Status of the MEG Experiment

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for the MEG collaboration

Outline

- Physics motivations for the MEG experiment
- MEG detector
- Status of the sub-detectors
    - Beam line
    - Photon detector
    - Positron spectrometer
        - Magnet
        - Drift chamber
        - Timing counter
    - Trigger, DAQ, and slow control
- Summary

MEG Collaboration

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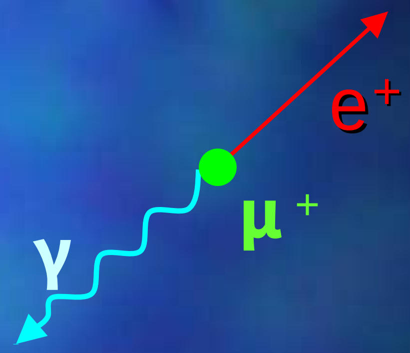
$\mu \rightarrow e\ \gamma$



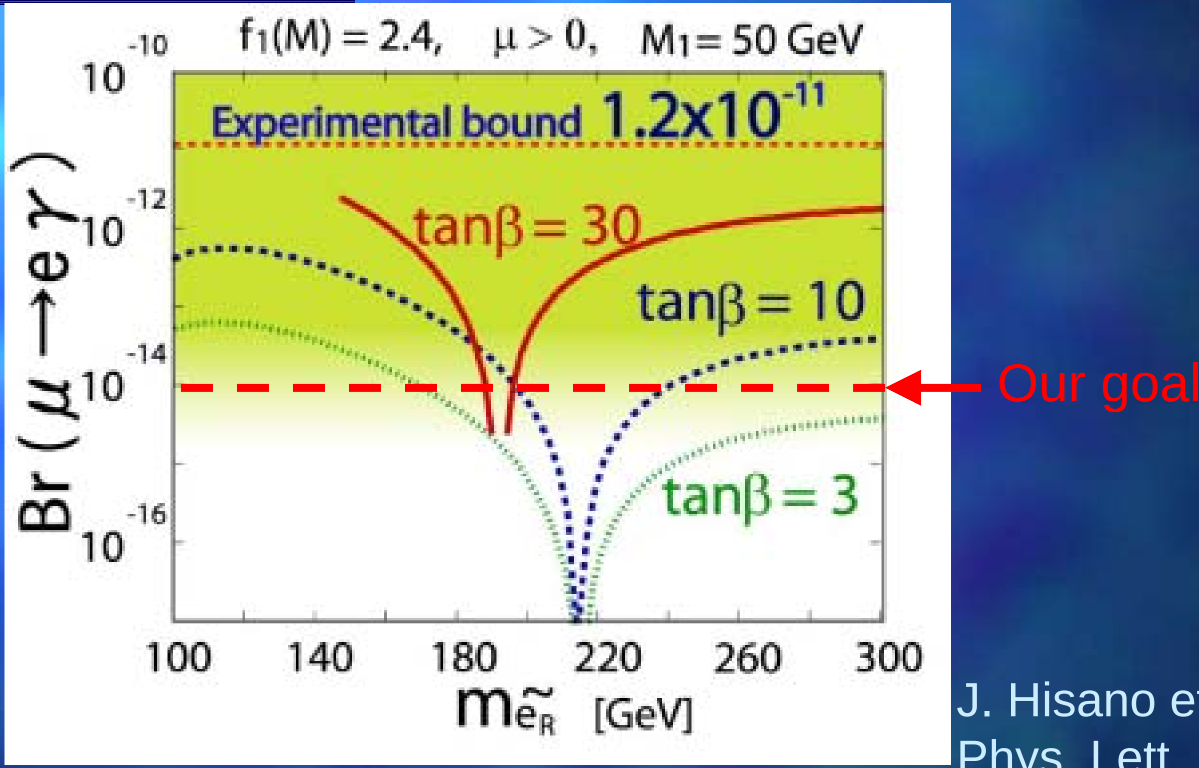
- Event signature
  - Back to back
  - Time coincident
  - $E_e = E\gamma = 52.8\mathrm{MeV}$
- Lepton-family-number nonconserving process
- Extremely small branching ratio in the standard model with finite neutrino mass

  ex.) $BR(\mu \rightarrow e\gamma) \sim 10^{-52}$ for $m_\nu \sim 0.05\mathrm{eV}$
- Sensitive to physics beyond the standard model

  SUSY-GUT, SUSY+ ν_R , …
- Present experimental bound

  $BR(\mu^+ \rightarrow e^+ \gamma) < 1.2 \times 10^{-11}$ (MEGA experiment, 1999)
- New experiment with a sensitivity of $BR \sim 10^{-14}$ planned at PSI

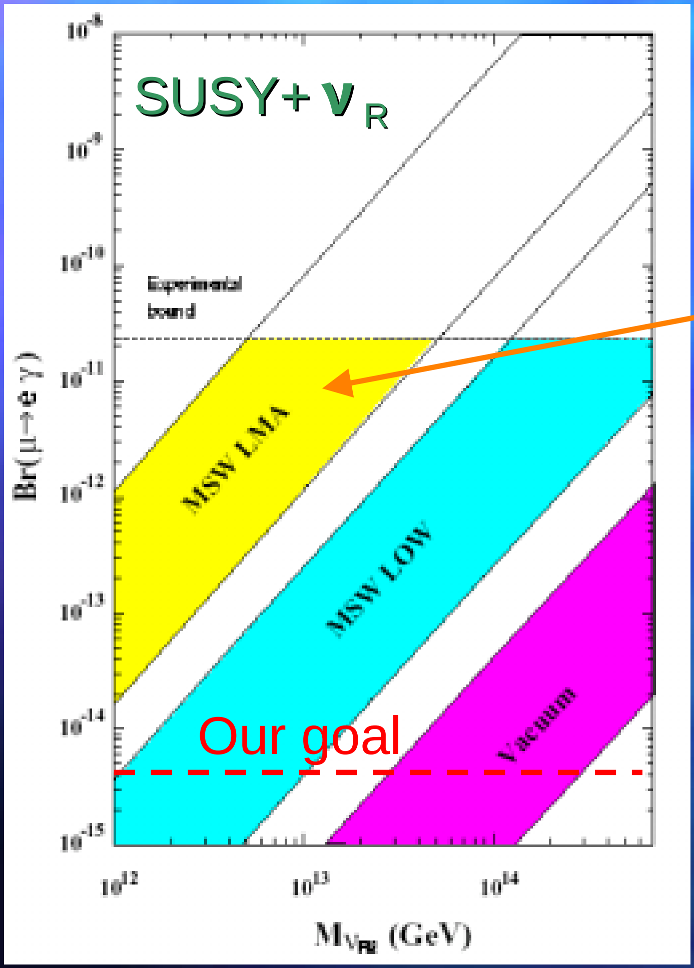
Physics Motivations



J. Hisano et al., Phys. Lett. B391 (1997) 341

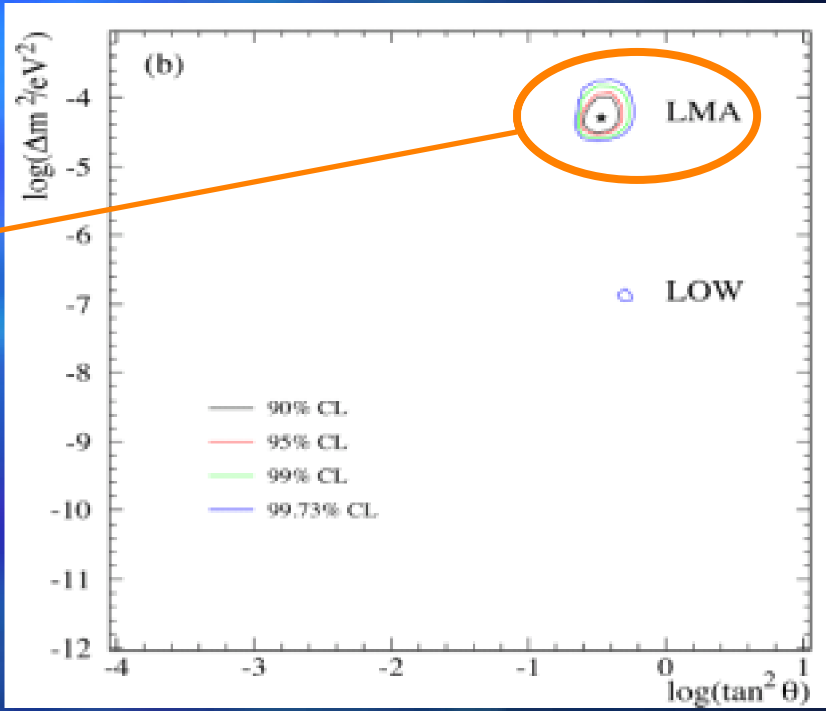
- SU(5) SUSY-GUT predicts BR $(\mu\rightarrow e\gamma) = 10^{-15} - 10^{-13}$
  (SO(10) SUSY-GUT: even larger value $10^{-13} - 10^{-11}$)
- Small tanβ excluded by LEP SUSY search

Physics Motivations, cont'd



J.Hisano and D.Nomura, PRD59(1999)116005

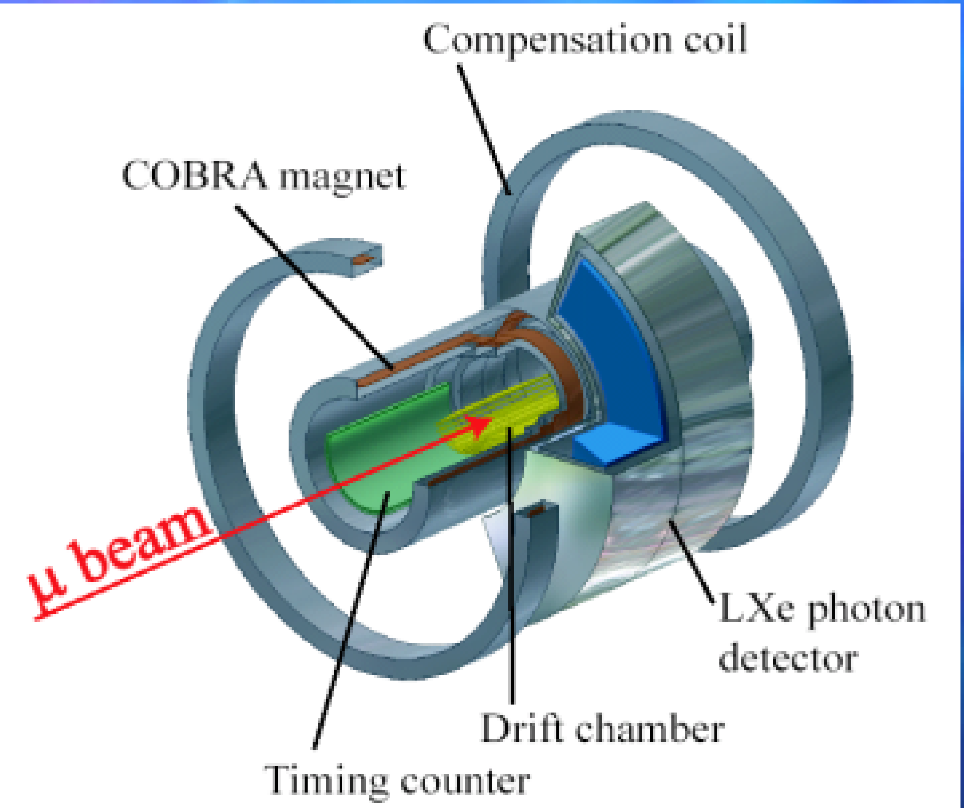
After the recent SNO measurements...



