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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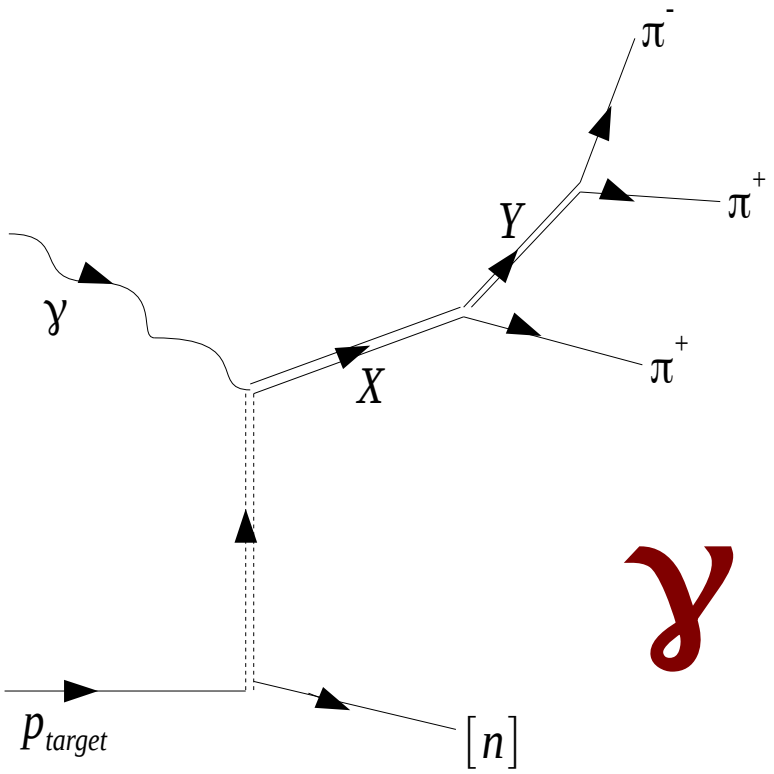
Florida State University

CLAS Collaboration Meeting
Newport News, VA
October 21-23, 2015



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

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.

- Analysis is being redone in preparation of publication
  - Error was found in the parametrization of the partial waves
  - New data selection and new Monte Carlo with analysis in line with g12 analysis note procedures

Error Found in the Parametrization of the Partial Waves

Craig	Aris
1-+0-P:iso=rho -1	1-+0-P:iso=rho -1
1-+1-P:iso=rho -1	2-+1-D:iso=f2 -1
1++1-S:iso=rho -1	2++1-D:iso=rho -1
2-+0-D:iso=f2 -1	2-+1-P:iso=rho -1
2-+0-P:iso=rho -1	2-+1-S:iso=f2 -1
2-+0-S:iso=f2 -1	1-+1-P:iso=rho -1
2-+1-D:iso=f2 -1	1++1-S:iso=rho -1
2++1-D:iso=rho -1	1-+1+P:iso=rho +1
2-+1-P:iso=rho -1	1++1+S:iso=rho +1
2-+1-S:iso=f2 -1	2-+0+P:iso=rho +1
1-+1+P:iso=rho +1	2-+0+D:iso=f2 +1
1++1+S:iso=rho +1	2-+0+S:iso=f2 +1
2-+1+D:iso=f2 +1	2-+1+D:iso=f2 +1
2++1+D:iso=rho +1	2++1+D:iso=rho +1
2-+1+P:iso=rho +1	2-+1+P:iso=rho +1
2-+1+S:iso=f2 +1	2-+1+S:iso=f2 +1
flatbg 0	flatbg 0

- helicity amplitudes are not parity eigenstates

- reflectivity amplitudes are linear combinations of helicity amps which are parity eigenstates.

$$|\epsilon a m\rangle = \left[|a m\rangle - \epsilon P(-1)^{J-m}|a - m\rangle\right]\theta(m) \qquad (38)$$

where P is the parity of the state 'a' and

$$\begin{aligned}\theta(m) &= \frac{1}{\sqrt{2}}, \quad m > 0 \\ &= \frac{1}{2}, \quad m = 0 \\ &= 0, \quad m < 0\end{aligned} \qquad (39)$$

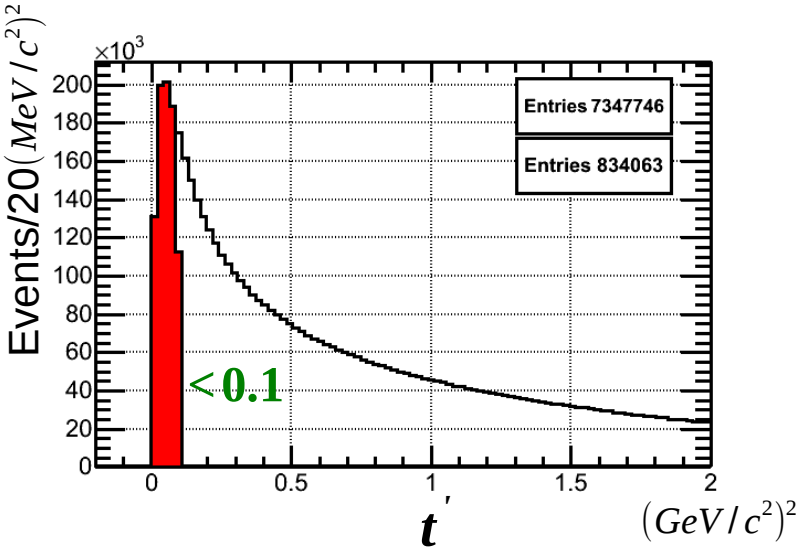
The reflectivity ϵ is here defined such that it coincides with the naturality of exchanged Regge trajectories. Note that

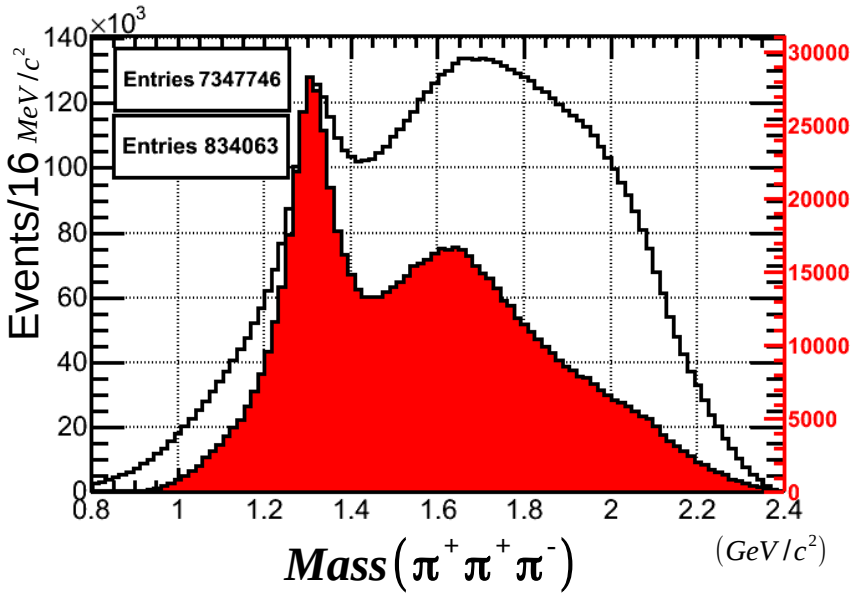
$$|\epsilon a m\rangle = 0 \text{ for } m = 0, \quad \text{if} \quad \epsilon = P(-1)^J \qquad (40)$$

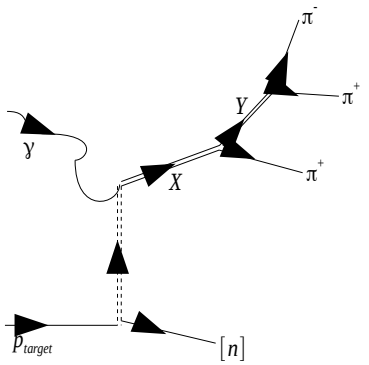
---------- Chung ----------

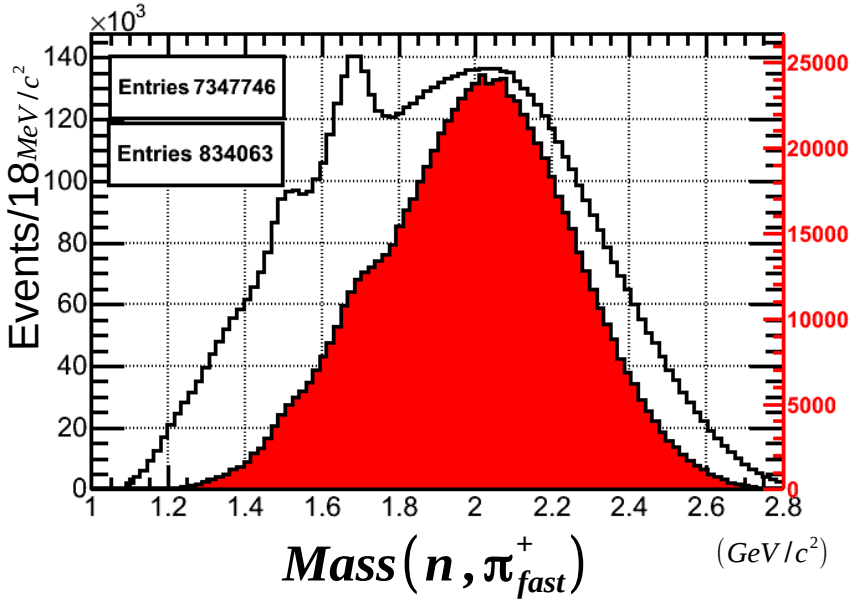
Enhance Peripheral Production

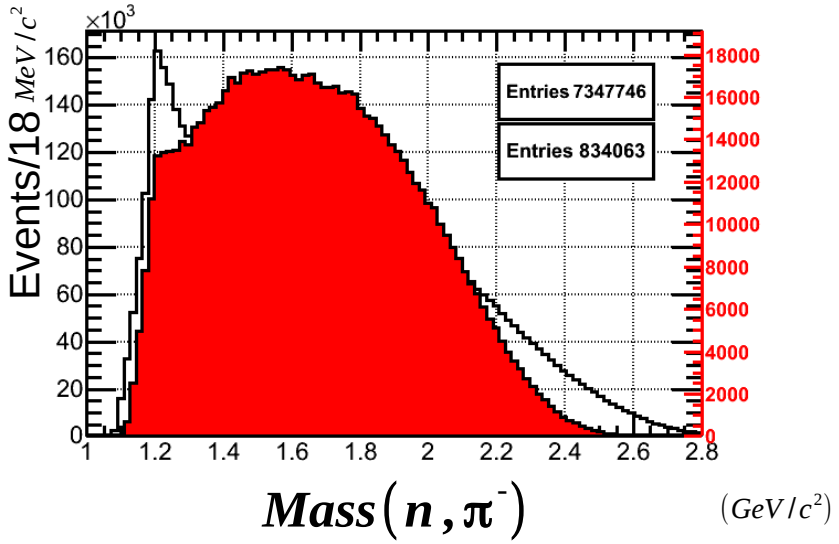
$\gamma p \rightarrow n \pi^+ \pi^+ \pi^-$







