System overview of liquid xenon calorimeter for the MEG experiment

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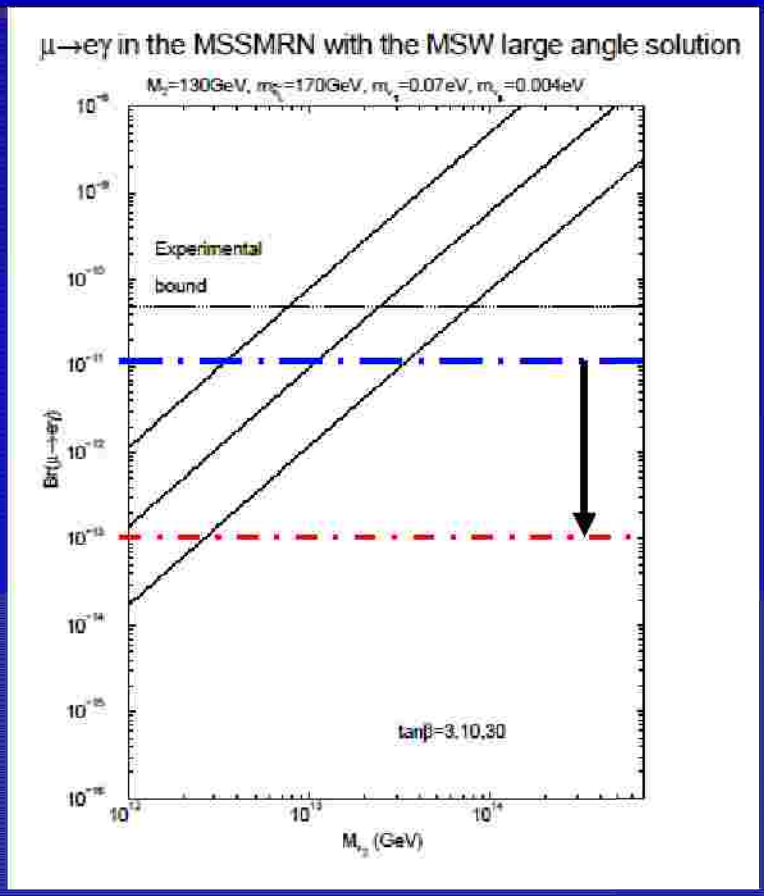
On behalf of the MEG Collaboration

Frontier Detectors for frontier physics
11th Pisa meeting on advanced detectors

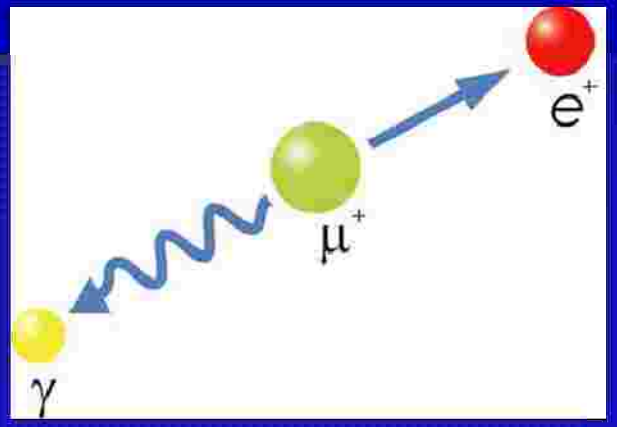
Lepton Flavor Violation in charged lepton process

- ->e is a lepton flavor violating process, and is never observed yet.
- Charged lepton LFV is a clear evidence of physics beyond the Standard Model
- Sizable LFV is predicted by new physics (SUSY-GUT, SUSY seesaw etc.)
- Current experimental bound
  - Br(à e) < 1.2 x 10^{-11}
- MEG goal : Br(à e) ~ 10^{-13}
  - To achieve that in one year (T˜ 10^{7}s), ˜10%, rate ˜ 10^{7}/s is needed

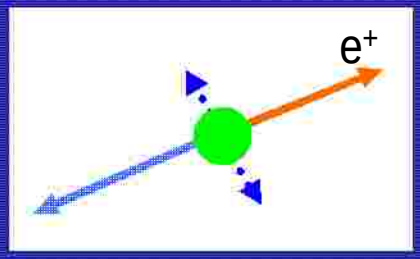


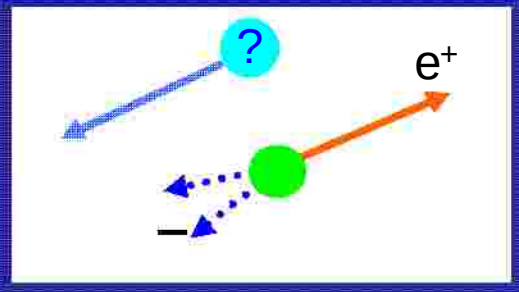
à e signal & background

- Signal (clear two body decay)
  - Back-to-back (180 °)
  - $E_e = E = 52.8$MeV
  - $T_e = T$



- Background
  - Accidental coincidence
    - à e + random (major background, B_{acc} ? E_eŸ t_e Ÿ(E)^{2}Ÿ($_e$)^2)
      - Good resolutions of all detectors are critical
  - Radiative muon decays
    - à e (suppressed, = 0.1B_{acc})



