IMPRESSIONS

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ITEP, Moscow/Northwestern University, Evanston

CALOR06 AGENDA

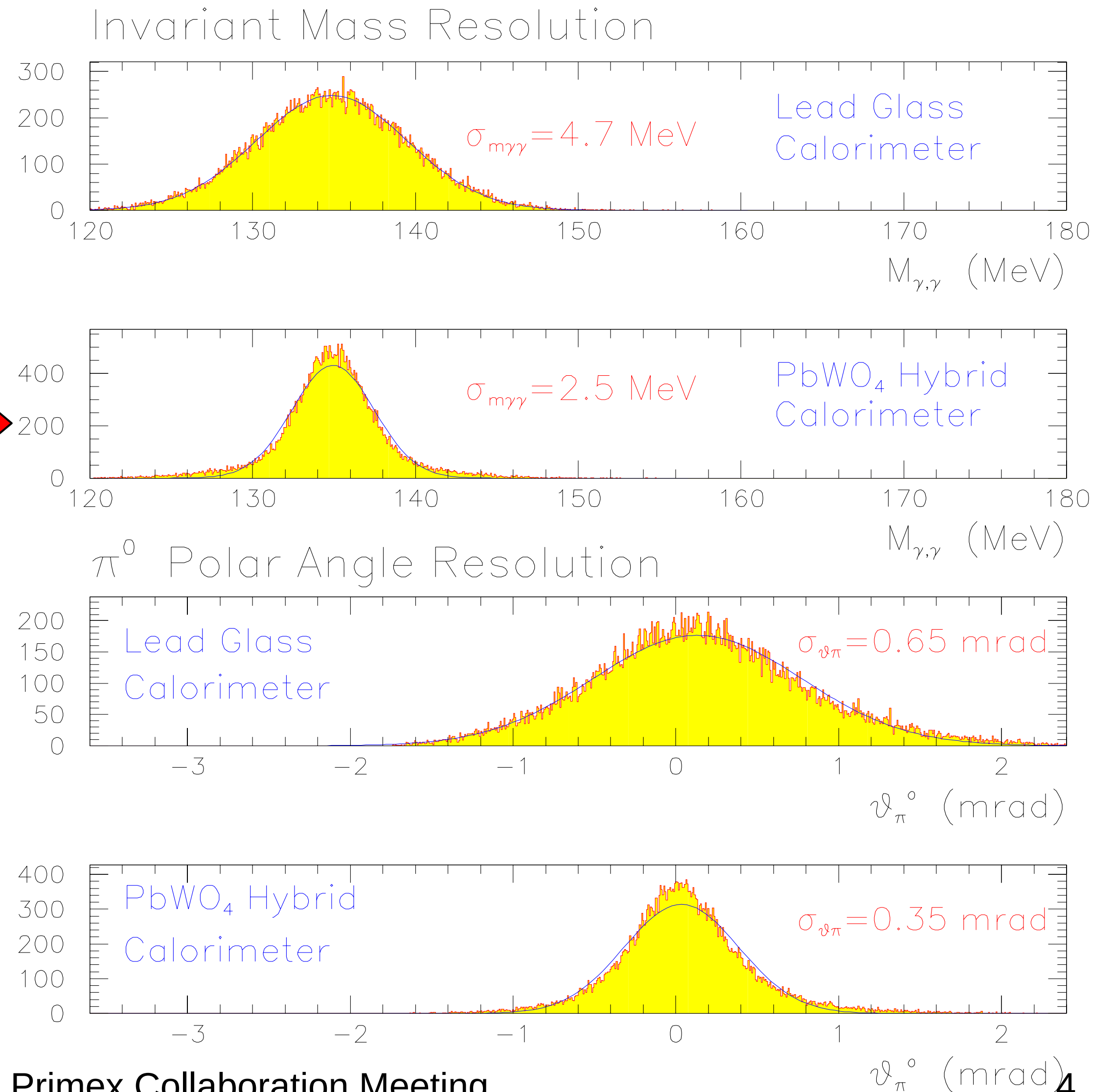
- Operating calorimeters:

  By far PRIMEX HYCAL over-performs any of presented operating calorimeters
- Calorimeter technologies: PANDA EMC
- Astroparticle and neutrino calorimetry/detectors
- LHC calorimetry status
- ILC calorimetry directions
- Medical applications (tomography) – only reviews
- Simulations

PRIMEX HYCAL PRESENTATION

- **Requirements for the Calorimeter**
- **The HYCAL calorimeter design**
- **Physics run performance**
- **Summary.**

