

High Performance 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.**

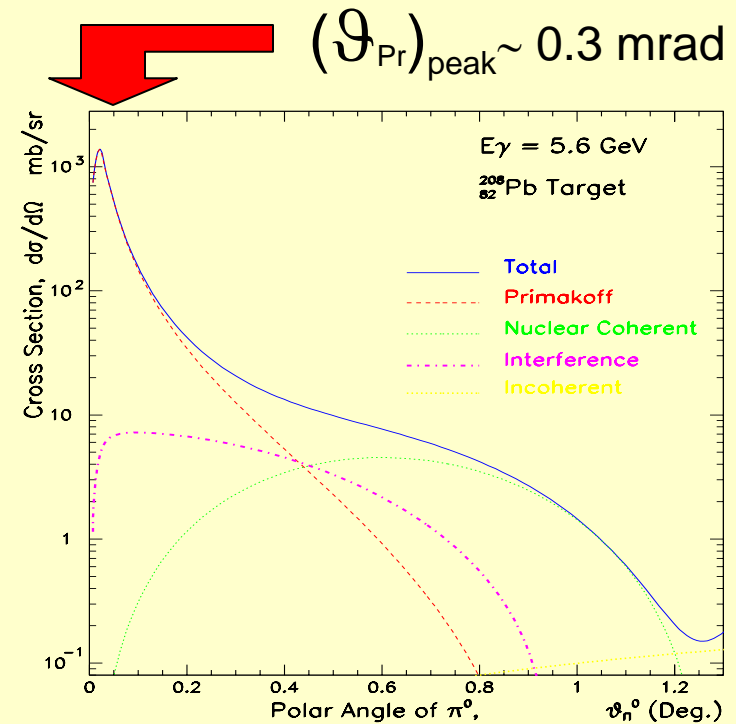
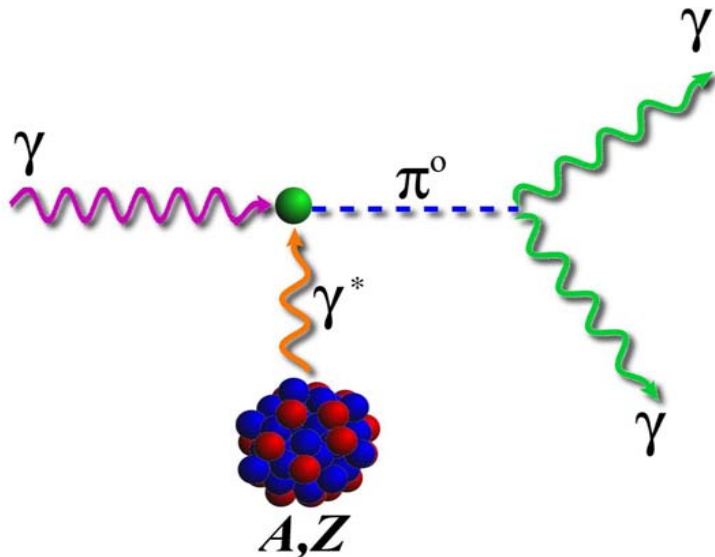
Requirements for the Calorimeter

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

@ 1- 10 GeV requires:

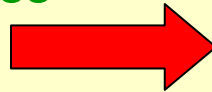
- High energy resolution;
- High position resolution;
- Good photon detection efficiency @ few GeV;
- Large geometrical acceptance.

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

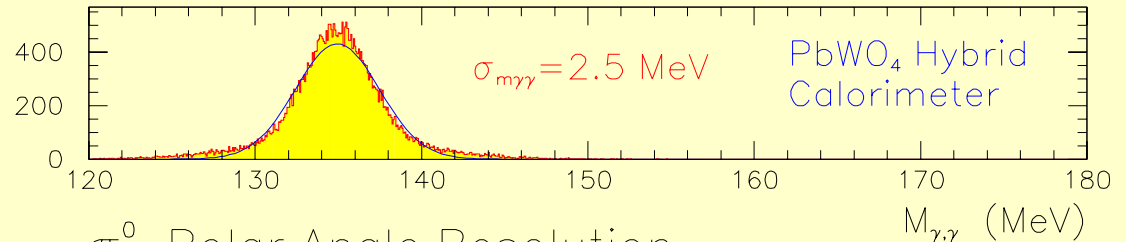
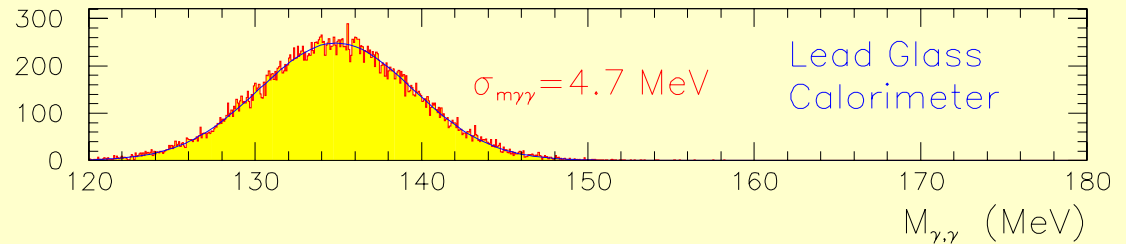


Design Concept and Resolutions

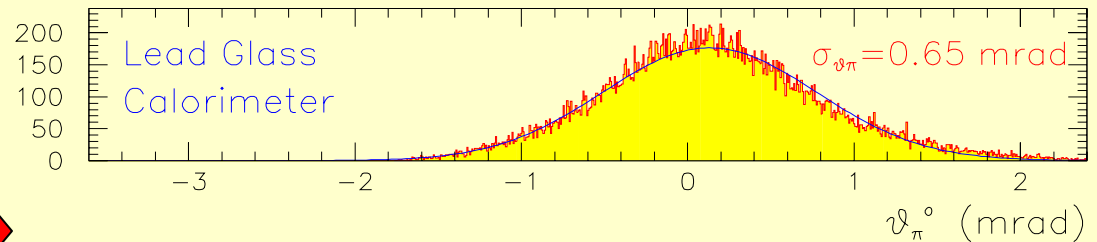
$\gamma\gamma$ Invariant Mass Resolution



