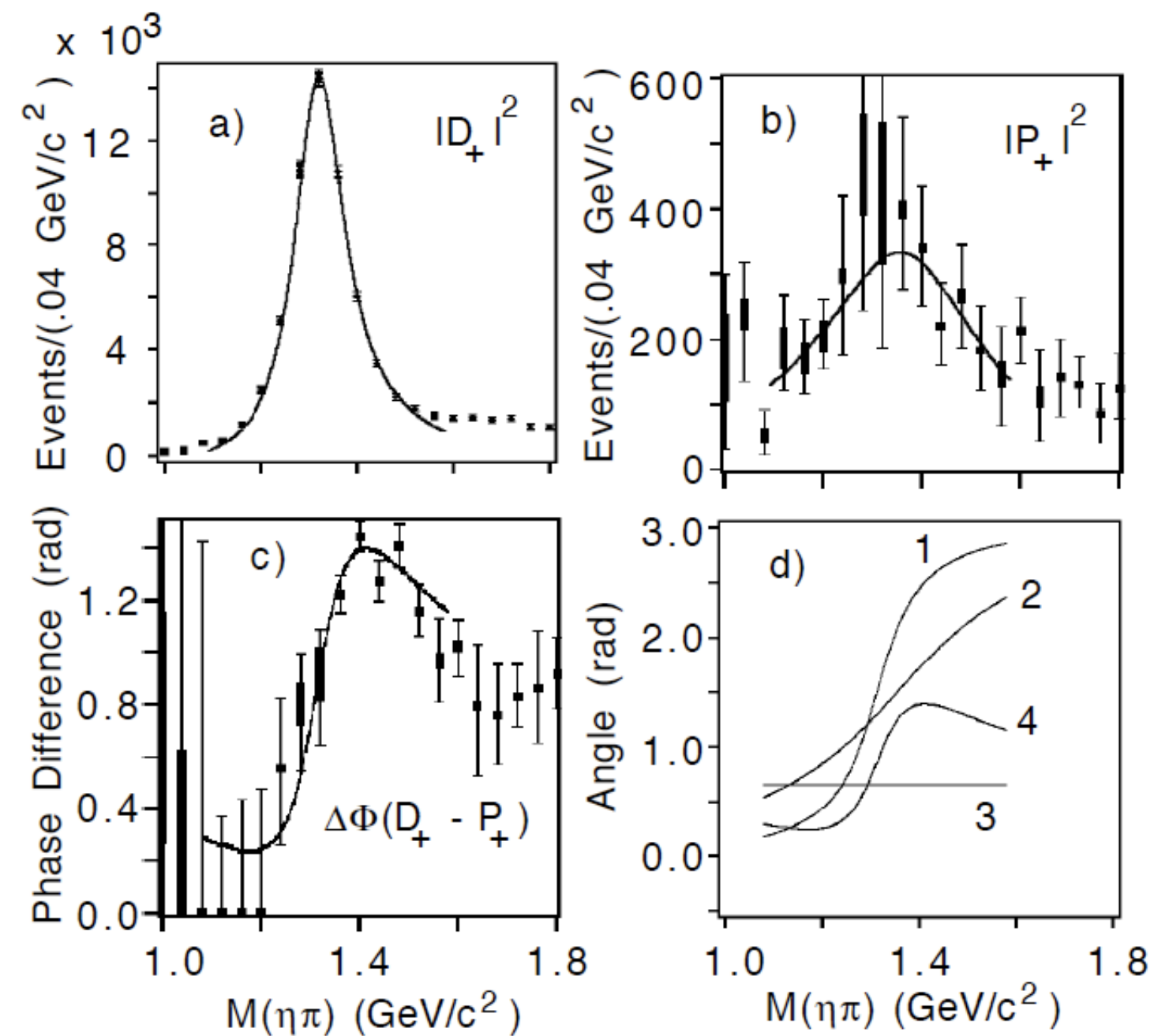


The Search for a $\pi_1(1400)$ Exotic Meson in the $\gamma p \rightarrow \Delta^{++} \eta \pi^-$ System with CLAS

Diane Schott, FIU



Previous Experiments



- $\Gamma = 385 \pm 40 \text{ MeV}$
- confirmed by Crystal Barrel
- $\bar{p} n \rightarrow \pi^- \pi^0 \eta$

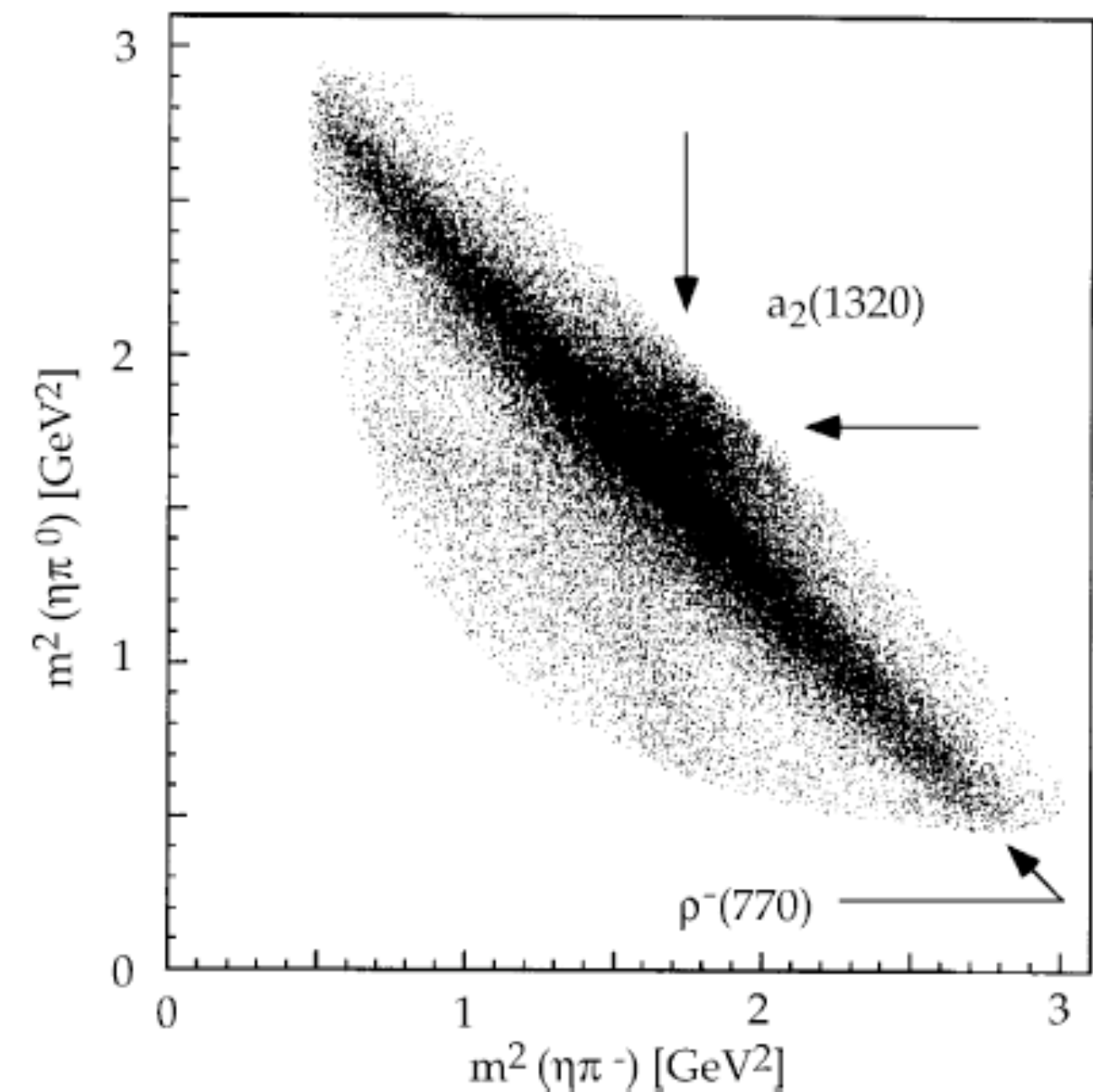


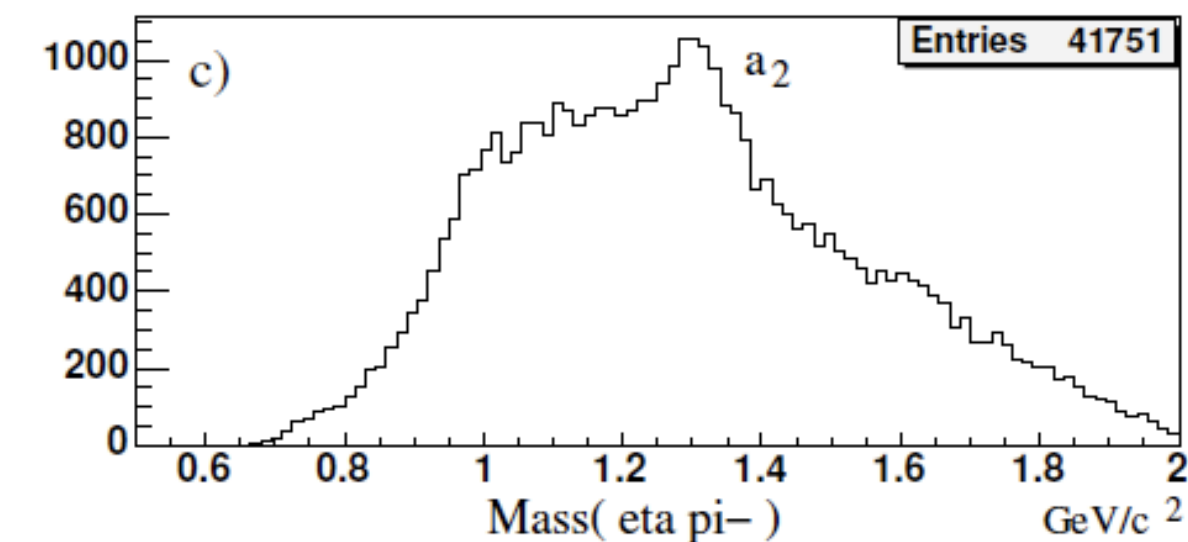
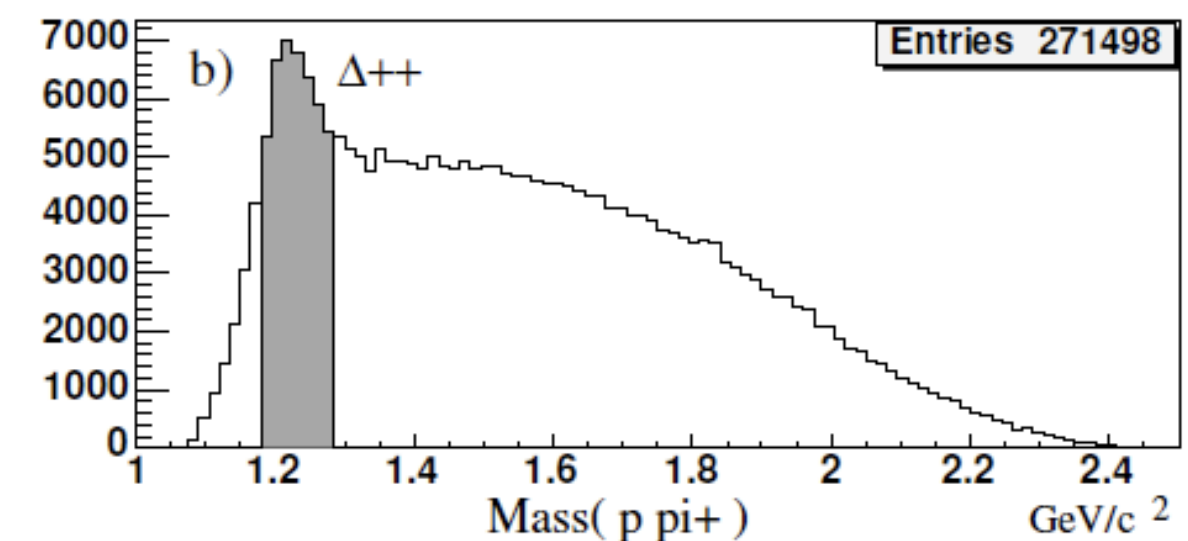
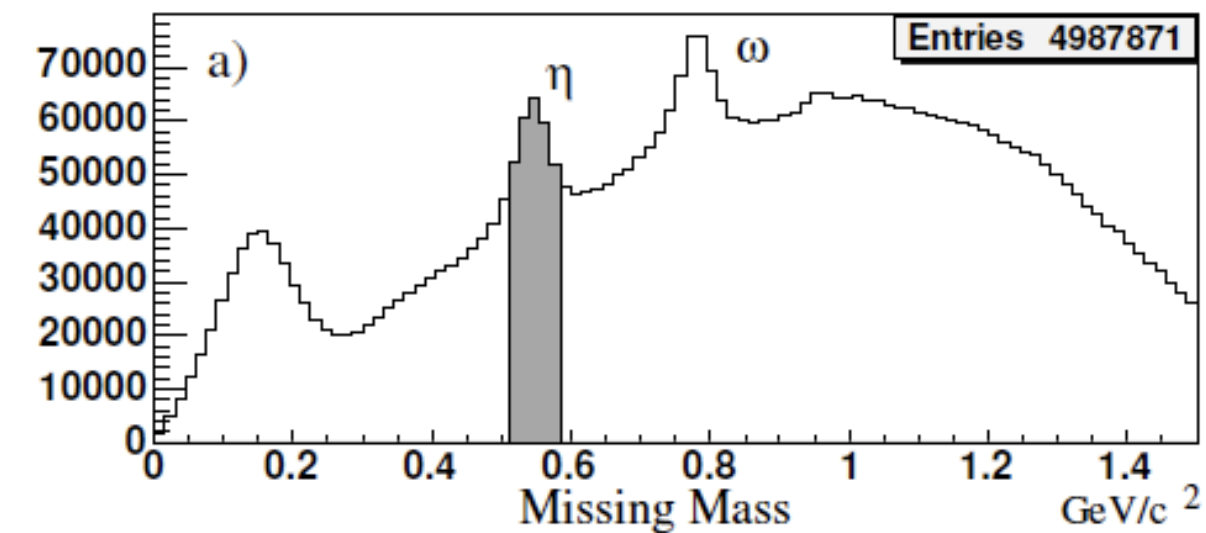
Fig. 37. Dalitz plot of $\bar{p}n \rightarrow \pi^- \pi^0 \eta$ (after Ref. [195]).

- E852 collaboration made a claim on $\pi_1(1400)$
 - $\pi^- p \rightarrow \pi^- \eta p$
 - $M = 1370 \pm 16 \text{ MeV}$

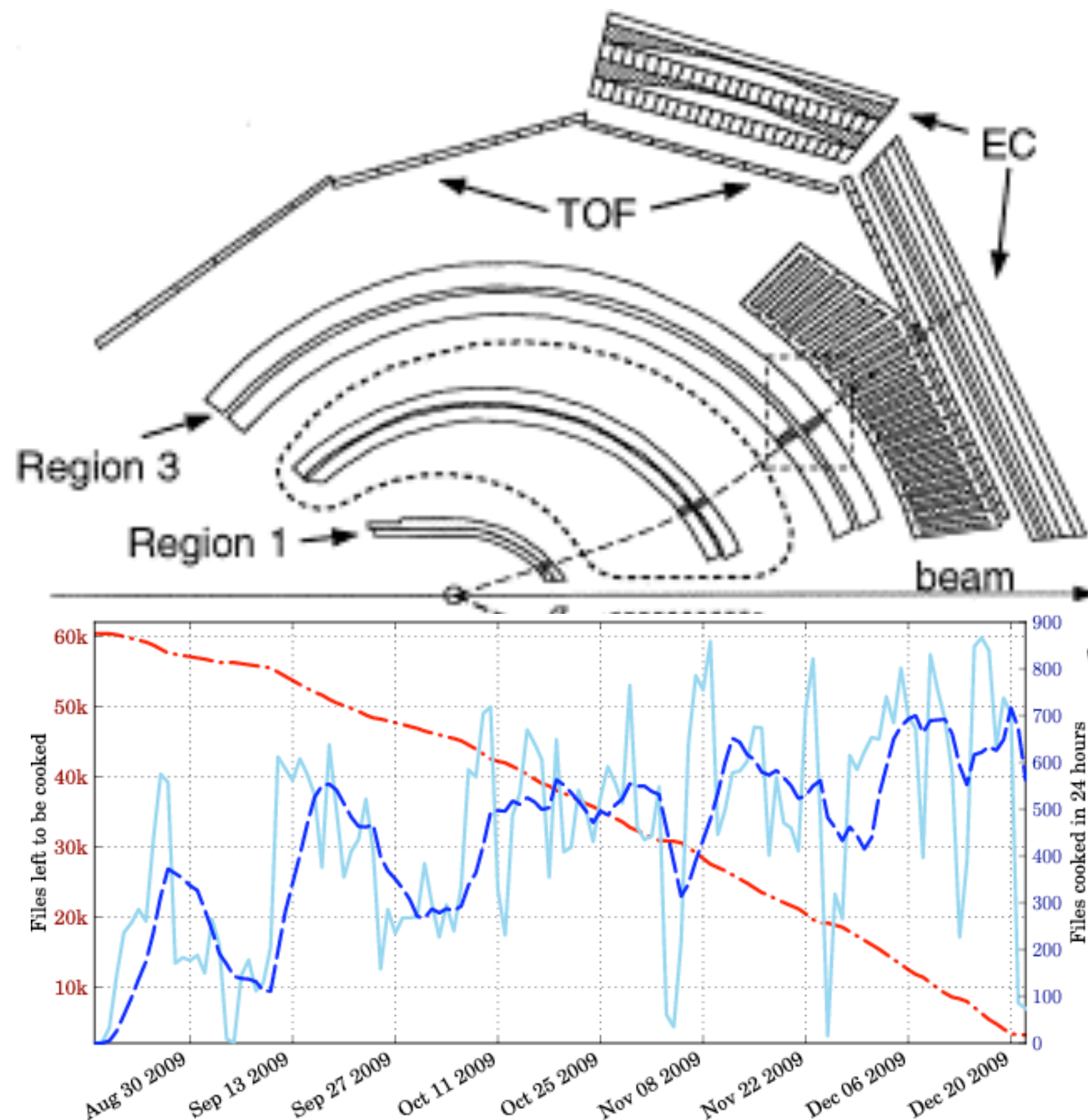
*From Phys. Rep. 389 (2004) 61-117

Searching for Exotic Mesons, JLab

- g6c - photoproduction in CLAS
- $\gamma p \rightarrow \Delta^{++} \eta \pi^-$
- were able to obtain $\Delta^{++} \eta \pi^-$ events
 - clear η in the missing mass, high background
 - a_2 seen in $\eta \pi^-$
 - not enough statistics to do PWA to find $\pi_1(1400)$ after background subtraction (~11,000 events)



