



中国科学技术大学

University of Science and Technology of China

Further Selection Criteria (1.1 Ver) in

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



- 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*:  $\theta \geq 10^\circ$

- ✓  $N_\gamma \geq 3$

- Particle identify:

- ✓  $P(\pi) > P(K) \ \&\& \ P(\pi) > P(p)$

- ✓  $P(K) > P(\pi) \ \&\& \ P(K) > P(p)$



- Kinematic fit:

- ✓  $ecms(\text{GeV}) = (0.034, 0, 0, 3.097)$

- ✓  $\chi^2 \leq 200$

- $\pi^0$  reconstruction:

- ✓  $ecms(\text{GeV}) = (0.034, 0, 0, 3.097)$

- ✓  $m_{\pi^0}(\text{GeV}) = 0.135$  (by iterating 2 – gamma combinations)

- ✓  $\chi^2 \leq 200$

# Cut1 two mass window



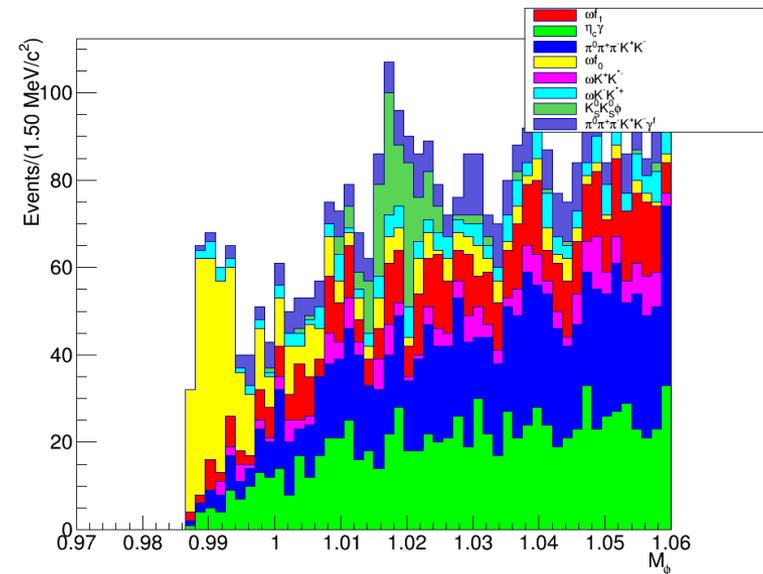
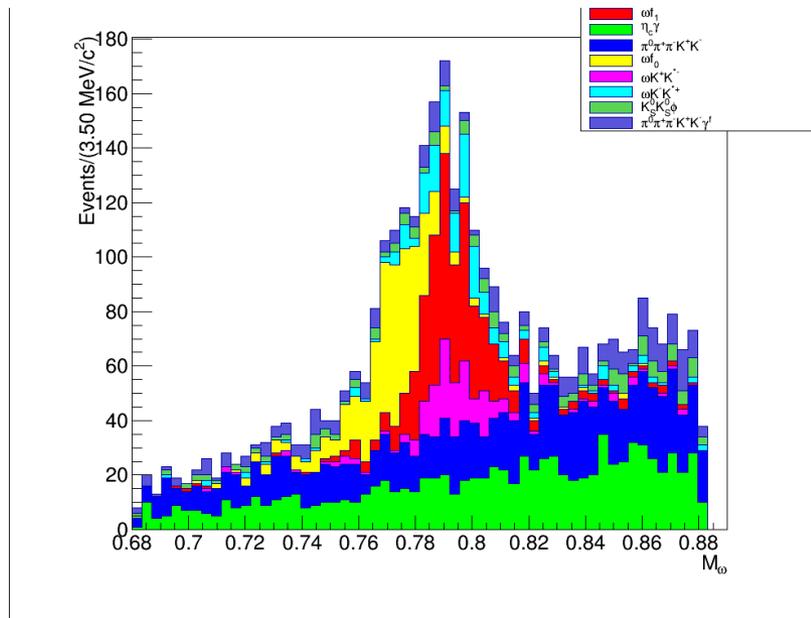
- $0.742 \leq M_\omega \leq 0.822 \text{ GeV}/c^2$
- $1.005 \leq M_\phi \leq 1.035 \text{ GeV}/c^2$
- $2.800 \leq M_{\eta_c} \leq 3.100 \text{ GeV}/c^2$
- $\chi_{5c}^2 \leq 50$

# Efficiency

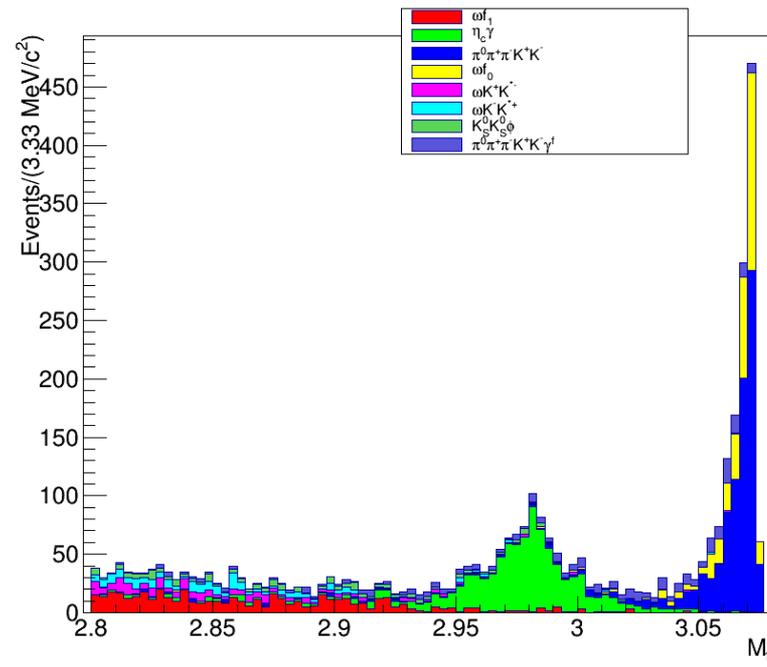


| Criteria                                  | events   | Efficiency(%) | Relative efficiency |
|---|----------|---------------|---------------------|
| SignalMC                                  | 2million | 100           |                     |
| $N_{good} = 4 \ \&\& \ Q_{total} = 0$     | 573218   | 28.66         |                     |
| $N_{\gamma} \geq 3$                       | 305289   | 15.26         |                     |
| Pass Pid                                  | 280427   | 14.02         |                     |
| Vertex Fit                                | 279012   | 13.95         |                     |
| Pass 4C                                   | 187933   | 9.40          |                     |
| Pass 5C                                   | 181437   | 9.07          |                     |
| cut1                                      | 129470   | 6.47          | 100                 |
| Cut2 veto $\pi_0^{red}$                   | 116531   | 5.83          | 90.01               |
| Cut2 veto $\pi_0^{mis}$ and $\pi_0^{red}$ | 85219    | 4.26          | 65.82               |

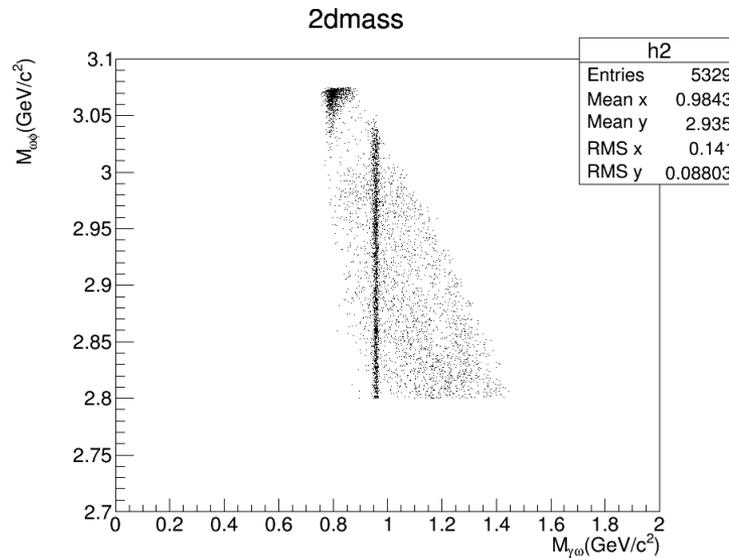
- The inclusive MC analysis under preliminary selection and cut1



- The yellow part has strange  $\omega$  shape and  $\phi$  shape, but there is no such structure in data, maybe its BR is over-estimated in inclusiveMC.



