Shower Calibration & efficiency for E97-110

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Abstract

The Fumili minimization method is used in the calibration for the total shower on HRS in Hall-A for the second period data in E97-110 experiment. Due to a large set of kinematics and changes in hardware(high voltage) settings, different calibrations were needed for the total shower. The detecting efficiency and cut efficiency were obtained for different kinematics.

Keywords: calibration,Fumili,efficiency,pion rejection

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1 Introduction

To separate electrons from other particles, a gas Cerenkov detector and an electromagnetic shower counter are used in each High Resolution Spectrometer of Hall-A. During the experiment E97-110, a long tank cerenkov counter was used. The right arm has a total shower detector which contains the entire energy deposited by a scattered electron.The main cluster in the total shower has been reconstructed by ANALYZER. One can just write a procedure to do the calibration. The total shower is made of two layers (Preshower and Shower counter) of leadglass blocks. The main components of both counter are PbO and SiO_2. The radiation length is $2.74cm$ for PreShower and $2.55cm$ for Shower. The configuration of the preshower is 2x24 and the shower is 16x5 [1] (Fig. 1).

The thickness are as following:

- PreShower: 10cm = 3.65 radiation length
- Shower: 35cm = 13.73 radiation length.

2 Calibration

2.1 Shower Detector Calibration channel by channel

The calibration for the shower detector is to define a set of coefficients which transform the ADC amplitude of each block into the energy deposition.

As the electron can deposit almost all energy in total shower, we can obtain the calibration constants for different channels by minimizing the function as following:

$$\chi^2 = \sum_{i=}^{n}[\sum C_j \cdot (A^i_j - P_j) + \sum C_j \cdot (A^i_k - P_k) - P^i_{kin}]^2 \qquad (1)$$

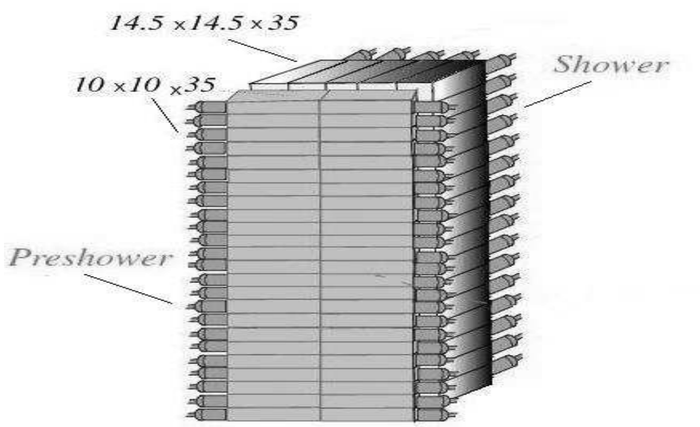

Fig. 1 Configuration of the total shower.

where i is the number of selected calibration event; j is the number of Preshower block, included in the cluster, reconstructed in the i-th event; k is the number of shower block, included in the cluster; M_{ps}^i is the set of Preshower blocks, included in the cluster; M_{sh}^i is the set of Shower blocks numbers, included in the cluster; A_j^i is the amplitude value in the j-th Preshower block; A_k^i is the amplitude value in the k-th Shower block; P_j is the mean value of pedestal of the j-th Preshower channel; P_k is the mean value of the pedestal of the k-th Shower channel; P_{kin}^i is the particle momentum corrected for the extended target effect ; C_j and C_k are the calibration constants to be fitted for the Preshower and shower, respectively. Total number of these constants is 128(48 of them for Preshower and 80 for shower)[3].

One should get the correct mean value of the pedestals from the calibration run first and then reset the databases *db_R.ps.dat* and *db_R.sh.dat* with the correct pedestals.

2.2 Calibration events selection

It is better to select a low π/e ratio run for the calibration. Runs in the Δ resonance region, where the pion production is suppressed, were used to do the calibration. To obtain a pure electron sample, the information in VDC, S1, S2 and Cherenkov detectors are used. The cuts for the sample selection are:

Data reconstruction in all of spectrometer detectors packages was successful;
Only one particle has been detected in the scintillators S1 and S2:
- R.s1.nthit · R.s1.nlahit · R.s1.nrahit == 1
- R.s2.nthit · R.s2.nlahit · R.s2.nrahit == 1;

Only one track has been reconstructed in the VDC system:
- R.vdc.u1.nclust · R.vdc.v1.nclust == 1
- R.vdc.u2.nclust · R.vdc.v2.nclust == 1;

Sum of amplitudes of Gas Cherenkov signals is greater than 1000 but less than 3000 (Fig. 2):
- R.cer.asum_c < 3000 && R.cer.asum_c > 1000;

