Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Overall Plan of Work and Status of EIC IR Cable Magnets

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Overall Plan of Work

- Choose the cable for all cable magnets. The chosen cable must have the same width for all cable magnets. The cable, however, may have two keystone angles.
- Perform an integrated review of all cable magnet designs at 2K and finalize the cable. Current choice is LHC ~15 mm wide cable (complete in about a week).
- Perform cross-section design of all five cable magnets (complete in about a month).
- Perform initial 3-d end design of all magnets with ROXIE and OPERA/COMSOL (complete in about 2 months from now, and at least one by the end of April)
- Provide info to start mechanical (ANSYS) analysis for these initial designs
- In parallel optimize the ends for
  - Reducing cross-talk
  - Improving the layout of the end blocks/turns (cable orientation, strain energy, etc.)
  - Reducing peak fields (increasing margin)
- This parallel approach should help complete the tasks within the schedule of MoU even if the final magnetic designs have evolved from the ANSYS models used

Status and Immediate Plans

- Review summary of the previous 2 K designs (Presentation today by Anis)
- Other work performed since the last MOU (Presentation today by Ramesh)
  - Initial design of B1pF at 2 K with LHC type ~15 mm wide cable
  - Initial design of B1ApF at 2 K with LHC type ~15 mm wide cable
- Future work on the cable magnets
  - Meetings for knowledge transfer with Febin and Mithlesh (couple of weeks ago) to optimize cross-section with ROXIE (others are expert already)
  - Febin to work on B1pF to further optimize (can be another magnet)
  - Mithlesh to work on B1ApF to further optimize (can be another magnet)
  - Distribution of work to optimize other magnets and get more expertise with ROXIE and finer details of design optimization

LHC Style Cable used in B1pF & B1ApF (can still be changed, but to be fixed soon)

Cable Definition

No	Name	Cable Geom.	Strand	Filament	Insul	Trans	Quench Mat.	T_o	Comment
1	EICLHC2KA	EICLHC01A	STREIC1	NBTII	ALLPOLYIL	TRANS1	NONE	2	LHC INNER FOR EIC
1	EICLHCR2K	EICLHC01R	STREIC1	NBTII	ALLPOLYIL	TRANS1	NONE	2	LHC INNER FOR EIC
2	EICLHC2K	EICLHC01	STREIC1	NBTII	ALLPOLYIL	TRANS1	NONE	2	LHC INNER FOR EIC

Cable Geometry

No	Name	height	width_i	width_o	ns	transp.	degrd	Comment
6	EICLHC01	15.1	1.786	2.014	28	115	5	LHC CABLE
7	EICLHC01A	15.1	1.814	1.986	28	115	5	LHC CABLE
7	EICLHC01R	15.1	1.9	1.9	28	115	5	LHC CABLE
8	CABLE01	15.1	1.736	2.064	28	115	5	MB INNER L
9	CABLE02	15.1	1.362	1.598	36	100	5	MB OUTER L

Block Data 2D

No	Type	NCab	X	Y	α	Current	Cable name	N1	N2	Imag	Turn
1	Cos	15	150	0.1	0	-8050	EICLHC2KA	2	30	0	0
2	Cos	25	150	15	15	-8050	EICLHC2KA	2	30	0	0
3	Cos	15	150	35	35	-8050	EICLHC2KA	2	30	0	0
4	Cos	10	150	55	55	-8050	EICLHC2KA	2	30	0	0
5	Cos	5	150	70	70	-8050	EICLHC2KA	2	30	0	0

