# The Search for an Exotic Meson in the $\gamma\, p \rightarrow \Delta^{++}\, \eta\, \pi^{-}$ Reaction

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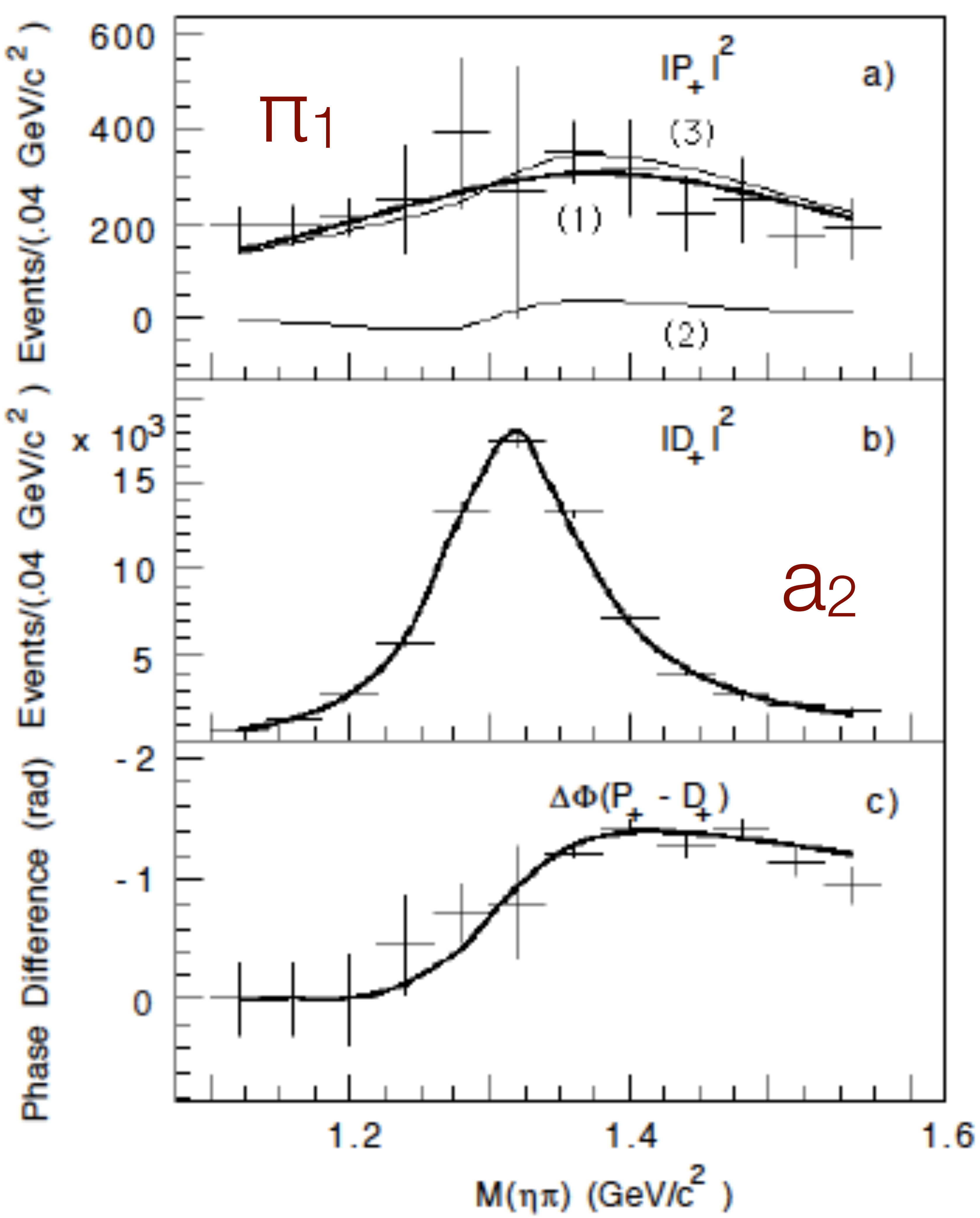
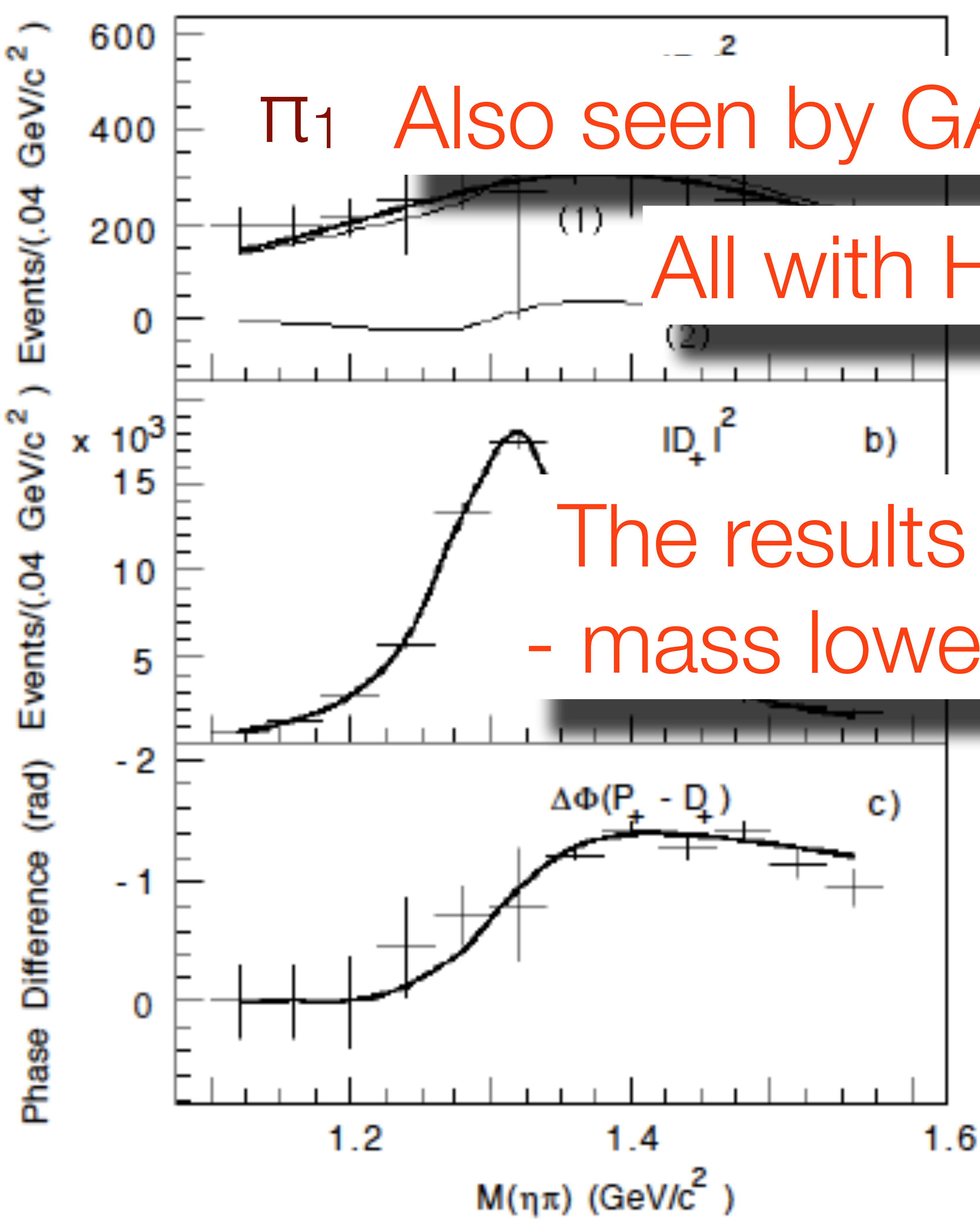
# Previous Results: $\pi_1$(1400)




- At Brookhaven, E852 collaboration:
  - $\pi^- p \rightarrow \pi^- \eta p$ (18.3 GeV)
  - M = 1370 ±16 MeV
  - Γ = 385 ± 40 MeV
- Published a mass and width of the $\pi_1$(1400).
- This was followed by the $\eta\pi^0$ analysis but no consistent set of amplitude parameters were found.

