A Study of 3π production in $\gamma p \rightarrow n\pi^+\pi^+\pi^-$ and $\gamma p \rightarrow \Delta^{++}\pi^+\pi^-\pi^-$ with CLAS at Jefferson Lab

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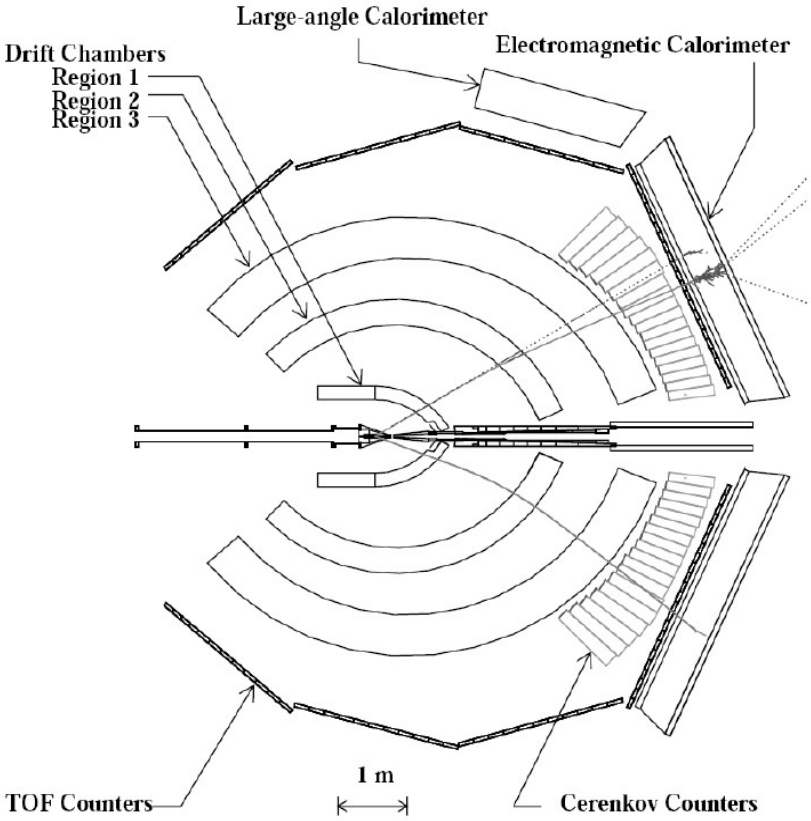
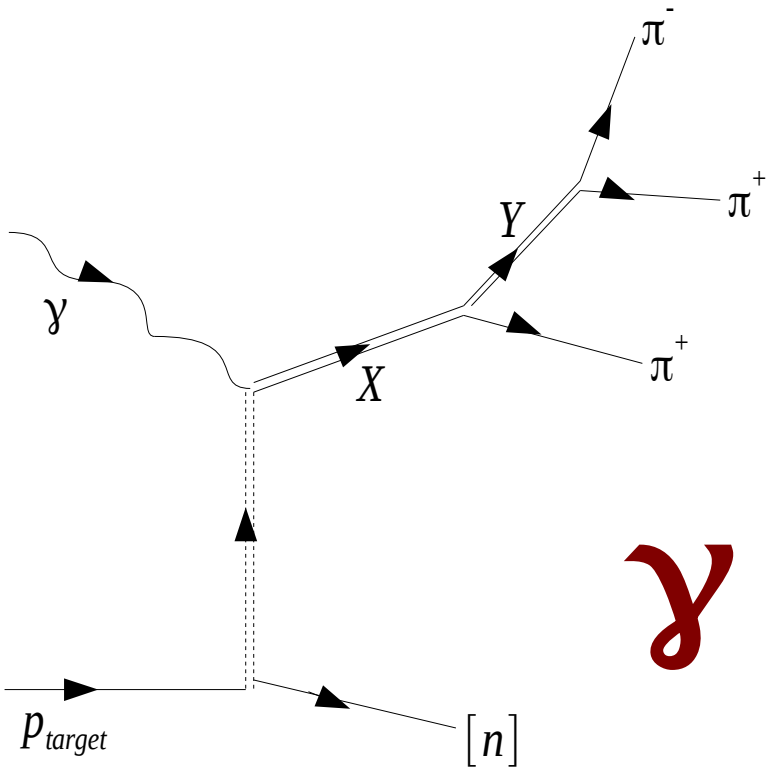
Photoproduction of 3π

- Exotic $\pi_1(1600) \rightarrow$ 3π
  - Has a rich and controversial history
- Theoretical work suggests enhanced hybrid production with photon beams
  - Expect exotic meson production equal to $q\bar{q}$ meson production
- Very little photoproduction data events
    - Resents results from CLAS
    - Upcoming results from GlueX/CLAS12
- n3π and Δ^{++}3π are complimentary channels

Jefferson Lab



CLAS spectrometer

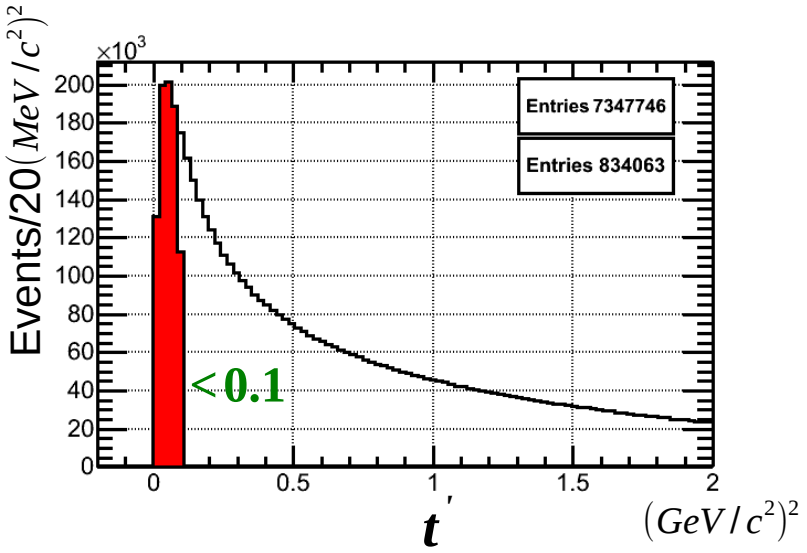


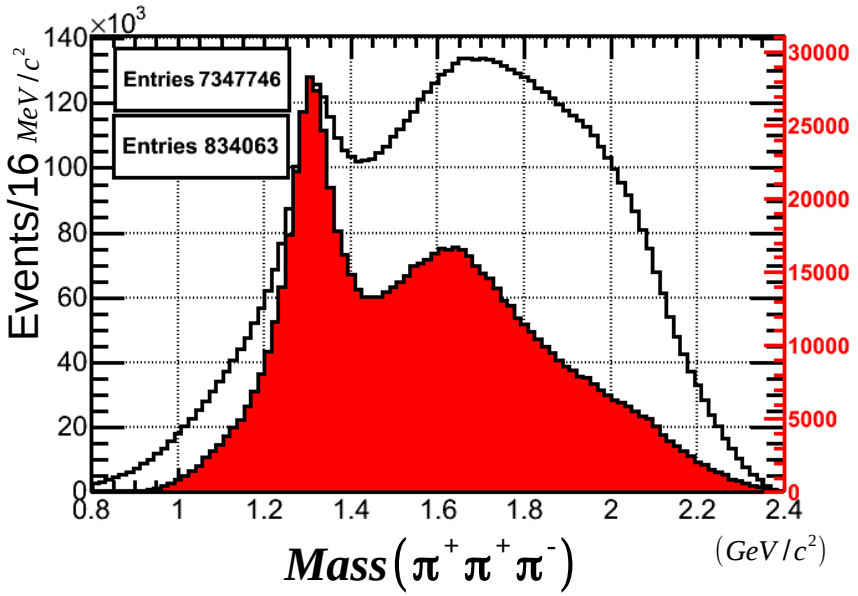
$$\gamma\, p \rightarrow n\, \pi^{+}\, \pi^{+}\, \pi^{-}$$

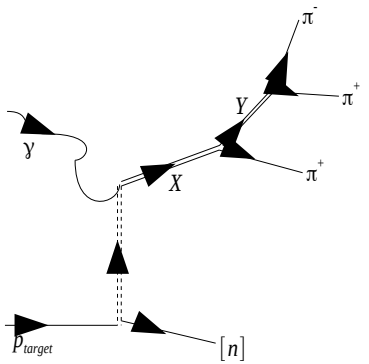
Using the CLAS-g12 dataset we selected events with three charge pions, measured by the CLAS spectrometer and identified a neutron by energy and momentum conservation.