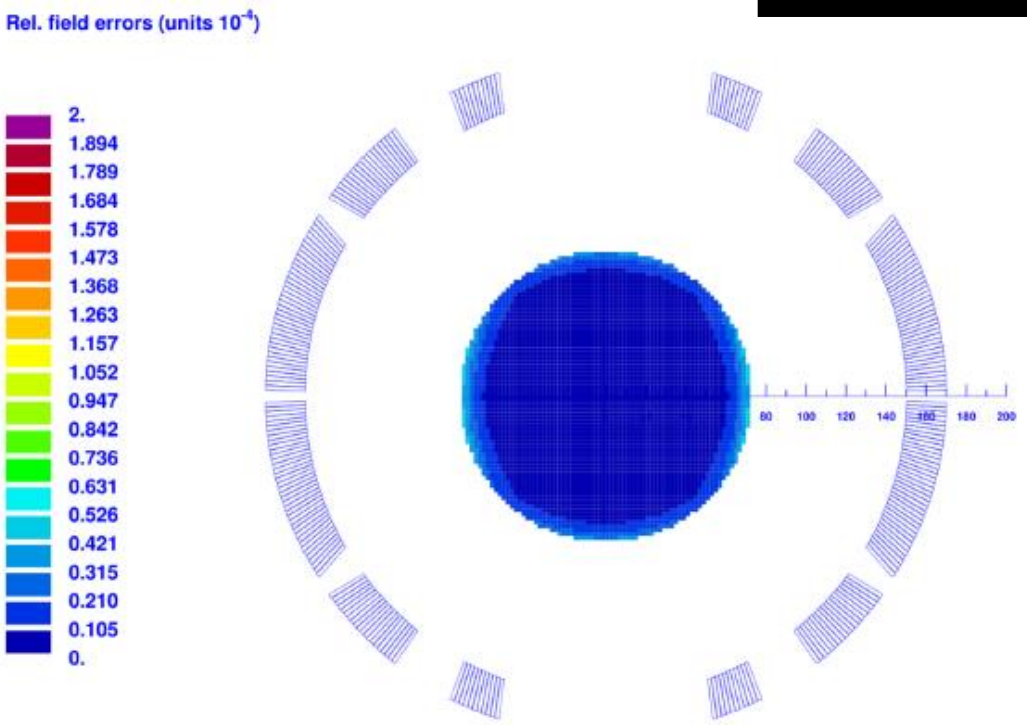
B1pF with LHC Style Cable

CDR Parameters and Design

Coil Radius: 150 mm

Table 6.8: Parameters of the B1PF magnet.

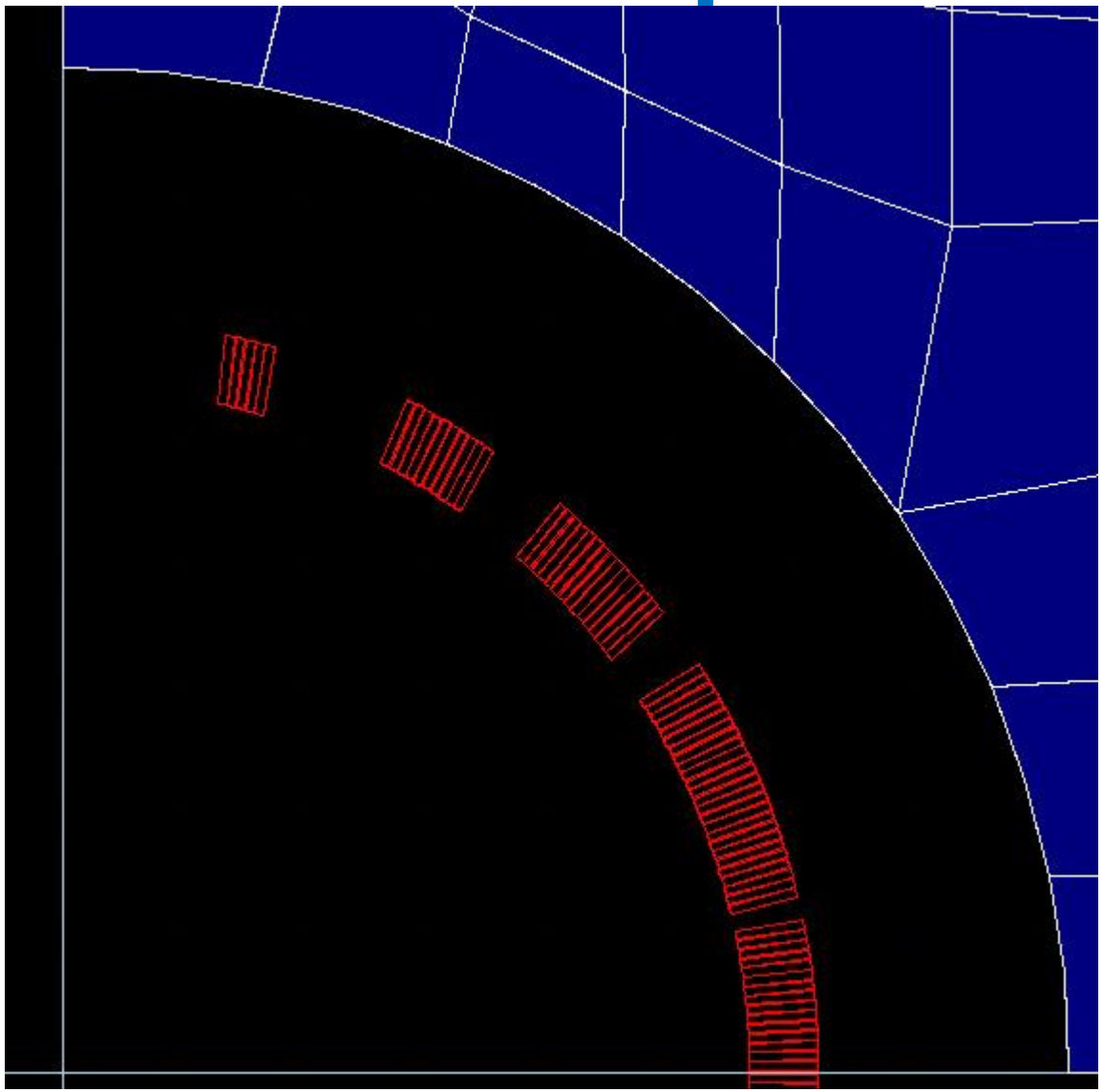
Parameter	Value
Magnetic length [m]	3
Maximum dipole field [T]	3.4
Aperture [m]	0.262
Required field quality [%]	0.01
Coil width [m]	0.34
Coil height [m]	0.34
Superconductor Type	NbTi
Current density [A/mm^2]	241
Cu:Sc ratio	1.3
Temperature [K]	4.2
Peak field wire [T]	4.37
Magnetic energy [MJ]	1.36
Ampere turns [MA·t]	1.16
Margin loadline [%]	58



