Space charge and EC effects

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GSI

BEAM07, CERN, Oct.1-6, 2007

*Francesco Ruggiero
Memorial Symposium*

# Outline

1) Space charge and EC incoherent effect
2) Modeling of the EC stripes
3) Consequences on particle dynamics
4) Application
5) Conclusion / Outlook

Acknowledgment

GSI

O. Choriny, W. Bayer, O. Boine-Frankenheim, C. Omet,
B. Franczak, P. Forck, T. Giacomini, I. Hofmann, M. Kirk,
H. Kollmus, T. Mohite, A. Parfenova, P. Schuett, P. Spiller

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E. Benedetto, C. Carli, R. Cappi, M. Giovannozzi, M. Martini,
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Space charge and EC effect

The long term storage of high intensity bunched beams creates dangerous space charge - lattice nonlinear components coupling

SIS100

$DQ_x = -0.14$
$DQ_y = -0.25$
$z_{rms} = 27m$

WP1:
$Qx = 18.84$
$Qy = 18.73$
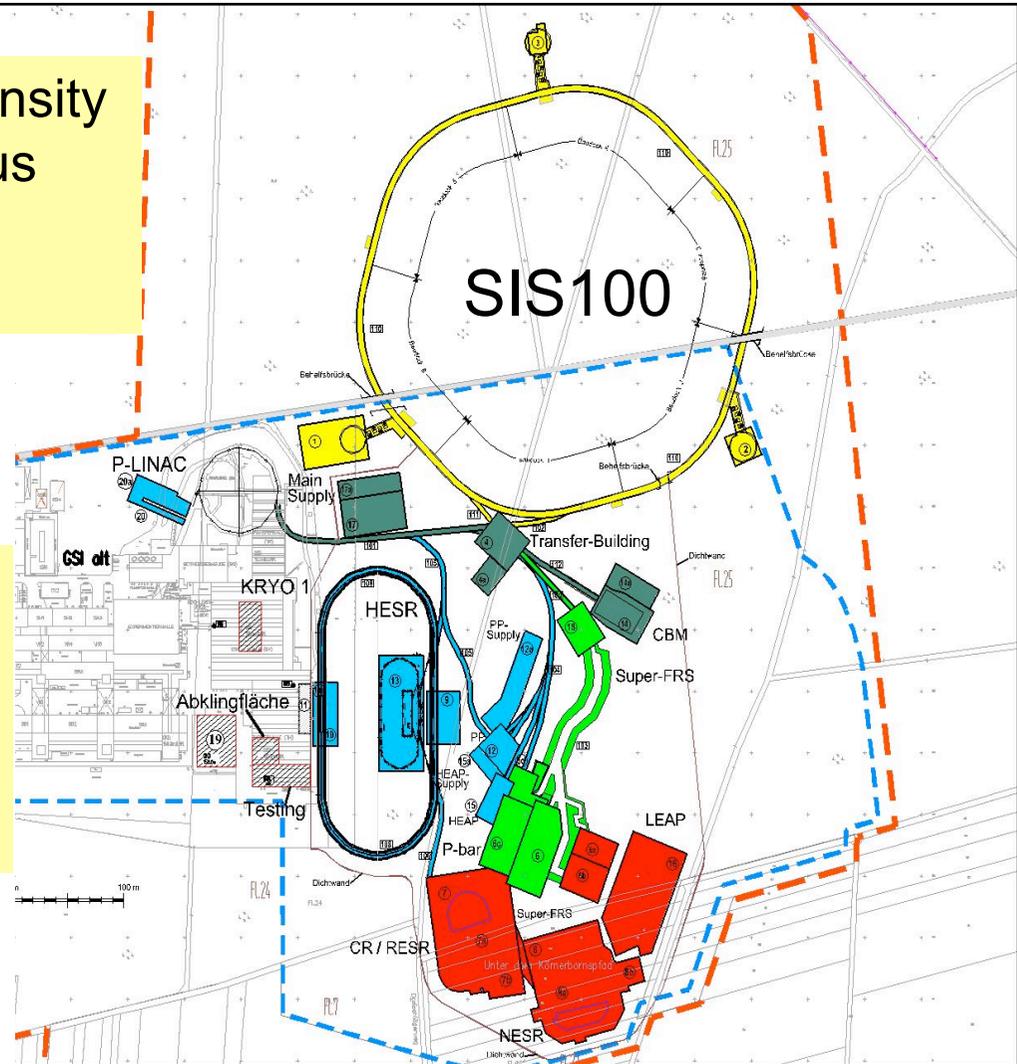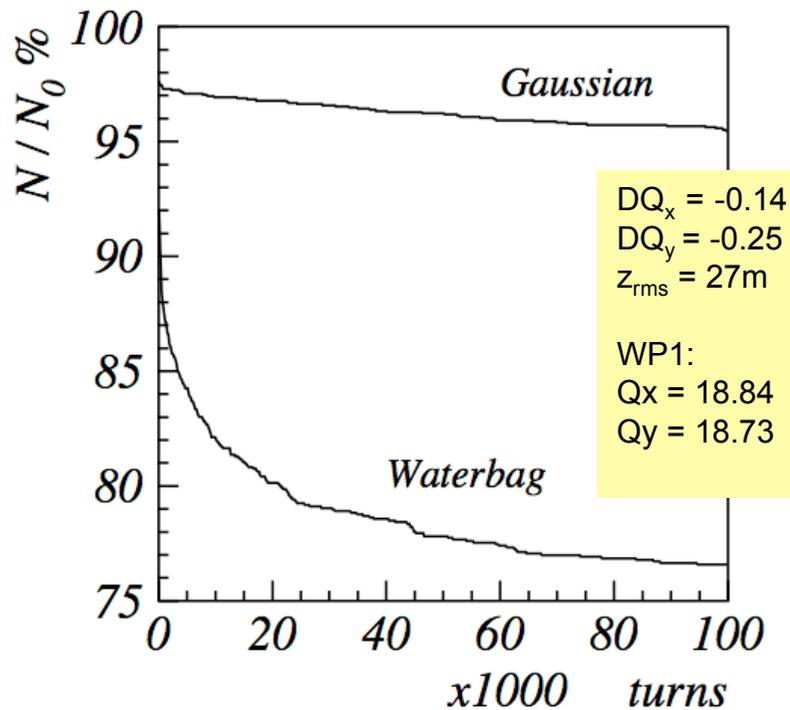
Experimental verification

At CERN-PS (2002-2003)

At GSI with S317 experiment
Preliminary results (Feb. 14th 2007)
Thorough presentation in near future

$\varepsilon_x / \varepsilon_{x0}$ Sim.

I / I_0 Sim.

$\varepsilon_x / \varepsilon_{x0}$ Exp.

I / I_0 Exp.

Coasting beam
Low intensity

Bunch
length

Bunched
intensity

Q_x
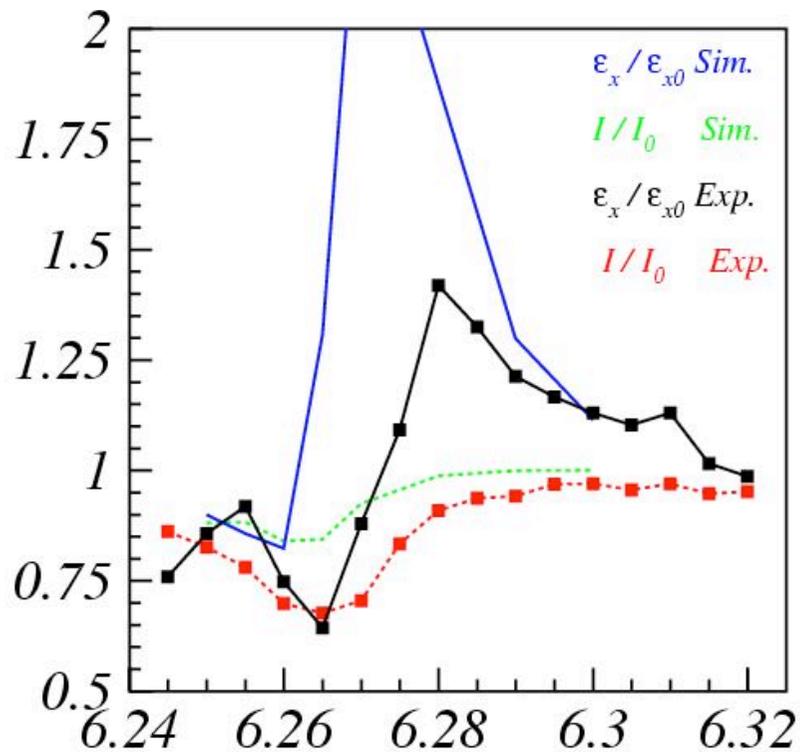
G.Franchetti, I.Hofmann,
M.Giovannozzi, E.Metral, M.Martini
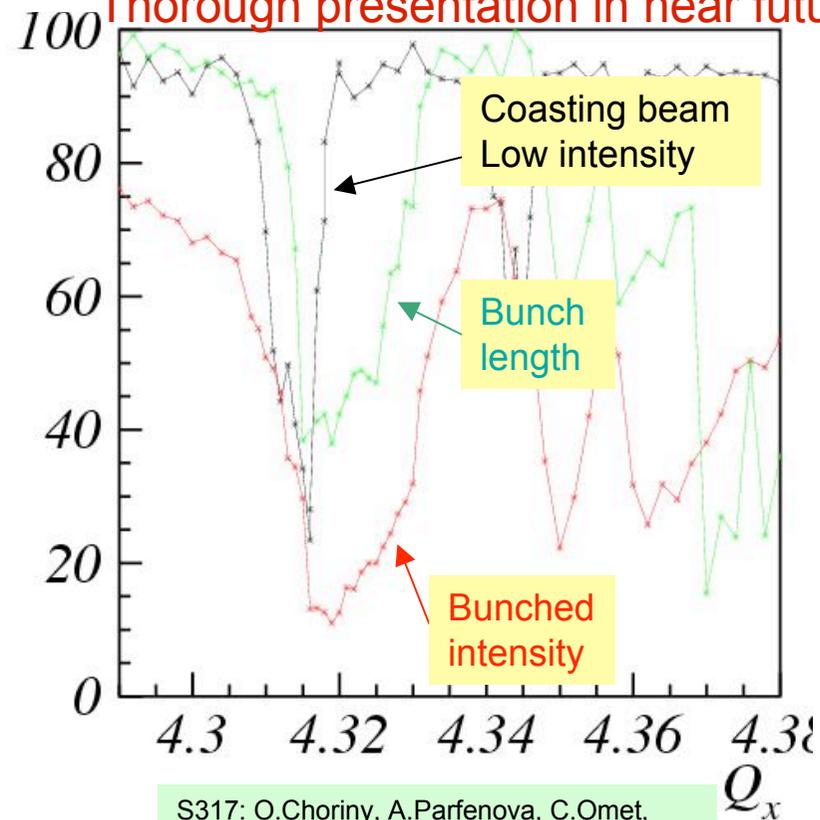
S317: O.Choriny, A.Parfenova, C.Omet,
M.Kirk, I.Hofmann, G.Franchetti, P.Schuett,
P. Spiller, T. Giacomini, P. Forck,
T. Mohite, O. Boine-Frankenheim

# Equivalence of
EC effects to long terms space charge effects
is relevant

head   EC   F. Zimmermann

tail

EC pinches

tail   head

EC has the maximum density

tail   head
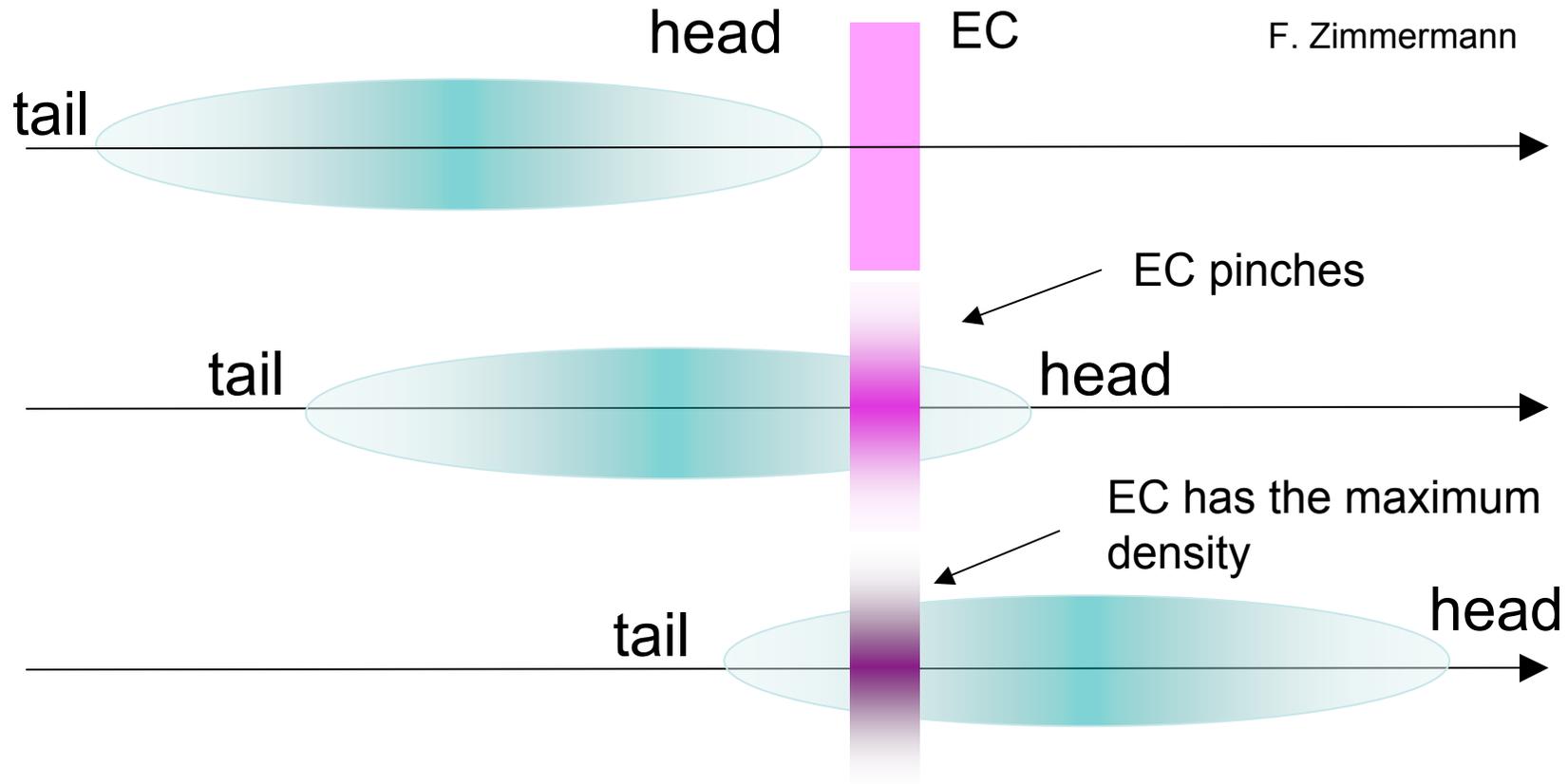
Correlation EC-density - position along the bunch

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

HEADTAIL simulations for SPS
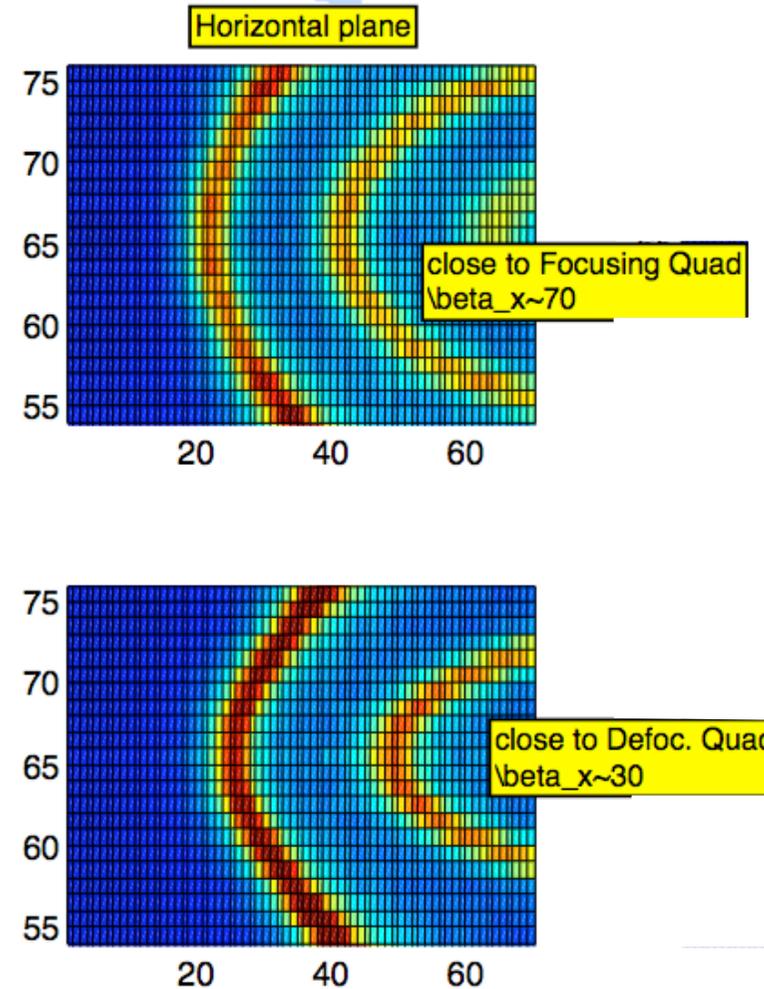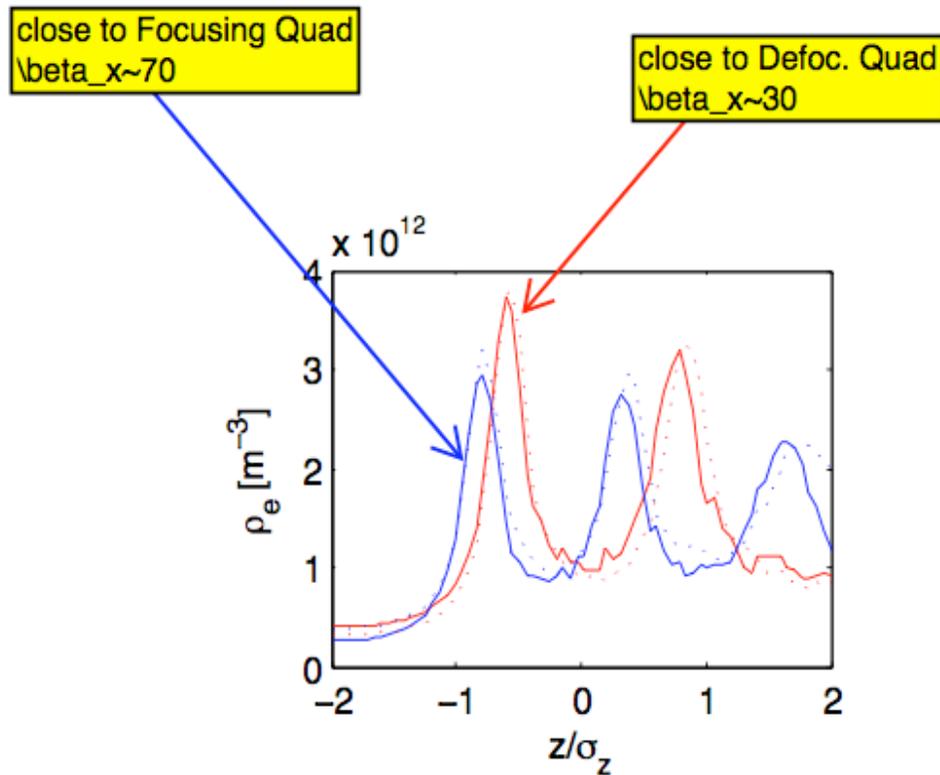

