Geomagnetic Field Compensation

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January 14, 2013 @ The 2nd open Hyper-K meeting

Introduction

- The PMTs (or HPDs) used in Hyper-K have large drift distances from the photocathode to the first multiplication stage.
 - Sensitive to magnetic fields on the order of 1 Gauss or less.
- The Earth's magnetic field can cause significant loss of efficiency.
- We have to lower the magnetic field inside the PMTs.

PMT response in a magnetic field



A. Suzuki et al., NIM A329 (1993) 299-313

Geomagnetic field at a HK candidate site

Can access the database for the Geomagnetic survey by GSI (Geospatial Information Authority of Japan, 国土地理院)

http://vldb.gsi.go.jp/sokuchi/geomag/menu_04/index-e.html

[Input value]							
Latitude	36°21'9"						
Longitude	137°18'50"						

[Result]

Declination	7 ° 35 ' (W+)	
Inclination	50°23'	
Total force	47520 nT 475	m
Horizontal intensity	30305 nT <mark>303</mark>	m¢
Vertical intensity	36602 nT <mark>366</mark>	m



W-

In the current design, the tank direction is along West-East. (may change by the rock condition)

Magnetic compensation coils

- Magnetic compensation by sets of direct-current powered coils.
- Used in the Super-K detector



 \rightarrow Consider the coil configuration for Hyper-K

Disclaimer

- The detailed designing of the magnetic coils has not been done until recently.
 - No description on the magnetic compensation in the HK LOI.
- As a first step :
 - Assume that the horizontal component of the Geomagnetic field is perpendicular to the tank axis.



- Consider the compensation at the inner detector PMT positions.
 - Compensation at the outer detector PMT positions → next step (The OD-PMTs are smaller and must be less affected by magnetic fields.)

Developed a tool to calculate the magnetic field

- C++ code
- Calculate the magnetic field at each of the 99,000
 ID-PMT positions
 - Contributions from each ~10 cm piece of a coil are calculated using the Biot-Savart law and are integrated over the whole coils.





Configuration after an initial optimization



Results



PMT positions w/ >100mG magnetic fields

 \perp to the PMT facing direction

Need more optimizations

Coil cables and heat load

- Each coil \rightarrow 4-turn coils
- Use 4-conductor cables
- Total length of conductor for a typical vertical coil (red line) = ~ 2500 m
- O If we use cables with 38mm^2 conductors (cable diameter = 28 mm), the supply voltage for this coil is V = RI = 0.491 Ω/km x 2.5 km x 37.5 A = 46 V
- Total heat load for one tank is ~50kW (rough estimation).
 - should increase if the tank is not perpendicular to the geomagnetic field.

Next steps

- More optimization to reduce magnetic fields further
- Configurations in case that the HK detector tank direction is not perpendicular to the geomagnetic field

- Check magnetic fields at the outer detector PMT positions
- Studies on passive magnetic shielding options (?)
 - Such as mu-metal wire cages for PMTs, etc.

Summary

- I have started a detailed designing of the magnetic compensation coils.
- I got a configuration which satisfies the remaining magnetic fields perpendicular to the PMT facing direction are below 100mG at >95% of the ID-PMT positions.
 - Need to reduce magnetic fields further.
- Your new ideas/studies are welcome.

Supplement

■4心

導 体					最 大		最 小	斯林氏目	許容電流	
公称断面積 (mm ²)	素線数/素線径 (mm)または形状	外 径 (mm)	絶稼体厚さ (mm)	ンース厚さ (mm)	仕上り外径 (約mm)	導体抵抗 (20℃) (Ω /km)	試験電圧 (V)	絶縁抵抗(20℃) (M Ω -km)	概昇筫重 (kg/km)	周囲温度40℃ (1条)(A)
2.0	7/0.6	1.8	0.8	1.5	12.0	9.42	1,500	2,500	180	23
3.5	7/0.8	2.4	0.8	1.5	13.5	5.30	1,500	2,500	260	33
5.5	7/1.0	3.0	1.0	1.5	16.0	3.40	1,500	2,500	370	44
8	7/1.2	3.6	1.0	1.5	17.0	2.36	1,500	2,000	485	54
8	一円形圧縮	3.4	1.0	1.5	16.5	2.34	1,500	2,000	460	54
14		4.4	1.0	1.5	19.0	1.34	2,000	1,500	745	76
22		5.5	1.2	1.6	23	0.849	2,000	1,500	1,120	100
38		7.3	1.2	1.8	28	0.491	2,500	1,500	1,800	140
60		9.3	1.5	2.0	35	0.311	2,500	1,500	2,800	190
100		12.0	2.0	2.4	44	0.187	2,500	1,500	4,650	260
150		14.7	2.0	2.6	51	0.124	3,000	1,000	6,760	340
200		17.0	2.5	2.9	60	0.0933	3,000	1,500	9,060	410
250		19.0	2.5	3.1	65	0.0754	3,000	1,000	11,300	470
325		21.7	2.5	3.4	72	0.0579	3,000	900	14,400	555

※4心の許容電流は、4心のうち1心を中性線又は接地線として使用する場合に適用する。