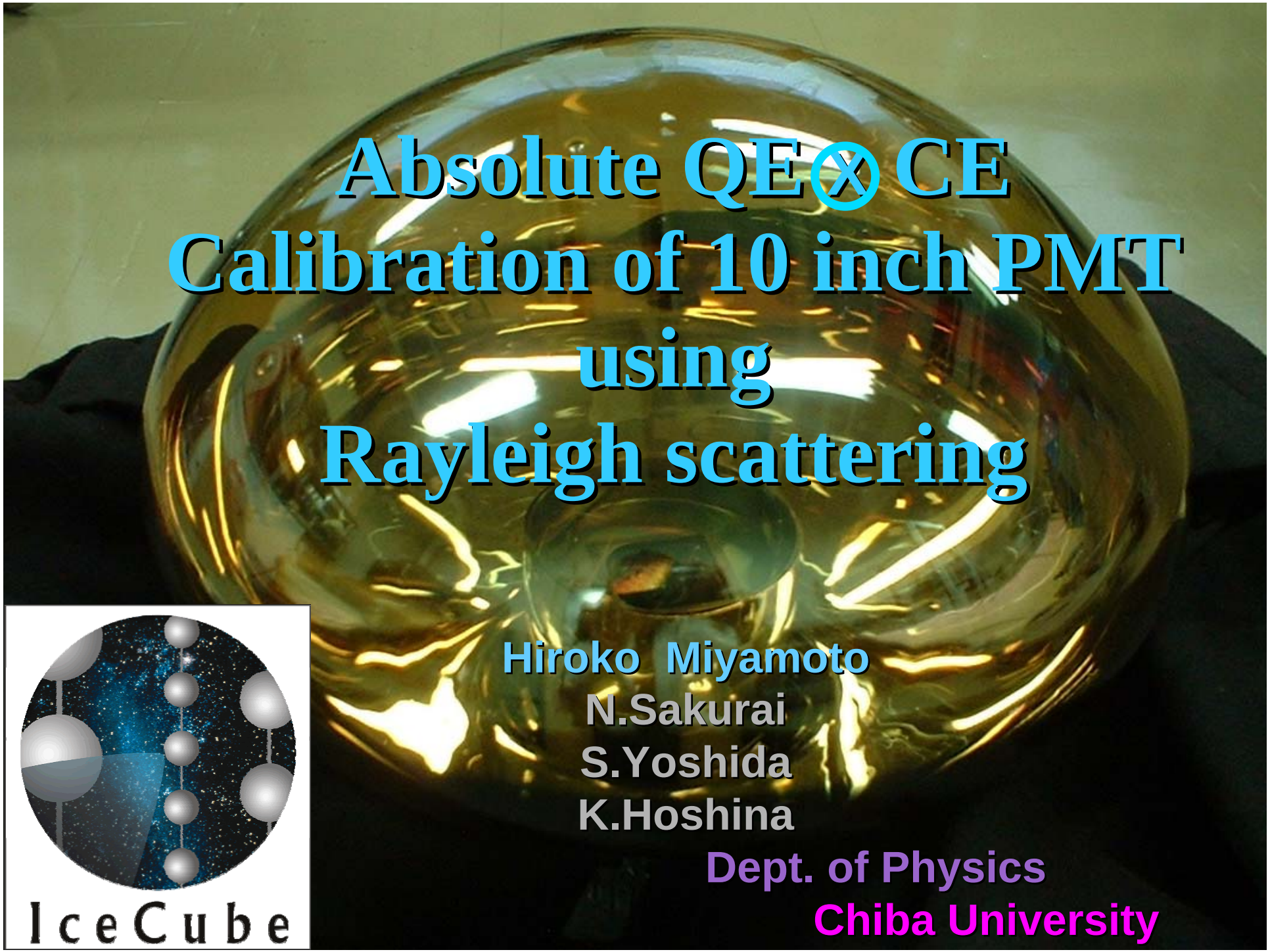

Absolute QE⊗CE Calibration of 10 inch PMT using Rayleigh scattering

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N.Sakurai
S.Yoshida
K.Hoshina

