GlueX Barrel ECal Simulations

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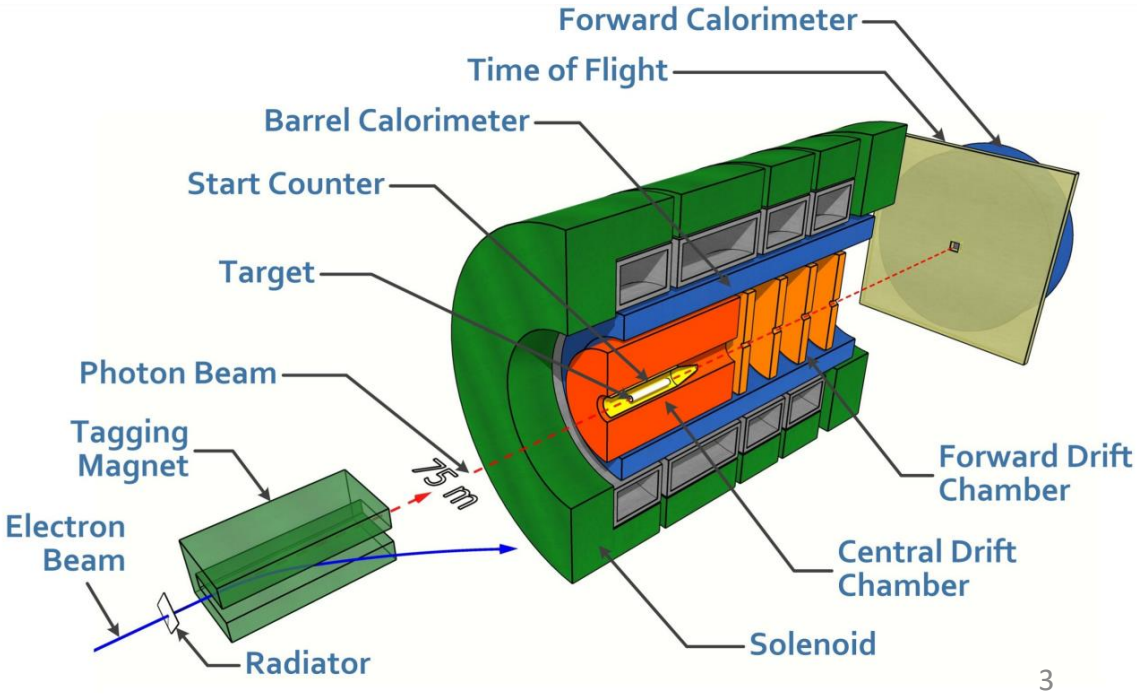
Discussion of BCAL Simulations @ GlueX

- I'll try to summarize GlueX work, mostly from NIM papers, some internal documentation
- Much of this work from late 2000s – early 2010s
  - Summarizing work by Zisis, George Lolos, and students
- Might not hit all points in detail, but hopefully we can determine what to focus and prioritize

GlueX Geometry & Kinematics

- Start time: known precisely, independent of BCAL
- Photons up to ~ 2.5 GeV
- ~ 15 radiation lengths at 90°
- SiPMs determine shower E, ϕ
  - fADC readout
- TDCs aid in determining z
  - Primary vertex: from tracking



References

Much of this talk documented in NIM papers on GlueX BCAL

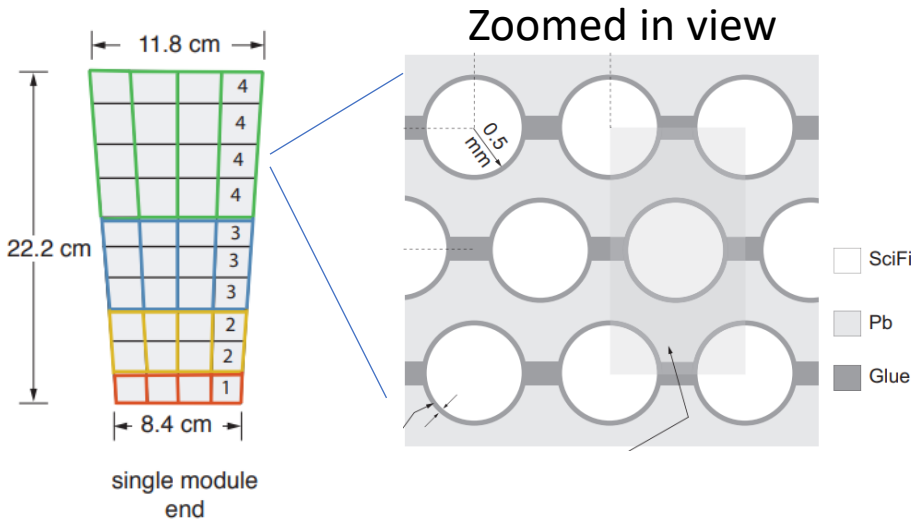
- GlueX NIM, all subsystems (2021): https://arxiv.org/abs/2005.14272

