

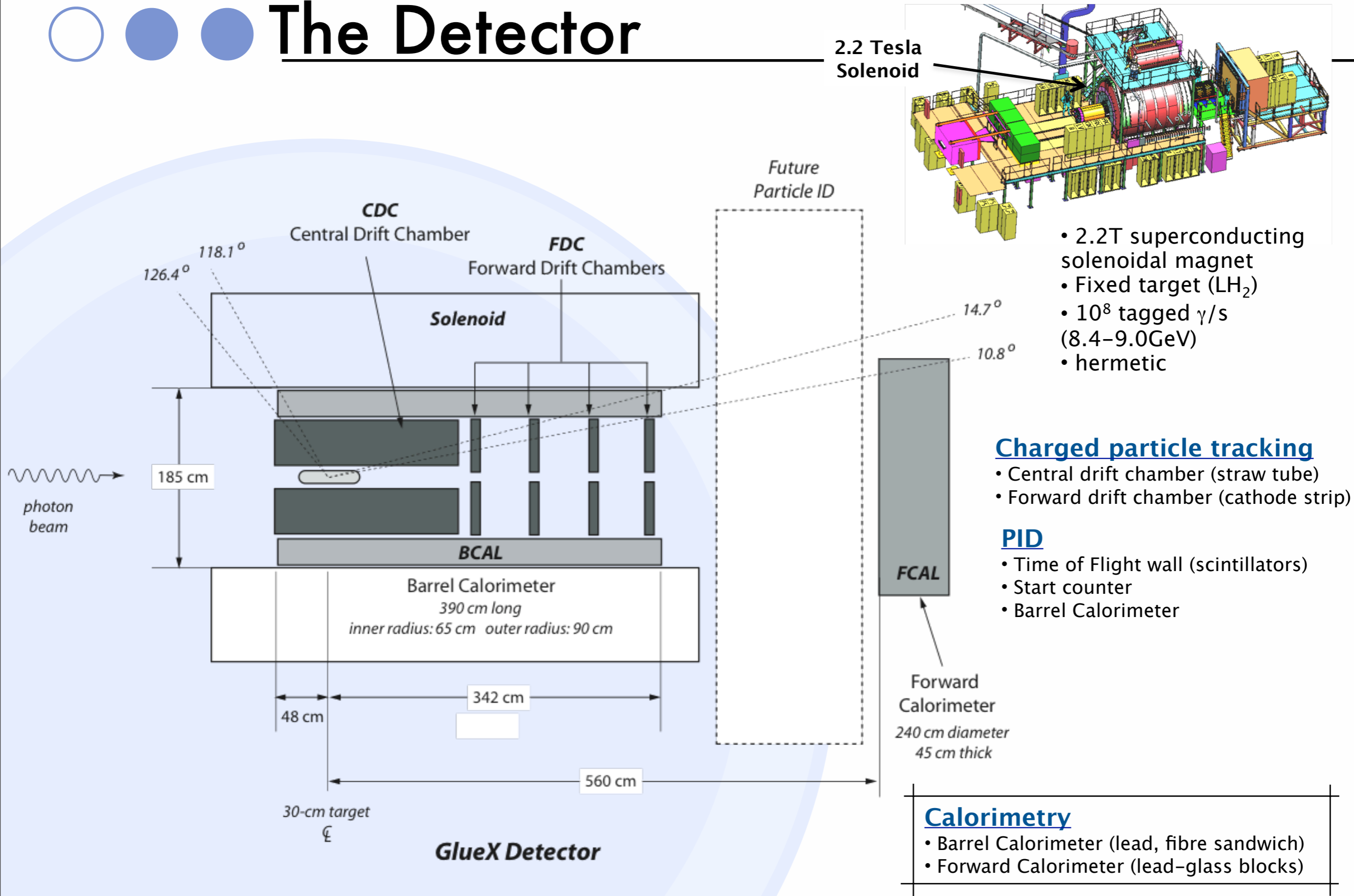


BCAL Overview

Readout Review
Jefferson Lab
July 21, 2009

Zisis Papandreou

The Detector



2.2 Tesla Solenoid

Future Particle ID

- 2.2T superconducting solenoidal magnet
- Fixed target (LH₂)
- 10⁸ tagged γ/s (8.4–9.0GeV)
- hermetic

Charged particle tracking

- Central drift chamber (straw tube)
- Forward drift chamber (cathode strip)

PID

- Time of Flight wall (scintillators)
- Start counter
- Barrel Calorimeter

Calorimetry

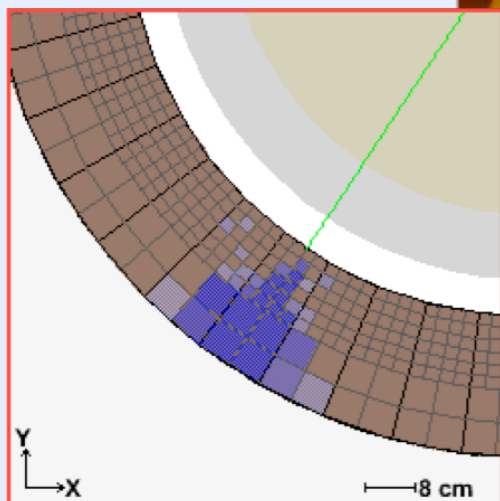
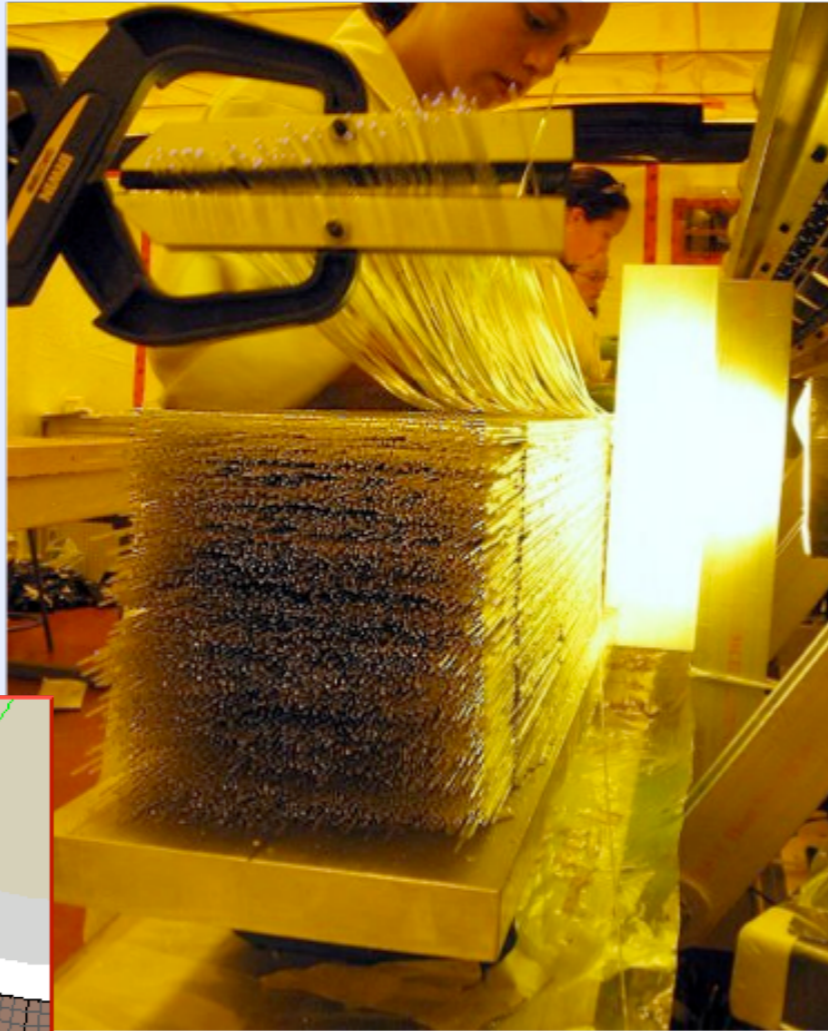
- Barrel Calorimeter (lead, fibre sandwich)
- Forward Calorimeter (lead-glass blocks)

Calorimetry

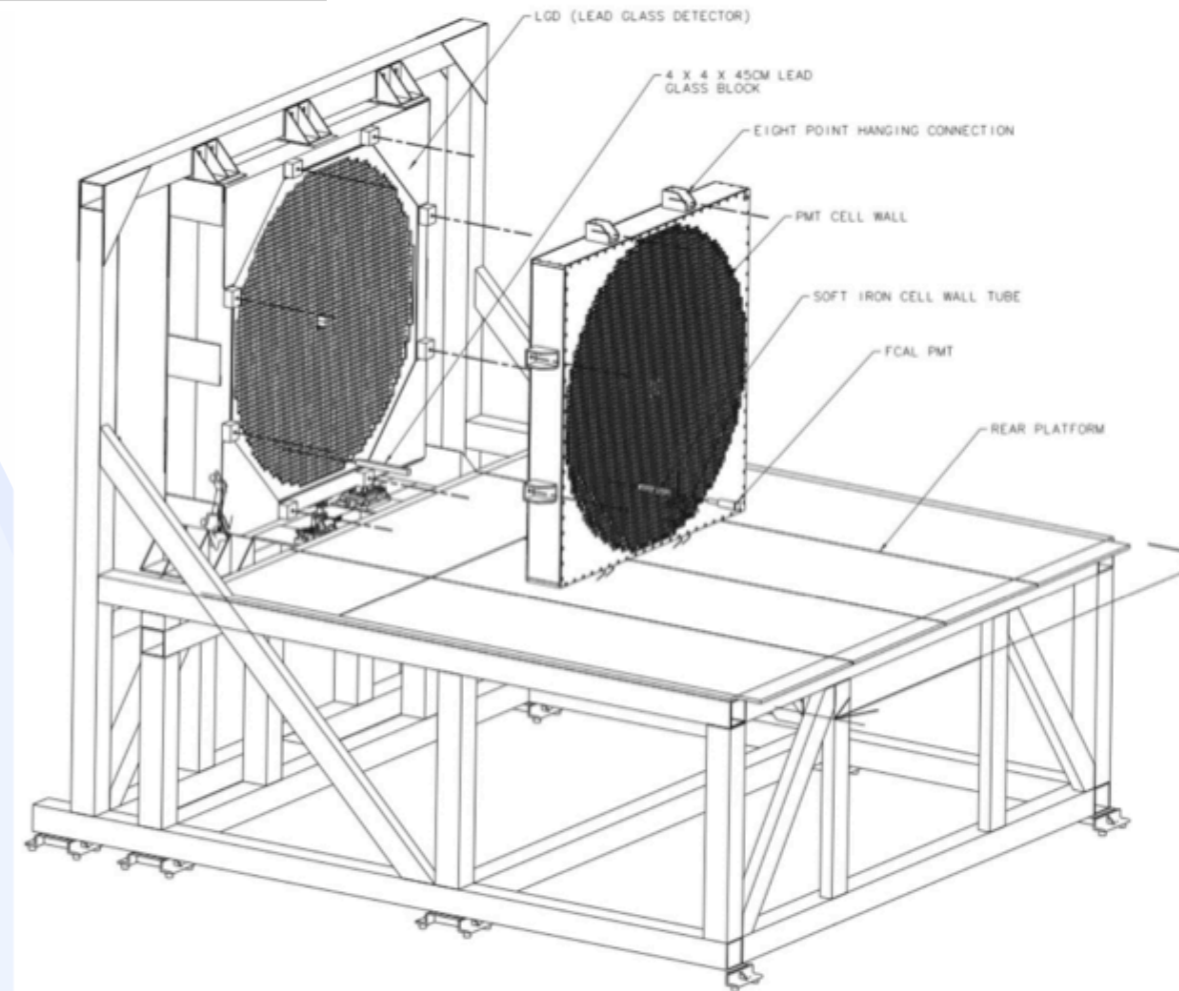
Detector Region	$\sigma(M_{\gamma\gamma})$ for π^0 [MeV/c ²]
FCAL	5.4
BCAL	9.2
FCAL + BCAL	7.6