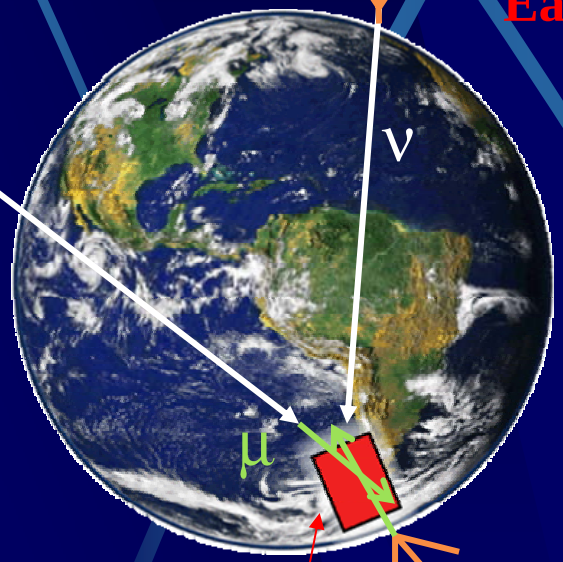
Dept. of Physics
Chiba University

IceCube

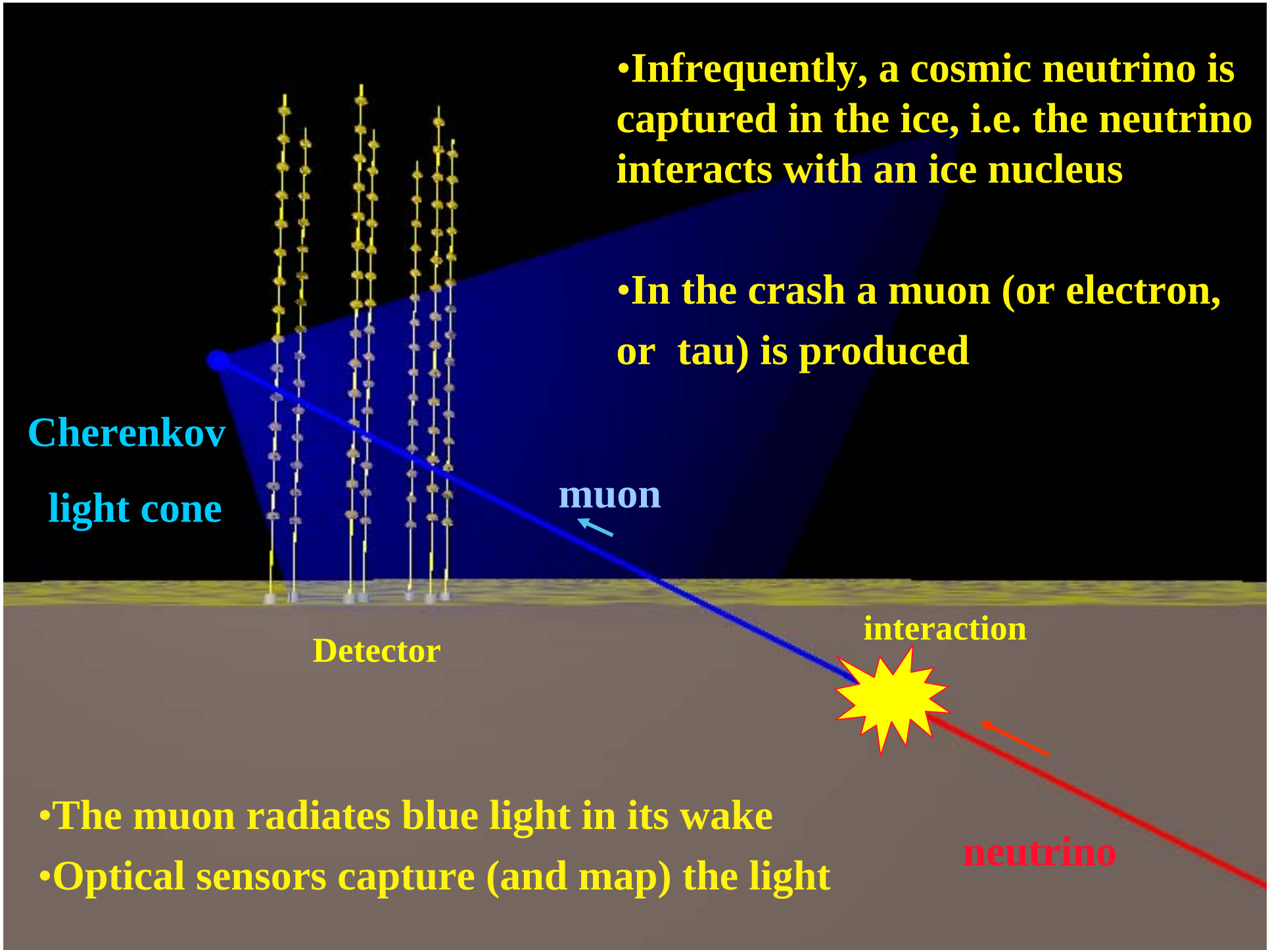
Contents

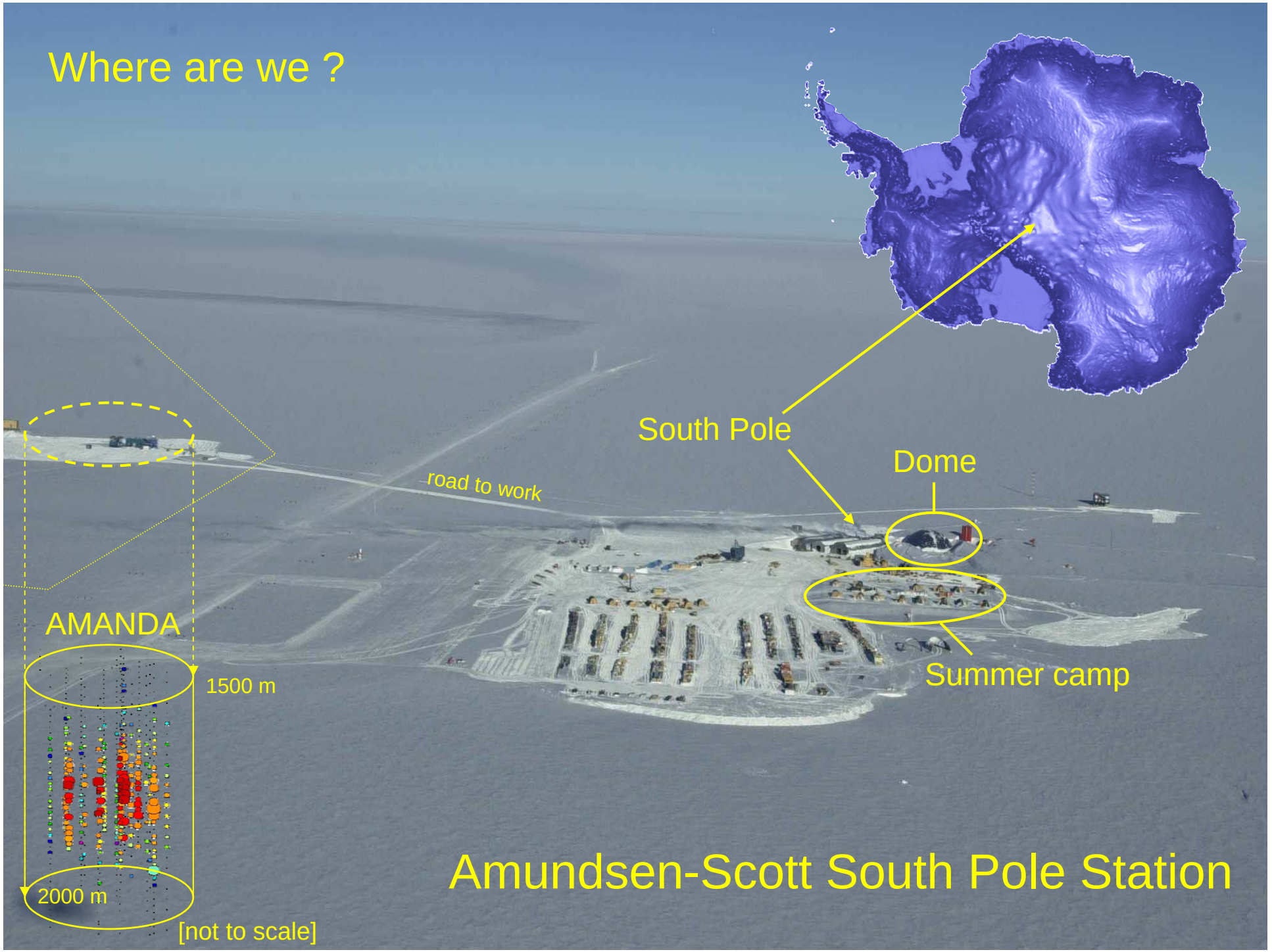
- What the hell is IceCube?
- PMT calibration at Chiba University
  ⇒ DOM simulation:
  K.Hoshina's presentation
- Absolute QE⊗CE Efficiency Calibration

- Look for the neutrino's interaction product (e,μ,τ)
- Use the earth as a filter



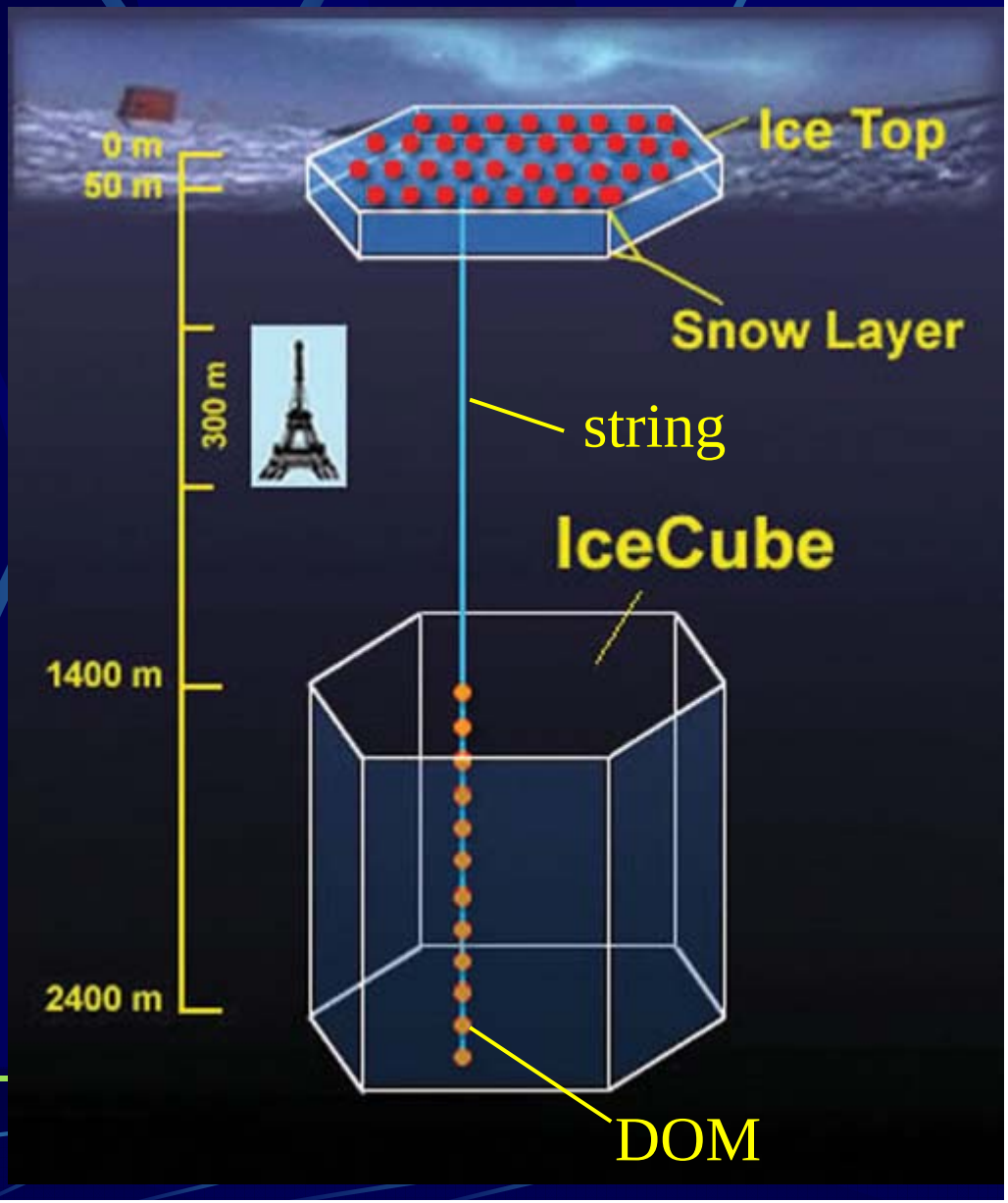
- 1:1,000,000 background rejection!


