

*Primary Monte-Carlo simulation generator of the process*  
$$e^+e^- \rightarrow f_0(1370)\rho(770)$$
*for the CMD-3 experiment*

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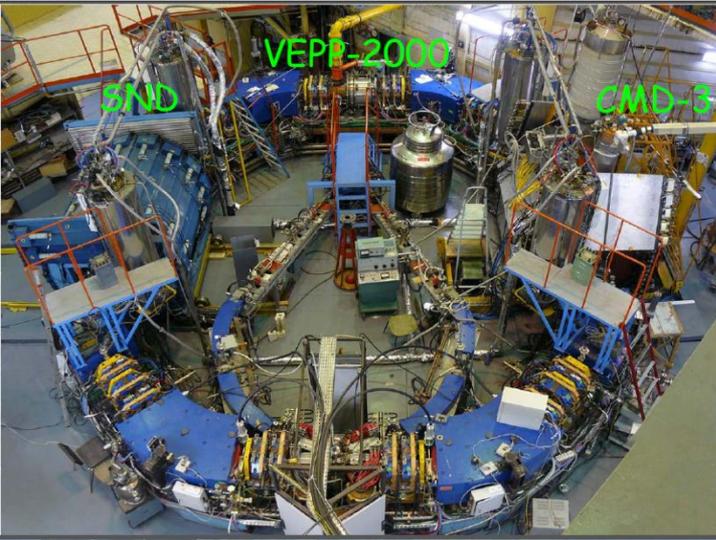
**XVII Radio MonteCarLow WG: LNF, 20-21 April 2015**



# *OUTLINE*

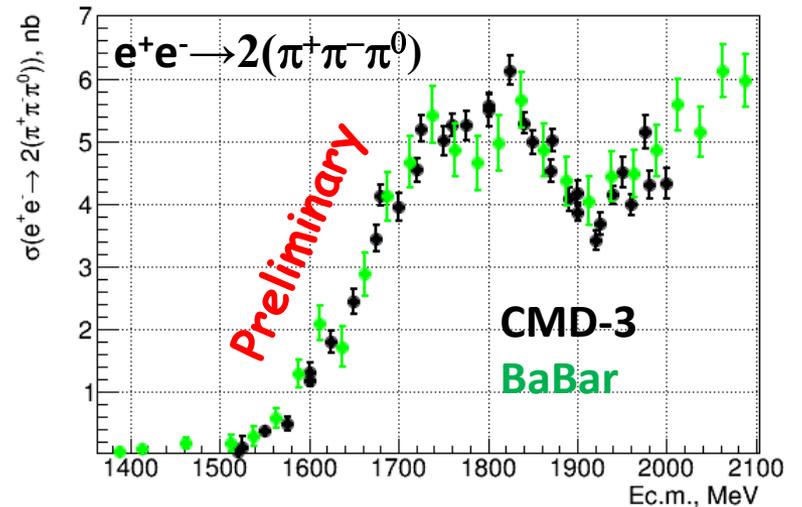
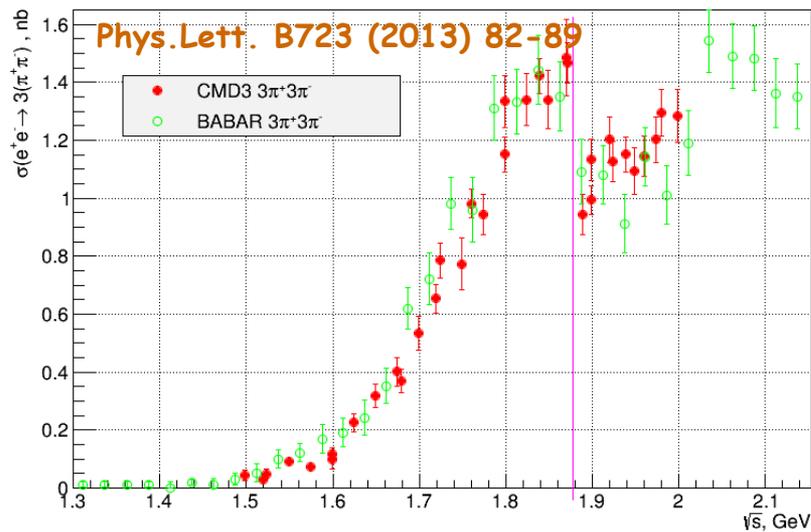
- INTRODUCTION
- MOTIVATION
- GENERATOR
- MASS AND ANGULAR DISTRIBUTIONS
- CONCLUSION

# INTRODUCTION



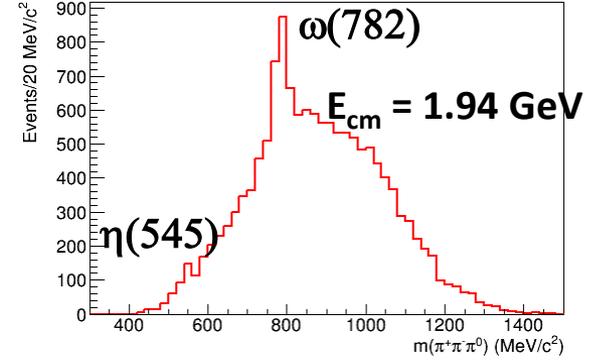
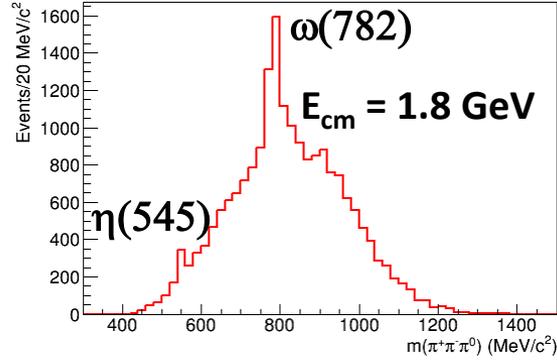
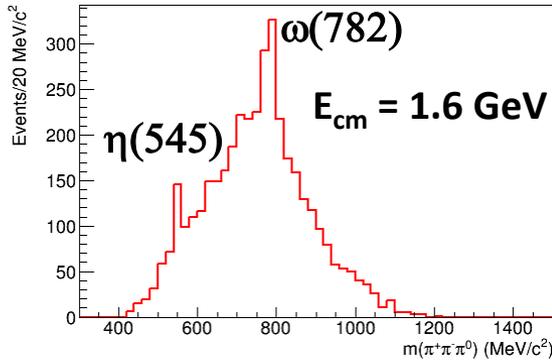
**VEPP-2000**  
 $2E = 0.32 - 2.0 \text{ GeV}$   
Round beams  
 $L = 2 \cdot 10^{31} \text{ cm}^{-2} \cdot \text{c}^{-1}$  at  $1.8 \text{ GeV}$

**CMD-3**  
DC – drift chamber,  
ZC – Z-chamber  
SC solenoid,  $B = 1.3 \text{ T}$   
LXe – LXe calorimeter (400 l)  
TOF – Time of Flight system  
CsI – CsI calorimeter (1152 cr)  
BGO – BGO calorimeter (680 cr)  
MU – muon range system



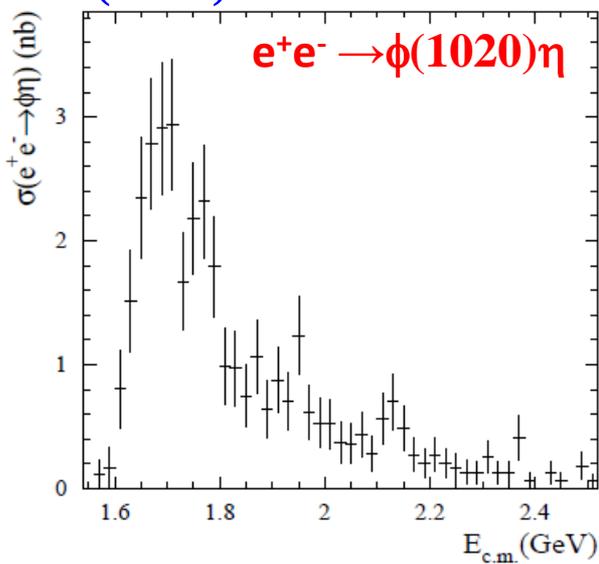
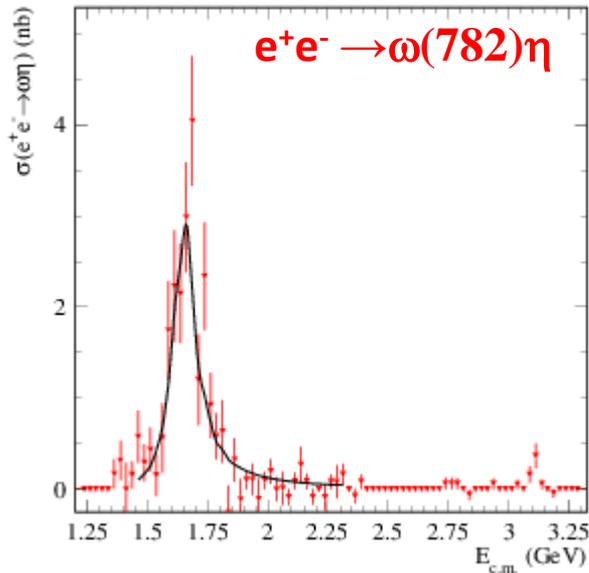
# GENERAL MOTIVATION

To calculate detection efficiency for  $e^+e^- \rightarrow 2(\pi^+\pi^-\pi^0)$  we have to correctly describe angular correlations between particles



$\sigma(4\pi 2\pi^0) = 0.61 \text{ nb @ } 1.7 \text{ GeV}$

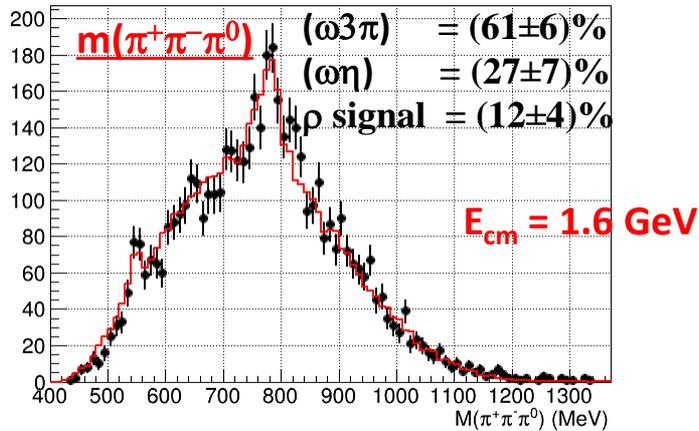
$\sigma(4\pi 2\pi^0) = 0.11 \text{ nb @ } 1.7 \text{ GeV}$



