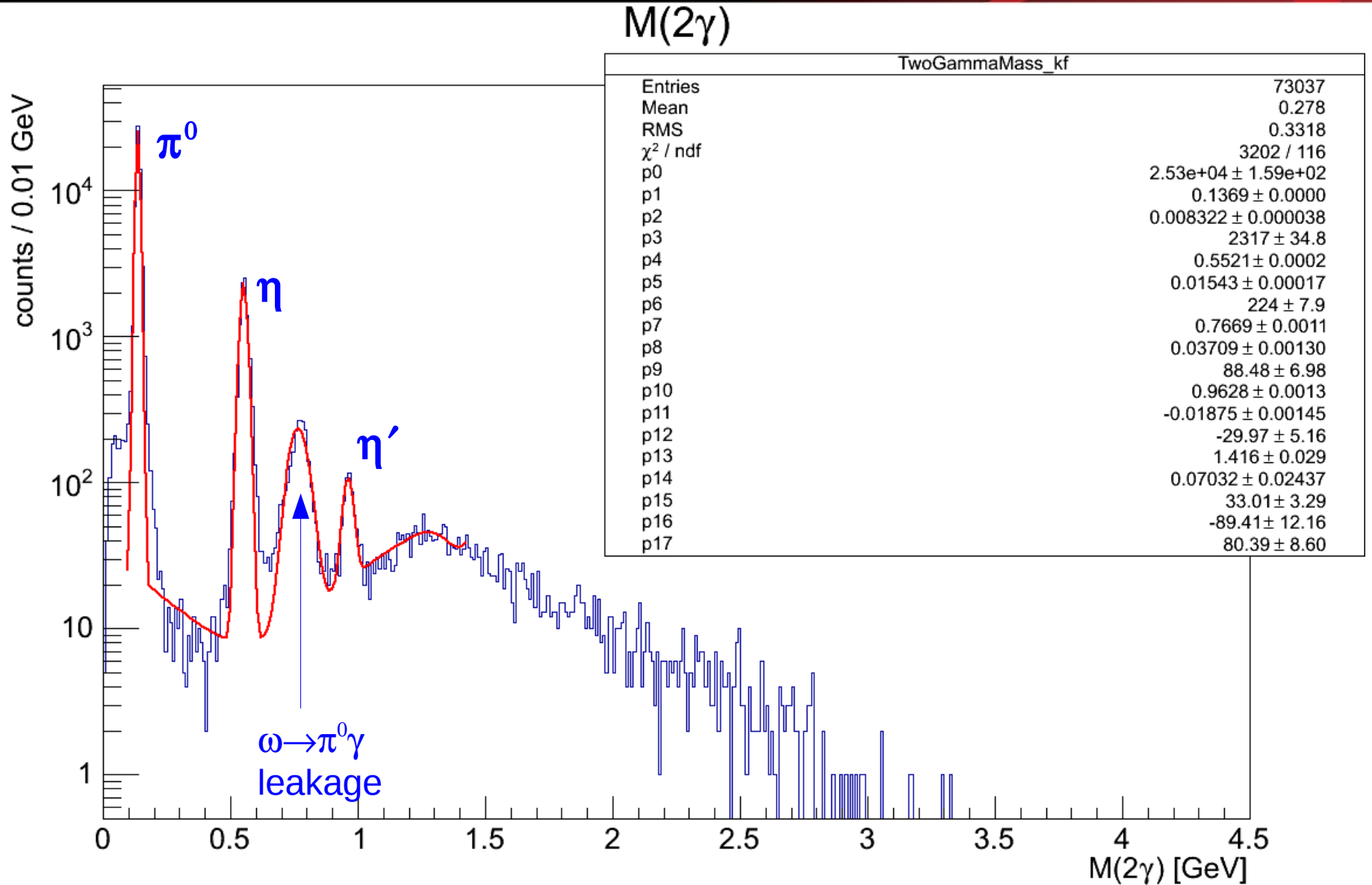


# Multi-photon surveys using v03 REST files

## Simon Taylor /JLab

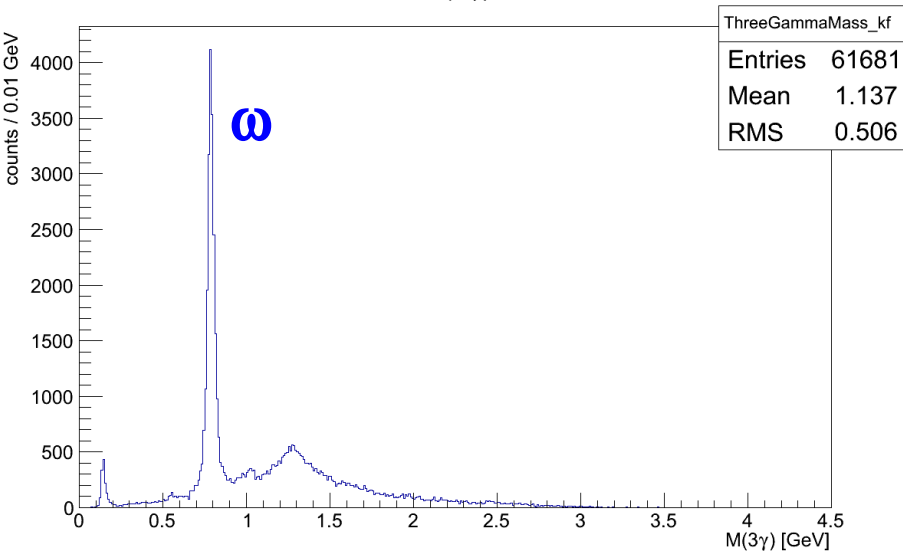
- Version 3 REST files, run range 10331-10913
- Minimum shower energy = 100 MeV
  - Veto events with neutral showers in FCAL within 12.5 cm of each other
- Survey I:
  - Require  $p + N\gamma$  (N=2-6)
  - Kinematic fit (energy and momentum), CL>0.1
- Survey II:
  - Require  $p\pi^+\pi^- + N\gamma$  (N=1-6)
  - Kinematic fit(energy/momentum+vertex), CL>0.1

# Two photons

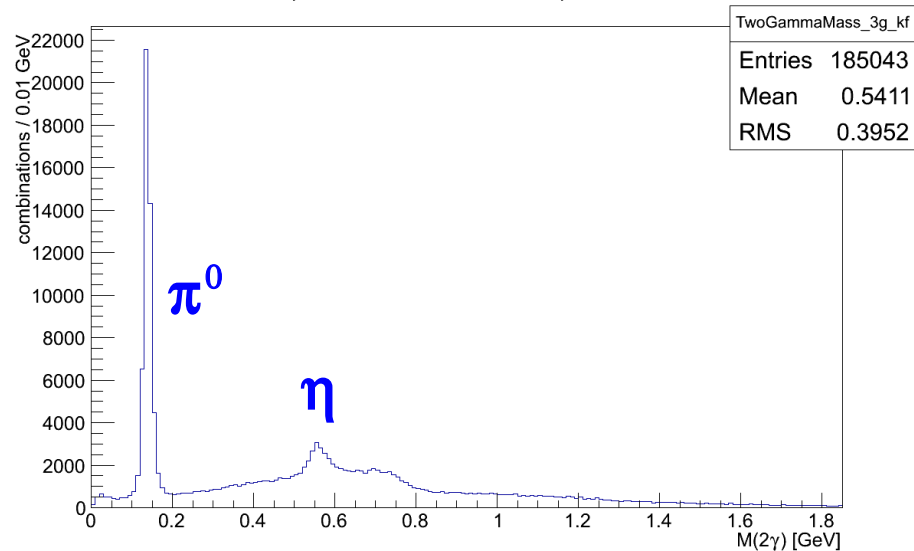


# Three photons

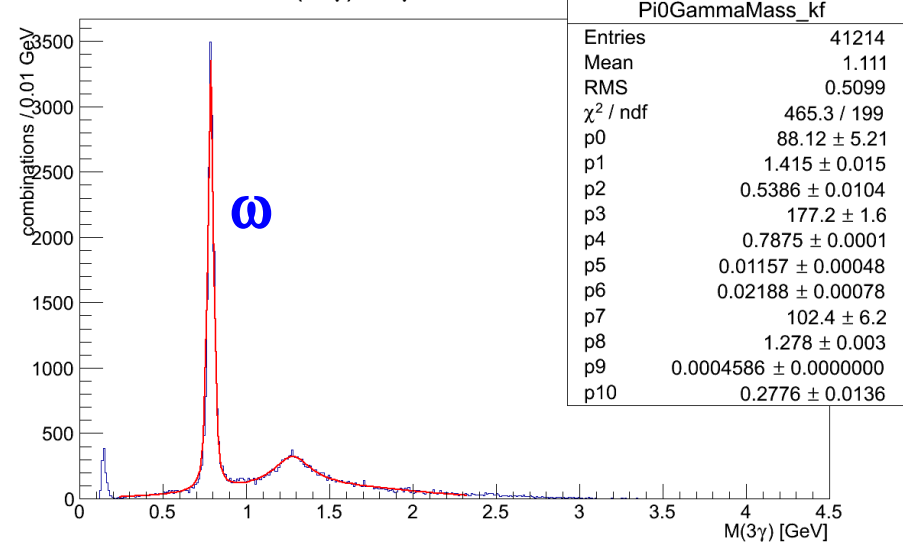
$M(3\gamma)$



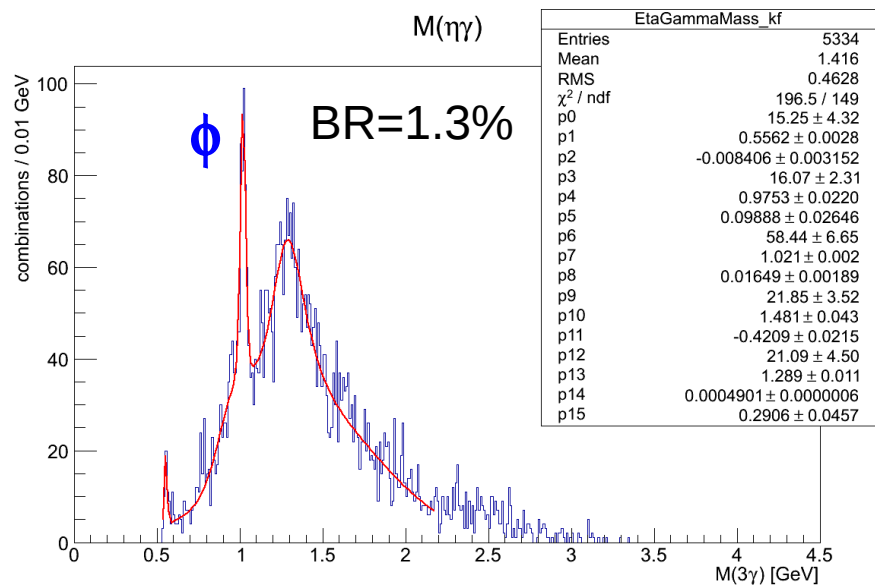
$2\gamma$  invariant mass for  $3\gamma$  events



