BNL EIC - IR

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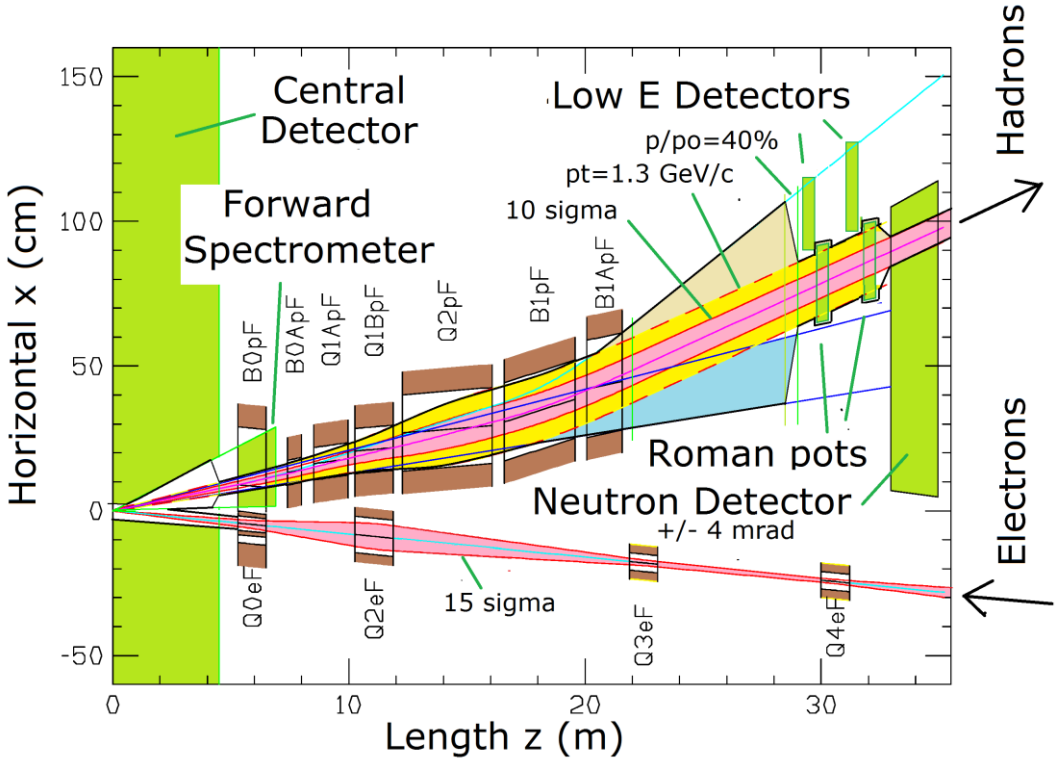
Electron Ion Collider – EIC at BNL

BROOKHAVEN NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY | Office of Science

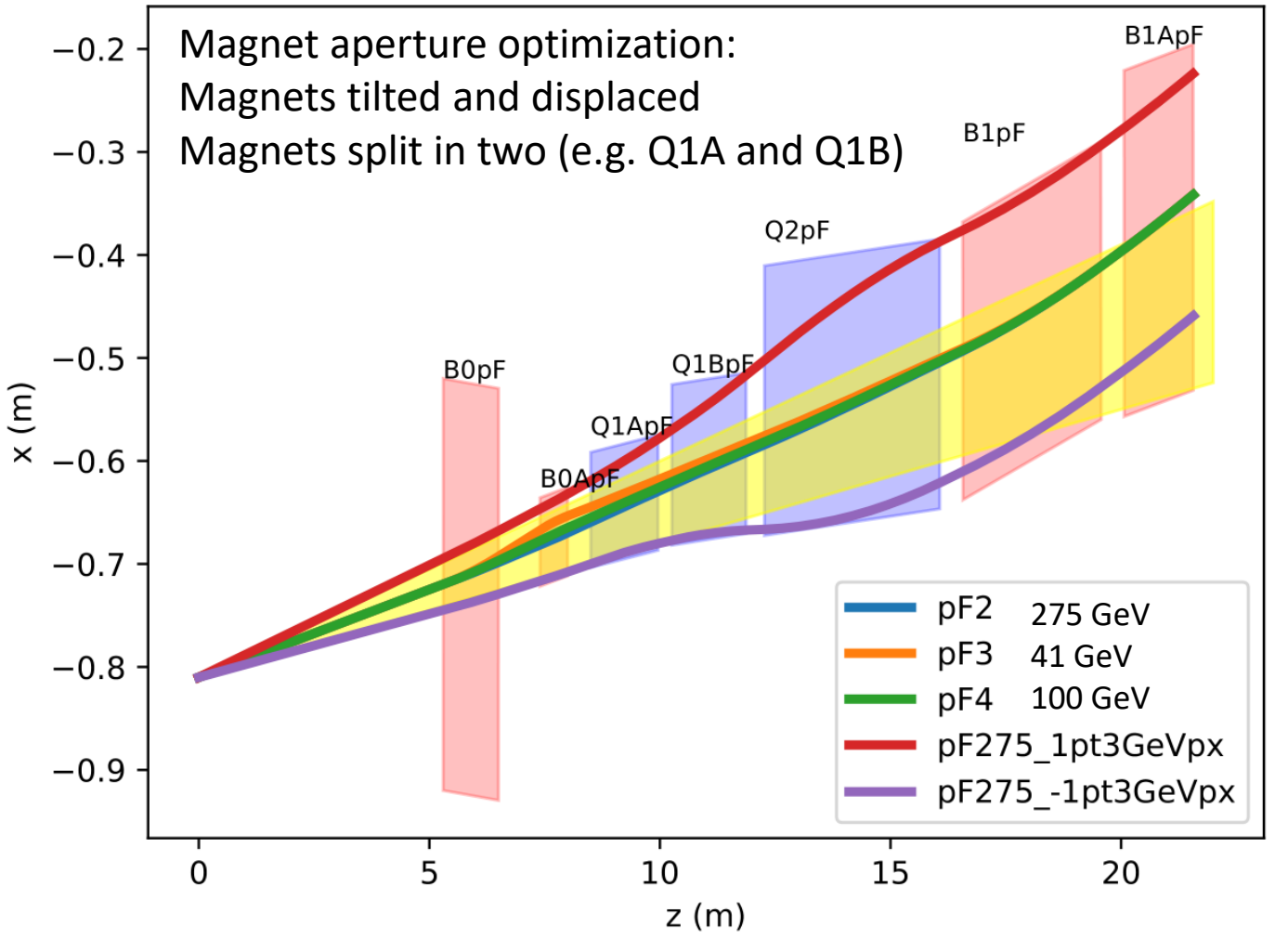
BNL EIC IR: Forward Direction



Name	R1	length	B	grad	B pole
	[m]	[m]	[T]	[T/m]	[T]
B0ApF	0.043	0.6	-3.3	0	-3.3
Q1ApF	0.056	1.46	0	-72.608	-4.066
Q1BpF	0.078	1.61	0	-66.18	-5.162
Q2pF	0.131	3.8	0	40.737	5.357
B1pF	0.135	3	-3.4	0	-3.4

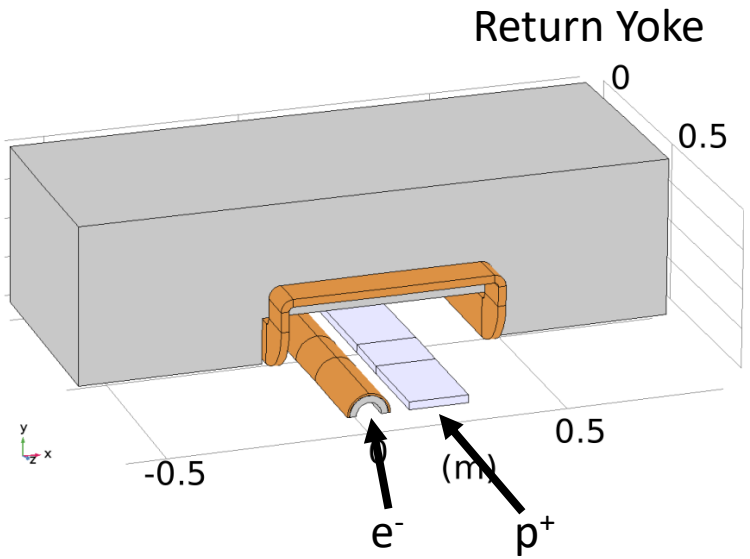
- Requirements for hadron beam direction
  - B0pF: Forward Spectrometer (6 - 20 mrad)
  - Neutron Detector (+/-4 mrad)
  - Roman pots (sensitive 1 to 5 mrad)
- Mostly interleaved magnets
  - Exception: B0 and Q1BpF/Q2eF
- Large apertures of proton forward magnets
  - See next slide