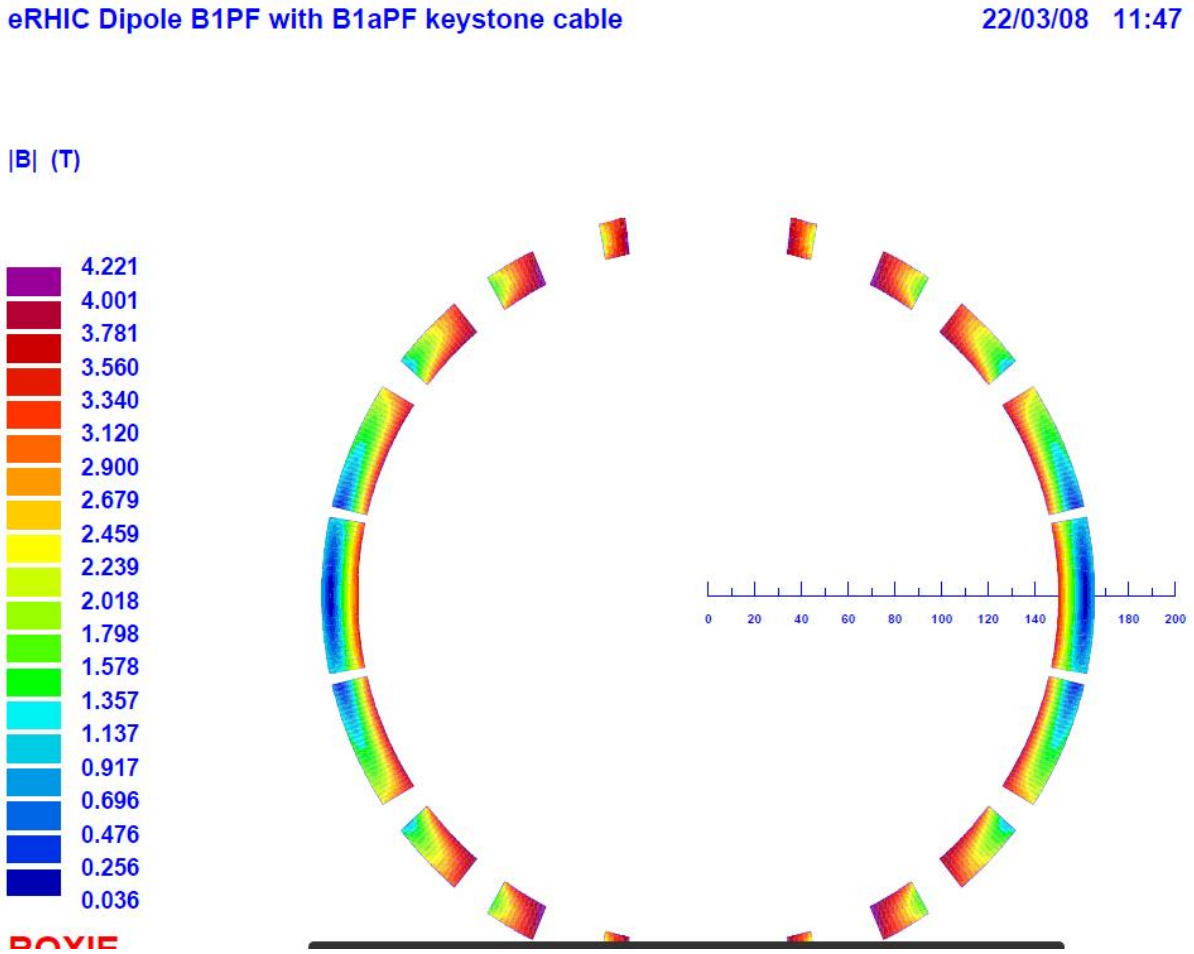
(b) Shielded region

Figure 6.34: Vertical magnetic field on the center plane for the hadron beam (a). Figure (b) shows the good field region.

