

Meson Spectroscopy via PWA

D.P. Weygand
CLAS Collaboration



Exotica

Mesons outside of the Naive Quark Model (NQM)

Glueballs

Hybrids

Multi-quark

Restrictions on fermion-anti fermion quantum numbers

$$P = (-1)^{L+1}$$

$$C = (-1)^{L+S}$$

$$J^{PC} \neq 0^{--}, 0^{+-}, 1^{-+}, 2^{+-}, 3^{-+}, \dots$$

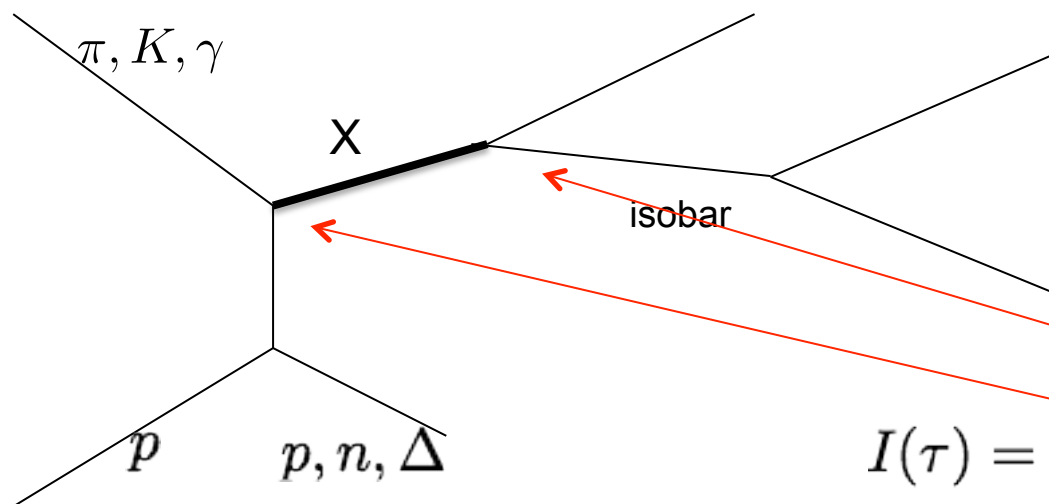
photoproduction

We would suggest that high-mass meson diffractive scattering will be particularly rich in hybrids. In the case where the beam flux tube is simply “plucked” by the target one will produce hybrids with the flavor and spin of the beam: A π beam would, for example, produce by this mechanism the nonexotic $I=1$, $J^{PC} = 1^{++}$ and 1^{--} hybrids. More complicated spin-flip and quantum-number exchange mechanisms in which the hybrid is produced by quark scattering rather than pure glue scattering could produce the other hybrids, including the desirable exotic ones. Diffractive photoproduction, on the other hand, can produce “plucked” ρ , ω , and ϕ states and so could be a good source for all four of the desirable exotics y_2^{+-} , z_2^{+-} , x_1^{-+} , and y_0^{+-} .

Isgur & Paton

Phys. Rev. Lett. 54, 869–872 (1985)

Partial Wave Analysis



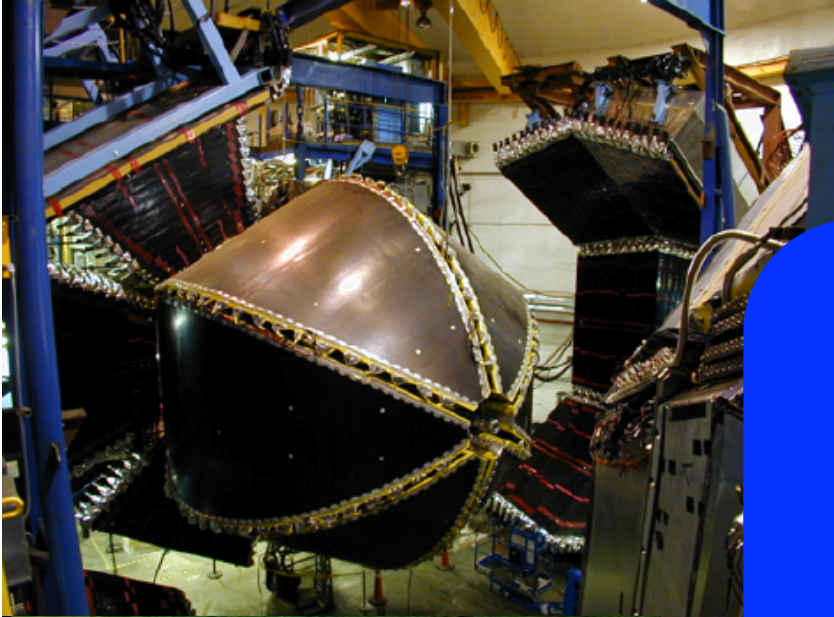
$$I(\tau) = \sum_{\epsilon, k} \left| \sum_{\beta} V_{k\beta}^{\epsilon} A_{\beta}^{\epsilon}(\tau) \right|^2$$

Likelihood function:

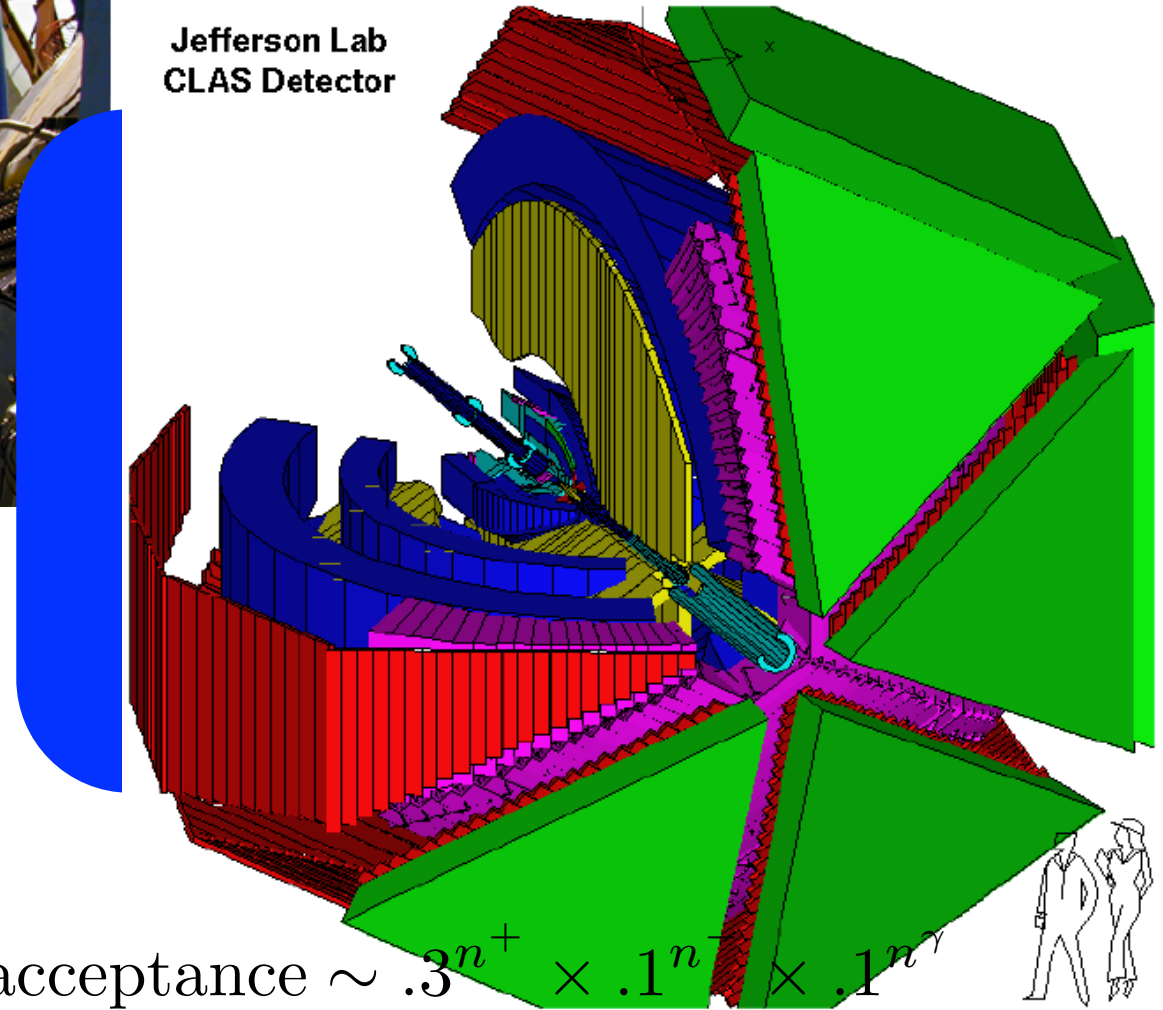
$$\mathcal{L} = \frac{\bar{n}^n}{n!} e^{-\bar{n}} \prod_i^n \frac{I(\tau_i)}{\int I(\tau) \eta(\tau) d\tau}$$

event based, unbinned

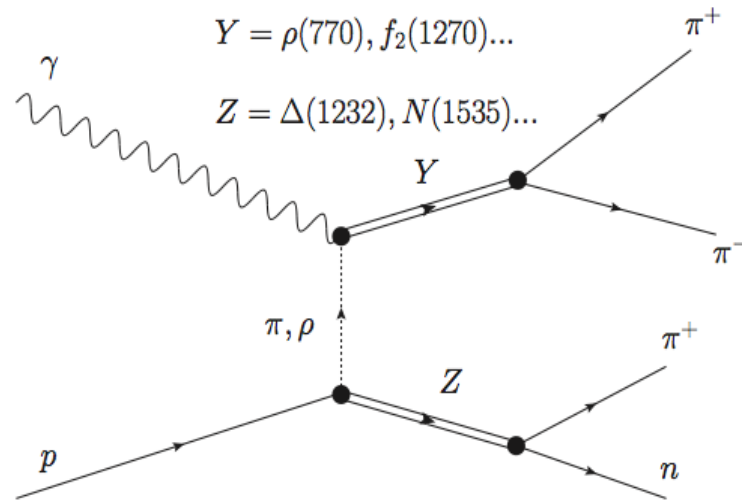
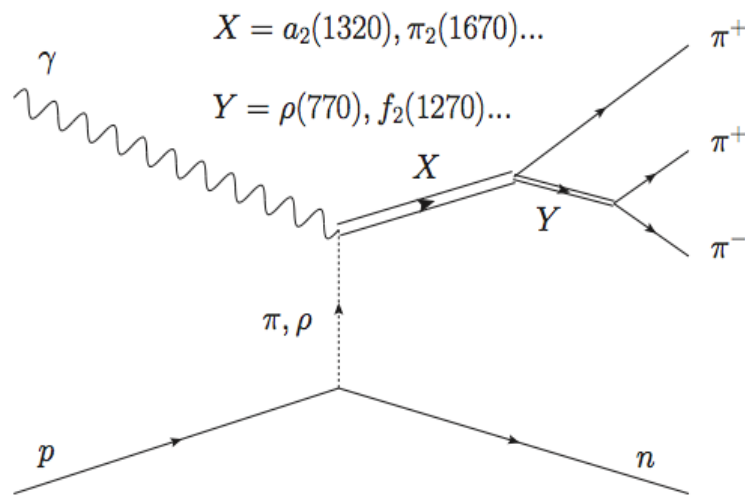
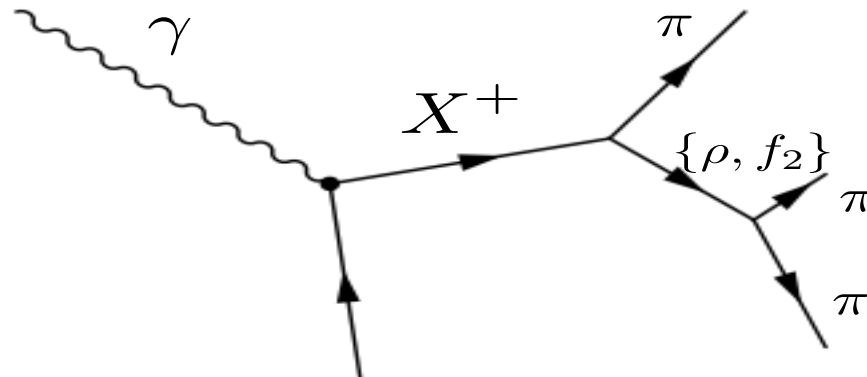
CLAS g_{12} run