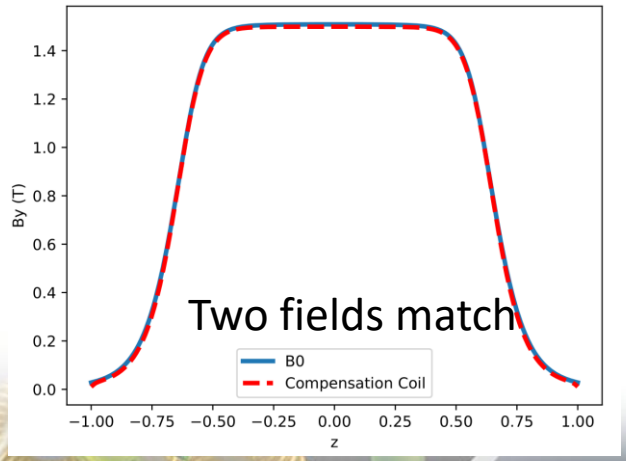
Hadron Forward - Apertures

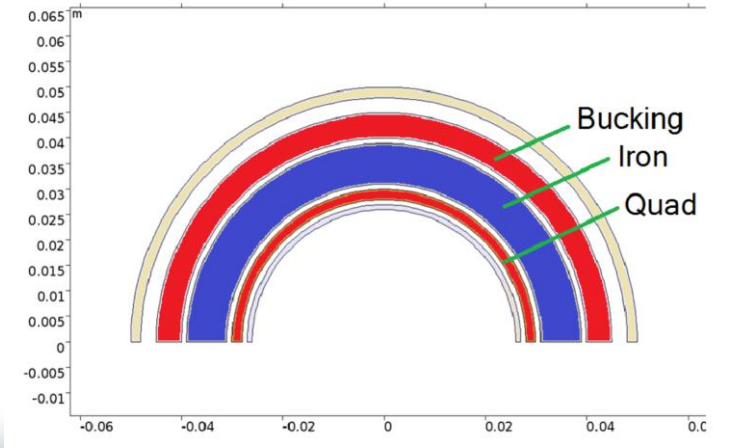


B0pF Spectrometer Magnet

- **Old concept**
- Superferric 1.3T magnet
  - Fixed field
  - Option: normal conducting
- Aperture: 0.23x0.5m^2
- Electrons: 15T/m gradient
  - In B0pF aperture
  - Requires cancellation dipole field
  - Bucking coil and iron collar







New Design - Overview

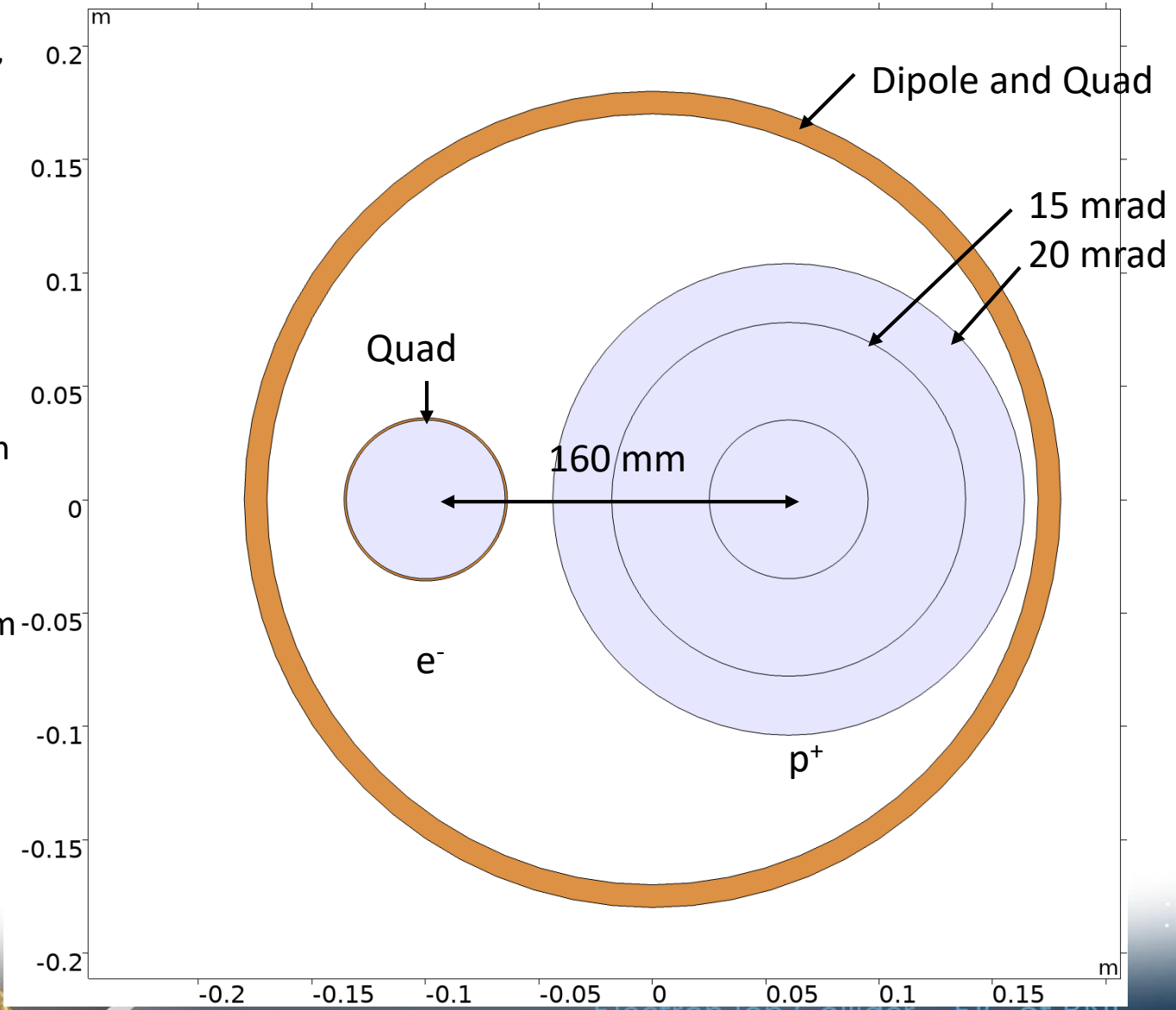
Idea: large aperture quad, generating correct gradient for electrons

Will automatically generate correct dipole field (+gradient) for hadrons

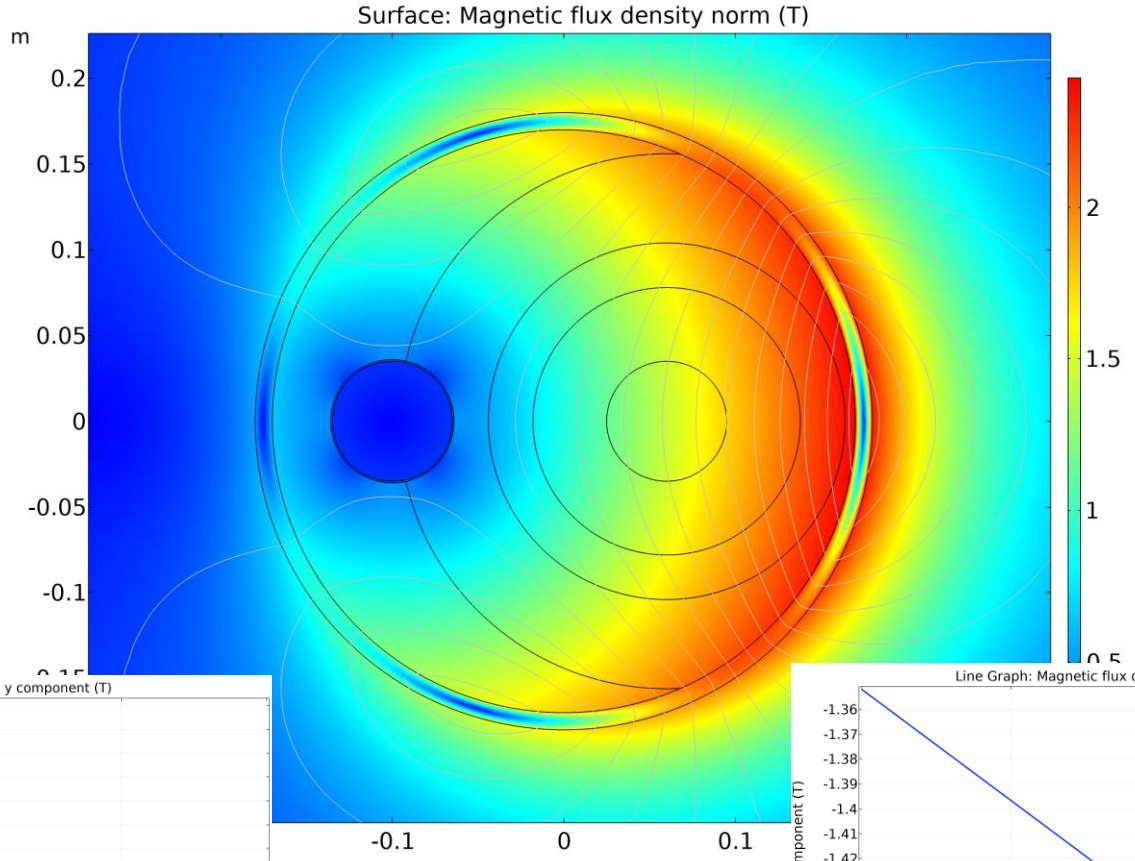
Better: combined function to reduce aperture

