中国科学技术大学
University of Science and Technology of China

Further Selection Criteria in

$$J/\psi \to \gamma\eta_c \to \gamma\omega\phi$$

Preliminary Selection

- Charged track selection:
  - ✓ $|V_z| \leq 10cm$
  - ✓ $|V_r| \leq 1cm$
  - ✓ $|Cos(\theta)| \leq 0.93$
  - ✓ $N_{good} = 4 \;\&\&\; Q_{total} = 0$
- Photon selection:
  - ✓ $Barrel: (|Cos(\theta)| \leq 0.8) \;\&\&\; E_\gamma \geq 25MeV$
  - ✓ $Endcap: (0.86 \leq |Cos(\theta)| \leq 0.92) \;\&\&\; E_\gamma \geq 50MeV$
  - ✓ $Time\ of\ flight: 0ns \leq TDC \leq 700ns$
  - ✓ $Angle\ with\ the\ nearest\ track: \theta \geq 10^o$
  - ✓ $N_\gamma \geq 3$
- Particle identify:
  - ✓ $P(\pi) > P(K) \;\&\&\; P(\pi) > P(p)$
  - ✓ $P(K) > P(\pi) \;\&\&\; P(K) > P(p)$

Preliminary Selection

- Kinematic fit:
  - ✓ $ecms(GeV) = (0.034,0,0,3.097)$
  - ✓ $\chi^2 \leq 200$

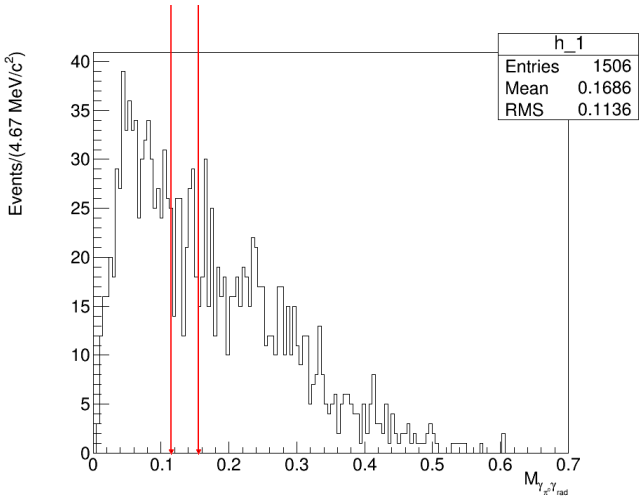
- $\pi^0\ reconstruction$:
  - ✓ $ecms(GeV) = (0.034,0,0,3.097)$
  - ✓ $m_{\pi^0}(GeV) = 0.135(by\ iterating\ 2-gamma\ combinations)$
  - ✓ $\chi^2 \leq 200$

Cut1 two mass window

- $0.742 \leq M_{\omega} \leq 0.822\ GeV/c^2$
- $1.005 \leq M_{\phi} \leq 1.035\ GeV/c^2$
- $2.800 \leq M_{\eta_c} \leq 3.100 GeV/c^2$
- $\chi^2_{5C} \leq 50$

Cut2 Veto π_0 from $\gamma_{rad}\gamma_{\pi_0}$

- Iteration the gamma pairs to get pi0, in which one gamma is from selected pi0 and the other is radiation gamma
- $0.155 \leq M_{\pi_0}\ and\ M_{\pi_0} \leq 0.115\ GeV/c^2$



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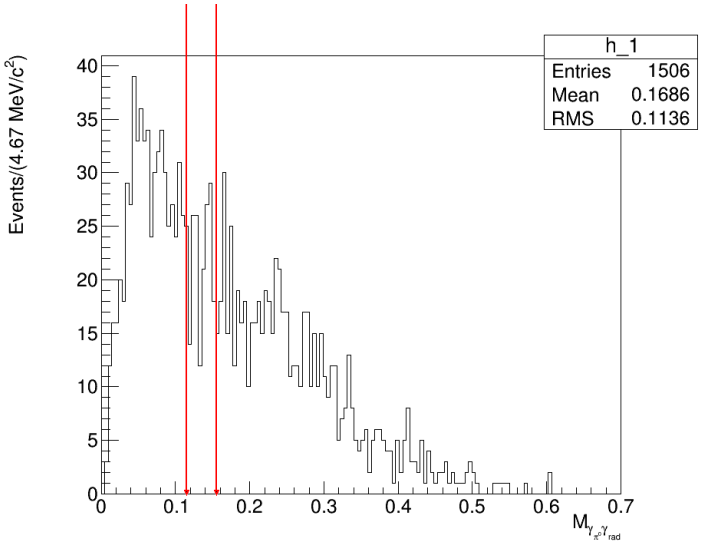
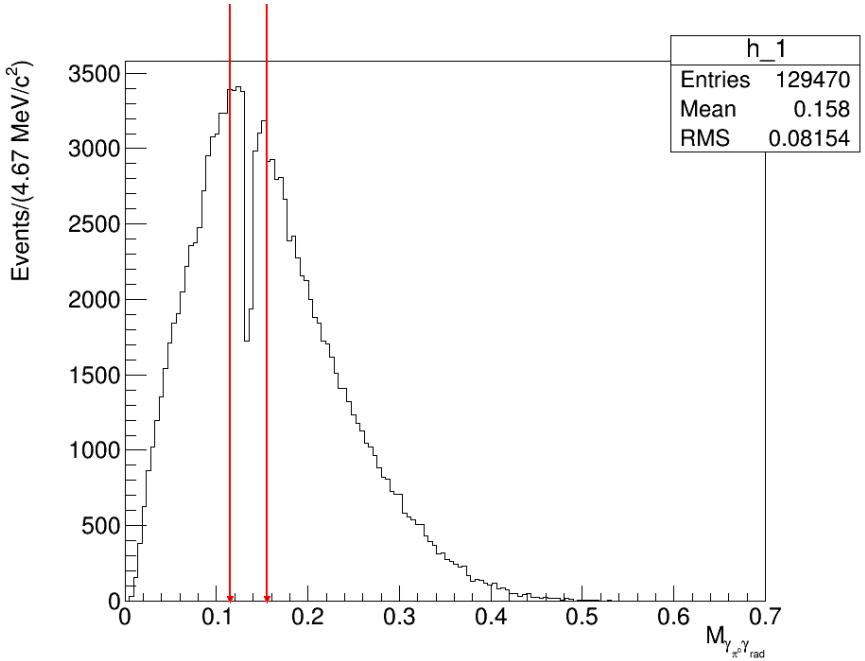


