GlueX and the BCAL

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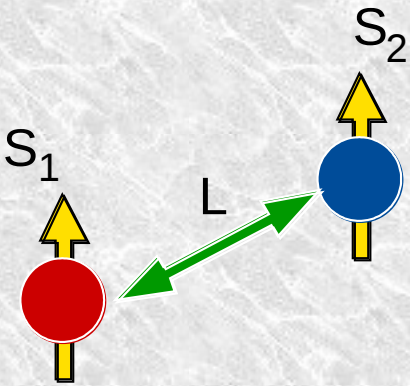
Outline

- What is GlueX? (what are we looking for?)
- How will we do it?
- BCAL: Regina's contribution to GlueX
- BCAL06 and analysis: A beam test of the electromagnetic calorimeter in Hall B at JLab

The physics goal of GlueX is to map the spectrum of hybrid mesons (gluonic excitations) starting with those with the unique signature of exotic quantum numbers. Normal mesons in the quark model cannot have exotic J^{PC}.

Spin and angular momentum configurations as well as radial excitation give us our current meson spectrum.



$$S = S_1 + S_2$$

$$J = L + S$$

$$P = (-1)^{L+1}$$

$$C = (-1)^{L+S}$$

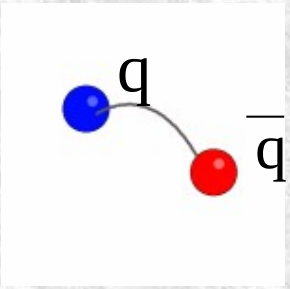
$J^{PC} = 0^{-+}\ 0^{++}\ 1^{--}\ 1^{+-}\ 2^{++}\ \ldots$

Allowed combinations

$J^{PC} = 0^{--}\ 0^{+-}\ 1^{-+}\ 2^{+-}\ \ldots$

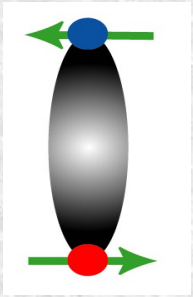
Not-allowed: exotic

The flux tube gives an extra degree of freedom with $J^{PC} = 1^{-+}$ or $J^{PC}=1^{+-}$ for the flux-tube in the first excited state.



Quarks ⊕ **Excited Flux Tube** → **Hybrid Meson**

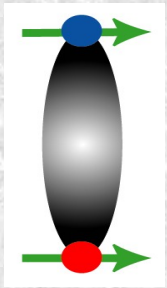
$S = 0$
$L = 0$
$J^{PC} = 0^{-+}$
like π, K



$J^{PC} = \begin{cases} 1^{+-} \\ 1^{-+} \end{cases}$

$J^{PC} = \begin{cases} 1^{--} \\ 1^{++} \end{cases}$

$S = 1$
$L = 0$
$J^{PC} = 1^{--}$
like γ, ρ



$J^{PC} = \begin{cases} 1^{+-} \\ 1^{-+} \end{cases}$

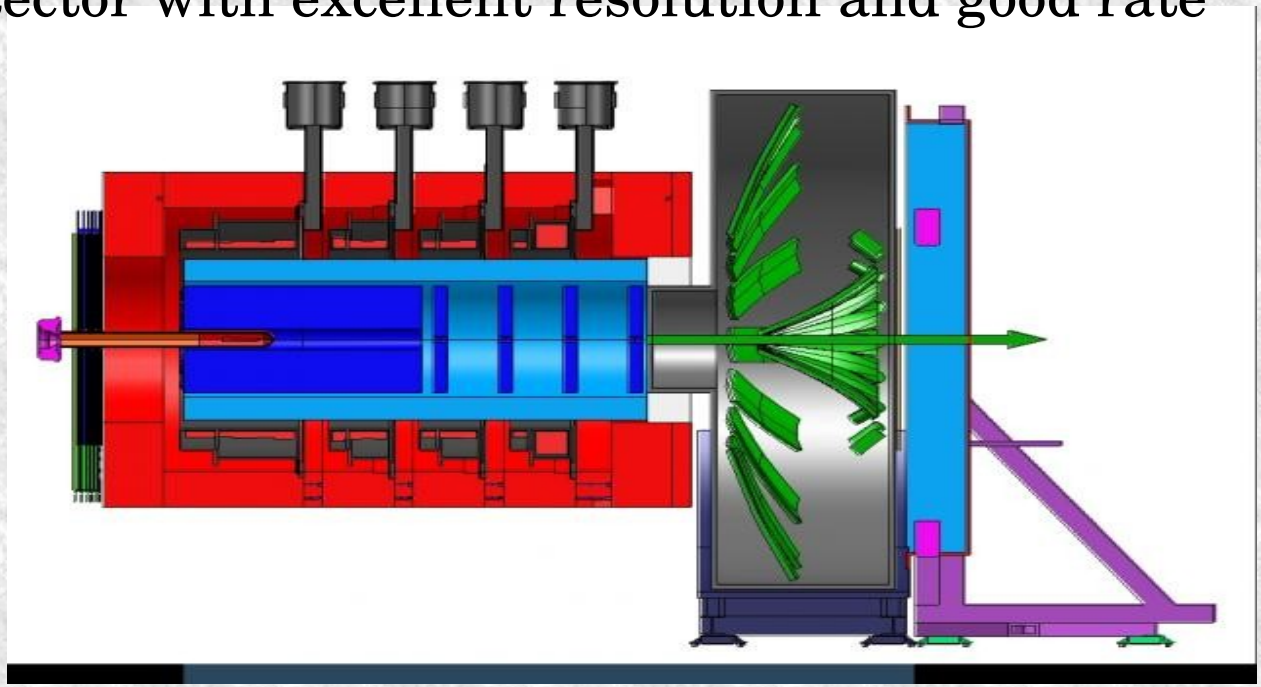
Exotic

$J^{PC} = \begin{cases} 0^{-+} & 1^{-+} & 2^{-+} \\ 0^{+-} & 1^{+-} & 2^{+-} \end{cases}$

