PID efficiency of Hall-A detectors

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http://www.jlab.org/∼xiaochao/e99117/pid/memo9.ps.gz

Contents:

1. Introduction

PID analysis, or more specifically, electron/pion identification analysis has been done for Hall-A detectors during experiment e94104, March, 2001.

First the performance of four PID detectors have been checked in section 2.

Then to analyze the PID efficiency, a routine procedure has been followed, which is:

(1) Selecting sample events:

Sample events, e.g. sample electron and pion events can be selected by one-dimensional cut(s) in gas cherenkov adc_sum_t and two-dimensional cuts in shower (pion rejector layer 2) energy and preshower(pion rejector layer 1) energy for the right (left) arm. Sample e or π events choosed from these cuts can be defined as "shower sample e", "gas cherenkov (gc) sample e", "pion rejector (PR) sample e", etc..

To cross-check the efficiency of different detectors, "shower sample events" ("pion rejector sample events") are used for GC efficiency and "GC sample events" are used for shower/preshower (pion rejector) efficiency.

(2) Obtainning effeciency:

Then different cuts are defined for each detector, the electron efficiency corresponding to each cut is thus obtained by checking how many sample electron events are selected by the cut. The pion contamination can be obtained in a similiar way.

(3) PID cut optimization:

For each detector, the PID cut can be optimized by comparing electron efficiency with pion contamination.

(4) For experiment E99117:

The major goal of the PID efficiency analysis, for a specific experiment, might not be just e/π separation. For E99117, the electrons need to be separated from all other background events, of which π's will be the major part. So in this analysis, an e/background separation has also been done for the right arm.

2. PID Detectors Overview

2.1 Gas cherenkov detector

The calibration of gas cherenkov detectors have been done a few times during experiment e94104. The pedestals are choosed as the first non-zero channel of each raw ADC spectrum. The single photo-electron peaks are aligned to channel 250(150) for the short (long) gas cherenkov detectors, respectively. The position of each mirror has also been checked at the beginning of January, by checking the distribution of single photo-electron events.

Figure 1 shows the adc_sum_t vs. x for the long gas cherenkov, the left one is for $y > 0$ and the bottom (right) one $y < 0$. This is a quick way to check if all mirror/PMTs are performing well.

Figure 2 shows the adc_sum_t for the long gas cherenkov. The big peak around channel 1400 are electrons, while there are pions and background events within the single photo-electron peak (channel 150). So far no problem has been observed for the long GC.

For short gas cherenkov detector. The PMTs for mirror #7 and #9 have been replaced during the experiment. However, PMT #7 and #8 have been found to have low efficiencies, as can be seen from Figure 3.

Figure 4 shows the adc_sum_t for the short gas cherenkov. The single photo-electron peak is invisible, which means the pion rate of this run is very low.

To check mirror #7, corrected ADC spectra are shown in Figure 5. It can be seen that the number of photo-electron for mirror #7 is significantly lower than others. Unfortunately, for this kinematics, mirror #7 and #8 cover almost half of the events.

