

**The Uniformity measurement
of the Hamamatsu 10 inch
PMT for the IceCube
Experiment**

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Our Work

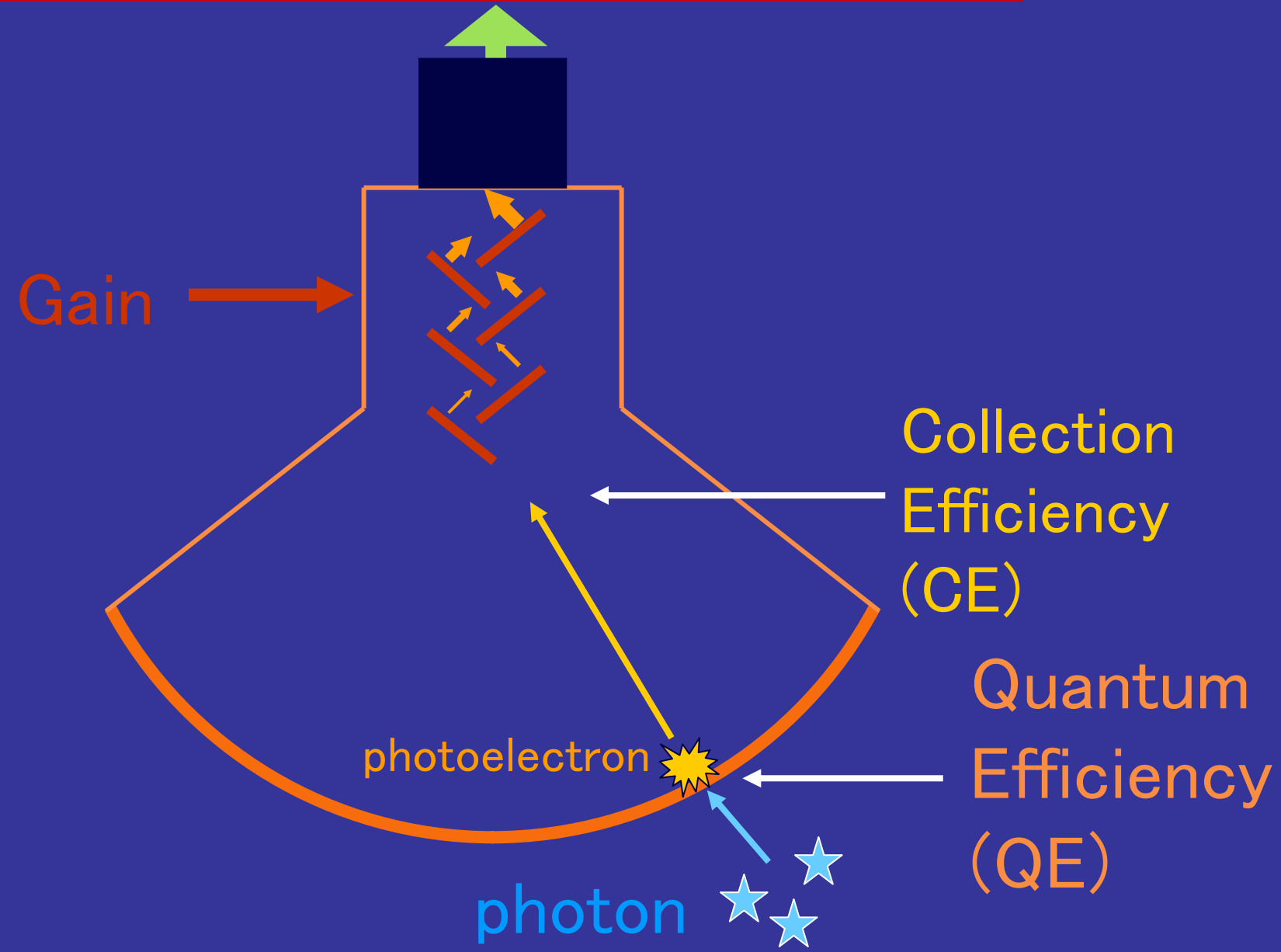
Chiba university group is working for both software and hardware part.

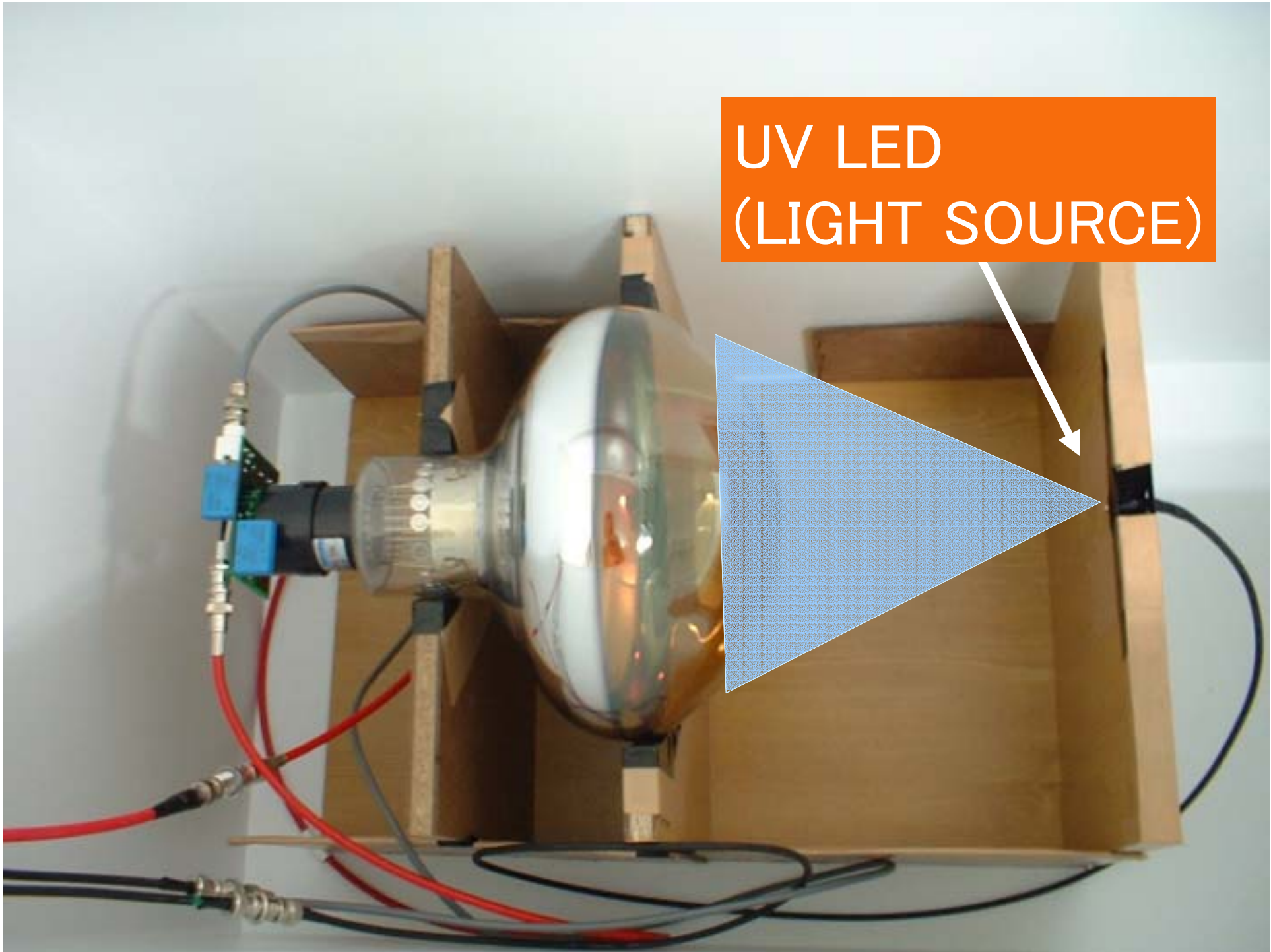
- **Software** – develop the Java-based propagator of high energy cosmic neutrino in the earth and the ice.
- **Hardware** – uniformity measurement of the PMT, gain measurement @-32°C, absolute QE, etc.