E. Benedetto

Modeling the EC stripes

EC stripes

G. Franchetti
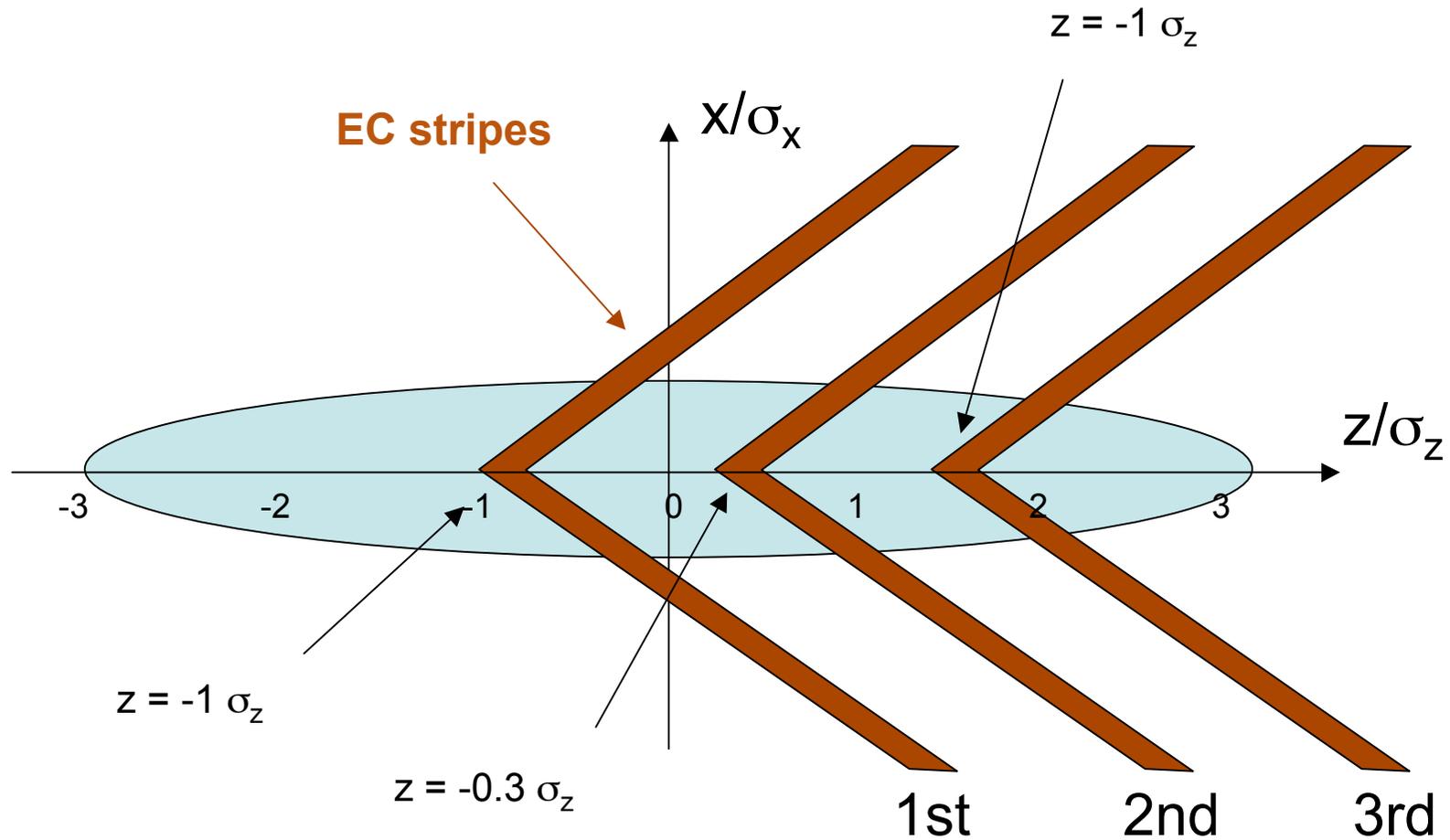
EC stripe modeling

Ansatz:
'local' infinite wall

x / σ_x

Constant
electric field

No
electric field

No
electric field

z / σ_z

-1

0

1

Electron density inside
the stripes constant

G. Franchetti
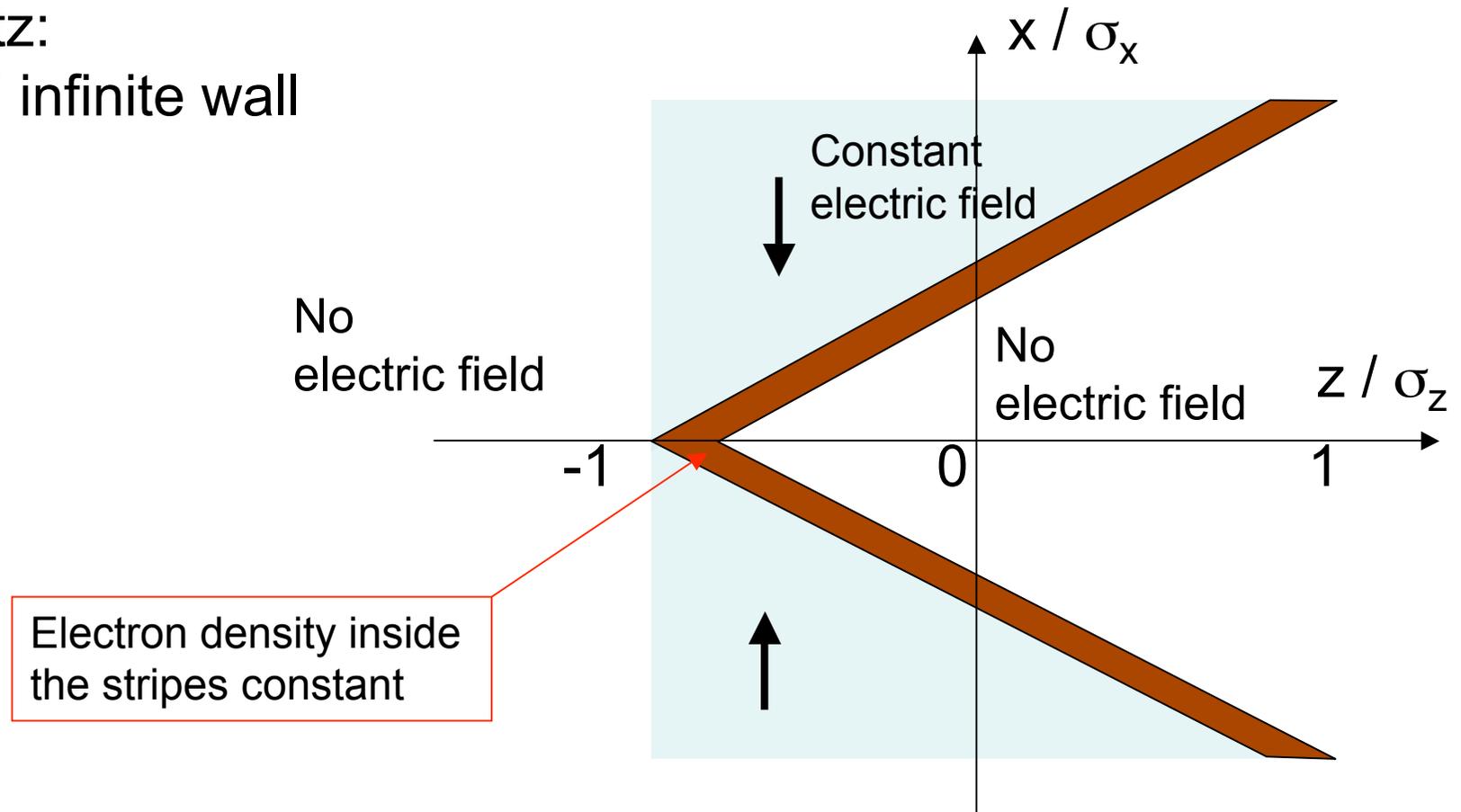
Parameterization of the EC stripe

$$E_x(x) = -\lambda x$$

slope

Uniform
EC density

E_x

X

Z

ΔR

R_1
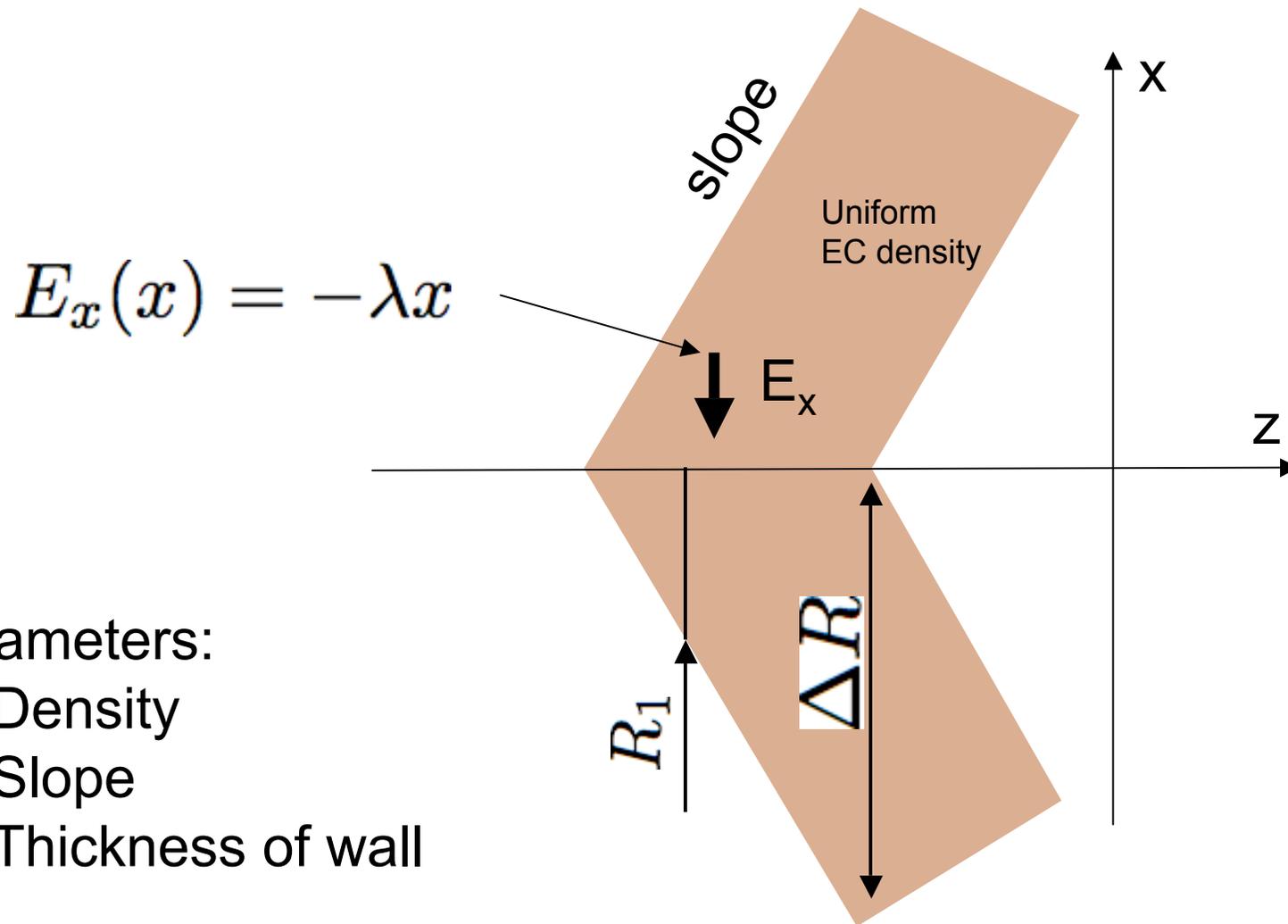
Parameters:
1) Density
2) Slope
3) Thickness of wall

One EC localized

One weak EC kick creates a detuning ΔQ_{ec}
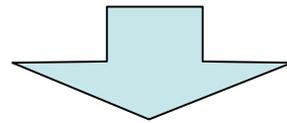
$$\lambda = \frac{4\pi}{\beta_x} \Delta Q_{ec}$$

For many kicks the tune is additive if is small:
otherwise higher order terms should be included

Detuning from EC stripes

The parameter λ is set to create ΔQ_{ec} here

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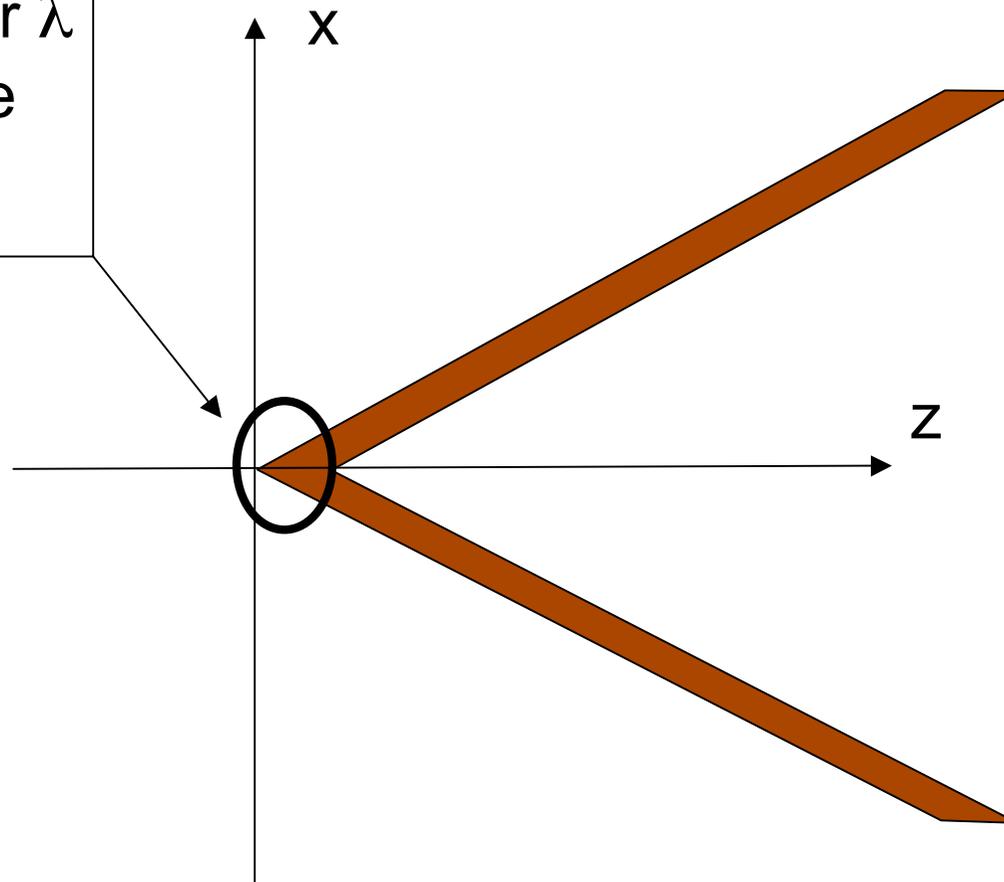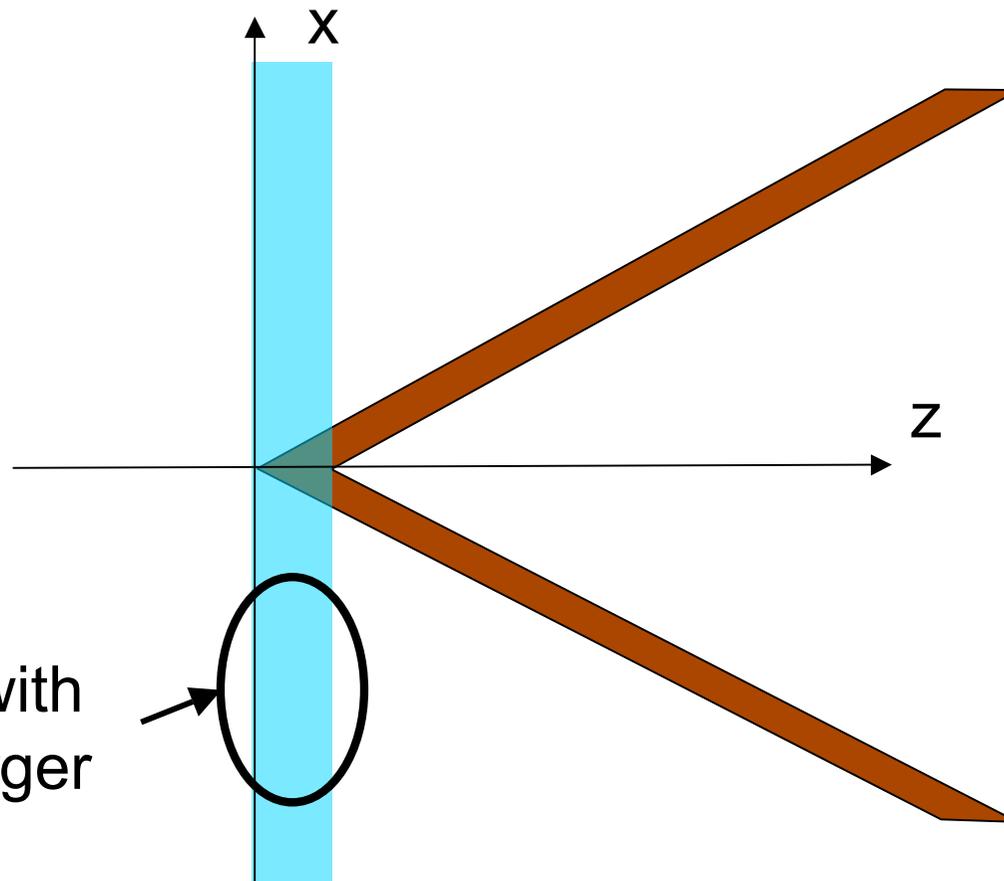
For particles with amplitudes larger then R_1 ?

EC detuning out of the stripes
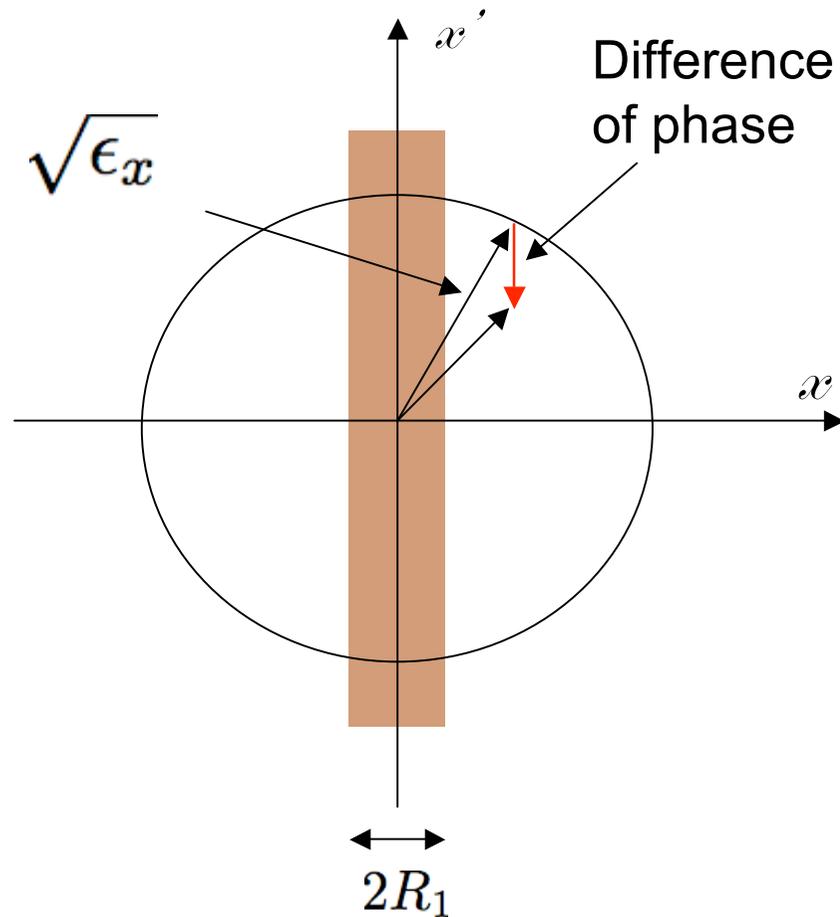
$$\Delta Q_{x,ec}(\epsilon_x) = \frac{4}{\pi} \frac{R_1 \Delta Q_{ec}}{\sqrt{\beta_x \epsilon_x}}$$

