Chapter 5

Background estimation

5.1 Introduction

5.2 $K^+ \to \pi^+\pi^o$ target scatters

The $K_{\pi 2}$decay, where the π^+ scatters in the Target, is the dominant background for the PNN2 analysis. As it has been shown with Monte Carlo simulations ([32]), the photon distribution from the π^o decay is more uniform in polar angle for events where the π^+ has scattered in the target, than for unscattered ones. Therefore, the Photon Veto rejection for TG scatter events is expected to be different than that for $K_{\pi 2}$events in the peak. The kinematic cut cannot be used anymore in the bifurcation study, since the PV rejection has to be measured inside the PNN2 kinematic box.

The other set of cuts used to supress this background are the TGCUTS. These eliminate events with evidence of a scattered pion in the target, either the scatter occured outside the Kaon fibers (scatters visible in xy, or "xy-scatters") or inside them (events where the π^+ started in the beam direction and then scattered into the detector acceptance, or "z-scatters"). The two categories are not mutually exclusive. By inverting some of these cuts and applying others, samples with varying mixtures of xy- and z-scatters can be created for the rejection branch. 13 such "classes" were used, described in Table 5.1, and the PV rejection was measured on them in the PNN2 kinematic box. The rejection in the $K_{\pi 2}$peak is also given for comparison. The PV rejections measured for different classes are consistent with each other within statistical uncertainties, therefore for the final PV rejection, class 12 was used, because it had adequate statistics and it is expected to be the richest in z-scatters. In the normalization branch (see Table 5.2), all the TGCUTS were applied, and the PV was inverted.

CLASS	TGCUTS	PV rejection
1	All cuts, KP2BOX	1016.4± 233.1
2	$\overline{CCDPUL}$, $\overline{EPIONK}$	1653.6± 389.6
3	$\overline{CCDPUL}$, $\overline{EPIONK}$, all others	1304.0±1303.5
4	CCDPUL, EPIONK, TGZFOOL, EIC, OPSVETO, $\overline{OTHERS}$	1313.0± 757.8
5	$\overline{CCDPUL}$, $\overline{EPIONK}$, $\overline{CHI567}$, $\overline{VERRNG}$	1773.5± 396.4
6	$\overline{CCDPUL}$, $\overline{EPIONK}$, $\overline{CHI567}$, $\overline{VERRNG}$, all others	1744.0±1743.5
7	$\overline{CHI567}$, $\overline{VERRNG}$	2360.0± 572.3
8	$\overline{CHI567}$, $\overline{VERRNG}$, all others	70.0± 69.5
9	$\overline{CCDPUL}$, $\overline{EPIONK}$, $\overline{CHI567}$, $\overline{VERRNG}$, KIC, PIGAP, TARGF, TPICS	1723.2± 417.8
10	$\overline{B4EKZ}$	1760.1± 622.1
11	$\overline{B4EKZ}$, all others	10.0± 9.5
12	$\overline{CCDPUL}$, $\overline{EPIONK}$, $\overline{B4EKZ}$	1754.2± 413.4
13	$\overline{CCDPUL}$, $\overline{EPIONK}$, $\overline{B4EKZ}$, all others	1534.0±1533.5

Table 5.1: Classes of events used to measure the PV rejection in the PNN2 kinematic box, and the rejection found. The PV rejection in the KP2 kinematic peak, after all TGCUTS were applied, is also given. The same setup cuts as in the normalization branch (Table 5.2) are applied.

CUT	Events
	30991832
BAD_RUN,KERROR	30406468
SKIM5,RECON	10483802
PSCUT06	3227433
DELCO3	3208449
KINCUT06	476189
$\overline{PVCUT}$, PNN2BOX	49255
B4EKZ(IC)	35182
TGZFOOL	34676
EPITG	19698
EPIMAXK	19698
TARGF	16999
DTGTTP	16994
RTDIF	16841
DRP	16613
TGKTIM	16330
EIC	15870
TIC	15870
TGEDGE	15517
TGDEDX	12321
TGENR	11782
PIGAP	11569
TGB4	10473
KIC	10469
PHIVTX	8332
OPSVETO	7382
TGLIKE	6980
TIMKF	5644
NPITG	5644
ALLKFIT	5244
TPICS	5238
EPIONK	5019
CHI567	3316
VERRNG	2836
CHI5MAX	1801
ANGLI	1793
CCDBADFIT	1443
CCDPUL	181

Table 5.2: The normalization branch for the $K_{\pi 2}$target scatter background.

