ILC 14mr IR FD based on Rutherford cable

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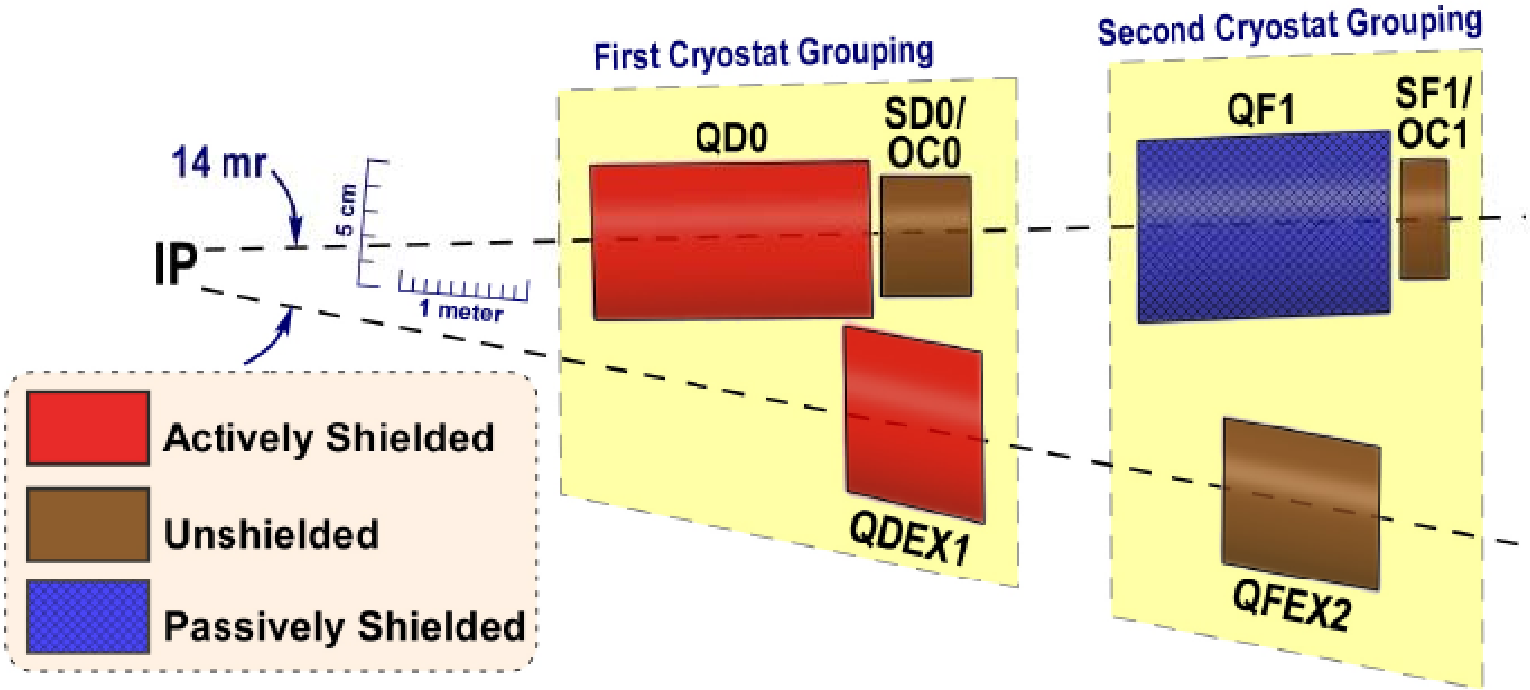
On behalf of HFM group at Fermilab

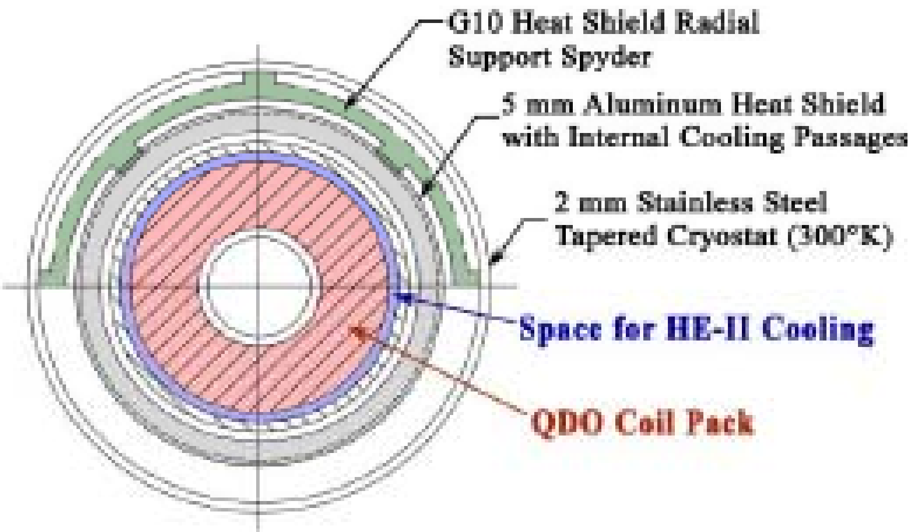
Outline

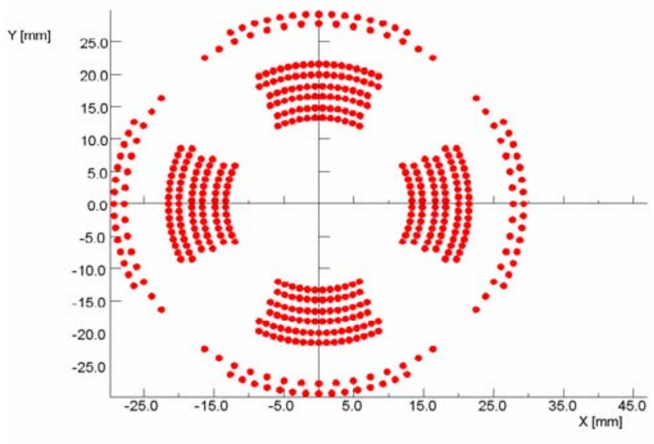
- Introduction
- Motivation
- FNAL concept
  - ✓ Two layer design (NbTi and Nb3Sn)
  - ✓ One layer design (Nb_3Sn)
    - Parameters
    - Active shield
    - Temperature margin
- Extraction quadrupole concept
- Final remarks

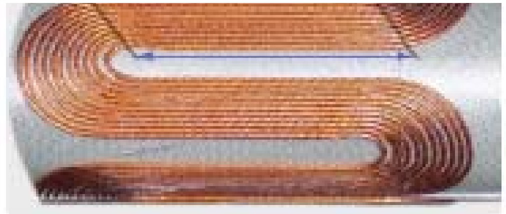
ILC-IR layout

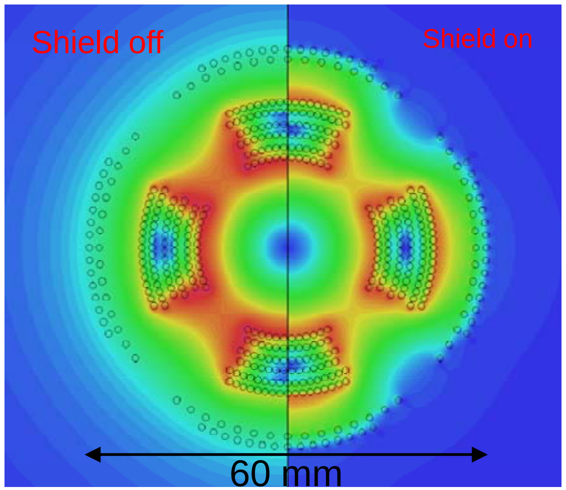


BNL design







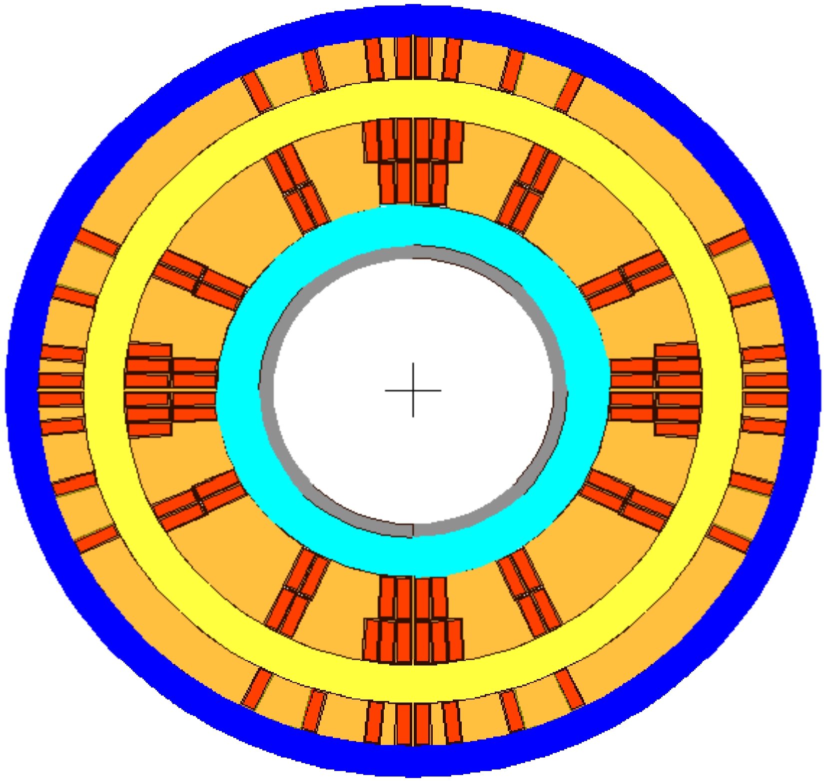


- Well advanced design based on the direct wind technology (BNL)