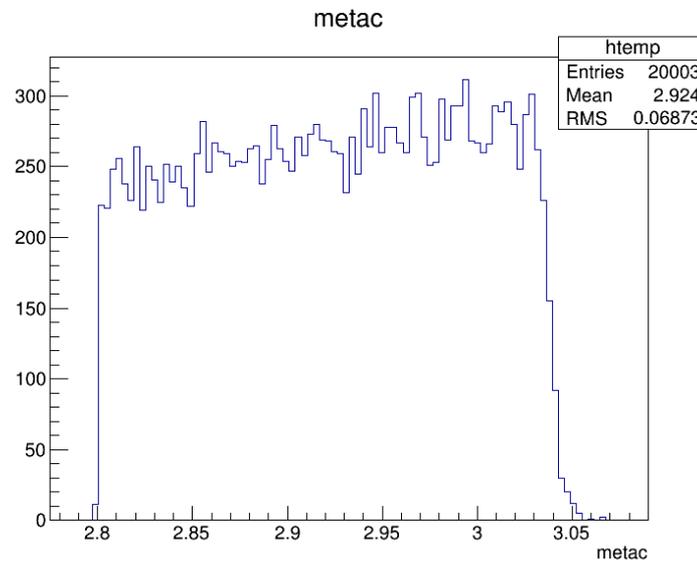
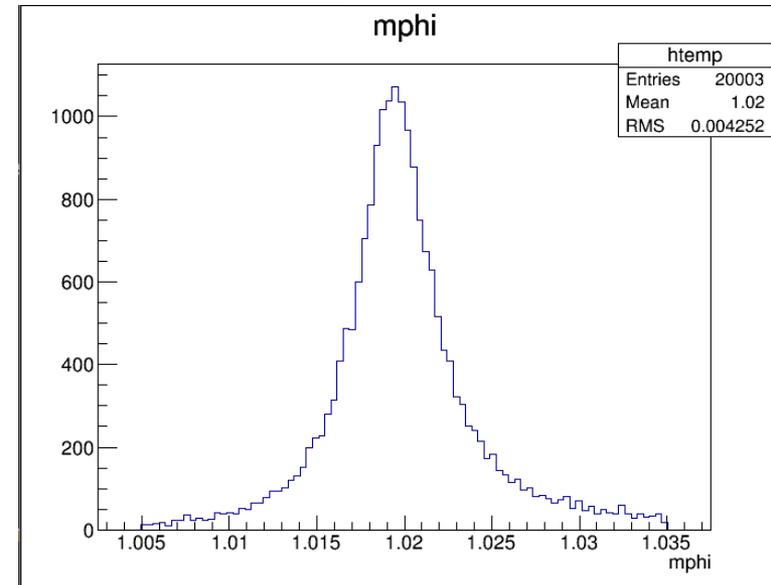
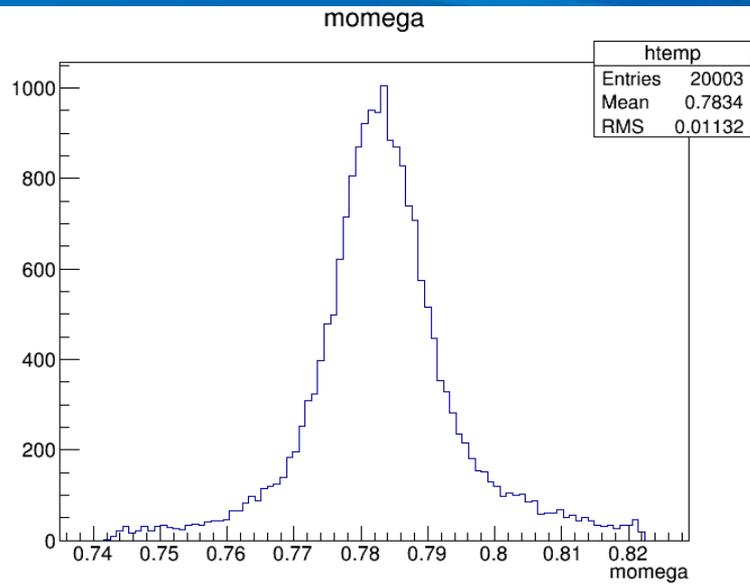
# A missed but dominant background



data

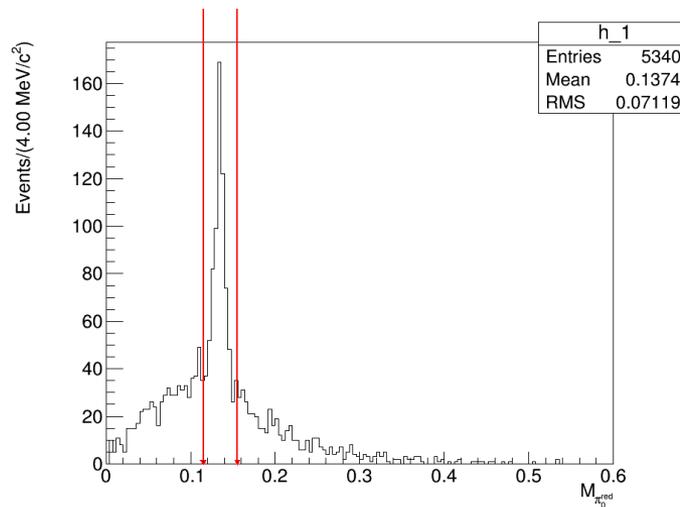
- $J/\psi \rightarrow \eta'(\gamma\omega)\phi(K^+K^-)$  exclusiveMC are generated.
- A kind of background which is missed in inclusiveMC, but it's a dominant background in signal area.
- The shape with the same preliminary selection:

# exclusive MC shape

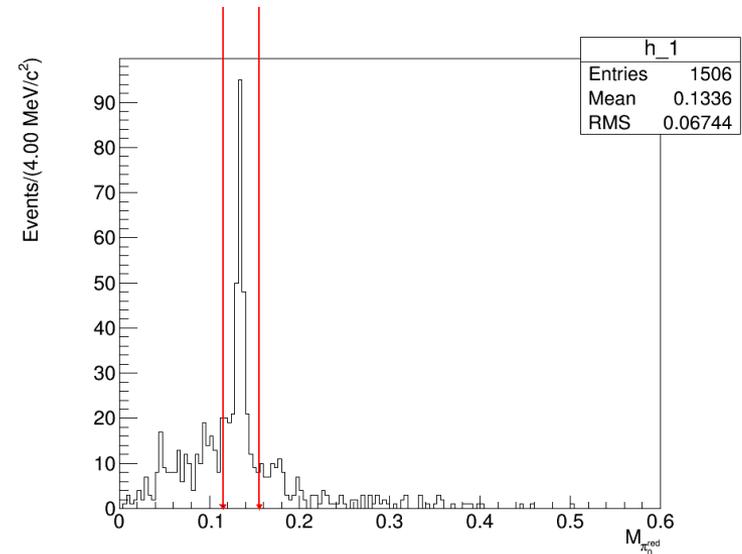




- Iteration all the gamma pairs to get redundant  $\pi_0$  (the closest one to 0.135 GeV), in which both gammas are not from  $\pi_0$
- $0.155 \leq M_{\pi_0^{red}}$  and  $M_{\pi_0^{red}} \leq 0.115 \text{ GeV}/c^2$