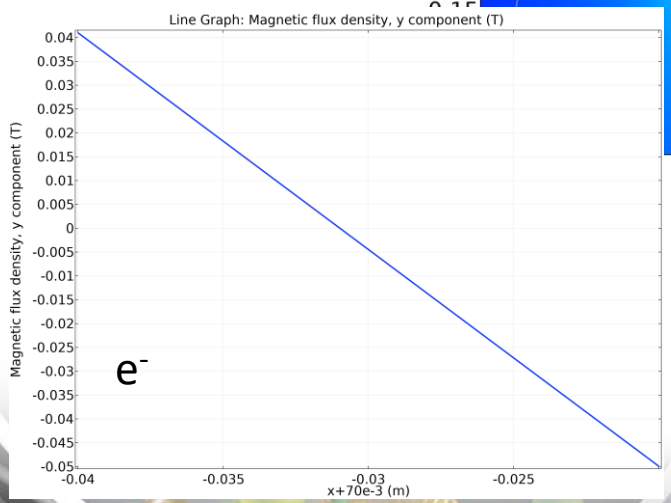
Challenge: 5 GeV operation requires 4.5 T/m gradient (low field for hadrons)

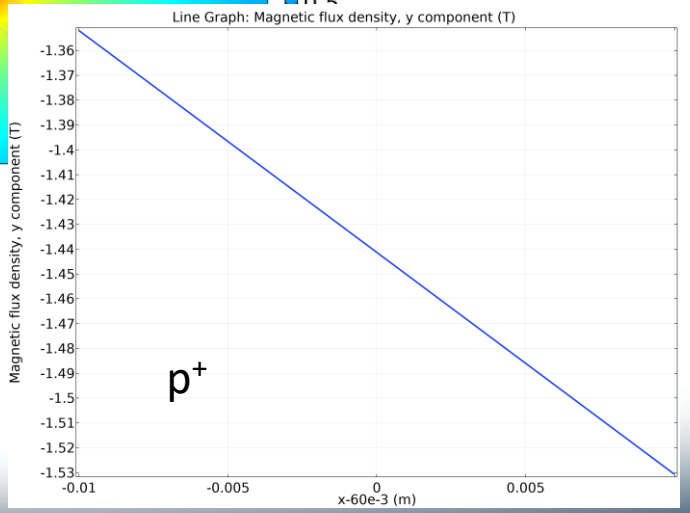
Requires additional electron quad



B0pF - Field

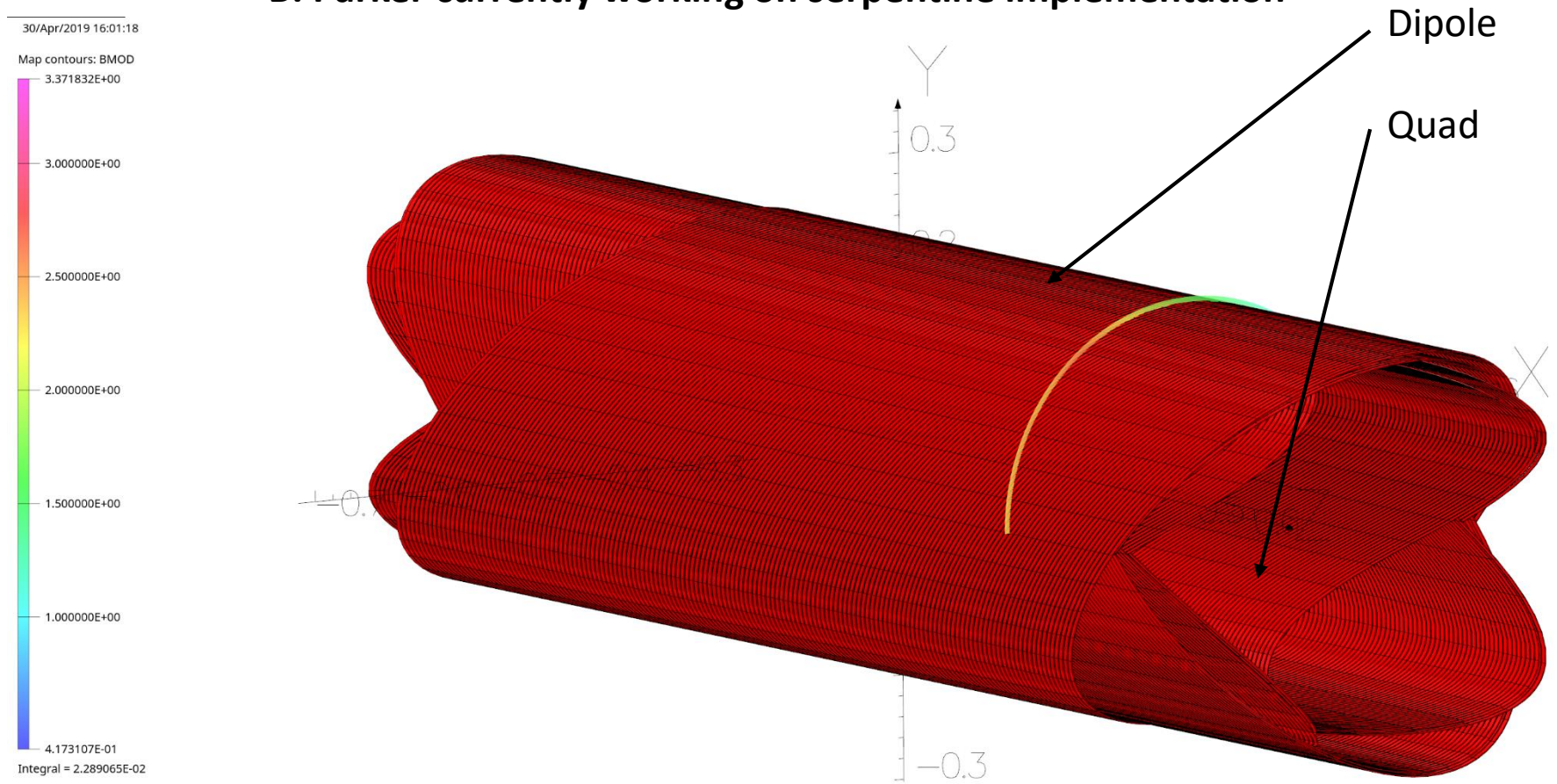

Surface: Magnetic flux density norm (T)
m
0.2
0.15
0.1
0.05
0
-0.05
-0.1
2
1.5
1
-0.1
0
0.1


Line Graph: Magnetic flux density, y component (T)
Magnetic flux density, y component (T)
x+70e-3 (m)
e-


Line Graph: Magnetic flux density, y component (T)
Magnetic flux density, y component (T)
x-60e-3 (m)
p+

Overview 3D

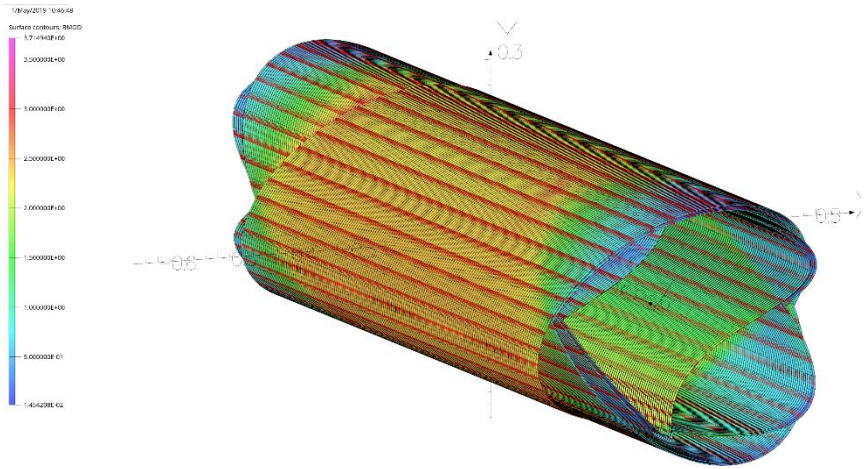
B. Parker currently working on serpentine implementation

