Instituto Universitario de Ciencias y Tecnologías Espaciales de Asturias (ICTEA)

Universidad de Oviedo

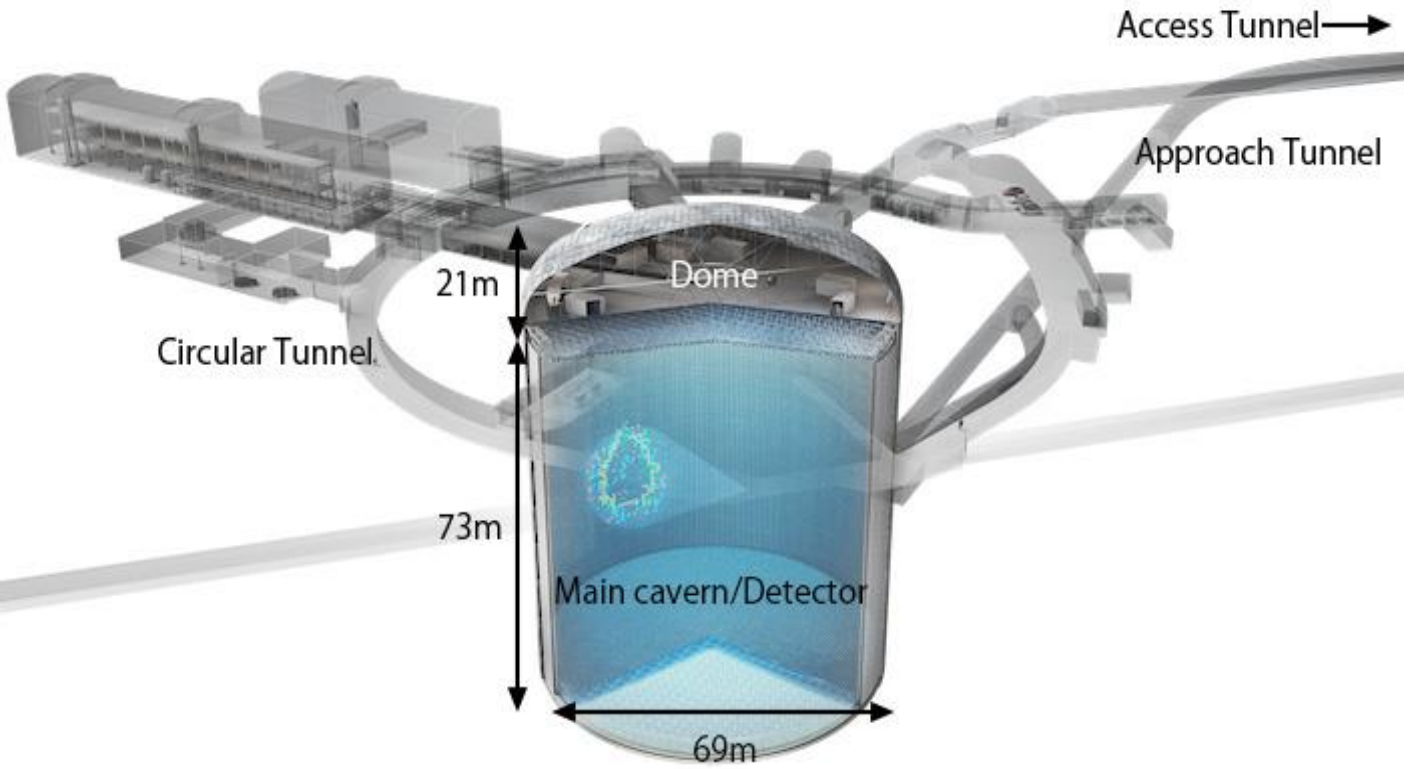
Geomagnetic compensation system design

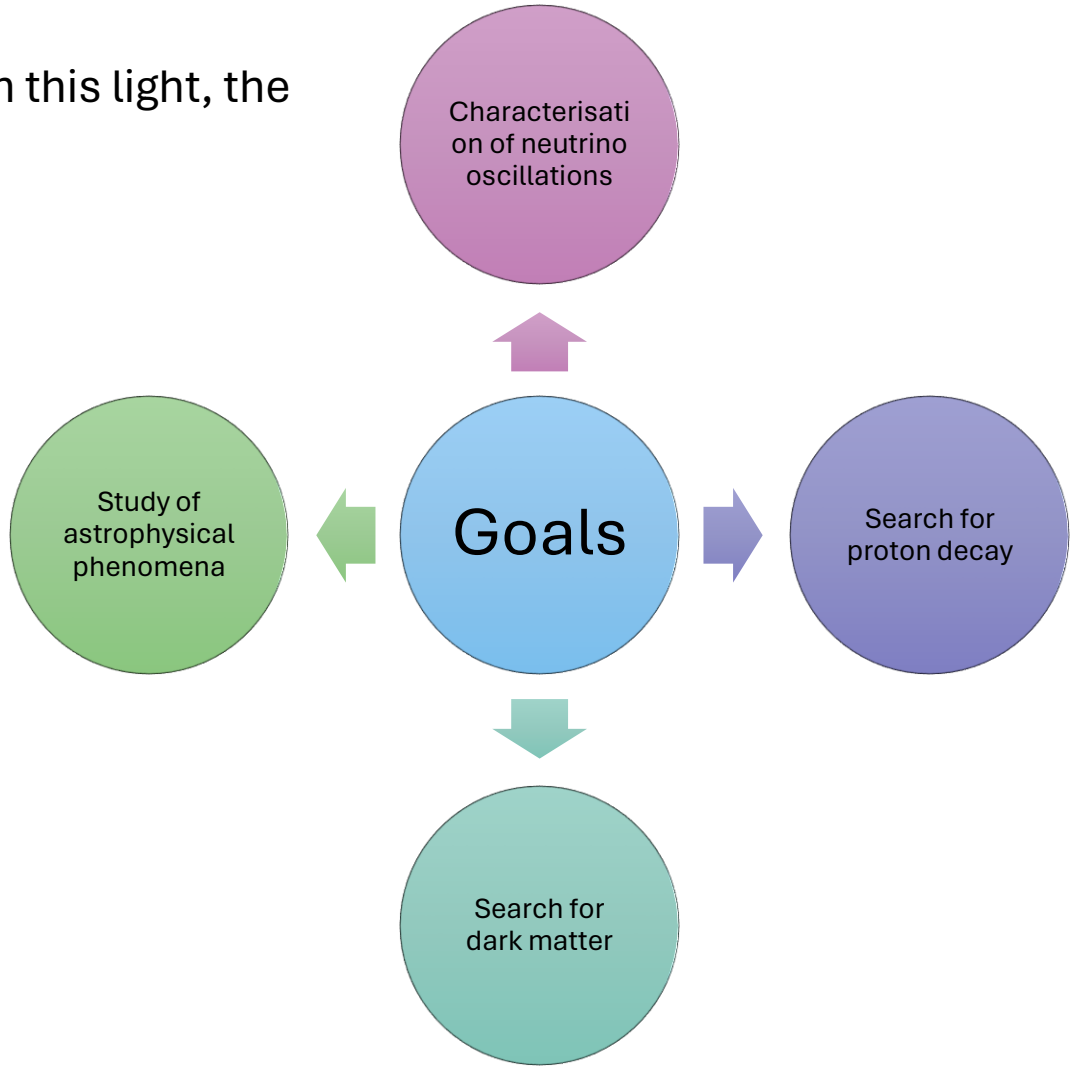
6th May 2024

I Jornadas del ICTEA

Hyper Kamiokande: Cherenkov-type neutrino detector located in Japan

- Successor to the Super-Kamiokande experiment and almost twice as big.
- Cherenkov light is detected by photomultipliers (PMTs). From this light, the characteristics of the interaction are reconstructed.





- The Earth's magnetic field significantly decreases the detection efficiency of the Hyper-Kamiokande detector's PMTs.