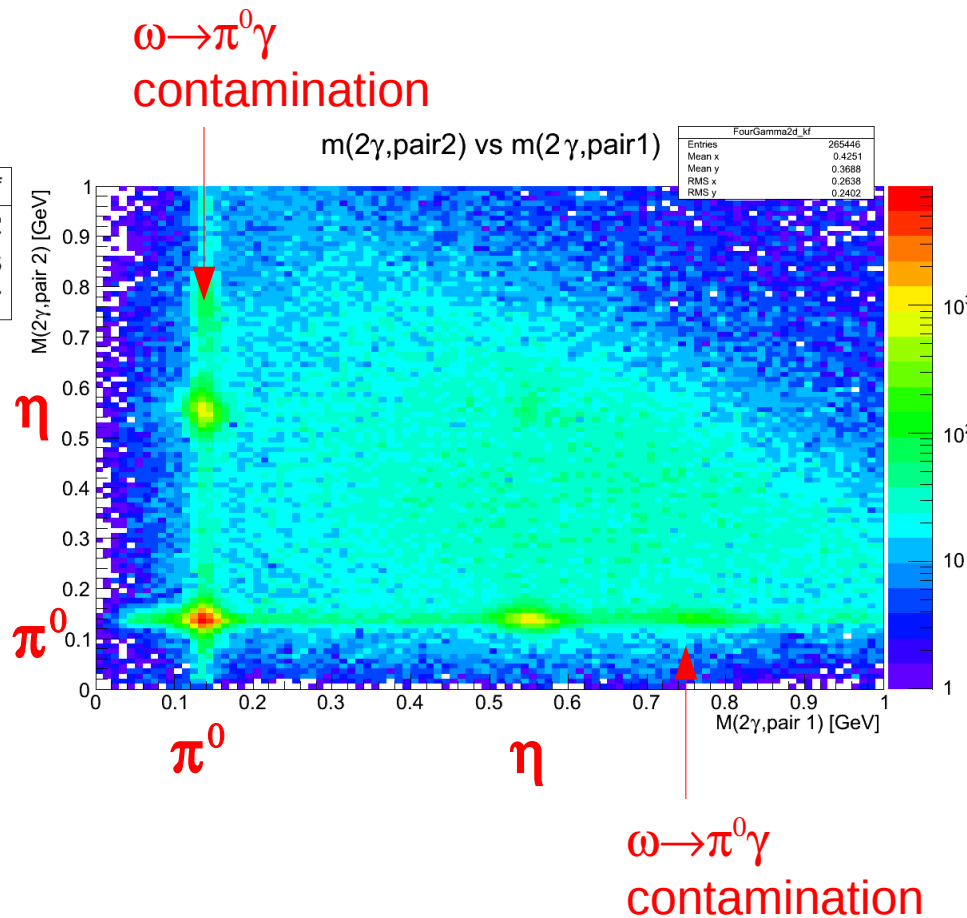
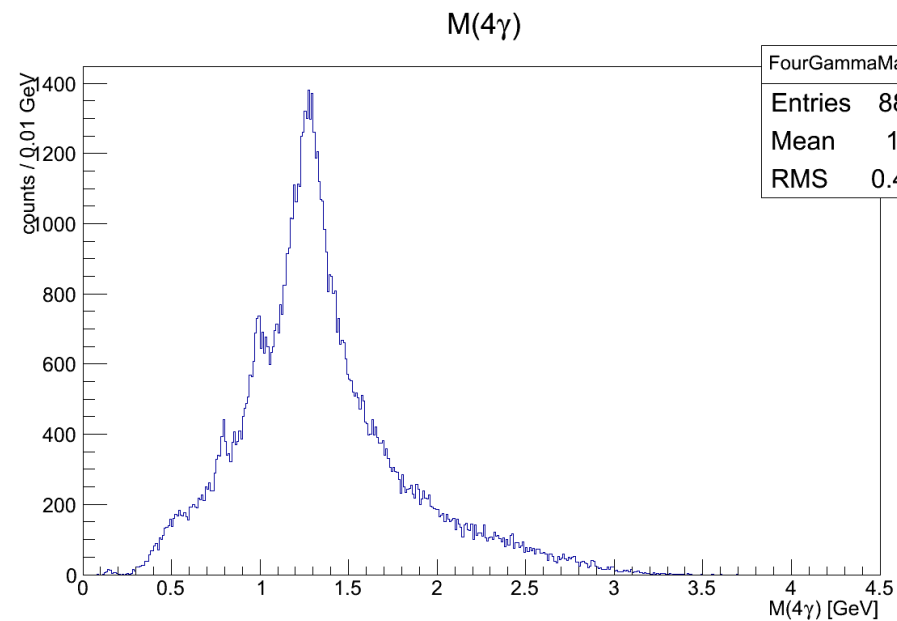
$M(\pi^0\gamma)$ :  $3\gamma$  mass with  $\pi^0$  cut



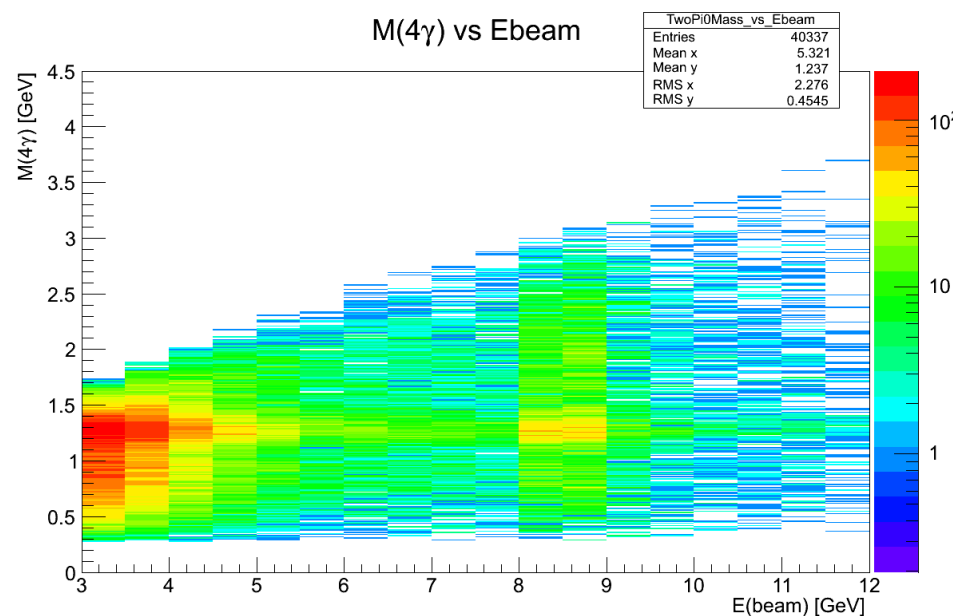
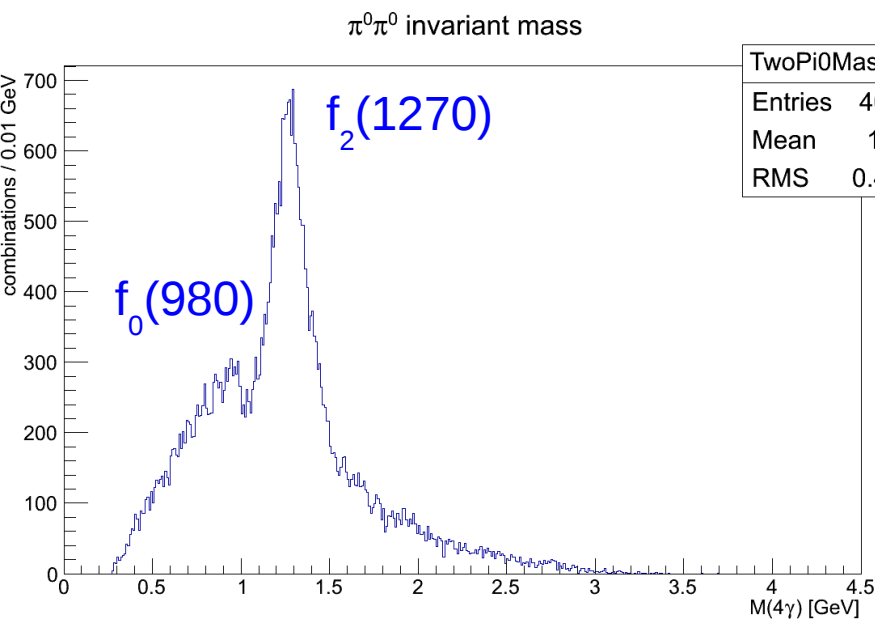
$M(\eta\gamma)$



# Four photons

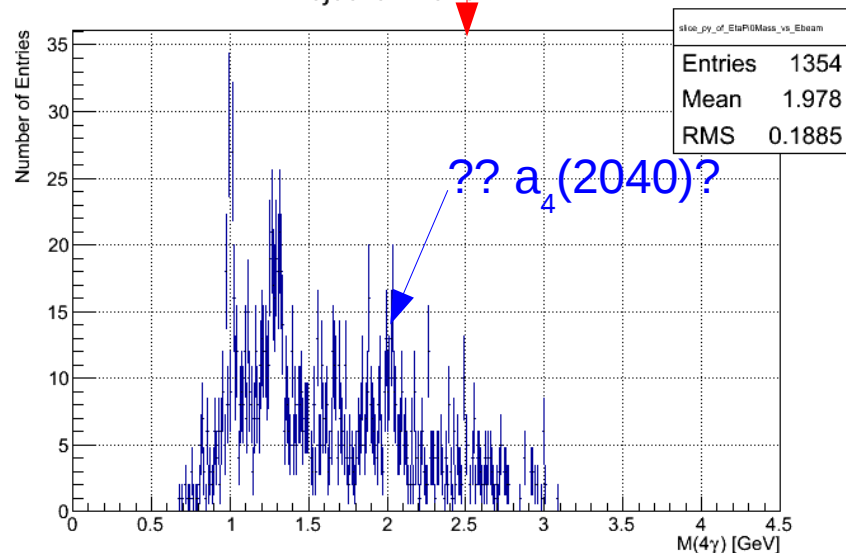
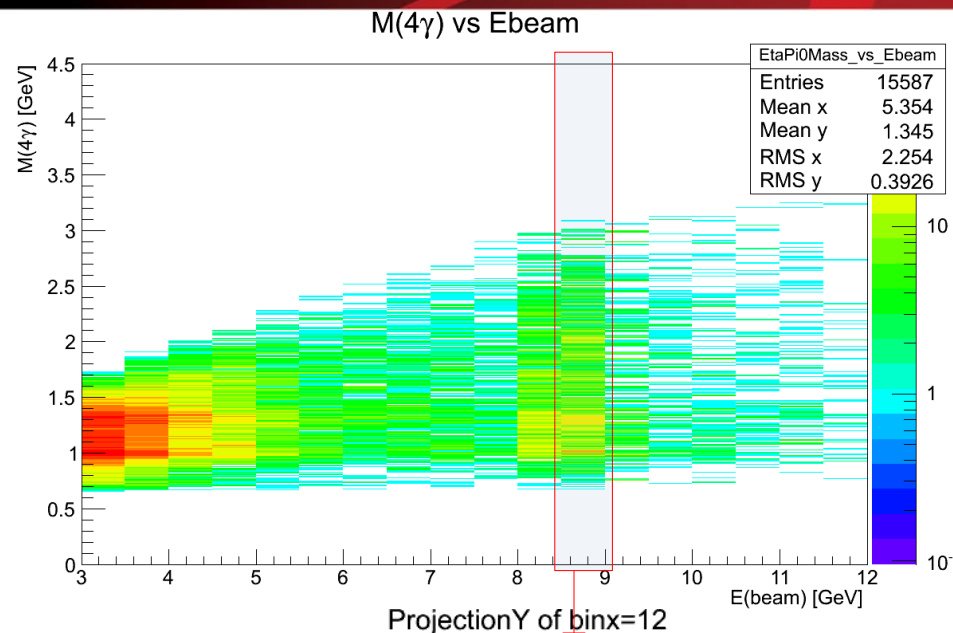
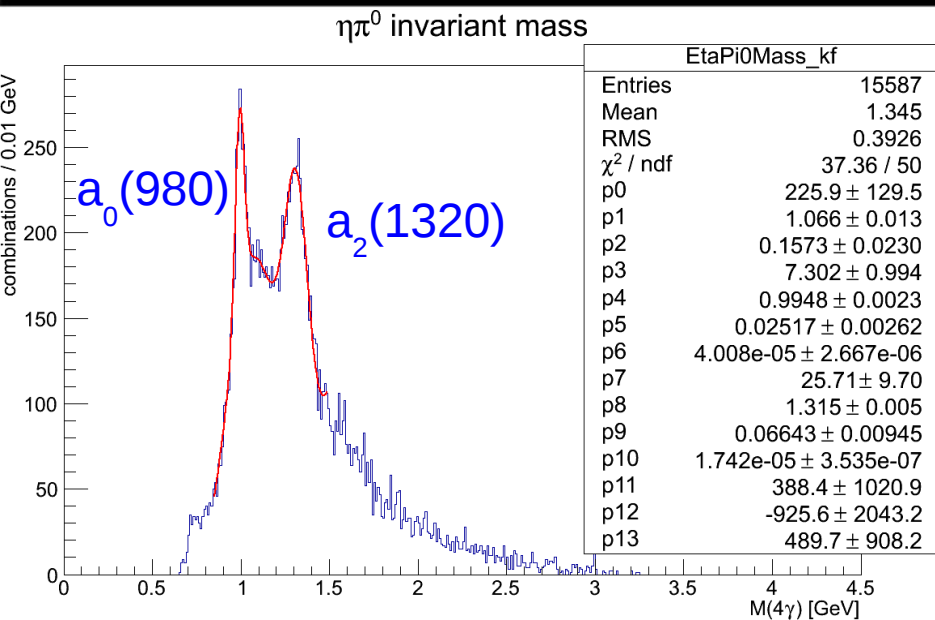