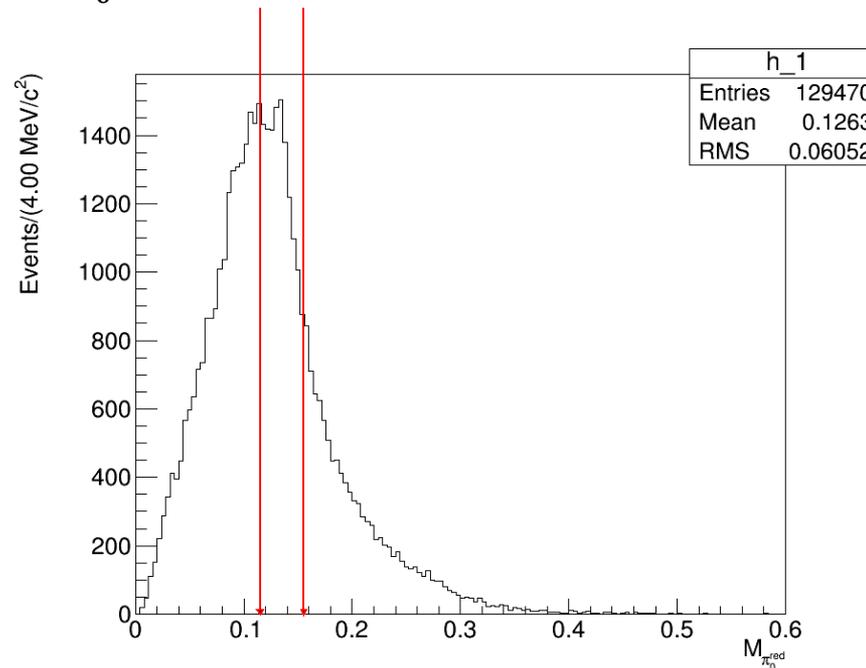
data



inclusiveMC



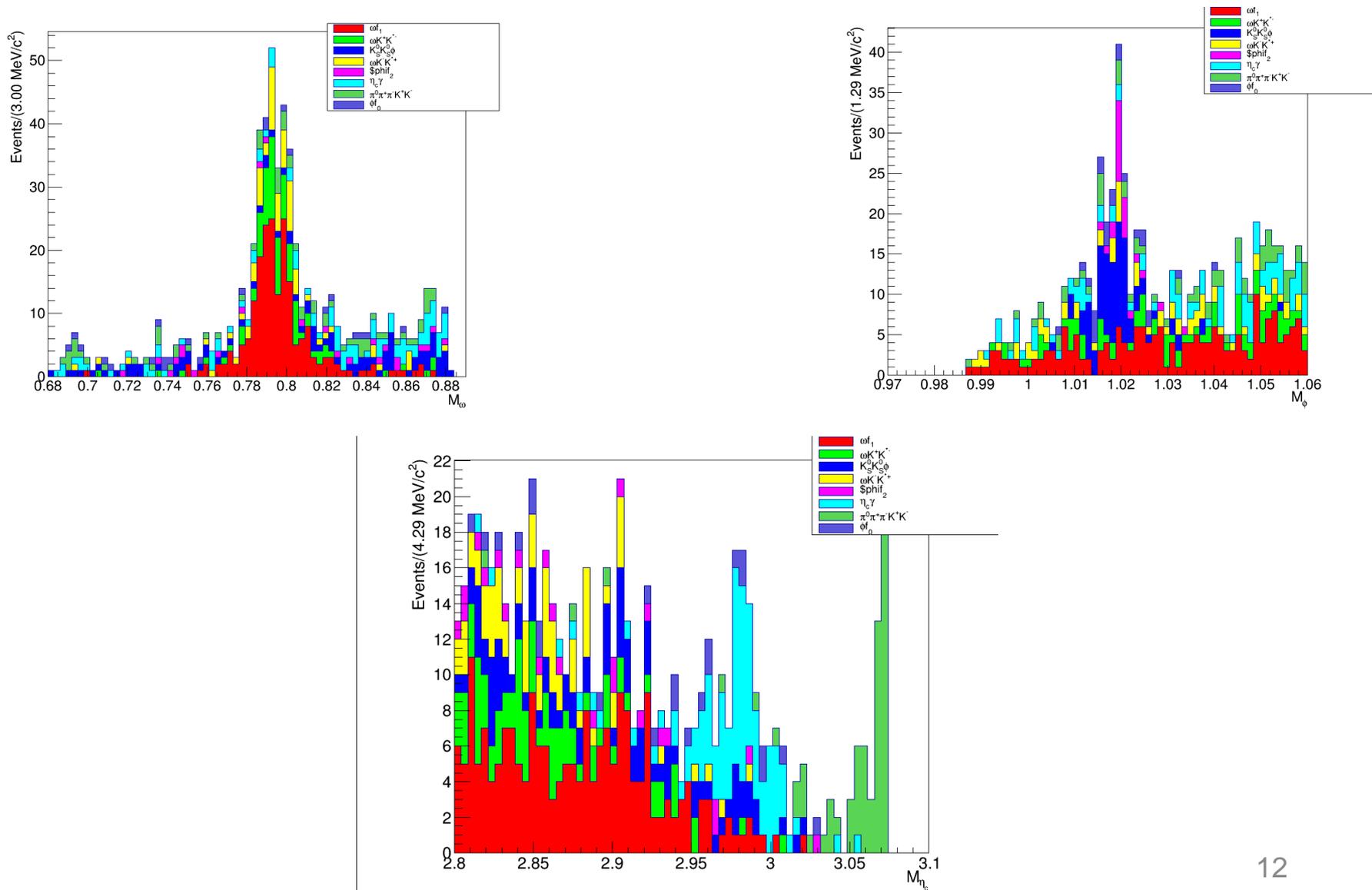
- $0.155 \leq M_{\pi_0^{red}}$  and  $M_{\pi_0^{red}} \leq 0.115 \text{ GeV}/c^2$



signalMC

- a large part can't have a redundant  $\pi_0$ , which leads to high efficiency

# background analysis of cut $\pi_0^{red}$ part



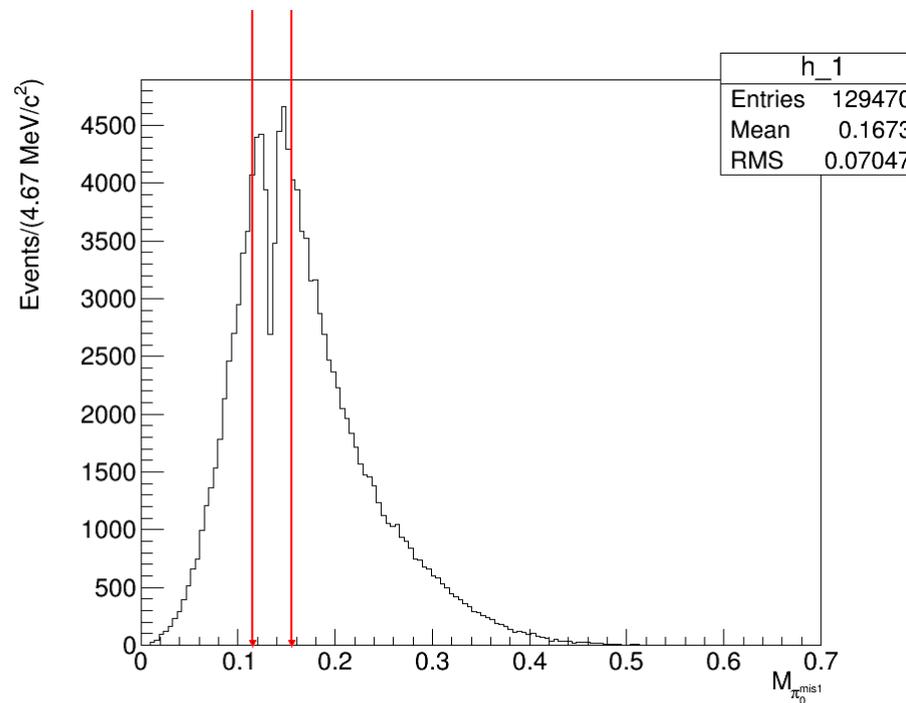
# further research of Veto $\pi_0^{red}$ from $\gamma n_0 \pi_0 \gamma n_0 \pi_0$



