The x(1280) Meson in CLAS g11

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- The $f_1(1285)$ & $\eta(1295)$ mesons
- Differential Cross Sections (preliminary)
- Dalitz Plot Analysis
- Branching Fractions
- Conclusions

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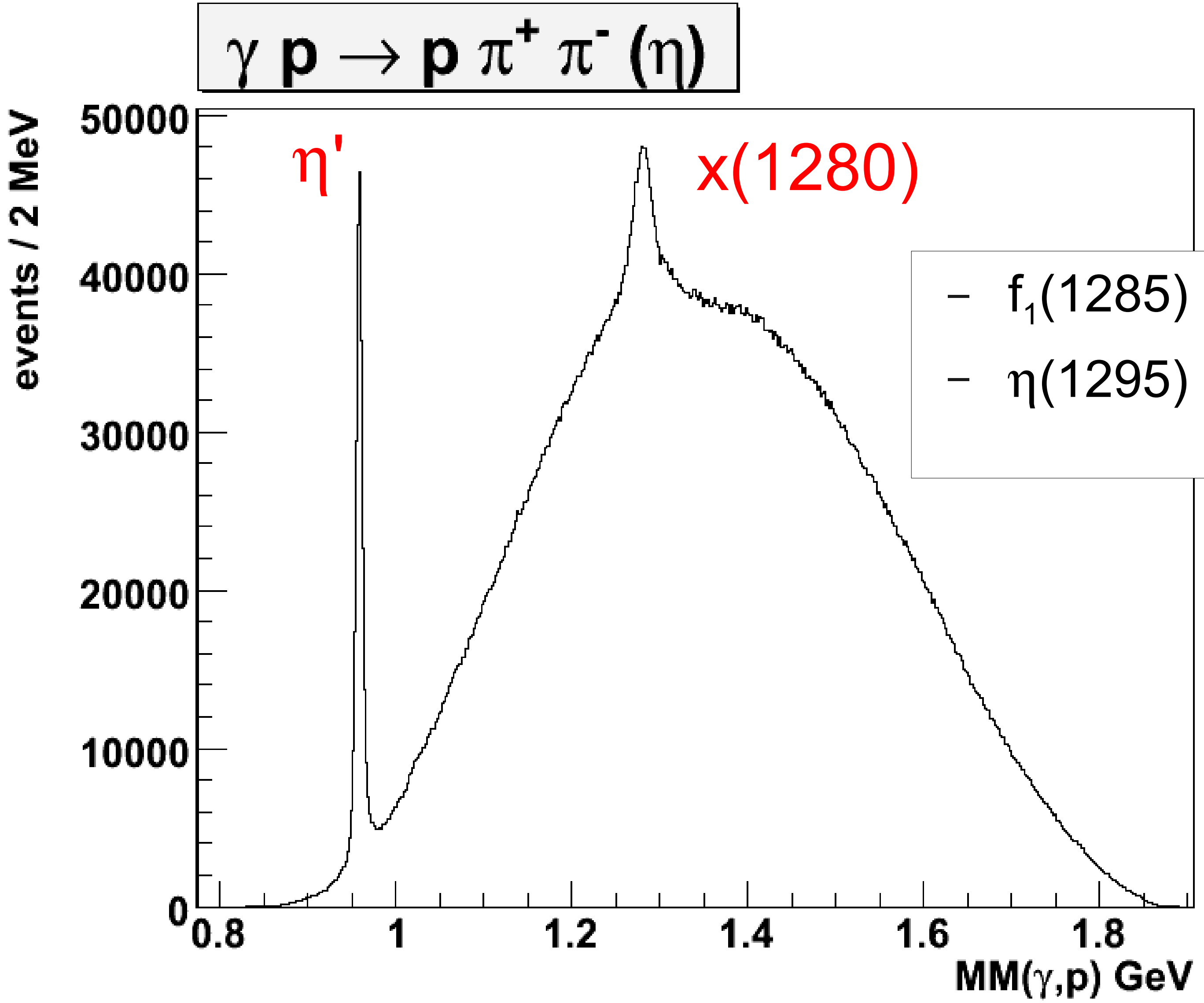
- Conclusion and Remaining Work

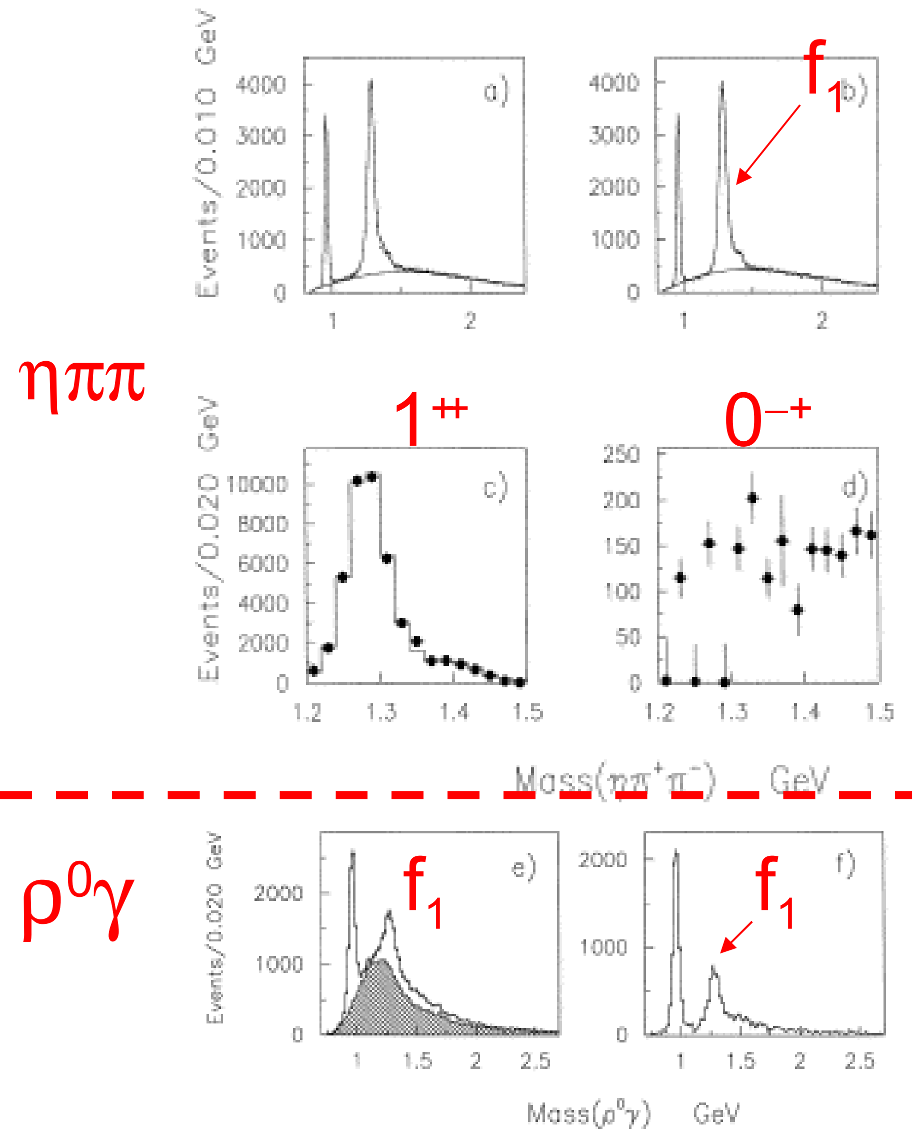
First Observation of $f_1(1285)/\eta(1295)$ in Photoproduction in CLAS at JLAB



- $f_1(1285)\ 1^{++}$, $\Gamma = 24$ MeV
- $\eta(1295)\ 0^{-+}$, $\Gamma = 55$ MeV (PDG)

- Great statistics in CLAS g11 data: ~1.5 x 10^5 events in peak

WA102 Results (pp → p(ηππ)p)



- WA102 (CERN) central production data shows 1^{++} with no 0^{-+} in ηππ
- Clear signal in the $\rho^0\gamma$ channel

$$\frac{\Gamma_{f_{\text{١}}(\text{١٢٨٥})\rightarrow\rho\gamma}}{\Gamma_{f_{\text{١}}(\text{١٢٨٥})\rightarrow\eta\pi\pi}} = \text{٠.١٠}\pm\text{.٠١}\pm\text{.٠٢}$$

BNL E852

- Using PWA of $\pi^- p \rightarrow \eta\pi\pi n$ determine that 1280 MeV signal is ~80% $\eta(1295)$ and calculate B.R.'s

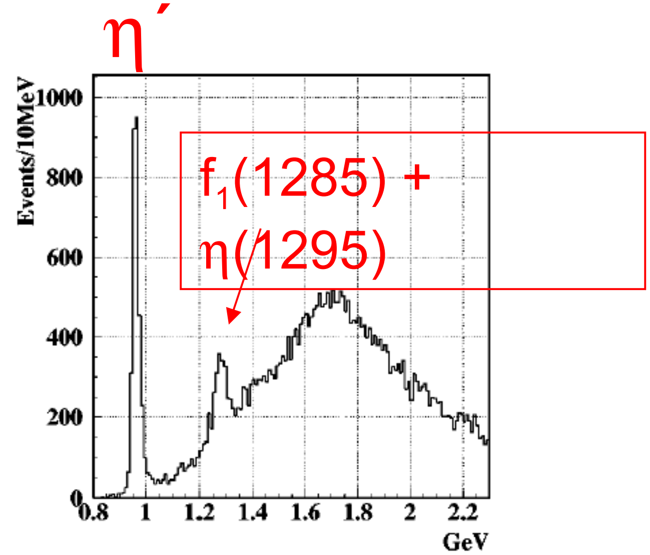
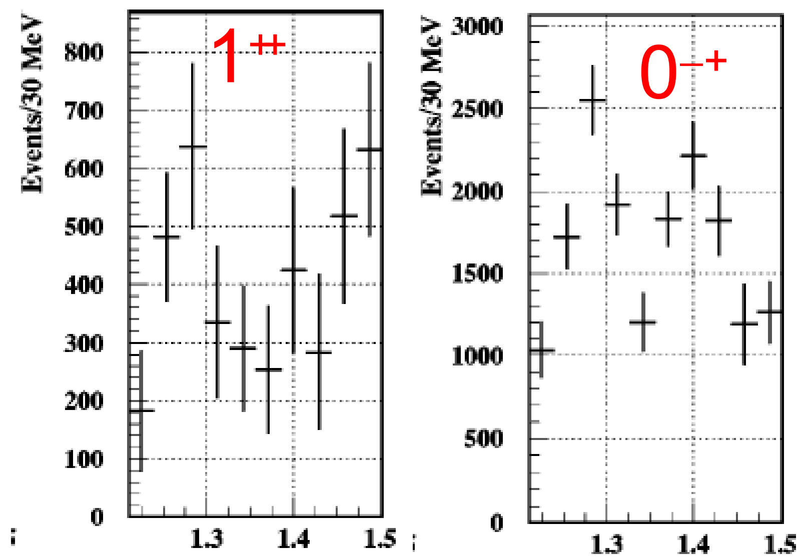


FIG. 3. $\eta\pi^+\pi^-$ three-body mass distribution (not corrected for acceptance).

TABLE III. f_1 branching fractions.

Decay mode	PDG [7]	BNL-E852	KEK-E179 [9,10]
4π	$35\pm4\%$	$65\pm4\%$	$59\pm5\%$
$\eta\pi\pi$	$50\pm18\%$	$7\pm3\%$	$16\pm5\%$
$\gamma\rho^0$	$5.4\pm1.2\%$	$10\pm4\%$	$9\pm3\%$
$K\bar{K}\pi$	$9.6\pm1.2\%$	$18\pm1\%$	$16\pm1\%$

*No measurements of $\rho^0\gamma$ channel



Using CLAS to Determine f_1/η Properties

Decay Mode	Measurements
$\eta\pi\pi$	$d\sigma/d\Omega$, mass, width, Branching Fraction
$a_0\pi \rightarrow \eta\pi\pi$	Dalitz plot analysis
$KK\pi$	$d\sigma/d\Omega$, Branching Fraction
$\rho^0\gamma$	Branching Fraction

CLAS at Jefferson Lab

CEBAF Large Acceptance Spectrometer – g11 run (2004)

- **Bremsstrahlung Photon Tagger ($\Delta E_\gamma/E_\gamma$ ~10^{-3})**
- **5 x 10^7 tagged photons/sec**
- **40 cm LH_2 target**
- **$\Delta p/p$ ~ 0.5-1 %**
- **Large multi-particle acceptance**
- **2 charged track requirement in trigger**