# Four photons



- $f_0(980)$ :  $\Gamma=40-100$  MeV,  $\pi\pi$  channel dominant
- $f_2(1270)$ :  $M=1275$  MeV,  $\Gamma=185$  MeV,  $\pi\pi$  BR=84.8%

# Four photons



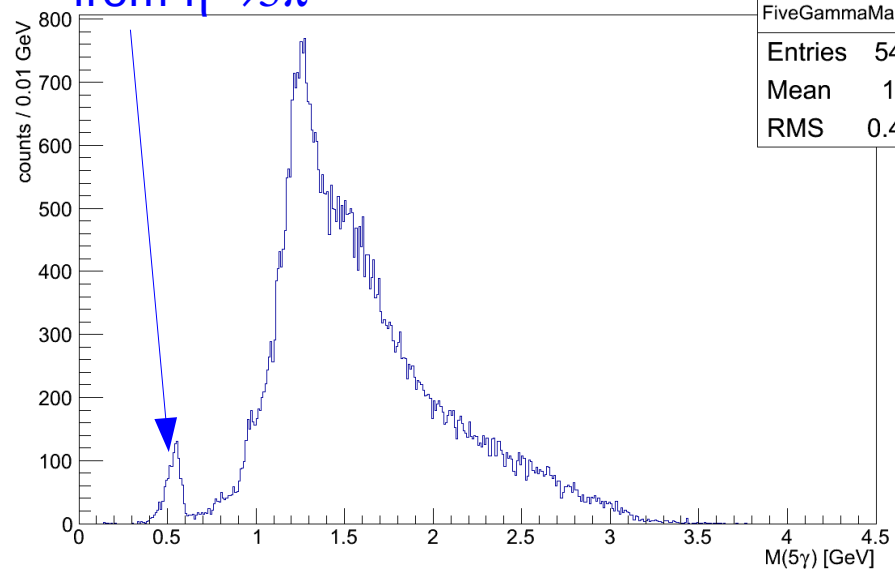
- $a_0(980)$ :  $\Gamma=50\text{-}100$  MeV,  $\eta\pi$  channel dominant
- $a_2(1320)$ :  $M=1318$  MeV,  $\Gamma=111$  MeV,  $\eta\pi$  BR=14.5%
- $a_4(2040)$ :  $M=2001$  MeV,  $\Gamma=313$  MeV,  $\eta\pi$  seen (BR=??)

# Five photons

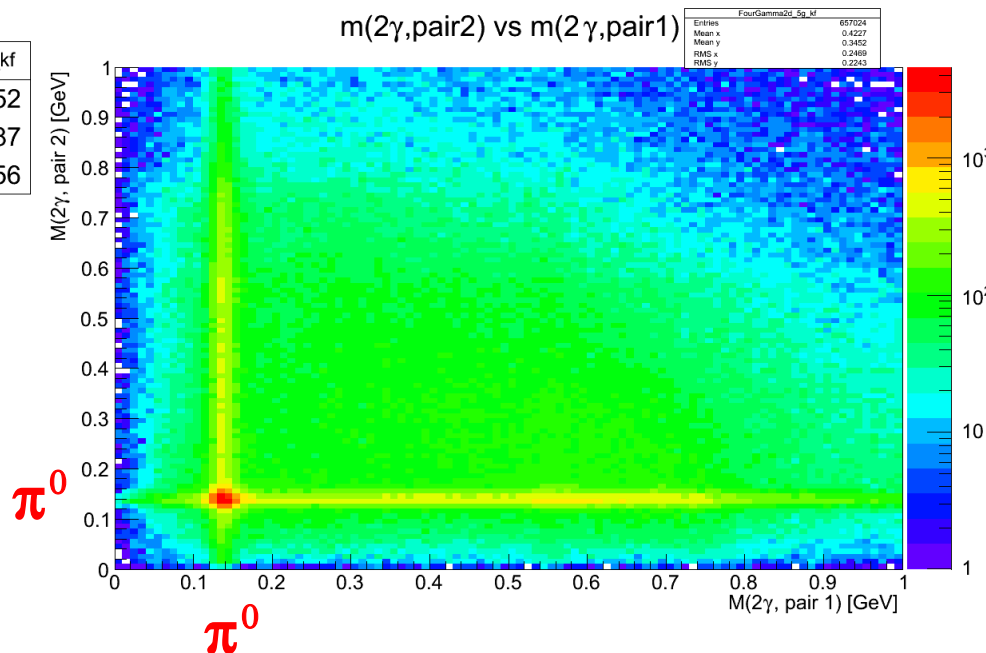
Missing  $\gamma$   
from  $\eta \rightarrow 3\pi^0$

$M(5\gamma)$

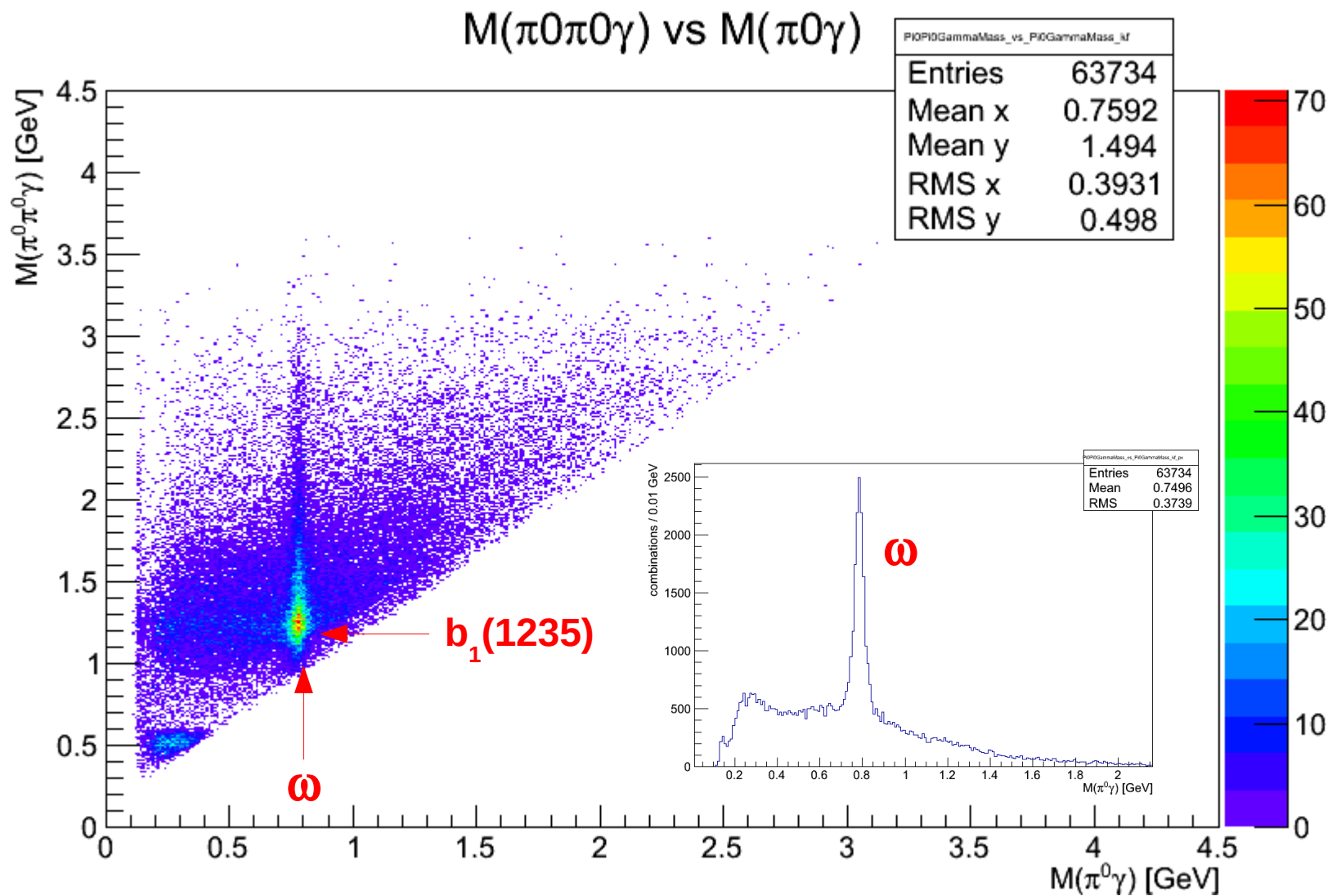
FiveGammaMass_kf	
Entries	54752
Mean	1.587
RMS	0.4956