*Phys. Rev. Lett. 79:9 (1997)

# Previous Results: $\pi_1(1400)$




$\pi_1$ Also seen by GAMS, KEK, Crystal Barrel

All with Hadron Production

The results are still controversial

- mass lower than models predict

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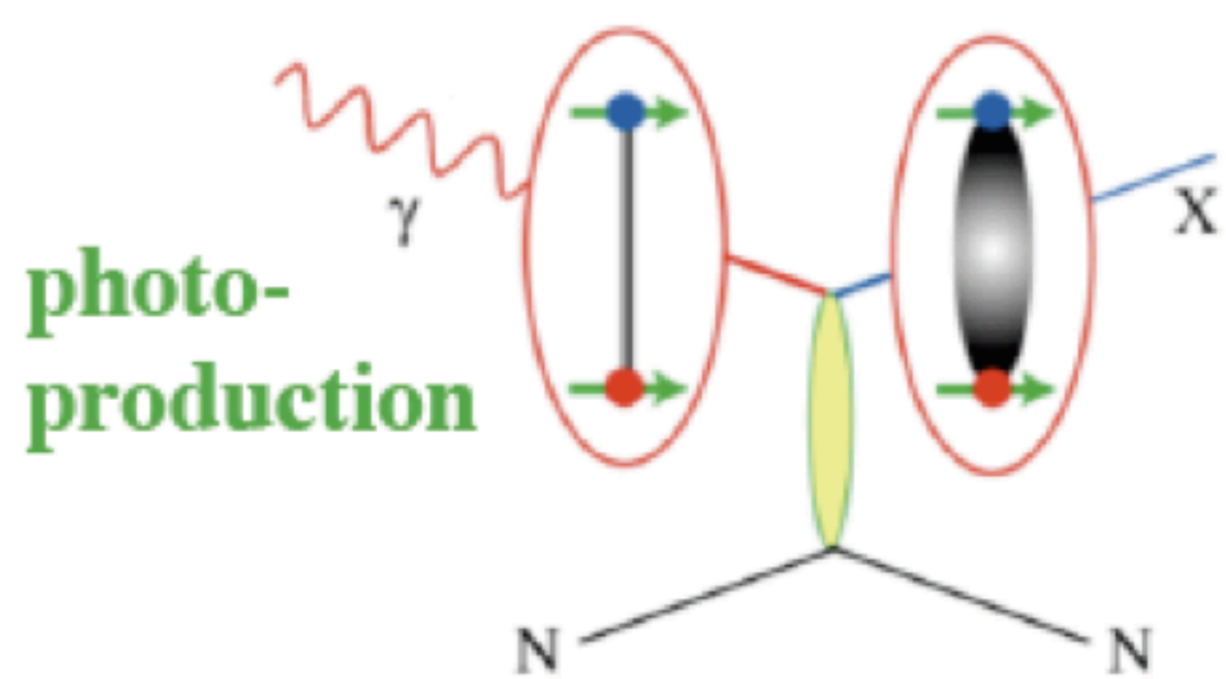
# Photoproduction

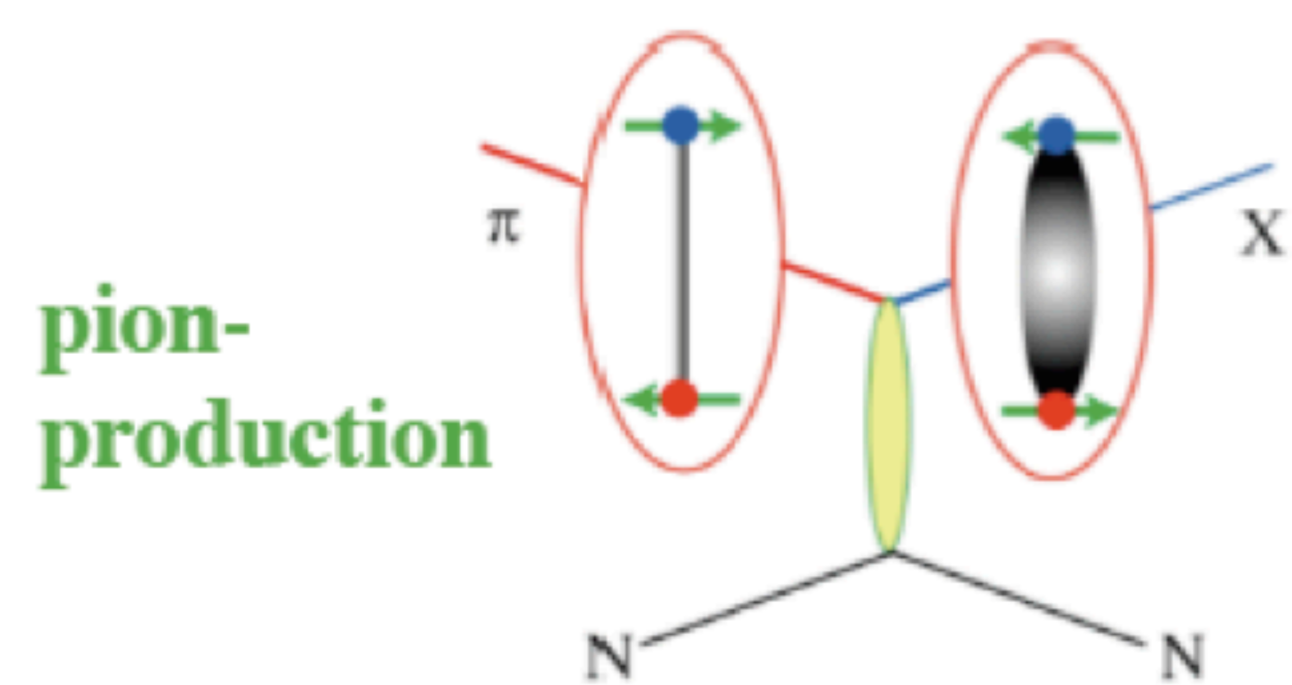
- Why look for exotics with photoproduction?
- Expect the production strength of gluonic hybrids to be favorable. $\pi_1/a_2 \sim 0.5$

- Close *et al*. Phys. Rev. D52:1706 (1995)
- Afanasev *et al*. Phys. Rev. D57:6771 (1998)
- Szczepaniak *et al*. Phys. Lett B516:72 (2001)

$${}_{quarks}J^{PC} \otimes {}_{gluonicflux}J^{PC} = 0^{-+}, 1^{-+}, 2^{+-}, \ldots$$



