The MEG Detector to Search for μ -> $e\gamma$ Decays

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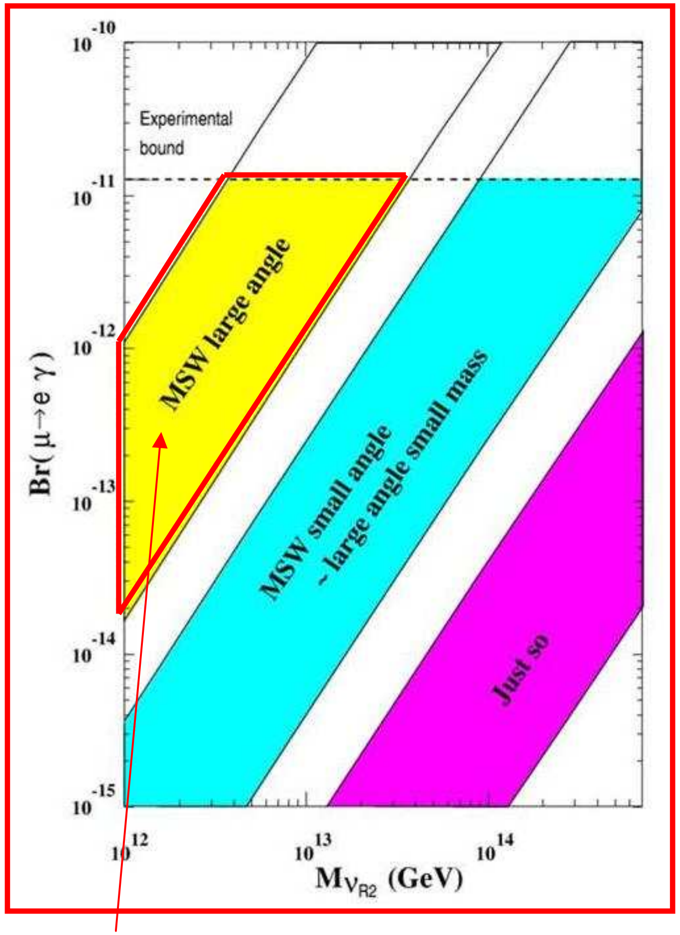
Contents

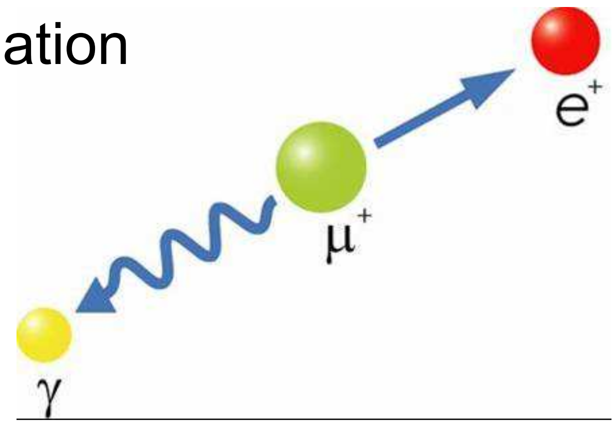
- Motivation & Event Signature
- MEG Experiment & Detector
- Beam Line
- COBRA Spectrometer
- Photon Detector
  - 1. TERAS Beam test
  - 2. π^0 beam test in PSI
- Summary

Motivation & Event Signature



Only allowed after KamLAND

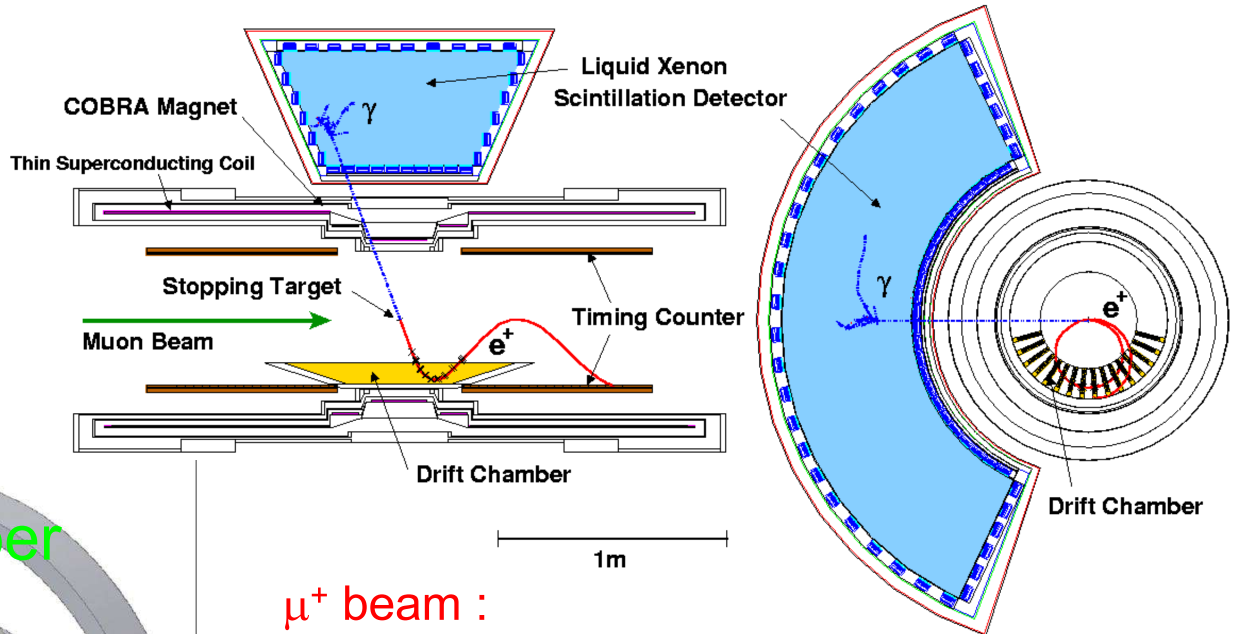
- Lepton flavor violating process
- Forbidden in the standard model
- Sensitive to the new physics such as SUSY-GUT, SUSY-seesaw etc.
- Our goal : Br(μ->eγ)>10^{-13}~10^{-14}
  Present limit < 1.2x10^{-11}(MEGA)
- Clear 2-body kinematics
  $E_e = E_\gamma$ = 52.8 MeV
  Back to back event
  Time correlation

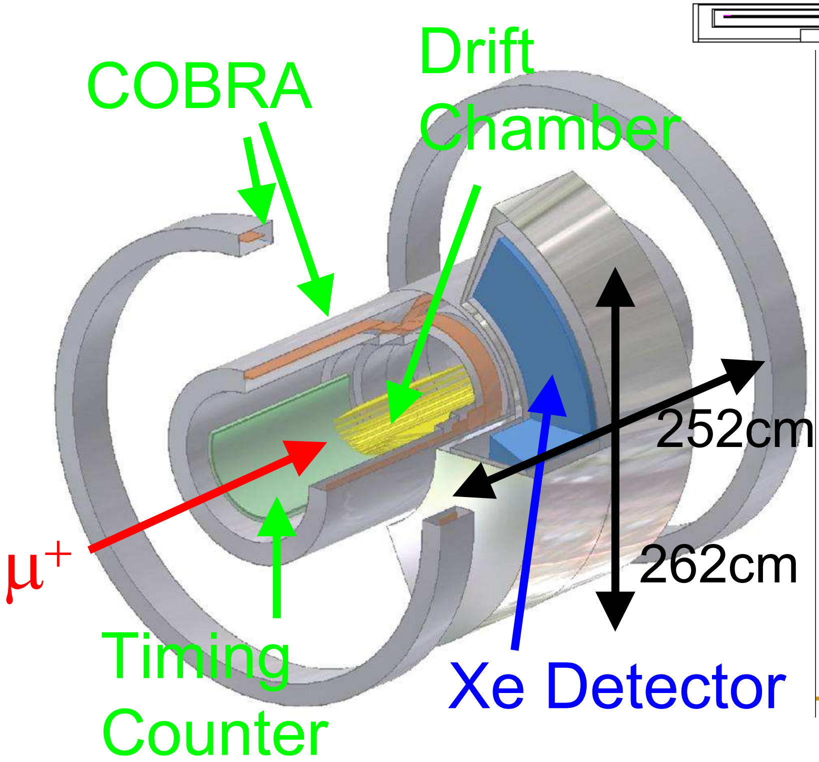


MEG Experiment & Detector

Approved in 1999,
at Paul Scherrer Institut

Physics run in 2006
Initial goal at 10^{-13},
finally to 10^{-14}



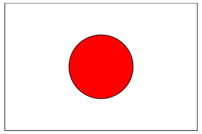


μ^+ beam :
World's most Intensive DC Beam 10^8 μ^+ /s

γ detector :
800liter liquid xenon scintillation detector
with 850 PMTs

e+ detector :
solenoidal magnetic spectrometer with a
gradient magnetic field (COBRA)