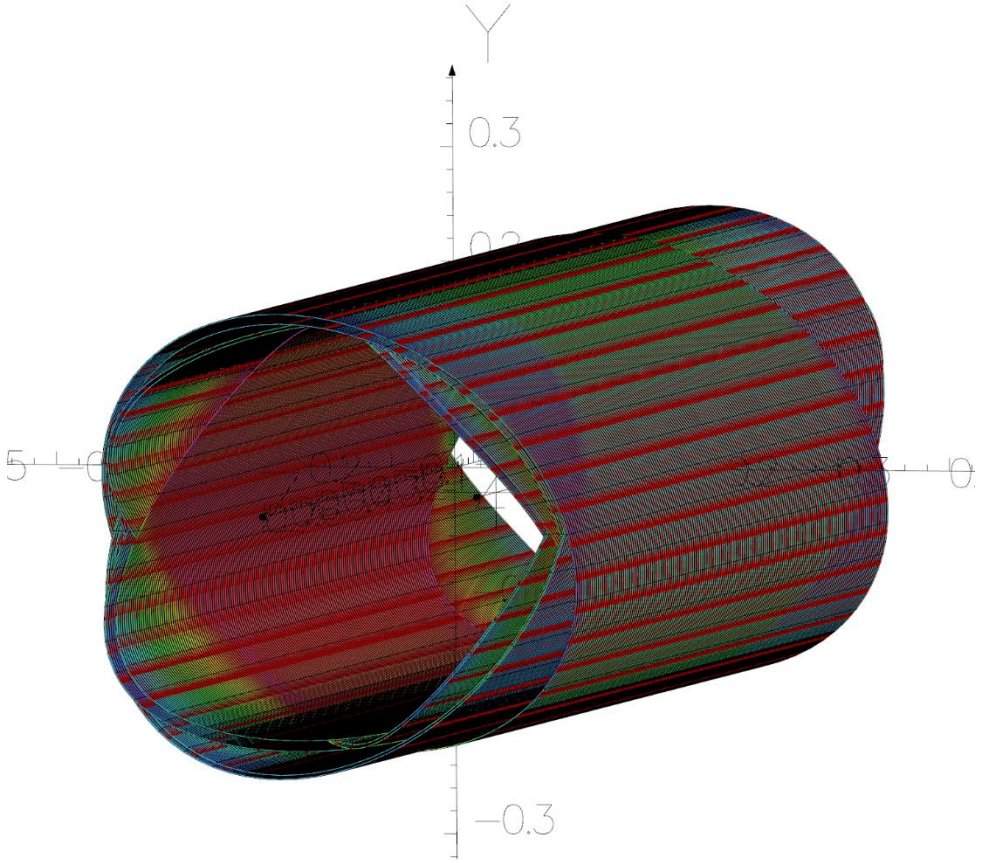


Implemented as double helix – could be a good choice, but up to discussion

Also possible: ‘true’ combined function

Peak Field Wire





Peak field: 3.71T

J_{dipole} = 500A/mm^2

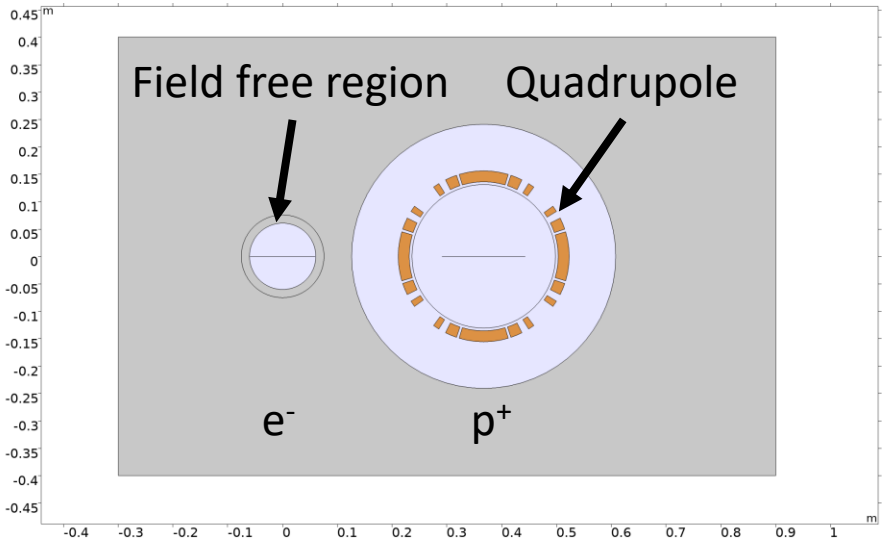
J_{quad} = 500A/mm^2

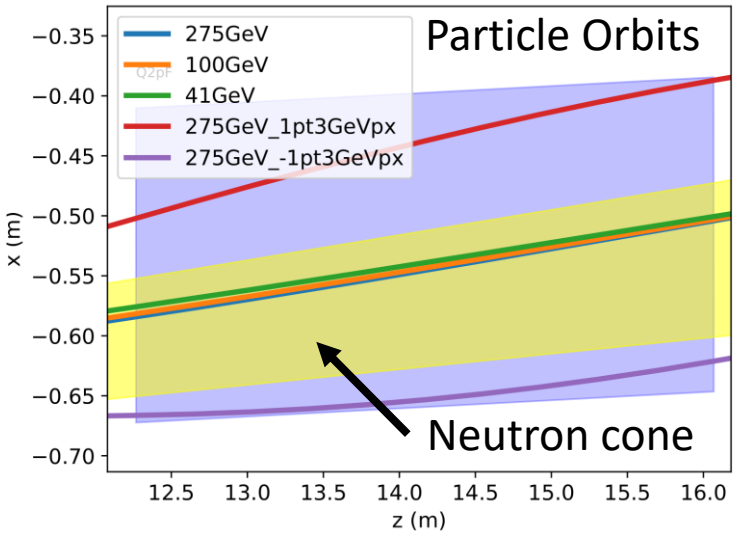
Cu:Sc ratio 1.3:1

Margin: 45%

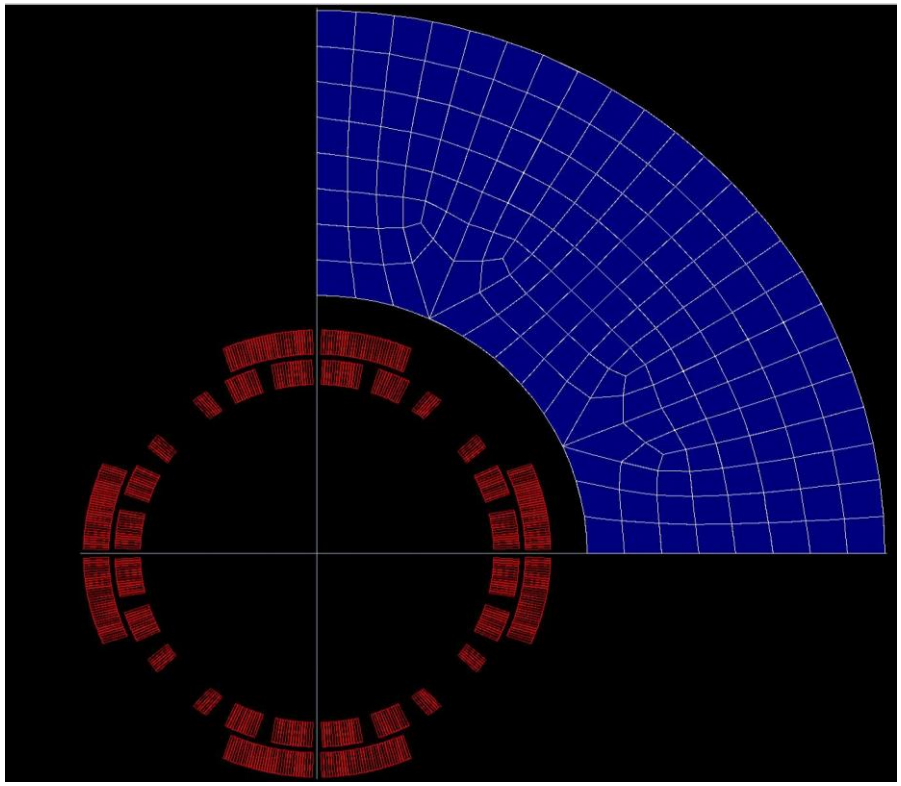
Q2pF – Collared Magnet

- Hadron quadrupole
  - Gradient: 41 T/m
  - 3.8m long
  - Aperture 262 mm
  - e-beam: 36-42cm distance
- Return yoke: 1.2x0.8 m^2
- Field-free region for electrons
- Magnet limitations
  - Gradient/field
  - Aperture
  - Stray field
- Old concept: Single layer
  - 2K operation