2.2 Shower/Preshower detector

Figure 1: Long gas cherenkov detector performance

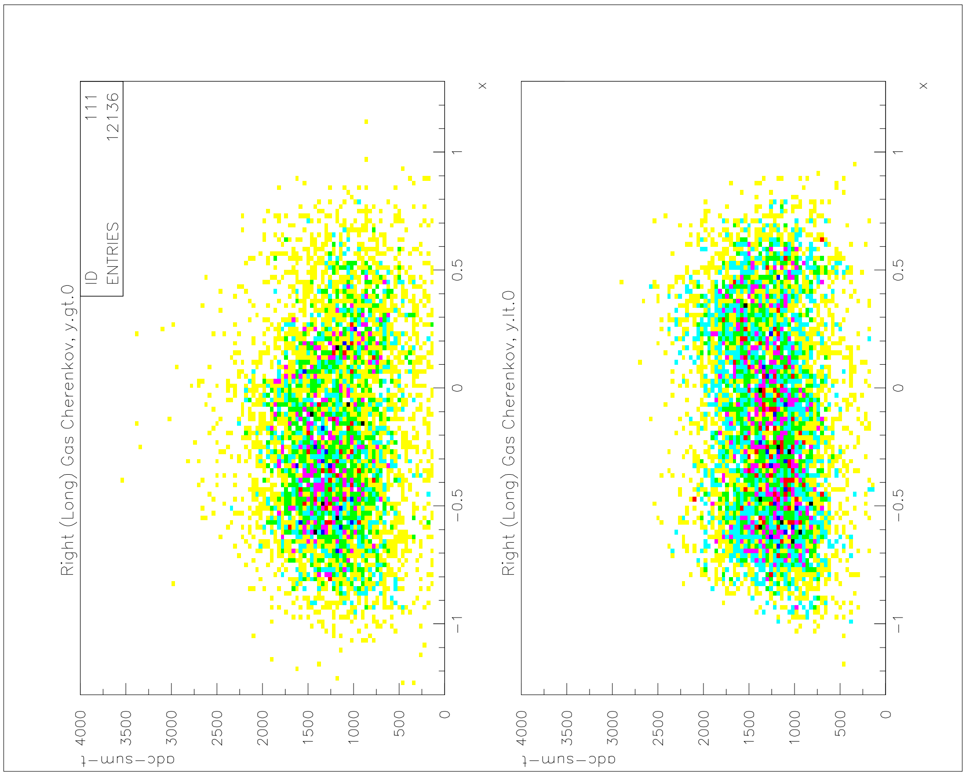


Figure 2: Long gas cherenkov detector adc_sum_t

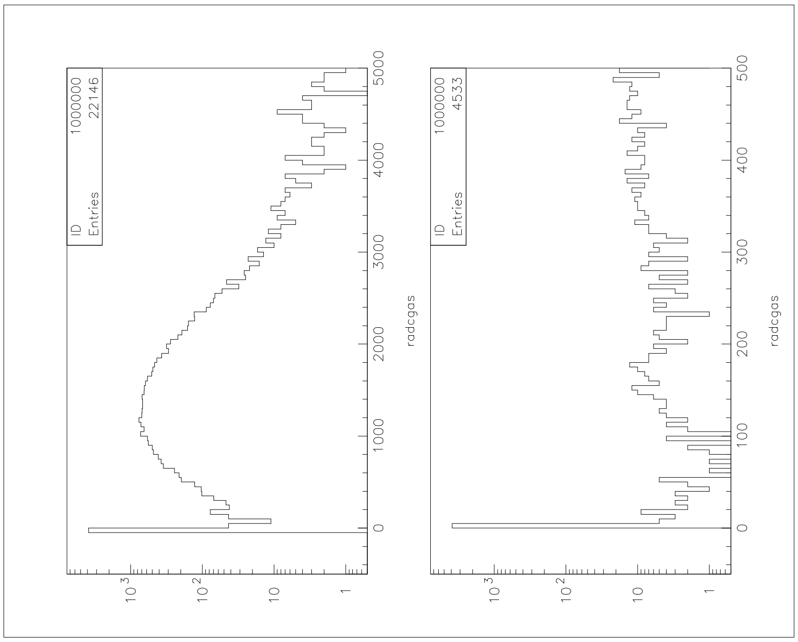


Figure 3: Short gas cherenkov detector performance

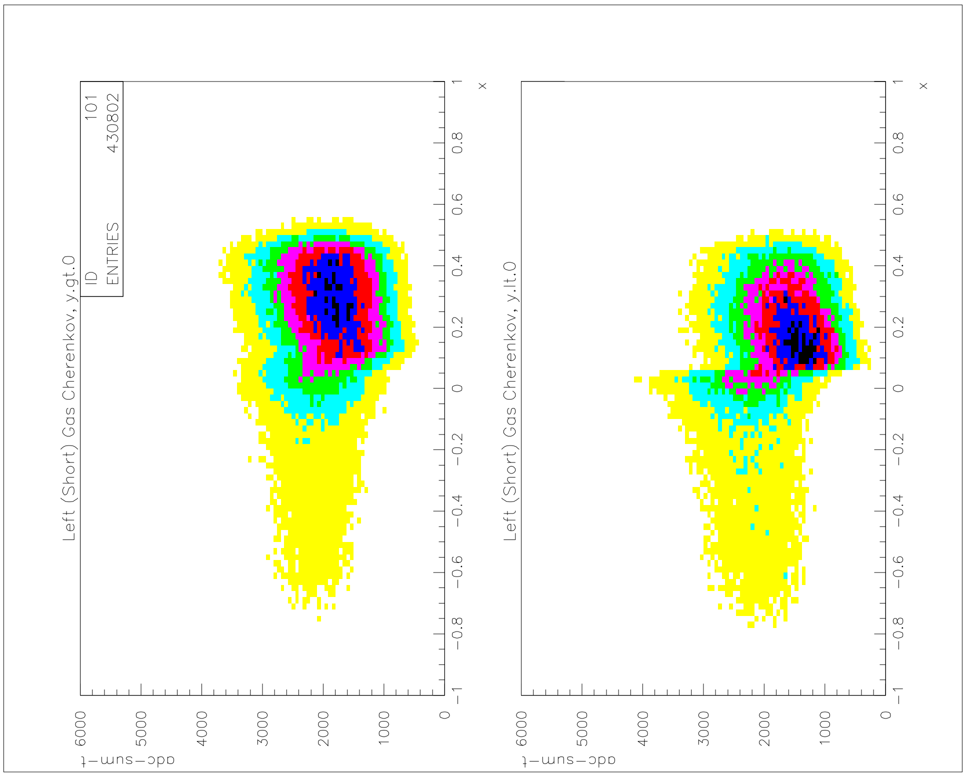


Figure 4: Short gas cherenkov detector adc_sum_t spectrum

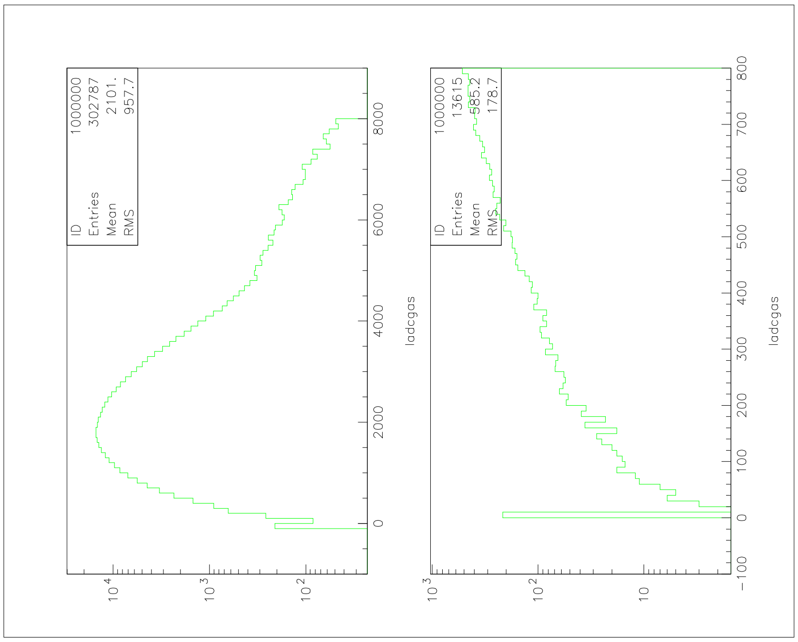
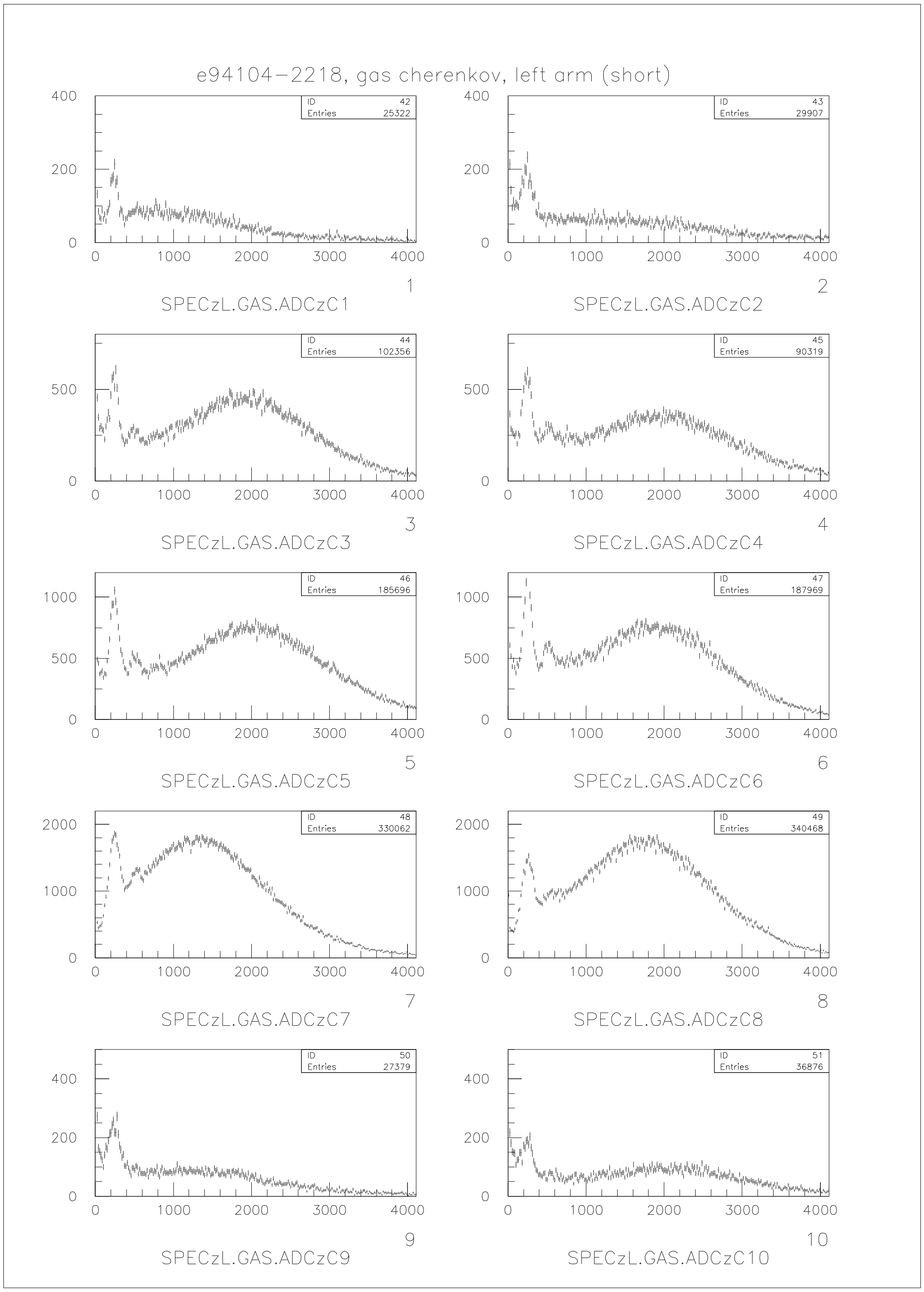


