Study of Kaon Tracking Efficiency

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Data set and MC samples

Control sample: $j/\psi \to K_s K^{\pm}\pi^{\pm} \to \pi^+\pi^- K^{\pm}\pi^{\pm}$

Data sets:

- 2018,2019 j/ψ data.

Boss Version:

- 708

MC samples:

- 2019 inclusive MC
- 2019,2018 DIY signal MC

Event selection

Good charged tracks:

- $|cos\theta| < 0.93$
- $|V_z| < 20$ cm, $V_r < 5$ cm for the tracks from K_s
- $|V_z| < 10$ cm, $V_r < 1$ cm for the tracks from j/ψ
- N_{Good} =3, $\sum Q_{track} = \pm 1$ for $K^{\pm}$. N_{Good} =4, $\sum Q_{track} = 0$

Vertex Fit:

- Using the second vertex fit to reconstruct K_s
- Retain the combination with the mass closest to K_s.
- $l/\sigma_l > 2$
- $|M_{\pi^+\pi^-} - K_s| < 10MeV$

PID:

- Tracks from K_s and the negative track from j/ψ:

$Prob_K < Prob_\pi \&\& Prob_p < Prob_\pi$

Event selection

Kinematic Fit:

- $\chi^2_{1c} < 5$
- Changing K and π, and $\chi^2_{1c} < \chi^2_{Exc}$

Further Selection:

- For the events with $N_{Good} = 4$, **the angle between the reconstructed Kaon track and the recoiled track should be smaller than** 2°.

Then tracking the Kaon as the nominal ISR_{KK} selection:

tracking method:

- $|cos\theta| < 0.93$
- $|V_z| < 10$ cm, $V_r < 1$ cm

The event number got without tracking the Kaon is N1 and the event number after tracking Kaon is N2. The tracking efficiency is:

$$\epsilon = N2/N1, \text{ and the error is } \mathrm{err}_\epsilon = \sqrt{\frac{\epsilon(1-\epsilon)}{N_1}}$$

