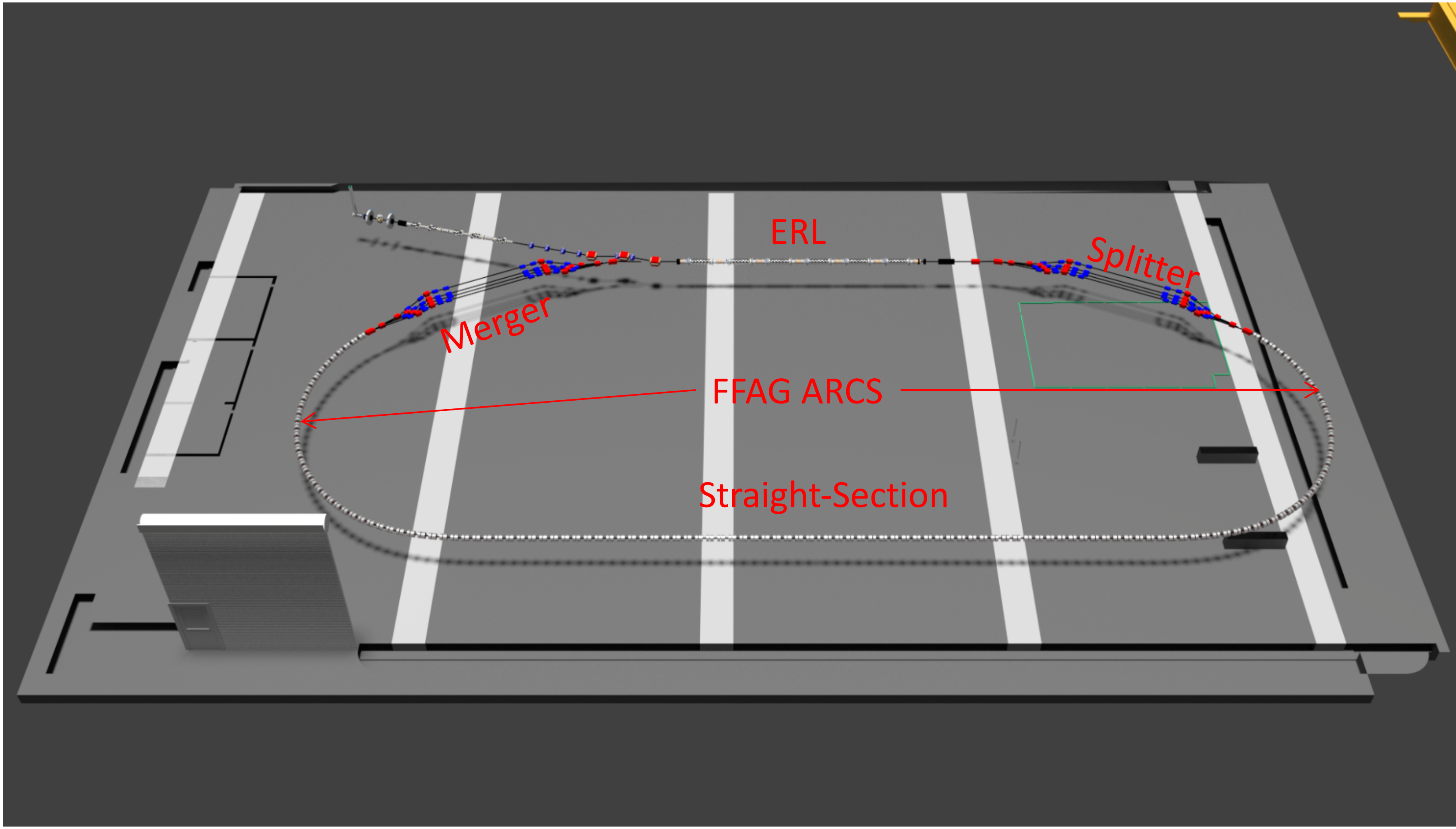
The CBETA Halbach type magnets and the correctors