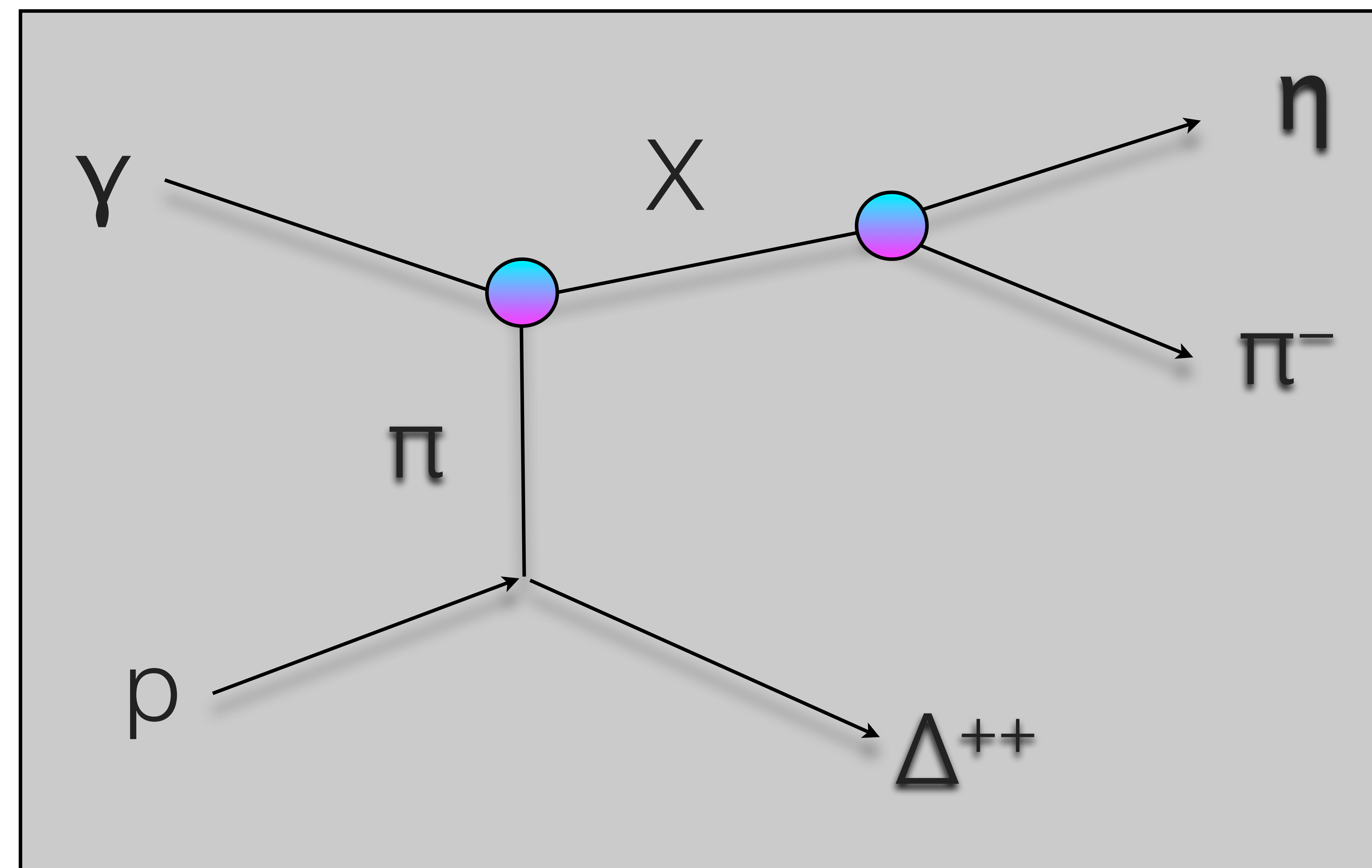

$${}_{quarks}J^{PC} \otimes {}_{gluonicflux}J^{PC} = 1^{--}, 1^{++}$$



# g12

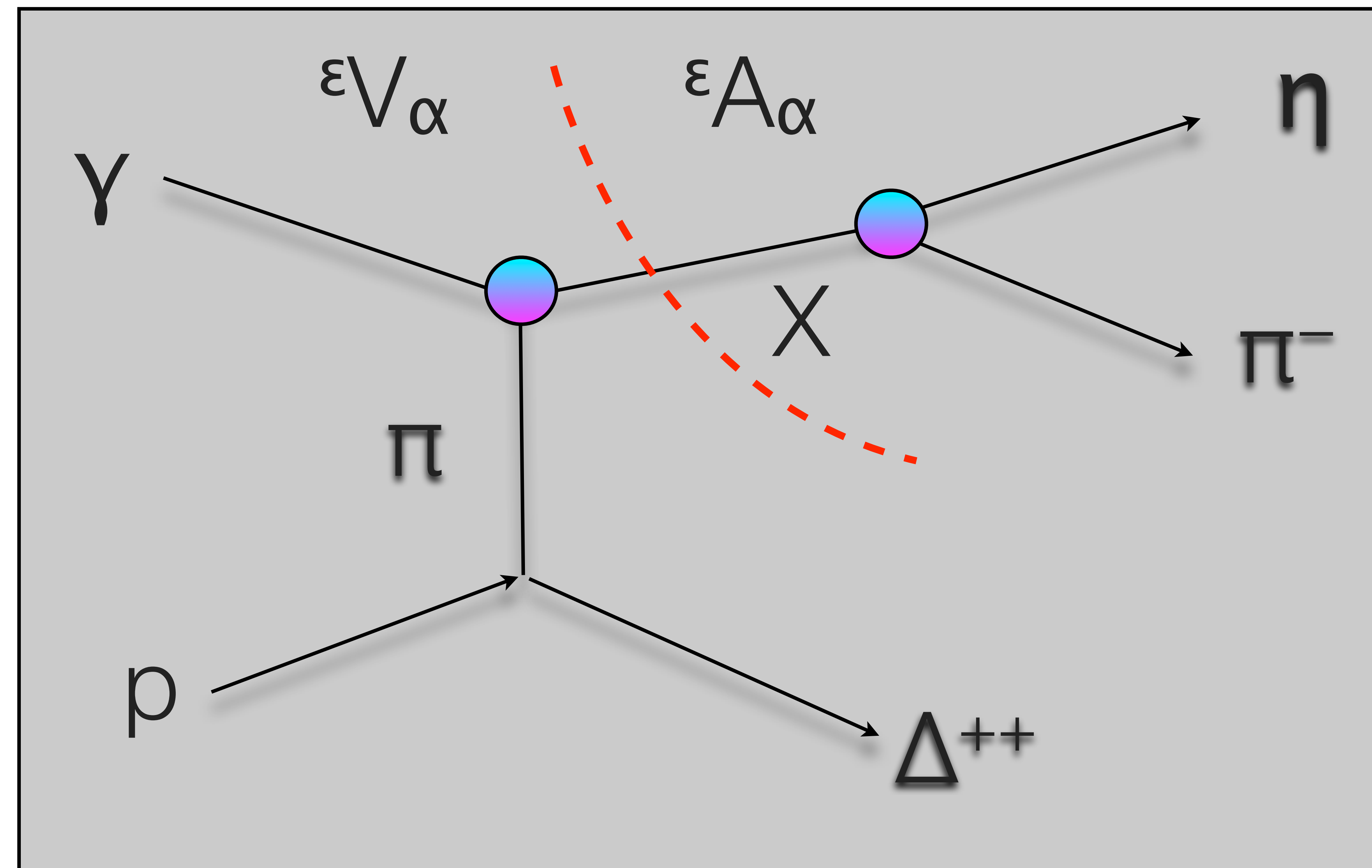
- The analysis goal is to select $\Delta^{++}\eta\pi^-$ events for PWA of $\eta\pi^-$.
  - The $\Delta^{++}$ will restrict the possible states of $X^- \rightarrow \eta\pi^-$.
  - Isospin:
    - $I_p = 1/2$
    - $I_{\Delta^{++}} = 3/2$
    - For isospin conservation, the exchange particle needs I = 1.

- Through G-parity conservation, the exchange particle is constrained to $I^G = 1^-$

