

# The Search for Exotic Mesons in $\gamma p \rightarrow \pi^+ \pi^+ \pi^- n$ with CLAS at Jefferson Lab

Craig Bookwalter

on behalf of the CLAS collaboration

Florida State University  
Tallahassee, FL USA

XIV International Conference on Hadron Spectroscopy (Hadron2011)  
Munich, Germany  
June 16, 2011

# Outline

- 1 Introduction and motivation
- 2 Brief overview of the detector and data collection
- 3 Event selection and features of the data
- 4 Partial-wave analysis setup and results

# Introduction

## Exotic mesons

- Quark model only allows select  $J^{PC}$ ; for mesons,

$$J = L + S$$

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

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

$$J^{PC}(QM) = 0^{-+}, 1^{--}, 2^{-+}, 3^{--} \dots$$

- States with exotic  $J^{PC} = 0^{+-}, 1^{-+}, 2^{+-}$  must then be manifestly non- $q\bar{q}$
- Study of non- $q\bar{q}$  states gives fundamental insight into QCD

# Past results: Exotics in $\pi^- p \rightarrow \pi^+ \pi^- \pi^- p$

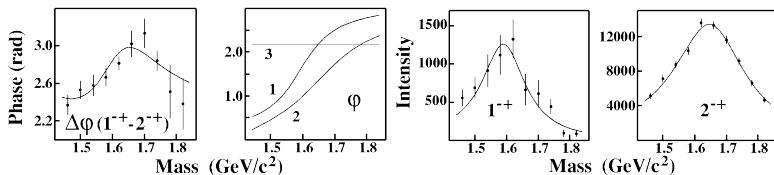


Figure: S.U. Chung *et al* [E852], Phys. Rev. **D65** 072001

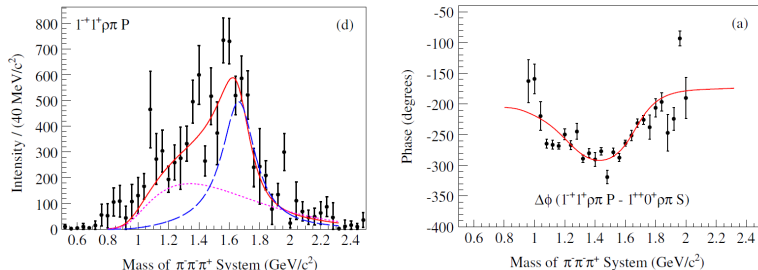
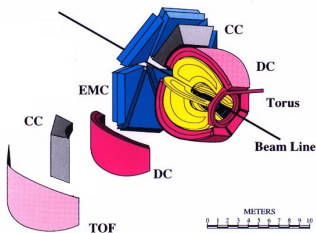


Figure: M. Alekseev *et al.* [COMPASS] Phys. Rev. Lett. **104**, 241803 (2010)

- Literature harbors claims of enhanced hybrid production with photon beams

# CEBAF, CLAS, and the g12 dataset



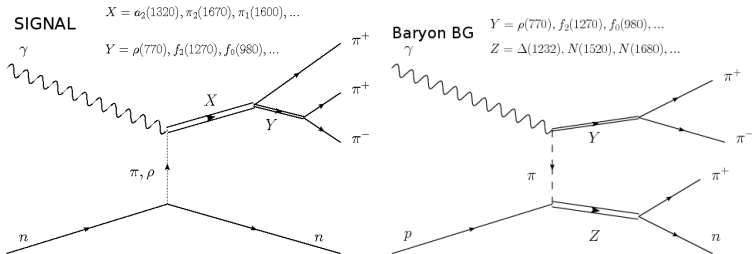
## g12 Run Summary (April 1, 2008 - June 9, 2008)

- CLAS geometry optimized for peripheral production acceptance
- 44.2 days of brehmsstrahlung photon beam up to 5.75 GeV
- 26.2 billion triggers ( $68 \text{ pb}^{-1}$ , 126 TB) of various topologies
- yields up to  $1\text{M } \gamma p \rightarrow \pi^+ \pi^+ \pi^- n$  events (depending on selections) for PWA

