Update and Status of Thai-JUNO Consortium

Narumon Suwonjandee
Chulalongkorn University
on behalf of Thai-JUNO Consortium

The 2nd Workshop on EMF Shielding for JUNO 2018 07/04/2018

Outlines

- Introduction
- JUNO's requirement
- Coil's configurations
  - Model A: two sets of coils
  - Model B: one set of coils
- EMF calculation and optimization for
  - ideal case
  - various concerns
- Result
- Summary

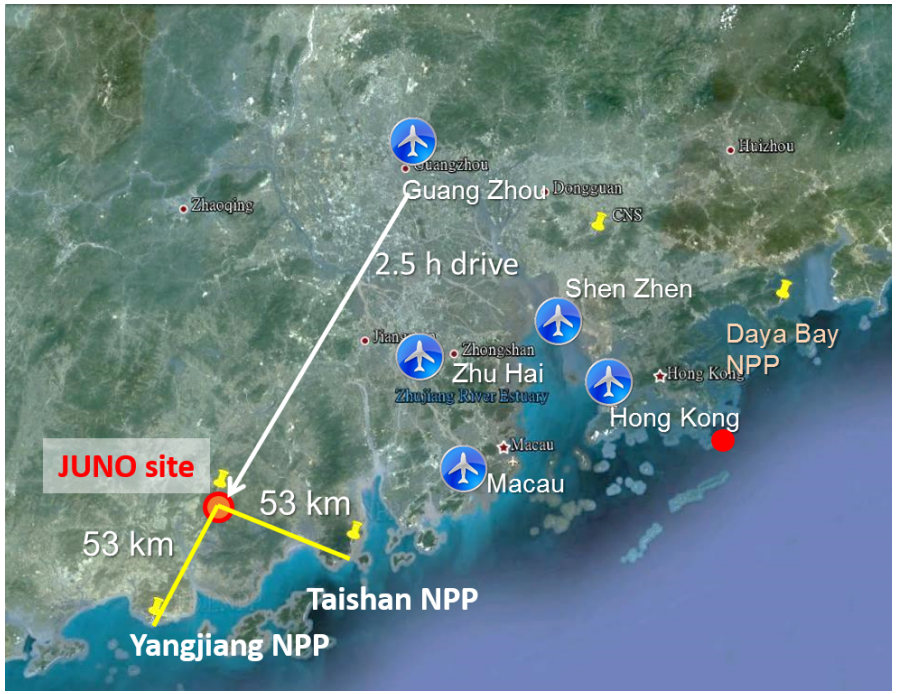
Thai-IHEP MoU

Her Royal Highness Princess Maha Chakri Sirindhorn presided over the MoU signing ceremony Between CU, SUT, NARIT and IHEP for the JUNO Experiment, China, on 7 April 2017.

Thai-JUNO Consortium MoU

21 June 2017

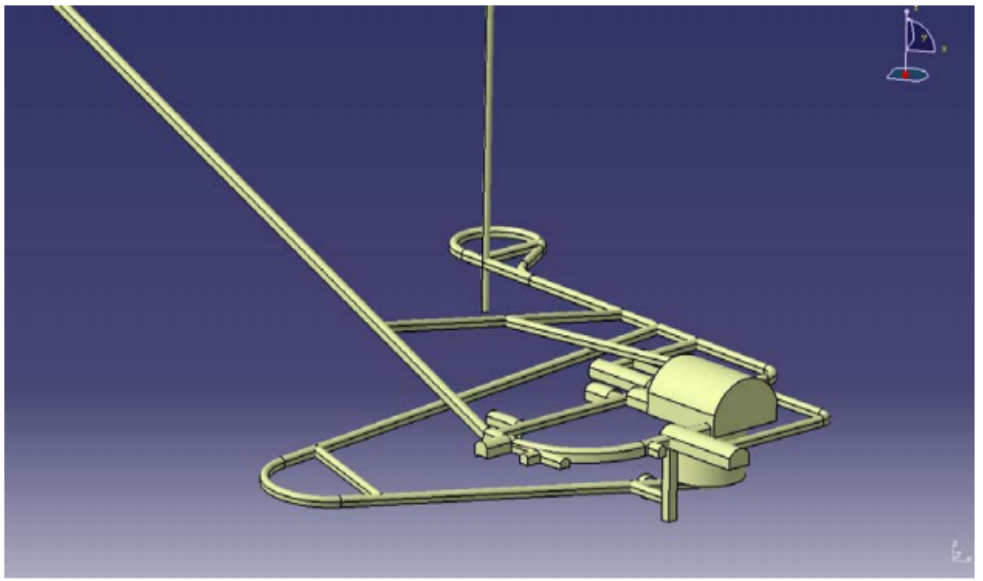
Introduction to JUNO



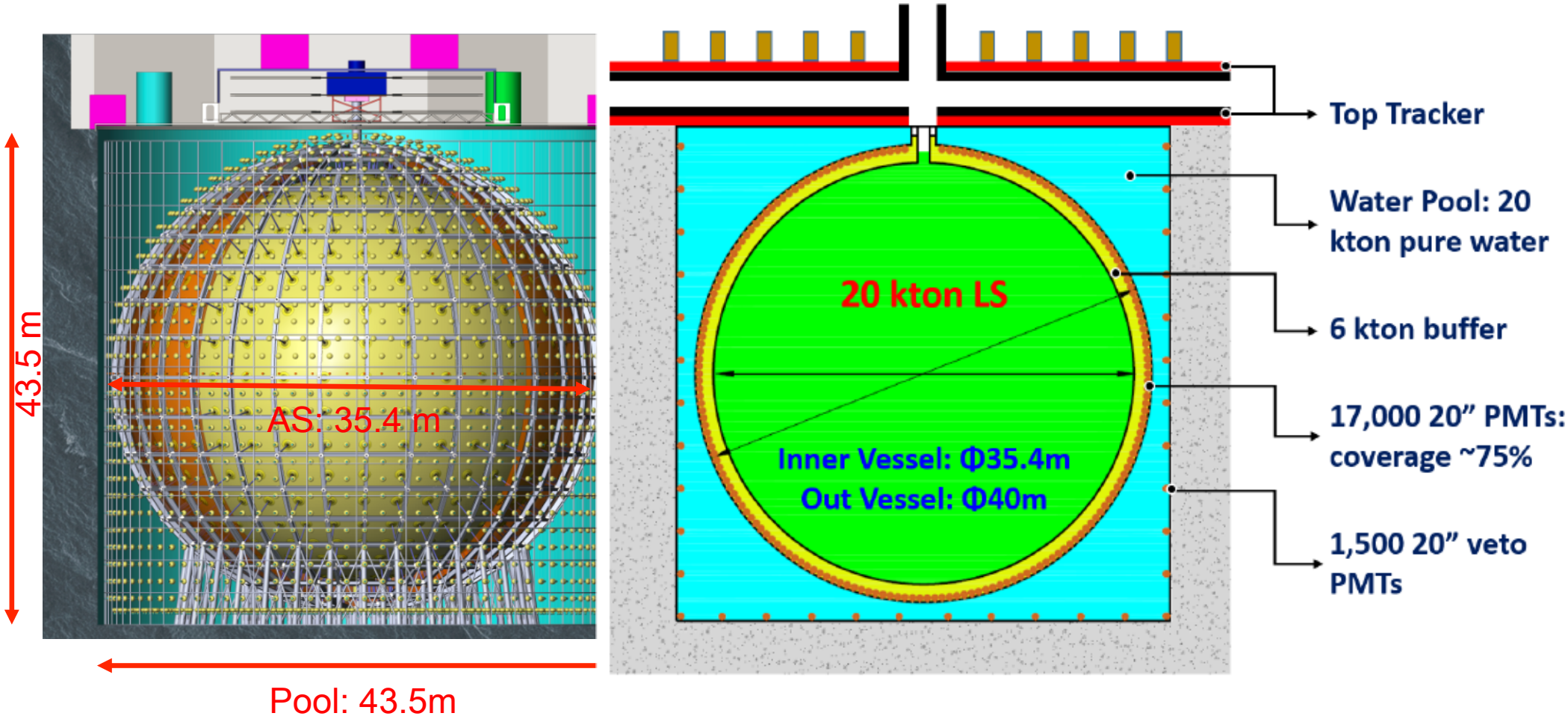
JUNO:
The Jiangmen Underground Neutrino Observatory

