Design options for DUNE Near Detector Magnet

Udai Giri P.S Sachan, S.Sundar Rajan, Sanjay Malhotra
Bhabha Atomic Research Centre
India

Outline

- Detector magnet requirements
- DUNE Magnet Design Options: Three Coils along with Shield Coils
- Magnetic field uniformity
- Stray field & Peak field
- Superconductor Options
- Summary

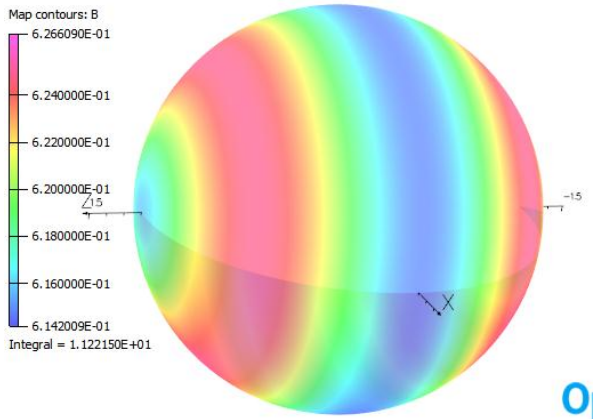
DUNE Near Detector Magnet Design

Requirements:*

- Central Magnetic Field : B(0,0,0) ~ 0.5T
- Magnet Diameter : >7 m
- Magnet Length: less than 10m
- Fringe Field :B(6,0,0) < 50 Gauss (5mT)
- Uniformity :< 20% in DSV of 5.2 m