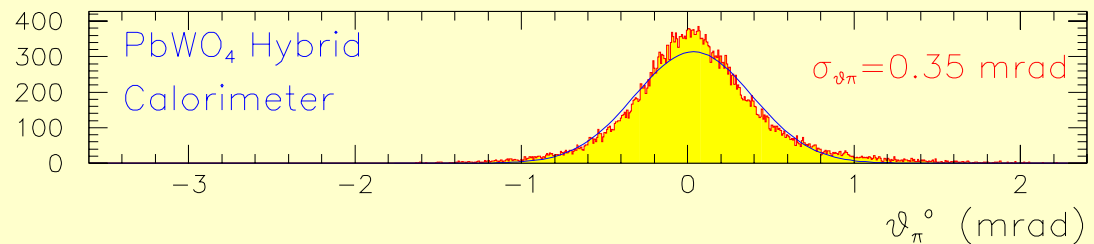
Invariant Mass Resolution



π^0 Polar Angle Resolution



Angular Resolution



Design Concept

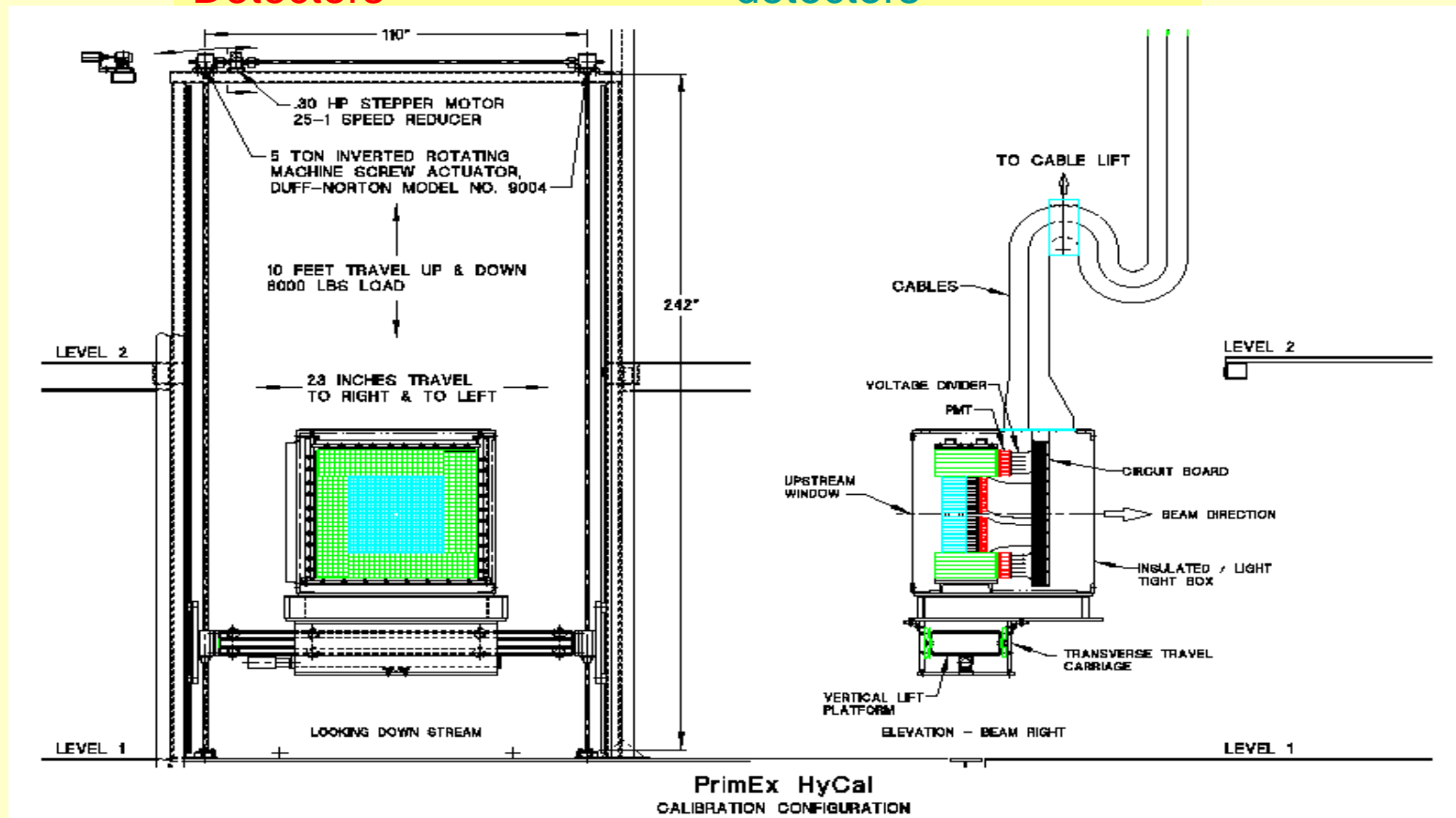
Resolution

PbWO₄ crystal
Detectors

+

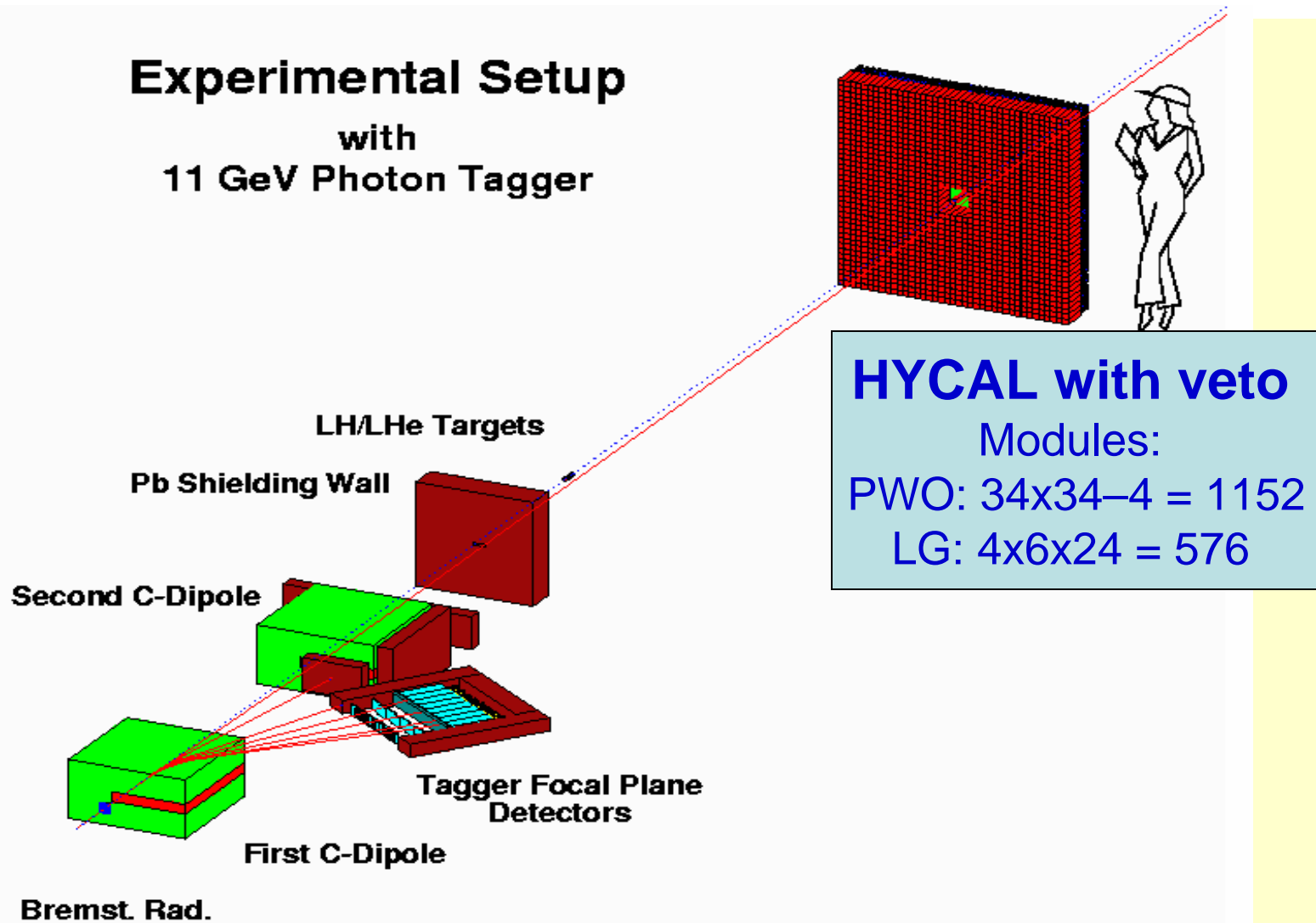
Budget

Pb – glass Cherenkov
detectors



Design Concept

Experimental Setup with 11 GeV Photon Tagger



PbWO₄ Crystal Dimensions

Dimensions:

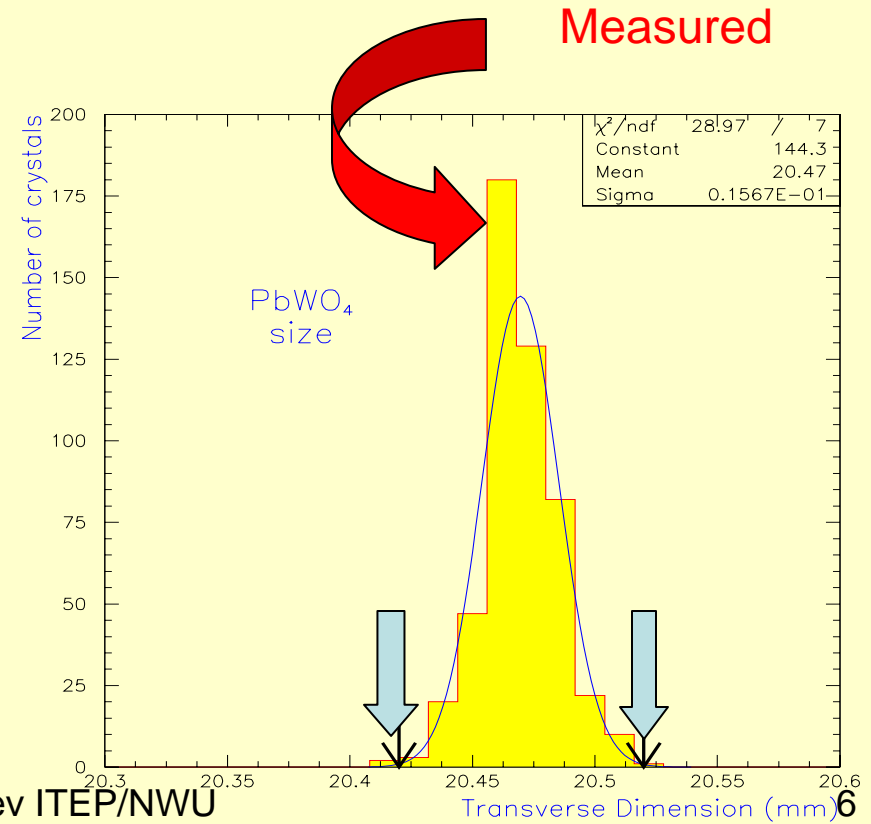
20.5 x 20.5 x 180.0 mm³

Tolerances (mm):

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



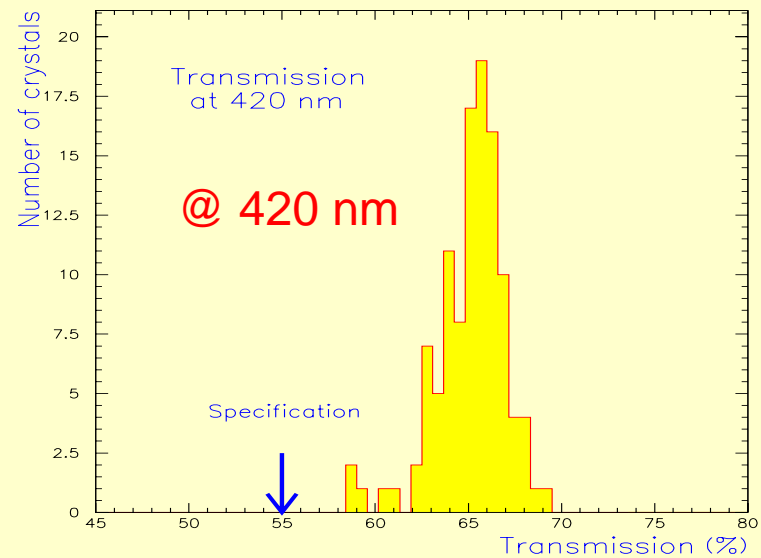
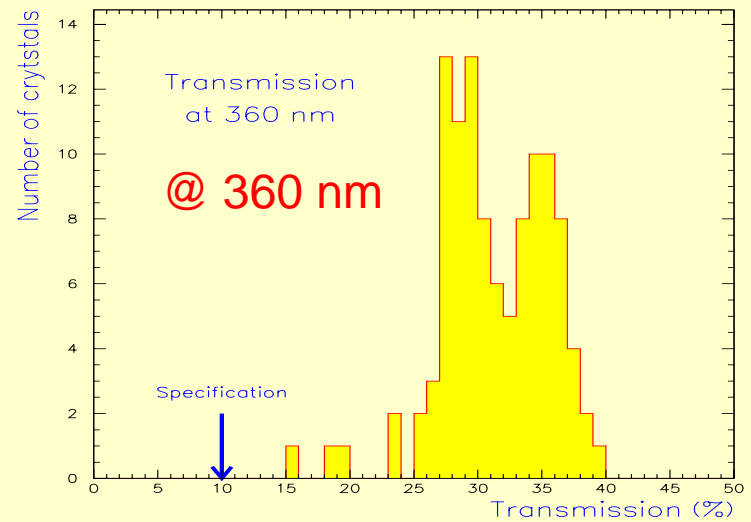
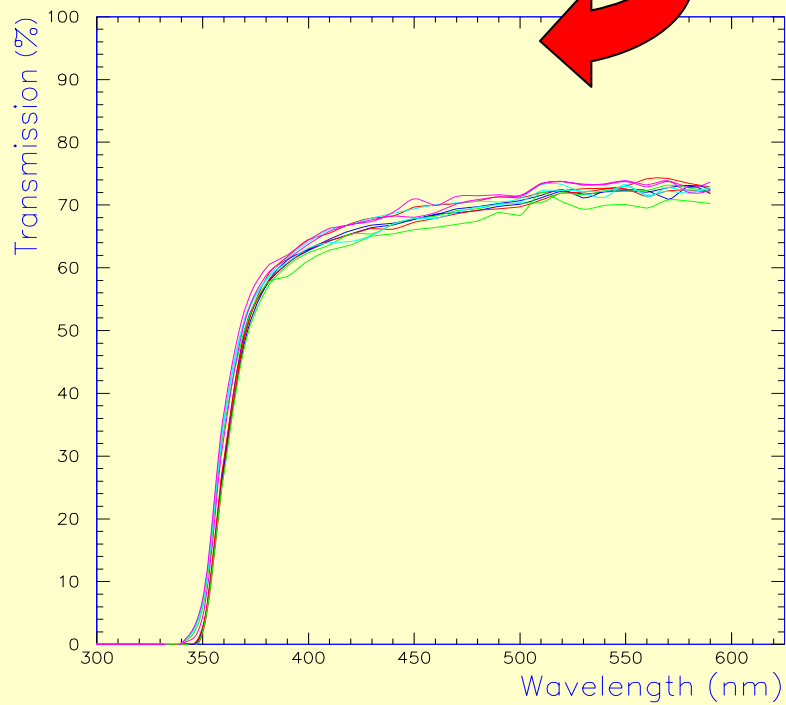
Calor-2006, June 05