B1pF with LHC Style Cable



Coil Radius: 150 mm



B1pF with LHC Style Cable

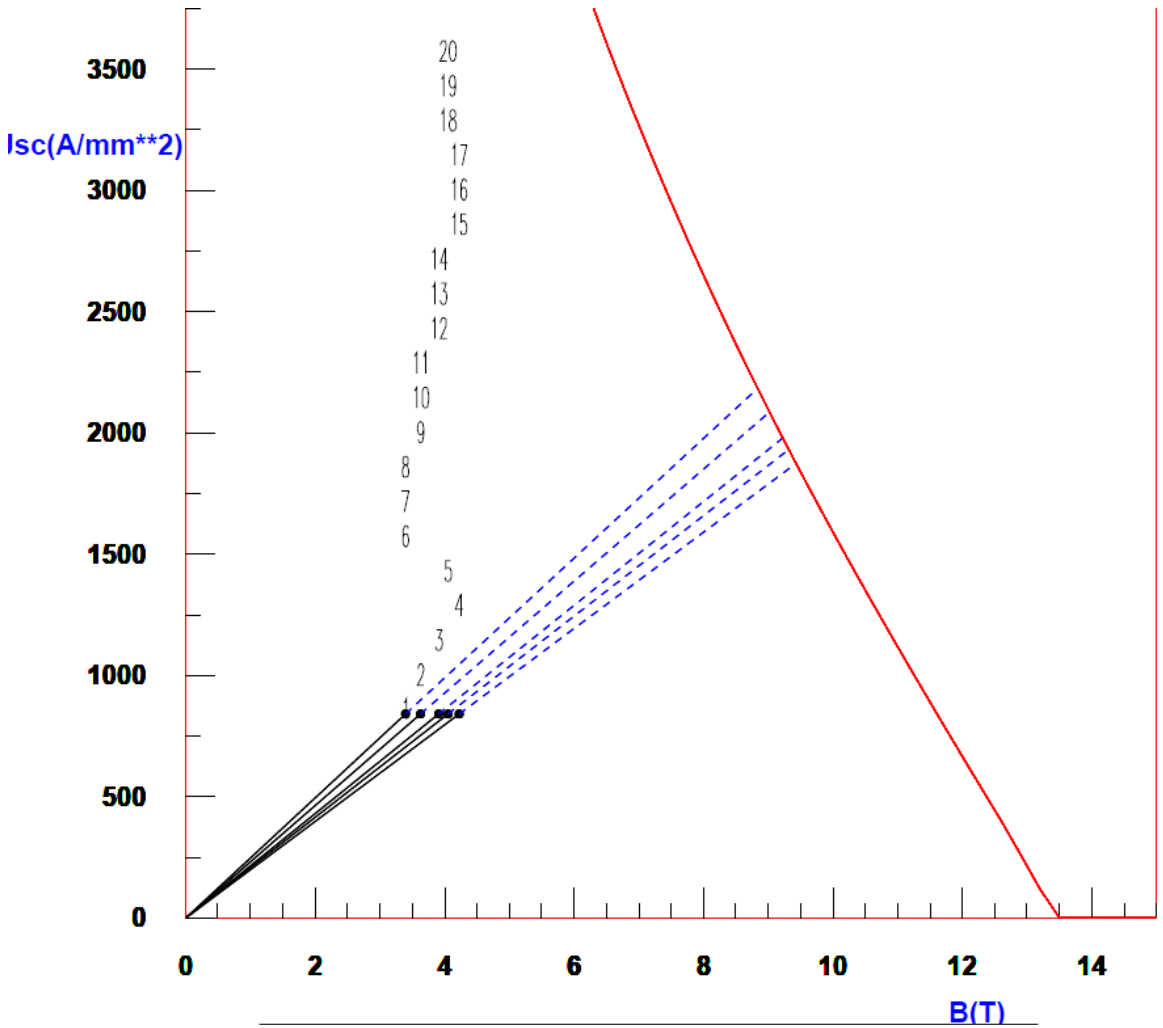
```
HARMONIC ANALYSIS NUMBER ..............................          1
MAIN HARMONIC ........................................          1
REFERENCE RADIUS (mm) ................................     73.0000
X-POSITION OF THE HARMONIC COIL (mm) .................      0.0000
Y-POSITION OF THE HARMONIC COIL (mm) .................      0.0000
MEASUREMENT TYPE ......................... ALL FIELD CONTRIBUTIONS
ERROR OF HARMONIC ANALYSIS OF Br ....................  0.1730E-04
SUM (Br(p) - SUM (An cos(np) + Bn sin(np))

MAIN FIELD (T) .......................................    3.406738
MAGNET STRENGTH (T/(m^(n-1)) .........................      3.4067

NORMAL RELATIVE MULTIPOLES (1.D-4):
b 1:  10000.00000  b 2:      0.00000  b 3:     -0.00144
b 4:      0.00000  b 5:     -0.00402  b 6:     -0.00000
b 7:     -0.01432  b 8:      0.00000  b 9:     -0.19807
b10:      0.00000  b11:     -0.11854  b12:     -0.00000
b13:      0.02329  b14:     -0.00000  b15:      0.00858
b16:      0.00000  b17:      0.00321  b18:      0.00000
b19:      0.00089  b20:     -0.00000  b
```

Field quality ok

B1pF with LHC Style Cable



Large Margin

B1ApF with LHC Style Cable

CDR Parameters and Design

Table 6.10: Parameters of the B1APF Dipole Magnet.

Parameter	Value
Magnetic length [m]	1.5
Maximum dipole field [T]	2.7
Aperture front [m]	0.3360
Aperture rear [m]	0.3360
Design field quality	1×10^{-4}
Physical length [m]	1.6
Physical width [m]	0.41
Physical height [m]	0.41
Superconductor type	NbTi
Conductor	Cable 20x2mm^2
Current density [A/mm^2]	148
Cu:Sc ratio	1.3
Temperature [K]	4.2
Peak field wire [T]	3.5
Magnetic energy [MJ]	0.717
Ampere turns [MA·t]	1.16
Number of turns	154
Current [A]	7670
Inductance [H]	0.024376
Margin loadline [%]	60