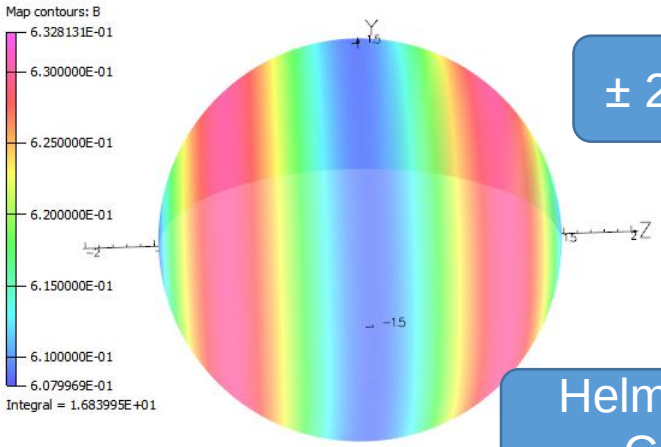
** As per DUNE-ND magnet meetings*

Magnetic Field uniformity in Two coil vs Three coil Design



± 1%

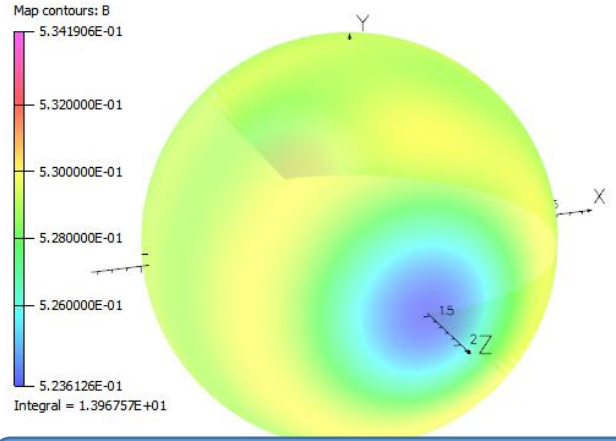
DSV : 2.4m



± 2%

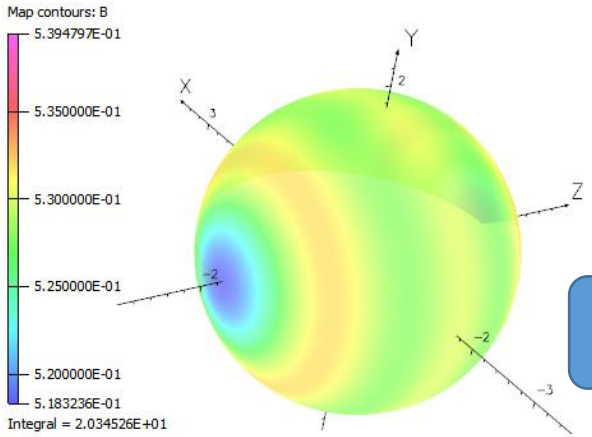
