Liquid Xe detector for $\mu^+ \rightarrow e^+\gamma$ search

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Outline

- Introduction
- prototype R&D
  - PMTs
  - small & large type
- summary

Three Talks

XENON01

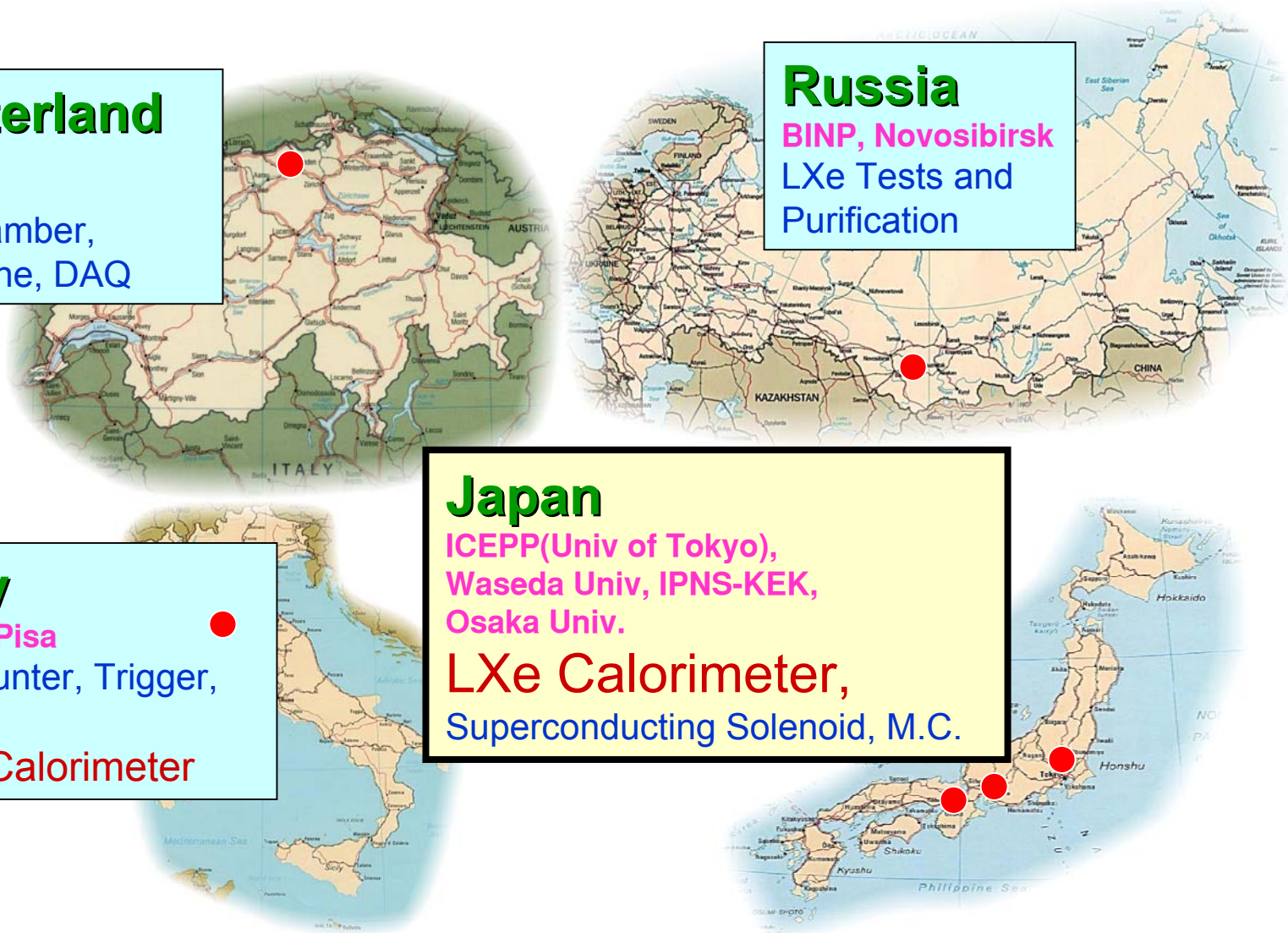
- LXe detector for $\mu \rightarrow e\gamma$ search
  Kenji Ozone

- Pulse tube refrigerator for liquid xenon
  Tomiyoshi Haruyama

NOON2001

- $\mu \rightarrow e\gamma$: status and prospects
  Wataru Ootani

Collaboration



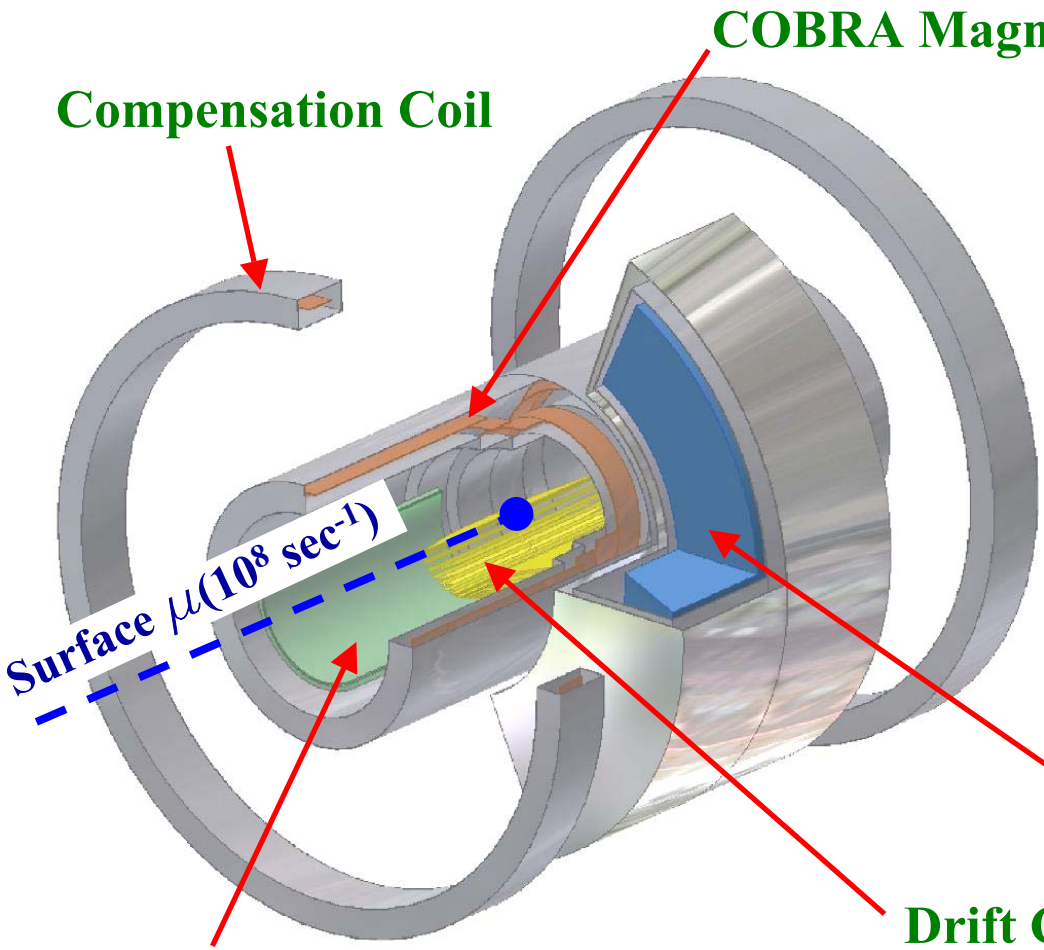
Physics Motivation

Detail → Ootani's Talk NOON01 08/Nov

Keywords

- Beyond the SM (SUSY)
- Br($\mu \to e\gamma$) < 1 x 10^{-14}
- High Performance Detector