inclusiveMC

Cut2 Veto π_0 from $\gamma_{rad}\gamma_{\pi_0}$

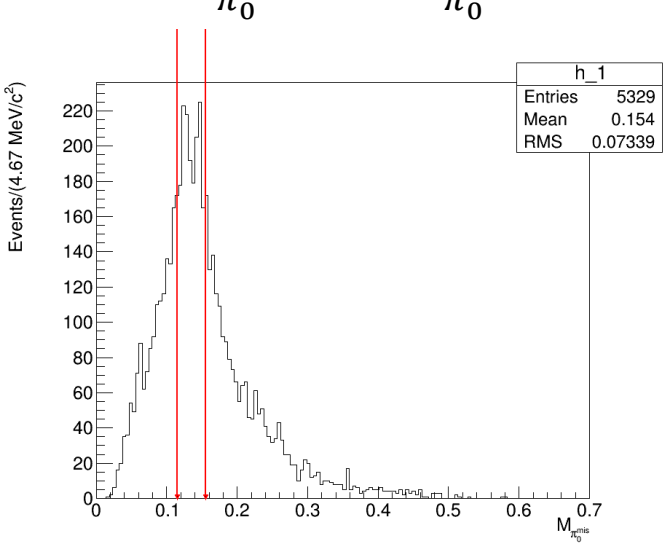
- $0.155 \leq M_{\pi_0}\ and\ M_{\pi_0} \leq 0.115\ GeV/c^2$



SignalMC

Cut2 Veto π_0^{mis} at $\gamma_{no\pi_0}\gamma_{\pi_0}$

- Iteration all the gamma pairs to get miscombined pi0, in which one gamma is from selected pi0 and the other is not from pi0
- $0.155 \leq M_{\pi_0^{mis}}\ and\ M_{\pi_0^{mis}} \leq 0.115\ GeV/c^2$



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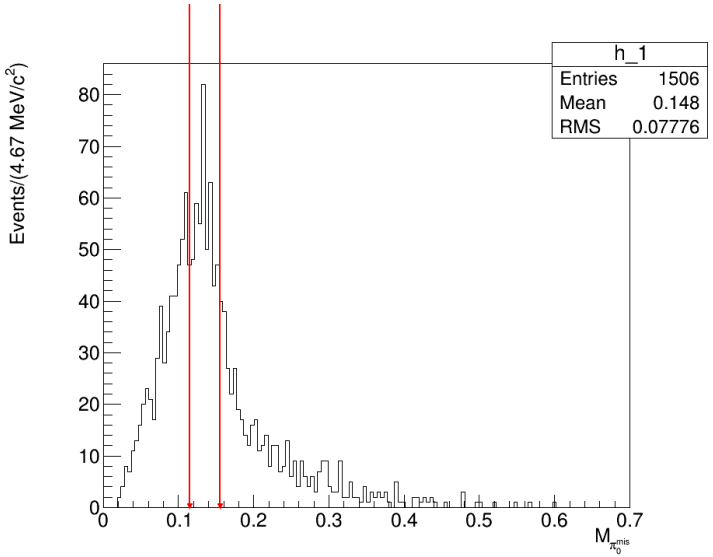
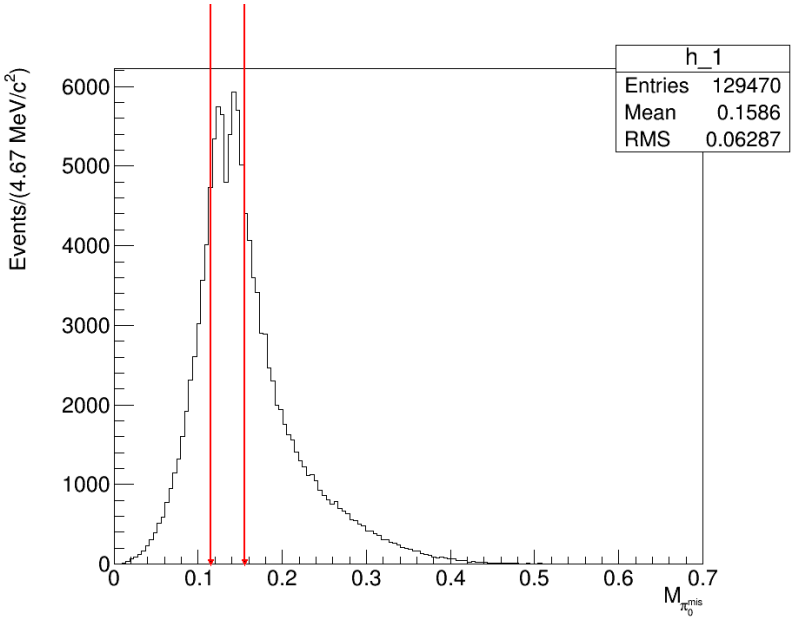