Barrel Calorimeter:

- 186 PbSciFi layers
- 12% sampling fraction
- readout: SiPM or FM
- $\sigma_E/E = 5.4\% \sqrt{E} \oplus 2.3\%$
- $\sigma_{\text{tdiff}} = 70\text{ps}/\sqrt{E}$
- $\sigma_z = 1.1\text{mm}/\sqrt{E}$
- polar coverage: $11^\circ < \theta < 126^\circ$
- Hadronic rate: 5 kHz
- Radiation: 14 rad/year



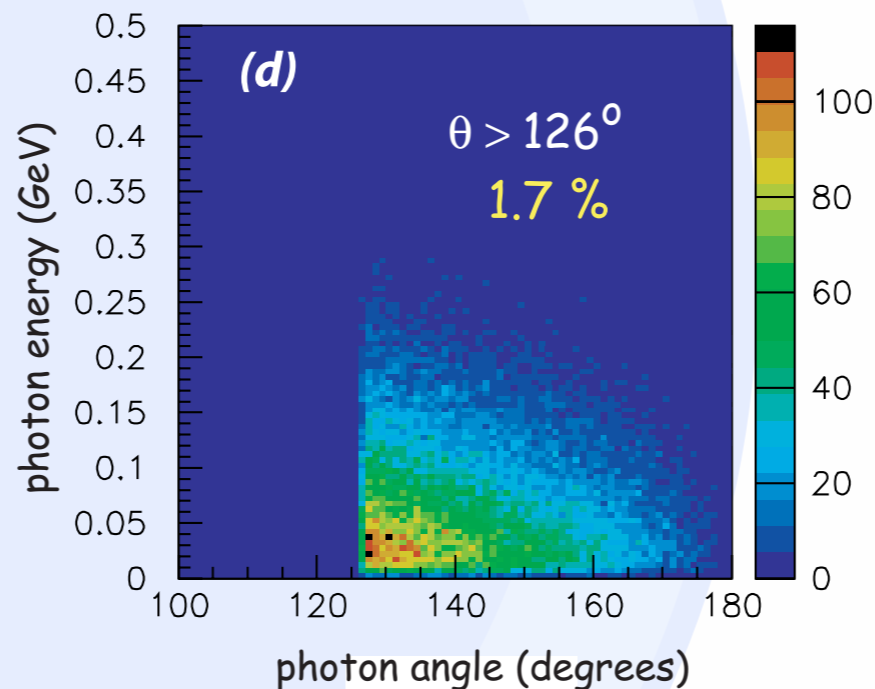
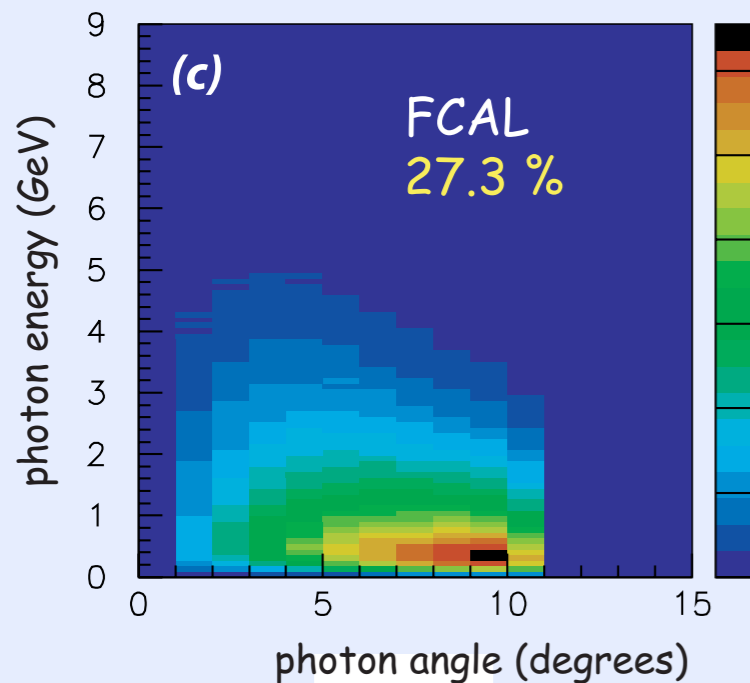
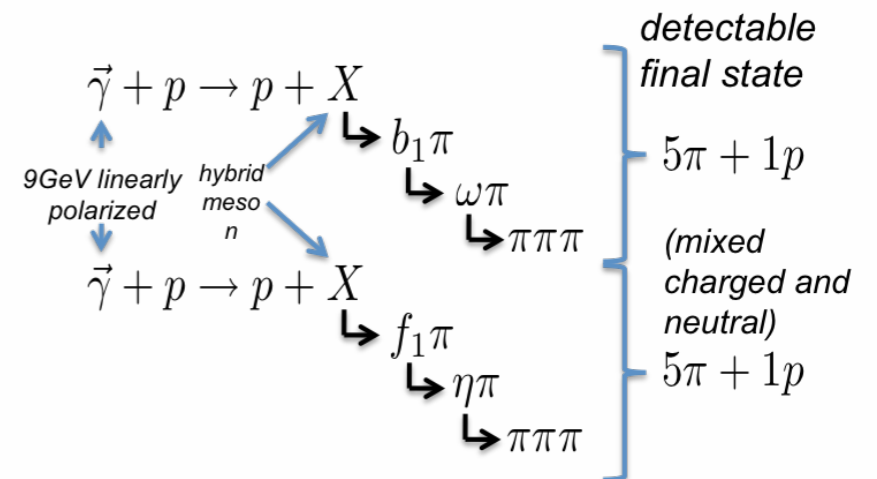
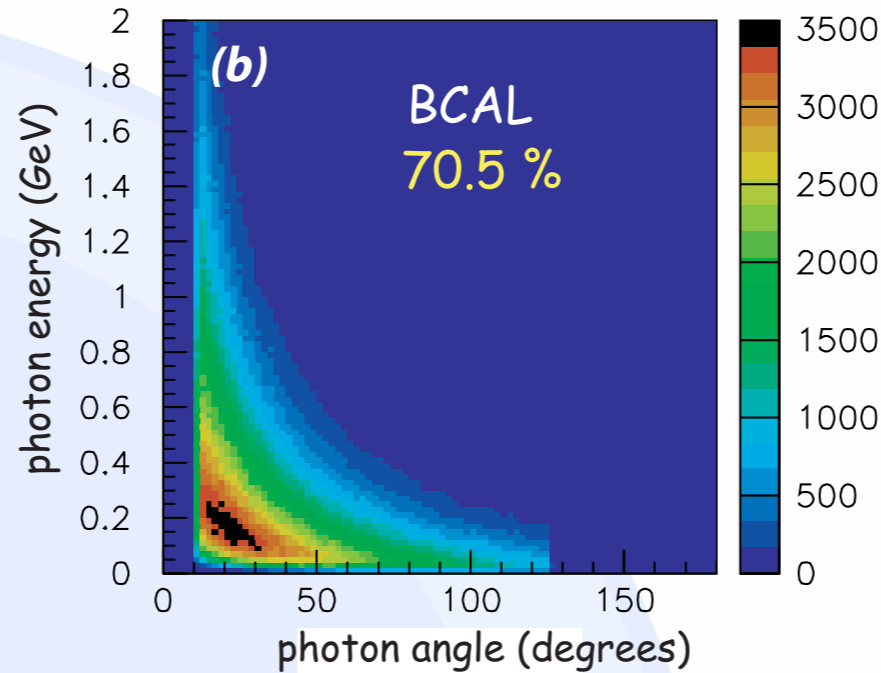
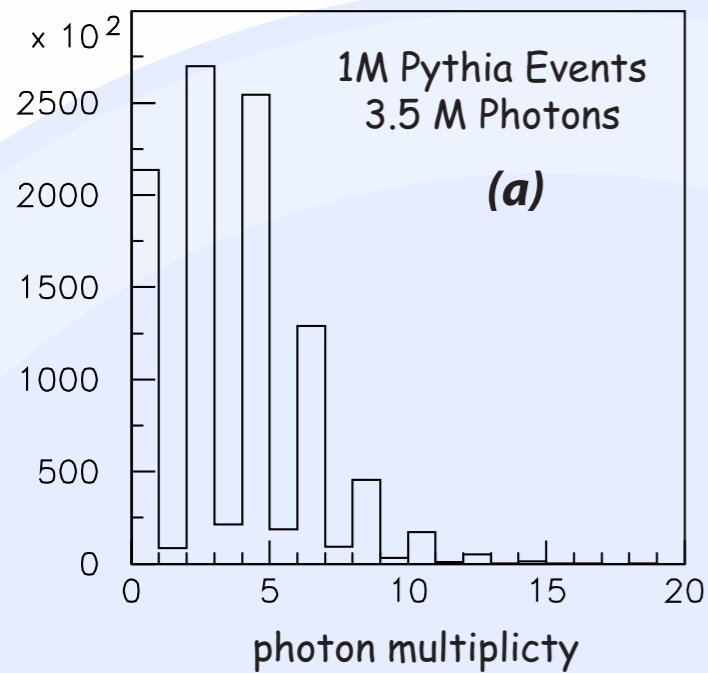
Modeled after the
KLOE Calorimeter (Frascati)
Thanks!



Forward Calorimeter:

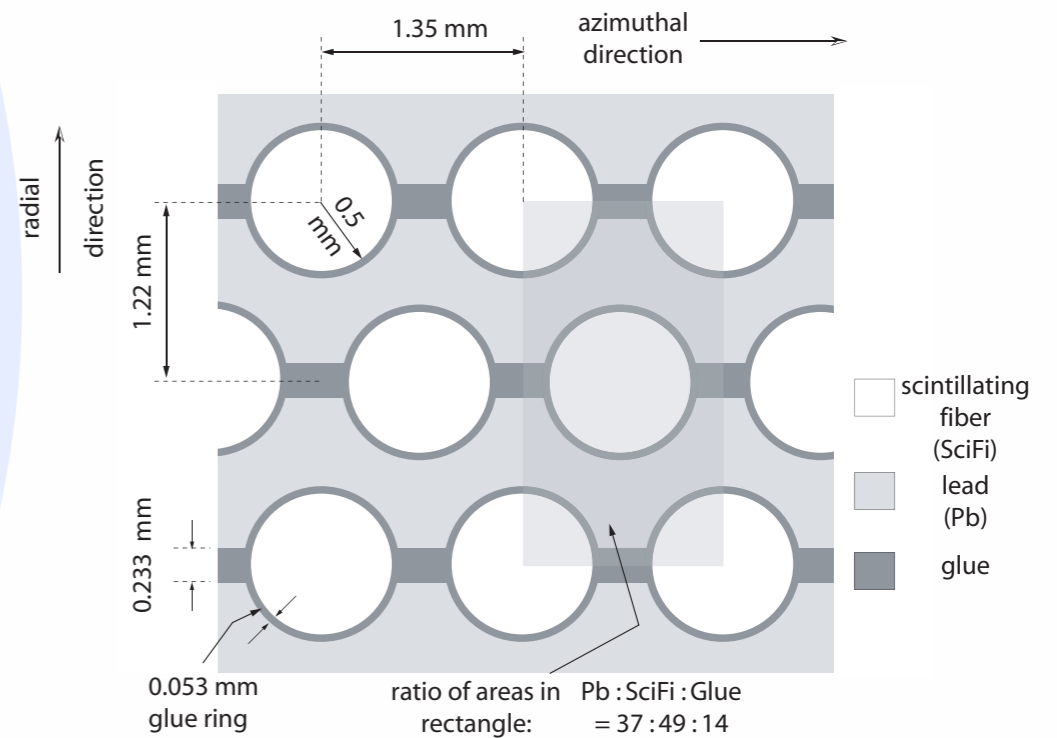
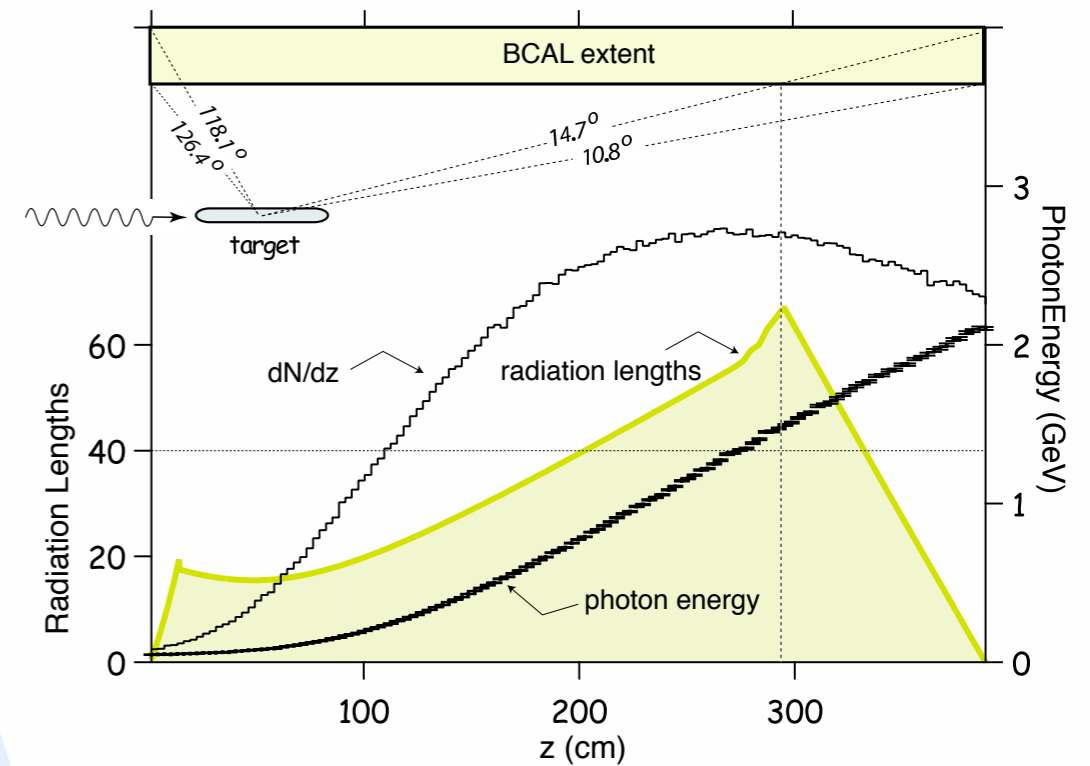
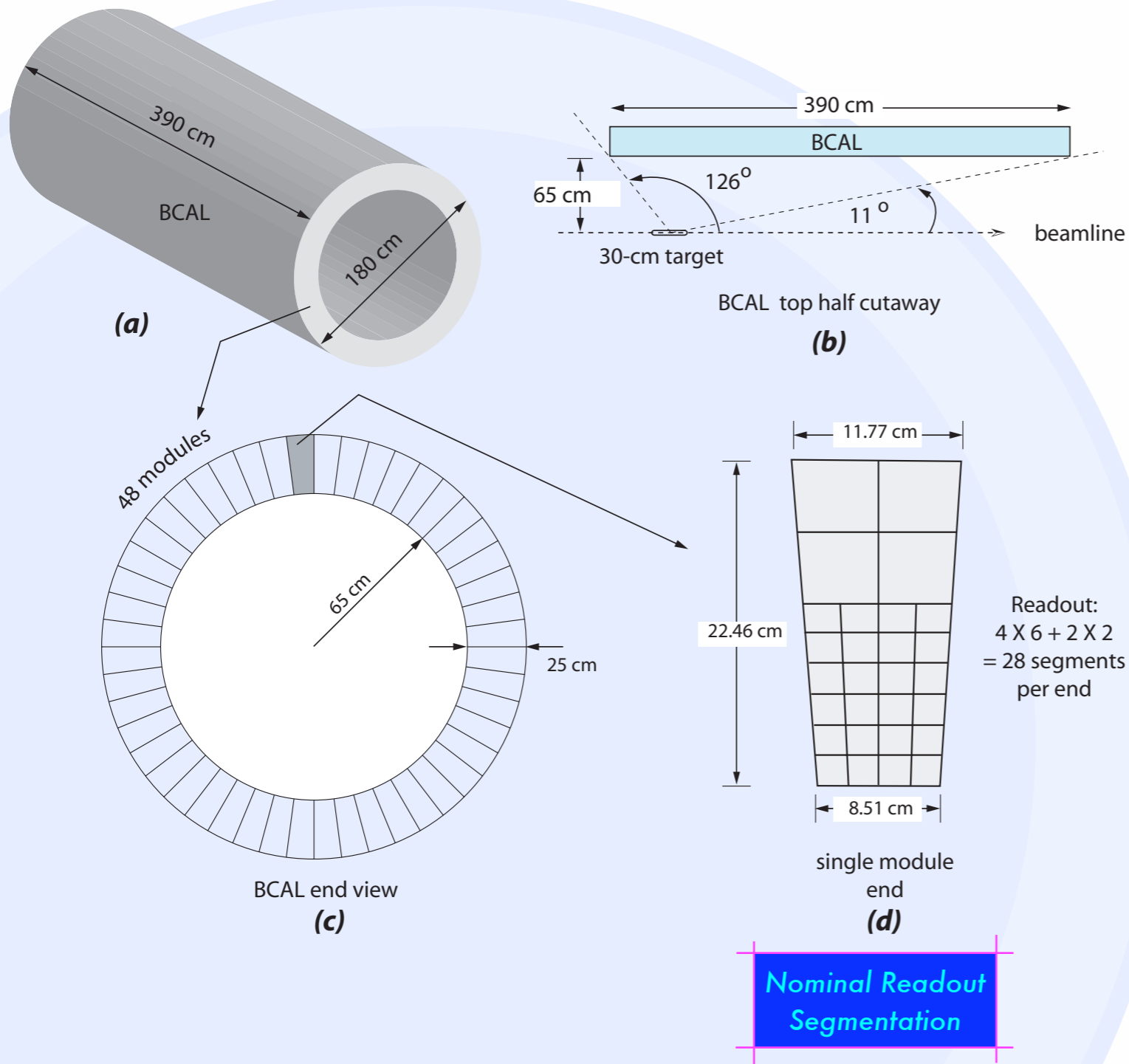
- 2800 F8-00 and F108 (center) Pb glass blocks
- 4cm x 4cm x 45 cm
- readout: PMTs
- $\sigma_E/E = 5.7\% \sqrt{E} \oplus 2.0\%$
- $\sigma_{xy} = 6.4\text{mm}/\sqrt{E}$
- polar coverage: $2^\circ < \theta < 11^\circ$

Decay Photon Distributions



- Detecting π 's and η 's is essential for GlueX
- PYTHIA simulations
 - 28% of photons in FCAL
 - 70% of decay photons are captured by BCAL
 - 50% of BCAL ones have energies $< 300\text{MeV}$
- BCAL has a large workload
- FCAL-BCAL handoff ($\sim 11^\circ$) very important

