Photon Detector

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Contents

- **Large Prototype R&D**

- Refrigeration and Purification → Haruyama-san

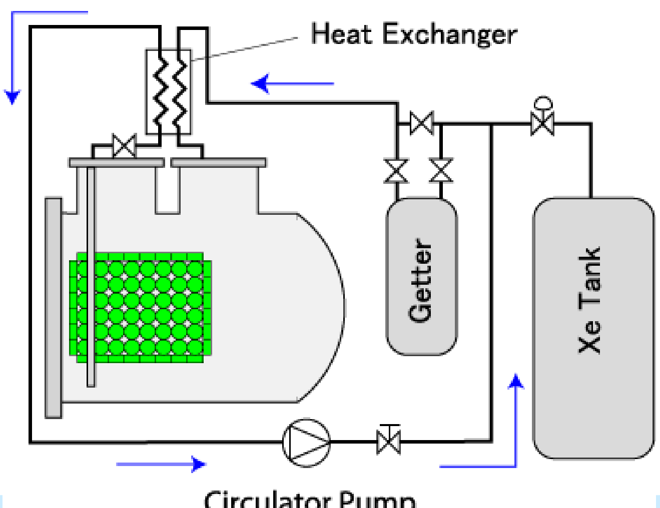
- **Final Detector Design (simulation)**
  - **Segmentation by PMT layers**
  - **Segmentation by reflectors**

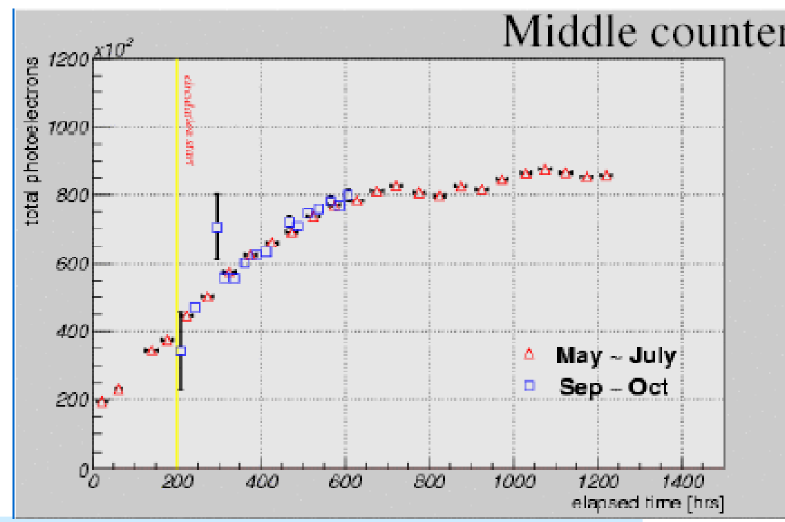
Large Prototype R&D

- **Maintenance work in Summer**
- **New analysis of alpha**
- **Electron beam test at KSR in Uji, Kyoto**
- **Near future plan**

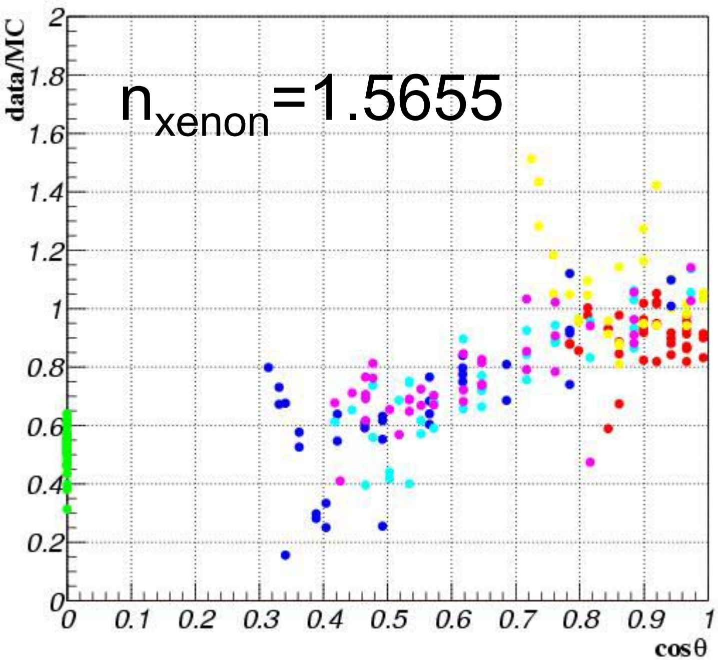
Maintenance in Summer

- Very long term operation in May-July for purification test.
- Acrylic plates replaced with Teflon plates
- Installation of
  - PMTs
  - heat exchanger for cooling returned gas with cold gas
  - Nitrogen trap





Alpha events in liquid angular dependence

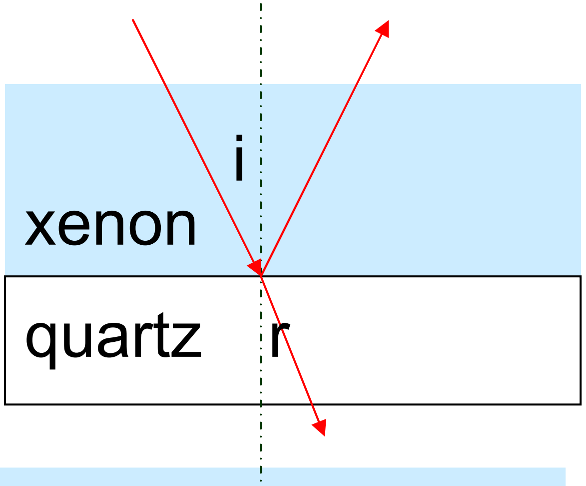


n_{xenon}=1.5655

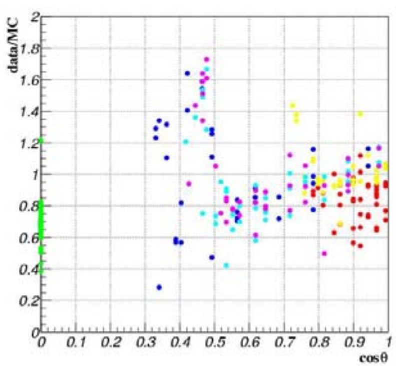
- Angular dependence
  - Reflection on the PMT window
  - Absorption by the window

Fresnel reflection(no polarization)

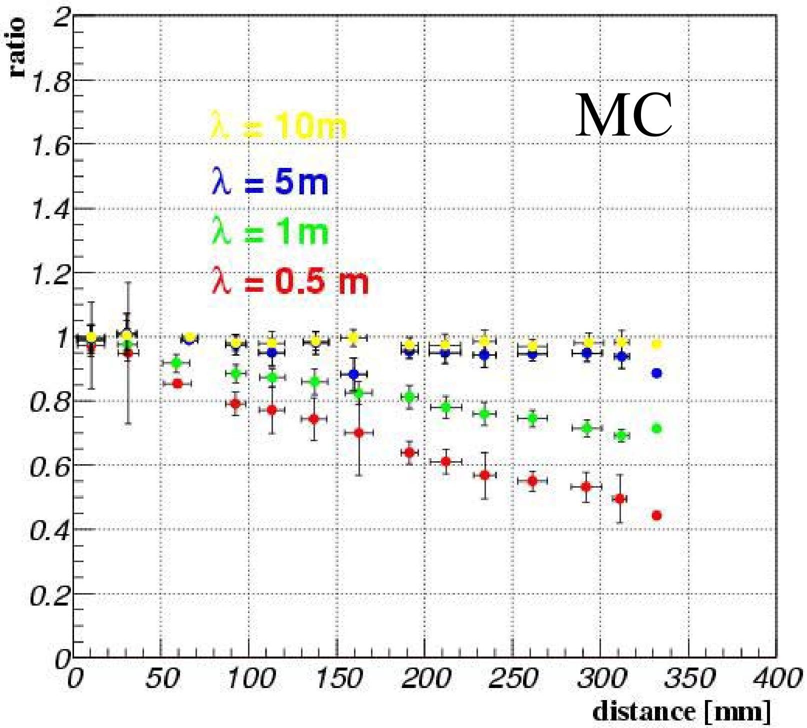
$$R = \frac{1}{2}\left(\frac{\sin^2(i-r)}{\sin^2(i+r)} + \frac{\tan^2(i-r)}{\tan^2(i+r)}\right)$$