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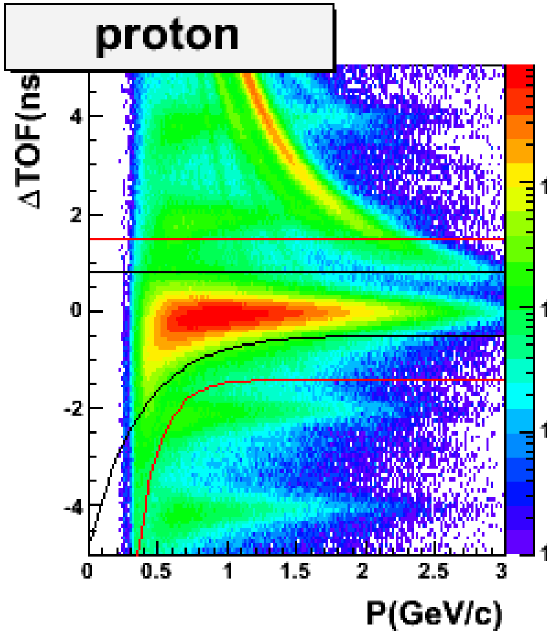
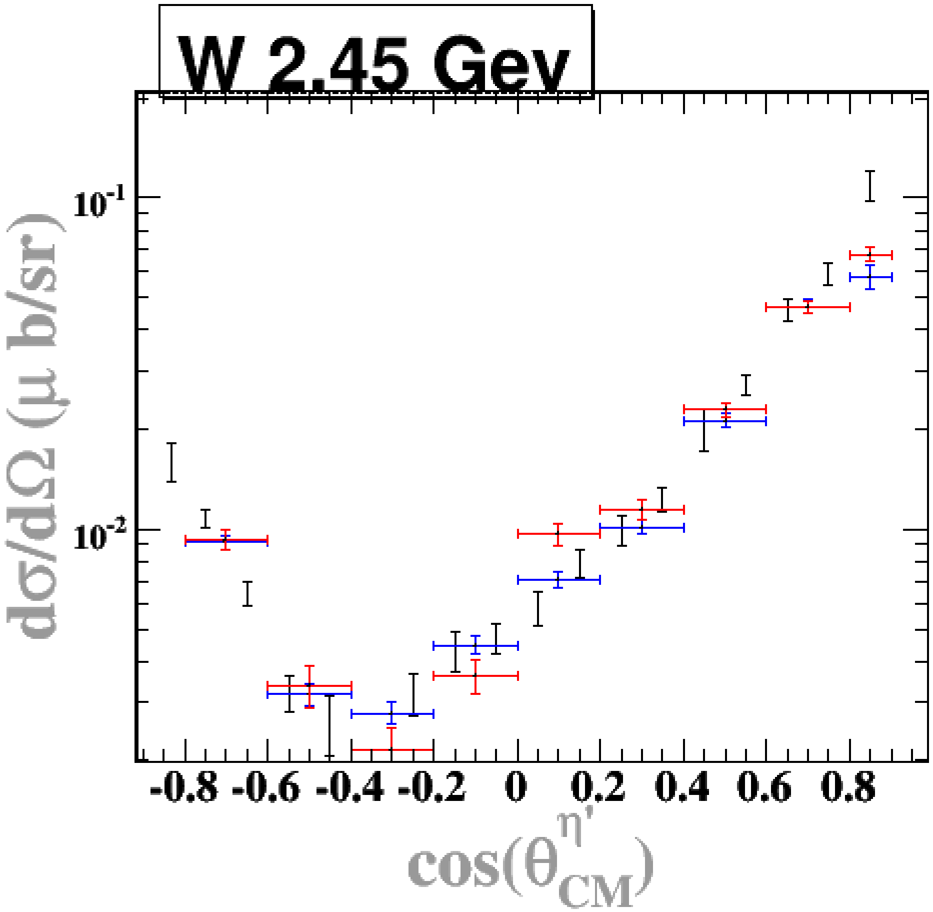
Event Selection

- Kinematic fit tracks to PID hypothesis
  - Eg. $\gamma\, p \rightarrow p\pi^{+}\pi^{-}(\eta)$
- ΔTOF to reject false identities, duplicate events and events paired with incorrect photon.
- Fiducial cuts



Event Selection: Calibration through $\gamma\, p \rightarrow \eta'\, p$

- Acts as a reference reaction
- η' $d\sigma/d\Omega$ in $\eta\pi\pi$ & $\rho^0\gamma$ decay modes



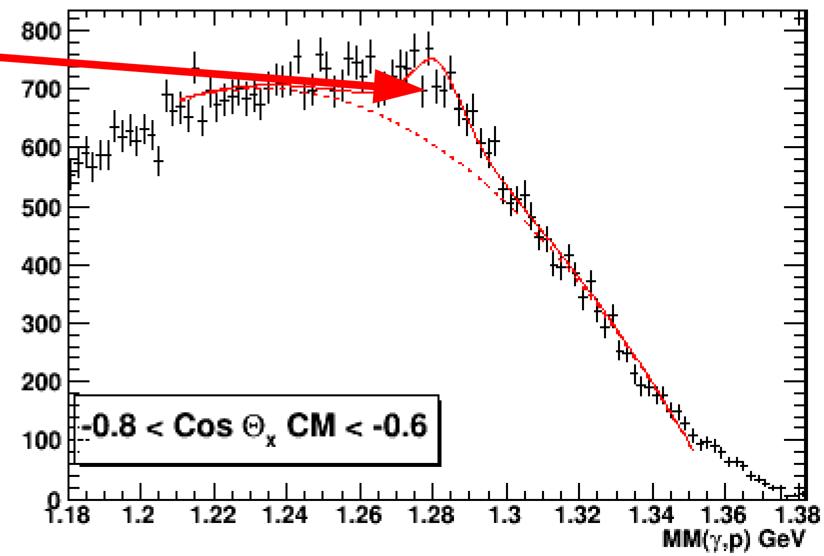
•Blue: this analysis $\eta\pi\pi$

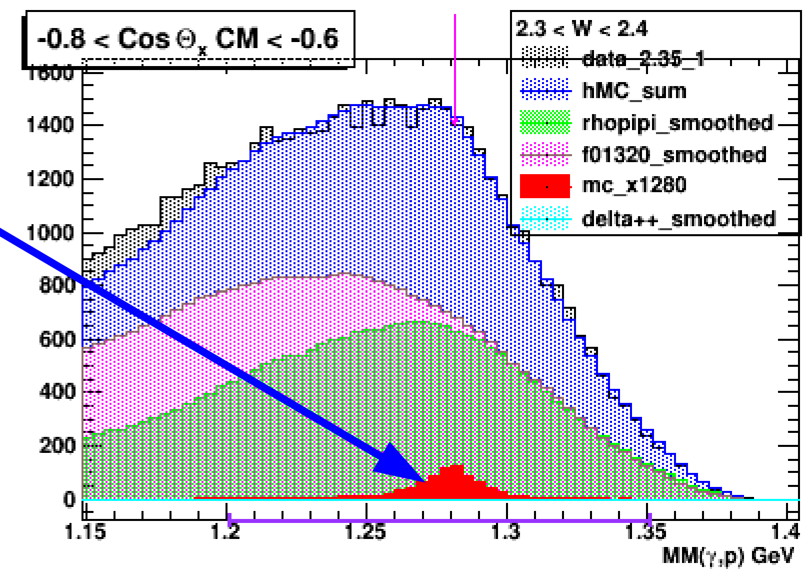
•Red: this analysis $\rho\gamma$

•Black: CLAS g11 (Williams, PRC 045213 (2009))

x(1280) yields: Two Methods

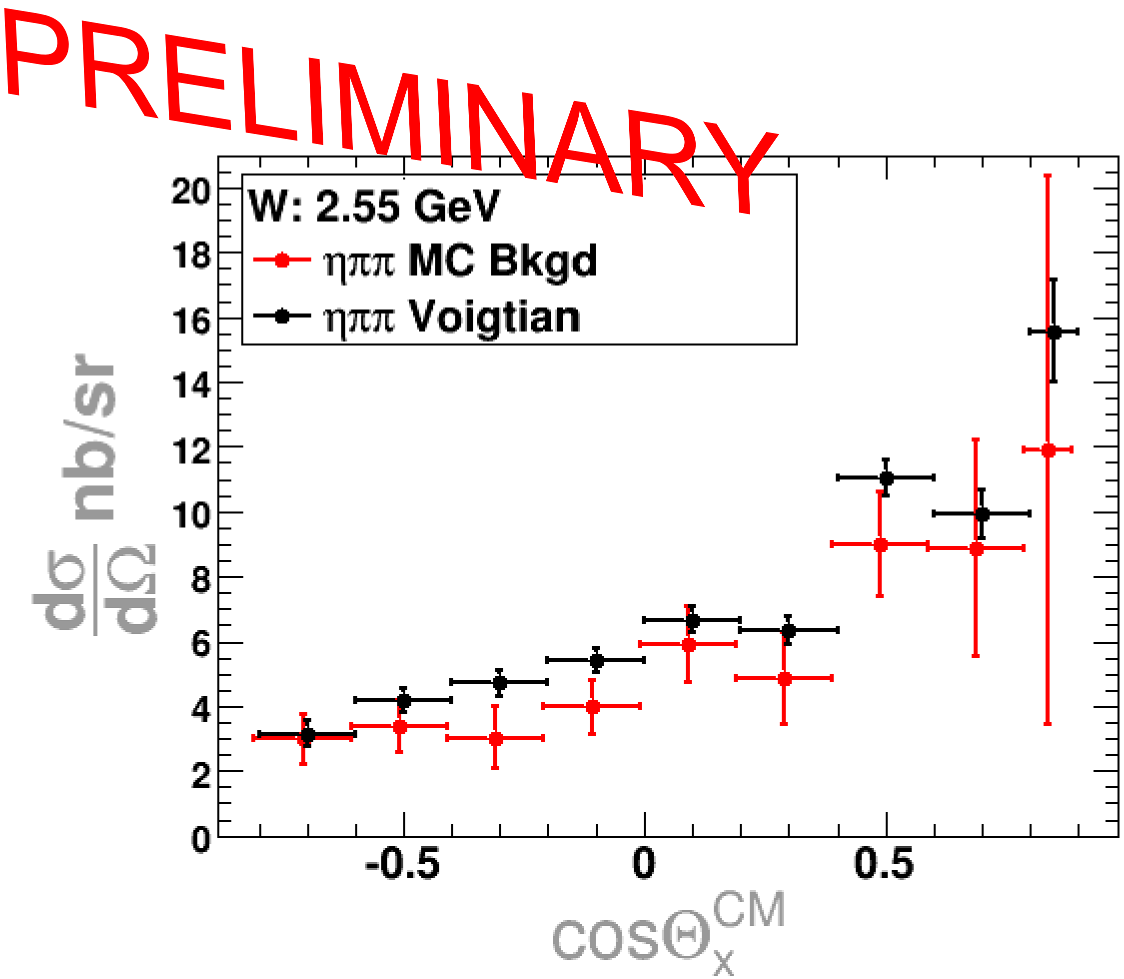
- Voigt + Polynomial fit
  - yields in $\eta\pi\pi$ and $KK\pi$
  - mass and Γ via $\eta\pi\pi$
- Monte Carlo signal and backgrounds fit
  - yields in $\eta\pi\pi$