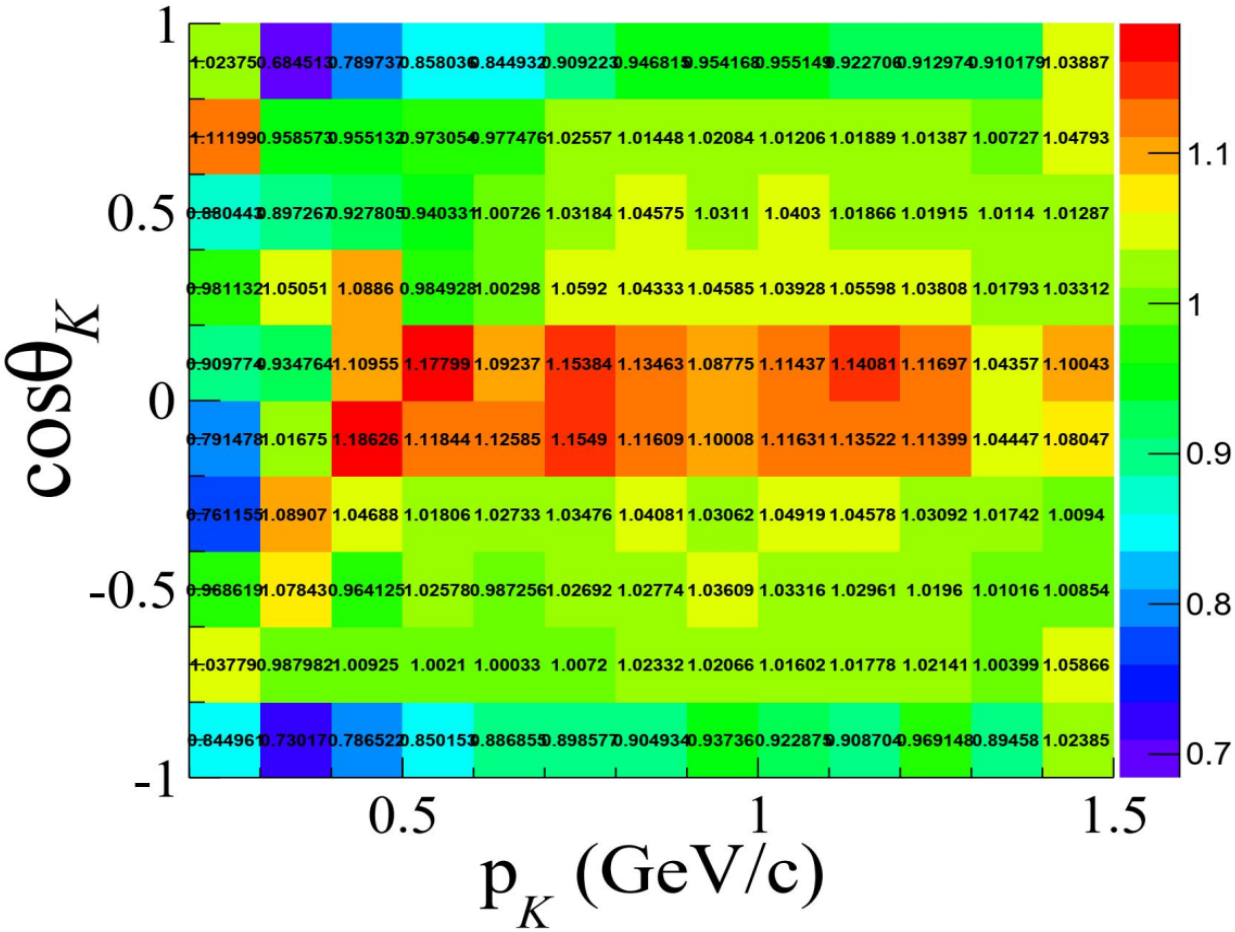
Topology without match angle cut

Table 1: Decay trees and their respective final states.

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$e^+e^- \to \pi^+ K_S^0 K^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^- K^-$	6	27992	27992
2	$e^+e^- \to K_S^0 K_S^0 \gamma^I, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma^I$	12	20807	48799
3	$e^+e^- \to \pi^0\pi^+\pi^+\pi^-\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	0	15980	64779
4	$e^+e^- \to \pi^+\pi^-\omega, \omega \to \pi^0\pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	7	10691	75470
5	$e^+e^- \to f_0(2200)\gamma^I, f_0(2200) \to K_S^0 K_S^0, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma^I$	14	9155	84625
6	$e^+e^- \to \pi^0 K^0 \bar{K}^0, K^0 \to K_S^0, \bar{K}^0 \to K_S^0, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	9	8938	93563
7	$e^+e^- \to \pi^- b_1^+, b_1^+ \to \pi^+\omega, \omega \to \pi^0\pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	22	7051	100614
8	$e^+e^- \to \pi^0\pi^+ K_S^0 K^-, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^- K^-$	26	5031	105645
9	$e^+e^- \to K^- K^{*+}, K^{*+} \to \pi^+ K^0, K^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^- K^-$	8	4642	110287
10	$e^+e^- \to K^0 \bar{K}^*, K^0 \to K_S^0, \bar{K}^* \to \pi^0 \bar{K}^0, K_S^0 \to \pi^+\pi^-, \bar{K}^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	31	3851	114138
11	$e^+e^- \to \bar{K}^0 K^*, \bar{K}^0 \to K_S^0, K^* \to \pi^0 K^0, K_S^0 \to \pi^+\pi^-, K^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	13	3775	117913
12	$e^+e^- \to \eta_c\gamma^I, \eta_c \to \pi^+ K^0 K^-, K^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^- K^-\gamma^I$	43	2847	120760
13	$e^+e^- \to \omega f_2(1270), \omega \to \pi^0\pi^+\pi^-, f_2(1270) \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	28	2846	123606
14	$e^+e^- \to \pi^0 K^- K^{*+}, K^{*+} \to \pi^+ K^0, K^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^- K^-$	4	2232	125838