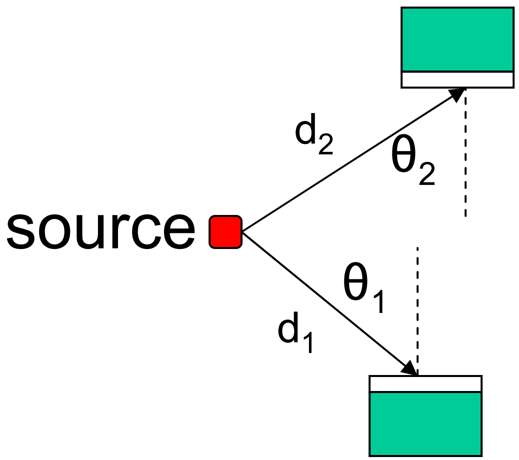


n_{xenon}=1.72



New Method of Absorption Length Estimation



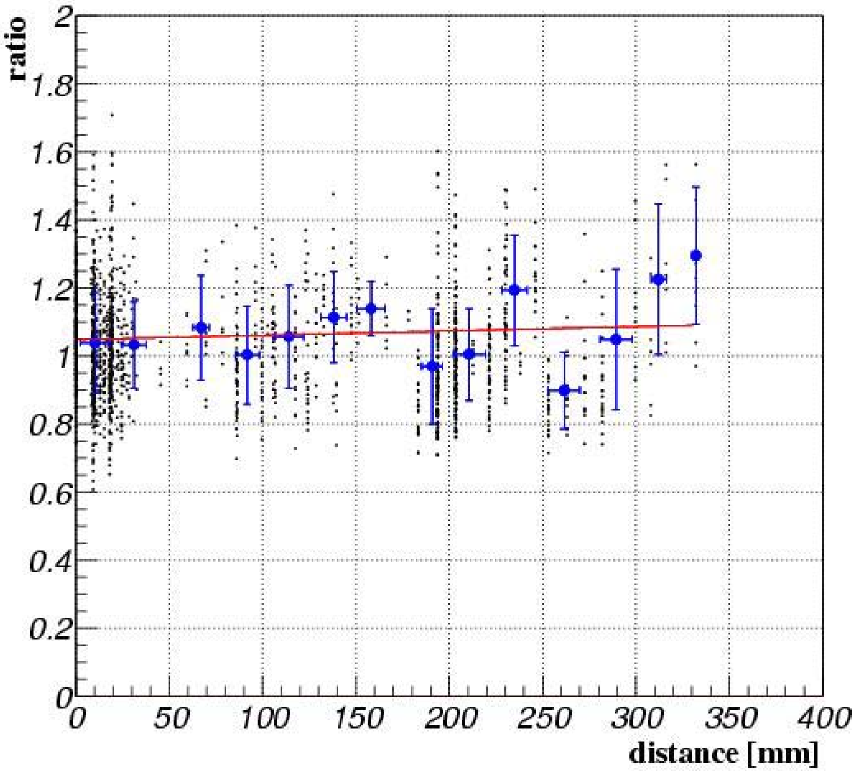


$abs(\cos(\theta_1) - \cos(\theta_2))<0.05$

distance = d2 - d1

ratio = $(Q_2/MC_2) / (Q_1/MC_1)$

Absorption Length Estimation



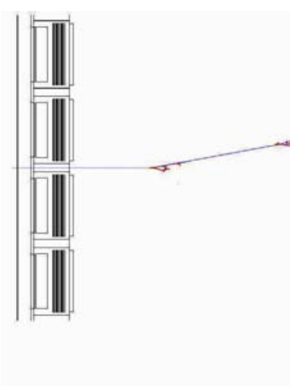
Absorption length	Confidence level
>1 m	99.7 %
>3 m	86.9 %
>5 m	78.7 %
>10 m	70.8 %

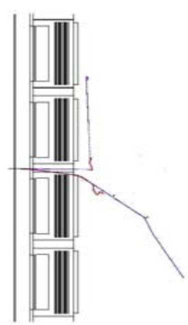
Electron Beam Test at KSR in Uji campus, Kyoto Univ.

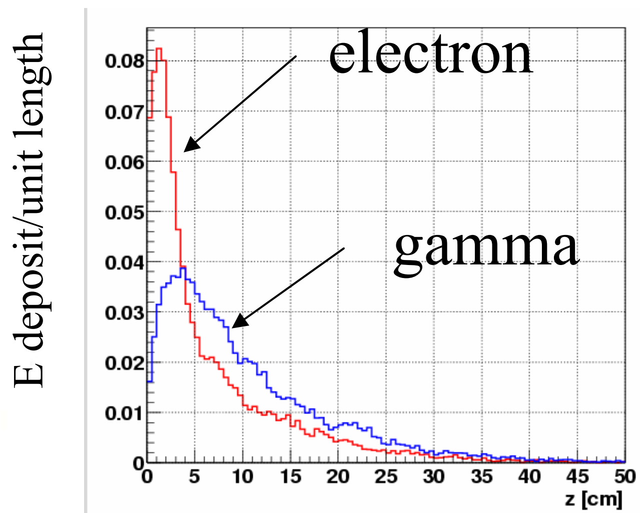
- Performed in Dec. 2002
- First time to operate the detector semi-remotely
  - We realized that
    - We need more mental exercise.
    - We need more remote controls.
      - Diaphragm pump control, circulation flow control…
- Investigation of the detector response to electrons
  - Gamma vs. Electron
    - Similar but not exactly same
- Getting information on the timing resolution of the detector
  - Electron arrival time can be easily determined with plastic scintillation counters.
  - $\sigma_\gamma^2 = \sigma_{electron}^2 + \sigma_{depth}^2$

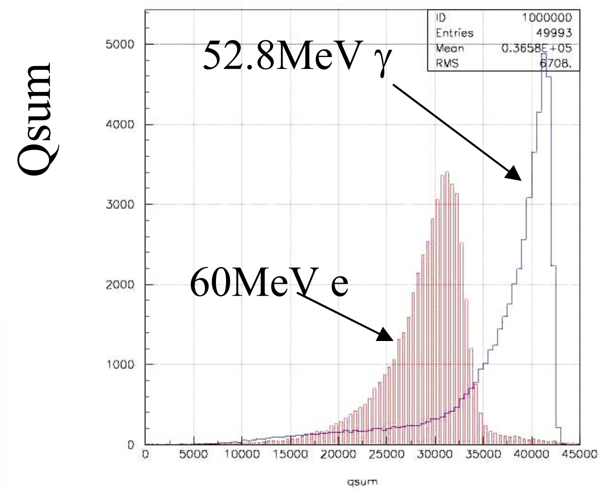
Detector response to electron and gamma

- Energy deposit distribution
  - Electron
  - gamma





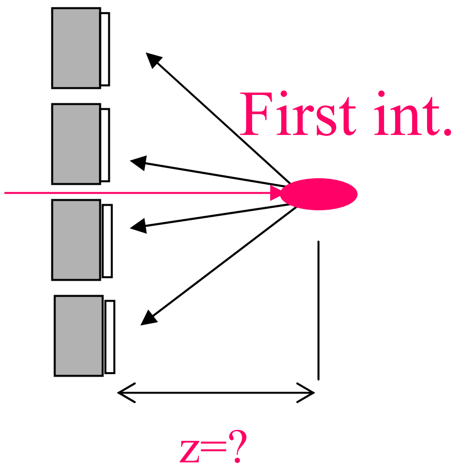


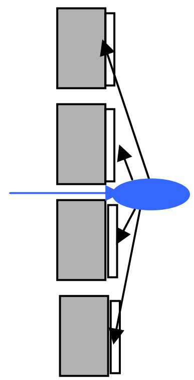


Due to electron Energy loss (15MeV) in material in front of xenon

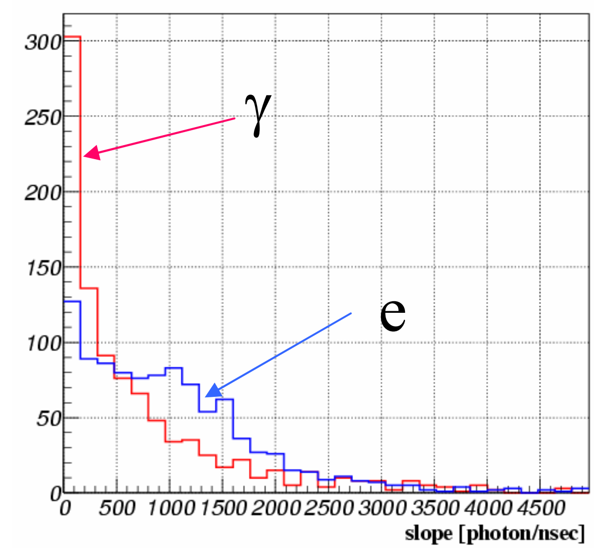
Detector response to Electron and Gamma

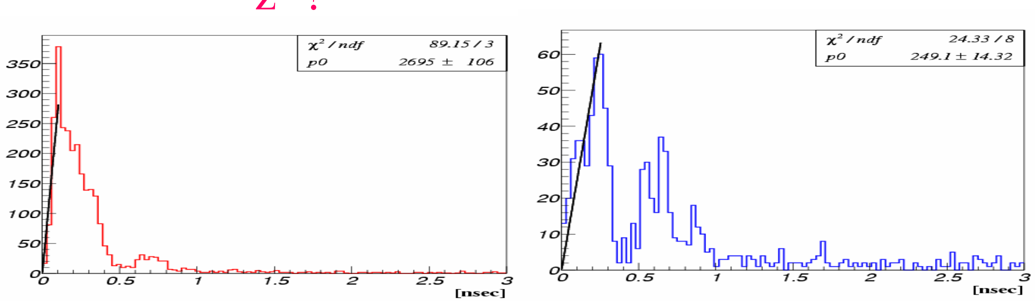
- Electron deposit energy close to the PMTs, while gamma does after the first interaction.