The MEG Collaboration

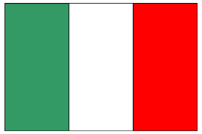


ICEPP, University of Tokyo Y. Hisamatsu, T. Iwamoto, T. Mashimo, S. Mihara, T. Mori, H. Nishiguchi, W. Ootani, K. Ozone, T. Saeki, R. Sawada, S. Yamada, S. Yamashita

KEK, Tsukuba T. Haruyama, A. Maki, Y. Makida, A. Yamamoto, K. Yoshimura, K. Kasami

Osaka University Y. Kuno

Waseda University T. Doke, J. Kikuchi, S. Suzuki, K. Terasawa, A. Yamaguchi, T. Yoshimura



INFN & Genova University S. Dussoni, F. Gatti, D. Pergolesi, R. Valle

INFN & Lecce University S. Spagnolo, C. Chiri, P. Creti, M. Panareo, G. Palama’

INFN & Pavia University A.de Bari, P. Cattaneo, G. Cecchet, G. Nardo’, M. Rossella

INFN & Pisa University A. Baldini, C. Bemporad, F.Cei, M.Grassi, F. Morsani, D. Nicolo’, R. Pazzi, F. Raffaelli, F. Sergiampietri, G. Signorelli

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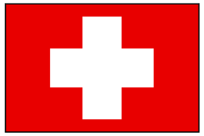
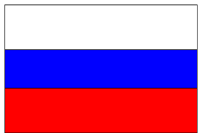


PSI, Villigen J. Egger, P. Kettle, M. Hildebrandt, S. Ritt



Budker Institute, Novosibirsk L.M. Barkov, A.A. Grebenuk, D.G. Grigoriev, B, Khazin, N.M. Ryskulov

Signal & Background

- Single event sensitivity

  $N\mu \sim 2.5\text{x}10^7/\text{s}$, $T=2.6\text{x}10^7\text{s}$, $\Omega/4\pi=0.09$, $\varepsilon_\gamma=0.6$, $\varepsilon_e=0.9$

  Sensitivity ($\mu \to e\gamma$) ~ $4.5\text{x}10^{-14}$ (1st phase, capable to $N\mu \sim 1\text{x}10^8/\text{s}$)

- Background

  Accidental :

  Michel decay ($\mu^+ \rightarrow e^+ \nu_e \nu_\mu$) + random γ

  Background Rate ~ 10^{-14}

  Radiative muon decays :

  $\mu^+ \rightarrow e^+ \nu_e \nu_\mu \gamma$

  Background Rate < 10^{-14}

Expected detector resolution

ΔE_γ : 4.5% (FWHM)

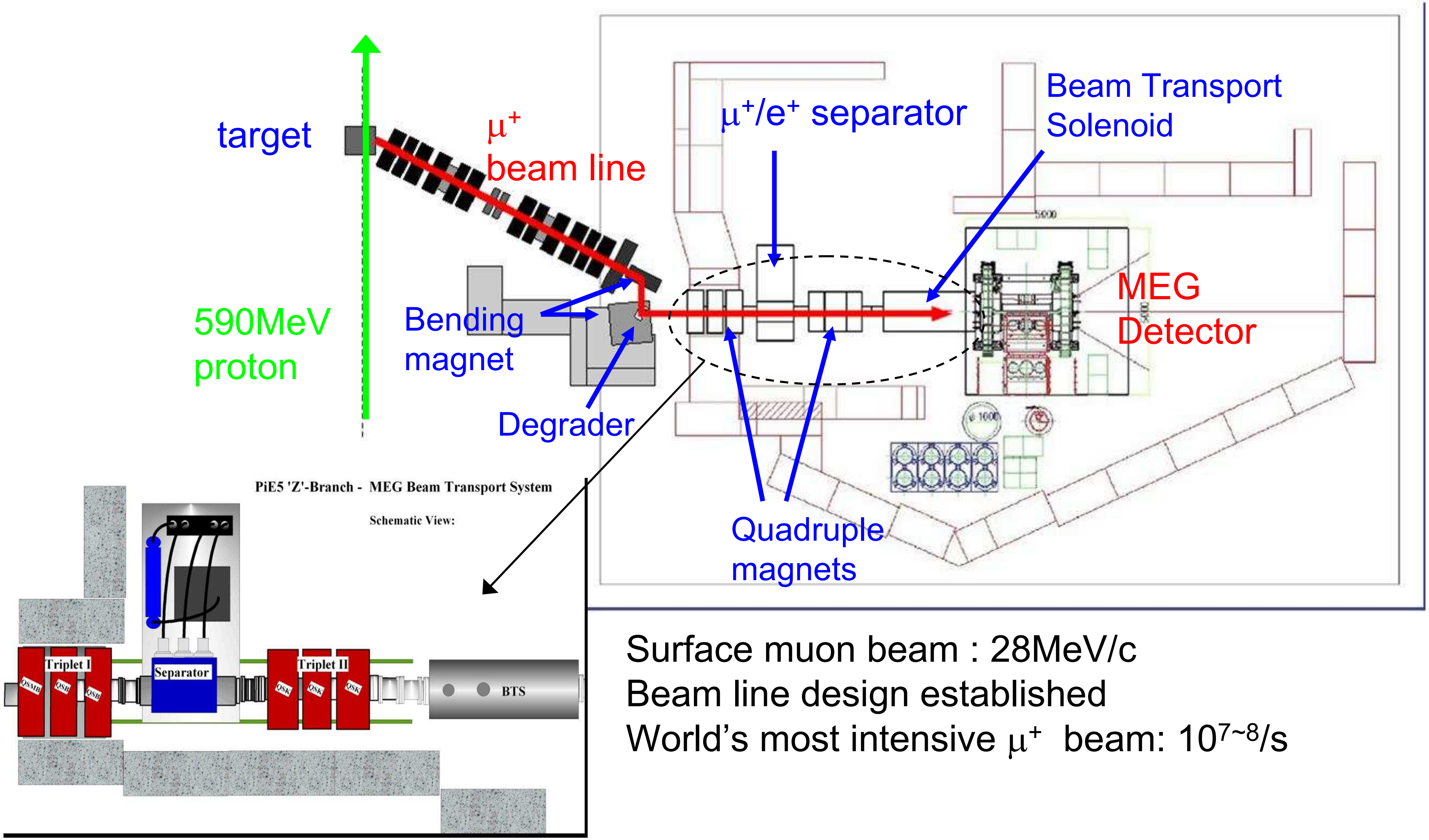
ΔE_e : 0.8% (FWHM)

$\Delta\theta_{e\gamma}$: 18mrad (FWHM)

$\Delta t_{e\gamma}$: 141ps (FWHM)

- Good energy, time and position resolutions are required for γ, e^+ detector.

