Performance of the Liquid Xenon Scintillation Detector for the MEG Experiment at PSI

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for the MEG collaboration

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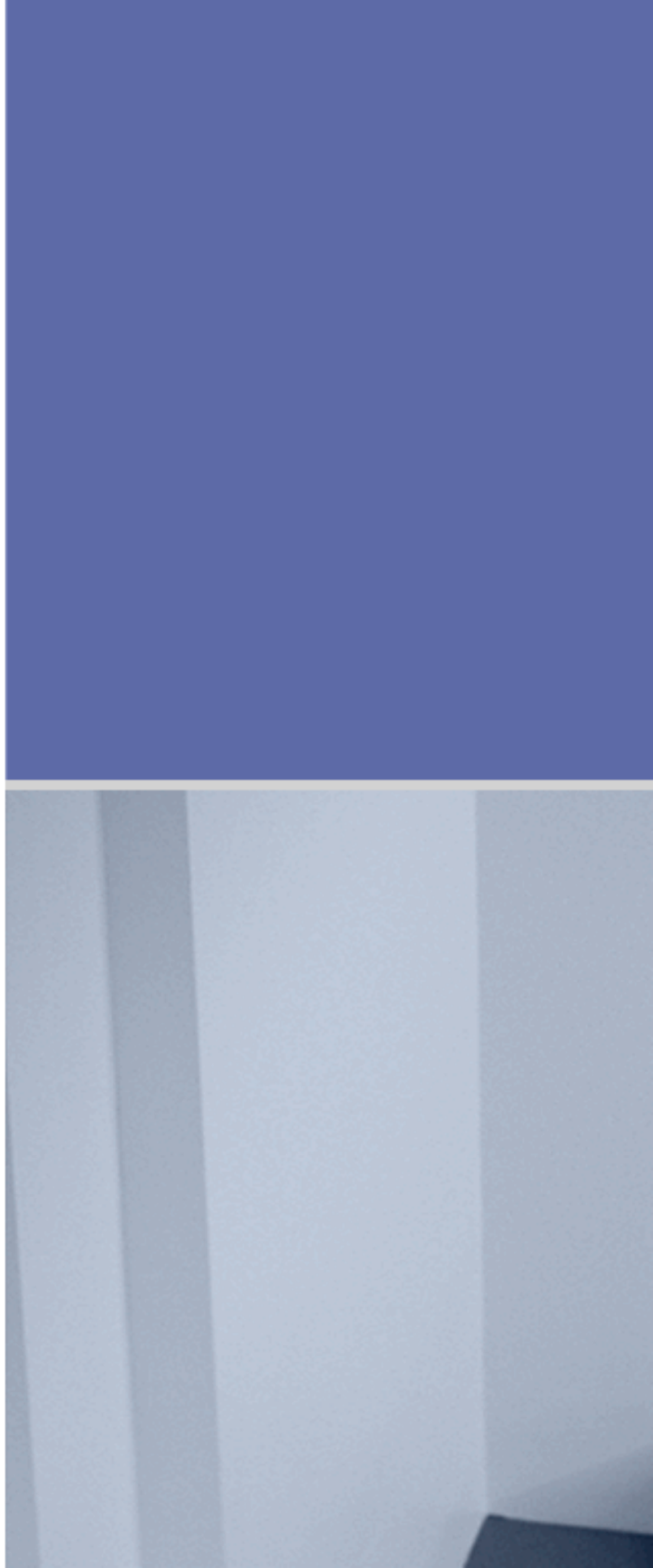

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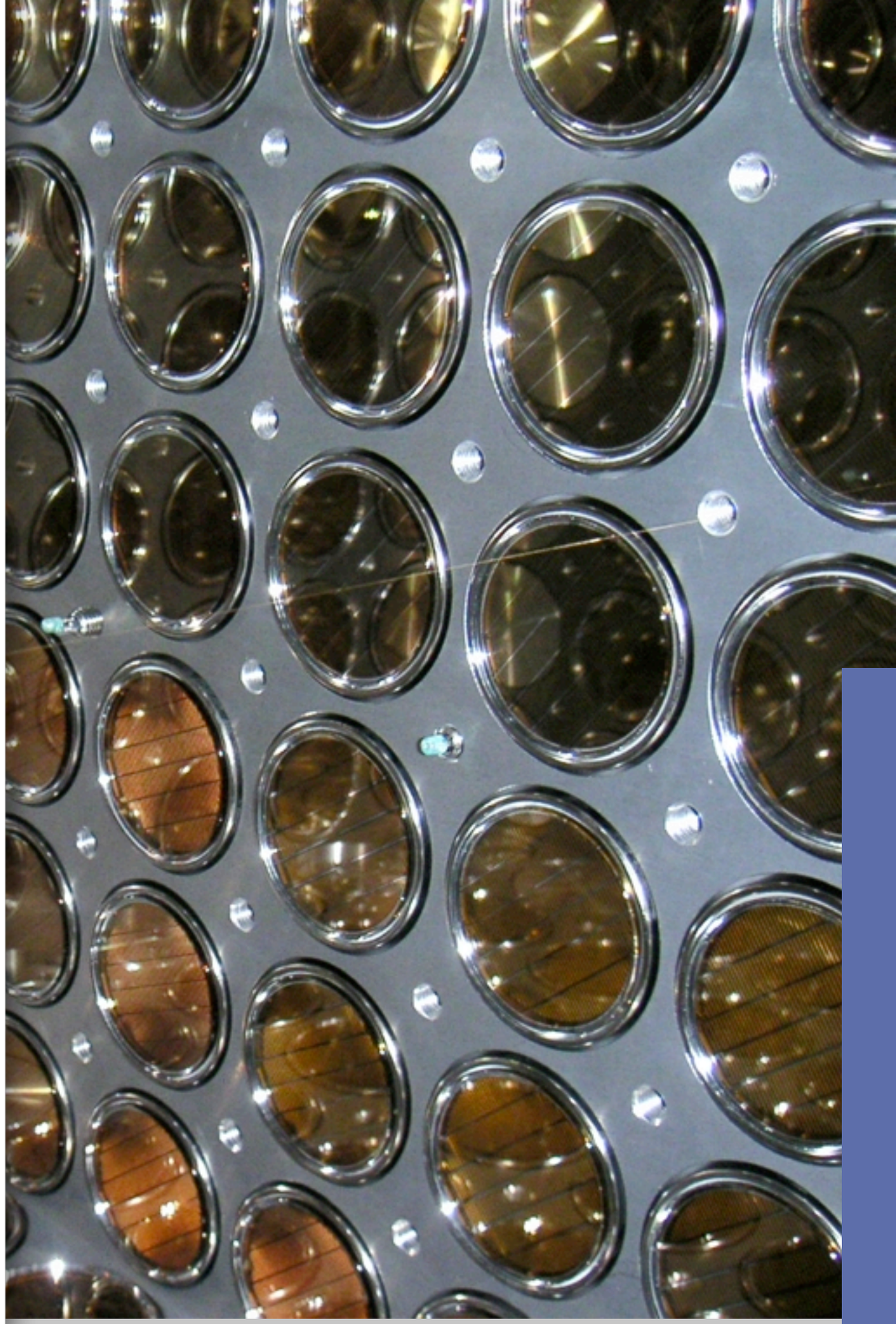
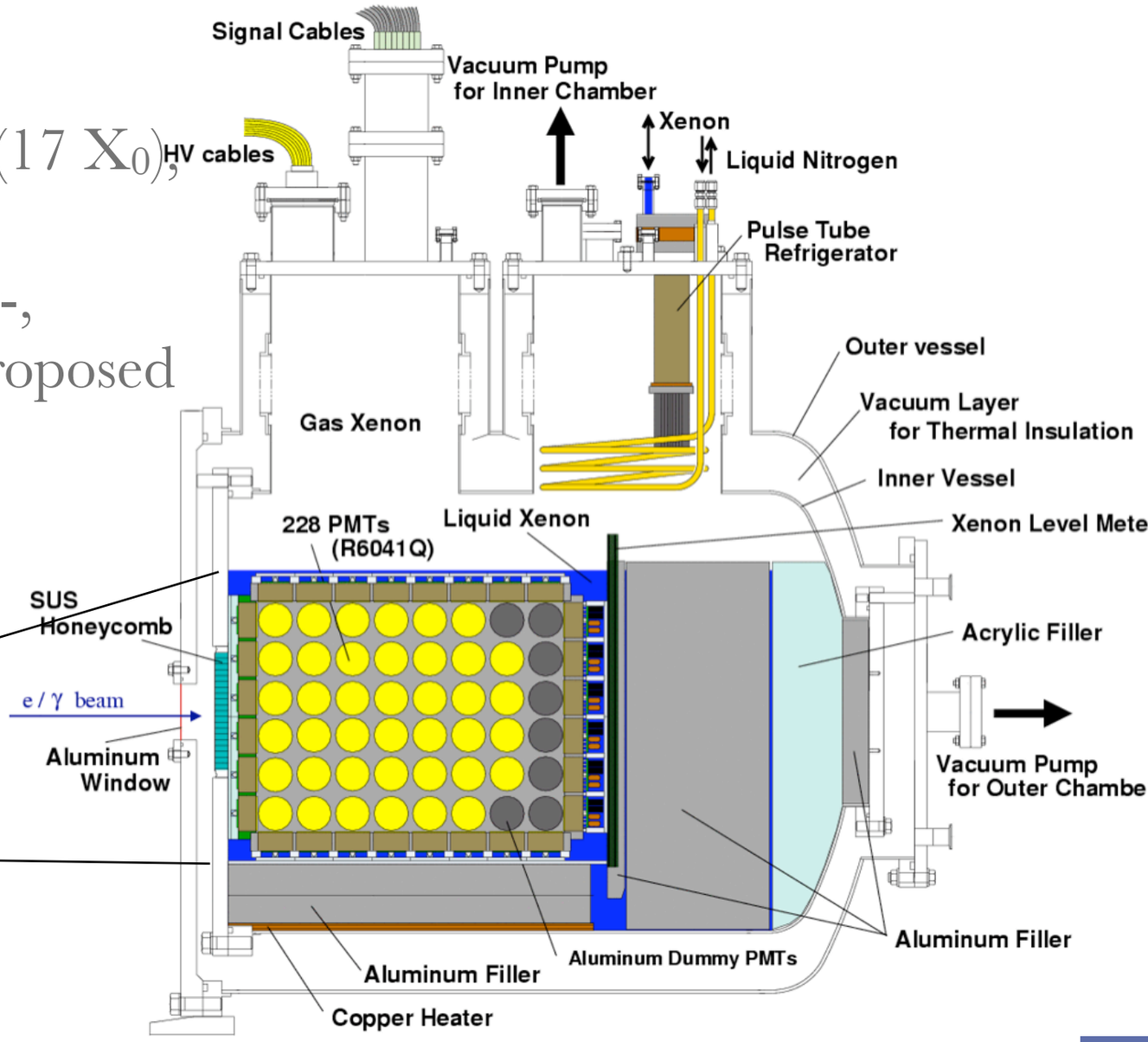