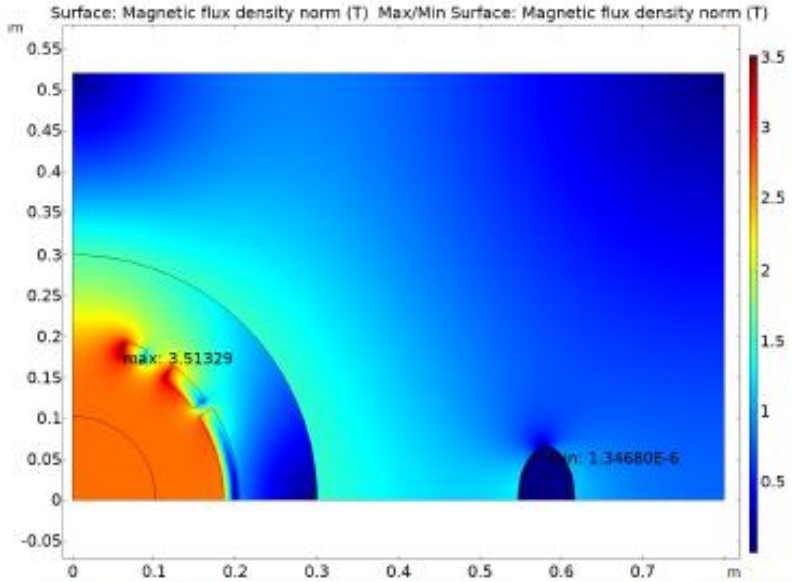
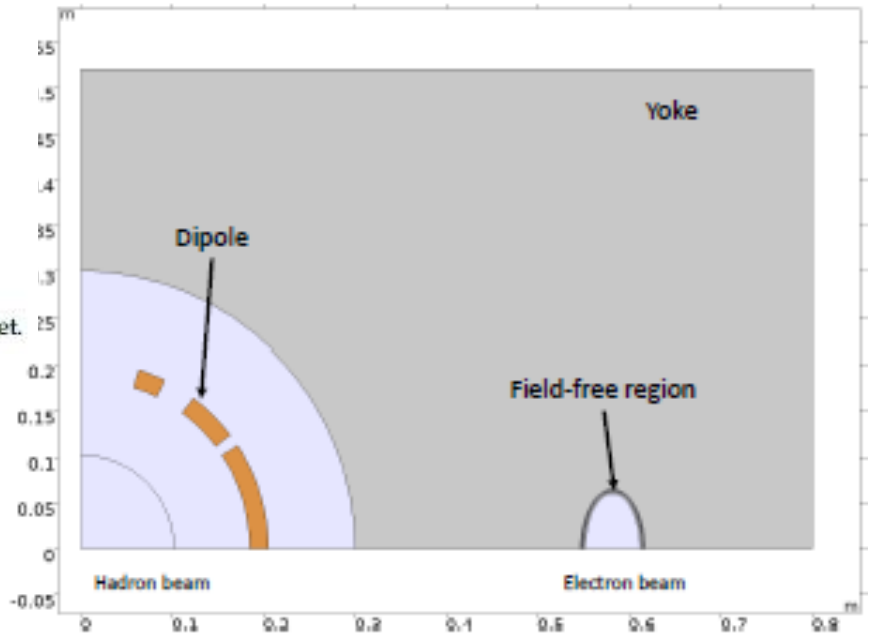


