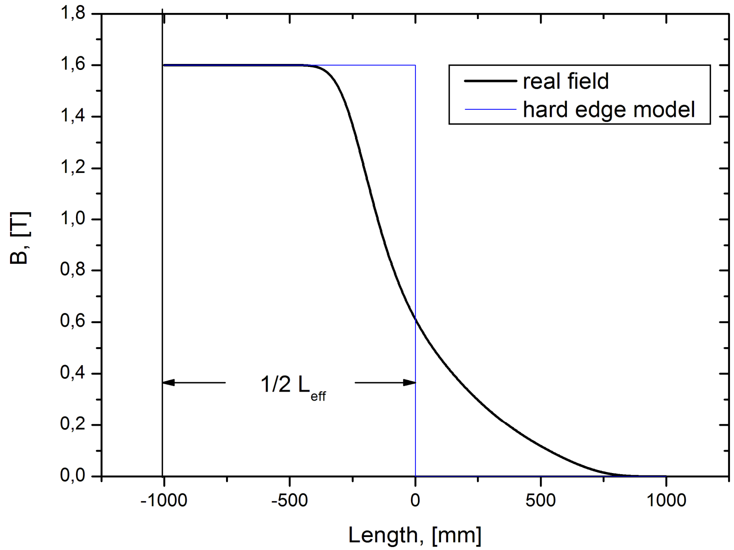
Field Interference of Magnets in the Collector Ring

Oleksii Gorda

Outline

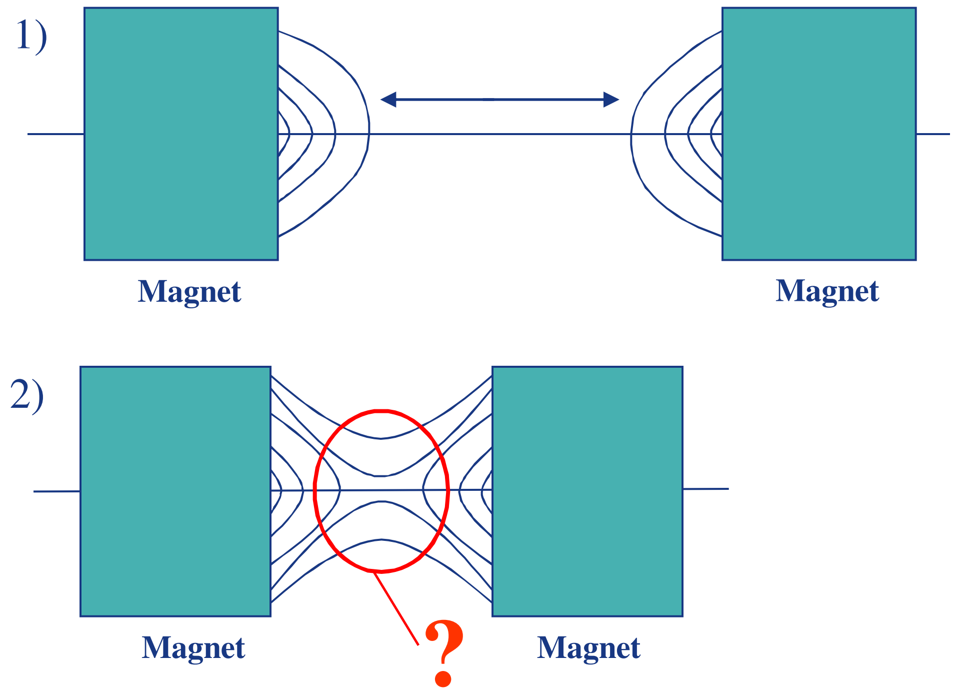
- Problem of magnetic field coupling
- Sources of field interference of magnets in the CR storage ring
- Magnetic field computations
- Effect on beam dynamics
- Conclusions

Field in magnets



- shape of the field fall-offs depends on the aperture of magnets
- fringe field effect can be estimated easily