SNO collaboration, Q.R.Ahamd *et al.*, PRL89(2002)010302

- Solar ν meas. strongly favor the LMA.
- Large tanβ → large μeγ rate

MEG Detector



- Liquid xenon photon detector
- Positron spectrometer with gradient magnetic field (COBRA spectrometer)
- World's most intense DC muon beam at PSI
- Sensitivity down to BR~10^{-14}
- Engineering/physics run will start in 2004

Sensitivity and Background

- Single event sensitivity

  N_μ=1x10^8/sec, T =2.2x10^{7}sec, $\Omega/4\pi$=0.09, ε_γ=0.7,ε_e=0.95

  ➡ BR($\mu^+ \rightarrow e^+ \gamma$) ~ 0.94 x 10^{-14}

- Major backgrounds
  - Accidental Coincidence

    Michel decay($\mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu$)

    + random γ

    $B_{accidental}$ ~ 5 x 10^{-15}
  - Radiative muon decays

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

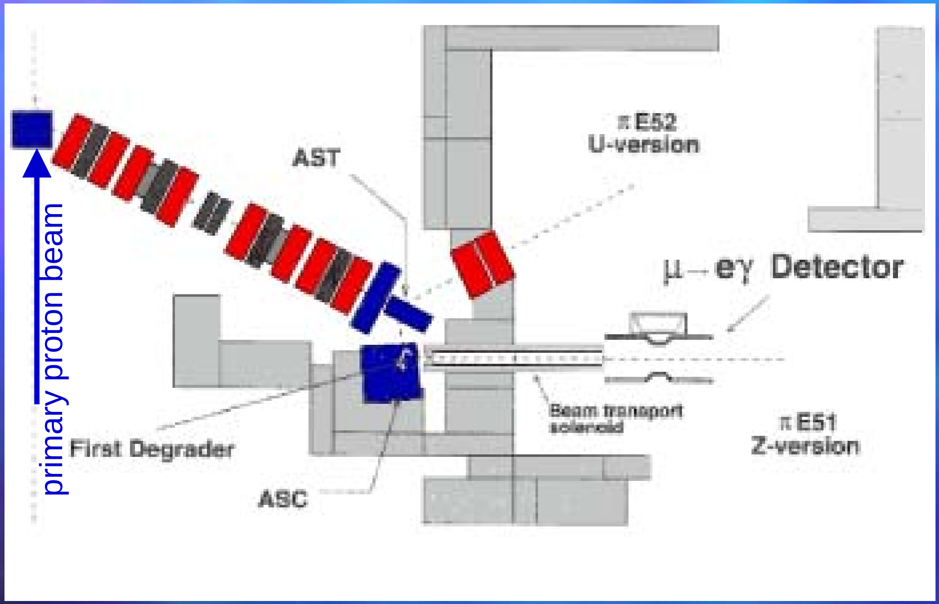
    B_{prompt} ~ 10^{-17}

Proposed detector performance

ΔE_e	0.7% (FWHM)
ΔE_γ	1.4 – 2.0 % (FWHM)
$\Delta \theta_{e\gamma}$	12 – 14 mrad(FWHM)
$\Delta t_{e\gamma}$	0.15 nsec (FWHM)

These values could be changed according to the actually achieved performance of the detector.

Beam Line



- DC muon beam rate above 10^8 μ/s at πE5 beam line
- Two beam branches ("U" and "Z")
- Comparative study of the branches is in progress.
- Positron contamination can be reduced by:
  (1) Combination of an energy degrader and a magnetic selection
  (2) Wien filter

Condition	"Z"-branch	"U"-branch
No degrader, transmitted to zone	$3.6\times10^8\mu^+/s$ $6.0\times10^8e^+/s$	$3.5\times10^8\mu^+/s$ $1.6\times10^9e^+/s$
Degrader at final focus	$2.0\times10^8\mu^+/s$	$3.2\times10^7\mu^+/s$
m/e ratio at Muon Peak	9	16.5

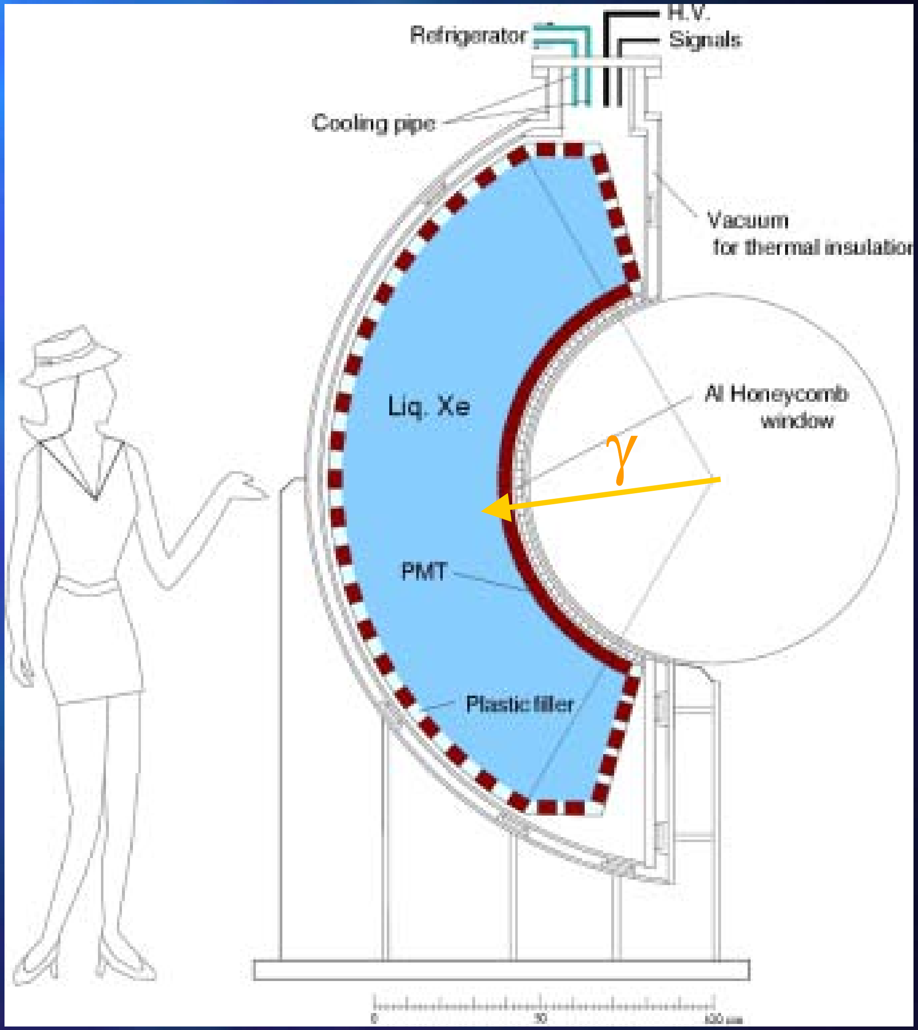
Decision on the choice of the beam branch will be made after the beam tests
with "U"-branch in Aug.2002 and
with "Z"-branch in Nov.2002

Liquid Xenon Photon Detector

- High light yield (75% of NaI(Tl))
- Fast signals
  →avoid accidental pileups
- Spatially uniform response
  →no need for segmentation

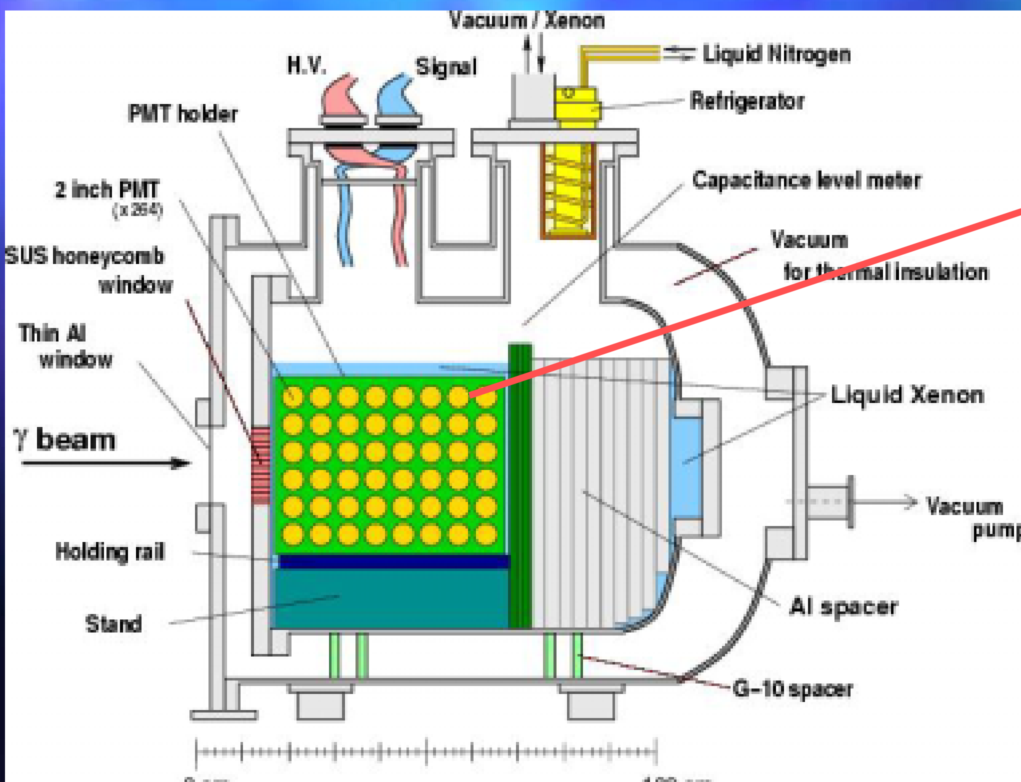
Current design

- Active volume of LXe: ~800 liter
- Scintillation light is collected by ~800 PMTs immersed in LXe
- Compact PMT with metal channel dynode structure and quartz window (Hamamatsu R6041Q)



