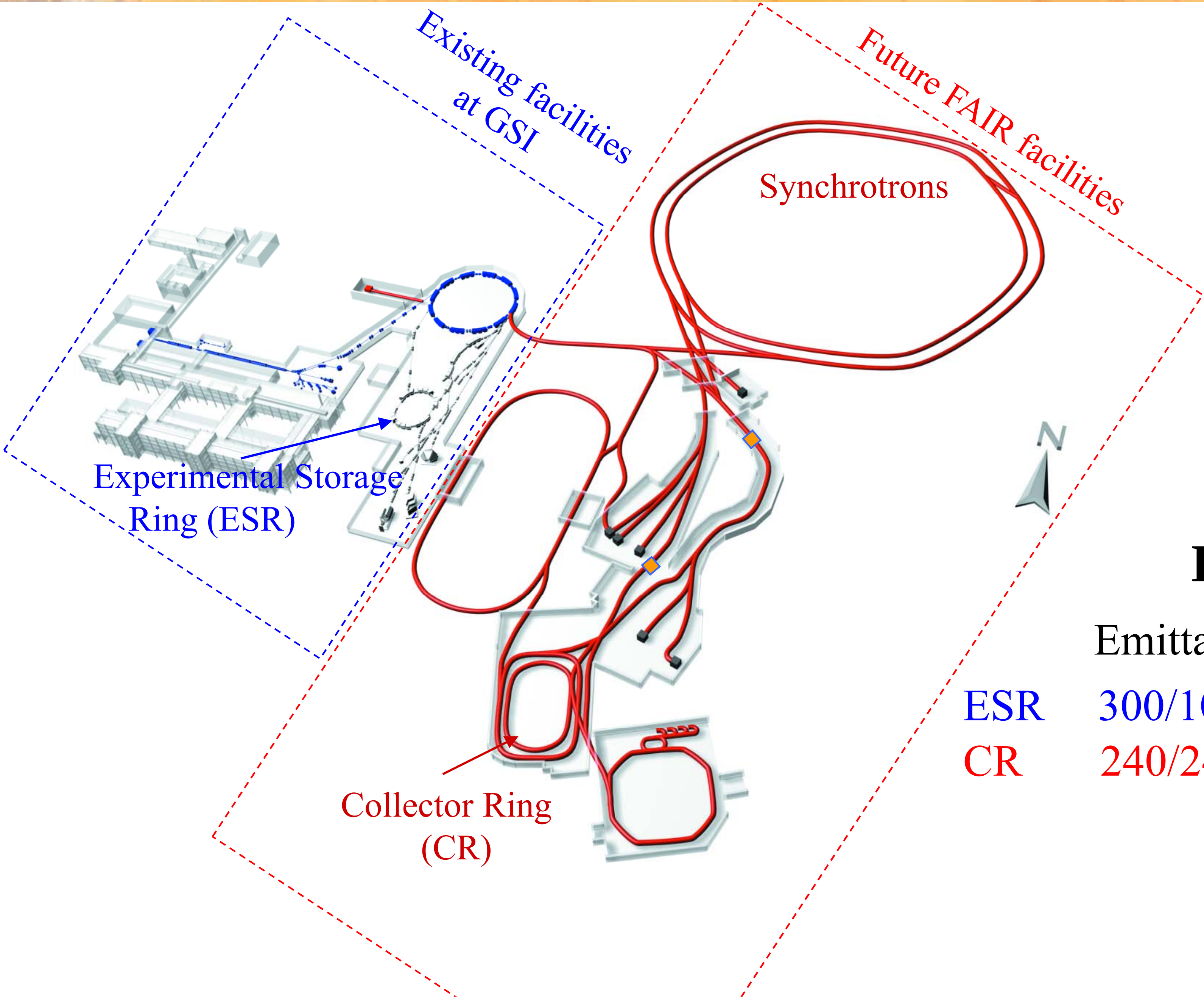
Nonlinear Beam Dynamics of Large Acceptance Storage Ring ESR at GSI

Oleksii Gorda

GSI-FAIR



GSI – Gesselschaft für Schwerionenforchung

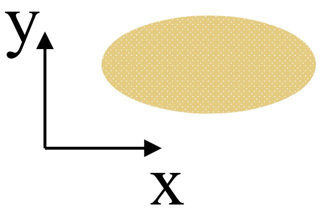
FAIR – Facility for Antiproton and Ion Research

Injected beam:

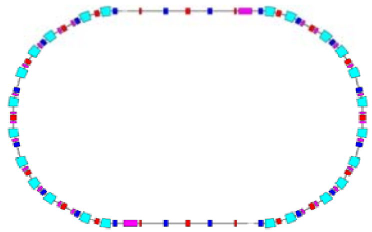
	Emittance x/y	Momentum
ESR	300/100 mm mrad	±1.5%
CR	240/240 mm mrad	±3%

