Multi-turn tracking studies for HERA-e

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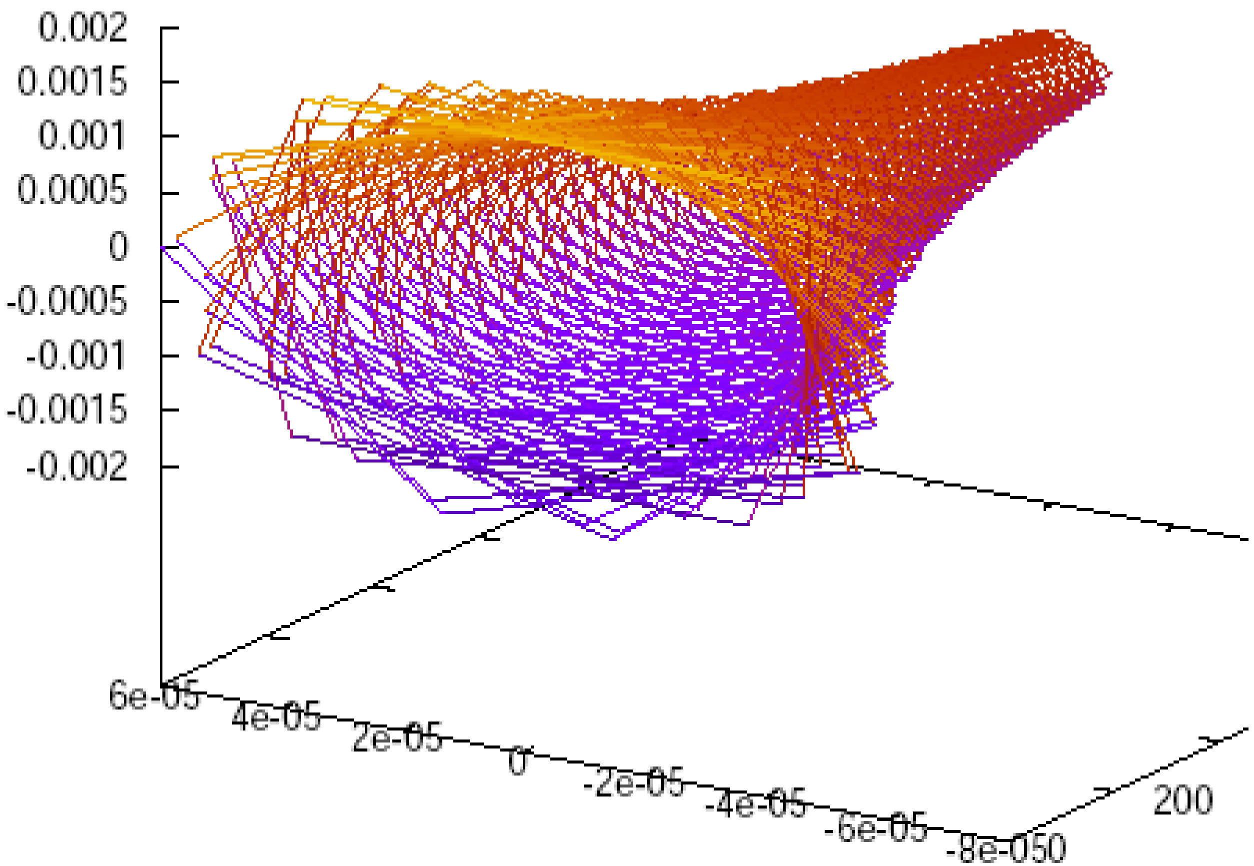
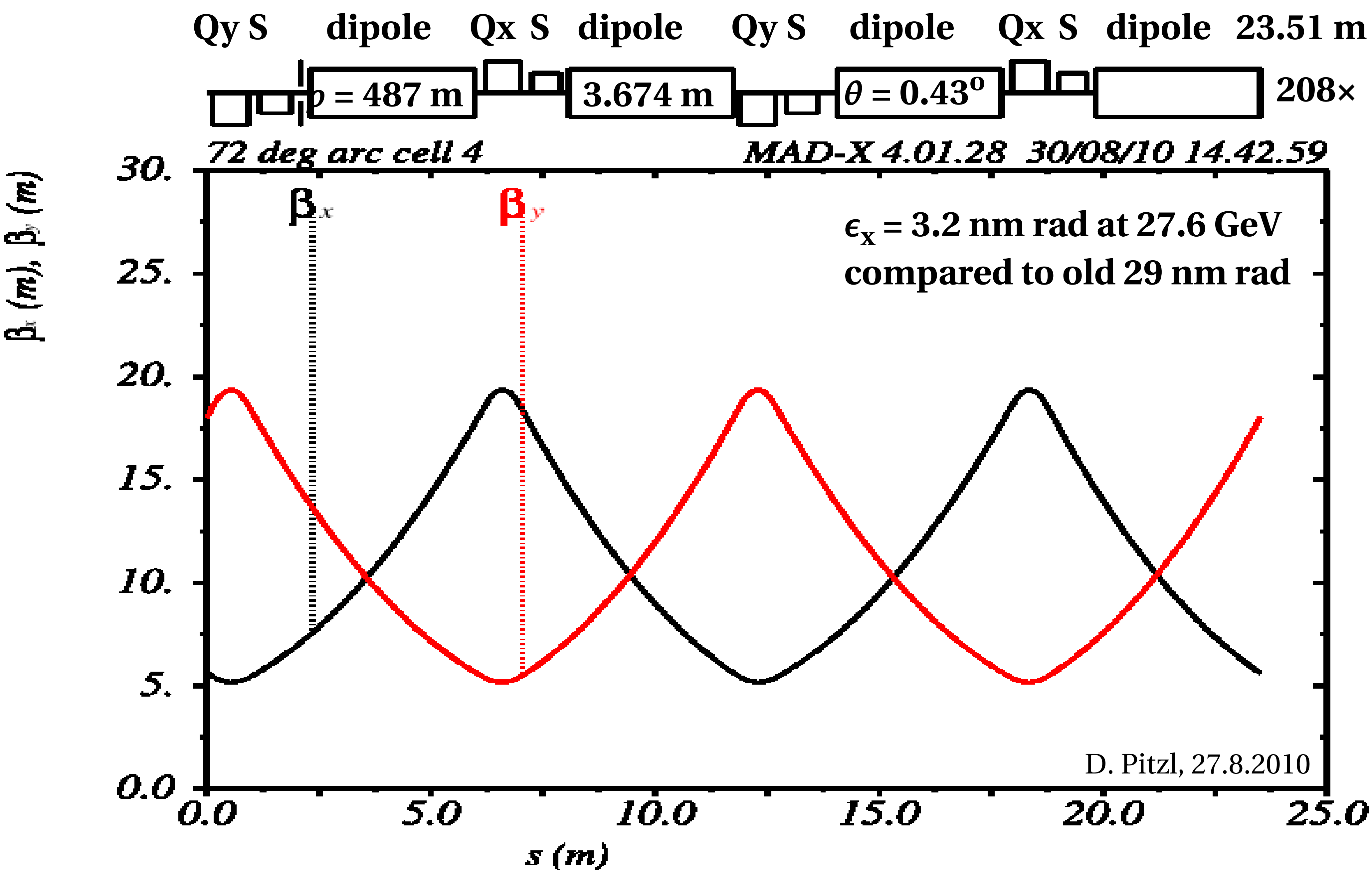