Valid for $\beta_x \epsilon_x >> R_1^2$

Example

$\Delta Q_{ec} = 0.02$

at $z = -0.9\ \sigma_z$
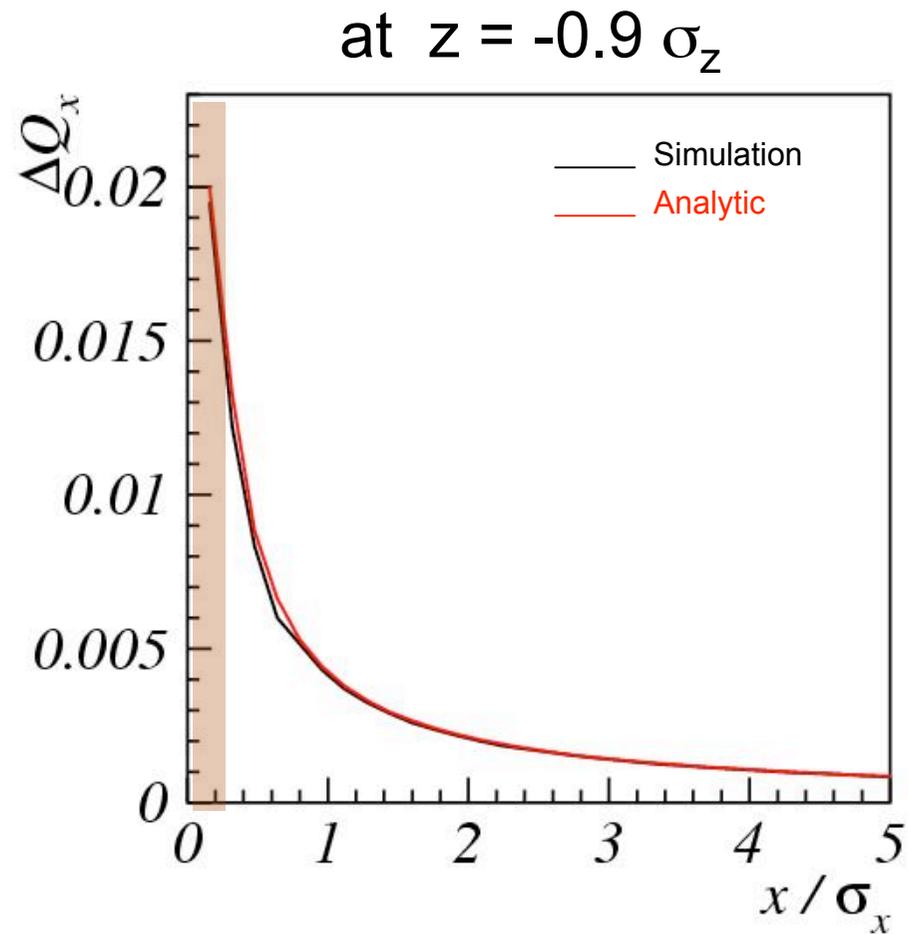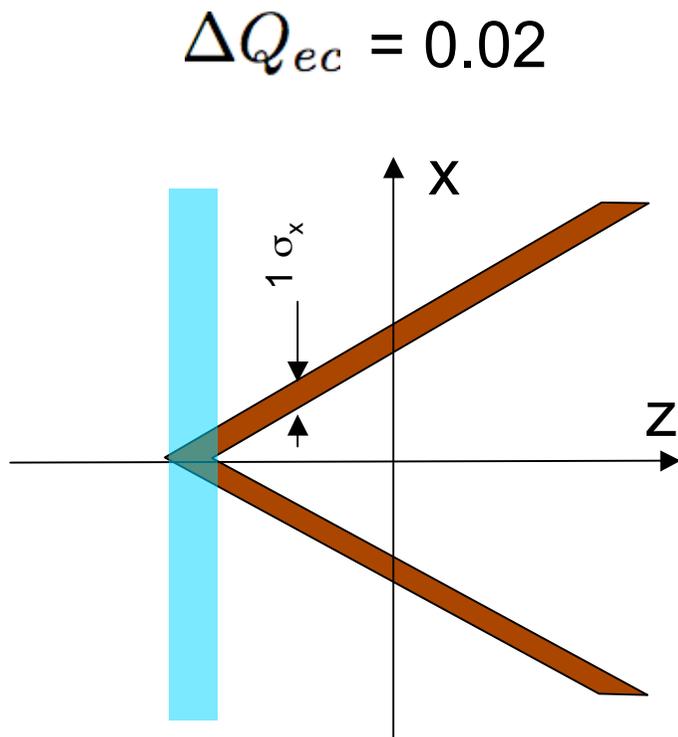
@ a different z position

Ec stripes

x'

x

X

Z

ΔR R_1
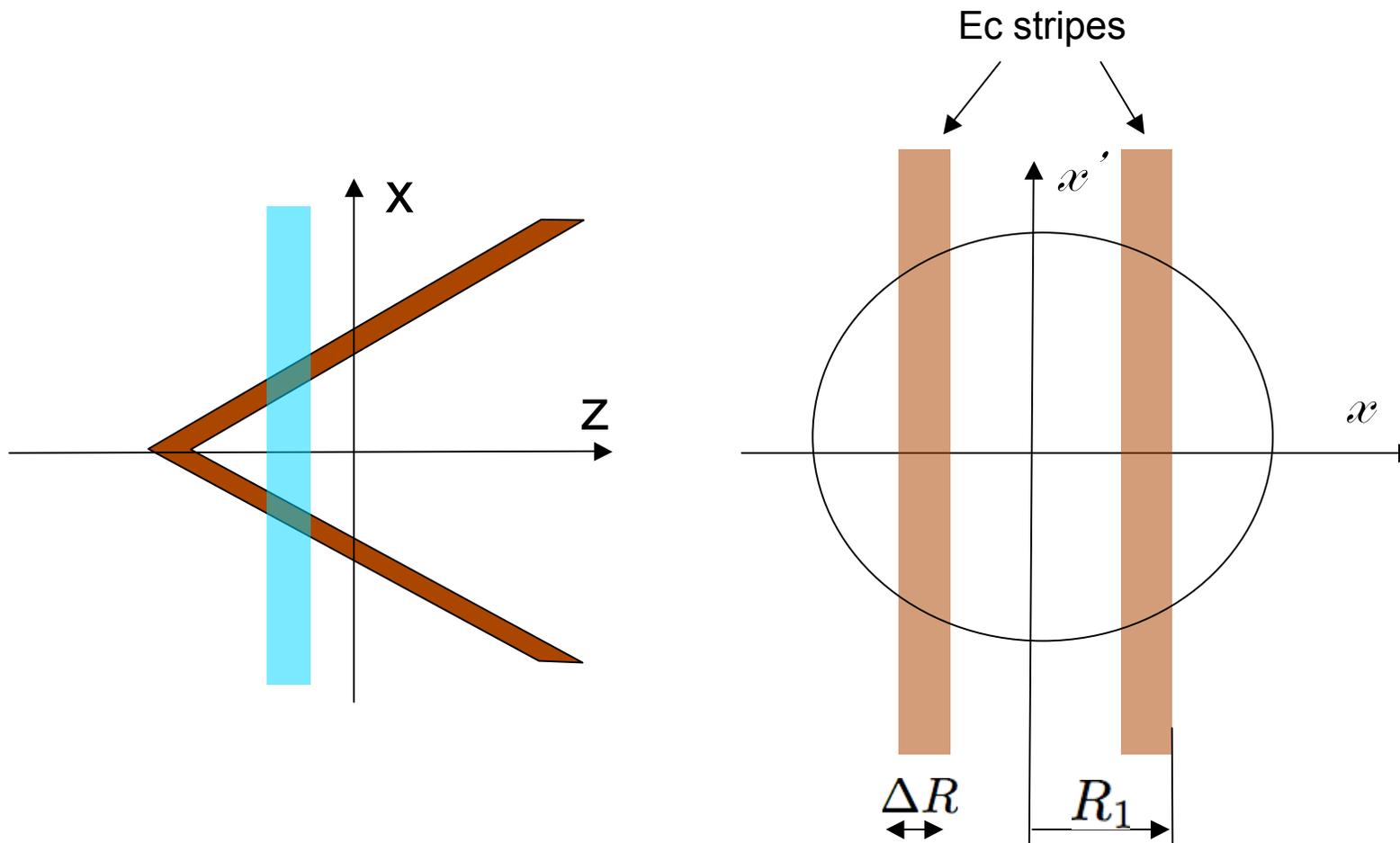
EC detuning becomes weaker when R_1 large

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Example

at $z = -0.6\,\sigma_z$

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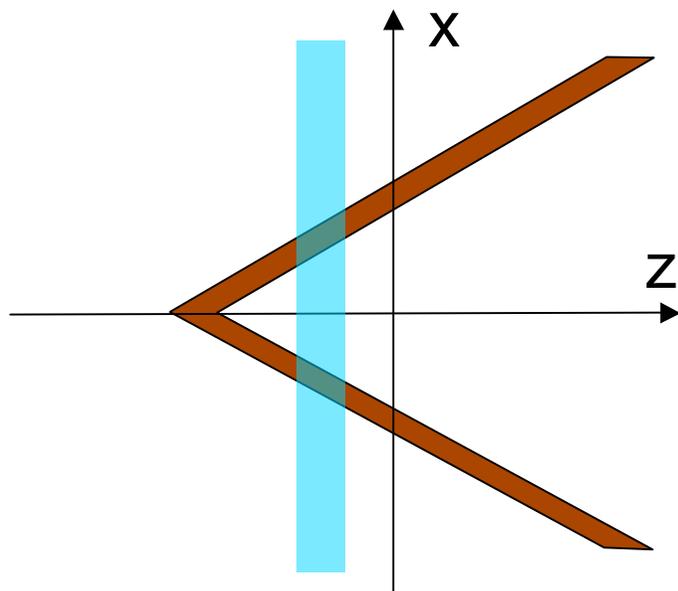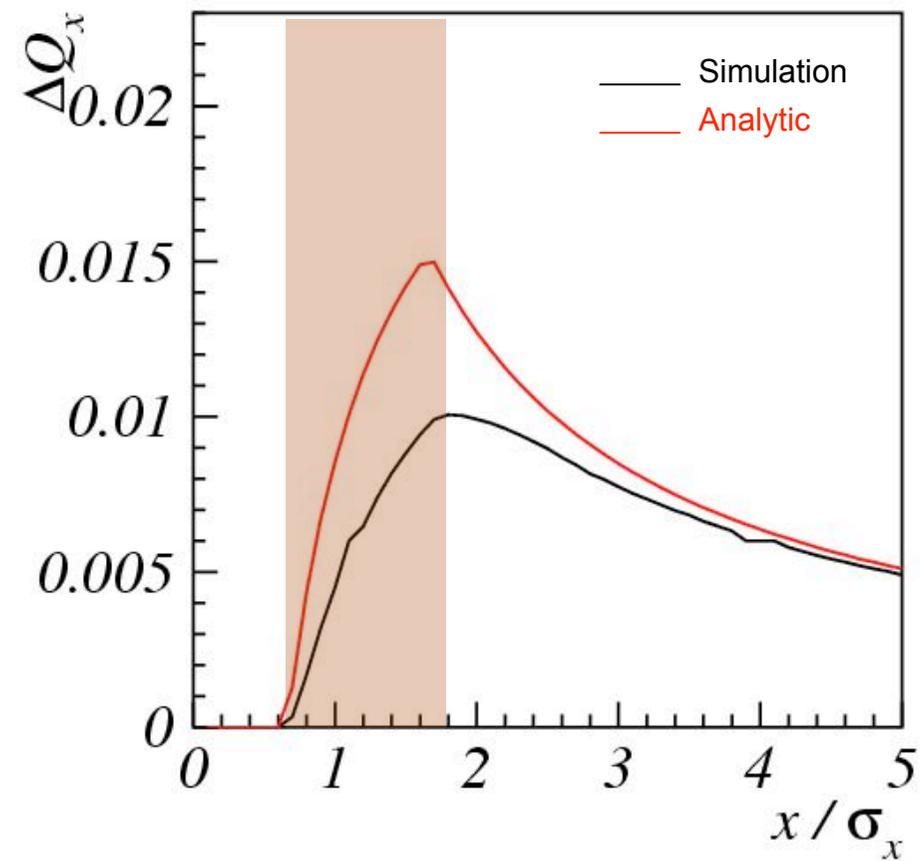
Detuning along 'z'

We keep $x_{max} = 2\,\sigma_z$ constant, the EC detuning vs. z
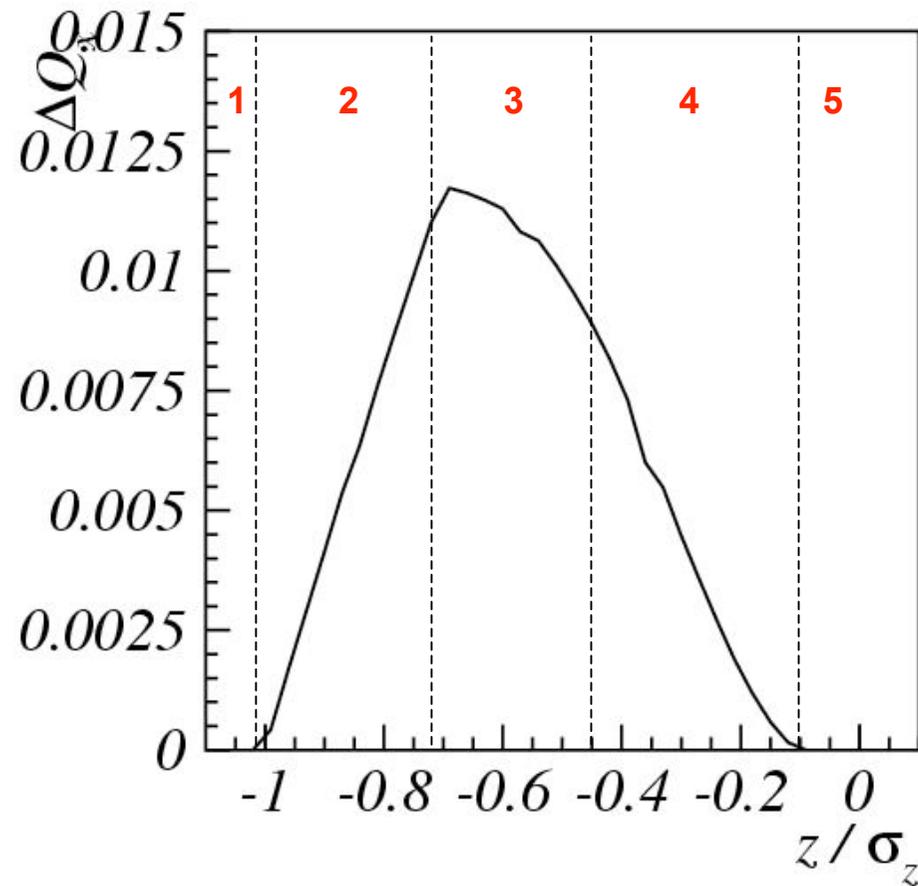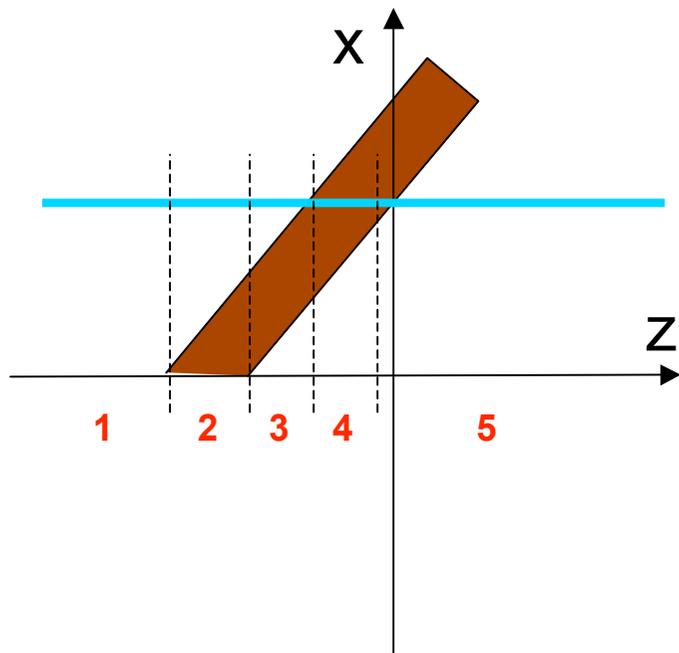
# With 3 stripes

Test particle with $x_{max} = 2\,\sigma_x$
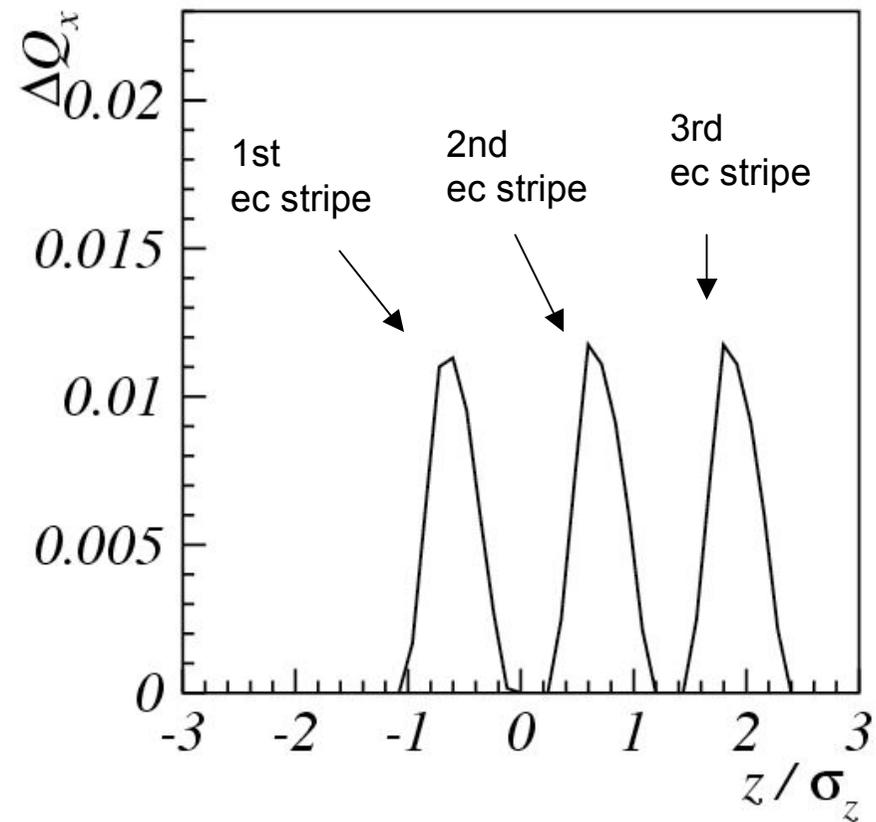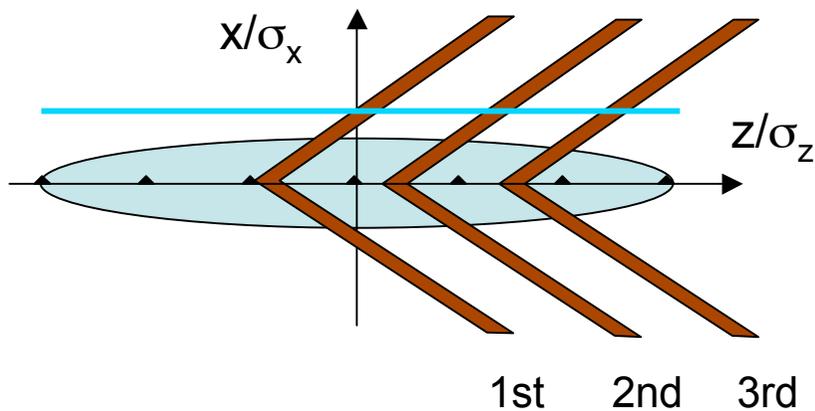
Effect of 3 stripes vs. x