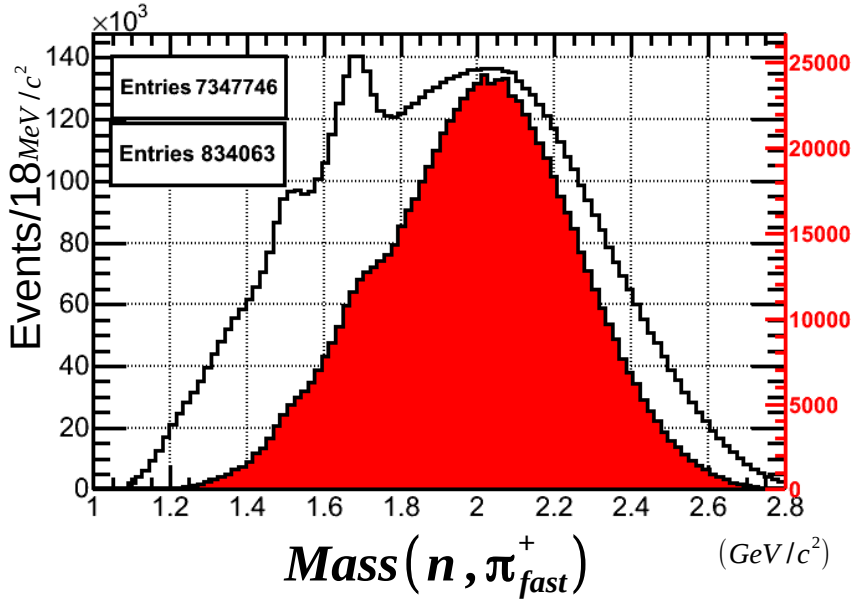
Enhance Peripheral Production

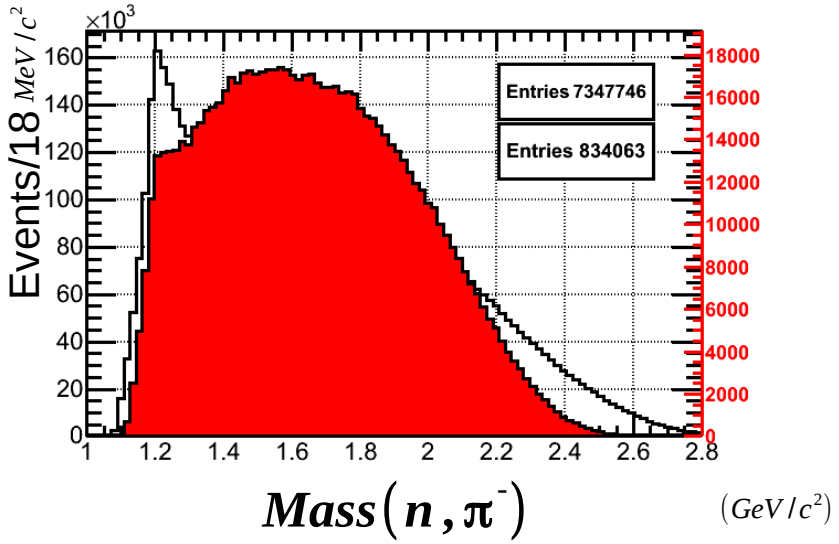
$\gamma p \rightarrow n \pi^+ \pi^+ \pi^-$