Q2pF – Cross-section

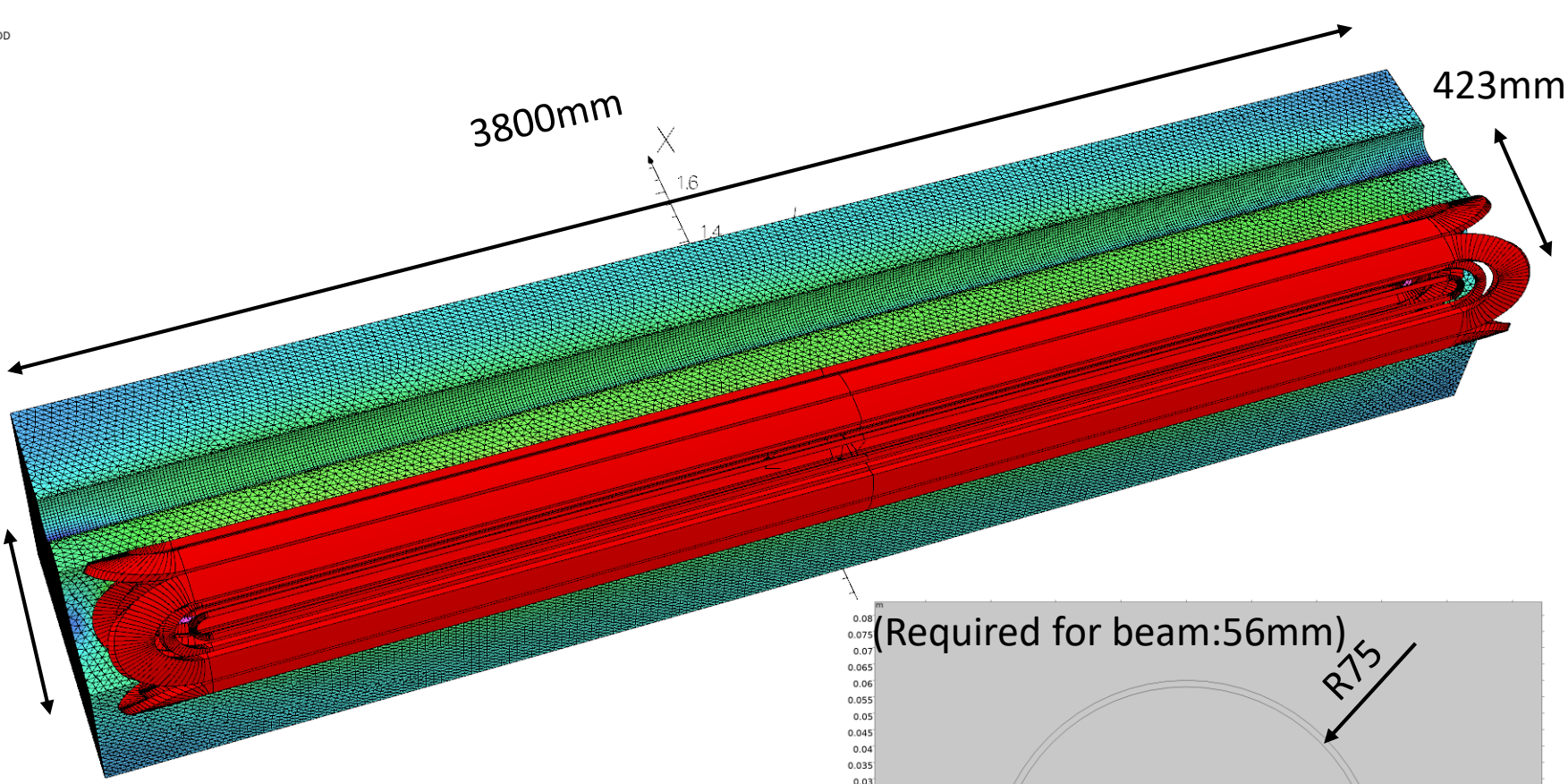


- Yoke: IR 214mm
- Coils:
  - IR1 140mm
  - IR2: 165mm
- (Req. by beam: R131mm)
- J_{av}: 220A/mm2
- Current: ≈9kA
- Peak field: 6.62T
- Field quality: 2×10^{-4}

Also: similar design by R. Gupta (BNL S-MD)

