Gain Calibrations of the BCAL using π^0s for Summer and Fall 2021 Run Period

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Abstract

This document gives a summary of the current status for the Gain Calibrations of BCAL for Summer and Fall 2021 Run period. In the detector, the photon shower positions coming from resonant particle decays are reconstructed using timing information. Since the energy of the photons produced by π^0 decay are determined by the SiPMs attached at the end of the Sci-Fibres, the Gain Calibration aims to equalize the gains across all SiPM readouts, for values below saturation. A brief study of optimal corrections and results of incorporating the new Gain Constants is shown and discussed, as well as the current status of the calibration.

Keywords: Silicon Photo Multipliers, Calibrations, Barrel Calorimeter, π^0 Calibrations

1. Background

In the energy range of 0.5 – 3 GeV, π^0 particles provide large statistics for photon shower position reconstruction. Taking the potential timing differences of the ADC readouts into account, along with different electronic components attached in the readout module, a calibration procedure is needed which equalizes for the SiPM readouts considering that they did not saturate. This method ensures consistent performance of the ADCs. This procedure is required at the end of each run period, meaning that two different gain calibrations (for two different run periods corresponding to the PrimEx and SRC experiments) will be discussed here. Layers that are included in the calibrations are the first three layers, which can be seen in Fig. 1, while the fourth layer is calibrated using cosmic muons.

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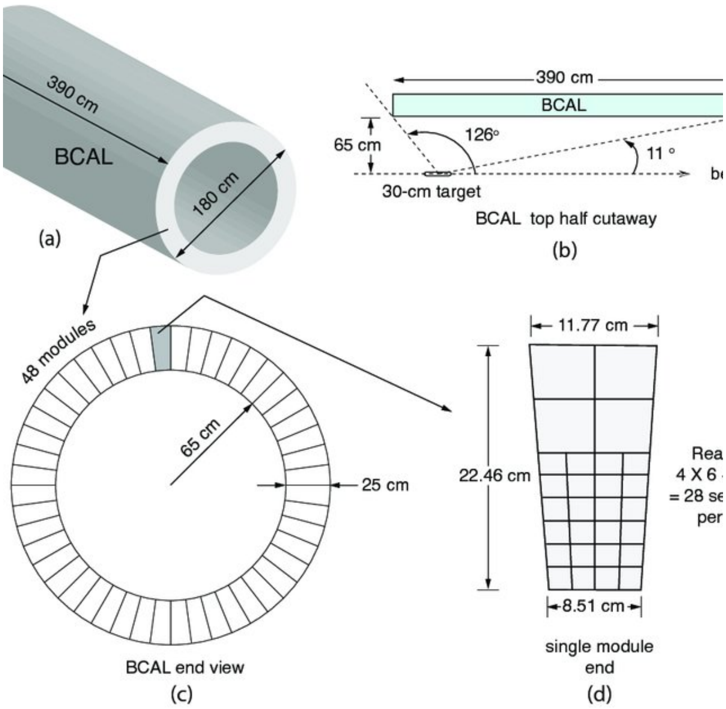

Figure 1: General geometrical attributes of the BCAL and its modules.

The algorithm behind the calibration registers π^0 events (along with at least two charged particles) which decay to a pair of photons, finds the vertex of the event using the charged particle information, determines the photon energies and at the end the invariant mass distribution is reconstructed for each π^0 particle. Using the peak of the distribution, a ratio with the PDG mass is calculated and used to adjust gains for each channel. A more in-depth explanation can be seen in [1]. This method is an iterative process, which at the final iteration, should adjust the ADC gain ratios so that the invariant mass of π^0 reconstructed in all given channels, show an uncertainty of less than 1%. This procedure introduces a strong nonlinear correlation between the measured energy of the photons to the reconstructed invariant mass, which is believed to be the dominant reason for the observed non-linearity. This has not been yet addressed in this analysis, however it was listed as an additional study that should be done.

