Study of $e^+e^- \to K^+K^- K^+K^-$

(R-Scan Data: $\sqrt{s}$=2.0GeV~3.08GeV)

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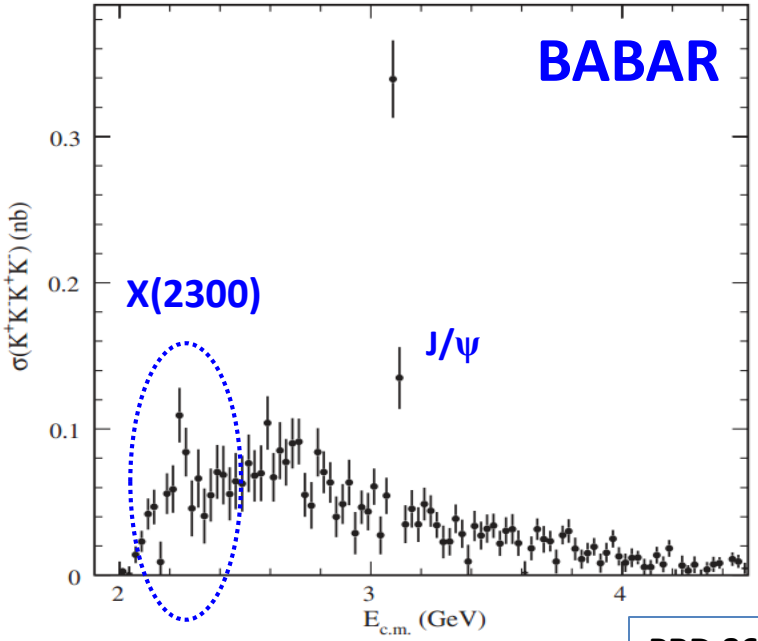
Outline

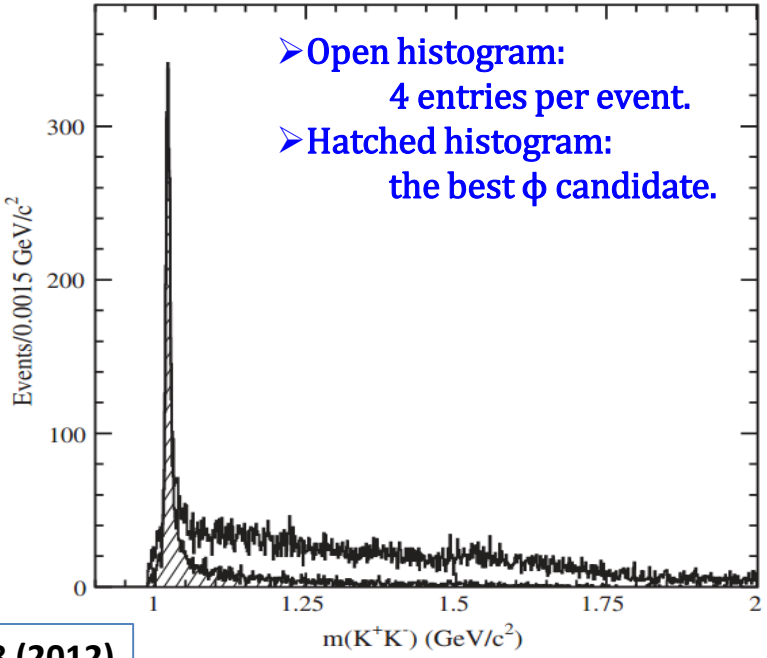
1. Introduction.
2. Data samples and MC simulation.
3. Event selection.
4. Cross section measurement.
5. Possible intermediate states.
6. Systematic error estimation.
7. Summary.

Introduction

(Cross section Line shape)

- Cross section line shape of $e^+e^- \to \gamma_{ISR}K^+K^-K^+K^-$.





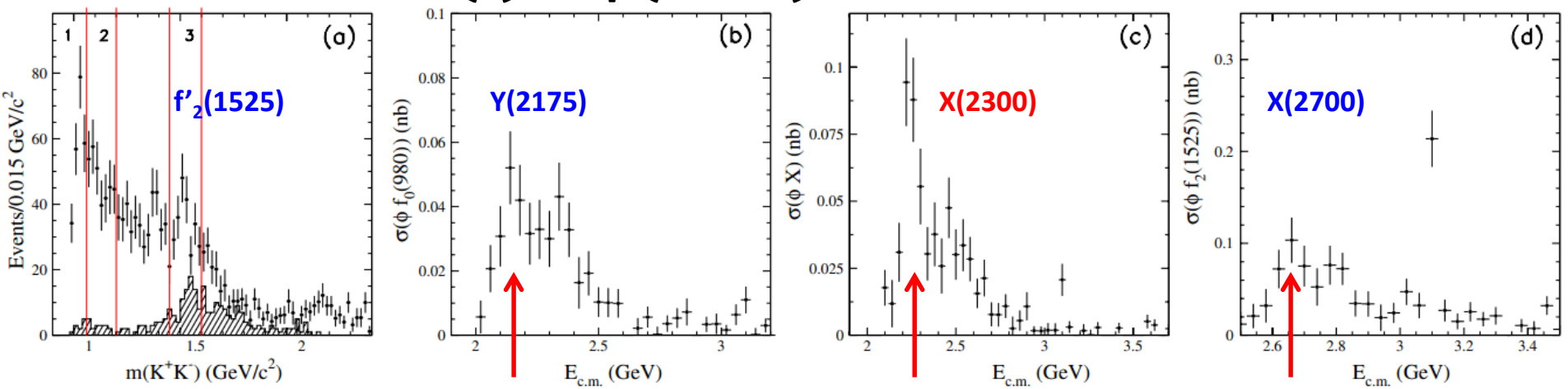
PRD 86, 012008 (2012)

- Possible narrow structure around 2.3GeV.
- $e^+e^- \to \phi(1020)K^+K^-$ channel dominants the $K^+ K^- K^+ K^-$ final states.

Introduction

(Cross section Line shape)

- Cross section line shape of $e^+e^- \to \phi(1020)K^+K^-$.
- Search of $Y(?) \to \phi(1020)K^+K^-$.



- Region1 and Figure(b): $e^+e^- \to Y(2175) \to \phi f_0(980) \to K^+K^-K^+K^-$ process.
- Region 2 and Figure(c): $e^+e^- \to X(2300) \to \phi K^+K^- \to K^+K^-K^+K^-$ process.
- Region 3 and Figure (d): $e^+e^- \to X(2700) \to \phi f'_2(1525) \to K^+K^-K^+K^-$ process.

Due to low statistic, BABAR do not give any explanations of these structures.

Studies with R-scan data may shed light on these possible structures.

Data sets and MC simulation

1. BOSS665p01.

2. R-scan data sets: (in 2012 and 2015)

√s (GeV)	Lum. (pb^{-1})
2.2324	2.64
2.400	3.42
2.800	3.76
3.080	126.185
3.020	17.290
3.000	15.881

√s (GeV)	Lum. (pb^{-1})
2.981	16.071
2.950	15.942
2.900	105.253
2.800	1.008
2.700	1.034
2.6464	34.003

√s (GeV)	Lum. (pb^{-1})
2.6444	33.722
2.500	1.098
2.396	66.869
2.3864	22.549
2.3094	21.089
2.2324	11.856

√s (GeV)	Lum. (pb^{-1})
2.200	13.699
2.175	10.625
2.150	2.841
2.125	108.49
2.100	12.167
2.050	3.343
2.000	10.074

3. 100K Signal MC by "ConExc" at each energy point.

(1) $e^+e^- \to K^+K^-K^+K^-$	(2) $e^+e^- \to \phi K^+K^-$	(3) $e^+e^- \to \phi f'_2(1525)$

Event selection

- **Good Charged Track:**

  $|V_z| < 10.0$ && $|V_r| < 1.0$ && $|\cos\theta| < 0.93$;

  $N_{Good} == 3||4$; (To improve detection efficiency: Missing one Kaon.)

- **PID with dE/dx and TOF:**

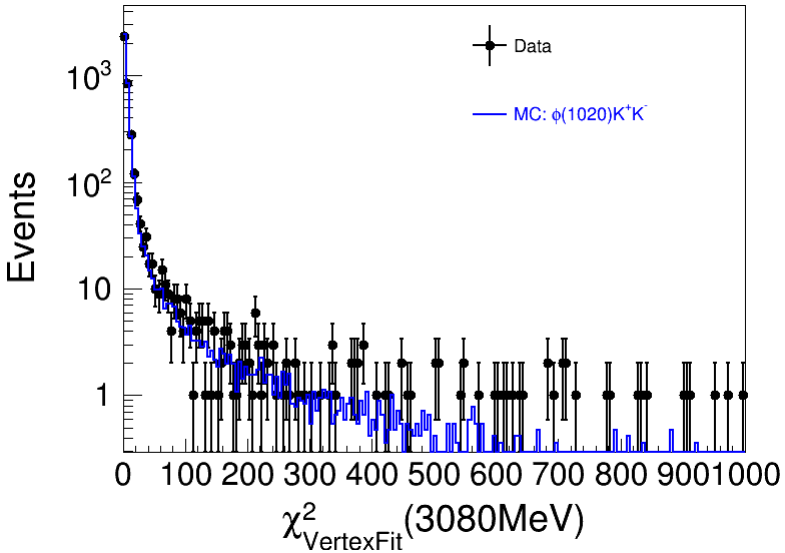
  Kaon: prob_K>prob_p && prob_K>prob_π;

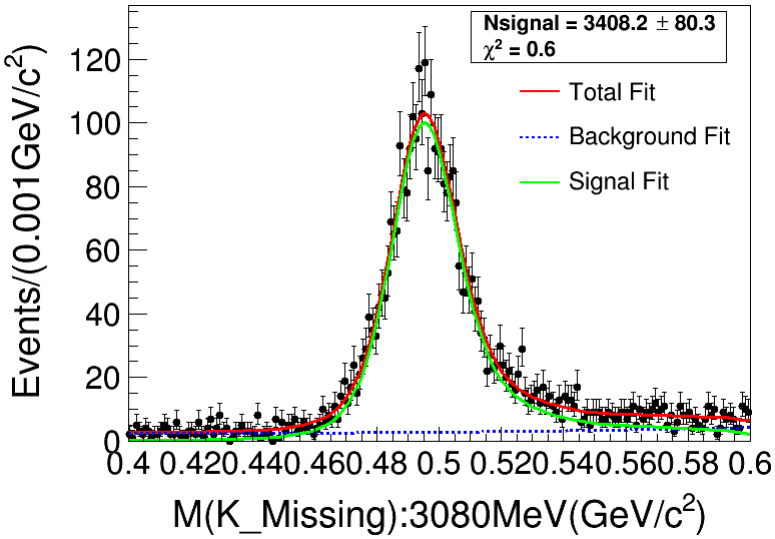
  At least three Kaons are indentified:

  $N(K^+) = N(K^-) = 2$; or $N(K^+) = 2$ && $N(K^-) = 1$; or $N(K^+) = 1$ && $N(K^-) = 2$;