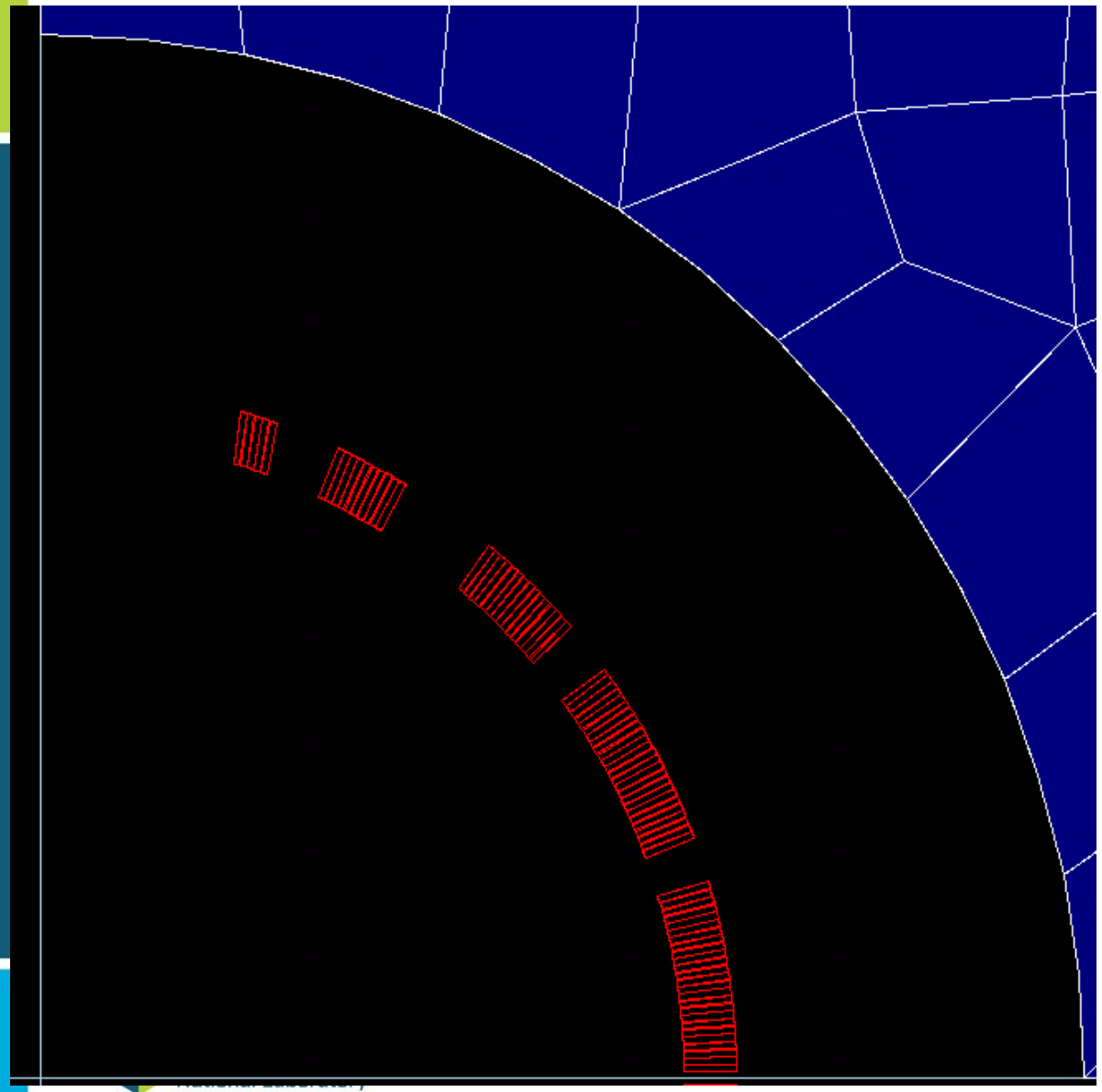
Figure 6.39: Magnetic field equivalent to the magnetization in the B1APF magnet.