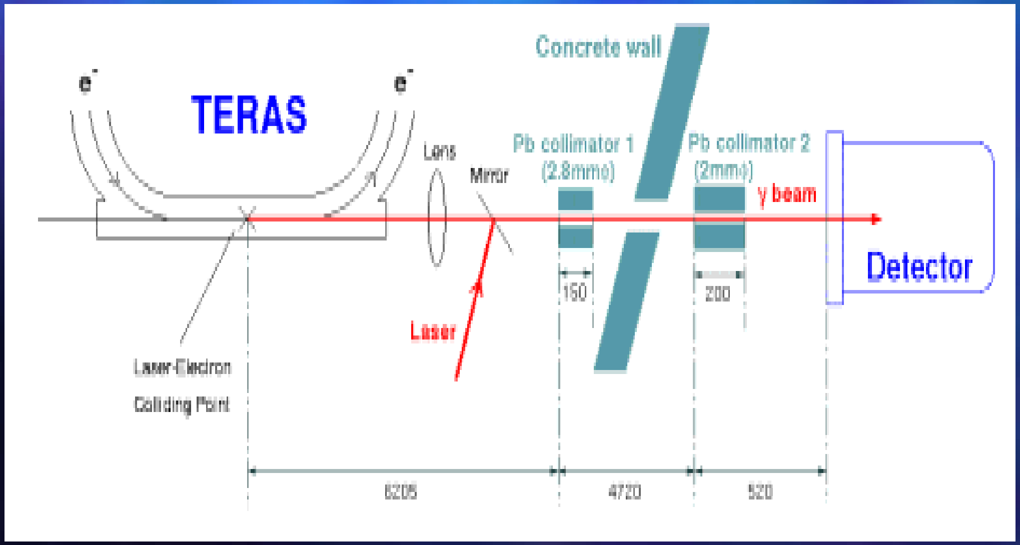
Photon Detector Prototype

- A total of 120 liter liquid xenon (active volume of 69 liter)
- Viewed by 240 PMTs
- Large enough to test with ~50MeV γ
- LEDs and α sources (^{241}Am) implemented for calibration

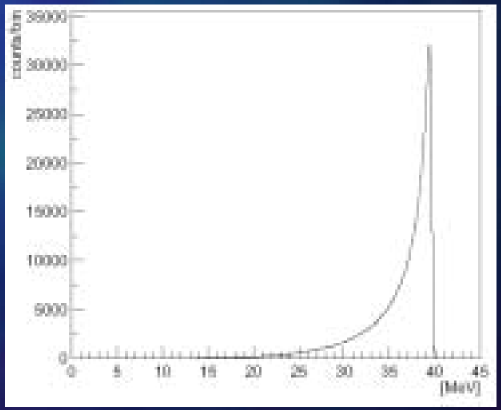


Gamma Beam Tests

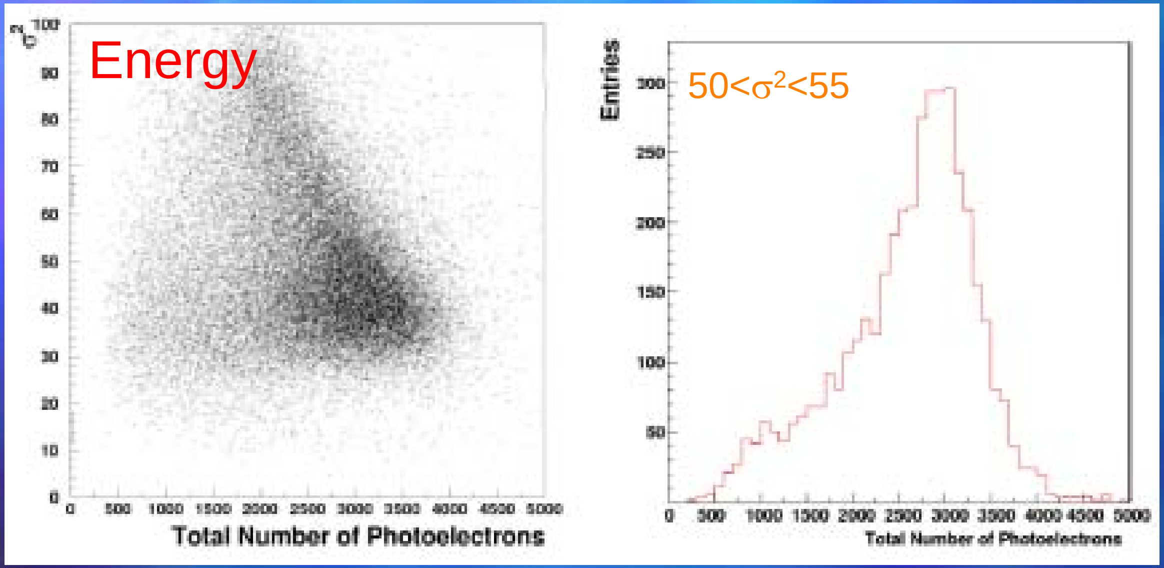
- Performance test of large prototype using high-energy gamma rays
- Laser Compton backscattering facility at TERAS electron storage ring of AIST, Tsukuba, Japan
- Gamma-ray beam with energy up to 40MeV
- Energy resolution evaluated by spread of Compton edge
- Position reconstructed by PMT output distribution with proper collimator
- Timing reconstructed by averaging arrival time
- Beam test in Feb. 2002

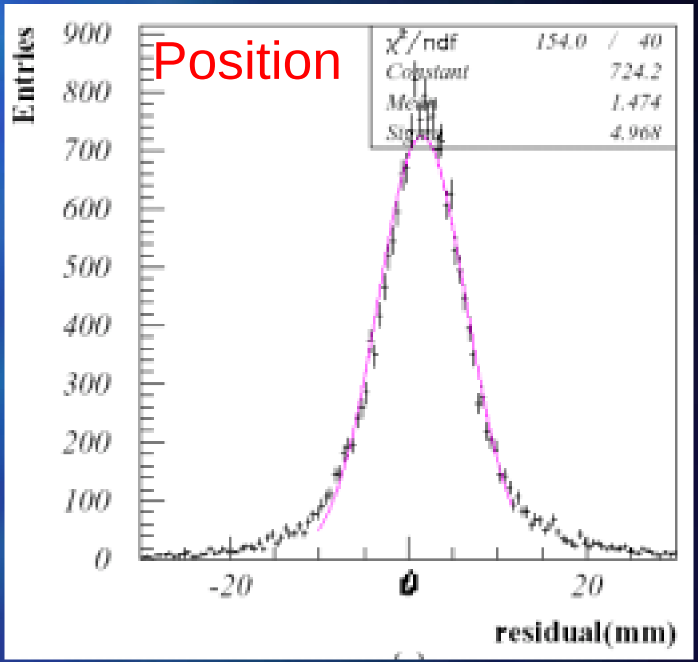


Energy spectrum of gamma beam with 1mmφ collimator (simulation)



Beam test in Feb. 2002





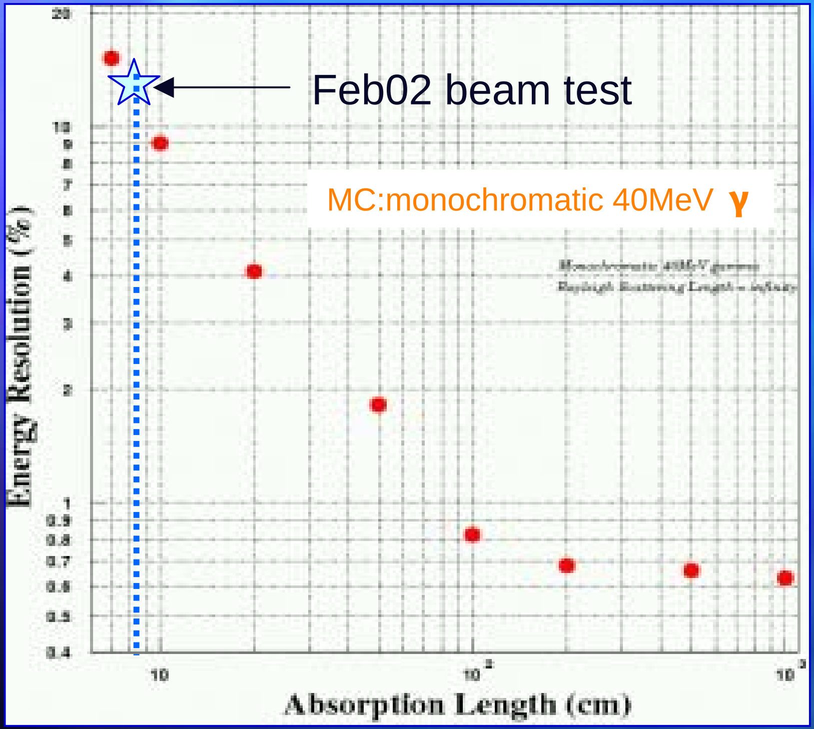
σ^2: conversion depth parameter

- Observed amount of light from 40MeV γ is smaller than expected. (~10%)
- Strong correlation between the conversion depth and N_{pe}
- Worse position resolution than expected

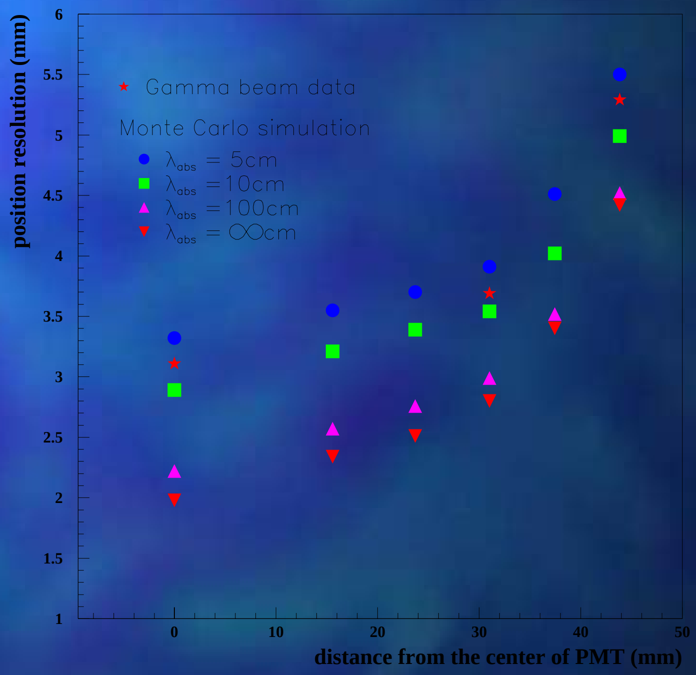
→ can be explained by strong light absorption in LXe