Requirements for the PRIMEX Calorimeter

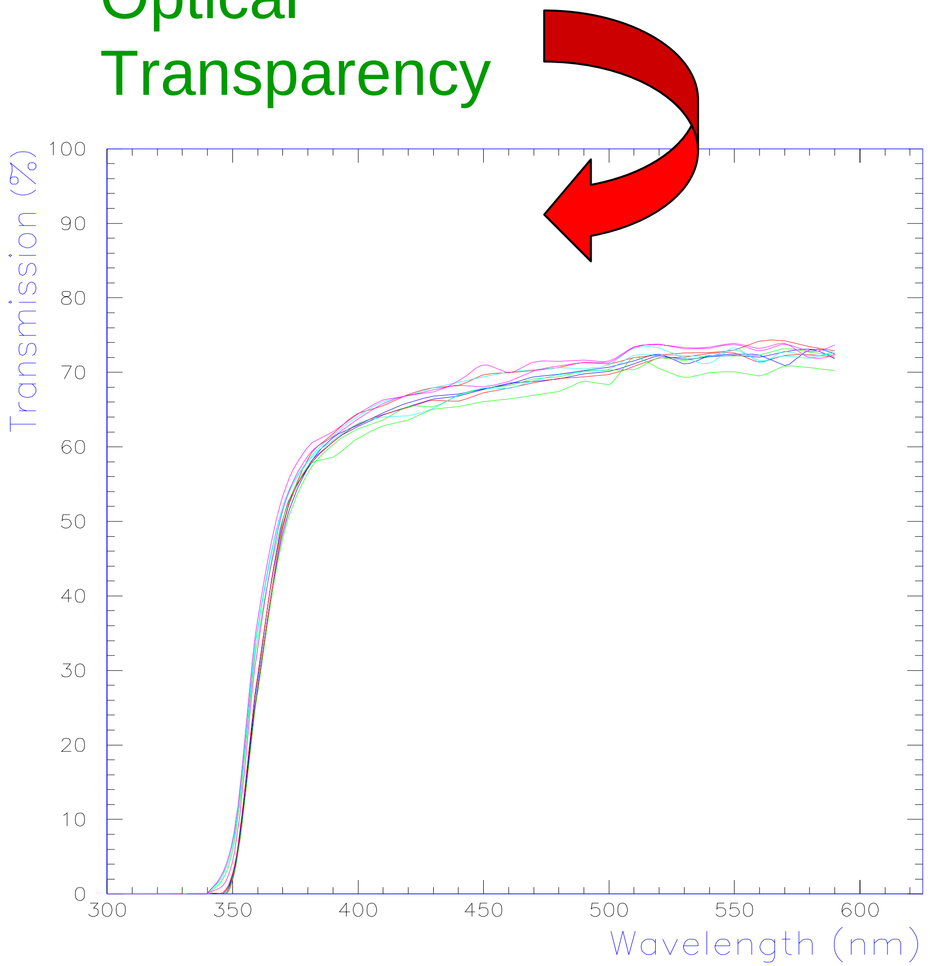


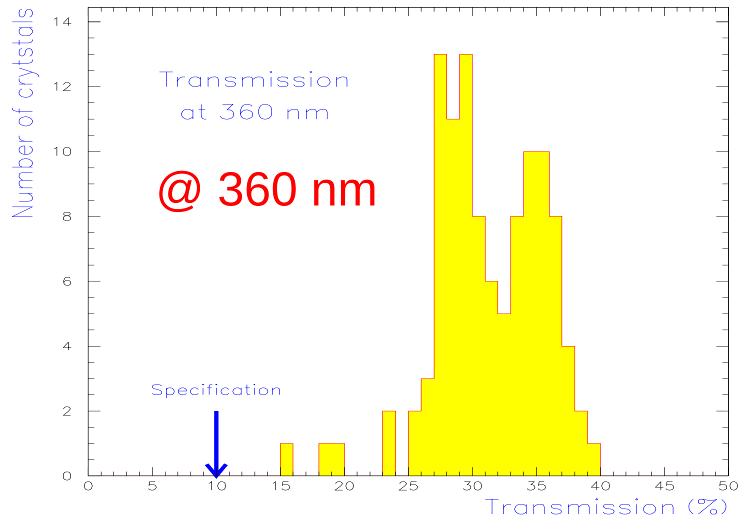
γγ Invariant Mass Resolution

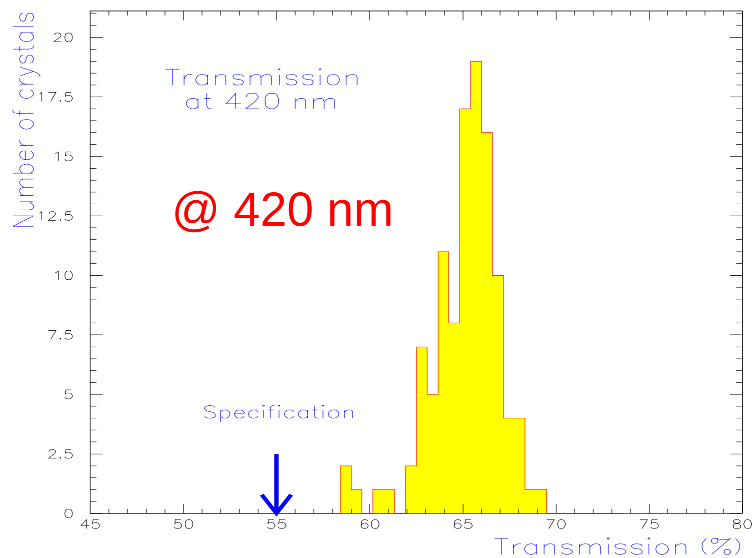
Angular Resolution

$PbWO_4$ Crystal Optical Properties

Optical Transparency

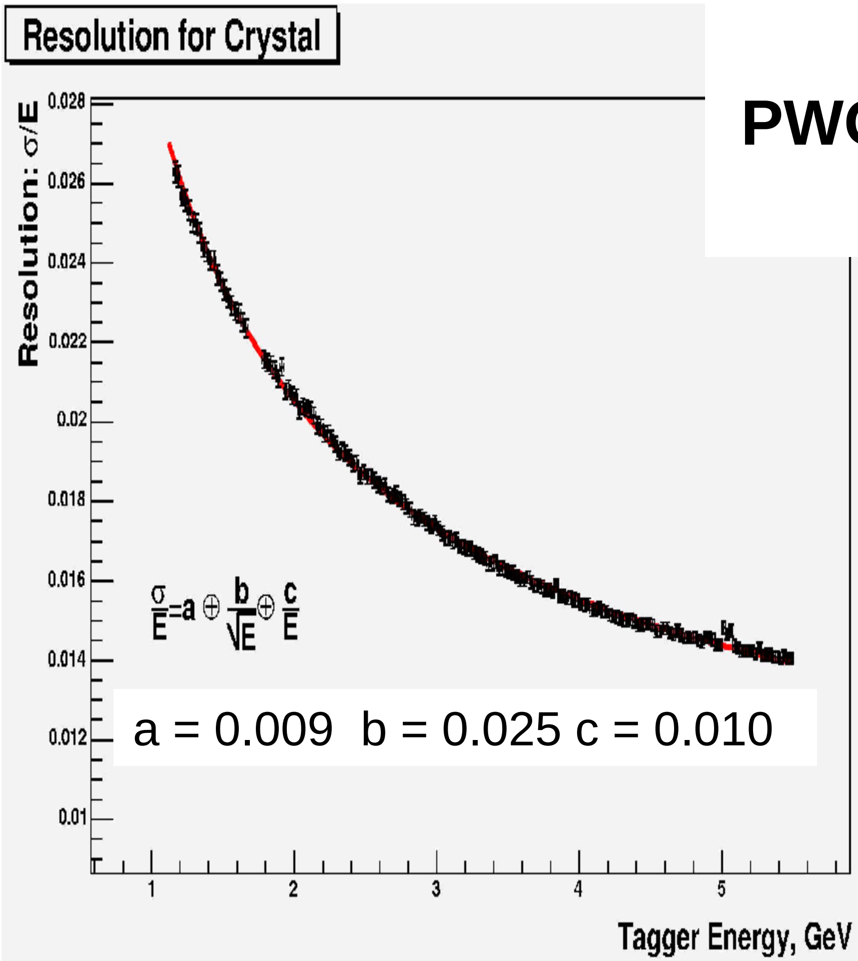




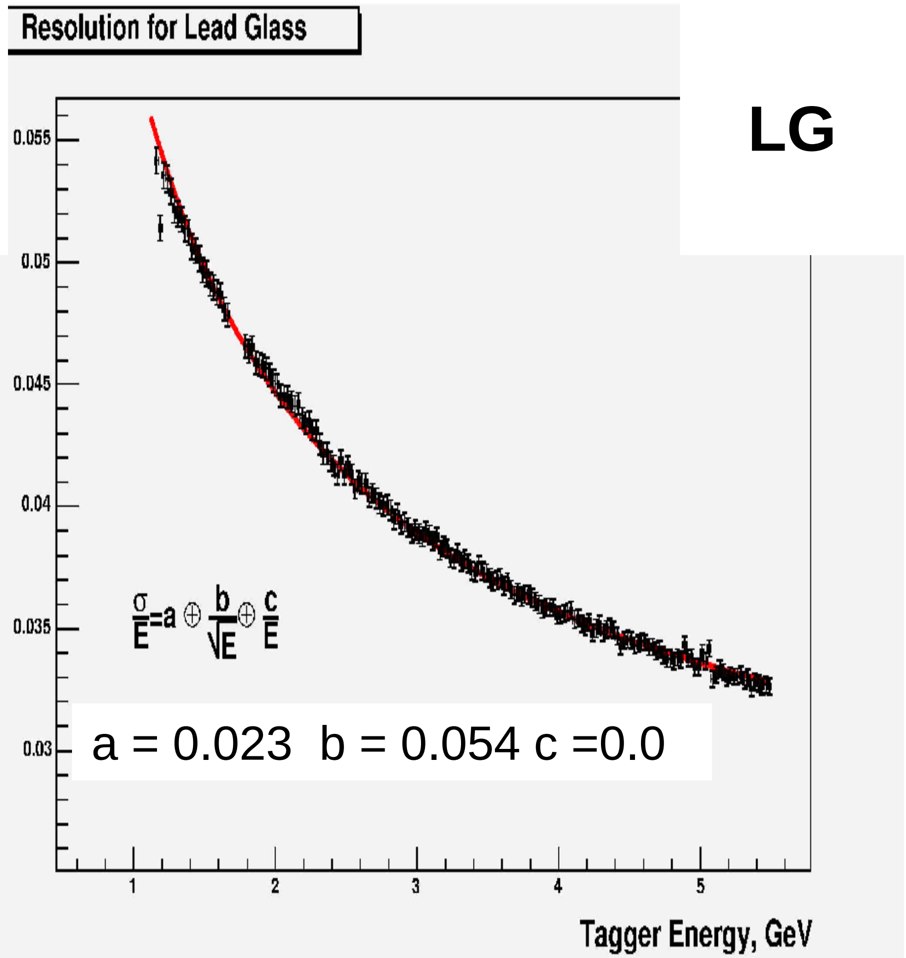


HYCAL Energy Resolution

- Calibration in the tagged photon beam

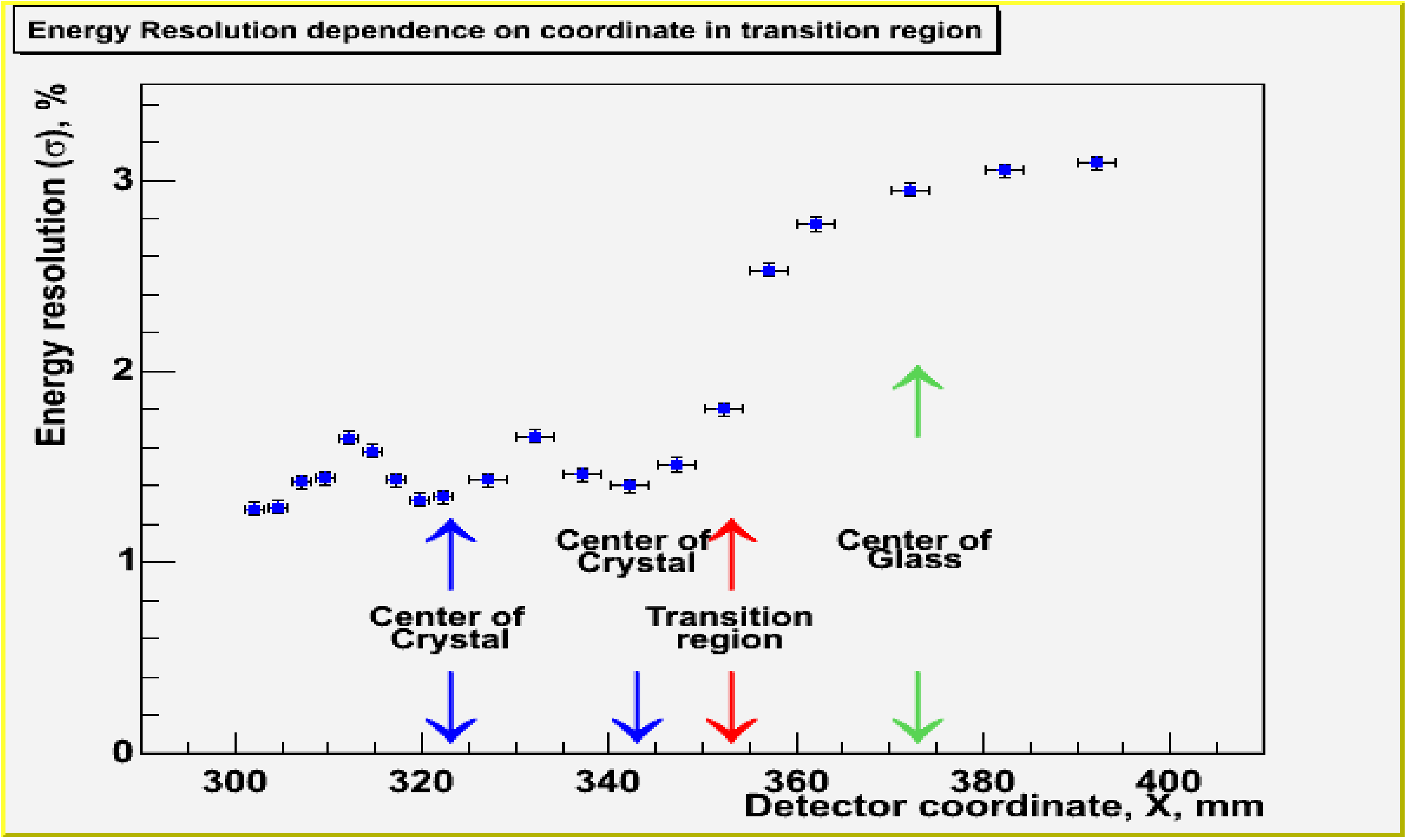


PWO



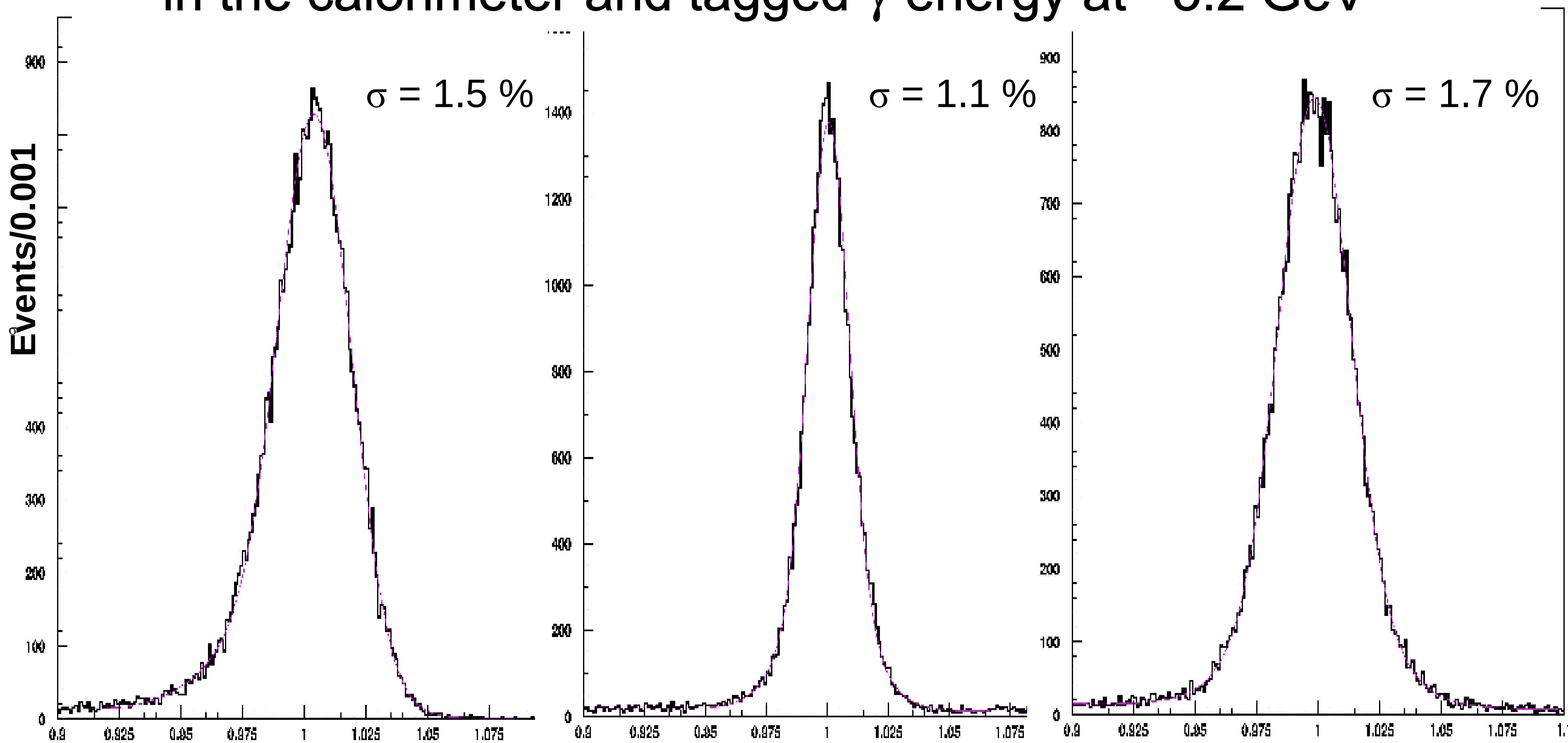
LG

HYCAL Energy Resolution



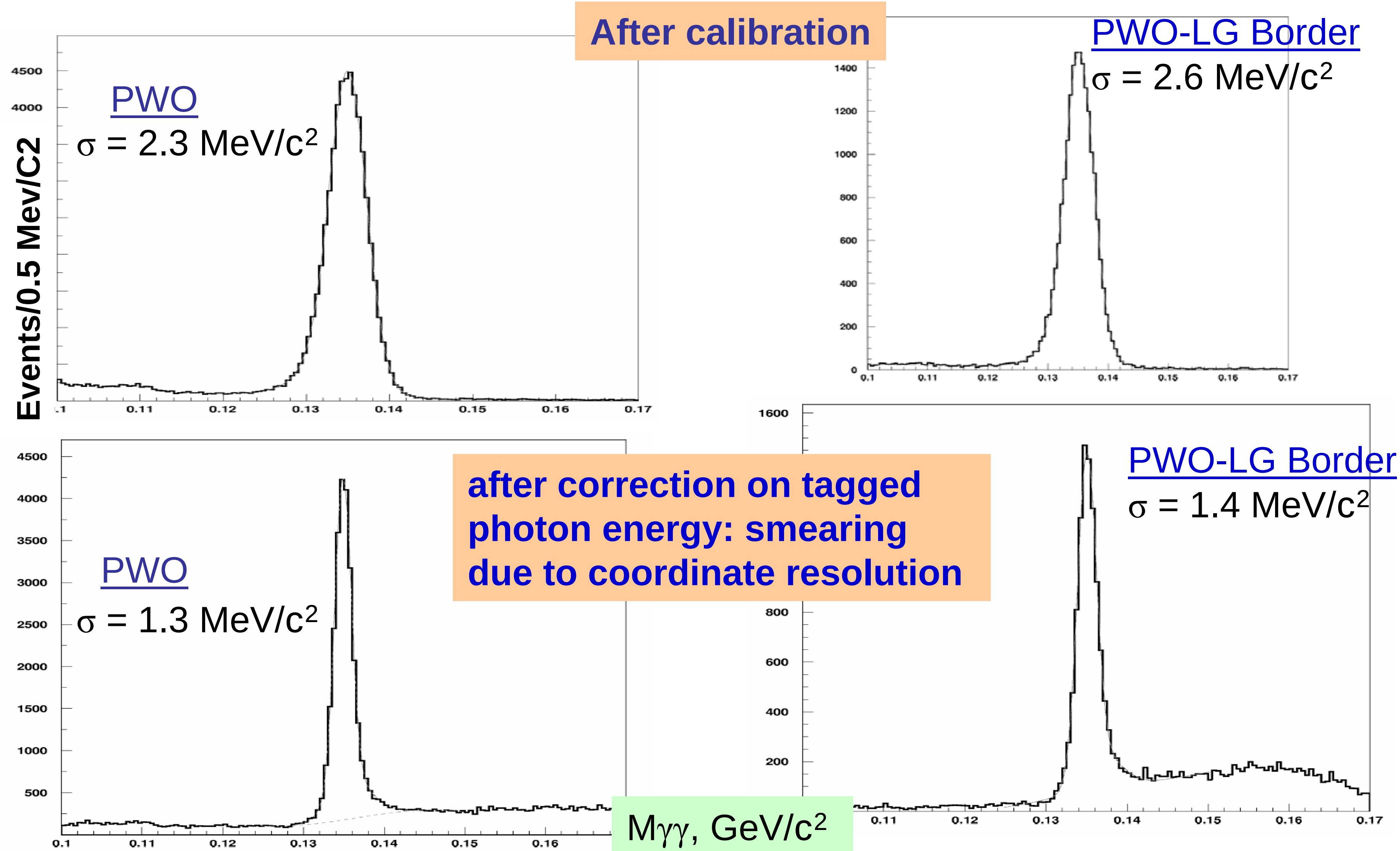
HYCAL Resolution for Compton

Ratio of sum of electron and photon energies measured in the calorimeter and tagged γ energy at ~5.2 GeV