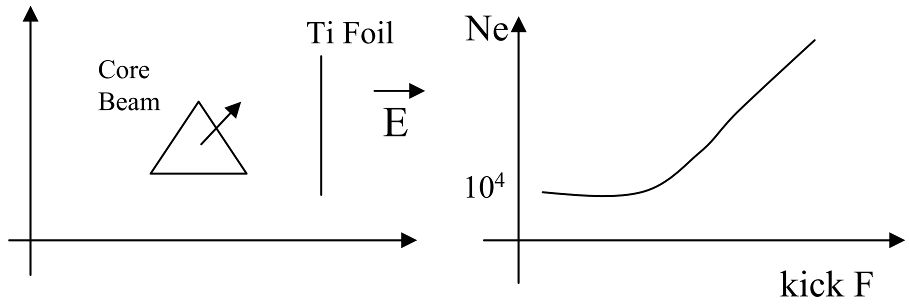
Distribution of the slopes for 1000 events

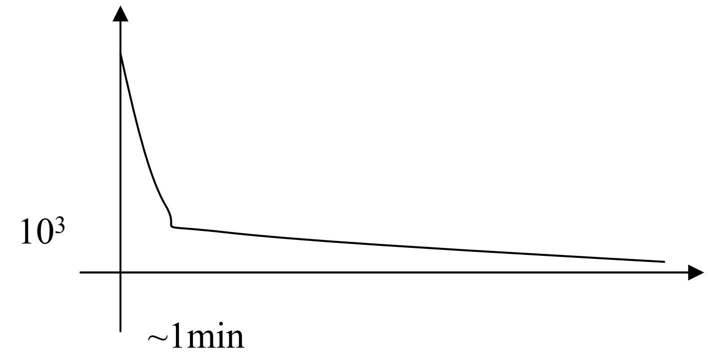




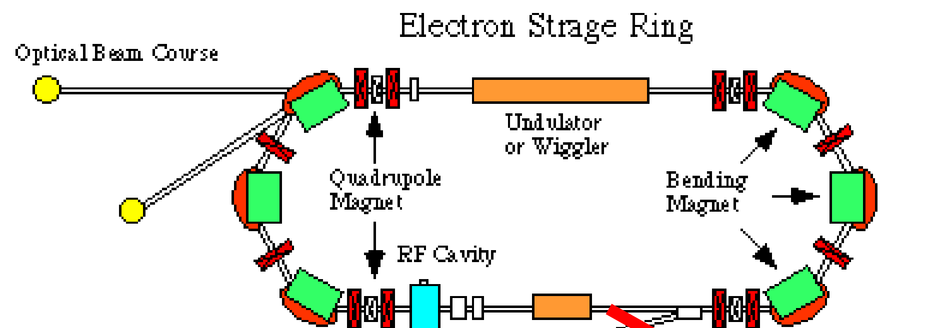
Arrival time distribution to F14 PMT of single γ and e incident

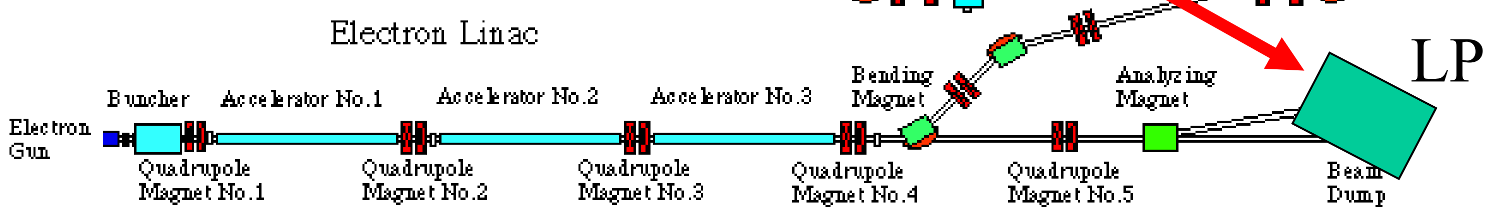
KSR beam





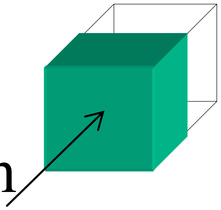
- Injection 10^8~10^7 electrons
- Extraction , 1 min later, 10^3Hz
- Life time 10~20 min
- dE/E < 2×10^{-3}, Spot size ~4mm(2 σ)



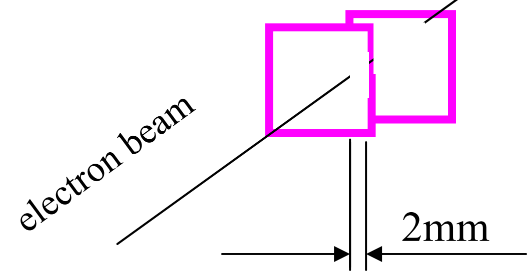


Setup

beam

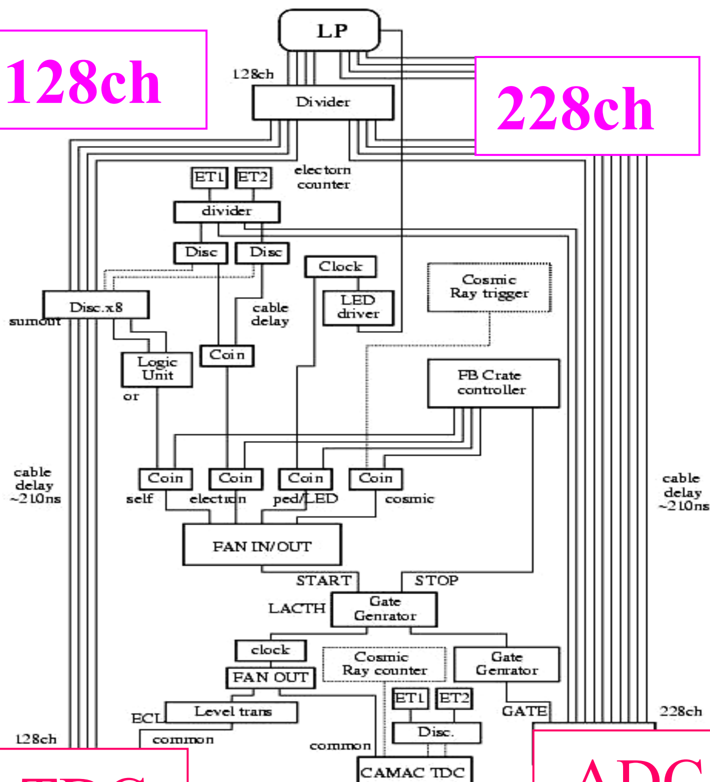


•2 plastic scintillator to define the start timing of electronics and the beam incident position.



128ch

228ch



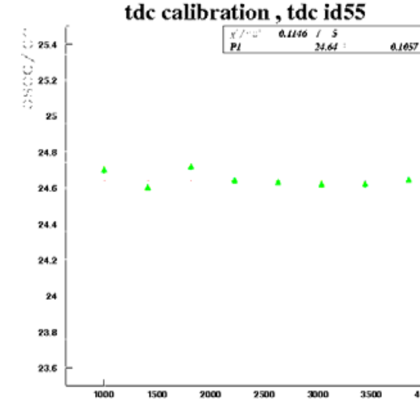
TDC

ADC

•divider

- •Passive
  - •f>>300Mhz
  - •128 ch
- •Active **MACRO**
  - •f = 100 Mhz
  - •128ch
- •Active **BINP amp**
  - •f>300 Mhz
  - •8ch