Beam Line



Surface muon beam : 28MeV/c
Beam line design established
World's most intensive μ^+ beam: $10^{7\sim8}$/s

COBRA Spectrometer

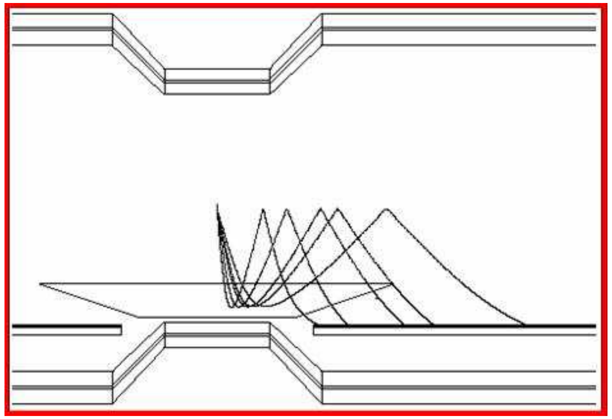
COBRA magnet was already installed into the πE5 area in PSI.

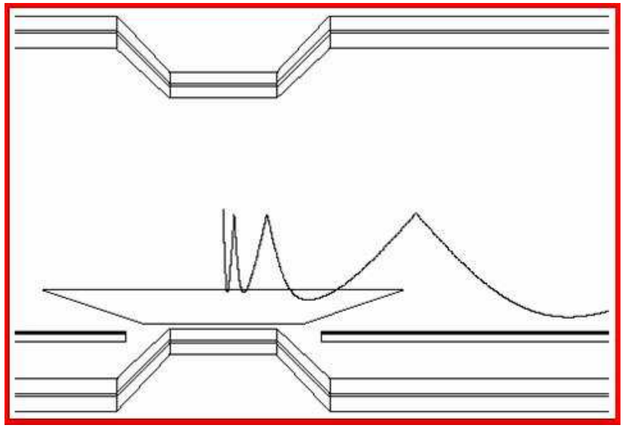
Constant bending radius independent of the emission angle

- e^+ momentum easily used at trigger level

Michel positrons are quickly swept out

- reduce the hit rate for stable operation





Photon Detector

- 800 liter liquid xenon detector with 850 PMTs
  (PMTs directly filled into the liquid Xenon)
- High light yield, fast response and good uniformity

Difficulties:

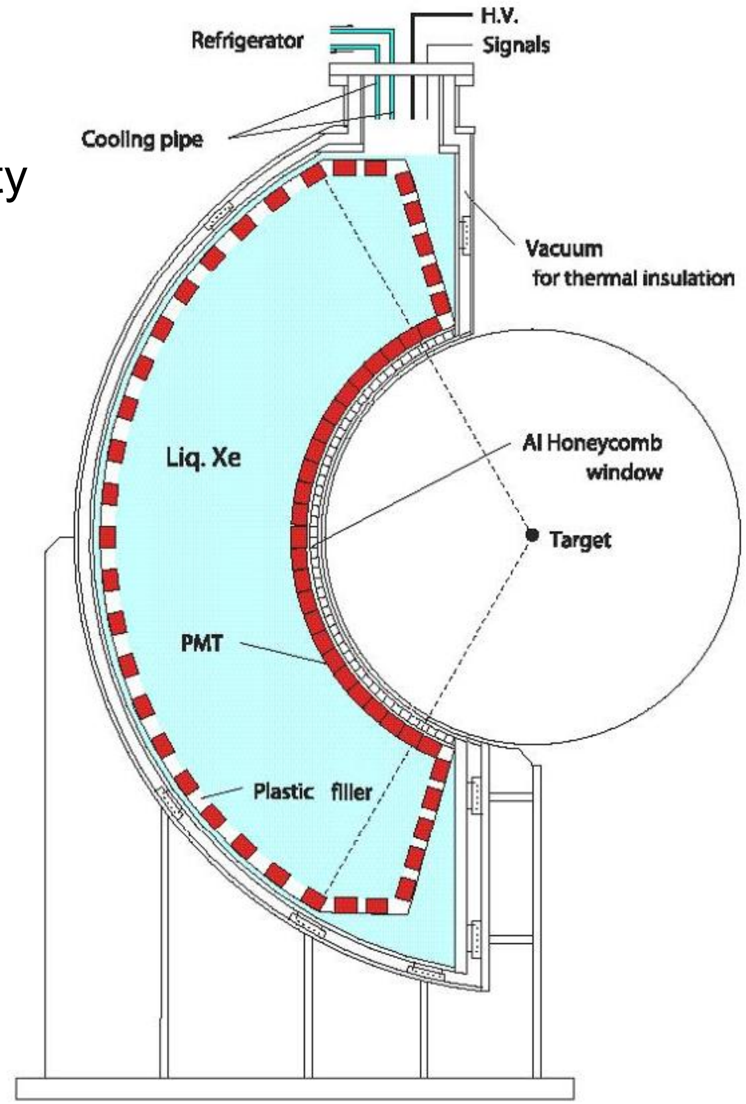
1. low temperature
   -> developed New PMT (Hamamatsu R9288)
   with special cathode treatment.
   use compact & powerful cryocooler (KEK)
2. Xe purity
   -> remove $H_2O(O_2)$ down to ~10ppb level

The strategy to develop Xe detector

✓ Small prototype (2.3 liter size)
confirmed the principle of Xe -> done

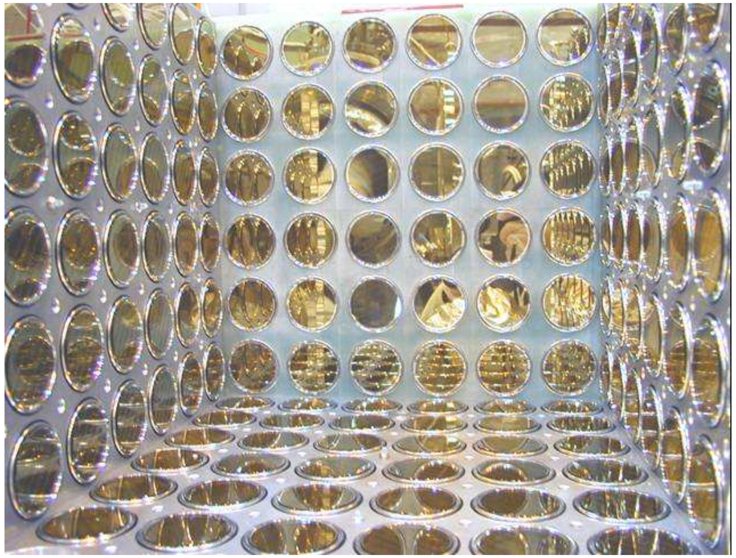
Large prototype (68.6 liter size)