at $z = 0.6\ \sigma_z$
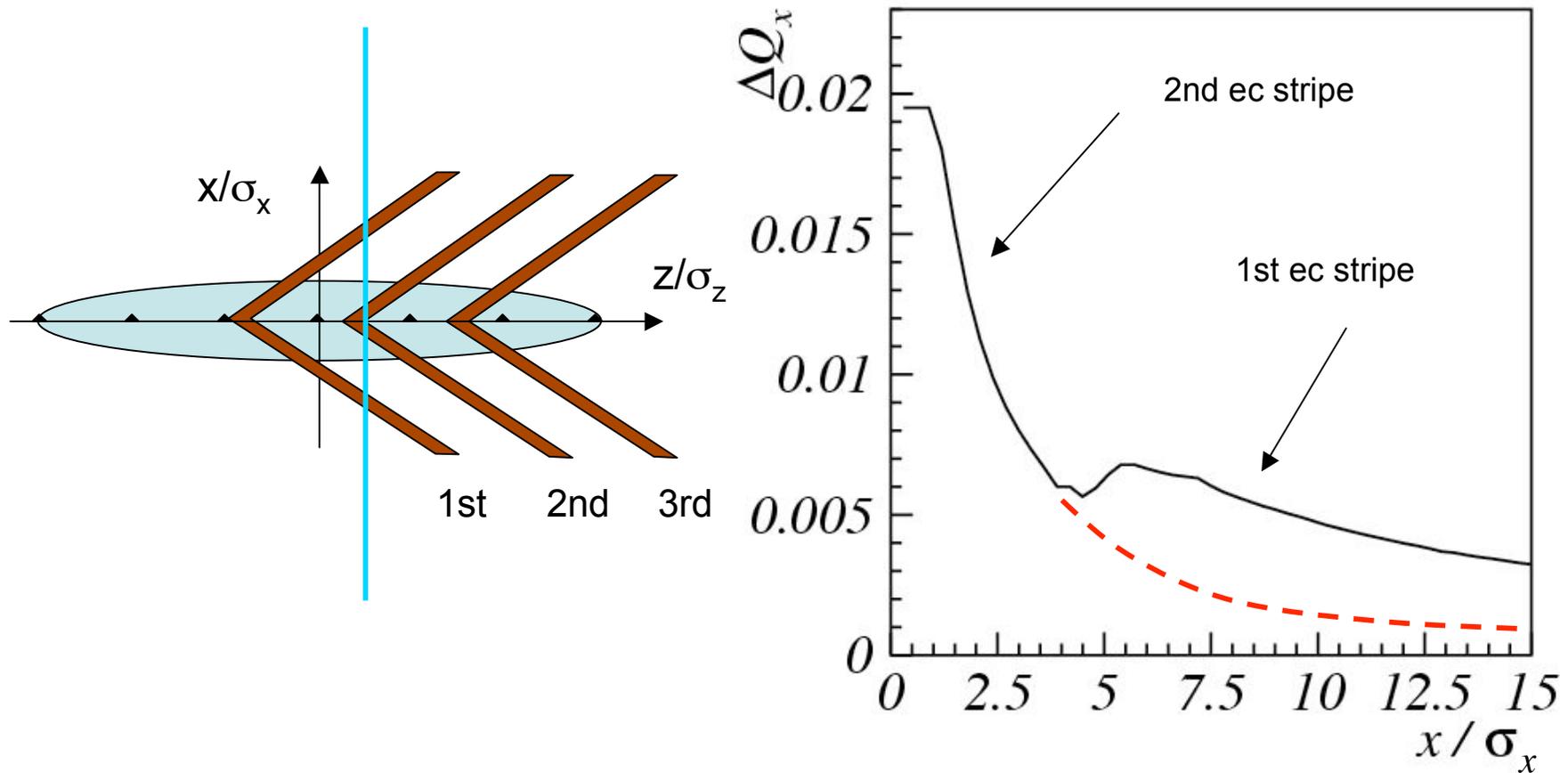
@ different z

at $z = 1.9\,\sigma_z$
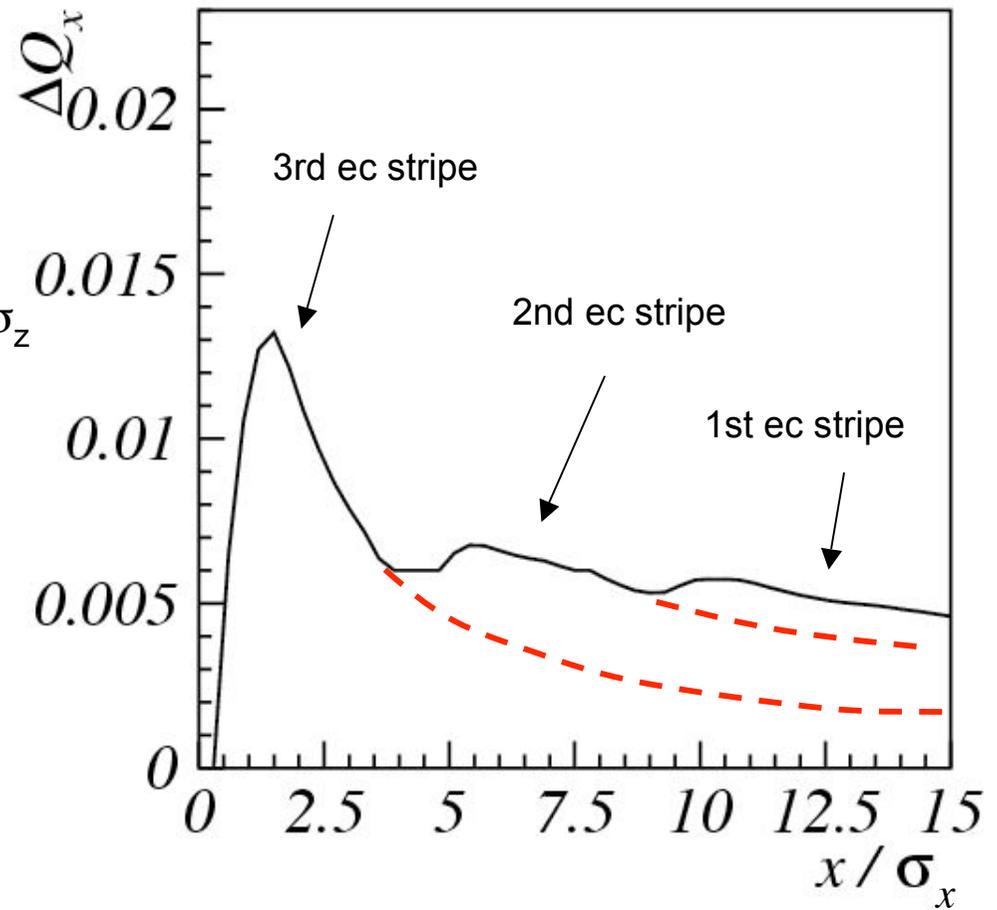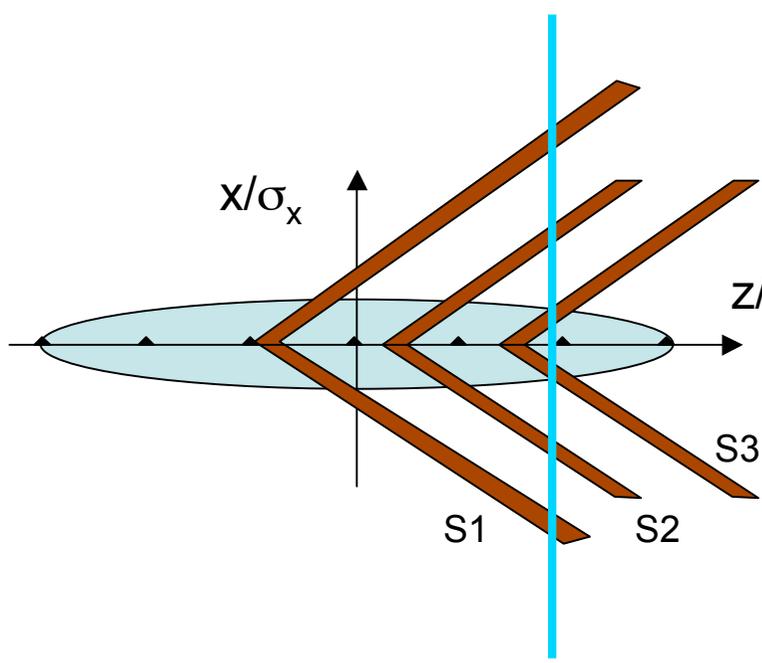
Summary on
EC stripe effects on detuning

1) EC stripes create a detuning which is amplitude dependent and decays as $1/\sqrt{\epsilon_x}$

2) The distance of the stripes from the axis creates a z-dependence of the detuning like for the space charge

3) The effect of multiple stripes creates a complex dependence of the detuning from z and x

# Dynamics induced by EC stripes

When the EC kick is "stronger"….

at $z = -0.9\, \sigma_z$

For $\Delta Q_{ec} = 0.1$

$Q_x = 26.185$
$Q_y = 26.136$

EC localized kick
self excites a
5 order resonance !

1st stripe

Characteristic
signature of
an island

Phase space

at $z = -0.9\ \sigma_z$

Characteristic signature of an island
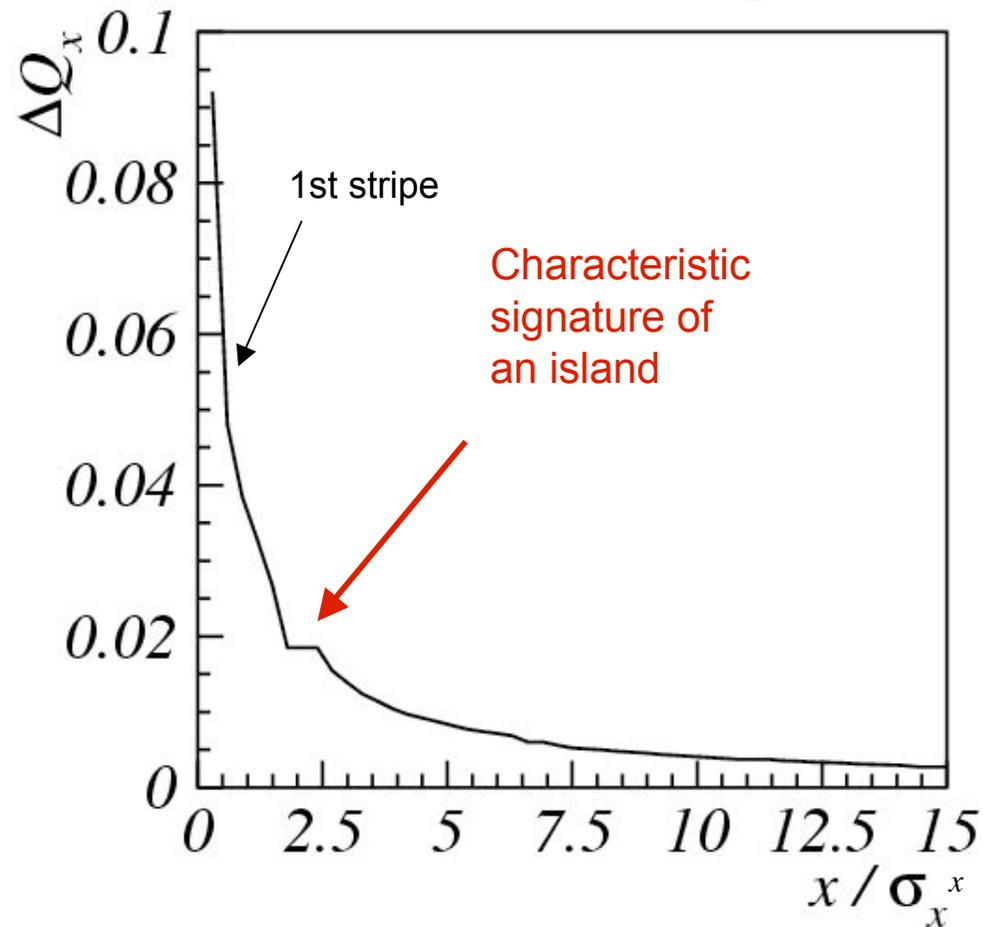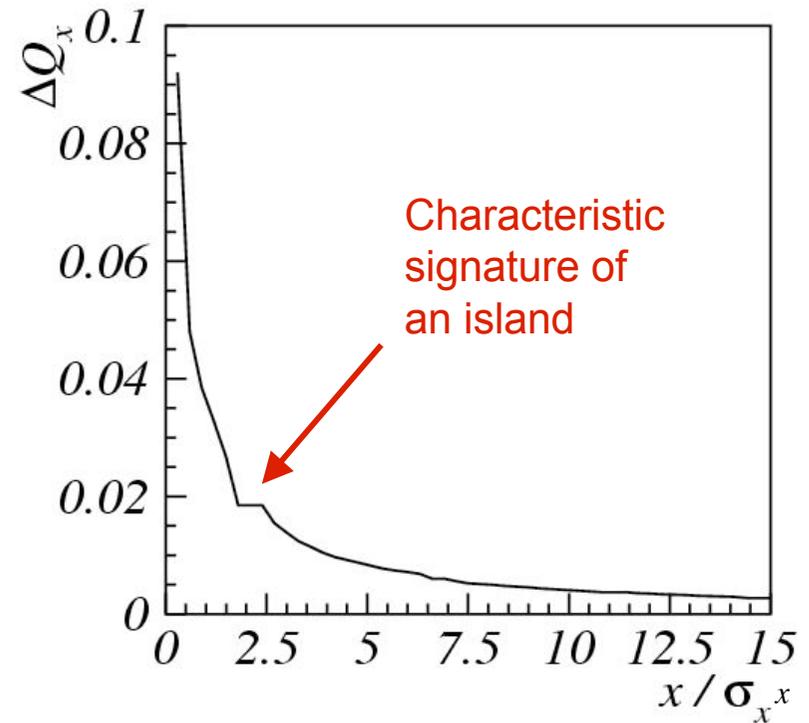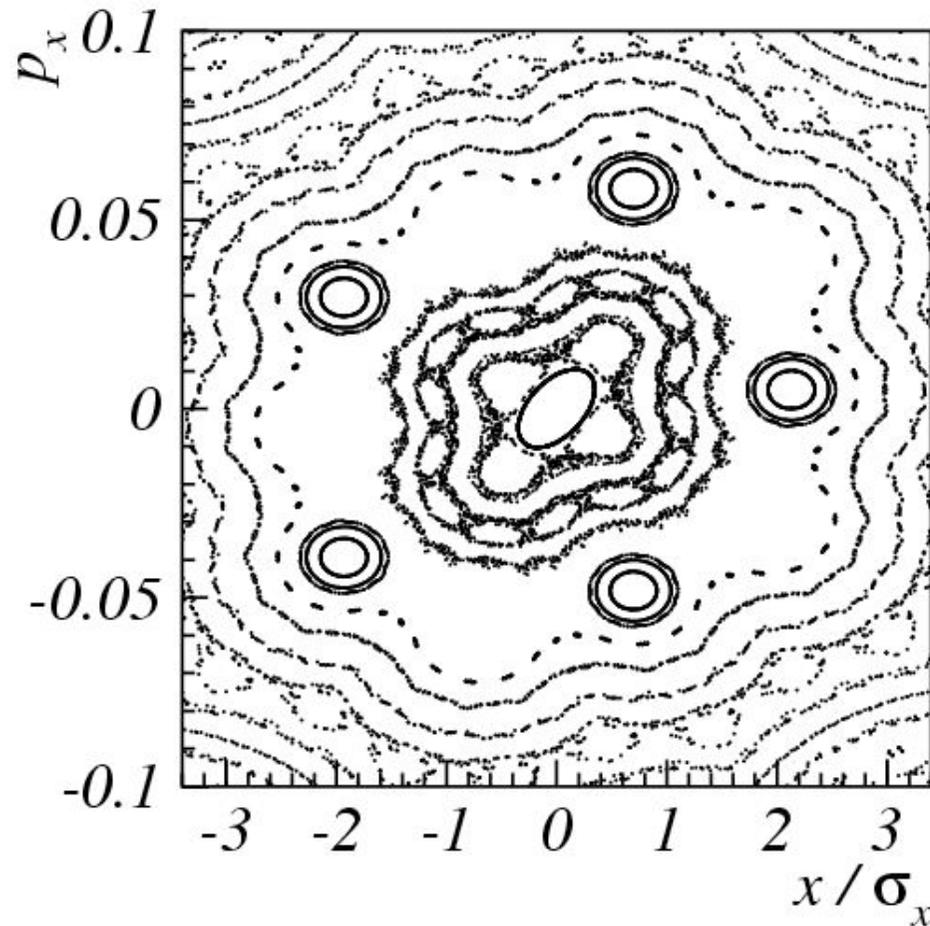
Wrong ! We have 5 islands in 10 holes: 10th order resonance

@ z = -0.6 σ_z

at z = -0.6 σ_z

Like for the space charge islands move out

1st stripe

Now it is outward

Phase space

at $z = -0.6\ \sigma_z$

Now it is outward

@ z = 0.22 σ_z
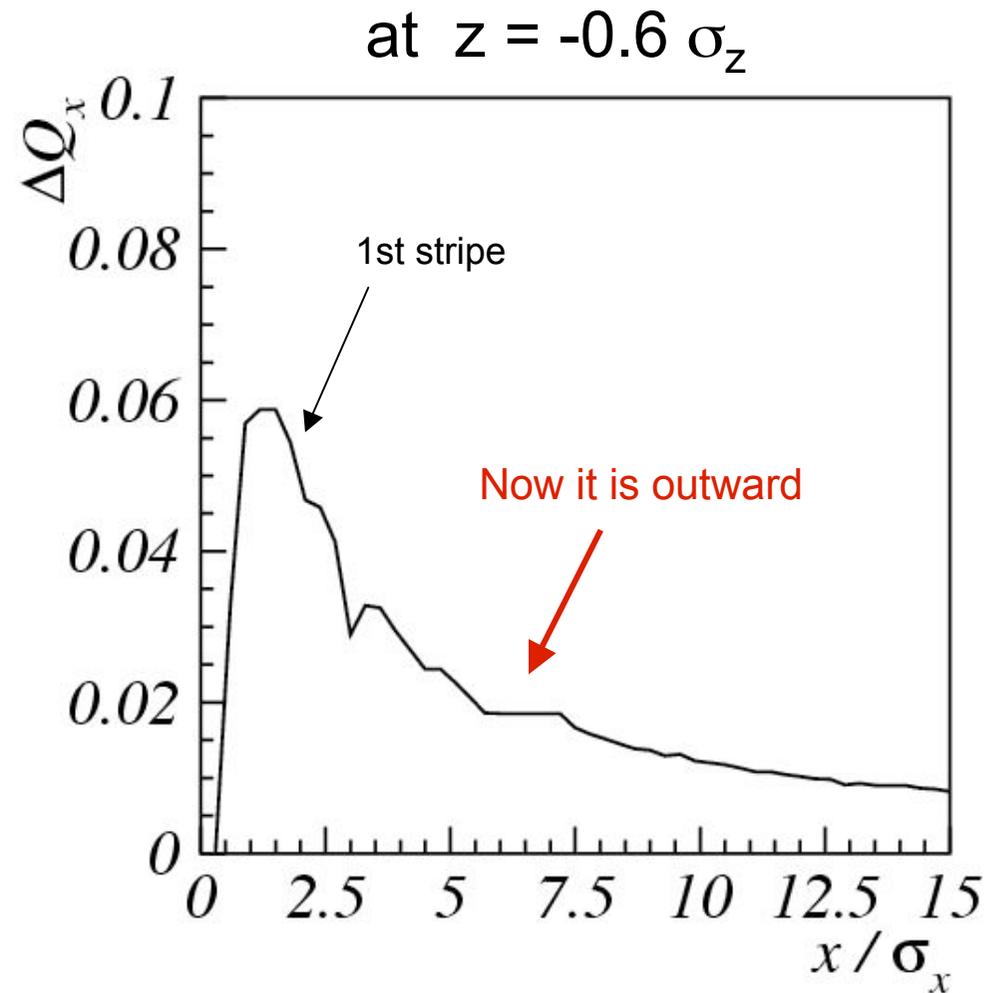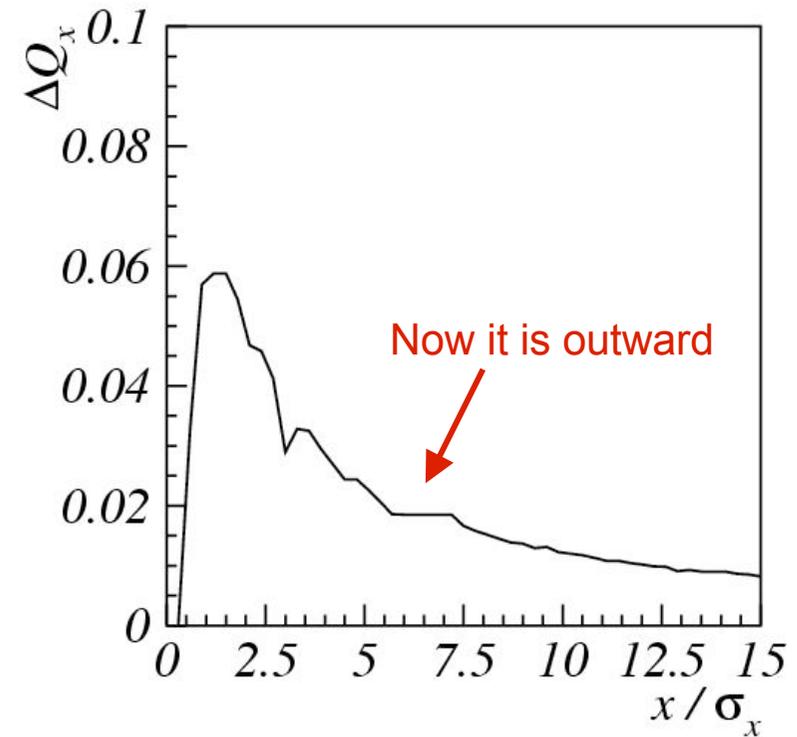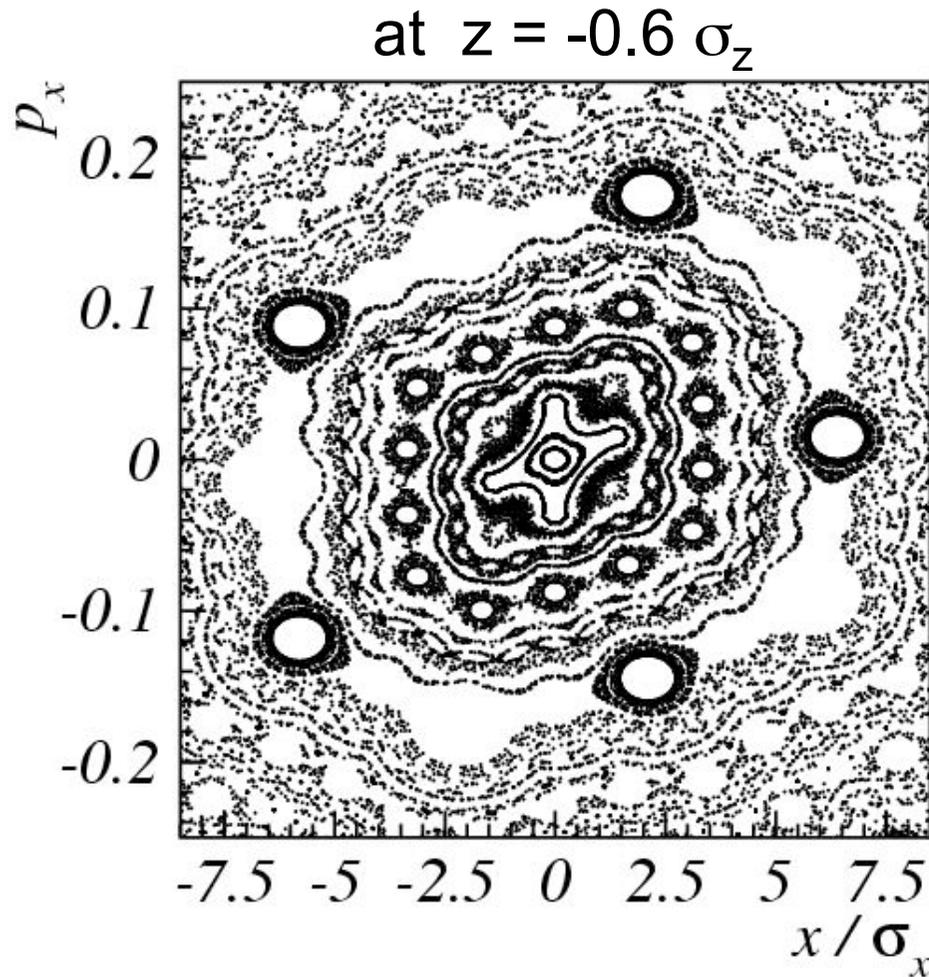
At z = 0.22 σ_z