# Event Selection

## Identification of $\gamma p \rightarrow \pi^+ \pi^+ \pi^- n$ events

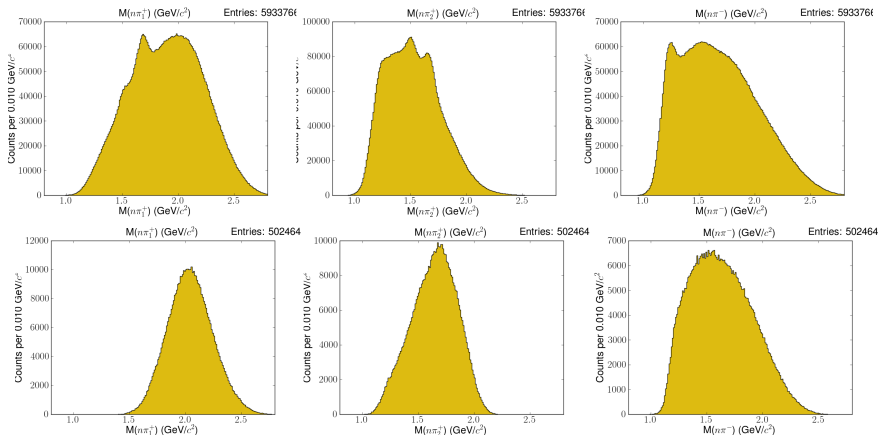
- $\pi^+ \pi^+ \pi^-$  events isolated by vertex and timing cuts
- neutron identified by missing mass



## Identification of $\gamma p \rightarrow Xn \rightarrow \pi^+ \pi^+ \pi^- n$ events

- $\gamma p \rightarrow N^* \pi \pi$  events removed by requiring low- $t'$  and small  $\theta_{lab}$  for both  $\pi^+$

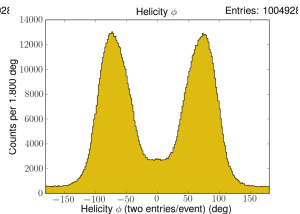
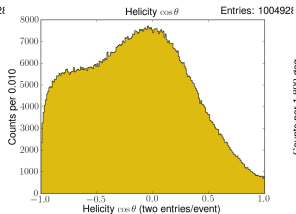
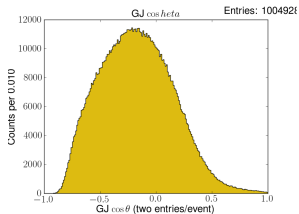
# Background reduction



## Physics cuts

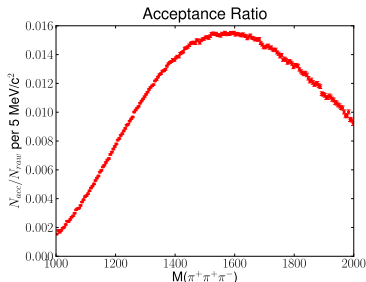
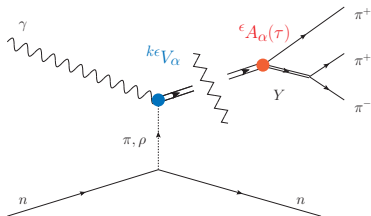
- $|t'| < 0.105$
- $\theta_{lab}(\pi^+) < 25^\circ$  (both)

# Features of selected data





# Partial-wave analysis setup



- Use helicity formalism with the reflectivity basis:

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

- Unpolarized photon beam  $\rightarrow$  equal population of both reflectivities for  $M = 1$

# PWA: Wavesets

## Waves used in the following results (Rank I)

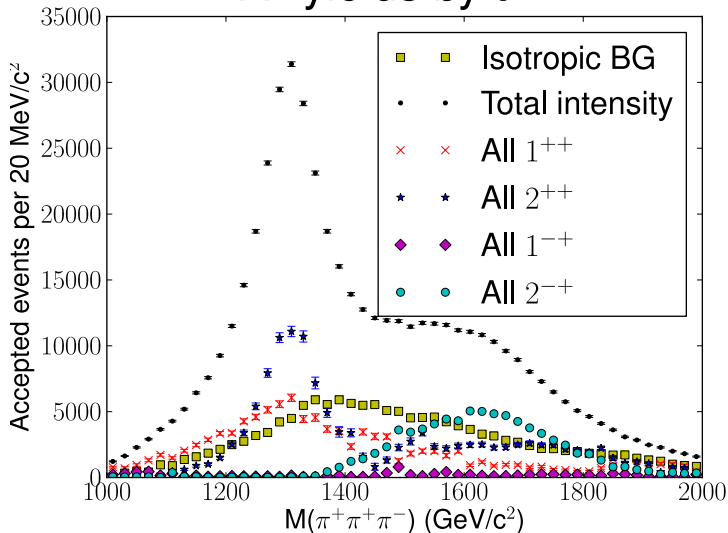
$J^{PC}$	$M^{\epsilon}$	$L$	$Y$	# waves
$1^{++}$	$0^{+}, 1^{\pm}$	$S, D$	$\rho(770)$	6
$1^{-+}$	$0^{-}, 1^{\pm}$	$P$	$\rho(770)$	3
$2^{++}$	$1^{\pm}$	$D$	$\rho(770)$	2
$2^{-+}$	$0^{-}, 1^{\pm}$	$S, P, D$	$f_2(1270), \rho(770)$	7