$m(2\gamma, \text{pair2})$  vs  $m(2\gamma, \text{pair1})$

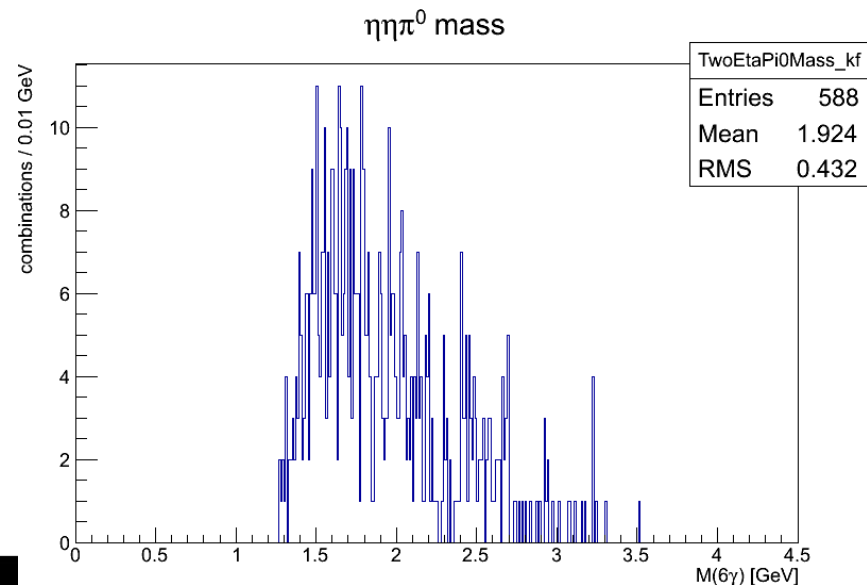
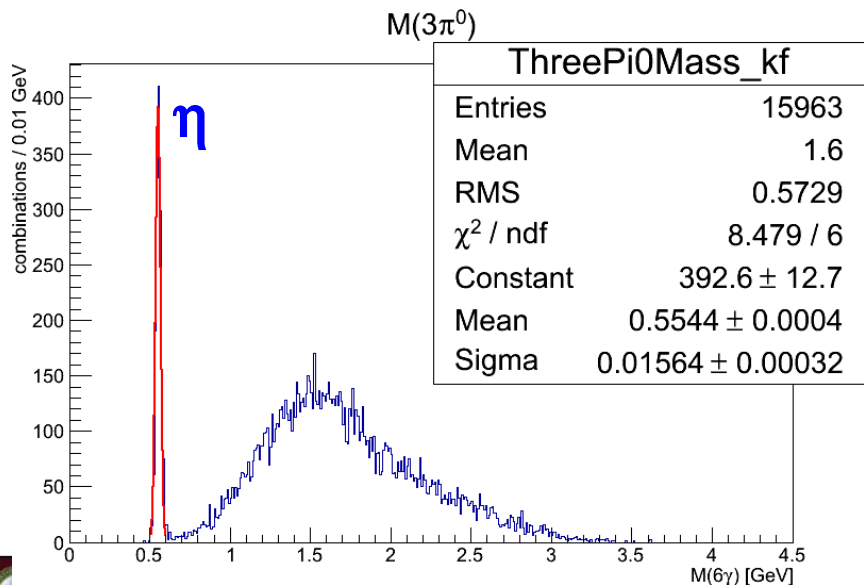
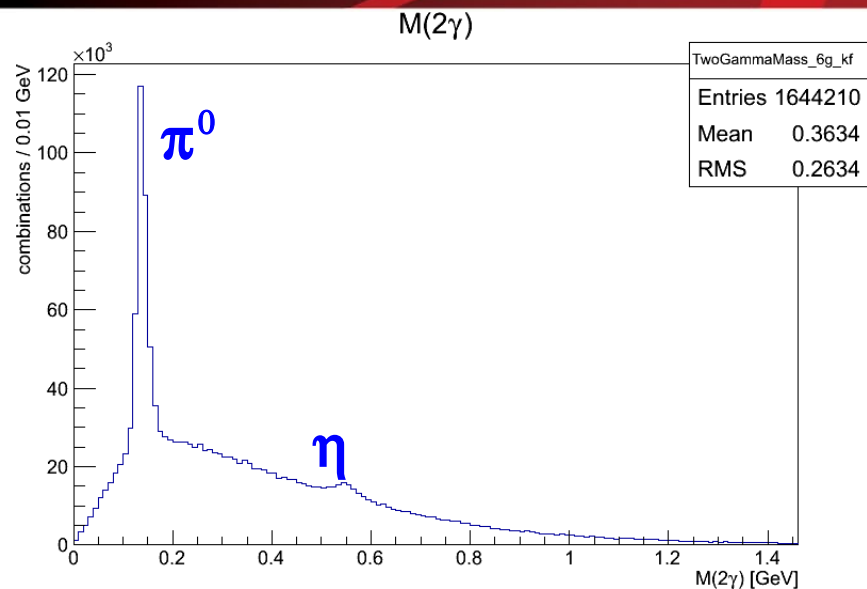
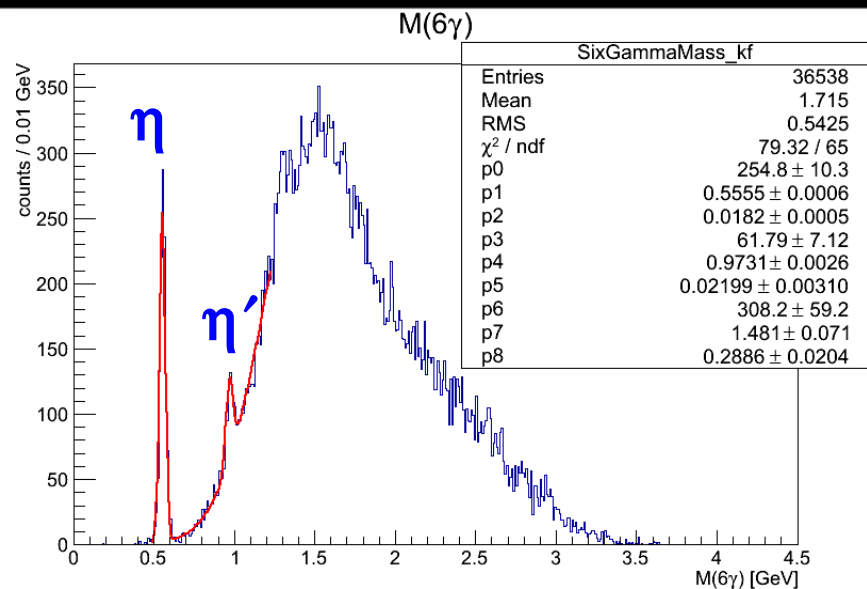


# Five photons

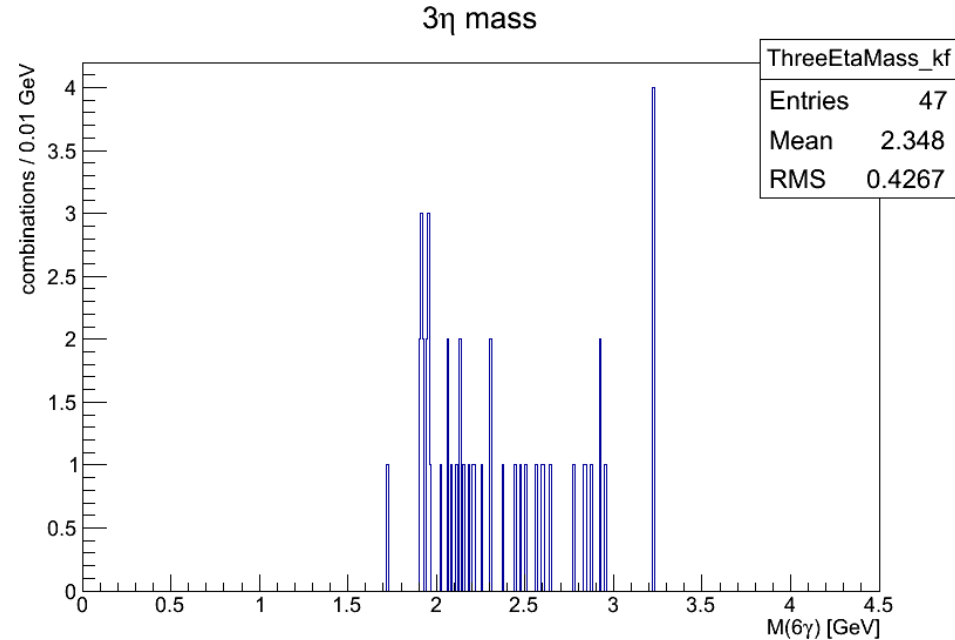
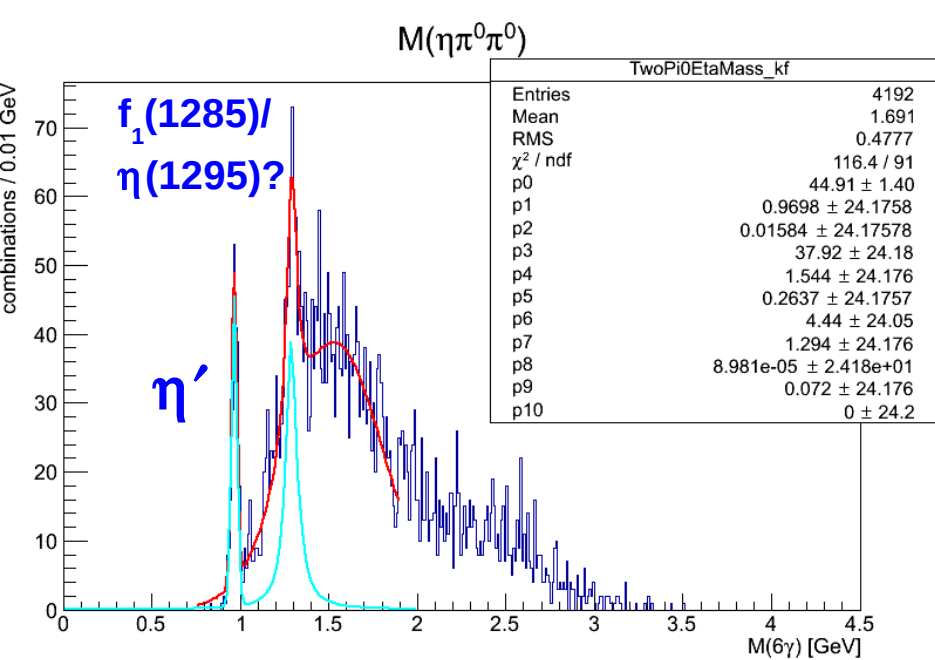




# Six photons



# Six photons



$$\text{BR}(\eta' \rightarrow \pi^0 \pi^0 \eta) = 20.7\%$$

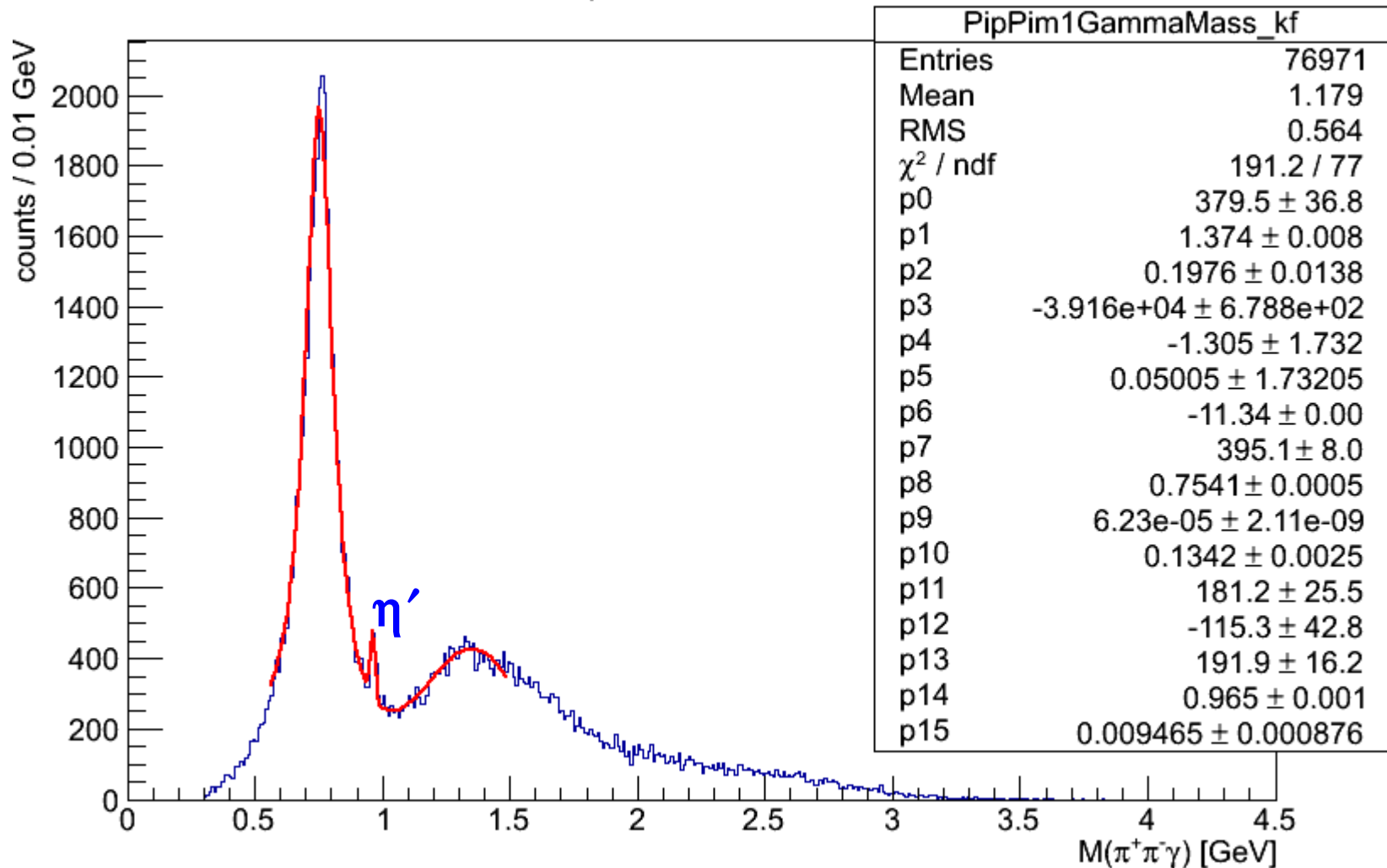
$$\text{BR}(f_1(1285) \rightarrow \pi\pi\eta) = 52\%$$