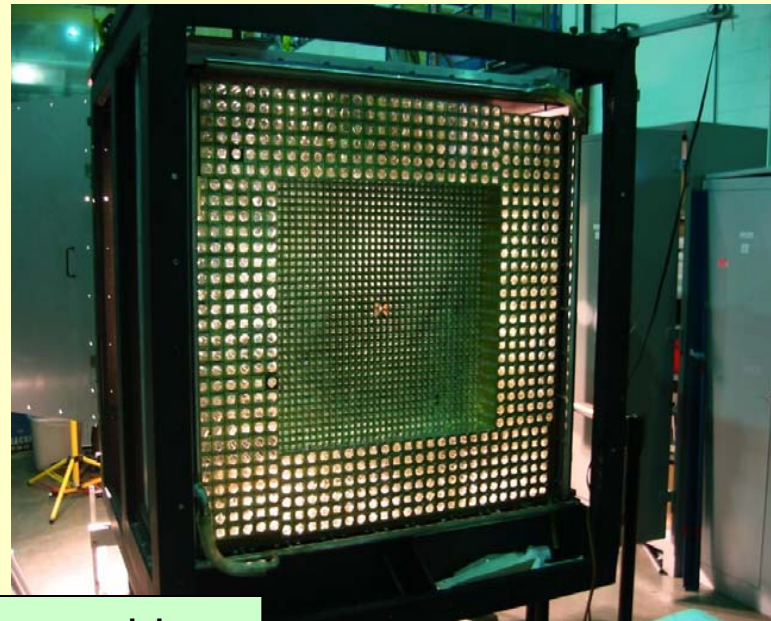
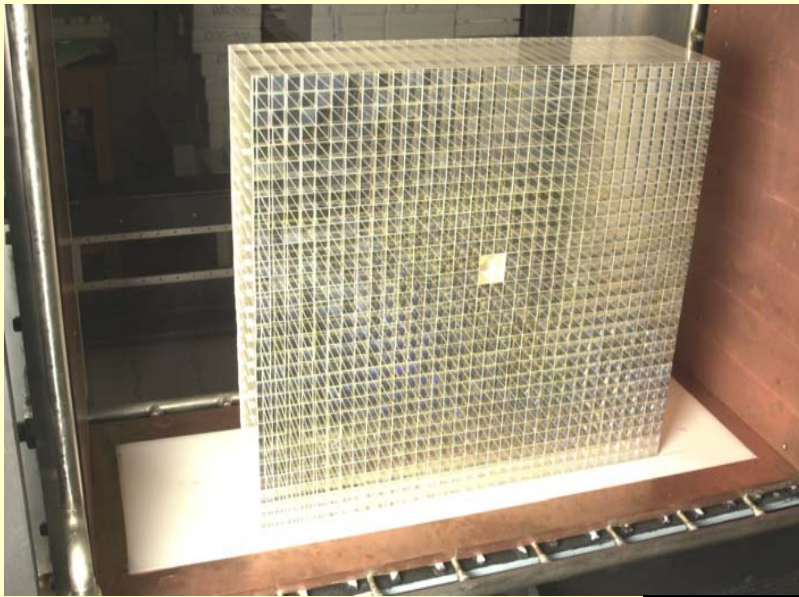
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PbWO₄ Crystal Optical Properties

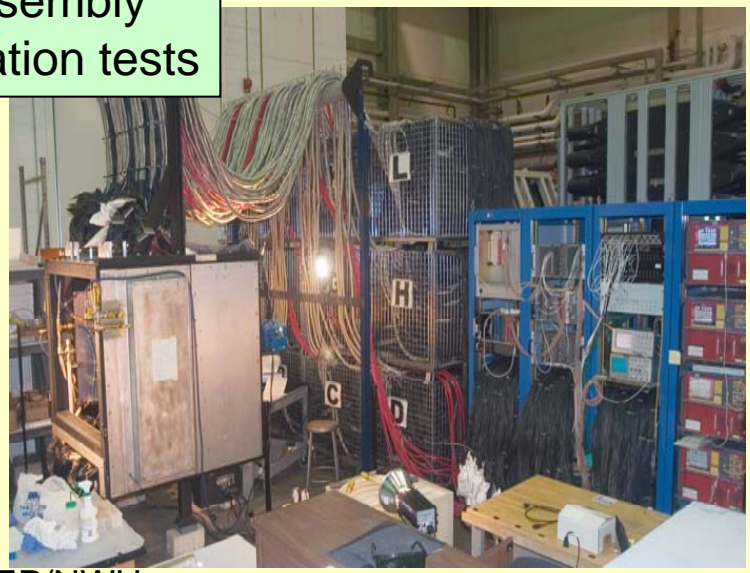
Optical Transparency



HYCAL – The Hybrid Calorimeter



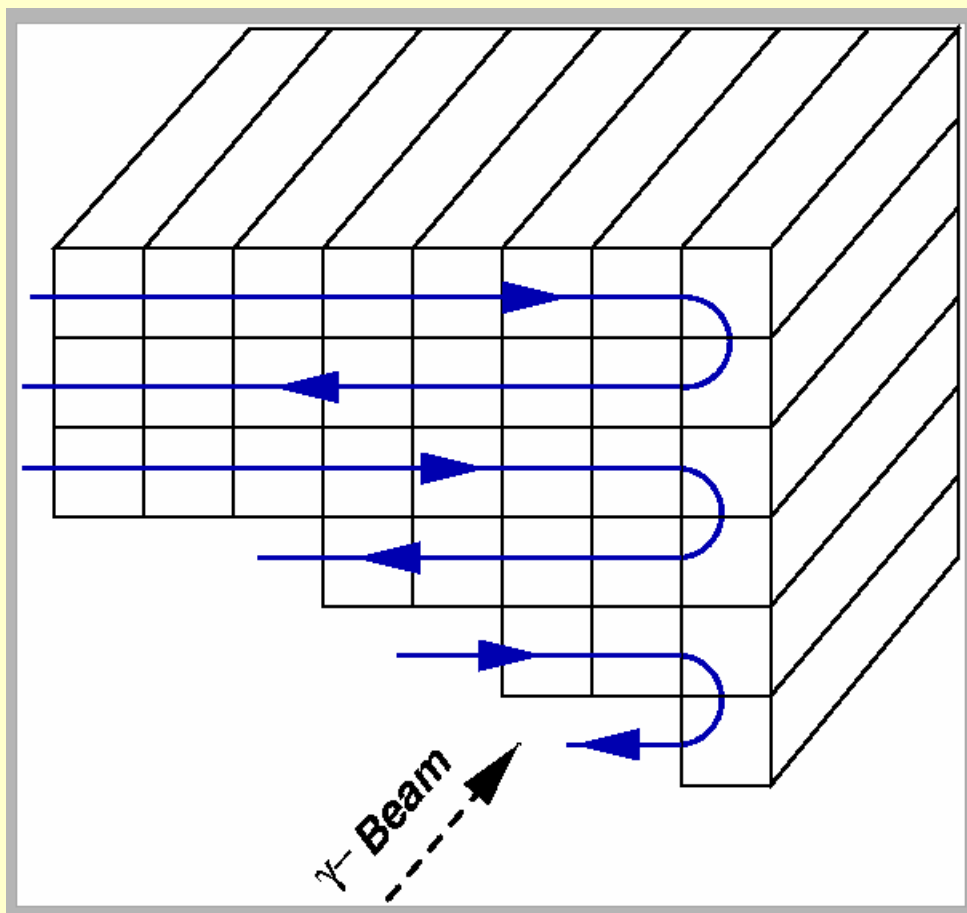
Detector assembly and preparation tests



Calor-2006, June 05

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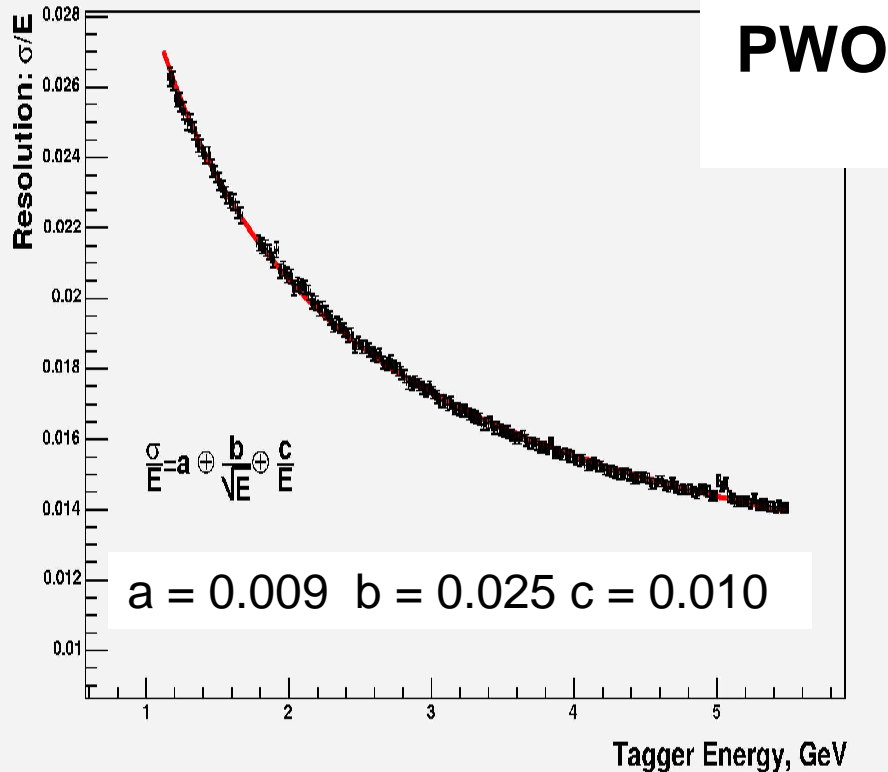
HYCAL Calibration