BCAL Layout



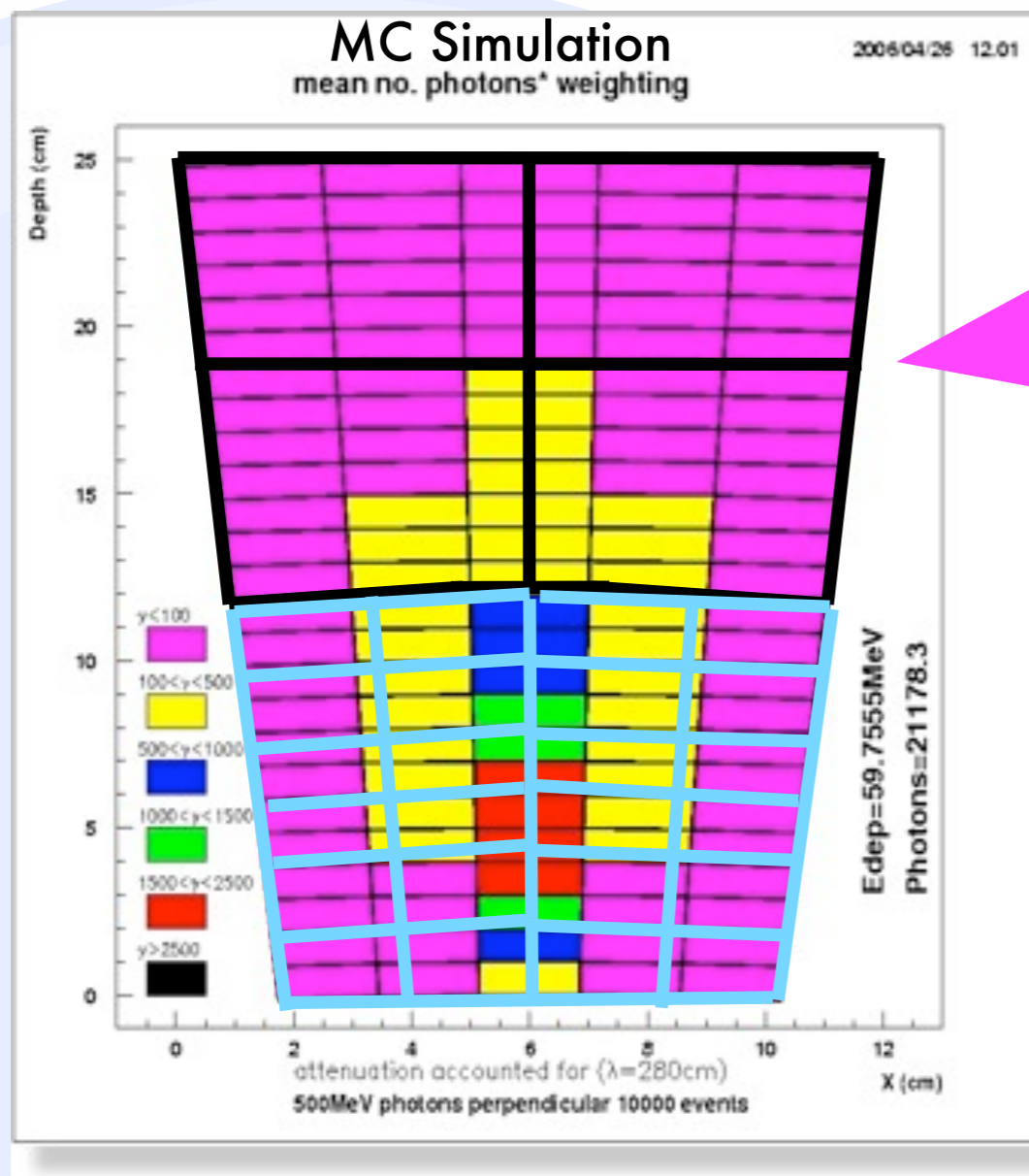


Energy Deposition

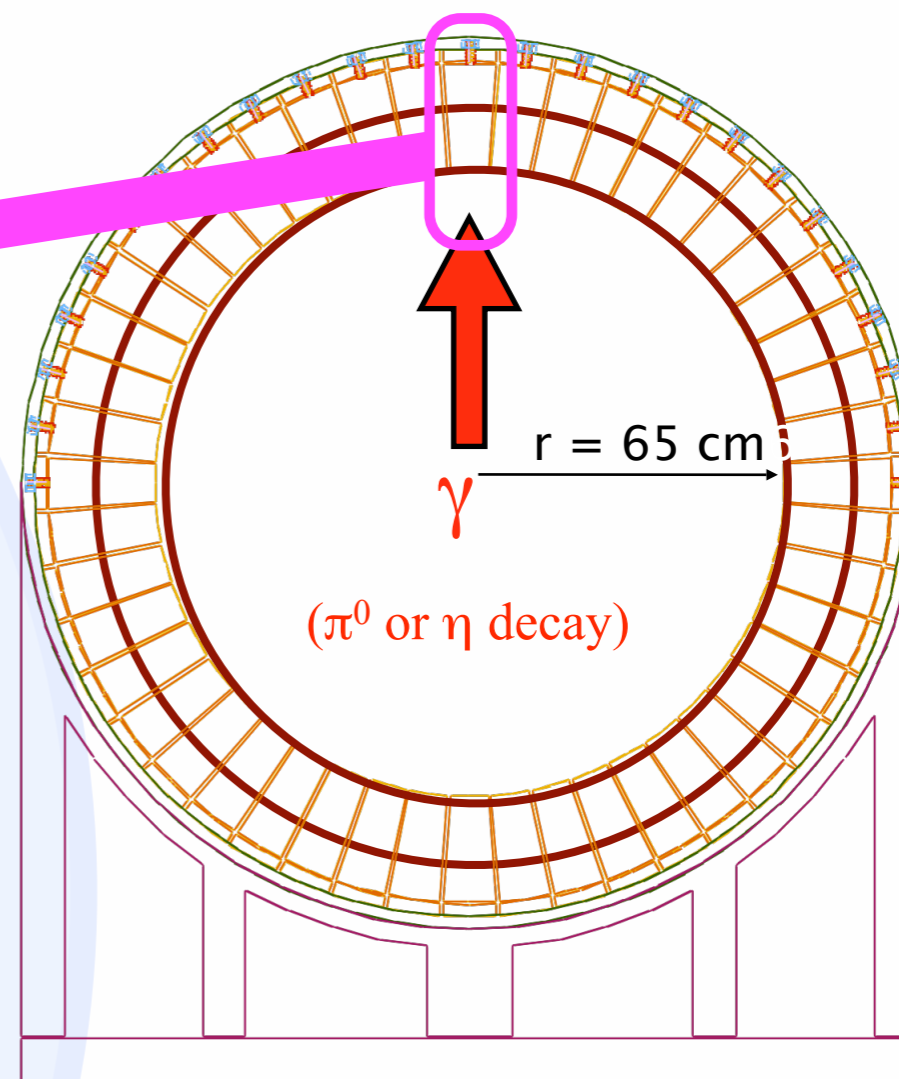


... will be immersed in a 2.2-2.5 T field!

Outer Layers



48 azimuthal modules \Rightarrow 25 tons!



Nominal Readout Segmentation

Inner layers (12cm depth): 4x6 SiPM arrays: 2304 units

Outer layers (10cm depth): 2x2 FM PMTs: 384 units

- PbSciFi Matrix (190 layers 0.5mm Pb)
- 780,000 1mm fibres Kuraray SCSF-78MJ
- Bicron 600 Optical Epoxy
- 390 cm long

○ ● ● Simulations

● Packages

○ GEANT 3.21

○ FLUKA 2008.3

● Detailed volumes

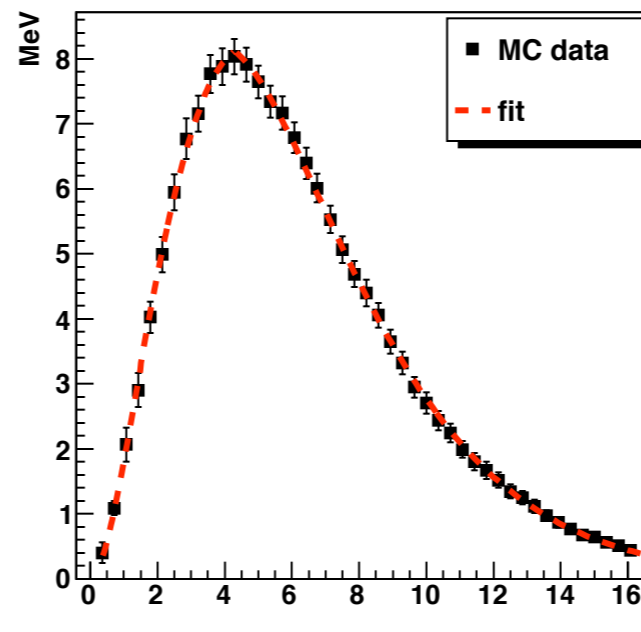
○ fibres, lead, glue

● Geometries

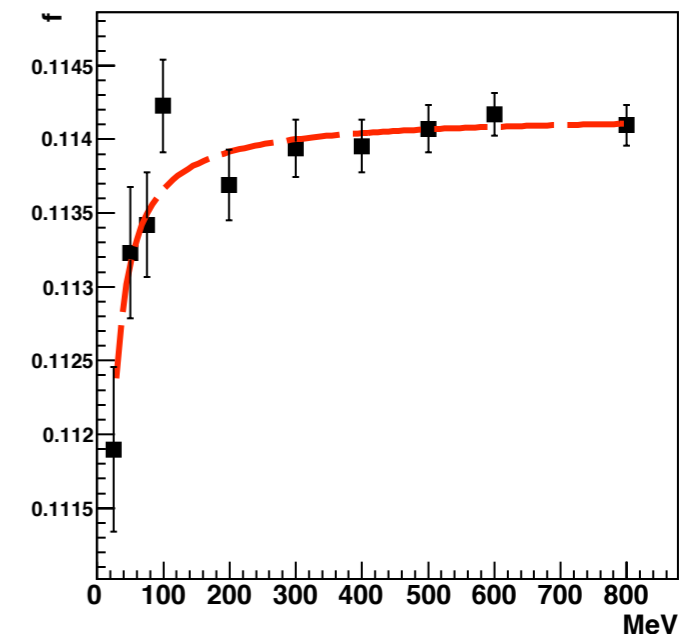
○ Fibre pitch

● Feed into HDGEANT

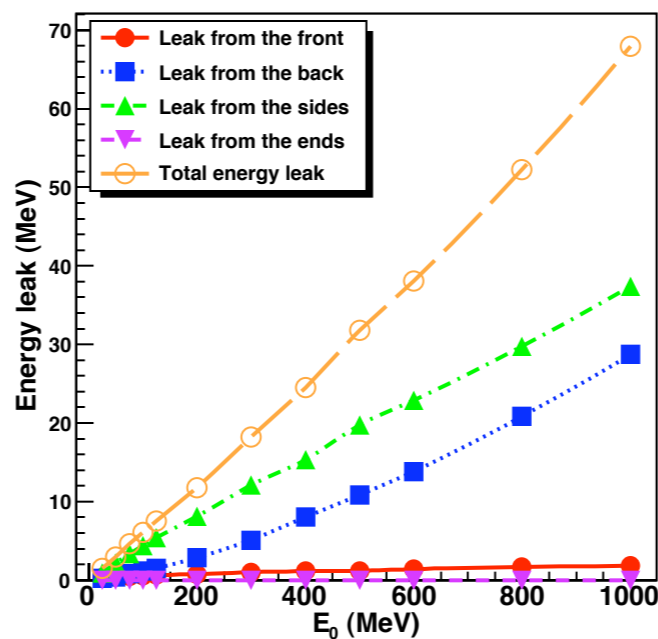
Longitudinal Shower Profile - 600 MeV @ 90°



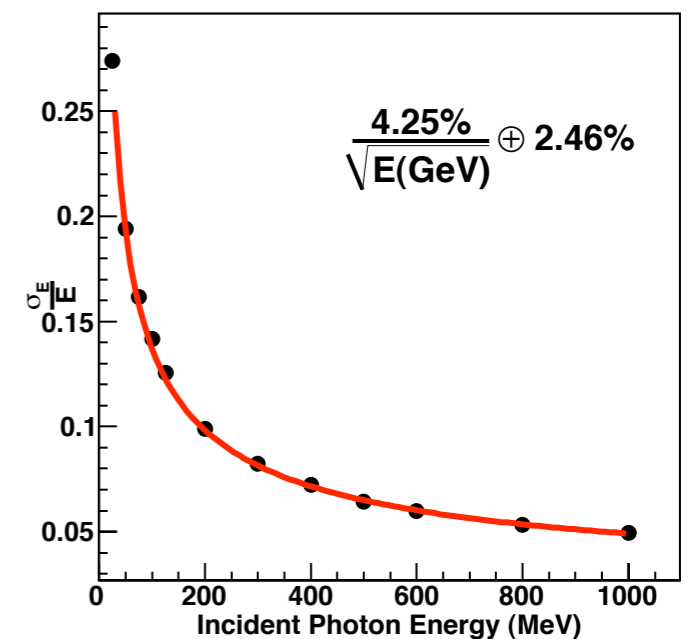
Fractional Energy Deposition - nominal geometry - 90°



