Study of $e^+e^- \to \omega/\phi\ K^+K^-/\pi^+\pi^-$ around J/ψ

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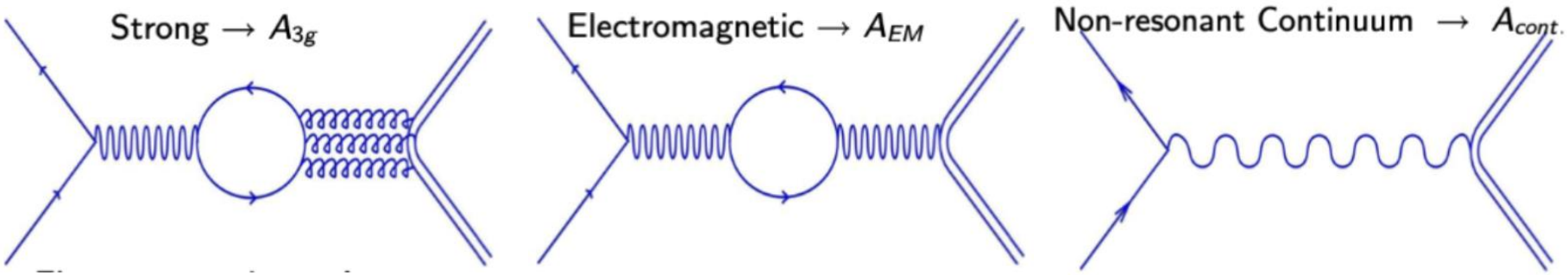
Content

Motivation

- For the lineshape of hardon cross section around charmonium is determined by the interference between resonance prodounction and non-resonance prodounction, we need to study the phase between resonance Strong and EM amptitudes from charmonium decay



To be determined Assumed to be zero

$$\sigma_{Born} = \left|A_{cont.} + \left(A_{EM} + A_{3g}e^{i\phi_{EM,3g}}\right)e^{i\phi_{cont.EM}}\right|^2$$

Motivation

- In theory ,the phase is predicted as 0°or 180° with QCD and $\pm 90^{\circ}$ with unsubtracted dispersion relations.

- In experiment, lots of phase between resonance Strong and EM amptitudes from charmonium decay are determined:
  $J/\psi \to 1^{-}0^{-}, 0^{-}0^{-}$: φ~$90^{\circ}$ Phys.Rev.D 41,1389
  $J/\psi \to N\overline{N}$: φ~91° Phys. Lett.B 444,111

- In this work, we aim to exactly measure the BFs of $J/\psi \to \omega/\phi\ K^{+}K^{-}/\pi^{+}\pi^{-}$ with interference and extract the relative phase.

Data set and MC samples

- Data set : BOSS 7.1.3 for J/ψ scan, 86 pb^{-1}

  BOSS 7.0.8 for J/ψ off-res @3080, 167 pb^{-1}

Datasets	Run Number	BEMS MeV	Corrected MeV	$\mathcal{L}(\mathrm{pb}^{-1})$	Boss version
3050	28312 - 28346	3050.21 ± 0.03	3049.658	14.92 ± 0.16	6.6.4.p01
3059	28347 - 28381	3059.25 ± 0.03	3058.709	15.06 ± 0.16	6.6.4.p01
3080	27147-27233,28241-28266 54982-55053,59016-59141	-	3080.000	167.06 ± 0.10	7.0.8
3083	28382 - 28387,28466 - 28469	3083.06 ± 0.02	3082.512	4.77 ± 0.06	6.6.4.p01
3089	28388 - 28416,28472 - 28475	3089.42 ± 0.02	3088.870	15.56 ± 0.17	6.6.4.p01
3092	28417 - 28453,28476 - 28478	3092.32 ± 0.03	3091.776	14.91 ± 0.16	6.6.4.p01
3095	28479 - 28482	3095.26 ± 0.08	3094.713	2.14 ± 0.03	6.6.4.p01
3096	28487 - 28489	3095.99 ± 0.08	3095.446	1.82 ± 0.02	6.6.4.p01
3097	28490 - 28492	3096.39 ± 0.08	3095.842	2.14 ± 0.03	6.6.4.p01
3098	28493 - 28495	3097.78 ± 0.08	3097.229	2.07 ± 0.03	6.6.4.p01
3099	28496 - 28498	3098.90 ± 0.08	3098.356	2.20 ± 0.03	6.6.4.p01
3100	28499 - 28501	3099.61 ± 0.09	3099.058	0.76 ± 0.01	6.6.4.p01
3102	28504 - 28505	3101.92 ± 0.11	3101.375	1.61 ± 0.02	6.6.4.p01
3106	28506 - 28509	3106.14 ± 0.09	3105.596	2.11 ± 0.03	6.6.4.p01
3112	28510 - 28511	3112.62 ± 0.09	3112.067	1.72 ± 0.02	6.6.4.p01
3120	28512 - 28513	3120.44 ± 0.12	3119.894	1.26 ± 0.02	6.6.4.p01

Data set and MC samples

- Inclusive MC: J/ψ 224M(2009), BOSS7.0.8.

- Signal MC: BOSS 7.1.3 for J/ψ scan

  BOSS 7.0.8 for J/ψ off-res @3080

  Under the 00-04-08 version of BesEvtGen, using the generator ConExc generated 100,000 events at each energy point

  Up to now, the generator is PHSP.

Event Selection

- Good charged track

  $V_{xy} < 1$ cm

  $V_z < 10$ cm

  $|\cos\theta| < 0.93$

- Particle Identification (dE/dx + TOF)

  $K^{\pm}$: $CL_K > CL_\pi$ && $CL_K > 0$

  $\pi^{\pm}$: $CL_\pi > CL_K$ && $CL_\pi > 0$

- π^0 reconstruction:

  $M_{\gamma\gamma} \in (0.080, 0.180)\mathrm{GeV}/c^2$

  1-c kinematic fit: $\chi^2 < 200$

Event Selection

- Photon:

  $E_\gamma > 0.025$ GeV for barrel

  $E_\gamma > 0.05$ GeV for endcap

  $0 \leq T_{EMC} \leq 14$

  $\theta_{c\gamma} > 10^\circ$

- No extra charge tracks

- Combination:

  We combinate the lower momentum $K^+K^-/\pi^+\pi^-\pi^0$ candidates as ϕ/ω particle

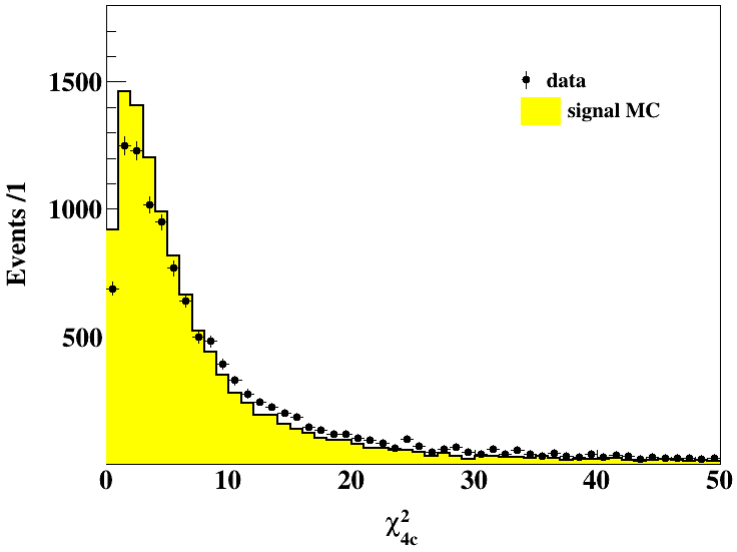
Event Selection

4C kinematic fit

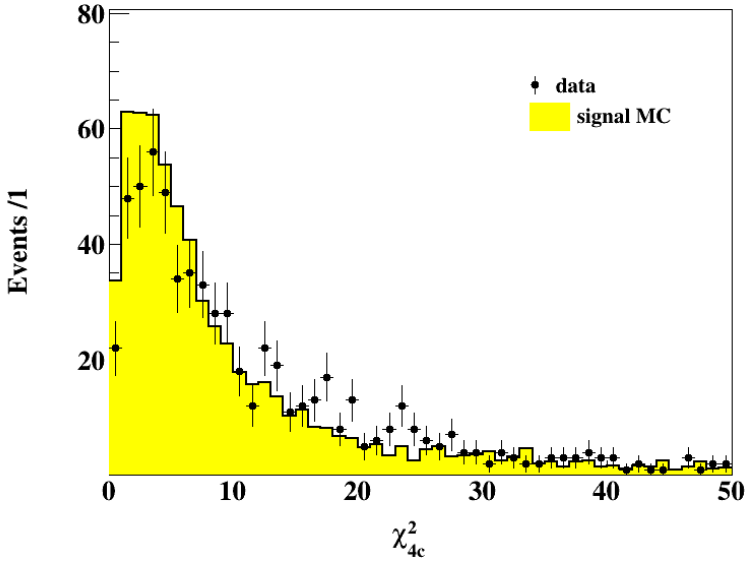
1:Energy-momentum constraint to energy point.

2:Choose the smallest χ^2_{4C}

3: χ^2_{4C}<50



@3.0972GeV



@3.0800GeV

Event Selection

rowNo	cascade decay branch of J/ψ	iCascDcyBrP	nCase	nCCase
1	$J/\psi \to \pi^0\pi^+\pi^-K^+K^-$	0	20330	20330
2	$J/\psi \to \omega f_2(1270), \omega \to \pi^0\pi^+\pi^-, f_2(1270) \to K^+K^-$	11	3893	24223
3	$J/\psi \to \pi^+K^*K^{*-}, K^* \to \pi^-K^+, K^{*-} \to \pi^0K^-$	4	3324	27547
4	$J/\psi \to \omega K^+K^-, \omega \to \pi^0\pi^+\pi^-$	2	3319	30866
5	$J/\psi \to \pi^-\bar{K}^*K^{*+}, \bar{K}^* \to \pi^+K^-, K^{*+} \to \pi^0K^+$	3	3260	34126
6	$J/\psi \to \pi^0K^*\bar{K}^*, K^* \to \pi^-K^+, \bar{K}^* \to \pi^+K^-$	10	887	35013
7	$J/\psi \to \pi^0\bar{K}^*K_2^{*0}, \bar{K}^* \to \pi^+K^-, K_2^{*0} \to \pi^-K^+$	5	740	35753
8	$J/\psi \to \pi^0K^*K_2^{*0}, K^* \to \pi^-K^+, K_2^{*0} \to \pi^+K^-$	16	723	36476
9	$J/\psi \to K^-K_1'^+, K_1'^+ \to \omega K^+$	15	678	37154
10	$J/\psi \to \omega f_0(980), \omega \to \pi^0\pi^+\pi^-, f_0(980) \to K^+K^-$	6	674	37828
11	$J/\psi \to K^+\bar{K}_1'^-, \bar{K}_1'^- \to \omega K^-$	26	662	38490
12	$J/\psi \to \pi^0\bar{K}^*K_0^0, \bar{K}^* \to \pi^+K^-, K_0^0 \to \pi^-K^+$	47	310	38800
13	$J/\psi \to \pi^0K^*\bar{K}_0^{*0}, K^* \to \pi^-K^+, \bar{K}_0^{*0} \to \pi^+K^-$	14	288	39088
14	$J/\psi \to \pi^+K^{*-}K_0^0, K^{*-} \to \pi^0K^-, K_0^0 \to \pi^-K^+$	17	142	39230
15	$J/\psi \to \pi^+K^*K_0^{*-}, K^* \to \pi^-K^+, K_0^{*-} \to \pi^0K^-$	32	131	39361
16	$J/\psi \to \pi^-\bar{K}^*K_0^{*+}, \bar{K}^* \to \pi^+K^-, K_0^{*+} \to \pi^0K^+$	48	131	39492
17	$J/\psi \to K^*K_2^{*0}, K^* \to \pi^-K^+, K_2^{*0} \to \pi^0\bar{K}^*$	18	130	39622
18	$J/\psi \to \pi^-K^{*+}\bar{K}_0^{*0}, K^{*+} \to \pi^0K^+, \bar{K}_0^{*0} \to \pi^+K^-$	43	124	39746
19	$J/\psi \to \pi^0\pi^+\pi^-K^+K^-\gamma^f$	41	120	39866
20	$J/\psi \to \pi^+\pi^-K^+K^-\gamma^F$	23	120	39986
21	$J/\psi \to K^*K_2^{*0}, K^* \to \pi^-K^+, K_2^{*0} \to \pi^+K^{*-}$	13	115	40101
22	$J/\psi \to \bar{K}^*K_2^{*0}, \bar{K}^* \to \pi^+K^-, K_2^{*0} \to \pi^0K^*$	30	110	40211
23	$J/\psi \to K^{*+}K_2^{*-}, K^{*+} \to \pi^0K^+, K_2^{*-} \to \pi^-\bar{K}^*$	9	105	40316
24	$J/\psi \to \bar{K}^*K_2^{*0}, \bar{K}^* \to \pi^+K^-, K_2^{*0} \to \pi^-K^{*+}$	20	99	40415
25	$J/\psi \to \bar{K}^*K_2^{*0}, \bar{K}^* \to \pi^+K^-, K_2^{*0} \to \rho^-K^+$	24	98	40513
26	$J/\psi \to K^{*-}K_2^{*+}, K^{*-} \to \pi^0K^-, K_2^{*+} \to \pi^+K^*$	12	92	40605
27	$J/\psi \to K^*K_2^{*0}, K^* \to \pi^-K^+, K_2^{*0} \to \rho^+K^-$	68	82	40687
28	$J/\psi \to \bar{K}^*K_2^0, \bar{K}^* \to \pi^+K^-, K_2^0 \to \pi^0K_2^{*0}$	38	60	40747
29	$J/\psi \to K^+K_1^-, K_1^- \to \omega K^-$	7	51	40798
30	$J/\psi \to K^-K_1^+, K_1^+ \to \omega K^+$	56	38	40836
31	$J/\psi \to \bar{K}^*K_2^0, \bar{K}^* \to \pi^+K^-, K_2^0 \to \pi^-K_2^{*+}$	51	38	40874
32	$J/\psi \to \rho^-\bar{K}^*K^+, \rho^- \to \pi^0\pi^-, \bar{K}^* \to \pi^+K^-$	81	37	40911

