SIS18 Booster (after acceleration)

1.5×10^{11} U^{28+} -ions /cycle

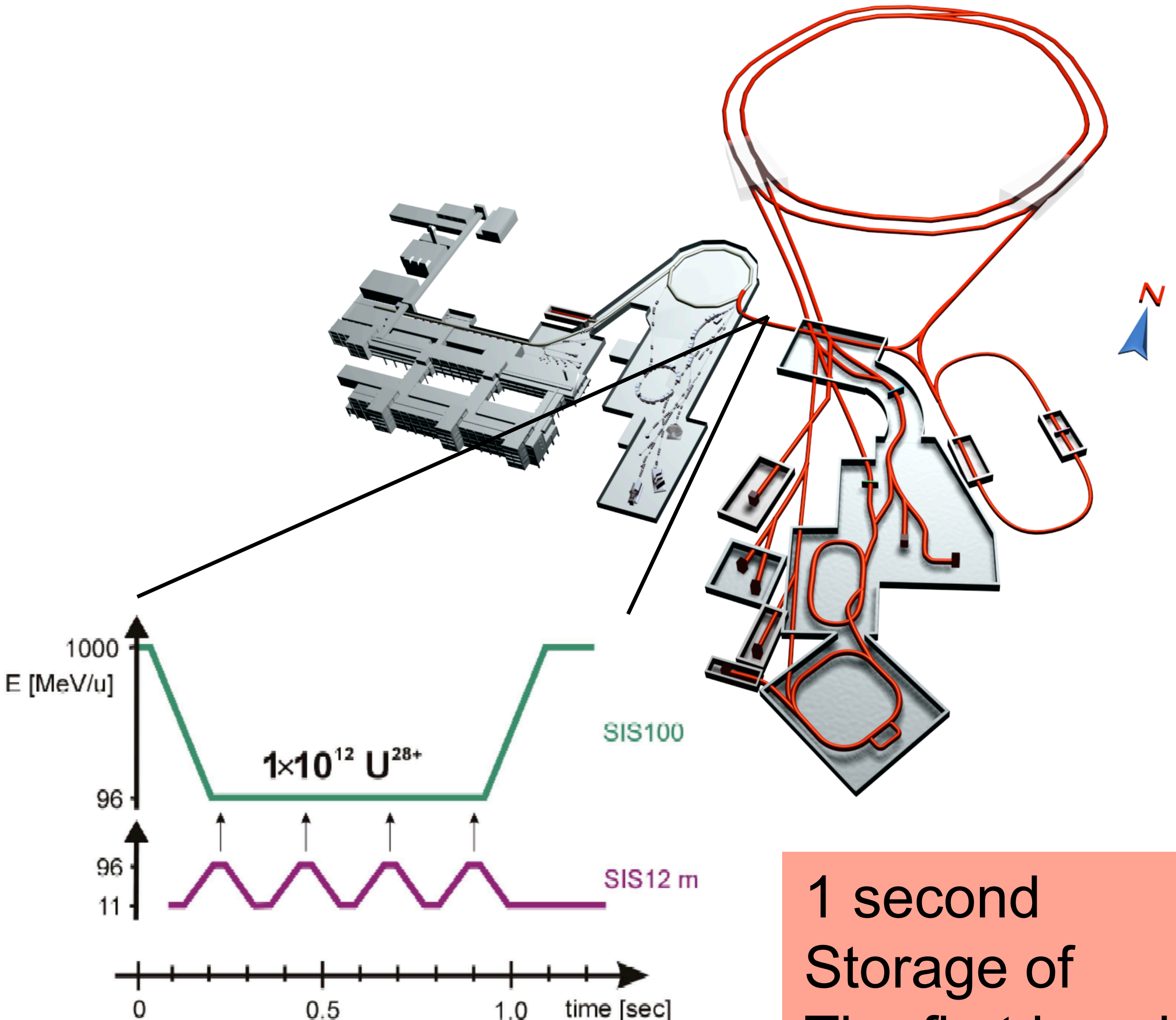
Required Intensity in SIS100

6×10^{11} U^{28+} -ions /cycle

Beam Life Time



Low charge states beams provide higher intensities but have shorter life time



1 second Storage of The first bunch

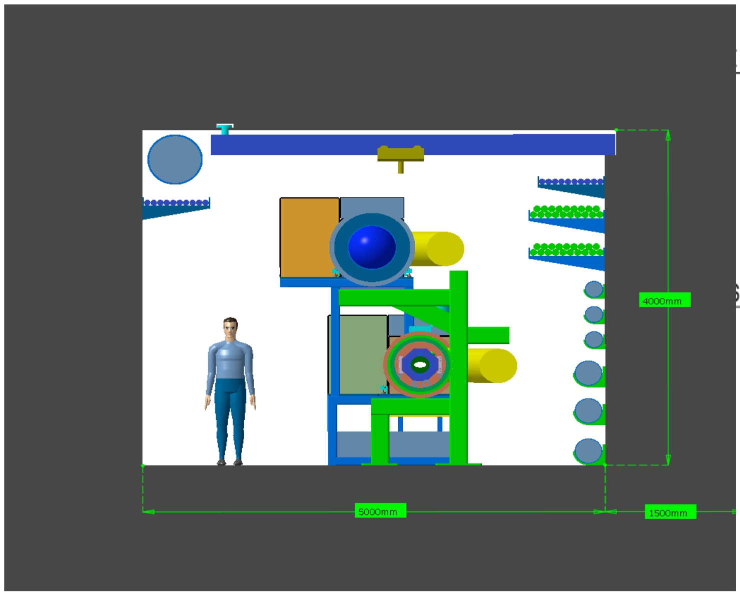
Requirements on Beam Loss

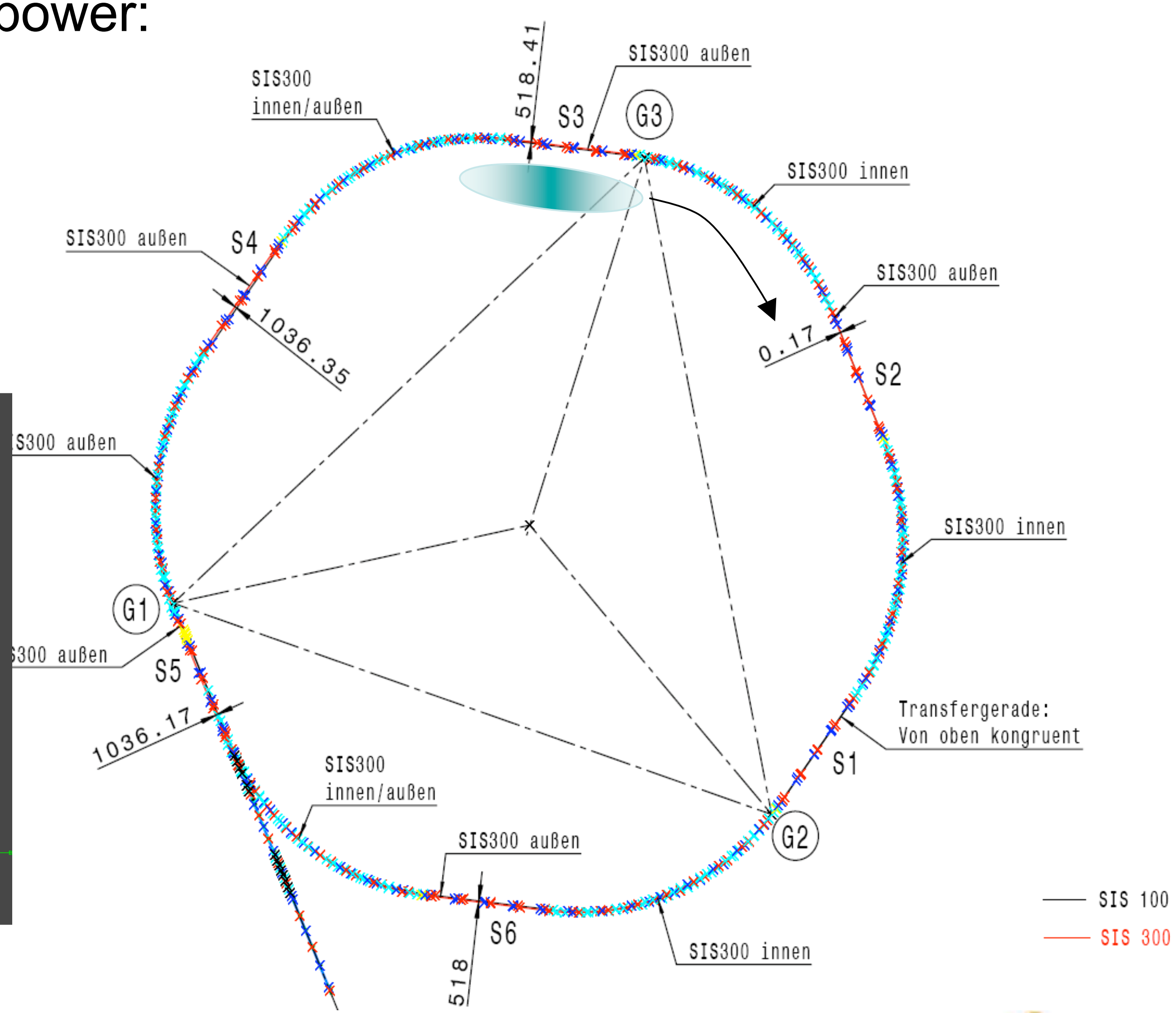
SIS 100/300 average (peak) power:

6 10^{11}/s 1.0 GeV/u U^{28+}: 23 kW

1 W/m tolerable beam loss

~5 % acceptable loss





The SIS100 Challenges

Storage time 10^5 turns

Intensity 0.75×10^{11}/ions U^{+28}

Space charge tune-shift $\Delta Q \sim 0.2$

SIS100 has SC dipoles --> Nonlinearities

Beam loss prediction
Localization of beam loss
Emittance increase prediction

Lattice design:
Collimation system

Magnet quality:
Nonlinear field control

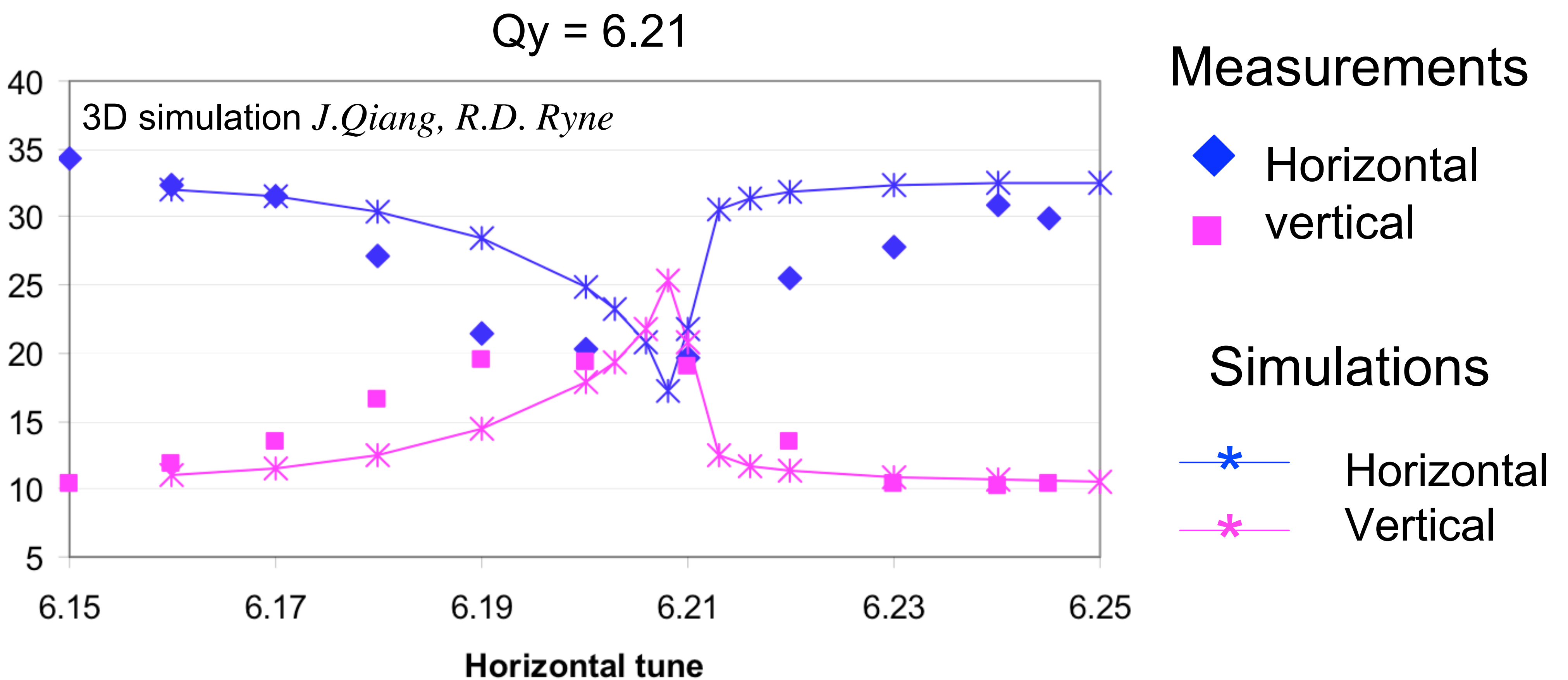
Resonance
compensation system

SPACE CHARGE ISSUES

- Montague
- Linear coupling in presence of space charge
- Periodic crossing of resonance via space charge
- The effect of the chromaticity
- The effect of the self-consistency