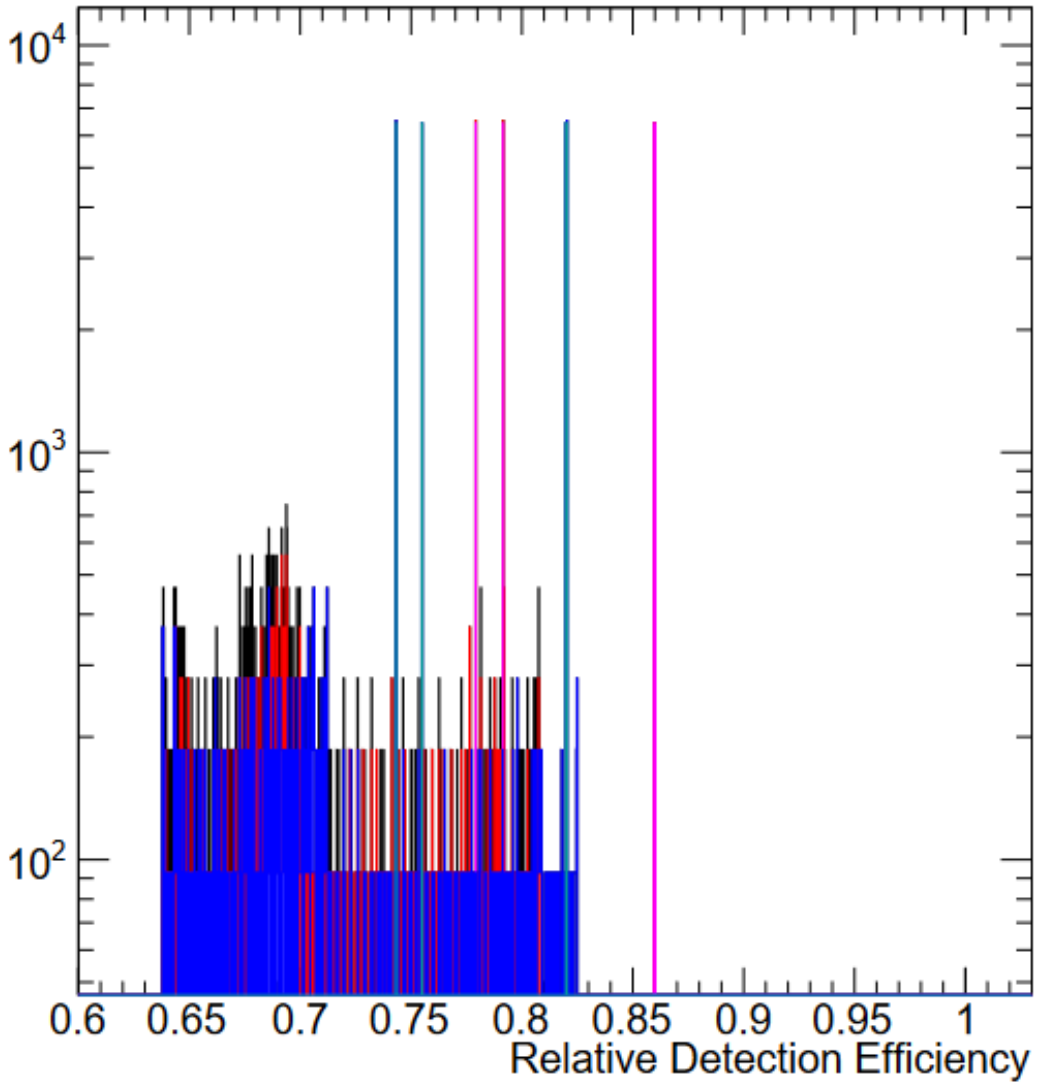
Geomagnetic field in HK location:

B = (0, 303, -366) mG

- The detection efficiency of PMTs is between 64% and 86% if the geomagnetic field is not compensated.

➢ The design of a coil-based compensation system is necessary to ensure the proper functioning of the detector.

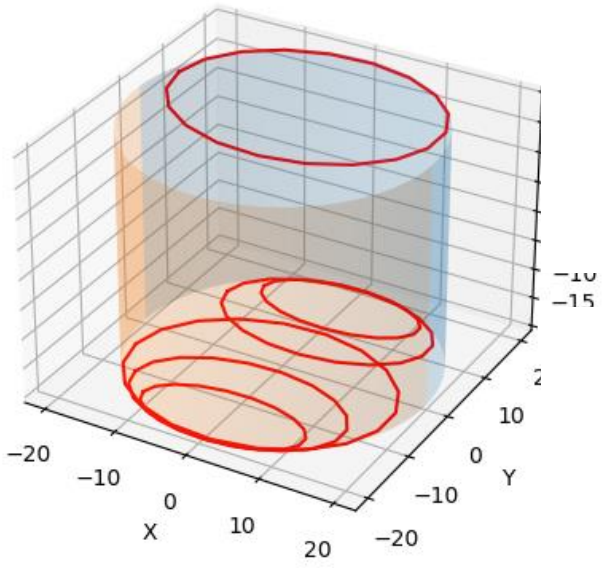
Relative detection efficiency



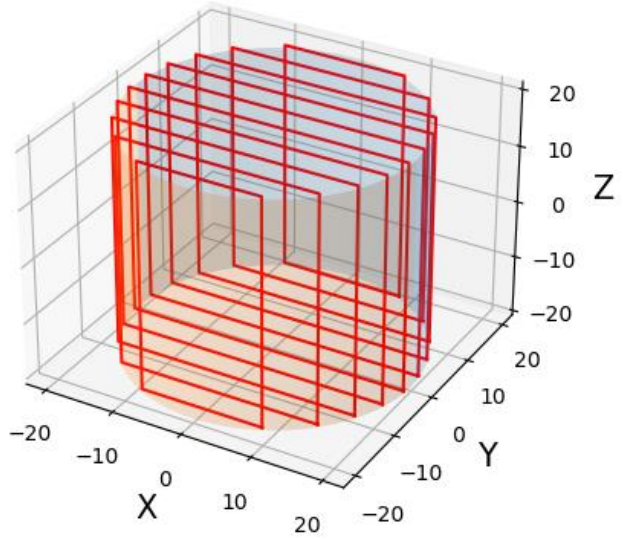
- Circular, rectangular and depending on the case elliptical coils are used to compensate for geomagnetic field.