MC Predictions with Absorption

Energy resolution



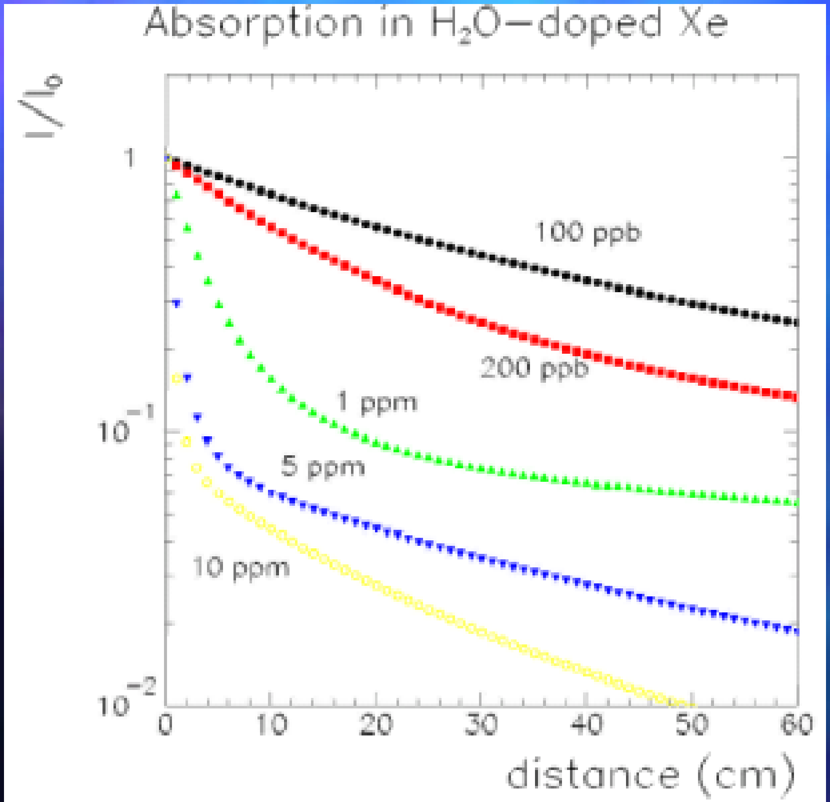
Position resolution



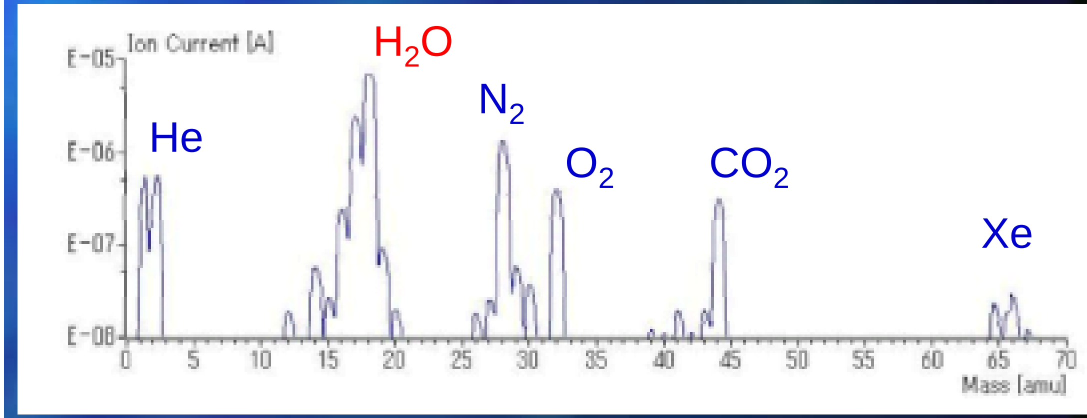
- MC predictions indicate λ_{abs} < 10cm in gamma beam test in Feb. 2002
- We need λ_{abs} > 100cm at least for an energy resolution of a few % order

Light Absorption in LXe

H_2O, C_2H_4, NH_3, O_2 can strongly absorb 175nm scintillation light from LXe → Contaminations in LXe?

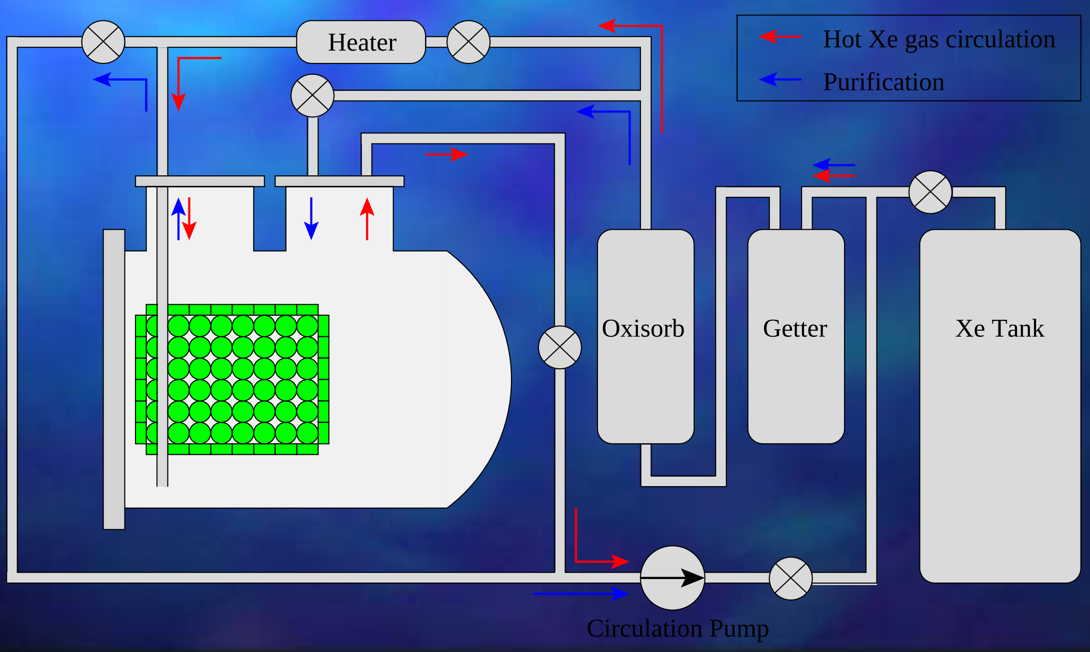


Mass spectrum for the remaining gas in the detector vessel

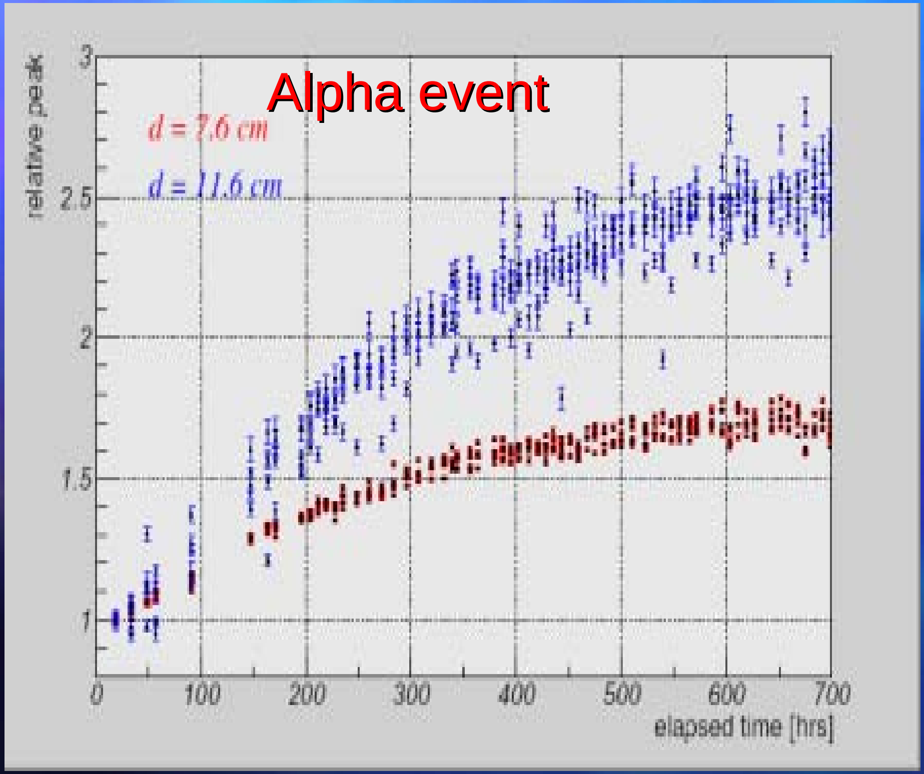


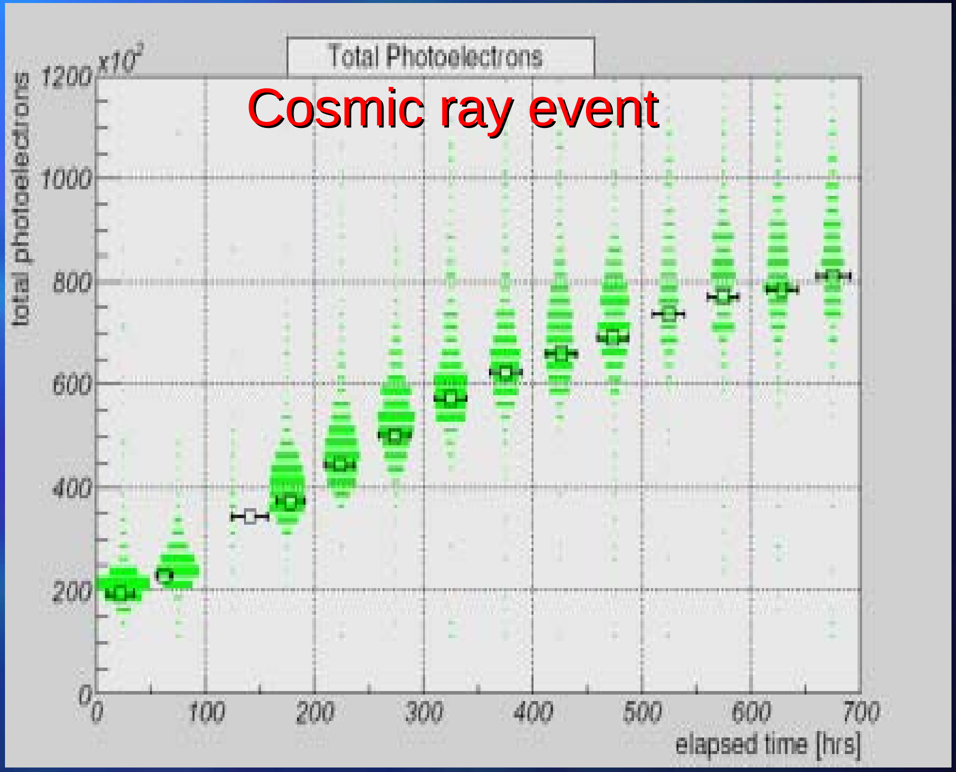
Purification

- New circulatory purification system is installed after the beam test in Feb.2002.
- Xenon vapor is purified in Zr-V-Fe getter and Oxisorb filter and recondensed by the refrigerator and LN_2 during the operation of the detector
- Circulation speed 10-12cc liq./minute