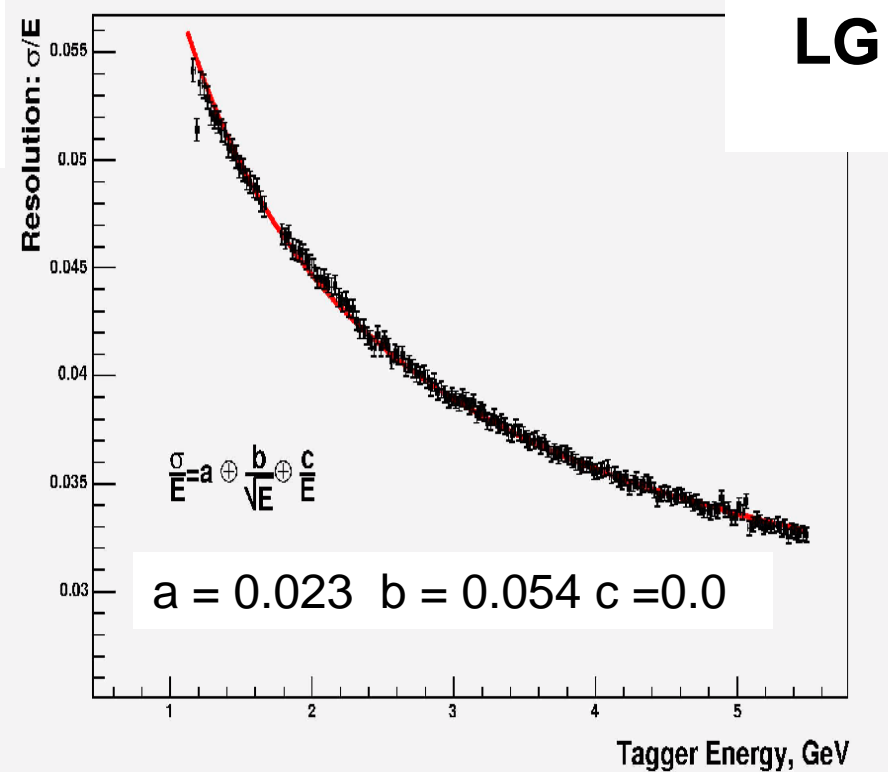
Scheme of calorimeter irradiation with tagged photon beam during calibration

HYCAL Energy Resolution

Resolution for Crystal

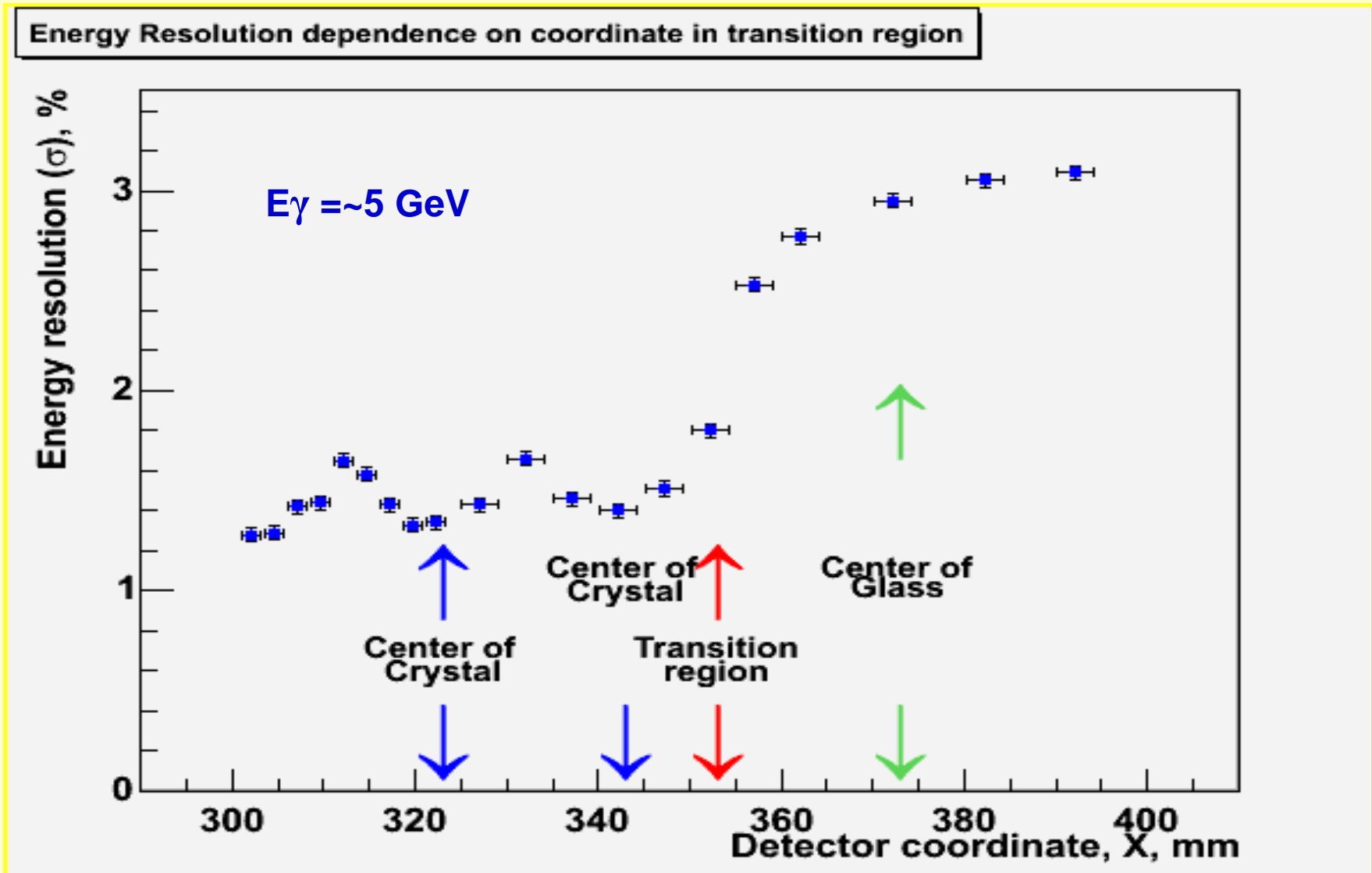


Resolution for Lead Glass

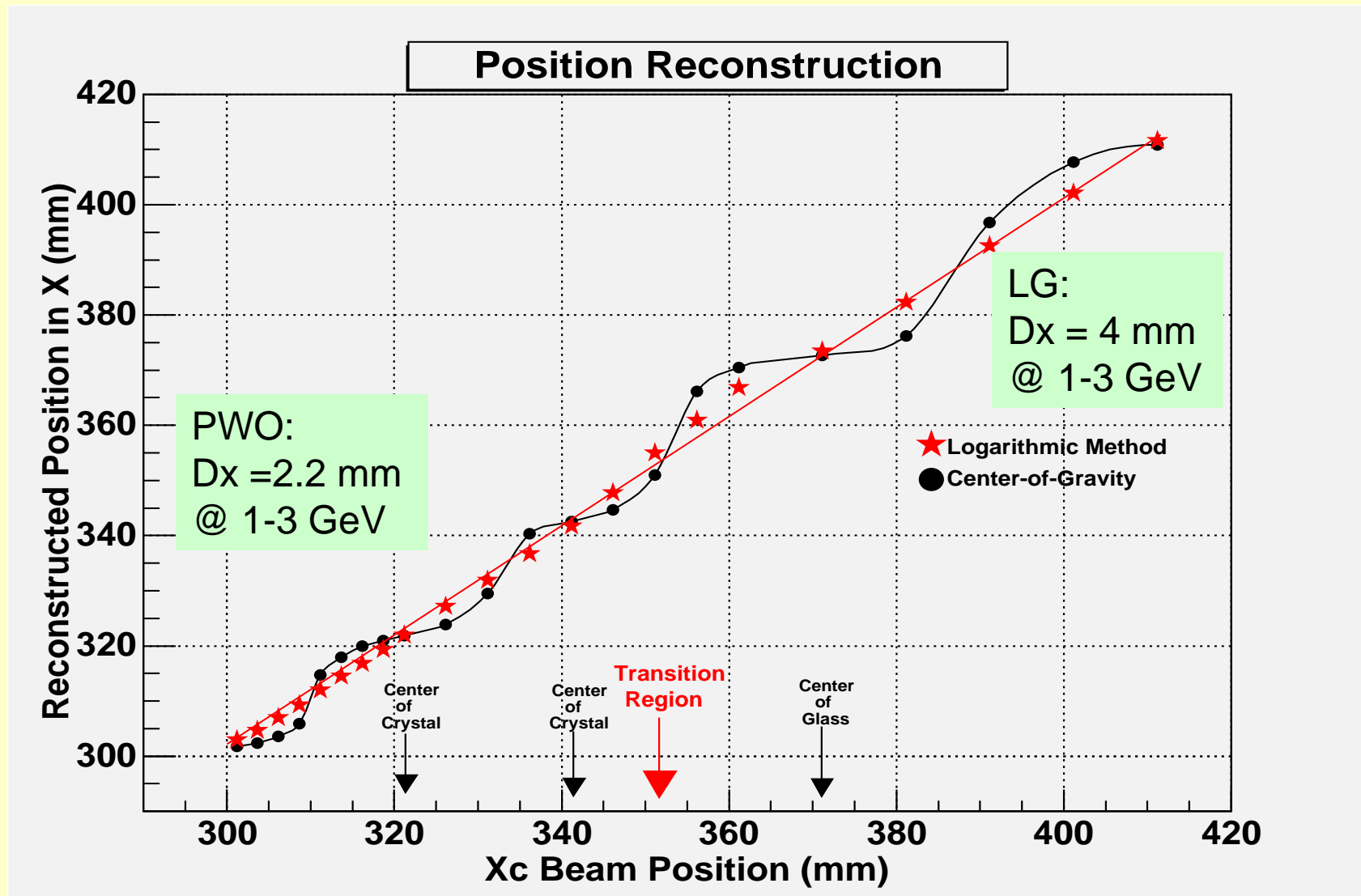


Energy resolution for the PWO crystal central part and lead glass periphery for tagged photons during calibration run