- new HERA-e
- working point
- multi-turn tracking
- dynamic aperture

new HERA-e arc cell

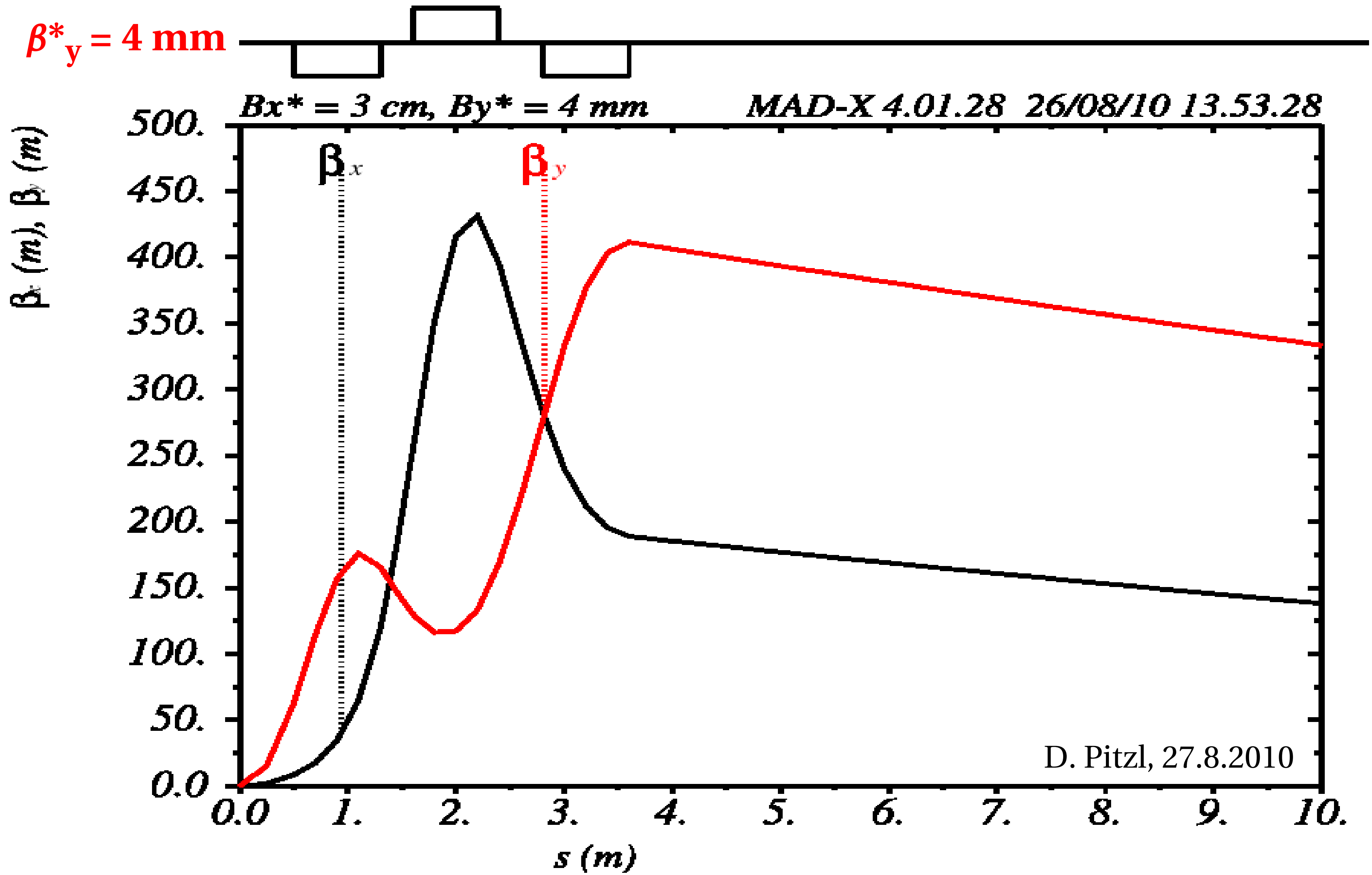


Interaction region

strong focusing super conducting quadrupole triplet

$\beta^*_x = 3$ cm

$\beta^*_y = 4$ mm

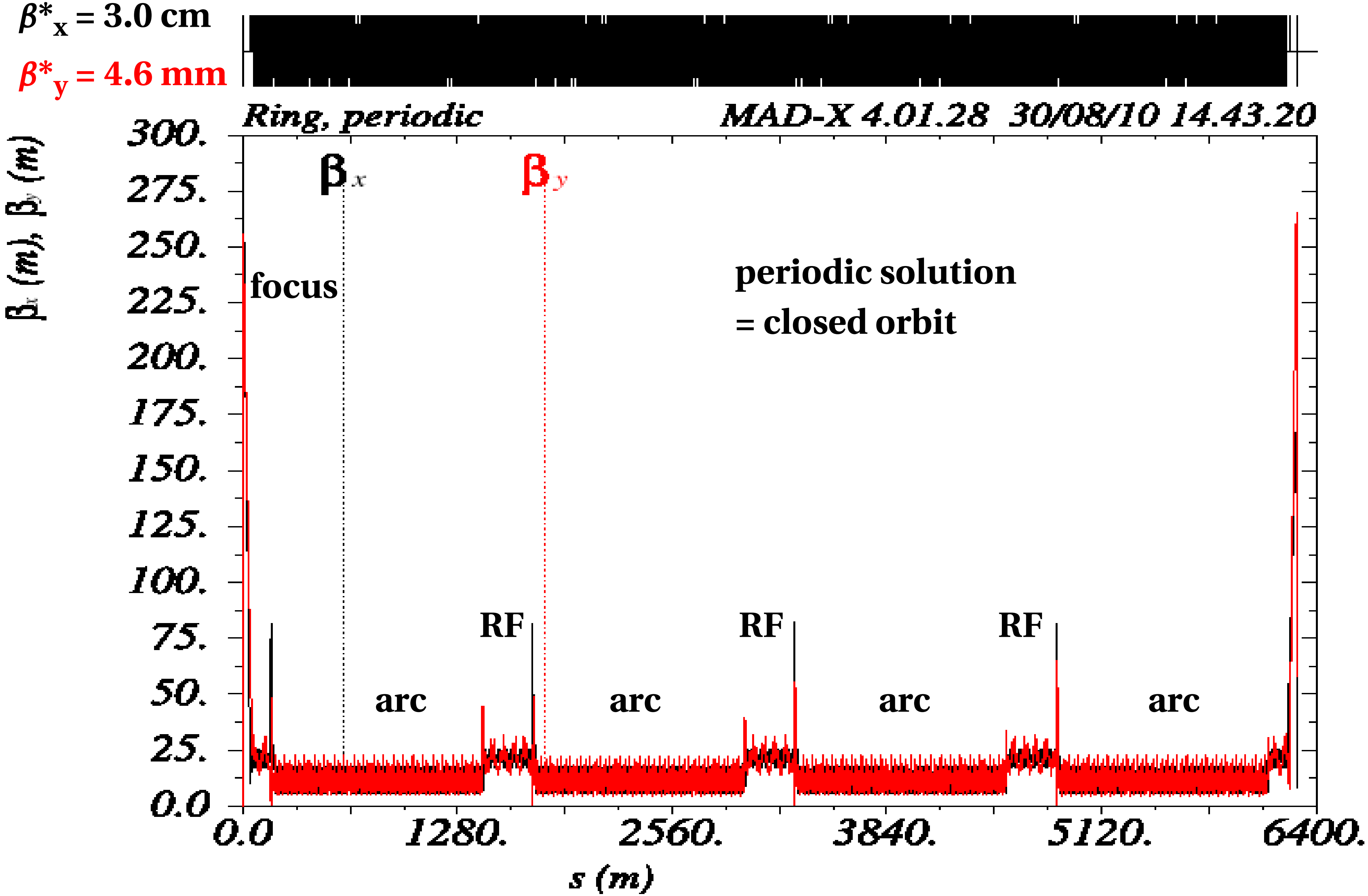


entire ring

from MAD-X:

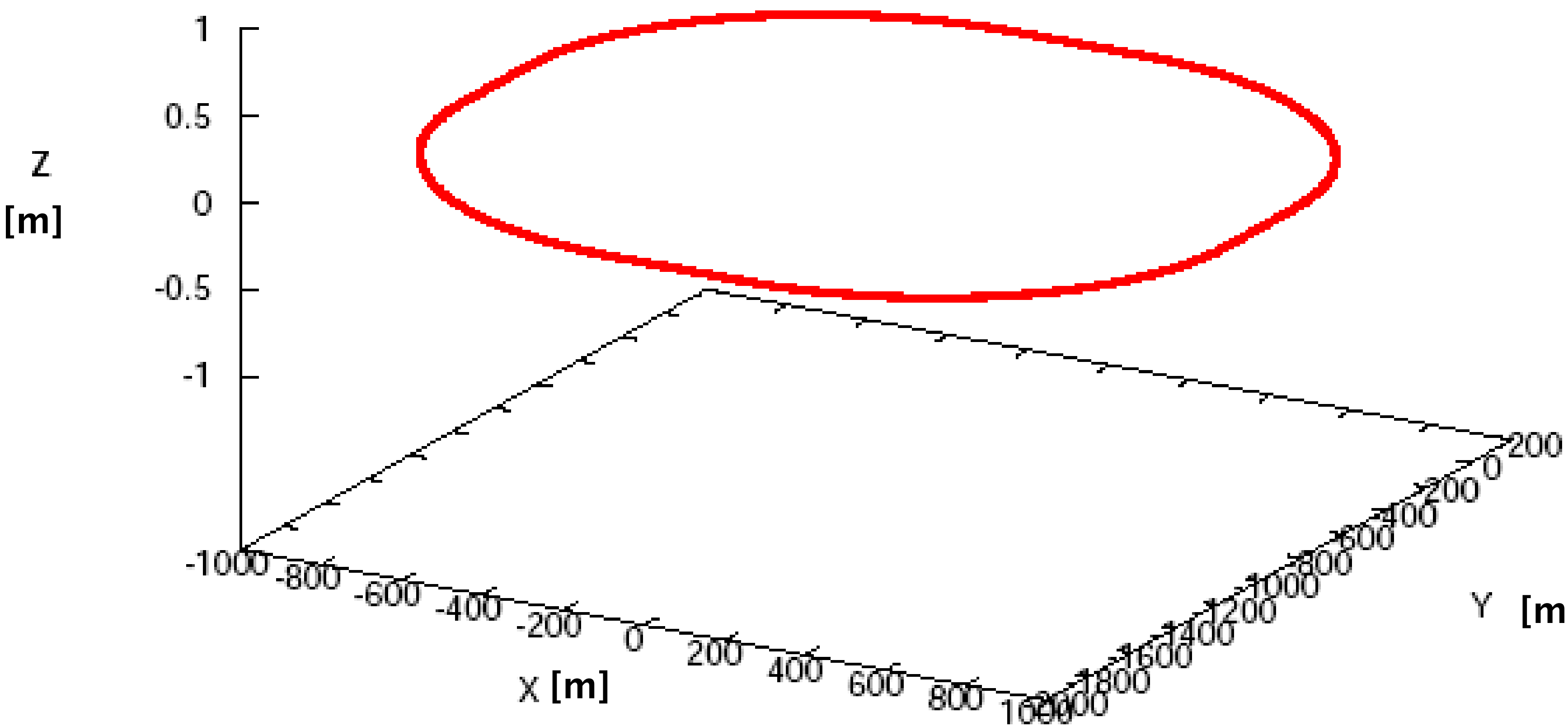
$\beta^*_x = 3.0$ cm

$\beta^*_y = 4.6$ mm



entire ring

MAD-X survey:



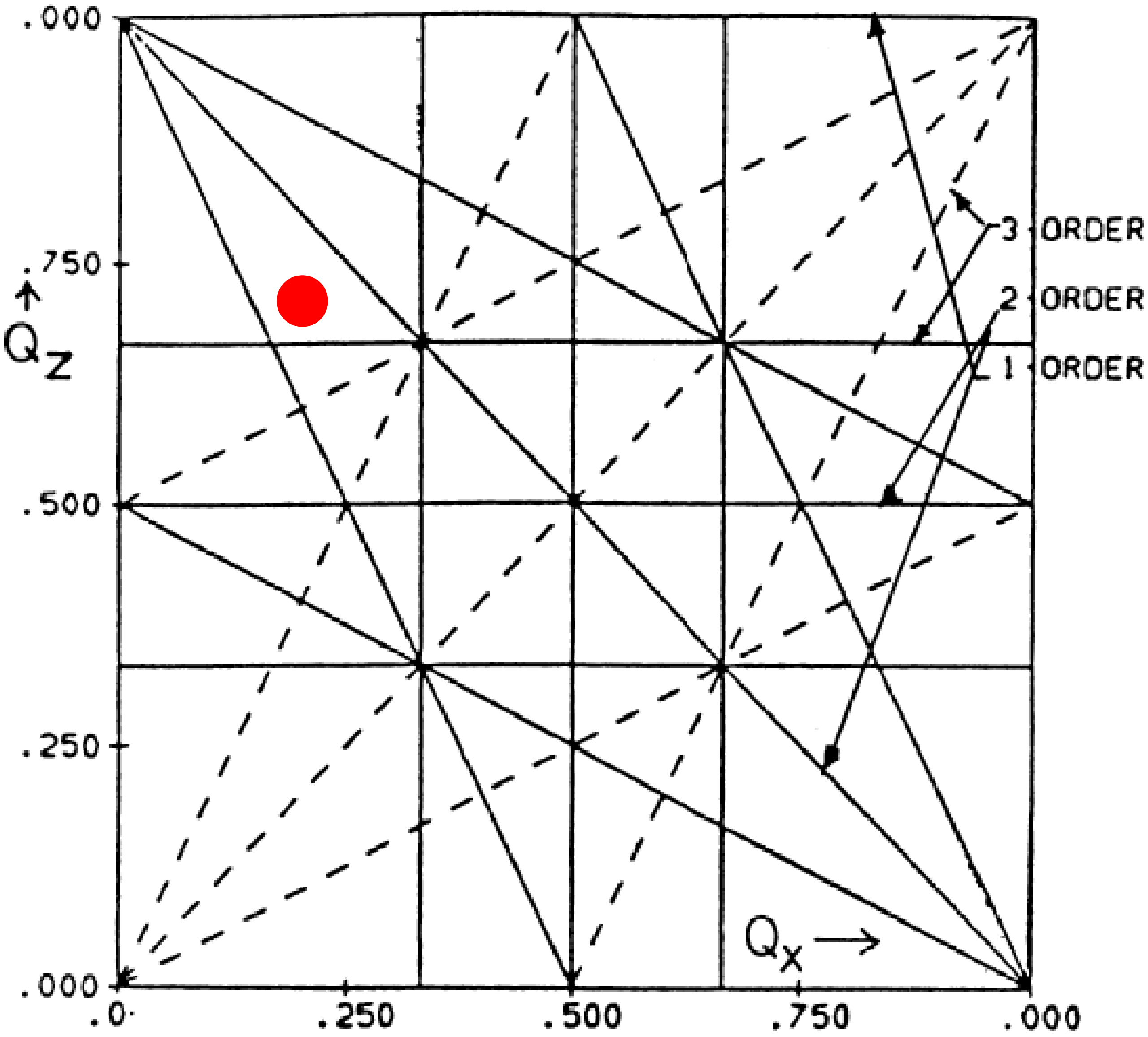
Open questions

- What is the dynamic aperture of the new e ring?
  - Beta function describes the 1 sigma envelope for nominal energy particles in linear approximation.
  - Strong sextupoles introduce x-y coupling and non-linear fields.
  - Beam has spread in position, angles, and energy.
  - Need to track individual particles with varying starting values for many turns to study non-linear effects.
- Goal:
  - Find parameter space for stable orbits.
  - Decide on viability of the new optics.
- Use old HERA-e as reference.

