Efficiency of the Cerenkov Trigger *

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Prior to 14:00, 1 Nov 2010 the hardware threshold on the Čerenkov analog sum was set to 200 mV. This caused the S2m∩Čer trigger (T10) to have an intrinsic 7% inefficiency. On 1 November, during a brief access, I lowered the Čerenkov thresholds to 50 mV. This increased the trigger rate by about 10–20%.

I. ČERENKOV DETECTOR ELECTRONICS

There are 10 PMT on the Gas Čerenkov. Each signal is passed through a ×10 NIM P/S776 amplifier module and then a JLab NIM linear fanout (×2). Four plus four plus two channels are then combined in three channels of a LeCroy 757 Linear Fan-In/Fan-Out. These three fan-in signals are then combined in the fourth channel of the 757 module. All ten raw signals, plus the analog sum feed a pair of common threshold NIM discriminators (P/S 706). The threshold readback on these discriminators equals the threshold value (not ×10, as is common). This threshold was previously set to 20 mV.

During commissioning, I set the Čerenkov thresholds to 200 mV, in order to visually establish the S2m∩Čer coincidence timing with cosmic rays on an oscilloscope. Also, the visual pulse height distribution on the scope seemed to have very few pulses below 200 mV. In spite of this high threshold, the raw and summed Cerenkov amplitude histograms display visible single photo-electron peaks.

* version 2.

II. TRIGGER EFFICIENCY RUNS

To test the electron trigger efficiency, we made several runs with the CODA configuration LeftHRS, with either $ps5 = 1$ or $ps3 = ps4 = 1$. These are summarized in Table I.

The triggers are formed as follows:

- T3: $S1 \cap S2m$
  Formed in programmable CAMAC logic
- T4: $[(S1 \cap Cer) \cup (S2 \cap Cer)] \cap \overline{(S1 \cap S2m)}$
  Formed in programmable Camac logic
- T5: $(S2 \cap Cer)$
  Formed in a FPGA of the DVCS Trigger module.

TABLE I: Trigger Efficiency Runs

Run	Date : Time	Cer Threshold	ps3	ps4	ps5	Events
8509	9 Nov 2010 : 07:09	50 mV	1	1	0	1M LD_2
8489	8 Nov 2010 : 15:45	50 mV	1	1	0	3.7M LD_2
8302	4 Nov 2010 : 01:50	50 mV	1	1	0	1.06M
8214	1 Nov 2010 : 15:15	50 mV	0	0	1	$51K$
8213	1 Nov 2010 : 15:00	50 mV	1	1	0	$400K$?
8205	1 Nov 2010 : 13:50	200 mV	0	0	1	$38K$
8204	1 Nov 2010 : 13:33	200 mV	1	1	0	$537K$
8161	31 Oct 2010 : 04:10	200 mV	1	1	0	$495K$
8160	31 Oct 2010 : 03:54	200 mV	0	0	1	$81K$

III. RUN 8161

I give a sample analysis of the T3 events in Run 8161. The online analyzer processed the first 80,000 events of this file. First I make moderately tight cuts on all tracking variables, to select only events with one clean track within the spectrometer acceptance. These cuts are in the file TightHRS.h, and listed in Table II.

TABLE II: Electron Selection Cuts in T3

Cut Name	Cut Value
	TightHRS.h
cGoodVDC	L.tr.n==1&&abs(L.tr.x)< 0.8&&abs(L.tr.y)< 0.1&&abs(L.tr.ph)< 0.05
cGoodAngles	abs(L.tr.tg_th)< 0.1&&abs(L.tr.tg_ph)< 0.05
cTarget	abs(rpl.z)< 0.07
cAccept	abs(L.tr.tg_dp)< 0.05
cCleanTrk	cGoodVDC && cGoodAngles && cAccept
	Cerenkov.h
cPR	L.prl1.asum_c+L.prl2.asum_c> 600 && L.prl1.asum_c> 250
cCerTime	abs(D.CerInT3−2300) < 300.
cT3	fEvtHdr.fEvtType==3
cPion	250 < L.prl1.asum_c+L.prl2.asum_c && L.prl1.asum_c+L.prl2.asum_c< 400

