

# High Performance $\text{PbWO}_4$ - Lead Glass Hybrid Calorimeter at Jefferson Lab

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**for the**

**PrimEx Collaboration**

## Outline

- 1. Requirements for the Calorimeter**
- 2. The HYCAL calorimeter design**
- 3. Physics run performance**
- 4. Summary.**

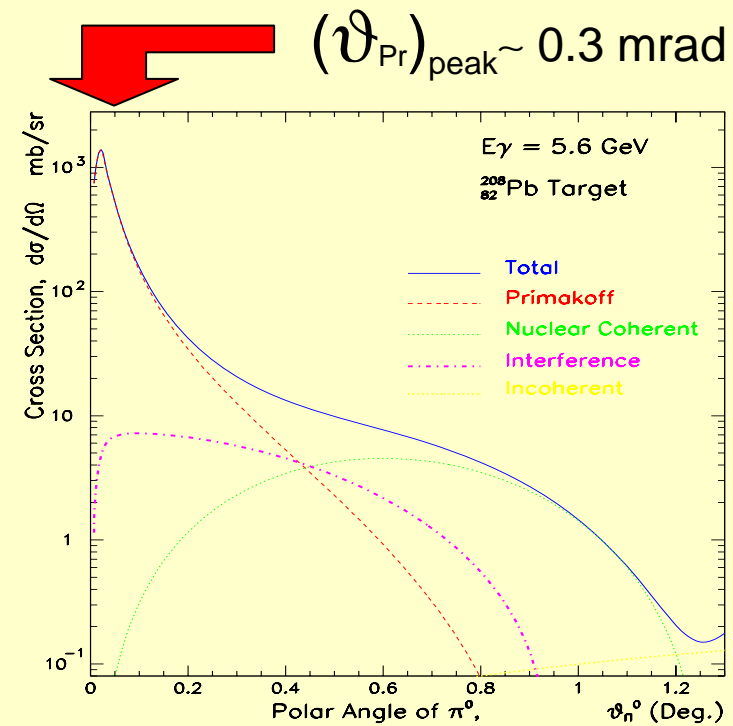
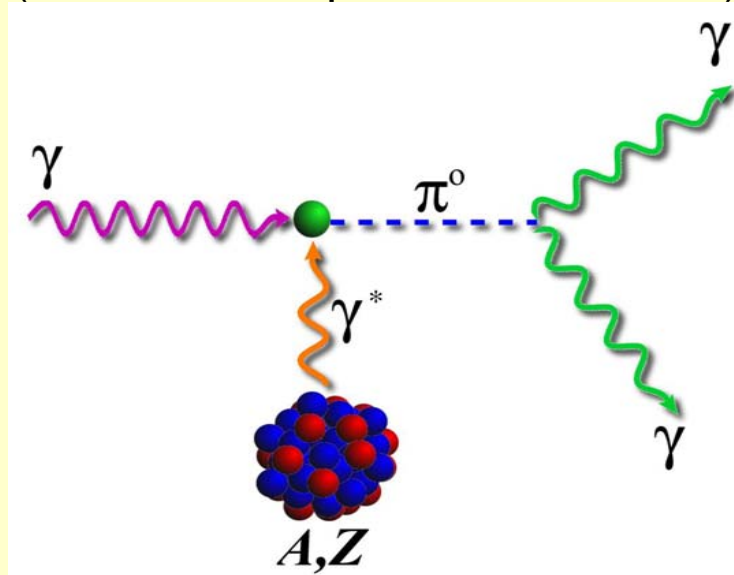
# Requirements for the Calorimeter

Forward electro-photoproduction of neutral mesons ( $\pi^0 \eta \eta'$ )

@ 1- 10 GeV requires:

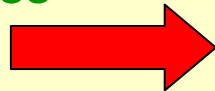
- High energy resolution;
- High position resolution;
- Good photon detection efficiency @ few GeV;
- Large geometrical acceptance.

$\pi^0$  life-time measurement at JLab  
(the PrimEx experiment E-02-103):

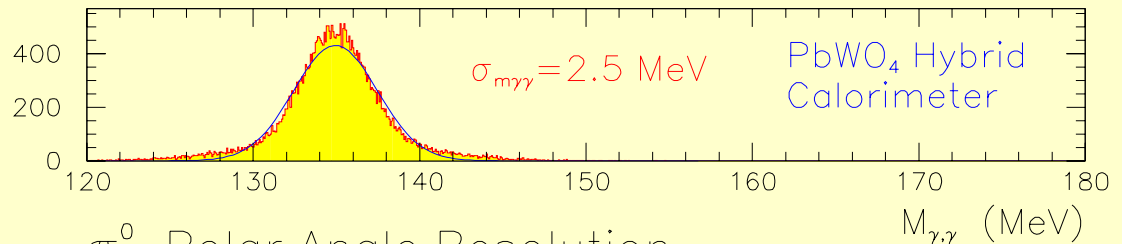
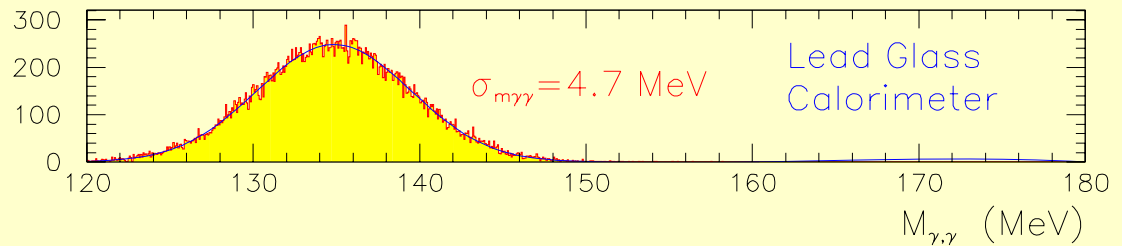


# Design Concept and Resolutions

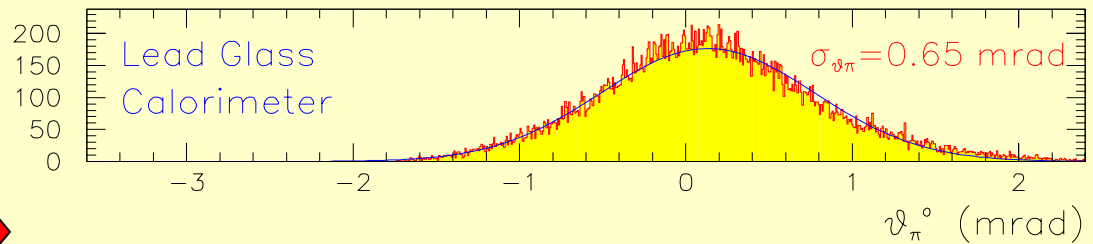
$\gamma\gamma$  Invariant Mass Resolution



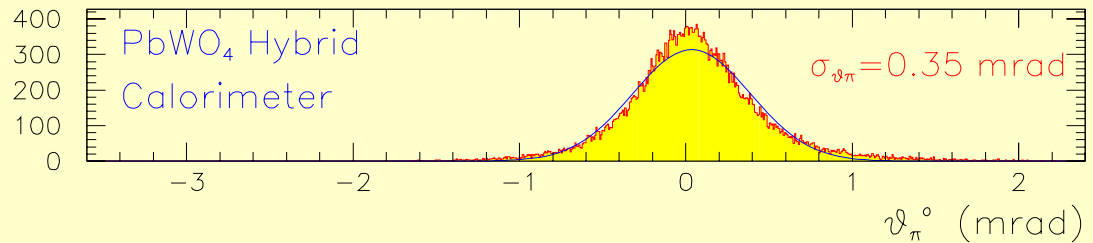
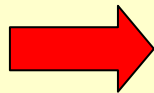
Invariant Mass Resolution