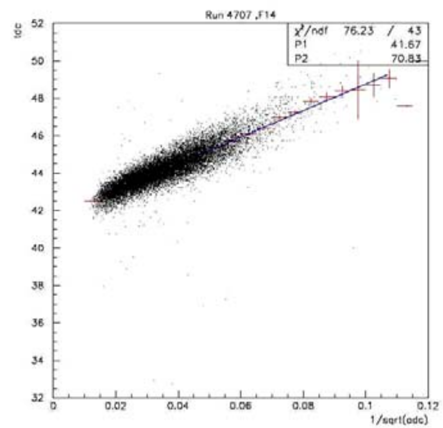
•TDC LeCroy 1877 TDC

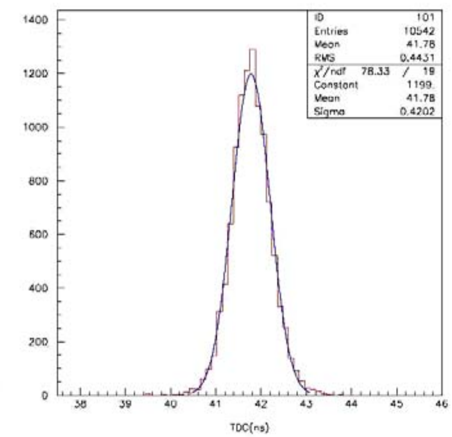


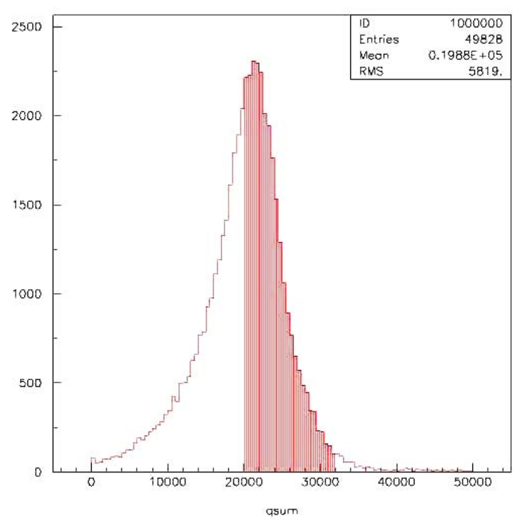
t_{least}~24.7 psec

Analysis

- Slewing correction to each PMT
- Select events 20000 < Npe <35000







Analysis 1 (intrinsic)

•Divide the PMTs into left and right groups.

•Calculate the mean arrival time in each group and compare the difference.

•No need to care of the start timing resolution.

Analysis 2

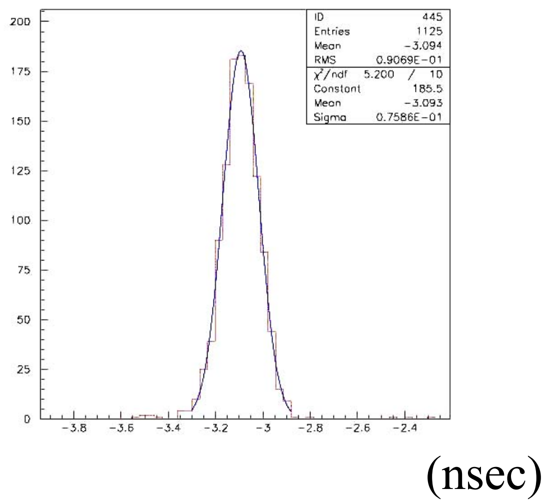
•Compare the arrival time with the start counter

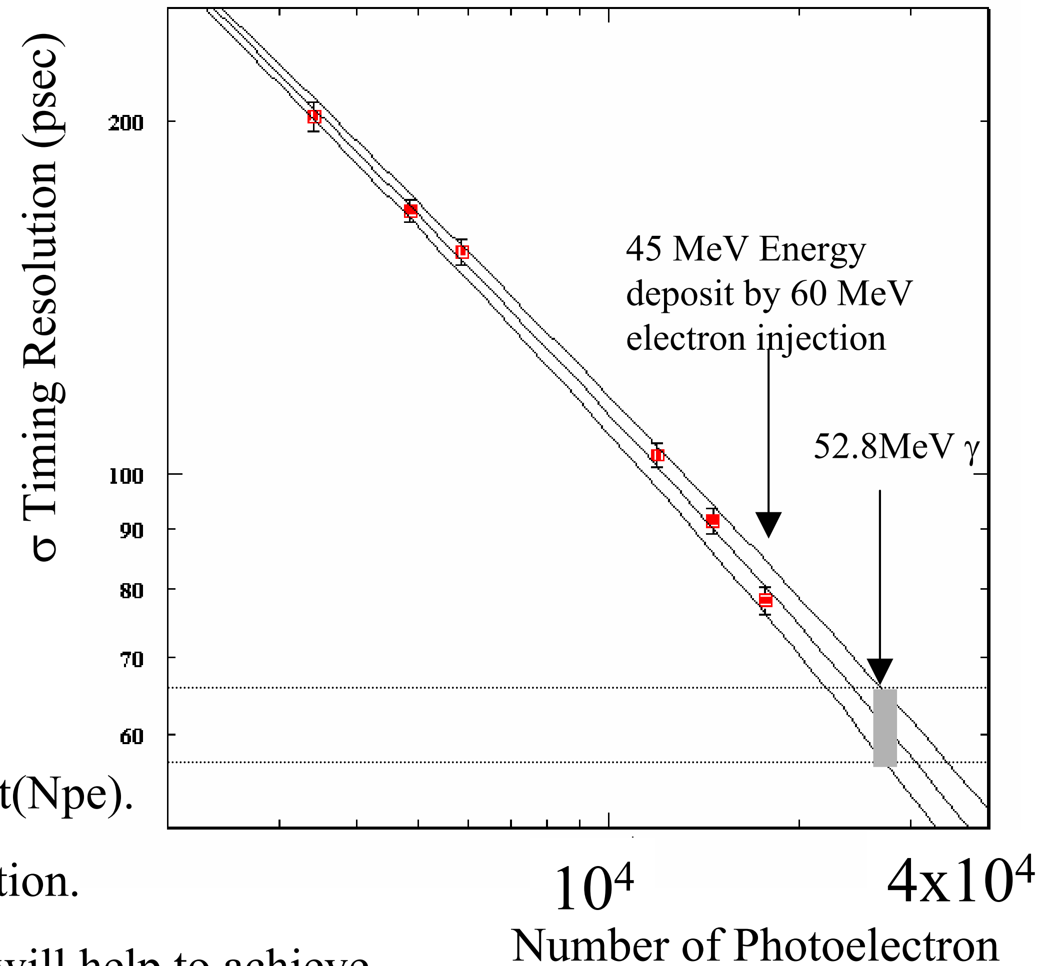
•Contains the start counter timing resolution

•Contains electron timing jitter in the material

Preliminary result

σ=75.6±2.0ps

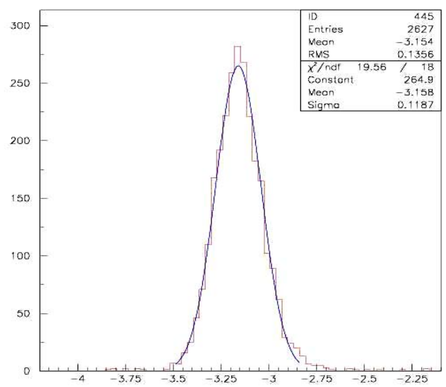




- Resolution improves in proportion to 1/sqrt(Npe).
- For 52.8 MeV γ, σ~60 psec⊕depth resolution.
- QE improvement and wave-form analysis will help to achieve better resolution.

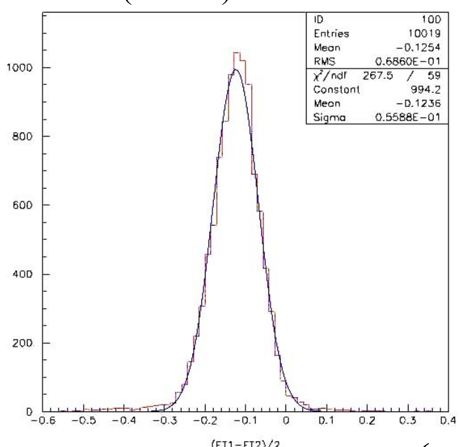
Preliminary results(2)