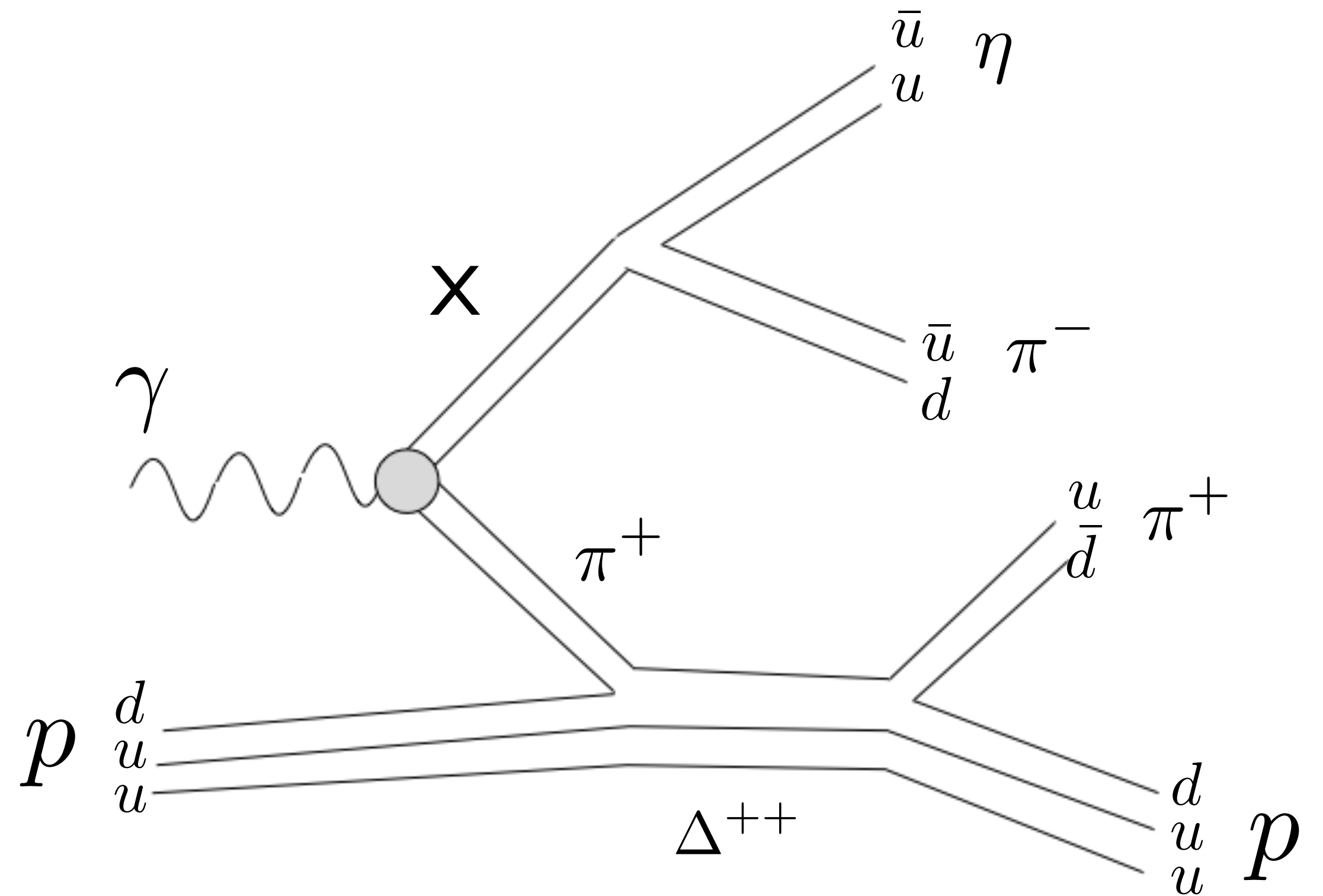
G12 Experiment



- Time frame: started April 1; ended June 9, 2008
- 3.0834×10^{13} photons $\sim 52 \text{ (pb)}^{-1}$ for $E_\gamma > 3.6 \text{ GeV}$
- current: 60 to 65 nA
- finished calibrations and finished final reconstruction pass
- finished in January 2010
- lost 1 silo tape of cooked data - to be re-cooked

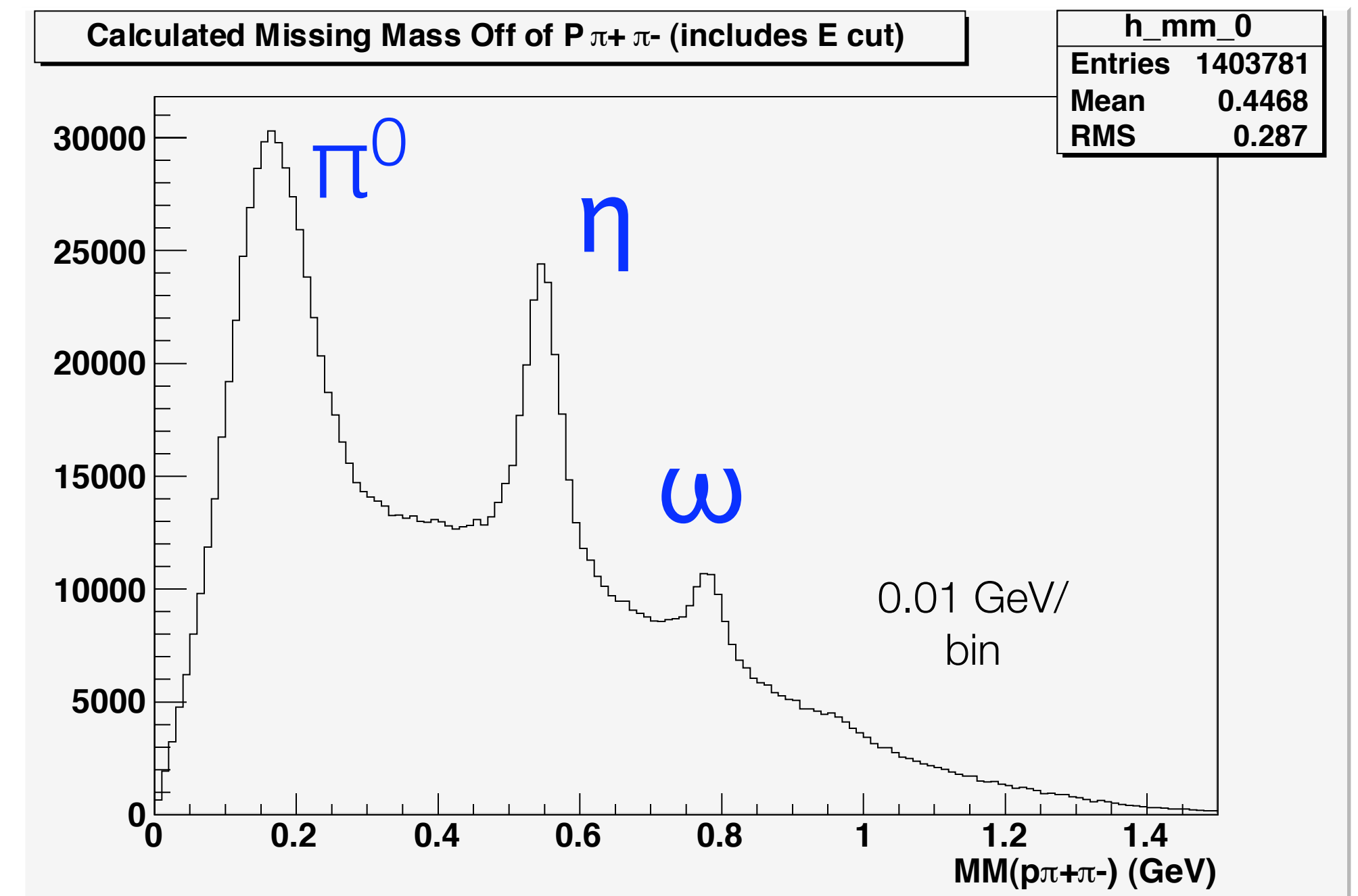
$$\gamma p \rightarrow \Delta^{++} \eta \pi^-$$

- goals:
 - look for a $\pi_1(1400)$
 - study asymmetries in GJ rest frame of X
 - calculate moments
 - PWA
- issues - large amounts of background



Data

plots show 99% of total data
initially only select $p \pi^+ \pi^- 2\gamma$ events
restrict η to decay of 2γ
stricter than initial g6c glimpse but 10 times
the raw data



Initial cuts

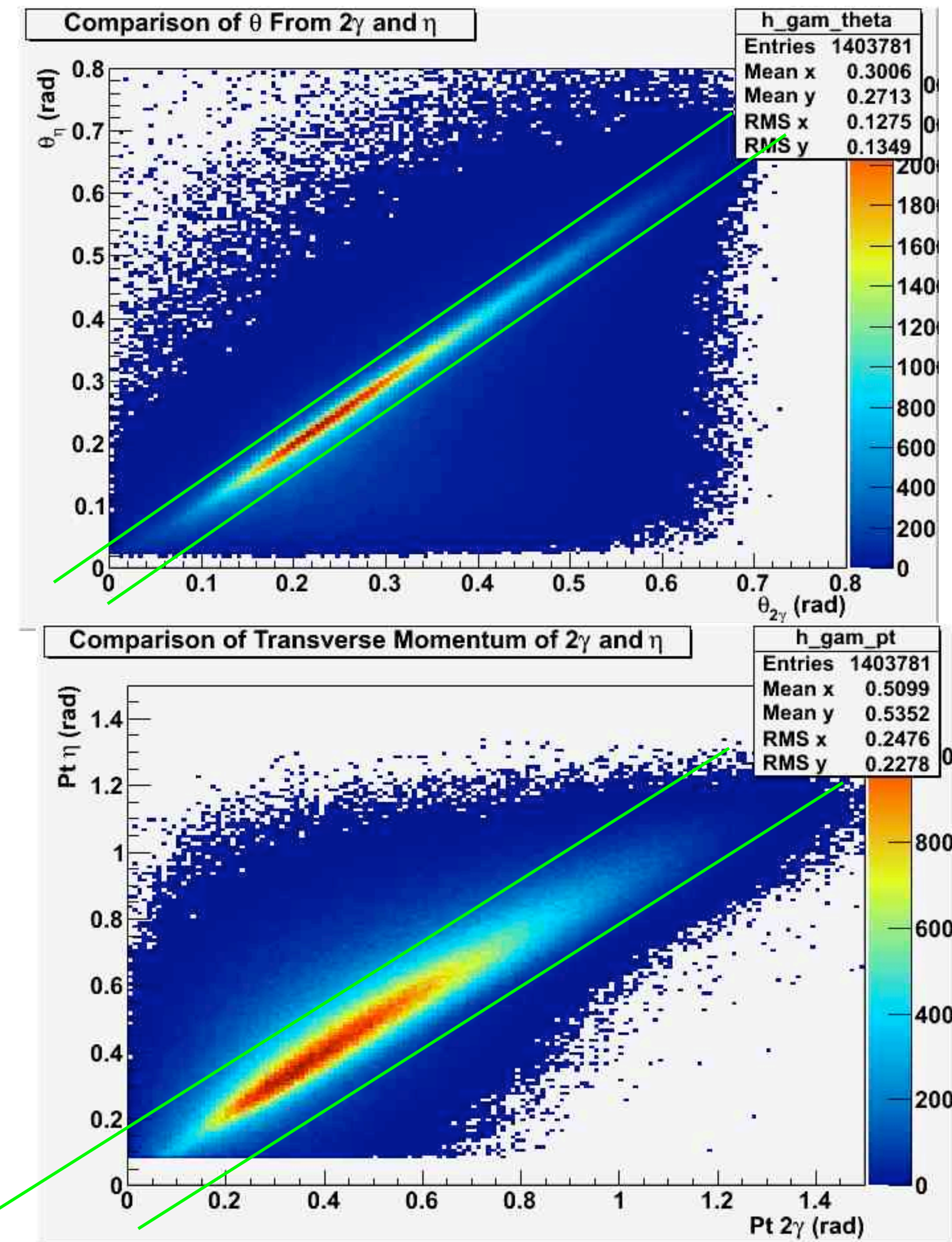
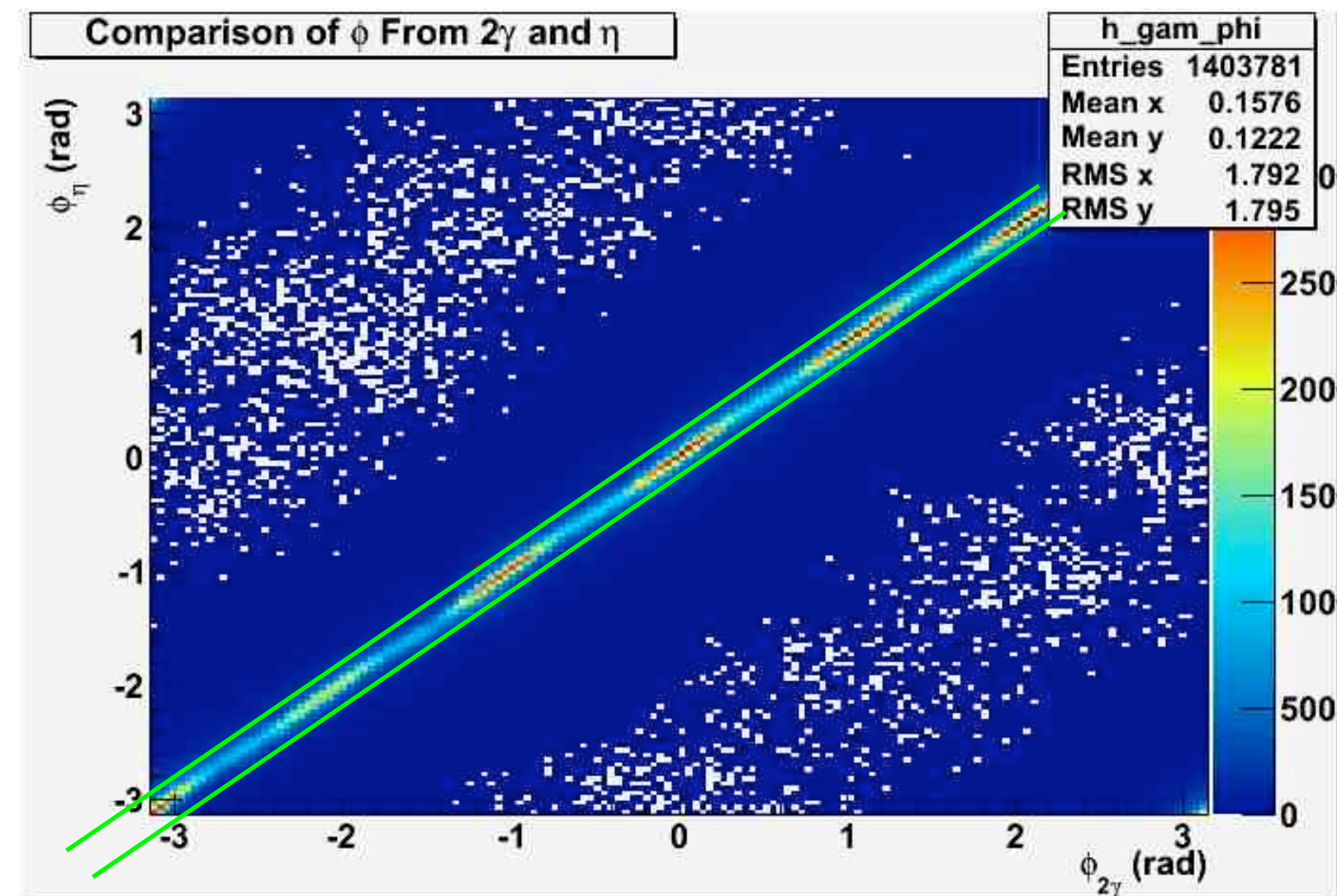
- $E_{\text{beam}} > 4.5 \text{ GeV}$
- charged particle timing must be within the beam bucket
- missing transverse momentum (calculated from the charged out going particles) is $> 0.085 \text{ GeV}$
 - this cuts out a lot of miss identified events
- vertex cuts
- beta cuts
 - $< 1 \& > 0$
- identify 1 or 2 good γ 's
 - $\text{ec_time} > 0 \text{ ns}$ and $< 50 \text{ ns}$
- ELOSS taken into account

Next level of cuts

- 2 photons - there must be a p , π^+ , π^- , and 2γ in the event
 - γ_1 and γ_2 have times within the event
 - require p , π^+ , π^- , and 2γ with no missing mass
 - compare missing particle's 4 - momentum to 2γ 4 - momentum
 - select η using 2-D cuts
 - $MM(p2\pi)$ vs $M(2\gamma)$
- 1 detected and 1 missing photon
 - γ_1 have a time within the event
 - require p , π^+ , π^- , and γ with no missing mass - there are possible 3 π events under η peak in MM spectrum
 - looking for further cuts... goal is signal to background to be $> .5$