$\pi^0$  Polar Angle Resolution



Angular Resolution



# Design Concept

Resolution



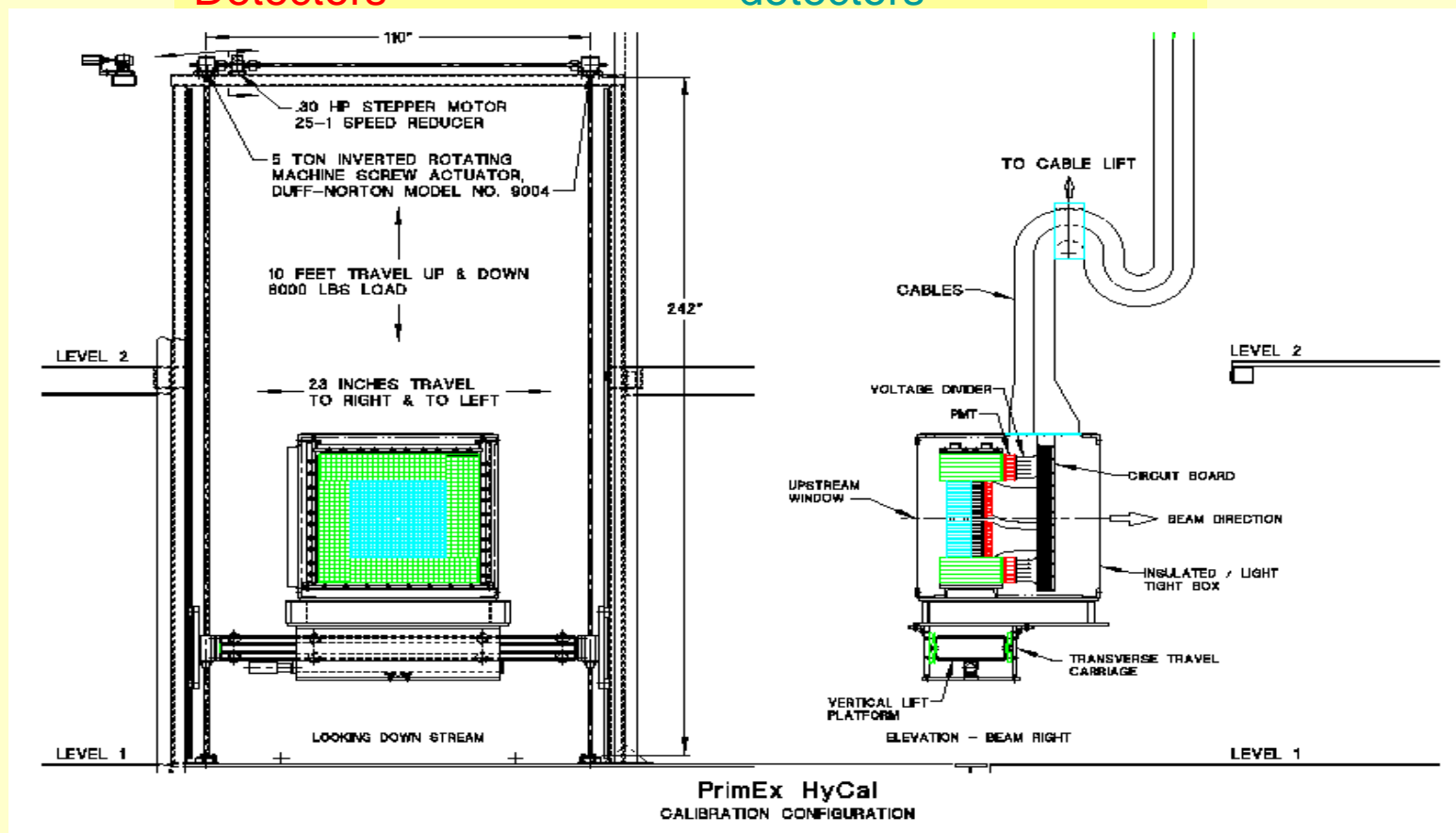
PbWO<sub>4</sub> crystal  
Detectors

+

Budget

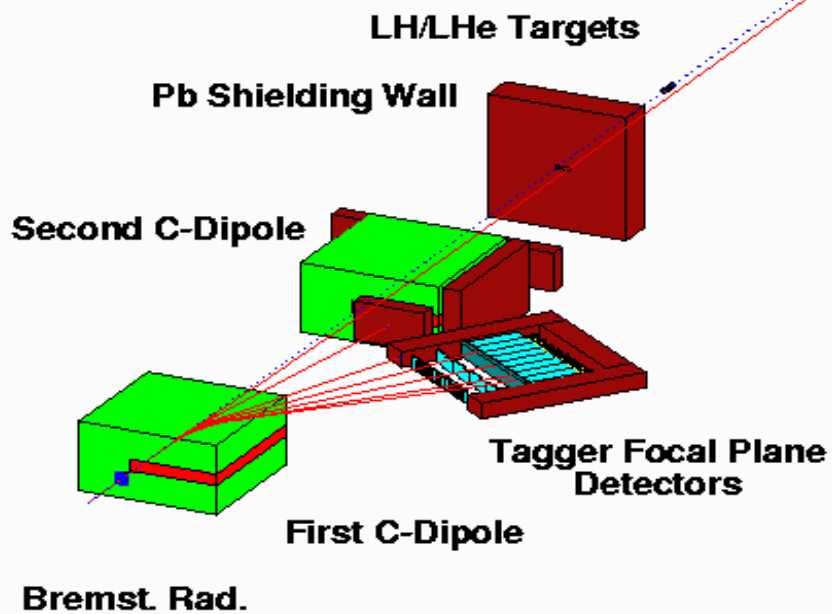


Pb – glass Cherenkov  
detectors



# Design Concept

## Experimental Setup with 11 GeV Photon Tagger



### HYCAL with veto

Modules:

PWO:  $34 \times 34 - 4 = 1152$

LG:  $4 \times 6 \times 24 = 576$

# PbWO<sub>4</sub> Crystal Dimensions

Dimensions:

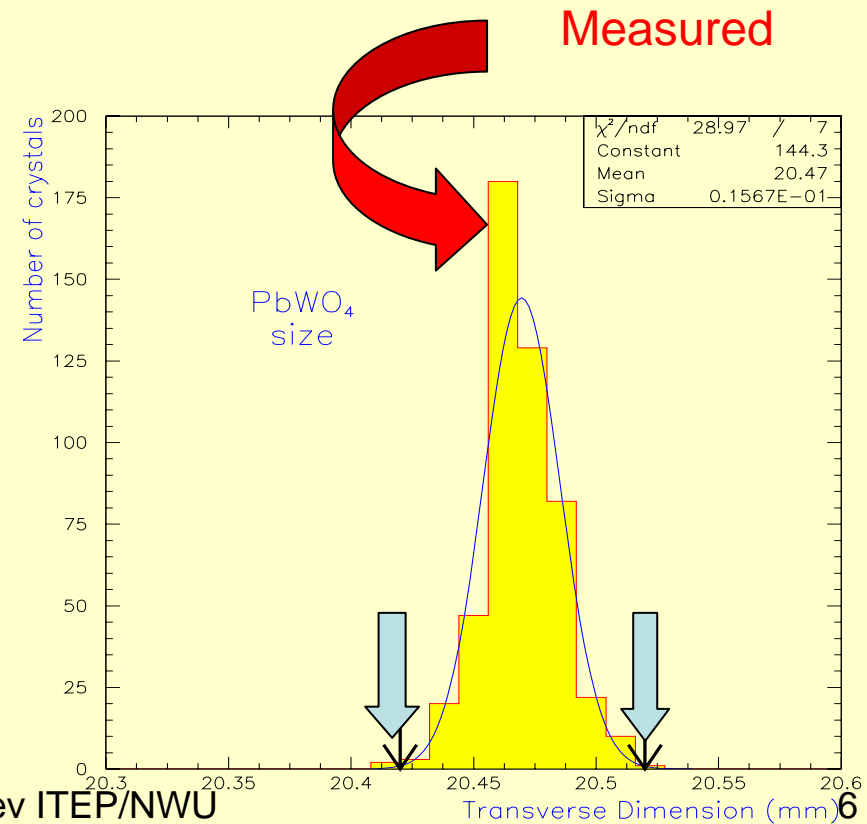
20.5 x 20.5 x 180.0 mm<sup>3</sup>

Tolerances (mm):

20.5 + 0.0 - 0.1 ← Specified  
180.0 + 0.3 - 0.0 ← Specified



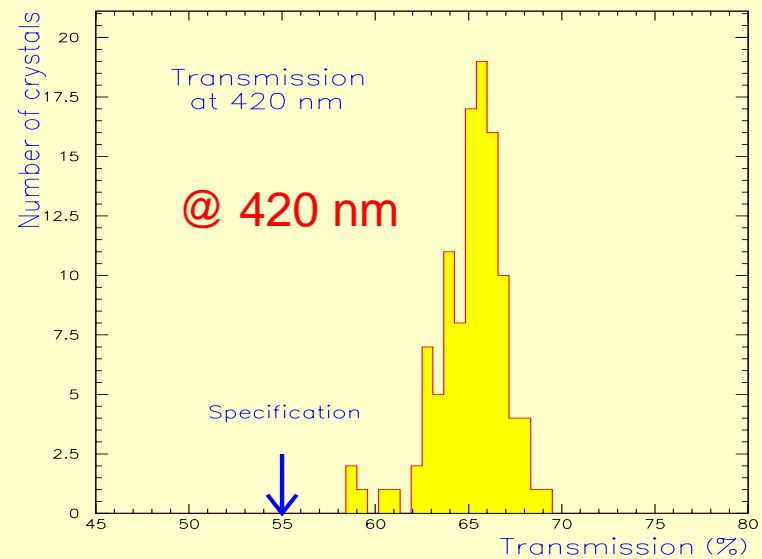
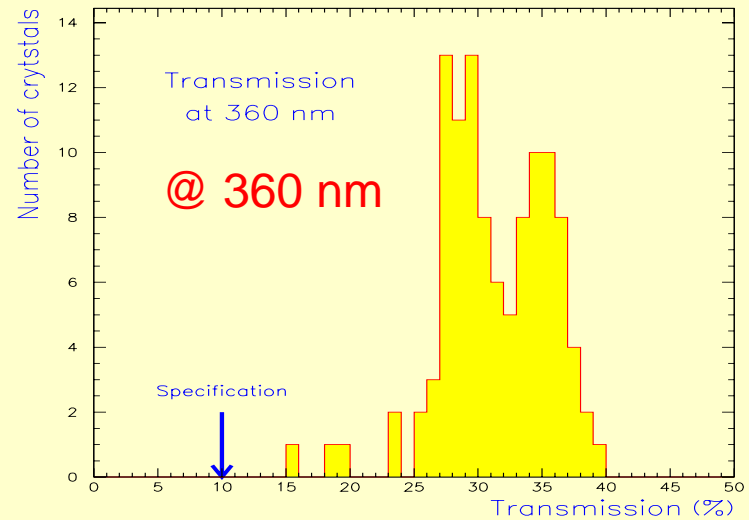
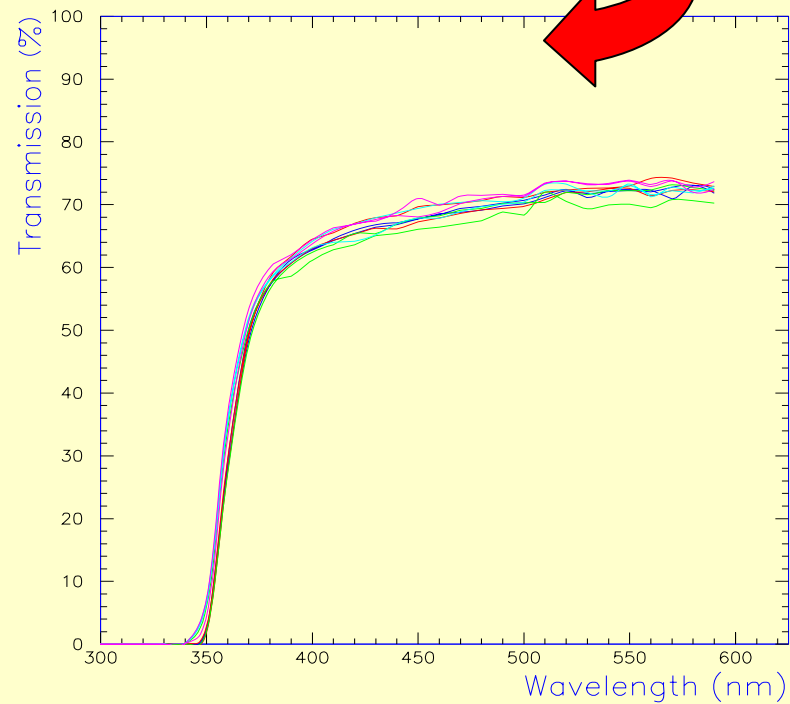
Calor-2006, June 05