MAD-X

- Code for Methodical Accelerator Design MAD developed at CERN: http://mad.web.cern.ch/mad/
- Use PTC thick lens tracking:
  - PTC = polymorphic tracking code by Etienne Forest.
  - ICASE = 6 = dimensions (x, x', y, y', t, E)
  - Model = 2 = Matrix-kick-matrix
  - Method = 2 = integration order
  - NST = 1 = integration steps
  - Radiation on: damping by synchrotron emission and RF cavity
  - turns = 1000

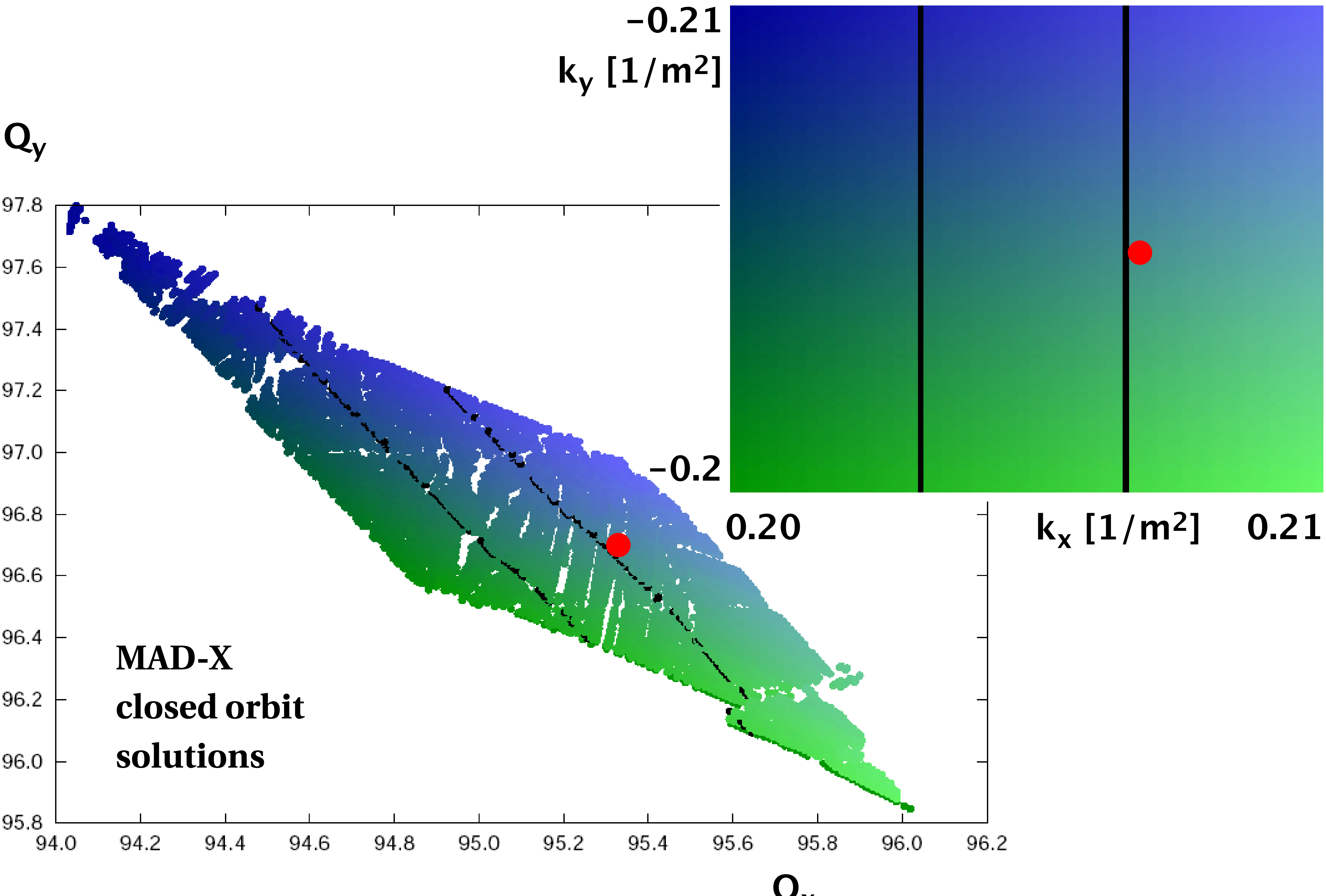
Working point in tune diagram



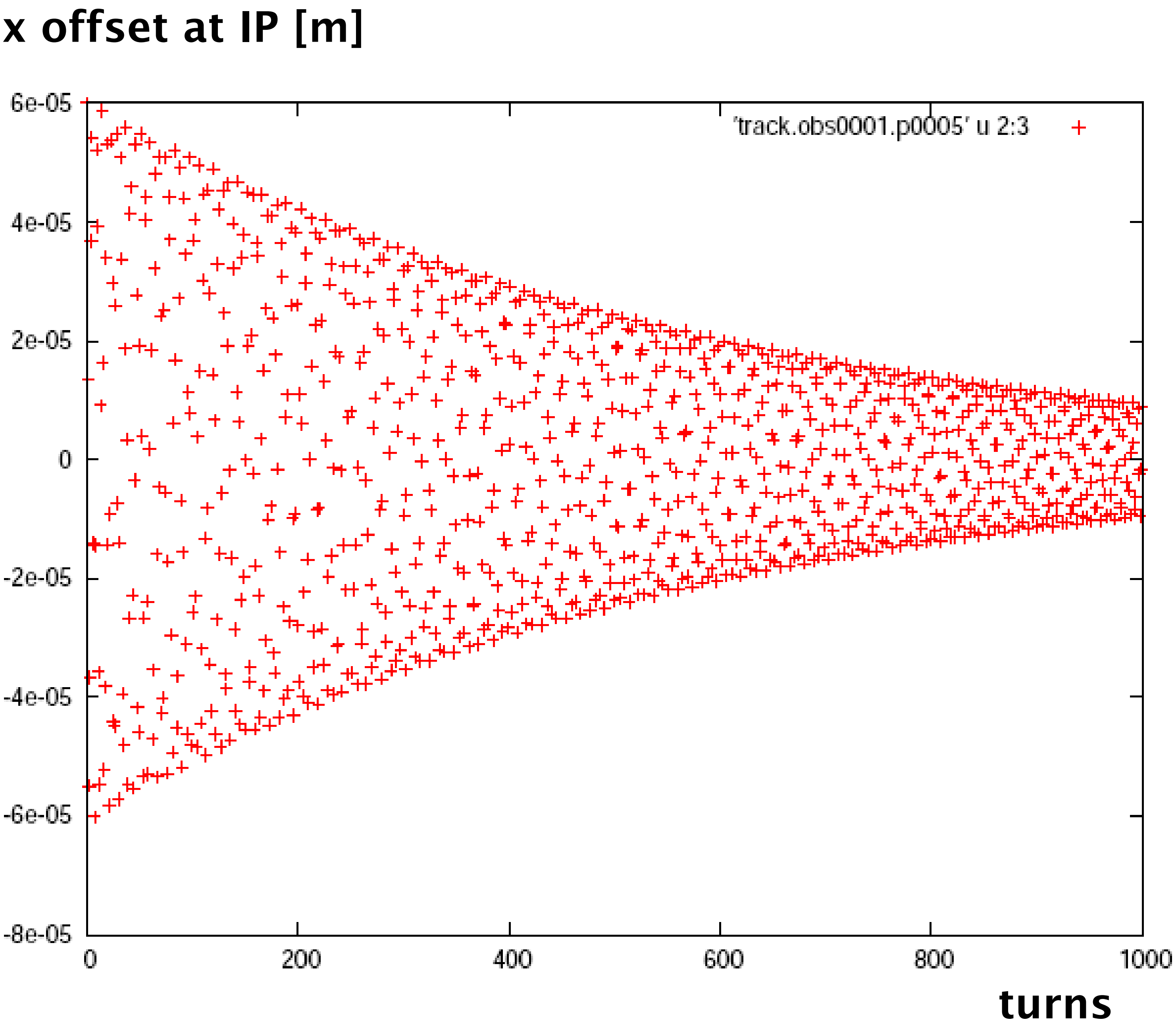
$$Q = \frac{1}{2\pi} \oint \frac{1}{\beta(s)} \, ds$$