For ωK^+K^-

rowNo	cascade decay branch of J/ψ	iCascDcyBrP	nCase	nCCase
1	$J/\psi \to \pi^+\pi^-\omega, \omega \to \pi^0\pi^+\pi^-$	1	241894	241894
2	$J/\psi \to \omega f_2(1270), \omega \to \pi^0\pi^+\pi^-, f_2(1270) \to \pi^+\pi^-$	0	81750	323644
3	$J/\psi \to \pi^0\pi^+\pi^+\pi^-\pi^-$	2	77705	401349
4	$J/\psi \to \pi^-b_1^+, b_1^+ \to \pi^+\omega$	4	44852	446201
5	$J/\psi \to \pi^+b_1^-, b_1^- \to \pi^-\omega$	3	44736	490937
6	$J/\psi \to \rho^0a_2^0, \rho^0 \to \pi^+\pi^-, a_2^0 \to \pi^-\rho^+$	11	3670	494607
7	$J/\psi \to \rho^0a_2^0, \rho^0 \to \pi^+\pi^-, a_2^0 \to \pi^+\rho^-$	17	3479	498086
8	$J/\psi \to \pi^+\pi^-\omega\gamma^f, \omega \to \pi^0\pi^+\pi^-$	6	2458	500544
9	$J/\psi \to \pi^-\rho(2S)^+, \rho(2S)^+ \to \pi^0\pi^+\pi^+\pi^-$	19	1960	502504
10	$J/\psi \to \omega f_0(980), \omega \to \pi^0\pi^+\pi^-, f_0(980) \to \pi^+\pi^-$	14	1959	504463
11	$J/\psi \to \pi^+\rho(2S)^-, \rho(2S)^- \to \pi^0\pi^+\pi^-\pi^-$	16	1883	506346
12	$J/\psi \to \omega f_2(1270), \omega \to \pi^0\pi^+\pi^-, f_2(1270) \to \pi^+\pi^-\gamma^f$	24	1725	508071
13	$J/\psi \to \pi^+\pi^-\omega, \omega \to \pi^0\pi^+\pi^-\gamma^f$	9	1630	509701
14	$J/\psi \to \pi^0\pi^+\pi^+\pi^-\pi^-\gamma^f$	5	1170	510871
15	$J/\psi \to \rho^+a_2^-, \rho^+ \to \pi^0\pi^+, a_2^- \to \rho^0\pi^-$	23	779	511650
16	$J/\psi \to \rho^-a_2^+, \rho^- \to \pi^0\pi^-, a_2^+ \to \rho^0\pi^+$	8	722	512372
17	$J/\psi \to \omega f_2(1270), \omega \to \pi^0\pi^+\pi^-\gamma^f, f_2(1270) \to \pi^+\pi^-$	10	543	512915
18	$J/\psi \to \pi^+b_1^-\gamma^f, b_1^- \to \pi^-\omega$	13	529	513444
19	$J/\psi \to \pi^0\pi^-a_2^+, a_2^+ \to \rho^0\pi^+$	7	491	513935
20	$J/\psi \to \pi^0\pi^+a_2^-, a_2^- \to \rho^0\pi^-$	26	487	514422
21	$J/\psi \to \pi^-b_1^+\gamma^f, b_1^+ \to \pi^+\omega$	40	487	514909
22	$J/\psi \to \pi^+\pi^+\pi^-\pi^-\gamma^F$	33	318	515227
23	$J/\psi \to a_2^0\pi^+\pi^-, a_2^0 \to \pi^-\rho^+$	28	315	515542
24	$J/\psi \to a_2^0\pi^+\pi^-, a_2^0 \to \pi^+\rho^-$	72	313	515855
25	$J/\psi \to \pi^0\pi^+\pi^-f_2(1270), f_2(1270) \to \pi^+\pi^-$	39	230	516085
26	$J/\psi \to \pi^+b_1^-, b_1^- \to \pi^-\omega\gamma^f$	18	219	516304
27	$J/\psi \to \pi^-b_1^+, b_1^+ \to \pi^+\omega\gamma^f$	34	216	516520
28	$J/\psi \to \pi^+\rho^-f_2(1270), \rho^- \to \pi^0\pi^-, f_2(1270) \to \pi^+\pi^-$	25	179	516699
29	$J/\psi \to \pi^0\pi^+a_1^-, a_1^- \to \rho^0\pi^-$	21	175	516874
30	$J/\psi \to \pi^-\rho^+f_2(1270), \rho^+ \to \pi^0\pi^+, f_2(1270) \to \pi^+\pi^-$	46	167	517041
31	$J/\psi \to \pi^0\pi^-a_1^+, a_1^+ \to \rho^0\pi^+$	38	167	517208
32	$J/\psi \to \pi^0\rho^0f_2(1270), \rho^0 \to \pi^+\pi^-, f_2(1270) \to \pi^+\pi^-$	61	130	517338

For $\omega\pi^+\pi^-$

No peaking background

Event Selection

rowNo	cascade decay branch of J/ψ	iCascDcyBrP	nCase	nCCase
1	$J/\psi \to K^+K^-\phi, \phi \to K^+K^-$	0	16493	16493
2	$J/\psi \to \phi f_2^{'}, \phi \to K^+K^-, f_2^{'} \to K^+K^-$	3	9386	25879
3	$J/\psi \to K^+K^+K^-K^-$	1	9282	35161
4	$J/\psi \to K^+K^-f_2^{'}, f_2^{'} \to K^+K^-$	2	6820	41981
5	$J/\psi \to \phi f_0(1710), \phi \to K^+K^-, f_0(1710) \to K^+K^-$	4	189	42170
6	$J/\psi \to \phi f_0(980), \phi \to K^+K^-, f_0(980) \to K^+K^-$	8	124	42294
7	$J/\psi \to f_2(1270)\phi, f_2(1270) \to K^+K^-, \phi \to K^+K^-$	6	116	42410
8	$J/\psi \to \phi f_2^{'}, \phi \to K^+K^-, f_2^{'} \to K^+K^-\gamma^f$	11	46	42456
9	$J/\psi \to K^+K^-f_2^{'}, f_2^{'} \to K^+K^-\gamma^f$	5	32	42488
10	$J/\psi \to K^+K^-\phi\gamma^f, \phi \to K^+K^-$	7	17	42505
11	$J/\psi \to K^+K^+K^-K^-\gamma^f$	13	12	42517
12	$J/\psi \to \eta_c\gamma, \eta_c \to K^+K^-\phi$	12	11	42528
13	$J/\psi \to \phi f_2^{'}, \phi \to K^+K^-\gamma^f, f_2^{'} \to K^+K^-$	15	4	42532
14	$J/\psi \to K^+K^-f_2^{'}\gamma^f, f_2^{'} \to K^+K^-$	9	3	42535
15	$J/\psi \to K^+K^-\phi, \phi \to K^+K^-\gamma^f$	10	3	42538
16	$J/\psi \to K^+K^-f_0(1710), f_0(1710) \to K^+K^-$	16	3	42541
17	$J/\psi \to \eta_c\gamma, \eta_c \to K^+K^+K^-K^-$	14	1	42542
18	$J/\psi \to f_2(1270)\phi, f_2(1270) \to K^+K^-\gamma^f, \phi \to K^+K^-$	17	1	42543
19	$J/\psi \to \phi f_0(980), \phi \to K^+K^-, f_0(980) \to K^+K^-\gamma^f$	18	1	42544
20	$J/\psi \to \phi f_0(1710), \phi \to K^+K^-, f_0(1710) \to K^+K^-\gamma^f$	19	1	42545

For ϕK^+K^-

rowNo	cascade decay branch of J/ψ	iCascDcyBrP	nCase	nCCase
1	$J/\psi \to \pi^+\pi^-\phi, \phi \to K^+K^-$	2	37599	37599
2	$J/\psi \to \pi^+\pi^-K^+K^-$	1	25693	63292
3	$J/\psi \to \phi f_0(980), \phi \to K^+K^-, f_0(980) \to \pi^+\pi^-$	5	7547	70839
4	$J/\psi \to f_2(1270)\phi, f_2(1270) \to \pi^+\pi^-, \phi \to K^+K^-$	3	7302	78141
5	$J/\psi \to \pi^-\bar{K}^*K^+, \bar{K}^* \to \pi^+K^-$	0	6367	84508
6	$J/\psi \to \pi^+K^*K^-, K^* \to \pi^-K^+$	7	6254	90762
7	$J/\psi \to \pi^-K_2^{*0}K^+, K_2^{*0} \to \pi^+K^-$	4	1241	92003
8	$J/\psi \to \pi^+K_2^{*0}K^-, K_2^{*0} \to \pi^-K^+$	8	1146	93149
9	$J/\psi \to \bar{K}^*K_2^{*0}, \bar{K}^* \to \pi^+K^-, K_2^{*0} \to \pi^-K^+$	15	1101	94250
10	$J/\psi \to K^*K_2^{*0}, K^* \to \pi^-K^+, K_2^{*0} \to \pi^+K^-$	6	1095	95345
11	$J/\psi \to \phi f_0(1710), \phi \to K^+K^-, f_0(1710) \to \pi^+\pi^-$	21	480	95825
12	$J/\psi \to \pi^+\pi^-a_0^0, a_0^0 \to K^+K^-$	19	234	96059
13	$J/\psi \to \pi^+\pi^-\phi\gamma^f, \phi \to K^+K^-$	18	210	96269
14	$J/\psi \to K_2^{*0}K_2^{*0}, K_2^{*0} \to \pi^-K^+, K_2^{*0} \to \pi^+K^-$	23	207	96476
15	$J/\psi \to \pi^+\pi^-K^+K^-\gamma^f$	25	174	96650
16	$J/\psi \to \phi f_2^{'}, \phi \to K^+K^-, f_2^{'} \to \pi^+\pi^-$	16	156	96806
17	$J/\psi \to f_2(1270)\phi, f_2(1270) \to \pi^+\pi^-\gamma^f, \phi \to K^+K^-$	20	141	96947
18	$J/\psi \to \bar{K}^*K_0^0, \bar{K}^* \to \pi^+K^-, K_0^0 \to \pi^-K^+$	11	123	97070
19	$J/\psi \to \phi f_0(980), \phi \to K^+K^-, f_0(980) \to \pi^+\pi^-\gamma^f$	9	114	97184
20	$J/\psi \to K^*\bar{K}_0^{*0}, K^* \to \pi^-K^+, \bar{K}_0^{*0} \to \pi^+K^-$	24	108	97292
21	$J/\psi \to K^+\bar{K}_1^{'-}, \bar{K}_1^{'-} \to \pi^-\bar{K}^*$	28	88	97380
22	$J/\psi \to K^-K_1^{'+}, K_1^{'+} \to \pi^+K^*$	13	83	97463
23	$J/\psi \to \pi^-K^+\bar{K}_0^{*0}, \bar{K}_0^{*0} \to \pi^+K^-$	10	54	97517
24	$J/\psi \to \pi^+K^-K_0^0, K_0^0 \to \pi^-K^+$	44	54	97571
25	$J/\psi \to K^+K^-f_2^{'}, f_2^{'} \to \pi^+\pi^-$	35	43	97614
26	$J/\psi \to \pi^-\bar{K}^*K^+, \bar{K}^* \to \pi^+K^-\gamma^f$	33	42	97656
27	$J/\psi \to \pi^-\bar{K}^*K^+\gamma^f, \bar{K}^* \to \pi^+K^-$	14	38	97694
28	$J/\psi \to \pi^+K^*K^-\gamma^f, K^* \to \pi^-K^+$	29	36	97730
29	$J/\psi \to \eta\phi, \eta \to \pi^+\pi^-\gamma^F, \phi \to K^+K^-$	46	33	97763
30	$J/\psi \to \pi^+K^*K^-, K^* \to \pi^-K^+\gamma^f$	26	29	97792
31	$J/\psi \to \pi^+\pi^-K^+K^-\gamma^F$	37	25	97817
32	$J/\psi \to \rho^0a_2^0, \rho^0 \to \pi^+\pi^-, a_2^0 \to K^+K^-$	17	22	97839