15	$e^+e^- \to f_2'\gamma^I, f_2' \to K_S^0 K_S^0, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma^I$	29	2229	128067
16	$e^+e^- \to \pi^+ K^* K^-, K^* \to \pi^0 K^0, K^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^- K^-$	40	1995	130062
17	$e^+e^- \to K^- K_1'^+, K_1'^+ \to \pi^+ K^*, K^* \to \pi^0 K^0, K^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^- K^-$	51	1717	131779
18	$e^+e^- \to K_S^0\pi^+\pi^- K_S^0, K_S^0 \to \pi^+\pi^-$	$K_L^0\pi^+\pi^+\pi^-\pi^-$	2	1694	133473
19	$e^+e^- \to K^- K_1'^+, K_1'^+ \to \pi^0 K^{*+}, K^{*+} \to \pi^+ K^0, K^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^- K^-$	24	1617	135090
20	$e^+e^- \to f_0(1710)\gamma^I, f_0(1710) \to K^0\bar{K}^0, K^0 \to K_S^0, \bar{K}^0 \to K_S^0, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma^I$	3	1543	136633
21	$e^+e^- \to K^0\bar{K}^*, K^0 \to K_S^0, \bar{K}^* \to \pi^+ K^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^- K^-$	18	1535	138168
22	$e^+e^- \to \pi^+\pi^+\pi^-\pi^-\gamma^I$	$\pi^+\pi^+\pi^-\pi^-\gamma^I$	96	1369	139537
23	$e^+e^- \to \rho^0 a_2^0, \rho^0 \to \pi^+\pi^-, a_2^0 \to \pi^+\rho^-, \rho^- \to \pi^0\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	10	1107	140644
24	$e^+e^- \to \pi^+ K_S^0 K^-\gamma^f, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^- K^-\gamma^f$	19	1047	141691
25	$e^+e^- \to \pi^+\pi^+\pi^-\pi^-$	$\pi^+\pi^+\pi^-\pi^-$	30	893	142584
26	$e^+e^- \to \rho^0 a_2^0, \rho^0 \to \pi^+\pi^-, a_2^0 \to \pi^-\rho^+, \rho^+ \to \pi^0\pi^+$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	52	885	143469
27	$e^+e^- \to f_2(1640)\gamma^I, f_2(1640) \to K_S^0 K_S^0, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma^I$	80	751	144220
28	$e^+e^- \to f_4(2050)\gamma^I, f_4(2050) \to K_S^0 K_S^0, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma^I$	69	684	144904
29	$e^+e^- \to \pi^+ b_1^-, b_1^- \to \pi^-\omega, \omega \to \pi^0\pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	20	667	145571
30	$e^+e^- \to K_S^0 K_S^0\gamma^I, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-\gamma^f$	$\pi^+\pi^+\pi^-\pi^-\gamma^I\gamma^f$	27	621	146192