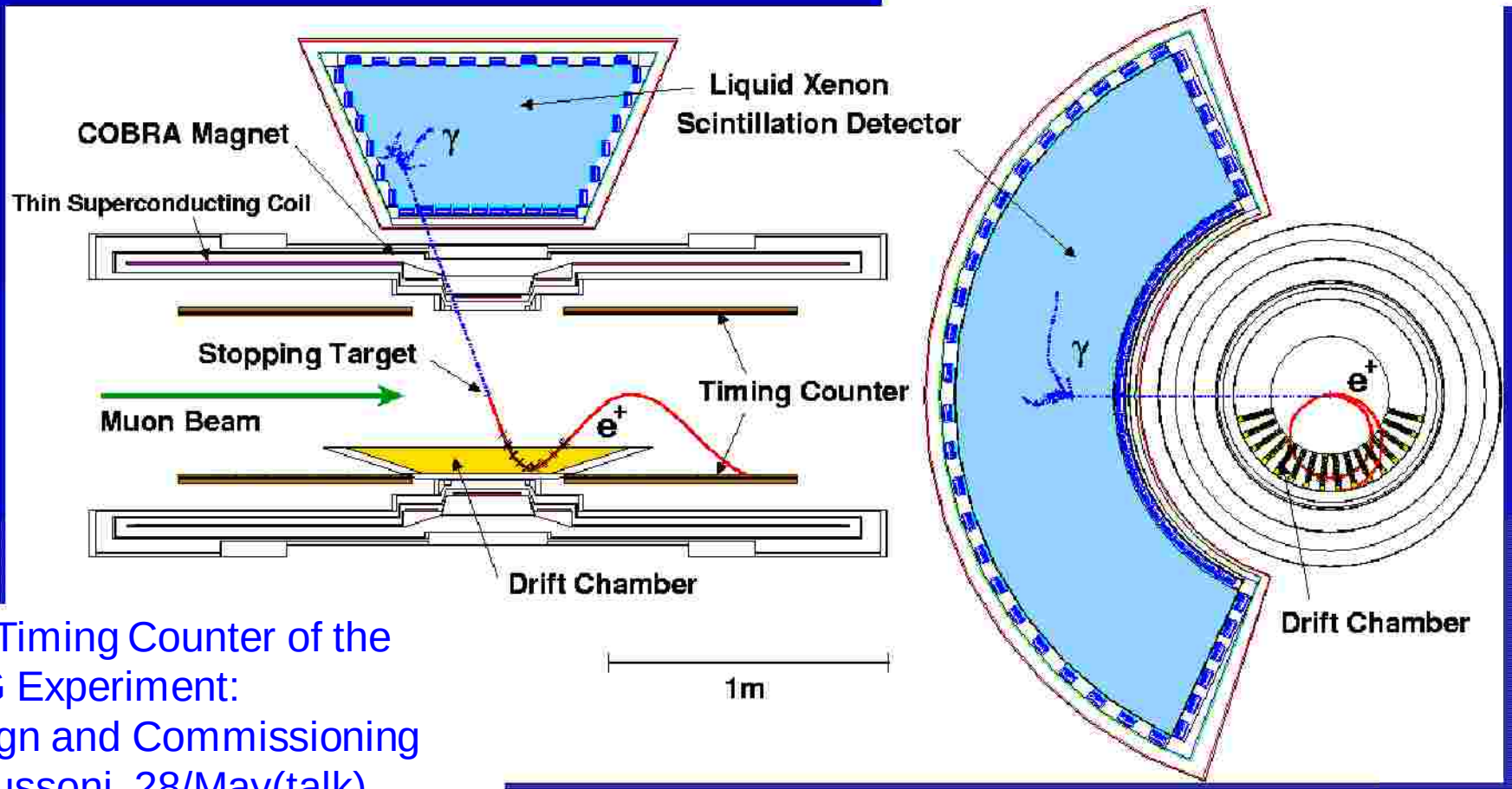


MEG experiment

- In 1999, proposal approved at PSI in Switzerland
- Most intense muon beam
  - 590MeV PSI proton cyclotron ~ 10^8 /s
- Innovative liquid xenon calorimeter to detect rays
  - 900 liter liquid xenon with 846 2” photomultiplier tubes
- e^+ spectrometer with special graded magnetic field
  - SC magnet, Drift chamber for e^+ tracking, e^+ timing counter
- In 2007, engineering runs for ~ 3 days
- In 2008, 3 months physics data
- We are analyzing data…, and data taking will be restarted in this September.

MEG detector

Gamma Ray Reconstruction with Liquid Xenon Calorimeter for the MEG Experiment
Y. Uchiyama, 26/May(poster)



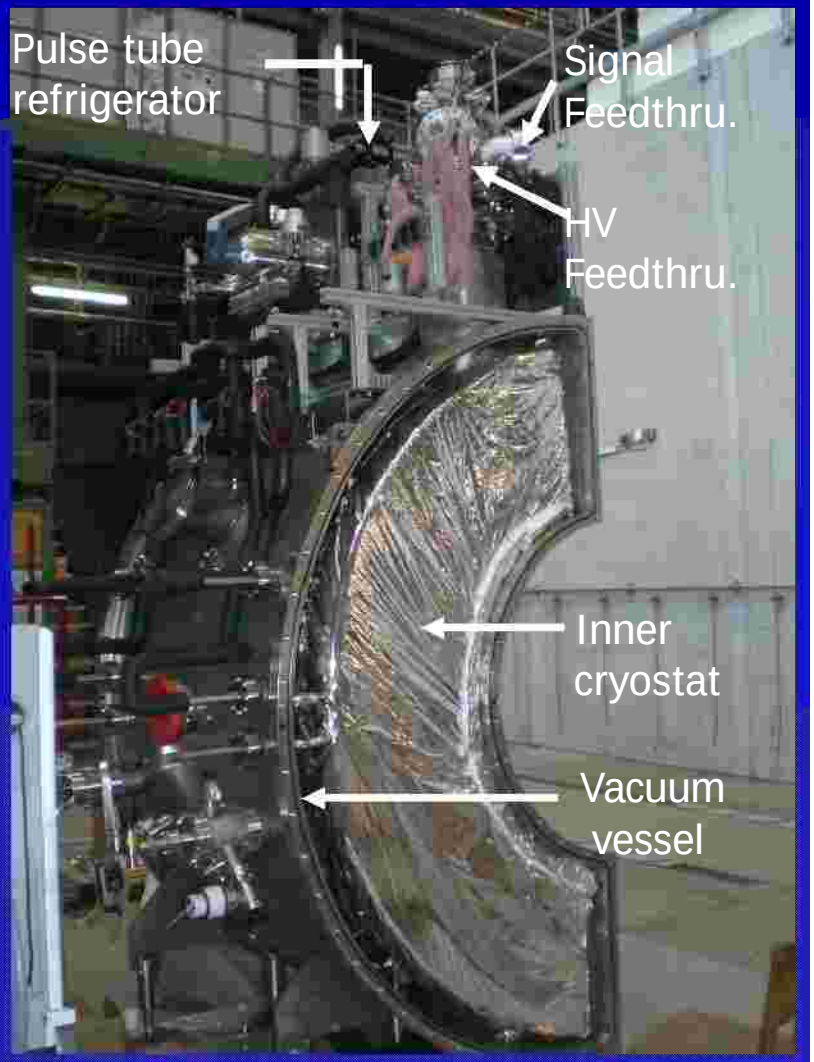
The Timing Counter of the MEG Experiment:
Design and Commissioning
S. Dussoni, 28/May(talk)