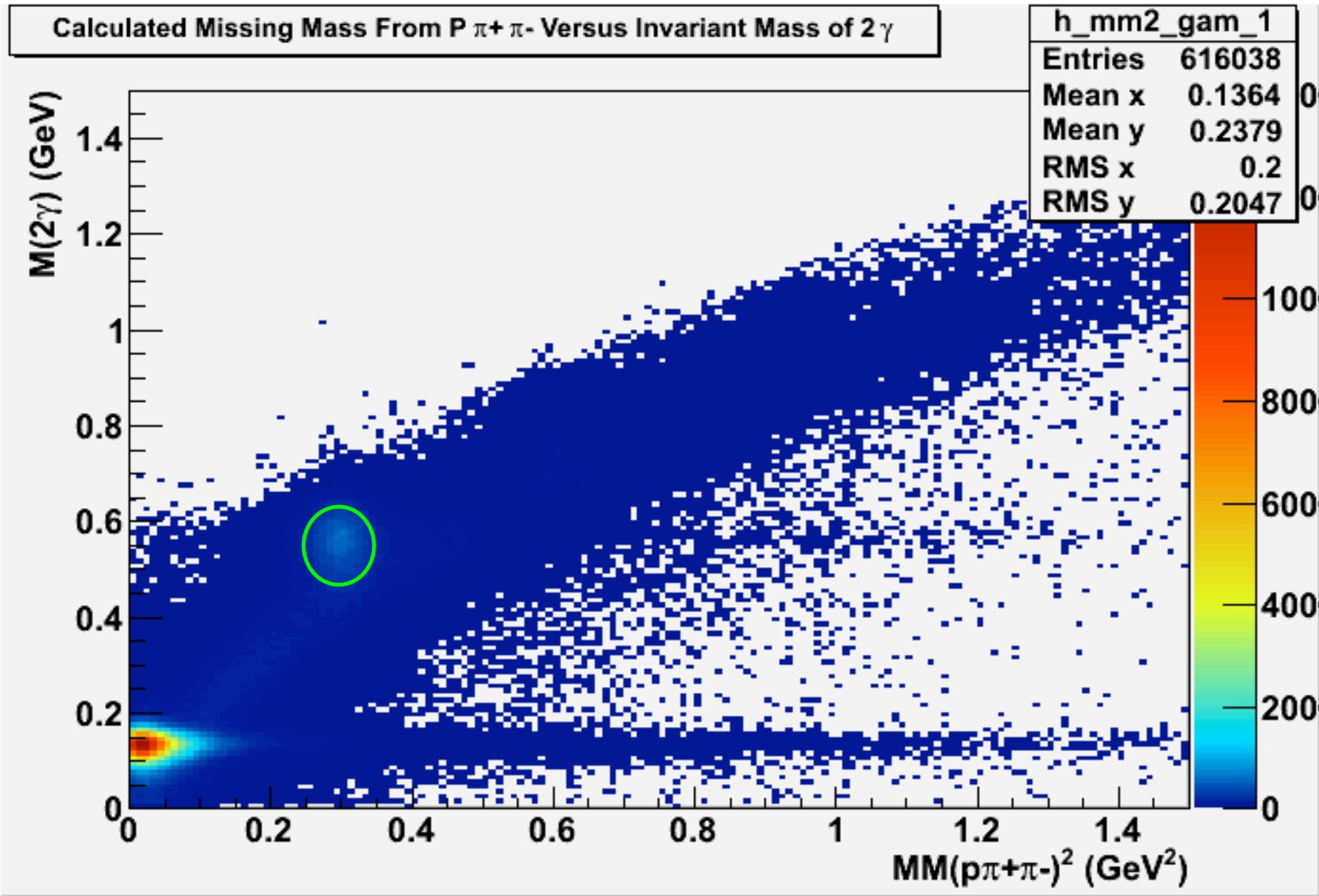
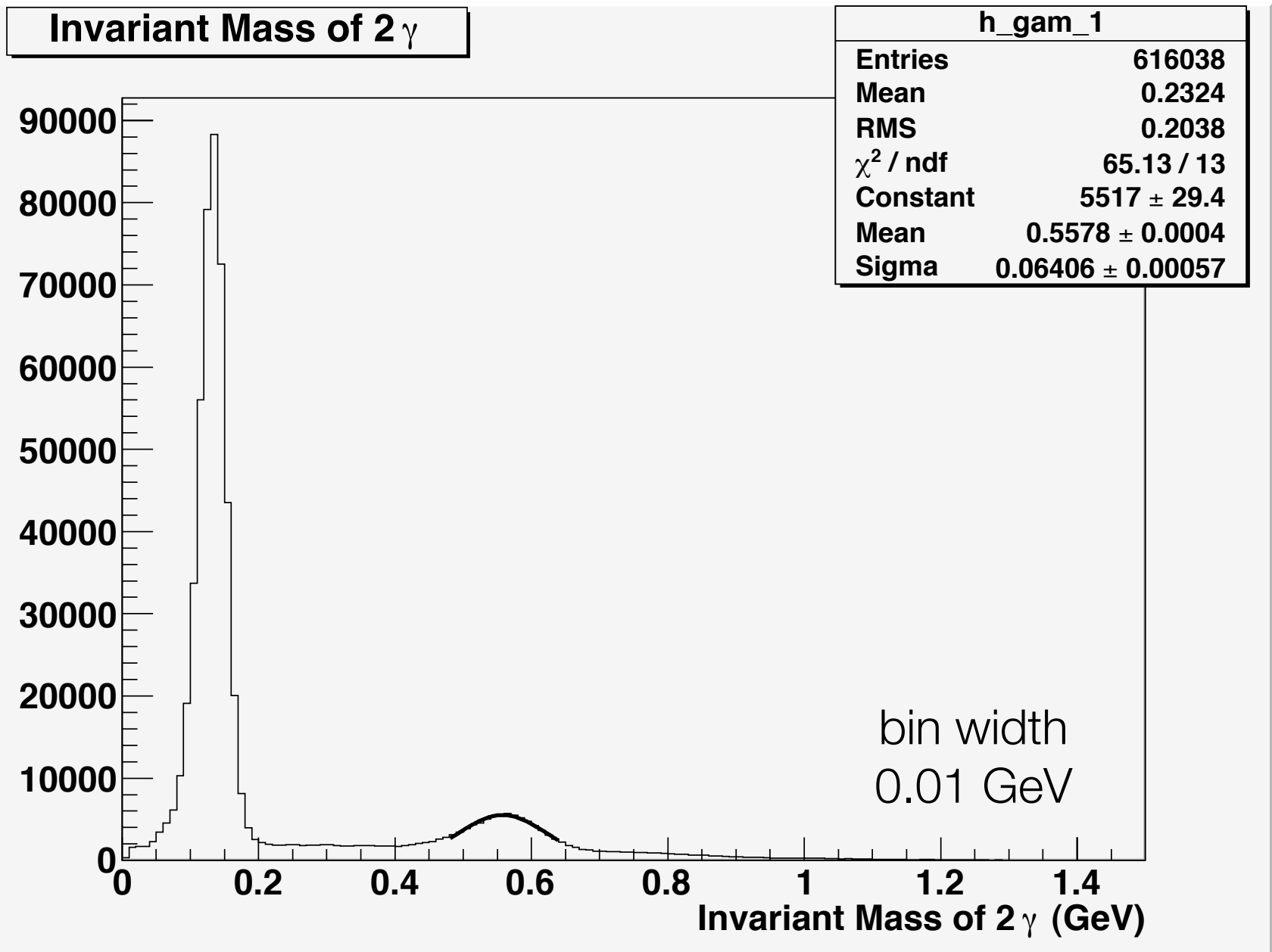
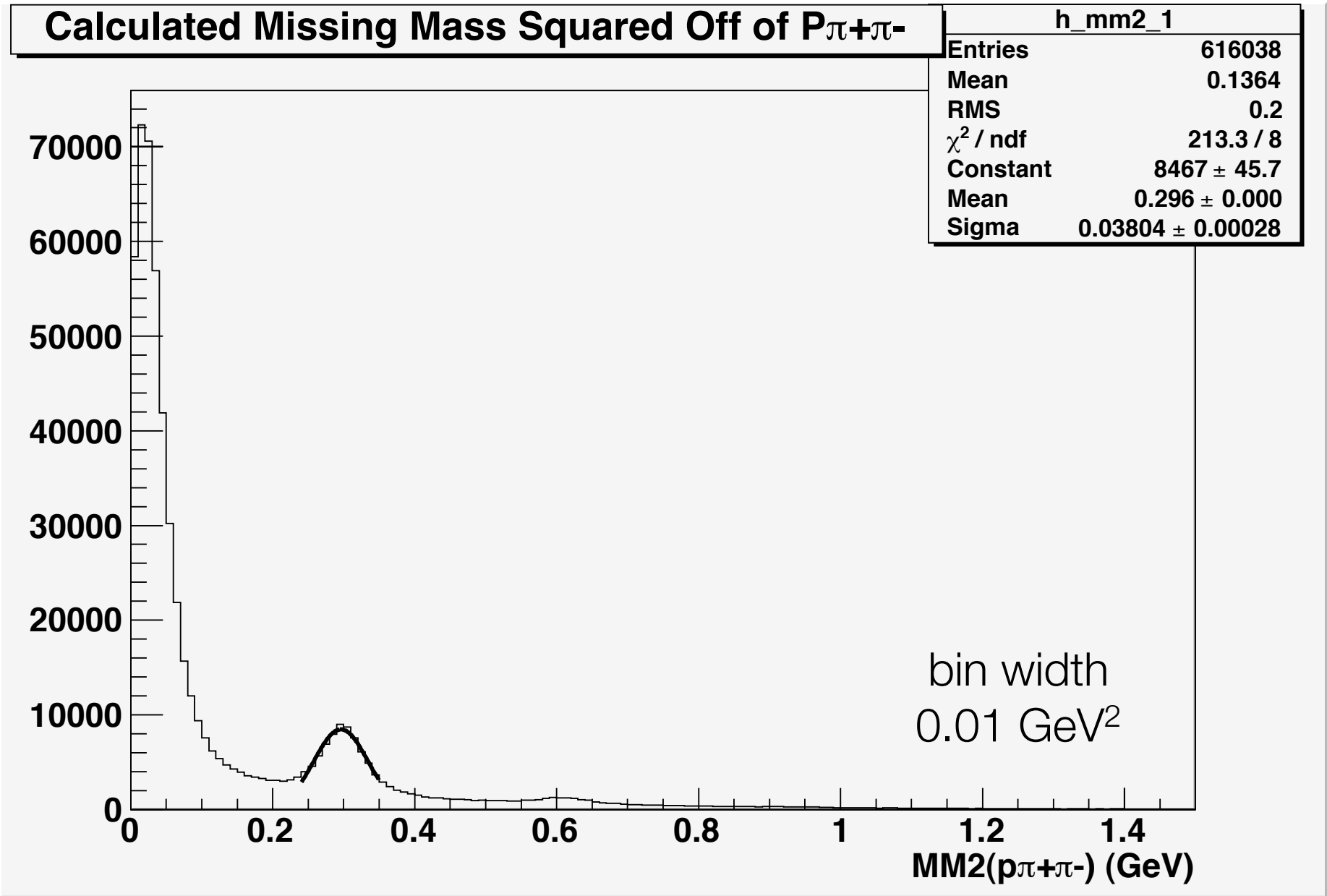
2γ : Data Selection

- reconstruct η two ways
 - conservation of 4-momentum, using charged final state particles
 - assume decay to 2γ (PDG: 39.3%)



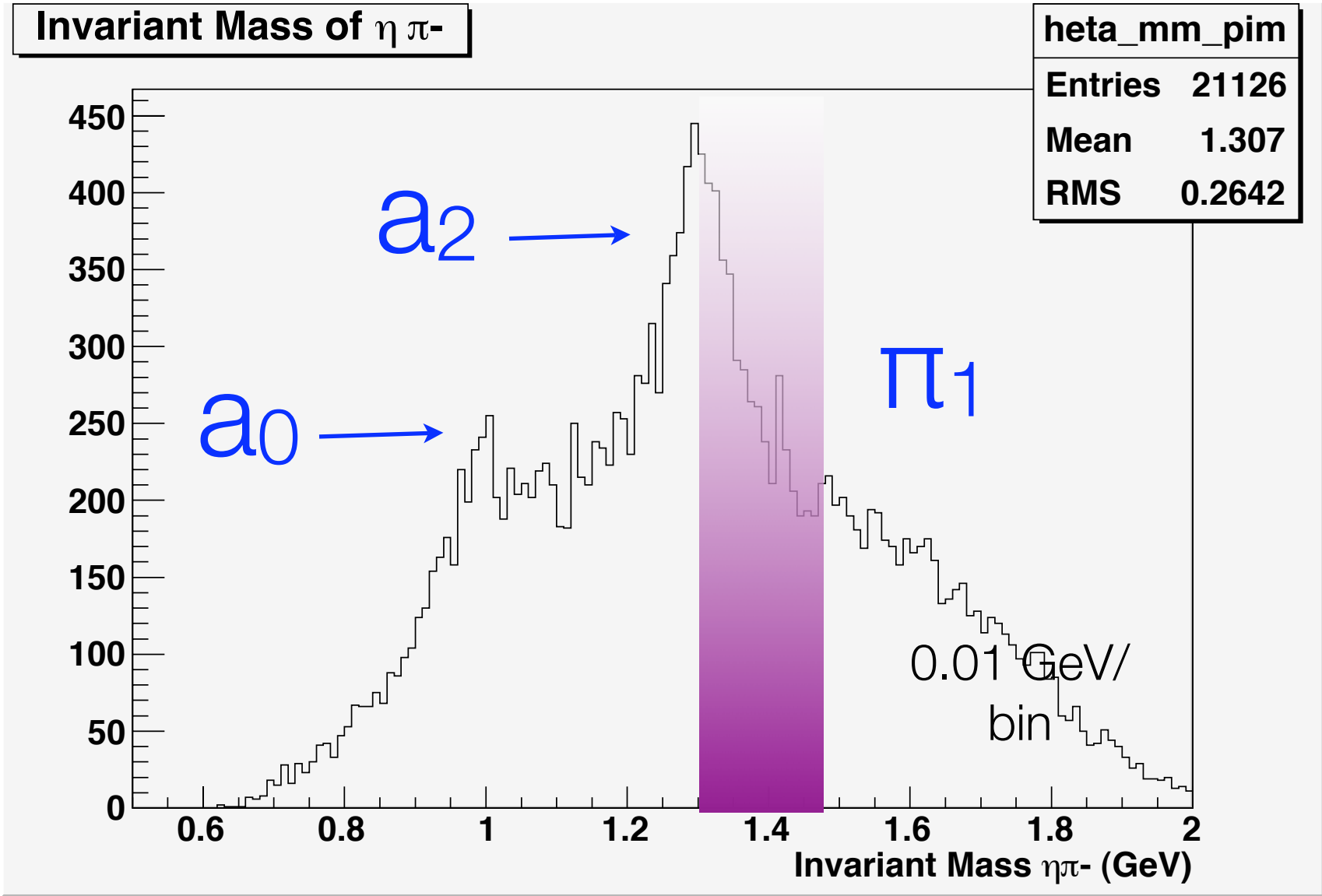
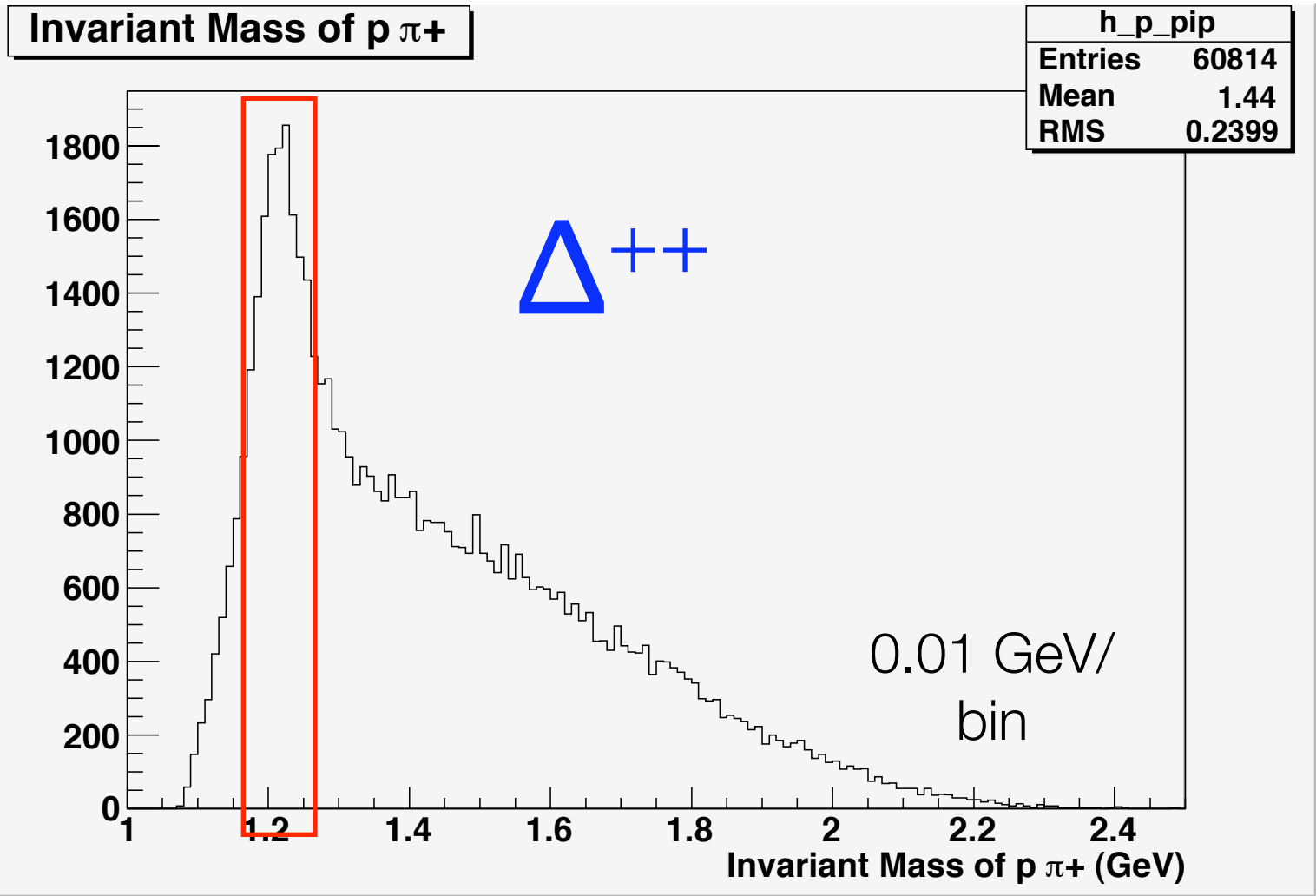
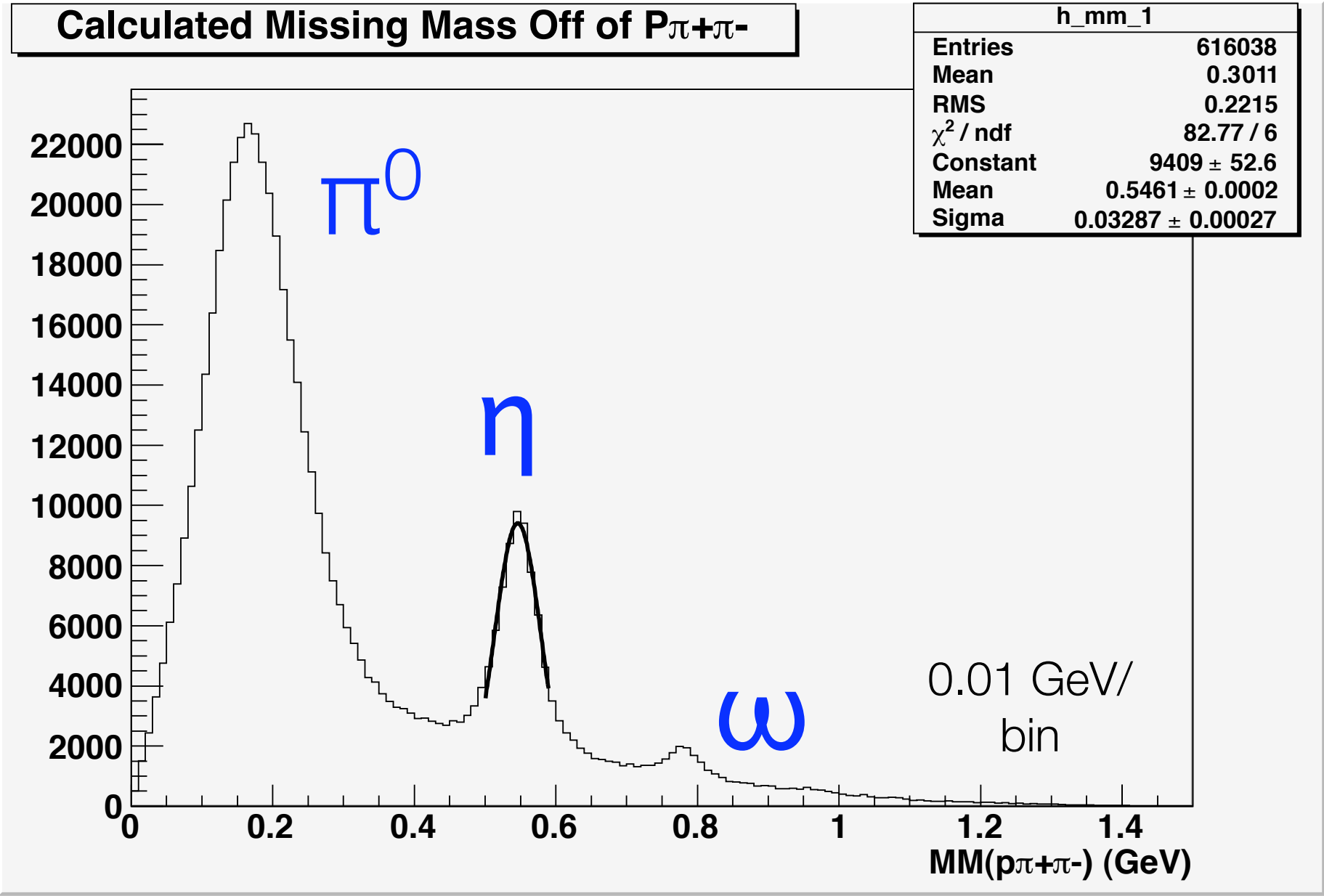
2γ: Data Selection

$$\left(\frac{(2\gamma) - 0.5578}{.13}\right)^2 + \left(\frac{MM^2 - 0.296}{.08}\right)^2 < 1$$