Introduction

100L Prototype

- 100L LXe (69L active volume)
- 238 PMTs immersed in LXe (→next talk)
- Large enough to contain 50MeV γ event (17 X_0), but with smaller acceptance
- Demonstration of performance in energy-, position- and time-mesurements of the proposed calorimeter for the MEG experiment.



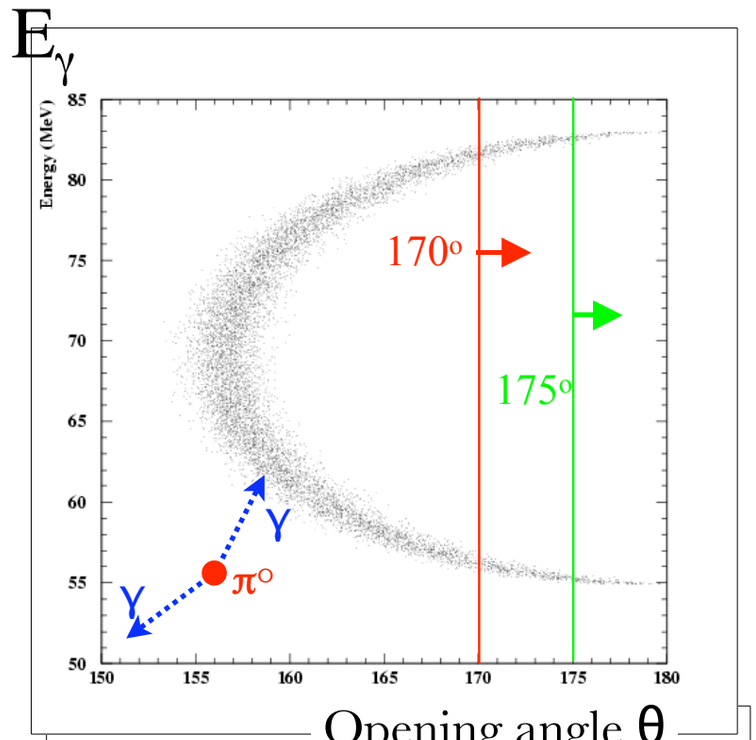
Beam Tests with Prototype

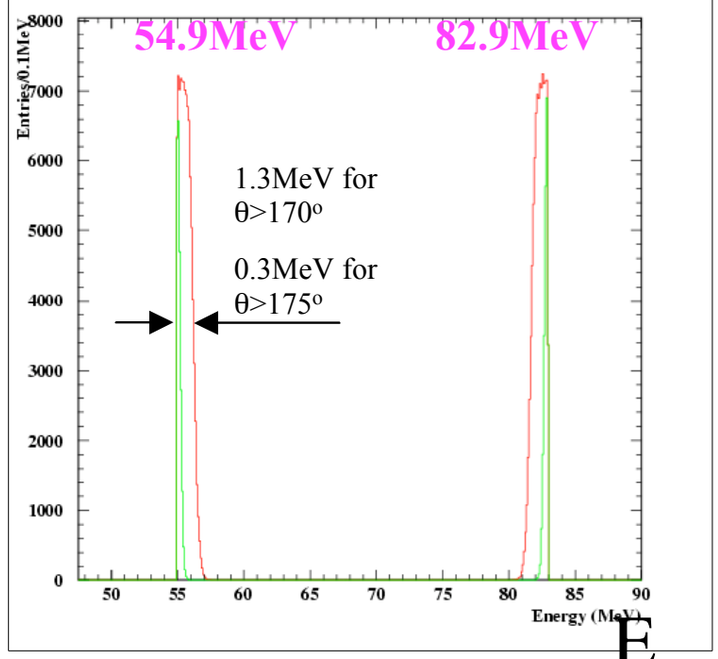
Beam Tests with the Prototype

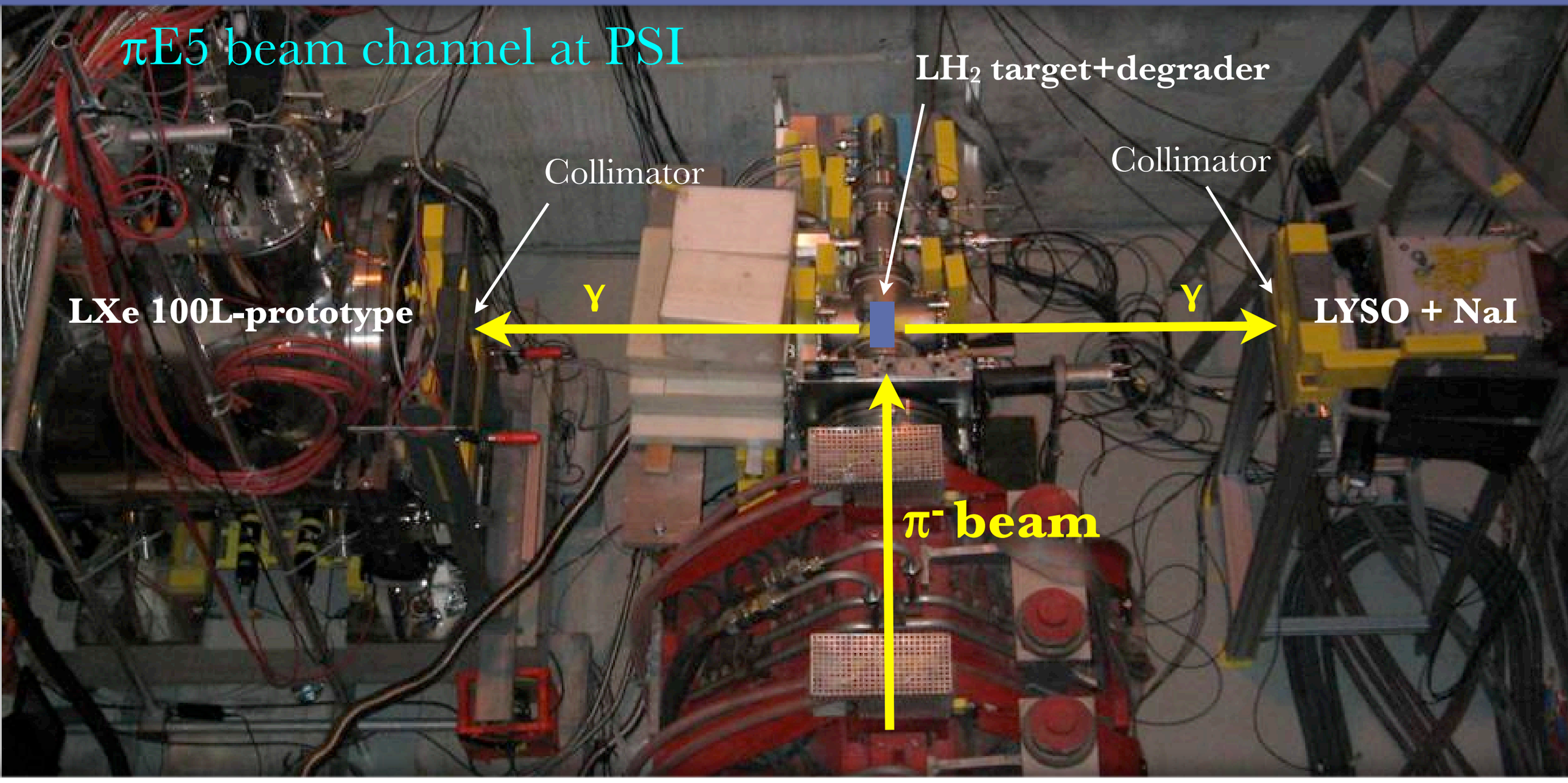
- Two complementary beam tests were performed to demonstrate the good performance of the LXe calorimeter for the MEG experiment.
  - Laser Compton backscattered (LCS) photons up to 40MeV
    - Energy and position measurements
- 55MeV and 83MeV photons from π^0 produced in charge exchange (CEX) process, $\pi^- + p \rightarrow \pi^0 + n$.
  - Energy and time measurements

Beam Tests with CEX Process

- Two photons from π^0 produced in charge exchange (CEX) process, $\pi^- + p \rightarrow \pi^0 + n$.
  - Almost monochromatic 55MeV and 83MeV photons by selecting two photons with an opening angle $\theta \sim 180°$
    - Energy spread: 0.5%(2.3%) requiring $\theta > 170°(175°)$ at 55MeV
- 129MeV photon from radiative capture process, $\pi^- + p \rightarrow \gamma + n$.
- Monochromatic photon (55, 83, and 129MeV) available, but
  - Limited photon intensity due to the small cross section of the CEX process.
  - Beam-related background
- Energy and time resolutions can be studied.