MEG Collaboration

- Japan, Italy, Switzerland, Russia, and USA
- ~ 60 Collaborators

Liquid xenon calorimeter

- 900 liter liquid xenon
- 846 2” PMTs directly soaked into liquid
- Only scintillation light
  - High light yield (~40000photons/MeV)
  - Fast response (4.2, 22, and 45ns)
- Good energy/position/timing resolution for 52.8MeV
- Waveform recorded: pileup rejection
- Pulse tube refrigerator: liquid xenon to 165K
- Purification system: H_2O/O_2 contami. removal



Brief history of LXe R&D

2000
- Small prototype test (2.3L, 32PMTs)
  - Energy, timing, and position resolution check by radioactive sources

2002
- Large prototype (LP) test (100L, 240PMTs)
  - Purification system, PMT stability
  - Performance check by 10, 20, and 40MeV Compton beam, and 60MeV electron beam

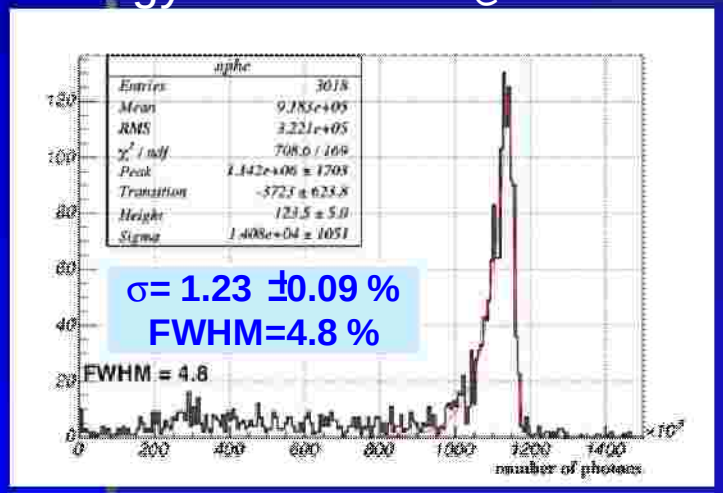
2004
- CEX calibration 55, 83MeV from $^{-}$p-> ^{0}n, ^{0}-> reaction
  - all resolutions were confirmed.
- Detector (900L, 846PMTs)

2006
  - construction
  - PMT test in liquid xenon by using LP and test station PISA
  - Cryostat delivered, PMT holders installation, evacuation, liquid xenon filling into the cryostat, purification, DAQ (~3days)

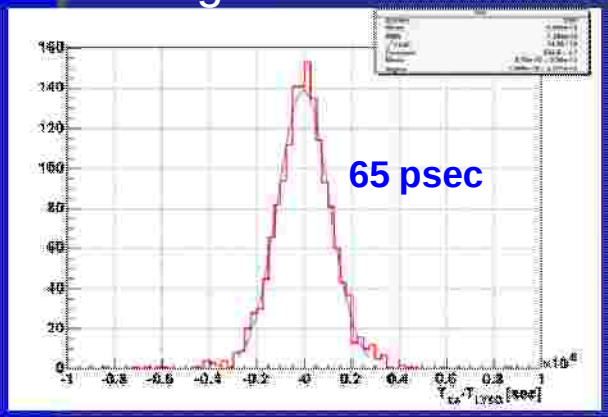
2008
- Physics run (~3months), full CEX calibration (1month)

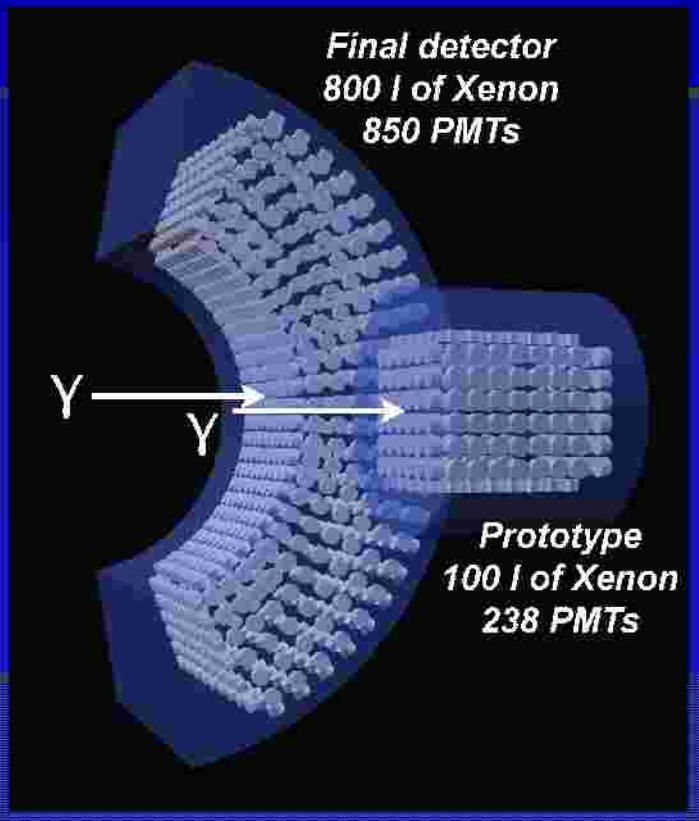
Performance of liquid xenon calorimeter by prototype