after calibration | **after Pt = 0 correction** | **only coordinate information**

HYCAL π^0 Resolution



HYCAL Presentation 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 σ_{π^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

Production and Development of Crystals for Calorimetry

- PWO for PANDA experiment:

  development new improved crystals with Russian vendors
- CMS EM PWO production experience:

  final results of production and conclusions
- no other new exciting crystals presented for calorimetry

R. Novotny
2nd Physics Institute
University Giessen

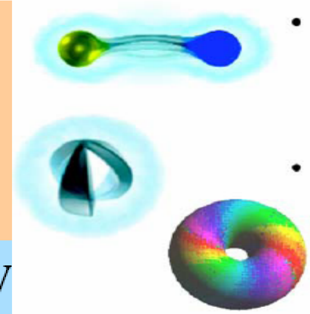
AntiProton ANnihilations at DArmstadt

- physics program
- experimental requirements

- the detector concept of the EMC
- the new generation of $PbWO_4$: PWO-II
  - the scintillation properties
  - thermal quenching
  - response functions (PM- or APD-readout)
  - ongoing R&D
- status and time-schedule for operation

PANDA PHYSICS & CALORIMETER

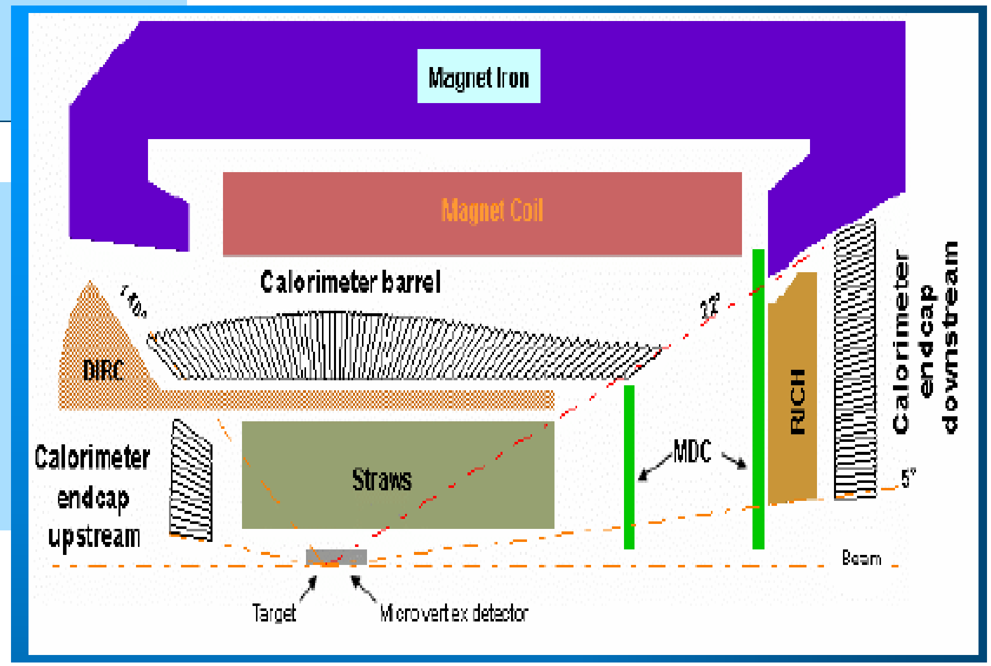
Physics with $\bar{p}$



- **hybrids**: "ordinary" quark states containing excited glue
- **glueballs**: gluonic states without valence quark contribution

- charmonium spectroscopy
- gluonic excitations (hybrids, glueballs, ...)
- open and hidden charm in nuclei
- γ-ray spectroscopy of hypernuclei

- **HESR** = High Energy Storage Ring
  - production rate 10^7/s
  - $P_{beam} = 1.5 - 15$ GeV/*c*
  - $N_{stored} = 5 \times 10^{10}\ \bar{p}$



PANDA CALORIMETER:

