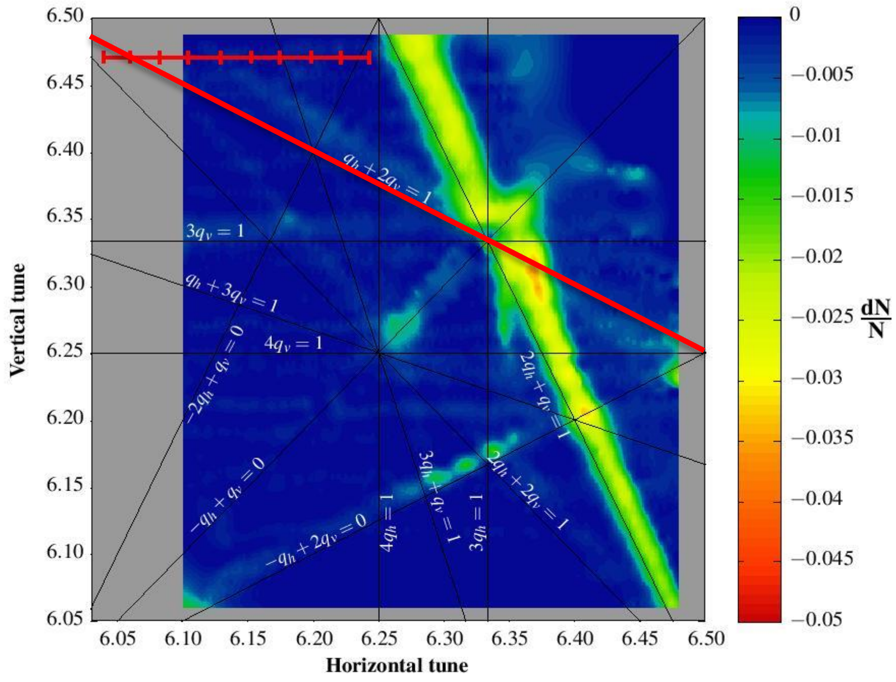
Experiment in PS

G. Franchetti, GSI

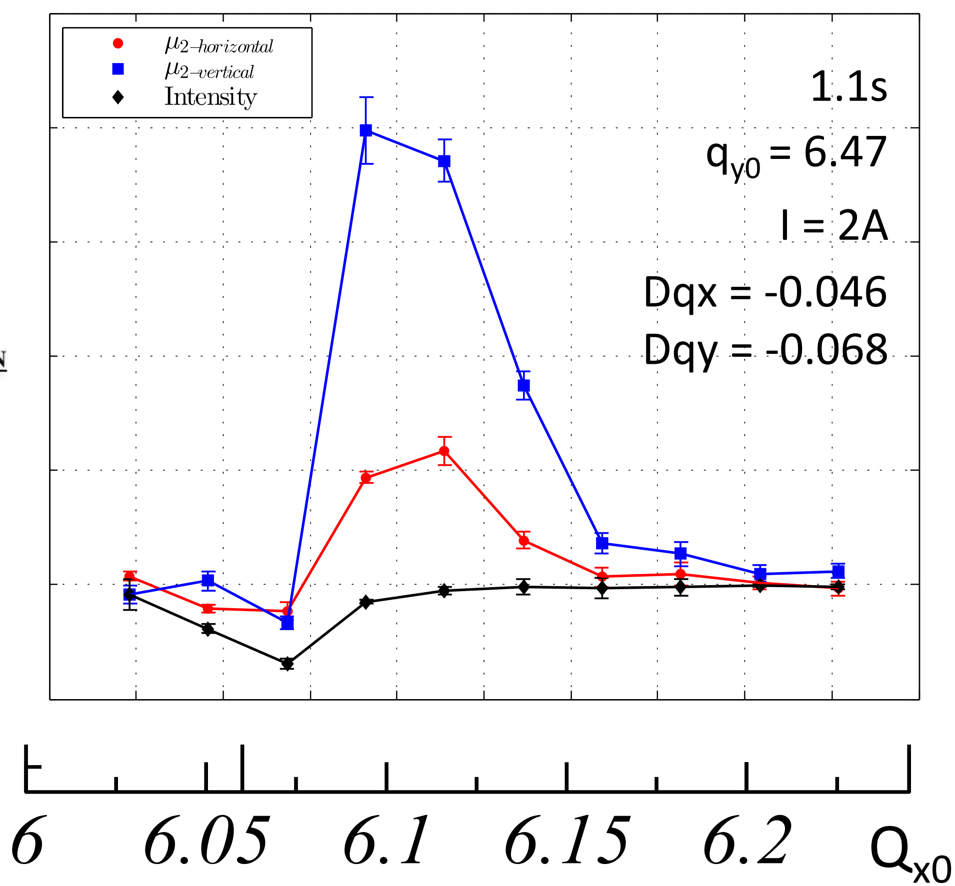
CERN, 20-21/5/2014

PS measurements 2012

Resonance: $q_x+2\,q_y = 19$



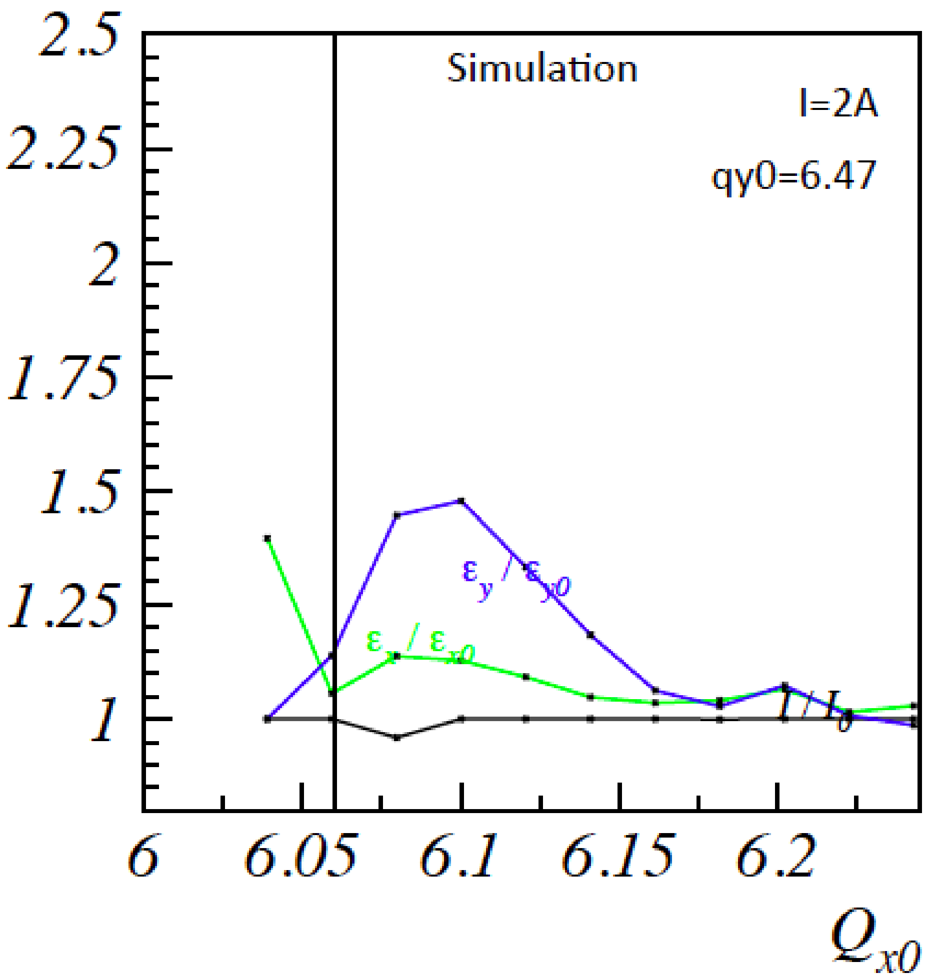
Measurement

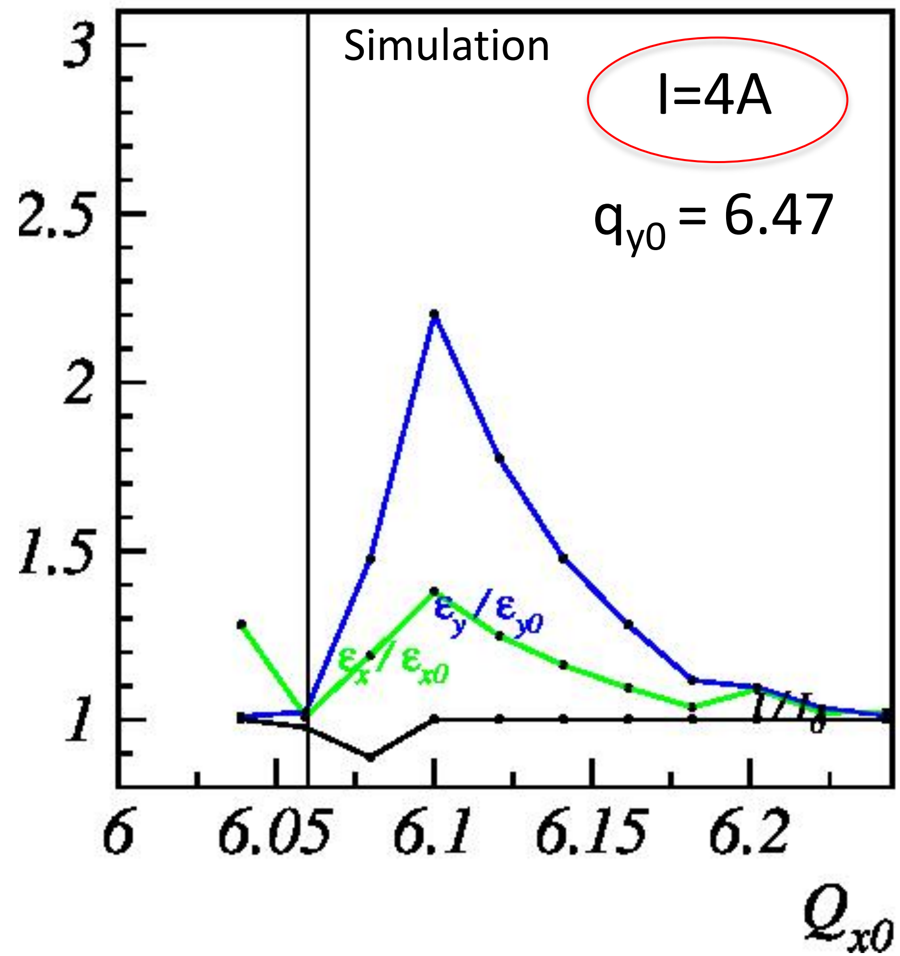


R. Wasef, A. Huschauer, F. Schmidt, S. Gilardoni, G.Franchetti

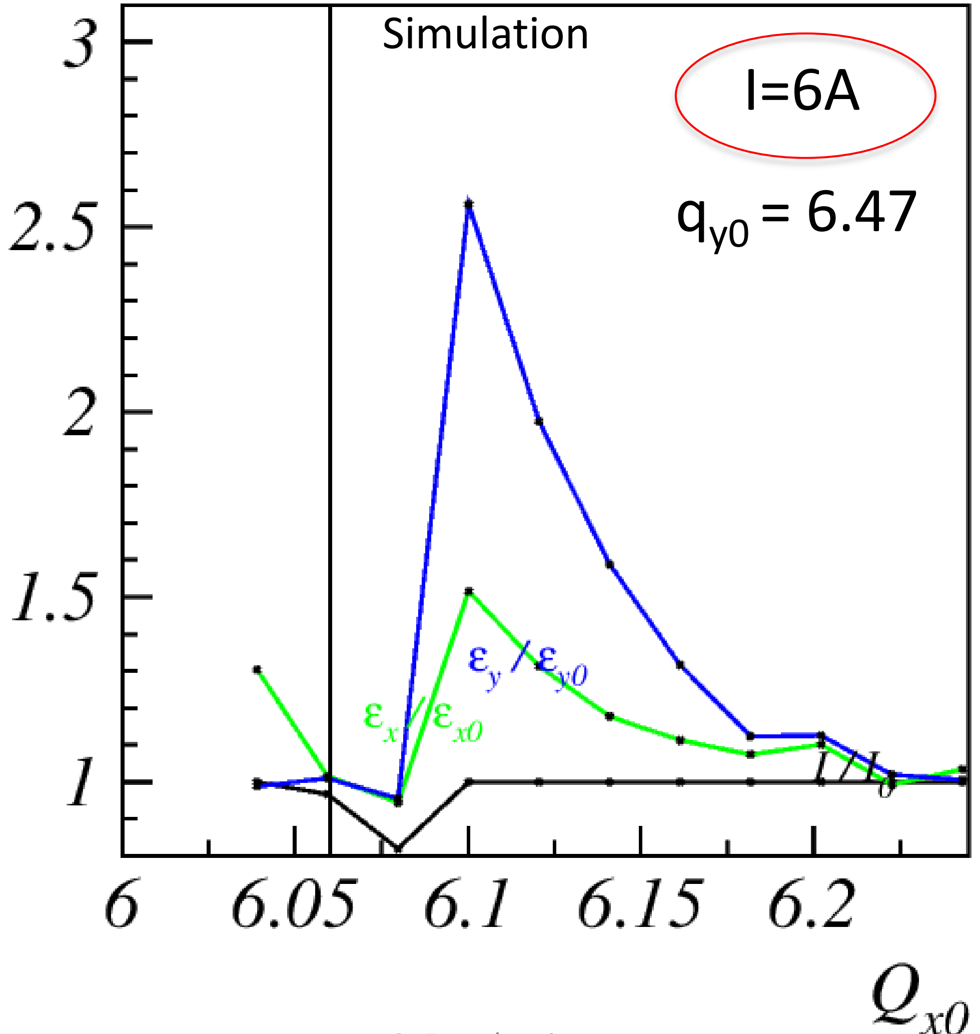
SPACE CHARGE 2013

Presence of natural resonance was not included, then we tried by enhancing the resonance strength