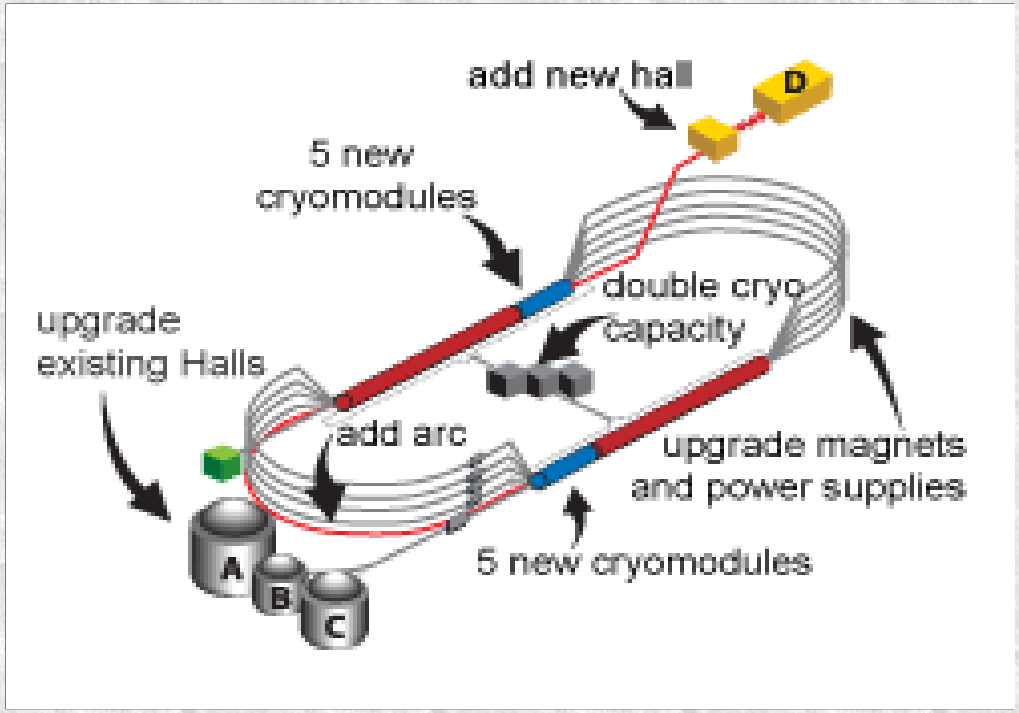
• The GlueX/Hall D collaboration was formed to design a photon beam and detector to map the exotic hybrid spectrum

•GlueX will collect statistics on mesons up to 2.5 GeV/c^2

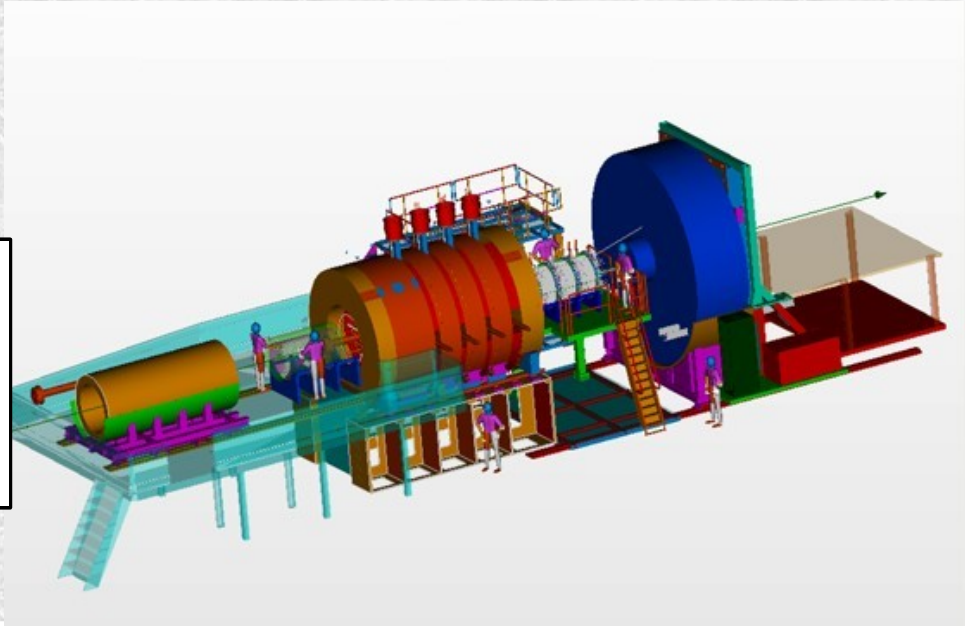
•Partial wave analysis (PWA) will be used to identify the quantum numbers of the mesons. This requires an hermetic detector with excellent resolution and good rate capabilities.

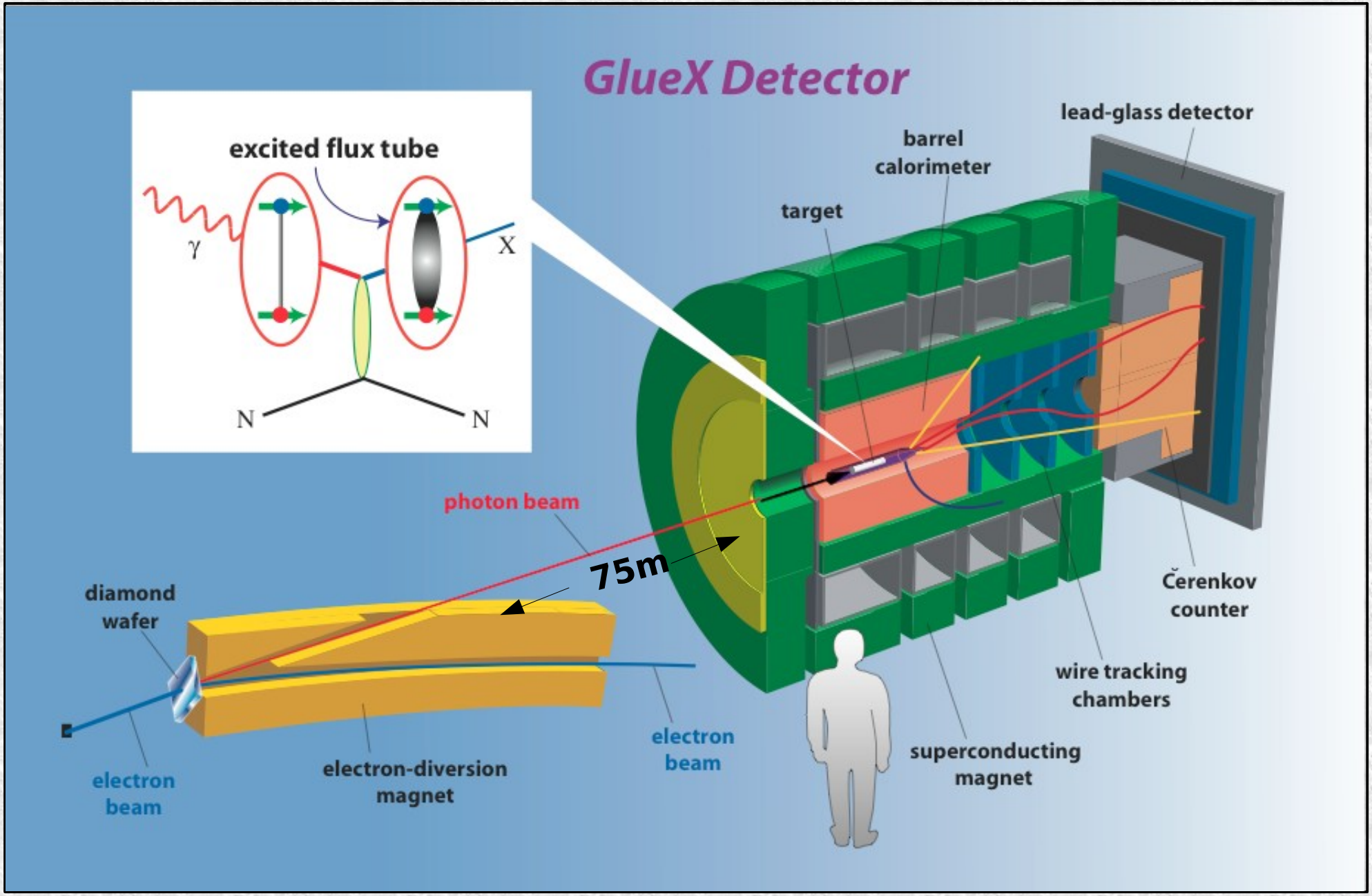


In addition, sensitivity to hybrid masses up to 2.5 GeV/c^2 requires 9 GeV photons which will be produced using coherent bremsstrahlung from 12 GeV electrons.