Montague Studies

E. Metral,M.Giovannozzi,M.Martini,R.Steerenberg,G.Franchetti,I.Hofmann EPAC04



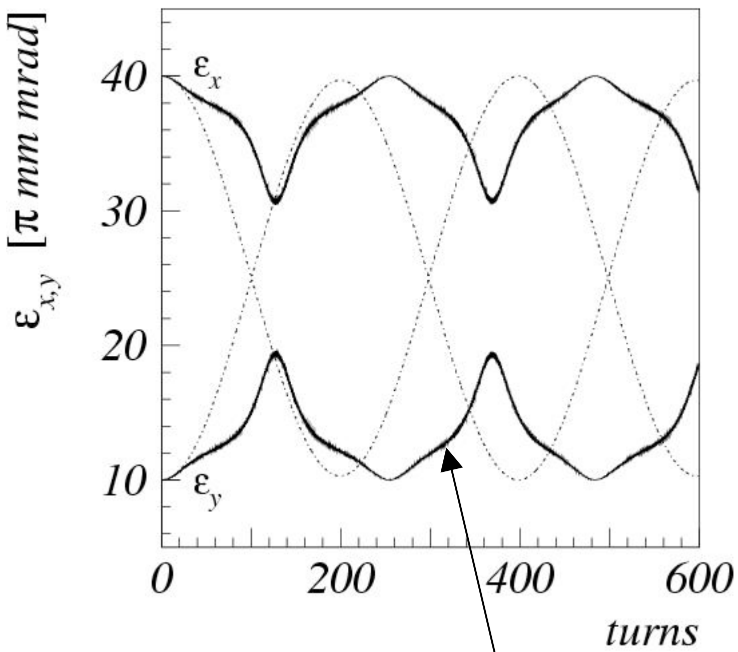
This resonance is critical because difficult to compensate

Space charge and Linear Coupling

When linear coupling is present in the ring and Qx, Qy satisfies the condition Qx + Qy = N, the beam emittances are periodically exchanged

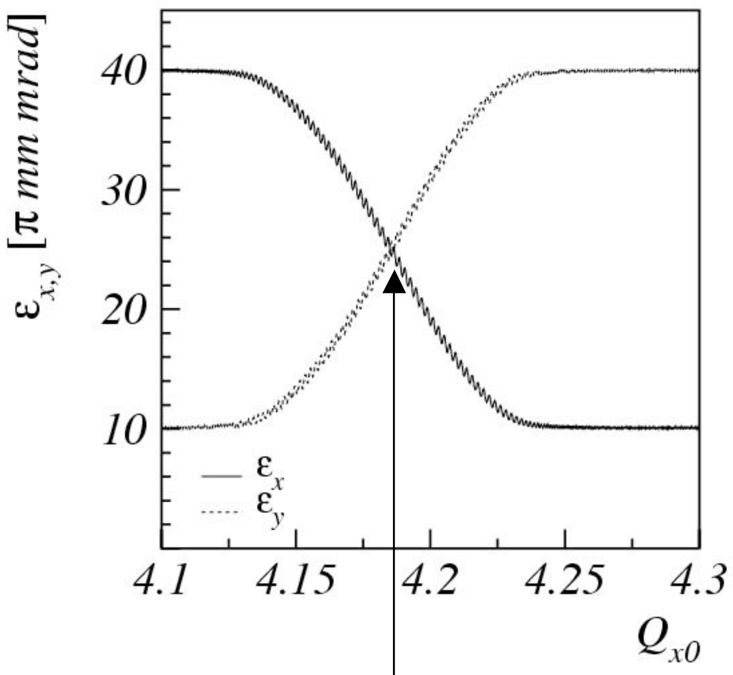
G.Franchetti et al. PRL ***94*** *194801 (2005)*

Qx = 4.16, Qy = 3.2



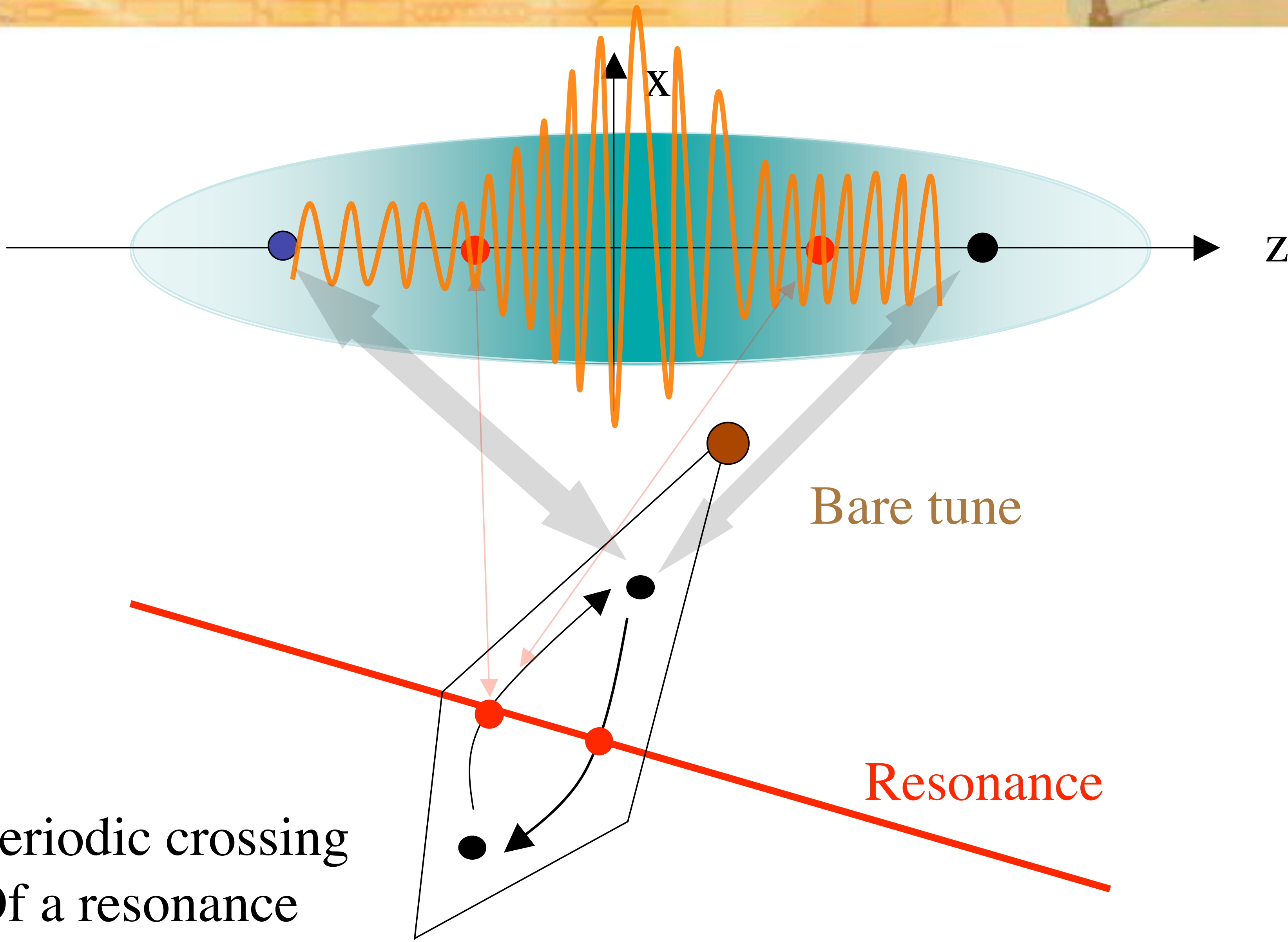
Even with space charge

Dynamic crossing



Equal emittances :)
Beam upright :)

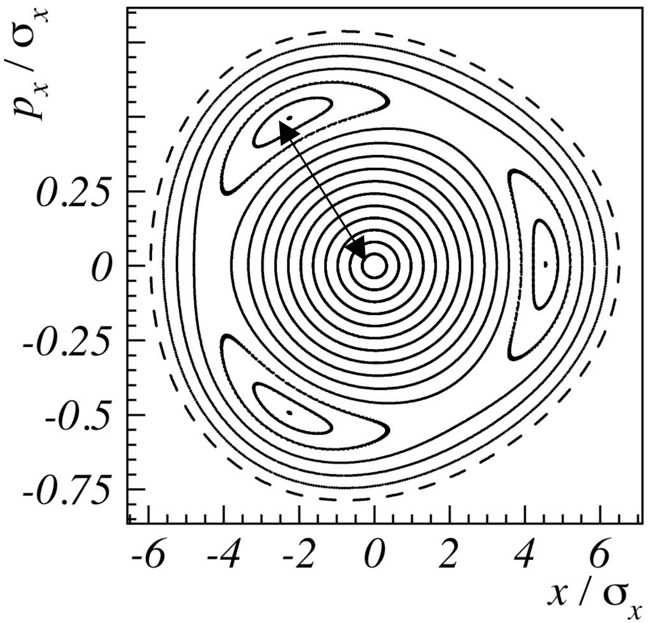
Synchrotron motion and trapping

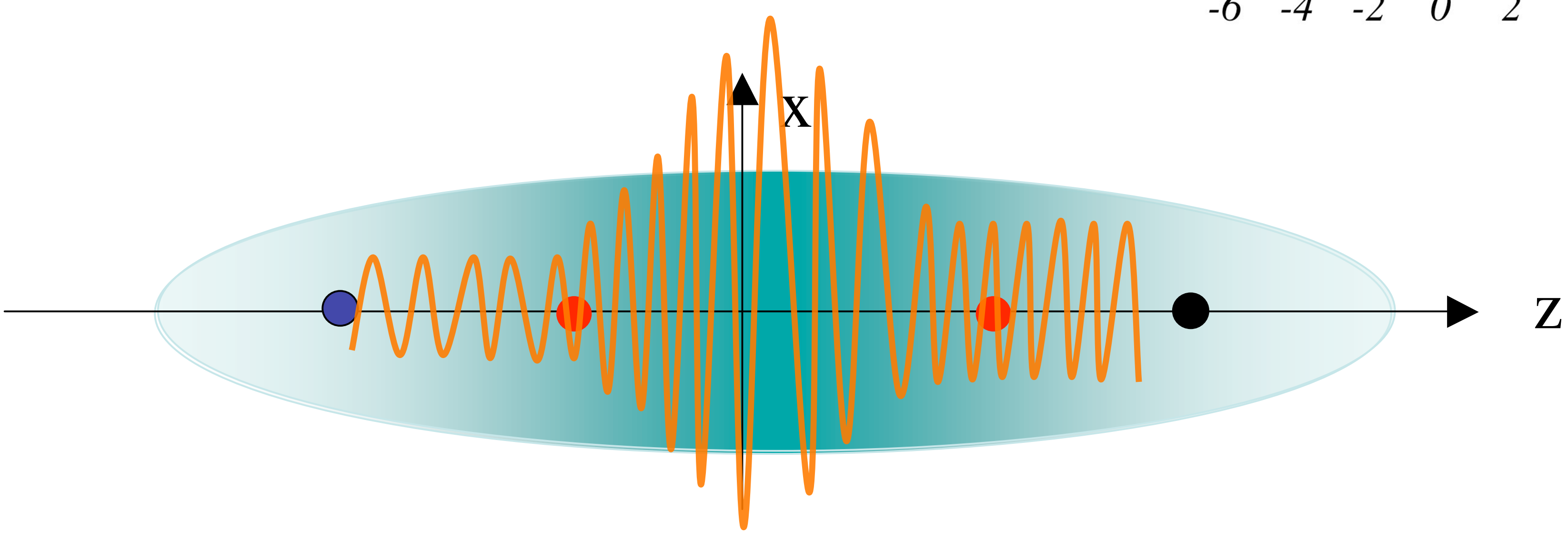


Periodic crossing
Of a resonance

Space charge control the islands

When the particle is trapped,
This orbit is resonant, and its
Amplitude is such to remove
The distance from the resonance





