KOPIO TN092
Some FastMC acceptance and background studies

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June 9, 2004

Abstract

I measured the change in the signal acceptance with the FastMC for a number of modifications that have taken place since the TDR. The increase in inactive area of the downstream beam hole results in a $\sim 9\%$ acceptance loss. Neither the angular dependence of the K_L^0 beam flux nor the production of the K_L^0 from an extended target with collimation consistent with the GEANT MC v07_4 significantly changes the acceptance. Moving the decay region downstream by 65 cm, as needed for the beam collimation, reduces the signal acceptance by $\sim 3\%$, consistent with expectations from the reduced K_L^0 flux.

The starting point, assumptions and methods of this study are described in TN053 [1] for the 100×5 mrad^2 aspect ratio. Additional information can be found in TN089 [2]. I incrementally made changes to take into account information from other studies or to improve the representation of the K_L^0 beam and detector in the FastMC.

The same sets of cuts are used for all configurations in this study. I did not attempt to re-optimize the cuts for any of the new configurations.

I only consider the rates for two photons converting in the PR for all studies in this note.

Initially the FastMC had a point target and a K_L^0 beam without angular dependence ("Kapinos1" spectrum). The decay region extended from 950 to 1350 cm from the target. The aperture of the upstream (downstream) beam pipe hole was 95×6 cm^2 (186.2×17.47 cm^2) at Z=950 (1350) cm.

The effect of increasing the downstream beam pipe hole is given in Table 1 and introduces a 9% acceptance loss. The effect of introducing an angular dependence to the beam ("Kapinos2" spectrum) is shown in Table 2. In addition Table 2 contains the results of introducing an extended target and collimating the beam. Neither change significantly changes the acceptance at the 2% level of the statistical uncertainty.

Moving the decay region downstream by 65 cm to (1015,1415) cm results in a loss of acceptance consistent with the loss of K_L^0 flux of $\exp(-\left\langle \frac{m\Delta z}{pc\tau} \right\rangle) = \exp(-0.0302) = 0.970$ which is consistent with the results in Table 3. Table 3 also shows the result of making all the changes described so far. The overall acceptance decrease is consistent with the product of decreases from the larger downstream beam hole ($\times 0.91$) and downstream displacement of the decay region.

Table 4 compares the signal and background for the initial and final configurations. With the current statistics, it is difficult to conclude whether the background rate has

Cut	Events(A)	Events(B)	Ratio (B/A)
MZ	28.9 ± 0.4	26.2 ± 0.4	0.907
AK basic	91.2 ± 0.7	83.6 ± 0.6	0.917
AK loose	60.2 ± 0.5	55.2 ± 0.6	0.917
AK lominal	53.6 ± 0.5	49.1 ± 0.6	0.916
AK tight	37.0 ± 0.4	33.8 ± 0.6	0.914
AK tighter	24.3 ± 0.3	22.2 ± 0.6	0.914
AK tightest	21.2 ± 0.3	19.4 ± 0.6	0.915
US hole	95×6 cm^2	95×6 cm^2	
DS hole	186.2×17.47 cm^2	220.5×23.1 cm^2	
K_L^0 angular dep.	none	none	
Target	Point	Point	
Collimation	none	none	
Decay region(cm)	(950,1350)	(950,1350)	

Table 1: Expected number of signal events for two configurations, labelled (A) and (B) for convenience. The same set of initial signal events was used for both configurations so the statistical uncertainty in the ratio is negligible. Collimation "none" means that the aspect ratio 100×5 mrad^2 determines the acceptance of the beam.

decreased consistent with the signal rate. Figure 1 compares the ratio of signal and background rates as a function of the signal rate for the initial configuration. Note that all the rate estimates for a single configuration use the same sample of events so there is some point-to-point correlation. The rate of the $K_L^0 \to \pi^0\pi^0\pi^0$, $K_L^0 \to \pi^0\pi^0$, $K_L^0 \to e^\pm\pi^\mp\nu\gamma$ and $K_L^0 \to \pi^0\pi^+\pi^-$ components of the background is compared in Tables 5 and 6.