Improvement of Light Yield

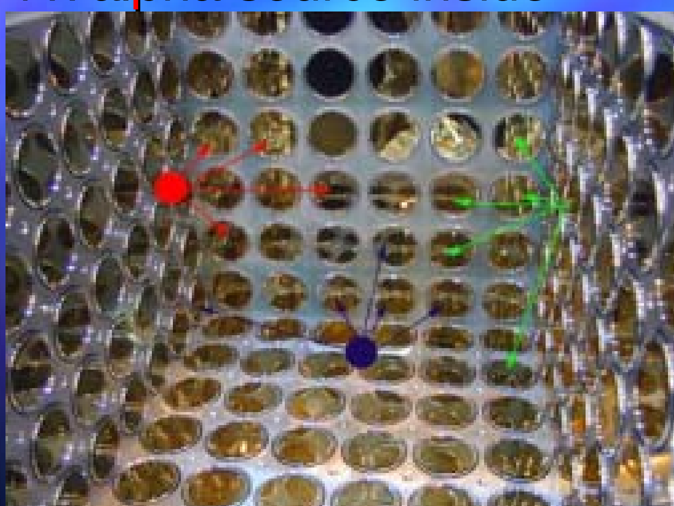




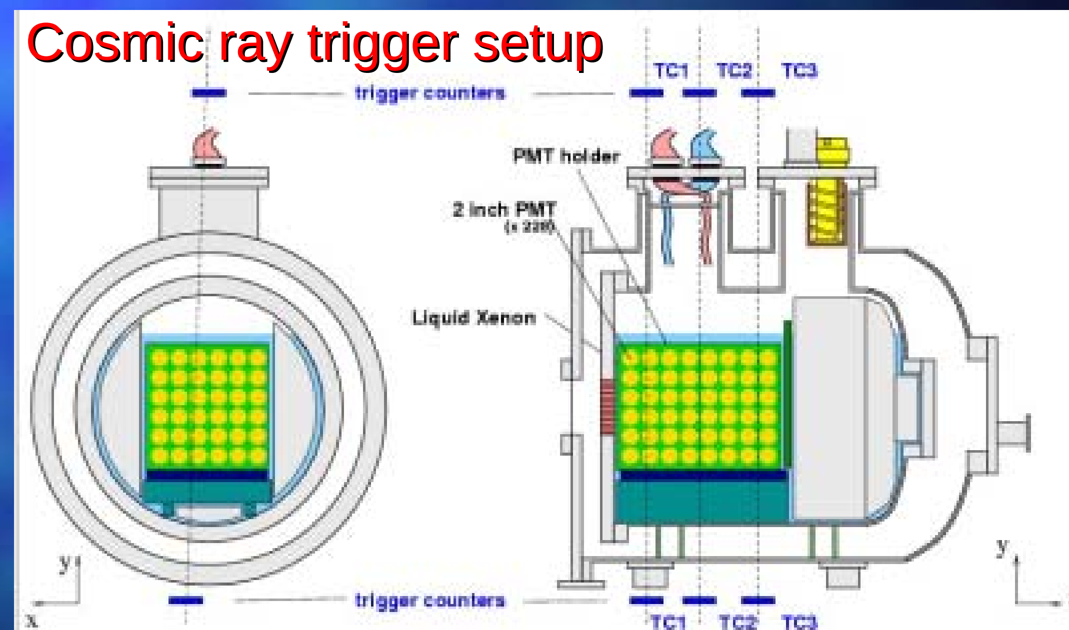
Absorption Length Estimation

Absorption length is estimated by seeing the absorption of the light from the alpha source event and cosmic ray event.