Emittance evolution in a full bunch

Code-Code Benchmarking

SIS18 (full AG lattice)

$Q_s = 10^{-3}$

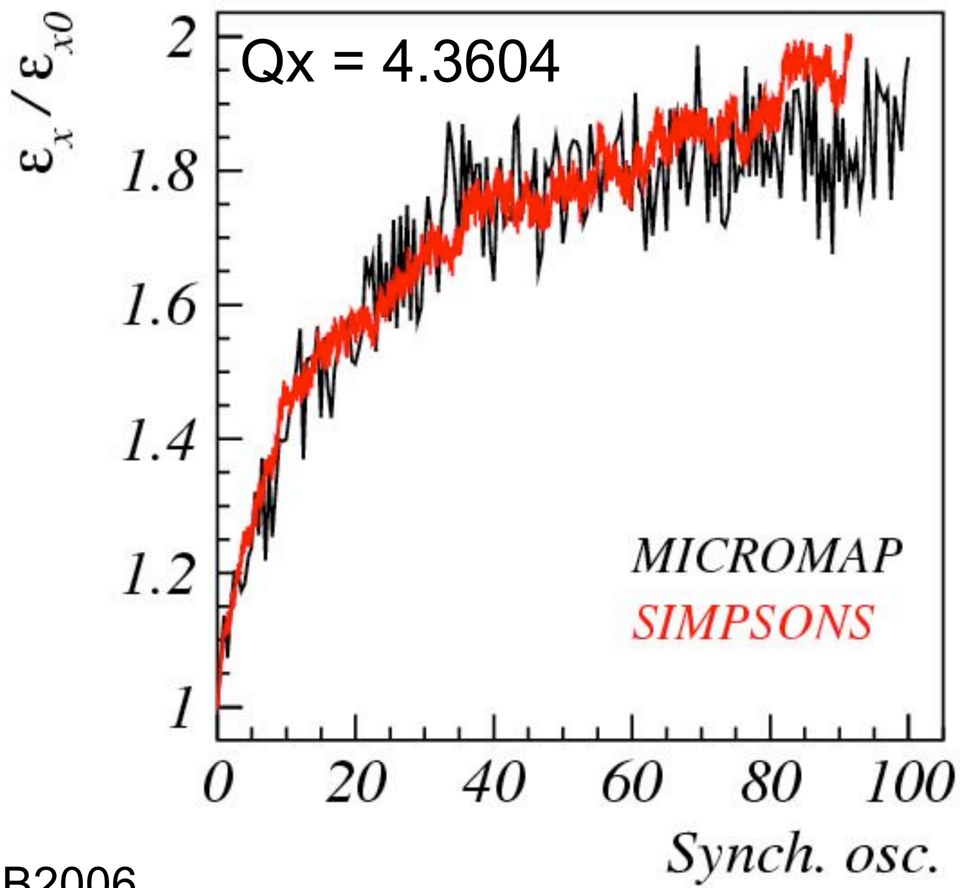
10^5 turns

10^3 macroparticles

In **SIMPSONS** (S. Machida)
the longitudinal dynamics
Is nonlinear

In **MICROMAP** (G.Franchetti)
the longitudinal dynamics
Is linear

Excellent Agreement !!
(on 10^5 turns)

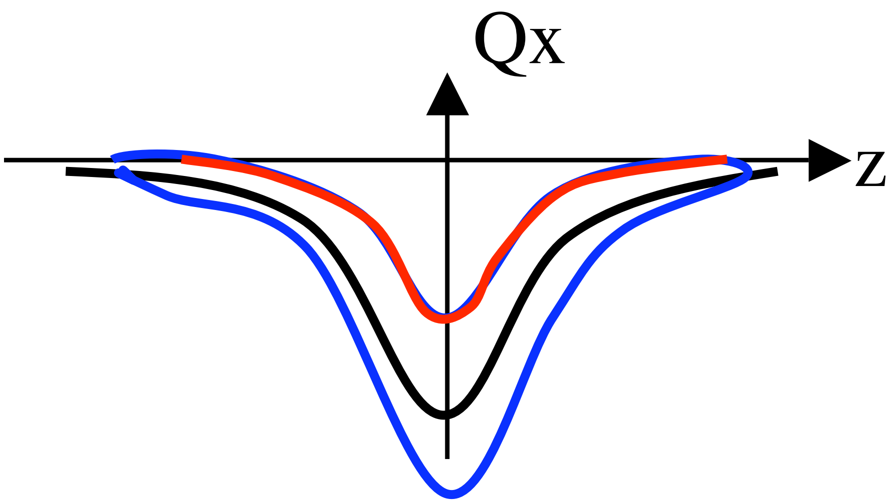


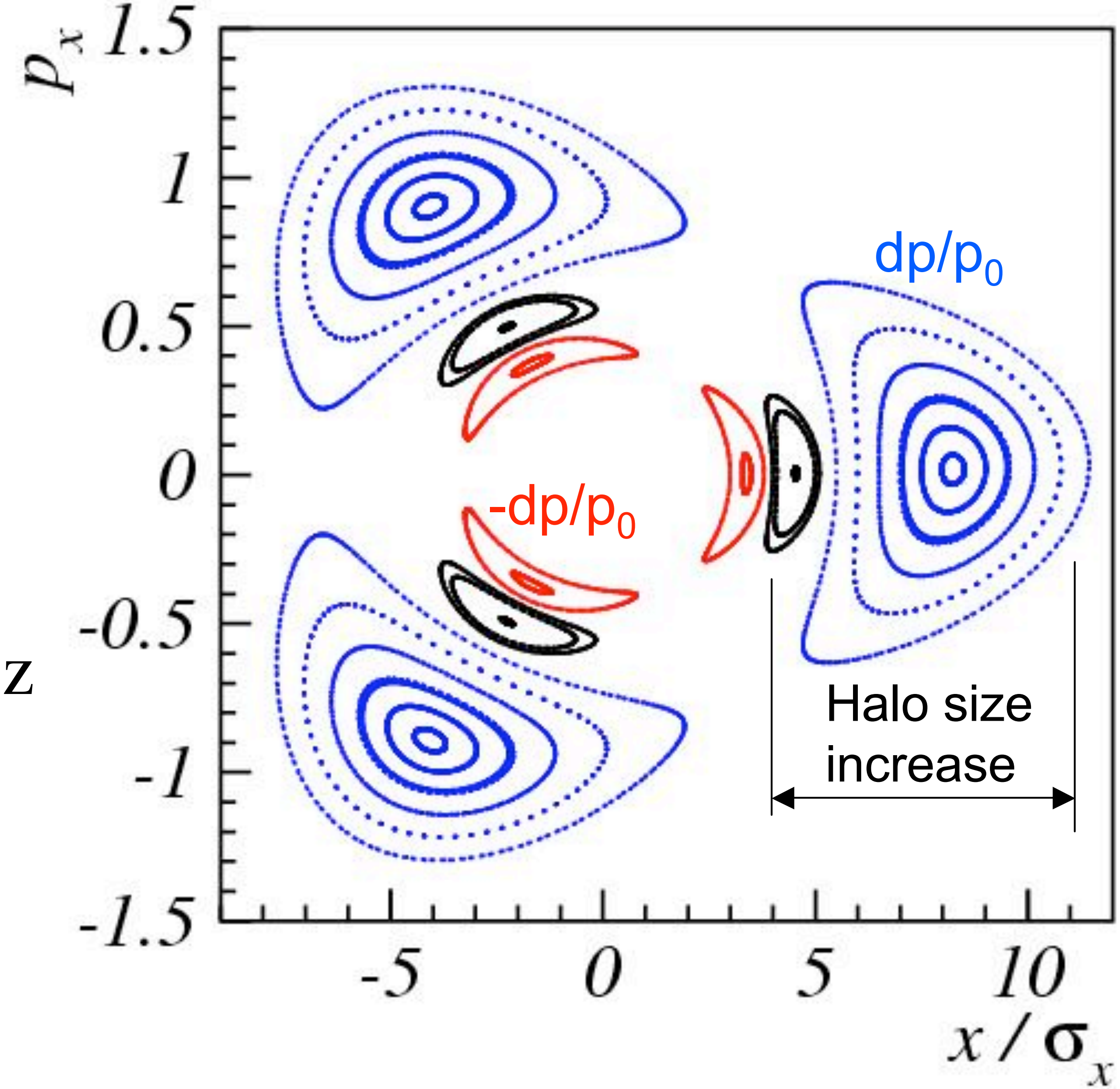
G. Franchetti,I. Hofmann, S. Machida HB2006

http://www-linux.gsi.de/~giuliano/research_activity/trapping_benchmarking/main.html

The Effect of Chromaticity

It further enhance/reduce
The position of the islands
According to the gain loss
Of longitudinal energy