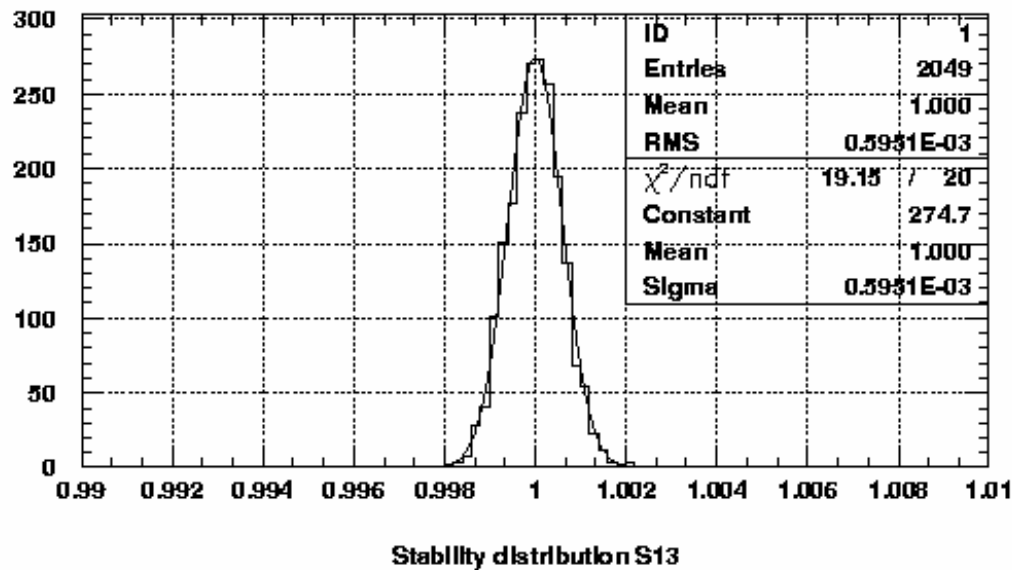
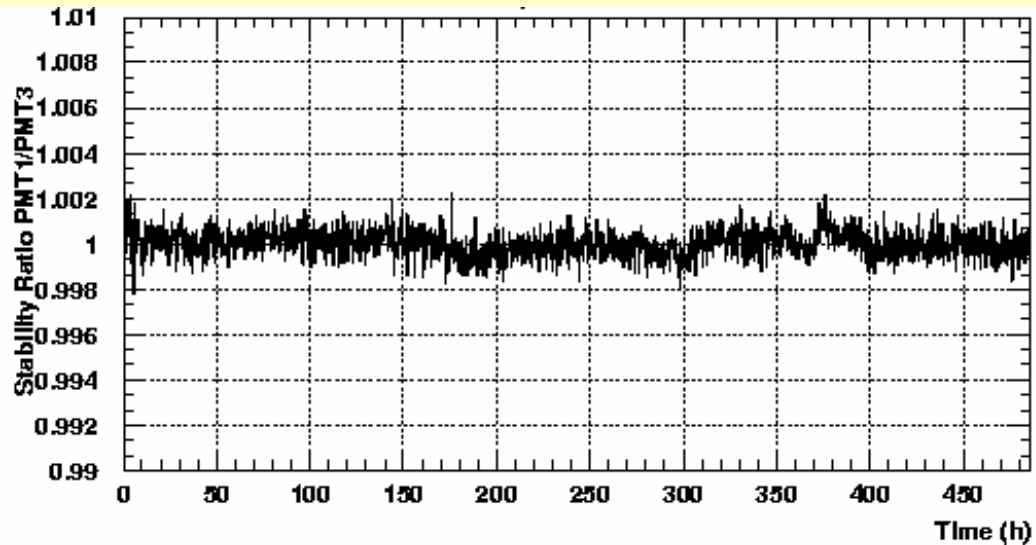
HYCAL Energy Resolution



HYCAL Position Resolution

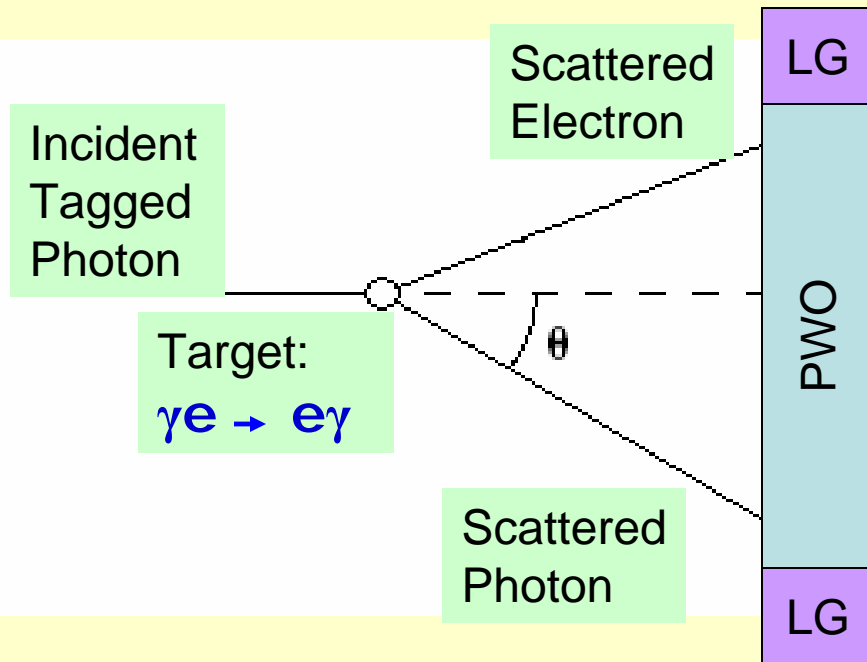


HYCAL Light Monitoring



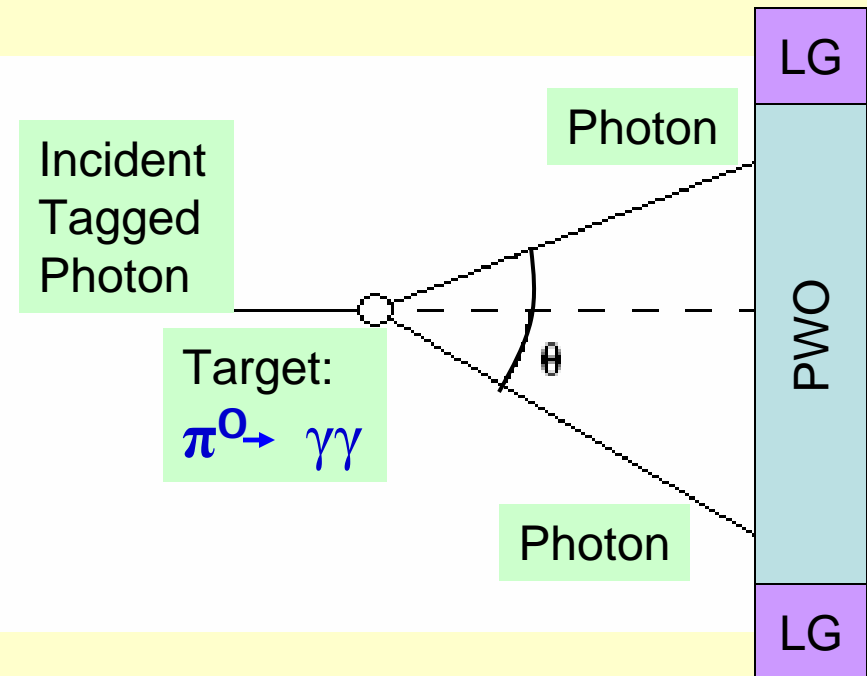
Light monitoring system with blue LED: stability over period of 500 hours

HYCAL Performance for Physics Processes:



Compton scattering at small angles mostly (only PWO):