Large Acceptance

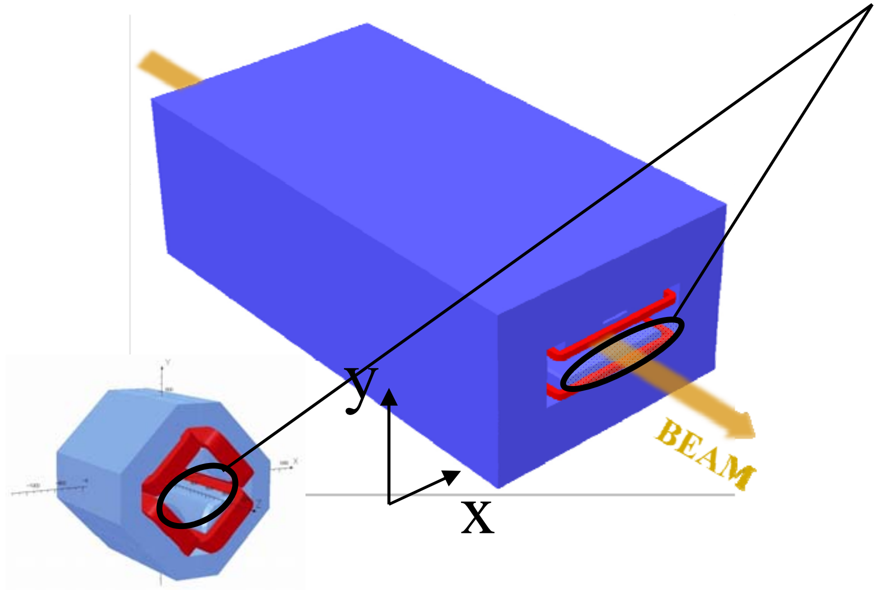
Beam size



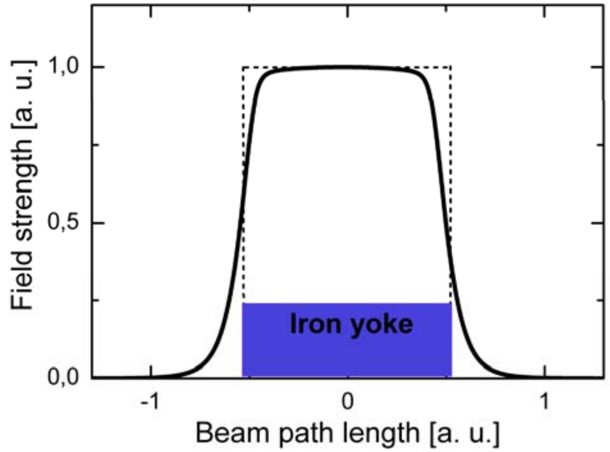
Ring acceptance



Magnet aperture

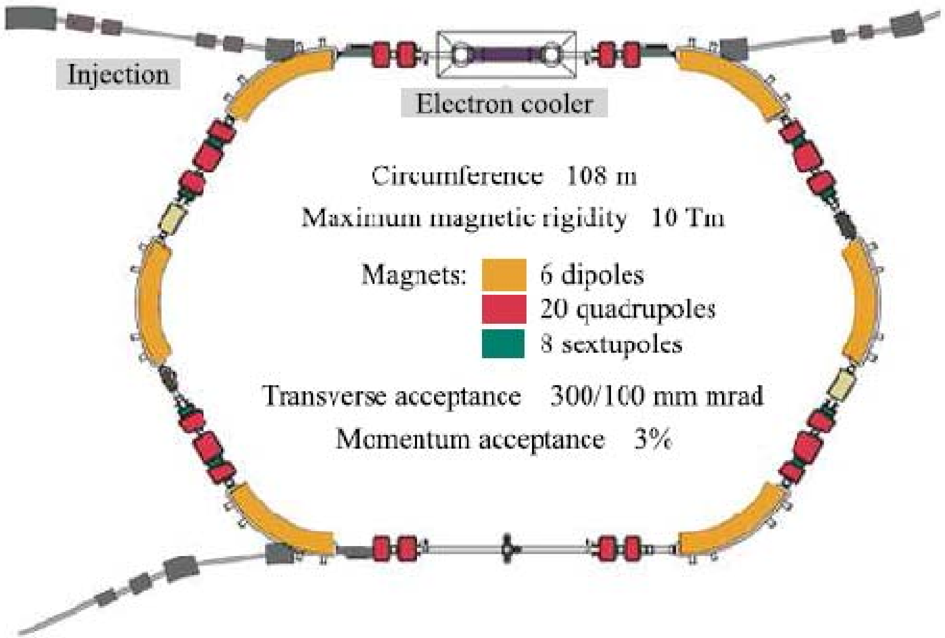


Field quality



The larger the magnet aperture, the stronger the field nonlinearities

Experimental Storage Ring (ESR)