N. Tsoupas for the CORNELL Collaboration
meeting Jan 20-21, 2016

Isometric view of the Cβ accelerator



Cβ Brooks_2015-12-11 Cell

QF magnet

B_y(local x) = B_0 + Gx

B_0 = -0.018693 T

G = -23.6236 T/m

Length = 0.114882 m

BD magnet

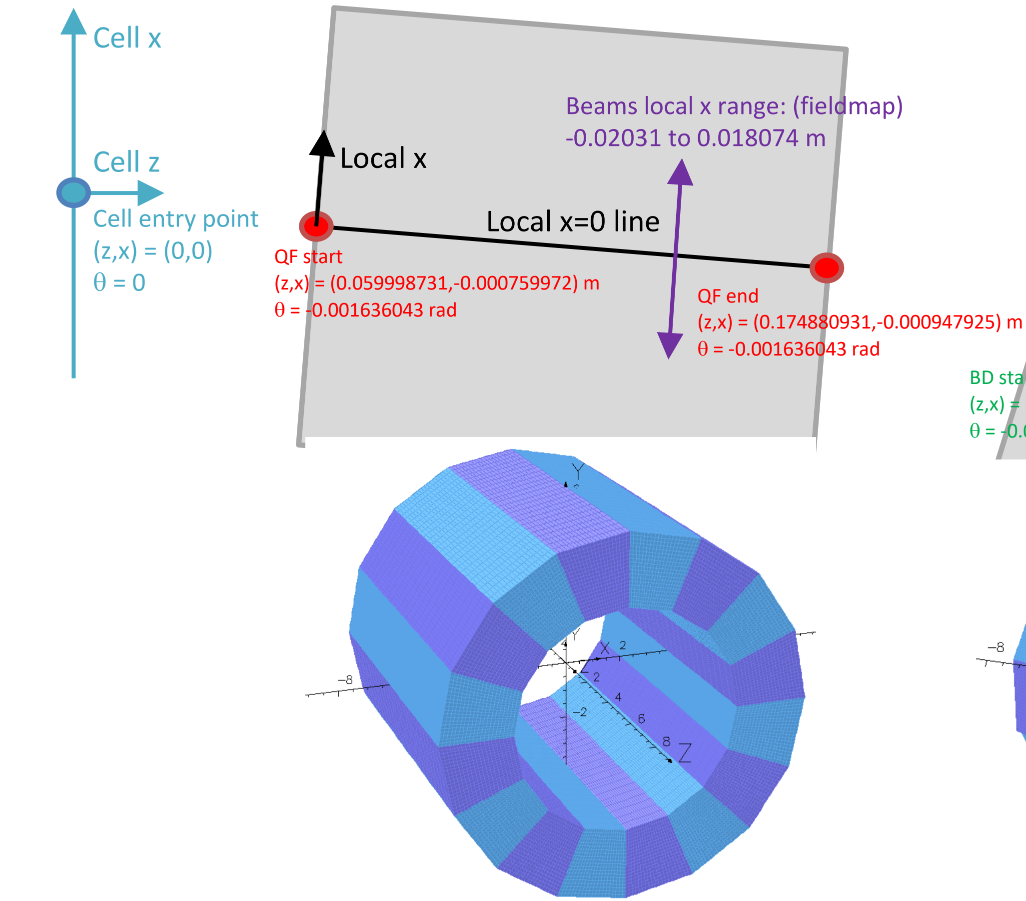
B_y (local x) = B_0 + Gx

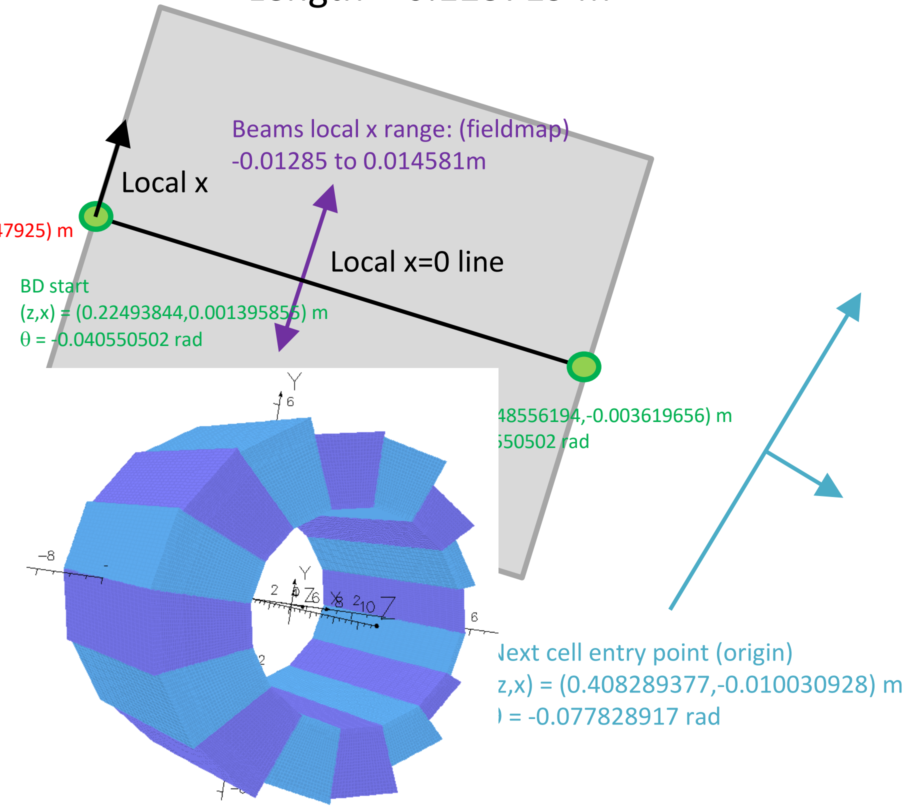
B_0 = -0.395517 T

G = 19.1191 T/m

Length = 0.123719 m

ORIGIN





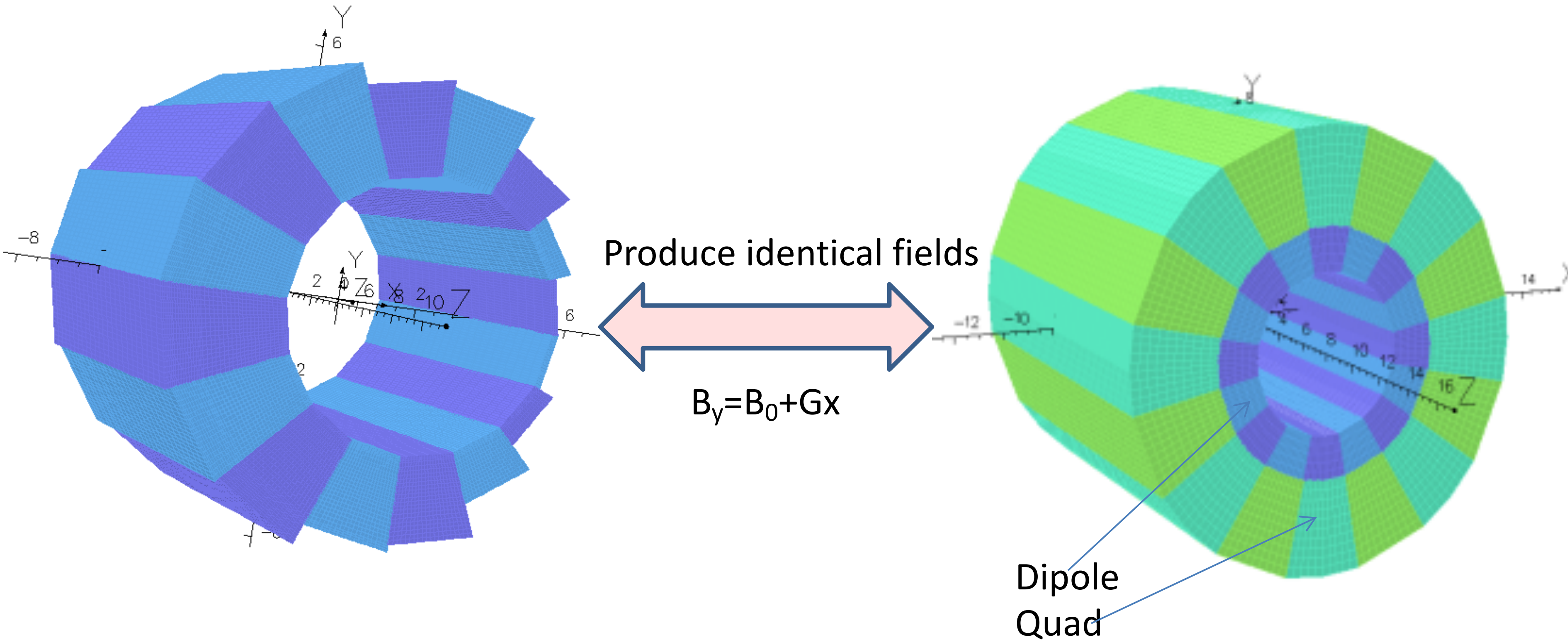
Objective of presentation

- Present results from 3D field calculations of the Cβ cell's magnets.
- Present possible correctors of the cell quadrupoles.

Corrector Requirements

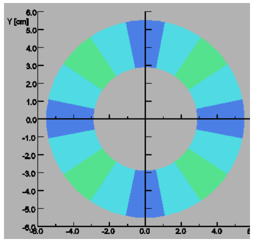
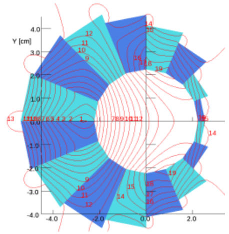
- The Dipole correctors should provide field of ± 50 [Gauss]
- The Quadrupole correctors should provide gradients ± 0.5 [T/m]
- Both dipole and Quadrupole correctors should introduce insignificant multipoles other than the ones they correct.
- If possible the correctors should be air-cooled

In the presentation I will use the pictures of two magnets interchangeably

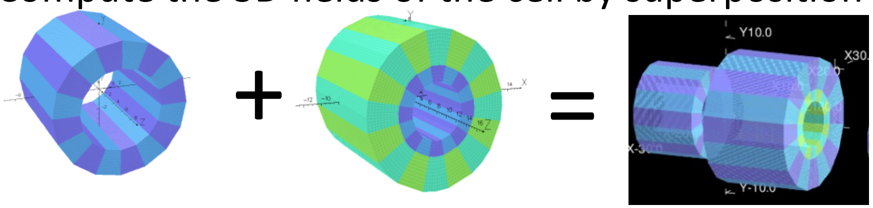


Procedure to calculate the 3D fields maps

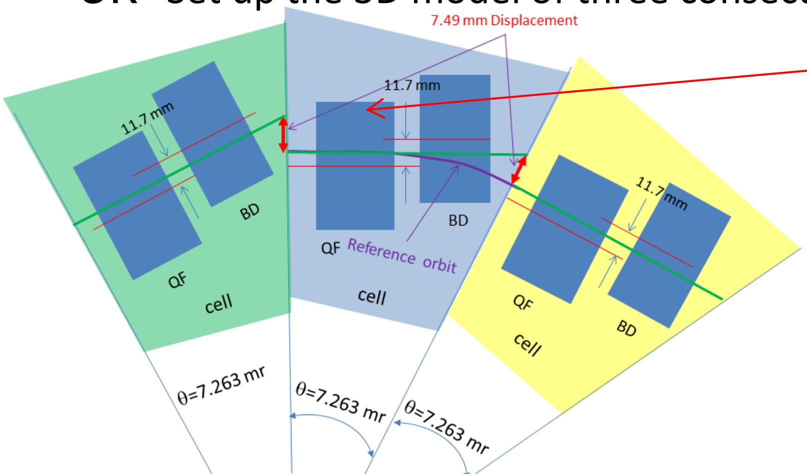
- Set up the 2D model and optimize the multipoles.

- Set up the 3D model of each magnet and compute the 3D field map of each magnet.
  Compute the 3D fields of the cell by superposition of the field maps of each magnet.