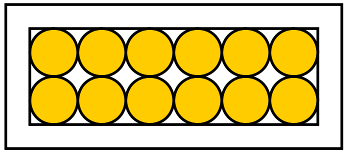
Issues:

- Works for NbTi strand
- Need inner support tube
- Limited radial and azimuthal thermal conductivity

FNAL concept



- Use Rutherford cable
  - Self-supported Roman arch
  - Smaller number of turns
  - Better turn position control
  - Low inductance
  - Better radial thermal conductivity
- Thermally decouple beam pipe and coil
- Active shield
- Same beam pipe size
- Smaller coil OD

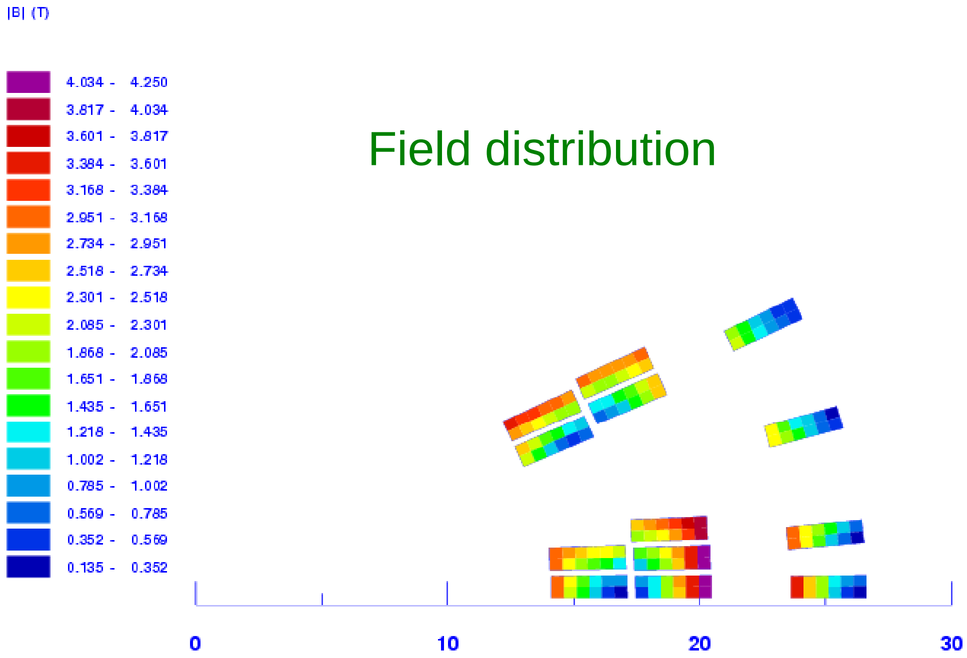


Cable:
N=12, D=0.5 mm
1 x 3 mm

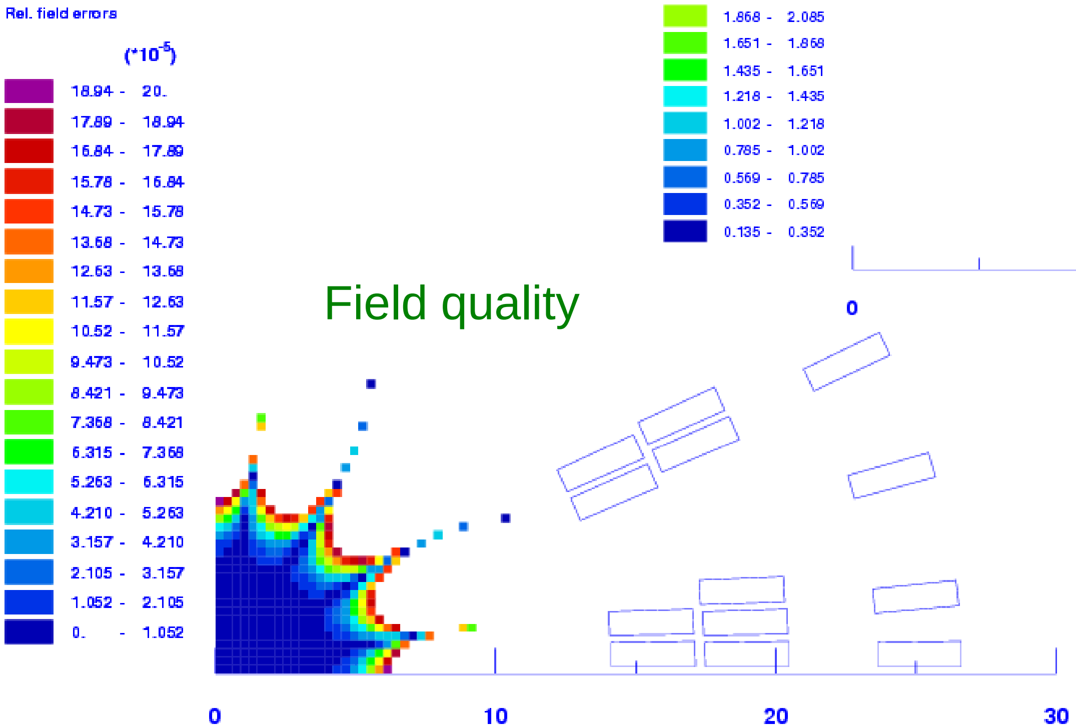
Two-layer design

(V1, NbTi or Nb3Sn)