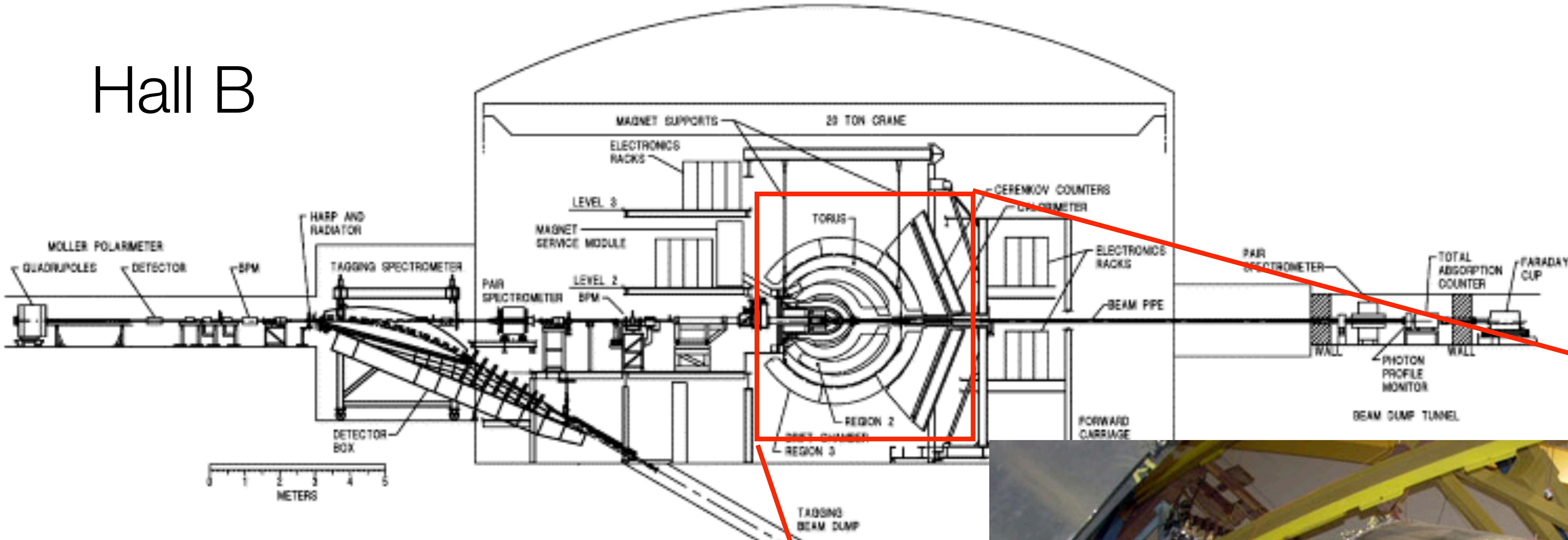


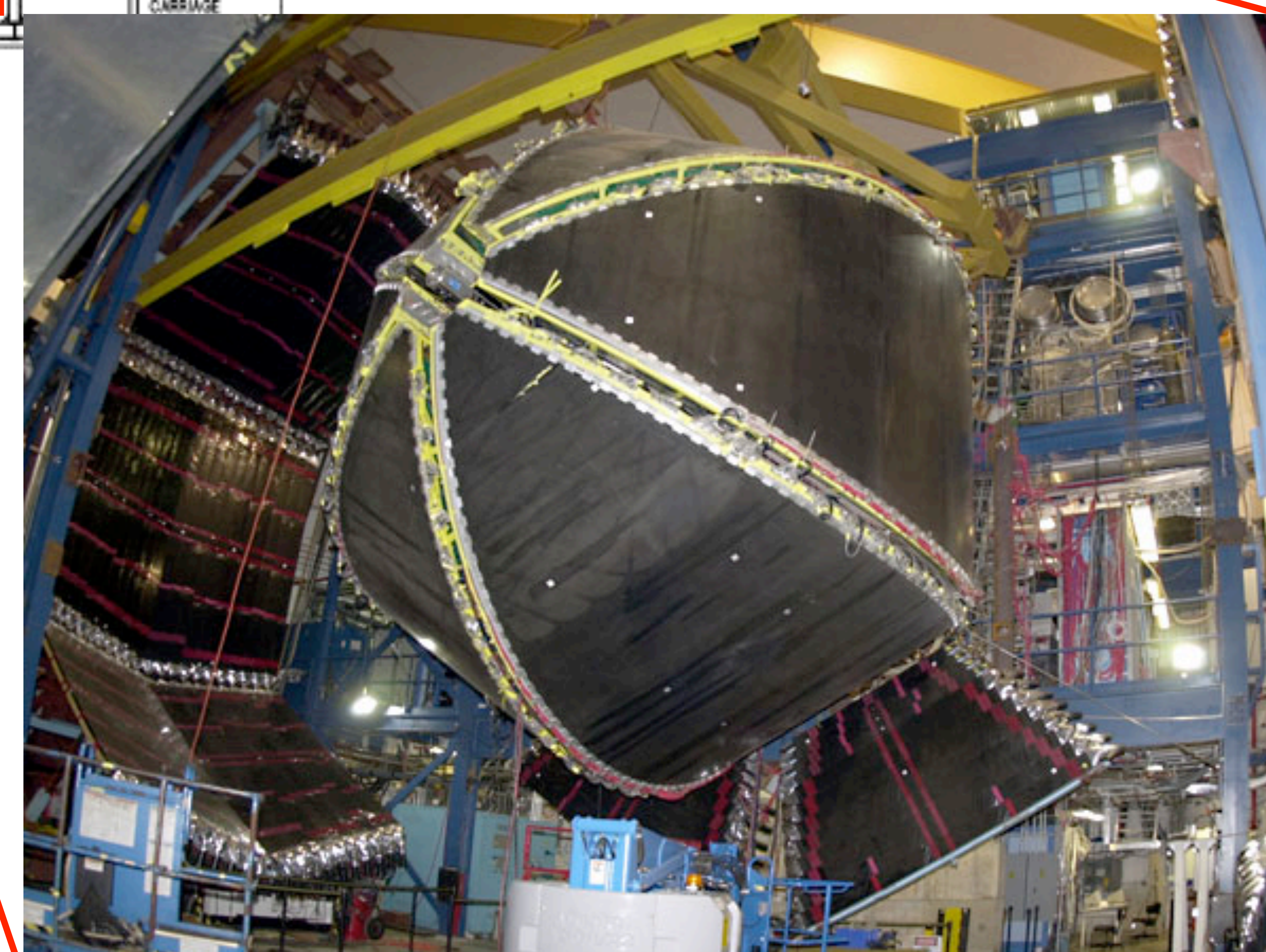
# Partial Wave Analysis

- So how do we differentiate noise, regular mesons and exotic mesons?
- The intensity is quantified as:
- $$I(\tau) = \sum_{\epsilon} \sum_{\alpha,\alpha'} \rho_\gamma \; {}^{\epsilon}V_\alpha \; {}^{\epsilon}A_\alpha \; {}^{\epsilon}V_{\alpha'} \; {}^{\epsilon}A_{\alpha'}$$
- α is the set {J, P, |M|, L, I, λ, S} used to describe the resonance X.
- Fit to find the maximum likelihood of the wave contributions.



# Hall B

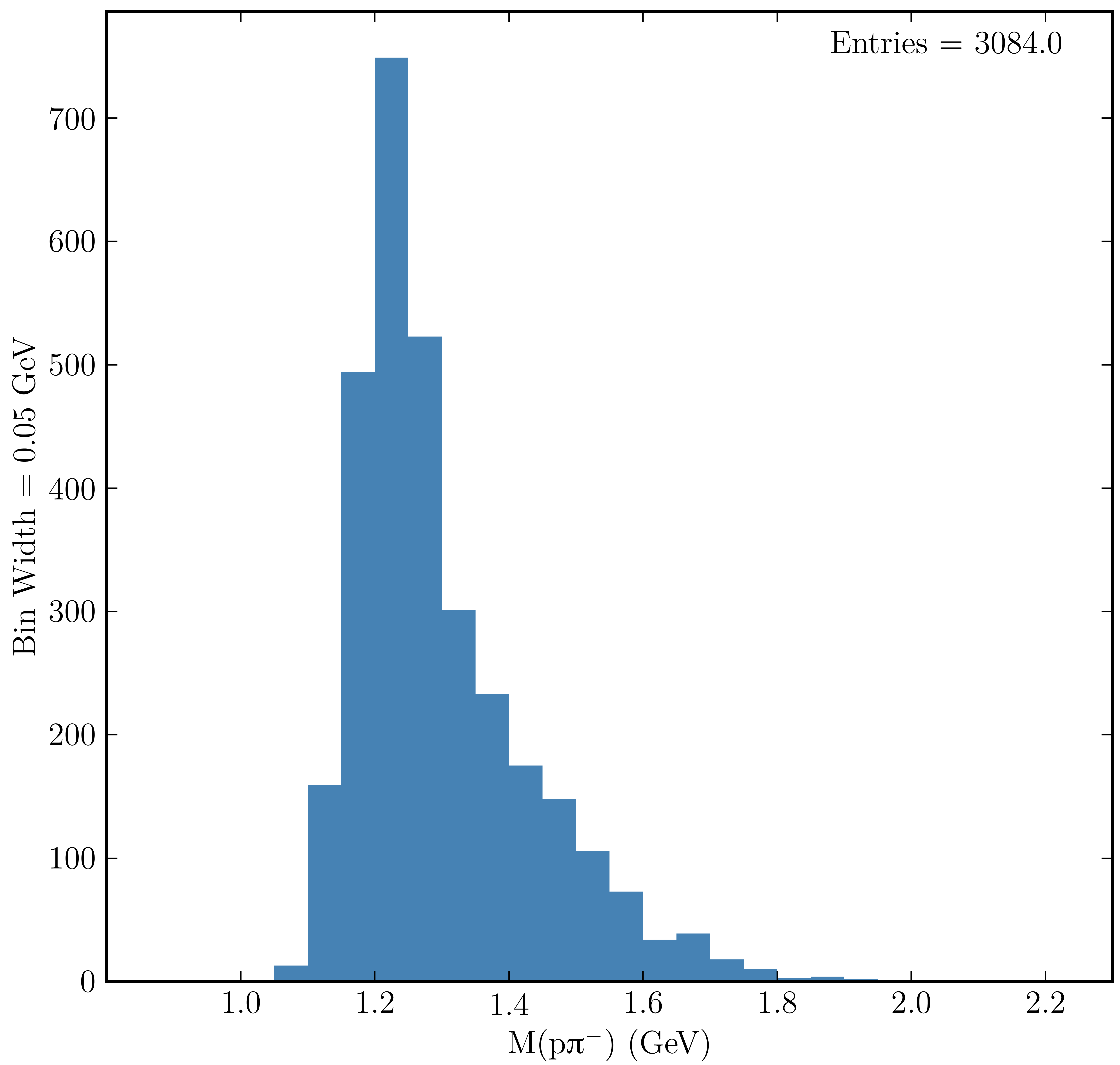


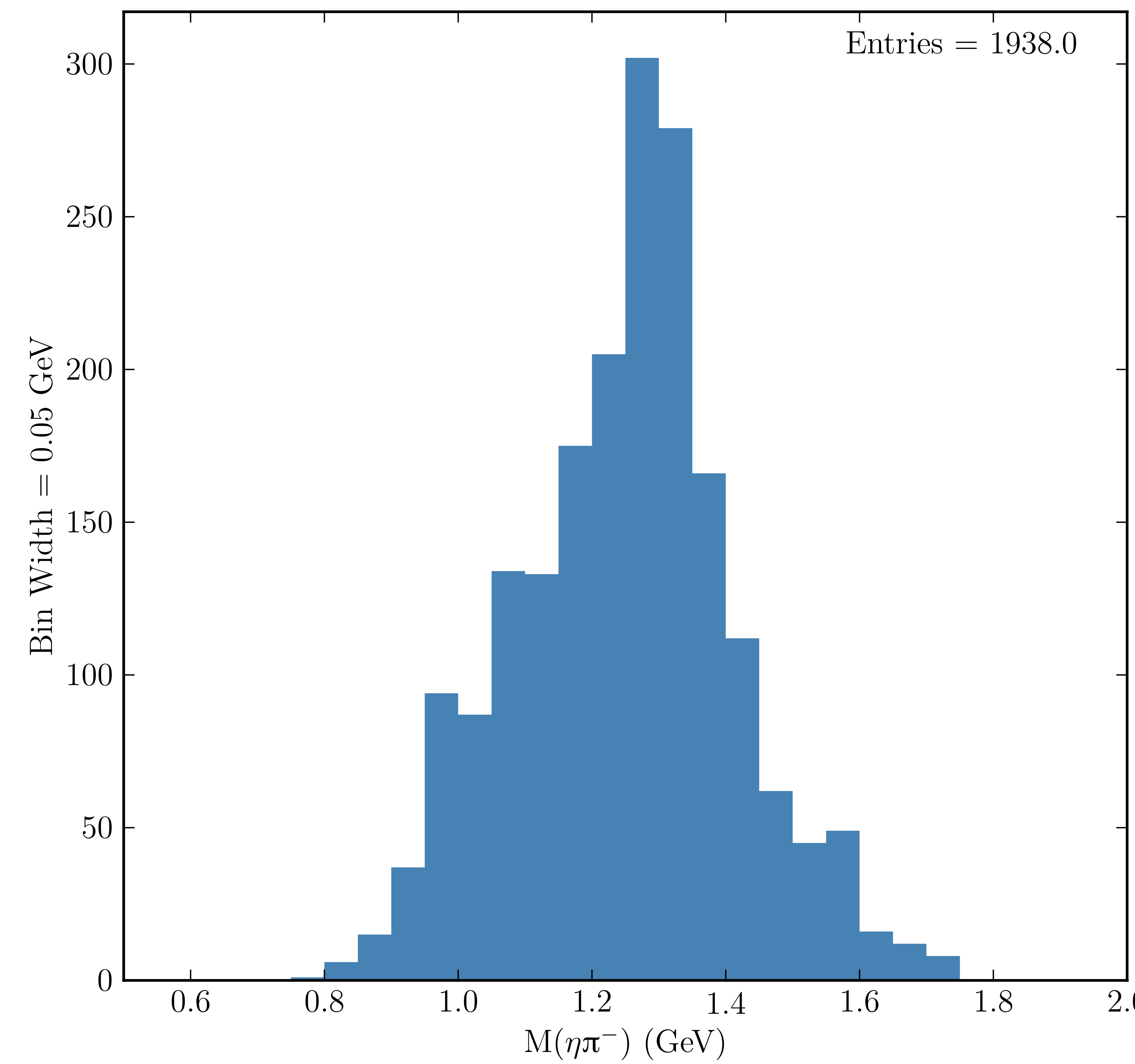
- Used for electro- and photo- production experiments that require multiple tracks to be detected.
- Hall B is the home of the CEBAF Large Acceptance Spectrometer (CLAS) detector.

