SIS18 space charge experiments

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Overview

The high intensity mechanism for emittance growth and beam loss in long term storage

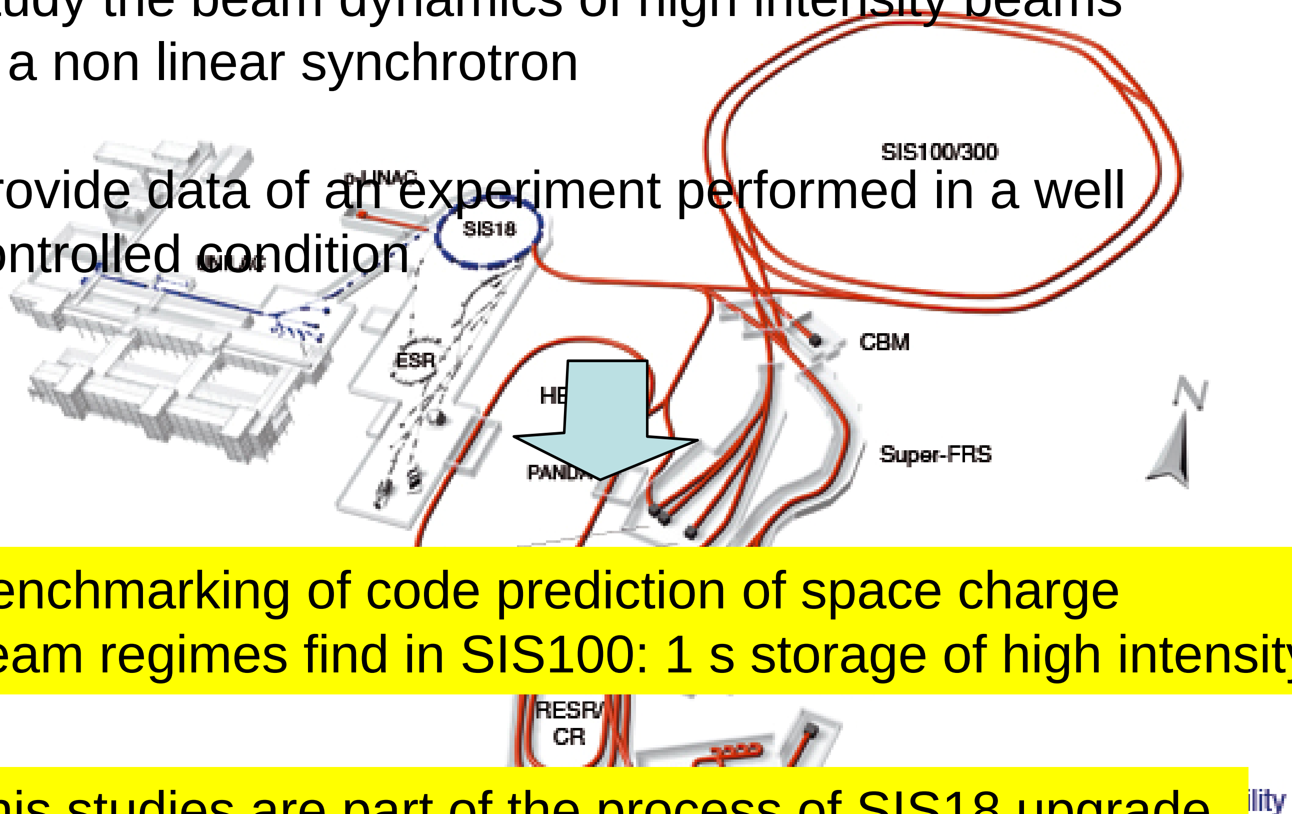
The S317 campaign and the experimental results

Outlook

The purpose

Study the beam dynamics of high intensity beams in a non linear synchrotron

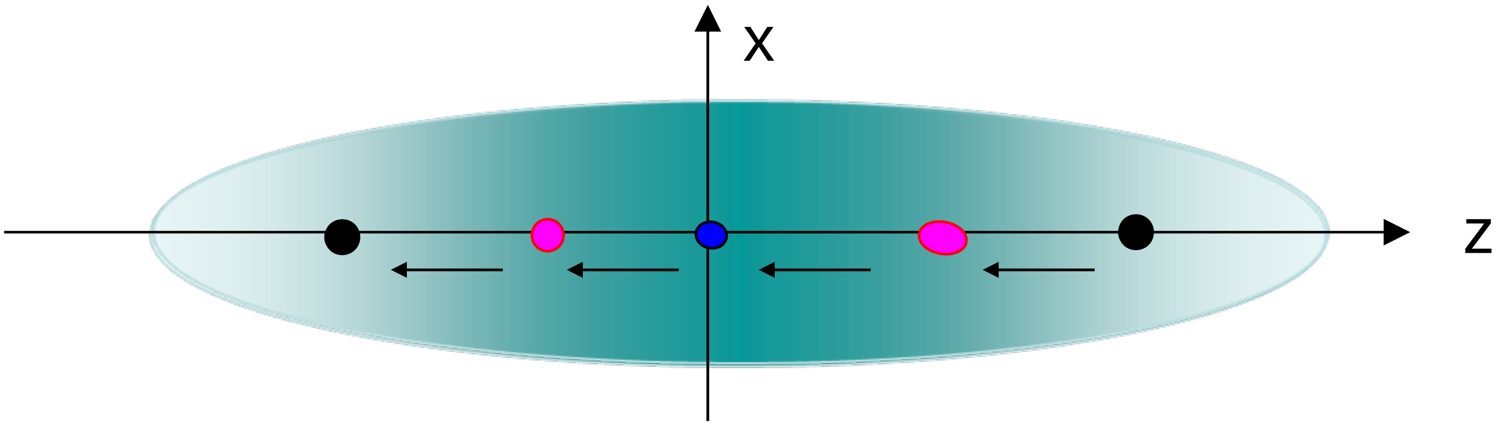
Provide data of an experiment performed in a well controlled condition

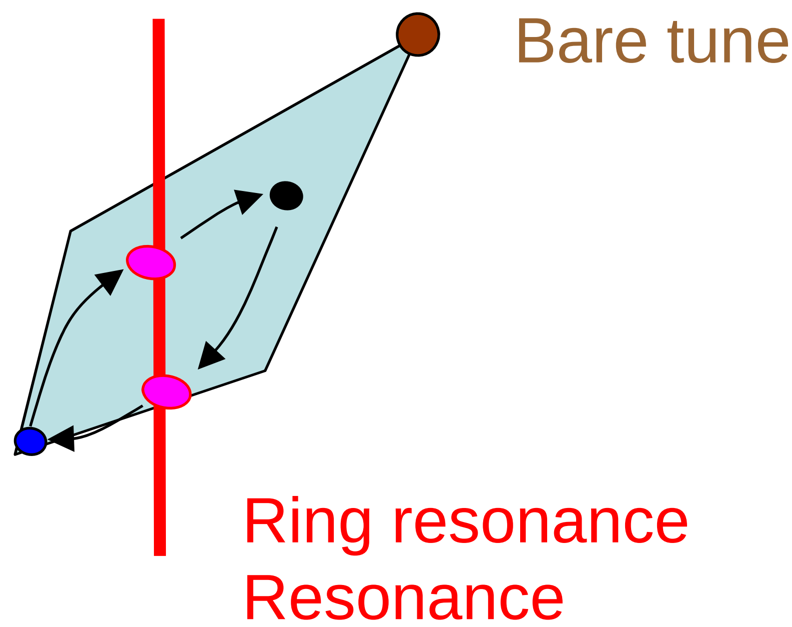


Benchmarking of code prediction of space charge beam regimes find in SIS100: 1 s storage of high intensity bunch

This studies are part of the process of SIS18 upgrade for reaching the FAIR parameters.

The beam physics case: space charge induced periodic crossing of a ring resonance