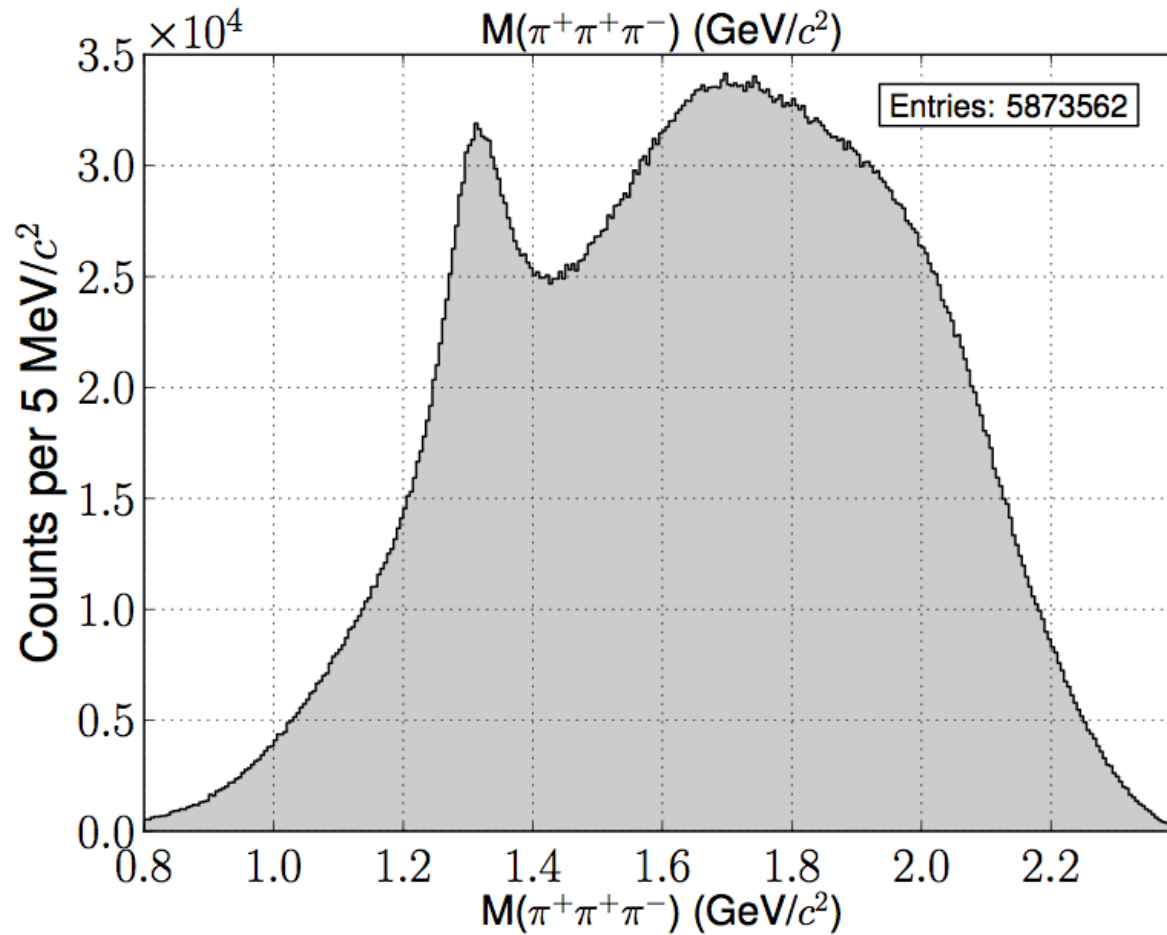
Jefferson Lab
CLAS Detector



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

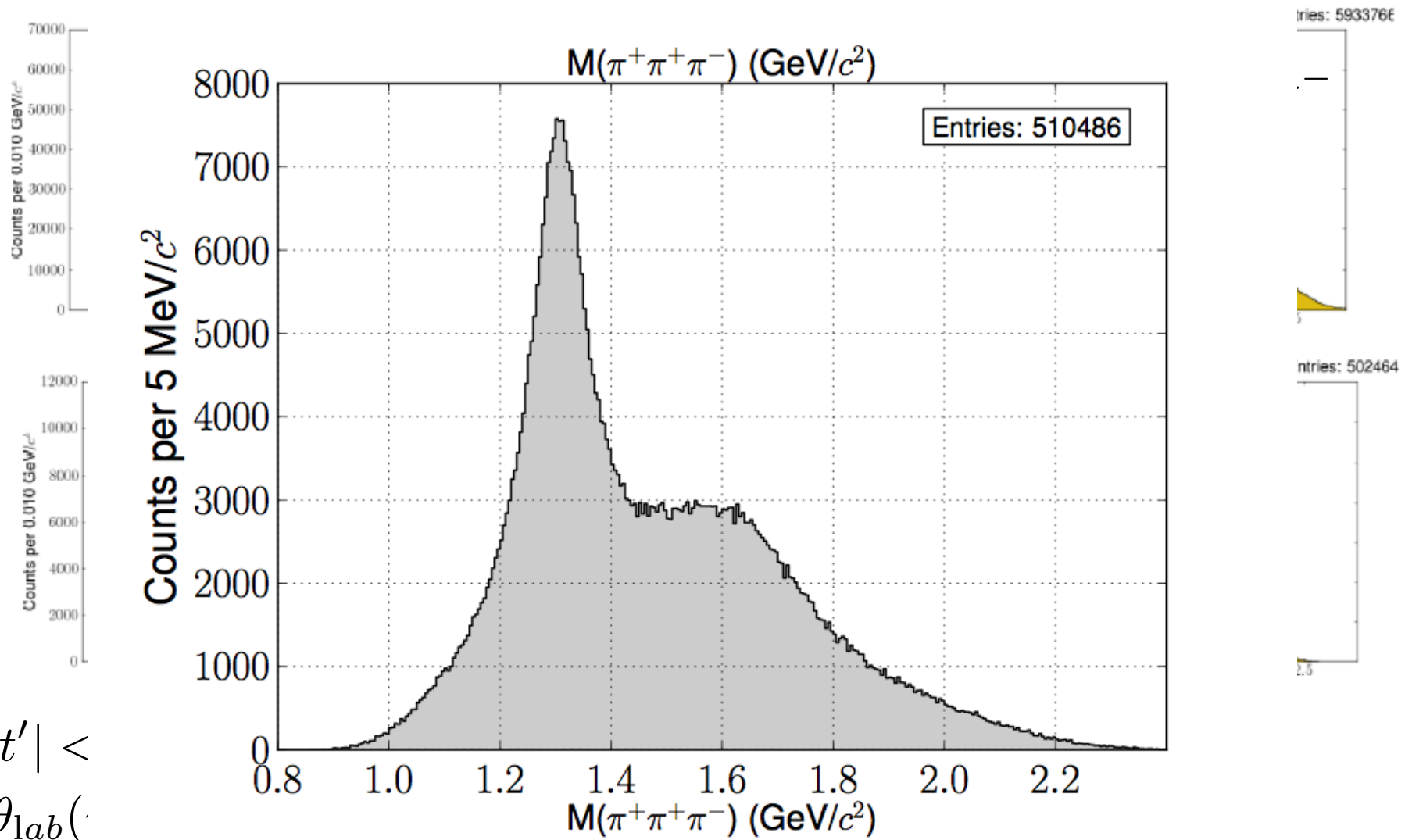


Raw $\pi\pi\pi$ mass spectra



C. Bookwalter thesis

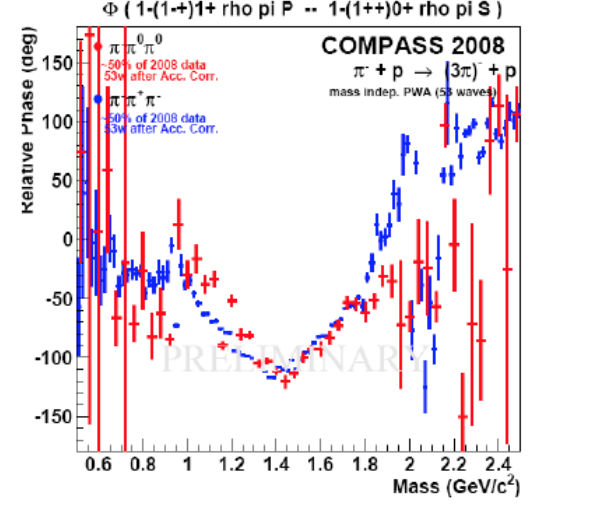
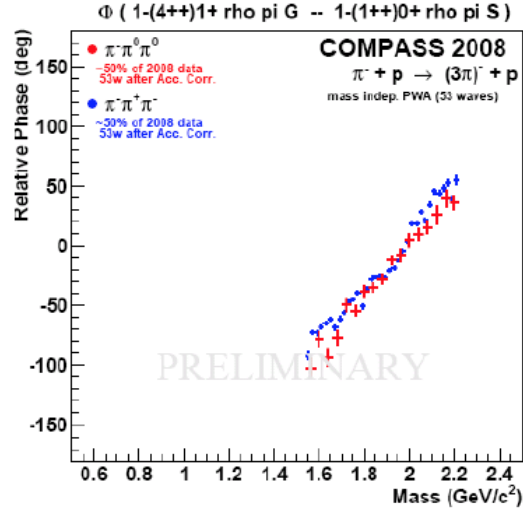
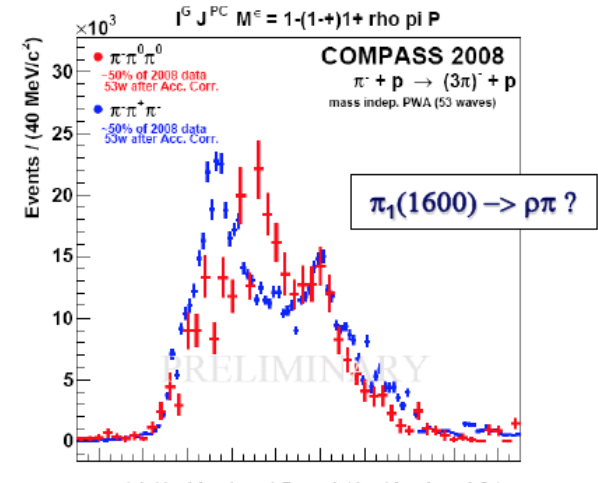
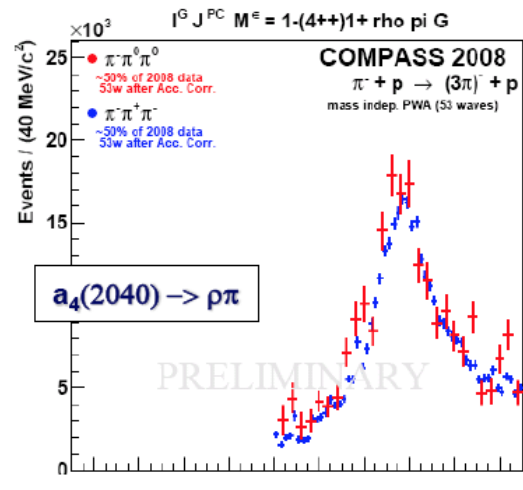
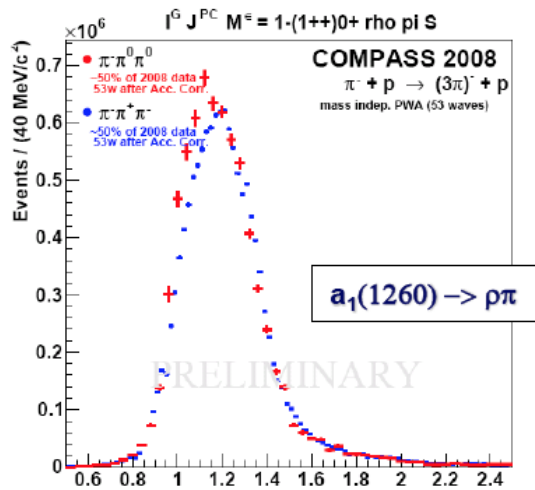
Baryon background



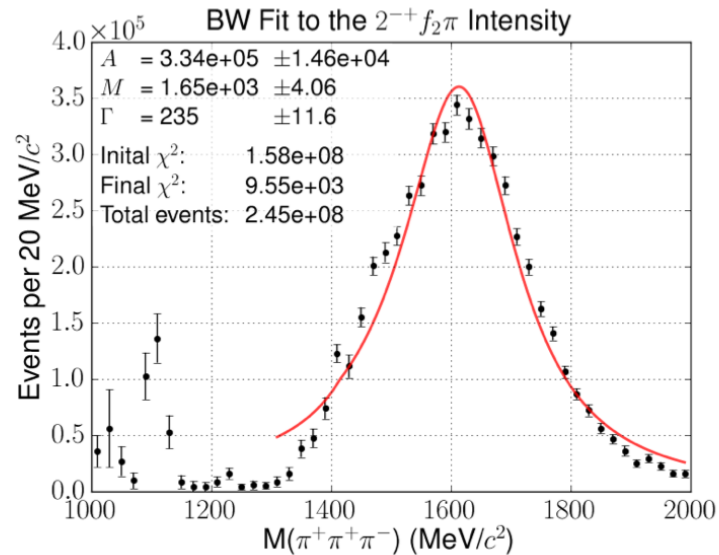
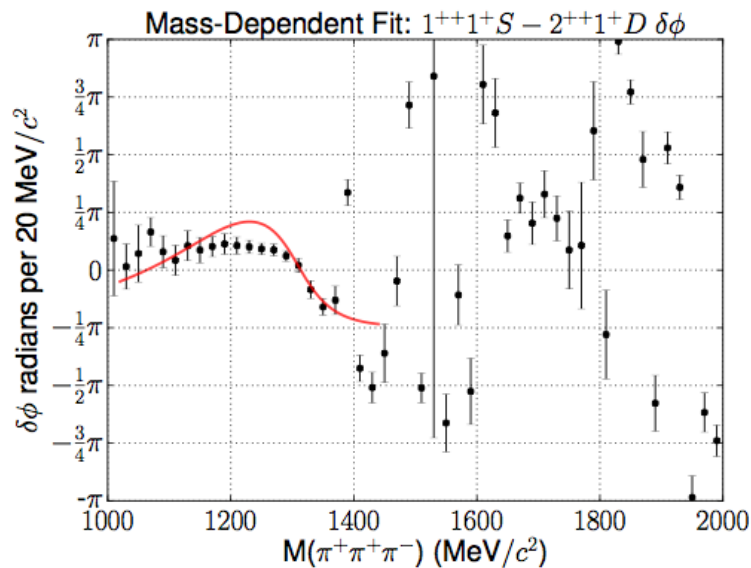
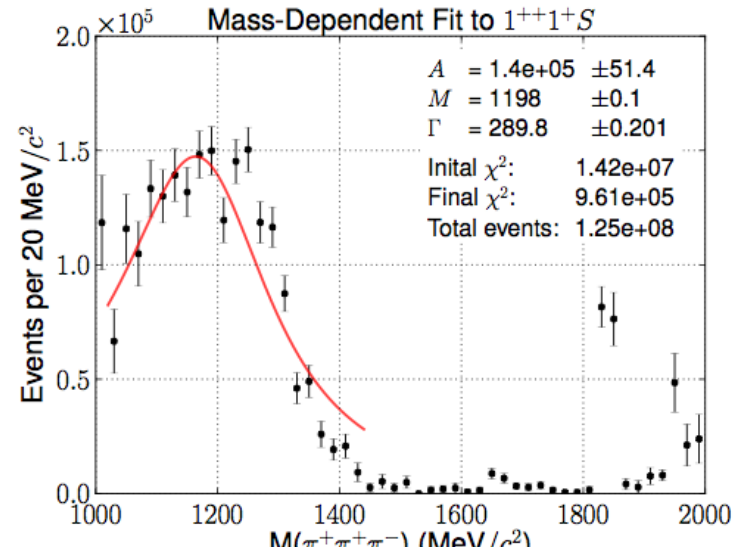
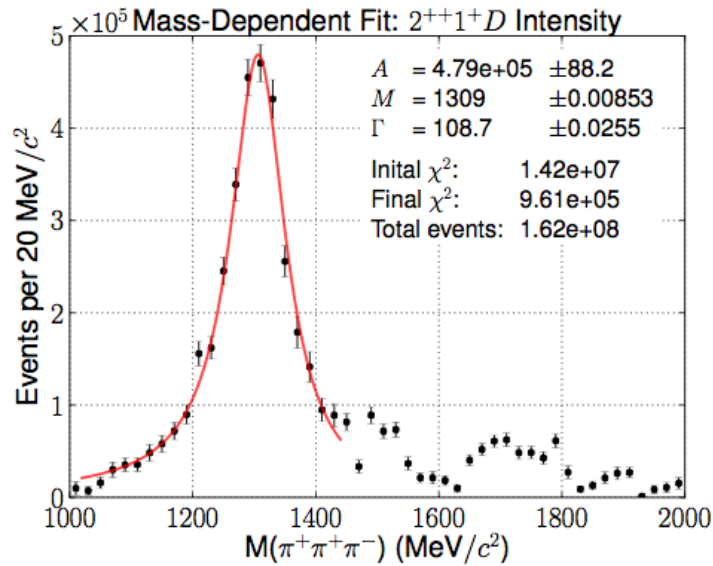
$$|t'| <$$

$$\theta_{lab}(\cdot)$$

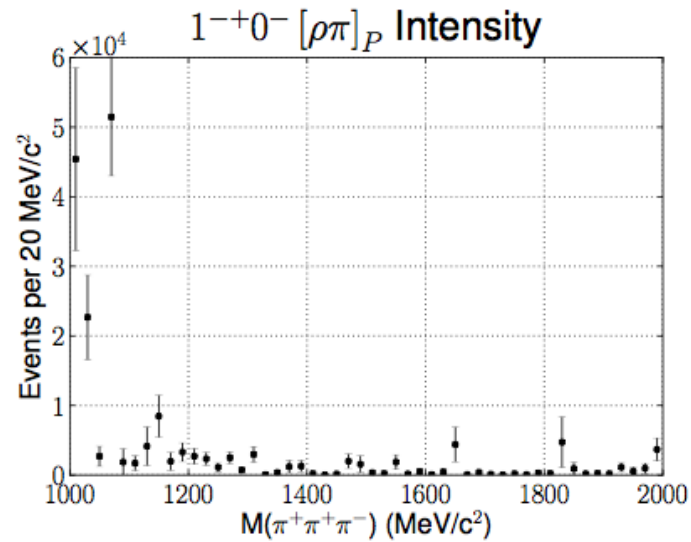
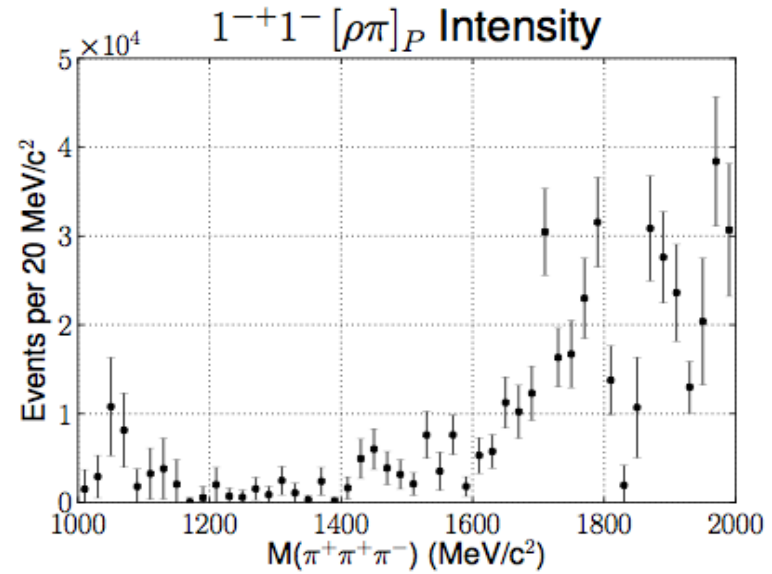
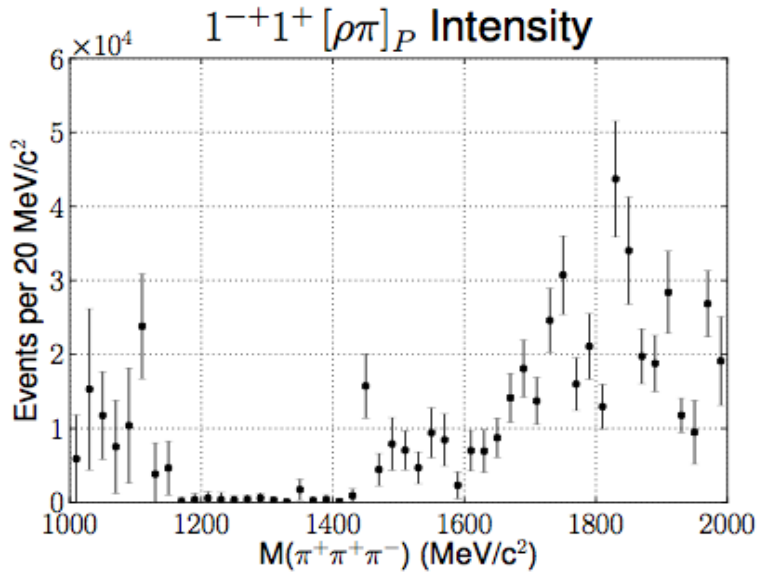
COMPASS