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

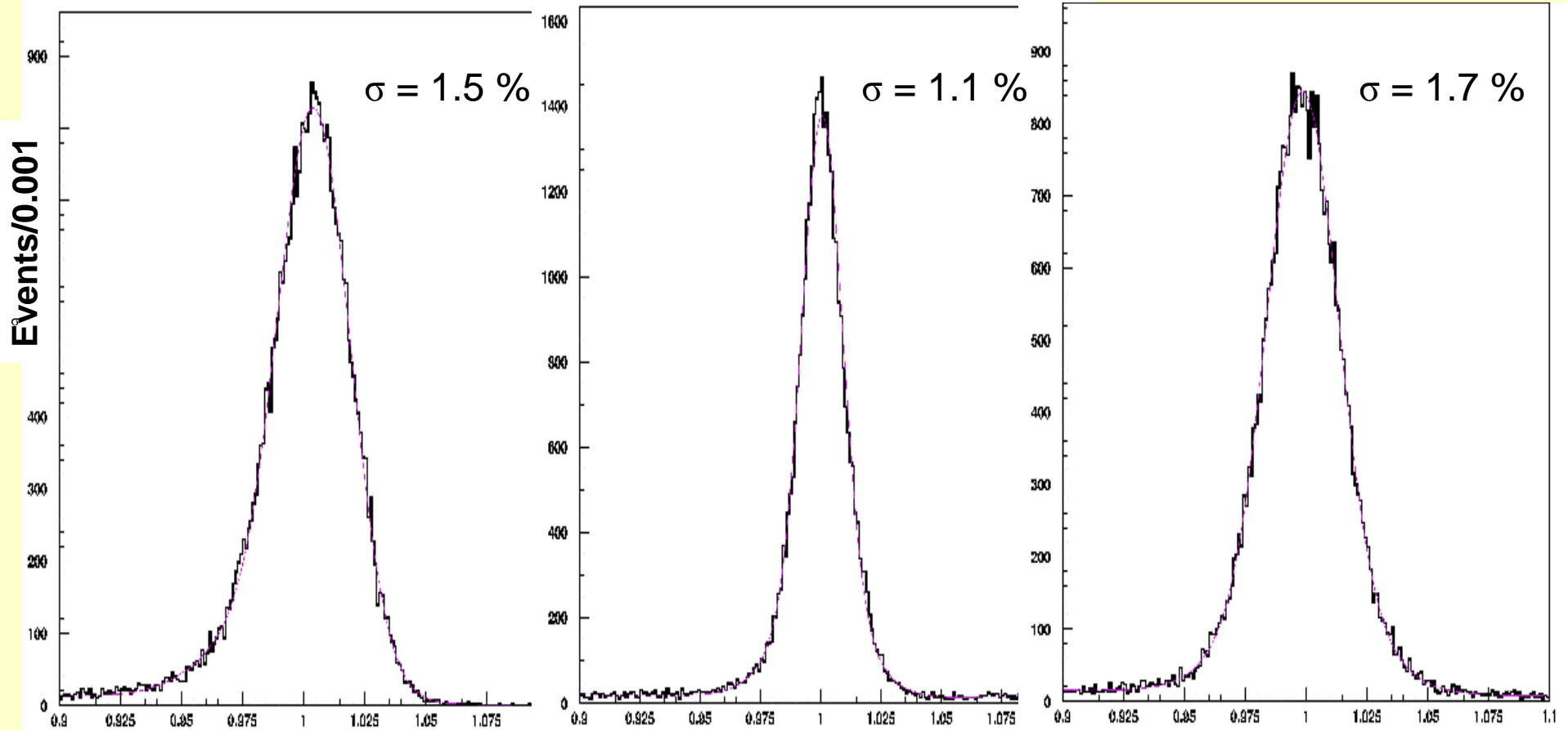


π^0 production and decay to two photons at all angles (PWO and LG):

- constraint on mass of π^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 γ energy at ~ 5.2 GeV



after calibration

Calor-2006, June 05

after Pt = 0 correction

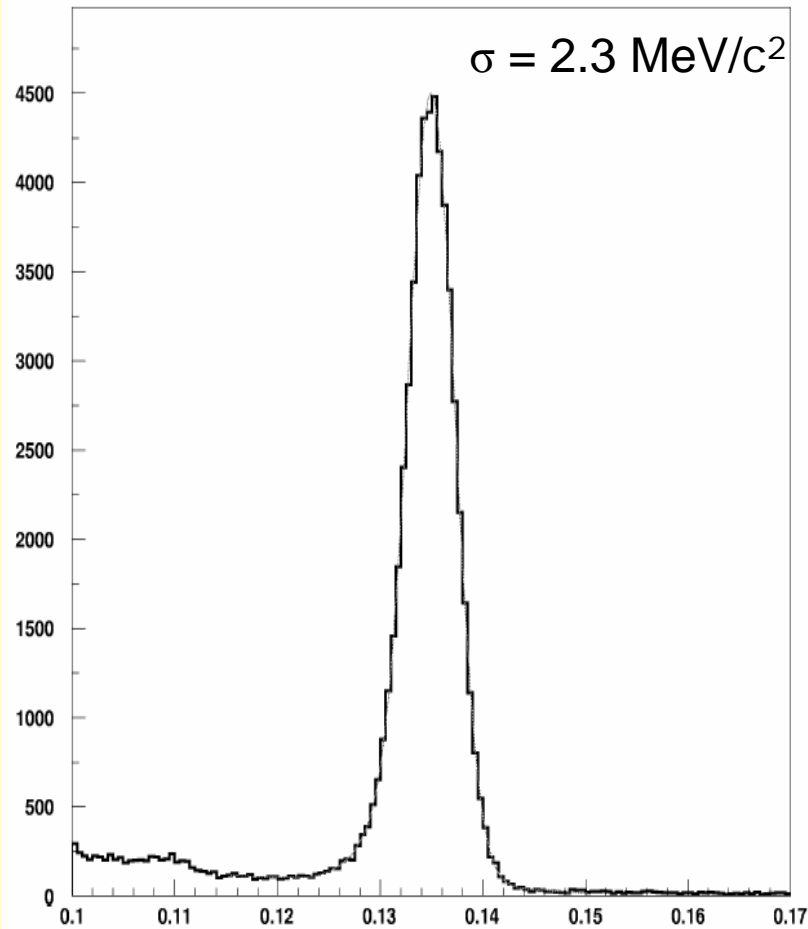
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only coordinate

