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Calorimeter Counter Calibration Correction for Small Angle GDH Experiment in Hall-A*

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Abstract The Fumili minimization method was used in the calibration for the calorimeter counter on HRS at Hall-A in Jefferson Jlab(JLab) for the data of small angle GDH experiment. Due to a large set of kinematics and changes in hardware settings, different calibrations were needed for the calorimeter detector. The resolution of the calorimeter for the scattering electron was about 0.06GeV when its momentum was at 1.0GeV.

Key words calibration, Fumili, resolution

1 Introduction

An electromagnetic cascade of energetically degraded secondaries(γ, e^+e^-) results when a high energy particle enters a dense material. As the cascade propagates, part of the original particle's energy is converted to heat and light. A calorimeter, to determine a particle's energy, is typically segmented into many individual cells or blocks with each block being monitored by a photomultiplier tube. Subsequently, a transformation must be made from raw ADC of the phototubes to the total energy deposition of the incident particle. This transformation is accomplished by determining calibration coefficients for each of the detector blocks. Since the cascade is in general spread laterally over several adjacent blocks, the output must be integrated over the entire detector volume to obtain the total detectable signal. When the calorimeter has been calibrated properly, the total deposited energy E shall be proportional to the particle's incident energy(or momentum p in the relativistic case). The basic phenomenon of the calorimeter development is statistical in nature so that the E/p peak obtained from each individual block will possess an intrinsic width.

The standard Hall-A detector configuration included two high resolution spectrometer(HRS) in JLab[1]. The spectrometers were initially equipped for the (e, e′p) reaction. Hence they were known as 'hadron' and 'electron' arms. For the small angle GDH experiment (E97-110)[2], only the electron arm HRS was set and configured for electron detection. As such we will refer the HRS as electron arm HRS.

The HRS consisted of a double-planed Vertical Drift Chamber(VDC), a pair of plastic scintillator plane and the particle identification(PID) system. The VDC was used to determine particle trajectory and provided the momentum analysis in conjunction with the dipole. The scintillator formed the trigger. The PID system was provided by two independent counters, a gas Cerenkov counter and a calorimeter counter. The HRS calorimeter, consisted of two segmented layers. The first 'preshower' layer was made of 48(24×2) blocks of TF-1 lead glass. The second 'shower' layer was made of 80(16×5) blocks of SF-5 lead glass. The thicknesses of two layer counters were

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10cm and 35cm, respectively. Because the energy of the scattering electron was less than 4GeV and the total radiation length of calorimeter counter was 17.4, the scattering electrons could deposit most part of their energies in the calorimeter.

2 Calibration

2.1 Calorimeter detector calibration channel by channel

The calibration for the calorimeter was to define a set of coefficients which transformed the ADC amplitude of each block into the deposit energy of the particle in this block.

The energy deposition in Preshower and Shower must be summed up for the total absorption of electron energy in both detectors.

As the calorimeter detector was intended for electro-magnetic showers registration and e/π identification in this experiment, it was necessary to have events, where electrons were registered by the detector.

The calibration constants were obtained with Fumili fitting method[1)], which was used to minimize the Chi-square function as the following:

$$\chi^2=\sum_{i=1}^{n}\left[\sum_{j\in M_{\rm ps}^i} C_j\cdot A_j^i+\sum_{k\in M_{\rm sh}^i} C_k\cdot A_k^i-P_{\rm kin}^i\right]^2, \quad (1)$$

where i was the number of selected calibration events; $j(k)$ was the number of Preshower(Shower) block included in the cluster, reconstructed in the i-th event; $M_{\rm ps}^i$ was the set of Preshower blocks, included in the cluster; $M_{\rm sh}^i$ was the set of Shower blocks numbers, included in the cluster; A_j^i and A_k^i were the amplitude value in the j-th Preshower block and k-th Shower block, respectively; $P_{\rm kin}^i$ was the particle momentum; C_j and C_k were the calibration constants to be fitted for the Preshower and shower, respectively.

2.2 Calibration events selection and constants calculation

To obtain a pure electron sample, it was better to select a run with less hadron for the calibration. Runs in the Δ resonance region, where the pion production was suppressed, were used to do the calibration. Further cuts were applied for the sample quality:

i) The data reconstruction in all of spectrometer detectors packages was successful; ii) Only one particle had been detected in the scintillator pair; iii) Only one track had been reconstructed by the VDC system; iv) The track was identified as electron with a tight cut on the information in Cerenkov detector, which might lose selection efficiency.

The A_j^i , A_k^i and $P_{\rm kin}^i$ in Eq. (1) could be obtained from the selected electron sample. So the calibration constants could be extracted with the Fumili fitting method.