- must avoid betatron resonances for the periodic closed orbit solution.
- Use quadrupoles in the straight sections to adjust fractional part of Q.

From quad strength to tune

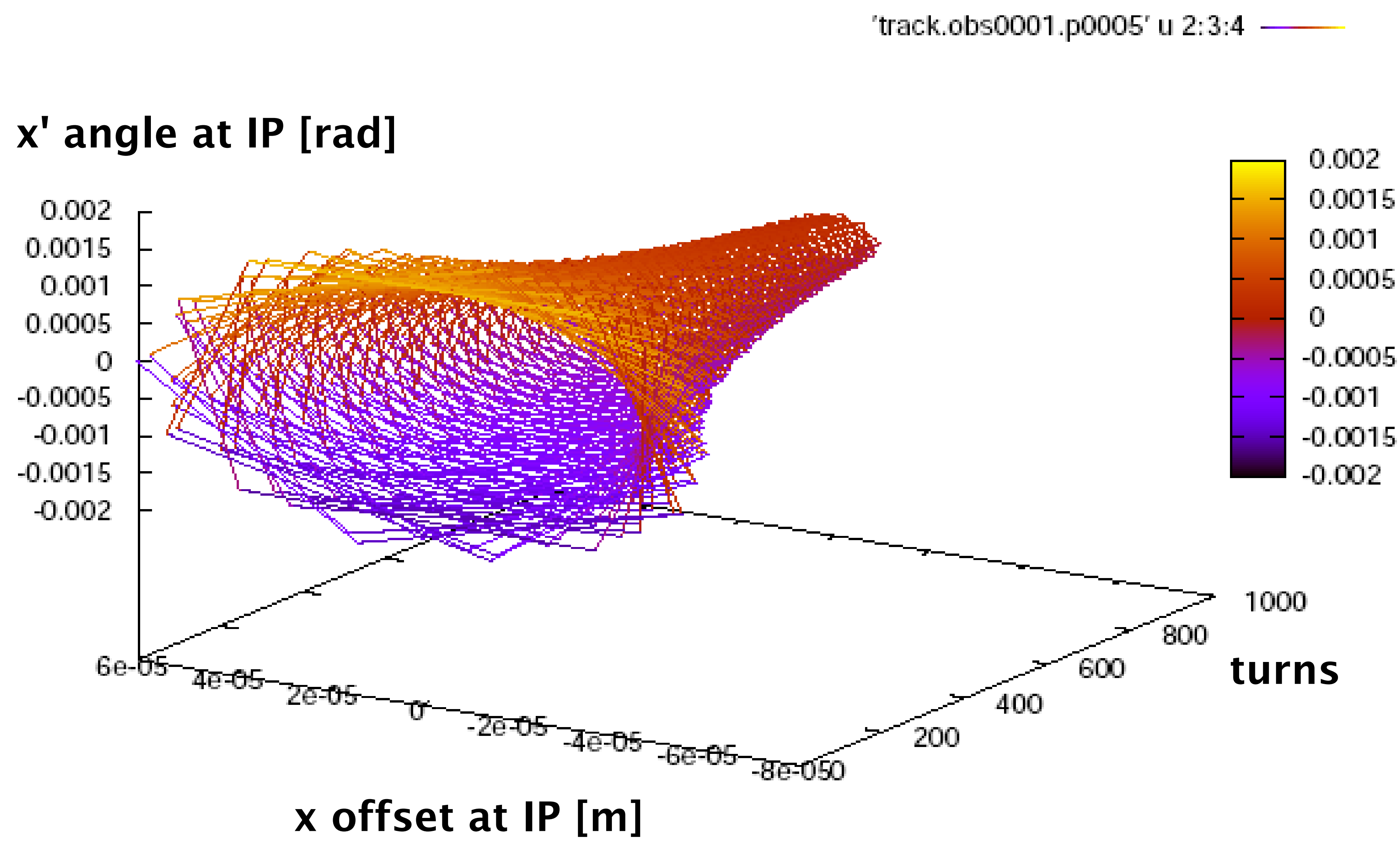


multi-turn damping of betatron oscillations

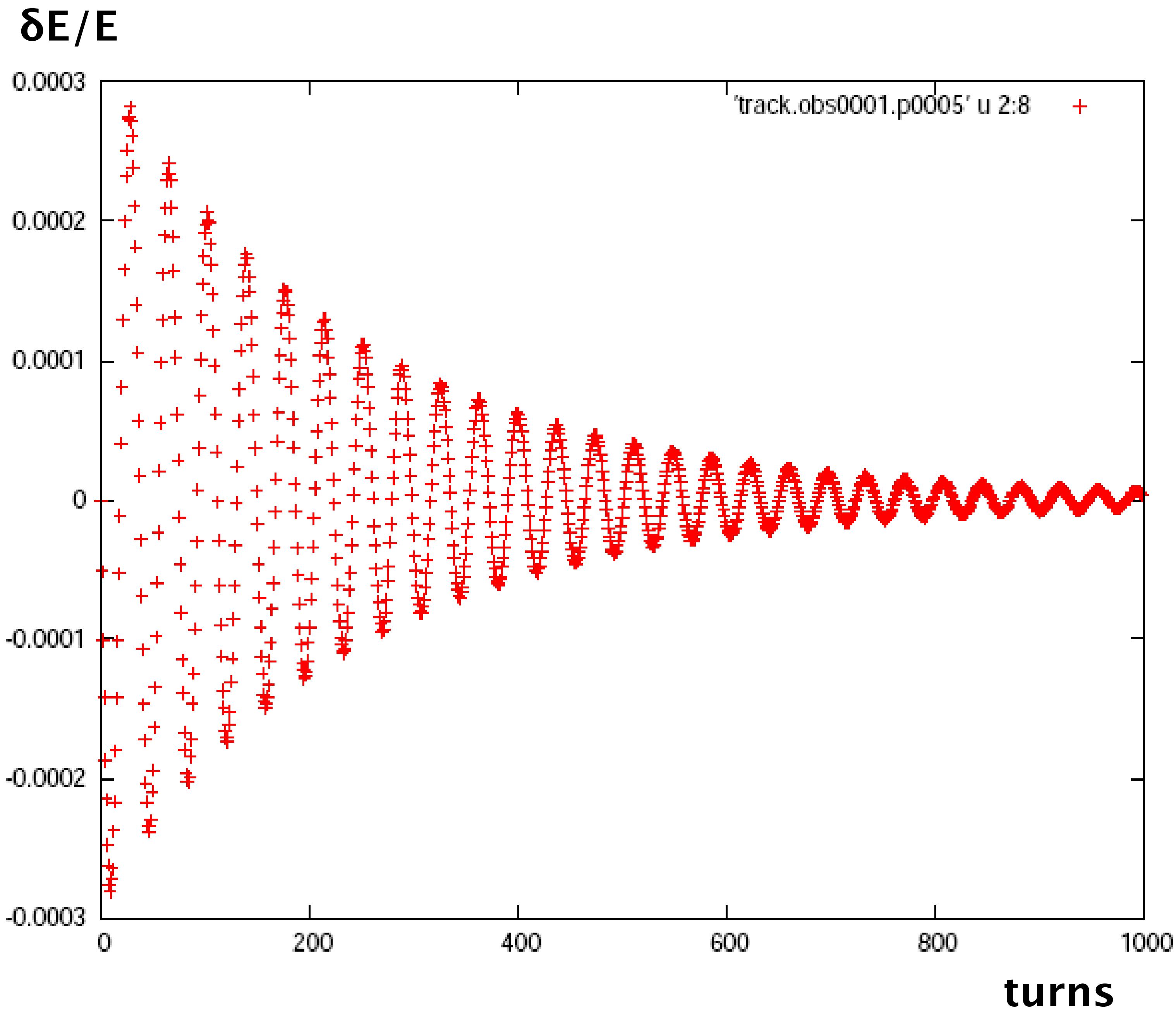


