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PID Efficiency for E01-012

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Abstract

The PID analysis for E01-012 is presented in this document. Due to several hardware problems, the same PID cuts cannot be used for asymmetry and cross section analyses and all details are described.

1 Introduction

2 Cerenkov

2.1 Detection efficiency

To determine the detection efficiency of the cerenkov detectors, a high electron run was selected: E = 3.028 GeV, P_0 = 2.150 GeV/c, $\theta = 25^\circ \Rightarrow$ W = 1.142 GeV (threshold for production of pions is at W = 1.08 GeV). First a tight cut on the electron "bulb" in the preshower vs. shower plot (or prl1 vs. prl2 plot for the left arm) is applied. The number of events selected in this cut is called η_{sh}. Then we count the number of these events that triggered the cerenkov detectors (η_{cer}). Thus the detection efficiency can be determined by Eq. 1:

$$\epsilon_{det} = \frac{\eta_{cer}}{\eta_{sh}} \tag{1}$$

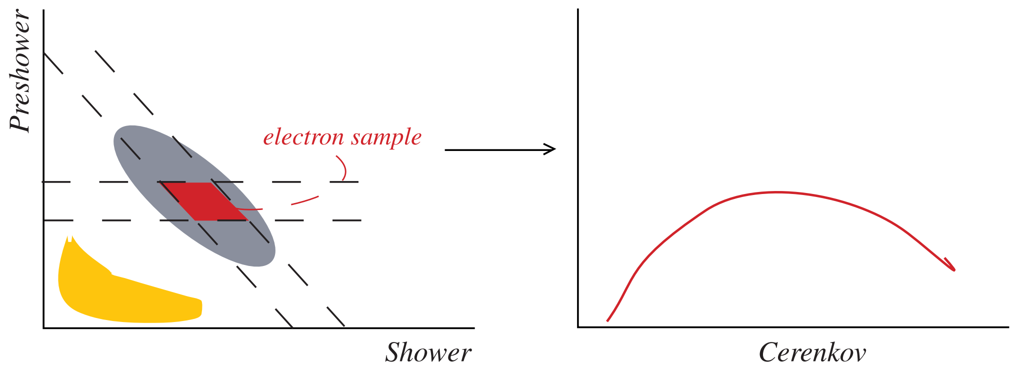


Figure 1: method to get detection efficiency for the cerenkov detector.

Thus we got ϵ_{det} = 99.99% for the right arm cerenkov detector and ϵ_{det} = 99.98% for the left one.

2.2 Cut efficiency

The goal of the PID analysis is to reject as many pions as possible while keeping a high electron efficiency (= low electron loss). To do so, π sample and e^- are selected in the 2D shower plot and then their distributions are observed in the cerenkov spectrum (Fig. 2 and Fig. 3).