Helmholtz Coil

DSV : 2.95m



DSV : 2.8m

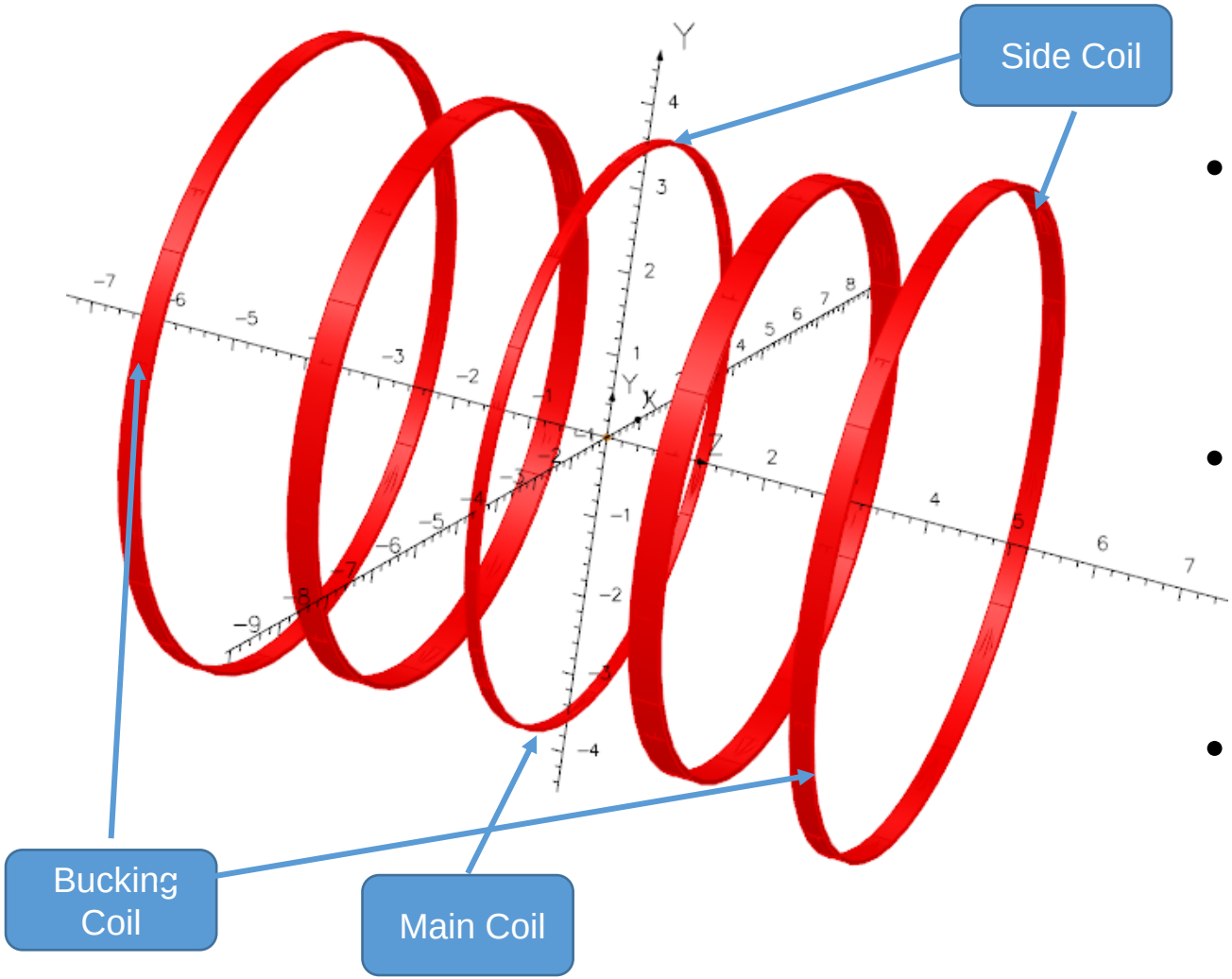
Better Uniformity can be achieved with 3 coil design



Three Coil

DSV : 3.5m

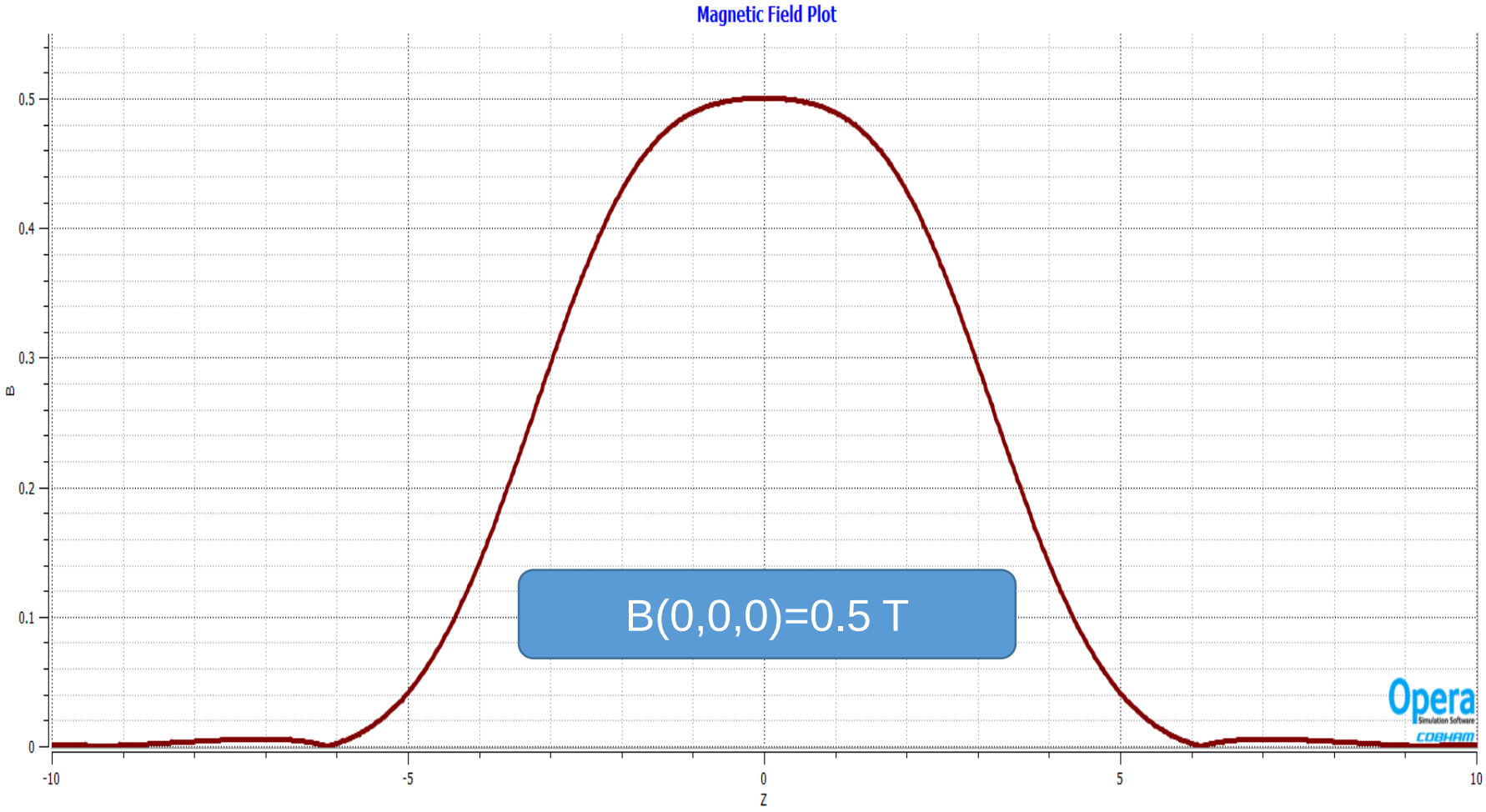
Three Coil Configuration with shield coils