Coil Radius: 185 mm

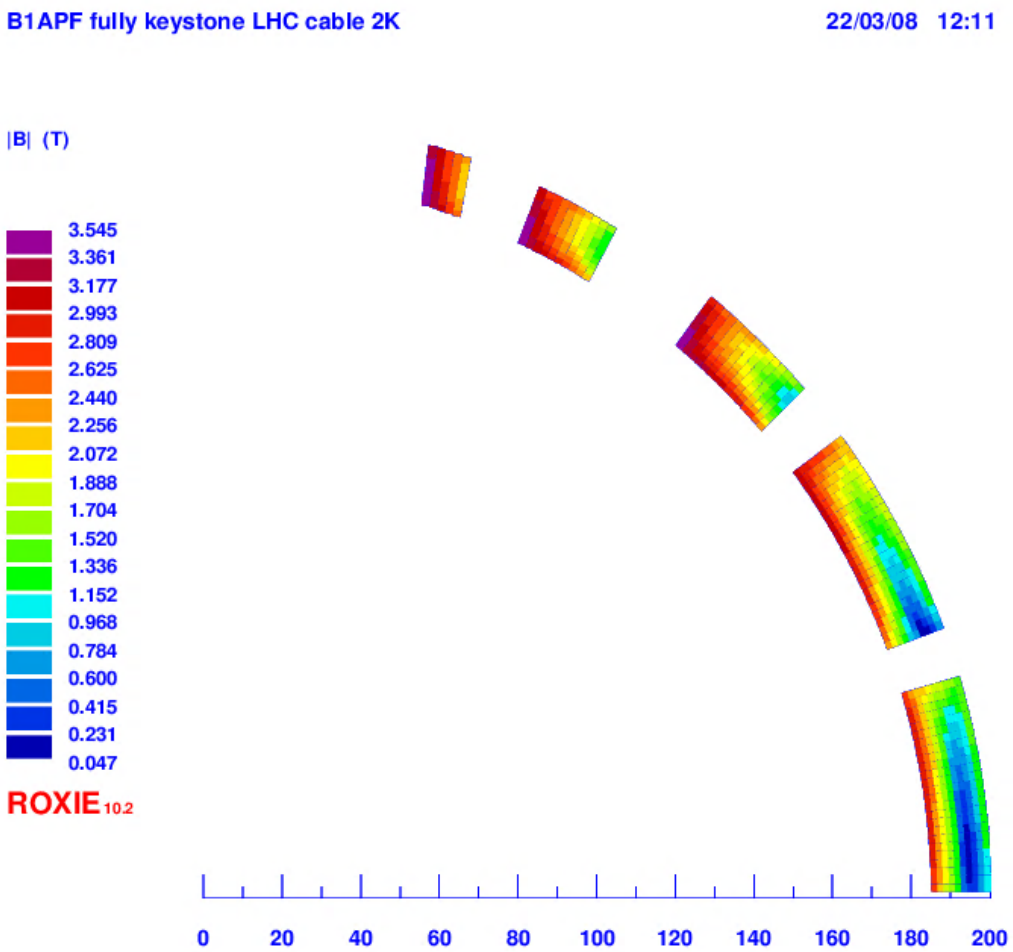


(a) Cross-section of B1APF

B1ApF with LHC Style Cable



Coil Radius: 185 mm



B1ApF with LHC Style Cable

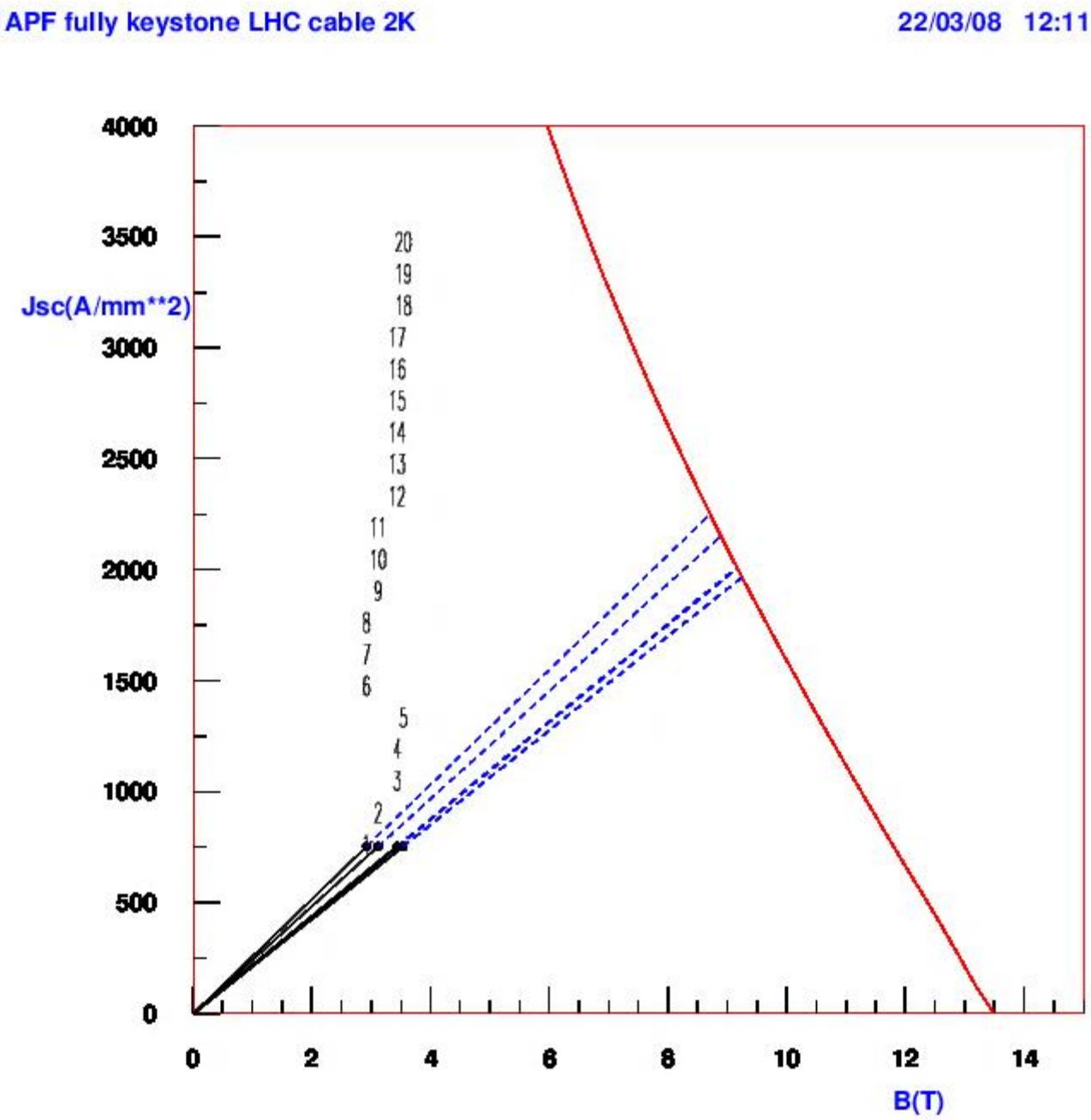
```
HARMONIC ANALYSIS NUMBER ..............................          1
MAIN HARMONIC ........................................          1
REFERENCE RADIUS (mm) ................................       80.0000
X-POSITION OF THE HARMONIC COIL (mm) .................        0.0000
Y-POSITION OF THE HARMONIC COIL (mm) .................        0.0000
MEASUREMENT TYPE ......................... ALL FIELD CONTRIBUTIONS
ERROR OF HARMONIC ANALYSIS OF Br ....................   0.1101E-05
SUM (Br(p) - SUM (An cos(np) + Bn sin(np))

MAIN FIELD (T) .......................................     2.700380
MAGNET STRENGTH (T/(m^(n-1)) .........................       2.7004

NORMAL RELATIVE MULTIPOLES (1.D-4):
b 1:  10000.00000  b 2:     -0.00000  b 3:      0.00322
b 4:     -0.00000  b 5:      0.00422  b 6:     -0.00000
b 7:      0.01289  b 8:     -0.00000  b 9:      0.01186
b10:      0.00000  b11:      0.15673  b12:     -0.00000
b13:     -0.00699  b14:      0.00000  b15:      0.00178
b16:     -0.00000  b17:      0.00018  b18:     -0.00000
b19:     -0.00024  b20:      0.00000  b
```