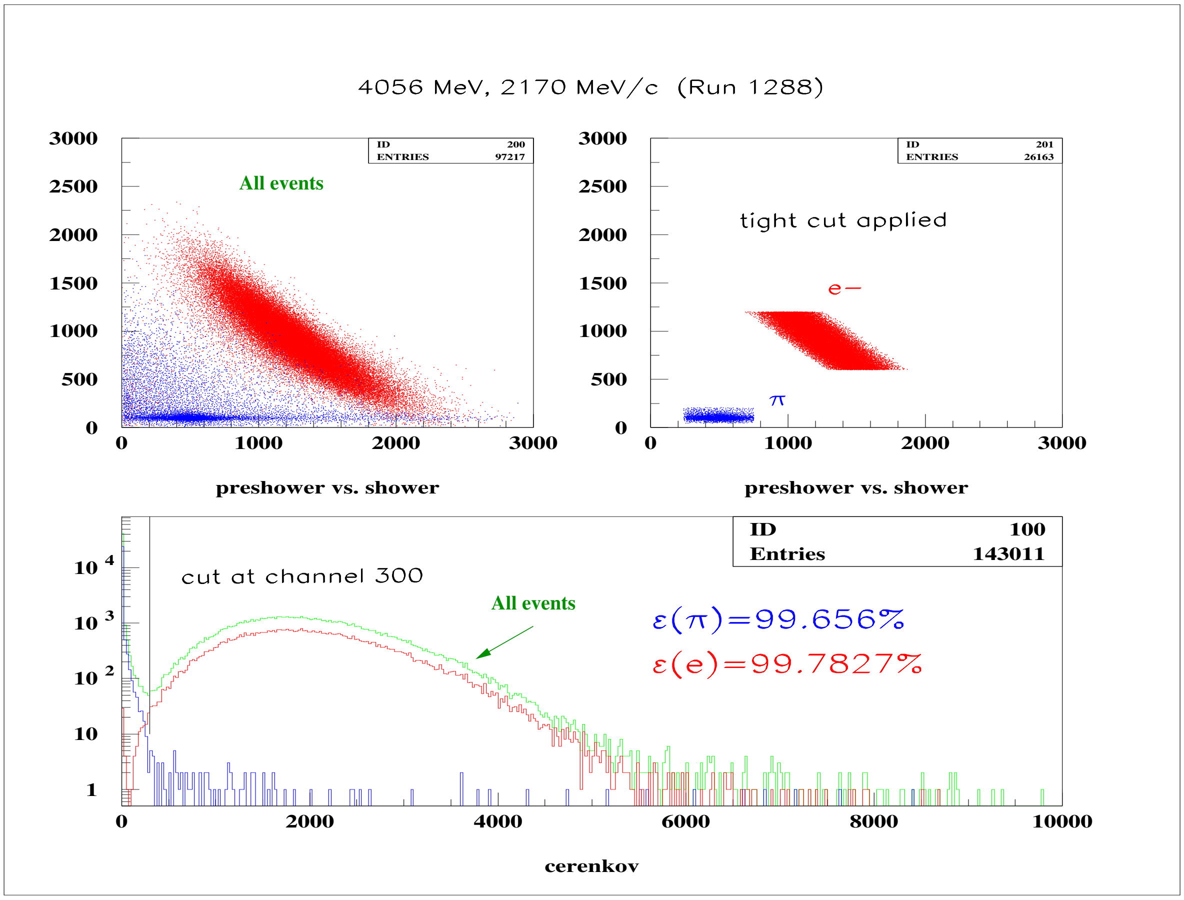


Figure 2: right cerenkov cut efficiency study

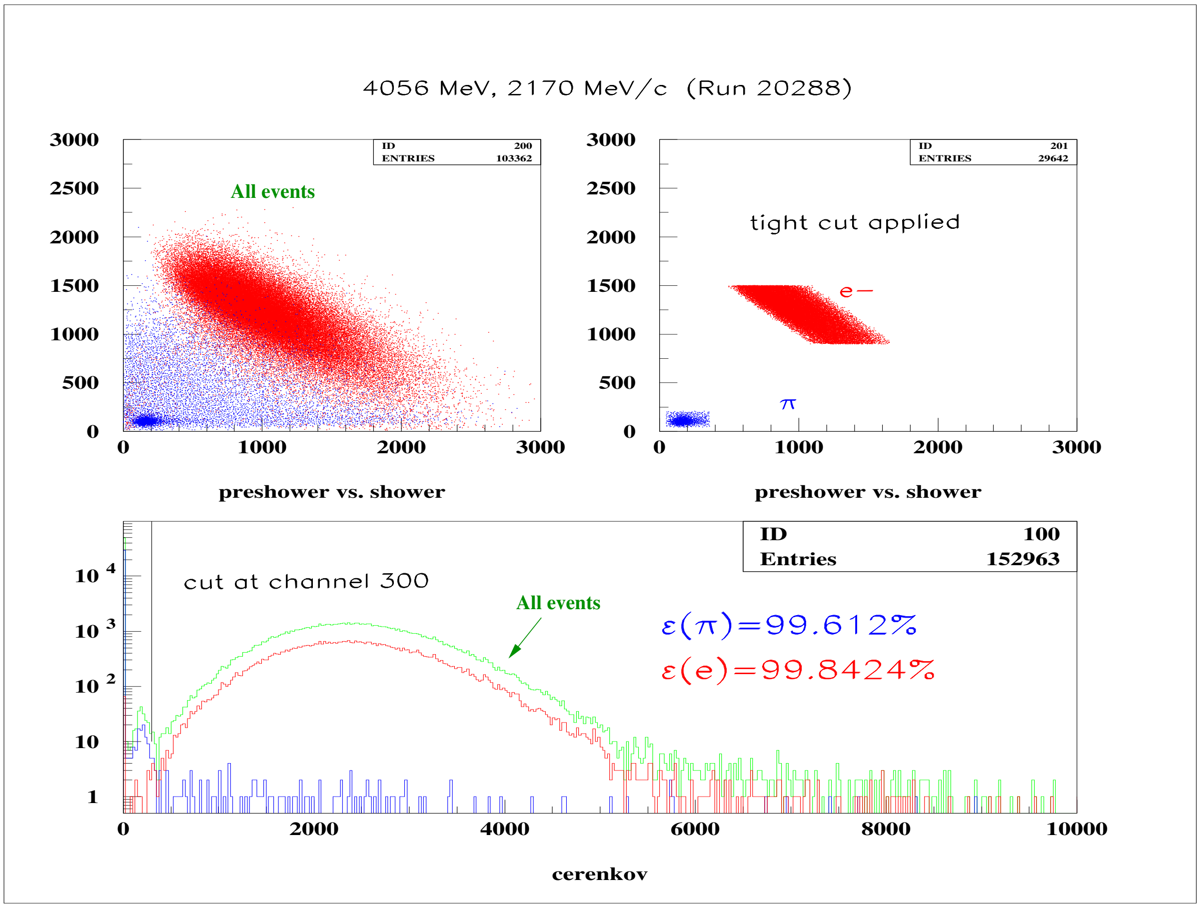
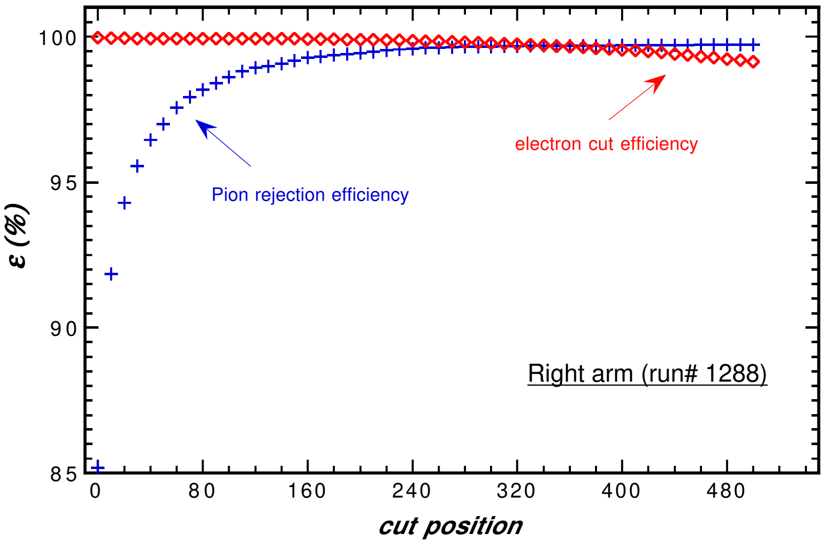


Figure 3: left cerenkov cut efficiency study

As it can be better observed in the left arm analysis, pions show up mostly in the pedestal and in the single photo-electron peak as knock-on electrons [2].
Fig. 4 shows the evolution of the electron cut efficiency and pion rejection efficiency in function of the cut applied on the cerenkov.



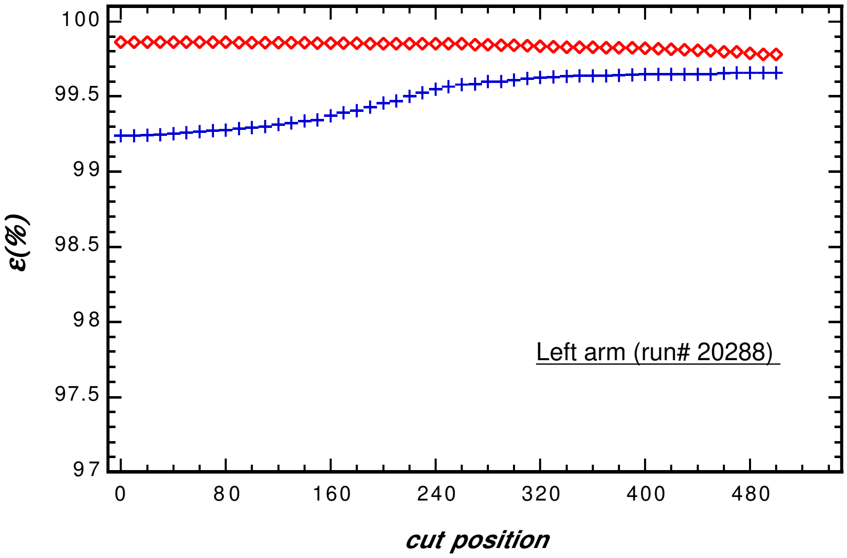


Figure 4: cerenkov cut efficiency study

For each kinematic, the cut was checked in order to optimize both electron efficiency and pion rejection efficiency (Table 1).