inclusiveMC

Cut2 Veto π_0^{mis} at $\gamma_{no\pi_0}\gamma_{\pi_0}$

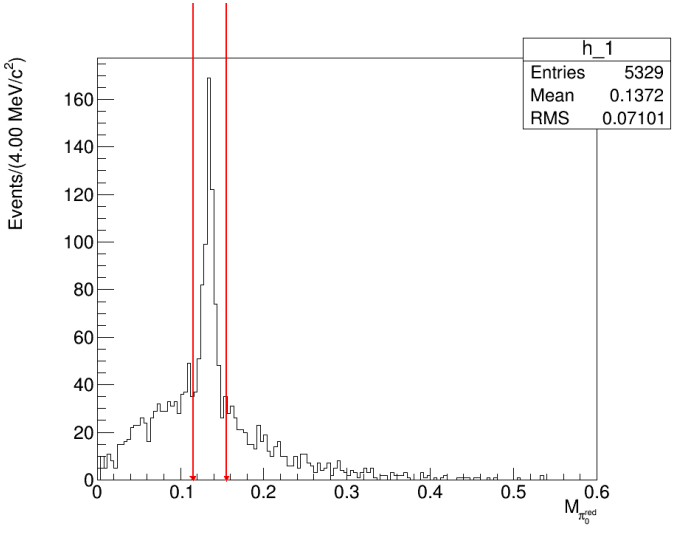
- $0.155 \leq M_{\pi_0^{mis}}\ and\ M_{\pi_0^{mis}} \leq 0.115\ GeV/c^2$



signalMC

Cut2 Veto π_0^{red} at $\gamma_{no\pi_0}\gamma_{no\pi_0}$

- Iteration all the gamma pairs to get redunant pi0, in which both gammas are not from pi0
- $0.155 \leq M_{\pi_0^{red}}\ and\ M_{\pi_0^{red}} \leq 0.115 GeV/c^2$



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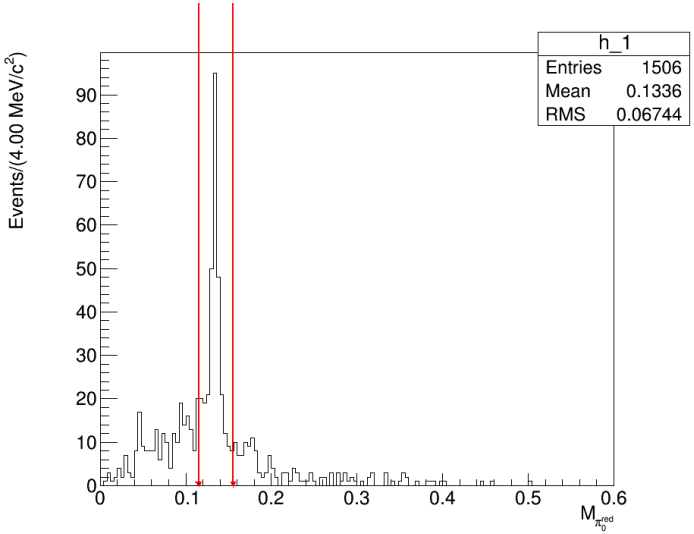
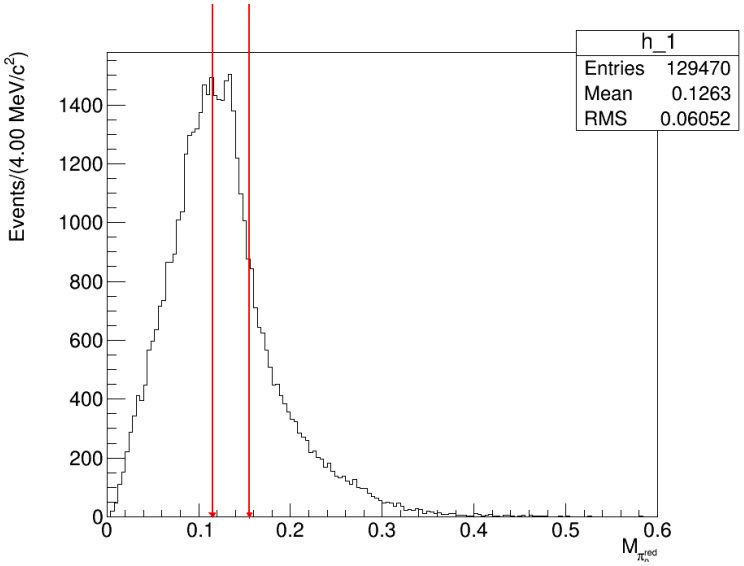


inclusiveMC

Cut2 Veto π_0^{red} at$\gamma_{no\pi_0}\gamma_{no\pi_0}$

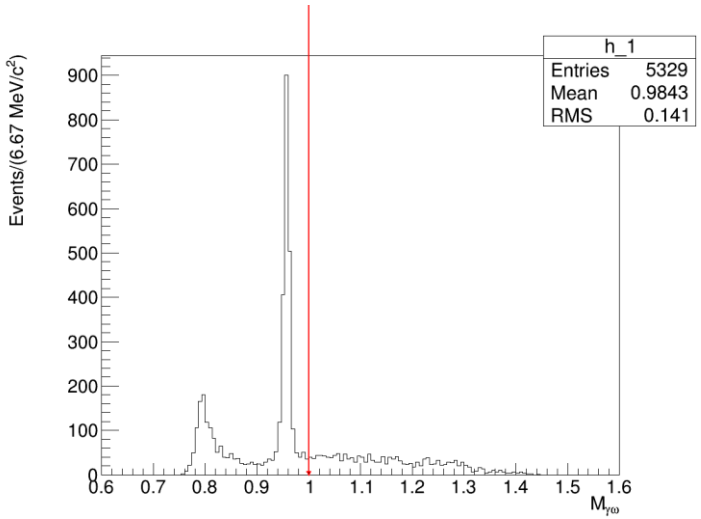
- $0.155 \leq M_{\pi_0^{red}}\ and\ M_{\pi_0^{red}} \leq 0.115 GeV/c^2$