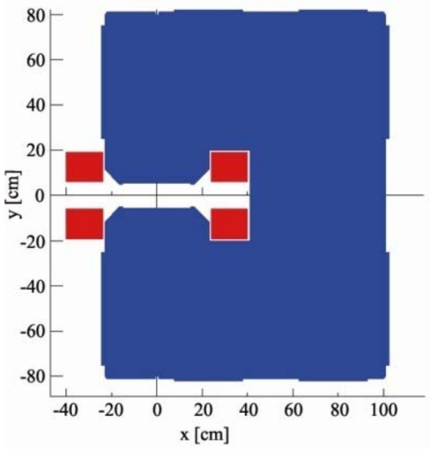


- ➢ Accumulation and storage of heavy ions
- ➢ Energy range: 40 MeV – 1 GeV
- ➢ Electron and stochastic cooling

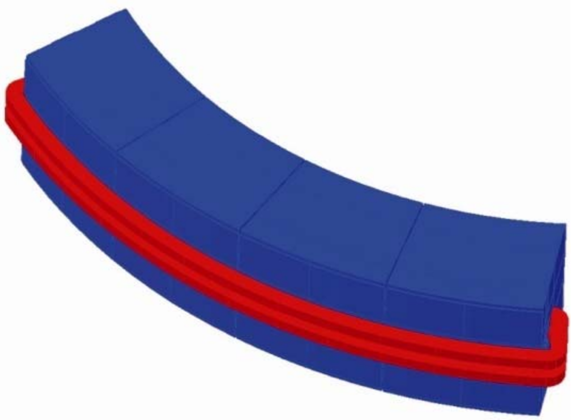
Magnets of the ESR

Dipole

Bending angle 60°
Maximum field 1.6 T
Horizontal aperture 30 cm
Vertical aperture 10 cm



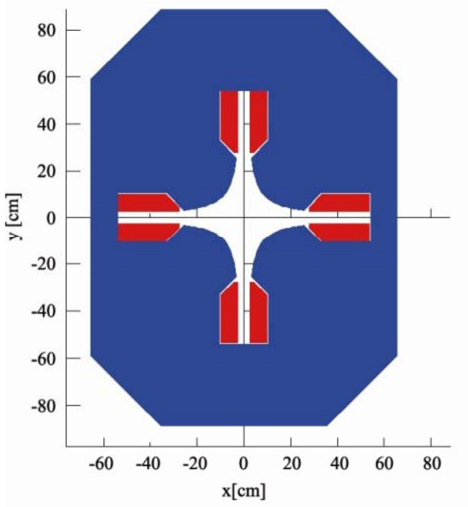
a) Cross section



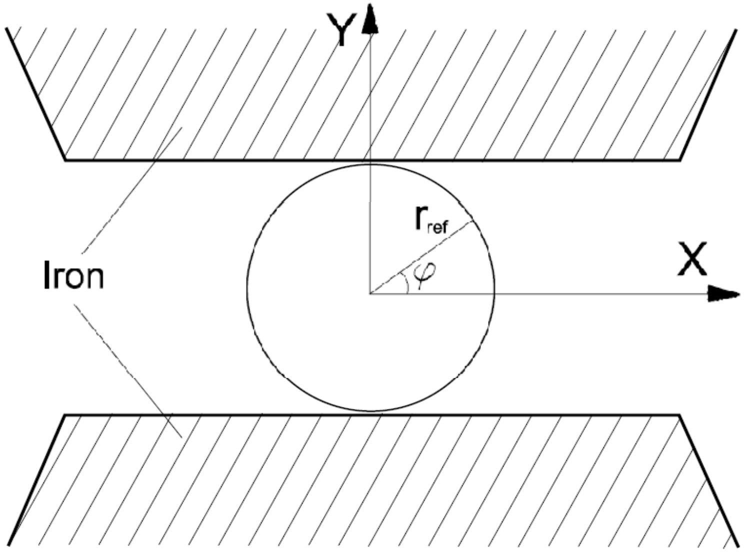
b) 3D view

Quadrupole

Maximum field gradient 6.2 T/m
Pole-gap aperture 25.6 cm



Field Analysis

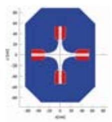


Multipole analysis

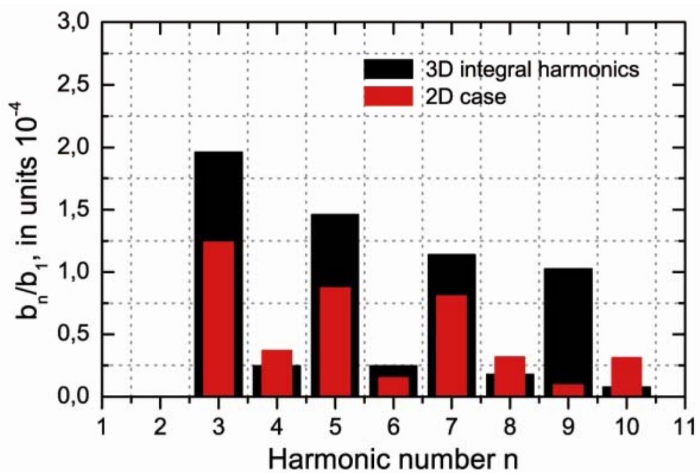
$$B_r(r_{ref},\varphi) = B_0 \sum_{n=1}^{\infty} \left(b_n(r_{ref}) \sin(n\varphi) + a_n(r_{ref}) \cos(n\varphi) \right)$$