More details:

- Post-construction BCAL NIM (2018): https://arxiv.org/pdf/1801.03088.pdf
- Beam test NIM (2008): https://doi.org/10.1016/j.nima.2008.08.137

(Nonstandard) Simulations for GlueX BCAL

- Used for special studies, not for physics analyses
- GEANT: simulate only one module (right)
  - Longitudinal shower distribution
  - Sampling fraction
  - Energy leakage
  - Determine expected resolution
  - GEANT 3.21…
- FLUKA: 5 modules
  - Deemed more accurate at lower energies
  - Study readout segmentation, low E response
  - Cross check to GEANT



Sampling Fraction From Simulation

- Fraction of energy deposited in SciFi / total module:

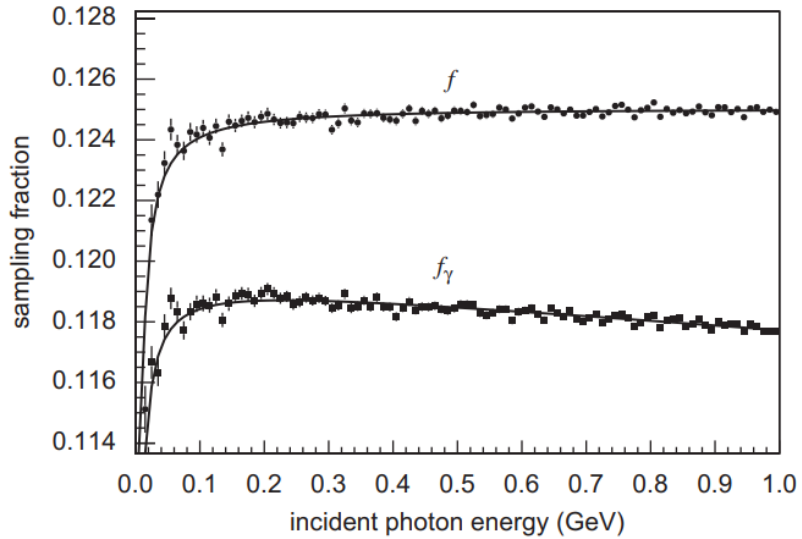
$$f = \frac{E_{SciFi}}{E_{mod}}$$

- Or fraction of energy deposited / photon E

$$f_\gamma = \frac{E_{SciFi}}{E_\gamma}$$

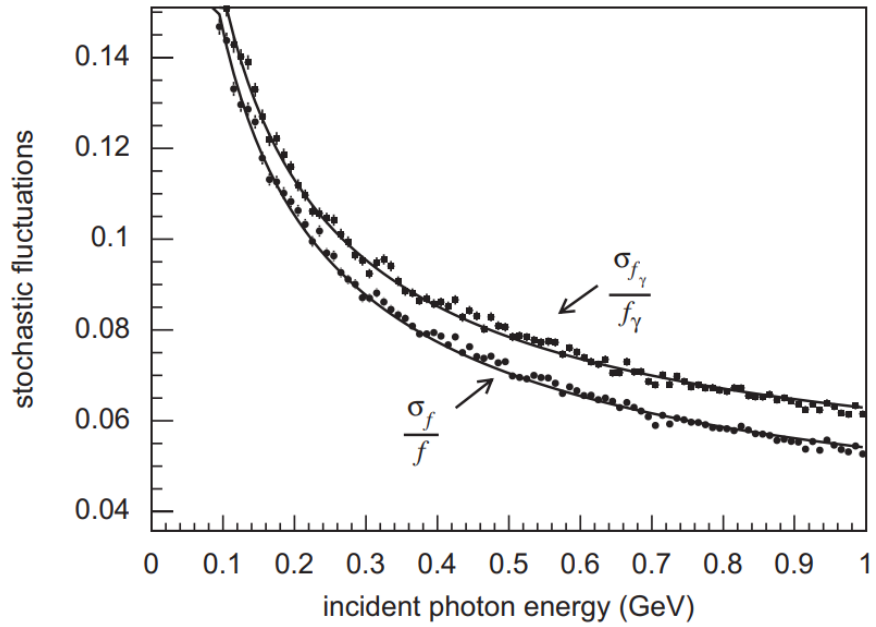
(f and f_γ differ in terms of whether leakage included in denominator)