A. Cerenkov Amplitude Analysis

The coincidence time spectrum of the Cerenkov discriminator, relative to the Level-1-Accept (L1A) common stop TDC is displayed in Fig.1. The cut cCerTime is a $\pm 4.5\sigma$ cut. The raw Cerenkov amplitude distribution is plotted in the top panel of Fig. 2. It shows a clear one photo-electron peak at chan 174. The lower panel makes a 4σ cut on the pedestal at L.cer.asum_c> 100. The resulting mean of 1208 corresponds to a mean of 7.6 photo-electrons. It is therefore statistically impossible that the single photo-electron peak arises from electrons only. The probability of a Poisson distribution of mean 7.6 yielding 1 photoelectron is

$$P_P(1|\mu = 7.6) = e^{-7.6}(7.6) = 4 \cdot 10^{-3} \quad (1)$$

With a sample of 10000 events, there should only be 40 events in the single photo-electron peak. There are instead roughly 10 times that many events. Thus the 1pe peak is *e.g.* delta-rays from pions. The lower panel of Fig. 2 also shows the Cerenkov amplitude distribution cut on the Čerenkov timing. This shows a significant inefficiency of the trigger up to several photo-electrons. From the ratio of the black and blue histograms, one could estimate the Cerenkov trigger inefficiency at 14.4%. However, due to the pion δ-ray contribution, I think this is a serious over estimate of the problem.

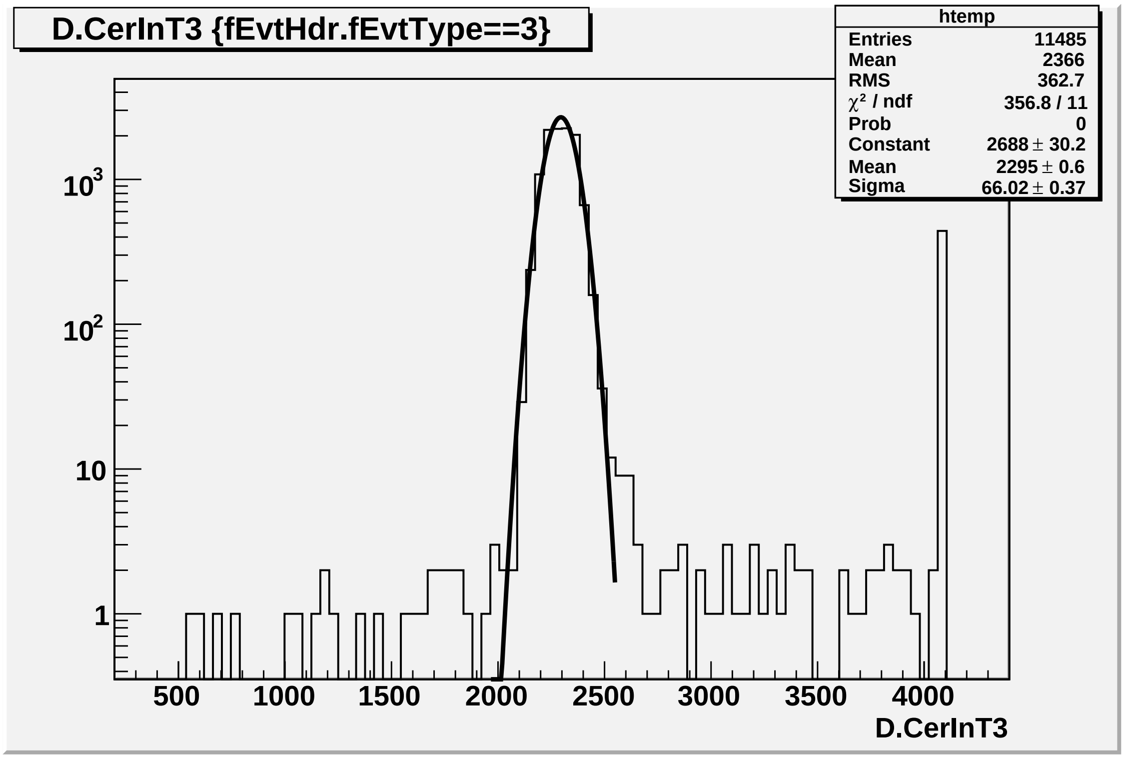

FIG. 1: Cerenkov coincidence timing, cut on cCleanTrk and fEvtHdr.fEvtType==3. FastBus TDC 1875A, 50 ps/count.