σ=118.7±2.0ps

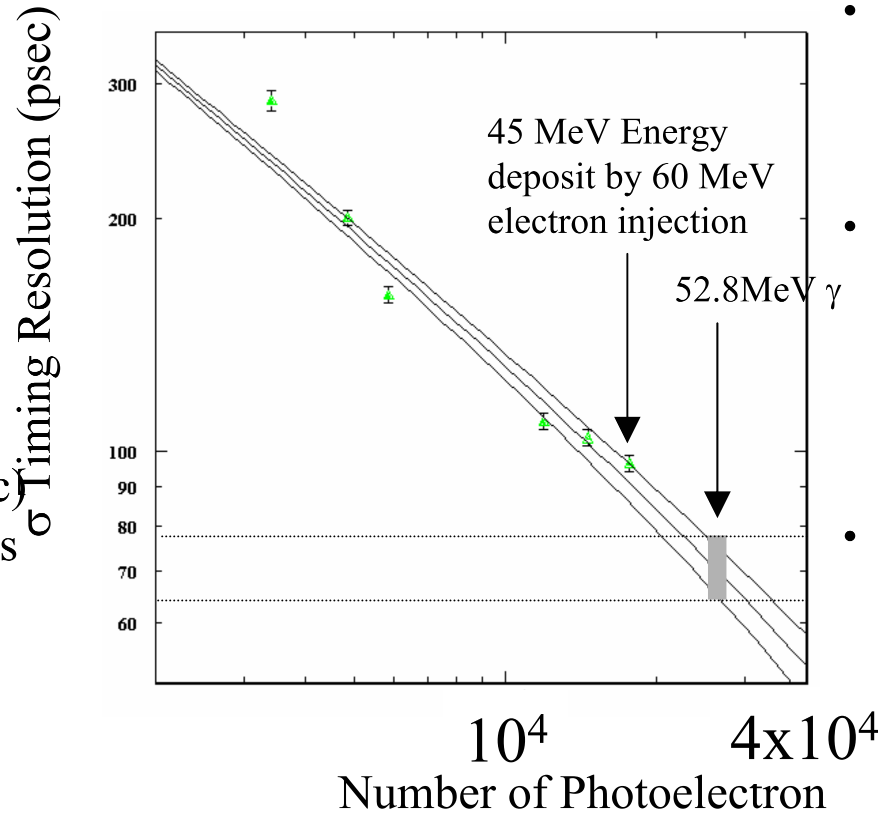


(nsec)

$\sigma_{start}=\sigma_{(et1-et2)/2}$=55.9±0.5ps



(nsec)

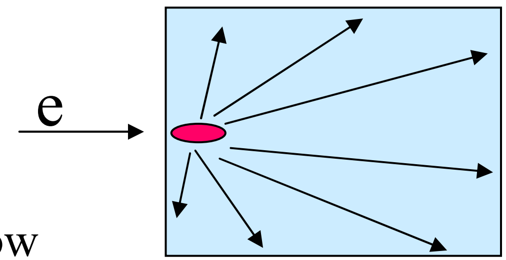


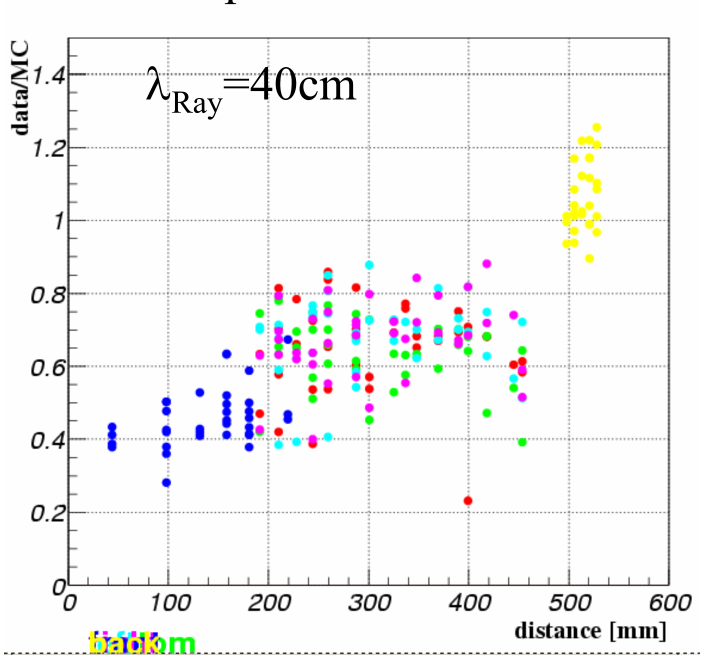
σ_0=104.7±2.0ps

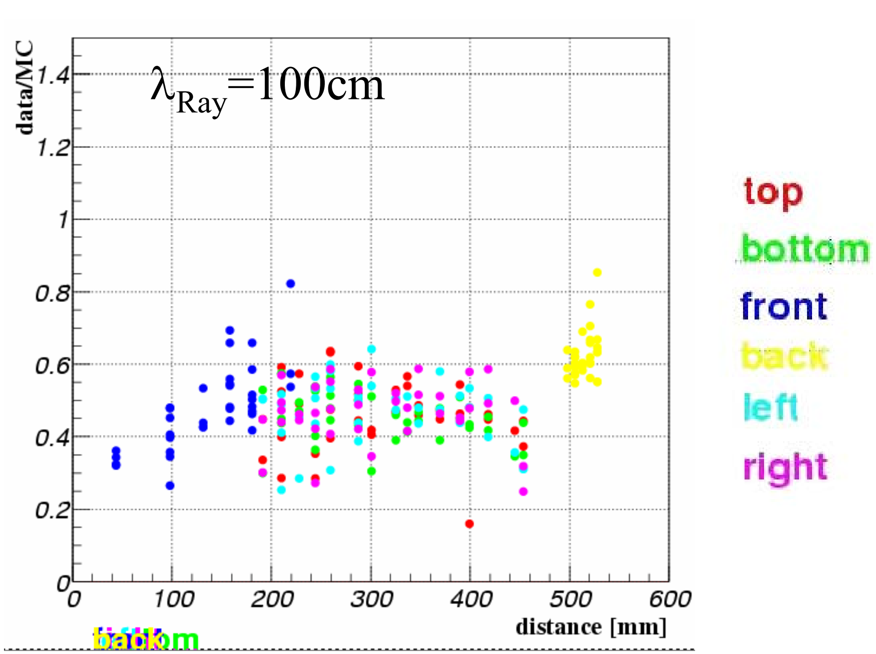
- Simple extrapolation indicates 70 psec(s) (⊕ depth resolution) for 52.8 MeV γ
- Other possible contributions from
  - Timing jitter in start signal for electronics
  - Cross talk
- Detailed analysis is in progress.

Absorption Length Estimation using Electron Data?

- λabs = inf cm, λ_{Ray}=40cm , 100 cm
- Reflection on the PMT window:
  - Fresnel reflection formula
  - n_{xenon} = 1.57 n_{silica}=1.49
- No absorption effect in the PMT window







Future Plan of LP R&D

- Nuclear Emission gamma @University of Tsukuba
  - Preliminary test using a 5inch NaI crystal on 17,18/Feb
    - ^{7}Li(p, γ)^{8}Be Ep=440keV, σ=~5mb, Eγ=17.64MeV, Γ_0=16.7eV
    - **^{11}B(p, γ)^{12}C Ep=7.2 MeV, σ=120μb, Eγ=22.6MeV , Γ_0=2500eV 1.26um 100 nA → 1kHz reaction rate**
    - ^{9}Be(^{3}He, γ)^{12}C E_{he}=6.51MeV, σ=1.5μb, Eγ=31.16MeV , Γ_0=2.2MeV
- Inverse Compton gamma @TERAS
  - Vacuum problem in wave guides
  - One month for full recovery
  - Next beam time will be after March
- $\pi^0 \to \gamma\gamma$ from $\pi^- p \to n\pi^0$ @PSI
  - Beam time in autumn requested