Using the numbers from tables 5.2 and 5.1, the $K_{\pi2}$target scatter background is

$$N_{K_{\pi2}-TGscat} = 3 \times \frac{N}{R_{PVclass12} - 1} = 3 \times \frac{181}{(1754.2 \pm 413.4) - 1} = 0.310 \pm 0.219 \tag{5.1}$$

5.3 $K^+ \rightarrow \pi^+\pi^o$ RS scatters

Pions from the $K_{\pi2}$decay can also undergo inelastic scattering in the Range Stack and fall into the PNN2 kinematic box by losing energy in the scattering process. However, for these events to be a background for this analysis, the pion momentum also has to be mis-measured and the photons from the π^o decay have to be missed. Therefore, this background is expected to be smaller compared to the $K_{\pi2}$target scattered background. The $K_{\pi2}$RS scatter background can be measured using the $K_{\pi2}$background sample.

It should be noted that these background events are already included in the normalization branch in Table 5.2, but they are not included in the Photon Veto rejection study in Table 5.1 because the target cuts were reversed to measure this Photon Veto rejection. The $K_{\pi2}$events which scattered in the RS should be assigned the same Photon Veto rejection as the KP2BOX events, since the pion did not scatter in the target.

The most effective cuts against this background are the Range Stack track quality cuts RSDEDX and PRRF (collectively referred to as RSCT), the BOX cut on *ptot* and the Photon Veto cut. Table 5.3 summarizes this background

CUT	Rejection PBOX from KP2BOX		Normalization $\overline{RSDEDX}$ or $\overline{CHIRF}$	
	KP2BOX	PNN2 RE BOX	KP2BOX	PNN2BOX
SETUP	39707	490	9847	1954
LAYER14	39640	490	9819	1954
FIDUCIAL	36366	432	8664	1877
UTCQUAL	32907	363	7438	1455
RNGMOM	32480	363	7267	72
RSDEDX	29050	81	NA	NA
PRRF	25213	59	NA	NA
PVCUT	21	0	4	0

Table 5.3: Background study for $K_{\pi 2}$RS scatters.

study. The SETUP cuts are the same with the $K_{\pi 2}$target scatter normalization branch. The second and the third columns of the table contain events in the $K_{\pi 2}$momentum peak. Events with the correct momentum as the $K_{\pi 2}$peak events, but lowered in range and energy are assumed to have scattered in the Range Stack.

The efficiency ϵ_{RSCT} and the rejection R_{RRSCT} of these cuts can be measured as

$$\begin{aligned}\epsilon_{RSCT} &= 25213/32480 &&= 0.776 \pm 0.002 \\ R_{RSCT} &= 363/59 &&= 6.153 \pm 0.733 \qquad (5.2)\end{aligned}$$

The fourth and fifth column of Table 5.3 are for normalization. The RSCT cut is reversed and all other cuts are applied. The various contributions to the total 72 events left in the PNN2BOX before the application of the PV have to be considered in order to calculate the background of interest. The largest component of this sample comes from scattering in the target that contaminated the RSCT reversed sample because of the inefficiency of the RSCT cuts. On the other hand, the total 181 events in the $K_{\pi 2}$target scatter normalization branch (Table 5.2) have a target scattered (N_{tg}) and a RS scattered (N_{rs}) component. Therefore

$$\begin{aligned} N_{tg} + N_{rs} &= 181 \\ (1-\epsilon_{RSCT}) \times N_{tg} + (R_{RSCT}-1) \times N_{rs} &= 72 \end{aligned} \tag{5.3}$$

Solving this system of equations, the real $K_{\pi 2}$RS scatter normalization is obtained, $N_{rs} = 6.382 \pm 0.952$. The final background from the RS scattered events can be measured by applying the $K_{\pi 2}$peak Photon Veto rejection to N_{rs} from the second column of Table 5.3, $R_{PV-K_{\pi 2}peak} = 25213/21 = 1200.6 \pm 458.2$:

$$N_{K_{\pi 2}-RSscat} = 3 \times \frac{N_{rs}}{R_{PV-K_{\pi 2}peak}-1} = 3 \times \frac{6.382 \pm 0.952}{(1200.6 \pm 458.2)-1} = 0.016 \pm 0.006 \tag{5.4}$$

5.4 Beam background

5.4.1 Single beam

The two cuts that suppress this background are DELCO3 and B4DEDX. In the rejection branch, after some basic setup cuts, B4DEDX is inverted, requiring B4 energy consistent with a pion ($b4abm\_atc < 1.0 MeV$), and the DELCO3 cut rejection is measured on this sample. The branch is divided into 3 sub-branches before DELCO3 is applied, of varying purity. Ideally, the rejection