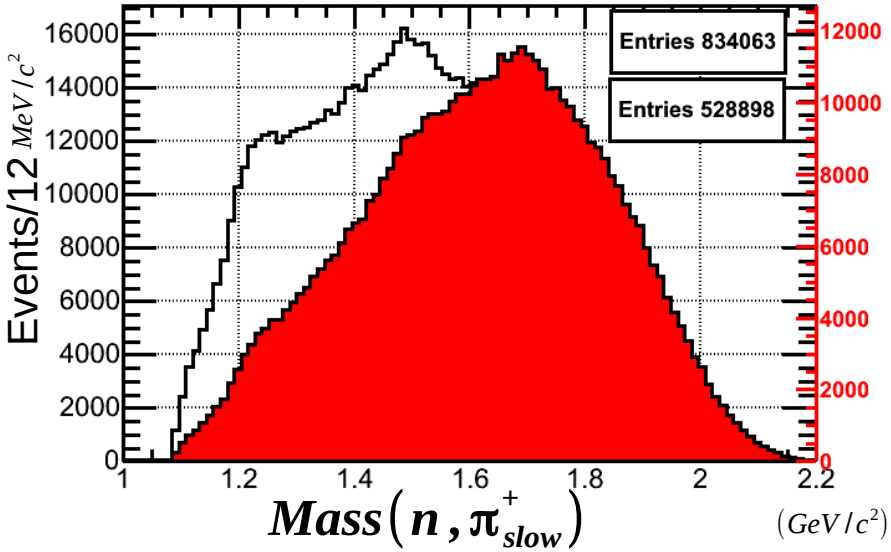


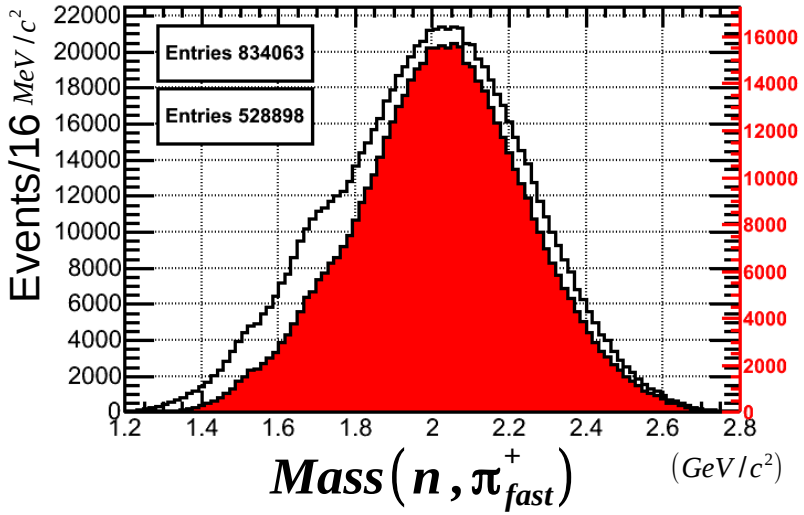


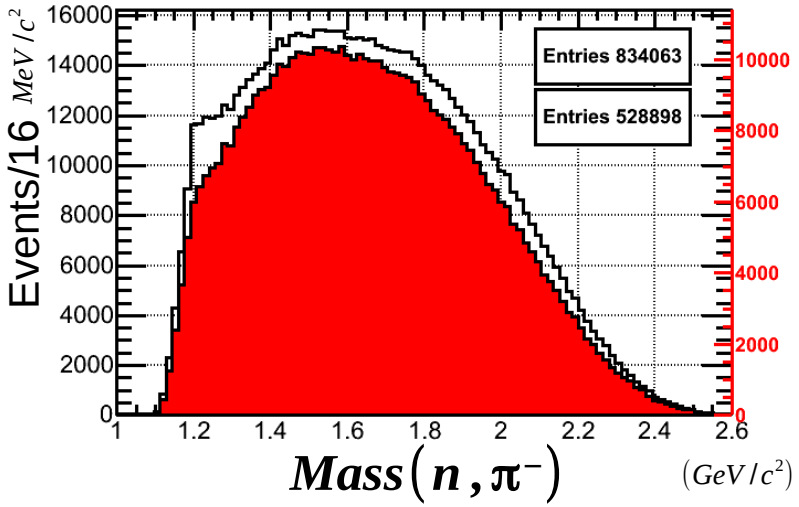
Further Reducing the Baryon Background

$\gamma p \rightarrow n\pi^+\pi^+\pi^-$

$\theta_{lab}[\pi^+_{slow}] < 25^o$

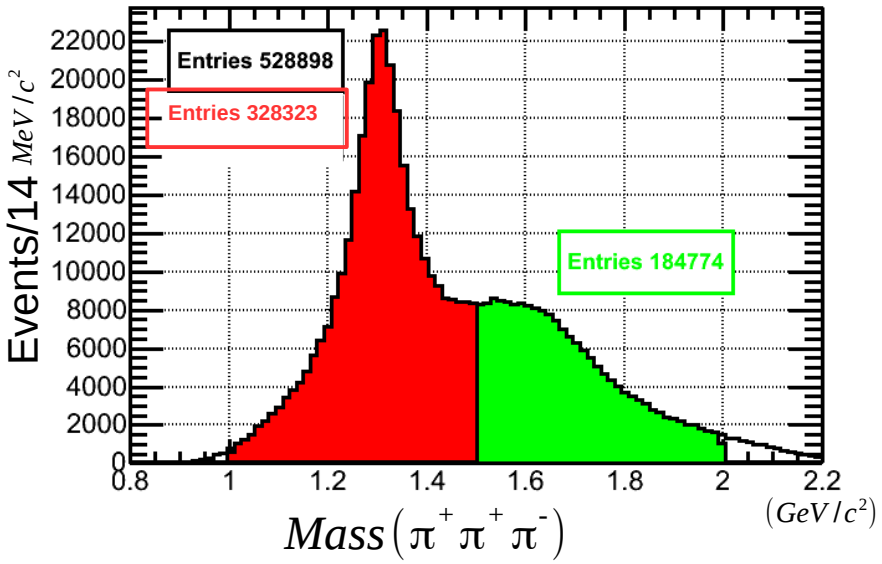


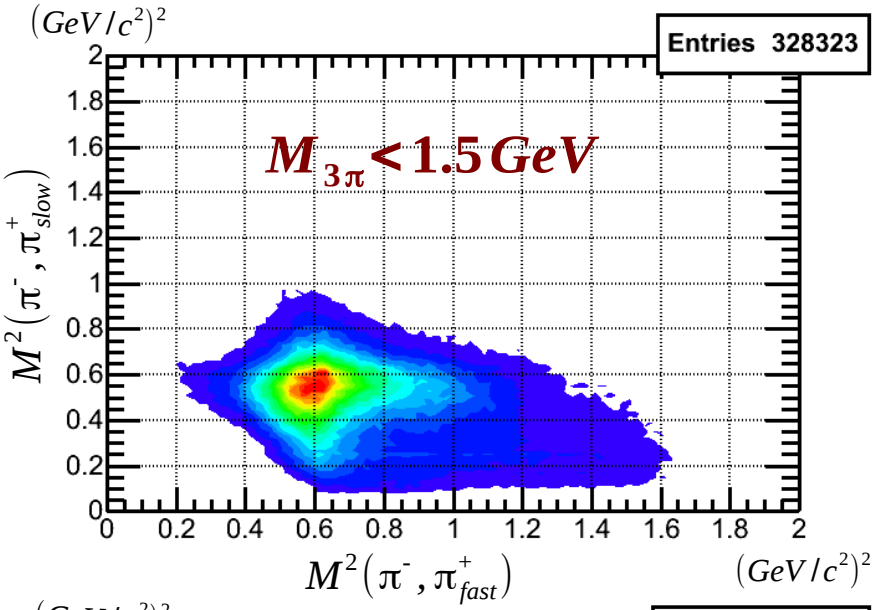


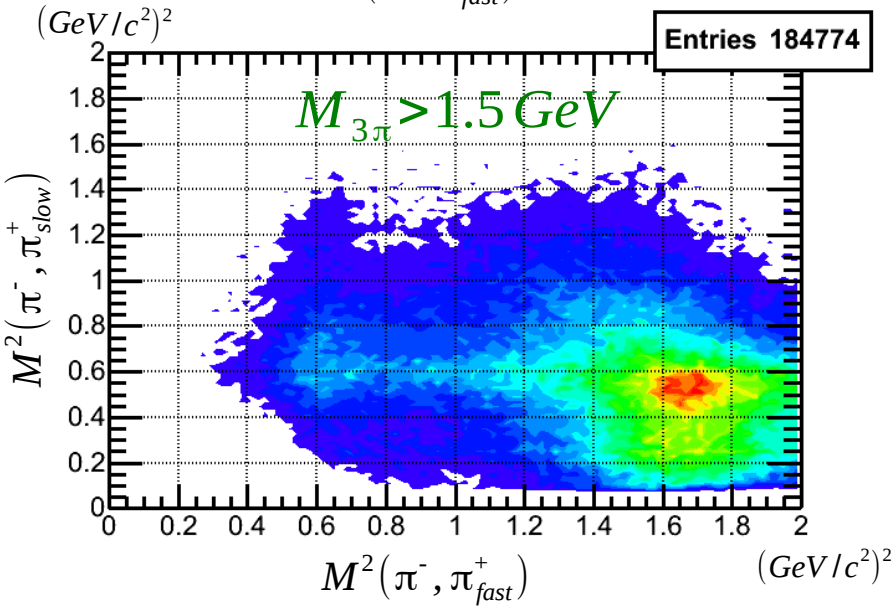


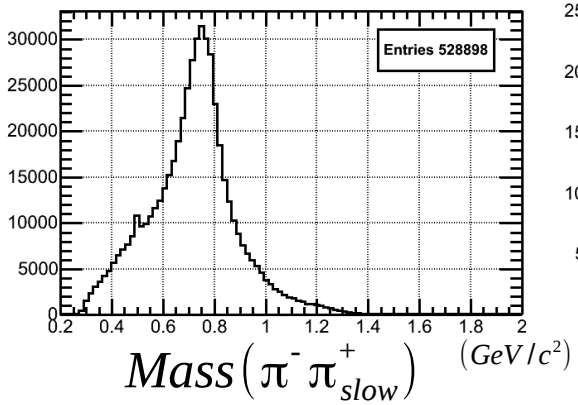
Features of the 3π sample

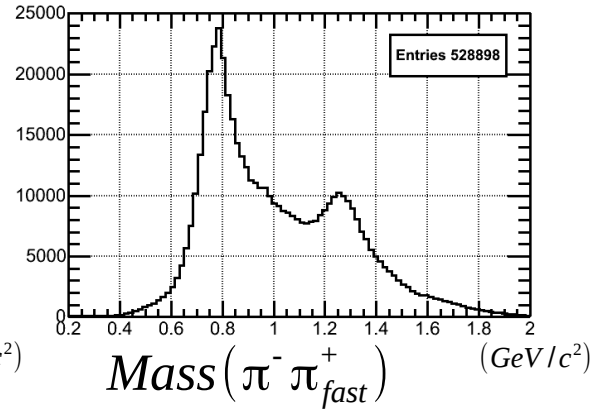
$\gamma p \rightarrow n\pi^+\pi^+\pi^-$











Partial Wave Analysis

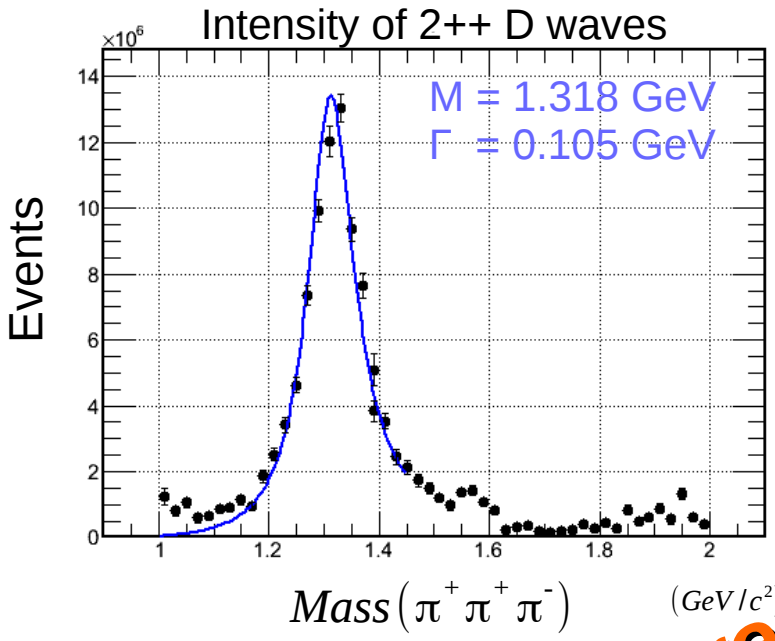
$\gamma p \rightarrow n \pi^+ \pi^+ \pi^-$

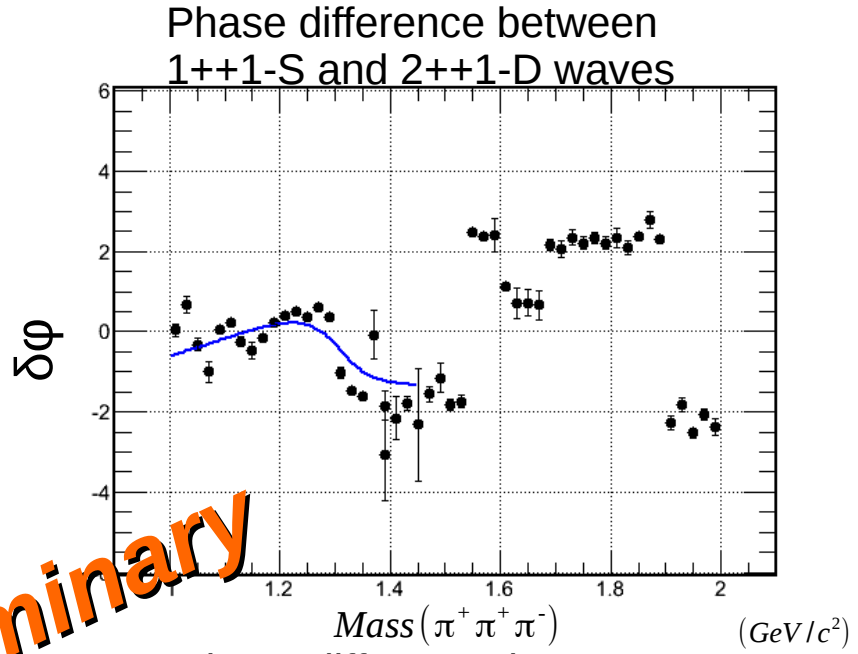
- A mass independent pwa is performed using an event based likelihood fit
- To calculate the amplitudes we used helicity formalism in the reflectivity basis using the isobar model

$$I(\tau) = \sum_{\kappa\epsilon} \left| \sum_{\alpha} {}^{\epsilon\kappa} V_{\alpha}{}^{\epsilon} A_{\alpha}(\tau) \right|^2$$

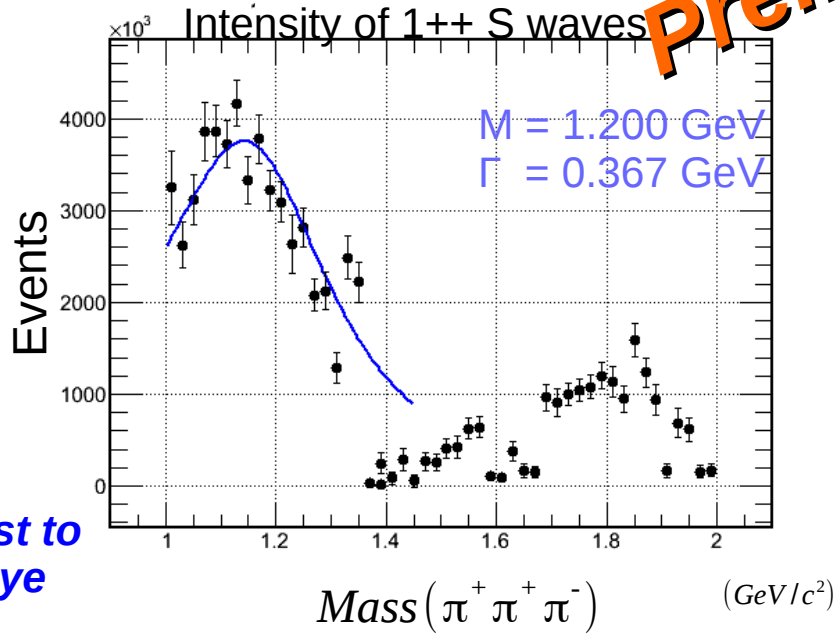
- For the current fit a total of 17 partial waves were used in the high mass region and 13 partial waves in the low mass region

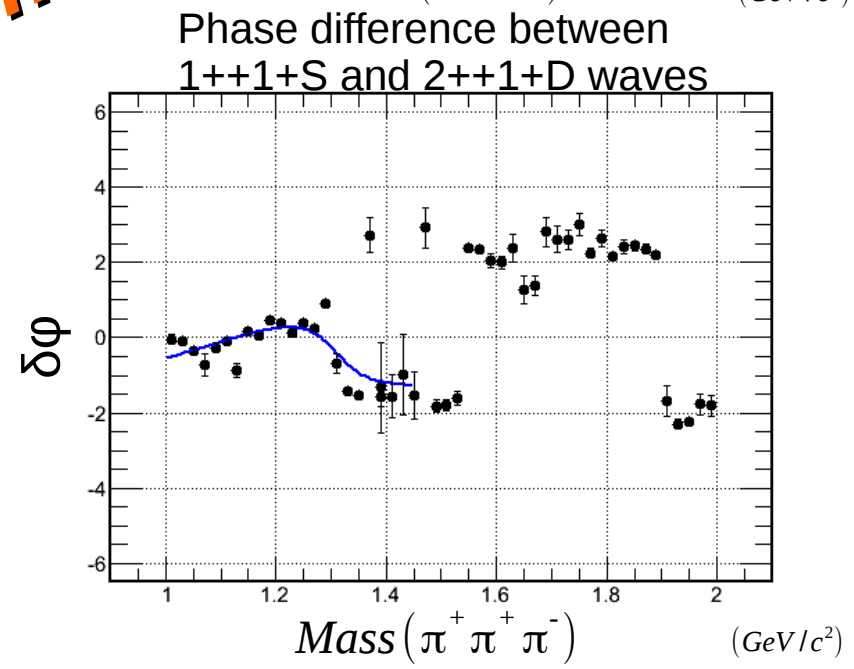
Features of the partial waves of the 3π System for the $\gamma p \rightarrow n\pi^+\pi^+\pi^-$