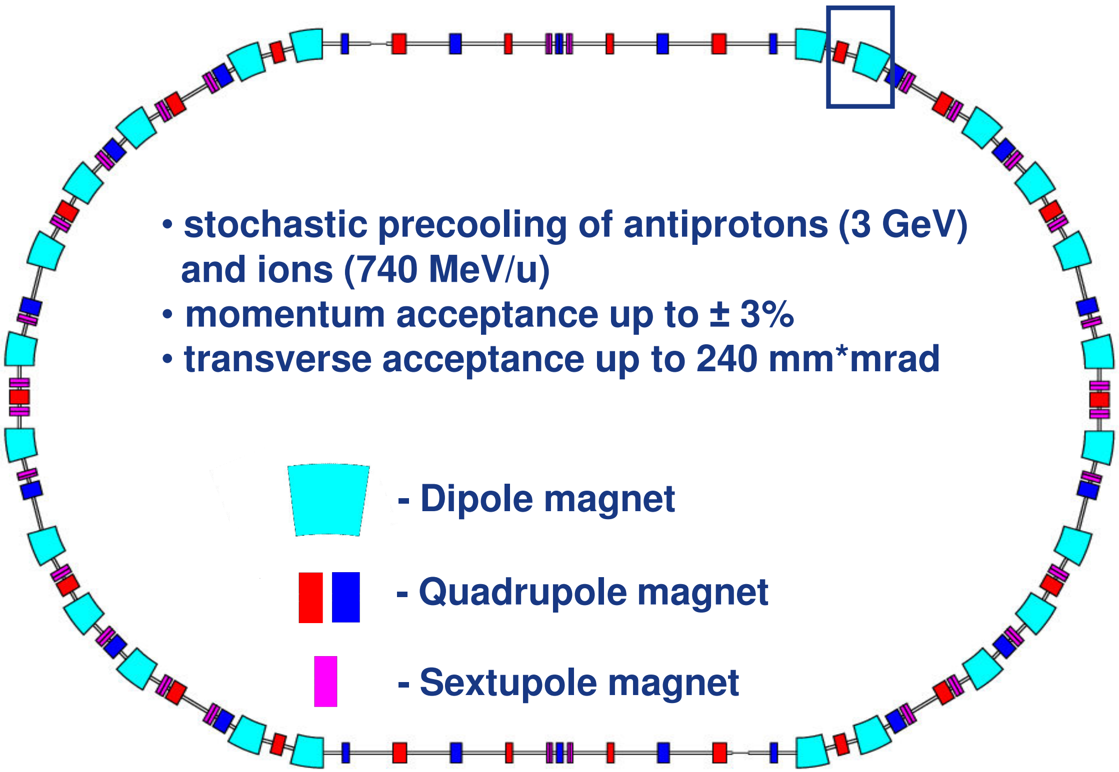
Field coupling



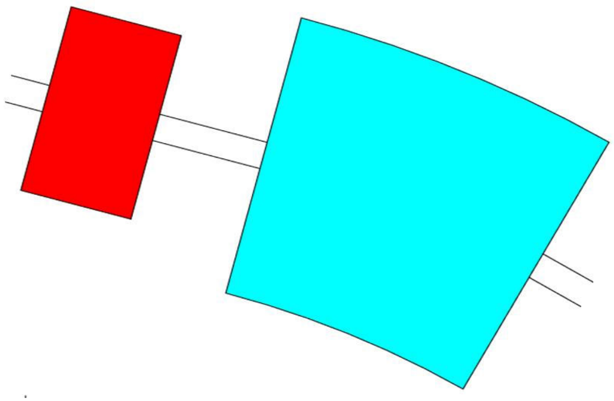
What is going on in the gap between tightly located magnets?