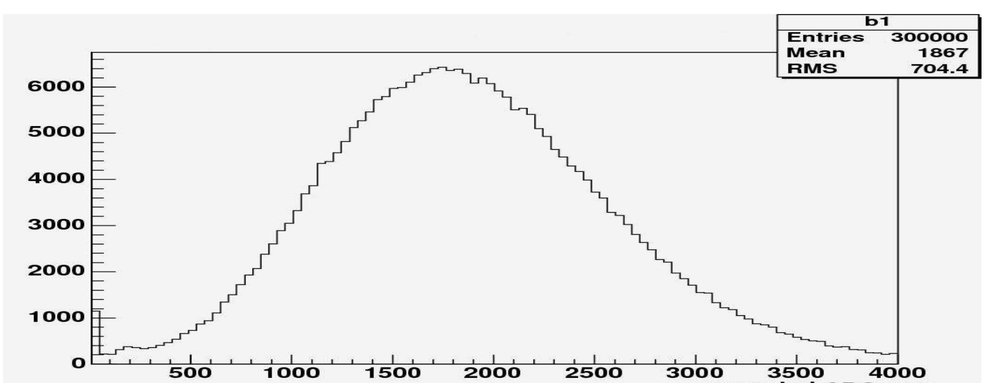

Fig. 2 corrected amplitude sum in Gas Cherenkov.

Each of reconstructed clusters is coincident with the golden track, who has the minimum timing offset $t_0 (t_0 \approx 0)$:

- |R.sh.x-R.sh.trx| < 0.15&&|R.sh.y-R.sh.try| <0.15
- |R.ps.x-R.ps.trx| < 0.10&&|R.ps.y-R.ps.try| <0.20;

The cluster has no information on the edge channels of Shower. Keep the edge block calibration constants fixed.

- R.sh.nblk[j] <63 && R.sh.nblk[j] > 16
- R.sh.nblk[j] $\neq 31, 32, 47, 48$, j is the number of block fired by a event.

The calibration events selection is realized by program */work/halla/gdh/luhj/T.C*(Appendix B), one can run it with analyzer processor as:

.L T.C $\swarrow$

T t $\swarrow$

t- Loop() $\swarrow$

p0 $\swarrow$

p0 is the central momentum of right arm for the calibration run.The unit is MeV. Then the run number and P^i_{kin} , M^i_{ps} , $A^i_j - P_j$, M^i_{sh}, $A^i_k - P_k$ for different events will be saved into a new file named *electrSamp*.

2.3 Calibration with the electron sample

When we obtained a good electron sample and those needed variables, which have been saved into a file, we can obtain the constants from the minimization function (1) with Fumili fitting method.

Program named */work/halla/gdh/luhj/Fumili.F* is used to realize this task. Then we can obtain a file named $fort.20$ in current directory.

The constants for Preshower and shower are saved in fort.20

3 Checking the calibration results

3.1 Reset the databases

Reset the databases *db_R.ps.dat* and *db_R.sh.dat* with new calibration constants and regenerate an analysis root file.

The E_{tot}/p should be around 1 for electrons after the calibration correction, where E_{tot} is the energy deposited in total shower and p is its momentum.

$$E_{tot} = E_{ps} + E_{sh} = \sum_{j \in M^i_{ps}} C_j \cdot (A^i_j - P_j) + \sum_{k \in M^i_{sh}} C_j \cdot (A^i_k - P_k) \tag{2}$$

We can apply these constants to other runs. If the peak of E_{tot}/p distribution of electron for a certain run is closed to 1 and the width is not bad, we say the constants are suitable for this run. Otherwise we have to re-obtain the constants for this run. Select a good run nearby this one, we just regenerate an *eletrSamp* from the selected run with $T.C$. Then we can obtain the constants with $Fumili.F$ and check these new constants again.

We obtained 4 sets of constants for those runs at 9 degree and 4 sets for 6 degree (the information of these calibration run are shown in Appendix D). The 4 sets of constants for runs at 9 degree are saved in $/work/halla/gdh/luhj/DB/20030808/db\_R.ps(sh).dat$.

The line $[config = xxxx]$ stands for the following calibration coefficients obtained from run xxxx. The ADC pedestals are their correspond mean value of pedestals. The 4 sets of constants are from runs 3590, 3771, 3902, 4173 respectively. The constants from run 3590 are suitable for runs at $E_{Beam} = 3.775$ or $1.147GeV$, where E_{Beam} is the energy of the beam. The constants from run 3771 are suitable for runs at $E_{Beam} = 2.235GeV$ and constants from run 3902 for runs at $E_{Beam} = 4.404GeV$. We did another calibration with run 4173 for the runs at $E_{Beam} = 3.320GeV$.