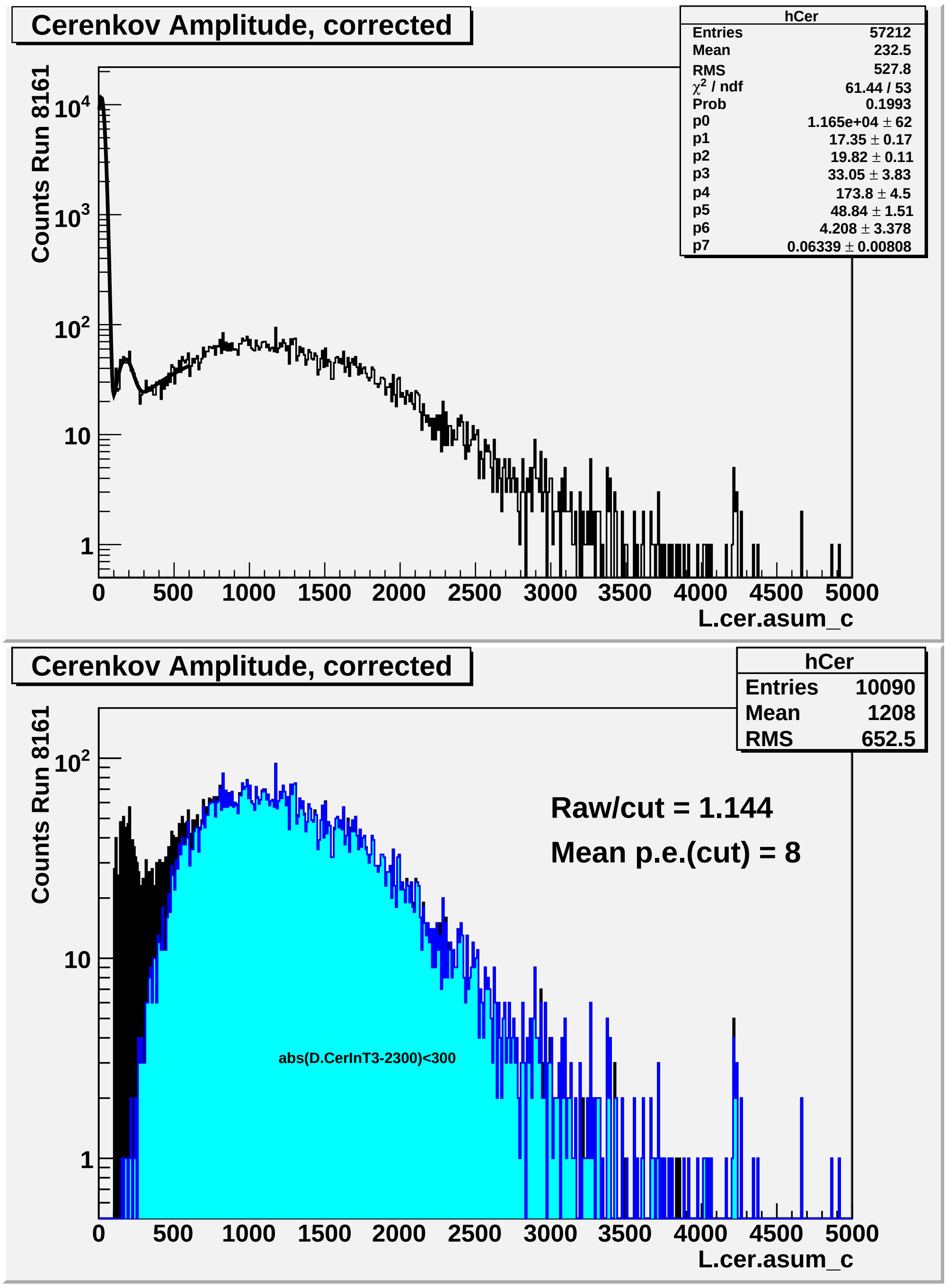

FIG. 2: Top: Summed spectrum of corrected Čerenkov amplitudes, cut on cCleanTrk and fEvtHdr.fEvtType==3. The fit to channels < 600 is a gaussian fit to the pedestal (first three parameters) plus a gaussian fit to the one photo-electron peak (p3–p5) plus a first order polynomial. The pedestal is at 17 and the the single photo-electron peak is 174. Bottom: The same spectrum, with a minimal cut of L.cer.asum_c$>$ 100 to reject the pedestal. The Blue/cyan curve has the additional cut on Cerenkov coincidence timing (Fig. 1). The mean at 1200 corresponds to $\approx$ 8 photoelectrons.