- **Vertex fit ($K^+K^-K^\pm$).**

@3080MeV: L=126.185pb^{-1}





(1) $\chi^2_{vertexfit}(K^+K^-K^+K^-)$ distribution;

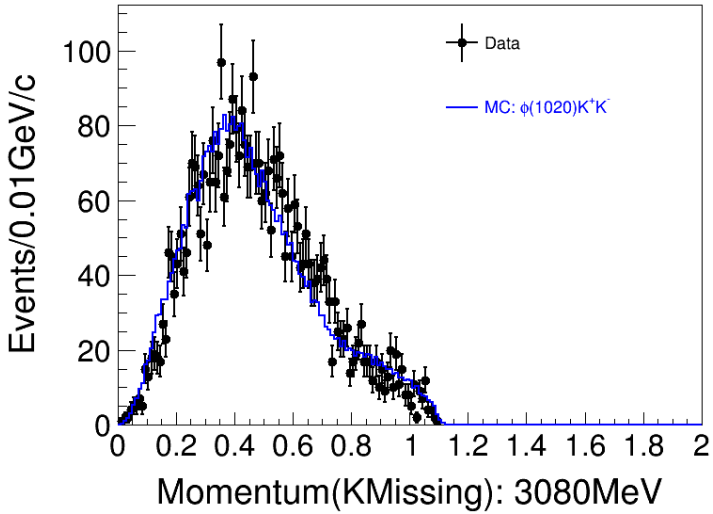
(2) K_Missing Fitting :

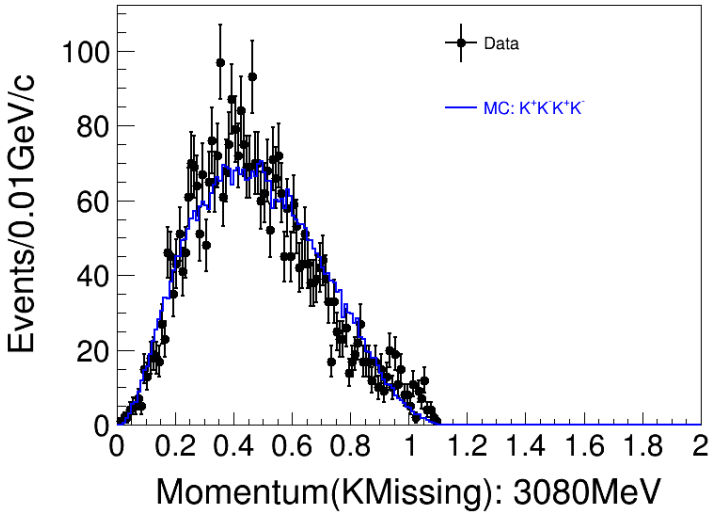
Signal: MC⊗ Gaussian;

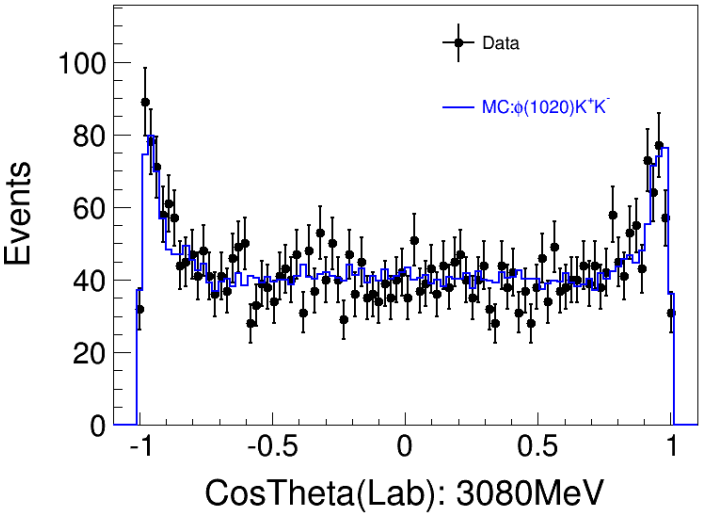
Background: Polynominal;

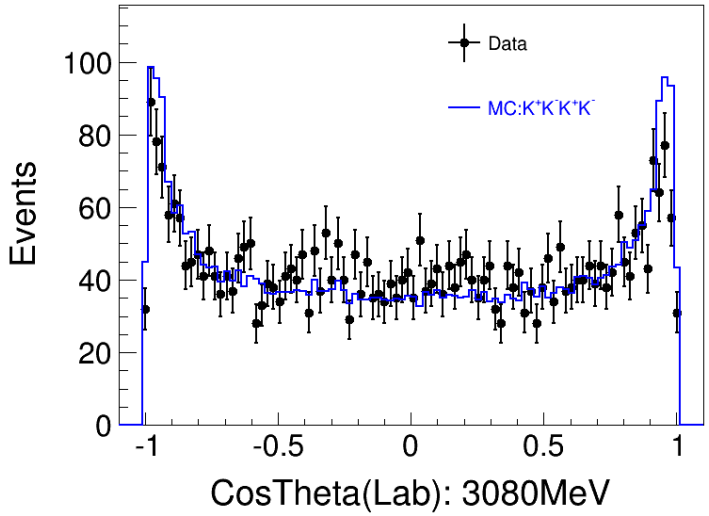
N=3408.2±80.3

@3080MeV: Momentum









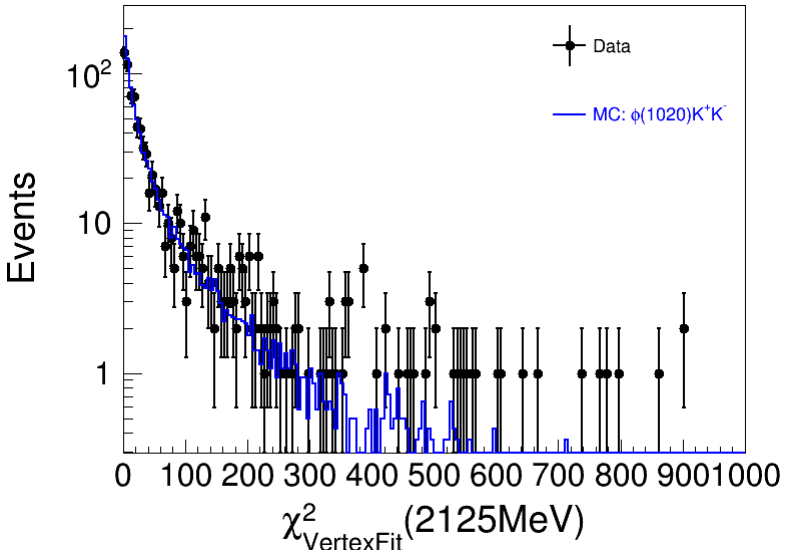
@3080MeV: L=120.56pb^{-1}

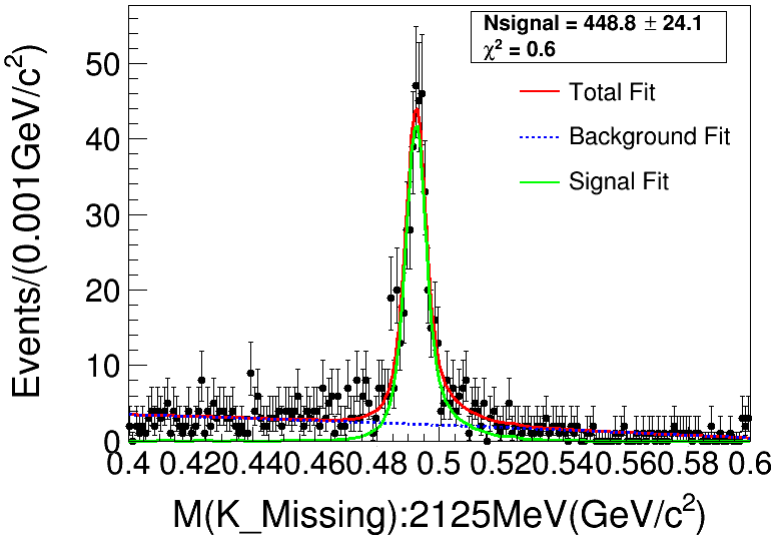
- To study backgrounds, MC topology analysis is performed with inclusive MC sample.

- Dominant signal is $e^+e^- \to \phi K^+ K^-$, $e^+e^- \to K^+ K^- K^+ K^-$.

No.	decay chain	final states	iTopo	nEvt	nTot
0	$e^+e^- \to K^-K^+\phi,\ \phi \to K^-K^+$	$e^+e^- \to K^+K^+K^-K^-$	0	1201	1201
1	$e^+e^- \to K^-K^-K^+K^+$	$e^+e^- \to K^+K^+K^-K^-$	1	384	1585
2	$e^+e^- \to \phi\phi,\ \phi \to K^-K^+,\ \phi \to K^-K^+$	$e^+e^- \to K^+K^+K^-K^-$	2	169	1754
3	$e^+e^- \to K^-\rho^-\pi^+K^+,\ \rho^- \to \pi^-\pi^0$	$e^+e^- \to K^+\pi^+\pi^0\pi^-K^-$	4	2	1756
4	$e^+e^- \to K^-\pi^-\pi^0\pi^+\pi^+K^*,\ K^* \to \pi^-K^+$	$e^+e^- \to K^+\pi^+\pi^+\pi^0\pi^-\pi^-K^-$	3	1	1757
5	$e^+e^- \to K^-\pi^+\eta K^*,\ \eta \to \gamma\gamma,\ K^* \to \pi^-K^+$	$e^+e^- \to \gamma\gamma K^+\pi^+\pi^-K^-$	5	1	1758
6	$e^+e^- \to K^-\pi^-\pi^+\omega K^+,\ \omega \to \pi^-\pi^0\pi^+$	$e^+e^- \to K^+\pi^+\pi^+\pi^0\pi^-\pi^-K^-$	6	1	1759
7	$e^+e^- \to K^-\pi^-\pi^+\eta K^+,\ \eta \to \gamma\gamma$	$e^+e^- \to \gamma\gamma K^+\pi^+\pi^-K^-$	7	1	1760
8	$e^+e^- \to K^-\rho^+K^*,\ \rho^+ \to \pi^0\pi^+,\ K^* \to \pi^-K^+$	$e^+e^- \to K^+\pi^+\pi^0\pi^-K^-$	8	1	1761

@2125MeV: L=108.49pb^{-1}





(1) $\chi^2_{vertexfit}(K^+K^-K^+K^-)$ distribution;

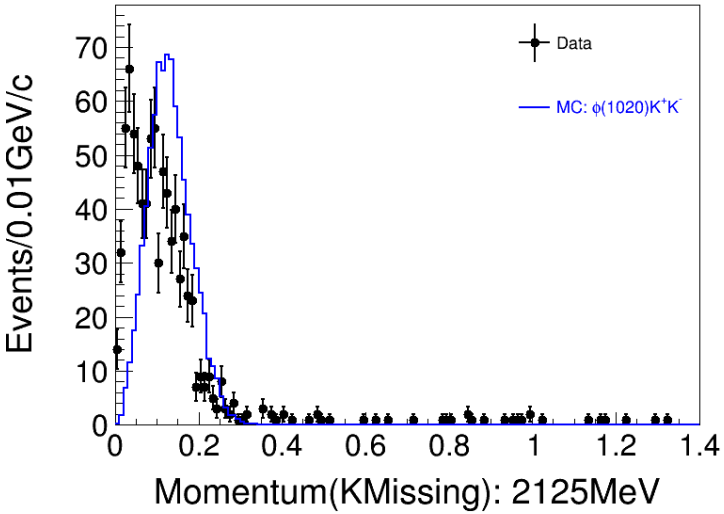
(2) K_Missing Fitting :