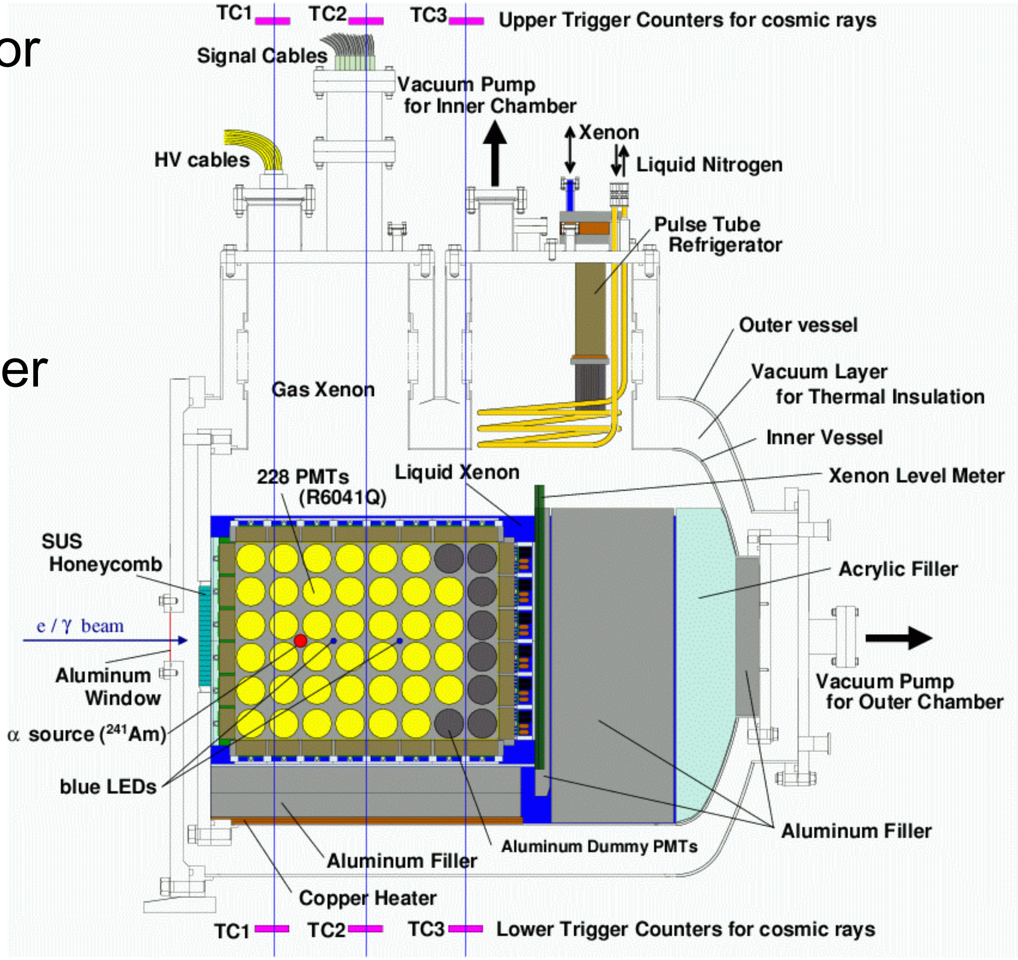
1. TERAS beam test
   energy resolution of 10~40MeV γ
   timing and vertex resolution
2. π^0 beam test in PSI
   energy resolution of 53~129MeV γ



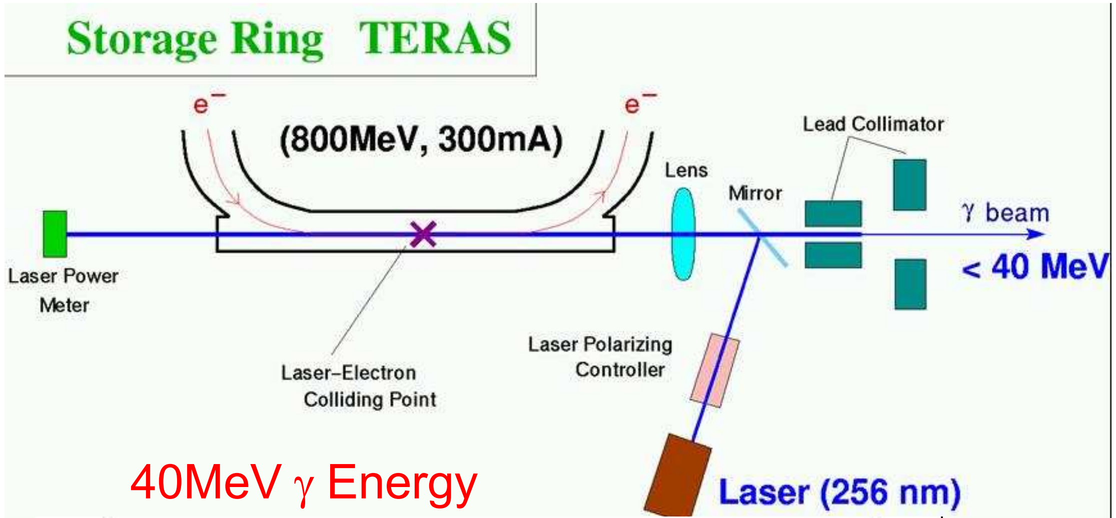
Large Prototype Detector

Large Prototype
- Smaller acceptance Xe detector
- Active volume : 68.6little
- 228 2” PMTs
- To check performances and learn how to operate including LN_2 free operation by cryocooler