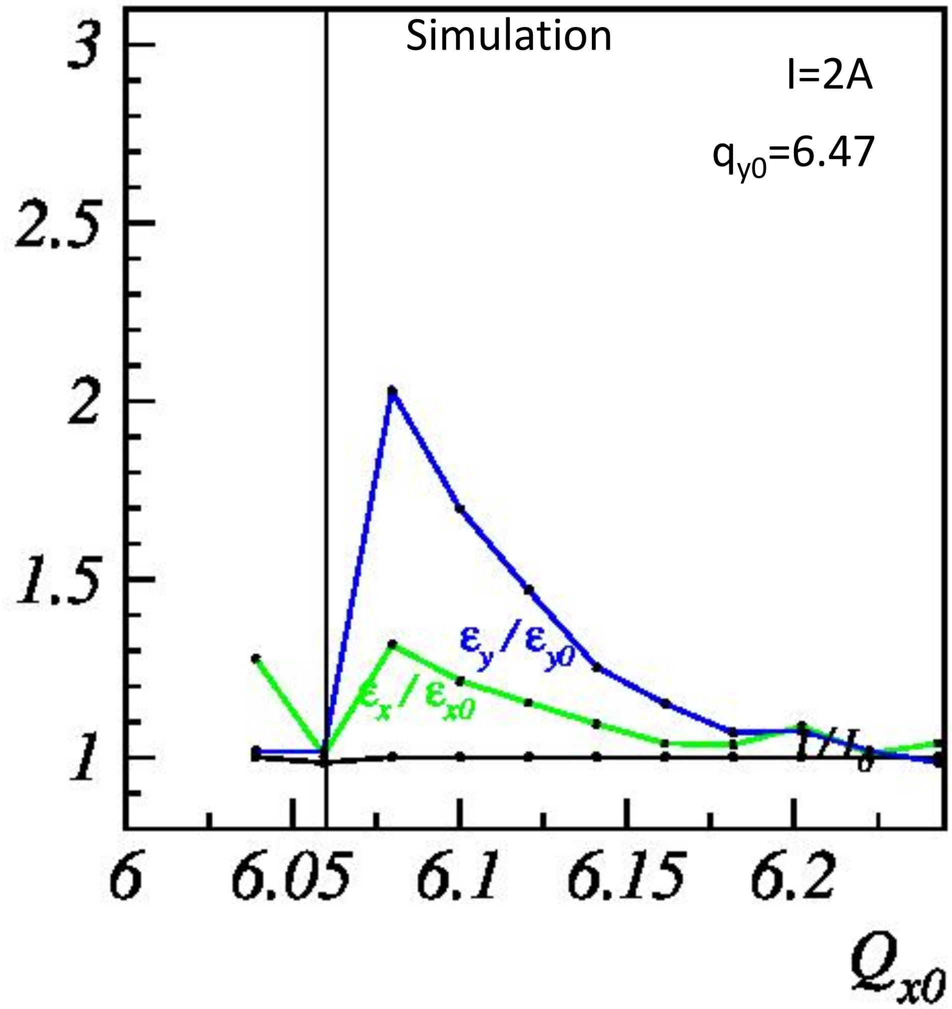


For a stronger resonance excitation but this is an artificial enhancement



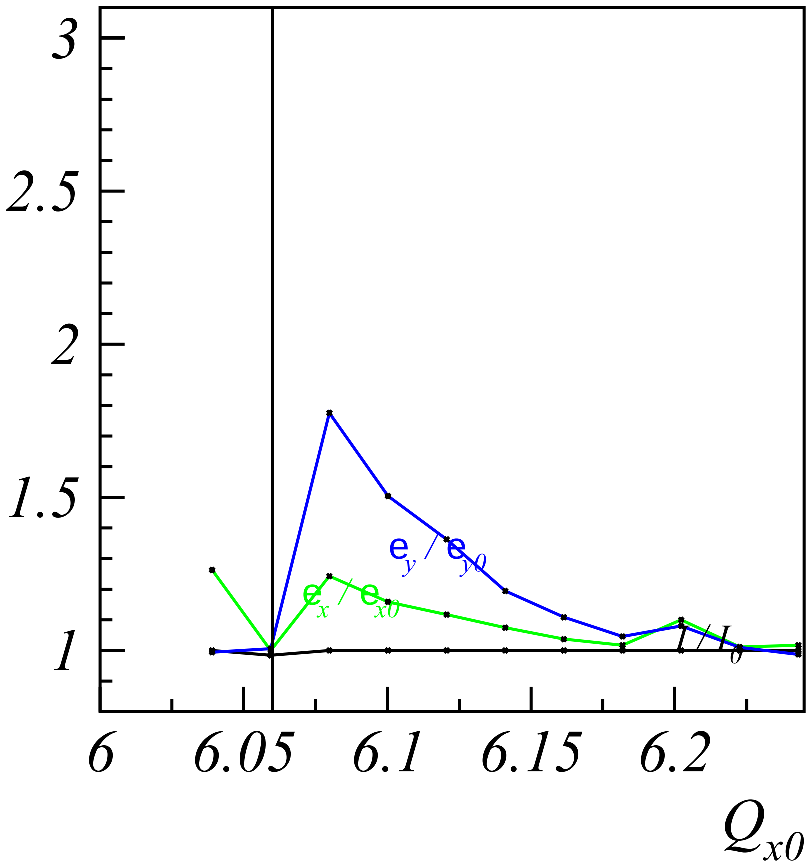
Modeling was still incomplete

new simulations performed after the visit of Frank Schmidt at GSI. Correcting the PS model in computer code.

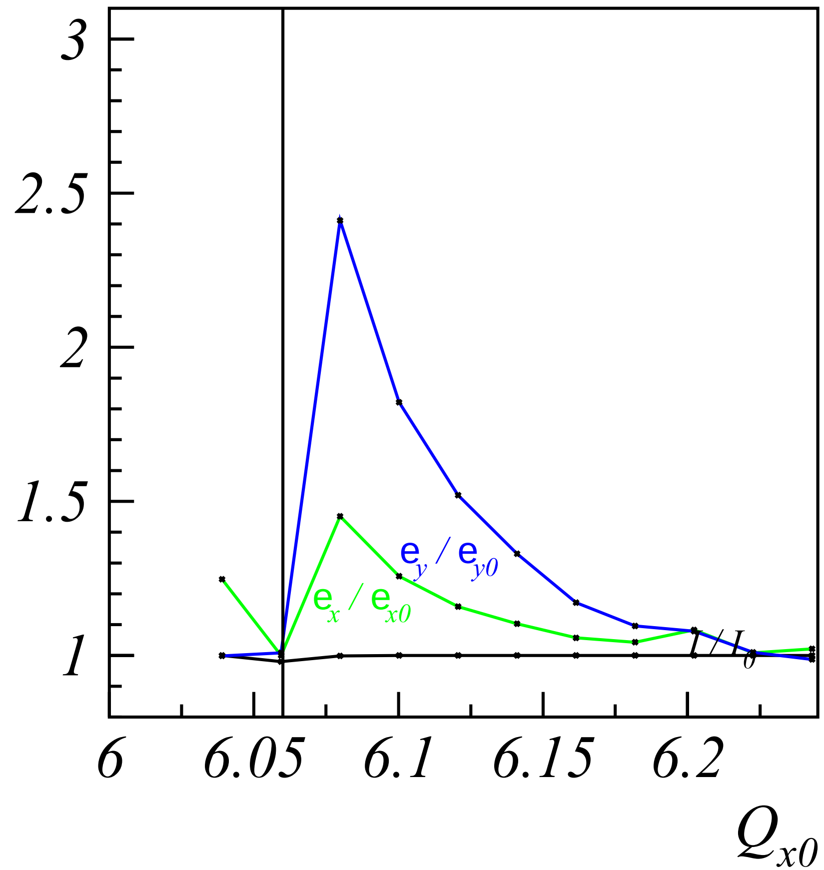


Adding random errors

sigma = 10%

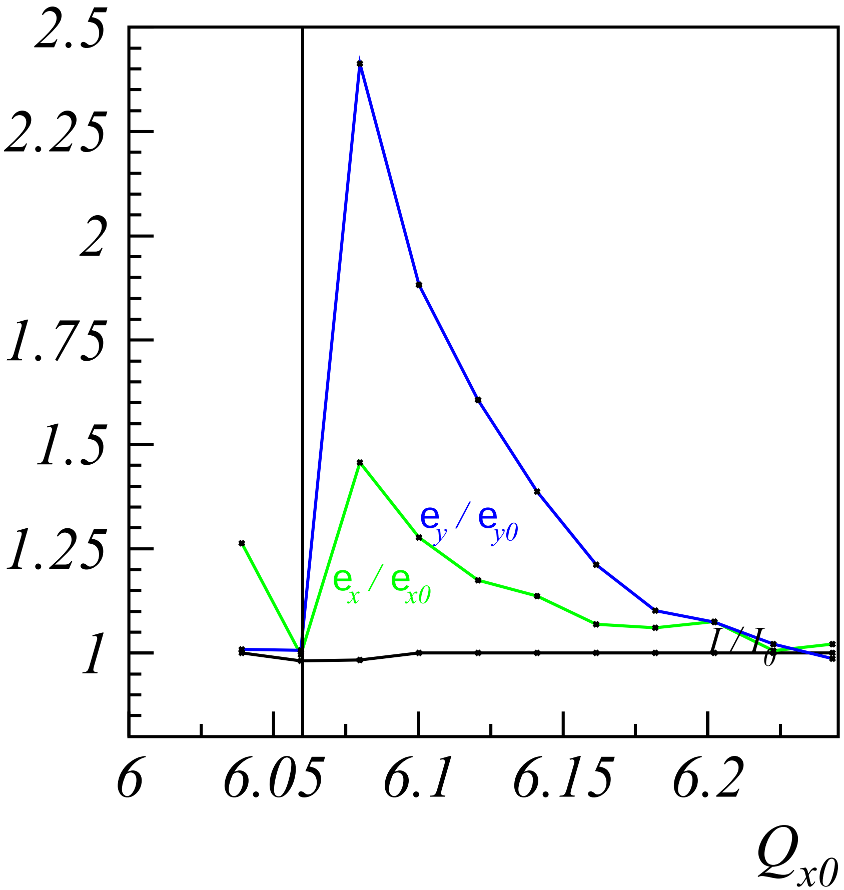


sigma = 10% but distribution of errors with inverted sign, same seed ("inverted seed")