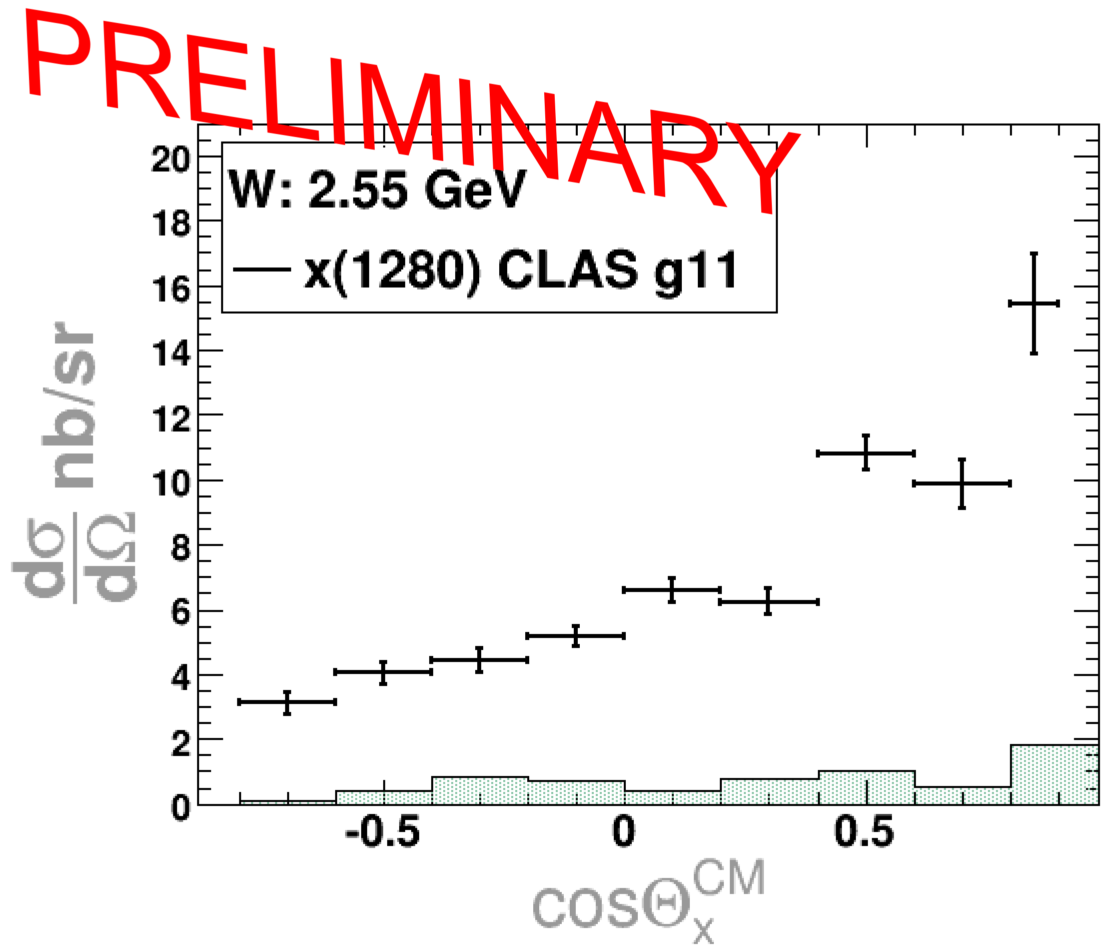
Differential Cross Sections

- x $\rightarrow \eta\pi\pi$
  - Both methods



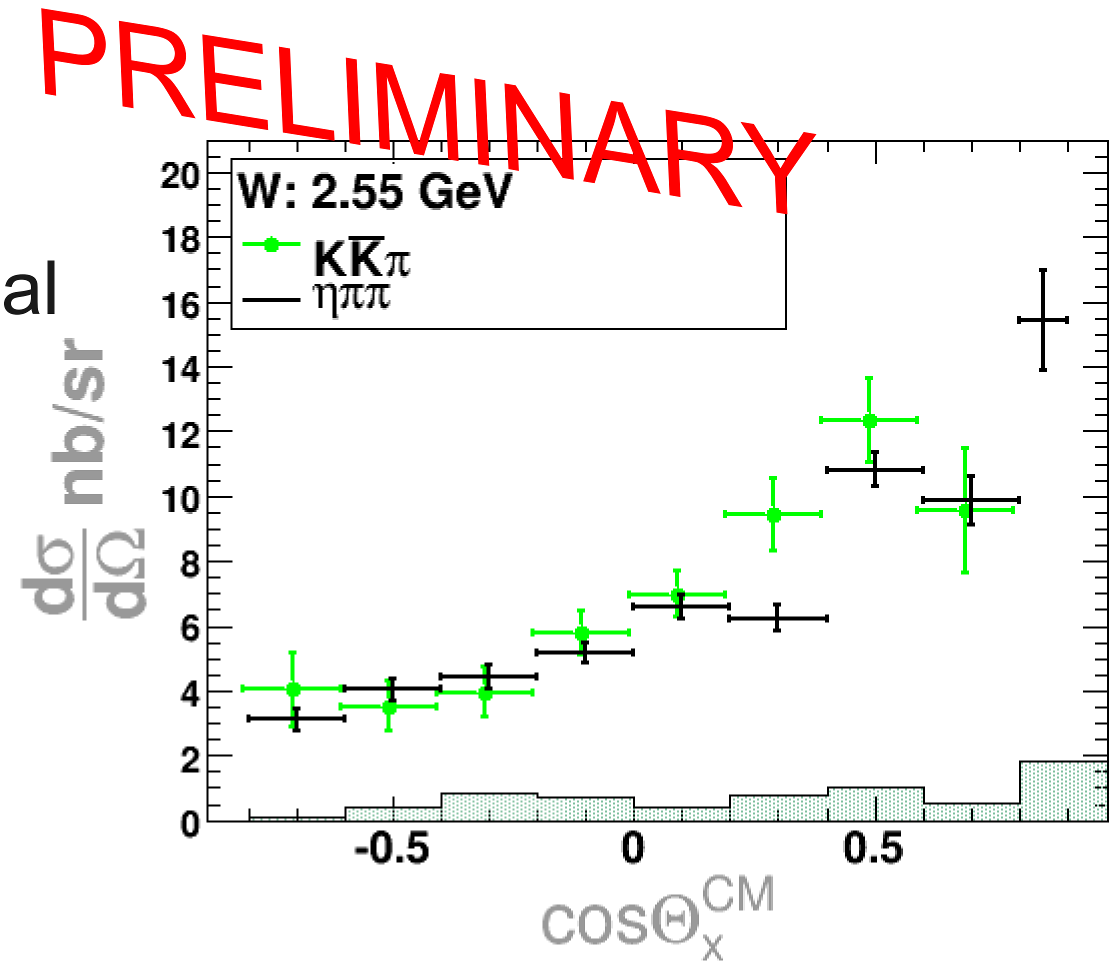
Differential Cross Sections

- x $\rightarrow \eta\pi\pi$
  - methods combined

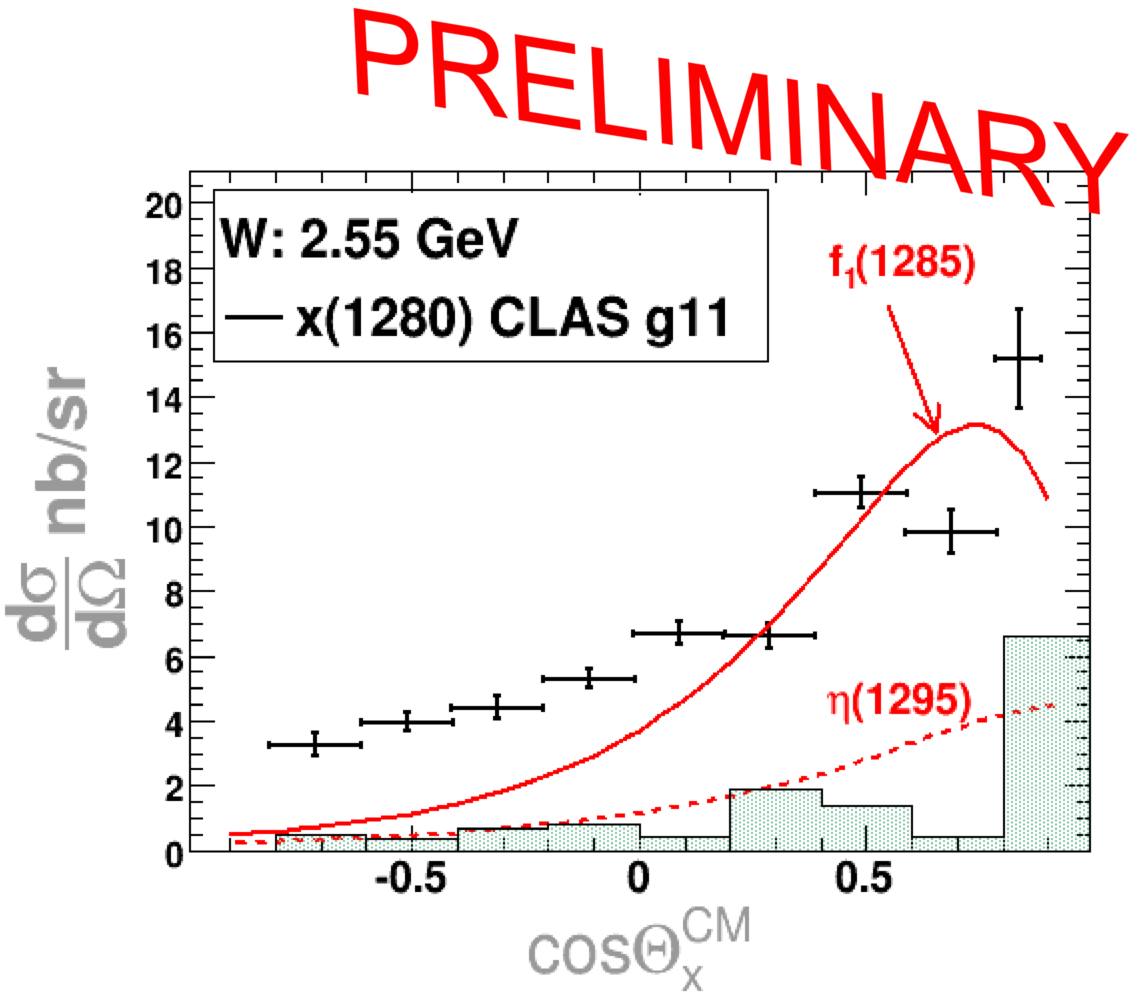


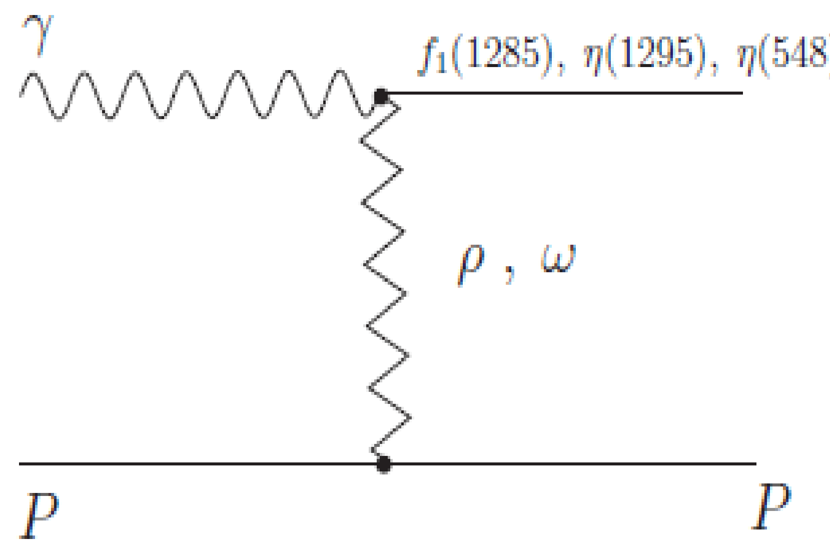
Differential Cross Sections

- Now add $KK\pi$
  - Scaled by global fit



Differential Cross Sections

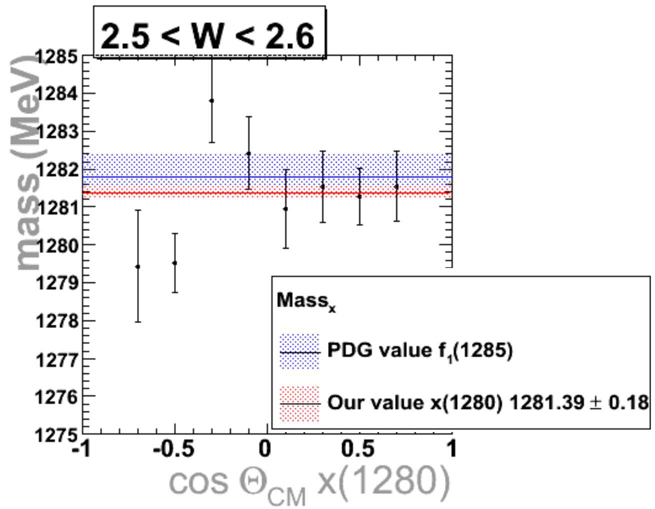


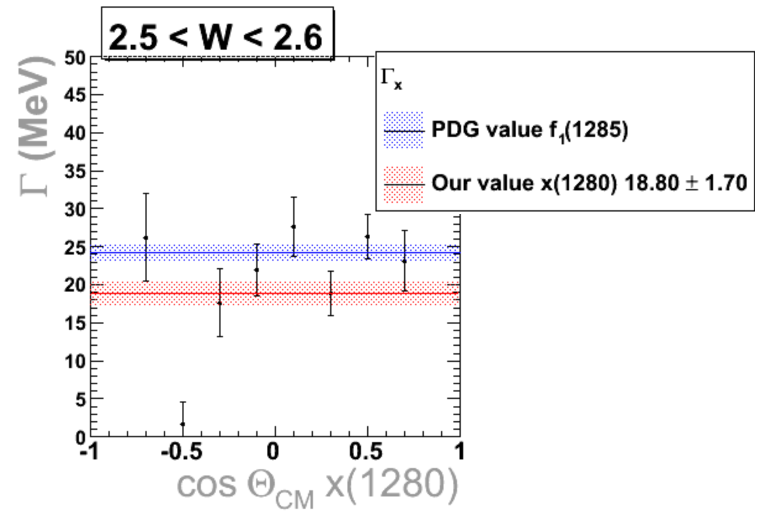


Regge model prediction
by N.I. Kochelev, et al.
(arXiv:0903.5369v1)

Mass and width from kinematic fit

$\gamma p \rightarrow x(1280)p \rightarrow p\pi\pi(\eta)$





	Mass	Width
CLAS x(1280)	1281.4 ± 0.2 MeV	18.8 ± 1.7 MeV
PDG f_1(1285)	1281.8 ± 0.6 MeV	24.2 ± 1.1 MeV
PDG η(1295)	1294 ± 4 MeV	55 ± 5 MeV

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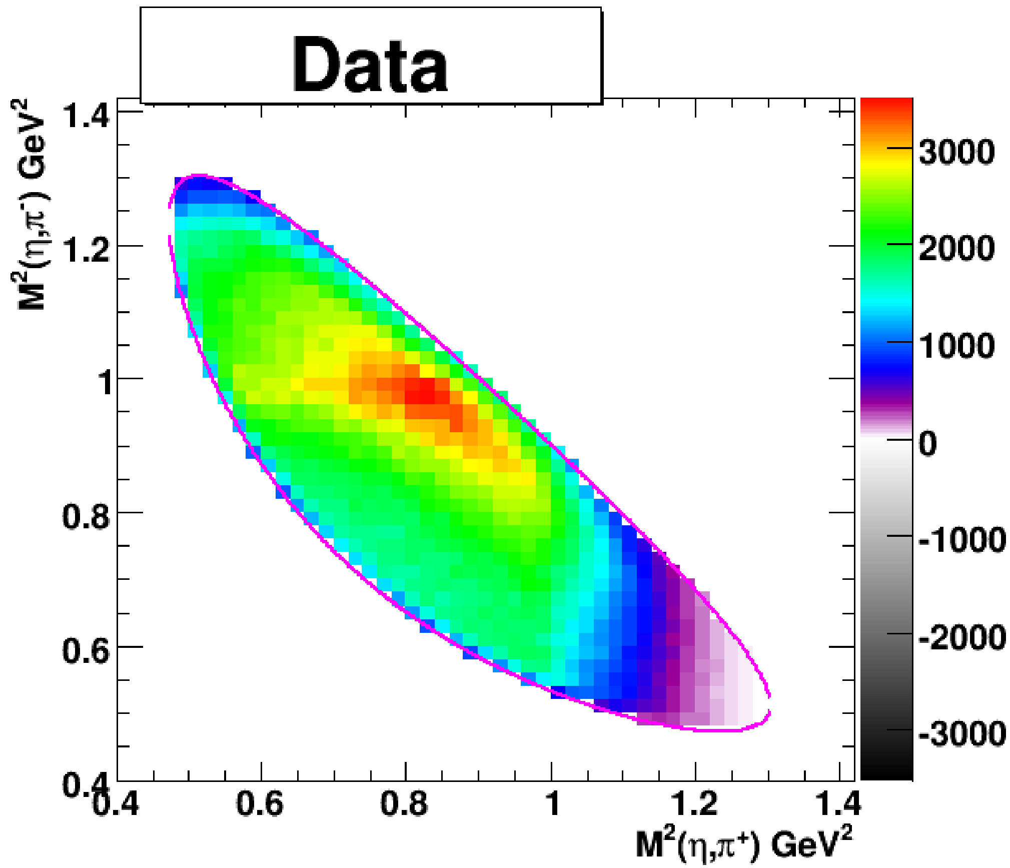
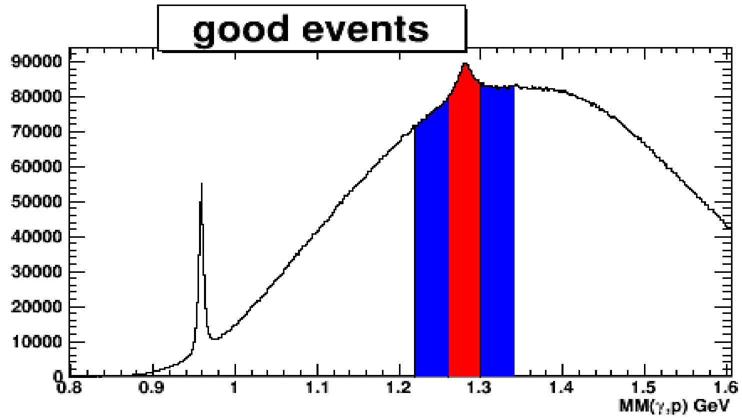
Dalitz Plot Analysis in x $\rightarrow \eta\pi\pi$