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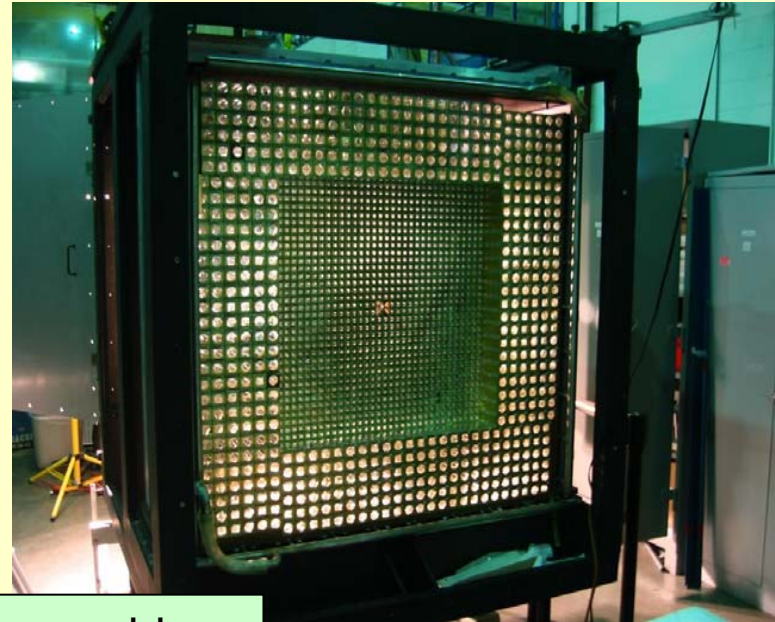
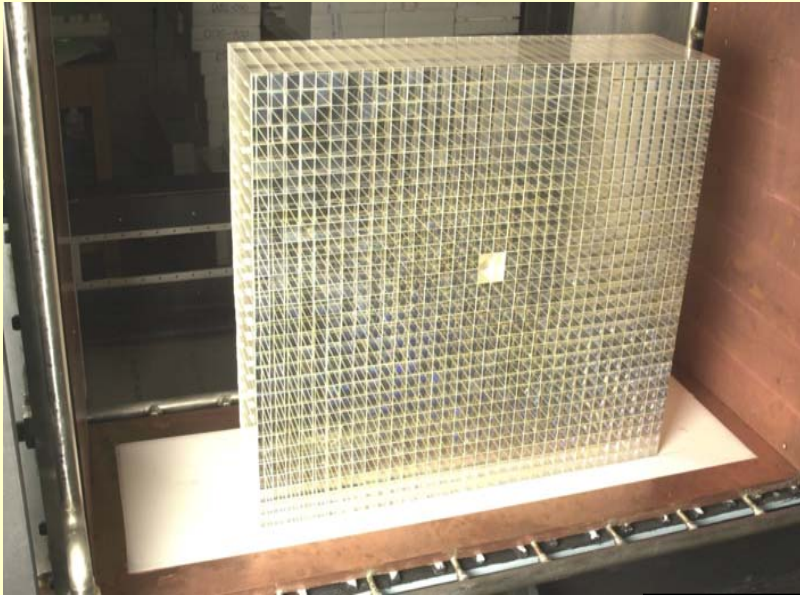
# PbWO<sub>4</sub> Crystal Optical Properties

## Optical Transparency

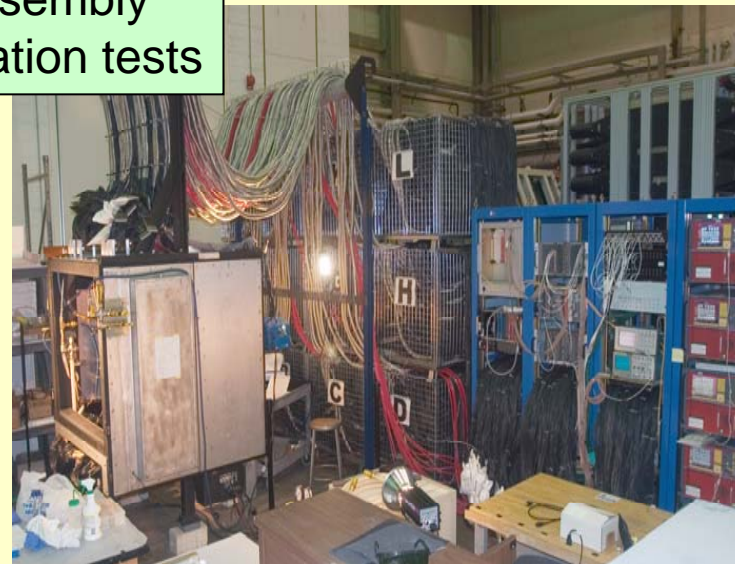




# HYCAL – The Hybrid Calorimeter



Detector assembly  
and preparation tests

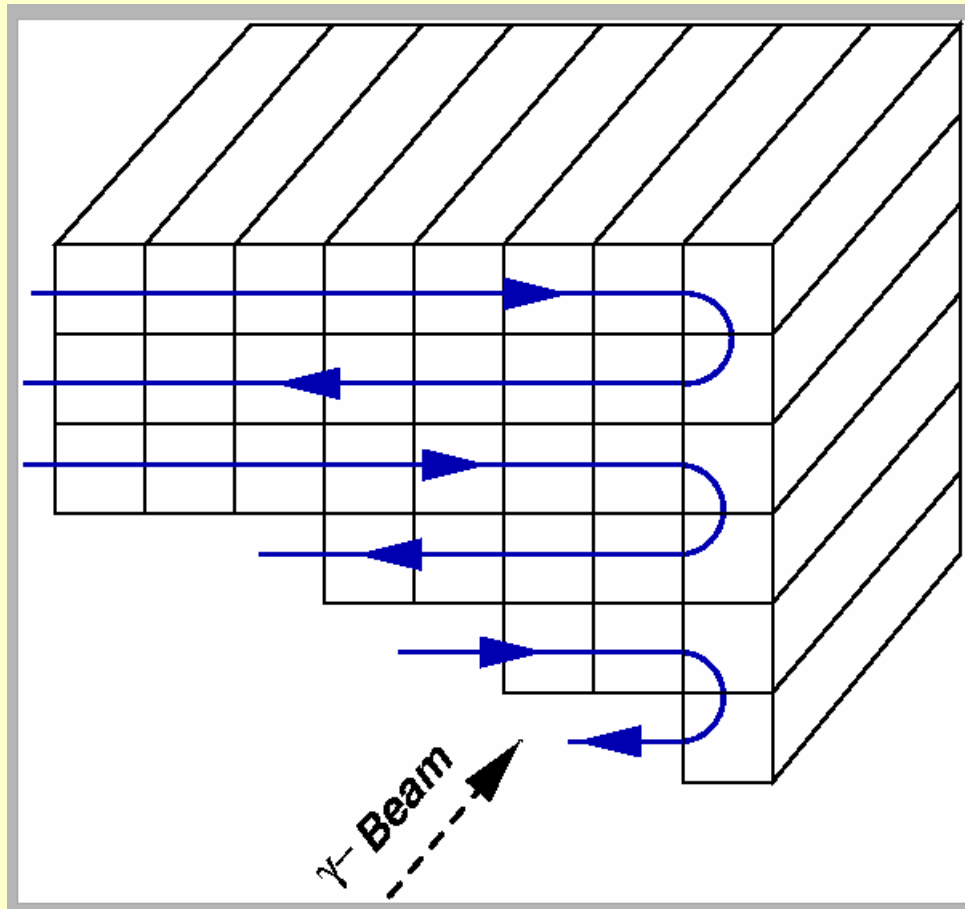


Calor-2006, June 05

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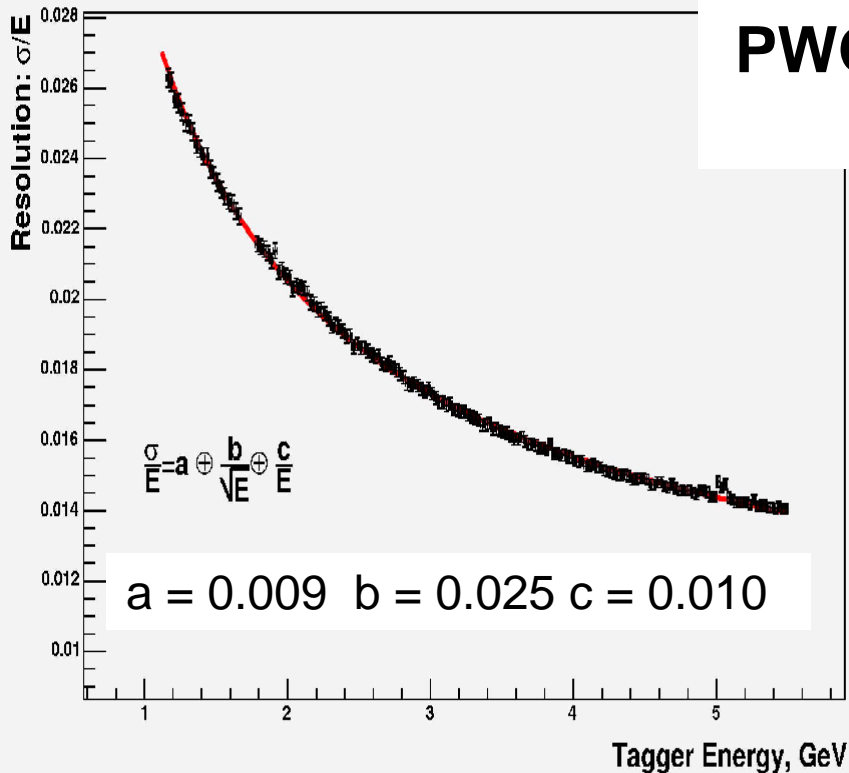
# HYCAL Calibration