• nearly 4π coverage	compactness	dense scintillator, small X_o, R_M
• high rate capabilities	granularity fast response	fast scintillator, short decay time timing information
• high resolution $10\ MeV < E_\gamma < 8\ GeV$	high luminescence effficient photosensor	bright scintillator insensitive to MF

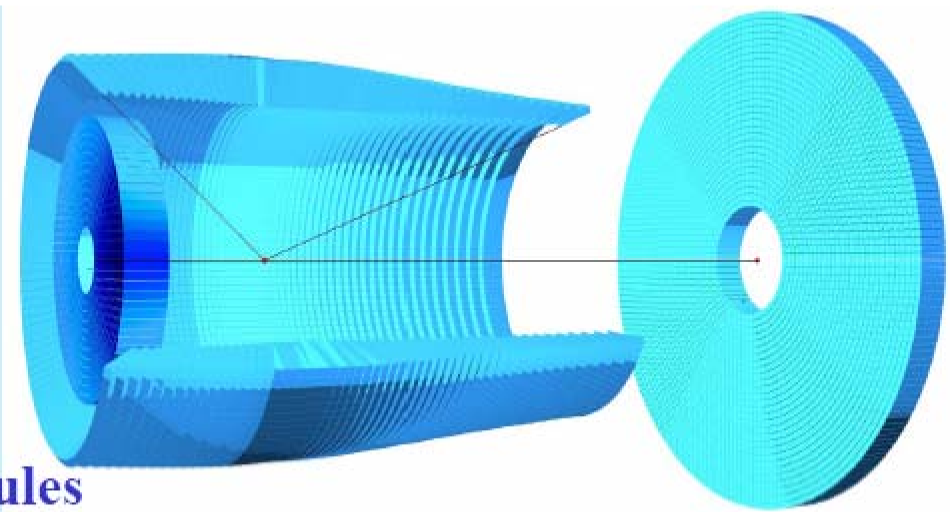
→ **PWO**

barrel:
11360 crystals

forward endcap:
6864 crystals

backward endcap:
816 crystals

total ~ 20,000 modules



PANDA PWO Crystal Development

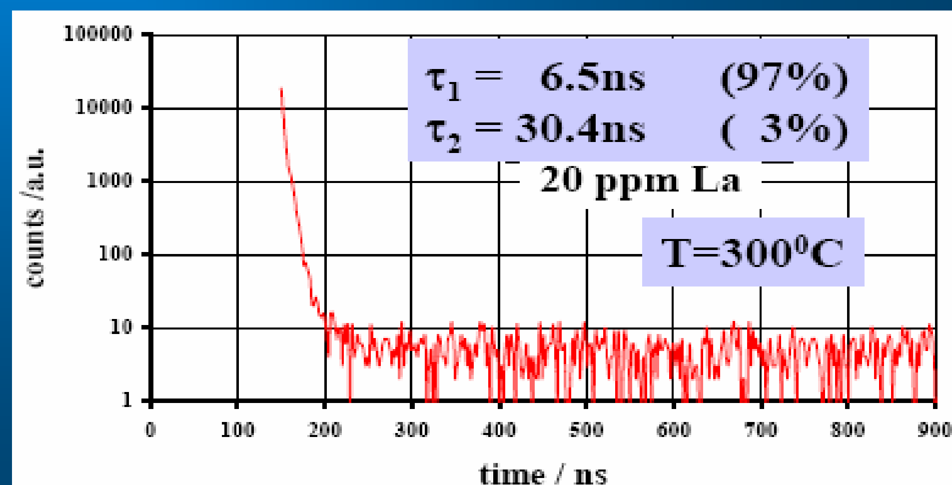
EMC development of PWO-II

optimization of $PbWO_4$ in collaboration with RINP, Minsk and the manufacturer BTCP at Bogoroditsk, Russia

- ✓ reduction of defects (oxygen vacancies)
- ✓ reduced concentration of La-, Y-Doping
- ✓ better selection of raw material
- ✓ optimization of production technology