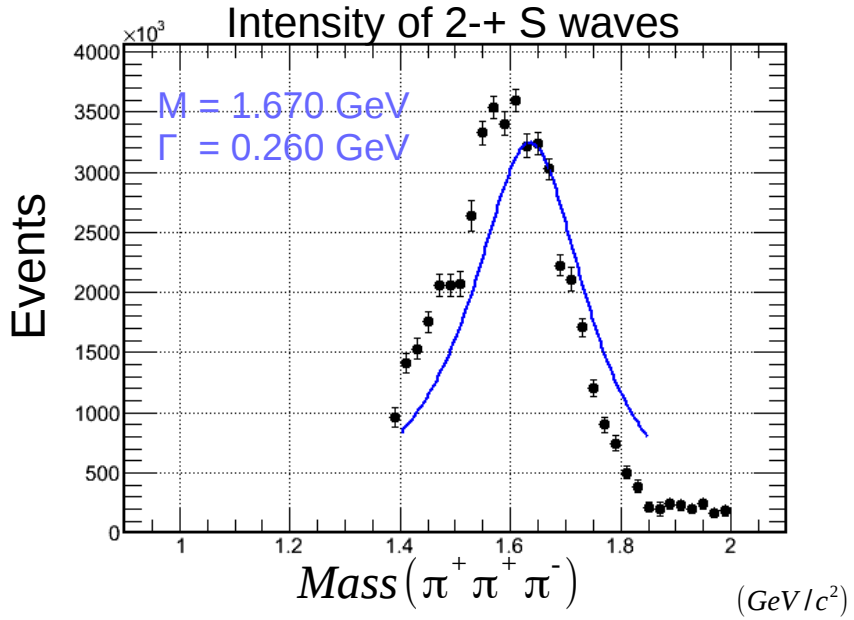
Preliminary

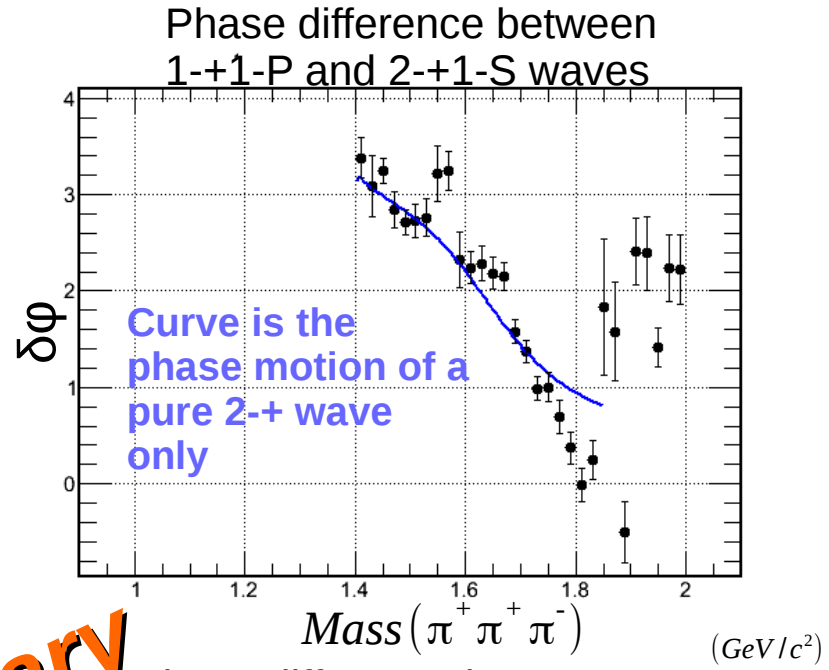


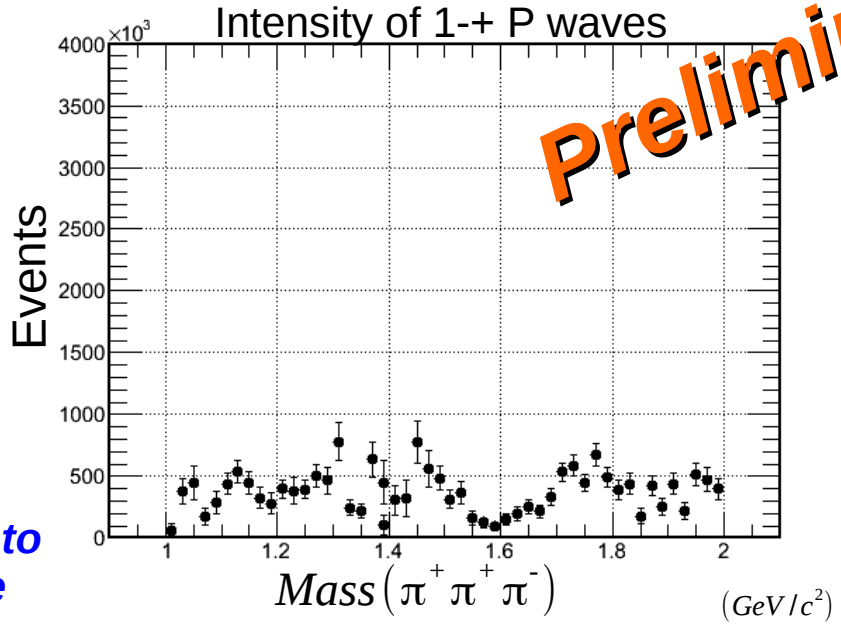


Curve is just to guide the eye

Features of the partial waves of the 3π System for the $\gamma\, p \rightarrow n\,\pi^+\pi^+\pi^-$







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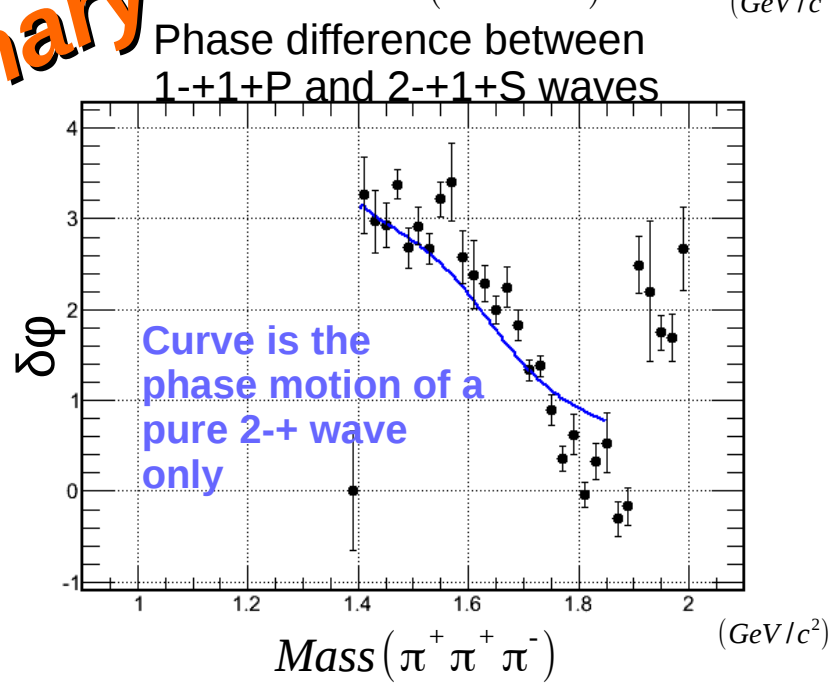

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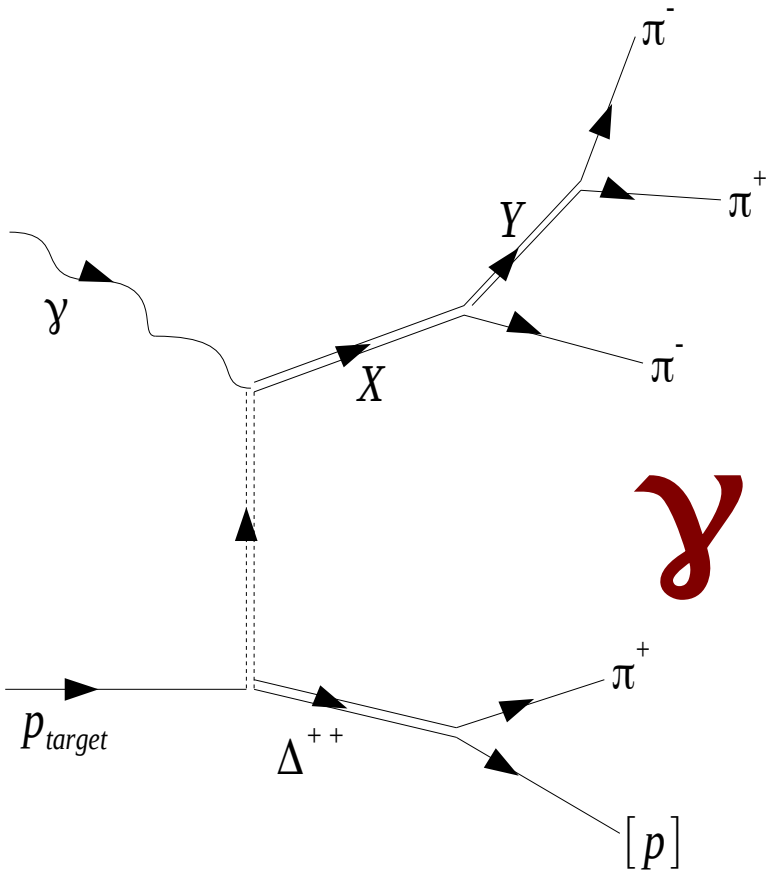


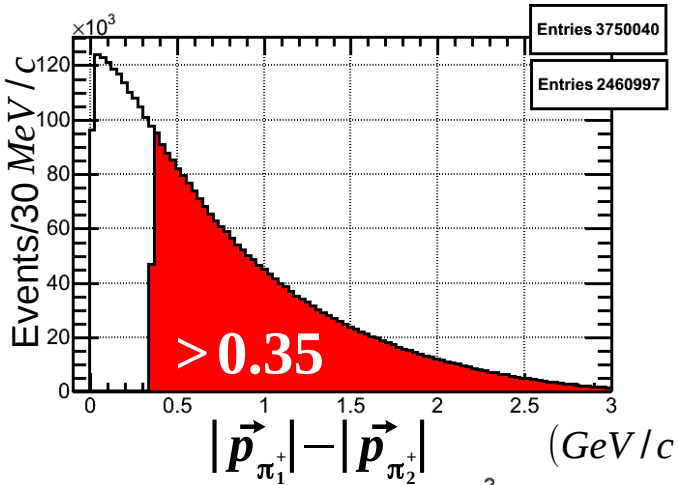
$$\gamma\, p \rightarrow \Delta^{++}\pi^{+}\pi^{-}\pi^{-}$$

Using the CLAS-g12 dataset we selected events with four charge pions, measured by the CLAS spectrometer and identified a proton by energy and momentum conservation.