1. TERAS Beam Test

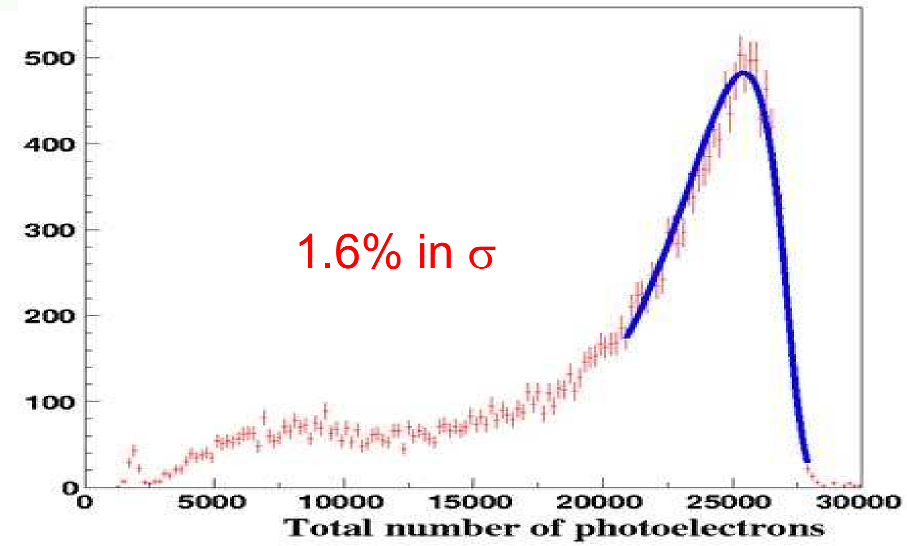


Inverse compton γ Energy : 10, 20, 40 MeV

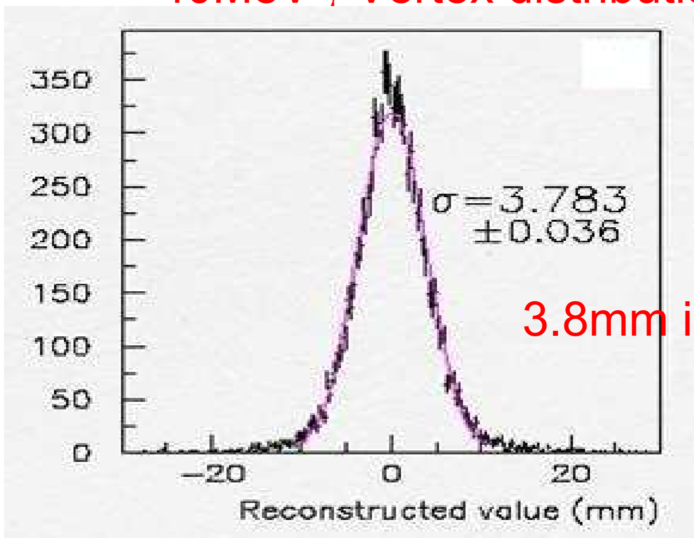
Incident position : detector center

Estimate energy resolution using compton edge

40MeV γ Energy



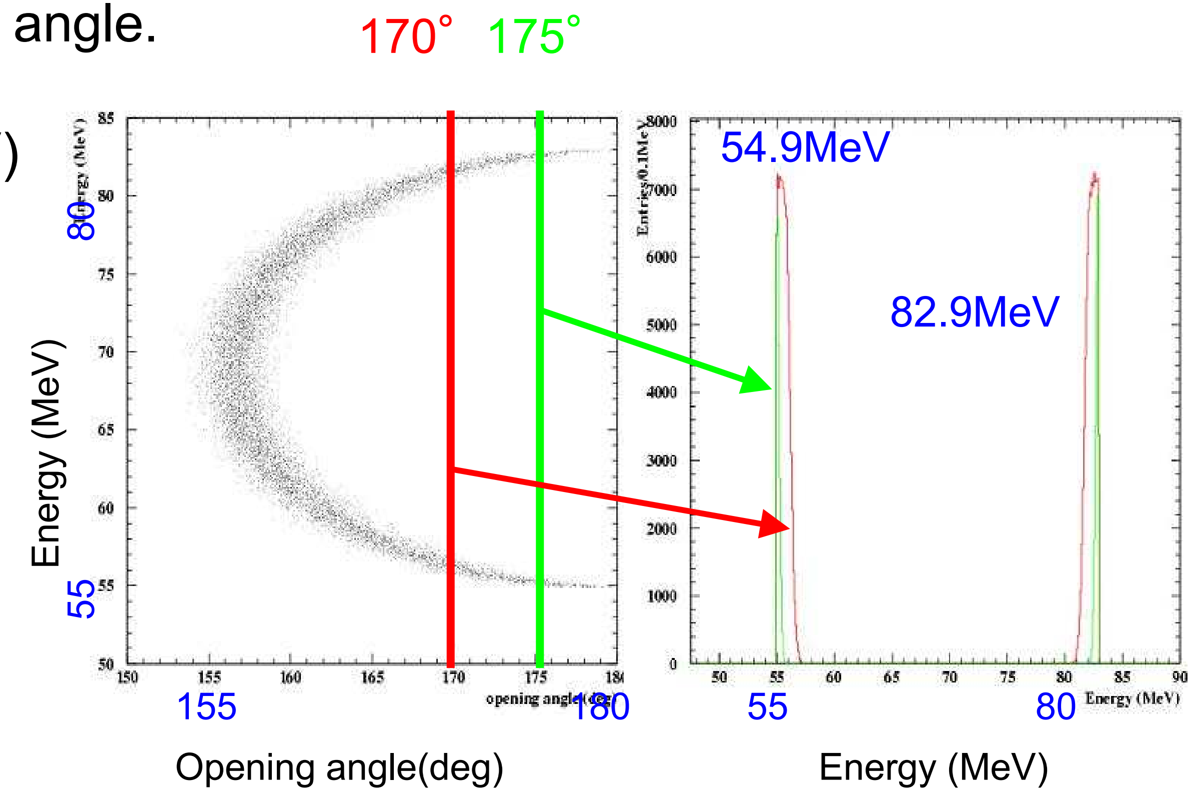
40MeV γ Vertex distribution



2. π^0 Beam Test at PSI

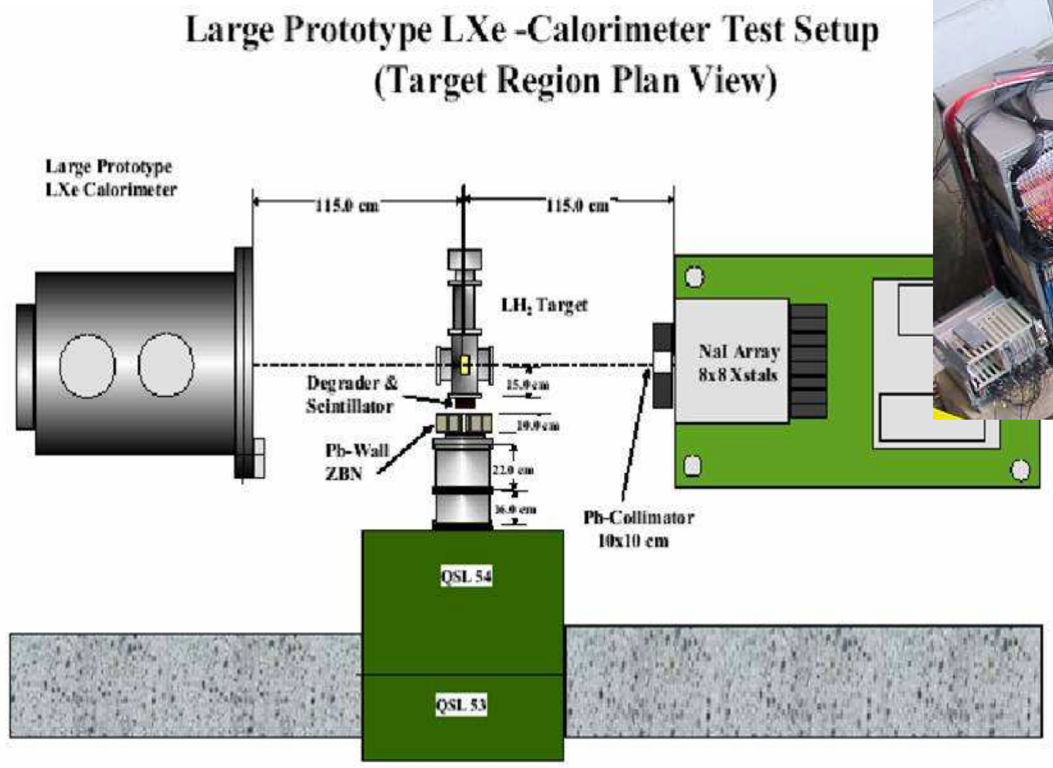
π^- (at rest) + p -> π^0 + n,
π^0(28MeV/c) -> $\gamma + \gamma$ (54.9MeV<Eγ<82.9MeV)
Almost monochromatic γ is available
by selecting opening angle.

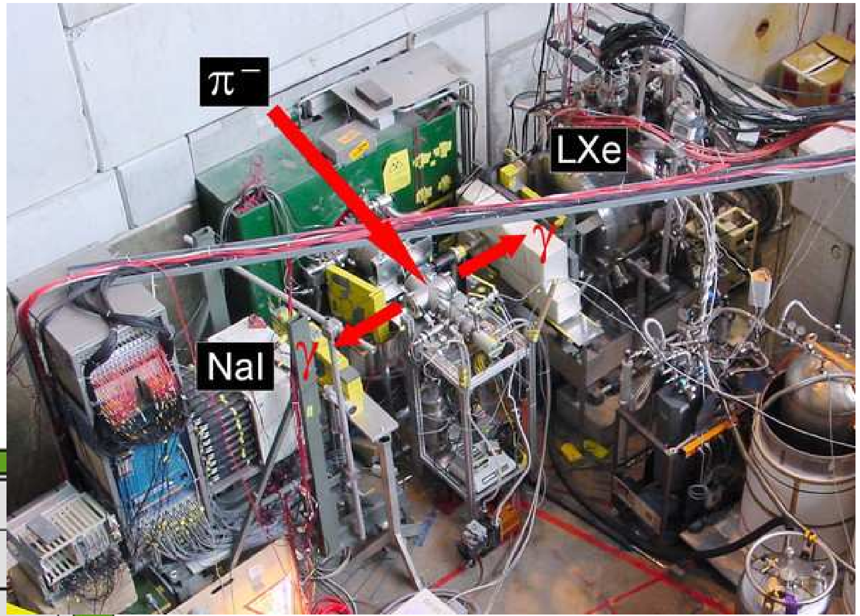
π^- + p -> n + γ (129MeV)
linearity check
using 55, 83 and 129MeV γ
neutron response



2. π^0 Beam Test at PSI

- 8x8 NaI array opposite to Large Prototype Xe detector to know opening angle
  each NaI is 6.3x6.3x40.6cm3
- Liquid H_2 target