$a_1(1260)/a_2(1320)/\pi_2(1670)$

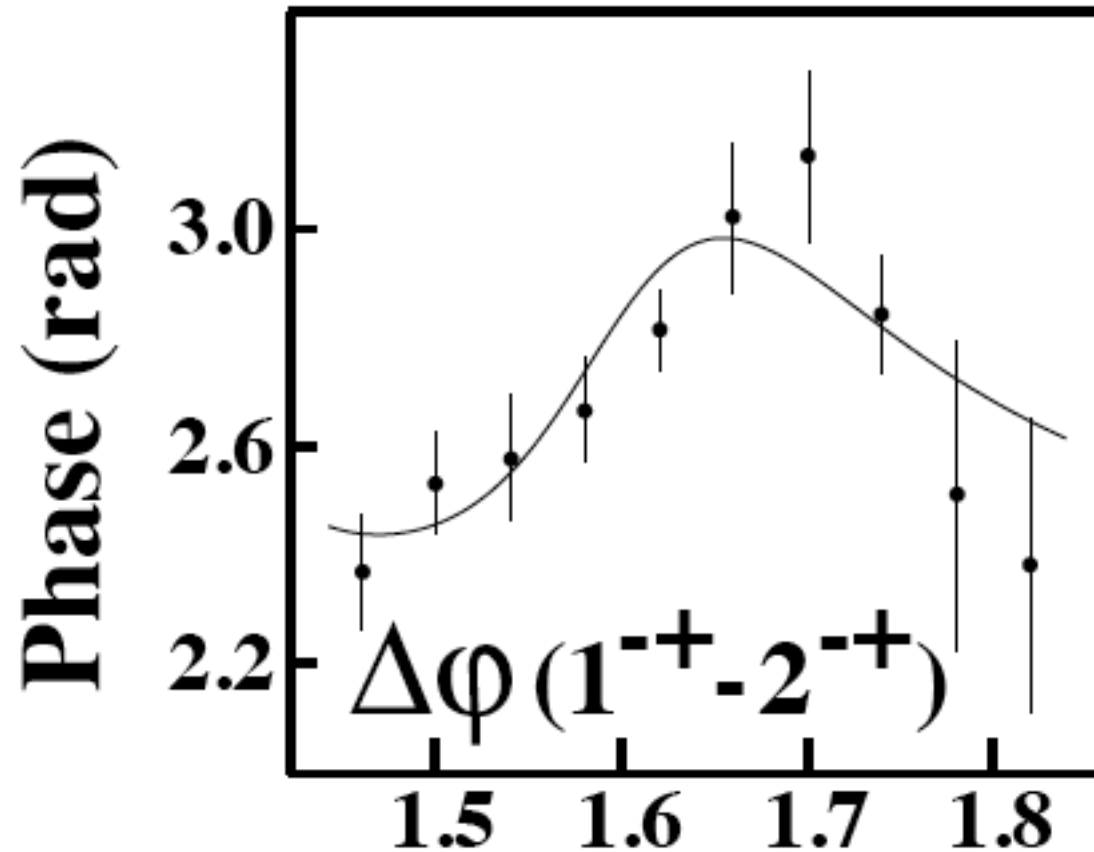


$$J^{PC} = 1^{-+}$$

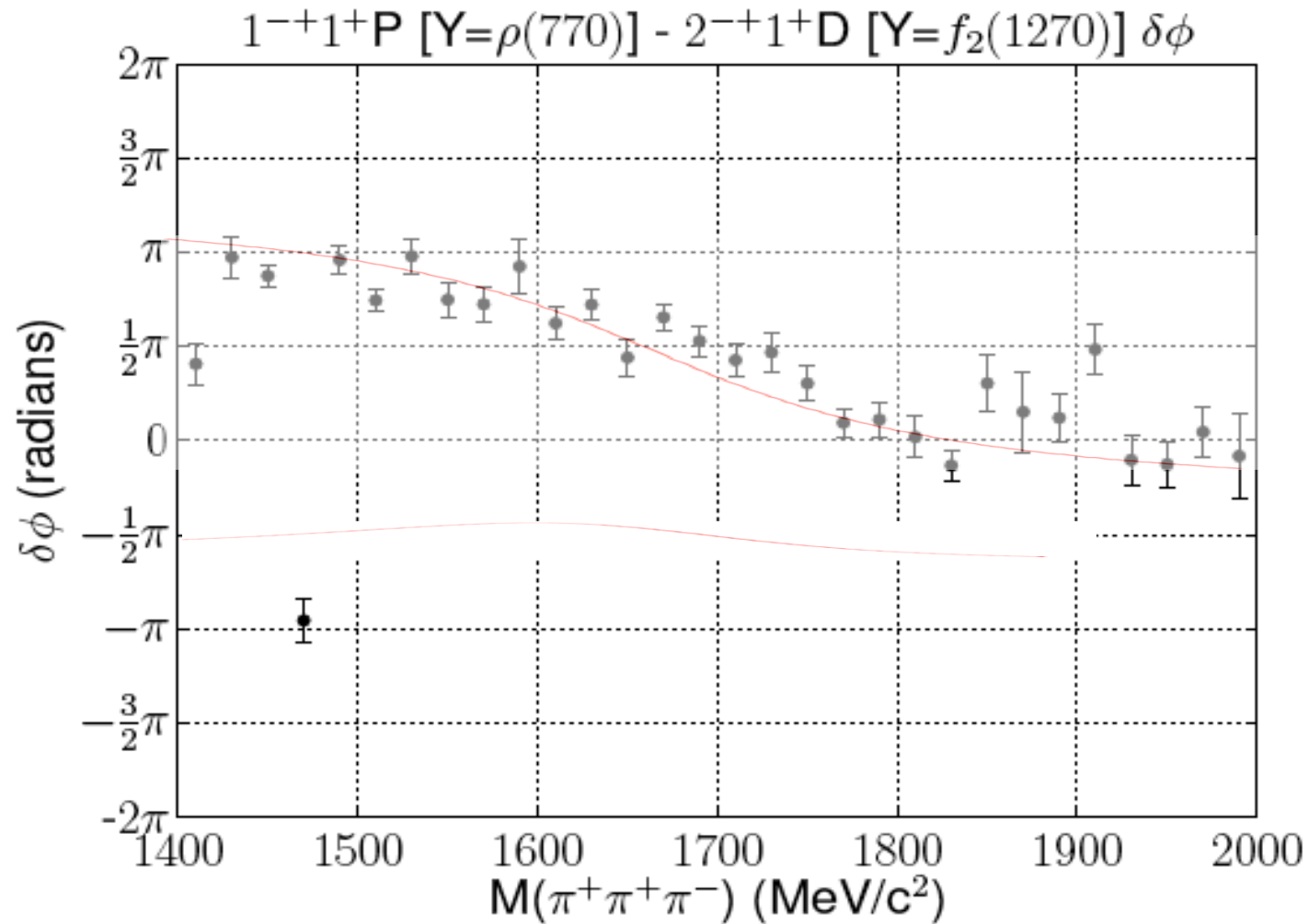


$\pi_1(1600)$ phase

E852/1998



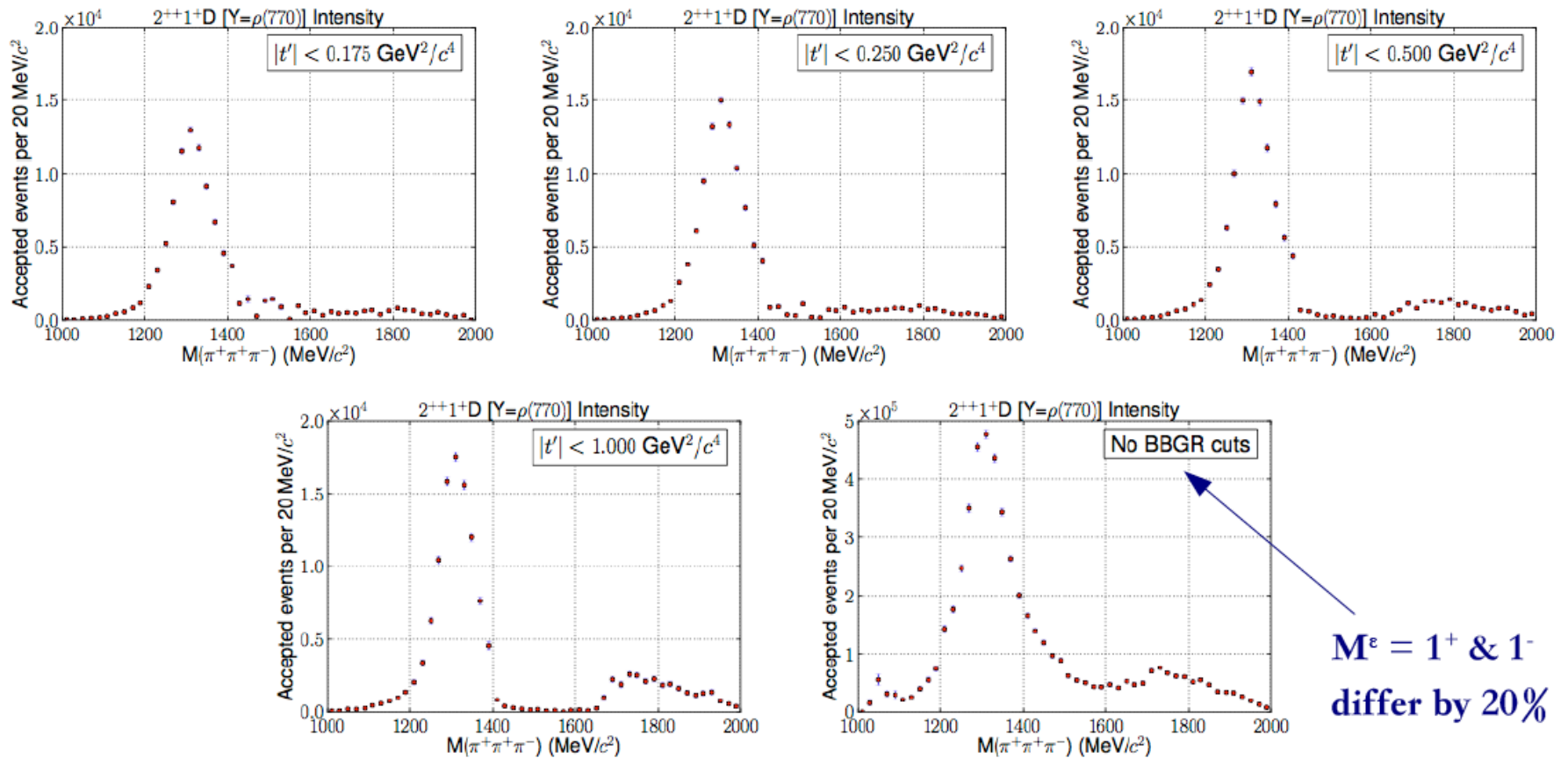
π_1/π_2 phase



Baryon Background

no π^+ lab angle cut and varying t' cut

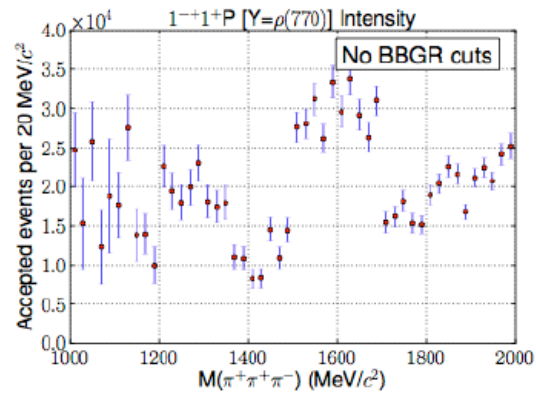
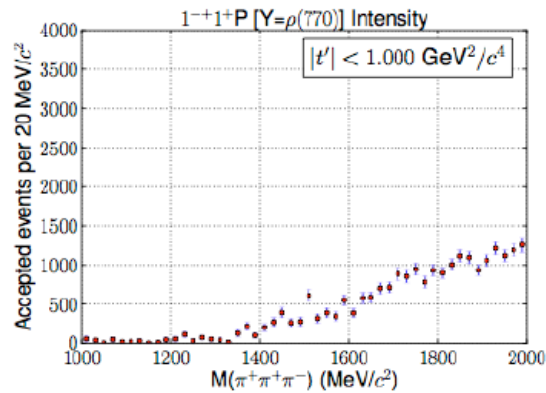
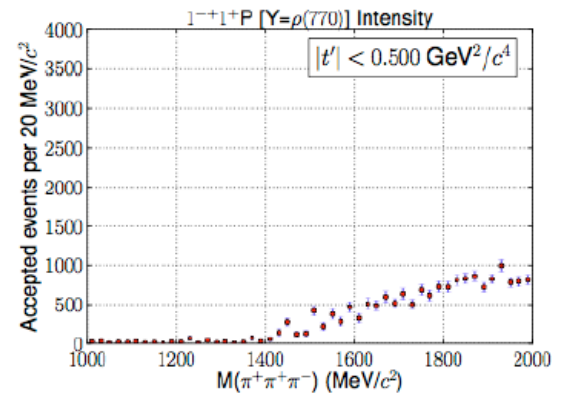
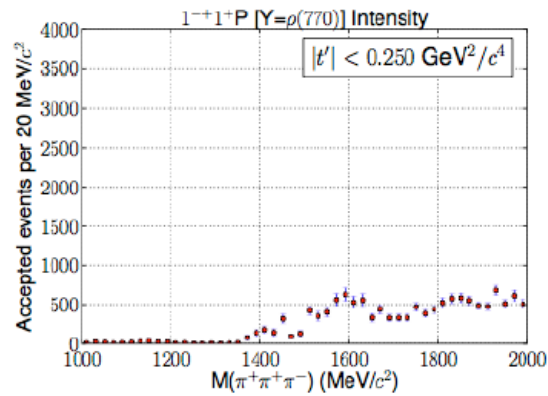
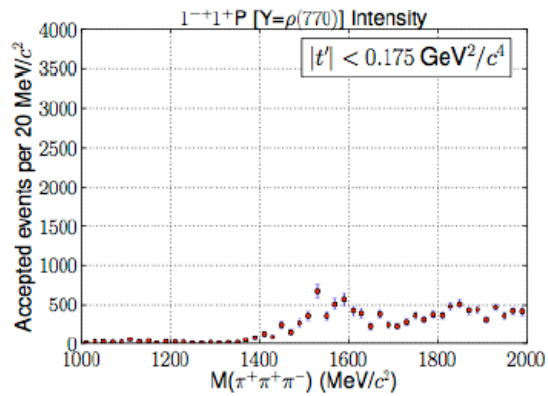
$\alpha_2(1320)$ seen in $2^{++}1^+D$ Intensities