Collector ring CR for FAIR

- stochastic precooling of antiprotons (3 GeV) and ions (740 MeV/u)
- momentum acceptance up to ± 3%
- transverse acceptance up to 240 mm*mrad



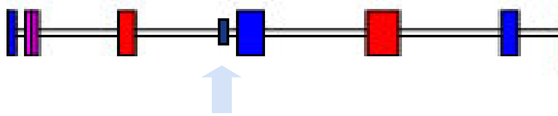
Dipole-Quadrupole section

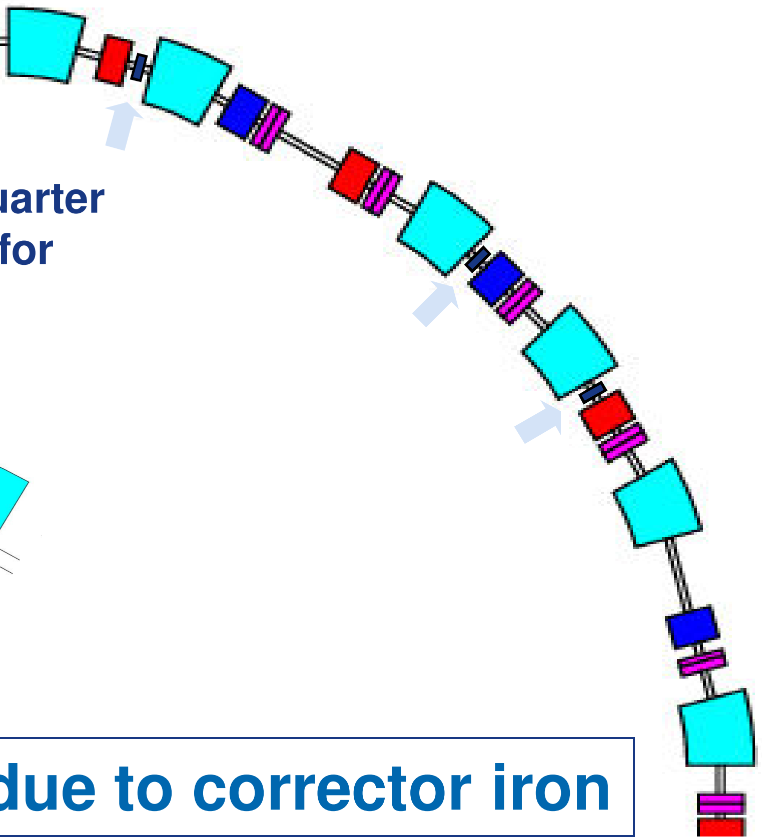


- short distance between the magnets (≈50cm)
- huge aperture of magnets

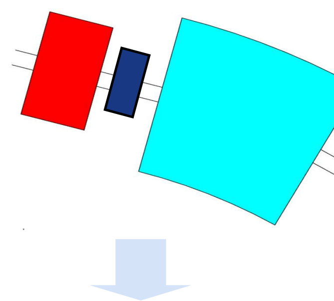
Interference between edge fields of magnets

Corrector magnets





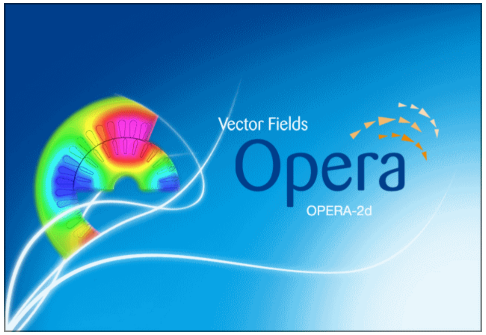
About 4-5 correctors per quarter of the ring will be installed for closed orbit corrections