Field distribution

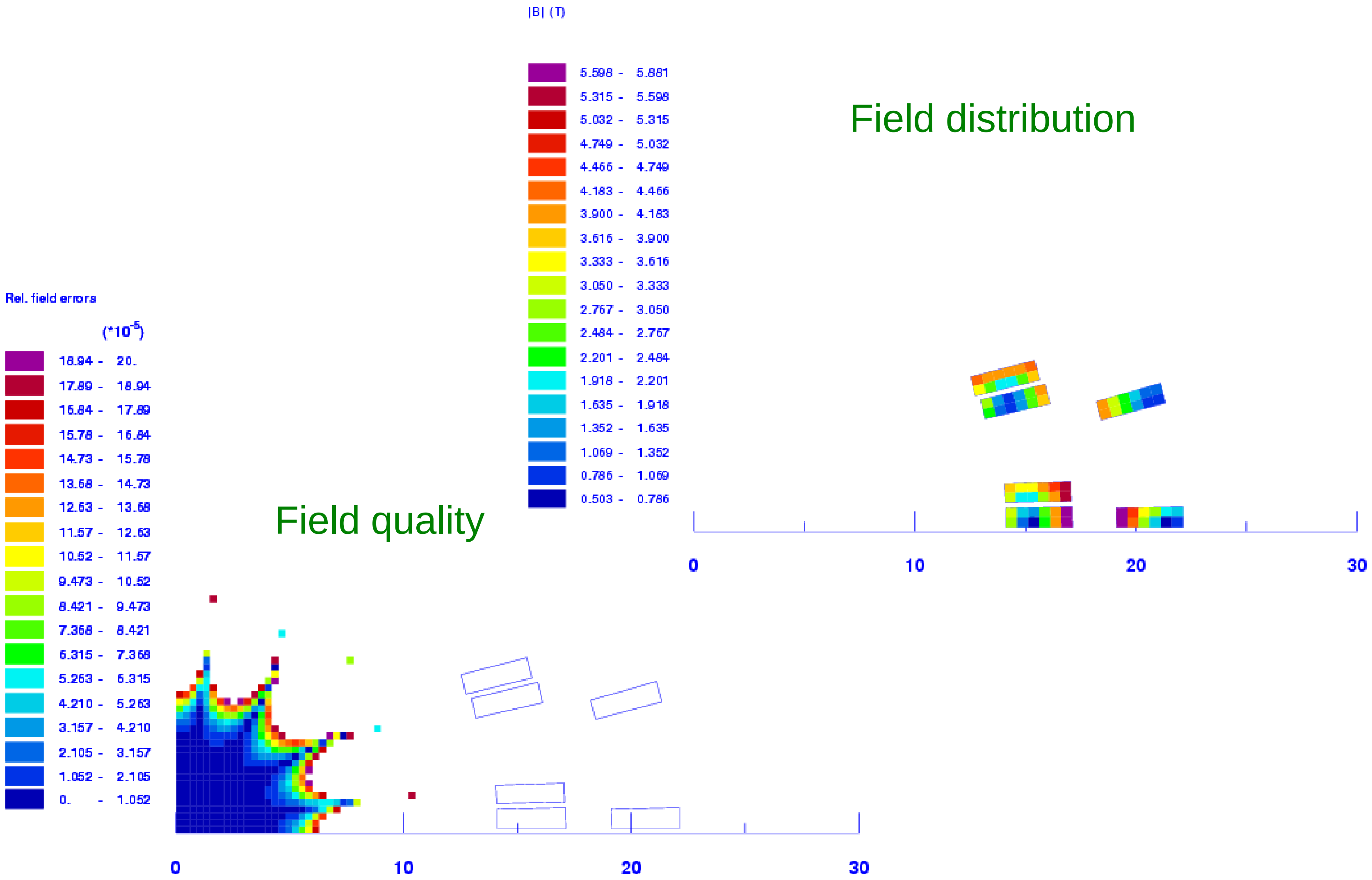


Field quality

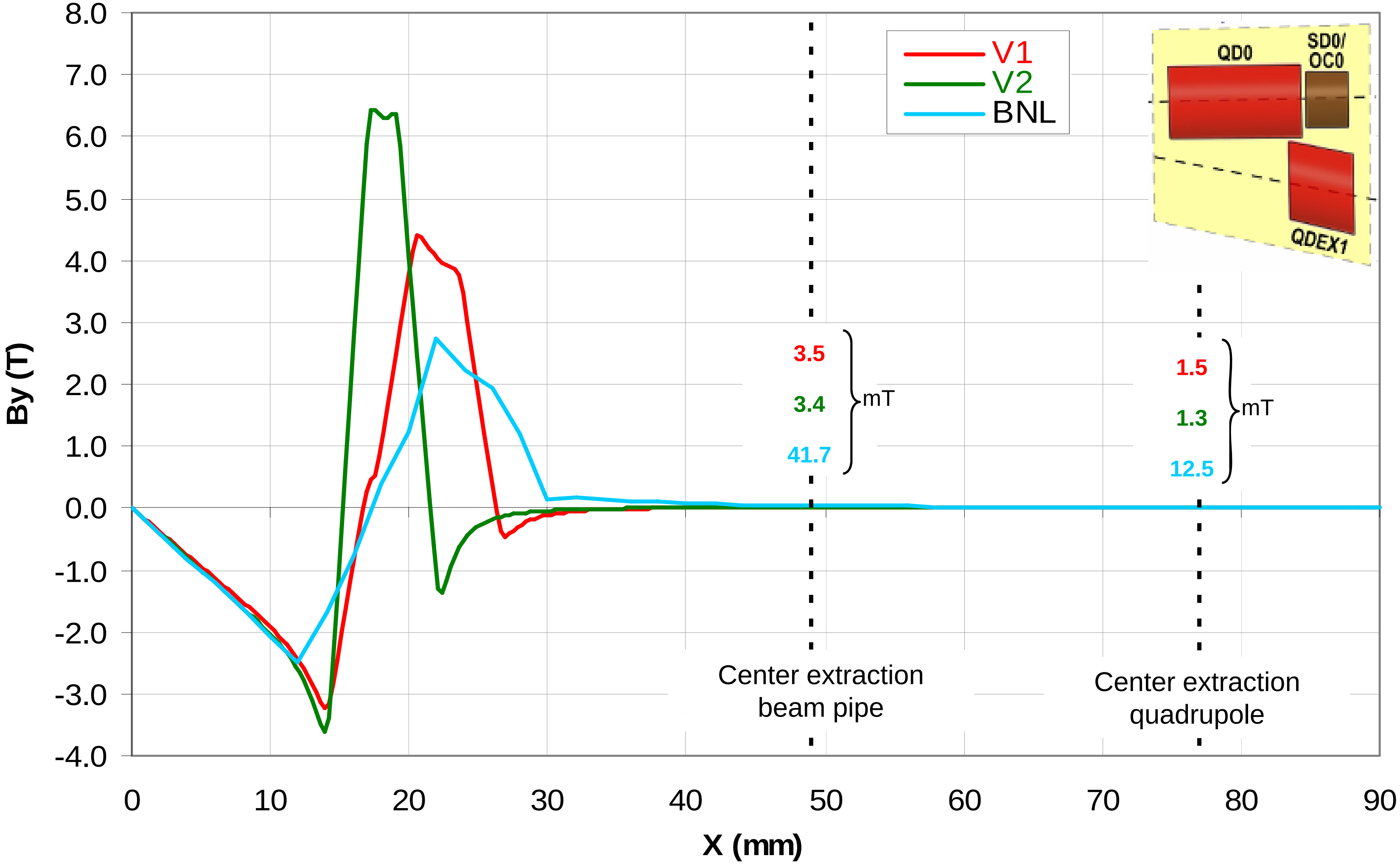


Single-layer design

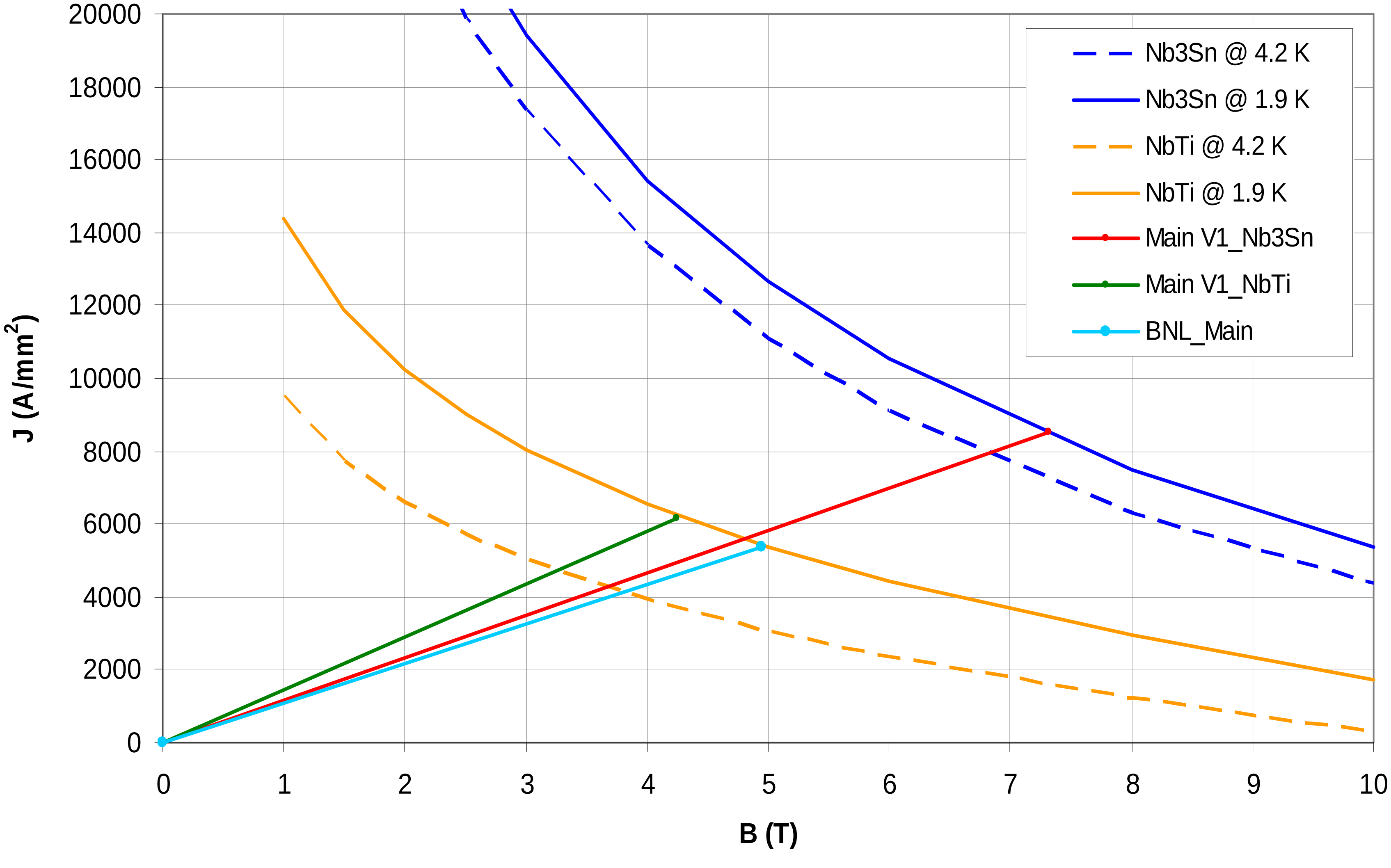
(V2, Nb3Sn)