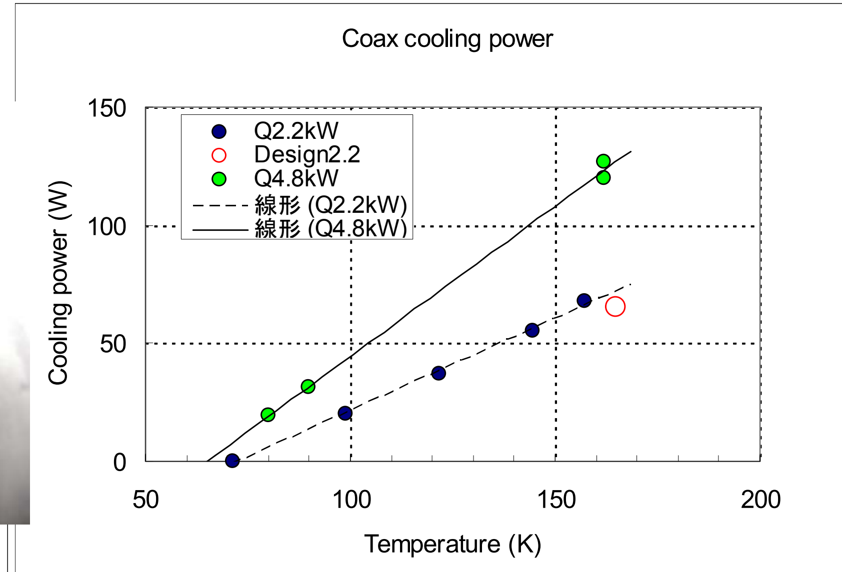
Refrigeration and Purification

- **Pulse tube refrigerator**

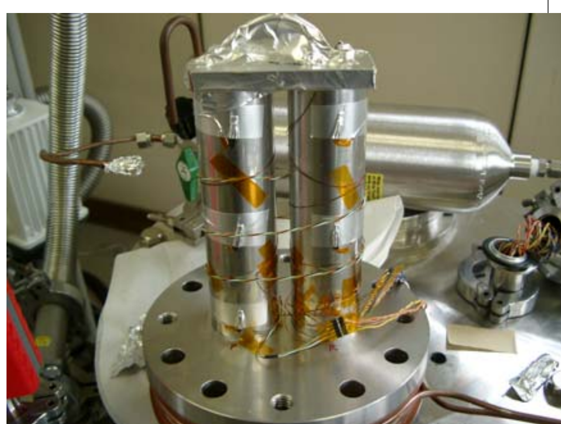
- **Liquid phase purification**

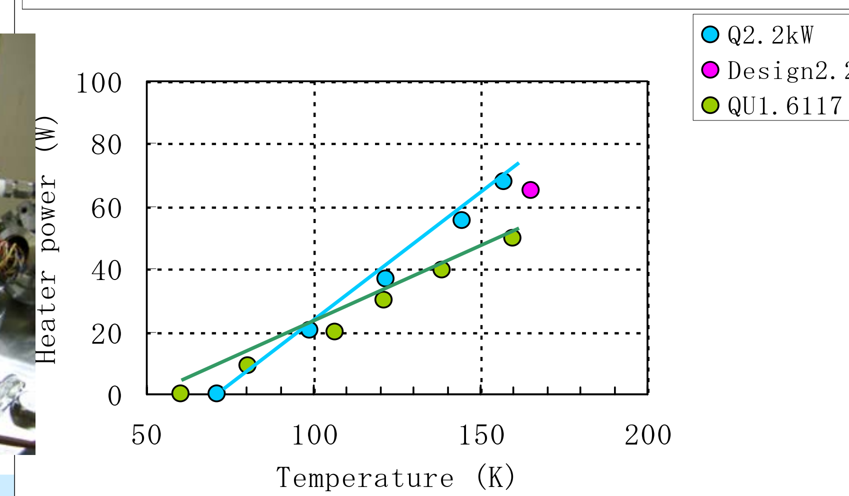
Pulse Tube Refrigerator

- Coaxial
  - COP 3%
  - 2.2/4.8 kW Compressor
  - 2.2kHz operation



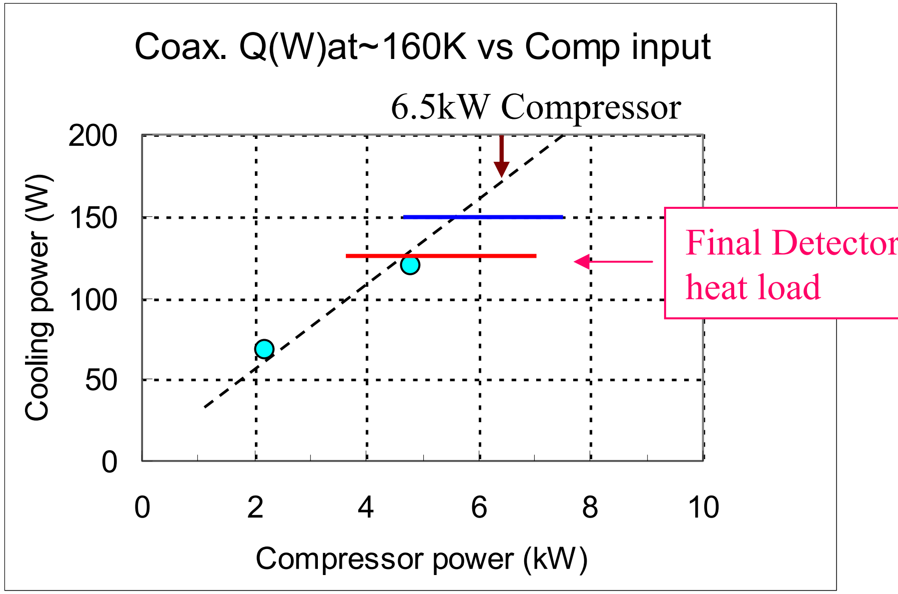
- U-shape
  - COP 3%
  - Not too much improvement
  - R&D is going on for better performance





Pulse Tube Refrigerator

1. **Coaxial**
   -Highly reliable by LP experience
   -Enough cooling power



2. **U-shape**
   -Not too much improvement
   -Still under R&D for large power

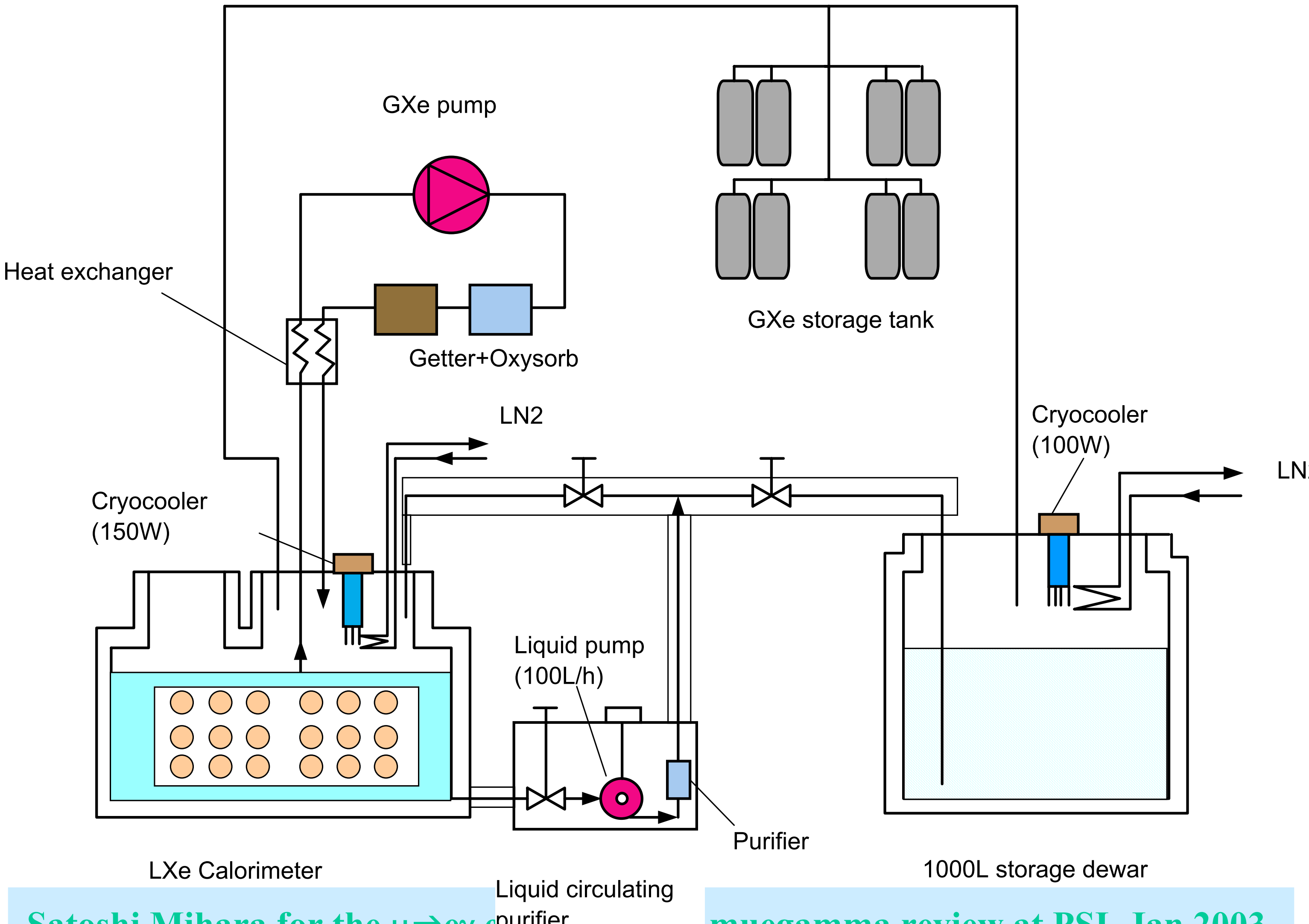
- Fabricate two coaxial pulse tube refrigerator
- One for main cryostat, one for spare or for storage dewar

Liquid Pump

1. Commercially available
   -Barber-Nichols Inc. centrifugal pump
   -100L/h,   ~0.1Mpa
   -applied to 9000L Kr calorimeter at CERN
   (1000L/h. 0.2MPa)

2. Hand made pump in Japan under R&D
   -centrifugal pump
   -using immersible DC motor (contamination?)
   - 10-50L/h,   ~0.1MPa