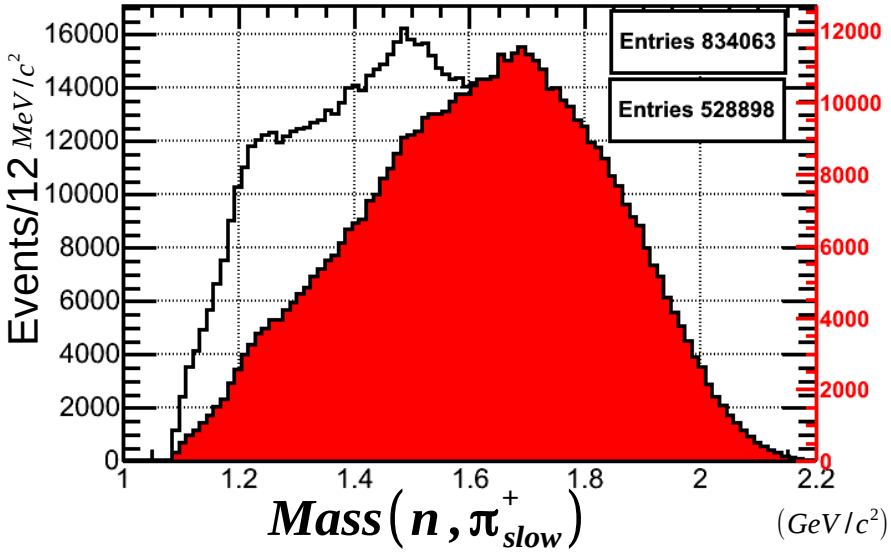


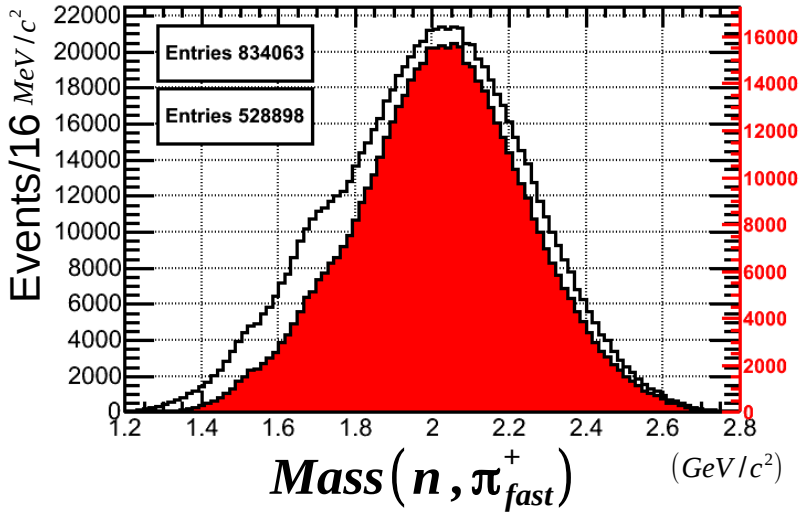


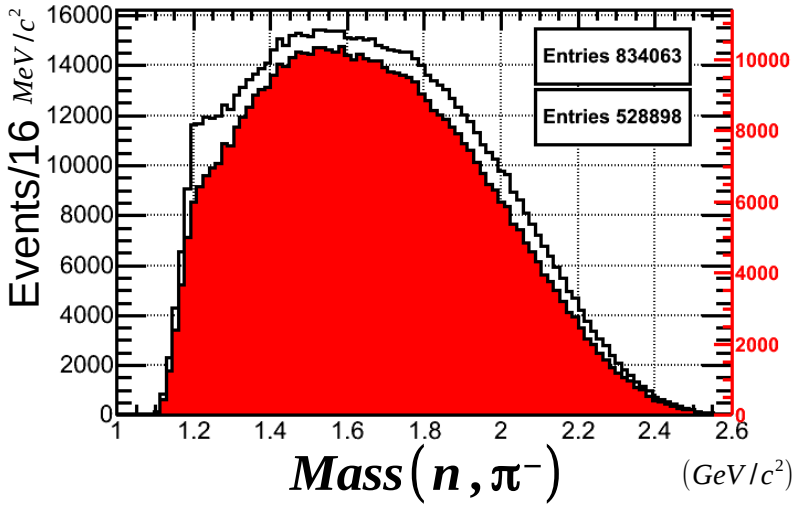
Further Reducing the Baryon Background

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

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

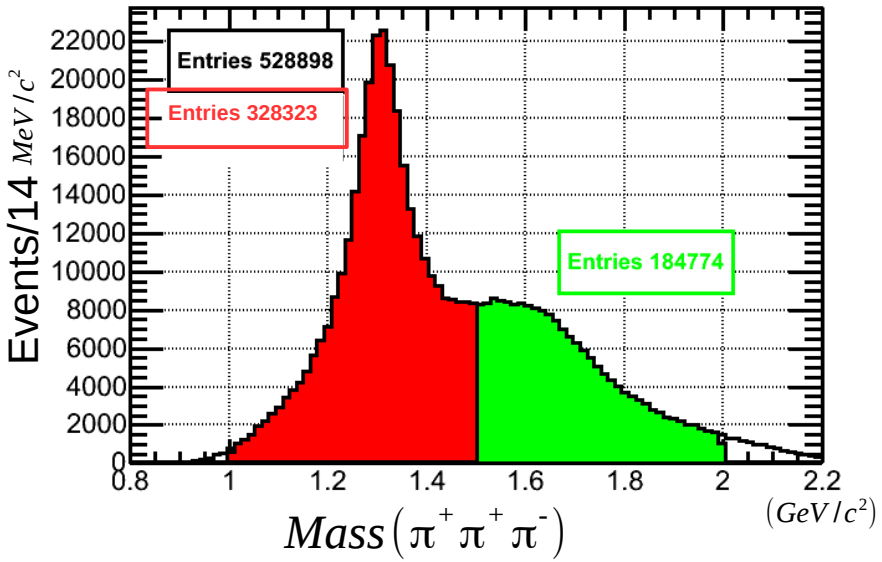


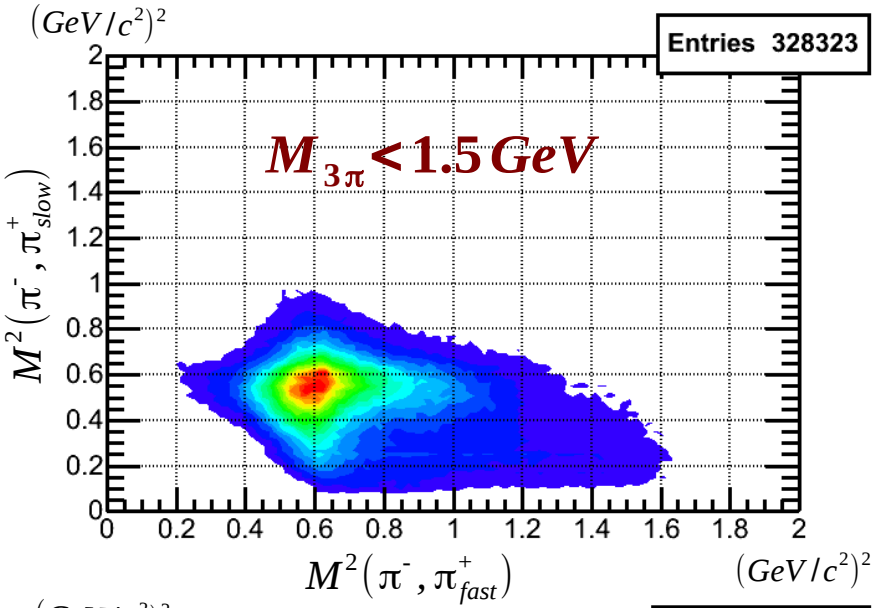


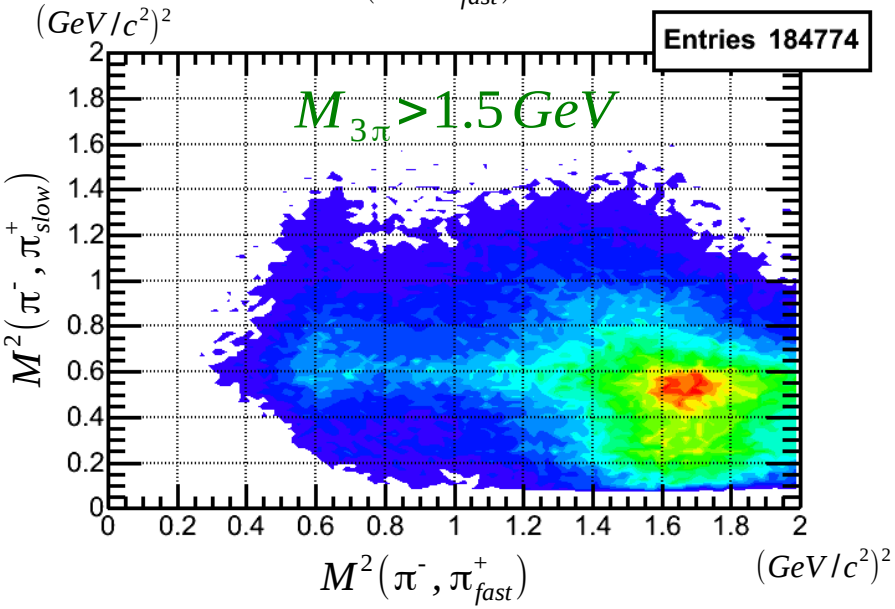


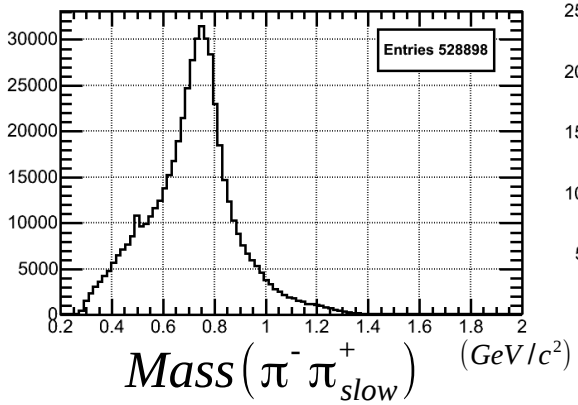
Features of the 3π sample

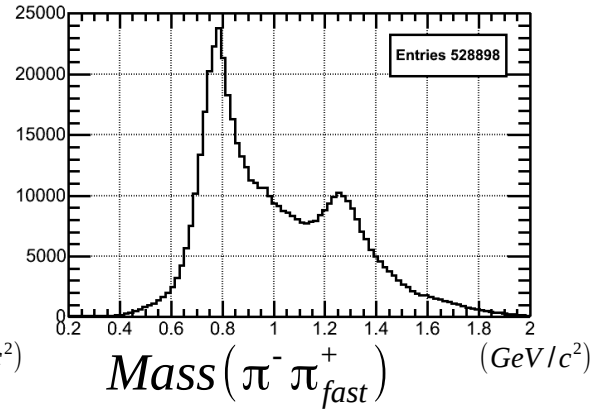
$\gamma p \rightarrow n\pi^+\pi^+\pi^-$











Partial Wave Analysis

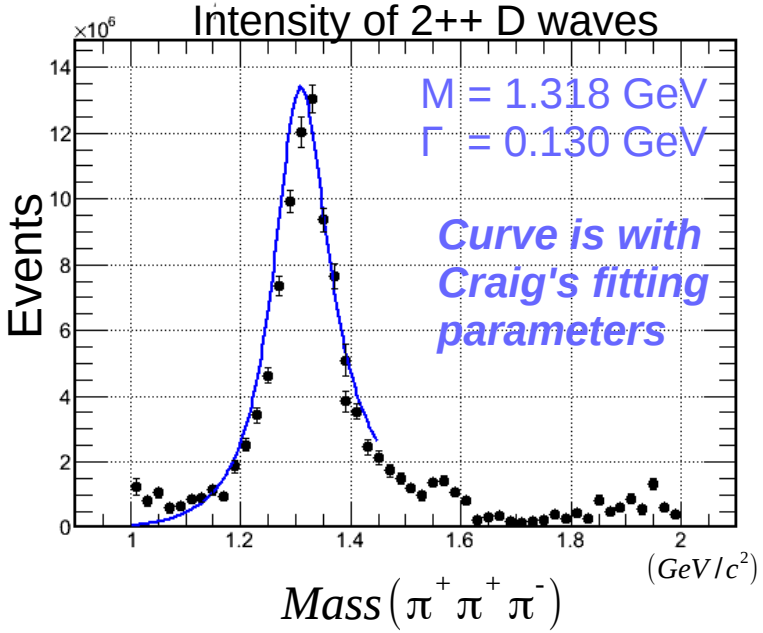
- A mass independent pwa is performed using an event based likelihood fit
