Photon Detector

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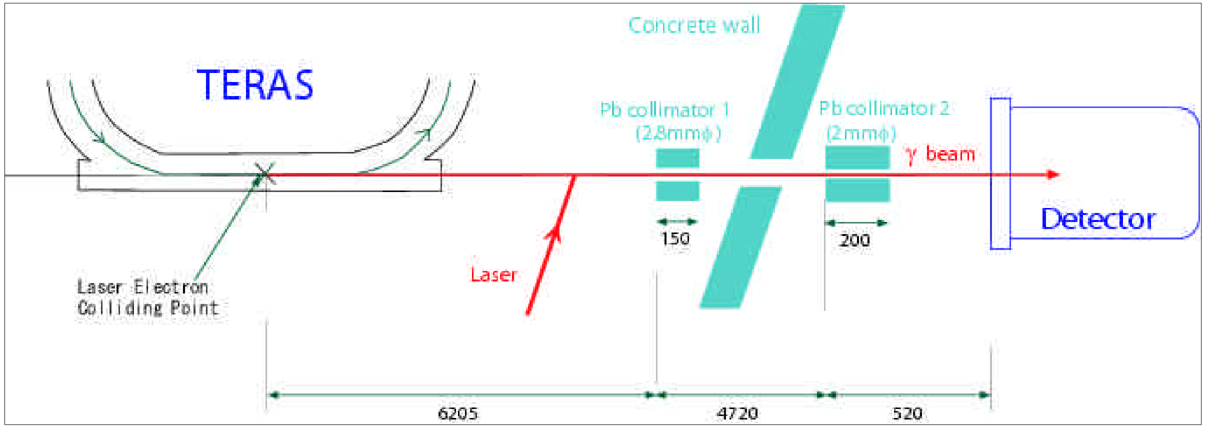
1. **Large Prototype Study**
   - ✍ Gamma beam test
   - ✍ Xenon purification
   - ✍ Absorption length measurements
2. **Other related R&D**
   - ✍ PMT development
   - ✍ Purity monitor
3. **Final Photon Detector**
   - ✍ Expected performance (MC) ✍ Giovanni
   - ✍ Calibration methods
   - ✍ Cryogenics design ✍ Tom
4. **Schedule**

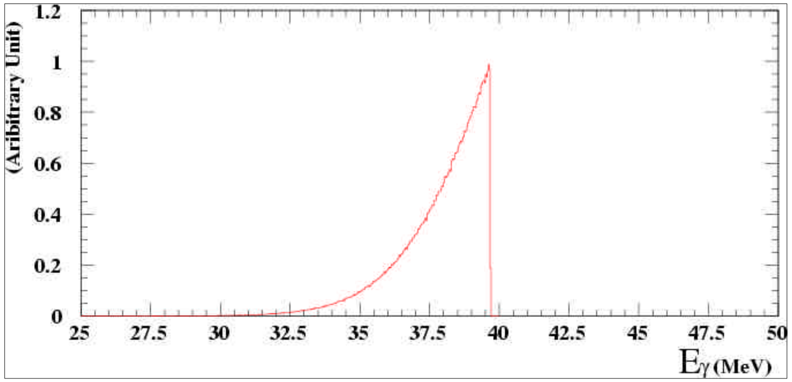
Gamma beam test

? beam at TERAS
Analysis

40MeV Compton Gamma at TERAS



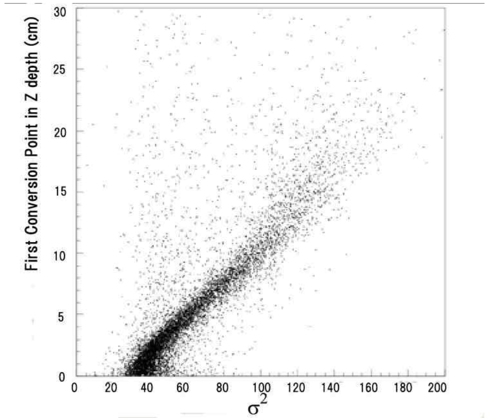
- Electron Energy:762MeV.
- Max. current 200mA.
- 40 MeV (20MeV, and 10MeV) Compton ? provided.
- Beam test in Feb. 2002 for 2 weeks

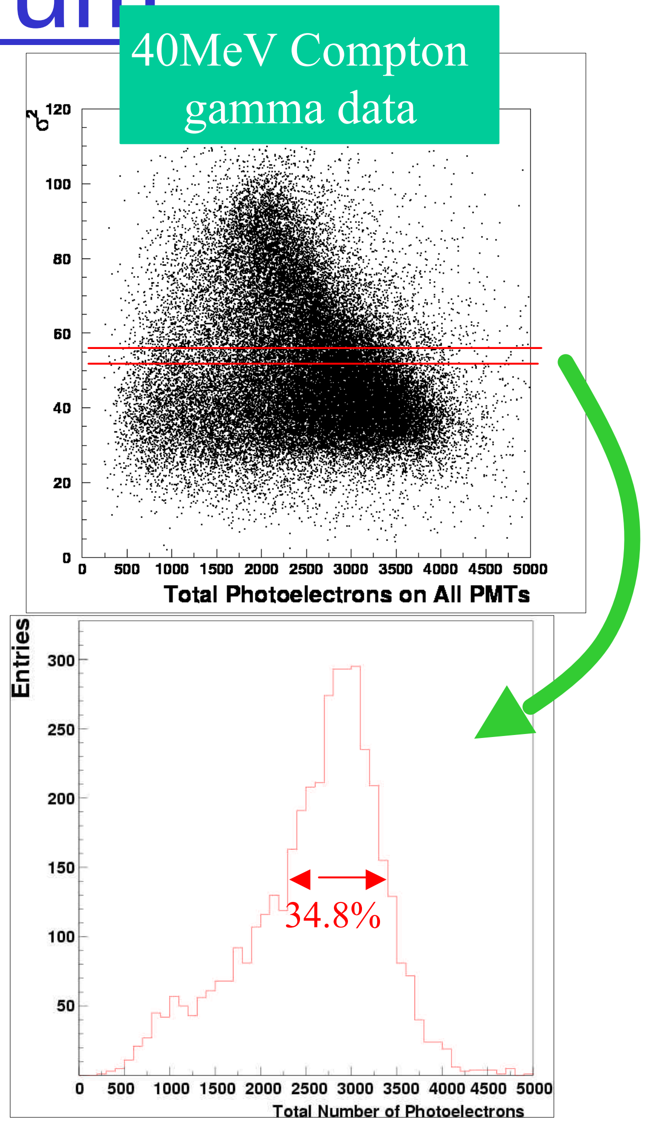


Energy Spectrum

- ?^{2} depth parameter:

$$\sigma^2 = \frac{\sum n_{pe}(i)x(i)^2 + n_{pe}(i)y(i)^2}{\sum n_{pe}(i)} - \left(\frac{\sum n_{pe}(i)x(i) + n_{pe}(i)y(i)}{\sum n_{pe}(i)}\right)^2$$