Detector for $\mu^+ \rightarrow e^+\gamma$ search at PSI



γ detection

- Liquid Xe Calorimeter

e^+ detection

- COBRA Spectrometer
  - Drift Chamber
  - Timing Counter
  - COBRA Magnet

STARTS IN 2003 and RUNS 1~ 2 years

Final Liquid Xenon Detector

PMTs IN LXe

Kamiokande-like

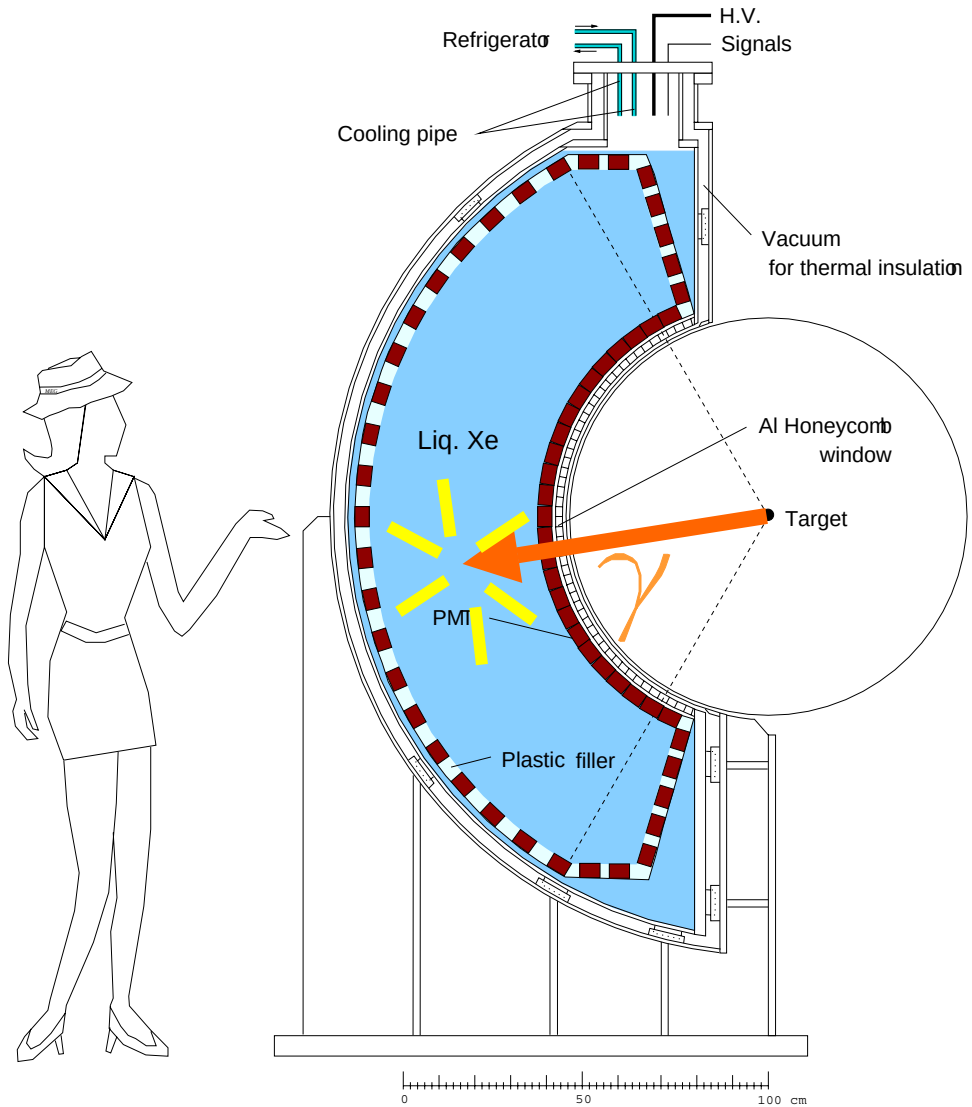
Low X_0 Materials

SUS honeycomb

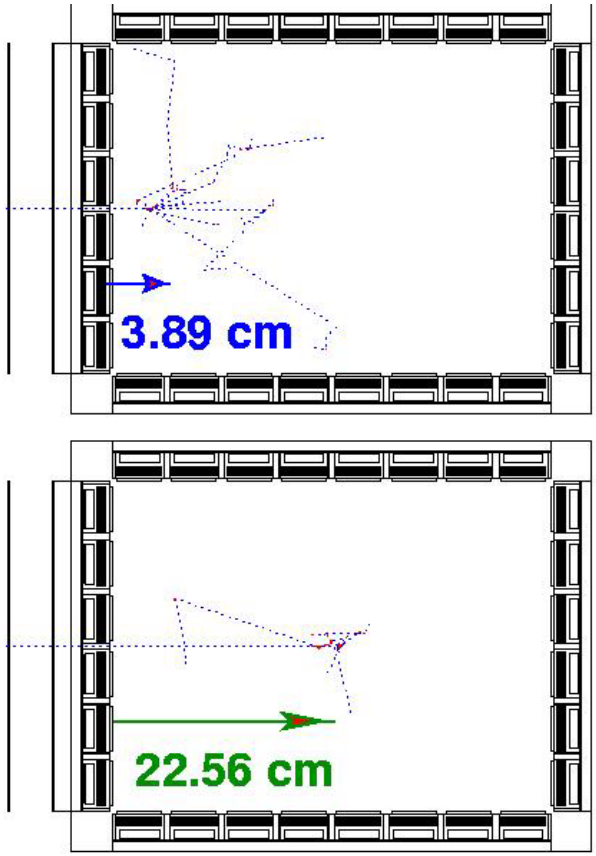
compact PMTs

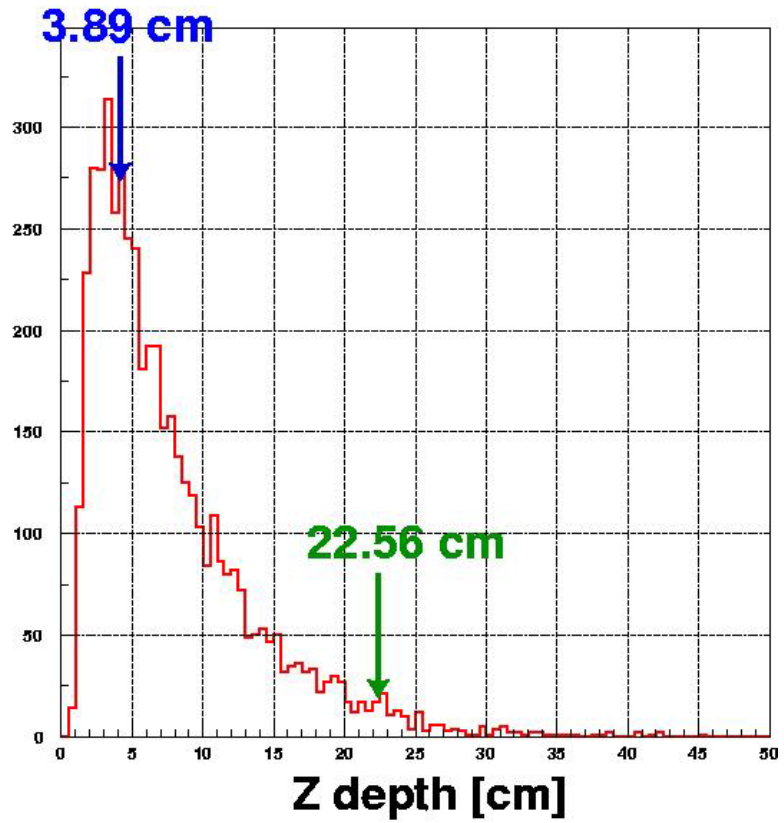
~ 800 PMTs

~ 800 liter LXe



M.C. simulation (GEANT3)



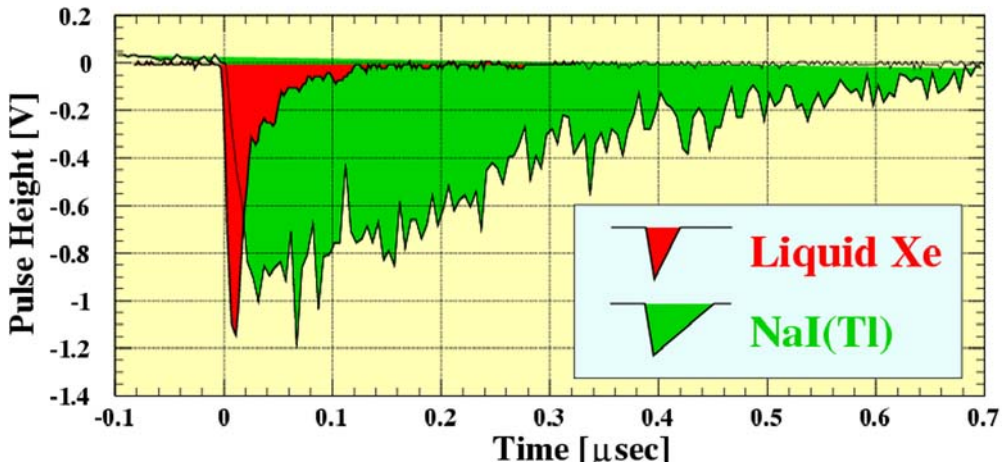


Position resolution: δx, δy ~ 4mm, δz ~ 16mm FWHM

Energy resolution: 1.4% FWHM

Why Liquid Xenon ?

- High Light Yield
  W_{ph} = 24 eV (NaI: 17 eV)
- Fast Decay
  ⇒ reduce pileups
  τ (fast) = 4.2 nsec
  τ (slow) = 22 nsec
  τ (recombi.) = 45 nsec (75%)



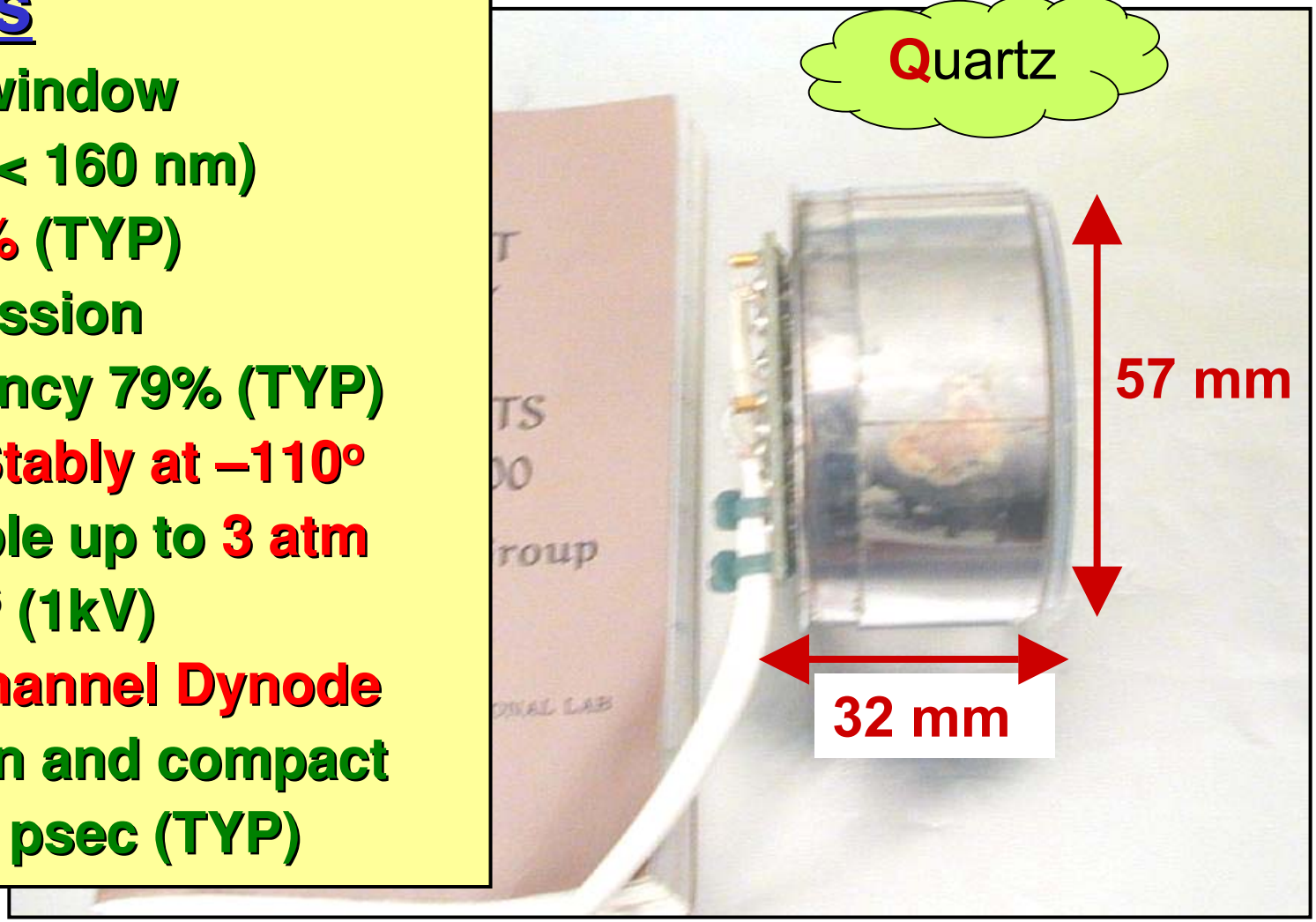
crystal scintillators

NaI: too slow
CsI, BGO: poor resolution at 52.8MeV
Inhomogeneous to cover large area