Energy distribution @ 55MeV



Timing distribution





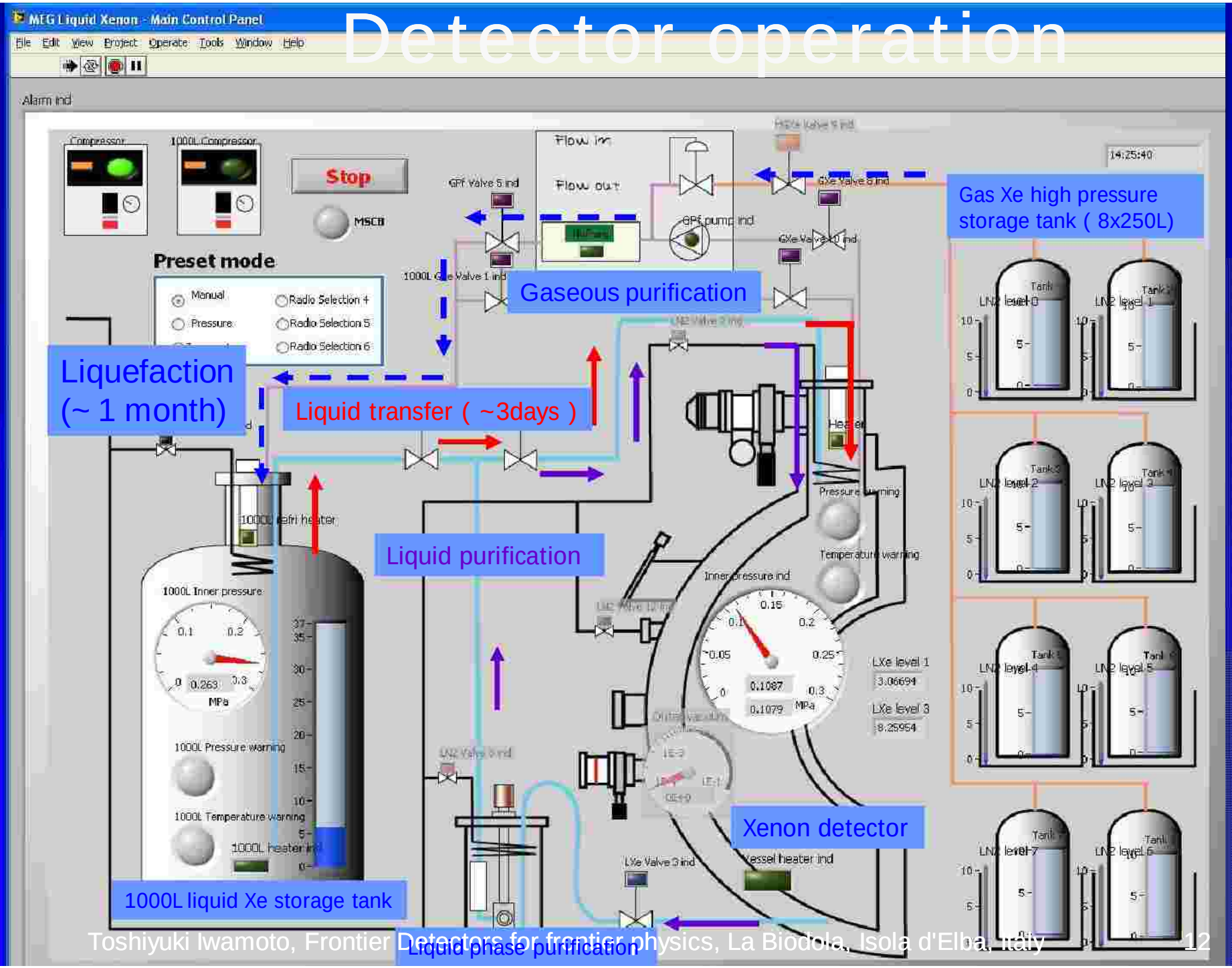
Expected Performances ( )
- Energy : 1.23%
- Timing : 65 psec
- Vertex : 4mm

Detector construction

- PMTs are installed into PMT holders
- PMT holders are installed into PMT support structure

Detector construction, cont.

Detector operation

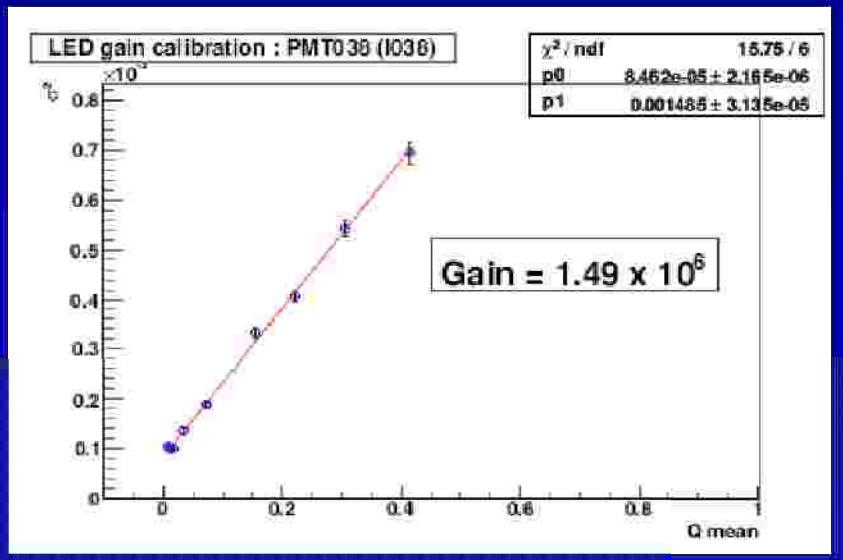


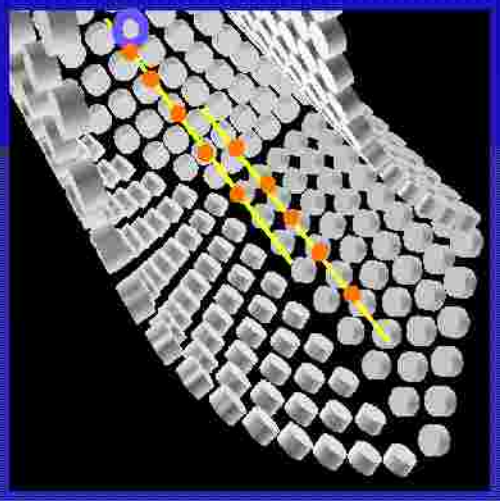
Strategy to calibrate & monitor liquid xenon calorimeter

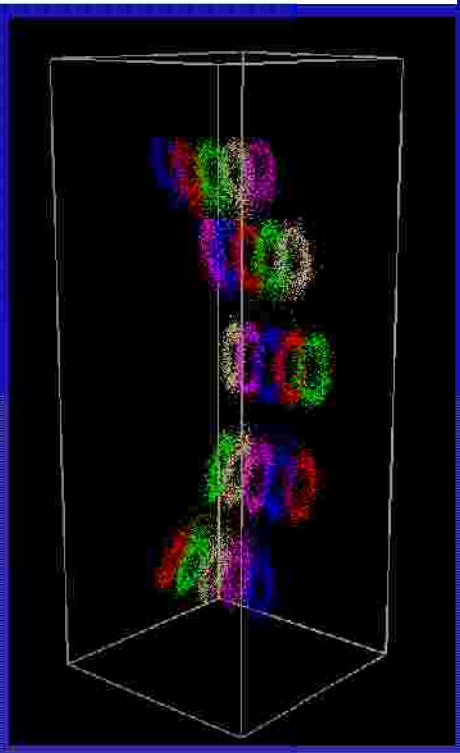
- Daily calibration
  - LED: absolute gain, relative gain monitor
  - source: absorption monitor, PMT output monitor
- Every two days
  - 17.6MeV via the reaction Li(p,)Be, (16.1, 11.7, 4.4)MeV via the reaction B(p,)C from CW proton accelerator: energy scale, light yield monitor, and uniformity check
- Every week
  - Radiative decay run (lower beam intensity ~ $1x10^6$ /s): absolute time resolution
- Once or twice a year
  - 55, 83MeV from $^-$p à ^{0}n, ^{0} à 2 reaction (CEX calibration) : energy scale, energy, timing, and position resolutions