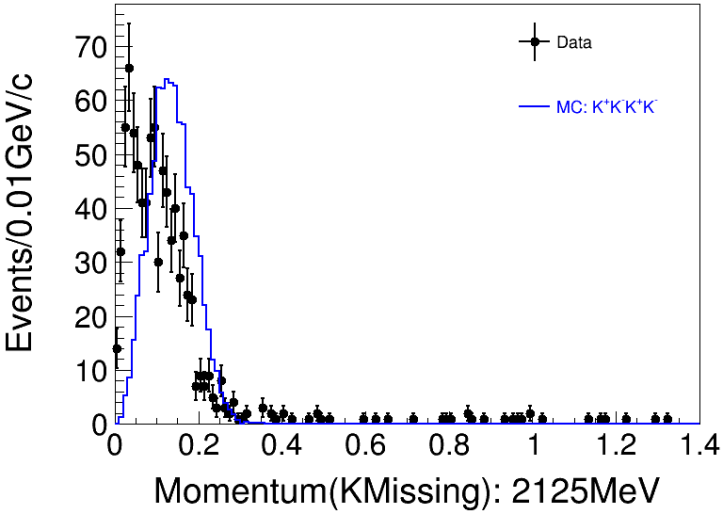
Signal: MC⊗ Gaussian;

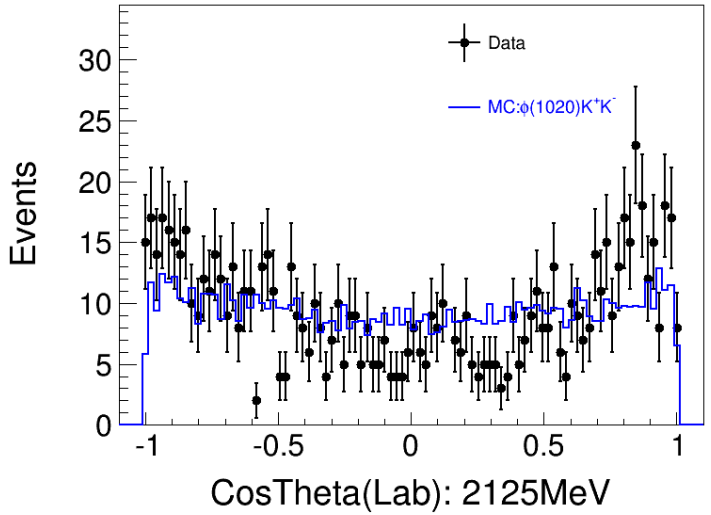
Background: Polynominal;

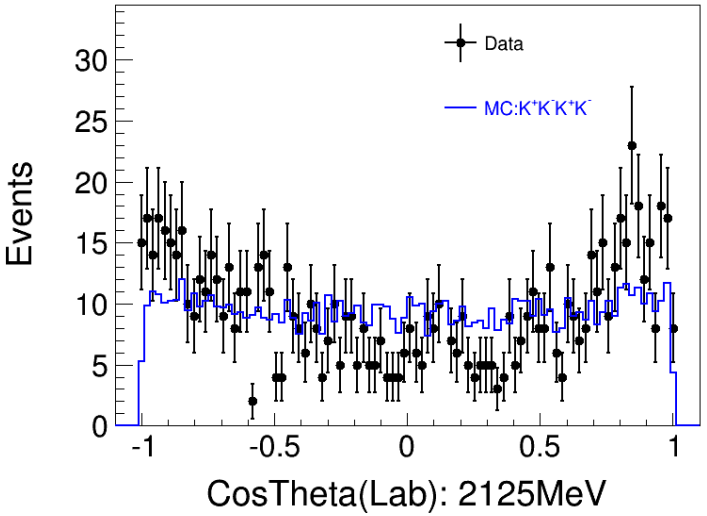
N=448.8 ± 24.1

@2125MeV :Momentum

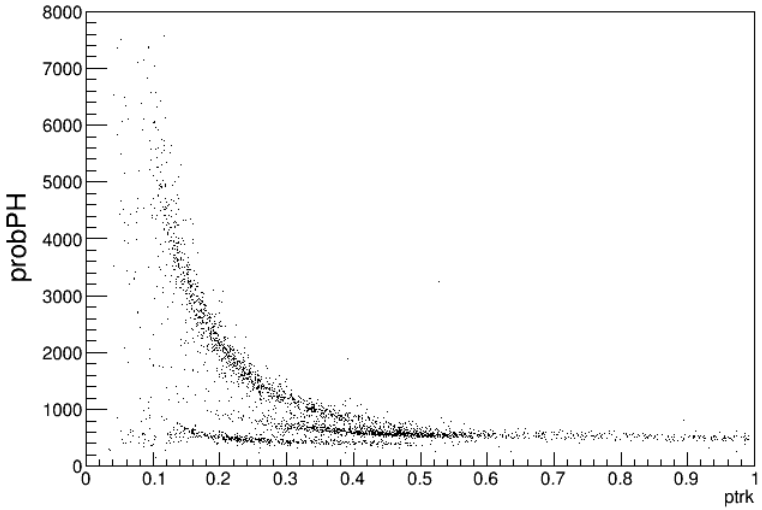


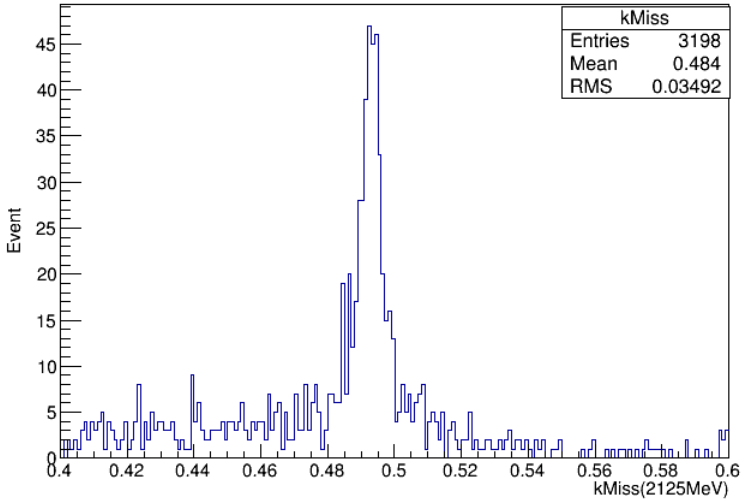


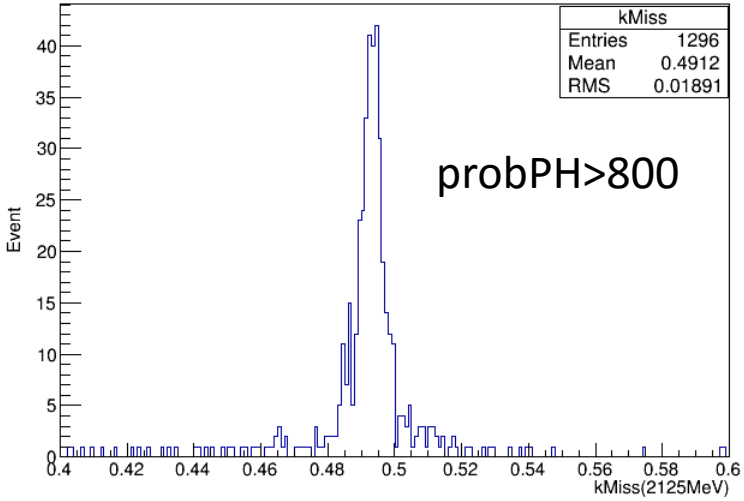




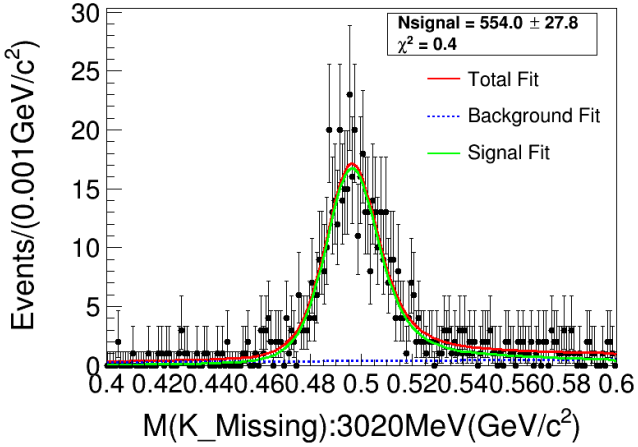
@2125MeV :Momentum

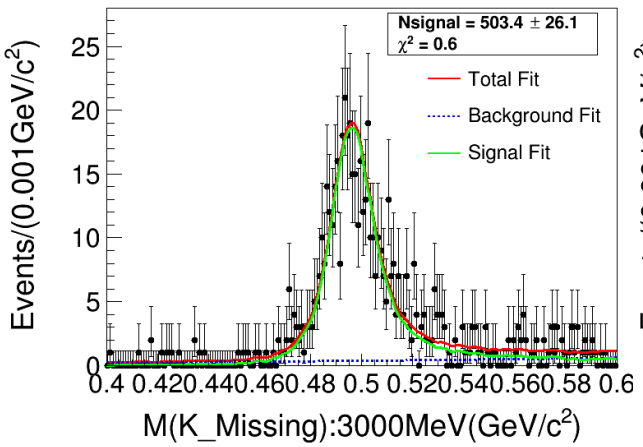


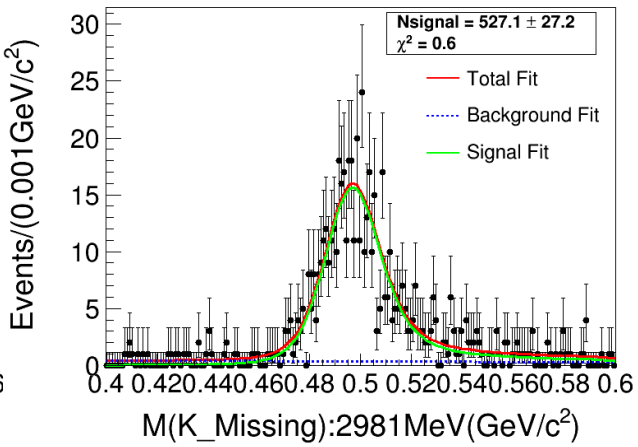


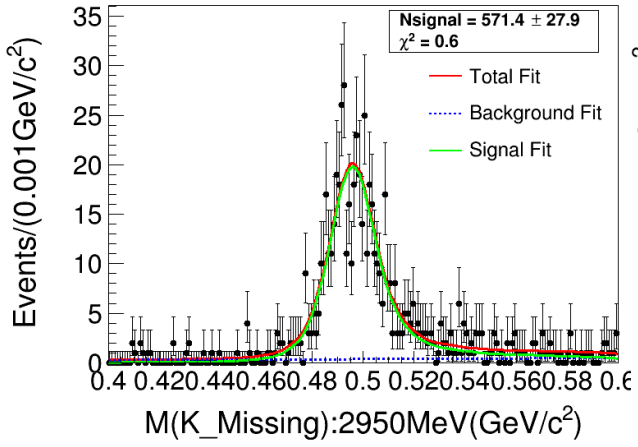


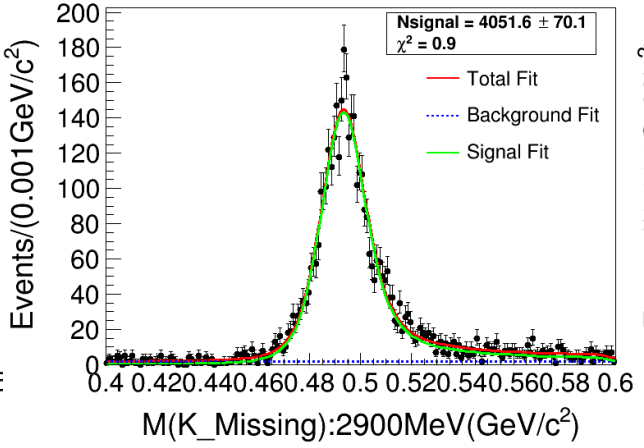
Other results (I)