- Designs are defined by the distance between the different coils, which leads to different values of optimal intensity of current

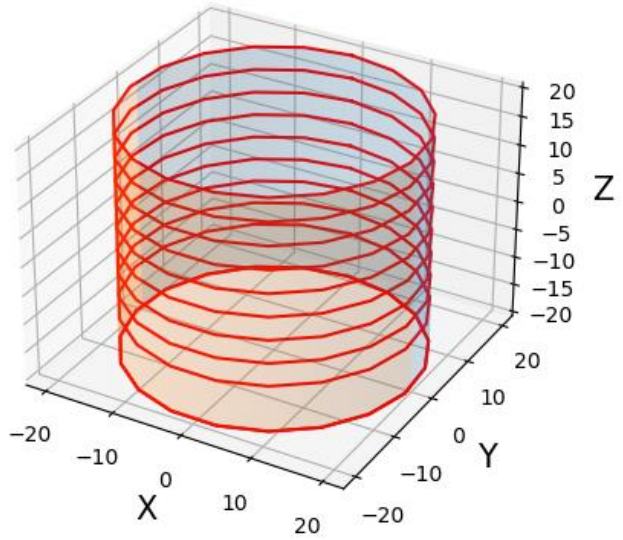
Elliptical coils



Rectangular coils

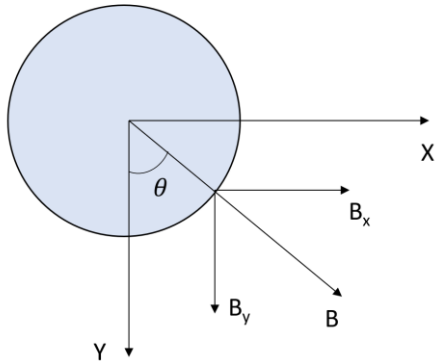


Circular coils



Three parameters are considered to evaluate compensation:

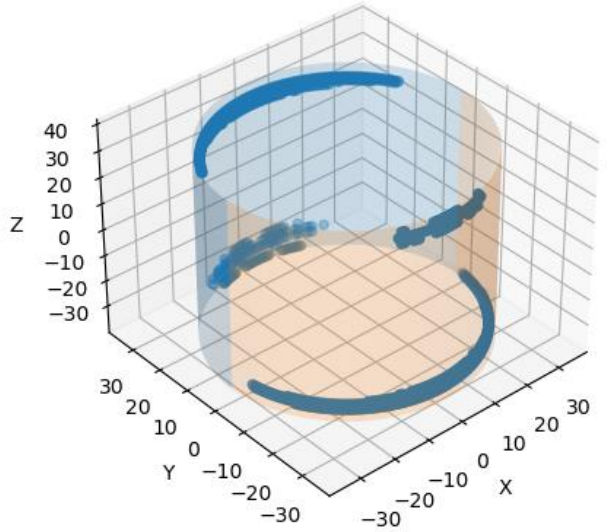
1. Proportion of PMTs above 100 mG
2. Average B_{perp} over the whole detector
3. Average loss of detection efficiency of PMTs

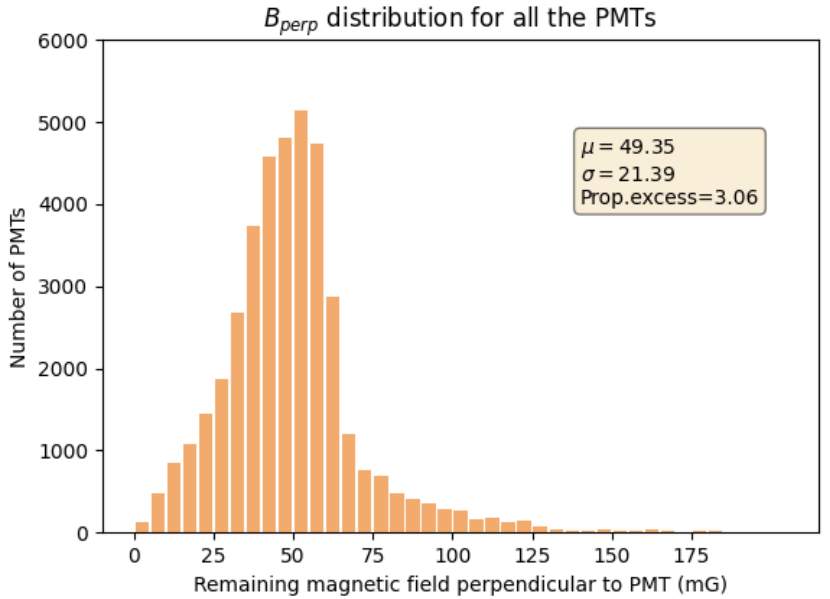


Calculation of ΔB_{perp} (mG)