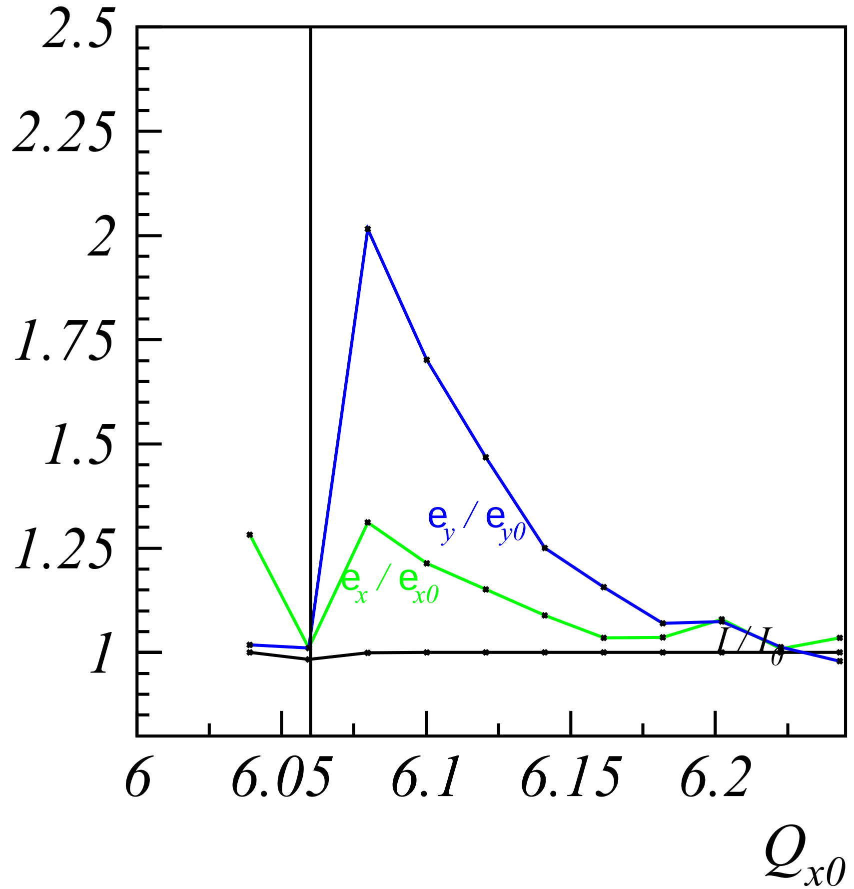


For larger random errors of the same seed

sigma = 20% inverted seed

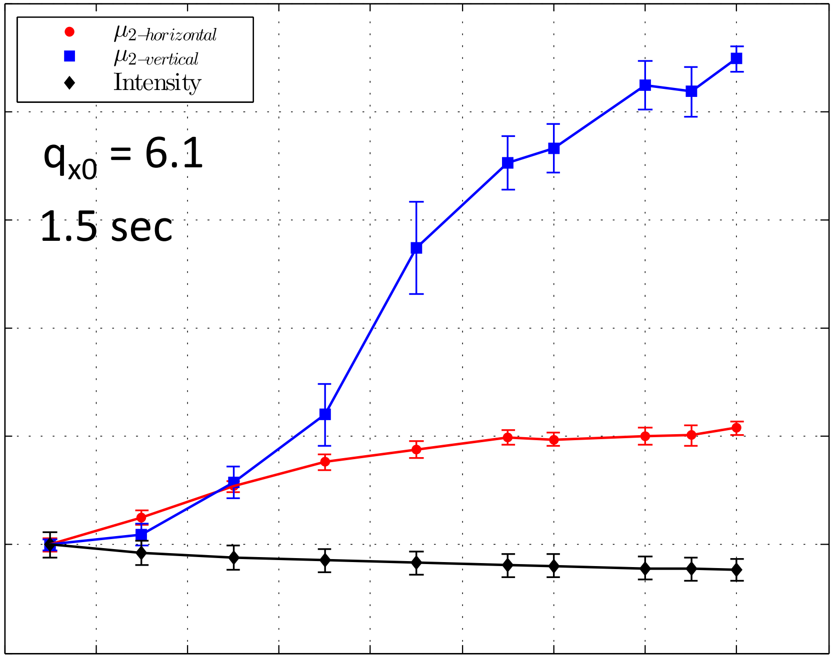


sigma = 40 % inverted seed

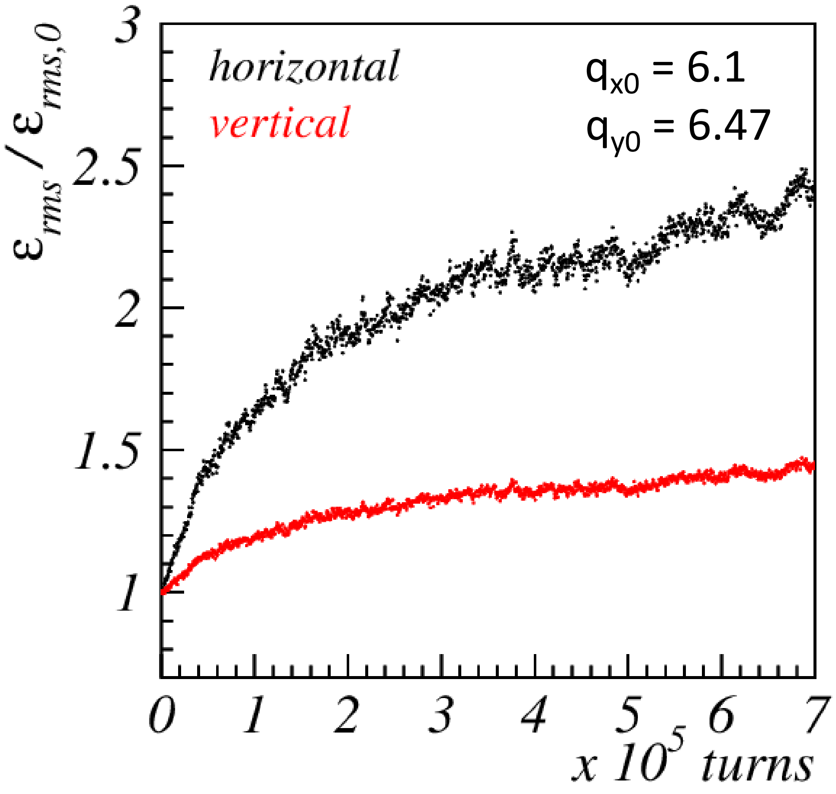


Emittance evolution

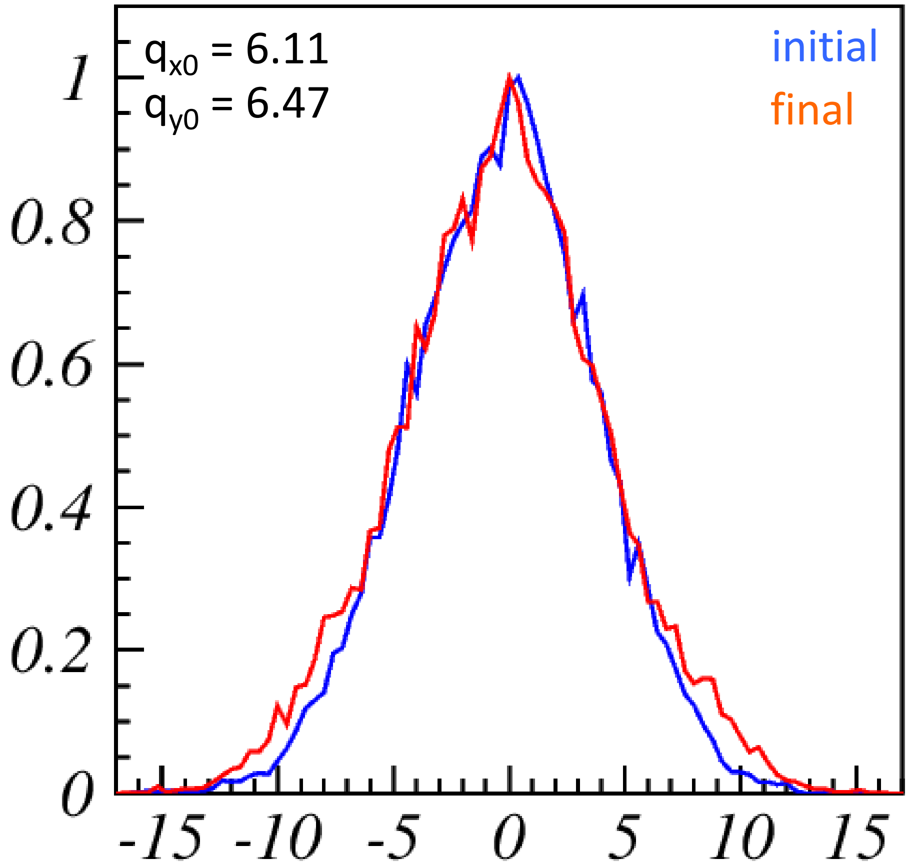
Measurement

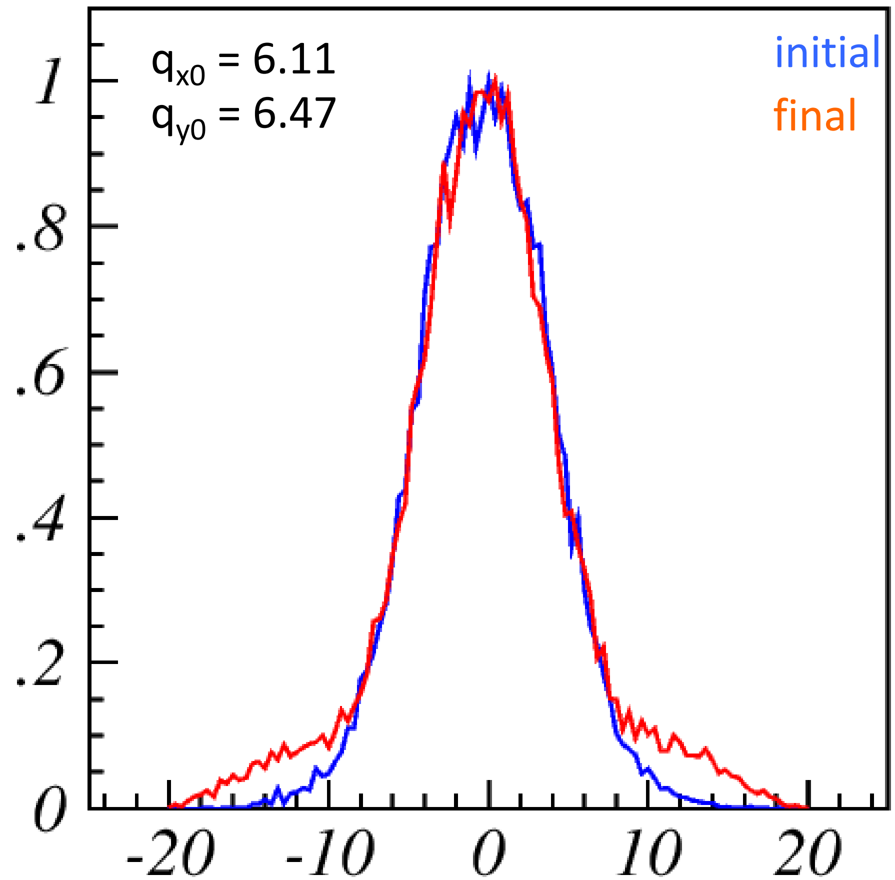


Simulation "inverted seed" 10%



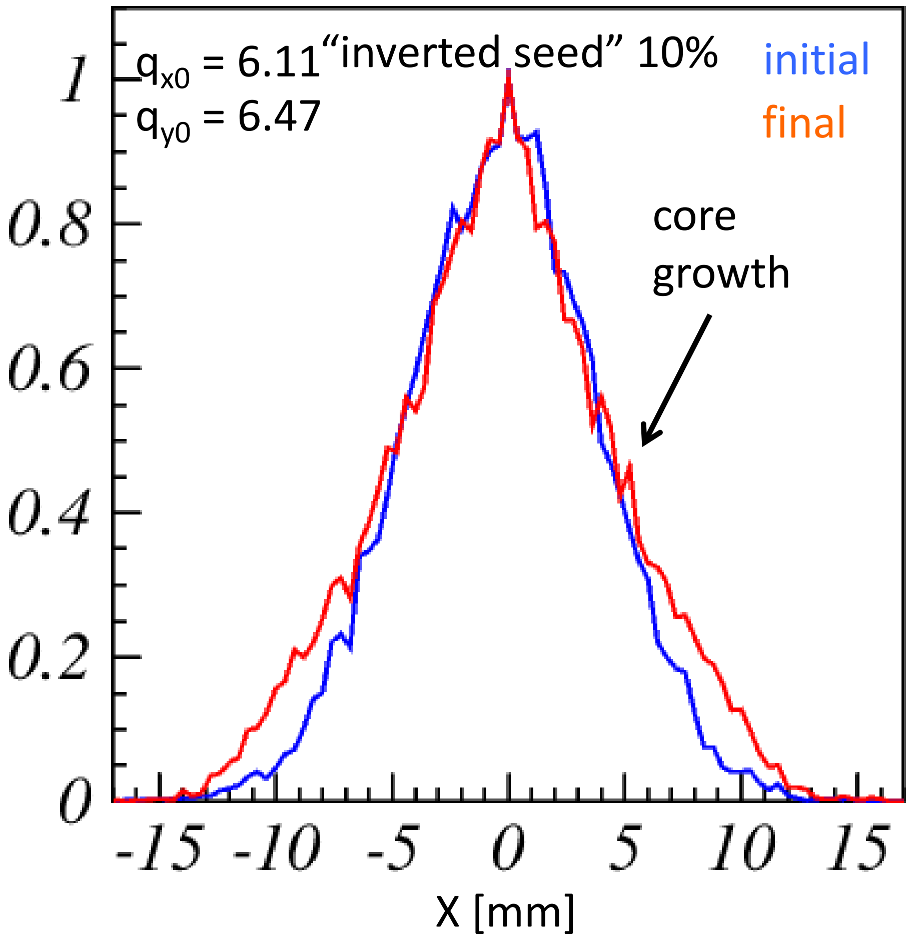
Final/Initial distribution for the "inverted seed" 10%, I=2A



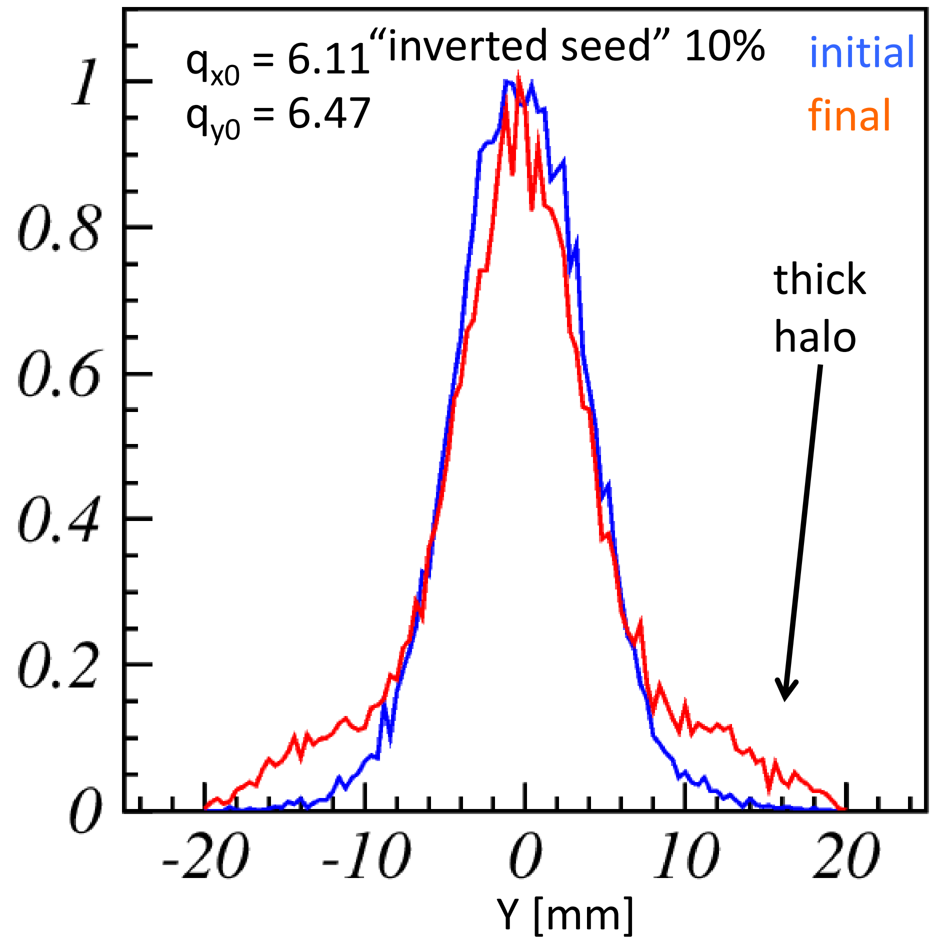


With a stronger current I=4A, to include artificially a pre-existing resonance

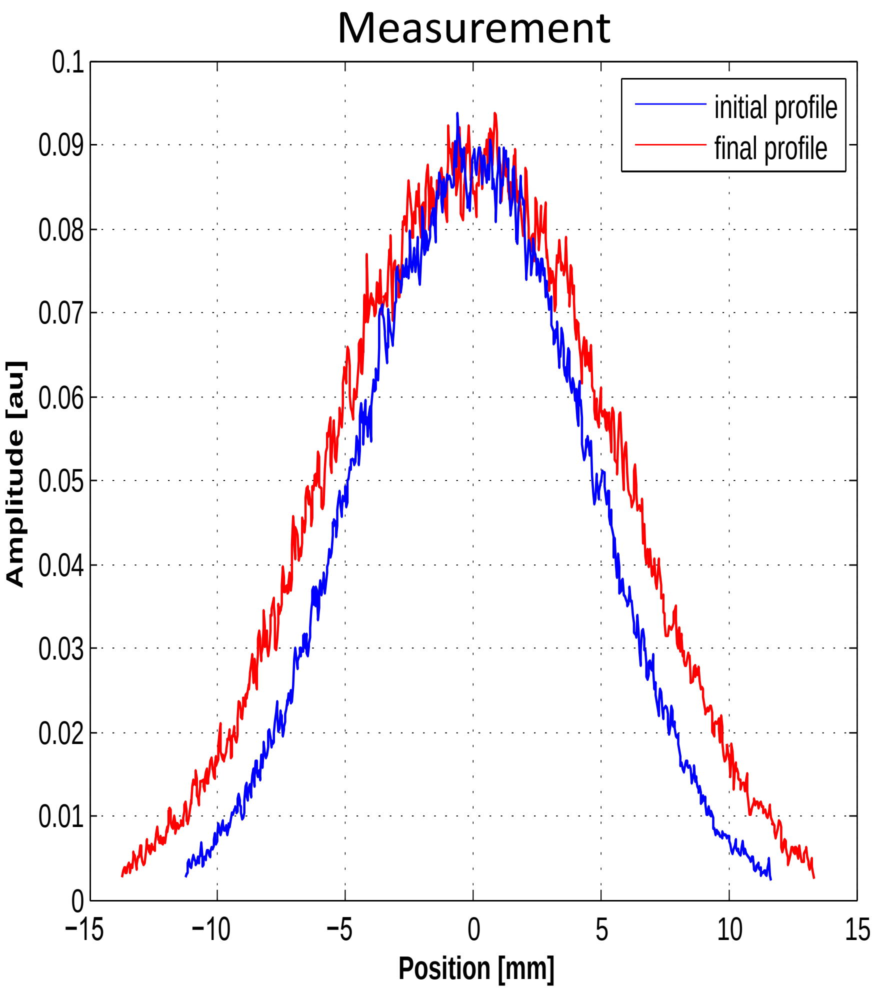
Simulation



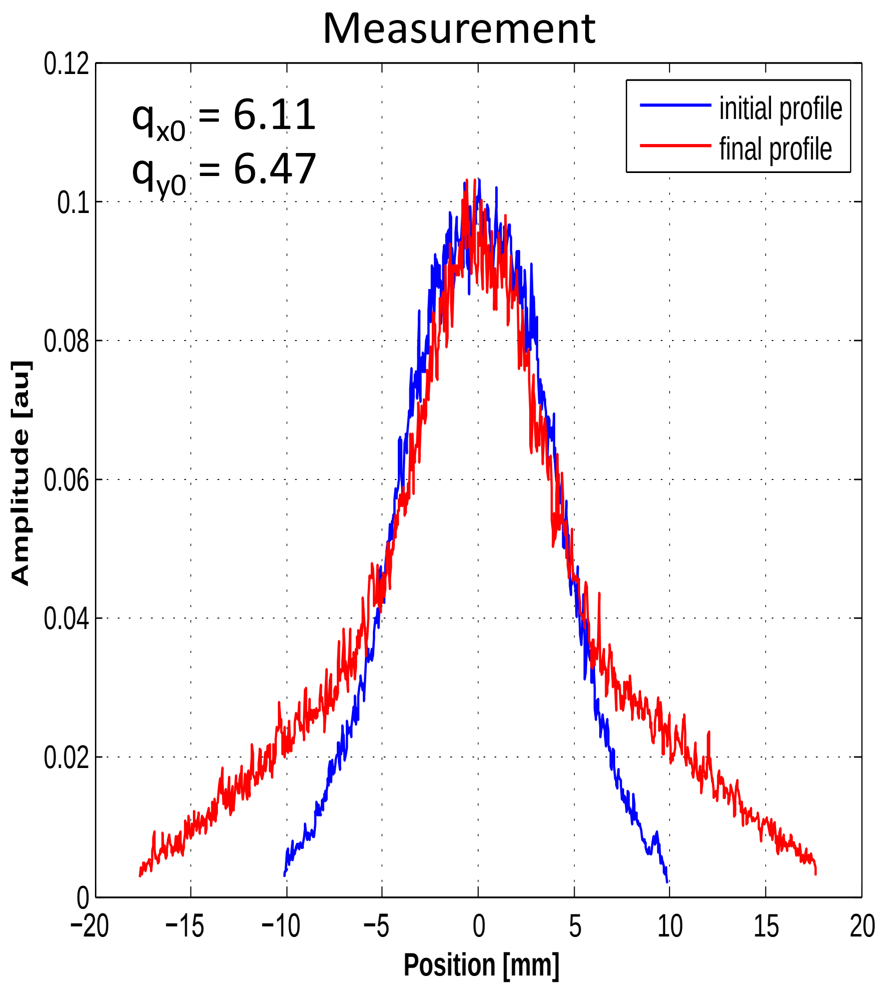
Simulation



Halo formation: experiment



X



Y

Challenges

The main challenges are 2

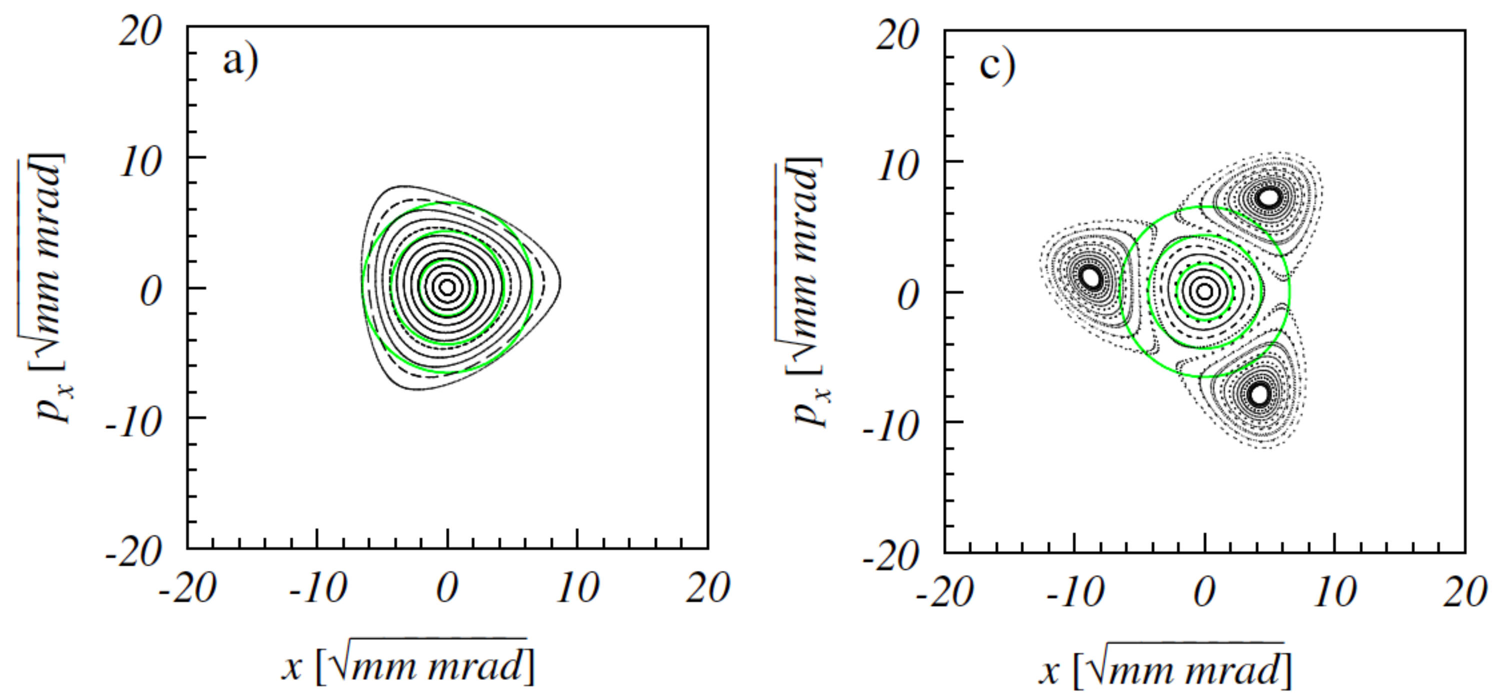
1) Reliable modeling of the nonlinear lattice