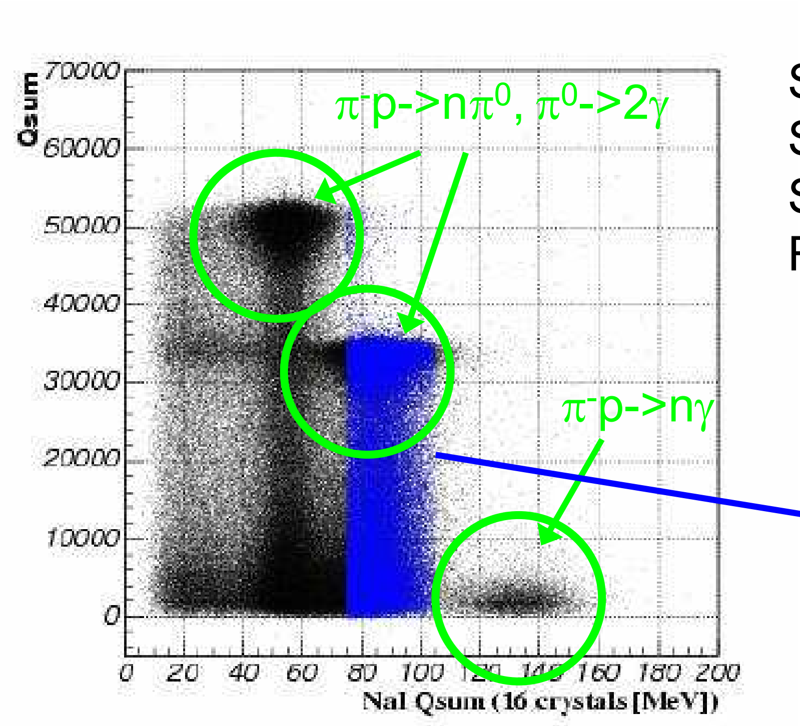


Typical Event Sample

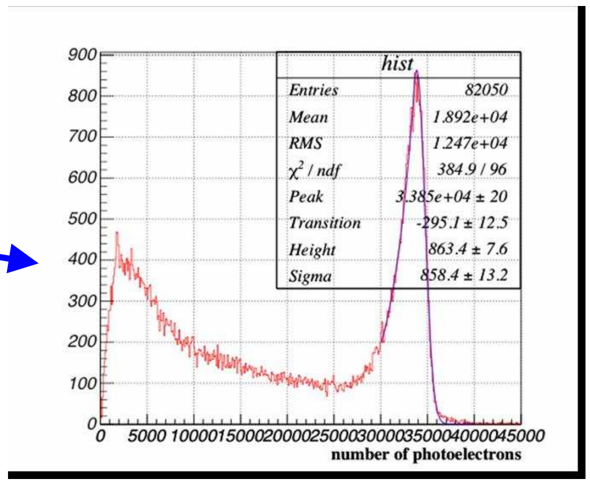
To get Energy Resolution

Select π^0 events
Select NaI energy
Select incident position in Xe detector
Remove too shallow and too deep events

Number of p.e. in Xenon

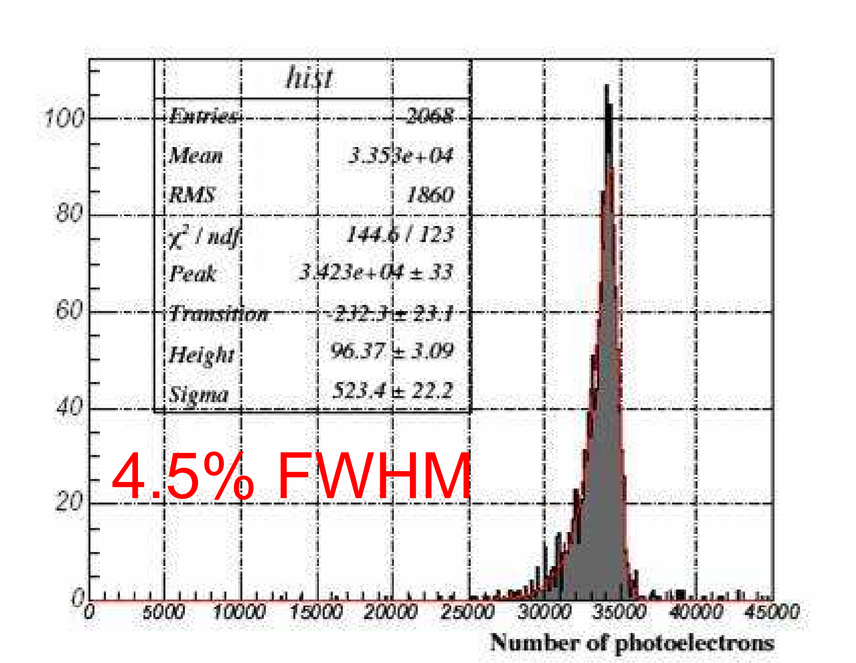


Energy of NaI (MeV)

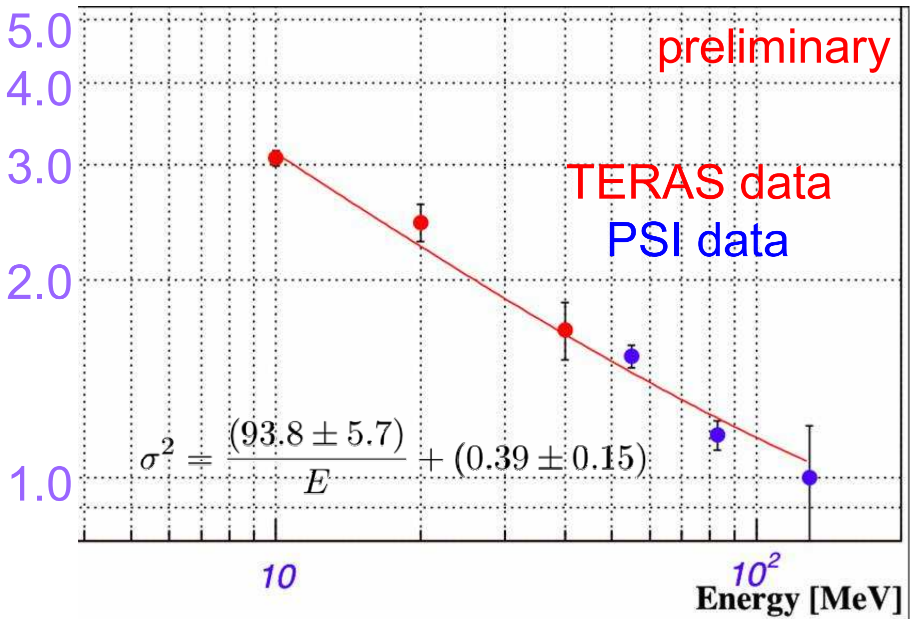


Number of p.e. in Xenon

Energy Resolution



Energy resolution in right σ(%)