Cut	Events(C)	Events(D)	Ratio (D/A)
MZ	29.5 ± 0.8	28.9 ± 0.8	1.00 ± 0.03
AK basic	90.7 ± 1.5	90.4 ± 1.5	0.99 ± 0.02
AK loose	59.2 ± 1.2	59.3 ± 1.2	0.99 ± 0.02
AK lominal	52.3 ± 1.1	52.8 ± 1.1	0.99 ± 0.02
AK tight	36.5 ± 0.9	35.9 ± 0.9	0.97 ± 0.03
AK tighter	24.3 ± 0.8	23.3 ± 0.7	0.96 ± 0.03
AK tightest	21.3 ± 0.7	20.2 ± 0.7	0.95 ± 0.04
US hole	95×6 cm^2	130×12 cm^2	
DS hole	186.2×17.47 cm^2	186.2×17.47 cm^2	
K^0_L angular dep.	Yes	Yes	
Target	Point	Extended	
Collimation	none	Yes	
Decay region(cm)	(950,1350)	(950,1350)	

Table 2: Expected number of signal events for two configurations, labelled (C) and (D) for convenience. Different sets of initial signal events was used for the different configurations so the statistical uncertainty in the ratio is not negligible. Collimation "none" means that the aspect ratio 100×5 mrad^2 determines the acceptance of the beam.

References

[1] D.E. Jaffe, *Beam aspect ratio and FastMC acceptance* KOPIO TN053, 27 Mar 2003.

[2] D.E. Jaffe, *FastMC User Manual* KOPIO TN089, 27 May 2004.

Cut	Events(E)	Events(F)	Ratio (E/D)	Ratio (F/E)	Ratio (F/A)
MZ	27.1 ± 0.8	25.0 ± 0.8	0.94 ± 0.04	0.92 ± 0.04	0.86 ± 0.03
AK basic	85.5 ± 1.4	77.9 ± 1.3	0.95 ± 0.02	0.91 ± 0.02	0.85 ± 0.02
AK loose	56.5 ± 1.1	51.4 ± 1.1	0.95 ± 0.02	0.91 ± 0.02	0.85 ± 0.02
AK lominal	50.6 ± 1.1	45.8 ± 1.0	0.96 ± 0.03	0.91 ± 0.03	0.85 ± 0.02
AK tight	34.4 ± 0.9	31.3 ± 0.8	0.96 ± 0.03	0.91 ± 0.03	0.85 ± 0.02
AK tighter	22.6 ± 0.7	21.3 ± 0.7	0.97 ± 0.04	0.94 ± 0.04	0.88 ± 0.03
AK tightest	19.2 ± 0.7	18.6 ± 0.7	0.95 ± 0.05	0.97 ± 0.05	0.88 ± 0.04
US hole (cm^2)	130×12	130×12 cm^2			
DS hole (cm^2)	186.2×17.47	220.5×23.1 cm^2			
K_L^0 angular dep.	Yes	Yes			
Target	Extended	Extended			
Collimation	Yes	Yes			
Decay region(cm)	(1015,1415)	(1015,1415)			

Table 3: Expected number of signal events for two configurations, labelled (E) and (F) for convenience. Different sets of initial signal events were used for the different configurations so the statistical uncertainty in the ratio is not negligible. The ratio E/D is consistent with the 3% loss expected when the decay region is moved downstream by 65 cm. The ratio F/E is consistent with the ratio B/A confirming that there is no significant loss due to the new K_L^0 angular dependence, extended target or collimation and that the loss is due to the increased DS beam hole aperture. The final column shows the overall loss of acceptance which is (marginally?) consistent with the expected loss of 88% = 91% × 97%.

Cut	Old $K_L^0 \to \pi^0\nu\bar{\nu}$	New $K_L^0 \to \pi^0\nu\bar{\nu}$	Old Background	New Background	New/Old
MZ	28.87 ± 0.3748	25.76 ± 0.3154	8.911 ± 0.4489	9.655 ± 1.259	1.08 ± 0.15
AK basic	91.22 ± 0.6632	81.31 ± 0.5576	145.4 ± 3.463	143.4 ± 7.980	0.99 ± 0.06
AK loose	60.15 ± 0.5394	53.60 ± 0.4531	55.22 ± 2.084	64.09 ± 7.303	1.16 ± 0.14
AK lominal	53.63 ± 0.5094	47.55 ± 0.4266	35.88 ± 0.7829	41.26 ± 4.025	1.15 ± 0.11
AK tight	36.98 ± 0.4226	32.79 ± 0.3540	16.80 ± 0.5579	17.00 ± 1.329	1.01 ± 0.09
AK tighter	24.34 ± 0.3427	21.83 ± 0.2895	7.351 ± 0.3439	6.226 ± 0.2494	0.85 ± 0.05
AK tightest	21.24 ± 0.3203	18.93 ± 0.2696	5.756 ± 0.3097	5.186 ± 0.2282	0.90 ± 0.06