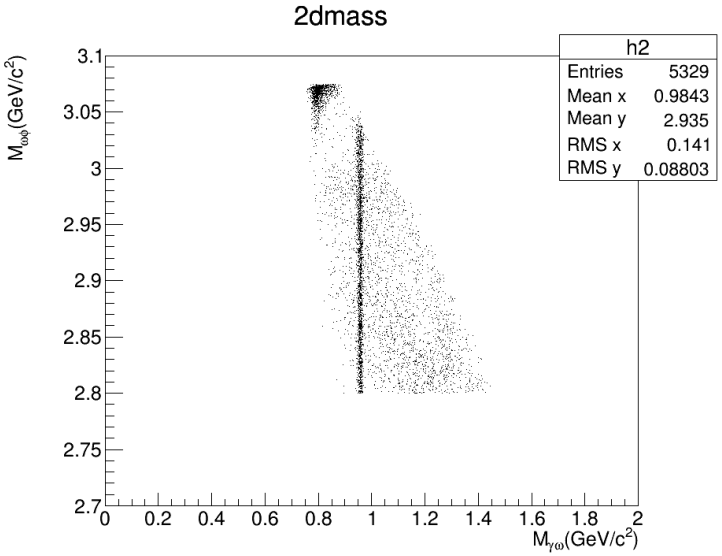


signalMC

Cut3 $M_{\gamma\omega}$window

- $1 \leq M_{\gamma\omega}\mathrm{GeV/c^2}$
- The gamma here is the radiation gamma form jpsi

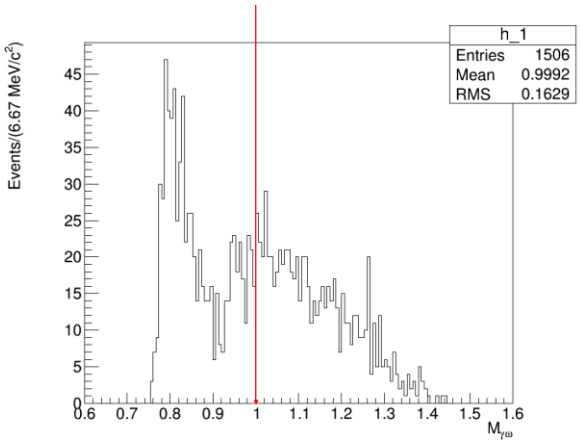


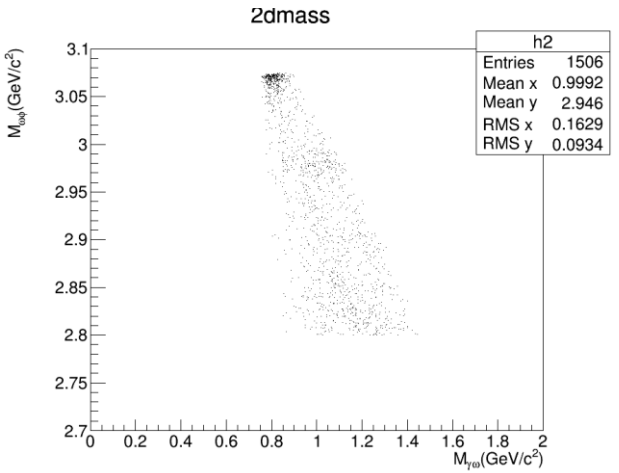


data

Cut3 $M_{\gamma\omega}$window

- $1 \leq M_{\gamma\omega}\mathrm{GeV/c^2}$

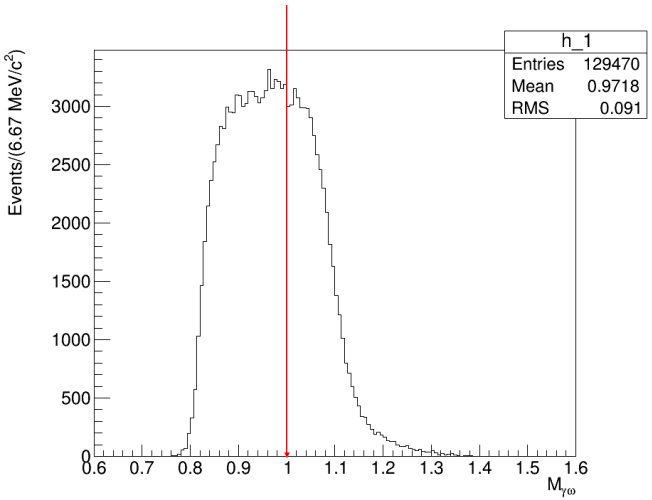


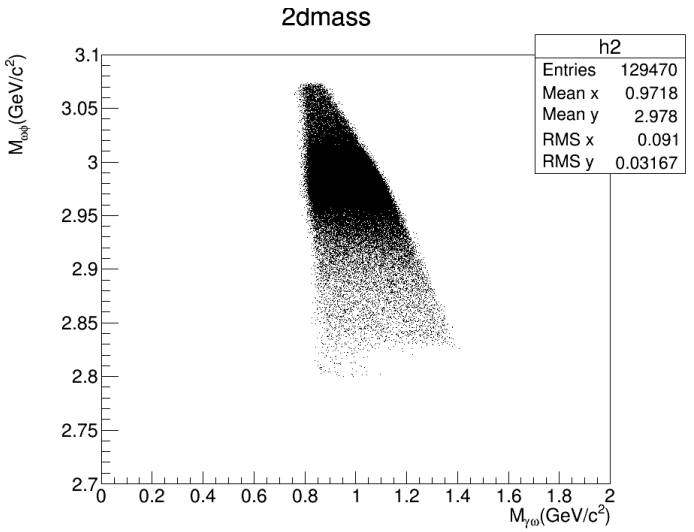


inclusiveMC

Cut3 $M_{\gamma\omega}$window

- $1 \leq M_{\gamma\omega}\mathrm{GeV/c^2}$





SignalMC

Cut3 $M_{\gamma\omega}$ window

- The first peak in data: $0.77 \leq M_{\gamma\omega} \leq 0.84\mathrm{GeV/c^2}$

Table 1: Decay trees and their respective final states.