GLUEX CITATIONS PERIMENT




GlueX Detector
excited flux tube
γ
X
N
N
lead-glass detector
barrel calorimeter
target
photon beam
75m
diamond wafer
Čerenkov counter
wire tracking chambers
electron beam
electron-diversion magnet
electron beam
superconducting magnet

GlueX Electromagnetic Barrel Calorimeter (BCAL)

A key component of the GlueX detector

1. crucial for reconstructing all the photons from pi-0 and eta decays which can come from produced mesons
2. required for providing timing information for charged particles
3. in conjunction with the CDC will provide the PID for proton detection
4. will provide secondary dE/dx and timing info for other systems

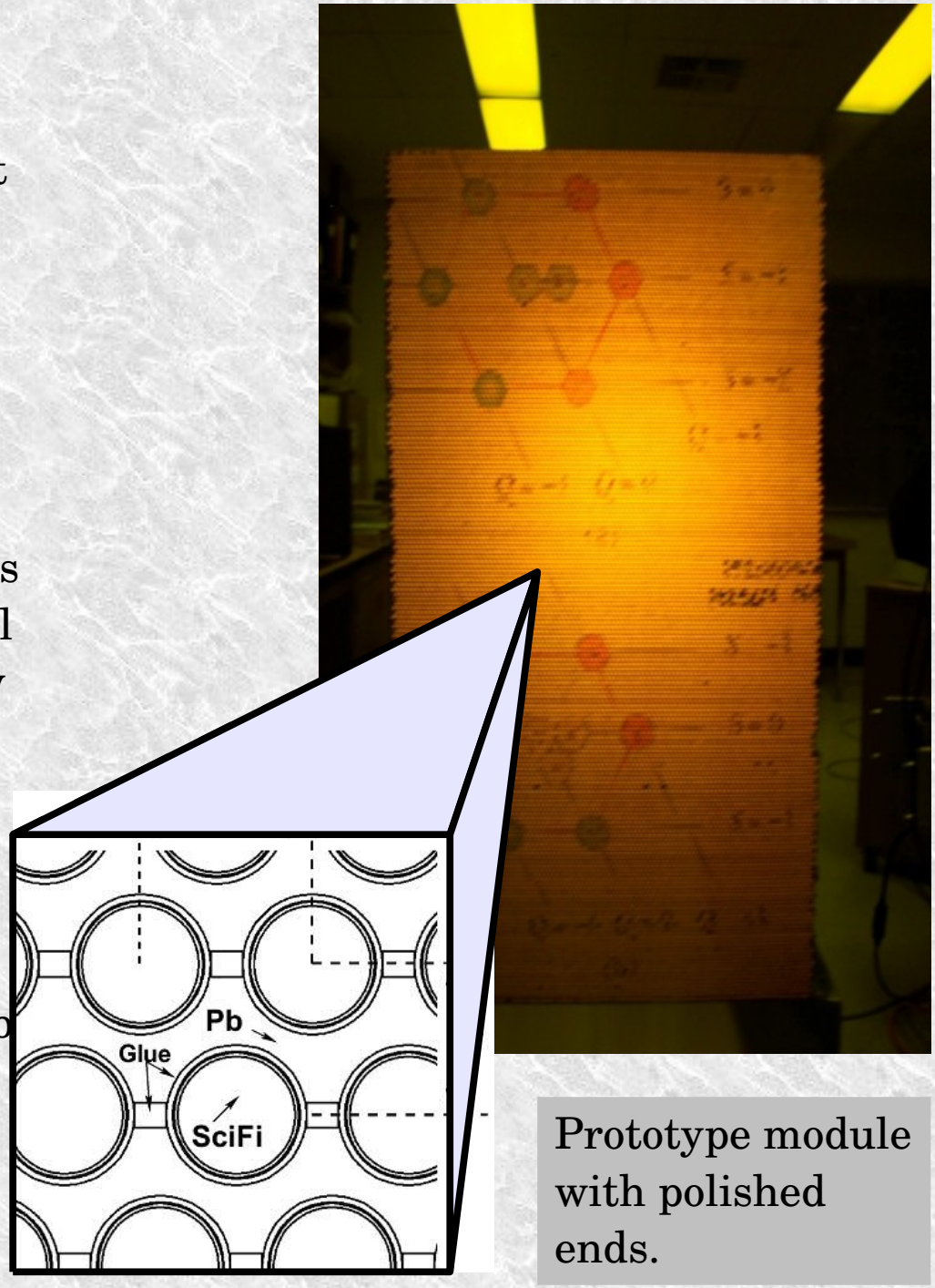
Students construct a prototype BCAL module in Edmonton, Alberta.

•Based on the KLOE design at DAΦNE but improved (better fibres, construction, etc.)

• The BCAL will consist of 48 modules 390cm long and 25cm thick in a barrel configuration (~40 tonnes)