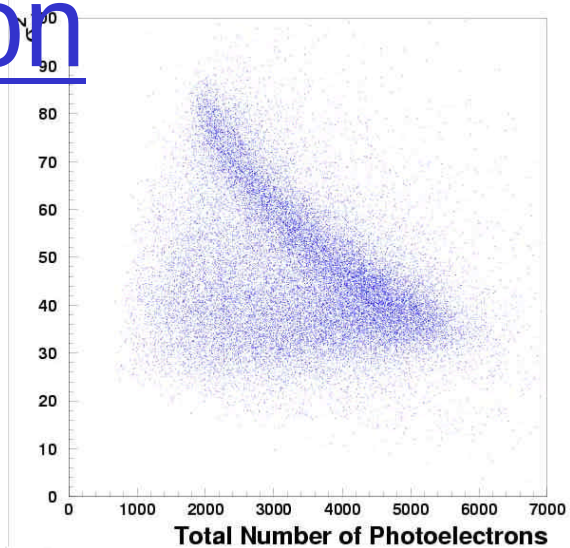


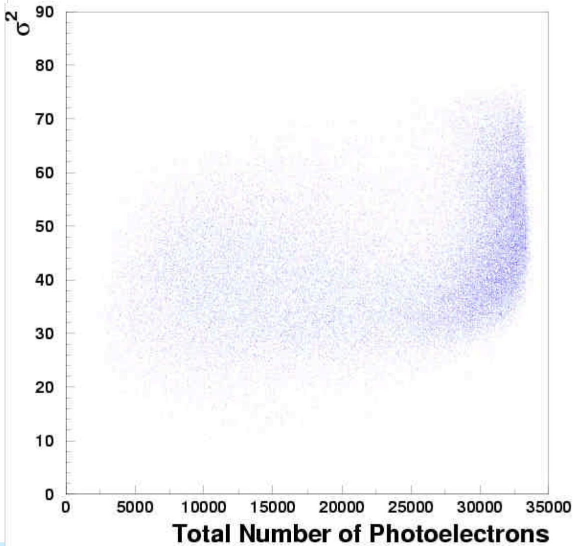


- Correlation between ?^{2} and N_{pe}
  ✍ short ?$_{abs}$ as explained later
- In the region of 50<?^{2}<55
  34.8%(FWHM) including the energy spread of Compton ?

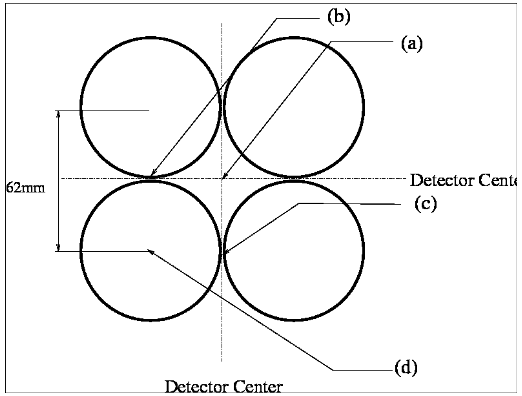
Comparison with MC with absorption

- Strong correlation between the ?^{2} and N_{pe} can be explained by introducing absorption effect into MC.
- MC with 7cm ?$_{abs}$ can explain the data.
- According to MC, ?$_{abs}$ longer than 1m is necessary to achieve the resolution of a few % order.

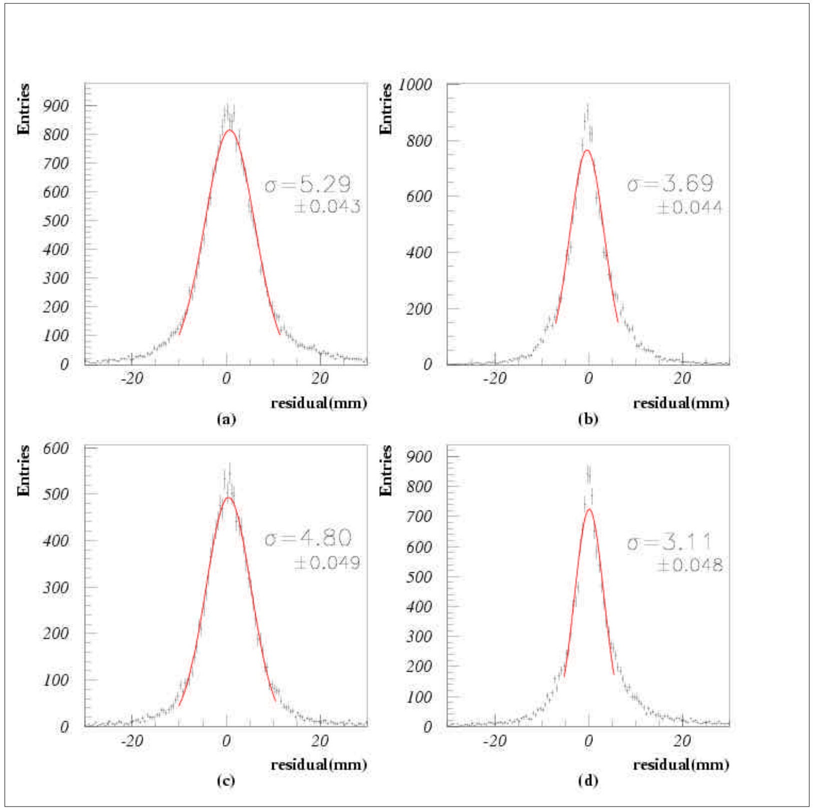




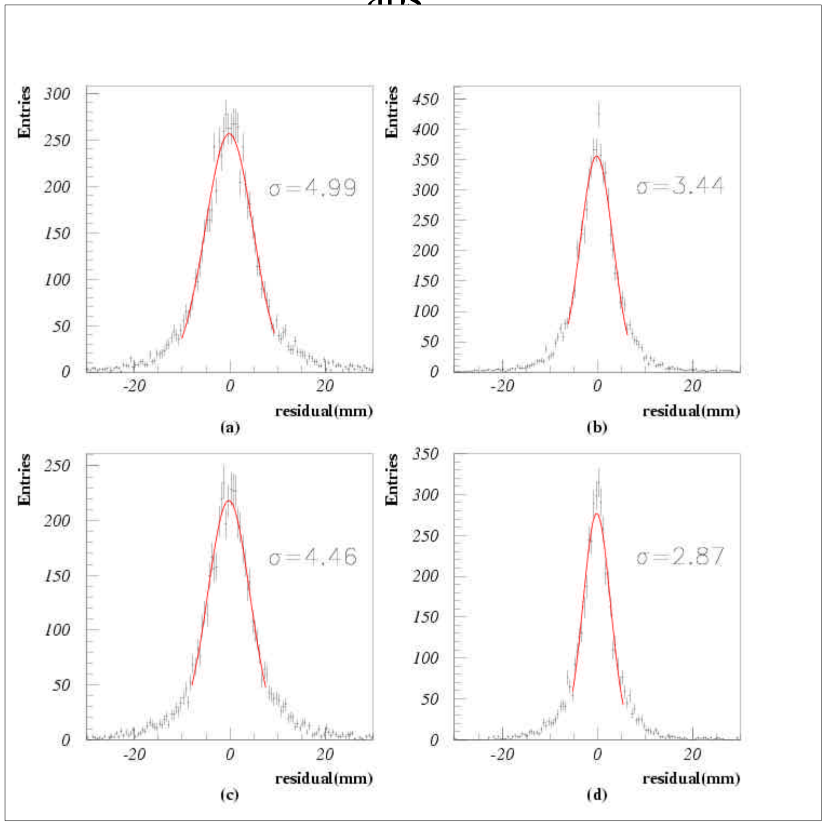
Position Resolution



- Data 40MeV Compton ?