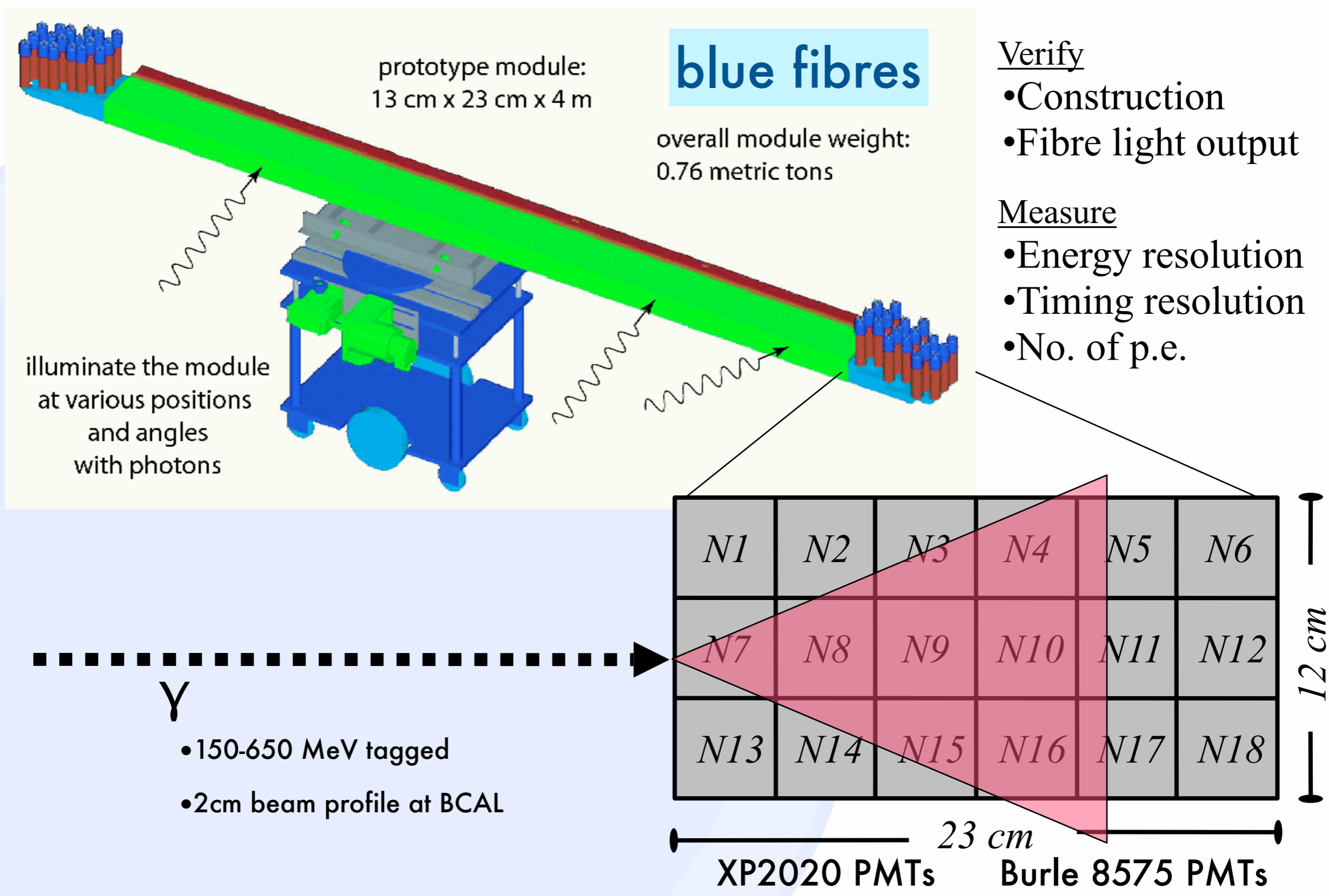
nominal geometry - 90°



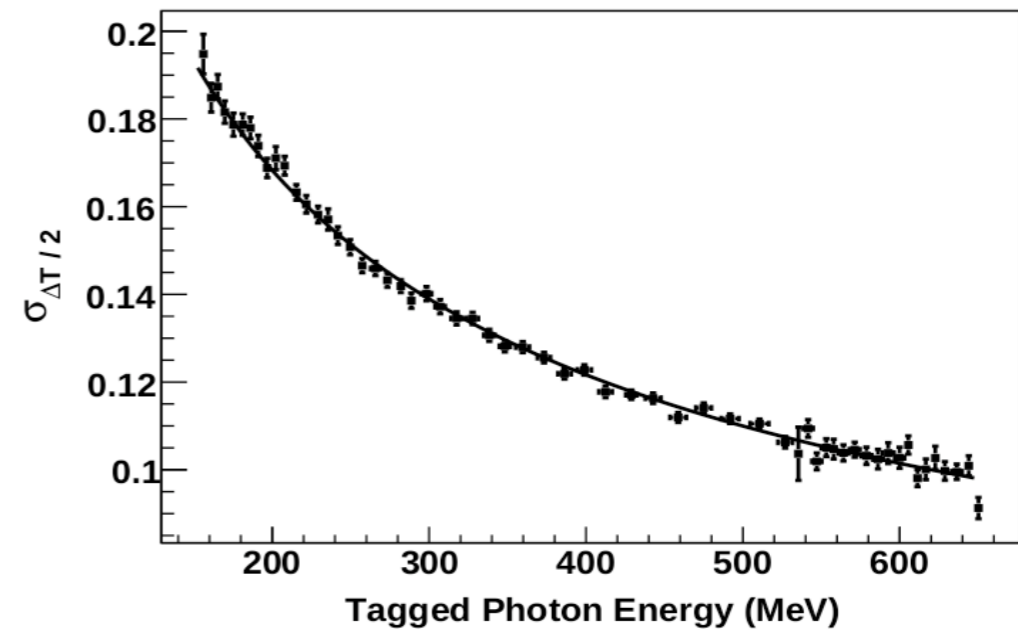
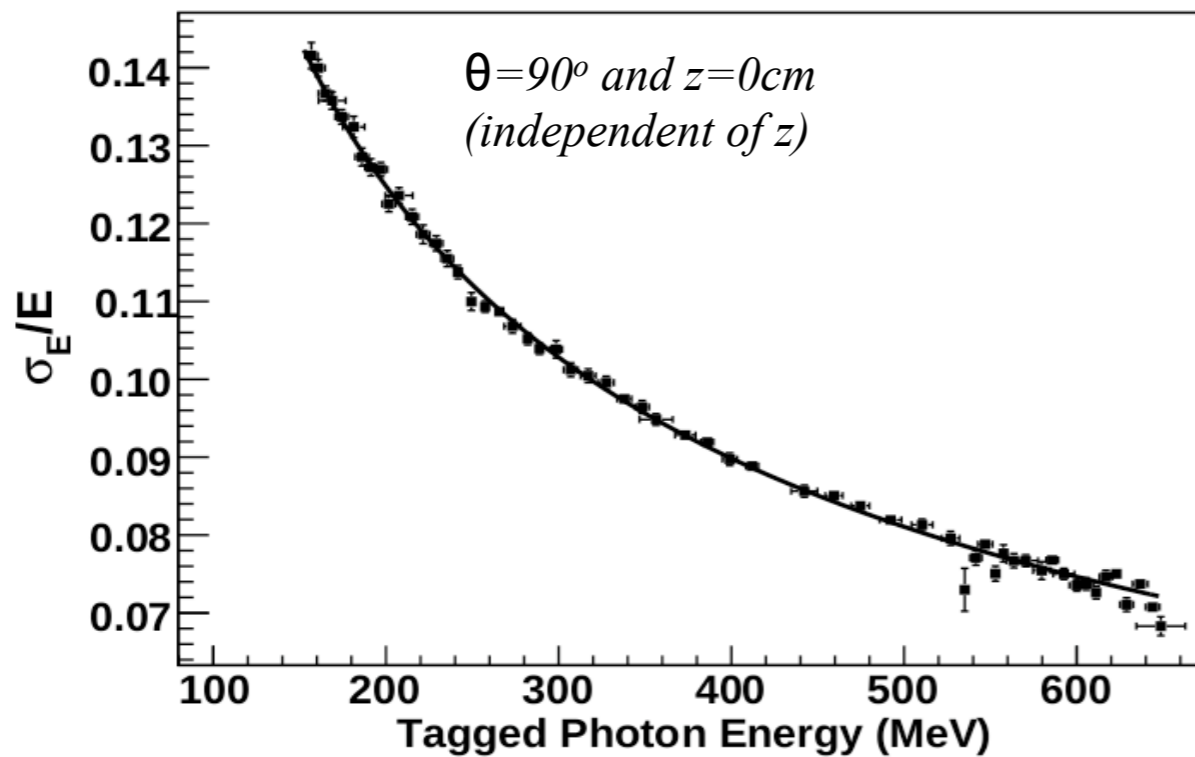
Energy Resolution - nominal geometry - 90°



Beam Test - Hall B (fall 2006)



Energy, Timing Resolution & No. p.e.



$$\frac{\sigma_E}{E} = \frac{5.5 \pm 0.1\%}{\sqrt{E}} \oplus 2.4 \pm 1\%$$

$$\text{KLOE} \left(\frac{\sigma_E}{E} = \frac{5.4\%}{\sqrt{E}} \oplus 0.7\% \right)$$

Cosmics: 480-600 p.e./GeV/side

time difference resolution

$$\sigma_{\Delta T/2} = \frac{70\text{ps}}{\sqrt{E(\text{GeV})}}$$

$$\text{KLOE} \left(\sigma_t = \frac{72\text{ps}}{\sqrt{E}} \right)$$

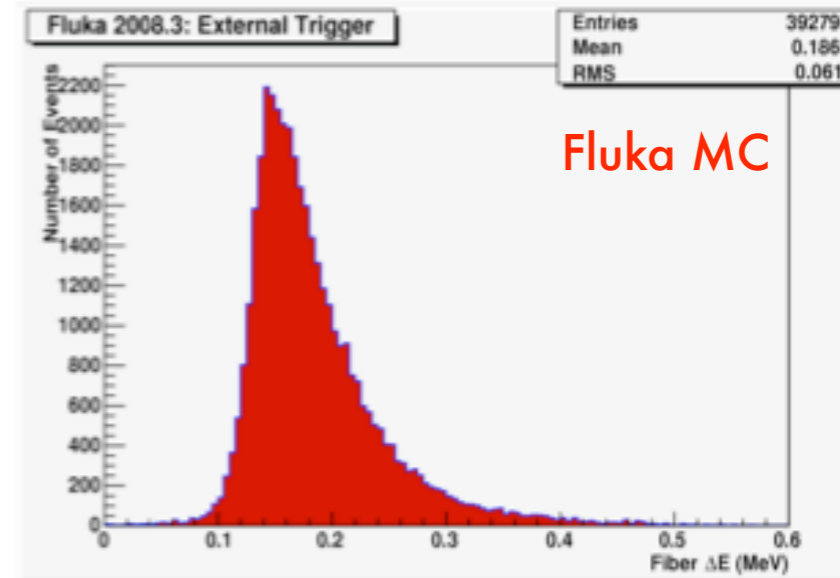
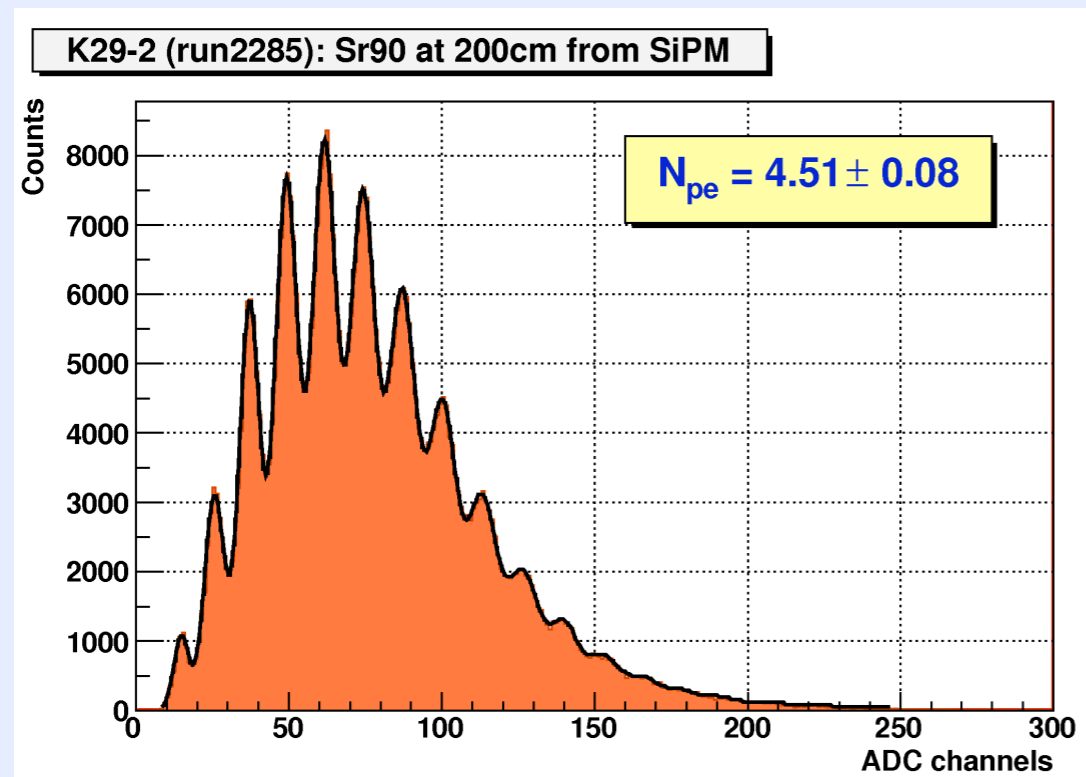
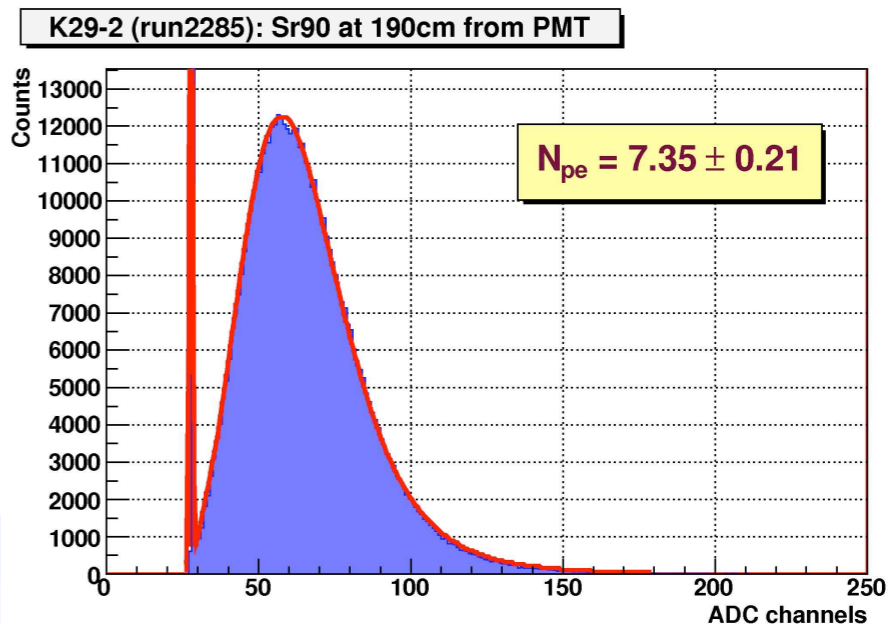
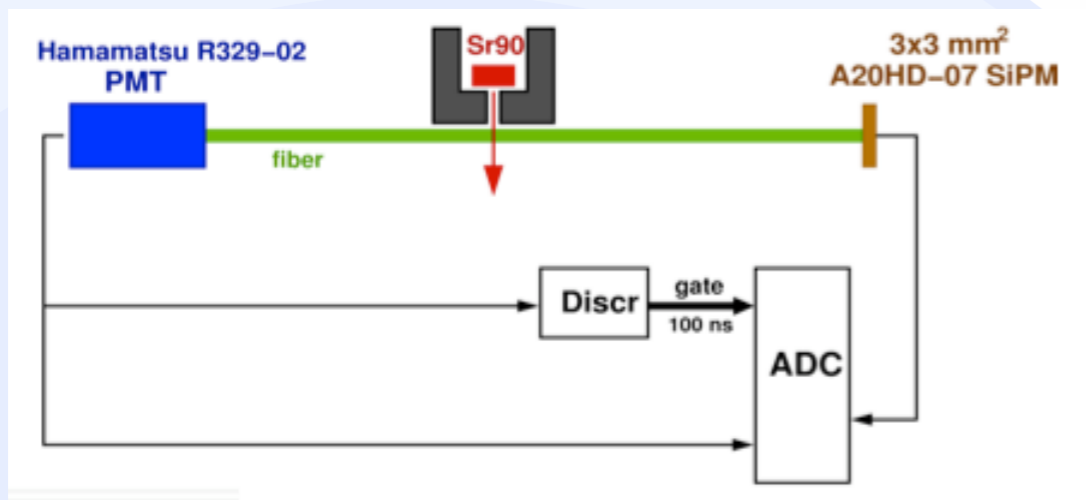
BCAL: 660 pe/GeV vs KLOE: 700 pe/GeV
• single clad fibres, better light guides