Under construction at Jiangmen in Southern China

700-meter underground to reduce the muon-induced backgrounds

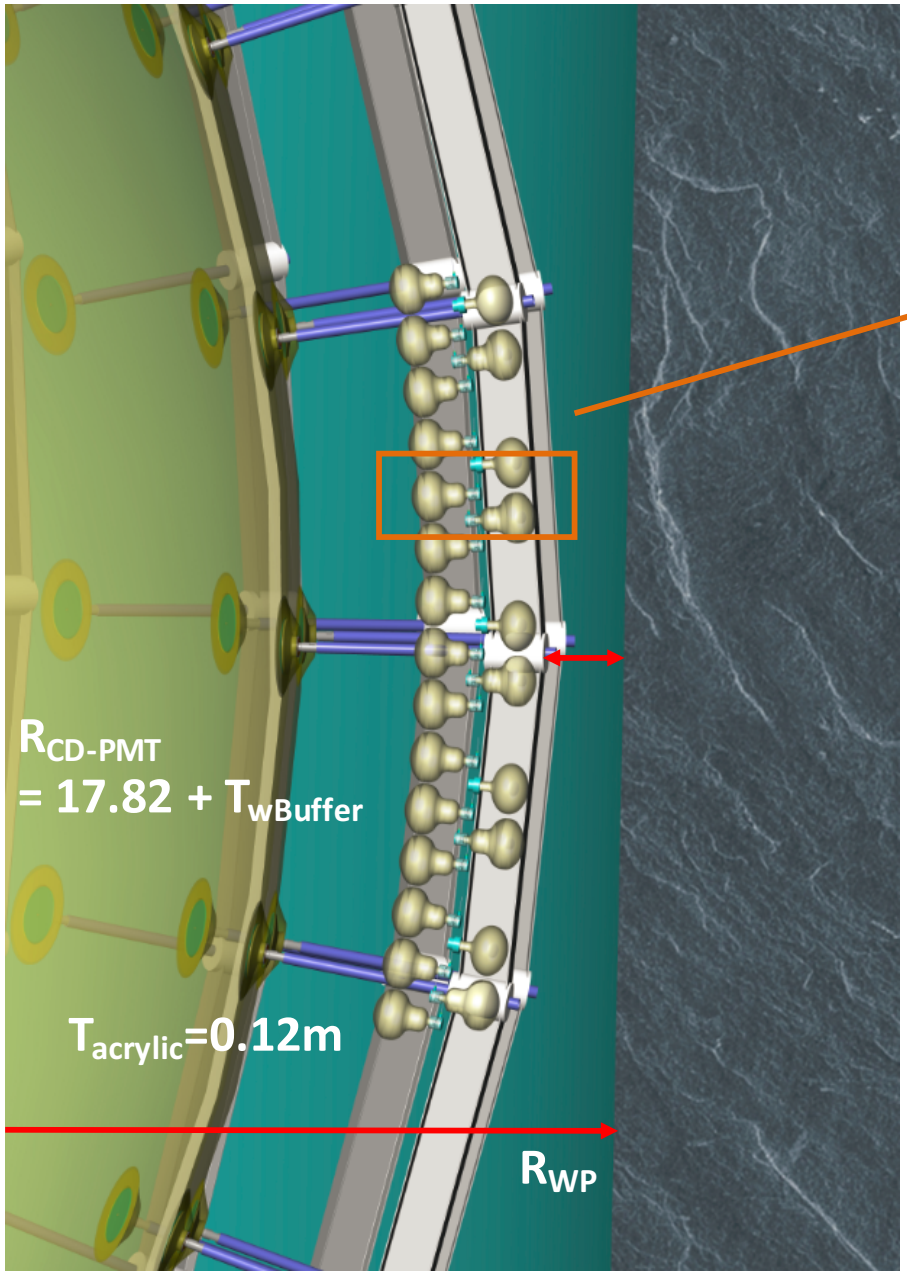


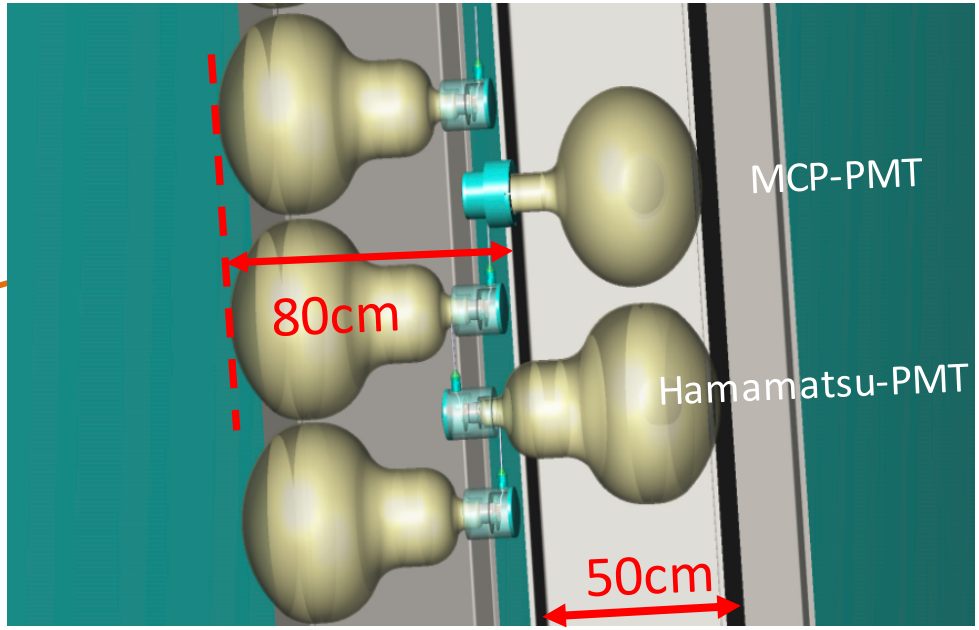
JUNO's Central Detector (CD)



20,000 tons of liquid scintillator (LS) are contained inside an acrylic sphere of 35.4 m diameter.

Parameters of Water Pool and PMT Locations





R_{LS} = 17.7m

$T_{acrylic}$=0.12 m, $T_{wBuffer}$ = 1.43 m, T_{WP} = 1.2 m

Size of the water pool: 43.5 m

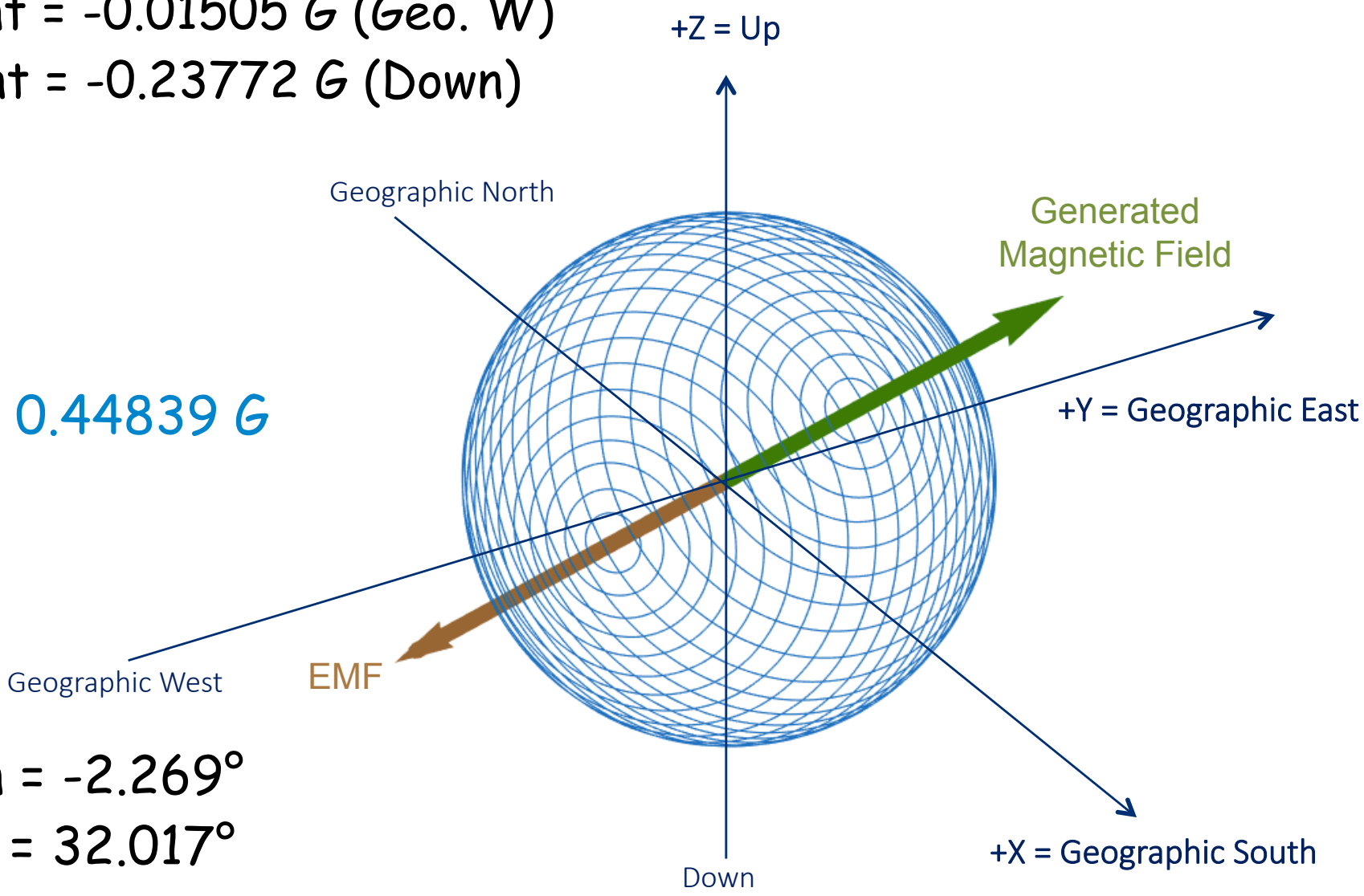
Radius to the faces of CD-PMTs: 19.25 m (Φ 38.5 m)

Radius to the faces of Veto PMTs: 20.55 m (Φ 41.1 m)

EMF Profile

X component = -0.37988 G (Geo. N)
Y component = -0.01505 G (Geo. W)
Z component = -0.23772 G (Down)