The 4 sets of constants for runs at 6 degree are saved in
$/work/halla/gdh/luhj/DB/20030701/db\_R.ps(sh).dat$.

– config=2670: for runs at $E_{Beam} = 2.134GeV$
– config=2840: for runs at $E_{Beam} = 4.210GeV$
– config=2965: for runs at $E_{Beam} = 2.135GeV$
– config=3230: for runs at $E_{Beam} = 2.845GeV$

We can apply these calibration constants to different runs by adding the following lines into the databases *db_run.dat*:

$--------[2003-mm-dd00:00:00]$

– Ebeam = ...
– R.theta = ...
– R.pcentral = ...
– L.theta = ...
– L.pcentral = ...
– R.ps.config = xxxx
– R.sh.config = xxxx

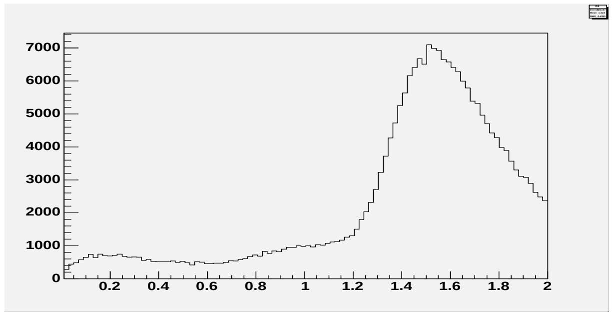

Fig. 3 E_{tot}/p for run 3771 without calibration correction(without any cuts)

The E_{tot}/p plots for total shower for a given run before and after calibration correction are shown in Fig.3 and Fig.4, respectively.

The peak position and width/p_0 from the gaussian fit of the E/p plot of electron for different kinematic settings are shown in Fig.5(at 9 degree) and Fig.6 (at 6 degree).

4 Efficiency

4.1 Detection efficiency

To determine the detection efficiency of the total shower detectors, a tight cut on the amplitude sum of track in Cherenkov detector ($R.cer.asum\_c$) is applied, besides quite loose cuts on geometry ($abs(R.gold.ph) < 0.5, abs(R.gold.th) < 0.5, abs(R.gold.dp) < 1$). Here we require it to be greater than 1500 but less than 2500. The number of events selected in this cut is called η_{cer}. Then we count the number(η_{sh}) of these events that triggered both layers of the total shower. Thus the detection efficiency is

$$\epsilon_{det} = \frac{\eta_{sh}}{\eta_{cer}} \tag{3}$$

The detection efficiency for different kinematics is shown in Fig. 7 and Fig. 8.

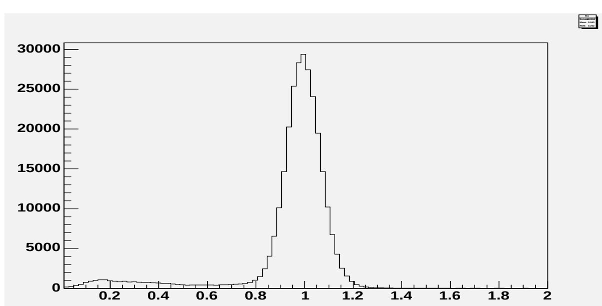

Fig. 4 E_{tot}/p for run 3771 with calibration correction(without any cuts)