B. Electron Sample from Pion Rejector

The pion rejector (PR) can be used to select an electron sample from the T3 events. However, we must consider that the "electron sample" is subject to contamination from pions. One mechanism for such contamination is the charge exchange reaction $\pi^- A \rightarrow \pi^0 X$ on a nucleus in the Pion Rejector, followed by $\pi^0 \rightarrow \gamma\gamma$ decay and showering of the two photons in the PbGlass of the PR.

The two dimensional distribution of the Pion Rejector Layer 1 corrected sum (L.prl1.asum_c) vs Layer 2 corrected sum (L.prl2.asum_c) is displayed in Fig. 3. The effect of the cut cPR is shown in red. In subsequent analysis, the threshold on the sum (diagonal) will be varied from 500 to 1200. The one dimensional distribution of the sum of the two PR layers is shown in Fig. 4. There is a clear minimum ionizing particle (MIP) peak at channel 300 and a clear electron distribution above channel 1000. After selecting events above pedestal in the Čerenkov amplitude distribution (Blue curve), one percent of the MIP peak persists, supporting the notion of δ-rays producing a 1 p.e. signal in the Cerenkov. This MIP signal is strongly suppressed when the Cerenkov timing cut is added (red curve).

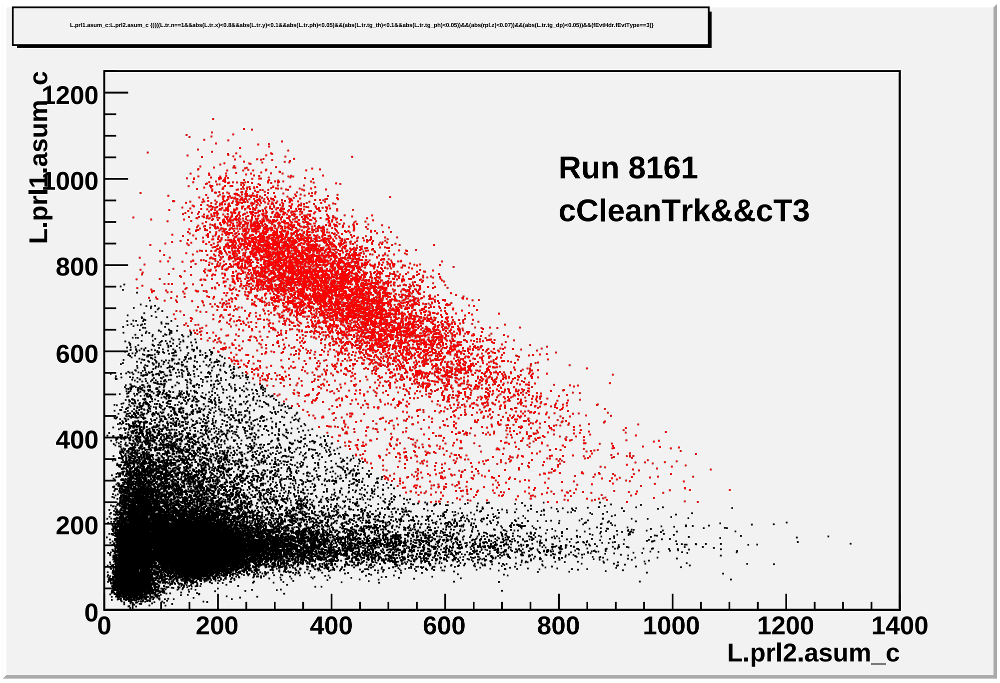

FIG. 3: Two dimension plot of the Pion Rejector amplitude. Events in red pass the cut cPR.

The Cerenkov inefficiency can now be estimated by comparing the number of events in