2. Summer 2021 Calibration

For the Summer 2021 Gain Calibration, the run numbers 81262 - 81716 were initially considered. Usually, the Gain Calibration is done for each data set featured in the current run, resulting in batches that were calibrated separately. Since the conditions of the experiments, as well as the fixed targets change, it is necessary to give attention to each data set individually. Because the run conditions for the PrimEx experiment (Summer 2021) proved to introduce difficult conditions for calibration, only one batch could be used to get reasonable gain ratios. The ideal (or operable) conditions for Gain Calibration would be with the solenoid turned on during the experiment—otherwise the background would include charged particles which would result in a large background that would make calibration very ineffective—and the CDC and FDC on. Other notable conditions were that the beam energy was 10.04 GeV, the beam current 10^{-4} X_0 and the converter 750μm Be. Since most of the run data sets did not have those conditions, only the He data sets with run numbers 81473 - 81531, 81564 - 81633, 81674 - 81716 could be considered. Those runs fulfilled the conditions perfectly. The first iteration plots can be seen in Fig. 2, which were made using the default GlueX 2020 ccdb constants, while the final iteration after the calibration can be seen in Fig. 3. For plots of each iteration, and additional plots which also show the coefficient of variation (CV) plots for different energy ranges, and the difference between the current and initial gain ratios, the reader is referred to [2].

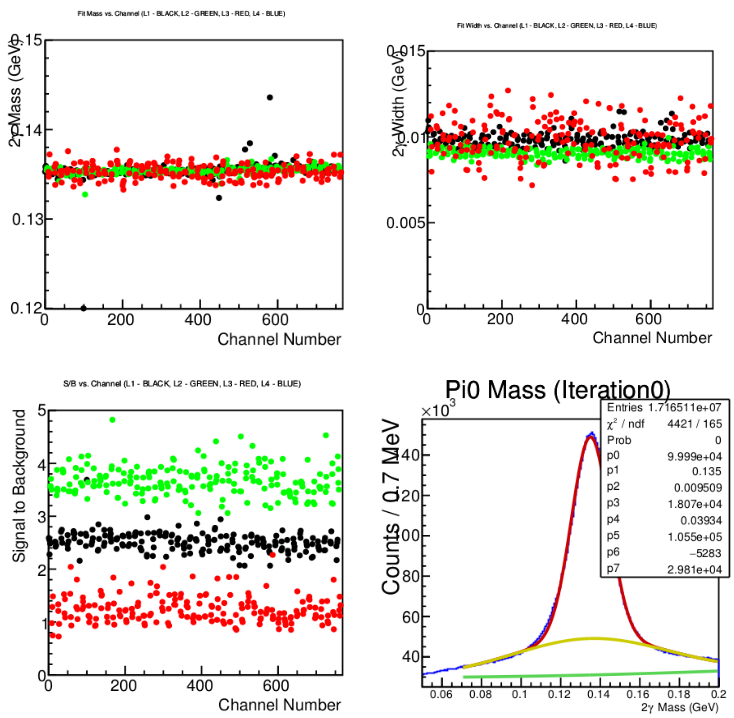

Figure 2: (Upper-left) Plot of the fit mass by layer for each channel in the BCAL using the 2020 ccdb constants. Ideally, this will be exactly at the value of the π^0 mass. (Upper-right) Plot of the fit width by layer for each channel. (Lower-left) Plot of the signal to background ratio by later for each channel. The first two layers yield the largest signal, as expected. (Lower-right) Reconstructed invariant π^0 mass along with the backgrounds.

From the plots, it can be seen that the calibration was successful and the π^0 invariant mass is well within 1% for each channel number. The gain ratios did not change too much in comparison with the previous ccdb constants, but there is still a considerable improvement for this data set