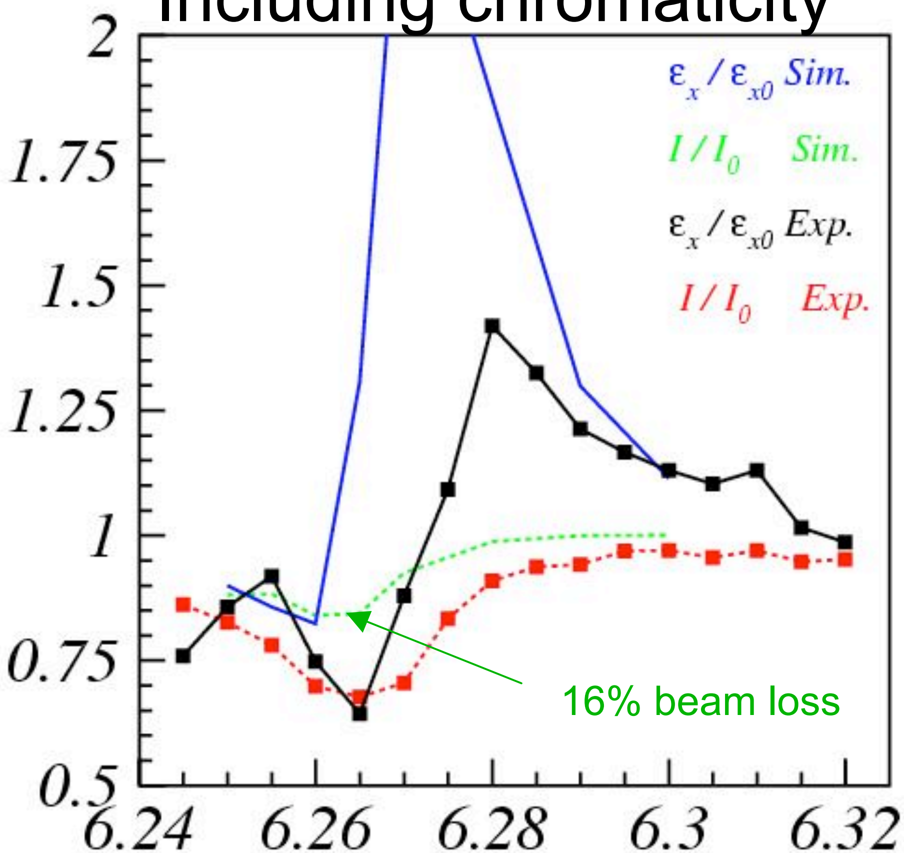




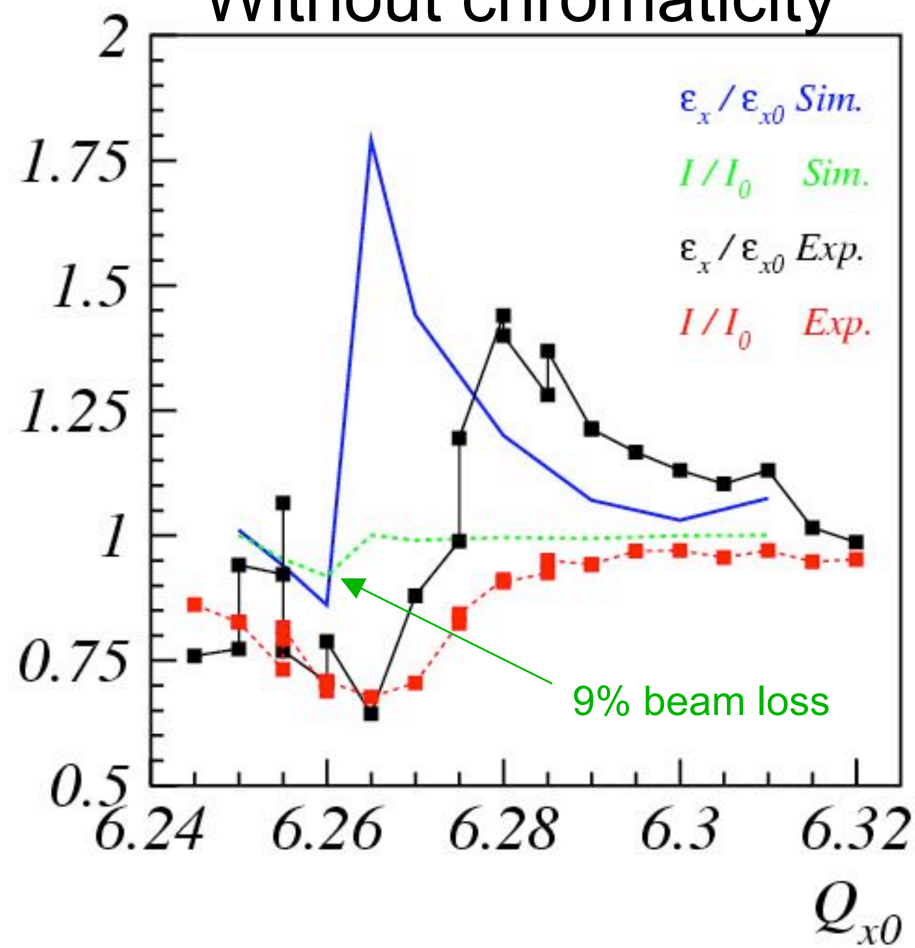
Simulation for CERN-PS Experiment

Modeling-Experiment Benchmarking

Including chromaticity



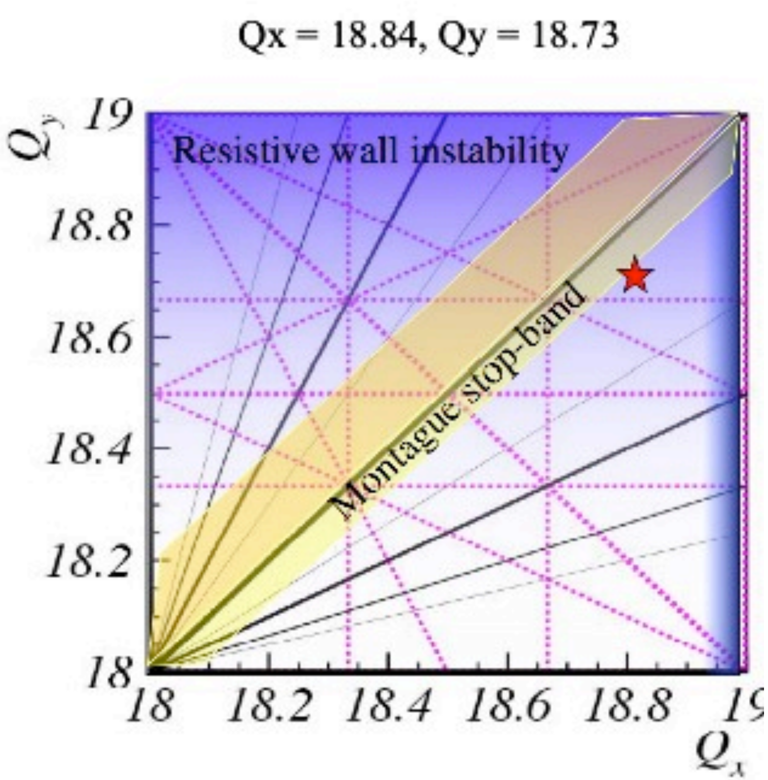
Without chromaticity



G.Franchetti, I.Hofmann,
M.Giovannozzi, E.Metral, M.Martini

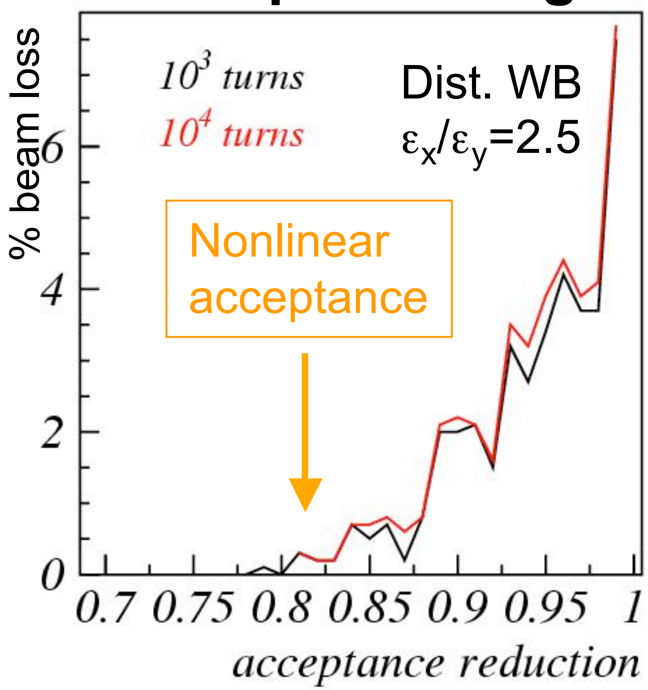
Maximum beam loss do not match measurements

SIS100: The working point for standard operations



I = 640A

No random errors
No space charge



Maximum Emittances (Er=2.5)

Ax = 97.5 mm-mrad
Ay = 39 mm-mrad

↓

Nonlinear Acceptance For 1000 turns

Ax = 78 mm-mrad
Ay = 31.2 mm-mrad

Aperture limmiting insertion are included

SIS100: Pessimistic Case

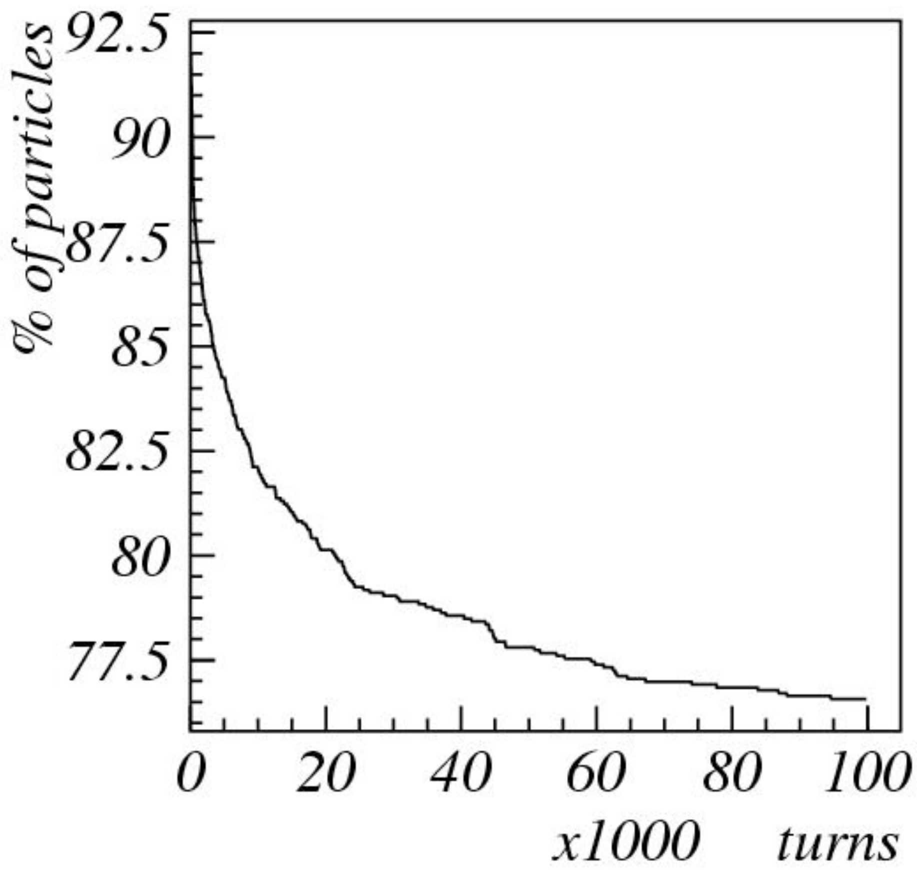
$\Delta Q_x = 0.14$, $\Delta Q_y = 0.25$