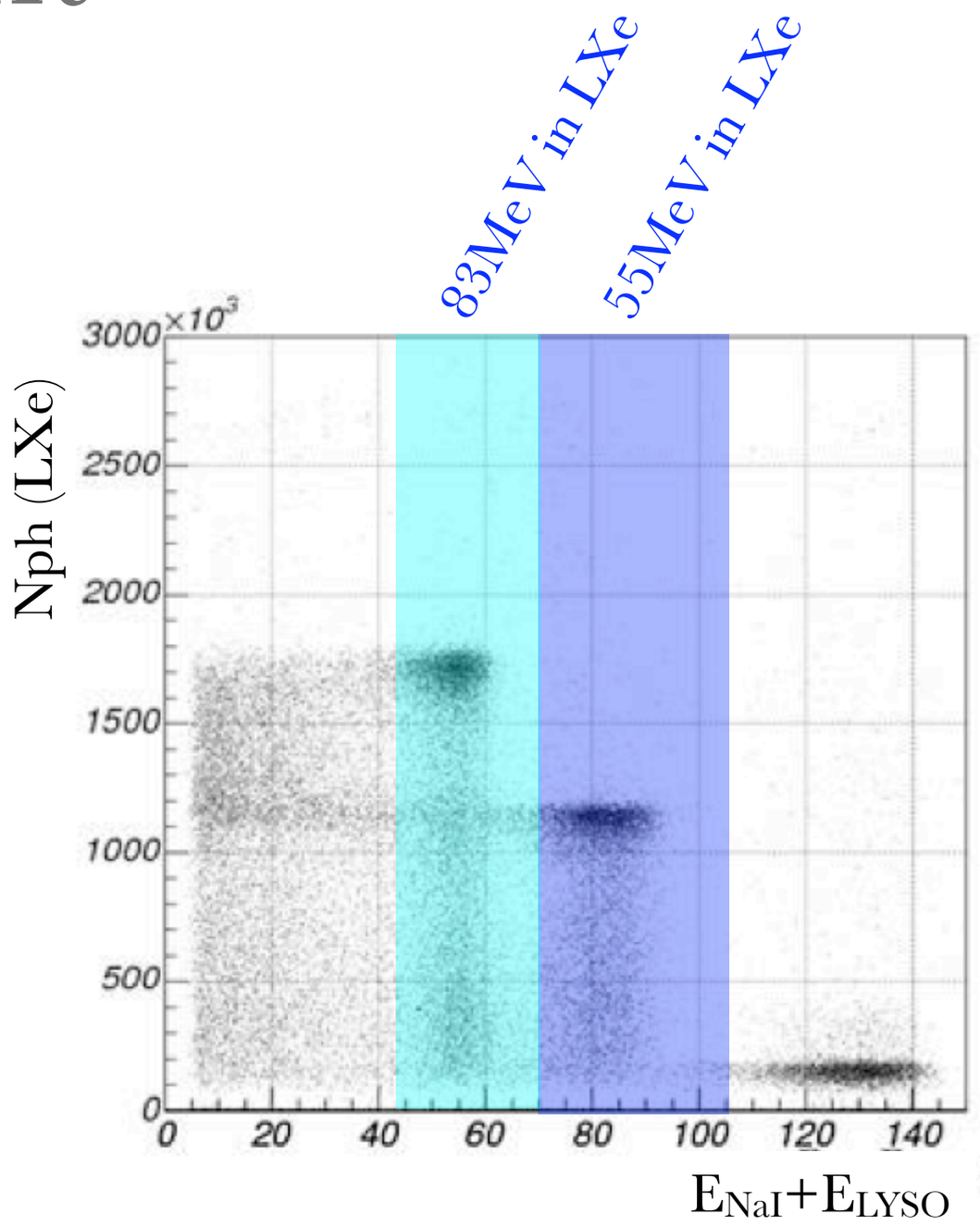




CEX Beam Test Setup

Energy Measurement

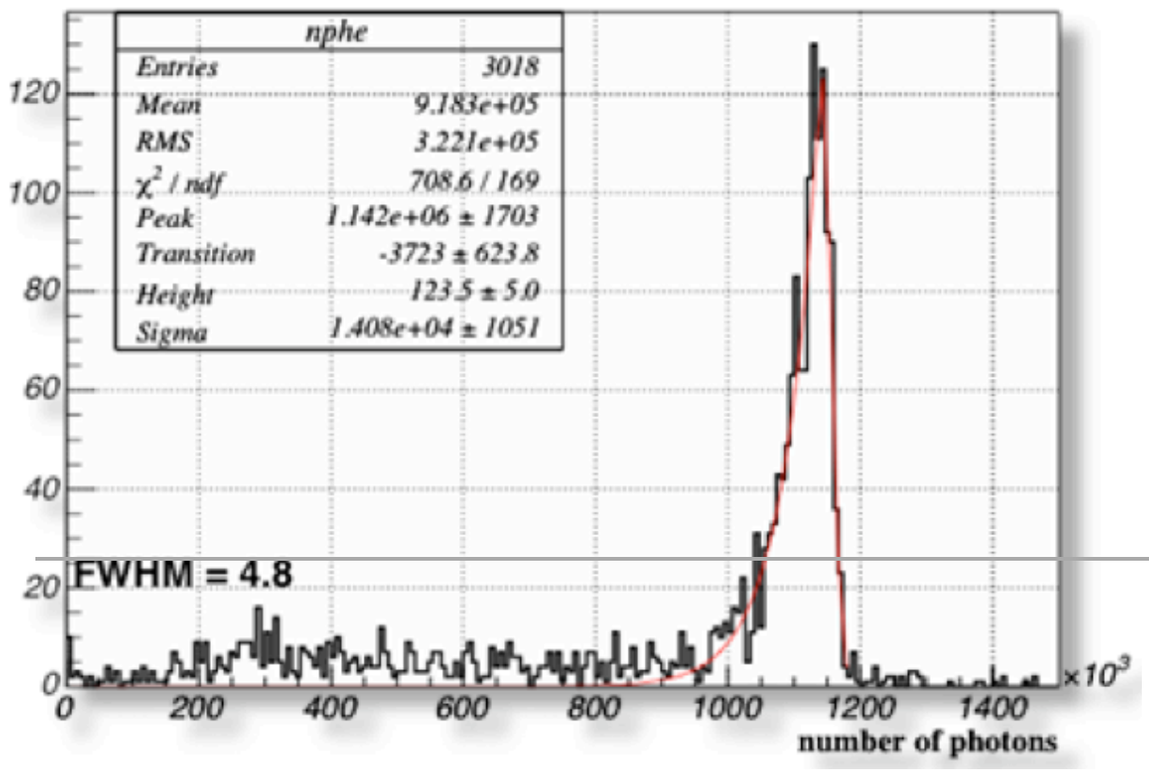
- 55MeV (83MeV) event in LXe by selecting 83MeV (55MeV) event in NaI
  - |x|, |y| < 2cm
  - 55MeV event in LXe
    - 45MeV < $E_{NaI}+E_{LYSO}$ < 70MeV
  - 55MeV event in LXe
    - 70MeV < $E_{NaI}+E_{LYSO}$ < 105MeV
  - Cut and correction with depth parameter



Energy Measurement, Results

- Energy resolution obtained in CEX test at detector center
  - 4.8%(FWHM)
  - 1.23%(σ at right side)

