BCAL gain Calibration using $\pi^0$s

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Outline

1. Detectors in GlueX

2. BCAL- design and working principle

3. BCAL Gain Calibrations
   a. Energy determination algorithm
   b. Calibration using pi0
   c. To address the presence of nonlinearity after the calibration.
BCAL detects $n, \gamma, p, \pi^+, \pi^-$

BCAL along with tracking chambers gives the PID information

Barrel Calorimeter (Bcal)

Pb-glass detector (Fcal)

Time-of-flight (tof)

Target ($LH_2$)

Tracking
Cathode strips
Drift chambers
Straw tubes

Superconducting
2 T solenoid

Hall D at Jefferson Lab

add 5 cryomodules
20 existing cryomodules
add arc

add 5 cryomodules
20 existing cryomodules
Barrel Calorimeter (BCAL)

- 4 m long detector with $r_\leq = 65 \text{ cm}$ and $r_\geq = 90 \text{ cm}$
- Polar acceptance $12^\circ < \theta < 126^\circ$
- Segmented into 48 azimuthal modules with each module containing 40 SiPMs. Provides almost $2\pi$ coverage
- 1 module has 185 layers of Pb sheet with 184 layers of double clad scintillating fibres.
- Total 685000 fibres connected to 3840 SiPMs (Resistant up to 2T) with 1536 readouts
BCAL before inserting into the bore magnet

\[ \frac{\sigma(E)}{\sqrt{E}} = \frac{5.2\%}{\sqrt{E}} \oplus 3.6\% \]

\[ \sigma(z) = 3\text{cm} \]

\[ \sigma(t) \approx 200\text{ps} \oplus 1\text{GeV} \]

SiPM attached readout module

Summing scheme
Determination of energy and calibration using $\pi^0$ in BCAL

$$\gamma p \rightarrow \eta p \rightarrow 3\pi^0 p \quad \pi^0 \rightarrow \gamma_1 \gamma_2$$

- Energy of photons are determined by the SiPM’s attached at the end of the Sci-Fibres.
- The position of photon shower is reconstructed using the timing information. The vertex of reaction is calculated from charged particle.
- $\pi^0$ s offer large statistics in the energy range of interest (0.5-3 GeV)
The Calibration Algorithm

1. Events with $\pi^0 \rightarrow 2 \gamma$ with at least 2 charged particles.
2. Determine photon energies $(E_{\gamma_1}, E_{\gamma_2})$
3. Find event vertex using the charged particles.
4. Select channels in layer 1 and 2 having more than 50% of the deposited energy $(E_{\gamma_1}$ and $E_{\gamma_2})$
5. Reconstruct invariant mass of $\pi^0$ using the $E_{\gamma}$'s and the vertex\(^1\), and fit it. $m^2 = 2E_1E_2(1 - \cos(\psi))$
6. Form ratio with PDG invariant mass (0.135 GeV) to the measured mean of invariant mass and use to adjust gains for each channel
7. The entire procedure is iterated till tolerance is less than 1%

\[1\] https://doi.org/10.1016/j.nima.2018.04.006
Calibration plots

Channel number vs reconstructed inv_mass (Iteration 0)

- Layer 1
- Layer 2
- Layer 3

Channel number vs reconstructed inv_mass (Iteration 5)

- Layer 1
- Layer 2
- Layer 3
Calibration plots (continued)

\[ \mu = 0.1349 \quad \sigma = 0.008 \]

\[ \mu = 0.1349 \quad \sigma = 0.0075 \]

Vs Iteration
Checks in Different energy ranges

σ/μ vs. Iteration (E1, E2 > 500 MeV)

σ/μ vs. Iteration (E1, E2 > 700 MeV)

σ/μ vs. Iteration (E1, E2 > 900 MeV)

σ/μ vs. Iteration (E1, E2 > 1100 MeV)
Nonlinearity after the calibration

- SiPM and FADC Saturation: FADC -> Constant pulse shape normalisation: SiPM No correction
- An empirical nonlinear function is fit to the plot and is used to correct for nonlinearity

$$\pi^0$$ Mean vs Energy bin

Before Linearity Correction

After Linearity Correction
Conclusions

- BCAL is a key detector in the GlueX experiment.
- The BCAL performance is monitored online.
- A new gain calibration for the BCAL is needed for every run period. BCAL is necessary. The π0 method shown here works well.
- SiPM saturation at high energies have also been employed.

References


- E. Smith “Note on Saturation in BCAL SiPMs” [GlueX-doc-3737-v4]
Thank you