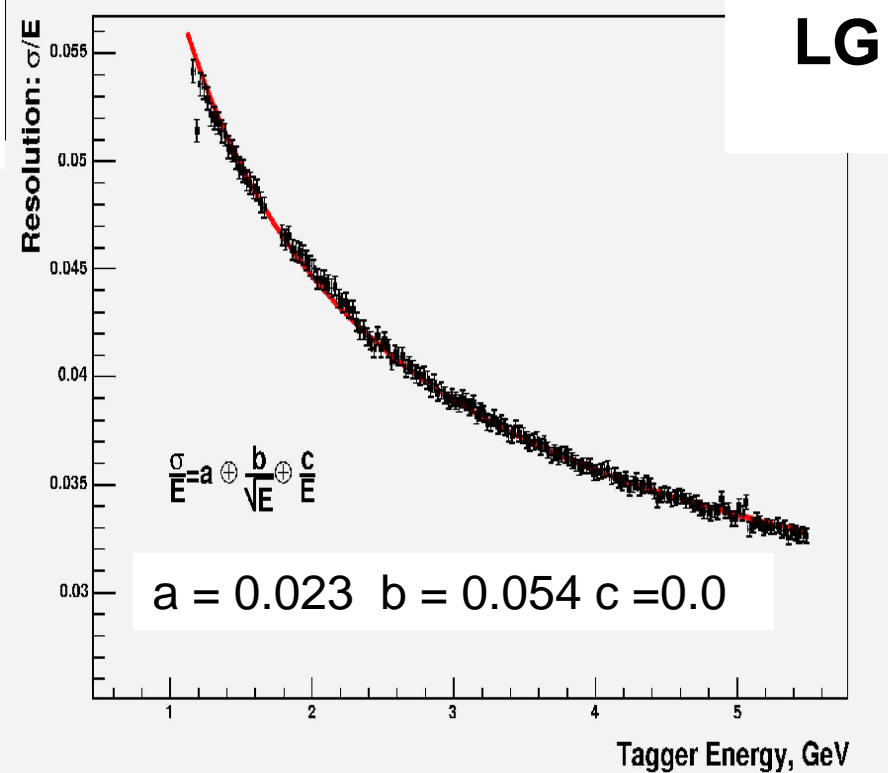
**Scheme of calorimeter irradiation with tagged photon beam during calibration**

# HYCAL Energy Resolution

Resolution for Crystal

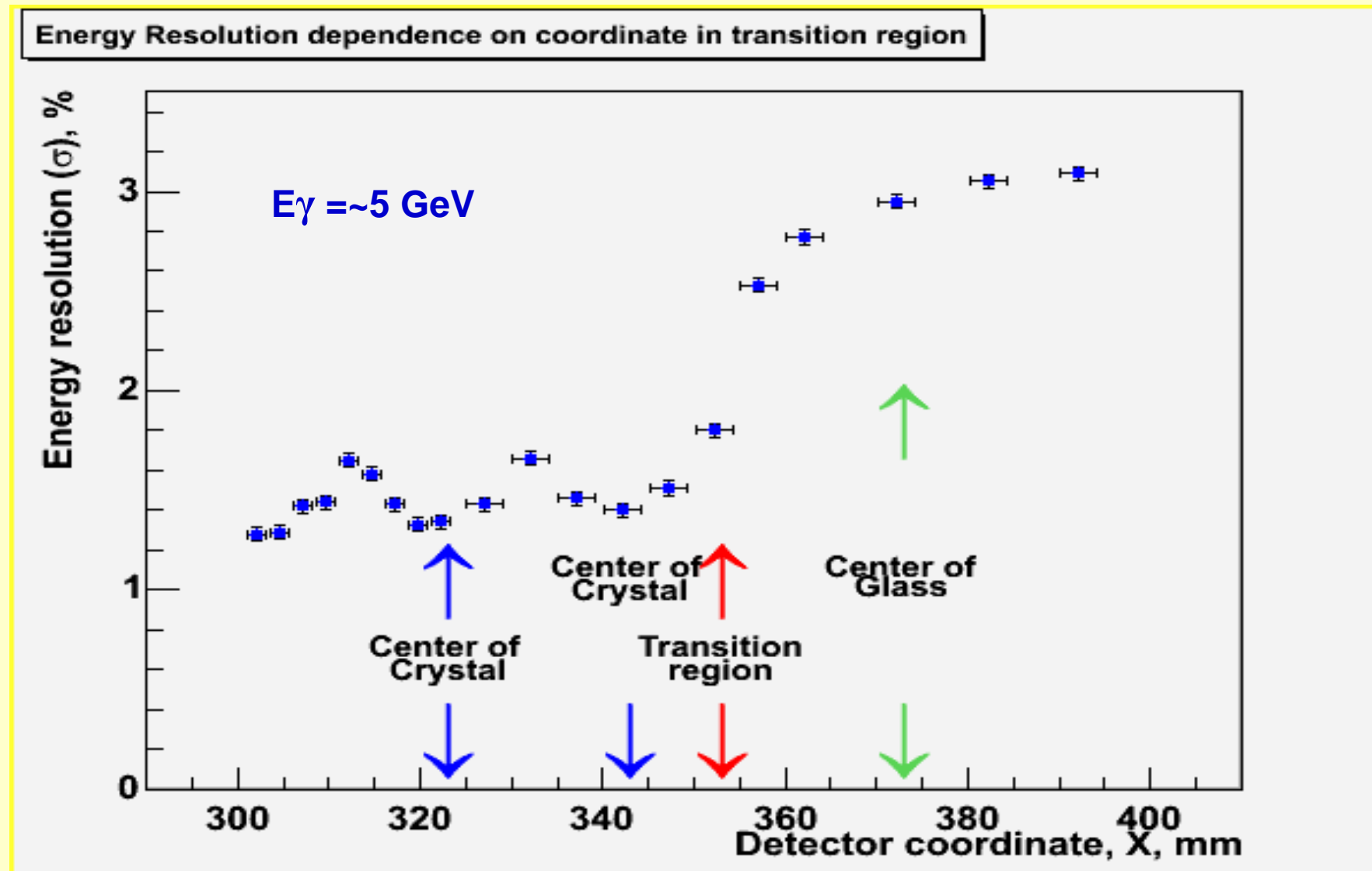


Resolution for Lead Glass

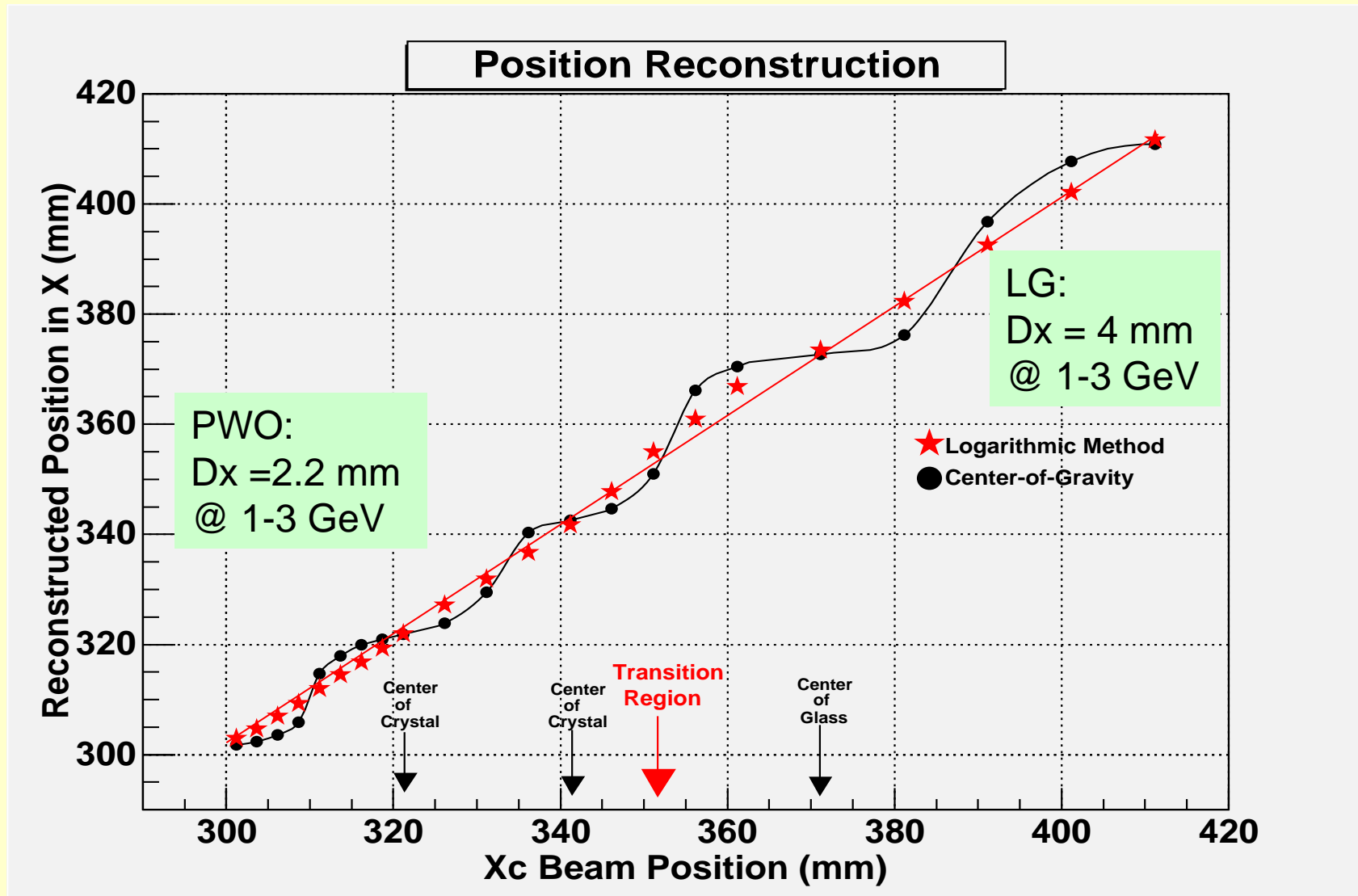


**Energy resolution for the PWO crystal central part and lead glass periphery for tagged photons during calibration run**