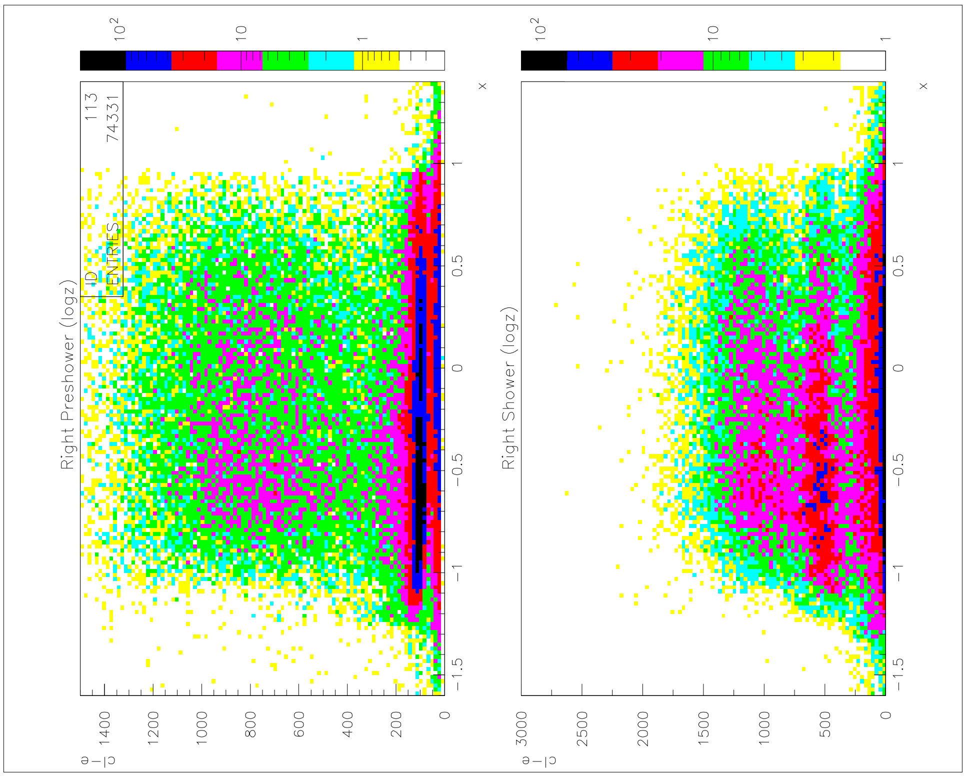
Figure 5: Short gas cherenkov detector corrected ADC spectrum



The normal calibration code for shower detector was fixed according to the detector changes and the electron/hadron → left/right name change. Last calibration of Shower/Preshower detectors was done on March 05.

Figure 6 shows the energy deposit (espace var: cl_e) vs. x for shower and preshower detectors. It shows that the pedestals are subtracted properly and the peak of each block is aligned well. From the raw ADC spectra, can see that blocks on the edge don't have enough events to observe the main peak. Calibration for these blocks are done roughly by experience, which will not affect the overall efficiency much if the production runs also do not have many events in these blocks.

Figure 6: Shower and Preshower detector performance



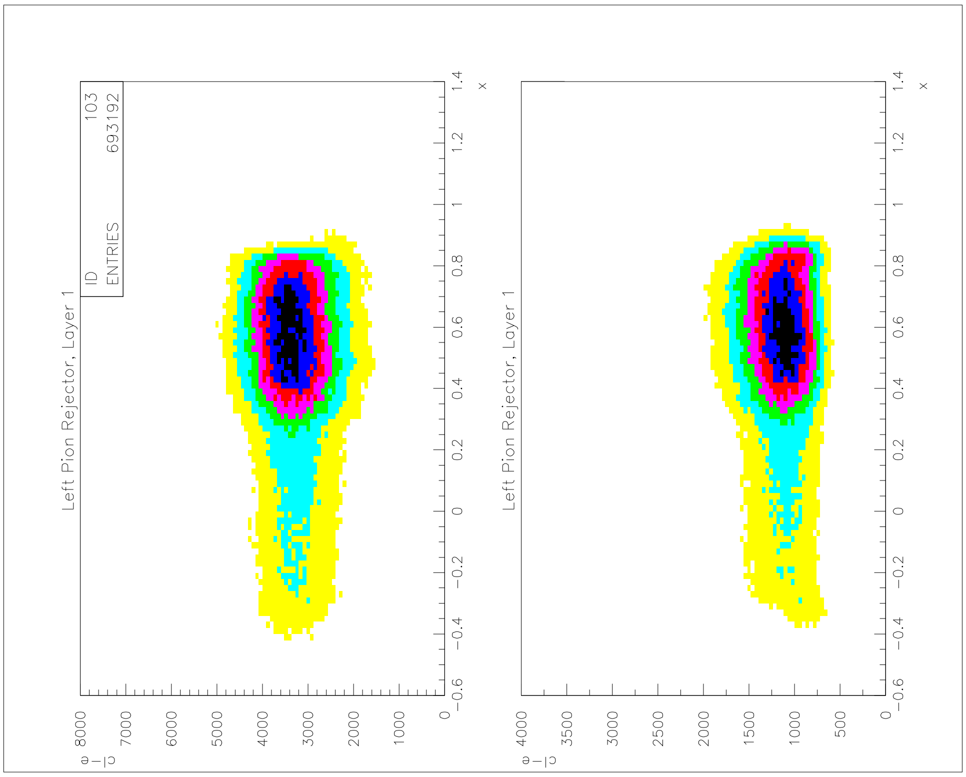
2.3 Pion rejector

The high voltage setting of pion rejectors had been changed during e94104 and the latest one was done on Feb. 22. The final calibration had been done by Feb.28.

Figure 7 shows the energy deposit (espace var: cl_e) vs. x for pion rejector first layer and second layer, respectively. It shows that the pedestals are subtracted properly. No obvious problem (i.e., high dark current, leakage or bad PMT) has been observed.

3. PID Efficiency for the Right Arm

Figure 7: Pion rejector performance



Run e94104-2436, a single-arm run with deutrium target was selected to analyze the PID performance for the right arm. It is at kinematics 15, e.g.

$E_{beam} = 4243.78$ GeV, $p_R = 1.967$ GeV/c, $\theta_R = 41.34^o$;

3.1 Overall cuts

Cuts in y_{target} and z are used to cut out the events from the target window. Cuts in θ_{rot}, and ϕ_{rot} are used to obtain good acceptance. Cut in momentum p is used to reject events with too low or too high momentum. After all these cuts, events with single track, event type 3 or 5 are defined as "good" events and are used for the PID analysis. In the following sections "all events" means all "good" events defined here, if not specified elsewhere.

3.2 Sample events

The sample events from long gas cherenkov are defined by cuts:

"GC sample" electron events:

800 < spec_r.gas.adc_sum_t < 4000 .and. (spec_r.show.cl_e+spec_r.preshow.cl_e)>1000;

"GC sample" pion events:

spec_r.gas.adc_sum_t > 10000;

Figure 8 show the preshower energy vs. shower energy for "gc sample" electron events (top, left) and "gc sample" pion events (top, right). The cut

spec_r.show.cl_e+spec_r.preshow.cl_e>1000

in "gc sample" electrons has been used to remove the inefficiency of GC detector (i.e., pion contamination). This cut is selected such that no "good electron" is cut out. Figure 9 shows the total energy deposit in shower and preshower detectors. The tail of electron peak (around 2000) vanishes below channel 1000.