Table 1: Efficiency of both arms cerenkov detectors after cut

kinematics			RIGHT ARM			LEFT ARM		
E (GeV)	θ (°)	P_0 (GeV/c)	cut	$\epsilon_{cut}(e^-)$ (%)	$\epsilon_{rej}(\pi)$ (%)	cut	$\epsilon_{cut}(e^-)$ (%)	$\epsilon_{rej}(\pi)$ (%)
3.026	25	1.3338	350	99.72	99.29	350	99.55	99.79
		1.448	350	99.70	99.12	350	99.74	99.80
		1.567	350	99.73	98.96	350	99.78	99.72
		1.696	350	99.74	99.01	350	99.88	99.71
		1.836	350	99.74	98.87	350	99.89	99.67
		1.987	350	99.72	98.85	350	99.91	99.54
		2.150	350	99.77	98.29	350	99.91	99.25
4.056	25	1.840	300	99.79	99.71	350	99.59	99.74
		2.000	300	99.81	99.61	350	99.69	99.78
		2.170	300	99.78	99.66	350	99.83	99.64
		2.350	N/A	N/A	N/A	350	99.85	99.54
		2.550	N/A	N/A	N/A	350	99.88	99.47
		2.760	N/A	N/A	N/A	350	99.91	99.45
5.056	25	2.333	N/A	N/A	N/A	350	99.52	99.74
		2.524	N/A	N/A	N/A	350	99.65	99.65
		2.732	N/A	N/A	N/A	350	99.78	99.57
		2.957	N/A	N/A	N/A	350	99.93	99.30
		3.200	N/A	N/A	N/A	350	99.89	99.57
5.056	32	2.031	300	99.58	99.66	350	99.46	99.68
		2.199	300	99.75	99.68	350	99.45	99.82
		2.379	300	99.83	99.92	350	99.85	99.66
		2.575	300	99.63	99.33	N/A	N/A	N/A
		2.625	300	99.59	99.18	N/A	N/A	N/A

2.3 Conclusion and comments

Fig. 5 shows the cerenkov cut efficiency for all runs and a trend can be observed (more pronounced in the left arm) where the efficiency drops in some kinematics. This is due to the fact that at high W, our electon sample is contaminated by pions. So the real estimate of the electron efficiency should be done at the lowest W of each kinematic.

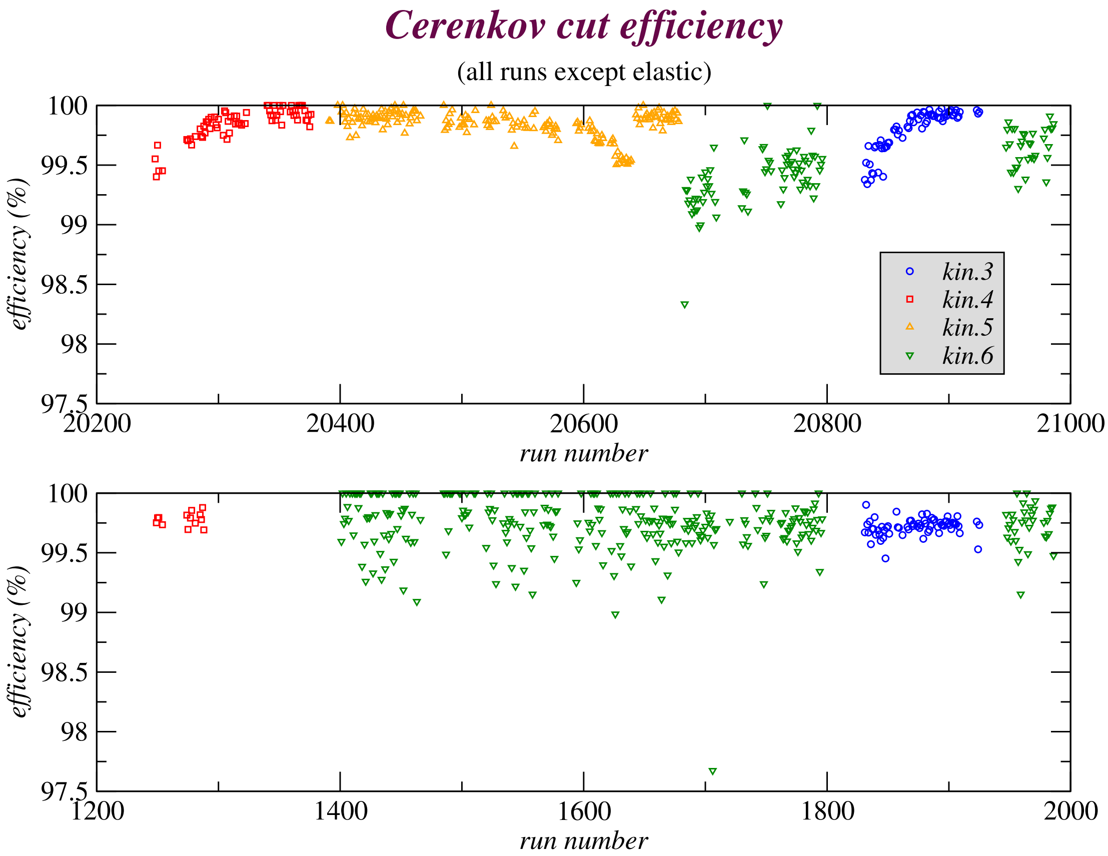


Figure 5: cerenkov cut efficiency for all runs for the left arm (top plot) and the right arm (bottom plot)

Table 2: cerenkov cut efficiency

	RIGHT ARM			LEFT ARM		
kin	CER cut	cut eff	pion rejection	CER cut	cut eff	pion rejection
1	300	99.89 ± 0.01	N/A	350	99.96 ± 0.01	N/A
4	300	99.79 ± 0.07	99.78 ± 0.08	350	99.94 ± 0.05	99.83 ± 0.05
3	350	99.73 ± 0.07	99.55 ± 0.07	350	99.93 ± 0.02	99.81 ± 0.07
5	N/A	N/A	N/A	350	99.90 ± 0.05	99.74 ± 0.03
6	300	99.78 ± 0.24	99.76 ± 0.14	350	99.65 ± 0.16	99.76 ± 0.09

3 Electromagnetic calorimeter

3.1 Detection efficiency

The kinematic selected was before two blocks in the right arm preshower became totally inefficient and after the base of block 4 in the left arm pion rejector second layer was replaced. Thus the detection efficiency was determined at: E = 4.018 GeV, P_0 = 2.0 GeV/c, $\theta = 25°$ and W = 1.8 GeV.