LED,

- LED
  - 36 LEDs installed to different positions
  - Absolute gain by statistical fluctuation of detected # of p.e.
  - Relative gain monitor
- ^{241}Am source
  - 5 sources on 5 wires (100 m)
  - Absorption monitor
  - Q.E. measurements
  - PMT output equalization







CW calibration

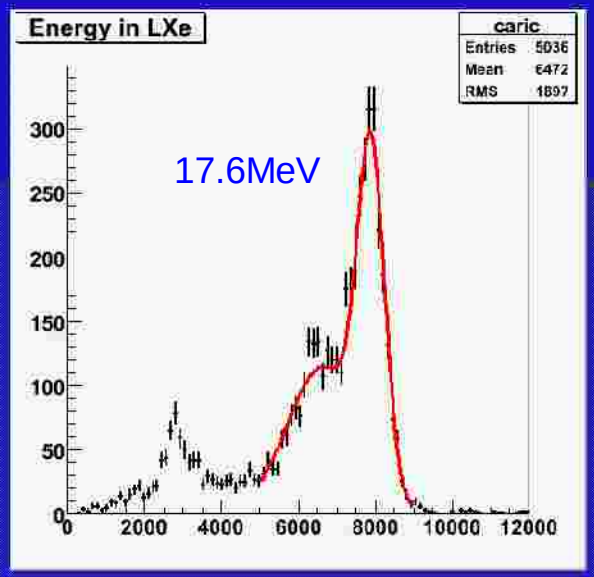
Cockcroft-Walton proton accelerator

Li(p,γ)Be 17.6MeV

peak energy E_p= 440 keV, σ_{peak} = 5 mb

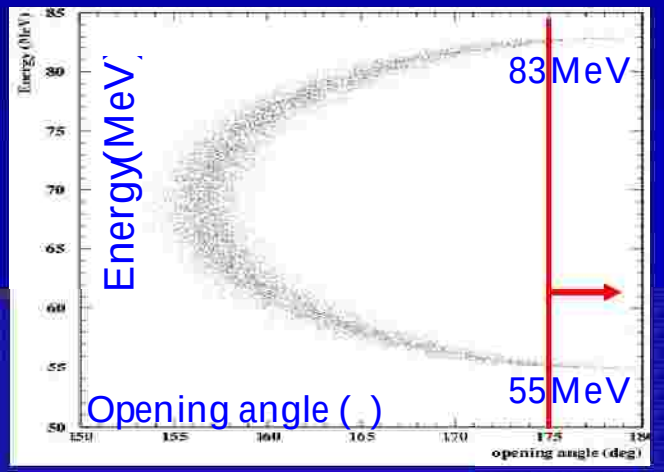
B(p,g)C (4.4, 11.7, 16.1)MeV

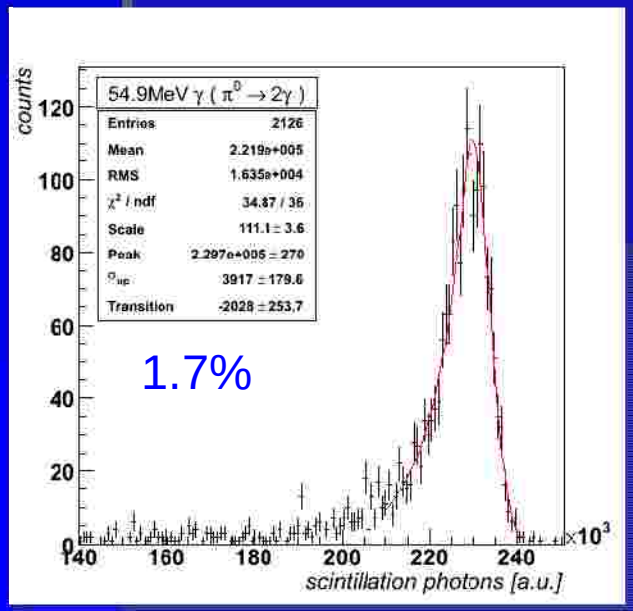
Ep = 163keV, σ_{peak} = 0.2 mb

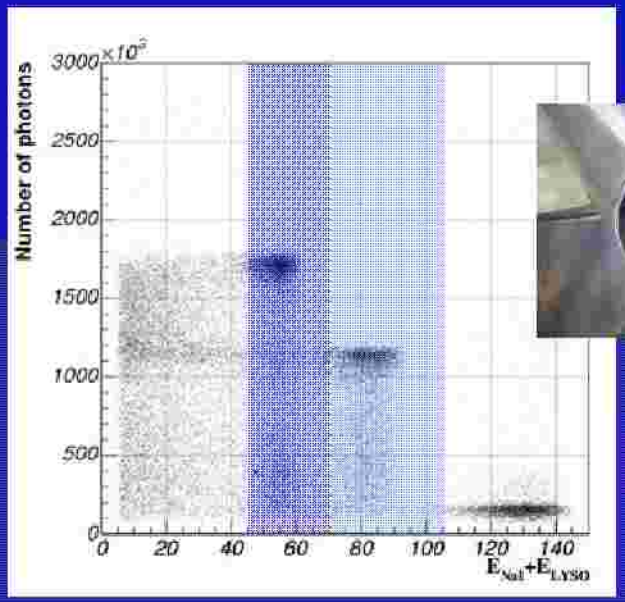


CEX calibration

- Back-to-back from ^{0}
- Almost monochromatic
- Energy close to our signal (52.8MeV)
- NaI + APD counter in opposite side of XEC
- LH_2 target to maximize the rate