Purification Scheme

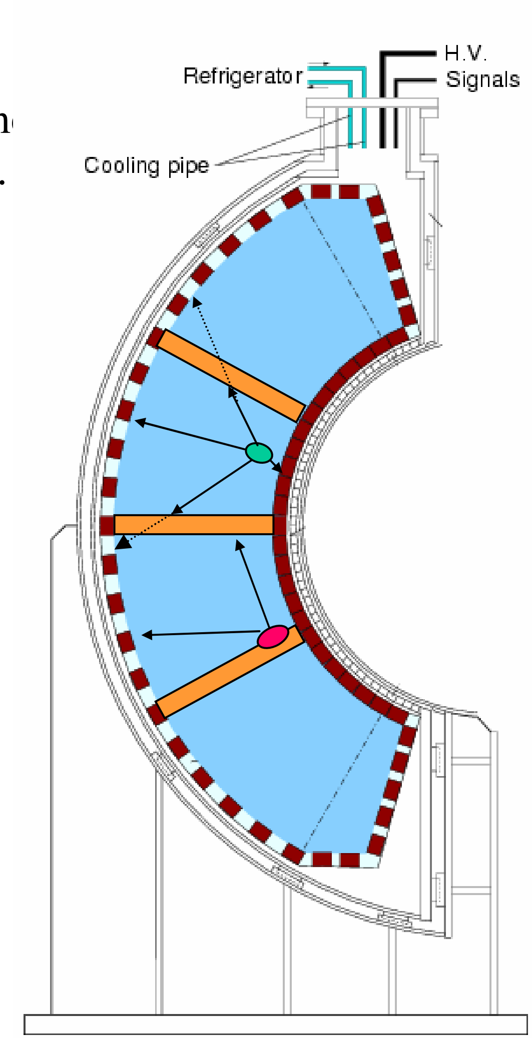


Final Detector

- **Segmentation**
  - **by PMT layers**
  - **by reflectors**
- **QE dependence, Shape → Signorelli-san**

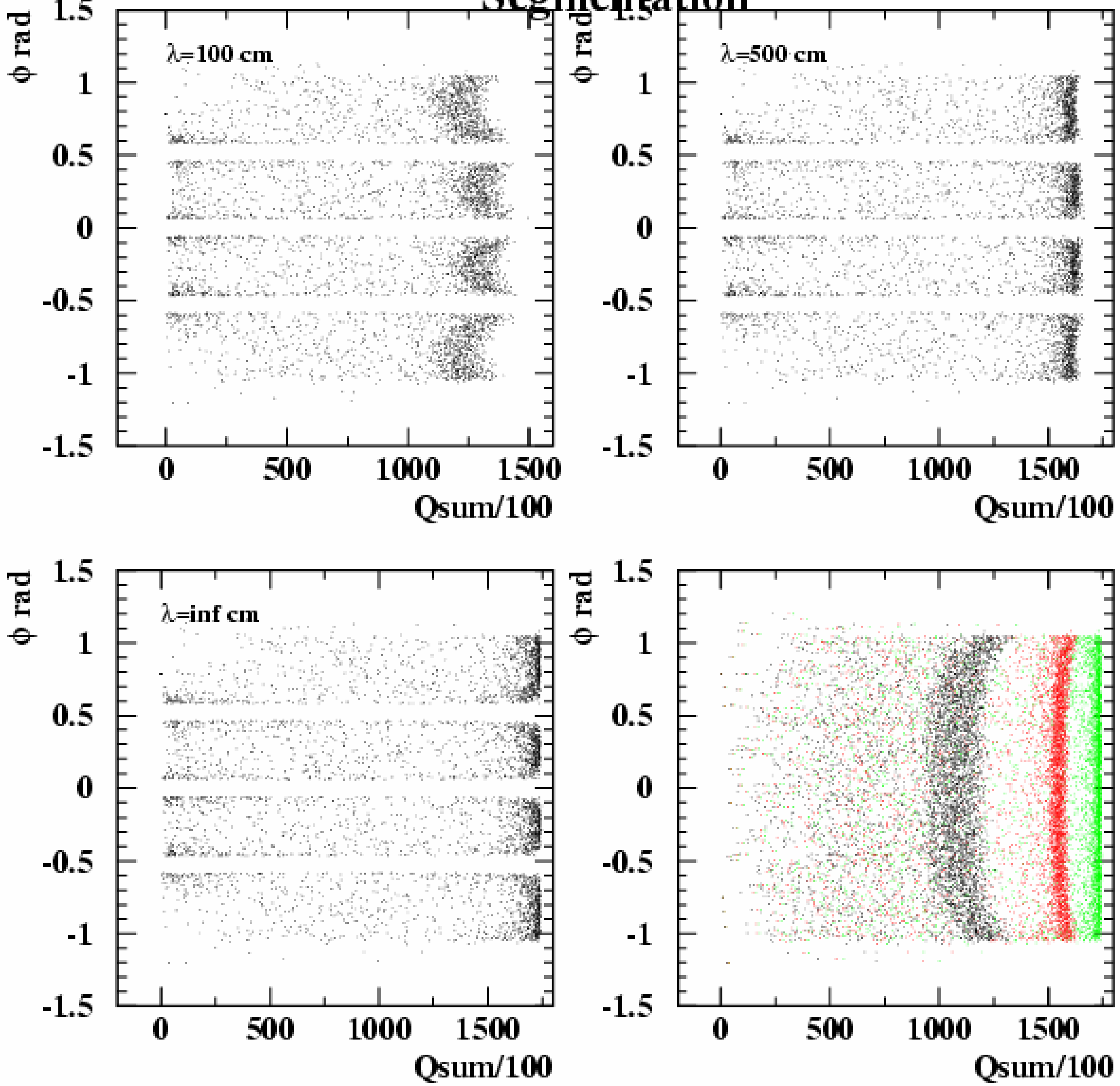
Segmentation by PMT layers

- 6 layers of PMTs inserted at –60, 0, and 60 degrees
  - PMTs are placed on all walls **with maximum density** to keep the homogeneity same in both segmented and non-segmented cases.
  - Resolution is estimated by using simple Qsum
- We can observe more pe in case of short λ_{abs}
  - λ_{abs}=1m: resolution 15.4%→11%
- We loose efficiency due to the dead volume occupied by inserted layers of PMTs in any case.
- In case of long λ_{abs}, energy leakage in the PMT layers cause deterioration of resolution in addition to the efficiency loss.



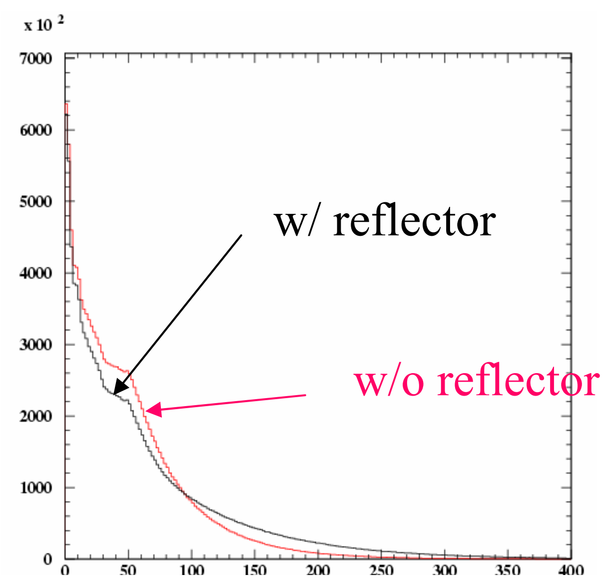
λabs	non-segmented	segmented	Eff loss(relative)
1m	**15.4%**	**9.7%**	**11%**
5m	**3.7%**	**3.7%**	**28%**
Inf m	**1.5%**	**2.0%**	**44%**

Segmentation



Segmentation by Reflectors

- Reflector does not help to reduce the flight length of scintillation light.
- Reflection efficiency (< 100%) can cause nonuniformity.