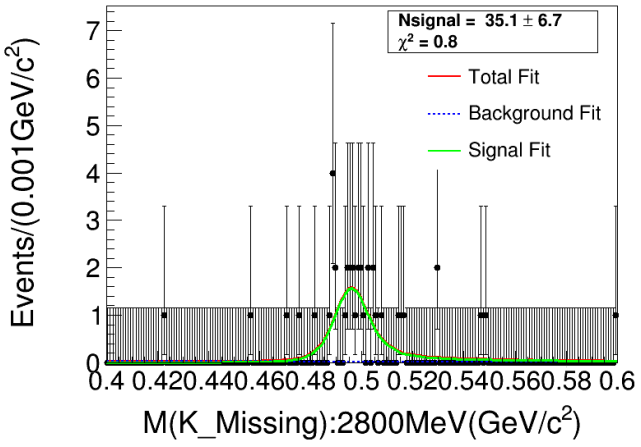












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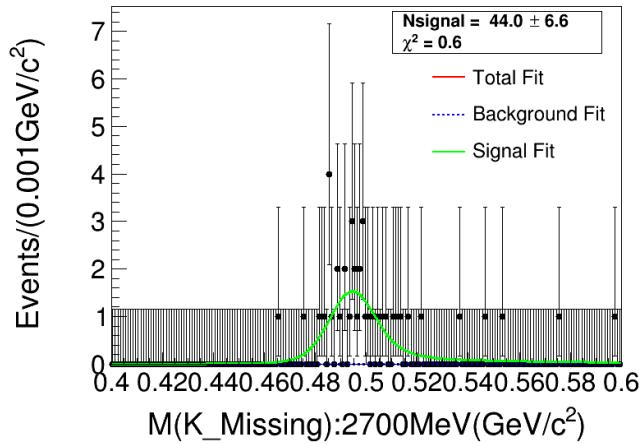
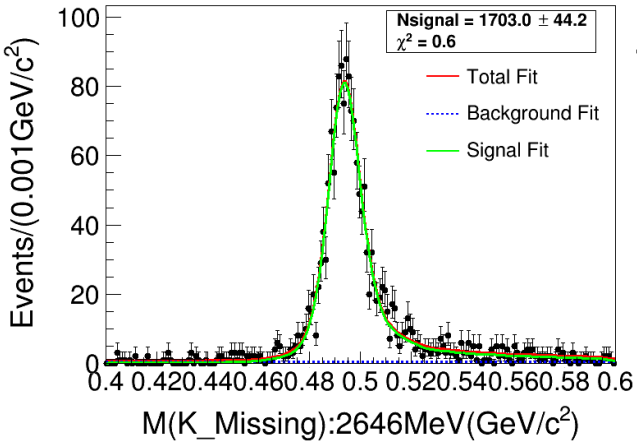
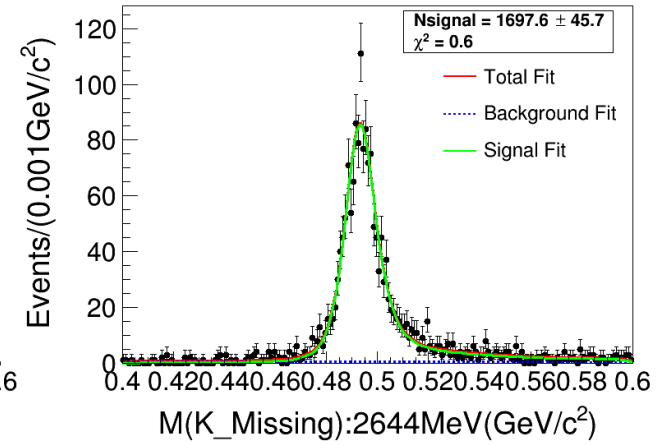
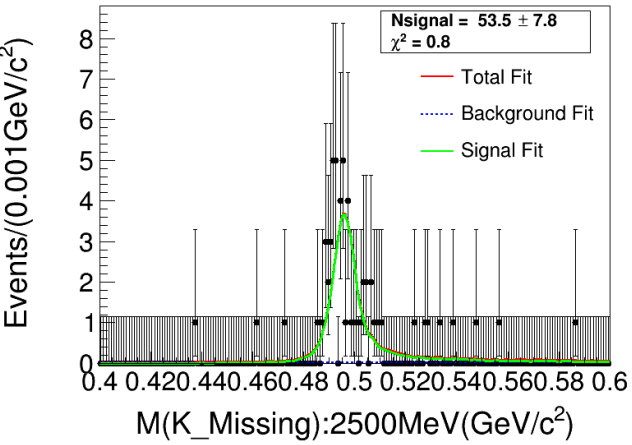
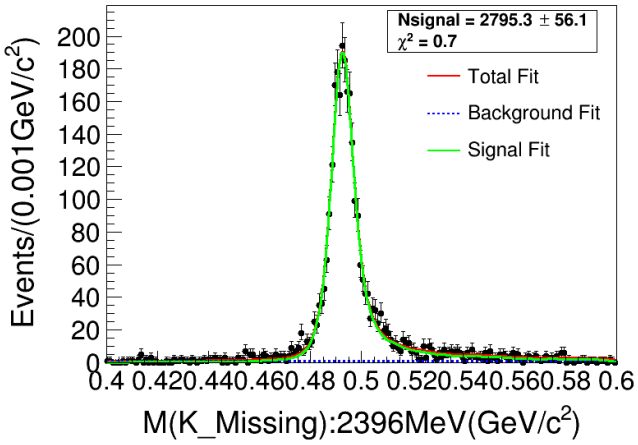
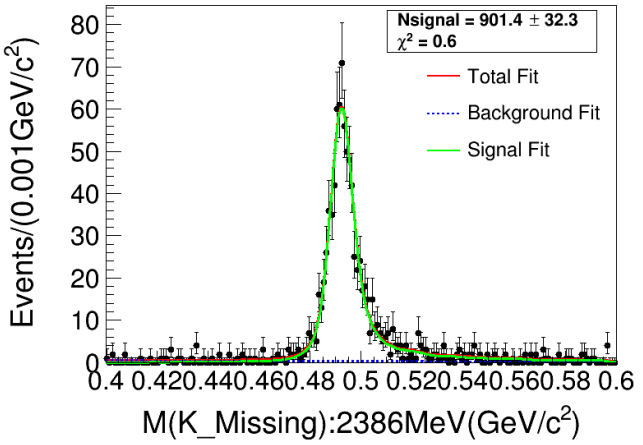




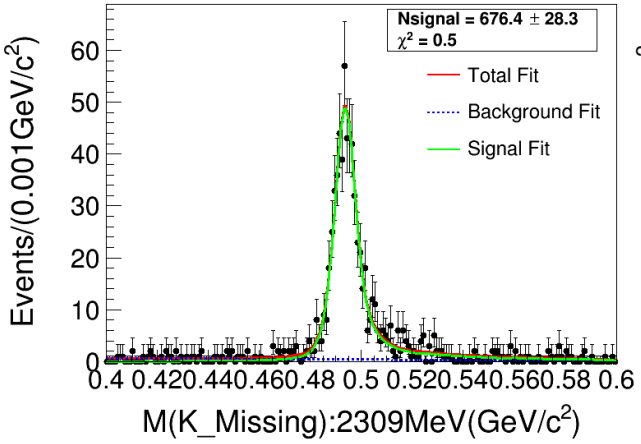


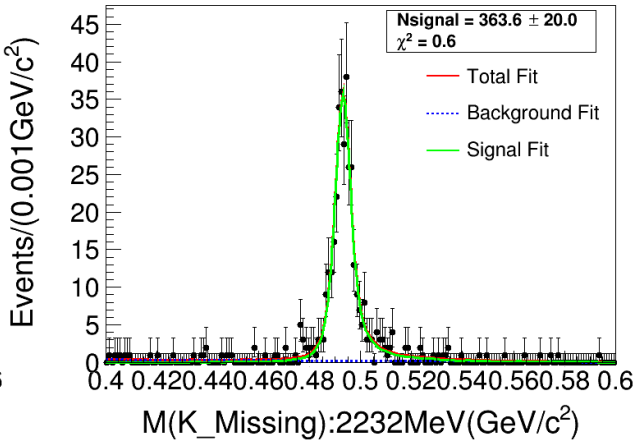


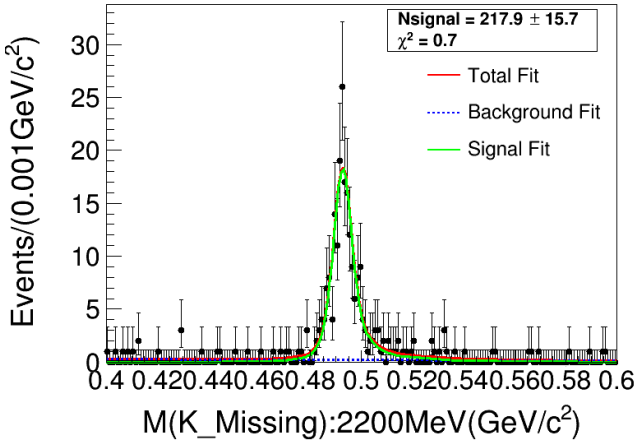


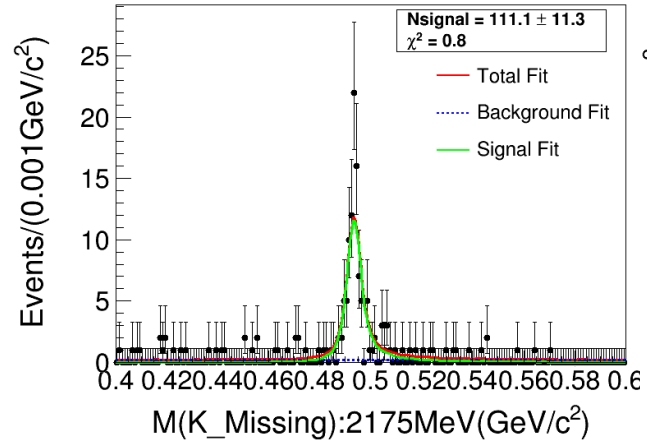


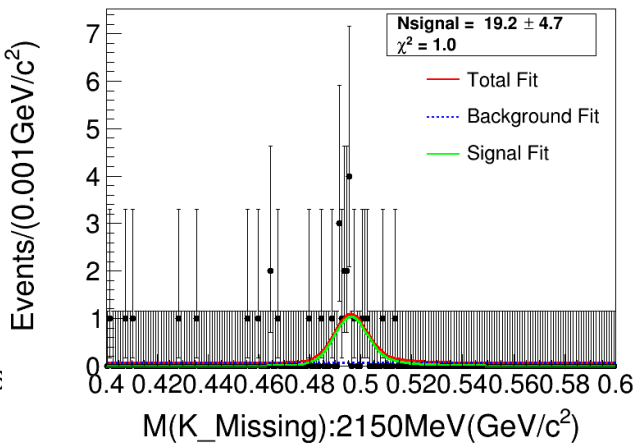
Other results (III)