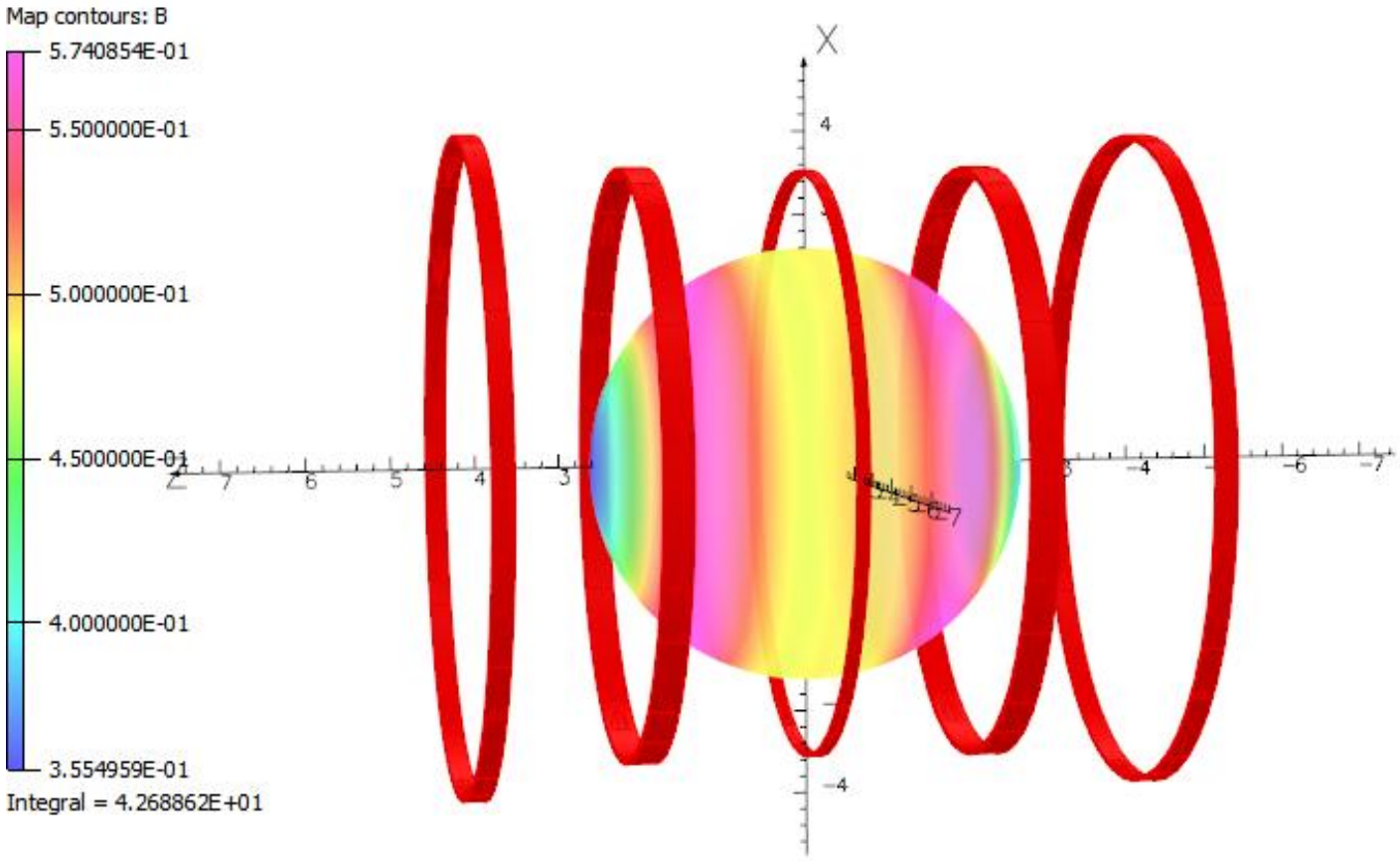
- Distance between main coil to side coil 2.3 m
- Distance between main coil to buck coil 4.37 m
- Main coil ID:7.1m