- Control sample: not clean enough (about 4%)!
- The main background are caused by the K, π misjudgments. And also many π^0 background.

Efficiency (2D)



- The weight factor is too large near $cos\theta = 0$.

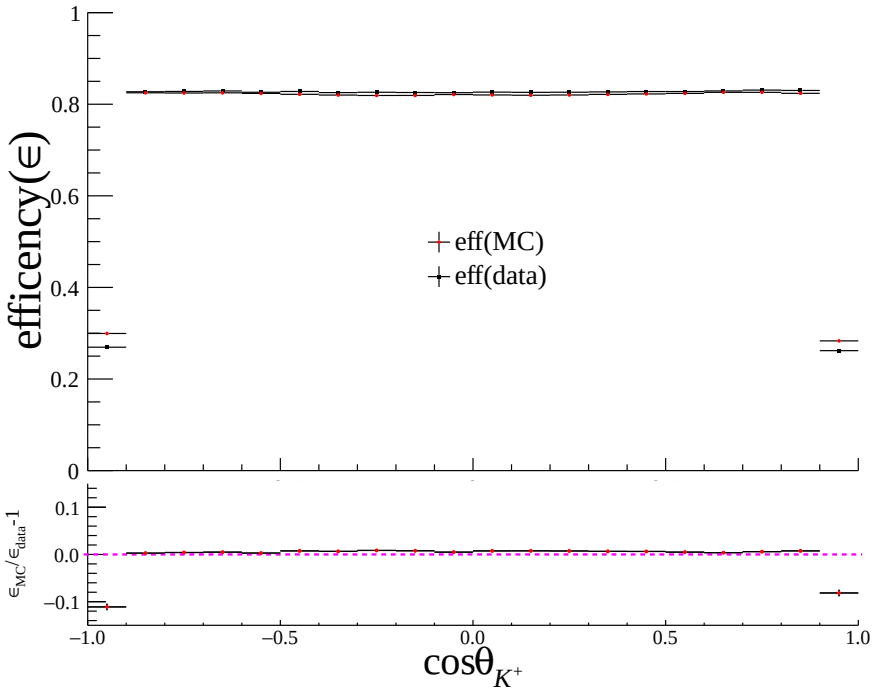
Topology after match angle cut

Table 1: Decay trees and their respective final states.