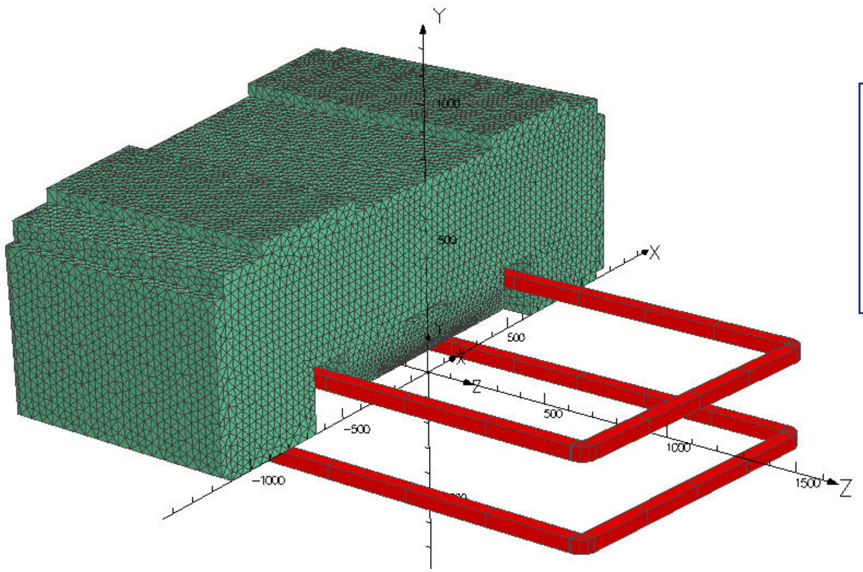
Additional interference due to corrector iron

Magnetic field computation

- **Experimental measurements**
  - no magnets, no measuremets
- **Computer simulations**
  - OPERA software was used



CR dipole magnet



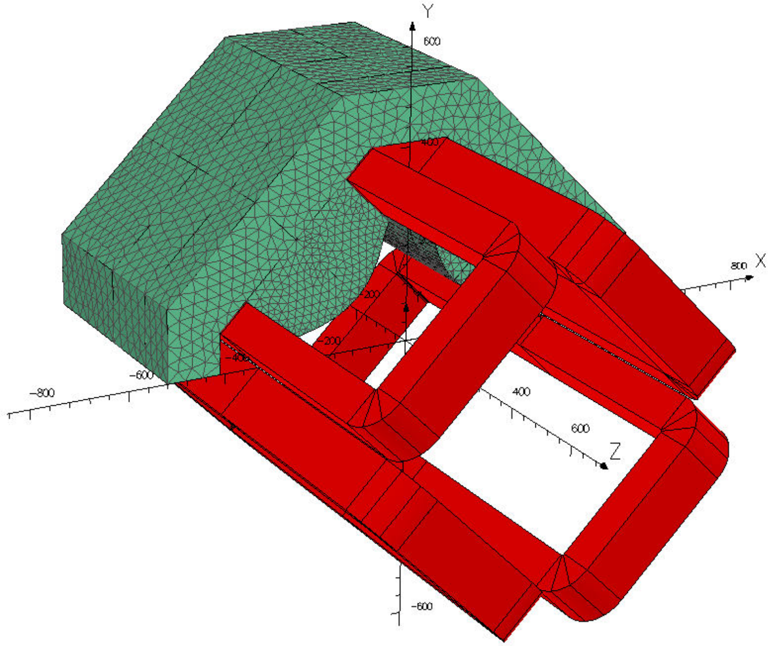
Bending angle	- 15 deg
Curvature radius	- 8.125 m
Maximum field	- 1.6 T

Field quality: By=1.6000±0.0003 T

Integral field harmonics at R=70mm

n	Absolute value, T	Relative to b_1 value
1	1.64	1.0
2	7.190039E-04	4.367172E-04
3	7.724153E-05	4.691588E-05
4	1.894155E-05	1.150494E-05
5	-5.067709E-05	-3.078086E-05
6	2.582382E-06	1.568518E-06
7	1.690610E-05	1.026863E-05
8	-3.194641E-06	-1.940399E-06
9	-3.397433E-06	-2.063574E-06
10	2.545534E-06	1.546137E-06