•Infrequently, a cosmic neutrino is captured in the ice, i.e. the neutrino interacts with an ice nucleus
•In the crash a muon (or electron, or tau) is produced
Cherenkov light cone
muon
Detector
interaction
neutrino
•The muon radiates blue light in its wake
•Optical sensors capture (and map) the light


Where are we ?
South Pole
Dome
road to work
Summer camp
AMANDA
1500 m
2000 m
[not to scale]
Amundsen-Scott South Pole Station

IceCube Observatory

- 80 Strings
- 4800 Digital Optical Modules (DOM)
- 1 km^3 volume
- AMANDA within IceCube
- Energy Range
  10^7 eV ~ 10^{20} eV



- Bartol Research Institute, Delaware, USA
- Univ. of Alabama, USA
- Pennsylvania State University, USA
- UC Berkeley, USA
- Clark-Atlanta University, USA
- Univ. of Maryland, USA

- IAS, Princeton, USA
- University of Wisconsin-Madison, USA
- University of Wisconsin-River Falls, USA
- LBNL, Berkeley, USA
- University of Kansas, USA
- Southern University and A&M College, Baton Rouge, USA

- Universidad Simon Bolivar, Caracas, Venezuela

- Chiba university, Japan
- University of Canterbury, Christchurch, NZ

- Universite Libre de Bruxelles, Belgium
- Vrije Universiteit Brussel, Belgium
- Université de Mons-Hainaut, Belgium
- Universität Mainz, Germany
- DESY-Zeuthen, Germany
- Universität Dortmund, Germany

- Universität Wuppertal, Germany
- Uppsala university, Sweden
- Stockholm university, Sweden
- Imperial College, London, UK
- Oxford university, UK
- Utrecht,university, Netherlands

PMT Calibration at Chiba University

Signal = QE ⊗ CE ⊗ Gain

Gain

(freezer)

Noise Rate,
Charge Response
After pulse

Collection
Efficiency
(CE), 2D Gain

(2DScan)

photoelectron

Quantum
Efficiency
(QE)

photon

?

PMT Calibration at Chiba Univ.

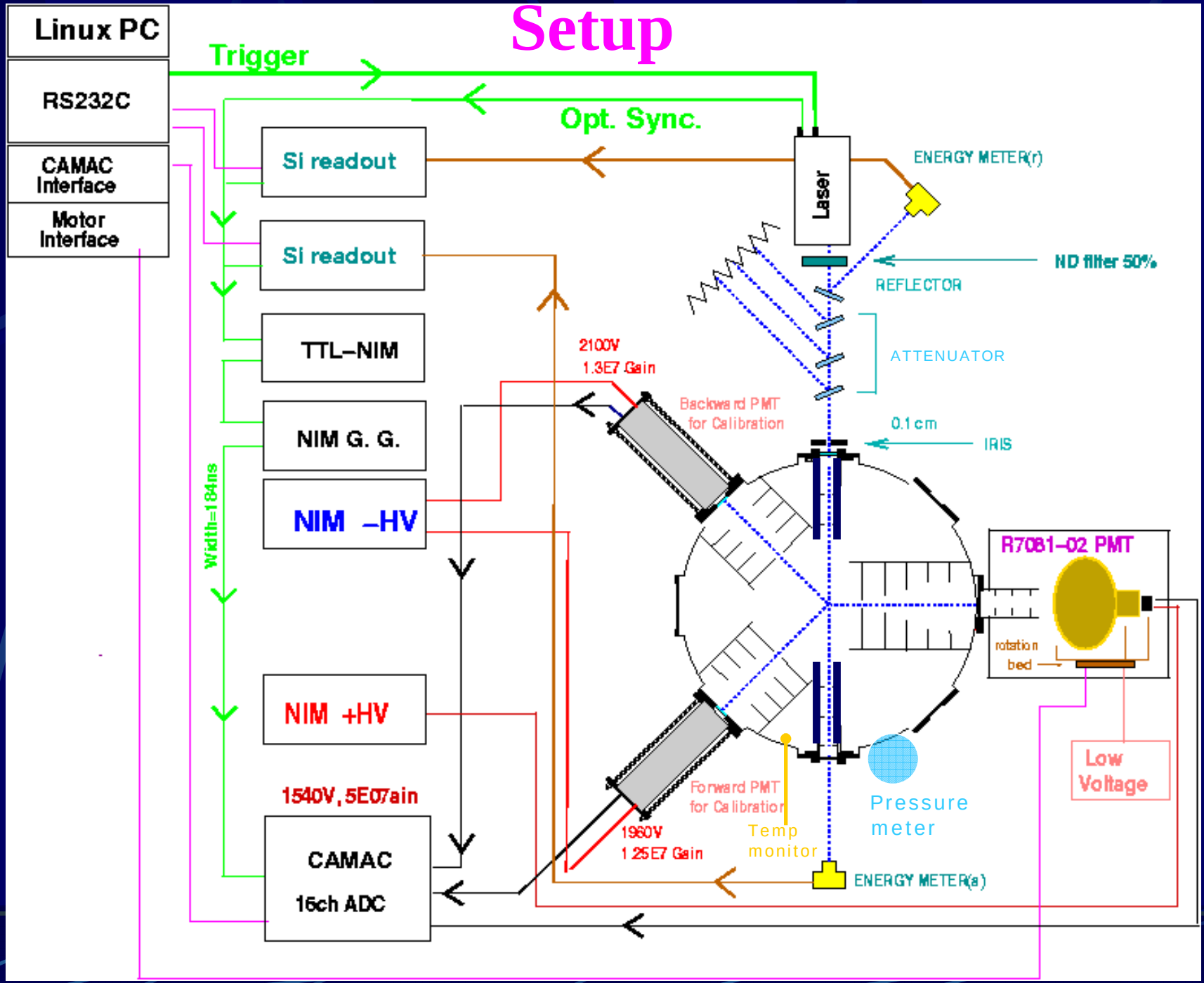
Absolute QE⊗CE Efficiency Calibration

What you need for Absolute Calibration?

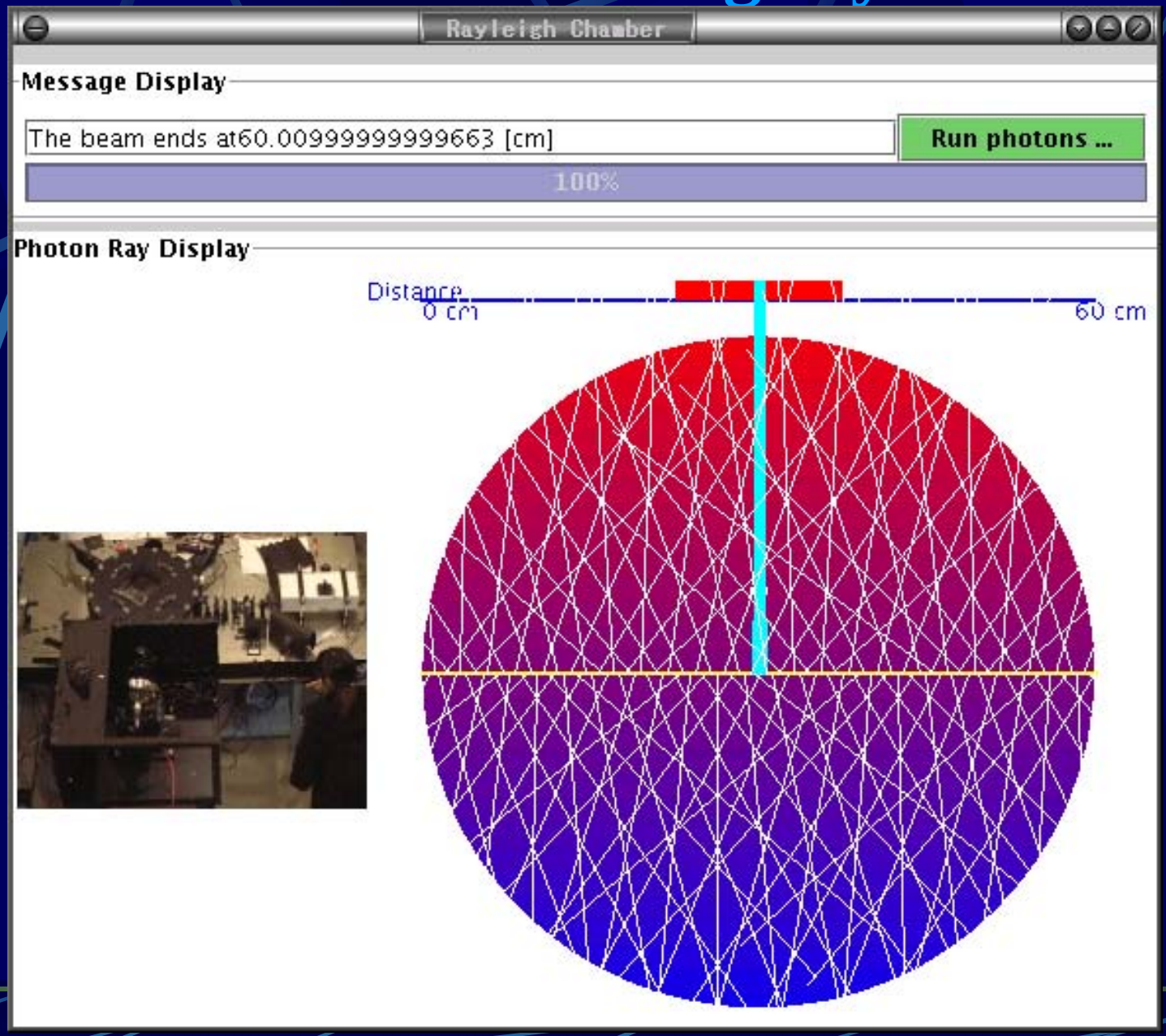
- **Pulsed light source bright enough to measure its luminosity.**
  - **Our solution N2 laser @337.1nm**
- **Dark enough to allow SPE-based measurement.**
  - **Our solution : Rayleigh scattering for beam dump.**