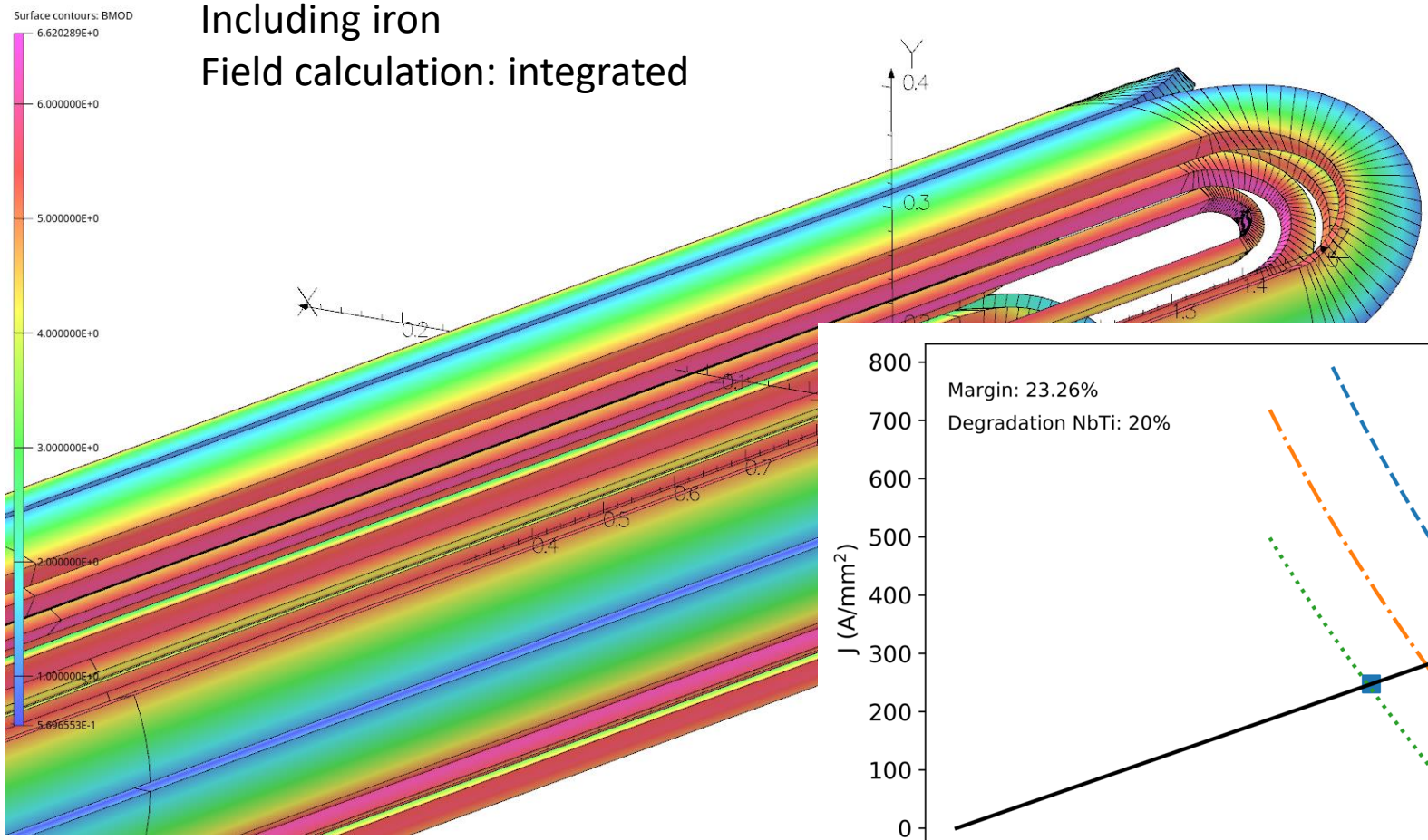
3D Geometry

'default' BH curve



3D – Geometry / Peak Field

6.62T



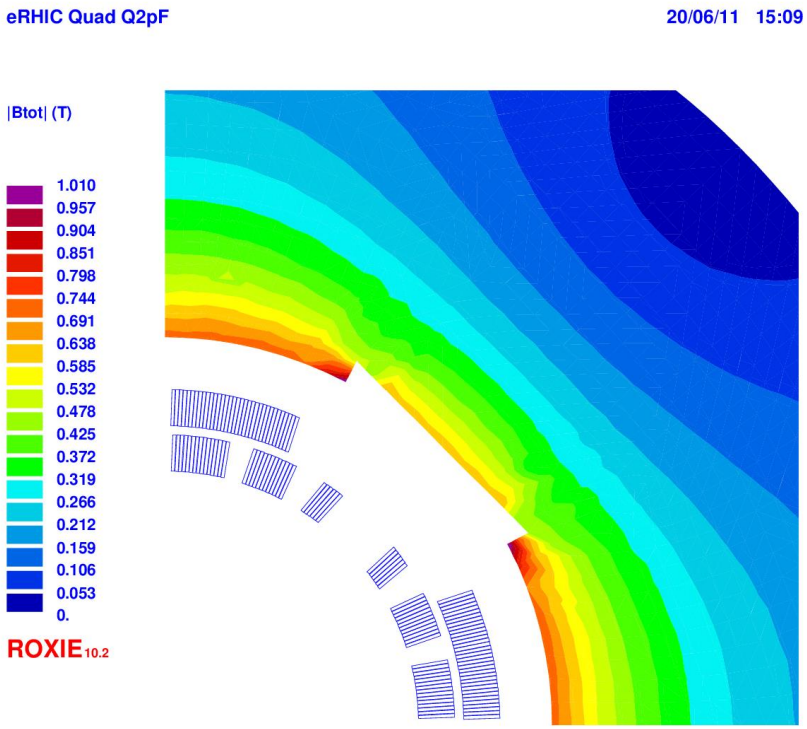
Including iron

Field calculation: integrated

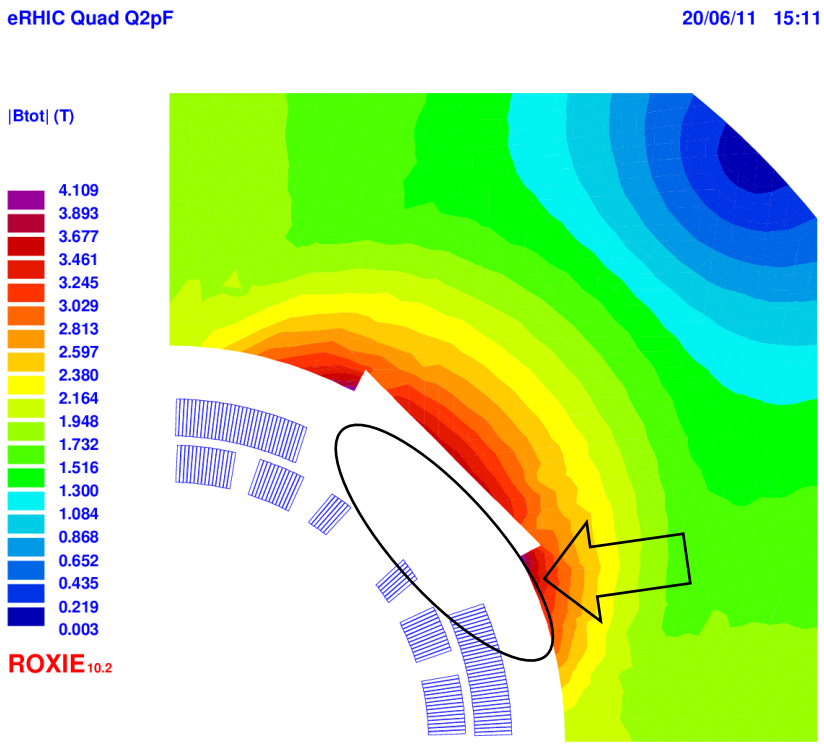
Yoke Optimization

Optimized for harmonics

41 GeV



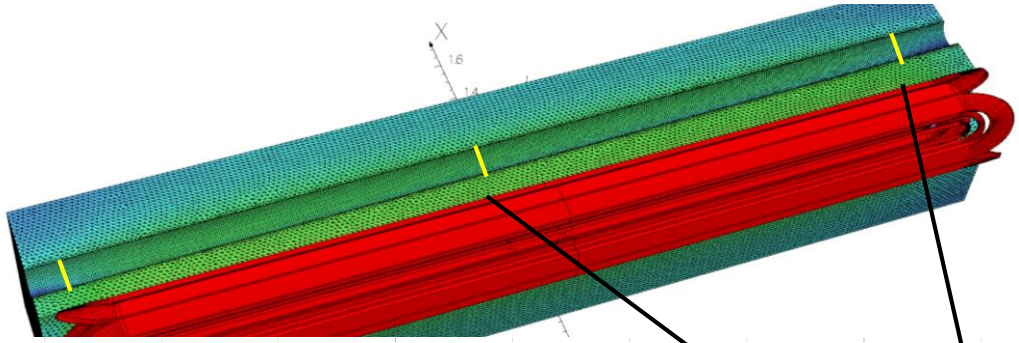
275 GeV

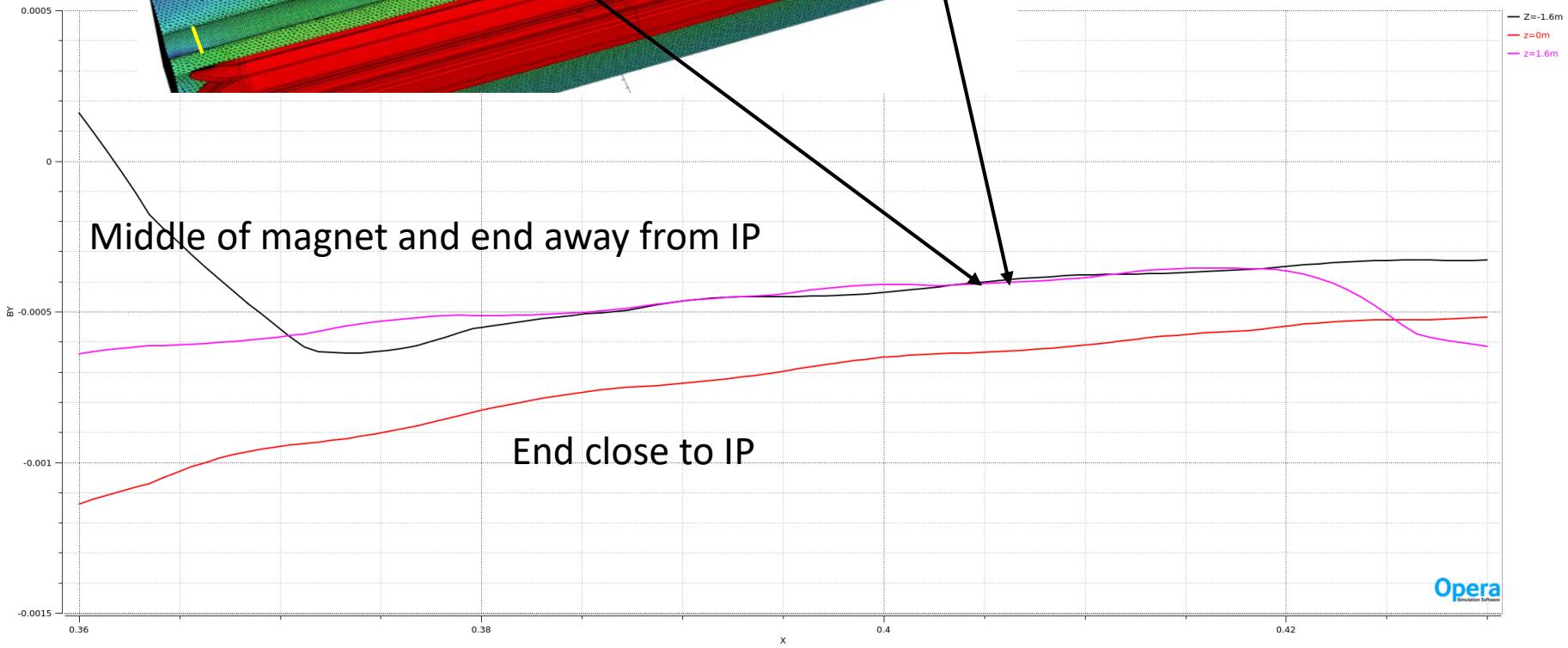



```
NORMAL RELATIVE MULTIPOLES (1.D-4):
b 1:      0.00000  b 2:  10000.00000  b 3:      0.00000
b 4:     -0.00311  b 5:     -0.00000  b 6:      0.14245
b 7:      0.00000  b 8:     -0.00011  b 9:     -0.00000
b10:     -0.29268  b11:      0.00000  b12:     -0.00000
b13:      0.00000  b14:      0.03575  b15:     -0.00000
b16:     -0.00000  b17:      0.00000  b18:      0.01138
b19:      0.00000  b20:     -0.00000  b
```