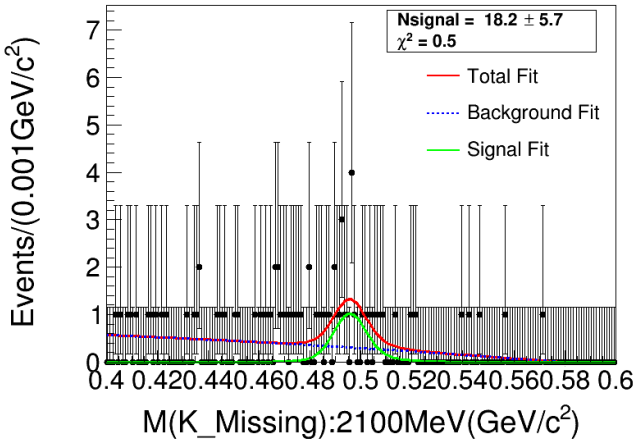












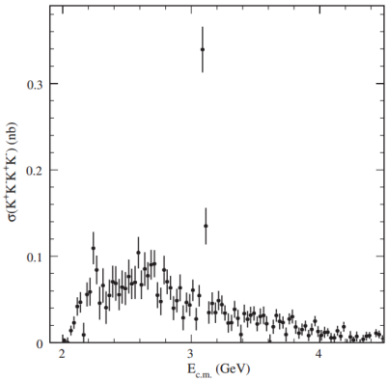
Cross section: $\sigma(e^+e^- \rightarrow \phi(1020)\, K^+K^-)$

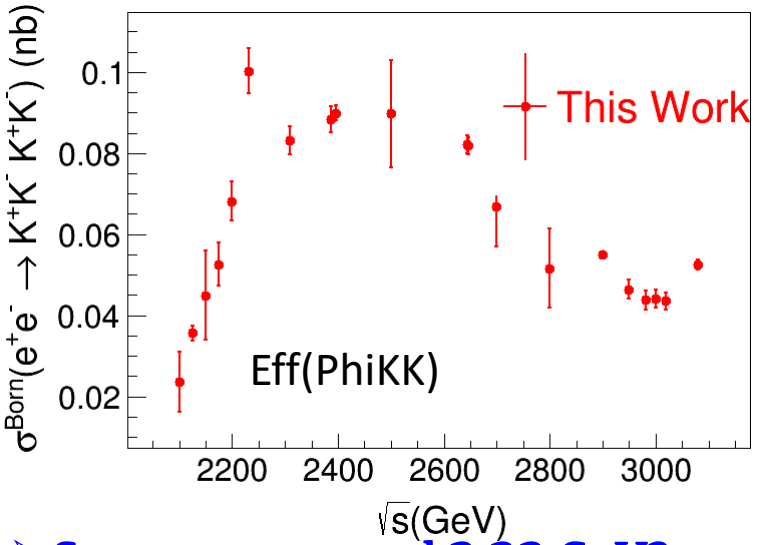
$$\sigma = \frac{N^{obs}}{L \times (1+\delta)^{VP} \times (1+\delta)^{ISR} \times \varepsilon}$$

- N^{obs}: is from the fit to M(K) distributions.
- L: is integrate luminosity.
- $(1+\delta)^{VP}$: is the correction factor from vacuum polarization.
- $(1+\delta)^{ISR}$: is the ISR correction factor.
- ε: is the selection efficiency from MC simulation.

Cross section: $\sigma(e^+e^- \to \phi(1020)\, K^+K^-)$

√s (GeV)	Lum. (pb^{-1})	N	$(1+\delta)^{ISR}$	ε(%)	Br	σ (pb)
2.000	10.074	±	---	---	1.0	±
2.050	3.343	±	---	---	1.0	±
2.100	12.167	18.2±5.7	0.8262	7.36	1.0	23.7±7.4
2.125	108.49	385.1±21.5	0.8563	12.33	1.0	35.6±1.9
2.150	2.841	19.2±4.7	0.9416	17.09	1.0	44.9±11.0
2.175	10.625	111.1±11.3	0.8809	22.71	1.0	52.6±5.3
2.200	13.699	217.9±15.7	0.8760	27.23	1.0	68.2±4.9
2.2324	11.856	363.6±20.0	0.8563	32.80	1.0	100.3±5.5
2.3094	21.089	676.4±28.3	0.9326	40.99	1.0	83.2±3.5
2.3864	22.549	901.4±32.2	0.9410	47.94	1.0	88.3±3.2
2.396	66.869	2795.3±56.1	0.9442	49.22	1.0	89.9±1.8
2.500	1.098	53.5±7.8	0.9584	56.69	1.0	89.7±13.1
2.6444	33.722	1697.6±45.7	0.9758	62.78	1.0	82.2±2.2
2.6464	34.003	1703.0±44.2	0.9804	62.44	1.0	81.8±2.1
2.700	1.034	44.0±6.6	0.9806	64.87	1.0	66.9±10.0
2.800	1.008	35.1±6.7	1.0021	67.37	1.0	51.6±9.8
2.900	105.253	4051.6±70.1	1.0195	68.83	1.0	54.9±0.9
2.950	15.942	571.4±27.9	1.1228	68.87	1.0	46.4±2.3
2.981	16.071	527.1±27.2	1.0689	70.04	1.0	43.8±2.3
3.000	15.881	503.4±26.1	1.0208	70.34	1.0	44.1±2.3
3.020	17.290	554.0±27.8	1.0423	70.59	1.0	43.5±2.2
3.080	126.185	3408.2±80.3	0.7090	72.49	1.0	52.6±1.2



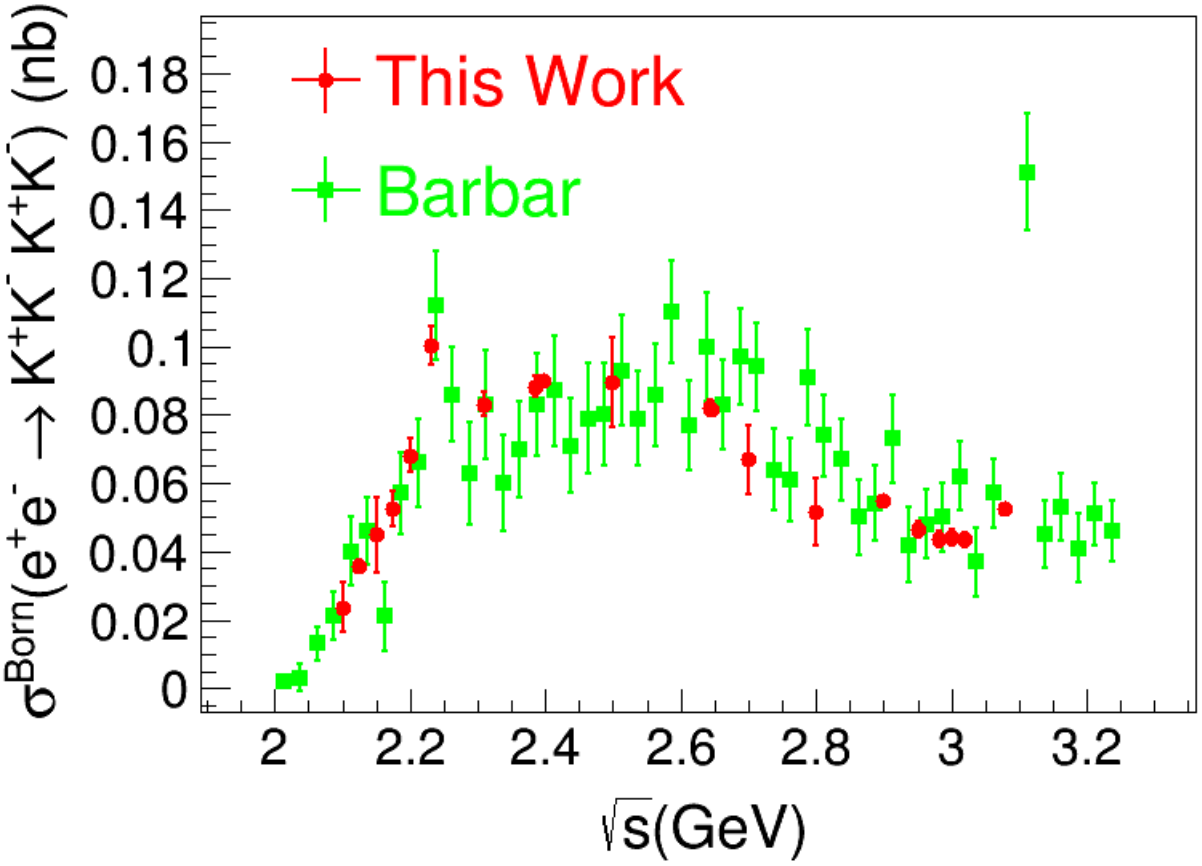


➢ Structure around 2.23 GeV?

(Same behaviors in BABAR results)

Summary

- Cross section measurements of $e^+ e^- \rightarrow K^+ K^- K^+ K^-$.
- Comparision of this work and Barbar's results .