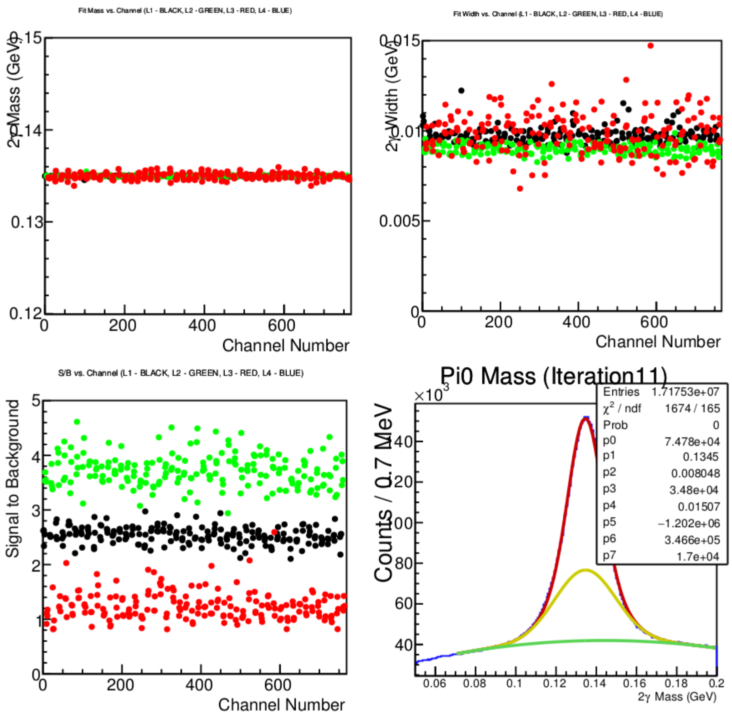

Figure 3: (Upper-left) Plot of the fit mass by layer for each channel in the BCAL after calibration using select PrimEx runs. (Upper-right) Plot of the fit width by layer for each channel after calbration. (Lower-left) Plot of the signal to background ratio by later for each channel after calibration. (Lower-right) Reconstructed invariant π^0 mass along with the backgrounds after calibration.

with the new gain ratios. One might argue that using just this small data set for the whole run period might not be very efficient, but considering the experiment conditions, this is the best that can be done in terms of calibration. Although the calibration was done, the new gain ratios were not uploaded to ccdb, because there was a notice that a new monitoring launch needs to be done, since running the timing of the BCAL channels was not good enough to be used to get the attenuation lengths and gain ratios.

3. Fall 2021 Calibration

For the Summer 2021 Gain Calibration, the run numbers 90033 - 90662 were initially considered. Comparing the conditions to the Summer 2021, they are considerably better for calibration and multiple batches are expected to be calibrated. For most of the data sets, the solenoid, CDC and FDC were on, while other conditions listed are the beam energy being equal to 10.8 GeV, beam current 140 - 150 nA, radiators $3.9 * 10^{-4}$ JD70-105, and $4.5 * 10^{-4}$ Al and the converter 75 mm Be. To start out, the He data set, with run numbers 90059 - 90200 was calibrated using the initial ccdb GlueX 2020 gain constants (same as the Summer 2021 run). This was preferred over using the new PrimEx (Summer 2021) conditions, since SRC (Fall 2021) would have more similar conditions to the GlueX ones. After the iterative process, the new gain ratios were placing the invariant π^0 well within 1% for each channel number. Due to a notice of the attenuation lengths for that run period being significantly altered, the gain ratios produced from that were multiplied upstream and downstream with the ones from the latest iteration. This required the calibration to be redone, since the discrepancy in π^0 mass was very large after the adjustment. This was expected to happen, since the initial gain ratios from GlueX 2020 were used for the attenuation length study, and those were already altered multiple times in this iterative process. Another way would be to directly start over from the initial GlueX conditions with the new gain ratios from the attenuation length study, but it's just a matter of time difference of which method would provide a faster convergence. The initial and final iteration plots can be seen in Fig. 4 and Fig. 5, while the other plots (similar as in Summer 2021) will be uploaded as a document when all of the data sets are calibrated.