|EMF| = 0.44839 G

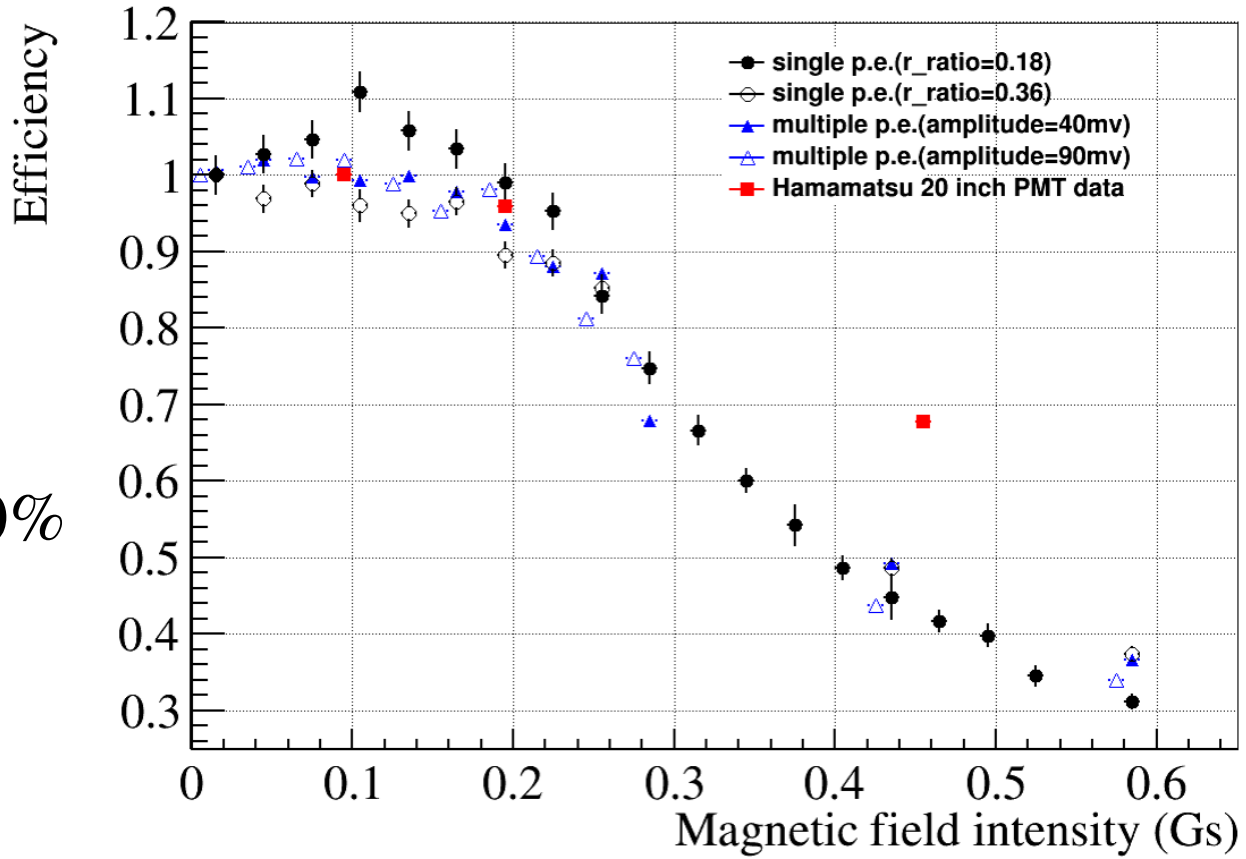


Declination = -2.269°
Inclination = 32.017°

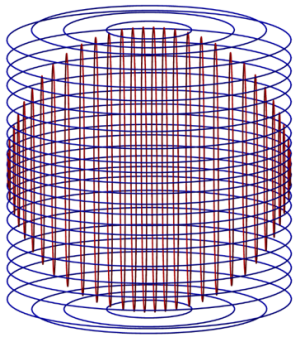
Our Aims

- Residual-B < 0.05 G (~ 10%)
- Practical coils' installation
- Minimized coils' cost

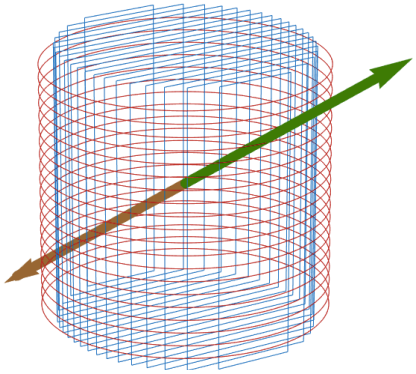
$$B_{res}^{\max} = \left(\frac{B - EMF}{EMF} \right)_{\max} \times 100\%$$



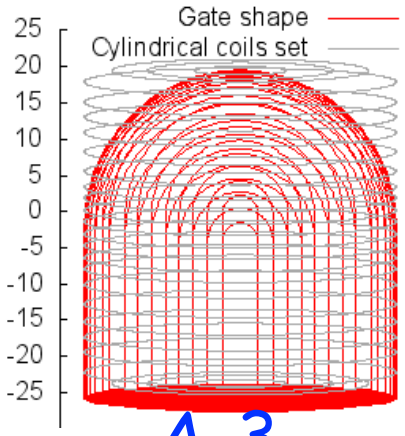
2 Sets of Coils



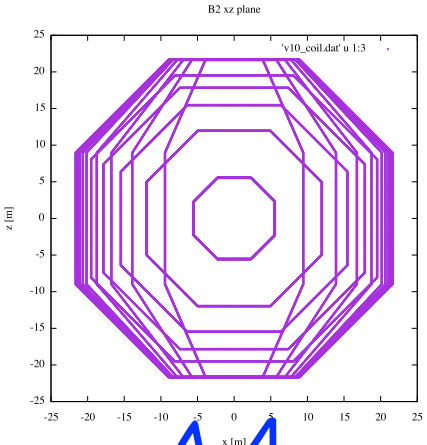
A-1



A-2



A-3



A-4

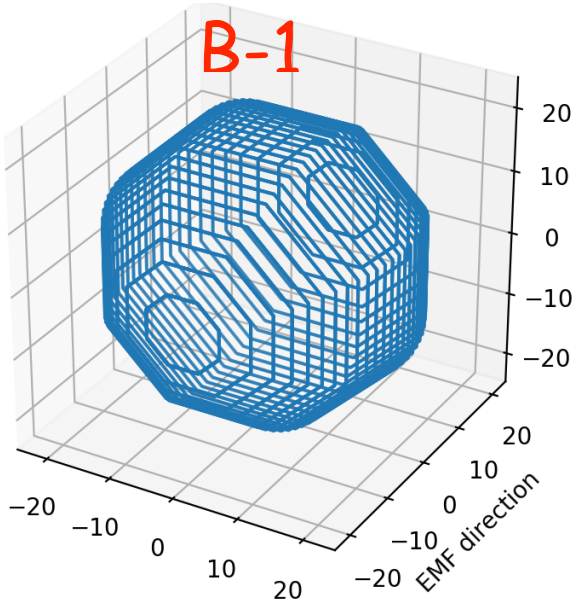
10

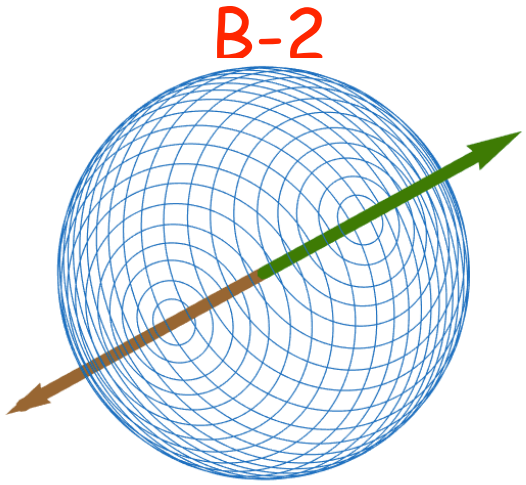
PMT regions	Max of Res to EMF (%)			
	A-1	A-2	A-3	A-4
CD	4.95	92.70	13.08	11.23
VETO	11.64	99.21	14.35	19.87

Conclusion: 2 sets of coils

- In the CD region
  - only Model A-1 (sphere + cylinder) gives good residual-B (< 10%)
- In the VETO region
  - no Models give residual-B < 10%

1 Set of Coils



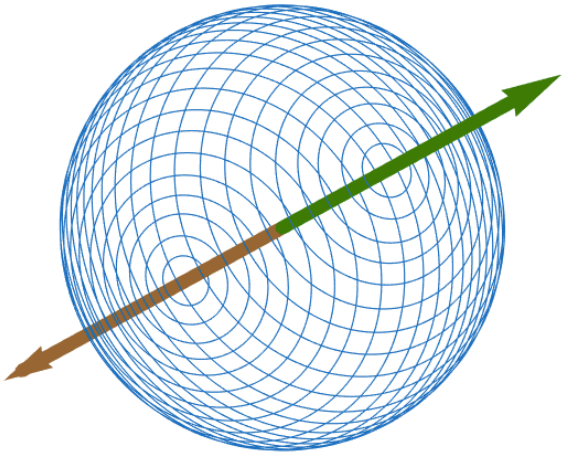


PMT regions	Max of Res to EMF (%)	
	B-1	B-2
CD	6.45	5.22
VETO	15.38	21.62

Conclusion: 1 set of coils

- In the CD region
  - Both models give residual-B < 10%
- In the VETO region
  - Octagon models give residual-B < 20%
- Octagon coils require good alignment in coil's installation
- Decision: 1 set of circular coils

Coils' Configuration



- 15 pairs of circular coils form a sphere of diameter ~ 43.3 m
- coils' axes lie almost opposite to the EMF axis
- Optimization on ϕ =39.5 m
- Currents in coils range from 12 to 122 A

coil	Location (m)	Radius (m)	Current (A)
1	0.79	21.64	85.54
2	2.38	21.52	85.54
3	4.06	21.26	97.76
4	6.01	20.80	109.98
5	8.05	20.10	109.98
6	10.20	19.10	122.20
7	12.49	17.69	122.20
8	14.56	16.02	97.76
9	16.26	14.30	85.54
10	17.75	12.40	73.32
11	19.00	10.39	61.10
12	19.90	8.53	36.66
13	20.56	6.74	36.66
14	21.26	4.62	24.44
15	21.50	2.59	12.22