- To calculate the amplitudes we used helicity formalism in the reflectivity basis using the isobar model

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

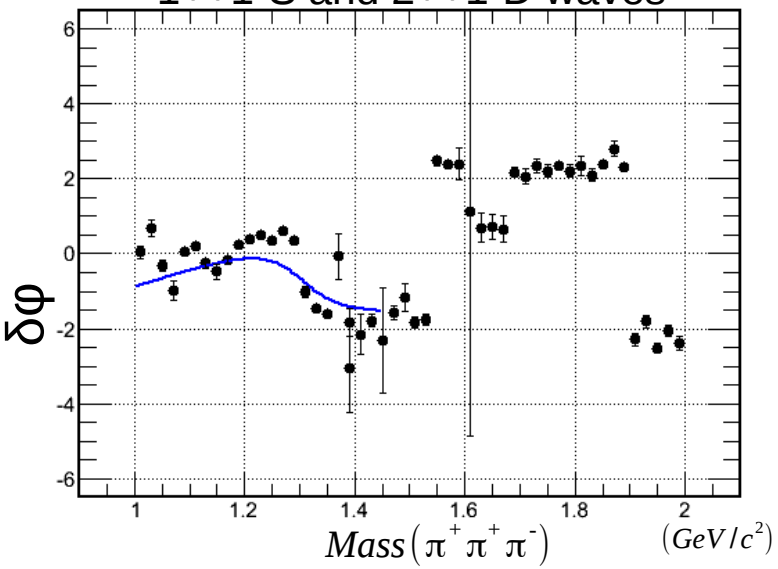
- For the current fit a total of 17 partial waves were used in the high mass region and 13 partial waves in the low mass region

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

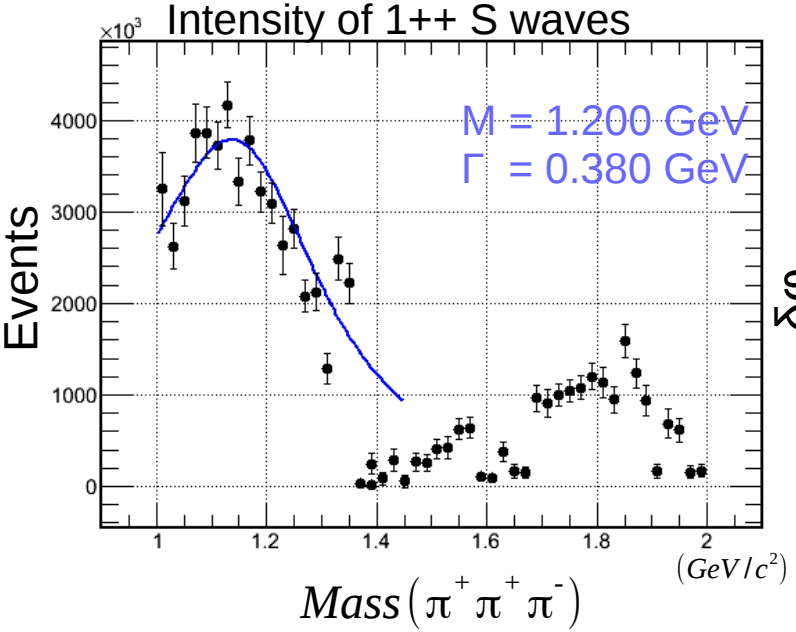
Intensity of 2++ D waves



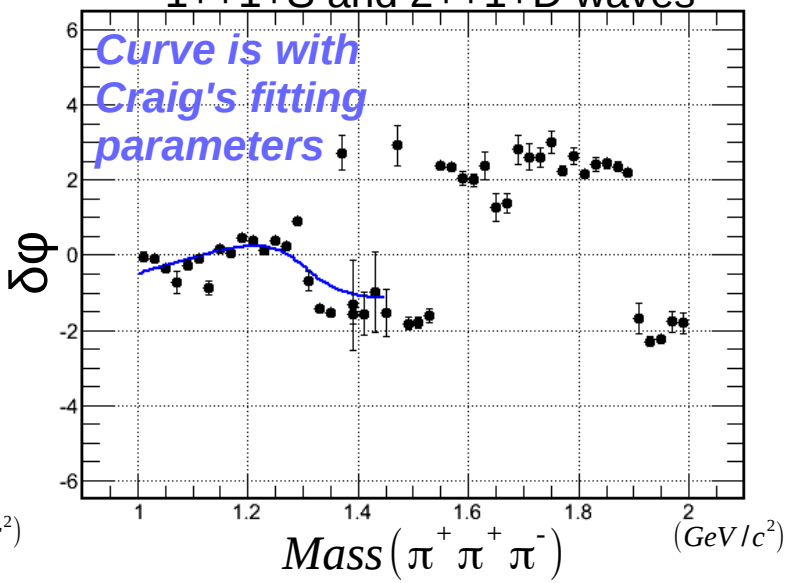
Phase difference between 1++1-S and 2++1-D waves



Intensity of 1++ S waves

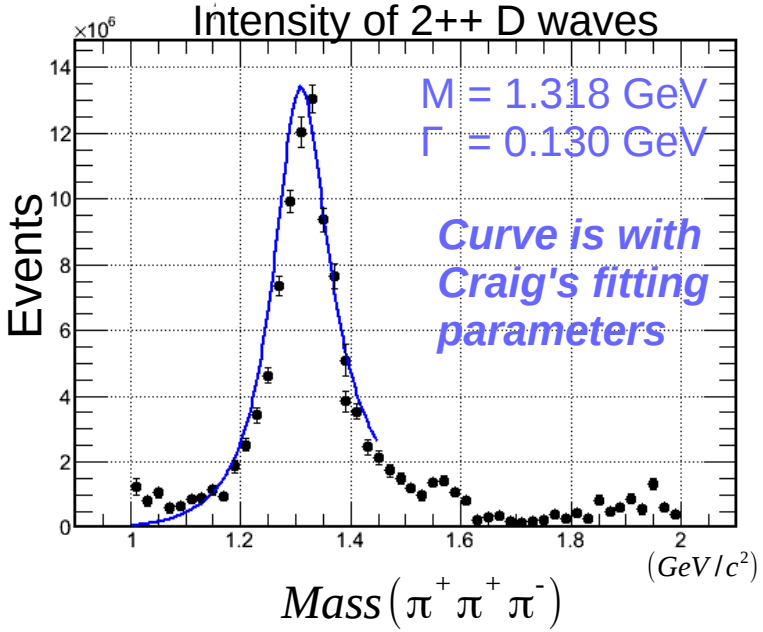


Phase difference between 1++1+S and 2++1+D waves

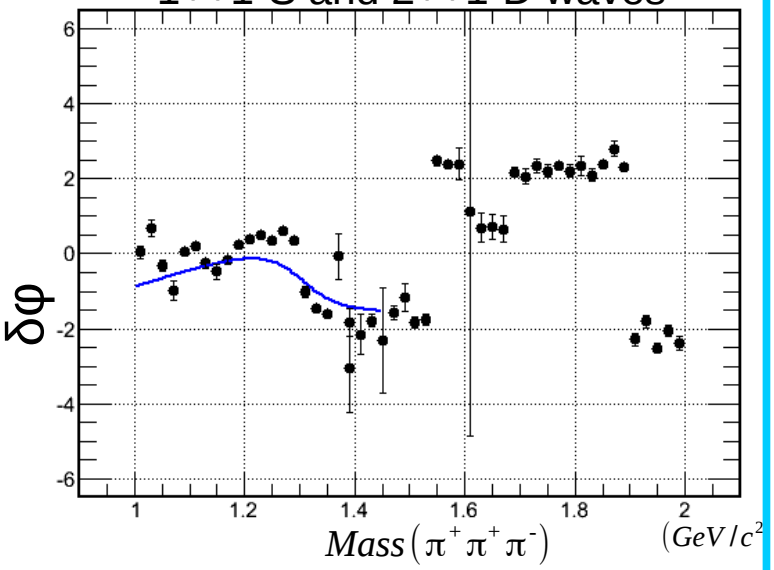


Features of the partial waves of the 3π System for the $\gamma p \rightarrow n\pi^+\pi^+\pi^-$