- Damping time constant from MAD-X:
  - τ_x = 11 ms = 520 turns.

multi-turn damping of betatron oscillations



multi-turn damping of synchrotron oscillations

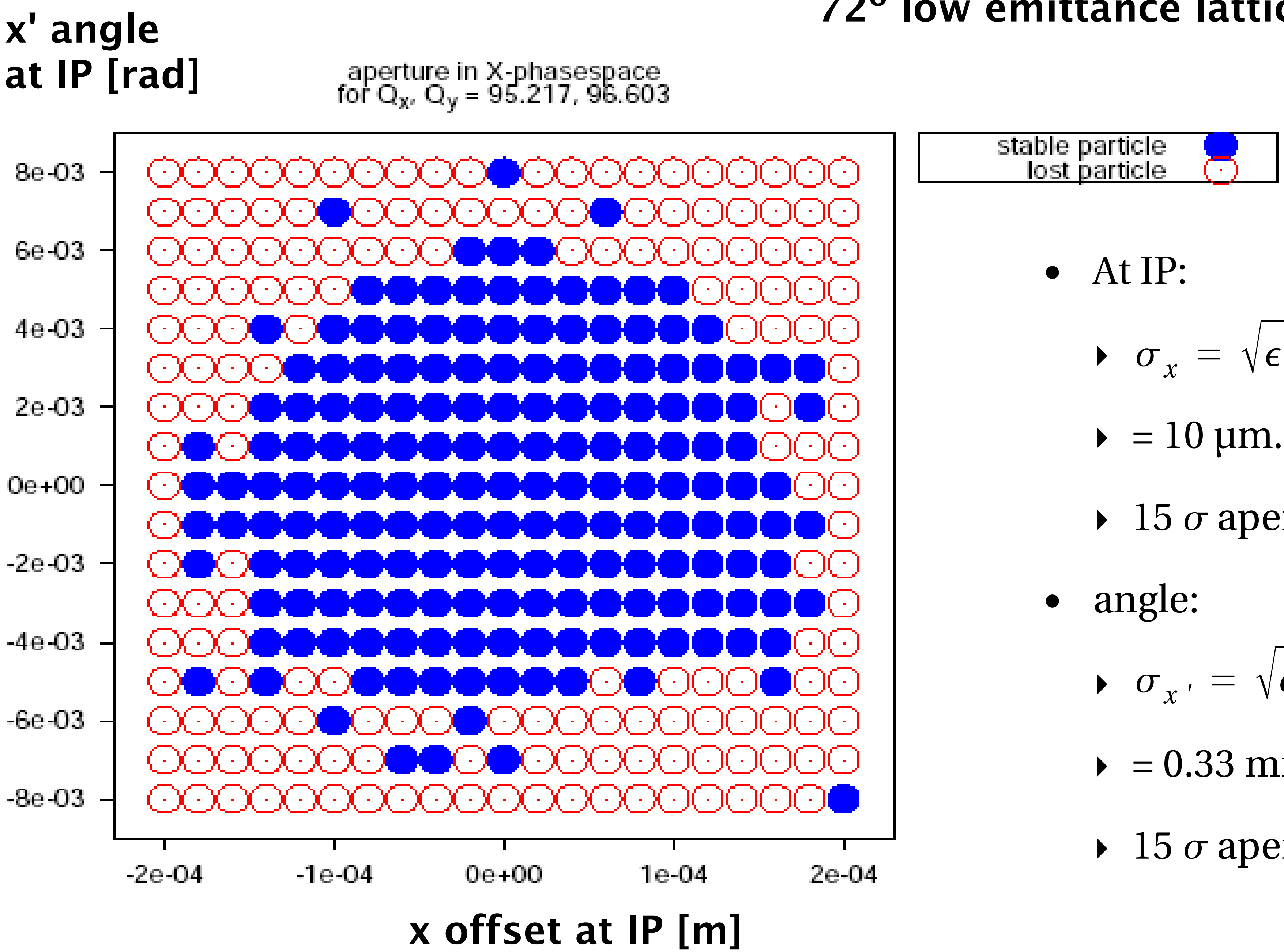


Damping time constant from MAD-X:

- $\tau_E = 5.5$ ms = 260 turns.
- Damping partition 1:1:2 (Robinson theorem).