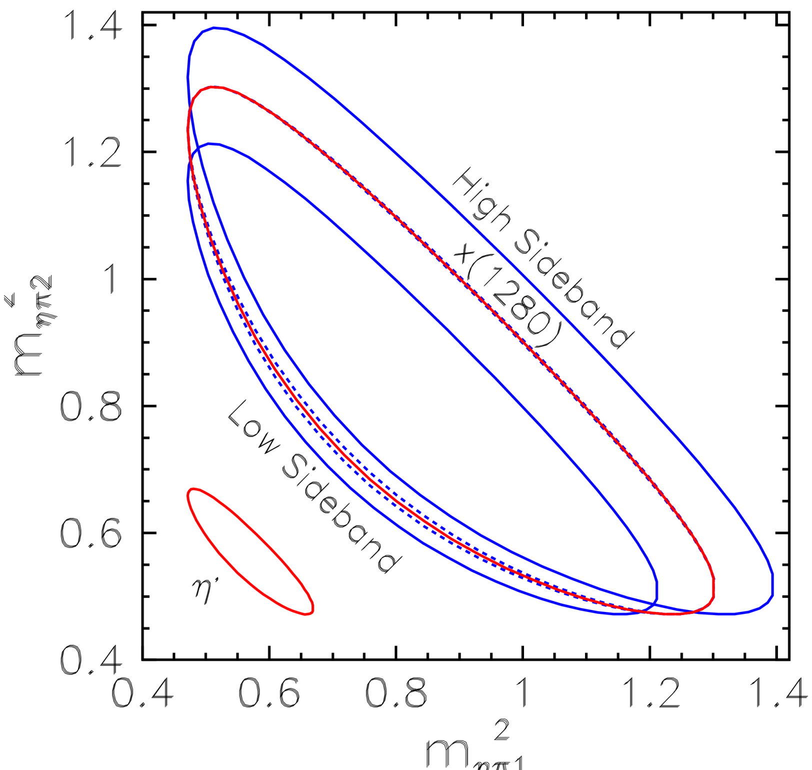
- A look at the structure of the x $\rightarrow \eta\pi\pi$ decay.
- Attempts to model the background were unsuccessful.
- Instead, we use sideband subtraction.

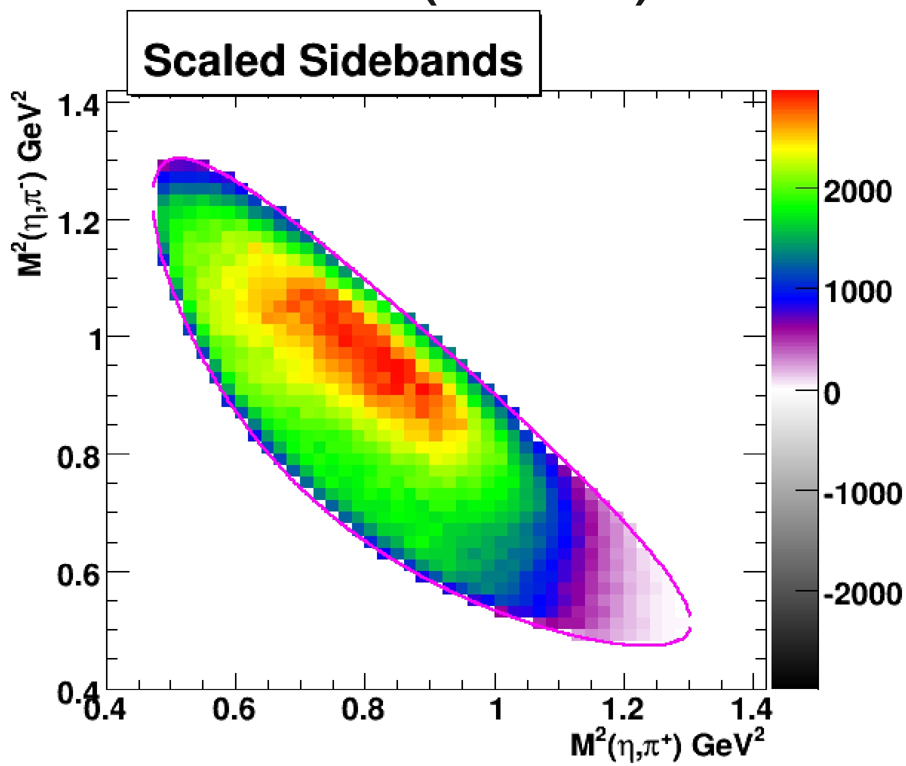


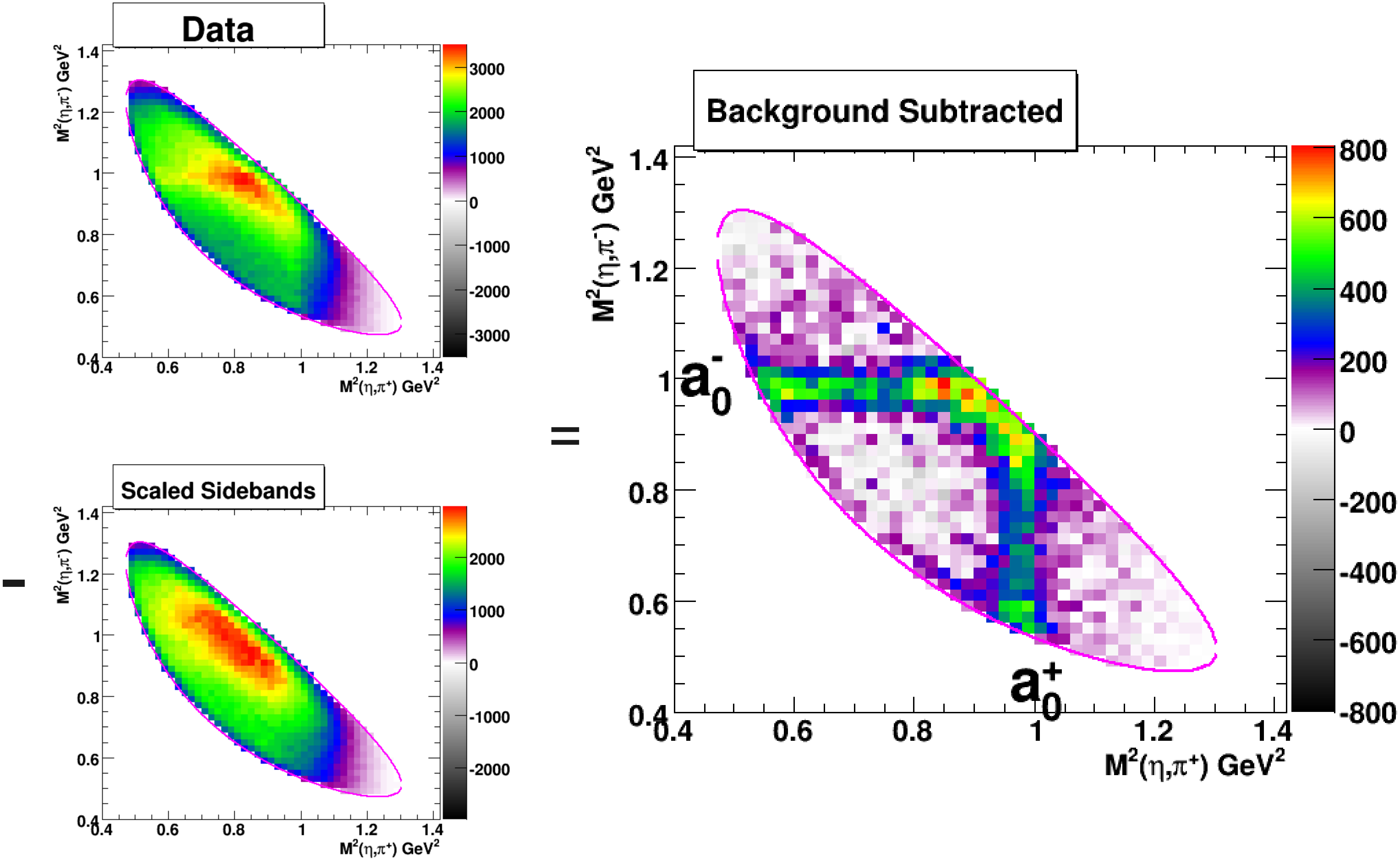
Sideband Scaling Method

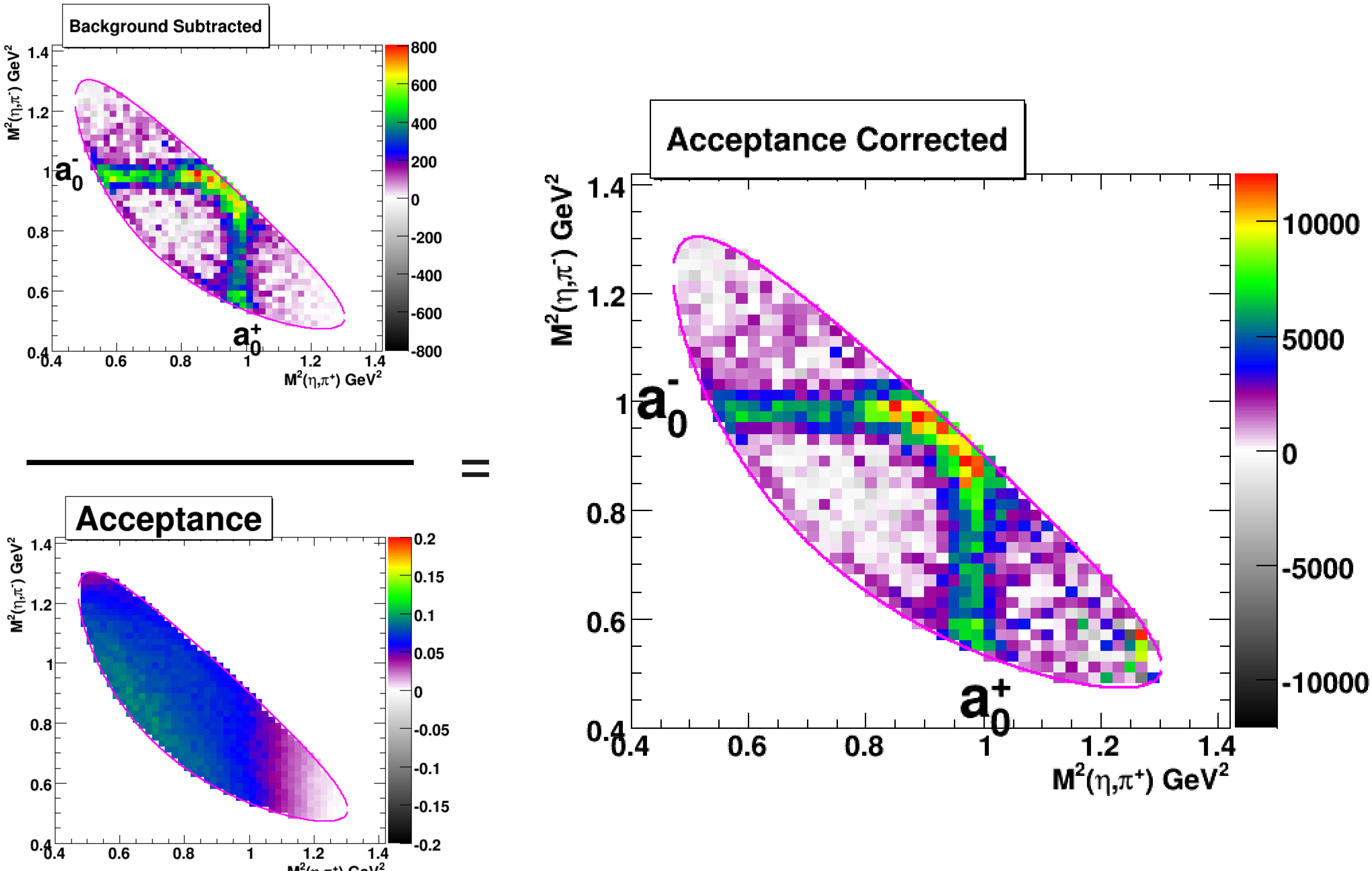


- We apply a linear transformation to bring the sidebands to the x(1280) mass.