- $J/\psi \rightarrow \phi \pi^+ \pi^- \pi^0 \pi^0$  and  $J/\psi \rightarrow \omega K^+ K^- \pi^0$  exclusive MC are in process to study this cut



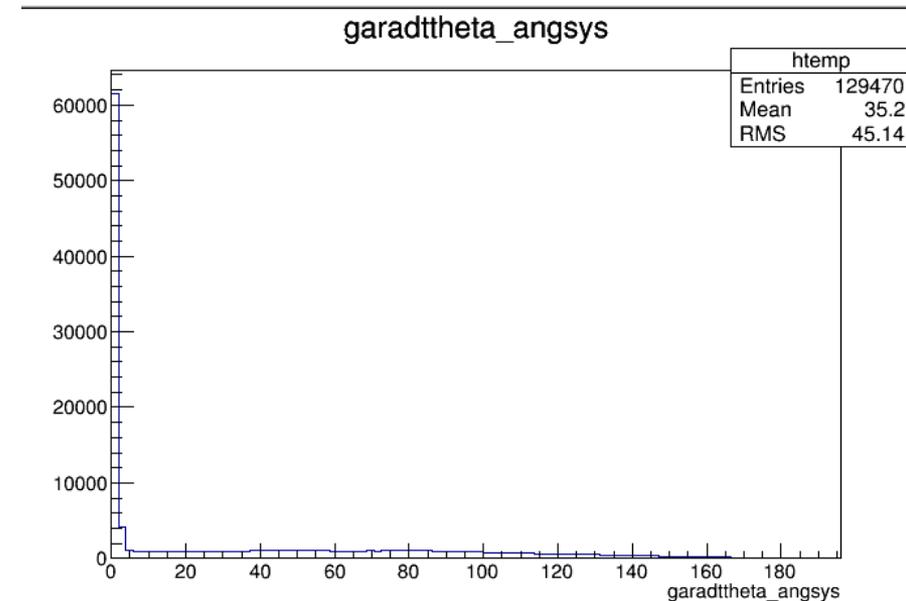
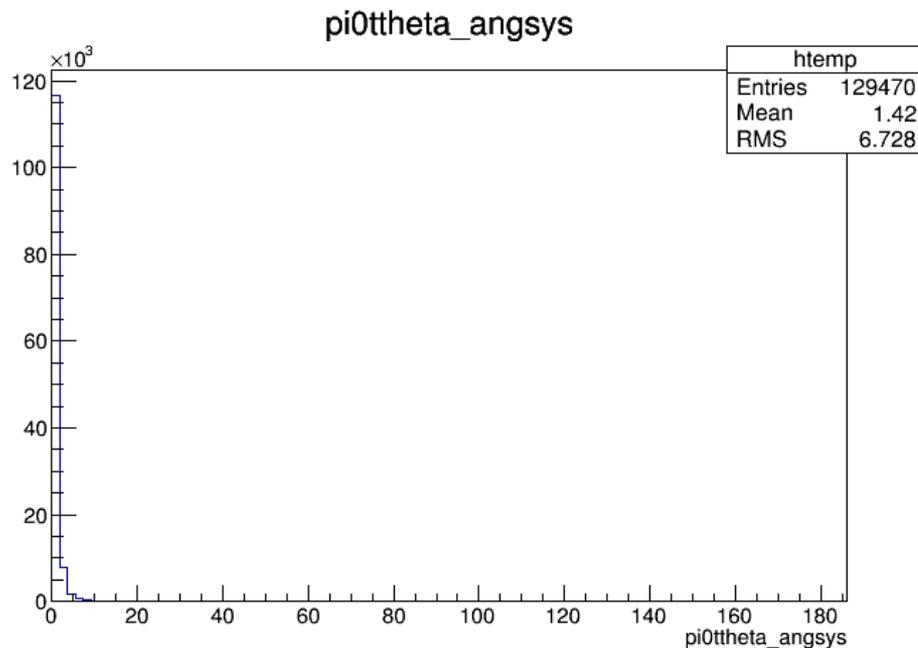
- Iterate the gamma pairs to get  $\pi_0$  (the closest one to 0.135 GeV), in which one gamma is from selected  $\pi_0$  and the other is radiation gamma
- $0.155 \leq M_{\pi_0}$  and  $M_{\pi_0} \leq 0.115 \text{ GeV}/c^2$



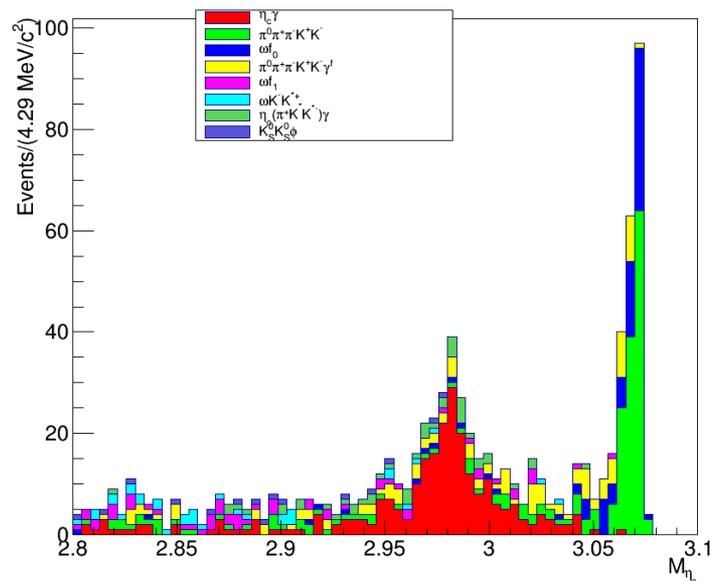
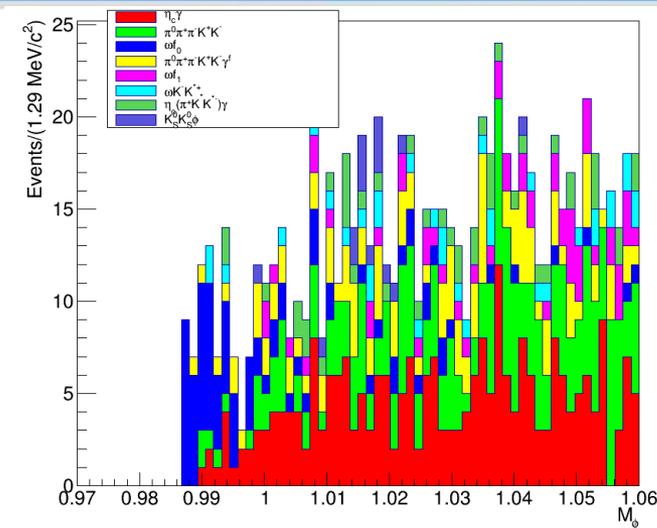
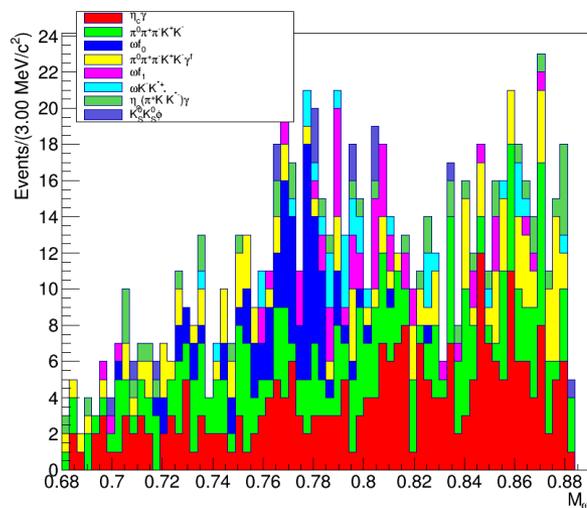
# angle distribution of reconstruction and truth