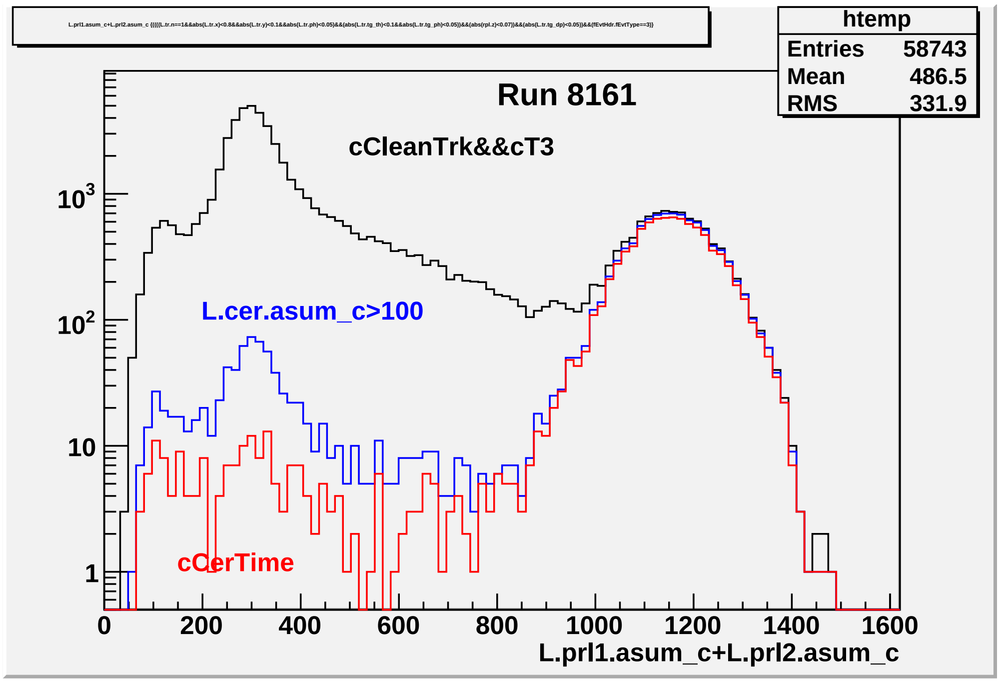

FIG. 4: The amplitude sum of the two layers of the Pion Rejector. The blue histogram is all events above pedestal in the Čerenkov amplitude distribution. The red histogram has the additional Čerenkov timing cut.

the blue and red histograms of Fig. 4, after imposing a variable electron selection cut cPR on the Pion Rejector amplitudes. The Cerenkov amplitude distributions, with a cut of 800 on the PR sum are shown in Fig. 5. The resulting correction factor for the discriminator inefficiency is 1.077, with a 1% statistical error. The statistical error can be reduced by analyzing all of the events in the run. However, there will remain a systematic uncertainty from possible pion contamination in the electron sample. To estimate this error, I did a stability study of the correction factor as a function of the cut on the PR sum. The results are shown in Table III. As the PR cut is lowered, more pions leak into the sample. As the PR cut is raised, the statistics are sharply reduced, though the electron purity should be improved.

The results for the Čerenkov efficiency correction factor for run 8161 are tabulated in Table III.