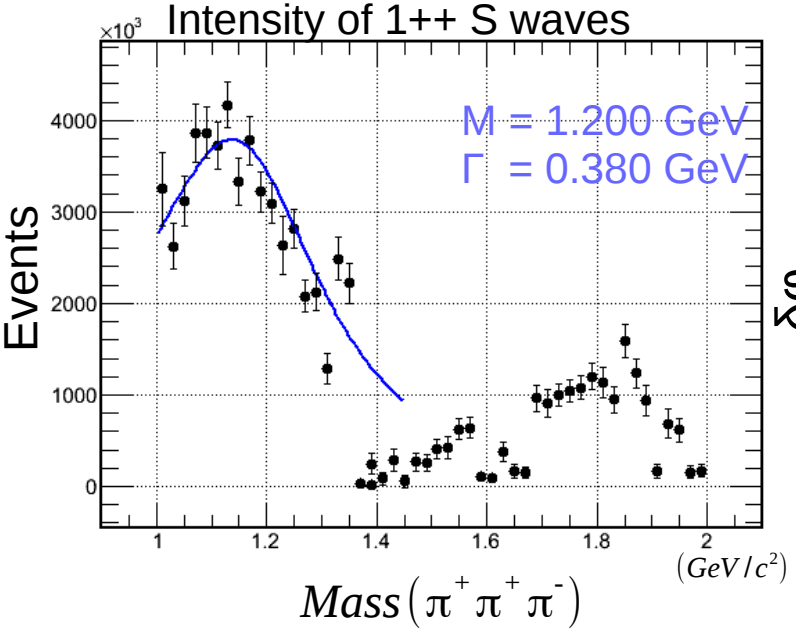
Intensity of 2++ D waves



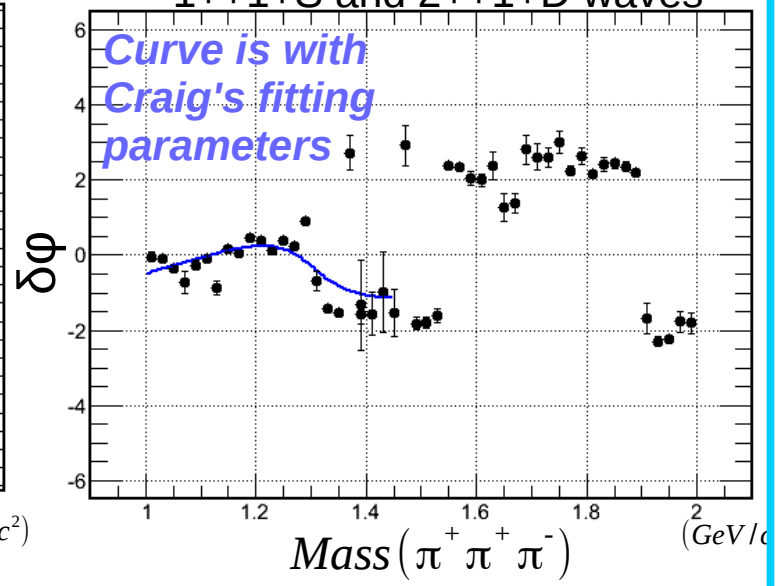
Phase difference between 1++1-S and 2++1-D waves



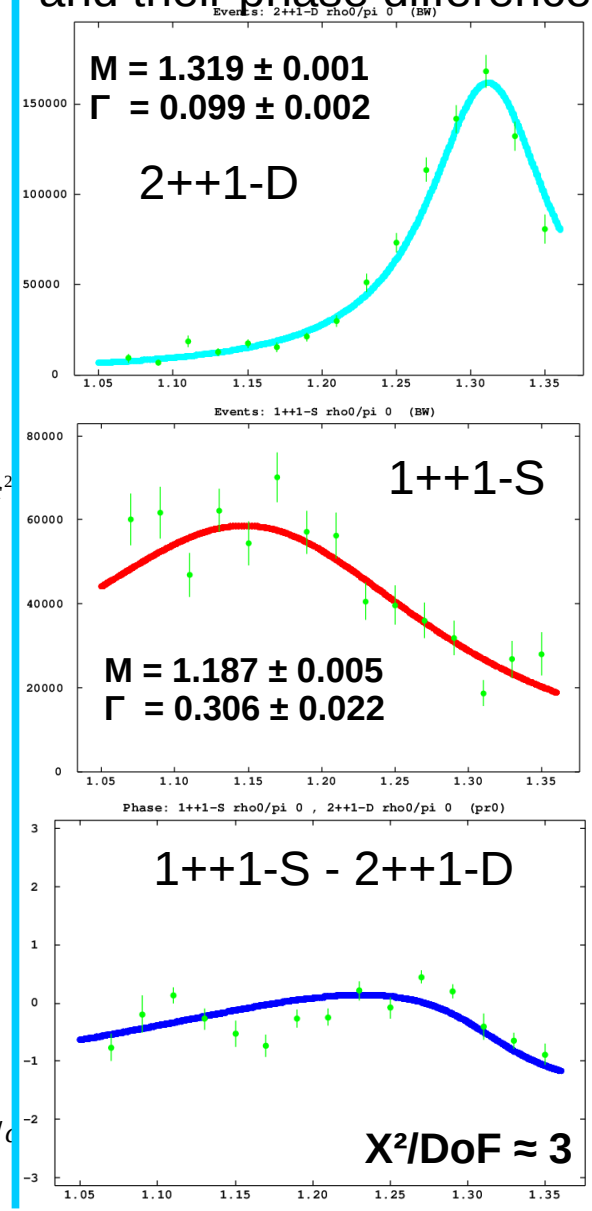
Intensity of 1++ S waves



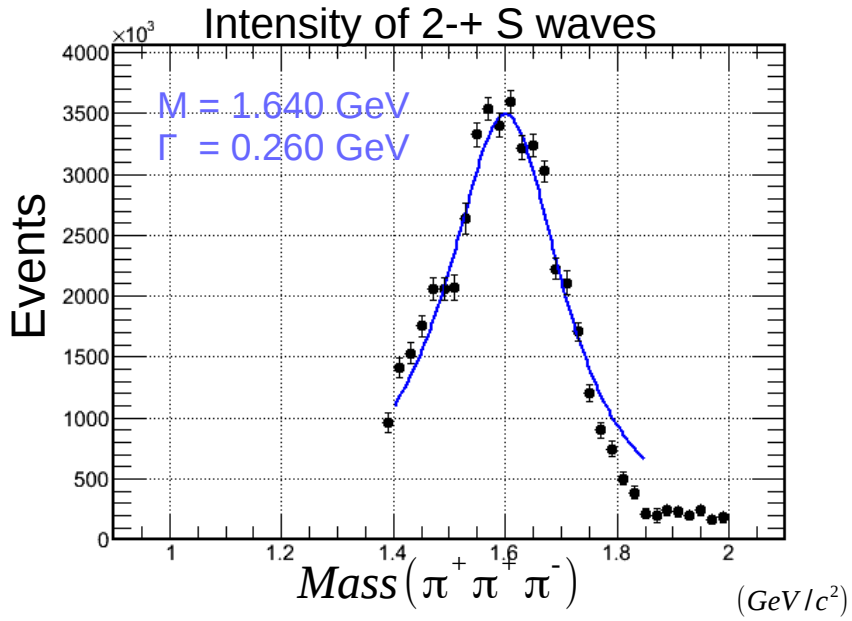
Phase difference between 1++1+S and 2++1+D waves

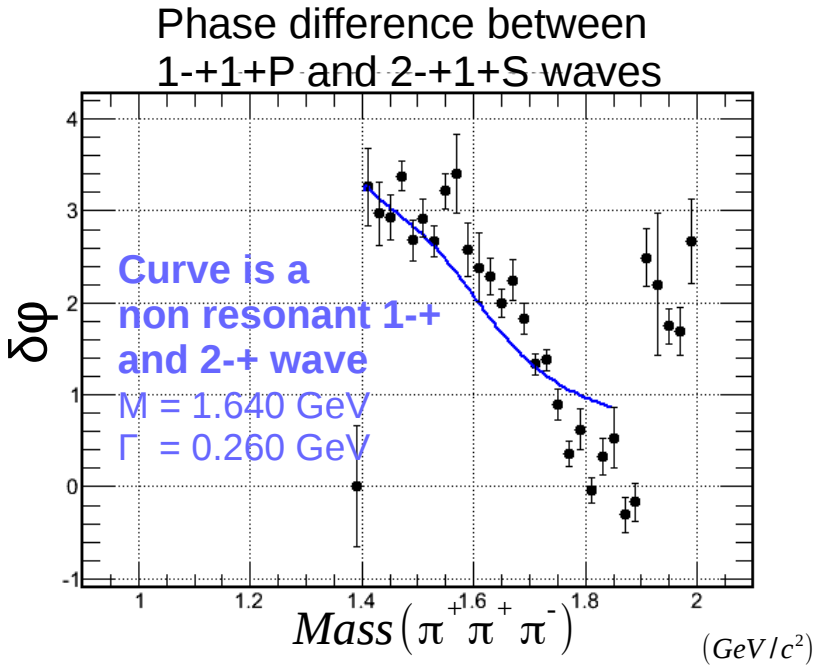


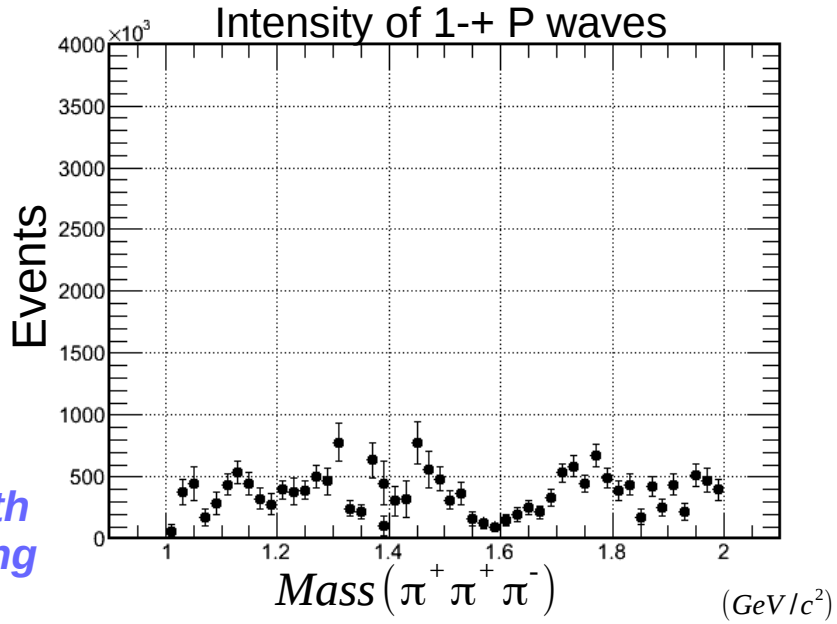
Fitting simultaneously intensities of 1++, 2++ and their phase difference