$\varepsilon_x = 78\ (2\sigma)$ mm-mrad

$\varepsilon_y = 31\ (2\sigma)$ mm-mrad

Bunch length (rms) = 27 m

Distribution **WB**



~23% beam loss due to space charge
And Lattice nonlinear components

Not acceptable

SIS100: Target Beam

$\Delta Q_x = 0.14$, $\Delta Q_y = 0.25$

$\varepsilon_x = 35$ (2σ) mm-mrad

$\varepsilon_y = 14$ (2σ) mm-mrad

$N_{bunch} = 0.75 \times 10^{11}$

Bunch length (rms) = 27 m

Distribution **WB**

**No beam loss
Found in present
Simulations with
The actual ring
modeling**

SIS100: Gaussian Beam

$\Delta Q_x = 0.14$, $\Delta Q_y = 0.25$

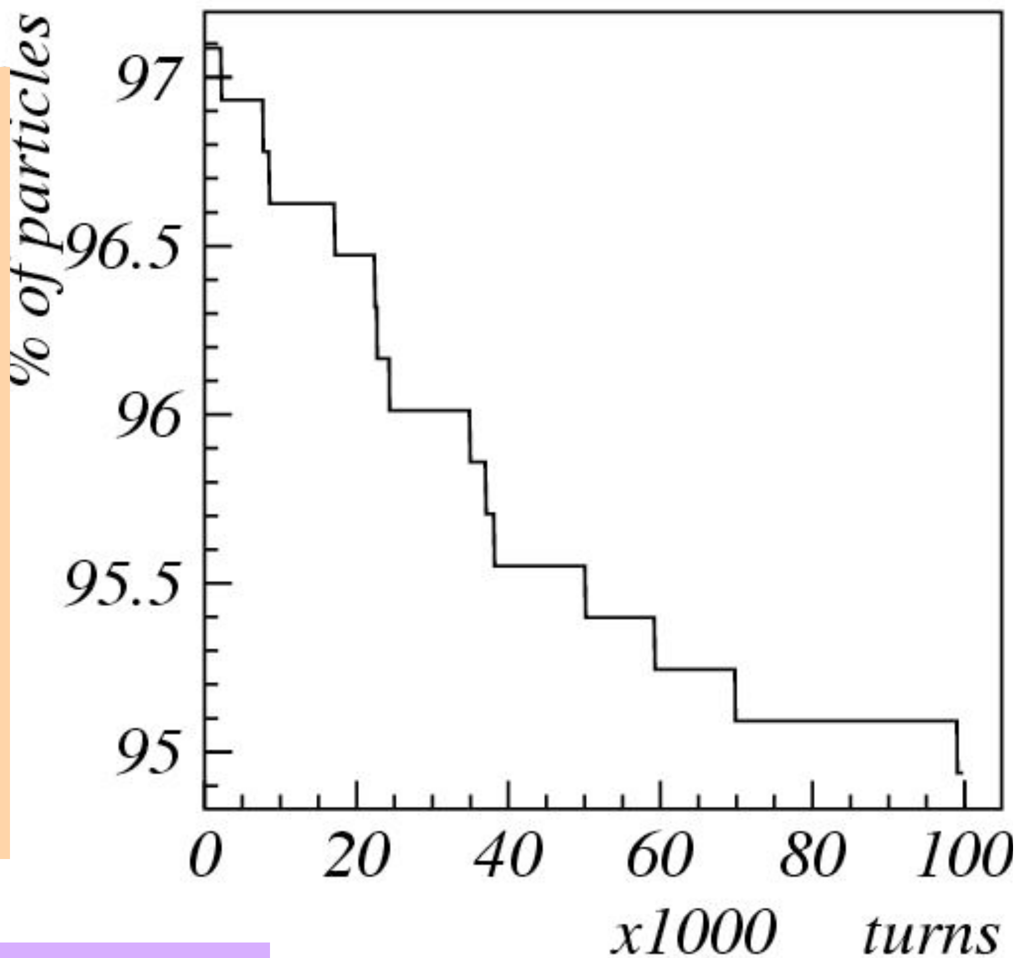
$\varepsilon_x = 35\ (2\sigma)$ mm-mrad

$\varepsilon_y = 14\ (2\sigma)$ mm-mrad

$N_{bunch} = 0.75 \times 10^{11}$

Bunch length (rms) = 27 m

Distribution **Gaussian**



~4% beam loss due to space charge
And Lattice nonlinear components

More studies needed

Further Issues

Beam Modeling

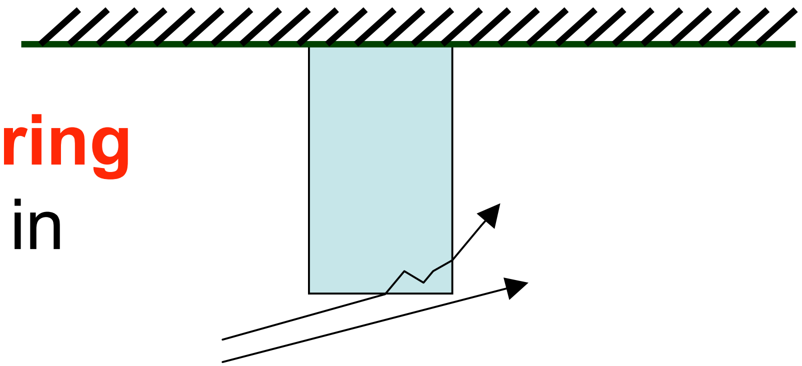
Effect of closed orbit distortions
Errors Injection at injections
Effect of intrabeam scattering

➡ Self adjustment
Of the beam some
Tail may develop

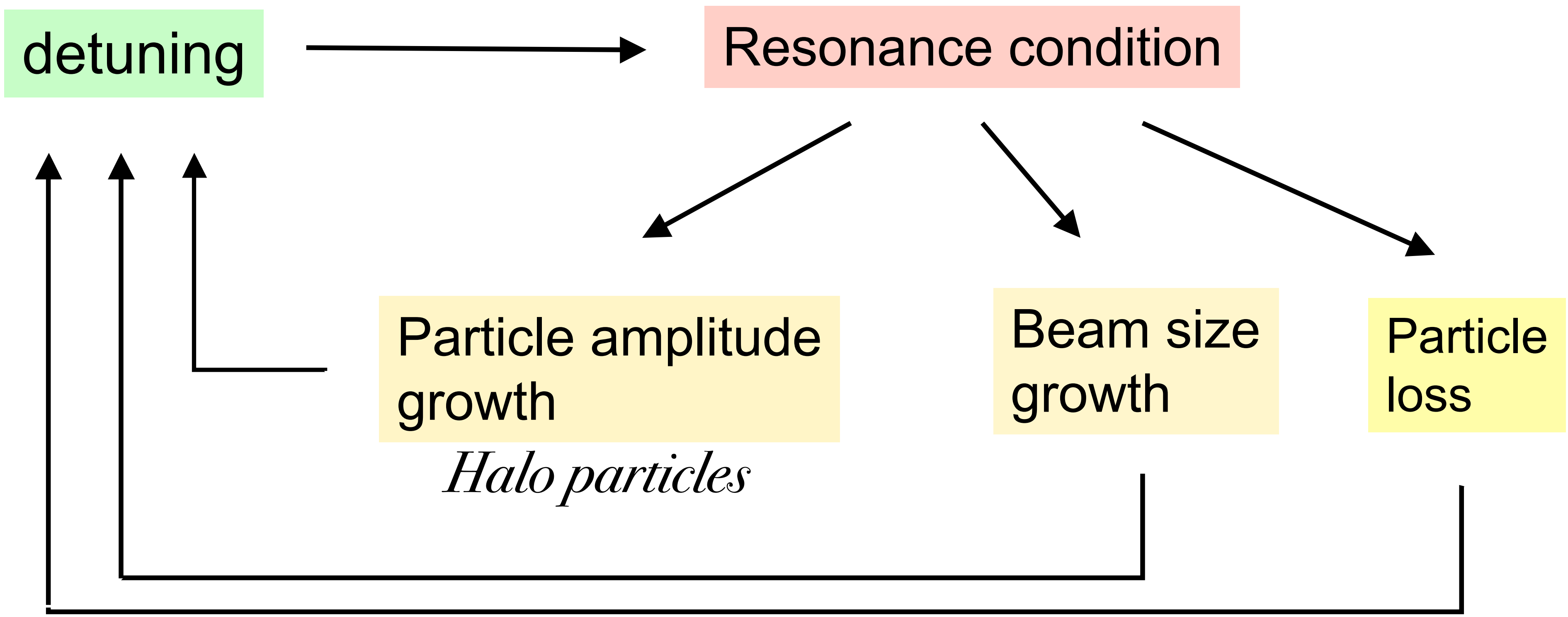
Gaussian Beam ??

Collimation Issue

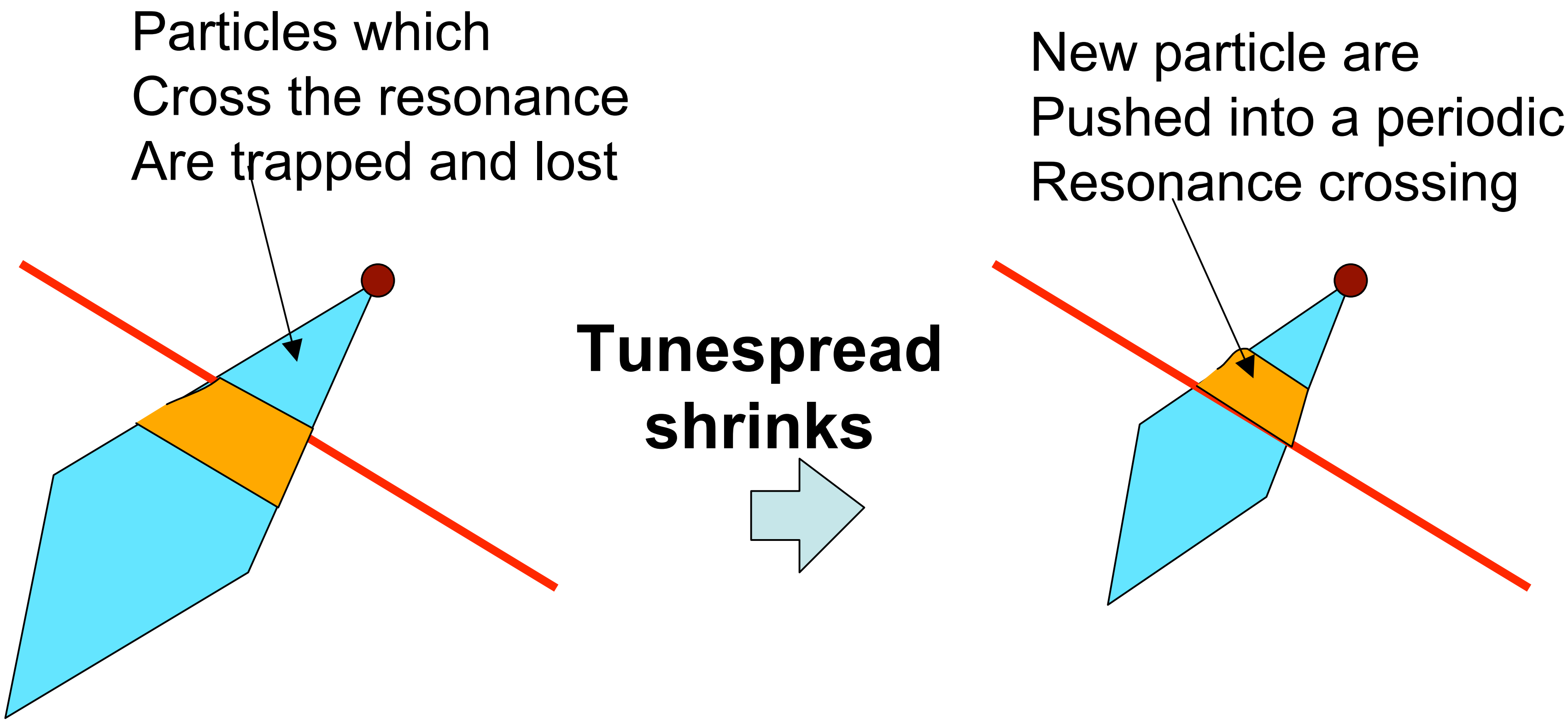
Effect of **dE/dx** or **multiple scattering**
On the dynamics of single particle in
Resonant nonlinear regime