4 x alpha source inside

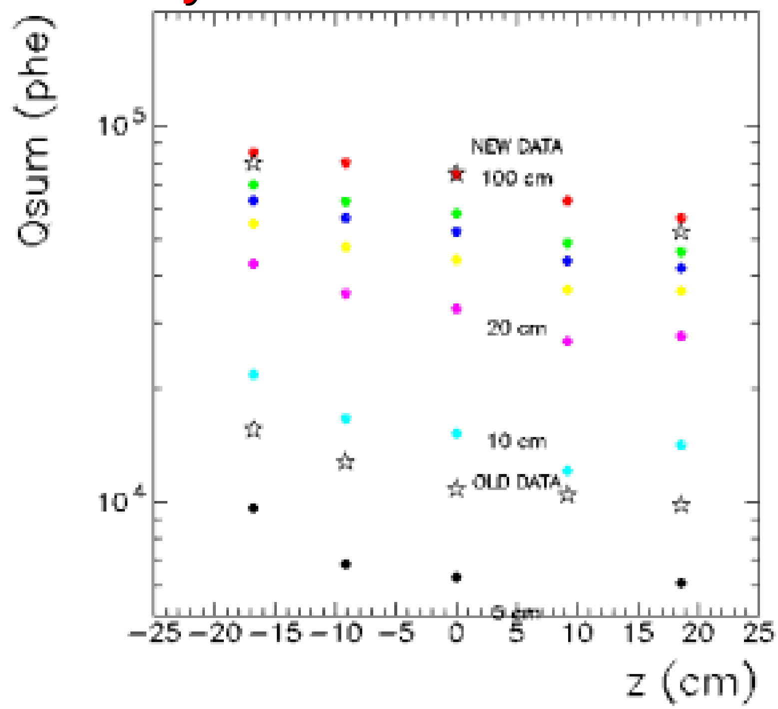


Cosmic ray trigger setup

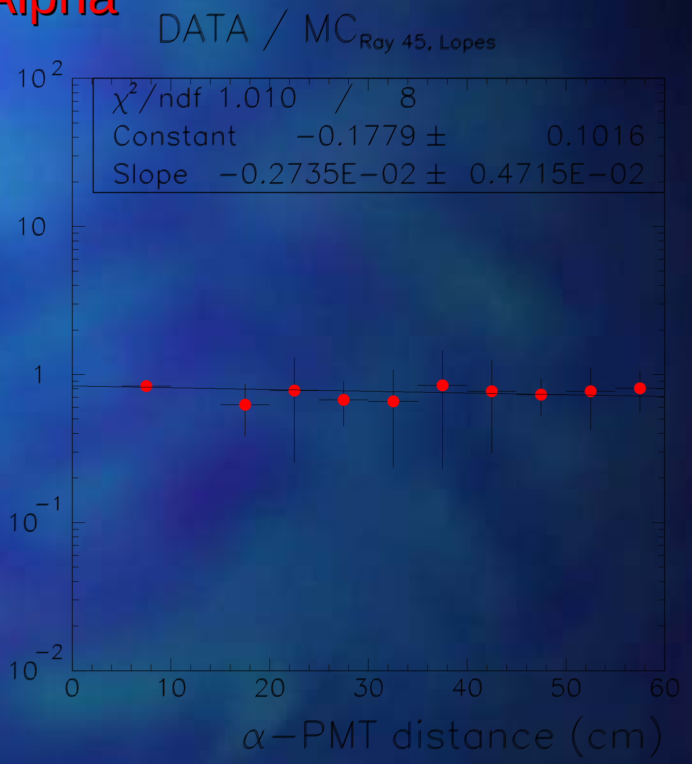


Absorption Length Estimation, cont'd

Cosmic ray



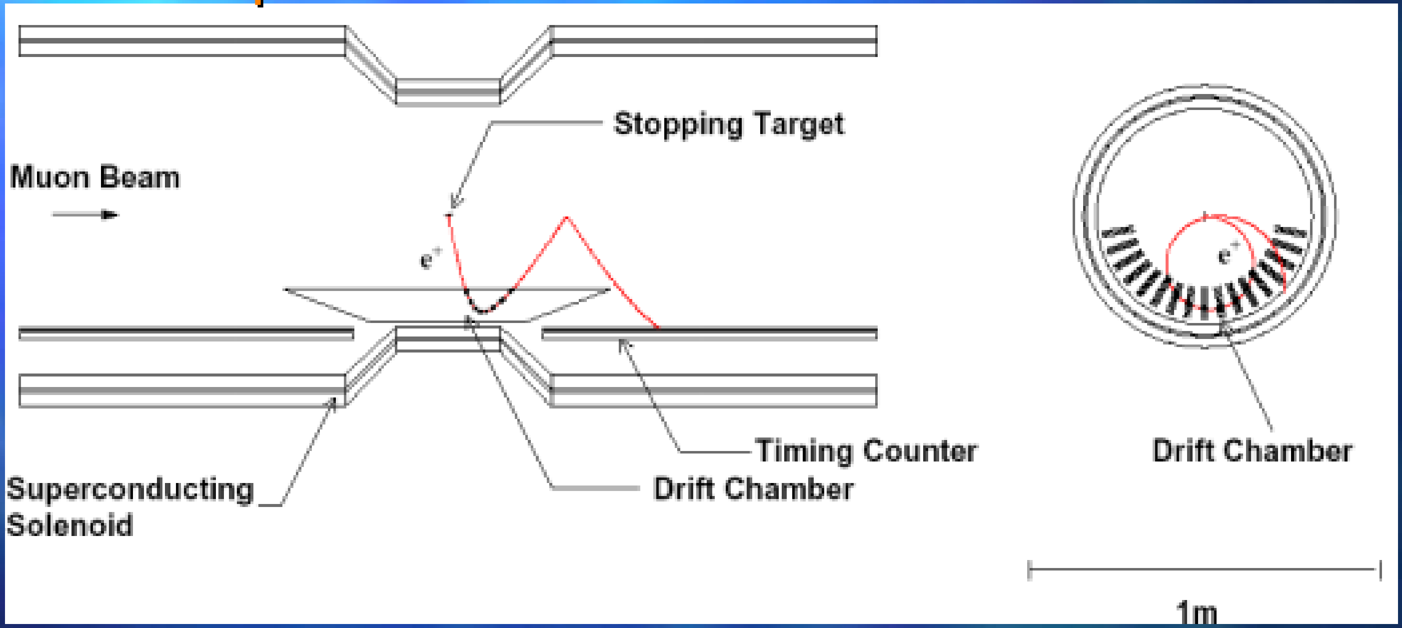
Alpha



Both measurements(CR and α) indicate λ_{abs} ~100cm after the purification

Positron Spectrometer

COBRA spectrometer

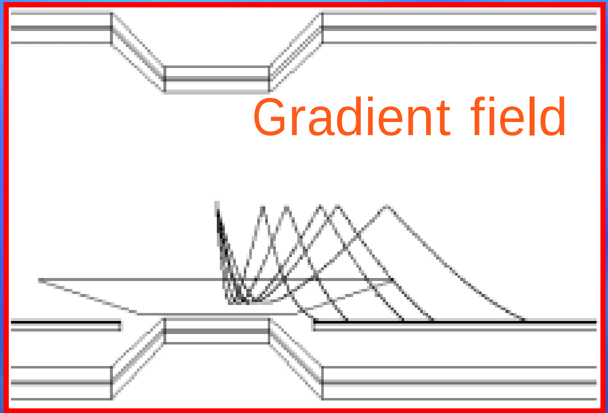


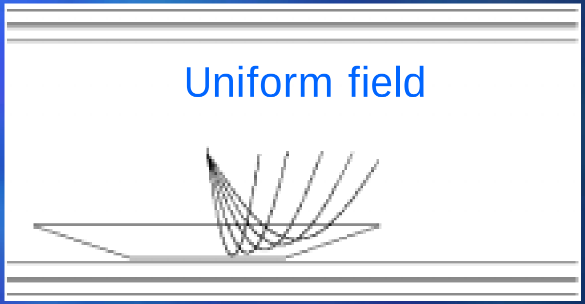
- Thin superconducting magnet designed to form gradient magnetic field
- Drift chamber for positron tracking
- Scintillation counters for timing measurement

Concept of COBRA Spectrometer

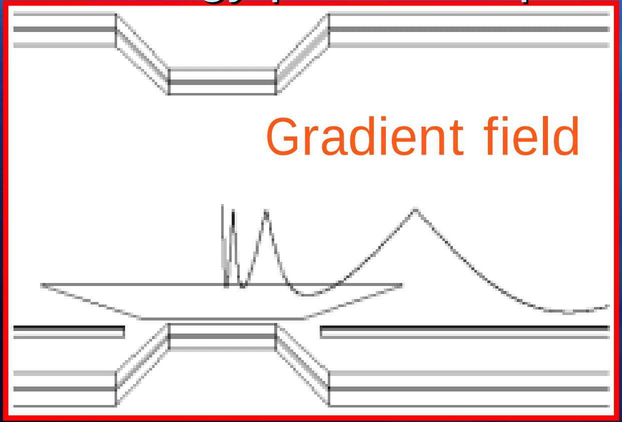
COBRA : COnstant Bending RAdius

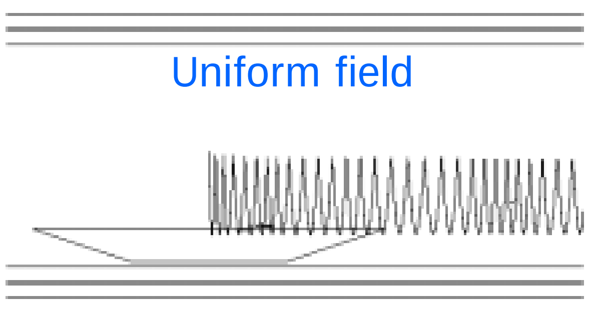
- Constant bending radius independent of emission angles





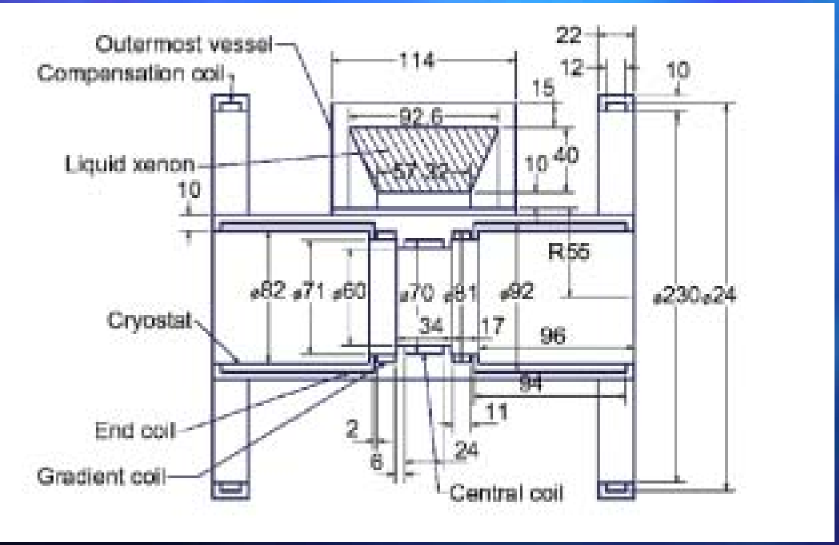
- Low energy positrons quickly swept out

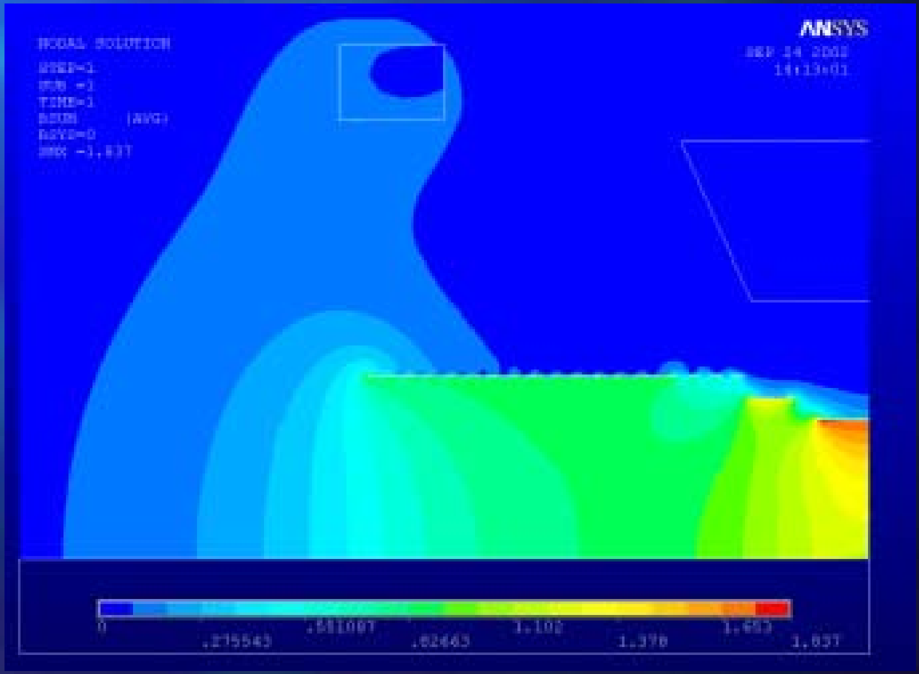




Magnet

- Five coils with three different diameter to form gradient field
- B_c = 1.26T, $B_{z=1.25m}$=0.49T@ operating current = 359A
- Compensation coils to suppress the residual field around the LXe detector down to ~50Gauss
- High-strength aluminum stabilized superconductor
  → thin superconducting coil: 0.2X_0

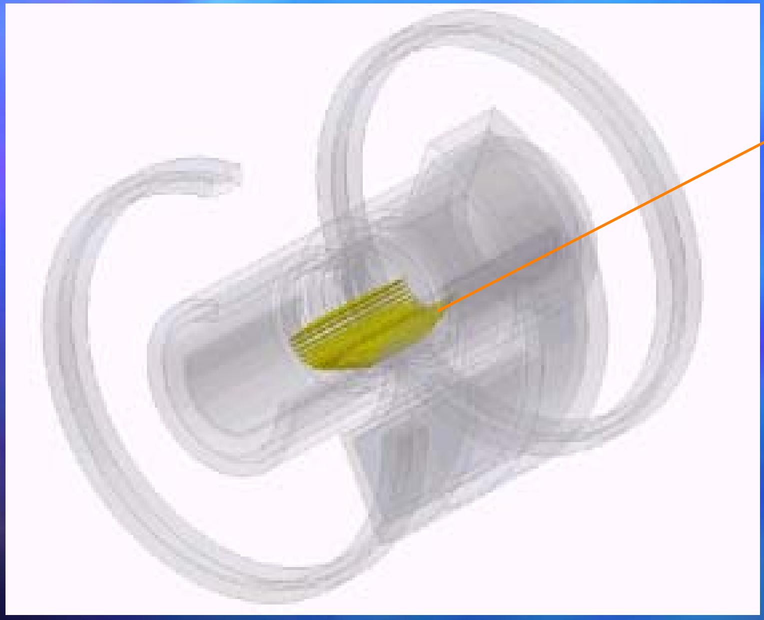


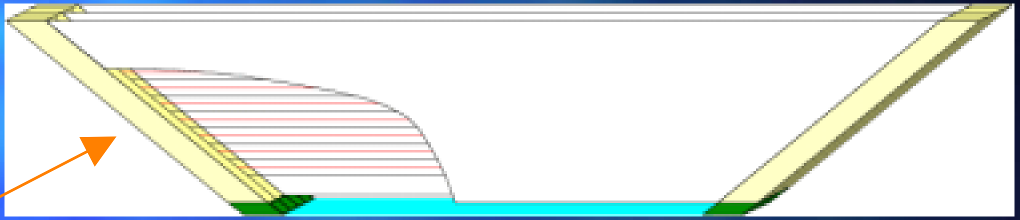


Construction of the Magnet

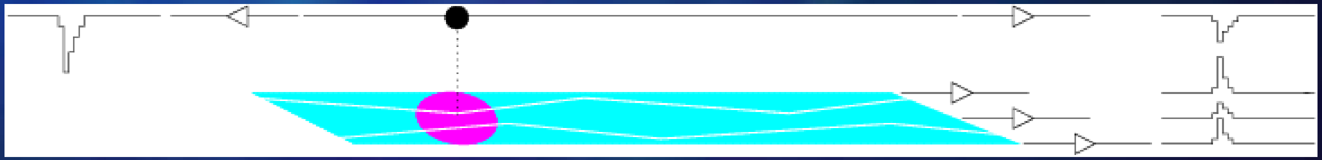
- Magnet design was finalized after detailed mechanical calculations and related experimental tests.
- Winding of the cable is in progress @ Toshiba.
- Excitation test for the central part of the magnet will be performed in October 2002.