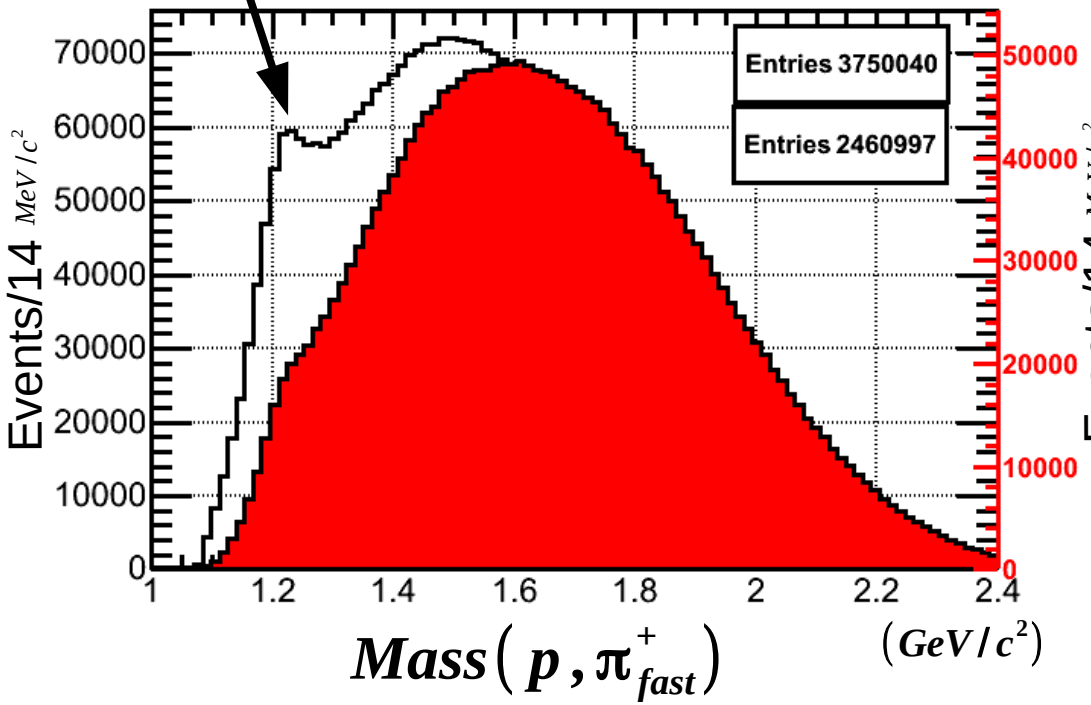
Kinematic Separation of the Δ^{++}

$\gamma p \rightarrow \Delta^{++} \pi^{+} \pi^{-} \pi^{-}$

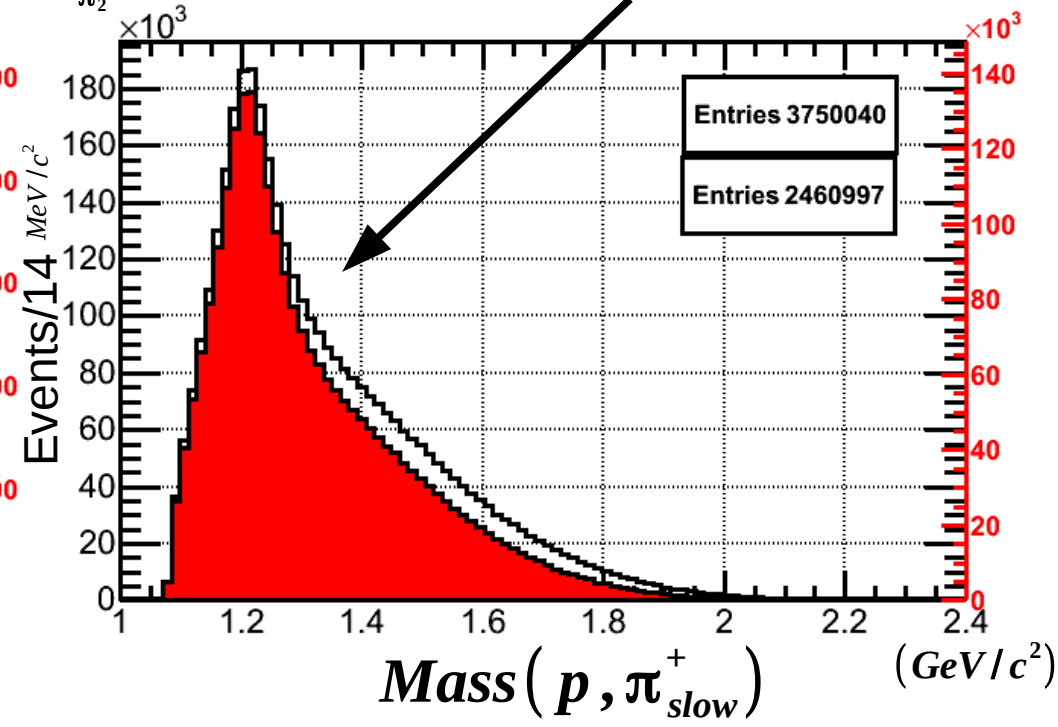
Momentum Difference:



Background Δ^{++}

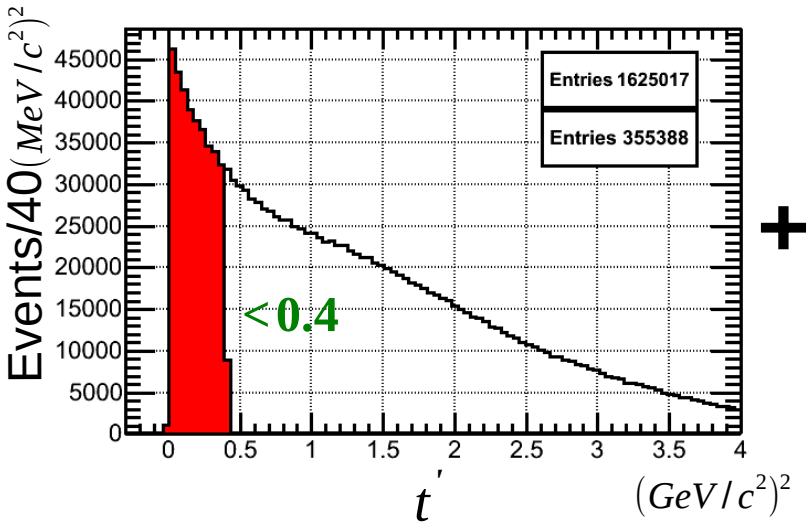


Signal Δ^{++}

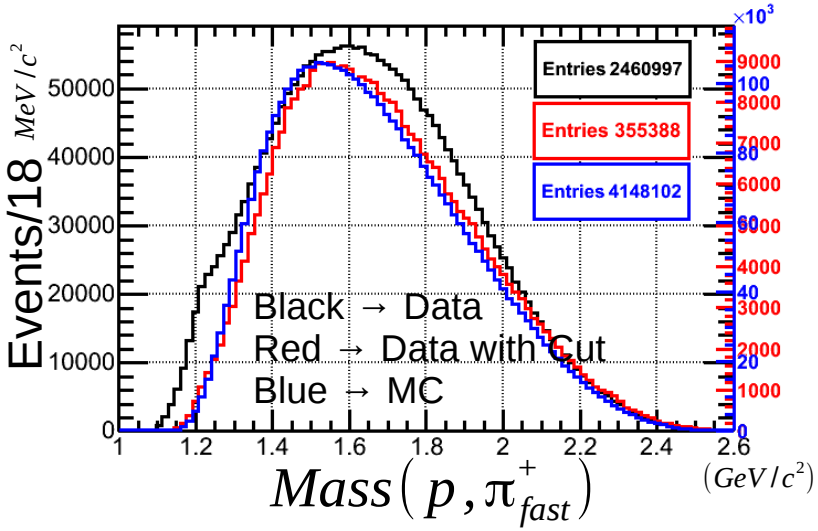


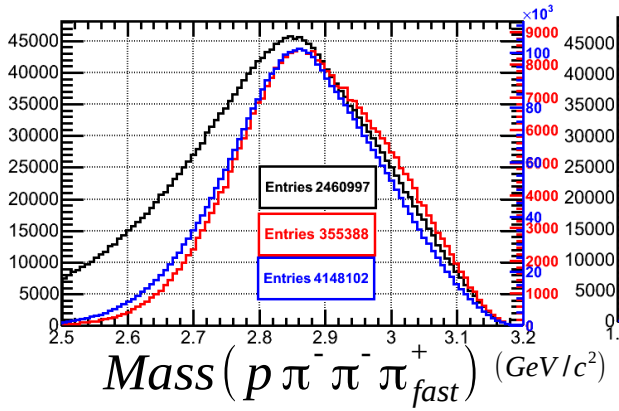
Data Selection and Background Reduction

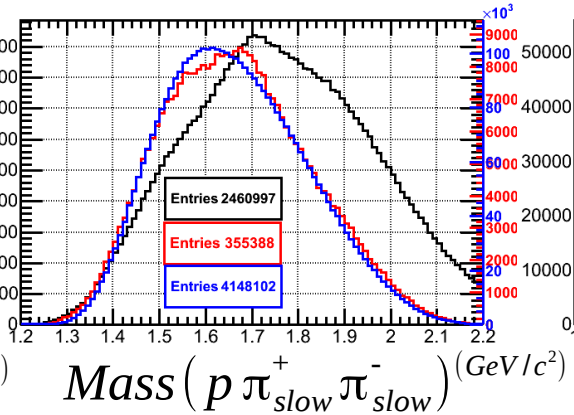
$\gamma p \rightarrow \Delta^{++} \pi^{+} \pi^{-} \pi^{-}$