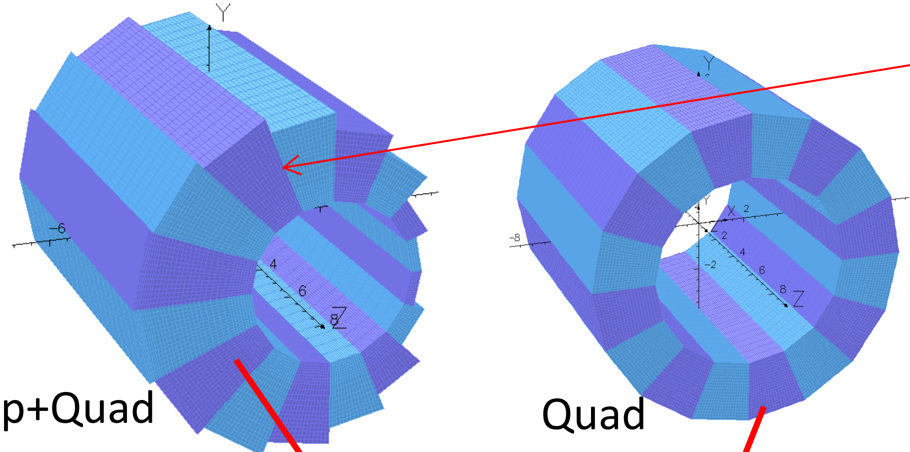


- OR Set up the 3D model of three consecutive cells and use the 3D field map of the middle cell.



This method includes the interference between the cell quadrupoles.

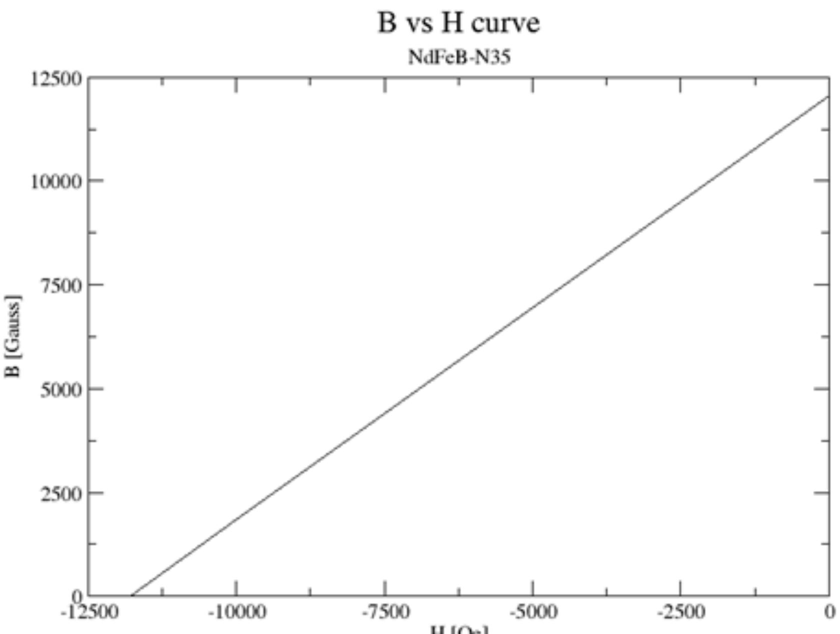
Calculate separately the 3D field maps of Dipole+Quad and Quad magnets:



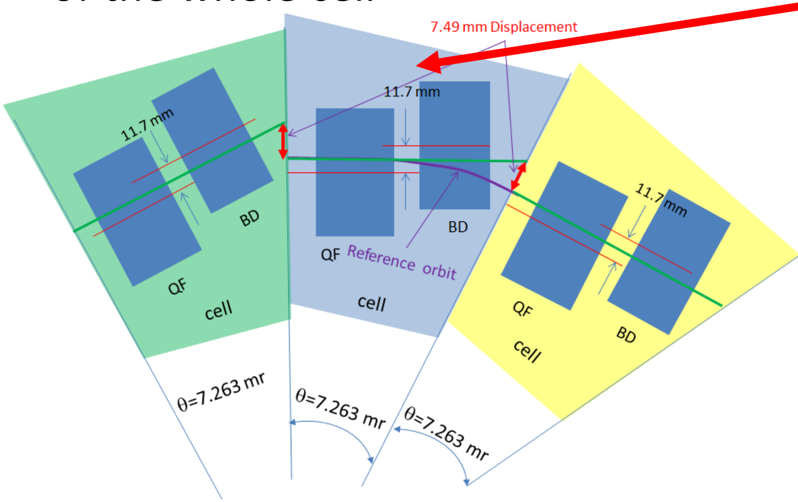
Magnets designed by Stephen Brooks. Five magnets have been ordered and will be measured.

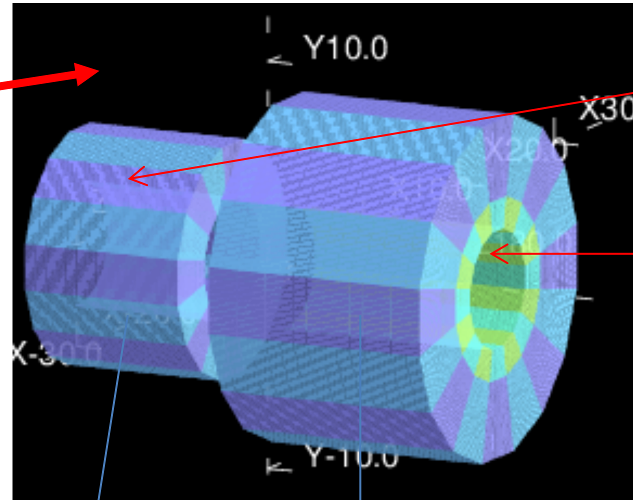
Effect of misalignments on the multipoles:
a) Error in magnitude of the magnetization vector.
b) Error in direction of the magnetization vector.
c) Error in position of the wedges.

Multipole	Integrated for BD N35 at R=1 [cm]	Integrated QF N35 at R=1 [cm]
Dipole [Gauss·cm]	46615.4	2.0
Quad [Gauss]	23667.6	27149.6
Sext. [Gauss/cm]	0.55	-1.1×10^{-5}
Oct. [Gauss/cm^2]	-0.21	-1.1×10^{-9}
Dec. [Gauss/cm^3]	0.01	-1.8×10^{-5}
12pole [Gauss/cm^4]	0.01	-0.005



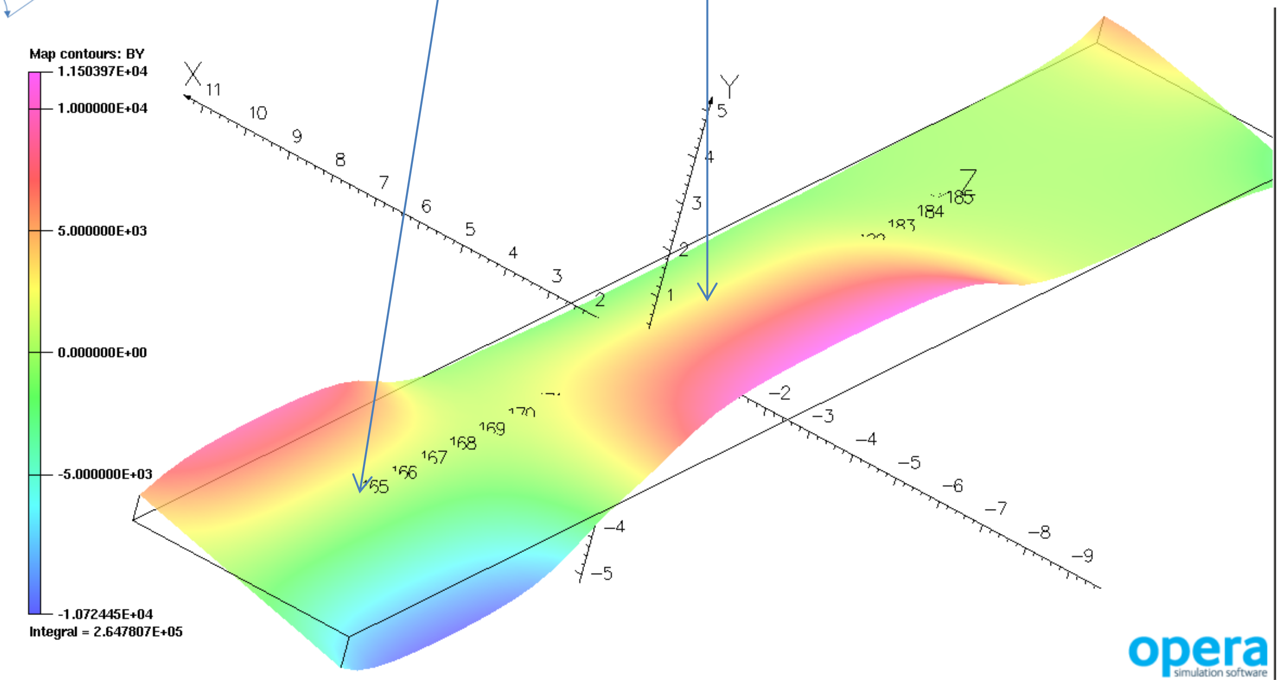
Method to calculate the field map of the whole cell