2 γ : Data Selection

- data
 - η :
 - mass 0.5461 GeV
 - σ 0.03287 GeV
 - Δ^{++} :
 - mass 1.222 GeV
 - σ 0.0478 GeV

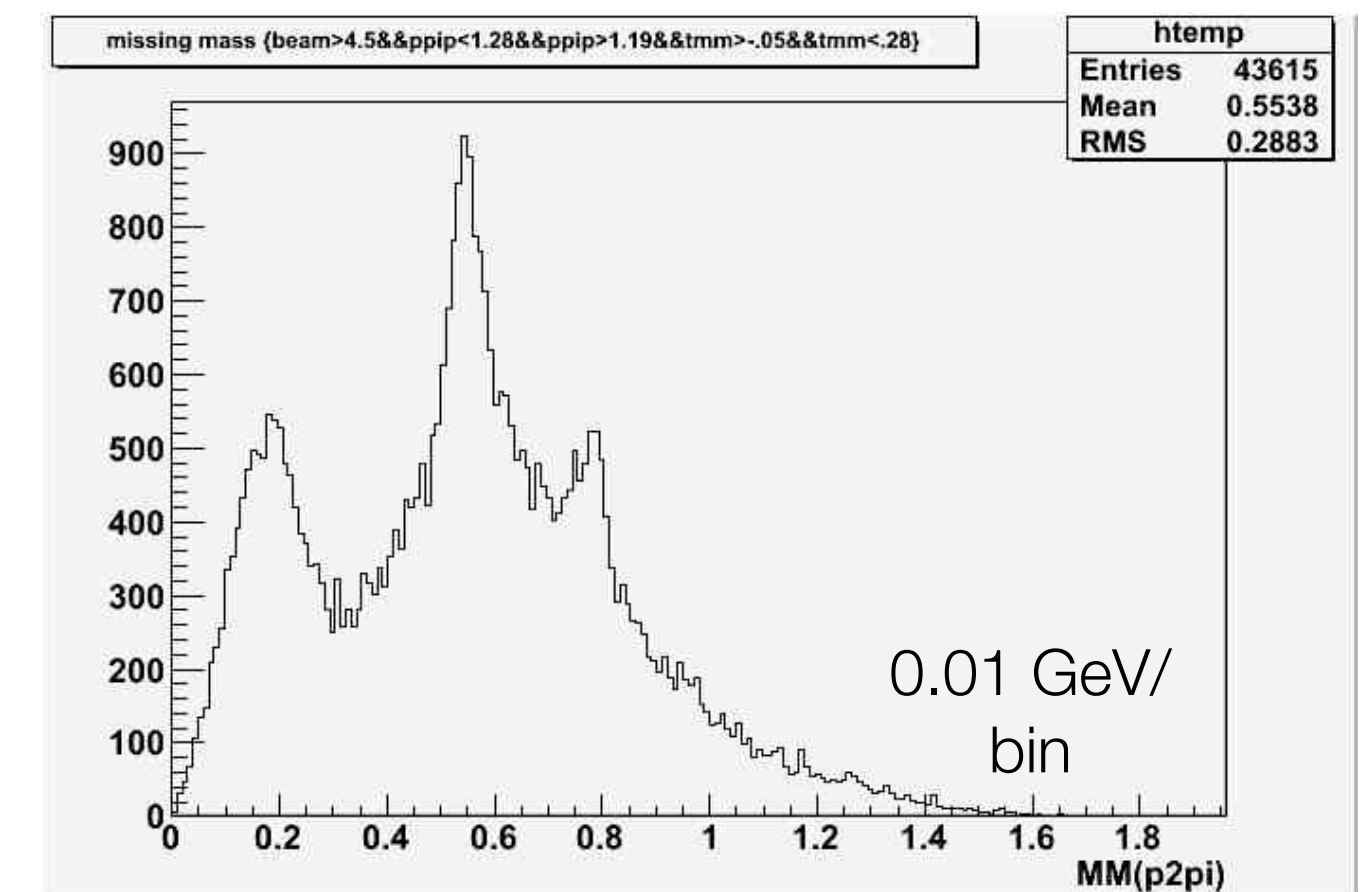
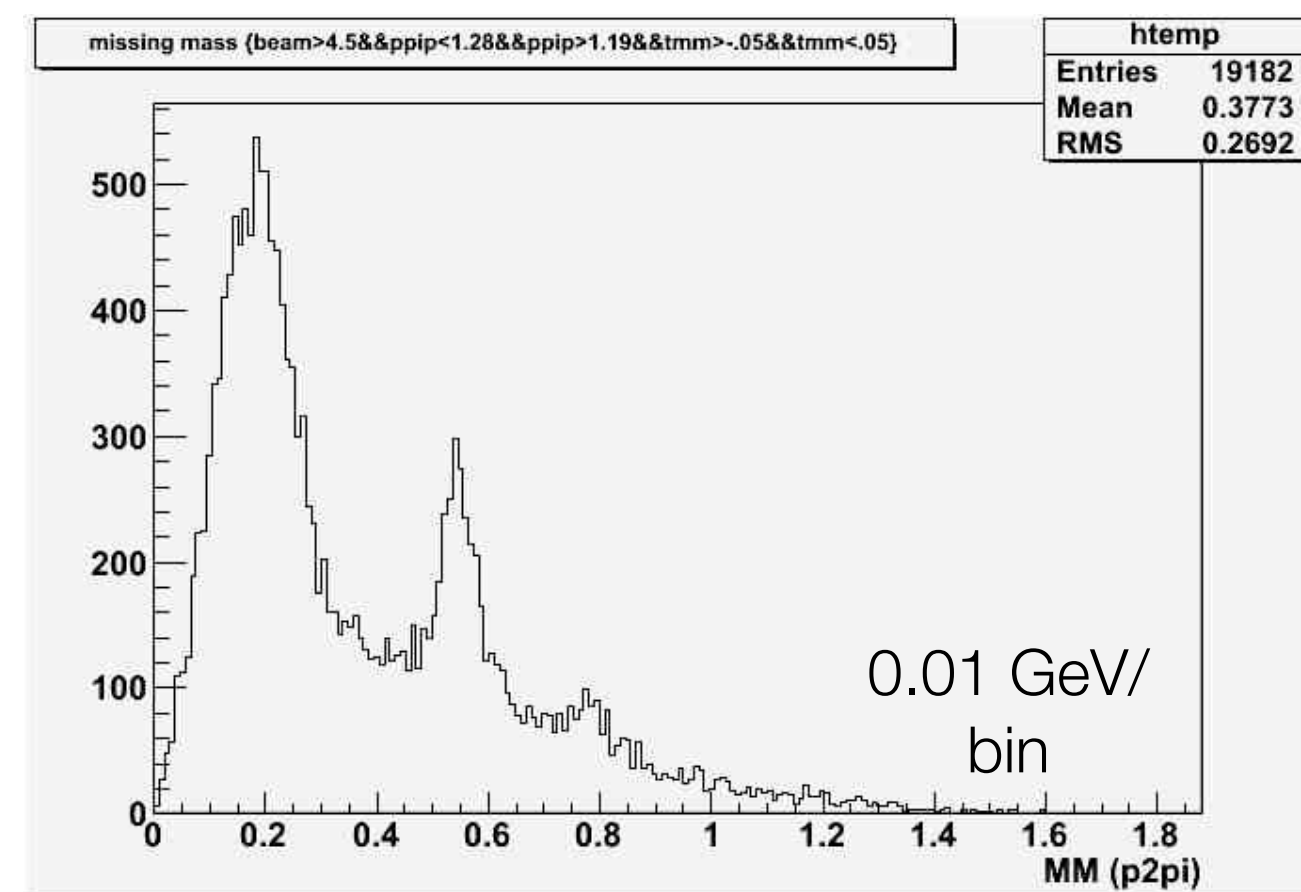
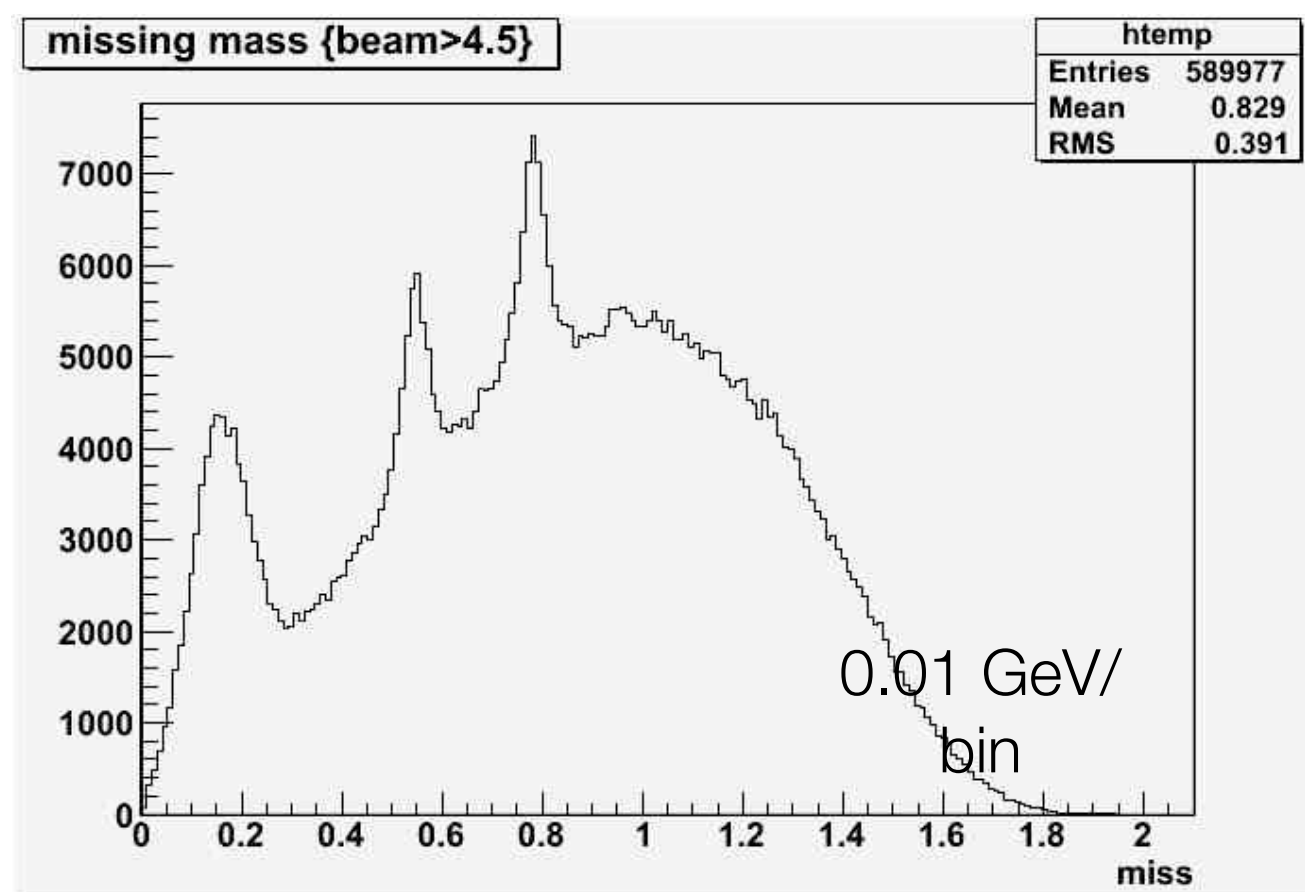
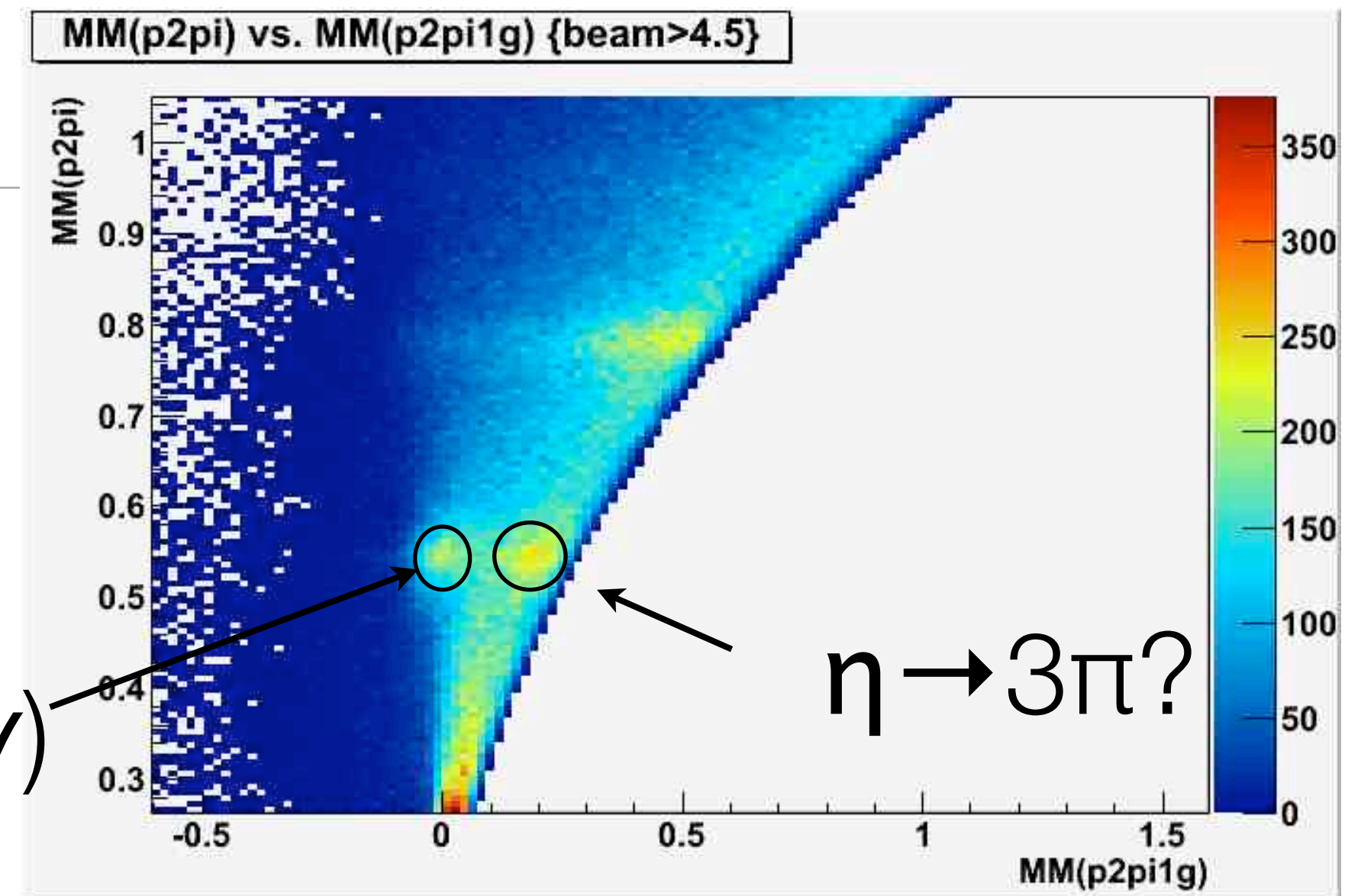