Change: b6 ≈ ±1 unit

Stray Field Electrons

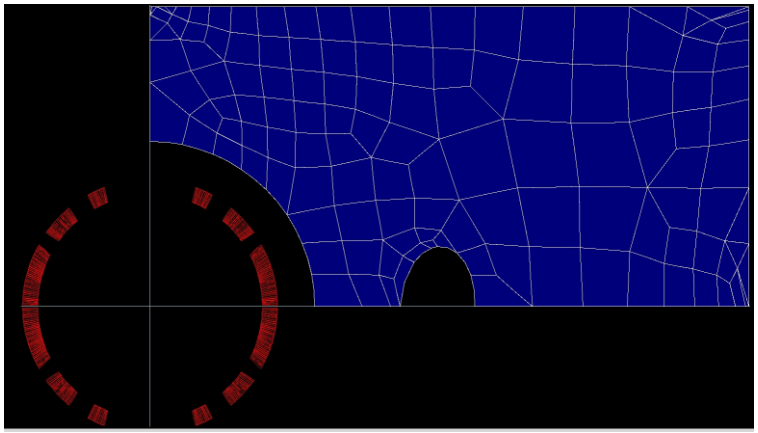




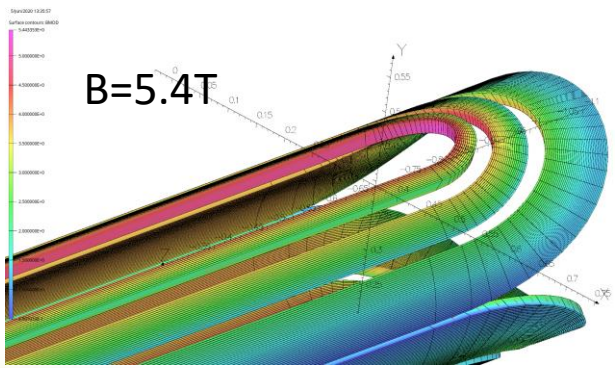
About 1 mT for end closer to IP
Can be shielded with mu-metal

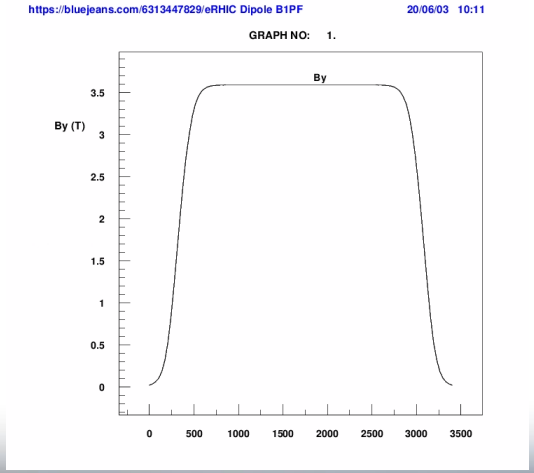
B1pF – Revised Design

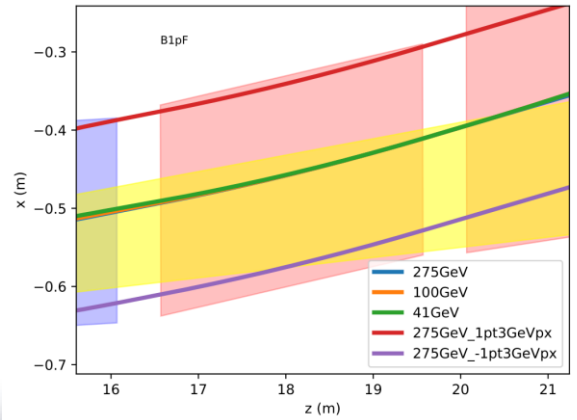
- Reduced length
- Optimized ends
- Fits in designated slot
- R_{turns}=150mm
  - Beampipe: R131mm
- I=9100A



```
NORMAL 3D INTEGRAL RELATIVE MULTIPOLES (1.D-4):
b 1:  10000.00000  b 2:      0.00000  b 3:     -0.24433
b 4:      0.00000  b 5:      0.59187  b 6:      0.00000
b 7:      0.33666  b 8:     -0.00000  b 9:     -0.03021
b10:      0.00000  b11:     -0.00236  b12:     -0.00000
b13:     -0.00177  b14:      0.00000  b15:      0.00007
b16:     -0.00000  b17:      0.00018  b18:      0.00000
b19:     -0.00005  b20:      0.00000  b
```

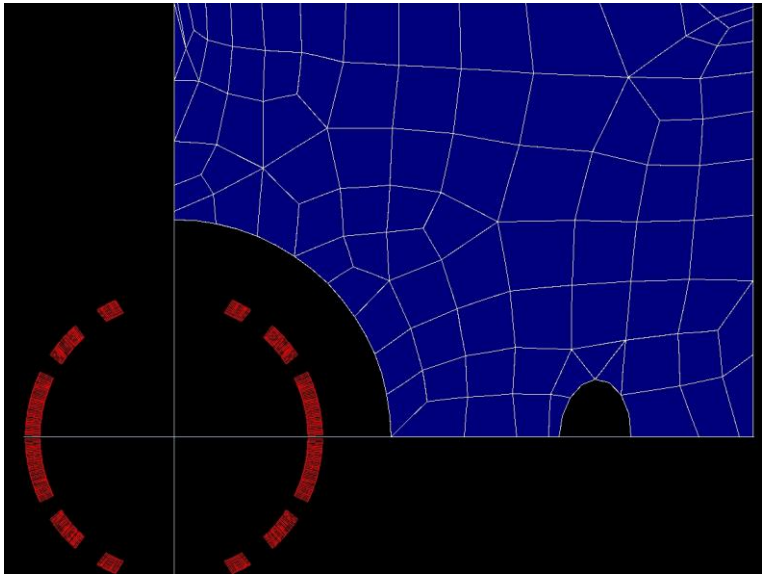


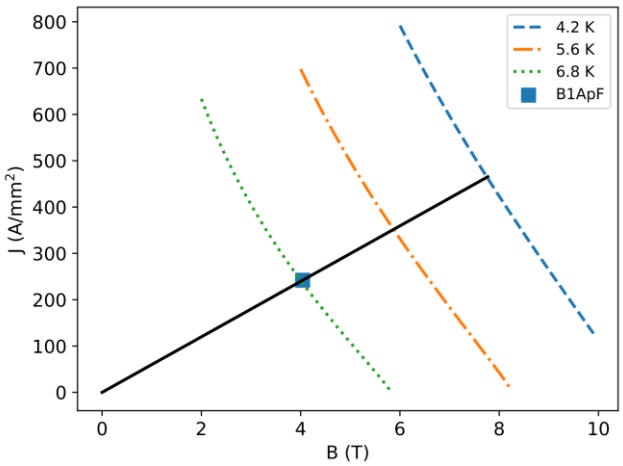


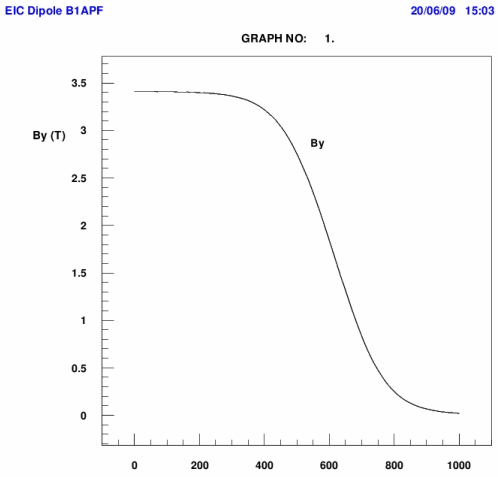


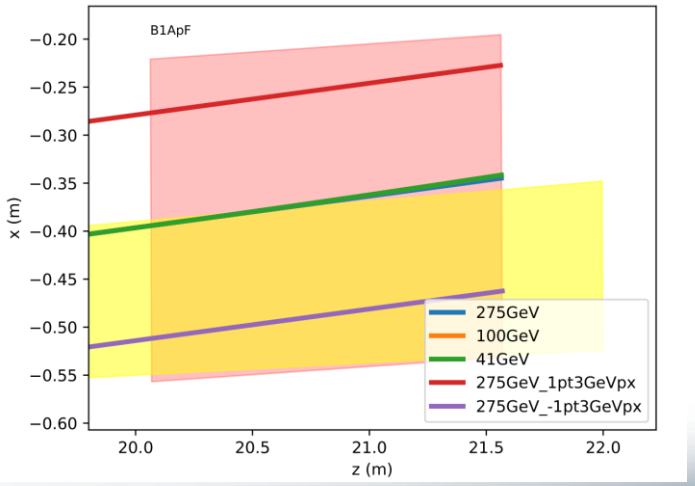
B1ApF

- Reduced length
- Optimized ends
- Fits in designated slot
  - With interface to B1pF
- R_{turns}=185mm
  - Beampipe: R168mm
- I=9200A