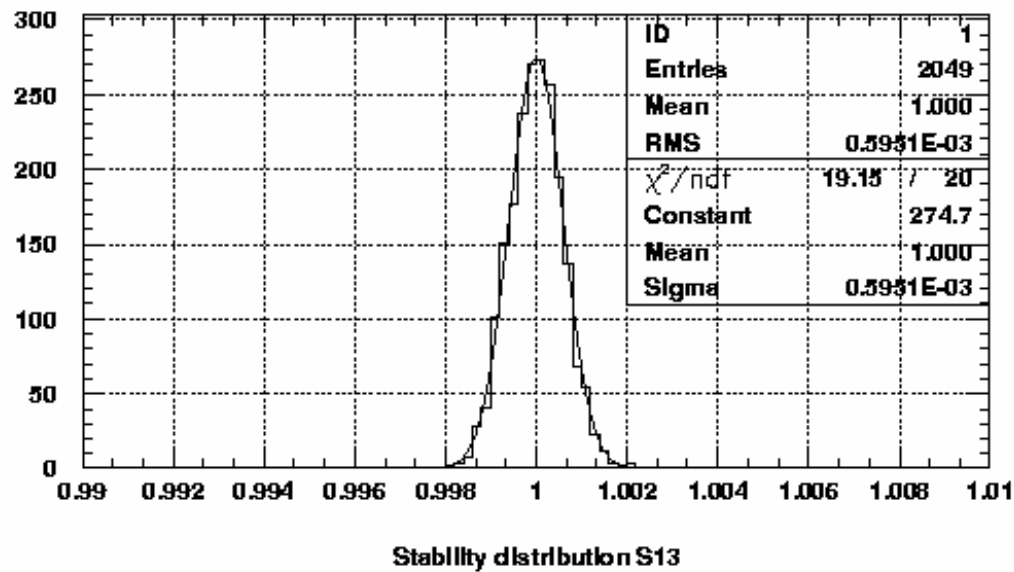
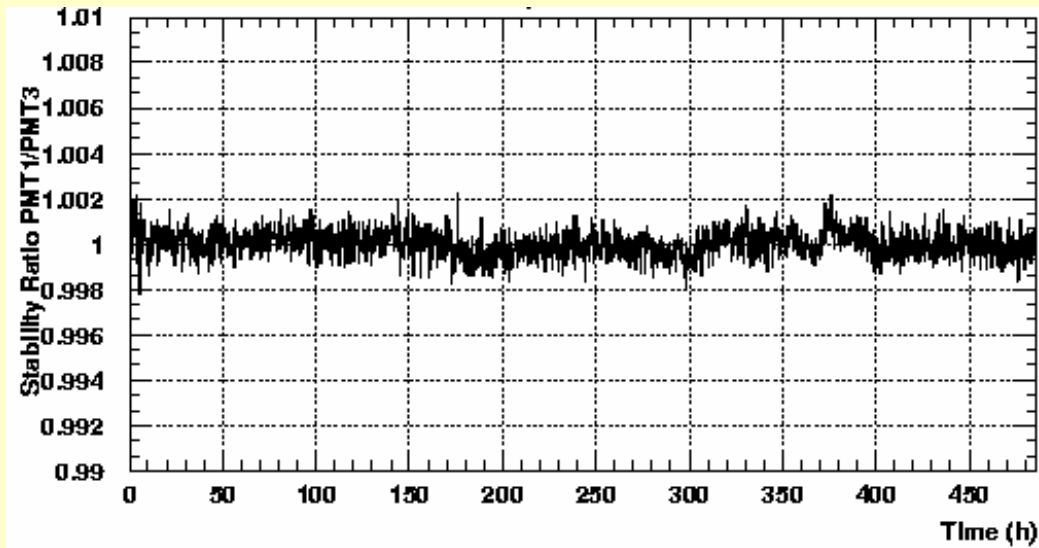
# HYCAL Energy Resolution



# HYCAL Position Resolution

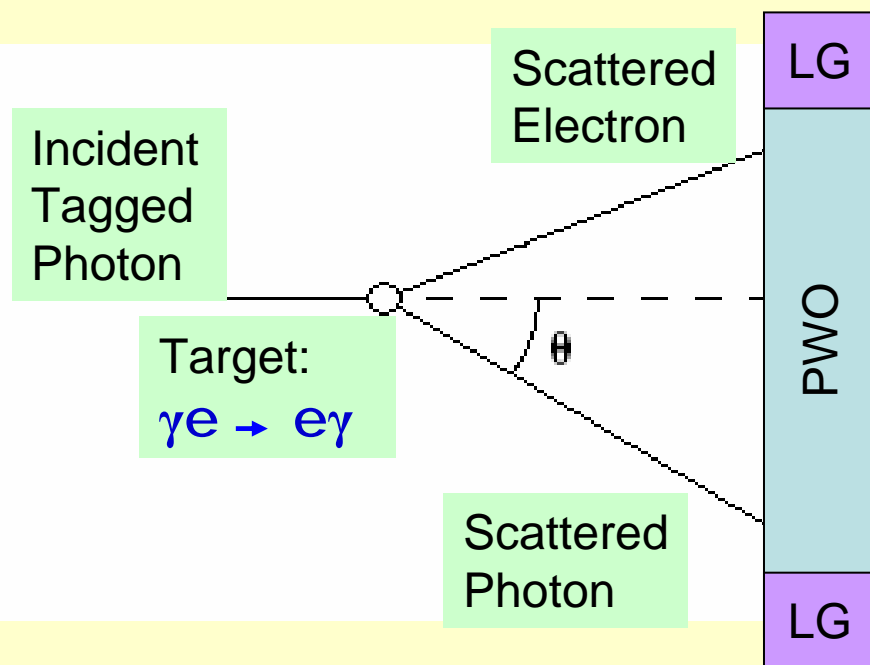


# HYCAL Light Monitoring



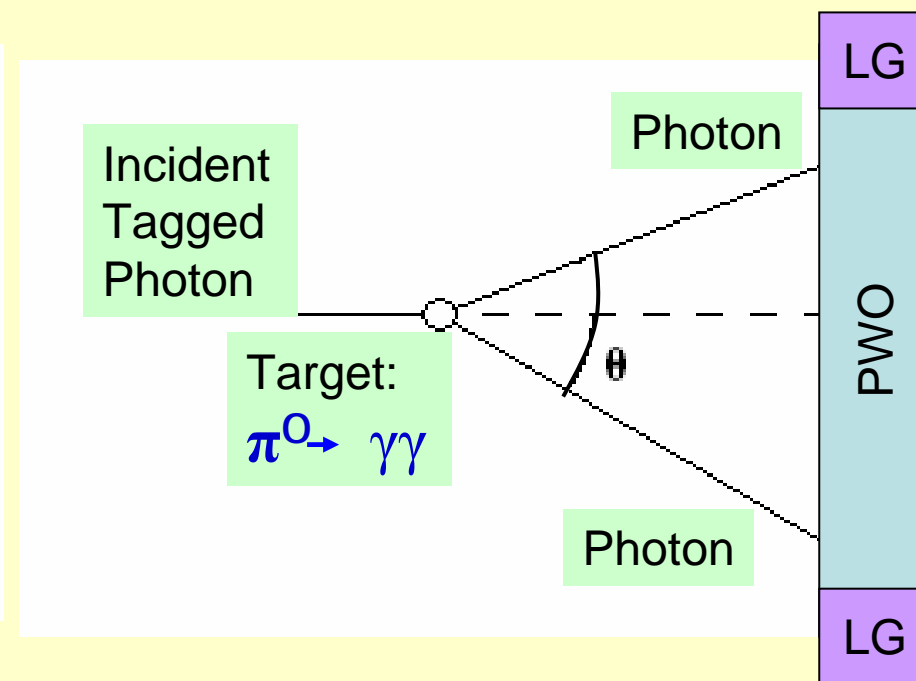
**Light monitoring system with blue LED: stability over period of 500 hours**

# HYCAL Performance for Physics Processes:



**Compton scattering** at small angles mostly (only PWO):

- $P_t = 0$  constraint
- angular correlations as additional check of resolution



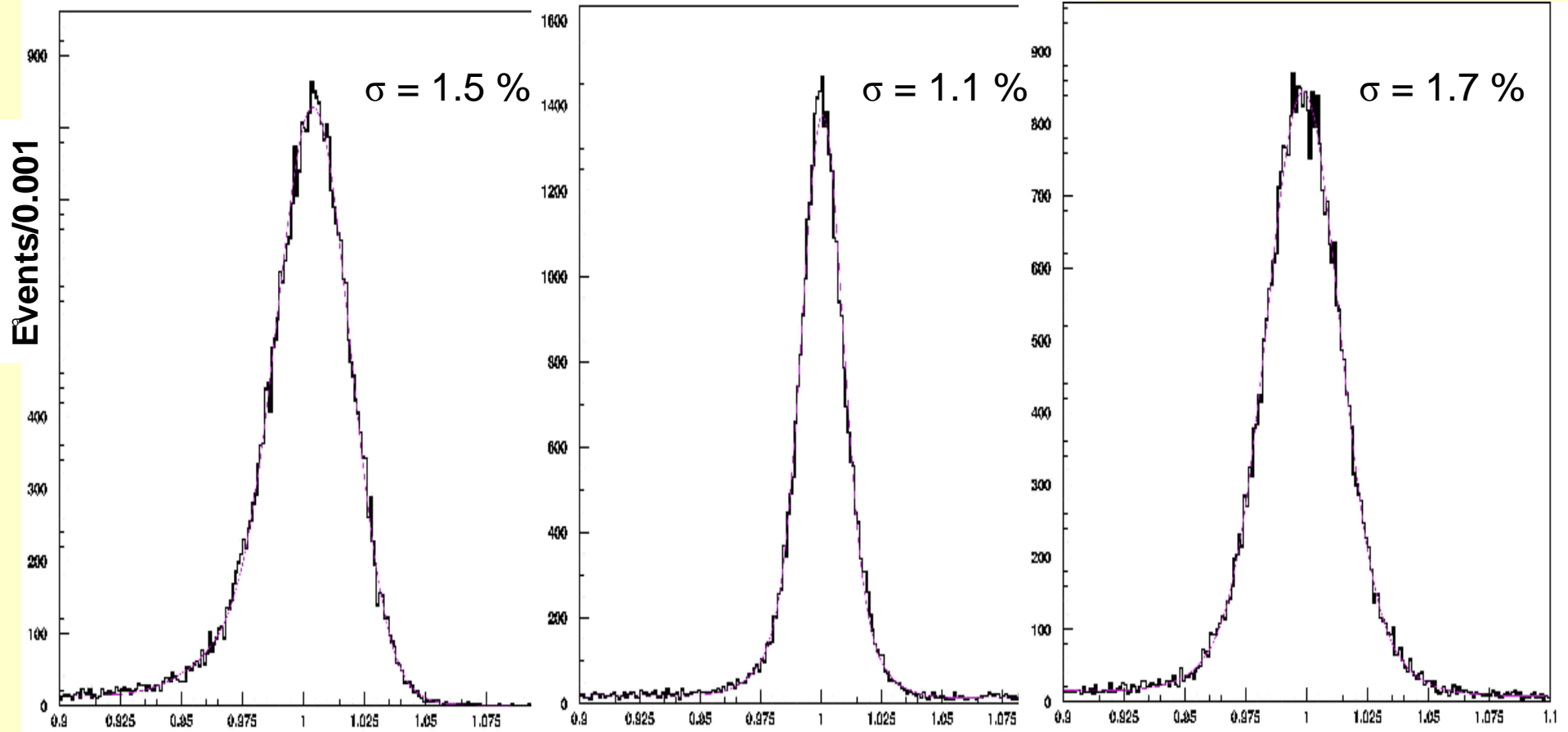
**$\pi^0$  production and decay** to two photons at all angles (PWO and LG):