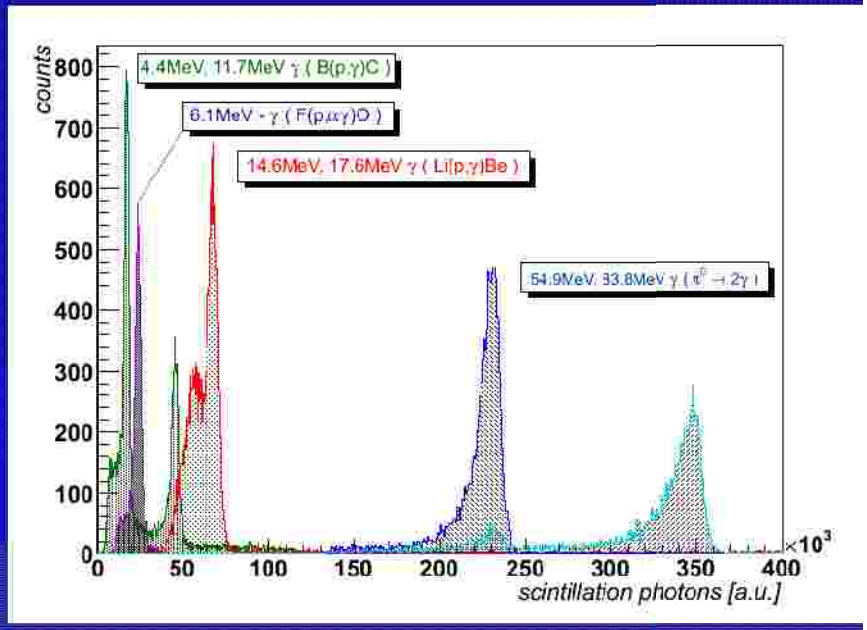






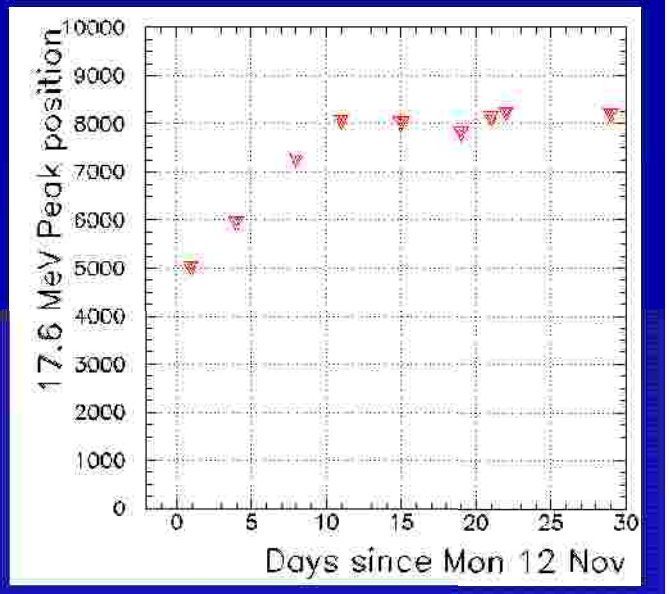
Status of liquid xenon calorimeter in 2008

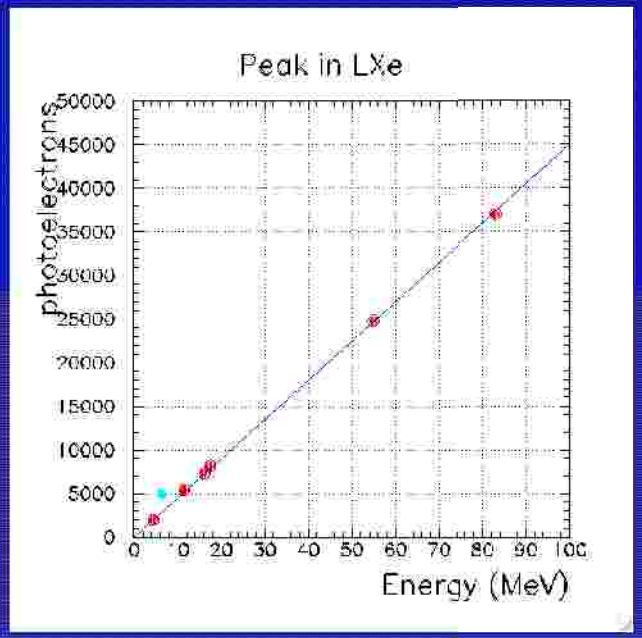
- All liquid xenon calorimeter operations including liquid and gaseous purification were confirmed. This is the largest liquid xenon calorimeter in the world currently in operation.
- Linearity check could be done by various energy
- Main issue: light yield
- Radiative decay data are analyzed
- Resolutions are being estimated (see Y. Uchiyama's poster today)
  - Energy < 2.3%
  - Timing < 100ps
  - Position < 5-6.5mm



Light yield

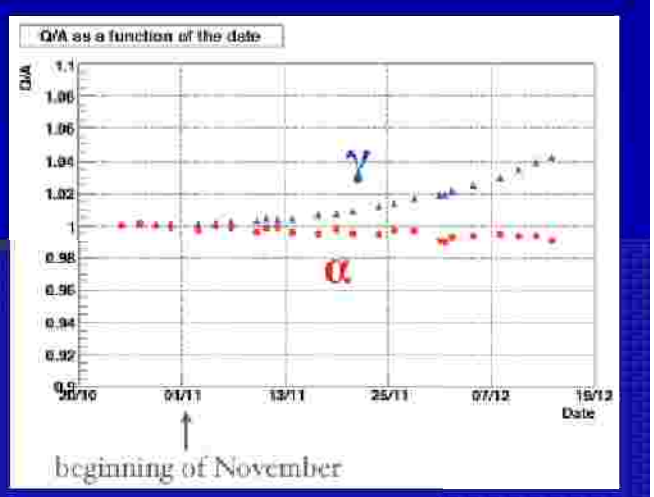
- In 2007, light yield increased after liquid puri.
- Light yield difference between and observed, light yield was less than
- Long component (45ns) for suppressed? has only short components.