2) Understanding the coupled dynamics
in the resonance crossing + space charge

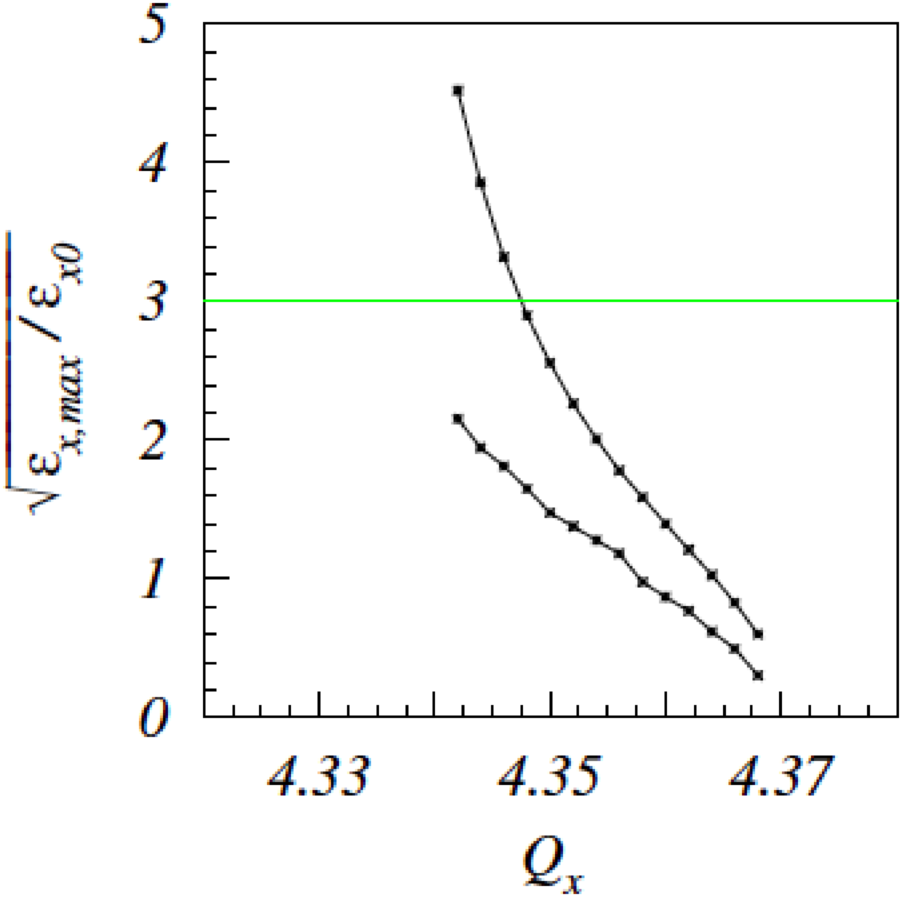
1D dynamics well understood

The asymmetric beam response is mainly attributed to the resonance crossing of a coupled resonance.

Third order resonance 1D



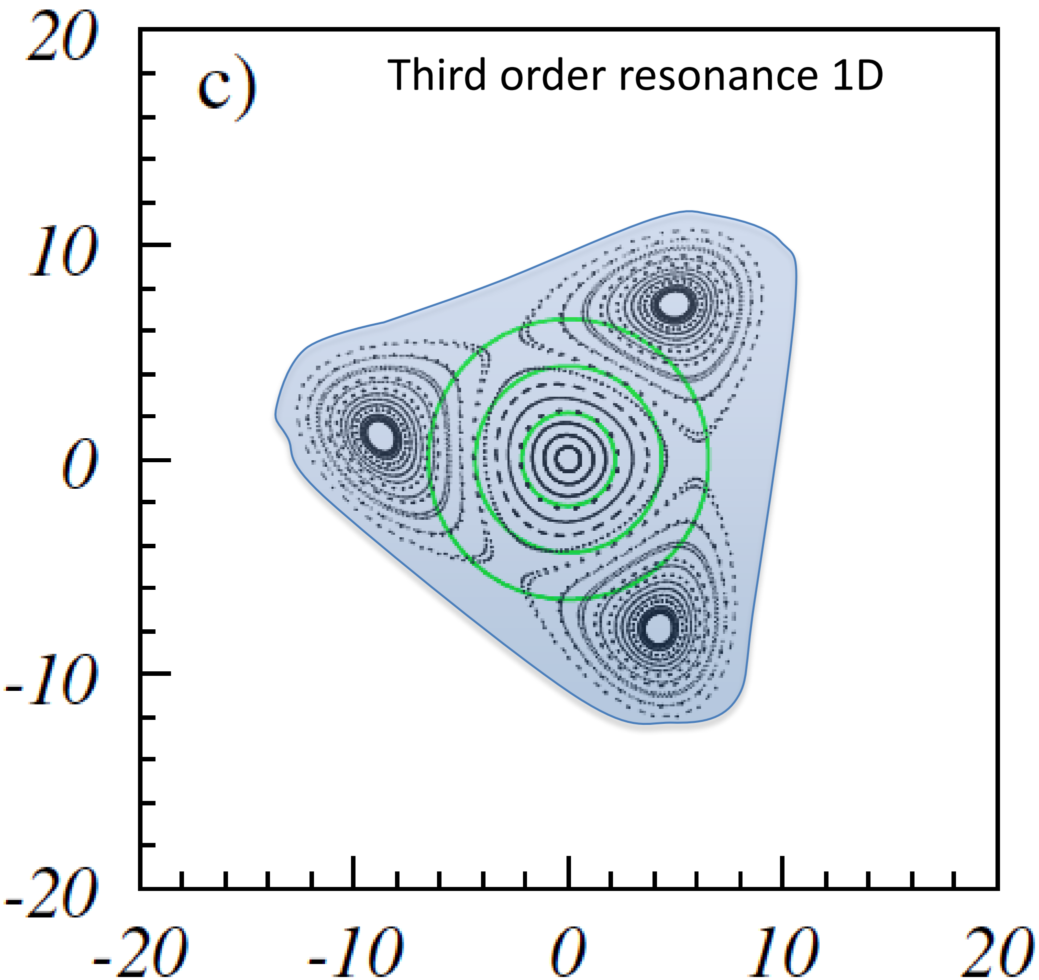
Halo formation/core formation

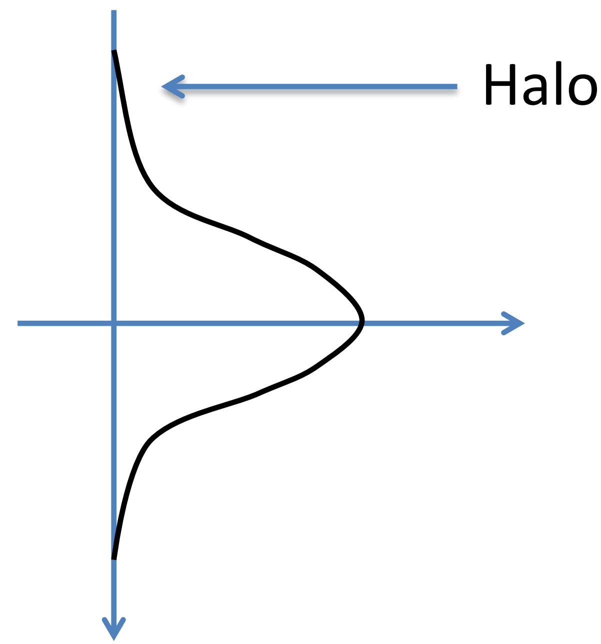


If the island of the frozen system go far out, than an halo is expected

If the islands of the frozen system remain inside the beam edge → core growth

Halo formation through non adiabatic resonance crossing





Coupled dynamics much more difficult

Resonance → $$Q_x + 2Q_y = N$$

What is it an island ?
What is it a fix point ?

Fix-lines

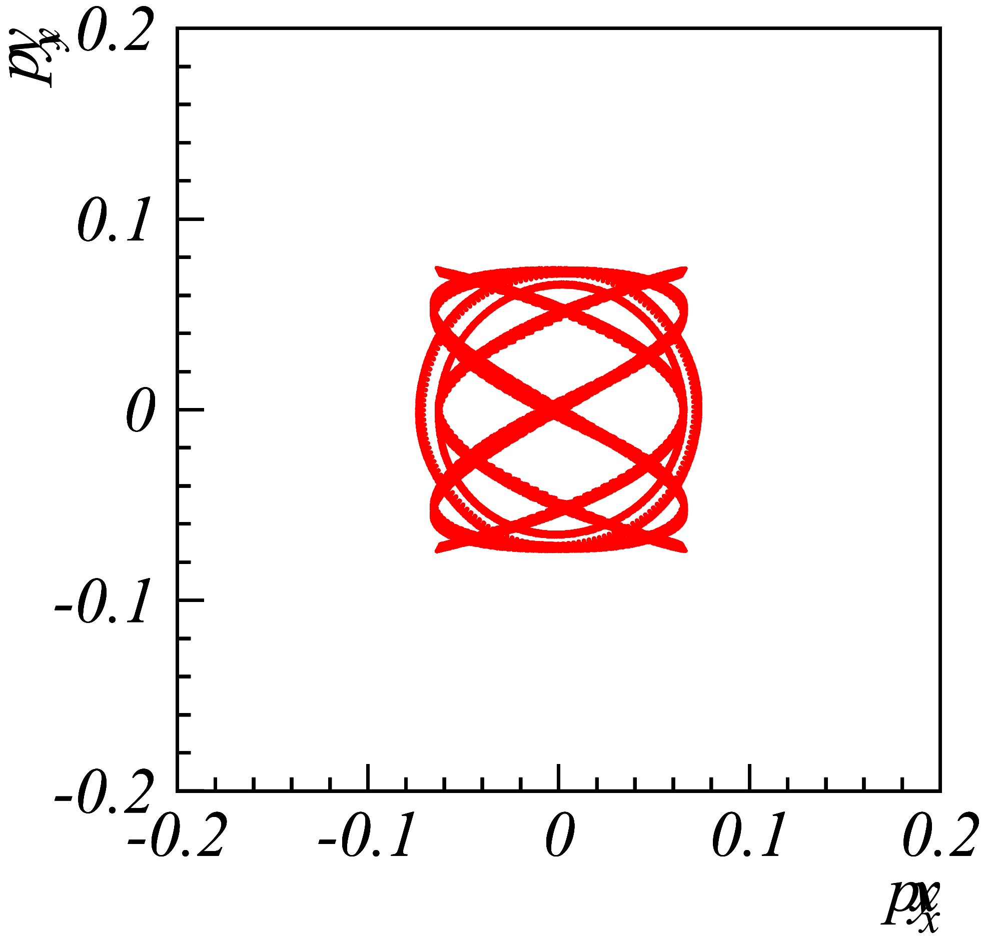
$$3\ Qx = N$$

Fix points are points in phase space that after 3 turns go back to their initial position

$$Qx + 2Qy = N$$

In 4D this dos not happen, but in 4D after 3 turns a point does not return back on the same point. However there are points that after each turn remains on a special curved line. This line is closed and it span in the 4D phase space.

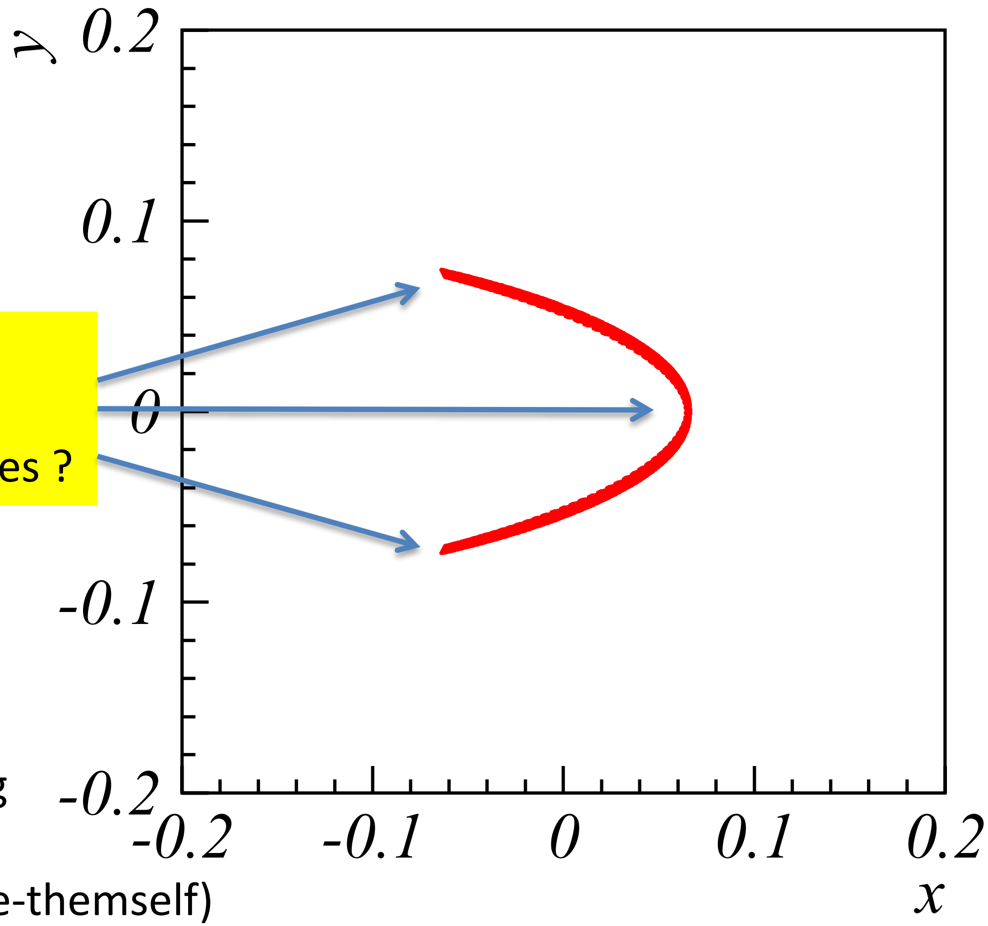
Fix-line projections



Frank
Schmidt
PhD

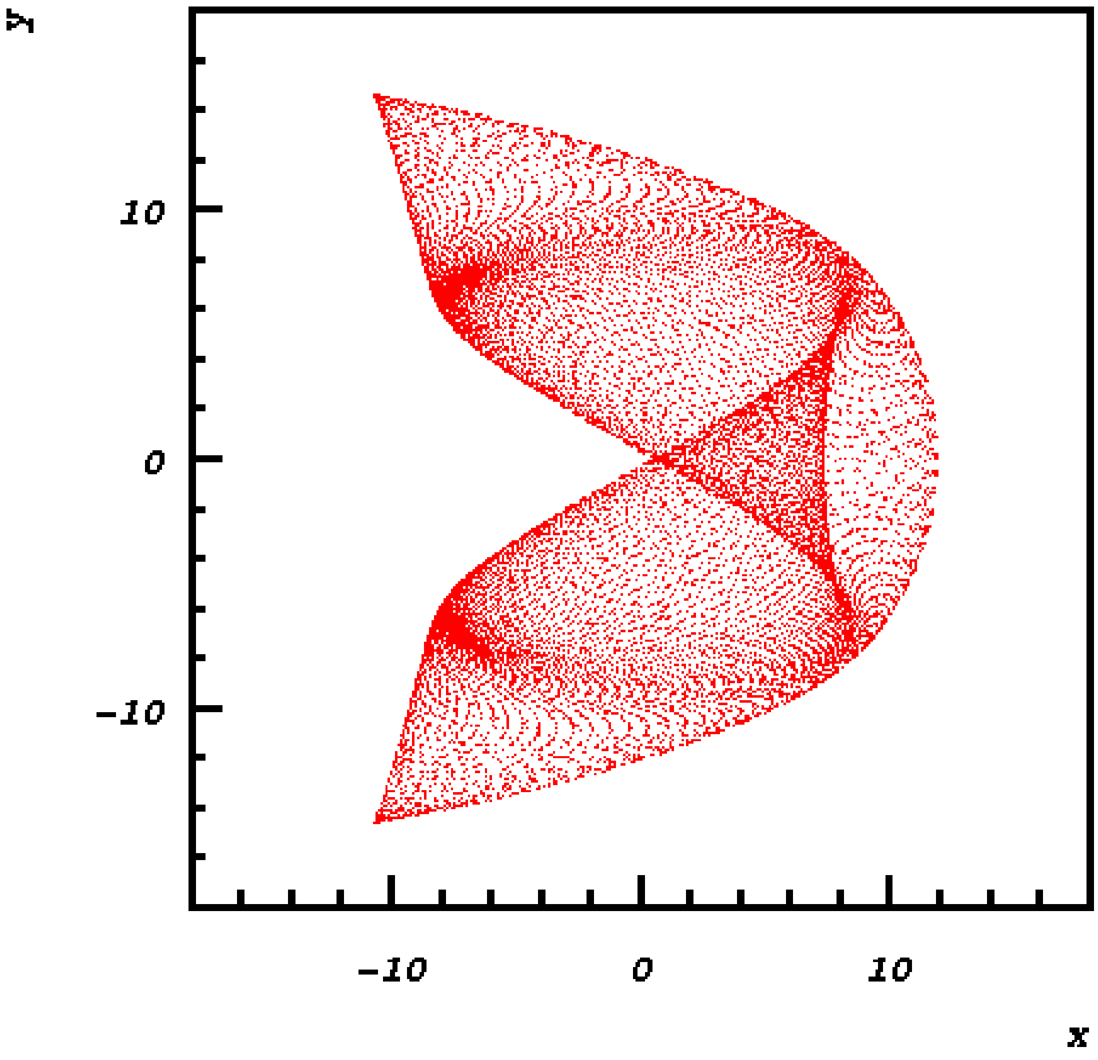
Properties

What are the parameters that fix these sizes ?