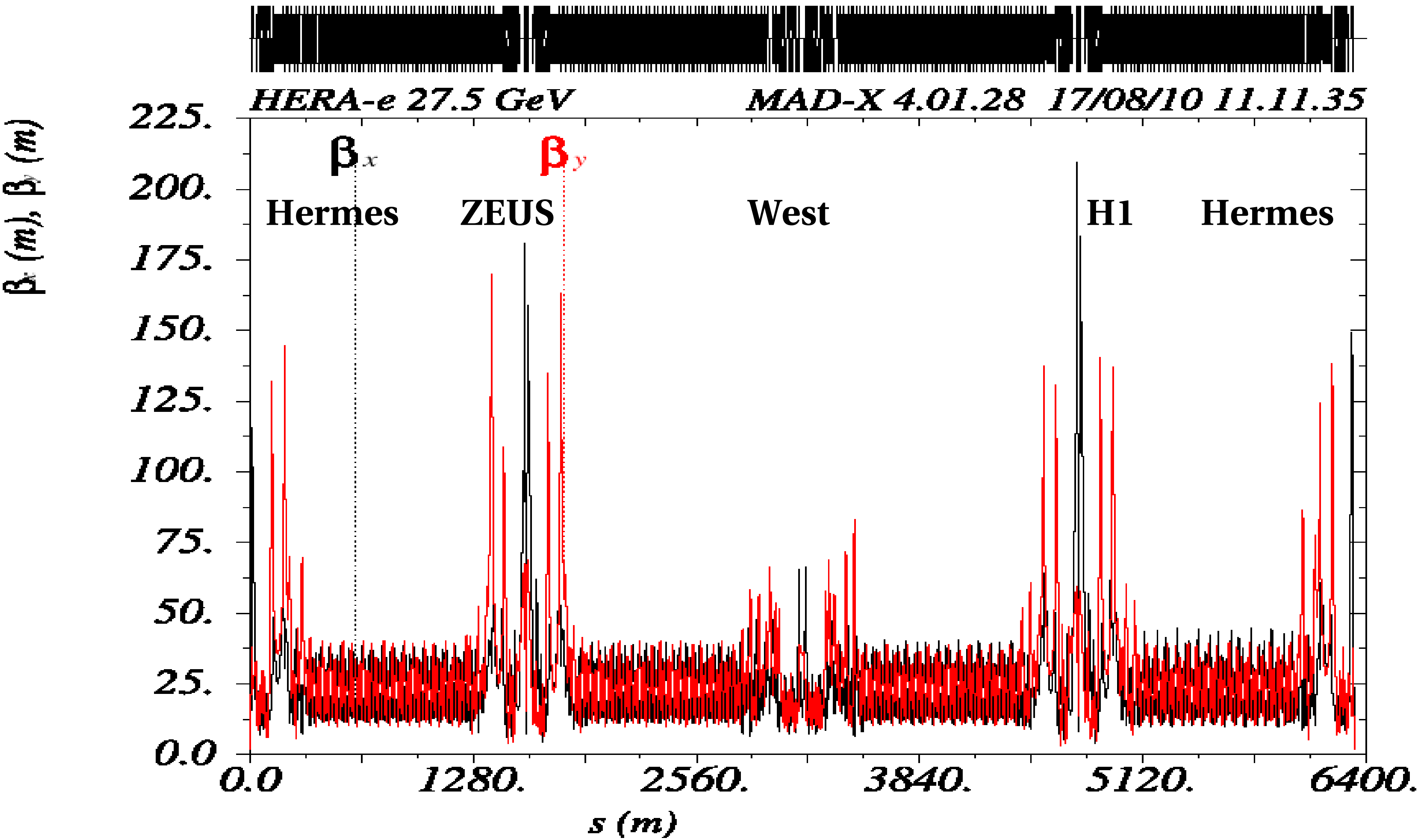
dynamic aperture

72° low emittance lattice

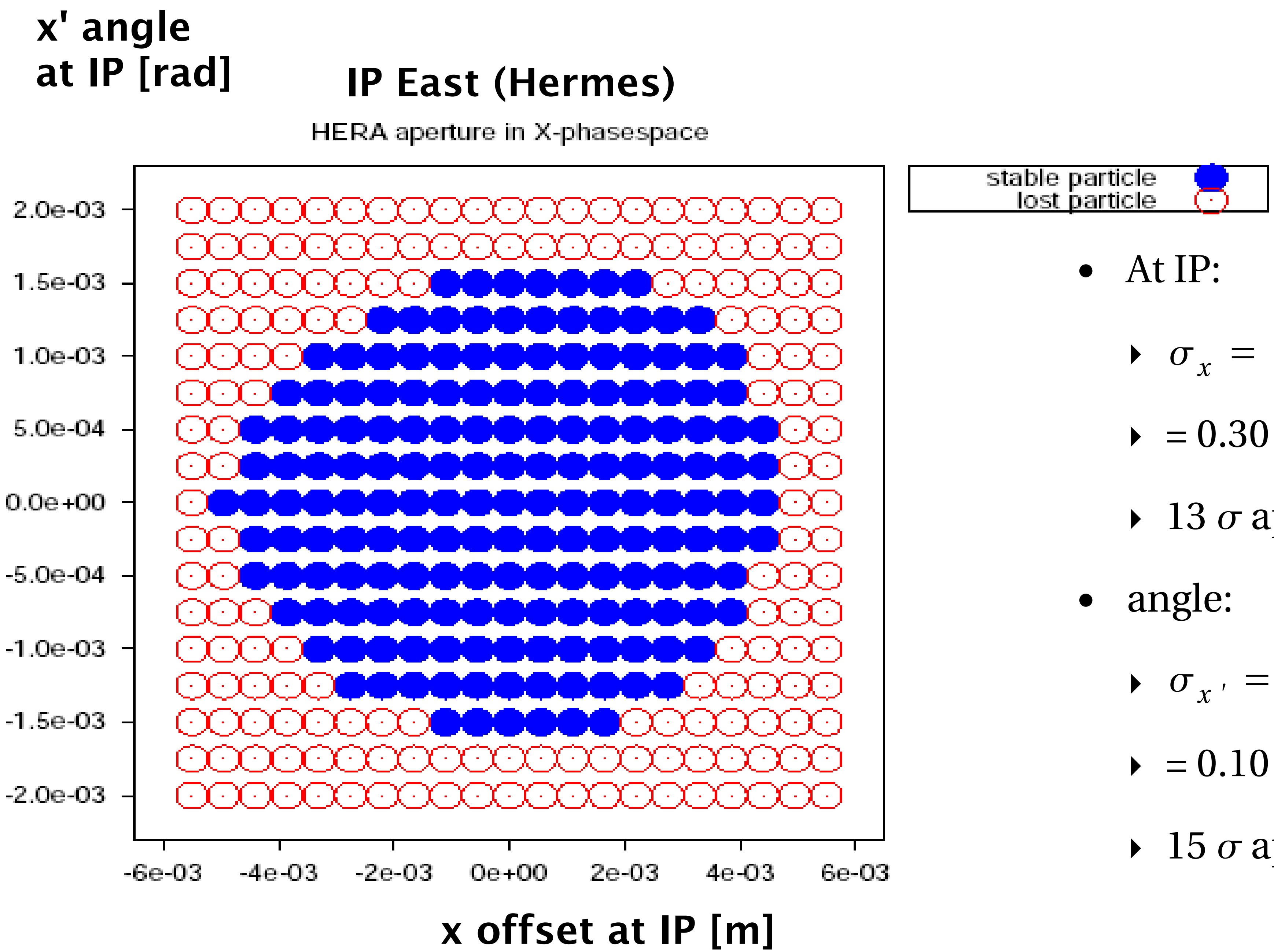


- At IP:
  - $\sigma_x = \sqrt{\epsilon_x \beta_x^\star}$
  - = 10 μm.
  - 15 σ aperture.
- angle:
  - $\sigma_{x'} = \sqrt{\epsilon_x / \beta_x^\star}$
  - = 0.33 mrad
  - 15 σ aperture.

Old HERA-e


HERA-e 27.5 GeV
MAD-X 4.01.28 17/08/10 11.11.35
β_x
β_y
Hermes
ZEUS
West
H1
Hermes
225.
200.
175.
150.
125.
100.
75.
50.
25.
0.0
0.0
1280.
2560.
3840.
5120.
6400.
s (m)
β_x (m), β_y (m)