For $\phi\pi^+\pi^-$

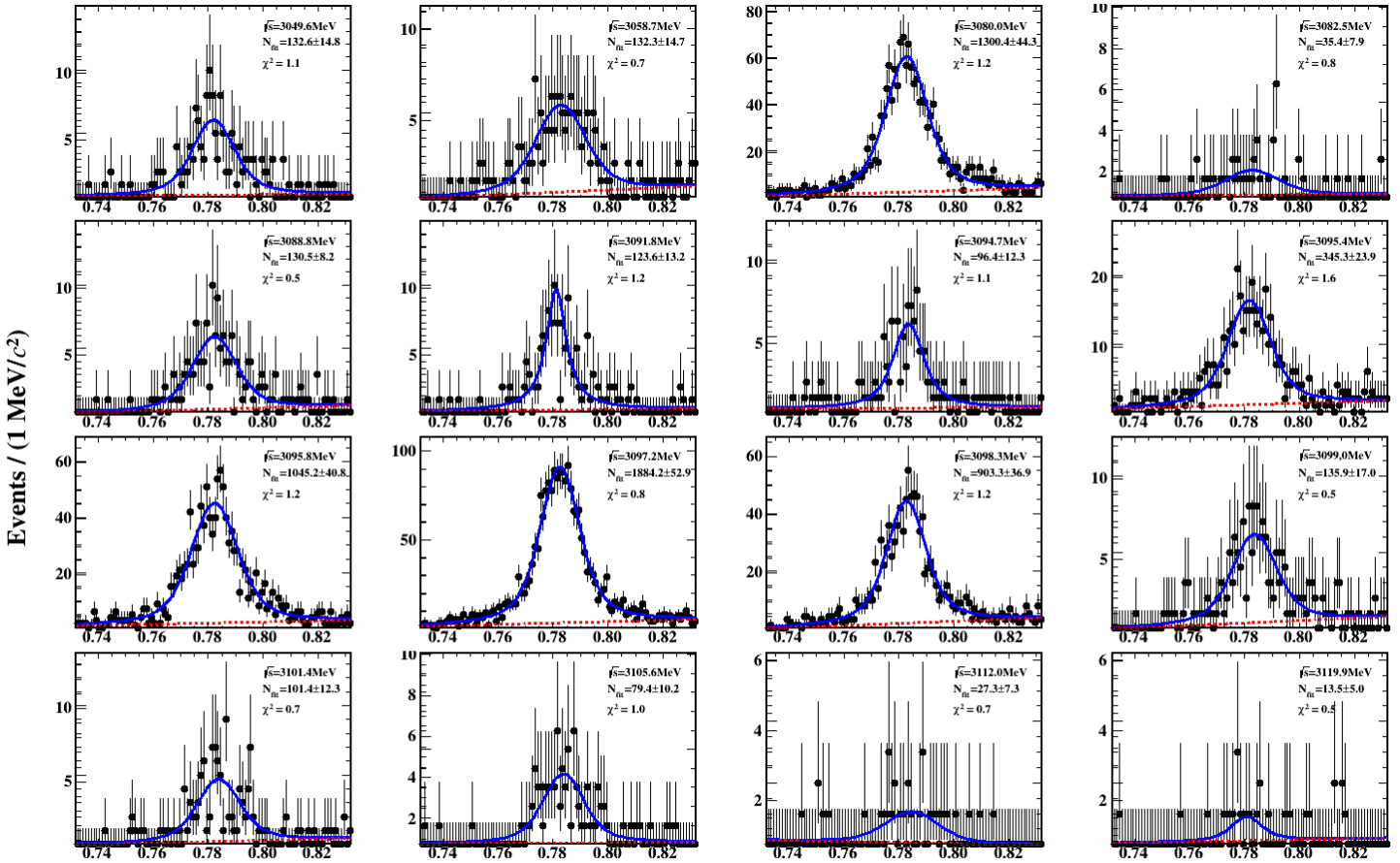
No peaking background

Signal yields

unbinned maximum likelihood fit to $M_{\pi^+\pi^-\pi^0}$ for ωK^+K^- :

Signal shape: Briet-Wigner (blue)

background: 1-st order Chebyshev polynomial (red dash line)



Signal yields

unbinned maximum likelihood fit to $M_{\pi^+\pi^-\pi^0}$ for $\omega\pi^+\pi^-$:

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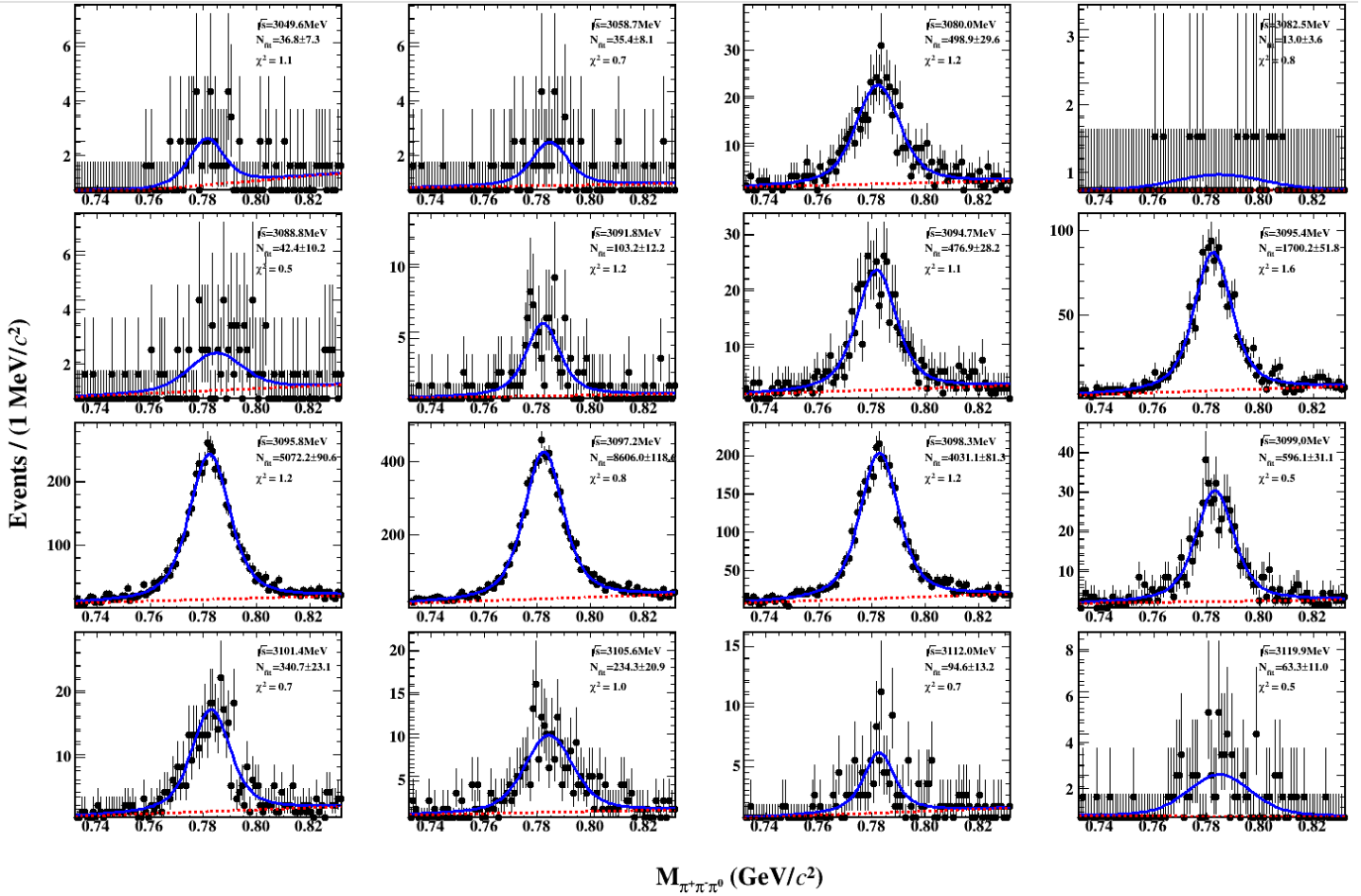
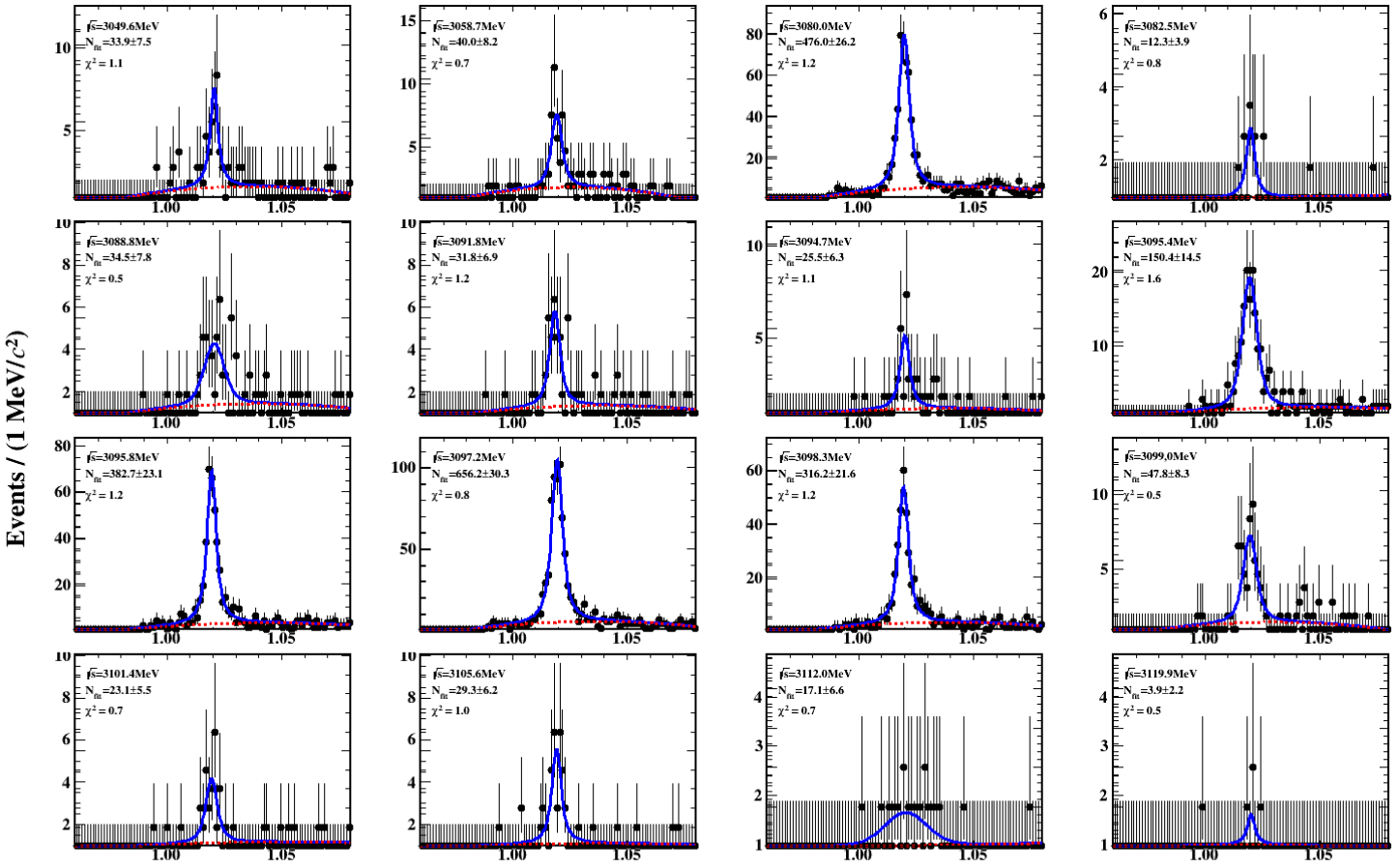


Signal yields

unbinned maximum likelihood fit to $M_{K^+K^-}$ for ϕK^+K^- :

Signal shape: Briet-Wigner (blue)

background: 1-st order Chebyshev polynomial (red dash line)