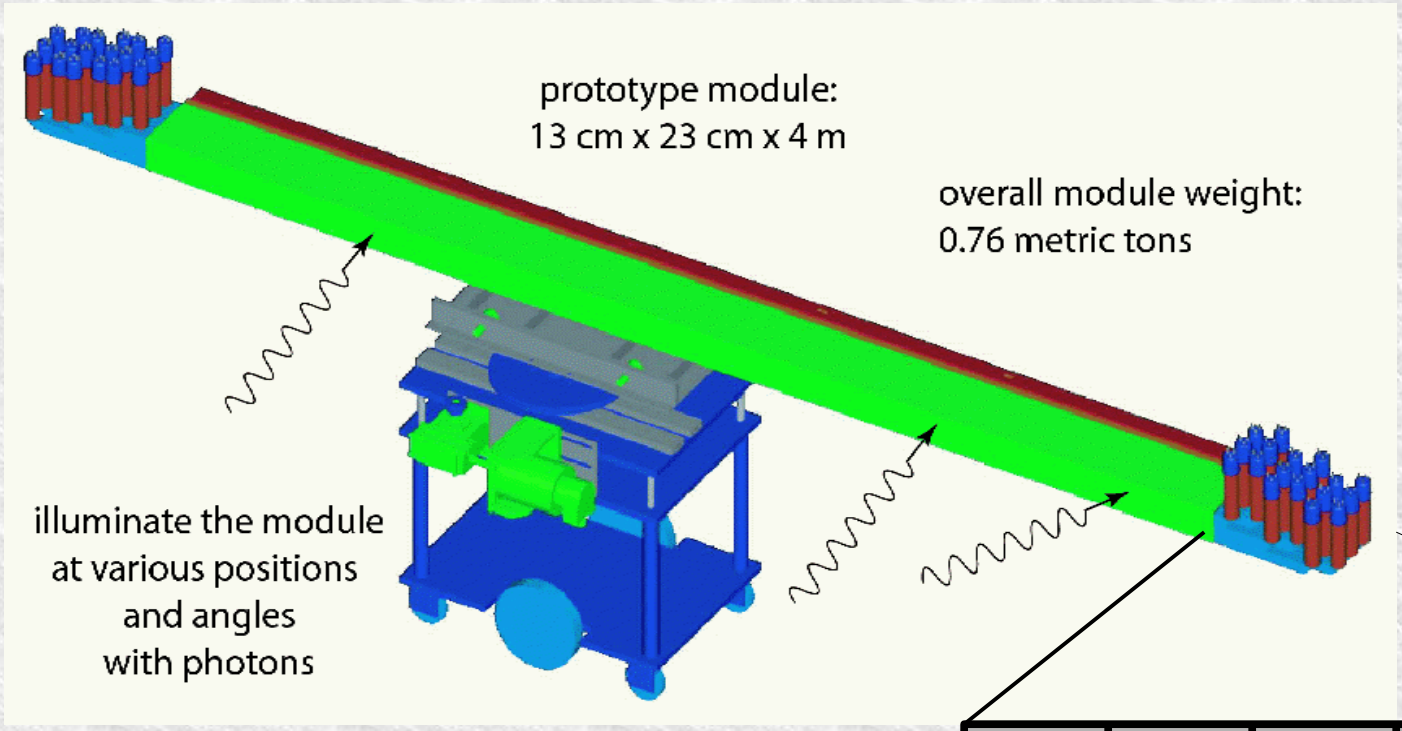
• Each module is made of alternating layers of lead, scintillating fibres and glue (optical epoxy) to bond them together (37:49:14 by vol.)

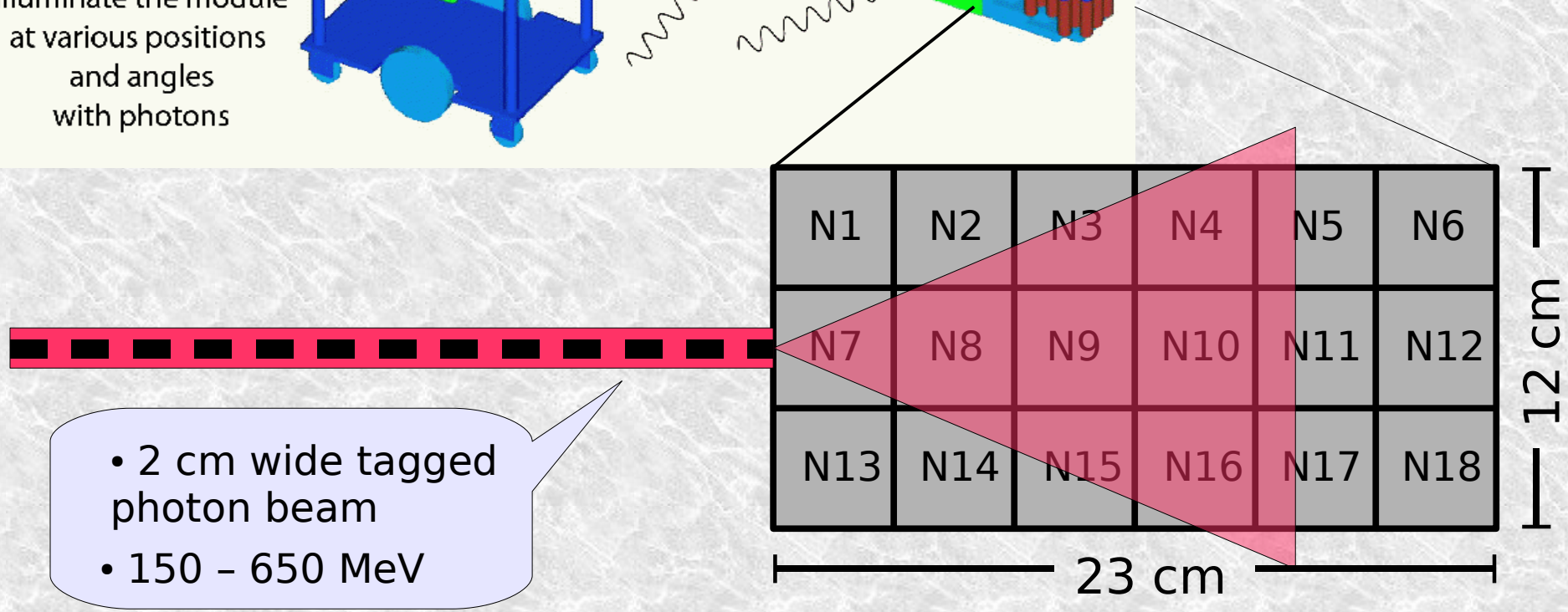
•The scintillating fibres (SciFi) have a polystyrene core which produces 8000 (4000) photons/MeV and are fast green or blue double clad (increases light captured b ~50%)



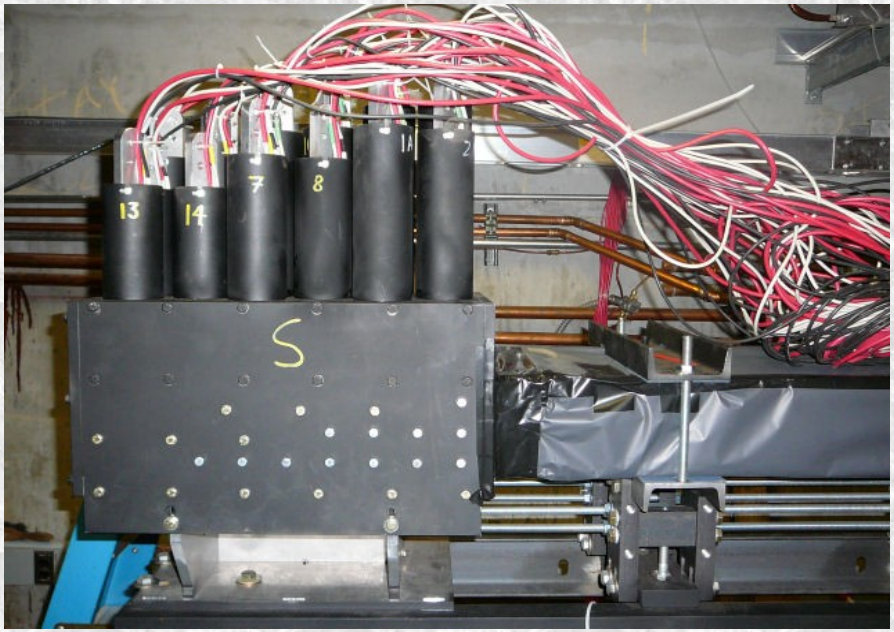
Prototype module with polished ends.