The 2st ec stripe
Make a too weak
Detuning:
The resonance
Is not crossed

1st stripe

Phase space

at z = 0.43 σ_z

At z = 0.22 σ_z

1st stripe

@ z = 0.43 σ_z
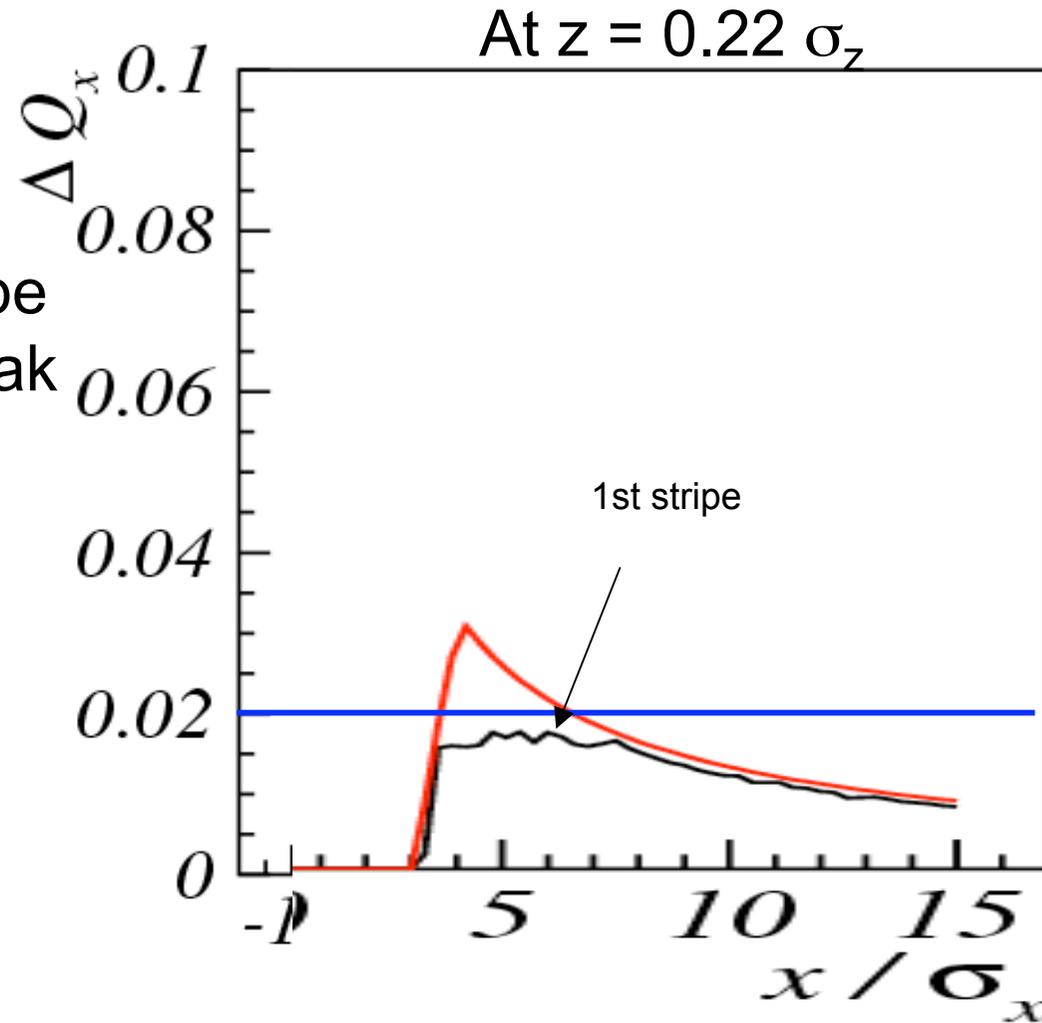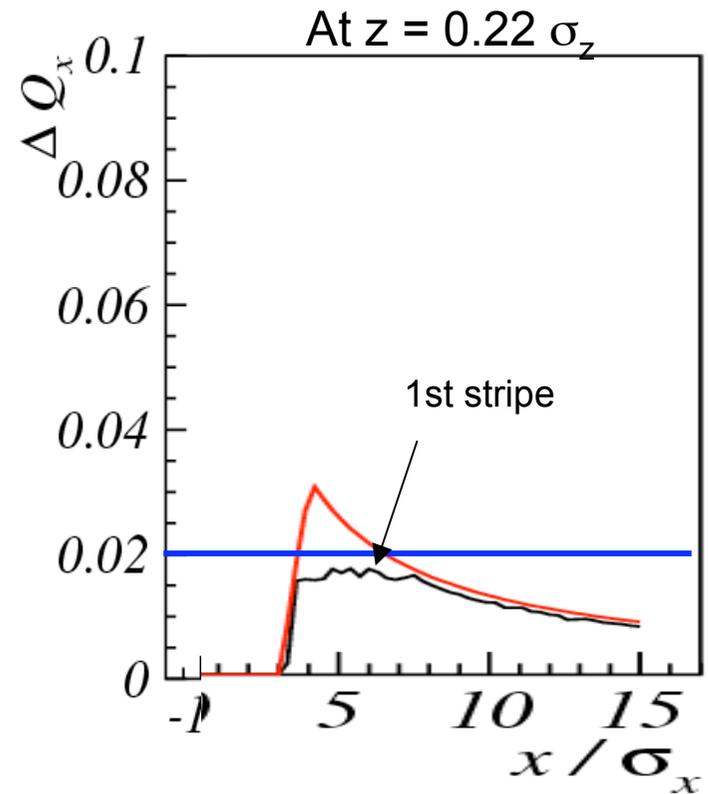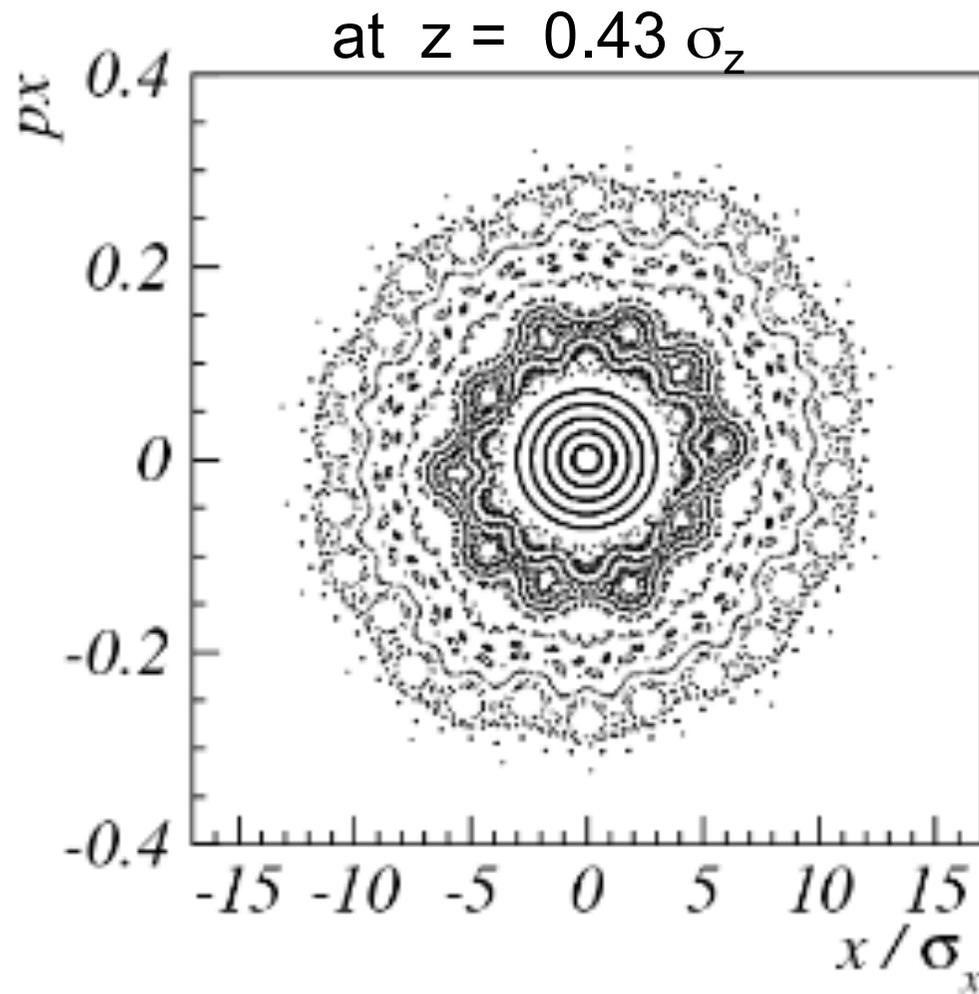
at z = 0.43 σ_z

When the 2nd
ec stripe is met,
a new island
is created

2nd stripe

1st stripe

More
Outward !

New
island

Phase space

at $z = 0.43\,\sigma_z$

@ z = 1.8 σ_z
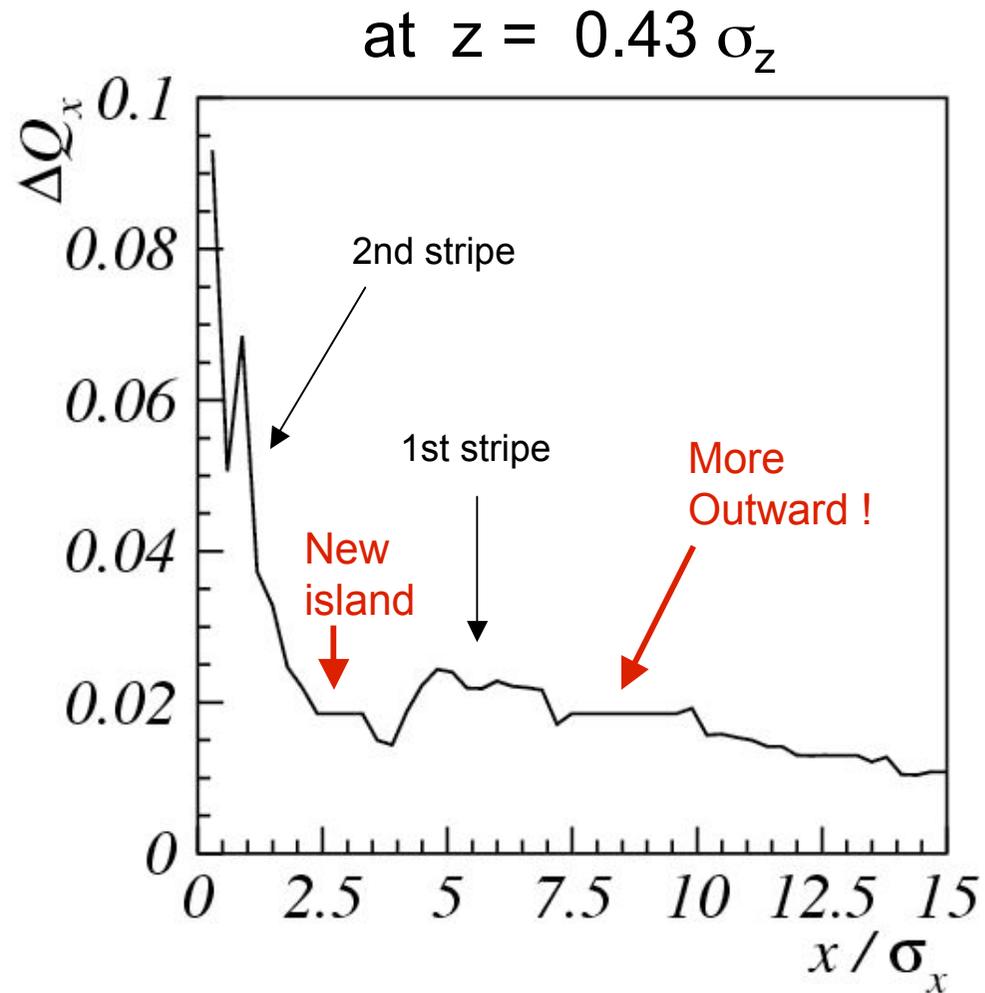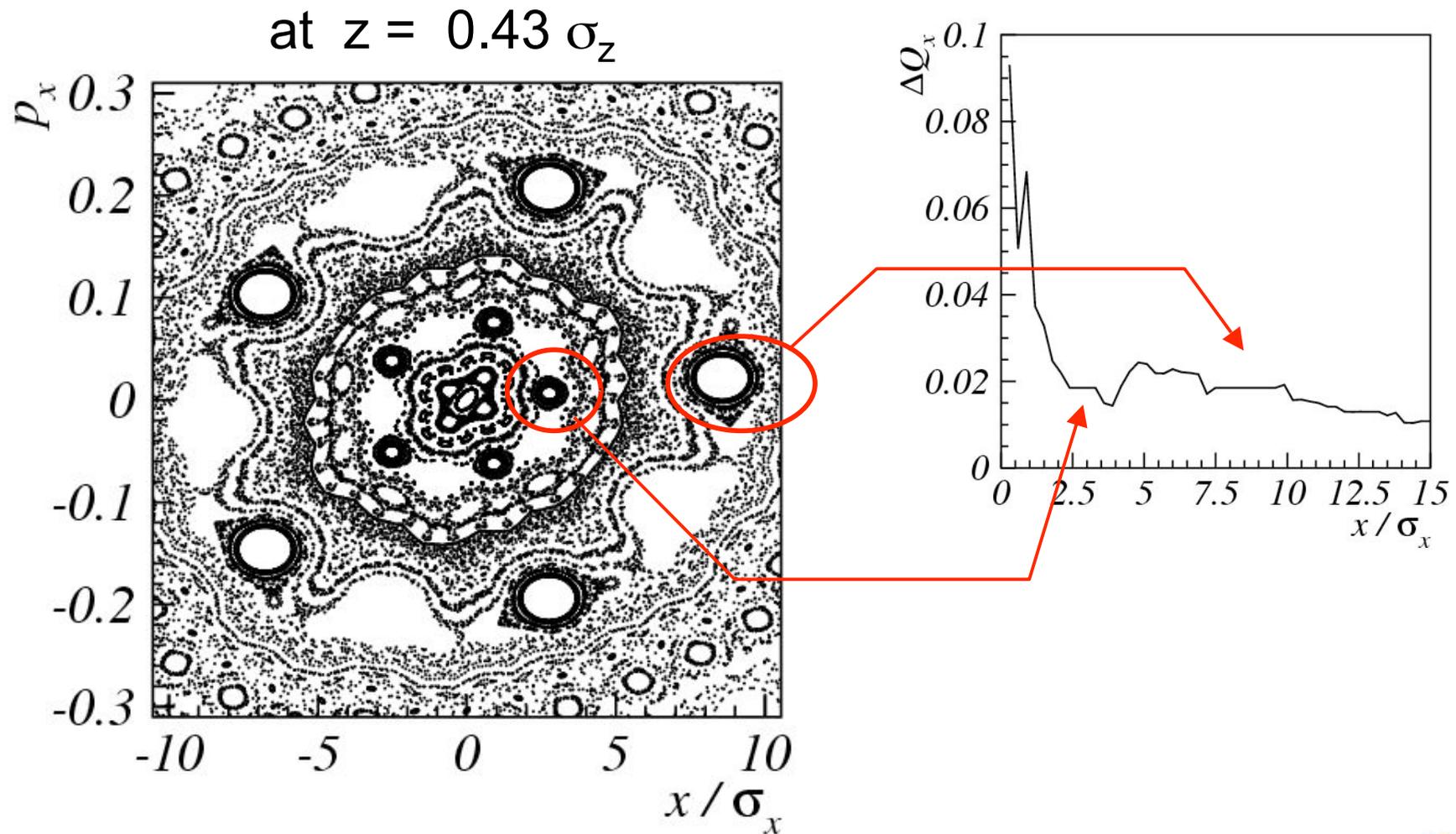
at z = 1.8 σ_z

When the 3rd
stripe is met,
the tuneshift
is to large:
**All islands
disappear !**
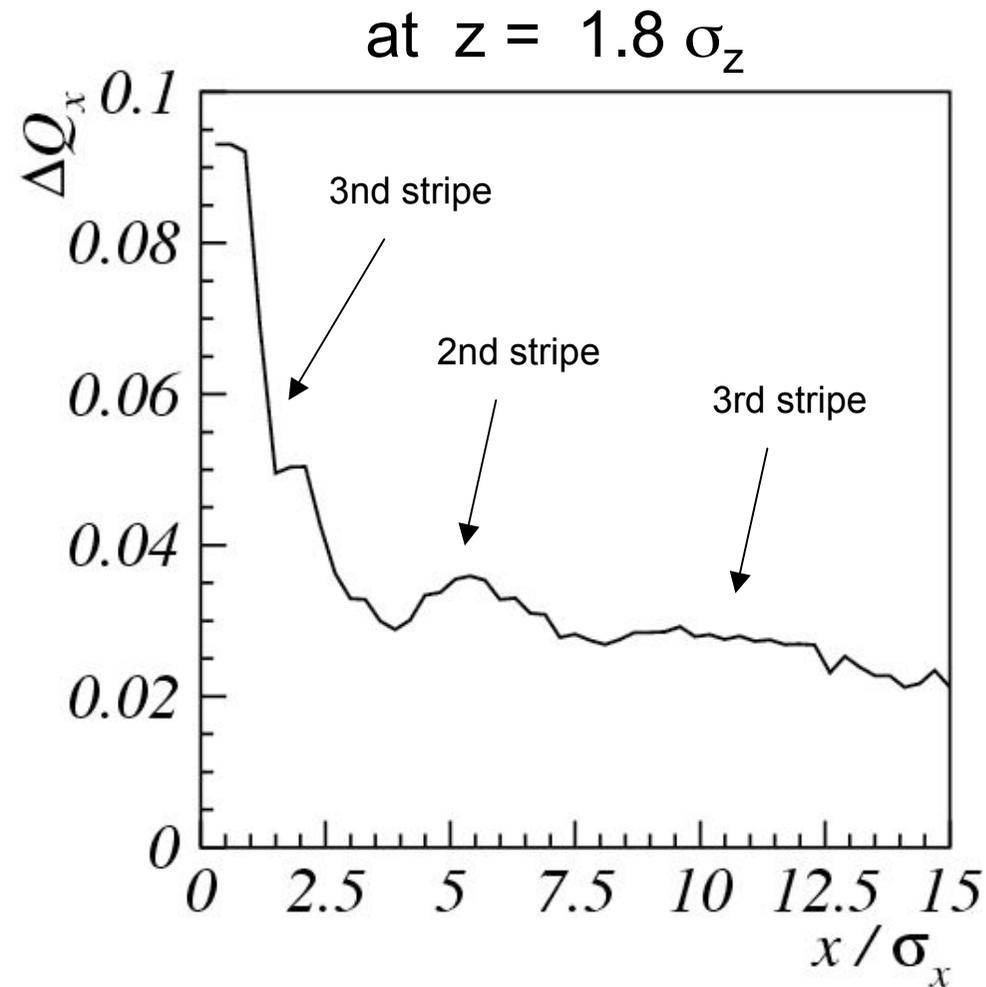
Phase space

at $z = 1.8\,\sigma_z$
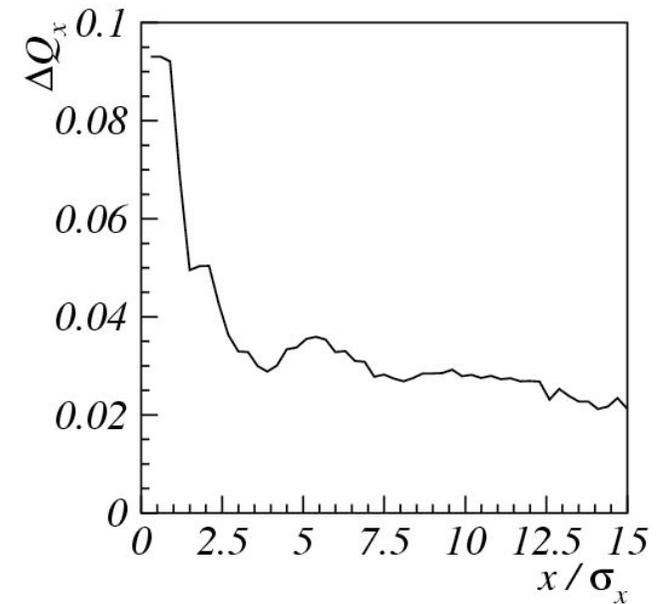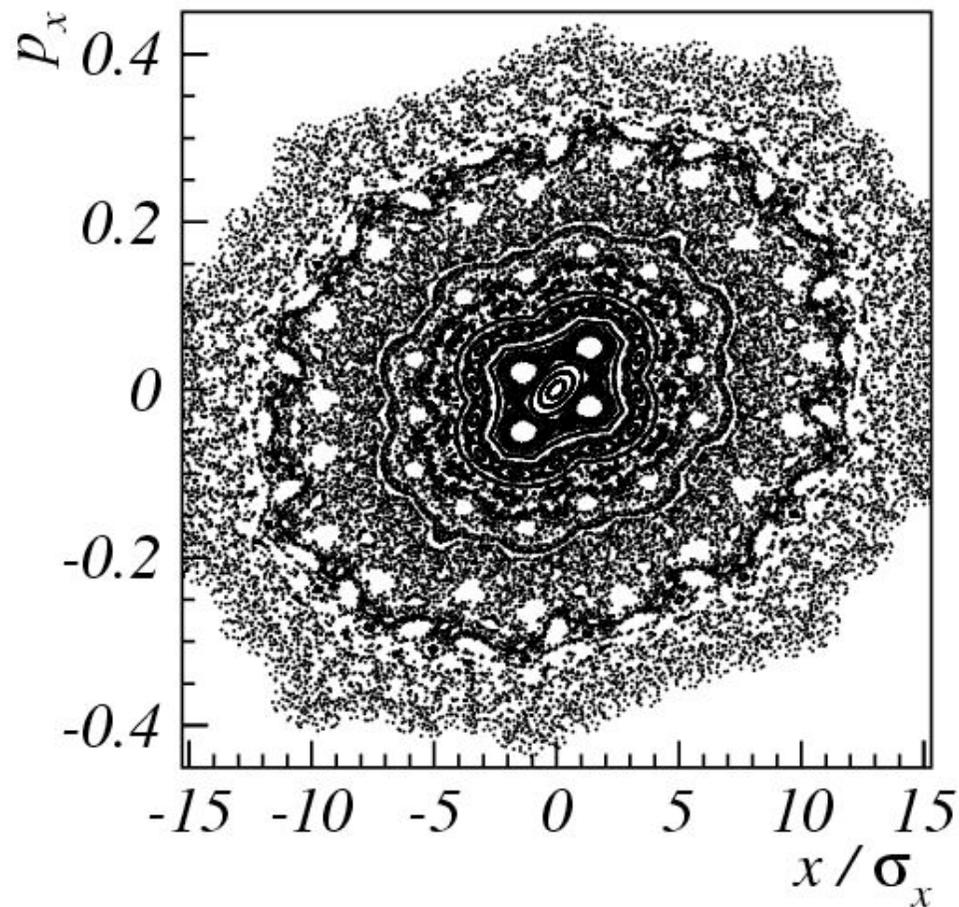

No islands are found
(almost…)

Summary 2

Like for the space charge
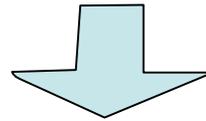
The EC stripes appear to create a x-z correlation
on the position of the transverse islands (self generated!)