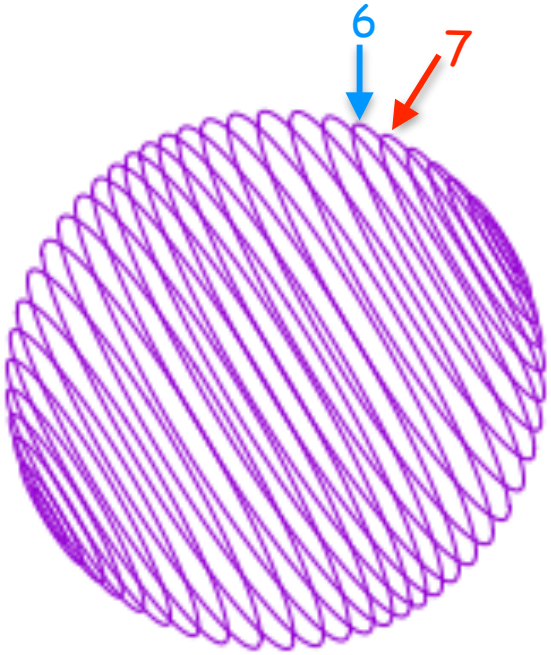
Various Concerns

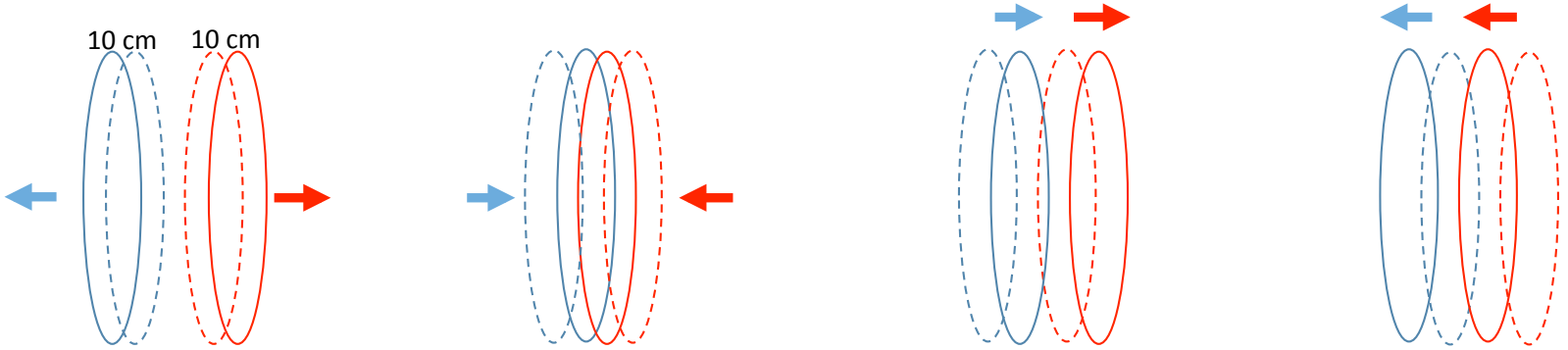
- Installation Errors
  - coils' displacement
  - coils' distortion

- Secular change in EMF

A. Coils' Displacement

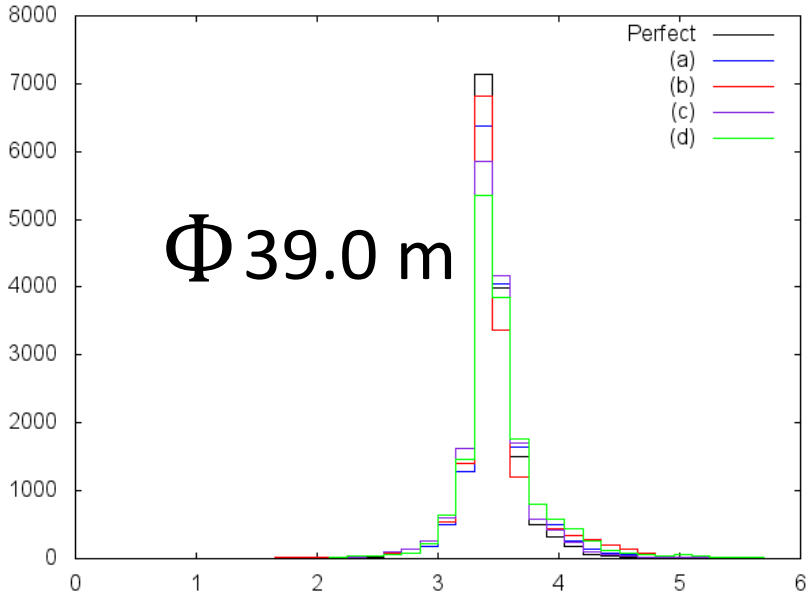
- Move coils No. 6 and 7 by 10 cm each in 4 ways:
  - A. move away from each other
  - B. move toward each other
  - C. move toward the pole
  - D. move toward the equator

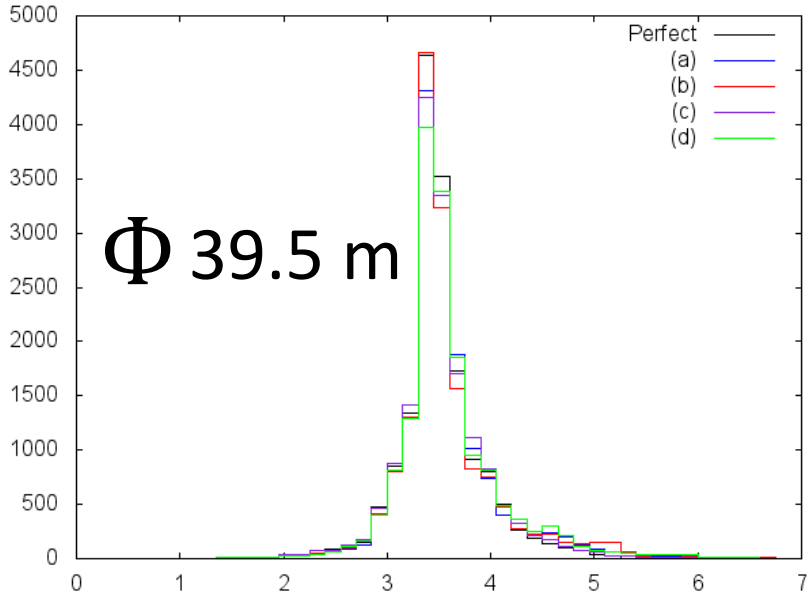


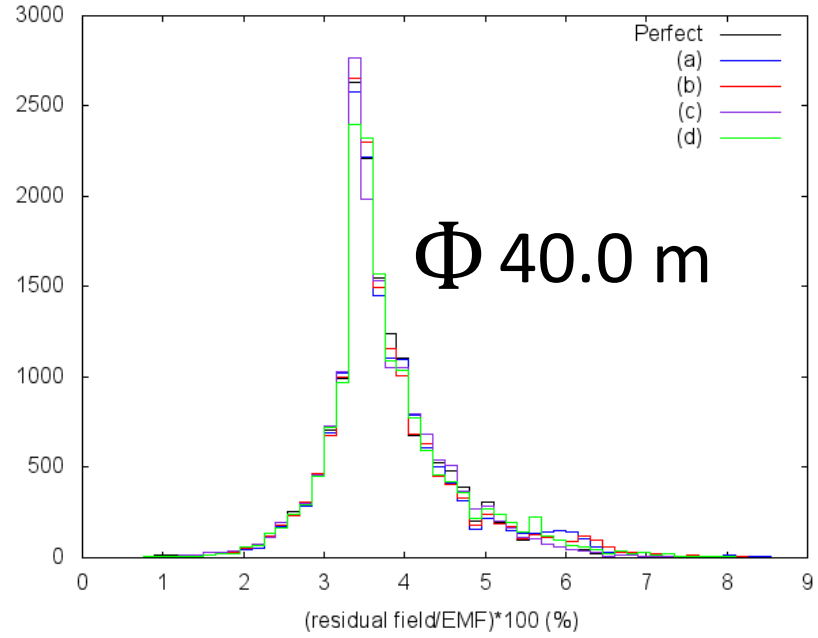


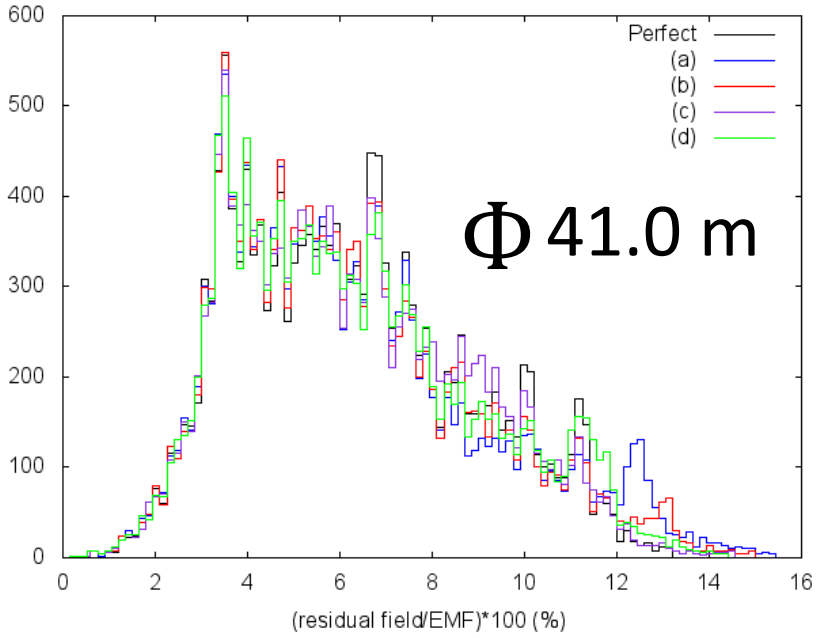
Coil's Displacement: Residual B-field

Perfect
A
B
C
D



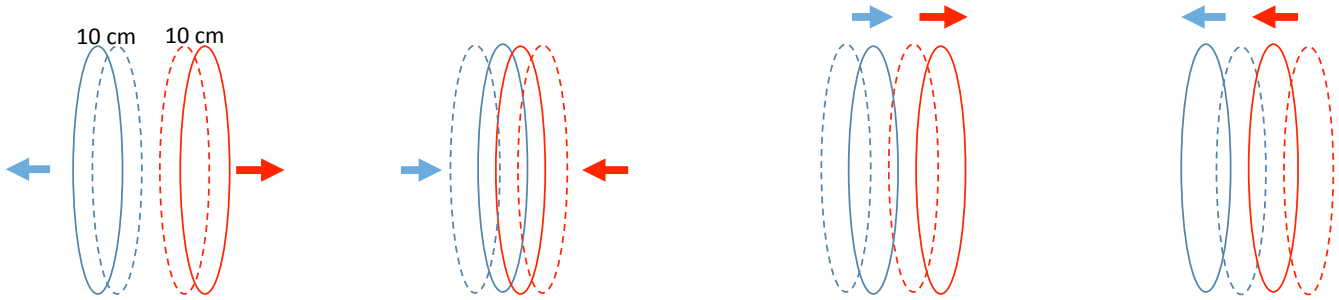






Result Coils' Displacement

$$B_{res}^{\max} = \left(\frac{B - EMF}{EMF} \right)_{\max} \times 100\%$$



Φ(m.)	PERFECT	Max of Res-B to EMF (%)			
		A	B	C	D
39	4.57	5.78	5.75	5.34	5.77
39.5	5.26	6.81	6.72	6.18	6.63
40	6.46	8.46	8.27	7.60	8.03
41	13.18	15.41	14.97	14.53	14.36

Coil's displacement causes insignificant change in residual-B.