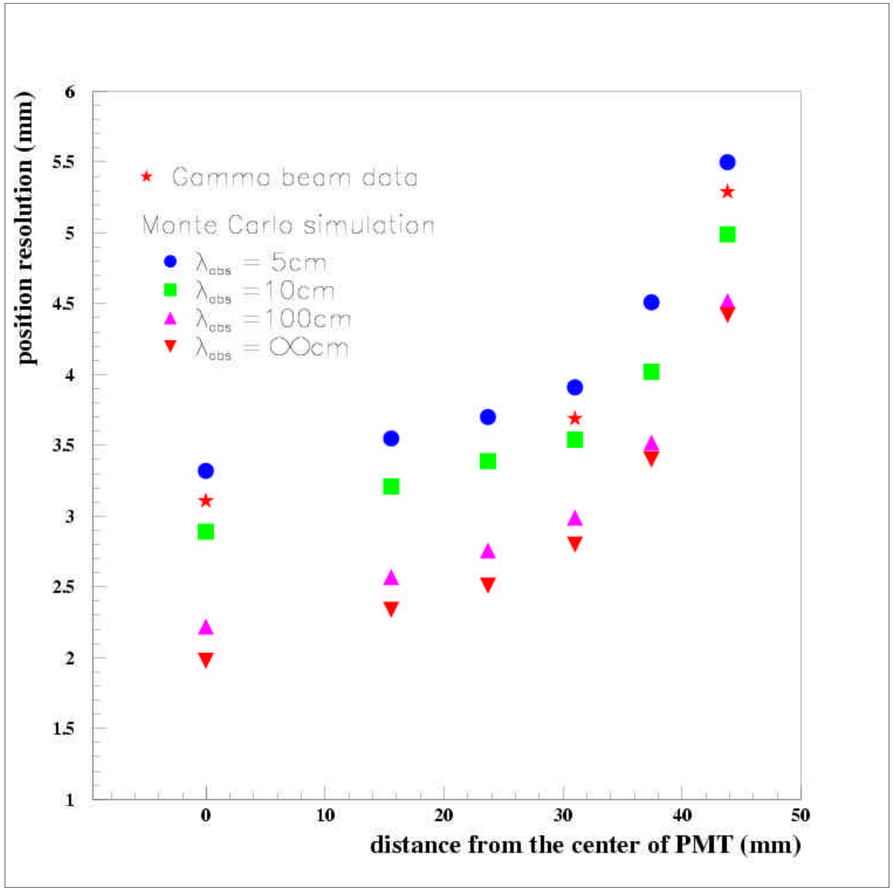


- MC with ?$_{abs}$=10cm



Comparison with MC

- MC
  - ? $_{abs}$=5,10,100,**8** cm
  - ? $_{abs}$=30cm
- Obtained resolutions agree with MC predictions including 5< ? $_{abs}$ <10cm.
- Further improvement expected with longer absorption length.

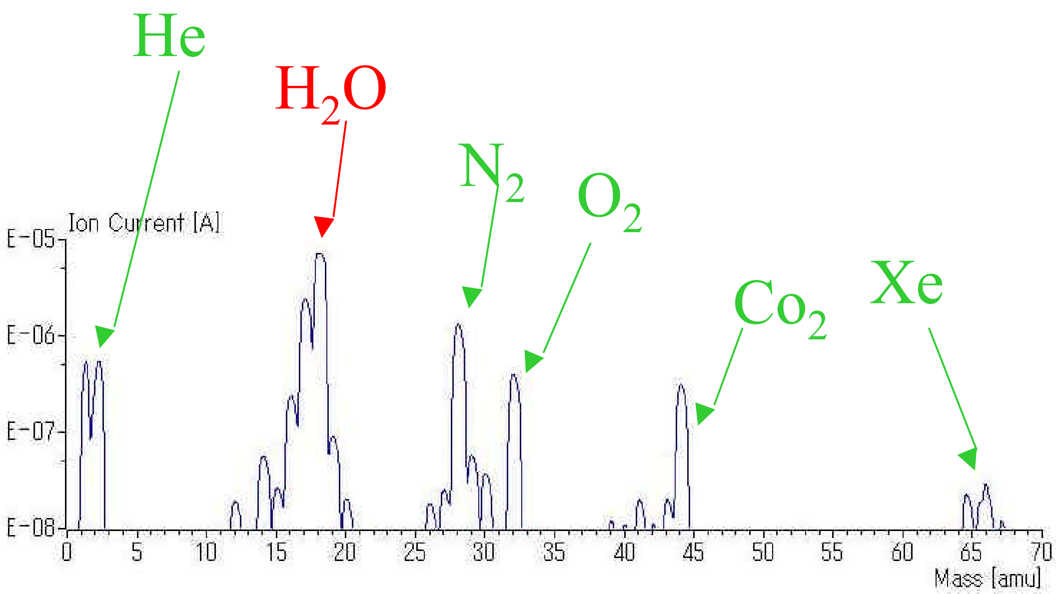


Xenon Purification

RGA with a mass spectrometer

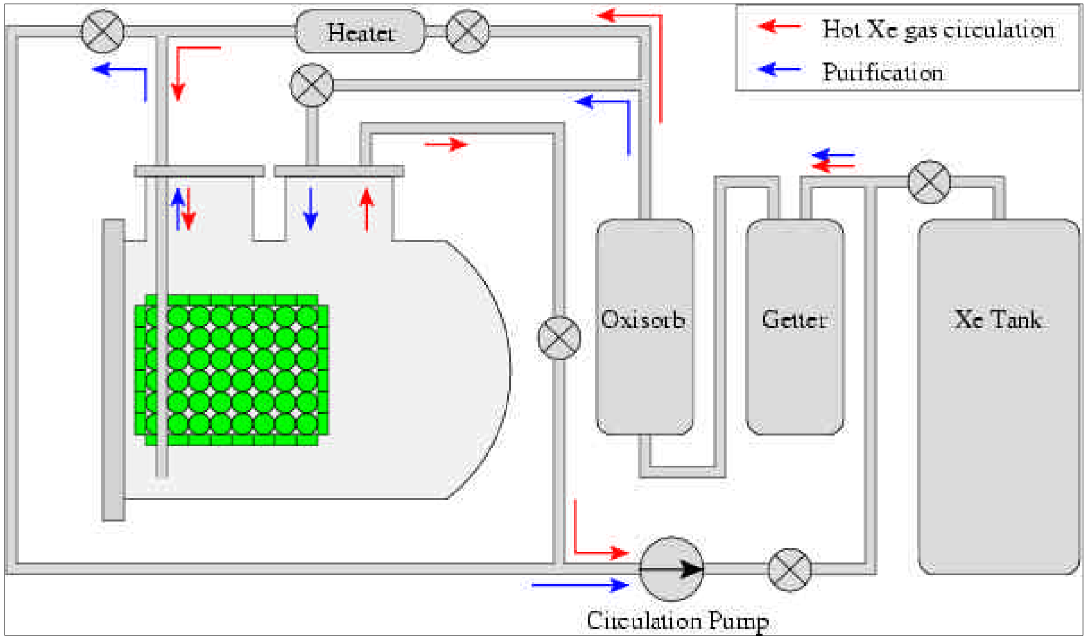
- Remaining Gas Analysis (RGA) for investigating what causes short absorption length in gamma beam test.
- Remaining gas in the chamber was sampled to the analyzing section.

- Vacuum level
  - LP Chamber 2.0x10-[2]Pa
  - Analyzing section 2.0x10-[3]Pa



Purification System

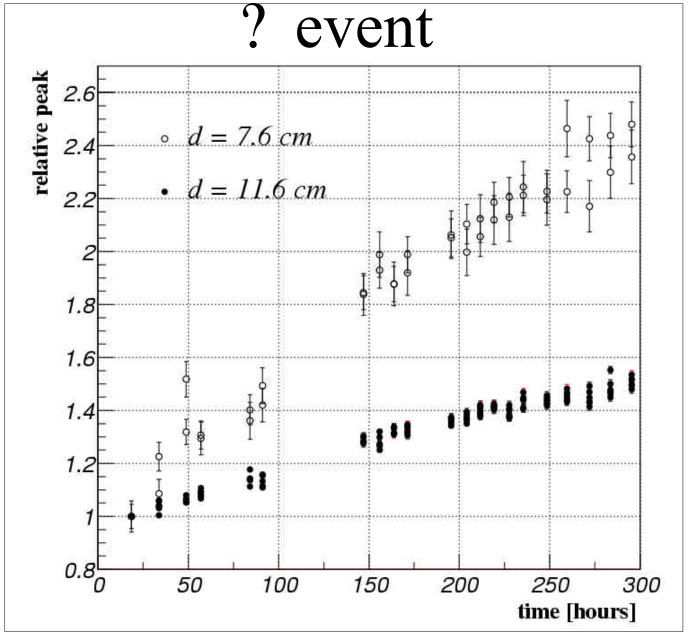
- Xenon extracted from the chamber is purified by passing through the getter.
- Purified xenon is returned to the chamber and liquefied again.
- Circulation speed 10-12cc/minute