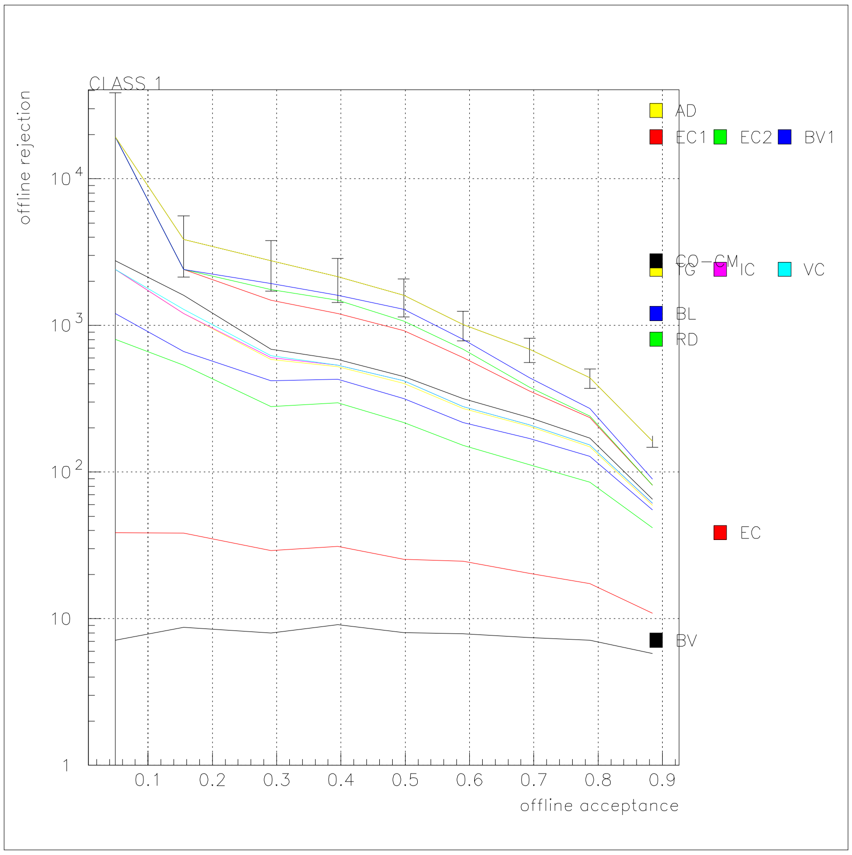
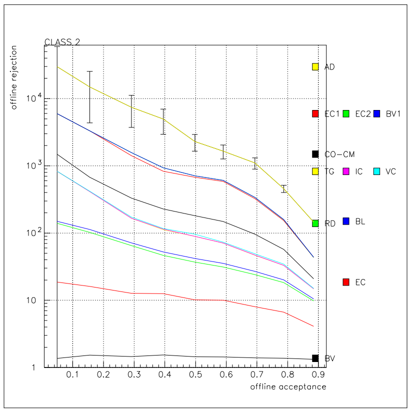
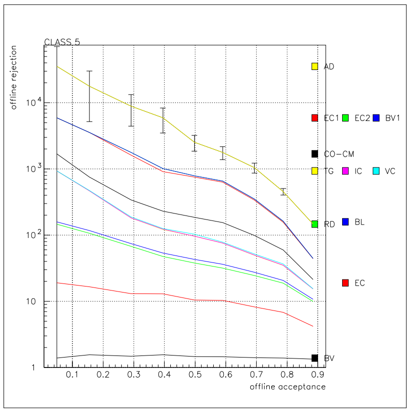


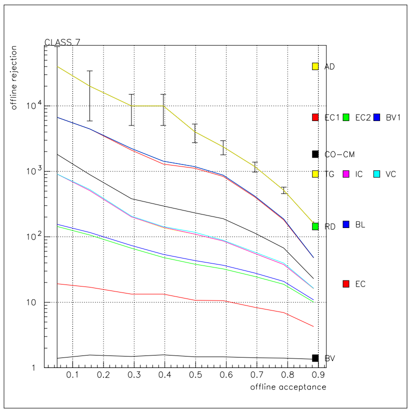
Figure 8.2: Offline rejection vs acceptance profile for the $K_{\pi 2}$peak, with each subsystem contribution.



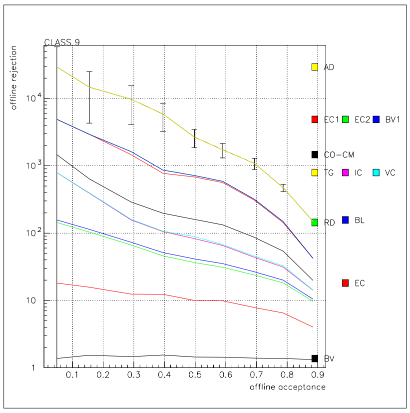
(a) CLASS2



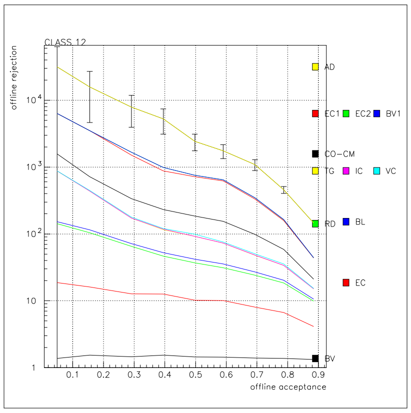
(b) CLASS5



(c) CLASS7



(d) CLASS9



(e) CLASS12

Figure 8.3: Offline rejection vs acceptance profile for the classes with significant statistics, with each subsystem contribution.