- pics are from signal MC
- the left panel is angle distribution between reconstructed  $\pi_0$  and truth  $\pi_0$ , while the right panel is angle distribution between reconstructed  $\gamma_{rad}$  and truth  $\gamma_{rad}$



# background analysis of veto $\pi_0^{mis}$ part



# further research Veto

$\pi_0^{mis}$  from  $\gamma_{rad}\gamma\pi_0$



- $J/\psi \rightarrow \gamma\phi\omega$  exclusive MC are in process to study this cut.



# Thanks!



Here starts  
backup



Table 1: Decay trees and their respective final states.

| rowNo | decay tree  | decay final state                    | iDcyTr | nEtr | nCEtr |
|-------|---|--------------------------------------|--------|------|-------|
| 1     | $J/\psi \rightarrow \omega f_1(1420), \omega \rightarrow \pi^0 \pi^+ \pi^-, f_1(1420) \rightarrow \pi^0 K^+ K^-$  | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 5      | 189  | 189   |
| 2     | $J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \pi^0 \pi^+ \pi^- K^+ K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$   | 3      | 179  | 368   |
| 3     | $J/\psi \rightarrow \pi^0 \pi^+ \pi^- K^+ K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^-$          | 2      | 147  | 515   |
| 4     | $J/\psi \rightarrow \omega f_0(980), \omega \rightarrow \pi^0 \pi^+ \pi^-, f_0(980) \rightarrow K^+ K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^-$          | 11     | 96   | 611   |
| 5     | $J/\psi \rightarrow \omega K^+ K^{*-}, \omega \rightarrow \pi^0 \pi^+ \pi^-, K^{*-} \rightarrow \pi^0 K^-$  | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 10     | 66   | 677   |
| 6     | $J/\psi \rightarrow \omega K^- K^{*+}, \omega \rightarrow \pi^0 \pi^+ \pi^-, K^{*+} \rightarrow \pi^0 K^+$  | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 0      | 64   | 741   |
| 7     | $J/\psi \rightarrow K_S^0 K_S^0 \phi, K_S^0 \rightarrow \pi^0 \pi^0, K_S^0 \rightarrow \pi^+ \pi^-, \phi \rightarrow K^+ K^-$   | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 16     | 63   | 804   |
| 8     | $J/\psi \rightarrow \pi^0 \pi^+ \pi^- K^+ K^- \gamma^f$   | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma^f$ | 30     | 54   | 858   |
| 9     | $J/\psi \rightarrow \pi^0 K^* K_2^{*0}, K^* \rightarrow \pi^- K^+, K_2^{*0} \rightarrow \pi^+ K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^-$          | 4      | 32   | 890   |
| 10    | $J/\psi \rightarrow \pi^0 K^* \bar{K}^* \gamma, K^* \rightarrow \pi^- K^+, \bar{K}^* \rightarrow \pi^+ K^-$   | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$   | 18     | 31   | 921   |
| 11    | $J/\psi \rightarrow f_2(1270) \phi, f_2(1270) \rightarrow \pi^0 \pi^0 \pi^+ \pi^-, \phi \rightarrow K^+ K^-$  | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 1      | 28   | 949   |
| 12    | $J/\psi \rightarrow \pi^0 \bar{K}^* K_2^{*0}, \bar{K}^* \rightarrow \pi^+ K^-, K_2^{*0} \rightarrow \pi^- K^+$  | $\pi^0 \pi^+ \pi^- K^+ K^-$          | 44     | 26   | 975   |
| 13    | $J/\psi \rightarrow \omega K^+ K^-, \omega \rightarrow \pi^0 \pi^+ \pi^-$   | $\pi^0 \pi^+ \pi^- K^+ K^-$          | 13     | 21   | 996   |
| 14    | $J/\psi \rightarrow \pi^0 \pi^- \bar{K}^* K^{*+}, \bar{K}^* \rightarrow \pi^+ K^-, K^{*+} \rightarrow \pi^0 K^+$  | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 34     | 20   | 1016  |
| 15    | $J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \pi^+ K^* K^{*-}, K^* \rightarrow \pi^- K^+, K^{*-} \rightarrow \pi^0 K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$   | 63     | 20   | 1036  |
| 16    | $J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \pi^- \bar{K}^* K^{*+}, \bar{K}^* \rightarrow \pi^+ K^-, K^{*+} \rightarrow \pi^0 K^+$  | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$   | 21     | 19   | 1055  |
| 17    | $J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \pi^0 K^* \bar{K}^*, K^* \rightarrow \pi^- K^+, \bar{K}^* \rightarrow \pi^+ K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$   | 53     | 18   | 1073  |
| 18    | $J/\psi \rightarrow \phi f_0(980), \phi \rightarrow K^+ K^-, f_0(980) \rightarrow K_S^0 K_S^0, K_S^0 \rightarrow \pi^0 \pi^0, K_S^0 \rightarrow \pi^+ \pi^-$                        | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 45     | 17   | 1090  |
| 19    | $J/\psi \rightarrow \eta' \phi, \eta' \rightarrow \pi^+ \pi^- \eta, \phi \rightarrow K^+ K^-, \eta \rightarrow \gamma \gamma$   | $\pi^+ \pi^- K^+ K^- \gamma \gamma$  | 50     | 14   | 1104  |
| 20    | $J/\psi \rightarrow K^0 \bar{K}^0 \phi, K^0 \rightarrow K_S^0, \bar{K}^0 \rightarrow K_S^0, \phi \rightarrow K^+ K^-, K_S^0 \rightarrow \pi^+ \pi^-, K_S^0 \rightarrow \pi^0 \pi^0$ | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 51     | 14   | 1118  |
| 21    | $J/\psi \rightarrow \pi^0 \bar{K}^* K_0^{*0}, \bar{K}^* \rightarrow \pi^+ K^-, K_0^{*0} \rightarrow \pi^- K^+$  | $\pi^0 \pi^+ \pi^- K^+ K^-$          | 28     | 11   | 1129  |
| 22    | $J/\psi \rightarrow \pi^+ K^* K^{*-} \gamma^F, K^* \rightarrow \pi^- K^+, K^{*-} \rightarrow \pi^0 K^-$   | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma^F$ | 54     | 11   | 1140  |
| 23    | $J/\psi \rightarrow \rho^- \bar{K}^* K^{*+}, \rho^- \rightarrow \pi^0 \pi^-, \bar{K}^* \rightarrow \pi^+ K^-, K^{*+} \rightarrow \pi^0 K^+$   | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 58     | 11   | 1151  |
| 24    | $J/\psi \rightarrow \pi^+ \pi^- \eta K^+ K^-, \eta \rightarrow \gamma \gamma$   | $\pi^+ \pi^- K^+ K^- \gamma \gamma$  | 43     | 11   | 1162  |
| 25    | $J/\psi \rightarrow \pi^0 \pi^+ K^* K^{*-}, K^* \rightarrow \pi^- K^+, K^{*-} \rightarrow \pi^0 K^-$  | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 65     | 11   | 1173  |
| 26    | $J/\psi \rightarrow K^0 \bar{K}^0 \phi, K^0 \rightarrow K_S^0, \bar{K}^0 \rightarrow K_S^0, \phi \rightarrow K^+ K^-, K_S^0 \rightarrow \pi^0 \pi^0, K_S^0 \rightarrow \pi^+ \pi^-$ | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 38     | 10   | 1183  |
| 27    | $J/\psi \rightarrow \pi^0 K^* \bar{K}_0^{*0}, K^* \rightarrow \pi^- K^+, \bar{K}_0^{*0} \rightarrow \pi^+ K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^-$          | 59     | 9    | 1192  |
| 28    | $J/\psi \rightarrow \pi^+ \pi^- K^{*+} K^{*-}, K^{*+} \rightarrow \pi^0 K^+, K^{*-} \rightarrow \pi^0 K^-$  | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 36     | 9    | 1201  |
| 29    | $J/\psi \rightarrow \rho^+ K^* K^{*-}, \rho^+ \rightarrow \pi^0 \pi^+, K^* \rightarrow \pi^- K^+, K^{*-} \rightarrow \pi^0 K^-$   | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 35     | 9    | 1210  |
| 30    | $J/\psi \rightarrow \phi f_1(1285), \phi \rightarrow K^+ K^-, f_1(1285) \rightarrow \pi^0 \pi^+ \rho^-, \rho^- \rightarrow \pi^0 \pi^-$   | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 66     | 9    | 1219  |
| 31    | $J/\psi \rightarrow \phi a_0^0, \phi \rightarrow K^+ K^-, a_0^0 \rightarrow \pi^0 \eta, \eta \rightarrow \pi^+ \pi^- \gamma^F$  | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma^F$ | 20     | 8    | 1227  |