Now we know where electrons and pions are, then more strict two-dimensional cuts in preshower/shower are used to define "shower sample" electrons and "shower sample" pions, which are:

"shower sample" electron events:

spec_r.preshow.cl_e > 300
spec_r.show.cl_e > 600
spec_r.preshow.cl_e + spec_r.show.cl_e > 1700

"shower sample" pion events:

70 < spec_r.preshow.cl_e < 140
300 < spec_r.show.cl_e < 800

Figure 8: Sample events for the right arm

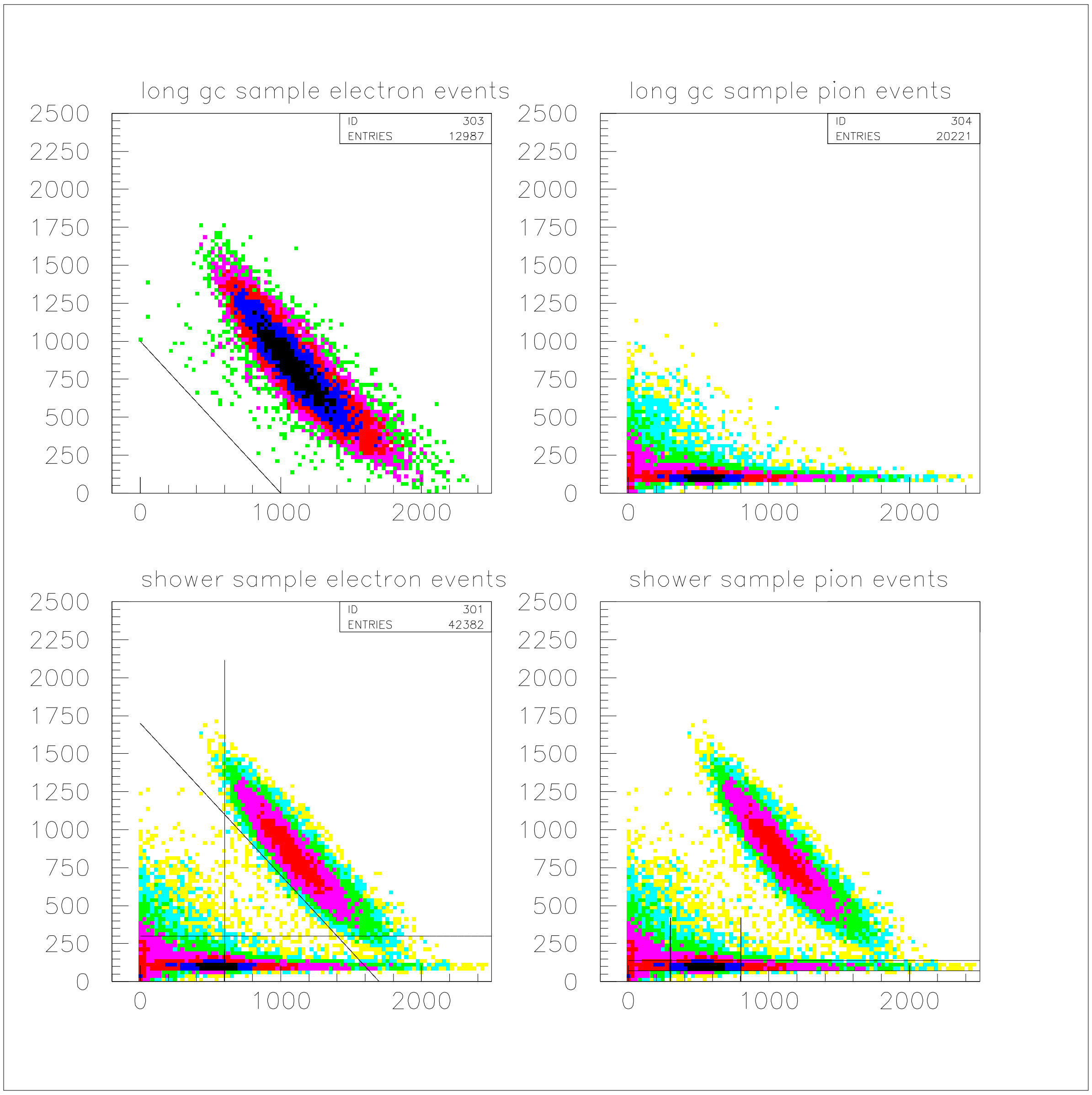
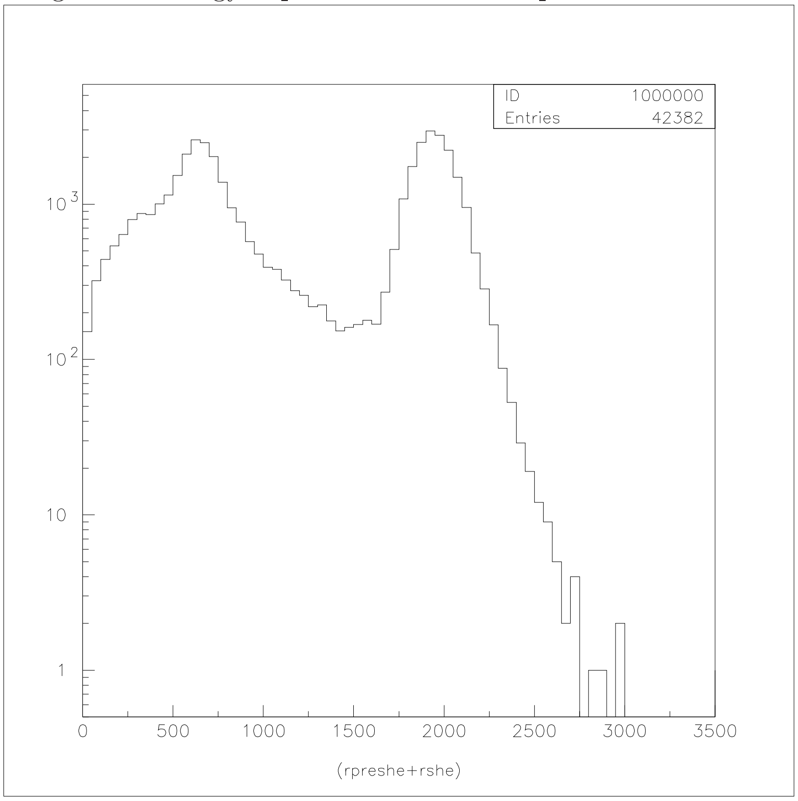


Figure 9: Energy deposit in shower and preshower detectors



The two plots at the bottom show these two cuts for all events, without any cut in gas cherenkov.

The "shower sample" background events have been defined as:

spec_r.preshow.cl_e + spec_r.show.cl_e < 1000

which consists pions and all other possible background events. It will be used to check the background rejection factor of gas cherenkov.

3.3 Efficiency

The electron efficiency for long gas cherenkov is defined as the number of "shower sample" electron events selected by the cut divided by the total number of sample events, e.g.

$$\eta_e^{GC} = N_e^{GC}/N^{TSsample,e}.$$

similarly, obtain pion contamination:

$$\eta_\pi^{GC} = N_\pi^{GC}/N^{TSsample,\pi}.$$

Figure 10 shows the electron efficiency and pion rejection factor for long gas cherenkov and shower/preshower detectors. For gas cherenkov detector (top), the horizontal axis is the low channel in cut [lower channel] $< adc\_sum\_t <$ 10000. Usually cut in gas cherenkov is selected at right above the single photo-electron peaks, or at 230 in this case.

For shower/preshower (bottom), the sample events are "gc sample electron" events. The horizontal axis shows the lower channel in cut $shower\_energy > [lowerchannel]$. And for each shower cut, cuts in preshower energy and the total energy (sum of preshower and shower) are also applied to obtain a reasonable 2D shape. Figure 11 shows these 2D cuts. Totally 100 cuts have been used in the analysis.