1 γ : Data Selection

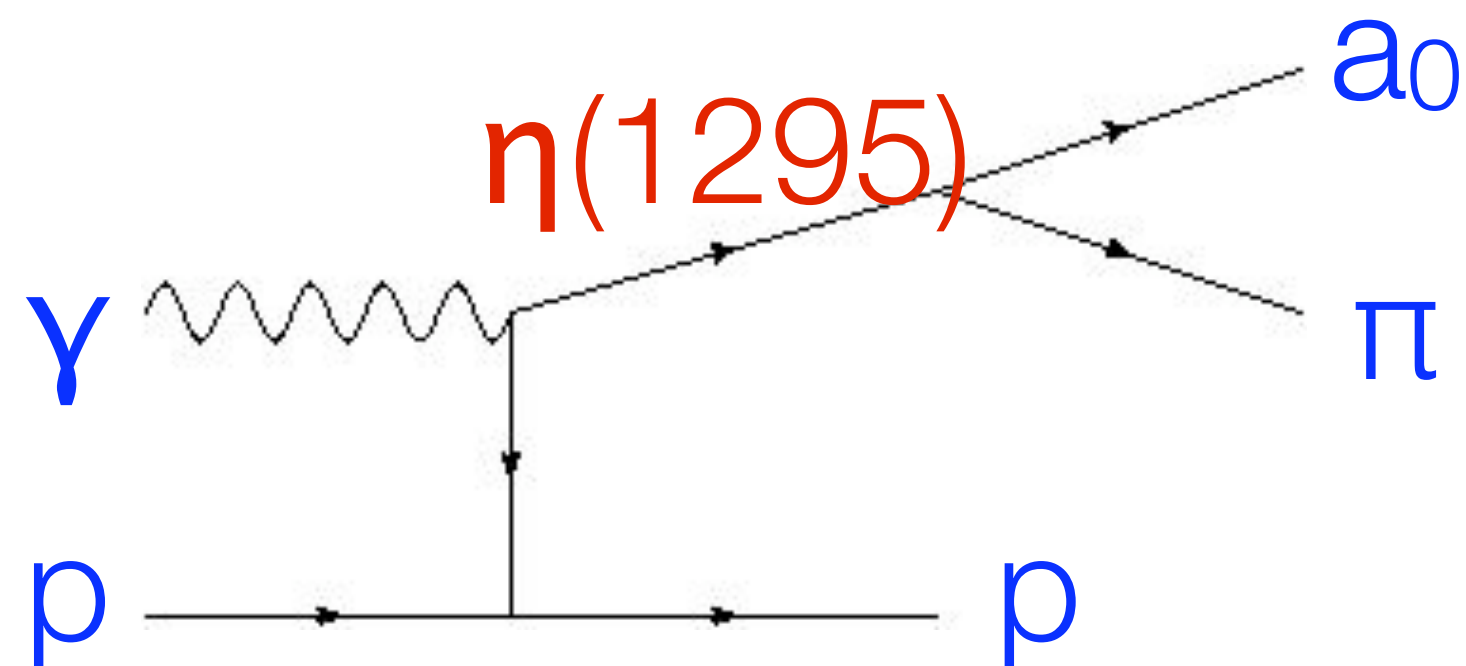
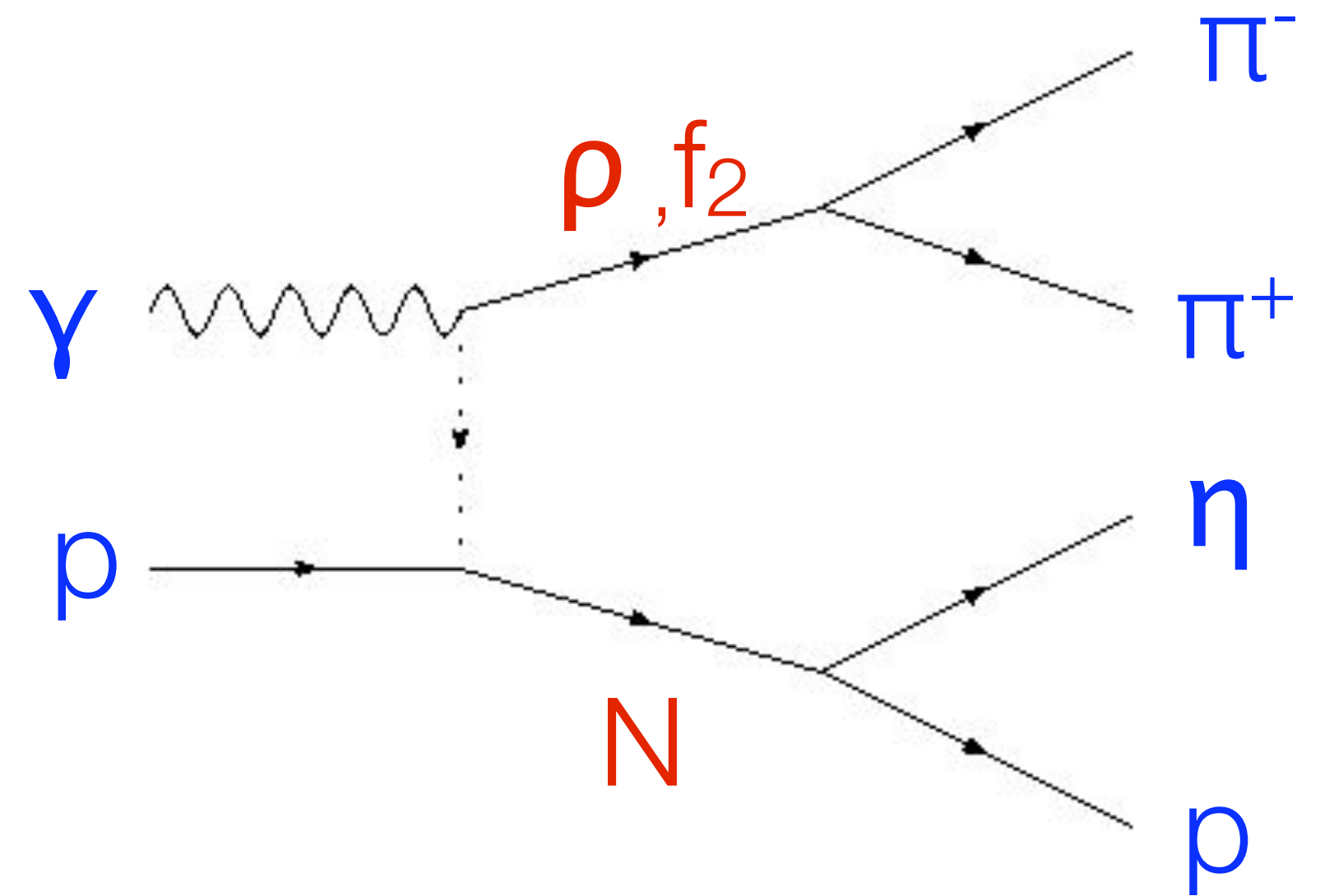
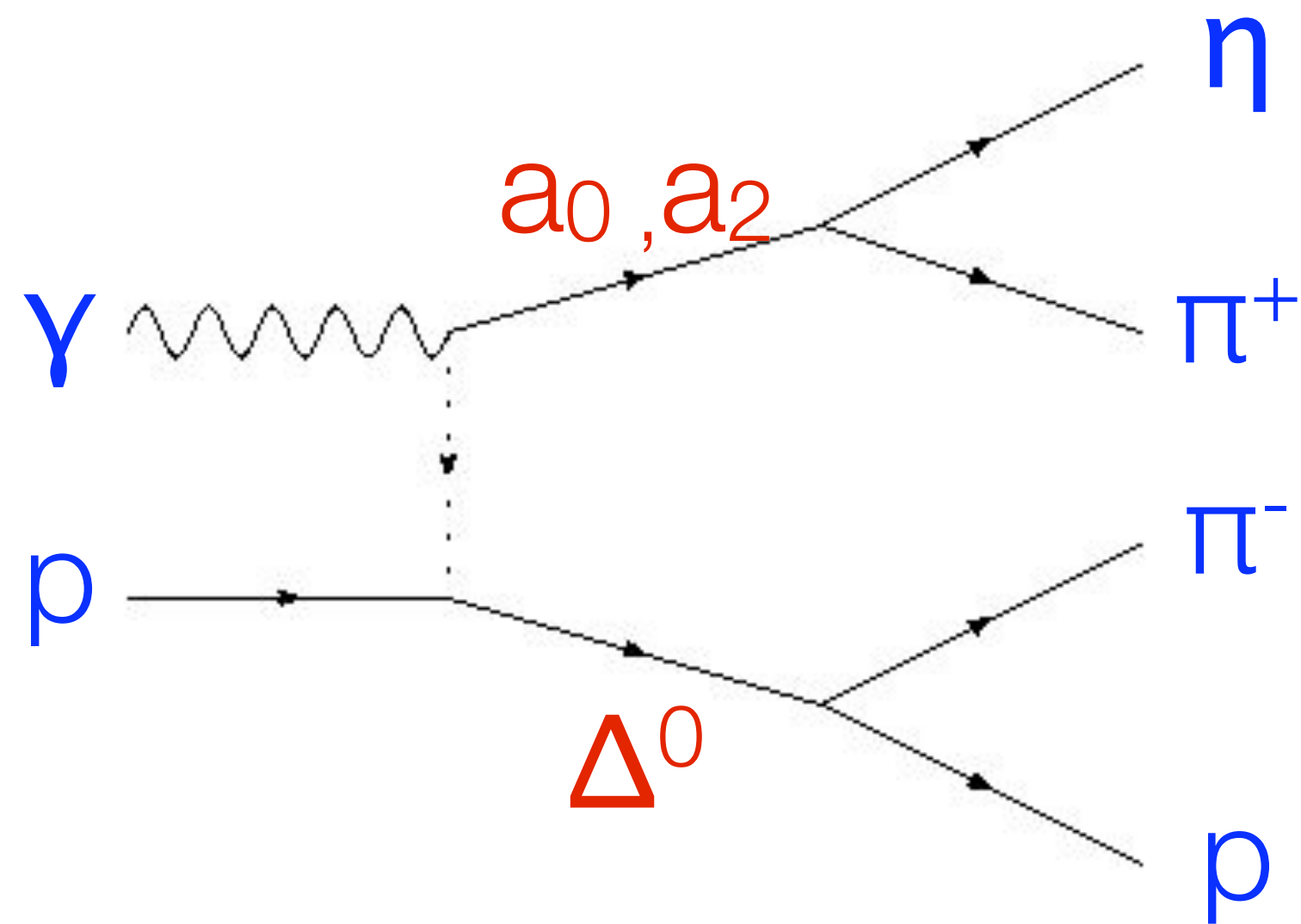
- plots include 25% of data
- photons within beam bucket but nothing to compare it to directly

$\eta \rightarrow \gamma(\gamma)$

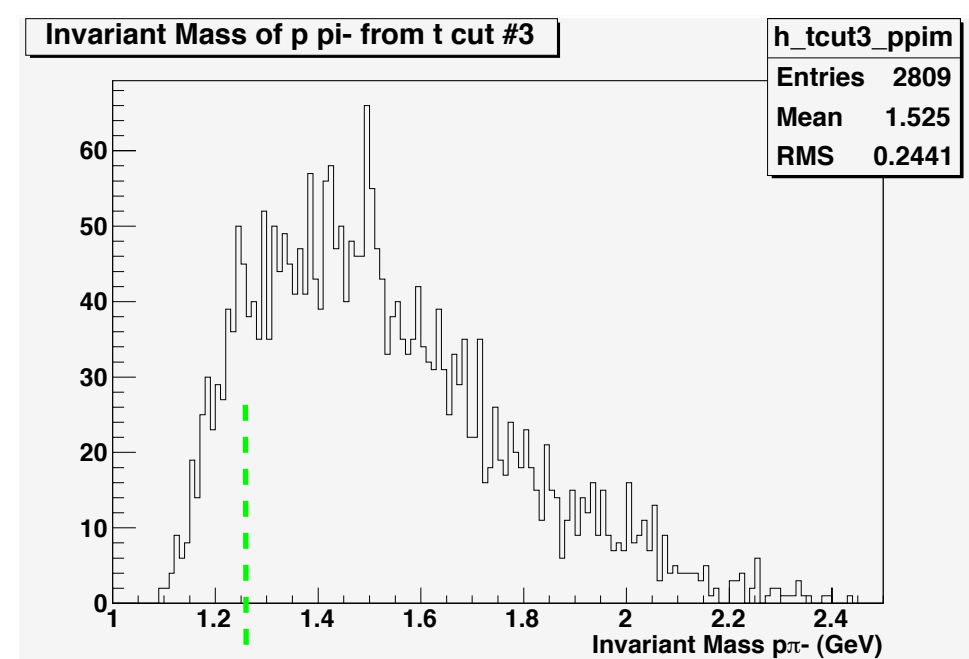
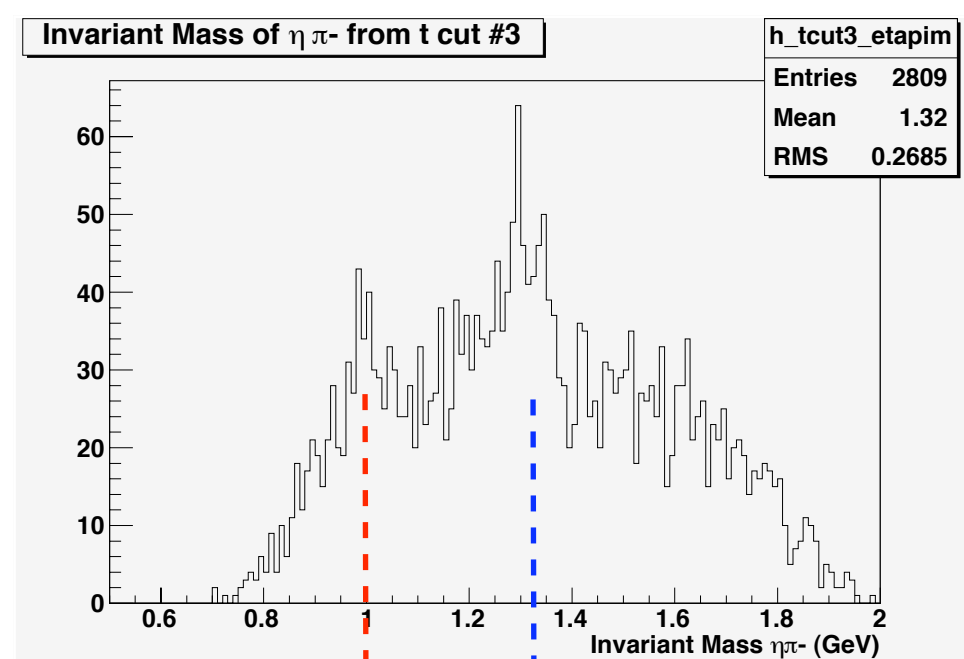
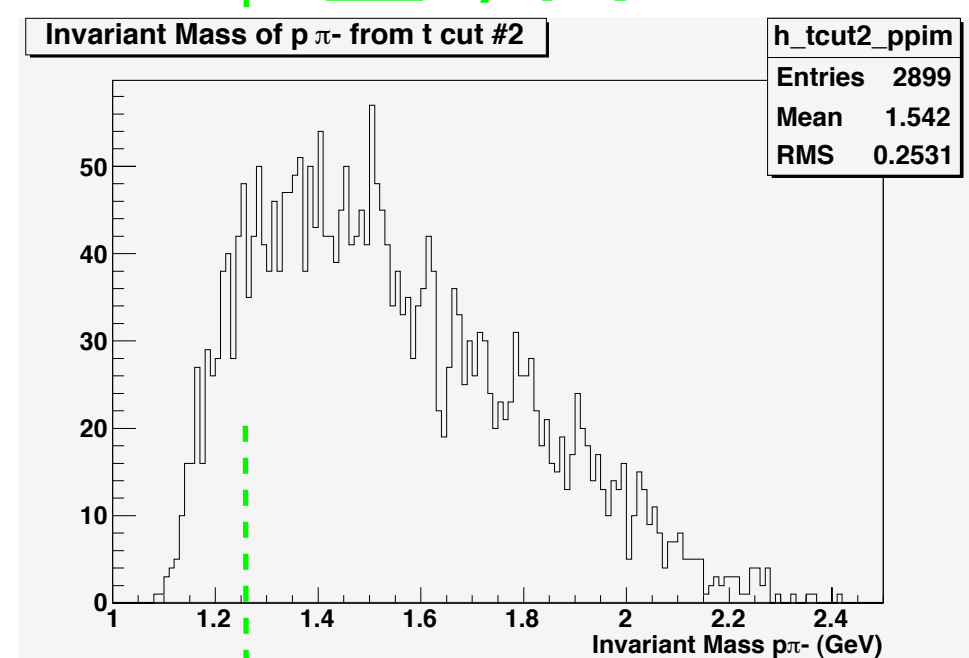
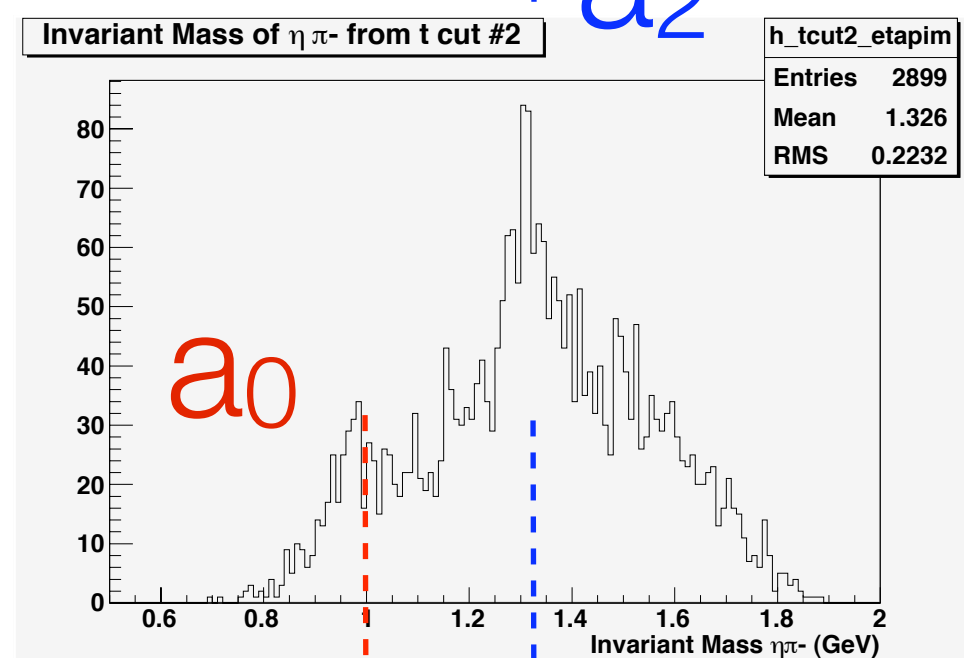
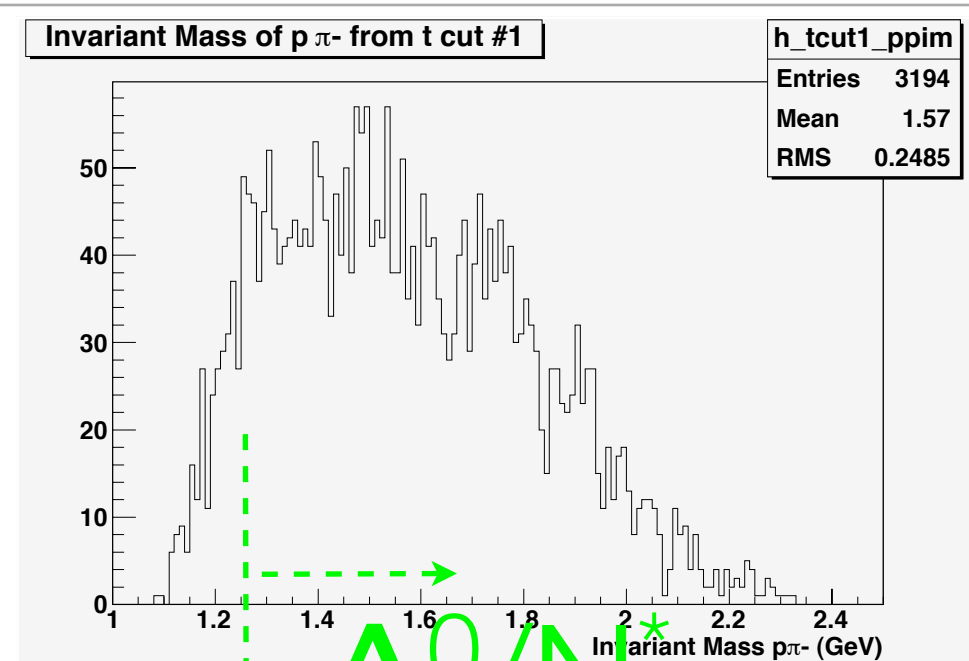
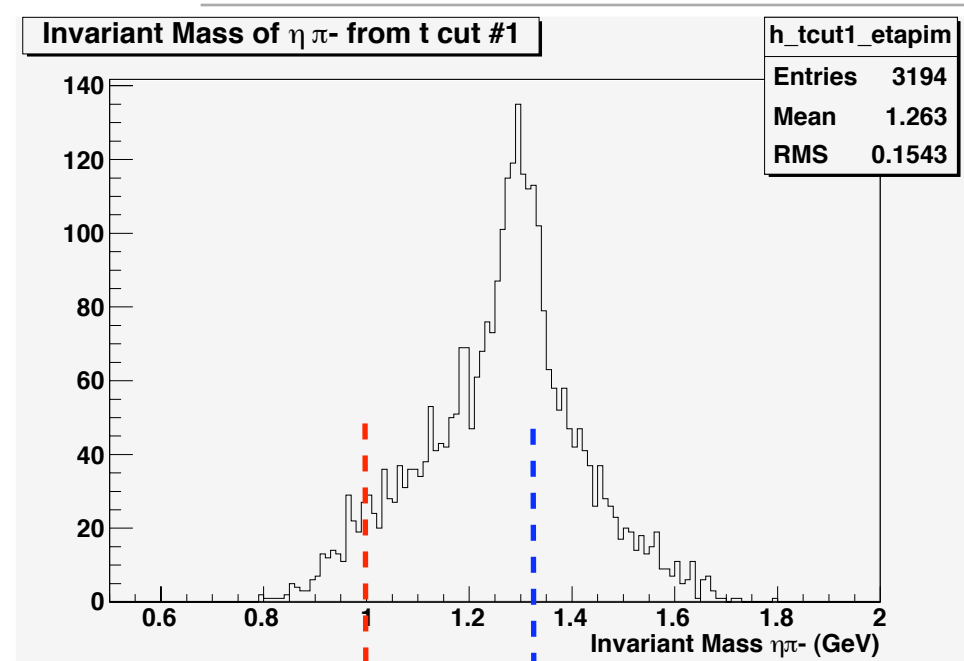
$\eta \rightarrow 3\pi?$



Possible Interference Channels



Momentum transfer



- Δ^0/N^{*0} interference dependent on t range.