- constraint on mass of  $\pi^0$
- comparison of regions of the HYCAL: PWO, LG, PWO-LG border



# HYCAL Resolution for Compton Events:

Ratio of sum of electron and photon energies measured in the calorimeter and tagged  $\gamma$  energy at  $\sim 5.2$  GeV



**after calibration**

Calor-2006, June 05

**after Pt = 0 correction**

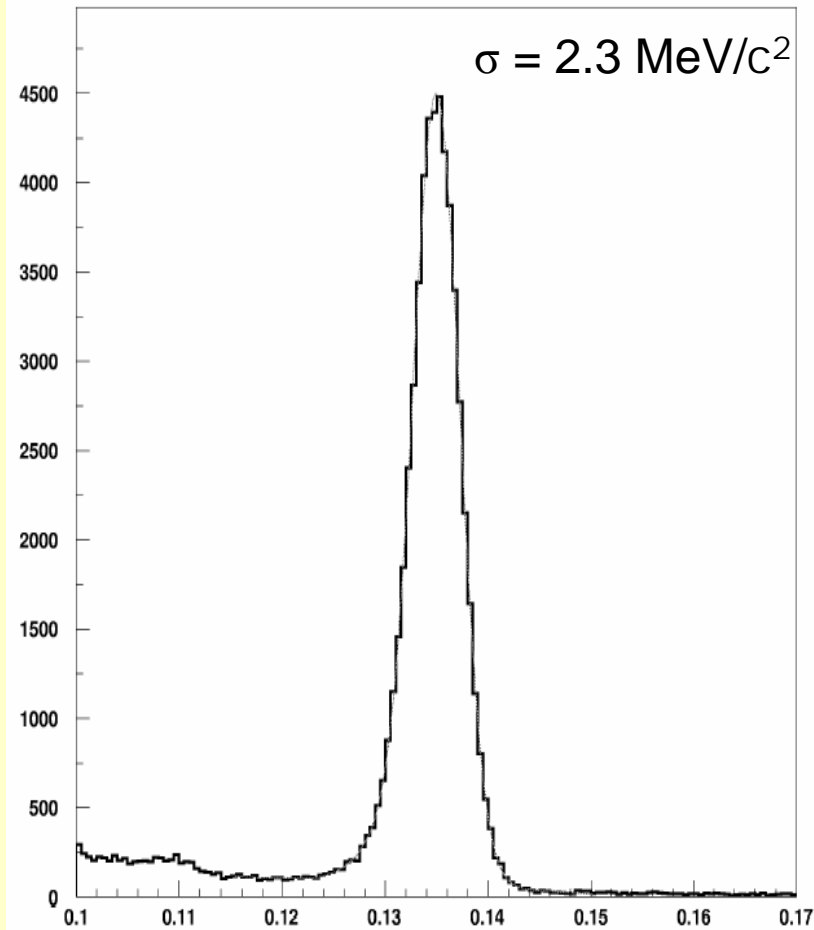
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**only coordinate**