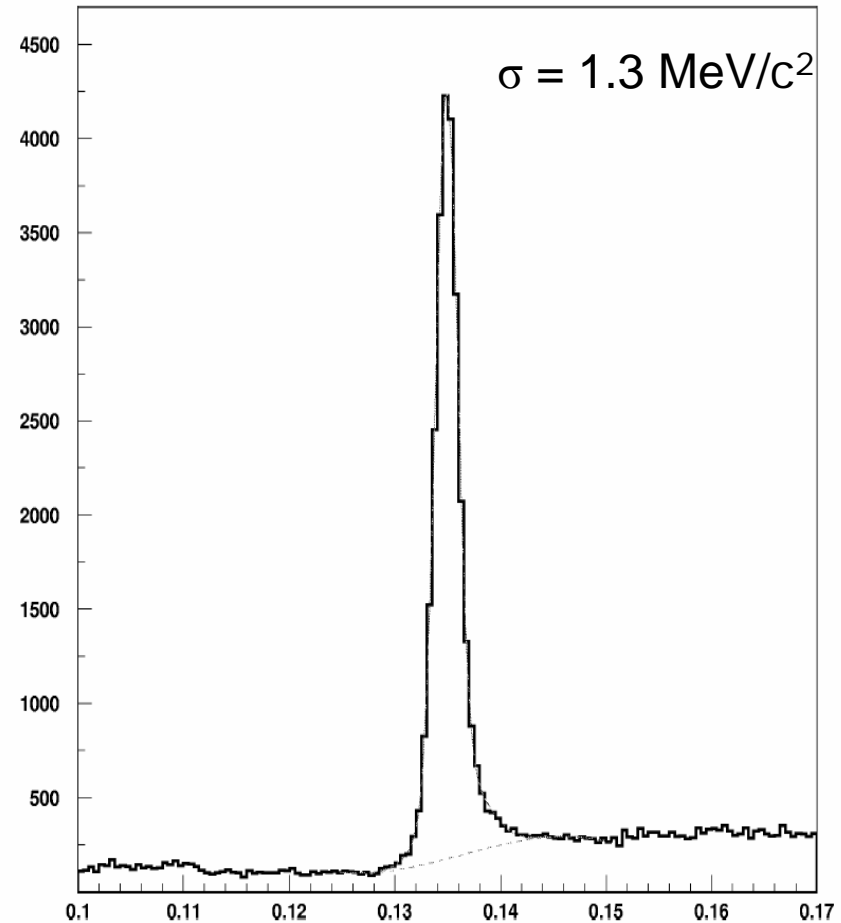
information 15

HYCAL π^0 Resolution: PWO

Events/0.5 MeV/C2

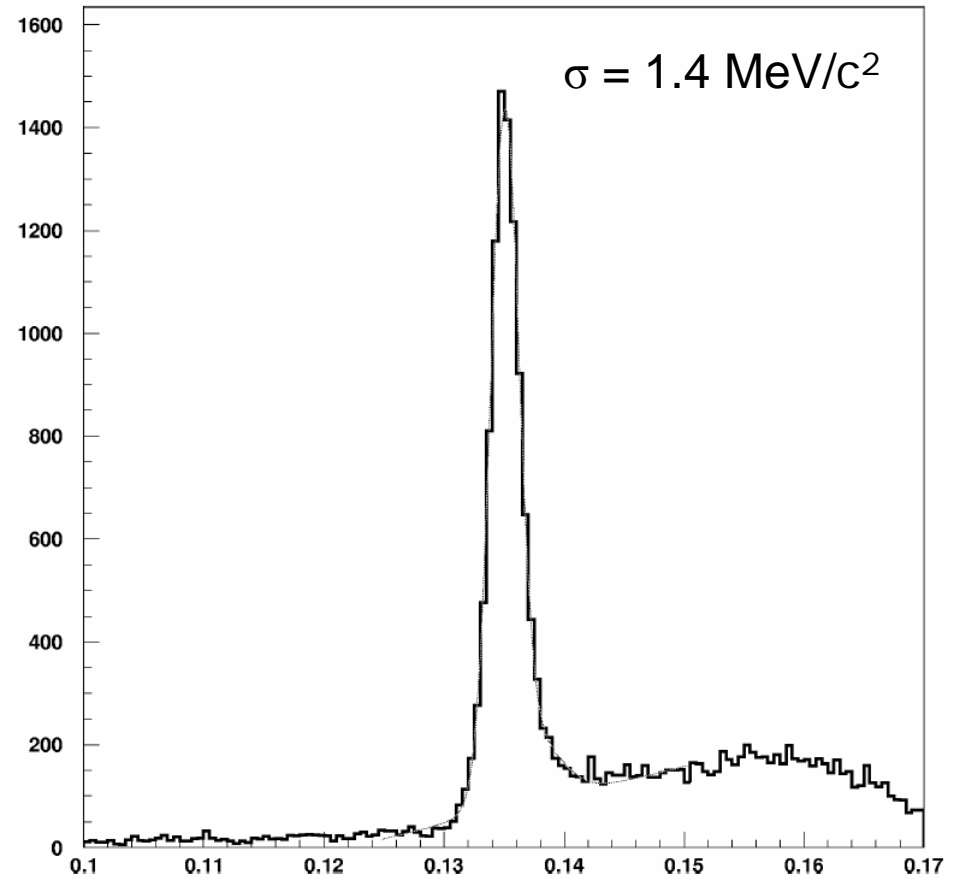
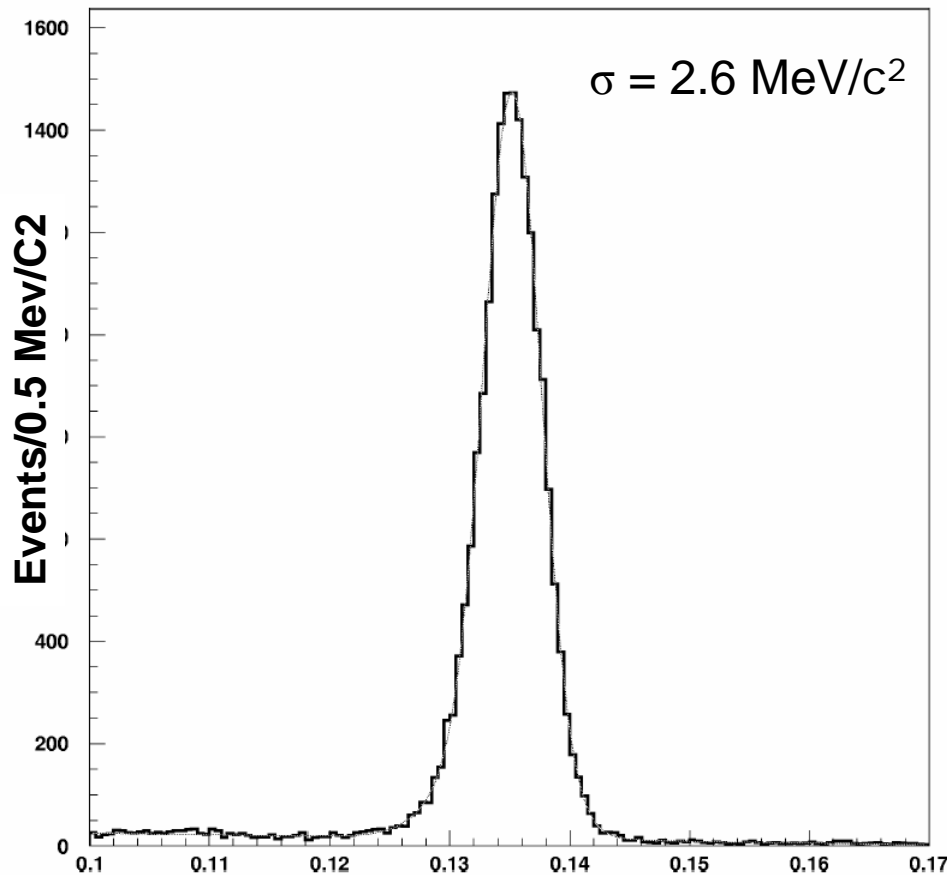


after calibration



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

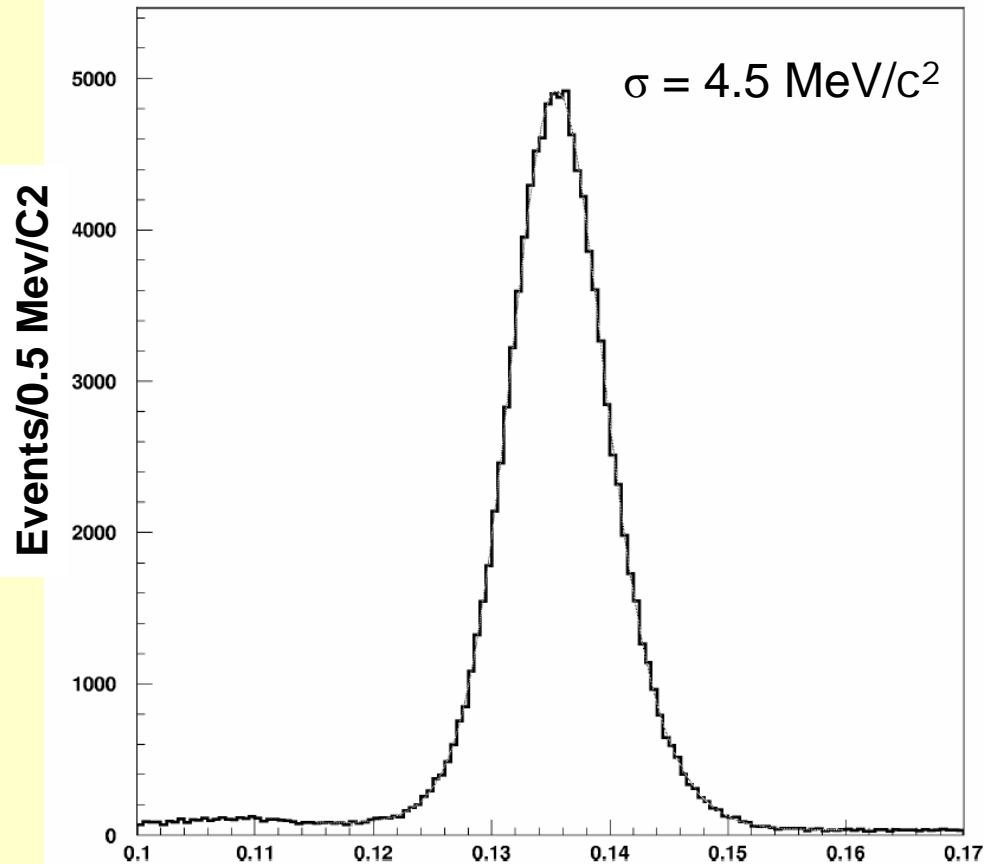
HYCAL π^0 Resolution: PWO-LG Border



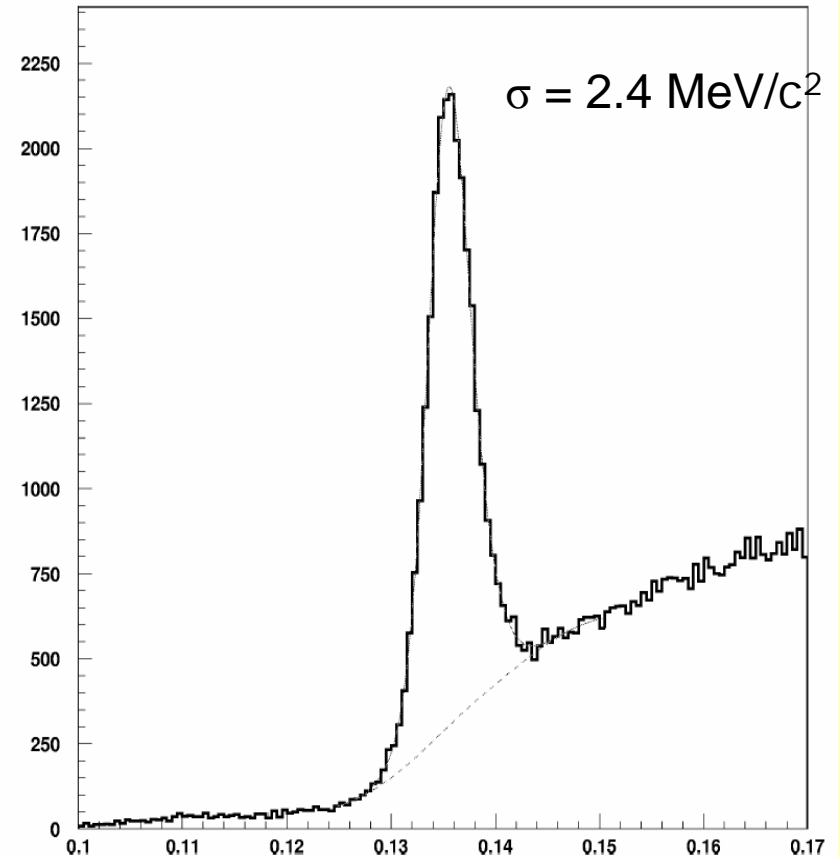
π^0 mass resolution after calibration: one photon in PWO another at the border