3.4 Optimization of PID cuts

Finally the cuts optimized for e/pion separation are

spec_r.gas.adc_sum_t > 320
spec_r.preshow.cl_e > 140
spec_r.show.cl_e > 260
spec_r.preshow.cl_e + spec_r.show.cl_e > 1170

Figure 10: PID efficiency on the right arm

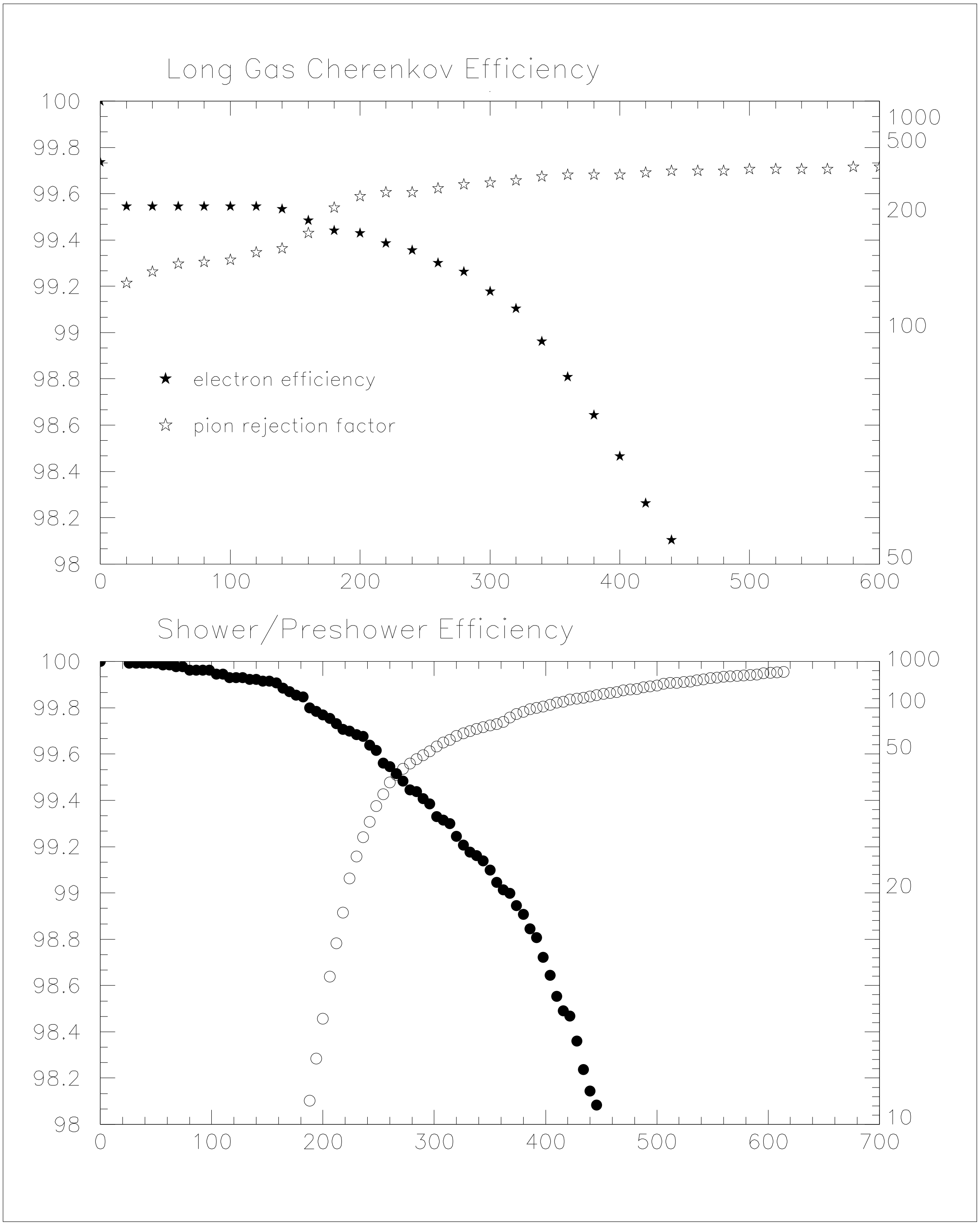
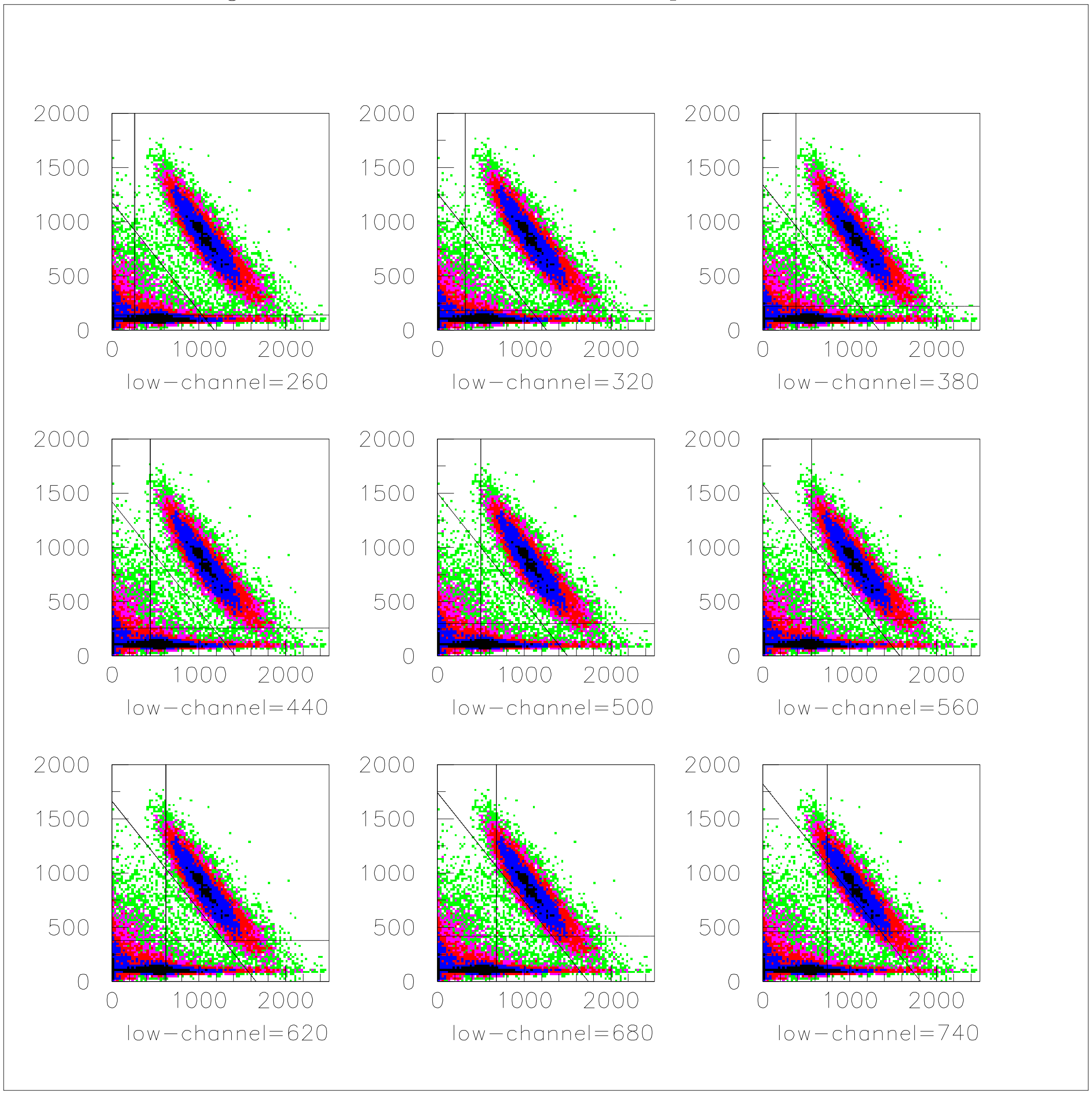