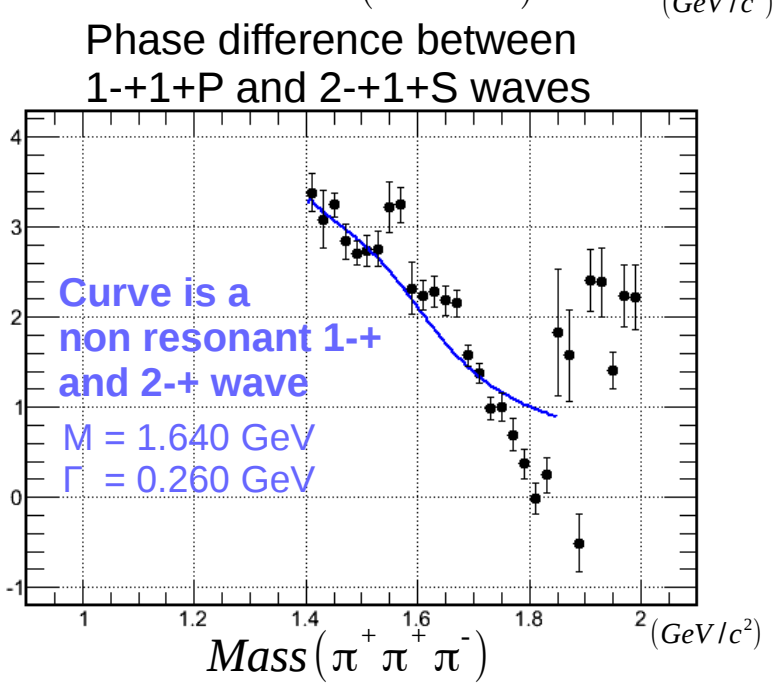


Features of the partial waves of the 3π System for the $\gamma p \rightarrow n\pi^+\pi^+\pi^-$









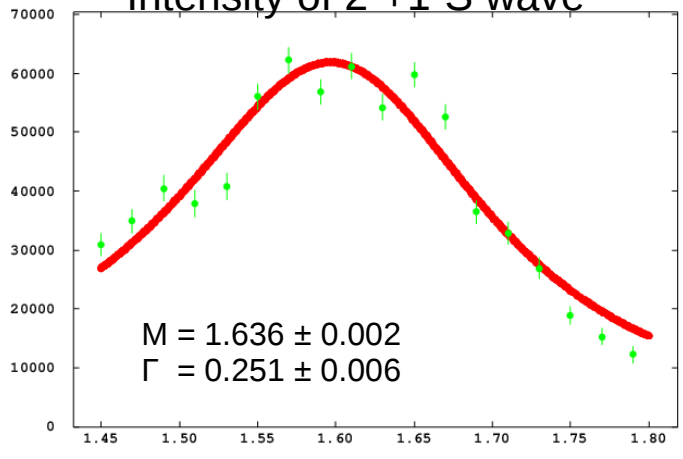
Curve is with Craig's fitting parameters

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

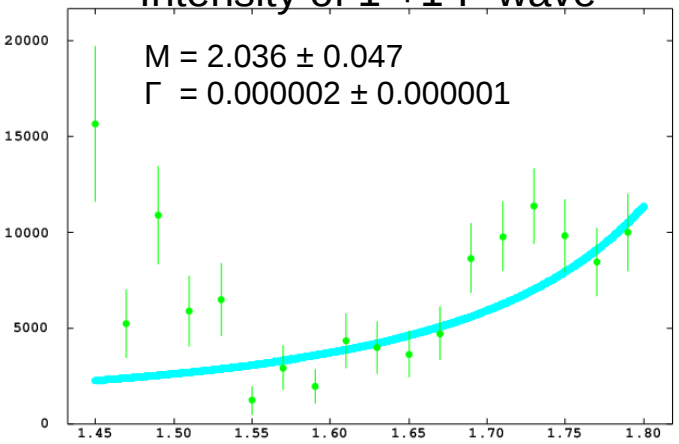
Fitting simultaneously intensities of 2-+, 1-+ and their phase difference

Fitting with 1-+ resonance results a non-resonant solution

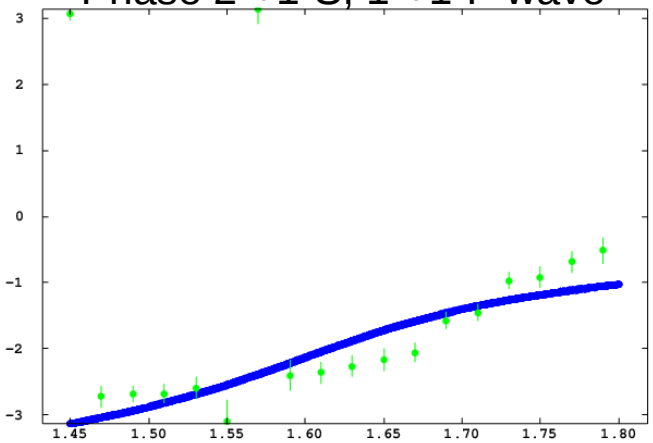
Intensity of 2-+1-S wave



Intensity of 1-+1-P wave

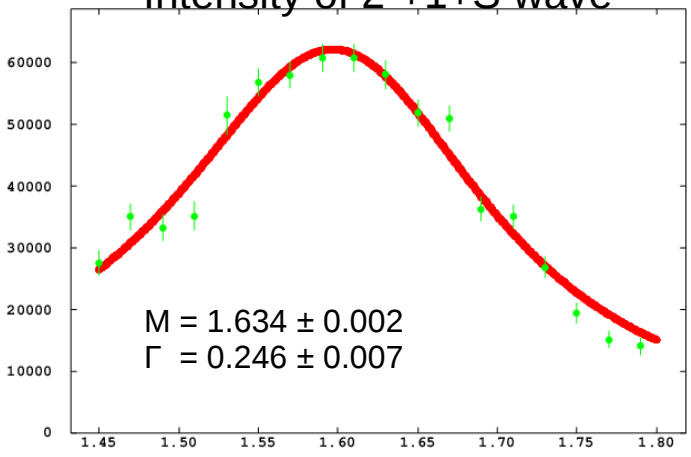


Phase 2-+1-S, 1-+1-P wave

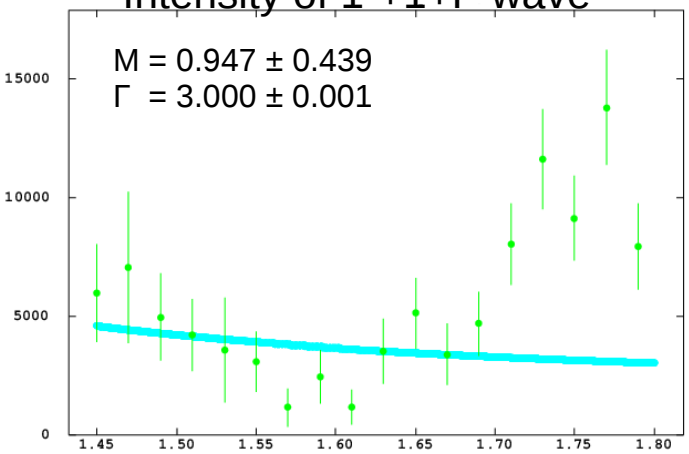


X²/DoF ≈ 5

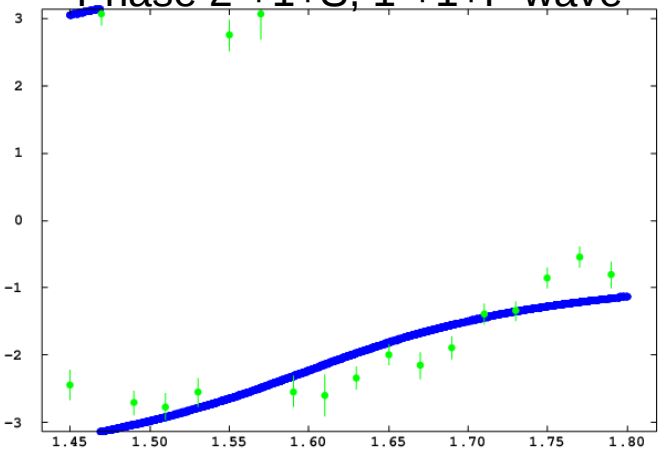
Intensity of 2-+1+S wave



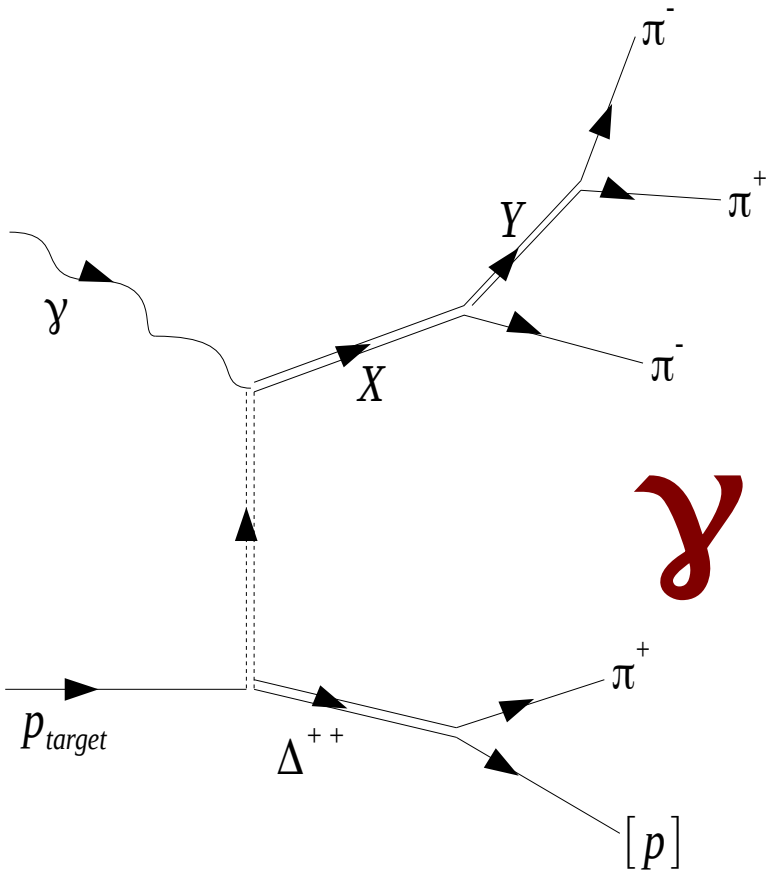
Intensity of 1-+1+P wave



Phase 2-+1+S, 1-+1+P wave



X²/DoF ≈ 4



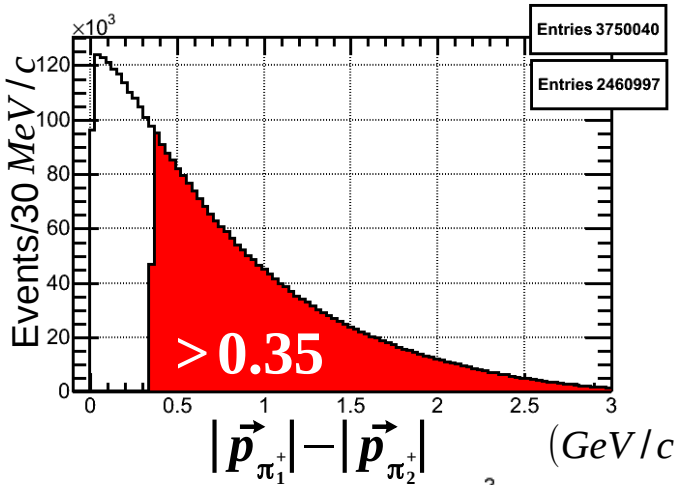
$$\gamma\, p \rightarrow \Delta^{++}\pi^{+}\pi^{-}\pi^{-}$$

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.