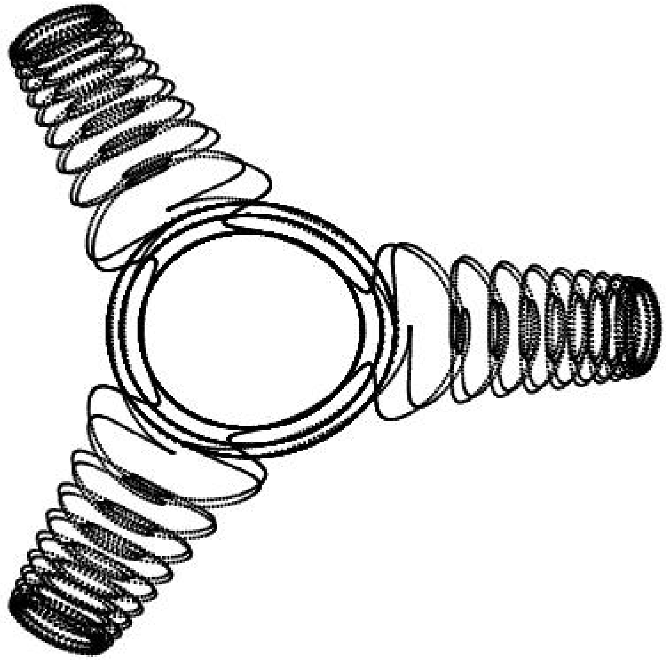




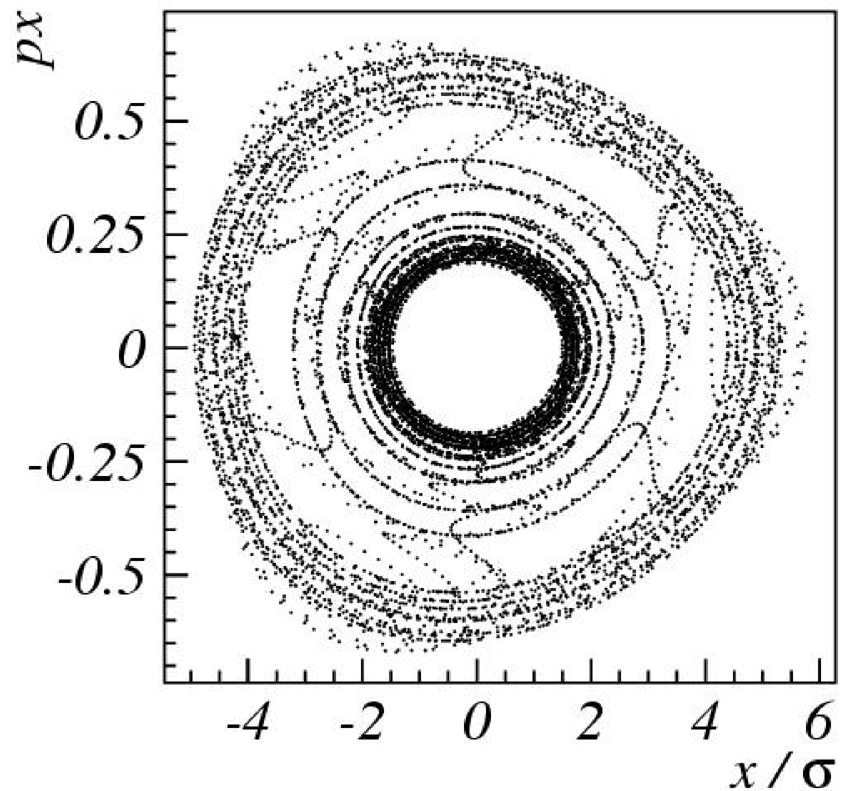
Trapping/scattering into resonances

Example for SIS18:

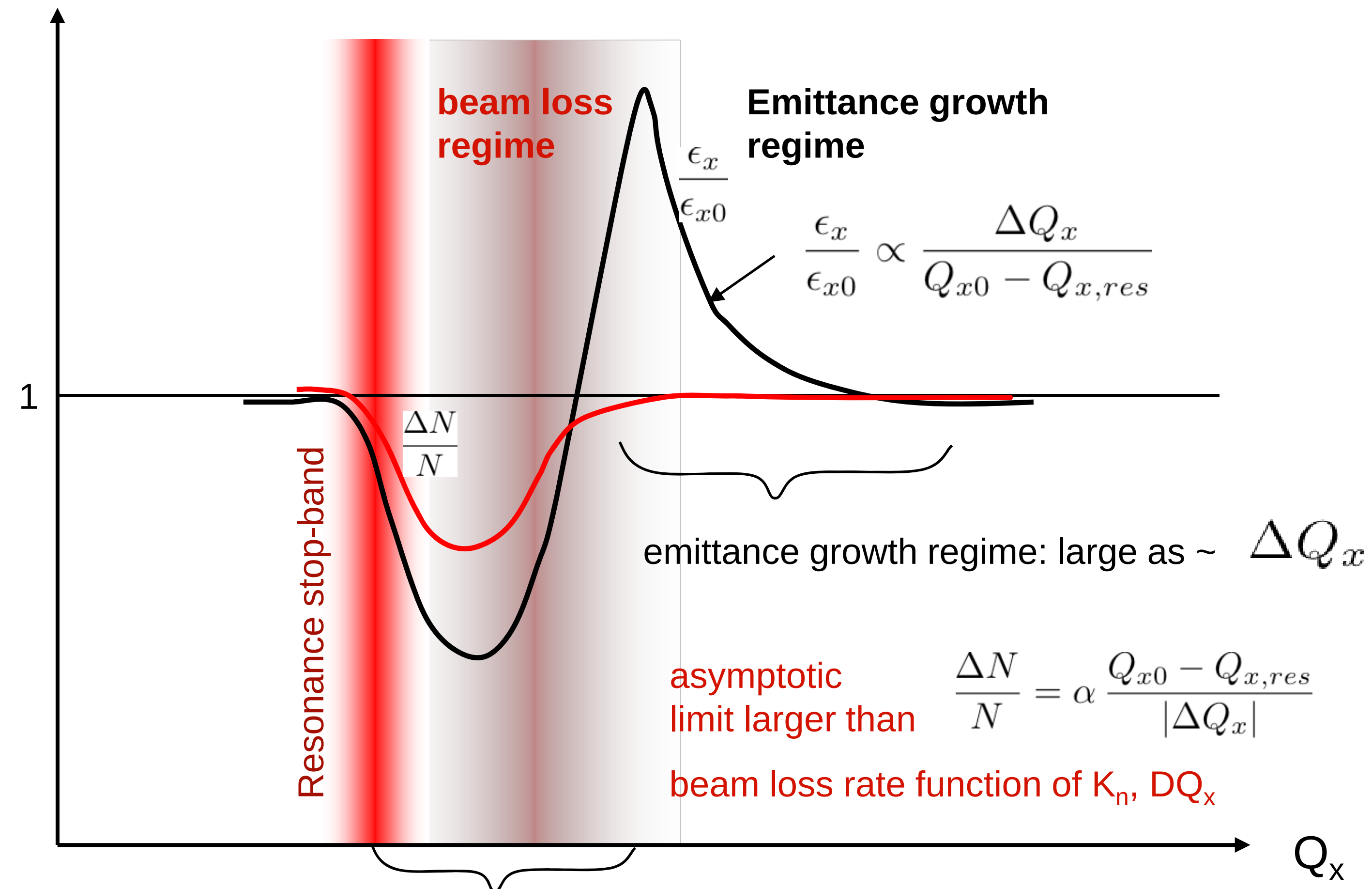
Trapping into 3rd order resonance



Scattering into 3rd order resonance

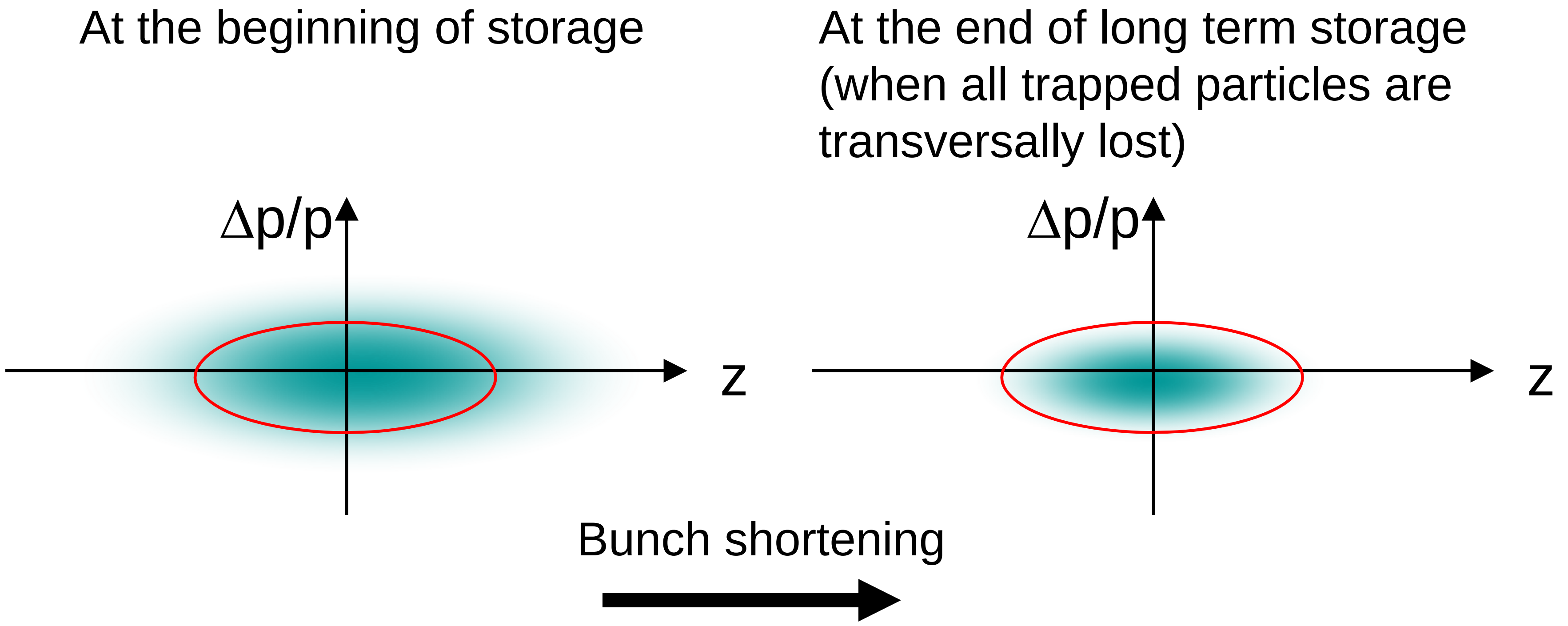


Consequences I: transverse beam blow up and beam loss



chromaticity induced stop-band large as $\Delta Q_{x,chr}$ or as function of pipe or DA intercepted