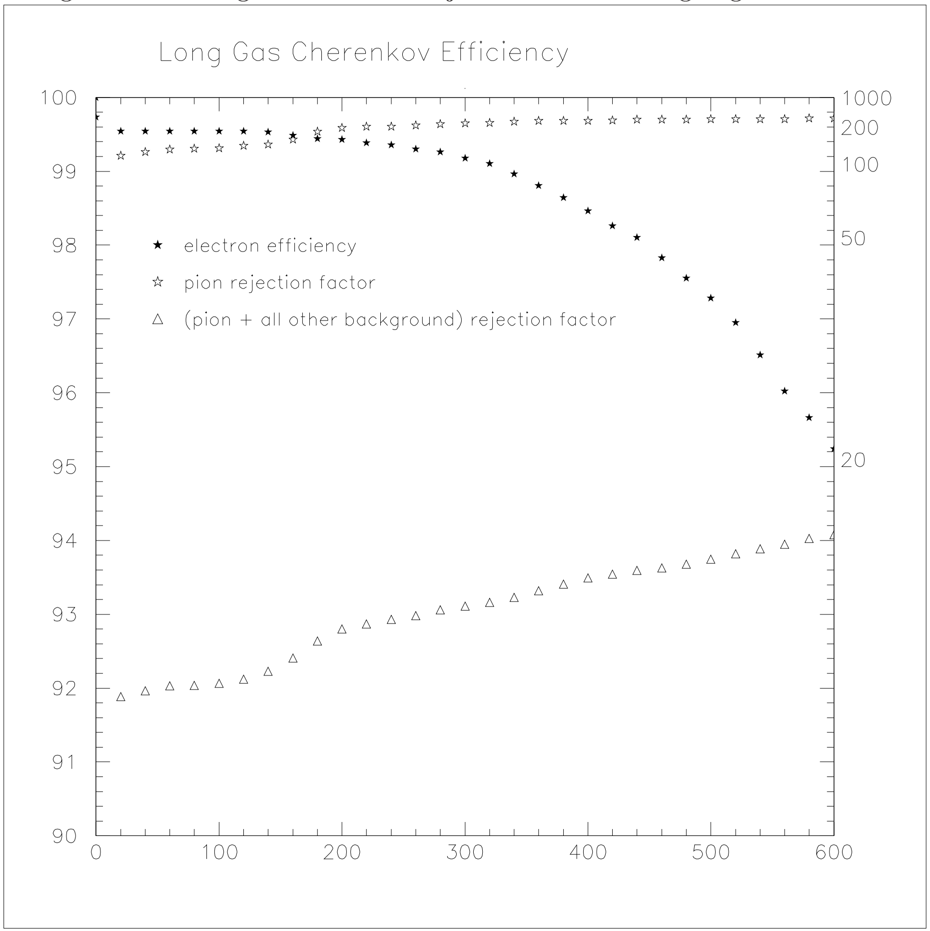
Figure 11: 2D cuts used for shower and preshower detectors



3.5 Background rejection

Rejection factor for other background events has also been analyzed and is shown in Figure 12.

Figure 12: Background events rejection factor of right gas cherenkov



4. PID Efficiency of Left Arm

Run e94104-2218, a coincidence run with He4 target was selected to analyze the PID performance for the left arm. It is at kinematics 13, e.g.

$E_{beam} = 4234.99$ GeV, $p_L = 3.489$ GeV/c, $\theta_R = 16.809^o$;

It is expected to have high electron rates so is not good for pion contamination analysis. But this is the only kinematics with negative polarity on the left arm after the latest high voltage change for PRs. Other runs with H2 or D2 targets are low in pion rates in principle, also show strong correlation in x vs. y so cannot cover the full area of the detectors.

4.1 Overall cuts

Cuts similiar to that used for the right arms are also used here, except that only event type 5 is selected.

4.2 Sample Events

The sample events from short gas cherenkov are defined by cuts:

"GC sample" electron events:
    1000 < spec_l.gas.adc_sum_t < 4000

"GC sample" pion events:
    spec_l.gas.adc_sum_t > 10000

Figure 13 shows the PR layer 1 energy vs. PR layer2 energy for "gc sample" electrons (top, left) and "gc sample" pions (top, right). Similiar to the right arm, strict two-dimensional cuts in PRL1/PRL2 are used to define "PR sample" electrons and "PR sample" pions, which are:

"PR sample" electron events:
    spec_l.prl1.cl_e>2100
    spec_l.prl2.cl_e>650
    spec_l.prl1.cl_e×0.4+spec_l.prl2.cl_e >2000

"PR sample" pion events:
    100 < spec_l.prl1.cl_e < 300
    50 < spec_l.prl2.cl_e < 200

The two plots in the middle show these two cuts for all events, without any cut in gas cherenkov. The pion events are very low so they are plotted with a different scale in the two plots in the bottom.

The "GC sample" electron events are different from the definition on the right arm. Cannot do a cut in pion rejector energy to remove possible pions from this sample and preserving all good electrons at the same time.

4.3 Efficiency

Figure 14 shows the electron efficiency and pion rejection factor for short gas cherenkov and pion rejectors.

Figure 15 shows the 2D cuts used in pion rejectors.

4.4 Optimization of PID cuts

Since the pion rate of this kinematics is very low so the the result for pion contamination is very susceptible. Furthur analysis needs to be done to obtain a reliable pion analysis for these two detectors, which require special test runs.