PMT Measurements

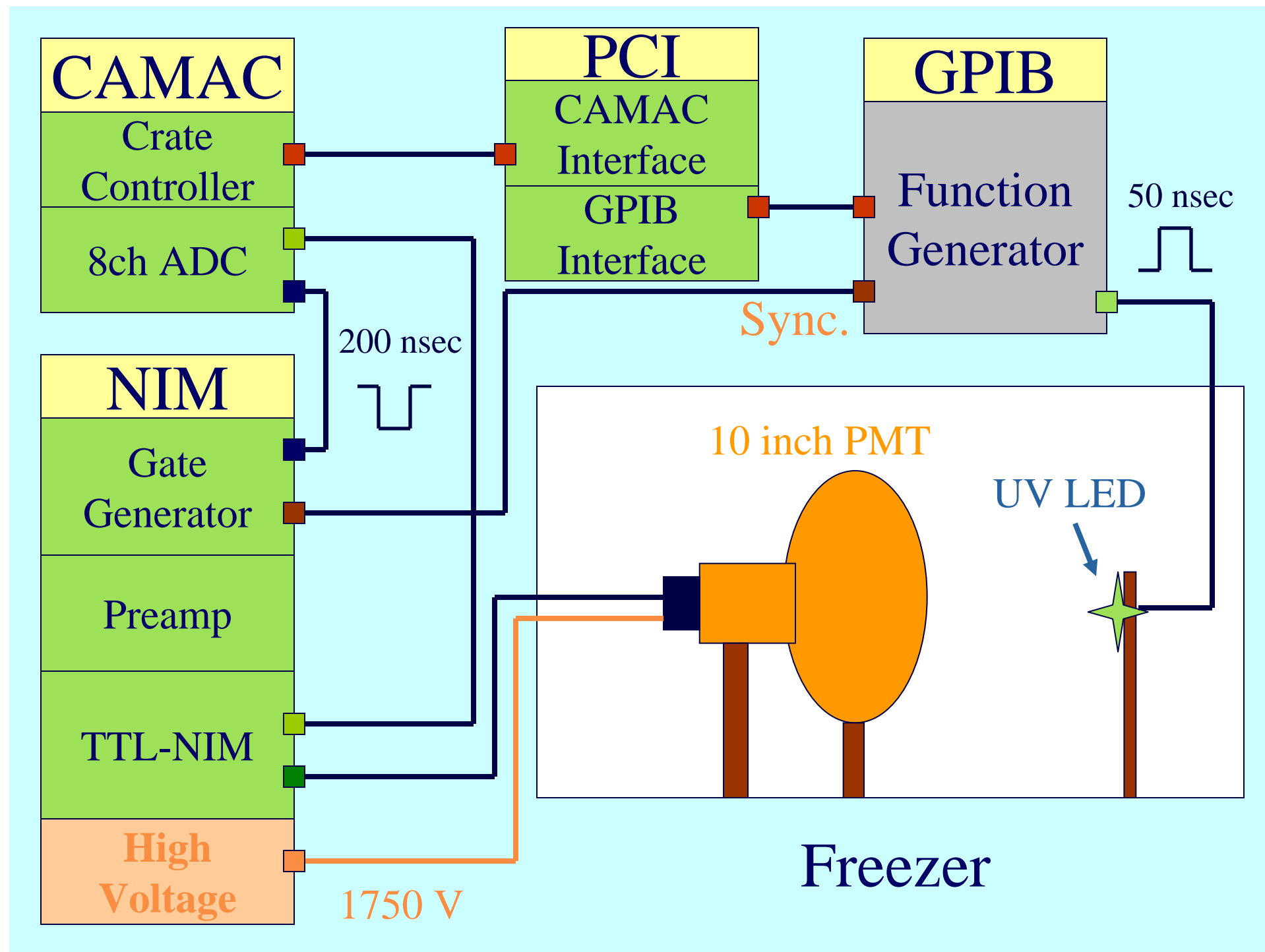


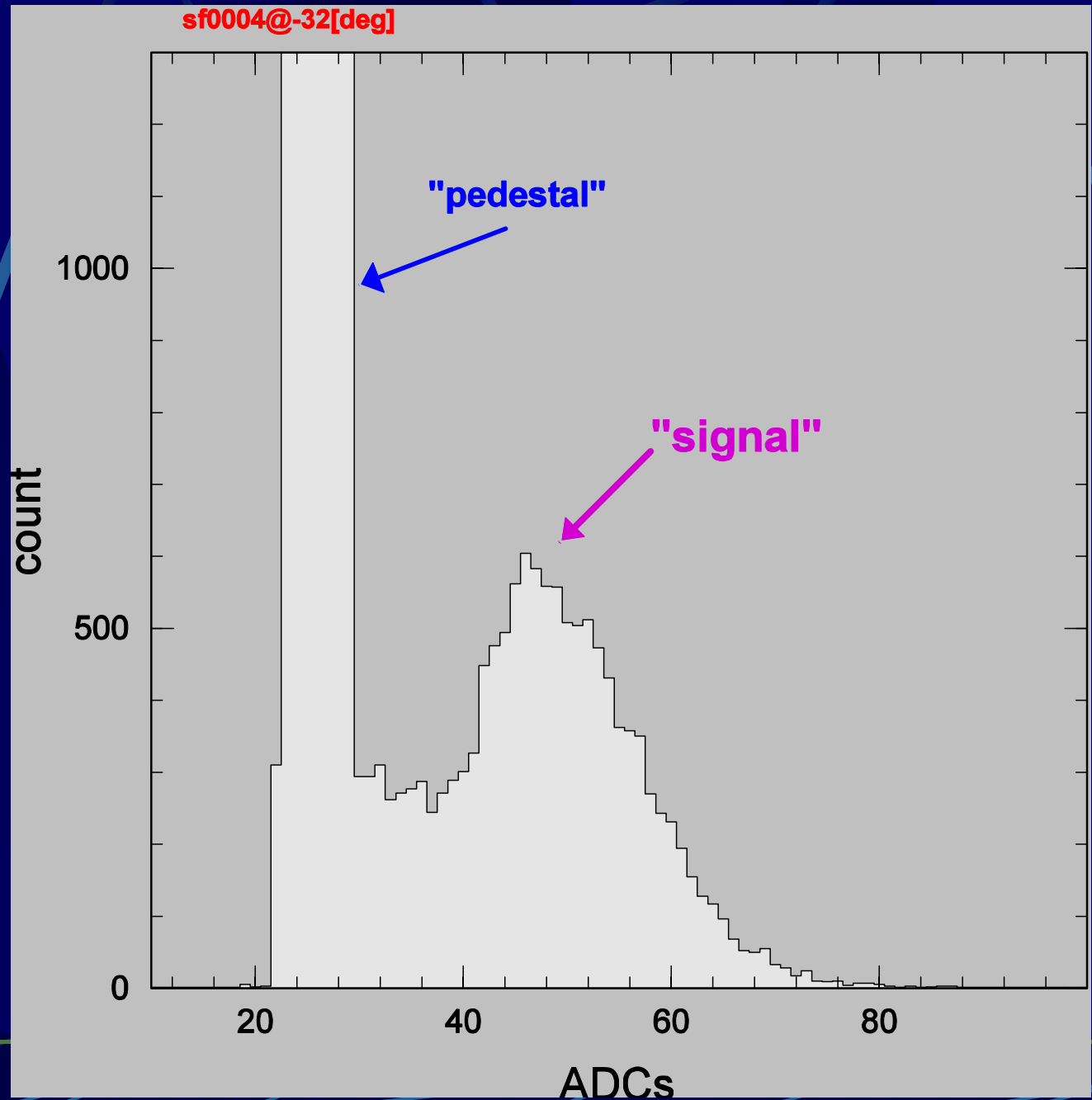
$$\text{Signal} = \text{QE} \otimes \text{CE} \otimes \text{Gain}$$





UV LED
(LIGHT SOURCE)





The Result of the Gain Measurement @ -32°C

Model turn	2000V	Error	1900V	Error	1800V	Error	1700V	Error	1600V	Error	1500V	Error
SF0001	4.05E+07	3.03E+06	3.03E+07	2.26E+06								
SF0004	5.05E+07	3.78E+06										
SF0010	1.21E+08	9.01E+06	8.25E+07	6.17E+06	5.80E+07	4.34E+06	4.22E+07	3.16E+06	2.00E+07	1.49E+06		
SF0016	1.24E+08	9.28E+06	8.62E+07	6.44E+06	5.92E+07	4.43E+06	4.24E+07	3.17E+06	2.11E+07	1.58E+06		
SF0023	3.83E+07	3.85E+05	2.90E+07	2.35E+05	1.71E+07	1.08E+05	1.15E+07	1.76E+05				
SF0030	4.58E+07	3.42E+06	3.21E+07	2.40E+06								
SF0037	7.56E+07	5.65E+06	5.46E+07	4.08E+06	3.97E+07	2.97E+06	2.67E+07	2.00E+06	1.32E+07	9.85E+05		
SF0043	1.11E+08	8.28E+06	7.77E+07	5.81E+06	5.53E+07	4.13E+06	3.88E+07	2.90E+06	1.98E+07	1.48E+06		
SF0050	3.79E+08	1.55E+06	2.55E+08	1.11E+06	1.69E+08	7.70E+05	1.09E+08	5.22E+05	6.78E+07	3.87E+05	4.64E+07	6.79E+06
SF0056	1.91E+08	1.43E+07	1.25E+08	9.34E+06	8.07E+07	6.04E+06	5.17E+07	3.87E+06				
SF0067	2.63E+08	1.97E+07	1.81E+08	1.36E+07	1.20E+08	8.98E+06	7.85E+07	5.87E+06	5.16E+07	3.86E+06	3.45E+07	2.61E+06
SF0070	2.14E+08	1.60E+07	1.46E+08	1.09E+07	1.02E+08	7.66E+06	6.67E+07	4.98E+06	4.64E+07	3.47E+06	2.82E+07	2.18E+06
SF0080	1.58E+08	1.18E+07	1.07E+08	7.99E+06	7.24E+07	5.41E+06	4.74E+07	3.54E+06	3.22E+07	2.41E+06	1.59E+07	1.54E+06
SF0086	2.91E+08	2.17E+07	1.93E+08	1.44E+07	1.27E+08	9.51E+06	8.16E+07	6.10E+06	5.27E+07	3.94E+06	3.28E+07	2.52E+06

See more results :

<http://www-ppl.s.chiba-u.jp/research/IceCube/pmt/screening/FY2003/index.html>

2D SCAN SYSTEM

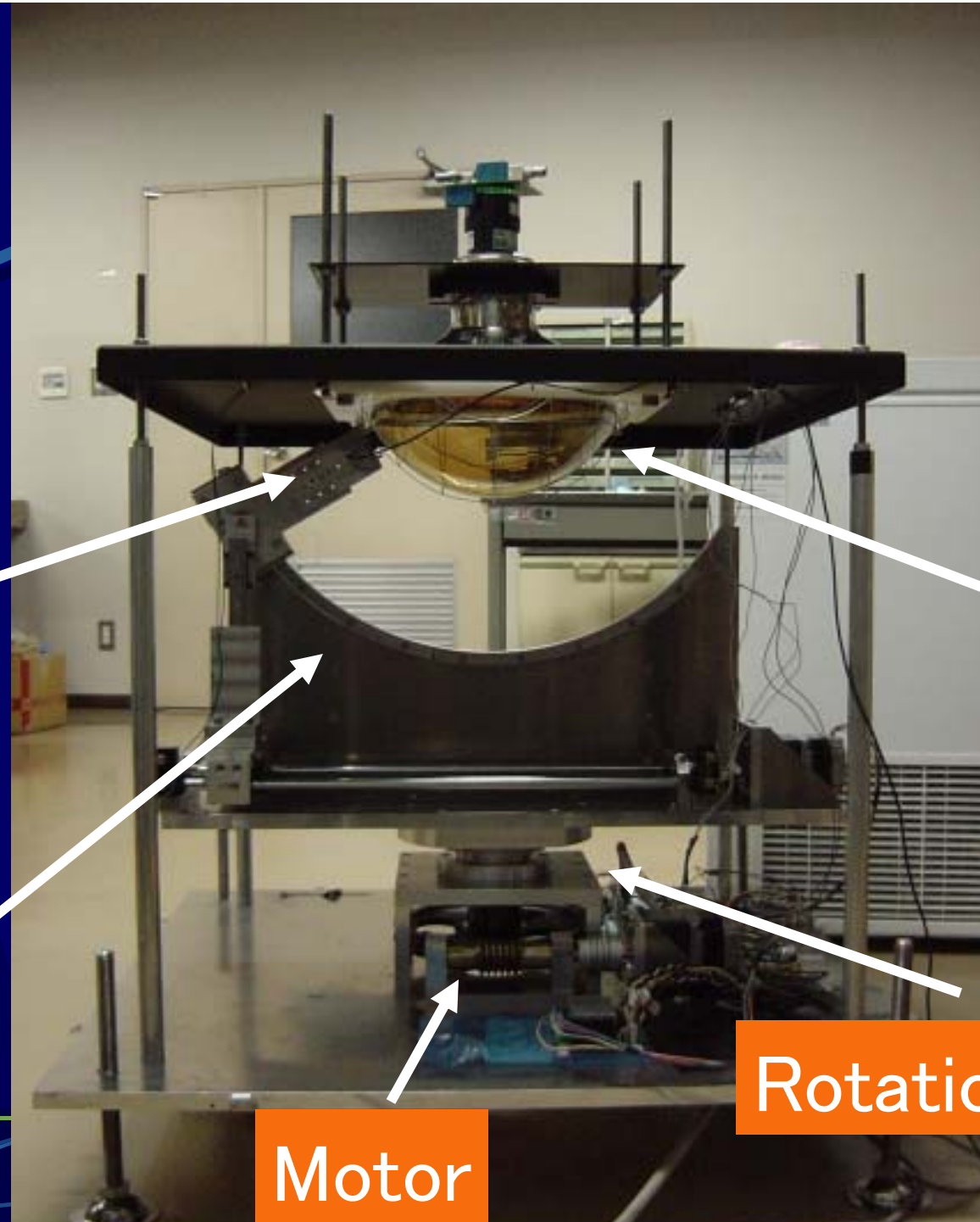
UV LED

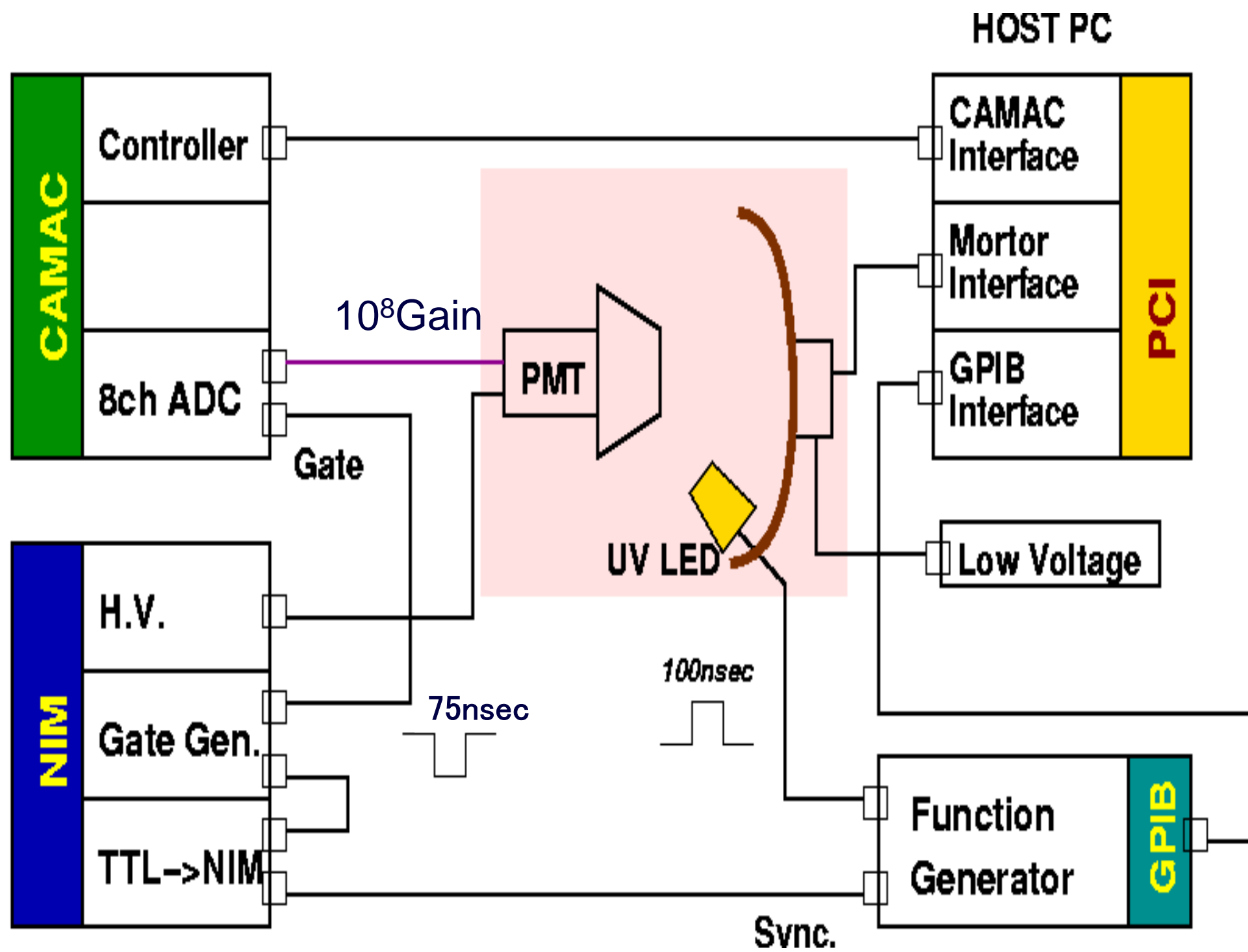
R-guide

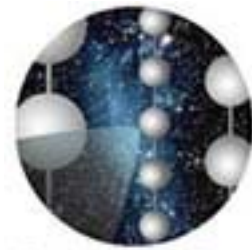
PMT

Rotation-bed

Motor







IceCube

The Measurement (of the first 14 PMTs)