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$J/\psi \to \pi^0\pi^+\pi^-K^+K^-$	$\pi^0\pi^+\pi^-K^+K^-$	0	103	103
2	$J/\psi \to \omega f_0(980), \omega \to \pi^0\pi^+\pi^-, f_0(980) \to K^+K^-$	$\pi^0\pi^+\pi^-K^+K^-$	4	83	186
3	$J/\psi \to \pi^0 K^* K_2^{*0}, K^* \to \pi^- K^+, K_2^{*0} \to \pi^+ K^-$	$\pi^0\pi^+\pi^-K^+K^-$	1	23	209
4	$J/\psi \to \pi^0 \bar{K}^* K_2^{*0}, \bar{K}^* \to \pi^+ K^-, K_2^{*0} \to \pi^- K^+$	$\pi^0\pi^+\pi^-K^+K^-$	13	22	231
5	$J/\psi \to \omega K^+K^-, \omega \to \pi^0\pi^+\pi^-$	$\pi^0\pi^+\pi^-K^+K^-$	5	20	251
6	$J/\psi \to \pi^0\pi^+\pi^-K^+K^-\gamma^f$	$\pi^0\pi^+\pi^-K^+K^-\gamma^f$	14	19	270
7	$J/\psi \to \pi^0 \bar{K}^* K_0^0, \bar{K}^* \to \pi^+ K^-, K_0^0 \to \pi^- K^+$	$\pi^0\pi^+\pi^-K^+K^-$	8	8	278
8	$J/\psi \to \pi^0 K^* \bar{K}^*, K^* \to \pi^- K^+, \bar{K}^* \to \pi^+ K^-$	$\pi^0\pi^+\pi^-K^+K^-$	11	7	285
9	$J/\psi \to \eta_c\gamma, \eta_c \to \pi^0\pi^+\pi^-K^+K^-$	$\pi^0\pi^+\pi^-K^+K^-\gamma$	19	6	291
10	$J/\psi \to \pi^0 K^* \bar{K}_0^{*0}, K^* \to \pi^- K^+, \bar{K}_0^{*0} \to \pi^+ K^-$	$\pi^0\pi^+\pi^-K^+K^-$	17	4	295
11	$J/\psi \to \pi^0\pi^0\phi, \phi \to K^+K^-$	$\pi^0\pi^0K^+K^-$	12	4	299
12	$J/\psi \to \pi^+ K^* K_0^{*-}, K^* \to \pi^- K^+, K_0^{*-} \to \pi^0 K^-$	$\pi^0\pi^+\pi^-K^+K^-$	20	4	303
13	$J/\psi \to \pi^+ K^* K^{*-}, K^* \to \pi^- K^+, K^{*-} \to \pi^0 K^-$	$\pi^0\pi^+\pi^-K^+K^-$	24	4	307
14	$J/\psi \to \pi^- \bar{K}^* K^{*+}\gamma^f, \bar{K}^* \to \pi^+ K^-, K^{*+} \to \pi^0 K^+$	$\pi^0\pi^+\pi^-K^+K^-\gamma^f$	21	3	310
15	$J/\psi \to \eta_c\gamma, \eta_c \to \pi^0 K^* \bar{K}^*, K^* \to \pi^- K^+, \bar{K}^* \to \pi^+ K^-$	$\pi^0\pi^+\pi^-K^+K^-\gamma$	16	3	313
16	$J/\psi \to \pi^- K_2^{*0} K_2^{*+}, K_2^{*0} \to \pi^+ K^-, K_2^{*+} \to \pi^0 K^+$	$\pi^0\pi^+\pi^-K^+K^-$	25	3	316
17	$J/\psi \to \omega f_0(980), \omega \to \pi^0\pi^+\pi^-\gamma^f, f_0(980) \to K^+K^-$	$\pi^0\pi^+\pi^-K^+K^-\gamma^f$	15	2	318
18	$J/\psi \to \pi^+\pi^-K^+K^-\gamma^F\gamma^f$	$\pi^+\pi^-K^+K^-\gamma^F\gamma^f$	7	2	320
19	$J/\psi \to \pi^- \bar{K}^* K^{*+}, \bar{K}^* \to \pi^+ K^-, K^{*+} \to \pi^0 K^+$	$\pi^0\pi^+\pi^-K^+K^-$	2	2	322
20	$J/\psi \to \pi^0 K^* K_2^{*0}, K^* \to \pi^- K^+\gamma^f, K_2^{*0} \to \pi^+ K^-$	$\pi^0\pi^+\pi^-K^+K^-\gamma^f$	3	2	324
21	$J/\psi \to \pi^0 \bar{K}^* K_2^{*0}, \bar{K}^* \to \pi^+ K^-, K_2^{*0} \to \pi^- K^+\gamma^f$	$\pi^0\pi^+\pi^-K^+K^-\gamma^f$	39	2	326
22	$J/\psi \to \omega f_0', \omega \to \pi^0\pi^+\pi^-, f_0' \to K^+K^-$	$\pi^0\pi^+\pi^-K^+K^-$	40	2	328
23	$J/\psi \to \pi^0 K^- K_1^+, K_1^+ \to \pi^+\pi^-K^+$	$\pi^0\pi^+\pi^-K^+K^-$	22	1	329
24	$J/\psi \to \pi^+ K_2^{*0} K_2^{*-}, K_2^{*0} \to \pi^- K^+, K_2^{*-} \to \pi^0 K^-$	$\pi^0\pi^+\pi^-K^+K^-$	23	1	330
25	$J/\psi \to \pi^- \bar{K}^* K_0^{*+}, \bar{K}^* \to \pi^+ K^-, K_0^{*+} \to \pi^0 K^+$	$\pi^0\pi^+\pi^-K^+K^-$	18	1	331
26	$J/\psi \to \pi^- K^+ \bar{K}_1^0, \bar{K}_1^0 \to \rho^+ K^-, \rho^+ \to \pi^0\pi^+$	$\pi^0\pi^+\pi^-K^+K^-$	9	1	332
27	$J/\psi \to \omega a_0^0, \omega \to \pi^0\pi^+\pi^-, a_0^0 \to K^+K^-$	$\pi^0\pi^+\pi^-K^+K^-$	26	1	333
28	$J/\psi \to \eta_c\gamma, \eta_c \to \pi^- K_2^{*0} K^{*+}, K_2^{*0} \to \pi^+ K^-, K^{*+} \to \pi^0 K^+$	$\pi^0\pi^+\pi^-K^+K^-\gamma$	27	1	334
29	$J/\psi \to \eta_c\gamma, \eta_c \to \pi^+ K^* K^{*-}, K^* \to \pi^- K^+, K^{*-} \to \pi^0 K^-$	$\pi^0\pi^+\pi^-K^+K^-\gamma$	28	1	335
30	$J/\psi \to \eta_c\gamma, \eta_c \to \pi^- \bar{K}^* K^{*+}, \bar{K}^* \to \pi^+ K^-, K^{*+} \to \pi^0 K^+$	$\pi^0\pi^+\pi^-K^+K^-\gamma$	29	1	336
31	$J/\psi \to \pi^0 K^- K^{*+}, \pi^0 \to e^+e^-\gamma^F\gamma^f, K^{*+} \to \pi^0 K^+$	$e^+e^-\pi^0K^+K^-\gamma^F\gamma^f$	30	1	337
32	$J/\psi \to \pi^- K_2^{*0} K^+, K_2^{*0} \to \pi^0 \bar{K}^*, \bar{K}^* \to \pi^+ K^-$	$\pi^0\pi^+\pi^-K^+K^-$	31	1	338