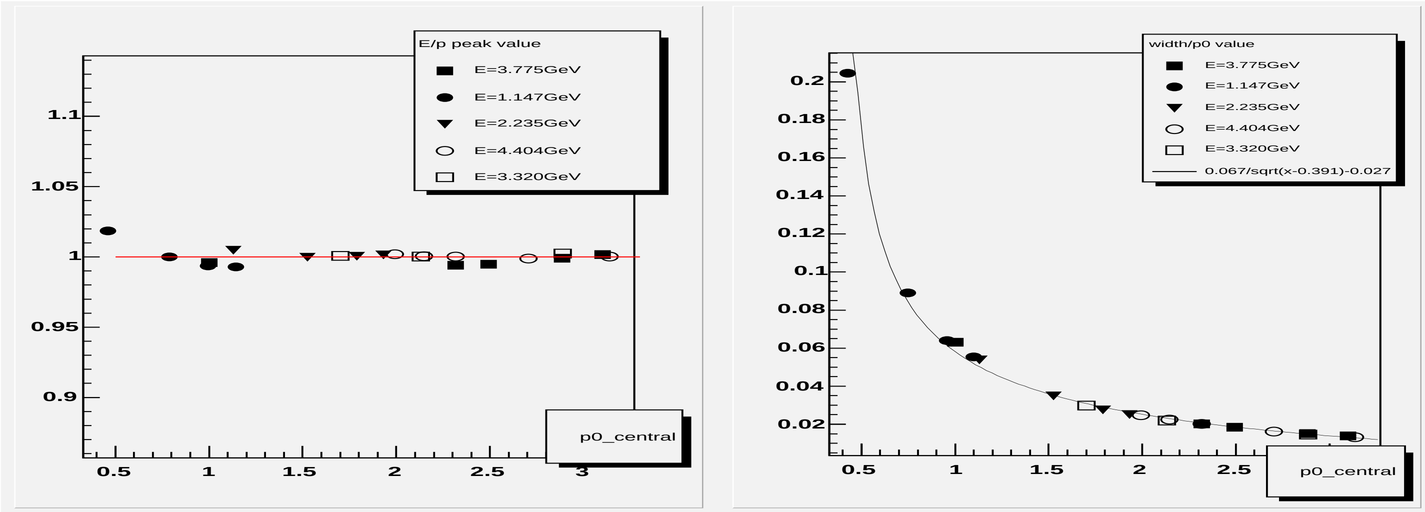

Fig. 5 E_{tot}/p peak (left) and width/p0 (right) at 9 degree for different p0

From the plots we can find that the ϵ_{det} is better than 99.8% except the run at $\mathrm{E}_{Beam} = 1.147GeV$ and p0_$central = 0.461GeV$.

This efficiency can be obtained by file $/work/halla/gdh/luhj/eff.c$. The output goes to a file $cutineff\_xxxx.dat$ (Appendix C).