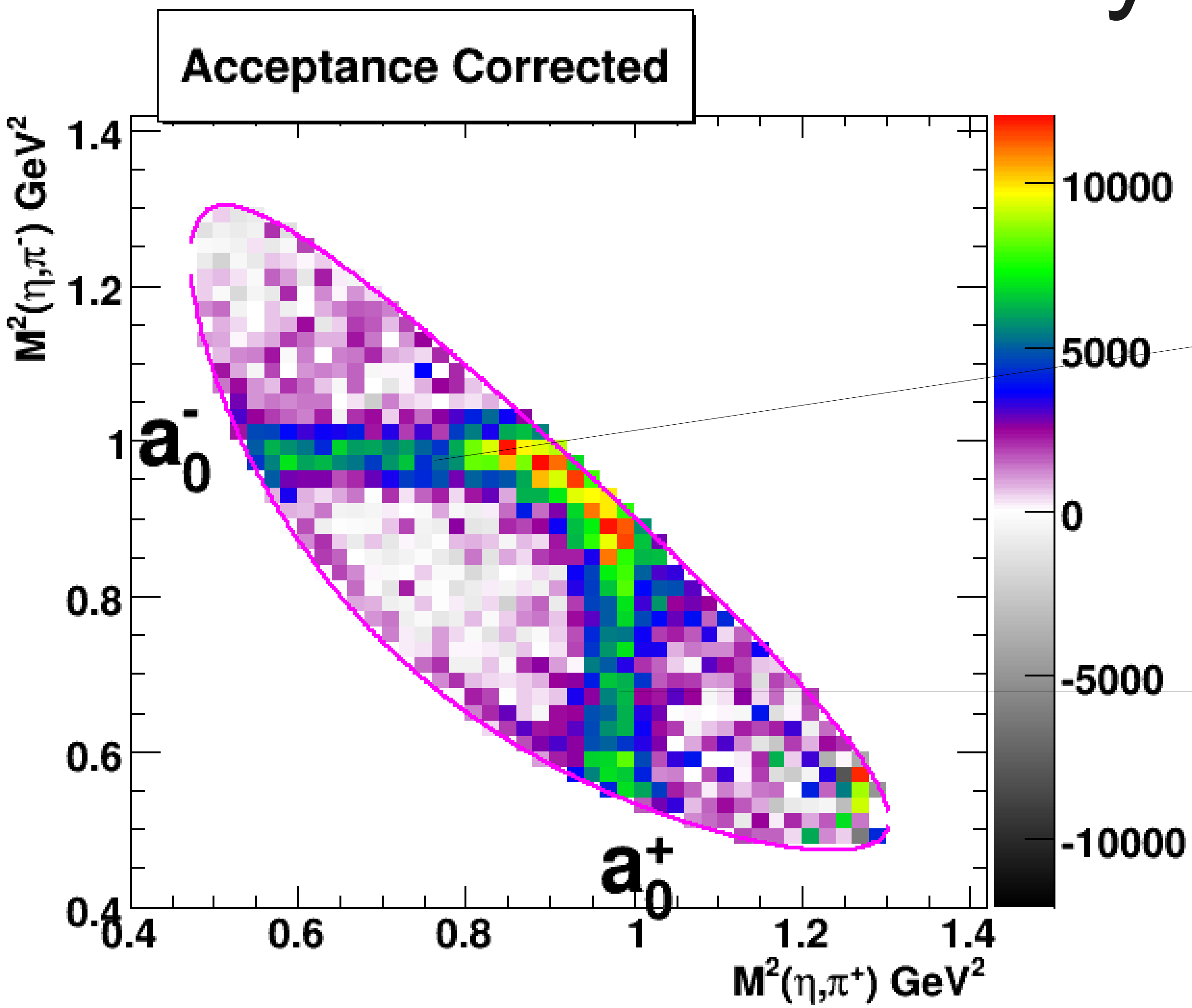


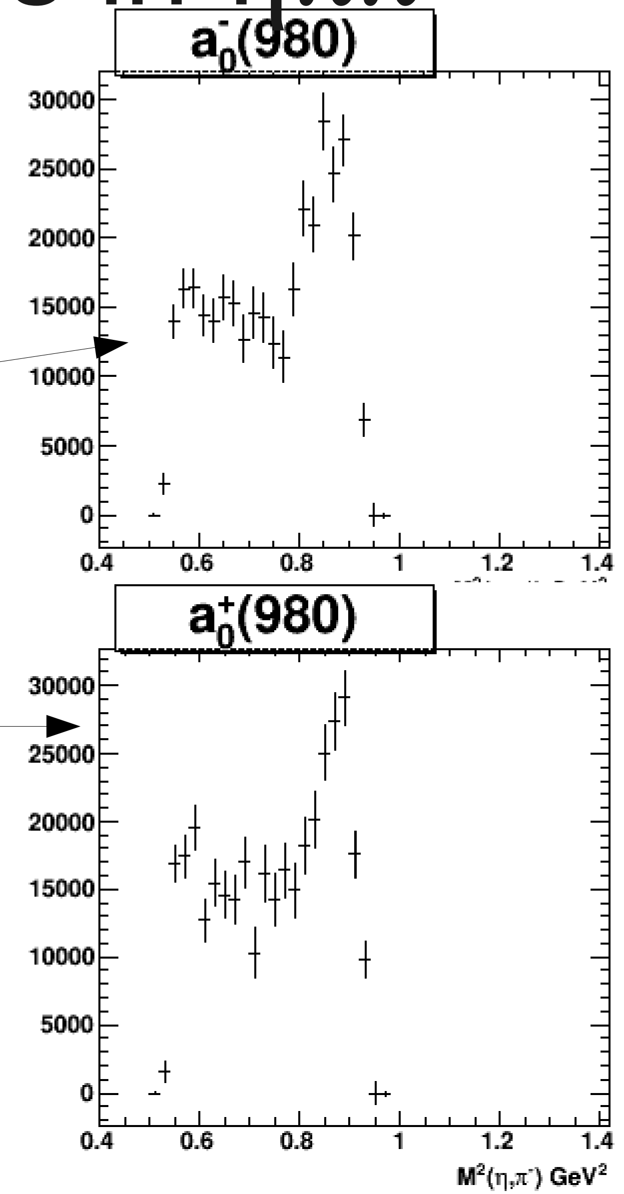



Data
Scaled Sidebands
Background Subtracted
-
=
$M^2(\eta,\pi^-)$ GeV^2
$M^2(\eta,\pi^+)$ GeV^2
a_0^-
a_0^+


Background Subtracted
$M^2(\eta,\pi^-)$ GeV^2
$M^2(\eta,\pi^+)$ GeV^2
a_0^-
a_0^+
Acceptance
$M^2(\eta,\pi^-)$ GeV^2
$M^2(\eta,\pi^+)$ GeV^2
=
Acceptance Corrected
$M^2(\eta,\pi^-)$ GeV^2
$M^2(\eta,\pi^+)$ GeV^2
a_0^-
a_0^+

Dalitz Plot Analysis in ηππ





Profiles consistent with coherent sum of Breit-Wigner

Dalitz Analysis Results

- Profile of a_0 bands consistent with coherent sum of Breit-Wigners
  - a_0^+ slightly stronger (~52%)
- Negligible non-resonant component
  - Difficult to quantify, as background subtraction is dominant contribution to errors

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Branching Fractions

- Measure <u>relative</u> branching fractions

$$\frac{\Gamma_{x(1280)\to KK\pi}}{\Gamma_{x(1280)\to \eta\pi\pi}}$$

$$\frac{\Gamma_{x(1280)\to \rho\gamma}}{\Gamma_{x(1280)\to \eta\pi\pi}}$$

Branching Fractions

- Measure relative branching fractions

$$\frac{\Gamma_{x(1280)\to KK\pi}}{\Gamma_{x(1280)\to \eta\pi\pi}}$$

$$\frac{\Gamma_{x(1280)\to \rho\gamma}}{\Gamma_{x(1280)\to \eta\pi\pi}}$$

- Yields easily computed
- Now look for $\rho^0\gamma$
  - Expect ~10% of $\eta\pi\pi$ strength
  - Difficult to seperate from $\gamma p \to p\pi^+\pi^-$ and $\gamma p \to p\pi^+\pi^-\pi^0$

Extracting x(1280) → $\rho^0\gamma$

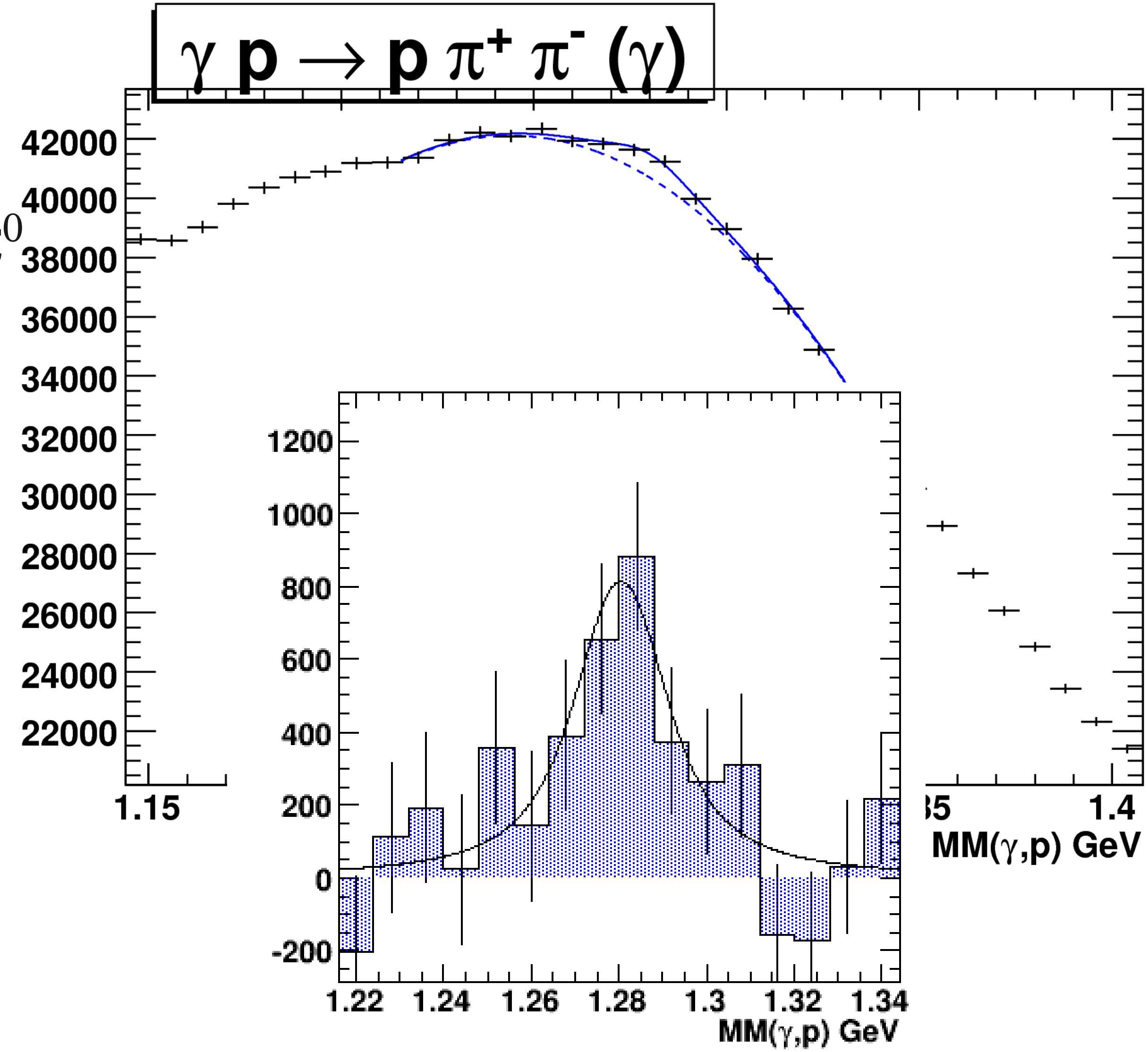
Reducing backgound

$\gamma p \rightarrow p\pi^+\pi^-$ & $\gamma p \rightarrow p\pi^+\pi^-\pi^0$

Additional Cuts:

Missing $P_\perp > 100$ MeV

$CL(\gamma p \rightarrow p\pi^+\pi^-\pi^0) < 0.01$



Preliminary Branching Fractions

step	value	stat. error	syst. error	PDG $f_1(1285)$
$\rho^0\gamma$ Yield	3790	789	35 %	
$\rho^0\gamma$ Acceptance	0.0298	0.00006		
$K^\pm K^0\pi^\mp$ Yield	7170	436	4.7%	
$K^\pm K^0\pi^\mp$ Acceptance	0.0149	0.00003		
$\eta\pi^+\pi^-$ Yield	151000	3590	19.8%	
$\eta\pi^+\pi^-$ Acceptance	0.0701	0.0001		
B.R.$\left(\frac{x\rightarrow\rho^0\gamma}{x\rightarrow\eta\pi^+\pi^-}\right)$	0.059	0.0124	0.0237	0.127 ± 0.014
B.R.$\left(\frac{x\rightarrow K^\pm K^0\pi^\mp}{x\rightarrow\eta\pi^+\pi^-}\right)$	0.187	0.0001	0.046	0.170 ± 0.012