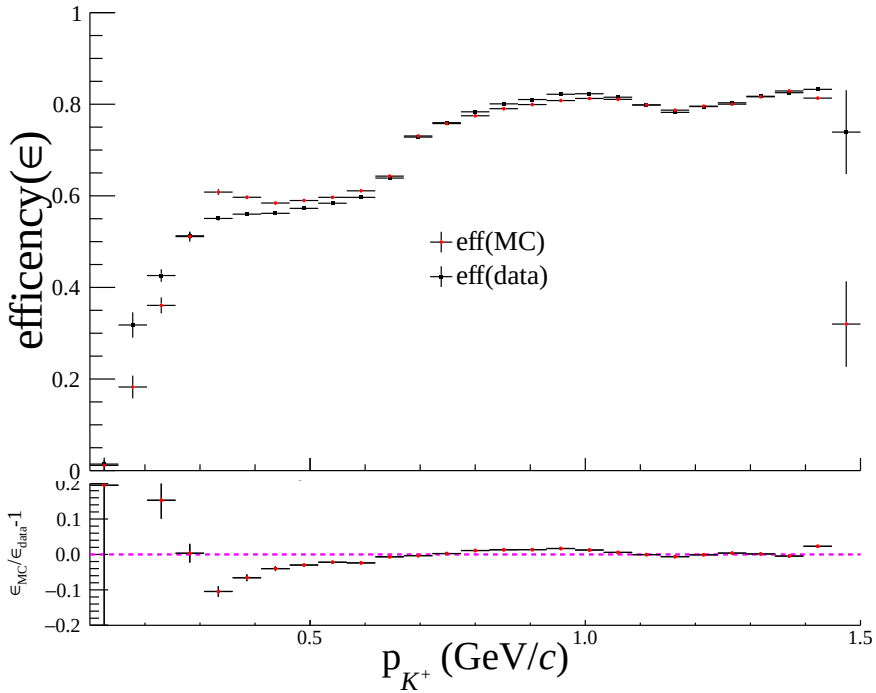
rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$e^+e^- \to \pi^+ K_S^0 K^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-K^-$	0	22107	22107
2	$e^+e^- \to K_S^0 K_S^0 \gamma^I, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma^I$	2	4814	26921
3	$e^+e^- \to K^- K^{*+}, K^{*+} \to \pi^+ K^0, K^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-K^-$	1	3360	30281
4	$e^+e^- \to f_0(2200)\gamma^I, f_0(2200) \to K_S^0 K_S^0, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma^I$	14	2464	32745
5	$e^+e^- \to \pi^0 K^0 \bar{K}^0, K^0 \to K_S^0, \bar{K}^0 \to K_S^0, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	23	1934	34679
6	$e^+e^- \to \pi^0\pi^+\pi^+\pi^-\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	11	1301	35980
7	$e^+e^- \to \pi^+\pi^-\omega, \omega \to \pi^0\pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	35	947	36927
8	$e^+e^- \to K^0\bar{K}^*, K^0 \to K_S^0, \bar{K}^* \to \pi^0\bar{K}^0, K_S^0 \to \pi^+\pi^-, \bar{K}^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	20	776	37703
9	$e^+e^- \to \bar{K}^0 K^*, \bar{K}^0 \to K_S^0, K^* \to \pi^0 K^0, K_S^0 \to \pi^+\pi^-, K^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	22	752	38455
10	$e^+e^- \to f_2'\gamma^I, f_2' \to K_S^0 K_S^0, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma^I$	38	626	39081
11	$e^+e^- \to \pi^- b_1^+, b_1^+ \to \pi^+\omega, \omega \to \pi^0\pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	13	545	39626
12	$e^+e^- \to K^0\bar{K}^*, K^0 \to K_S^0, \bar{K}^* \to \pi^+ K^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-K^-$	29	530	40156
13	$e^+e^- \to \pi^0\pi^+ K_S^0 K^-, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-K^-$	10	501	40657
14	$e^+e^- \to f_0(1710)\gamma^I, f_0(1710) \to K^0\bar{K}^0, K^0 \to K_S^0, \bar{K}^0 \to K_S^0, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma^I$	34	449	41106
15	$e^+e^- \to \pi^+ K_S^0 K^-\gamma^f, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-K^-\gamma^f$	40	431	41537
16	$e^+e^- \to \pi^0 K_L^0 K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^0 K_L^0\pi^+\pi^-$	25	346	41883
17	$e^+e^- \to \pi^+\pi^+\pi^-\pi^-$	$\pi^+\pi^+\pi^-\pi^-$	7	331	42214
18	$e^+e^- \to \pi^+ a_2^-, a_2^- \to \bar{K}^0 K^-, \bar{K}^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-K^-$	17	295	42509
19	$e^+e^- \to \eta_c\gamma^I, \eta_c \to \pi^+ K^0 K^-, K^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-K^-\gamma^I$	18	271	42780
20	$e^+e^- \to \omega f_2(1270), \omega \to \pi^0\pi^+\pi^-, f_2(1270) \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	12	268	43048
21	$e^+e^- \to K_S^0 K_S^0\gamma^I, K_S^0 \to \pi^0\pi^0, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^0\pi^+\pi^-\gamma^I$	15	258	43306
22	$e^+e^- \to \pi^+ K^0 K^-, K^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-K^-$	24	254	43560
23	$e^+e^- \to \pi^0 K^- K^{*+}, K^{*+} \to \pi^+ K^0, K^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-K^-$	4	229	43789
24	$e^+e^- \to \pi^+ K_S^0 K^-, K_S^0 \to \pi^+\pi^-\gamma^f$	$\pi^+\pi^+\pi^-K^-\gamma^f$	61	211	44000
25	$e^+e^- \to \pi^+ K^* K^-, K^* \to \pi^0 K^0, K^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-K^-$	37	207	44207
26	$e^+e^- \to K_L^0\pi^+\pi^- K_S^0, K_S^0 \to \pi^+\pi^-$	$K_L^0\pi^+\pi^+\pi^-\pi^-$	77	207	44414
27	$e^+e^- \to f_2(1640)\gamma^I, f_2(1640) \to K_S^0 K_S^0, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma^I$	39	202	44616
28	$e^+e^- \to f_4(2050)\gamma^I, f_4(2050) \to K_S^0 K_S^0, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma^I$	28	201	44817
29	$e^+e^- \to K^- K_1'^+, K_1'^+ \to \pi^+ K^*, K^* \to \pi^0 K^0, K^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-K^-$	86	177	44994
30	$e^+e^- \to K^- K_1'^+, K_1'^+ \to \pi^0 K^{*+}, K^{*+} \to \pi^+ K^0, K^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^+\pi^-K^-$	5	174	45168