CR quadrupole magnet



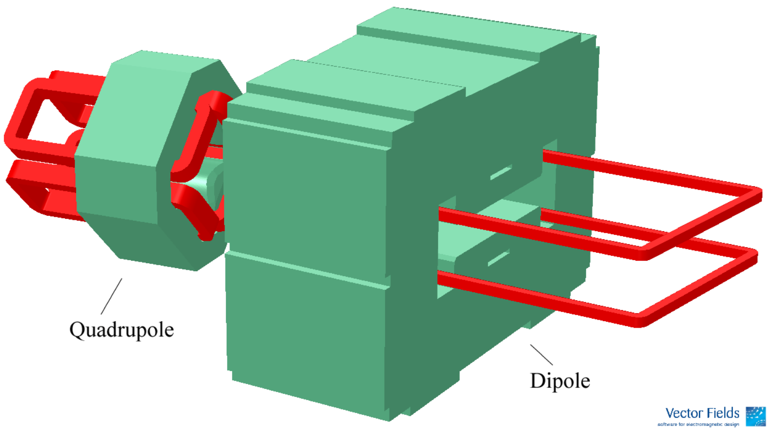
Field quality: dB/dr=4.0000±0.0004 T/m

Effective length - 1.0 m
Maximum gradient - 4.7 T/m

n	Absolute value, T/m	Relative to b_1 value
2	4.2	1.0
6	4.104426E-04	9.772442E-05
10	-3.847831E-04	-9.151602E-05
14	2.576344E-04	6.134152E-05
18	-0.756387E-04	-1.800921E-05

Integral field harmonics at R=150mm

“Single” 3D-model



Simulation technique (different modes):