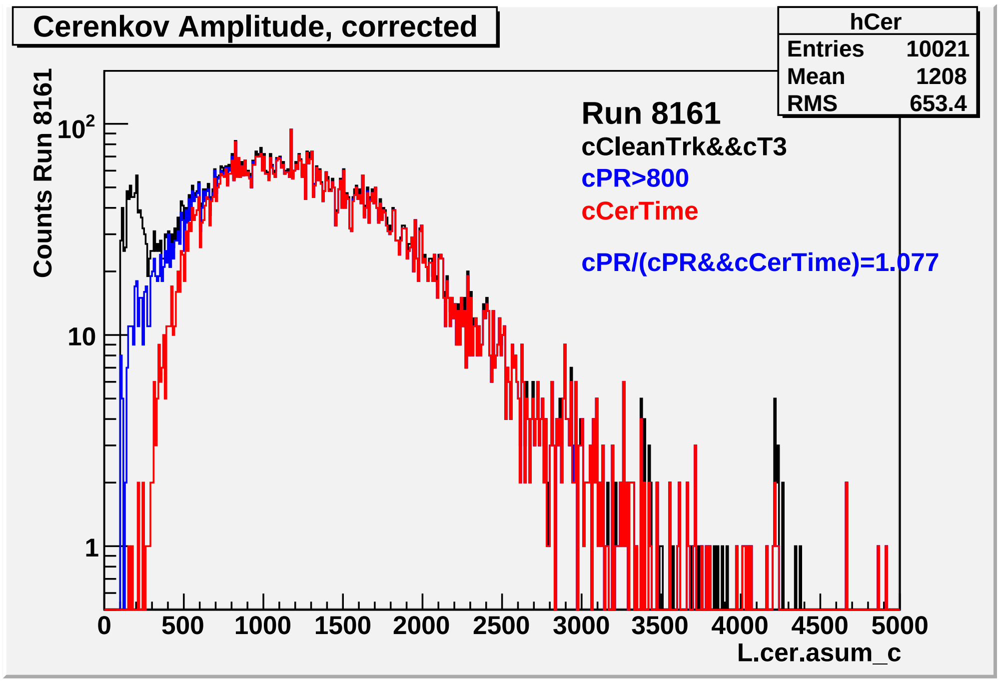

FIG. 5: Čerenkov amplitude distributions. All distributions are cut on Čerenkov amplitude > 100 to remove the pedestal. Black: all T3 events passing tight tracking cuts. Blue: Additional cut on Pion Rejector, with sum threshold at 800. Red: Additional Čerenkov timing selection. The ratio of blue to red gives the estimated correction factor for the inefficiency of the Cerenkov timing discriminator.

TABLE III: Run 8161 Correction factor for Čerenkov trigger inefficiency. The correction is the ratio of all events passing the Pion Rejector (PR) electron selection cut, divided by the number of events with the additional selection of the Cerenkov coincidence timing from the Čerenkov trigger discriminator. All events have tight tracking cuts applied. Error bar is statistical only, from analysis of first 80K events.

PR Sum cut	cPR/cPR&&cCerTime
500	1.081
600	1.079
700	1.077
800	1.077 ± 0.01
900	1.076
1000	1.075
1100	1.080
1200	1.088 ± 0.02

C. Cerenkov signal from Pions

Figure 6 shows the Čerenkov summed amplitude with a selection cut on the MIP signal in the Pion Rejector. As expected, most of the events are in the Čerenkov pedestal. However, the majority of the events in the raw one photo-electron peak persist in the pion (MIP) sample.

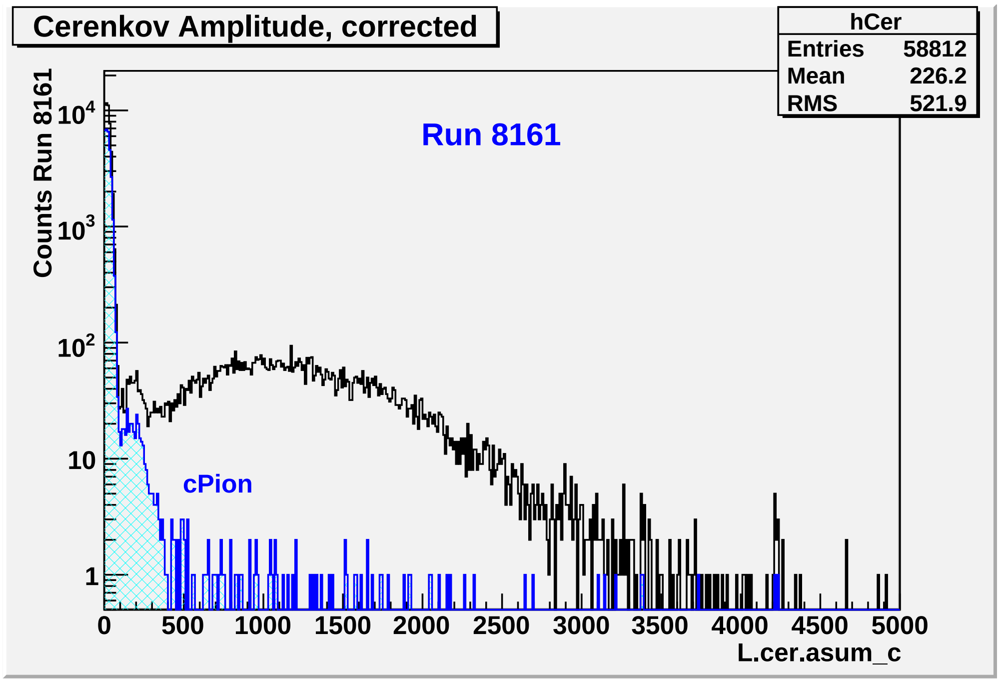

FIG. 6: Čerenkov amplitude signal with a selection on the MIP signal in the Pion Rejector.

IV. RUN 8213, ČERENKOV THRESHOLD AT 50 MV

I repeated the analysis with the first 100,000 events from run 8213. This is the first run after setting the Čerenkov thresholds to 50 mV. The results, as a function of the PR cut, are listed in Table IV. I surprised by the persistent 1.5% "inefficiency". This 1.5% seems to be uniform over the entire Čerenkov amplitude distribution. I do not know if S1∩S2 or S2∩Čer accidentals can affect this result.