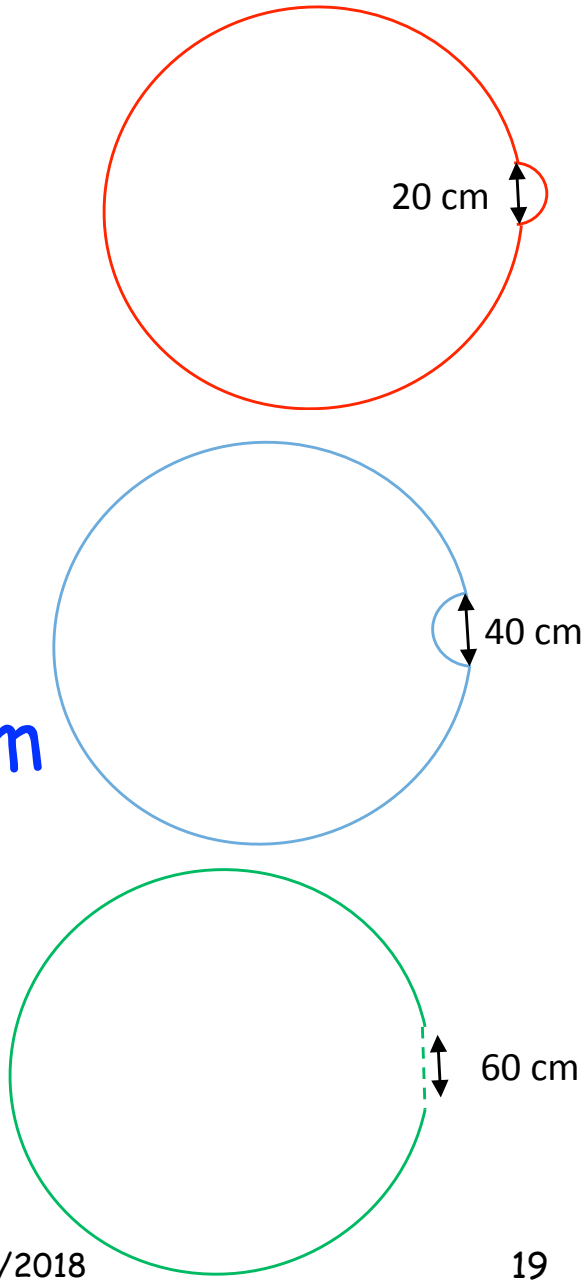
B. Coils' Distortion

Make a bump as a semicircle on coils number 5-8 (high current coils) to surround the structure in 3 ways:

I. outer semicircles of radius 10 cm

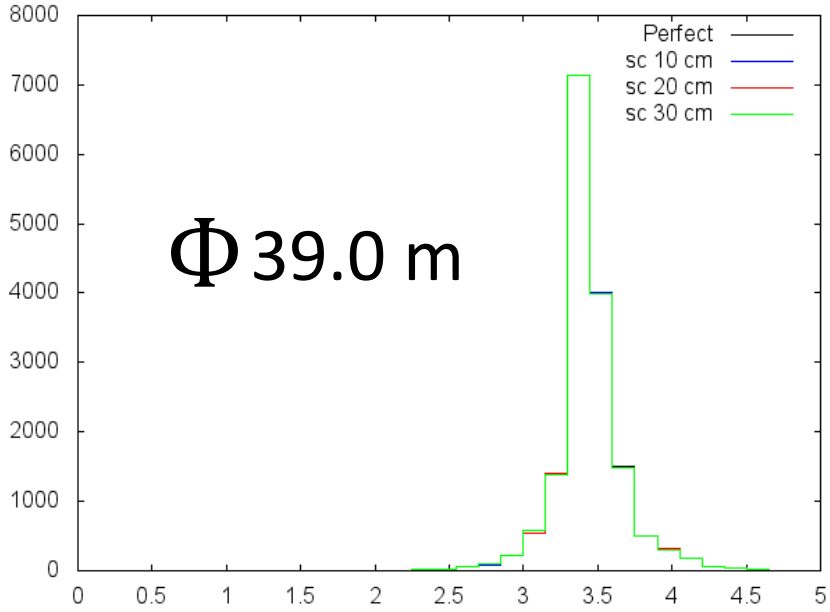
II. inner semicircles of radius 20 cm

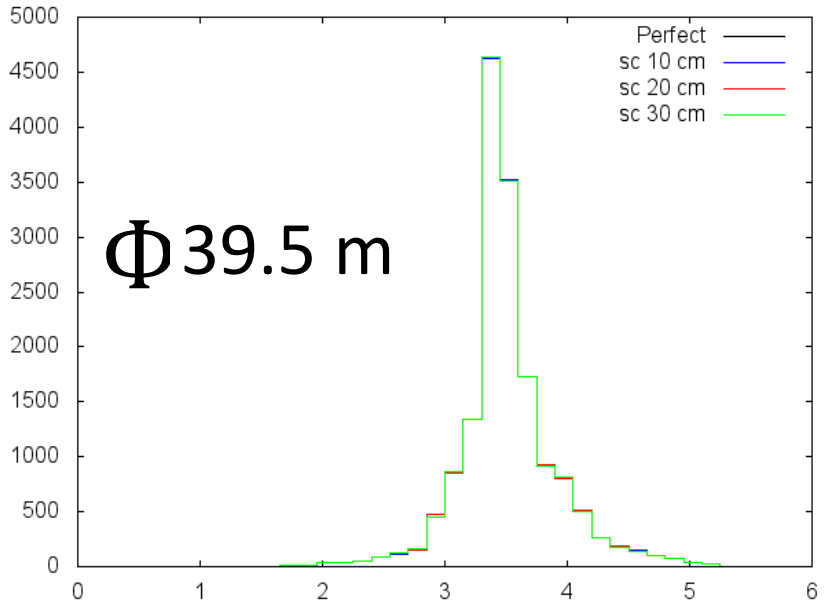
III. semicircles of radius 30 cm perpendicular to the coil.