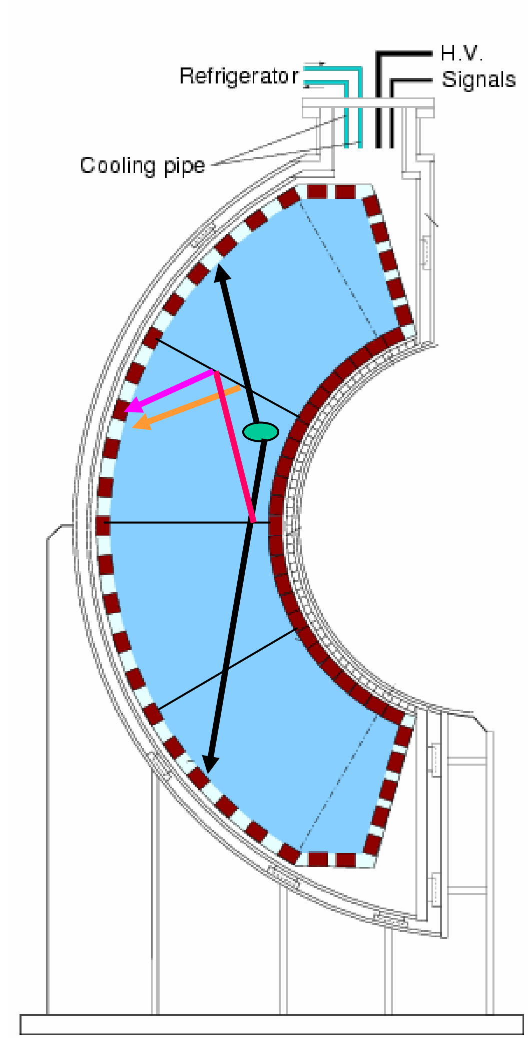


λ_{Ray}=30cm

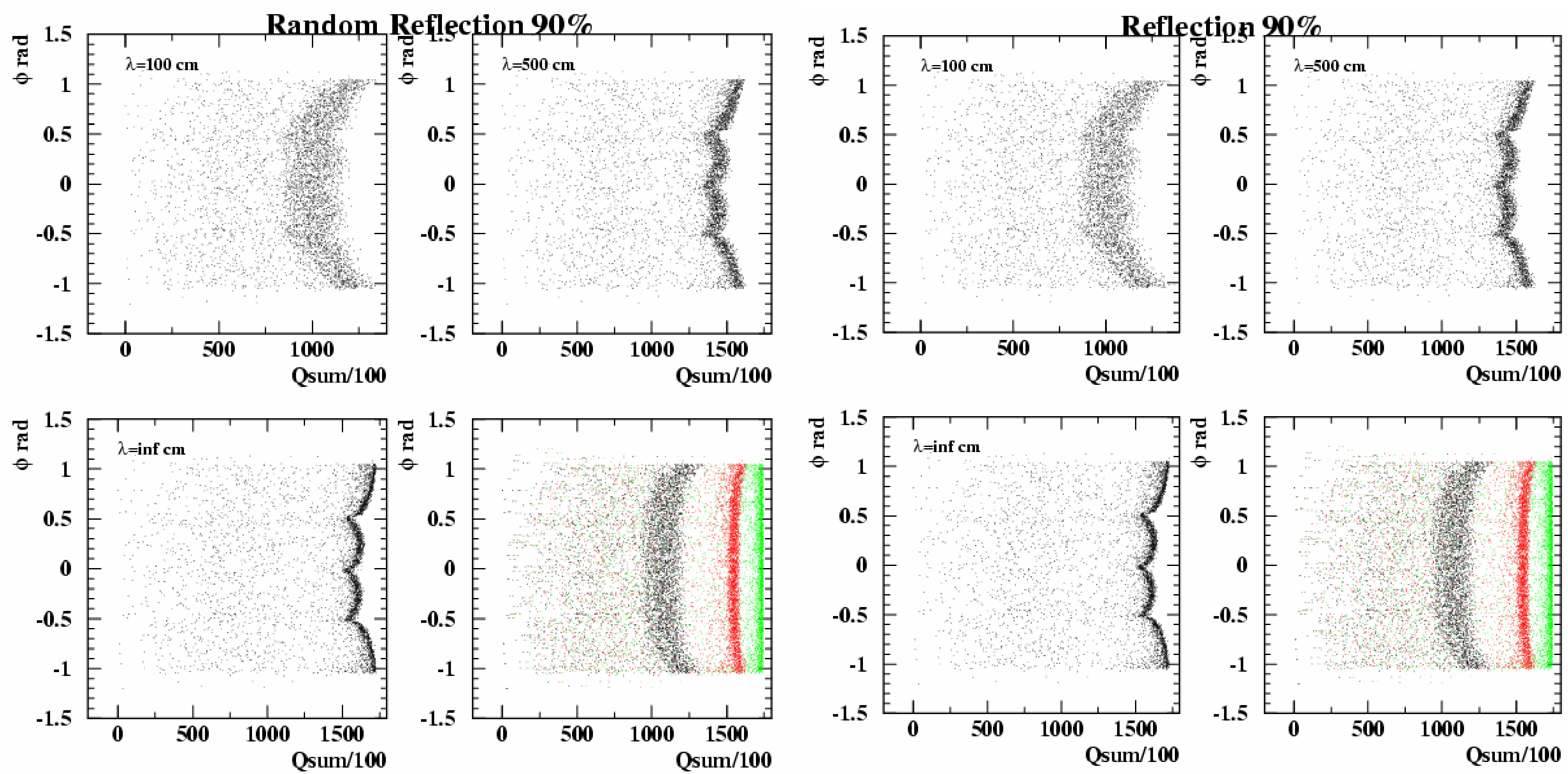
Ref eff = 100%

No absoption

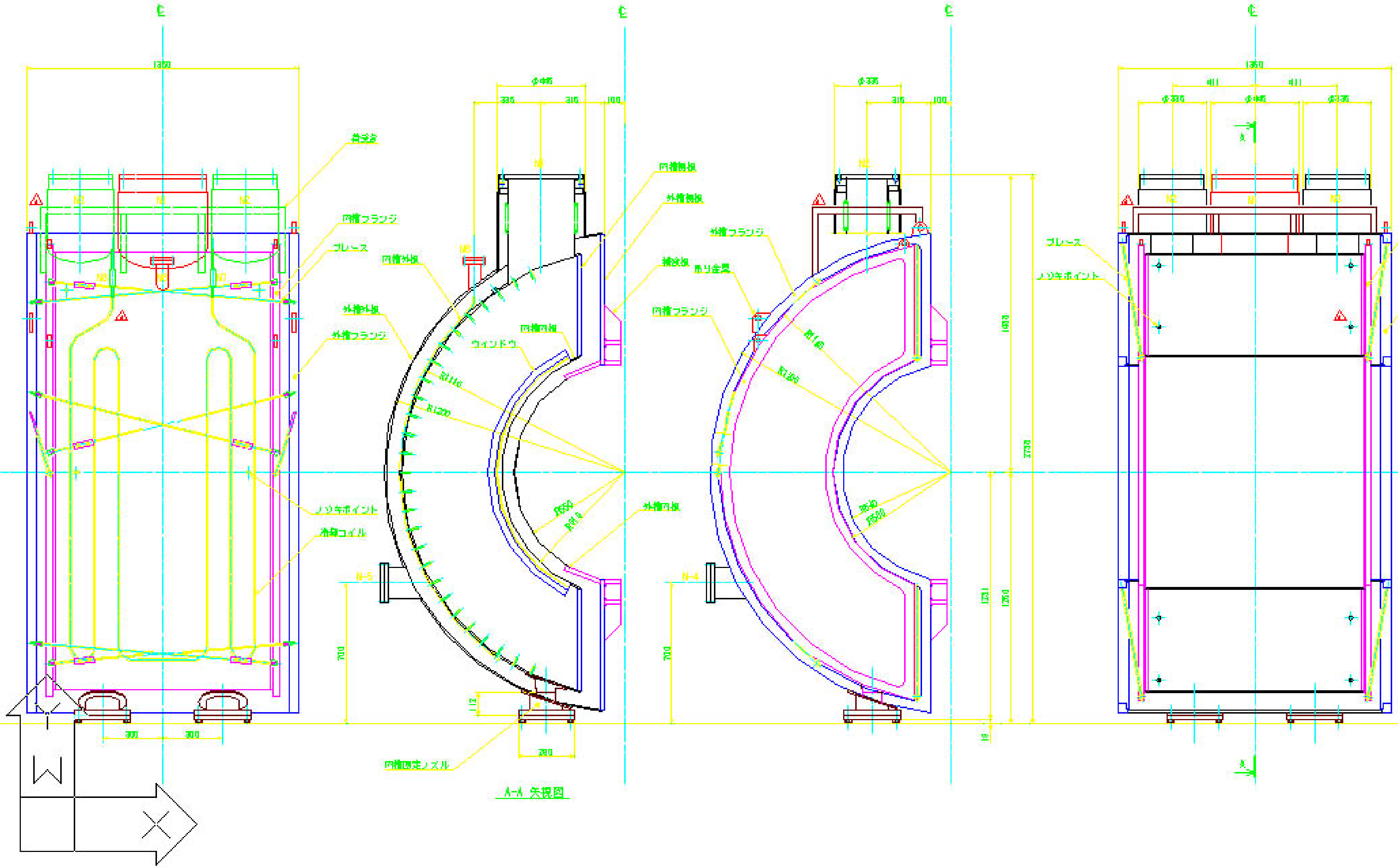
Flight length distribution of scintillation light



Segmentation by Reflectors[2]



Cryostat design



Summary

- Large prototype
  - Electron beam test was performed in Dec 2002.
    - Data analysis is in progress.
  - γ beam tests are scheduled in 2003
- Refrigerator
  - Co-axial
    - Highly reliable in LP experience.
    - Performance test with a 6.5kW compressor
  - U-shape
    - Not too much improvement
    - R&D is still ongoing for higher power
- Liquid Phase Purification
  - Low temperature liquid pump
- Final Detector
  - Segmentation by PMT layers and reflectors.
  - QE dependence and detector shape
  - Cryostat design is ready for construction.

W-value