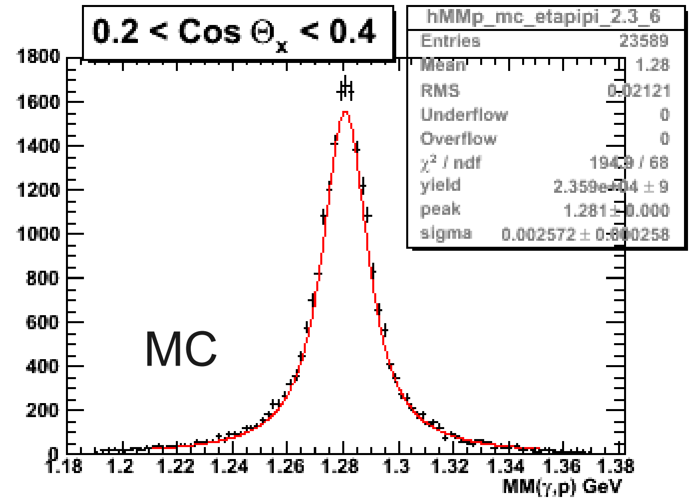
Conclusions

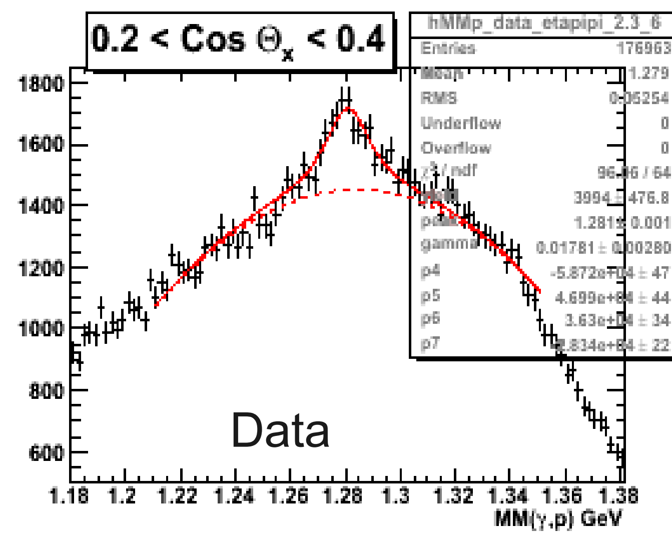
- First photoproduction measurements of x(1280), seen in several decay channels.
  - η' mass and cross sections used to calibrate methods.
- Mass and width of the state are more consistent with the PDG values for $f_1(1285)$ than for $\eta(1295)$.
- Dalitz plot analysis of $\eta\pi\pi$ final state shows dominance of $a_0(980)\pi$ decay mode.
- Branching Ratio measurements for $KK\pi/\eta\pi\pi$ and $\rho\gamma/\eta\pi\pi$ consistent with PDG $f_1(1285)$.

Backup Slides

Method 1: Voigt + Polynomial

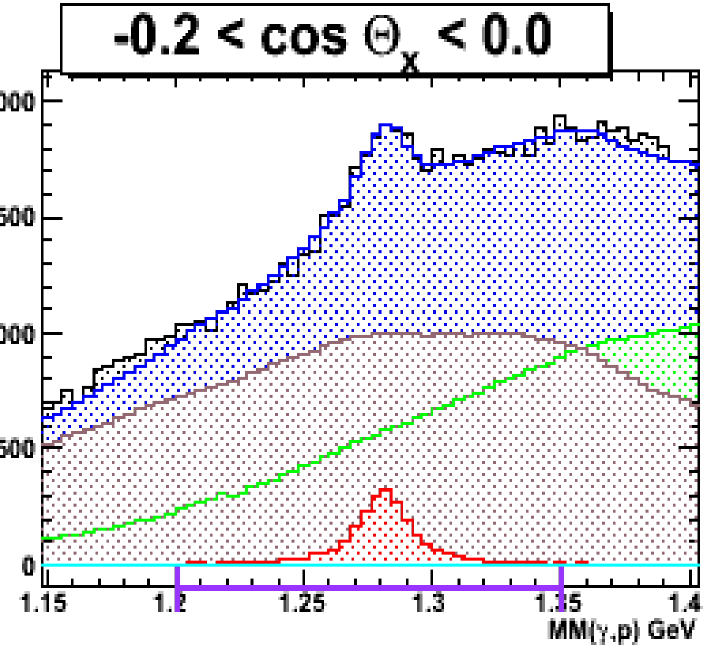
- Voigtian Lineshape works well to extract yield.
  - Fit our x(1280) Monte Carlo to determines this σ in each kinematic bin.
  - Fix this parameter in our data fits.
- Mass and width are free parameters in bins with good statistics and favorable background.





Method 2: MC Signal + Bkgd

- Chosen smoothed background distributions were fit in conjunction with x(1280) $\rightarrow \eta\pi\pi$ MC spectra.
- Yields are the integrated MC scaled by the fit coefficient from each bin



Blue: Bkgd Sum
Green: $p\rho\pi\pi$
Brown: $\Delta^{++}\pi\pi\pi$
Lt. Blue: $f_0(1320)$
Red: x(1280)

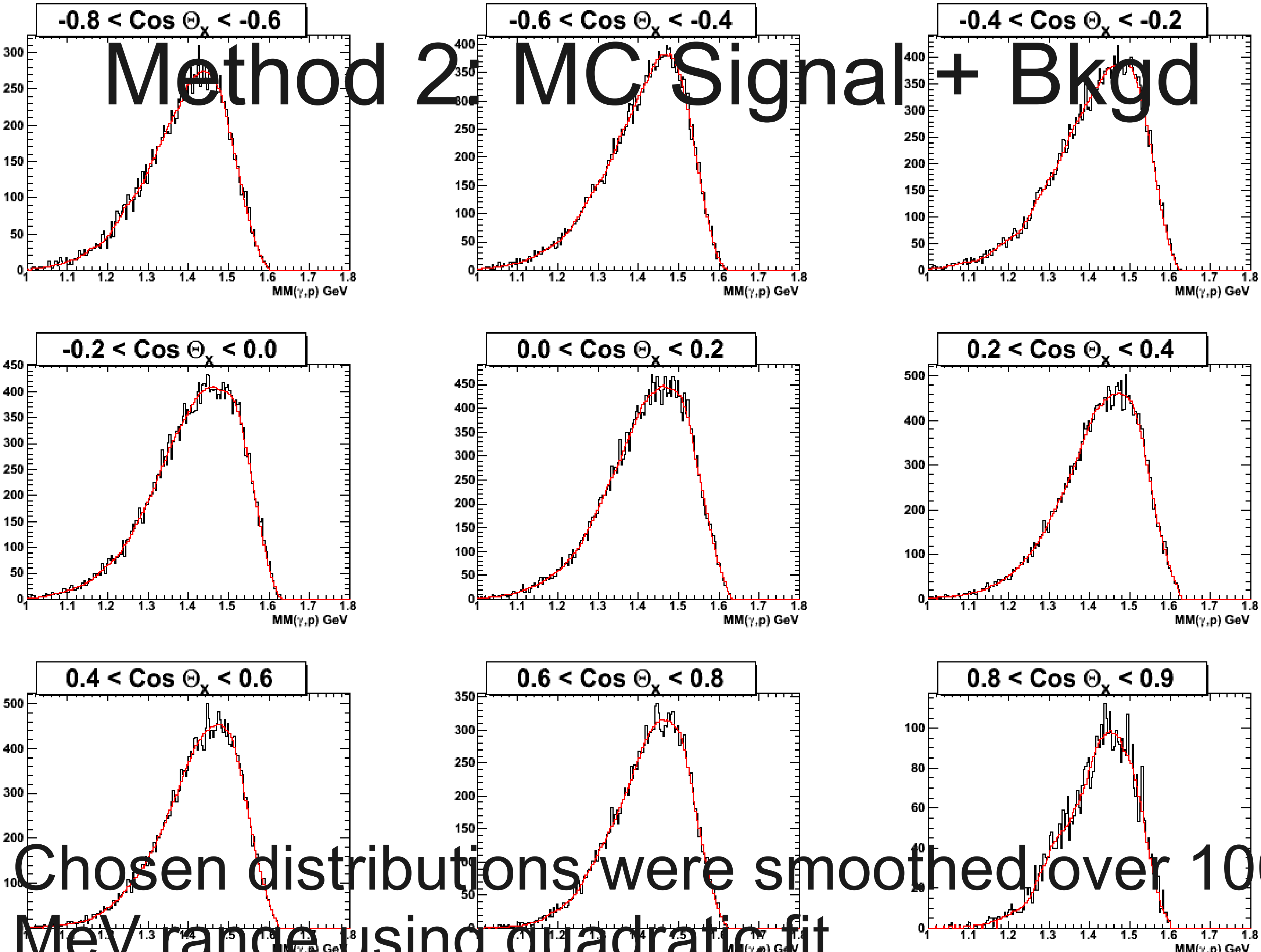
Method 2: MC Signal + Bkgd

- Several channels processed to model the background shape seen in data.
  - $p\ \pi\ \pi\ \pi\ \pi$
  - $p\ \rho\ \pi\ \pi$
  - $\Delta^{++}\pi^{-}\ \pi\ \pi$, $\Delta^{+}\pi^{0}\ \pi\ \pi$, $\Delta^{0}\pi^{+}\ \pi\ \pi$
  - $p\ f_0(1370)$
- Four pion final states populate kinematic space of our data.
- Chosen distributions were smoothed and fit in conjunction with $x(1280) \rightarrow \eta\pi\pi$ MC spectra

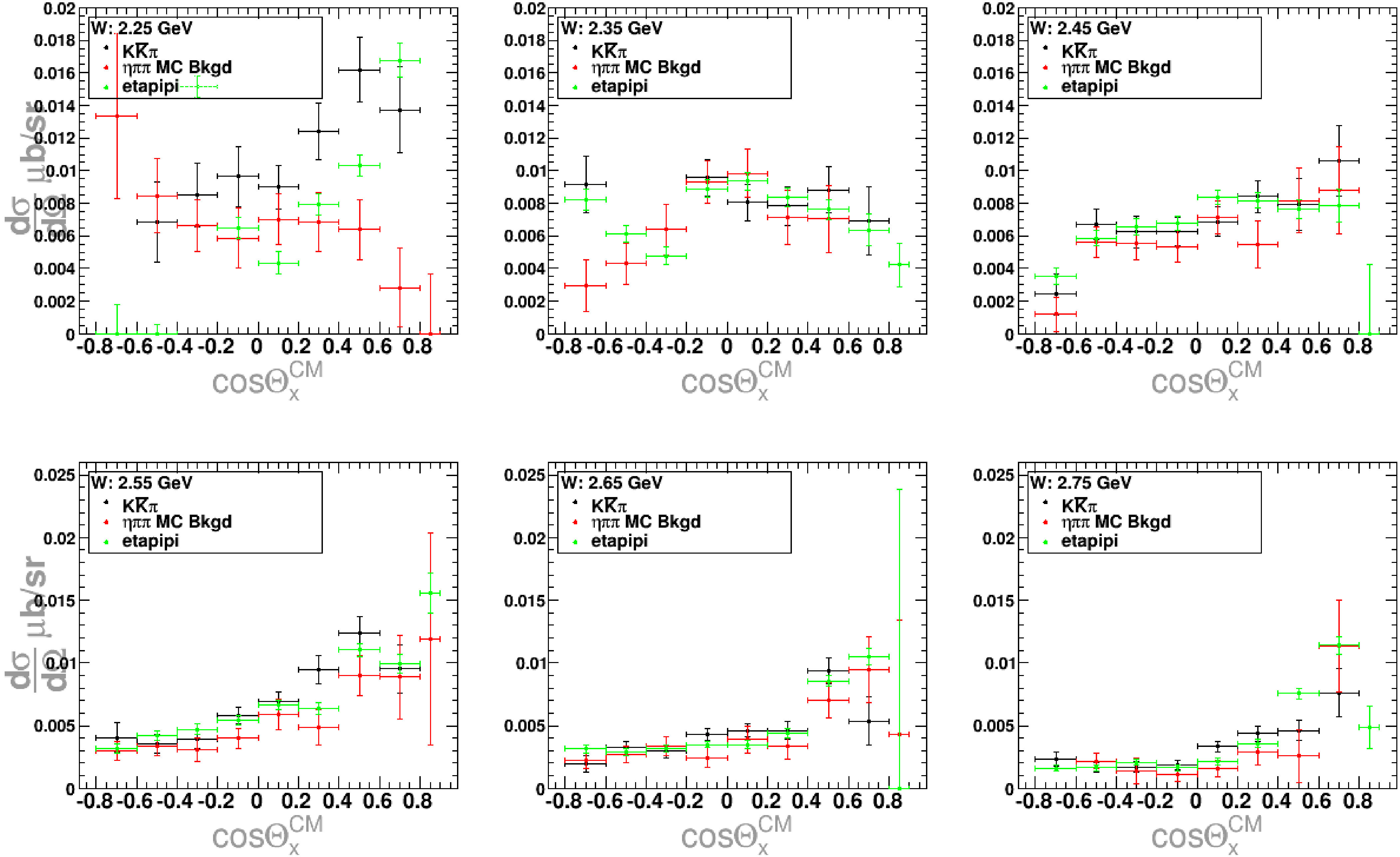
Method 2: MC Signal + Bkgd

- Several channels processed to model the background shape seen in data.
  - $p \pi \pi \pi \pi$
  - $p \rho \pi \pi$
  - $\Delta^{++} \pi^- \pi \pi$, $\Delta^+ \pi^0 \pi \pi$, $\Delta^0 \pi^+ \pi \pi$
  - $p f_0(1370)$
- Four pion final states populate kinematic space of our data.
- Chosen distributions were smoothed and fit in conjunction with $x(1280) \rightarrow \eta\pi\pi$ MC spectra

Method 2: MC Signal + Bkgd



- Chosen distributions were smoothed over 100 MeV range using quadratic fit.