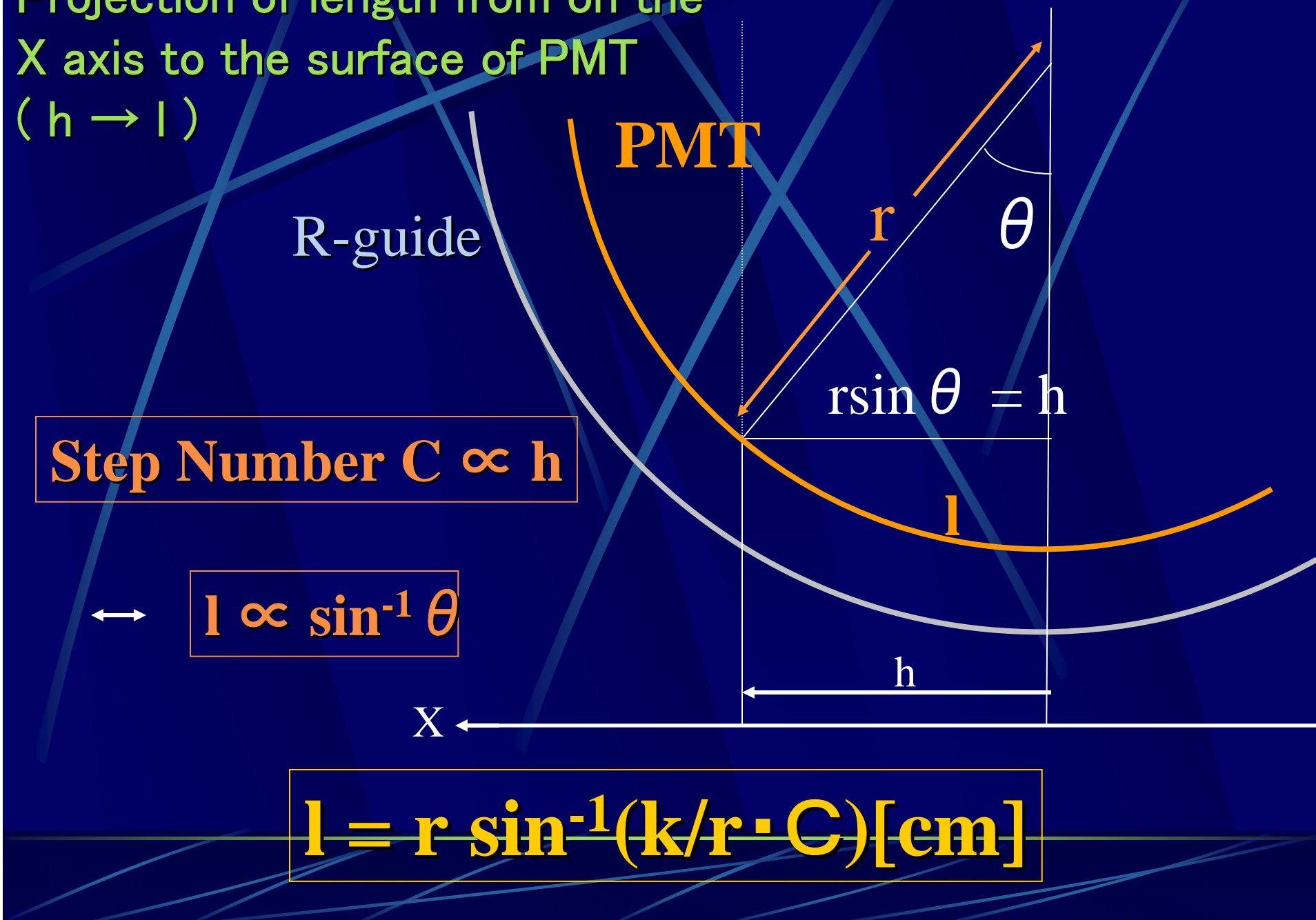
- **The Light Source – UV (380 nm) Nichiya LED (220 Ω driving)**
Collimated to less than 1mm diameter on the surface of PMT.
Flashing at the every 1.3mm point on the R-guide.
- **The Pulse is formed by the Agilent Func. Generator (100 nsec)**
- **30 photoelectrons/shots, corresponding the average of 3000 shots. [204 points/slice]**
- **PMT – Hamamatsu R7081 " –02 tube.**
- **HV – 2000 V, 5E7 ~ 5E8 Gain**
- **Dark current ~ 404 μ A @ 2000V (~363 μ A @ 1800V)**
- **Noise Rate ~100 Hz ~2.5kHz with 50 mV threshold @ room temperature.**

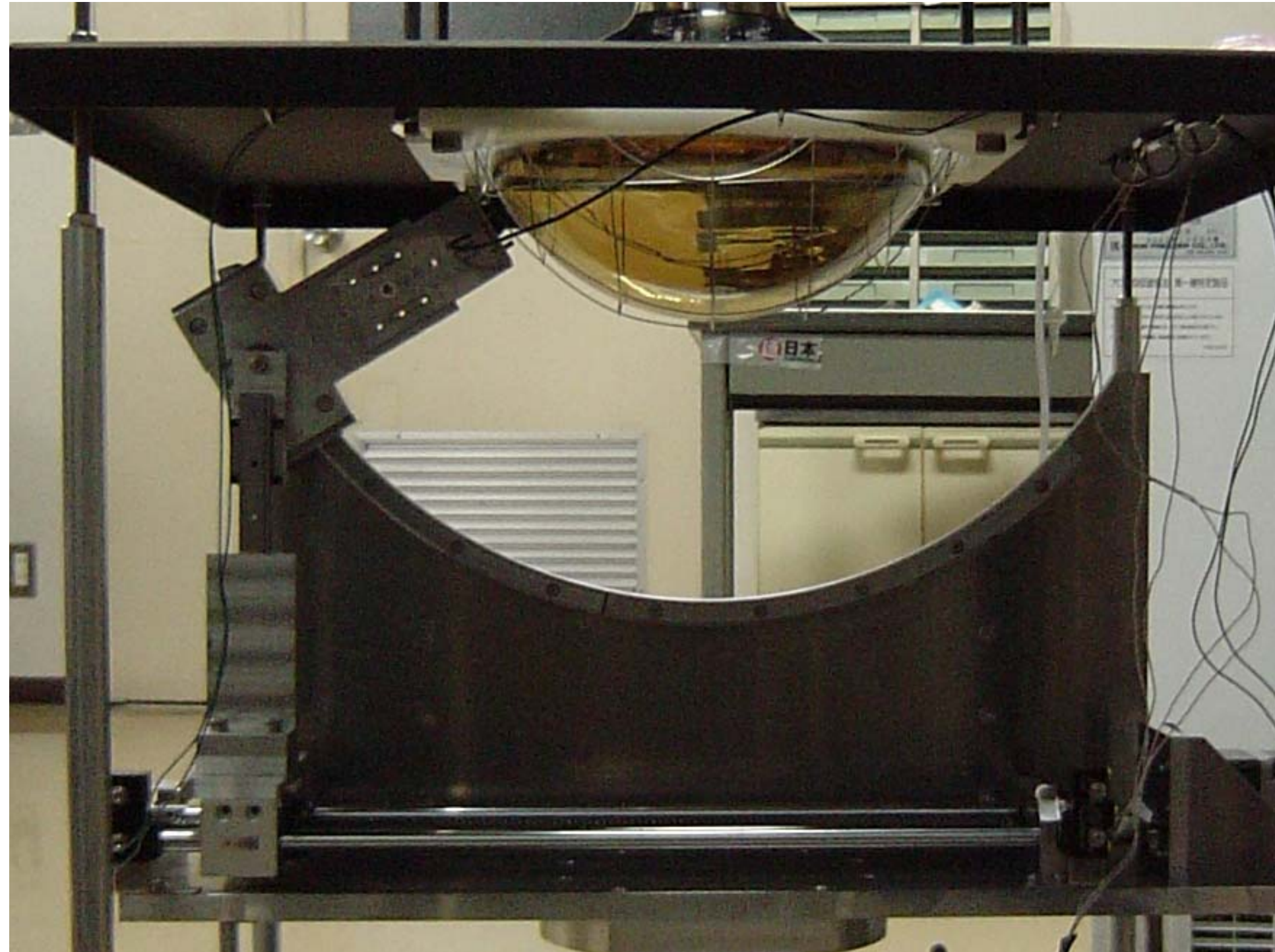
Table 2 : Possible Error

Possible Error	
▶Position of LED (stepping motor) : Δs	$\ll \pm 0.1 \text{ mm}$
▶Center Position : Δc	$< \pm 0.2 \text{ mm}$
▶PMT Alignment : ρ	$\leq \pm 5.0 \text{ mm}$
▶PMT Radius : Δr	$= \pm 5.0 \text{ mm}$
▶Translation from Step Number to Length on Cathode depends on the PMT Radius : Δl_{ρ}	$\approx \pm 2.53 \text{ mm}$
▶Translation from Step Number to Length on Cathode depends on the PMT Alignment : $\Delta l_{\Delta r}$	$\approx \pm 4.02 \text{ mm}$
▶Total Translation from Step Number to Length on Cathode : $\Delta l_{\text{total}} \approx \text{sum}(\Delta l_{\rho}^2 + \Delta l_{\Delta r}^2)$	$\approx \pm 4.8 \text{ mm}$

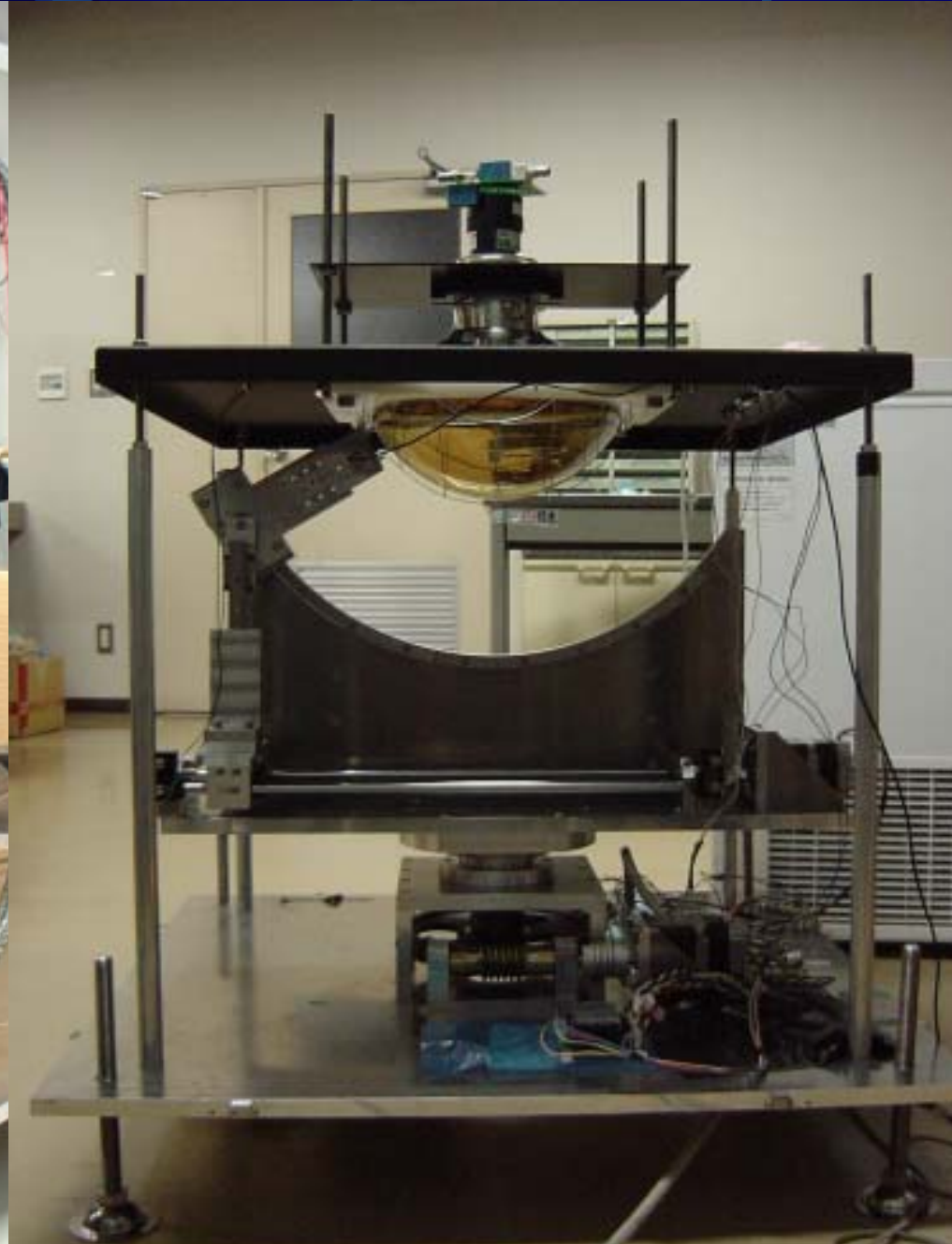
The total length on cathode : 26.6 cm

Projection of length from on the
X axis to the surface of PMT
($h \rightarrow l$)