$B_y(x) = G_f x$
$B_x(y) = G_f y$

$B_y(x) = B_0 + G_d x$
$B_x(y) = B_0 + G_d y$



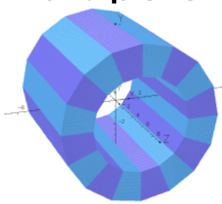
The beam optics of the cell

- The 3D field mad is being used to calculate the beam optics of the cell by integrating the equation of motion $\frac{dp}{dt} = q \cdot v \times B$ of a particle the magnetic field which is provided by the 3D field map.

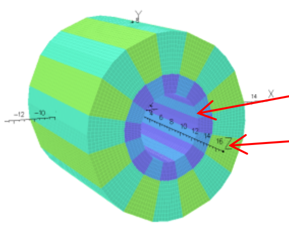
Zgoubi computer code (Francois Meot)
Muon1 computer code (Stephen Brooks)
RAYTRACE computer code.

Some advantages of the Halbach-type permanent magnets

- Use No power. Also true for iron-dominated permanent magnets.
- Occupy small volume yet they provide a strong desired multipole with good quality over the space of the beam.



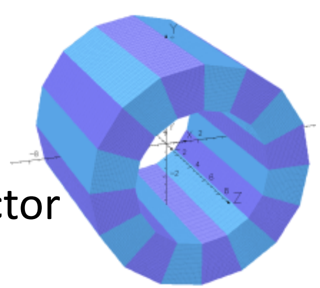
- The fields of the permanent magnets can be superimposed (μ≈1.05)

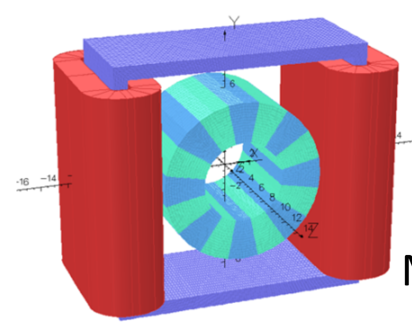


Halbach Dipole
Halbach Quad

- Can accept external fields (μ≈1.05) thus low field electromagnets can be used to correct the main multipoles of the permanent magnets.

Magnet with No corrector

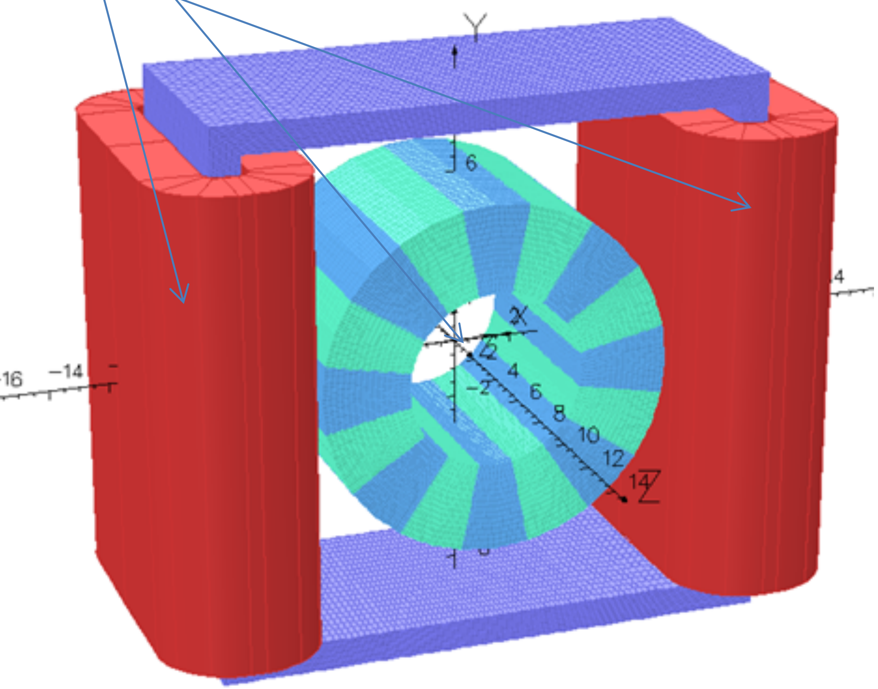


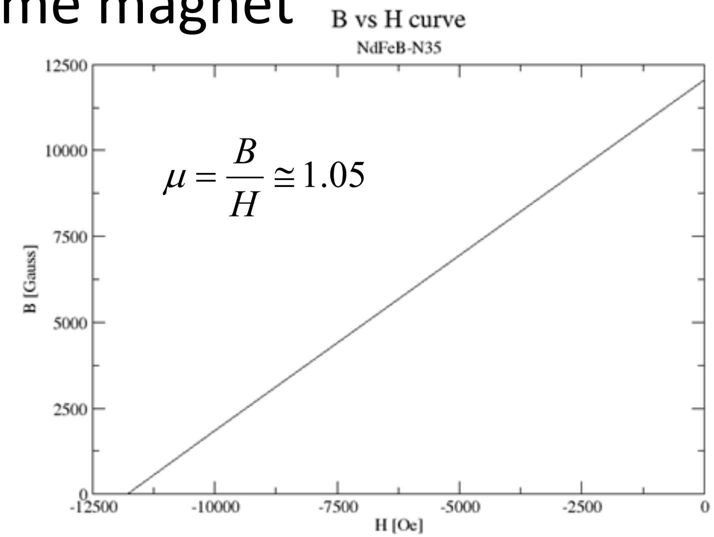


Magnet with corrector

Proposed correctors: The dipole window frame magnet

Air cooled. J=100 A/cm^2
B_{field} ~150 Gauss
Power ~30 W both coils





How are the multipoles affected when the corrector is powered?

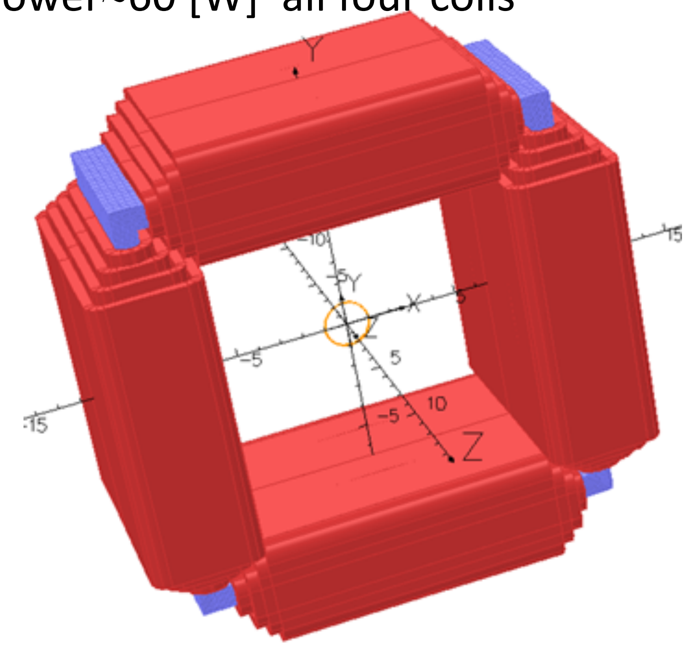
Multipole	Integr. Multipol. at R=1 [cm] NO-Corrector	Integr. Multipol. at R=1 [cm] With-Corrector
Dipole [Gauss·cm]	15	4797
Quad [Gauss]	35152	35197
Sext. [Gauss/cm]	2.0	-9.7
Oct. [Gauss/cm^2]	-1.2	-1.8
Dec. [Gauss/cm^3]	0.5	2.5
12pole [Gauss/cm^4]	5.7	5.7

Measurements will be performed to test the effect of the dipole corrector on the main magnet's field.