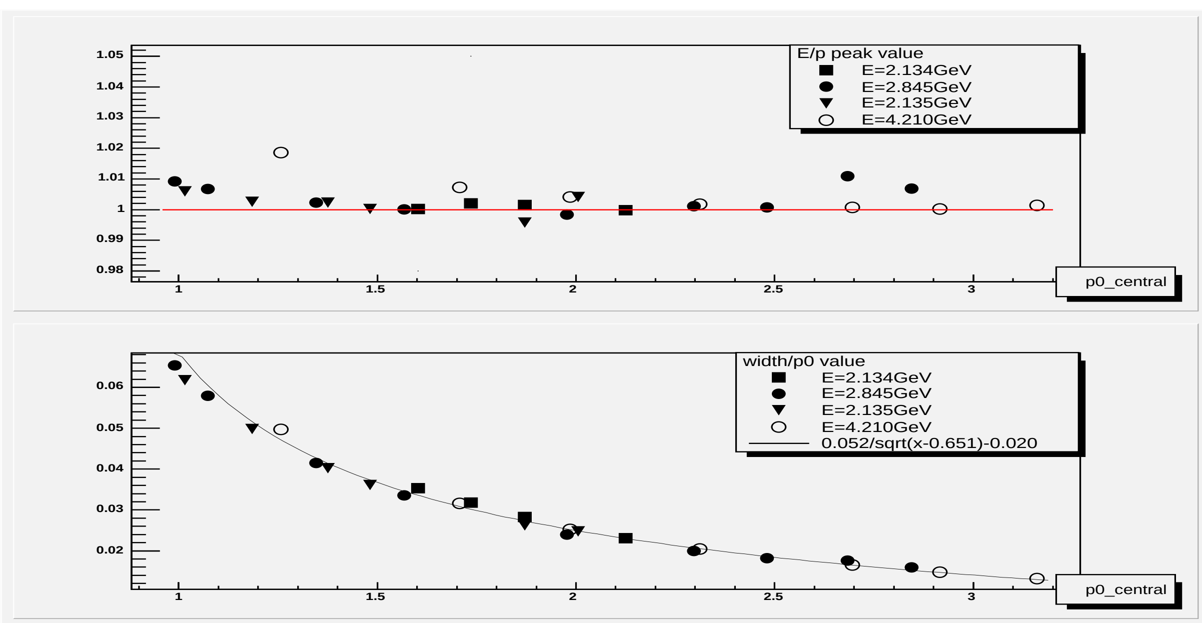

Fig. 6 E_{tot}/p peak (up) and width/p0 (down) at 6 degree for different p0

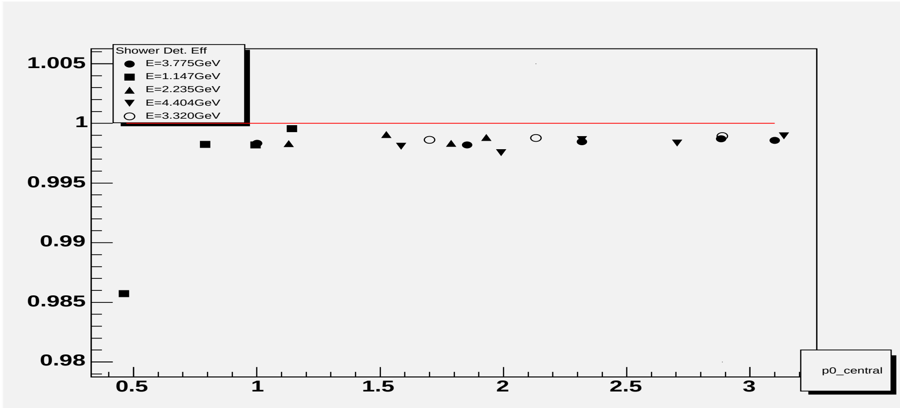

Fig.7 Detection efficiency for total shower at 9 degree

4.2 Cut efficiency

We characterize the cut efficiency with two variables: electron accept efficiency η_e and pion rejection $\bar{\eta}_\pi$.

To discriminate between electrons and pions, the information of the tracks in cherenkov is used. Here we apply the cut on the ADC sum ($1000 < R.cer.asum\_c < 3000$) in cherenkov. Then we can apply two shower cuts, $E_{tot} > x0$(cut 1) and $E_{ps} > x1$(cut 2), to improve the PID analysis, where E_{tot} and E_{ps} are deposit energies in total shower and preshower, respectively. Fig. 2. shows the corrected ADC sum in Cherenkov. Then we can adjust x0 and x1 to let the acceptance for electron being accepted by the shower cuts be better than 99%. Because the two cuts are not independent, we must avoid double calculating the efficiency. We can follow the following steps to adjust x0 and x1: 1) Select a good electron sample with the help of other detectors, here we used the count of the number of events N_{tot}; 2) Apply cut 1 while x0 at different value to the sample. Count the number $\bar{N}_{x0}$ of events dropped by cut 1; 3) Get the max x0(x0max) while $\bar{\epsilon}_{x0} = \frac{\bar{N}_{x0}}{N_{tot}} < xIneff$, where $xIneff$ is a predefined value, here we set it to 0.005. The number of events dropped or accepted by cut 1 while $x0 = x0_{max}$ are $\bar{N}_{x0max}$,N_{x0max}. 4) Apply cut 1 while $x0 = x0max$, then apply cut 2 while x1 at different value. Count the