Relevance of the self-consistency



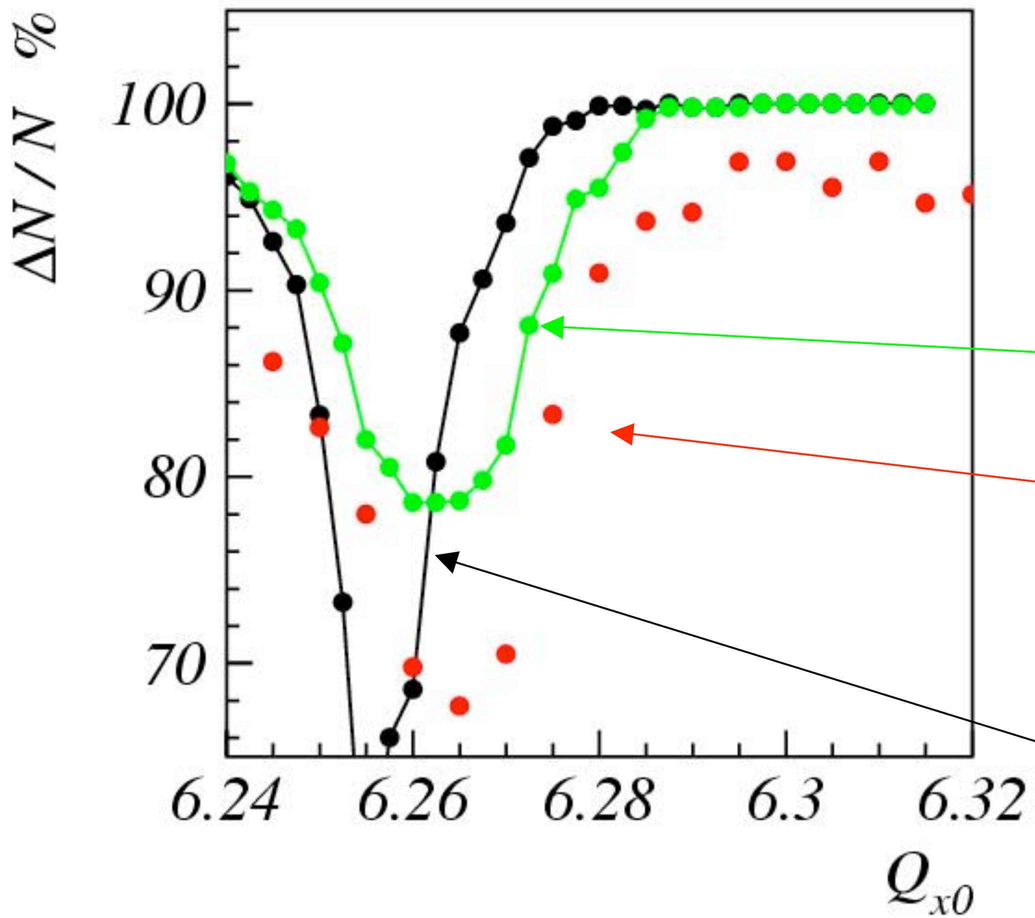
Effect of beam loss



The result on long term beam loss are sensitive
To the modeling on how new particles are drawn
Close the resonance.

ISSUES: better modeling and further Experiment-code Benchmarching

Including the effect of beam loss



CF modeling of PS
Including chromaticity

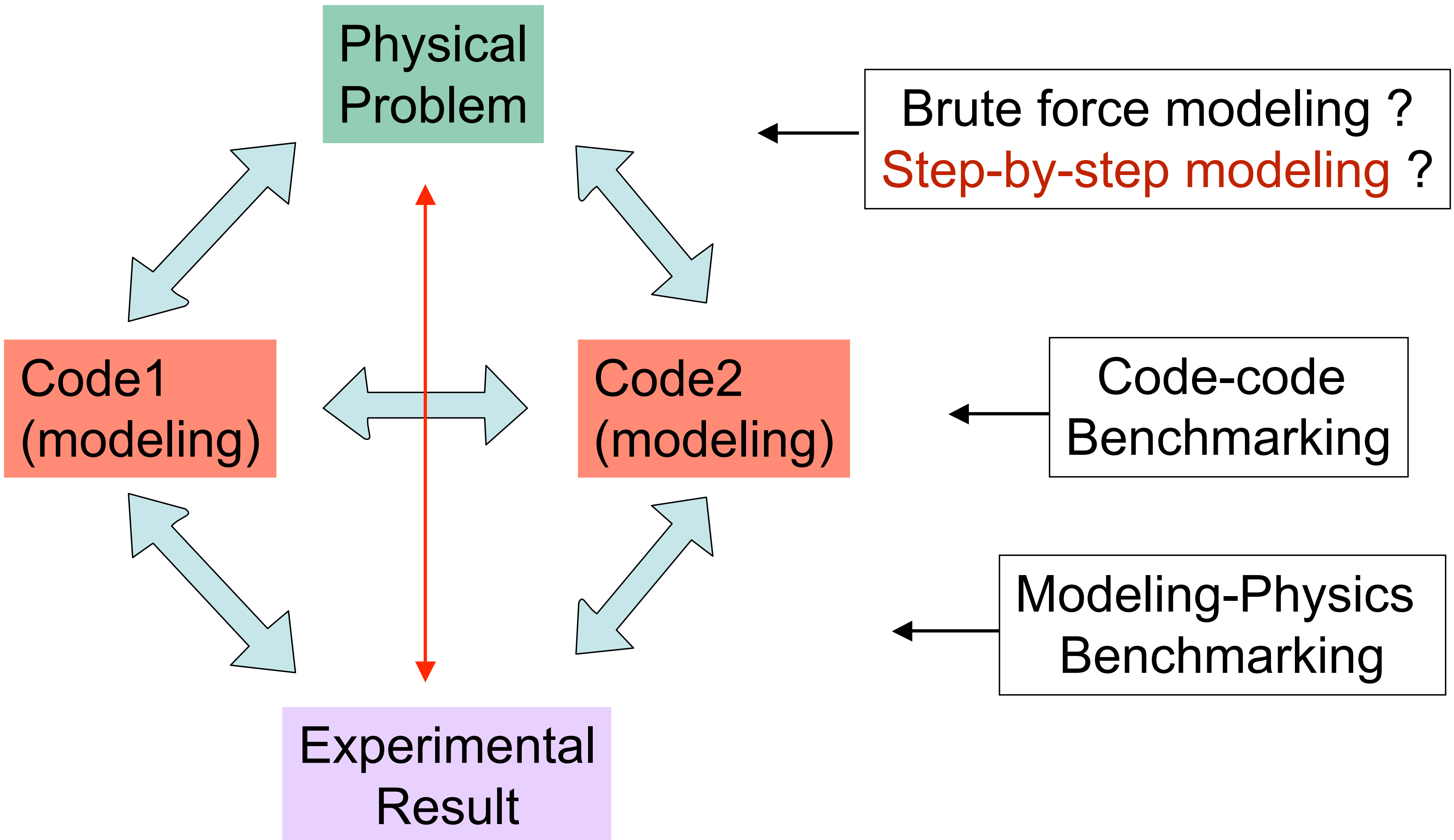
$2x10^6$ turns

Measurement
at CERN-PS

Attempt of long
Term beam loss
Prediction including
Semi-self consistency
$4x10^5$

This prediction is not correct because
Self-consistency important on how many
particles are pushed Into the resonance

Benchmarking / Validation Essential for Design (high confidence)

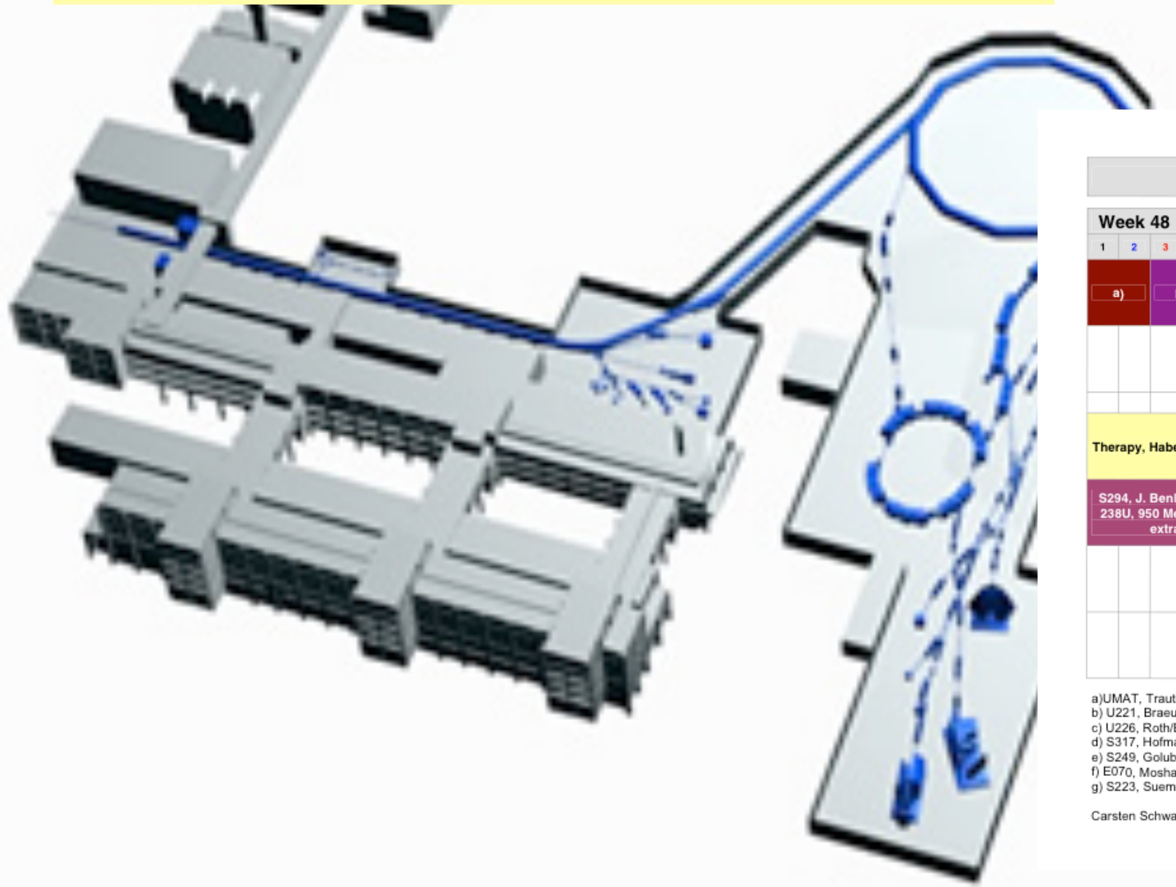


Benchmarking Experiments @ GSI

Experiment S317

- 4 Measurement campaign starting from December 2006.
- 24 shifts of beam

Controlled highly resolved measurement data will be available for benchmarking codes, on emittance growth and beam loss perdition