Summary 2

Like for the space charge
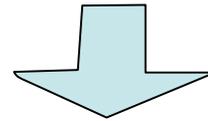
The EC stripes appear to create a x-z correlation
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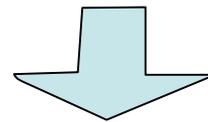
Can we obtain
trapping or scattering regimes ??

By changing dynamically Q_{x0}

Move Q_{x0} through the 10th order resonance ($\Delta Q_{ec} = 0.05$)

Test particle: $x = 2\,\sigma_x$, $z = -0.95\,\sigma_z$, $p_x = p_z = 0$
Synchrotron motion frozen

10^4 turns

$Q_x = 26.185$
$Q_y = 26.136$

$Q_x = 26.22$
$Q_y = 26.136$

$Q_x = 26.2$
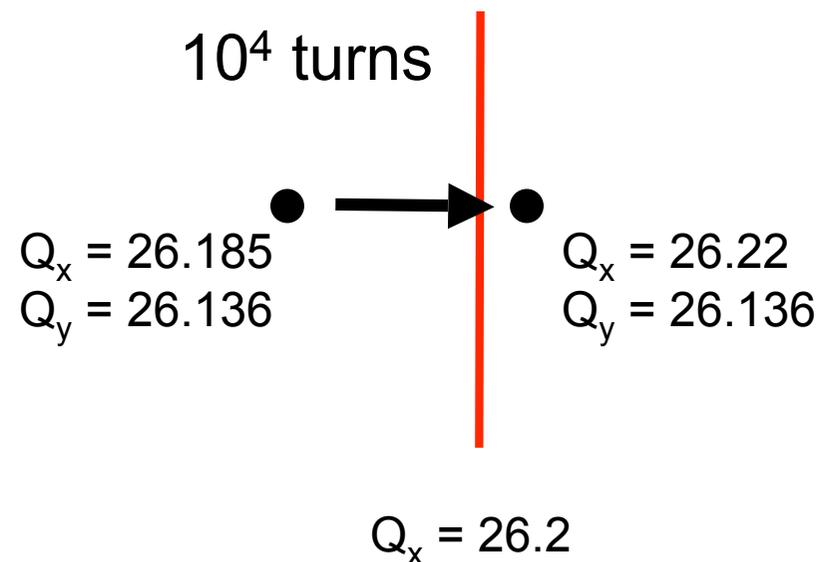
Trapping induced by dynamic change of Q_{x0}
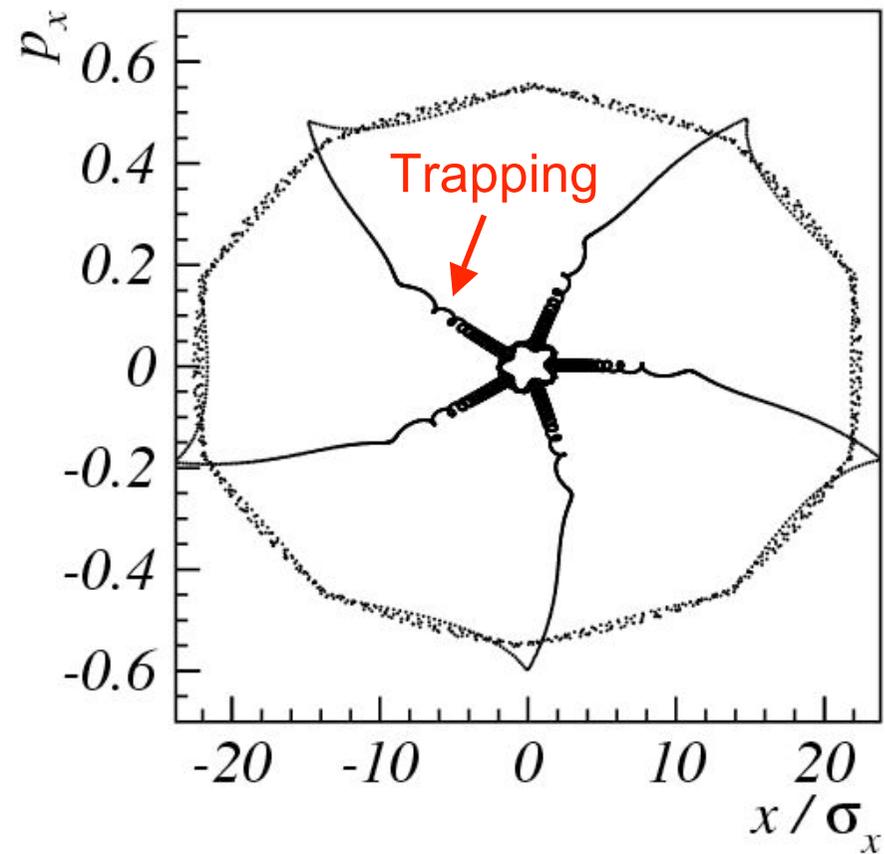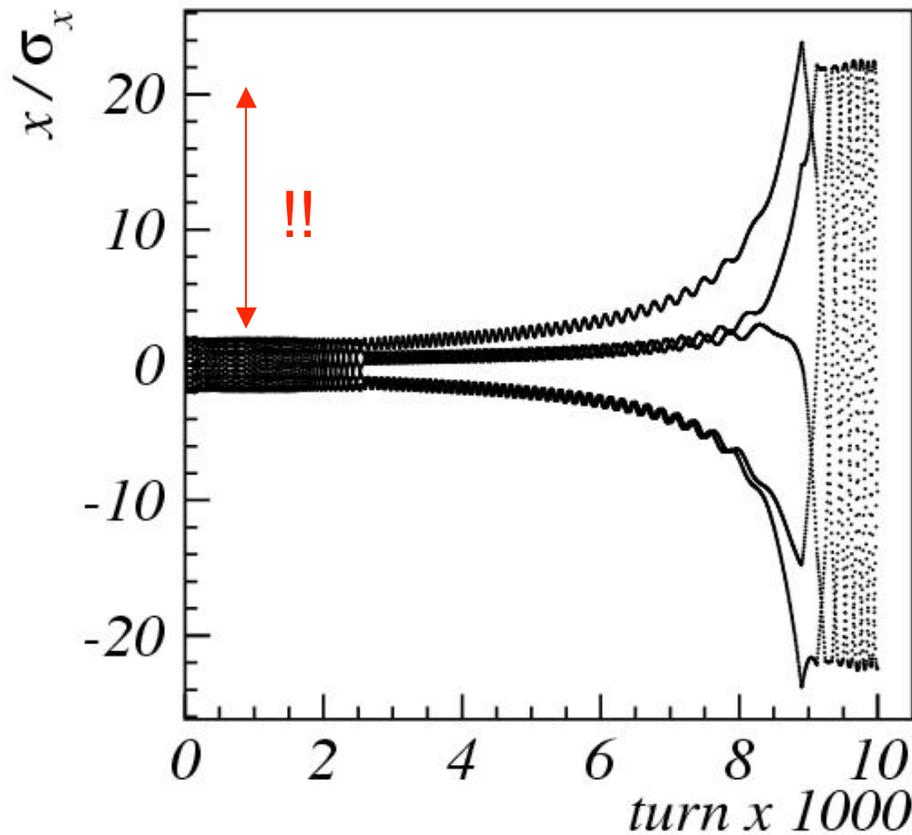
Detail of trapping

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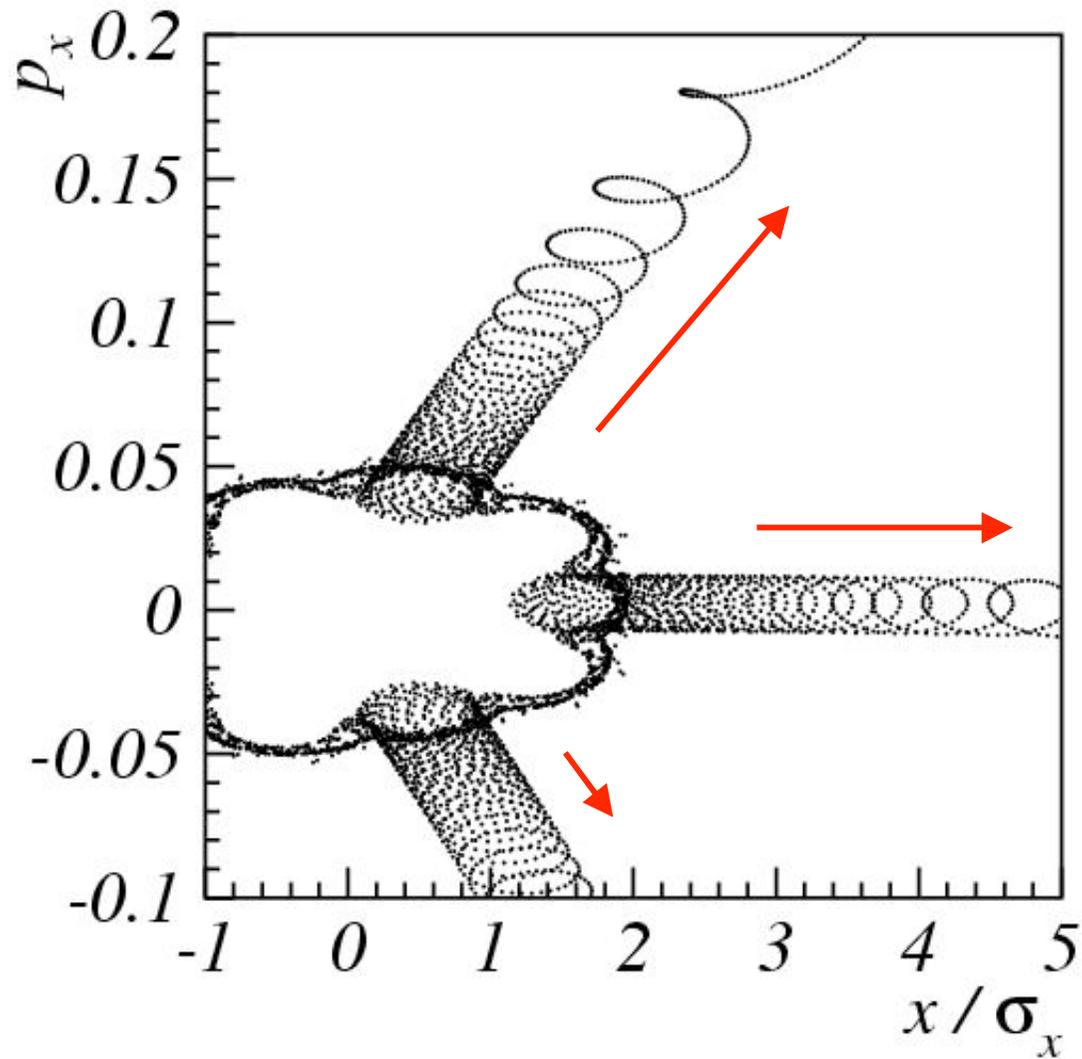
By activating the synchrotron motion

Now the working point is fixed
($\Delta Q_{ec} = 0.1$)

$Q_x = 26.185$
$Q_y = 26.136$

Synchrotron motion: 1 synch osc. in 2×10^4 turns

10^4 turns
(half synch osc.)

Ec detuning

$Q_x = 26.185$
$Q_y = 26.136$

$Q_x = 26.2$
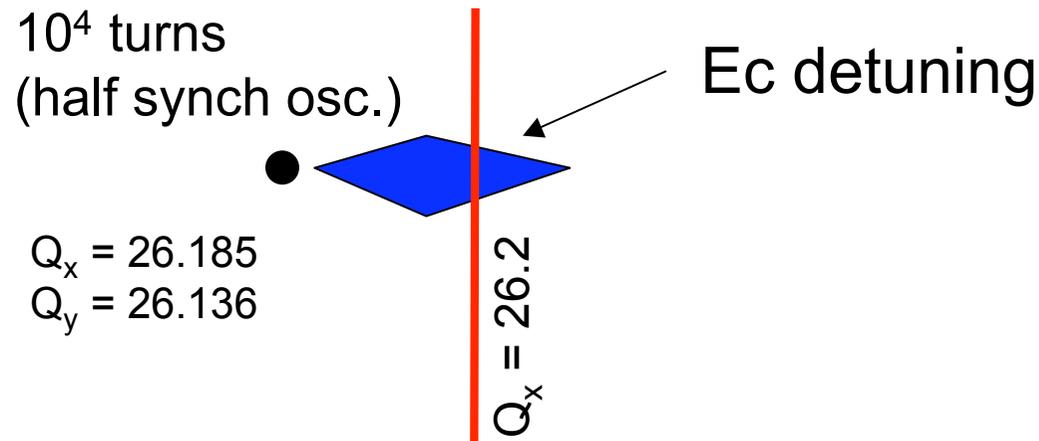
Test particle: $x = 2\,\sigma_x$, $z = -3\,\sigma_z$, $p_x = p_z = 0$

Effect of EC stripes and synchrotron motion
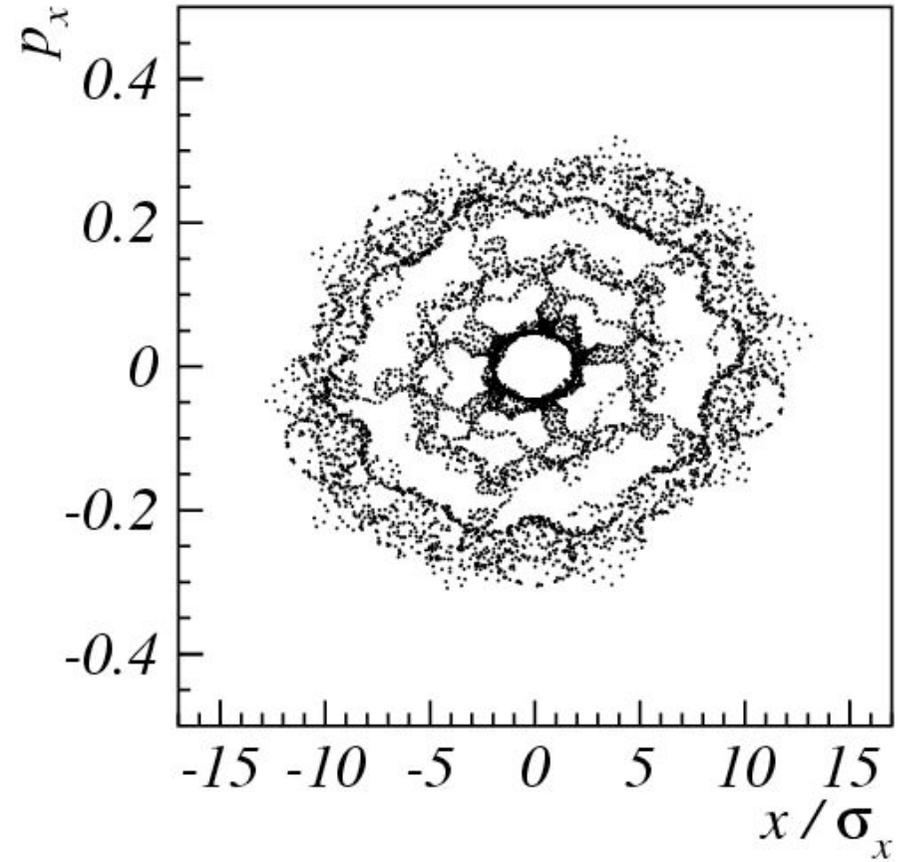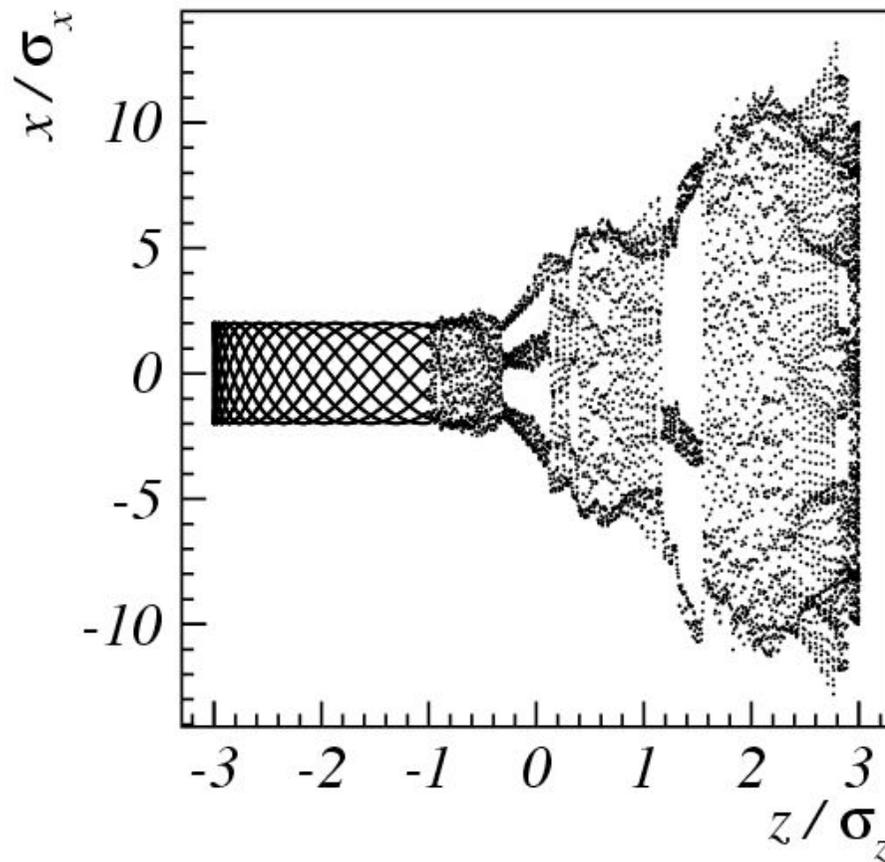
The inverted crossing does not exhibits trapping

A very complex picture!
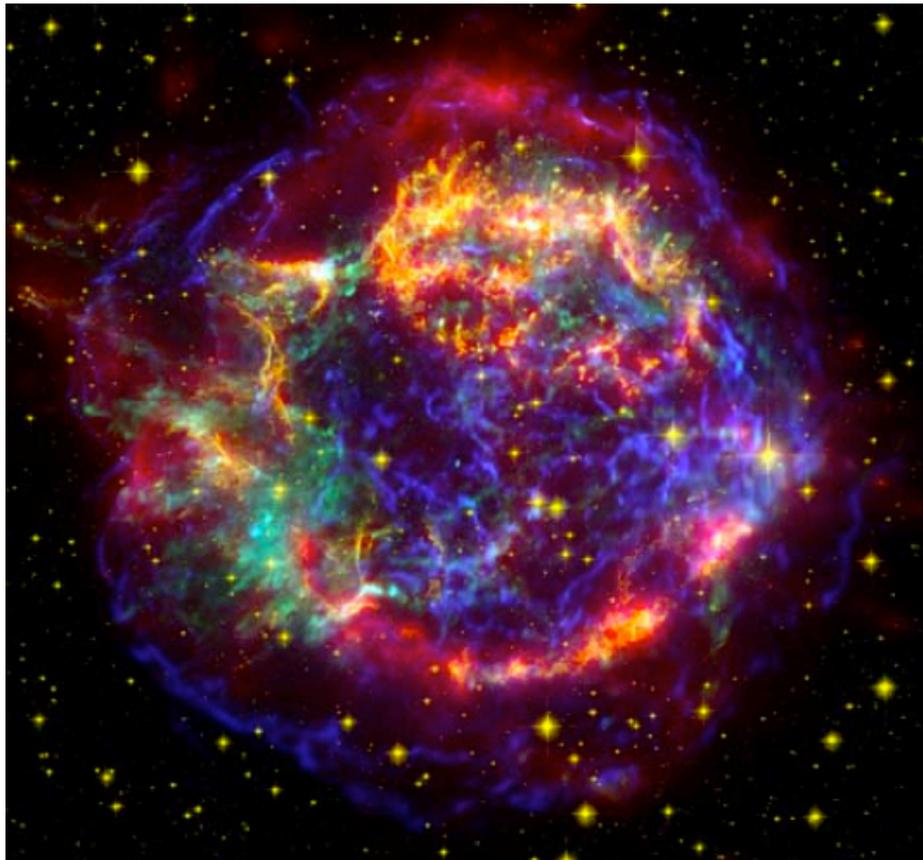


Cassiopea A   Chandra X-ray Observatory ACIS Image

Interpretation

Trapping on 1st ec stripe

10th order islands
Disappear: chaos!