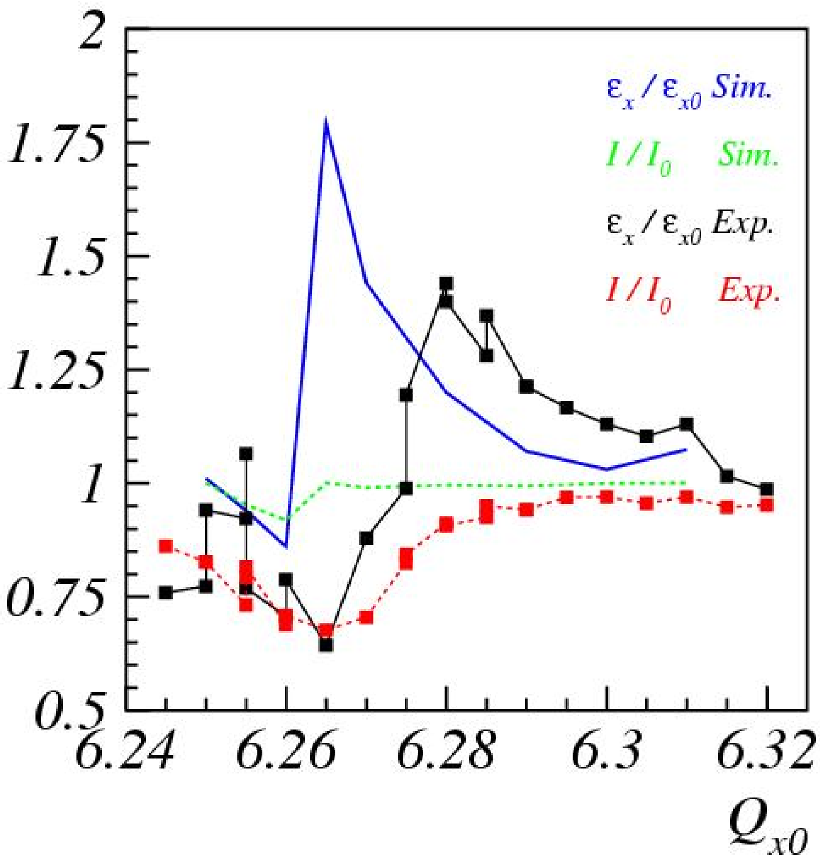
Consequences II: effect of beam loss on longitudinal profile

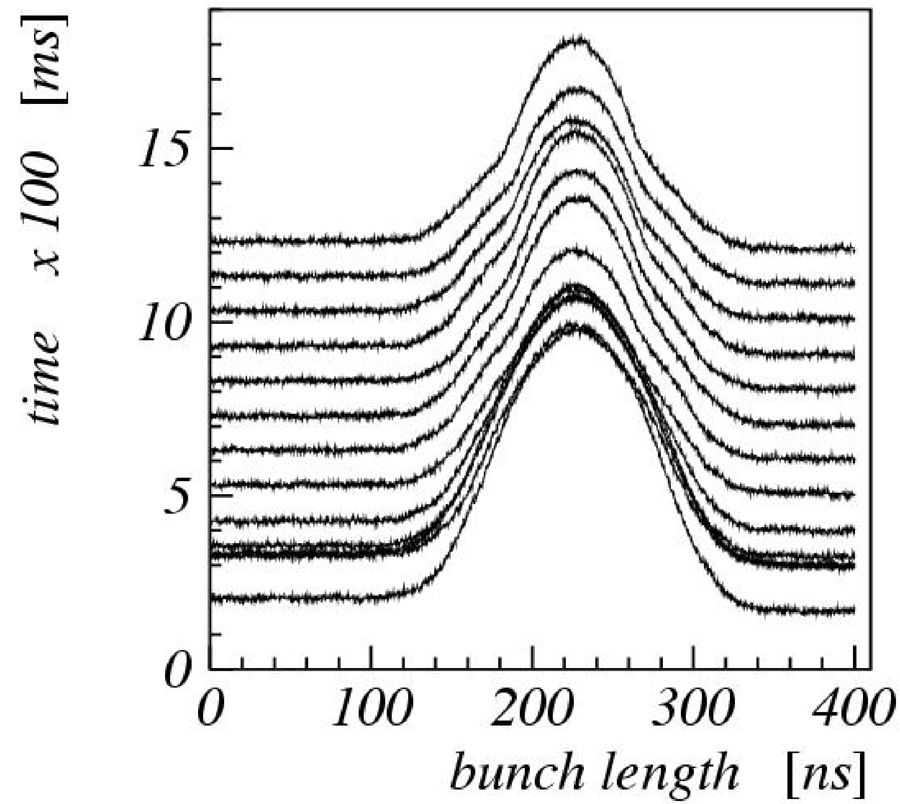


Correlation beam loss vs. bunch shortening

Precedent experimental campaign: CERN-PS

R. Cappi, G. Franchetti, M. Giovannozzi, I. Hofmann, E. Metral, M. Martini, R.Steeremberg ICFA2004





4th-order resonace

The space charge campaign at GSI

S317

Law of experimentalists:

“Never replicate a successful experiment”

The people

I. Hofmann, W. Bayer, F. Becker, U. Blell,
O. Boine-Frankenheim, O. Chorniy, P. Forck,
T. Giacomini, M. Kirk, V. Kornilov, T. Mohite,
C. Omet, A. Parfenova, S. Paret, P. Schuett,
S. Sorge, P. Spiller

Systematic in the experiments

	low intensity (**L**)	high intensity (**H**)
Coasting Beam (**CB**)	only single particle nonlinear dynamics: transverse blow-up and beam loss	no resonance periodic crossing: but transverse emittance growth
Bunched Beam (**BB**)	single particle nl dynamics + chromaticity: larger transverse beam blow-up	Space charge trapping/scattering effects: beam loss/bunch-shortening

The SIS18 synchrotron

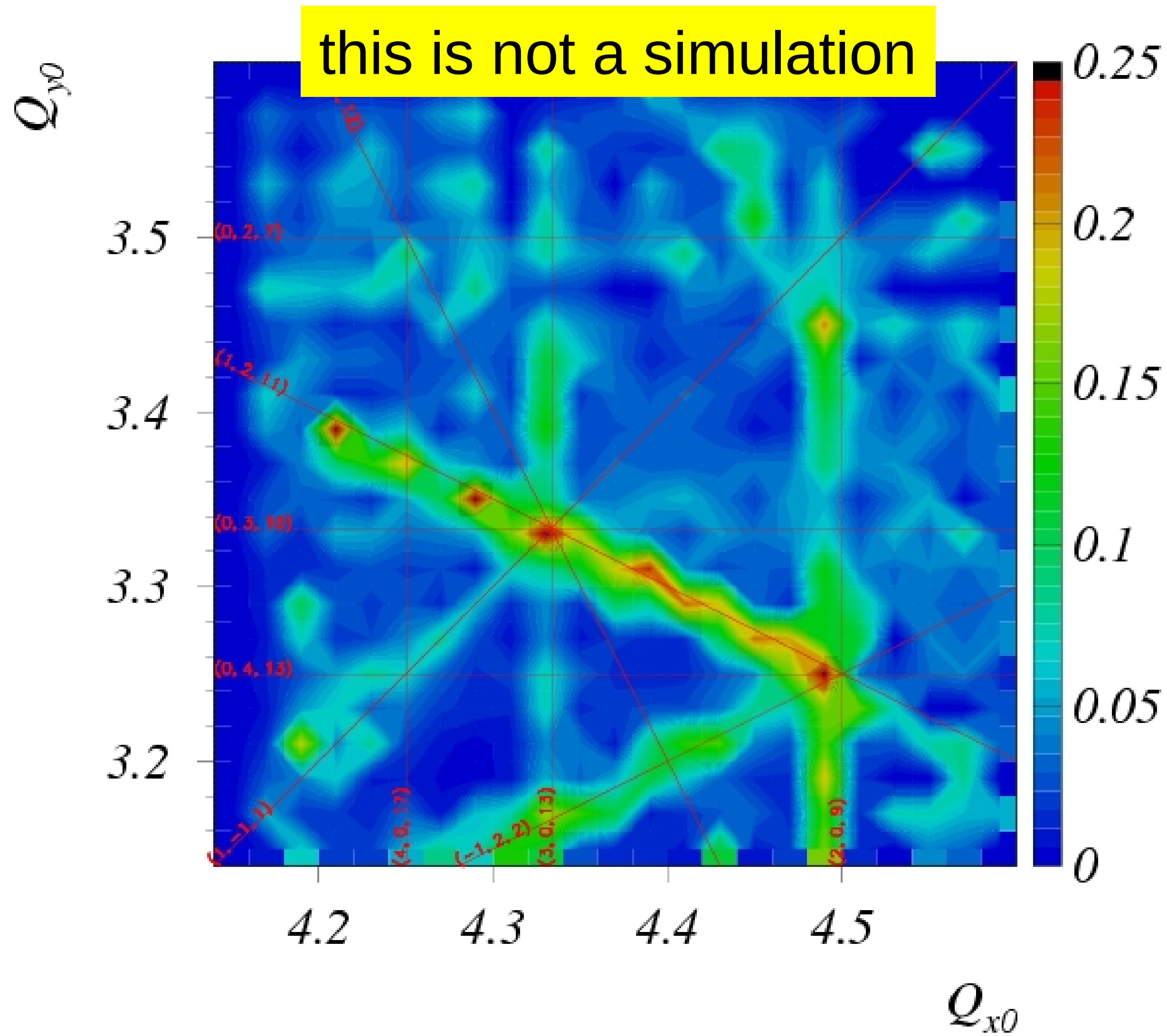
- 12 Auxiliary windings in the dipoles
  (only 6 works well)
- 12 small vertical dipoles
- 4 quadrupole correctors
- 8 skew quadrupoles (independent)
- 2 skew sextupoles (independent)
- 12 sextupoles located every other period
  close to the F and D quads (independent)