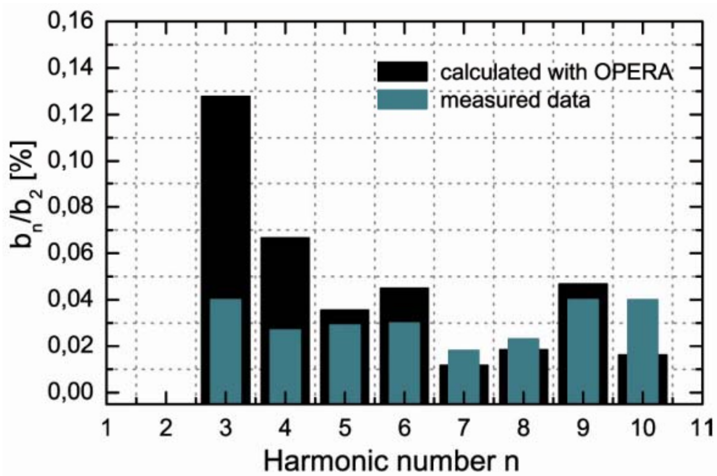
B_0 – main field harmonics
b_n – normal component
a_n – skew component
n=1, 2, 3.. corresponds to dipole, quadrupole, sextupole comp. etc.

Dipole

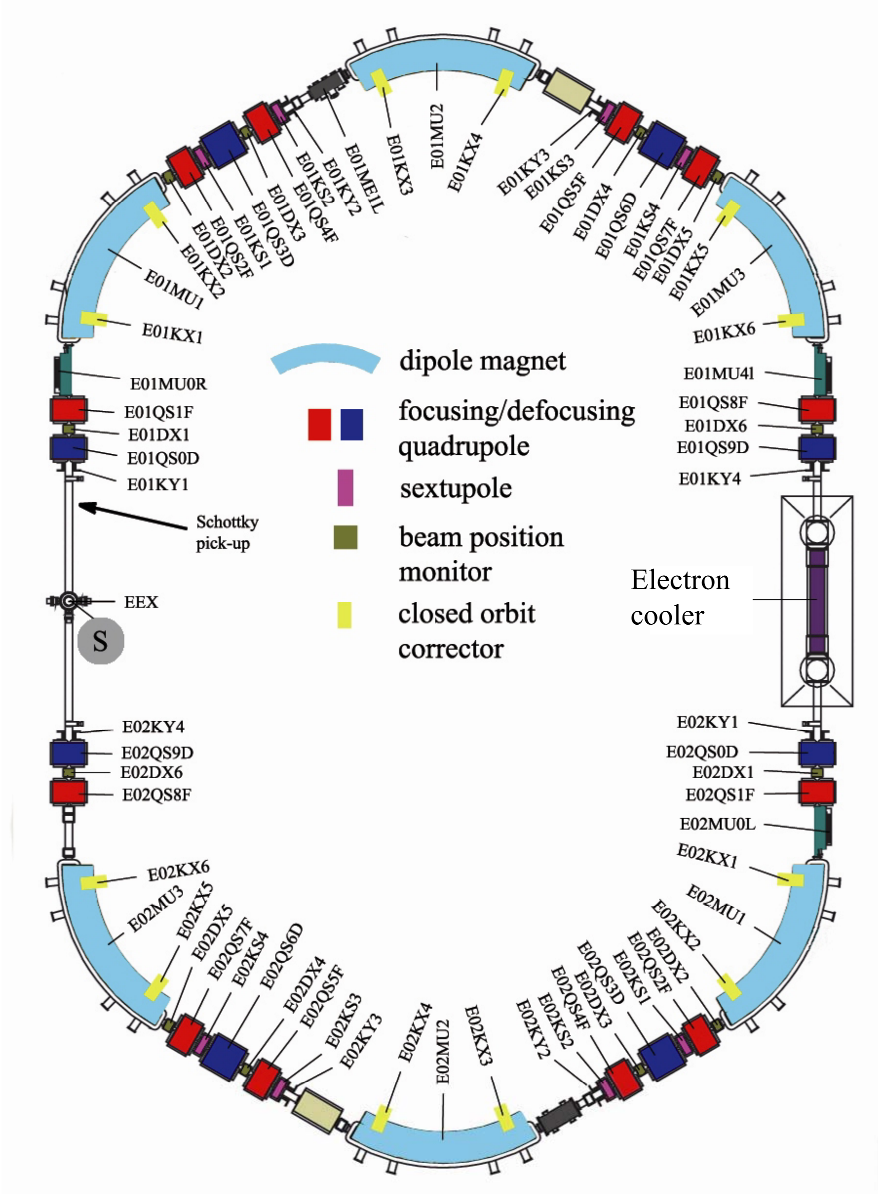