Panofski Quad for Quadrupole corrector

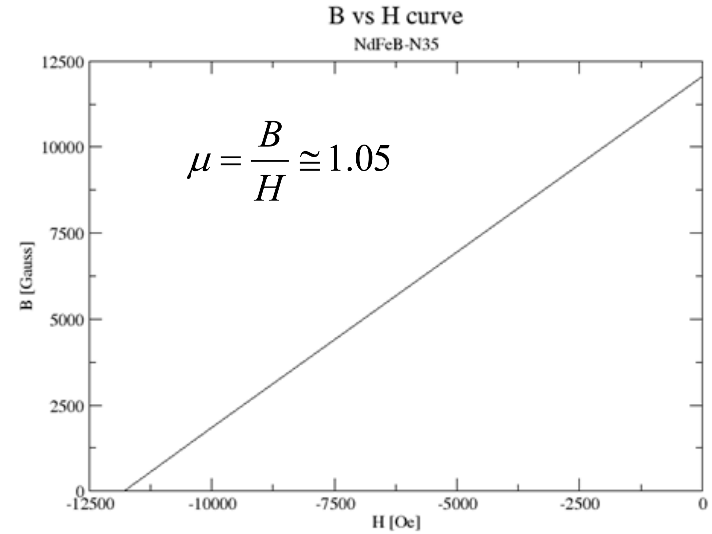
$J=100\ A/cm^2$

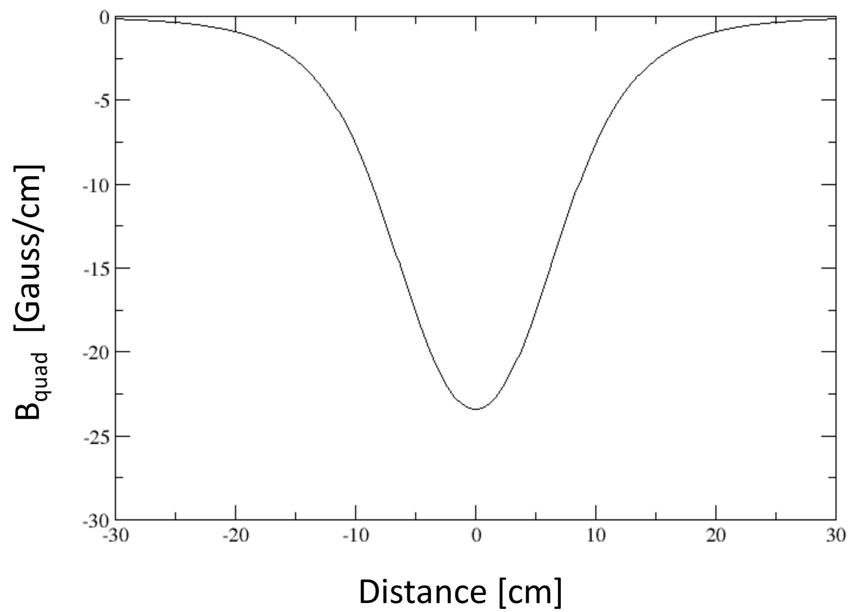
Power~60 [W] all four coils



Gradient ~0.36 [T/m]

Integrated Gradient(at R=1cm)= 410 Gauss

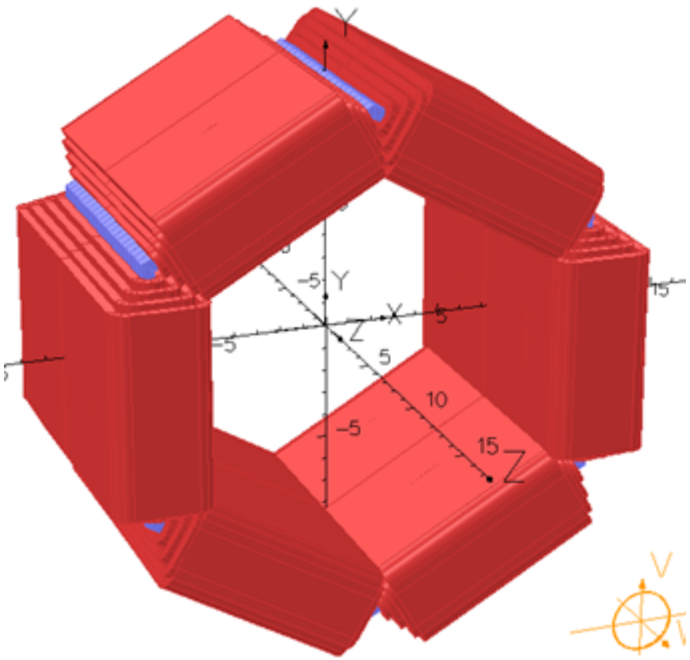


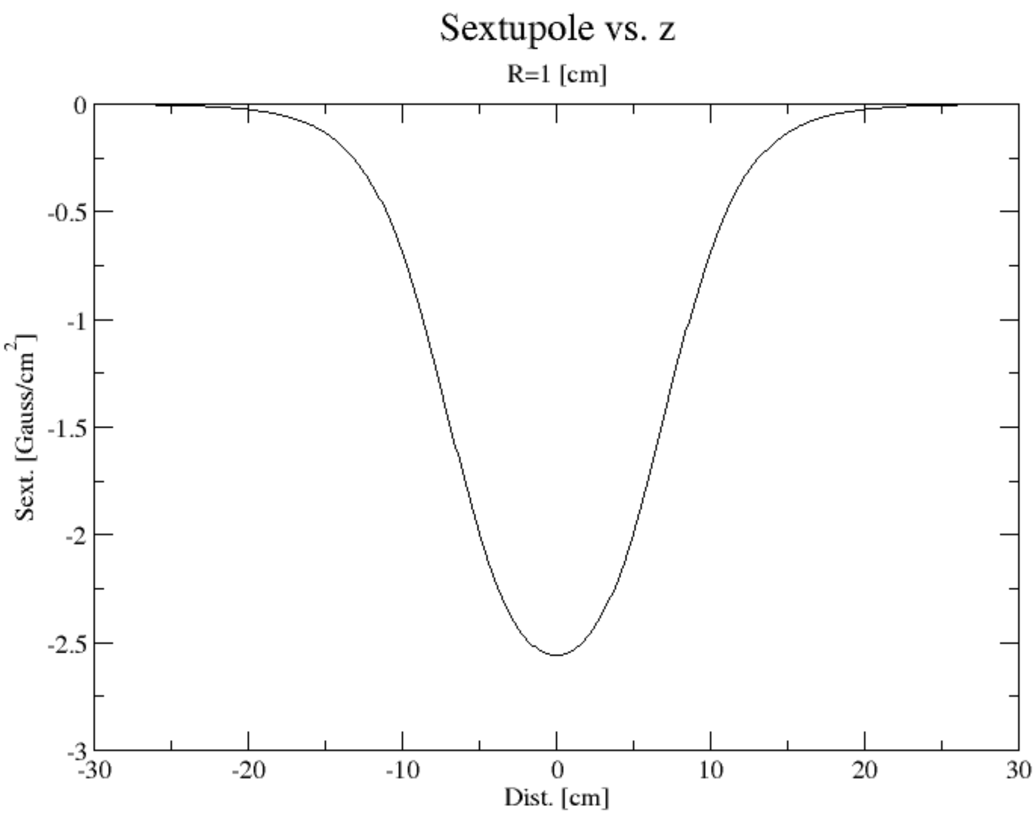


Integrated Normal or Skew sextupole

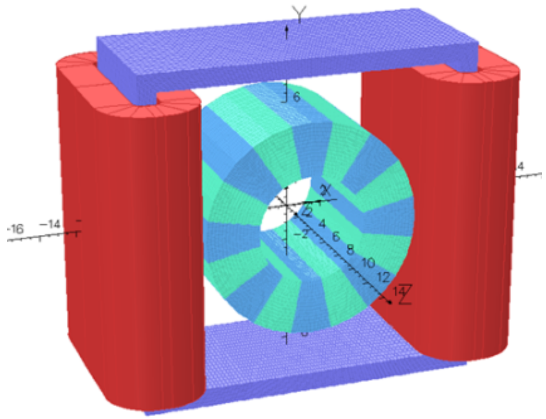
$J=100\ A/cm^2$
Length of iron 8 cm

Integrated sextupole (at R=1 [cm]=40 [Gauss.cm^{-1}]