- 4 Q_y=13 cannot be controlled (no octupoles)
- Skew 3rd order: 2 Q_x+ Q_y=12, 3 Q_y=10, 2 Q_x- Q_y = 5 (difficult with 2 skew)
- Normal 3rd order: -Q_x + 2 Q_y = 2, 3 Q_x = 13, Q_x + 2 Q_y = 11

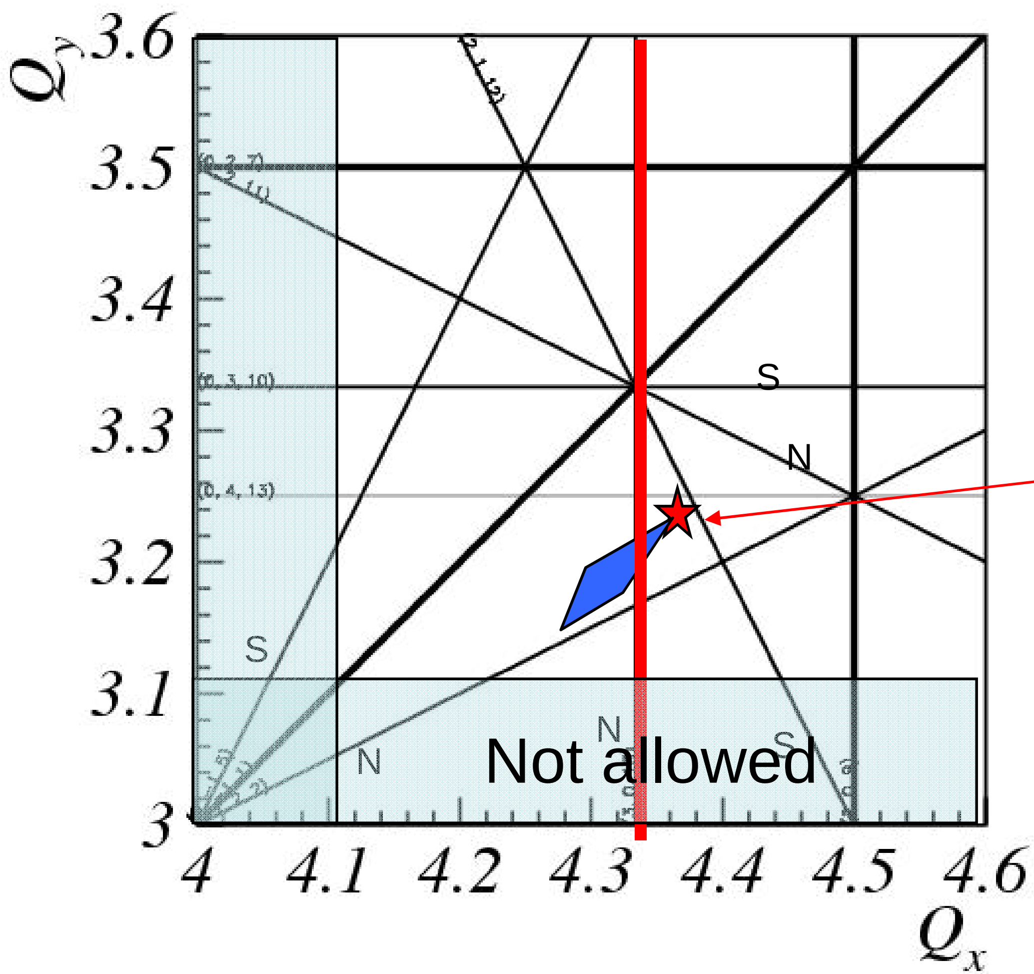
NO octupole present in SIS18

(B. Franczak, A. Redelbach, C. Mühle)