I_{op}=5000A

Detector Magnet Three Coil Configuration-Option1



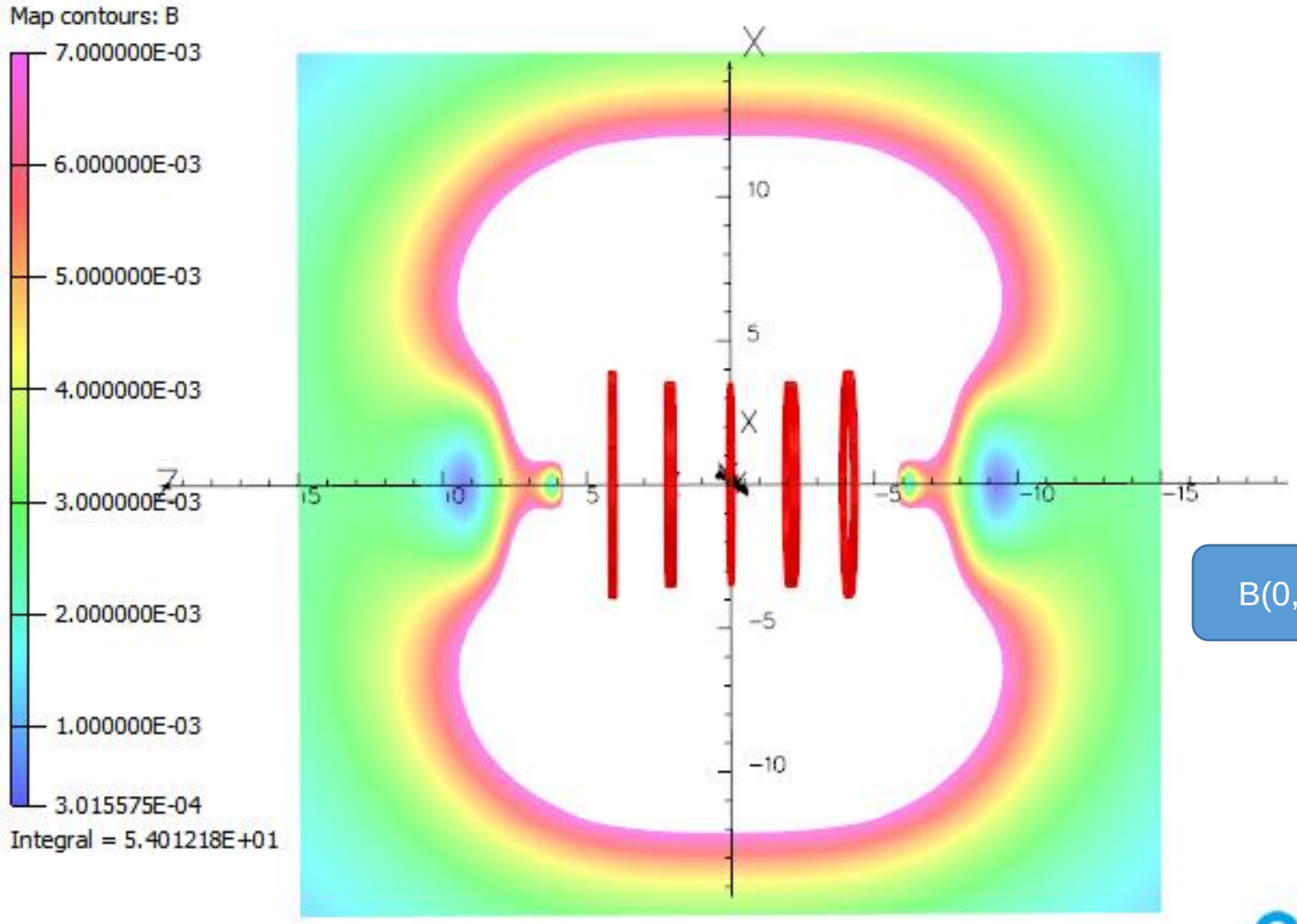
Design Option-1: Field Uniformity



B(0,0,0)=0.5 T

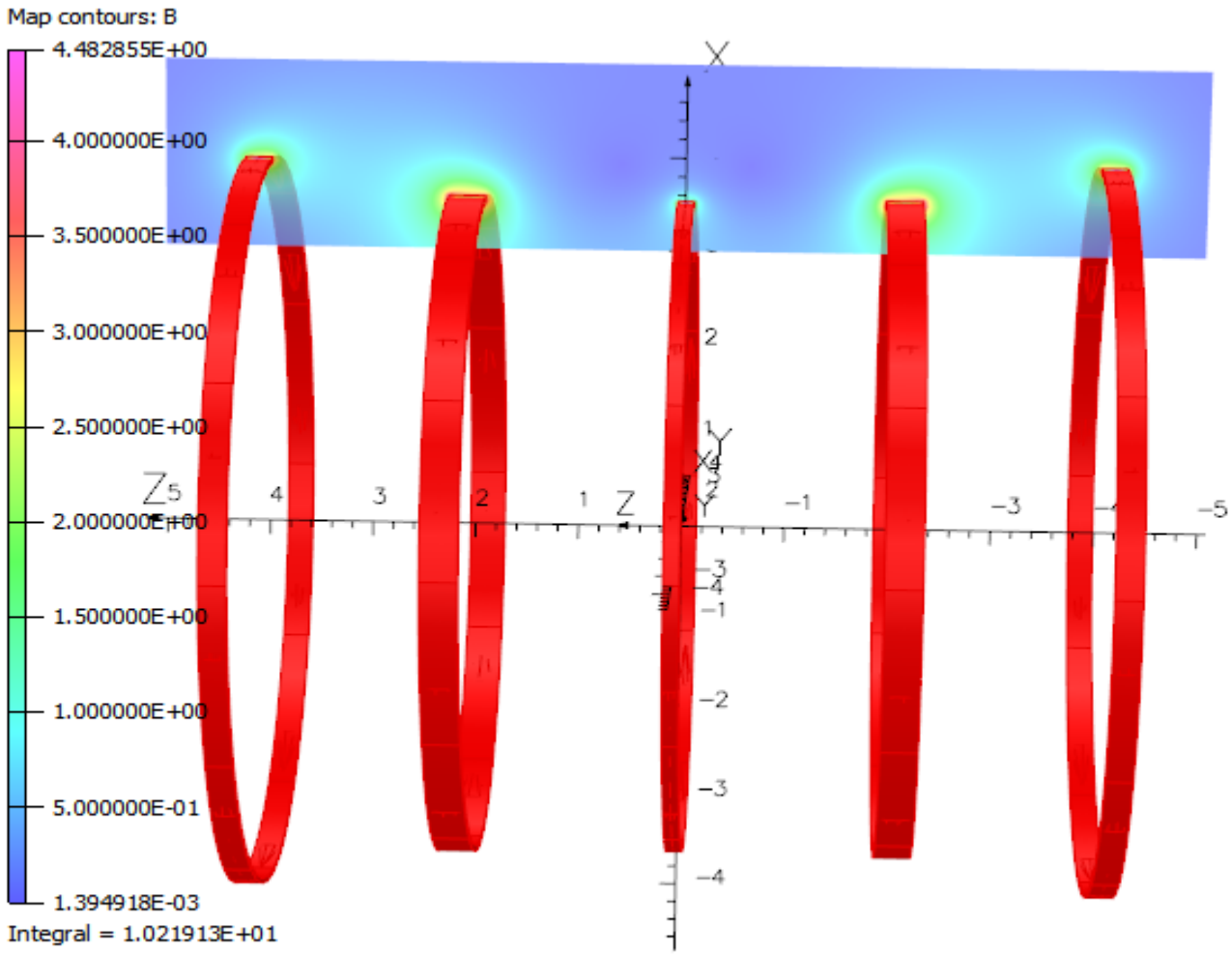
$B_{uniformity}$= 21%

Design Option1- Stray Magnetic Field