1) Dipole alone
2) Quadrupole alone
3) Dipole+Quadrupole

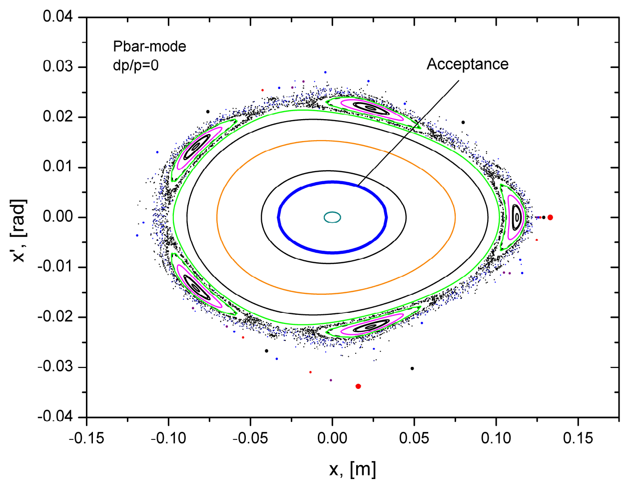
Field errors

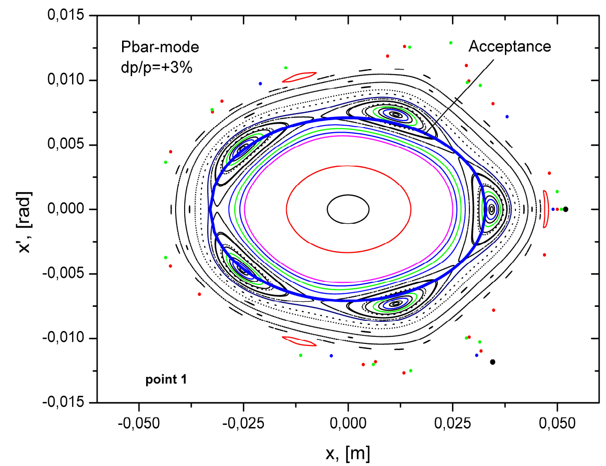
Vector Fields

$n \backslash b_n$	Dipole	Dipole + Quadrupole / Variation of b_n (Δb_n)	Quadrupole
3	3.447105E-005	2.680470E-004 / +24,04 %	1.691510E-004
4	1.902490E-005	8.394228E-005 / +1,29 %	6.383320E-005
5	-3.173116E-006	3.517228E-005 / +12,53 %	3.393690E-005
6	-8.823165E-007	-1.061247E-005 / +0,73 %	-9.807560E-006
7	-7.470479E-006	6.326022E-006 / -4,82 %	1.410140E-005
8	4.495581E-006	1.452088E-005 / +0,30 %	9.981660E-006
9	1.348757E-005	2.165166E-005 / +0,14 %	8.134600E-006
10	-3.639640E-006	3.338382E-006 / +0,54 %	6.959940E-006

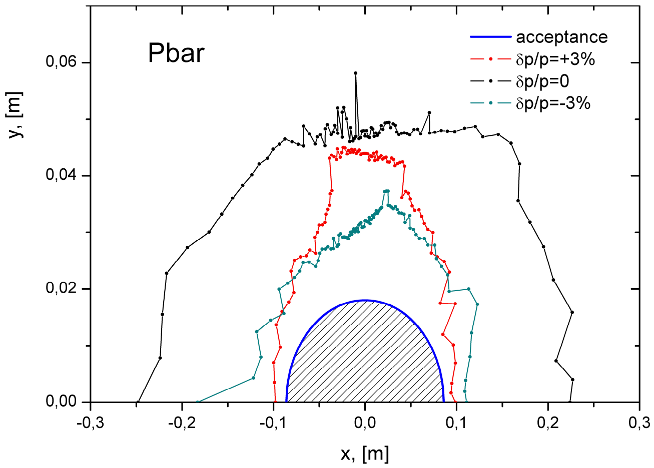
Effect on beam dynamics

- Single particle tracking
- Dynamic aperture calculations
- Tunes and resonances
- Take computed field errors into account