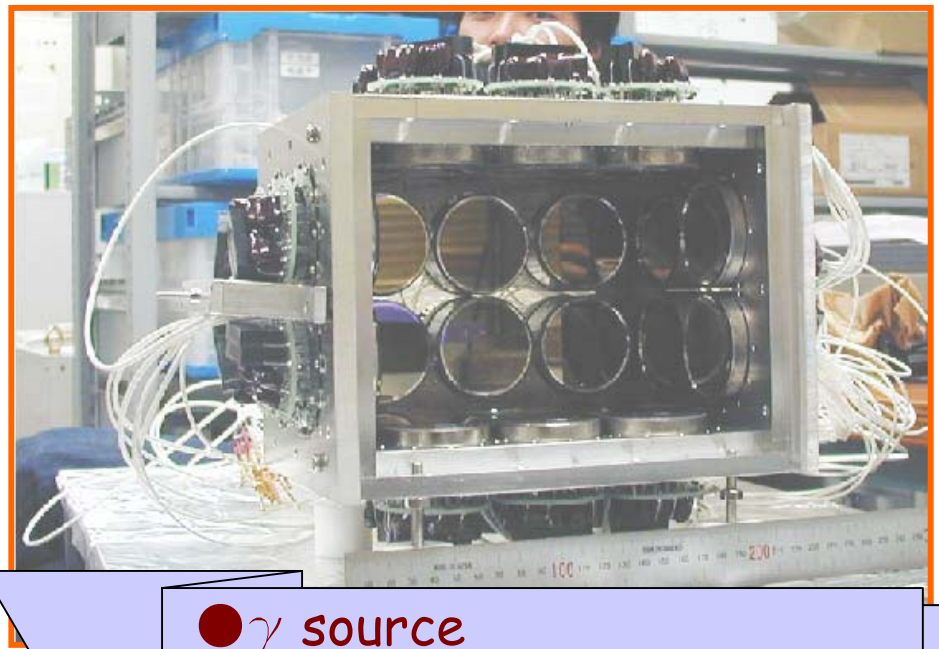
PMT (HAMAMATSU R6041Q)

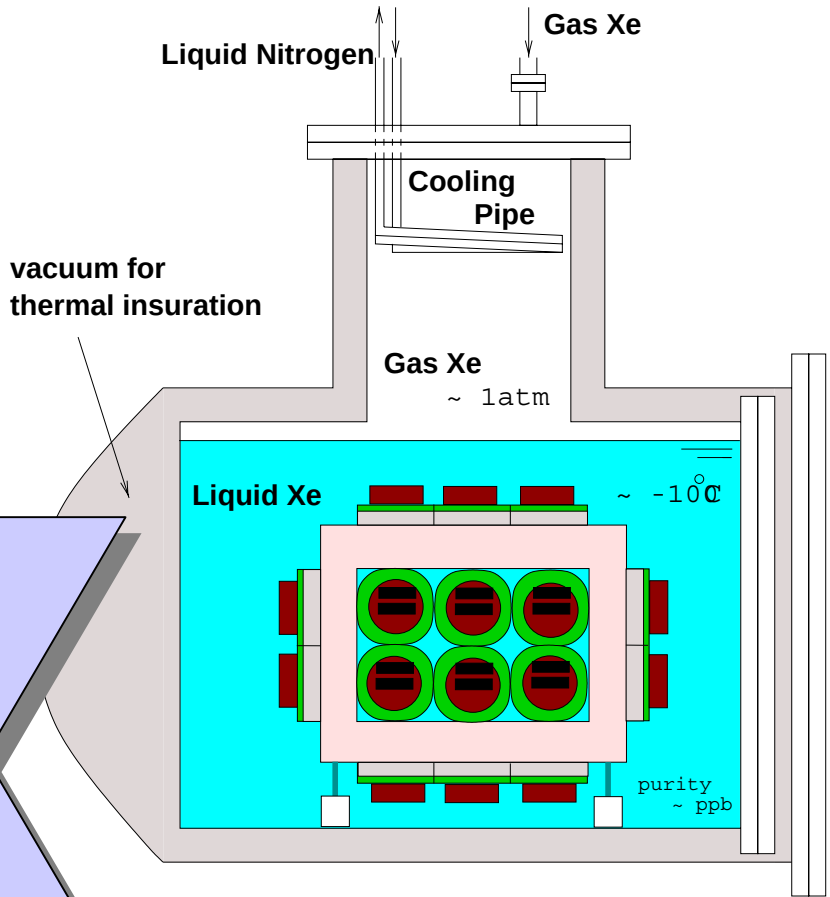
Features

- Quartz window
  (cut < 160 nm)
- Q.E. 10% (TYP)
- Transmission
  efficiency 79% (TYP)
- Works Stably at –110°
- Endurable up to 3 atm
- Gain 10^6 (1kV)
- Metal Channel Dynode
  → thin and compact
- TTS 750 psec (TYP)



Small Prototype

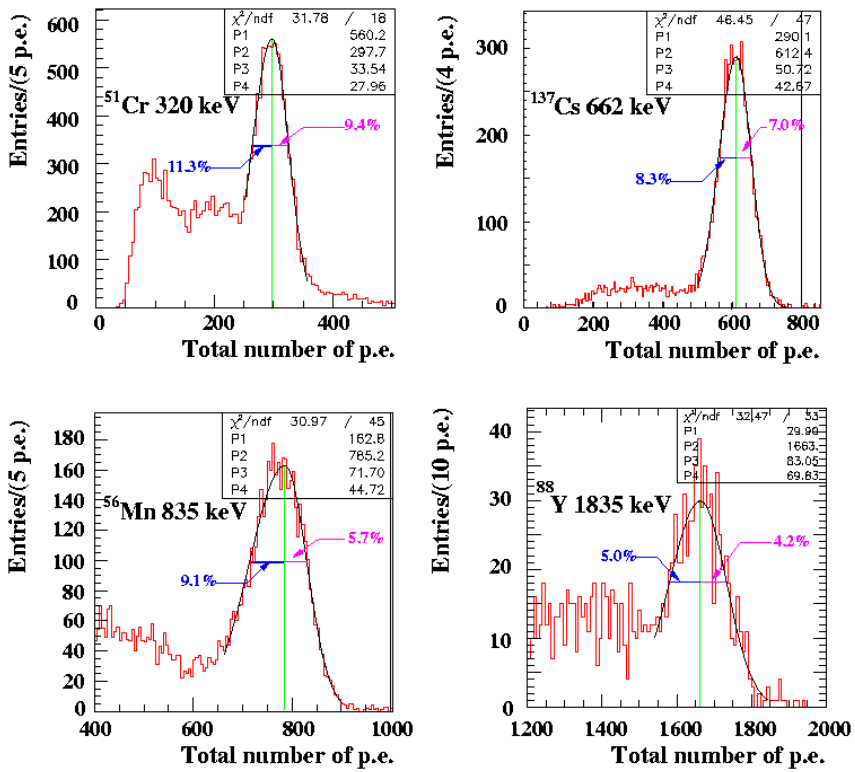


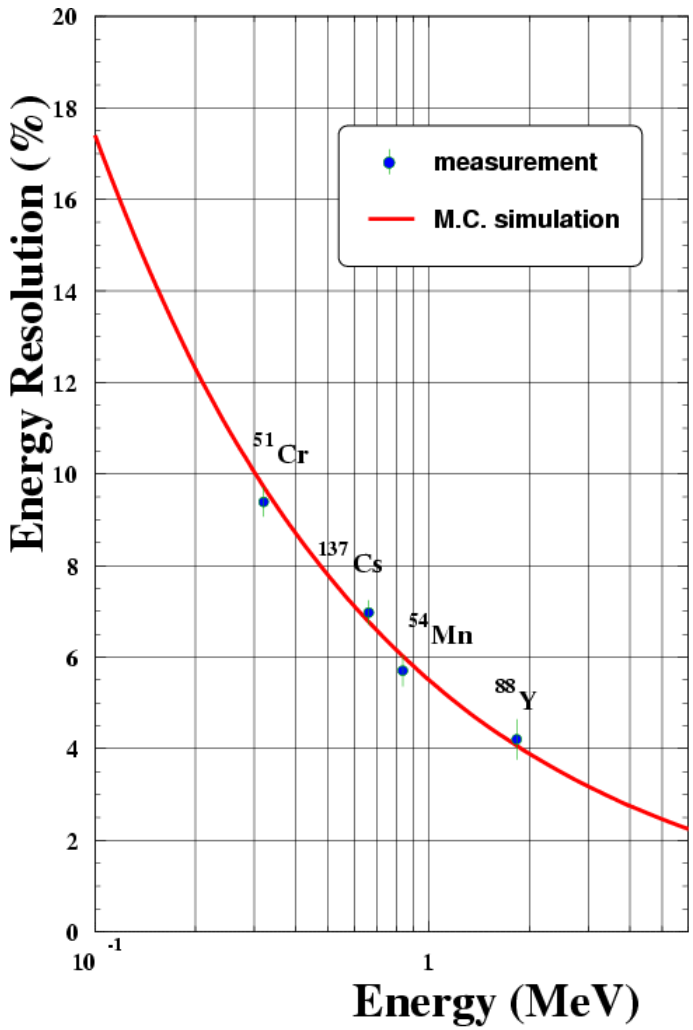


- γ source (^{137}Cs, ^{51}Cr, ^{54}Mn, ^{88}Y)
- α source (^{241}Am) for PMT calibration
- LED for gain adjustment
  - 2.34 liter Liquid Xe
  - 32 PMTs