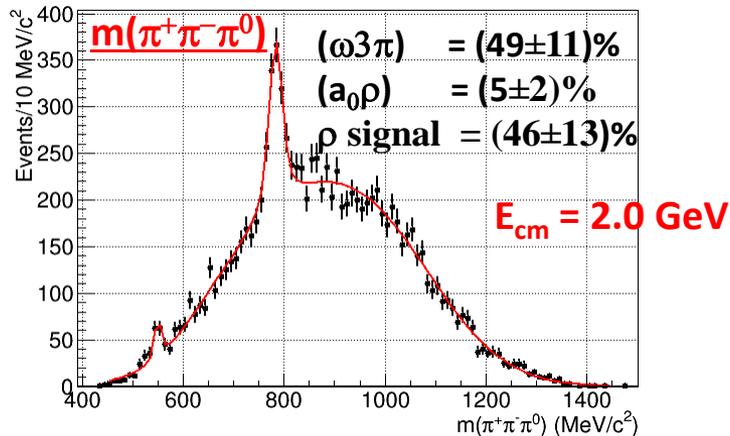
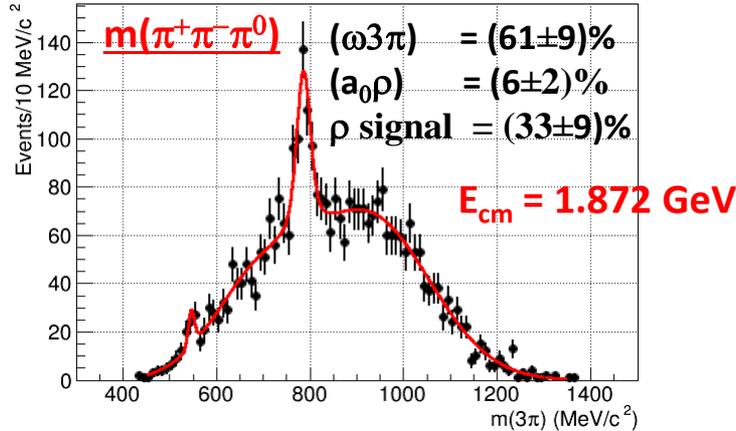
At least we need:

- $\omega(782)3\pi$
- $\omega(782)\eta$
- $\eta 3\pi$
- $a_0(980)\rho(770)$
- $\rho(770)4\pi$

# METHOD

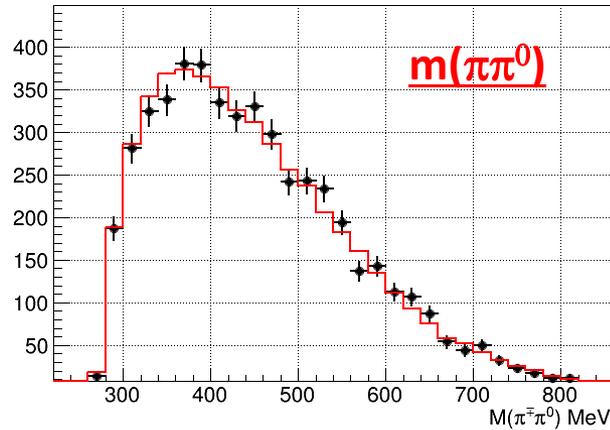
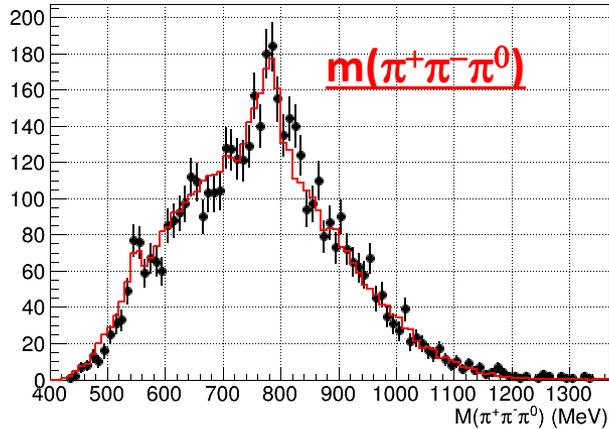


$\omega(782)$  and  $\eta(550)$  signals are from the fit.  
 $\rho(770)$  signal – is all the rest.  
No interference is assumed



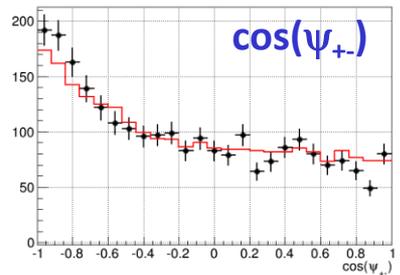
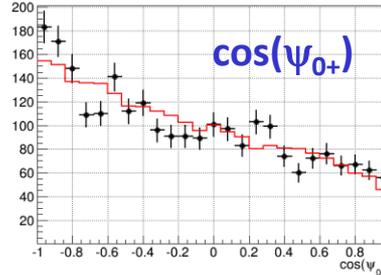
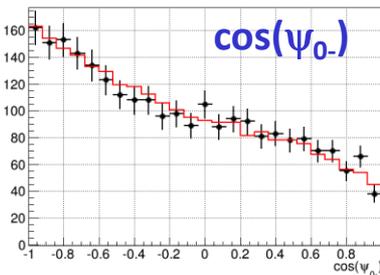
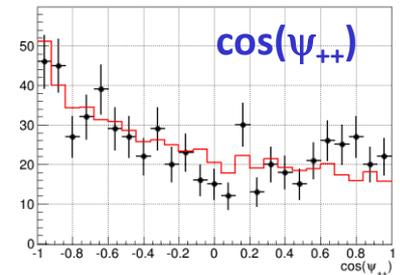
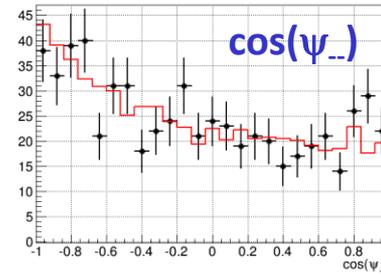
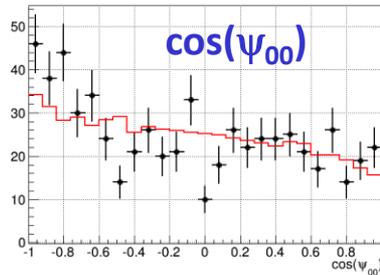
# MOTIVATION(I)

Talk @ XV RadioMonteCarlo (Mainz, Germany, 11/04/2014):



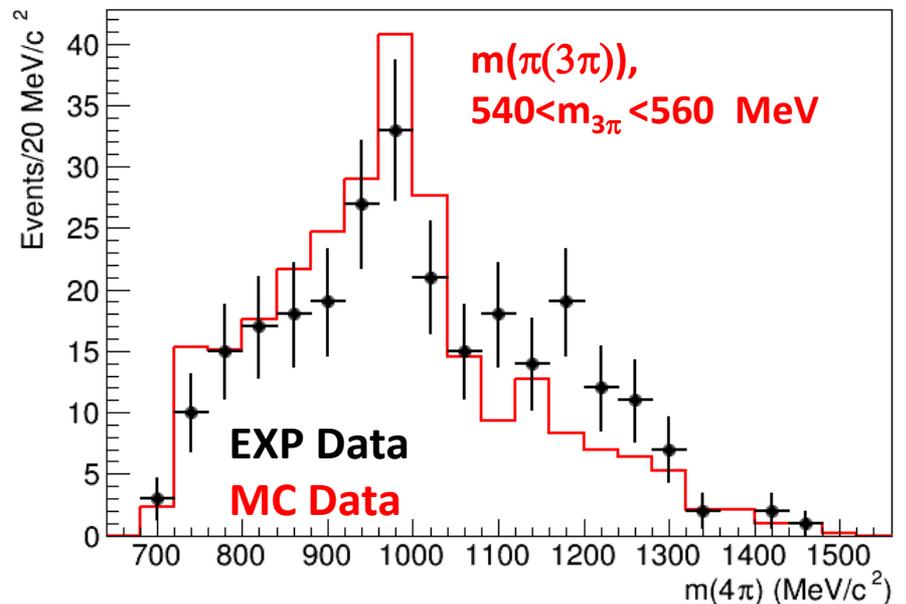
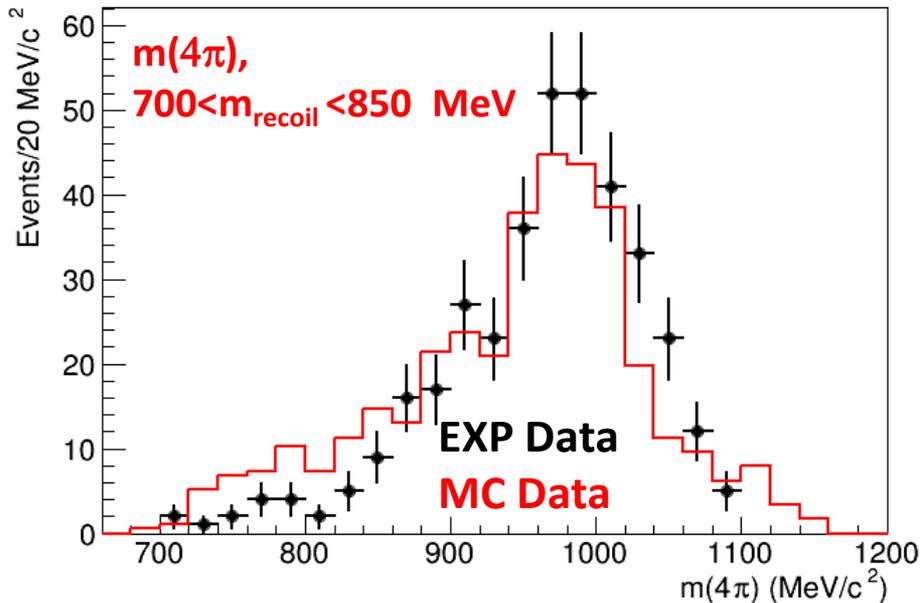
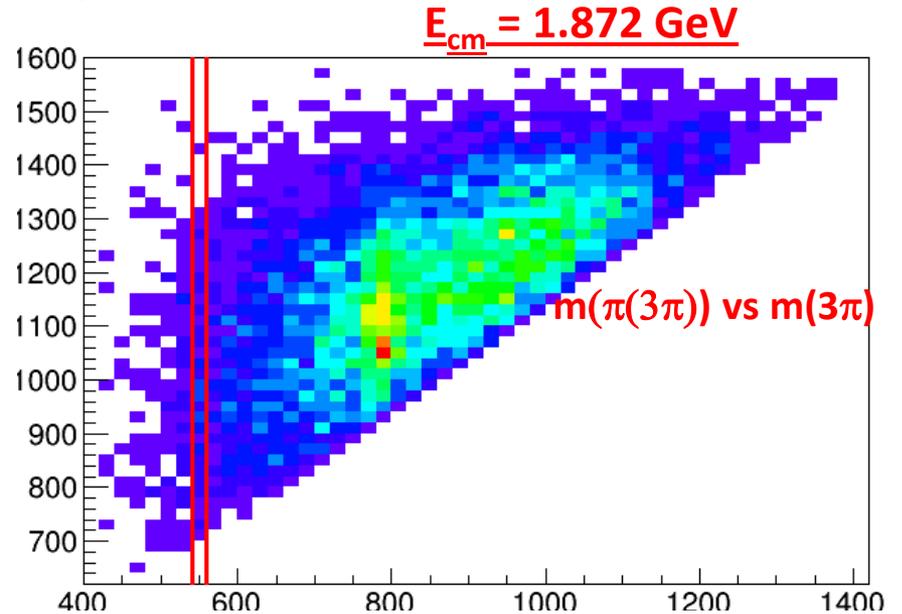
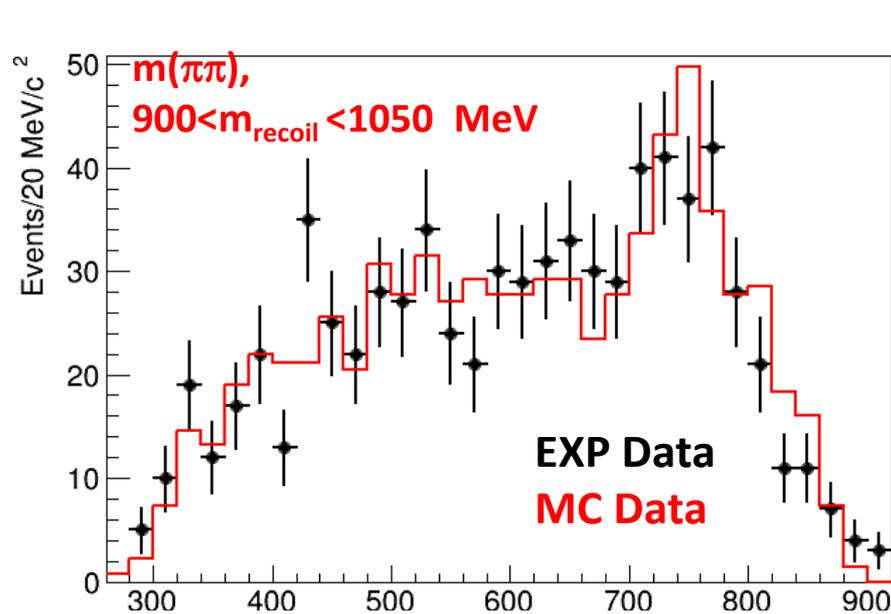
$E_{\text{cm}} = 1.6 \text{ GeV}$