inclusiveMC

after all cuts

Table 1: Decay trees and their respective final states.

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$J/\psi \to \omega f_1(1420), \omega \to \pi^0\pi^+\pi^-, f_1(1420) \to \pi^0 K^+ K^-$	$\pi^0\pi^0\pi^+\pi^- K^+ K^-$	3	83	83
2	$J/\psi \to \eta_c\gamma, \eta_c \to \pi^0\pi^+\pi^- K^+ K^-$	$\pi^0\pi^+\pi^- K^+ K^-\gamma$	2	60	143
3	$J/\psi \to \omega K^- K^{*+}, \omega \to \pi^0\pi^+\pi^-, K^{*+} \to \pi^0 K^+$	$\pi^0\pi^0\pi^+\pi^- K^+ K^-$	0	26	169
4	$J/\psi \to K_S^0 K_S^0\phi, K_S^0 \to \pi^0\pi^0, K_S^0 \to \pi^+\pi^-, \phi \to K^+ K^-$	$\pi^0\pi^0\pi^+\pi^- K^+ K^-$	7	23	192
5	$J/\psi \to \omega K^+ K^{*-}, \omega \to \pi^0\pi^+\pi^-, K^{*-} \to \pi^0 K^-$	$\pi^0\pi^0\pi^+\pi^- K^+ K^-$	4	22	214
6	$J/\psi \to \pi^0 K^* \bar{K}^*\gamma, K^* \to \pi^- K^+, \bar{K}^* \to \pi^+ K^-$	$\pi^0\pi^+\pi^- K^+ K^-\gamma$	23	17	231
7	$J/\psi \to f_2(1270)\phi, f_2(1270) \to \pi^0\pi^0\pi^+\pi^-, \phi \to K^+ K^-$	$\pi^0\pi^0\pi^+\pi^- K^+ K^-$	1	13	244
8	$J/\psi \to \pi^0\pi^- \bar{K}^* K^{*+}, \bar{K}^* \to \pi^+ K^-, K^{*+} \to \pi^0 K^+$	$\pi^0\pi^0\pi^+\pi^- K^+ K^-$	32	10	254
9	$J/\psi \to \pi^+\pi^-\eta K^+ K^-, \eta \to \gamma\gamma$	$\pi^+\pi^- K^+ K^-\gamma\gamma$	13	7	261
10	$J/\psi \to \phi f_1(1285), \phi \to K^+ K^-, f_1(1285) \to \pi^0\pi^-\rho^+, \rho^+ \to \pi^0\pi^+$	$\pi^0\pi^0\pi^+\pi^- K^+ K^-$	6	6	267
11	$J/\psi \to \pi^+\pi^- K^{*+} K^{*-}, K^{*+} \to \pi^0 K^+, K^{*-} \to \pi^0 K^-$	$\pi^0\pi^0\pi^+\pi^- K^+ K^-$	26	6	273
12	$J/\psi \to \phi f_1(1285), \phi \to K^+ K^-, f_1(1285) \to \pi^0\pi^+\rho^-, \rho^- \to \pi^0\pi^-$	$\pi^0\pi^0\pi^+\pi^- K^+ K^-$	22	6	279
13	$J/\psi \to \rho^+ K^* K^{*-}, \rho^+ \to \pi^0\pi^+, K^* \to \pi^- K^+, K^{*-} \to \pi^0 K^-$	$\pi^0\pi^0\pi^+\pi^- K^+ K^-$	11	5	284
14	$J/\psi \to K^- K^{*+}\eta', K^{*+} \to \pi^0 K^+, \eta' \to \pi^+\pi^-\gamma^F$	$\pi^0\pi^+\pi^- K^+ K^-\gamma^F$	21	5	289
15	$J/\psi \to \pi^0\pi^+\pi^- K^+ K^-\gamma^f$	$\pi^0\pi^+\pi^- K^+ K^-\gamma^f$	36	5	294
16	$J/\psi \to \pi^0\pi^+ K^* K^{*-}, K^* \to \pi^- K^+, K^{*-} \to \pi^0 K^-$	$\pi^0\pi^0\pi^+\pi^- K^+ K^-$	38	5	299