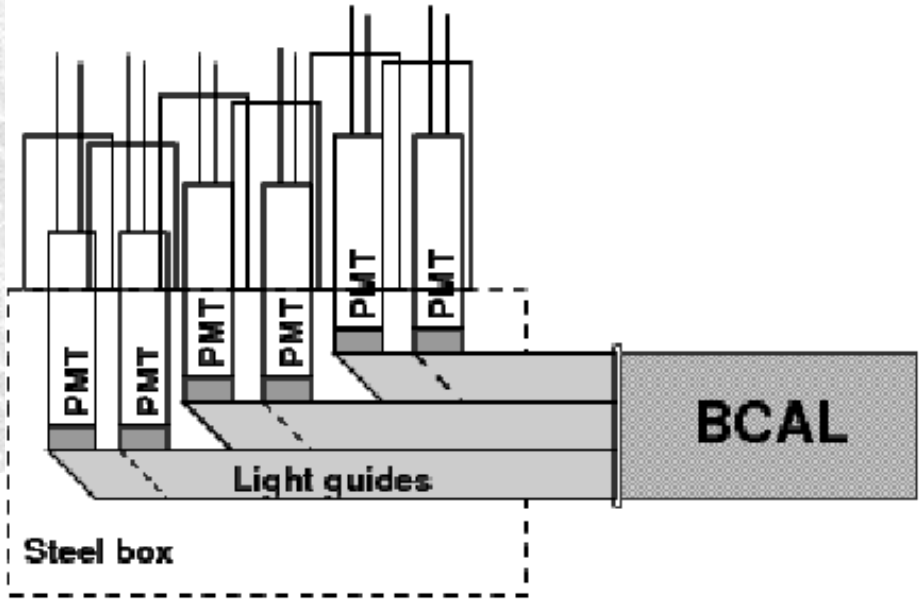
Hall B beam test of the BCAL in Fall 2006

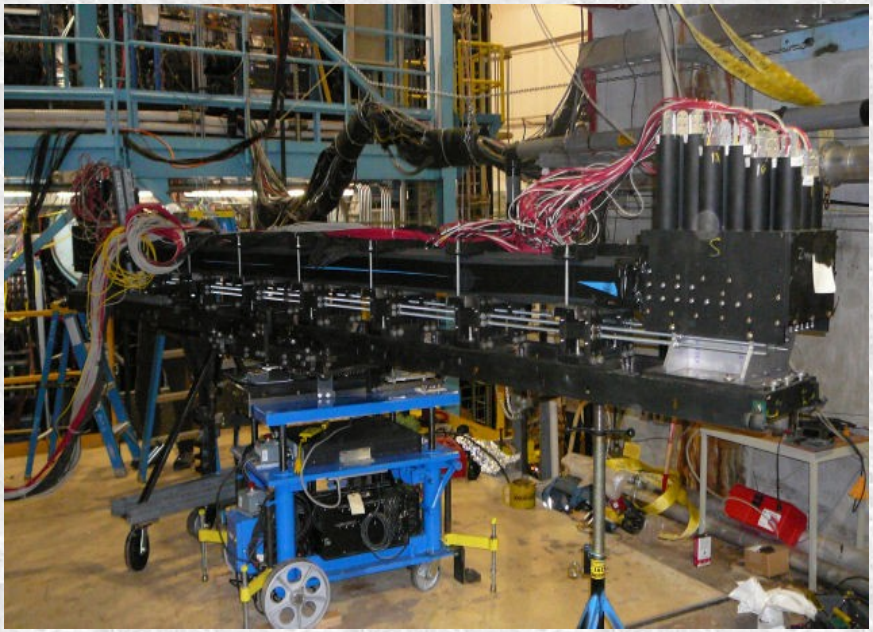


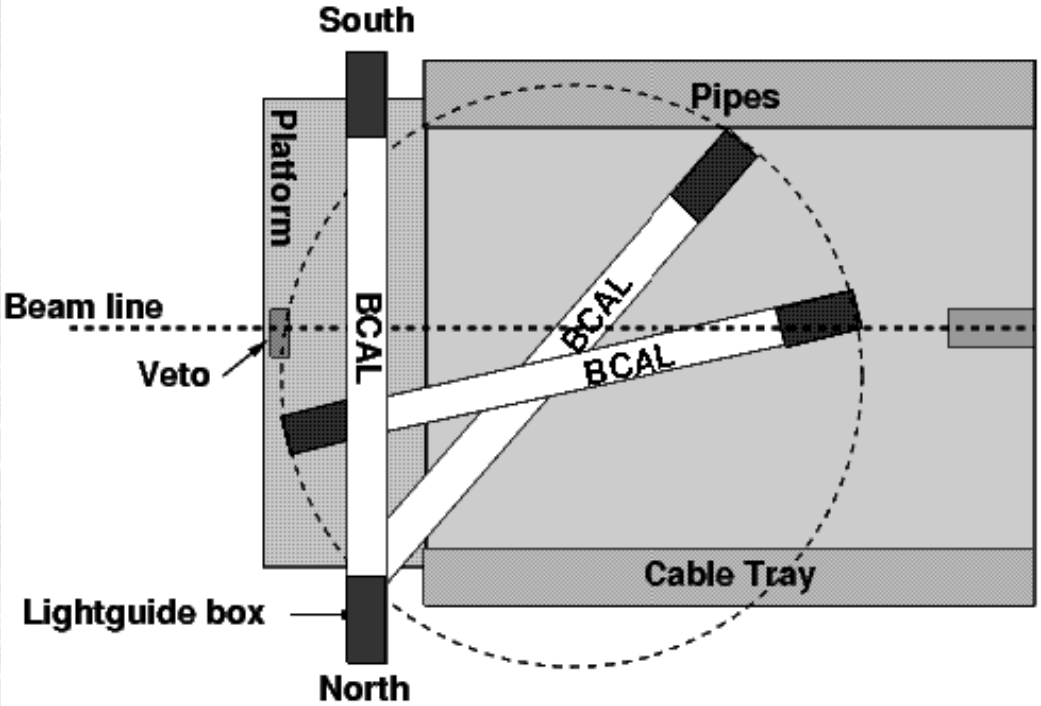


- 2 cm wide tagged photon beam
- 150 – 650 MeV




PMT
PMT
PMT
PMT
PMT
PMT
BCAL
Light guides
Steel box




South
Pipes
Platform
Beam line
BCAL
BCAL
BCAL
Veto
Cable Tray
Lightguide box
North

Goals of the beam test: measure the energy, timing and position resolution of the calorimeter module.
Requirements of Gluex: ~5%/√E energy resolution and ~1 cm/√E position resolution for photon reconstruction

KLOE final resolutions:

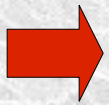
Energy

$$\frac{\sigma(E)}{E} = \frac{5.4\%}{\sqrt{(E(GeV))}} \oplus 0.7\%$$

"The resolution is dominated by sampling fluctuations with a contribution from photoelectron statistics of ~2.4%. [1]"