Determined the fractions of  $\omega 3\pi$ ,  $\omega \eta$ ,  $\rho 4\pi$  from the fit of  $m(3\pi)$  we could describe  $m(2\pi)$  and angular correlations well enough.

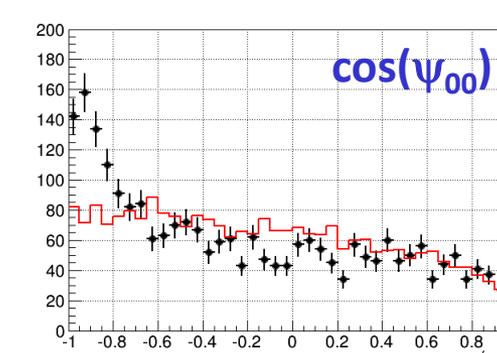
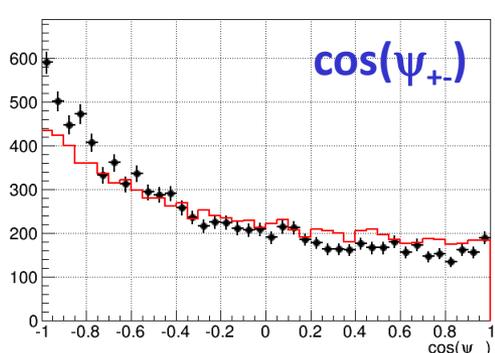
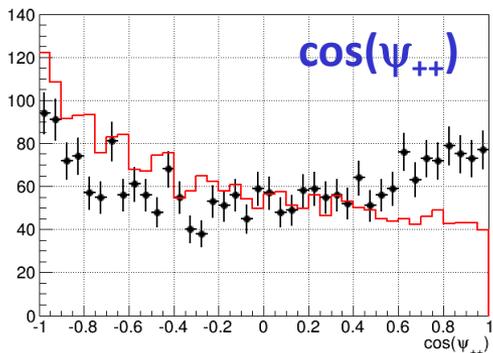
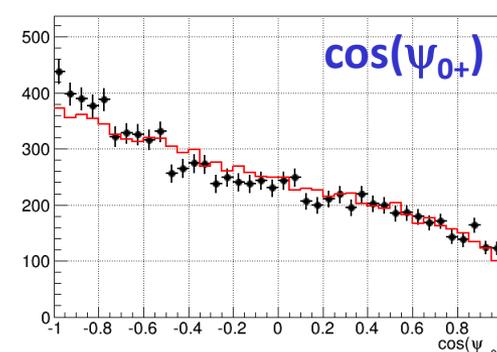
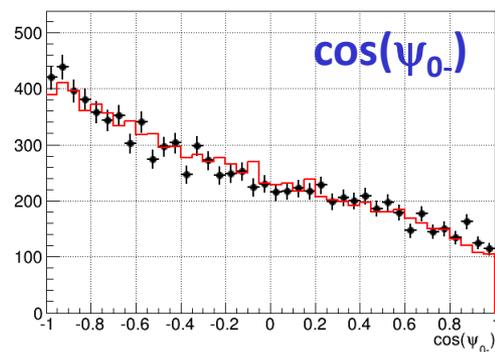
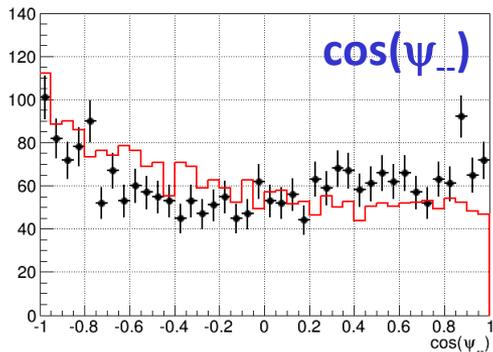
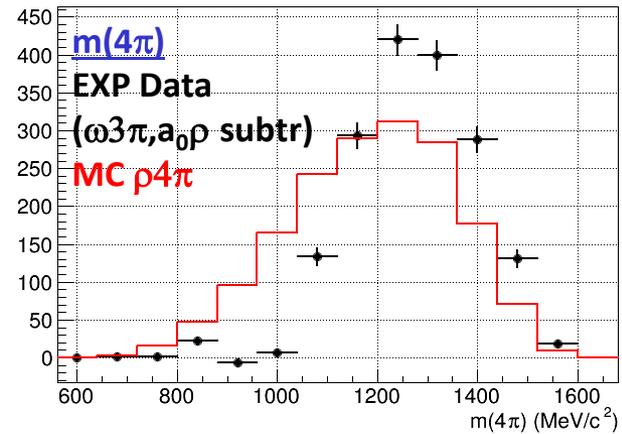
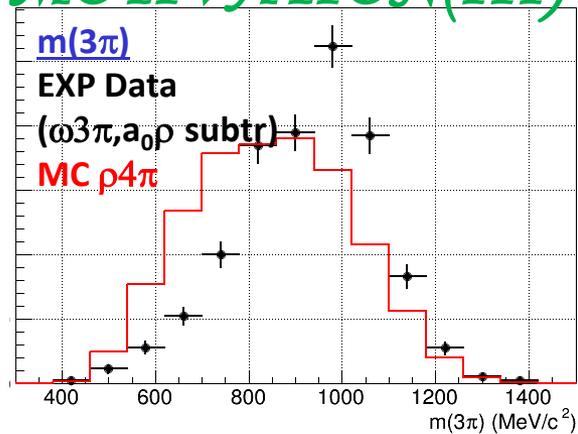
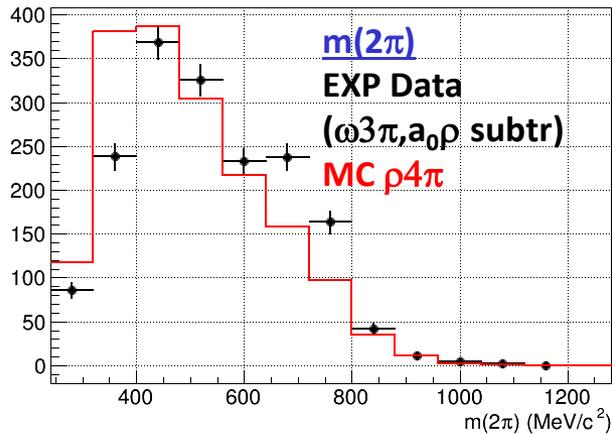


# MOTIVATION(II)

Talk @ XVI RadioMonteCarlo (LNF, Frascati, Italy, 18/11/2014):



# MOTIVATION(III)



**We described  $\omega(782)$  and  $\eta(545)$  signals, but we still have to describe the rest ( $\rho(770)$  etc.)**

# GENERATOR(I)

$f_0(1370)$

$$I^G(J^{PC}) = 0^+(0^{++})$$

## $f_0(1370)$ T-MATRIX POLE POSITION

Note that  $\Gamma \approx 2 \operatorname{Im}(\sqrt{s_{\text{pole}}})$ .

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
(1200–1500)–i(150–250)	OUR ESTIMATE		

## $f_0(1370)$ DECAY MODES

	Mode	Fraction ( $\Gamma_i/\Gamma$ )
$\Gamma_1$	$\pi\pi$	seen
$\Gamma_2$	$4\pi$	seen
$\Gamma_3$	$4\pi^0$	seen
$\Gamma_4$	$2\pi^+2\pi^-$	seen
$\Gamma_5$	$\pi^+\pi^-2\pi^0$	seen
$\Gamma_6$	$\rho\rho$	dominant

# GENERATOR(II)

For the mode with  $2\pi^+$ ,  $2\pi^-$  and  $2\pi^0$  mesons in the final state we have (here  $q_1$  and  $q_4$  are momenta of  $\pi^+$ ,  $q_2$  and  $q_5$  are momenta of  $\pi^-$ ,  $q_3$  and  $q_6$  are momenta of  $\pi^0$ ):

$$e^+e^- \rightarrow f_0(1370)\rho(770) \rightarrow 3\rho(770)$$

$$\begin{aligned} M(p_1, p_2; q_1, q_2, q_3, q_4, q_5, q_6) &= -e^2 G \left( q_2 - q_1 \right)_\nu (q_4 - q_3)(q_6 - q_5) \bar{v}_{e^+}(p_2) \gamma_\mu u_{e^-}(p_1) \\ &\times \frac{1}{q^2} \left( g^{\mu\nu} q q_{12} - q^\nu q_{12}^\mu \right) \frac{1}{q_{3456}^2 - M_{f_0}^2 + iM_{f_0} \Gamma_{f_0}} \\ &\times \frac{1}{q_{12}^2 - M_\rho^2 + iM_\rho \Gamma_\rho} \frac{1}{q_{34}^2 - M_\rho^2 + iM_\rho \Gamma_\rho} \frac{1}{q_{56}^2 - M_\rho^2 + iM_\rho \Gamma_\rho} \end{aligned}$$

$$e^+e^- \rightarrow f_0(1370)\rho(770) \rightarrow \rho(770)4\pi$$

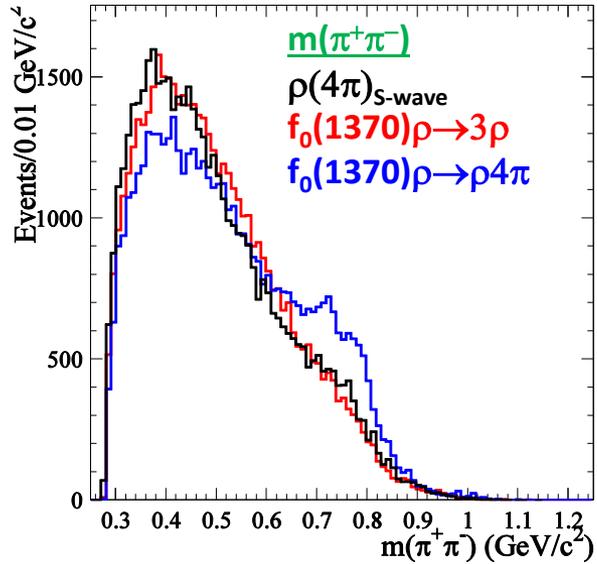
$$\begin{aligned} M(p_1, p_2; q_1, q_2, q_3, q_4, q_5, q_6) &= -e^2 G \left( q_2 - q_1 \right)_\nu \bar{v}_{e^+}(p_2) \gamma_\mu u_{e^-}(p_1) \\ &\times \frac{1}{q^2} \left( g^{\mu\nu} q q_{12} - q^\nu q_{12}^\mu \right) \frac{1}{q_{3456}^2 - M_{f_0}^2 + iM_{f_0} \Gamma_{f_0}} \\ &\times \frac{1}{q_{12}^2 - M_\rho^2 + iM_\rho \Gamma_\rho}, \end{aligned}$$

where  $G = g_{\rho\pi\pi} g_{f_0 2\pi^+2\pi^-2\pi^0} g_{f_0 \rho\gamma}$  is resulting effective coupling constant, where