Interpretation 3
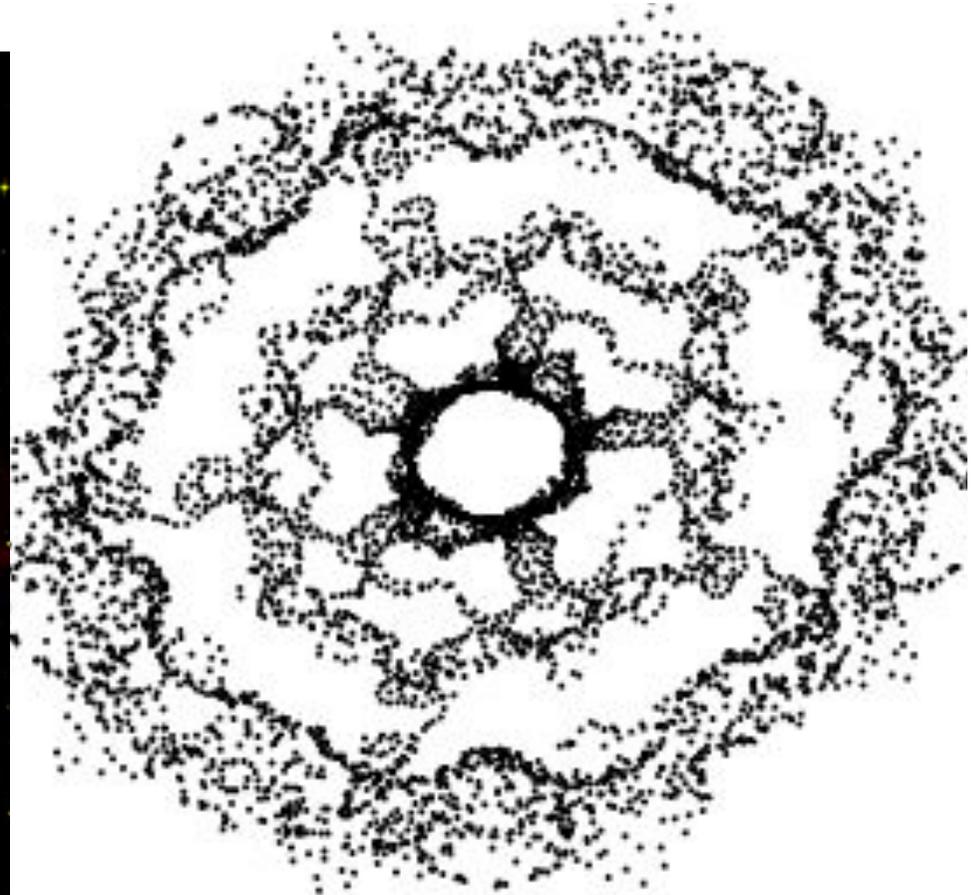
10th order islands reappear because ec stripe1 + ec stripe2 Again trapping!
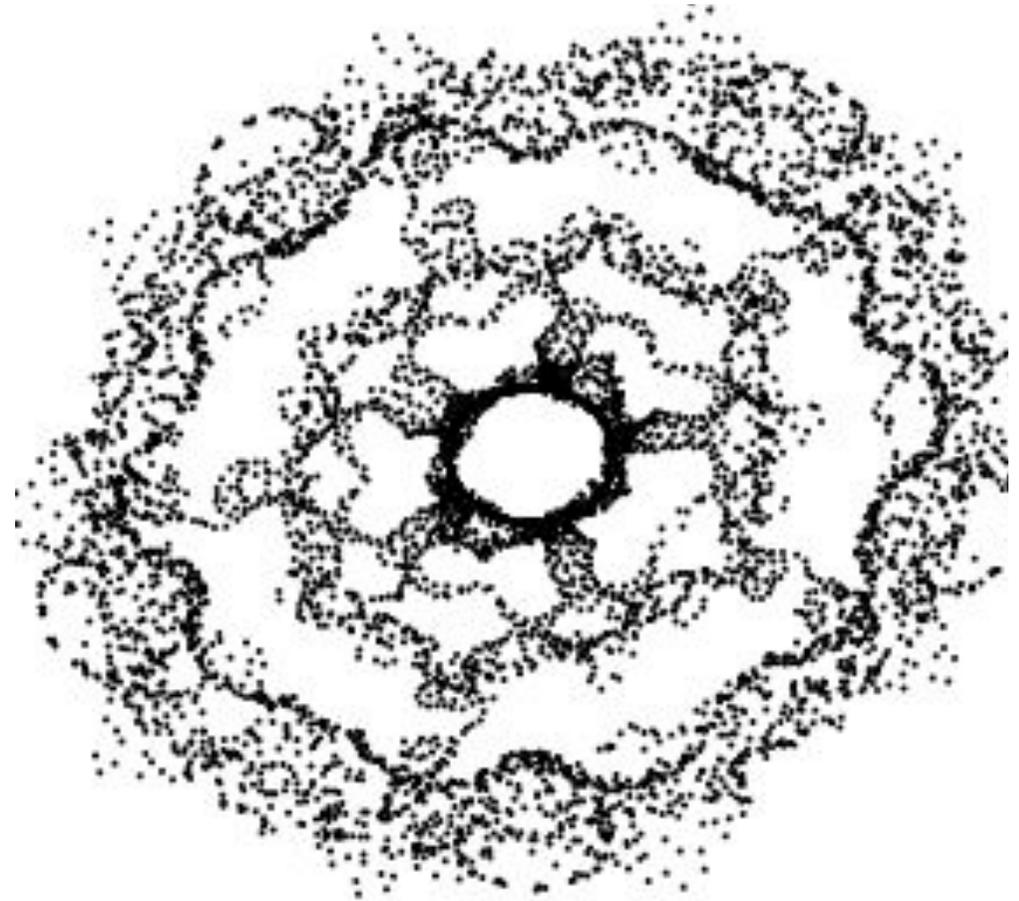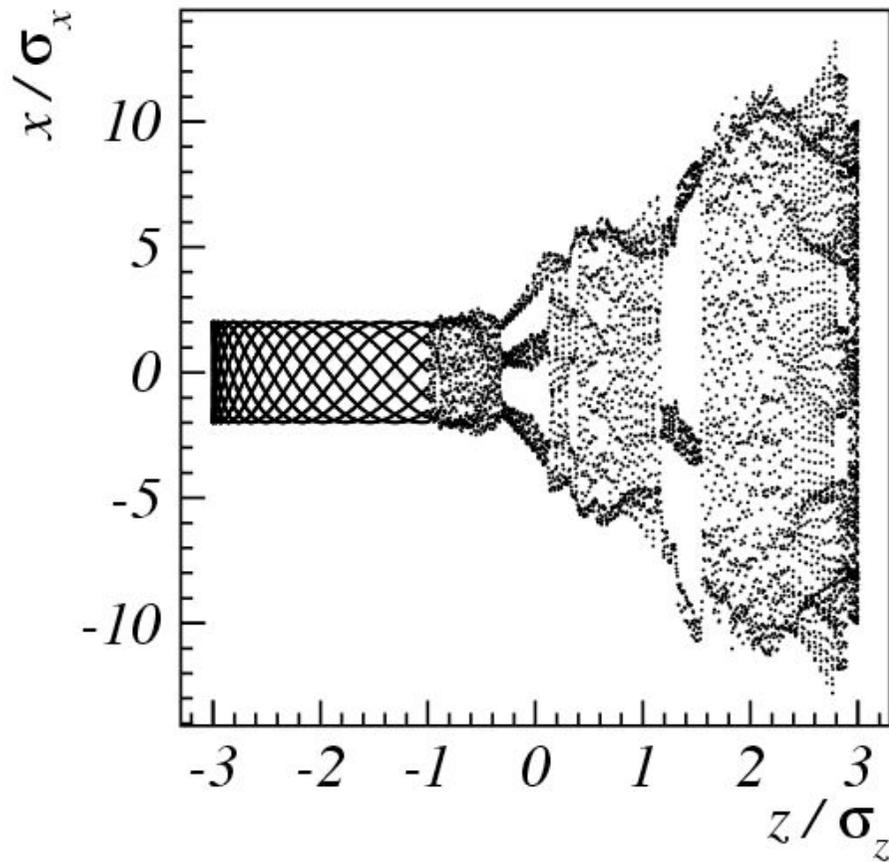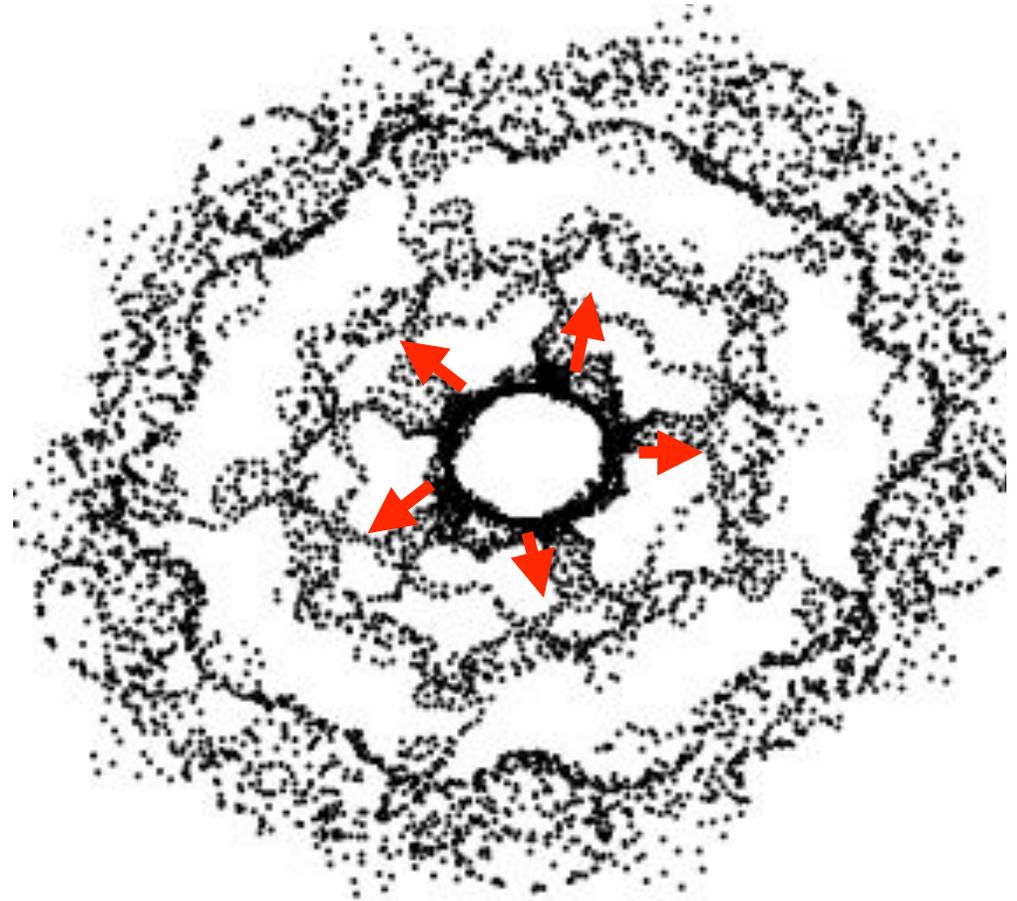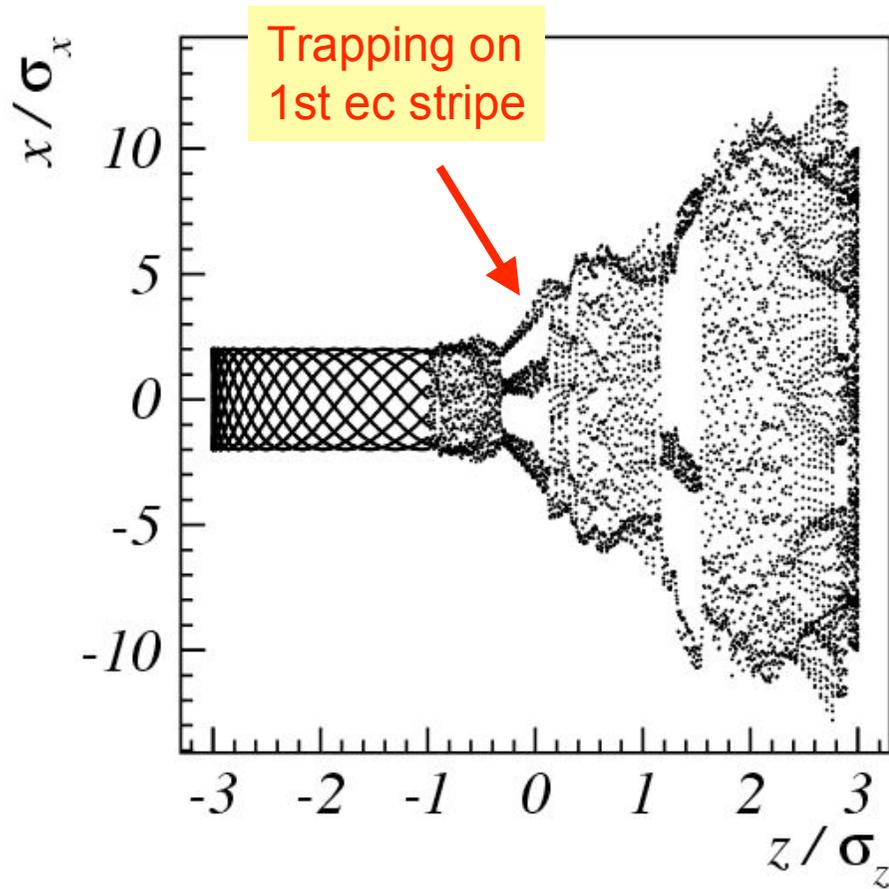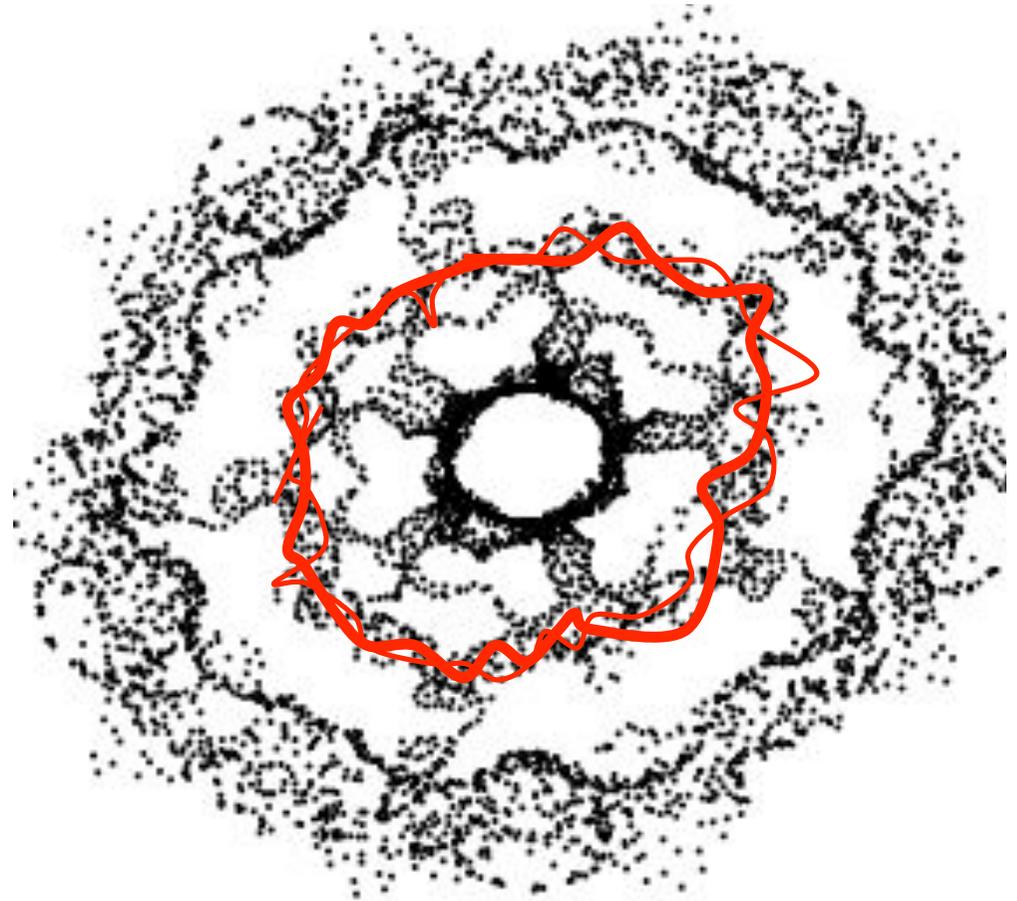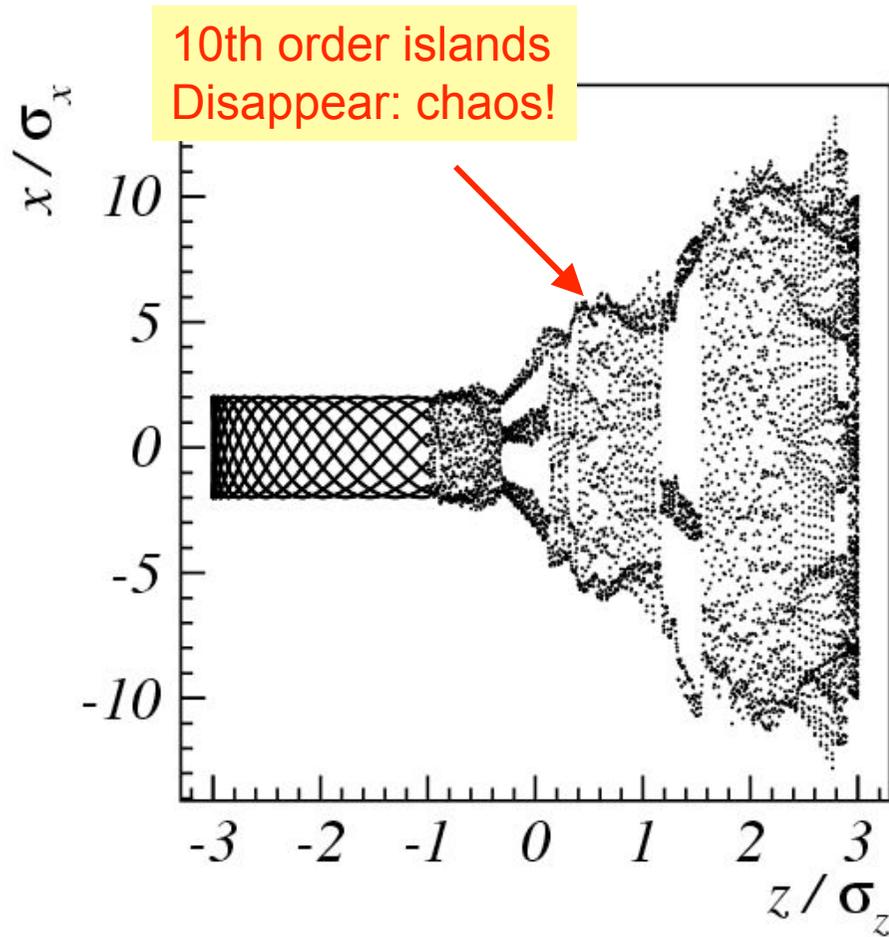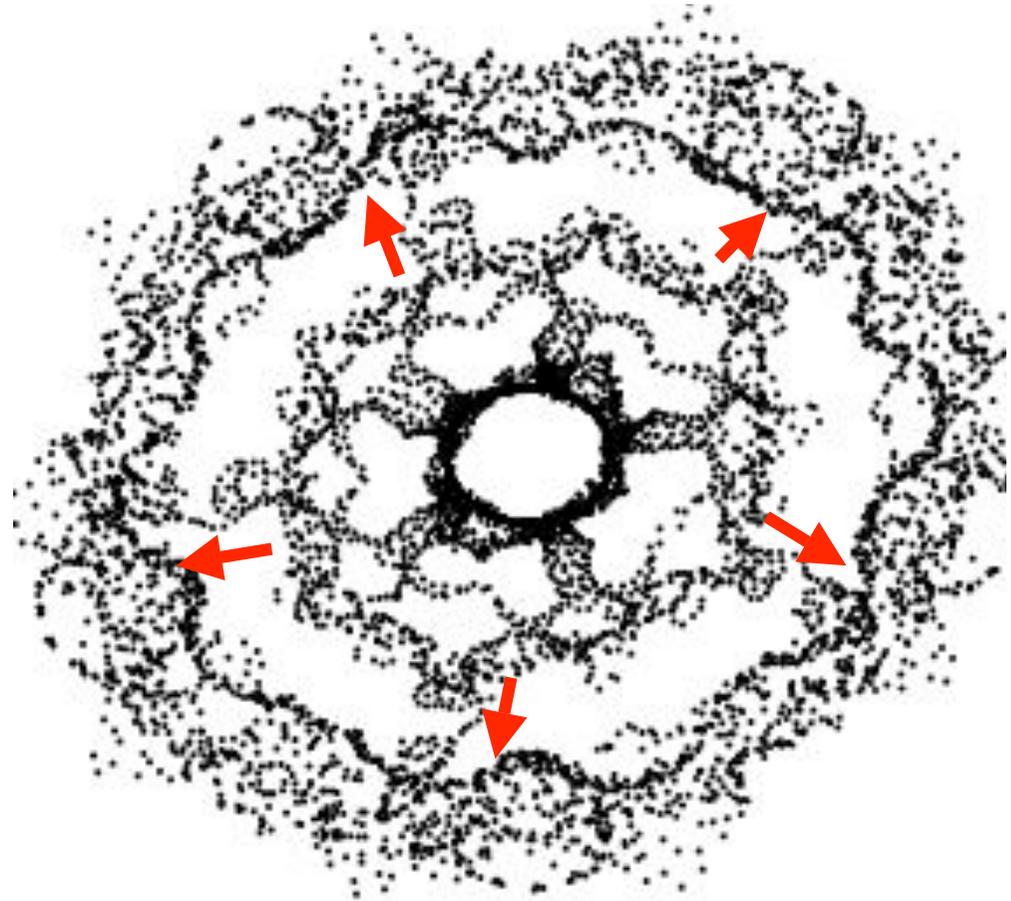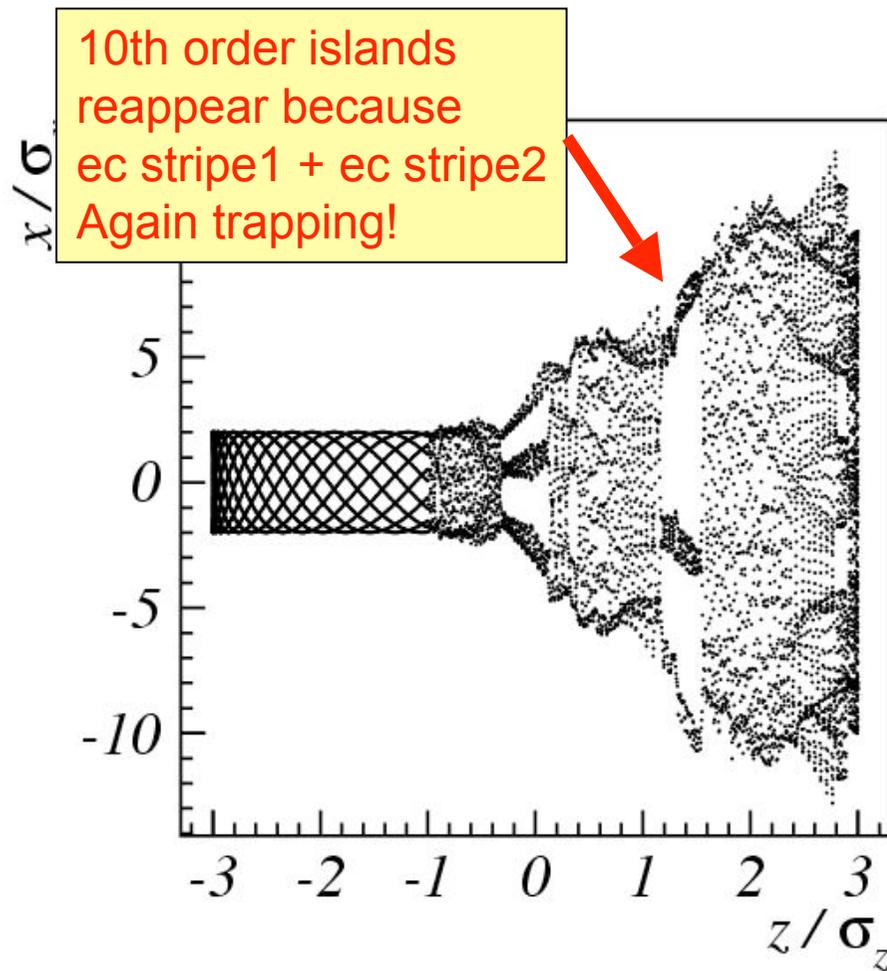
Interpretation 4