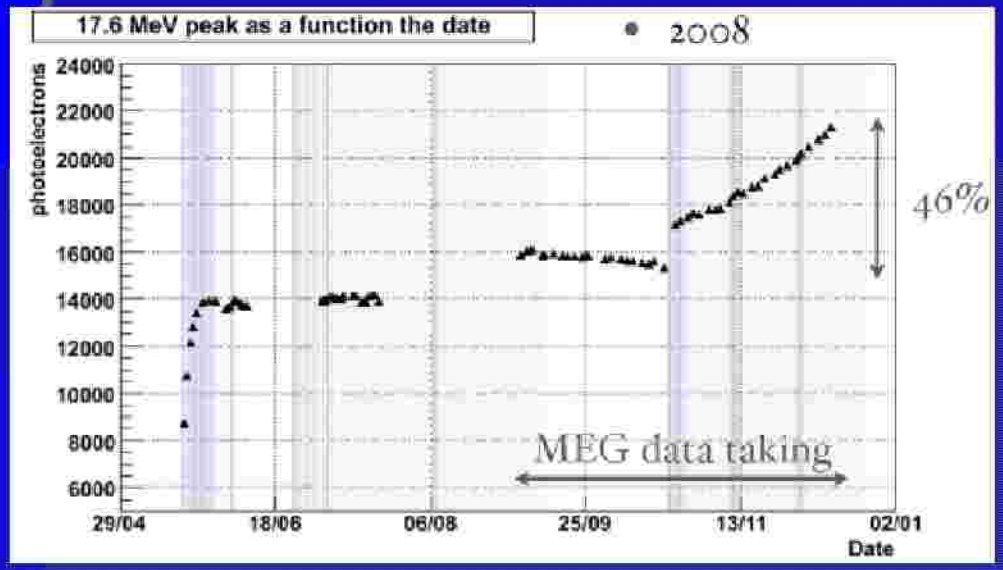


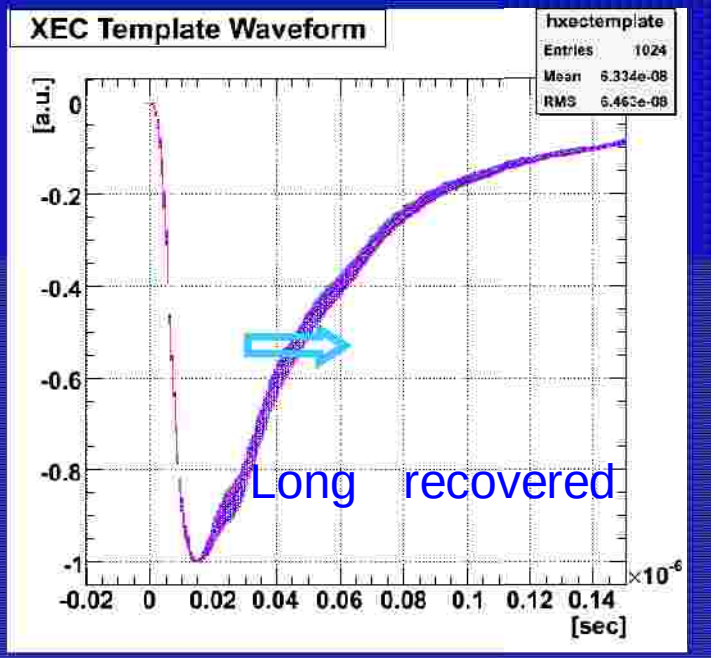


Light yield in 2008

- Further liquid purification with molecular sieves + O_2 getter
- Gaseous purification, too
- Large light yield increase (46%) during MEG data taking (successfully monitored by calibration systems)
- light yield recovered (already saturated), and is still increasing (30% lower than the light yield of large prototype)