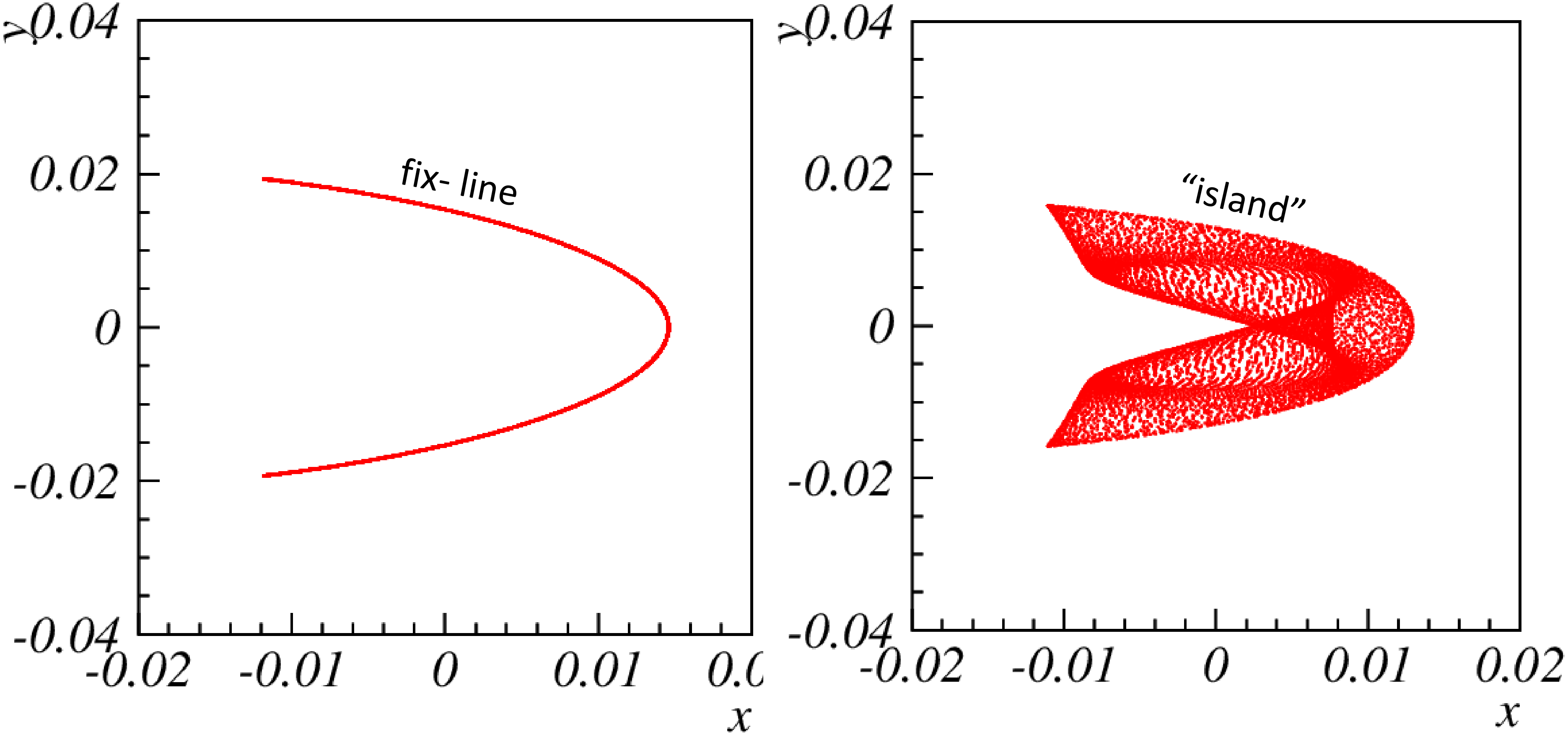


Δ_r
K2 (driving term)
Stabilizing detuning (space charge, octupole, sextupole-themself)

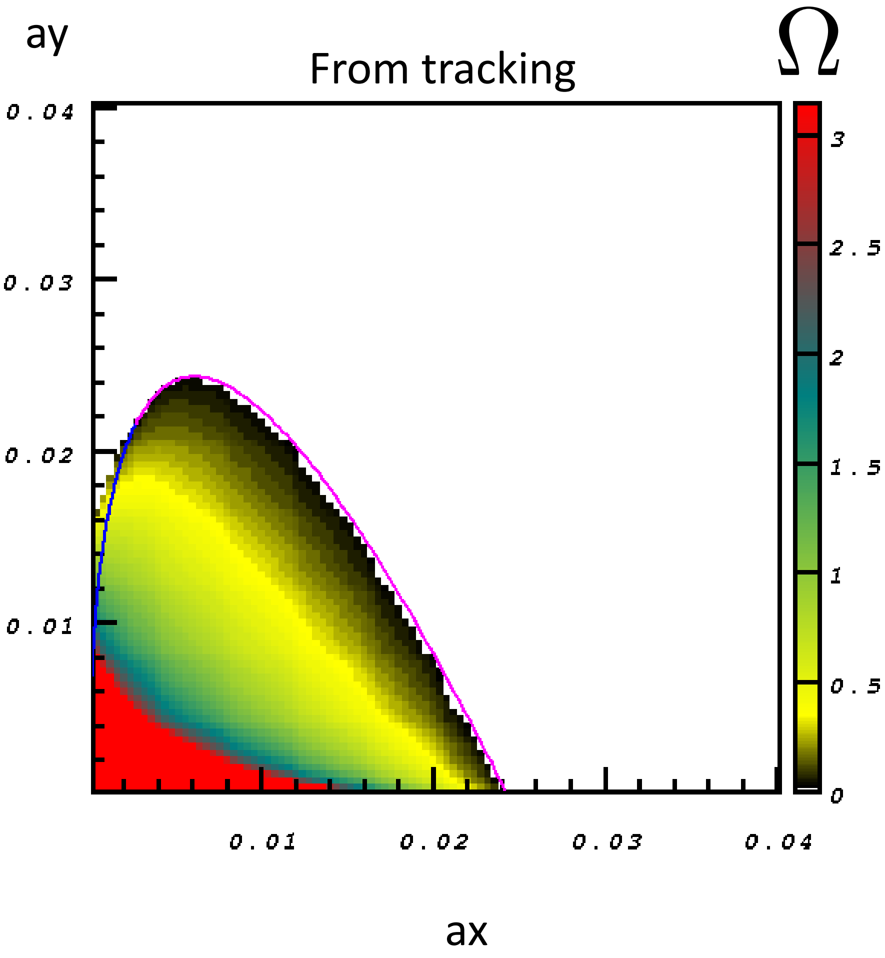
What happen to the islands ?

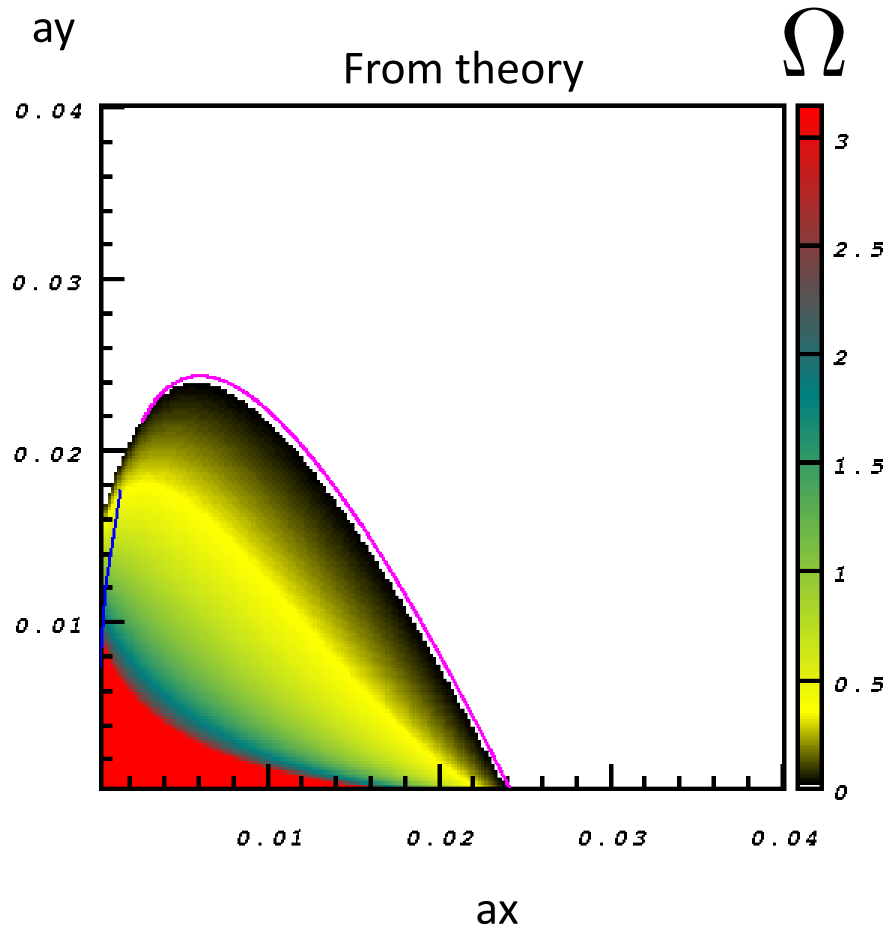


What happen to the islands ?

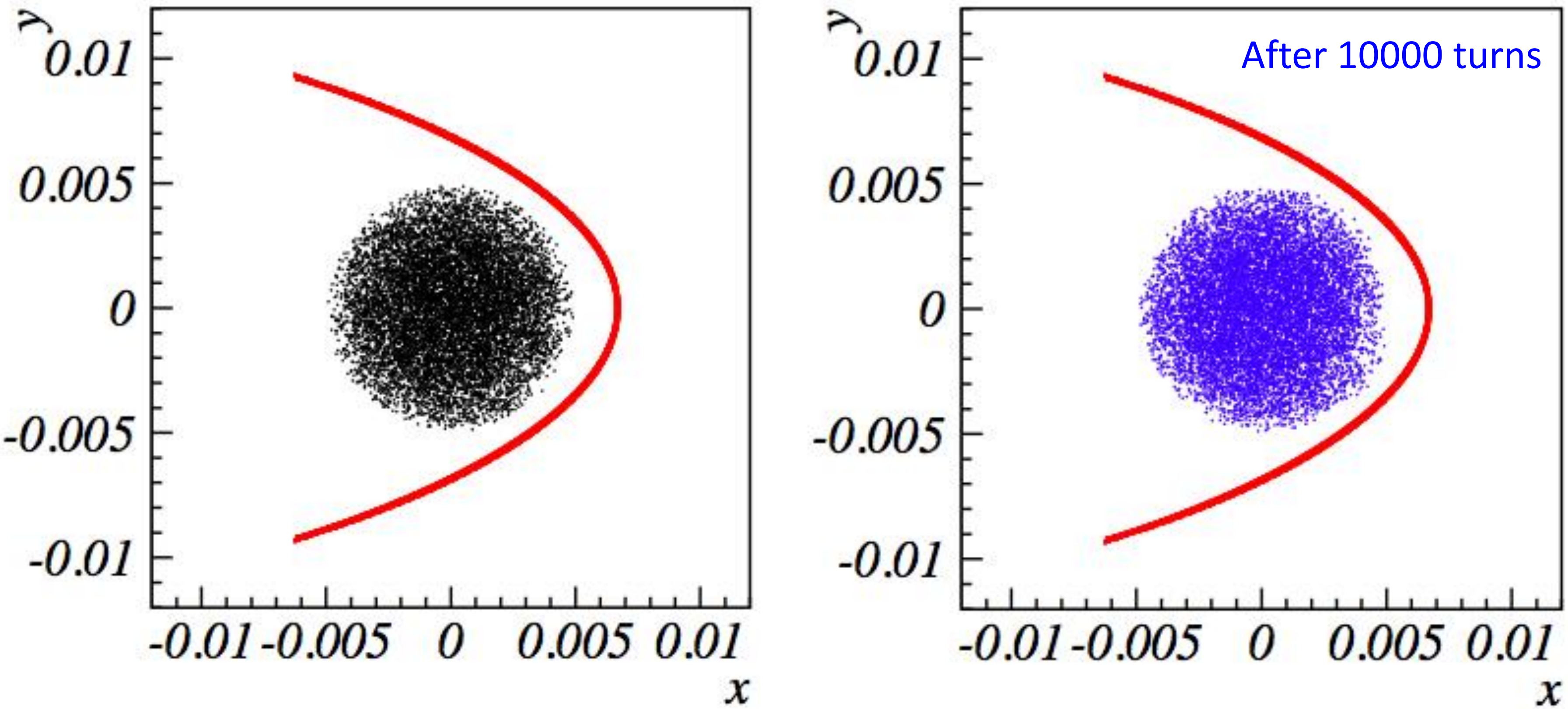


For sextupoles alone fix-lines set DA !