Energy spectrum for 55MeV γ



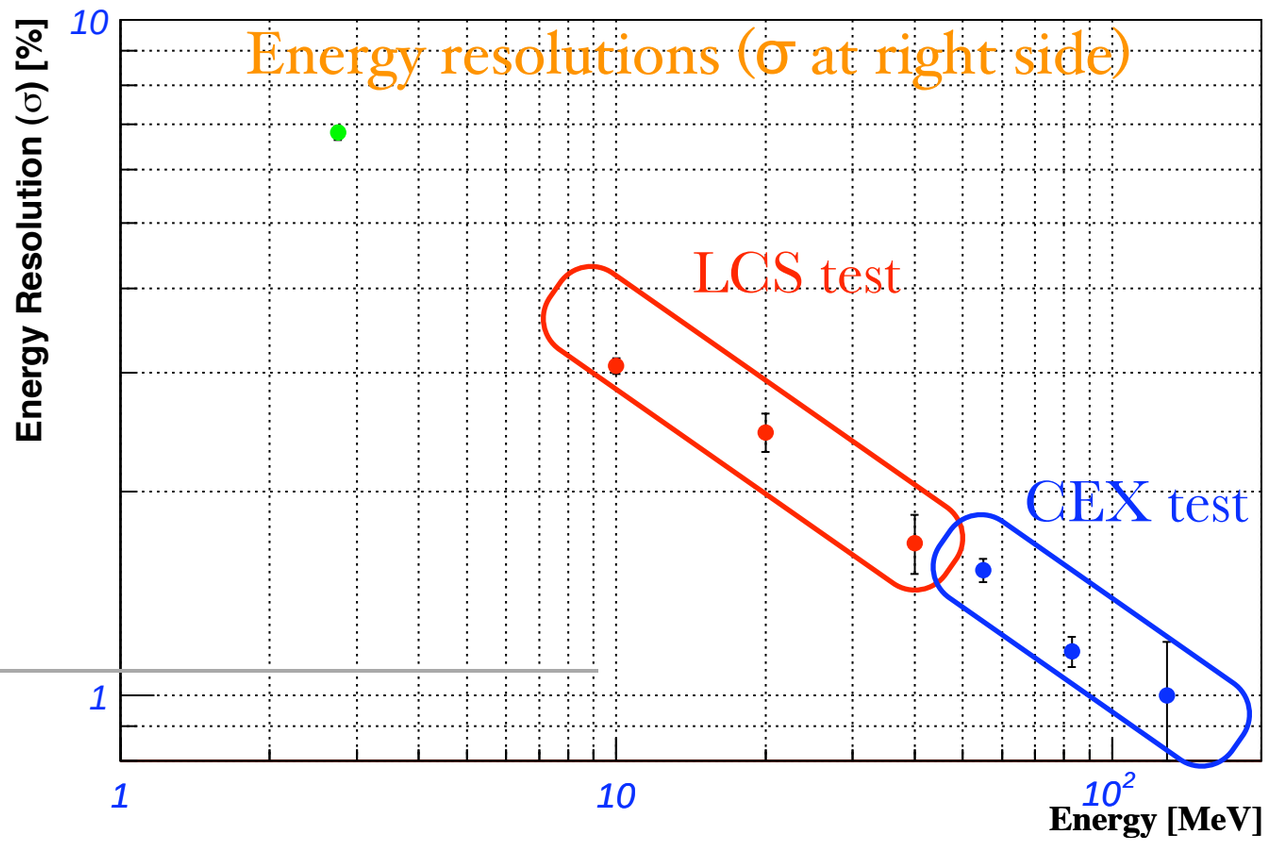
Resolution map

PMT PMT

4.5 ± 0.5	5.1 ± 0.5	6.2 ± 0.8
5.6 ± 0.5	4.9 ± 0.5	4.9 ± 1.1
5.3 ± 0.7	4.9 ± 0.5	5.2 ± 2.0

Energy Measurements Summary

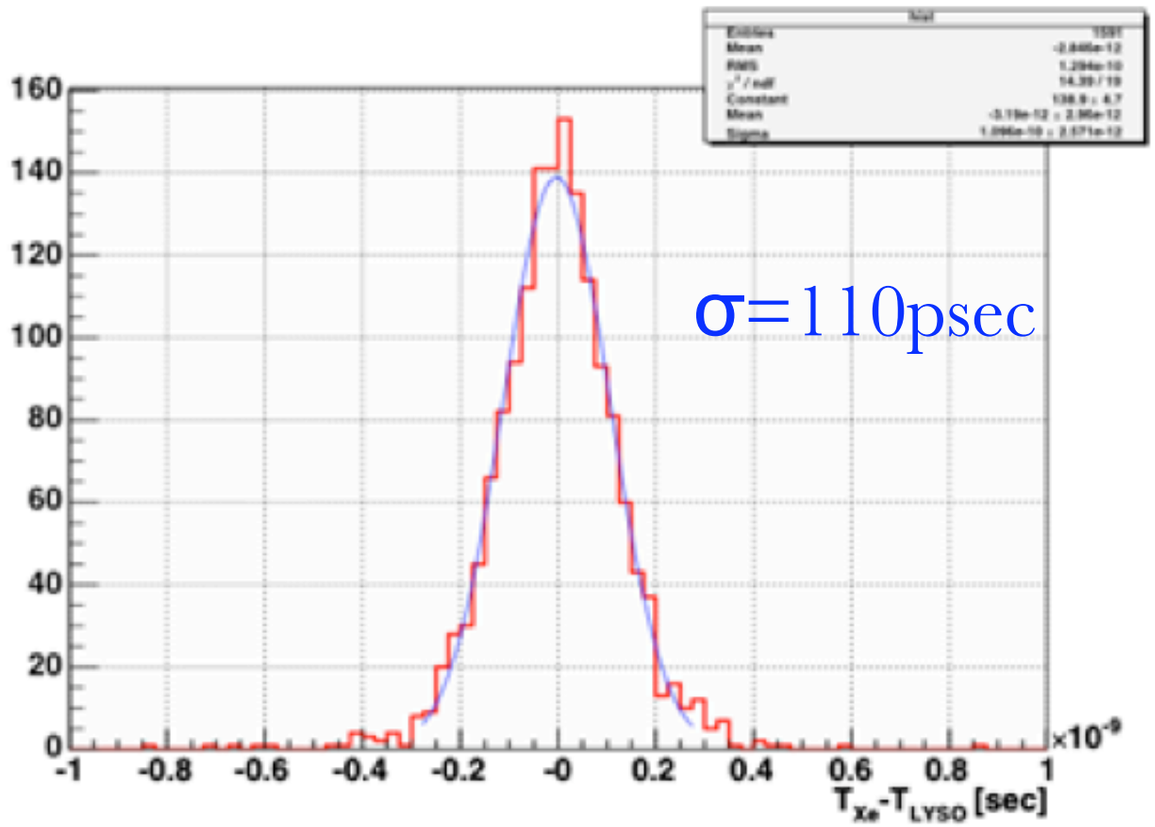
- Combined results on energy resolutions from LCS and CEX beam tests
- Energy resolution improves as number of photoelectrons increases.



Time Measurement

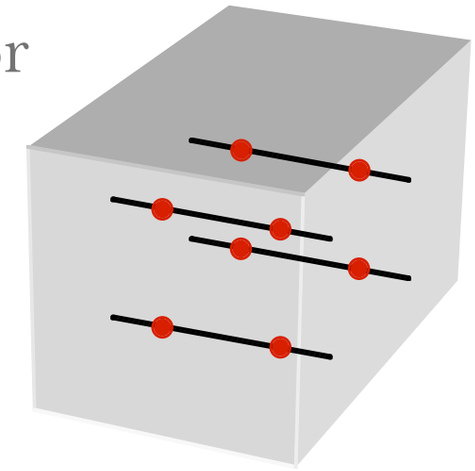
- Timing of the event was measured with a time reference counter (LYSO counter).
- After corrections for time-walk and position, we obtained at 55MeV
  - σ = 110 psec
- This includes timing resolution of reference counter (64 psec) and target size effect (61 psec)
  - σ = 110psec - 64psec - 61psec
    = 65psec

Reconstructed time spectrum for 55MeV

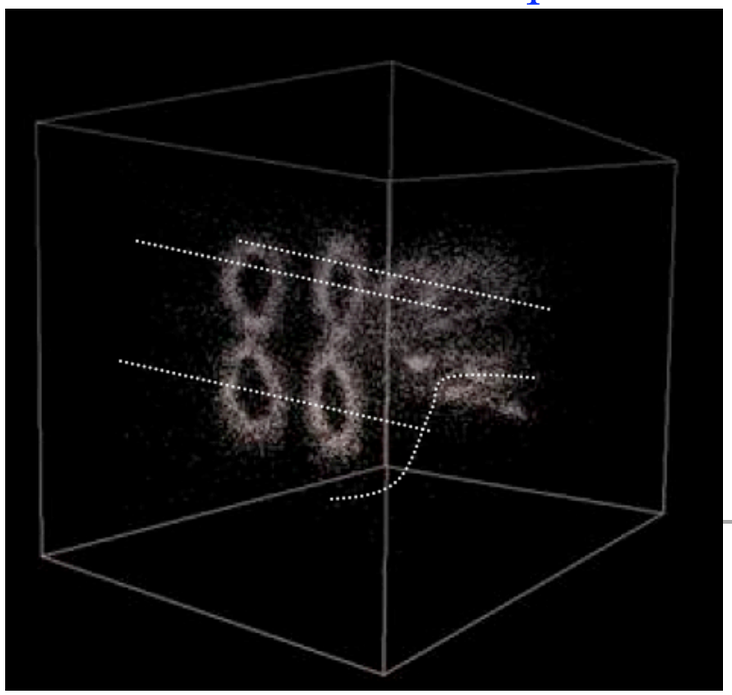


α spot sources on wire

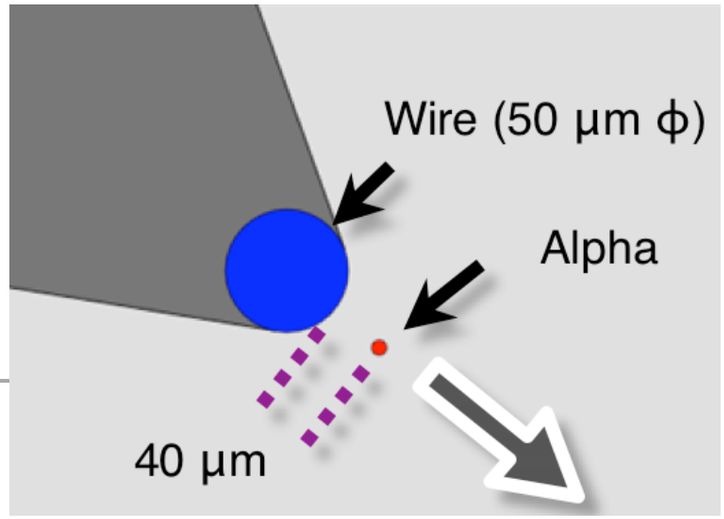
- Alpha spot sources on wire for calibration and stability monitor
- Po-210 electrodeposited on a gold-plated tungsten wire (50μmϕ)
- Eight spot sources (two on each wire) with 30-100Bq/source.
- Each PMT can see the light from alpha sources at different distances.

