CLAS-NOTE 2002-009
CVS: docs/clas_notes/e16_kskim
Original: July 12, 2002
Version: 1.0

A Kaon Skim Program for e1-6

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July 12, 2002

1 Introduction

The following describes the operation, implementation and motivation for an updated kaon skim program for the e1-6 run. [1] Until just recently, the kaon skim program for electron runs relied on reconstructed mass cuts to select an event. This is fine at lower energies because such a cut serves to eliminate high energy (high momentum) ambiguities which are not considered in low energy analyzes anyway. However, as we move to higher beam energies, this mass cut results in the skim program throwing away interesting events [1]. To remedy this bias associated with the earlier skims, the reconstructed mass cut has been replaced with a cut on the particle flight time.

2 Kaon Filter

The kaon filter **KK_filter** is comprised of three source files contained in CVS (packages/utilities/KK_filter), which is based upon earlier work by Konstantine Lukashin [2]. These are: **KK_filter.c**, **KKEvent.c**, and **DEvent.c**. KK_filter.c is the main routine of the program. This routine scans the TRGS bank to get Faraday cup information and more importantly, a count on the number of scalar events. At this point DEvent is called, which is a function that counts deuterons and can be used as an independent estimator of the luminosity. It has no effect on the logic. Finally and most importantly, KKEvent is called. This is the event filtering function. First, KKEvent loops over the PART bank in a search for candidate electrons. The only cut used to select these electrons is a requirement that $PID = 3$. See appendix A for a description of what constitutes a particle with $PID = 3$. Some kinematic variables such as Q^2 and W are then calculated. The next cut to be made is a requirement that $W \geq 1.5$ which corresponds to the $epK+$ threshold value. Next the code enters its

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[1] A skim program is a function which returns **1** if an event from a unskimmed cooked file is to be kept and **0** otherwise.

second and last loop over the PART bank. Here it selects all charged particles, that are not electrons and whose β values are greater than 0. Quantities such as track length, measured flight time,the expected β values for kaons and protons and the time difference between measured and calculated flight times are now computed. The heart of the skim program is contained in the subsequent, logically exclusive selection of protons and kaons.

if Particle makes proton cut AND not the Kaon Cut ⇒ Particle is a Proton
if Particle makes Kaon cut AND not the Proton Cut ⇒ Particle is a Kaon

This is how we select clean, unambiguous protons and kaons. There is a third contingency where the particle satisfies both the proton and kaon timing cut.[2] This is the so-called high momentum ambiguity **high-mom**, where the timing cut includes both kaons and protons. In this case, the particle is tagged as a high momentum ambiguous kaon candidate.

if Particle makes proton cut AND the Kaon Cut ⇒ Particle is a high-momentum kaon candidate

Finally, after all these particles have been identified, the filter requirement for KKevent to return a **1** is that the event must contain:

(An electron **AND** a Kaon) **OR** (an electron **AND** a high-mom)

3 Results

The filter was tested on runs from the e1-6 data set using 12 files from runs 30921 and 31068. This period had a nominal electron beam energy of 5.759 GeV. To study the effect of various cuts, an file was produced using a timing cut of $\pm 10\sigma$. The filter was run twice, once requiring an eK$^+$ final state, and next with an epK$^+$ final state [3] as the filter requirement. With this timing cut, the eK$^+$ sample comprise 6.4% of the total unskimmed event sample, and the file size of the skimmed file is 100 Mbytes or 8.3% of the unskimmed file size. The selected epK$^+$ events comprise 1.1% of the total unskimmed event sample and the file size of the skimmed files is 18 Mbytes or 1% of the total unskimmed file size.

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[2] The nominal timing cut is a $\pm 7\sigma$ cut on the time difference between measured and calculated Kaon times where $\sigma = .150ns$, which is the average resolution of the TOF counters.

[3] The epK$^+$ final state requires there to be an electron, proton, and K$^+$ in the event or an electron, proton and **high-mom** or an electron, K$^+$ and **high-mom**, or an electron and two **high-mom** particles.