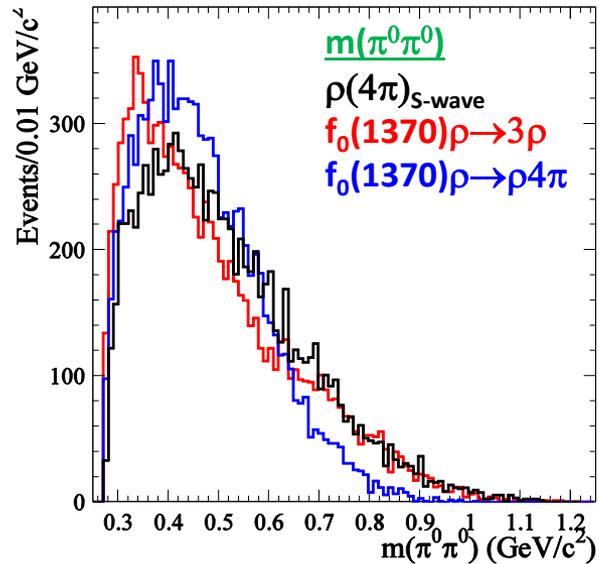
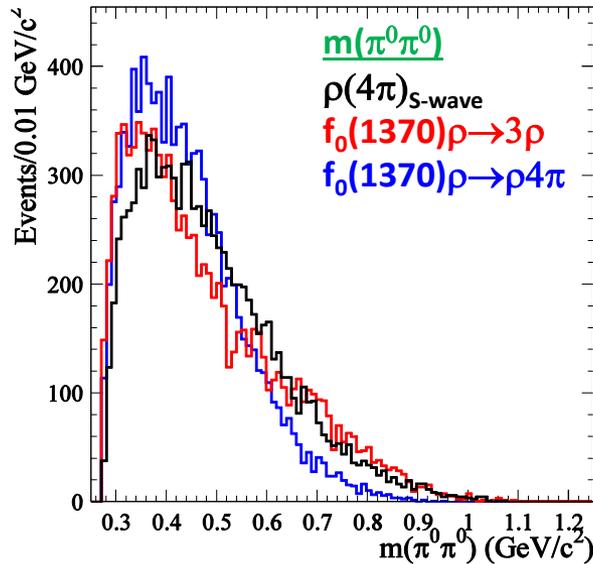
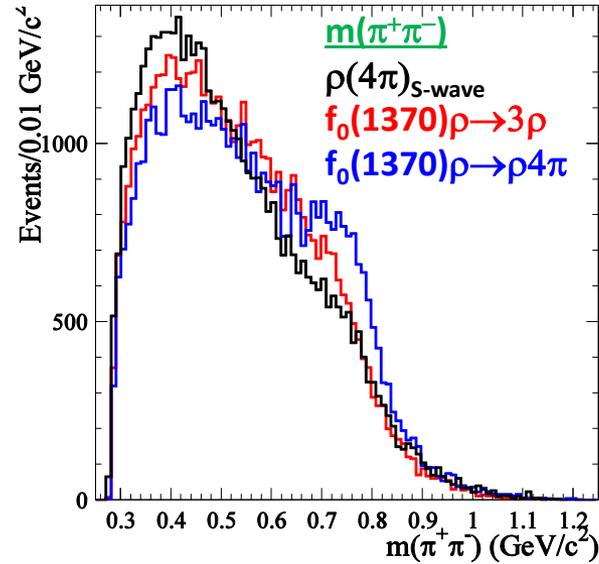
$$\begin{aligned} g_{f_0 2\pi^+2\pi^-2\pi^0} &= \frac{4}{3} \left[ \frac{1}{\sqrt{2}} B_{i1} c_d^s + \frac{1}{\sqrt{3}} B_{i2} c_d^g \right] \left[ q_3 q_4 + q_5 q_6 - \frac{1}{4} (q_3 + q_4)(q_5 + q_6) \right] \\ &+ \frac{4}{3} M_\pi^2 \left[ B_{i1} \frac{c_m^s}{\sqrt{2}} + B_{i2} \frac{c_m^g}{\sqrt{3}} \right] \end{aligned}$$

# MASS DISTRIBUTIONS(I)

**E = 1872 MeV**

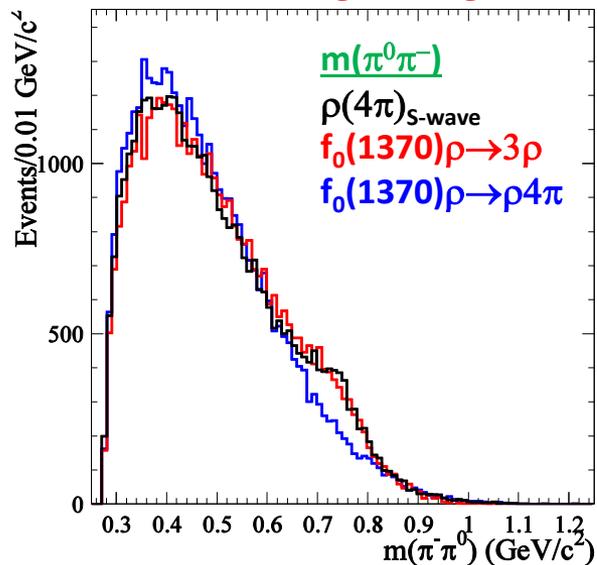


**E = 2000 MeV**

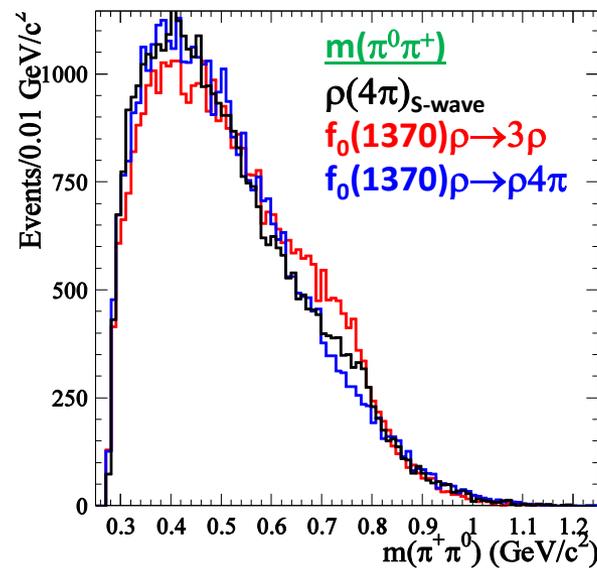
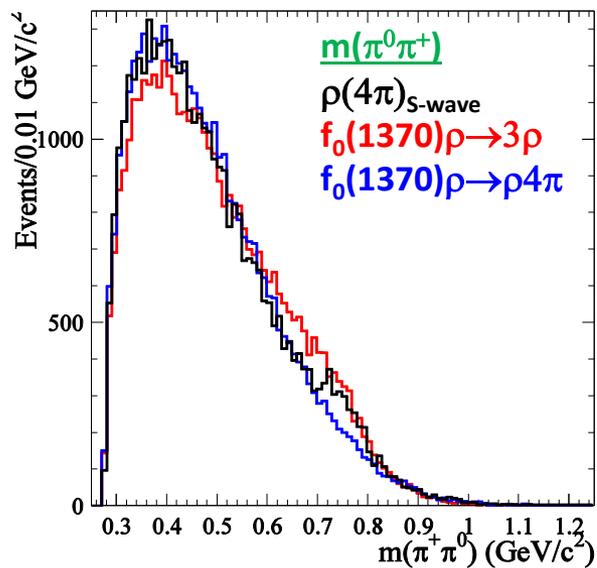
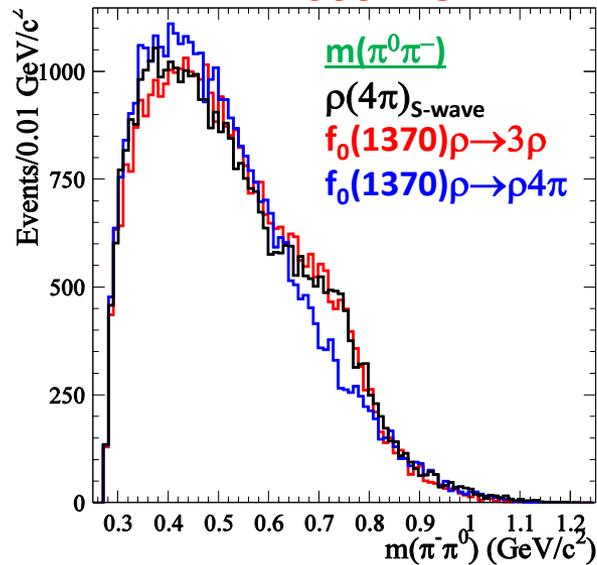


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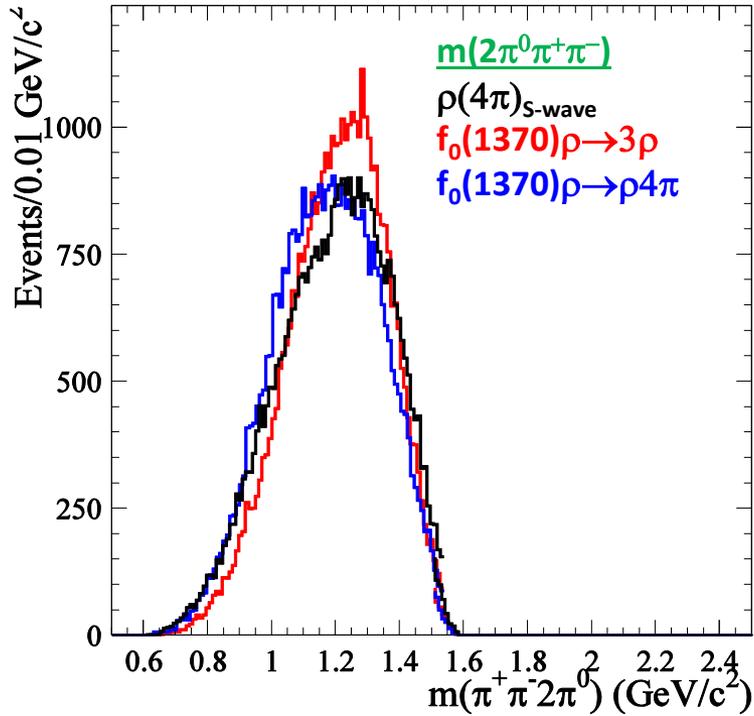