Table 4: Background includes $K_L^0 \to \pi^0\pi^0\pi^0$, $K_L^0 \to \pi^0\pi^0$, $K_L^0 \to e^\pm\pi^\mp\nu\gamma$ & $K_L^0 \to \pi^0\pi^+\pi^-$. Background from $K_L^0 \to \pi^0\gamma\gamma$ is included for "New" only, and contribures < 0.3 events for all cuts. 2γ conversions in PR only. No reoptimization of cuts for "New" rates. "Old" corresponds to configuration "A" in Table 1. "New" corresponds to configuration "F" in Table 3. The final column gives the ratio of the background rates for the two configurations and can be compared with the ratio (F/A) in Table 3.

Cut	Old $K_L^0 \to \pi^0\pi^0\pi^0$	New $K_L^0 \to \pi^0\pi^0\pi^0$	Old $K_L^0 \to \pi^0\pi^0$	New $K_L^0 \to \pi^0\pi^0$
MZ	1.001 ± 0.3574	1.947 ± 0.9727	3.715 ± 0.1485	3.899 ± 0.7853
AK basic	1.891 ± 0.3867	2.985 ± 0.9966	110.3 ± 3.379	109.6 ± 7.906
AK loose	0.8845 ± 0.06686	2.146 ± 0.9742	45.24 ± 2.055	53.43 ± 7.234
AK lominal	0.8843 ± 0.06686	2.146 ± 0.9742	26.74 ± 0.7125	31.35 ± 3.899
AK tight	0.6664 ± 0.06446	1.929 ± 0.9739	10.02 ± 0.4826	9.680 ± 0.8856
AK tighter	0.4500 ± 0.05326	0.3694 ± 0.03991	3.176 ± 0.2626	2.380 ± 0.1970
AK tightest	0.4031 ± 0.05228	0.3404 ± 0.03974	2.370 ± 0.2388	1.758 ± 0.1747

Table 5: $K_L^0 \to \pi^0\pi^0$ and $K_L^0 \to \pi^0\pi^0\pi^0$ rate estimation from FastMC. "Old" corresponds to configuration "A" in Table 1. "New" corresponds to configuration "F" in Table 3 .

Cut	Old $K_L^0 \to e^\pm\pi^\mp\nu\gamma$	New $K_L^0 \to e^\pm\pi^\mp\nu\gamma$	Old $K_L^0 \to \pi^0\pi^+\pi^-$	New $K_L^0 \to \pi^0\pi^+\pi^-$
MZ	3.536 ± 0.2103	3.007 ± 0.1330	0.6595 ± 0.08657	0.7203 ± 0.05313
AK basic	17.34 ± 0.5010	15.17 ± 0.3391	15.89 ± 0.4141	15.35 ± 0.2456
AK loose	6.856 ± 0.2972	6.195 ± 0.2043	2.233 ± 0.1597	2.164 ± 0.08806
AK lominal	6.031 ± 0.2747	5.508 ± 0.1914	2.228 ± 0.1596	2.142 ± 0.08771
AK tight	4.679 ± 0.2398	3.999 ± 0.1630	1.437 ± 0.1291	1.311 ± 0.06786
AK tighter	3.028 ± 0.1934	2.715 ± 0.1349	0.6971 ± 0.09529	0.6947 ± 0.05023
AK tightest	2.542 ± 0.1757	2.464 ± 0.1291	0.4408 ± 0.07297	0.5589 ± 0.04695

Table 6: $K_L^0 \to e^\pm\pi^\mp\nu\gamma$ and $K_L^0 \to \pi^0\pi^+\pi^-$ rate estimation from FastMC. "Old" corresponds to configuration "A" in Table 1. "New" corresponds to configuration "F" in Table 3 .