Energy Resolution

Fitted with asym. Gaussian

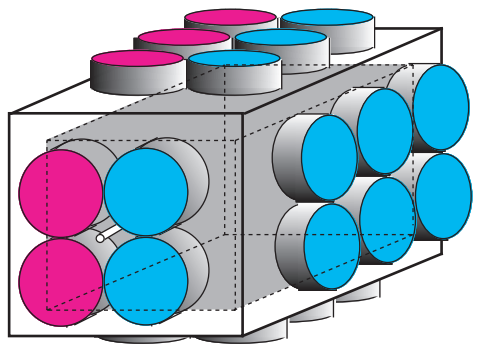


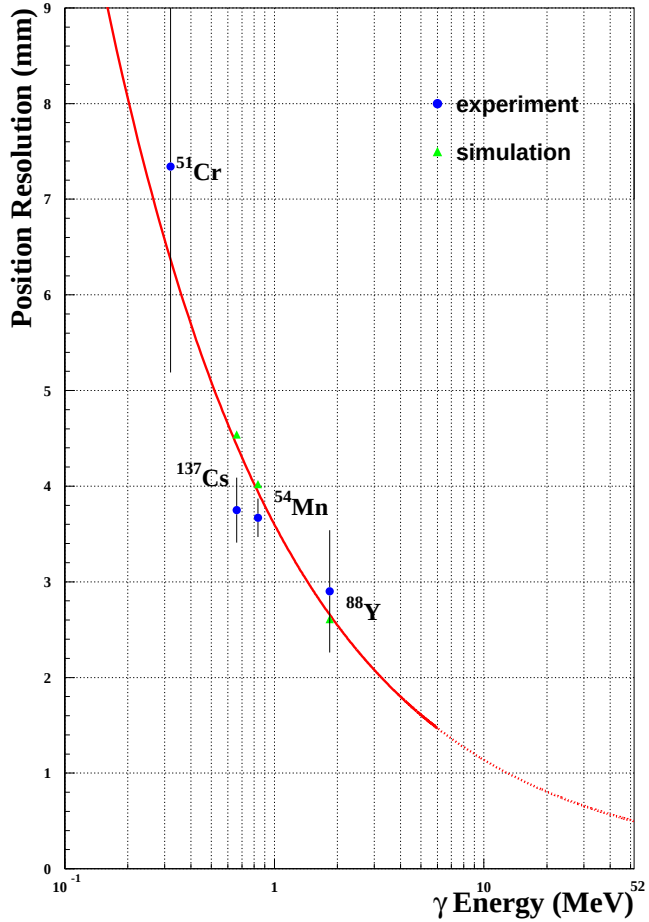


~1% in σ is expected at 52.8MeV.

Position Resolution

- PMTs are divided into two groups by the y-z plane.
  - γ int. positions are calculated in each group and then compared with each other.
  - Position resolution is estimated as $\sigma_{z1-z2}/\sqrt{2}$



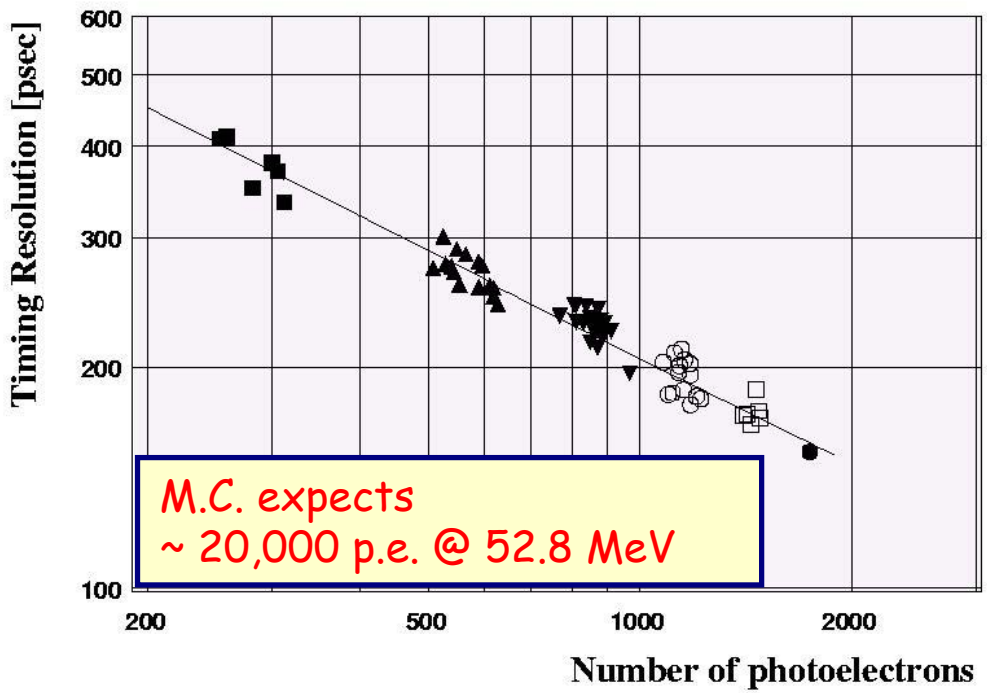


- Possible to achieve for 52.8MeV γ

A few mm in position meas.

Time Resolution (small prototype)

- PMTs are divided again into two groups by the y-z plane.
- In each group the average of the time measured by TDC is calculated after slewing correction for each PMT.
- The time resolution is estimated by taking the difference between two groups.
- Resolution improves as $\sim 1/\sqrt{Npe}$
- σ<50psec at 52.8 MeV.



Brief Summary on Small Prototype

Extrapolation to Higher Energy

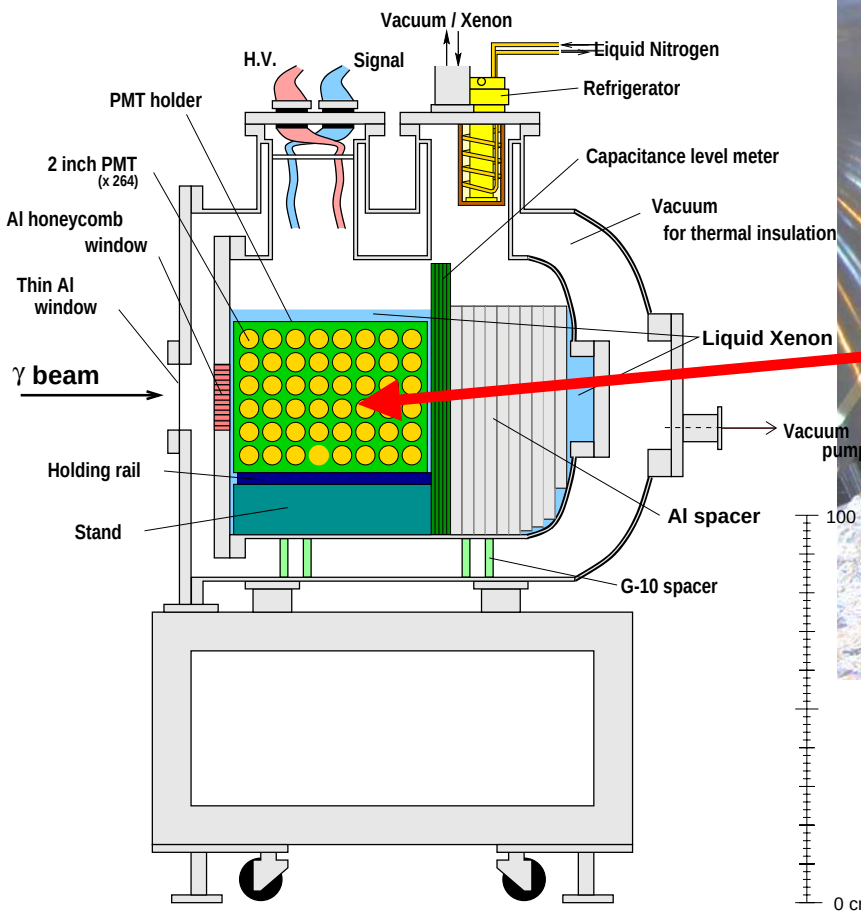
- Energy: ~1%
- Position; a few mm
- Time; ~50psec

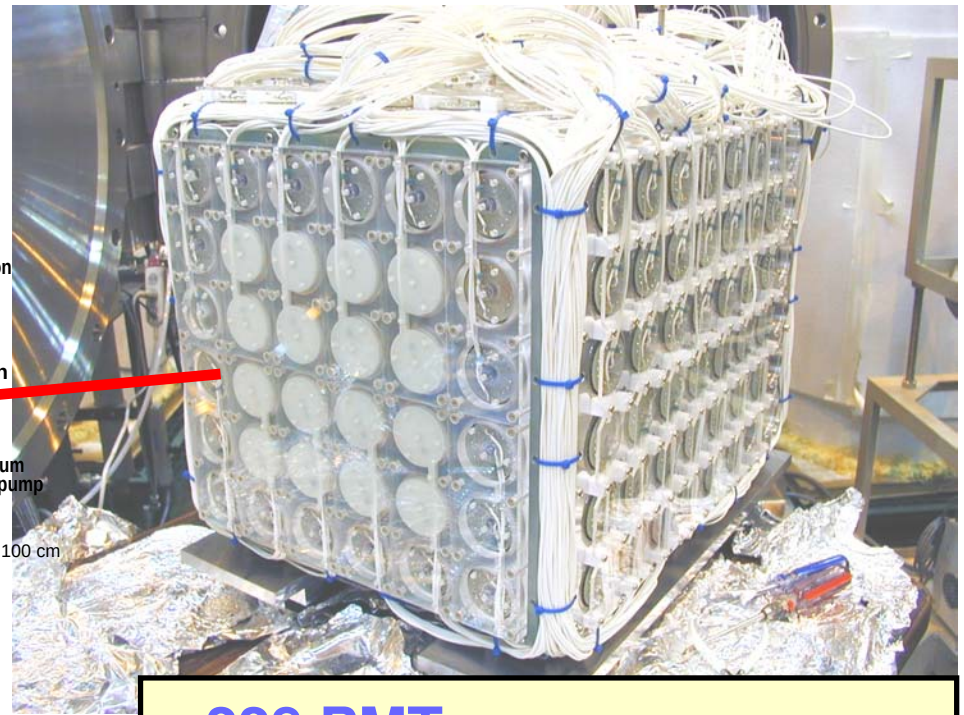
in σ at 52.8MeV

Go to the next stage!!