Timing

$$\sigma_t = \frac{56\,ps}{\sqrt{(E(GeV))}} \oplus 133\,ps$$



"The constant term is mostly due to the instrinsic time spread due to the finite length in the z direction of the luminous point. [1]"

[1] NIM A 494(2002)326-331

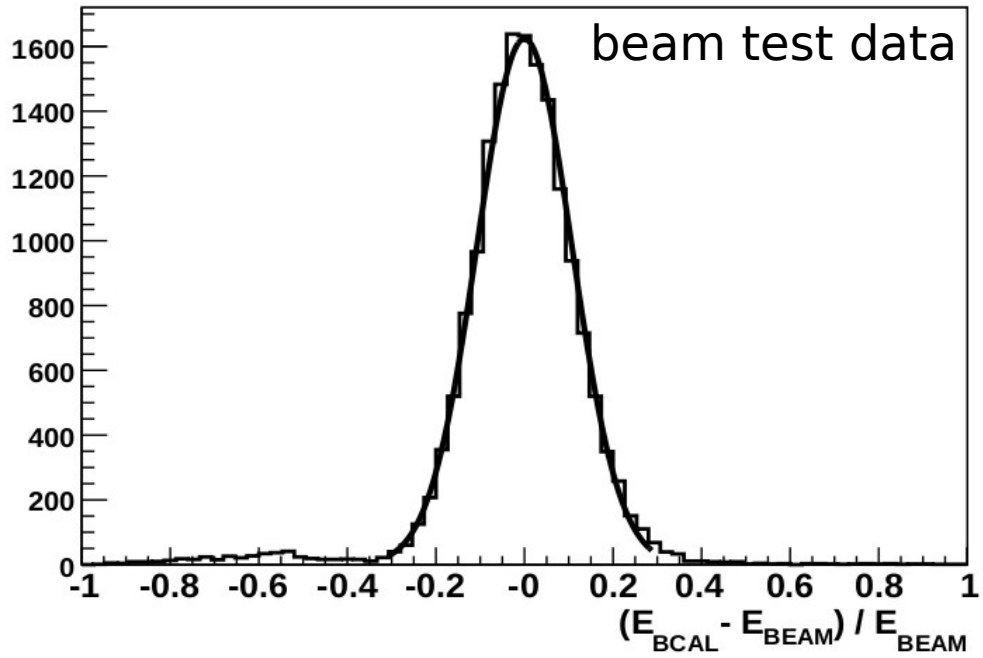
BCAL Beamtest Energy Resolution

Important step: Gain balance all 36 of the PMTs

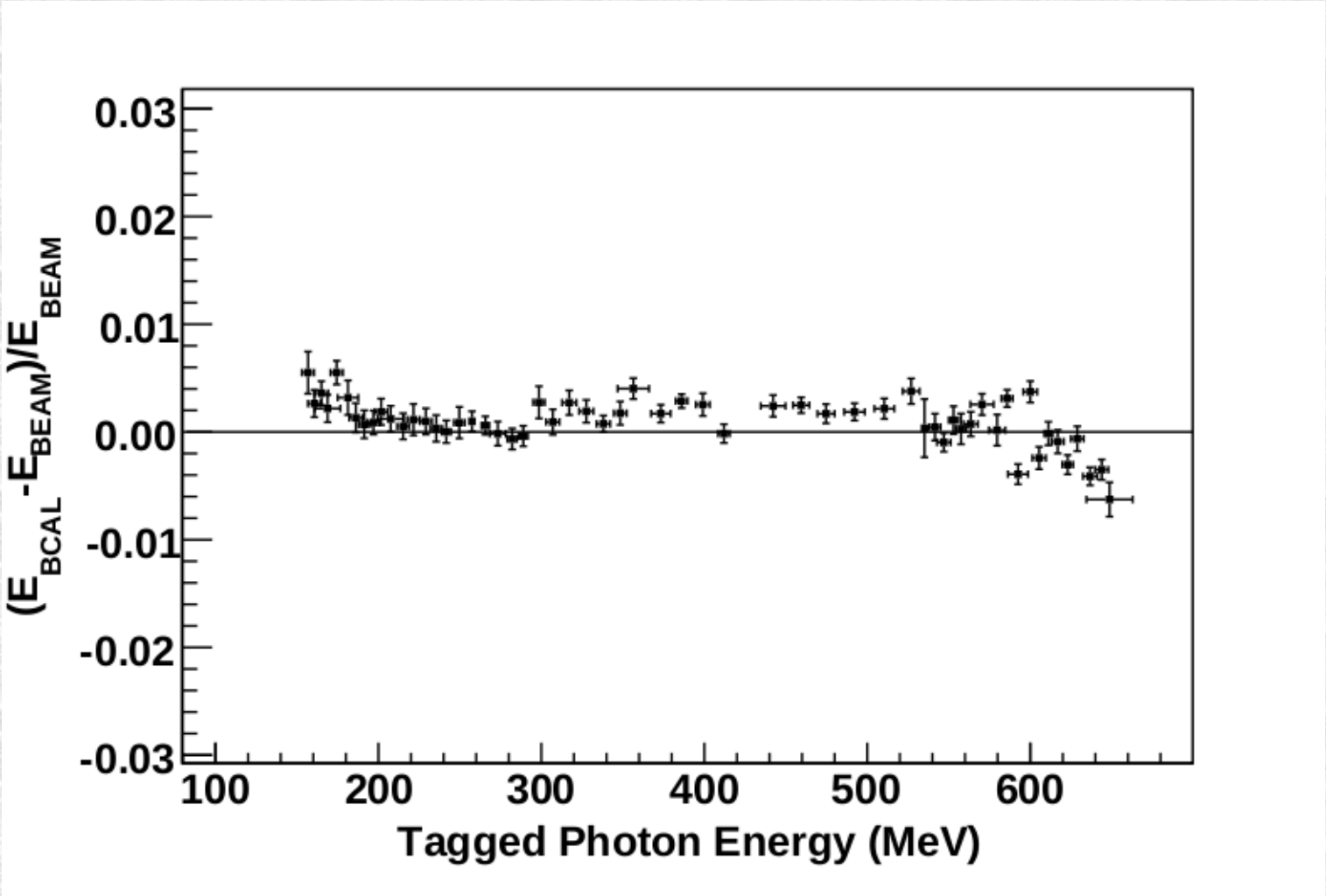
Online: the means of the cosmic ADC spectra were balanced to within 10% during setup; some channels deviated by up to a factor of 2

