MEG実験用液体キセノン検出器の現状

東京大学素粒子物理国際研究センター

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2007年9月24日

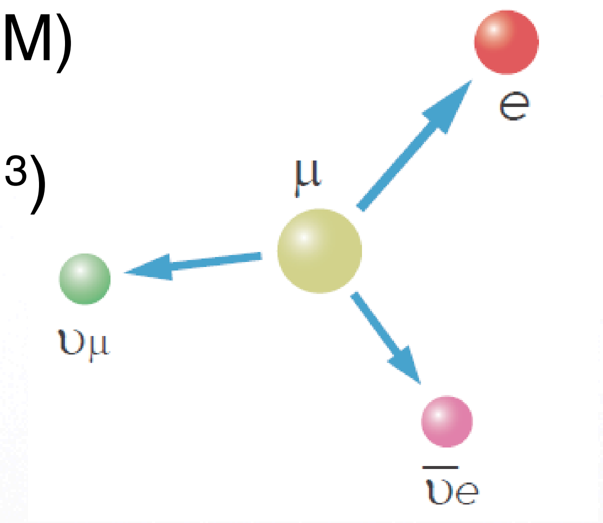
日本物理学会 第62回年次大会

北海道大学

Outline

- MEG Experiment
- MEG Calorimeter
  - System
  - Calibration
- Other part of MEG experiment
- Summary

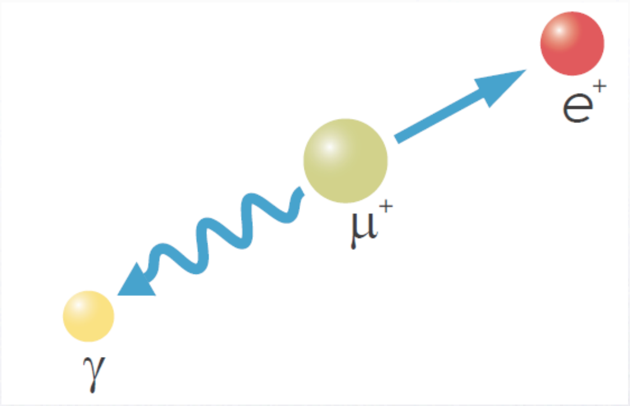
- Lepton flavor violation is forbidden in the standard model (SM)
- Physics beyond the SM predict observable B.R. (10^{-15} - 10^{-13})
- Current limit is given by MEGA(1999). 1.2×10^{-11}
- Expected sensitivity of MEG is around 10^{-13}.



Michel decay

Backgrounds

Prompt : Michel decay with high energy e^+ and γ.
Accidental : High energy e^+ and γ (radiative muon decay, AIF...)



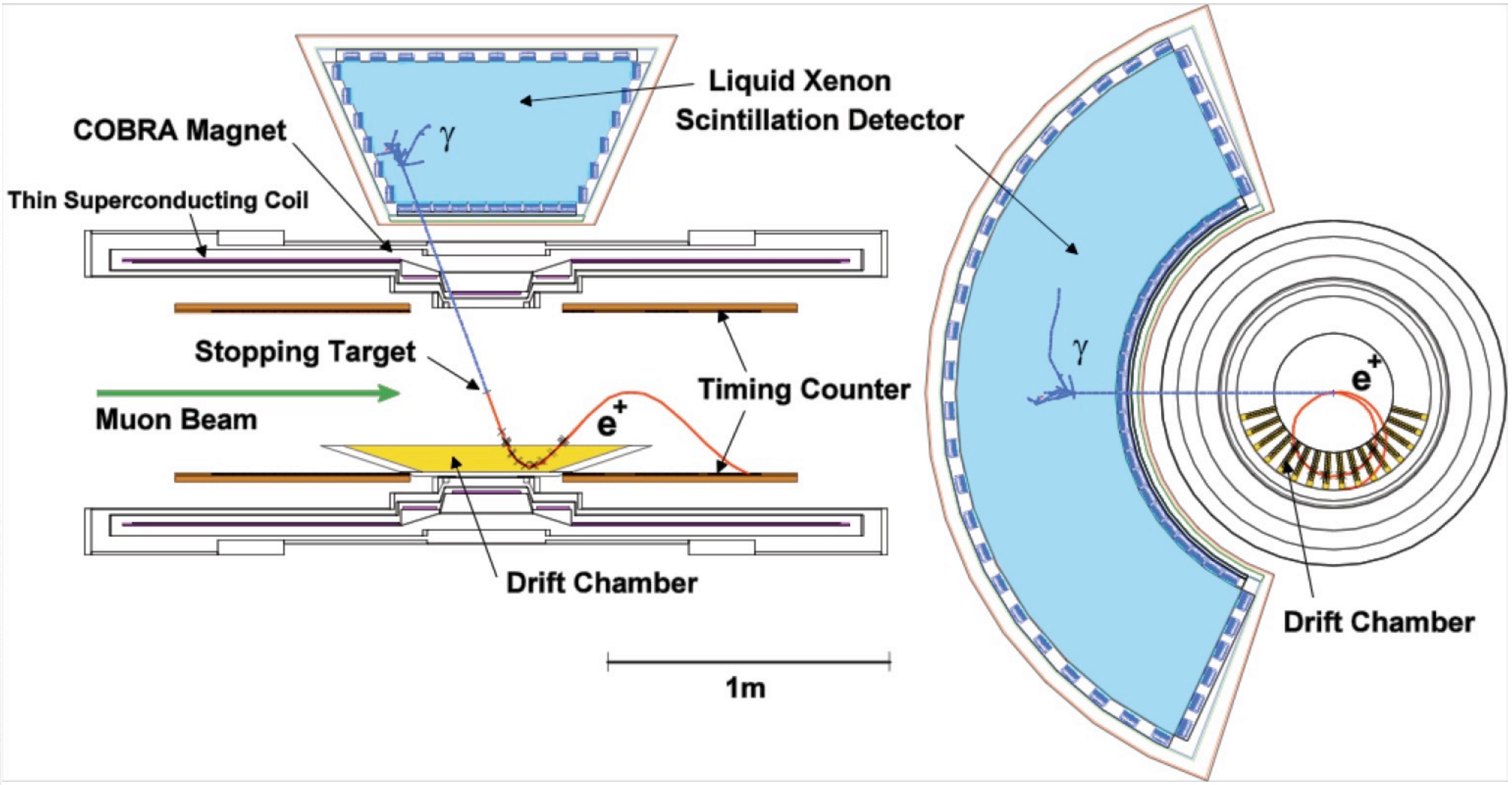
μ→eγ

Precise energy, time and opening angle measurement is important.

Apparatus

The most intense DC muon beam at PSI in Switzerland. (1.8 mA proton current)

COBRA magnet with gradient field

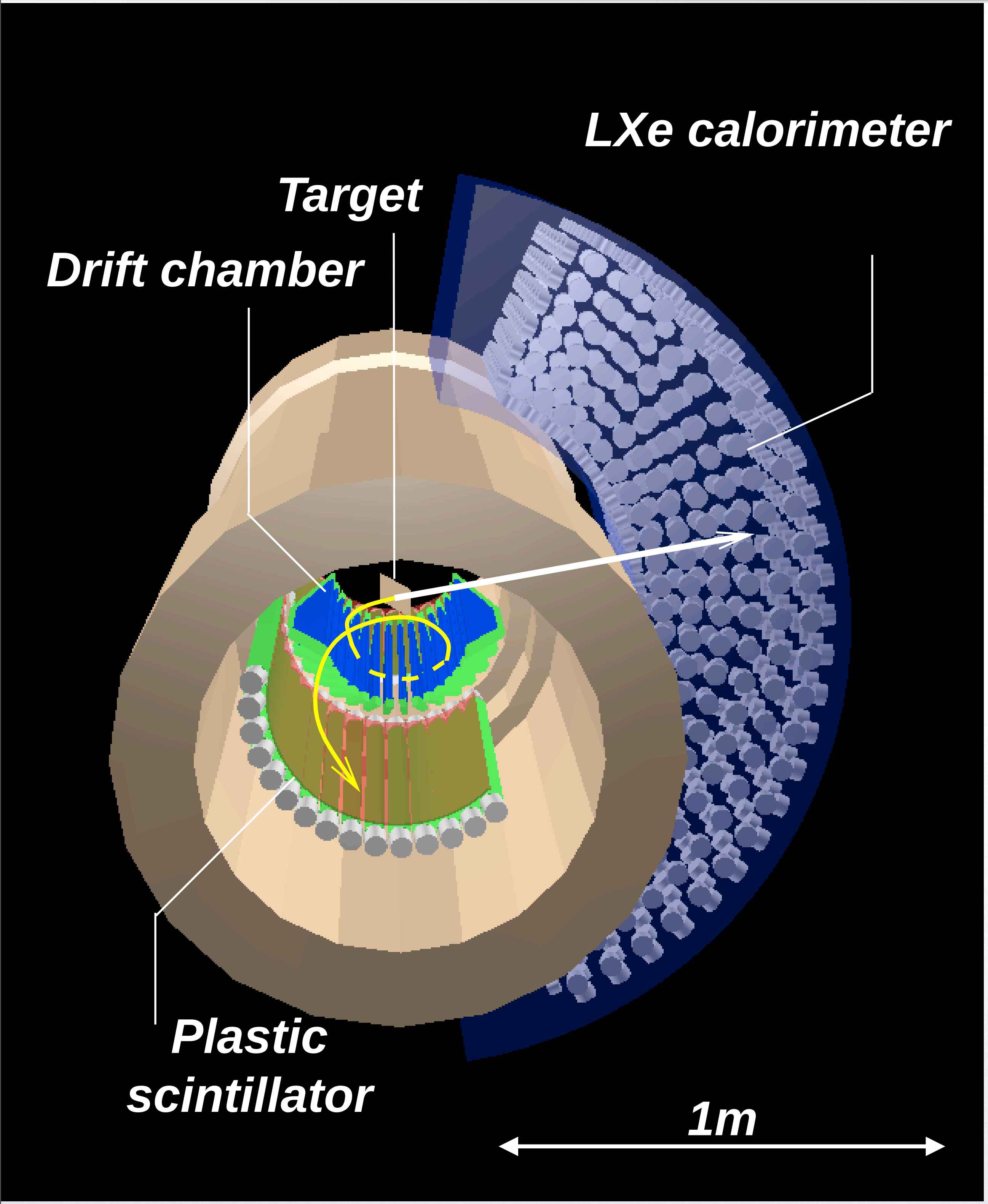


Liquid xenon gamma ray detector

Plastic scintillator to measure precise time of positron

Very thin drift chamber to measure low energy positrons

MEG Calorimeter



- Liquid xenon scintillation calorimeter.
- With 800 litter(~3 ton) xenon and 846 PMTs surrounding the fiducial volume
- Unsegmented
- Optimized for ~50 MeV gamma ray detection
- One detector measures energy, position and time with high resolutions
- Pile up detection/separation by time and space pattern recognition