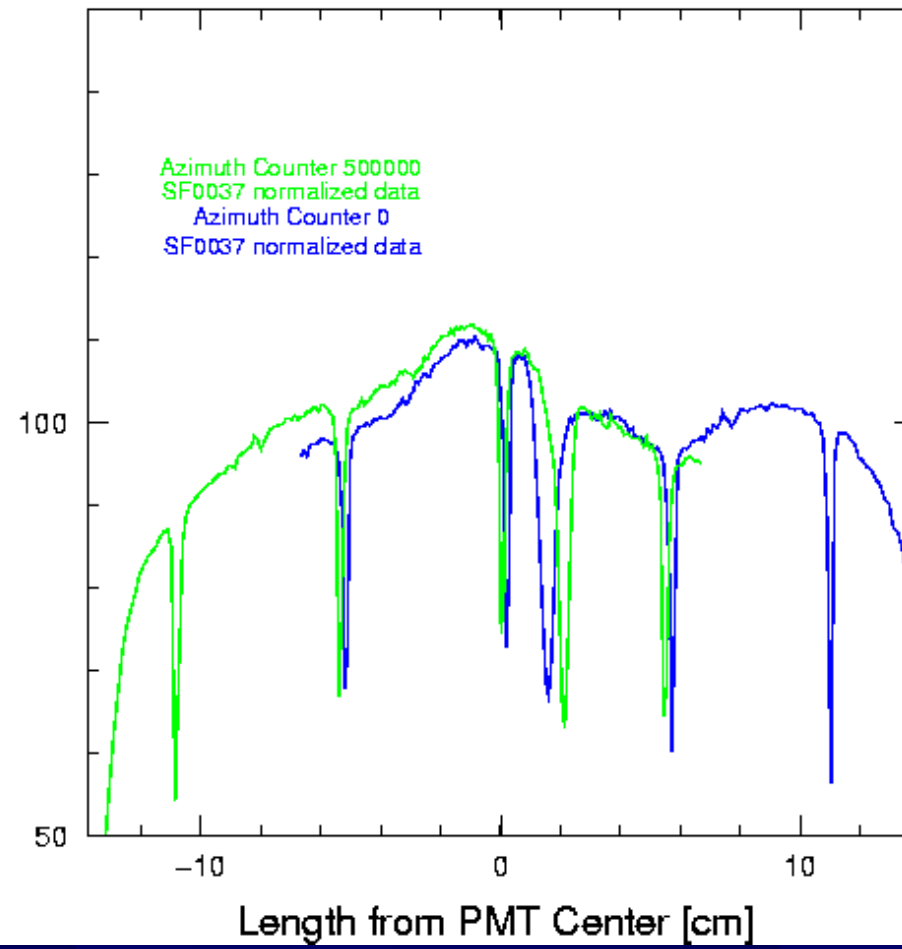
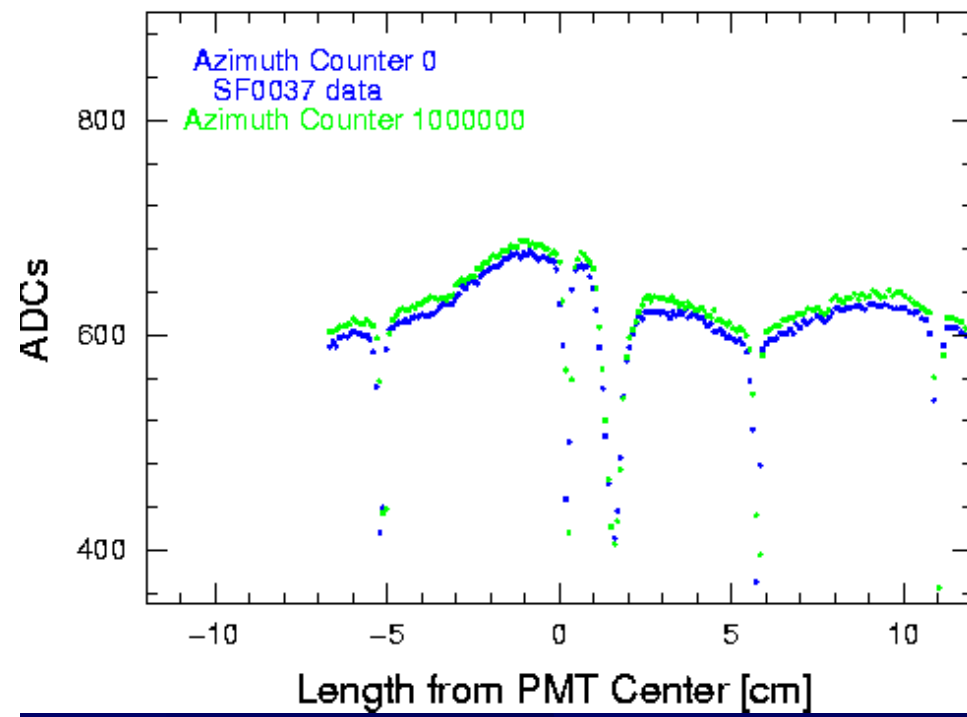
Improvements of measurement systems.



Results

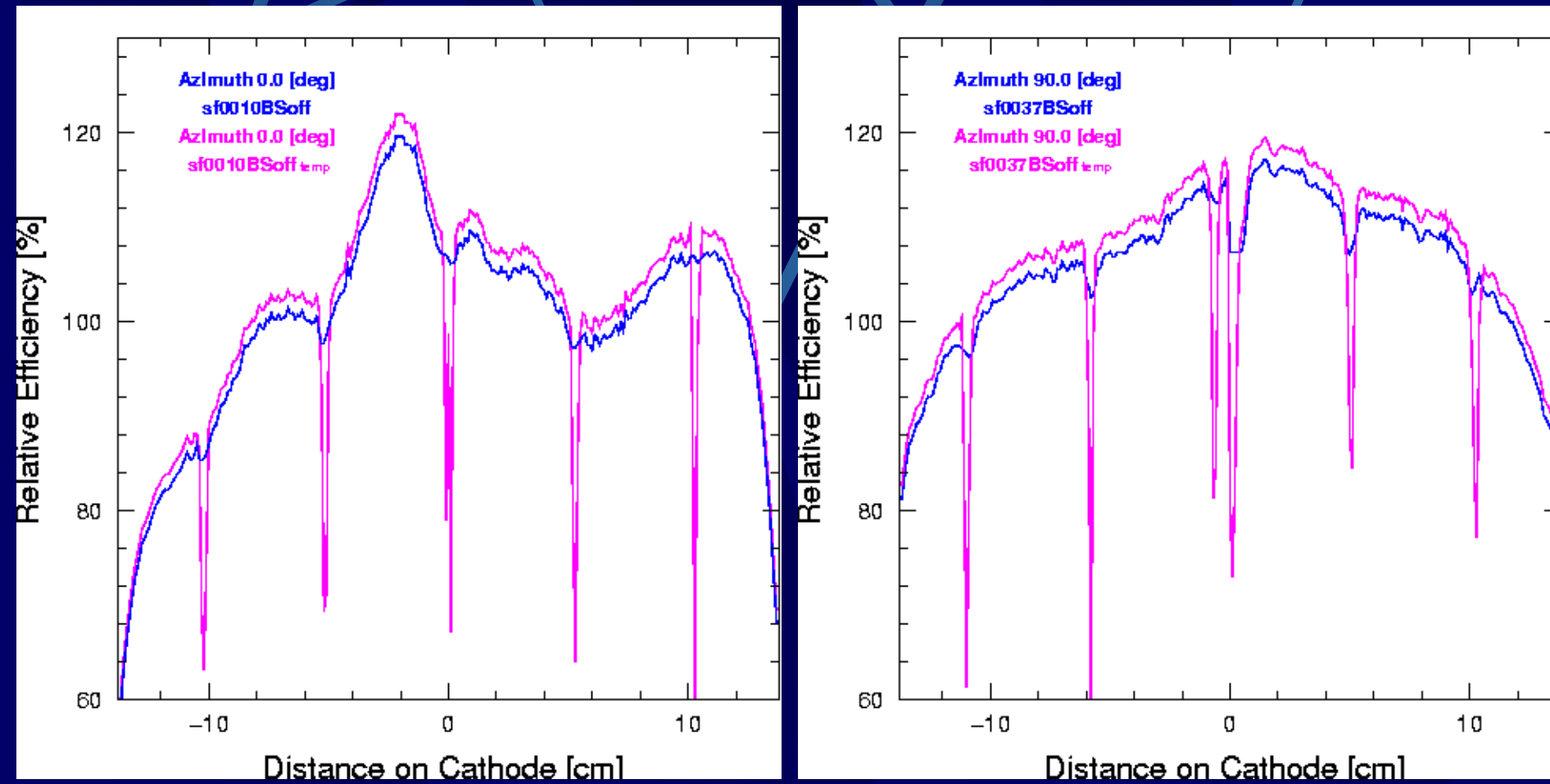
- Calibration for data analysis
- Effect of the geomagnetic field
- Gain dependence
- PMT by PMT difference

Calibration 1: The fluctuation of LED

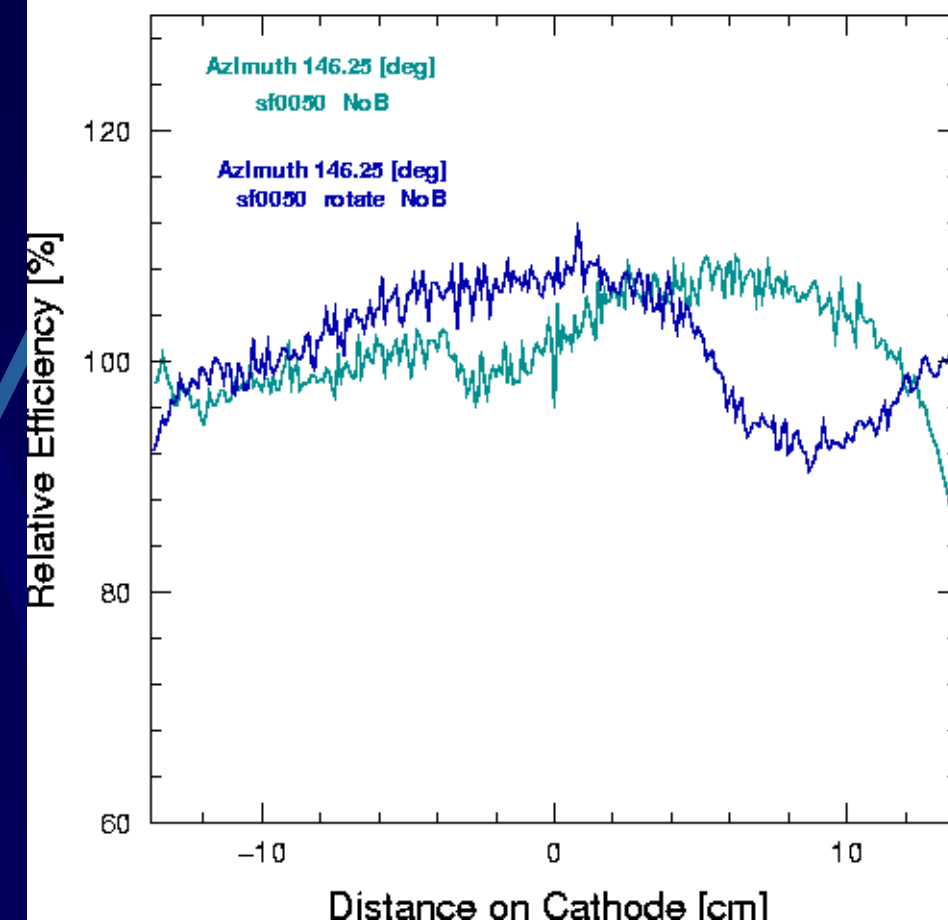
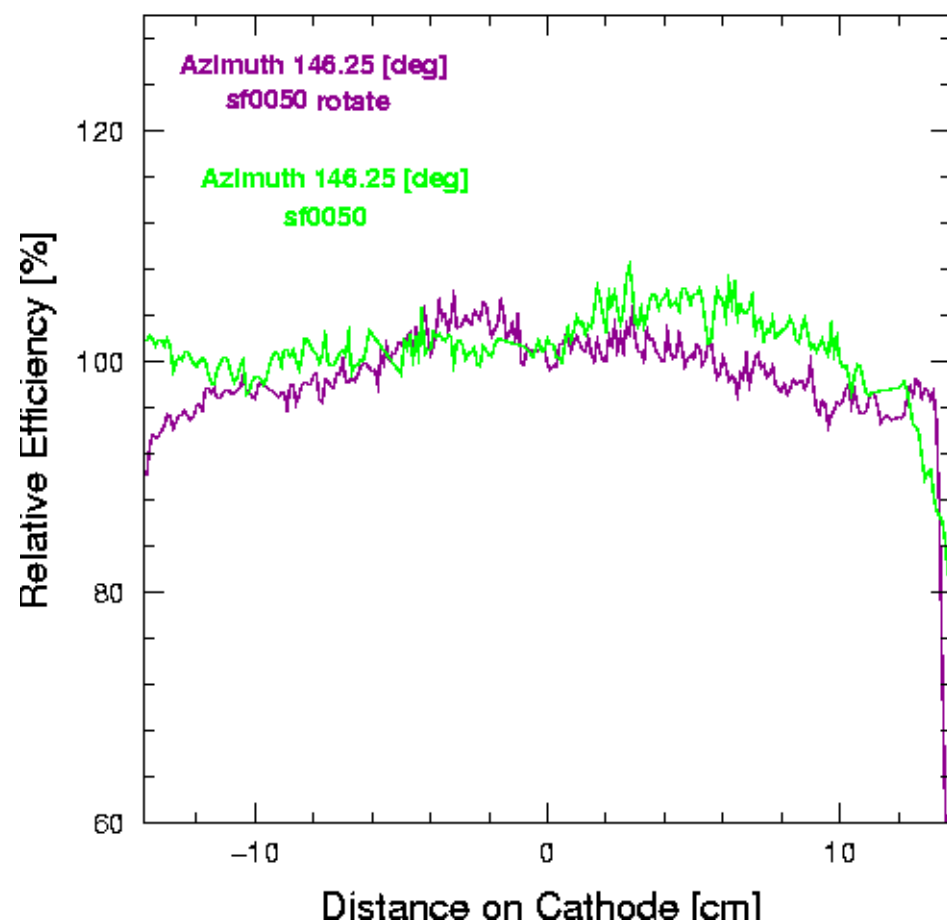


0 [deg] vs 360[deg] 0[deg] vs 180[deg]

Calibration 2 : Reduction of the shape of crack of Magnetic Shield.