B(0,0,6)=0.007 T

Design Option1- Peak Magnetic Field



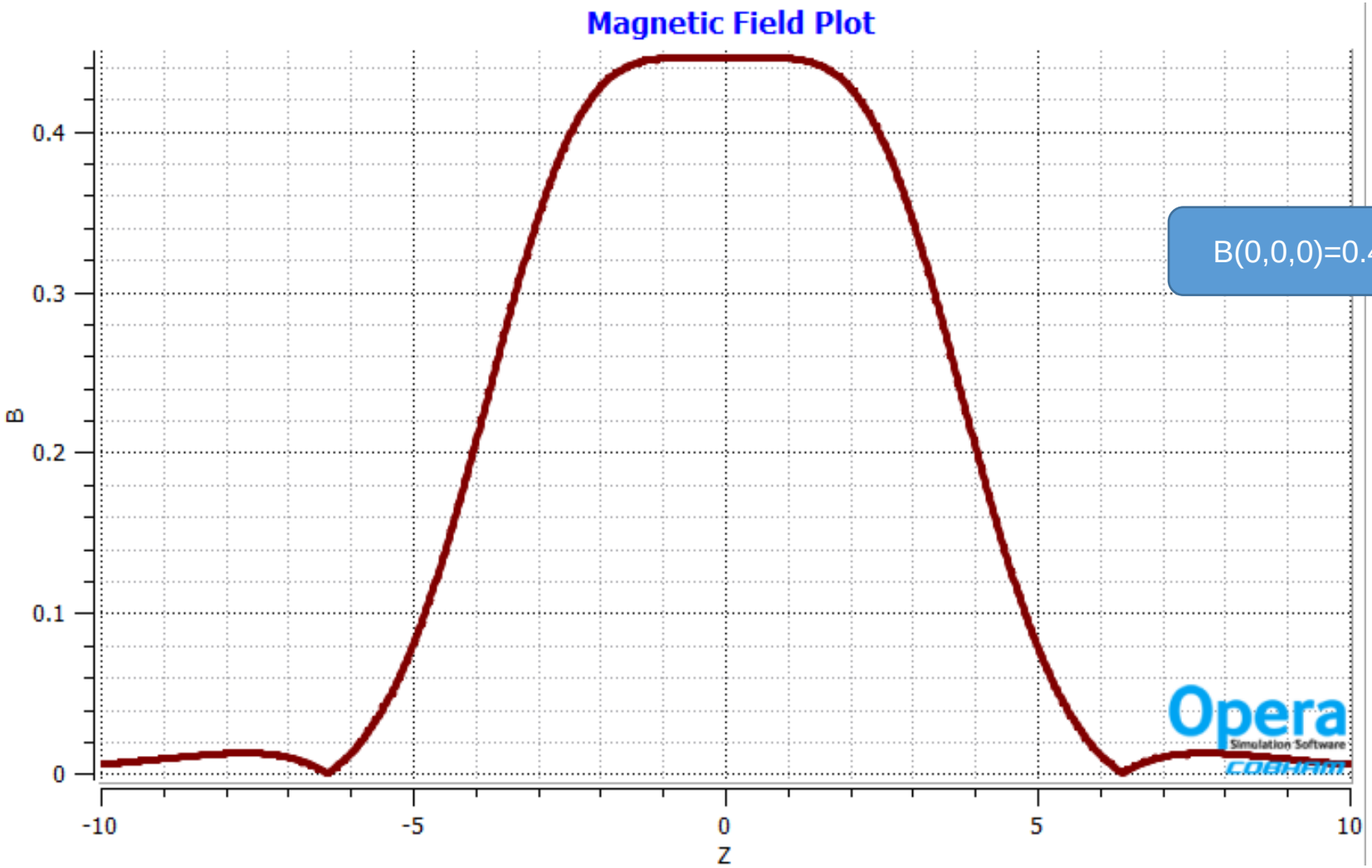
B_{peak}=4.5 T

Stored Energy = 118 MJ

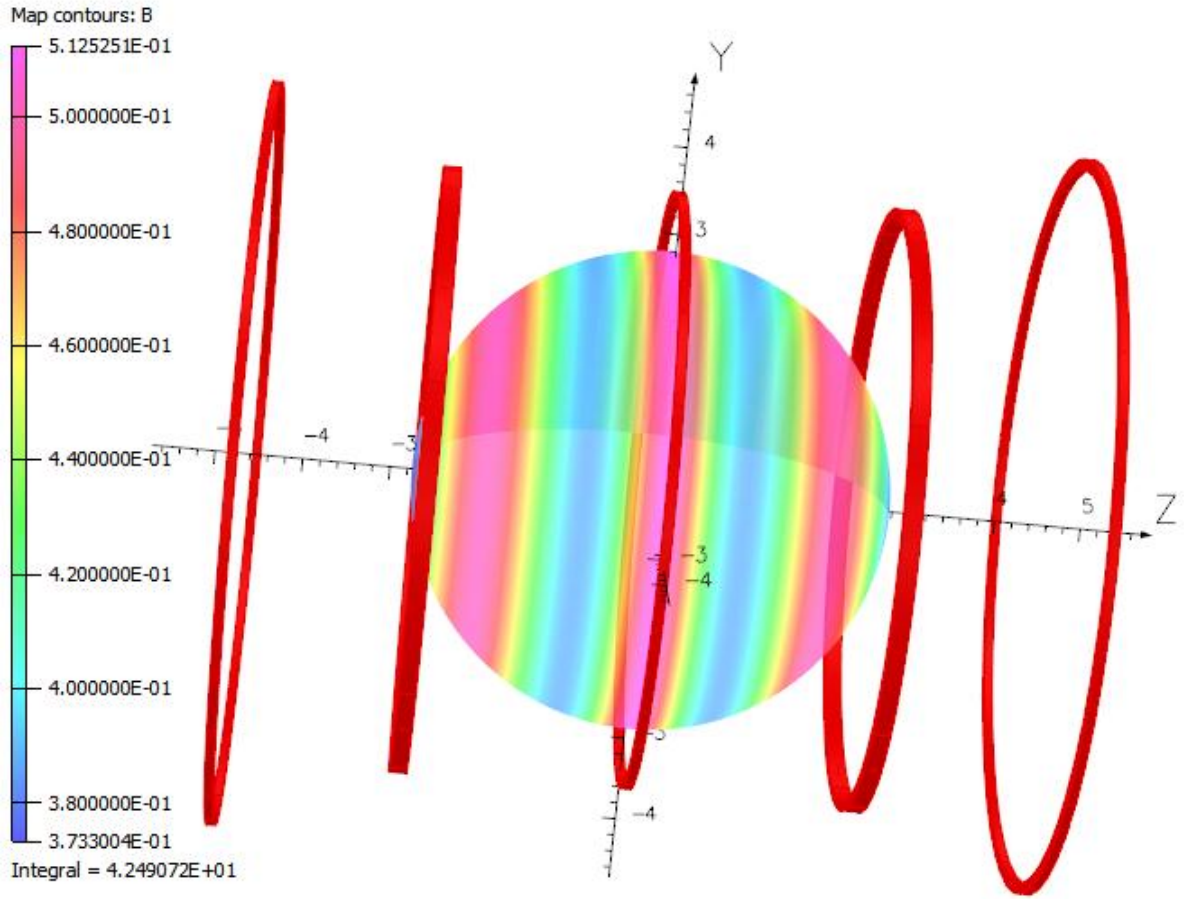
<u>Forces on the Coil</u>
Side Coils: F_z= 3.62MN
Bucking Coils : Fz=8.18MN