Principle of analysis

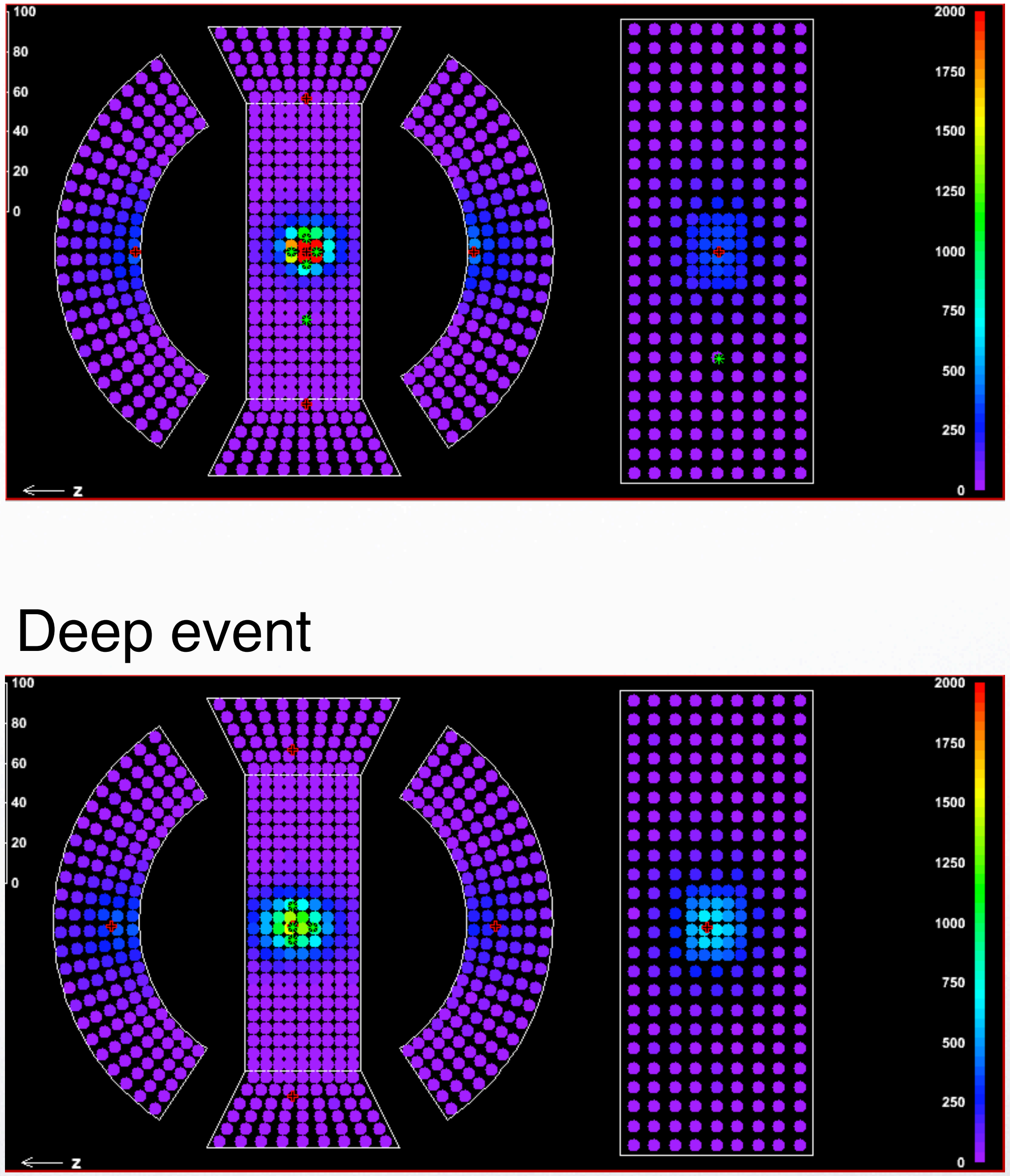
- Reconstruction
  - Energy : Weighted sum of all PMT outputs
  - Position : Peak of light distribution
  - Depth : Broadness of light distribution
  - Time : Weighted mean of time of PMTs

⇨ Correction of position/depth dependence with using calibration data (shown in later slides) or MC.