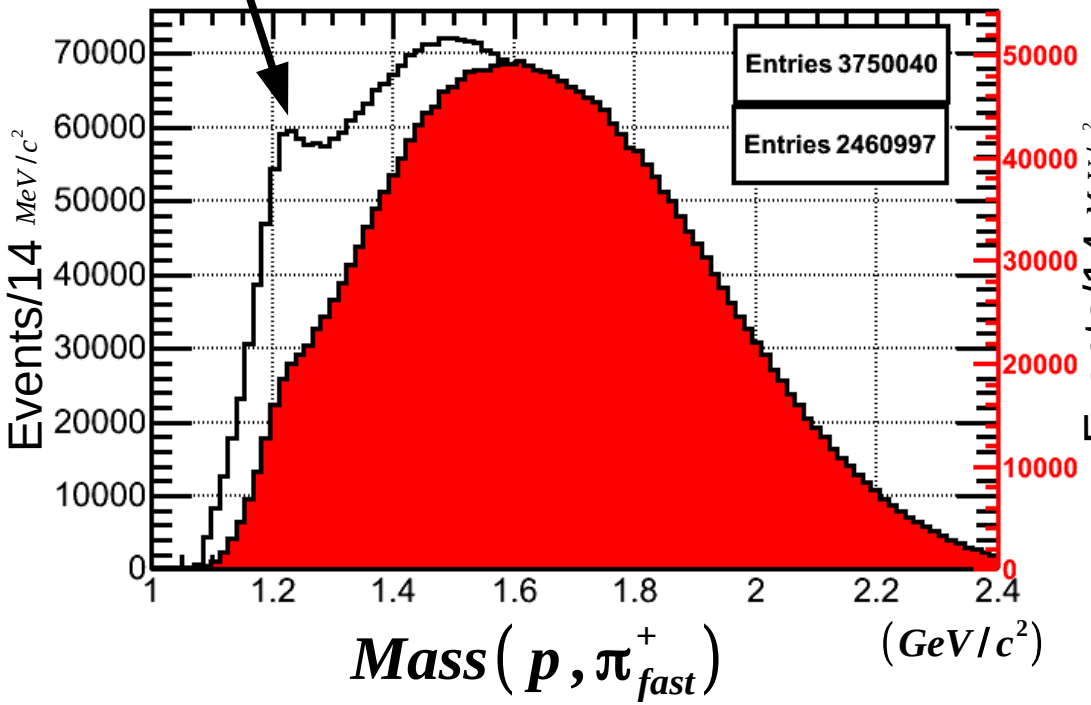
Kinematic Separation of the Δ^{++}

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

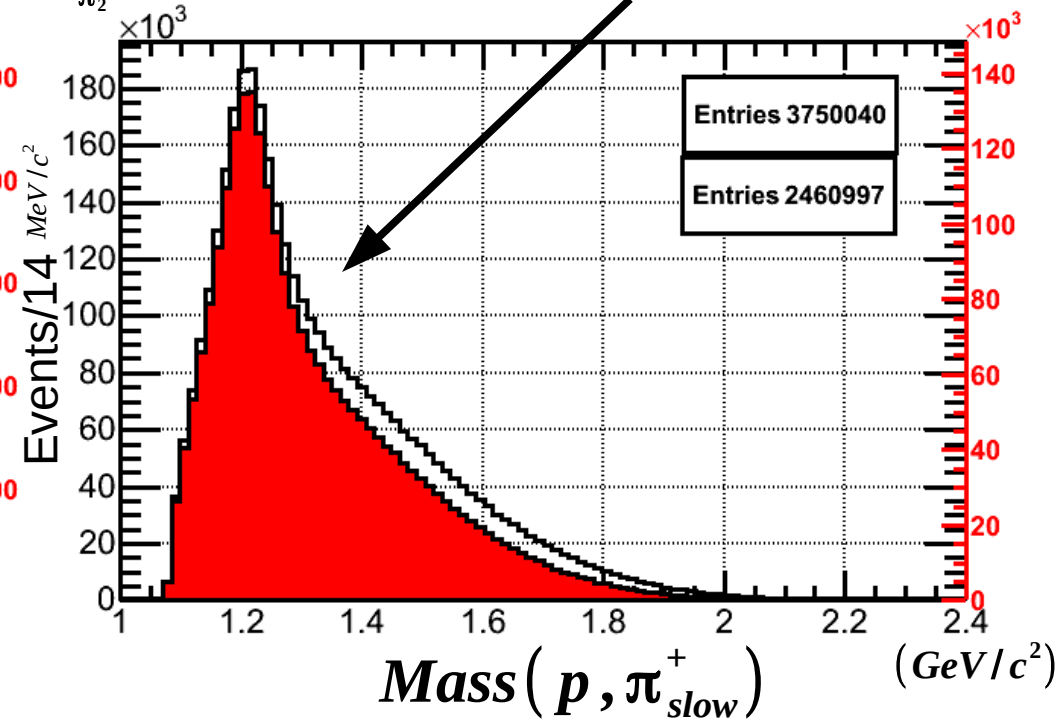
Momentum Difference:



Background Δ^{++}

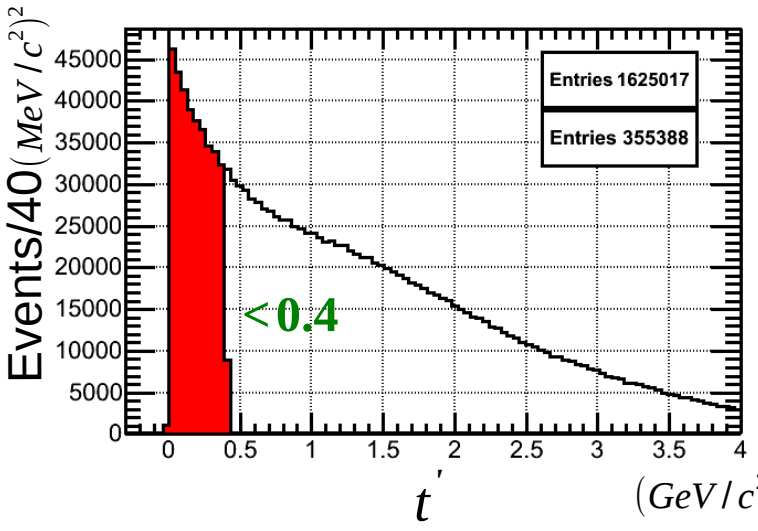


Signal Δ^{++}

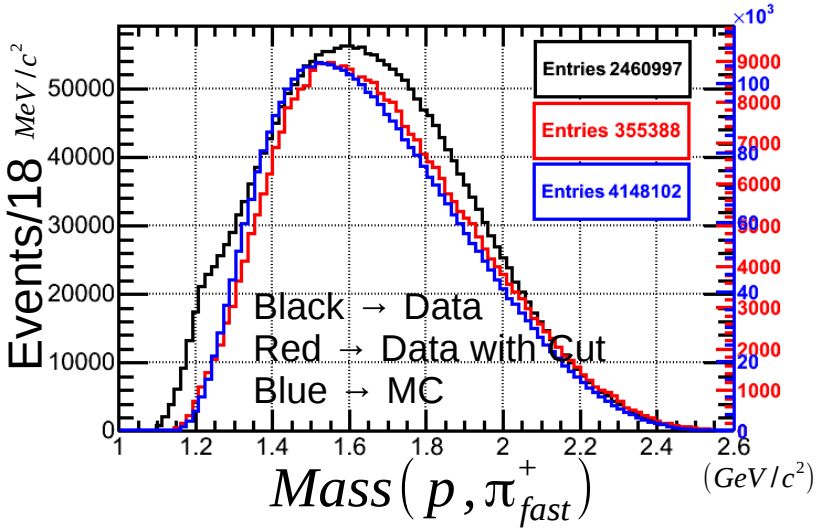


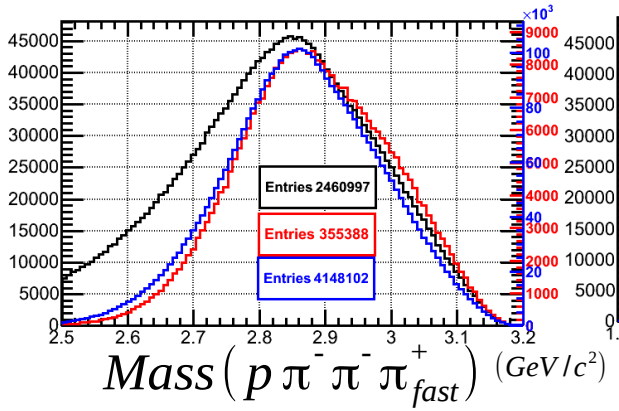
Data Selection and Background Reduction

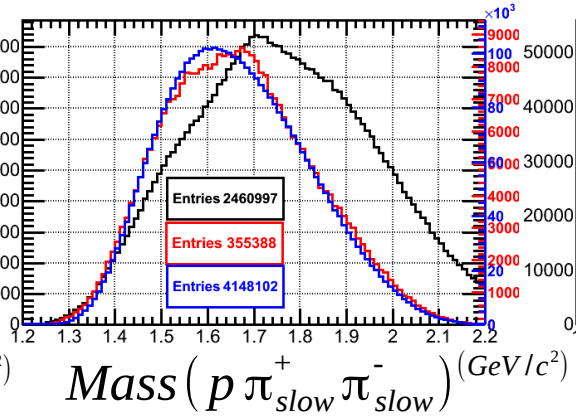
$$\gamma p \rightarrow \Delta^{++} \pi^{+} \pi^{-} \pi^{-}$$