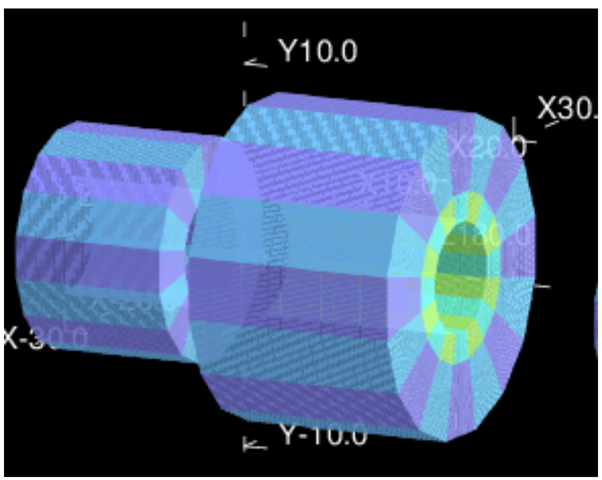


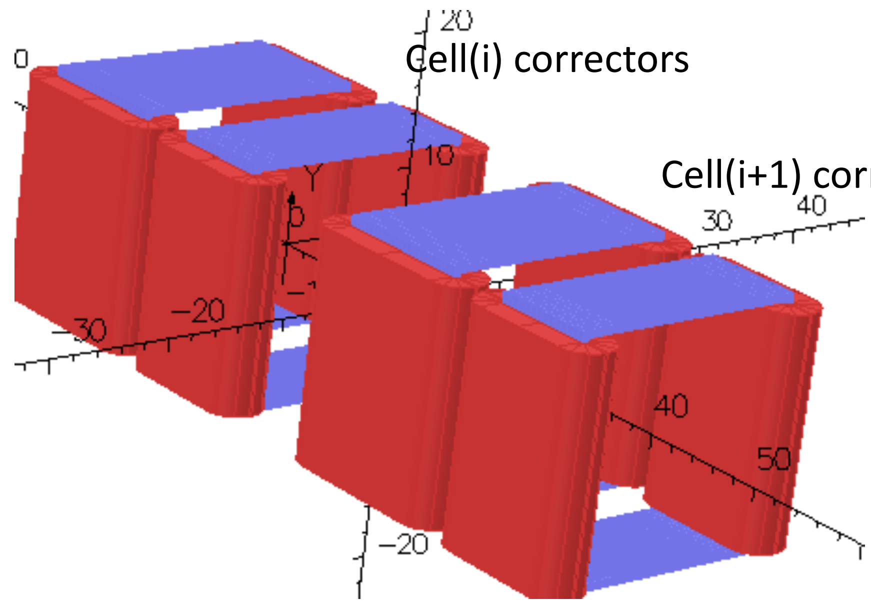


The calculations show that the window-frame corrector will not affect the field of the permanent magnet.

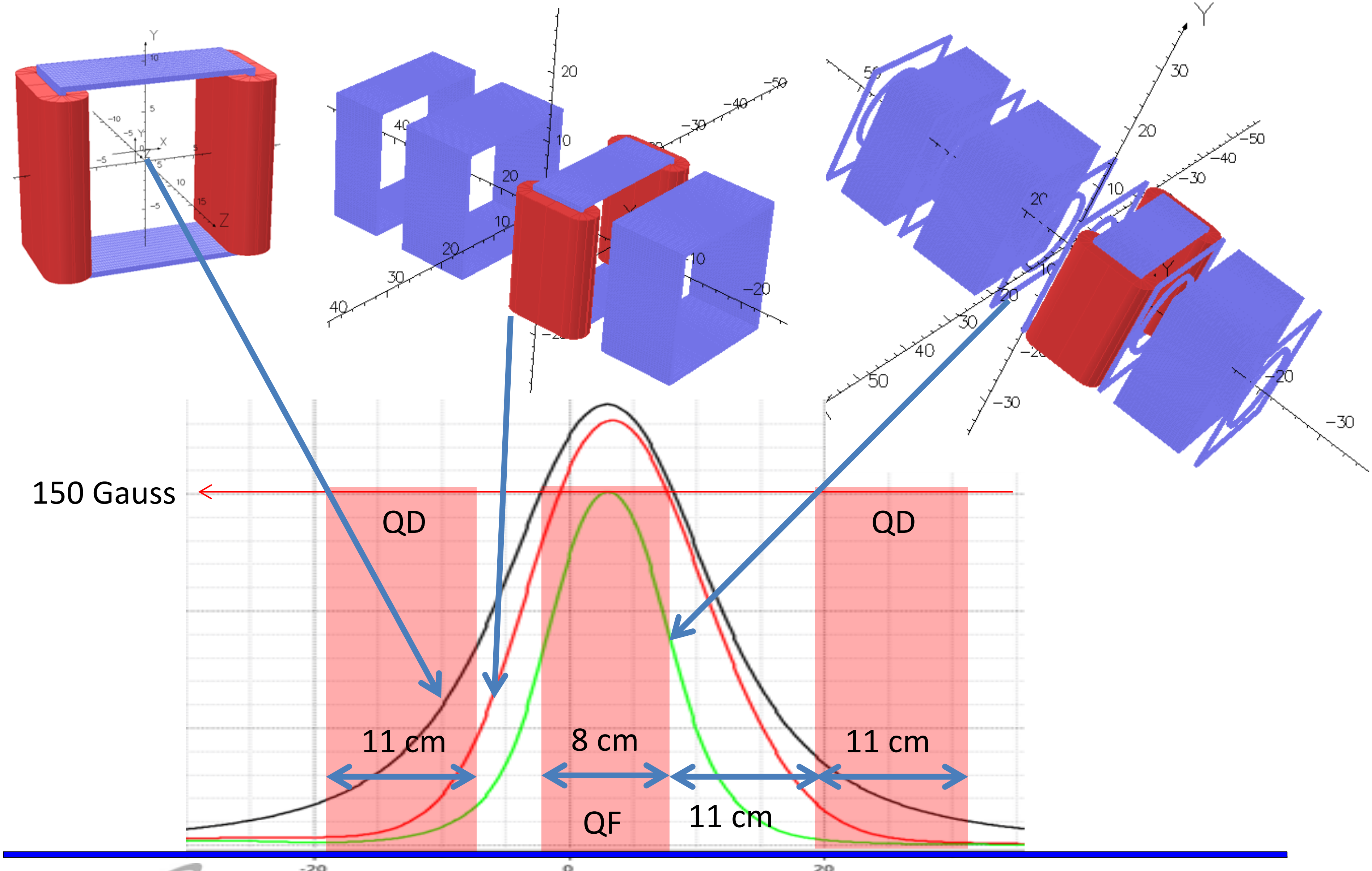


How does the interference of the correctors affects the correction field itself?