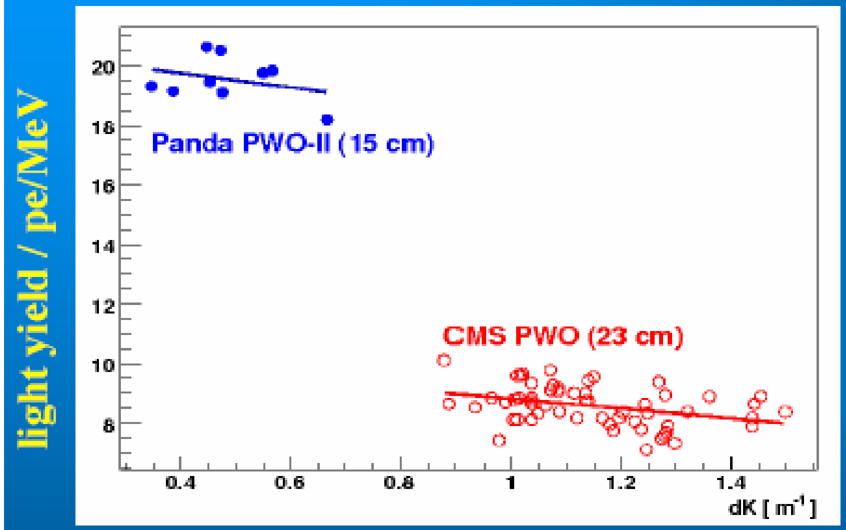
scintillation mechanism

- extreme short decay time (even at -25°C)
- **no** slow components



PANDA PWO Crystal Development

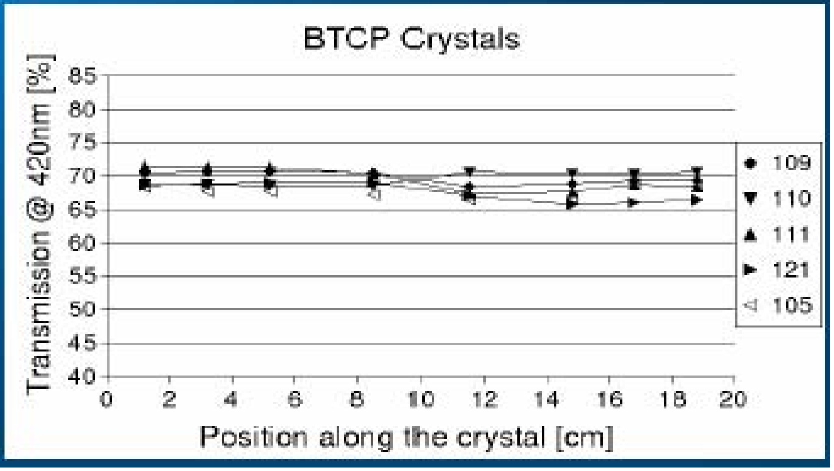
luminescence yield



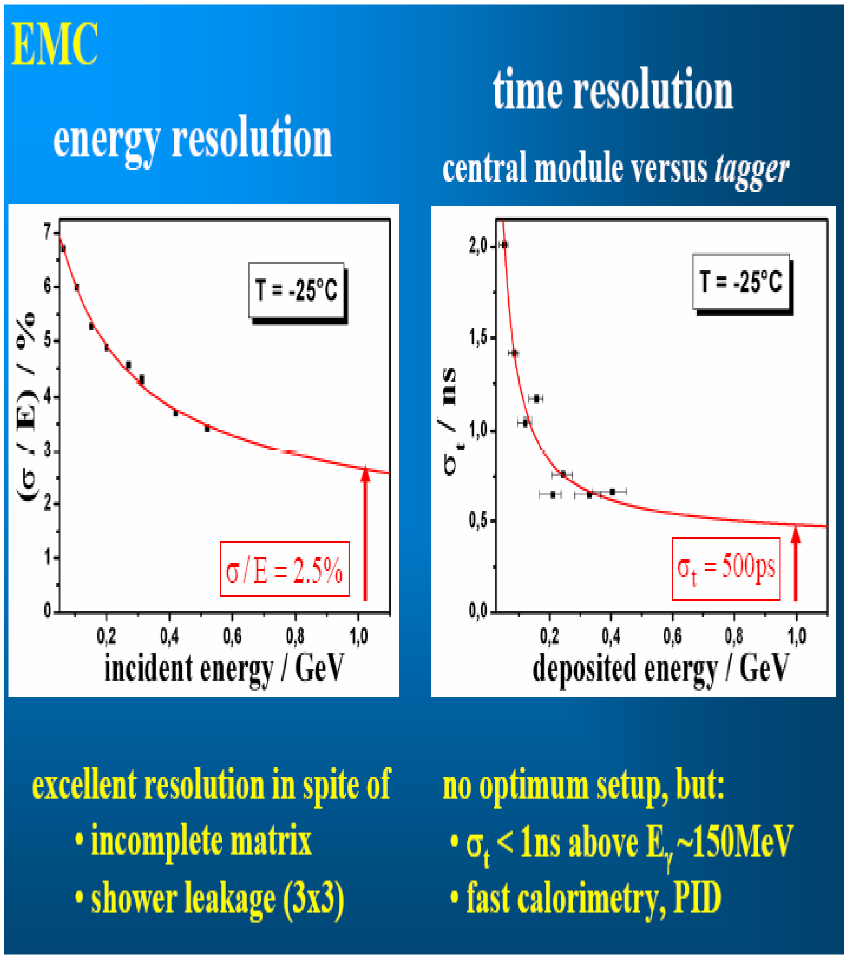
60 prototype crystals for PANDA

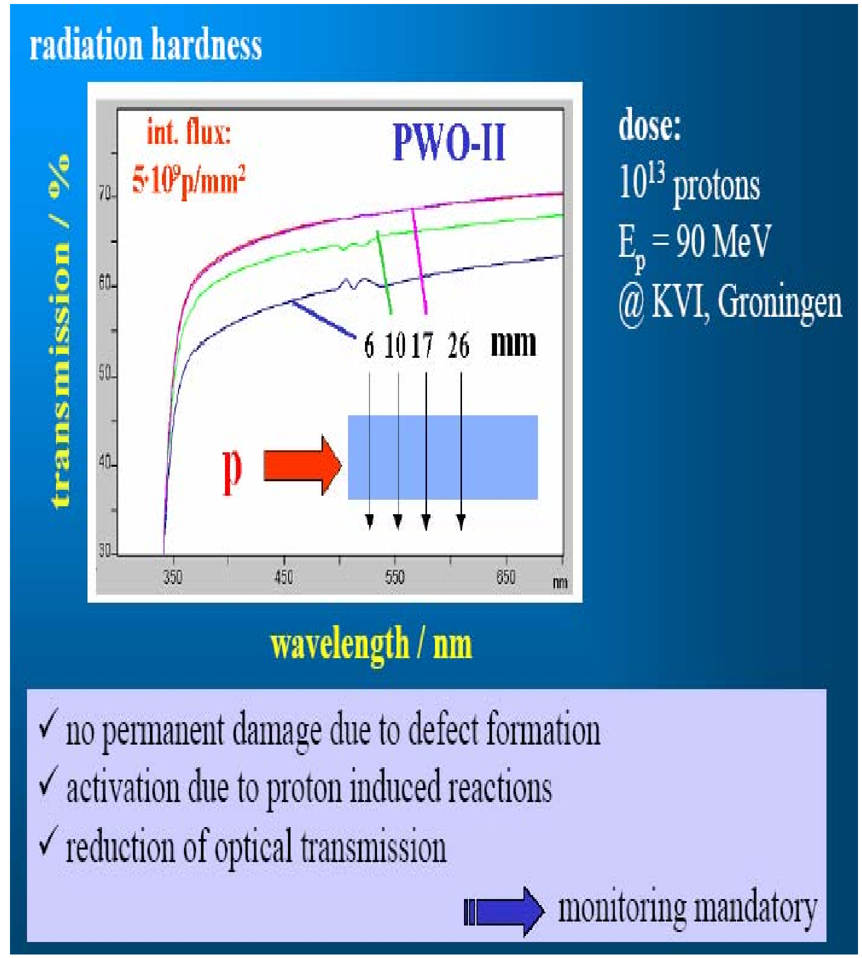
✓ no absorption bands
✓ low absorption edge

✓ extreme **homogeneity**
along the full crystal length of 20cm



PANDA PWO Crystal Development





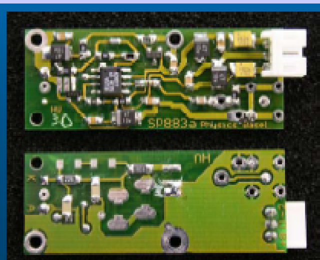
PANDA PWO Crystal Development

readout with **L**arge **A**rea **A**valanche **P**hoto **D**iodes (LAAPD)

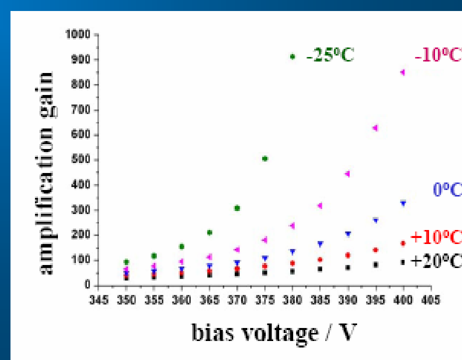
in collaboration with
Hamamatsu Photonics

$10x10mm^2$ $5x5mm^2$

- excellent performance
  at RT and T = –25°C
- radiation resistent
  up to 10^{13} protons
  in particular at T = -25°C
- preamplifier development

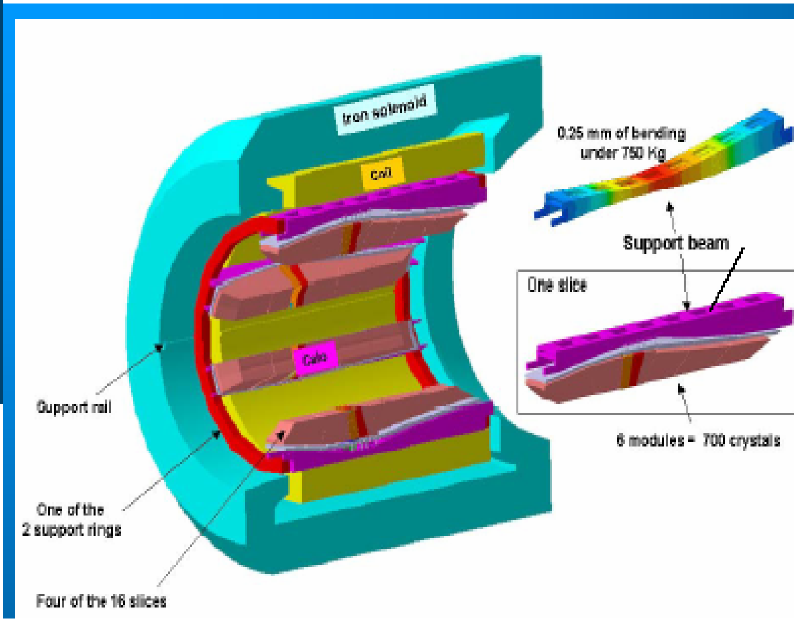


18mm



Calorimeter to be operated at

– (25.0±0.1)°C !