Active Shield



NbTi vs. Nb_3Sn

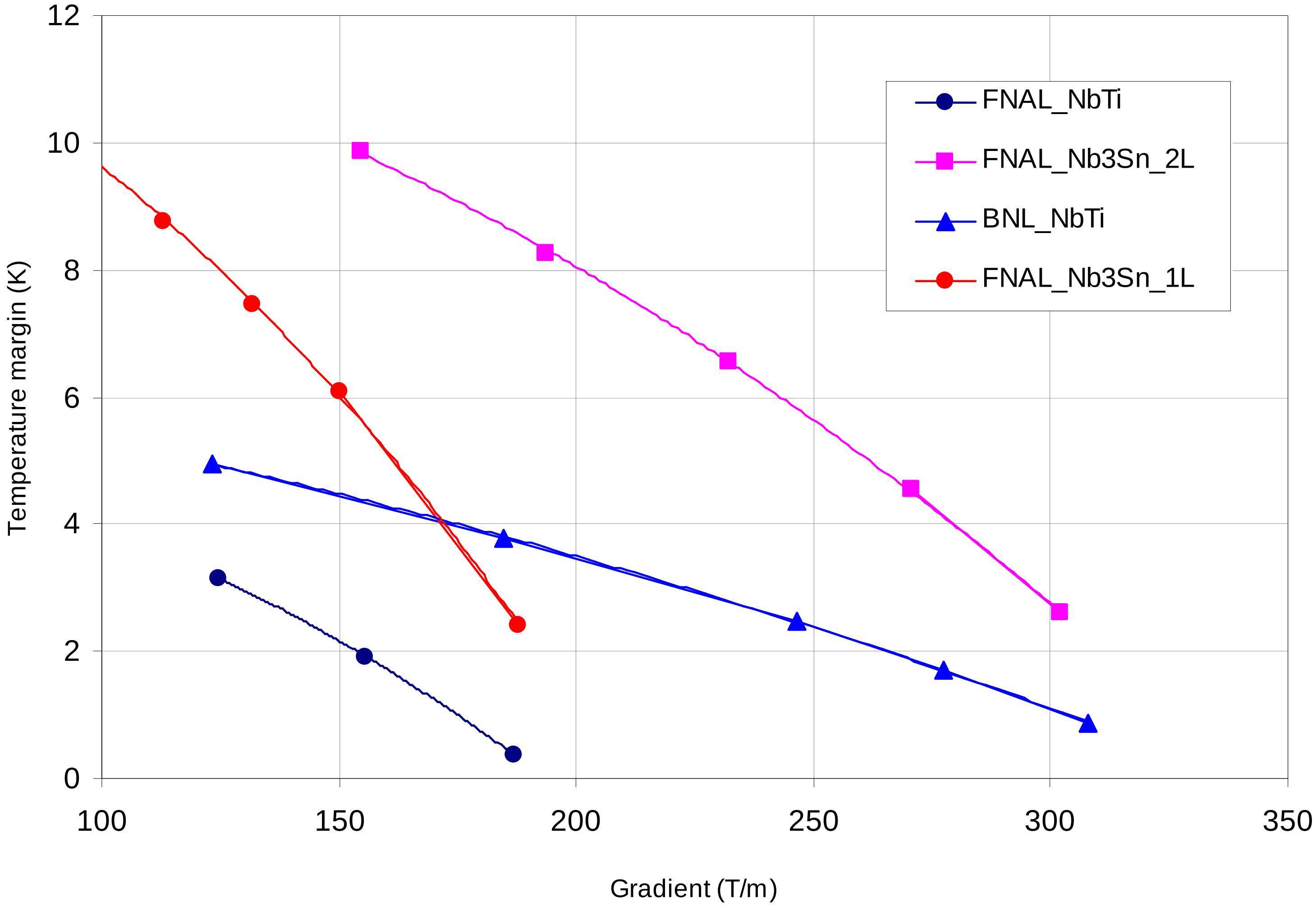


Parameters

	BNL*	FNAL V1 ($NbTi$)	FNAL V1 (Nb_3Sn)	FNAL V2 (Nb_3Sn)
Strand Diameter (mm)	1.0	0.5	0.5	0.5
Cable dimensions (mm)	Ø 1.0	3.0 x 1.0	3.0 x 1.0	3.0 x 1.0
Cable Insulation (μm)	-	125	125	125
Number of layers for the main coil	6	2	2	1
Outer radius (mm)	29.8	26.7	26.7	22.2
Total SC cross section (mm^2)	364	245	245	113
Bmax (T)	3.04	4.25	7.31	5.88
Imax (kA)	1.8	6.3	10.8	13.7
Gmax (T/m)	330.0	191.0	330.0	200.0
Stored Energy (kJ/m)	8.5	3.36	9.44	3.52
Inductance (mH/m)	5.08	0.17	0.16	0.04