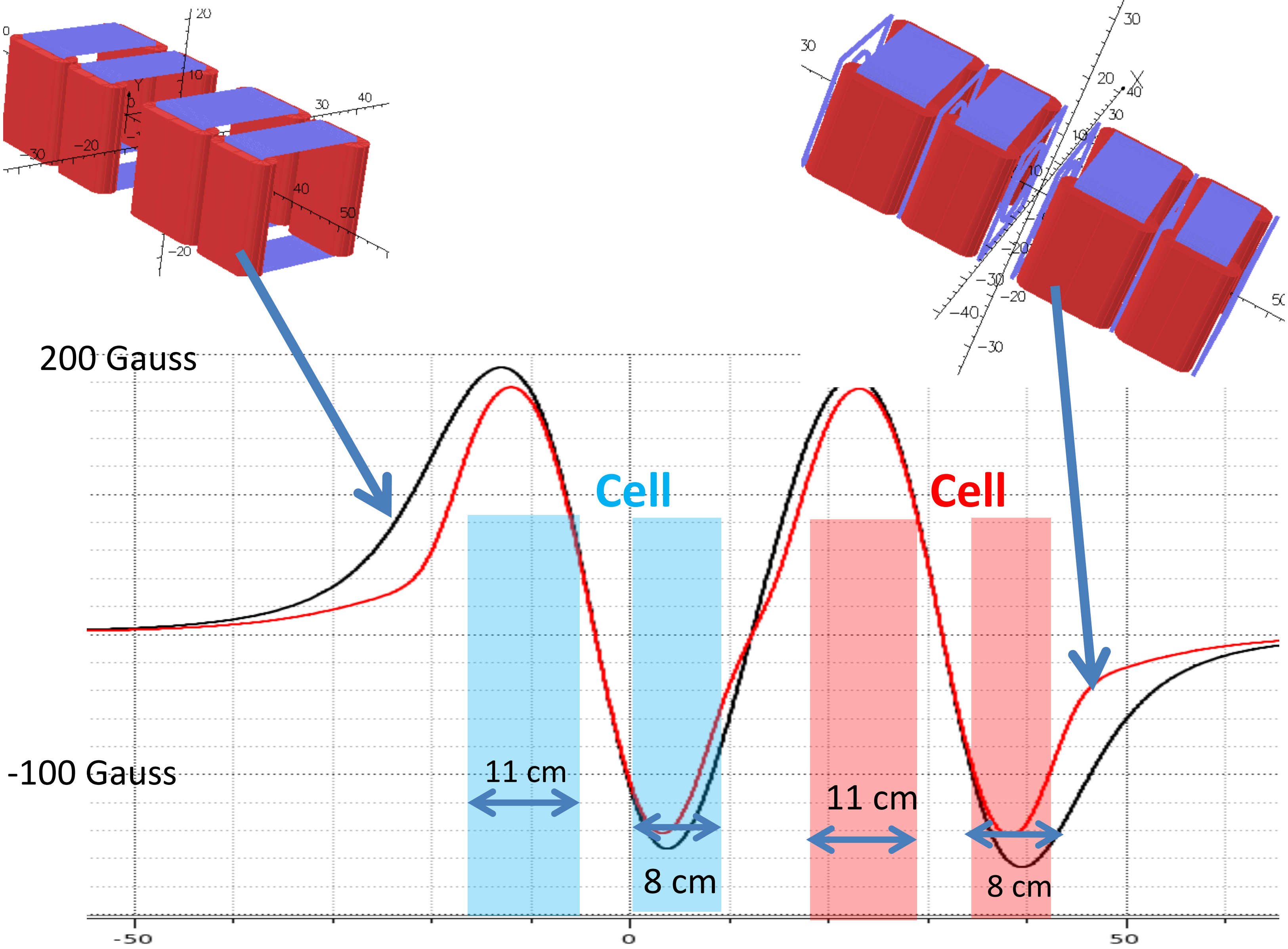




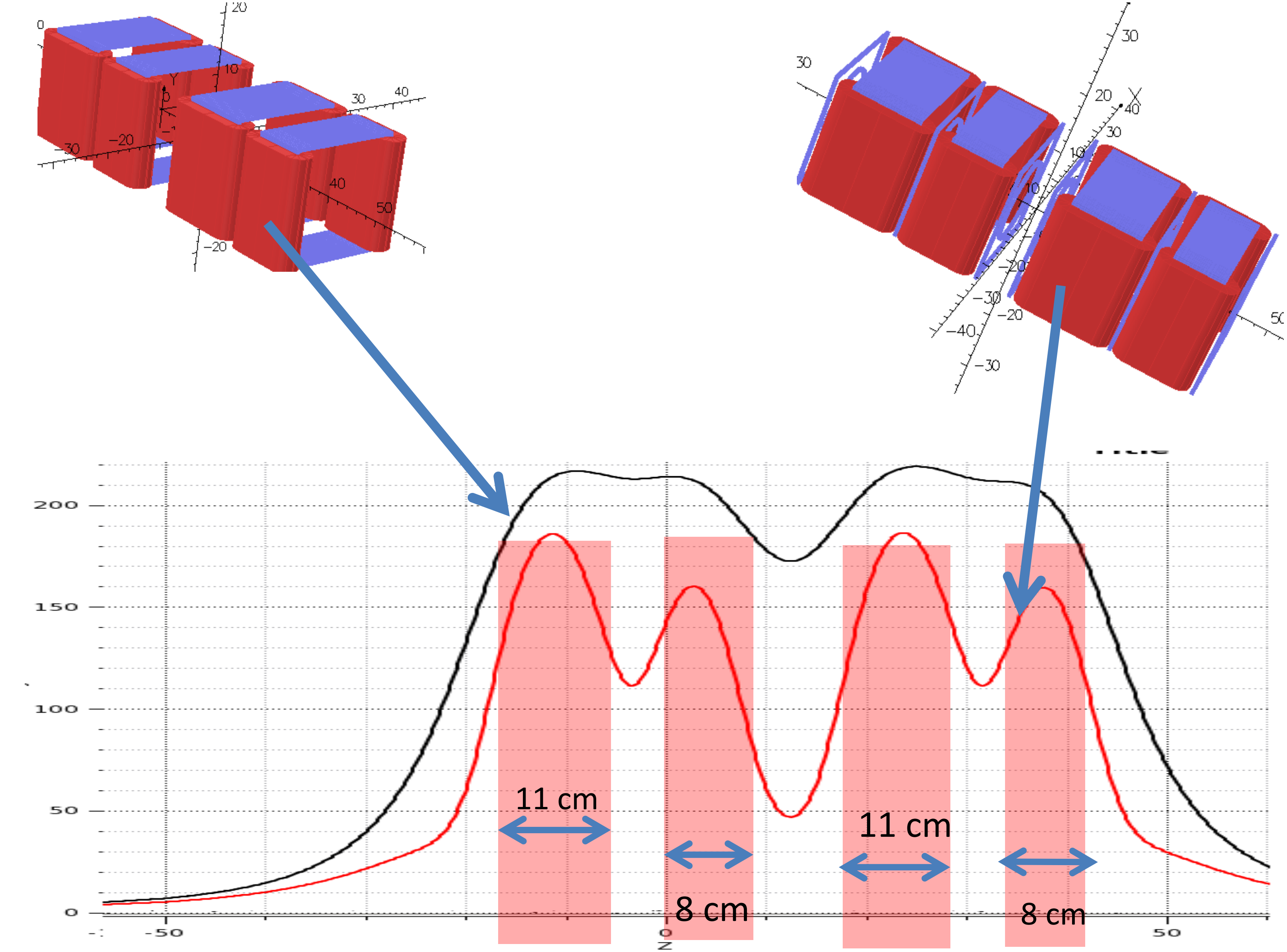
Effect of a single-dipole-corrector on the adjacent magnets