Table 1: Decay trees and their respective final states.

| rowNo | decay tree  | decay final state                       | iDecyTr | nEtr | nCEtr |
|-------|---|---|---------|------|-------|
| 1     | $J/\psi \rightarrow \omega f_1(1420), \omega \rightarrow \pi^0 \pi^+ \pi^-, f_1(1420) \rightarrow \pi^0 K^+ K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^-$             | 2       | 75   | 75    |
| 2     | $J/\psi \rightarrow \omega K^+ K^{*-}, \omega \rightarrow \pi^0 \pi^+ \pi^-, K^{*-} \rightarrow \pi^0 K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^-$             | 8       | 32   | 107   |
| 3     | $J/\psi \rightarrow K_S^0 K_S^0 \phi, K_S^0 \rightarrow \pi^0 \pi^0, K_S^0 \rightarrow \pi^+ \pi^-, \phi \rightarrow K^+ K^-$   | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$       | 10      | 30   | 137   |
| 4     | $J/\psi \rightarrow \omega K^- K^{*+}, \omega \rightarrow \pi^0 \pi^+ \pi^-, K^{*+} \rightarrow \pi^0 K^+$  | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$       | 17      | 24   | 161   |
| 5     | $J/\psi \rightarrow f_2(1270) \phi, f_2(1270) \rightarrow \pi^0 \pi^0 \pi^+ \pi^-, \phi \rightarrow K^+ K^-$  | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$       | 6       | 10   | 171   |
| 6     | $J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \pi^0 \pi^+ \pi^- K^+ K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$      | 1       | 10   | 181   |
| 7     | $J/\psi \rightarrow \pi^0 \pi^+ \pi^- K^+ K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^-$             | 22      | 9    | 190   |
| 8     | $J/\psi \rightarrow \phi f_0(980), \phi \rightarrow K^+ K^-, f_0(980) \rightarrow K_S^0 K_S^0, K_S^0 \rightarrow \pi^0 \pi^0, K_S^0 \rightarrow \pi^+ \pi^-$                        | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$       | 27      | 9    | 199   |
| 9     | $J/\psi \rightarrow K^0 \bar{K}^0 \phi, K^0 \rightarrow K_S^0, \bar{K}^0 \rightarrow K_S^0, \phi \rightarrow K^+ K^-, K_S^0 \rightarrow \pi^+ \pi^-, K_S^0 \rightarrow \pi^0 \pi^0$ | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$       | 14      | 8    | 207   |
| 10    | $J/\psi \rightarrow \pi^0 \pi^- \bar{K}^* K^{*+}, \bar{K}^* \rightarrow \pi^+ K^-, K^{*+} \rightarrow \pi^0 K^+$  | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$       | 4       | 8    | 215   |
| 11    | $J/\psi \rightarrow K^0 \bar{K}^0 \phi, K^0 \rightarrow K_S^0, \bar{K}^0 \rightarrow K_S^0, \phi \rightarrow K^+ K^-, K_S^0 \rightarrow \pi^0 \pi^0, K_S^0 \rightarrow \pi^+ \pi^-$ | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$       | 11      | 7    | 222   |
| 12    | $J/\psi \rightarrow \omega f_0(980), \omega \rightarrow \pi^0 \pi^+ \pi^-, f_0(980) \rightarrow K^+ K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^-$             | 15      | 6    | 228   |
| 13    | $J/\psi \rightarrow \rho^- \bar{K}^* K^{*+}, \rho^- \rightarrow \pi^0 \pi^-, \bar{K}^* \rightarrow \pi^+ K^-, K^{*+} \rightarrow \pi^0 K^+$   | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$       | 12      | 5    | 233   |
| 14    | $J/\psi \rightarrow \phi a_0^0, \phi \rightarrow K^+ K^-, a_0^0 \rightarrow \pi^0 \eta, \eta \rightarrow \pi^0 \pi^+ \pi^-$   | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$       | 9       | 4    | 237   |
| 15    | $J/\psi \rightarrow \pi^0 \pi^+ \pi^- K^+ K^- \gamma^f$   | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma^f$    | 7       | 4    | 241   |
| 16    | $J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \pi^+ K^* K^{*-}, K^* \rightarrow \pi^- K^+, K^{*-} \rightarrow \pi^0 K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$      | 25      | 4    | 245   |
| 17    | $J/\psi \rightarrow \omega K^+ K^-, \omega \rightarrow \pi^0 \pi^+ \pi^-$   | $\pi^0 \pi^+ \pi^- K^+ K^-$             | 0       | 4    | 249   |
| 18    | $J/\psi \rightarrow \pi^0 K^* \bar{K}^* \gamma, K^* \rightarrow \pi^- K^+, \bar{K}^* \rightarrow \pi^+ K^-$   | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$      | 29      | 4    | 253   |
| 19    | $J/\psi \rightarrow \phi f_1(1285), \phi \rightarrow K^+ K^-, f_1(1285) \rightarrow \pi^0 \pi^+ \rho^-, \rho^- \rightarrow \pi^0 \pi^-$   | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$       | 21      | 3    | 256   |
| 20    | $J/\psi \rightarrow \pi^0 \pi^+ K^* K^{*-}, K^* \rightarrow \pi^- K^+, K^{*-} \rightarrow \pi^0 K^-$  | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$       | 36      | 3    | 259   |
| 21    | $J/\psi \rightarrow \pi^0 \bar{K}^* K_2^{*0}, \bar{K}^* \rightarrow \pi^+ K^-, K_2^{*0} \rightarrow \pi^- K^{*+}, K^{*+} \rightarrow \pi^0 K^+$                                     | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$       | 16      | 2    | 261   |
| 22    | $J/\psi \rightarrow \pi^0 \pi^0 \phi, \phi \rightarrow K^+ K^-$   | $\pi^0 \pi^0 K^+ K^-$                   | 13      | 2    | 263   |
| 23    | $J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \pi^0 K^* \bar{K}^*, K^* \rightarrow \pi^- K^+, \bar{K}^* \rightarrow \pi^+ K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$      | 32      | 2    | 265   |
| 24    | $J/\psi \rightarrow \rho^+ K^* K^{*-}, \rho^+ \rightarrow \pi^0 \pi^+, K^* \rightarrow \pi^- K^+, K^{*-} \rightarrow \pi^0 K^-$   | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$       | 35      | 2    | 267   |
| 25    | $J/\psi \rightarrow \pi^+ \pi^- K^{*+} K^{*-}, K^{*+} \rightarrow \pi^0 K^+, K^{*-} \rightarrow \pi^0 K^-$  | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$       | 18      | 2    | 269   |
| 26    | $J/\psi \rightarrow \pi^0 K^* K_2^{*0}, K^* \rightarrow \pi^- K^+, K_2^{*0} \rightarrow \pi^+ K^{*-}, K^{*-} \rightarrow \pi^0 K^-$   | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$       | 42      | 2    | 271   |
| 27    | $J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \pi^+ K^* K_2^{*0}, K^* \rightarrow \pi^- K^+, K_2^{*0} \rightarrow \pi^0 K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$      | 57      | 2    | 273   |
| 28    | $J/\psi \rightarrow K^+ K^{*-} \eta', K^{*-} \rightarrow \pi^0 K^-, \eta' \rightarrow \pi^+ \pi^- \gamma^F$   | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma^F$    | 20      | 1    | 274   |
| 29    | $J/\psi \rightarrow \eta K^+ K^{*-}, \eta \rightarrow \pi^+ \pi^- \gamma^F, K^{*-} \rightarrow \pi^0 K^-$   | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma^F$    | 28      | 1    | 275   |
| 30    | $J/\psi \rightarrow \pi^- K_S^0 K_2^{*+}, K_S^0 \rightarrow \pi^0 \pi^0, K_2^{*+} \rightarrow \omega K^+, \omega \rightarrow \pi^0 \pi^+ \pi^-$                                     | $\pi^0 \pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$ | 5       | 1    | 276   |
| 31    | $J/\psi \rightarrow a_0^0 b_1^0, a_0^0 \rightarrow K^+ K^-, b_1^0 \rightarrow \pi^0 \omega, \omega \rightarrow \pi^0 \pi^+ \pi^-$   | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$       | 30      | 1    | 277   |