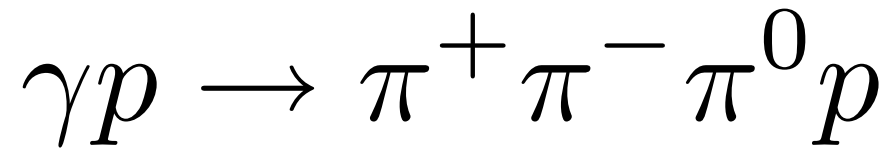
$M^\epsilon = 1^+ \text{ \& } 1^-$
differ by 20%

Baryon Background

no π^+ lab angle cut and varying t' cut

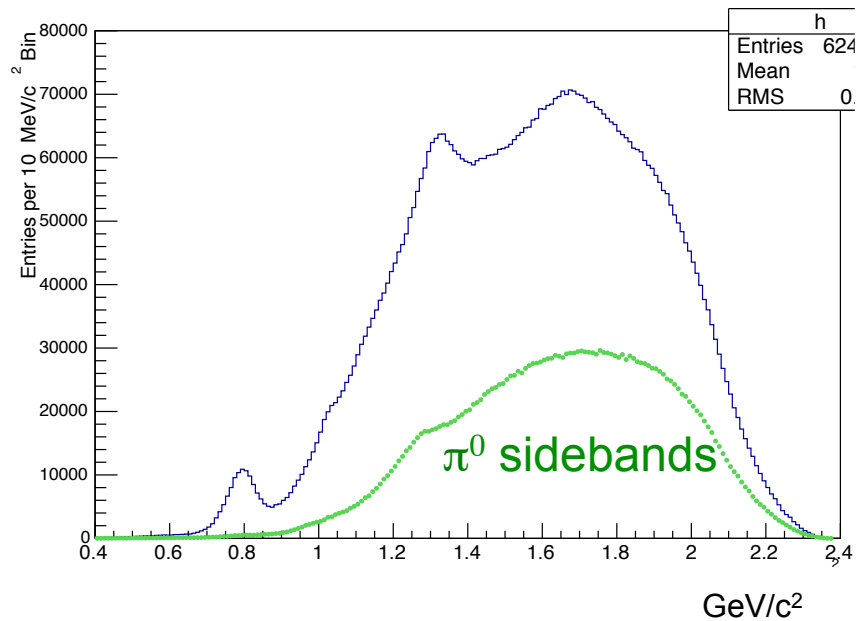


Exotic $1^{-+}1^{-}P$ Intensities

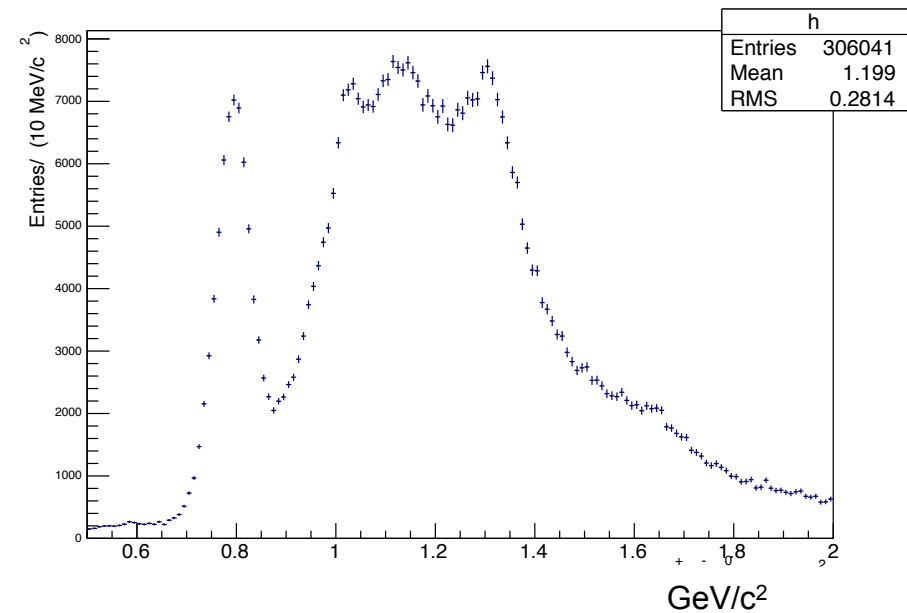


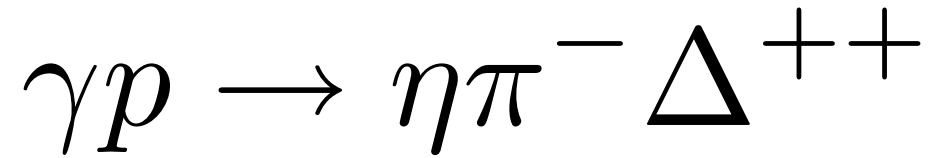
in progress

$\pi\pi\pi$ mass

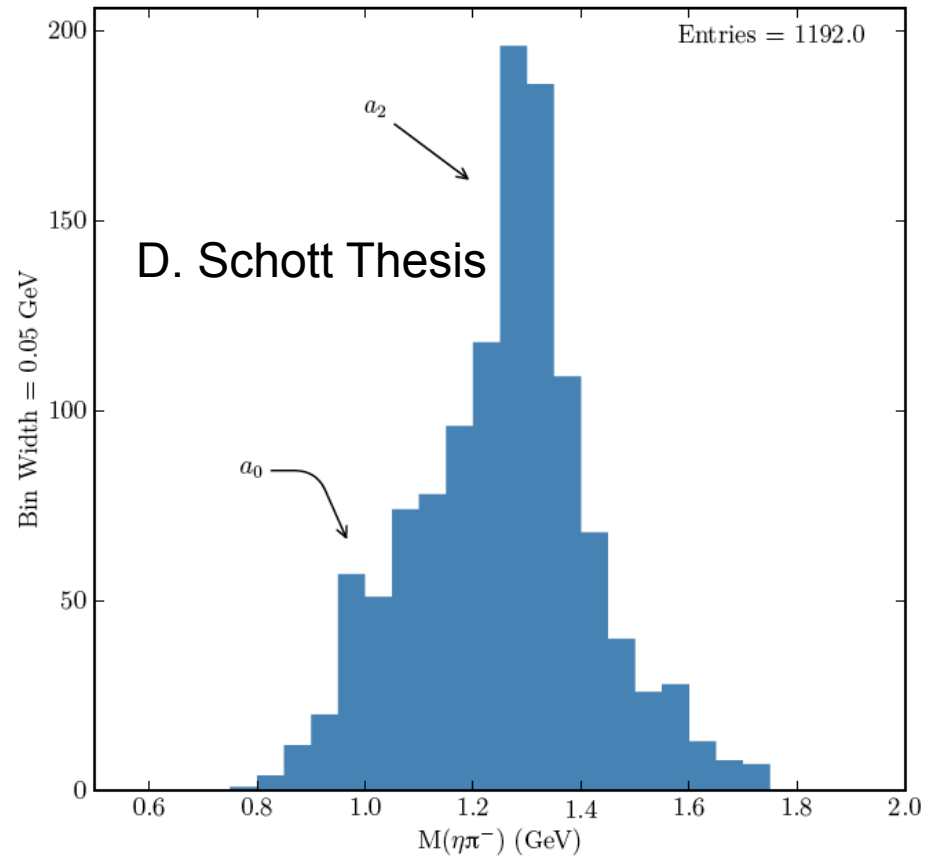
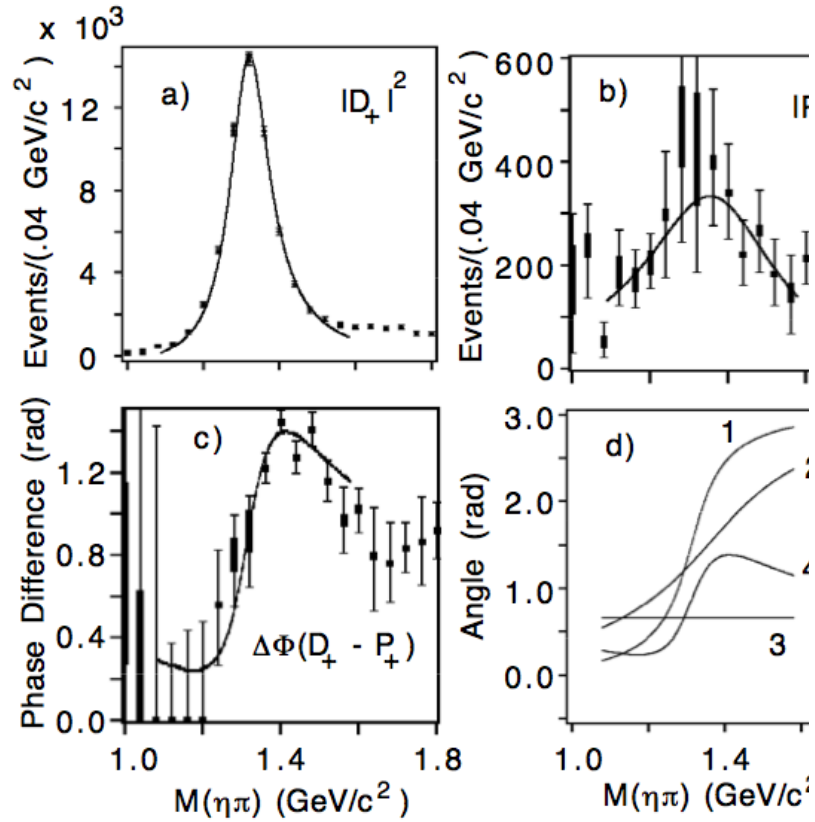