Offline: minimize the width of the difference between the tagged beam energy, E_{beam} and the reconstructed energy in the BCAL, E_{bcal}

$$D = \frac{E_{beam} - E_{bcal}}{E_{beam}}$$

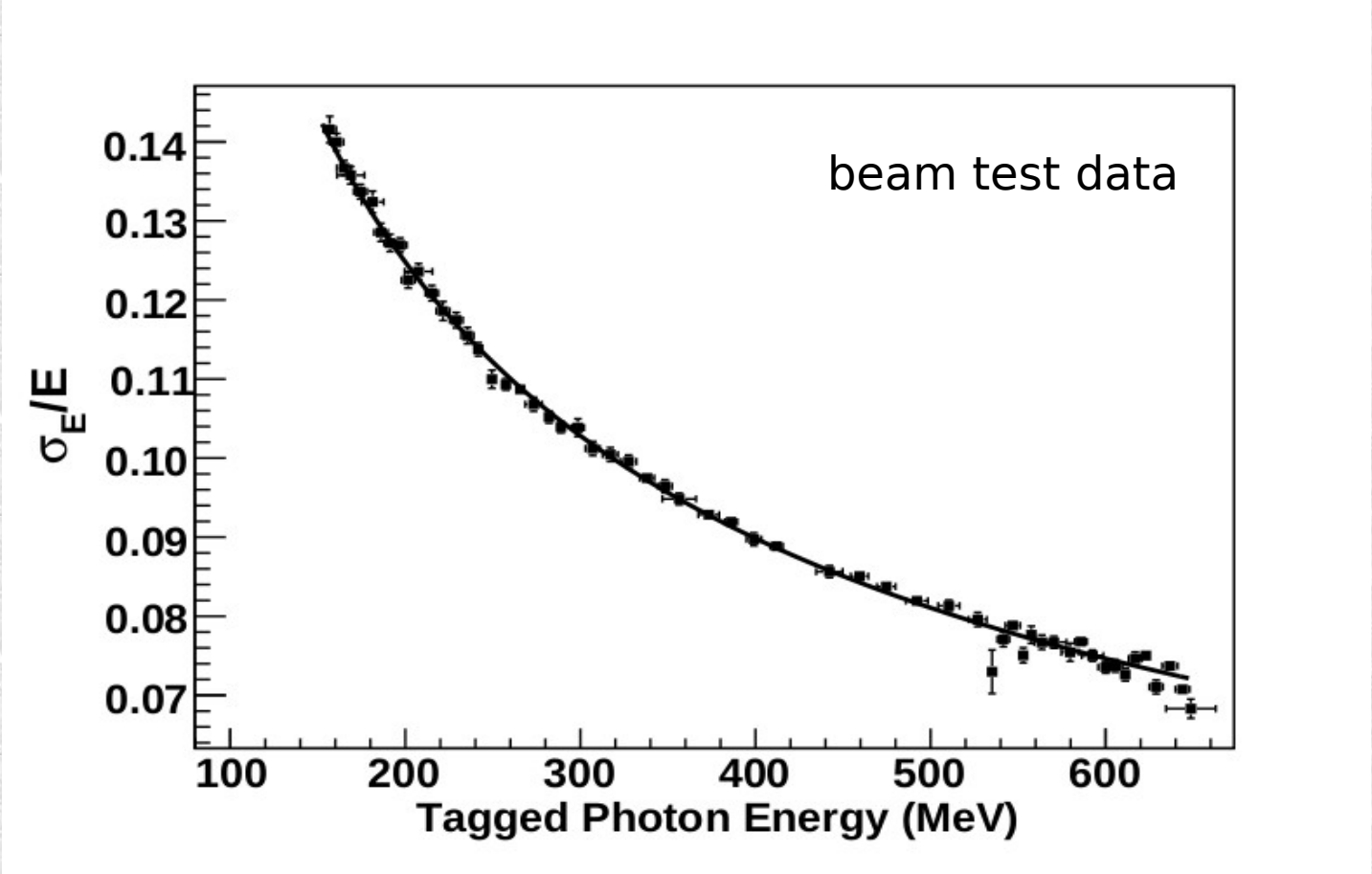


• D = $(E_{bcal} - E_{beam})/E_{beam}$ from beam test data after gain balancing and calibration.
• Notice that the deviations from zero are typically less than 0.5 %



The energy resolution vs. E_{beam} for photons for $\theta=90^{o}$ and z=0cm.

$$\frac{\sigma_E}{E}=\frac{5.5\pm0.1\%}{\sqrt{E}}\oplus 2.4\pm1\%$$

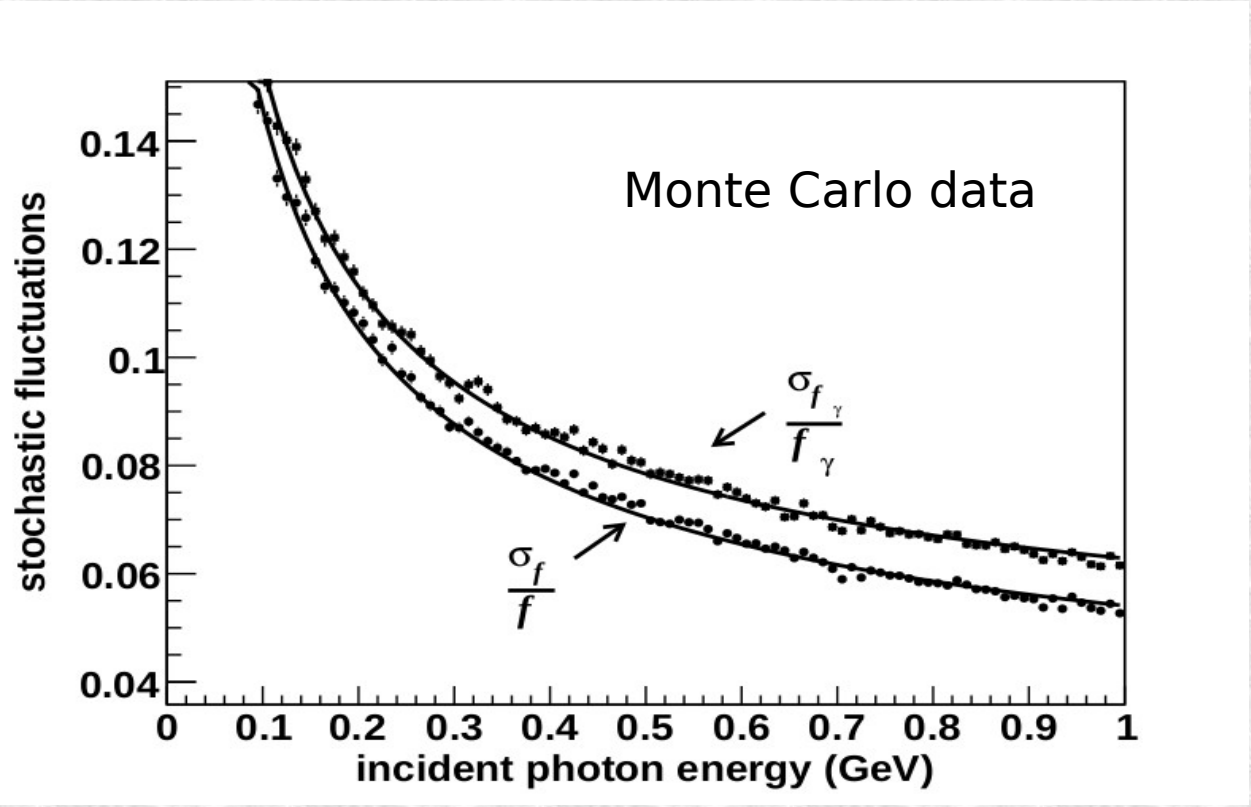


contributions to energy resolution

• the dominant contribution to the energy resolution is the *fluctuations in the energy sampling* by the scintillating fibres