Table 1: Decay trees and their respective final states.

| rowNo | decay tree  | decay final state                    | iDcyTr | nEtr | nCEtr |
|-------|---|--------------------------------------|--------|------|-------|
| 1     | $J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \pi^0 \pi^+ \pi^- K^+ K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$   | 6      | 46   | 46    |
| 2     | $J/\psi \rightarrow \pi^0 \pi^+ \pi^- K^+ K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^-$          | 0      | 31   | 77    |
| 3     | $J/\psi \rightarrow \omega f_0(980), \omega \rightarrow \pi^0 \pi^+ \pi^-, f_0(980) \rightarrow K^+ K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^-$          | 4      | 21   | 98    |
| 4     | $J/\psi \rightarrow \pi^0 \pi^+ \pi^- K^+ K^- \gamma^f$   | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma^f$ | 29     | 15   | 113   |
| 5     | $J/\psi \rightarrow \omega f_1(1420), \omega \rightarrow \pi^0 \pi^+ \pi^-, f_1(1420) \rightarrow \pi^0 K^+ K^-$  | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 9      | 12   | 125   |
| 6     | $J/\psi \rightarrow \omega K^- K^{*+}, \omega \rightarrow \pi^0 \pi^+ \pi^-, K^{*+} \rightarrow \pi^0 K^+$  | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 3      | 12   | 137   |
| 7     | $J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \pi^+ K^* K^{*-}, K^* \rightarrow \pi^- K^+, K^{*-} \rightarrow \pi^0 K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$   | 27     | 9    | 146   |
| 8     | $J/\psi \rightarrow K_S^0 K_S^0 \phi, K_S^0 \rightarrow \pi^0 \pi^0, K_S^0 \rightarrow \pi^+ \pi^-, \phi \rightarrow K^+ K^-$   | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 37     | 8    | 154   |
| 9     | $J/\psi \rightarrow \pi^0 \bar{K}^* K_2^{*0}, \bar{K}^* \rightarrow \pi^+ K^-, K_2^{*0} \rightarrow \pi^- K^+$  | $\pi^0 \pi^+ \pi^- K^+ K^-$          | 21     | 7    | 161   |
| 10    | $J/\psi \rightarrow \pi^0 K^* K_2^{*0}, K^* \rightarrow \pi^- K^+, K_2^{*0} \rightarrow \pi^+ K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^-$          | 43     | 7    | 168   |
| 11    | $J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \pi^0 K^* \bar{K}^*, K^* \rightarrow \pi^- K^+, \bar{K}^* \rightarrow \pi^+ K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$   | 13     | 6    | 174   |
| 12    | $J/\psi \rightarrow \omega K^+ K^-, \omega \rightarrow \pi^0 \pi^+ \pi^-$   | $\pi^0 \pi^+ \pi^- K^+ K^-$          | 34     | 5    | 179   |
| 13    | $J/\psi \rightarrow \omega K^+ K^{*-}, \omega \rightarrow \pi^0 \pi^+ \pi^-, K^{*-} \rightarrow \pi^0 K^-$  | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 14     | 5    | 184   |
| 14    | $J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \pi^- \bar{K}^* K^{*+}, \bar{K}^* \rightarrow \pi^+ K^-, K^{*+} \rightarrow \pi^0 K^+$  | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$   | 22     | 5    | 189   |
| 15    | $J/\psi \rightarrow \phi \phi \gamma, \phi \rightarrow \pi^- \rho^+, \phi \rightarrow K^+ K^-, \rho^+ \rightarrow \pi^0 \pi^+$  | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$   | 39     | 4    | 193   |
| 16    | $J/\psi \rightarrow f_2(1270) \phi, f_2(1270) \rightarrow \pi^0 \pi^0 \pi^+ \pi^-, \phi \rightarrow K^+ K^-$  | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 20     | 4    | 197   |
| 17    | $J/\psi \rightarrow K^0 \bar{K}^0 \phi, K^0 \rightarrow K_S^0, \bar{K}^0 \rightarrow K_S^0, \phi \rightarrow K^+ K^-, K_S^0 \rightarrow \pi^+ \pi^-, K_S^0 \rightarrow \pi^0 \pi^0$ | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 11     | 3    | 200   |
| 18    | $J/\psi \rightarrow \pi^+ \pi^- \eta K^+ K^-, \eta \rightarrow \gamma \gamma$   | $\pi^+ \pi^- K^+ K^- \gamma \gamma$  | 7      | 3    | 203   |
| 19    | $J/\psi \rightarrow \phi a_0^0, \phi \rightarrow K^+ K^-, a_0^0 \rightarrow \pi^0 \eta, \eta \rightarrow \pi^0 \pi^+ \pi^-$   | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 36     | 3    | 206   |
| 20    | $J/\psi \rightarrow \pi^- \bar{K}^* K^{*+} \gamma^F, \bar{K}^* \rightarrow \pi^+ K^-, K^{*+} \rightarrow \pi^0 K^+$   | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma^F$ | 2      | 3    | 209   |
| 21    | $J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \phi \phi, \phi \rightarrow \pi^+ \rho^-, \phi \rightarrow K^+ K^-, \rho^- \rightarrow \pi^0 \pi^-$                           | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$   | 38     | 3    | 212   |
| 22    | $J/\psi \rightarrow \phi f_0(980), \phi \rightarrow K^+ K^-, f_0(980) \rightarrow K_S^0 K_S^0, K_S^0 \rightarrow \pi^0 \pi^0, K_S^0 \rightarrow \pi^+ \pi^-$                        | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 25     | 3    | 215   |
| 23    | $J/\psi \rightarrow \eta_c \gamma, \eta_c \rightarrow \pi^+ K^* K_2^{*-}, K^* \rightarrow \pi^- K^+, K_2^{*-} \rightarrow \pi^0 K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$   | 17     | 3    | 218   |
| 24    | $J/\psi \rightarrow \phi \phi \gamma, \phi \rightarrow \pi^+ \rho^-, \phi \rightarrow K^+ K^-, \rho^- \rightarrow \pi^0 \pi^-$  | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma$   | 45     | 3    | 221   |
| 25    | $J/\psi \rightarrow \pi^+ K^* K^{*-} \gamma^F, K^* \rightarrow \pi^- K^+, K^{*-} \rightarrow \pi^0 K^-$   | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma^F$ | 48     | 3    | 224   |
| 26    | $J/\psi \rightarrow \pi^0 K^* \bar{K}_0^{*0}, K^* \rightarrow \pi^- K^+ \gamma^f, \bar{K}_0^{*0} \rightarrow \pi^+ K^-$   | $\pi^0 \pi^+ \pi^- K^+ K^- \gamma^f$ | 35     | 2    | 226   |
| 27    | $J/\psi \rightarrow \phi f_1(1285), \phi \rightarrow K^+ K^-, f_1(1285) \rightarrow \pi^+ \pi^- \eta, \eta \rightarrow \gamma \gamma$   | $\pi^+ \pi^- K^+ K^- \gamma \gamma$  | 10     | 2    | 228   |
| 28    | $J/\psi \rightarrow \rho^- \bar{K}^* K^{*+}, \rho^- \rightarrow \pi^0 \pi^-, \bar{K}^* \rightarrow \pi^+ K^-, K^{*+} \rightarrow \pi^0 K^+$   | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 28     | 2    | 230   |
| 29    | $J/\psi \rightarrow K^0 \bar{K}^0 \phi, K^0 \rightarrow K_S^0, \bar{K}^0 \rightarrow K_S^0, \phi \rightarrow K^+ K^-, K_S^0 \rightarrow \pi^0 \pi^0, K_S^0 \rightarrow \pi^+ \pi^-$ | $\pi^0 \pi^0 \pi^+ \pi^- K^+ K^-$    | 19     | 2    | 232   |
| 30    | $J/\psi \rightarrow \eta' \phi, \eta' \rightarrow \pi^+ \pi^- \eta, \phi \rightarrow K^+ K^-, \eta \rightarrow \gamma \gamma$   | $\pi^+ \pi^- K^+ K^- \gamma \gamma$  | 30     | 2    | 234   |
| 31    | $J/\psi \rightarrow \pi^+ K^* K_0^{*-}, K^* \rightarrow \pi^- K^+, K_0^{*-} \rightarrow \pi^0 K^-$  | $\pi^0 \pi^+ \pi^- K^+ K^-$          | 31     | 2    | 236   |