Fibres: No of p.e.

Manufacturers claim:

8000 photons/MeV * fibre capture (0.056) * 0.56 attenuation * 117 (MeV/ γ -GeV) * 0.10 PDE =
 ~3000 pe/GeV/side

We use: 1500 pe/GeV/side



Mean $\Delta E = 0.18$ MeV/mm

$\Rightarrow 26$ pe/MeV/side

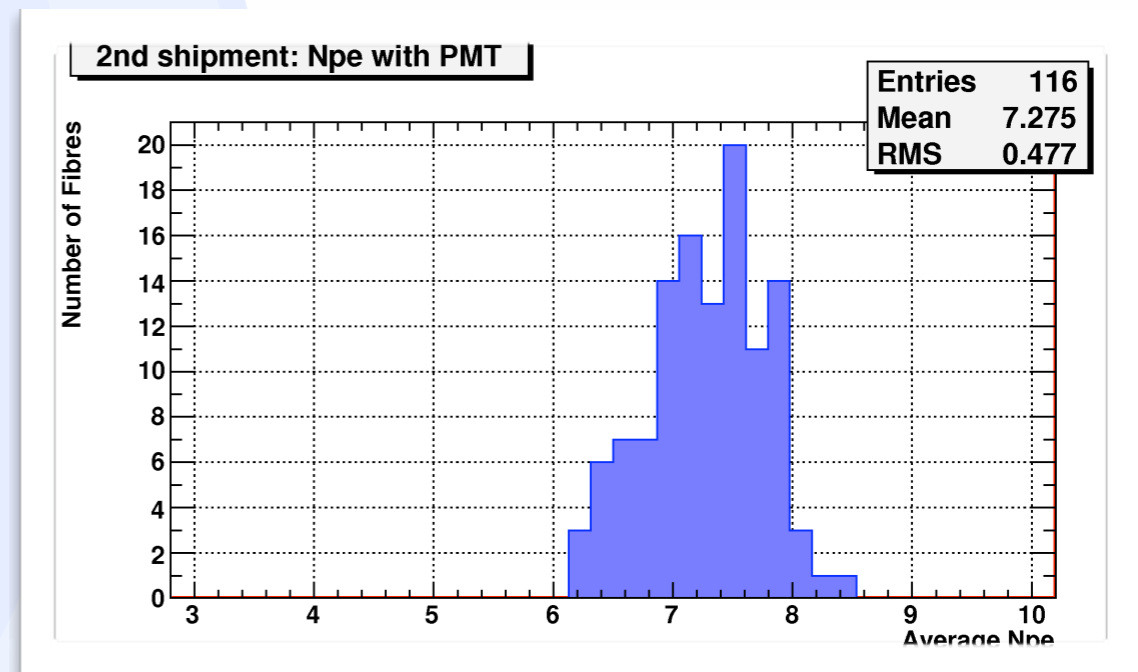
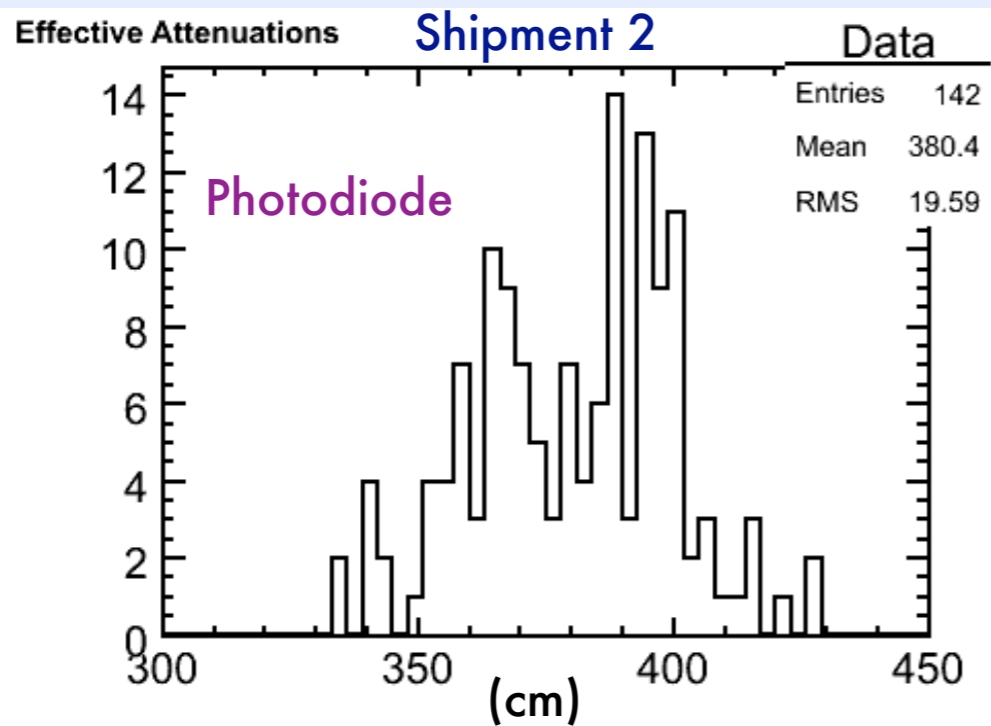
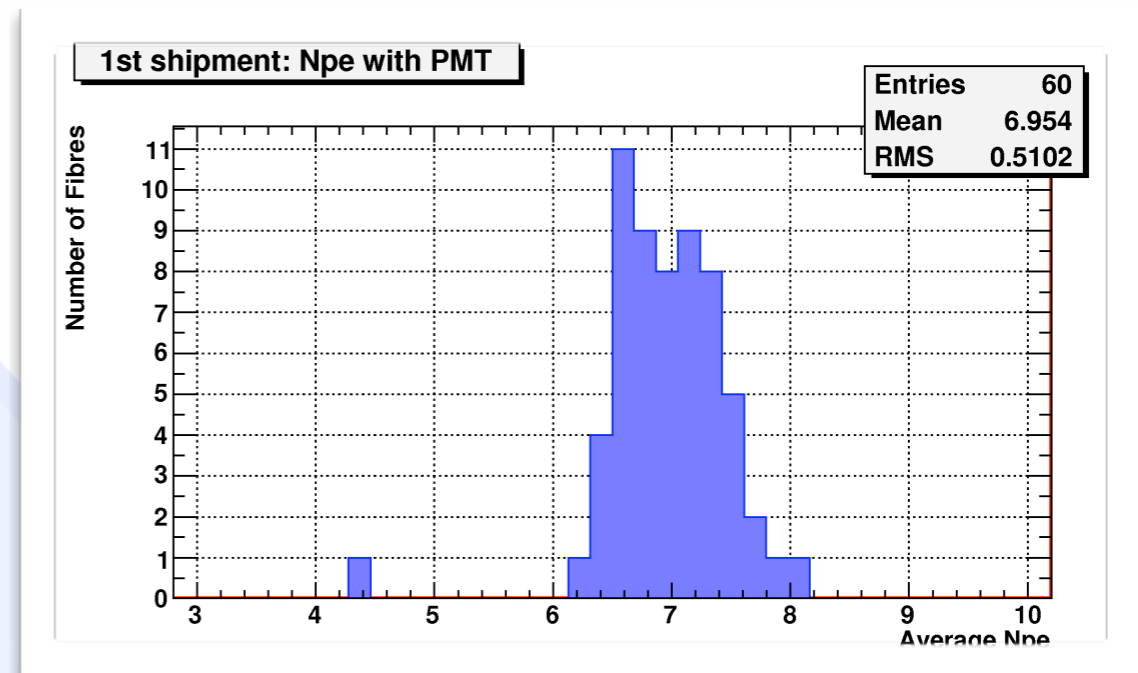
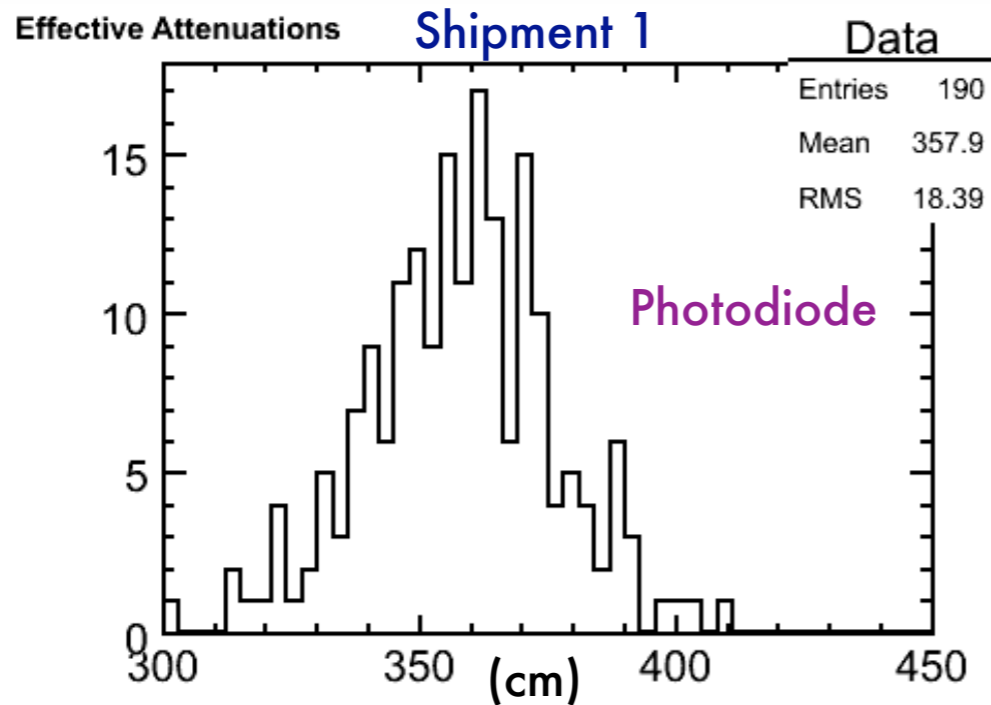