Typical dumping factor 1E-11

Setup

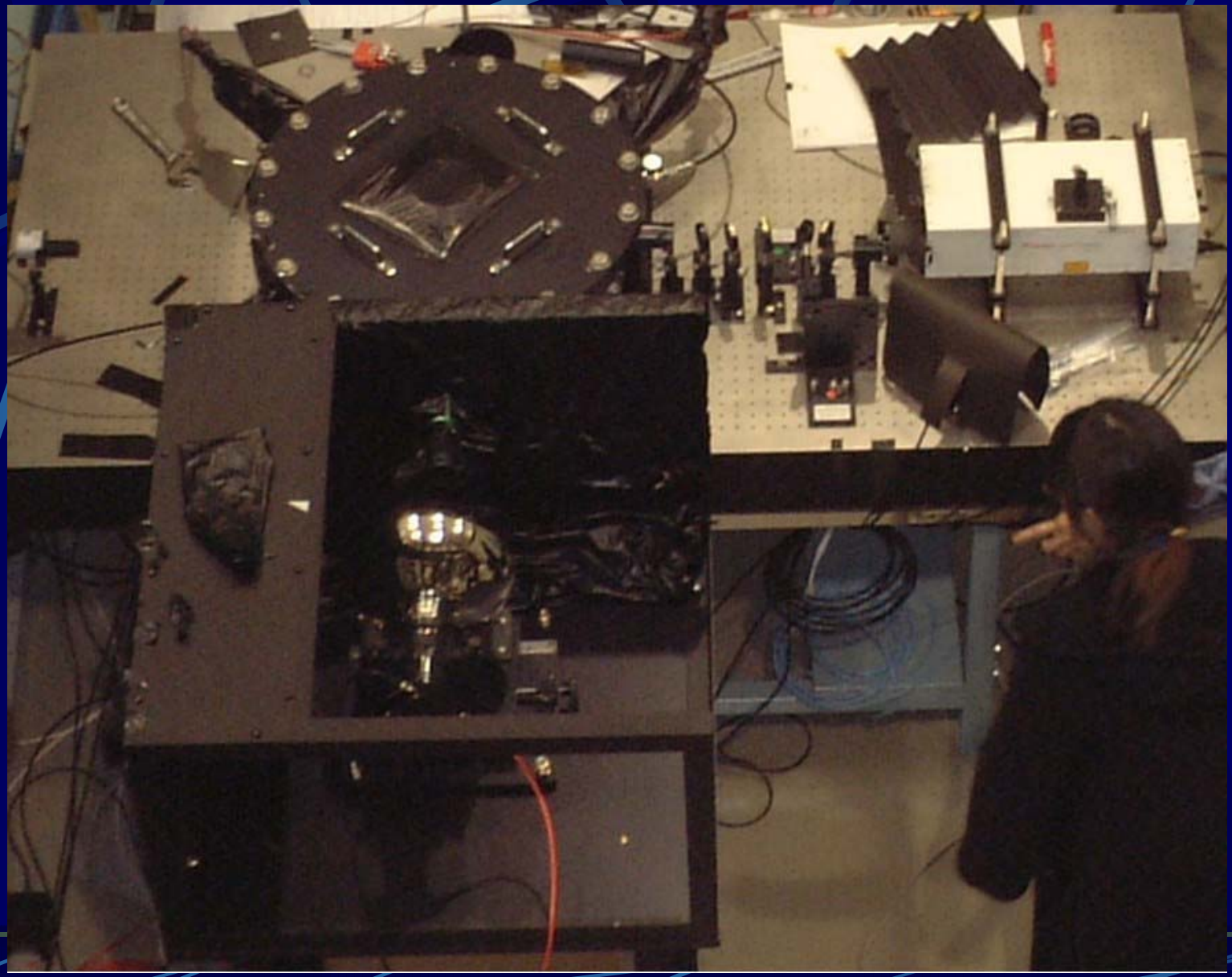

Linux PC
RS232C
CAMAC Interface
Motor Interface
Trigger
Opt. Sync.
Si readout
Si readout
TTL–NIM
NIM G. G.
NIM –HV
NIM +HV
CAMAC
16ch ADC
Width=184ns
1540V, 5E07ain
Laser
ENERGY METER(r)
ND filter 50%
REFLECTOR
ATTENUATOR
2100V
1.3E7 Gain
Backward PMT
for Calibration
0.1 cm
IRIS
R7081–02 PMT
rotation
bed
Low
Voltage
Forward PMT
for Calibration
1960V
1.25E7 Gain
Temp
monitor
Pressure
meter
ENERGY METER(a)

Calculation of “light yield”