$$\cos(\theta_{\pi^+, \pi^-}) > 0.9$$

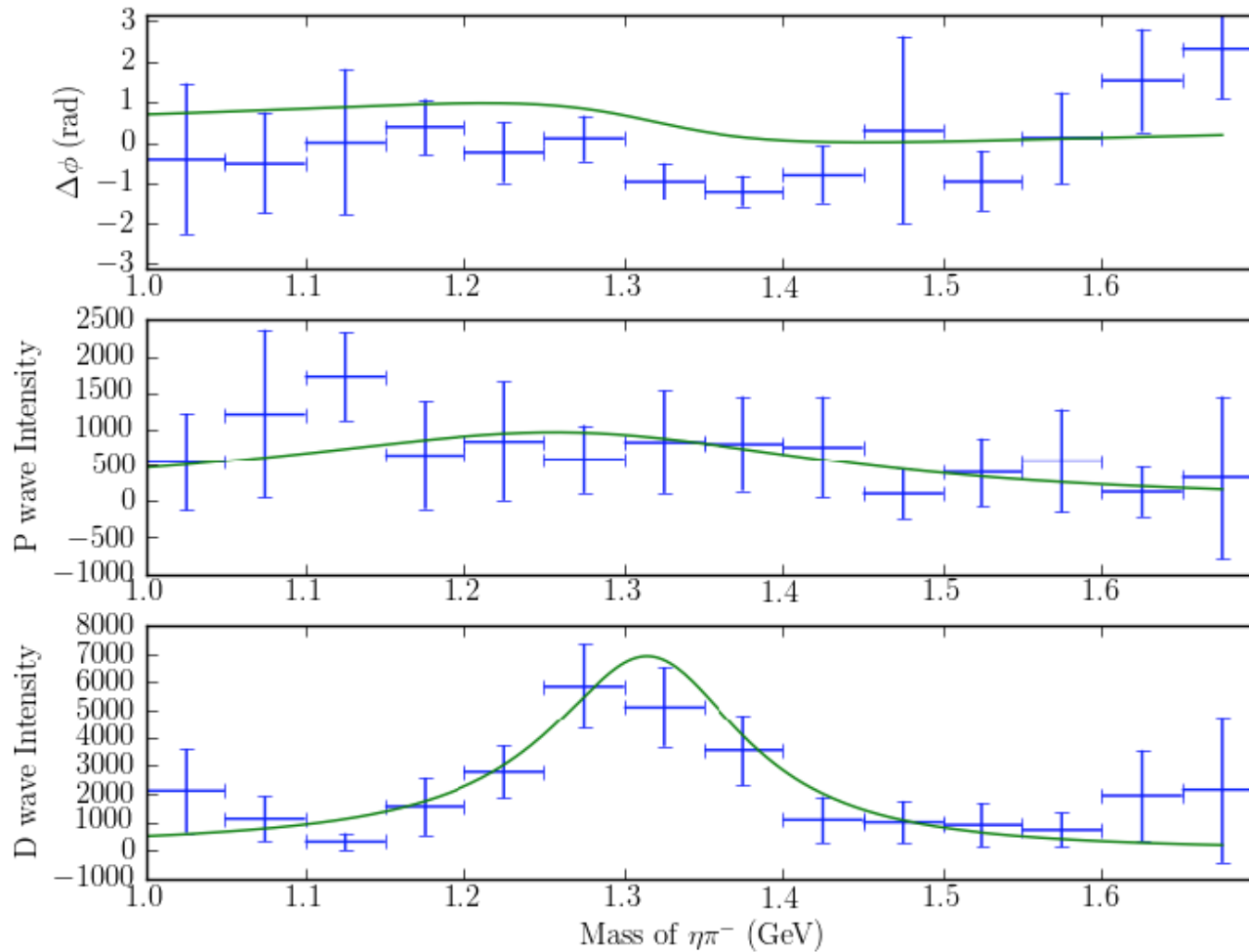




E852 1997



$\eta\pi^-$ PWA



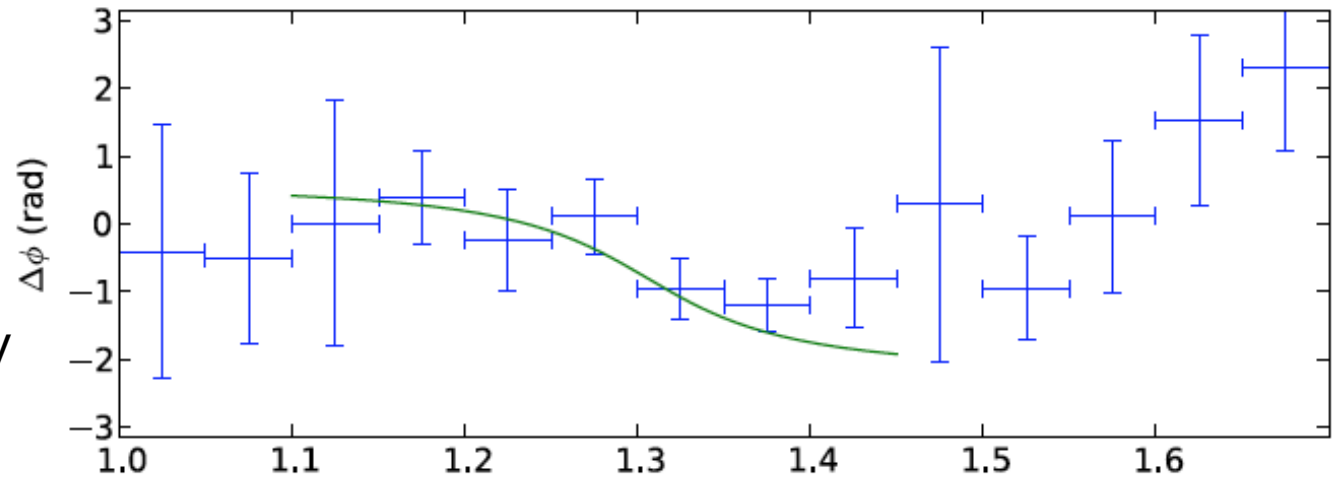
$\Delta\phi$

P M=1

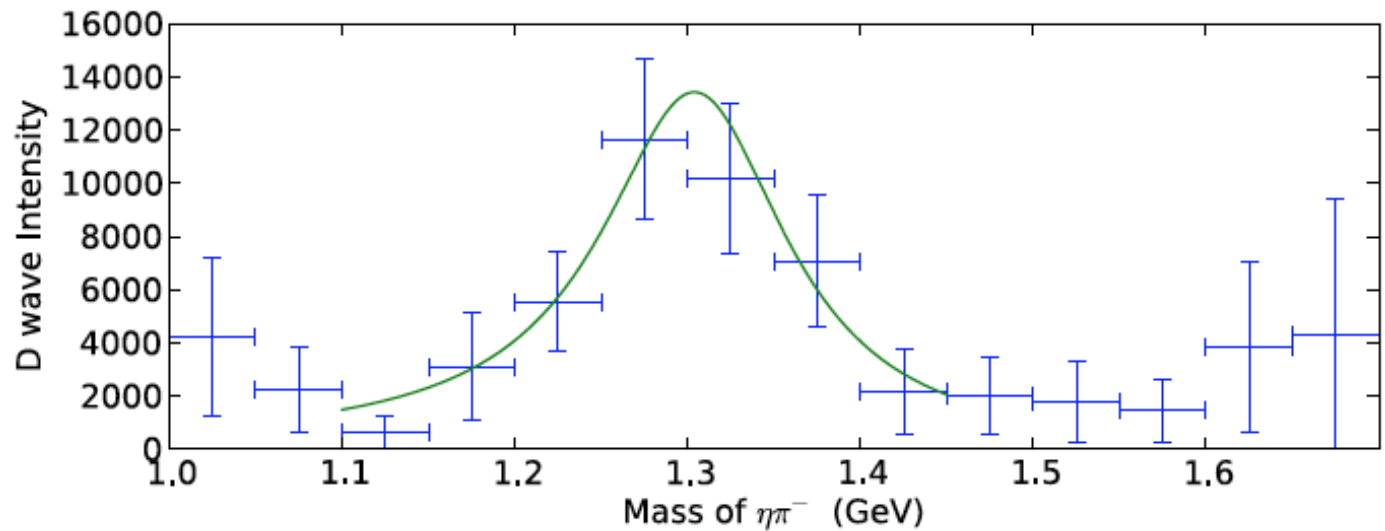
D M=1

a2(1320) Breit-Wigner

mass = 1.32 ± 0.01 GeV



$\Gamma = 0.14 \pm 0.01$ GeV



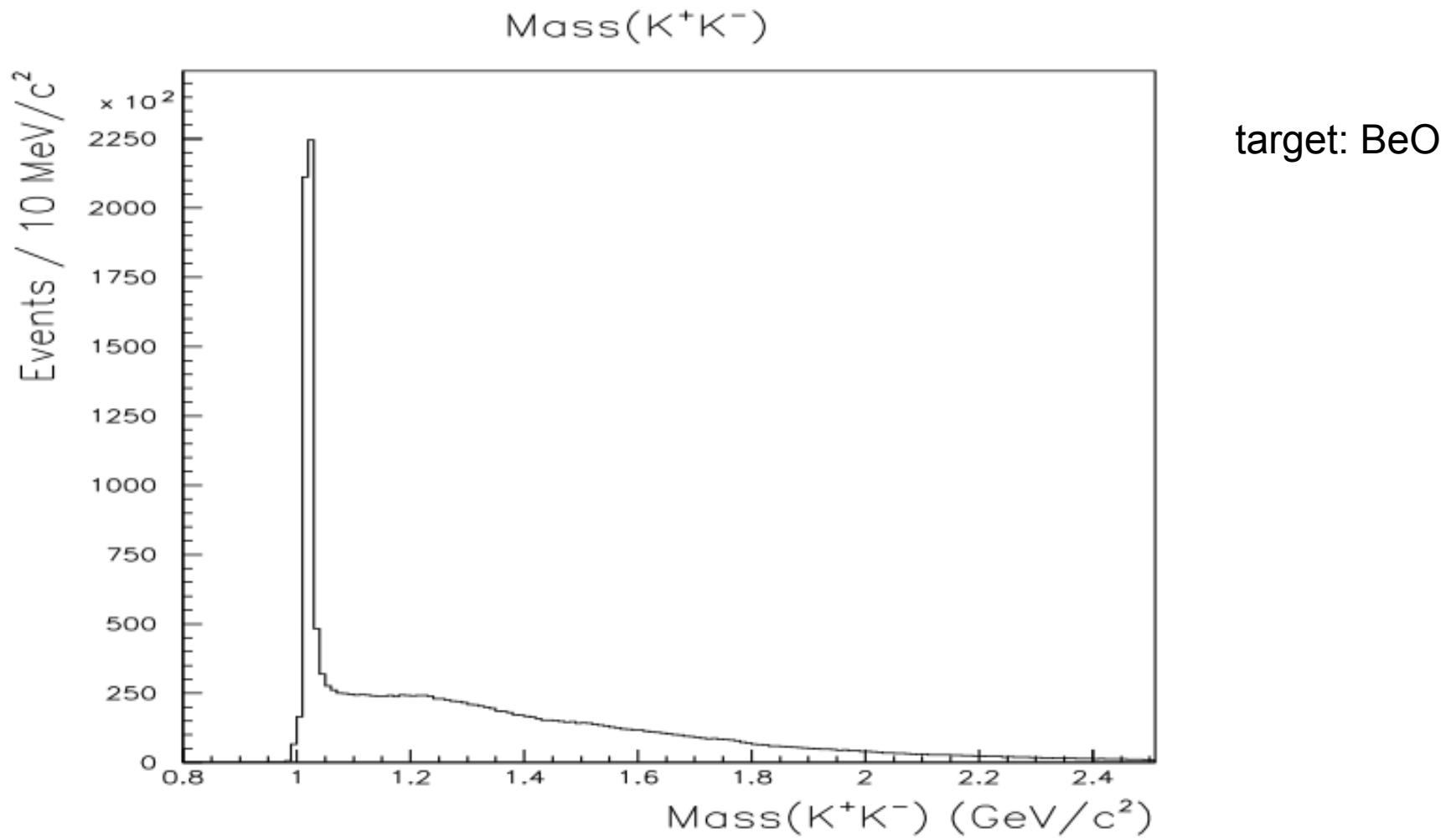
Strangeonium

Radial Excitations of S: the Φ

1S	1019 (Φ) $\Gamma_{th}=2.5\text{MeV}$ $\Gamma_{exp}=4.26\text{MeV}$	$\Gamma_{th}=2.5\text{MeV}$			
→ 2S	1680 (Φ) $\Gamma_{th}=378\text{MeV}$ $\Gamma_{exp}=150\text{MeV}$	$\Gamma_{th}=89\text{MeV}$	$\Gamma_{th}=245\text{MeV}$	$\Gamma_{th}=44\text{MeV}$	
3S	2050 (Φ) $\Gamma_{th}=378\text{MeV}$		$\Gamma_{th}=20\text{MeV}$	$\Gamma_{th}=21\text{MeV}$	$\Gamma_{th}=337\text{MeV}$
		KK	KK*	$\eta\phi$	K*K* KK ₁₍₂₎ $\eta'\phi$...

(3P_0 decay model: Barnes, Black, Page: 2002)

Focus: 20-160 GeV photons



Focus (FNAL)

at 60 GeV
 $|t| < 0.017 \text{ GeV}^2$

target: BeO

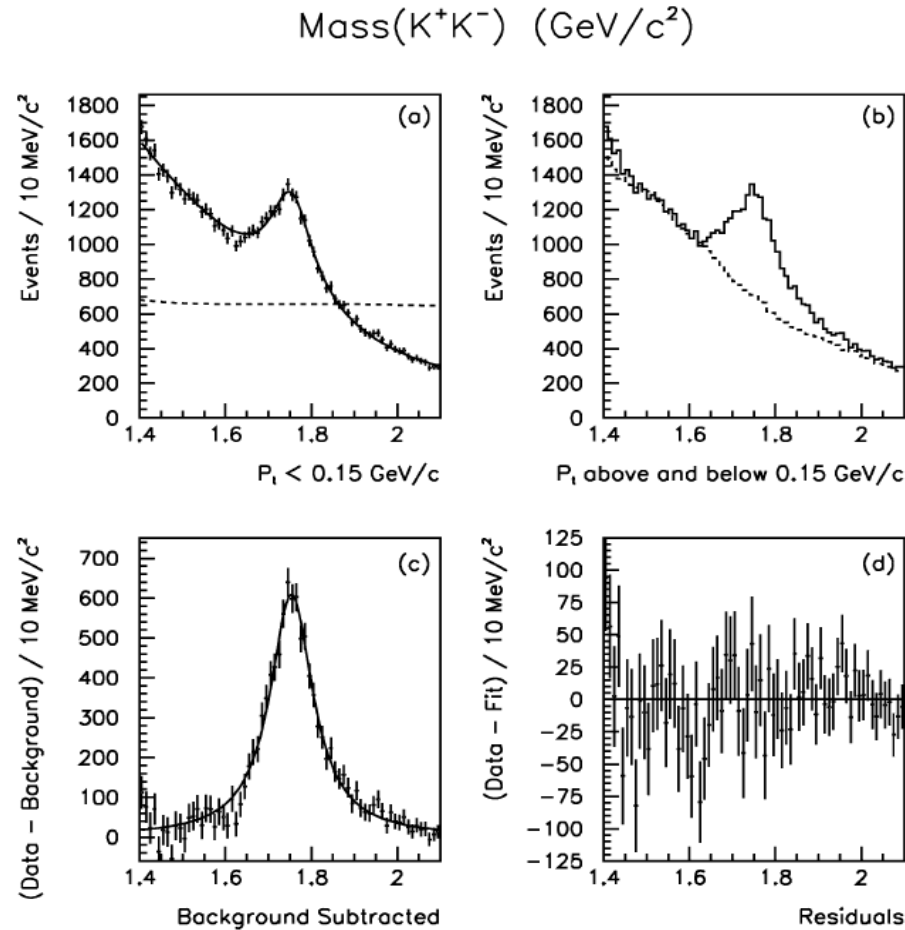


Fig. 3. (a) The K^+K^- mass spectrum with the requirement that $p_T < 0.15 \text{ GeV}/c$. The spectrum is fit with a non-relativistic Breit-Wigner distribution and a quadratic background. The dotted line is the Monte Carlo efficiency on a scale from 0 to 100%. (b) The K^+K^- mass spectrum with the requirement that $p_T < 0.15 \text{ GeV}/c$. The solid line is the K^+K^- mass spectrum with $p_T < 0.15 \text{ GeV}/c$. The dotted line is the K^+K^- mass spectrum with $p_T > 0.15 \text{ GeV}/c$ scaled to the size of the low p_T spectrum for comparison. (c) The data and fit after subtracting the quadratic polynomial background shape. (d) The data minus the fit.