The SIS18 resonances



Choice of the working point

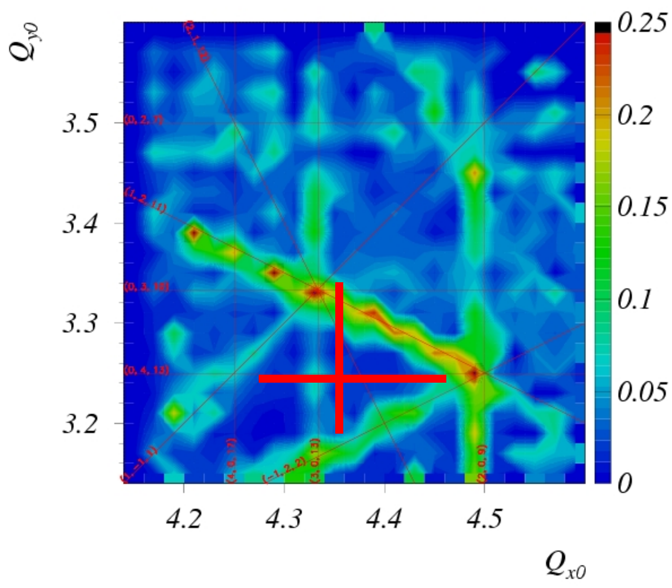


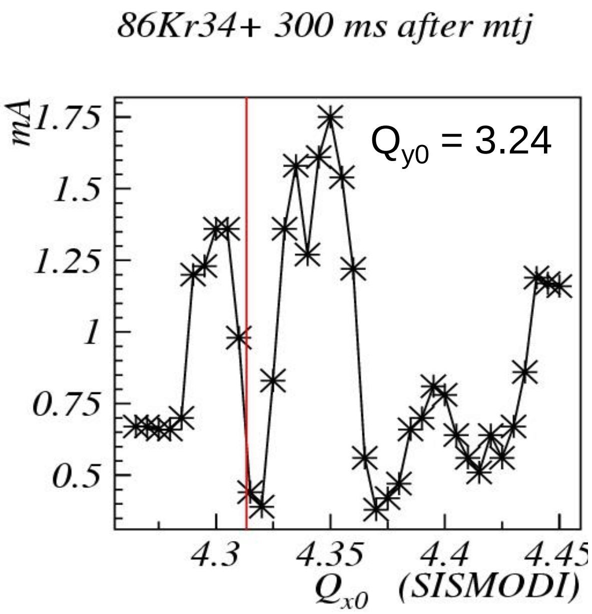
WP

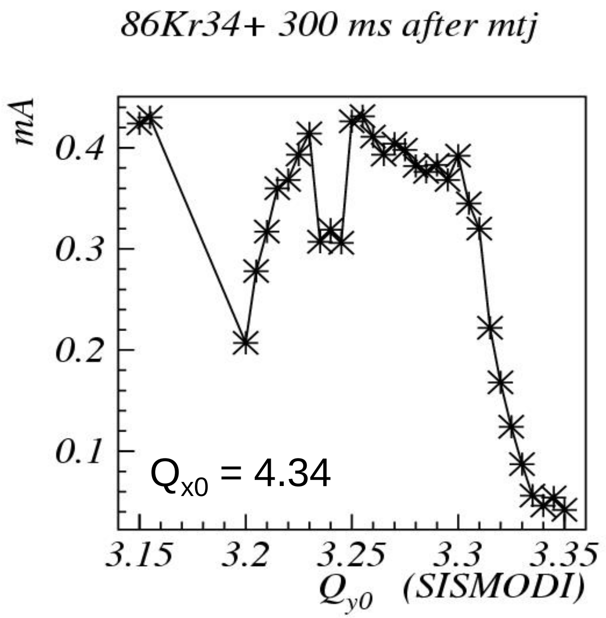
Allocate

□DQ=0.075

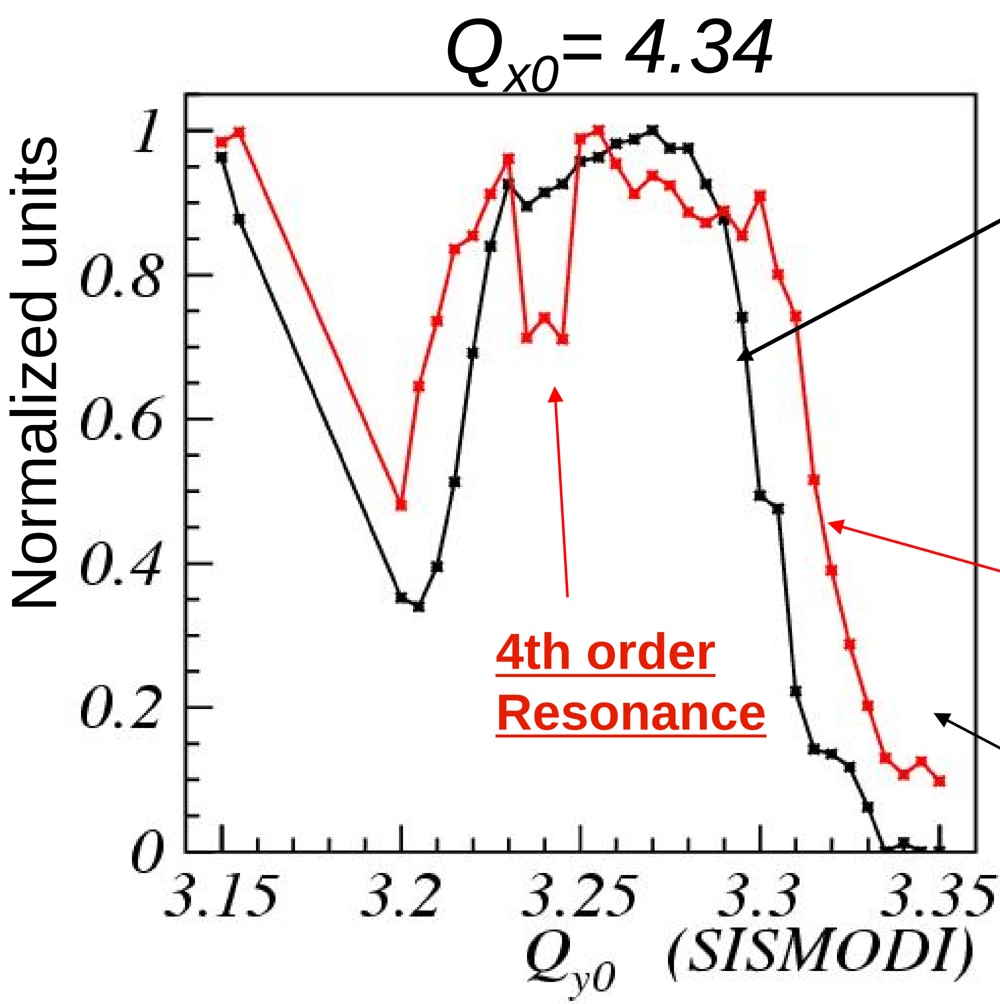
scans in proximity of the 3rd order resonance







After correction of the closed orbit



30SI14+ At 500MeV/u
Measured 955 ms after injection after acceleration. The acceleration starts at 400ms. Full chopper Windows. Vertical closed orbit corrected at injection and extraction