# Final Data

## $M(p\pi^+) < 1.3$ GeV




## $M(\eta\pi^-)$



# PWA: Mass Independent Fit

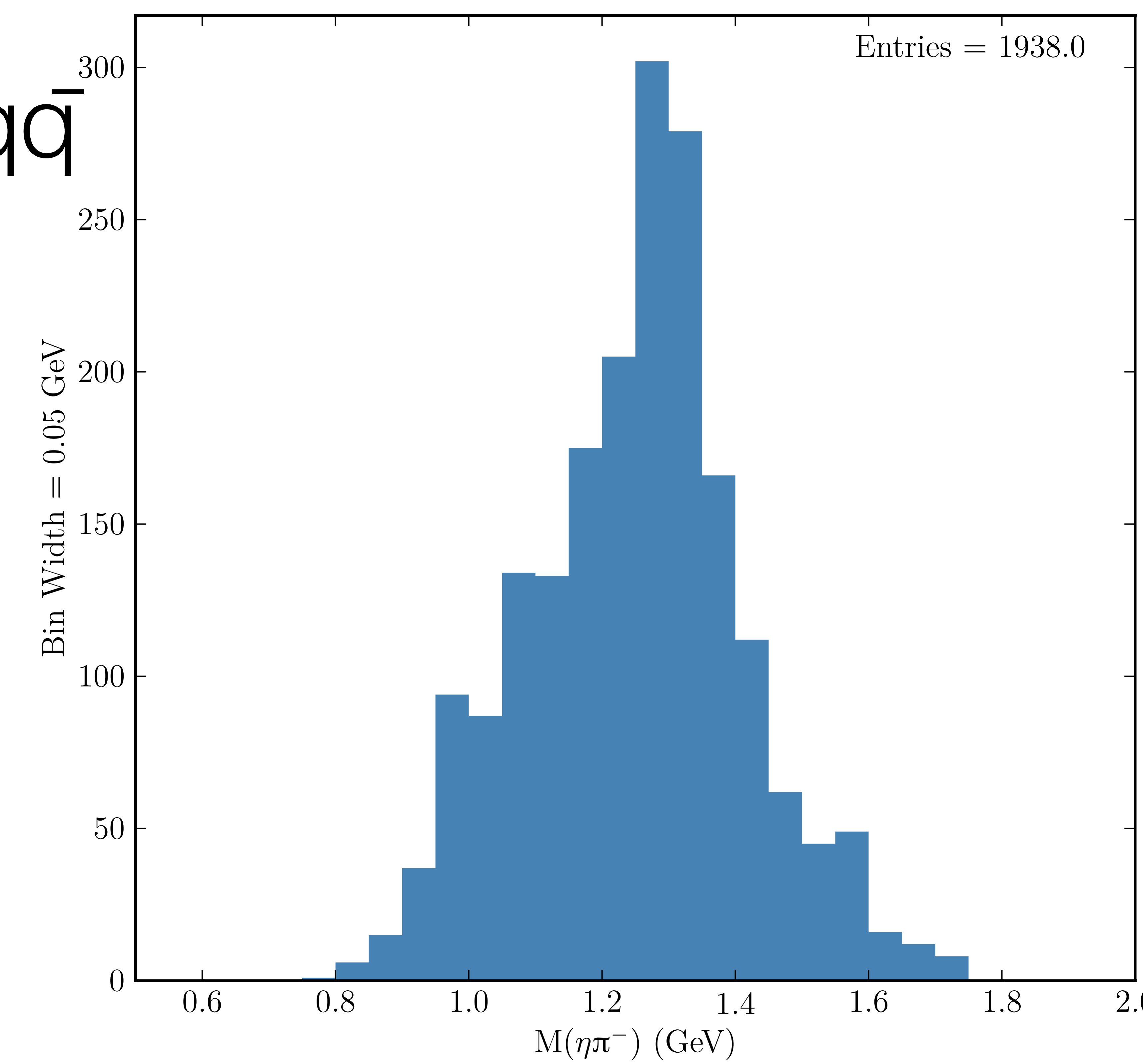
- The allowed wave set is

| wave | $J^P M \epsilon$ | corresponding particle |
|---|---|---|
| S | $0^+0^-$ | $a_0(980)$ |
| P | $1^-1^{(\pm)}$ | $\pi_1(1400)$<br>$\pi_1(1600)$ |
| D | $2^+1^{(\pm)}$ | $a_2(1320)$ |