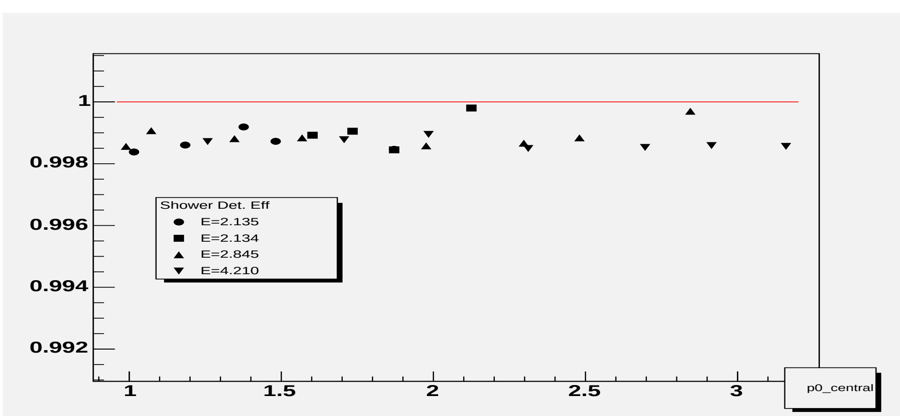

Fig.8 Detection efficiency for total shower at 6 degree

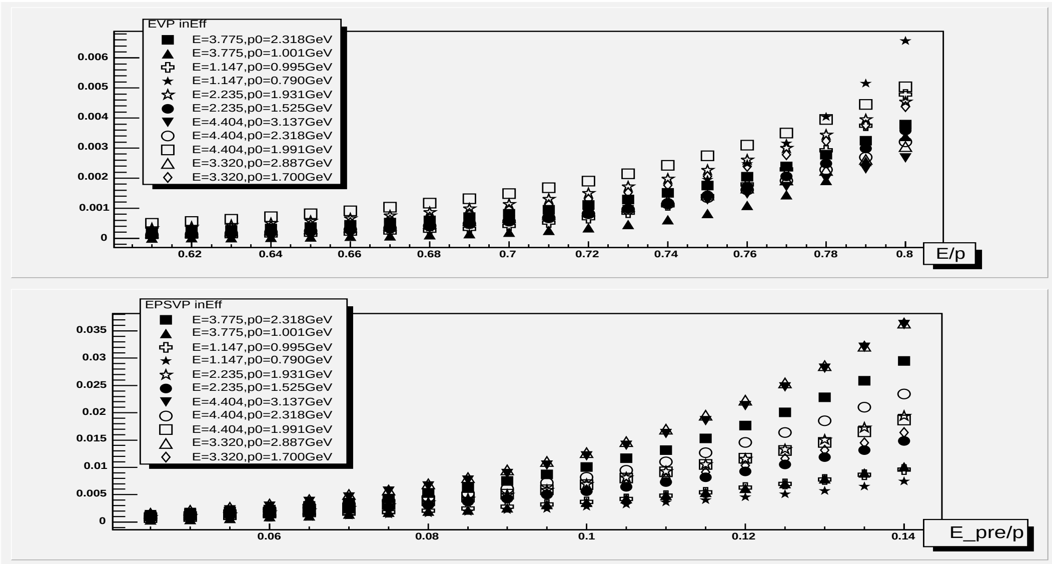

Fig. 9 electron acceptance inefficiency for different cut 1(up) and cut 2(down) at 9 degree

number of events N_{x1} passed these cuts. 5) Then the accept efficiency for electron passing the cuts $\eta_e = 1 - \bar{\epsilon}_{x0max} - \bar{\epsilon}_{x1}$, where $\bar{\epsilon}_{x1} = \frac{N_{x0max} - N_{x1}}{N_{tot}}$ and $\bar{\epsilon}_{x0max}$ is the $\bar{\epsilon}_{x0}$ with $x0 = x0max$. 6) Get the max x1(x1max) while $\eta_e > 0.99$ with $x0 = x0max$[4].

The electron acceptance inefficiency for cut 1 and 2 are shown in Fig. 9(at 9 degree) and Fig.10(at 6 degree), respectively.

The pion rejection is defined as $\bar{\eta}_\pi = \frac{N2}{N1}$, where N1 is the number of events of pion sample selected by other detectors, N2 is the number of events in the pion sample dropped by cut 1 and cut 2.

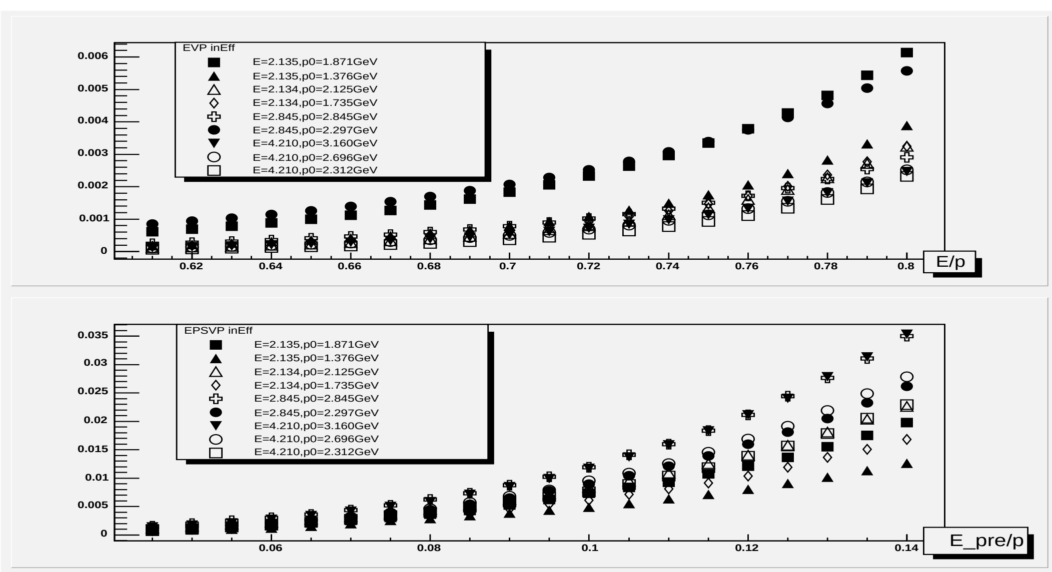

Fig. 10 electron acceptance inefficiency for different cut 1(up) and cut 2(down) at 6 degree

To obtain electron acceptant efficiency, it is better to select runs with high e/π and select runs with low e/π for pion rejection.

The cut efficiency can be obtained by file $/work/halla/gdh/luhj/eff.c$. The output goes to a file $cutineff\_xxxx.dat$(Appendix C).