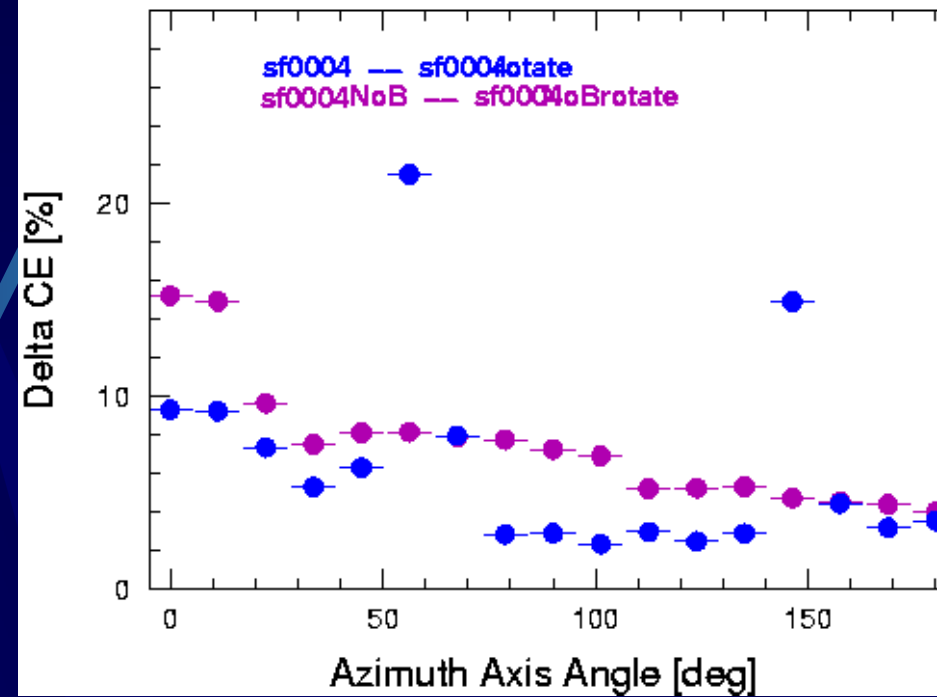
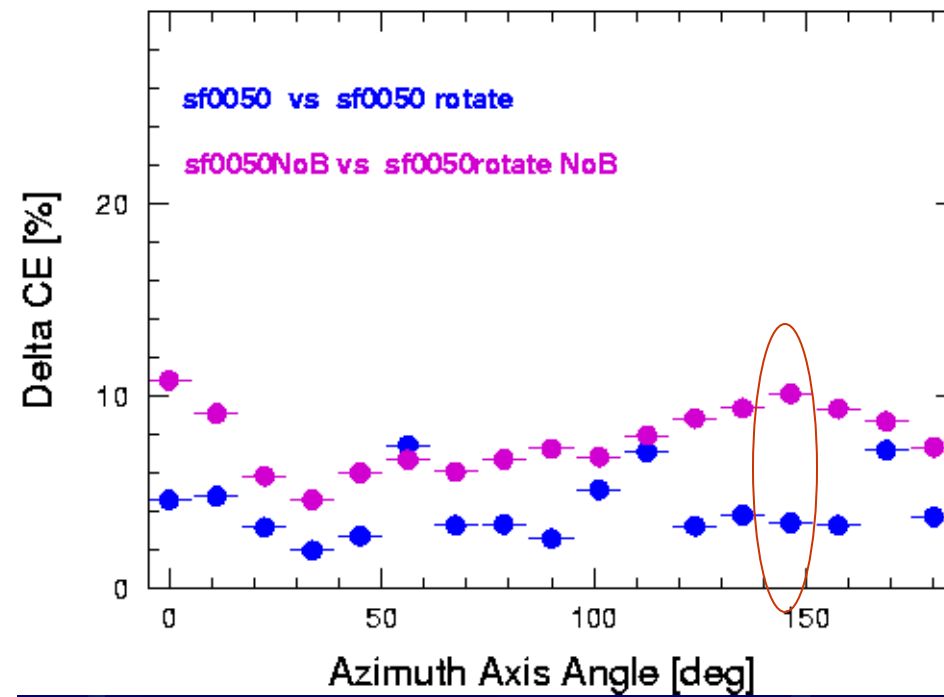
Result 1: The effect of the geomagnetic field



With B shield

Without B shield

Compare the average of the effect of B shield.



Blue : with B shield

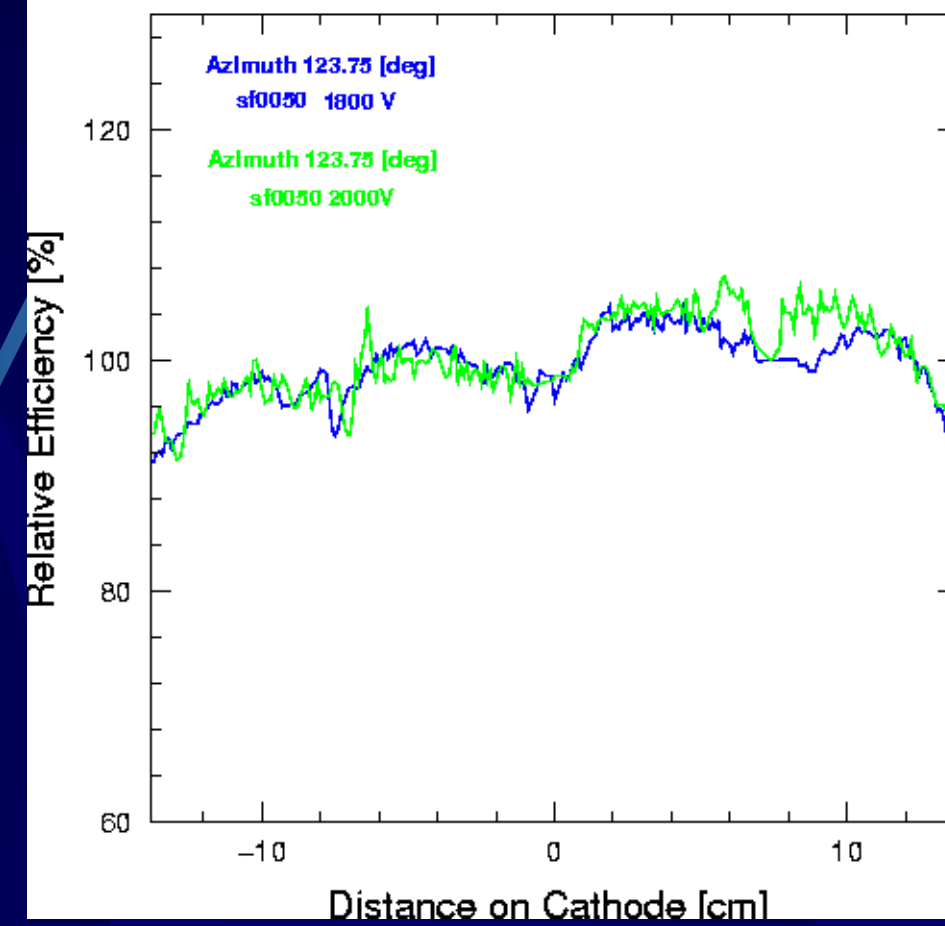
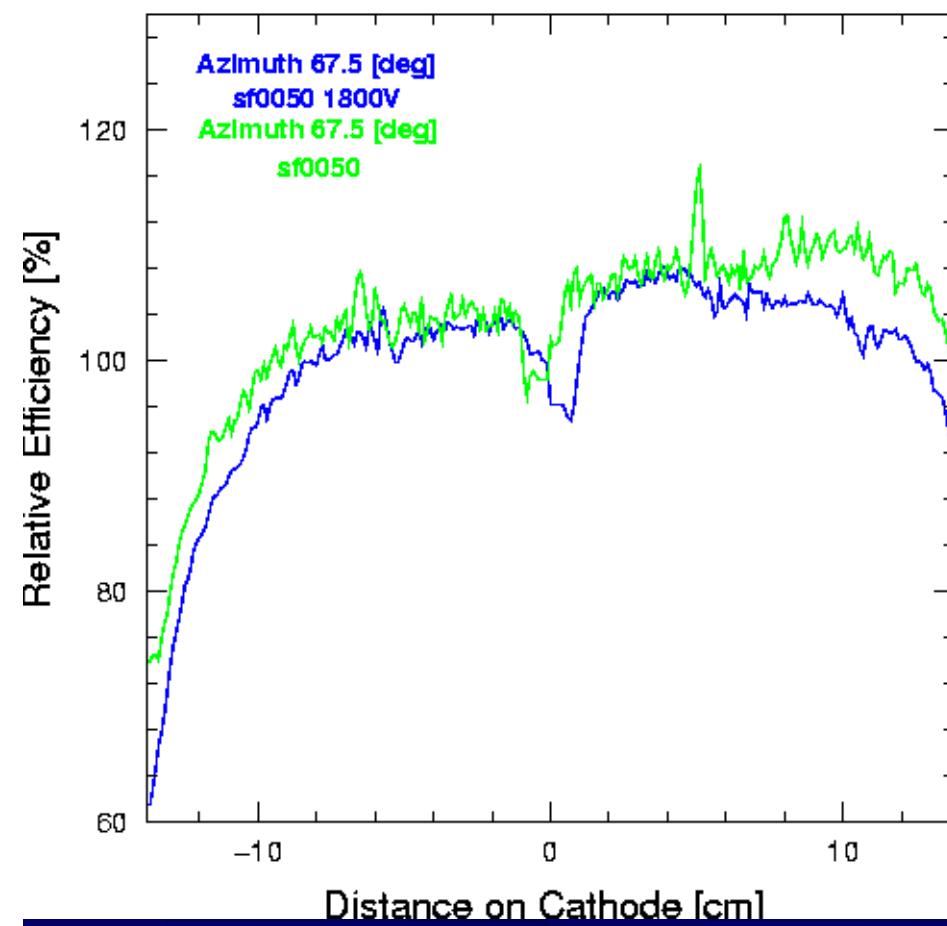
Magenta : without B shield

Summary 1 : the effect of geomagnetic field and B shield

- The effect of the geomagnetic field can be seen at ~10% level.
- B shield reduces the effect of geomagnetic field, ~5% still remains.