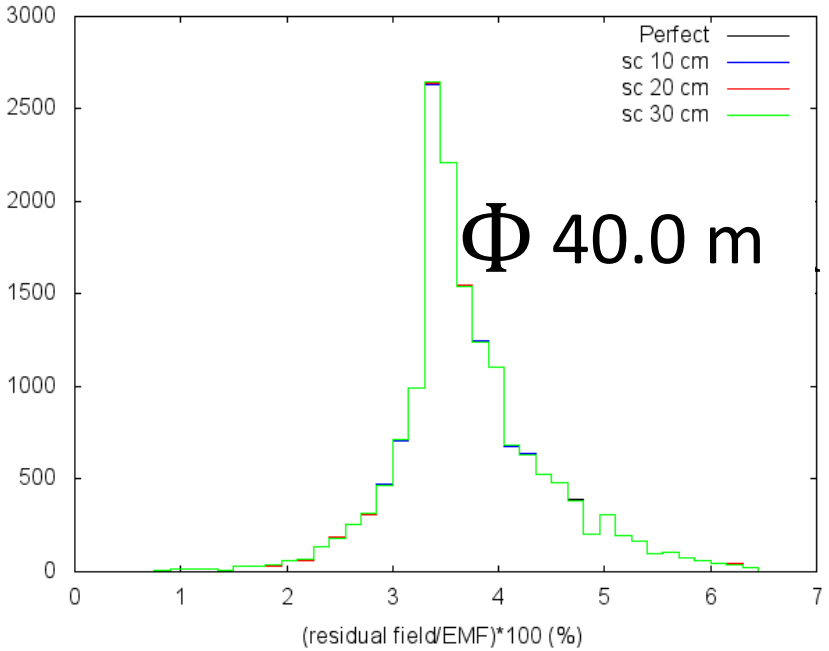


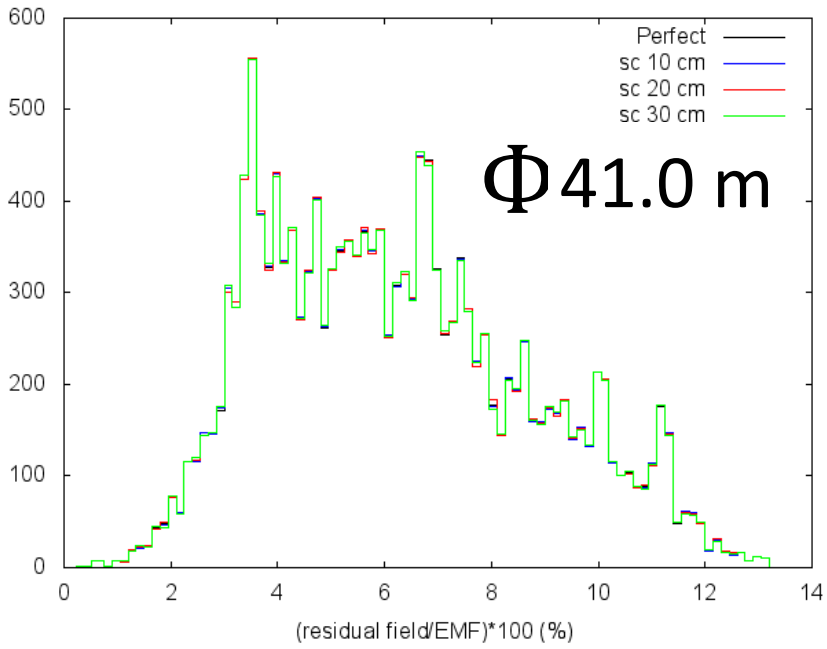
Coil's Distortion: Residual B-field

Perfect
sc 10 cm
sc 20 cm
sc 30 cm

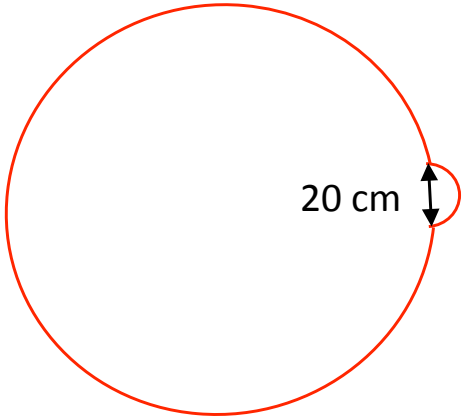




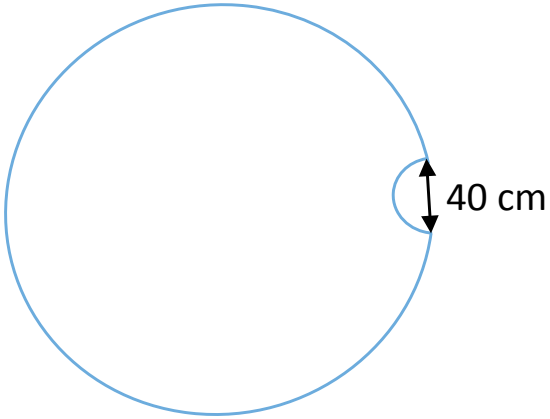




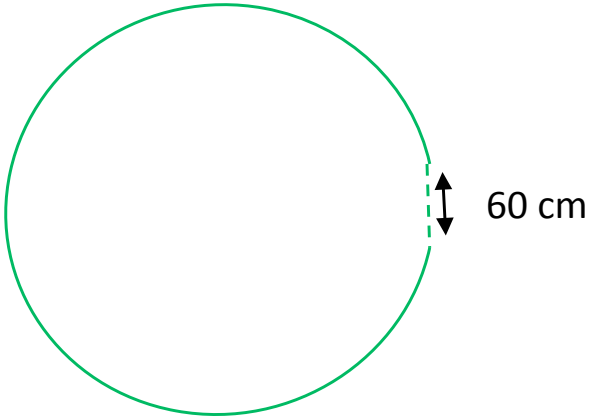
Result for Coils' Distortion



Outer



Inner



Perpendicular

Φ(m.)	PERFECT	SC 10 CM	SC 20 CM	SC 30 CM
39	4.57	4.59	4.58	4.57
39.5	5.26	5.27	5.26	5.26
40	6.46	6.46	6.48	6.47
41	13.18	13.18	13.18	13.18

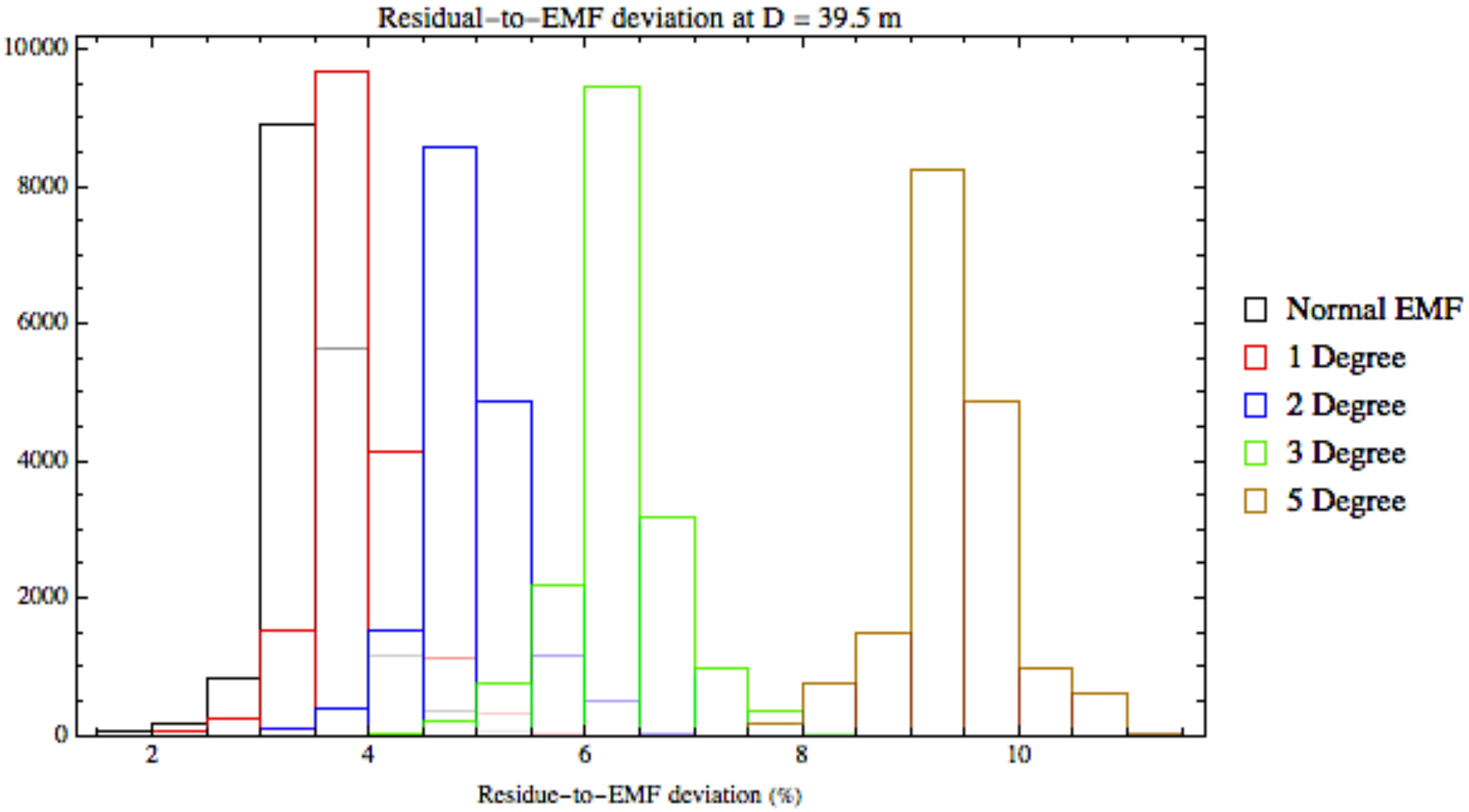
Coil's distortion gives negligible change in residual-B.

C. The secular change in EMF

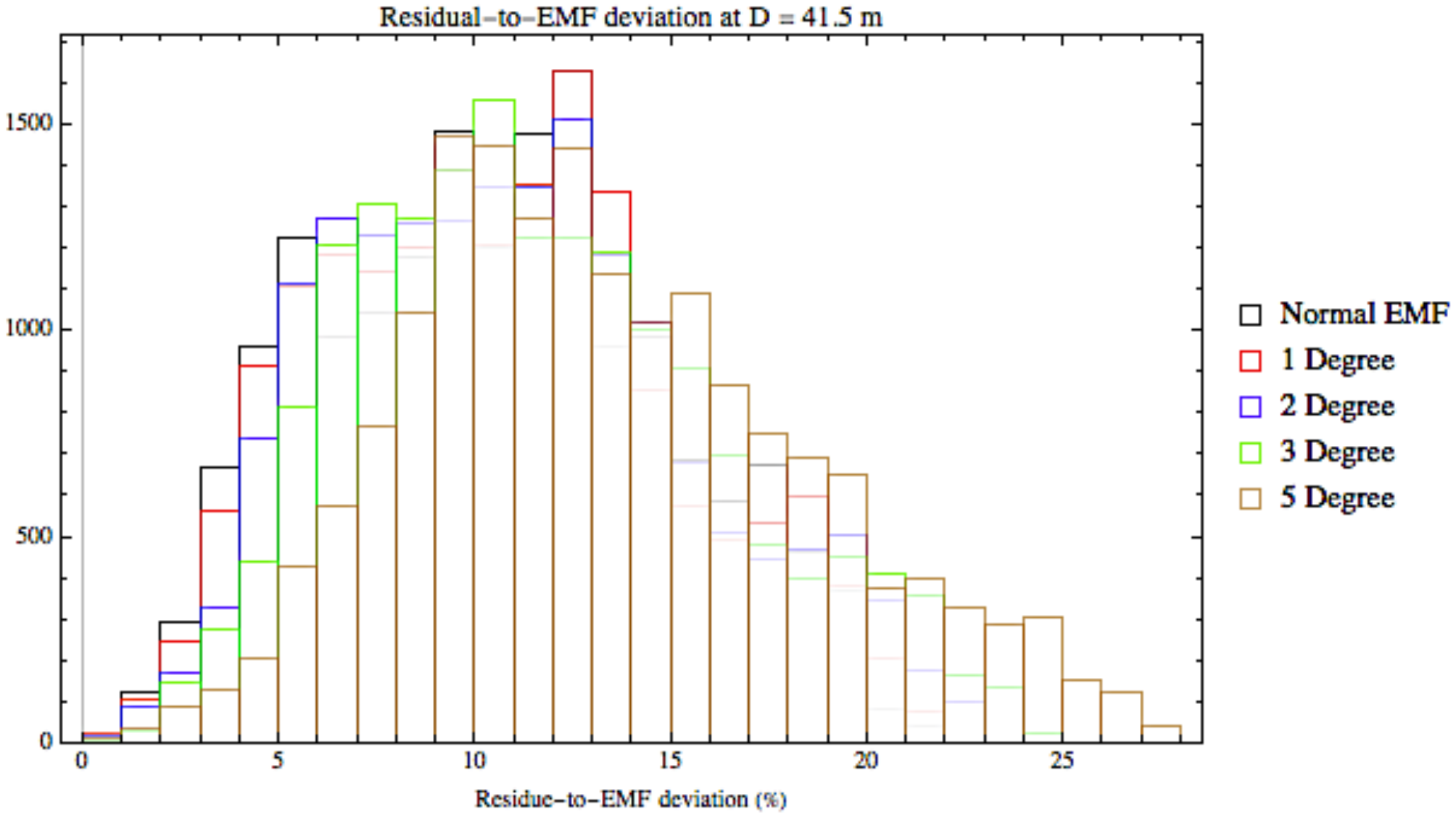
- The EMF axis changes -0.0607°/yr for declination and 0.1437°/yr for inclination*
- Within 20 years the axis will be deviated by ~3°
- Calculate the magnetic field if the axis is deviated by 1°, 2°, 3° and 5° in each direction separately