$q\bar{q}g$ → P

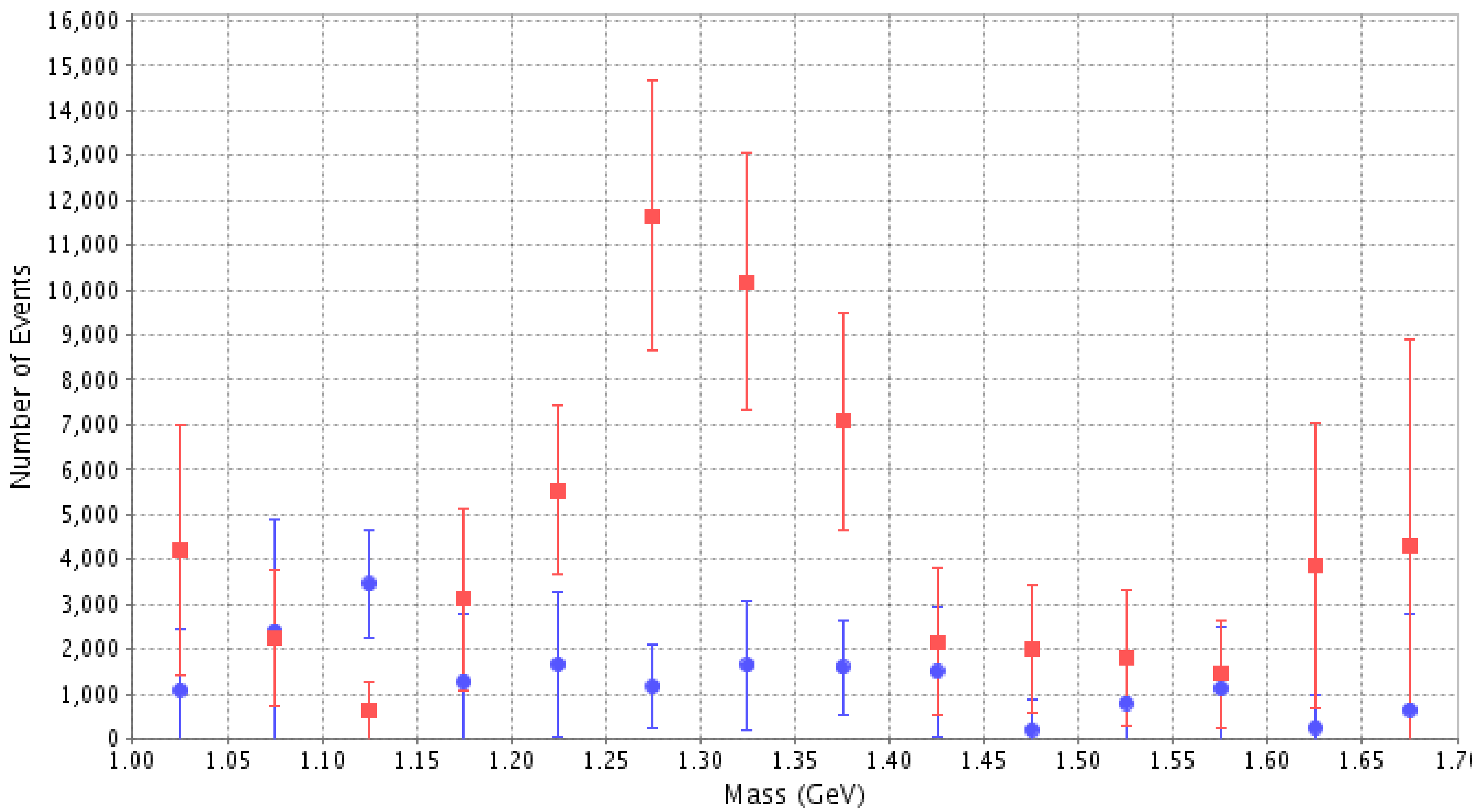
$q\bar{q}$ → S, D

$M(\eta\pi^-)$



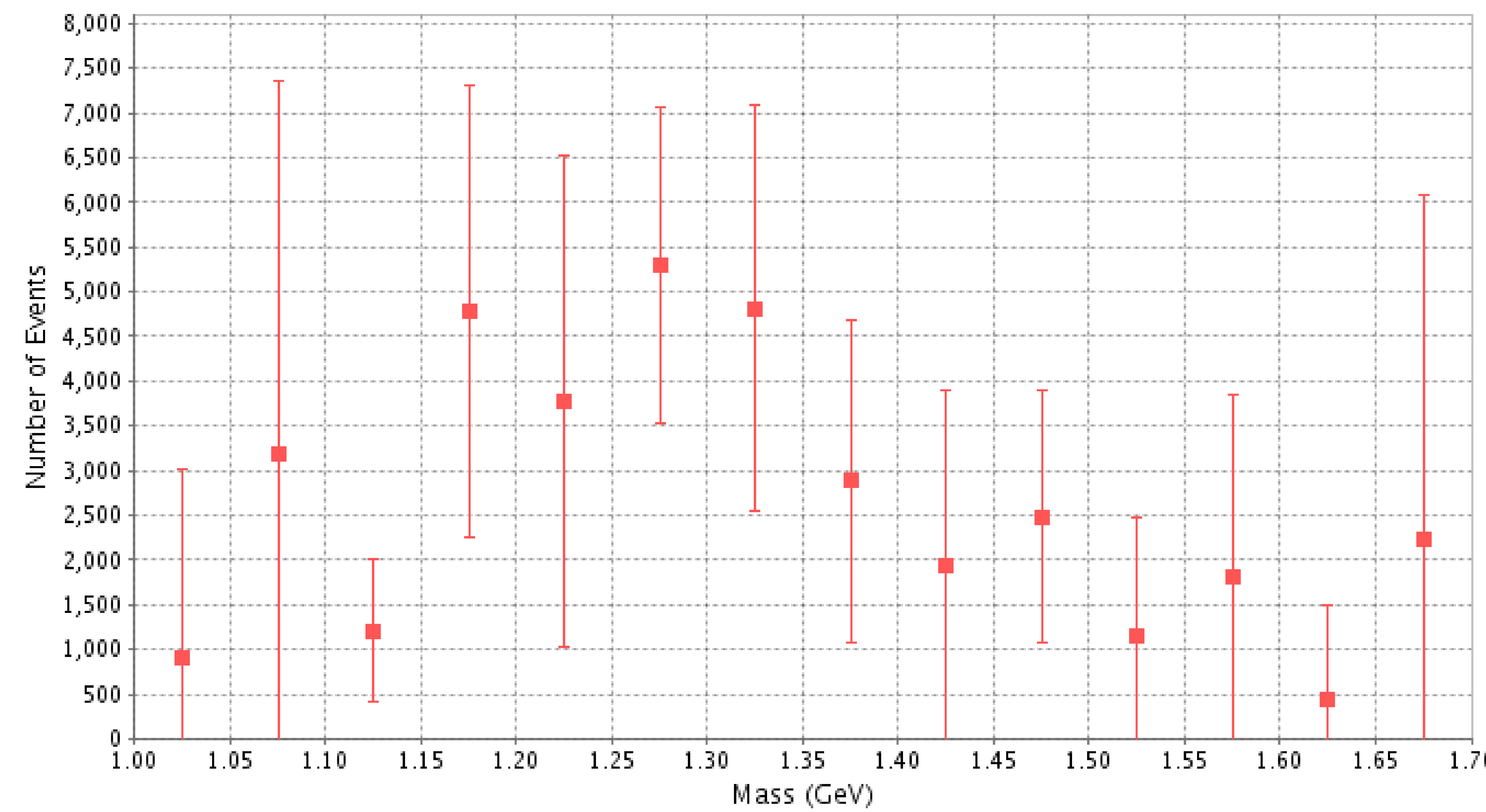
# PWA: Mass Independent Fit

$J^{PC}m = 1^{-+}1, 2^{++}1$




- The strongest contribution is from the D wave.
- The P waves shows no bump and is roughly 1/5 of the D wave.

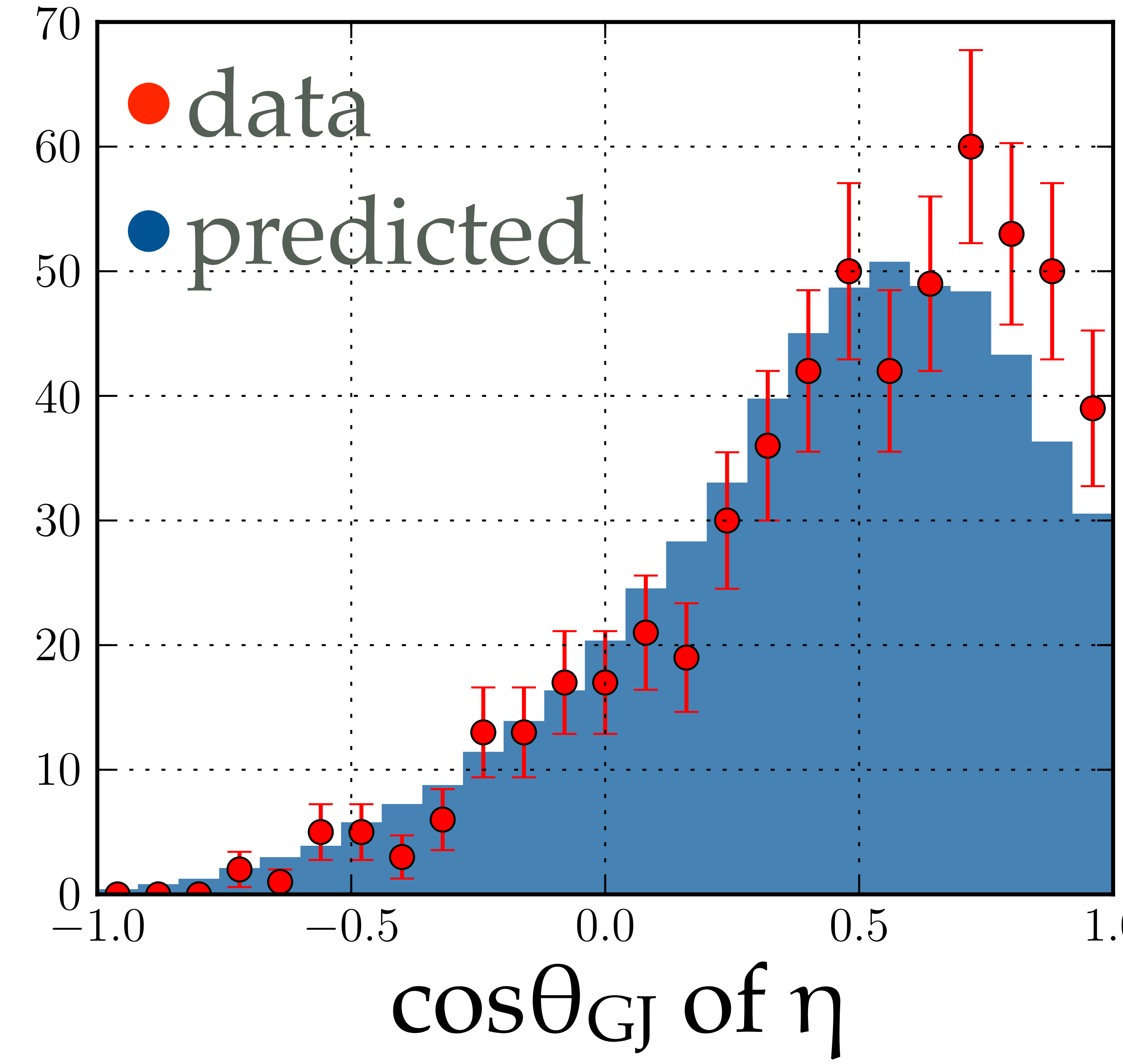
$J^{PC}m = 0^{++}0$

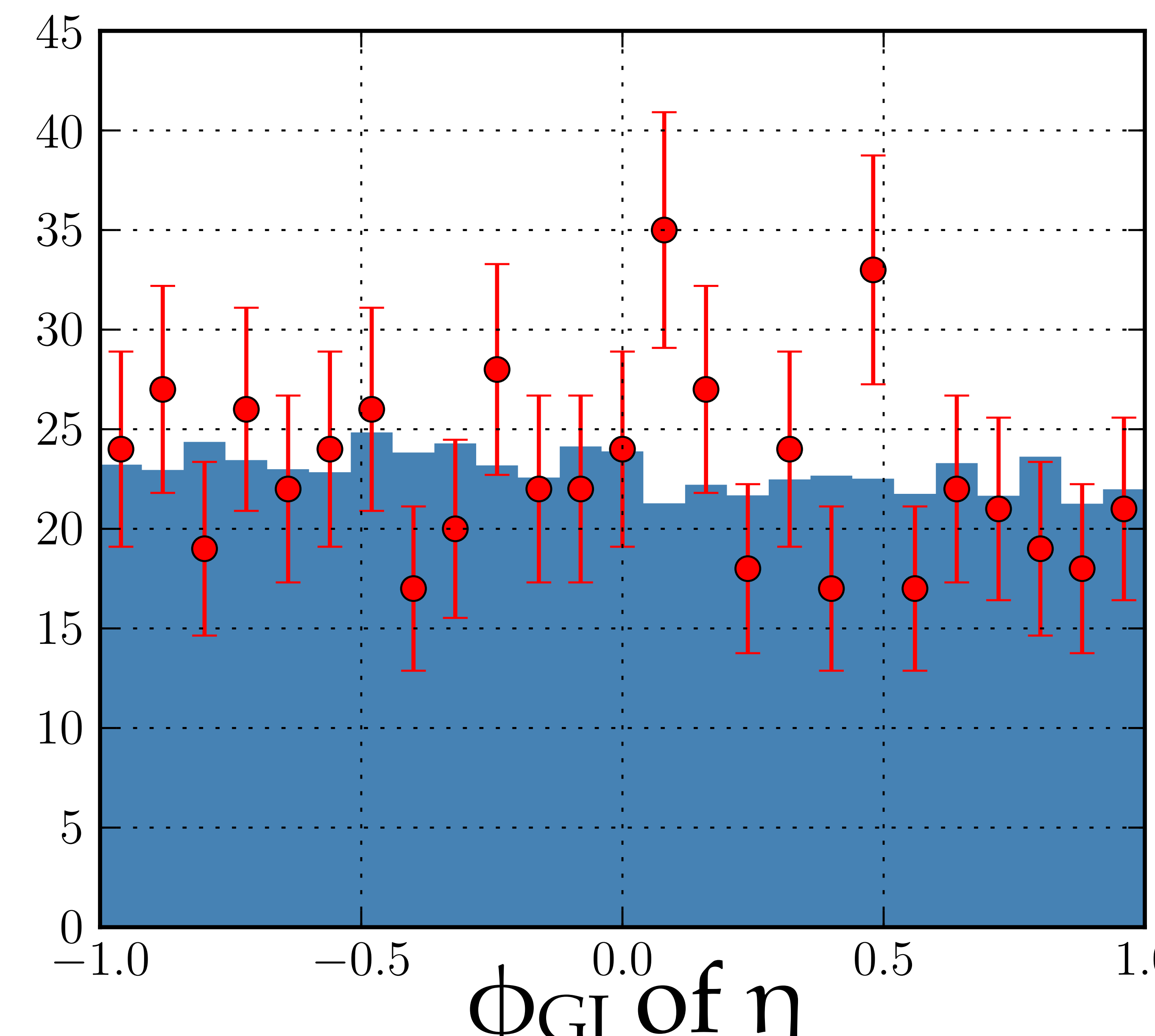



- The S wave shows a broad background with 1/2 the intensity of the D wave.