**E = 2000 MeV**

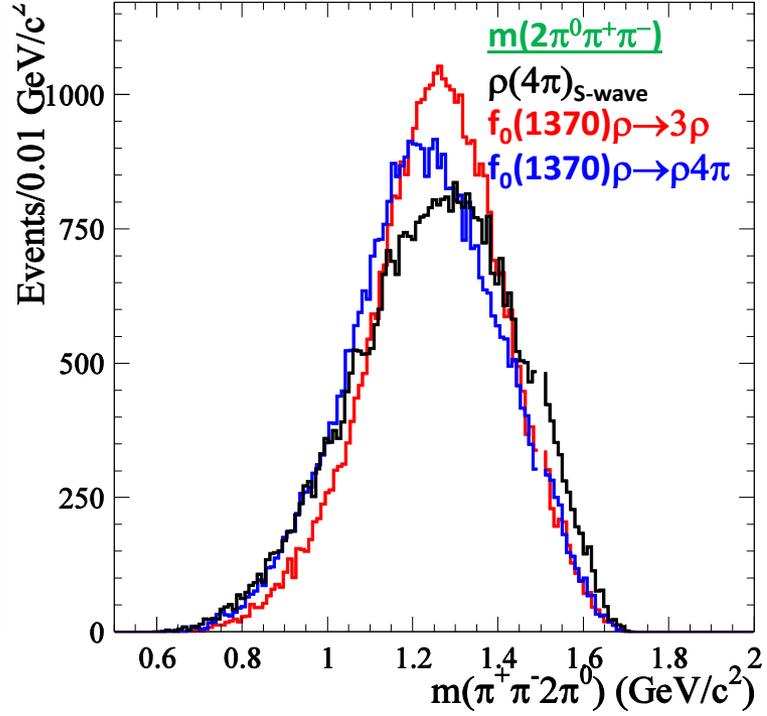


# MASS DISTRIBUTIONS(III)

**E = 1872 MeV**



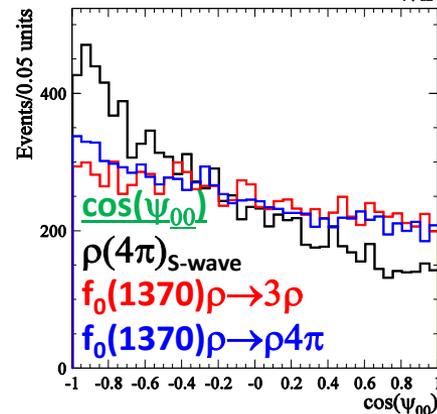
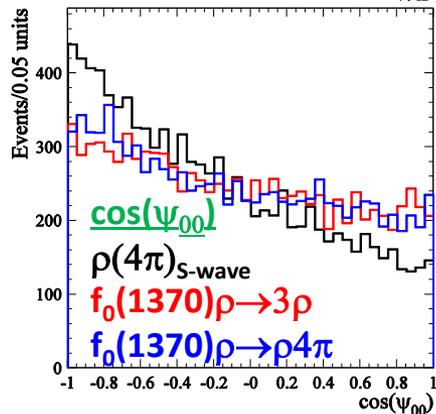
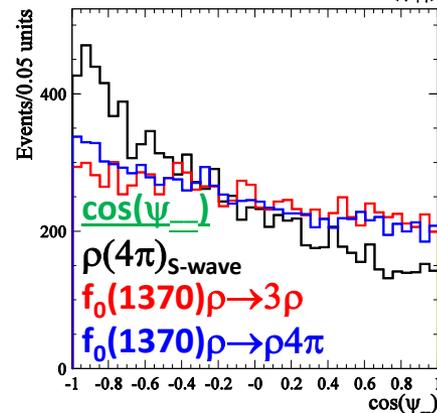
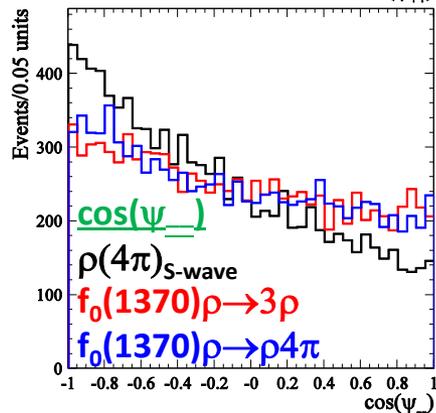
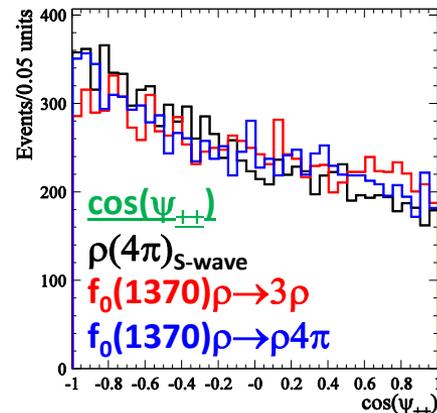
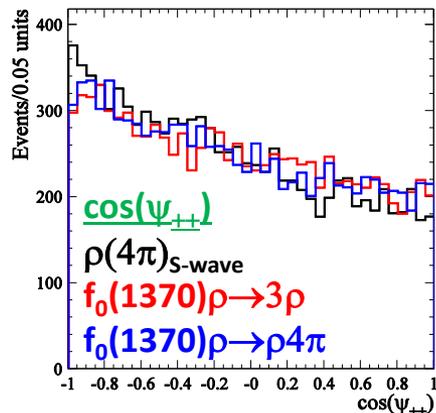
**E = 2000 MeV**



# ANGULAR DISTRIBUTIONS(I)

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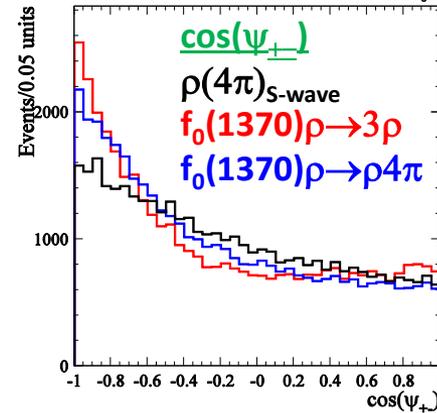
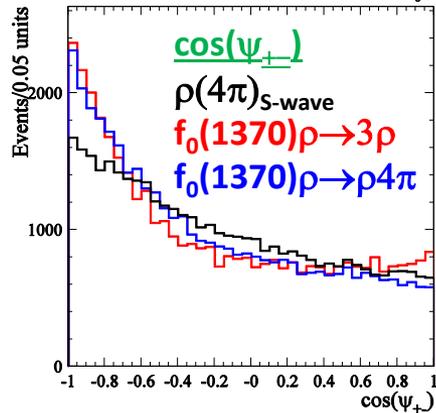
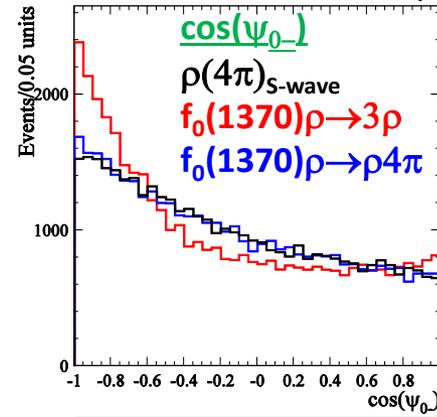
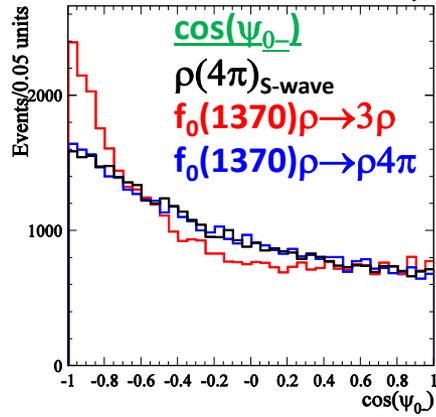
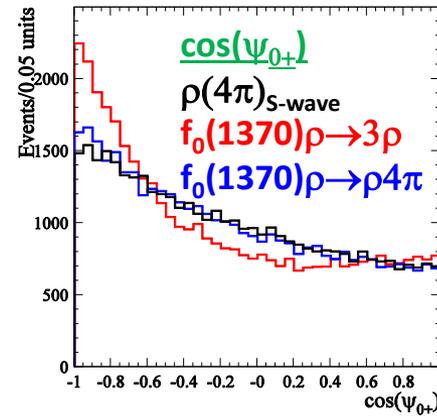
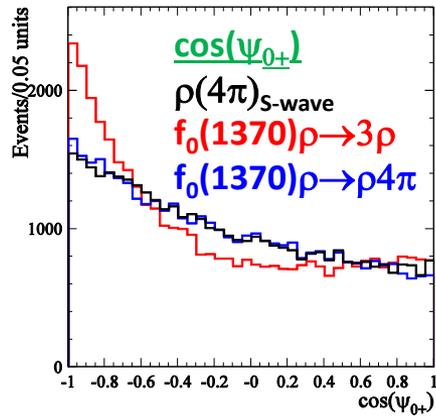
**E = 2000 MeV**