BCAL Properties

Property	Value
Number of Modules	48
Module Length	390 cm
Module Inner Cord	8.51 cm
Module Outer Cord	11.77cm
Module Thickness	22.5 cm
Module Azimuthal Bite	7.5°
Lead sheet Thickness	0.5 mm
Radial fibre pitch	1.24 mm
Azimuthal fibre pitch	1.35 mm
Fibre Diameter	1 mm
First cladding thickness	0.03 mm
Second cladding thickness	0.01 mm
Core refractive index	1.60
First clad refractive index	1.49
Second clad refractive index	1.42
Trapping Efficiency	5.3% (min), 10.6% (max)
Attenuation Length	> 350 cm
Effective Speed of Light	16 cm/ns

Property	Value
Volume Ratios	37:49:14
Effective Mass Number	179.9
Effective Atomic Number	71.4
Effective Density	4.88 g/cm ²
Sampling Fraction	0.117
Radiation Length	7.06 g/cm ² or 1.45cm
No. of Radiation Lengths	15.5X ₀
Critical Energy	11 MeV (8.4 MeV)
Location of Shower Max	5X ₀ at 1 GeV
Thickness for 95% containment	20X ₀ at 1 GeV
Moliere Radius	17.7 g/cm ² or 2.63 cm
Energy Resolution	5.4%/√E ⊕ 2.3%
Time difference Resolution	70ps/√E
z-position Resolution	1.1cm/√E
Azimuthal Resolution	8.5 mrad
Polar Angle Resolution	8 mrad

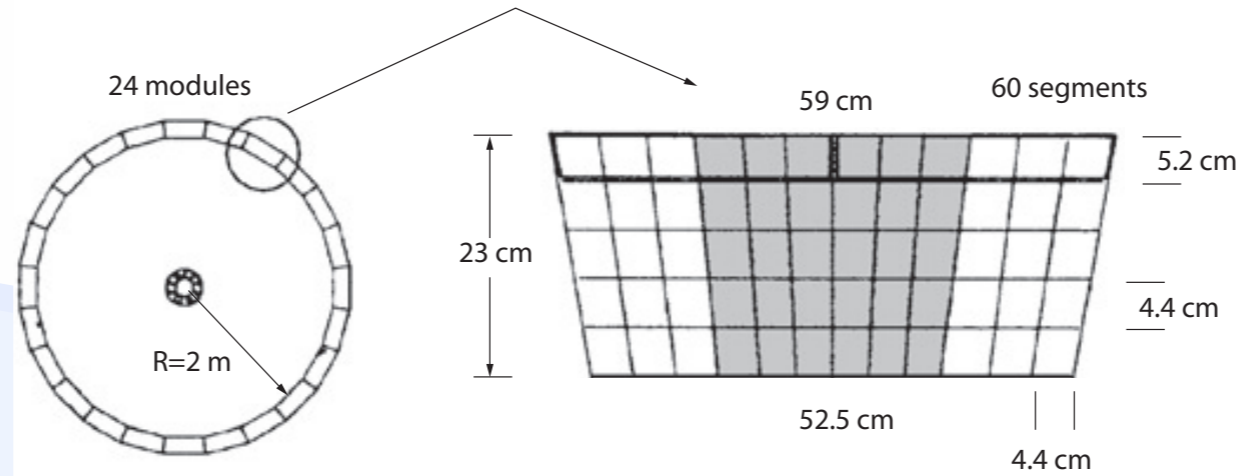
Fibre Quality: Kuraray SCSF-78-MJ



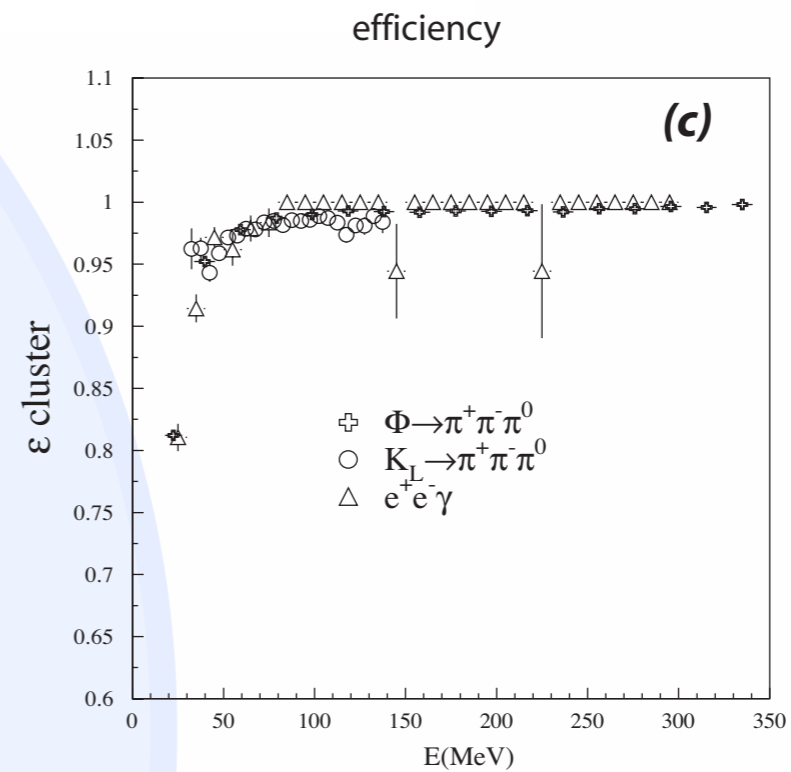
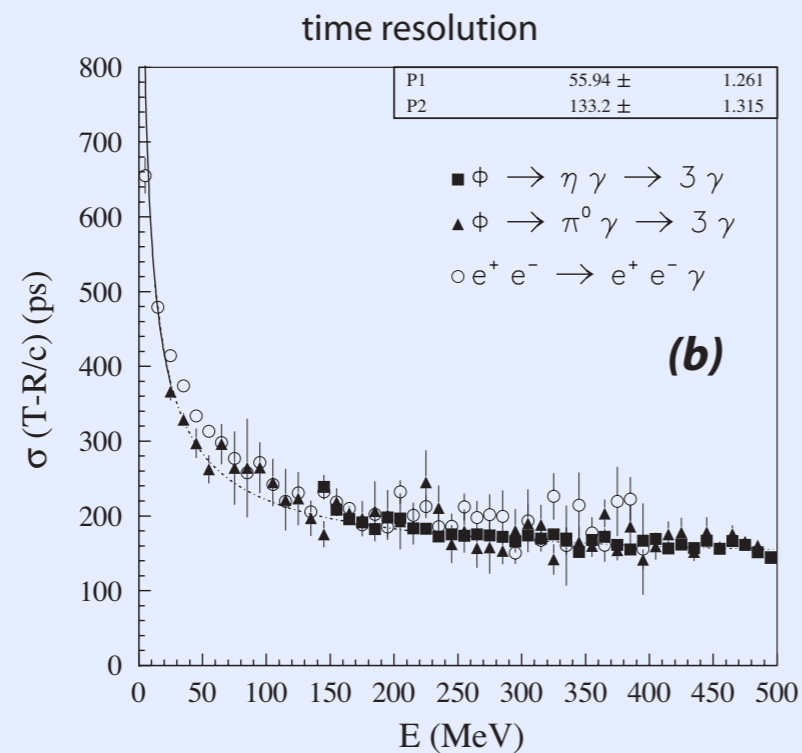
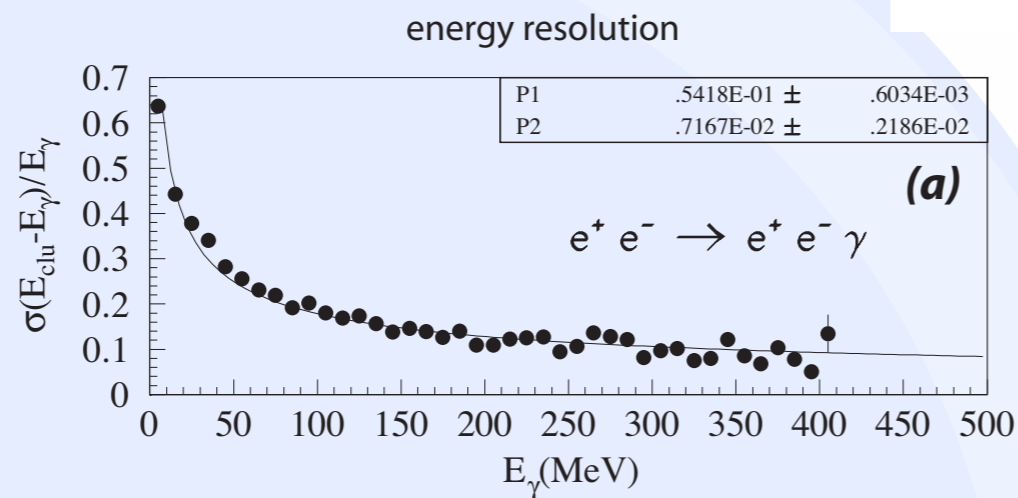
○ ● ● Conclusions

- BCAL meets resolution specs (with blue fibres and PMTs)
- Kuraray fibres of good quality: no of p.e. improves
- First Article Lead being evaluated
- Construction Prototype under way soon
- Optimize readout

Alternate Slides



KLOE calorimeter - readout segmentation (one end)