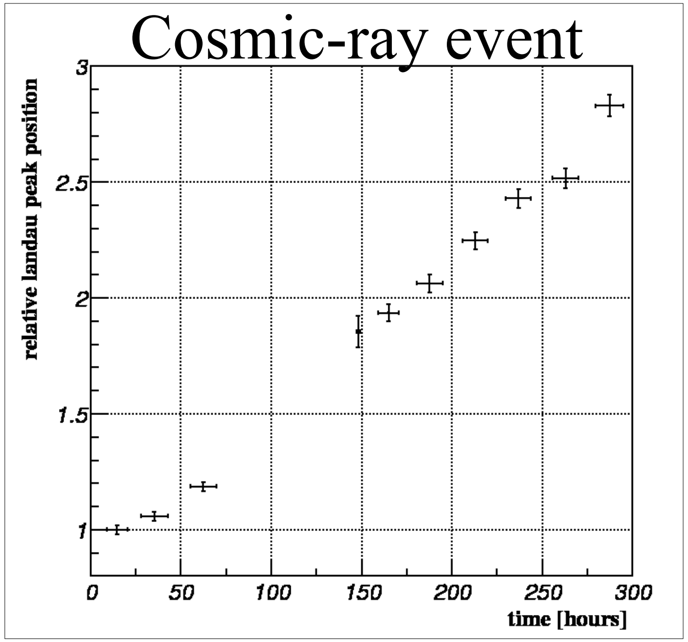


Performance of the purification

- Modeling: $$N(r,t) = N_\infty exp(\frac{r}{\lambda_0} exp(\frac{t}{\tau}))$$

if no continuous outgassing

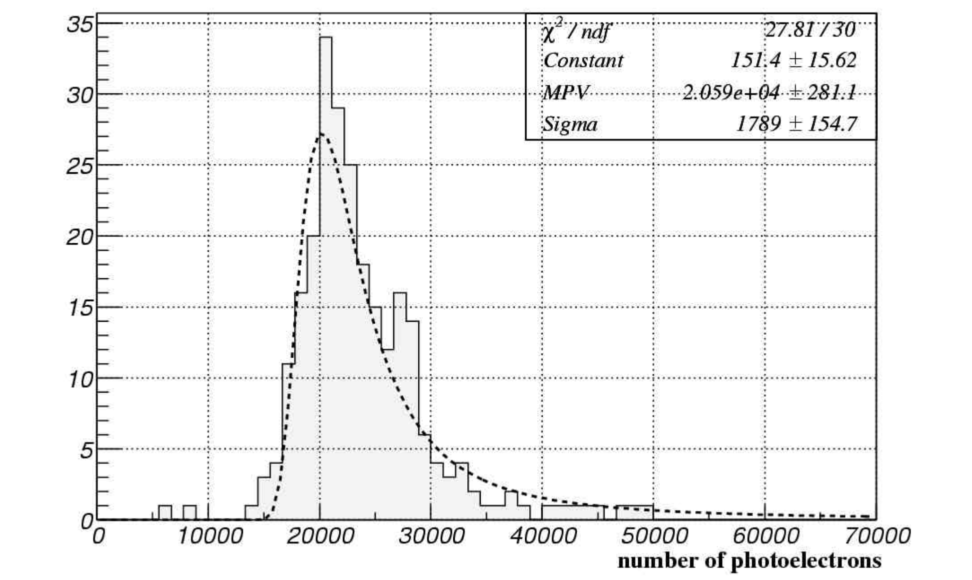




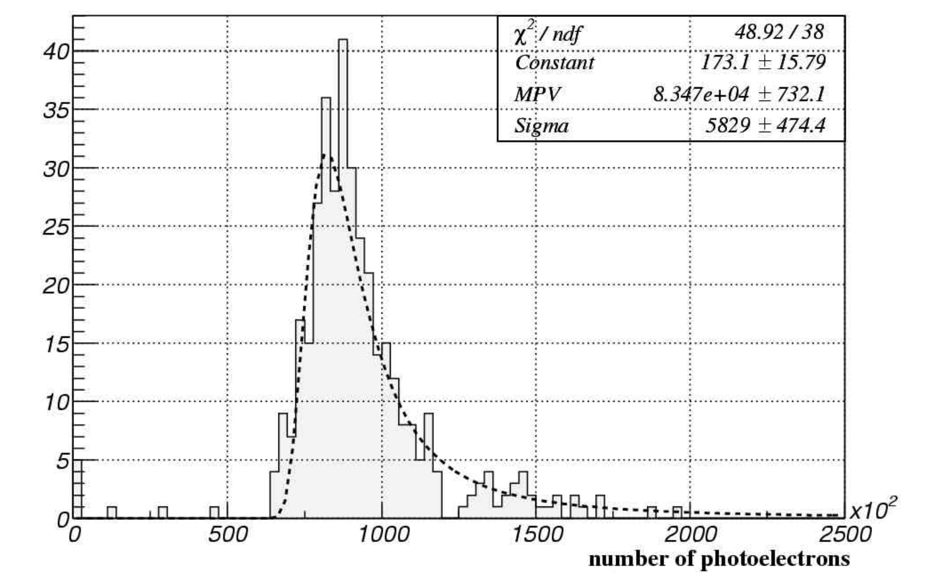
After 600 hours…

- Light yield increased by factor of 4.
- Comparison with MC prediction ✍ $?_{abs}$ > 1m

Before purification
20590 photoelectrons



After purification
83470 photoelectrons

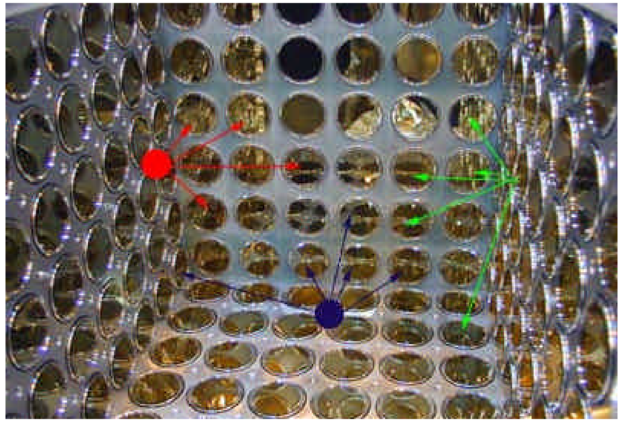


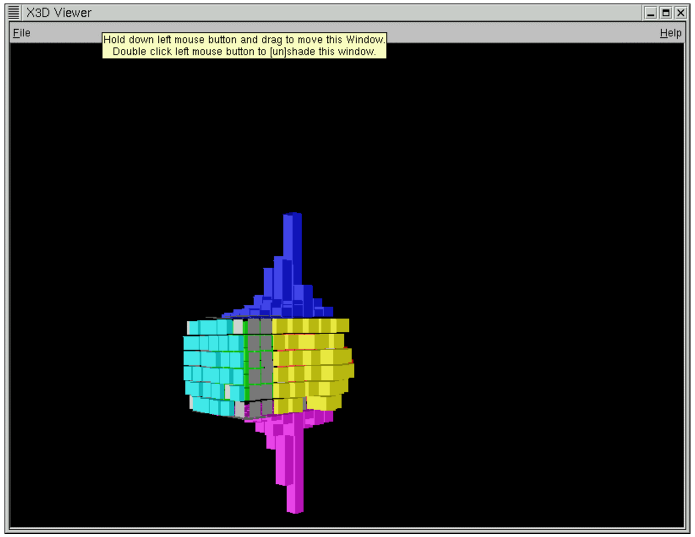
Absorption Length Measurements

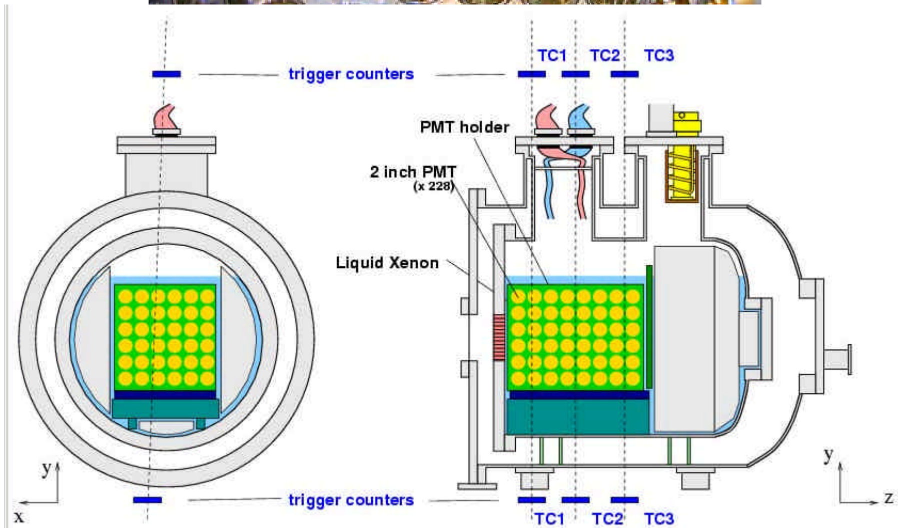
before purification
after purification

Estimation of Absorption Length

- ? ?& cosmic-events.
  - Relation between the light yield and distance from the light source to PMTs.