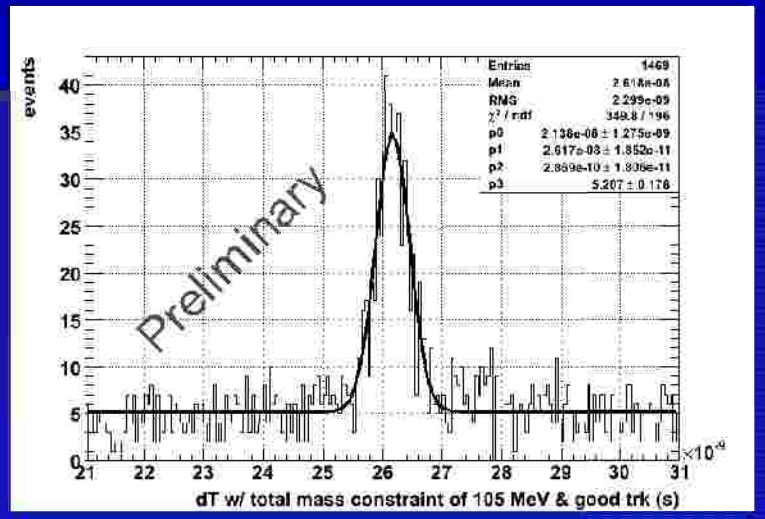


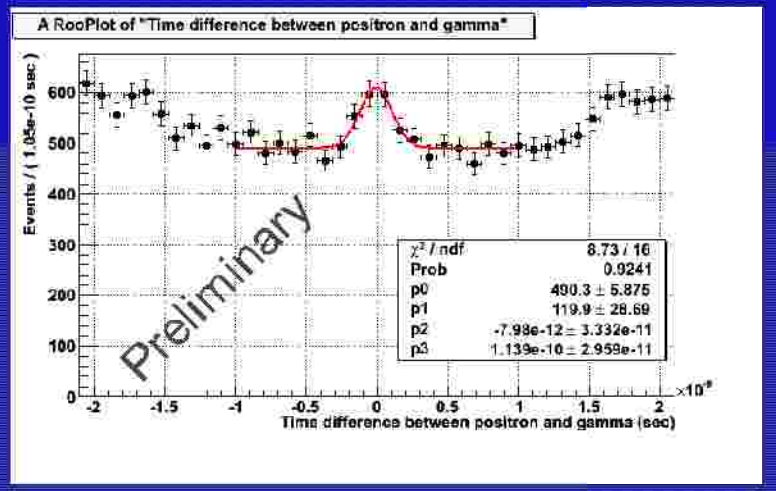




Radiative decay data

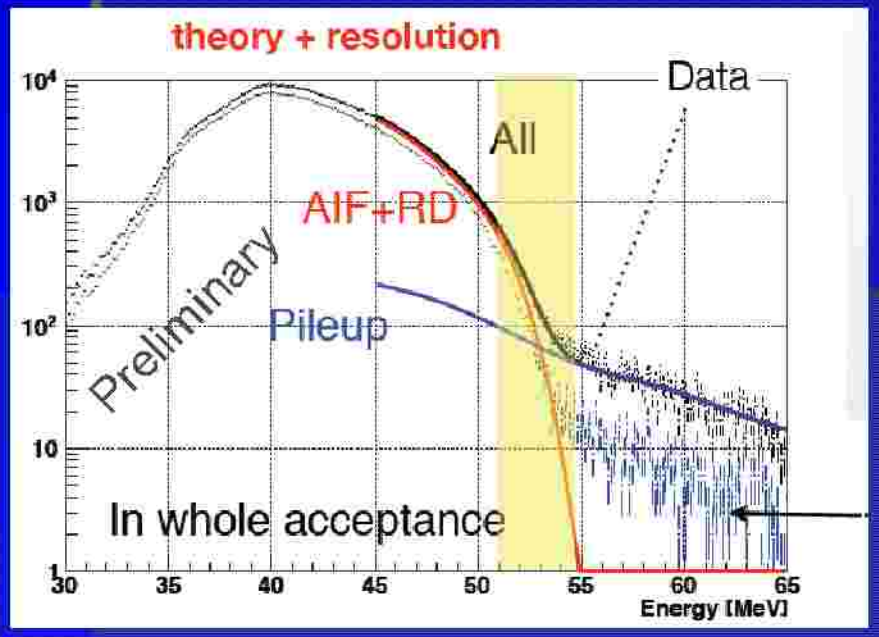
- It's important to detect radiative decay (RD) events (->e) to check our capability, especially to test absolute timing
- Dedicated RD runs (1x10^6 /s)
  - Lower muon beam
  - Lower accidental BG (better S/N)
- RD events in physics runs (3x10^7 /s)
  - Higher accidental BG
- We successfully saw clear peaks of time difference between photon and positron from both data.
- We are really sensitive to the ->e events

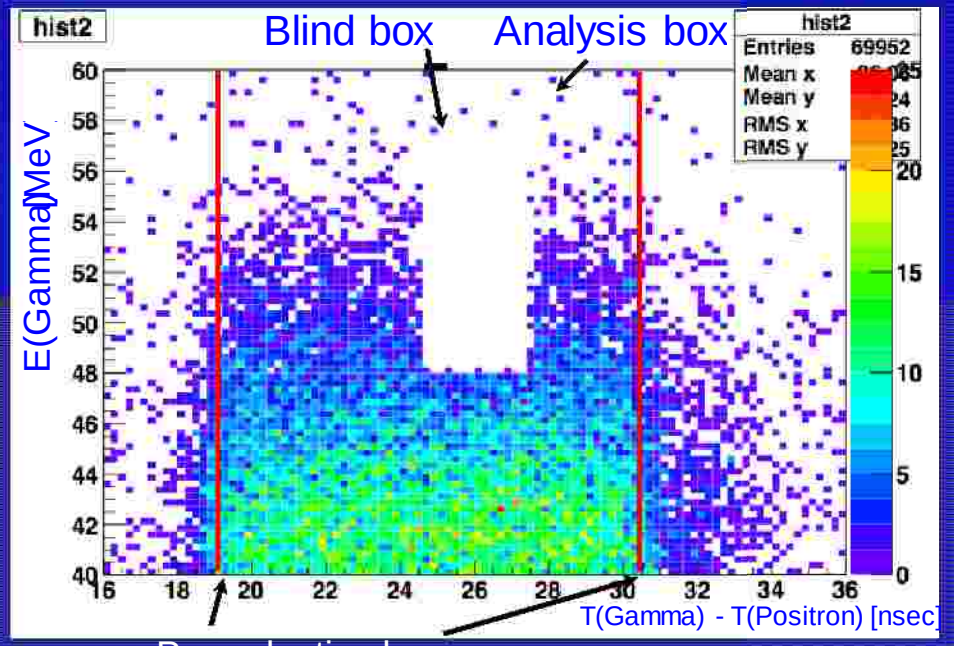




Plan 2009

- 2008 physics data are being analyzed to get the result by this summer.
- E and Te are blinded at signal region
- In September 2009, physics runs will be restarted.
- Purification of the liquid xenon calorimeter will be started at this July.
- To reach our target sensitivity ~ 10^{-13}, MEG experiment will be continued at least until 2011.





Efficiencies

CAUTION: All 2008 numbers are provisional

Still lots of things to learn from the data

- Blue numbers likely to change - Grey numbers may vanish

(%)	"Goal"	2008 Provisional Lower Limits	2009 Provisional Prospects
Gamma	> 40	> 50 (depth) x (65 (pileup) x 85)	> 50 x 90
e+	65	30 (DC) x 40 (DC-TC)	85 x 50
Trigger	100	100 (energy) x 99 (time) x 80 (direction)	> 99
Selection	$90^4 = 66$	$90^3 \times 95 = 69$	69
DAQ	(> 90)	> 80 (live) x 93 (run transition)	> 90 x 99
Calibration Run etc	(> 95)	~70	90
Running Time (week)	100*	11.5**	11.5
Single Event Sensitivity (10^{-13})	0.5	< 30 - 50	< 3 - 5

* 1 week = 4×10^5 sec (66%) ** CEX runs not included

CAUTION: All 2008 numbers are provisional

Resolutions

Resolutions are improving as we understand the detectors better.

(in sigma)	"Goal"	2008 Provisional	2009 Provisional Prospects
Gamma Energy (%)	1.2 - 1.5	< 2.3	< 1.7
Gamma Timing (ps)	65	< 100*	< 80
Gamma Position (mm)	2 - 4	5 - 6.5	5
e+ Momentum (%)	0.35	1.5 - 2.0	0.7 - 0.8
e+ Timing (ps)	45	< 60 - 90	60
e+ Angle (mrad)	4.5	9 - 18	11
mu Decay Point (mm)	0.9	3 - 4	2
Gamma - e+ Timing (ps)	80	150	100
Background (10^{-13})	0.1 - 0.3	-	< 0.6 - 3

* clock error of ~60ps included

Summary

- MEG experiment has started physics data taking since 2007.
- Liquid xenon calorimeter has also been working since then.
  - Operation techniques to keep liquid xenon, to do liquid and gaseous purification etc. are confirmed.
  - Light yield is still increasing, and the performance is also improving.
- We are blind to our signal region, two parameters (E_e, T_e) at signal region are hidden.
- We are analyzing data intensively to present the result by this summer, and the physics run will be restarted this summer.
- To reach our target sensitivity ~ 10^{-13}, MEG experiment will be continued at least until 2011.