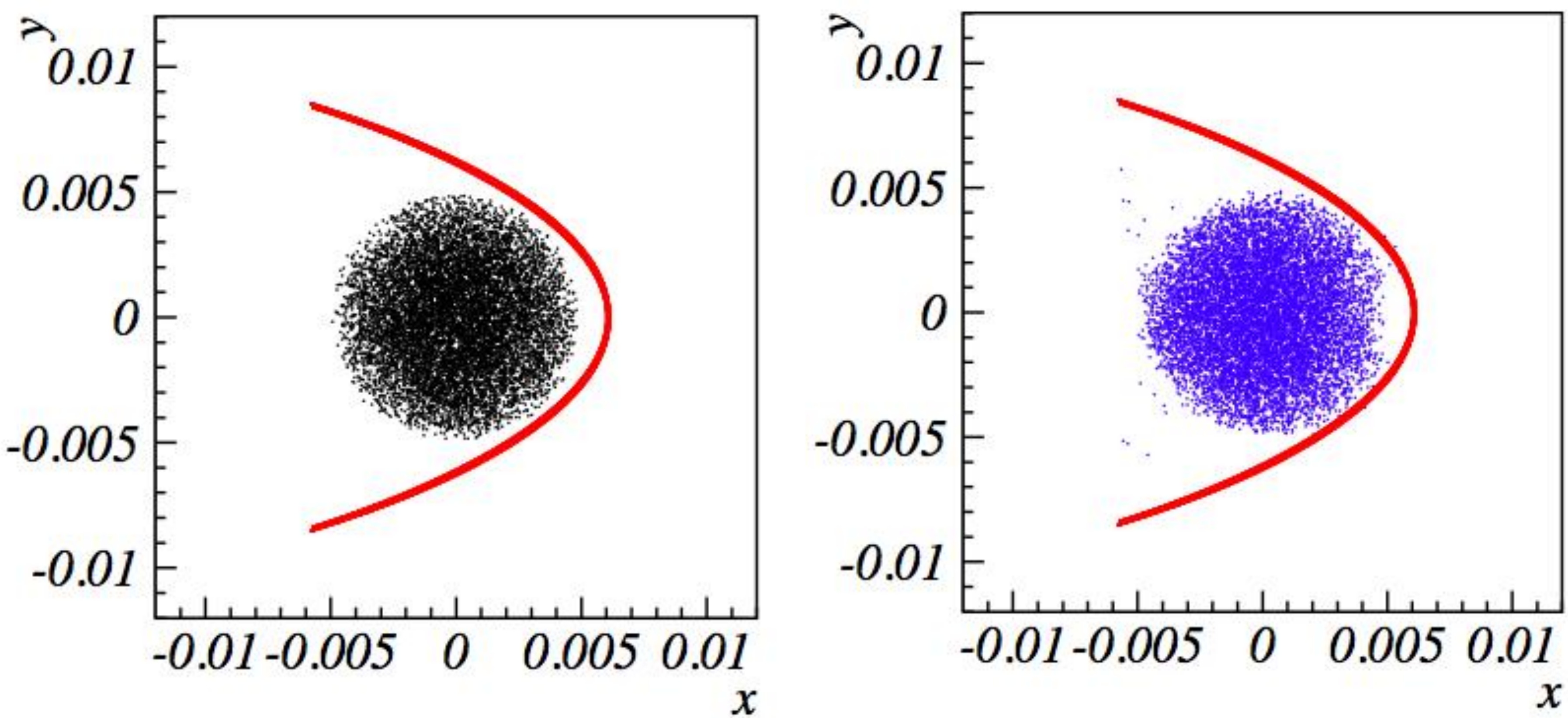


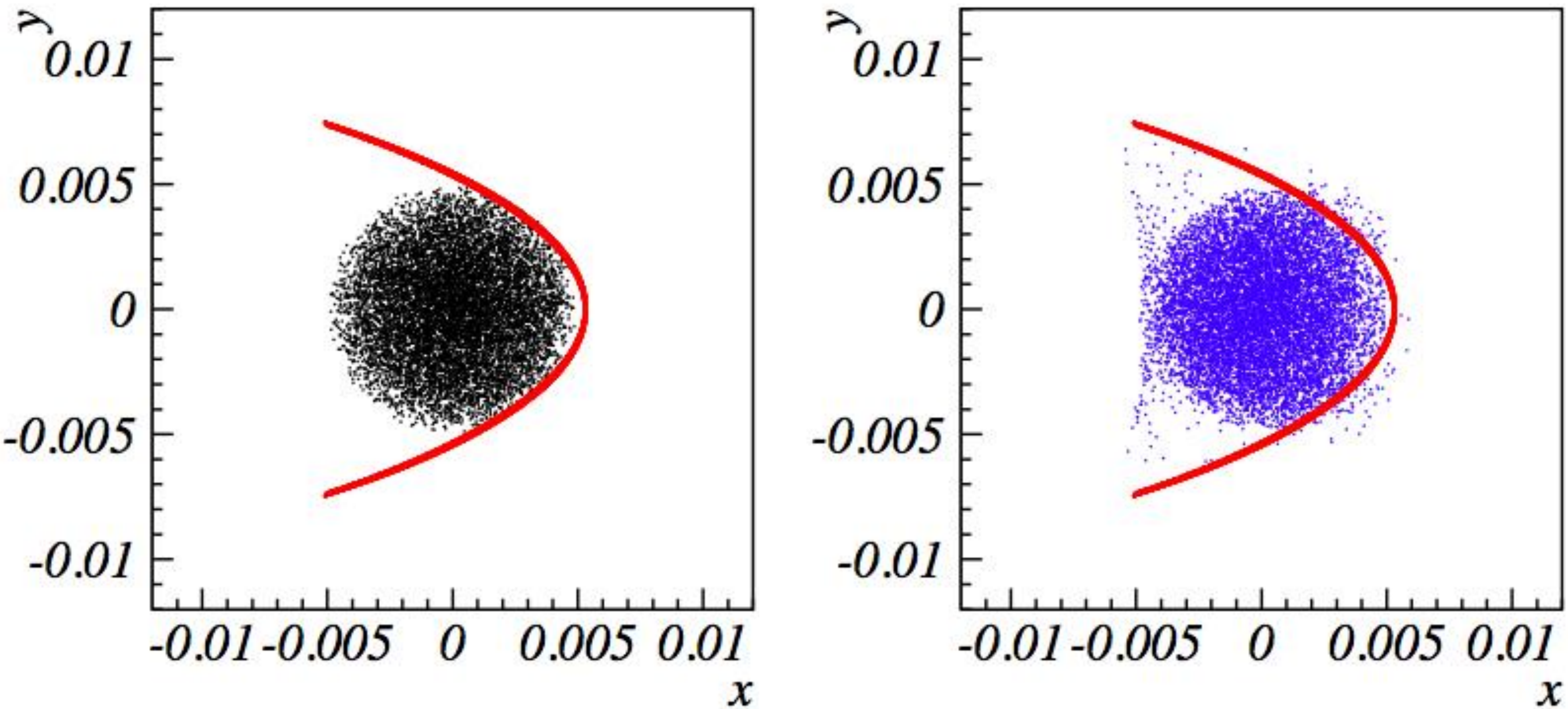


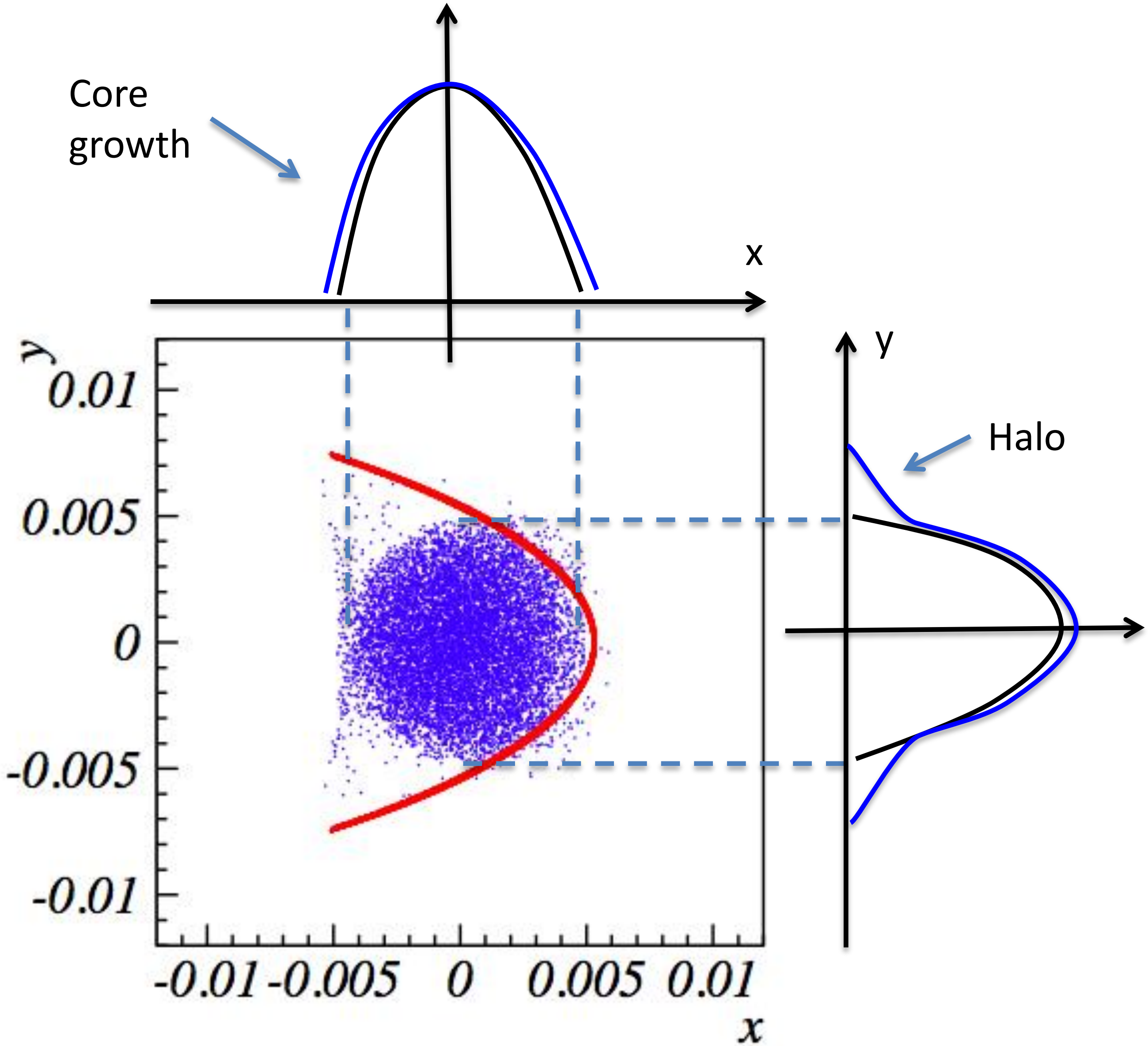
What do the stable fix-lines do to the beam ?

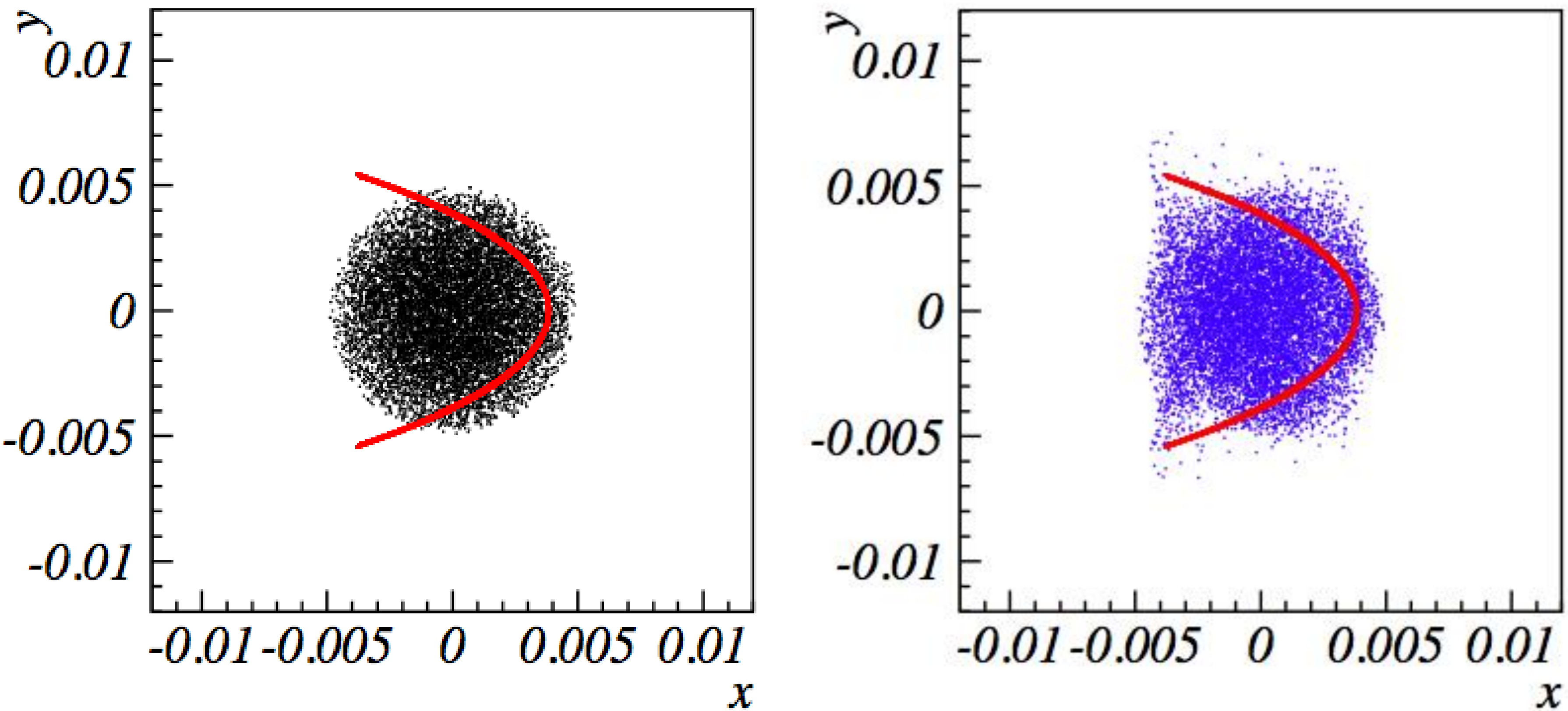


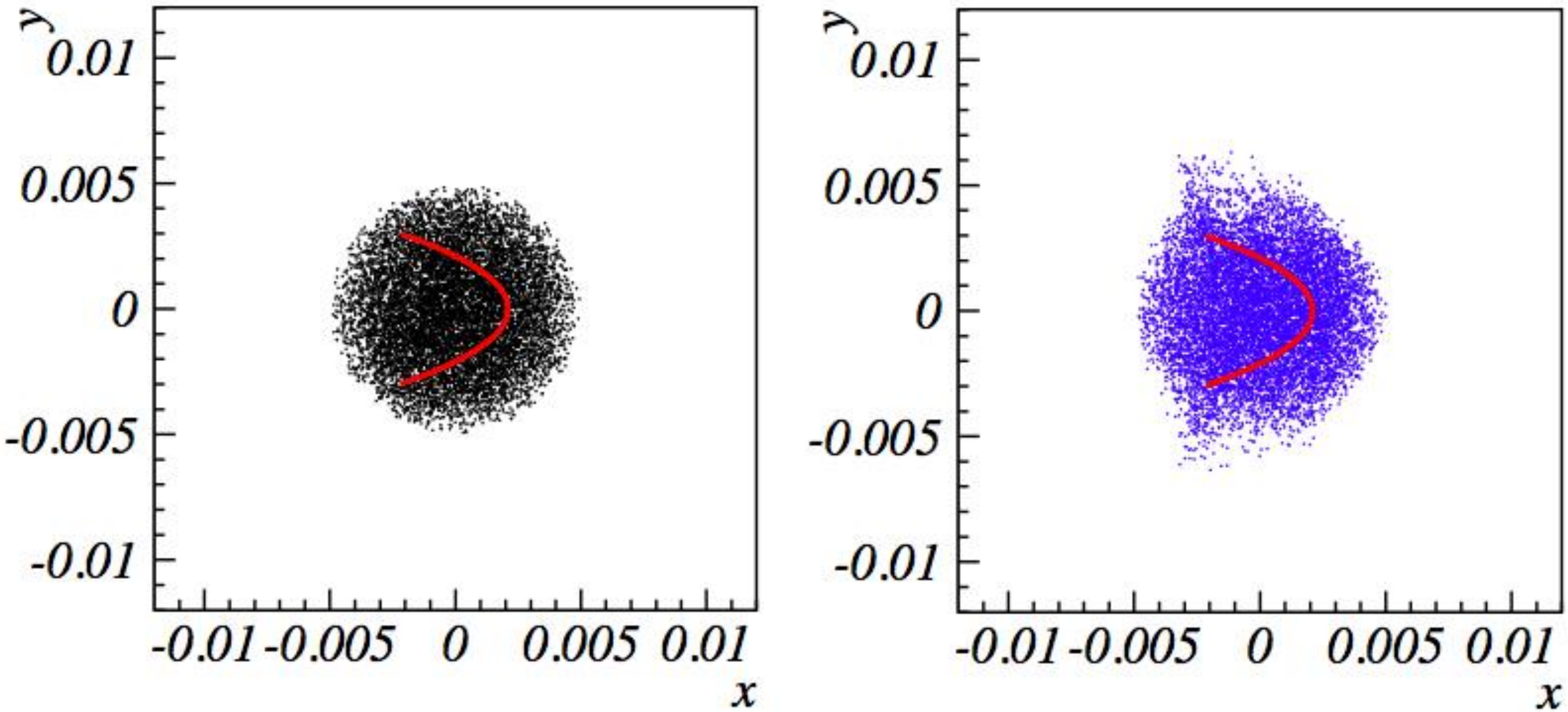
Here we change the distance of the resonance. Stabilization with an octupole