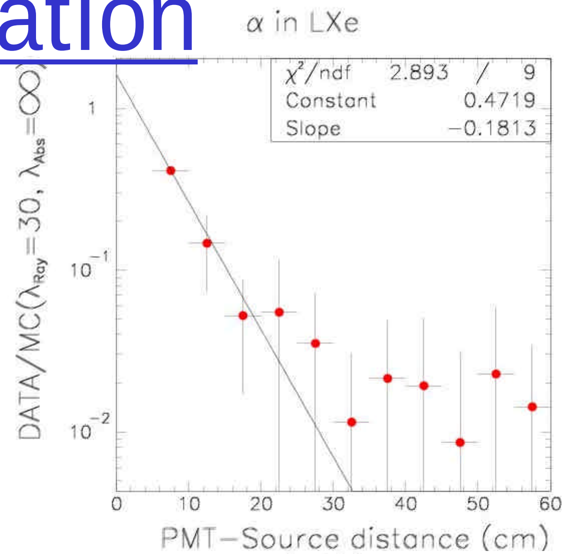


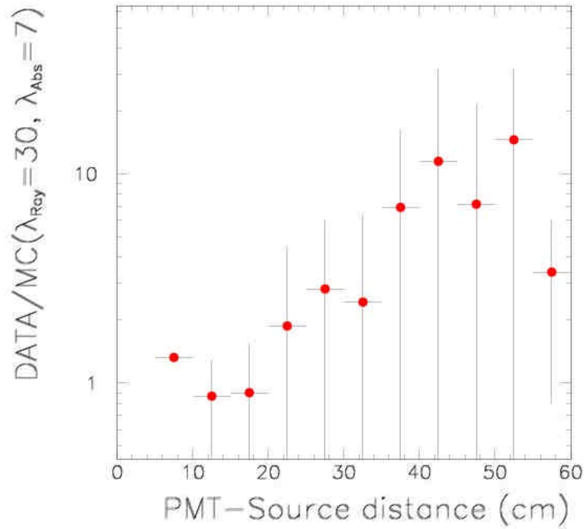




Absorption Length (?)
before purification

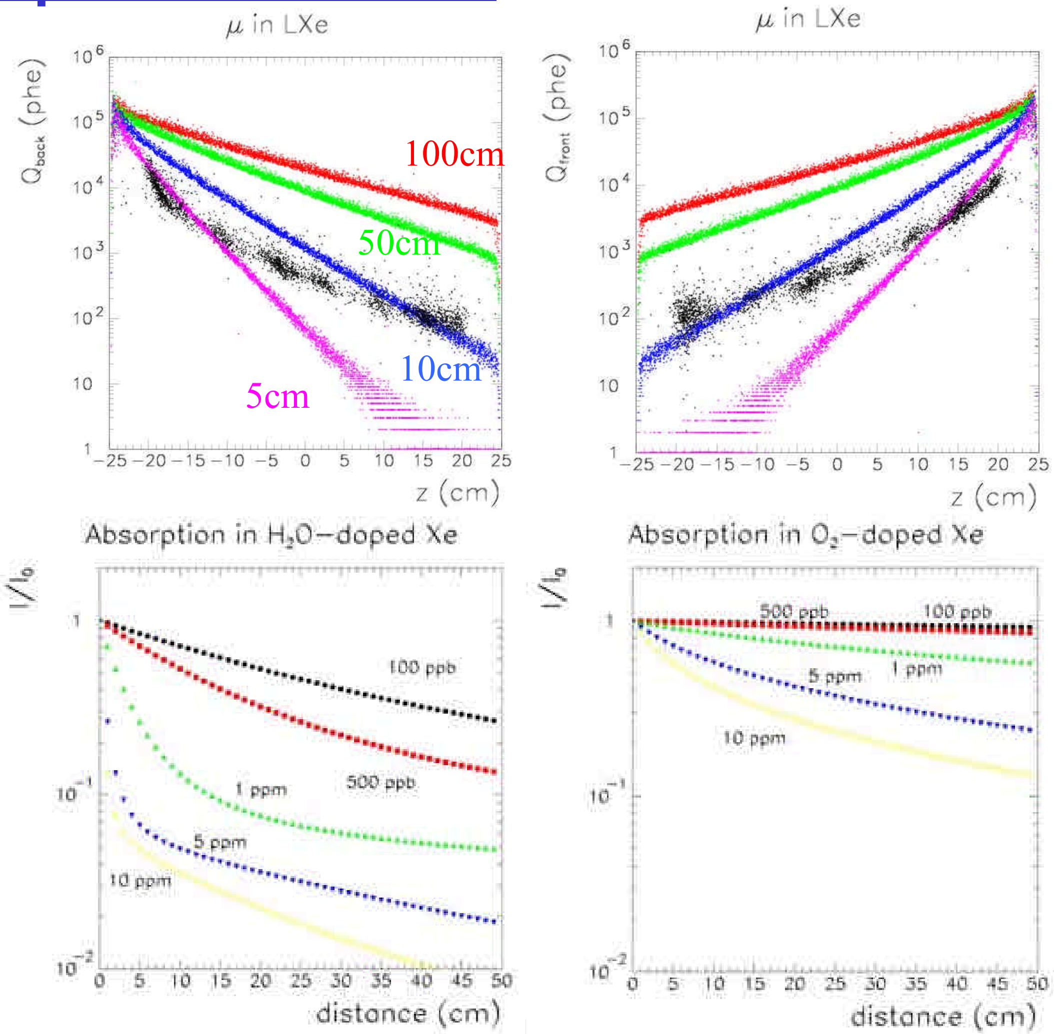
- Data/MC as a function of the distance from the alpha source to the PMTs
  - MC: $?_{Ray} = 30$cm
    $?_{abs} = 8$ cm and 7cm
- MC with 7cm absorption can explain rapid decrease of the light yield at short distance.