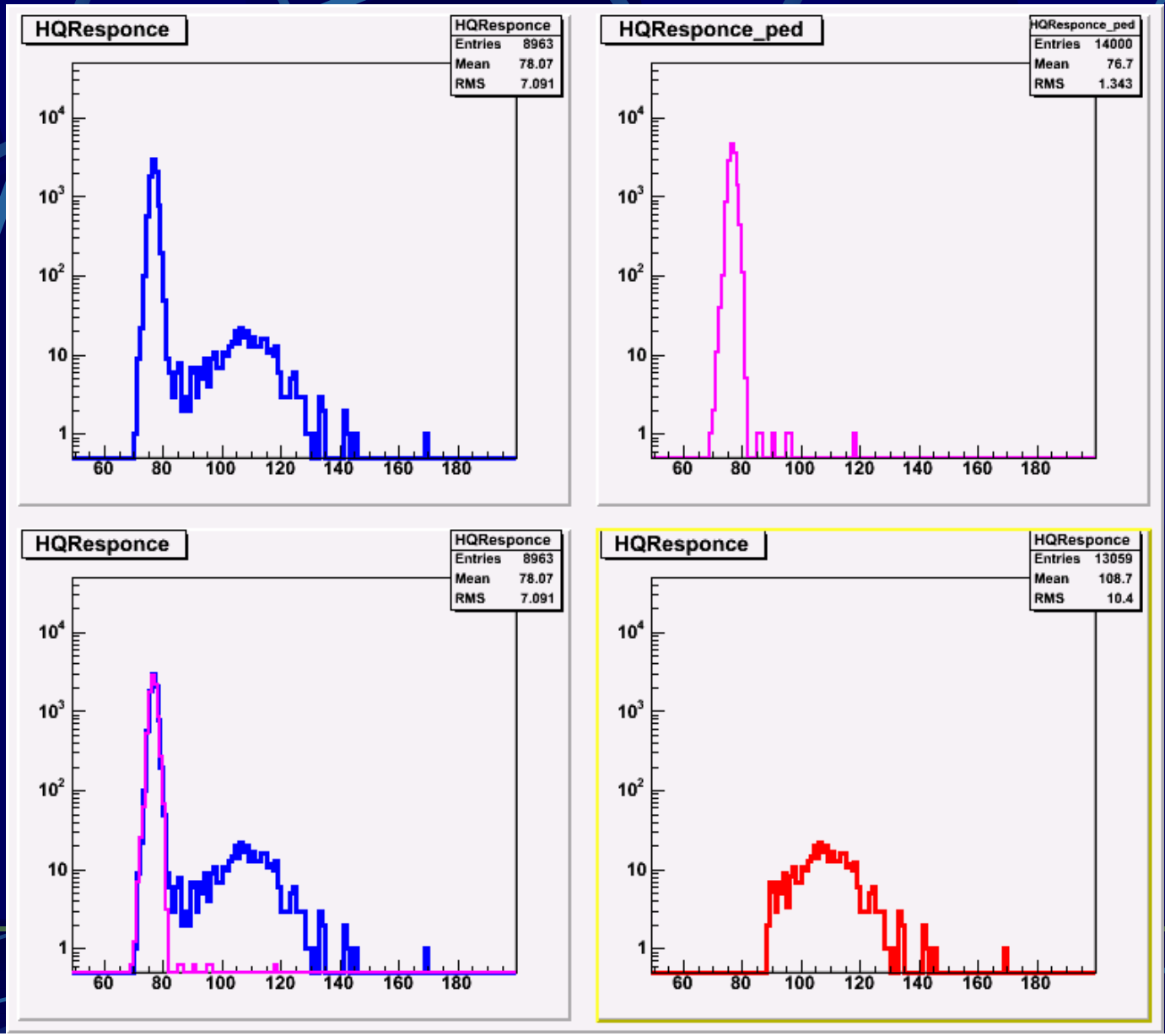
Typically 4.76495751889224 1E-11 dumped

Setup photo

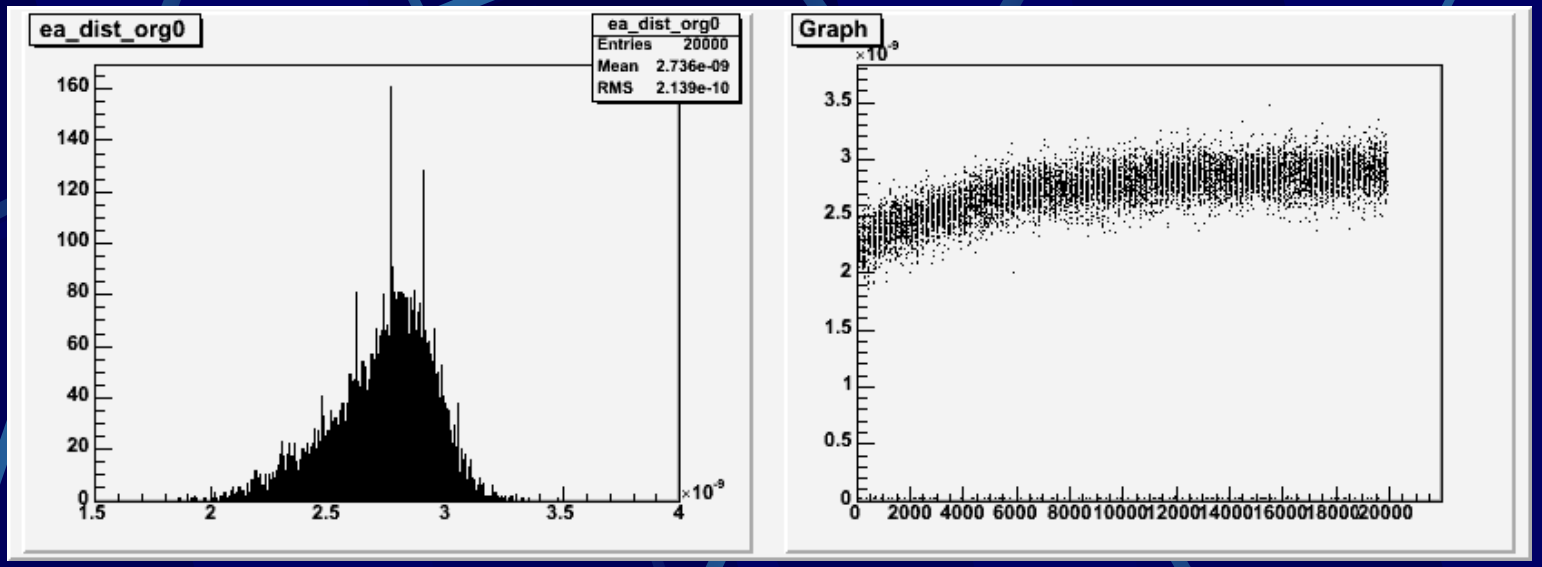


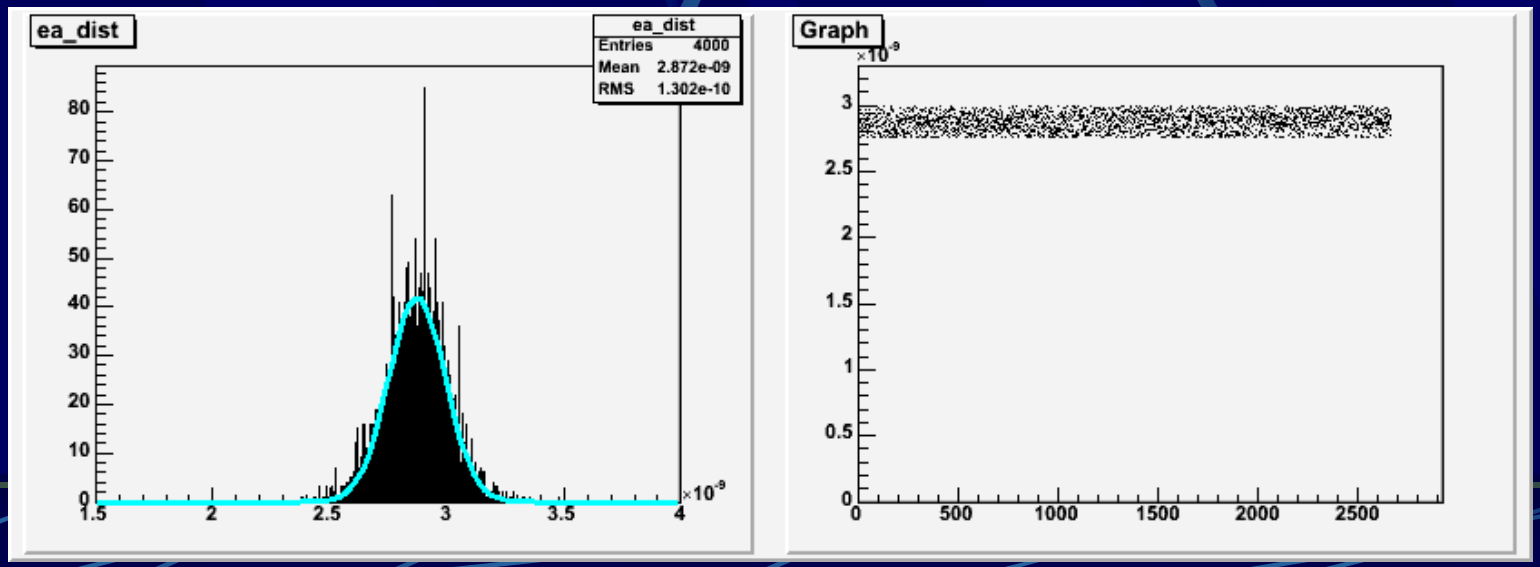
Signal subtraction

sf0077@1atm



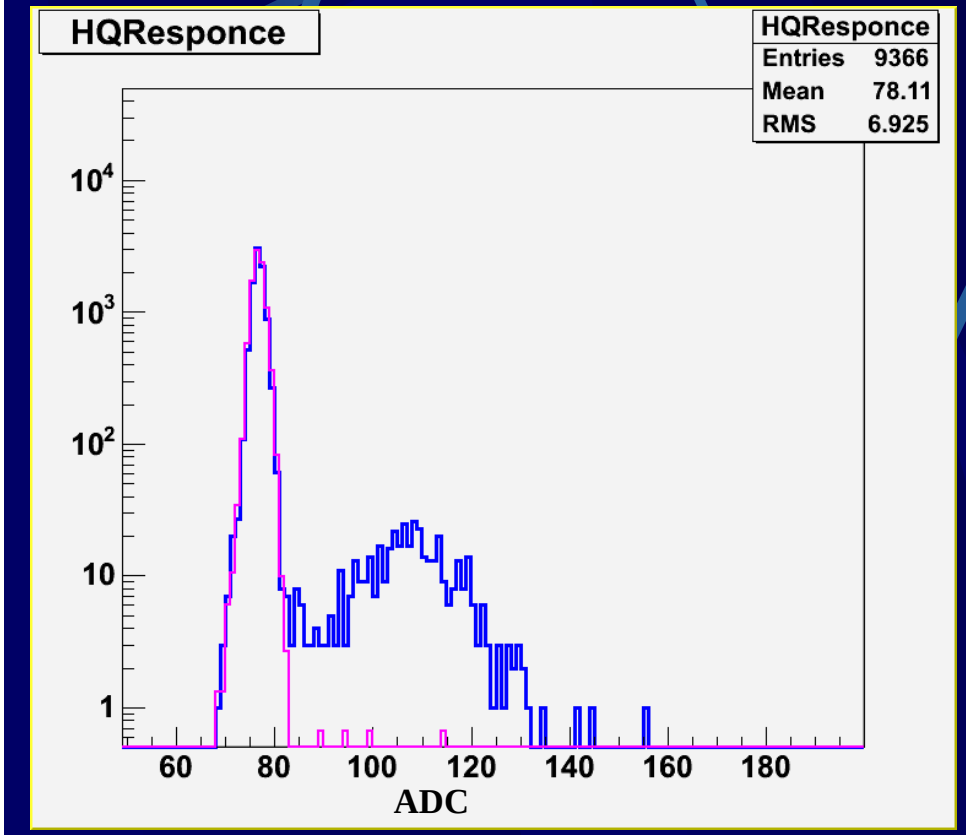
Event cut
(for more accuracy…)