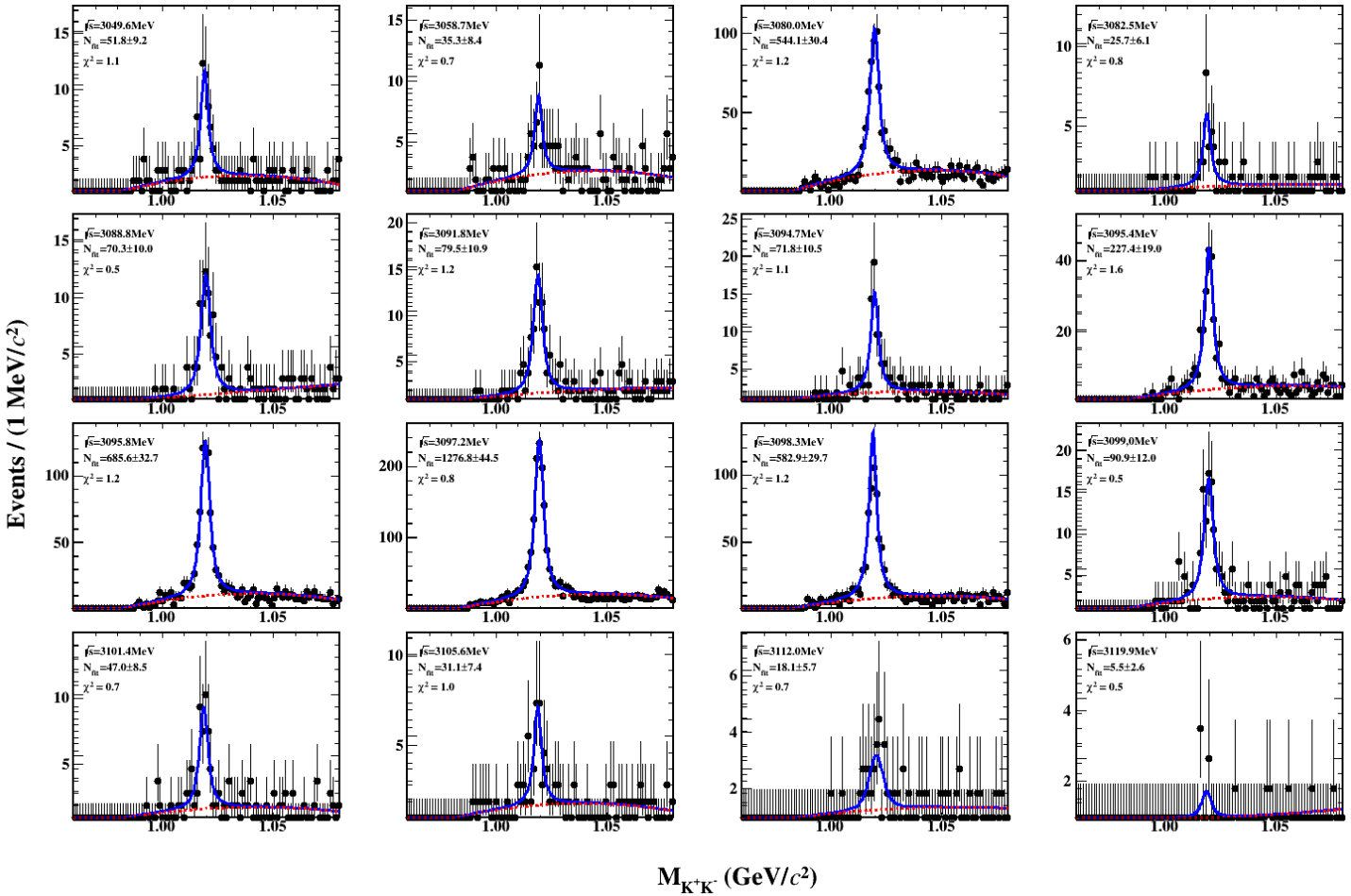


Signal yields

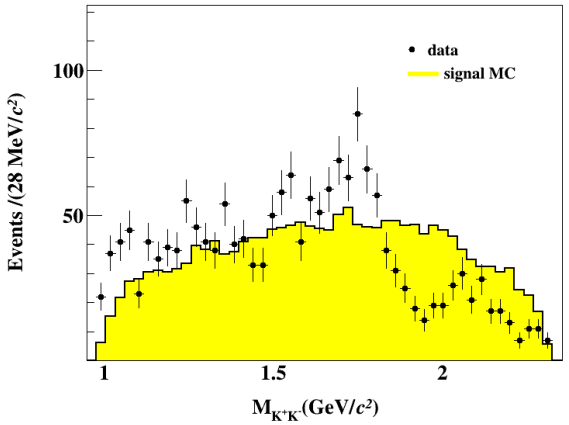
unbinned maximum likelihood fit to $M_{K^+K^-}$ for $\phi\pi^+\pi^-$:

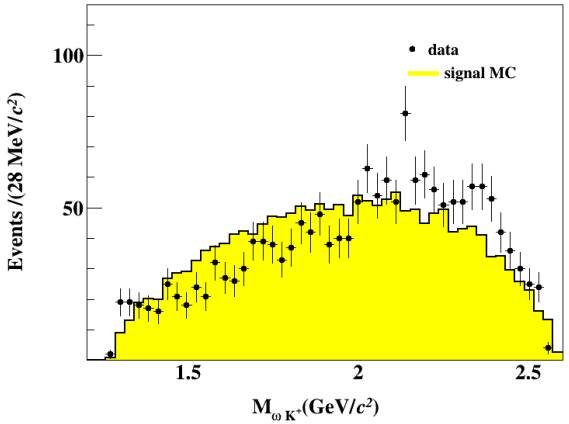
Signal shape: Briet-Wigner (blue)

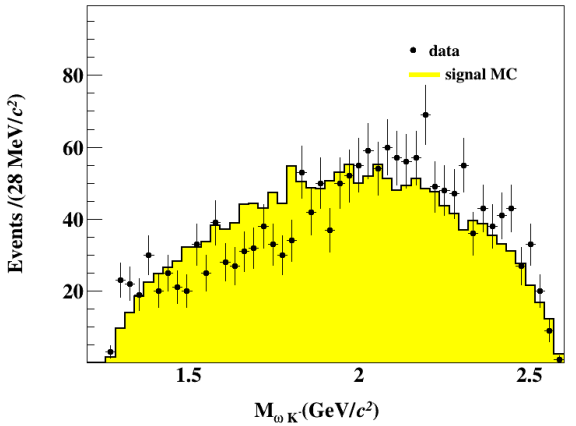
background: 1-st order Chebyshev polynomial (red dash line)



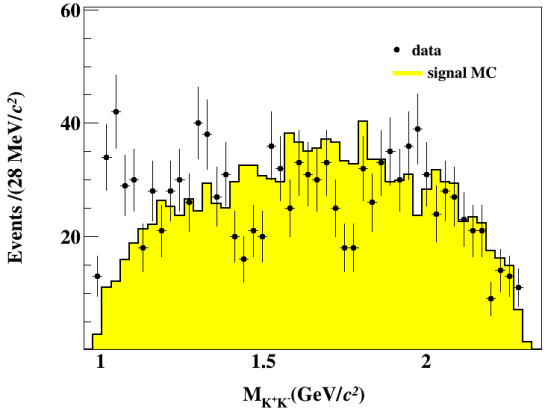
Comparison of data and MC for $\omega K^+ K^-$

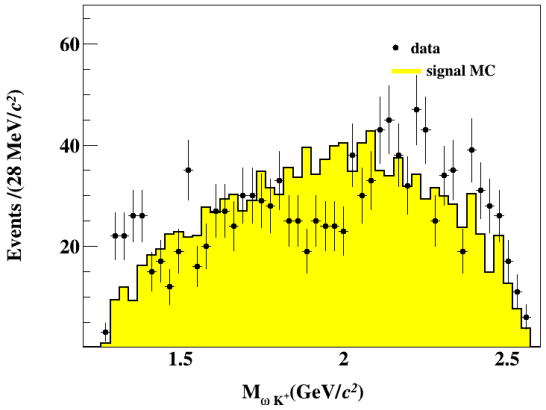


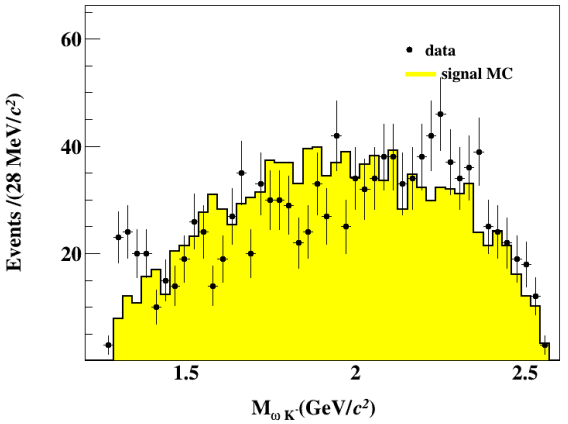




On-Resonance (@3.0972GeV)

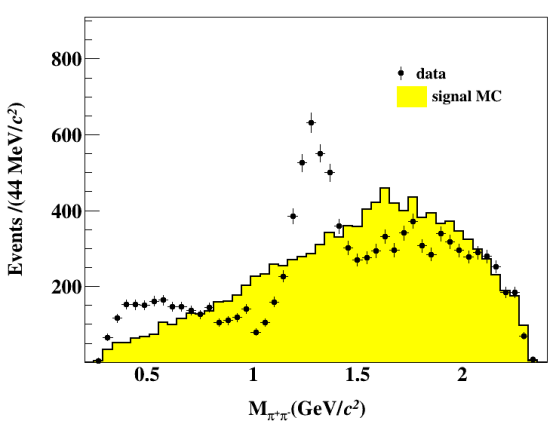


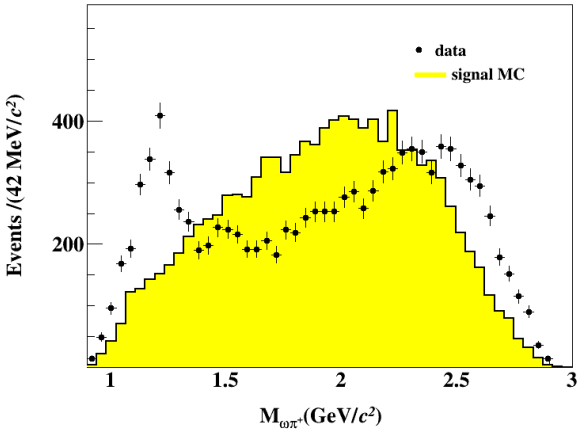


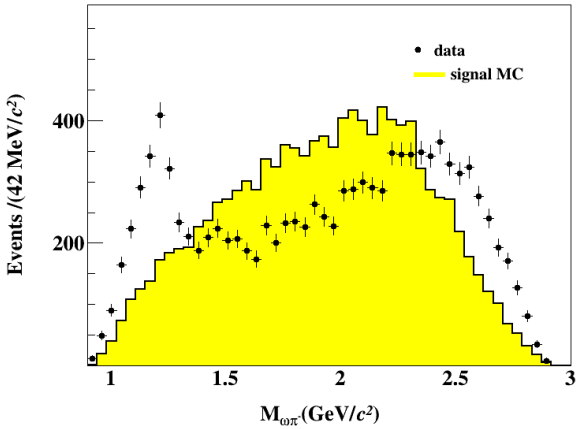


Off-Resonance (@3.0800GeV)

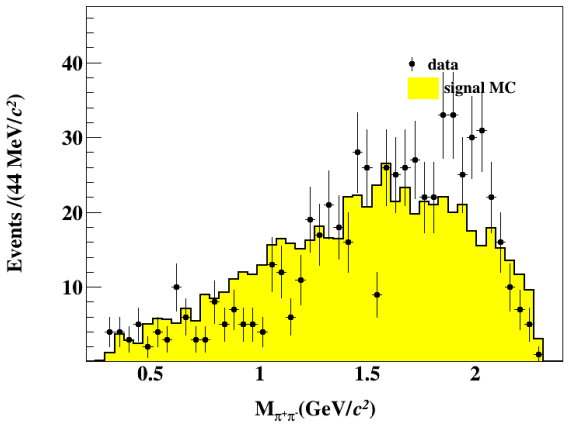
Comparison of data and MC for $\omega\pi^+\pi^-$

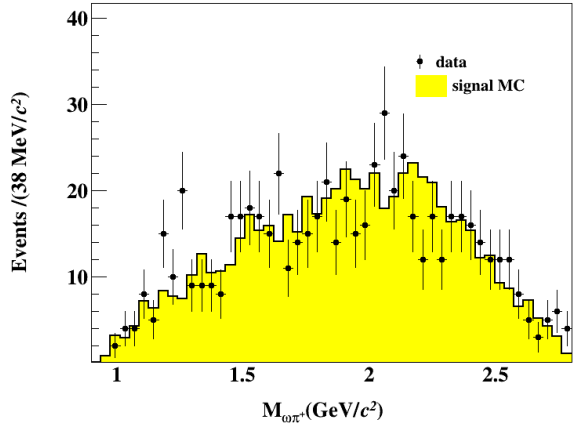


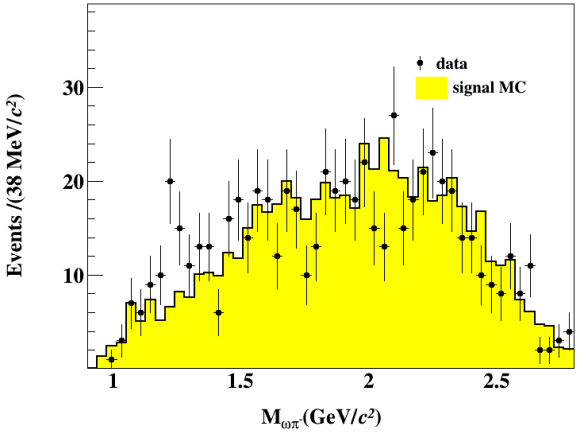




On-Resonance (@3.0972GeV)

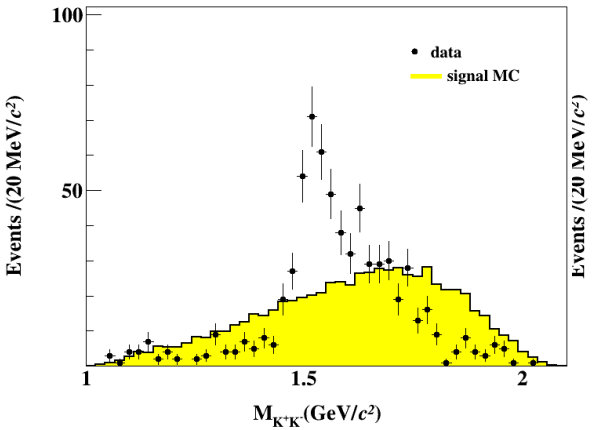


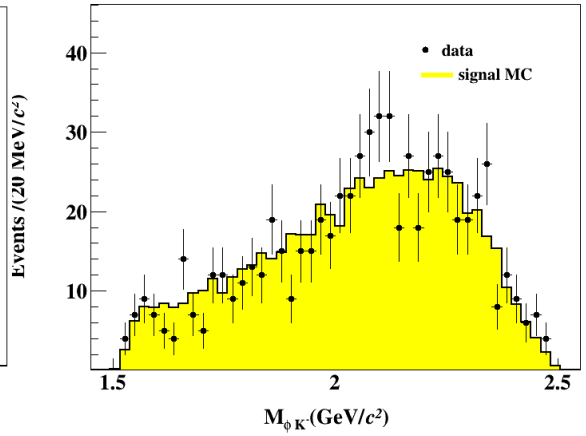


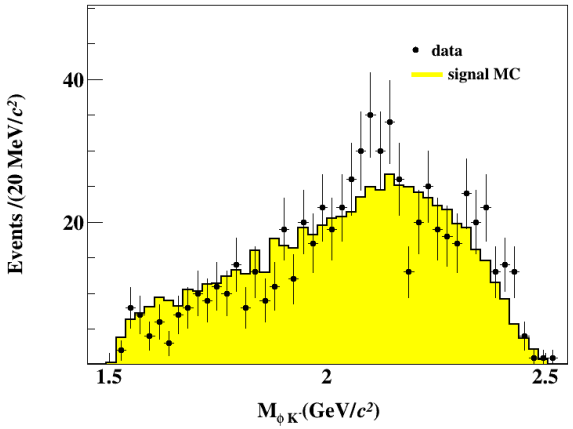


Off-Resonance (@3.0800GeV)