KLOE Calorimeter Performance

Energy resolution: $\frac{\sigma(E)}{E} = \frac{5.4\%}{\sqrt{E(\text{GeV})}}$

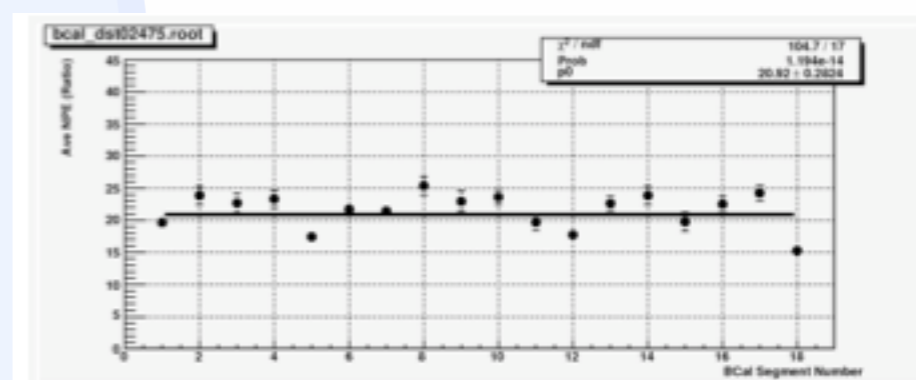
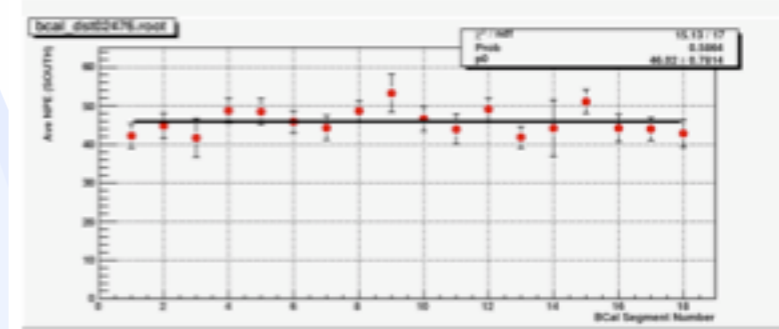
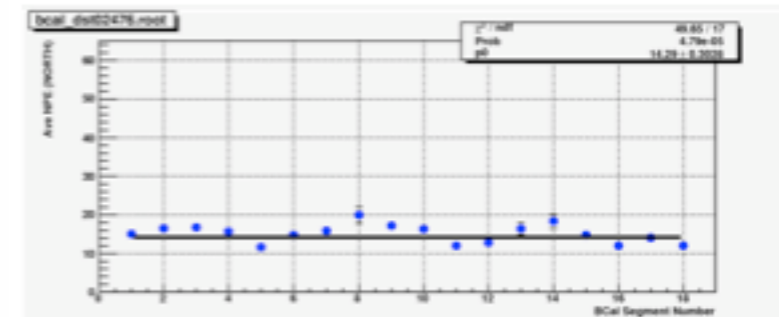
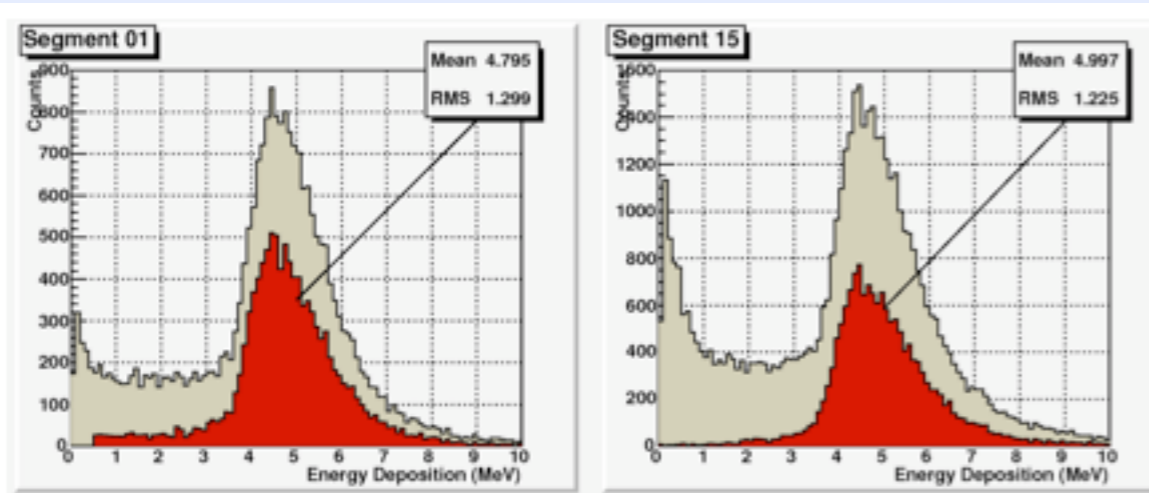
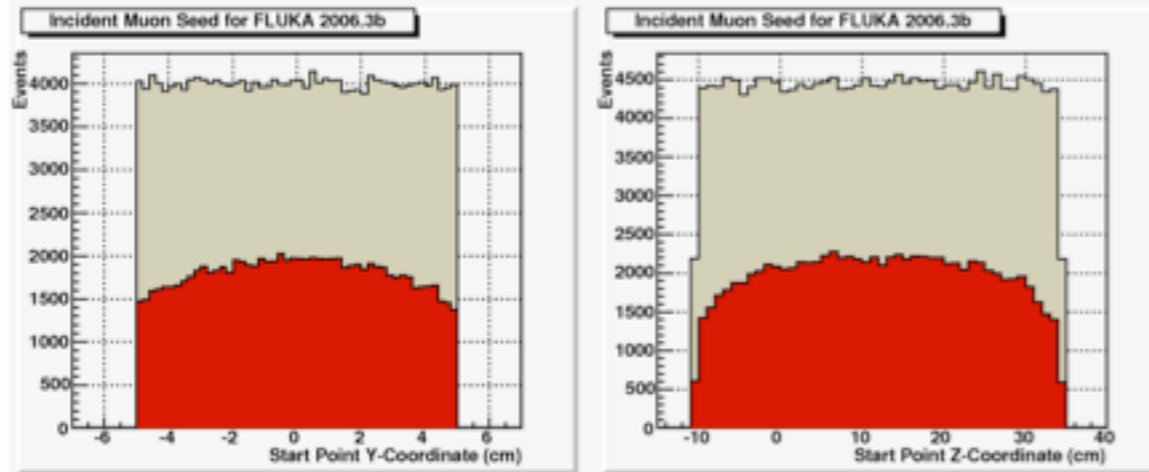
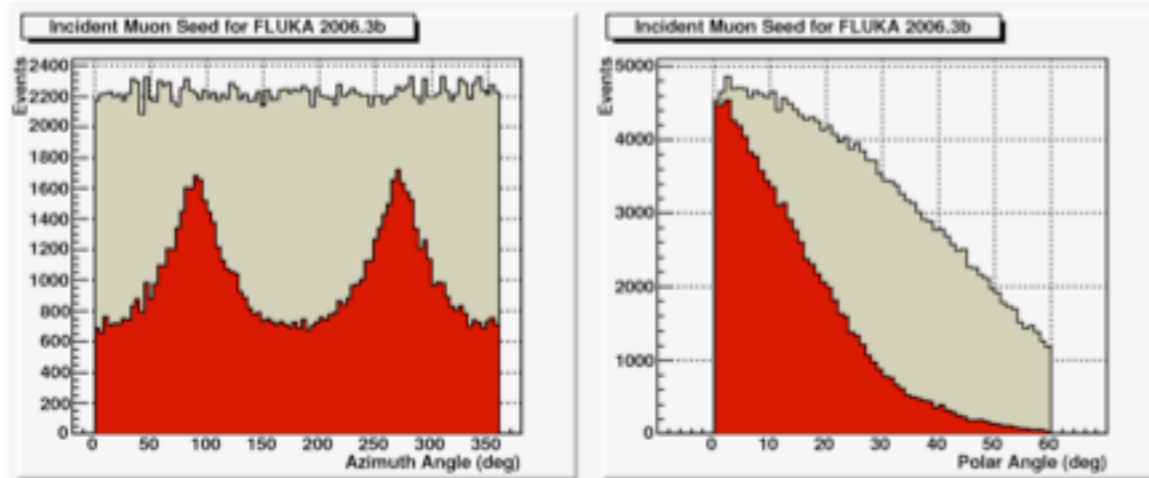
Time resolution: $\sigma_t = \frac{56\text{ps}}{\sqrt{E(\text{GeV})}} \oplus 133\text{ps}$

Source: M. Adinolfi et al Nucl. Intr. Meth. A494(2002) 326

Cosmics (Blue fibres and PMTs)

↓ Cosmic Ray Direction

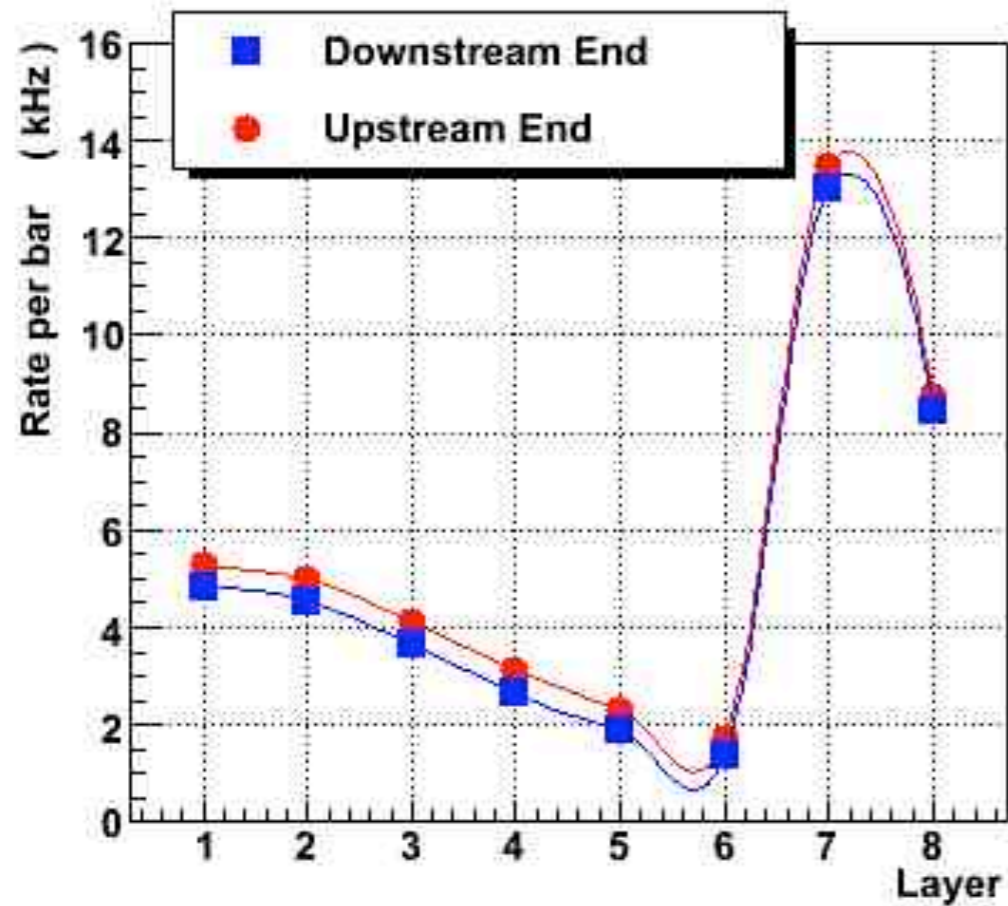
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	<10	?	<10		
	<10	>70	<10		



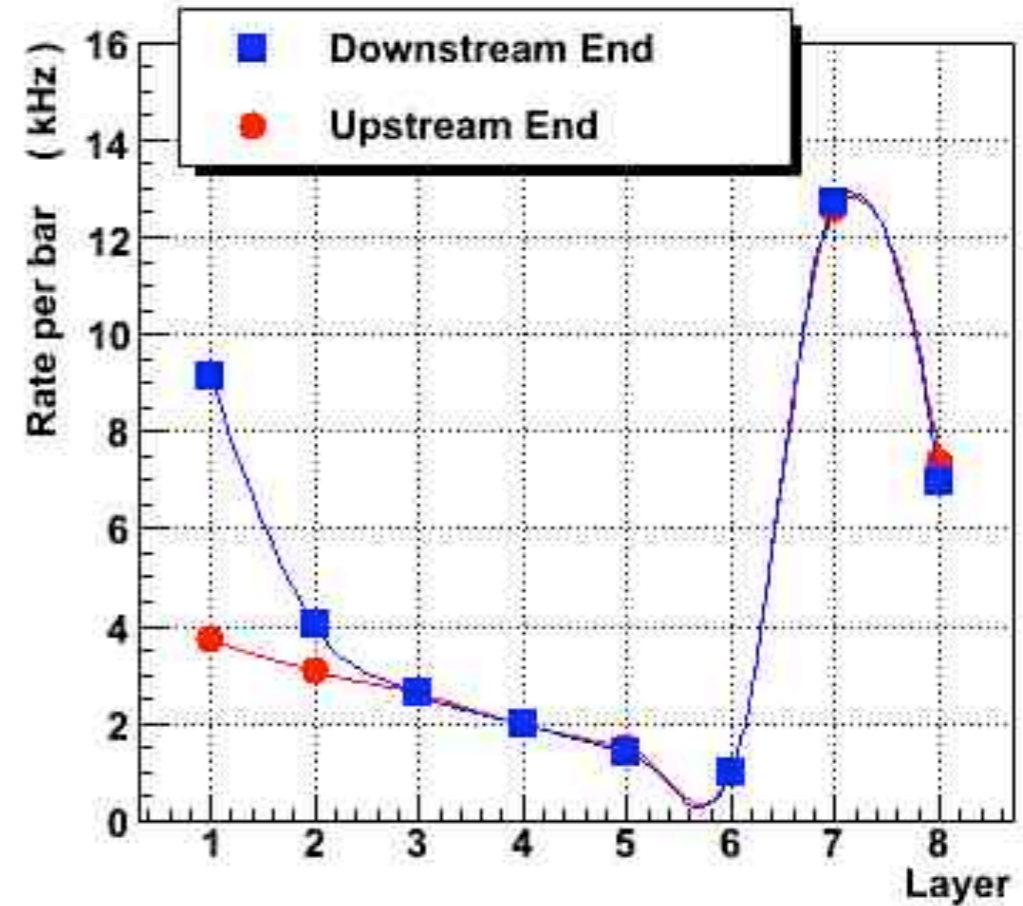
22-25 pe/segment →
 4-5 pe/MeV/side →
 480-600 pe/GeV/side

BCAL Rates

Hadronic events



EM background



Thresholds: 6.7 MeV (9 ph.el) - Inner
1.0 MeV - Outer