- Pileup detection
  - Waveform
  - Light distribution pattern

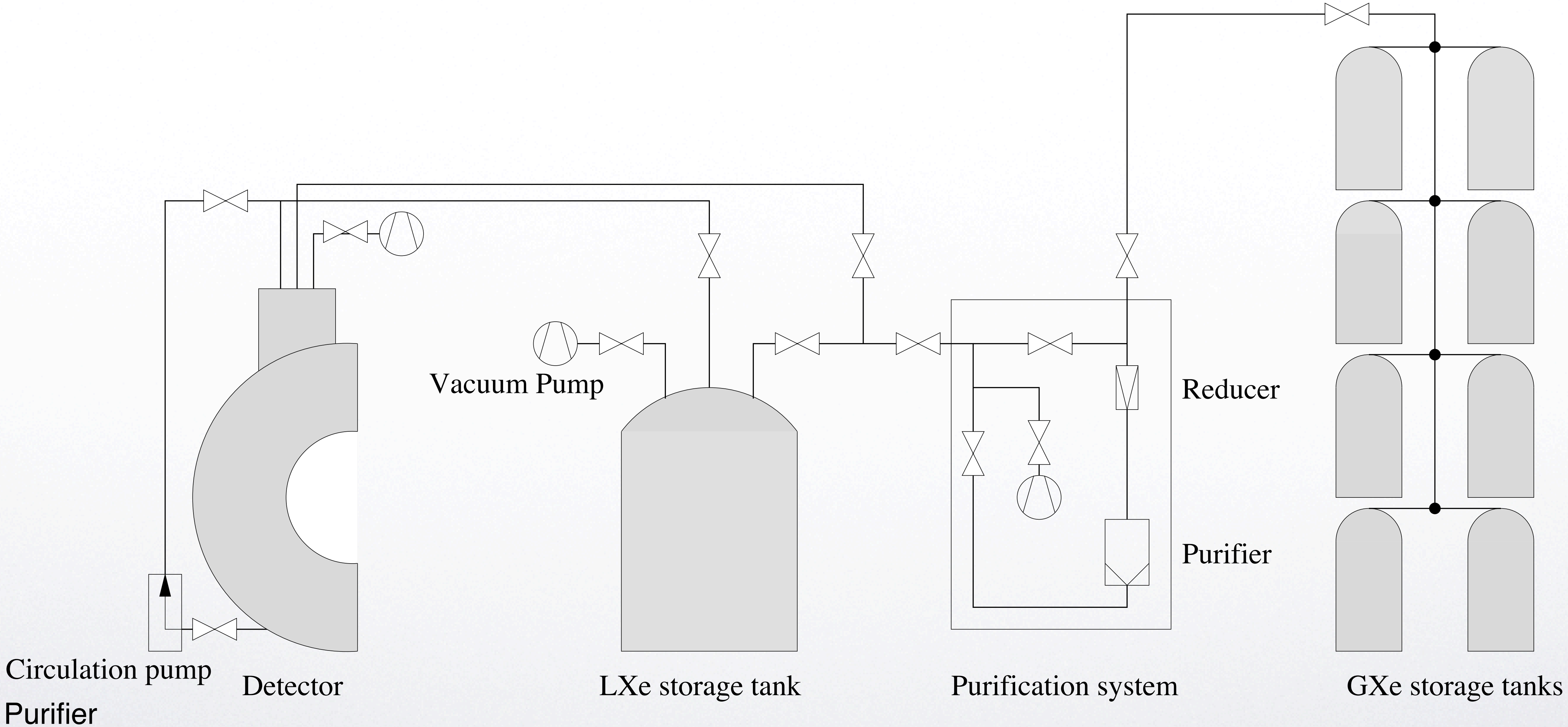
Shallow event

Deep event



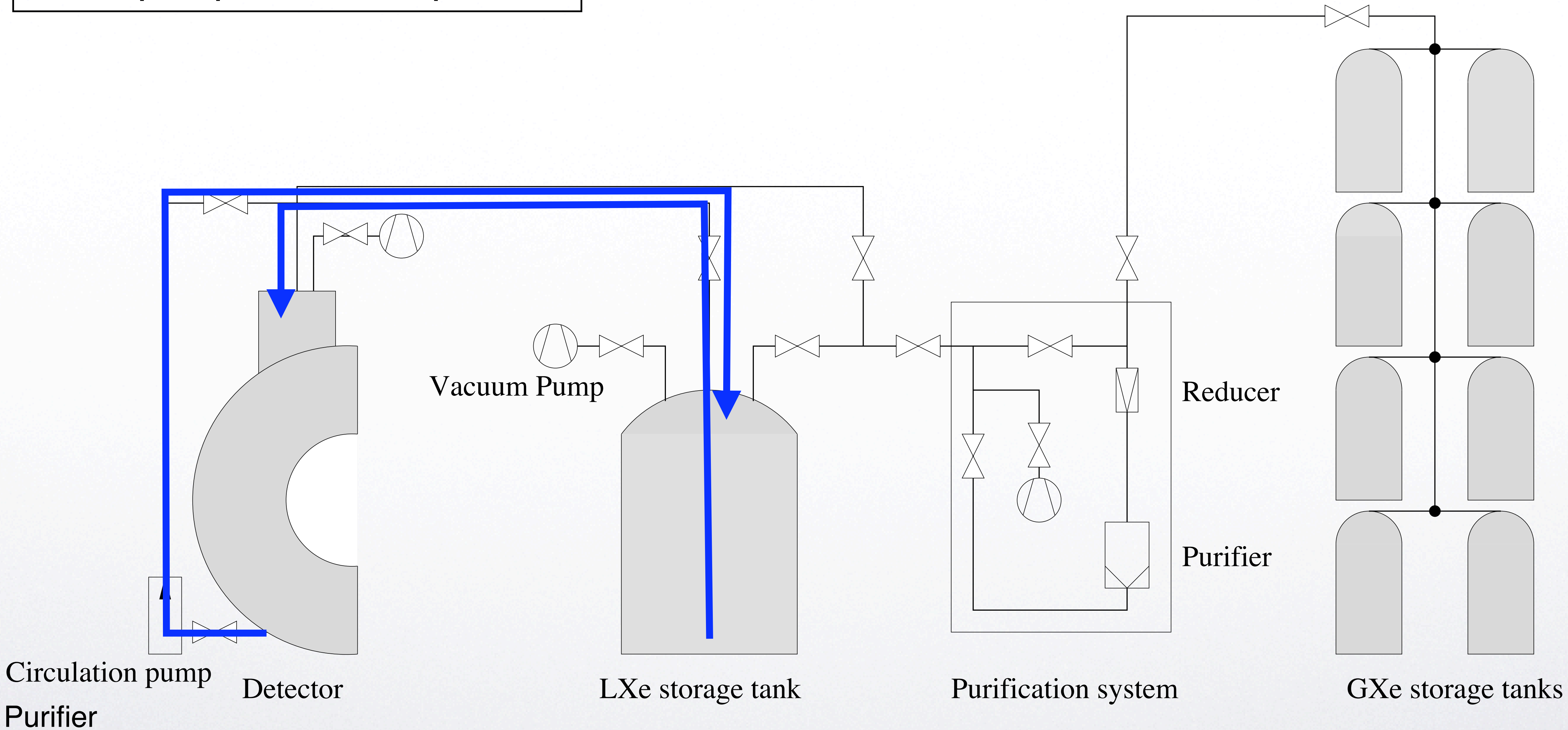
System

Xenon Gas System



Xenon Gas System

Liquid phase transport

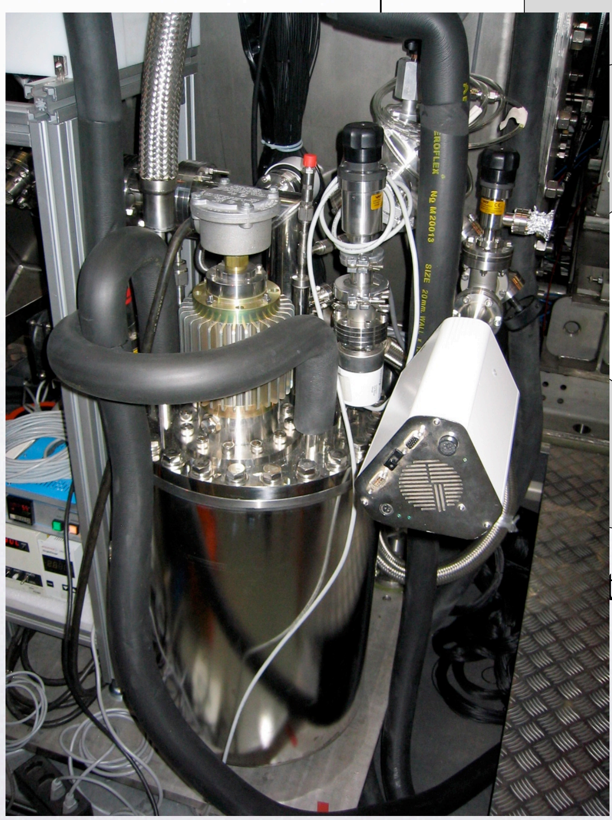


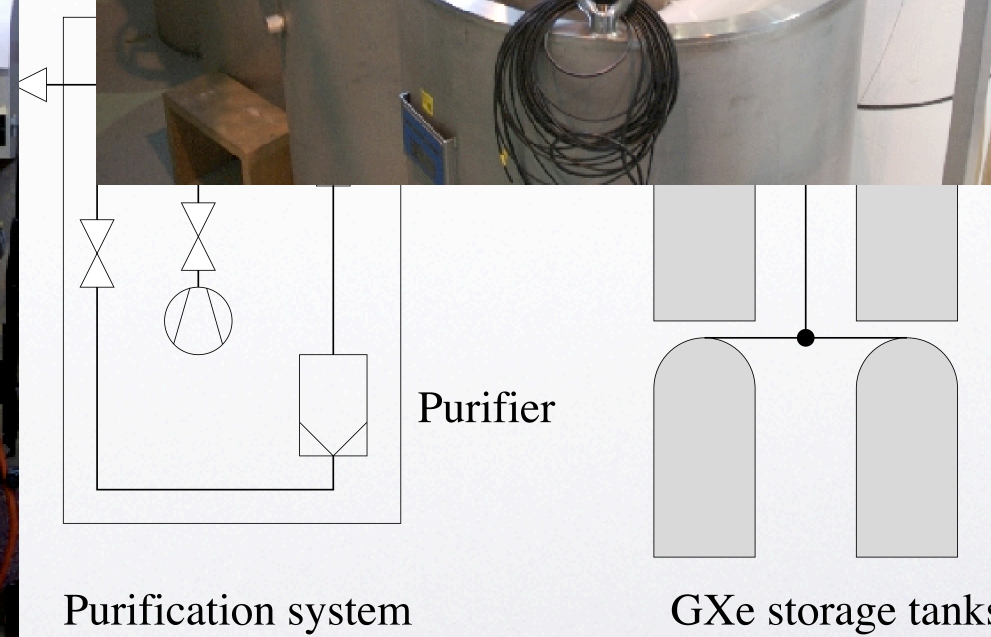
Xenon Gas System

250 l x 8 tanks

1000 l Dewar tank

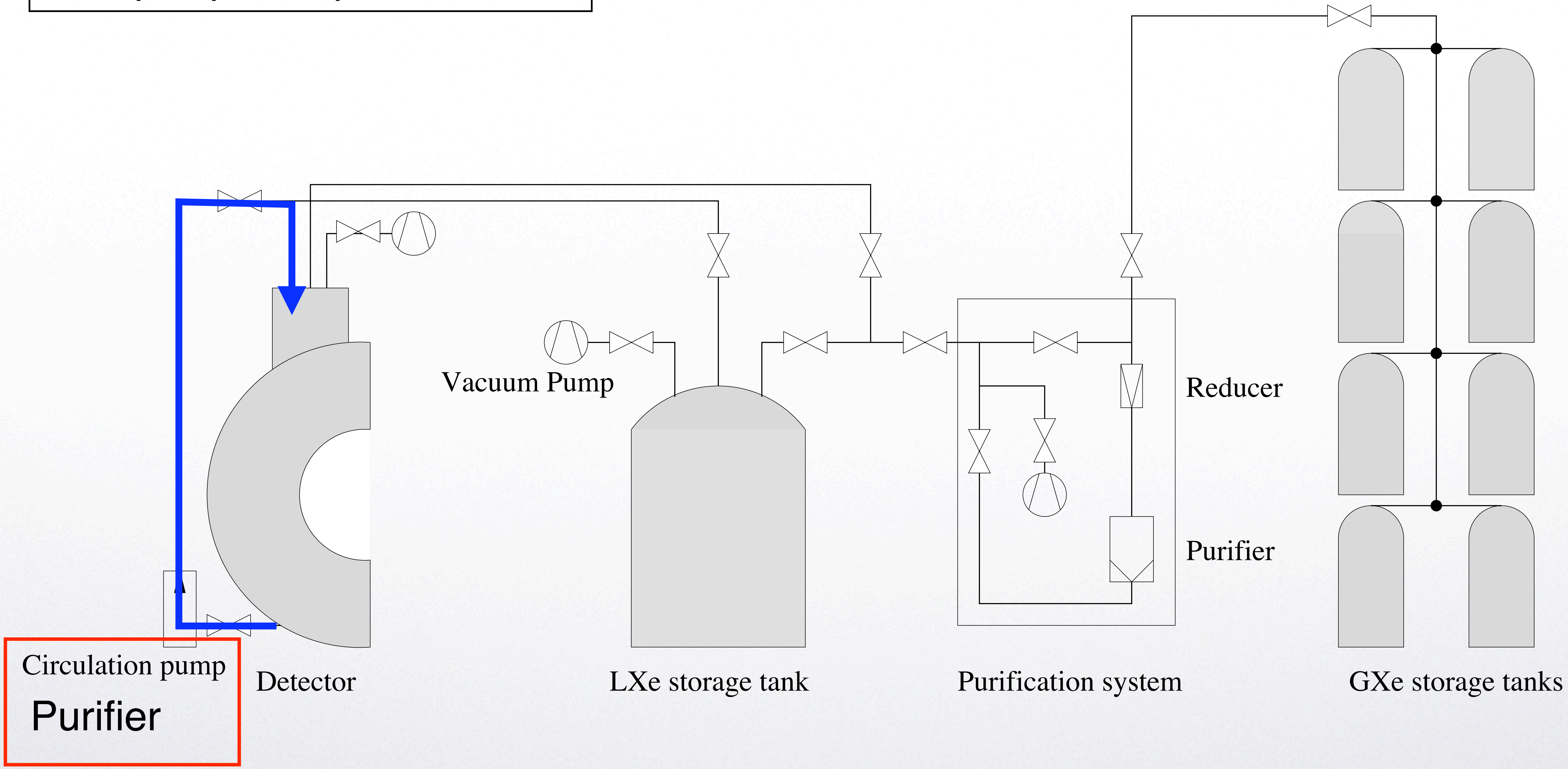
Liquid phase purifier





Xenon Gas System

Liquid phase purification



Cryostat construction

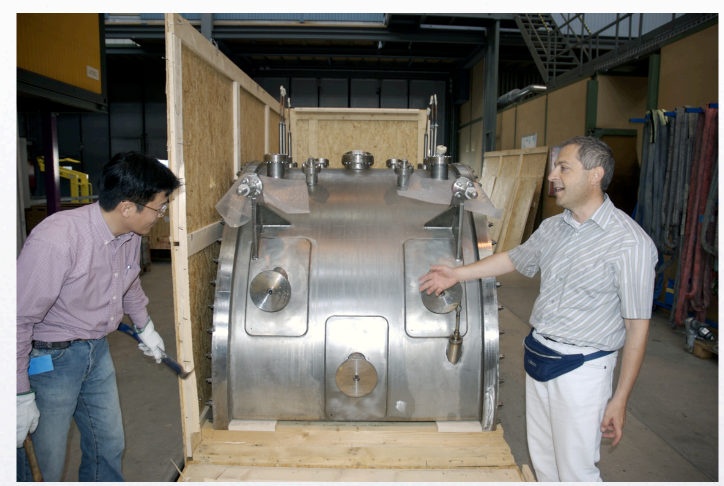

Inner vessel


Inner vessel and window

Cryostat is made of low permeability stainless steel (<1.008)

cooling test

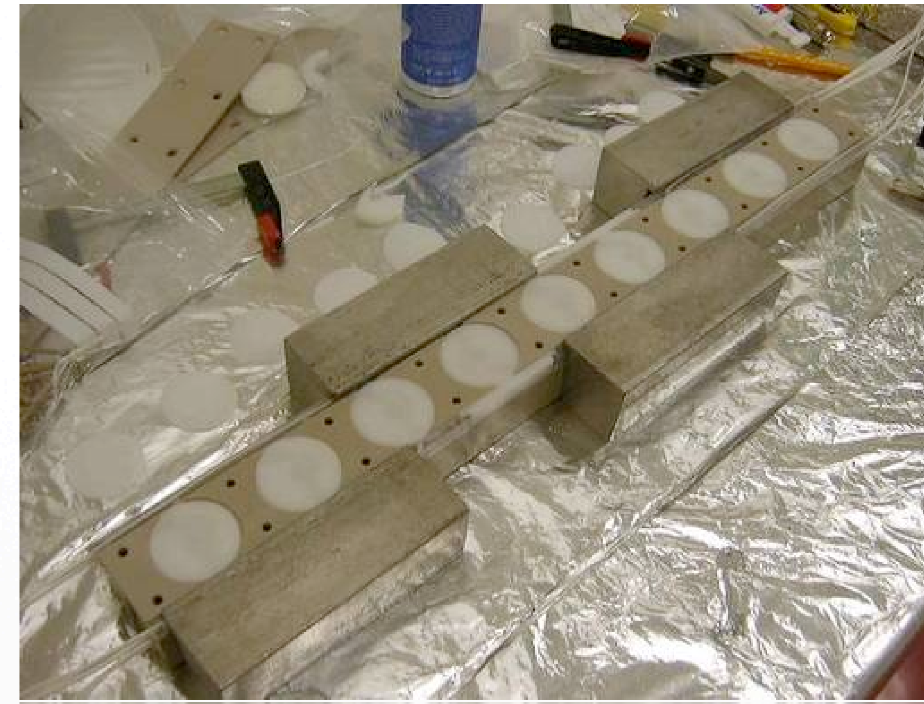

Honeycomb window with carbon fiber plates

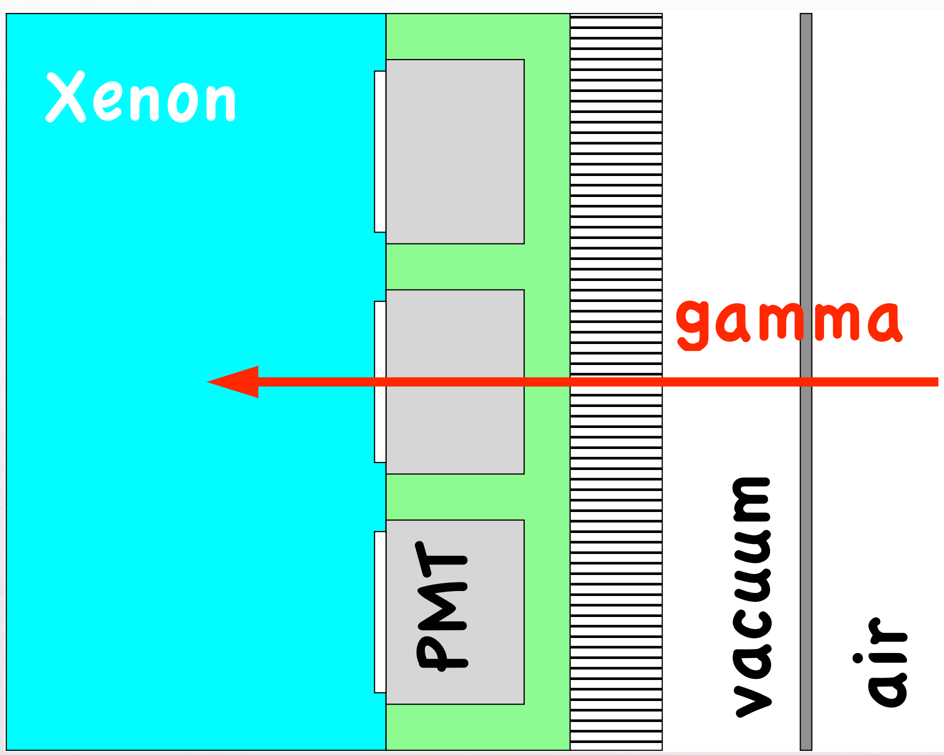

Arrived at PSI on June

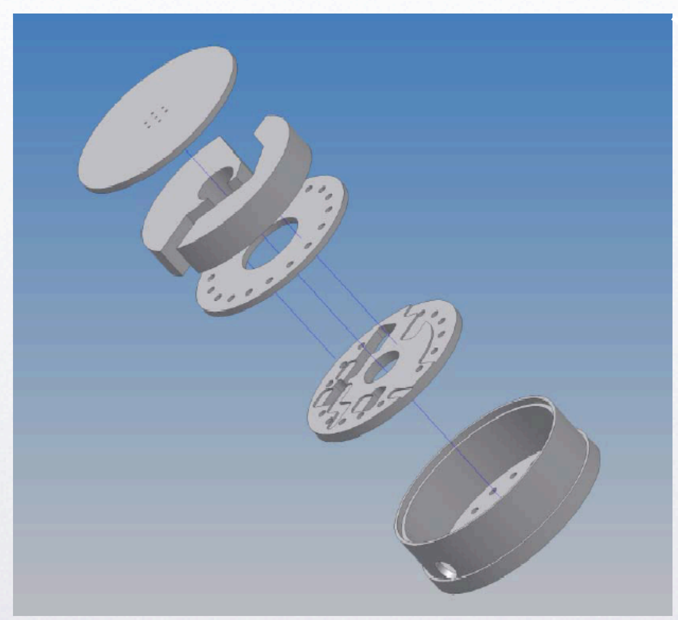
PMT Installation

Space around base circuit is filled with grass beads to avoid xenon entering there.