Positron Tracker

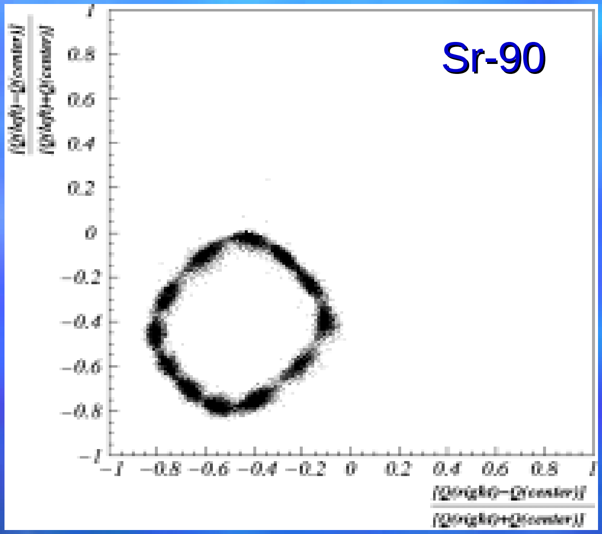


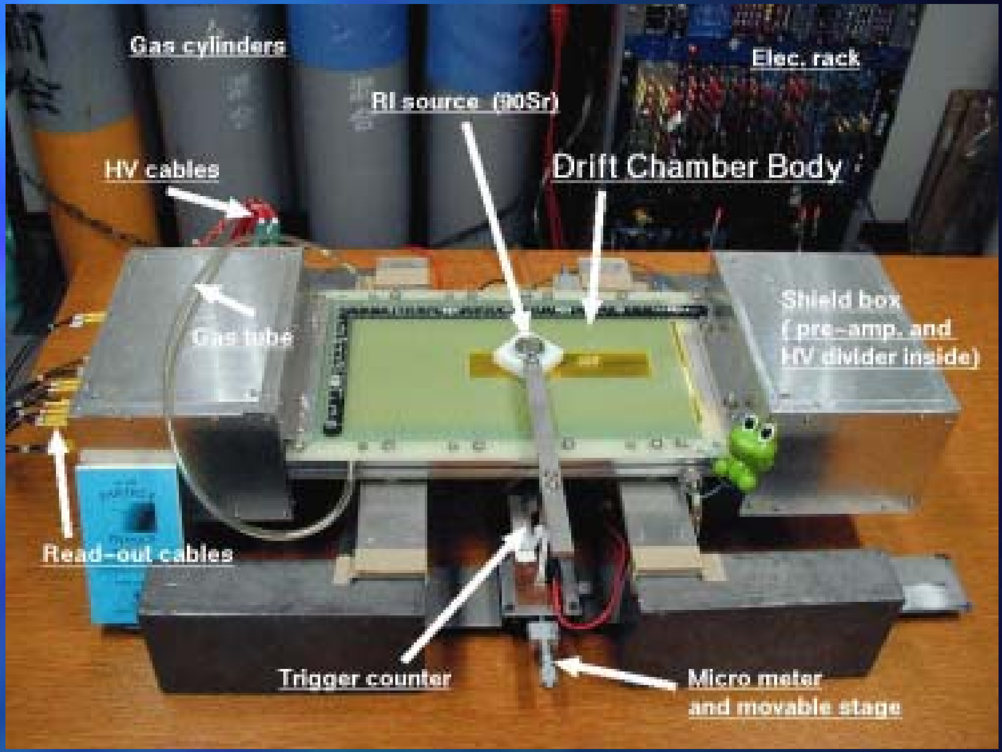


- 17 chamber sectors aligned radially with 10 ° intervals
- Two staggered arrays of drift cells
- Chamber gas: He-C_2H_6 mixture
- Vernier pattern on the cathode foil to determine z-position



First Prototype of the Chamber

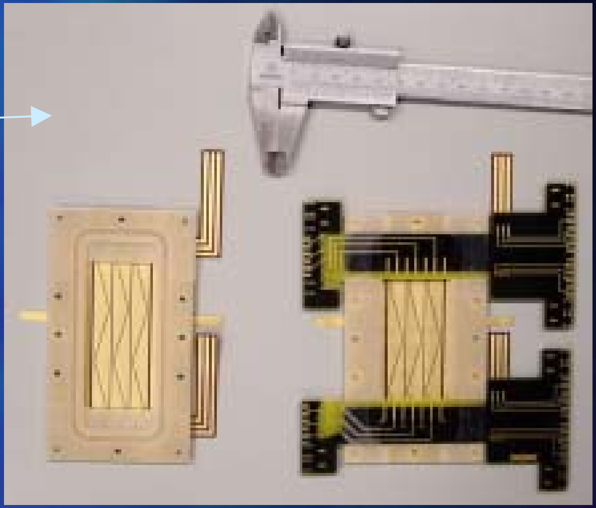


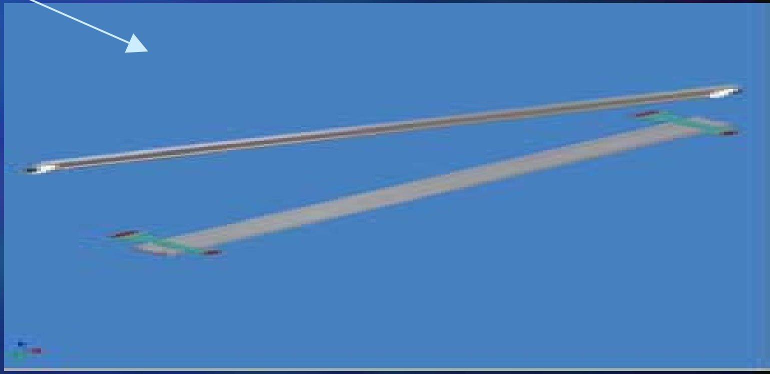


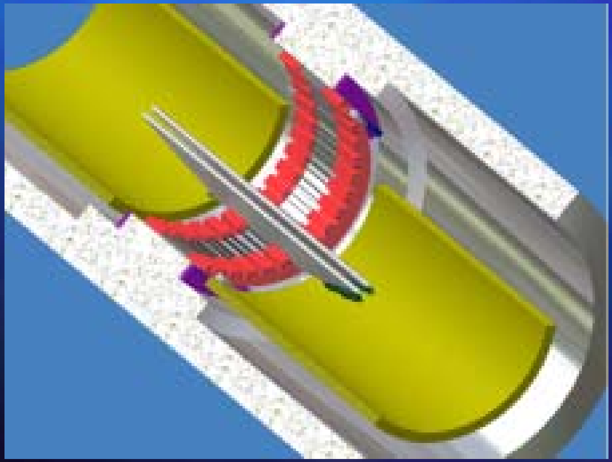
Resolution(σ)	
Drift time measurement	100-150μm
Vernier cathod measurement	425μm
Charge division measurement	2cm
Drift velocity and drift time	4-12ns

Chambers System R&D in PSI

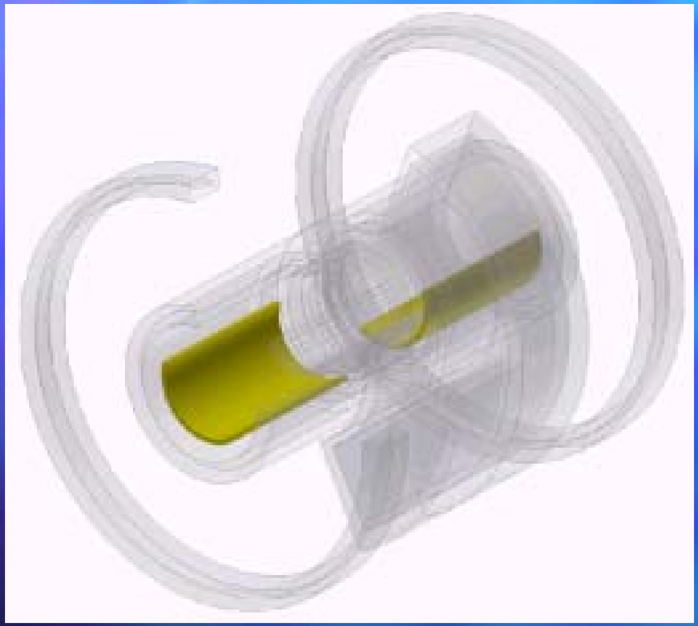
- Two prototypes are under construction at PSI.
  - "Double cathode" test chamber
    - Two separated double-strip cathodes for each chamber layer
      → homogeneous position sensitivity
    - Test in 1 Tesla magnetic field
  - "Charge division" test chamber
    - Charge division test
    - 1m-long W(330W/m) or Steel(1200W/m)
- Supporting system is also under development.