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

HYCAL π^0 Resolution: PWO + LG

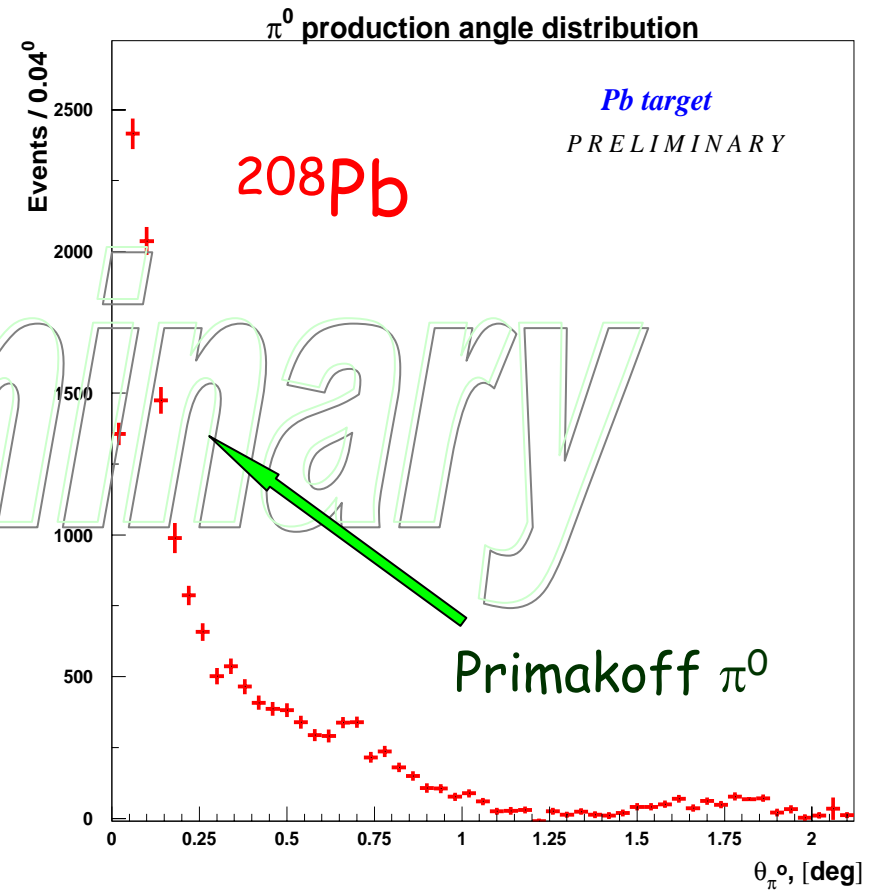
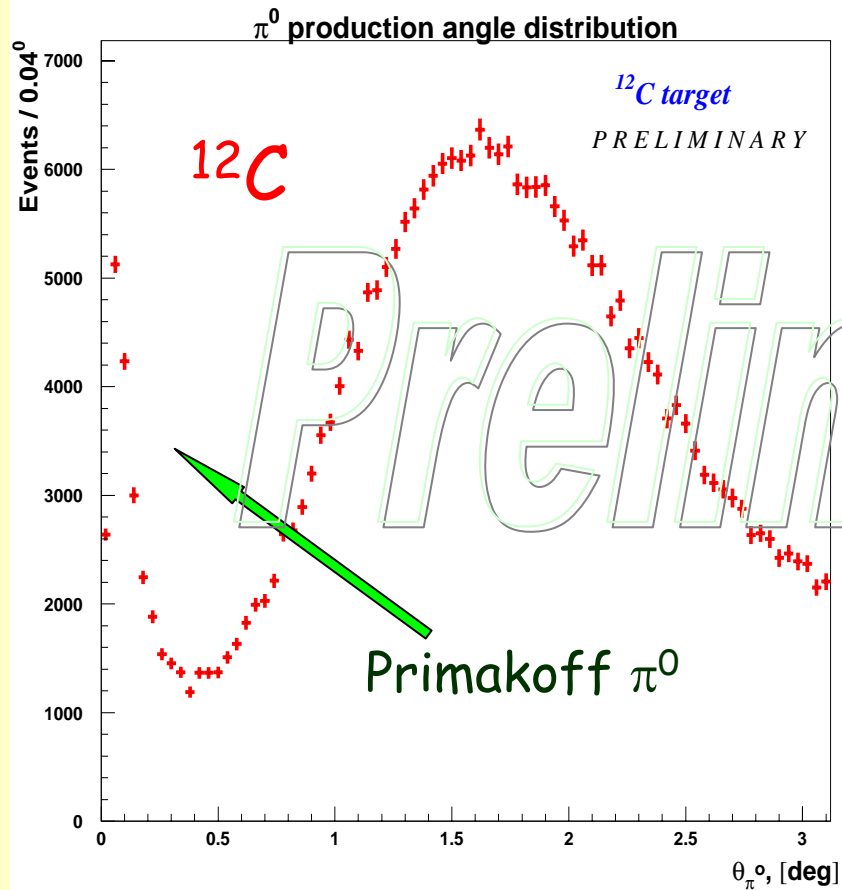


π^0 mass resolution after calibration: one photon in PWO another in LG



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

π^0 Angular Distribution (experiment, preliminary)

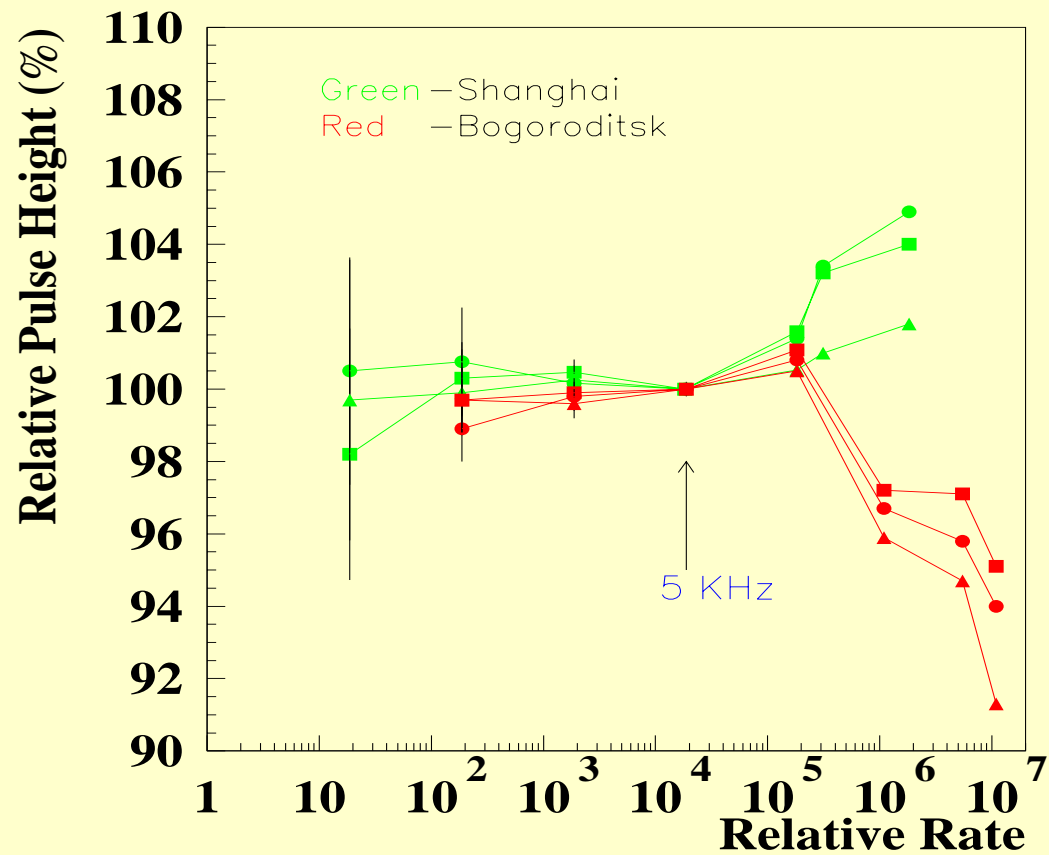


Summary

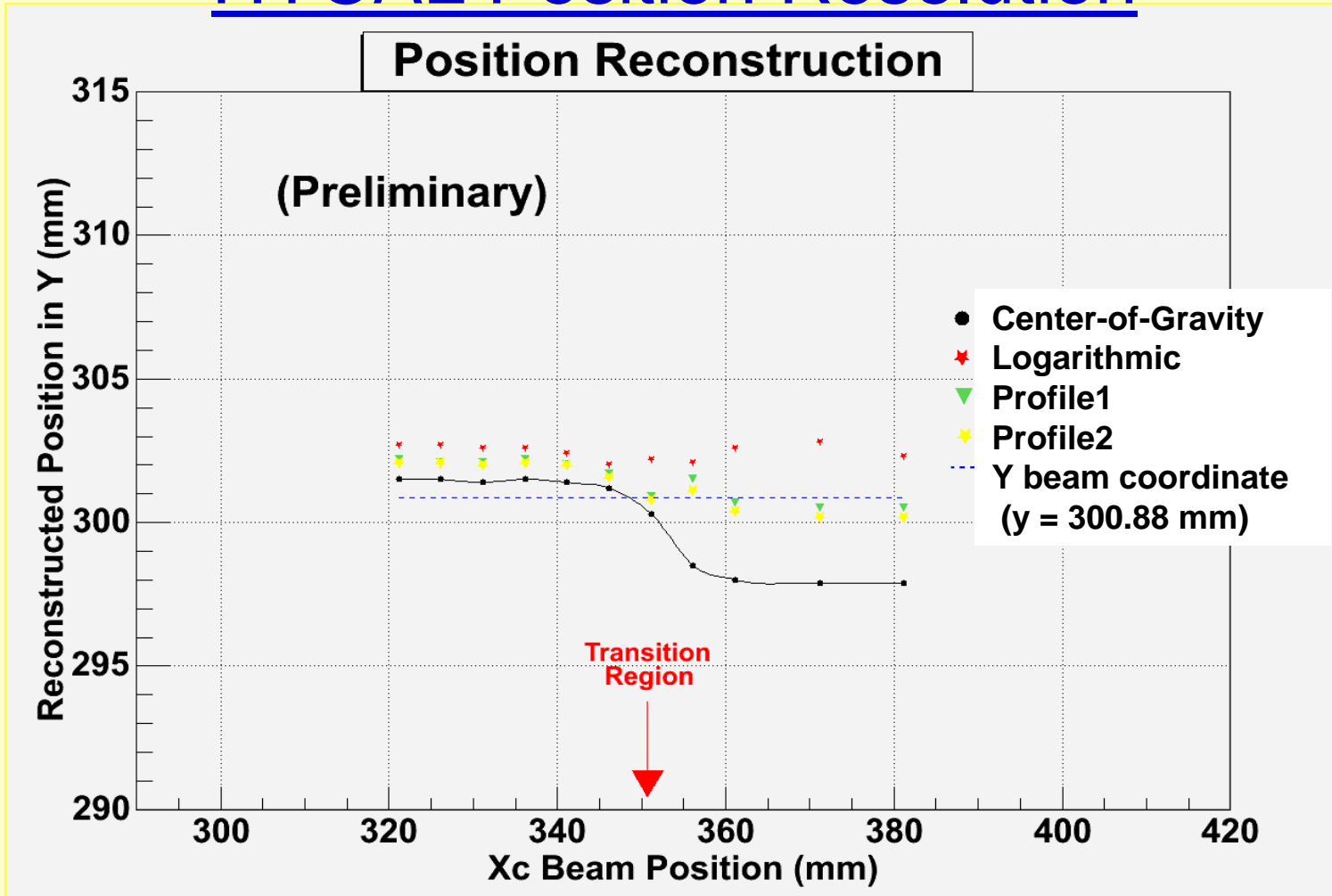
- A high performance hybrid PbWO_4 calorimeter (~2000 channels) has been developed, constructed and run in PrimEx experiment at JLab.
- HYCAL took physics data in November 2004:
 - ❑ Energy and position calibration with tagged photons of 1 – 5.5 GeV
 - ❑ π^0 mass resolution $\sigma_{\pi^0} = 2.3$ MeV (PWO),
(with energy constraint on the tagger 1.3 MeV)
 - ❑ Rich high quality data sets have been collected to extract π^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

PbWO₄ 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:

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