The output file was analyzed using **phi_accept**. Phi_accept has additional cuts on calorimeter energy, in addition to the PID cut, to select electrons. As a result of this, approximately 68% of the electron candidates from the skimmed file survive. The output file of selected events was subsequently put through phi_accept 10 times, each of these with a different timing cut ranging from 1σ to 10σ. The findings are summarized in Table 1. Fig. 2 shows effectiveness of the selection by plotting the number of epK^+ and eK^+ events kept as a function of the timing cut. The efficiency of the cut is estimated by fitting the missing mass spectrum, illustrated in Fig. 11, for the number of Σ and Λ in the sample. Fig. 2 shows the number of Σ's + Λ's vs timing cut for epK^+ and eK^+ final states. For very wide timing cuts, the signal-to-background ratio is very poor and estimating the number of Σ's + Λ's is difficult, so these are omitted from the table and plots. The sample of eK^+ events includes the 33% branching fraction of Λ into $\mathrm{n}\pi^0$ in addition to the $\mathrm{p}\pi^-$ decay mode. The yield is a factor of 2 higher, where we expect the yield to increase due to the inclusion of the additional branching mode and also for the proton acceptance. A plateau region is reached for a timing cut of approximately 0.7 ns. To be conservative we propose using a $\pm 7\sigma$ cut (1.05 ns) for e1-6.

For the purpose of cataloging event topologies of the unskimed file, we give a multiplicity breakdown of the most common charged particle types in Table 2. The breakdown is also presented graphically in Figs. 3-10. Fig. 3 is the multiplicity plot for electrons with a PID cut applied plus some additional cuts that are applied in **phi_accept**. Figs. 4 and 5 are the multiplicity plots for protons and K^+'s respectively with the timing cuts of the skim applied. Figs. 6-10 show the electron, proton, K^+, π^+, and π^- multiplicity plots using the nominal PID particle ID status. These show a slight increase in number for electrons going from phi_accept cuts to just the PID cut, which is expected. We also observe an increase in number for protons going from the timing cut to the PID cut, which is also expected. There was no significant change however in the K^+ number going from the timing cut to the PID cut.

4 Conclusion

It has been shown that the updated kaon skim, with the newly implemented timing cut has been successful in including the high momentum ambiguities that the older reconstructed mass cuts discarded. Also, the reduction of the data file to 8.3% of it's original size using a $\pm 7\sigma$ timing section cut (1.05 ns) has proven the effectiveness of this skim for use not only in this run, but in future electron runs.

A PID=3

The identification of an electron in PID is accomplished through the following code from makePart.c located in the CVS repository in /packages/pid.

```
int ElectronID(bid_t * tbid, int tbid_index, part_t * part){
  int tbtr_index = tbid->track-1;
  int echb_index = tbid->ec.id -1;
  int e_p_cut=0;
  float e_p;
  float ECEnergy, Mo;
  clasECHB_t * ECHB = getBank(&bcs_, "ECHB");
  clasTBTR_t * TBTR = getBank(&bcs_, "TBTR");
  echb_t * ECIn  = NULL;
  echb_t * ECOut = NULL;

  part->pid = Unknown;
  /* require  - charged track, match to ec & cc, ECHB & TBTR banks */
  if (ECHB && TBTR && (TBTR->tbtr[tbtr_index].q < 0.0) && tbid->track
&& tbid->ec.stat && tbid->cc.stat){
    ec_Whole2InOut(&ECHB->echb[echb_index], &ECIn, &ECOut);
    ECEnergy = ECHB->echb[echb_index].e__hit;
    Mo = v3mag(TBTR->tbtr[tbtr_index].p);
    e_p_cut = ((ECEnergy*E_P_SLOPE_CUT + E_P_INT_LOW_CUT) < Mo) &&
      (Mo < (ECEnergy*E_P_SLOPE_CUT + E_P_INT_HIGH_CUT));

/***** if ec match was fiducial (GOOD_MATCH), use ec energy for cut */
    if ((tbid->ec.stat==GOOD_MATCH &&
       (e_p_cut && ECIn && (ECIn->e__hit > EC_IN_CUT))) ||
(tbid->ec.stat==NONFIDUCIAL_MATCH)){
      part->pid = Electron;
      part->trkid = tbid_index + 1; /*pointer to TBID bank, FORTRAN style*/
      trk2part(tbid, TBTR, ELECTRON_MASS, part);
      part->qpid = ECEnergy;
      part->flags = tbid->ec.stat;  /* use ec hit matching status
                                       so nonfiducials are flagged */
     }
    }
  return 1;
}
```

where:

```
#define EC_IN_CUT        0.045/* Cuts out pions.
#define E_OVER_P_CUT     0.7  /* also gets pions, and nonfiducial electrons*/
#define E_P_SLOPE_CUT   3.23
#define E_P_INT_LOW_CUT -0.26
#define E_P_INT_HIGH_CUT 0.56
```

References

[1] J. McNabb, “Kaon Filtering for CLAS Data” CLAS-NOTE 2001-01, 30 Jan 2001

[2] K. Loukachine, “Electroproduction of $\phi(1020)$ Vector Mesons at 4 GeV,” Sect. 4.1.2, Ph.D. Thesis V.P.I., Feb, 2000.