Flat distribution of detection efficiency

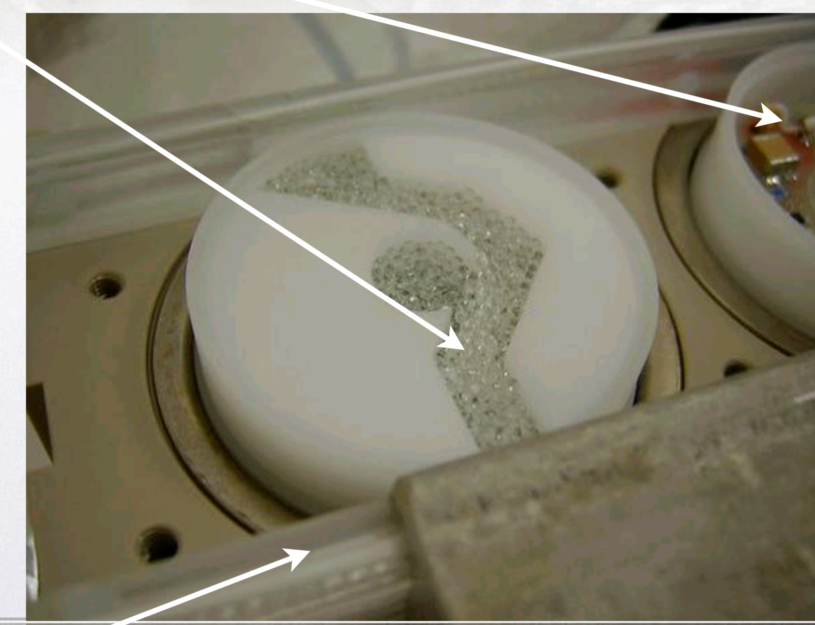






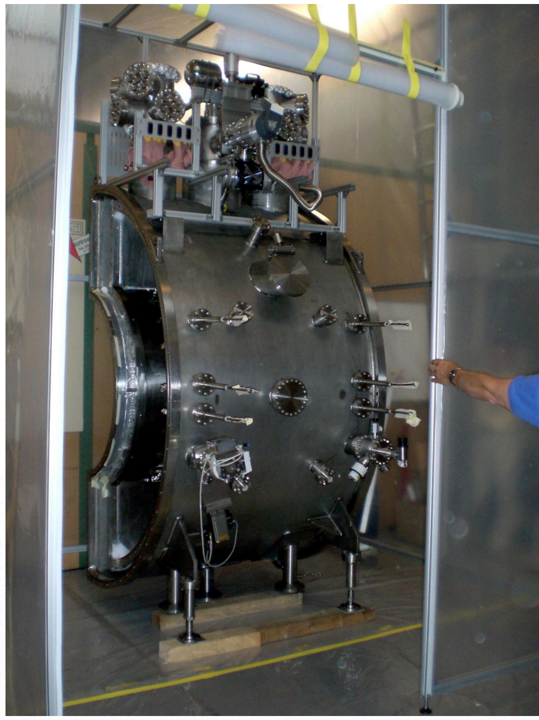
Glass beads

Base circuit



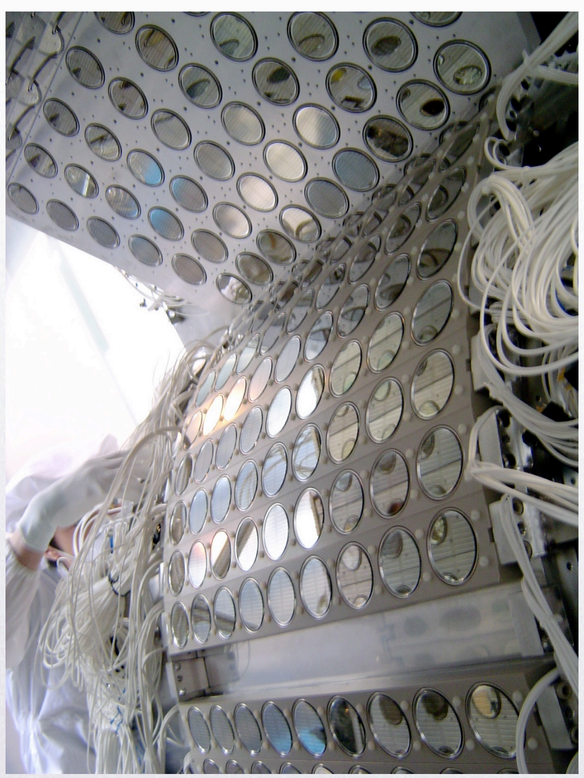
Cable

PMT mounting



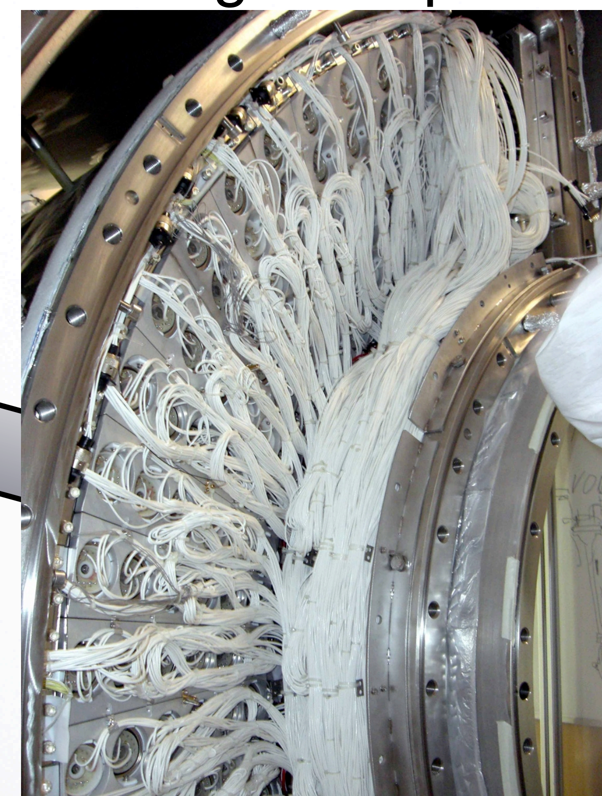
Class 1000, clean room

lateral face



Inner face

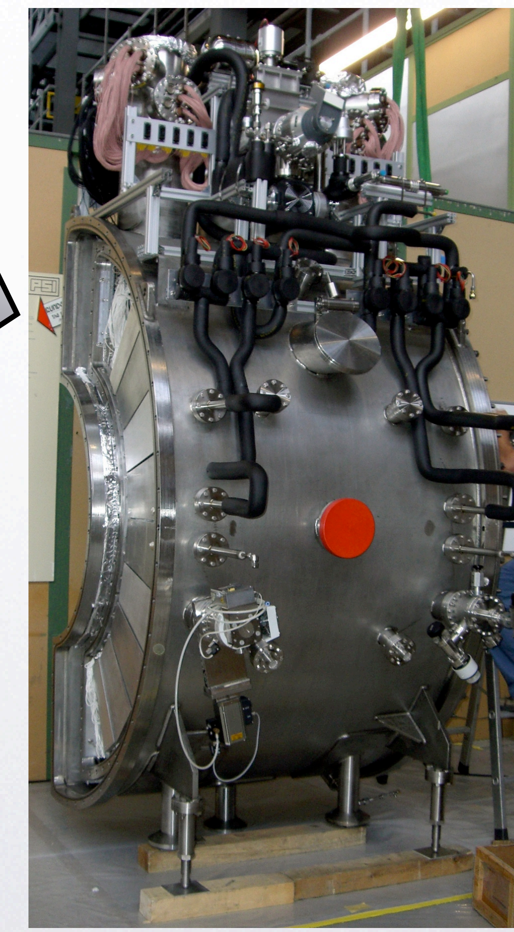
Cabling and spacer



+

Calibration Am,
LED, Optical fiber.
Level meter,
Temperature sensor

Completed



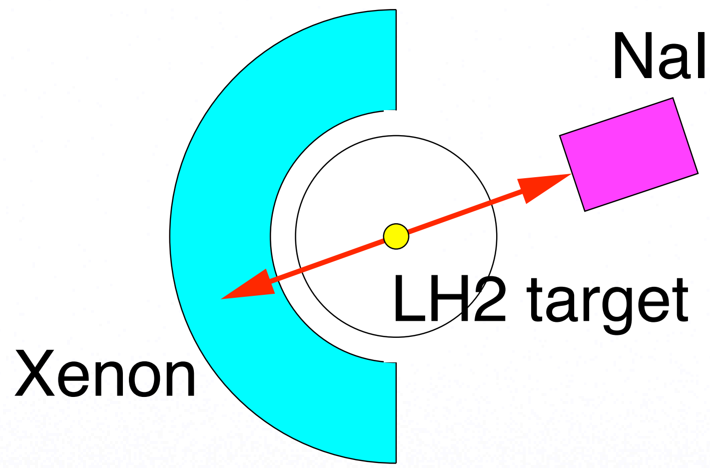
Calibration

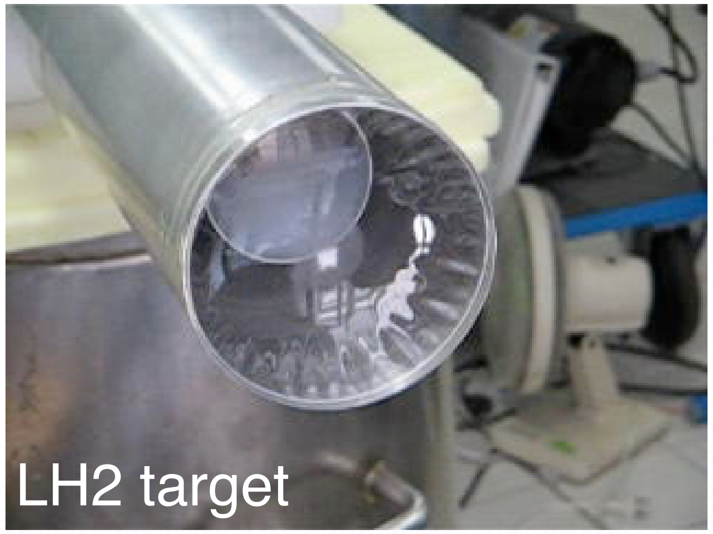
$\pi^- + p \to \pi^0 + n$

$\pi^0 \to \gamma\gamma$ (55MeV, 83MeV)

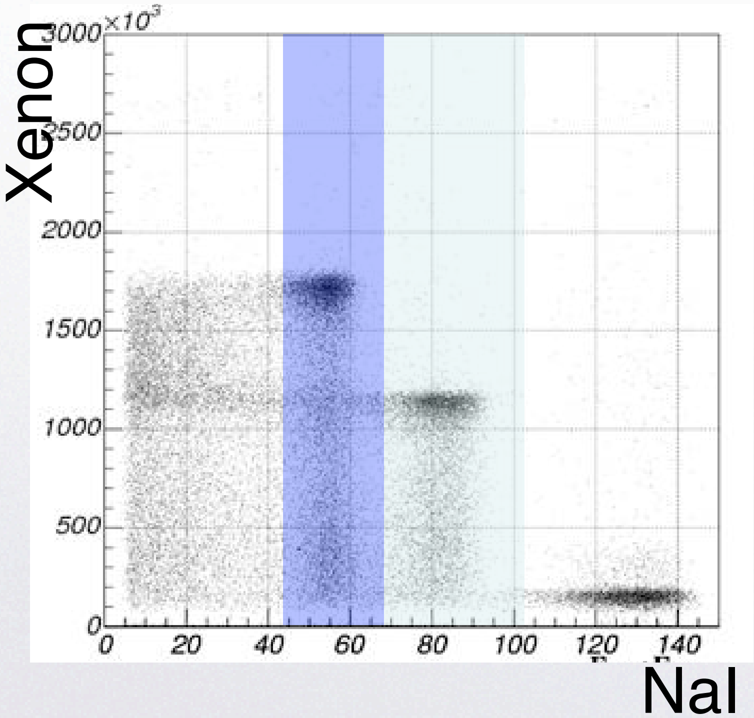
$\pi^- + p \to \gamma + n$ (129MeV)

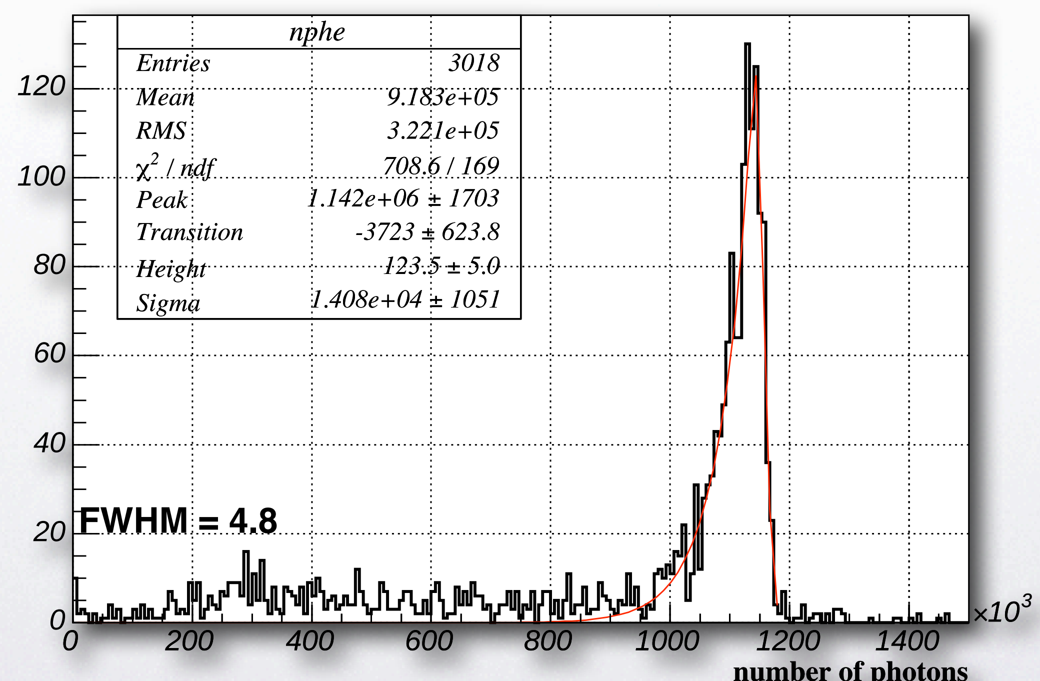
LH_2 target





Two beam tests with prototype in 2003, 2004.