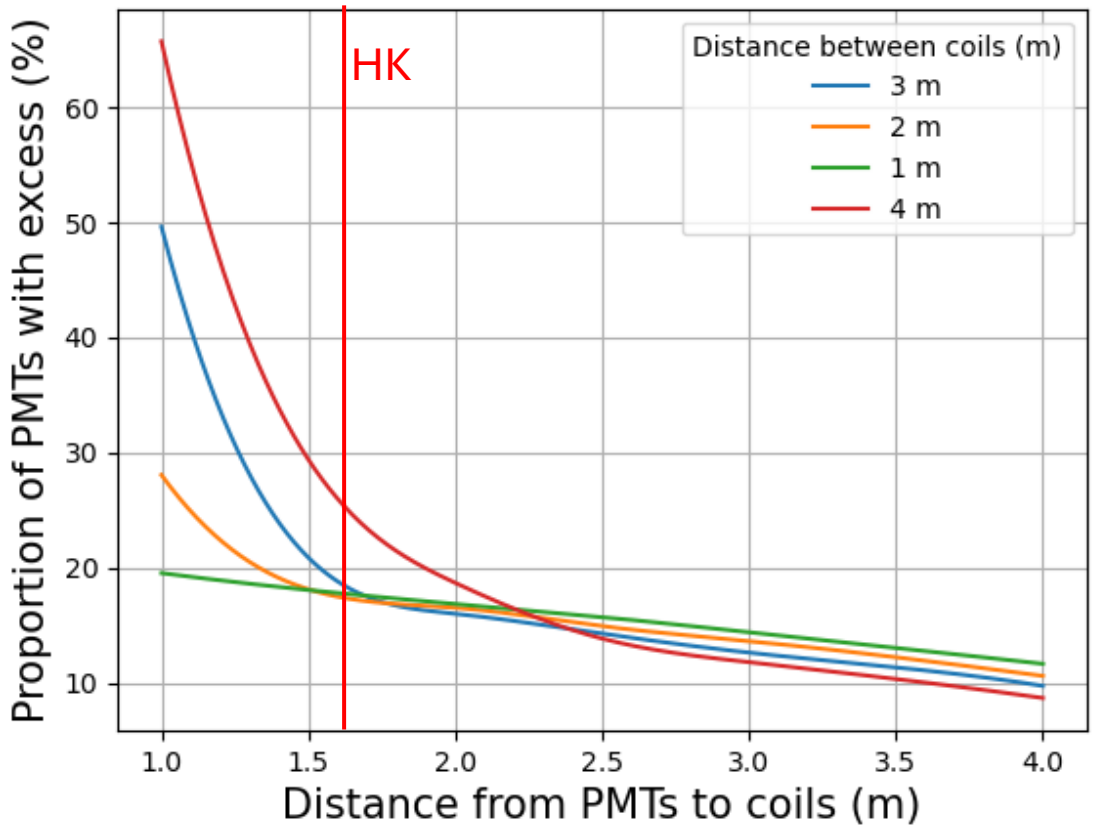
- In the barrel: $\Delta B_{perp} = \left[\left(B_x \sin\theta - B_y \cos\theta\right)^2 + B_z^2\right]^{1/2}$
- Top and bottom lids: $\Delta B_{perp} = \left(B_x^2 + B_y^2\right)^{1/2}$

% PMTs with magnetic field excess





- The optimum spacing between coils varies depending on the distance between the PMTs and the coils.
- The larger the distance to the PMTs, the more efficient the geomagnetic field compensation is, and the larger the optimal distance between the coils.
- An optimal distance between coils is expected to be around 2 m
- By increasing the distance between coils and PMTs by just 40 cm, the optimum distance would be 3 m and the necessary installation cost would be significantly reduced.



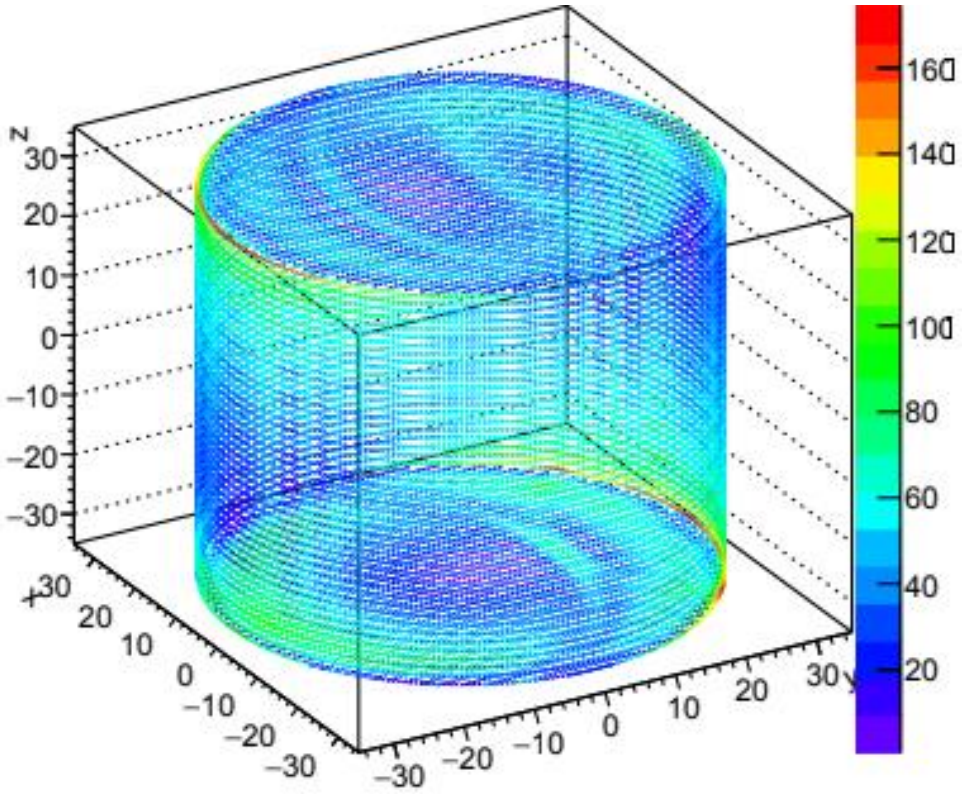
Distance from PMTs to coils in HK = 1.6 m