* Estimated

Temperature margin

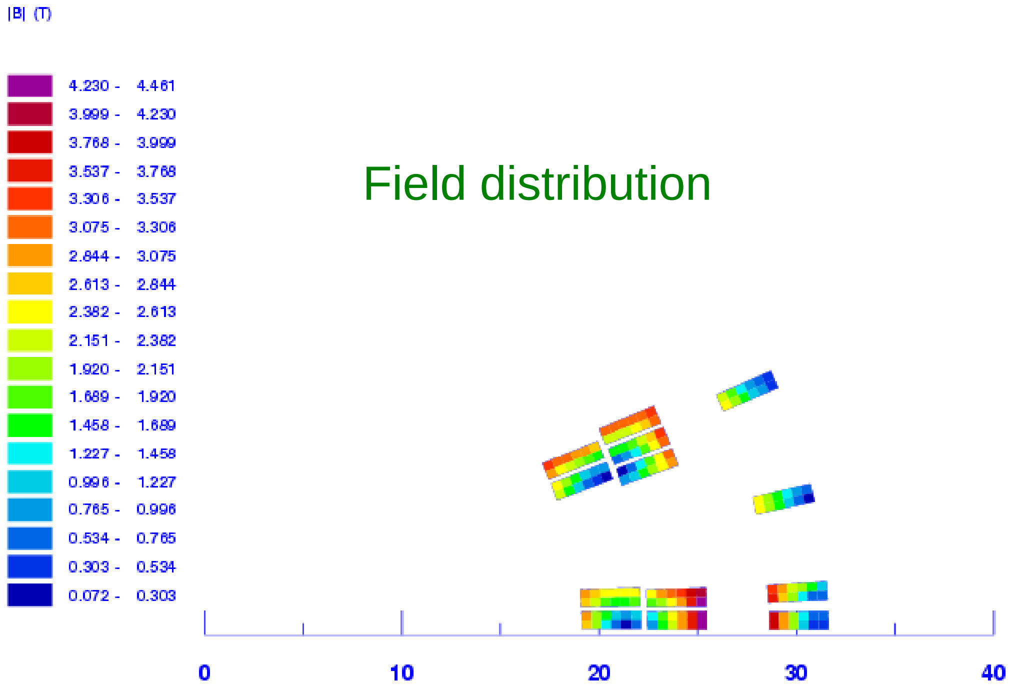


QDEX1

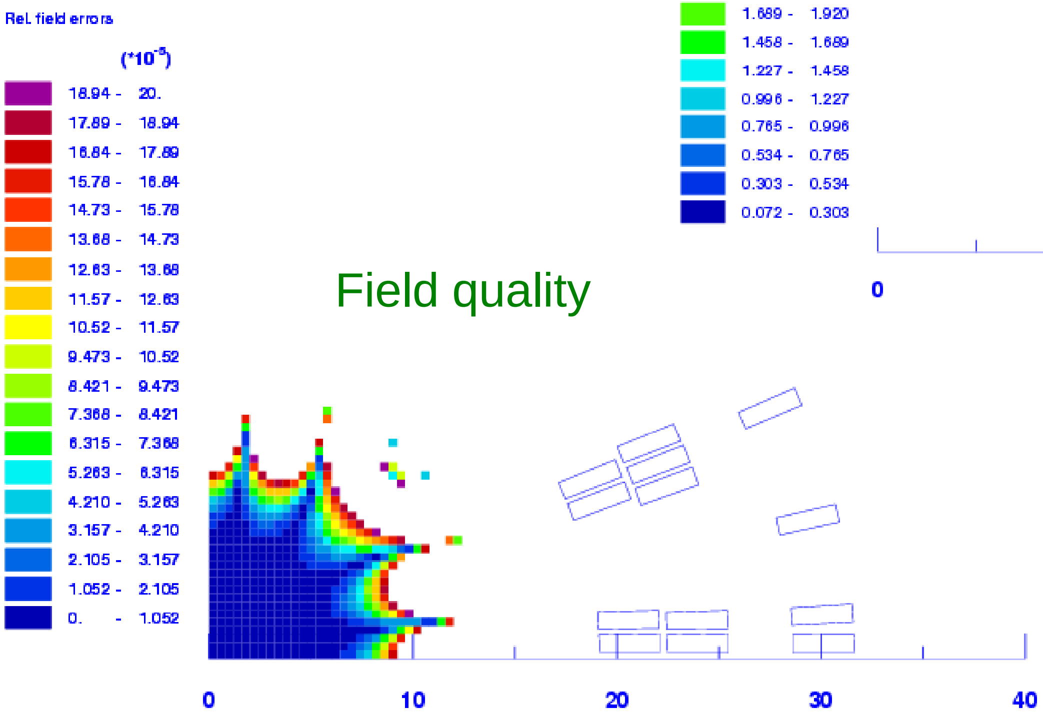
Two-layer design

(V1, NbTi or Nb3Sn)

Field distribution



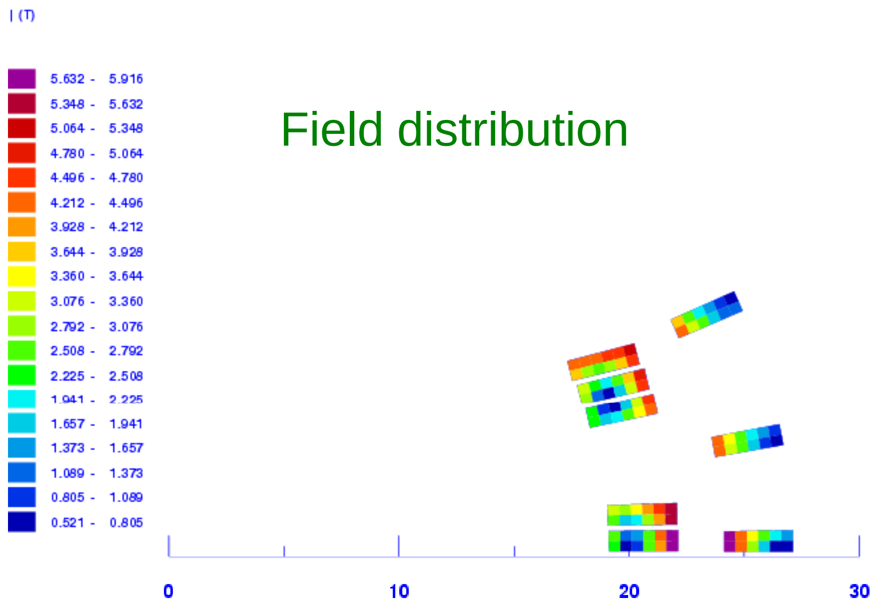
Field quality



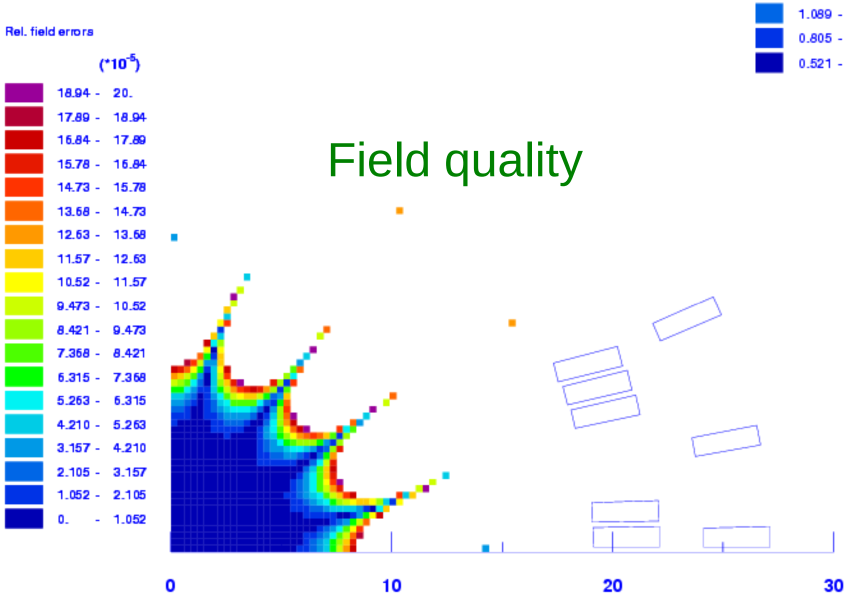
Single-layer design

(V2, Nb_3Sn)