Energy spectrum @ 54.9 MeV γ
This satisfies the requirement

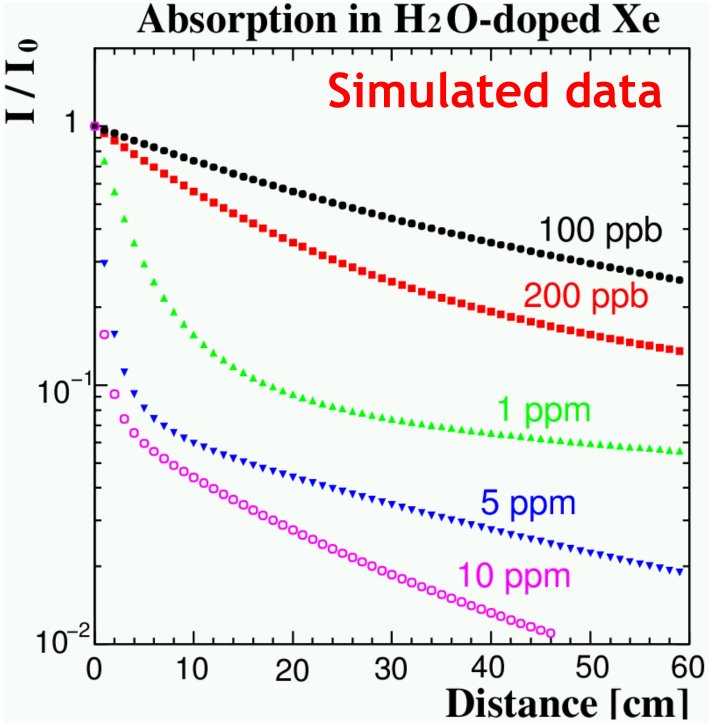
Right σ is a good function of energy

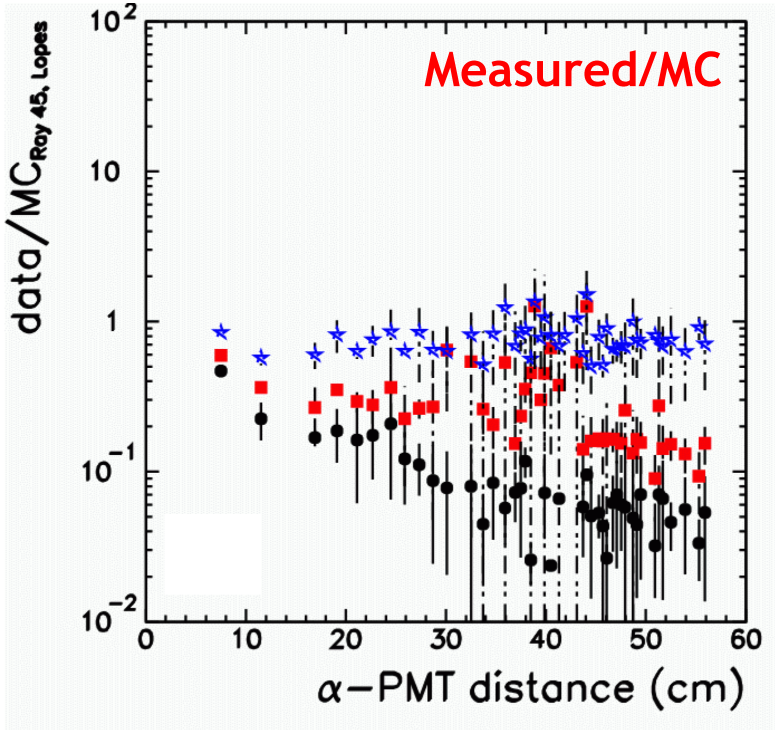
Summary

- MEG experiment will search for a rare muon decay, μ->eγ, to explore SUSY-GUT, and currently being prepared at Paul Scherrer Institut in Switzerland.
- COBRA magnet was installed into the πE5 area, and is ready to use.
- Large prototype of the xenon detector has been tested at around 52.8MeV, and the excellent energy resolution was shown in the PSI beam test.
- Physics run will start in 2006.

End of Transparency

How much water contamination?

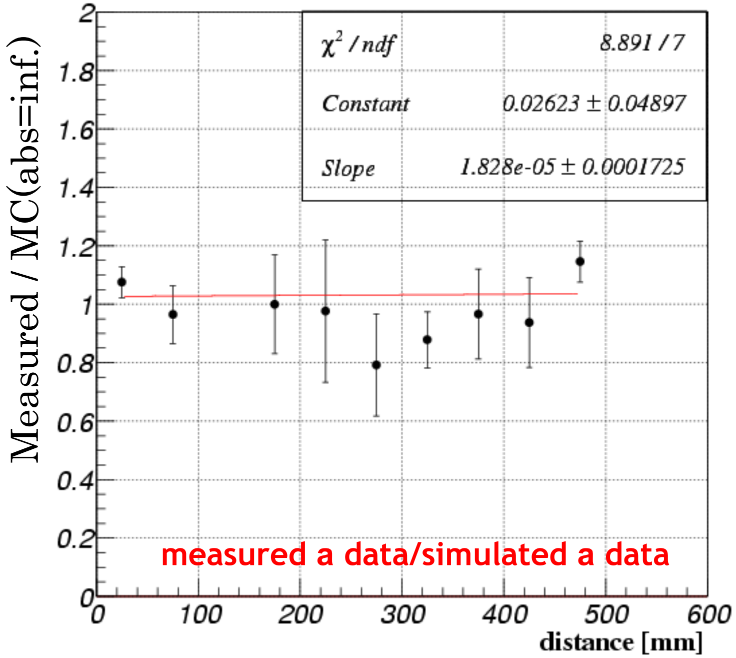


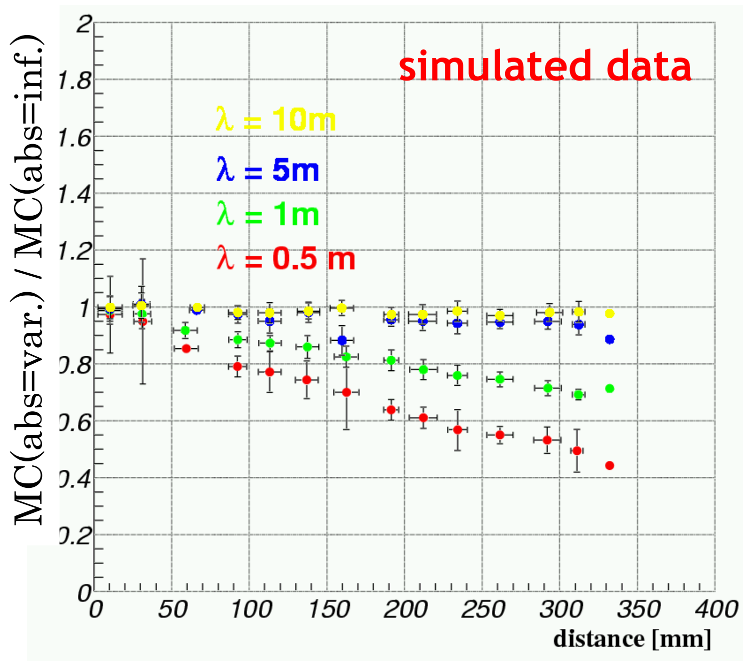


Before purification: ~10 ppm

After purification: ~10 ppb

Absorption length estimation





Comparing the two results,

the absorption length is estimated to be

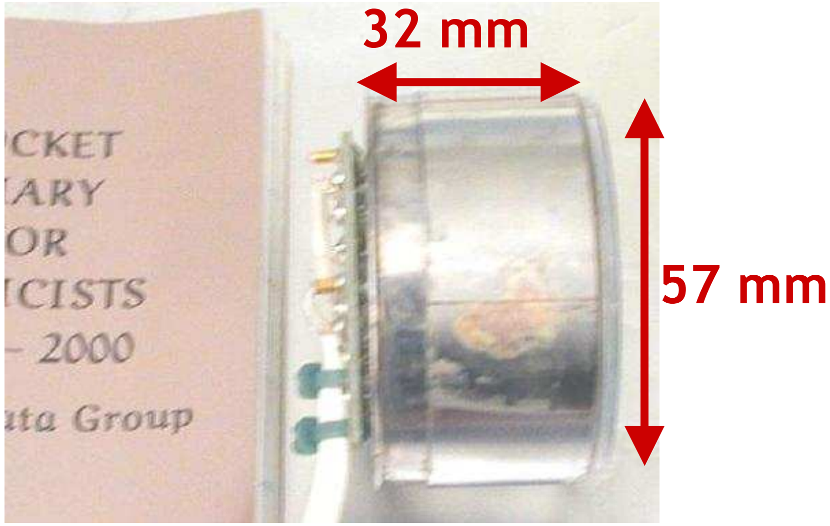
over 3m (97.8% C.L.).

PMT (HAMAMATSU R6041Q)

Features

- 2.5-mmt quartz window
- Q.E.: 6% in LXe (TYP)

  (includes collection eff.)
- Collection eff.: 79% (TYP)
- 3-atm pressure proof
- Gain: 10^6 (900V supplied TYP)
- Metal Channel Dynode → thin and compact
- TTS: 750 psec (TYP)
- Works stably within a fluctuation of 0.5 % at 165K



Motivation

➢Under high rate background, PMT output (old Type PMT, R6041Q) reduced by 10-20%.

➢This output deterioration has a time constant (order of 10min.):

→ Related to the characteristics of photocathode whose surface resistance increases at low temperature.