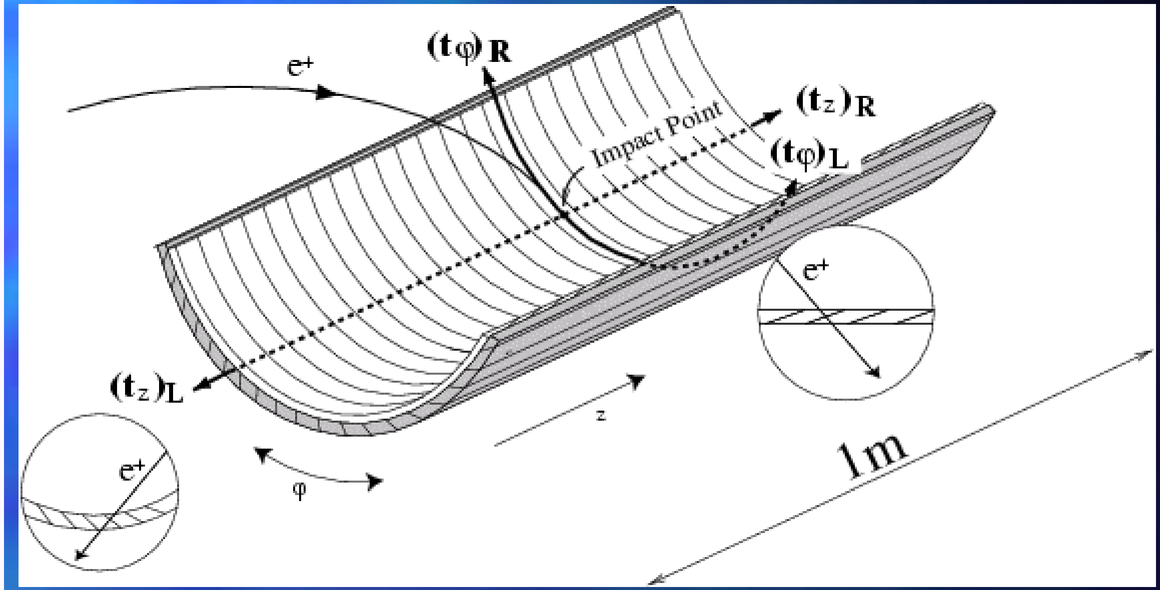






Timing Counter

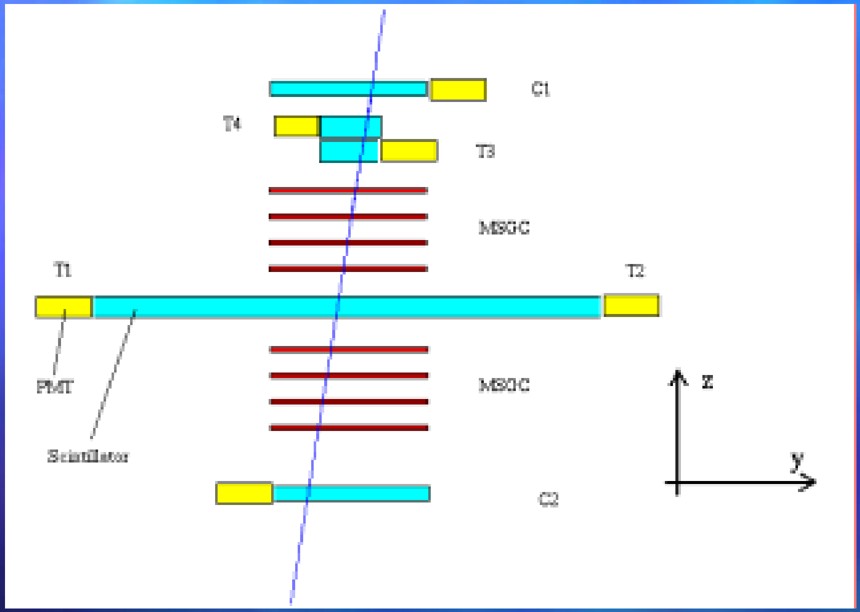


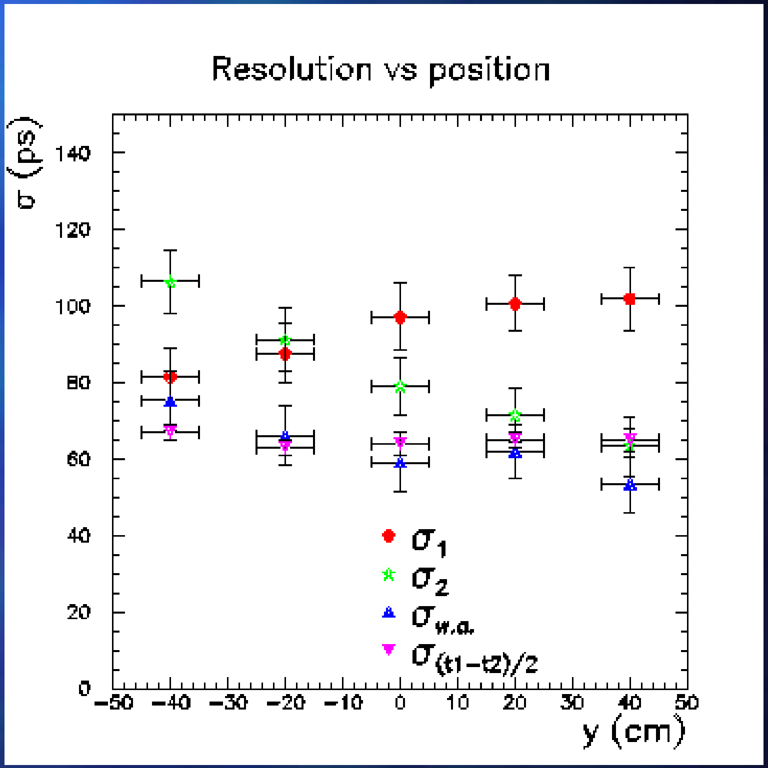


- Two layers of scintillator hodoscopes placed at right angles with each other
  Outer: timing measurement
  Inner: additional trigger information
- Goal σ_{time}~ 50psec

Timing Counter Prototype

CORTES: Timing counter test facility with cosmic rays at INFN-Pisa





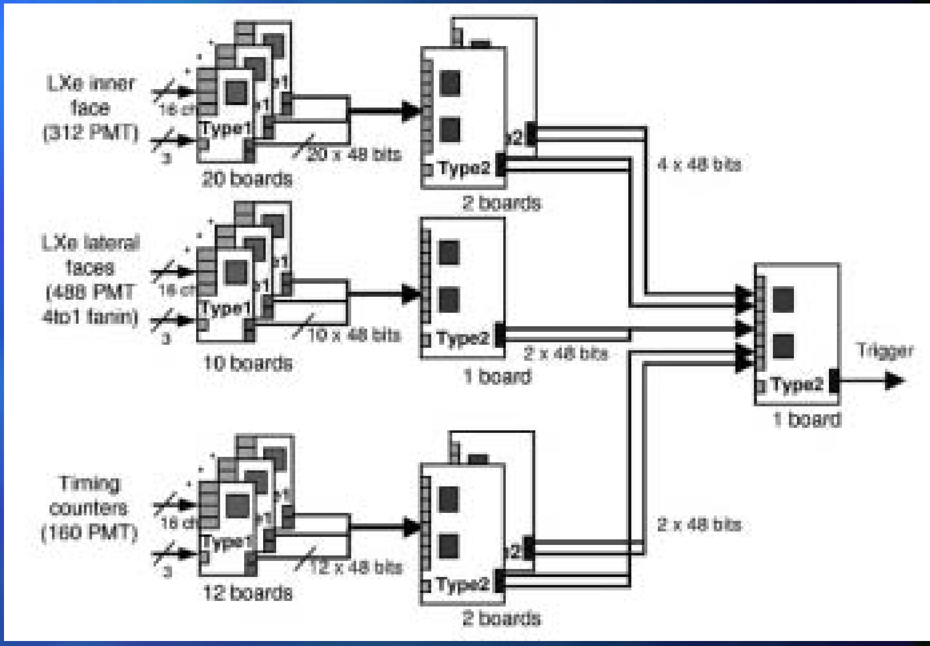
- Scintillator bar (5cm x ^{t}1cm x 100cm long)
- Telescope of 8 x MSGC
- Measured resolutions

  σ_{time}~60psec independent of incident position
- σ_{time} improves as ~$1/\sqrt{Npe}$ → use thicker counter ~^{t}2cm

Trigger Electronics

- Beam rate 10^8 s^{-1}
- Fast LXe energy sum >45MeV 2×10^3 s^{-1}
- γ interaction point
- e^+ hit point in timing counter
- Time correlation γ-e^+ 200 s^{-1}
- Angular correlation 20 s^{-1}

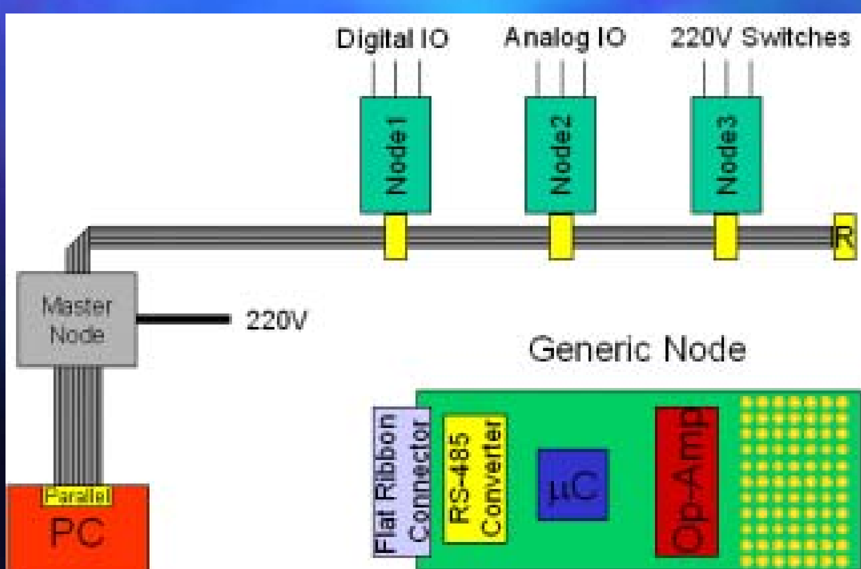
Trigger system structure

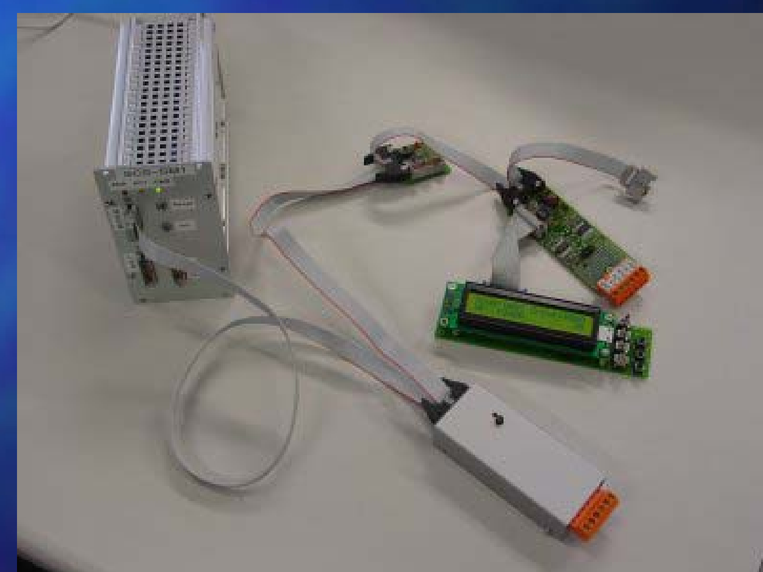


- Design and simulation of type1 board completed
- Prototype board delivered in Pisa by this fall

Slow Control

- New field bus system under development for a reliable control of cryogenics of LXe detector, superconducting magnet, high voltage supply
- Low cost (typ. 20 US$ per node)
- Several prototypes have been built and tested at PSI
- See http://midas.psi.ch/mscb





Summary

- R&D work on the sub-detectors for the MEG experiment are going well.
- Performance of the LXe photon detector prototype is improving thanks to the improvement of the light yield.
- A beam test of the photon detector prototype with the purified xenon will be performed in Oct. 2002.
- Beam line tuning with the COBRA magnet and assembly of the sub-detectors will start in 2003.
- Engineering run will start in 2004.

Updated status can be seen at three mirrored sites:

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

http://meg.psi.ch/

http://meg.pi.infn.it/