86Kr34+
At 300ms after injection
Without closed orbit correction

3rd order resonance

Experimental setup

UNILAC beam optimized for high intensity
Barth, Dahl, Groening

Beam injection optimized *(P. Spiller, P. Schuett)*

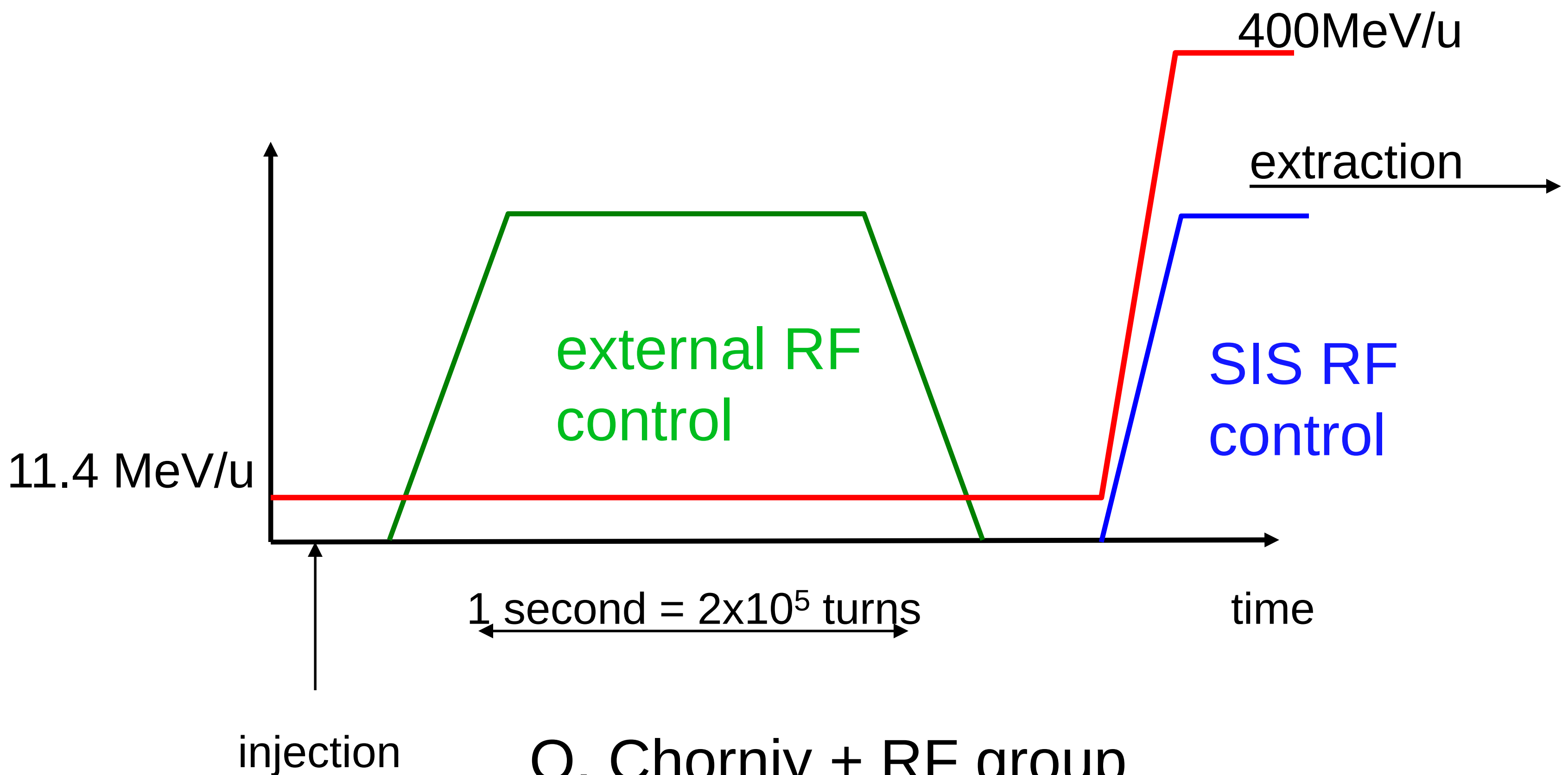
Goal ⟶

high intensity

beam size smaller than SIS acceptance

RF capture obtained via an ‘external’ RF cycle control *(O.Choriny + RF group)*

RF control



O. Chorniy + RF group

Beam @ injection

Ion: 40Ar+18

ε_x ~ 6 mm-mrad

ε_y ~ 4 mm-mrad

dp/p rms ~ 10^{-3}

harmonic = 4

RF voltage = 4 KV

Injection energy = 11.4 MeV/u

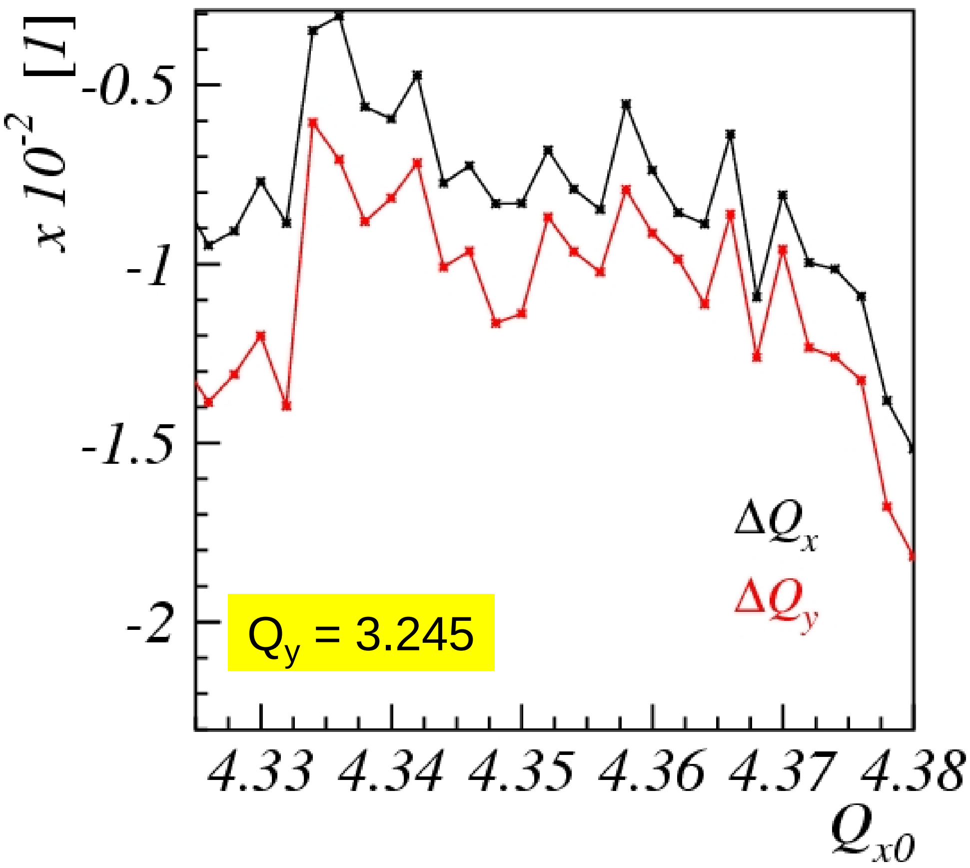
Storage time = 1 sec. = 2×10^5 turns

Beam evolution

Systematic use of the RGM for the transverse

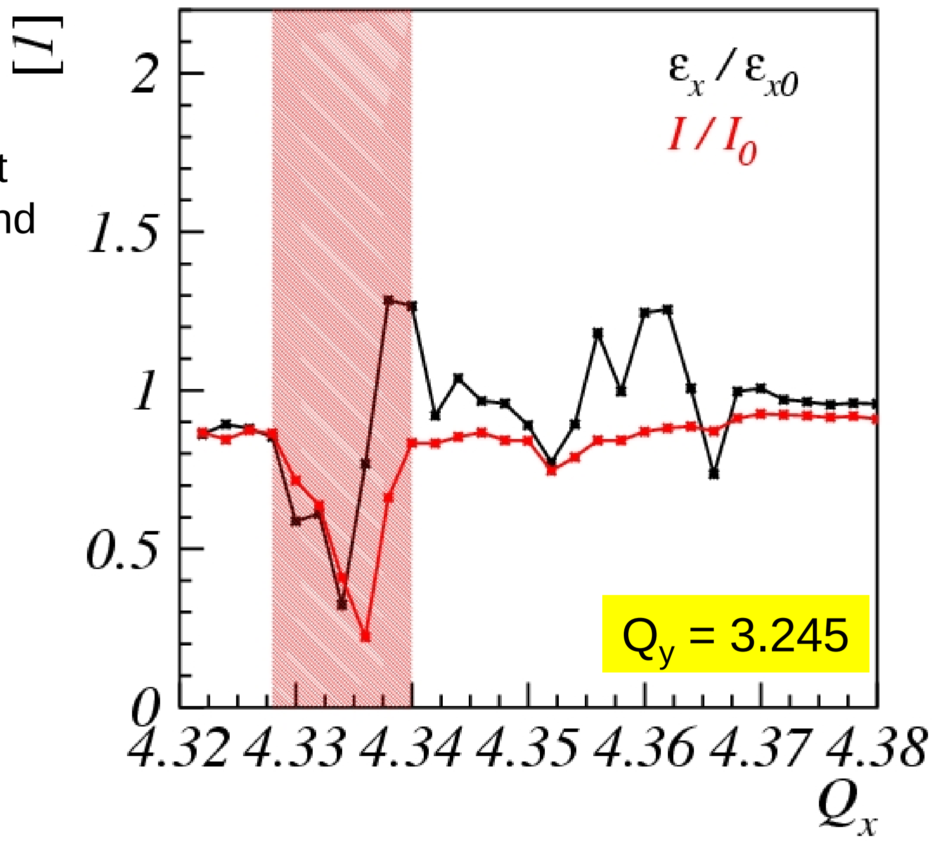
Simultaneous acquisition of transverse/longitudinal beam profiles during 1 second storage time.

CBL: peak tuneshift



CBL: measurement of stop band

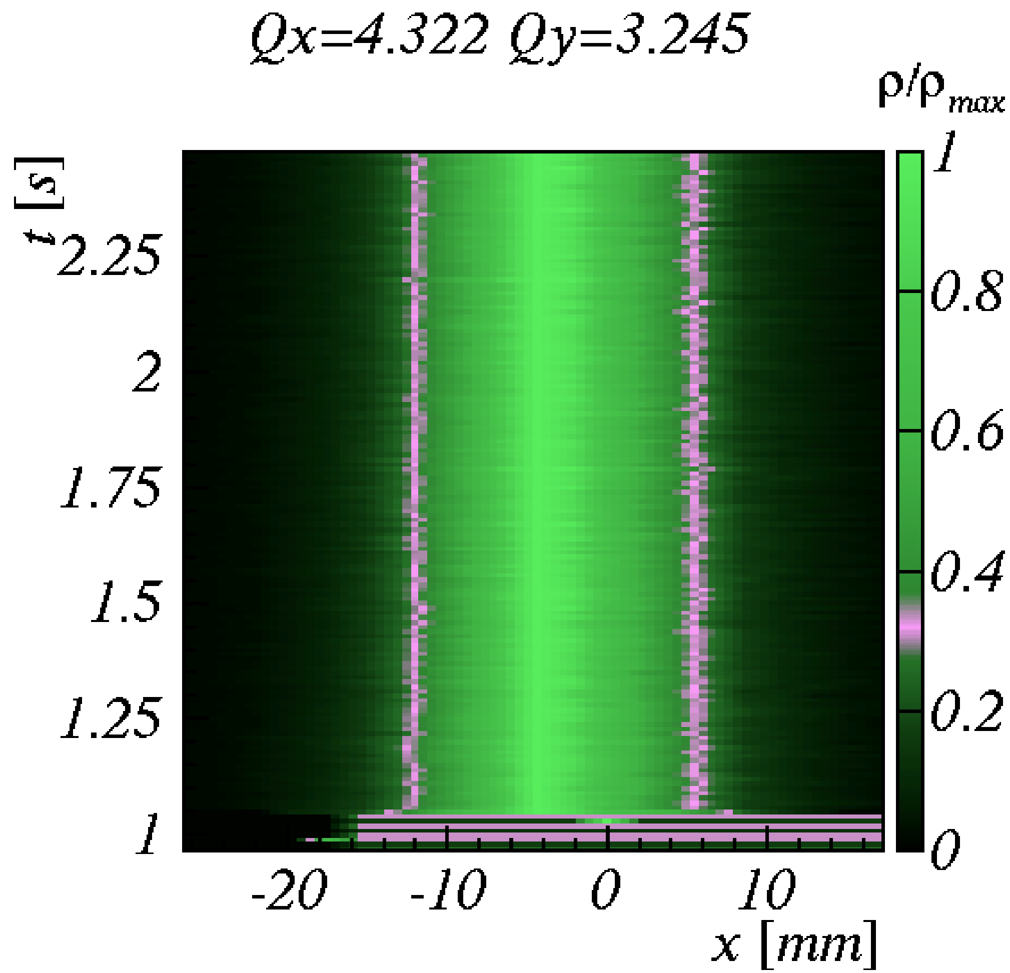
Coasting beam low intensity



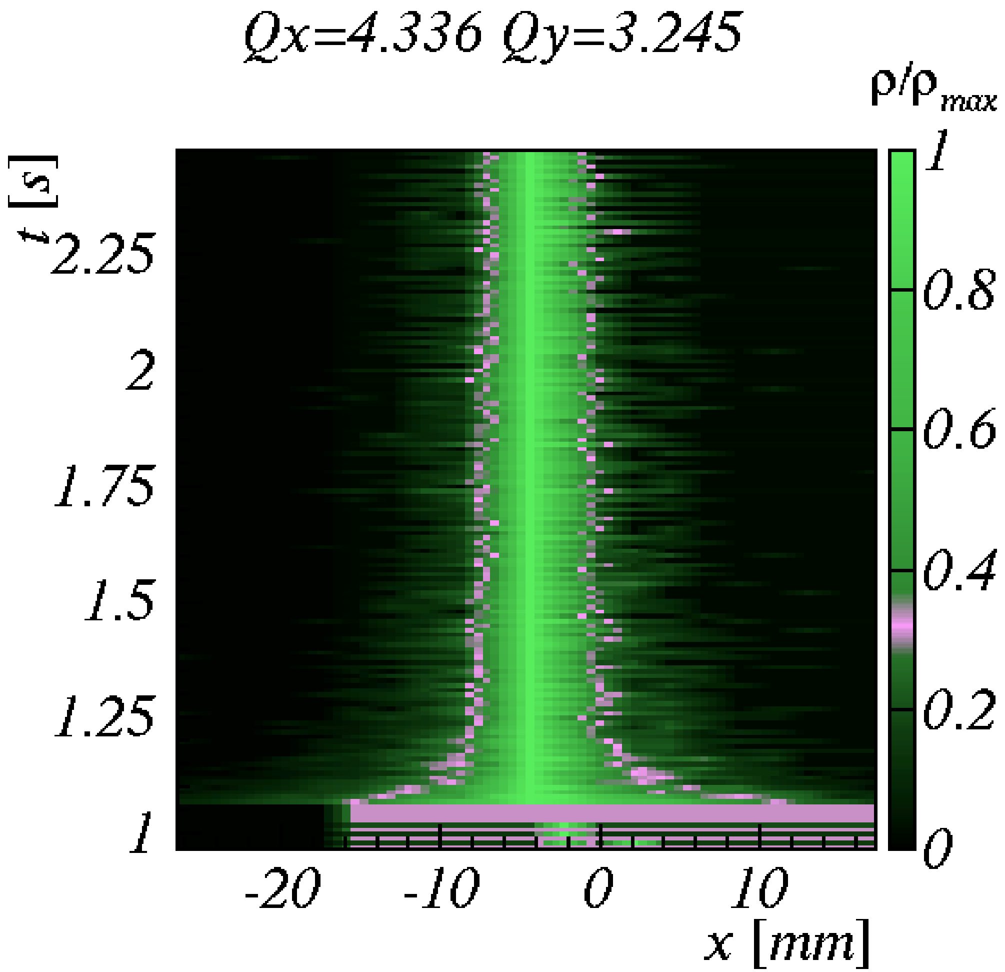
with this measurement we detect the stop-band of the resonance