Large Prototype

Large Prototype





- 228 PMTs
- 68.6 liter LXe
- beam test for< 40 MeV γ

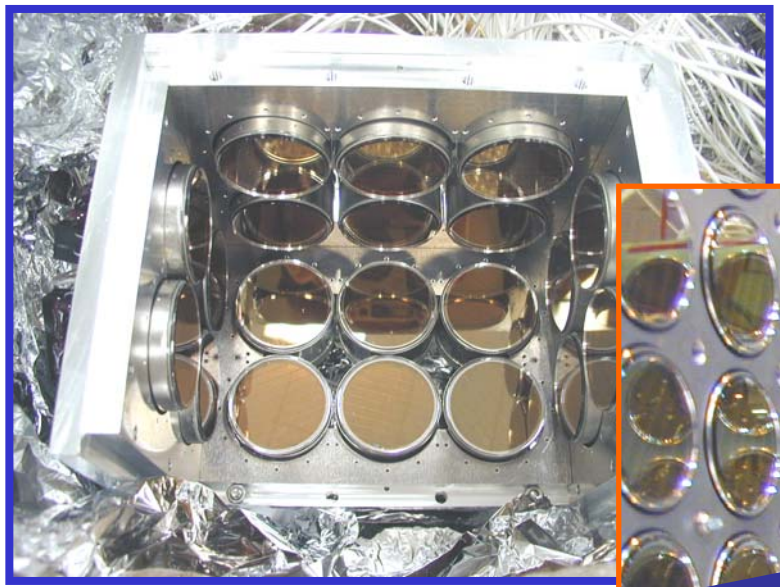
Purpose of Large Prototype

- **Pre-Final Detector**
- Test for detector components

  PMTs, feedthroughs(HV, signal), refrigerator, vacuum chamber, cables, PMT holder, DAQ, ...
- Performance Test
  - Energy, Time, Position
  - Small proto: < 2MeV ..... Compton scat.

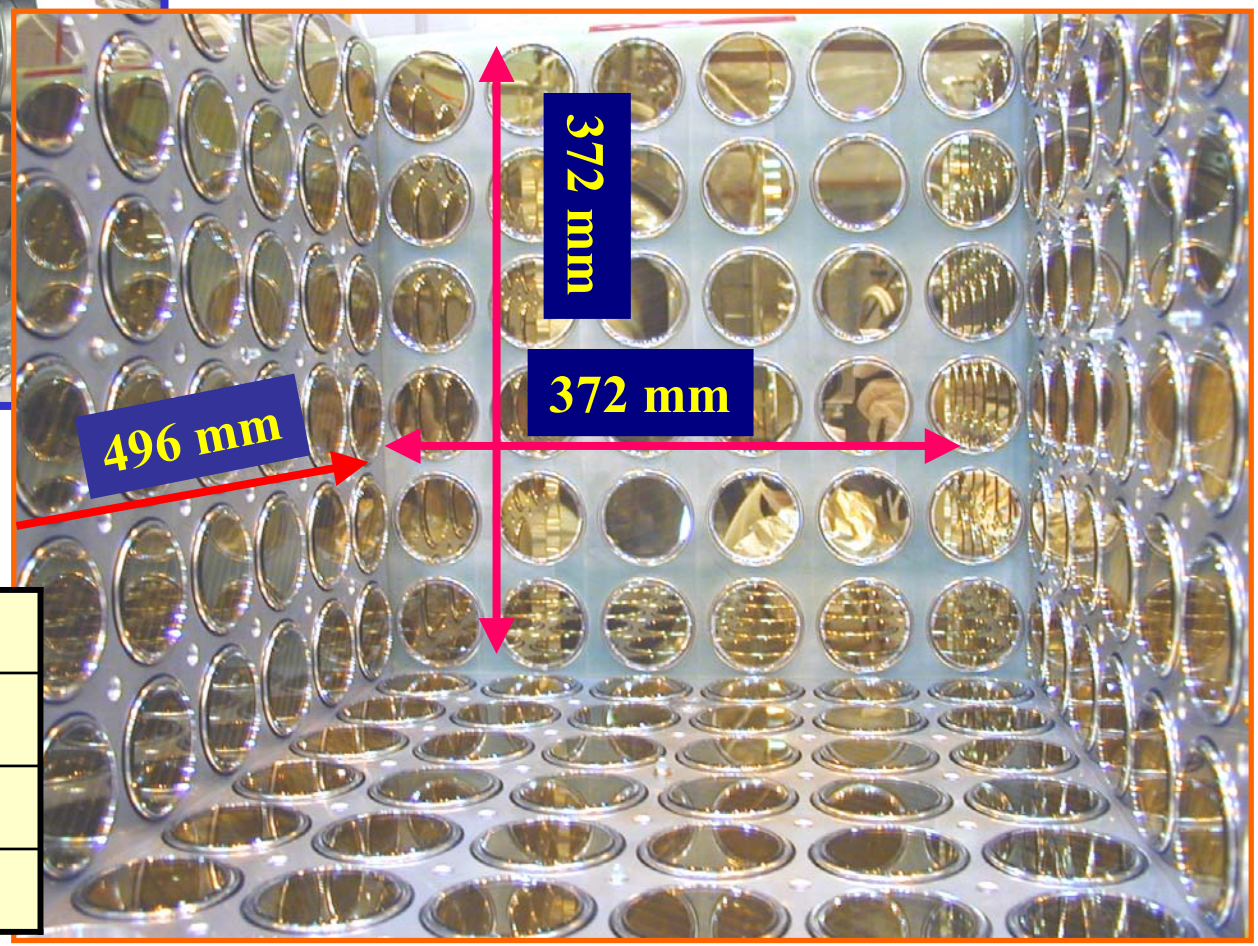
    Large proto: < 40 MeV ... pair creation
- Attenuation Length Measurement

Inside — Mini-Kamiokande



Small Prototype
(116x116x174 mm^3)

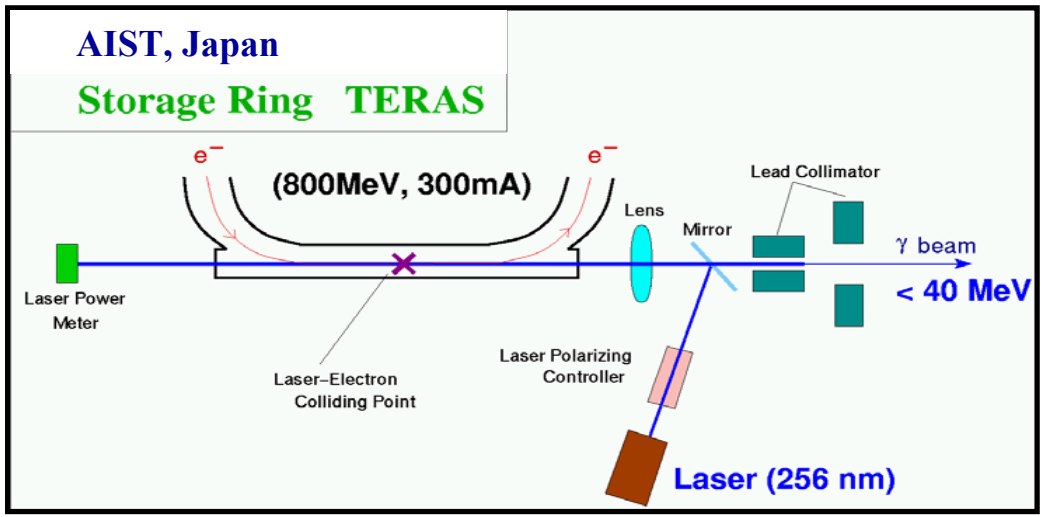
Large Prototype

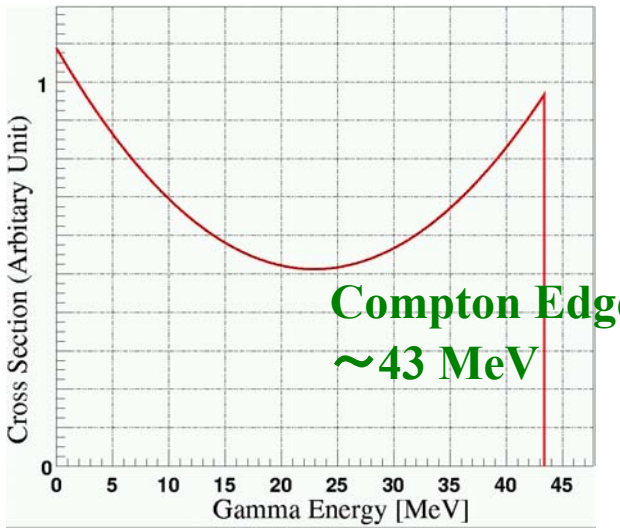


	Xe [liter]	PMTs
SMALL	2.34	32
LARGE	68.6	228
FINAL	~800	~800

1st Beam Test

For 1 weeks in June, 2001





Everything worked very well.

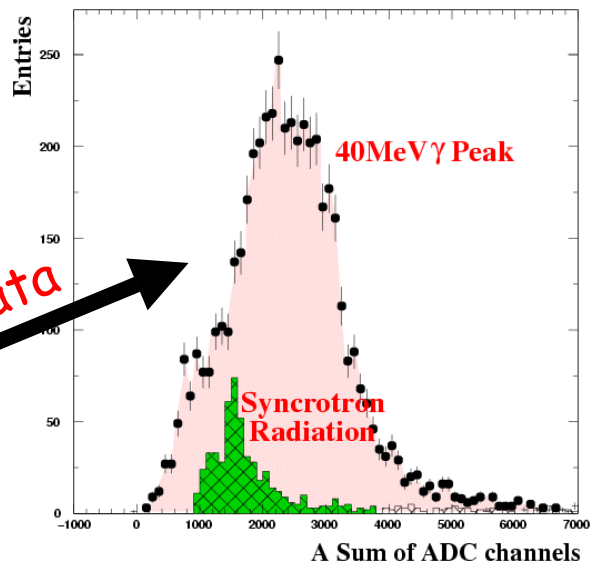
But …

ADC broken . . .