- ➢Rb-Sc-Sb + Mn layer used in R6041Q
- ➢Not easy to obtain "high" gain. Need more alkali for higher gain.
- ➢Larger fraction of alkali changes the characteristic of PC at low temp

Al Strip Pattern

➢Low surface resistance

So, New Type PMTs, R9288 (TB series) were tested under high rate background environment.

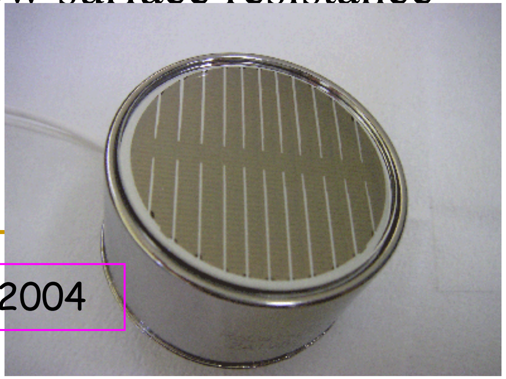
- ➢K-Sc-Sb + Al strip used in R9288
- ➢Al strip, instead of Mn layer, to fit with the dynode pattern

Confirmed stable output. (Reported in last BVR)

But slight reduction of output in very high rate BG

→ Add more Al Strip

R9288 ZA series



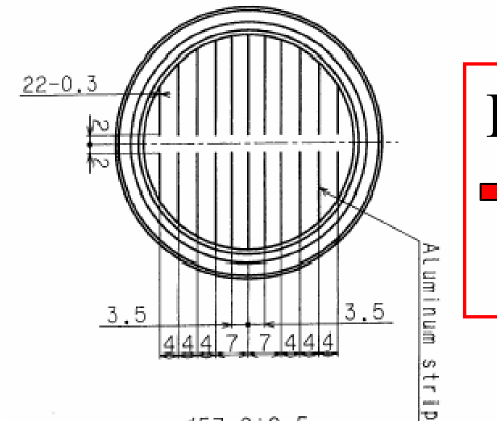
Yasuko HISAMATSU MEG VRVS Meeting @PSI June 2004

Works on Final! Design of PMT

Two Issues to be solved:

1. Output deterioration caused by high rate background.
   (Effects of ambient temperature on Photocathode)

Ans. Reduce Surface Resistance by adding Aluminum Strip Pattern



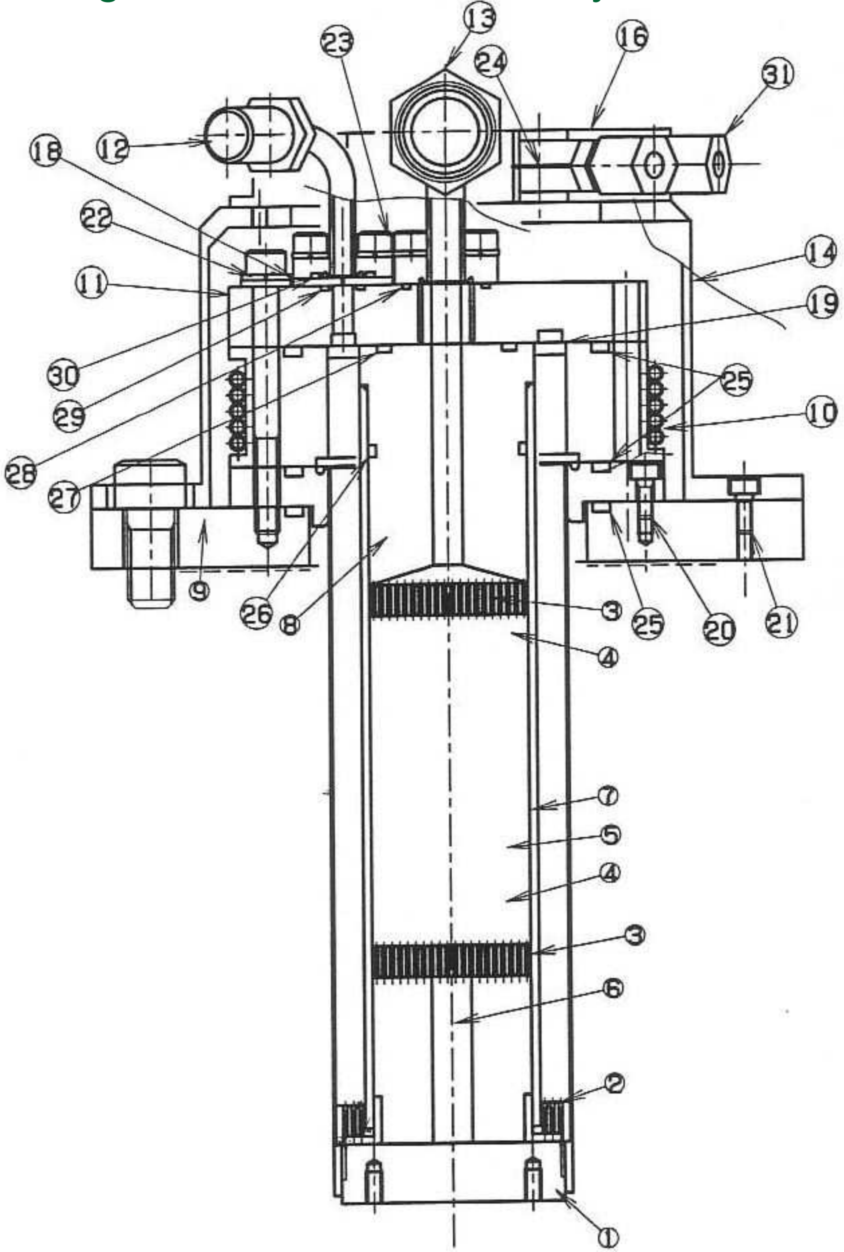
Delivered from HPK in April
➡ Rate Dependence Test
@ Liq.Xe

2. Shortage of Bleeder Circuit Current

Ans. Improve Design of the Circuit by adding Zener Diode

➡ HPK has started to work on new bleeder circuit design

Large Power Pulse Tube Cryocooler



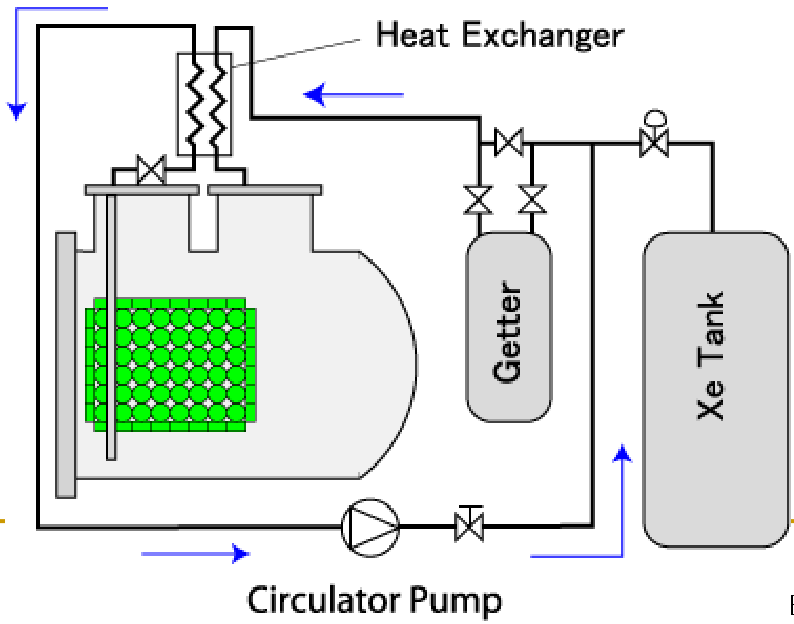
Technology transfered to Iwatani Co., Ltd

Designed:

150 W @165K

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 5-6cc/minute



- Enomoto Micro Pump MX-808ST-S
  - 25 liter/m
  - Teflon, SUS