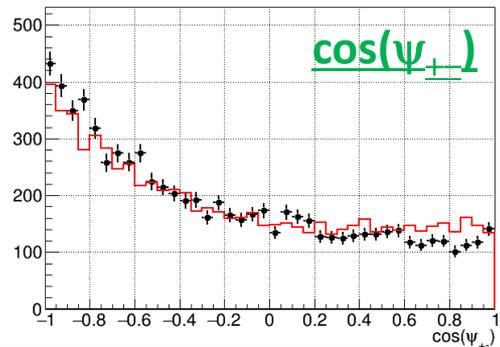
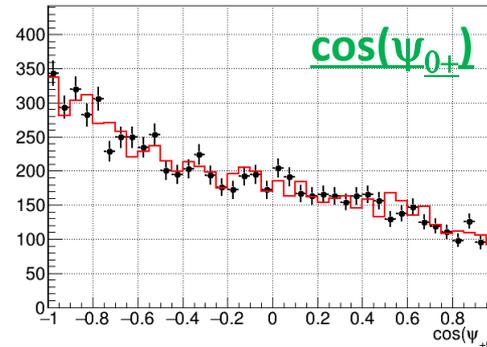
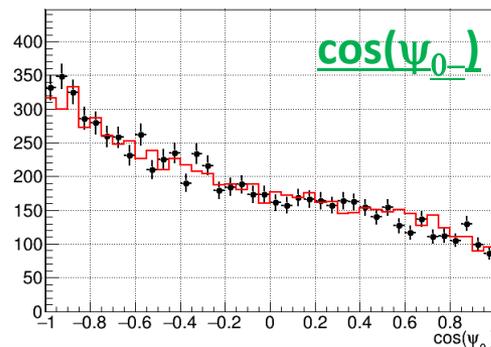
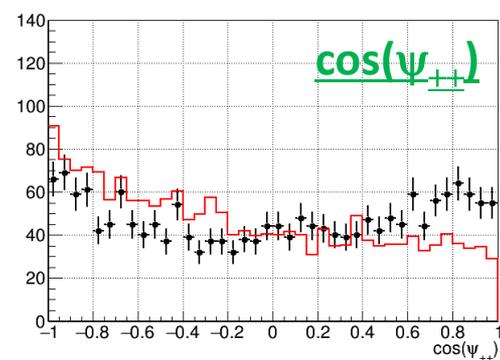
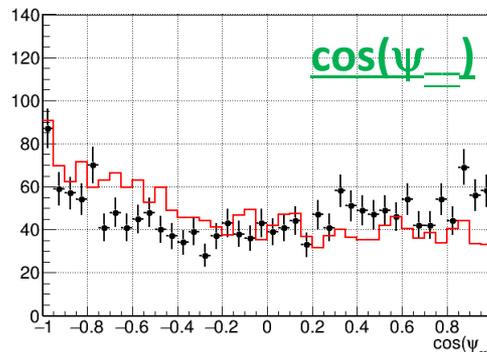
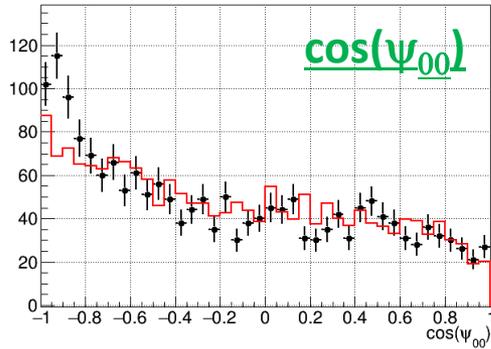
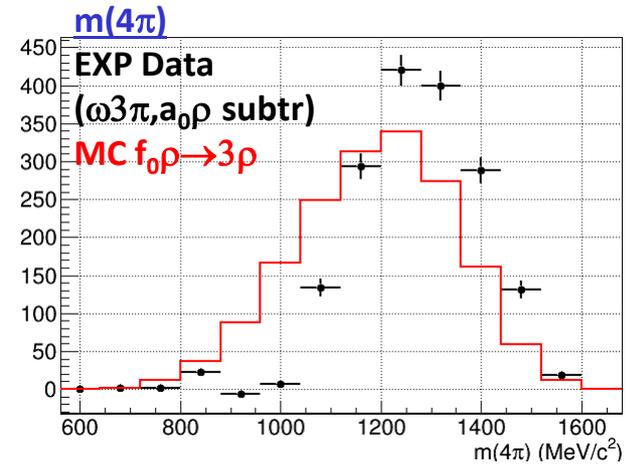
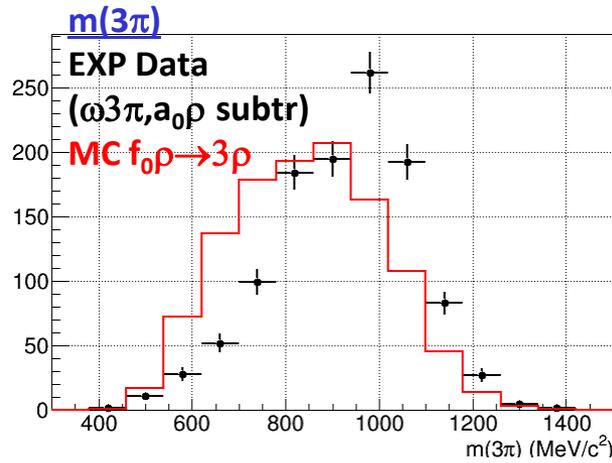
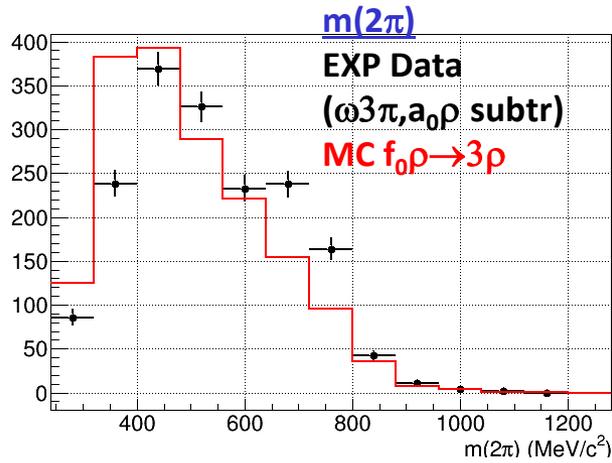
# ANGULAR DISTRIBUTIONS(II)

E = 1872 MeV

E = 2000 MeV

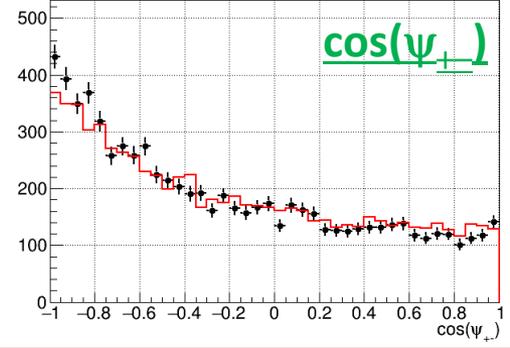
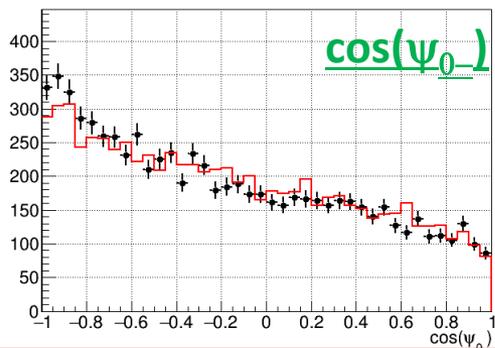
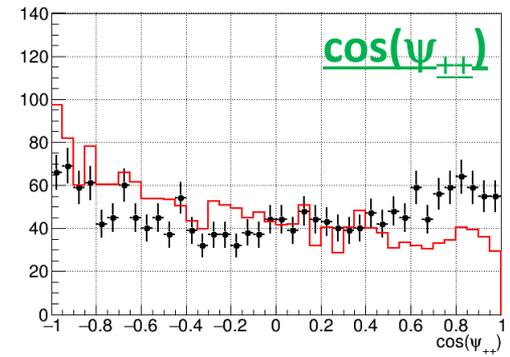
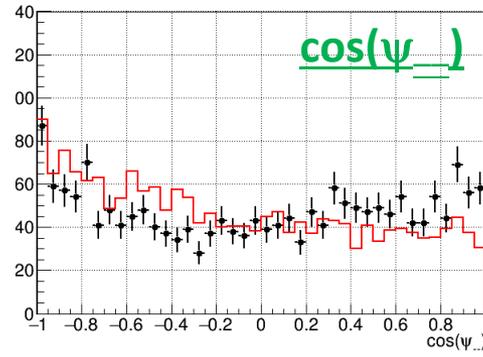
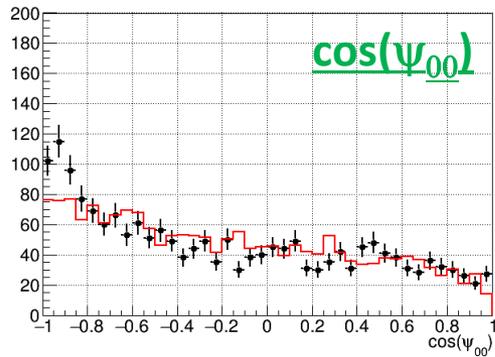
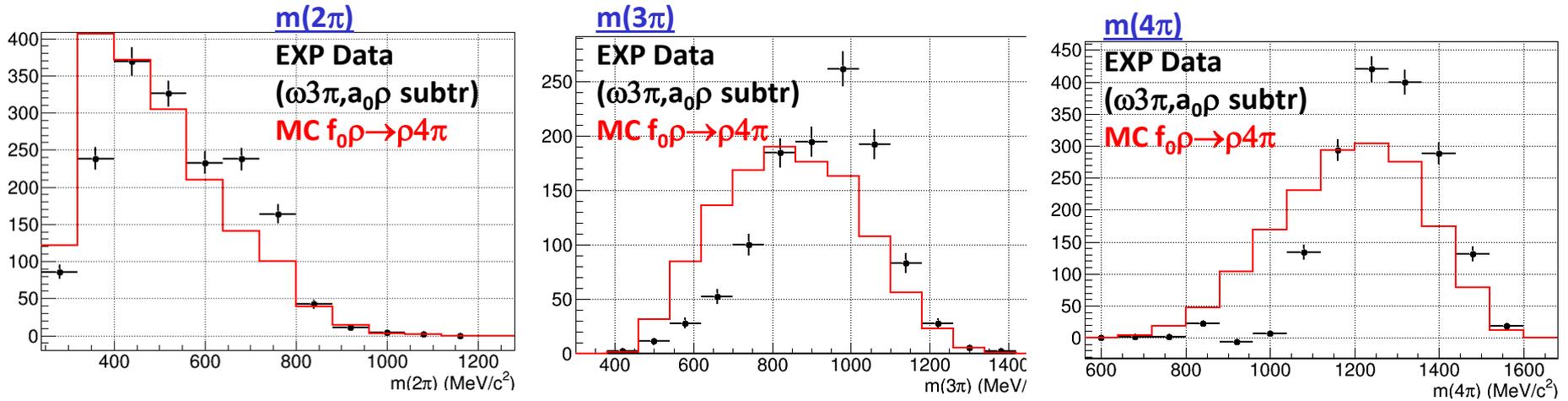


# MC $e^+e^- \rightarrow f_0(1370)\rho(770) \rightarrow 3\rho(770)$ vs EXP @ $E_{cm} = 1.872$ GeV.



**We failed to describe mass and angular correlations @  $E_{cm} = 1.872$  GeV with  $f_0\rho \rightarrow 3\rho$  contribution**

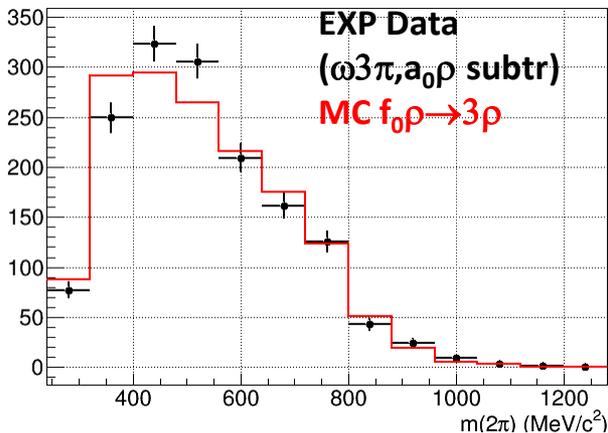
# MC $e^+e^- \rightarrow f_0(1370)\rho(770) \rightarrow \rho(770)4\pi$ vs EXP @ $E_{cm} = 1.872$ GeV.