Absorption Length (CR) before purification

- Data distribution is steeper near the face and falls less violently for large z.
- The discrepancy can be explained by introducing wavelength-dependent absorption effect by water.
- Absorption length: 5~10cm

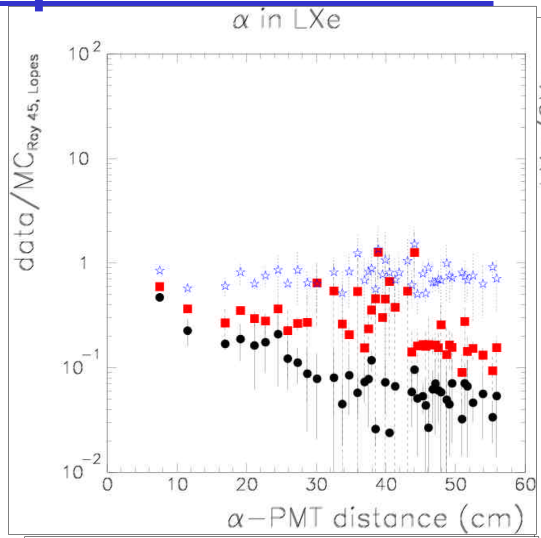


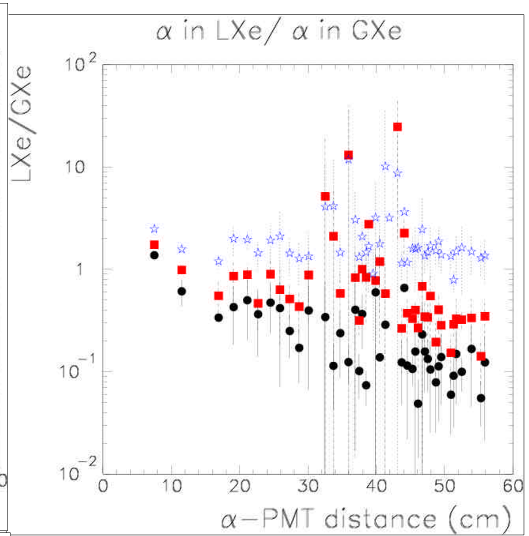
Absorption Length after purification

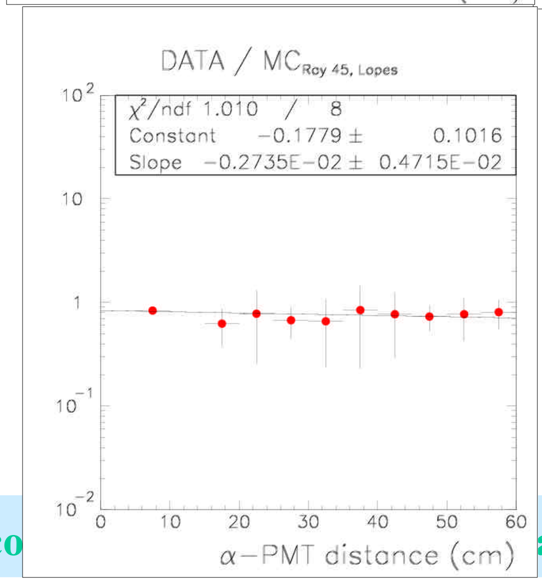
- Fit the data with a function : A exp(-x/ ?$_{abs}$)
- ?$_{abs}$ >100cm (95% C.L) from comparison with MC.

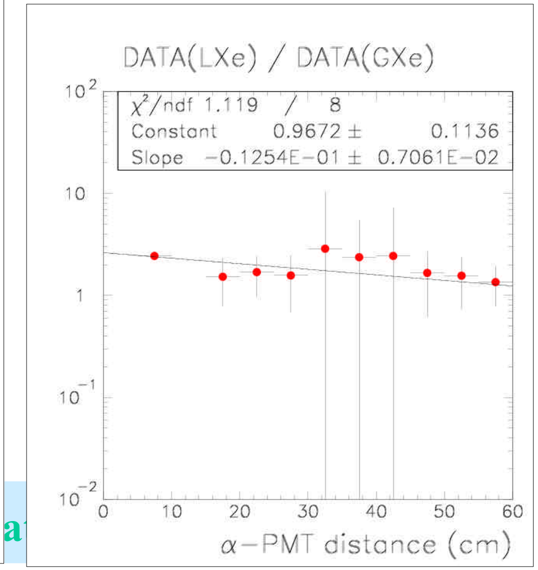
(?$_{abs}$>80cm from comparison with cold gas data which however includes diffusion effect)

- CR data indicate that ?$_{abs}$ > 100cm has been achieved after purification.









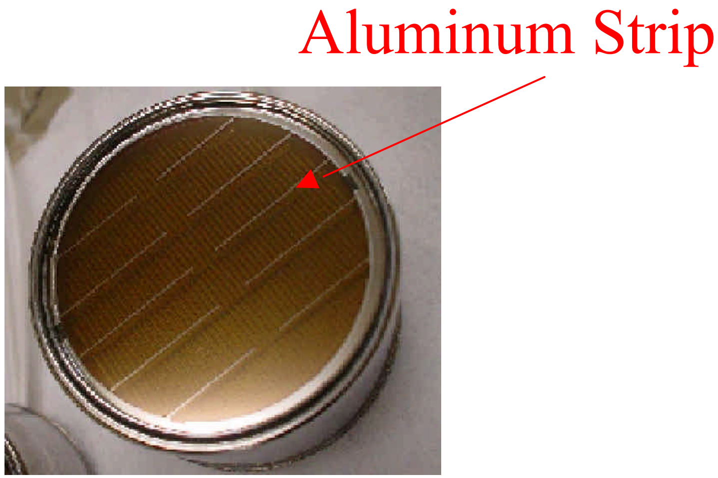
Other related R&D

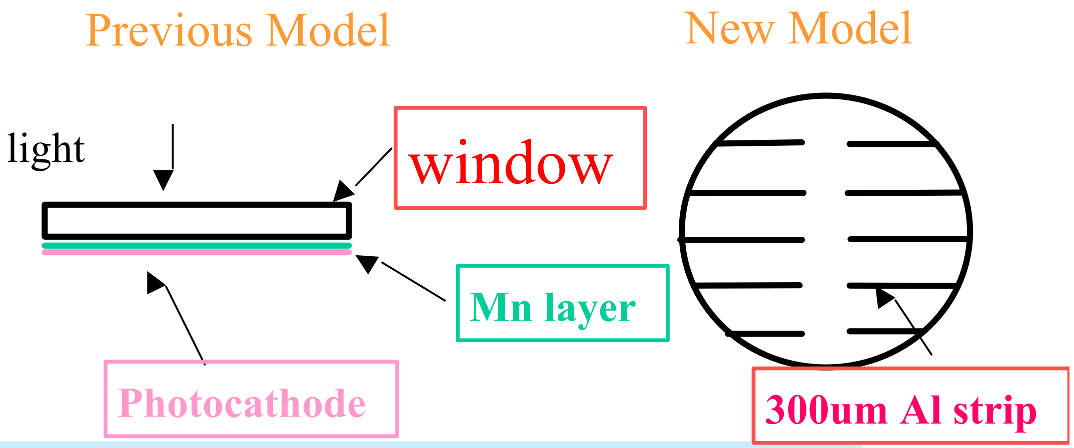
PMT

Purity monitor

PMT Development

- The previous model used a Mn layer to keep the surface conductivity of the photocathode at low temperature.
- The new model uses Al strip instead of the Mn layer.
- QE is expected to improve and PMT production in more constant quality.