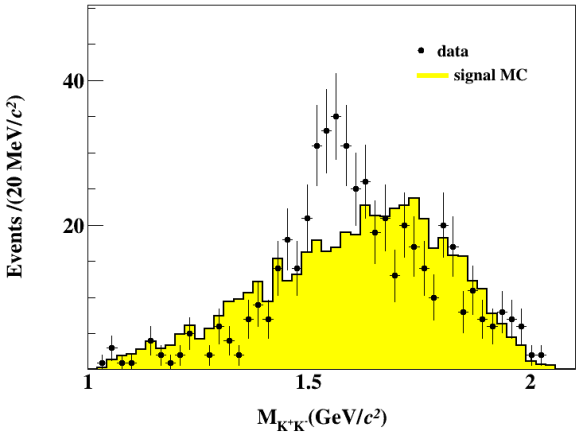
Comparison of data and MC for $\phi K^+ K^-$

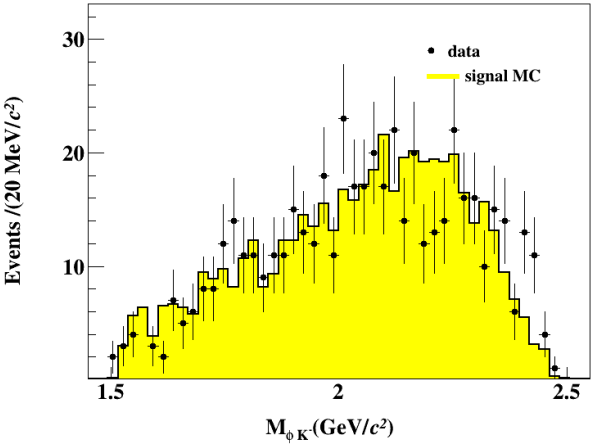


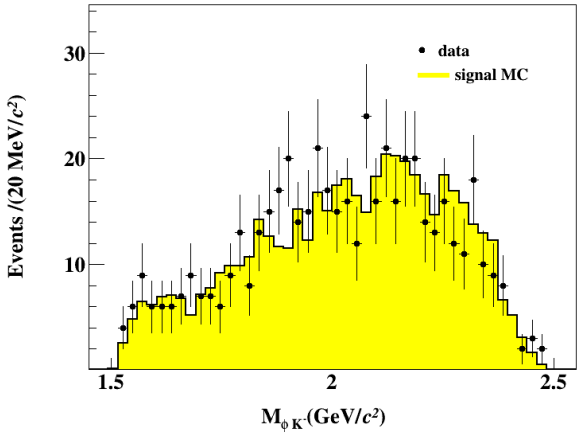




On-Resonance (@3.0972GeV)

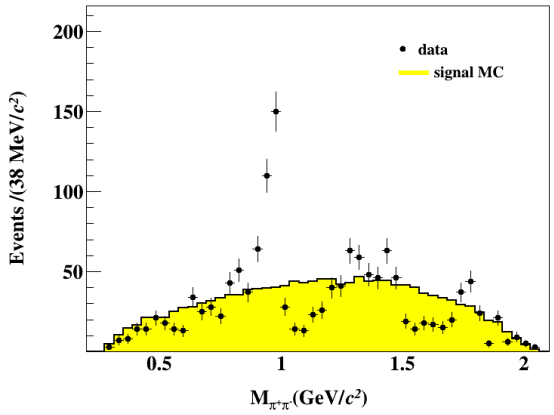


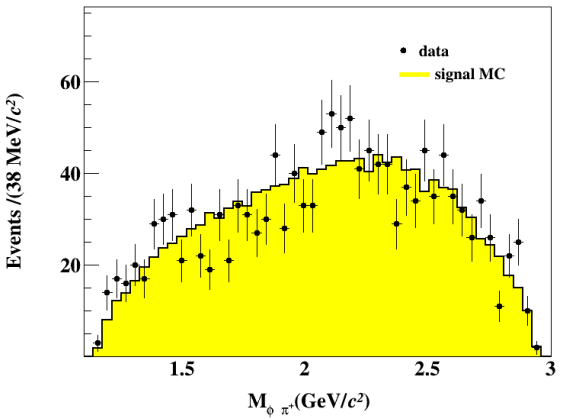


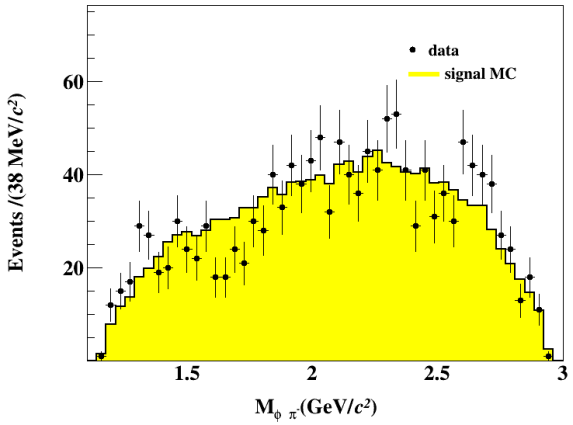


Off-Resonance (@3.0800GeV)

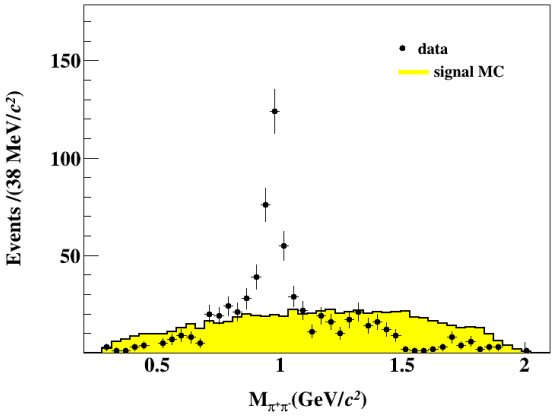
Comparison of data and MC for $\phi\pi^+\pi^-$

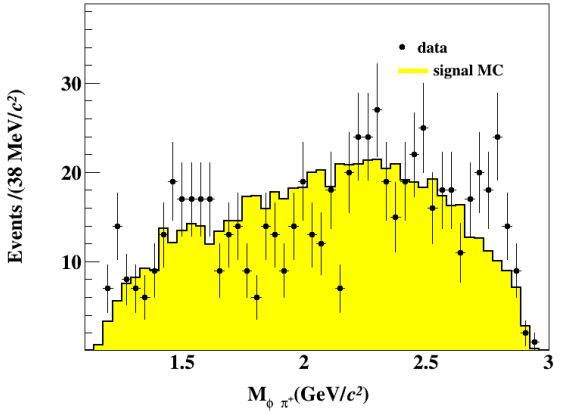


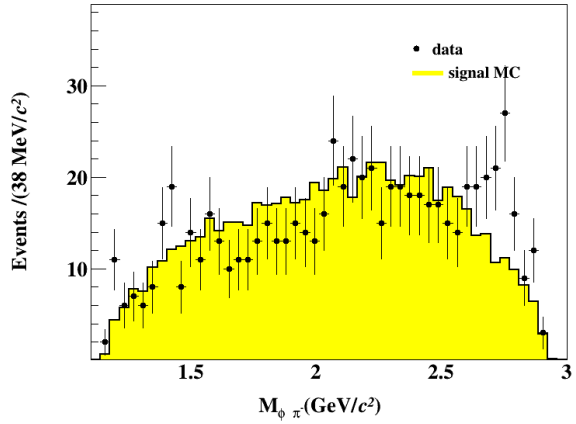




On-Resonance (@3.0972GeV)

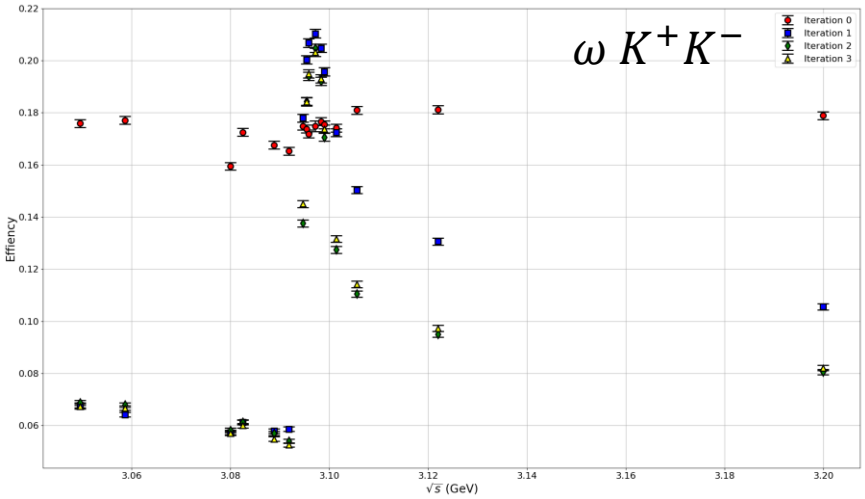


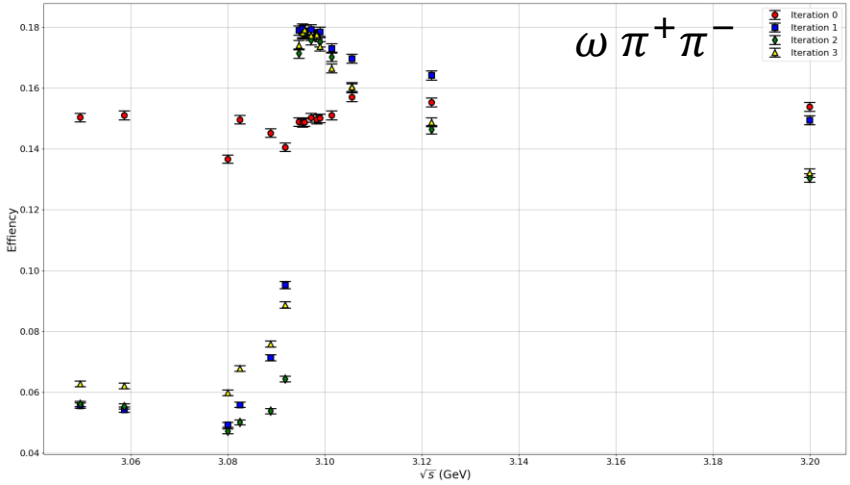




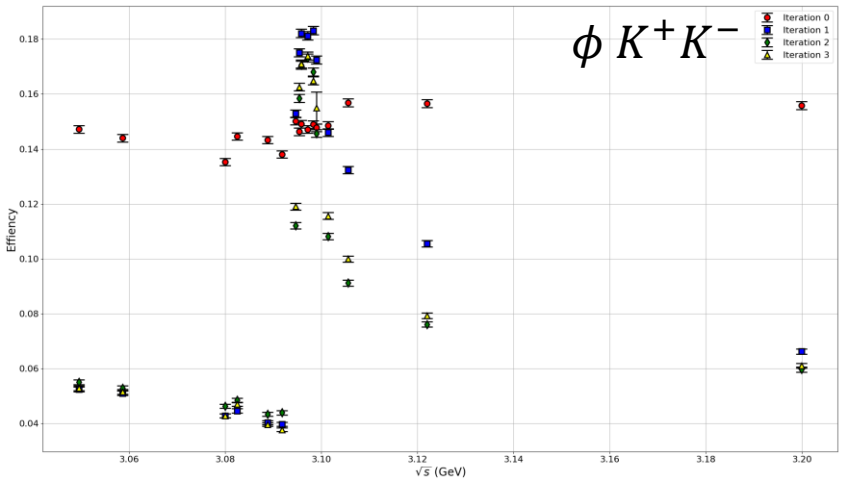
Off-Resonance (@3.0800GeV)