Field quality ok

B1ApF with LHC Style Cable

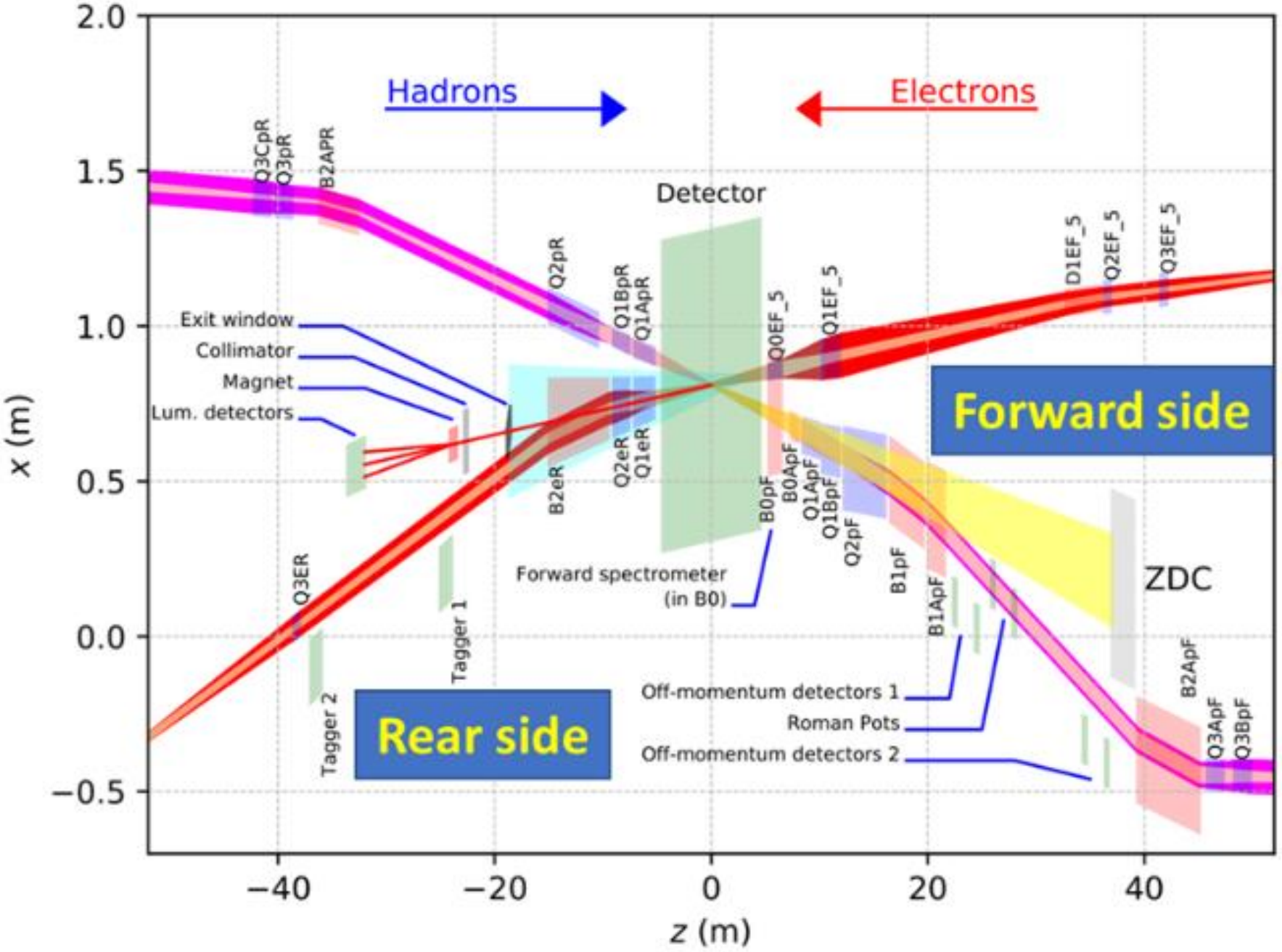


Very Large Margin

Next Step

- The cable must be chosen based on the Quad design.
- Margins are (very) large.
- Reevaluate the design after the cable is chosen.
- One can drop the number of turns to reduce margins.

Extra Slides


Hadrons
Electrons
Detector
Forward side
Rear side
ZDC
Exit window
Collimator
Magnet
Lum. detectors
Forward spectrometer
(in B0)
Off-momentum detectors 1
Roman Pots
Off-momentum detectors 2
Q3CpR
Q3pR
B2APR
Q2pR
Q1BpR
Q1ApR
Q0EF_5
Q1EF_5
D1EF_5
Q2EF_5
Q3EF_5
B2eR
Q2eR
Q1eR
B0pF
B0ApF
Q1ApF
Q1BpF
Q2pF
B1pF
B1ApF
Q3ER
Tagger 1
Tagger 2
B2ApF
Q3ApF
Q3BpF
x (m)
z (m)
2.0
1.5
1.0
0.5
0.0
−0.5
−40
−20
0
20
40