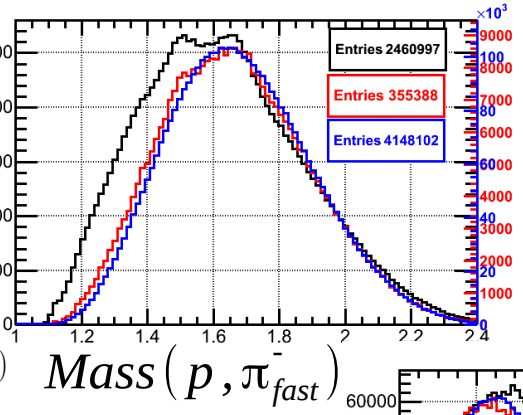


$$+ M_{p\pi^{+}_{slow}} < 1.35$$

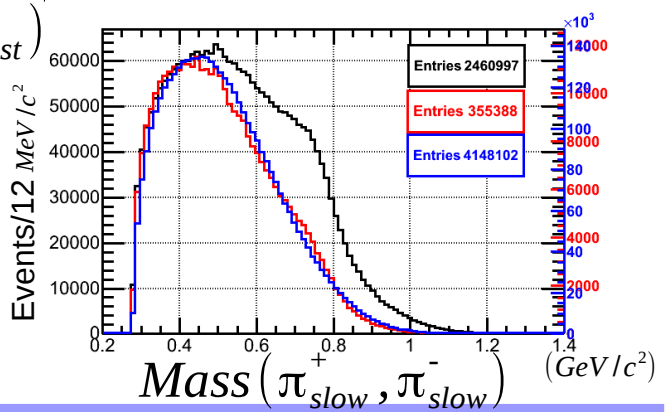






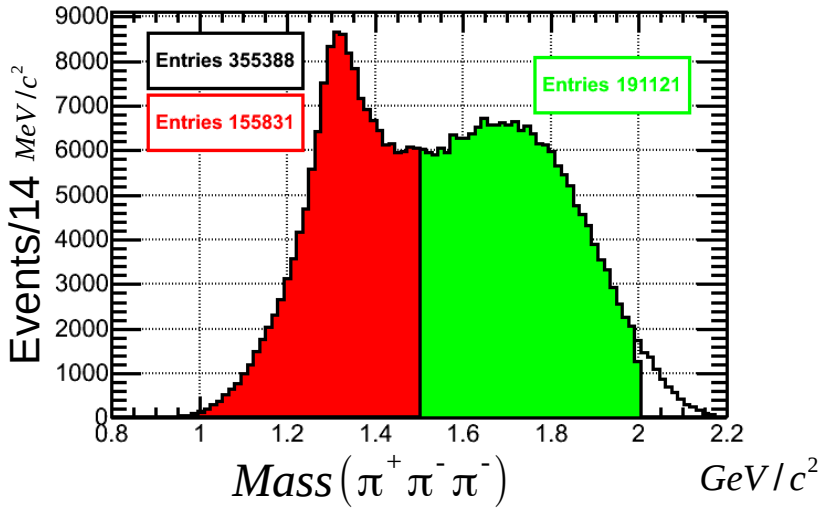


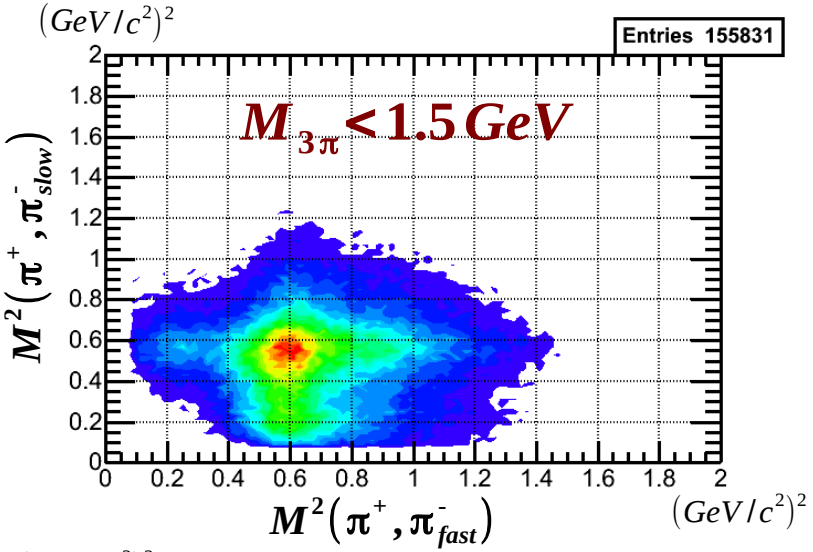
Black → Data
Red → Data with Cuts
Blue → MC with Cuts

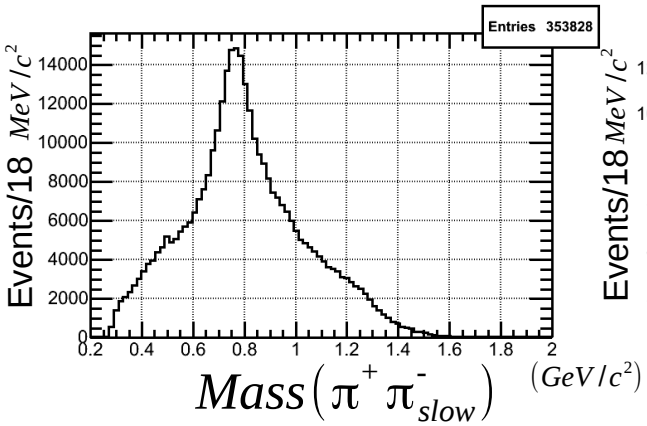


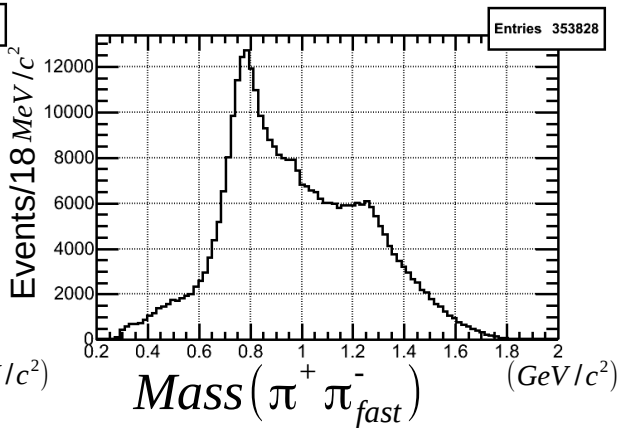
Features of the 3π sample

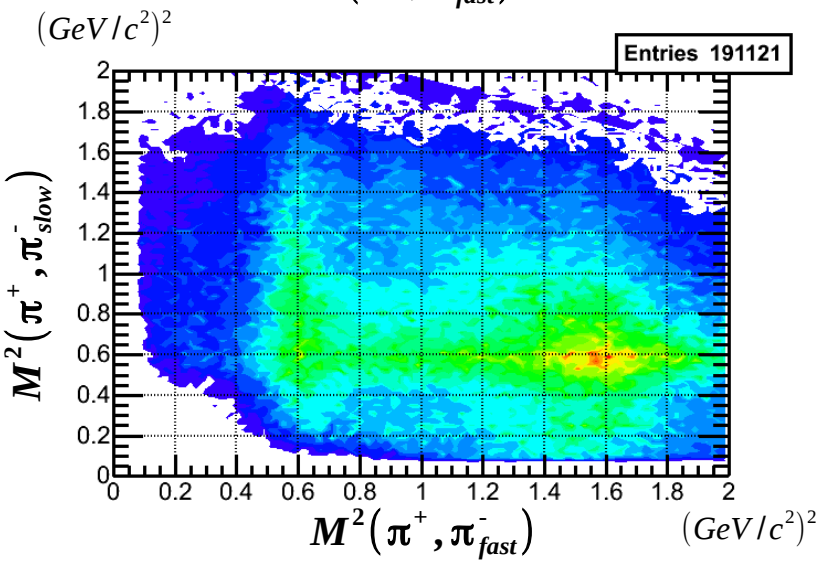
$\gamma p \rightarrow \Delta^{++} \pi^{+} \pi^{-} \pi^{-}$











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

Partial Wave Analysis

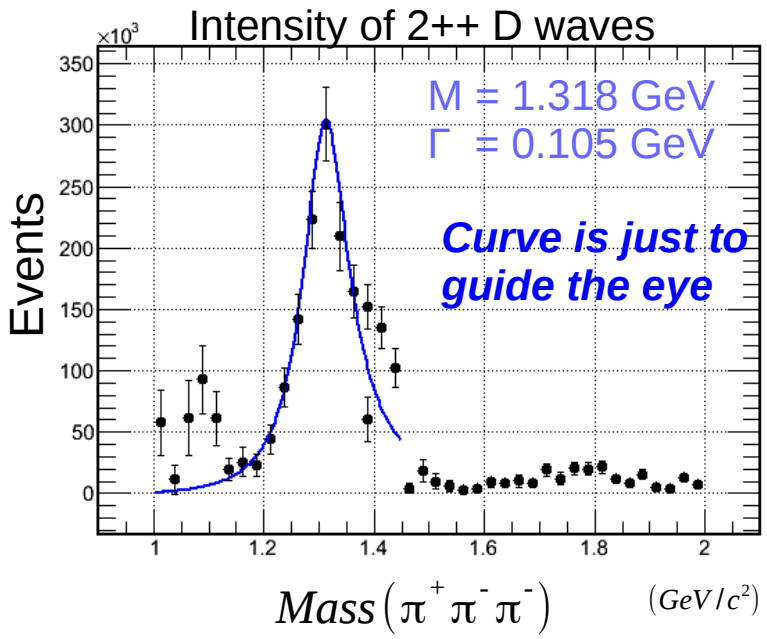
$\gamma p \rightarrow \Delta^{++} \pi^{+} \pi^{-} \pi^{-}$

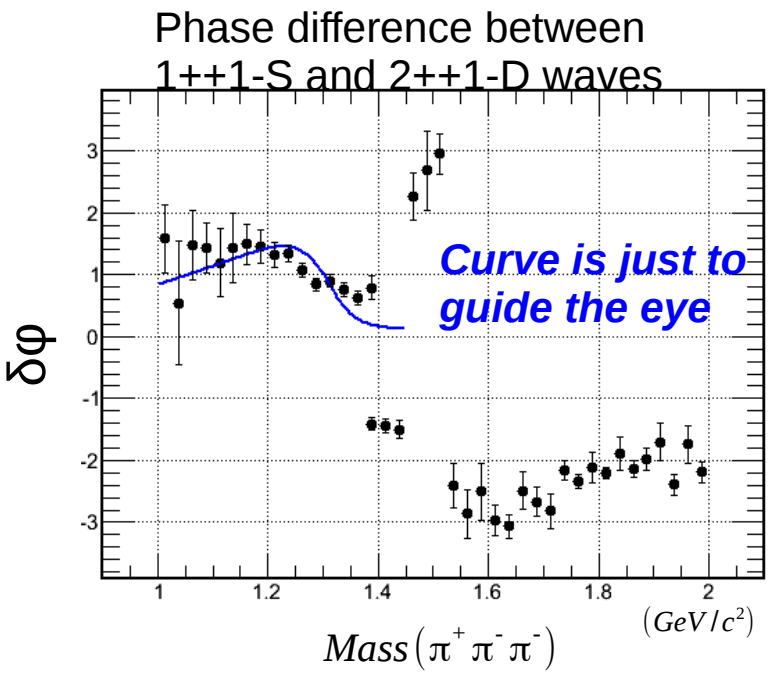
- A mass independent pwa is performed using an event based likelihood fit
- To calculate the amplitudes we used helicity formalism in the reflectivity basis using the isobar model