Focus: t-distribution

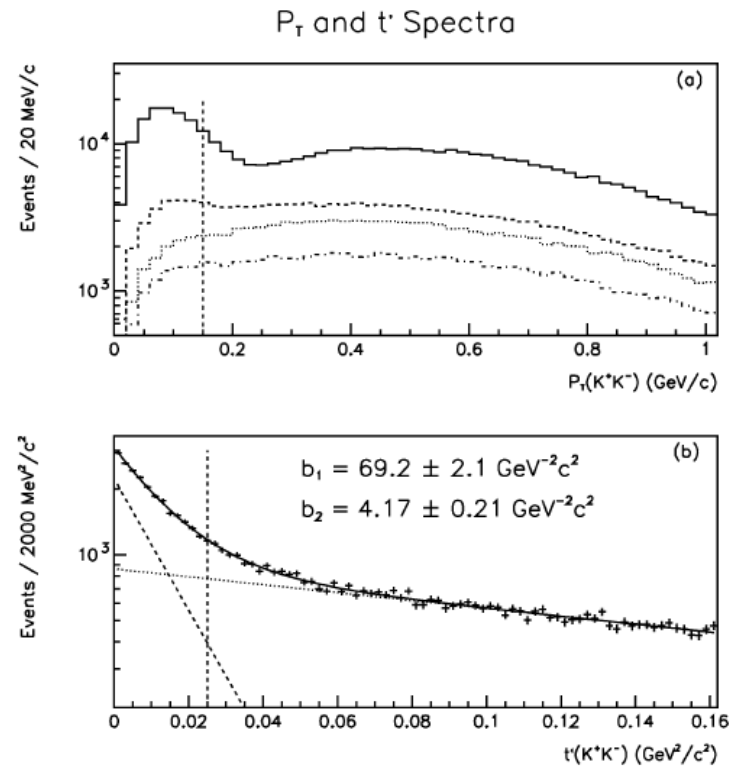
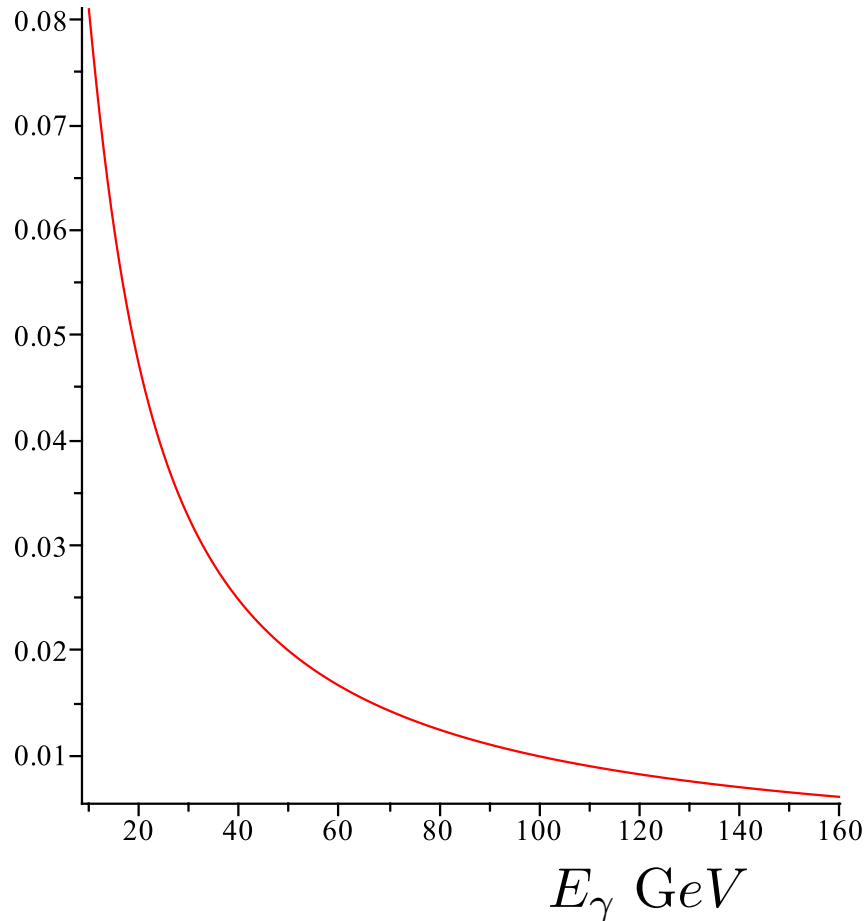
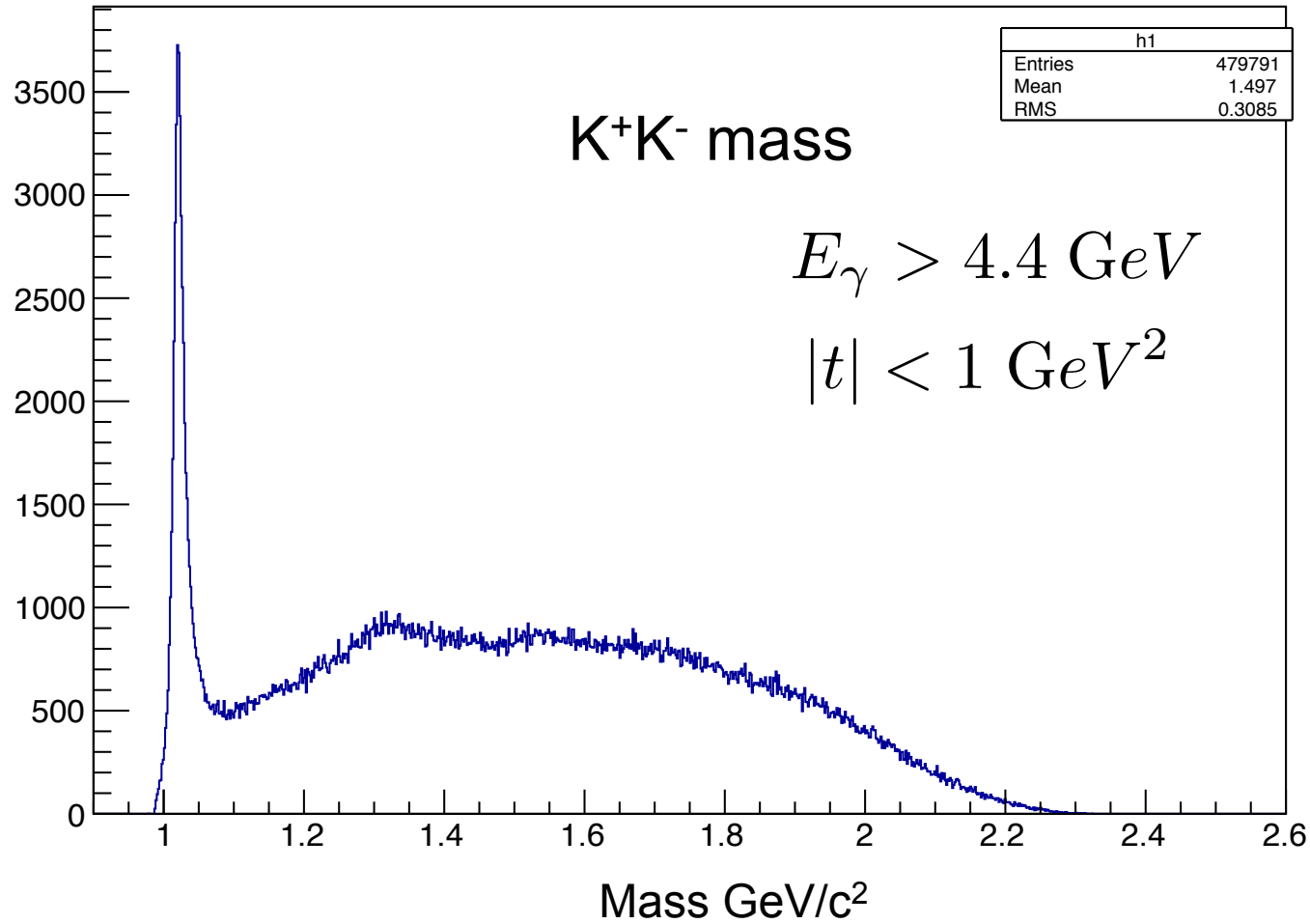


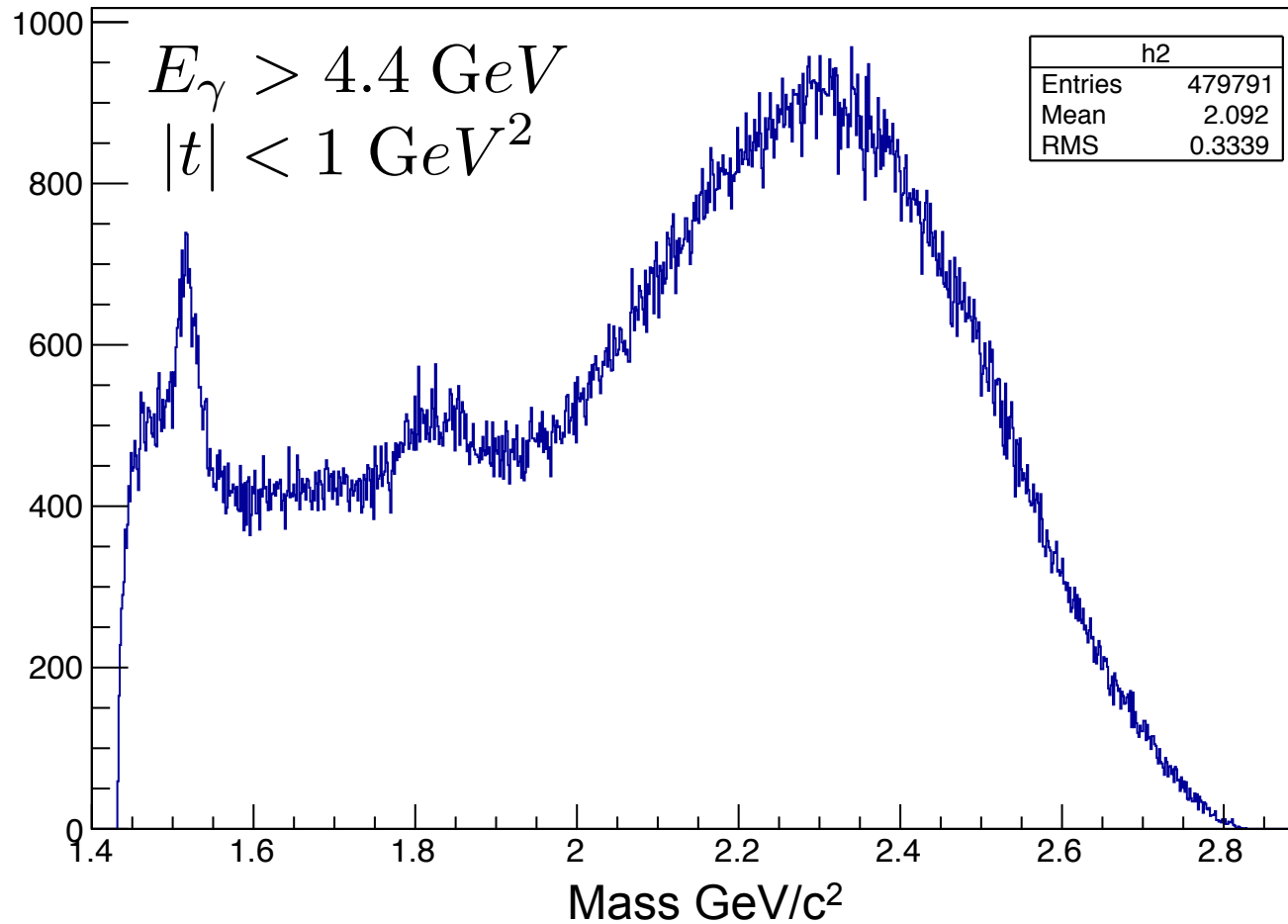
Fig. 2. (a) The $K^+K^- p_T$ spectra. The solid line is the p_T spectrum for the $\phi(1020)$. The top dotted line is the p_T spectrum for K^+K^- masses between 1640 and 1860 MeV/c^2 ; the middle is the left sideband (1500–1600 MeV/c^2); and the bottom is the right sideband (1900–2100 MeV/c^2). (b) The t' spectrum for K^+K^- masses between 1640 and 1860 MeV/c^2 fitted using two exponentials, $A_1 e^{-b_1 t'} + A_2 e^{-b_2 t'}$. In each plot, the vertical line represents the p_T cut used in this analysis.

CLAS g_{12} K^+K^-



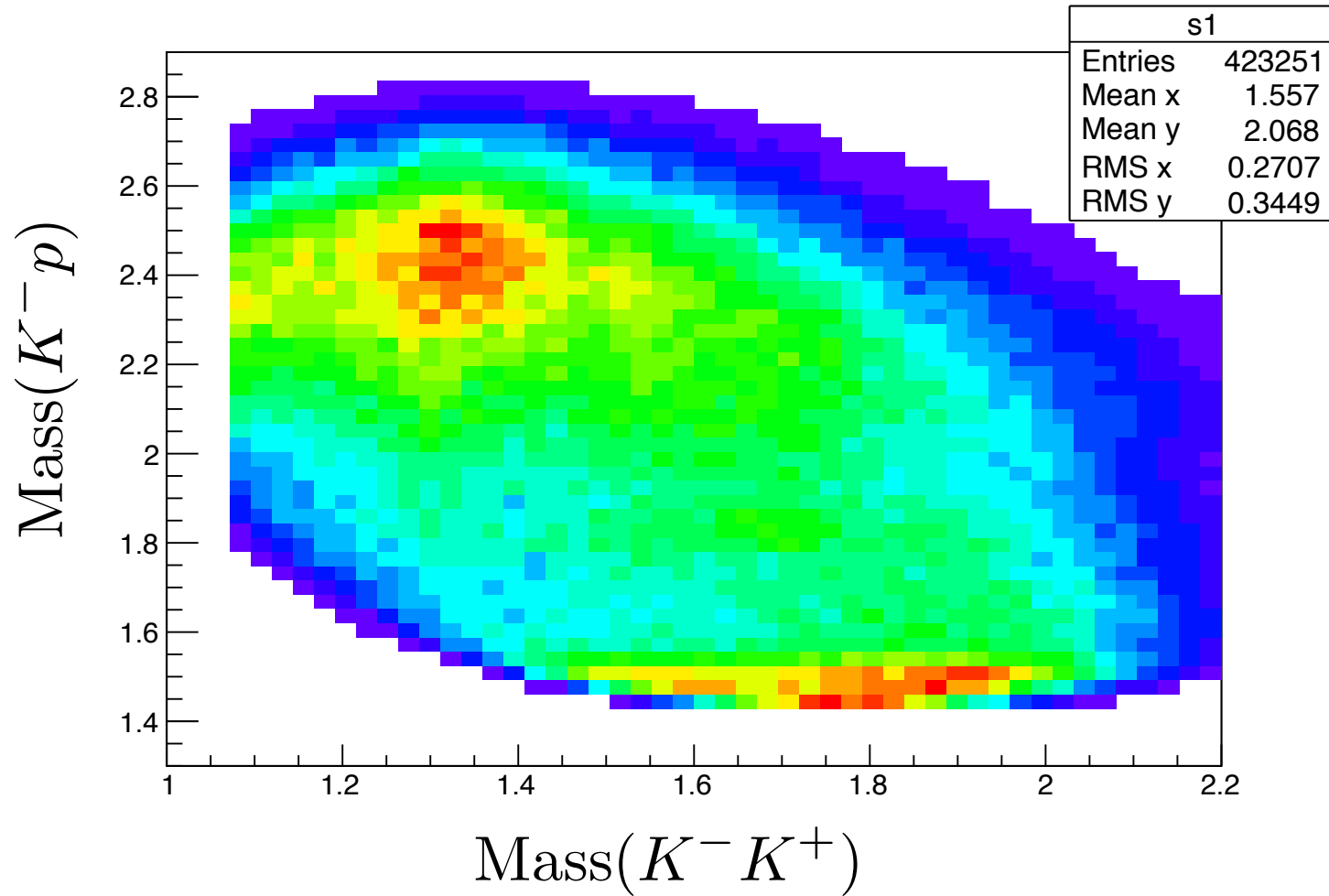
CLAS g_{12} K^+K^-

Mass(K^-p)