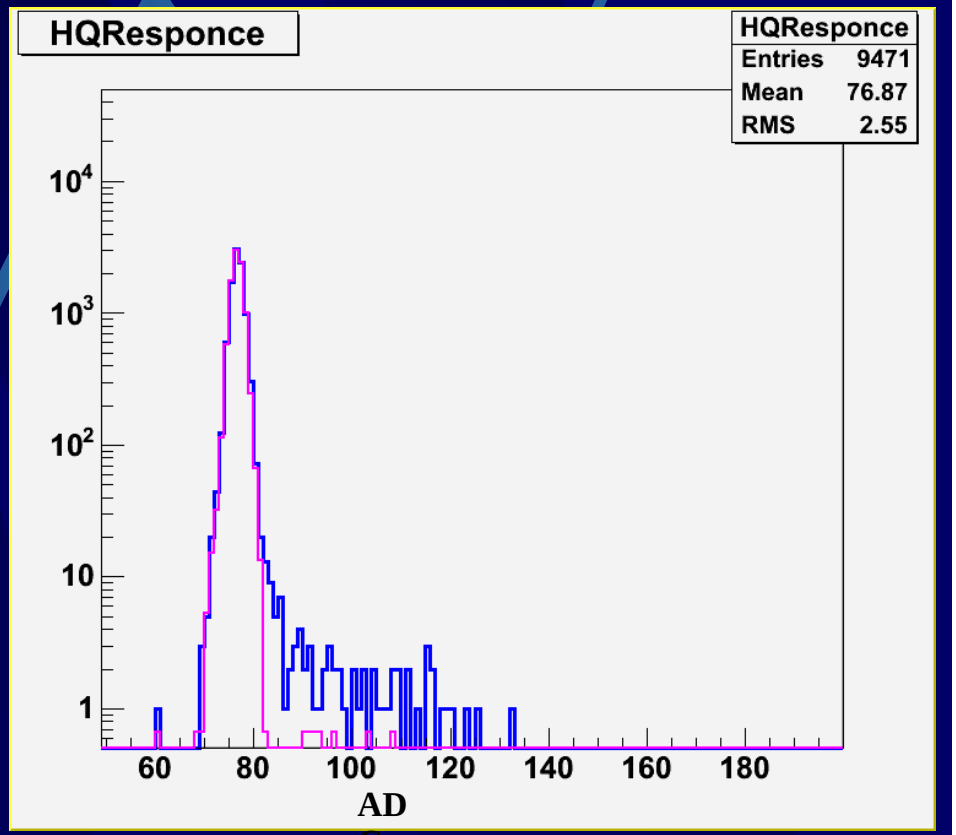




Result

ADC spectrum of Center and Edge of photocathode

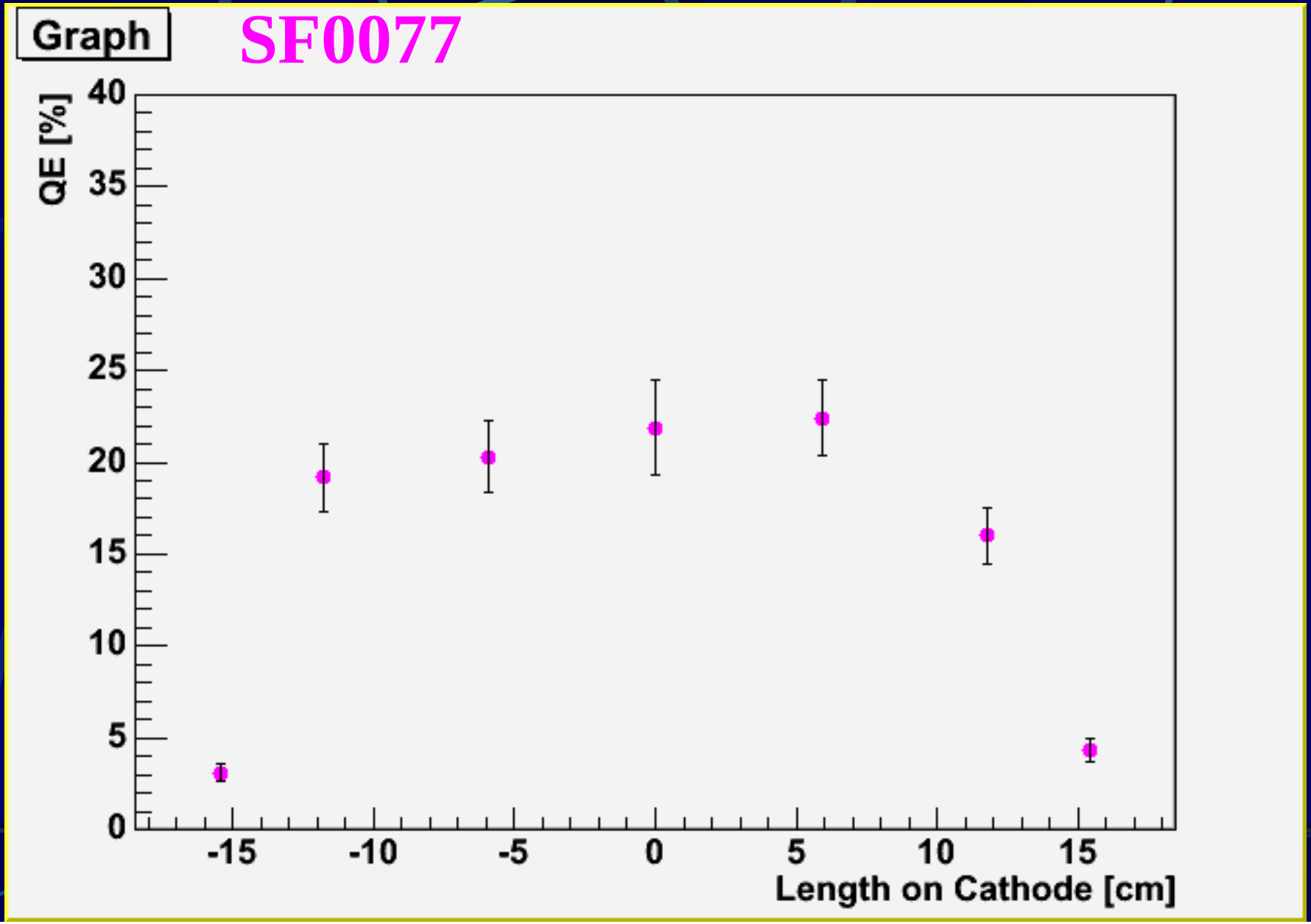




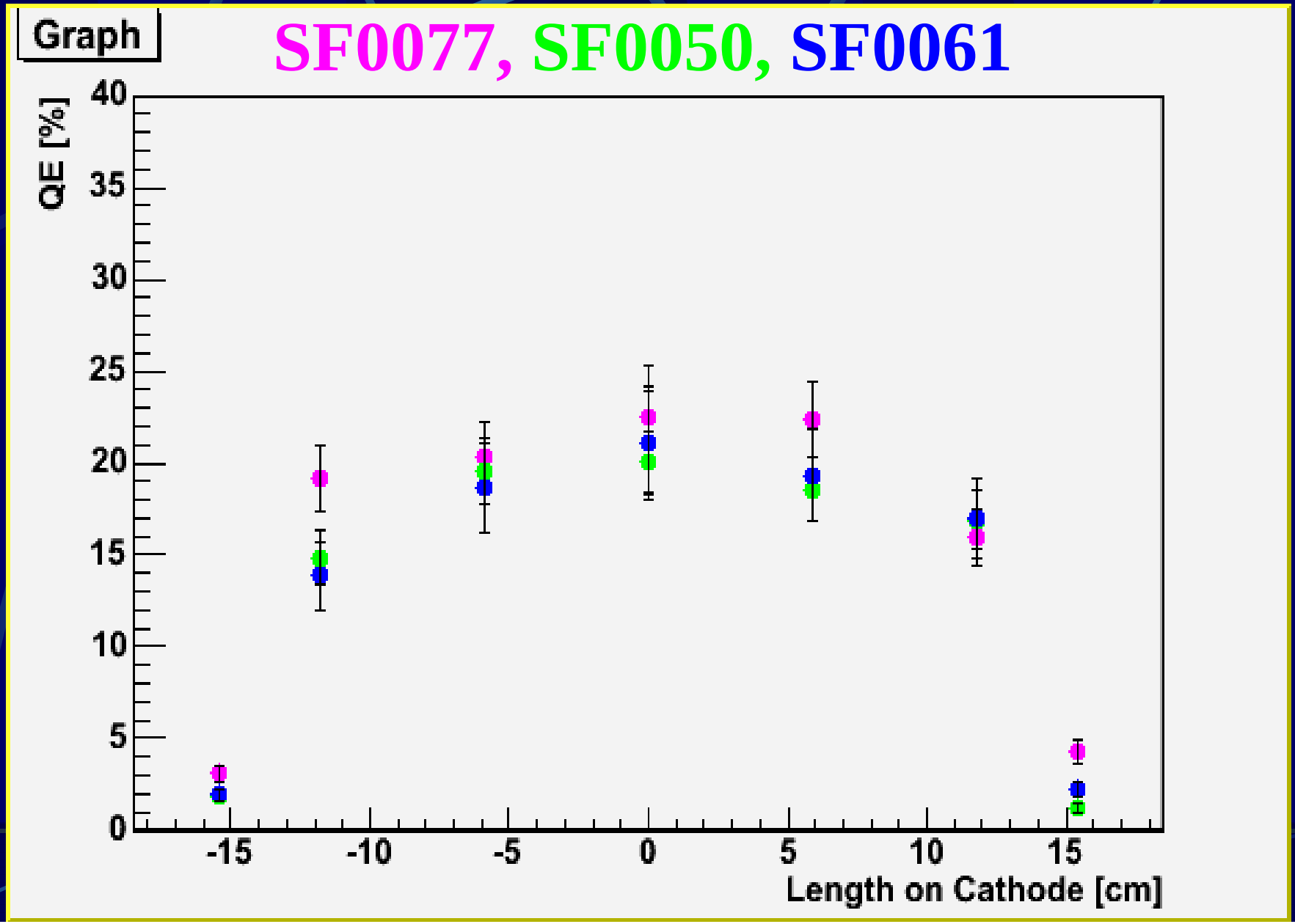
Center

Edge
(~15 cm from the center)