3Qx = 13

CBL: transverse evolution off the 3rd order resonance

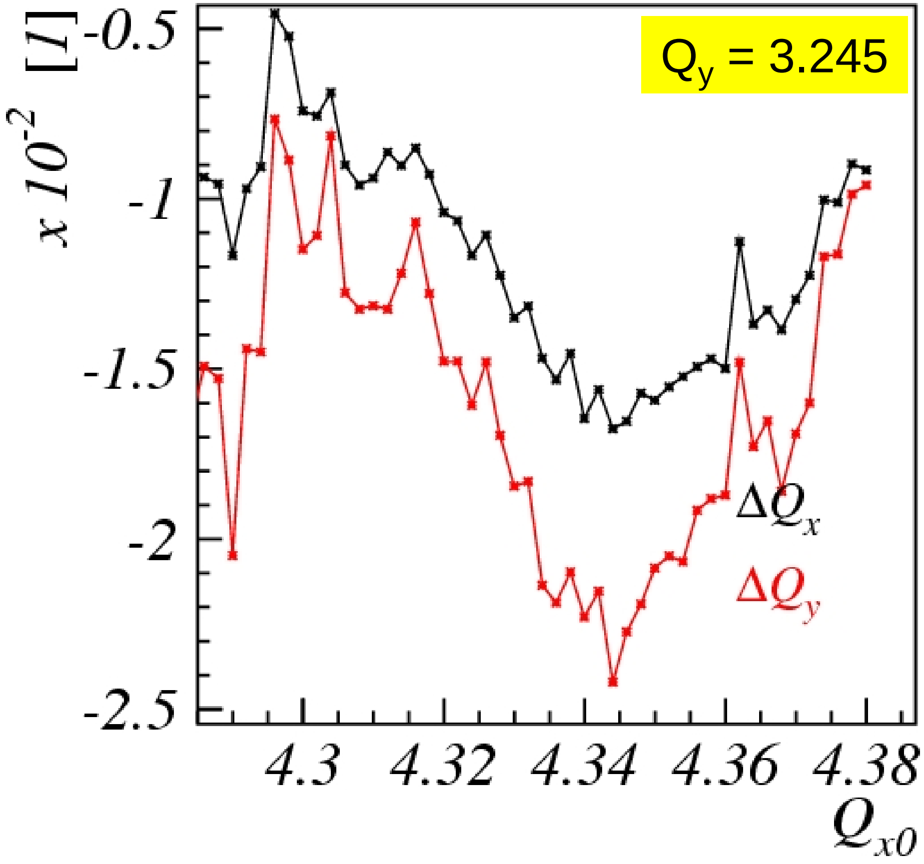


CBL: transverse evolution in the 3rd order resonance



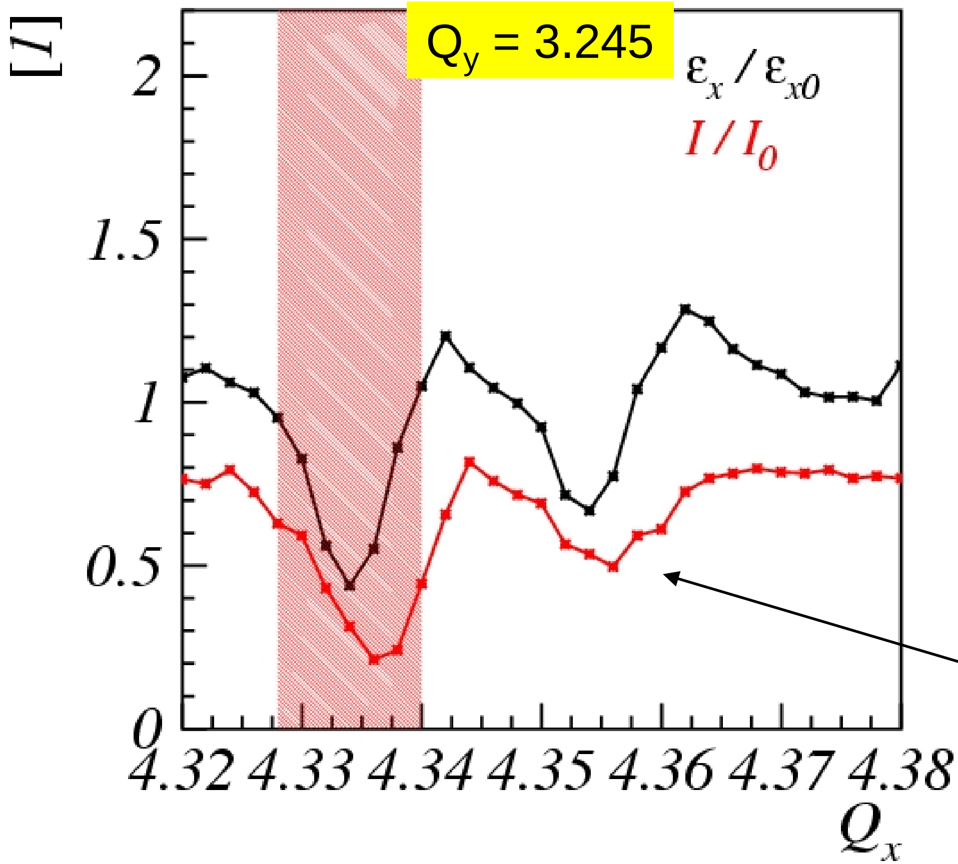
BBL: peak tune-shift

B_f = 1/3



BBL: beam loss and emittance graowth

bunched beam low intensity

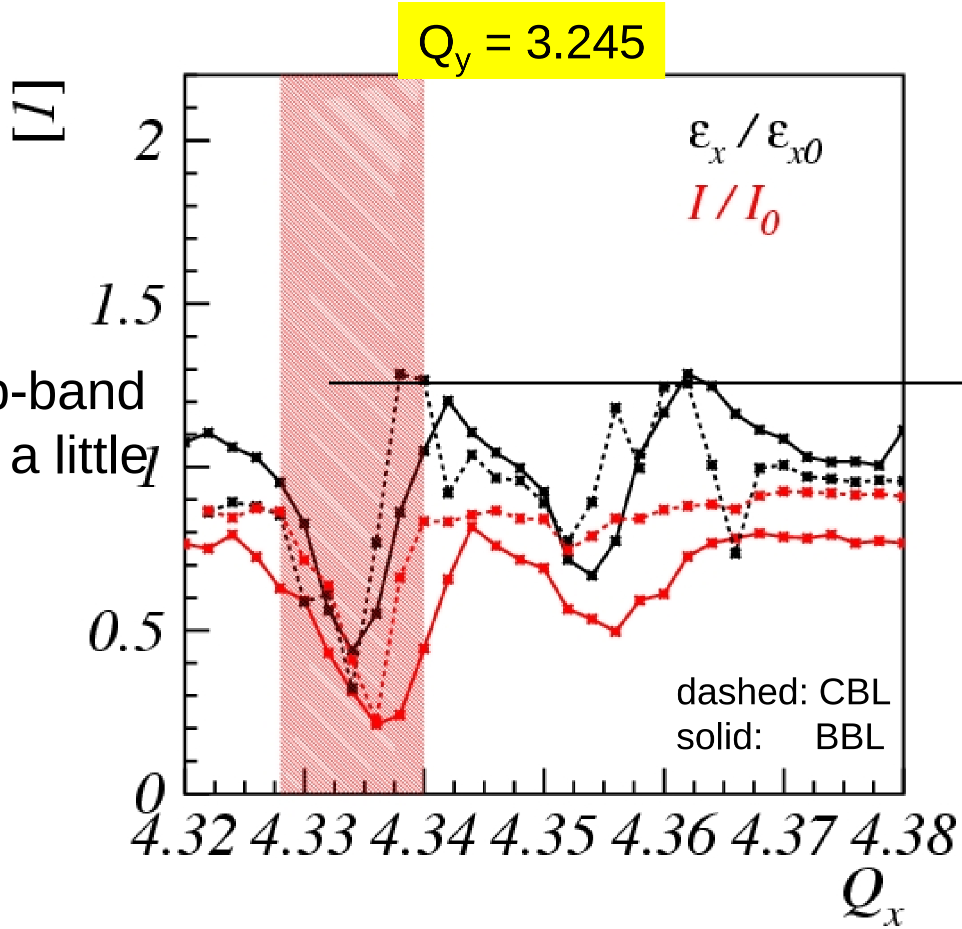


Chromaticity compensated

but a residual chromaticity remains

structure resonance
2 Qx + Qy = 12 ???