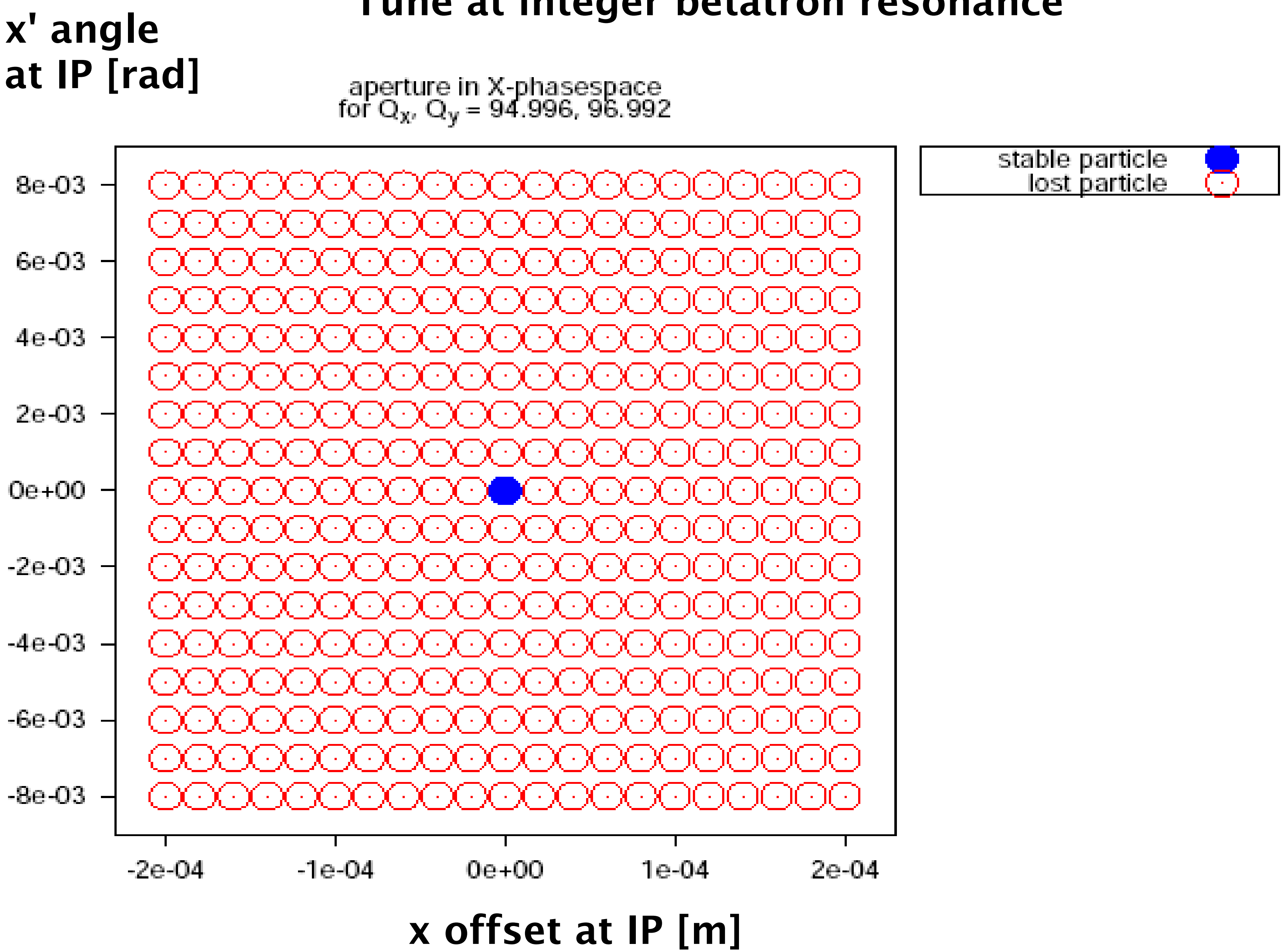
dynamice aperture for old HERA-e



- At IP:
  - $\sigma_x = \sqrt{\epsilon_x \beta_x^\star}$
  - = 0.30 mm.
  - 13 σ aperture.
- angle:
  - $\sigma_{x'} = \sqrt{\epsilon_x / \beta_x^\star}$
  - = 0.10 mrad
  - 15 σ aperture.

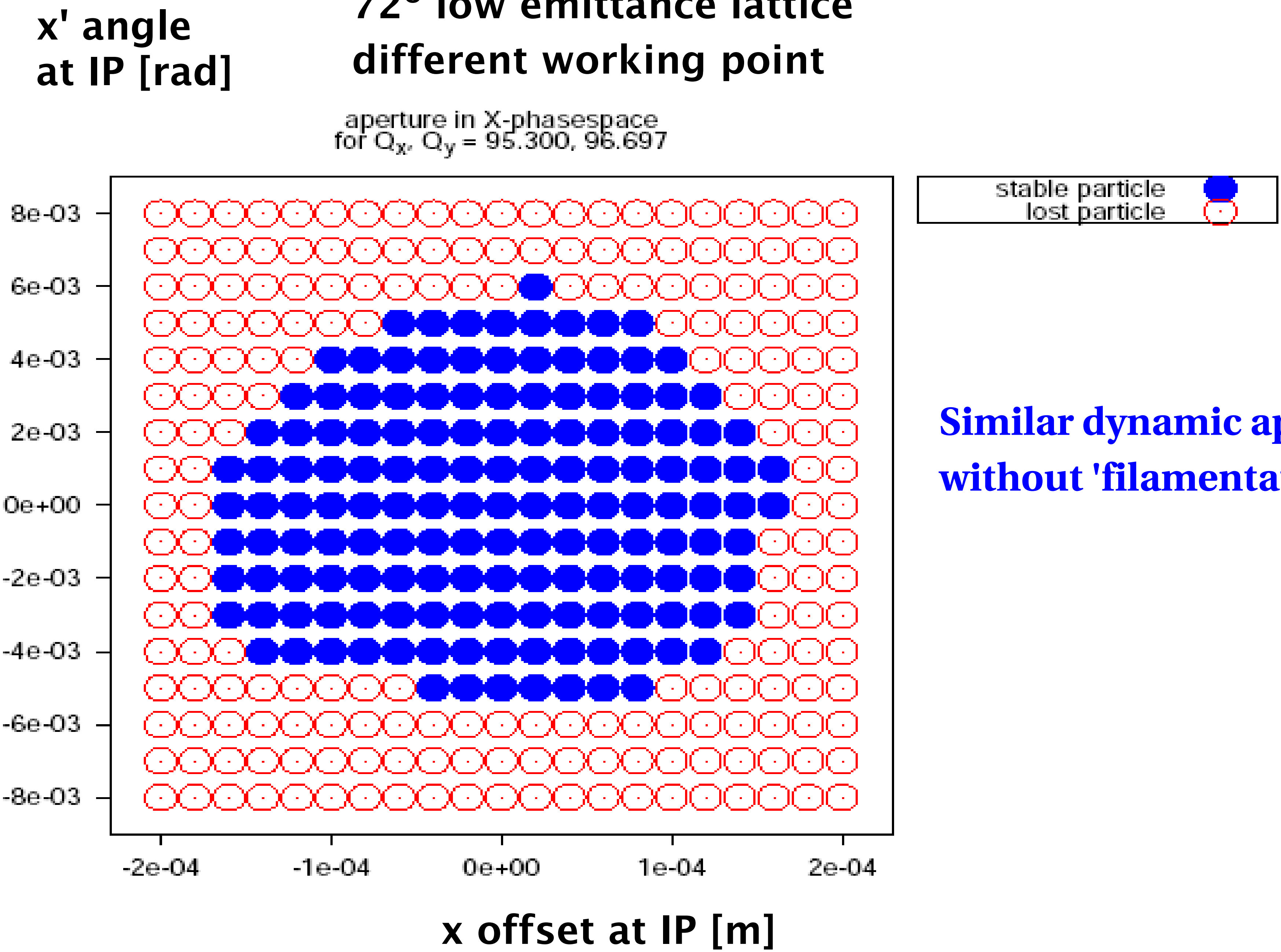
dynamic aperture close to resonance

Tune at integer betatron resonance



dynamic aperture

72° low emittance lattice
different working point



Similar dynamic aperture, without 'filamentation'.

old and new HERA-e

MAD-X	**old**	**new**
Dipole bend:	0.86^o	0.43^o
Emittance:		
ϵ_x [nm rad]	29.8	**3.2**
Tune:		
Q_x	53.27	95.2
Q_y	51.41	98.6
Dynamic aperture:		
x	13 σ	15 σ
x'	15 σ	15 σ
$\delta E/E$	$0.005 = 5\ \sigma$	$0.005 = 5\ \sigma$

Summary

- Dynamic aperture of the lower emittance HERA-e lattice studied with tracking in MAD-X:
  - seems to be similar to old HERA-e, at least in x-x'.
- Next:
  - Explore full 6-D parameter space (x, x', y, y', t, E)
  - Try 108^{o} optics (factor 2.5 smaller emittance, stronger focussing, larger chromaticity).
- Further:
  - Study beam-beam interactions.