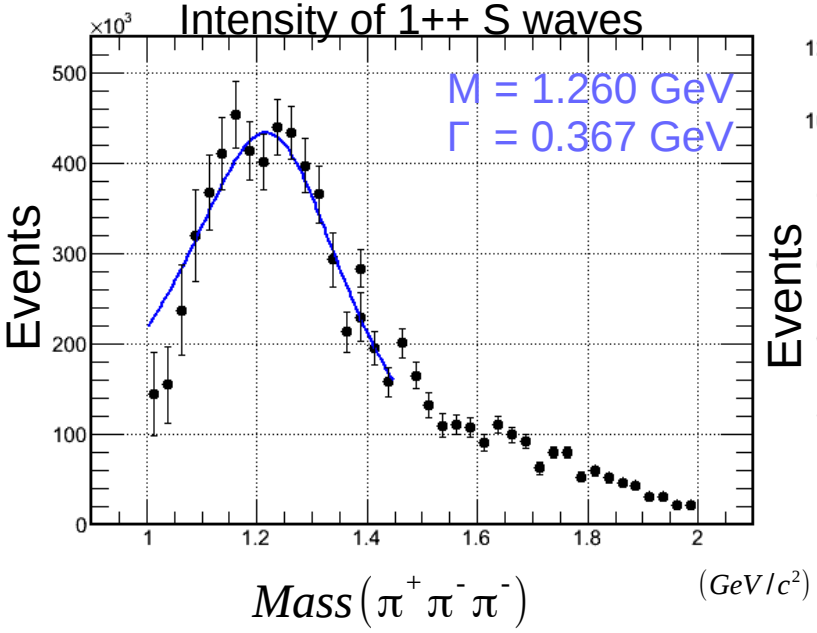
$$I(\tau) = \sum_{\kappa\epsilon} \left| \sum_{\alpha} {}^{\epsilon\kappa} V_{\alpha}{}^{\epsilon} A_{\alpha}(\tau) \right|^2$$

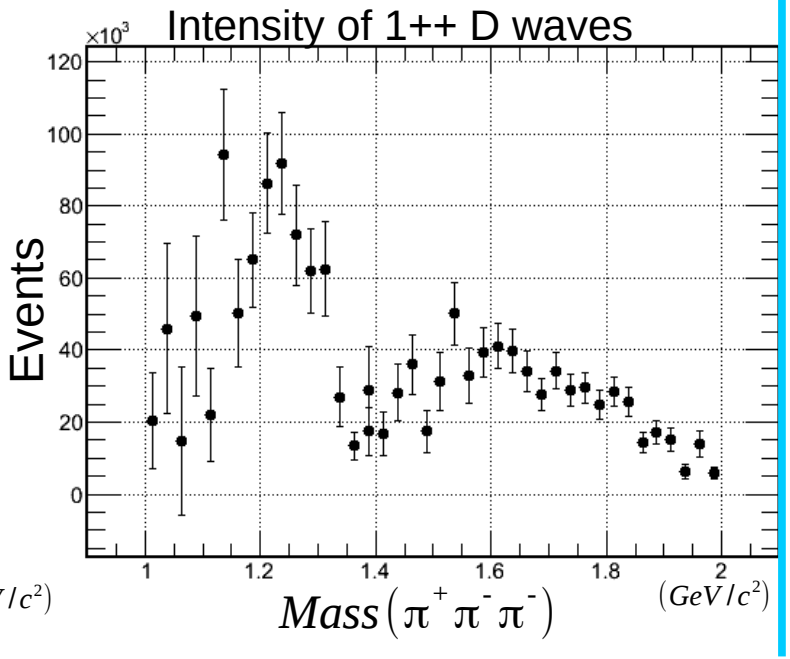
- For the current fit a total of 13 partial waves were used in the high mass region and 9 partial waves in the low mass region

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

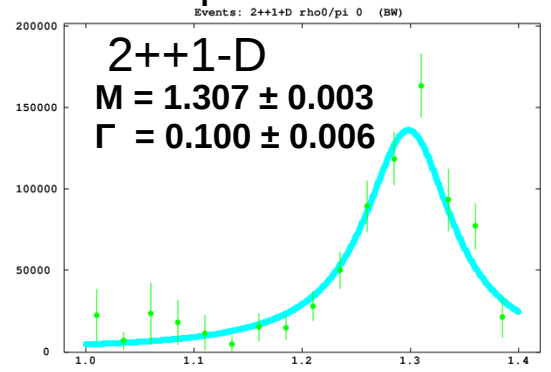


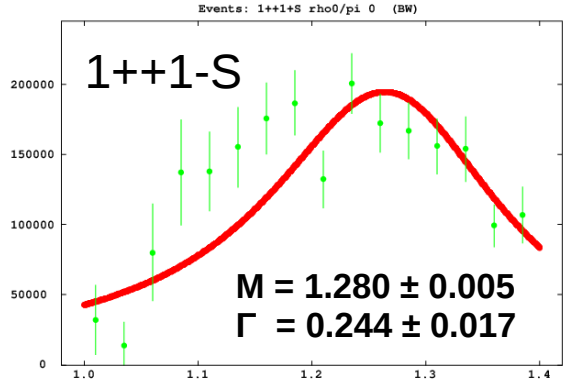


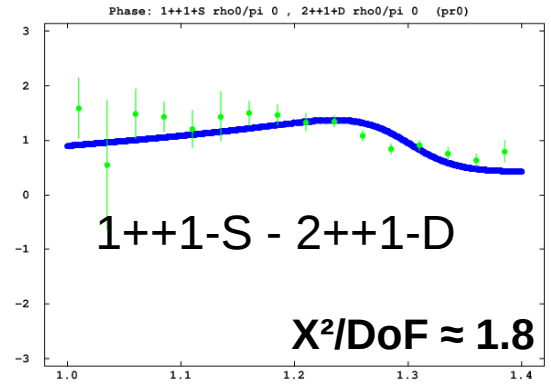




Fitting simultaneously intensities of 1++, 2++ and their phase difference

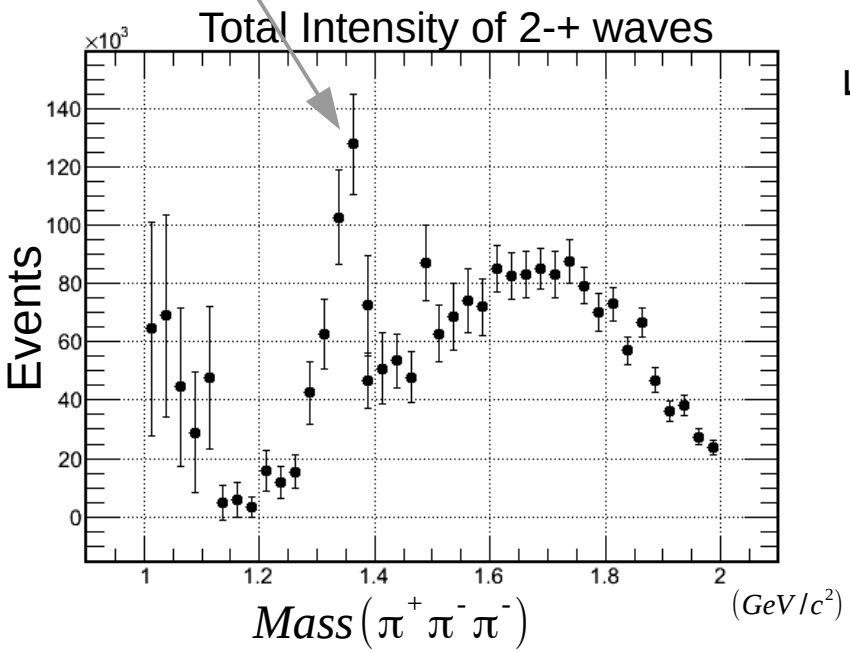


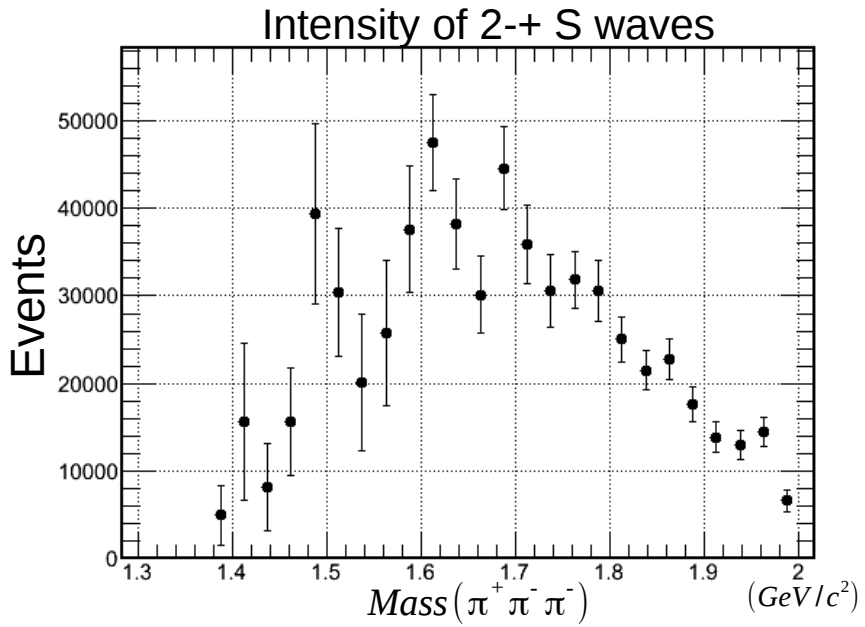


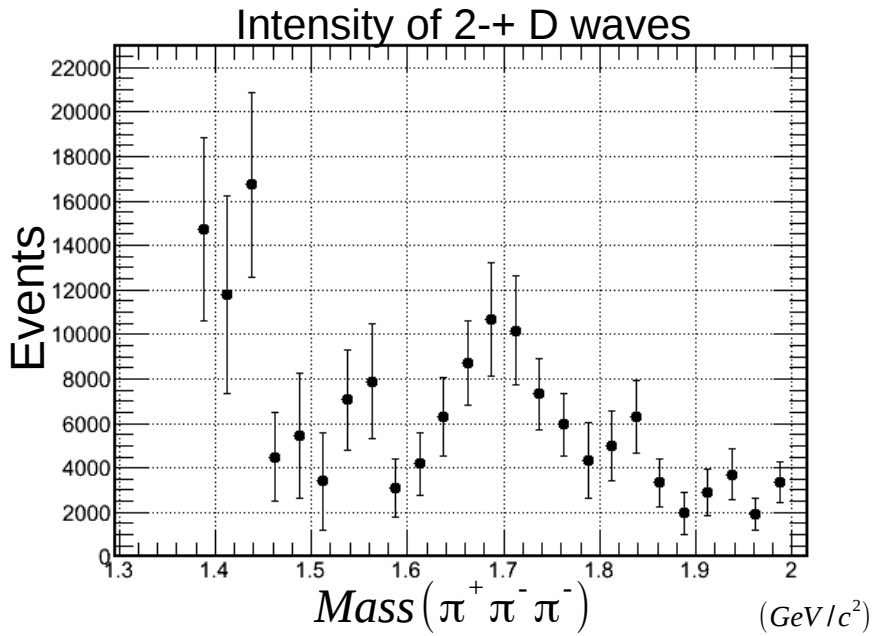


Features of the partial waves of the 3π System for the $\gamma p \rightarrow \Delta^{++} \pi^+ \pi^- \pi^-$

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







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				

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

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^{-+}	$1^{-/+}$	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				

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

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