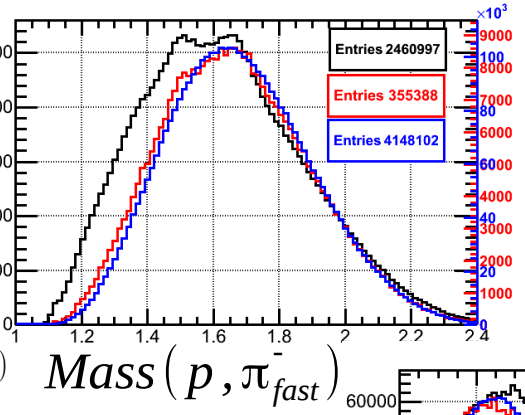


$+ M_{p\pi^{+}_{slow}} < 1.35$

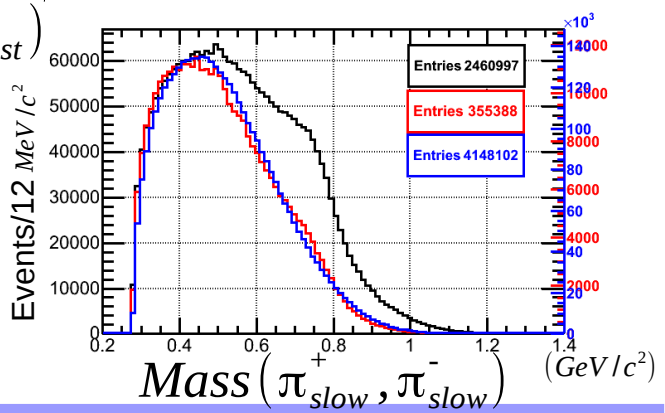






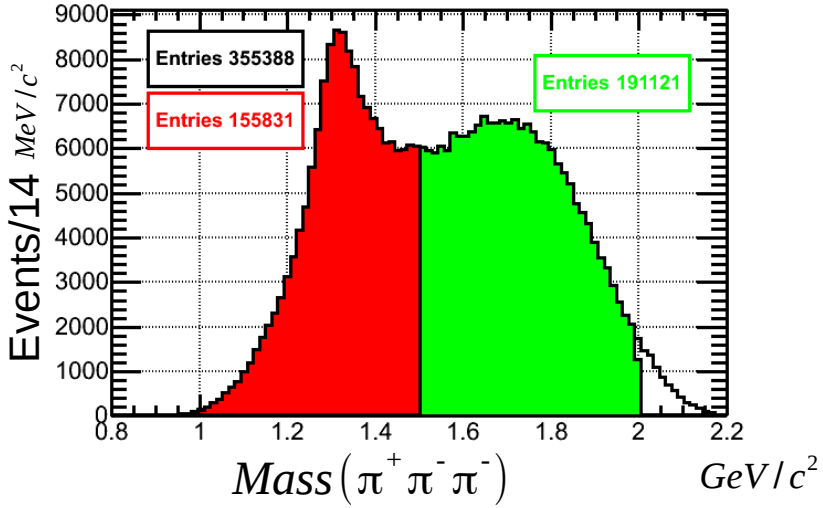


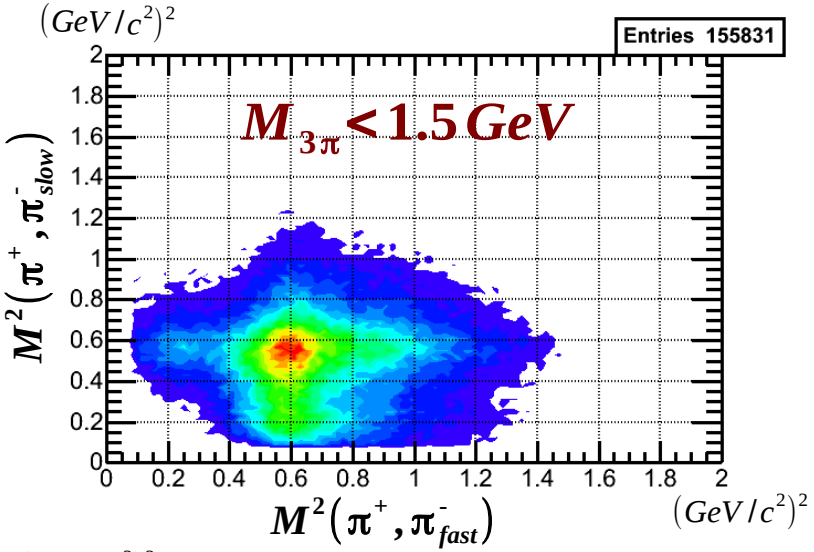
Black → Data
Red → Data with Cuts
Blue → MC with Cuts

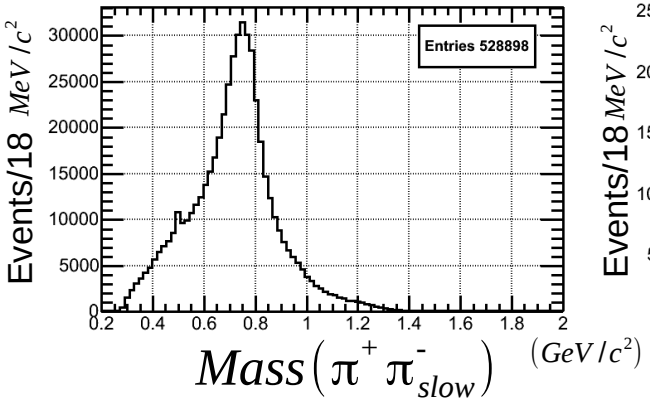


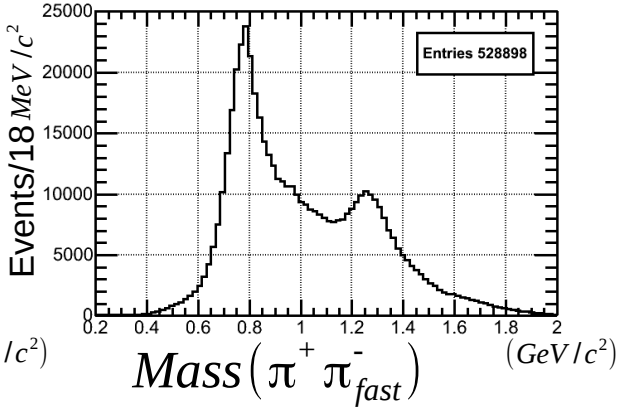
Features of the 3π sample

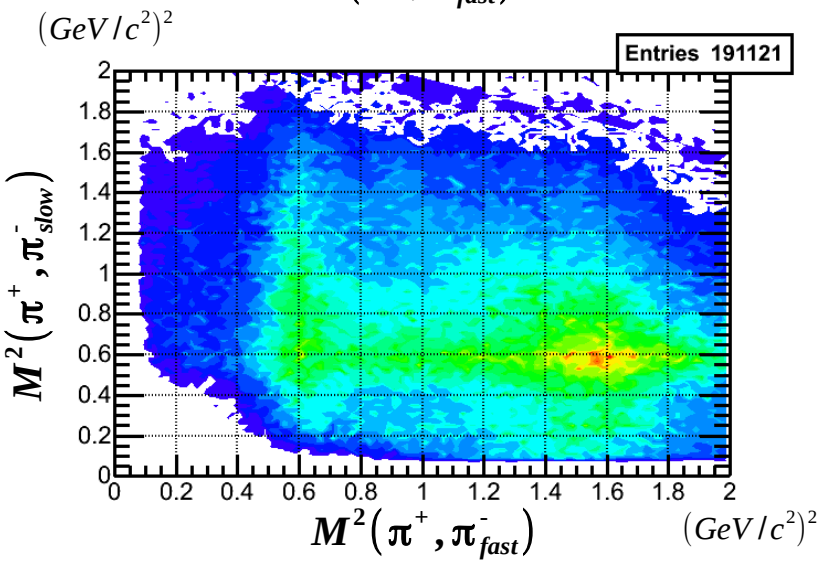
$\gamma p \rightarrow \Delta^{++}\pi^{+}\pi^{-}\pi^{-}$