Scheduling

Block 4 / 2006 — December 2006 — Schedule as of 12-Oct-2006

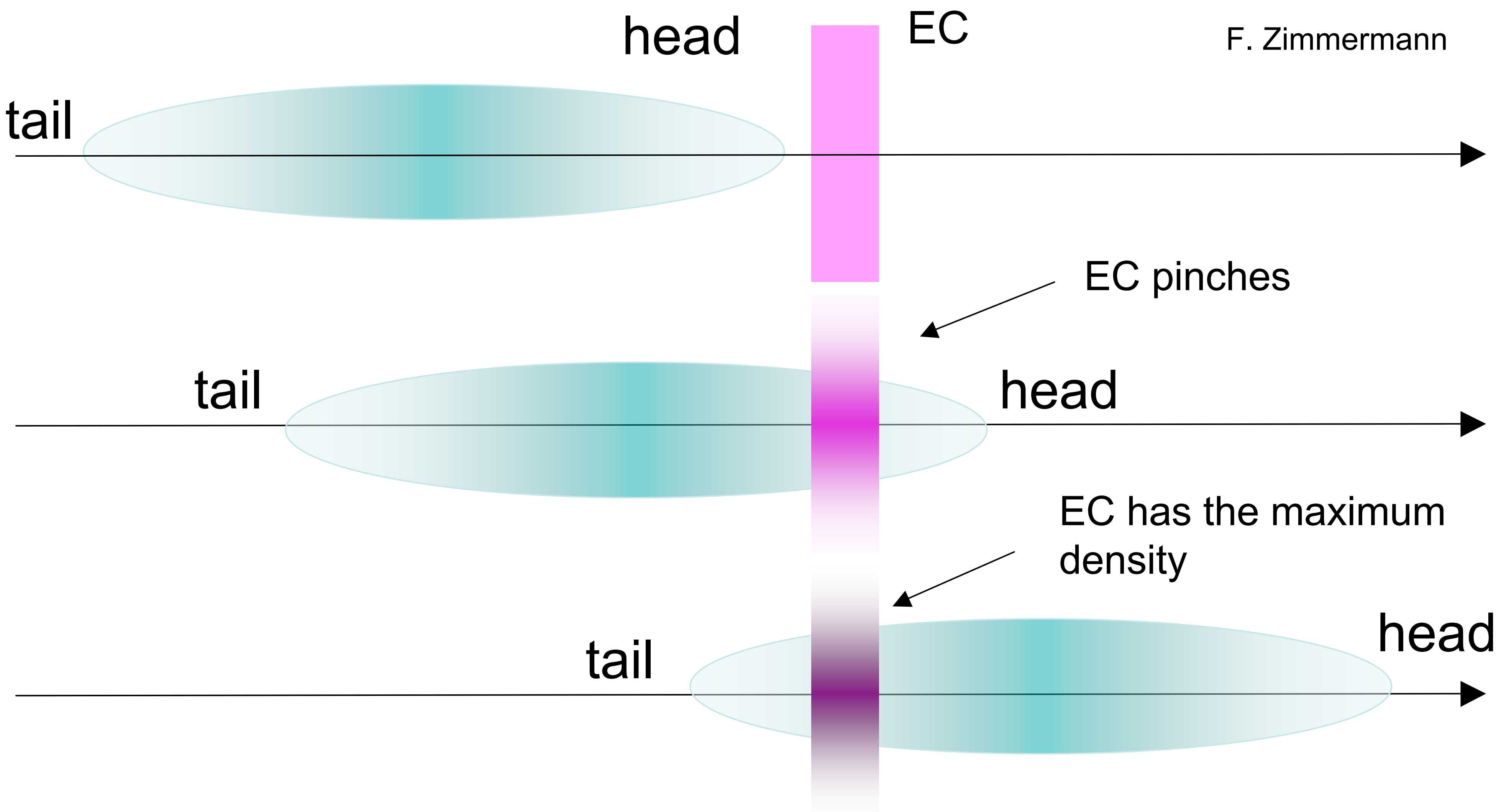
Week 48			Week 49							Week 50							Week 51							Week 52						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
a)		b)					U217, Block, 40Ar, 4.5 MeV/u, 1 puA, 1ms,5Hz Y7					U217, Block, 48Ca / ECR, 3.4 4.0 MeV/u, 1 puA, Y7 - SHIPTRAP					B													
				UBIO, Scholz/Scholz, C, 11.4 MeV, 2 TnA, 50Hz, 5 ms, X6				c)				UBIO, Scholz/Scholz, U, 11.4 MeV, 2 TnA, X6																		
Therapy, Haberer, 12C (ECR), HTM							d)			S300, Bruce/Gerl, U-238, 750, max, spill flat long extraction, S4							S000 machine experiments													
S294, J. Benlliure/K.-H. Schmidt, 238U, 950 MeV/u,2e10/spill, 10 s extraction, FRS							e)			S302, Mintsev/Varentsov, 238U73+ (PIG), 300-400 MeV/u, 5e9/spill, fast extraction, bunch compression, SIS cooler, HHT																				
					g)		f)			E045, Stoehlker, U91+, U92+, 350 MeV/u, 1e8 in ESR, SIS cooler, deceleration in ESR to 20-50 MeV/u, ESR electron cooler																				
										SMAT, Trautmann/Trautmann, U, 150 MeV/u, 3e8 ions/spill, -, HTA																				

a)UMAT, Trautmann/Trautmann Christina, 238U, 11.4 MeV/u, 10 nA, 5ms, 50Hz, (if possible), X0
b) U221, Braeuning-Demian/Mann, 238U, 5 MeV/u bis 11.4 MeV/u, ,<5Hz, 1ms, X4
c) U226, Roth/Blazevic, Ar, 11.4, 250 pnA, Z6
d) S317, Hofmann/Franchetti, Ar, 11.4 MeV/u, SIS18 injection energy, maximum intensity (space charge limit), day only, SIS/UNILAC
e) S249, Golubev/Mustafin, Ar, 1600 MeV/u, 1e7/spill SIS, days only HTA
f) E070, Moshammer/Hagmann, He-like Xe to U, 100 -400AMeV, 1e8/spill, SIS cooler, ESR jet target
g) S223, Suemmerer/Aumann, 12C, 500, 1E3/spill, slow extraction, days only, HTC

Carsten Schwarz, Phone +49-6159-712765, Fax +49-6159-713762, E-mail beamtime@gsi.de Thursday, 12 October, 2006 09:35

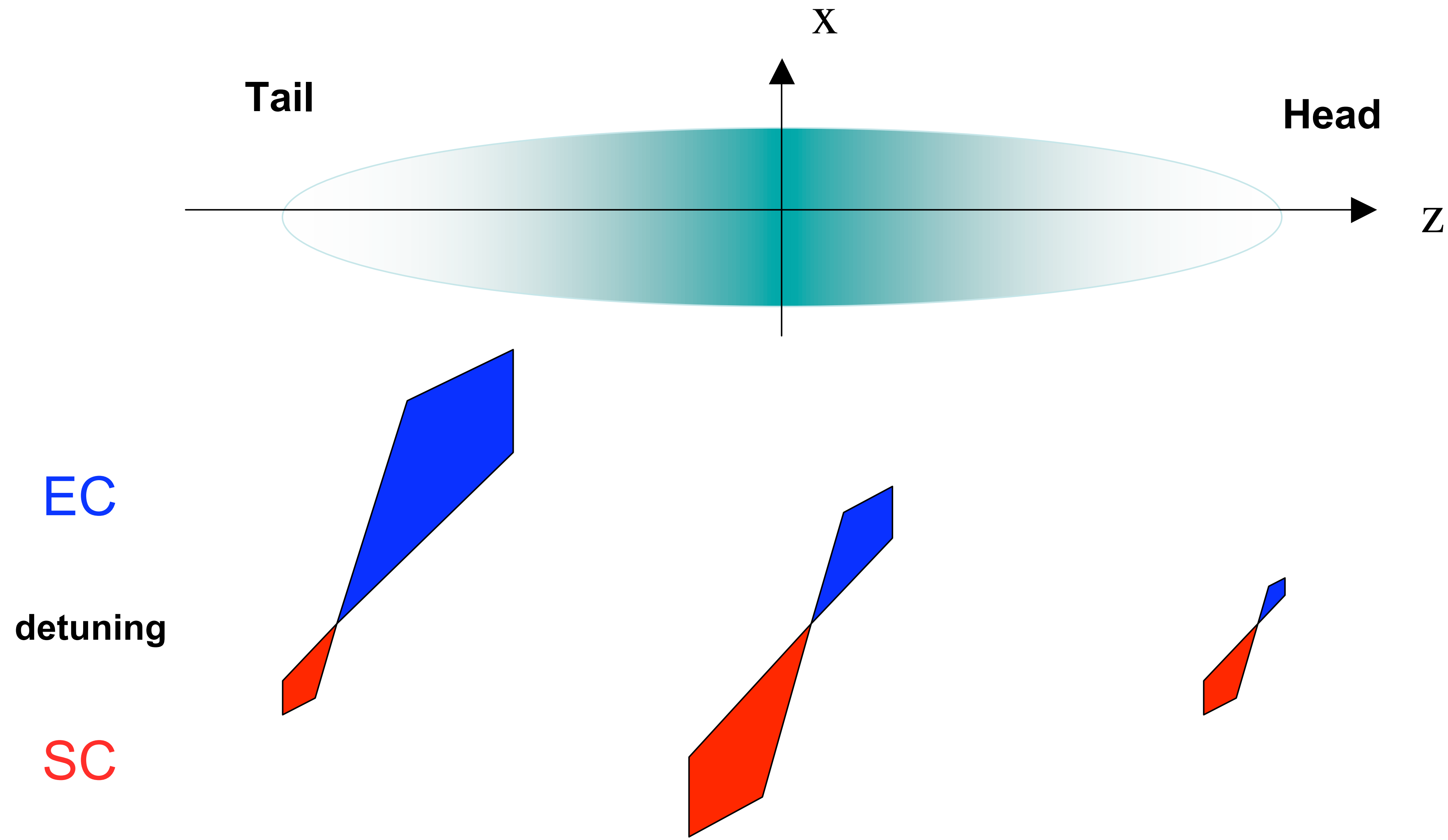
E-Cloud vs. Space Charge

http://ab-abp-rlc.web.cern.ch/ab-abp-rlc/AP-literature/e-cloud-incoherent-effects.htm



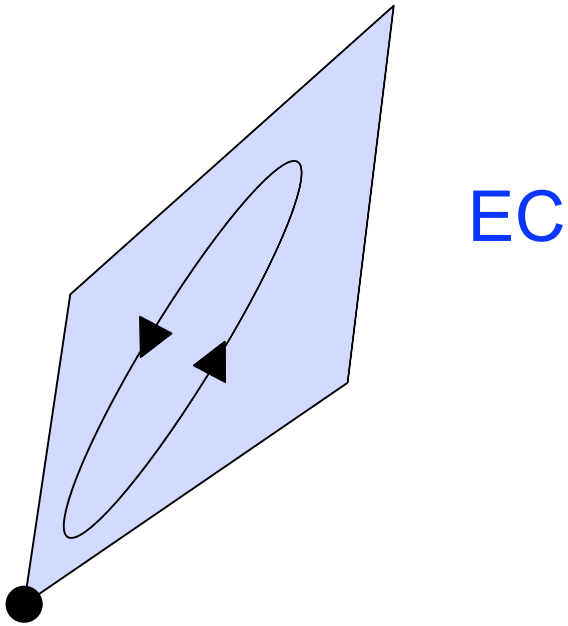
Correlation EC-density - position along the bunch