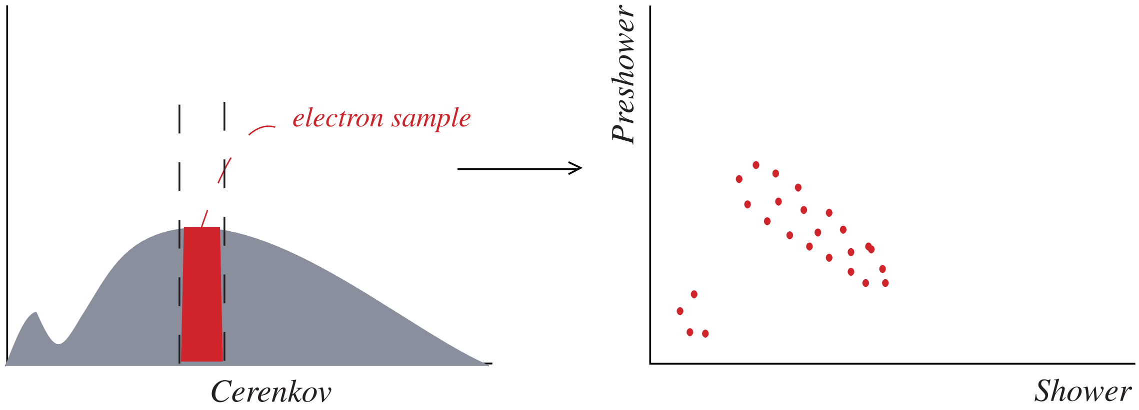


Figure 6: method to get detection efficiency

The procedure is as followed: a tight cut is applied on the main peak of the cerenkov spectrum. The number of events in this cut is called η_{cer}. Then we count the number of these events that triggered both layers of the EM calorimeter (η_{sh}). Thus the detection efficiency can be determined by Eq. 2:

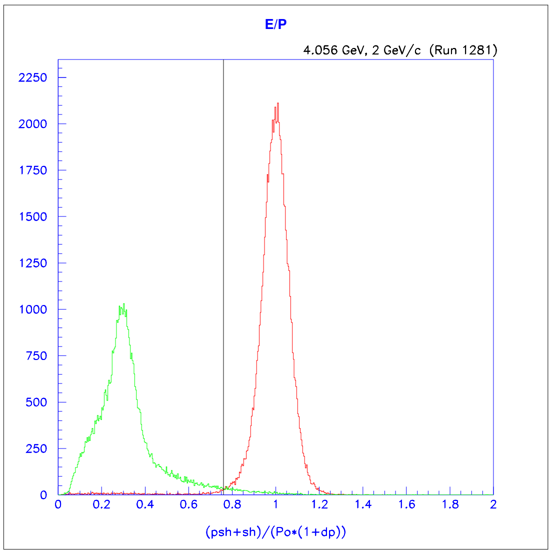
$$\epsilon_{det} = \frac{\eta_{sh}}{\eta_{cer}} \tag{2}$$

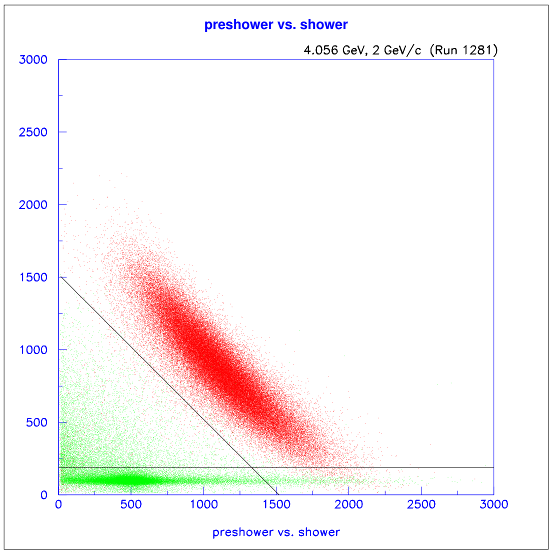
We got $\epsilon_{det} = 99.67\%$ for the left arm pion rejector and $\epsilon_{det} = 99.76\%$ for the right arm total shower. Since for most of the kinematics the right arm preshower cannot be used, the shower detection efficiency was determined to be 99.89%.

3.2 Cut efficiency

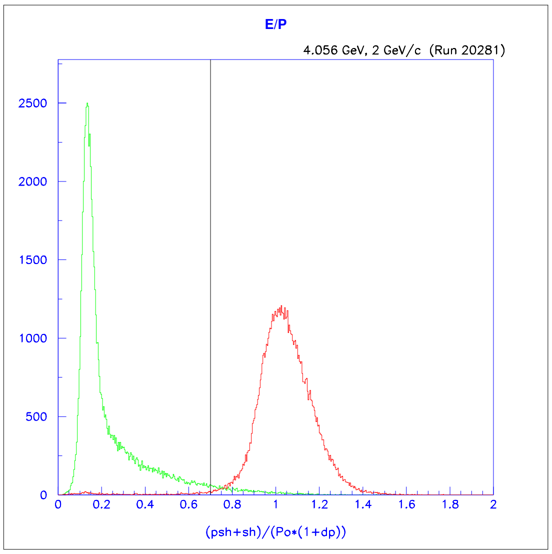
In complement of the cerenkov cut, the PID analysis can be improved by applying cuts on the EM calorimeters. To discriminate between electrons (in red) and pions (in green), a cerenkov and anti-cerenkov cuts are applied. Then a two-step method is used as in [1]: cuts on E/P spectrum and on preshower versus shower plot (or prl1 versus prl2) are optimized in order to get a total efficiency greater than 99% as illustrated by the following figures:

- right arm





- left arm



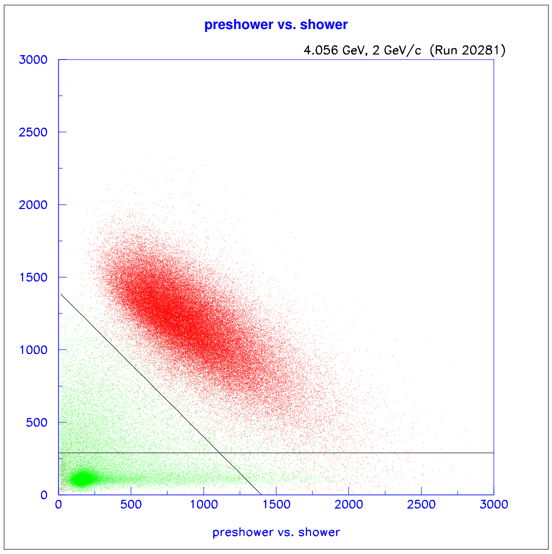


Table 3 lists the cuts on the EM calorimeters that will be applied in the data analysis for each kinematic setting and the remaining pion contamination.

3.3 Conclusion and comments

By combining the cerenkov detector with the electromagnetic calorimeter, we are able to reduce the π/e^- ratio by a factor of about 10^4 while keeping the electron efficiency better than 99% when no hardware problems occured. For the kinematics with inefficient lead glass blocks, the pion contamination is at a 10^{-3} level.

Table 3: cut applied in order to achieve better than 99% efficiency

kinematics			RIGHT ARM				LEFT ARM			
E (GeV)	θ ($^\circ$)	P_0 (GeV/c)	π/e cut	E/P cut	PSH/P	π cont.	π/e cut	E/P cut	PSH/P	π cont.
3.026	25	1.3338	2.019	0.73	0.080	0.70E-3	1.966	0.67	0.175	0.18E-3
		1.448	1.242	0.75	0.075	0.62E-3	1.207	0.70	0.175	0.16E-3
		1.567	0.774	0.77	0.085	0.32E-3	0.750	0.68	0.170	0.18E-3
		1.696	0.477	0.79	0.080	0.33E-3	0.464	0.74	0.170	0.14E-3
		1.836	0.298	0.81	0.055	0.88E-3	0.285	0.71	0.165	0.18E-3
		1.937	0.161	0.79	0.050	1.42E-3	0.156	0.77	0.165	0.13E-3
		2.150	0.079	0.80	0.050	1.31E-3	0.076	0.76	0.170	0.12E-3
4.056	25	1.840	1.385	0.75	0.095	0.20E-3	1.362	0.68	0.195	0.26E-3
		2.000	0.873	0.77	0.095	0.17E-3	0.882	0.70	0.165	0.18E-3
		2.170	0.558	0.79	0.100	0.17E-3	0.556	0.71	0.165	0.18E-3
		2.350					0.352	0.73	0.170	0.16E-3
		2.550					0.218	0.74	0.160	0.13E-3
		2.760					0.127	0.74	0.160	0.09E-3
5.056	25	2.333					1.128	0.78	0.160	0.19E-3
		2.524					0.674	0.79	0.160	0.17E-3
		2.732					0.394	0.79	0.170	0.14E-3
		2.957					0.292	0.75	0.130	0.16E-3
		3.200					0.260	0.75	0.135	0.13E-3
5.056	32	2.031	2.563	0.81	0.030	0.21E-3	2.440	0.76	0.160	0.18E-3
		2.199	1.755	0.82	0.040	0.14E-3	1.707	0.79	0.165	0.15E-3
		2.379	1.217	0.82	0.020	0.21E-3	1.211	0.79	0.175	0.11E-3
		2.575	1.514	0.82	0.025	0.15E-3				
		2.625	1.794	0.78	0.085	0.06E-3				

4 Summary

4.1 Cuts used in asymmetry analysis

For the asymmetry analysis, the PID cuts as defined before are used. The plots in Fig. 7 show a comparison between asymmetries generating only with a cut on the cerenkov and asymetries with all PID cuts applied. The differences are negligleable that brings us to the conclusion that the cerenkov by itself is a very performant PID detector and that increasing a little bit the pion contamination doesn't affect the asymmetries.

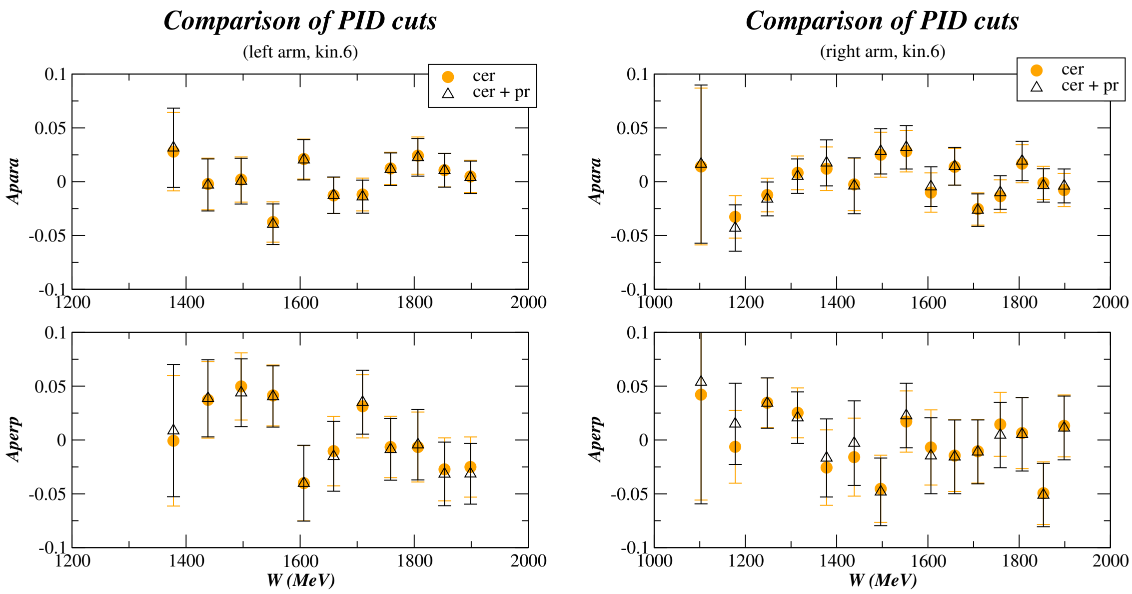


Figure 7: Study of the behavior of the asymmetries with PID cuts.