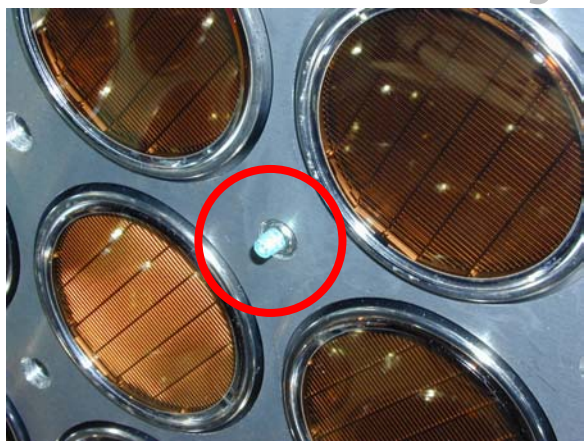
- Pedestal shift
- ADC overflow

Most of data became unavailable

survived data

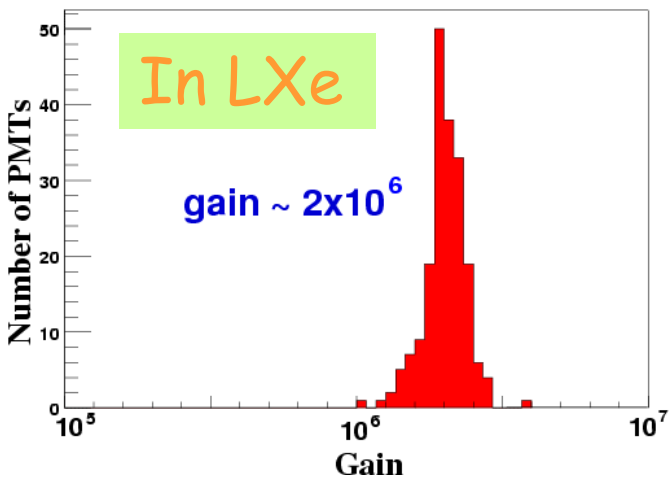


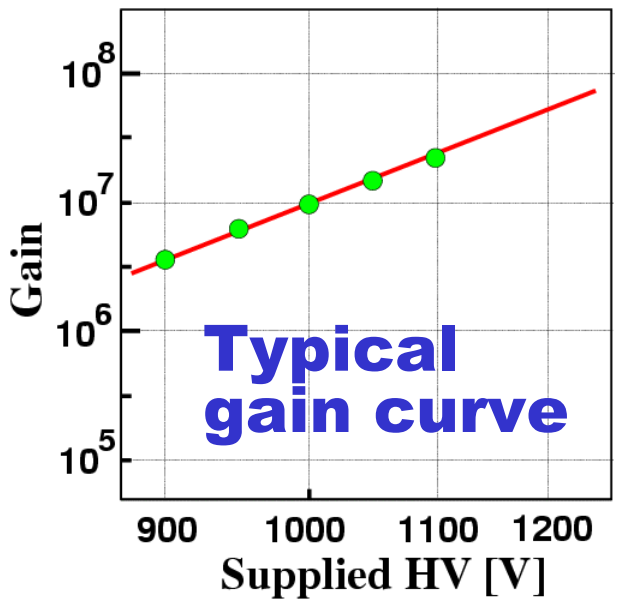
Gain adjustment with LEDs



- 8 LEDs inside PMT holder
- Scan HV to get gain curves for all PMTs

- Gain = 2×10^6
- Gain was roughly adjusted.





After 1st Beam Test

- First Beam Test in June
  - Every components tested. → All OK!
  - Ready for next test.
- Attenuation Length Measurement with Large Proto
  - Now running and analyzing (to be talked someday)
- Second test scheduled in Sep. was suspended by the machine trouble at AIST.

Next Beam test
@ AIST
at the beginning of 2002y

A Plan for Attenuation Length Measurement

Step1

PMT1:Absorption + Scattering Length measurement

PMT2: used as a reference.

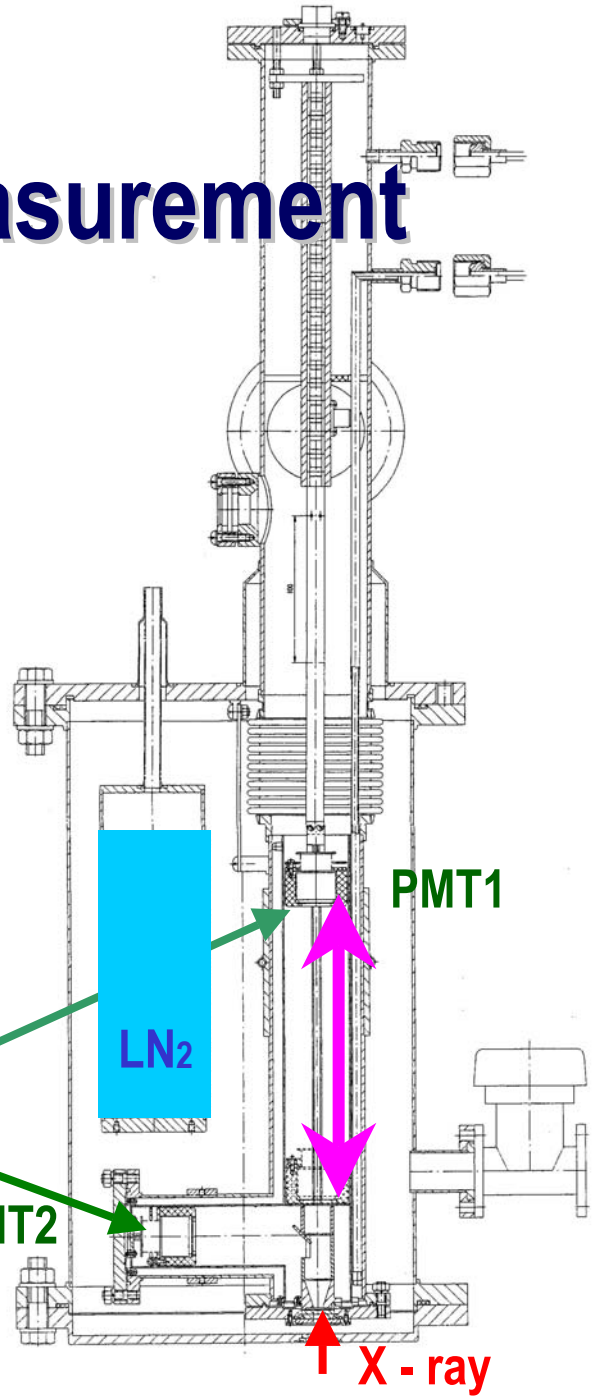
Collimators to prevent scinti. light from hitting the wall.

Mask in front of PMT1 to define the illuminated area on the photo cathode.

Step2

PMT2: Scatt. Length meas.

PMT1: reference at a fixed point.



$dL/L \sim 5 \times L(m)\ [\%]$

Summary

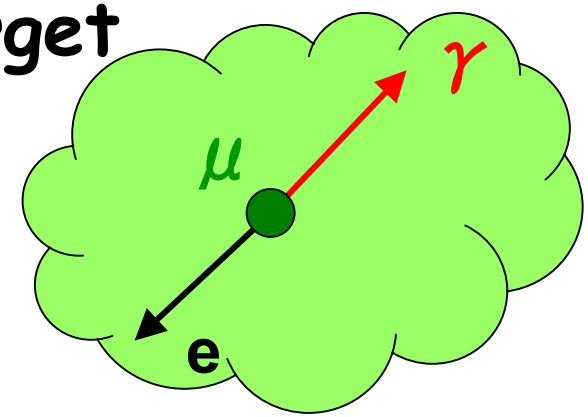
- Small Prototype
  - Result in successful
  - expected performance at 52.8 MeV;
    σ_E ~ 1%, σt ~ 50 psec, σ_{pos} ~ a few mm
- Large Prototype
  - The next beam test is scheduled at the beginning of next year.
  - Attenuation length measurement with cosmic ray in Tsukuba, Japan
- Others
  - Attenuation length measurement with X-ray source in Novosibirsk, Russia

http://meg.icepp.s.u-tokyo.ac.jp

End of Transparencies

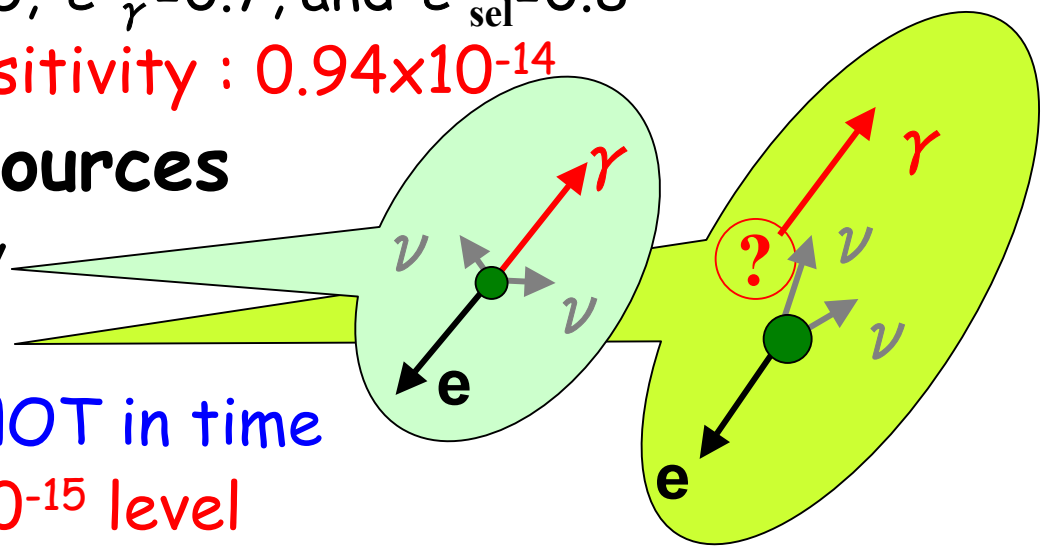
Signal and Backgrounds

- μ beam stopped on the target 10^8/sec
  - E_e=52.8MeV E_γ=52.8MeV
    Back to back, in time