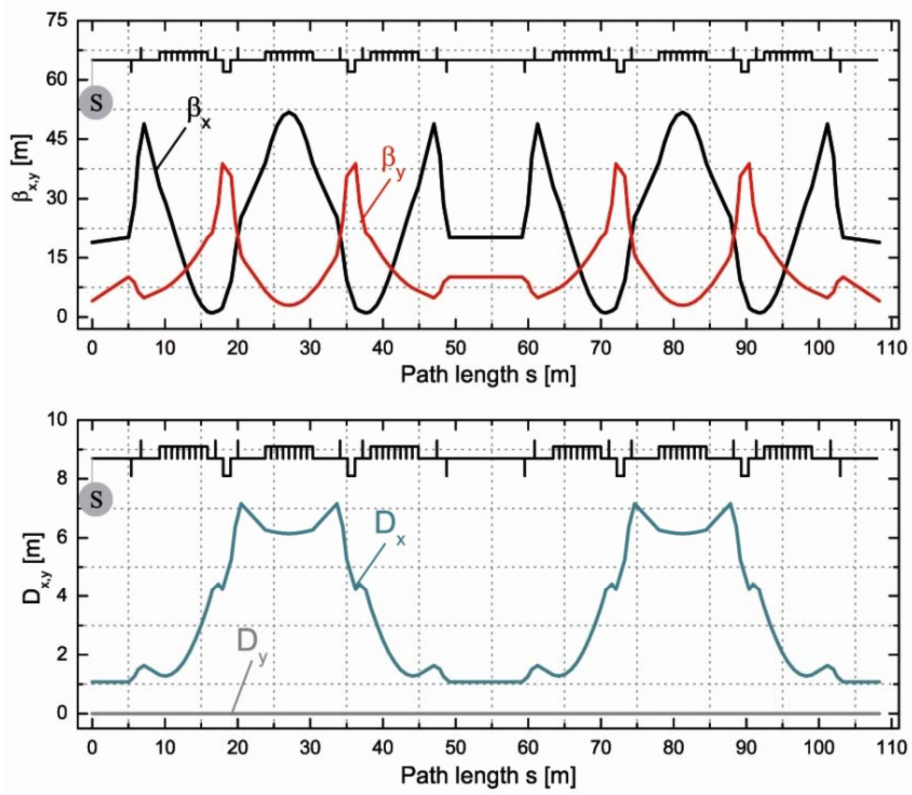
Quadrupole





ESR Lattice





Electron cooler:

Ion energy range 30 – 560 MeV

Electron energy 16 – 310 keV

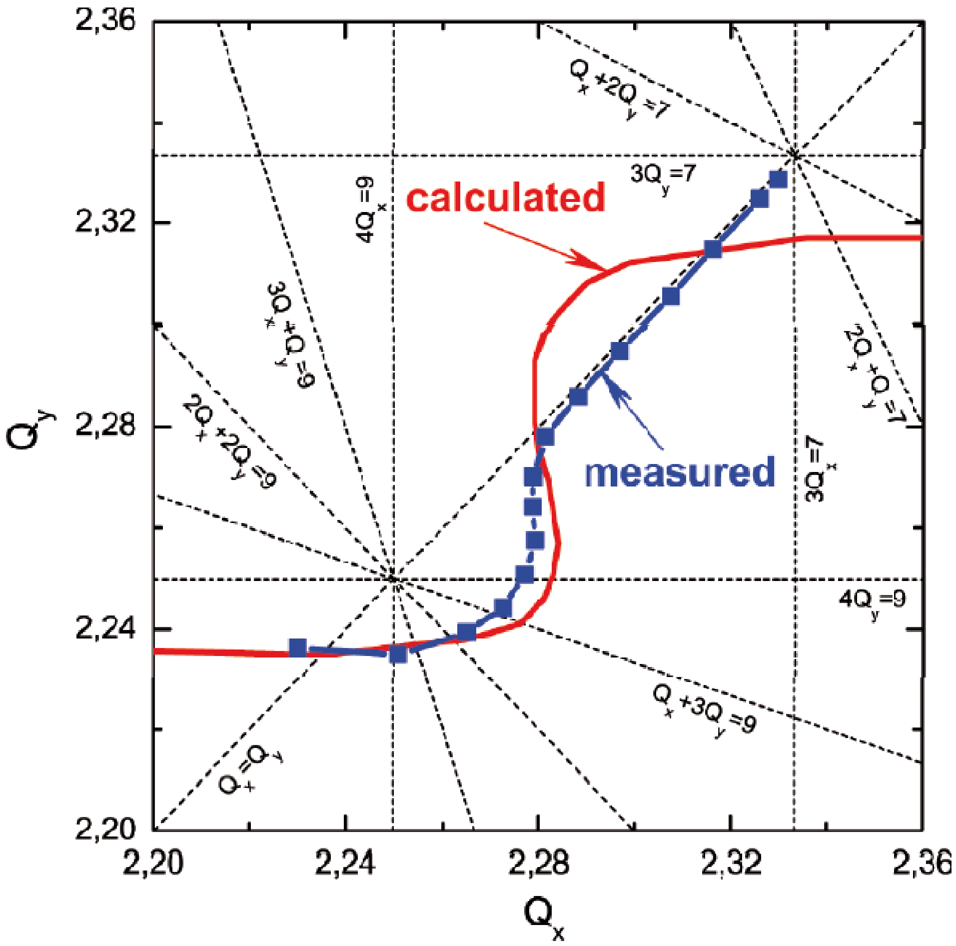
Chromaticity correction:

8 sextupoles

Chromatic Tune Shift

$Q_{x,y}$ – number of particle oscillations per revolution, or the tune. Crossing of resonance lines leads to unstable motion of particles

PTC – Polymorphic Tracking Code

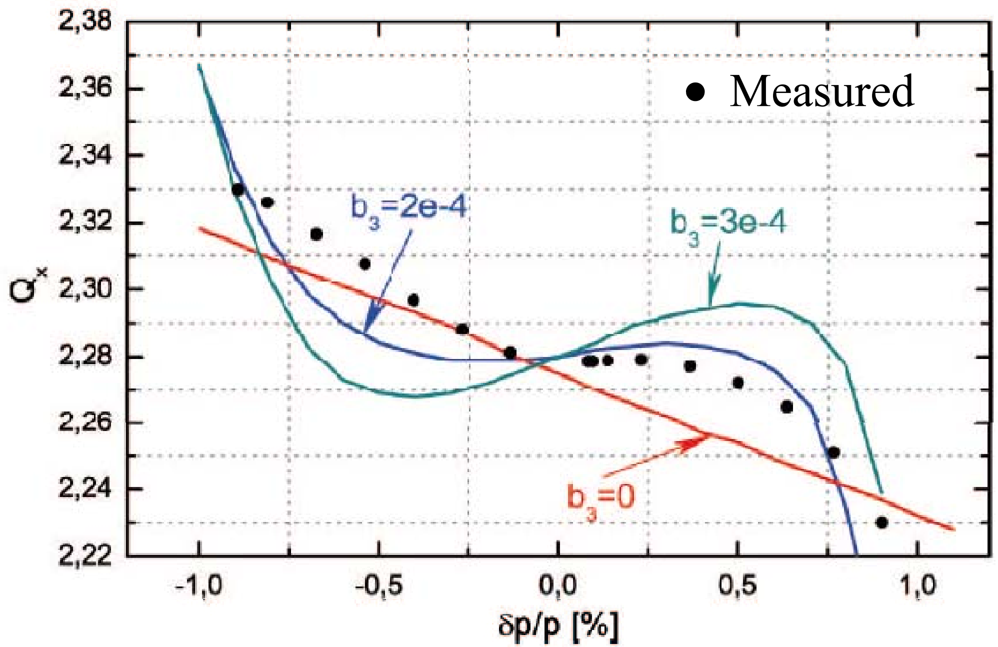


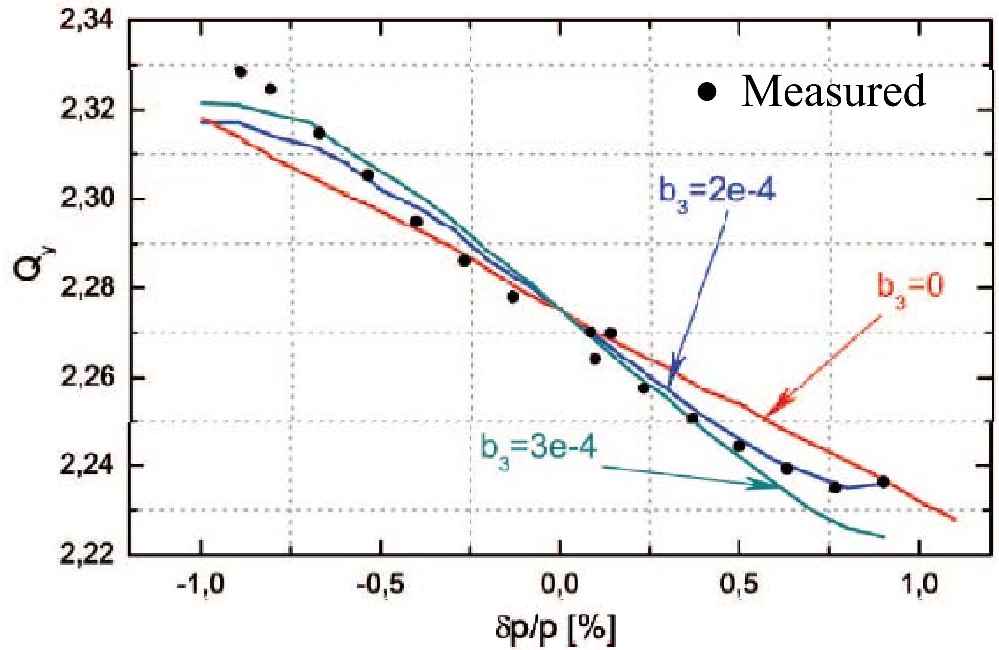
Measurements were performed with $^{64}Ni^{28}$ at 400 MeV/u. The beam energy was changed by adjusting the electron beam energy.