Backup

Hadronic MC @3080MeV

No.	decay chain	final states	iTopology	nEvt	nTot
0	$e^+e^- \to \gamma^*, \gamma^* \to K^+K^-K^+K^-$	$K^-K^-K^+K^+$	3	2694	2694
1	$e^+e^- \to \gamma^*, \gamma^* \to K^+K^-\pi^+\pi^-$	$\pi^-K^-\pi^+K^+$	1	1463	4157
2	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^+K^-K^+K^-$	$K^-K^-\gamma K^+K^+$	7	881	5038
3	$e^+e^- \to \gamma^*, \gamma^* \to K^*K^+\pi^-, K^* \to K^+\pi^-$	$\pi^-\pi^-K^+K^+$	27	381	5419
4	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to K^+K^-f_0(1710), f_0(1710) \to K^-K^+$	$K^-K^-\gamma K^+K^+$	2	360	5779
5	$e^+e^- \to \gamma^*, \gamma^* \to K^*K^-\pi^+, K^* \to K^+\pi^-$	$\pi^-K^-\pi^+K^+$	4	346	6125
6	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^+K^-\pi^+\pi^-$	$\pi^-K^-\pi^+\gamma K^+$	8	323	6448
7	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to f_2^{'}K^+K^-, f_2^{'} \to K^+K^-$	$K^-K^-\gamma K^+K^+$	0	321	6769
8	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to K^+K^-h_1(1380), h_1(1380) \to K^{*+}K^-, K^{*+} \to K^+\pi^0$	$K^-K^-\pi^0\gamma K^+K^+$	16	258	7027
9	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to K^-h_1(1380)K^+, h_1(1380) \to K^{*-}K^+, K^{*-} \to K^-\pi^0$	$K^-K^-\pi^0\gamma K^+K^+$	11	223	7250
10	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to K^-h_1(1380)K^+, h_1(1380) \to \bar{K}^*K^0, \bar{K}^* \to K^-\pi^+$	$K^-K^-K_L\pi^+\gamma K^+$	22	164	7414
11	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to h_1(1380)K^+K^-, h_1(1380) \to K^*\bar{K}^0, K^* \to K^+\pi^-$	$\pi^-K^-K_L\gamma K^+K^+$	23	135	7549
12	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^*K^+\pi^-, K^* \to K^+\pi^-$	$\pi^-\pi^-\gamma K^+K^+$	17	119	7668
13	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to h_1(1380)K^+K^-, h_1(1380) \to K^{*-}K^+, K^{*-} \to \bar{K}^0\pi^-$	$\pi^-K^-K_L\gamma K^+K^+$	12	116	7784
14	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to h_1(1380)K^+K^-, h_1(1380) \to K^{*+}K^-, K^{*+} \to K^0\pi^+$	$K^-K^-K_L\pi^+\gamma K^+$	36	107	7891
15	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^*K^-\pi^+, K^* \to K^+\pi^-$	$\pi^-K^-\pi^+\gamma K^+$	34	103	7994
16	$e^+e^- \to \gamma^*, \gamma^* \to K^+K^-\rho^0, \rho^0 \to \pi^+\pi^-$	$\pi^-K^-\pi^+K^+$	39	74	8068
17	$e^+e^- \to \gamma^*, \gamma^* \to K_2^{*0}K^-\pi^+, K_2^{*0} \to K^+\pi^-$	$\pi^-K^-\pi^+K^+$	50	55	8123
18	$e^+e^- \to \gamma^*, \gamma^* \to K_2^{*0}K^+\pi^-, K_2^{*0} \to K^+\pi^-$	$\pi^-\pi^-K^+K^+$	66	49	8172
19	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to K^+K^-K^+K^-$	$K^-K^-\gamma K^+K^+$	37	47	8219
20	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^+K^-\rho^0, \rho^0 \to \pi^+\pi^-$	$\pi^-K^-\pi^+\gamma K^+$	61	45	8264
21	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to f_1(1420)K^+K^-, f_1(1420) \to K^+K^-\pi^0$	$K^-K^-\pi^0\gamma K^+K^+$	32	45	8309
22	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to K^+K^-h_1(1380), h_1(1380) \to \bar{K}^*K^0, \bar{K}^* \to K^-\pi^+, K_S \to \pi^0\pi^0$	$K^-K^-\pi^0\pi^0\pi^+\gamma K^+$	69	44	8353
23	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^+K^-$	$K^-\gamma K^+$	18	43	8396
24	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to K^+K^-h_1(1380), h_1(1380) \to K^*\bar{K}^0, K^* \to K^+\pi^-, K_S \to \pi^0\pi^0$	$\pi^-K^-\pi^0\pi^0\gamma K^+K^+$	19	43	8439

Hadronic MC @3080MeV

No.	decay chain	final states	iTopology	nEvt	nTot
0	$e^+e^- \to \gamma^*,\gamma^* \to K^+K^-K^+K^-$	$K^-K^-K^+K^+$	2	2604	2604
1	$e^+e^- \to \gamma^*,\gamma^* \to R_A\gamma, R_A \to K^+K^-K^+K^-$	$K^-K^-\gamma K^+K^+$	6	180	2784
2	$e^+e^- \to \gamma^*,\gamma^* \to K^+K^-\pi^+\pi^-\pi^0$	$\pi^-K^-\pi^+\gamma\gamma K^+$	5	136	2920
3	$e^+e^- \to \gamma^*,\gamma^* \to R_B\gamma, R_B \to K^+K^-f_0(1710), f_0(1710) \to K^-K^+$	$K^-K^-\gamma K^+K^+$	1	119	3039
4	$e^+e^- \to \gamma^*,\gamma^* \to R_B\gamma, R_B \to f_2^{'}K^+K^-, f_2^{'} \to K^+K^-$	$K^-K^-\gamma K^+K^+$	0	105	3144
5	$e^+e^- \to \gamma^*,\gamma^* \to R_B\gamma, R_B \to f_0(1710)K^+K^-, f_0(1710) \to K^-K^+$	$K^-K^-\gamma K^+K^+$	3	103	3247
6	$e^+e^- \to \gamma^*,\gamma^* \to R_B\gamma, R_B \to K^+K^-f_2^{'}, f_2^{'} \to K^+K^-$	$K^-K^-\gamma K^+K^+$	8	103	3350
7	$e^+e^- \to \gamma^*,\gamma^* \to R_B\gamma, R_B \to K^-f_0(1710)K^+, f_0(1710) \to K^-K^+$	$K^-K^-\gamma K^+K^+$	16	63	3413
8	$e^+e^- \to \gamma^*,\gamma^* \to R_B\gamma, R_B \to K^-f_2^{'}K^+, f_2^{'} \to K^+K^-$	$K^-K^-\gamma K^+K^+$	19	53	3466
9	$e^+e^- \to \gamma^*,\gamma^* \to R_A\gamma, R_A \to K^+K^-\pi^+\pi^-$	$\pi^-K^-\pi^+\gamma K^+$	14	36	3502
10	$e^+e^- \to \gamma^*,\gamma^* \to R_B\gamma, R_B \to K^+K^-K^+K^-$	$K^-K^-\gamma K^+K^+$	15	26	3528
11	$e^+e^- \to \gamma^*,\gamma^* \to R_A\gamma, R_A \to K^*K^+\pi^-, K^* \to K^+\pi^-$	$\pi^-\pi^-\gamma K^+K^+$	10	20	3548
12	$e^+e^- \to \gamma^*,\gamma^* \to R_A\gamma, R_A \to K^+K^-\pi^+\pi^-\pi^0$	$\pi^-K^-\pi^+\gamma\gamma\gamma K^+$	13	20	3568
13	$e^+e^- \to \gamma^*,\gamma^* \to R_A\gamma, R_A \to K^*K^-\pi^+, K^* \to K^+\pi^-$	$\pi^-K^-\pi^+\gamma K^+$	20	16	3584
14	$e^+e^- \to \gamma^*,\gamma^* \to R_B\gamma, R_B \to K^-K^+K^-K^+$	$K^-K^-\gamma K^+K^+$	27	12	3596
15	$e^+e^- \to \gamma^*,\gamma^* \to R_B\gamma, R_B \to f_0(1710)f_0(1710), f_0(1710) \to K^-K^+, f_0(1710) \to K^-K^+$	$K^-K^-\gamma K^+K^+$	37	6	3602
16	$e^+e^- \to \gamma^*,\gamma^* \to R_B\gamma, R_B \to K^+b_1^0K^-, b_1^0 \to \omega\pi^0, \omega \to \pi^-\pi^+\pi^0$	$\pi^-K^-\pi^+\gamma\gamma\gamma\gamma\gamma K^+$	47	6	3608
17	$e^+e^- \to \gamma^*,\gamma^* \to R_B\gamma, R_B \to K^-K^+h_1(1170), h_1(1170) \to \rho^0\pi^0, \rho^0 \to \pi^+\pi^-$	$\pi^-K^-\pi^+\gamma\gamma\gamma K^+$	12	5	3613
18	$e^+e^- \to \gamma^*,\gamma^* \to K^+K^-\pi^+\pi^-\eta, \eta \to \gamma\gamma$	$\pi^-K^-\pi^+\gamma\gamma K^+$	9	4	3617
19	$e^+e^- \to \gamma^*,\gamma^* \to K_2^{*0}K^-\pi^+, K_2^{*0} \to \rho^-K^+, \rho^- \to \pi^-\pi^0$	$\pi^-K^-\pi^+\gamma\gamma K^+$	23	4	3621
20	$e^+e^- \to \gamma^*,\gamma^* \to K^+K^-\pi^+\pi^-\eta, \eta \to \pi^0\pi^0\pi^0$	$\pi^-K^-\pi^+\gamma\gamma\gamma\gamma\gamma\gamma K^+$	39	4	3625
21	$e^+e^- \to \gamma^*,\gamma^* \to R_B\gamma, R_B \to f_2^{'}f_0(1710), f_2^{'} \to K^+K^-, f_0(1710) \to K^-K^+$	$K^-K^-\gamma K^+K^+$	24	4	3629
22	$e^+e^- \to \gamma^*,\gamma^* \to R_A\gamma, R_A \to K^+K^-\rho^0, \rho^0 \to \pi^+\pi^-$	$\pi^-K^-\pi^+\gamma K^+$	54	3	3632
23	$e^+e^- \to \gamma^*,\gamma^* \to R_B\gamma, R_B \to h_1(1170)K^-K^+, h_1(1170) \to \rho^-\pi^+, \rho^- \to \pi^-\pi^0$	$\pi^-K^-\pi^+\gamma\gamma\gamma K^+$	31	2	3634
24	$e^+e^- \to \gamma^*,\gamma^* \to R_B\gamma, R_B \to h_1(1170)K^-K^+, h_1(1170) \to \rho^0\pi^0, \rho^0 \to \pi^+\pi^-$	$\pi^-K^-\pi^+\gamma\gamma\gamma K^+$	34	2	3636