$$\text{BR}(\eta(1295) \rightarrow \pi^0 \pi^0 \eta) \text{ "seen"}$$

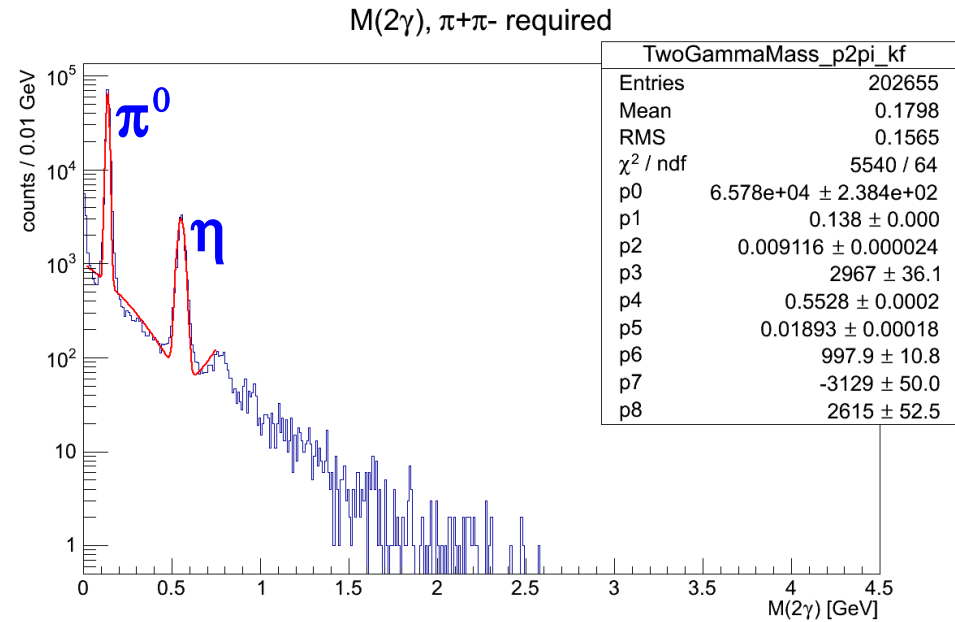
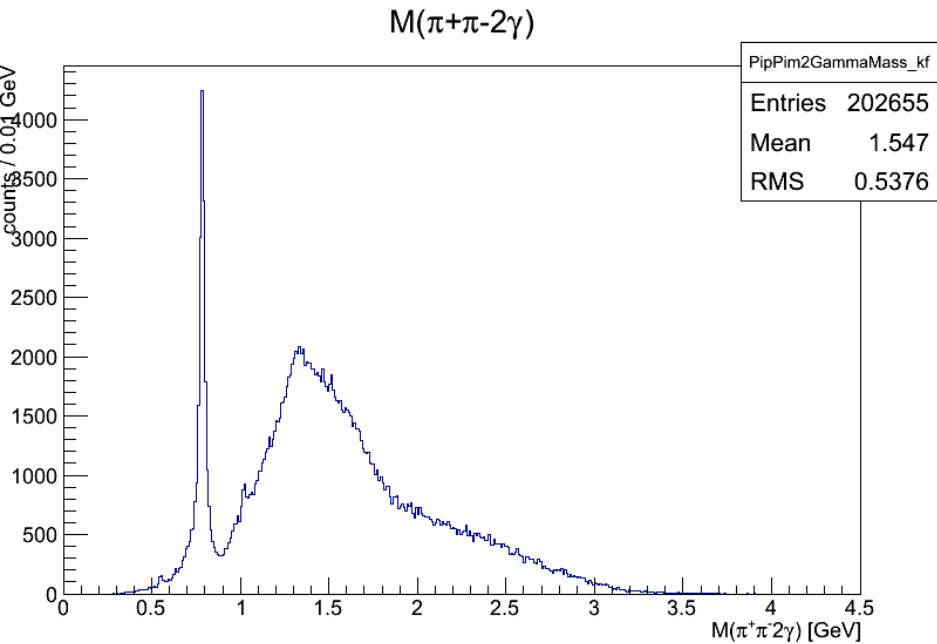
# $\pi^+\pi^- + 1$ photon

$BR(\eta' \rightarrow \pi^+\pi^-\gamma) = 29.4\%$

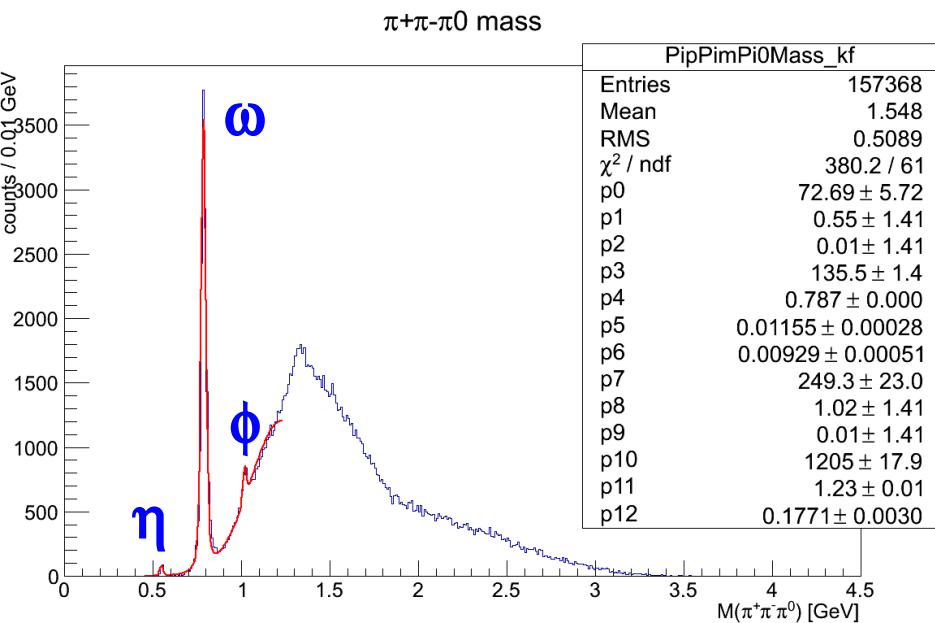
$\pi^+\pi^-\gamma$  invariant mass



# $\pi^+\pi^- + 2$ photons



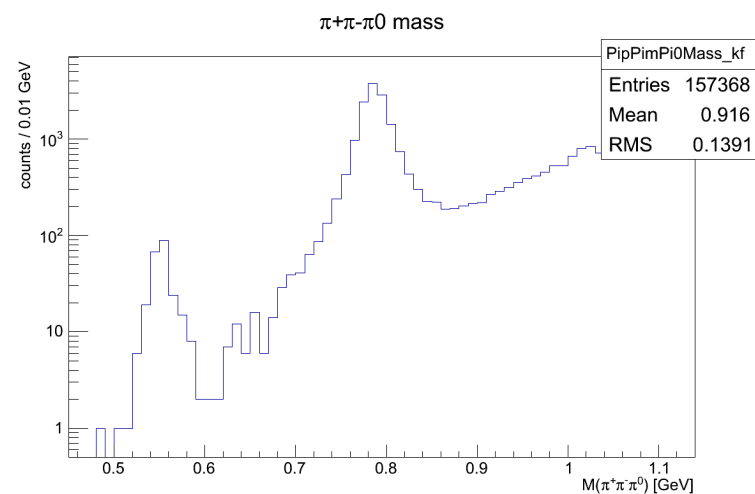
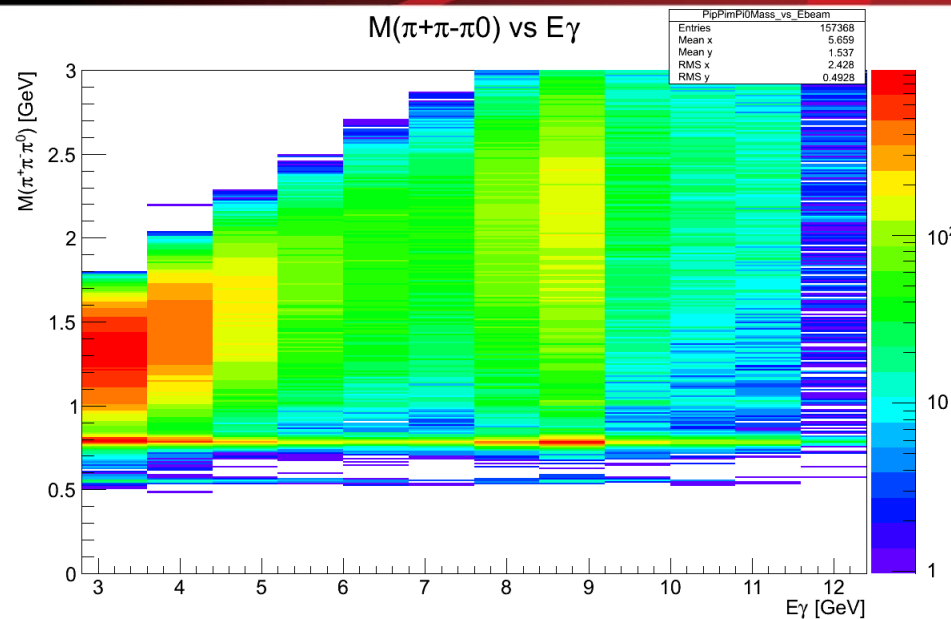
# $\pi^+\pi^-\pi^0 + 2$ photons



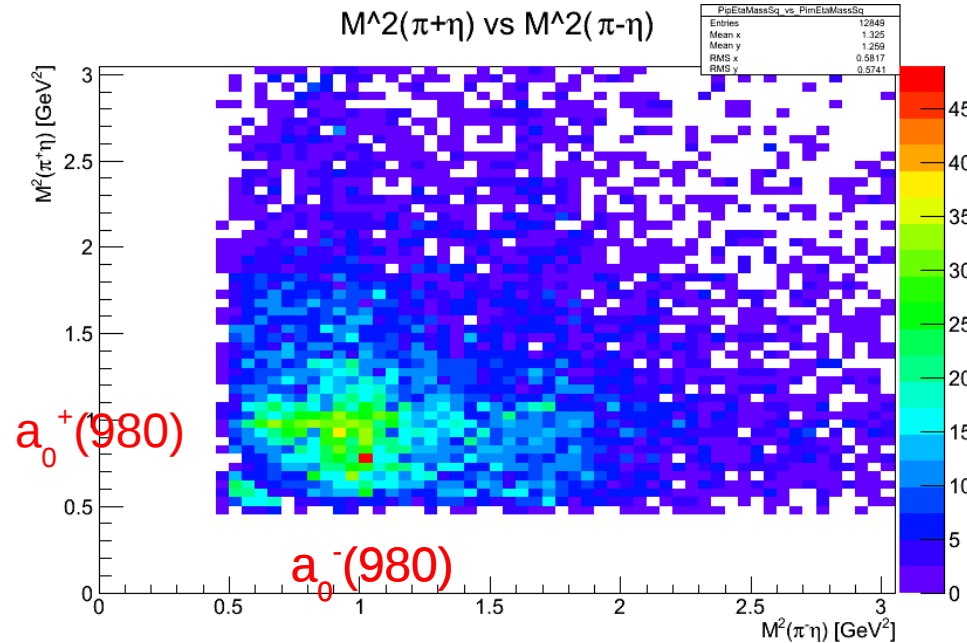
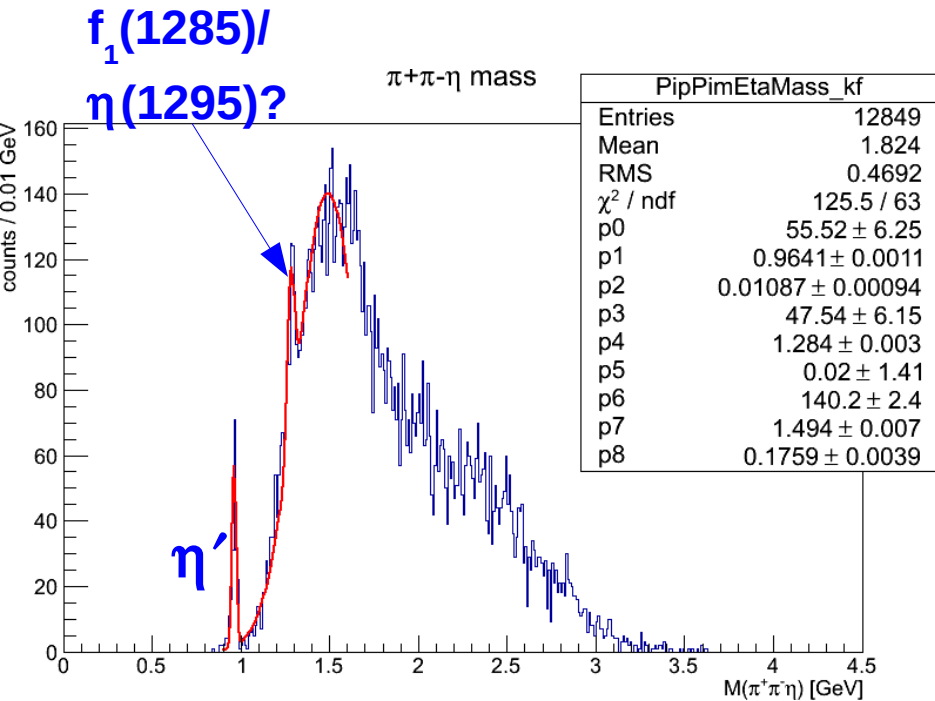
$$\text{BR}(\omega \rightarrow \pi^+\pi^-\pi^0) = 89.2\%$$