+ isotropic background wave

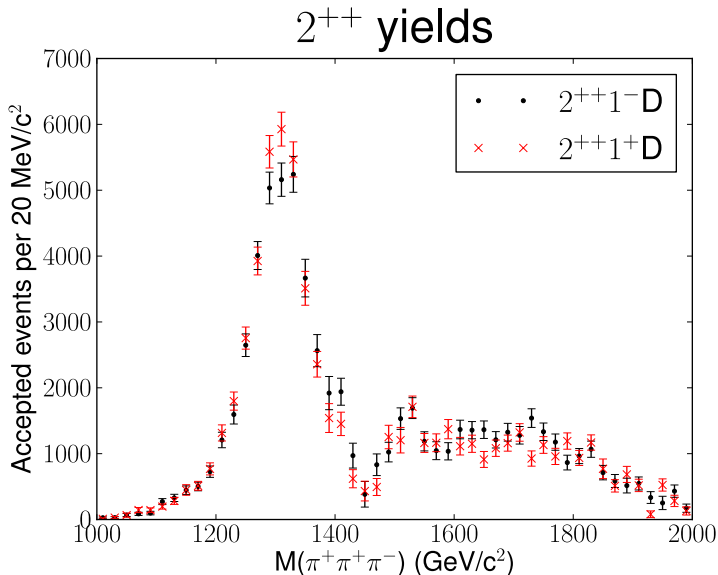
- 502K events in this fit
- Other configurations studied:
  - ▶ constraining  $M=1$  reflectivities to be equal
  - ▶ increasing rank
  - ▶ other physics cuts combinations

# PWA: Overall accepted yields

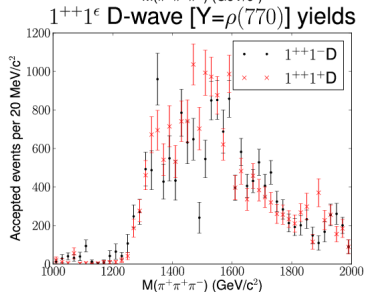
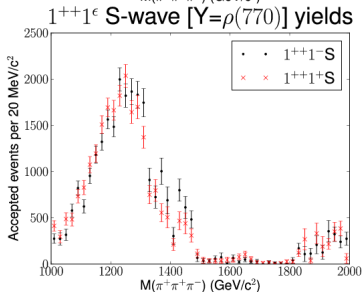
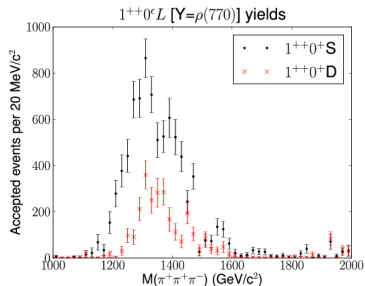
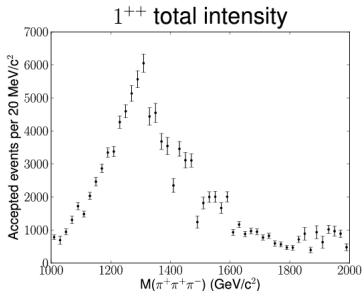
## All yields by $J^{PC}$



# PWA: $2^{++}$ accepted yields

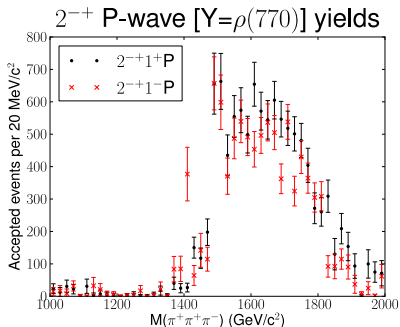
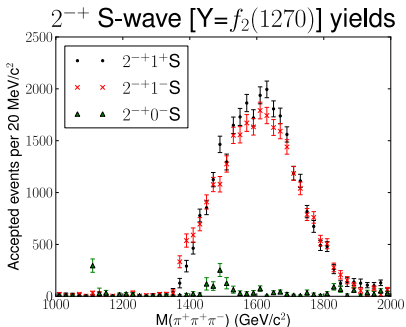