3 Checking the calibration results

3.1 Calculating the deposit energy and position in the calorimeter

With the calibration constants C in Preshower and Shower, the energy deposition E and the X,Y coordinates of an incident particle in the calorimeter detector could be calculated by the formulae:

$$E_{\rm ps(sh)}=\sum_{j\in M_{\rm ps(sh)}} C_j\cdot A_j\ ,\quad E=E_{\rm ps}+E_{\rm sh}\ ,$$

$$X_{\rm ps(sh)}=\frac{\sum\limits_{j\in M_{\rm ps(sh)}} x_j\cdot C_j\cdot A_j}{E_{\rm ps(sh)}}\ , \quad (2)$$

$$Y_{\rm ps(sh)}=\frac{\sum\limits_{j\in M_{\rm ps(sh)}} y_j\cdot C_j\cdot A_j}{E_{\rm ps(sh)}}\ ,$$

where j was the number of Preshower(Shower) detector block; x_j,y_j were the coordinates of block j of Preshower(Shower); $E_{\rm ps(sh)}$ was the deposit energy in Preshower(Shower) and E was the total deposit energy in the calorimeter.

3.2 Check E/p of the particles

The E/p of electrons should be around 1 after the calibration correction if the electrons were completely absorbed, where E was the deposit energy calculated from Eq. (2) and p was the momentum.

1) http://seal.web.cern.ch/seal/apiref/class_FumiliBuilder.html

As a comparison, the E/p plot with all coefficients set to 1 was shown in Fig. 1 as "before calibration". The plot after calibration correction was shown in Fig. 2, where non-calibration runs were the runs except calibration ones.

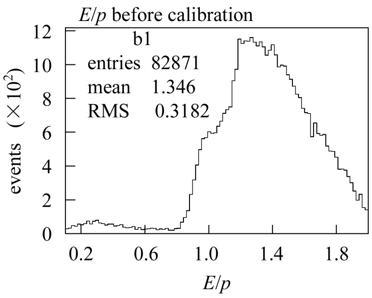

Fig. 1. The E/p plot before calibration for a non-calibration run.

The E/p plot for electrons should be a good Gaussian distribution plus a tail. The width of the Gaussian represented the detector's resolution. From Fig. 1 one could find E was meaningless without calibration correction. With the calibration correction, Fig. 2 was reasonable. The tail at low momentum was from the uncompleted absorbed electron and secondary production, including electron and hadron.

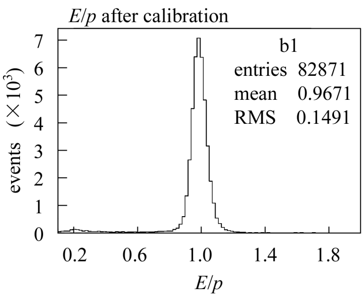

Fig. 2. The E/p plot after calibration for a non-calibration run.

Applied to other data sets, these constants were suitable for those runs if the peak of E/p distribution of electron was closed to 1 and the width was not bad. Otherwise the constants had to be re-calibrated for those runs. Because of a large set of kinematics and the changes of the high voltage for the calorimeter during the data-taking, different calibrations with the same method were needed for this experiment. In this experiment, 4 sets of constants for runs were obtained.

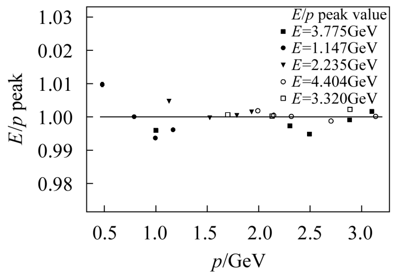

Fig. 3. The peak of E/p plot for all kinematic runs in E97-110.

The peak of E/p for different kinematic runs was shown in Fig. 3 and the σ/p was shown in Fig. 4, where σ was the width of the E/p plot. In both Fig. 3 and 4, the x axis was the momentum of scattering electron. Different runs with different beam energies were shown as different markers. The curve in Fig. 4 was fitted with the σ/p, which corresponded to the resolution of the calorimeter detector.

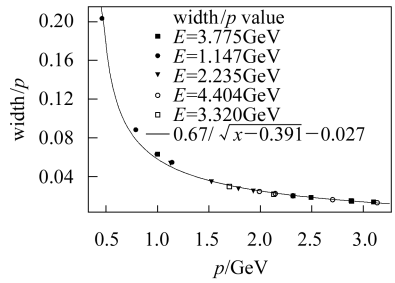

Fig. 4. The σ/p for all kinematic runs in E97-110.

4 Conclusion

The Hall-A HRS calorimeters had been calibrated throughout the small angle GDH experiment. Due to a large set of kinematics and the changes of high voltage, 4 different calibration constants were obtained. The E/p plots for all runs with the corresponding constants were reasonable, the peak for all runs were close to 1, which meaned the calibration was successful. The resolution of the calorimeter on Hall-A HRS for the scattering electron was about 0.06GeV when its momentum was 1.0GeV.

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Hall-A 上小角度 GDH 实验中量能器的刻度修正*

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摘要　在 JLab 的 A 大厅上的小角度 GDH 实验中, 采用了 Fumili 拟合方法对位于高分辨谱仪上的量能器进行刻度. 因为实验过程中硬件条件的变化以及大量的运动学数据的存在, 对该实验数据分批进行了刻度. 刻度结果表明, 此刻度修正是合适的. 在散射电子动量为 1GeV 的时候, 量能器对该粒子的分辨率为 0.06GeV.

关键词　刻度　Fumili　分辨率

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