- 3 t ranges

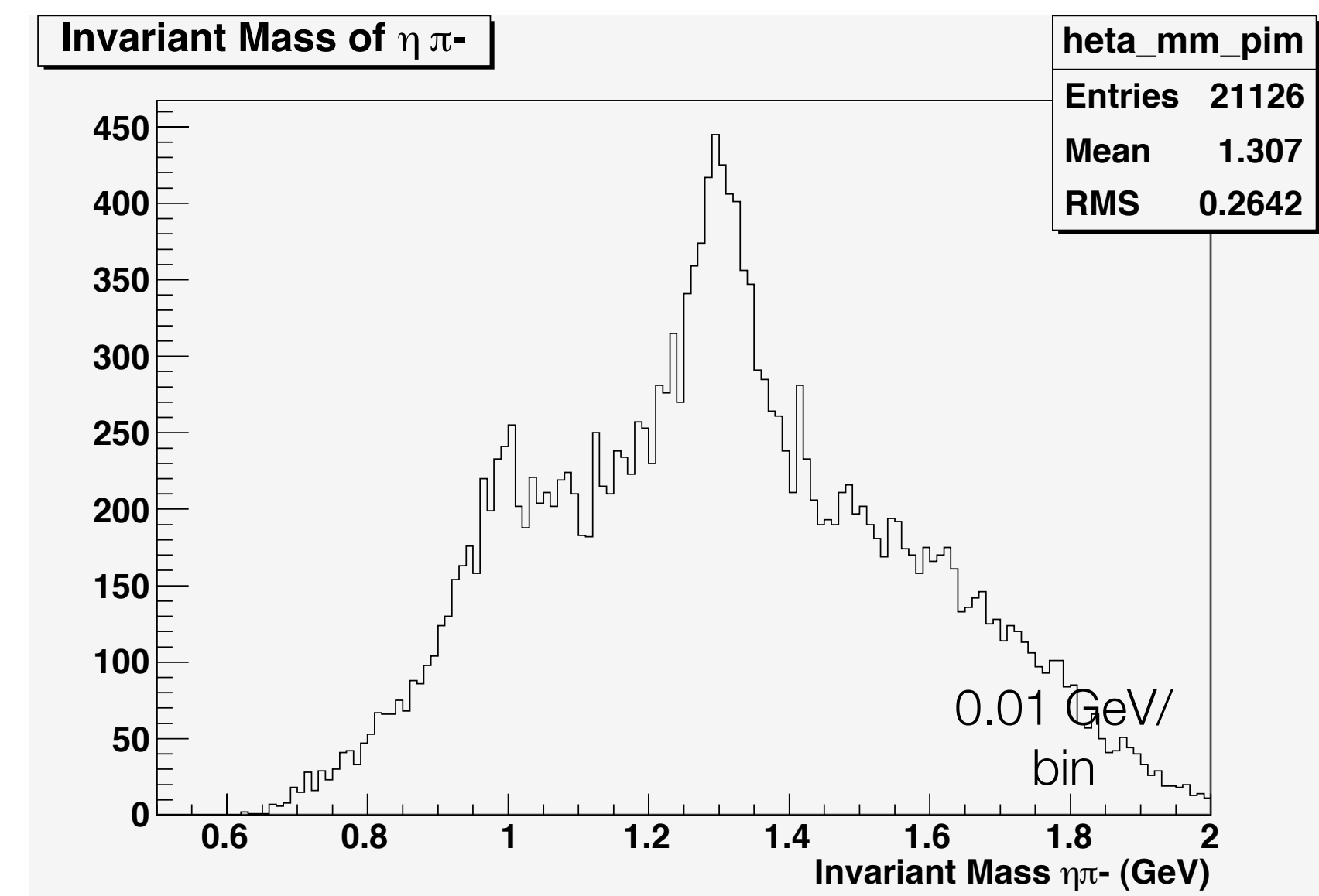
- $-t < 0.5 \text{ GeV}^2$

- $0.5 \text{ GeV}^2 < -t < 0.75 \text{ GeV}^2$

- $0.75 \text{ GeV}^2 < -t < 1.0 \text{ GeV}^2$

Moments Analysis, PWA

and future plans



Moments

- ϕ_i, θ_i are the Gottfried-Jackson angles for the η in the $\eta\pi^-$ rest frame
- L and M are the degree and order of the spherical harmonic
- n is in the number of events in a given $M(\eta\pi^-)$, E_γ , and t bin

$$H(LM) = \sum_i^n D_{M0}^L(\phi_i, \theta_i, 0)$$

- using moments as a precursor to PWA
- depending on LM combinations, can show sensitivity to subsets
- directly derived from data

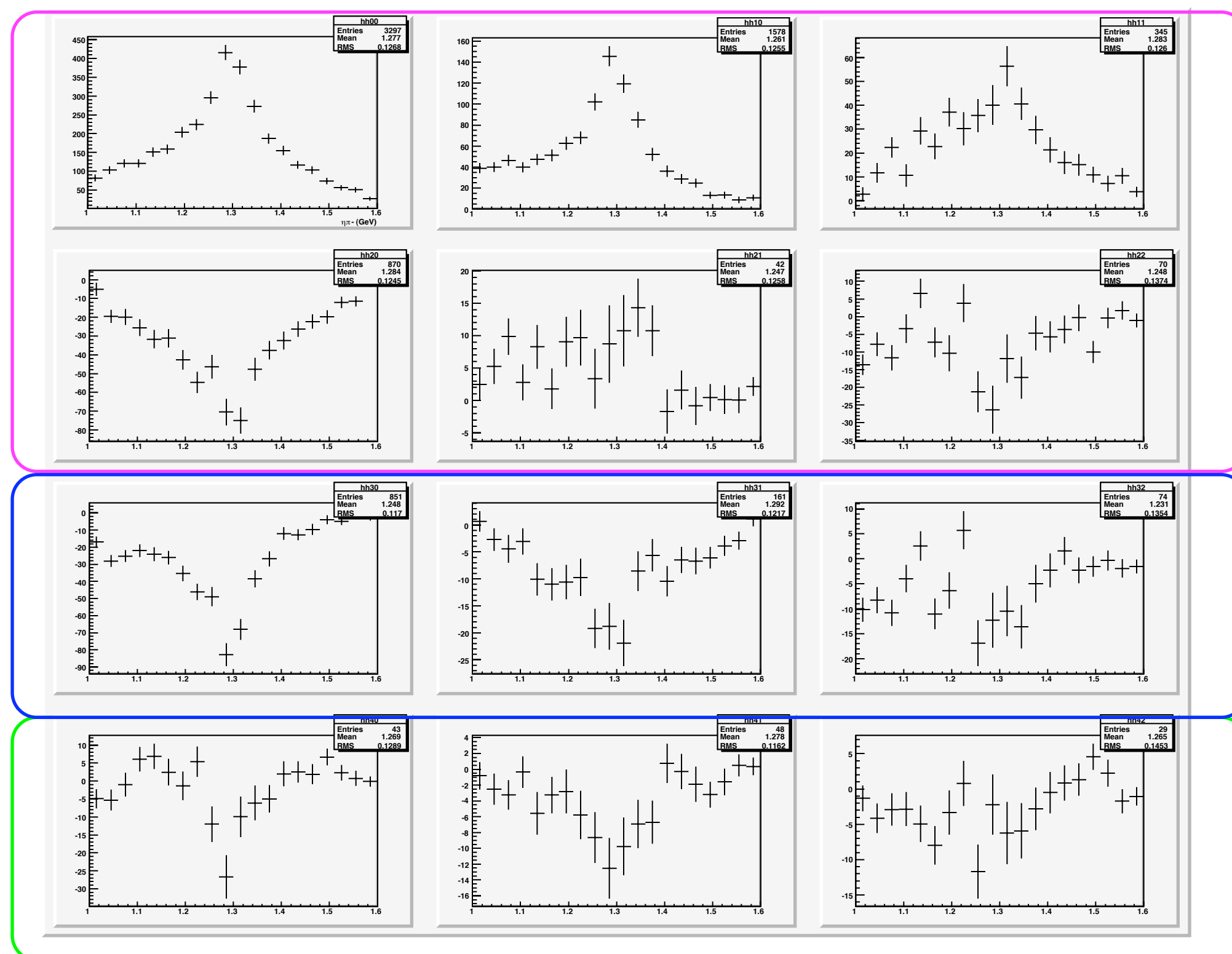
$$H(00) = |S_0|^2 + |P_0|^2 + |P_-|^2 + |D_0|^2 + |D_-|^2 + |P_+|^2 + |D_+|^2$$

$$H(10) = \frac{2}{\sqrt{3}}S_0P_0^* + \frac{4}{\sqrt{15}}P_0D_0^* + \frac{2}{\sqrt{5}}P_-D_-^* + \frac{2}{\sqrt{5}}P_+D_+^* \quad \dots \quad H(42) = \frac{\sqrt{10}}{21}|D_-|^2 - \frac{\sqrt{10}}{21}|D_+|^2$$

Moments and MC

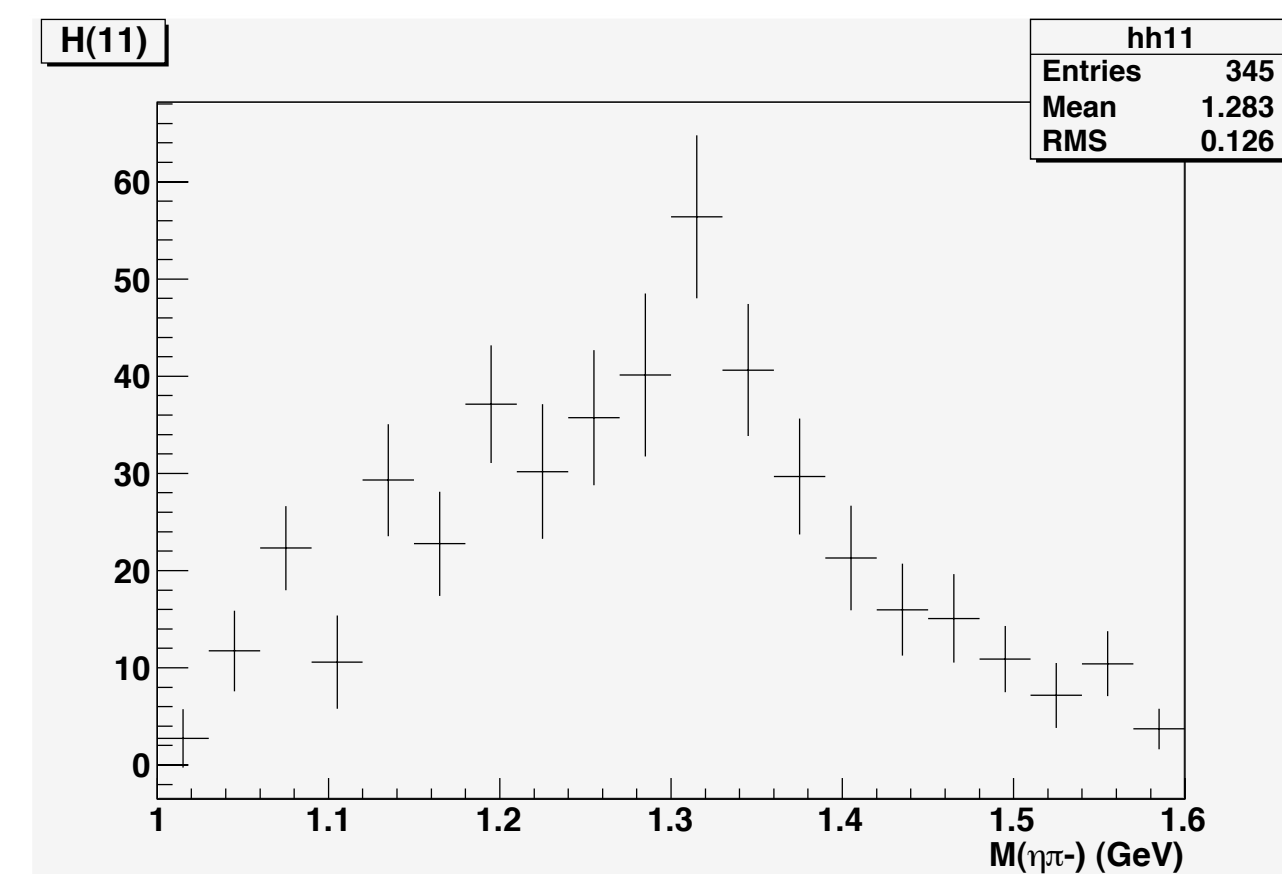
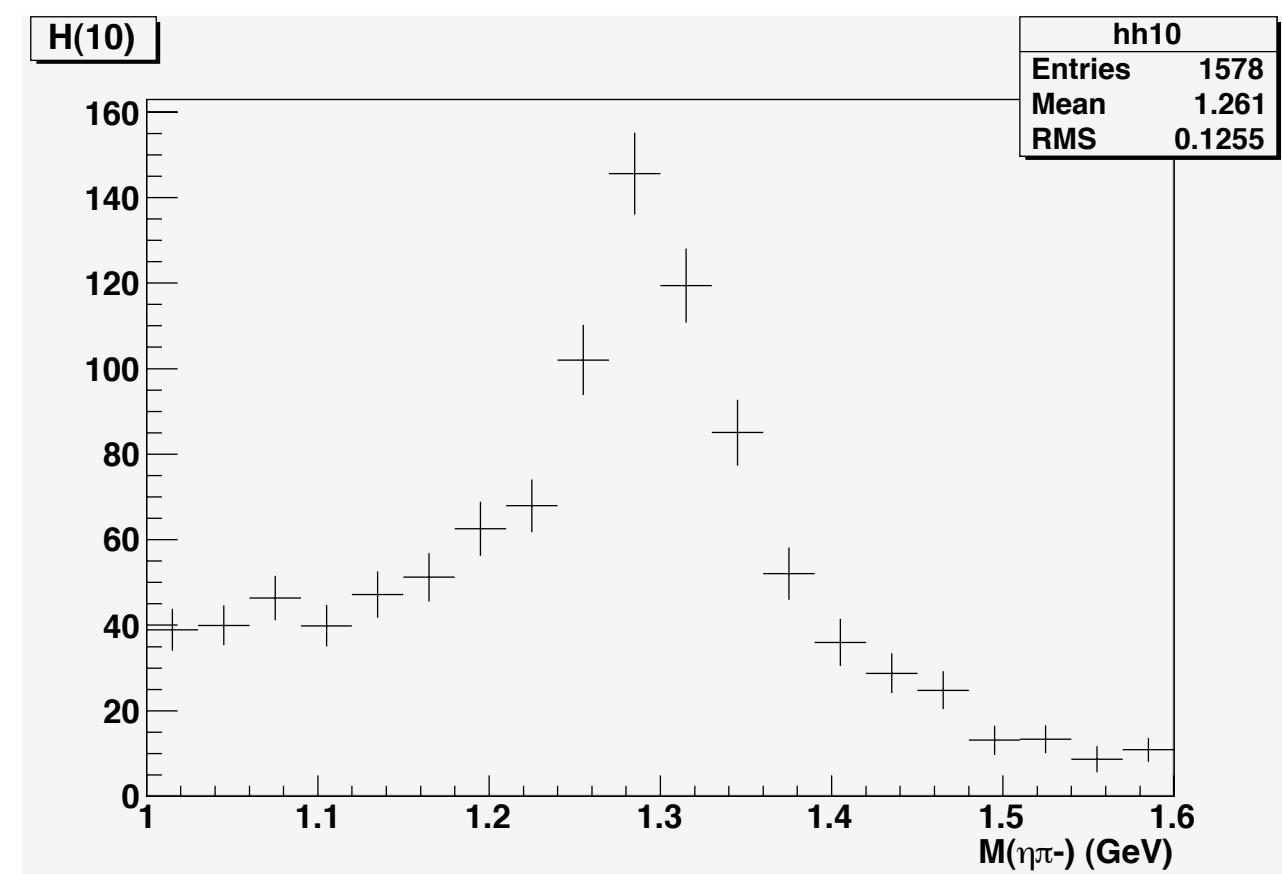
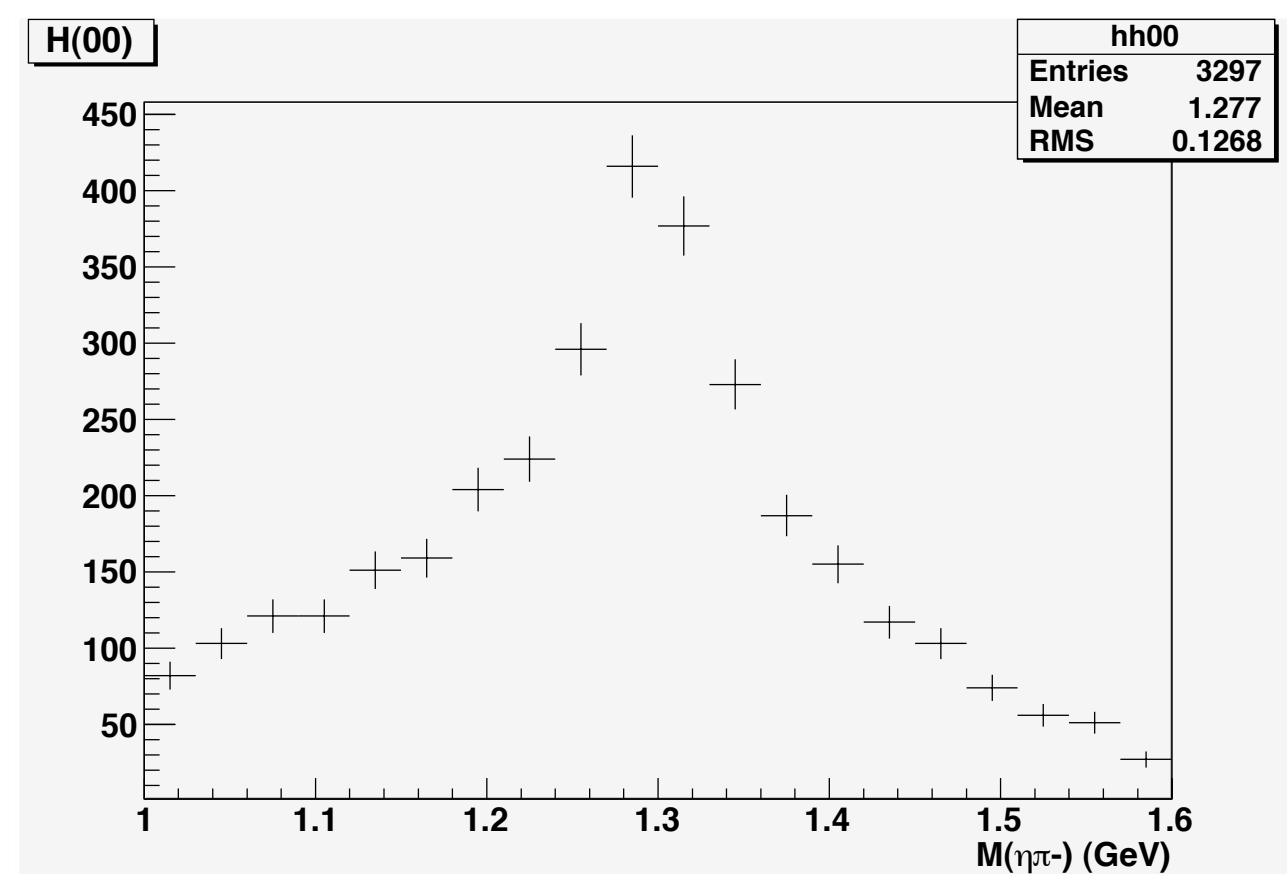
- raw moments from 99%
- for $-t < 0.5 \text{ GeV}^2$

- have working MC, but 2γ inv. mass is 1 GeV lower than seen in data. exploring GPP and GSIM handling of EC



- MC generates $\gamma + p \rightarrow \Delta^{++} + a_2$
 - $\Delta^{++} \rightarrow p + \pi^+$
 - $a_2 \rightarrow \pi^- + \eta$
 - $\eta \rightarrow 2\gamma$