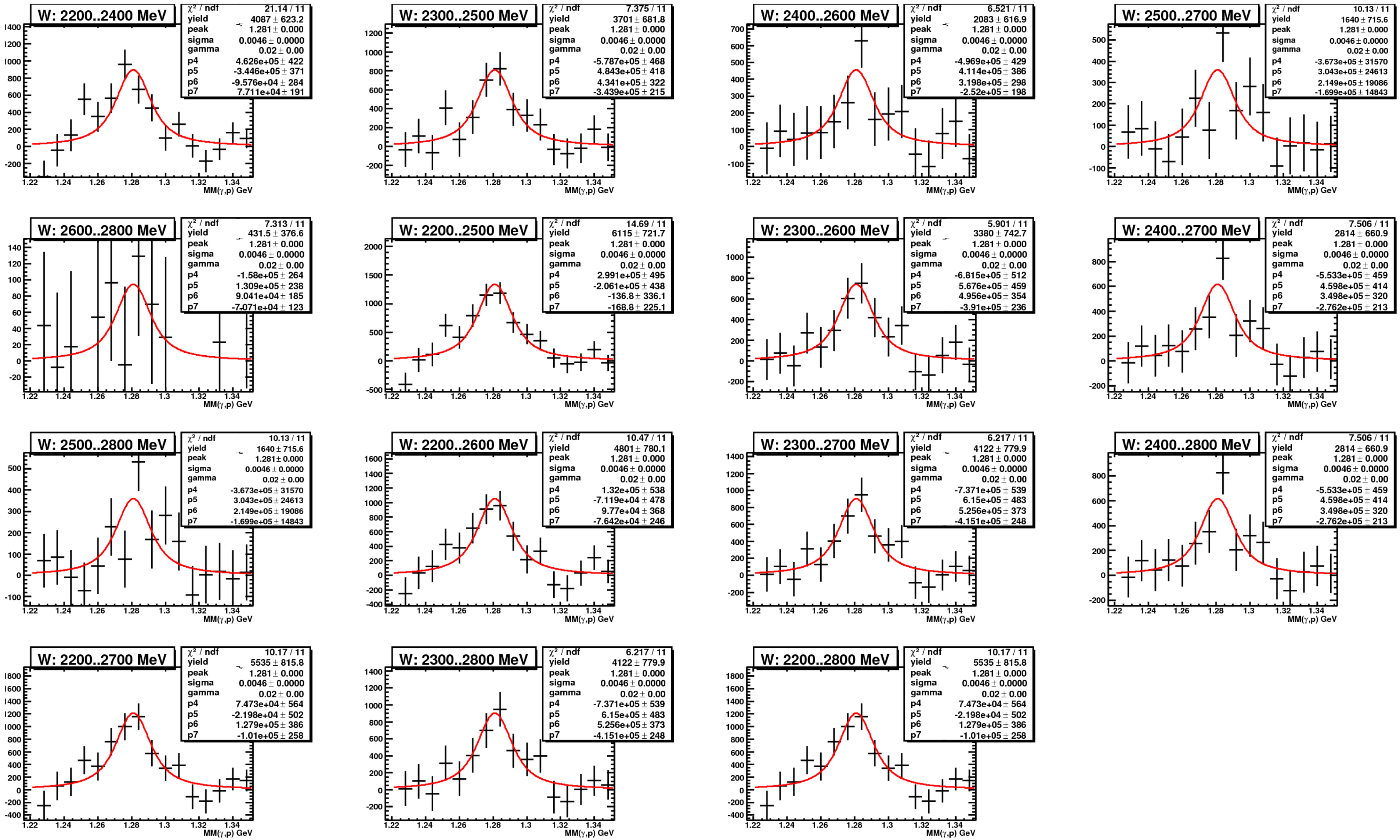

W: 2.25 GeV
W: 2.35 GeV
W: 2.45 GeV
W: 2.55 GeV
W: 2.65 GeV
W: 2.75 GeV
$K\bar{K}\pi$
$\eta\pi\pi$ MC Bkgd
etapipi
$\frac{d\sigma}{d\Omega}$ $\mu b/sr$
$\cos\Theta_x^{CM}$

Sideband scaling Method

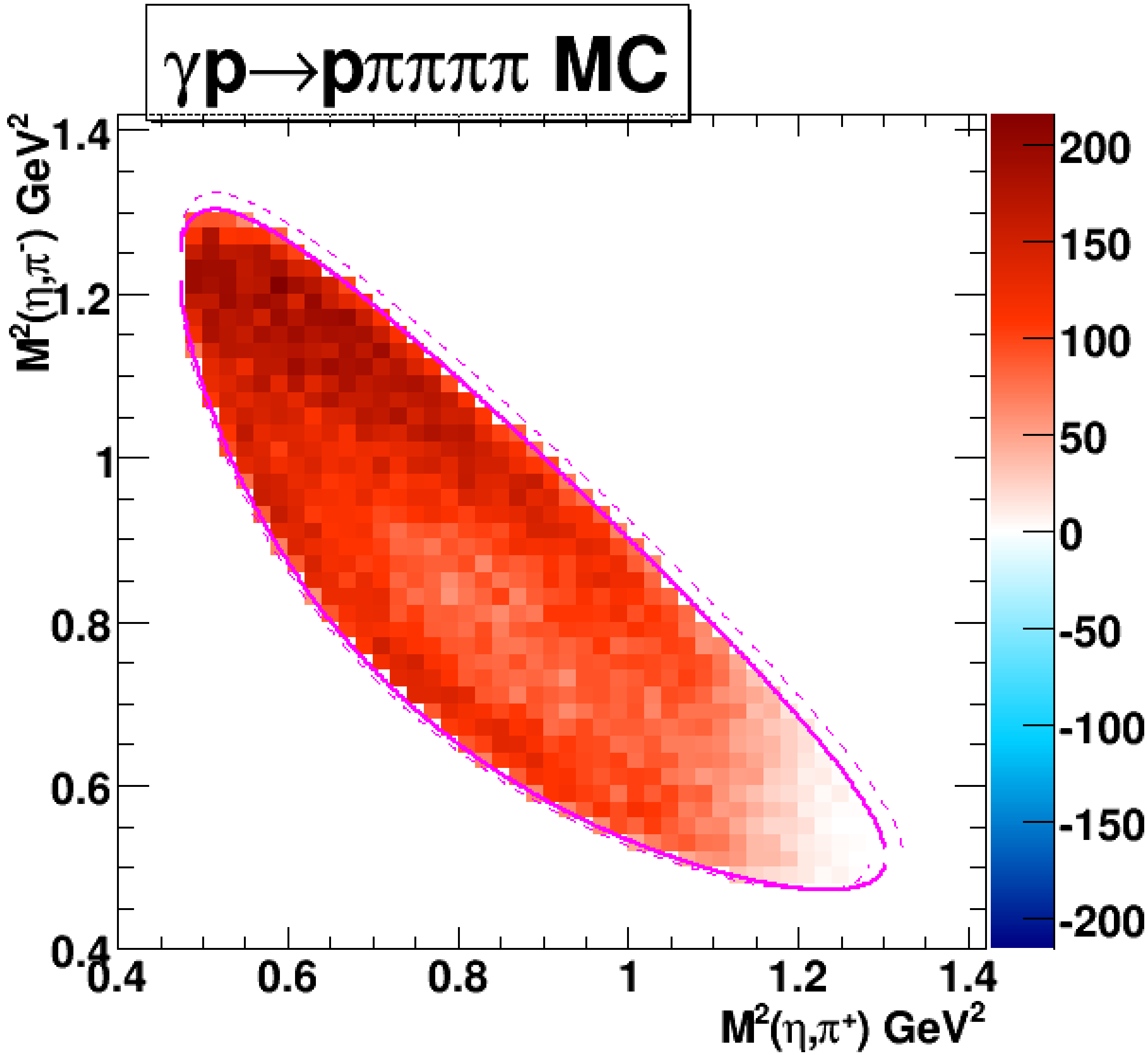
$$M \rightarrow \; m_i \; m_j \; m_k$$

$$\begin{aligned}
m'^2_{ij} &= f(M, M', m_{ij}, m_k) \\
m^2_{ij}{}^{min} &= (m_i + m_j)^2 \\
m^2_{ij}{}^{max} &= (M - m_k)^2 \\
r(M, m_{ij}, m_k) &= m^2_{ij}{}^{max} - m^2_{ij}{}^{min} \\
m'^2_{ij} &= \frac{r(M, m_{ij}, m_k)}{r(M', m_{ij}, m_k)}(m^2_{ij} - m^2_{ij}{}^{min}) + m^2_{ij}{}^{min}
\end{aligned}$$