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Appendix A: ANALYZER Variables

The variables used in the calibration and PID analysis are:

in Cherenkov :

- $R.cer.asum\_c$ — the corrected ADC sum in gas Cherenkov detector.

in PreShower :

- $R.ps.x, R.ps.y$ — the X-, Y- coordinate in PreShower of the main cluster.
- $R.ps.trx, R.ps.try$ — the X-, Y- coordinate in PreShower of the Golden Track.
- $R.ps.a[i], i = 1, 48$ — the ADC value in $i - th$ channel
- $R.ps.a\_p[i], i = 1, 48$ — the pedestal subtracted ADC value in $i - th$ channel.
- $R.ps.a\_c[i]$ — the corrected ADC value in $i - th$ channel
- $R.ps.mult$ — the total number of blocks in preshower fired by the main cluster.
- $R.ps.nblk[j], j = 0, R.ps.mult - 1$ — the numbers of block fired by the main cluster.
- $R.ps.e$ — energy deposited in preshower for the main cluster

in Shower :

- $R.sh.x, R.sh.y$ — the X-, Y- coordinate in shower of the main cluster.
- $R.sh.trx, R.sh.try$ — the X-, Y- coordinate in shower of the Golden Track.
- $R.sh.a[i], i = 1, 80$ — the ADC value in $i - th$ channel
- $R.sh.a\_p[i], i = 1, 80$ — the pedestal subtracted ADC value in $i - th$ channel.
- $R.sh.a\_c[i]$ — the corrected ADC value in $i - th$ channel
- $R.sh.mult$ — the total number of blocks in shower fired by the main cluster.
- $R.sh.nblk[j], j = 0, R.sh.mult - 1$ — the numbers of block fired by the main cluster.
- $R.sh.e$— energy deposited in shower for the main cluster

in Scintillator :

- $R.s1.nlahit, R.s2.nlahit$ — Number of Left paddles ADCs amps in S1,S2
- $R.s1.nrahit, R.s2.nrahit$ — Number of Right paddles ADCs amps in S1,S2
- $R.s1.nthit, R.s2.nthit$ — Number of paddles with l&r TDCs in S1,S2

in VDC :

- $R.u1.nclust, R.u2.nclust$ — Number of clusters in u1,u2 plane
- $R.v1.nclust, R.v2.nclust$ — Number of clusters in v1,v2 plane

some others :

- $R.gold.ph$ — Tangent of target phi angle for the GoldenTrack
- $R.gold.th$ — Tangent of target theta angle for the GoldenTrack
- $CorR.dp$ — delta momentum for the GoldenTrack corrected for the extended target effect
- $R.tr.n$ — Number of track reconstructed
- $g.evtyp$ — event type from bit pattern
- $g.runnum$ — run number
- $R.status$ — Bits of completed analysis stages

Appendix B: Calibration procedure

The calibration procedure includes two steps: 1) events selection; 2) minimization.

The first step is realized by $/work/halla/gdh/luhj/T.C$. But the head file $T.h$ maybe need to be regenerated if the variables are not absolute the same as the old $T.h$. Copying the $T.C$ to a backup file first, then run the ANALYZER and open the rootfile for calibration. Then he can get $T.h$ and $T.C$ by making class (T->MakeClass()). Copying the backup file to $T.C$, one can obtain the electron sample with the following command with analyzer: 1) .L T.C; 2) T t; 3) t->Loop(); 4) xxxx.xx. The xxxx.xx is the p0_central(MeV) for the calibration run. The information of the electron sample is saved in the output file *eletrSamp*. The first line of the file is the run number of this run. The $3*i-1$ -th line is the momentum corrected for the extend target for the i-th electron. The $3*i$ -th line is the information in preshower for the i-th electron. The $3*i+1$ -th line is the information in shower for the i-th electron.

In the $3*i$ -th and $3*i+1$ -th line, the first one is the total number of blocks fired by the i-th electron in that detector. Then it is followed by the number of the block fired and the pedestal subtracted ADCs in that block.

The minimization is realized by $/work/halla/gdh/luhj/Fumili.F$. One can finish the calibration by two commands: 1) f77 Fumili.F, 2) ./a.out

The calibration constants are saved into $fort.20$ in current directory.

Appendix C: Efficiency procedure

The detection efficiency of Shower, Cherenkov and cuts efficiency are realized by $/work/halla/gdh/luhj/eff.C$

A soft link to *pro.root* from the analysis root file is needed. Then one can input $analyzer\ eff.C(p0Central)$ to start to do the analysis, where p0Central is the p0Central(MeV) of the right arm for the analysis run. A file named $cutineff\_xxxx.dat$ will be generated in the current directory. $xxxx$ is the run number. The output in the file has been described partly by itself.

Here we list the meanings of the variables in the file:

p0Central,CerDEff,ShDEff : Central momentum for the run, Detection efficiency of the Cherenkov detector, Detection efficiency of the total Shower.