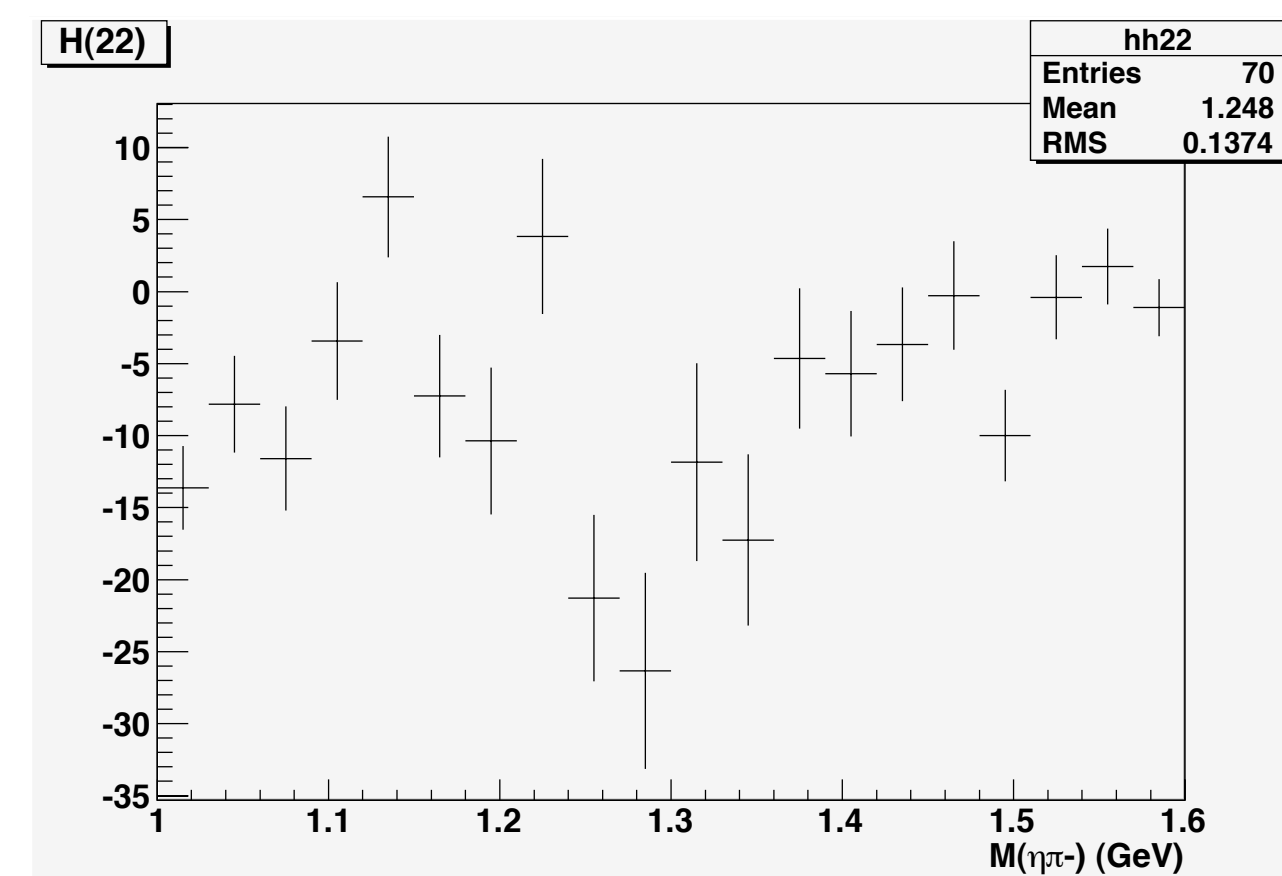
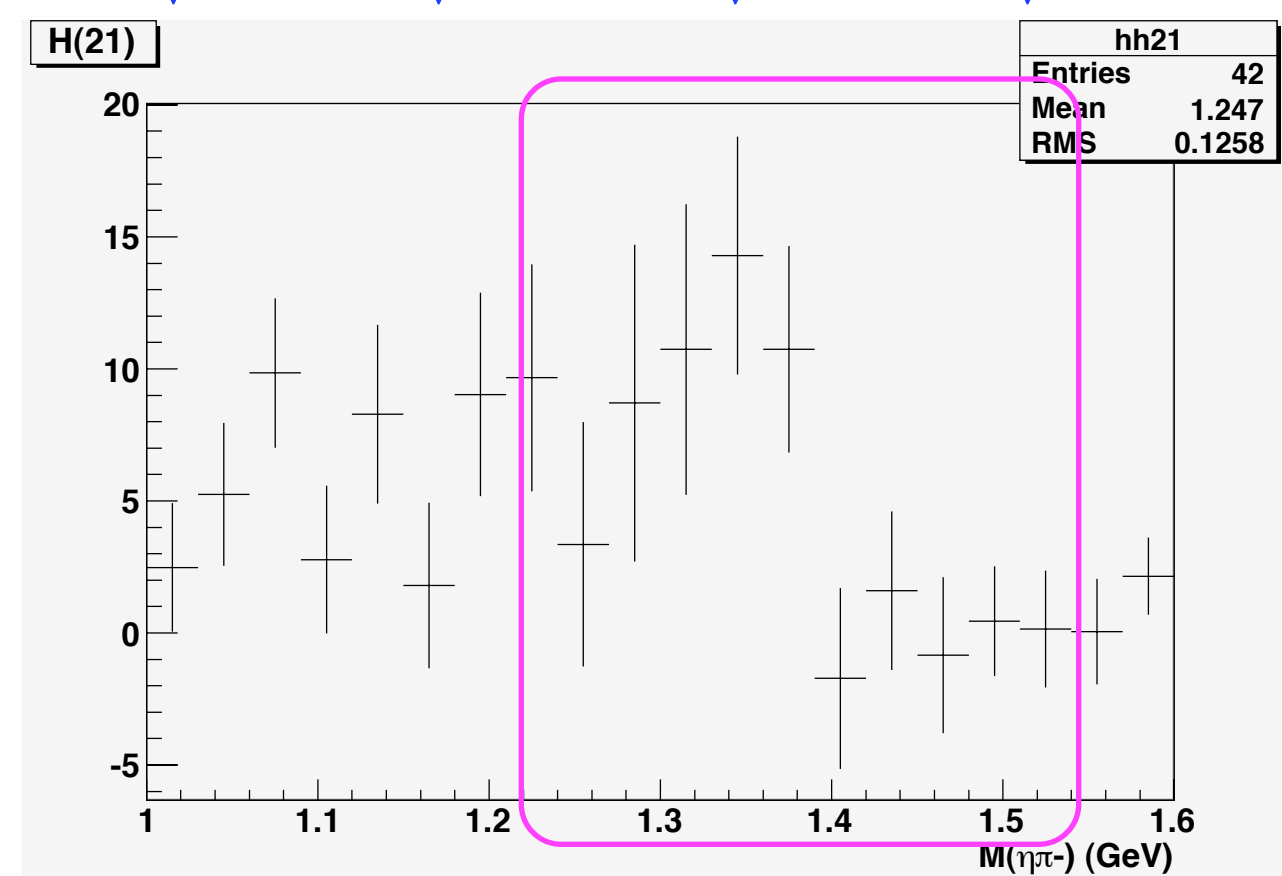
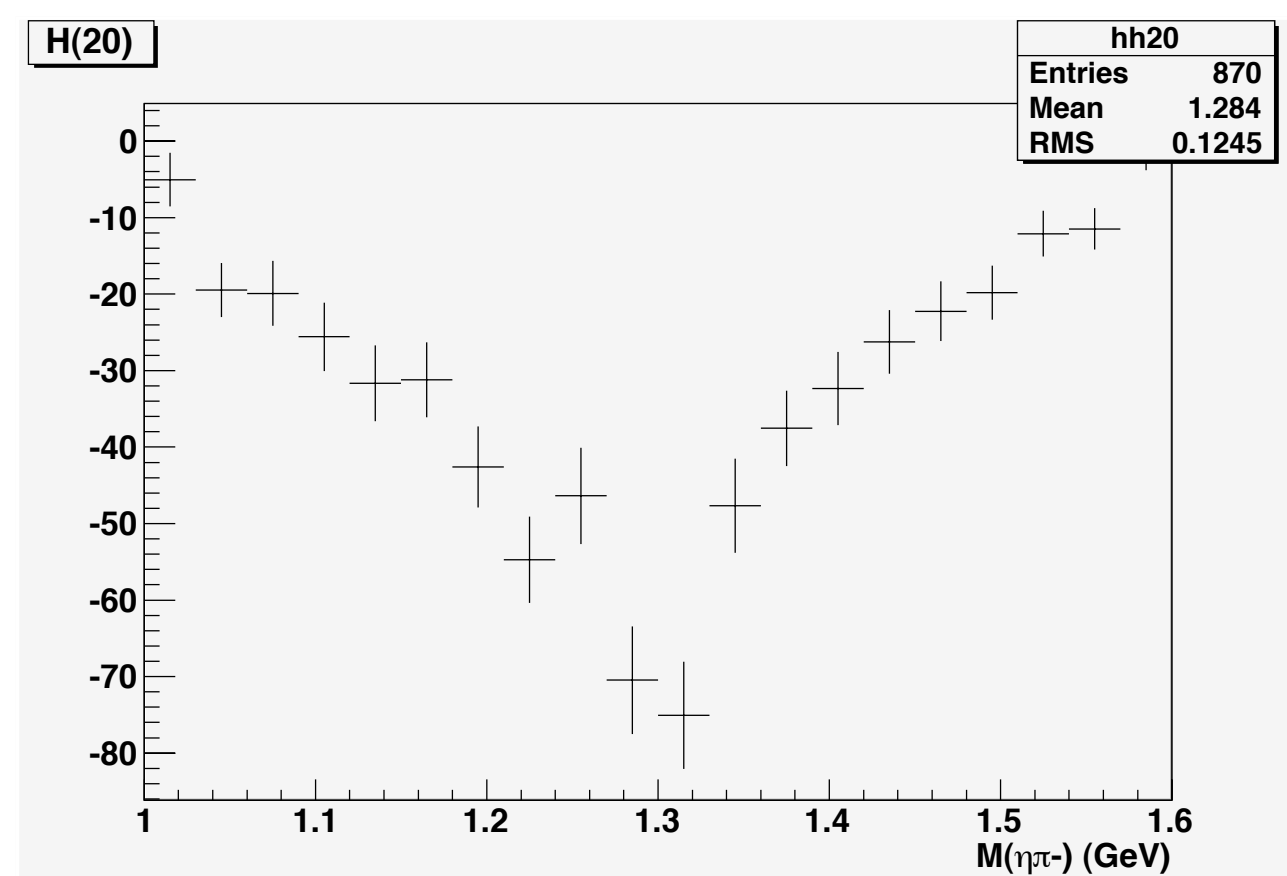
Moments - P and D Wave interference



$$H(00) = |S_0|^2 + |P_0|^2 + |P_-|^2 + |D_0|^2 + |D_-|^2 + |P_+|^2 + |D_+|^2$$

$$H(10) = \frac{2}{\sqrt{3}} S_0 P_0^* + \frac{4}{\sqrt{15}} P_0 D_0^* + \frac{2}{\sqrt{5}} P_- D_-^* + \frac{2}{\sqrt{5}} P_+ D_+^*$$

$$H(11) = \frac{2}{\sqrt{6}} S_0 P_-^* + \frac{2}{\sqrt{10}} P_0 D_-^* - \frac{2}{\sqrt{30}} P_- D_0^*$$



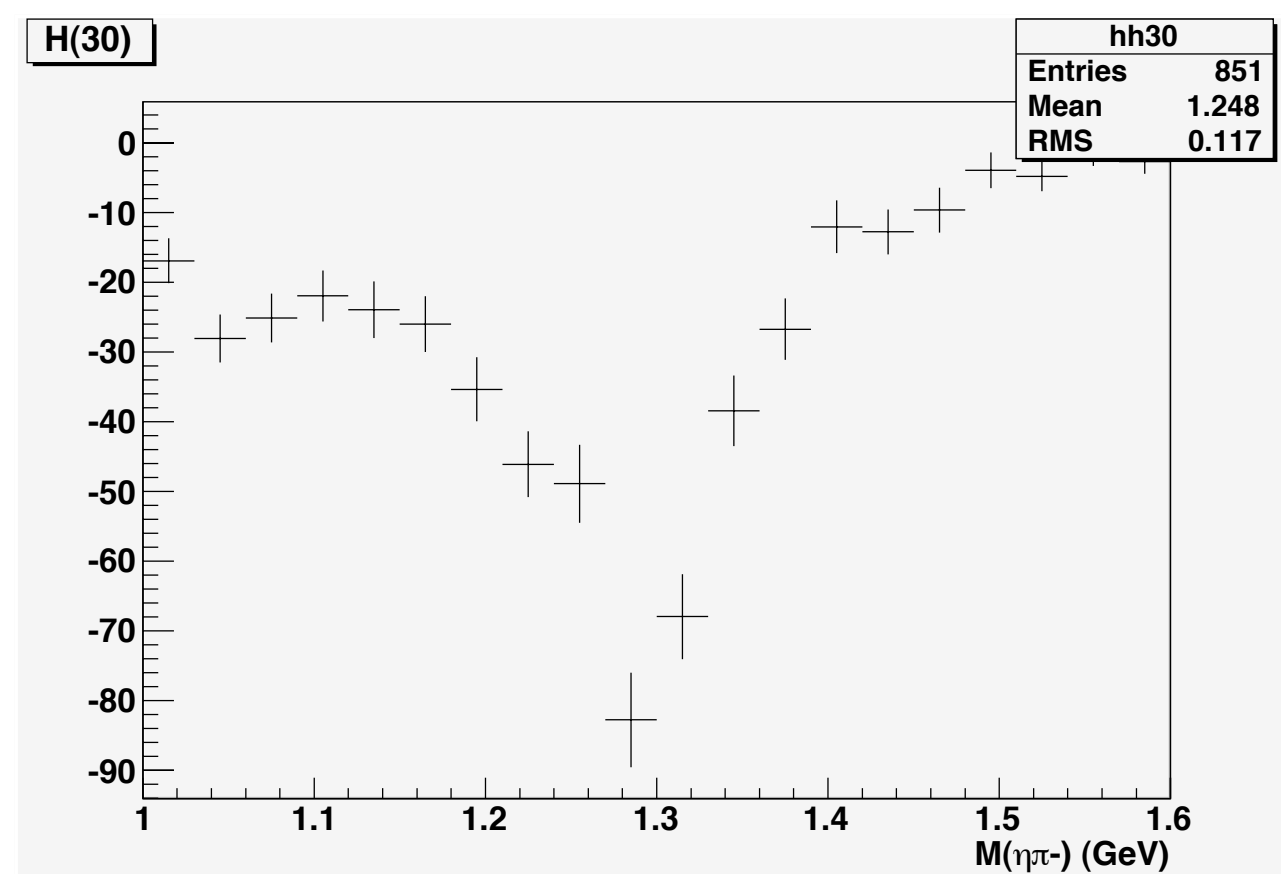
$$H(20) = \frac{2}{\sqrt{5}} S_0 D_0^* + \frac{2}{5} |P_0|^2 - \frac{1}{5} |P_-|^2 - \frac{1}{5} |P_+|^2 + \frac{2}{7} |D_0|^2 + \frac{1}{7} |D_-|^2 + \frac{1}{7} |D_+|^2$$

$$H(21) = \frac{2}{\sqrt{10}} S_0 D_-^* + \frac{2}{5} \sqrt{\frac{3}{2}} P_0 P_-^* - \frac{2}{7\sqrt{2}} D_0 D_-^*$$

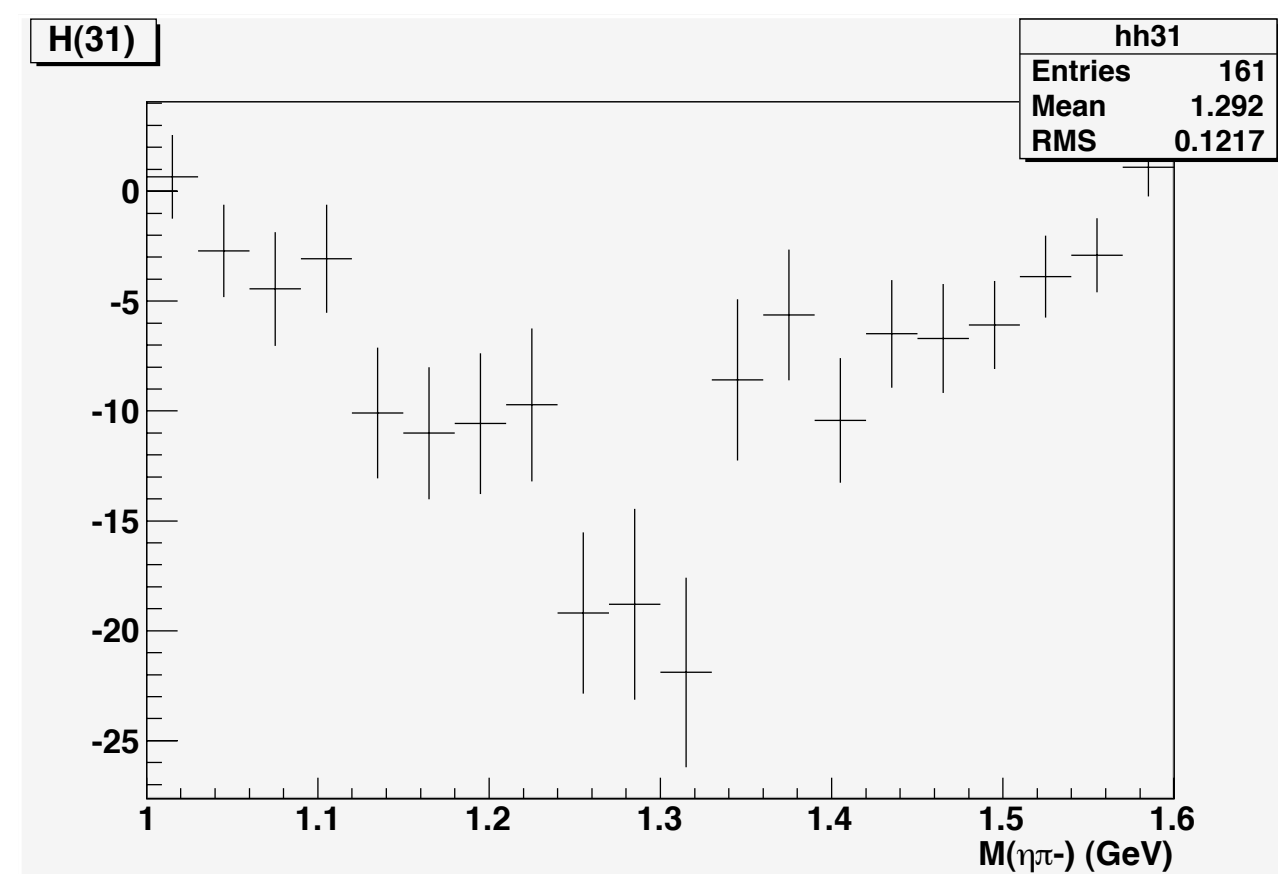
$$H(22) = \frac{1}{5} \sqrt{\frac{3}{2}} |P_-|^2 - \frac{1}{5} \sqrt{\frac{3}{2}} |P_+|^2 + \frac{1}{7} \sqrt{\frac{3}{2}} |D_-|^2 - \frac{1}{7} \sqrt{\frac{3}{2}} |D_+|^2$$