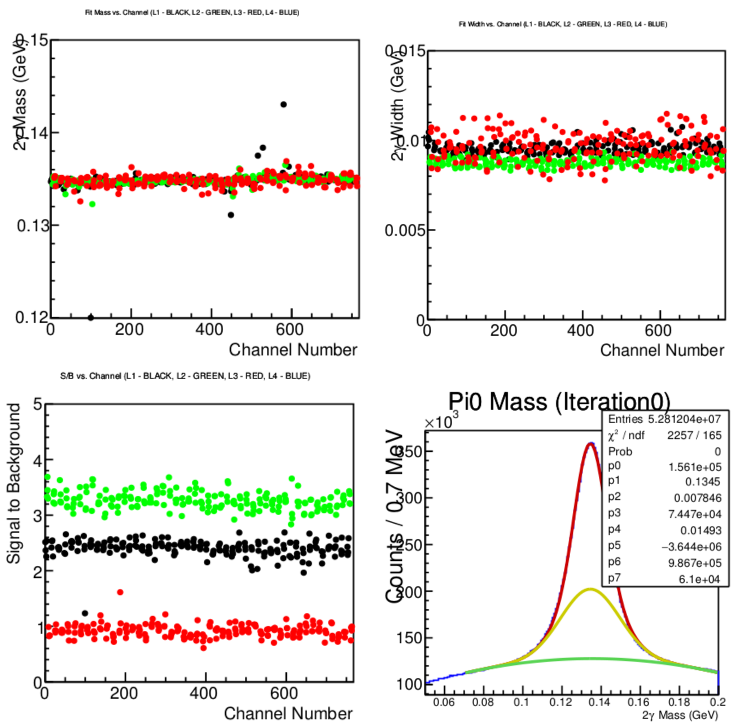

Figure 4: (Upper-left) Plot of the fit mass by layer for each channel in the BCAL using the 2020 ccdb constants. (Upper-right) Plot of the fit width by layer for each channel. (Lower-left) Plot of the signal to background ratio by later for each channel. (Lower-right) Reconstructed invariant π^0 mass along with the backgrounds.

The plots after calibration show that the π^0 mass is well within 1% after the last iteration. There is also a significant improvement in the signal to background ratio by layer in each channel after the calibration after the attenuation length study. Other data sets are still yet to be calibrated, so the new gain ratios were still kept within a local copy of ccdb. Non-linearity studies are also still listed as an additional study that should be done.

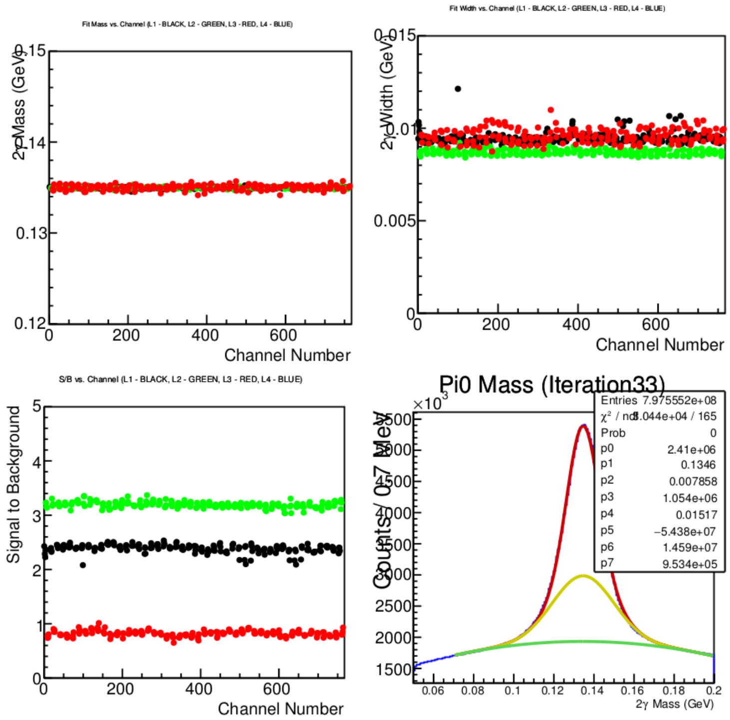

Figure 5: (Upper-left) Plot of the fit mass by layer for each channel in the BCAL after calibration using select SRC runs. (Upper-right) Plot of the fit width by layer for each channel. (Lower-left) Plot of the signal to background ratio by later for each channel. The first two layers yield the largest signal, as expected. (Lower-right) Reconstructed invariant π^0 mass along with the backgrounds.

4. Summary and Conclusion

4.1. Conclusion

The calibration for the Summer(PrimEx) and Fall(SRC) 2021 data was done and new gain ratios were produced using an iterative method. The summer runs were calibrated using a single batch that provided excellent conditions for calibration, while the other data sets were not considered. A monitoring launch is expected to be done, so a new attenuation length study will give gain ratios which will require a part of the current calibration to be redone as well as the non-linearity studies. The fall runs, at this point of time, are calibrated for one data set, leaving the other ones still in line. Gain ratios from attenuation studies have been implemented and the final pi^0 mass is within 1% of deviation from the PDG value. Non-linearity studies are yet to be completed and the full documentation will be uploaded when all of the batches are successfully calibrated.

4.2. Summary and Action Items

The PrimEx calibration is done and documented, but not uploaded to ccdb since another monitoring launch is still expected, which will change the gain ratios and require some number of iterations for the π^0 mass to within 1%. The calibration for the SRC experiment is done for the He data set, but are not uploaded to ccdb as of yet or documented, since it is by convention that this is done when all batches are calibrated.

References

[1] Karthik Suresh et al., GlueX Experiment Document 3881-v1
[2] Stjepan Oresic et al., GlueX Experiment Document 5530-v1