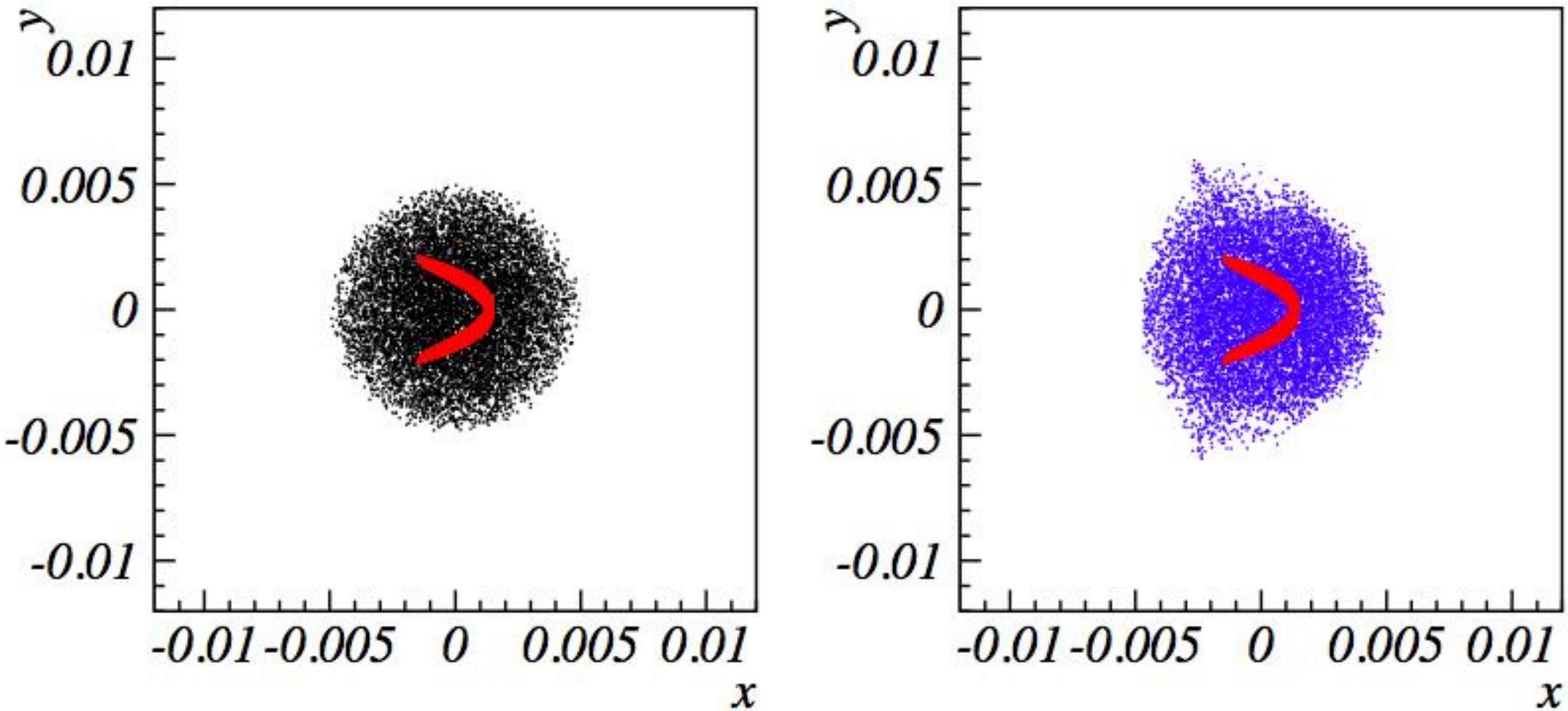

y
0.01
0.005
0
-0.005
-0.01
-0.01 -0.005 0 0.005 0.01
x
y
0.01
0.005
0
-0.005
-0.01
-0.01 -0.005 0 0.005 0.01
x


y
0.01
0.005
0
-0.005
-0.01
-0.01 -0.005 0 0.005 0.01
x
y
0.01
0.005
0
-0.005
-0.01
-0.01 -0.005 0 0.005 0.01
x

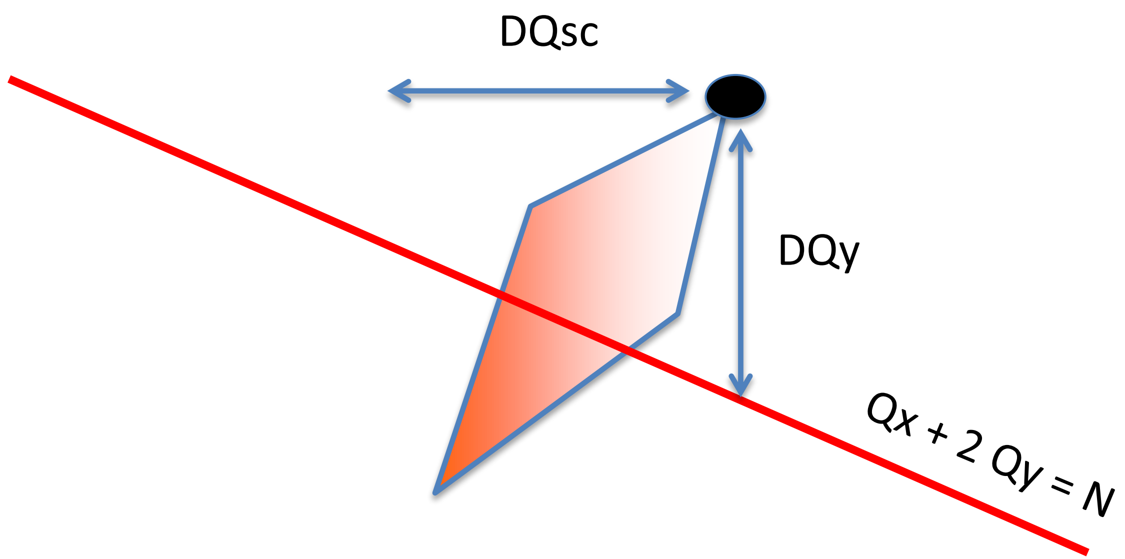

Core
growth
x
y
Halo
0.01
0.005
0
-0.005
-0.01
-0.01 -0.005 0 0.005 0.01
x


y
0.01
0.005
0
-0.005
-0.01
-0.01 -0.005 0 0.005 0.01
x
y
0.01
0.005
0
-0.005
-0.01
-0.01 -0.005 0 0.005 0.01
x

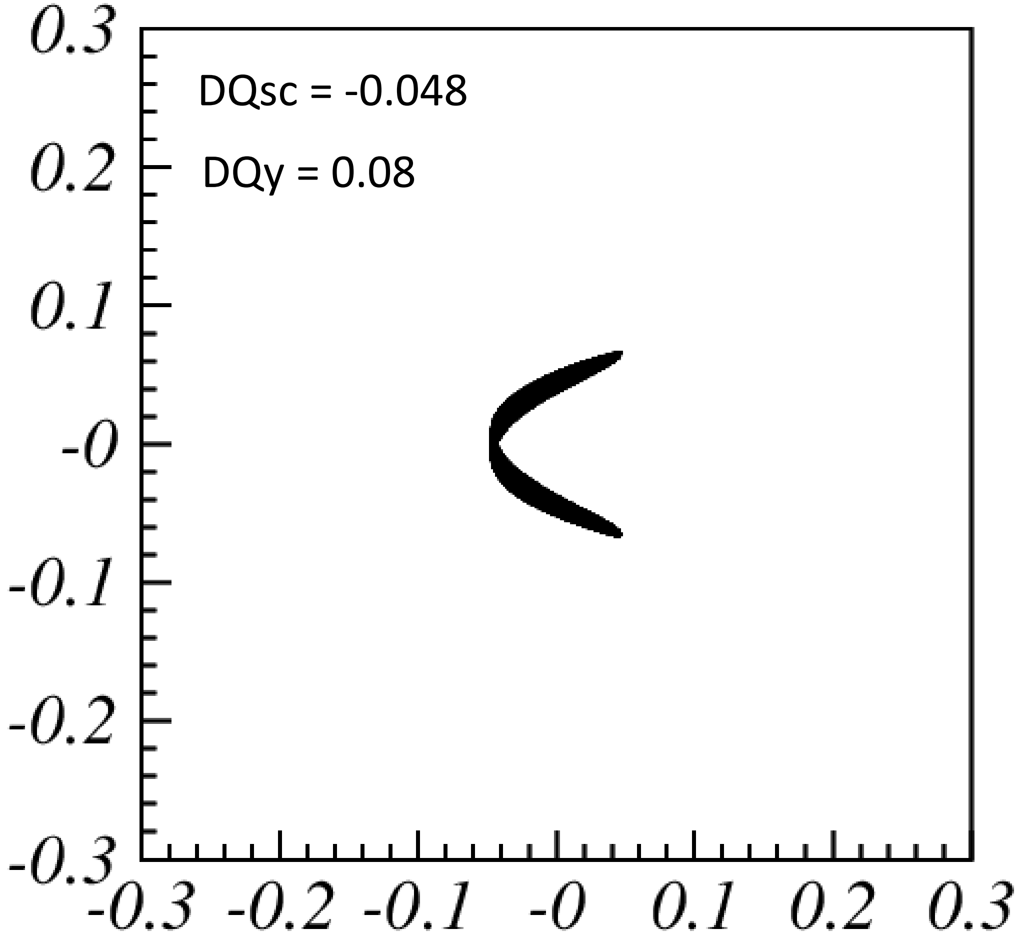

y
0.01
0.005
0
-0.005
-0.01
-0.01 -0.005 0 0.005 0.01
x
y
0.01
0.005
0
-0.005
-0.01
-0.01 -0.005 0 0.005 0.01
x

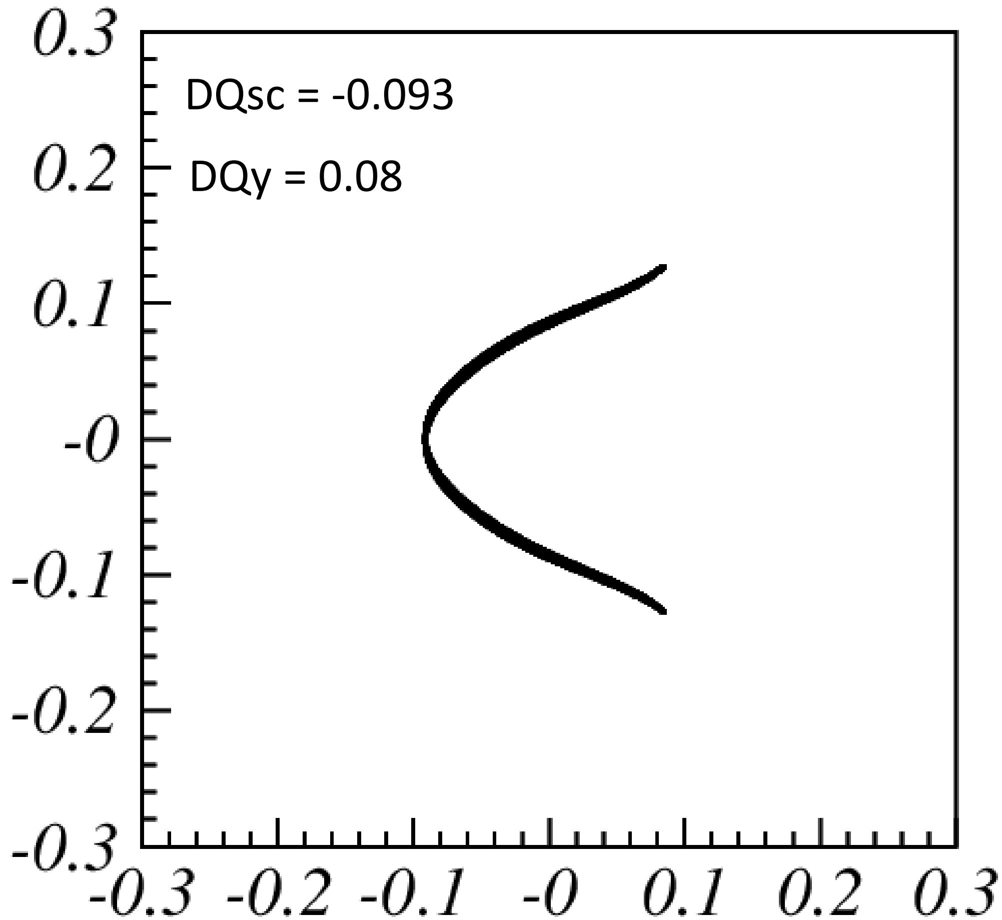

y
0.01
0.005
0
-0.005
-0.01
-0.01 -0.005 0 0.005 0.01
x
y
0.01
0.005
0
-0.005
-0.01
-0.01 -0.005 0 0.005 0.01
x

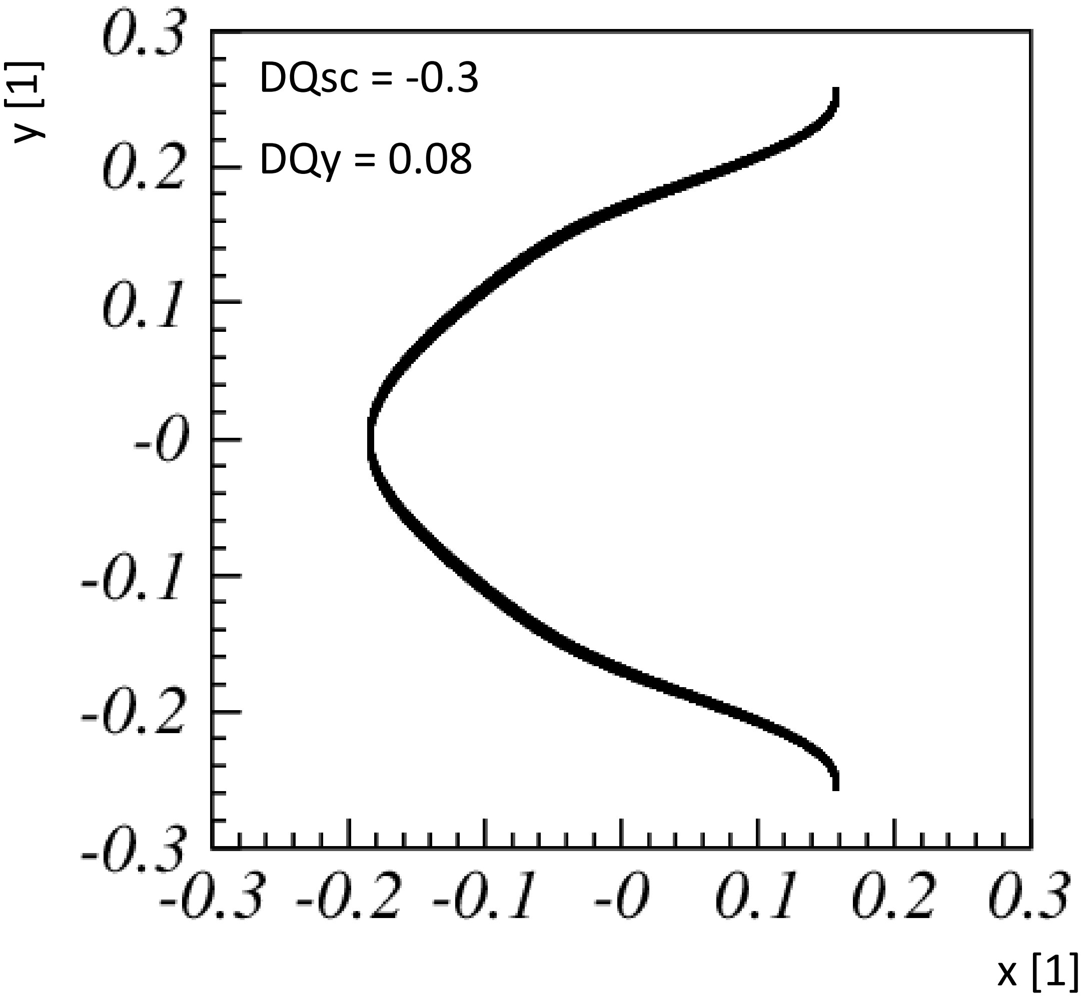
Effect of space charge: Gaussian round beam



3rd order fix-line controlled by the space charge of a Gaussian CB

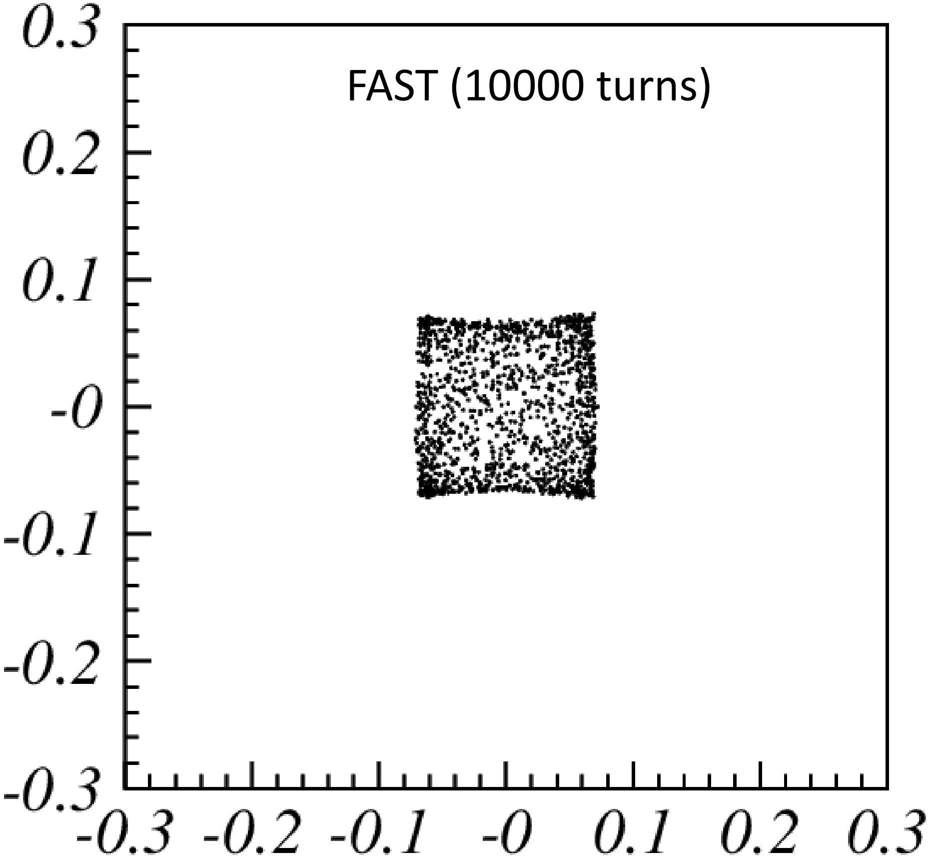



DQsc = -0.093
DQy = 0.08
0.3
0.2
0.1
-0
-0.1
-0.2
-0.3
-0.3 -0.2 -0.1 -0 0.1 0.2 0.3