possible interference

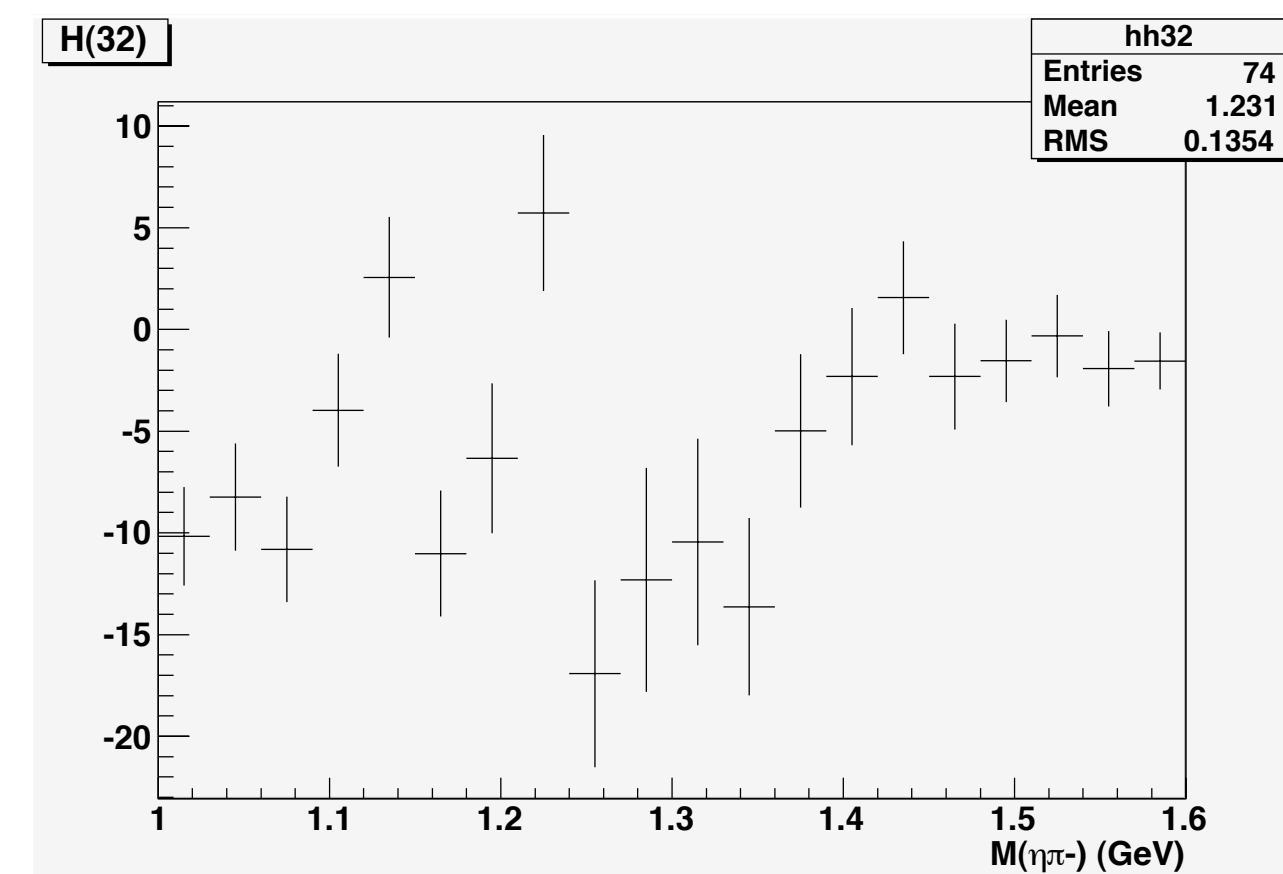
Moments



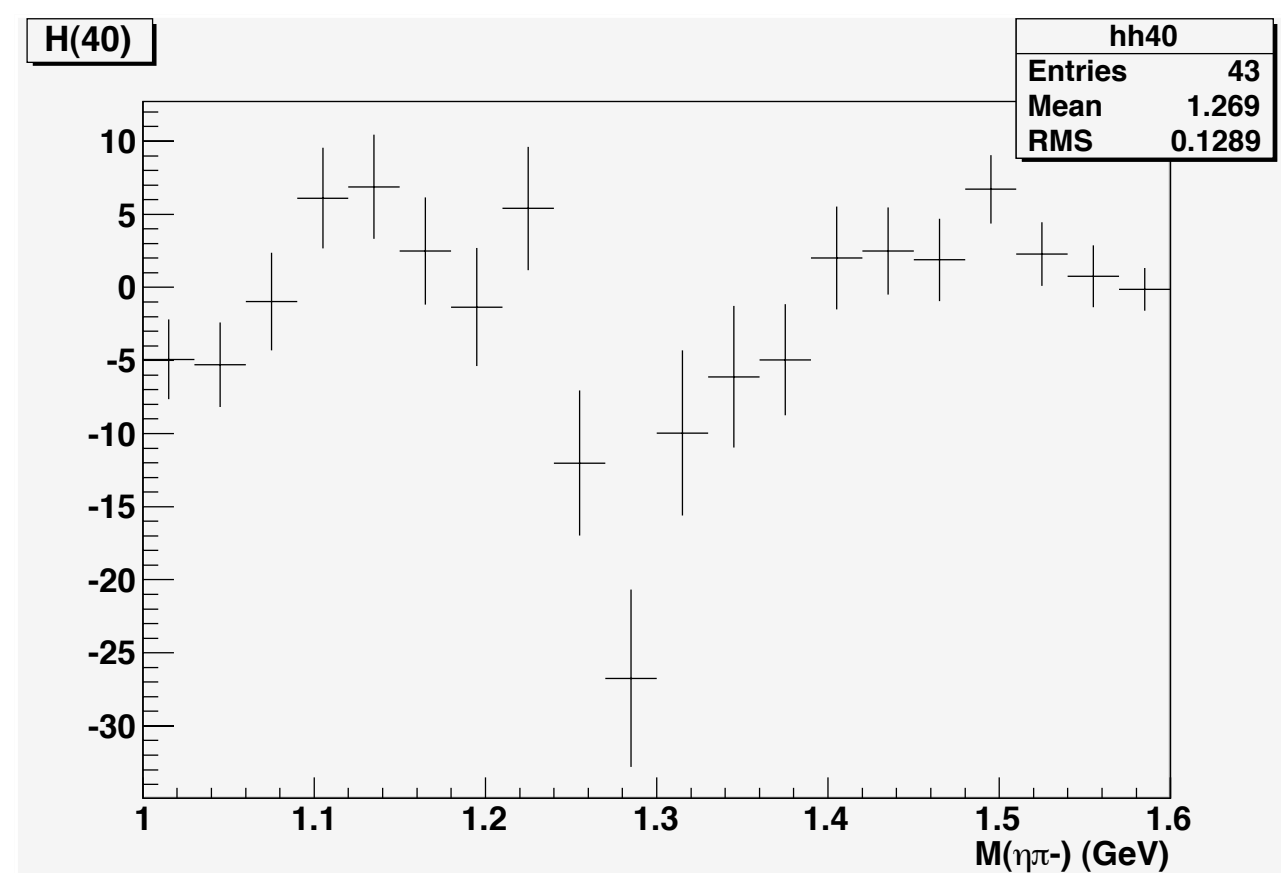
$$H(30) = \frac{6}{7}\sqrt{\frac{3}{5}}P_0D_0^* - \frac{6}{7\sqrt{5}}P_-D_-^* - \frac{6}{7\sqrt{5}}P_+D_+^*$$



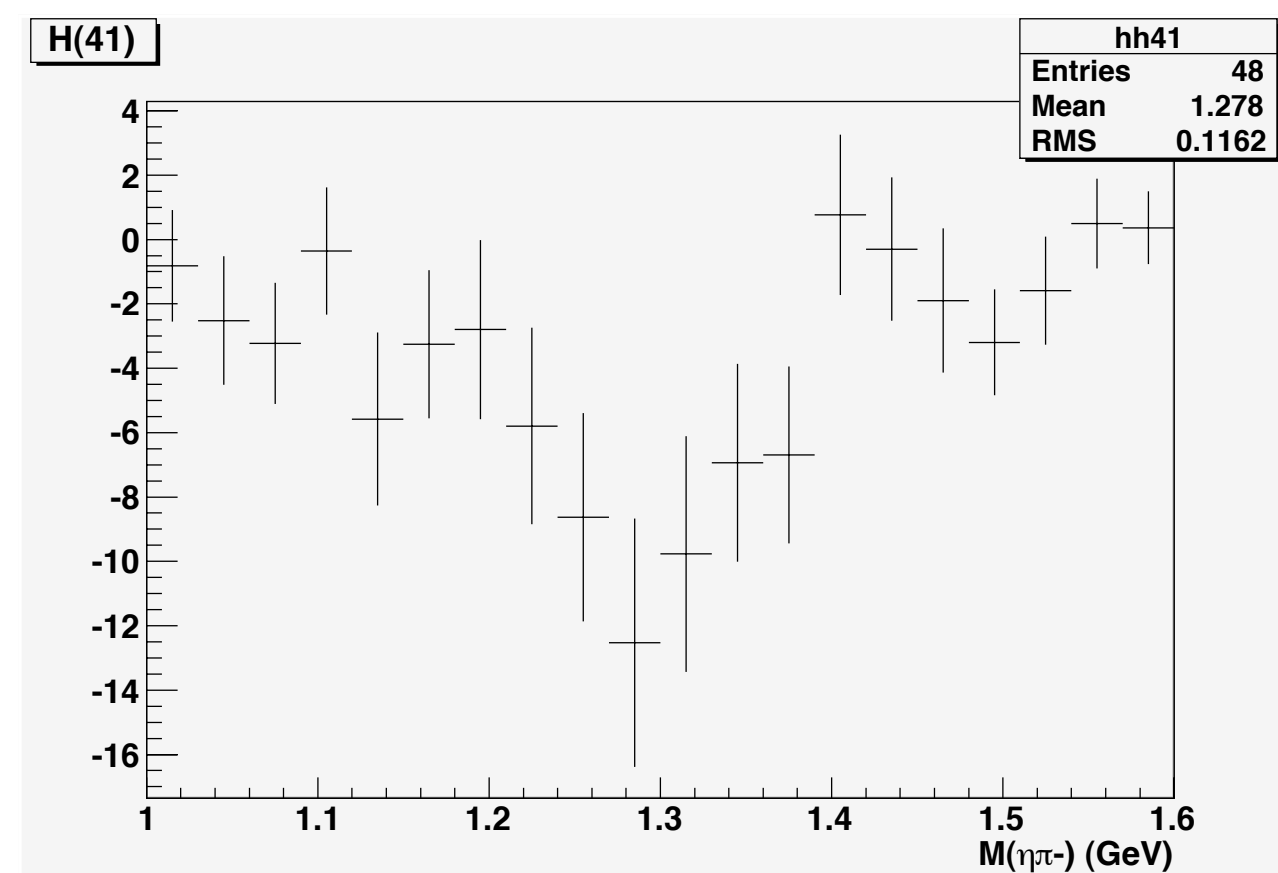
$$H(31) = \frac{4}{7}\sqrt{\frac{3}{5}}P_0D_-^* - \frac{6}{7\sqrt{5}}P_-D_0^*$$



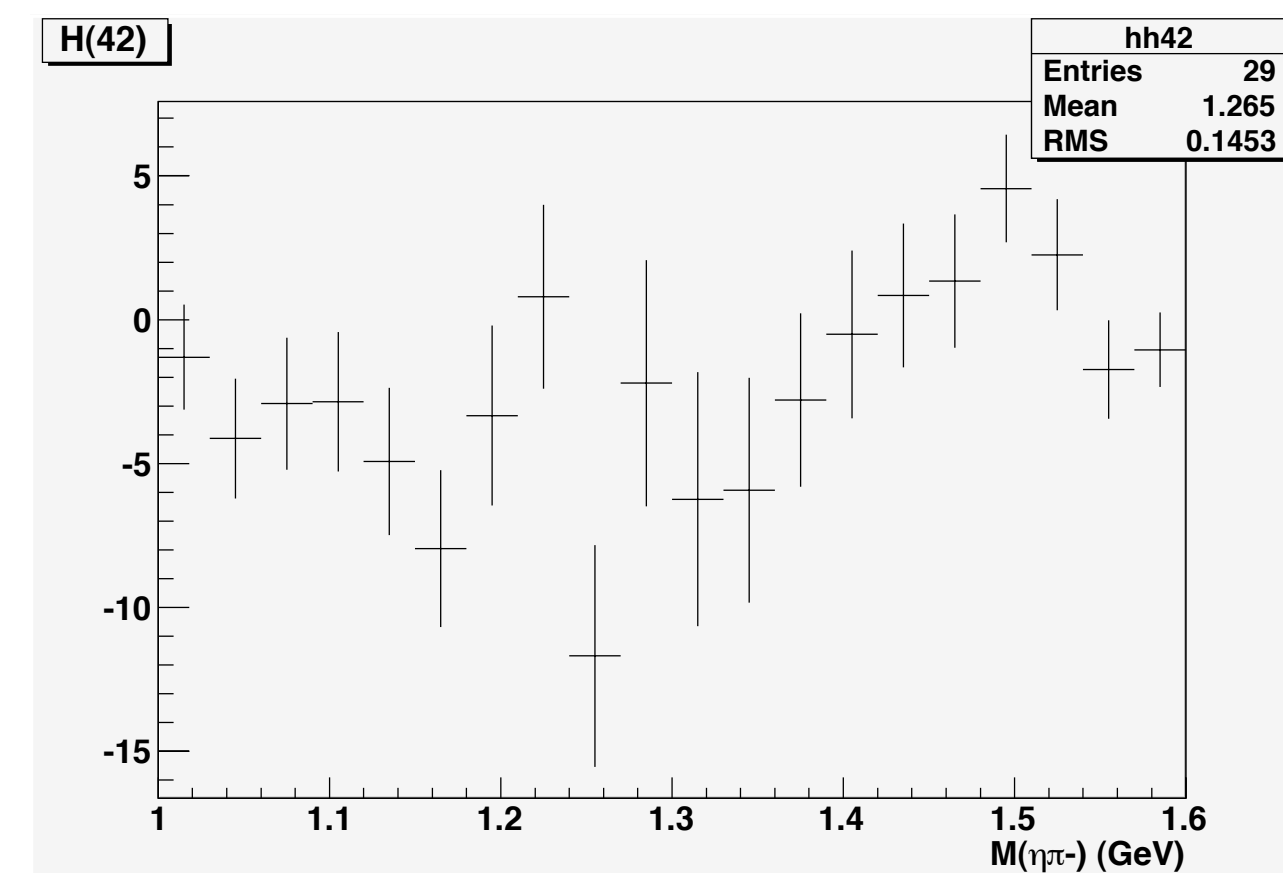
$$H(32) = \frac{2}{7}\sqrt{\frac{3}{2}}P_-D_-^* - \frac{2}{7}\sqrt{\frac{3}{2}}P_+D_+^*$$



$$H(40) = \frac{2}{7}|D_0|^2 - \frac{4}{21}|D_-|^2 - \frac{4}{21}|D_+|^2$$



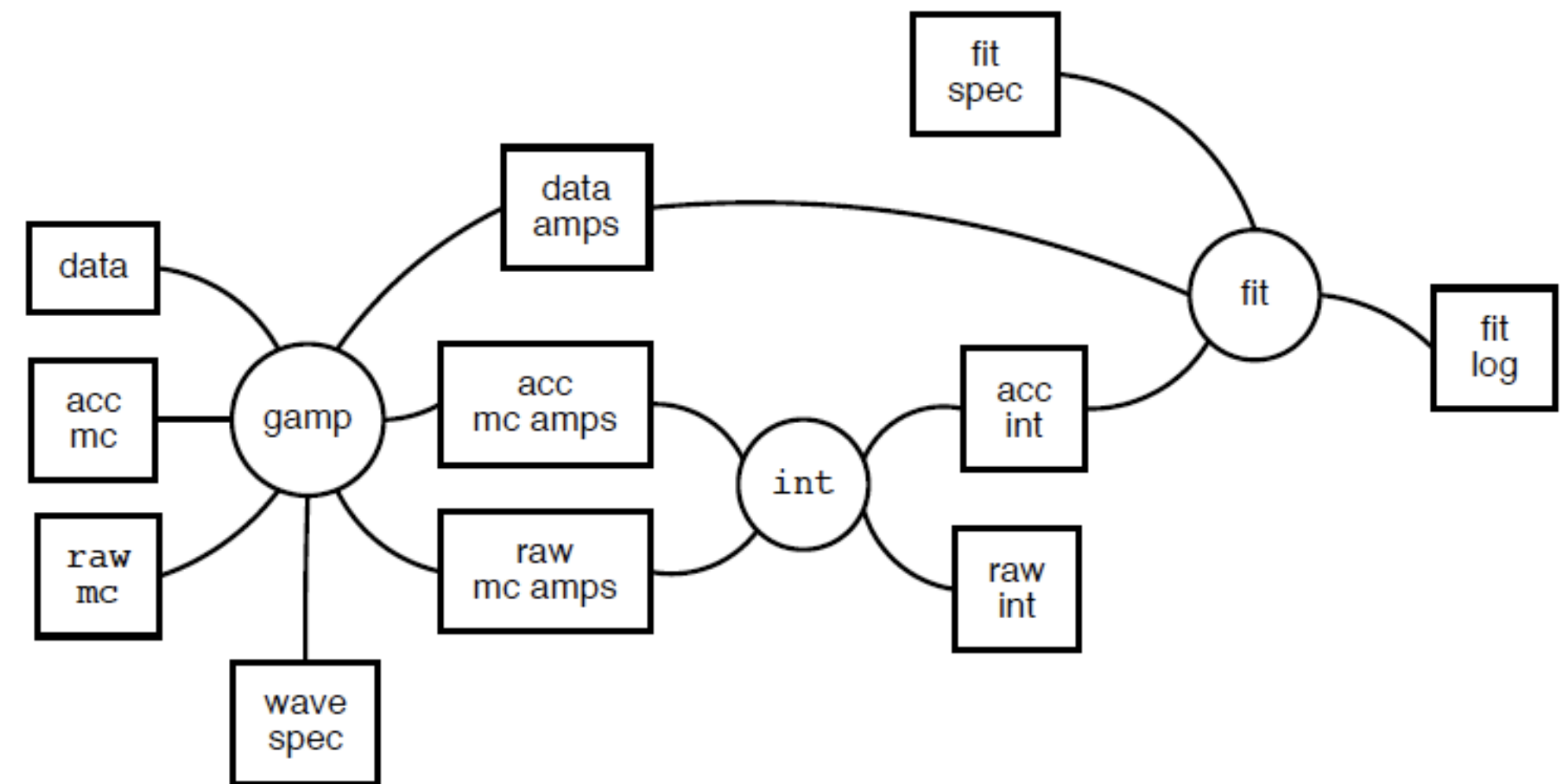
$$H(41) = \frac{2}{7}\sqrt{\frac{5}{3}}D_0D_-^*$$



$$H(42) = \frac{\sqrt{10}}{21}|D_-|^2 - \frac{\sqrt{10}}{21}|D_+|^2$$

PWA

- PWA2000
 - used in BNL and g6c PWA
 - consists of gamp, int and fit...
 - is written in C++/NOWEB
 - in the process of rewriting for G12 and CLAS12 in JAVA
 - fit - looking at possibly using CMU's



Future Plans

- finalize cuts to use $p \pi^+ \pi^- \gamma$ skim - bring the background to less than 30%, currently > 50%
- EC time and energy cuts
- Final goal: Partial Wave Analysis