Optimization algorithm

1. Optimization of the intensity of current of all circular coils and all rectangular coils

2. Increasing the number of turns of the upper and lower circular coils until a minimum is reached for B_{perp}

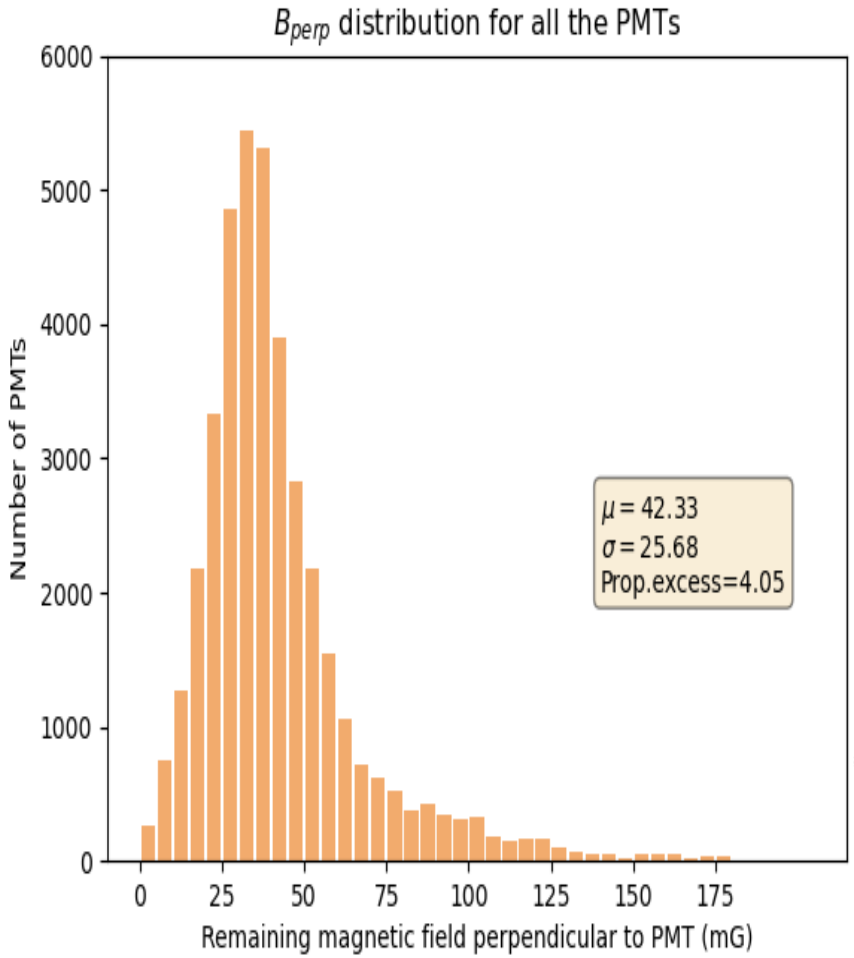
3. Addition of a circular coils at both top and bottom ends of smaller radius