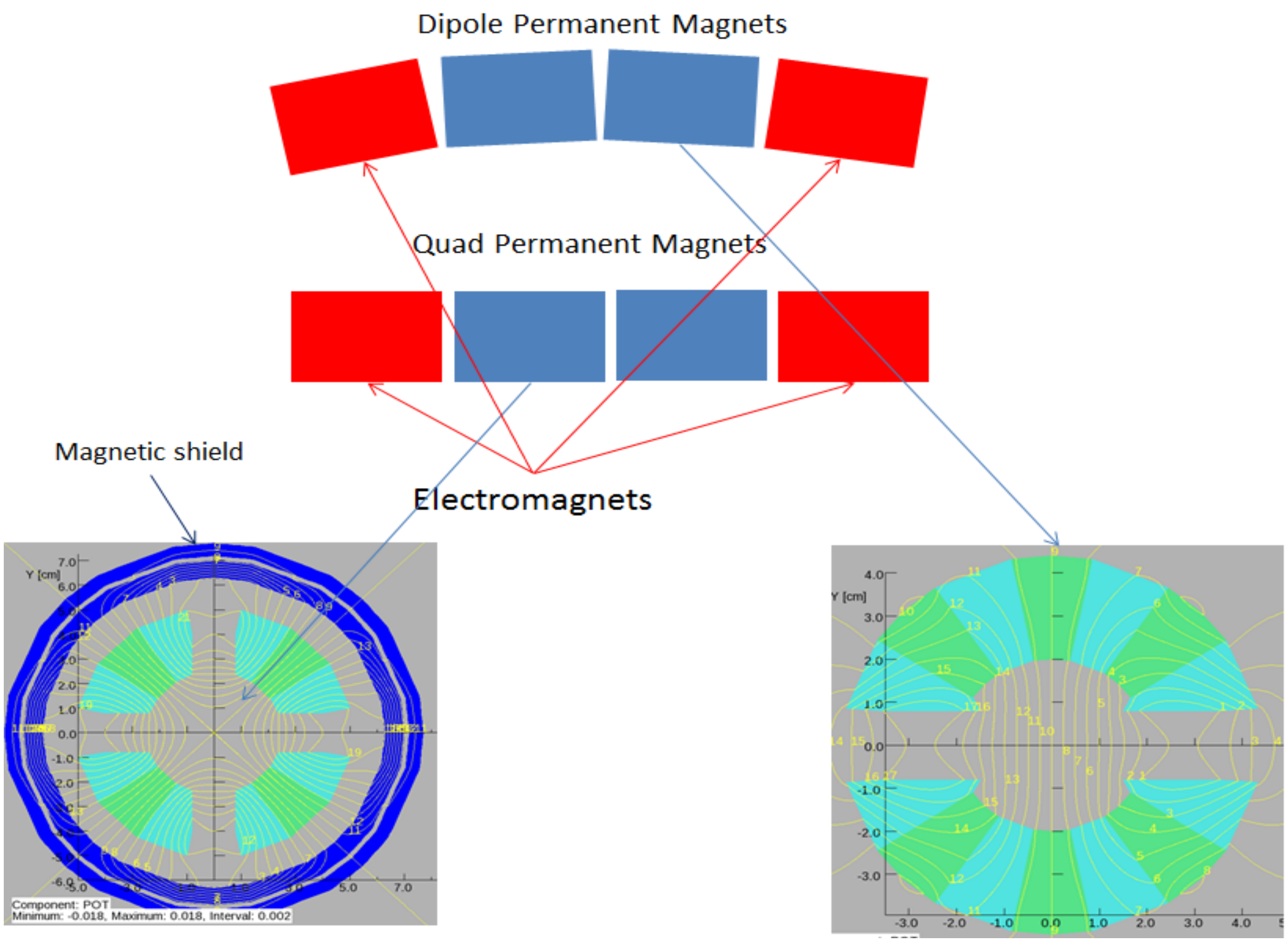
Interference of four corrector-dipoles with polarities (+, -, +, -)



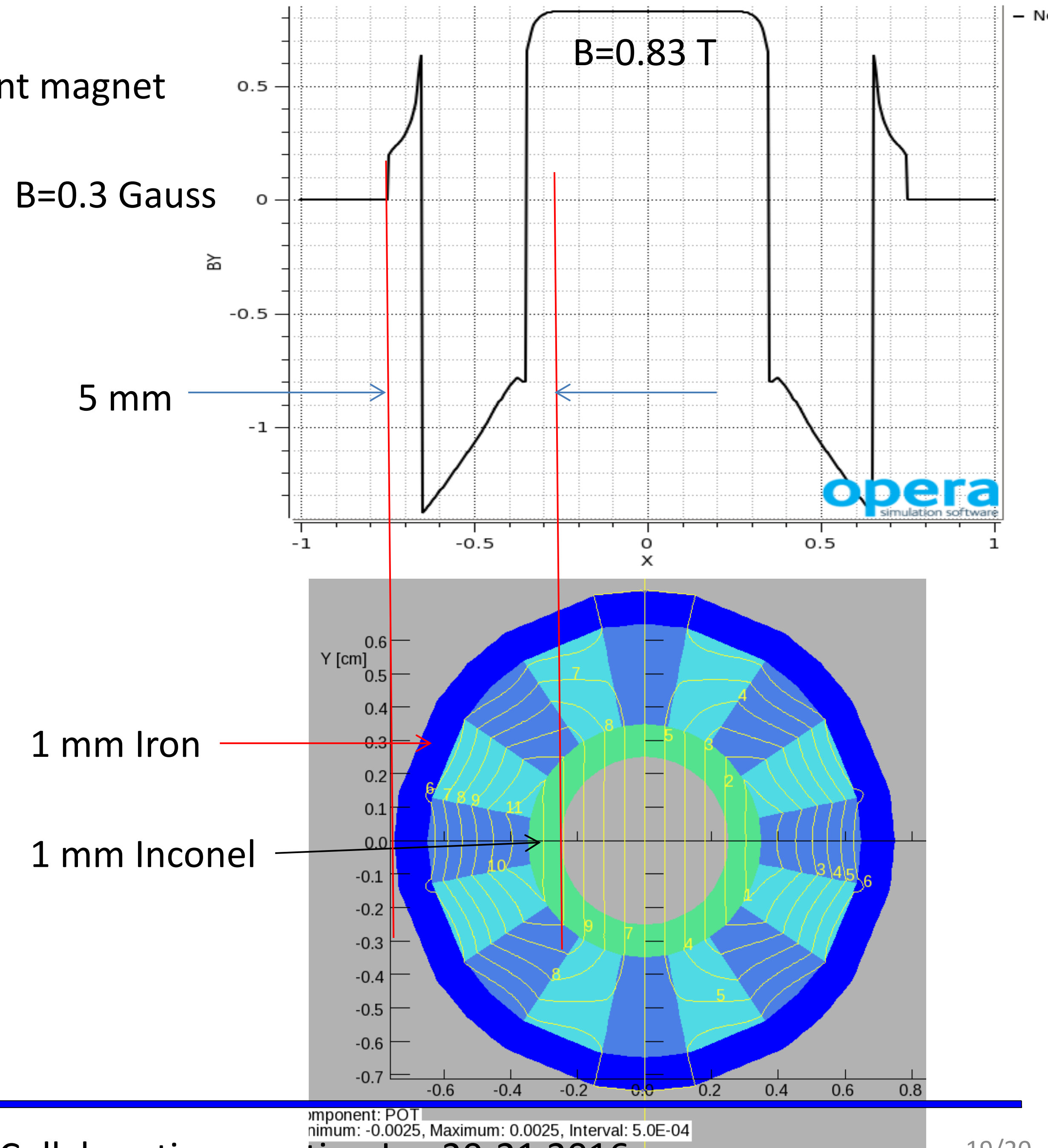
Interference of four corrector-dipoles with polarities (+, +, +, +)



Possible magnet arrangement for splitter/merger



5 mm Septum Permanent magnet



Conclusions

- The Halbach-type permanent magnet quadrupoles are good candidates to be used as cell's quadrupoles of the Cβ project.
  - Small volume
  - Good field quality
  - Good reproducibility (few measurements of Halbach-type magnets)
  - Can easily accept dipole, qudrupole and sextupole correctors.
- The window frame magnet correctors are good candidates to be used as corrector magnets of the Cβ cell magnets.
  - Introduce insignificant multipoles other than the ones to correct.
  - The interference of the correctors among each other presents no problem.

Thank you
for your attention