Result 2:

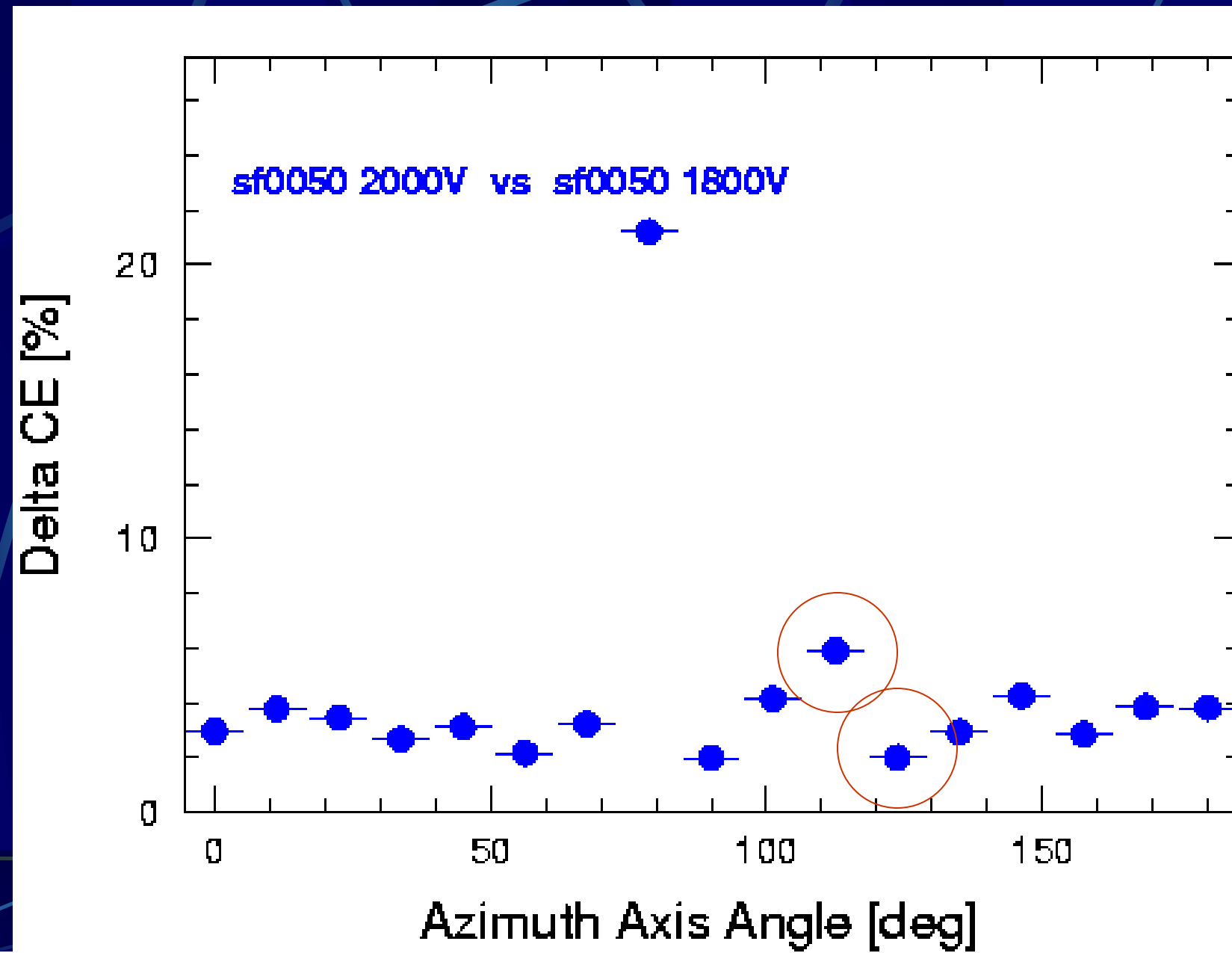
Gain dependence 2000V vs 1800V



sf0050 azimuth 67.5[deg]

sf0050 azimuth 123.75[deg]

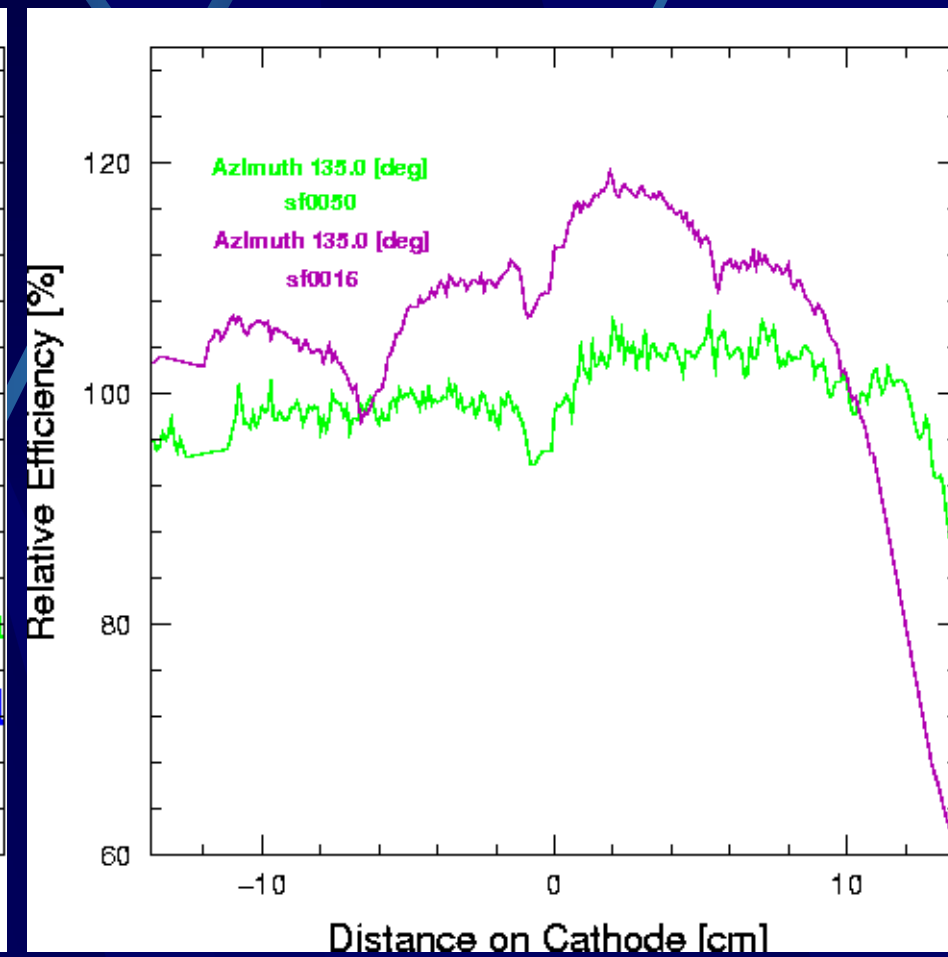
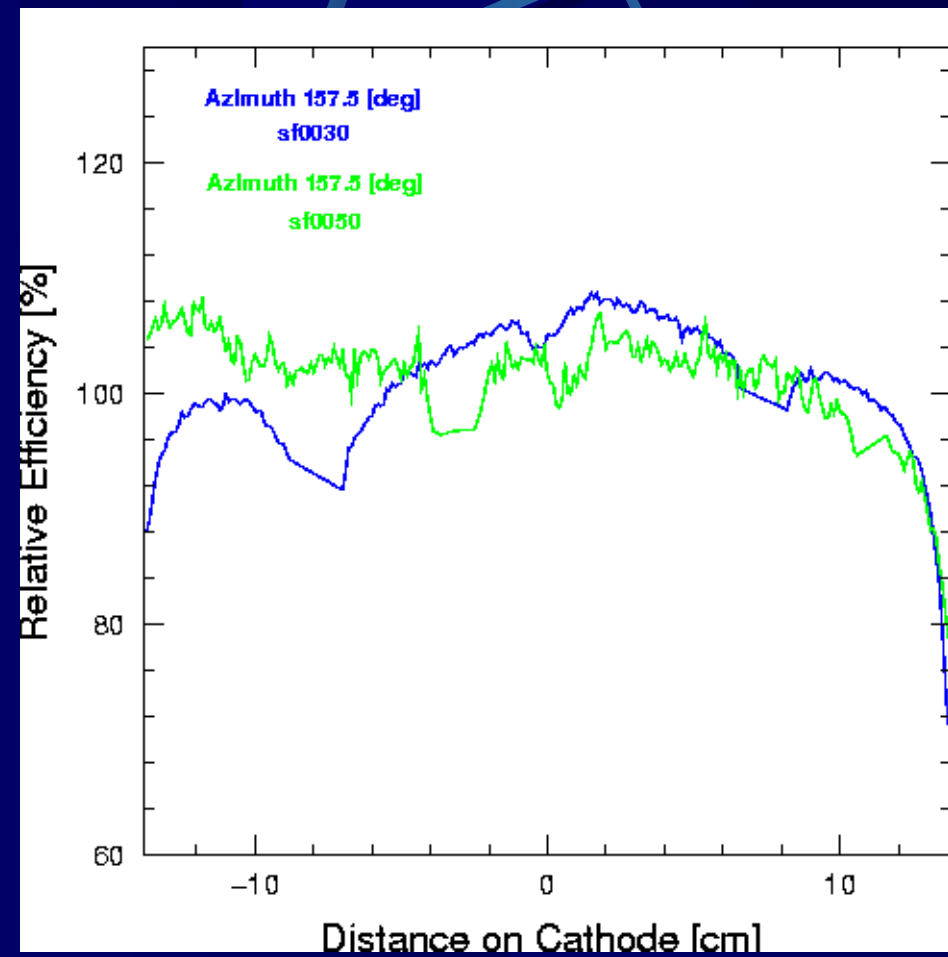
Averaged Difference 2000V vs 1800V



Summary 2: Gain dependence

- The gain difference of the efficiency is at **5%** level, which is not significant except around the edge.