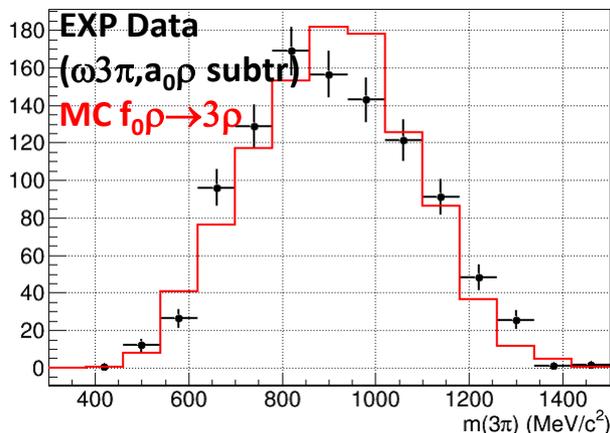
**We failed to describe mass and angular correlations @  $E_{cm} = 1.872$  GeV with  $f_0\rho \rightarrow \rho 4\pi$  contribution**

# MC $e^+e^- \rightarrow f_0(1370)\rho(770) \rightarrow 3\rho(770)$ vs EXP @ $E_{cm} = 2.0$ GeV.

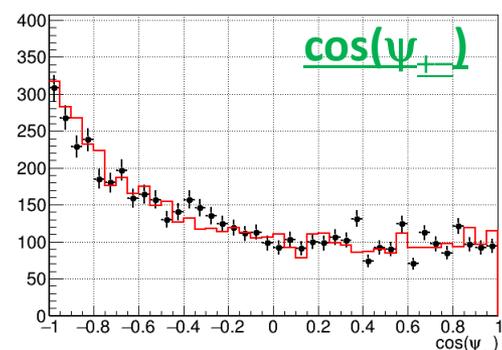
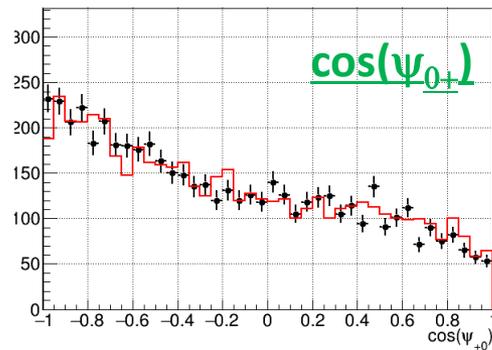
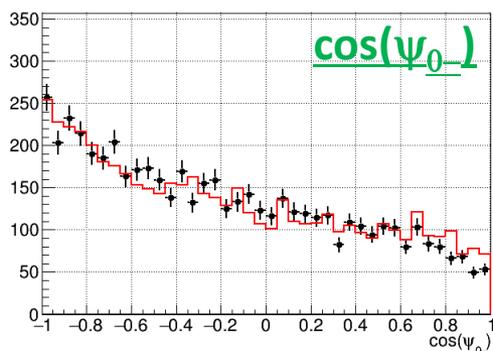
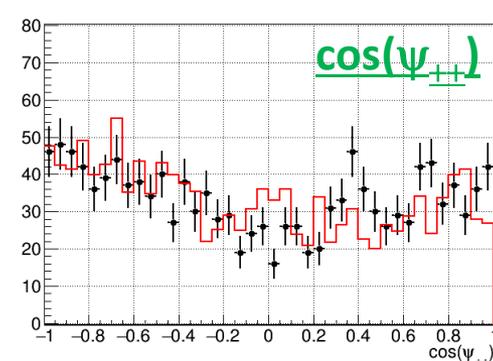
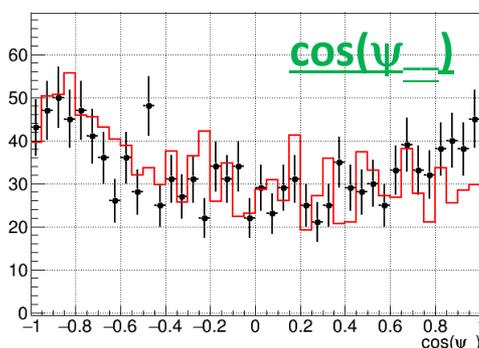
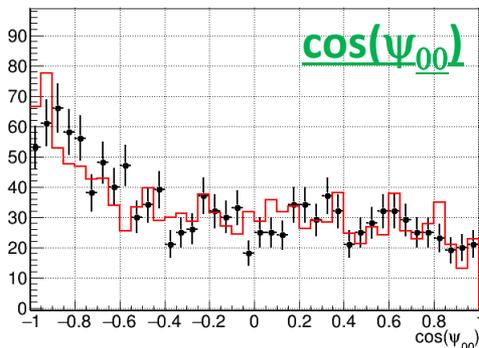
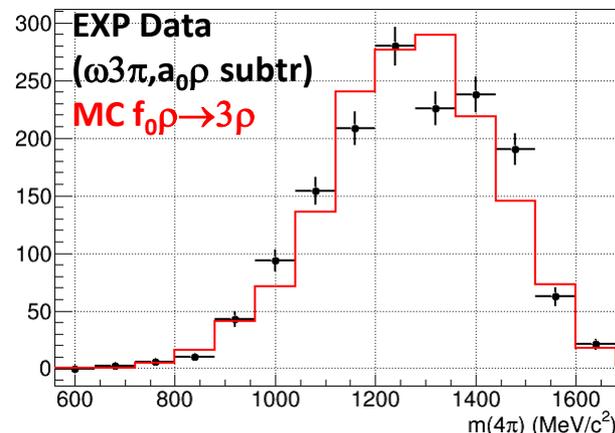
$m(2\pi)$



$m(3\pi)$

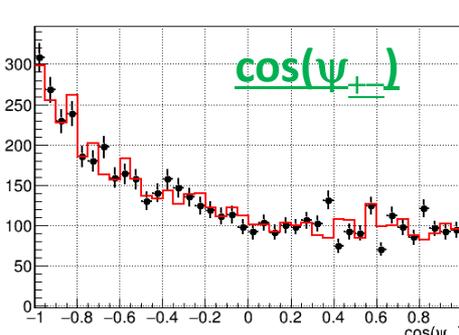
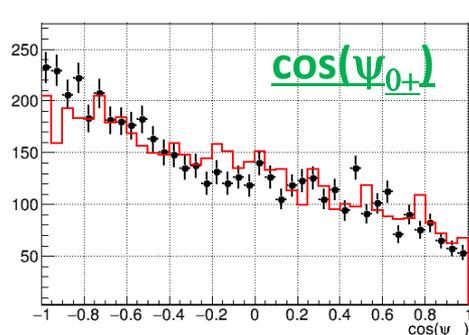
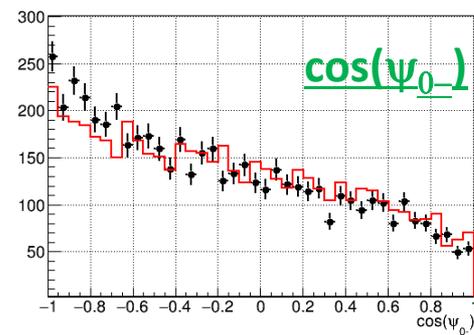
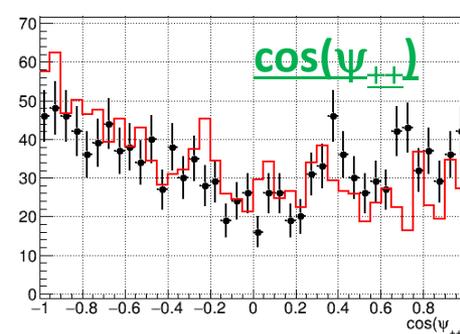
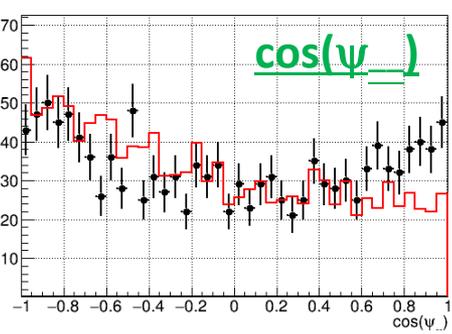
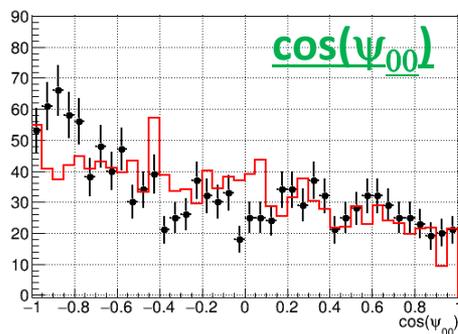
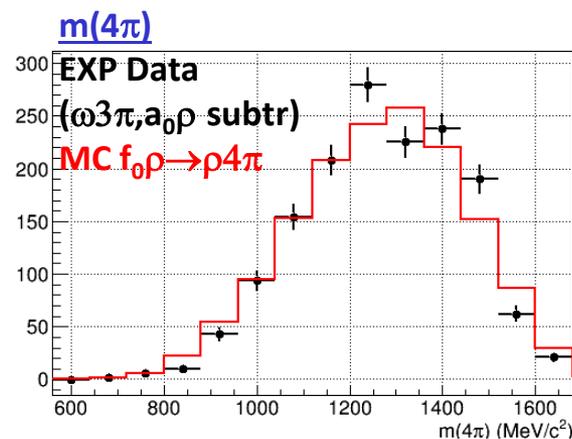
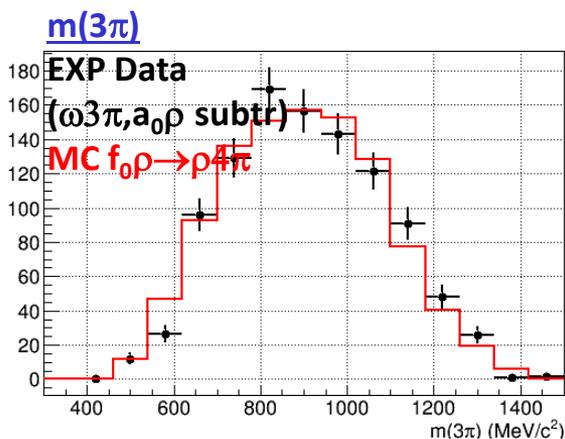
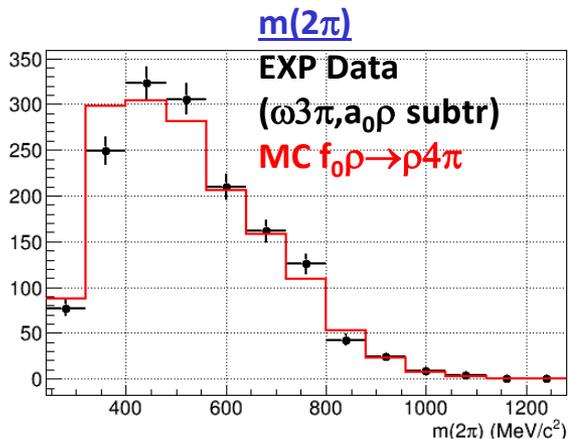