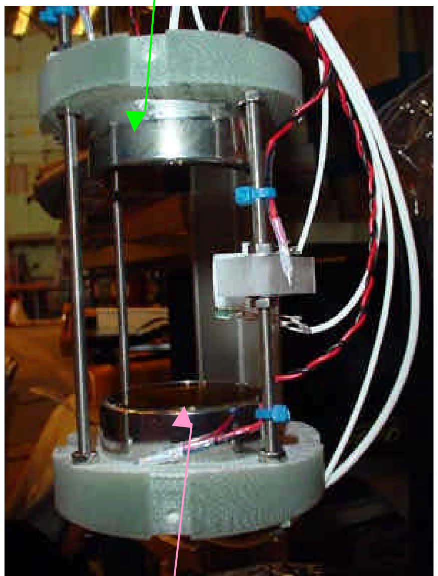


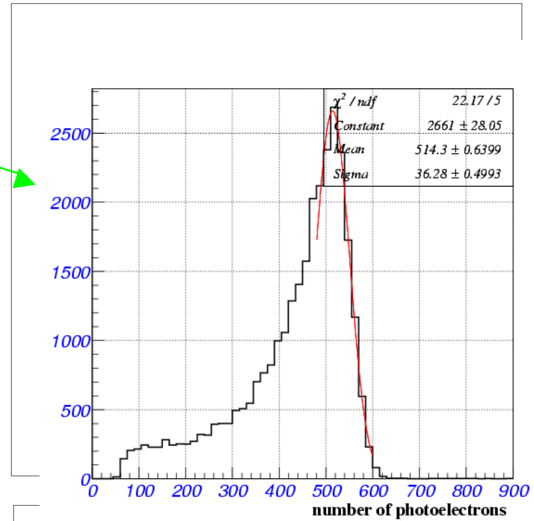


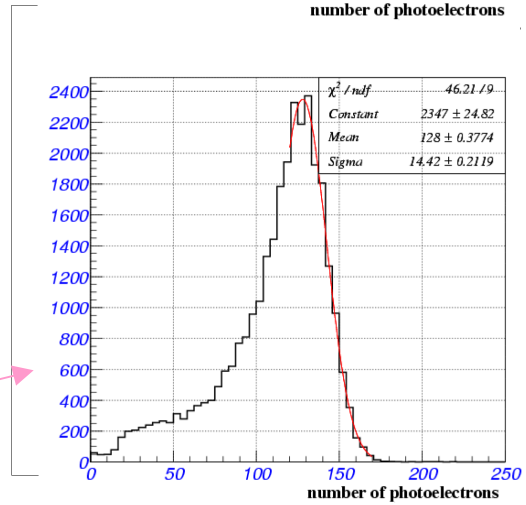
PMT test in gas/liquid xenon

- Tests in cold gas and in liquid xenon performed.
- QE improved by factor of 2-3.
- Rate dependence is similar or slightly better. (need careful check)
- K-Cs-Sb photocathode can probably be used (Previous model with Rb-Cs-Sb) ✍ possible to achieve higher gain with same HV.

New model





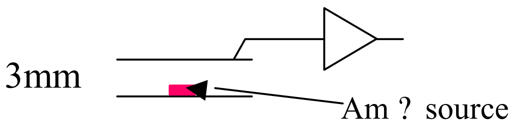


Previous model

Purity Monitor

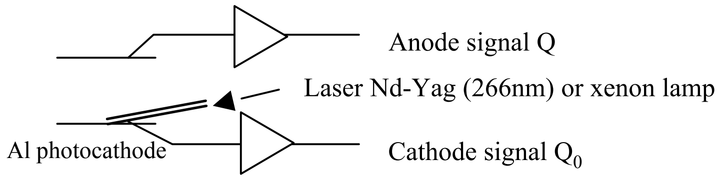
1. By measuring concentration of electro-negative impurities

- ? source ionization chamber



  - Simple and stable.
  - Possible to measure impurity of 10~100ppb.
  - Signal amplitude is rather small, a few mV level for 100ppb impurity.
  - Implemented in LP.

- Laser-induced ionization chamber



  - Laser stability can be monitored by measuring cathode signal.
  - Large amount of light yield.
  - Possible to measure impurity 1ppm~1ppb.
  - Need development, but we can use a similar one as ICARUS developed.

2. By measuring absorption of scintillation light

•Cosmic-ray event	Possible to measure $?_{abs}$ >1m but low rate.
• ? event	Possible to measure $?_{abs}$ ~1m but small signal.
•Other possibilities	Direct observation of laser light through xenon (Exima laser is a candidate, under investigation).

Final Detector

calibration

expected performance

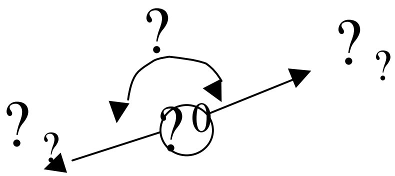
cryogenics design

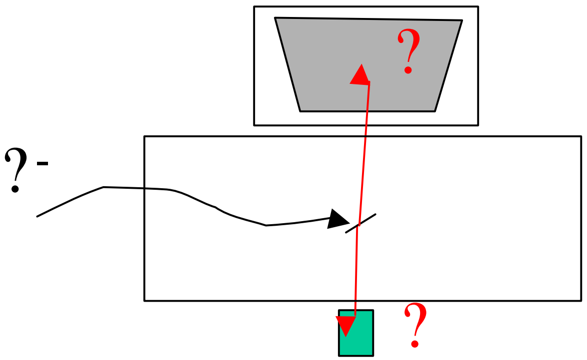
Calibration

?? ?$^-$p ✍ ?^{0}n

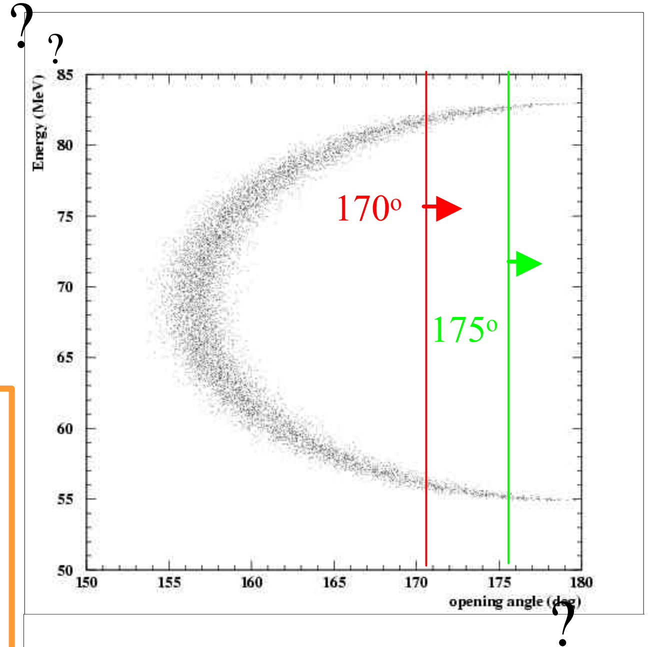
?^{0}(28MeV/c) ✍ ??

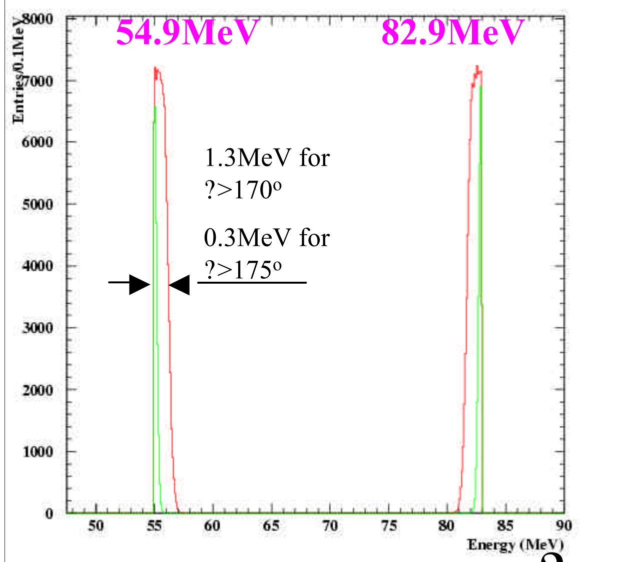
????MeV ?? ???? ????? eV





- Requiring ?????
  FWHM = 1.3 MeV
- Requiring ? > 175^o
  FWHM = 0.3 MeV





•No need of excellent energy resolution.

•Position resolution of ? =4~5cm is enough.

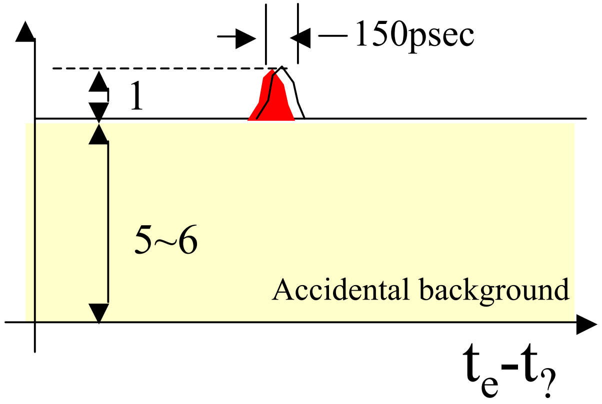
•Timing resolution (? < ~1nsec) is required for timing calibration of the xenon detector.