CerCut,piRej,CerCutEff,CerEff : different cut value on the corrected ADCs sum in Cherenkov, pion rejection of this Cherencov cut,electron acceptance efficiency of this cut, CerCutEff*CerDEff

EVP_peak,EVP_width : The peak value and width of distribution energy deposited in total shower over momentum for electron

EVP_cut,Cut_inef : different cut value on cut 1 ($(R.sh.e + R.ps.e)/p > x0$),the cut inefficiency of this cut

EPSVP_cut,Cut_inef : different cut value on cut 2 ($R.ps.e/p > x1$), the cut “inefficiency” of this cut.

E/p,E_ps/p , Cut_eff, Cut_Rej : the adjusted x0, x1, the electron acceptance efficiency of these cuts(cut 1 and cut 2), the pion rejection of the cuts

Appendix D: Calibration Constants

Information of the calibration runs.

– run 2670:$E_{Beam} = 2.134GeV$,$p0_{central} = 1.603GeV$,$\theta = 6°$,Targ: Helium3;
– run 2840:$E_{Beam} = 4.210GeV$,$p0_{central} = 3.160GeV$,$\theta = 6°$,Targ: Helium3;
– run 2965:$E_{Beam} = 2.135GeV$,$p0_{central} = 1.482GeV$,$\theta = 6°$,Targ: Helium3;
– run 3230:$E_{Beam} = 2.845GeV$,$p0_{central} = 1.568GeV$,$\theta = 6°$,Targ: Helium3;
– run 3590:$E_{Beam} = 1.147GeV$,$p0_{central} = 0.790GeV$,$\theta = 9°$,Targ: Helium3;
– run 3771:$E_{Beam} = 2.235GeV$,$p0_{central} = 1.788GeV$,$\theta = 9°$,Targ: Helium3;
– run 3902:$E_{Beam} = 4.404GeV$,$p0_{central} = 3.137GeV$,$\theta = 9°$,Targ: Helium3;
– run 4173:$E_{Beam} = 3.320GeV$,$p0_{central} = 2.231GeV$,$\theta = 9°$,Targ: Helium3;

pedestals

There are two pedestal runs for right arm in the second period data taking: run3262 and run4091.

The pedestals for 128 channels of total shower from two pedestal runs are about the same:

PreShower : 350. 335. 377. 390. 400. 373. 453. 512. 348. 394. 368. 316. 417. 422. 406. 432. 307. 302. 335. 299. 459. 384. 395. 391. 386. 356. 360. 304. 462. 398. 395. 439. 465. 326. 287. 319. 434. 549. 453. 514. 292. 275. 351. 334. 500. 471. 444. 337.
Shower : 439. 341. 330. 291. 453. 384. 426. 431. 455. 429. 417. 402. 557. 458. 380. 631. 405. 547. 321. 492. 515. 693. 647. 571. 446. 483. 398. 317. 513. 428. 588. 582. 305. 472. 371. 357. 596. 448. 532. 621. 483. 438. 443. 328. 484. 528. 396. 519. 629. 475. 329. 391. 360. 444. 434. 372. 352. 506. 462. 327. 502. 564. 386. 540. 393. 294. 382. 478. 473. 553. 503. 522. 340. 381. 309. 409. 501. 599.

Calibration constants: Here we just show the constants from run 3771

PreShower : 0.80300 0.99400 0.95312 0.92424 0.90532 0.89653 0.88402 1.04538 0.92794 0.87188 0.85953 0.89416 0.95349 0.93818 0.88233 0.96353 0.94581 0.85754 0.94360 1.05135 0.95294 0.90953 0.45309 0.46515 0.45423 0.47102 0.97456 0.92000 0.97229 1.01948 0.98640 0.88186 0.91775 0.92576 0.90014 0.89525 1.02552 0.95183 0.87147 0.80266 0.88629 0.82805 0.88252 0.88784 0.97302 0.89135 1.36337 0.62700
Shower : 0.82000 1.08688 0.80317 0.85291 1.08581 0.82000 0.82000 1.08510 0.86102 0.85477 1.13164 1.49000 0.82000 0.82124 0.97673 0.90353 0.91614 0.58214 0.51549 0.53841 0.61542 0.94201 0.91503 0.73692 0.64983 0.66755 0.73350 0.56015 0.54837 0.59701 0.64045 0.86850 0.92773 0.42738 0.56066 1.14603 0.67345 0.44188 0.71947 0.73396 0.50126 0.58858 0.45182 0.45232 0.83906 1.01332 0.80140 1.24900 1.23600 0.31763 0.34188 0.79667 0.47337 0.41446 0.78542 0.45618 0.83324 0.66637 0.43084 0.45121 0.97178 0.82825 0.40759 1.09277 0.81744 1.09800 1.27900 0.92452 0.88351 1.25415 0.81698 1.27600 1.23700 1.05322 0.90122 0.72072 0.84246 1.35300 1.31700 0.79827

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