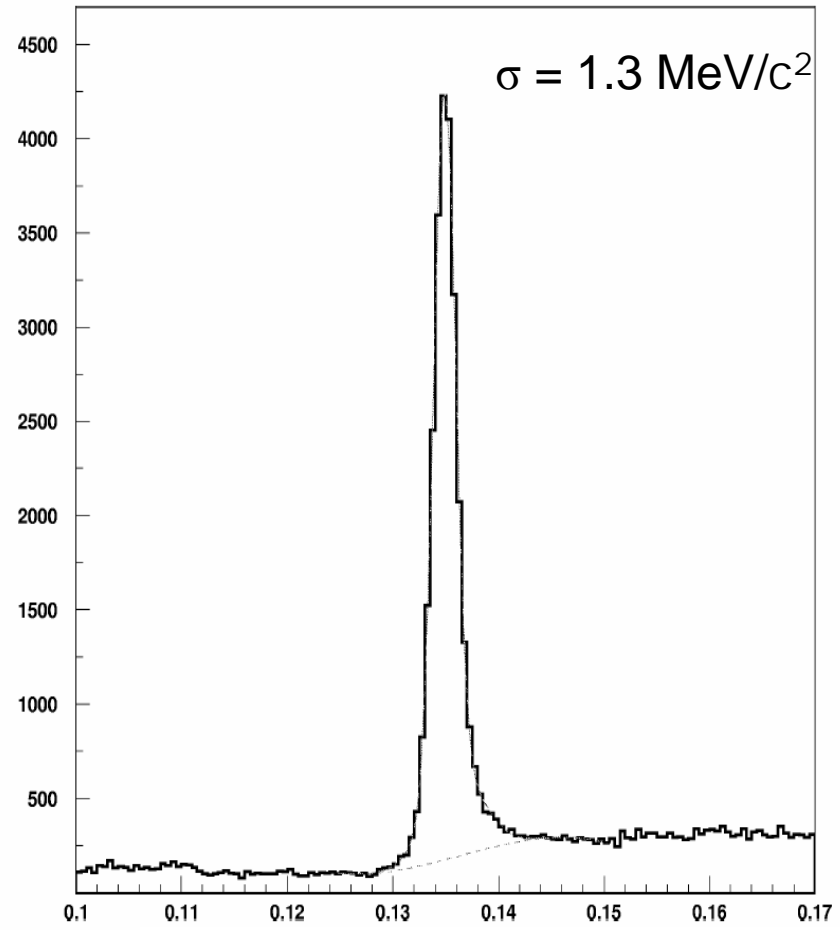
**information 15**

# HYCAL $\pi^0$ Resolution: PWO

Events/0.5 MeV/C2

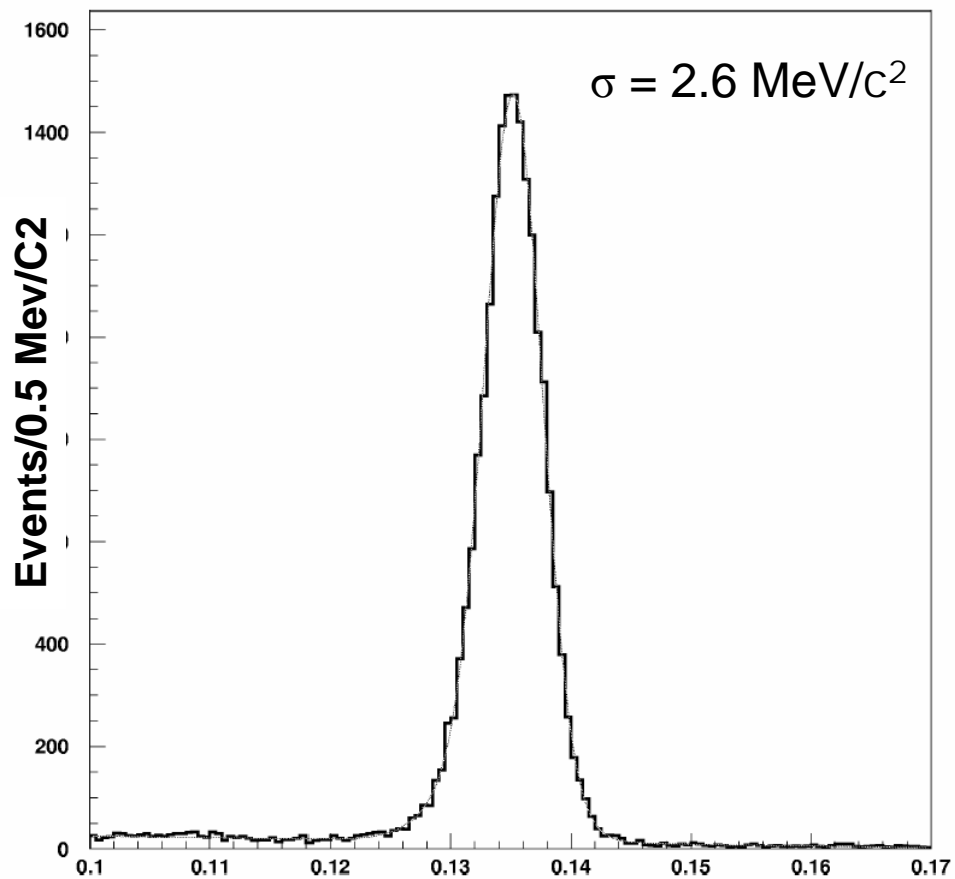


after calibration

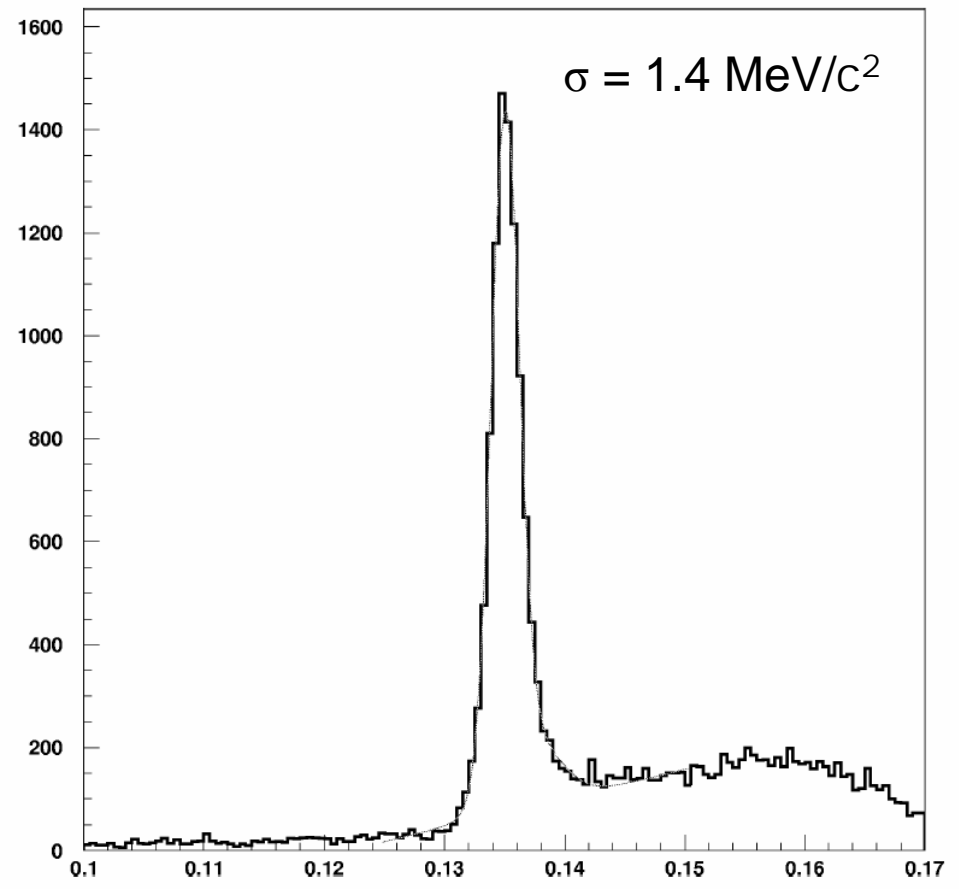


after correction on tagged  
photon energy: smearing  
due to coordinate resolution

# HYCAL $\pi^0$ Resolution: PWO-LG Border

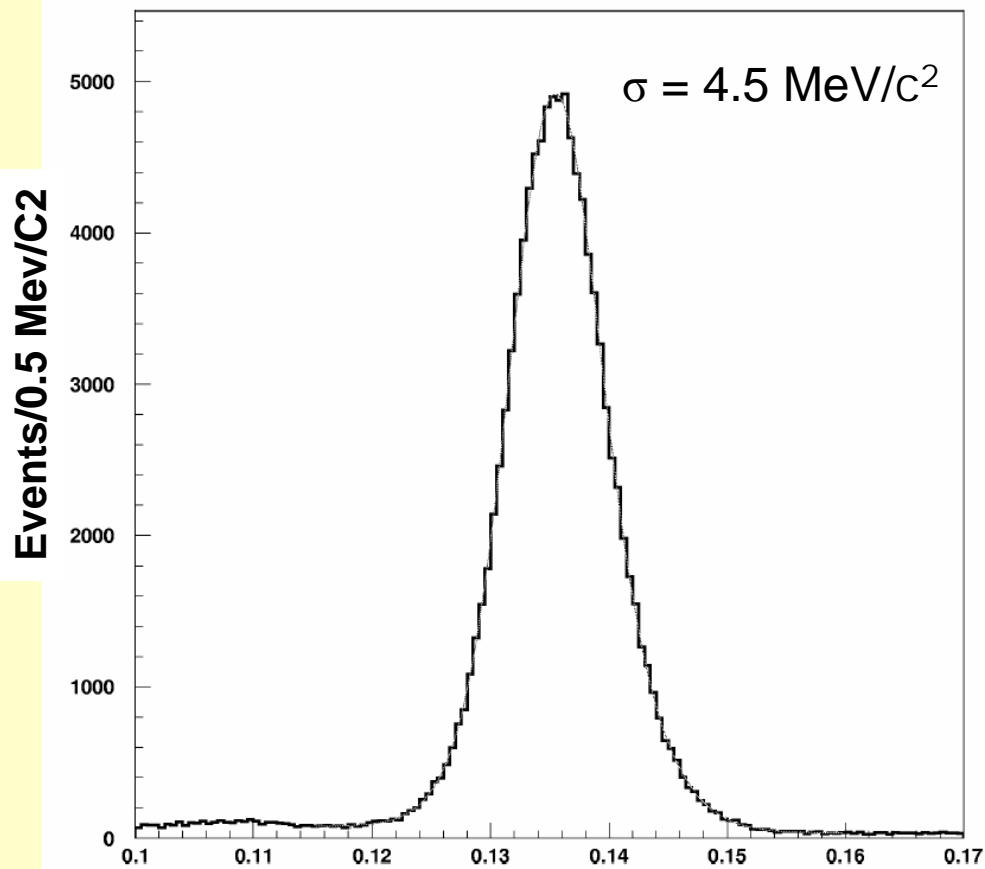


$\pi^0$  mass resolution after calibration: one photon in PWO another at the border

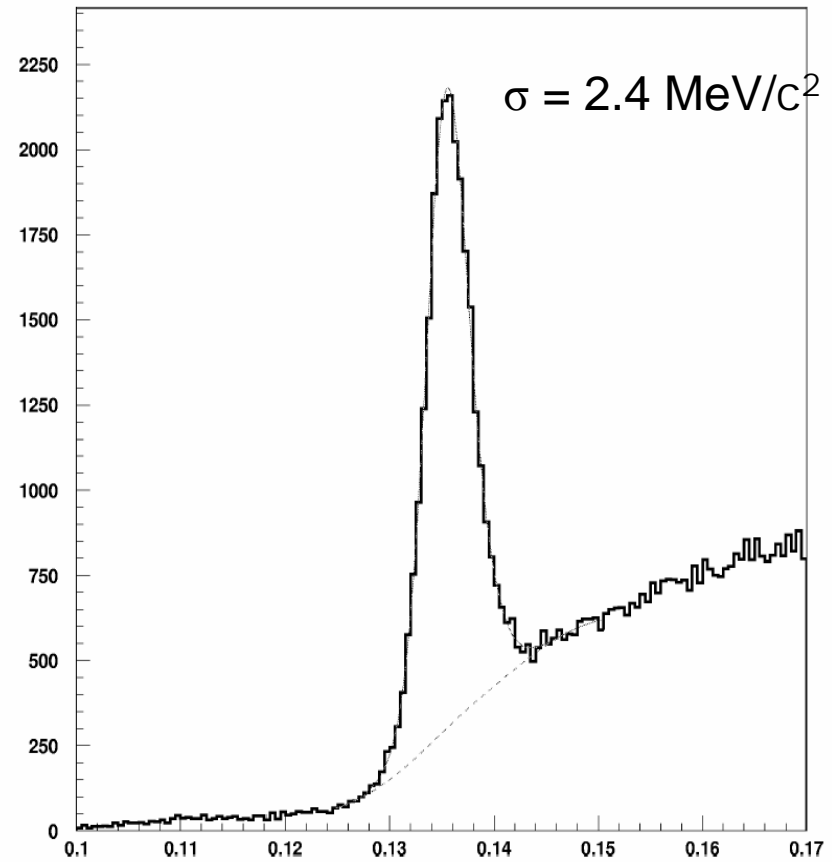


$M_{\gamma\gamma}$ ,  $\text{GeV}/c^2$  after correction on tagged photon energy: smearing due to coordinate resolution

# HYCAL $\pi^0$ Resolution: PWO + LG

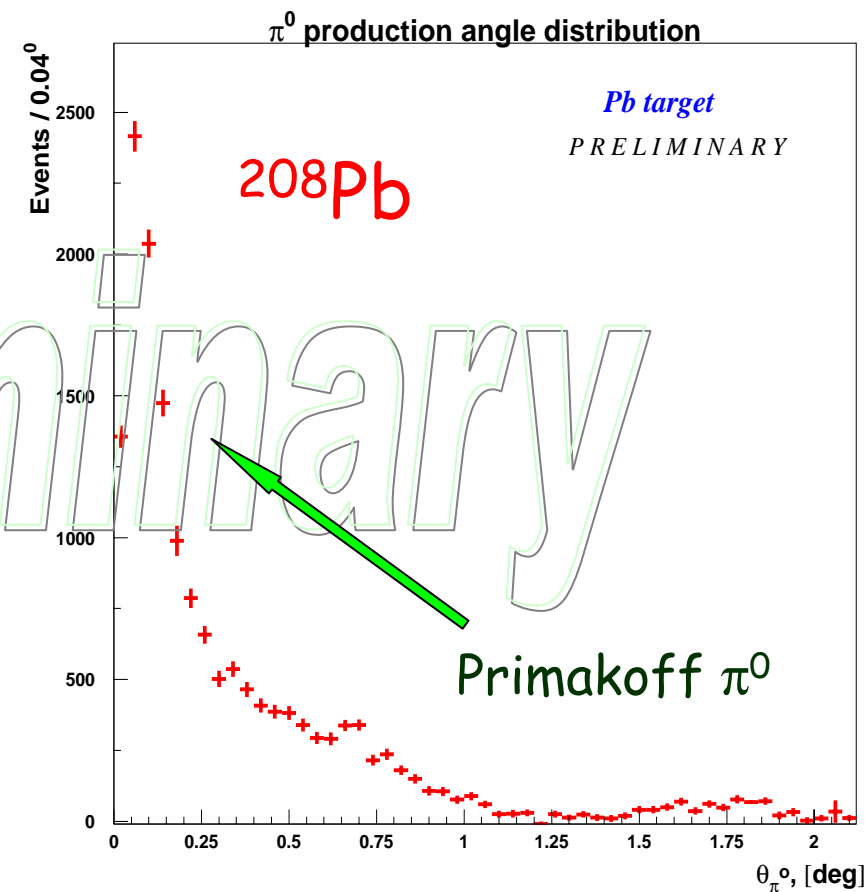
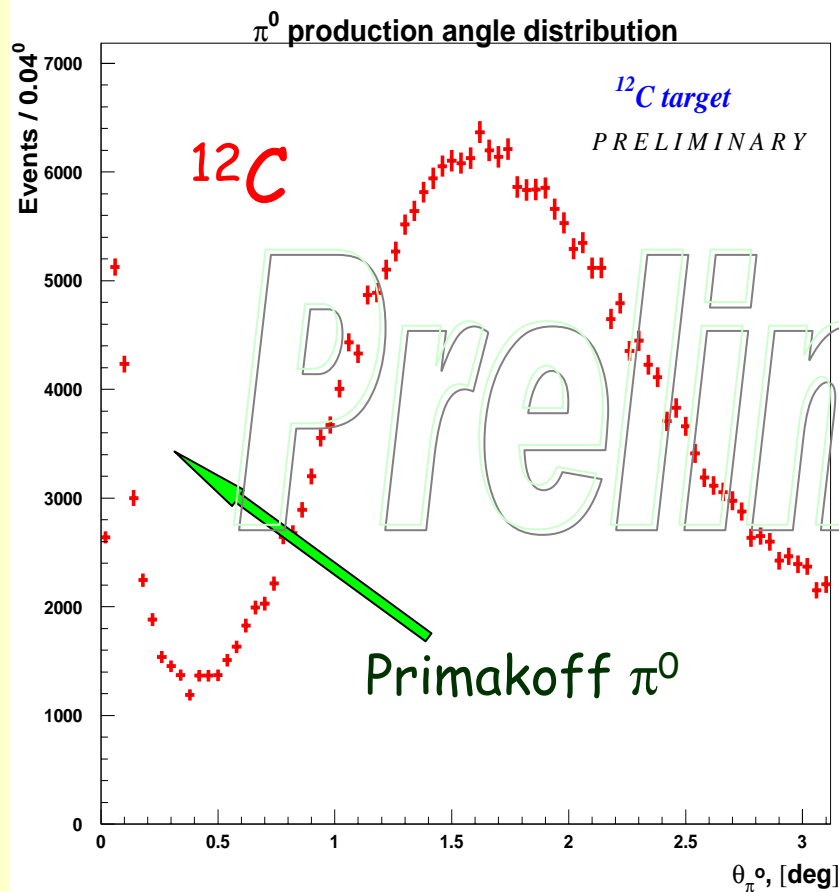