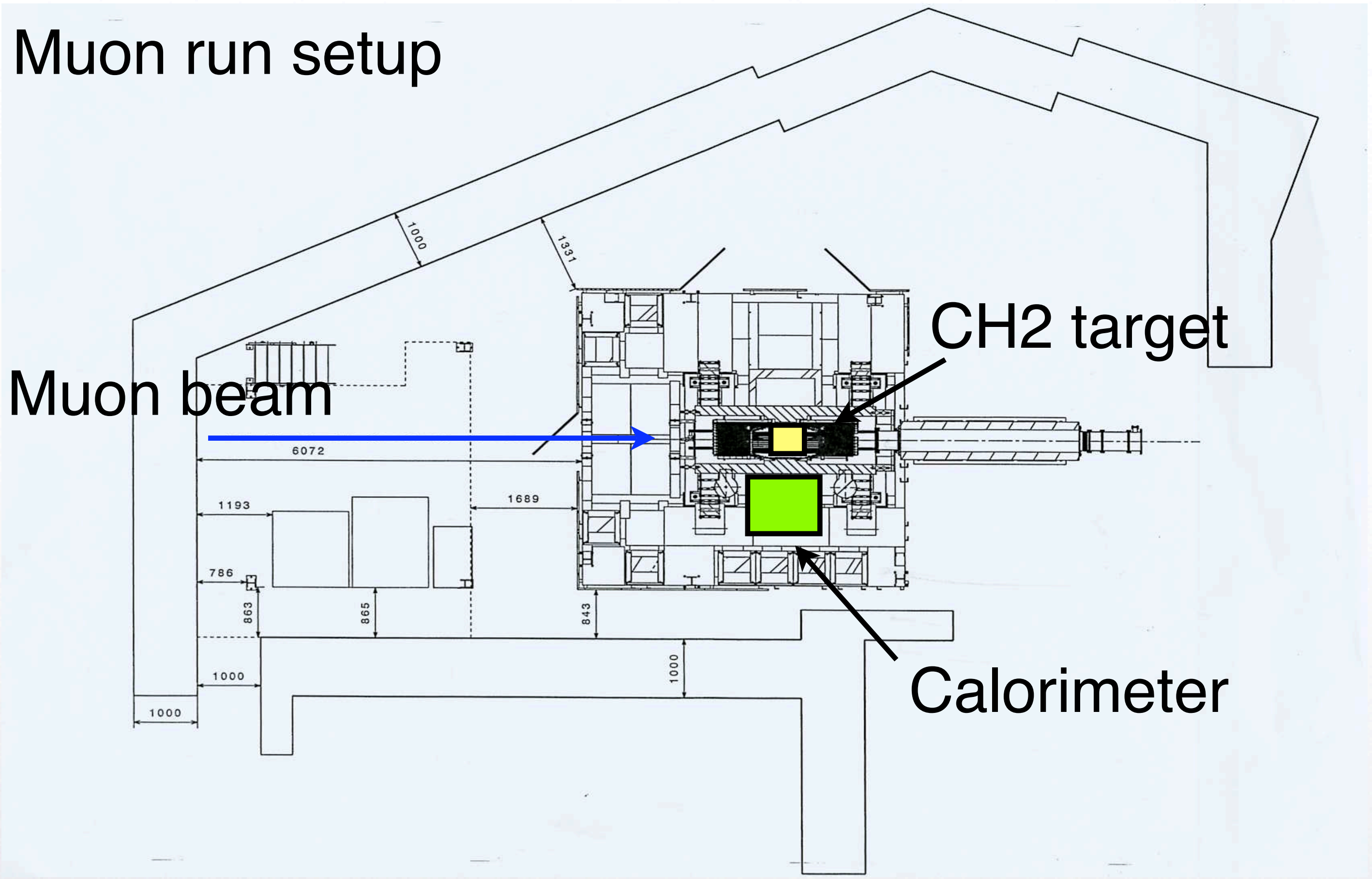


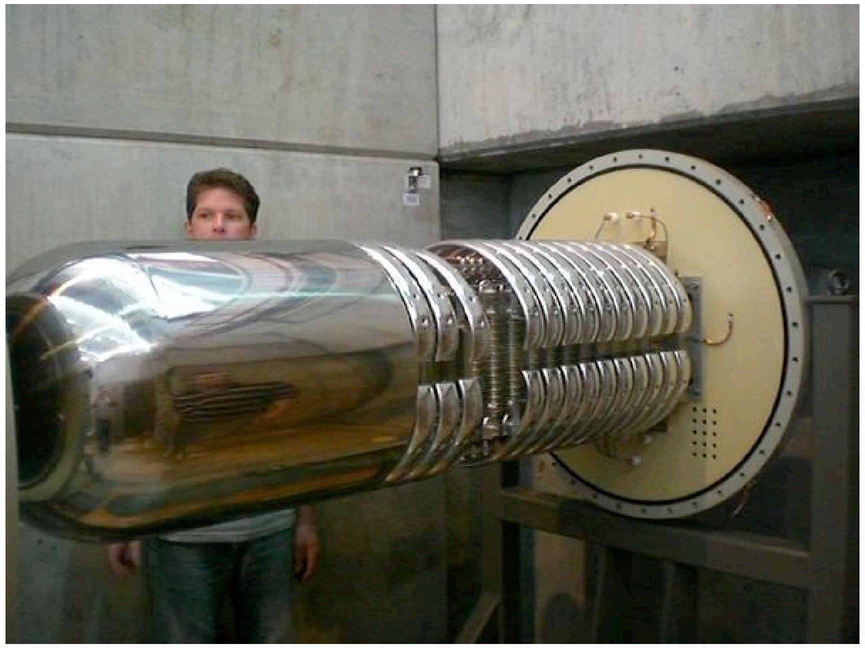


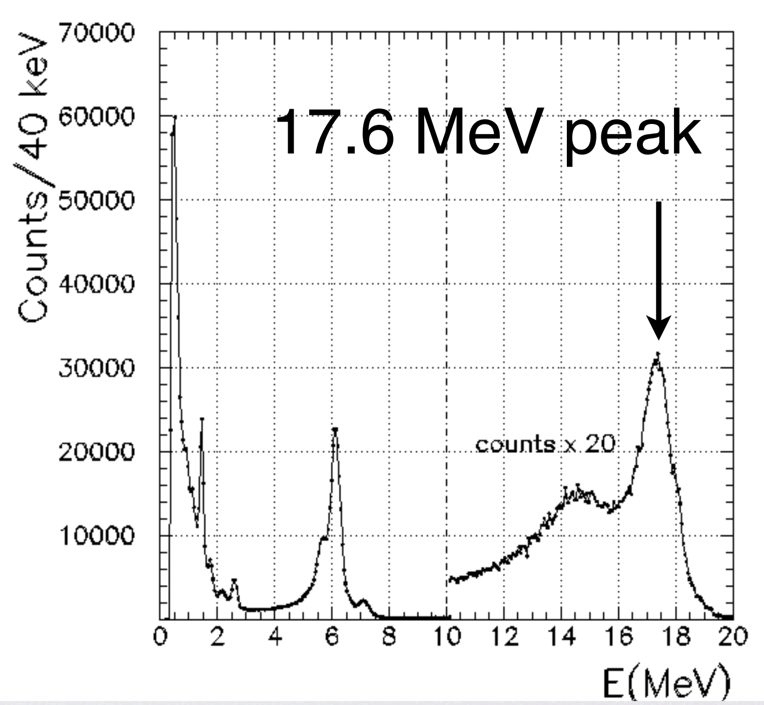
Detector Calibration 2

Cockcroft-Walton Proton Accelerator

Li(p,γ)Be Daily calibration is possible.