# Acceptance and Fit Quality

- for simulation: generated $\Delta^{++}X^{-} \rightarrow (p\,\pi^{+})(\eta\,\pi^{-})$
    - where the $(p\,\pi^{+})$ and $(\eta\,\pi^{-})$ mass spectra is generated to match the data
    - use momentum transfer ~3 GeV$^2$ from t-slope of $a_2$
- weighted events for the PWA solution and detector acceptance



# PWA fitter test

- generated pure waves and process with the standard CLAS simulation package.
- followed the same fitting procedure as the PWA of real data

| generated wave | fit wave | % |
|---|---|---|
| D+, D- | p-, p+ | 0.11 |
| | s | 0.004 |
| | d+, d- | 99.89 |
| P+, P- | p-, p+ | 95.62 |
| | s | 4.29 |
| | d+, d- | 0.09 |
| S- | p-, p+ | 0.8 |
| | s | 98.83 |
| | d+, d- | 0.36 |

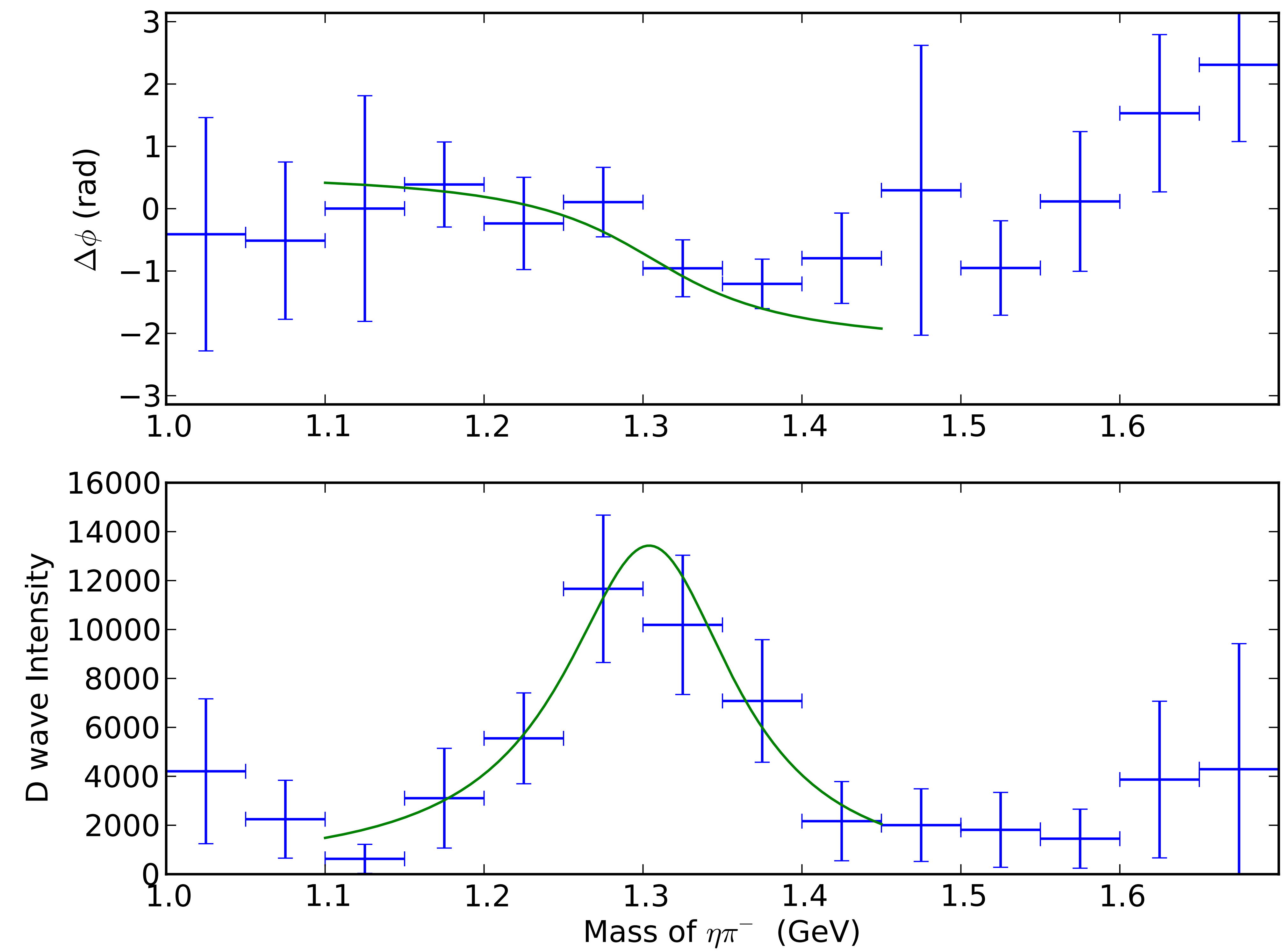
# Mass Dependent Fit

- Used relativistic BW amplitudes to fit the partial wave intensity and phase together using a $\chi^2$ fit.
  - Includes error matrix calculated from PWA.
- mass: 1.32 ± 0.01 GeV
- width: 0.14 ± 0.01 GeV

$a_2$

- PDG values:
  - mass: 1.318 ± 0.0006 GeV
  - width: 0.107 ± 0.005 GeV

$M(\eta\pi^-)$



# Mass Dependent Fit

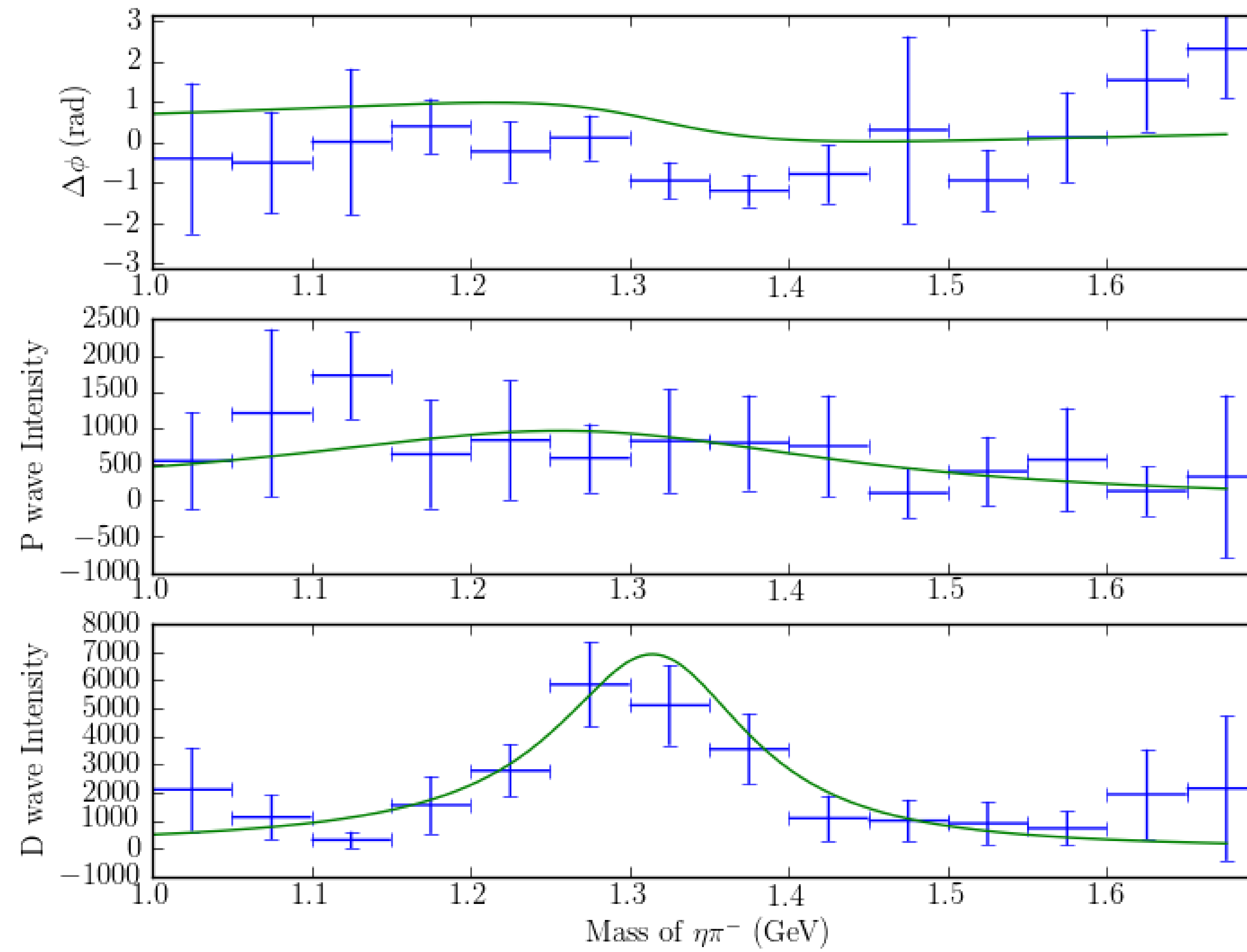
- Included $\pi_1$ with $a_2$

- $a_2$ mass: 1.343 ± 0.003 GeV
- $a_2$ width: 0.174 ± 0.003 GeV

$a_2$

- $\pi_1$ mass: 1.39 ± 0.23 GeV
- $\pi_1$ width: 0.58 ± 0.05 GeV

M($\eta\pi^-$)