Opera Simulation Software
COBHAM

Detector Magnet Three Coil Configuration-Option 2



Field Uniformity Configuration-02

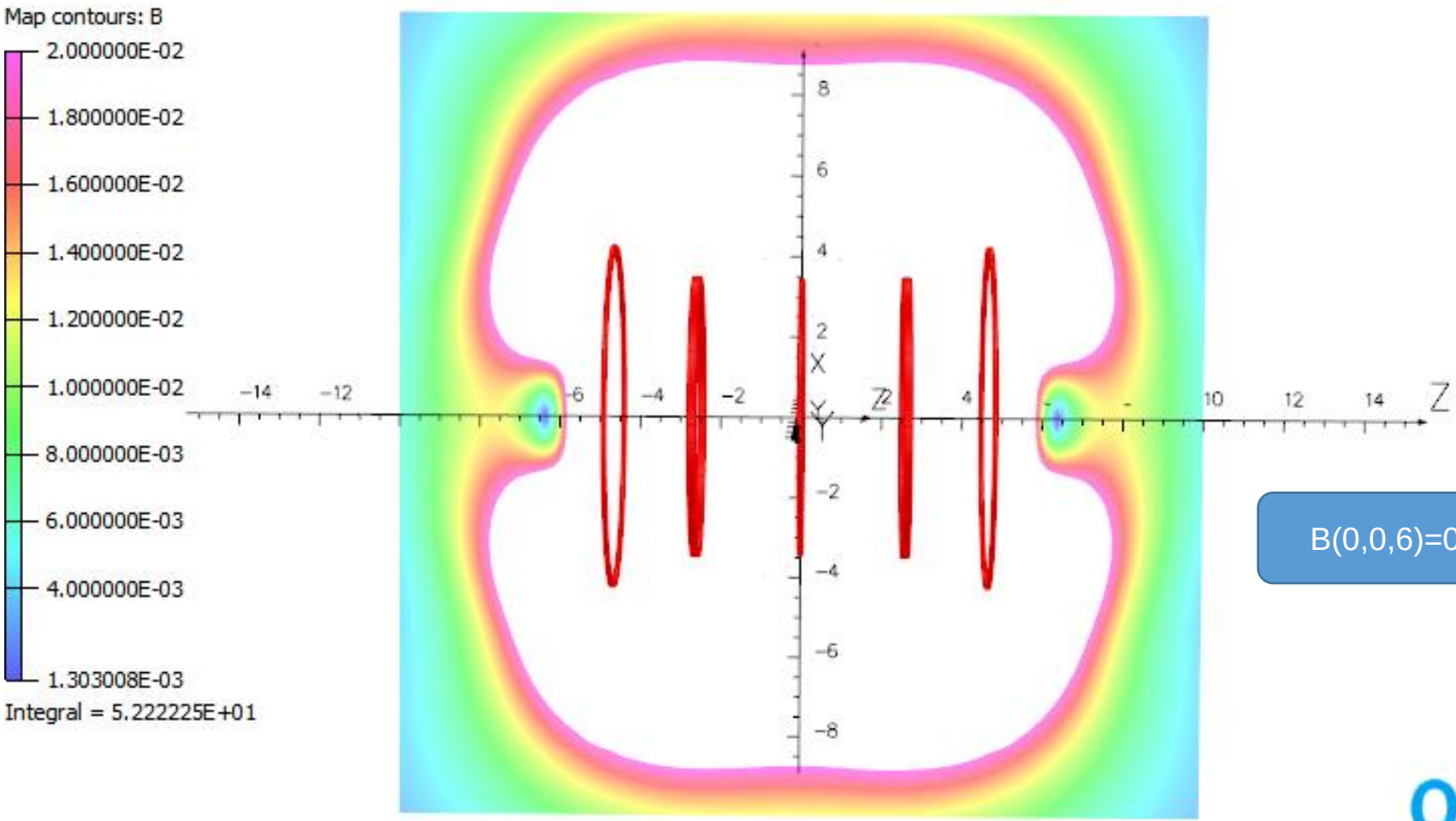


Opera Simulation Software COBHAM

B(0,0,0)=0.45 T

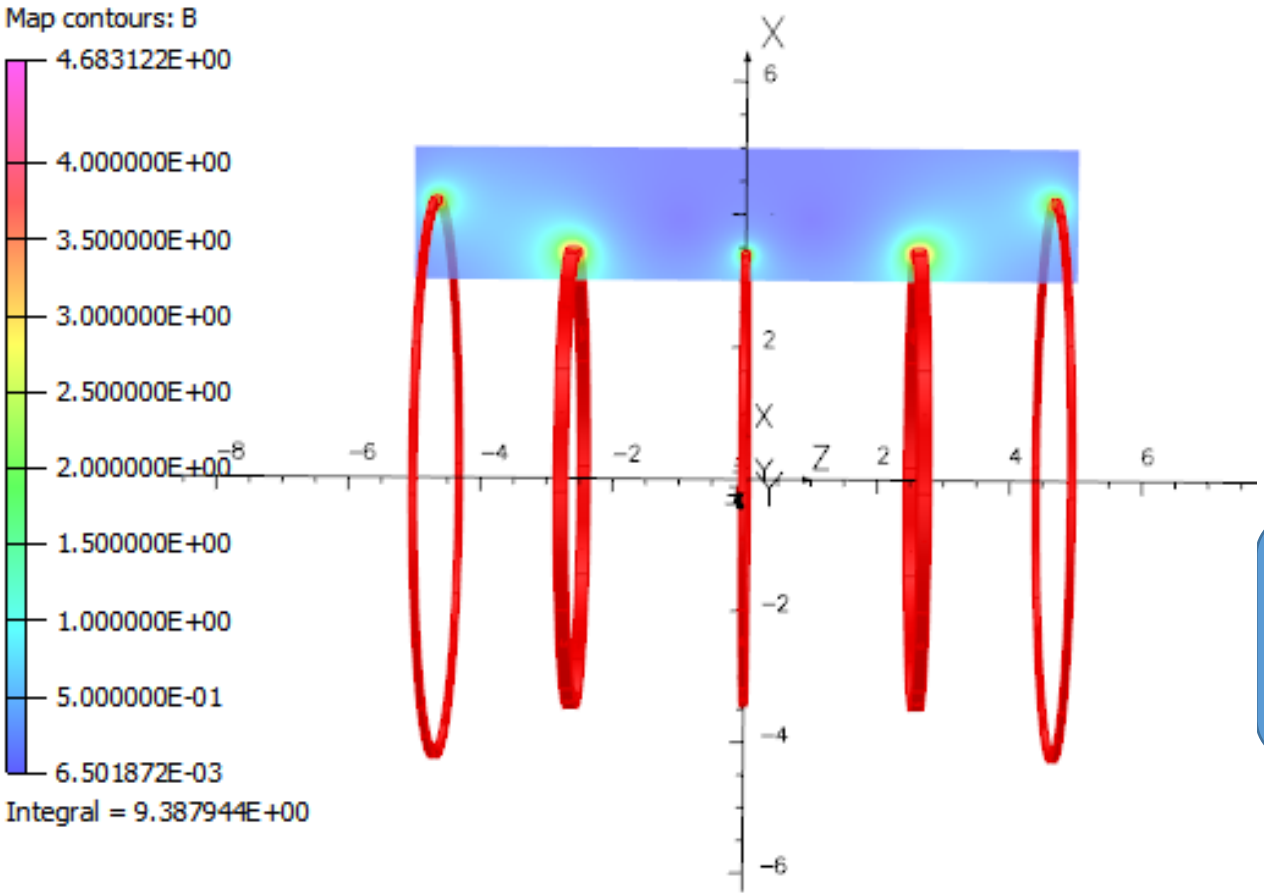
$B_{uniformity}$= 17%

Stray Magnetic Field Configuration-02



B(0,0,6)=0.02 T

Peak Magnetic Field



B_{peak}=4.7 T

Stored Energy = 112 MJ

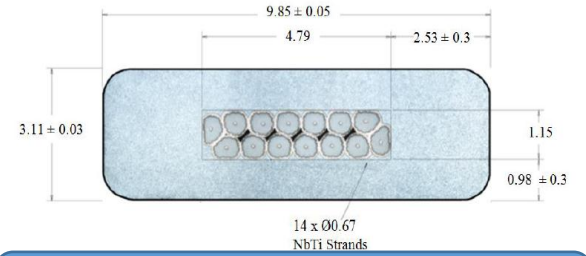
<u>Forces on the Coil</u>
Side Coils: F_z= 2.97 MN
Bucking Coils : Fz=5.98 MN