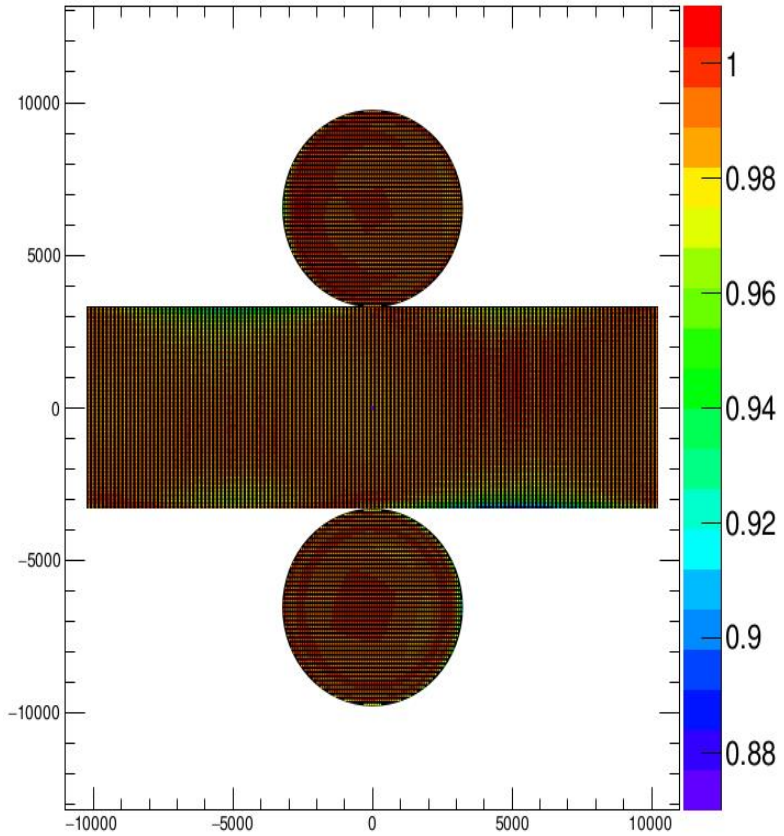


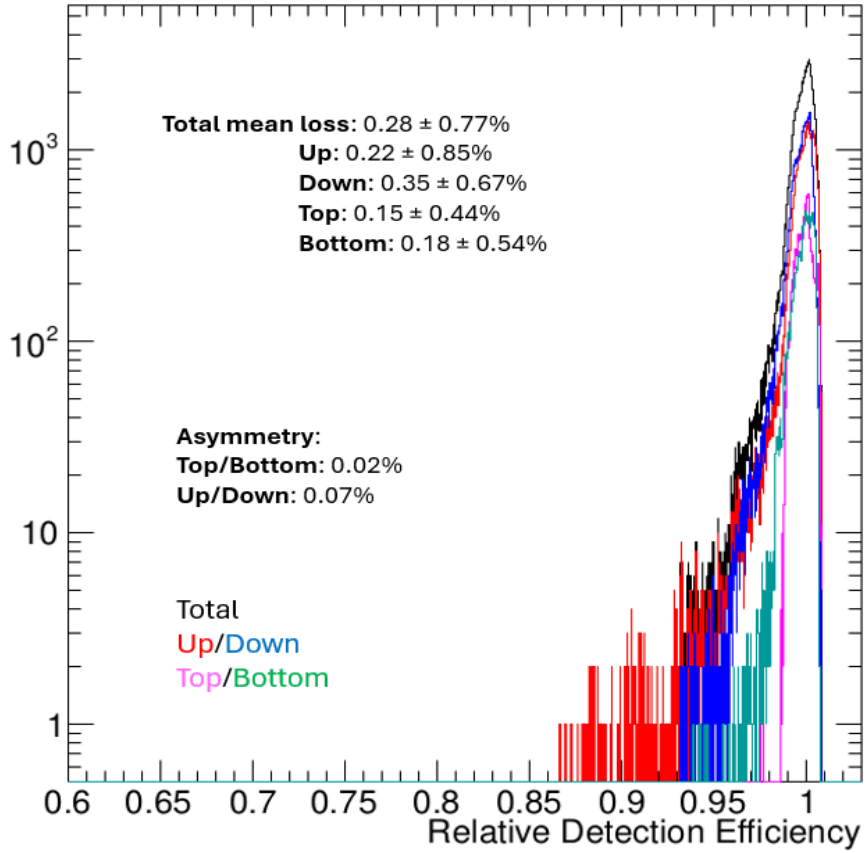
➢ Difficulty in compensating for the geomagnetic field at the top and bottom of walls

Configuration	Prop. PMTs with excess (%)	Average B_{perp} (mG)	Average loss of efficiency (%)	Cable length (km)
2 m v1	3.06	49.35 ± 21.39	0.33 ± 0.72	18.31
2 m v2	3.20	47.79 ± 21.50	0.32 ± 0.71	18.51
2 m v3	2.71	48.76 ± 22.18	0.34 ± 0.76	18.73
2 m+ elliptical	1.85	50.34 ± 19.90	0.33 ± 0.72	17.99
2.35 v1	3.88	43.85 ± 24.58	0.30 ± 0.75	17.35
2.35 v2	3.62	43.54 ± 23.70	0.29 ± 0.73	17.23
2.35 v3	3.89	43.44 ± 26.57	0.30 ± 0.81	17.46
2.4 v1	4.05	42.33 ± 25.68	0.28 ± 0.77	17.02
2.4 v2	3.38	43.55 ± 24.63	0.29 ± 0.76	17.22
2.4 v3	3.76	45.48 ± 25.95	0.32 ± 0.80	17.44
1 m	4.65	49.59 ± 27.17	0.38 ± 0.81	33.33
2 m – 1m	5.74	57.24 ± 23.10	0.44 ± 0.81	25.16
1 m – 2 m	4.17	44.25 ± 25.55	0.31 ± 0.78	26.27
3 m	5.90	49.03 ± 30.90	0.42 ± 1.01	12.09
4 m	9.78	55.10 ± 34.03	0.51 ± 0.98	9.86