$$\text{BR}(\eta \rightarrow \pi^+\pi^-\pi^0) = 22.73\%$$

$$\text{BR}(\phi \rightarrow \pi^+\pi^-\pi^0) = 15.25\%$$



# $\pi^+\pi^-\eta$ + 2 photons



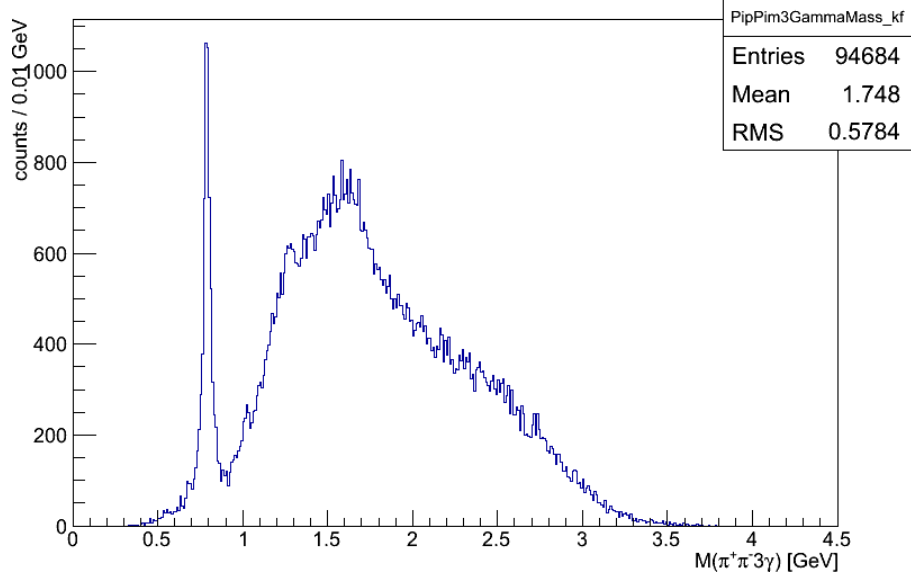
$$\text{BR}(\eta' \rightarrow \pi^+\pi^-\eta) = 44.6\%$$

$$\text{BR}(f_1(1285) \rightarrow \pi\pi\eta) = 52\%$$

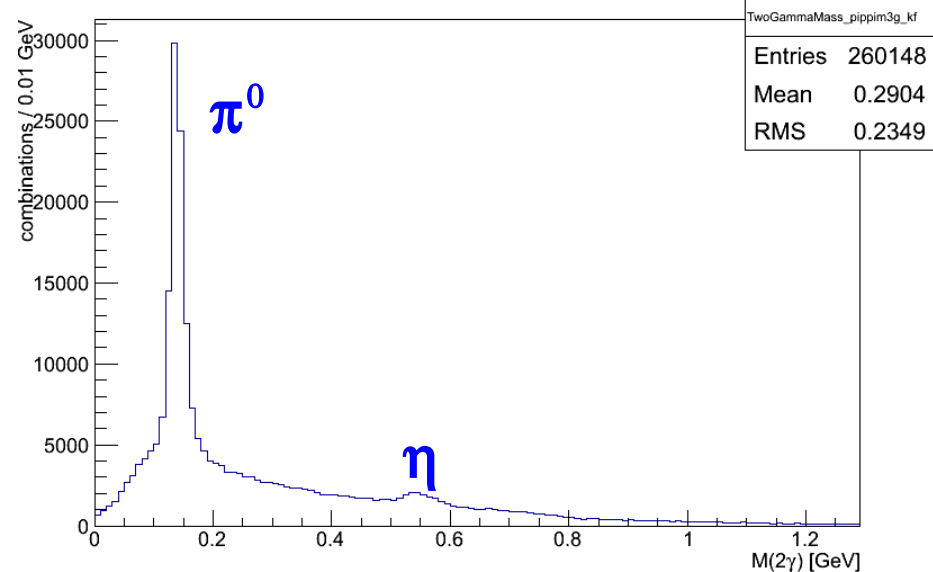
$$\text{BR}(\eta(1295) \rightarrow \pi^+\pi^-\eta) \text{ "seen"}$$

# $\pi^+\pi^- + 3$ photons

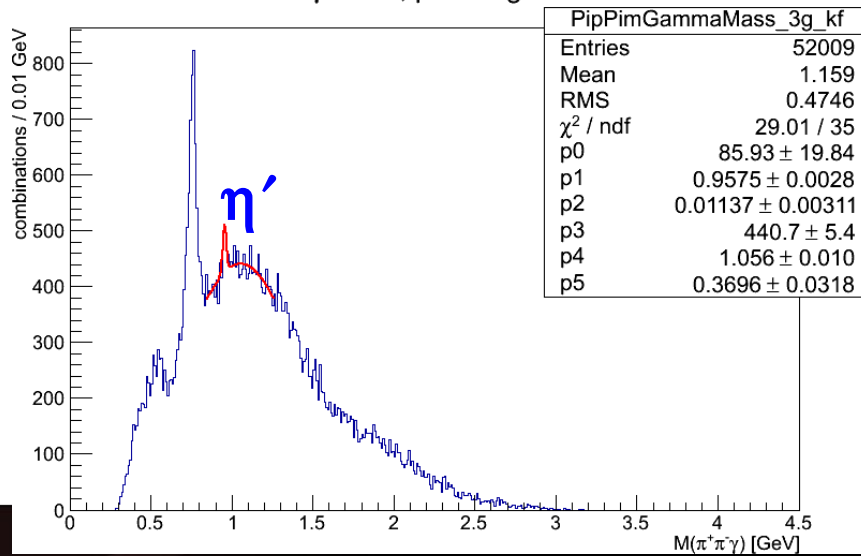
$\pi^+\pi^-3\gamma$  invariant mass



$M(2\gamma)$



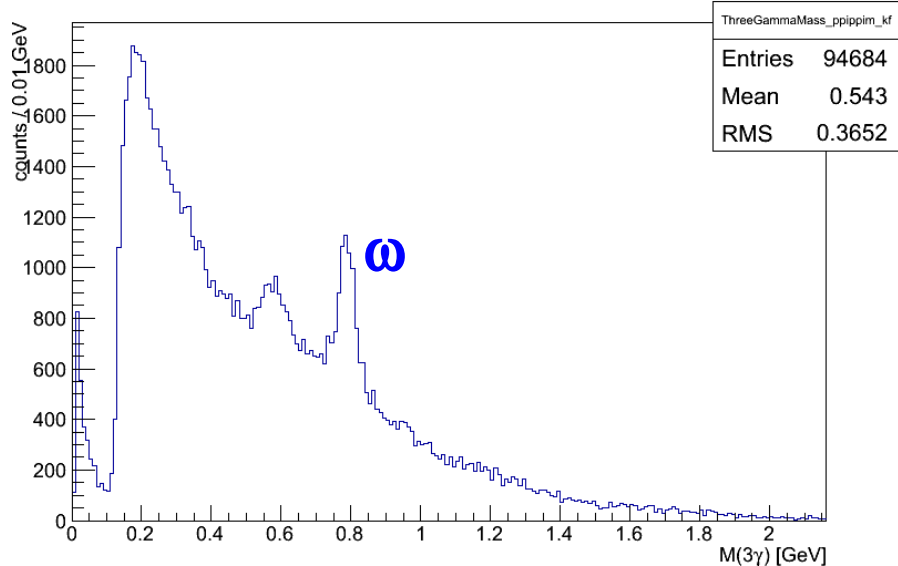
$\pi^+\pi^- \gamma$  mass,  $\rho\pi^+\pi^-3g$  events



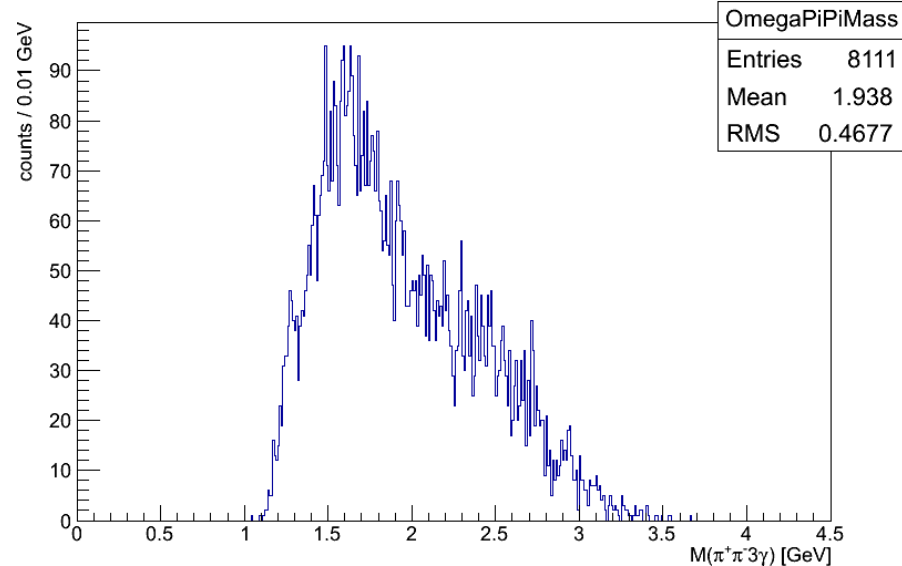
# $\pi^+\pi^- + 3$ photons

## Evidence for $p\pi^+\pi^-\omega$ events

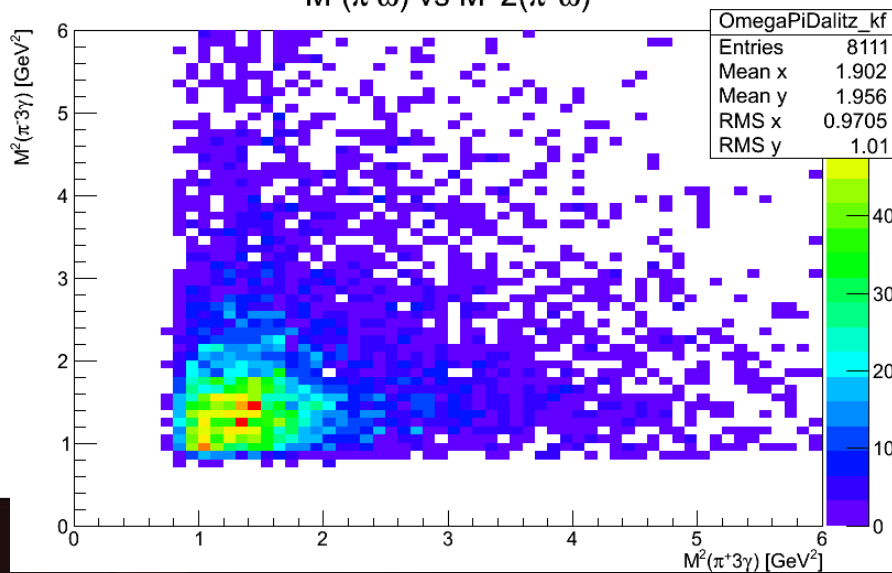
3 $\gamma$  mass,  $p\pi^+\pi^-$  events