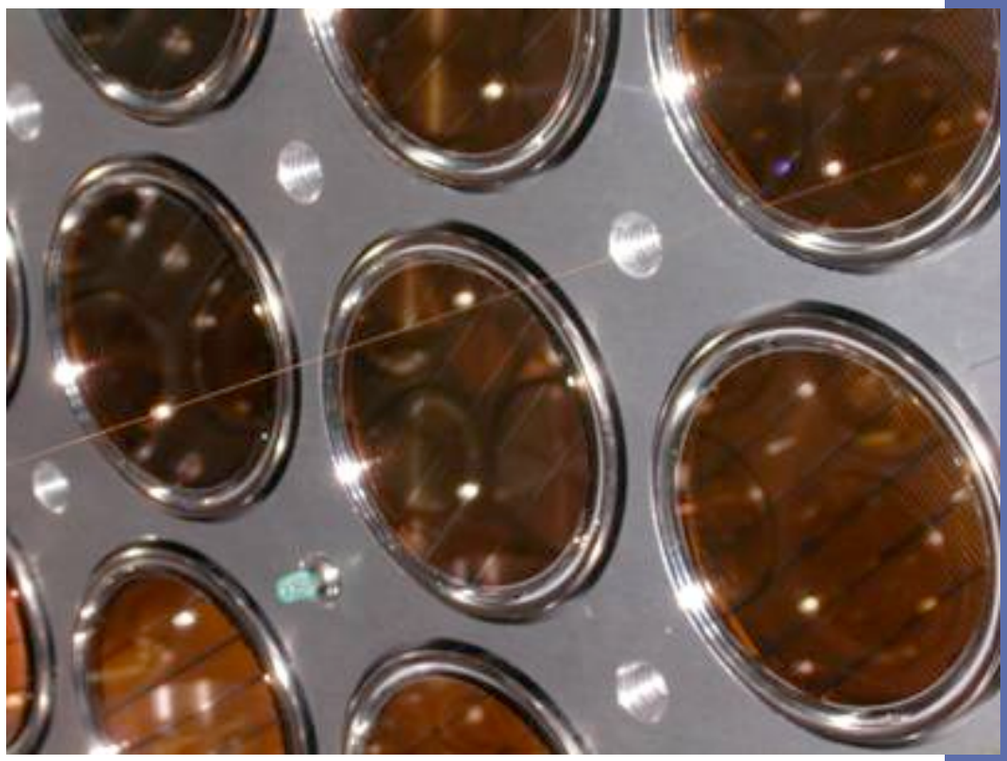


Reconstructed source position



Shadow effect

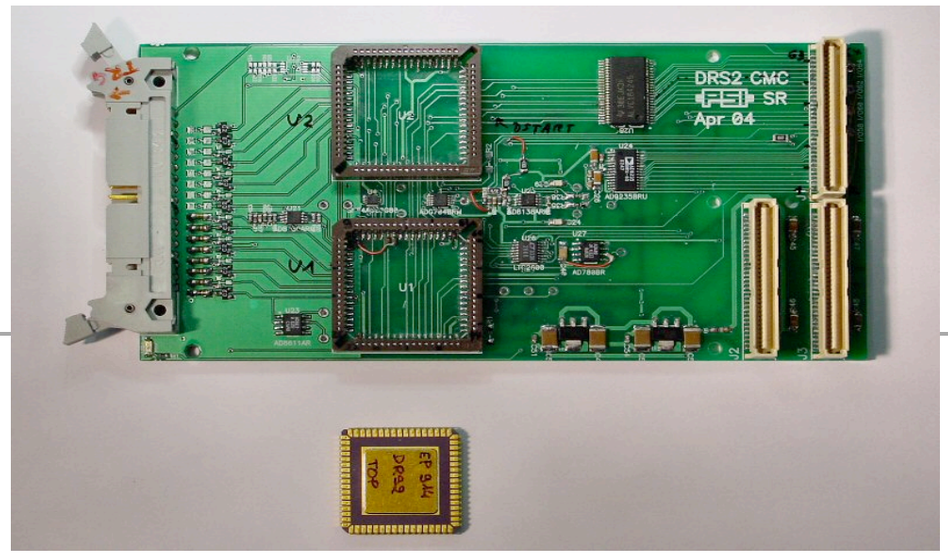




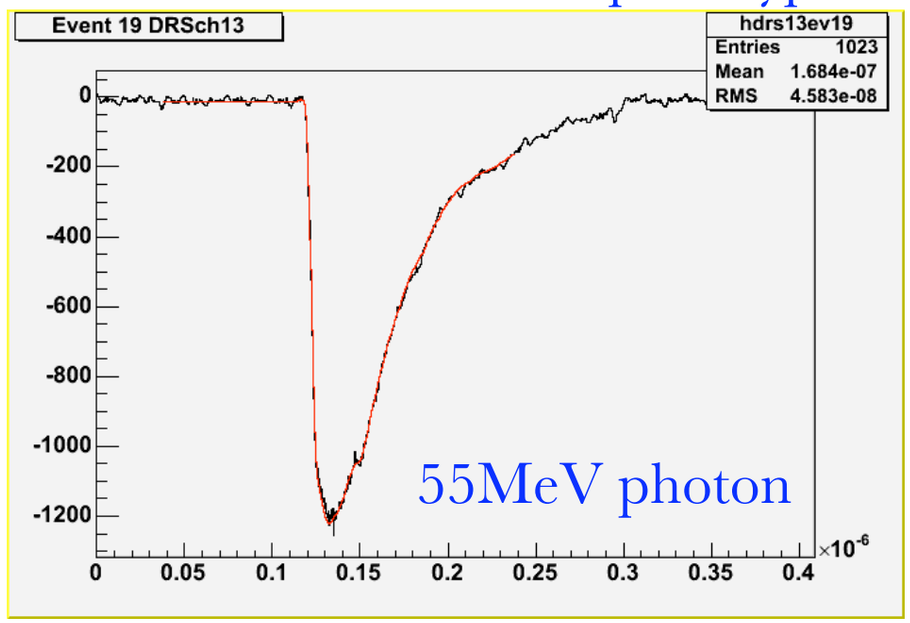
Waveform Digitizer

- All 830 PMTs will be read by fast waveform digitizer developed at PSI (Domino Ring Sampling Chip)
- DRS chip (2nd version) was tested in the 100L prototype.
  - 10ch/chip (8 for data and 2 for calibration)
  - 2.5GHz sampling (400ps/sample)
  - 1024 sampling cells
  - Readout 40MHz 12bit