- **very complex and ambitious detector**
- **concept mostly fixed, but R&D still ongoing:**

  cooling technology

  FE-electronics (ASIC), large dynamic range
  energy and timing information
  photosensor of forward endcap (APD/VPT)

EMC very advanced – design to be fixed in middle of 2007

ordering crystals in 2008

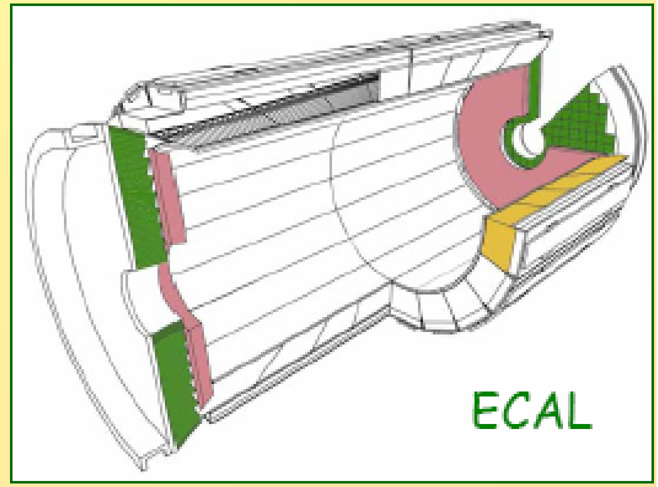
- **PANDA detector to be completed in 2011**
- **2012: start of operation of *PHASE 1***

Crystal Production and Properties in CMS - ECAL

Riccardo Paramatti
INFN - Roma1
on behalf of CMS ECAL Group
Chicago - 6 june 2006

CMS ECAL

- Homogenous calorimeter
- Lead Tungstate Crystals $PbWO_4$
- Solenoidal Magnetic Field: 4 Tesla



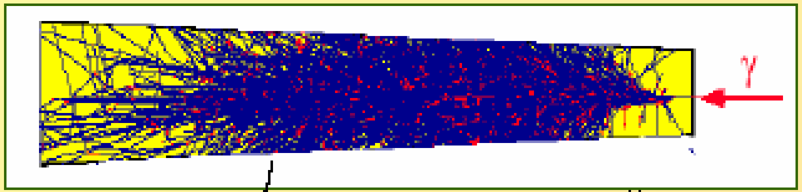
Parameter	Barrel	Endcap
η coverage	$\|\eta\| < 1.48$	$1.48 < \|\eta\| < 3.0$
Granularity ($\Delta\eta\times\Delta\phi$)	0.0175×0.0175	varies in η
Crystal Dims. (cm^3)	$2.18\times2.18\times23$	$2.85\times2.85\times22$
Depth in X_0	25.8	24.7 ($+3X_0$)
No. of crystals	61,200	14,950
Crystal Volume (m^3)	8.14	3.04
Photodetector	APDs	VPTs
Modularity	36 supermodules	4 Dees

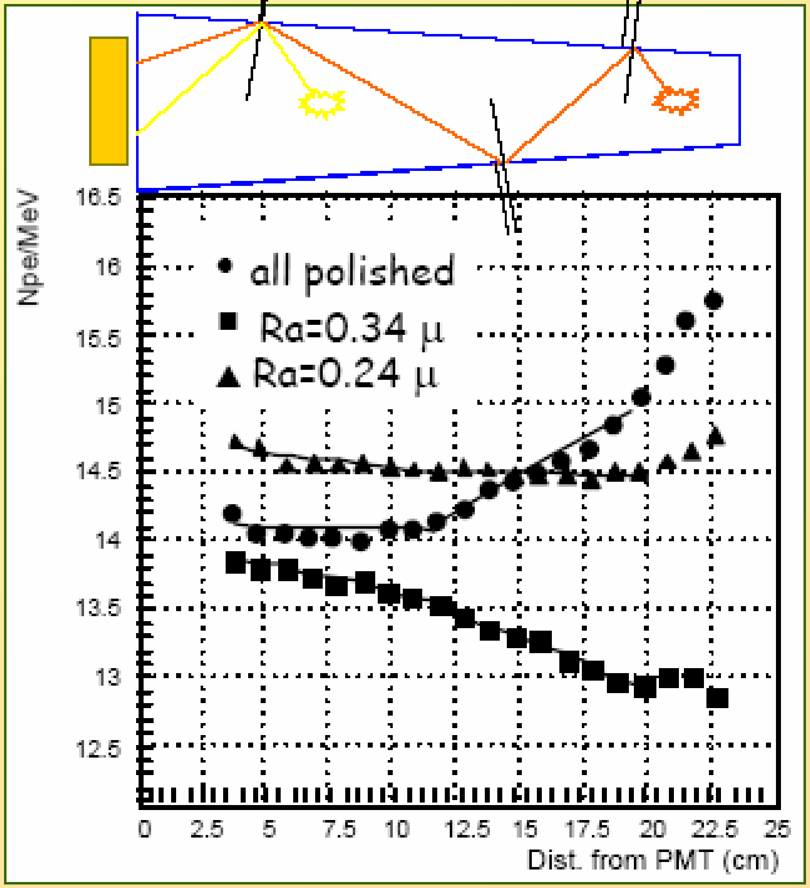
Crystal Producers: Bogoroditsk (Russia), Shanghai Institute of Ceramics (China)
Construction Regional Centers: CERN in Geneva and INFN/ENEA in Rome

Non uniformity of light collection

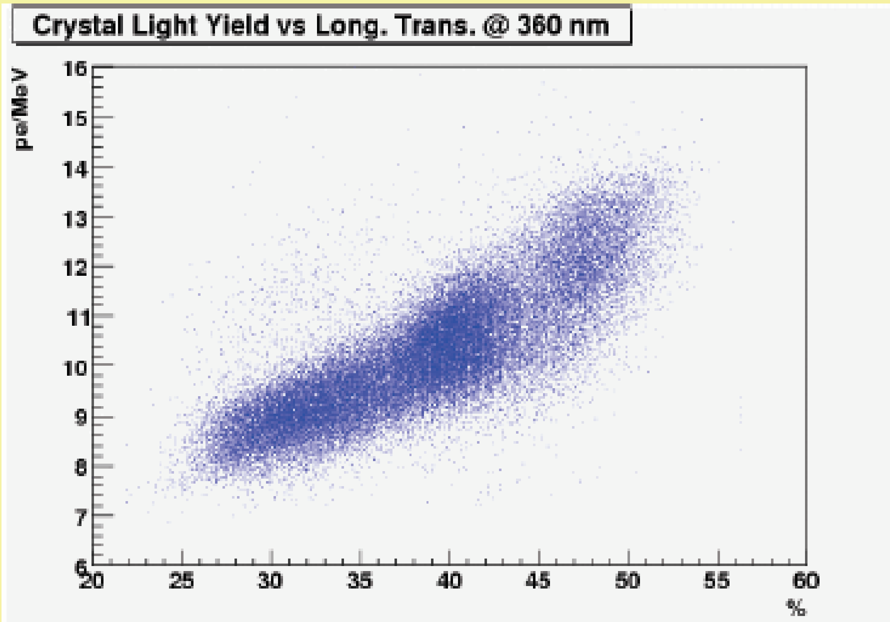
- Smearing of the response at fixed energy due to shower fluctuations (can not be corrected)
- Focusing effect due to tapered shape of crystals: non linearity of the response (can be corrected).
- Uniformity can be controlled by depolishing one lateral face with a given roughness (paying a loss in LY)
- Uniformity treatment is performed in the Prod. Centers.

The contribution to the constant term due to crystal non uniformity should not exceed 0.3% (the global constant term is 0.5%)





LY - Transm. Correlation



<u>Crystal LY is correlated with the position of the absorption edge.</u>

- This correlation is not only self absorption i.e. cannot be entirely attributed to variations of the optical transmission. There is a more general correlation between the amount of light produced and transmission curve edge.

There is no correlation at different wavelength (even in the scintillation peak)

Light Yield vs	Correlation
LT @ 360 nm	77,3%
LT @ 420 nm	1,5%
LT @ 620 nm	1,1%

CMS PWO EM Status

- The construction of CMS ECAL Barrel is in the final phase; the construction of the Endcaps is starting now.