2. Am-Be ? source 4.43 MeV

Calibration cont'd

- ? ✍ e???
  - $E_e > 0.85$ $E_? > 0.8$ $?_{e?} > 120^o$

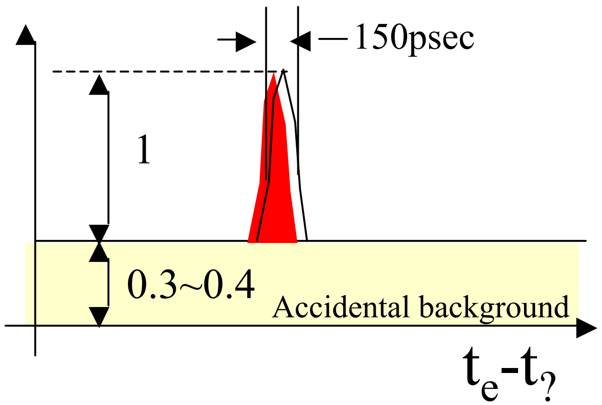
10^8? /sec



10^7? /sec

Signal 1/10

Background <1/100



Crystal box
PRD 38(1988)2077

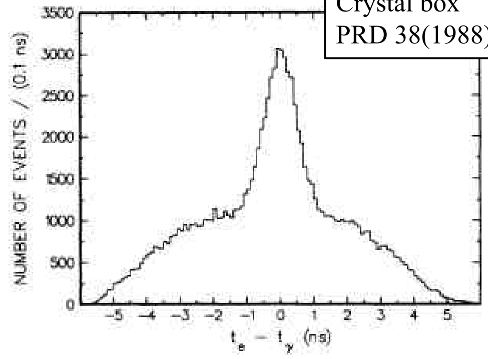
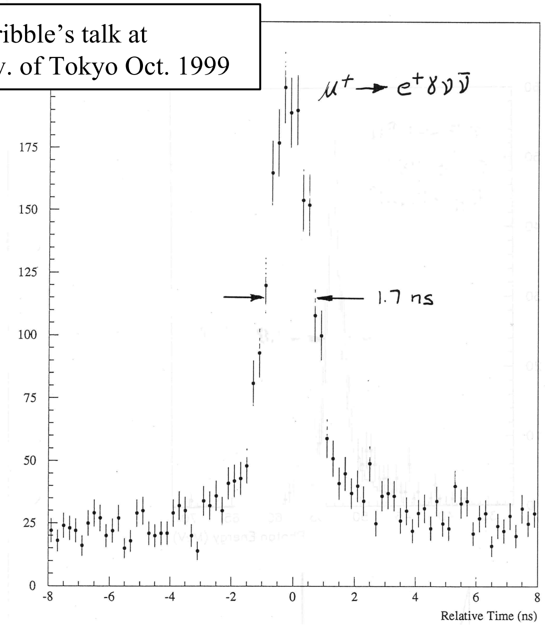
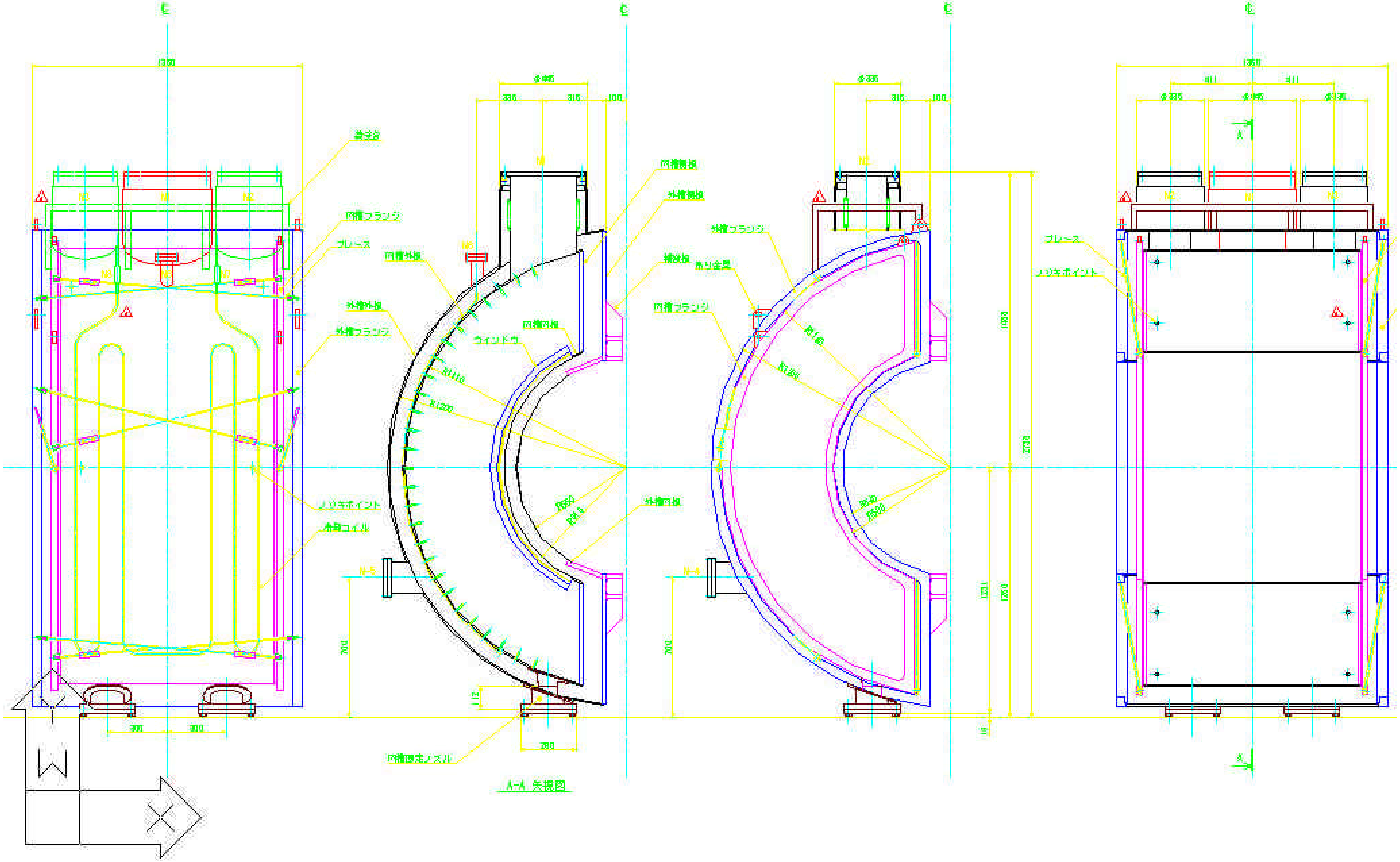


FIG. 9. The relative positron-photon timing for $e\gamma$ triggers.

R.Tribble's talk at
Univ. of Tokyo Oct. 1999



Cryostat design



Schedule

Jul/02 Jul/02 Aug/02 Sep/02 Oct/02 Nov/02 Dec/02 Jan/03 Feb/03 Mar/03

Large Prototype R&D

Purification R&D

- 1st Purification test -------->
- Purity monitor <---------------------------------->- - - - - - - -
- 2nd purification test <---------->

PMT R&D --->

3rd ? beam test <----------->
(Electron beam test) <----------->
Analysis <------------------------>

Final detector construction

Cryostat design ----------> - - - - - -
Honeycomb -
R&D, construction - - - - - - <--->
Cryostat construction <--->
PMT delivery <--

Summary

- 2nd ? beam test in Feb. 02
  - Worse resolutions than our expectation due to short absorption length caused by contaminant impurity.
- Purification system has been developed and 1st test was successfully done.
  - Recent CR and alpha data indicate $?_{abs}$>1m.
  - Increasing purification speed is the next step for quick start of the detector operation.
  - Development of purification monitor is an important issue.
- Another tests are planed with purified xenon using ? and e beams in autumn.
- Other R&D works are going.