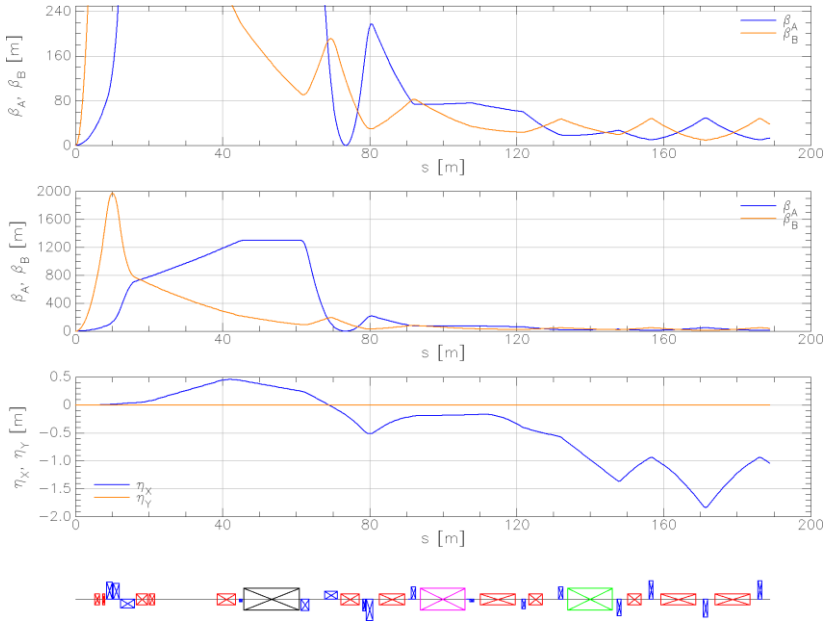




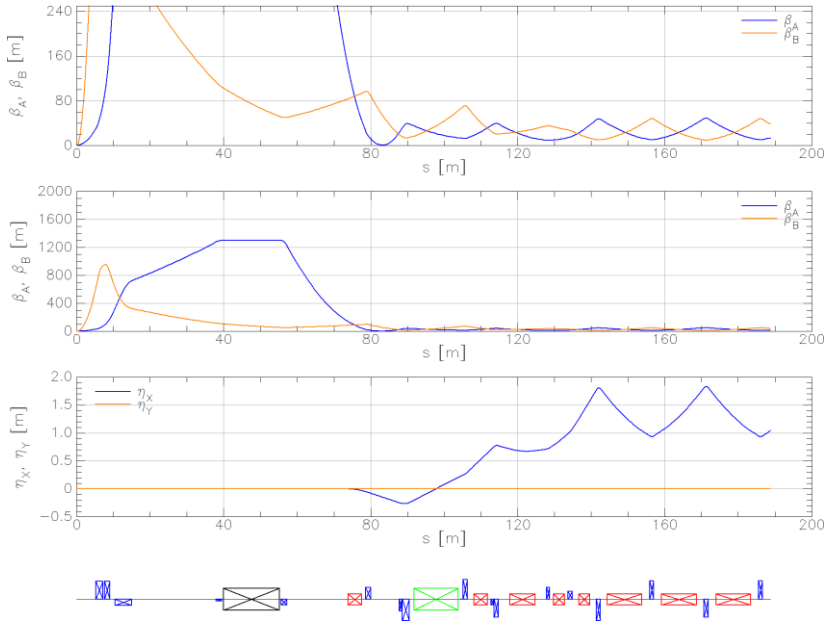


Matching into RHIC Arcs

Forward



Rear

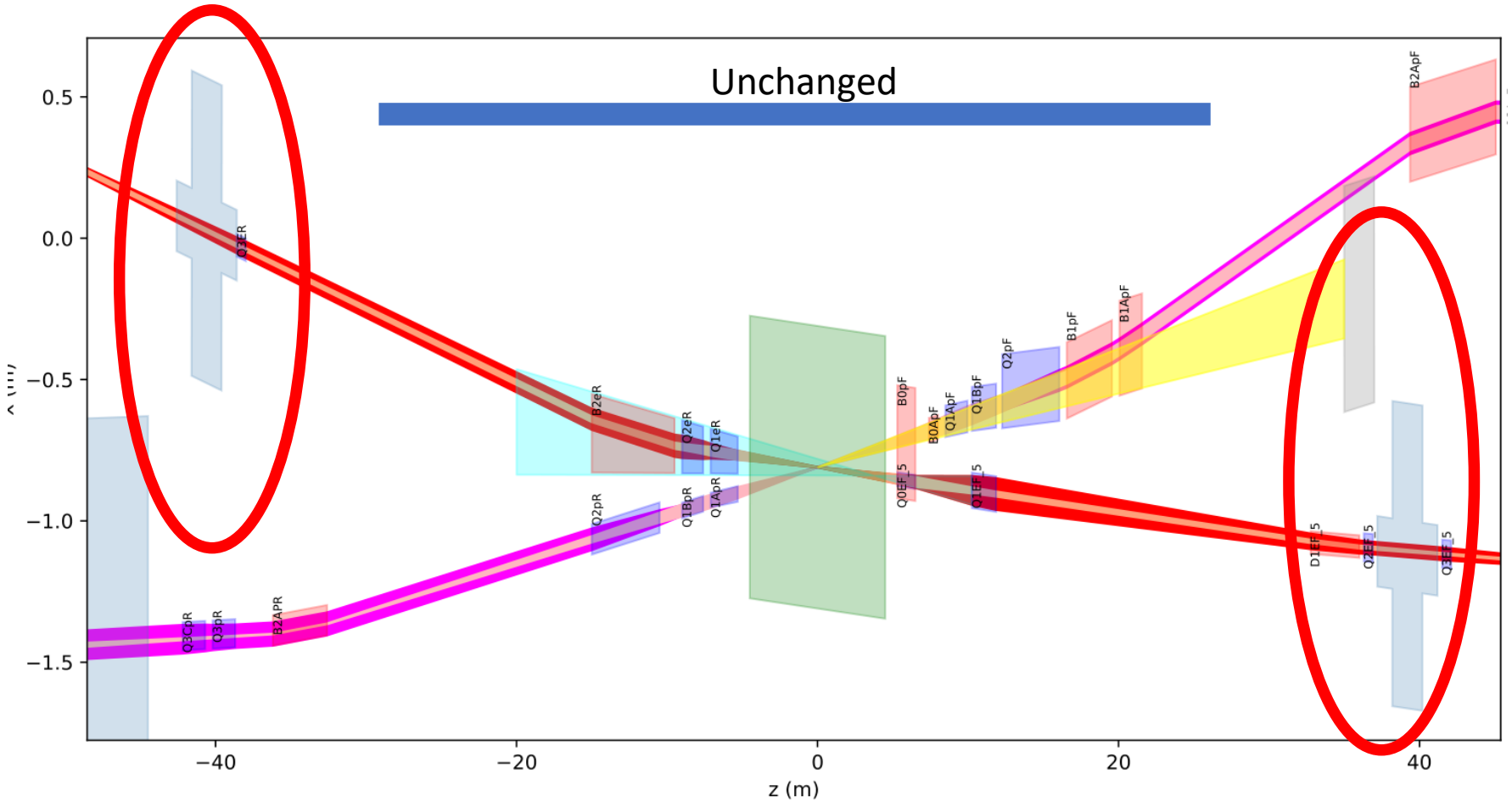


Severe space constraints

Re-use as many RHIC magnets as possible

Courtesy of S. Berg

Electron Lattice



Electron crab cavity after ZDC (avoids interference with neutron cone)

No dipole in front of crab cavity (avoids synchrotron radiation issue)

Summary

- Inner IR lattice unchanged
- New matches for electrons and hadrons
  - Avoids several issues
  - Re-cycles more magnets for hadrons
  - Lower chromaticity
- Magnet designs
  - Q2pF, B1pF and B1ApF revised
  - New concept for B0pF