4.2 Cuts used in cross section analysis

However for cross section analysis, due to the high inefficiency of block 8 and 16 of the preshower for kin 3 and kin 6, the preshower had to be removed from the PID analysis. Fig. 8 shows the holes created in the ν spectrum due to the preshower inefficiency comparing the spectrum when only cerenkov cut is applied (blue) and when all PID cuts are applied (red). The left arm spectrum is showing as a reference of how it should look like when everything is working properly. Then Fig. 9 shows the effect on the cross section.

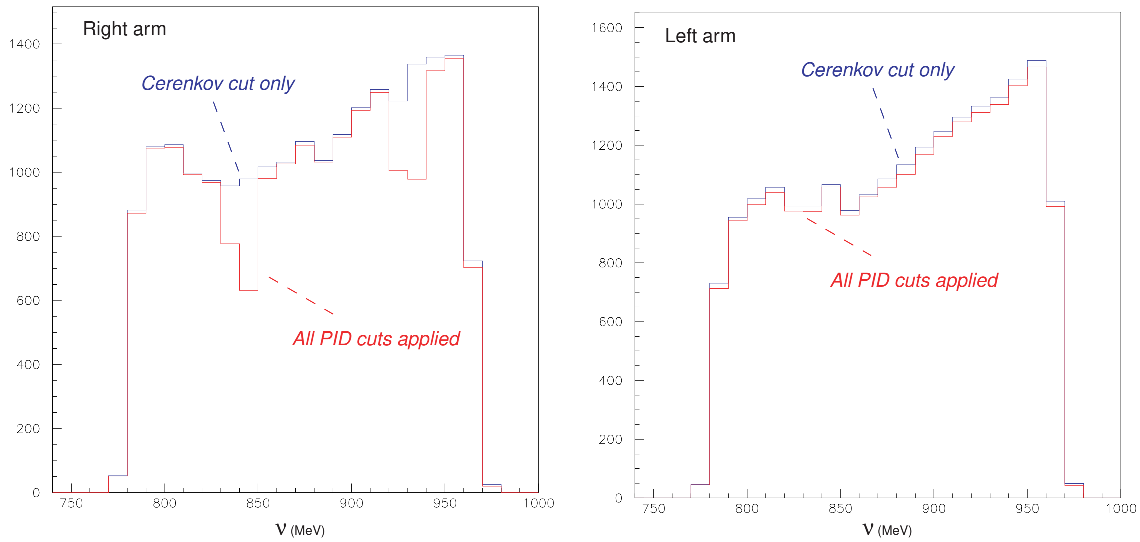


Figure 8: Study of the behavior of the asymmetries with PID cuts.

Thus a new analysis was done removing the preshower from the PID set and adjusting a cut only on the shower spectrum. Tables 4 and 5 show the cuts applied in the cross section analysis.
Finally the π/e^- ratio before and after PID cuts for each kinematic is plotted versus ν in figures 10 and 11.

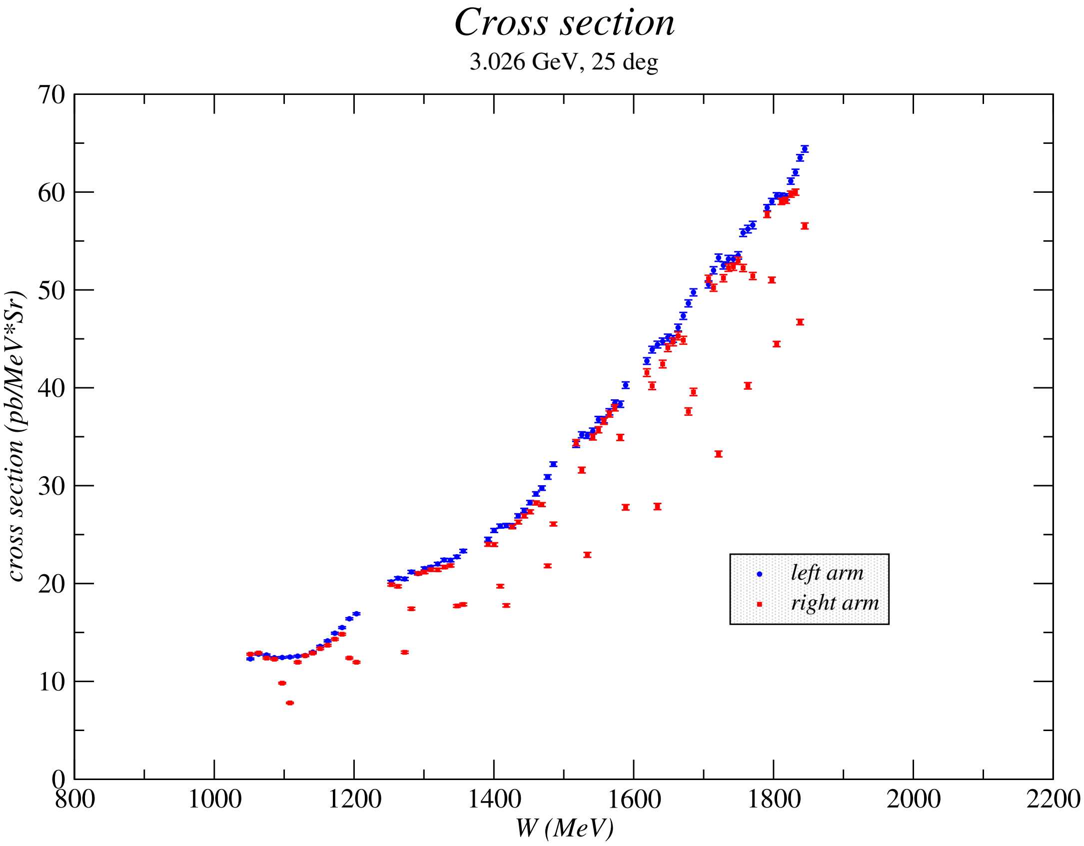


Figure 9: glitches in cross section due to preshower blocks inefficiency

Table 4: PID cuts summary (right arm)