Comparison CBL vs. BBL

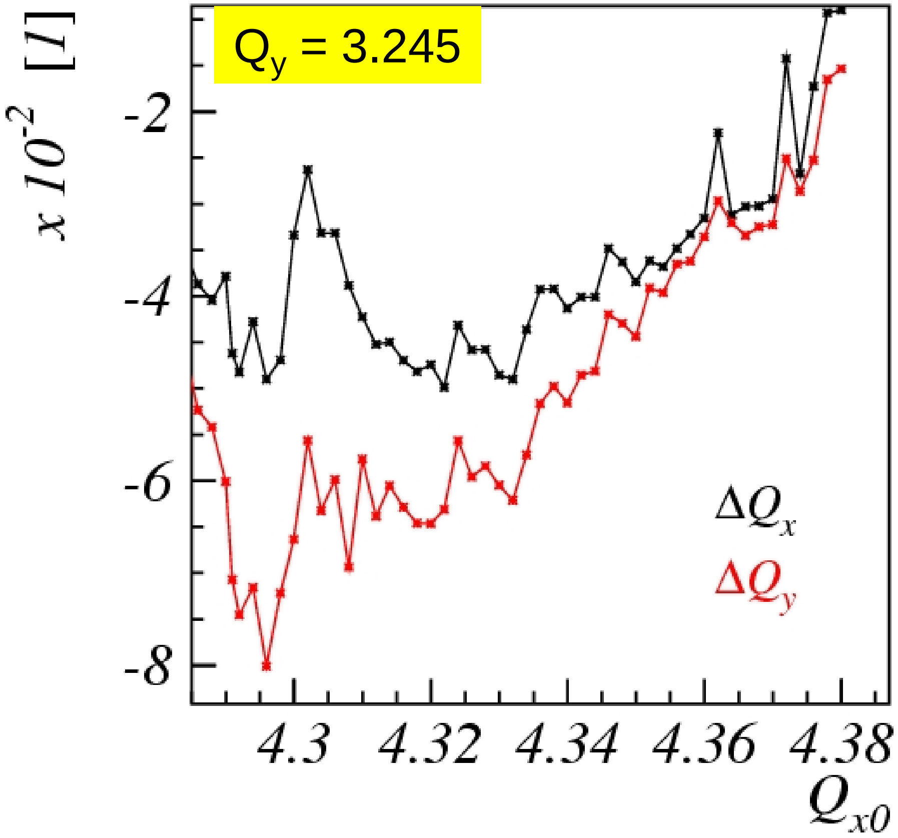


The stop-band appears a little lager

Max emittance growth ~25%

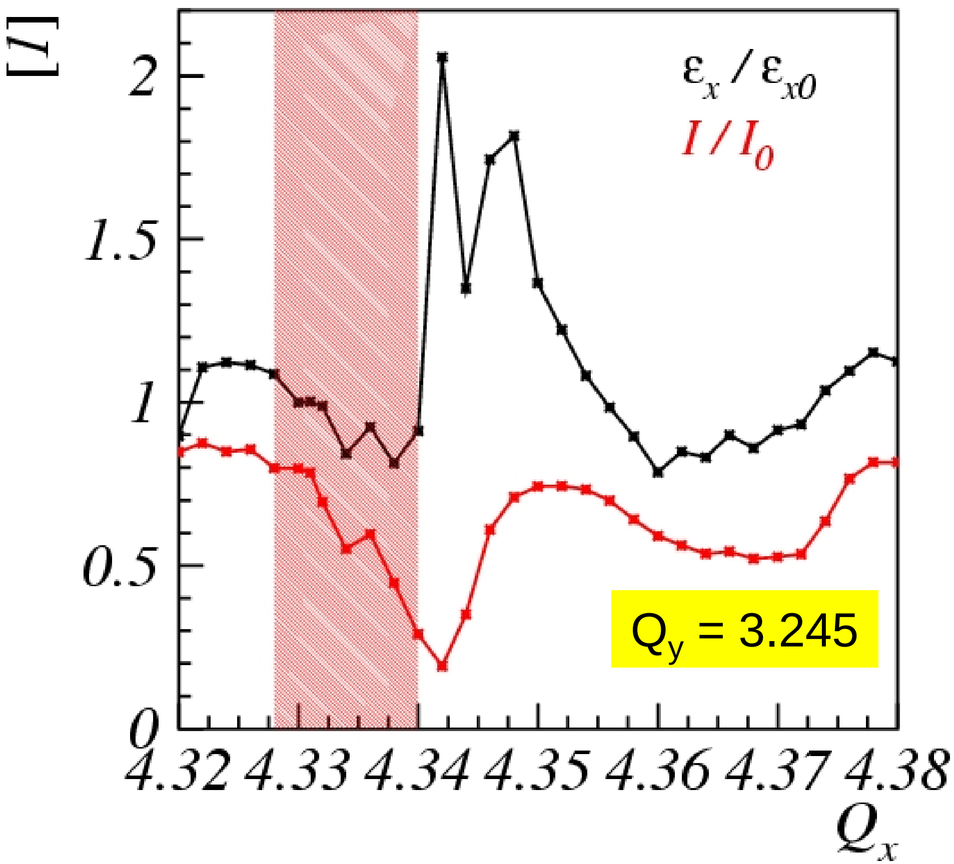
BBH: peak tune-shift

at injection

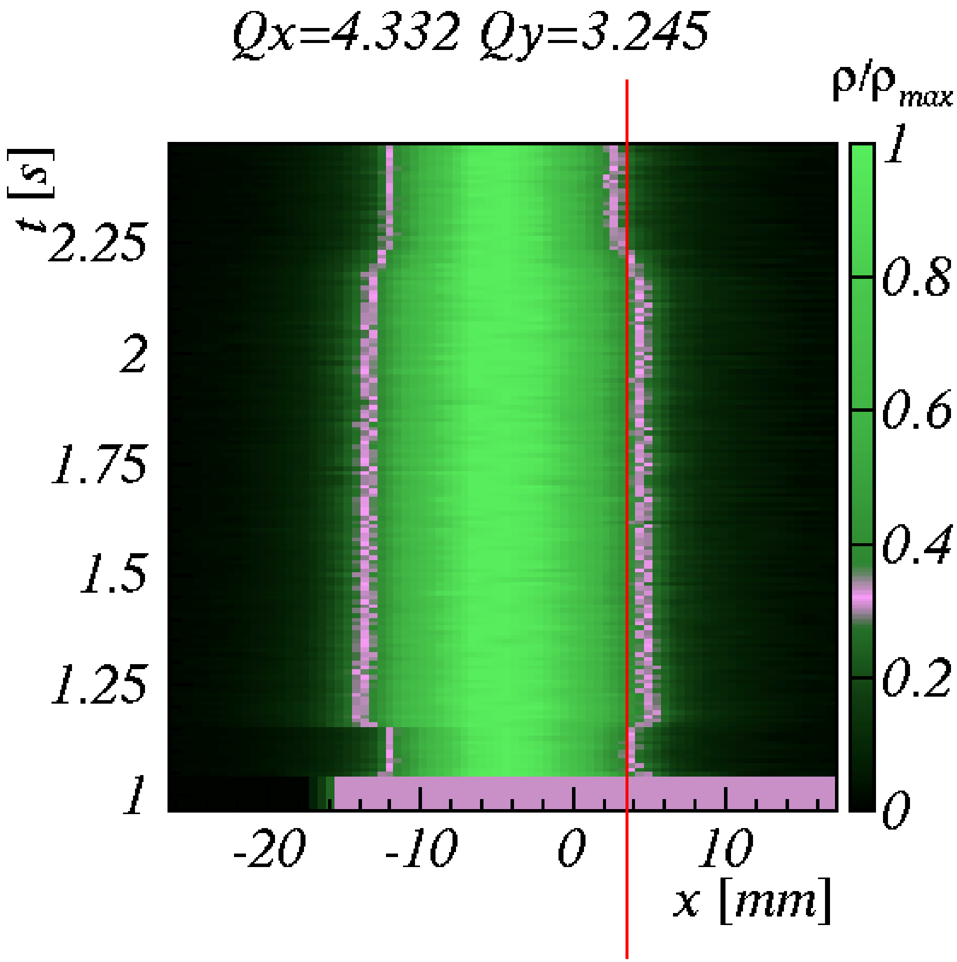


BBH: beam loss and emittance growth

bunched beam high intensity



Transverse evolution BBH



SIS acceleration

de-bunching

1 second storage

RF Capture

injection

Conclusion/Outlook

We compared 4 beams: CBL,CBH,BBL,BBH

We find that only when a beam is bunched and the intensity is high the beam evolution, in terms of transverse emittance growth and beam loss and longitudinal beam shrinking, is consistent with the theoretical mechanism of particle trapping/scattering into a **3rd order resonance**

We have expended the experimental studies started in the CERN-PS in 2002/2003 and retrieved identical beam behavior

Simulation-benchmarking of this experiment