V. RUN 8509, LD_2

The analysis of Deuterium run 8509 is also tabluated in Table IV. The inefficiency is stable with respect to the cut at 1.1%.

VI. RUN 8626

The Cerenkov summed spectrum is shown for run 8616 in Fig. 7. The Black histogram is all events satisfying the Pion Rejector electron cut (PR sum > 800). The cyan-filled histogram has the Cerenkov timing coincidence cut also. The discrepancy of 1.1% is almost invisible, but seems to be uniform over the spectrum.

TABLE IV: Run 8213 Correction factor for Čerenkov trigger inefficiency, first 120K events. See Table III for definitions.

	Run 8213	Run 8509
PR Sum cut	cPR/cPR&&cCerTime	cPR/cPR&&cCerTime
600	1.016 ± 0.009	1.012 ± 0.005
700	1.016 ± 0.009	1.012 ± 0.005
800	1.015 ± 0.009	1.012 ± 0.005
900	1.015 ± 0.009	1.011 ± 0.005
1000	1.015 ± 0.009	1.011 ± 0.005
1100	1.014 ± 0.012	1.011 ± 0.005
1200	1.015 ± 0.020	1.010 ± 0.006

VII. CONCLUSION

Run 8161 is representative of the data taken with the Čerenkov threshold at 200 mV. From Table III, the best estimate of the Čerenkov efficiency correction factor is 1.077 ± 0.011. Once the threshold was lowered to 50 mV, the efficiency is at least 98.5% (Run 8213).

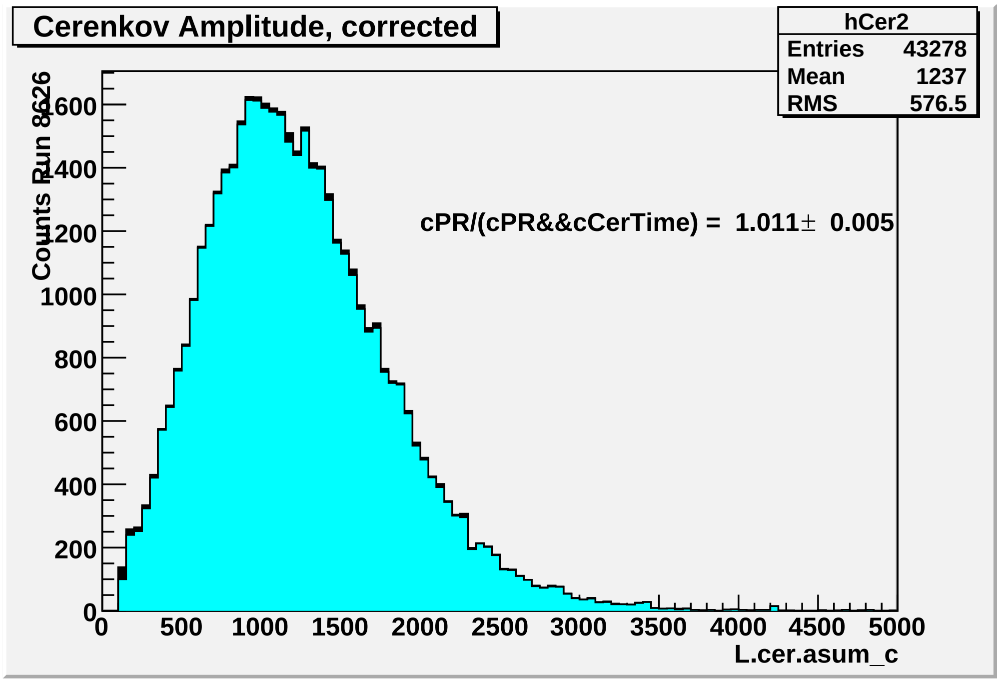

FIG. 7: Čerenkov amplitude distributions. All distributions are cut on Čerenkov amplitude > 100 to remove the pedestal. Black: all T3 events passing tight tracking cuts and additional cut on Pion Rejector, with sum threshold at 800. Cyan: Additional Čerenkov timing selection. The ratio gives the estimated correction factor for the inefficiency of the Cerenkov timing discriminator. 240K events analyzed.