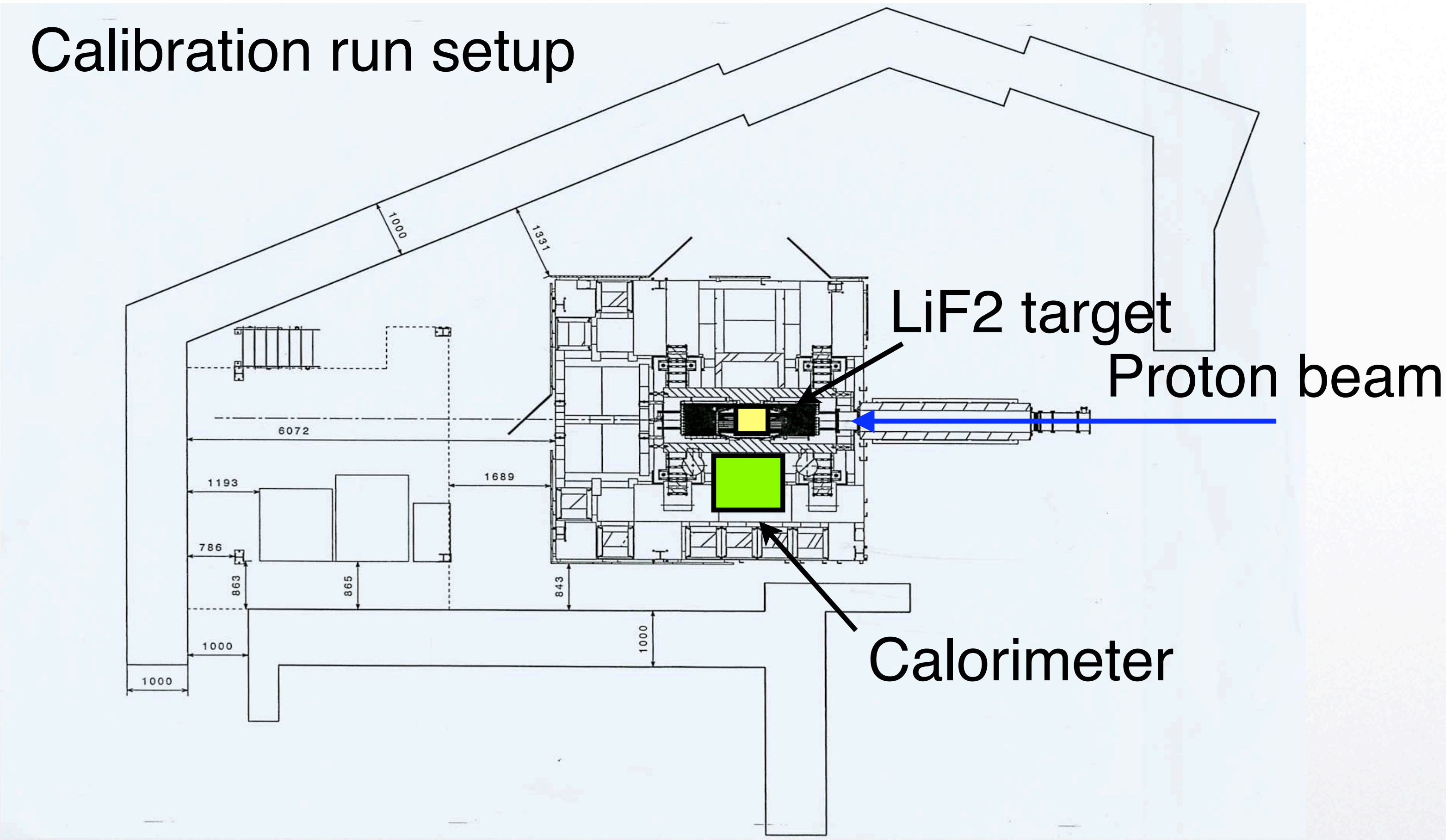


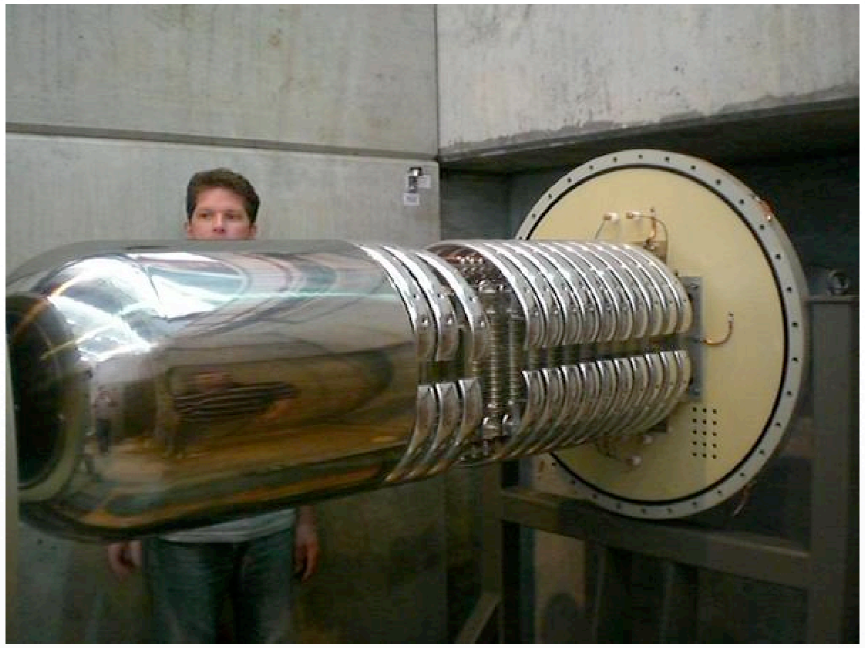


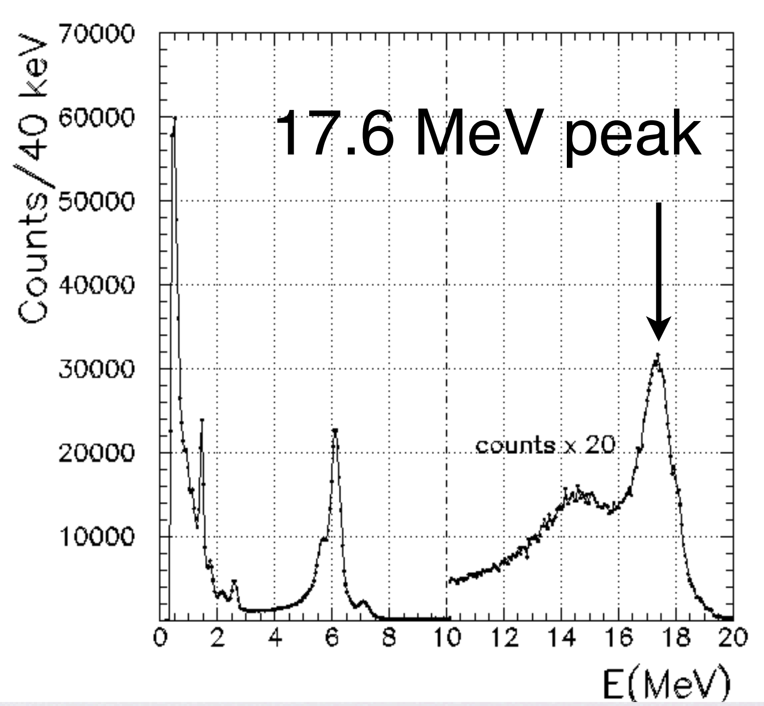
PMT Q.E., Energy scale calibration/monitor, response linearity...

Cockcroft Walton Proton Accelerator

Li(p,γ)Be Daily calibration is possible.



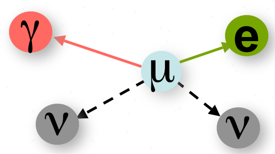


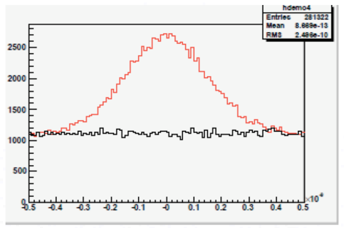


PMT Q.E., Energy scale calibration/monitor, response linearity...

Various calibration sources

μ radiative decay



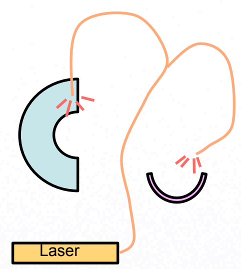


- Lower beam intensity < 10^7
- Is necessary to reduce pile-ups
- Better σ_t, makes it possible to take data with higher beam intensity
- A few days ~ 1 week to get enough statistics

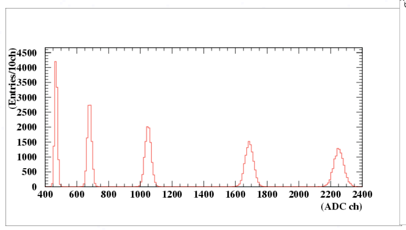
Laser

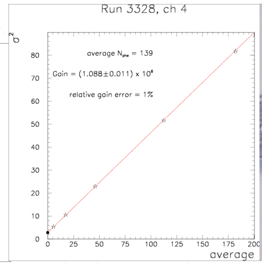
(rough) relative timing calib.

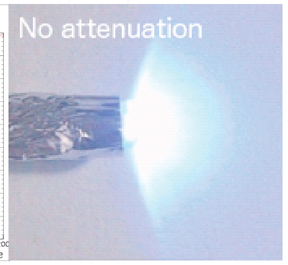
< 2~3 nsec



LED



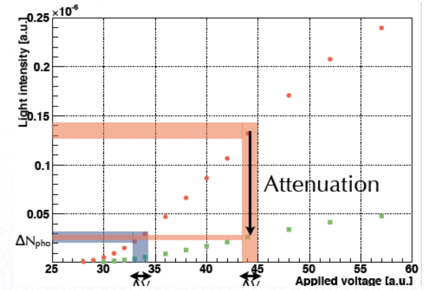


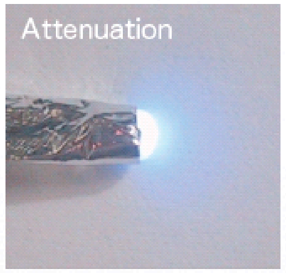


PMT Gain

Higher V with light att.

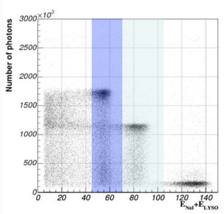
Can be repeated frequently

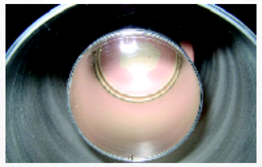




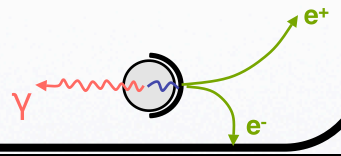
Xenon Calibration

$\pi^0 \rightarrow \gamma\gamma$





- $\pi^- + p \rightarrow \pi^0 + n$
  - $\pi^0 \rightarrow \gamma\gamma$ (55MeV, 83MeV)
- $\pi^- + p \rightarrow \gamma + n$ (129MeV)
- 10 days to scan all volume precisely
- (faster scan possible with less points)
- LH_2 target

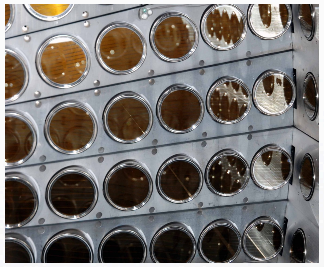


alpha

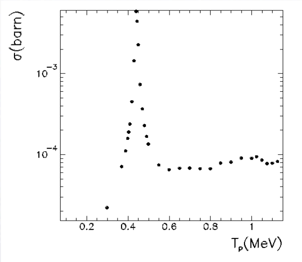
PMT QE & Att. L

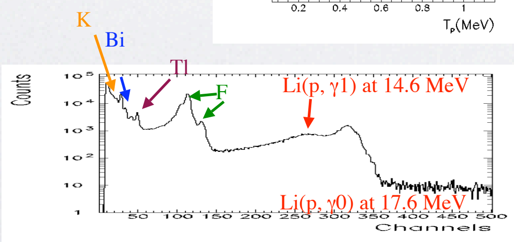
Cold GXe

LXe



Proton Acc

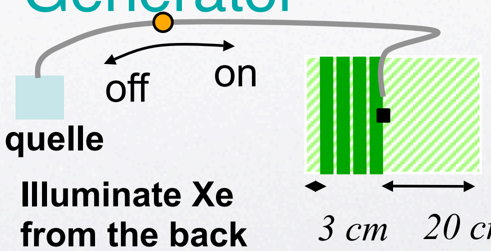




Li(p,γ)Be

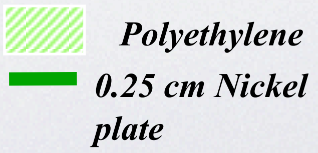
- LiF target at COBRA center
- 17.6MeV γ
- ~daily calib.
- Can be used also for initial setup