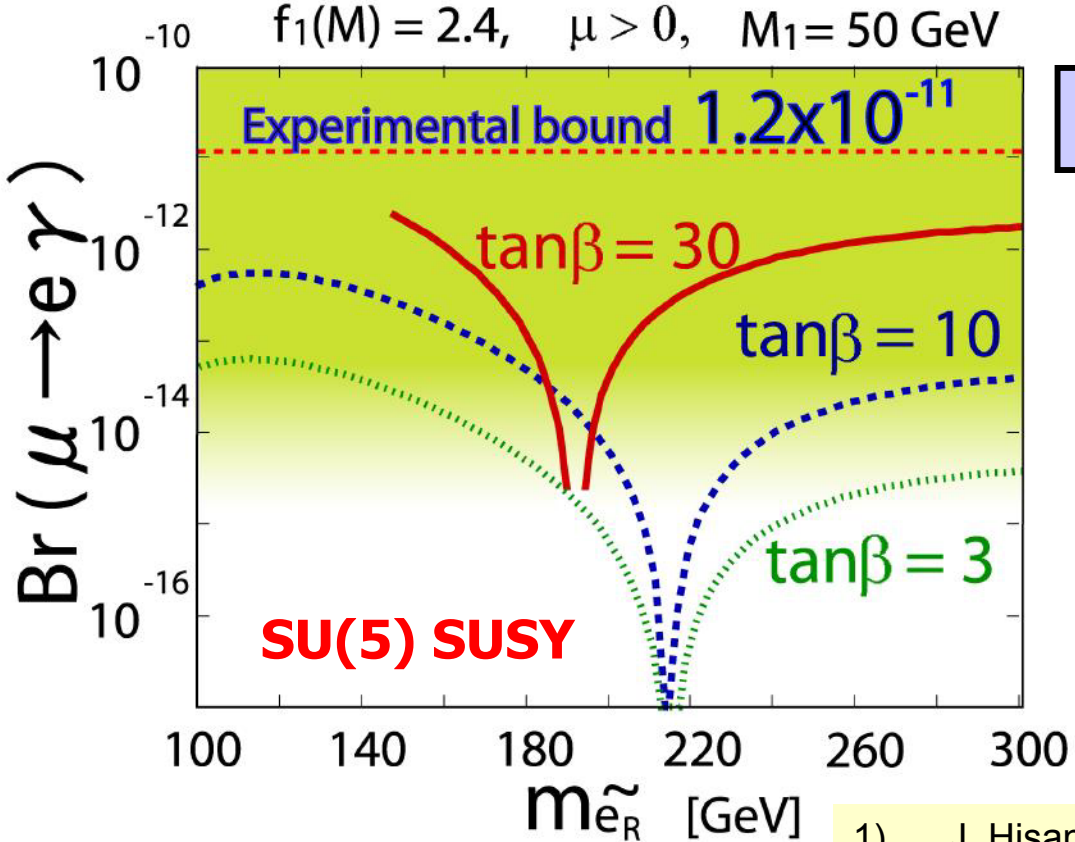


- **Sensitivity**
  - N_μ=1x10^8/sec, 2.2x10^7 sec running
    $\Omega/4\pi$=0.09, ε_e=0.95, ε_γ=0.7, and ε_{sel}=0.8
    ⇨Single Event sensitivity : 0.94x10^{-14}
- **Main background sources**
  - Radiative μ^+ decay
  - Accidental overlap

  NOT back to back, NOT in time
  ⇨Reduced down to 10^{-15} level



Physics Motivation



Associated Topics

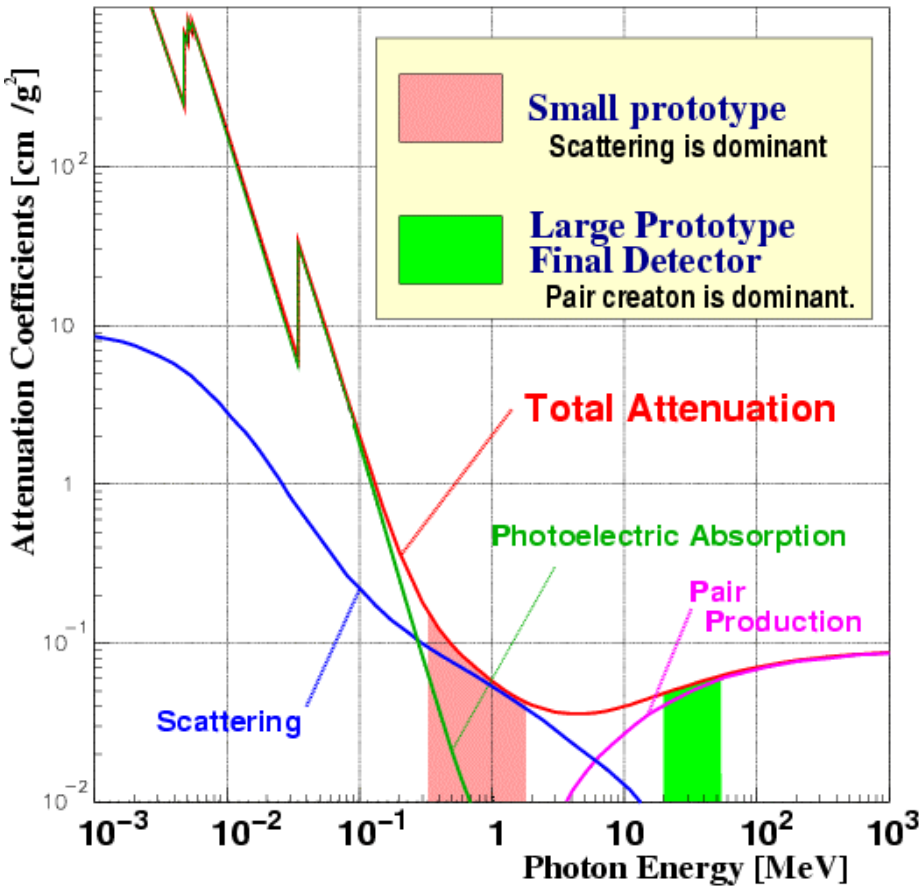
- **MEGA** (～1999)
  Br <1.2 × 10^{-11}
- **SINDRUM II**
  (μ e conversion search)
- SK (neutral lepton)
- Anomalous Muon (g-2)

1) J. Hisano et al., Phys. Lett. B391 (1997) 341
2) MEGA collaboration, hep-ex/9905013

$\mu \rightarrow e\,\gamma$ search is a promising field to find physics beyond the SM

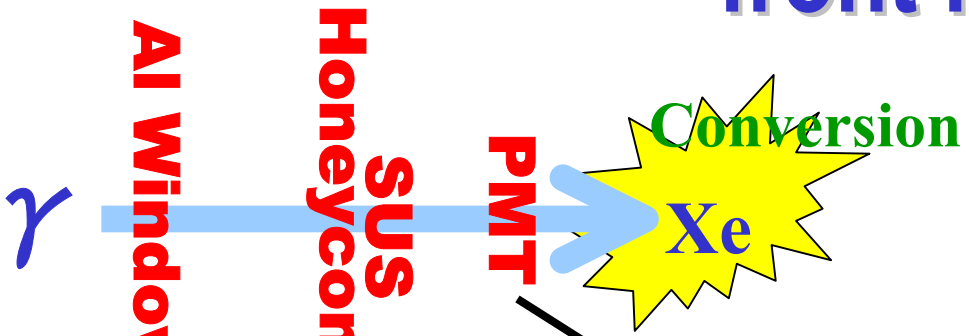
What's the difference ?

	Xe [liter]	PMTs	E_γ[MeV]
SMALL	2.34	32	0.3 ~ 1.8
LARGE	68.6	228	20 ~ 40
FINAL	~800	~800	≦ 52.8