Space charge - EC detuning

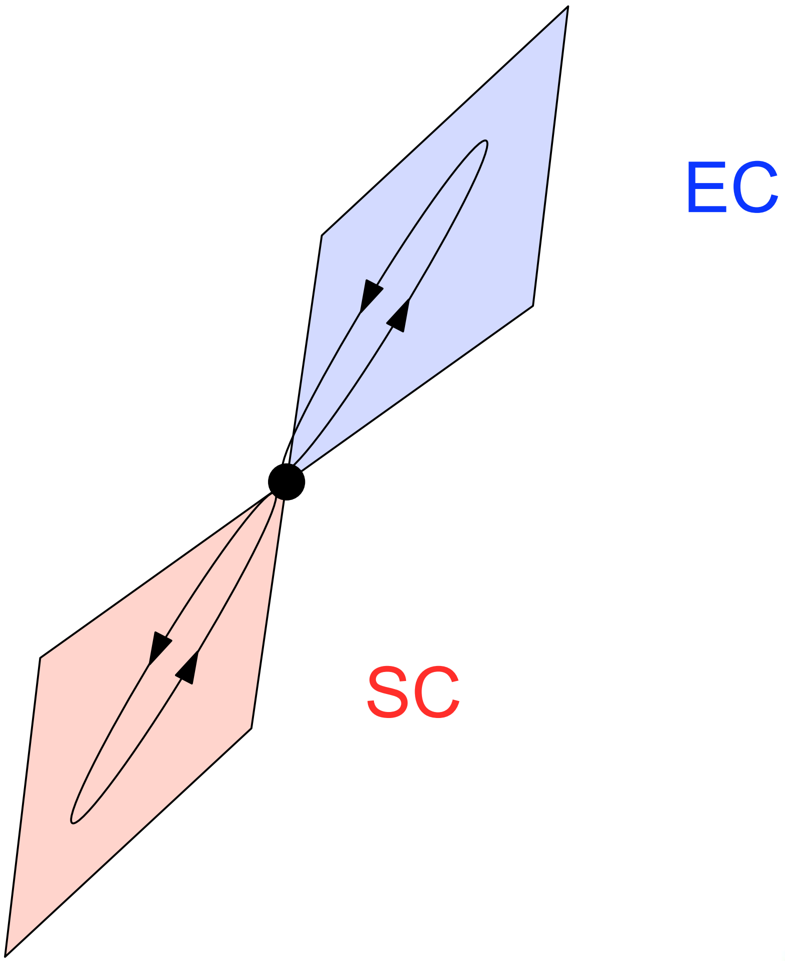


Dynamics of tunes

At high energy

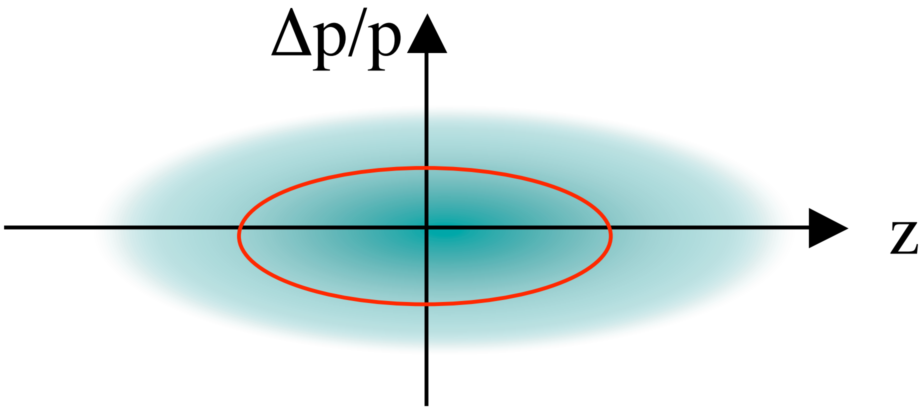


When space charge Effect is comparable EC

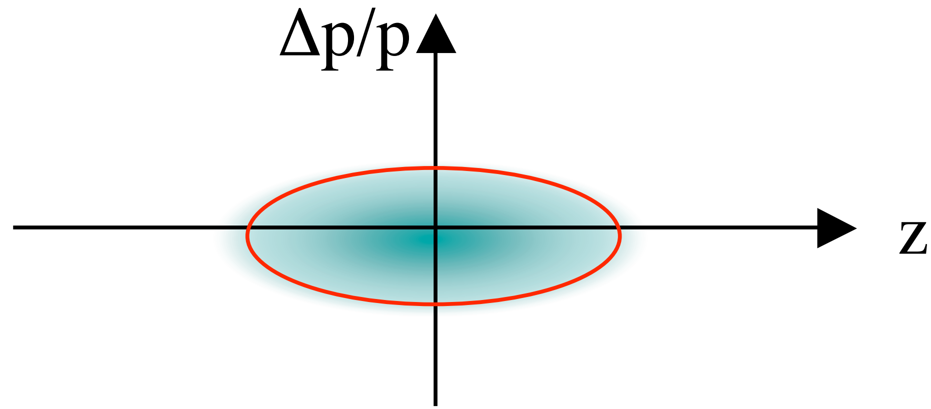


Correlation lost particlesvs. Bunch shortening

At the beginning of storage



After lost term storage
(when all trapped particle are lost)



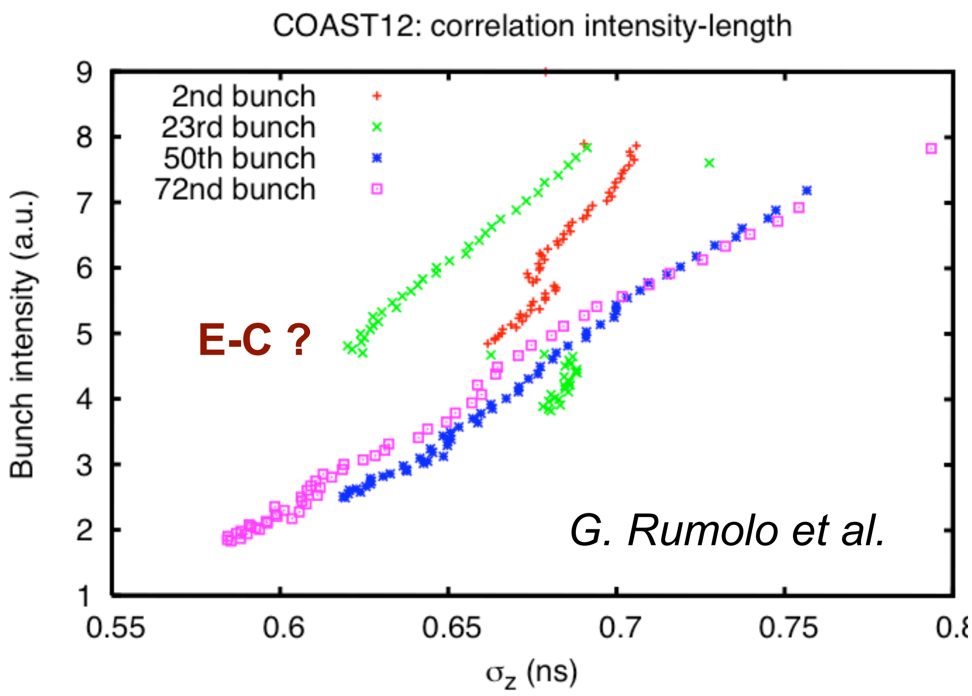
Bunch shortening

Correlation beam loss vs.. Bunch shortening

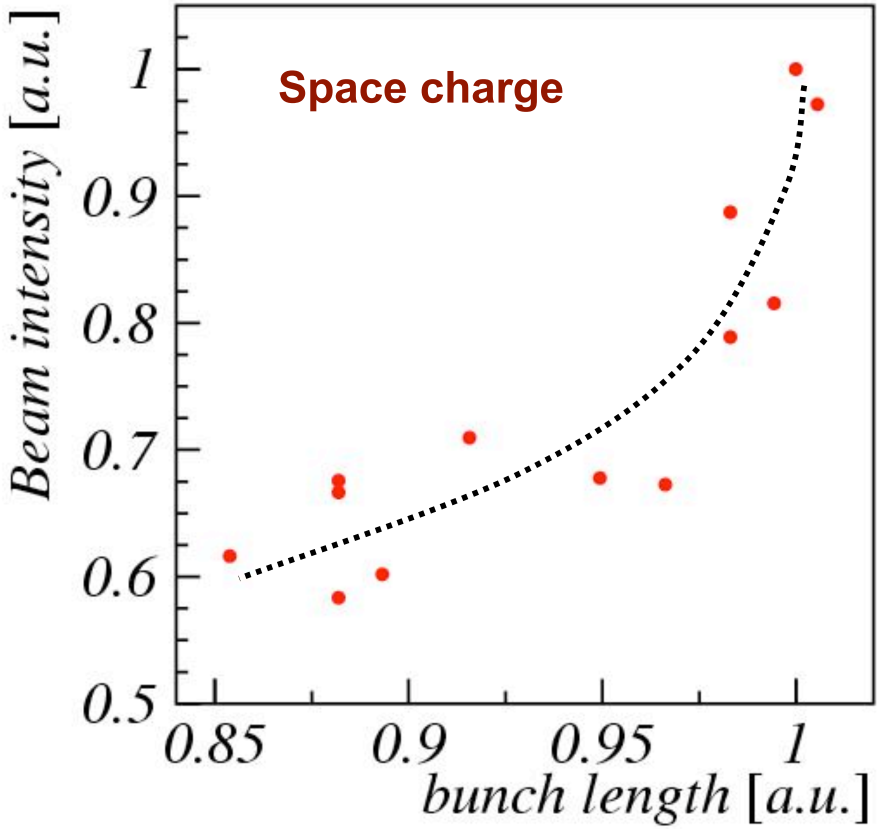
PS experiment and SPS bunch shortening

SPS measurements

Bunch shortening for the selected bunch

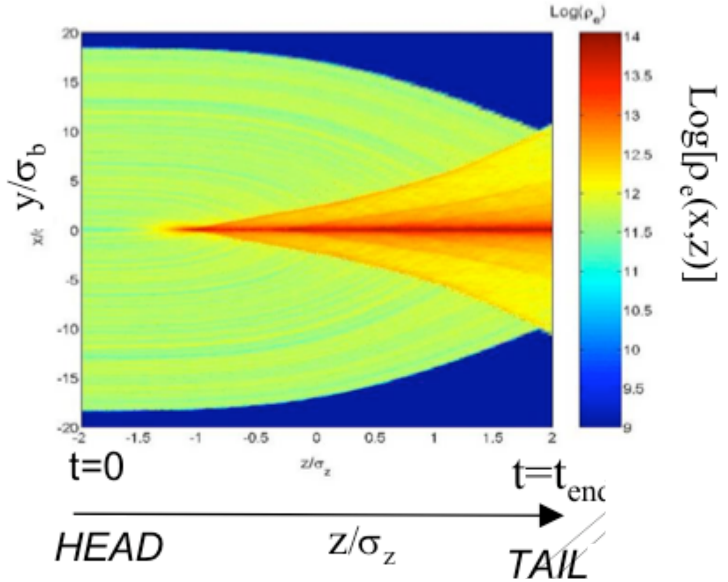


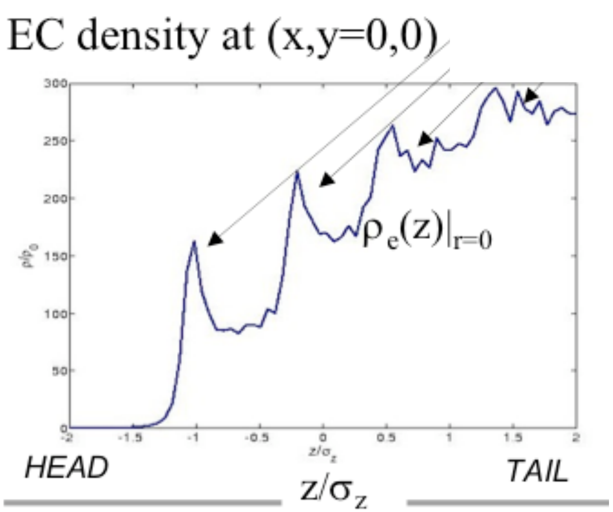
PS experiment



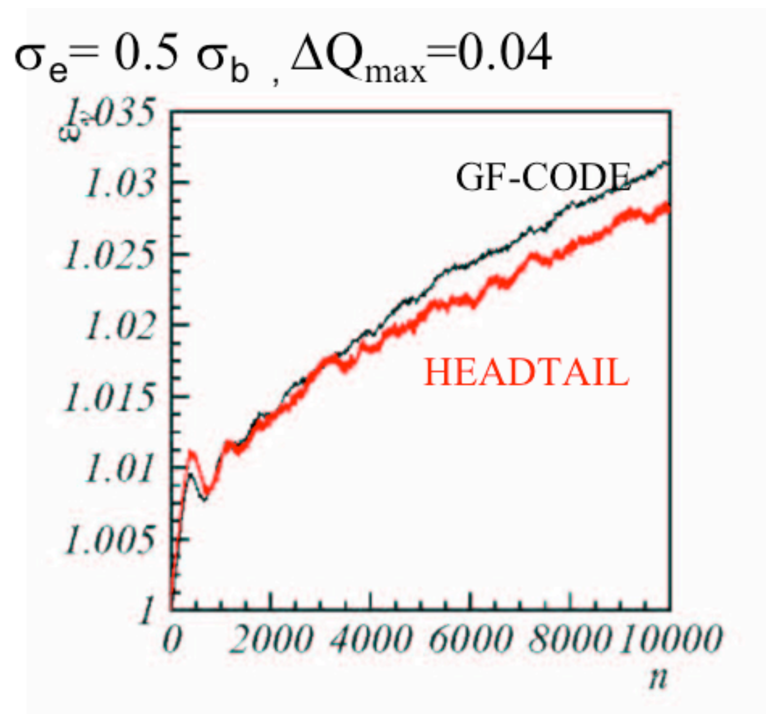
E-Cloud incoherent effects

Code-simplified-model benchmarking





Periodic crossing of resonances and **particle trapping Induced by EC pinch**



E.Benedetto, G.Franchetti, F. Zimmermann
PRL, **97**, 034801 (2006)

Conclusion / Outlook

Space charge plays an important role for emittance Growth and beam loss

A new mechanism for beam loss in high intensity has been found which gives good quantitative explanation the experimental results

Present simulation for SIS100 shown that beam loss ~ 4% are expected: further effect should be included

In the framework of the HHH meetings a synergy Between space charge studies and EC-studies has began on the incoherent EC effects.