$M_{3\pi} > 1.5\,GeV$

Partial Wave Analysis

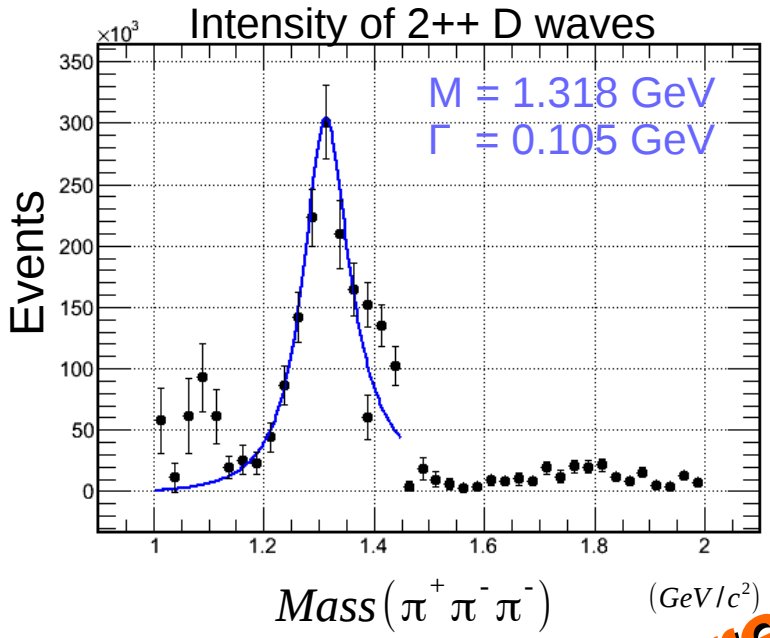
$\gamma p \rightarrow \Delta^{++} \pi^{+} \pi^{-} \pi^{-}$

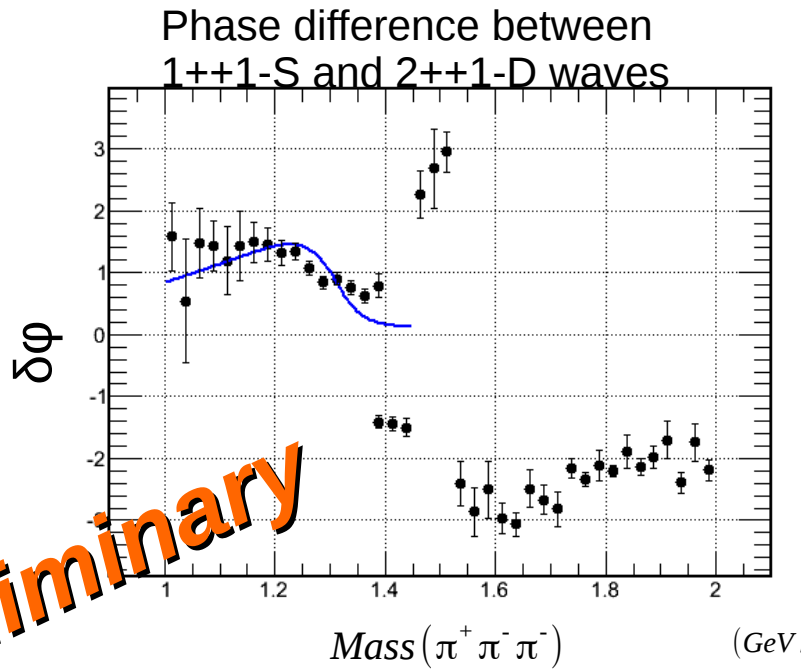
- A mass independent pwa is performed using an event based likelihood fit
- To calculate the amplitudes we used helicity formalism in the reflectivity basis using the isobar model

$$I(\tau) = \sum_{\kappa\epsilon} \left| \sum_{\alpha} {}^{\epsilon\kappa} V_{\alpha}{}^{\epsilon} A_{\alpha}(\tau) \right|^2$$

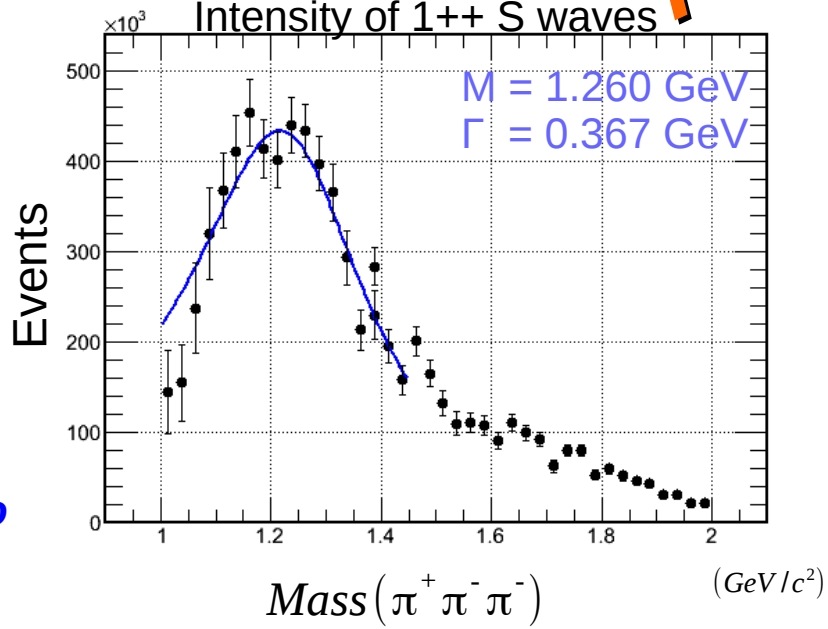
- For the current fit a total of 13 partial waves were used in the high mass region and 9 partial waves in the low mass region

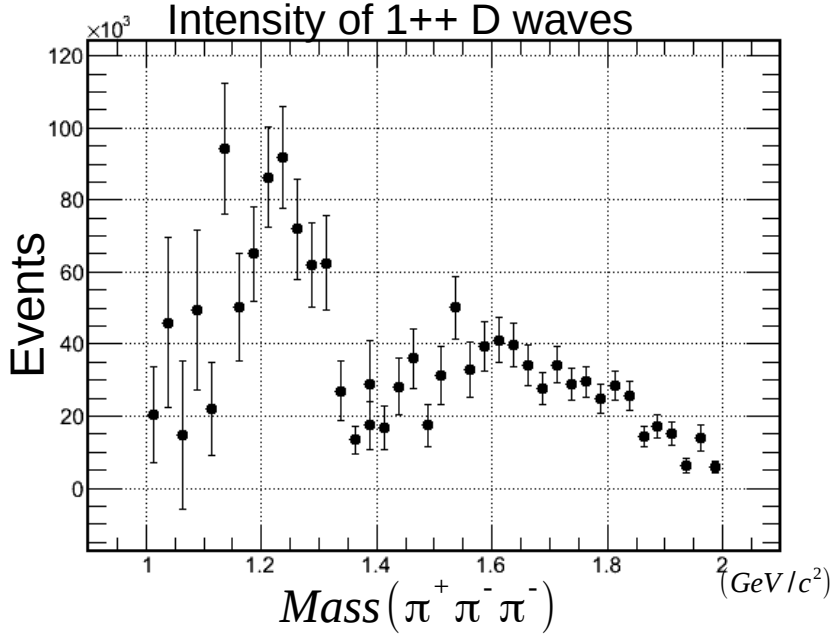
Features of the partial waves of the 3π System for the $\gamma p \rightarrow \Delta^{++}\pi^{+}\pi^{-}\pi^{-}$