Hadronic MC @2125MeV

No.	decay chain	final states	iTopology	nEvt	nTot
0	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to K^-K^+K^-K^+$	$K^-K^-\gamma K^+K^+$	3	534	534
1	$e^+e^- \to \gamma^*, \gamma^* \to K^+K^-\pi^+\pi^-$	$\pi^-K^-\pi^+K^+$	5	364	898
2	$e^+e^- \to \gamma^*, \gamma^* \to K^+K^-K^+K^-$	$K^-K^-K^+K^+$	1	259	1157
3	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^+K^-\pi^+\pi^-$	$\pi^-K^-\pi^+\gamma K^+$	0	213	1370
4	$e^+e^- \to \gamma^*, \gamma^* \to \phi f_0(980), \phi \to K^+K^-, f_0(980) \to K^+K^-$	$K^-K^-K^+K^+$	6	136	1506
5	$e^+e^- \to \gamma^*, \gamma^* \to K^*K^+\pi^-, K^* \to K^+\pi^-$	$\pi^-\pi^-K^+K^+$	7	109	1615
6	$e^+e^- \to \gamma^*, \gamma^* \to K^*K^-\pi^+, K^* \to K^+\pi^-$	$\pi^-K^-\pi^+K^+$	2	105	1720
7	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^*K^-\pi^+, K^* \to K^+\pi^-$	$\pi^-K^-\pi^+\gamma K^+$	4	80	1800
8	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^+K^-K^+K^-$	$K^-K^-\gamma K^+K^+$	16	61	1861
9	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^*K^+\pi^-, K^* \to K^+\pi^-$	$\pi^-\pi^-\gamma K^+K^+$	17	59	1920
10	$e^+e^- \to \gamma^*, \gamma^* \to K^+K^-\rho^0, \rho^0 \to \pi^+\pi^-$	$\pi^-K^-\pi^+K^+$	10	58	1978
11	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^+K^-\rho^0, \rho^0 \to \pi^+\pi^-$	$\pi^-K^-\pi^+\gamma K^+$	9	42	2020
12	$e^+e^- \to \gamma^*, \gamma^* \to \phi\pi^-\pi^+, \phi \to K^+K^-$	$\pi^-K^-\pi^+K^+$	14	37	2057
13	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to \phi f_0(980), \phi \to K^+K^-, f_0(980) \to K^+K^-$	$K^-K^-\gamma K^+K^+$	24	33	2090
14	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^+K^-$	$K^-\gamma K^+$	15	32	2122
15	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^{*-}K^+\pi^0, K^{*-} \to K^-\pi^0$	$K^-\pi^0\pi^0\gamma K^+$	22	25	2147
16	$e^+e^- \to \gamma^*, \gamma^* \to K^{*+}K^-\pi^0, K^{*+} \to K^+\pi^0$	$K^-\pi^0\pi^0K^+$	23	23	2170
17	$e^+e^- \to \gamma^*, \gamma^* \to K^+K^-\pi^0\pi^0$	$K^-\pi^0\pi^0K^+$	12	23	2193
18	$e^+e^- \to \gamma^*, \gamma^* \to K^{*-}K^+\pi^0, K^{*-} \to K^-\pi^0$	$K^-\pi^0\pi^0K^+$	34	23	2216
19	$e^+e^- \to \gamma^*, \gamma^* \to \phi f_0(980), \phi \to K^+K^-, f_0(980) \to \pi^+\pi^-$	$\pi^-K^-\pi^+K^+$	11	20	2236
20	$e^+e^- \to \gamma^*, \gamma^* \to \omega K^+K^-, \omega \to \pi^-\pi^+\pi^0$	$\pi^-K^-\pi^0\pi^+K^+$	29	19	2255
21	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^{*+}K^-\pi^0, K^{*+} \to K^+\pi^0$	$K^-\pi^0\pi^0\gamma K^+$	20	18	2273
22	$e^+e^- \to \gamma^*, \gamma^* \to \phi\gamma, \phi \to K^+K^-$	$K^-\gamma K^+$	21	16	2289
23	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to K^-K^+\pi^-\pi^+$	$\pi^-K^-\pi^+\gamma K^+$	8	16	2305
24	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to \phi\pi^-\pi^+, \phi \to K^+K^-$	$\pi^-K^-\pi^+\gamma K^+$	19	14	2319

Hadronic MC @2125MeV

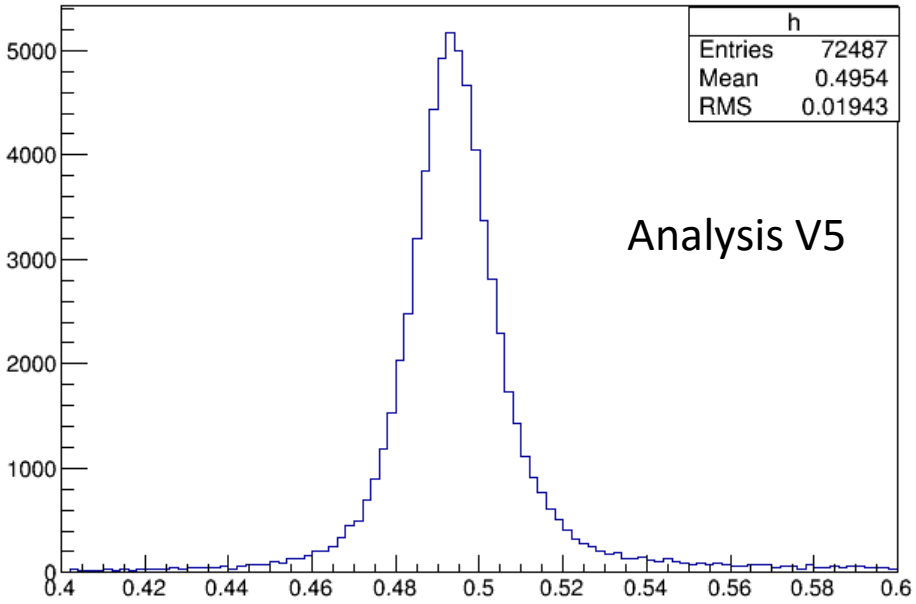
kMissing: Kmass[0.4,0.6]

No.	decay chain	final states	iTopology	nEvt	nTot
0	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to K^-K^+K^-K^+$	$K^-K^-\gamma K^+K^+$	1	309	309
1	$e^+e^- \to \gamma^*, \gamma^* \to K^+K^-K^+K^-$	$K^-K^-K^+K^+$	0	257	566
2	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to K^+K^-K^+K^-$	$K^-K^-\gamma K^+K^+$	3	217	783
3	$e^+e^- \to \gamma^*, \gamma^* \to \phi f_0(980), \phi \to K^+K^-, f_0(980) \to K^+K^-$	$K^-K^-K^+K^+$	2	134	917
4	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^+K^-K^+K^-$	$K^-K^-\gamma K^+K^+$	4	61	978
5	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to \phi f_0(980), \phi \to K^+K^-, f_0(980) \to K^+K^-$	$K^-K^-\gamma K^+K^+$	5	33	1011
6	$e^+e^- \to \gamma^*, \gamma^* \to K^+K^-$	K^-K^+	9	3	1014
7	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^+K^-$	$K^-\gamma K^+$	7	2	1016
8	$e^+e^- \to \gamma^*, \gamma^* \to R_A\gamma, R_A \to K^{*-}K^+\pi^0, K^{*-} \to K^-\pi^0$	$K^-\gamma\gamma\gamma\gamma\gamma K^+$	8	1	1017
9	$e^+e^- \to \gamma^*, \gamma^* \to K^+K^-\pi^+\pi^-\eta, \eta \to \pi^-\pi^+\pi^0$	$\pi^-\pi^-K^-\pi^+\pi^+\gamma\gamma K^+$	6	1	1018
10	$e^+e^- \to \gamma^*, \gamma^* \to K^{*+}K^-\pi^0, K^{*+} \to K^+\pi^0$	$K^-\gamma\gamma\gamma\gamma K^+$	10	1	1019
11	$e^+e^- \to \gamma^*, \gamma^* \to R_B\gamma, R_B \to \pi^-\eta\pi^+K^-K^+\pi^0, \eta \to \pi^-\pi^+\pi^0$	$\pi^-\pi^-K^-\pi^+\pi^+\gamma\gamma\gamma\gamma\gamma K^+$	11	1	1020
12	$e^+e^- \to \gamma^*, \gamma^* \to K^+K^-\pi^+\pi^-\eta, \eta \to \gamma\gamma$	$\pi^-K^-\pi^+\gamma\gamma K^+$	12	1	1021
13	$e^+e^- \to \gamma^*, \gamma^* \to K^+K^-\pi^+\pi^-\pi^0$	$\pi^-K^-\pi^+\gamma\gamma K^+$	13	1	1022

BesEvtGen-00-03-18(xs_ter.txt1)

/besfs/users/sunyk/my_run665-p01/Y2175/KpKmKpKm_V1_Missing/MCData/PhiKK_MC_V5/3080/PhiKK_ConExc/root

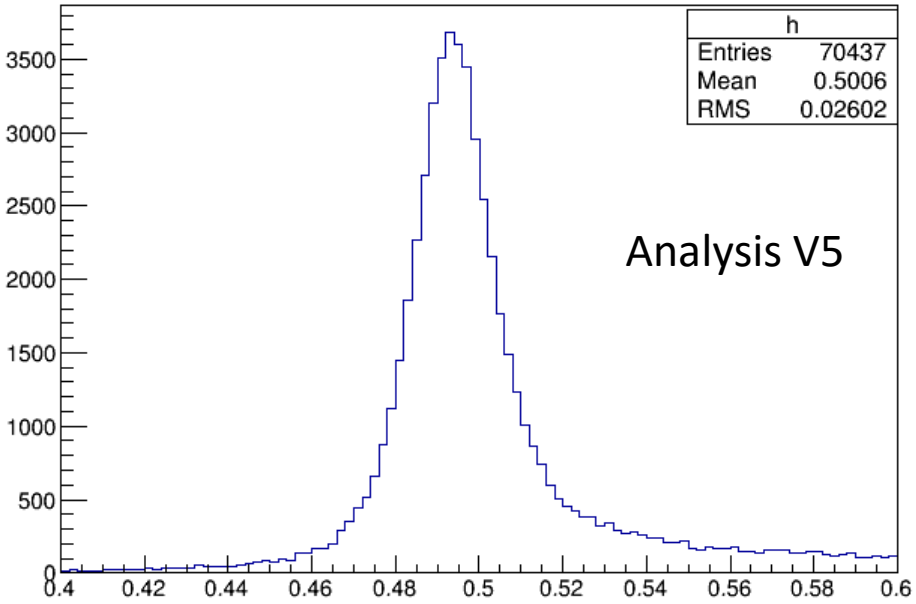
No.	decay chain	final states	iTopology	nEvt	nTot
0	$e^+e^- \to \gamma^*, \gamma^* \to \phi K^+K^-, \phi \to K^+K^-$	$K^-K^-K^+K^+$	1	56428	56428
1	$e^+e^- \to \gamma^*, \gamma^* \to \gamma R_A, R_A \to \phi K^+K^-, \phi \to K^+K^-$	$K^-K^-\gamma K^+K^+$	0	15453	71881
2	$e^+e^- \to \gamma^*, \gamma^* \to \phi K^+K^-\gamma_{FSR}, \phi \to K^+K^-$	$\gamma_{FSR}K^-K^-K^+K^+$	2	482	72363
3	$e^+e^- \to \gamma^*, \gamma^* \to \gamma R_A, R_A \to \phi K^+K^-\gamma_{FSR}, \phi \to K^+K^-$	$\gamma_{FSR}K^-K^-\gamma K^+K^+$	3	102	72465
4	$e^+e^- \to \gamma^*, \gamma^* \to \phi K^+K^-, \phi \to K^+K^-\gamma_{FSR}$	$\gamma_{FSR}K^-K^-K^+K^+$	6	18	72483
5	$e^+e^- \to \gamma^*, \gamma^* \to \phi K^+K^-\gamma_{FSR}\gamma_{FSR}, \phi \to K^+K^-$	$\gamma_{FSR}\gamma_{FSR}K^-K^-K^+K^+$	7	2	72485
6	$e^+e^- \to \gamma^*, \gamma^* \to \gamma R_A\gamma_{FSR}, R_A \to \phi K^+K^-, \phi \to K^+K^-$	$\gamma_{FSR}K^-K^-\gamma K^+K^+$	4	1	72486
7	$e^+e^- \to \gamma^*, \gamma^* \to \gamma R_A, R_A \to \phi K^+K^-, \phi \to K^+K^-\gamma_{FSR}$	$\gamma_{FSR}K^-K^-\gamma K^+K^+$	5	1	72487