- Control sample: Cleaner than before (just about 1.5%)!
- Most four π background and π^0 background have been cut off.

Efficiency 1D



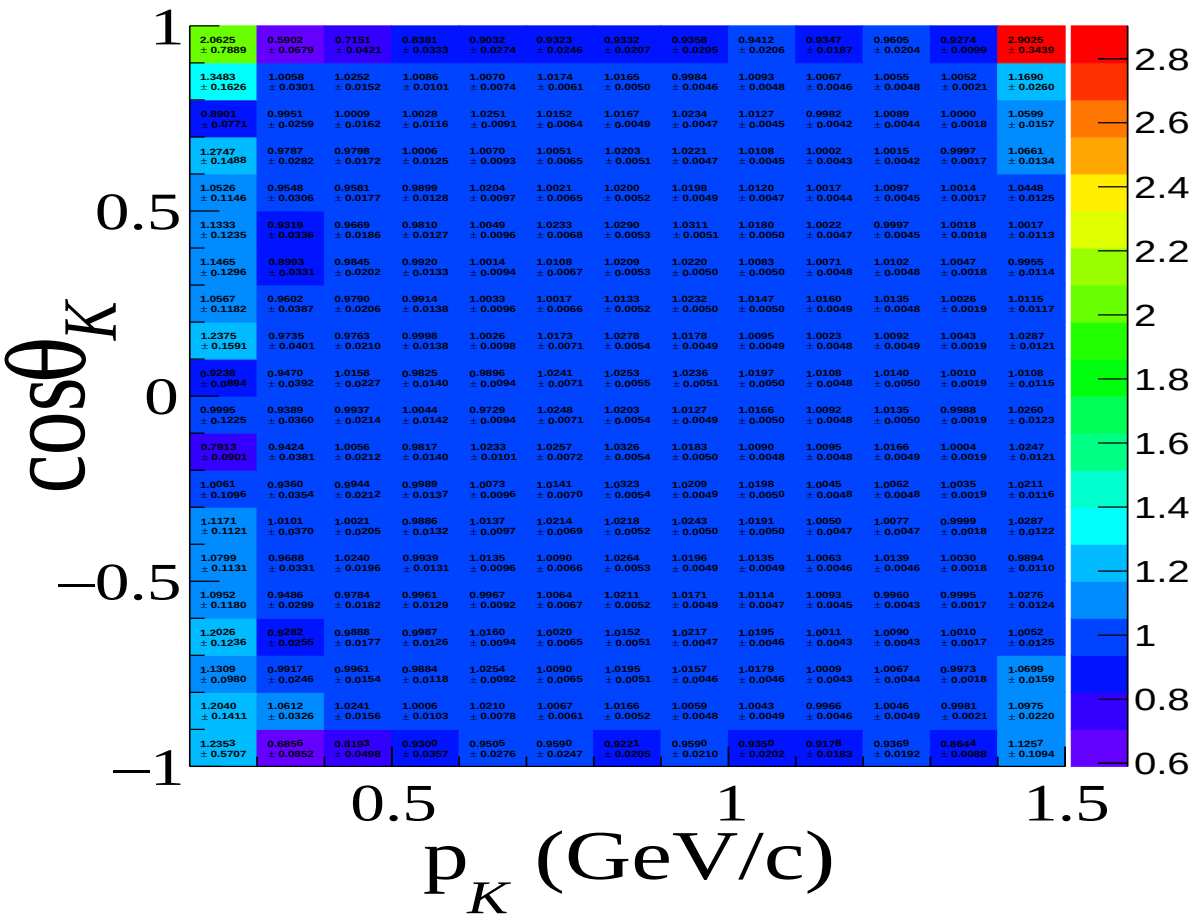
(a)



(b)

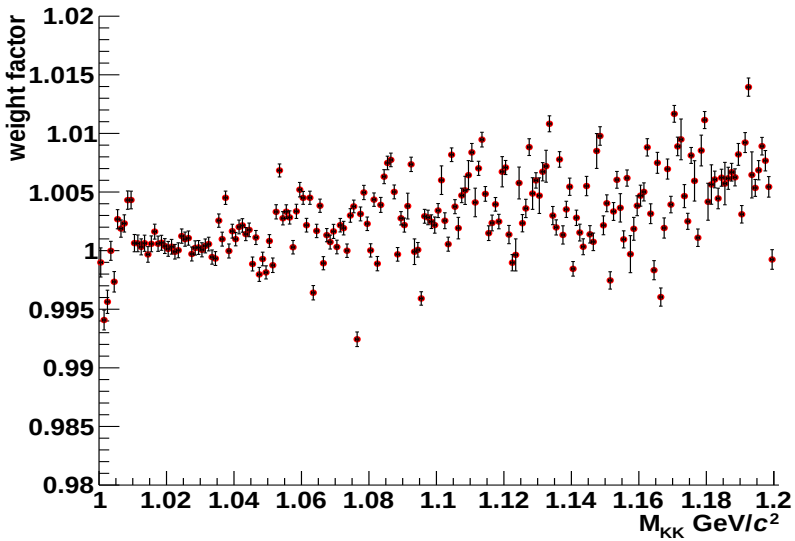
- Match well at the region we are interested in.

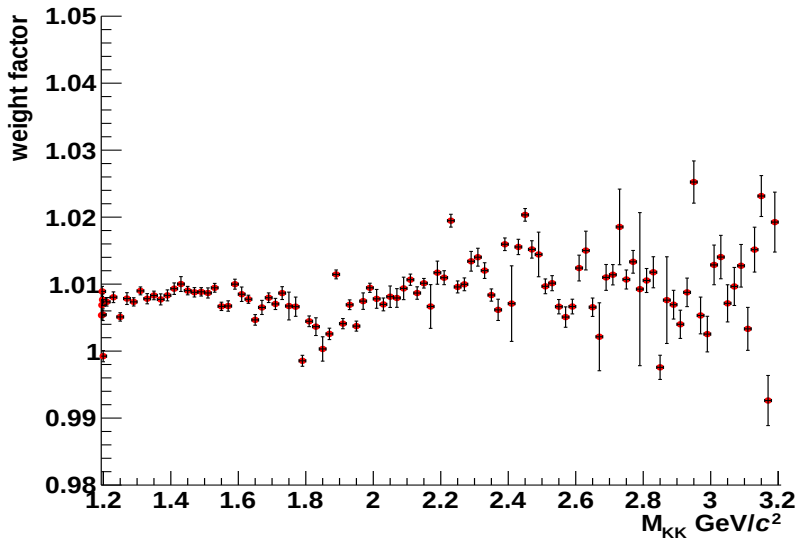
Efficiency (2D)