•the *properties of the scintillating fibres* and *coupling* will affect the photon statistics contribution to the resolution

$$\frac{\sigma_E}{E} = \frac{\sigma_f}{f(E)} \oplus \frac{\sigma_{pe}}{E}$$



sampling fluctuations

$$\frac{\sigma_f}{f(E)} = \frac{4.5\%}{\sqrt{E(GeV)}} \oplus 1\%$$

photoelectron statistics

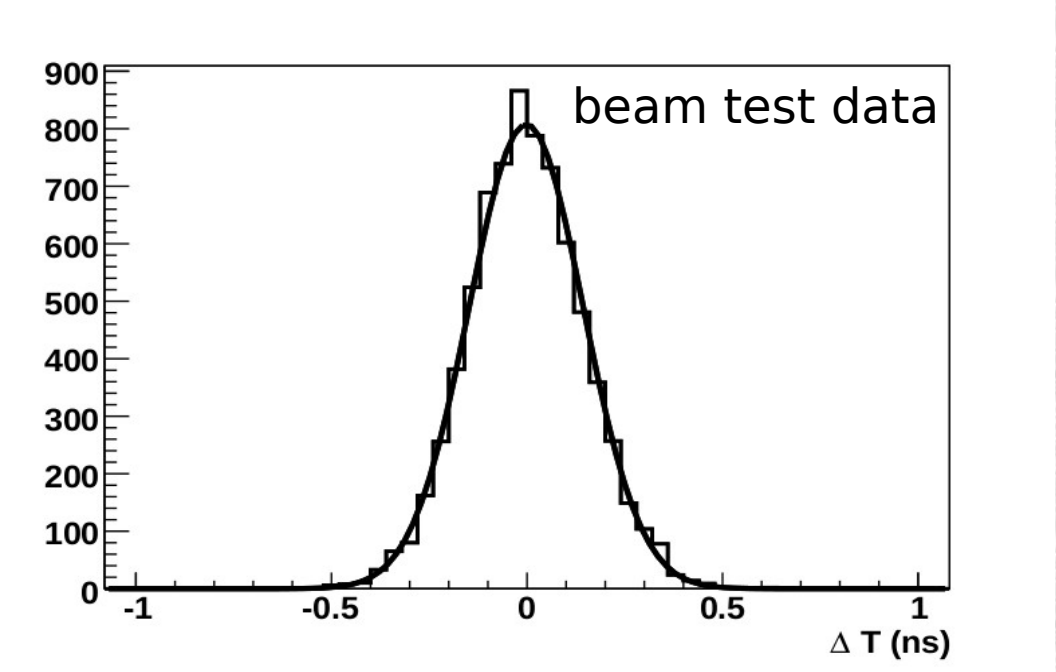
$$\frac{\sigma_{pe}}{E} = \frac{3.1\%}{\sqrt{E(GeV)}}$$

BCAL Beam test Timing Resolution

The time difference resolution will provide position information for neutral particles. A good resolution is then need for reconstructing events that contain neutral final states.

Time difference

$$\frac{\Delta T}{2} = \frac{1}{2} \frac{\sum_i E_i (T_{N,i} - T_{S,i})}{\sum_i E_i}$$

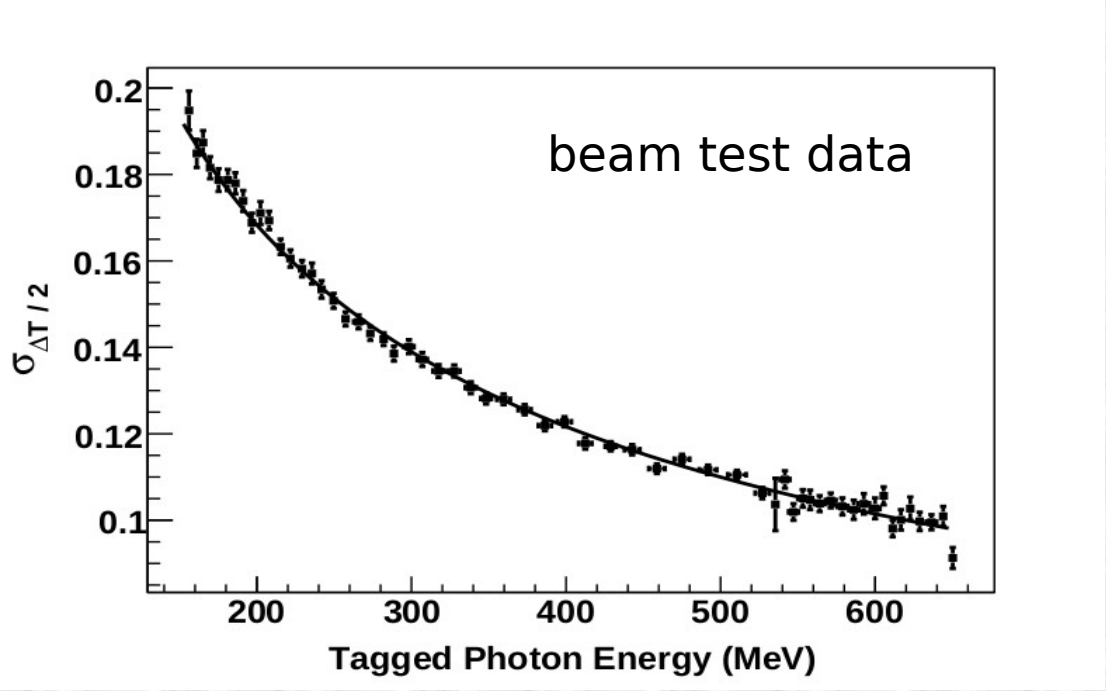


time difference resolution

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

position resolution

$$\sigma_z = \sigma_{\Delta T/2} c_{eff} = \frac{1.1\,cm}{\sqrt{E(GeV)}}$$



The width of the beam (1.8 cm at the BCAL) contributed to the resolution (sigma/√12) = 30ps and was removed.

Summary

• The majority of the analysis is completed showing that the BCAL will perform well for the GlueX experiment

•Some final work on determining the resolution at angles and near the end of the module is being done

•GlueX is an important experiment in understanding gluonic excitations in meson spectroscopy and QCD.

•This work is in the process if being submitted as a NIM article

Acknowledgments

Many thanks to my fellow collaborators on the beam test:

G.J.Lolos[1], Z.Papandreou[1], R.Hakobyan, G.M.Huber[1], K.L.Janzen[1], A.R.Dzierba[2], E.B.Scott[2], M.R.Shepherd[2], D.S.Carman[3], D.W.Lawrence[3], E.Smith[3], S.Taylor[3], E. Wolin[3], F.Klein[4], J.P.Santoro[4], D.I.Sober[4], C. Kourkoumeli[5]

[1]University of Regina , [2]Indiana University, [3]Thomas Jefferson National Accelerator Facility, [4]The Catholic University of America, [5]University of Athens