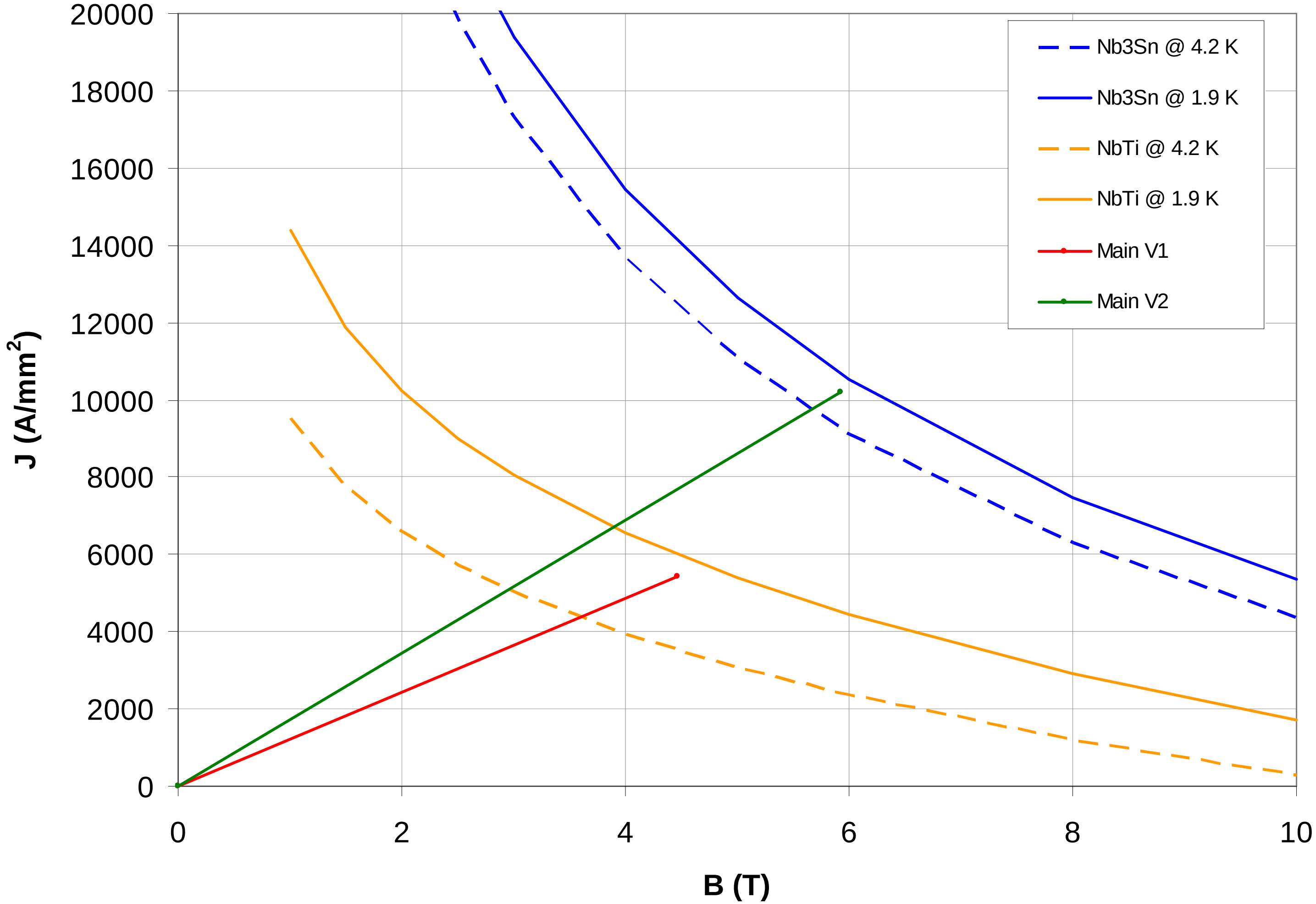
Field distribution



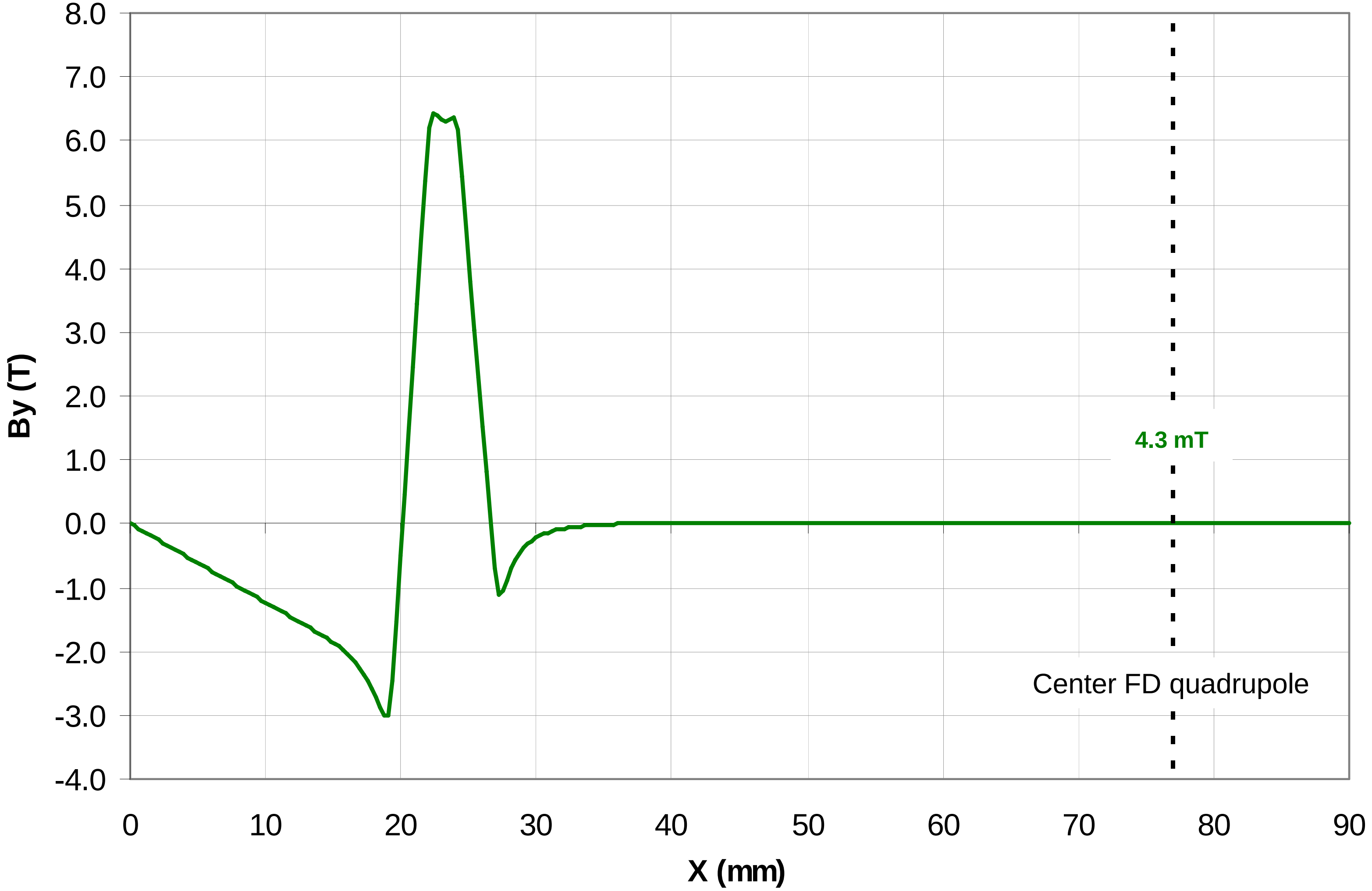
Field quality



NbTi vs. Nb_3Sn



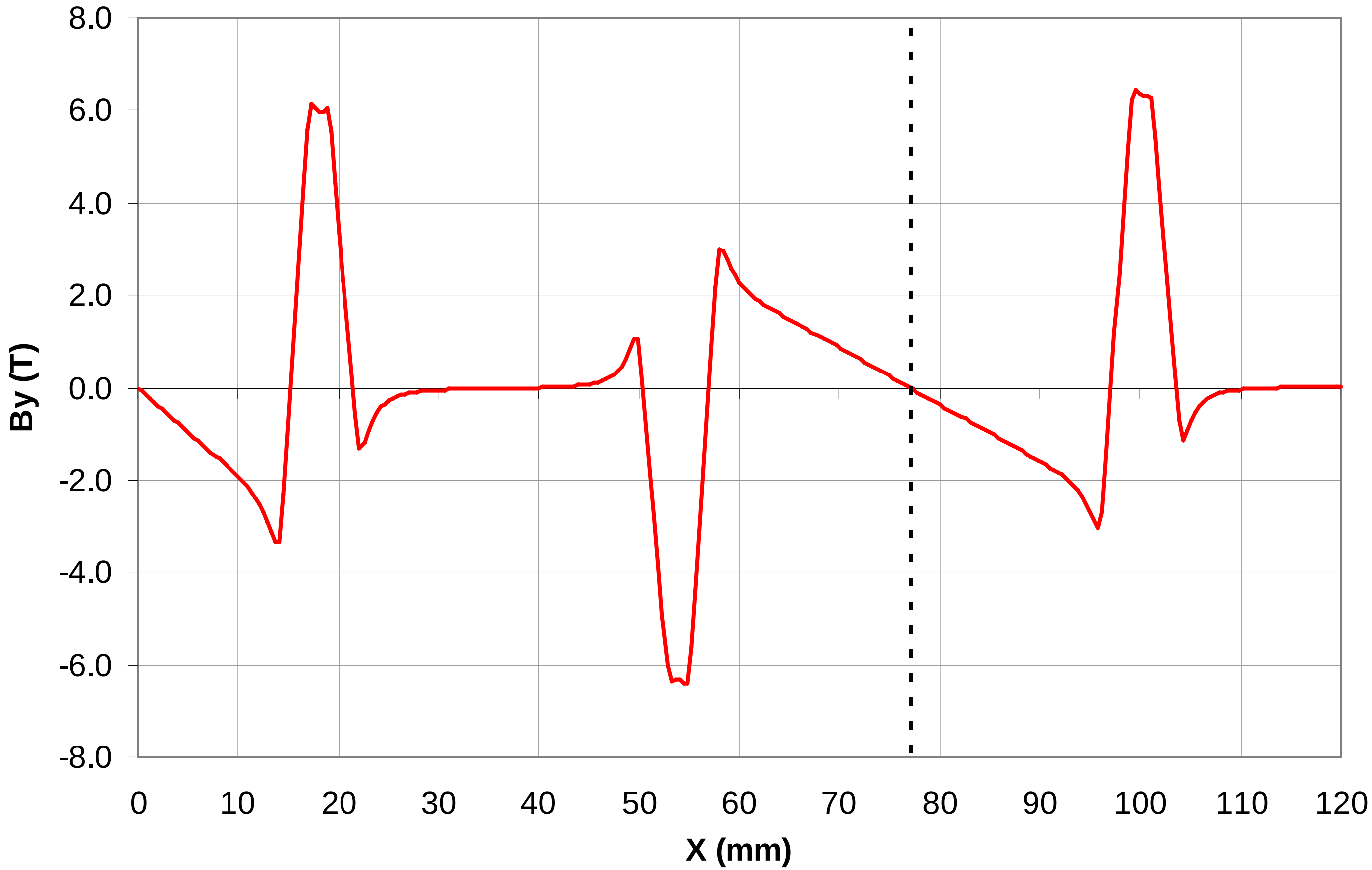
Active Shield



Parameters

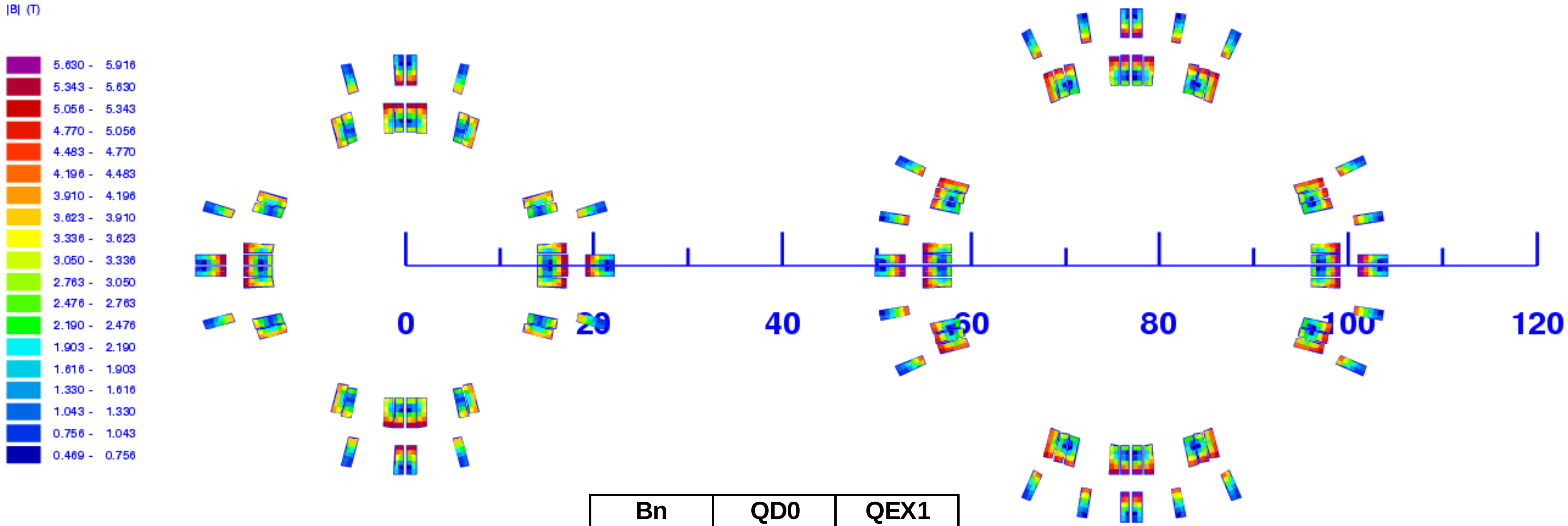
	V1	V2
Strand Diameter (mm)	0.5	0.5
Cable dimensions (mm)	3.0 x 1.0	3.0 x 1.0