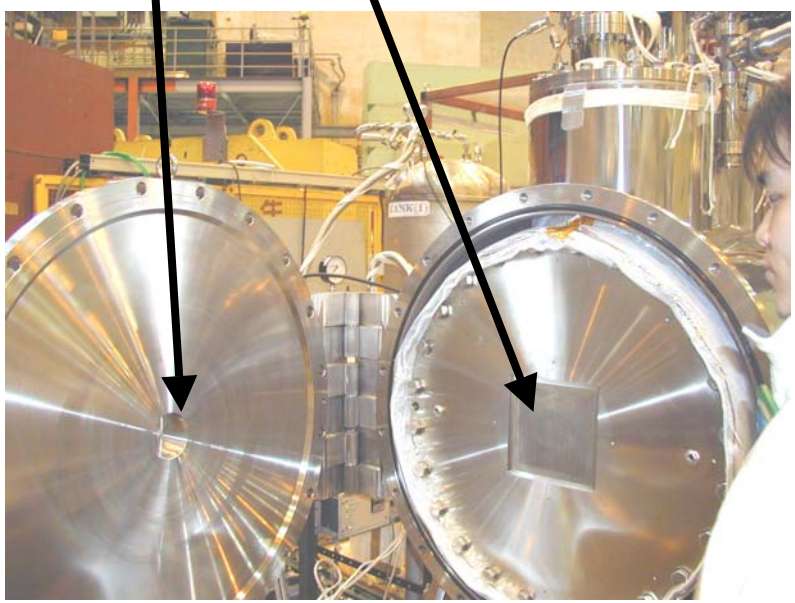


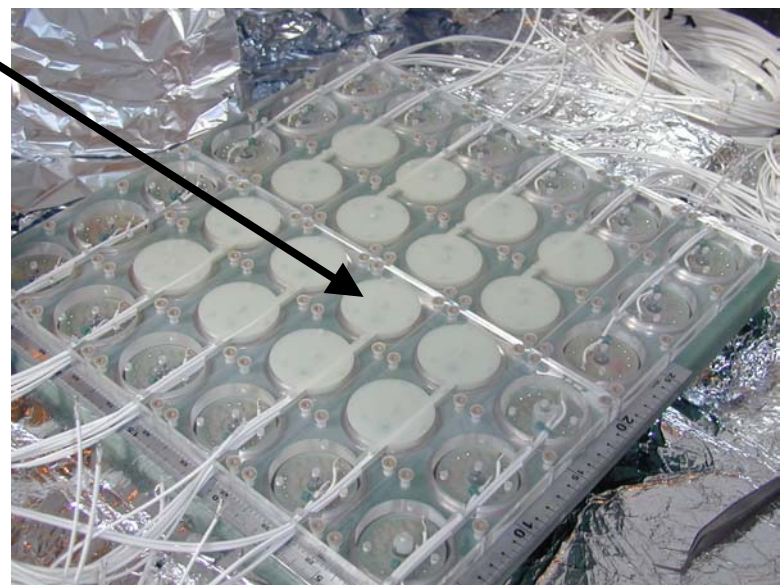
Max 0.23 X_0

front face

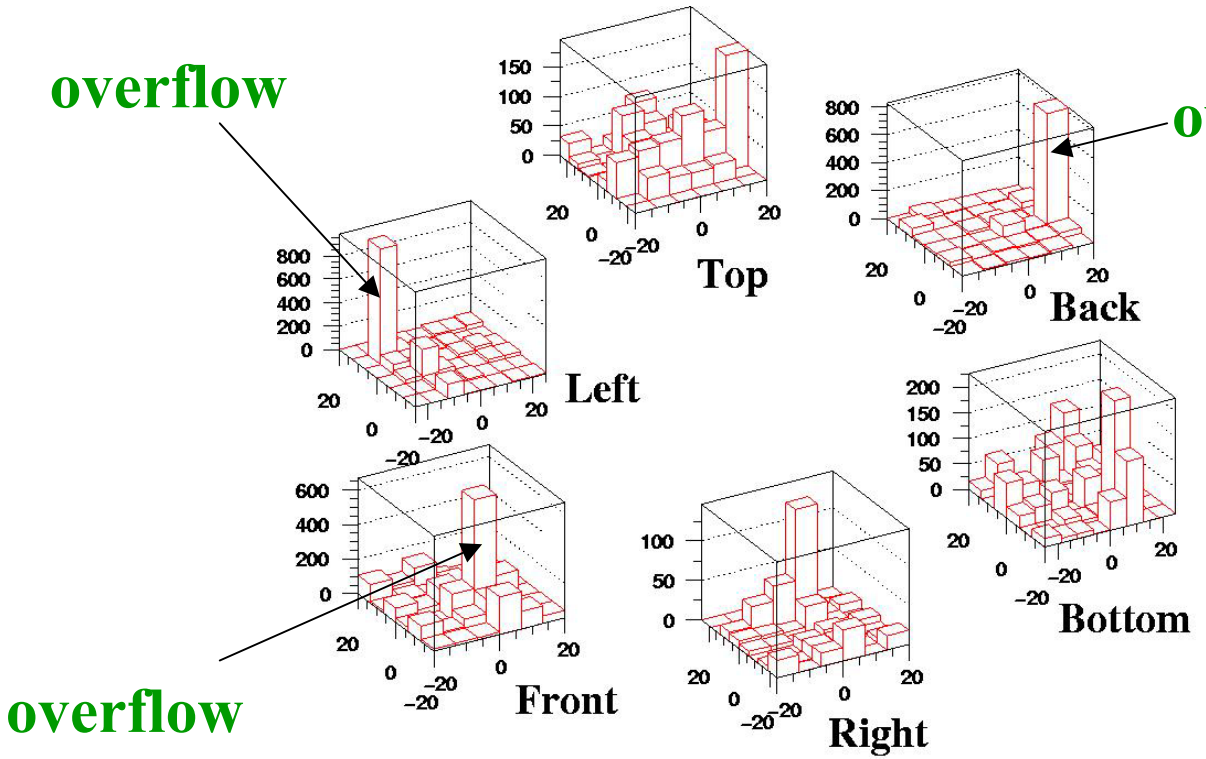


	X_0 (cm)	thickness
LXe	2.87	—
G10	19.4	0～0.15 X_0
Lucite	34.4	0.009 ～ 0.04 X_0
RTV	10~30?	0～10^{-2} X_0





ADC trouble



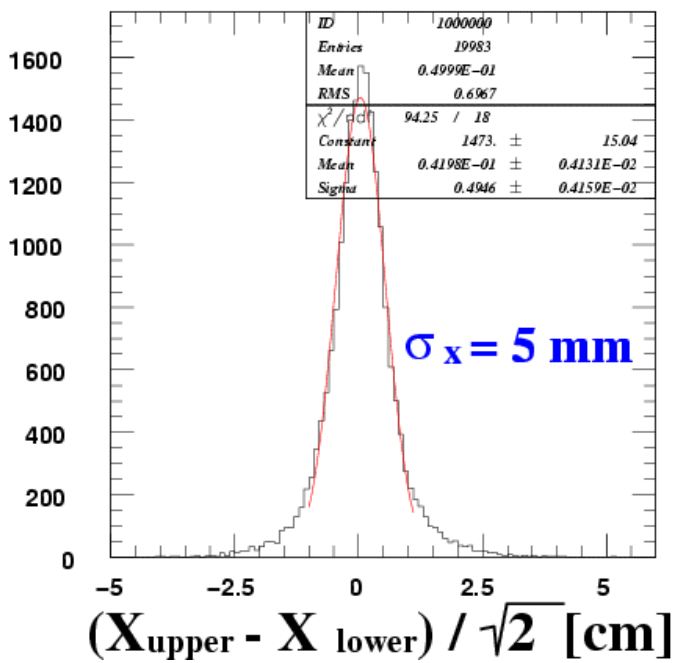
- ✧ overflow
- ✧ Pedestal shift

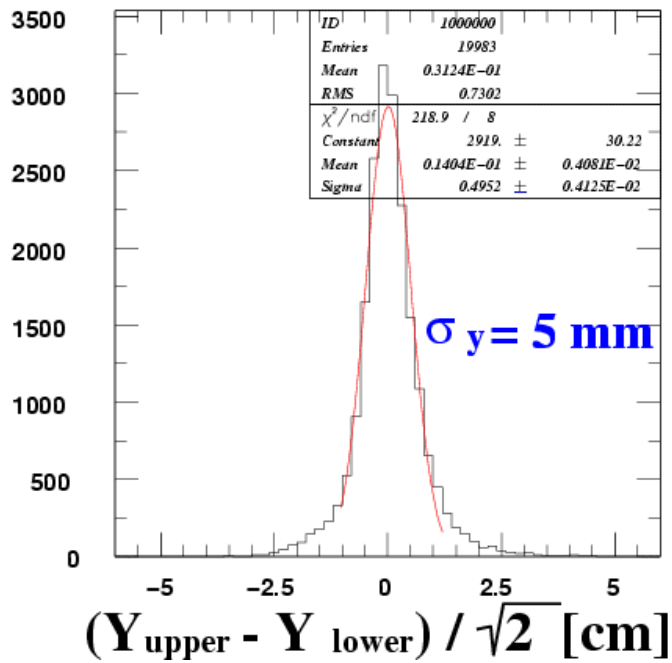
Some broken amps on an ADC caused heavy damage to many amps on all ADCs.

➡ Impossible to estimate resolutions with all PMTs.

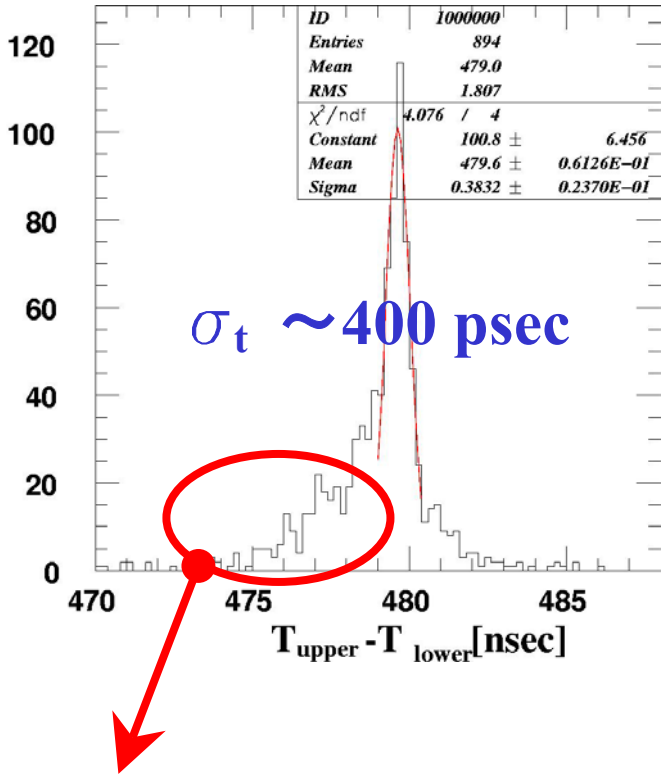
Position resolution (preliminary)

- Survived 10 PMTs were divided into two groups, Upper and Lower.
- Estimated position in each group was compared with each other.





Timing resolution (preliminary)



- Similarly to the small type, calculated by taking the difference between two groups.
- ADC trouble prevented from making slewing correction and selecting adequate events.

If slewing correction had been made, this tail would have been put together into the peak.

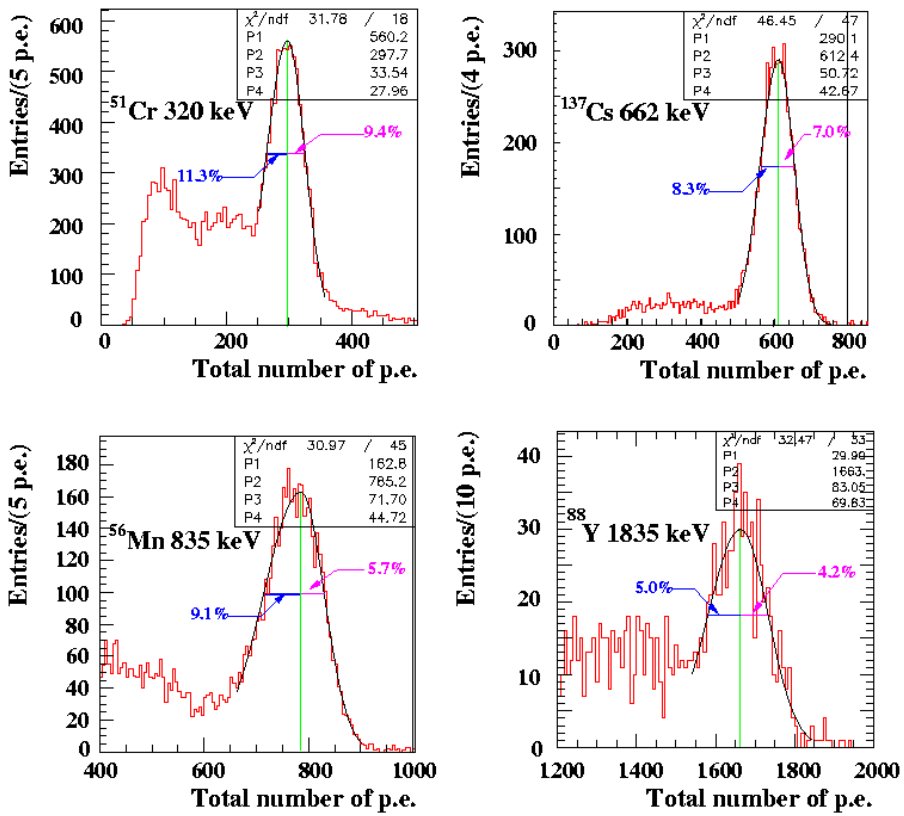
Analysis

- Position of γ interaction:

  Weighting the position of the PMTs with their individual pulse heights

- For selecting the fully contained events:

  Requiring the γ int. position should lie within a central region of 2cmx1cmϕ



Analysis

γ-ray

- Not be tagged by electron
- Energy is not monochromatic（Compton edge）
- Focused with a 1-mm ϕ collimator

Resolutions

■ **Energy** is estimated by means of **the spread of Compton edge.**

■ **Position** is calculated as the difference of position estimated in two groups.
(like the case of small ptototype)

■ **Time** is the difference of the average time estimated in two groups.