*American National Centers for Environmental Information

Residue to EMF Deviation at CD Region



Residue to EMF Deviation at VETO Region



Result for Secular Change in EMF

$$B_{res}^{\max} = \left(\frac{B - EMF}{EMF} \right)_{\max} \times 100\%$$

Φ (m)	Perfect	1	-1	2	-2	3	-3	5	-5
39.5	5.22	5.70	5.65	6.77	6.69	8.10	8.05	11.27	11.18
41.5	21.62	21.95	21.98	22.98	22.95	24.27	24.16	27.35	27.28

Secular change in EMF gives small change in residual-B within 20 years (<10%)

New Improvement

- Use 16 pairs of circular coils

  —> lower the maximum current

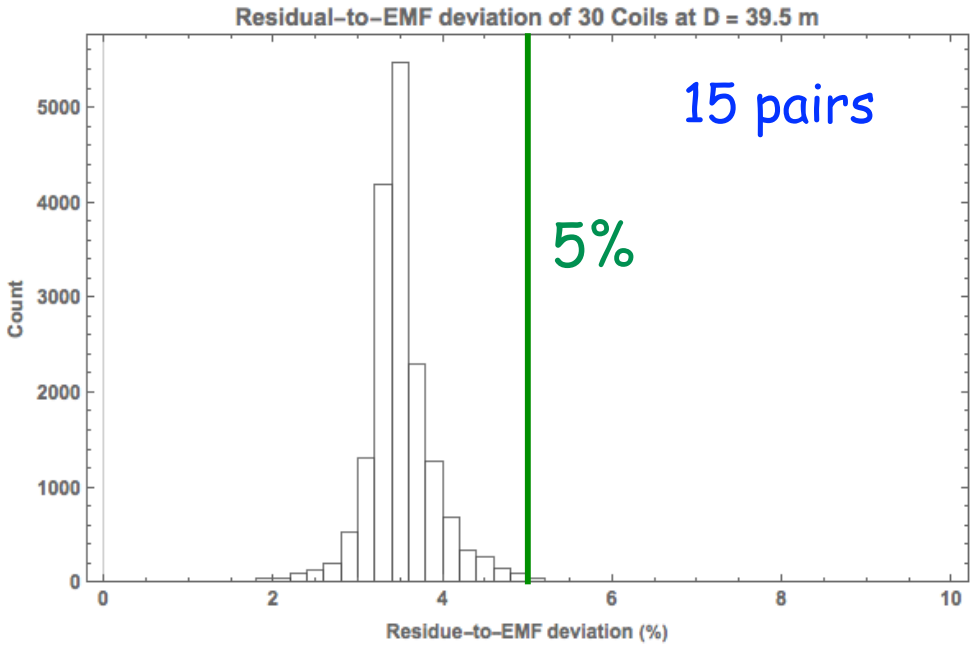
- Each coil has equally spacing

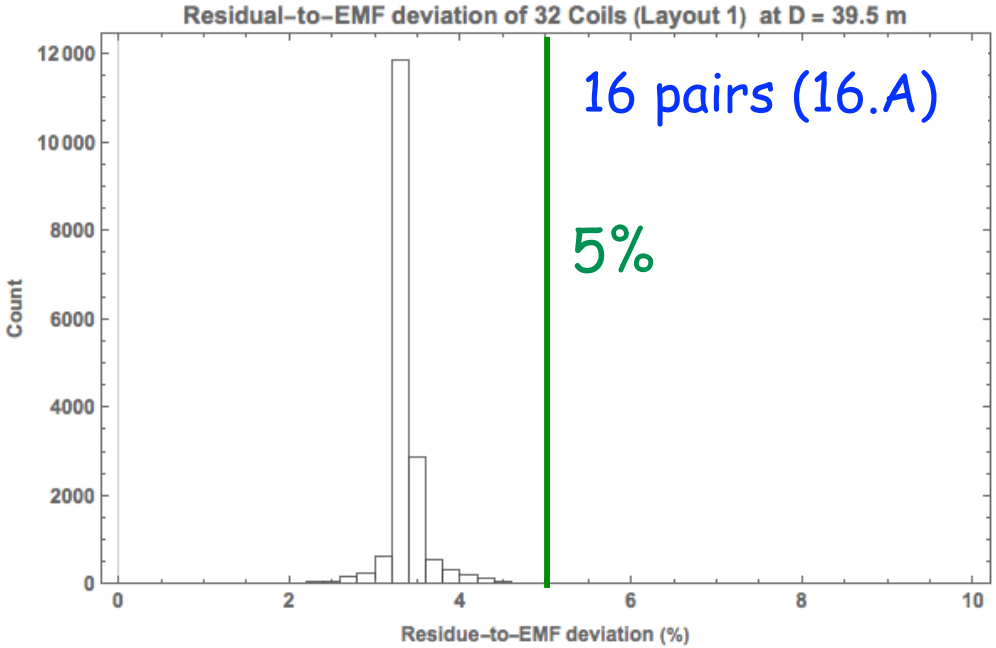
  —> same current to minimize the cost of power supplies

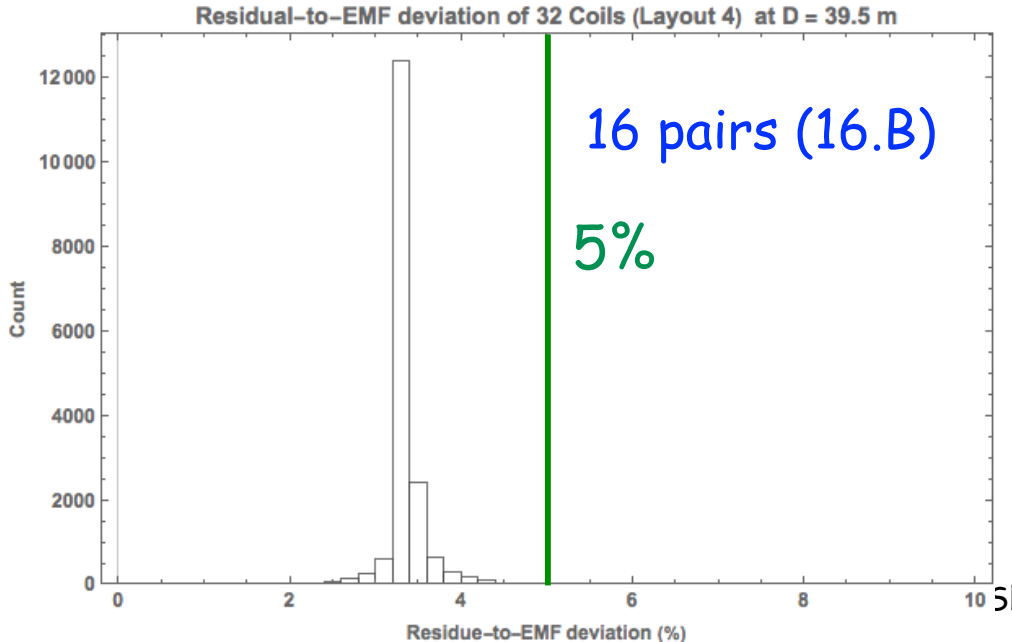
16 Pairs Modification

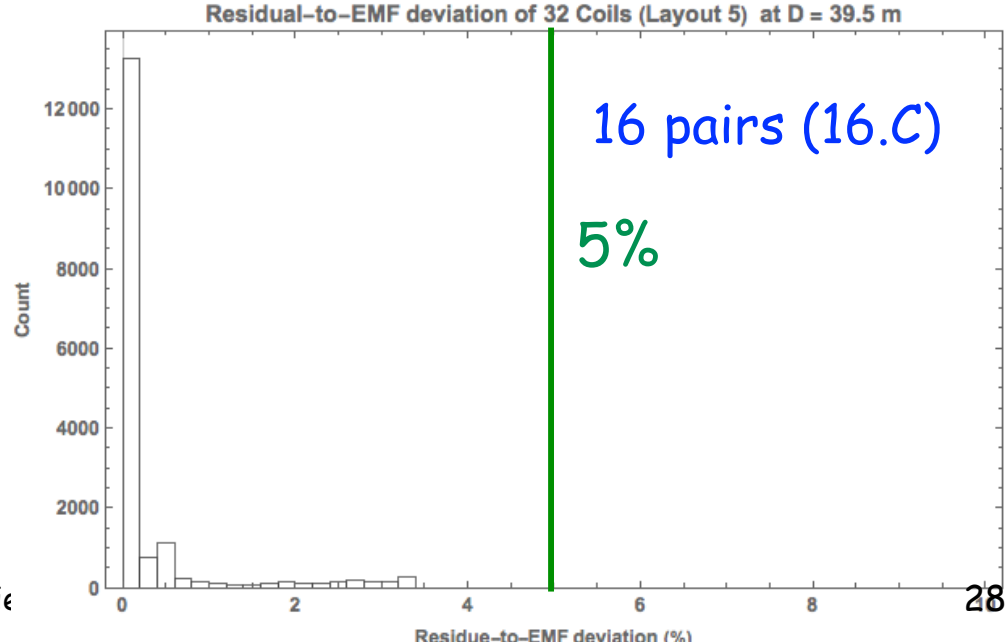
- Optimize on a sphere of diameter 39.5 m
- Vary the spacing between the coils
  - Layout 16.A: coils 1-13 with spacing of 1.48 m, less spacing in small coils
  - Layout 16.B: coils 1-12 with spacing of 1.50 m, less spacing in small coils
  - Layout 16.C: equal spacing of 1.35 m in all coils

Residual-B to EMF at CD region (D=39.5 m)