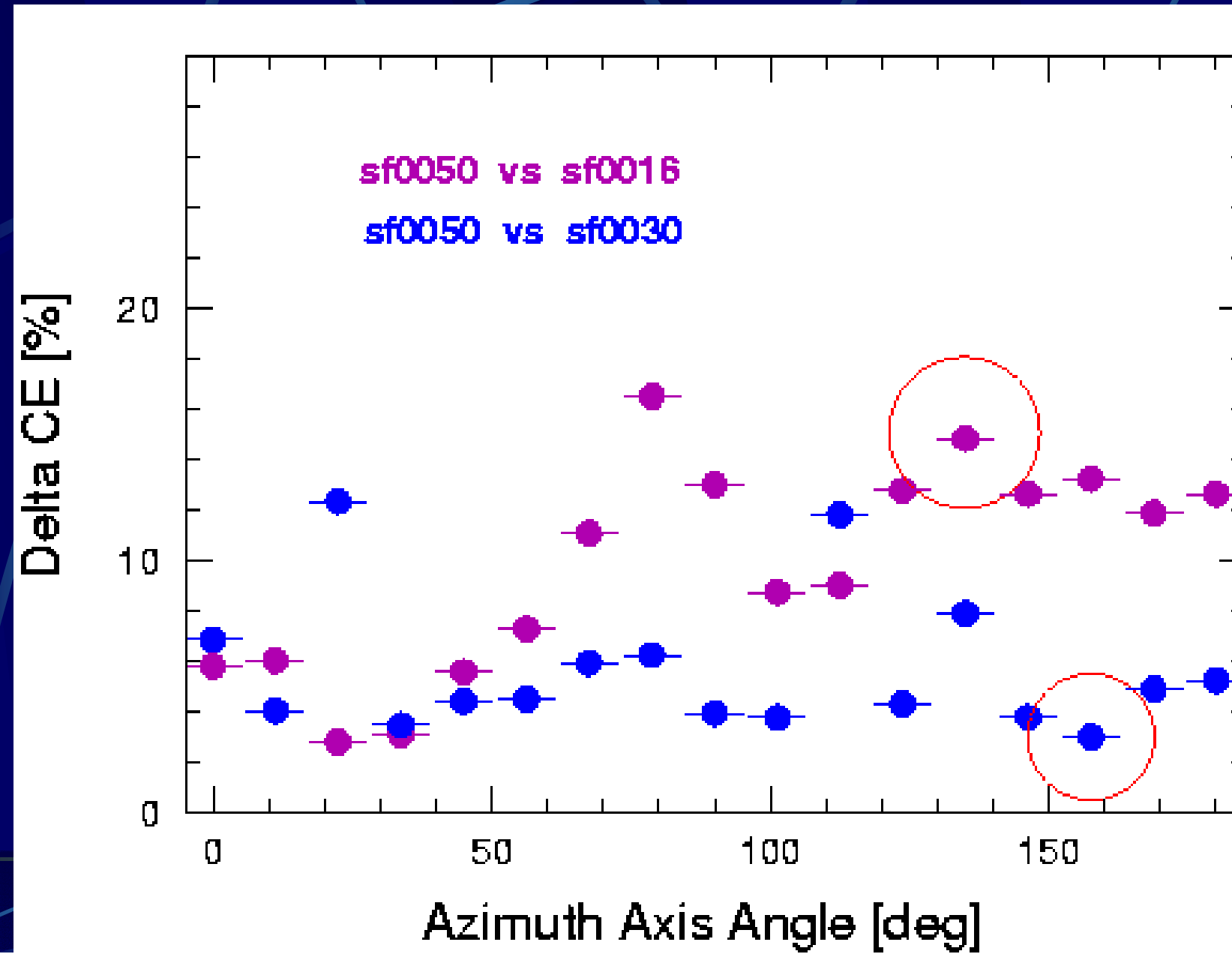
Result 3: PMT by PMT difference



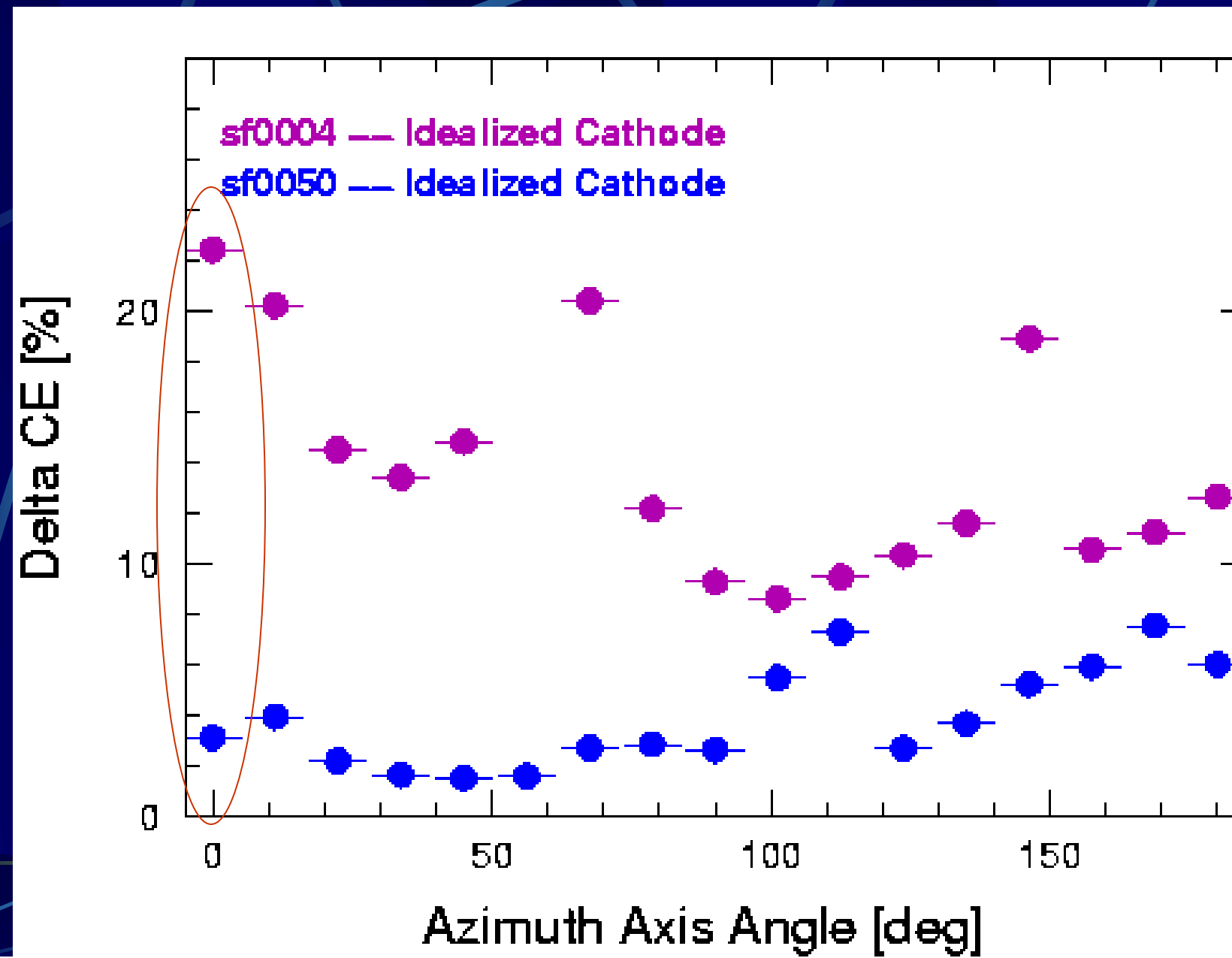
SF0030 vs SF0050

SF0016 vs SF0050

Averaged Difference sf0050 vs sf0030 and sf0050 vs sf0016



Averaged Difference sf0004 vs flat and sf0050 vs flat

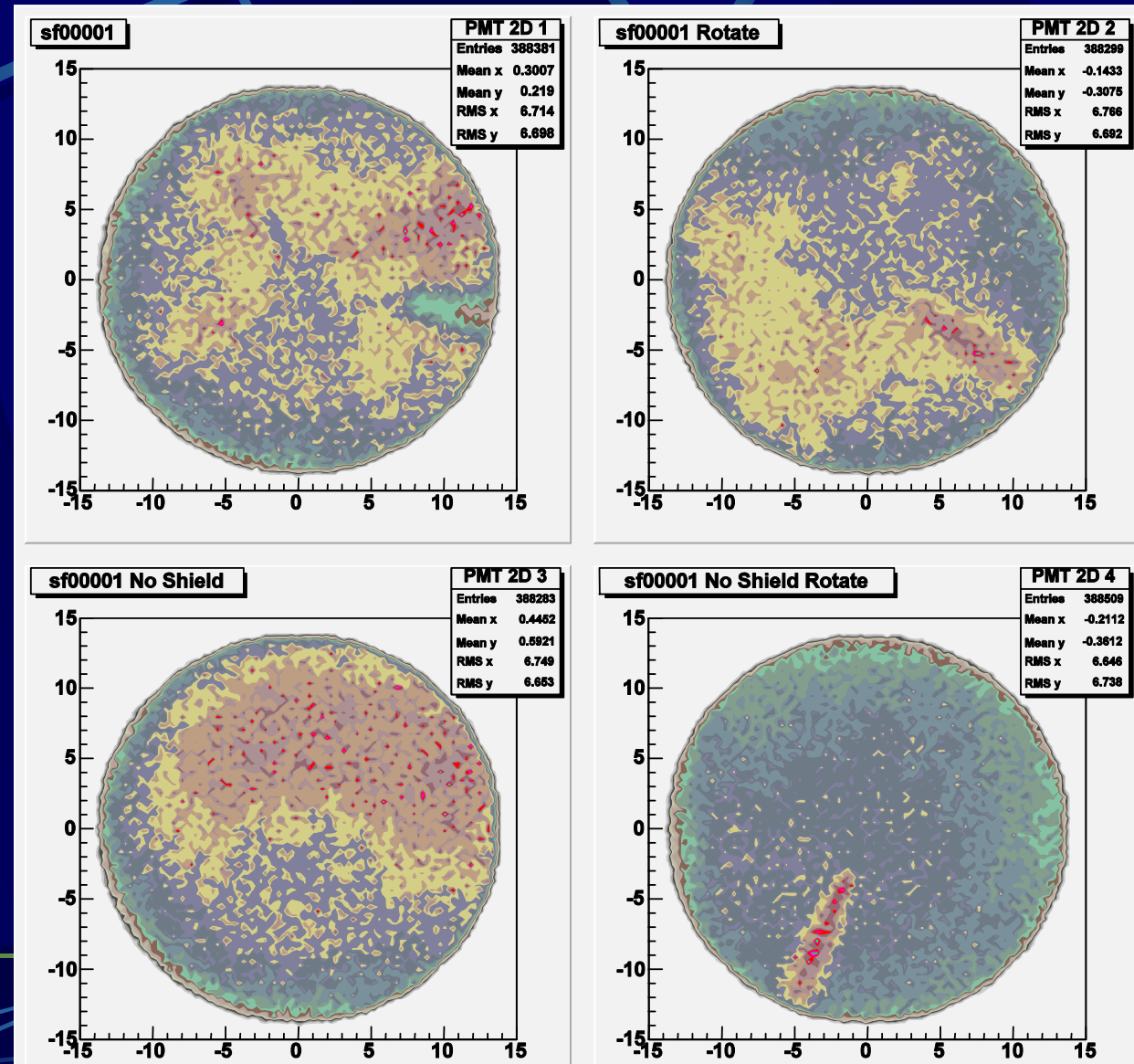


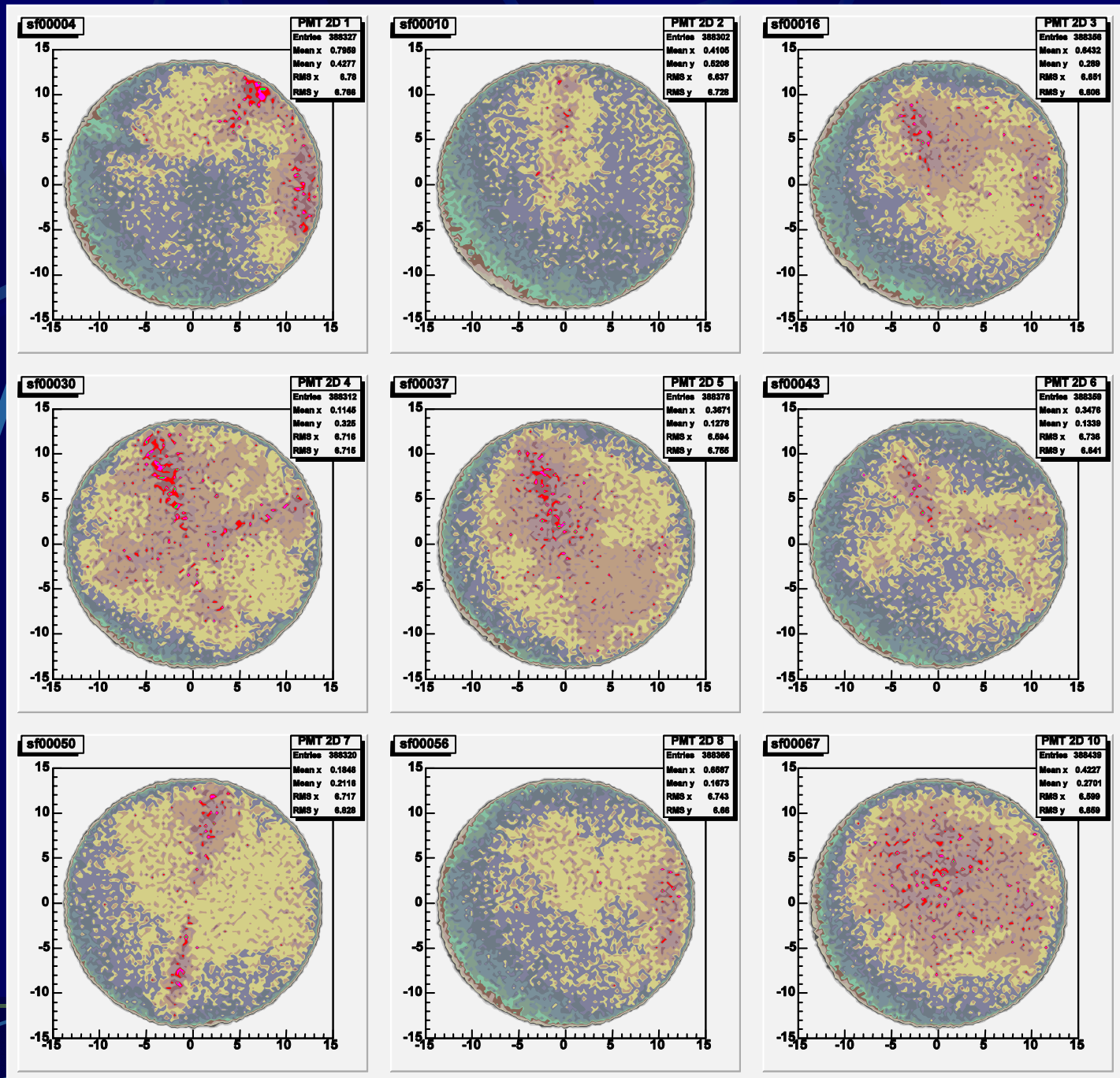
Summary 3 : PMT by PMT difference

- The difference of the collection efficiency from a PMT to PMT shows the variance by 10% at maximum in the average, but, point to point difference reach 20% level.
- A single PMT cannot represent all PMTs.

Discussion:

2 dimensional view of the cathode surface





Executive Summary

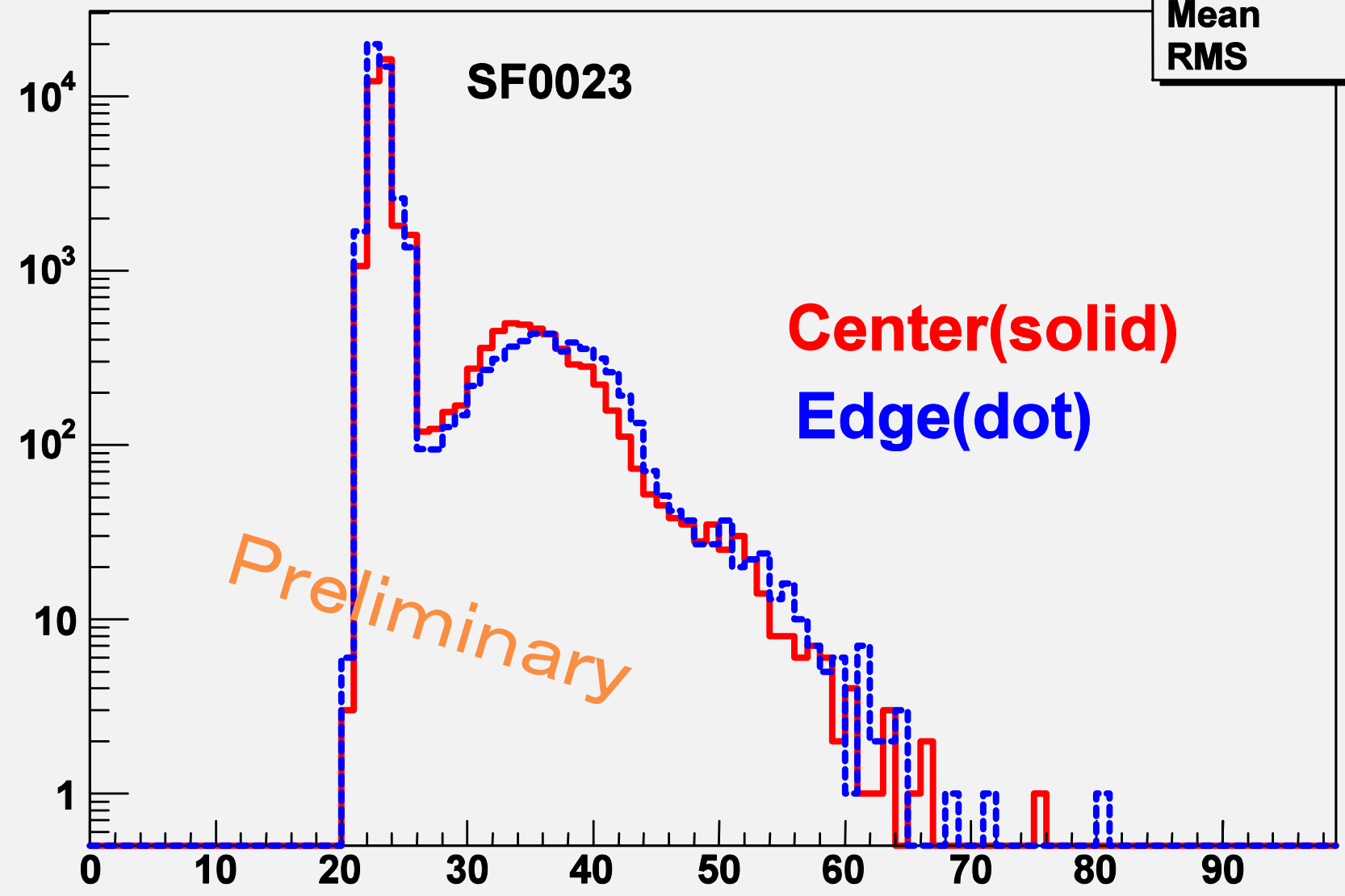
- Completed the 2D survey data for IceCube detector MC implementation.
- Geomagnetic field effects at $\sim 5\%$ level.
- Gain vs Collection efficiency is not significant, less than $\sim 5\%$.
- PMT by PMT difference is remarkable which reach $\sim 20\%$ level.