2 Dimensional Absolute Efficiency

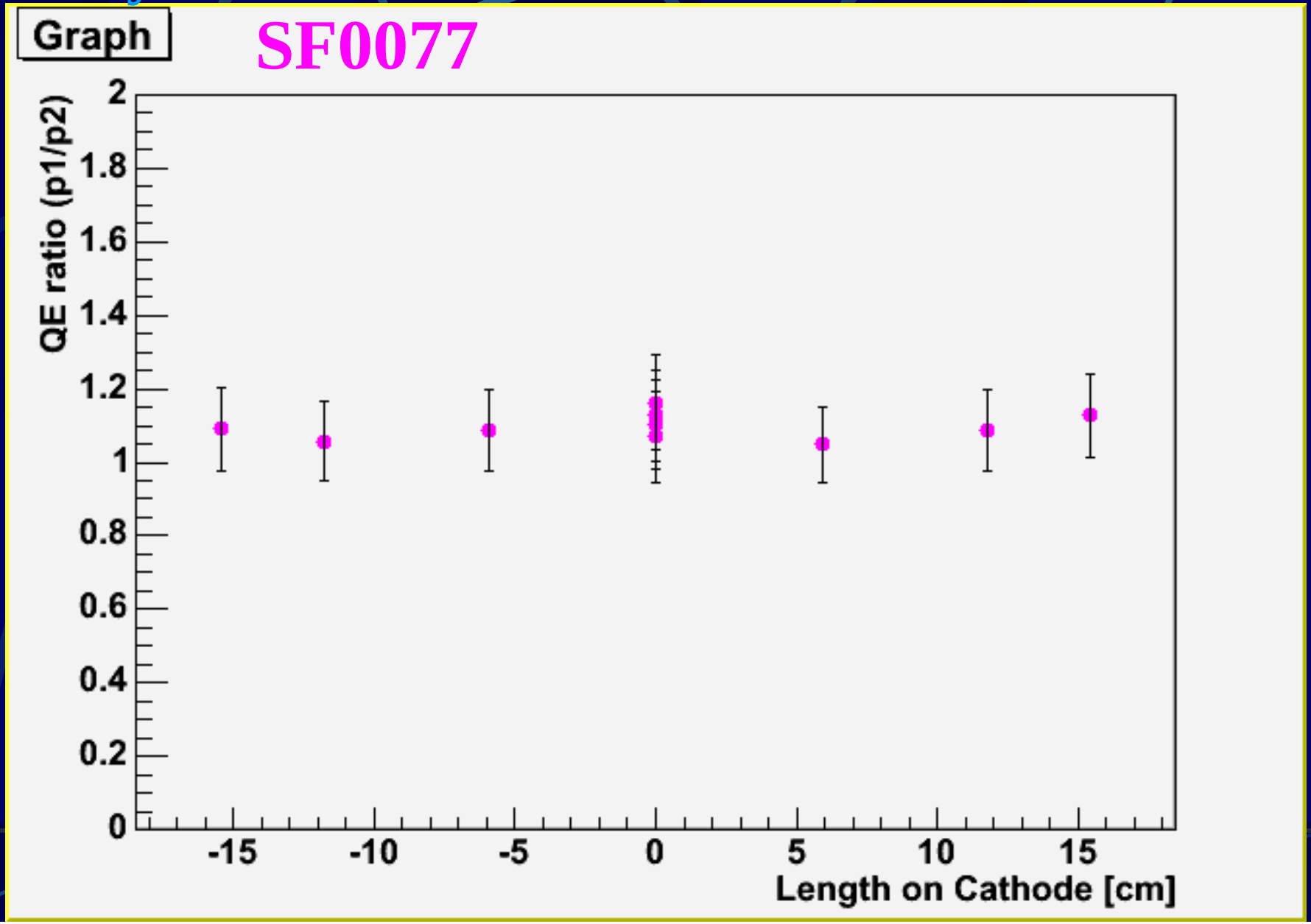


2 Dimensional Absolute Efficiency

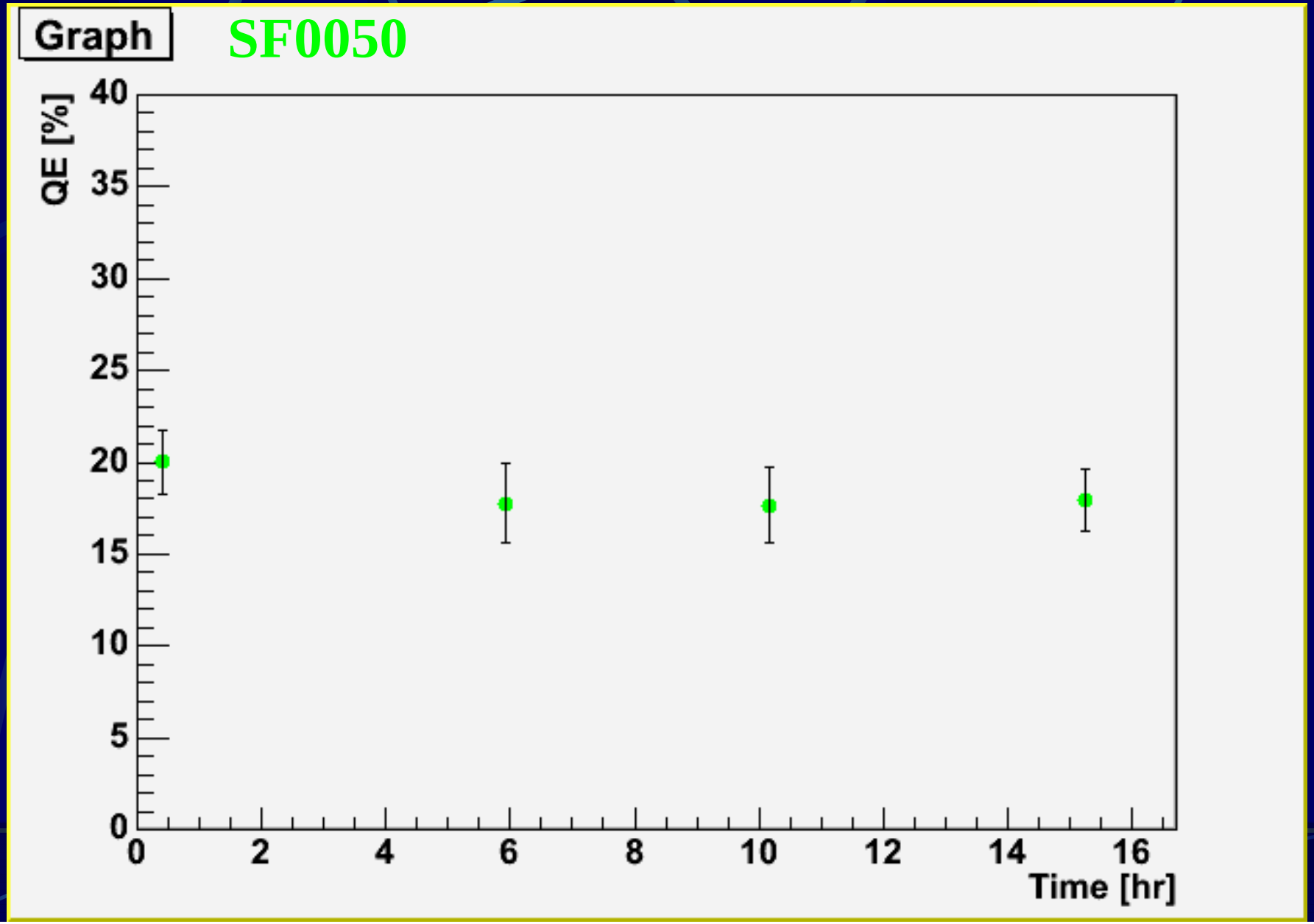


Verification

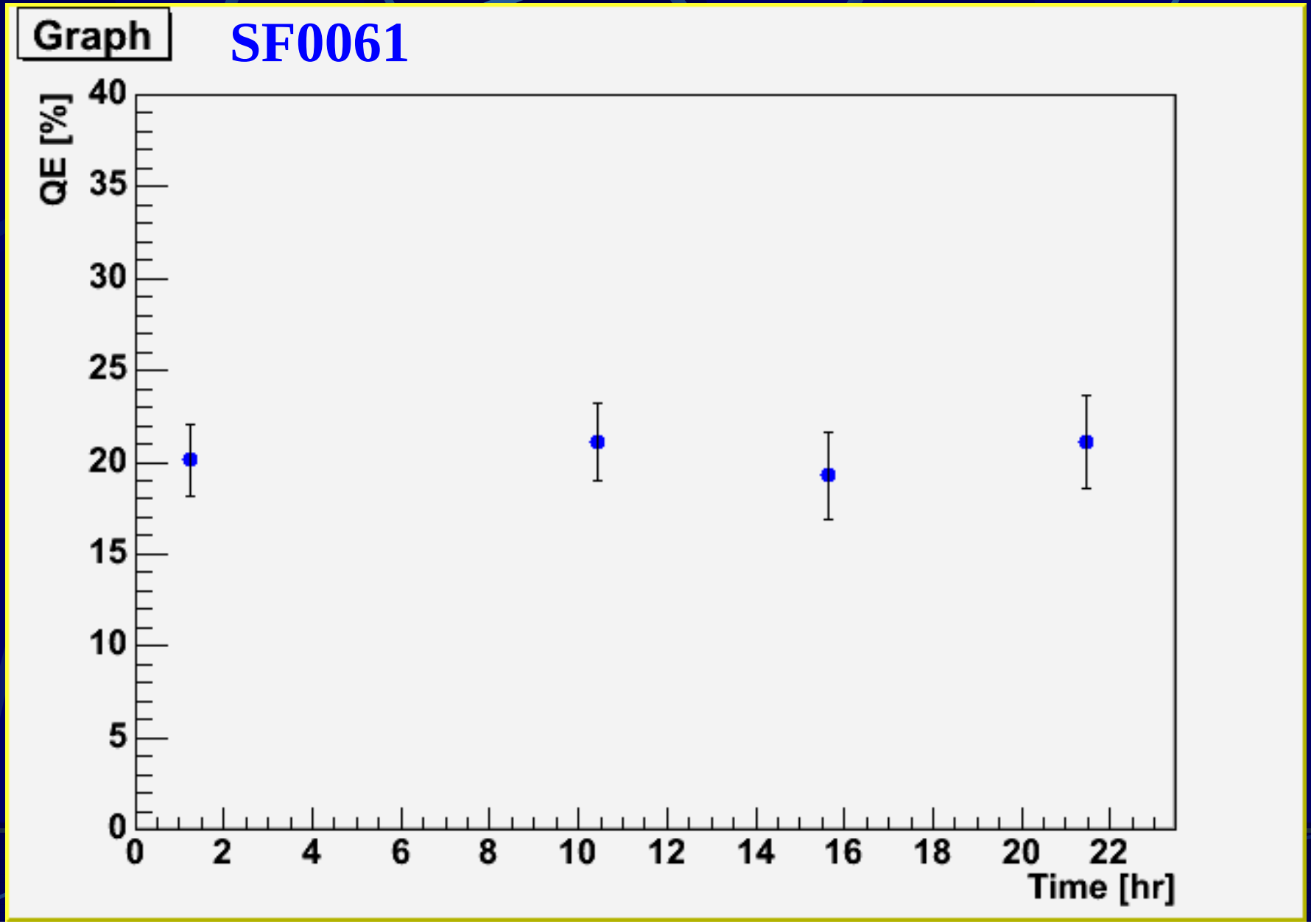
Check air condition (Rayleigh dominant) by forward and backward monitor PMT



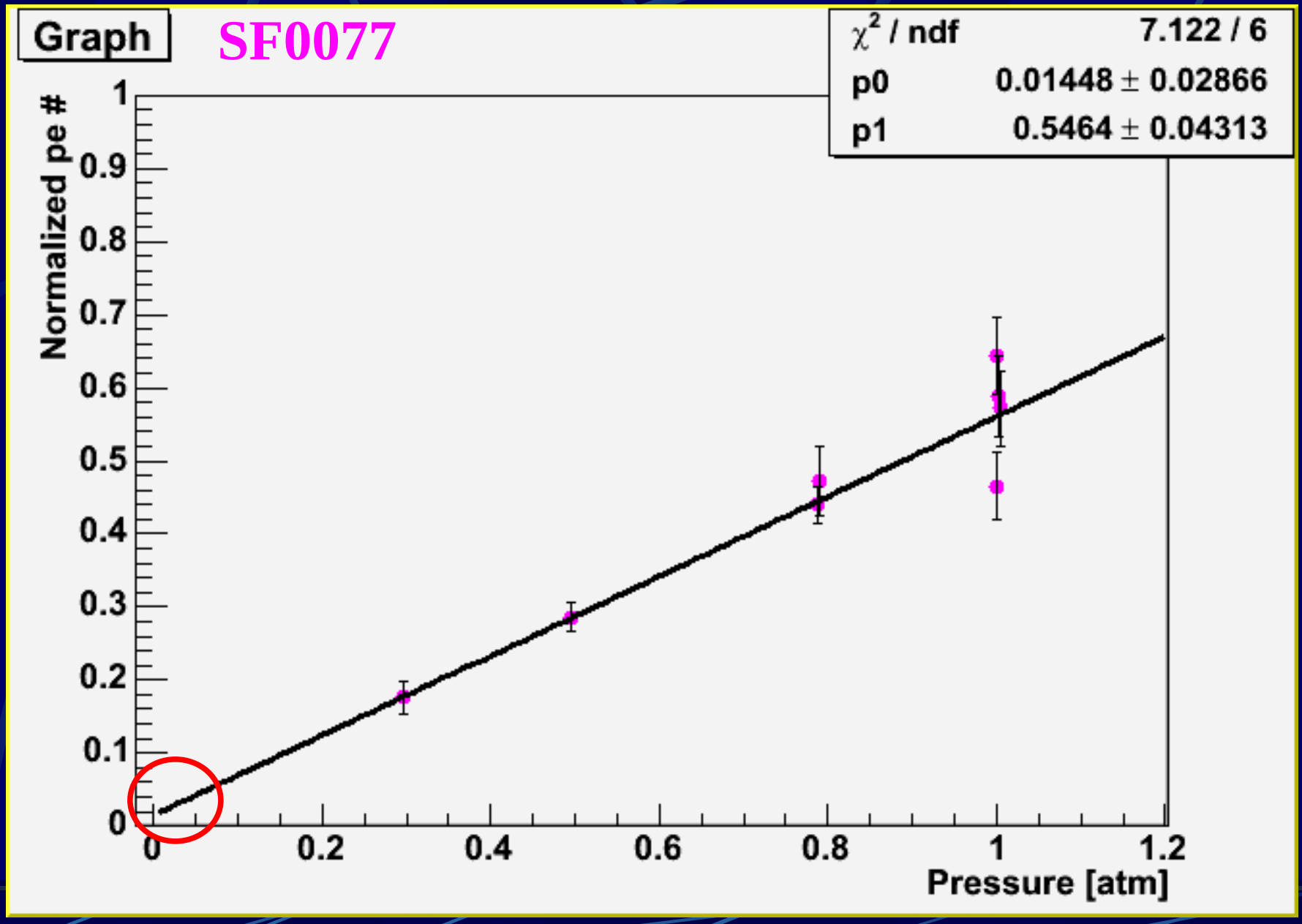
Stability Check



Stability Check



Really see only scattered photons?



-> 'YES' There's no other factors(offset) for data

Typical Error Budget

- **Statistics**
  - photoelectron # : 10%
- **Systematics**
  - photoelectron # : 1%
  - Light yeild (aperture) : 4%
  - Initial photon fluctuation : 4%
  - Pressure : 1%
  - Photon energy probe: 5%

Total Error Budget : 12.7%

Summary

- **Absolute efficiency of R7081-02 is 20% at** photocathode center, consistent with the typical QE provided by HAMAMATSU.
- **Tube by tube difference ~4%.**
- Statistical error budget can be more reduced with **event-by-event analysis** or taking more data.

Next Step

- Study λ dependence
- Use likelihood for shot by shot analysis
- Compare the measurement result with that of calibrated IceCube PMT by HAMAMATSU
- Absolte 'DOM' efficiency

End