$\pi^+\pi^-3\gamma$  invariant mass, cut on  $M(3\gamma)$



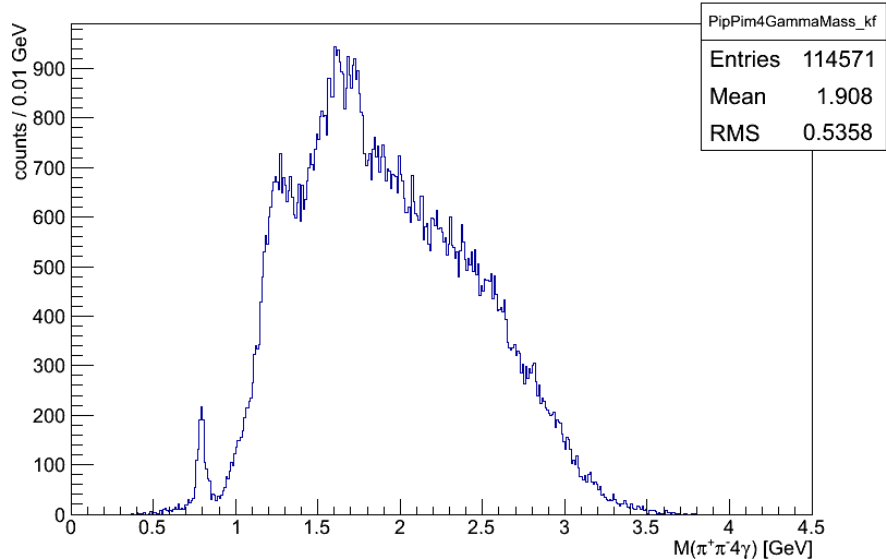
$M^2(\pi^-\omega)$  vs  $M^2(\pi^+\omega)$



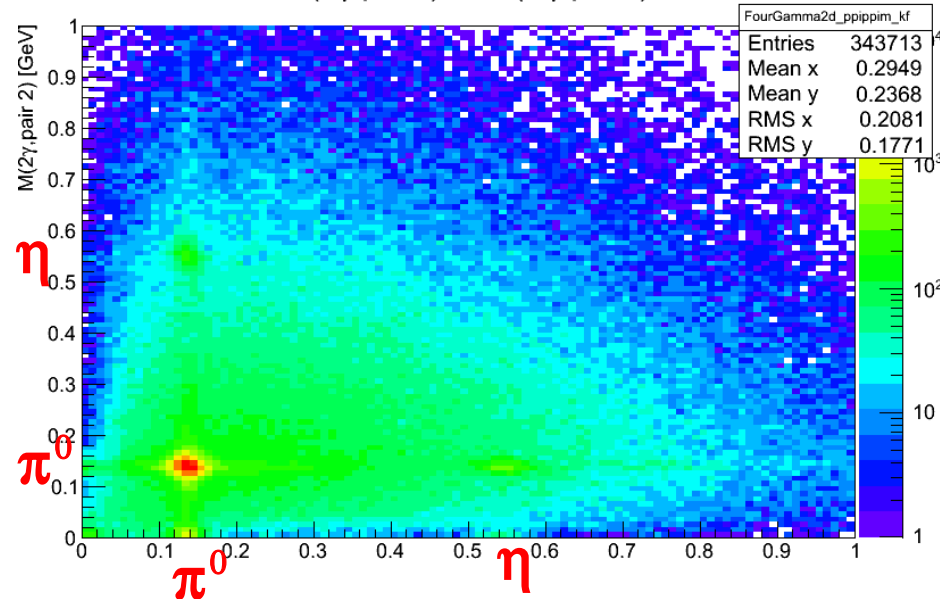


# $\pi^+\pi^- + 4$ photons

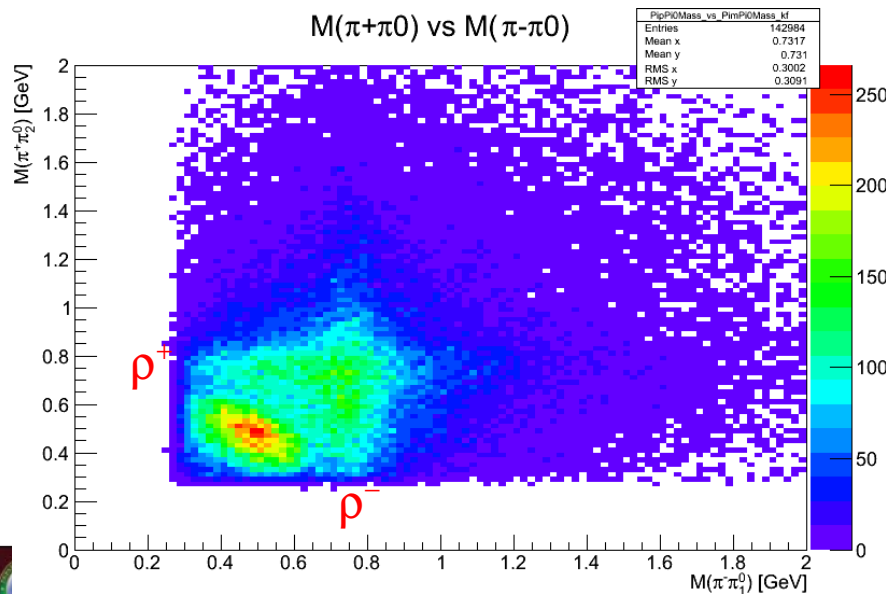
$\pi^+\pi^-4\gamma$  invariant mass



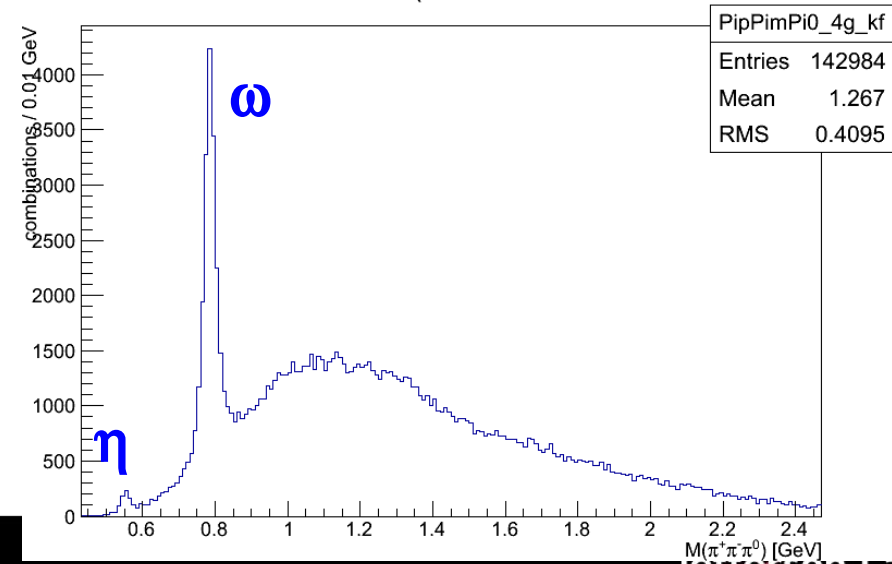
$m(2\gamma, \text{pair2})$  vs  $m(2\gamma, \text{pair1})$



$M(\pi^+\pi^0)$  vs  $M(\pi^-\pi^0)$



$m(\pi^+\pi^-\pi^0)$

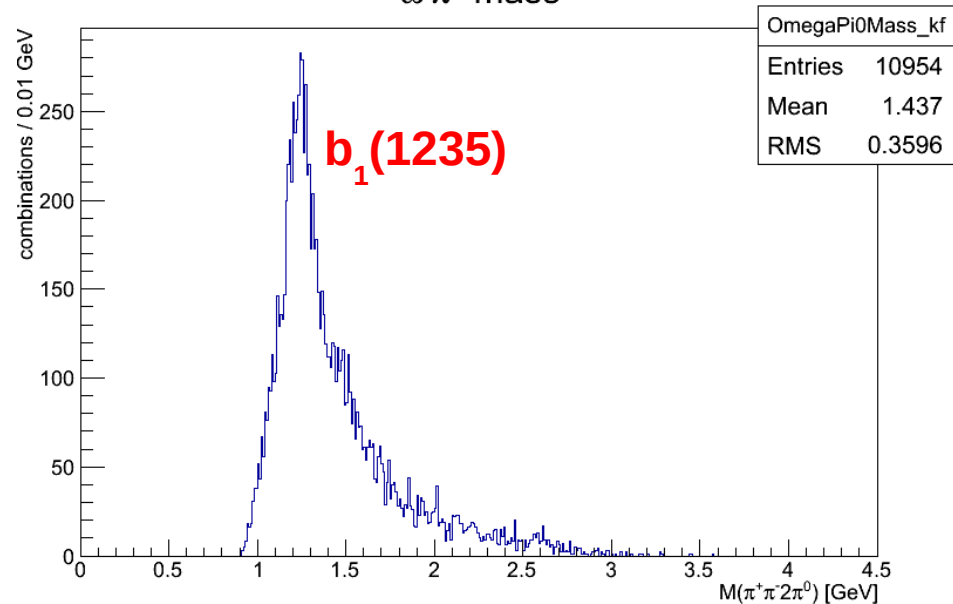


# $\pi^+\pi^- + 4$ photons

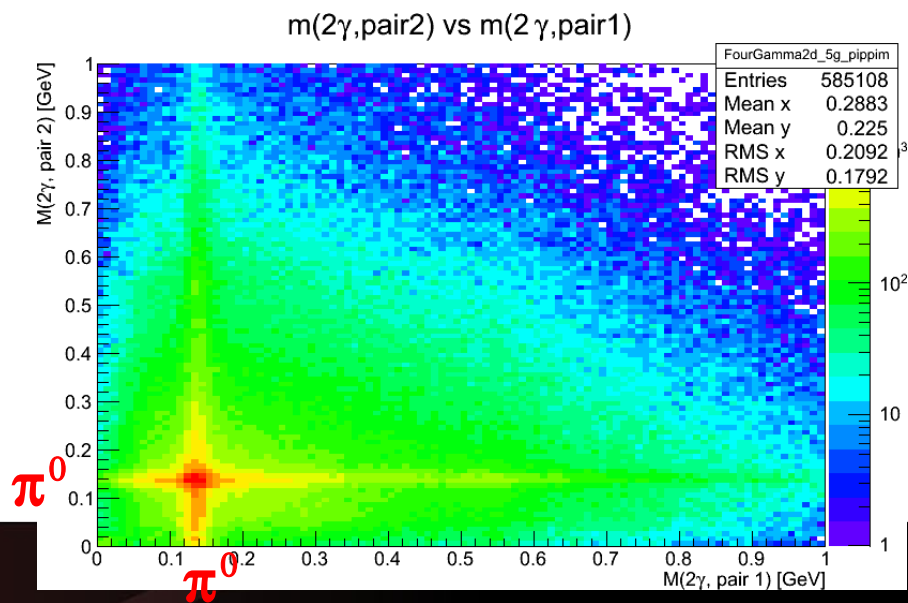
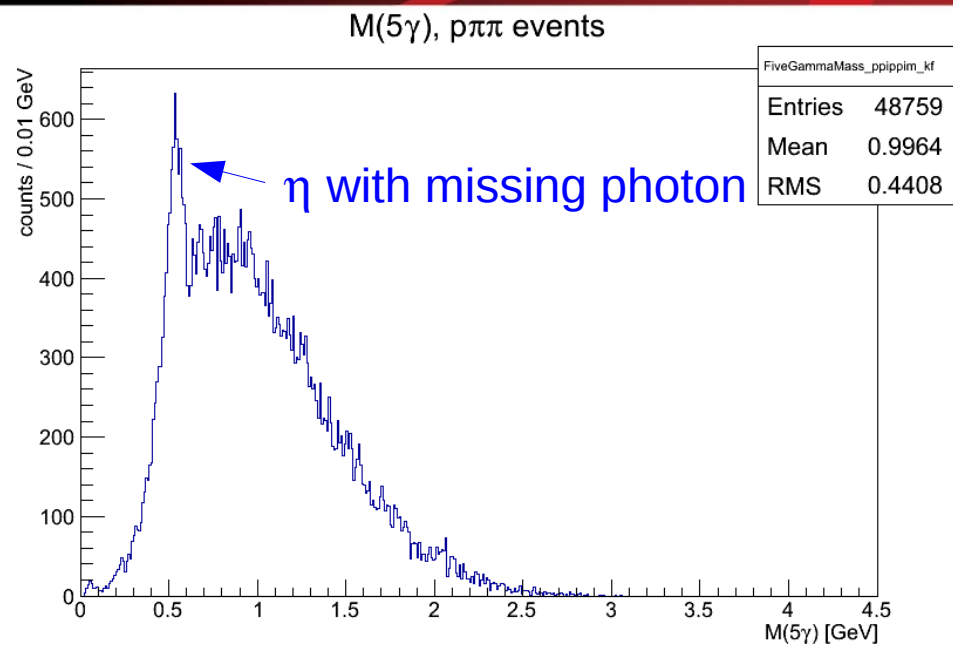
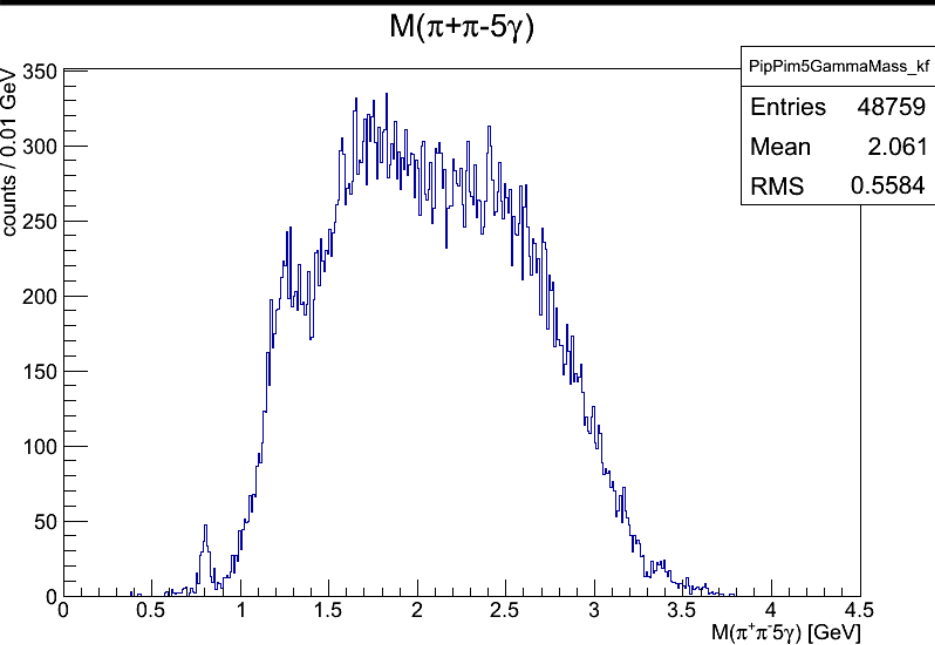
$\eta\pi^0$  mass