BesEvtGen-00-03-18(xs_ter.txt6)

/besfs/users/sunyk/my_run665-p01/Y2175/KpKmKpKm_V1_Missing/MCData/PhiKK_MC_V5/3080_test_V5/PhiKK_ConExc/root

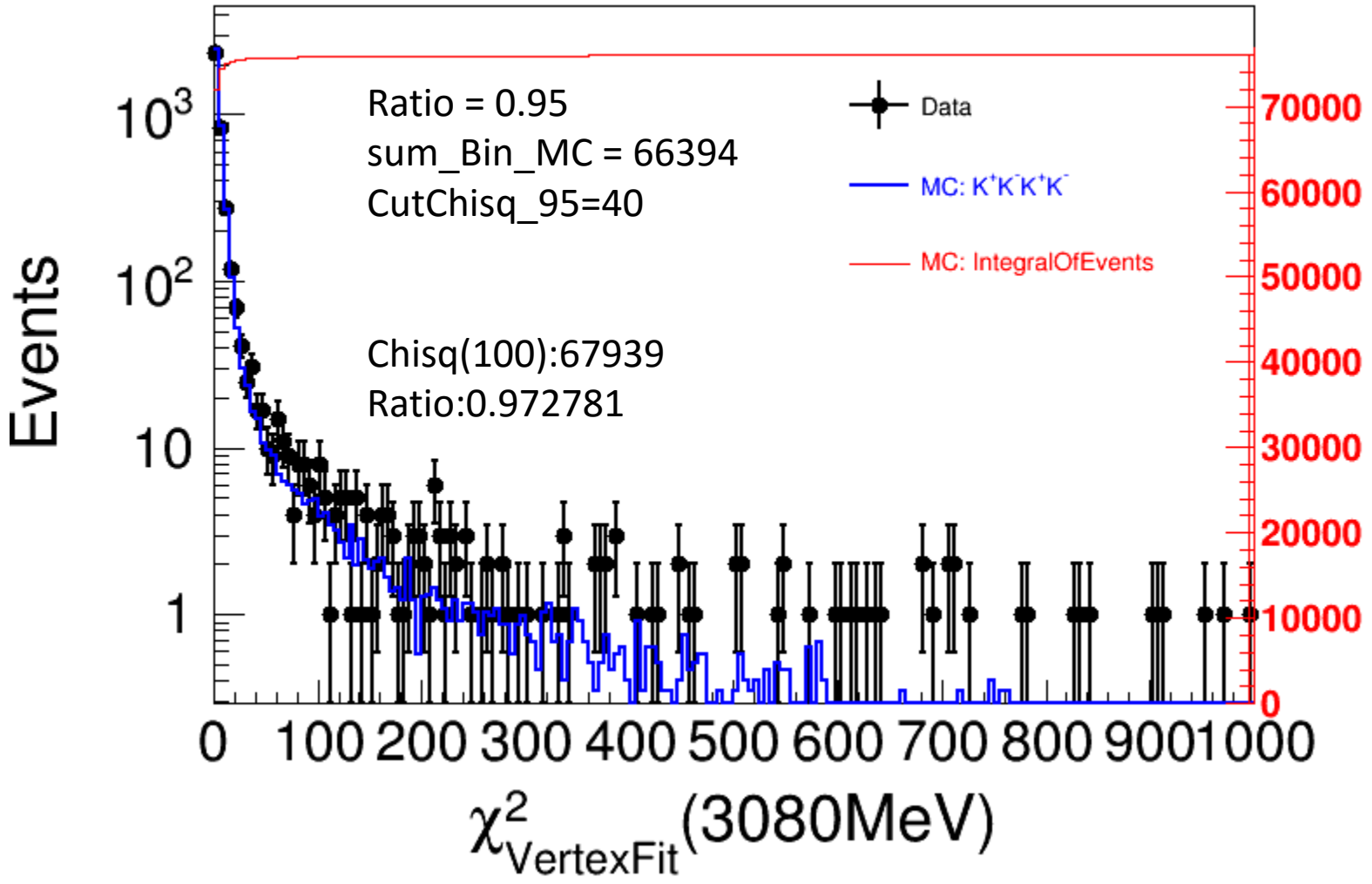
No.	decay chain	final states	iTopology	nEvt	nTot
0	$e^+e^- \to \gamma^*, \gamma^* \to \phi K^+K^-, \phi \to K^+K^-$	$K^-K^-K^+K^+$	1	40050	40050
1	$e^+e^- \to \gamma^*, \gamma^* \to \gamma R_A, R_A \to \phi K^+K^-, \phi \to K^+K^-$	$K^-K^-\gamma K^+K^+$	0	29838	69888
2	$e^+e^- \to \gamma^*, \gamma^* \to \phi K^+K^-\gamma_{FSR}, \phi \to K^+K^-$	$\gamma_{FSR}K^-K^-K^+K^+$	2	312	70200
3	$e^+e^- \to \gamma^*, \gamma^* \to \gamma R_A, R_A \to \phi K^+K^-\gamma_{FSR}, \phi \to K^+K^-$	$\gamma_{FSR}K^-K^-\gamma K^+K^+$	3	217	70417
4	$e^+e^- \to \gamma^*, \gamma^* \to \phi K^+K^-, \phi \to K^+K^-\gamma_{FSR}$	$\gamma_{FSR}K^-K^-K^+K^+$	6	8	70425
5	$e^+e^- \to \gamma^*, \gamma^* \to \gamma R_A, R_A \to \phi K^+K^-, \phi \to K^+K^-\gamma_{FSR}$	$\gamma_{FSR}K^-K^-\gamma K^+K^+$	5	5	70430
6	$e^+e^- \to \gamma^*, \gamma^* \to \gamma R_A\gamma_{FSR}, R_A \to \phi K^+K^-, \phi \to K^+K^-$	$\gamma_{FSR}K^-K^-\gamma K^+K^+$	4	5	70435
7	$e^+e^- \to \gamma^*, \gamma^* \to \gamma R_A, R_A \to \phi K^+K^-\gamma_{FSR}\gamma_{FSR}, \phi \to K^+K^-$	$\gamma_{FSR}\gamma_{FSR}K^-K^-\gamma K^+K^+$	7	1	70436
8	$e^+e^- \to \gamma^*, \gamma^* \to \phi K^+K^-\gamma_{FSR}\gamma_{FSR}, \phi \to K^+K^-$	$\gamma_{FSR}\gamma_{FSR}K^-K^-K^+K^+$	8	1	70437



Comparision of Cross Section

Energy	Eff_PhiKK	ISR	Eff*ISR	Cross	Cro_Err		Eff_KKKK	ISR	Eff*ISR	Cross	Cro_Err
3080	0.7249	0.7090	0.5139	52.5551	1.2382	***	0.7497	0.7090	0.5315	50.8145	1.1972
3020	0.7059	1.0423	0.7358	43.5466	2.1852	***	0.7324	1.0423	0.7634	41.9734	2.1062
3000	0.7034	1.0208	0.7180	44.1470	2.2889	***	0.7305	1.0208	0.7457	42.5092	2.2040
2981	0.7004	1.0689	0.7487	43.8096	2.2607	***	0.7266	1.0689	0.7767	42.2281	2.1791
2950	0.6887	1.1228	0.7732	46.3531	2.2633	***	0.7150	1.1228	0.8028	44.6475	2.1800
2900	0.6883	1.0195	0.7017	54.8564	0.9491	***	0.7128	1.0195	0.7267	52.9693	0.9165
2800	0.6737	1.0021	0.6752	51.5755	9.8449	***	0.7008	1.0021	0.7023	49.5840	9.4647
2700	0.6487	0.9806	0.6361	66.8977	10.0346	***	0.6771	0.9806	0.6639	64.0917	9.6138
2646	0.6244	0.9804	0.6121	81.8177	2.1235	***	0.6527	0.9804	0.6399	78.2653	2.0313
2644	0.6278	0.9758	0.6126	82.1799	2.2123	***	0.6575	0.9758	0.6416	78.4640	2.1123
2500	0.5669	0.9584	0.5433	89.6786	13.0746	***	0.5962	0.9584	0.5714	85.2714	12.4321
2396	0.4922	0.9442	0.4648	89.9446	1.8051	***	0.5219	0.9442	0.4928	84.8313	1.7025
2386	0.4794	0.9410	0.4511	88.6162	3.1754	***	0.5080	0.9410	0.4780	83.6272	2.9966
2309	0.4099	0.9326	0.3822	83.9118	3.5108	***	0.4406	0.9326	0.4109	78.0593	3.2659
2232	0.3280	0.8563	0.2808	109.1997	6.0066	***	0.3491	0.8563	0.2989	102.5871	5.6429
2200	0.2723	0.8760	0.2385	66.6848	4.8047	***	0.2896	0.8760	0.2537	62.7012	4.5177
2175	0.2271	0.8809	0.2001	52.2668	5.3161	***	0.2352	0.8809	0.2072	50.4668	5.1330
2150	0.1709	0.9416	0.1609	42.0060	10.2827	***	0.1728	0.9416	0.1627	41.5344	10.1673
2125	0.1233	0.8563	0.1056	39.1904	2.1045	***	0.1223	0.8563	0.1047	39.5012	2.1212
2100	0.0736	0.8263	0.0608	24.5873	7.7004	***	0.0677	0.8263	0.0559	26.7410	8.3749

Chisq(Vertex Fit)



Luminosity: @Boss665p01

(For Cross section Measurement of $e^+e^- \rightarrow K^+K^- K^+K^-$)

Luminosity Results for all energy points

Ecm(GeV)	$\mathcal{L}$ (pb^{-1})	Ecm(GeV)	$\mathcal{L}$ (pb^{-1})
2.0000	10.074±0.005±0.067	2.6444	33.722±0.013±0.216
2.0500	3.343±0.003±0.027	2.6464	34.003±0.013±0.282
2.1000	12.167±0.006±0.085	2.7000	1.034±0.002±0.007
2.1500	2.841±0.003±0.024	2.8000	1.008±0.002±0.007
2.1750	10.625±0.006±0.091	2.9000	105.253±0.025±0.905
2.2000	13.699±0.007±0.092	2.9500	15.942±0.010±0.143
2.2324	11.856±0.007±0.087	2.9810	16.071±0.010±0.095
2.3094	21.089±0.009±0.143	3.0000	15.881±0.010±0.110
2.3864	22.549±0.010±0.176	3.0200	17.290±0.011±0.123
2.3960	66.869±0.017±0.475	3.0800	126.185±0.029±0.921
2.5000	1.098±0.002±0.009		