kin	PSH/P cut	E/P	CER cut	$(\pi/e)_{before}$	$(\pi/e)_{after}$	PID eff.
1.1	0.125	0.65	300	(3.91 ± 0.07)E-03	(1.14 ± 0.07)E-03	98.38 ± 0.01
4.2	0.095	0.75	300	1.410 ± 0.002	(1.45 ± 0.05)E-04	98.97 ± 0.01
4.3	0.100	0.77	300	0.900 ± 0.018	(1.15 ± 0.06)E-04	98.74 ± 0.02
4.4	0.095	0.79	300	0.570 ± 0.002	(1.18 ± 0.06)E-04	98.82 ± 0.01
kin	SH/P cut		CER cut	$(\pi/e)_{before}$	$(\pi/e)_{after}$	PID eff.
3.1	0.08		350	1.990 ± 0.009	(7.30 ± 0.26)E-03	99.06 ± 0.03
3.2	0.11		350	1.230 ± 0.003	(7.70 ± 0.13)E-03	99.09 ± 0.03
3.3	0.15		350	0.766 ± 0.001	(8.40 ± 0.32)E-03	99.06 ± 0.03
3.4	0.19		350	0.473 ± 0.003	(9.01 ± 0.19)E-03	99.07 ± 0.05
3.5	0.22		350	0.295 ± 0.002	(8.74 ± 0.17)E-03	99.07 ± 0.03
3.6	0.24		350	0.162 ± 0.002	(6.79 ± 0.16)E-03	99.07 ± 0.03
3.7	0.27		350	0.081 ± 0.001	(5.09 ± 0.09)E-03	98.99 ± 0.04
6.1	0.27		300	1.89 ± 0.42	(9.29 ± 1.73)E-03	99.05 ± 0.407
6.2	0.30		300	1.62 ± 0.23	(7.89 ± 0.99)E-03	99.00 ± 0.87
6.3	0.30		300	1.27 ± 0.06	(7.23 ± 0.55)E-03	98.81 ± 0.89
6.4	0.28		300	1.72 ± 0.05	(9.85 ± 0.85)E-03	98.94 ± 0.34
6.5	0.24		300	2.50 ± 0.04	(14.4 ± 1.0)E-03	99.02 ± 0.22

Table 5: PID cuts summary (left arm)

kin	PRL1/P cut	E/P	CER cut	$(\pi/e)_{before}$	$(\pi/e)_{after}$	PID eff.
1.1	0.200	0.75	350	(2.40 ± 0.06)E-03	(2.76 ± 0.18)E-04	97.23 ± 0.01
4.2	0.190*	0.67*	350	1.38 ± 0.006	(2.18 ± 0.08)E-04	98.68 ± 0.04
4.3	0.160	0.70	350	0.905 ± 0.016	(1.17 ± 0.14)E-04	98.82 ± 0.18
4.4	0.145	0.72	350	0.572 ± 0.006	(1.27 ± 0.03)E-04	98.94 ± 0.06
4.5	0.160	0.74	350	0.354 ± 0.002	(1.05 ± 0.06)E-04	98.81 ± 0.04
4.6	0.160	0.74	350	0.219 ± 0.003	(0.94 ± 0.08)E-04	98.86 ± 0.04
4.7	0.140	0.75	350	0.132 ± 0.009	(0.75 ± 0.12)E-04	98.96 ± 0.08
3.1	0.170	0.67	350	1.990 ± 0.005	(1.41 ± 0.07)E-04	98.88 ± 0.12
3.2	0.170	0.70	350	1.220 ± 0.005	(1.22 ± 0.14)E-04	98.81 ± 0.17
3.3	0.165	0.70	350	0.759 ± 0.003	(1.29 ± 0.13)E-04	98.88 ± 0.19
3.4	0.170	0.74	350	0.467 ± 0.002	(1.06 ± 0.17)E-04	98.76 ± 0.24
3.5	0.170	0.71	350	0.289 ± 0.001	(1.14 ± 0.11)E-04	98.85 ± 0.13
3.6	0.165	0.77	350	0.158 ± 0.002	(0.86 ± 0.04)E-04	98.85 ± 0.41
3.7	0.170	0.79	350	0.078 ± 0.001	(0.86 ± 0.10)E-04	98.57 ± 0.29
5.1	0.150	0.76	350	0.27 ± 0.02	(0.69 ± 0.13)E-04	98.97 ± 0.20
5.2	0.160	0.80	350	0.30 ± 0.01	(0.85 ± 0.13)E-04	98.65 ± 0.27
5.3	0.170	0.80	350	0.41 ± 0.01	(0.93 ± 0.09)E-04	98.79 ± 0.07
5.4	0.165	0.79	350	0.68 ± 0.01	(1.07 ± 0.03)E-04	98.85 ± 0.06
5.5	0.170	0.79	350	1.15 ± 0.01	(1.14 ± 0.12)E-04	98.74 ± 0.06
6.3	0.175	0.80	350	1.24 ± 0.05	(0.83 ± 0.11)E-04	98.63 ± 0.25
6.4	0.170	0.79	350	1.70 ± 0.06	(1.13 ± 0.15)E-04	98.64 ± 0.24
6.5	0.165	0.78	350	2.50 ± 0.03	(1.28 ± 0.12)E-04	98.84 ± 0.16