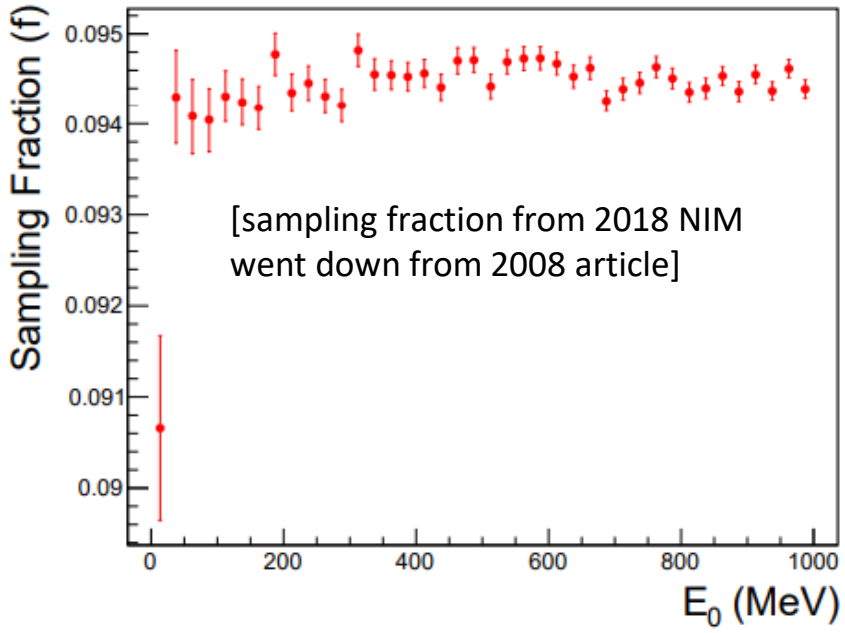
Angle of incidence: 90°



Sampling Fraction and Resolution

- Stochastic variation in sampling fraction main driver of resolution
- Care in fiber description: only core considered sensitive for f
  (not two layers of cladding outside core, which are also in geometry)





Standard GlueX Simulations (reference)

- Main BCAL simulation code on GitHub (class `GlueXSensitiveDetectorBCAL`)

- Homogeneous mix of Pb + SciFi + glue
  - XML geometry on GitHub
  - XML Pb+SciFi material on GitHub

- GlueX Geant4 Guru: Richard Jones (richard.t.jones@uconn.edu)

Table 1: Summary of BCAL properties.

Property	Value
Number of modules	48
Module length	390 cm
Module inner/outer widths	84.0 mm/118.3 mm
Lead-scintillator matrix thickness	221.9 mm
Inner/outer Al plates thickness	8 mm/31.75 mm
Module azimuthal bite	7.5°
Total number of fibers	685000
Lead sheet thickness	0.5 mm
Kuraray SCSF-78MJ multi-clad fiber	1.0 mm
Fiber pitch radial/lateral	1.22 mm/1.35 mm
Weight fractions (% Pb:SF:Glue)	86.1: 10.5: 3.4
Effective density	4.88 g/cm^3
Effective Radiation Length	1.45 cm
Effective Molière radius	3.63 cm
Effective Atomic Weight	71.4
Effective Atomic Number	179.9
Sampling fraction	0.095
Total weight	28 t

GlueX Simulation Parameters (another reference)

Parameters read from calibrations database for BCAL:

- Minimum energy for cell hit (1 MeV)
- Minimum time between hits (merge hits in cell if < 50 ns)
- Max hits allowed per cell (100)
- Attenuation length of SciFi
- c_{eff} for SciFi

Shower Progression in GlueX MC

As shower progresses through sensitive material

1. Collect hits in cell above min 1 MeV
2. Calculate hit time and attenuated energy at end of fiber
3. Merge hits if closer than 50 ns from arrival at BCAL end
4. Calculate upstream and downstream ends separately

Simplifications (by my potentially flawed reading)

- After hit(s) in cell collected, nothing explicitly modeled by geant(?)
- Energy attenuated (no stochasticity)
- Hits merged by simple energy weight E_i/E_{tot}

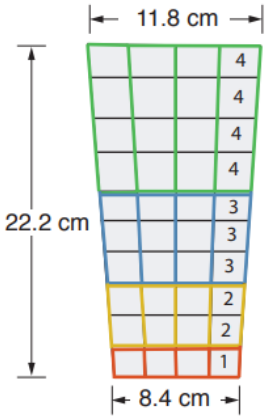
Shower Progression, cont.

- Attenuation:
  - Assume single exponential, no stochasticity
  - Double exponential found to describe SciFi better, but not used
- Timing:
  - No explicity modeling of light guide, SiPM, preamp, etc. ?

- Energy and time are smeared empirically after geant4 simulation

Cluster Reconstruction: Short Sketch

- Start with highest energy cell as “seed”
  - Add additional cells based on proximity, energy until possibilities exhausted
  - This forms a “cluster”, repeat until no more “seed” cells
- Double check if cell fits another cluster better
- Merge clusters, if close enough together
- No attempts at splitting
  (no mention in documentation, at least)



single module
end

(1 cell = readout from 1-4 SiPMs and 0 or 1 TDCs)

Shower Reconstruction (reference)

- Clusters can be reconstructed independent of other subsystems

- Going from cluster ⇒ neutral shower object:
  - Get initial vertex in target determined from tracking
  - Veto likely hadronic showers via track projections to BCAL, timing
  - Apply nonlinear corrections

- Shower position:
  - Determined by energy square weighted average
  - To do: dig into shower-level correction factors, if any