Cable Insulation (μm)	0.125	0.125
Number of layers	2	2
Outer radius (mm)	31.7	27.1
Total SC cross section (mm^2)	245	113
Bmax (T)	4.46	5.93
Imax (kA)	6.9	13.0
Gmax (T/m)	120.0	120.0

Cross-talk I



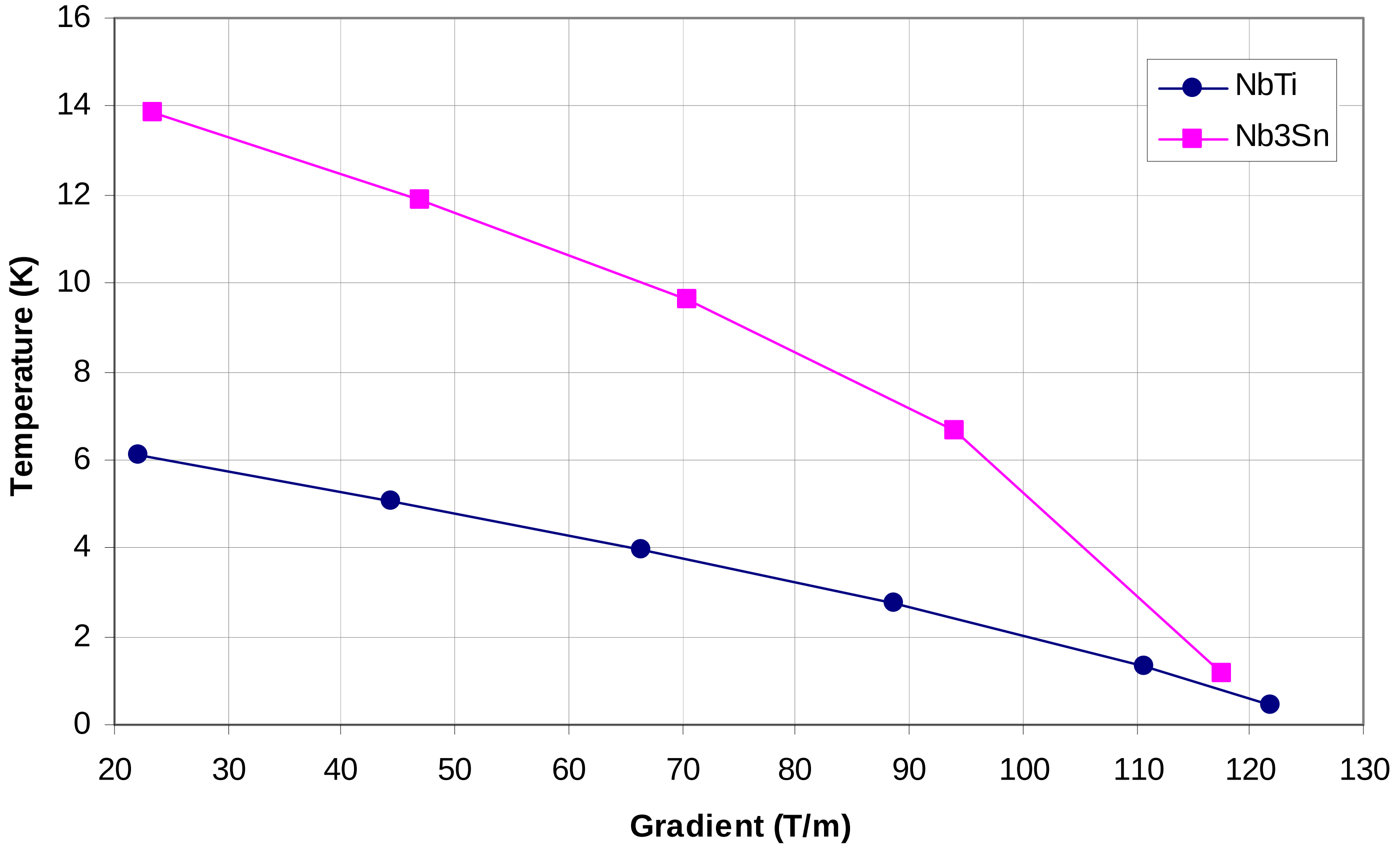
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
By (T)
0
10
20
30
40
50
60
70
80
90
100
110
120
X (mm)