Design chosen: 2.4 m (v1) configuration



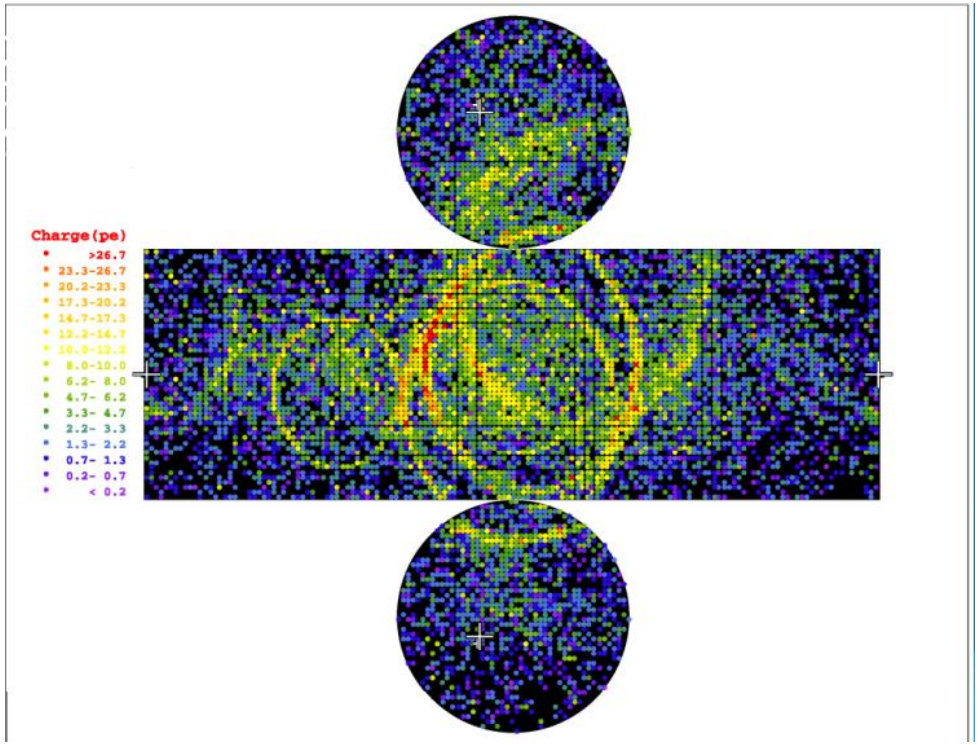




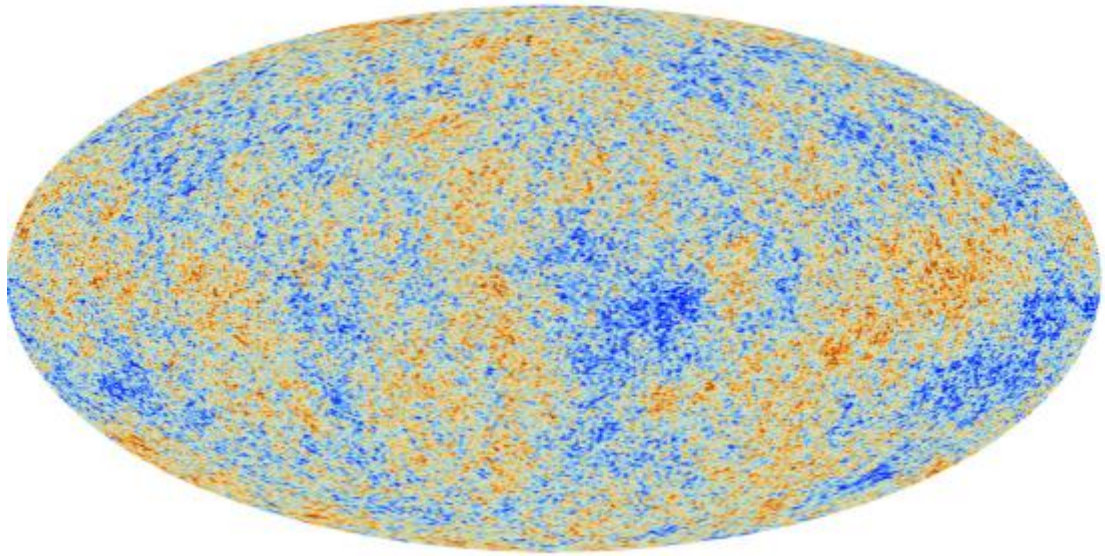
➢ This configuration provides the lowest value of average detection efficiency loss

What comes next...

Software development for the analysis of neutrino detection data at HK



Cosmological analysis of CMB and development of neural networks to recover its properties



Thank you for your attention