Outlook

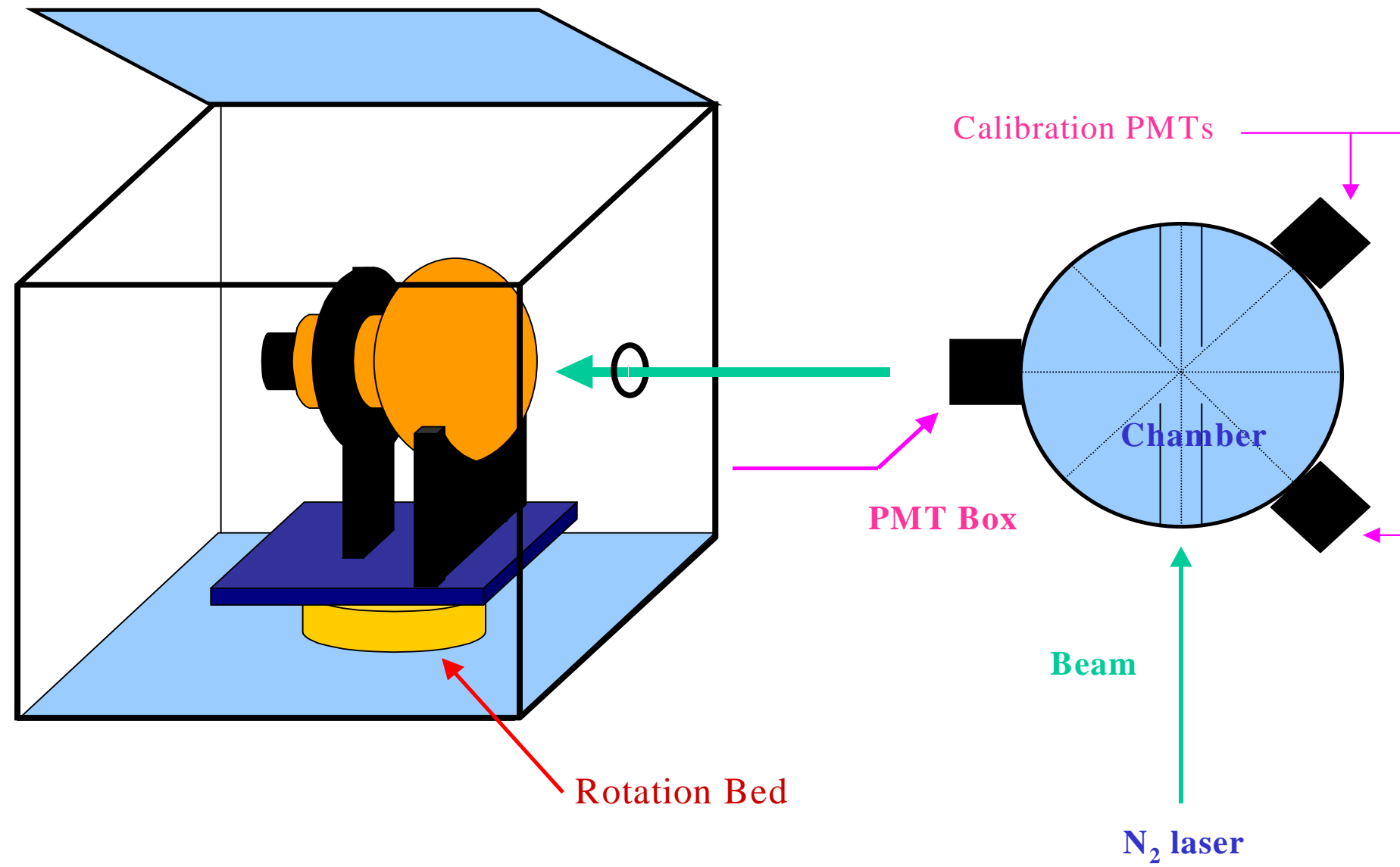
- Absolute Quantum Efficiency :
PMT/DOM
- Gain Scanning
- Wave Form data taking
- Angular Response
- DOM simulation

Charge Responce single p.e.

qresponce0_evt0	
Entries	1000
Mean	25
RMS	4.91

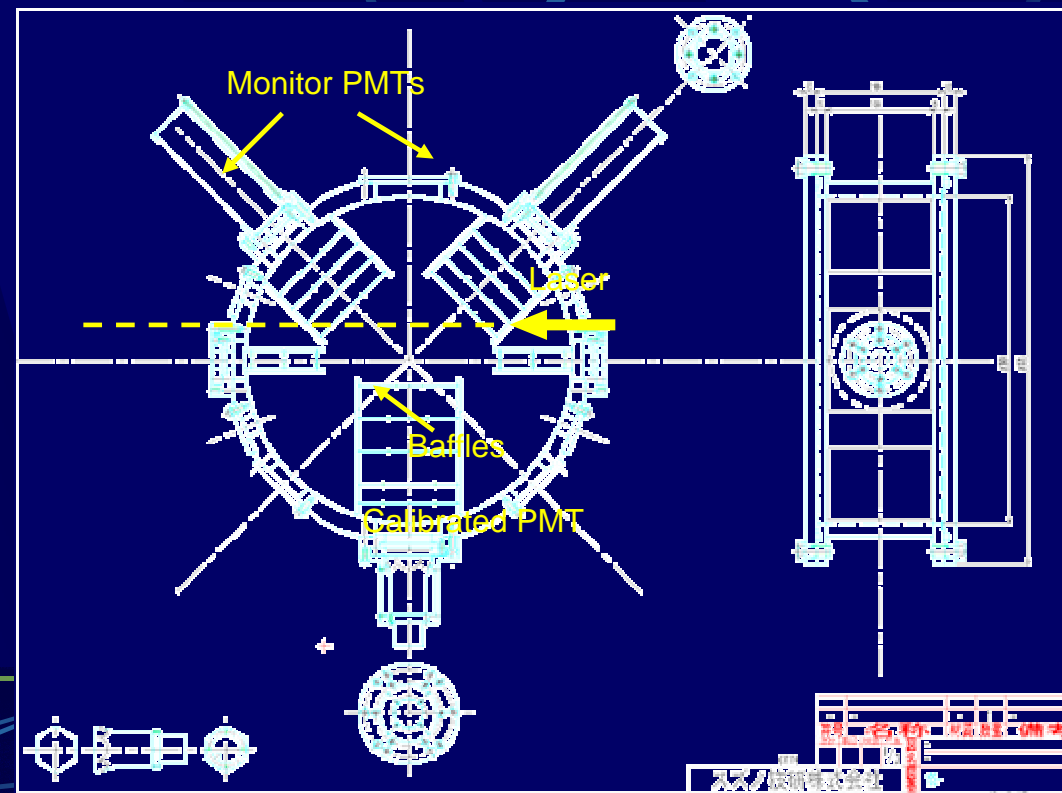


Absolute QE measurement

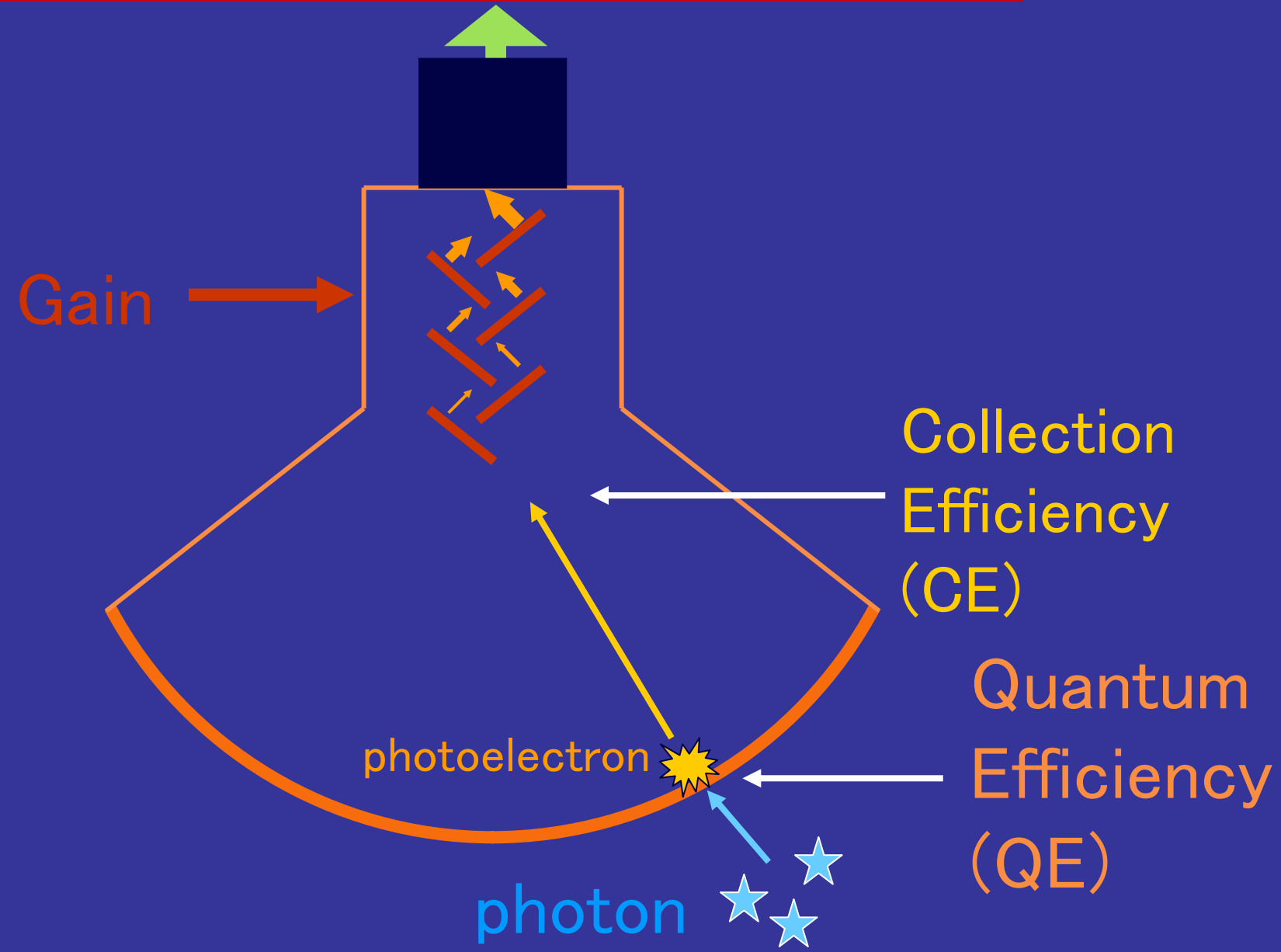


Future plan

- Now, we start developing new scattering box.
- Easy to change PMTs → Useful to calibrate many PMTs
- To exchange gas, we will use vacuum pump
→ We can easily control the gas quality.



$$\text{Signal} = \text{QE} \otimes \text{CE} \otimes \text{Gain}$$



The background is a dark blue field filled with various geometric shapes and lines. There are several large, overlapping triangles and quadrilaterals in different shades of blue, creating a layered, abstract effect. A network of thin, light blue lines crisscrosses the entire area, some intersecting the larger shapes. At the bottom, a thin horizontal line separates a dark blue base from the rest of the composition.

The End