Figure 13: Sample events for the left arm

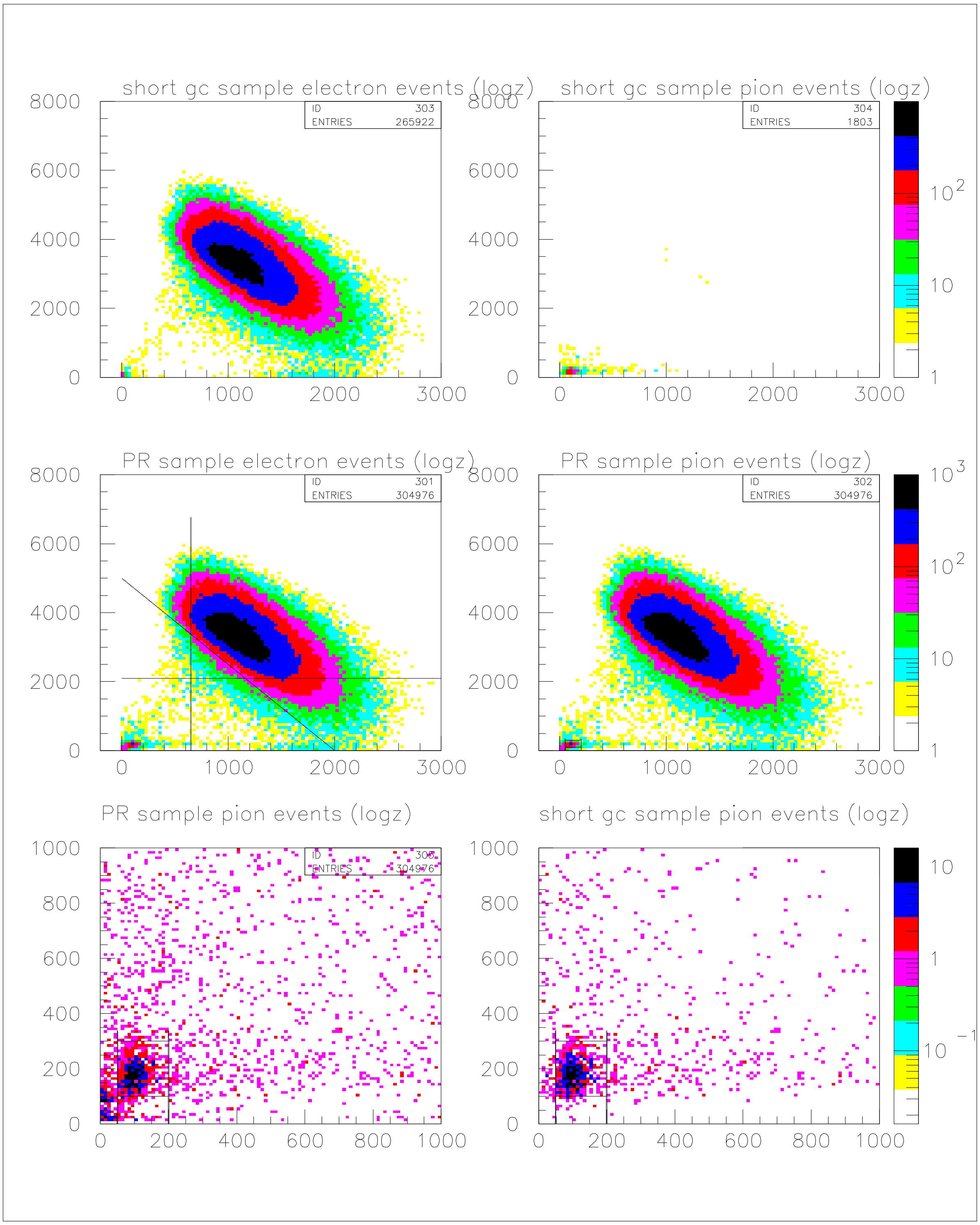


Figure 14: PID efficiency on the left arm

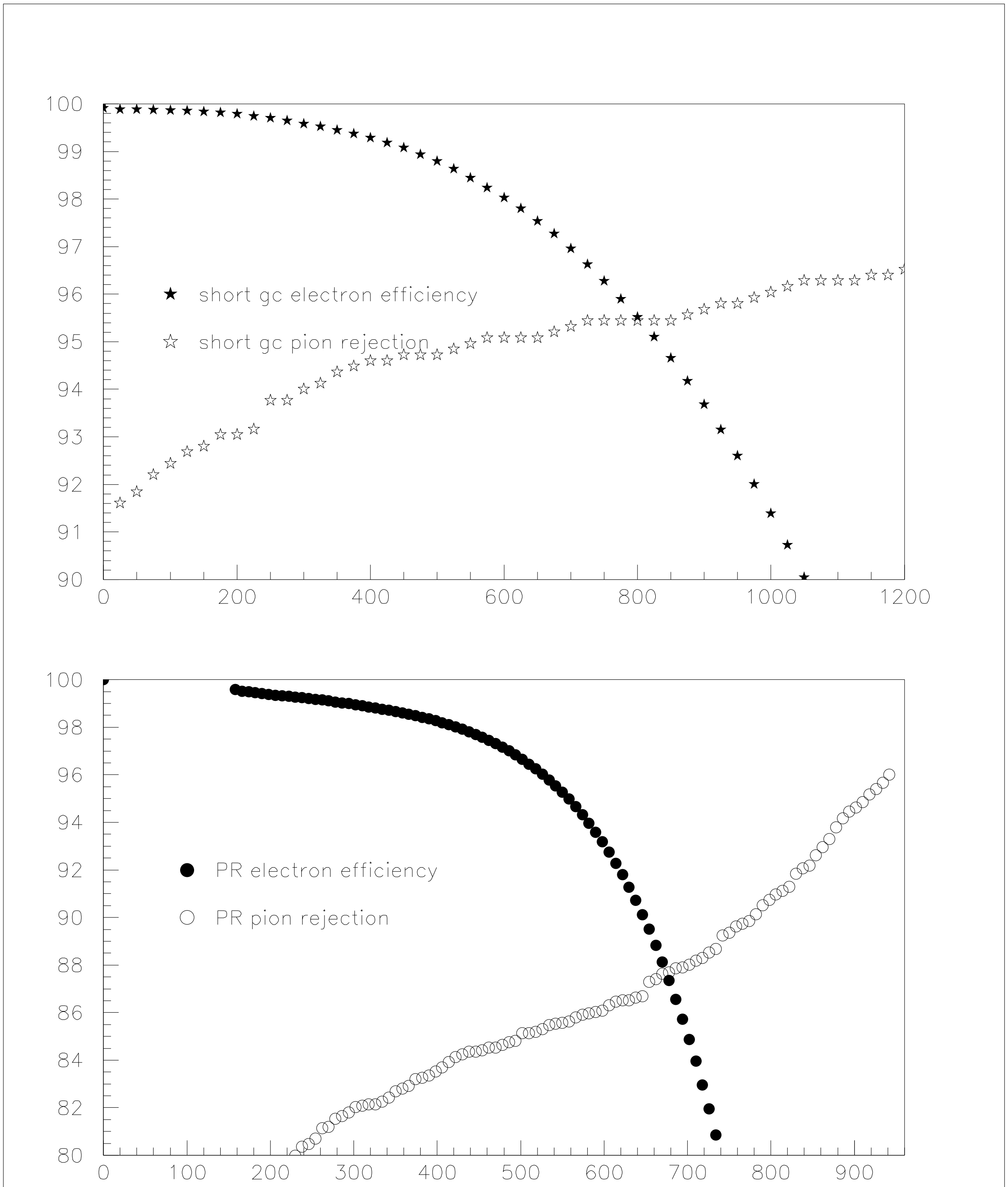
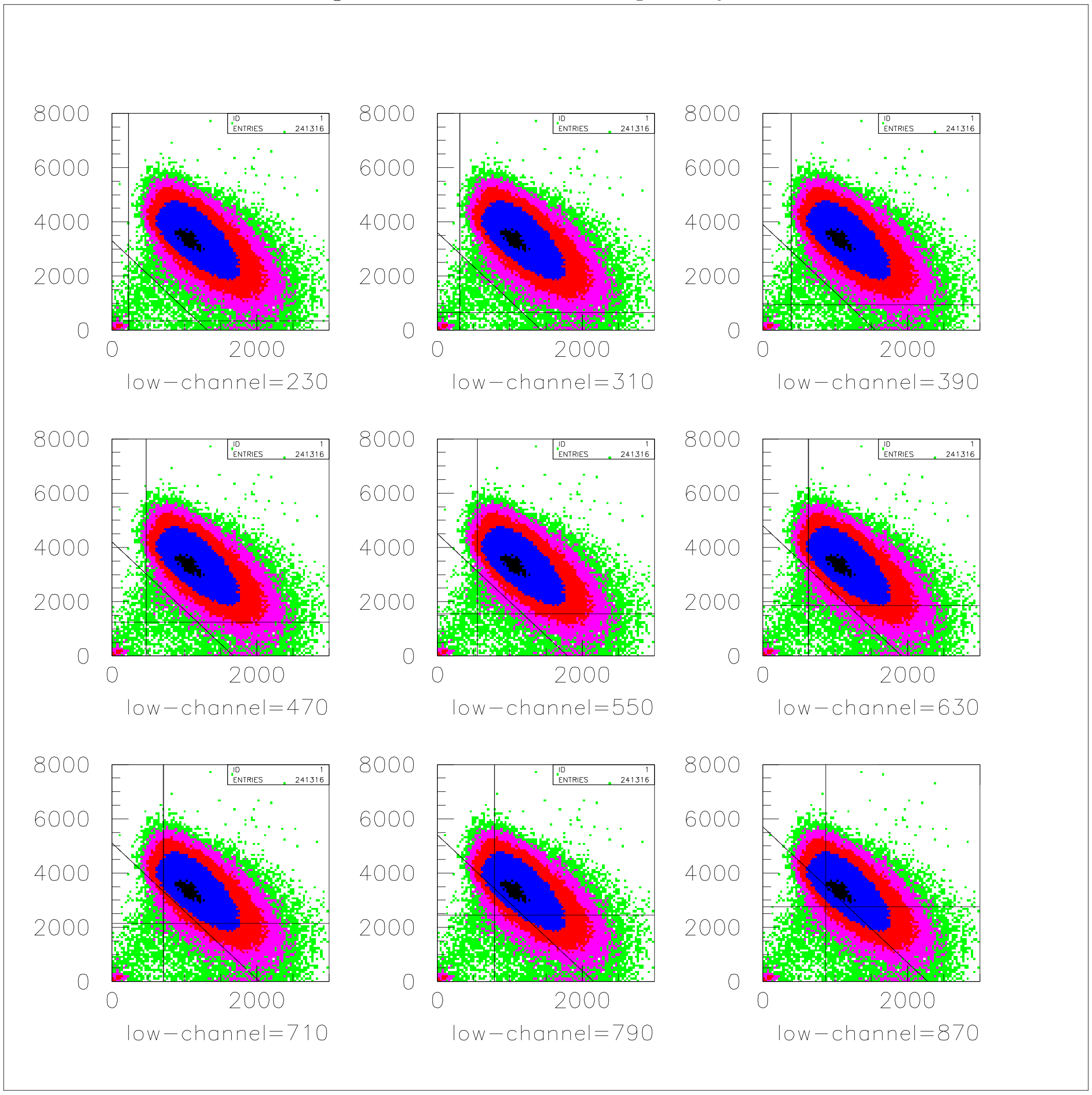