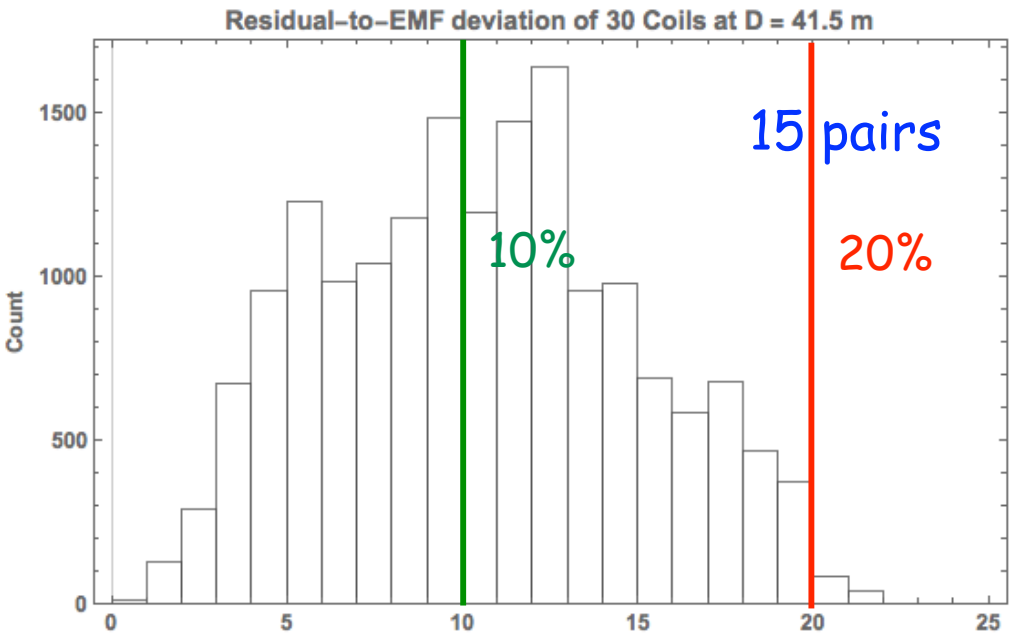


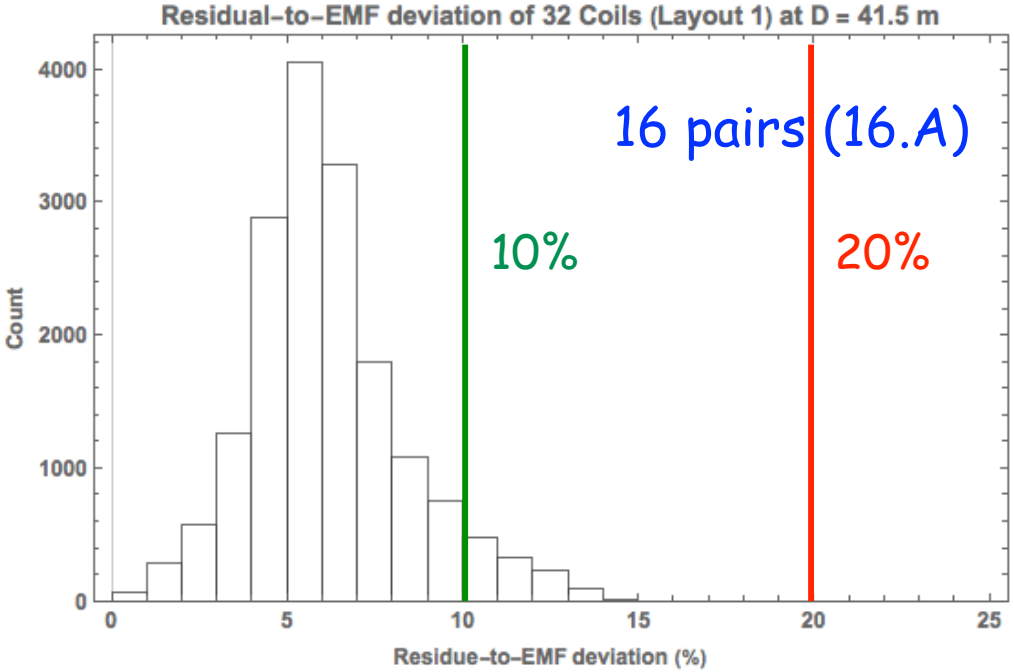


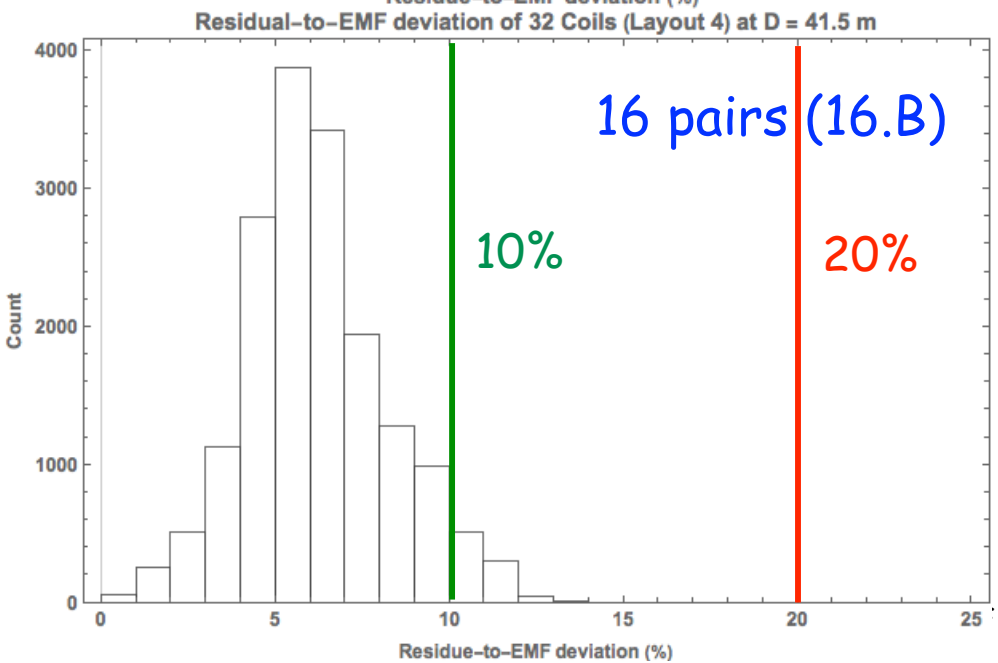


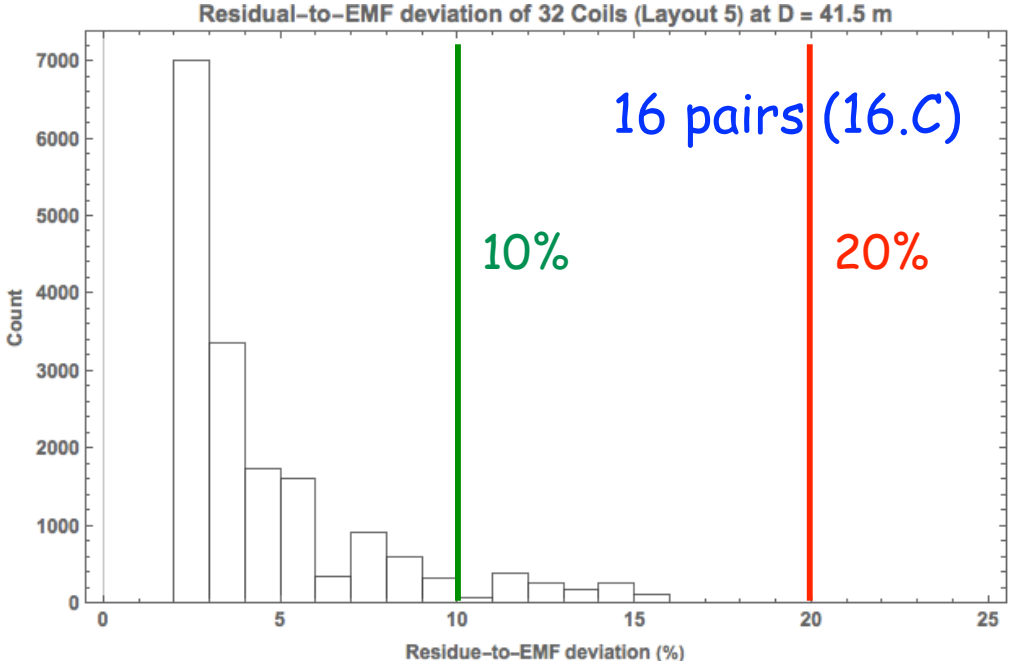


Residual-B to EMF at VETO region (D=41.5 m)









Shie

Comparison of 15 vs 16 pairs (Preliminary Result)

$$B_{res}^{\max} = \left(\frac{B - EMF}{EMF} \right)_{\max} \times 100\%$$

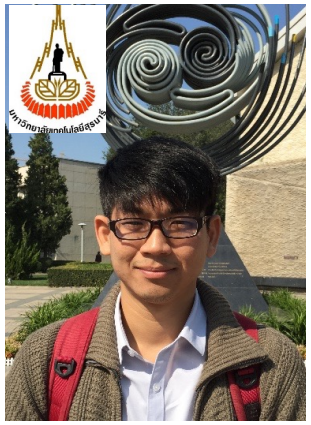
Diameter (m)	Max of Res-B to EMF (%)			
	15 pairs	16 pairs		
		16.A	16.B	16.C
39.5 (CD)	5.22	4.68	4.84	3.37
41.5 (VETO)	21.62	14.15	13.13	15.35
Current	12 - 122 A	26 - 85 A (7 coils-80 A)	27 - 83 A (10 coils-80 A)	58 - 76 A (13 coils-73 A)

Summary

- Coil's configuration
  - 15 pairs of circular coils form a sphere ϕ ~ 43.3 m
  - coils' axes lie almost opposite to the EMF axis
  - optimization on sphere of ϕ =39.5 m
  - currents in coils range from 12 to 122 A
- B-field deviation due to
  - coils' displacement and coils' distortion are ~ 5%
  - secular change in EMF is ~ 10% within 20 years
- 16 pairs of equal spacing give lower residual B-field

Acknowledgement

- IHEP, Chinese Academy of Sciences
- SUT-Suranaree University of Technology
- NARIT-National Astronomical Research Institute of Thailand (Public Organisation)
- CU-Chulalongkorn University



Julanan Songwadhana
SUT 3rd grad student

Teerapat Payupol
CU 3rd grad student

Anut Sangka
NARIT research assist.

Thank You for Your Attention