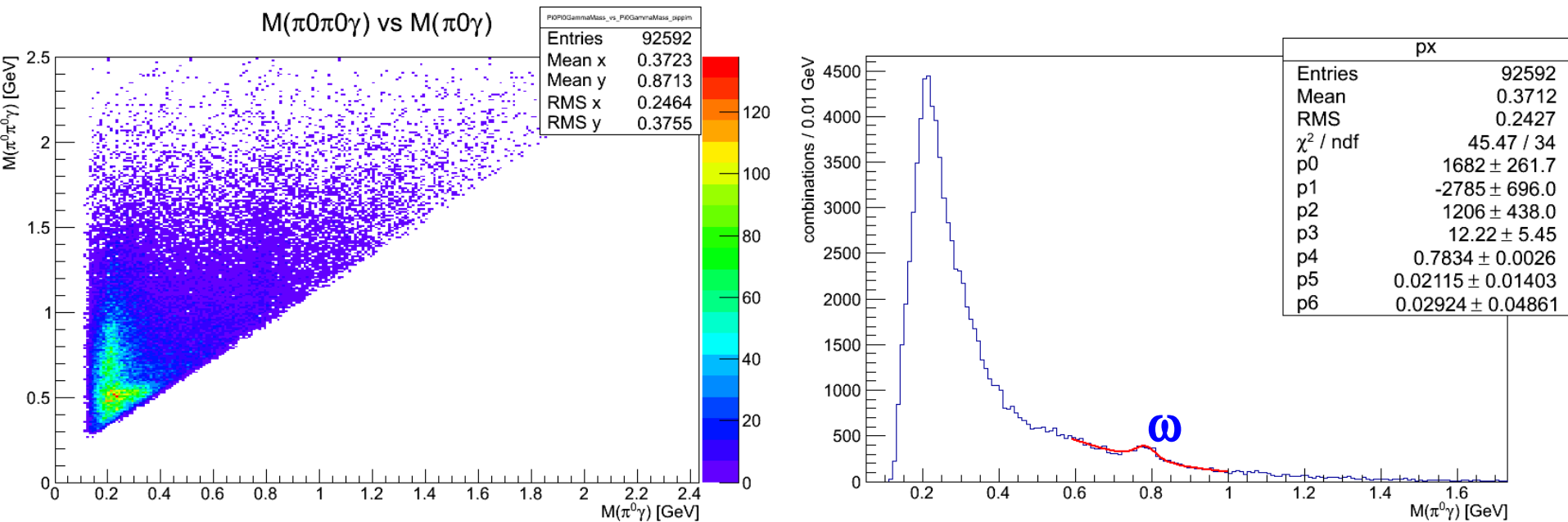
$\omega\pi^0$  mass



# $\pi^+\pi^- + 5$ photons



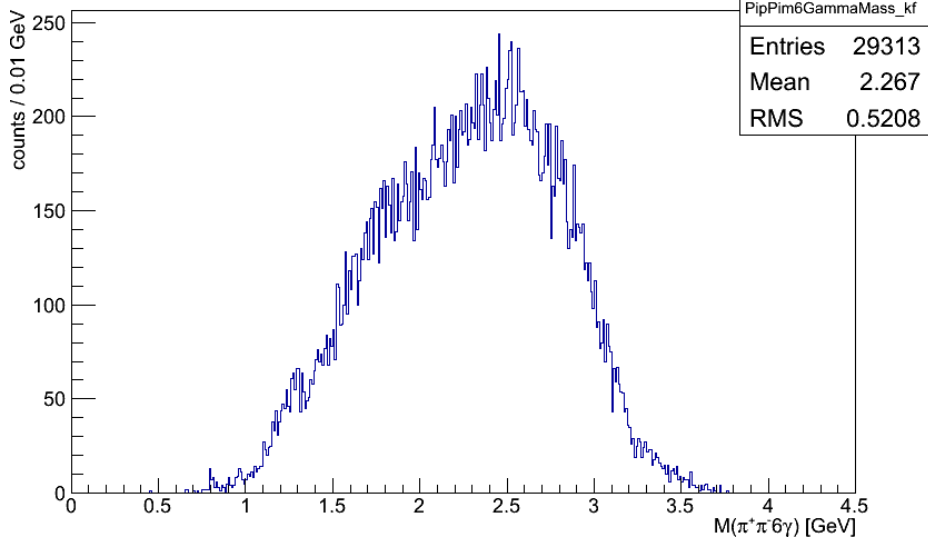
# $\pi^+\pi^- + 5$ photons



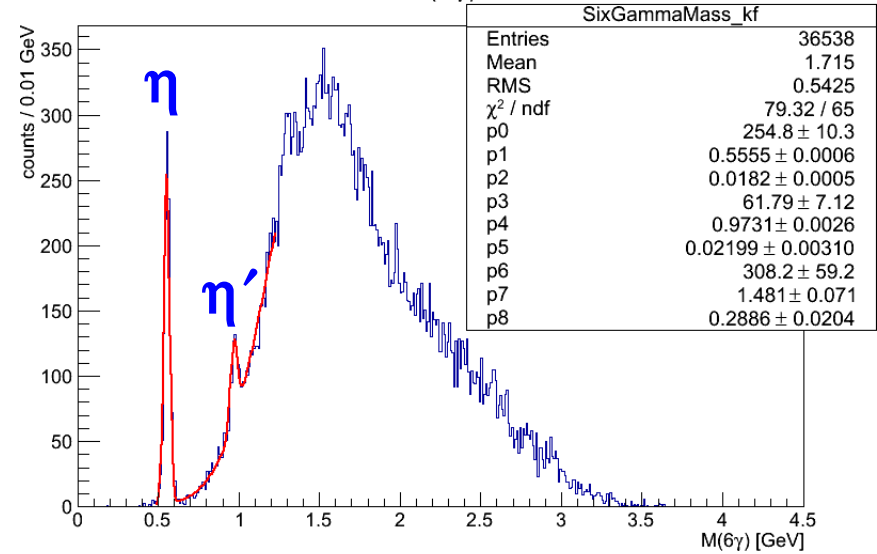
Evidence for  $\rho\pi^+\pi^-\omega\pi^0$  events  $\Rightarrow X \rightarrow \pi^+\pi^-\omega\pi^0$  ???

# $\pi^+\pi^- + 6$ photons

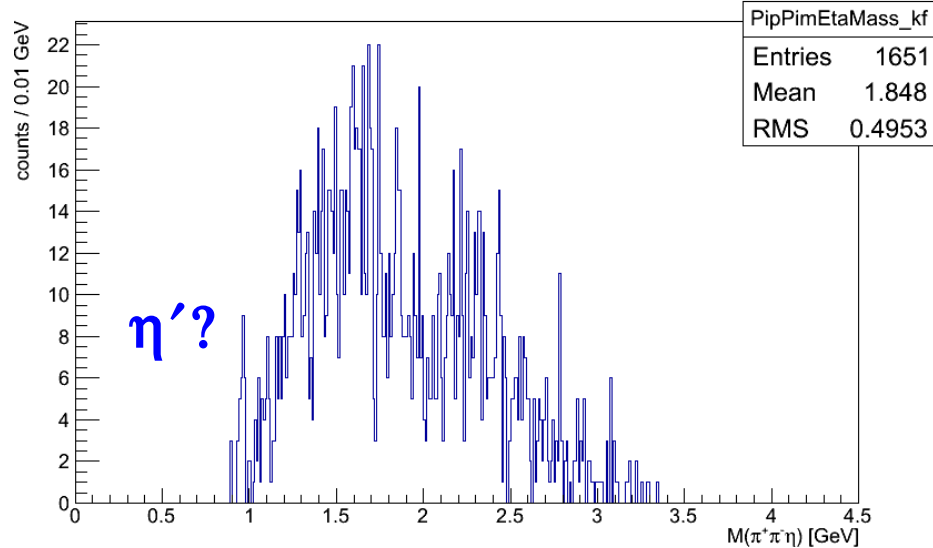
$M(\pi^+\pi^-6\gamma)$



$M(6\gamma)$



$\pi^+\pi^-\eta$  mass,  $\eta \rightarrow 6\gamma$



# Summary

- ◆ Robust signals for  $\pi^0 \rightarrow 2\gamma$ ,  $\eta \rightarrow 2\gamma$ ,  $\eta' \rightarrow 2\gamma$ ,  $\phi \rightarrow \eta\gamma$  and  $\omega \rightarrow \pi^0\gamma$
- ◆ Signals for  $\eta \rightarrow 3\pi^0$ ,  $\eta \rightarrow \pi^+\pi^-\pi^0$ ,  $\eta' \rightarrow \eta\pi^0\pi^0$ ,  $\eta' \rightarrow \eta\pi^+\pi^-$
- ◆ Strong signal for  $f_2(1270) \rightarrow \pi^0\pi^0$ , even at high beam energies
- ◆  $a_0(980) \rightarrow \eta\pi^0$  reconstructed using two  $\eta$  decay channels
- ◆  $b_1(1235) \rightarrow \omega\pi^0$  reconstructed using two  $\omega$  decay channels
- ◆ Evidence for  $p\pi^+\pi^-\eta'$  events
- ◆ Evidence for  $p\pi^+\pi^-\omega$  and  $p\pi^+\pi^-\omega\pi^0$  events