DRS2



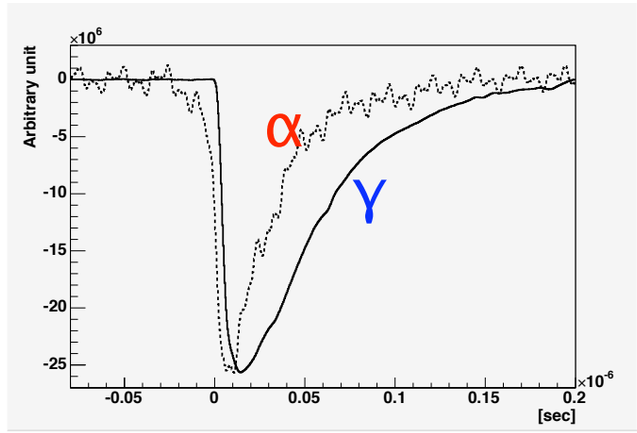
Waveform from 100L prototype



Waveform Digitizer, cont'd

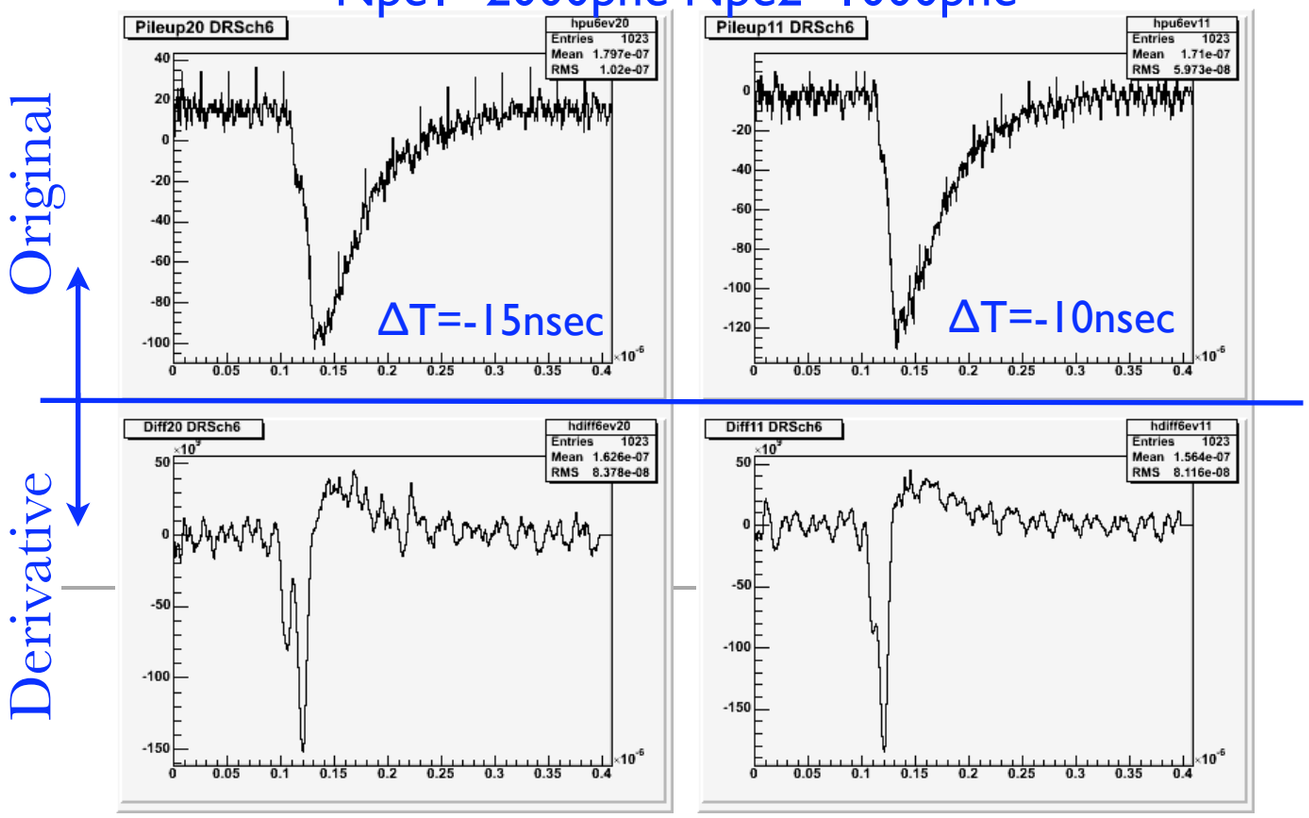
- Pulse shape discrimination
- Timing resolution comparable as obtained with TDC.
- Pileup rejection power is being studied.