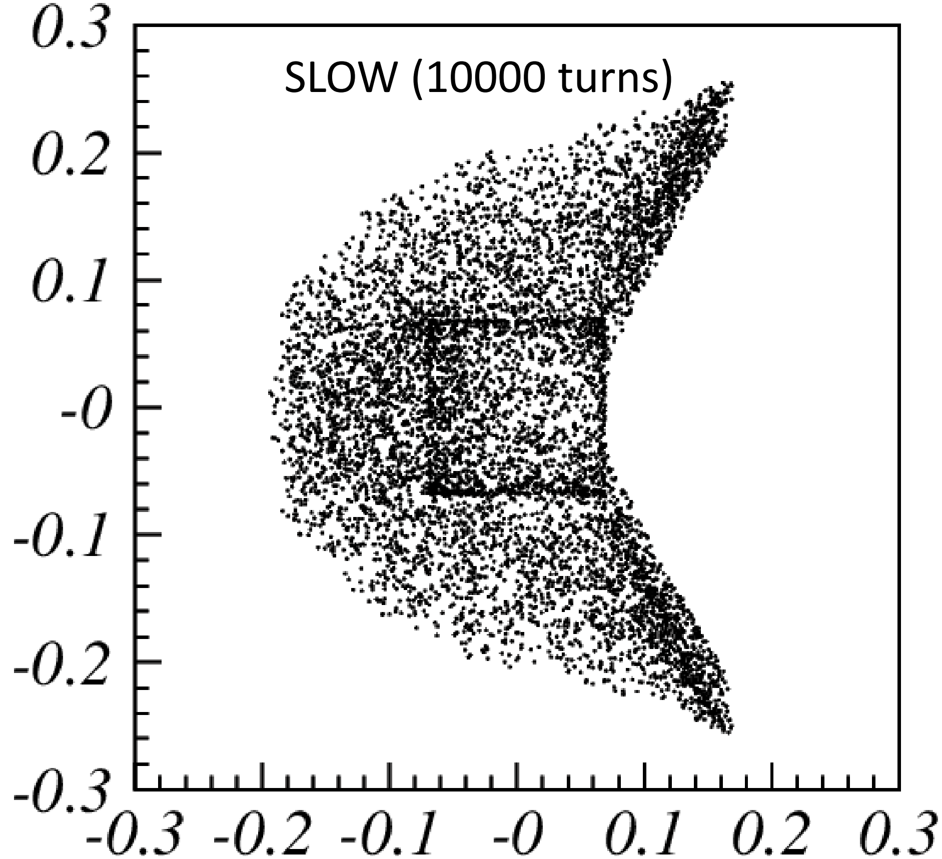

DQsc = -0.3
DQy = 0.08
y [1]
0.3
0.2
0.1
-0
-0.1
-0.2
-0.3
-0.3
-0.2
-0.1
-0
0.1
0.2
0.3
x [1]

trapping/non trapping

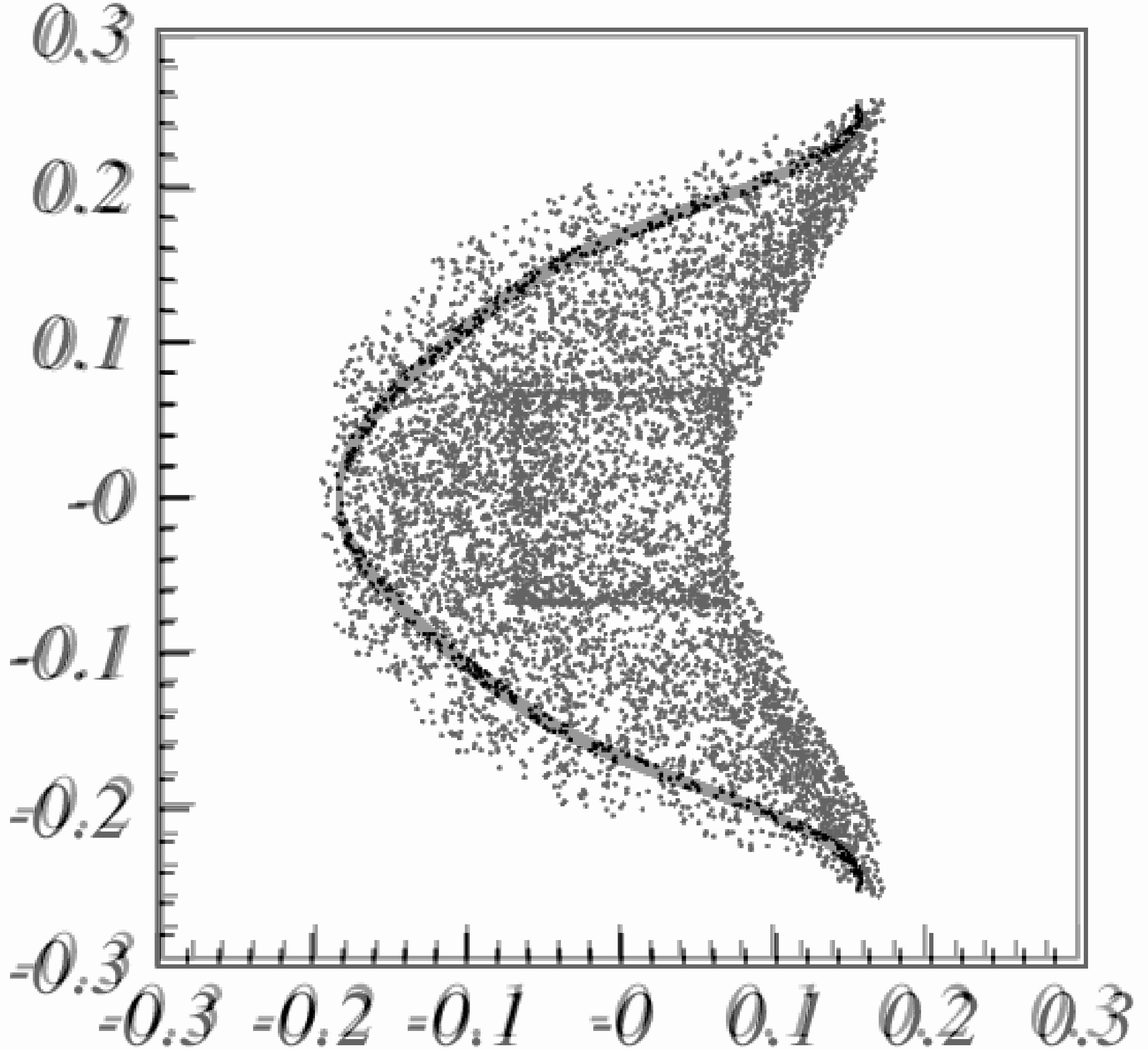
Resonance crossing without trapping



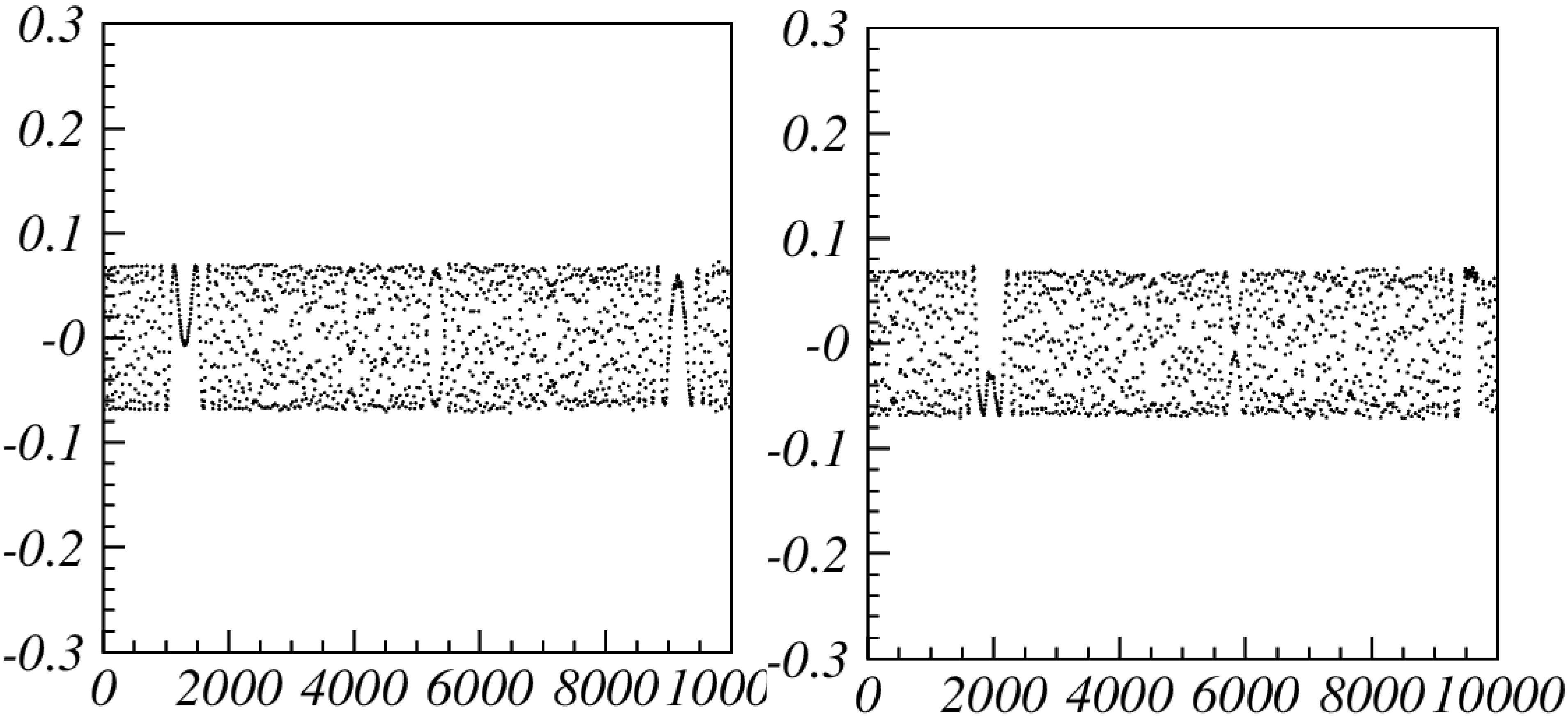
Resonance crossing with trapping



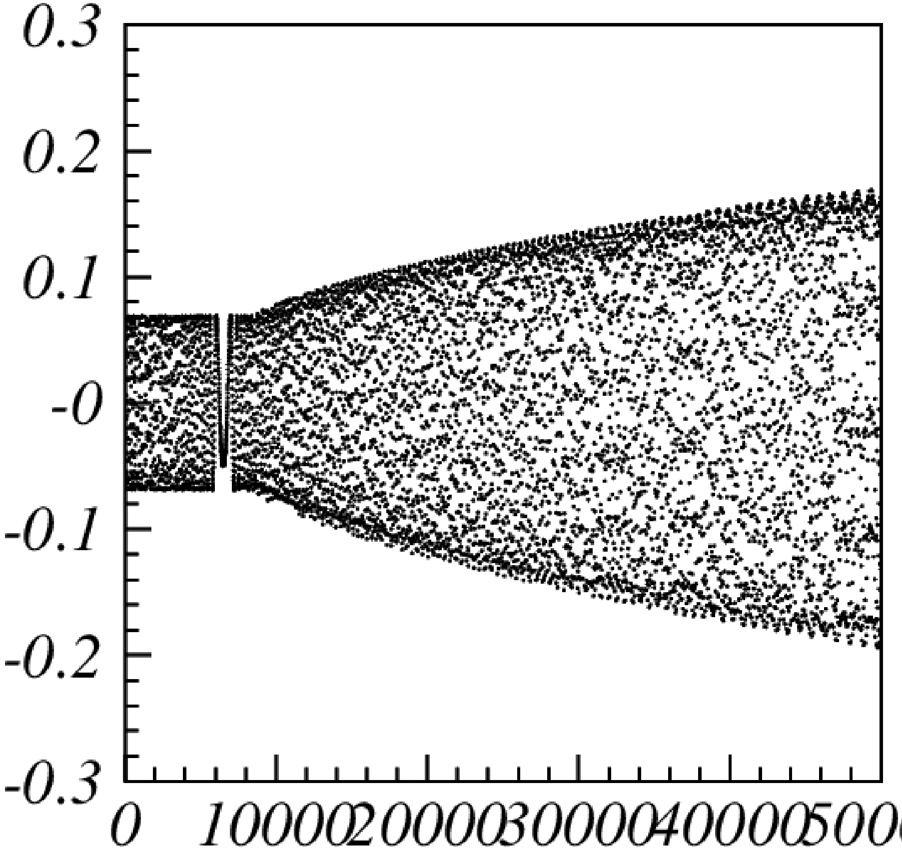
Resonance crossing with trapping + larger fix-line

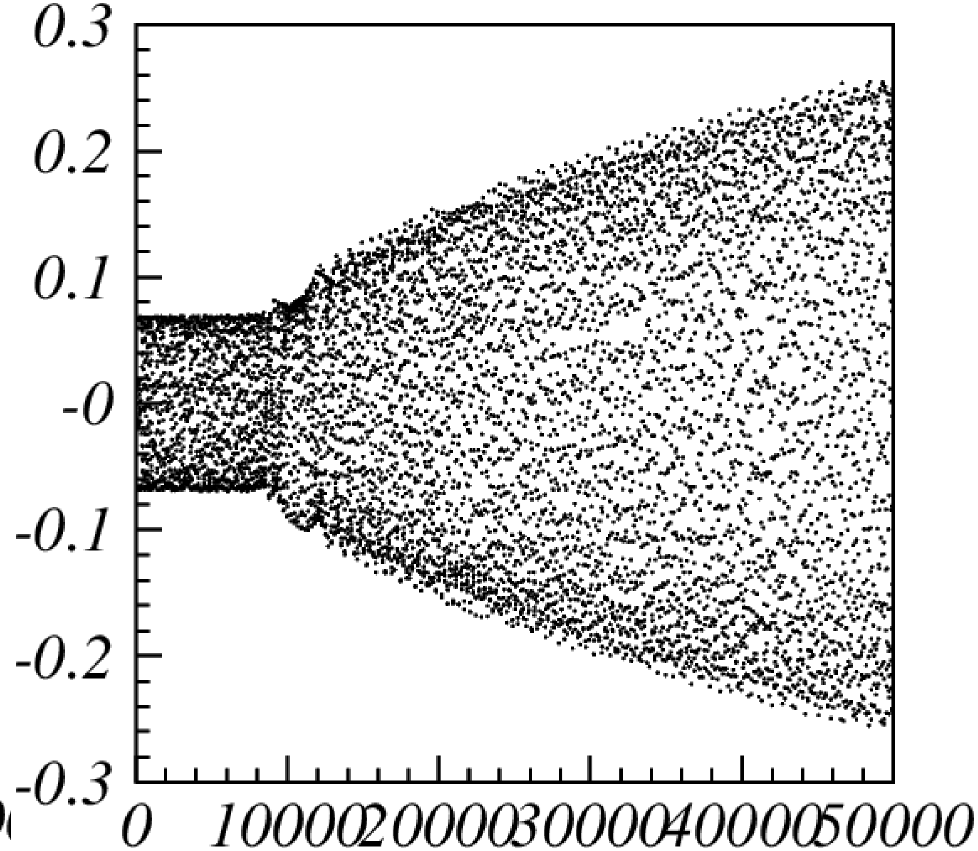


time evolution fast crossing



time evolution slow crossing





Summary

- After the lattice model is improved the simulation shows an emittance increase ratio of 2
- Random errors have a significant effect and may bring the emittance growth ratio to 2.5
- A pre-existing resonance is not properly included
- Beam distribution from simulations have the same pattern as for the measured
- The asymmetric beam response is explained in terms of the periodic crossing of fix-lines with the beam
- Theory of the fix-lines with detuning (space charge or octupoles) is essential to understand the extension and population of the halo/core growth → hence to control the negative effects: impact on effective resonance compensation in SIS100…. but it would be nice to measure it!