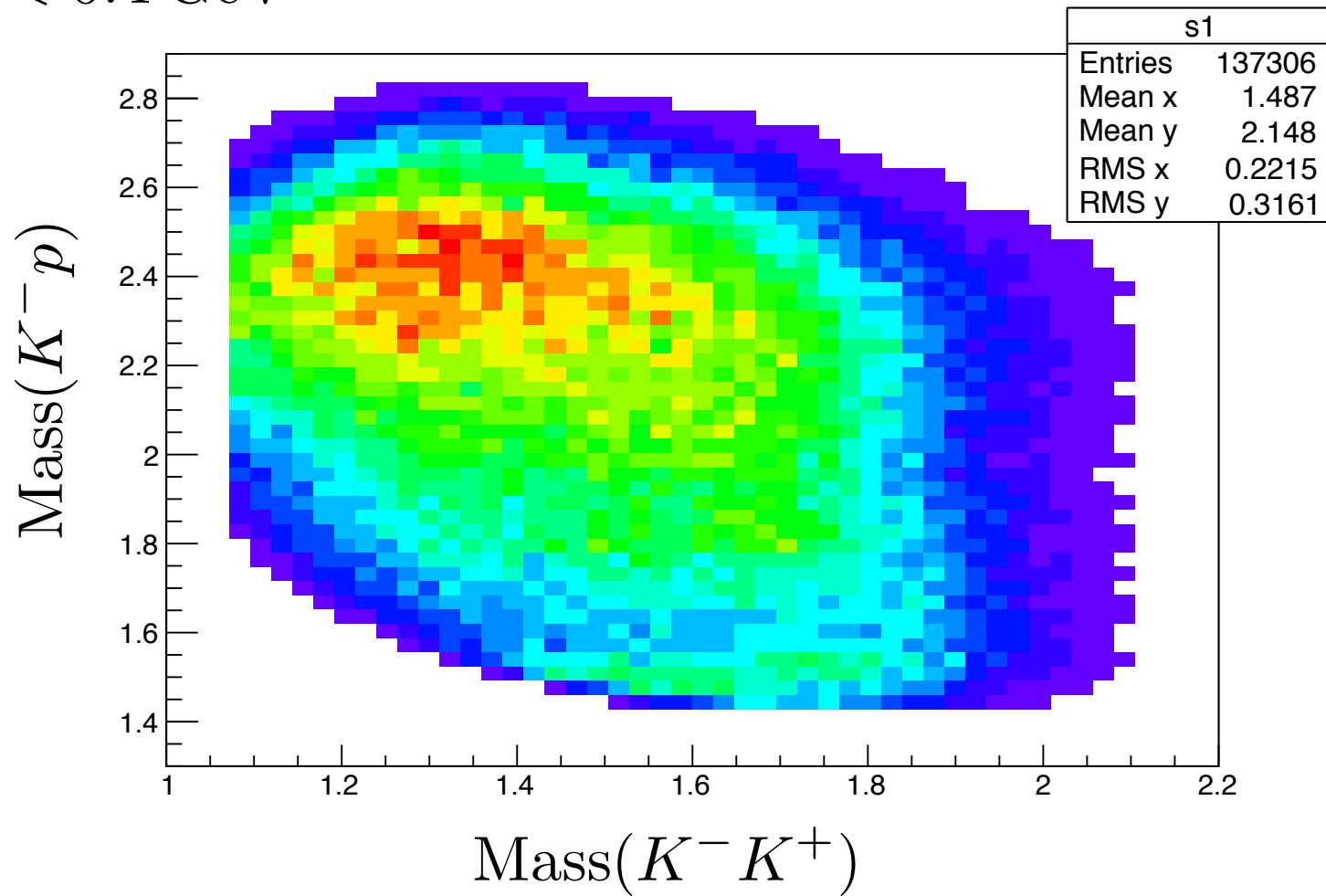
CLAS g_{12} K^+K^-

$$|t_{KK}| < 1 \text{ GeV}^2$$

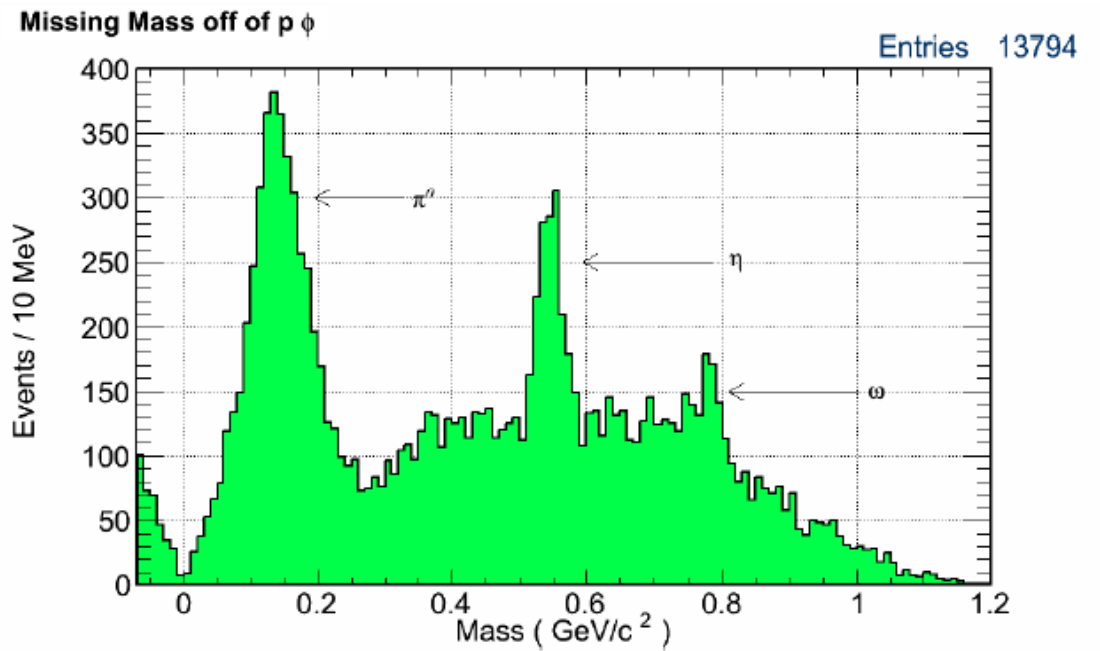
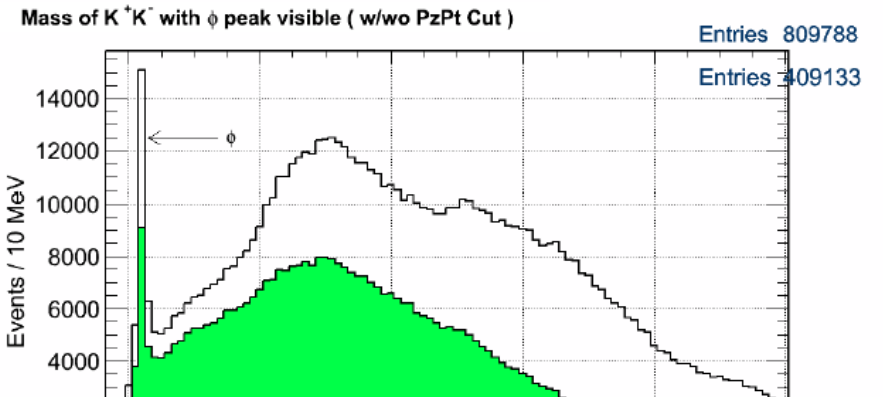
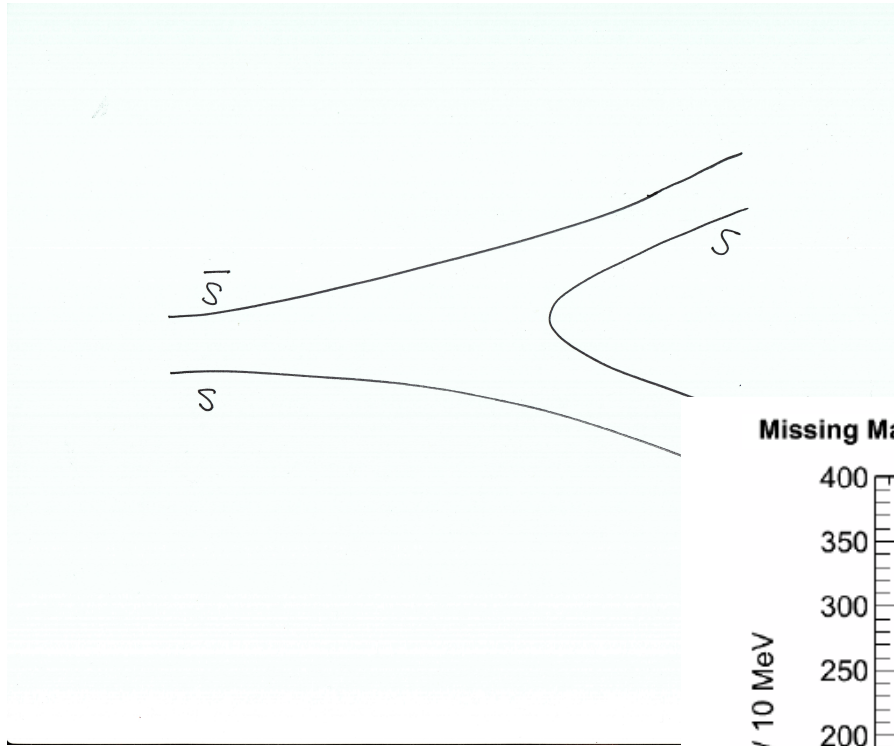


CLAS g_{12} K^+K^-

$$|t_{KK}| < 0.4 \text{ GeV}^2$$



$$\gamma p \rightarrow \phi \eta p$$

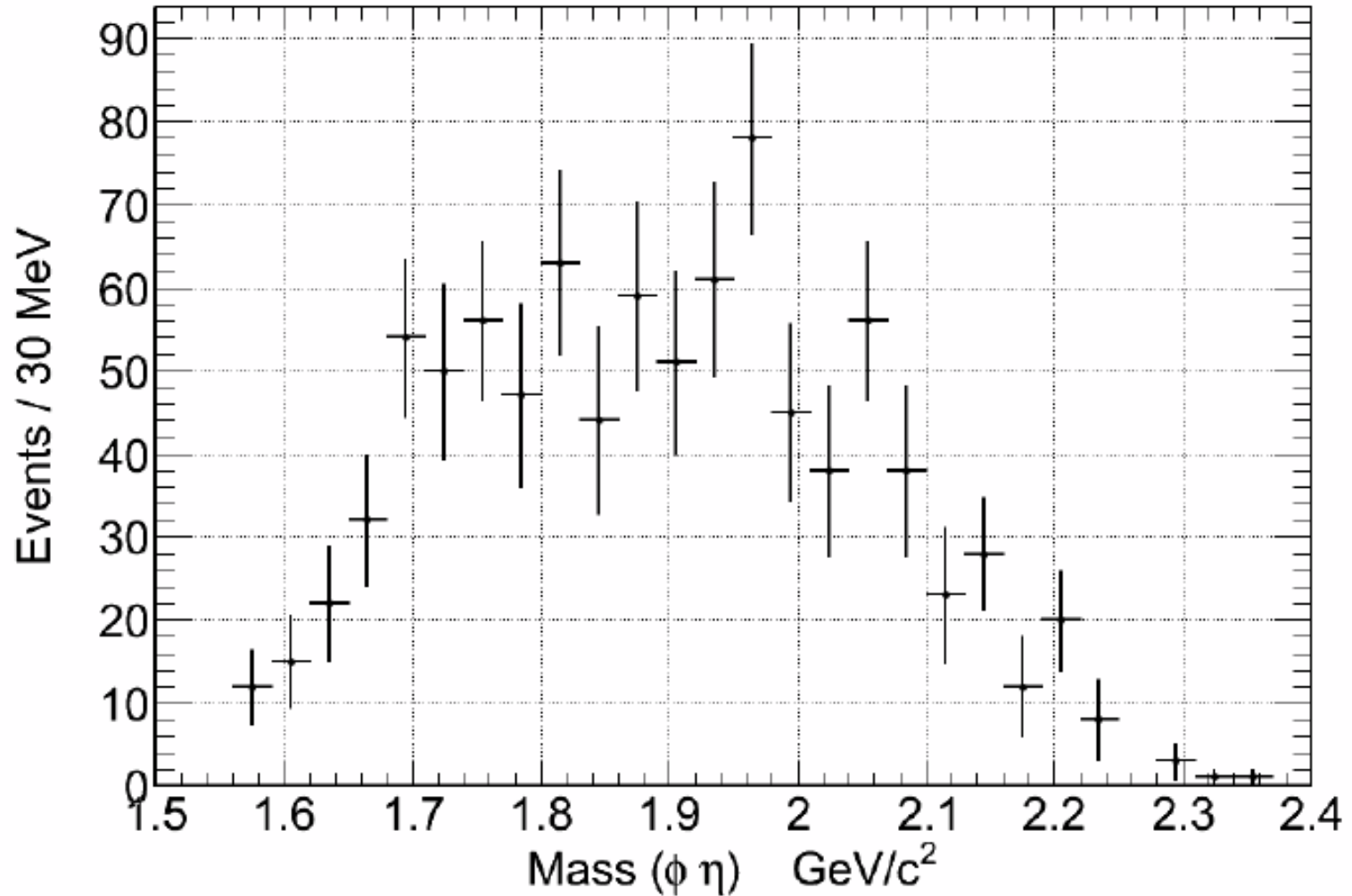


M. Saini Thesis

$$\gamma p \rightarrow \phi \eta p$$

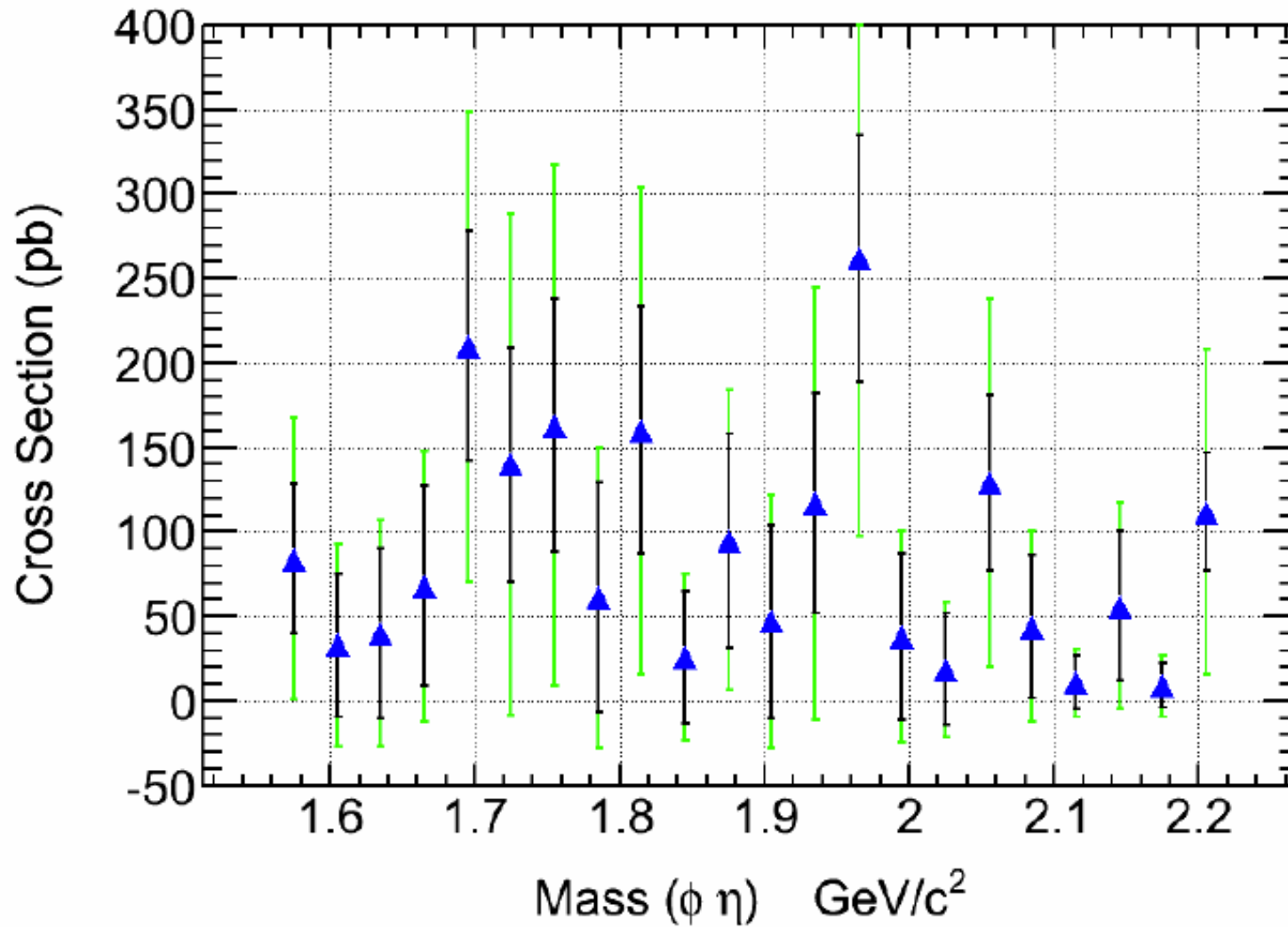
Invariant Mass of (ϕ - η) with the Sideband Subtracted

Entries 909



$\sigma_{\phi\eta}$ upper limits

(90%)



Summary

- CLAS-g12: High luminosity, high energy data set (5.5 GeV/c, 68 pb⁻¹)
- $\sim 10^6$ exclusive $\gamma p \rightarrow n \pi^+ \pi^+ \pi^-$ events
 - PWA from 1 to 2 GeV
 - Clear signals for $a_1(1260)$, $a_2(1320)$ and $\pi_2(1670)$
 - No evidence for $\pi_1(1600)$ exotic (neither intensity *nor phase*)
 - Consistent with previous CLAS result
 - Consistent with Pomeron exchange
- Search for exotic $\pi_1(1400)$ in $\eta\pi^-$ (π exchange)
 - Clear signal for $a_2(1320)$
 - No evidence for $\pi_1(1400)$
- Strangeonium ($\phi \eta, K^+ K^-$)
 - No significant resonant structures
- Prospects
 - Neutral $\pi^+ \pi^- \pi^0$ (in progress)
 - $K_s K_s$ (in progress)
 - $K^* K$