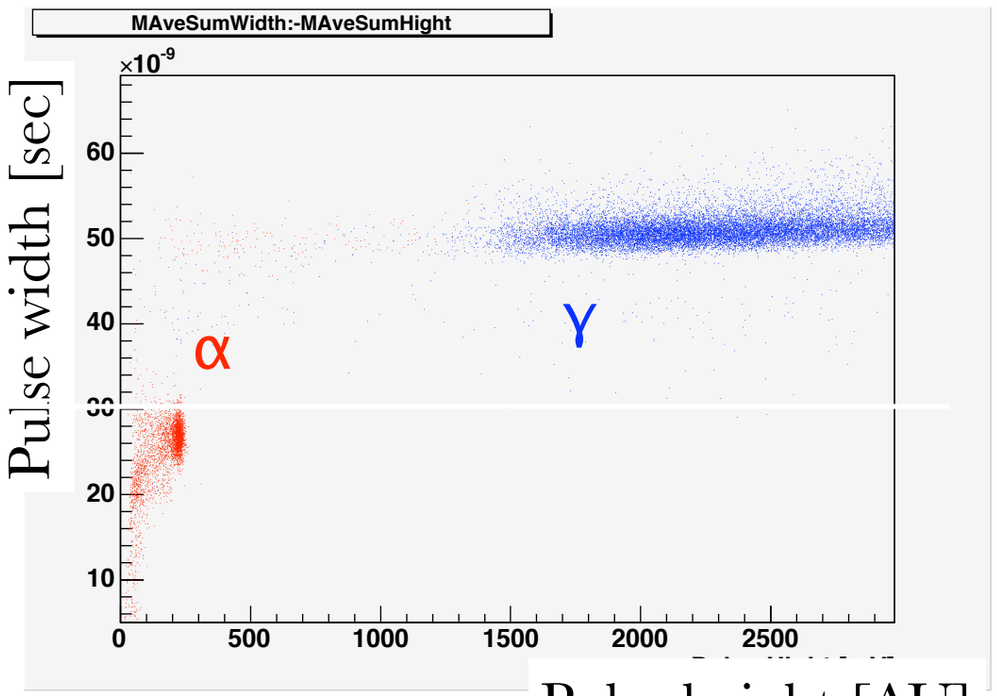
Pulse shape discrimination



Pileup rejection

Npe1=2000phe Npe2=1000phe

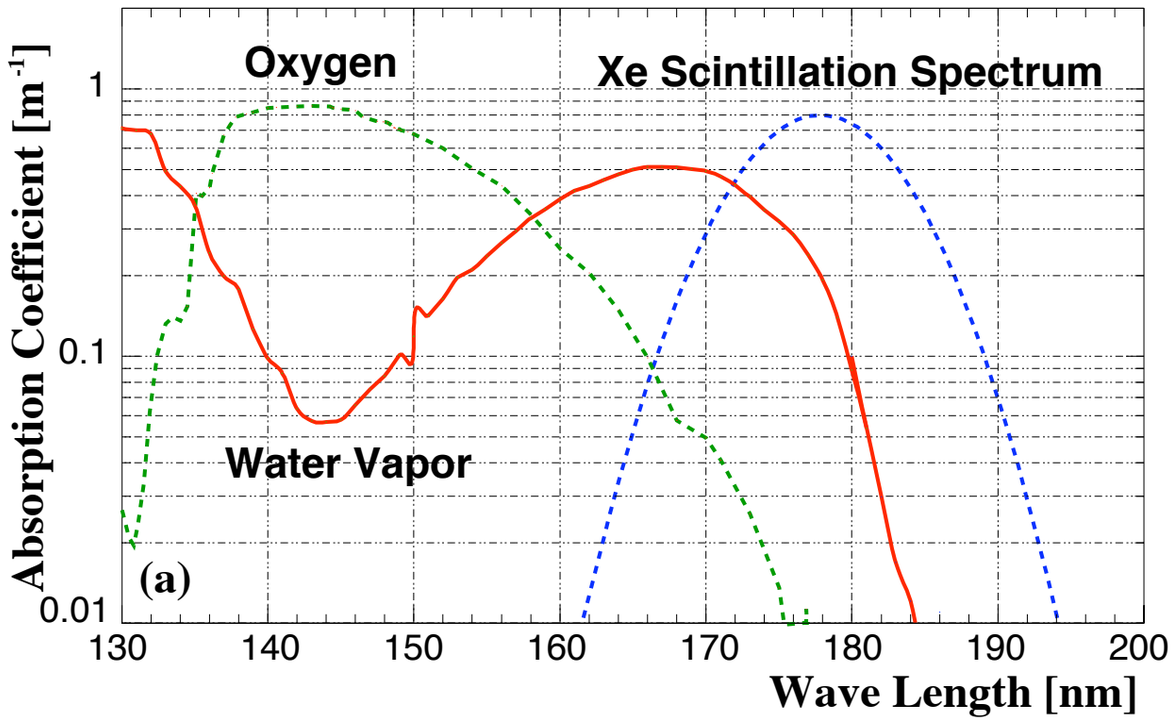




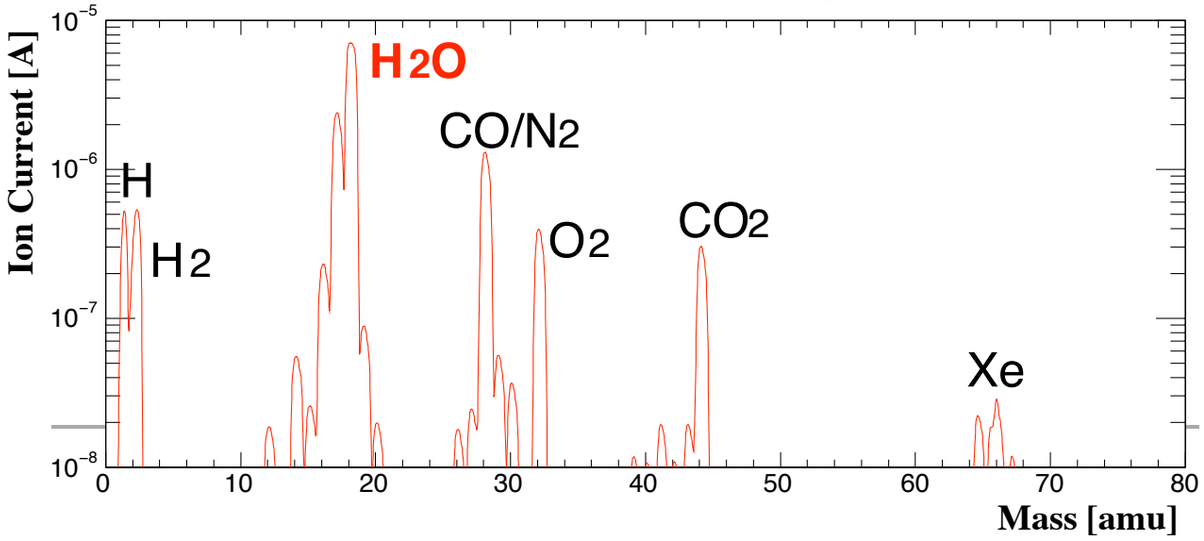
LXe Purification System

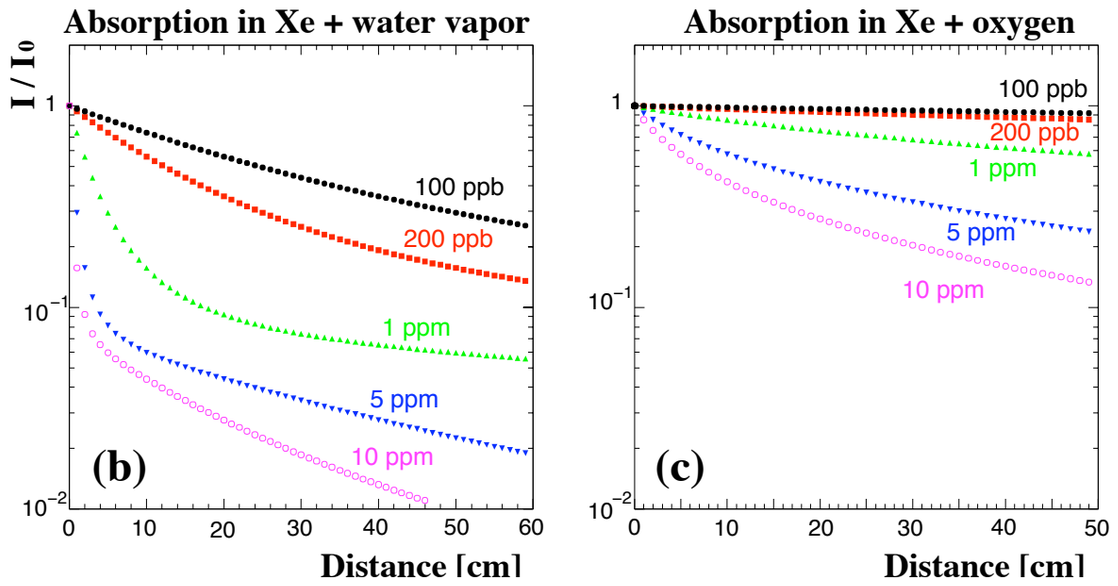
Scintillation Light Absorption by Impurities

- Scintillation light can be absorbed by impurities in LXe.
- H_2O is the most dangerous contaminants for our detector.



Residual Gas Analysis in prototype chamber

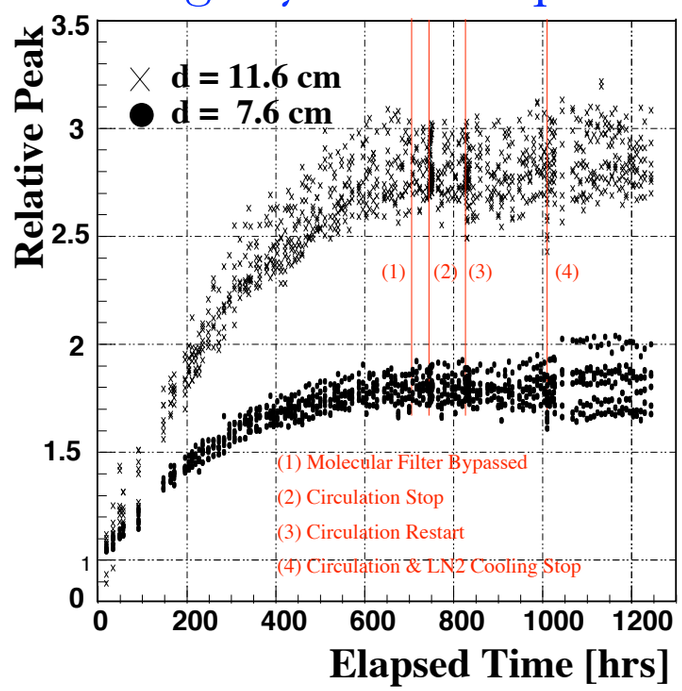


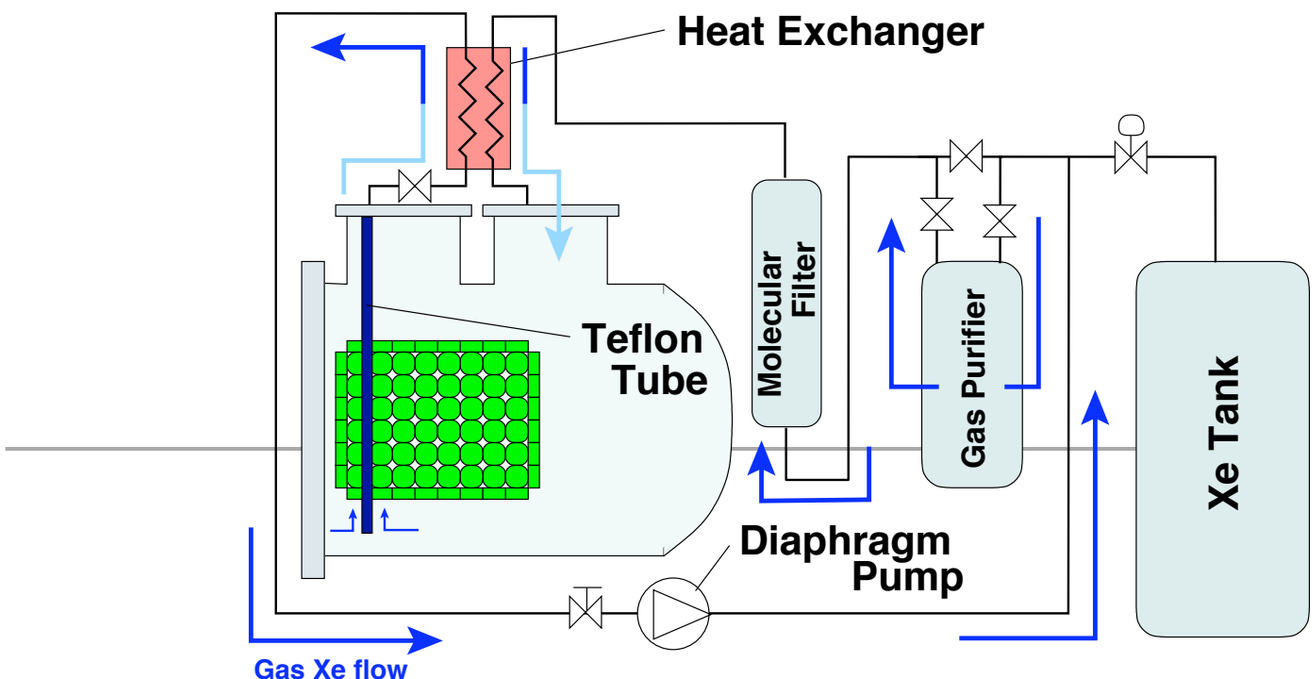


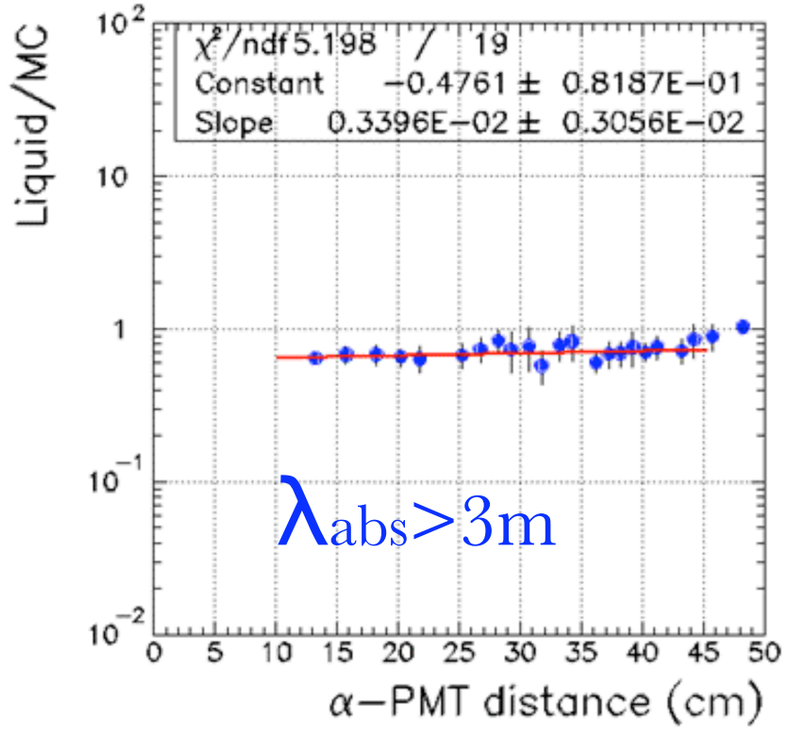
Gas Phase Purification

- Purification system developed to remove water from LXe. (**physics/0407033, to be published in NIMA**)
- Absorption length > 3m achieved.
- It works great, but takes long time because of the limited flow rate.
  - Flow rate 5L/min in gas.
  - Normally two weeks for the prototype.