Figure 15: 2D cuts used for pion rejectors

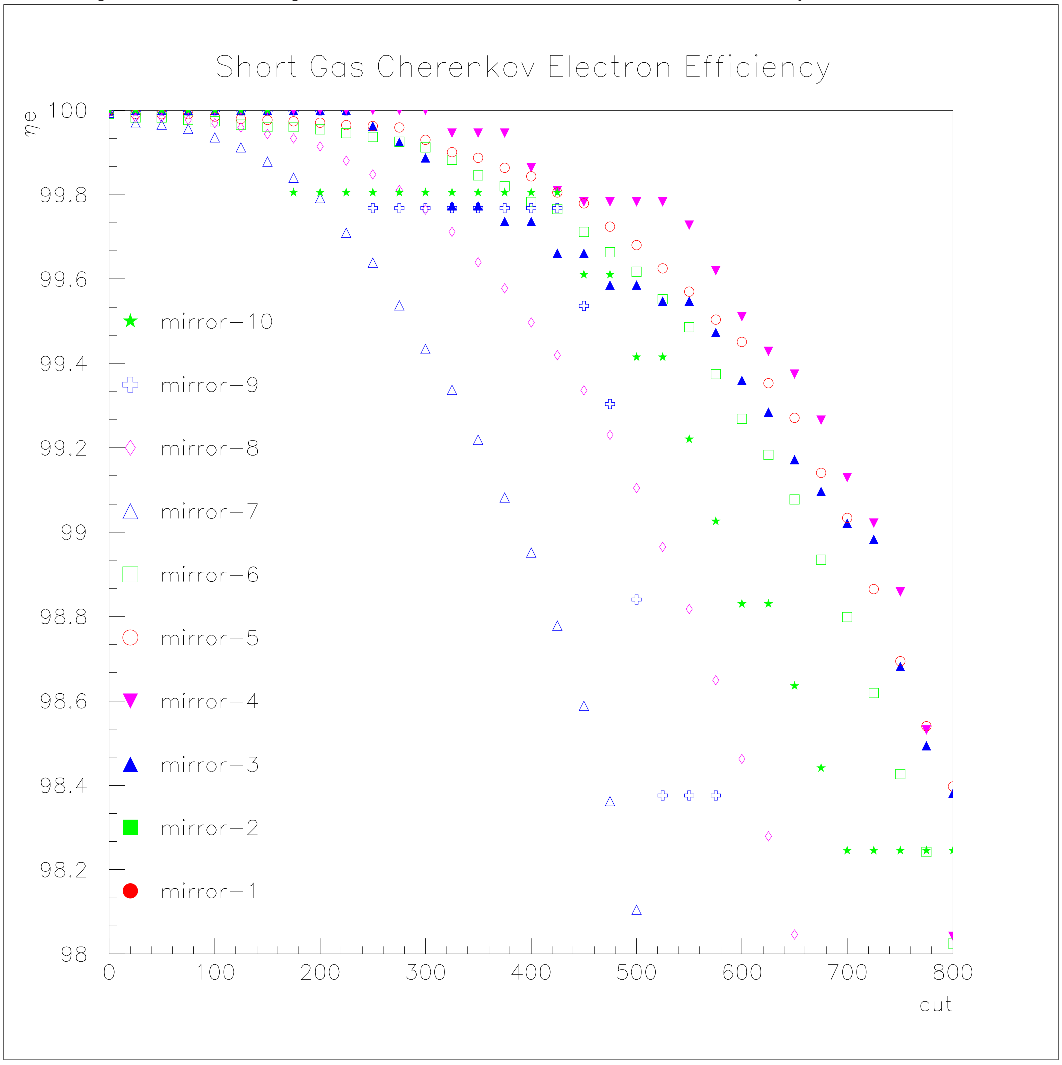


5. For the Short Gas Cherenkov Detector

It has been mentioned in section 2 that two mirrors of short GC have low efficiencies. But how will this affect the overall efficiency, and exactly what are the efficiencies for these two mirrors?

Figure 16 shows the electron efficiency for each channel (mirror+PMT), mirror #7 is the worst one, then mirror #8, as expected from the raw ADC spectra. Only events within the center part of each mirror have been analyzed. Mirror #1, #2 are too close to the edge and have no sample electrons. Though it can be noticed that all of them are higher than 99.0% at channel 380 (e.g., right above the single photo-electron peak, where the cut is usually chosed to be), more work needs to be done to improve the efficiency of short gas cherekov detector.

Figure 16: Short gas cherenkov detector electron efficiency for each mirror



6. Future Work, Testrun request and Preliminary Conclusion

For the right arm, from the results above, we have:

Gas cherenkov: the η_π is about 300 at $\eta_e = 99.0\%$;
Shower/Preshower: $\eta_\pi \sim 100$ at $\eta_e = 99.0\%$.

Therefore we can conclude that the PID efficiency is good enough for the experiments, which is expected to have $\pi/e \sim 100$ (kinematics #3 of E99117).

For the left arm, the electron efficiency is found to be high. For cuts used in usuall analysis they are found to be above 99.0% for both short gas cherenkov and pion rejectors. Performance of short gas cherekov could be improved further, probably by changing PMTs. But no conclusion can be made for pion rejection at this moment because of the quality in sample pion events. So we strongly recommend to take some high pion runs, with negative polarity on the left arm, such that we will be able to feel confident about the data quality in the E99117 real runs.