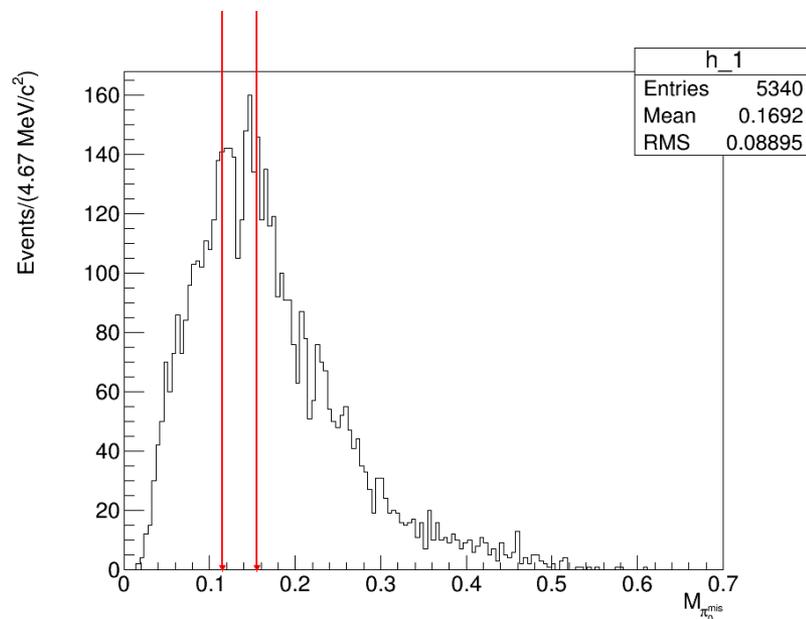
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1 Decay J/psi
2 1.000 phi eta' HELAMP 1.0 0.0 0.0 0.0 1.0 3.1415926;
3 Enddecay
4
5 Decay eta'
6 1.000 omega gamma SVP_HELAMP 1.0 0.0 1.0 0.0;
7 Enddecay
8
9 Decay omega
10 1.000 pi- pi+ pi0 OMEGA_DALITZ;
11 Enddecay
12
13 Decay phi
14 1.000 K+ K- VSS;
15 Enddecay
16
17 Decay pi0
18 1.000 gamma gamma PHSP;
19 Enddecay
20
21 End
22
23
24
25
```

:q

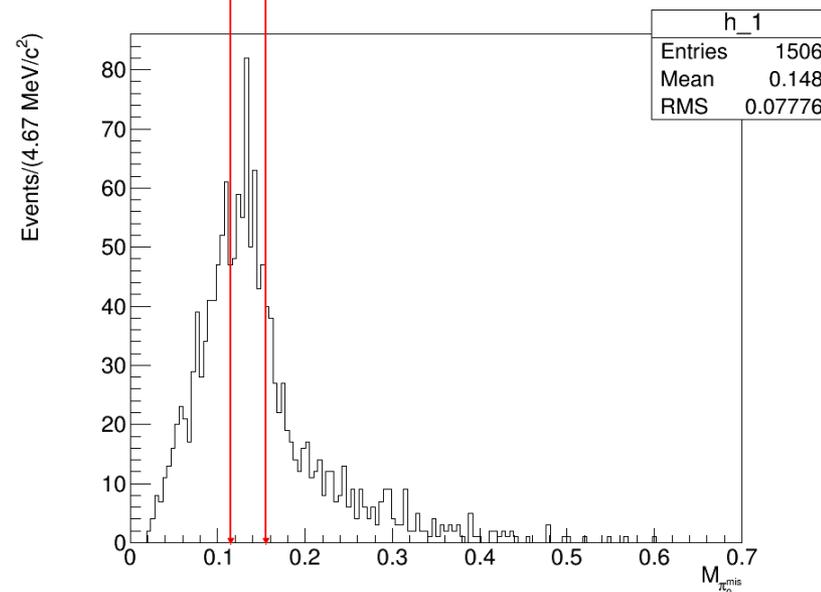
10,26-27

All

# pi0mis after cut1



data



inMC

# Efficiency



| Criteria                                  | events | Efficiency(%) | Relative efficiency |
|---|--------|---------------|---------------------|
| InclusiveMC                               | 10b    | 100           |                     |
| $N_{good} = 4 \ \&\& \ Q_{total} = 0$     | 1.3b   | 13            |                     |
| $N_{\gamma} \geq 3$                       | 66m    | 6.6           |                     |
| Pass Pid                                  | 63m    | 6.3           |                     |
| Vertex Fit                                | 62m    | 6.2           |                     |
| Pass 4C                                   | 17m    | 1.7           |                     |
| Pass 5C                                   | 15m    | 1.5           |                     |
| cut1                                      | 1506   |               | 100                 |
| Cut2 veto $\pi_0^{red}$                   | 1200   |               | 79.68               |
| Cut2 veto $\pi_0^{mis}$ and $\pi_0^{red}$ | 942    |               | 62.55               |