Preliminary



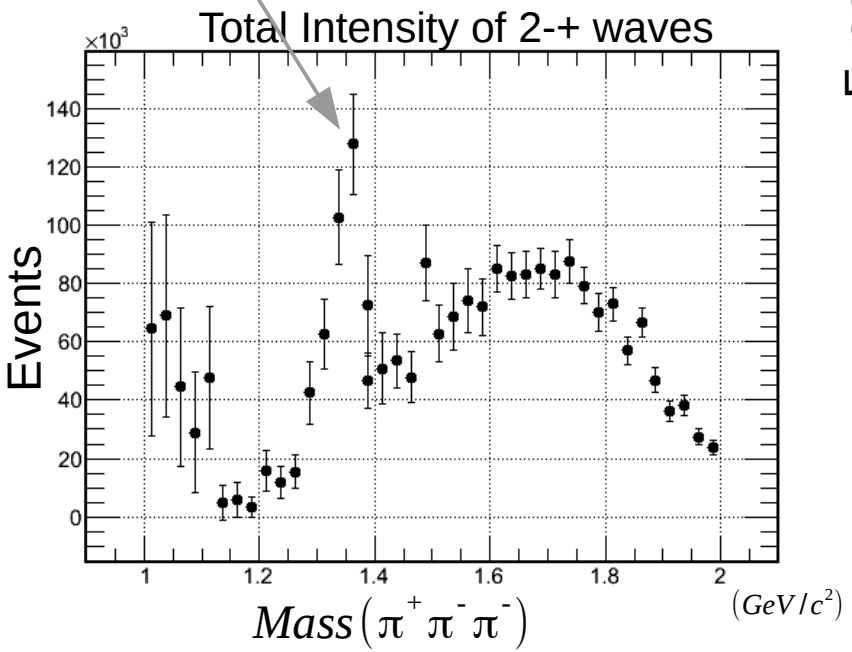


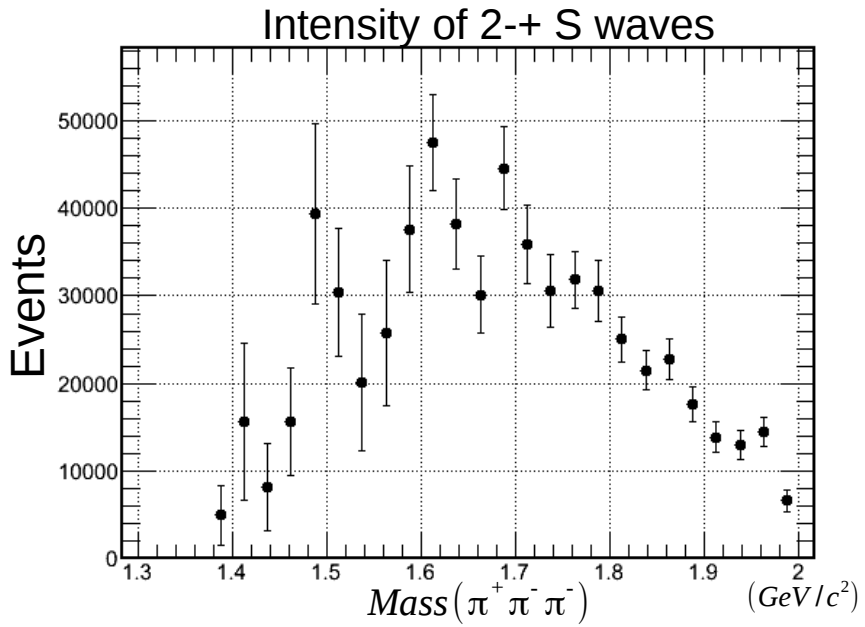
Curve is just to guide the eye

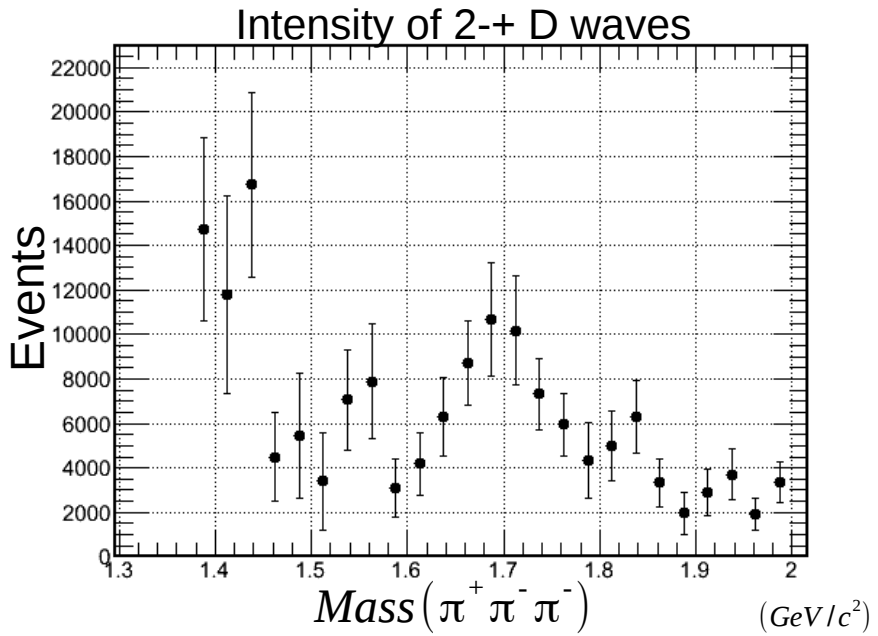
Features of the partial waves of the 3π System for the $\gamma p \rightarrow \Delta^{++} \pi^+ \pi^- \pi^-$

Preliminary

leakage of $a_2(1320)$ into the P-wave







The importance of the $J^{PC} = 1^{-+}$ partial wave is still being investigated.

Summary

- $\gamma p \rightarrow n\pi^+\pi^+\pi^-$:
  - The $a_2(1320)$ and the $a_1(1260)$ are observed
  - The $\pi_2(1670)$ is observed
  - The $J^{PC}=1^{-+}$ appears to have no phase motion relative to the $\pi_2(1670)$
- $\gamma p \rightarrow \Delta^{++}\pi^+\pi^-\pi^-$:
  - A first time PWA of the $\Delta^{++}3\pi$ system
  - The $a_2(1320)$ and the $a_1(1260)$ are observed
  - The $\pi_2(1670)$ is observed

Work In Progress...

Back up slides

List of Waves used for the current Fit $\gamma p \rightarrow n\pi^+\pi^+\pi^-$

$M_{3\pi} < 1.4\,GeV$

J^{PC}	M^{ϵ}	L	Y	Number of waves
1^{++}	$1^{-/+}$	S,P,D	$\rho(770),\sigma$	6
1^{-+}	$1^{-/+}$	P	$\rho(770)$	2
2^{++}	$1^{-/+}$	D	$\rho(770)$	2
2^{-+}	$1^{-/+}$	P	$\rho(770)$	2
Isotropic background wave				

$M_{3\pi} > 1.38\,GeV$

J^{PC}	M^{ϵ}	L	Y	Number of waves
1^{++}	$1^{-/+}$	S,P,D	$\rho(770),\sigma$	6
1^{-+}	$1^{-/+}$	P	$\rho(770)$	2
2^{++}	$1^{-/+}$	D	$\rho(770)$	2
2^{-+}	$1^{-/+}$	S,P,D	$\rho(770), f_2(1270)$	6
Isotropic background wave				

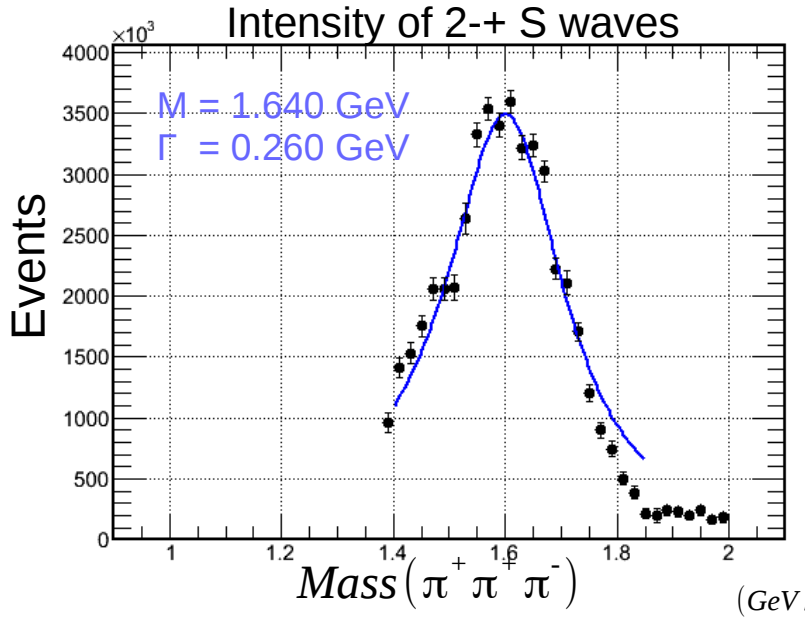
List of Waves used for the current Fit $\gamma p \rightarrow \Delta^{++} \pi^{+} \pi^{-} \pi^{-}$

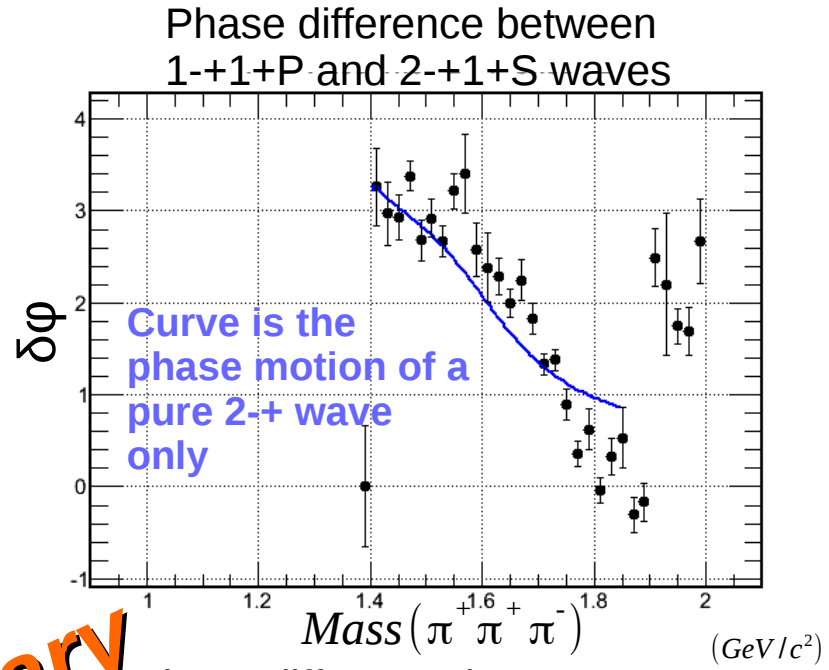
$M_{3\pi} < 1.4\,GeV$

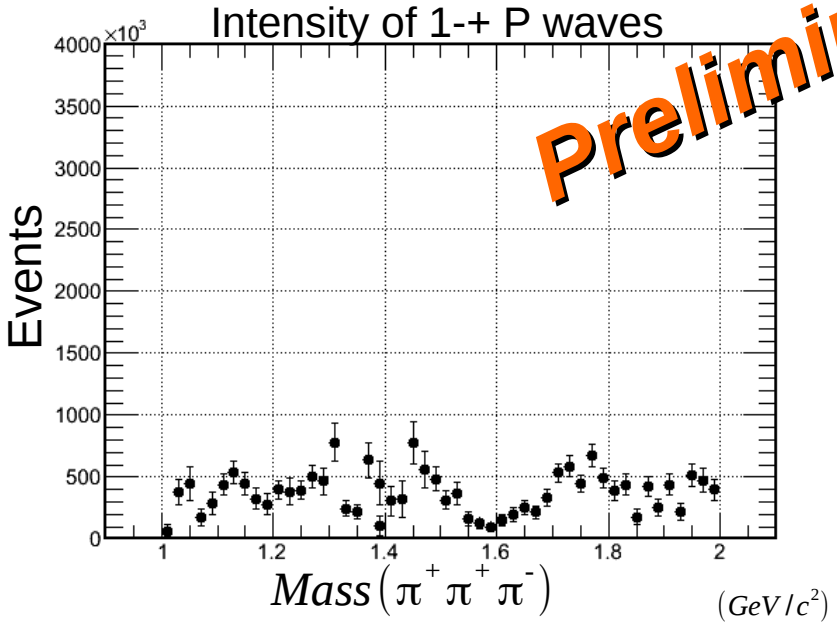
J^{PC}	M^{ϵ}	L	Y	Number of waves
1^{++}	$1^{-/+}$	S, D	$\rho(770)$	4
2^{++}	$1^{-/+}$	D	$\rho(770)$	2
2^{-+}	$1^{-/+}$	P	$\rho(770)$	2
Isotropic Background Wave				

$M_{3\pi} > 1.35\,GeV$

J^{PC}	M^{ϵ}	L	Y	Number of waves
1^{++}	$1^{-/+}$	S, D	$\rho(770)$	4
2^{++}	$1^{-/+}$	D	$\rho(770)$	2
2^{-+}	$1^{-/+}$	S, P, D	$\rho(770), f_2(1270)$	6
Isotropic Background Wave				







Preliminary