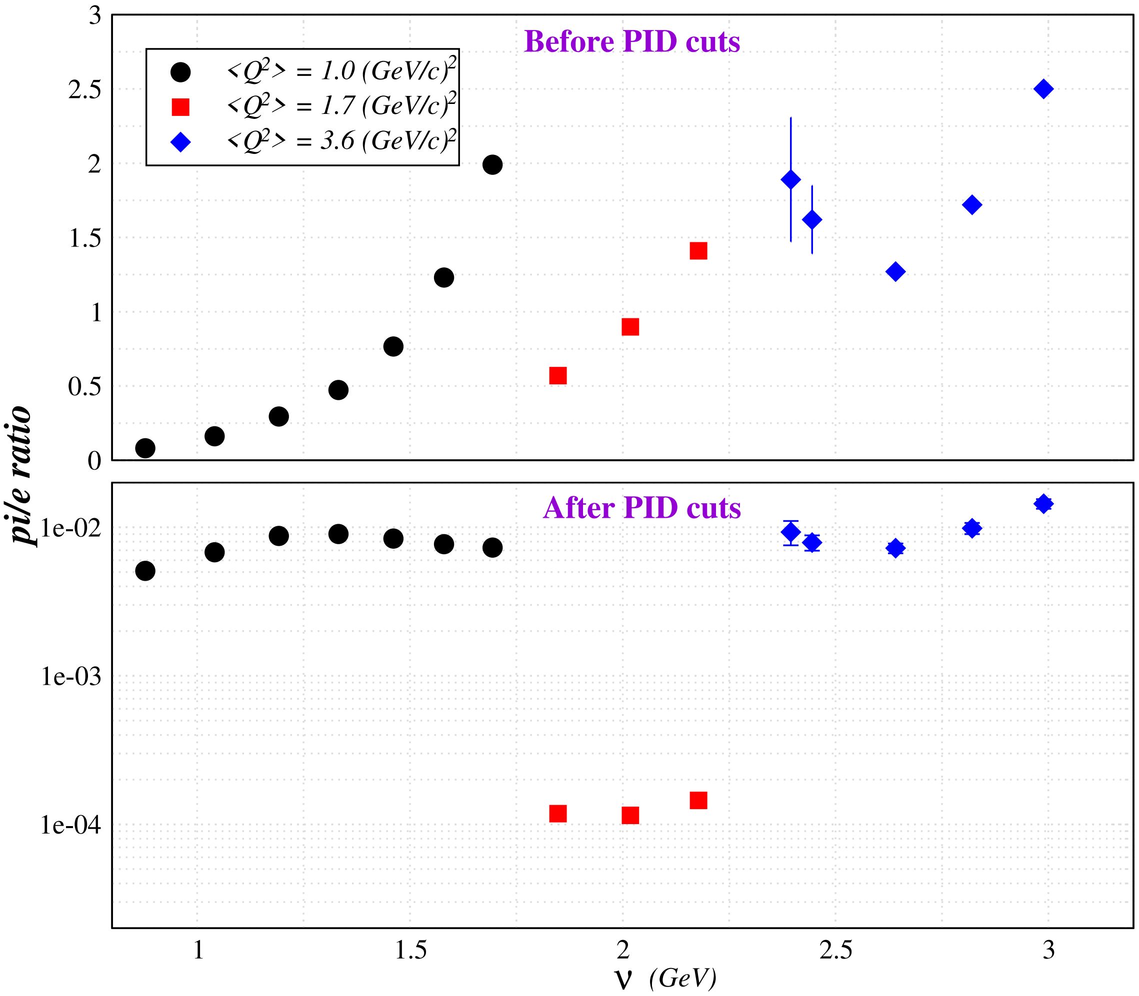


Figure 10: π/e^- ratio before and after PID cuts for cross section analysis were applied (right arm)

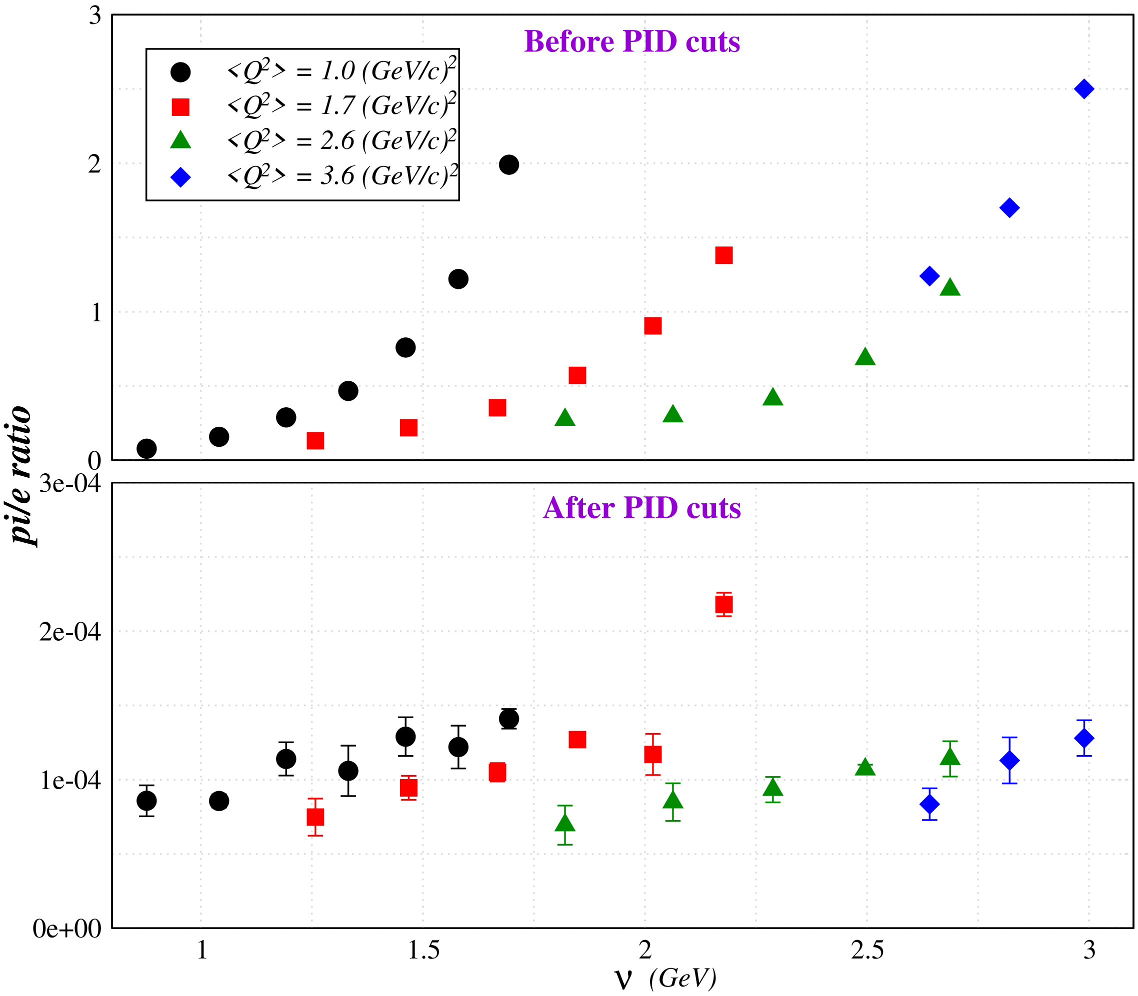


Figure 11: π/e^{-} ratio before and after PID cuts for cross section analysis were applied (left arm)

Acknowledgments

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References

[1] K. Slifer,"*Shower Detector Calibration and Cut Optimization for E94010*", E94010 Technical Note 31 (200 0).

[2] A. Deur,"*Knock-On of δ-electrons in the Hall A Electron Arm. Effect of the Aerogel Cerenkov.*", JLab-TN-98-028 (1998).