Cross-talk II

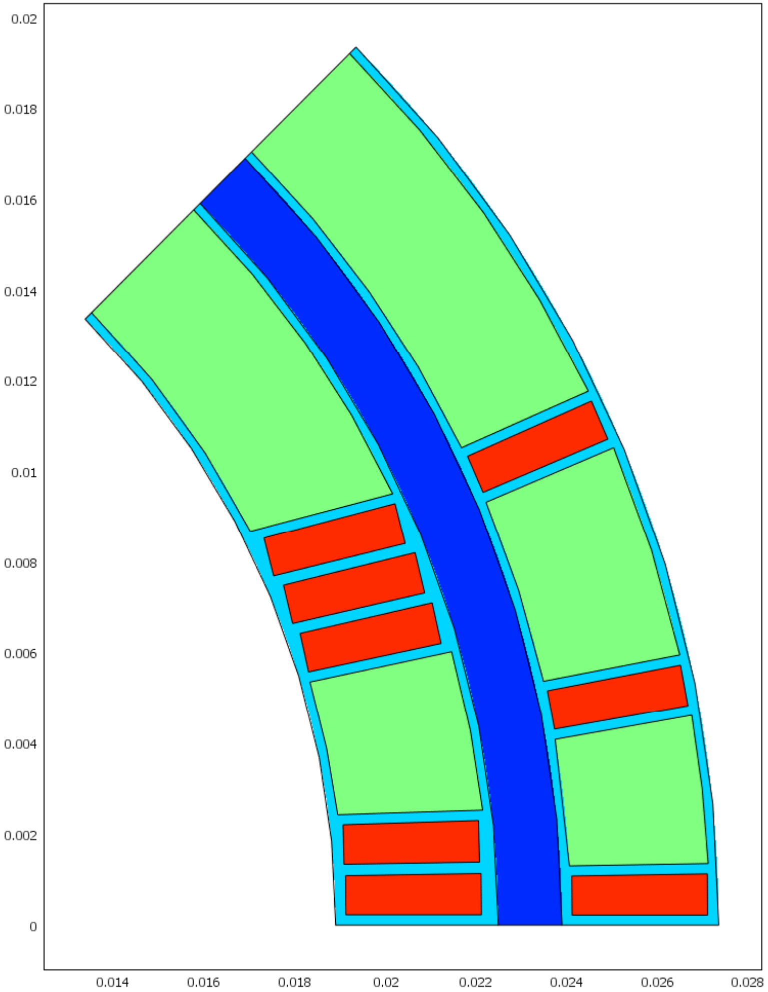


Bn	QD0	QEX1
1	44.61	-20.16
2	10000	10000
3	0.94	-0.39
4	0.08	0.03
5	0.00	0.00
6	0.00	0.00
7	0.00	0.00
8	0.00	0.00
9	0.00	0.00
10	0.31	-0.04
11	0.00	0.00
12	0.00	0.00
13	0.00	0.00
14	0.02	0.00

Temperature margin

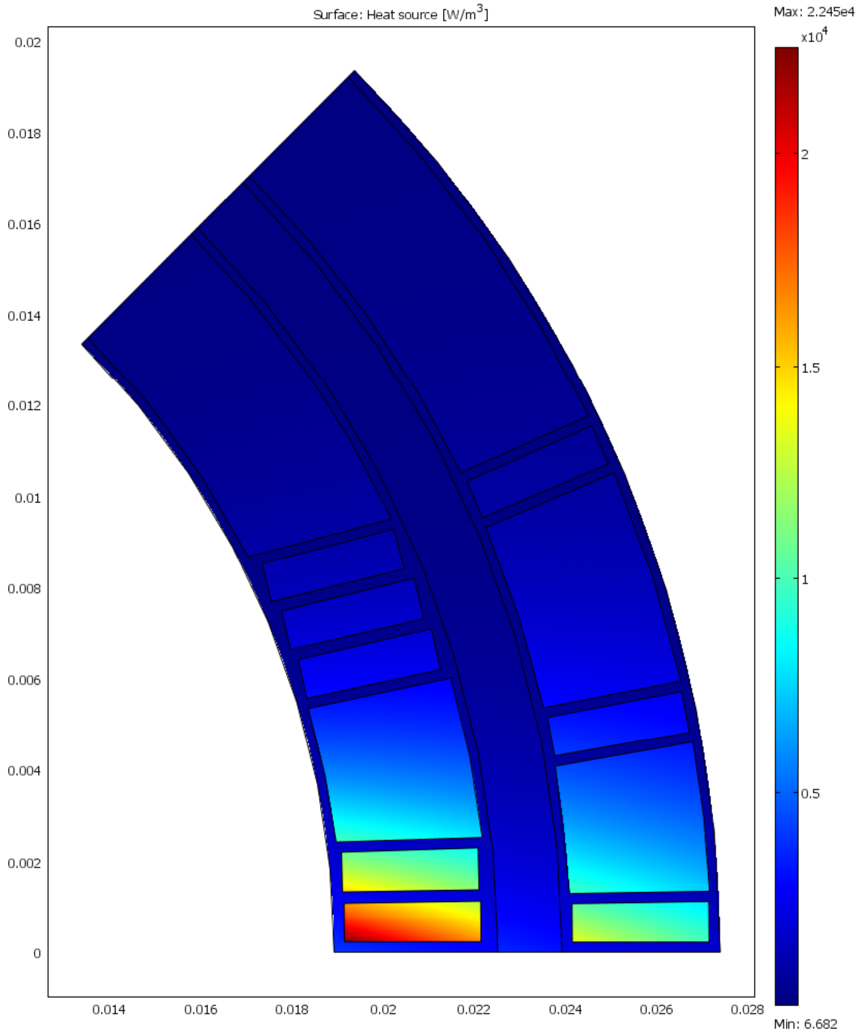


Thermal model



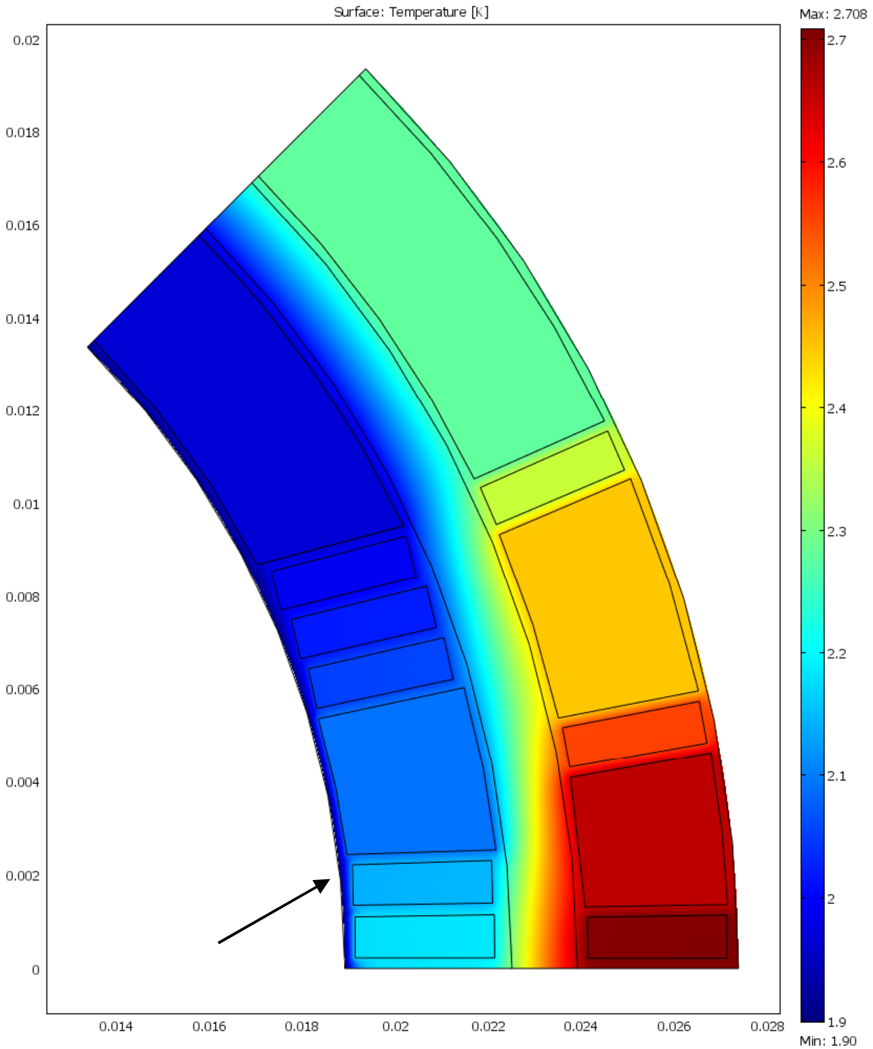
- Nb_3Sn cable insulated by S2-glass + epoxy
- Cu wedges between coil blocks
- G10 or Cu spacer between the layers
- Helium cooling channel between the beam pipe and coil surface. Can also be incorporated into the interlayer spacer.

Heat depositions



- Peak heat depositions of 2.7 mW/g taken from N. Mokhov's analysis of the 20-mrad design.
- Analytically parameterized as functions of radius and angle by the law determined for LHC IR magnets.
- Assumed constant heat depositions.

Temperature profile I



- Cooling at the inner surface only.
- Maximum temperature is 2.7K in the outer layer midplane.

Final remarks

- *NbTi* and *Nb_3Sn* design options (with active shielding)
- High gradient (?!)
- Small outer diameter
- Low inductance
- Small SC volume
- Good temperature margin

Next Steps

- Optimization of the coil sizes based on the actual requirements
- Design of the other magnets
- More extensive thermal analysis

ILC-IR layout