Table 1: Summary Table for Kaon Skim Program when an **epK$^+$** is required or just an **eK$^+$**. Some entries for the number of Λ and Σ events are missing due to unreliable extraction of the signal due to the high background.

	Unfiltered	**Skim eK$^+$** ($\pm 10\sigma$)	**Skim epK$^+$** ($\pm 10\sigma$)
Number of Events (12 Files)	1500K	97K	17K
Percent of Total	100%	6.4%	1.1%
File Size (Mbytes/file)	1200	100	18
File Size Percent	100%	8.3%	1.5%
Timing Cut (ns)	**# of Events**	**# of eK$^+$ Events**	**# of epK$^+$ Events**
0.15	1500K	6622	469
0.30	-	13,148	1,528
0.45	-	19,564	2,736
0.60	-	25,957	3,771
0.75	-	32,462	4,743
0.90	-	39,375	5,538
1.05	-	-	-
1.20	-	-	-
1.35	-	59,785	7,108
1.50	-	97,000	17,000
		$(\#\Lambda + \#\Sigma)$	$(\#\Lambda + \#\Sigma)$
0.15		483	146
0.30		719	232
0.45		710	263
0.60		791	279
0.75		-	297
0.90		-	272
1.05		-	253
1.20		-	277
1.35		-	-
1.50		-	-

Table 2: Particle multiplicities for a single unskimed file (with approximately 125k events) giving the numbers of particles selected with the pid status as well as other selection criteria described in the text. The number of protons and kaons selected with the timing cut include the high momentum ambiguous events, so double counting is possible.

Particle Type	N=0	N=1	N=2	N=3
Electrons	81967	29508	205	-
Electrons (pid=3)	69686	41114	348	
Protons timing cut	90293	20767	451	
Protons (pid=14)	76335	34351	954	190
π^+ (pid= 8)	53191	43351	13297	1063
π^- (pid= 9)	55866	54469	1257	-
K^+ timing cut	107238	4021	-	-
K^+ (pid= 11)	107239	3753	-	-

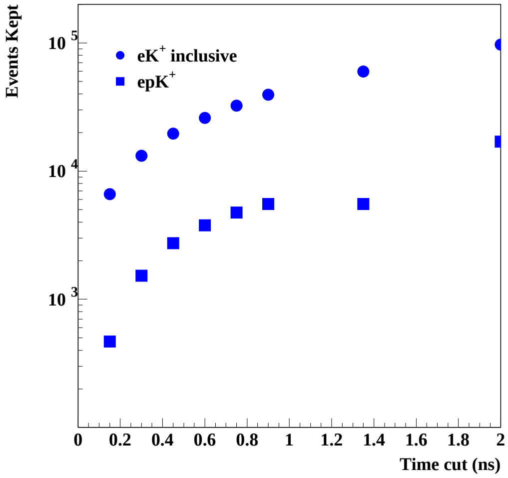

Figure 1: Kept events vs timing cut for eK^+ and epK^+ final states. The numbers plotted at 2 ns are for the original unprocessed skimed file.

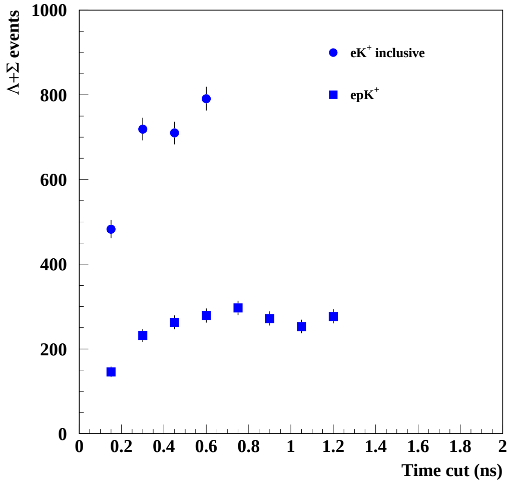

Figure 2: Number of Λ's plus Σ's vs timing cut for eK^+ and epK^+ final states.

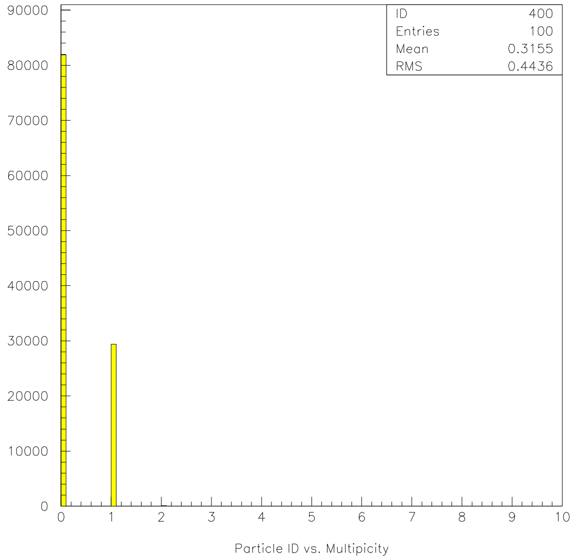

Figure 3: Multiplicity for electrons with a tighter cut than PID.