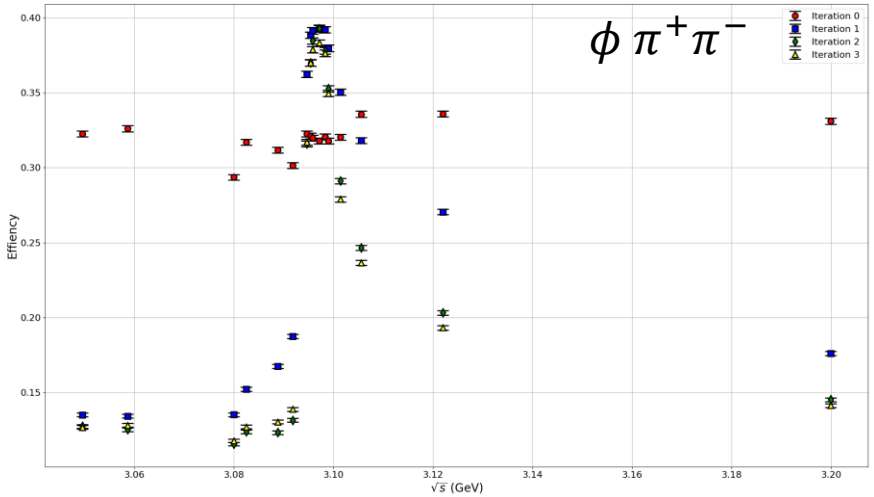
Efficiencies iteration for $\omega\ K^+K^-/\pi^+\pi^-$





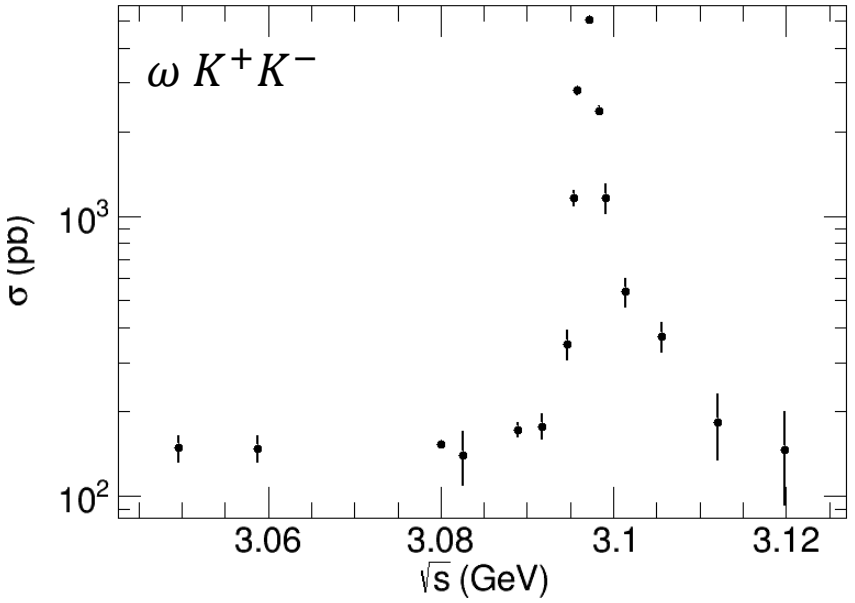
Efficiencies iteration



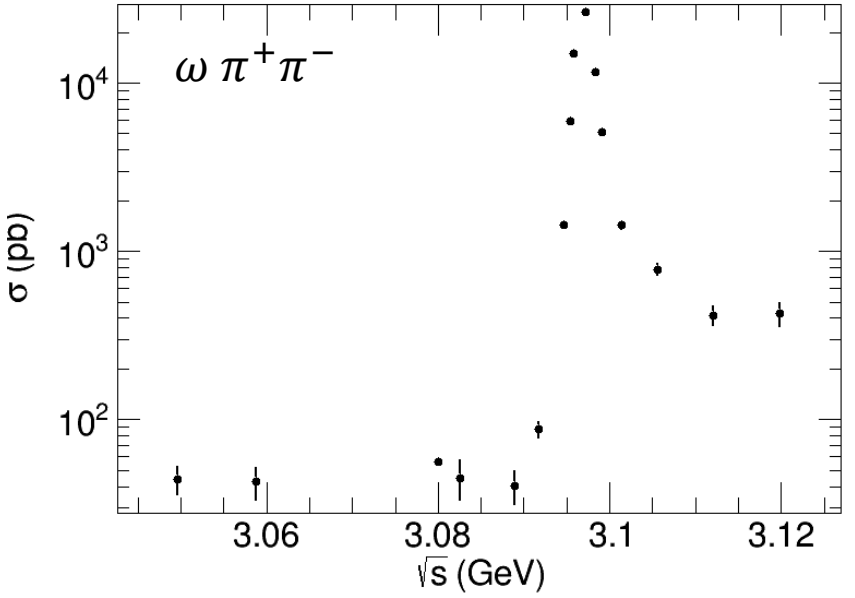


Observed cross sections for $\omega K^+K^-/\pi^+\pi^-$

$\sqrt{s}$ (MeV)	$N_{obs}^{\omega K^+K^-}$	$\epsilon(\%)$	$\mathcal{B}(\mathrm{sub})(\%)$	$\mathcal{L}(\mathrm{pb}^{-1})$	$\sigma_{\mathrm{obs}}^{\omega K^+K^-}$ (pb)
3049.6 ± 0.1	132.6 ± 14.8	6.7 ± 0.1	89.02 ± 0.03	14.92 ± 0.16	148.2 ± 16.6
3058.7 ± 0.1	132.3 ± 14.7	6.7 ± 0.1	89.02 ± 0.03	15.06 ± 0.16	147.8 ± 16.4
3080.0 ± 0.1	1300.4 ± 44.3	5.7 ± 0.1	89.02 ± 0.03	293.27 ± 0.91	153.4 ± 5.2
3082.5 ± 0.1	35.4 ± 7.9	6.0 ± 0.1	89.02 ± 0.03	4.77 ± 0.06	139.1 ± 31.2
3088.8 ± 0.1	130.5 ± 8.1	5.5 ± 0.1	89.02 ± 0.03	15.56 ± 0.17	171.7 ± 10.7
3091.8 ± 0.1	123.6 ± 13.2	5.3 ± 0.1	89.02 ± 0.03	14.91 ± 0.16	177.3 ± 18.9
3094.7 ± 0.1	96.4 ± 12.3	14.5 ± 0.1	89.02 ± 0.03	2.14 ± 0.03	348.6 ± 44.5
3095.4 ± 0.1	345.3 ± 23.9	18.4 ± 0.1	89.02 ± 0.03	1.82 ± 0.02	1159.5 ± 80.3
3095.8 ± 0.1	1045.2 ± 40.8	19.5 ± 0.1	89.02 ± 0.03	2.14 ± 0.03	2820.3 ± 110.0
3097.2 ± 0.1	1884.2 ± 52.9	20.3 ± 0.2	89.02 ± 0.03	2.07 ± 0.03	5036.0 ± 141.4
3098.3 ± 0.1	903.3 ± 36.9	19.3 ± 0.1	89.02 ± 0.03	2.20 ± 0.03	2386.7 ± 97.4
3099.0 ± 0.1	135.9 ± 17.0	17.4 ± 0.1	89.02 ± 0.03	0.76 ± 0.01	1162.3 ± 145.5
3101.4 ± 0.1	101.4 ± 12.3	13.2 ± 0.1	89.02 ± 0.03	1.61 ± 0.02	537.2 ± 65.1
3105.6 ± 0.1	79.4 ± 10.2	11.4 ± 0.1	89.02 ± 0.03	2.11 ± 0.03	371.2 ± 47.8
3112.0 ± 0.1	27.3 ± 7.3	9.7 ± 0.1	89.02 ± 0.03	1.72 ± 0.02	183.2 ± 49.2
3119.9 ± 0.1	13.5 ± 5.0	8.2 ± 0.1	89.02 ± 0.03	1.26 ± 0.02	146.1 ± 53.8

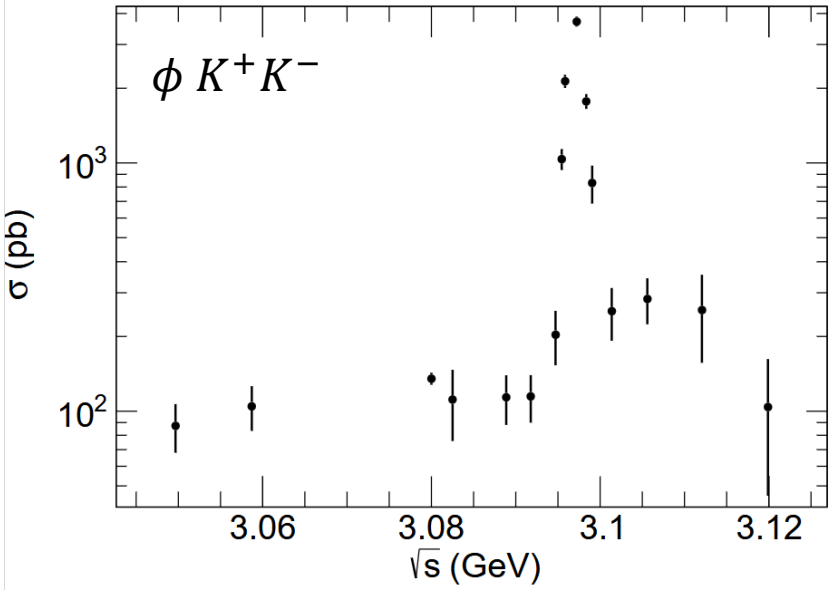


$\sqrt{s}$ (MeV)	$N_{obs}^{\omega\pi^+\pi^-}$	$\epsilon(\%)$	$\mathcal{B}(\mathrm{sub})(\%)$	$\mathcal{L}(\mathrm{pb}^{-1})$	$\sigma_{\mathrm{obs}}^{\omega\pi^+\pi^-}$ (pb)
3049.6 ± 0.1	36.8 ± 7.3	6.3 ± 0.1	89.02 ± 0.03	14.92 ± 0.16	44.1 ± 8.8
3058.7 ± 0.1	36.4 ± 8.1	6.2 ± 0.1	89.02 ± 0.03	15.06 ± 0.16	42.6 ± 9.7
3080.0 ± 0.1	498.9 ± 29.6	6.0 ± 0.1	89.02 ± 0.03	293.27 ± 0.91	56.1 ± 3.3
3082.5 ± 0.1	13.0 ± 3.6	6.8 ± 0.1	89.02 ± 0.03	4.77 ± 0.06	45.1 ± 12.5
3088.8 ± 0.1	42.4 ± 10.2	7.6 ± 0.1	89.02 ± 0.03	15.56 ± 0.17	40.4 ± 9.7
3091.8 ± 0.1	103.2 ± 12.2	8.9 ± 0.1	89.02 ± 0.03	14.91 ± 0.16	87.6 ± 10.4
3094.7 ± 0.1	476.9 ± 28.3	17.4 ± 0.2	89.02 ± 0.03	2.14 ± 0.03	1434.8 ± 85.0
3095.4 ± 0.1	1700.2 ± 51.8	17.8 ± 0.2	89.02 ± 0.03	1.82 ± 0.02	5899.0 ± 179.6
3095.8 ± 0.1	5072.2 ± 90.6	17.9 ± 0.2	89.02 ± 0.03	2.14 ± 0.03	14883.6 ± 266.0
3097.2 ± 0.1	8606.0 ± 118.6	17.7 ± 0.2	89.02 ± 0.03	2.07 ± 0.03	26342.0 ± 363.1
3098.3 ± 0.1	4031.1 ± 81.3	17.8 ± 0.2	89.02 ± 0.03	2.20 ± 0.03	11573.1 ± 233.4
3099.0 ± 0.1	596.1 ± 31.1	17.4 ± 0.2	89.02 ± 0.03	0.76 ± 0.01	5095.1 ± 265.7
3101.4 ± 0.1	340.7 ± 23.1	16.6 ± 0.2	89.02 ± 0.03	1.61 ± 0.02	1425.5 ± 96.5
3105.6 ± 0.1	234.3 ± 20.9	16.0 ± 0.1	89.02 ± 0.03	2.11 ± 0.03	779.0 ± 69.6
3112.0 ± 0.1	94.6 ± 13.2	14.9 ± 0.1	89.02 ± 0.03	1.72 ± 0.02	414.9 ± 58.1
3119.9 ± 0.1	63.3 ± 11.0	13.2 ± 0.1	89.02 ± 0.03	1.26 ± 0.02	425.9 ± 74.0