Light yield for alpha

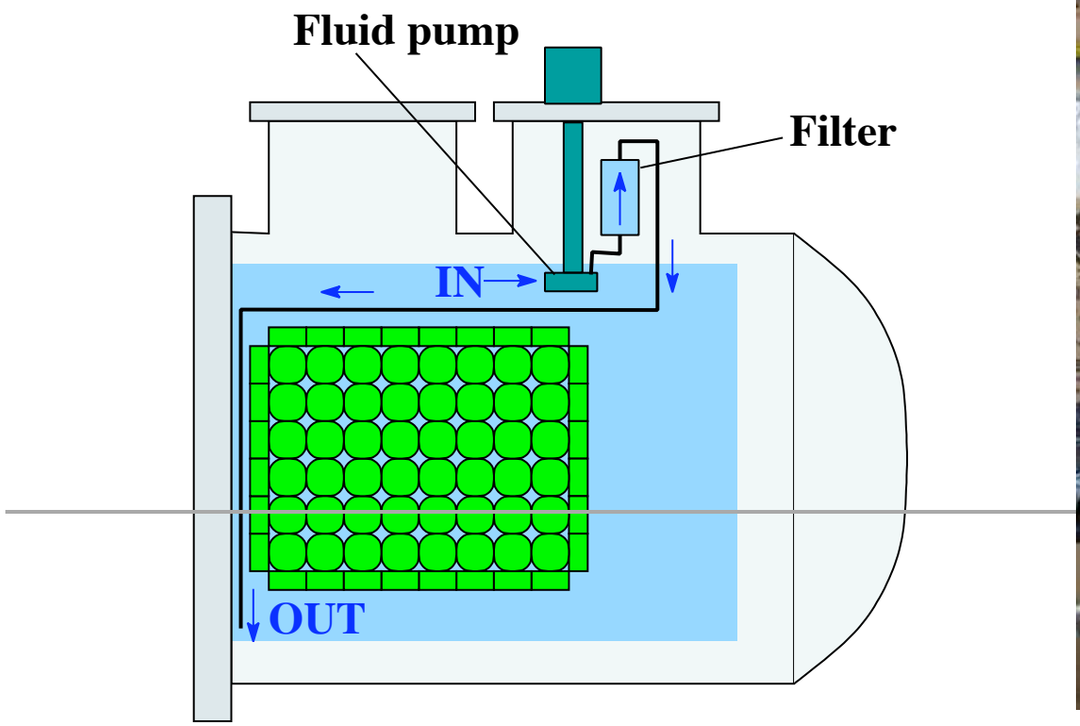






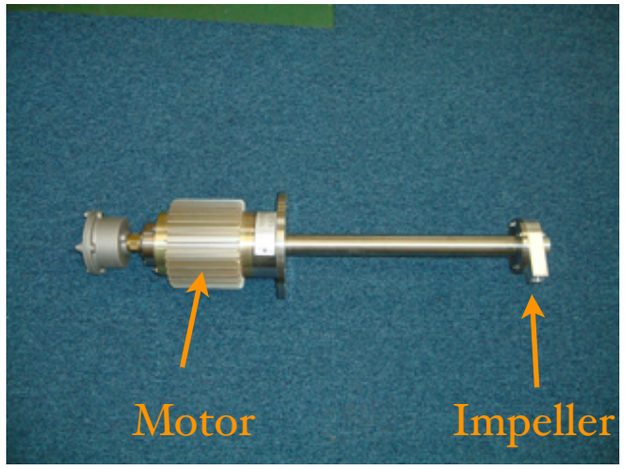
Liquid Phase Purification

- A new purification system is being developed to increase purification speed for purification in full-scale detector (800L LXe).
- Fluid pump + moisture filter (molecular sieve) inside the chamber.
- Cryogenic fluid pump
  - Barber-Nicols BNCP-62-000
  - Flow rate: 100L/hr in liquid (design)
  - Rot. speed: 3175rpm



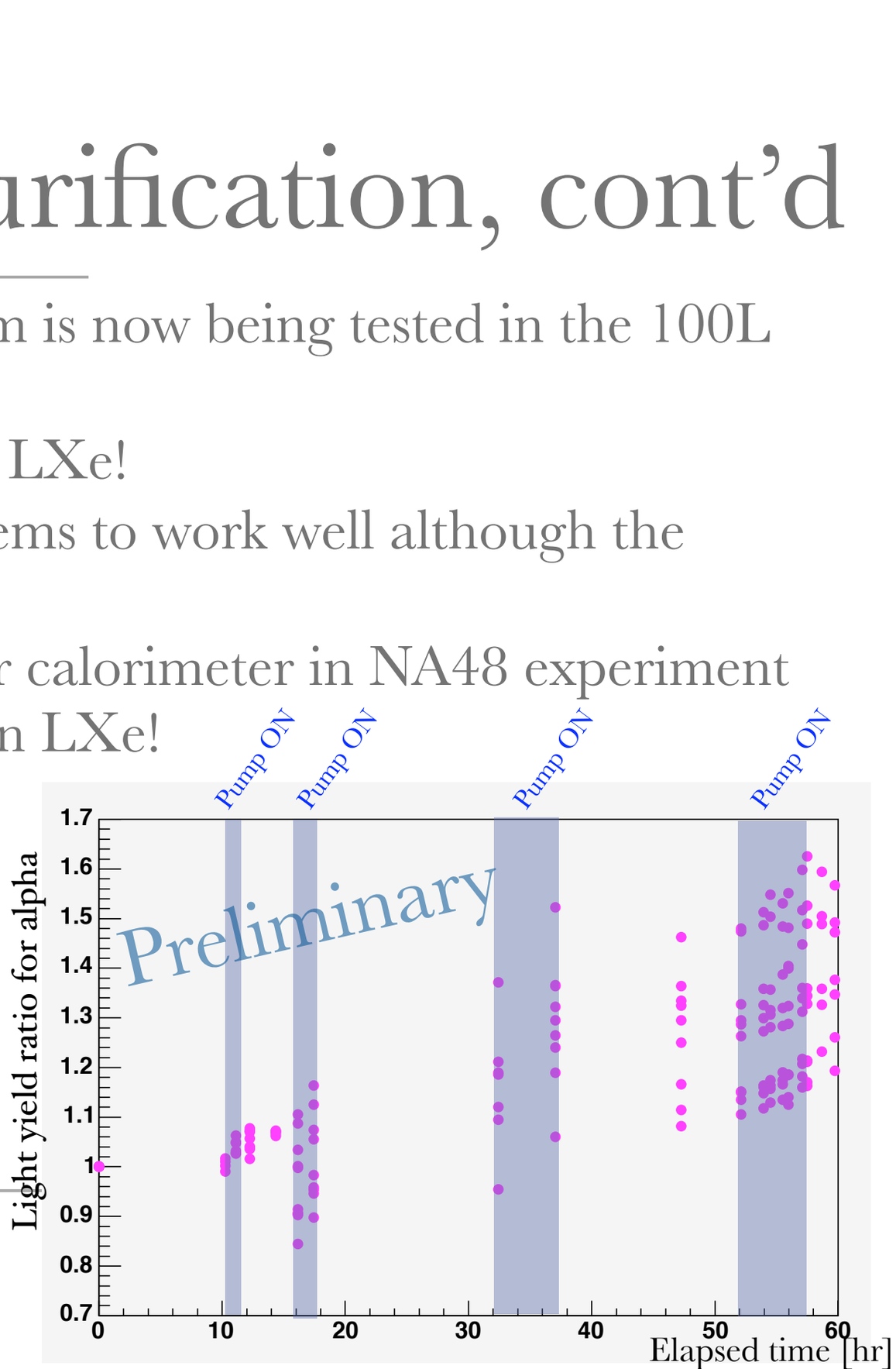
Purification system installed in 100L prototype

Fluid pump



Liquid Phase Purification, cont'd

- Liquid phase purification system is now being tested in the 100L prototype at PSI.
- Cryogenic fluid pump works in LXe!
- Purification with this system seems to work well although the details are being analyzed.
- Same technique is used for LKr calorimeter in NA48 experiment at CERN, but the first success in LXe!



Summary

- A prototype detector with 100L LXe was developed to demonstrate the good performance of the planned LXe calorimeter.
- Two complementary beam tests were successfully carried out with the prototype.
- From these tests it can be concluded that the proposed LXe calorimeter will fulfill the requirements for the calorimeter in the MEG experiment to search for $\mu \rightarrow e\gamma$ with an sensitivity of $BR<10^{-13}$.
- New purification system based on cryogenic fluid pump is being developed and purification speed seems much faster than that of gas phase purification system.