Magnet Design Options comparison

Magnet Parameters	Design option-1			Design Option-2		
Magnet ID (m)	7.1	7.1	7.8	7.1	7.1	8.2
Length(m)	0.085	0.2	0.145	0.085	0.2	0.1
Number of turns	112	481	270	112	481	252
Length of cable (km)	36			38		
Operating current(A)	5000			5000		
B_{peak} (T)	4.5			4.7		
Stored energy(MJ)	118			112		
Overall Magnet Length(m)	9			10		
B_{stray} (Gauss)	70			200		
Uniformity	21%			17 %		

Conductor Selection

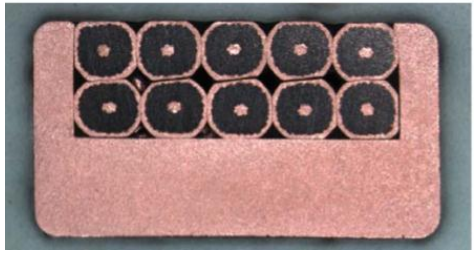
Option:1



Rutherford cable extruded with high purity Al

Price : $ 60/m

Option:2



RIC Conductor used in 11.75 Tesla Iseult MRI Magnet

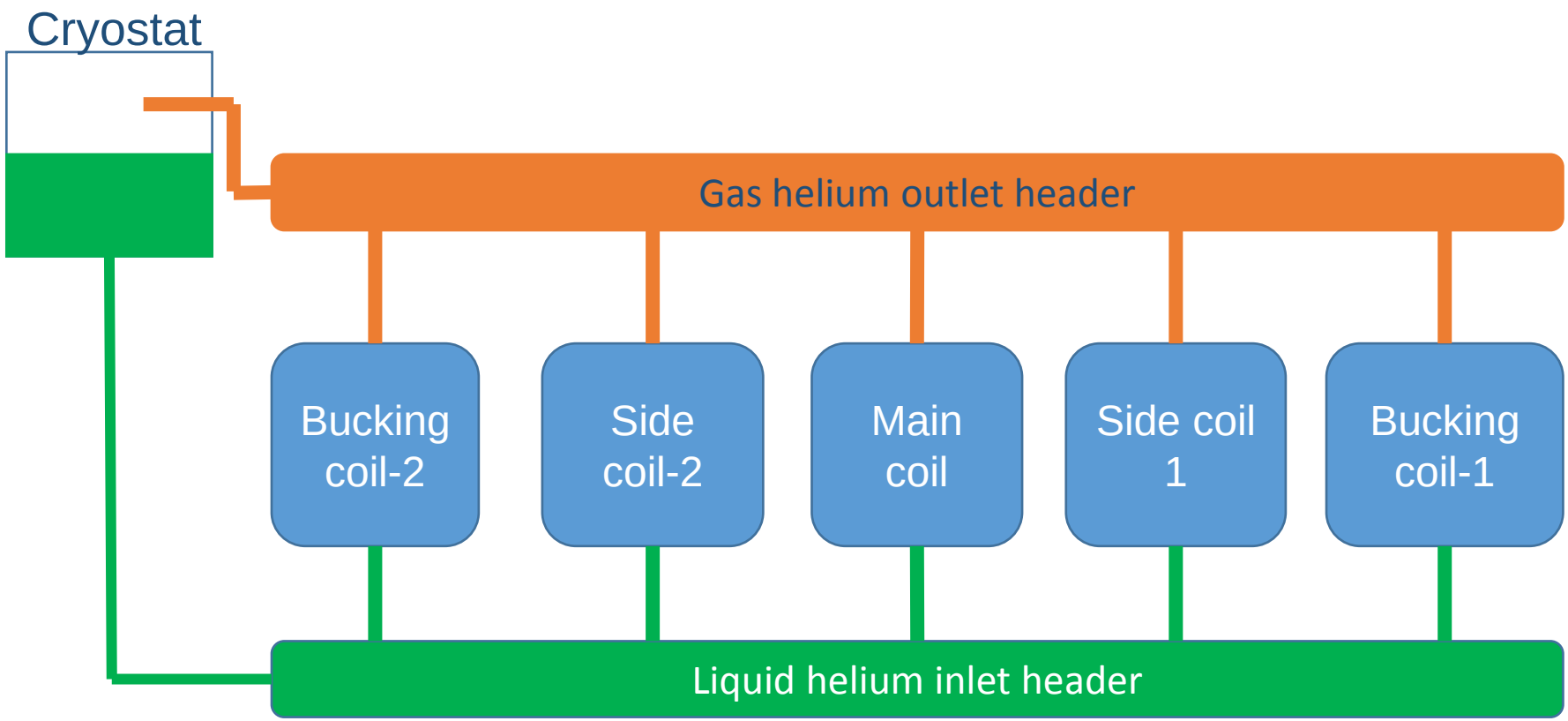
Piece Length : 1.6 Km
Lead Time : 9 Months
Price : $ 30/m

Conductor Type	Cable in channel
Bare Dimension (mm)	9.18 x 4.88
No of SC strands in cable	10
No of filaments in each strand	480
Cu/SC of SC Strand	1.23
Filament Diameter	37 microns
Filament twist	50 mm
Overall Cu/SC	10
Ic (5T, 4.2K)	> 10,000A
RRR	> 100
0.2% Yield Strength	> 200 MPa

Ref: “ Production Results of 11.75 Tesla Iseult/INUMAC MRI Magnet conductor at Luvata “, H.Kanithi , D Blasiak , J.Lajewski , C.Berriaud

Cooling Scheme

- The coils will be conduction cooled through pipe which are wounded on its OD.
- Indirect cooling through two phase thermosiphon cooling loops



Summary & Future Work

- Preliminary design of Three coil along with shield coils configuration based DUNE near detector magnet is carried out
- We would like to part of this magnet development collaboration and wish to take detailed design of the magnet.

Thank you