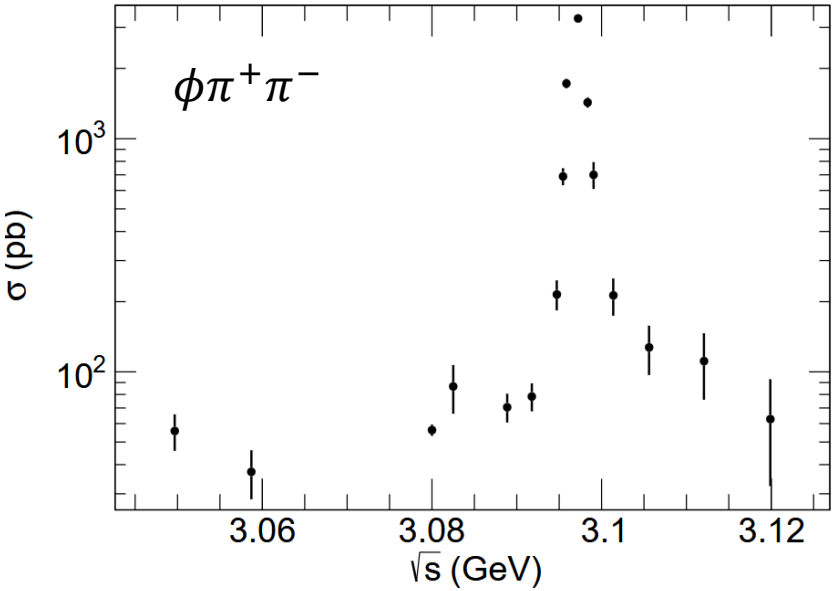


Observed cross sections for $\phi\, K^+K^-/\pi^+\pi^-$

$\sqrt{s}$ (MeV)	$N_{obs}^{\phi K^+K^-}$	$\epsilon(\%)$	$\mathcal{B}$(sub)(%)	$\mathcal{L}$(pb^{-1})	$\sigma_{\rm obs}^{\phi K^+K^-}$ (pb)
3049.6 ± 0.1	33.9 ± 7.5	5.3 ± 0.1	49.1 ± 0.5	14.92 ± 0.16	87.4 ± 19.4
3058.7 ± 0.1	40.0 ± 8.2	5.2 ± 0.1	49.1 ± 0.5	15.06 ± 0.16	104.7 ± 21.4
3080.0 ± 0.1	476.0 ± 26.3	4.3 ± 0.1	49.1 ± 0.5	293.27 ± 0.91	135.3 ± 7.5
3082.5 ± 0.1	12.3 ± 3.9	4.7 ± 0.1	49.1 ± 0.5	4.77 ± 0.06	111.3 ± 35.5
3088.8 ± 0.1	34.5 ± 7.8	4.0 ± 0.1	49.1 ± 0.5	15.56 ± 0.17	113.8 ± 25.8
3091.8 ± 0.1	31.8 ± 6.9	4.0 ± 0.1	49.1 ± 0.5	14.91 ± 0.16	114.8 ± 24.9
3094.7 ± 0.1	25.5 ± 6.3	11.9 ± 0.1	49.1 ± 0.5	2.14 ± 0.03	203.3 ± 50.3
3095.4 ± 0.1	150.4 ± 14.5	16.2 ± 0.1	49.1 ± 0.5	1.82 ± 0.02	1037.1 ± 100.3
3095.8 ± 0.1	382.7 ± 23.1	17.1 ± 0.1	49.1 ± 0.5	2.14 ± 0.03	2135.2 ± 129.1
3097.2 ± 0.1	656.2 ± 30.3	17.3 ± 0.2	49.1 ± 0.5	2.07 ± 0.03	3714.5 ± 171.6
3098.3 ± 0.1	316.2 ± 21.6	16.5 ± 0.1	49.1 ± 0.5	2.20 ± 0.03	1722.4 ± 121.1
3099.0 ± 0.1	47.8 ± 8.3	15.5 ± 0.1	49.1 ± 0.5	0.76 ± 0.01	830.6 ± 145.5
3101.4 ± 0.1	23.1 ± 5.5	11.6 ± 0.1	49.1 ± 0.5	1.61 ± 0.02	252.8 ± 144.5
3105.6 ± 0.1	29.3 ± 6.2	10.0 ± 0.1	49.1 ± 0.5	2.11 ± 0.03	283.6 ± 59.6
3112.0 ± 0.1	17.1 ± 6.6	7.9 ± 0.1	49.1 ± 0.5	1.72 ± 0.02	255.6 ± 98.8
3119.9 ± 0.1	3.9 ± 2.2	6.1 ± 0.1	49.1 ± 0.5	1.26 ± 0.02	103.9 ± 58.2



$\sqrt{s}$ (MeV)	$N_{obs}^{\phi\pi^+\pi^-}$	$\epsilon(\%)$	$\mathcal{B}$(sub)(%)	$\mathcal{L}$(pb^{-1})	$\sigma_{\rm obs}^{\phi\pi^+\pi^-}$ (pb)
3049.6 ± 0.1	51.8 ± 9.2	12.7 ± 0.1	49.1 ± 0.5	14.92 ± 0.16	55.8 ± 9.9
3058.7 ± 0.1	35.3 ± 8.4	12.8 ± 0.1	49.1 ± 0.5	15.06 ± 0.16	37.2 ± 8.8
3080.0 ± 0.1	544.0 ± 30.4	11.8 ± 0.1	49.1 ± 0.5	293.27 ± 0.91	56.3 ± 3.1
3082.5 ± 0.1	25.7 ± 6.1	12.7 ± 0.1	49.1 ± 0.5	4.77 ± 0.06	86.6 ± 20.4
3088.8 ± 0.1	70.3 ± 9.9	13.0 ± 0.1	49.1 ± 0.5	15.56 ± 0.17	70.6 ± 9.9
3091.8 ± 0.1	79.8 ± 10.9	13.9 ± 0.2	49.1 ± 0.5	14.91 ± 0.16	78.5 ± 10.8
3094.7 ± 0.1	71.8 ± 10.5	31.7 ± 0.2	49.1 ± 0.5	2.14 ± 0.03	215.1 ± 31.5
3095.4 ± 0.1	227.4 ± 19.0	37.0 ± 0.2	49.1 ± 0.5	1.82 ± 0.02	689.3 ± 57.6
3095.8 ± 0.1	685.6 ± 32.7	37.9 ± 0.2	49.1 ± 0.5	2.14 ± 0.03	1726.4 ± 82.4
3097.2 ± 0.1	1276.8 ± 44.5	38.3 ± 0.2	49.1 ± 0.5	2.07 ± 0.03	3278.9 ± 114.4
3098.3 ± 0.1	582.9 ± 29.7	37.6 ± 0.2	49.1 ± 0.5	2.20 ± 0.03	1431.5 ± 73.1
3099.0 ± 0.1	90.9 ± 12.0	34.9 ± 0.2	49.1 ± 0.5	0.76 ± 0.01	700.9 ± 92.4
3101.4 ± 0.1	47.0 ± 8.5	27.9 ± 0.2	49.1 ± 0.5	1.61 ± 0.02	212.7 ± 38.6
3105.6 ± 0.1	31.1 ± 7.4	23.6 ± 0.2	49.1 ± 0.5	2.11 ± 0.03	127.4 ± 30.4
3112.0 ± 0.1	18.1 ± 5.7	19.3 ± 0.2	49.1 ± 0.5	1.72 ± 0.02	111.2 ± 35.2
3119.9 ± 0.1	5.5 ± 2.6	14.1 ± 0.1	49.1 ± 0.5	1.26 ± 0.02	62.7 ± 30.3



Fitting formula of observed cross sections

Fitting the observed cross section with taking into account the ISR and the beam energy spread

$$\sigma_{\text{obs}}(\sqrt{s}) = \int_{\sqrt{s}-5\delta}^{\sqrt{s}+5\delta} G(\sqrt{s}'-\sqrt{s},\delta)d\sqrt{s}' \int_{0}^{1-\frac{s_{\text{min}}}{s}} dx \cdot F_{ISR}(x,s) \cdot \sigma_{\text{born}}(s(1-x))$$

$\sigma_{born}(s)$ is the Born cross sections.

$G(\sqrt{s}' - \sqrt{s}, \delta)$ is the normal distribution to describe energy spread.

F_{ISR} is the ISR function by Kuraev and Fadin.

s is the square of energy, and $\sqrt{s}$ is the center of mass system.

The details can be found in: Doc-1552 or Doc-1569

χ^2 construction function

The χ^2 is constructed by this formula:

$$\chi^2 = (\Delta\vec{X})^T (M^{-1})(\Delta\vec{X})$$

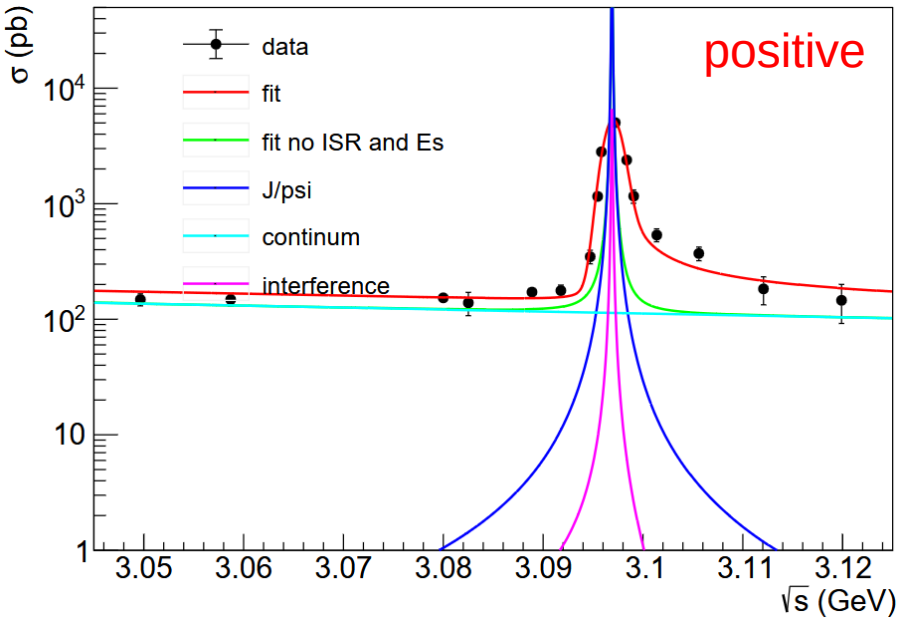
The $\Delta\bar{X}_i = y_i^{obs} - y_i^{expect}(\bar{\theta})$, y_i^{obs} is the measured Born cross sections, $y_i^{expect}(\bar{\theta})$ is the expected value calculated from the cross-section lineshape for each CM energy and $\bar{\theta}$ is the fit parameters. The M is the covariance matrix, where the diagonal elements of M are the total uncertainties calculated with:

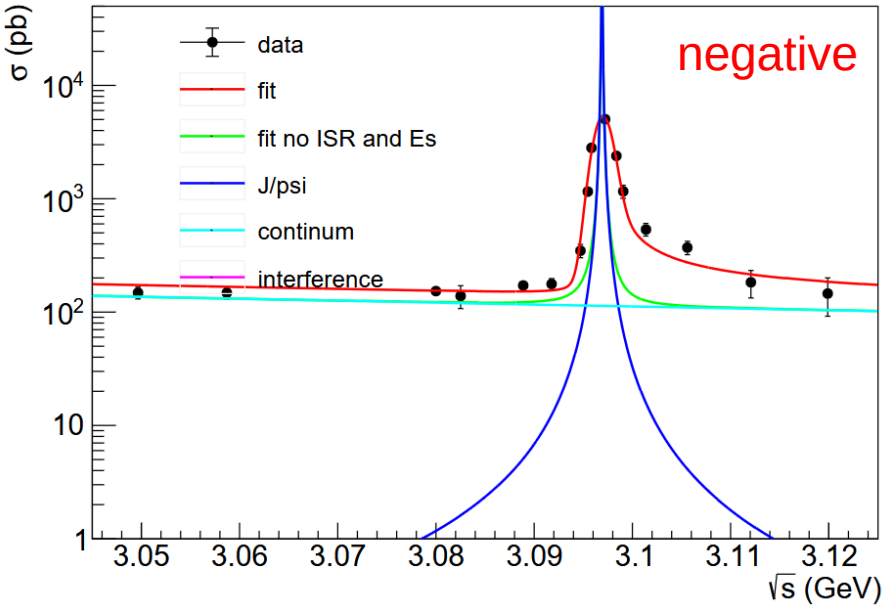
$$M_{ii} = M_{\mathrm{stat},i}^{\sqrt{s}} + M_{\mathrm{sys-cor},i} + M_{\mathrm{sys-uncor},i},$$

Where the $M_{\mathrm{stat},i}^{\sqrt{s}}$ is the statistical uncertainties, $M_{\mathrm{sys-cor},i}$ is the correlated system uncertainties and $M_{\mathrm{sys-uncor},i}$ is the un-correlated system uncertainties.