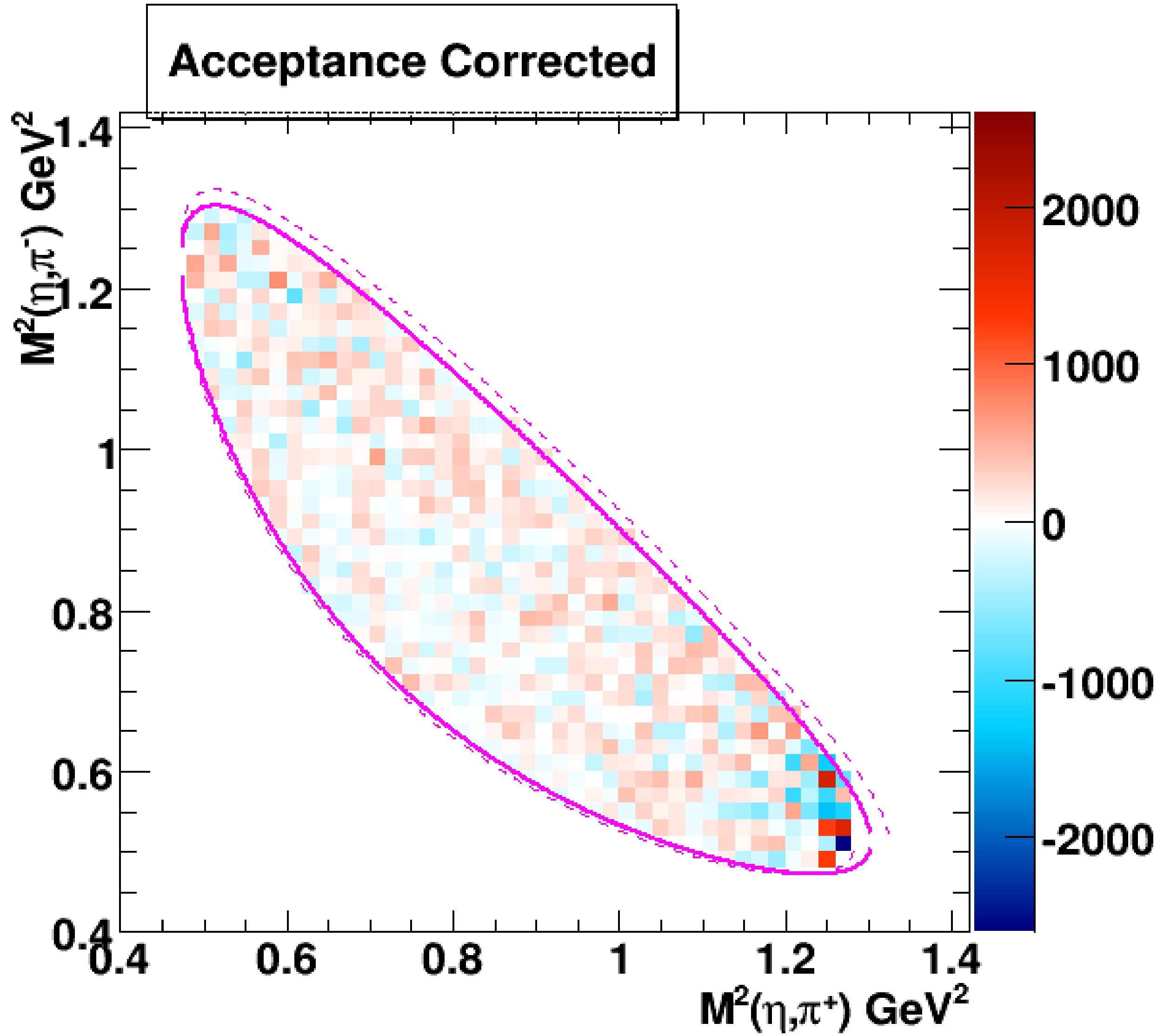
Systematic Test of Fits versus W



Dalitz Plot Systematics

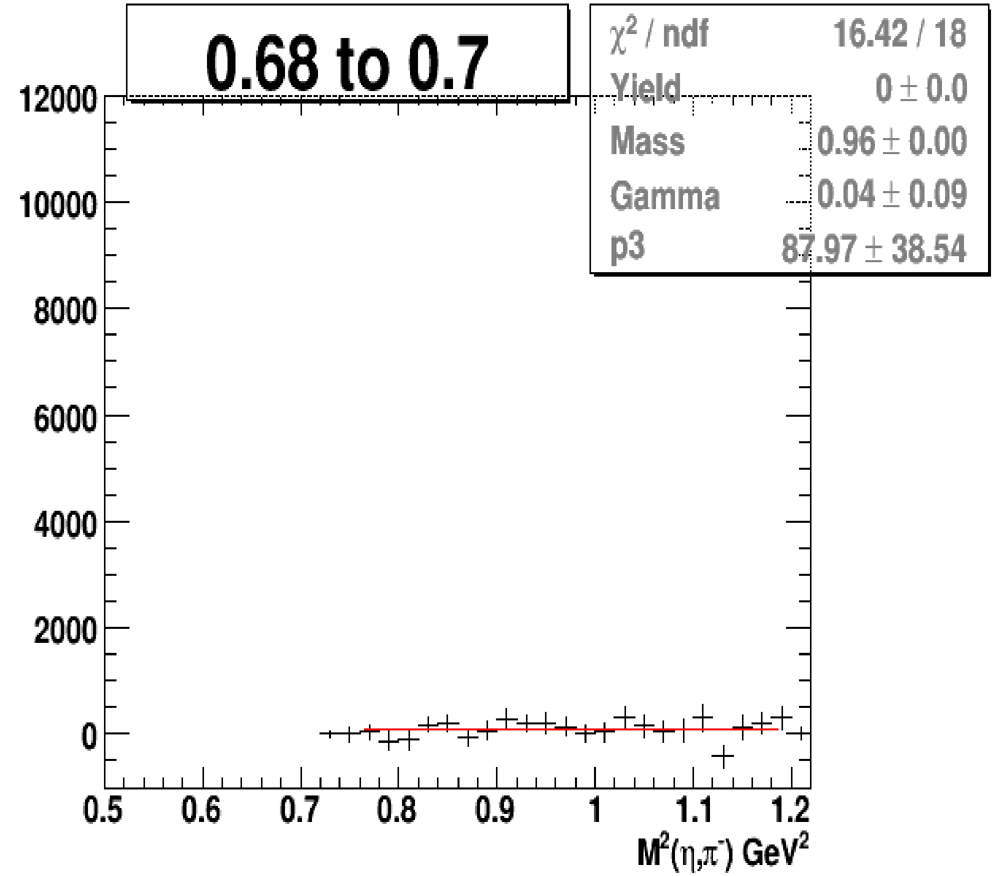


Dalitz Plot Systematics

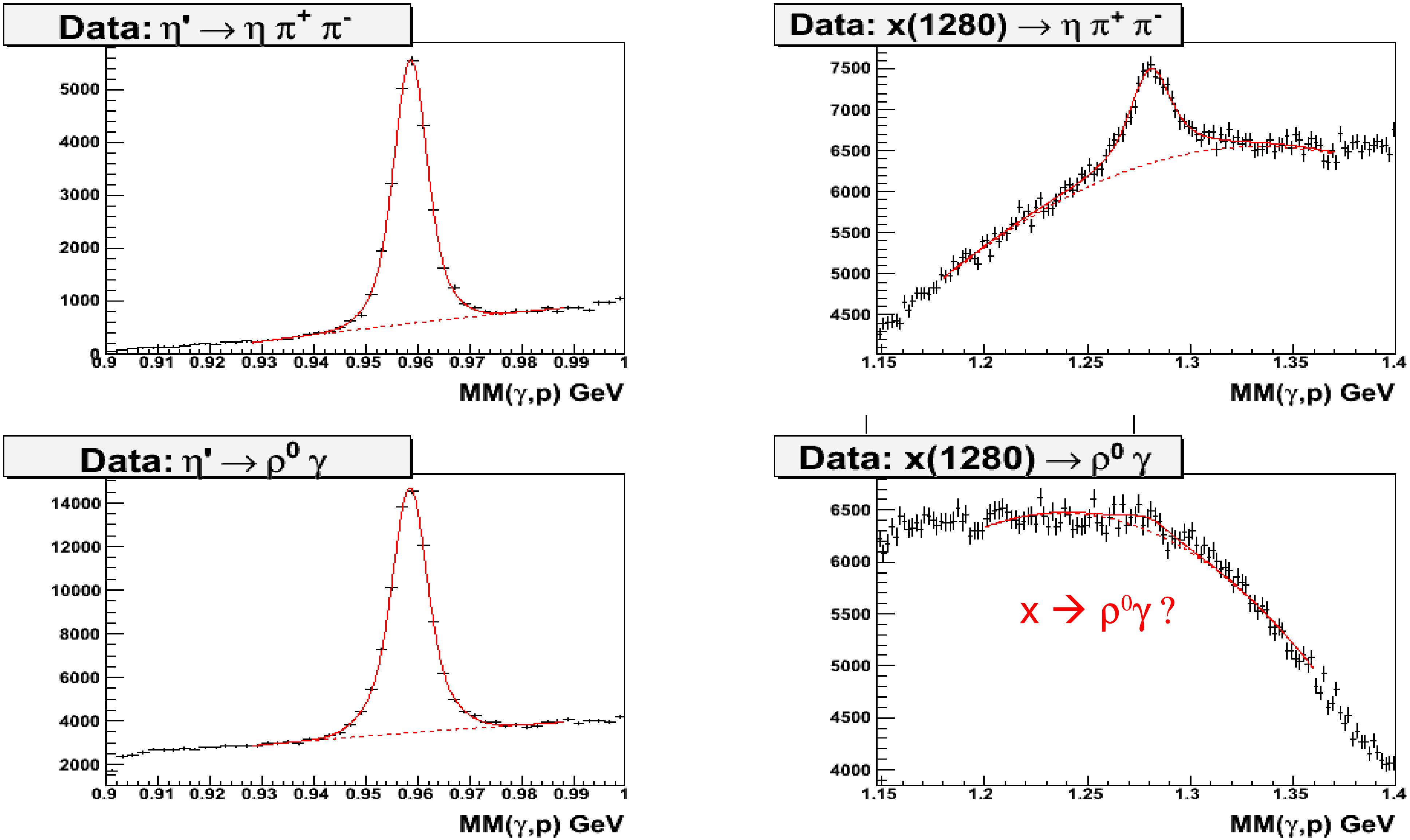


Dalitz Plot Systematics

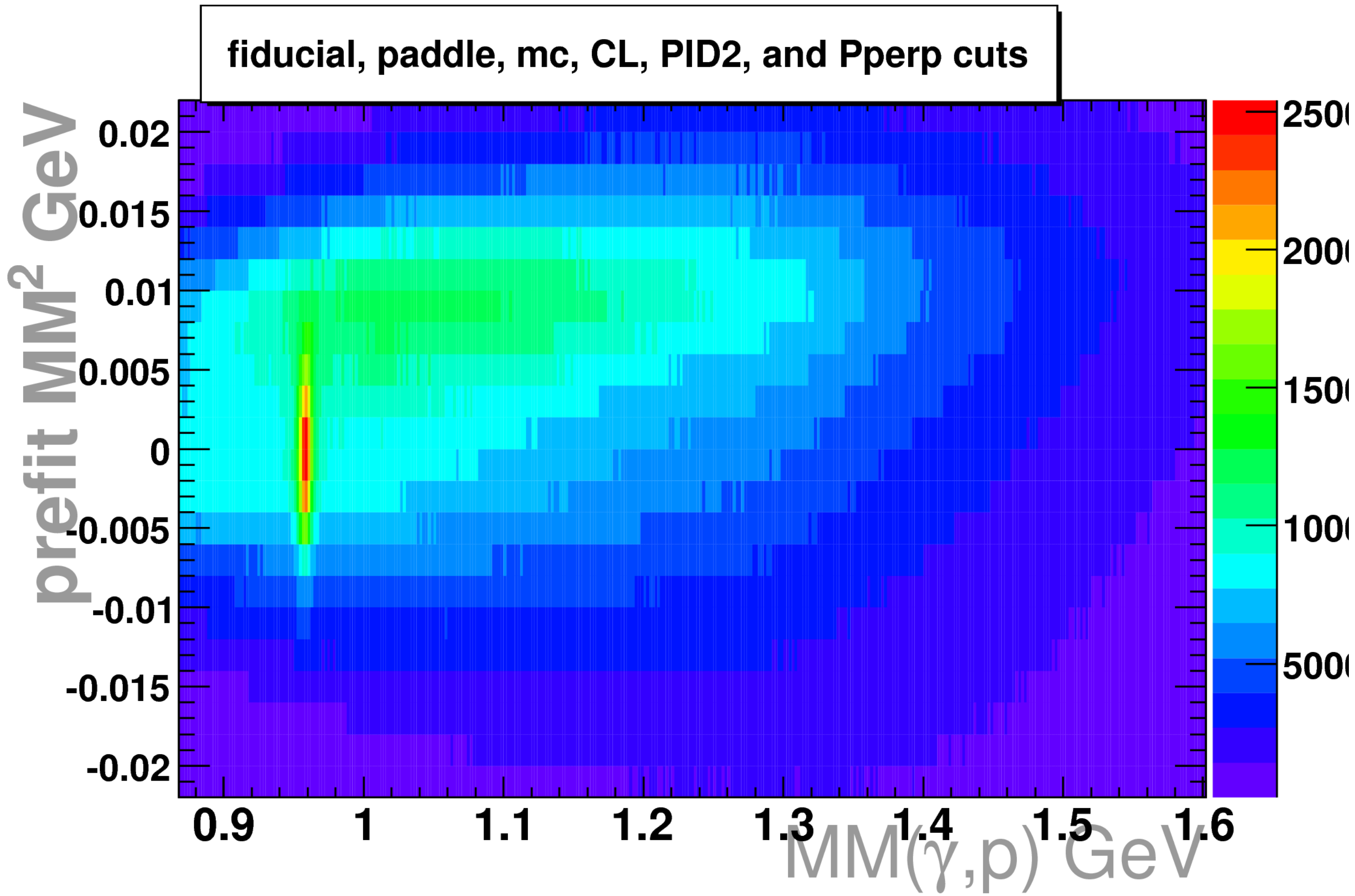
- Fitting slices shows no apparent bias from our scaling function.
- Still working on quantifying the systematic error from this method



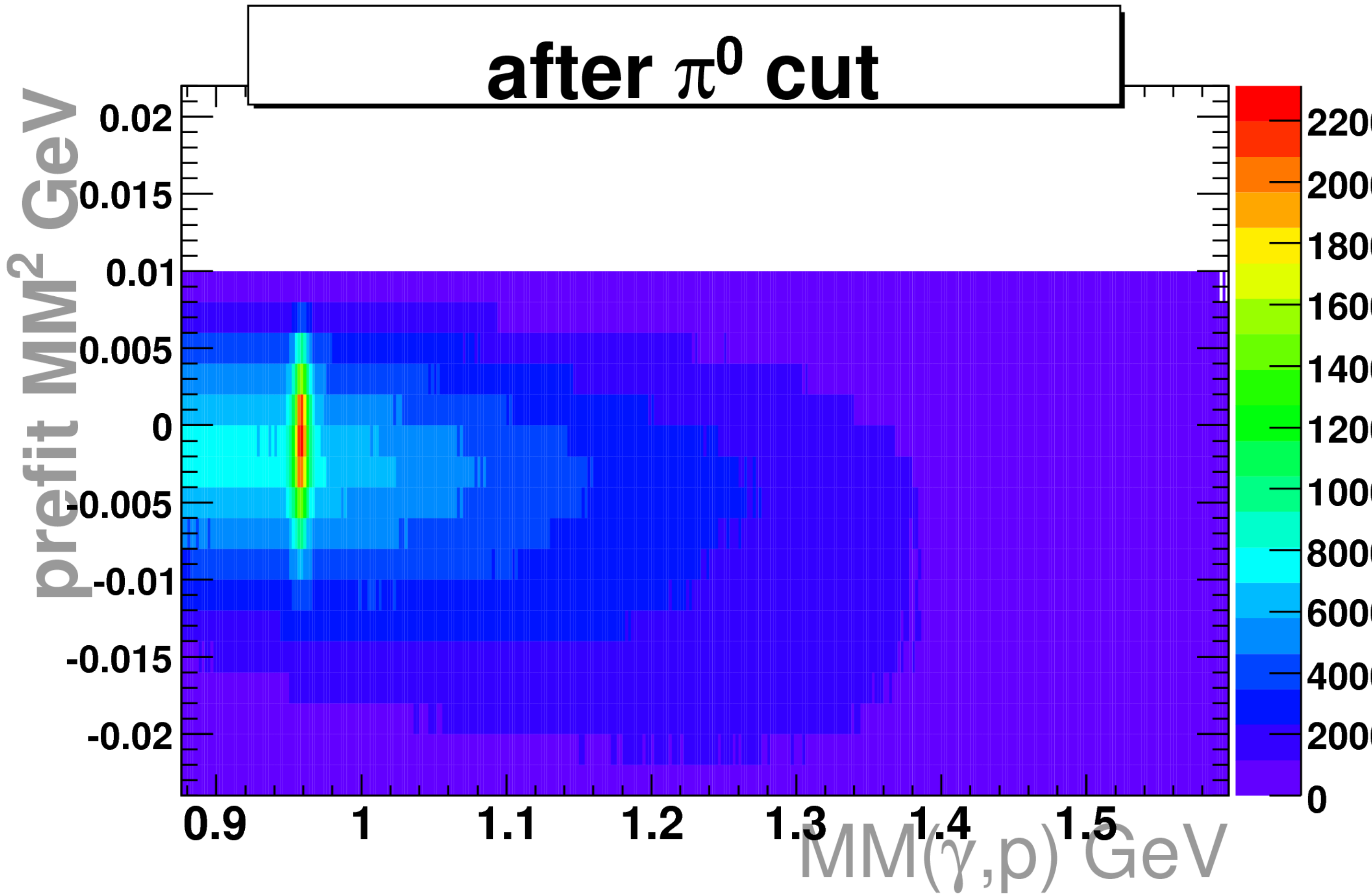
$\rho^0\gamma$ decay mode, missing?



$\gamma p \rightarrow p\pi\pi(\gamma)$ contains π^0 Background



Remove π^0 via Kinematic Fit < 0.01 CL



KKπ PID and method.

- Kaon identification requires tighter ΔTOF cuts of +/- 0.5 ns.
- Statistics were still limited with the $K^+K^-\pi^0$ channel invisible in our binning.
  - $K^+K^0\pi^-$ and $K^-K^0\pi^+$ channels combined and fit using voigtian with mass and width fixed from $\eta\pi^+\pi^-$ mode results.
  - Finally both the KKπ and $\eta\pi^+\pi^-$ yields were scaled by the appropriate isospin Clebsch-Gordon values to account for the missing $K^+K^-\pi^0$ and $\eta\pi^0\pi^0$ channels.

Corrections & Cuts of Data and Monte Carlo

- Tagger Photon Energy Corrections
- Drift Chamber Momentum Corrections
- CMU studies (need better heading here)
  - Monte Carlo trigger efficiency
  - MC momentum smearing (instead of gpp)
  - MC scaling (throw away events where GSIM is still ‘too efficient’ compared to data)
  - TOF Paddle and fiducial cuts as well of course

$\gamma p \to p\pi\pi(\eta)$

mc

data