$\pi^0$  mass resolution after calibration: one photon in PWO another in LG



$M_{\gamma\gamma}, \text{GeV}/c^2$  after correction on tagged photon energy: smearing due to coordinate resolution

# $\pi^0$ Angular Distribution (experiment, preliminary)



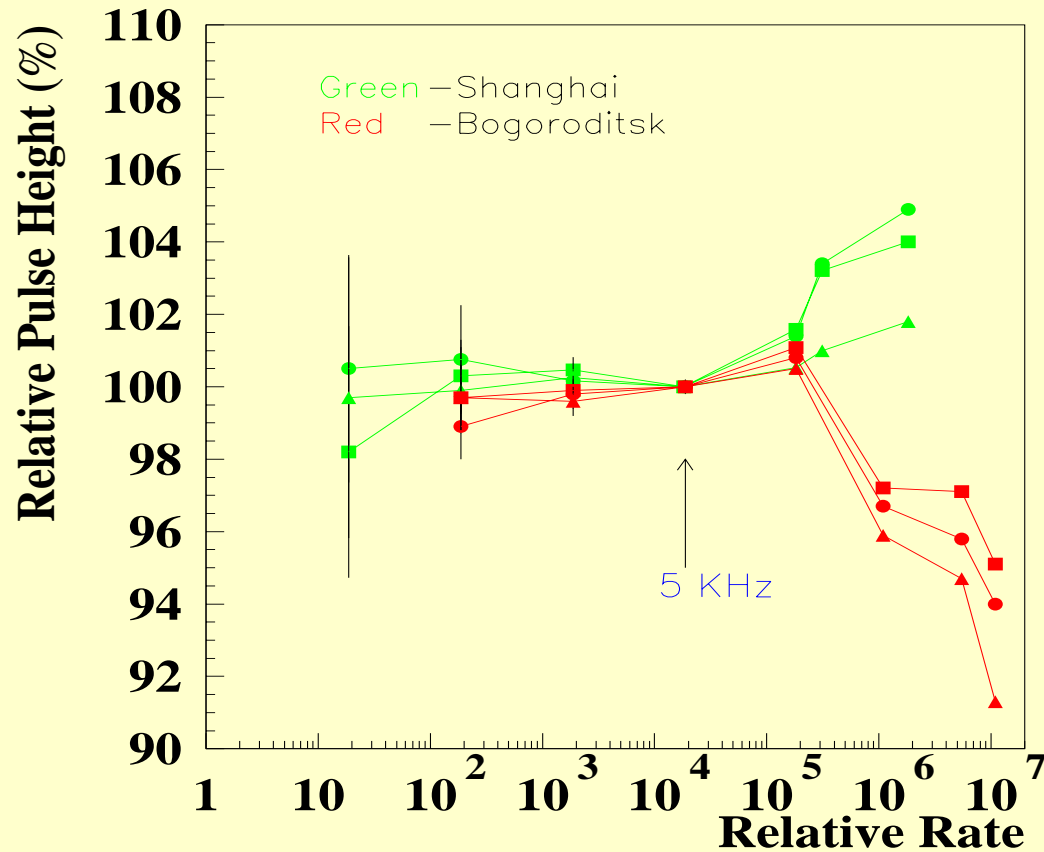
# Summary

- A high performance hybrid  $\text{PbWO}_4$  calorimeter (~2000 channels) has been developed, constructed and run in PrimEx experiment at JLab.
- HYCAL took physics data in November 2004:
  - Energy and position calibration with tagged photons of 1 – 5.5 GeV
  - $\pi^0$  mass resolution  $\sigma_{\pi^0} = 2.3$  MeV (PWO),  
(with energy constraint on the tagger 1.3 MeV)
  - Rich high quality data sets have been collected to extract  $\pi^0$  life time
- We expect first physics results this summer:
  - <http://www.jlab.org/primex/>
  - ❖ This project is supported by the US NSF MRI grant (PHY-0079840)
  - ❖ This project is supported by the RFBR Grant 04-02-17466

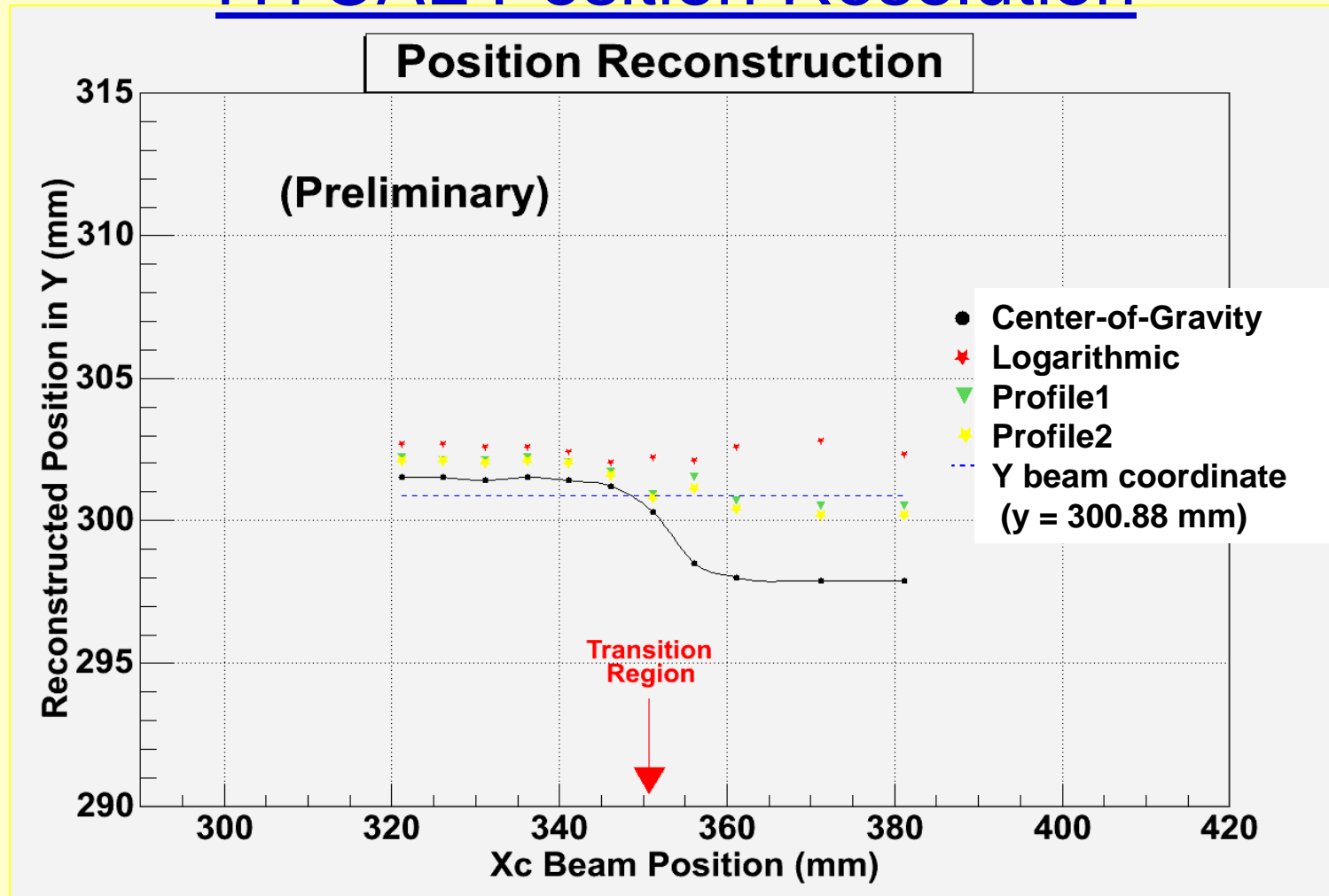


# Spare slides

# PbWO<sub>4</sub> Detector Response vs. Dose Rate



# HYCAL Position Resolution



**Reconstruction of photon positions in the transition region between PWO crystal central part and lead glass periphery**

# HYCAL Position Resolution

**Coordinate of the cluster:**

$$X_c = \Sigma(x_i w_i) / \Sigma w_i$$

**Center-of-Gravity:**

$$W_i = E_i$$

**Logarithmic:**

$$W_i = 4.2 + \ln(E_i/E_9)$$