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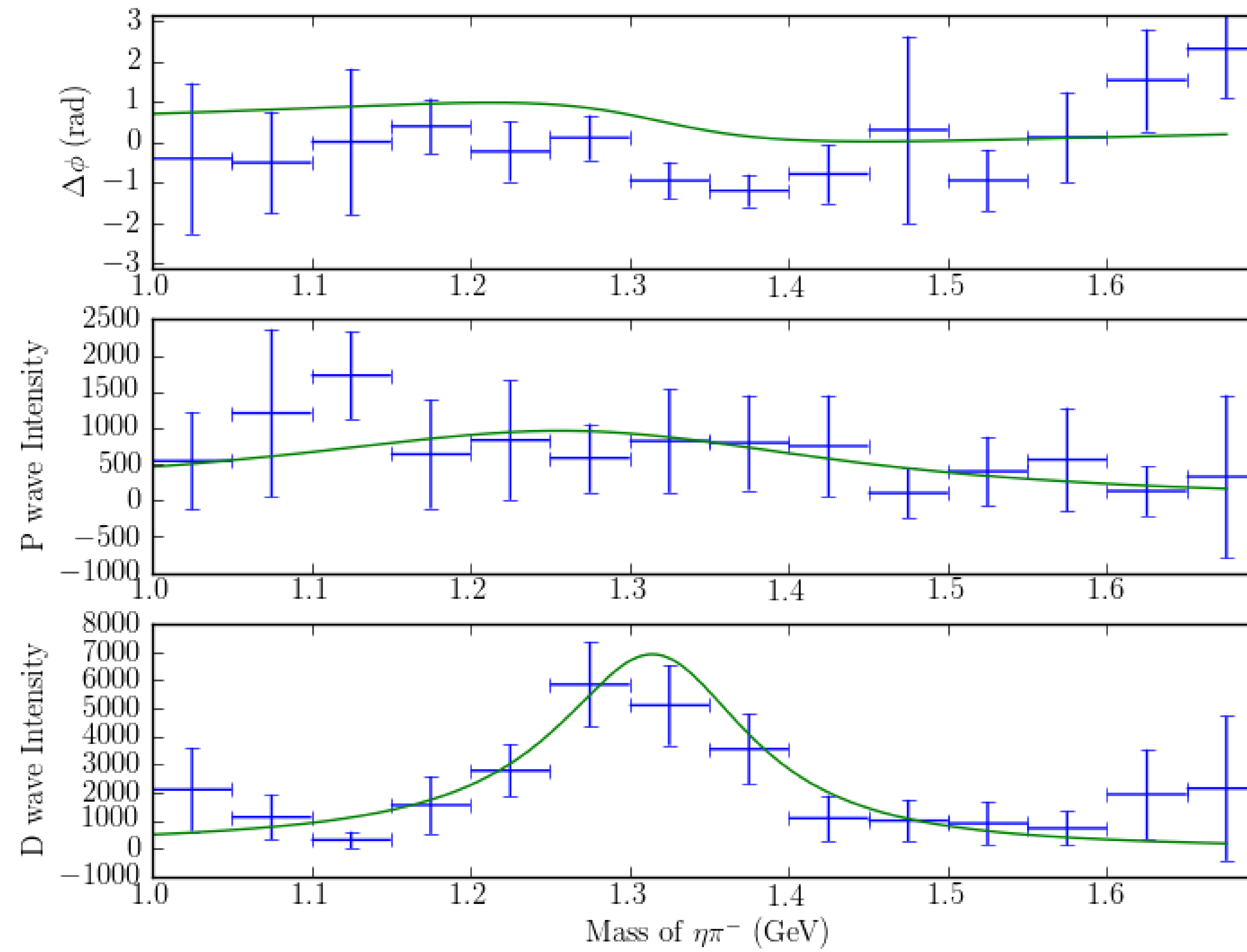
  - $\pi_1$ mass: 1.39 ± 0.23 GeV
  - $\pi_1$ width: 0.58 ± 0.05 GeV
- Results of the fit varied greatly. The best fit for the $\pi_1$ resulted in large errors for the mass and a width broader than the pion production value.

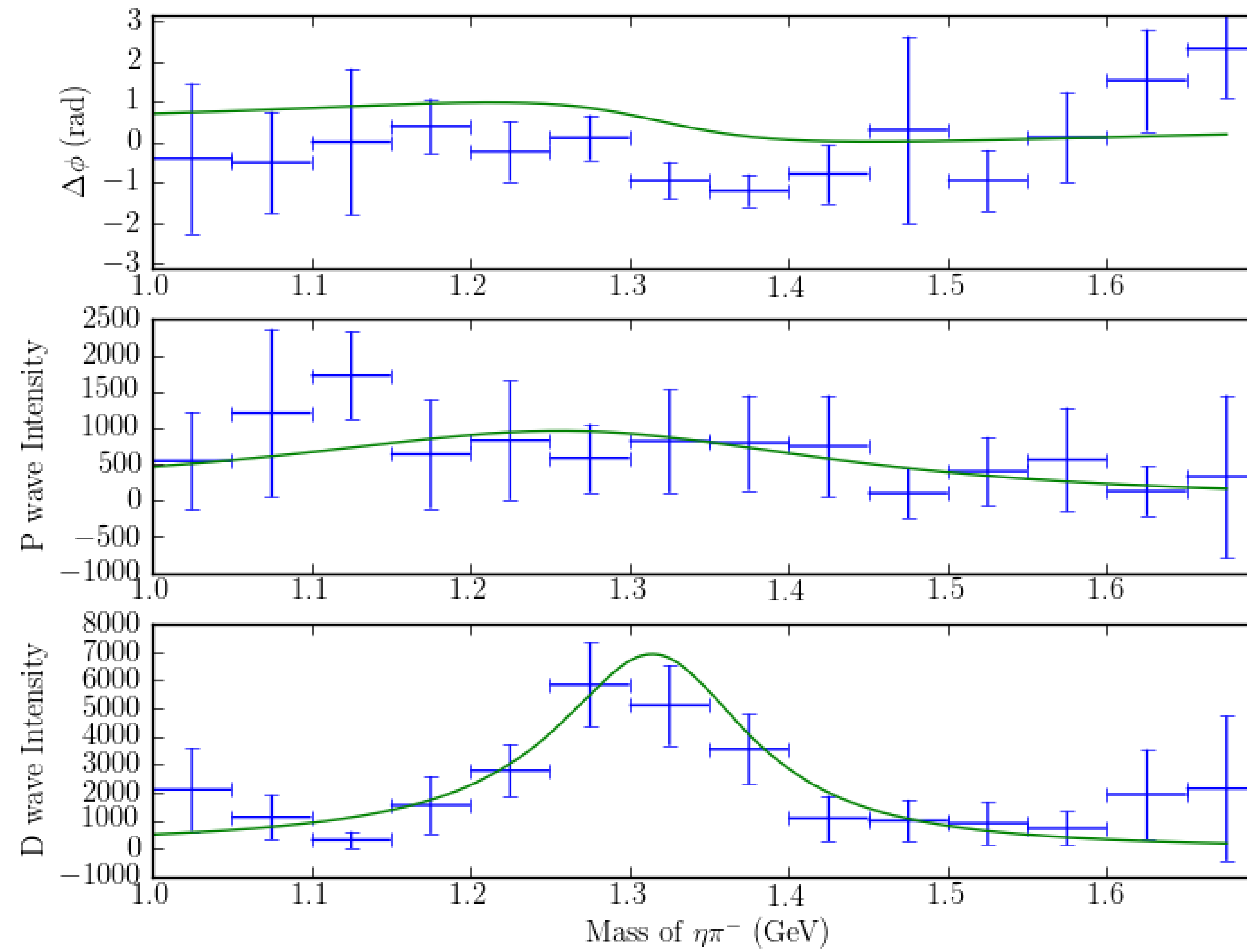
$M(\eta\pi^-)$



# Mass Dependent Fit

- No exotic was concluded to be seen in the final fit.
- The baryon vertex constrained the wave set as expected.
- This is the first look into $\eta\pi^-$ using photoproduction!

M($\eta\pi^-$)



# Summary

- The PWA of the $M(\eta\pi^-)$ resulted in:
  - the wave set to be dominated by the $2^{++}$ partial wave coinciding with the $a_2$
  - the $1^{-+}$ partial wave intensity shows no structure
  - the phase difference between $1^{-+}$ and $2^{++}$ shows a shift
- The fits of the PWA intensity and phase difference resulted in the fit of the $a_2$ but not of the $\pi_1$.