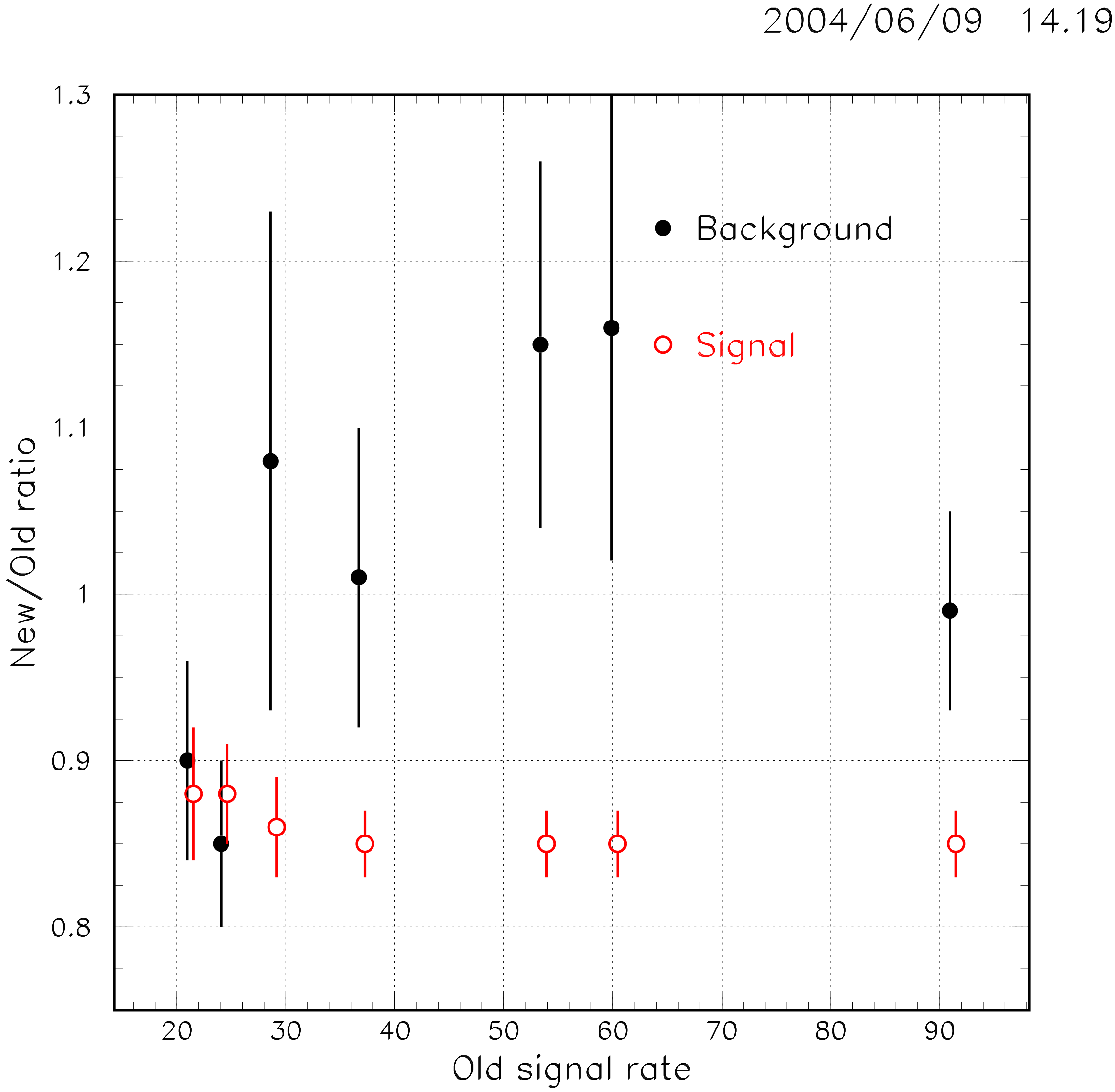

Figure 1: Comparison of the “New” to “Old” signal and rates as a function of the signal rate for the “Old” configuration. The points are slightly displace horizontally make the error bars visible.