- The large weight factors near $cos\theta = 0$ decrease to nearly one.

weight factor varies with M_{KK}

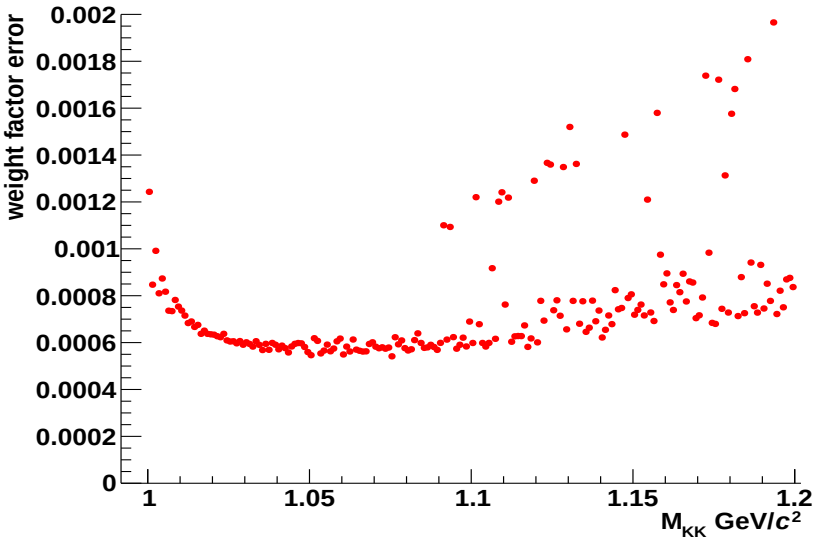


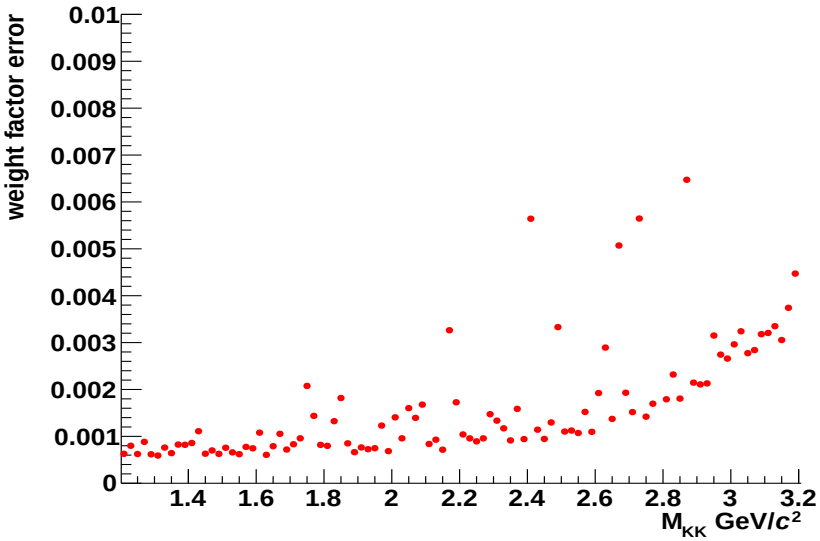


How to get the weight factor varying with M_{KK}:

- Get the $cos\theta_\gamma$ and E_γ 2D distribution of different M_{KK} bins.
- Then calculate the ratio of each 2D bin to the total event number of the M_{KK} bin and get the corresponding weight factor.
- Sum over the product of the weight factor and the ratio, then we can get the weight factor of the MKK bin. The error of it is calculated as: $err = \sqrt{\sum(ratio * err_{weight})^2}$

Systematic uncertainties of tracking efficiency





- For now, we take the error of the weight factor as the systematic uncertainties. Below the 1.2 GeV/c^2 the systematic uncertainty is taken as 0.08% for one track. Above 1.2 GeV/c^2, the systematic uncertainty is taken as 0.4%.