$m(4\pi)$



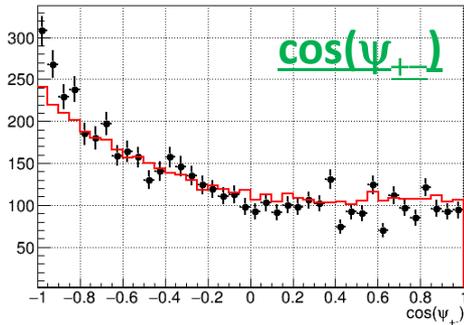
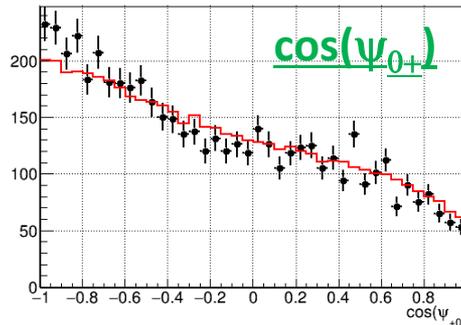
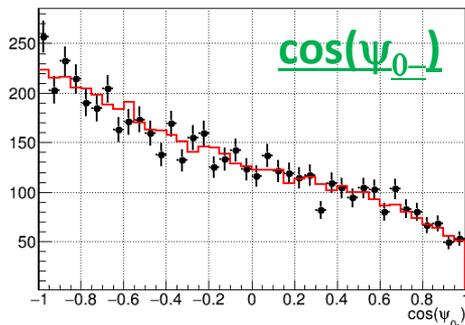
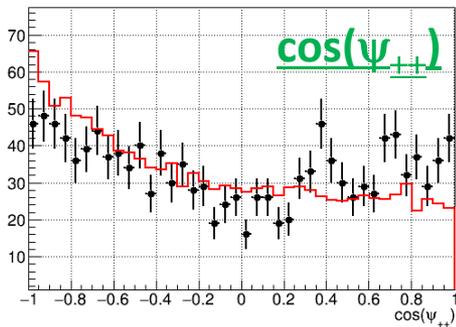
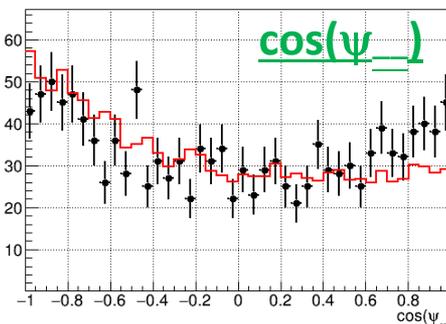
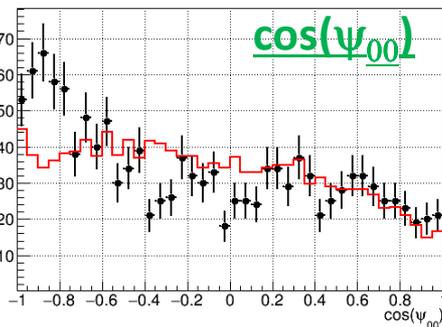
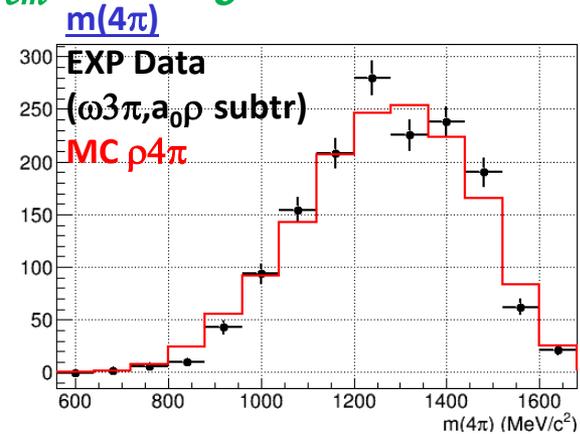
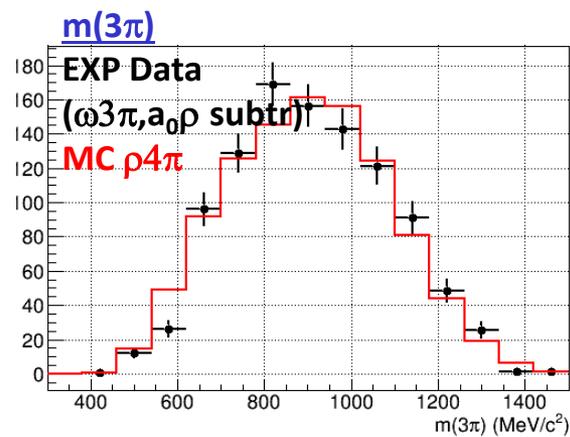
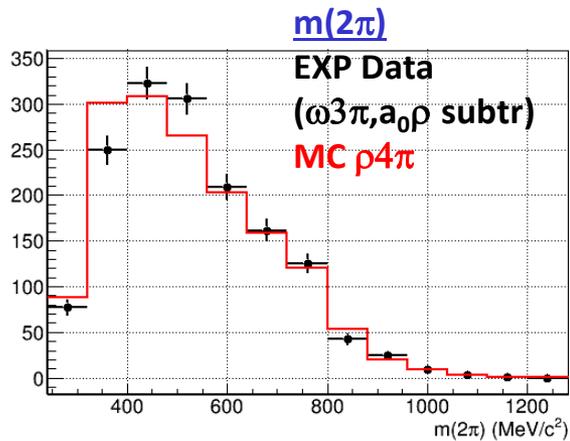
Reasonable description of mass and angular correlations @  $E_{cm} = 2.0$  GeV with  $f_0\rho \rightarrow 3\rho$  contribution

# MC $e^+e^- \rightarrow f_0(1370)\rho(770) \rightarrow \rho(770)4\pi$ vs EXP @ $E_{cm} = 2.0$ GeV.



**Good mass description and poor angular description @  $E_{cm} = 2.0$  GeV with  $f_0\rho \rightarrow \rho 4\pi$  contribution**

# MC $e^+e^- \rightarrow \rho(770)4\pi$ $s$ -wave vs EXP @ $E_{cm} = 2.0$ GeV.



**Good mass description and poor angular description @  $E_{cm} = 2.0$  GeV with  $\rho 4\pi$  contribution**

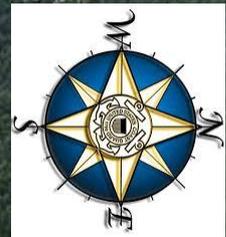
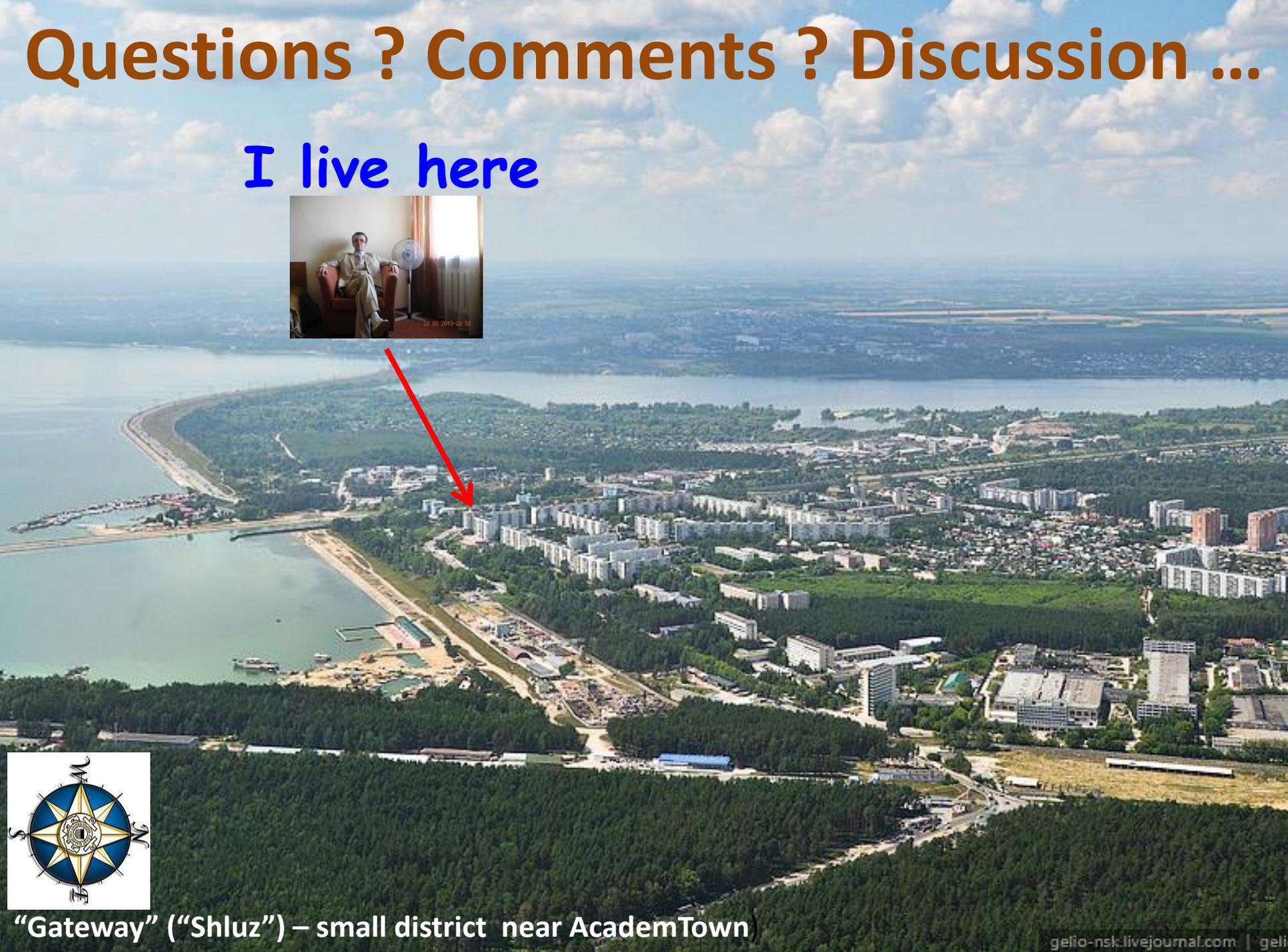
# CONCLUSION

- ❑ Primary MC Generator of the process  $e^+e^- \rightarrow f_0(1370)\rho(770) \rightarrow 2(\pi^+\pi^-\pi^0)$  has been created for the 2  $f_0(1370)$  decay modes:  $f_0(1370) \rightarrow \rho(770)^+\rho(770)^-$  and  $f_0(1370) \rightarrow \pi^+\pi^-2\pi^0$
- ❑ Mass and angular distributions @  $E_{\text{cm}} = 1.872$  GeV after subtraction of  $\omega(782)$  and  $\eta(545)$  signals could not be described by  $f_0(1370)$  contributions mentioned above.
- ❑ At  $E_{\text{cm}} = 2.0$  GeV the best mass and angular correlations description is achieved with  $f_0(1370) \rightarrow \rho(770)^+\rho(770)^-$  contribution, although  $f_0(1370) \rightarrow \pi^+\pi^-2\pi^0$  and  $\rho(770)4\pi_{\text{S-wave}}$  intermediate states could not be excluded as well as interference between these channels.
- ❑ We still have to find good candidate to describe  $\rho(770)$  signal at  $E_{\text{cm}} = 1.872$  GeV.

**Thank You! Stay tuned!**

# Questions ? Comments ? Discussion ...

I live here



“Gateway” (“Shluz”) – small district near AcademTown)