# PWA: $1^{++}$ accepted yields



# PWA: $1^{++} - 2^{++}$ phase motion

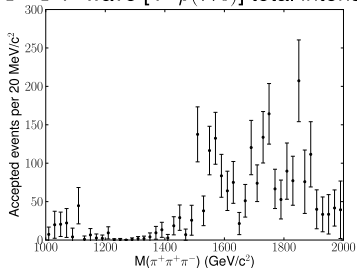
# PWA: $2^{-+}$ accepted yields



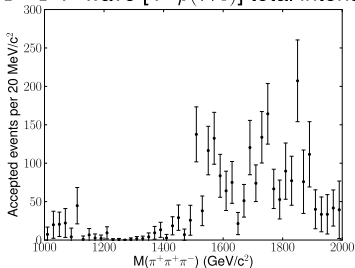
- Yield of  $2^{-+} \rightarrow f_2(1270)\pi$  : yield of  $2^{-+} \rightarrow \rho(770)\pi \approx 3$

# PWA: $1^{-+}1^{+}$ accepted yields

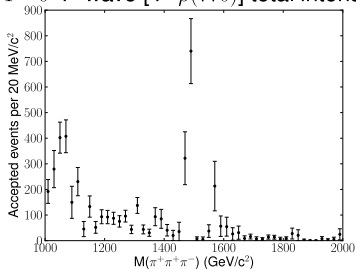
$1^{-+}1^{+}$ -P-wave [ $Y=\rho(770)$ ] total intensity



$1^{-+}1^{-}$ -P-wave [ $Y=\rho(770)$ ] total intensity



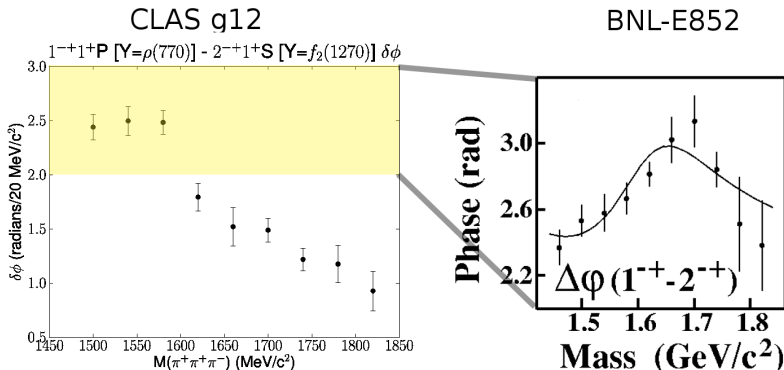
$1^{-+}0^{-}$ -P-wave [ $Y=\rho(770)$ ] total intensity



- accounts for up to 2% of total intensity

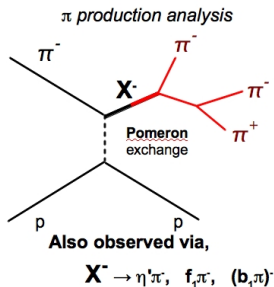
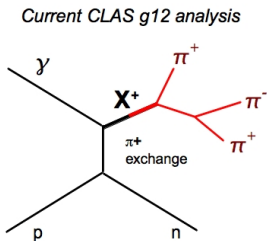


# PWA: $1^{-+} - 2^{-+}$ phase motion comparison with E852



- No resonant phase motion for the  $1^{-+}$  relative to the  $2^{-+}$  observed.

# Where is the $\pi_1(1600)$ in photoproduction?



- Our results consistent with  $\pi_1(1600)$  production via Pomeron exchange
- Awaiting results from  $\gamma p \rightarrow \pi^+\pi^-\pi^0 p$  analysis in g12 data...

# Conclusions

- $\approx 1\text{M } \gamma p \rightarrow \pi^+ \pi^+ \pi^- n$  events have acquired with CLAS; 500K subjected to a PWA over 1 to 2  $\text{GeV}/c^2$  in  $3\pi$  mass
- PWA remains in progress, but early results show strong evidence for resonant behavior corresponding to well-known  $a_1(1260)$ ,  $a_2(1320)$ , and  $\pi_2(1670)$
- No evidence for a  $J^{PC} = 1^{-+}$  resonance is observed
- Assuming  $\pi_1(1600)$  exists, non-observation in charge-exchange reactions is consistent with Pomeron production
  - ▶  $\gamma p \rightarrow \pi^+ \pi^- \pi^0 p$  analysis underway