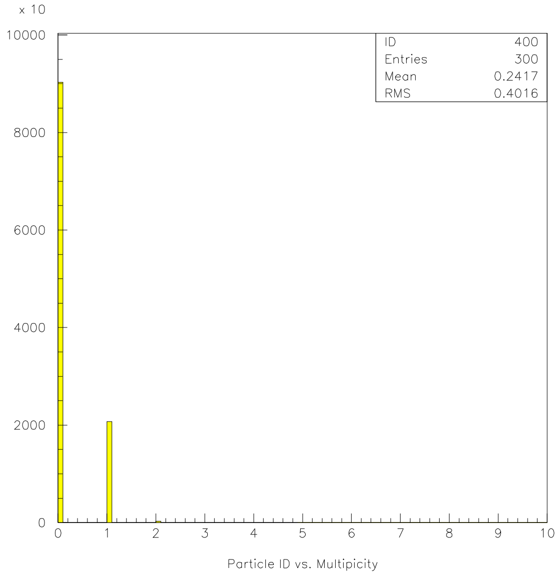

Figure 4: Multiplicity for Protons with a timing cut.

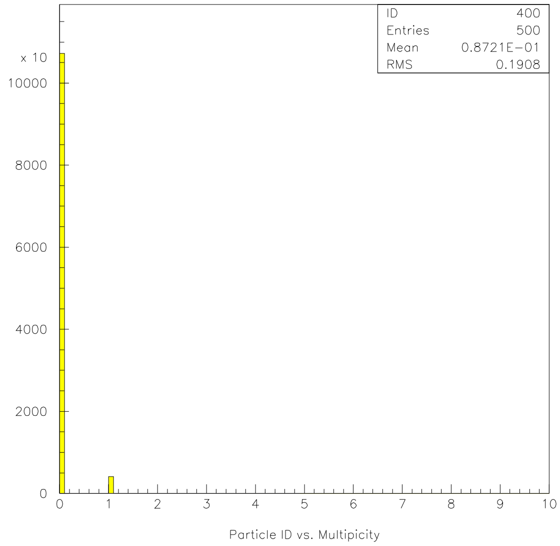

Figure 5: Multiplicity for K^+ with a timing cut.

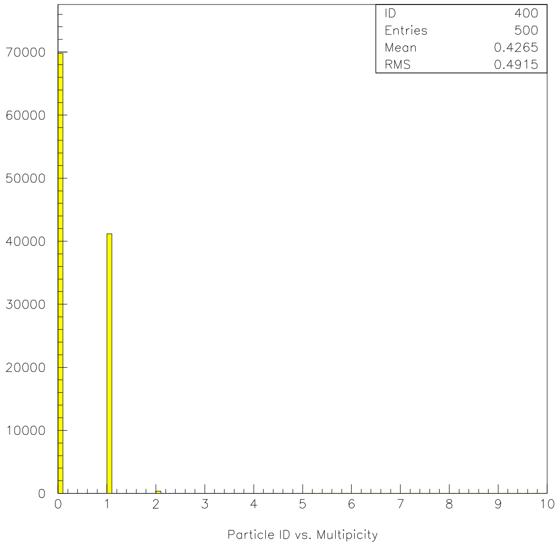

Figure 6: Multiplicity for electrons with PID cut.

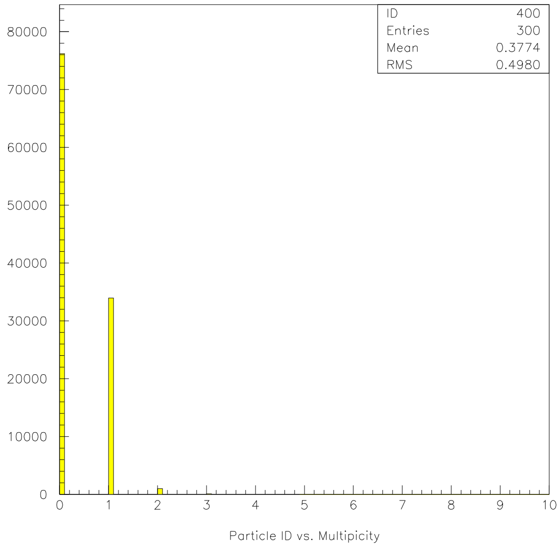

Figure 7: Multiplicity for Protons with PID cut.