The details can be found in: Doc-1552 or Doc-1569

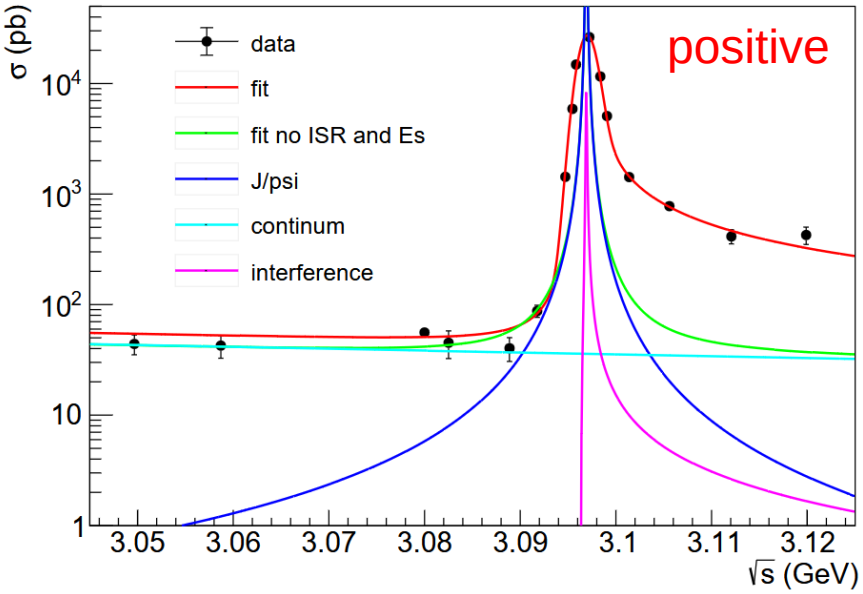
Results of fit to cross sections for $e^+e^- \to \omega K^+K^-$

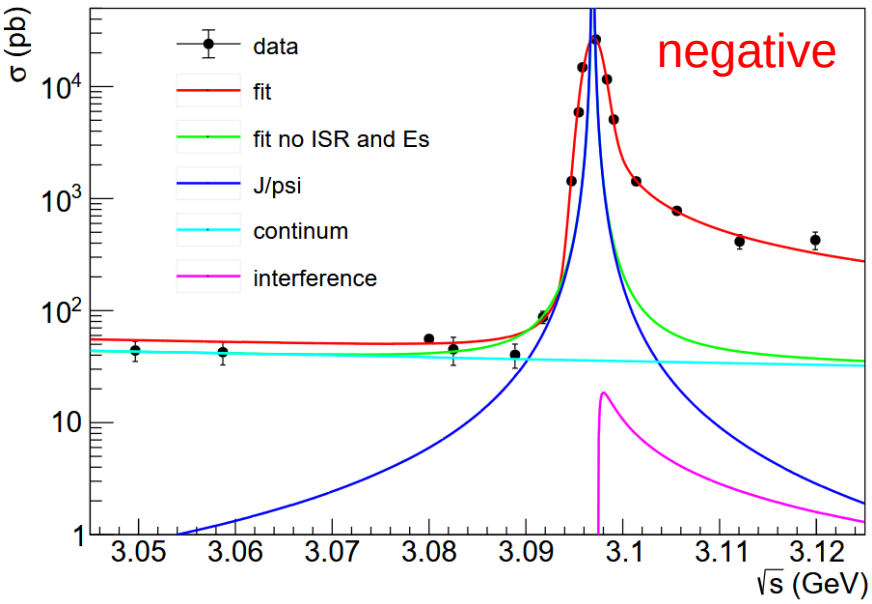




Solution	φ (°)	δ (MeV)	A	$\mathcal{B}(J/\psi \to \omega K^+K^-)$ (10^{-3})	χ^2/ndf
Positive	126.7 ± 9.9	0.89 ± 0.03	1.68 ± 0.25	1.46 ± 0.05	24.4/12
Negative	-125.1 ± 10.7	0.89 ± 0.03	1.75 ± 0.26	1.63 ± 0.05	24.4/12

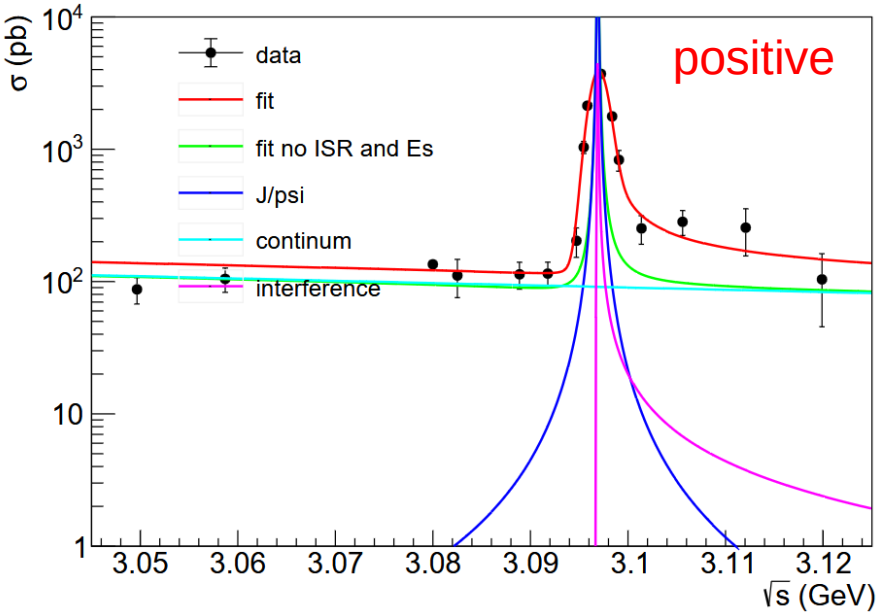
Results of fit to cross sections for $e^+e^- \to \omega\pi^+\pi^-$

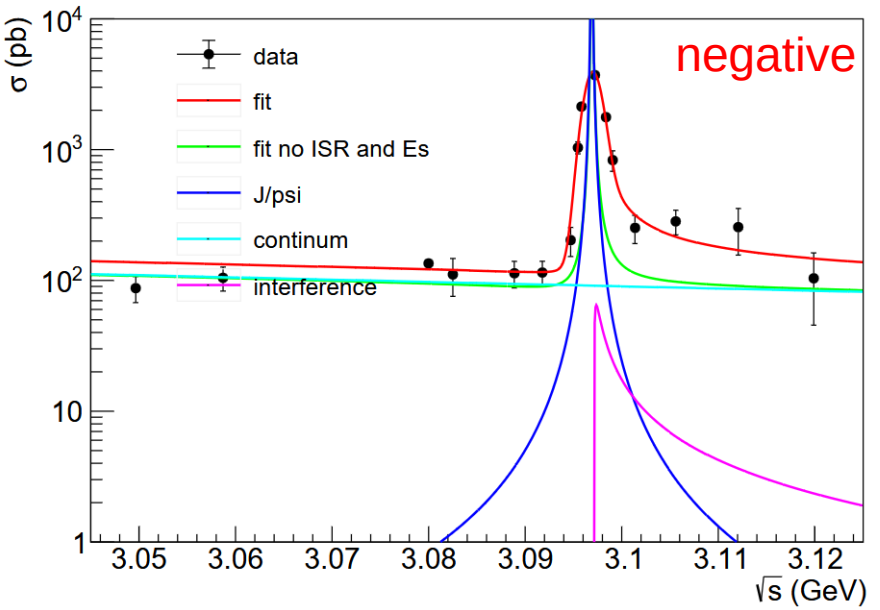




Solution	φ (°)	δ (MeV)	A	$\mathcal{B}(J/\psi \to \omega\pi^+\pi^-)$ (10^{-3})	χ^2/ndf
Positive	95.2 ± 9.5	0.90 ± 0.02	5.66 ± 0.46	8.06 ± 0.18	24.4/12
Negative	-95.1 ± 9.4	0.90 ± 0.02	5.73 ± 0.46	8.28 ± 0.18	24.4/12

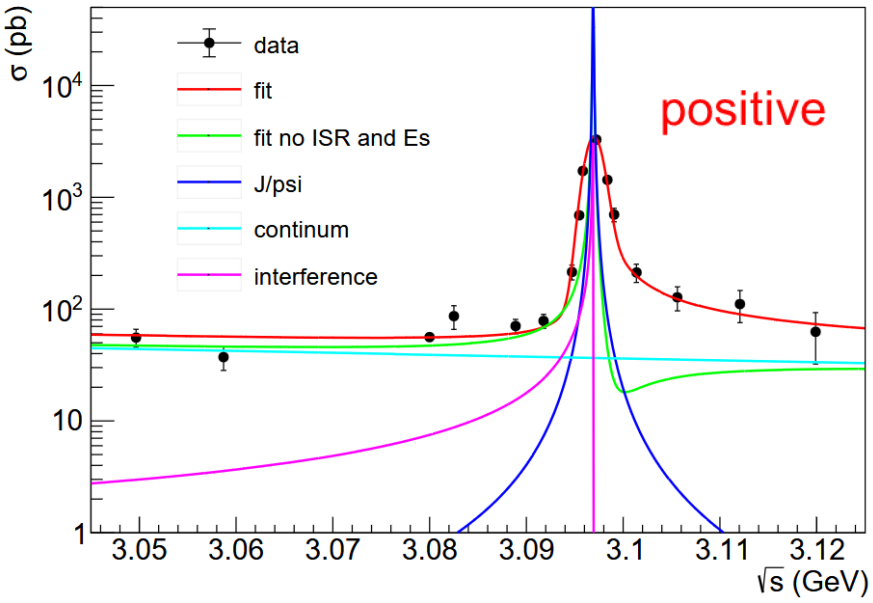
Results of fit to cross sections for $e^+e^- \to \phi K^+K^-$

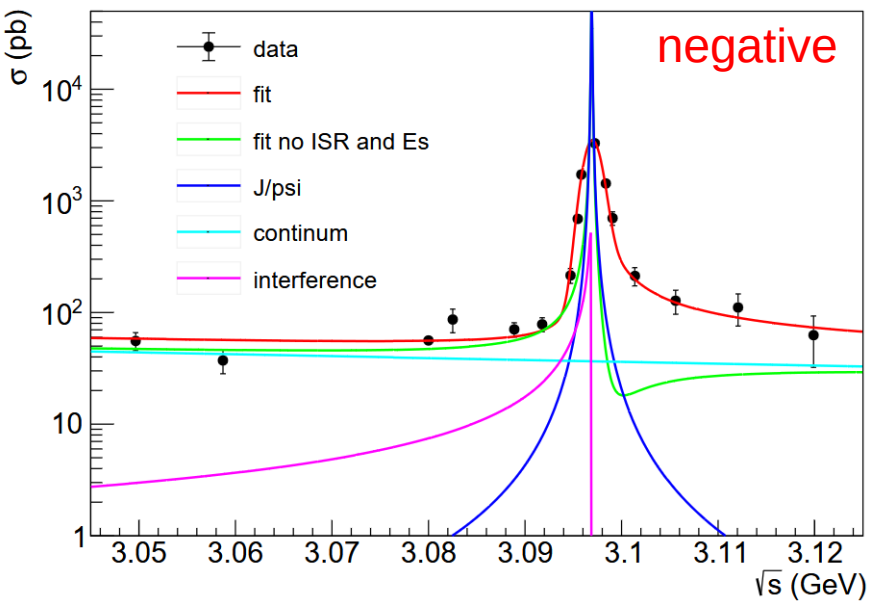




Solution	φ (°)	δ (MeV)	A	$\mathcal{B}(J/\psi \to \phi K^+K^-)$ (10^{-4})	χ^2/ndf
Positive	119.9 ± 15.2	0.89 ± 0.04	1.45 ± 0.39	10.66 ± 0.45	20.5/12
Negative	-118.4 ± 14.8	0.89 ± 0.04	1.52 ± 0.37	11.97 ± 0.48	20.5/12

Results of fit to cross sections for $e^+e^- \to \phi\pi^+\pi^-$





Solution	φ (°)	δ (MeV)	A	$\mathcal{B}(J/\psi \to \phi\pi^+\pi^-)$ (10^{-4})	χ^2/ndf
Positive	150.5 ± 22.0	0.87 ± 0.03	2.75 ± 0.35	9.66 ± 0.40	16.6/12
Negative	-149.1 ± 21.8	0.87 ± 0.03	2.79 ± 0.35	10.22 ± 0.38	16.6/12

Results comparison

Experiment	$\mathcal{B}(J/\psi \to \omega K^+K^-)$ (10^{-3})	$\mathcal{B}(J/\psi \to \omega\pi^+\pi^+)$ (10^{-3})
DM2	...	7.0 ± 1.6
KEDR	$1.52 \pm 0.30 \pm 0.01$	$10.6 \pm 1.2 \pm 0.1$
PDG	1.52 ± 0.31	8.5 ± 1.0
This work	1.46 ± 0.05	8.06 ± 0.18
	1.63 ± 0.05	8.28 ± 0.18

Experiment	$\mathcal{B}(J/\psi \to \phi K^+K^-)$ (10^{-4})	$\mathcal{B}(J/\psi \to \phi\pi^+\pi^-)$ (10^{-4})
BABAR	$8.32 \pm 1.12 \pm 0.09$	$8.10 \pm 0.89 \pm 0.09$
BES	...	$10.9 \pm 0.2 \pm 1.3$
PDG	8.3 ± 1.1	9.4 ± 1.5
This work	10.66 ± 0.45	9.66 ± 0.40
	11.97 ± 0.48	10.22 ± 0.38

Summary

1: By analyzing the data taken around J/ψ ,we measured the cross sections of $e^+e^- \to \omega/\phi\ K^+K^-/\pi^+\pi^-$

2: The phase angles between the strong and electromagnetic amplitudes in $e^+e^- \to \omega/\phi\ K^+K^-/\pi^+\pi^-$ are extracted from the fits to these cross sections.

3: The branching fractions of $J/\psi \to \omega/\phi\ K^+K^-/\pi^+\pi^-$ are also obtained. The branching fractions of $J/\psi \to \omega\ K^+K^-/\pi^+\pi^-$ and $J/\psi \to\ \phi\,\pi^+\pi^-$ are consistent with PDG within 1σ. The branching fractions of $J/\psi \to\ \phi\,K^+K^-$ is consistent with PDG in 2σ (postive) and 3σ (negative).

Next to do

1:TFPWA to obtain more reliable efficiencies

2:Systematic uncertainties

Thanks For Your Attention

Backup slides

$$\sigma_{\text{born}}(s) = |A_{\text{cont}} + A_\gamma + A_{3g}|^2$$

$$= \sigma_0(\mathcal{B}) \left| \frac{1}{s} + \frac{3/\alpha\sqrt{\Gamma_{ee}\Gamma_{ee}/s}}{(s - M^2) + iM\Gamma} \cdot \left(1 + Ae^{i\varphi}\right) \right|^2 \cdot q(s)$$

M and Γ are the mass and total width of charmonium

And $\sigma_0(B)$ is expressed by

$$\sigma_0(\mathcal{B}) = \frac{4\pi\alpha^2}{3s} \cdot \frac{\mathcal{B}(J/\psi \to K_S^0 K^+ \pi^-)}{\mathcal{B}(J/\psi \to ee)} \cdot \frac{M^4}{|1 + Ae^{i\varphi}|^2 \cdot q\,(M^2)}$$