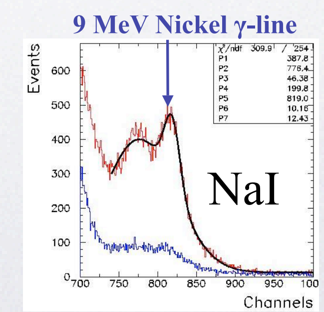
Nickel γ Generator



Illuminate Xe from the back

Source (Cf) transferred by comp air → on/off



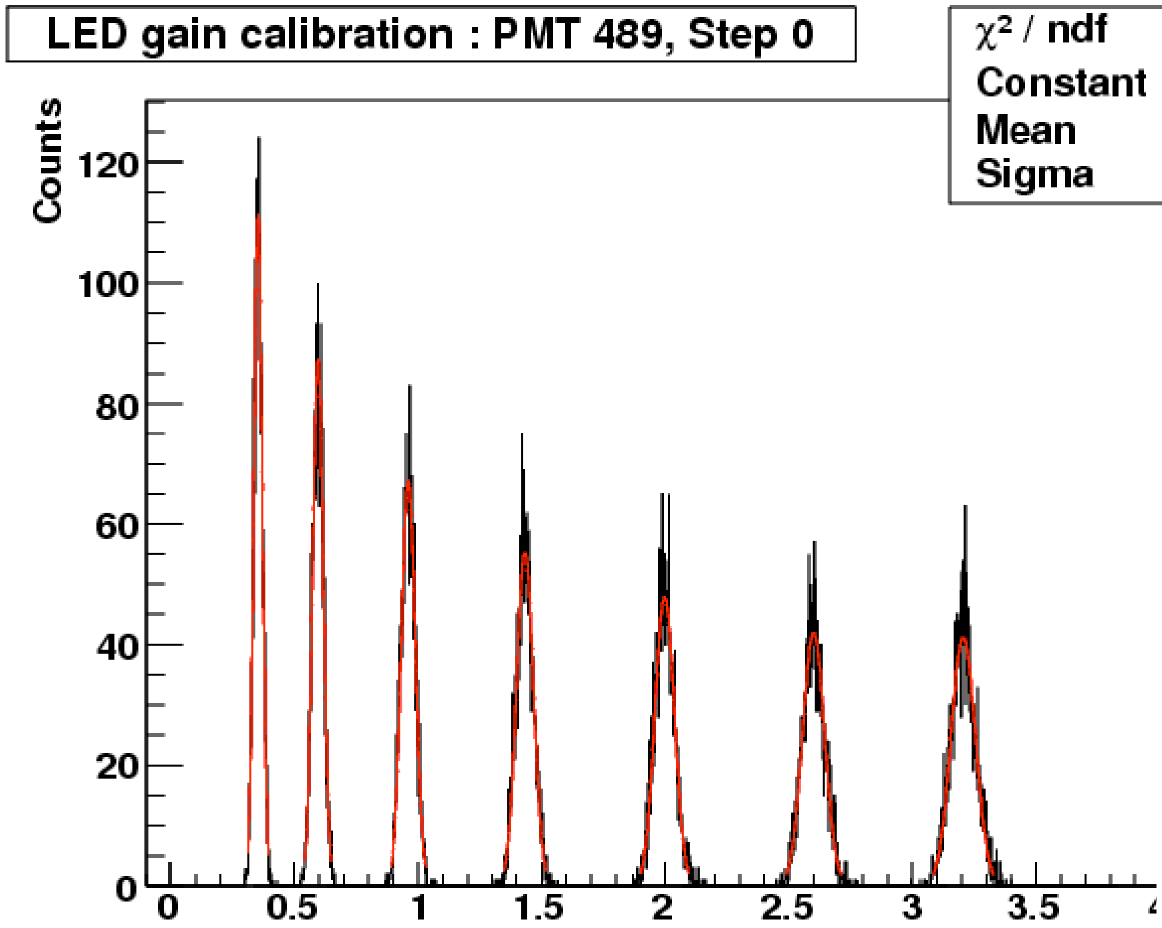


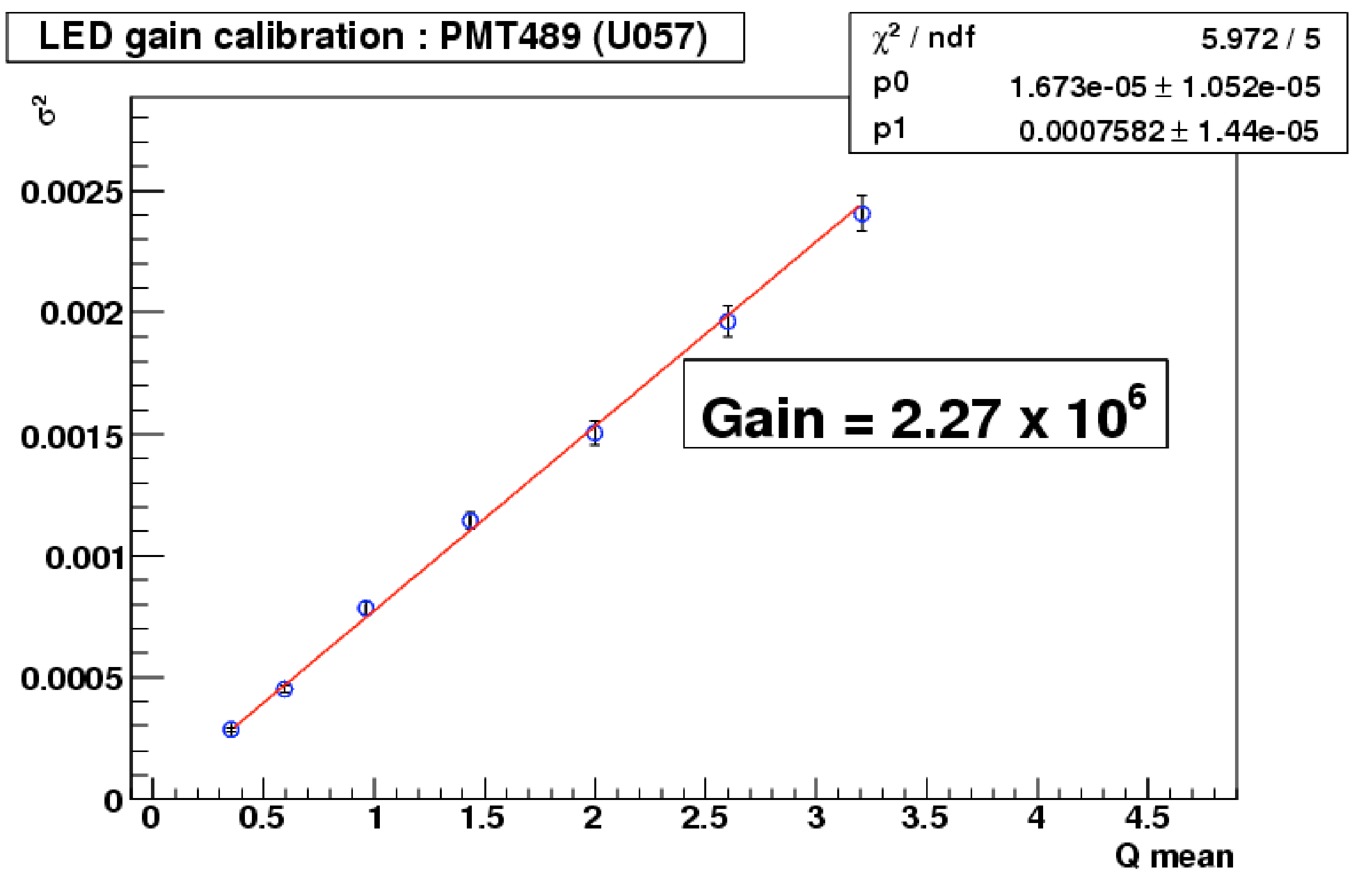
Time line

- Cryostat delivered. 5/June
- Leak test and fix. 6/June → 22/June
- Alignment in the area. 25/June → 1/July
- PMT installation, assembly. 2/July → 28/July
- Vacuum pipes, cabling. 30/July → 11/Aug
- Leak test, Evacuation, cooling test. 13/Aug → 9/Sep
- Pre-cooling, PMT HV up, DAQ test. 10/Sep →
- Transport of xenon from storage tank to the detector (middle/Sep)
- System debugging and purification in parallel (End/Sep) ⟵ Now
- Calibration and physics data taking (Oct→)

Pictures from recent real data

Recent data (on 22/Sep) LED Gain Calibration





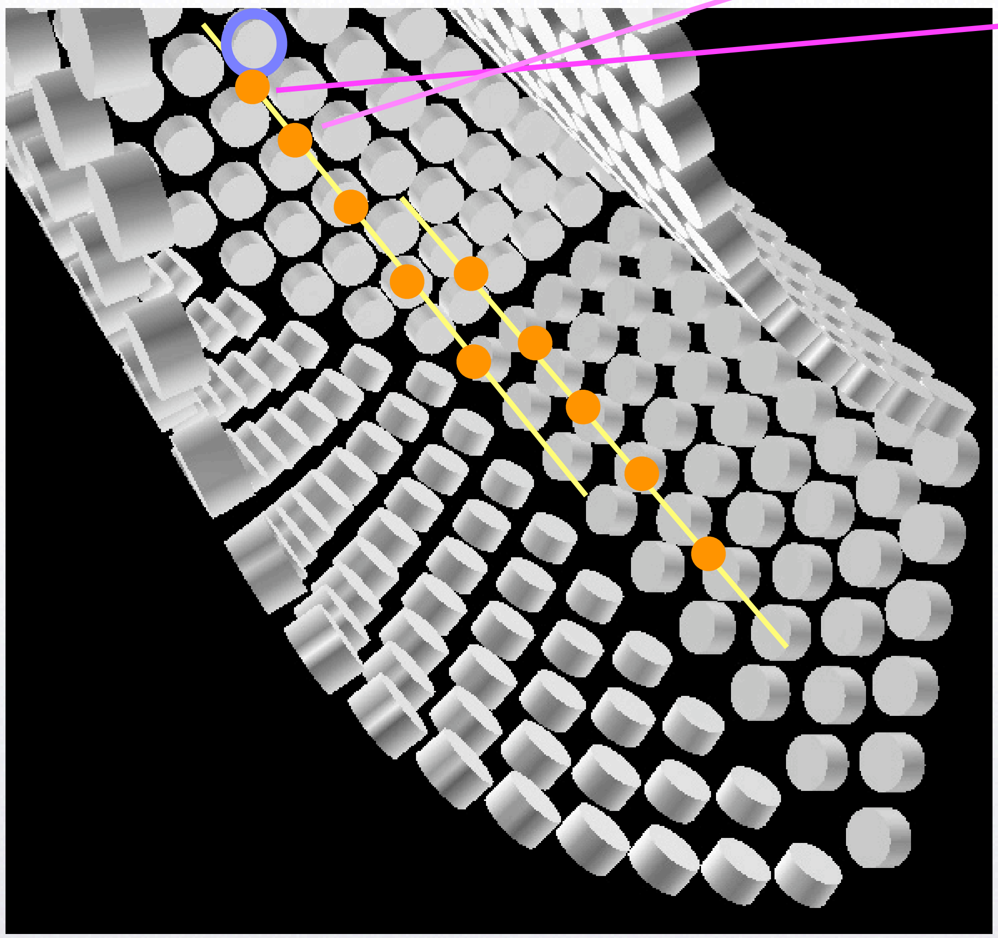
Recent data (on 22/Sep) Calibration alpha source

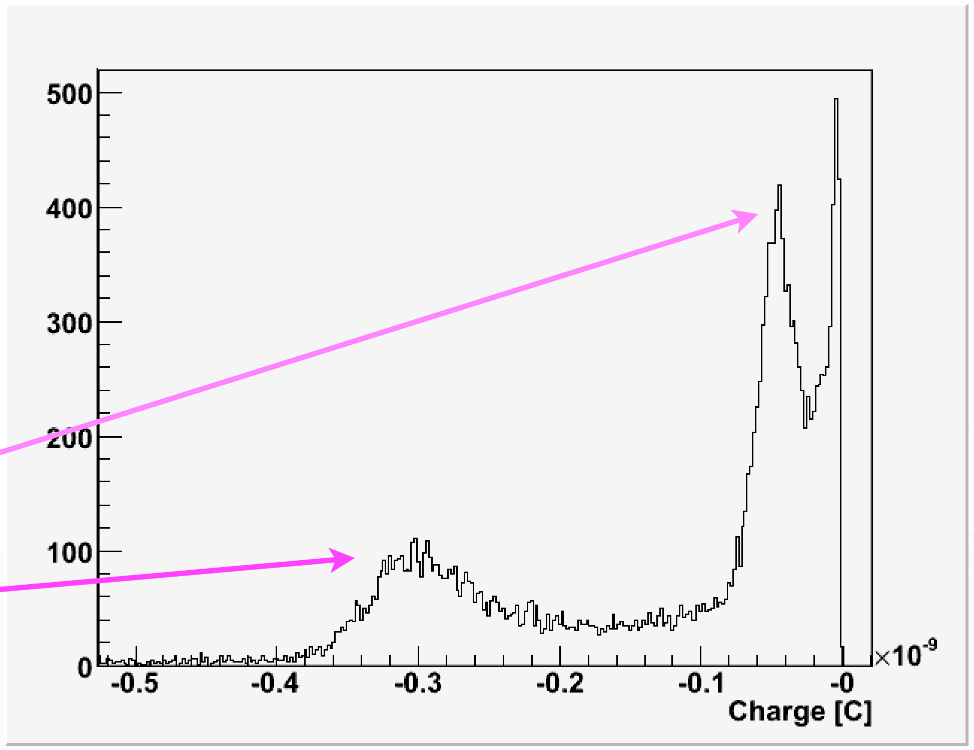
Waveform and Charge distribution of a PMT

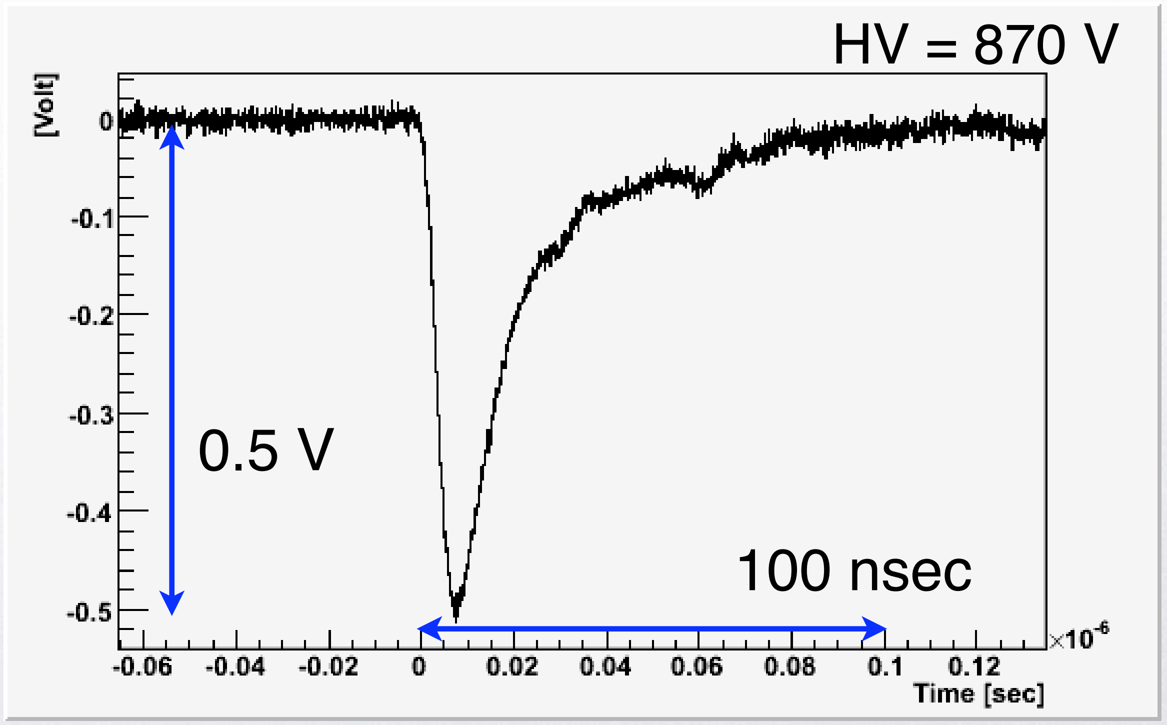
Pulse from calibration alpha source on wires.