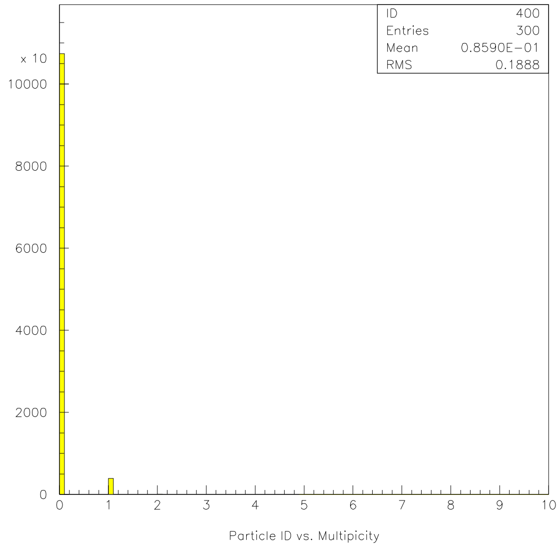

Figure 8: Multiplicity for K^+ with PID cut.

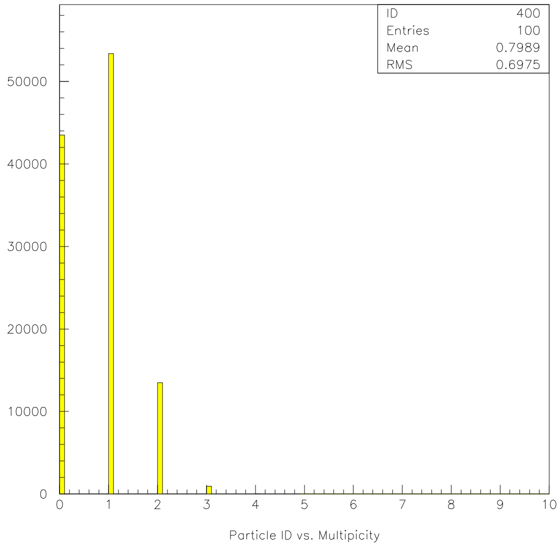

Figure 9: Multiplicity for π^+ with PID cut.

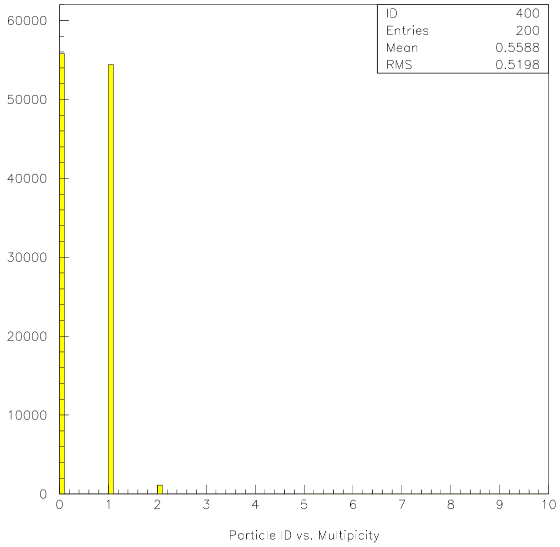

Figure 10: Multiplicity for π^- with PID cut.

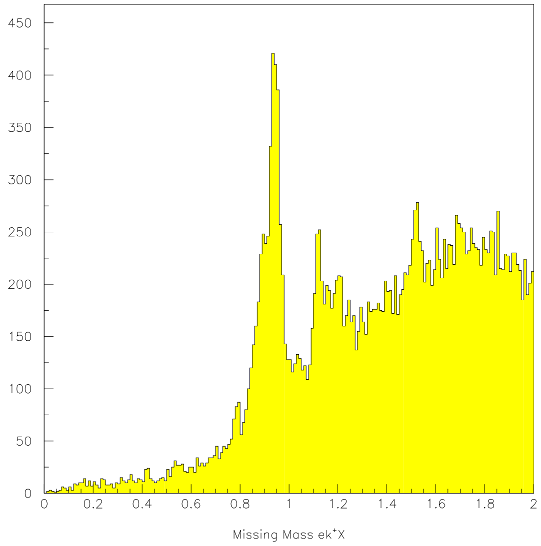

Figure 11: Missing mass ekX plot, with a prominent neutron peak when pions are misidentified as kaons and the smaller Λ and Σ peaks on the right.