10th order islands disappear AGAIN because of the 3rd stripe! Again CHAOS!
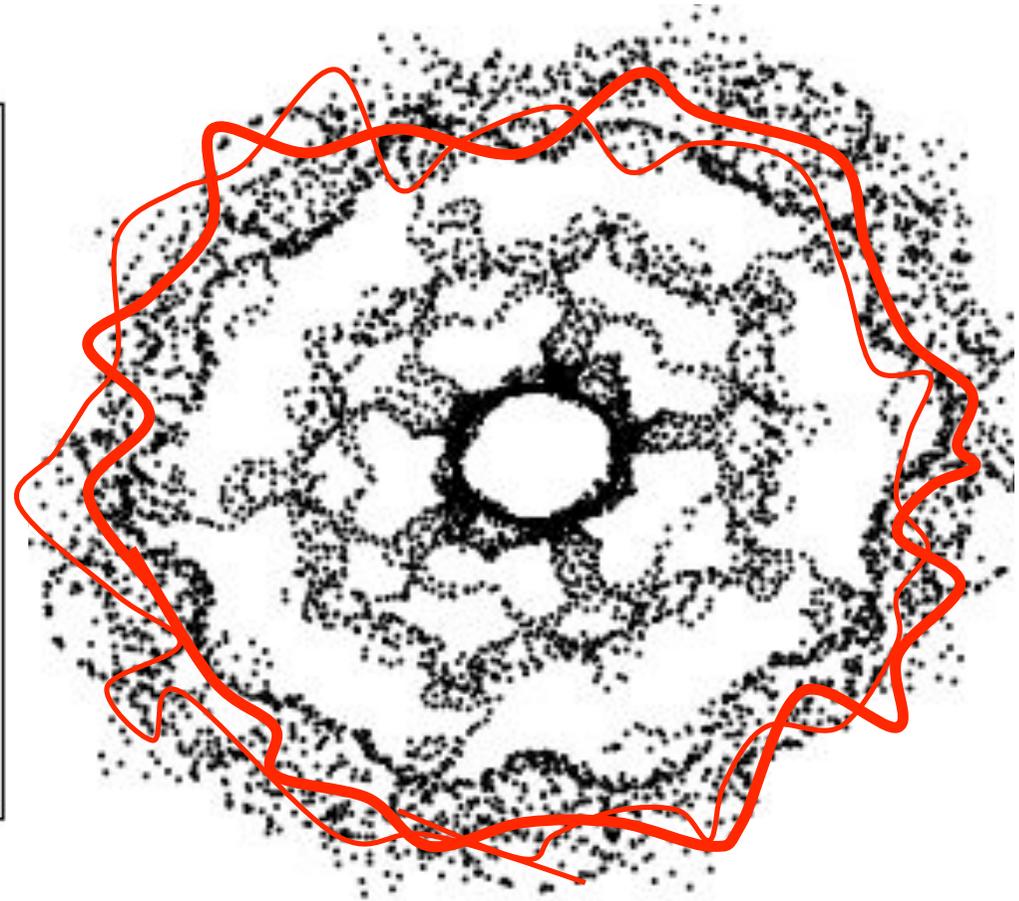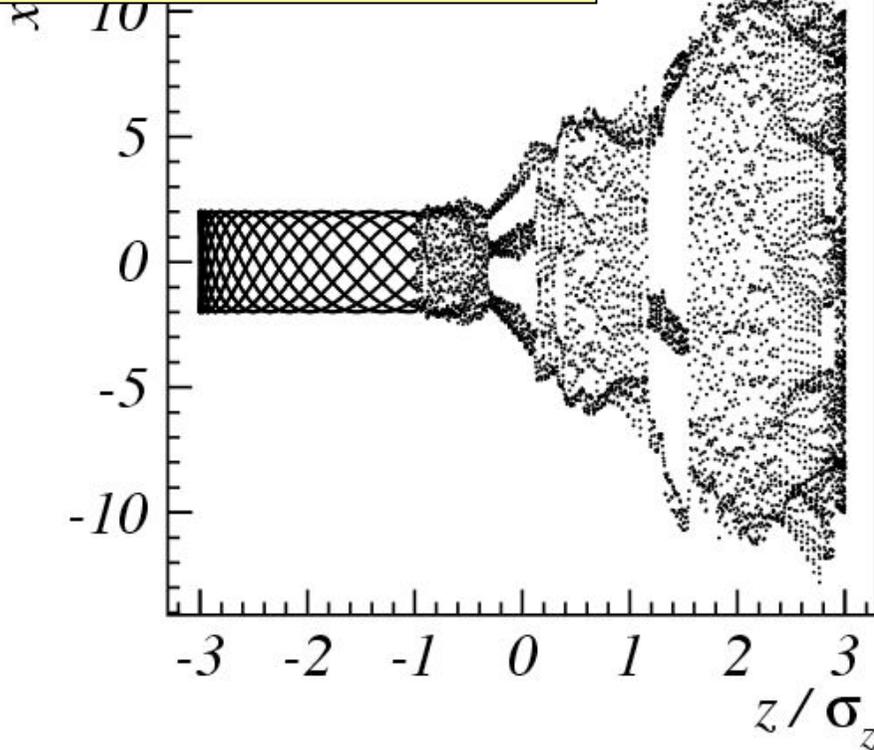
Summary on trapping

EC stripes can induce a trapping both
by dynamic change of tune, or by
synchrotron motion

The presence of many stripes alternate
bands of trapping to bands of scattering!

Application

Application to SPS

No chromaticity, smooth focusing, linear lattice

120 EC kick equally distributed

$Q_{x0} = 26.185$ $Q_{y0} = 26.136$
$Q_{x0} = 26.136$ $Q_{y0} = 26.185$

744 EC kick according to
The SPS symmetry

$Q_{x0} = 26.185$ $Q_{y0} = 26.136$
$Q_{x0} = 26.136$ $Q_{y0} = 26.185$
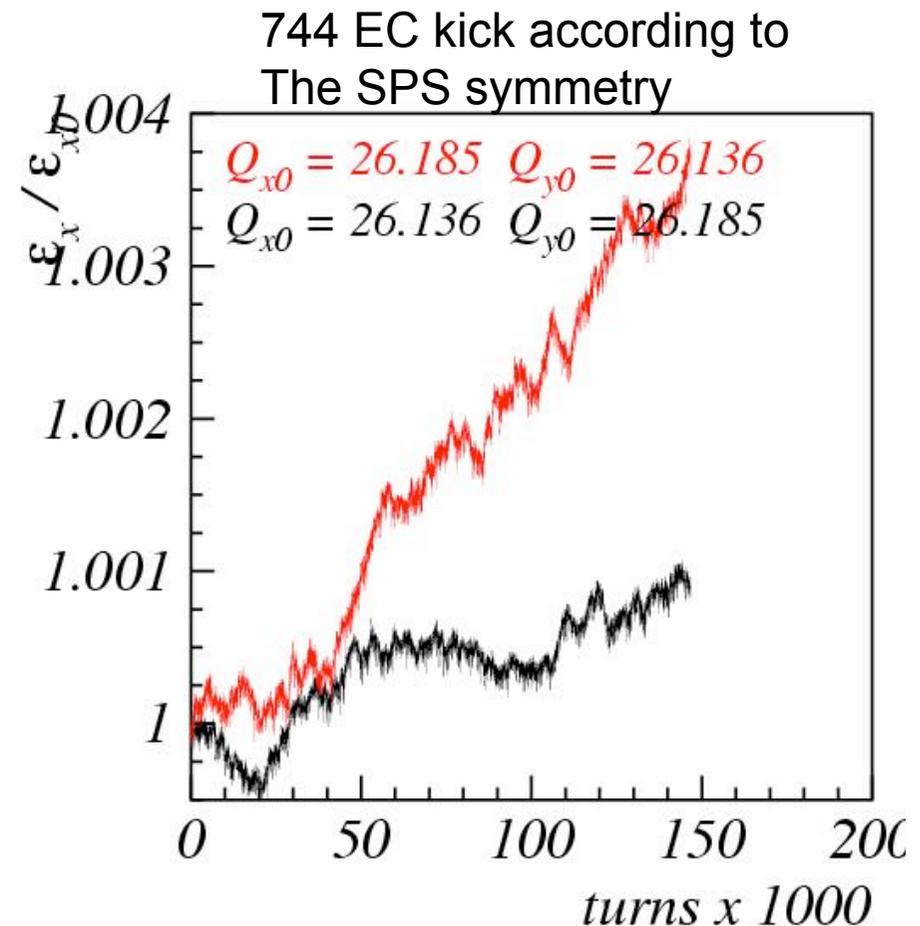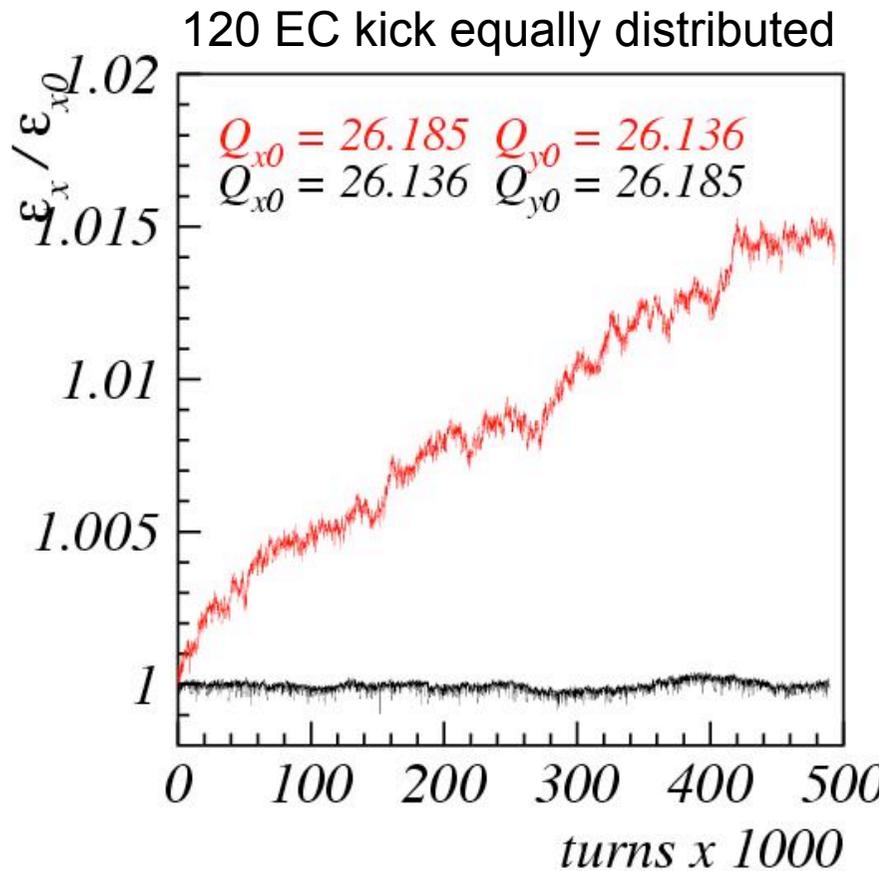
In agreement with observation ??

In SIS100

EC in SIS100 is not assessed

G.Rumolo,O. Boine-Frankenheim GSI-Acc-Note-2003-10-001

No chromaticity, smooth focusing, linear lattice

$\Delta Q_{ec} = 0.1$ WP1: Qx = 18.84, Qy = 18.73

108 EC kicks, one per bend

~1% particle brought out 3 σ_x
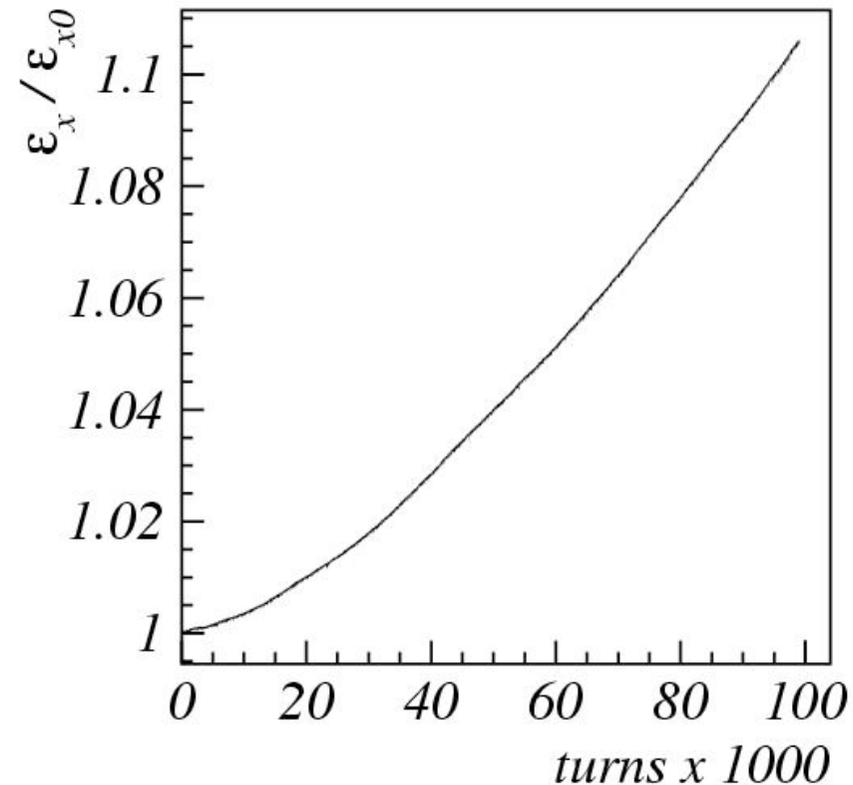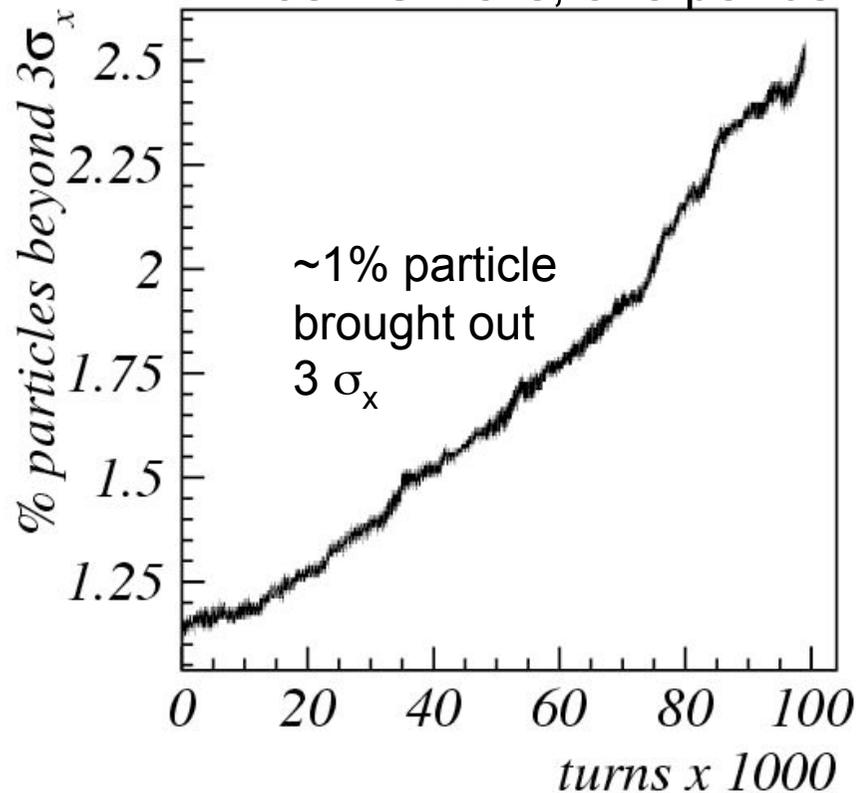
Conclusion / Outlook

- Uniform ec stripes induced a
  trapping/scattering dynamics as for the space charge
- Results on SPS show that high order resonances may be induced by localized ec stripe kick
- For SIS100 first estimate show that ~1% particle are brought on halo
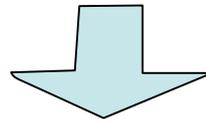
1) More solid verification of EC density level and EC stripes in SIS100
2) Better modeling of ec stripe (non-wall modeling, no uniformity)