25 wire alpha sources are installed.

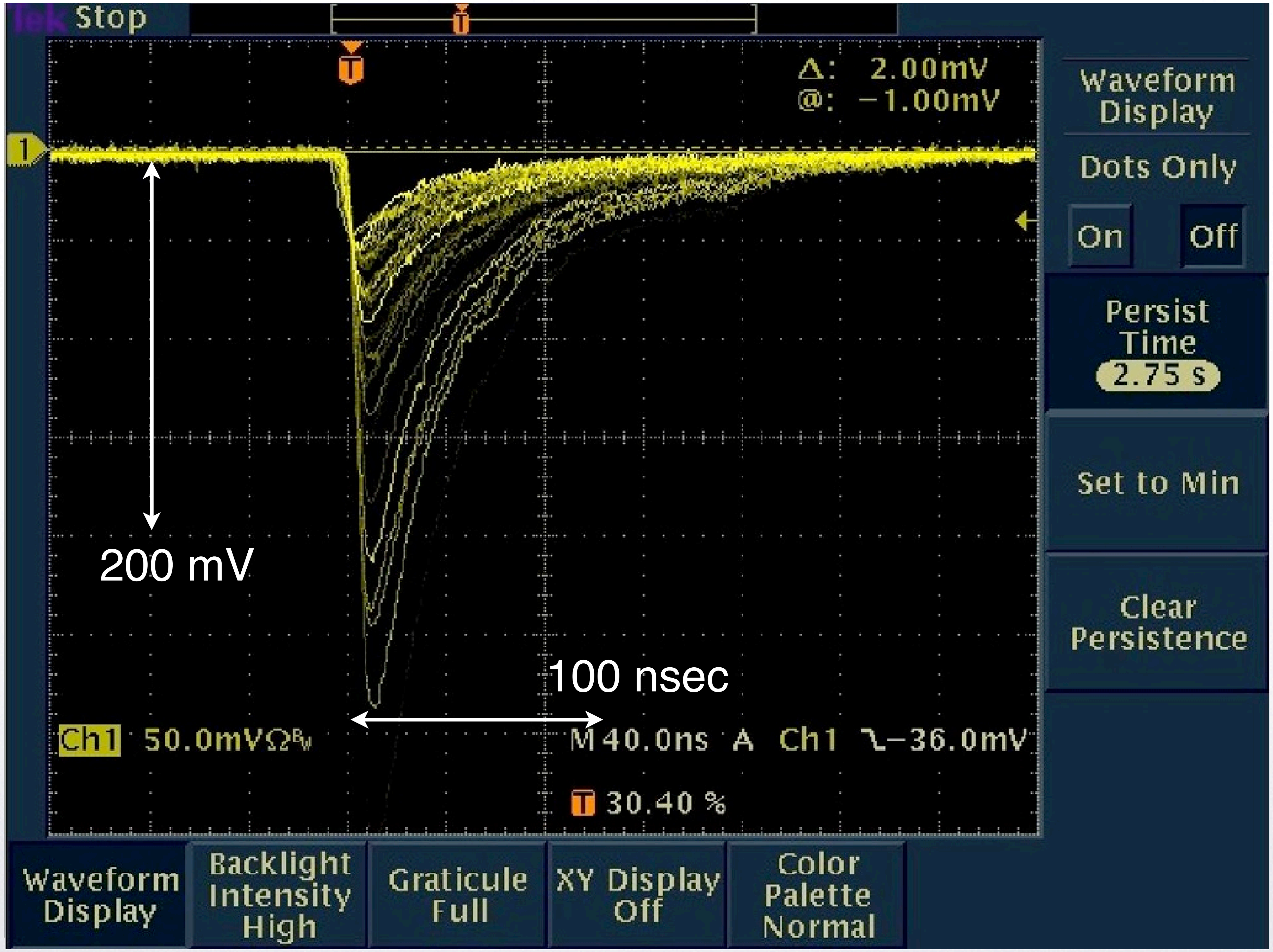
5.4 MeV







PMT signal by 17.6 MeV gamma ray from Li(p,γ)Be



HV = 700 V

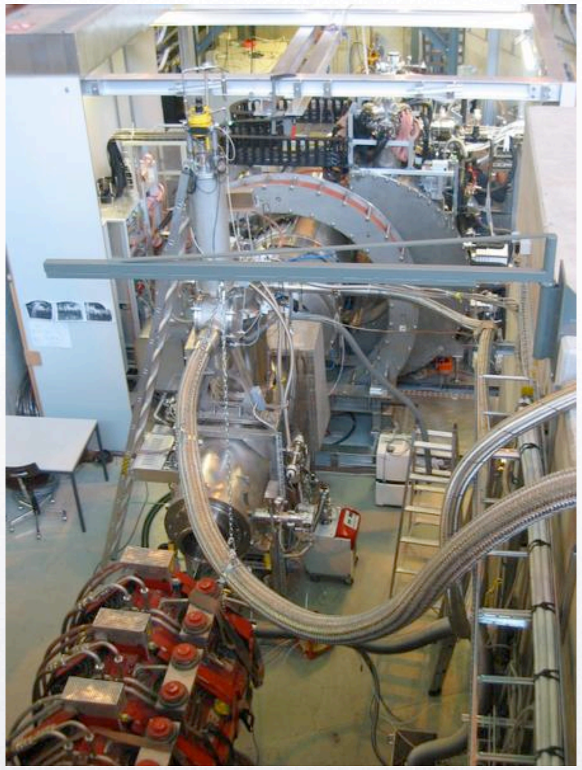
Electronics

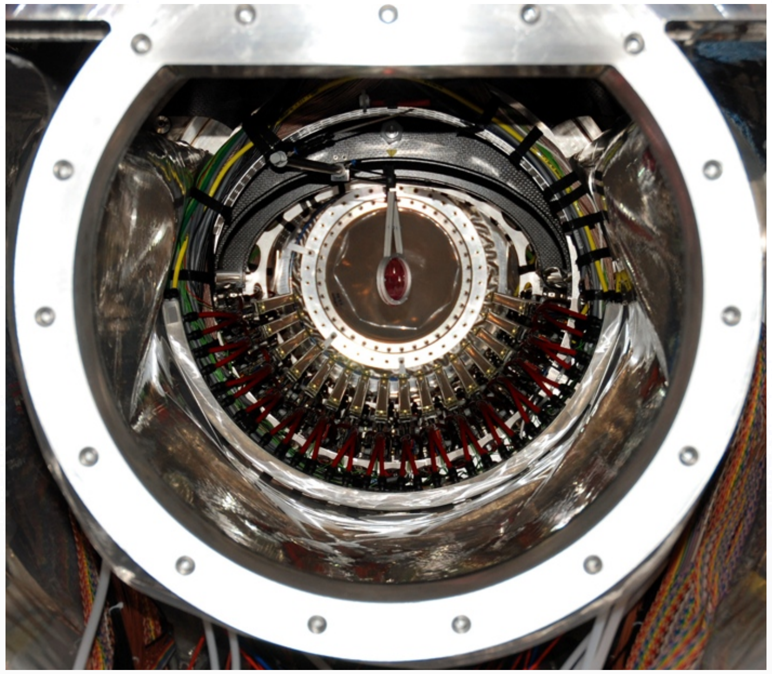
- ✔ Trigger
- ✔ Digitizer
- ✔ DAQ
- ✔ Online monitor

Magnets

- ✔ Separator
- ✔ Transport solenoid
- ✔ COBRA magnet

Beam tuning in Oct.





Drift chamber and the target

✔ All chambers are installed

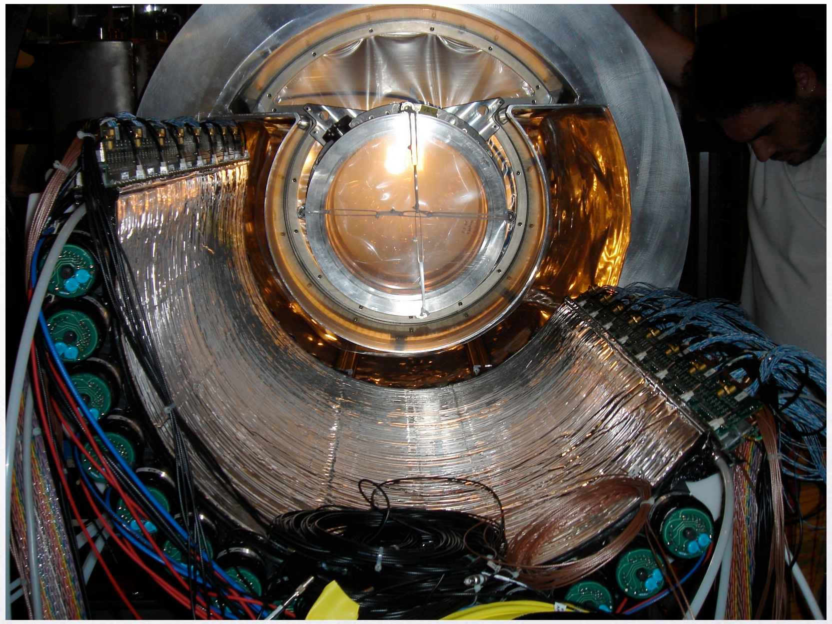
Testing using cosmic rays

Test and calibration in October

Timing counter

✔ All counters are installed

Test and calibration by using muon beam in October



Toward to the physics result

Data

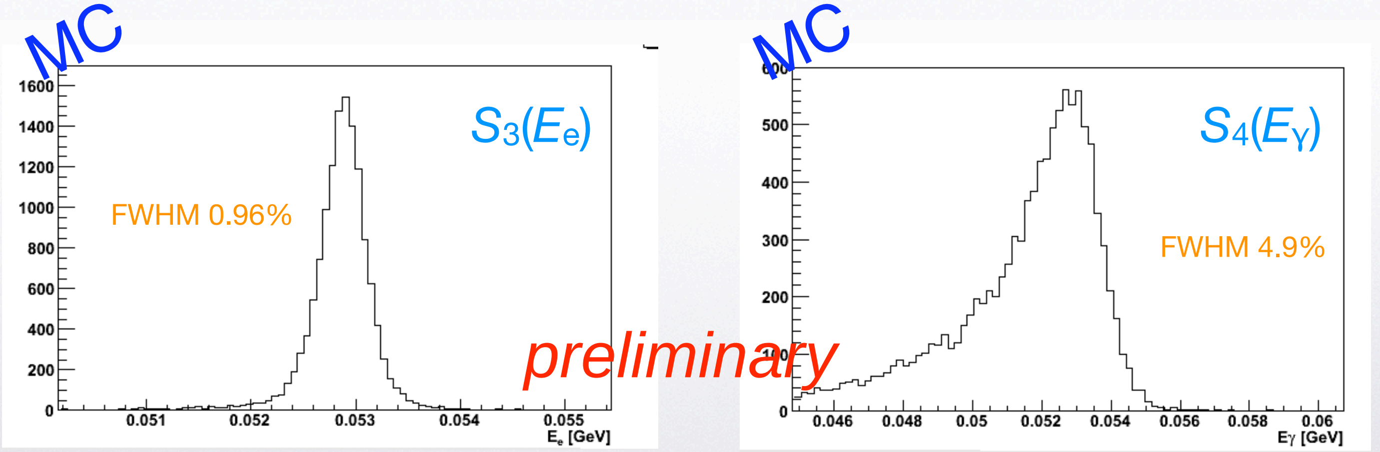
- Sub-detector calibration — $\pi^0 \to \gamma\gamma$, cosmic ray, CW, Michel....
- Sub-detector inter-calibration — Radiative muon decay, $\pi^0 \to \gamma\gamma$ + converter...
- Sub-detector performance — $\pi^0 \to \gamma\gamma$, Michel positron...
- Muon decay

Physics analysis

- Blind analysis
- Maximum likelihood method

PDF

Signal : From calibration run (radiative decay, π-) and muon run (Michel)
Background : Experimental and MC data (Michel, radiative decay)



Example of PDF build with MC data and current reconstruction algorithms

Summary

- Cryostat of calorimeter arrived on June. Assemblies and testing was done until September.
- Many technical challenges. (Structure design of C-shaped detector, large honeycomb window with light materials, liquid phase xenon handling, very small space behind PMT, low out-gas materials in the detector including PMT, cooling system without electric noise, Americium source wire, CW accelerator for calibration....)
- Xenon was already filled. Currently it is debugging stage of the system.
- Other parts of experiment are at the final stage of preparation too.
- Beam commissioning in October.
- Calibration and muon decay data taking from November.

Please look forward to the next JPS meeting.