17	$J/\psi \to \eta_c\gamma, \eta_c \to \pi^+ K^* K^{*-}, K^* \to \pi^- K^+, K^{*-} \to \pi^0 K^-$	$\pi^0\pi^+\pi^- K^+ K^-\gamma$	29	4	303
18	$J/\psi \to \pi^+ K^* K^{*-}\gamma^F, K^* \to \pi^- K^+, K^{*-} \to \pi^0 K^-$	$\pi^0\pi^+\pi^- K^+ K^-\gamma^F$	16	4	307
19	$J/\psi \to K^+ K^{*-}\eta', K^{*-} \to \pi^0 K^-, \eta' \to \pi^+\pi^-\gamma^F$	$\pi^0\pi^+\pi^- K^+ K^-\gamma^F$	12	3	310
20	$J/\psi \to K^0\bar{K}^0\phi, K^0 \to K_S^0, \bar{K}^0 \to K_S^0, \phi \to K^+ K^-, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^0\pi^0$	$\pi^0\pi^0\pi^+\pi^- K^+ K^-$	20	3	313
21	$J/\psi \to \eta_c\gamma, \eta_c \to \pi^- \bar{K}^* K^{*+}, \bar{K}^* \to \pi^+ K^-, K^{*+} \to \pi^0 K^+$	$\pi^0\pi^+\pi^- K^+ K^-\gamma$	9	3	316
22	$J/\psi \to \rho^- \bar{K}^* K^{*+}, \rho^- \to \pi^0\pi^-, \bar{K}^* \to \pi^+ K^-, K^{*+} \to \pi^0 K^+$	$\pi^0\pi^0\pi^+\pi^- K^+ K^-$	27	3	319
23	$J/\psi \to \pi^+ K_2^{*0} K^{*-}\gamma^F, K_2^{*0} \to \pi^- K^+, K^{*-} \to \pi^0 K^-$	$\pi^0\pi^+\pi^- K^+ K^-\gamma^F$	40	3	322
24	$J/\psi \to \eta_c\gamma, \eta_c \to \pi^0 K^* \bar{K}^*, K^* \to \pi^- K^+, \bar{K}^* \to \pi^+ K^-$	$\pi^0\pi^+\pi^- K^+ K^-\gamma$	46	3	325
25	$J/\psi \to \phi f_0(980), \phi \to K^+ K^-, f_0(980) \to K_S^0 K_S^0, K_S^0 \to \pi^0\pi^0, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^0\pi^+\pi^- K^+ K^-$	59	3	328
26	$J/\psi \to \omega K^- K^{*+}, \omega \to \pi^0\pi^+\pi^-, K^{*+} \to K^+\gamma$	$\pi^0\pi^+\pi^- K^+ K^-\gamma$	60	3	331
27	$J/\psi \to K^0\bar{K}^0\phi, K^0 \to K_S^0, \bar{K}^0 \to K_S^0, \phi \to K^+ K^-, K_S^0 \to \pi^0\pi^0, K_S^0 \to \pi^+\pi^-$	$\pi^0\pi^0\pi^+\pi^- K^+ K^-$	42	2	333
28	$J/\psi \to \pi^+ K^* K_2^{*-}\gamma^F, K^* \to \pi^- K^+, K_2^{*-} \to \pi^0 K^-$	$\pi^0\pi^+\pi^- K^+ K^-\gamma^F$	43	2	335
29	$J/\psi \to \eta' h_1(1380), \eta' \to \pi^+\pi^-\gamma^F, h_1(1380) \to K^- K^{*+}, K^{*+} \to \pi^0 K^+$	$\pi^0\pi^+\pi^- K^+ K^-\gamma^F$	15	2	337
30	$J/\psi \to \pi^- \bar{K}^* K^{*+}\gamma^f, \bar{K}^* \to \pi^+ K^-, K^{*+} \to \pi^0 K^+$	$\pi^0\pi^+\pi^- K^+ K^-\gamma^f$	47	2	339
31	$J/\psi \to \pi^0\pi^0 K^* \bar{K}^*, K^* \to \pi^- K^+, \bar{K}^* \to \pi^+ K^-$	$\pi^0\pi^0\pi^+\pi^- K^+ K^-$	57	2	341