In the tracking simulations with the PTC, the field errors calculated by the OPERA were used.

Influence of Sextupolar Fields

b_3 -sextupole component of the dipole magnet





Chromatic sextupoles: switched OFF

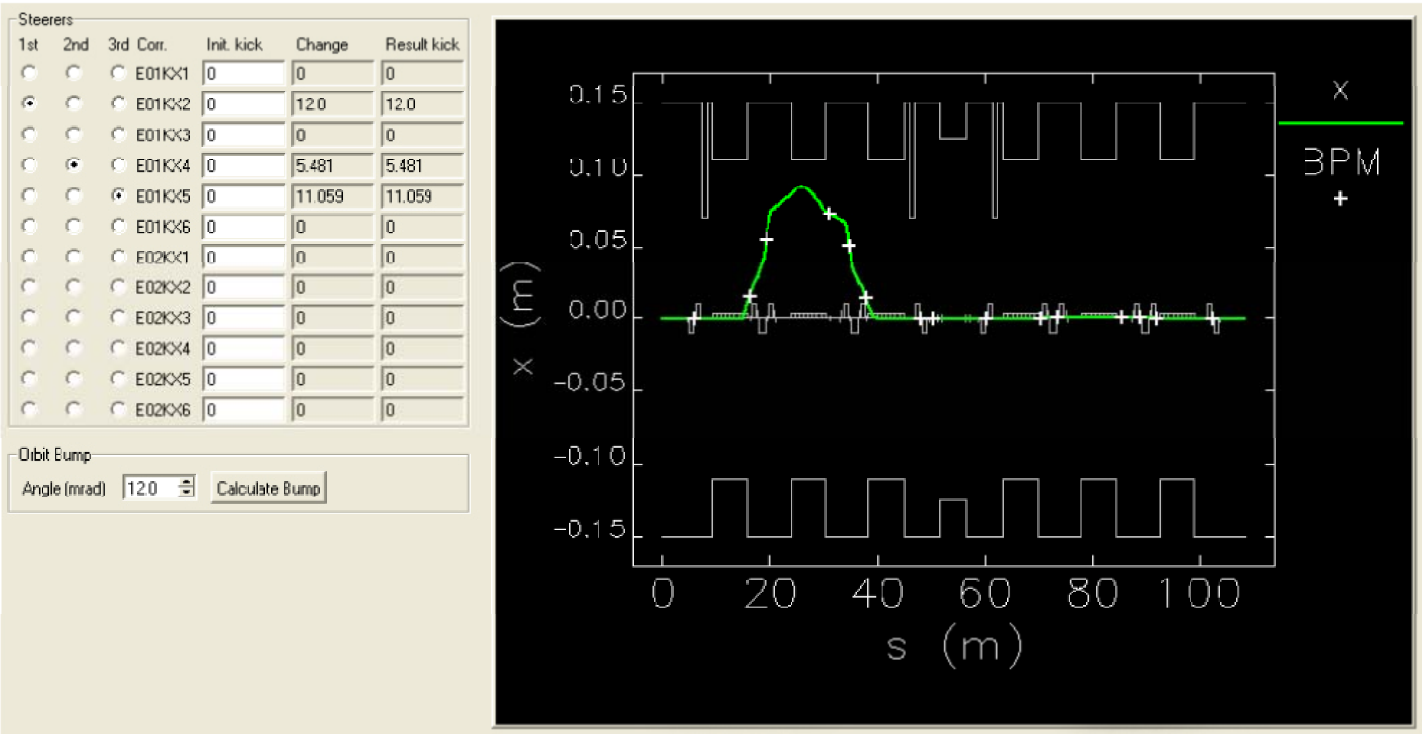
Local Distortion of Closed Orbit (CO)

Three-steerer CO distortion:

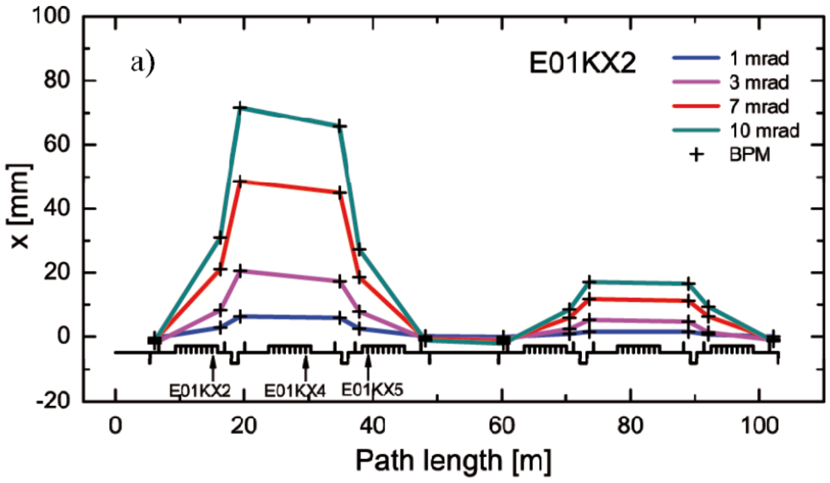
$$\theta_2 = -\theta_1 \sqrt{\frac{\beta_1}{\beta_2}\frac{sin(\psi_{31})}{sin(\psi_{32})}}$$

$$\theta_3 = \theta_1 \sqrt{\frac{\beta_1}{\beta_3}\frac{sin(\psi_{21})}{sin(\psi_{32})}}$$

θ – kick angle of the steerer

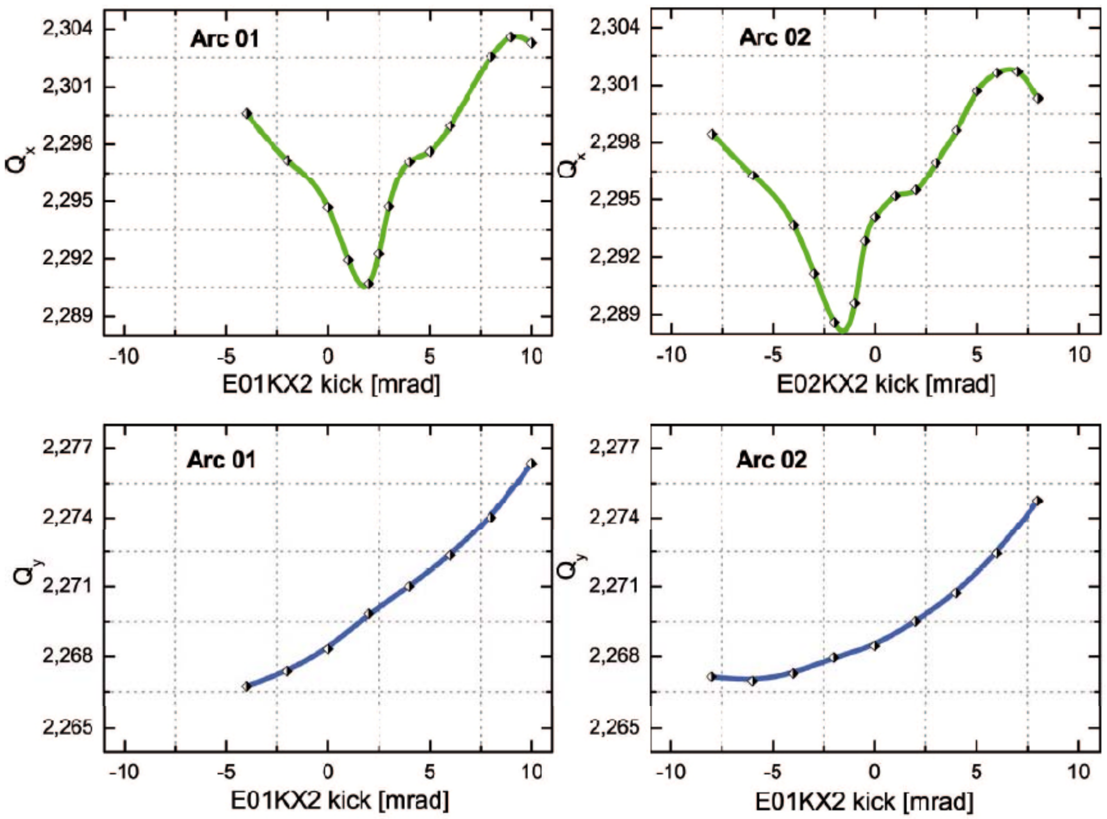


Three-steerer CO distortion



$^{64}Ni^{28}$ at 400 MeV/u.

Beam position measurements (bunched beam)



a) Bump E01KX2-E01KX4-E01KX5 b) Bump E02KX2-E02KX4-E02KX5

Tune measurements (coasting beam)

Conclusions

- Field analysis has been performed for the ESR dipole and quadrupole magnet
- Beam dynamics is influenced by higher-order field harmonics of the ESR dipole magnet
- Field imperfections at the ESR are of systematic character