- Production and delivery of crystals drive the calorimeter construction schedule.
  - ~ 51000 (out of 61200) barrel crystals and ~ 500 (out of 14648) endcap crystals.
  - ~ 50000 from Bogoroditsk and ~ 1500 from SIC.
  - 27 (out of 36) barrel SuperModules are mechanically assembled.
  - 18 barrel SuperModules are ready to be installed in CMS.

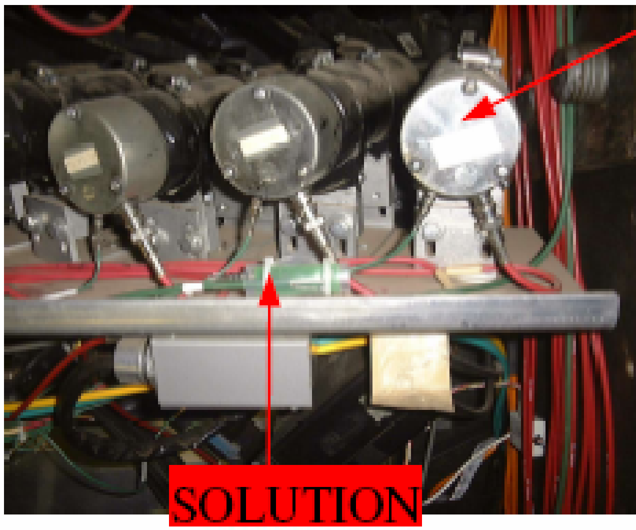
- Crystals are very uniform thanks to the precise depolishing of one lateral face; this allows to reach the foreseen energy resolution.

- A very interesting correlation between LY and Longitudinal Transmission is observed. This additional and independent measurement of the crystal LY leads to an improvement of the LY resolution.

SOME NICE HARDWARE:

Calorimeter Timing System at CDF

Max Goncharov for Texas A&M Group



CEM PMT Base

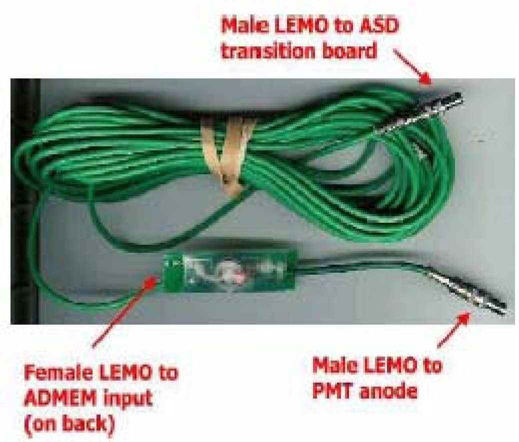
anode provides energy readout

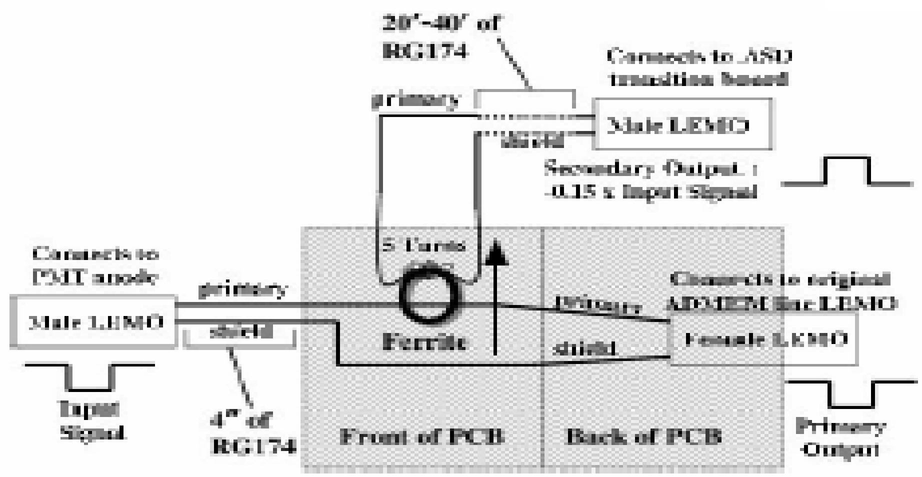
has no dynode readout ...

modify PMT base? ...

cut into the anode line? ...

Whatever you do – DO NOT CHANGE ENERGY READOUT,





Topics not covered

- Neutrino detectors:

  Earth atmosphere or Antarctic ice sheet –

  Cherenkov radiator for calorimetric measurements
- High precision ILC calorimetry: silicon + tungsten, etc
- Simulations

CONCLUSIONS

- Most of the Conference talks were about calorimeters under construction or development or design
- Significant part are not ordinary calorimeters: for example, neutrino detectors, calorimeters for satellites (GLAST)

Spare Slides

Calorimetry in Medical Applications

PET & SPECT

(Positron Emission Tomography and Single-Photon Emission Tomography)

Chin-Tu Chen, Ph.D.

Department of Radiology &

Committee on Medical Physics

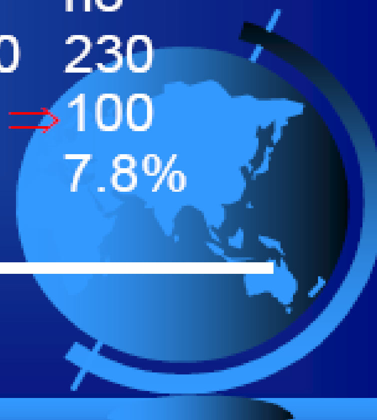
Pritzker School of Medicine &

Biological Sciences Division

The University of Chicago

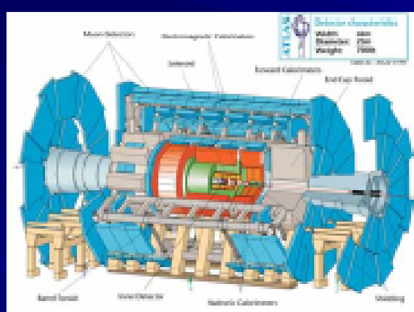
Characteristics of Selected Scintillators

	LSO	BGO	GSO	NaI
Density (g/cc)	⇒ 7.4	7.13	6.7	3.67
Effective atomic number	66	⇒ 75	59	51
Mean Free Path (cm)	1.16	⇒ 1.05	1.43	2.88
Hygroscopic?	⇒ no	no	no	yes
Rugged?	⇒ yes	yes	no	no
Decay Time (nsec)	⇒ 40	300	56,600	230
Relative Light Output	75	15	25	⇒ 100
Energy Resolution	10%	10.1%	9.5%	7.8%

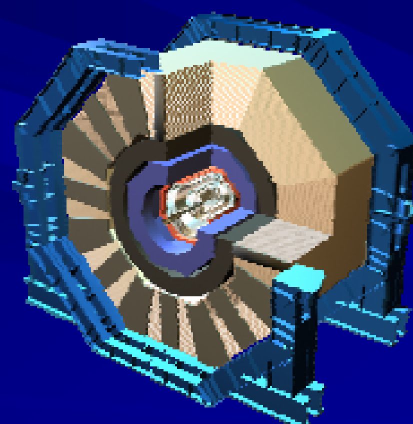


Contribution of HEP Calorimeter Read out Electronics Techniques to the Medical Imaging Field

P. Le Dû
pledu@.cea.fr



LHC/CERN



ILC

TEP

Contributions of HEP calorimeters

Conclusions

- The well-tried concepts of HEP experiments may successfully be transferred to the medical imaging field...
- The pixelisation of the detector and the subsequent pipelined independent reading electronics scheme will enable:
  - → to attain the highest count rates by suppressing deadtime
  - → to cancel out the time contributions of CFD and TDC
  - → to compute both energy and time by using the same channel
- The power and the flexibility of the digital filter will enable to suit future needs if the TOF accuracy is to be increased
- A powerful trigger DAQ system based on modern telecom technologies can make a real time treatement of the data.