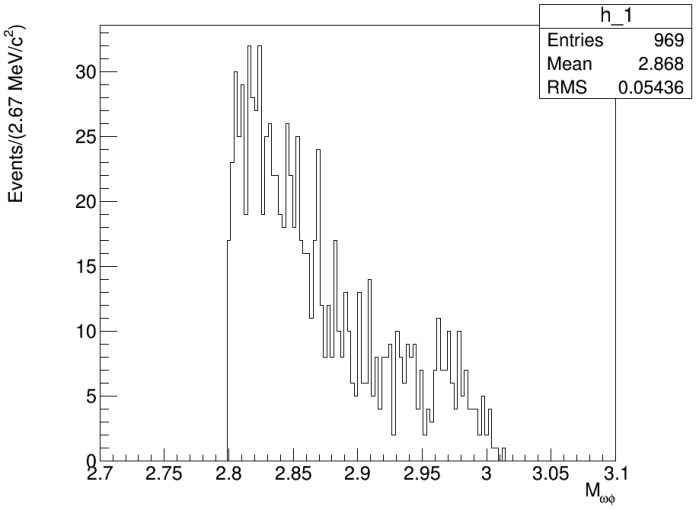
Efficiency

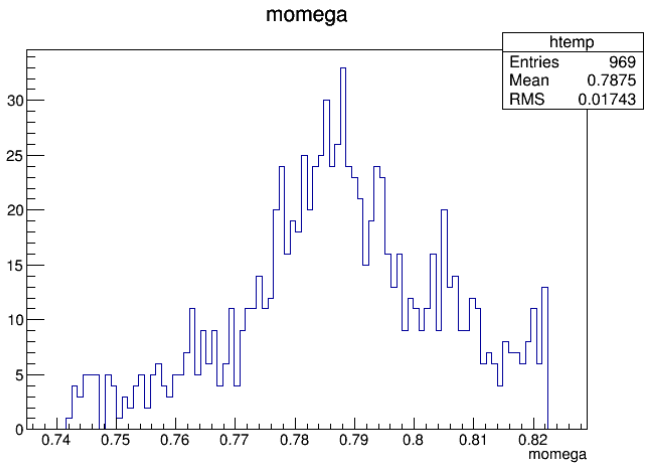
Criteria	events	Efficiency(%)	Relative efficiency
SignalMC	2million	100	
Preliminary selection	181437	9.07	
cut1	129470	6.47	100
Cut1 and Veto π_0^{red}	116531	5.83	90.00
Cut1 and Veto π_0^{mis}	83318	4.17	64.35
Cut 1 and cut2	77444	3.87	59.82
Cut 1, cut2 and cut3	32999	1.65	25.49

Data events number

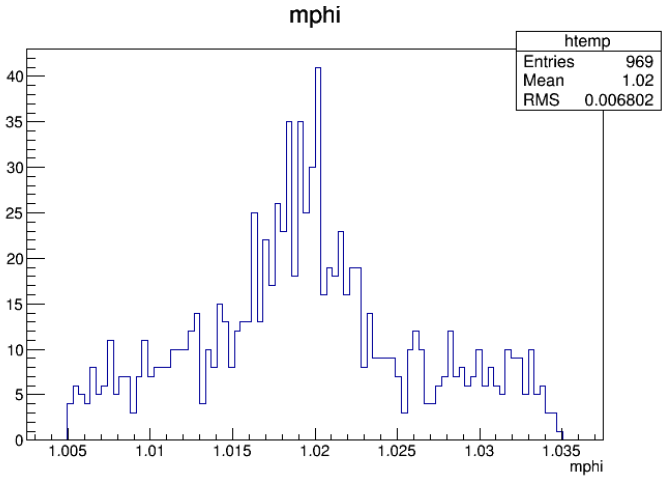
Criteria	events
data	10billion
Preliminary selection	13m
cut1	5329
Cut 1 and cut2	3227
Cut 1, cut2 and cut3	969

after all cuts

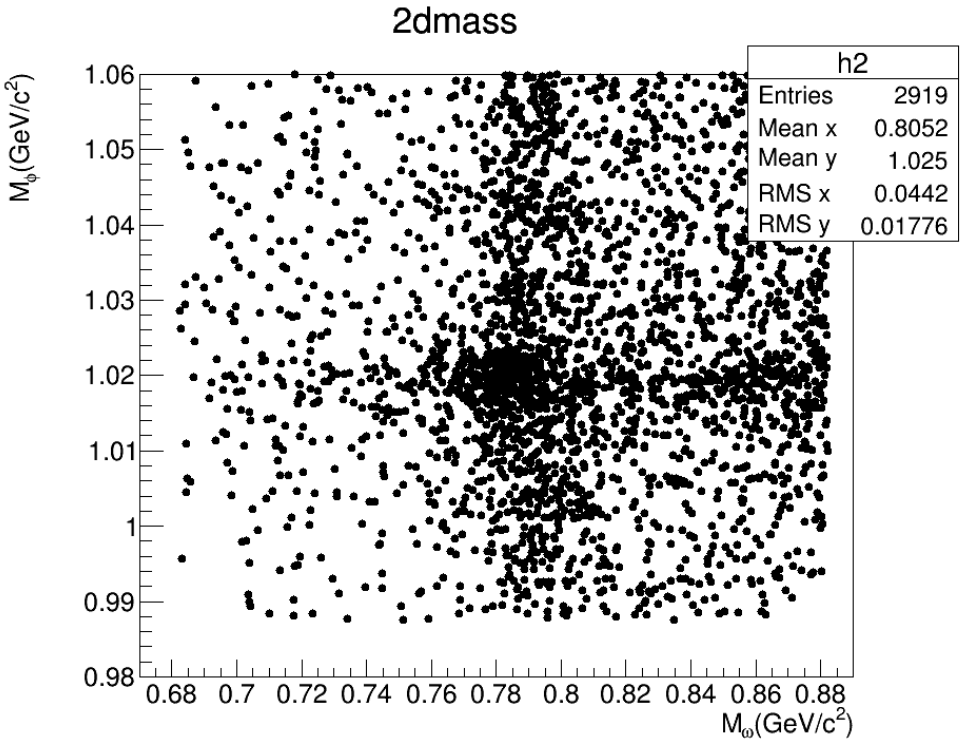




data



in larger ω and ϕ area



Thanks!