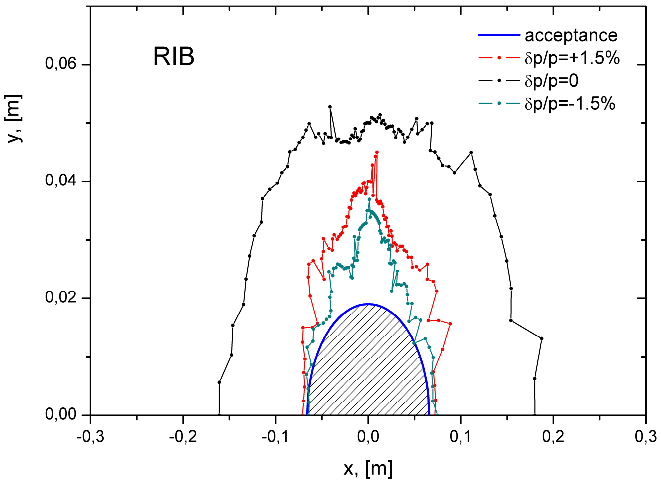




Dynamic aperture of the CR

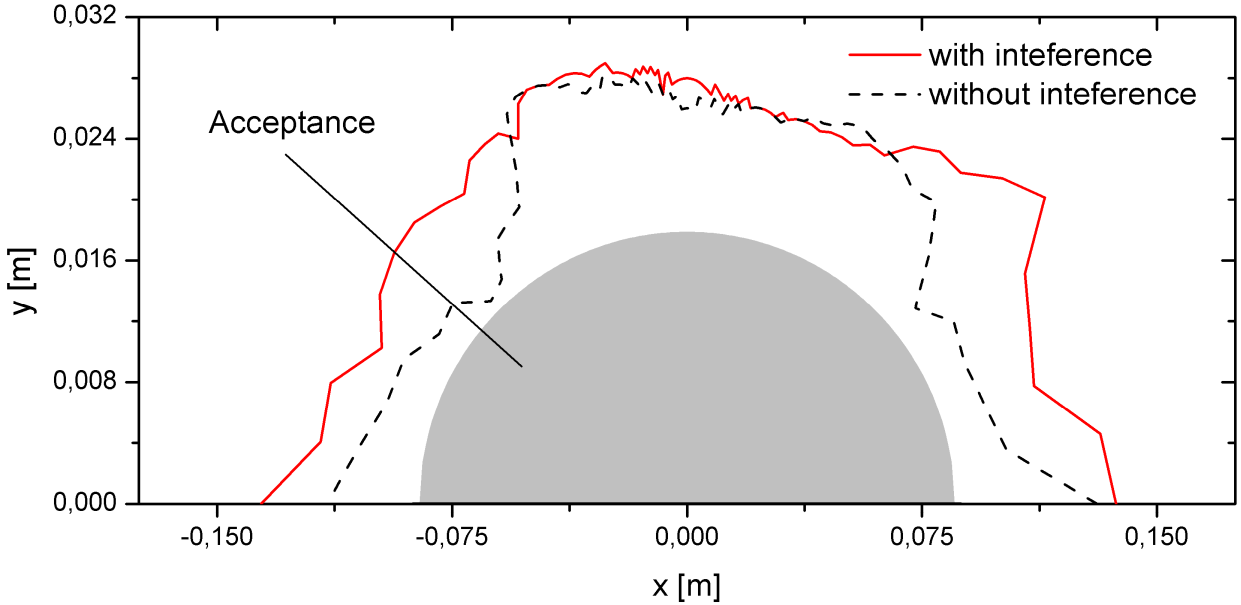


Antiprotons



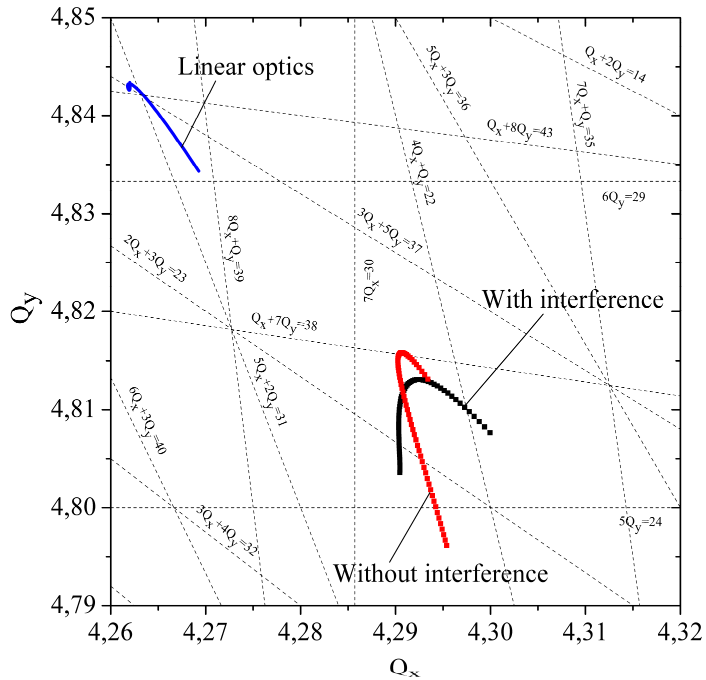
Ions

Effect of field interference



Slight increase of dynamic aperture is observed when taking the field interference effect into account

Tune calculations



Q – number of oscillations per turn

Cross of resonance lines results in an unstable motion of particles

Tune spread is changed due to field interference effect, some dangerous resonances are avoided

Conclusions

- Magnetic field simulations are performed to study and quantify the field interference between the dipole, corrector and quadrupole in the CR
- No harmful effect on beam dynamics is found
- dynamic aperture is slightly increased due to the compensation of the field errors with the interference effect

That’s all!
Thanks for your attention!