Collaborative (Jlab, GWU) Effort to Include Baryon Resonances in PWA

The End



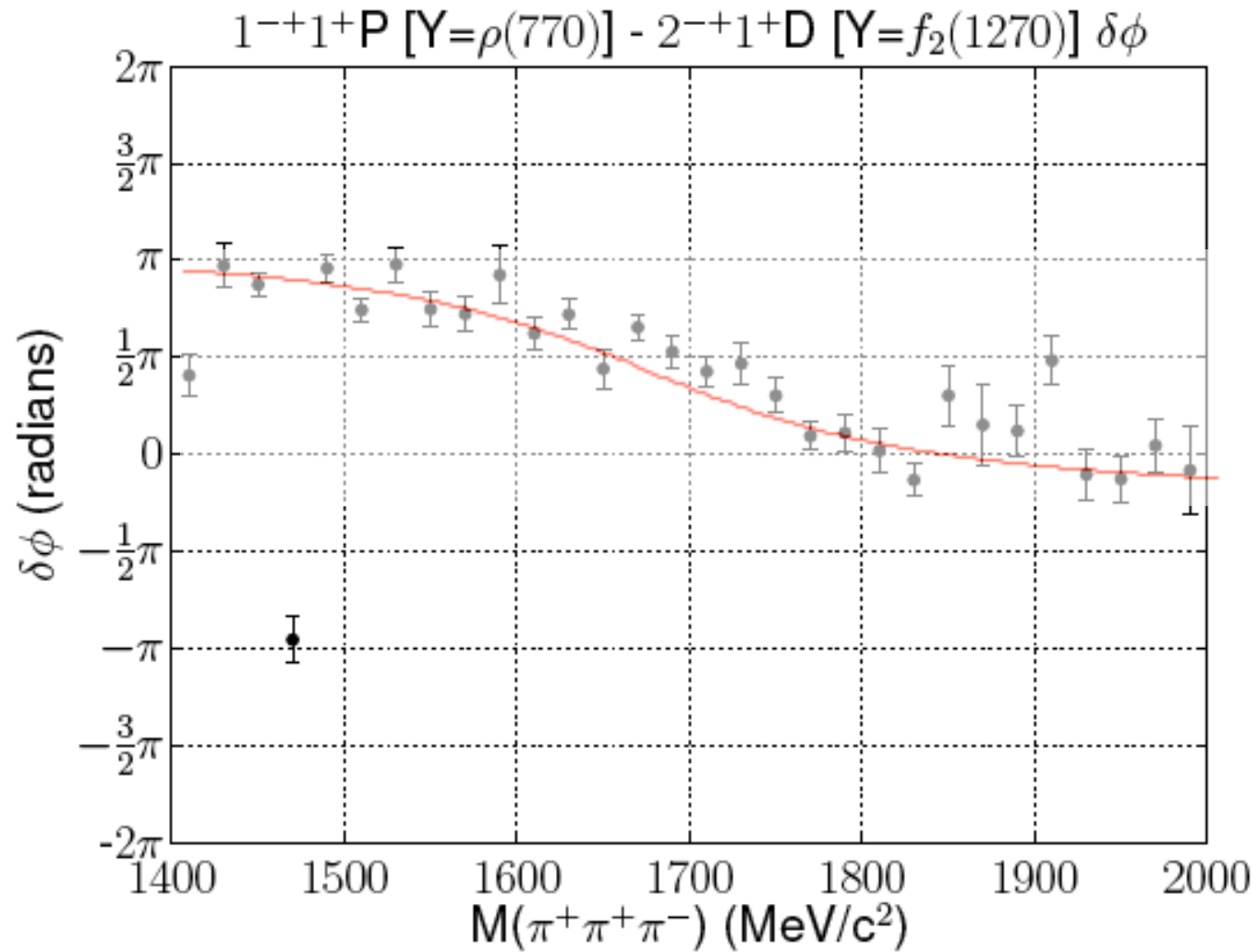
Other Slides

Strangeonium

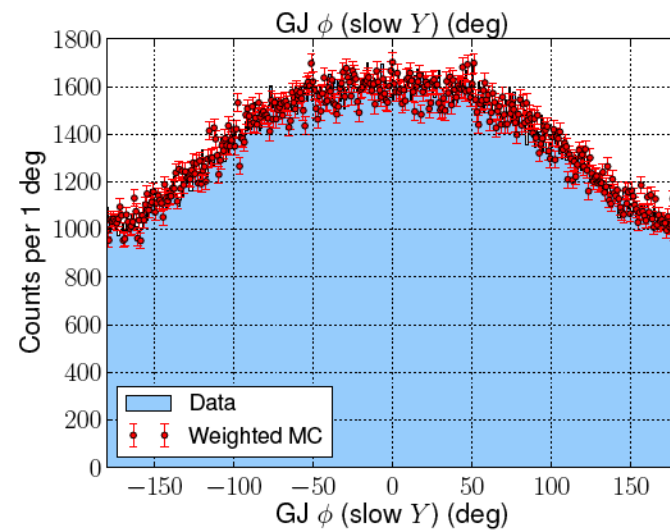
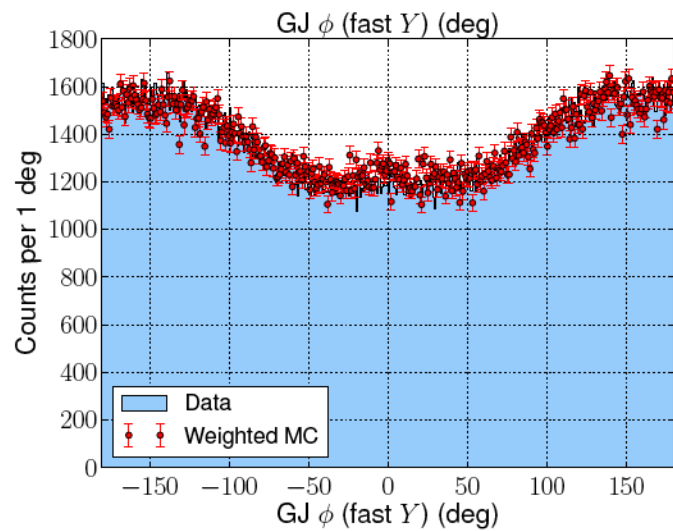
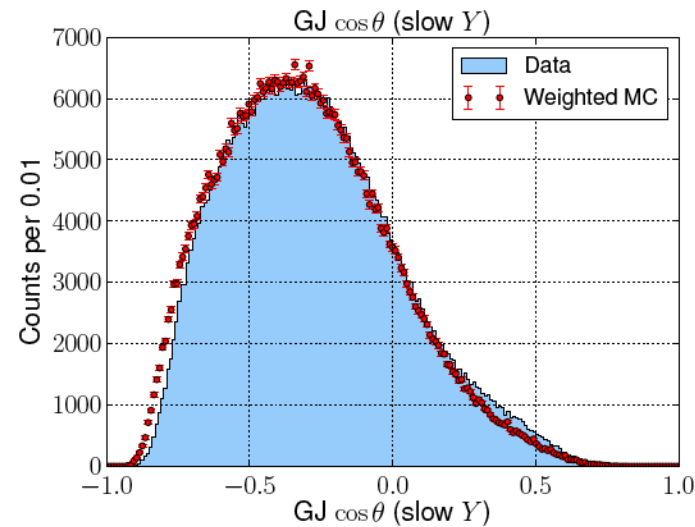
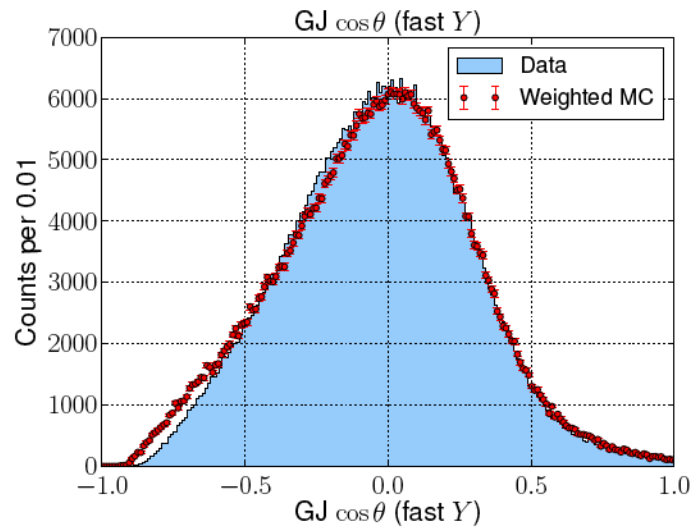
J^{PC}	Mass (MeV)
1^{--}	1023 1819 1862
2^{--}	1979
3^{--}	2123
1^{+-}	1489

State	Predicted Decay Width Theory MeV/c ²	Observed Decay Width Expt. MeV/c ²
$\phi(1680)$ 2S	$\Gamma_{theory} = 378$ $\Gamma_{\phi\eta} = 44$	$\Gamma_{expt} = 150 \pm 50$
$\phi(2050)$ 3S	$\Gamma_{theory} = 378$ $\Gamma_{\phi\eta} = 21$	$\Gamma_{expt} = \text{unknown}$
$h_1(1850)$ 2P	$\Gamma_{theory} = 193$ $\Gamma_{\phi\eta} = 33$	$\Gamma_{expt} = \text{unknown}$
$\phi_3(1854)$ 1D	$\Gamma_{theory} = 104$ $\Gamma_{\phi\eta} = 3$	$\Gamma_{expt} = 87^{+28}_{-23}$
$\phi_2(1850)$ 1D	$\Gamma_{theory} = 214$ $\Gamma_{\phi\eta} = 53$	$\Gamma_{expt} = \text{unknown}$
$\phi(1850)$ 1D	$\Gamma_{theory} = 652$ $\Gamma_{\phi\eta} = 29$	$\Gamma_{expt} = \text{unknown}$
$h_3(2200)$ 1F	$\Gamma_{theory} = 249$ $\Gamma_{\phi\eta} = 5$	$\Gamma_{expt} = \text{unknown}$

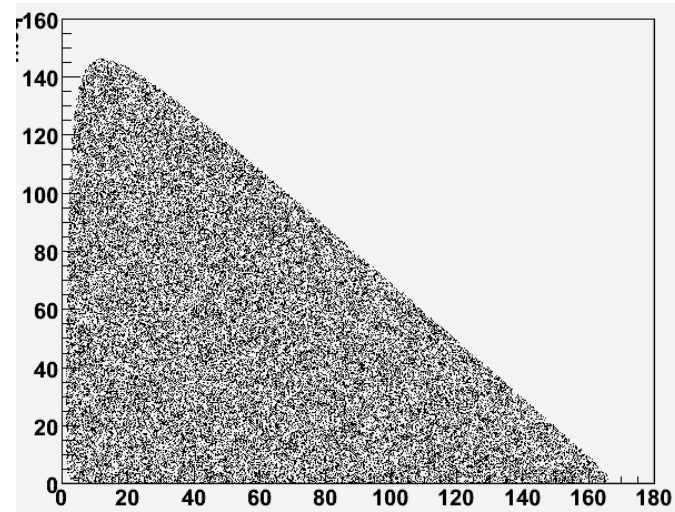
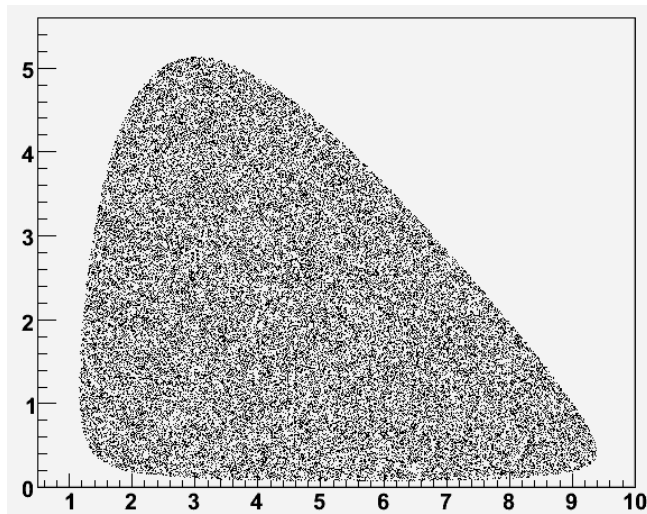
$\pi_1(1600)$ phase



Jackson Frame Angles

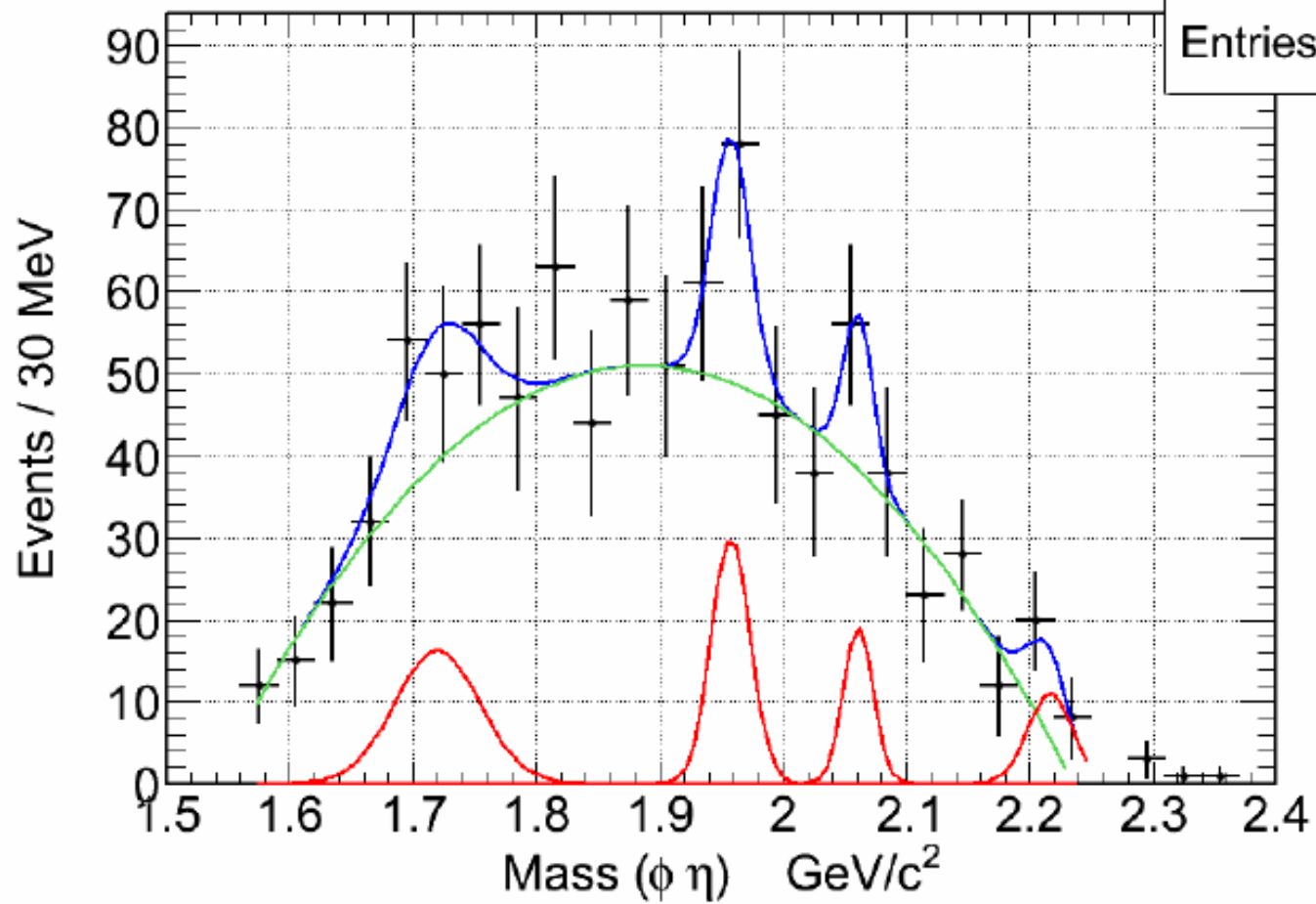


3 Body Dalitz Plots



$$\gamma p \rightarrow \phi \eta p$$

Invariant Mass of ($\phi - \eta$) with the Sideband Subtracted



$$\gamma p \rightarrow \phi \eta p$$

