## A study of the $\gamma d \rightarrow \pi^+ \pi^- d$ reaction

Taya Chetry Ken Hicks Ohio University

Reinhard Schumacher Carnegie Mellon University









- Dibaryon: Particle with baryon number B = 2.
- Composed of six valence quarks
  - Six quarks in a bag.
- Theoretically expected and long sought resonances.

dibaryon	Ι	S	SU(3)	legend	mass			
$\mathcal{D}_{01}$	0	1	$\overline{10}$	deuteron	A			
${\cal D}_{10}$	1	0	<b>27</b>	nn	A			
${\cal D}_{12}$	1	2	<b>27</b>	$N \Delta$	A + 6B			
$\mathcal{D}_{21}$	2	1	<b>35</b>	$N \Delta$	A + 6B			
$\mathcal{D}_{03}$	0	3	$\overline{10}$	$\Delta\Delta$	A + 10B			
${\cal D}_{30}$	3	0	<b>28</b>	$\Delta \Delta$	A + 10B			
Freeman J. Dyson and Nguyen-Huu Xuong								

Phys. Rev. Lett. 13, 815 – Published 28 December 1964



Introduction

- Dyson-Xuong mass formula:
  - $-\,\mathrm{M}_{\rm NA}\approx2160\;\mathrm{MeV}$
  - $-\,\mathrm{M}_{\mathrm{AA}} \approx 2350\;\mathrm{MeV}$
- A. Gal, H Garcilazo, "3-body model calculations of N Δ and ΔΔ dibaryon resonances" Nuclear Physics A 928 (2014) 73-88
- H. Clement, "On the History of Dibaryons and their Final Observation", Progress in Particle and Nuclear Physics 93 (2017) 195-242

### A study of the $\gamma d \rightarrow \pi^+ \pi^- d$ reaction

#### T. Chetry, Ohio University



- The WASA@COSY result for  $\Delta\Delta$  by studying:  $pn \rightarrow d\pi^0\pi^0$
- M ~ 2370 MeV, Γ ~ 70 MeV
- $I(J^P) = O(3^+)$ : Fact arrived from the reaction is purely isoscalar.
  - P. Adlarson, et al., Phys. Lett. B 721 (2013) 229
    P. Adlarson, et al., Phys. Rev. C 88 (2013) 055208
    P. Adlarson, et al., Phys. Lett. B 743 (2015) 325
    P. Adlarson, et al., Phys. Rev. Lett. 112 (2014) 202301
    P. Adlarson, et al., Phys. Rev. C 90 (2014) 035204



# pp Elastic Scattering

- Partial Wave Analysis.
- ${}^{1}D_{2}$  wave in pp elastic scattering: structure at 2148 – *i* 63 MeV.
- Prominent "resonance pole" seen in the SAID analysis.
- The total partial wave strength is consistent with the sum of its parts



Goal

Hunting Dibaryons



Investigate NA using  $d\pi\pi$  in the final state.

- $d\pi^+$  channel  $\rightarrow d^{*++}$
- $d\pi^0$  channel  $d^{*+}$
- $d\pi$  channel  $d^{*_0}$

Verify the resonance and extract the differential cross section.

# CLAS @ JLab



- Photons on deuteron target
- Spin:
  - $1 + 1 \rightarrow J = \{0, 1, 2\}$
- Isospin:
  - $\{0, 1\} + 1 \rightarrow \{0, 1\}$
- Coherent production removes complicated partial waves for nucleon mixtures.



## **Event Selection**



- Final state particles detected: two charged pions and a coherent deuteron.
- Particle identification is done based on momentum-dependent timing analysis.

A study of the  $\gamma d \rightarrow \pi^+ \pi^- d$  reaction

# **Cuts Applied**

- Timing cuts made using momentumdependent analysis
  - One "good photon", |Δt|<1 ns</li>
- -37 cm < **z**<sub>vertex</sub>< -13 cm
- Fiducial cuts applied
  - Minimum Theta Cut
- Minimum Momentum Cuts
- −0.01 < MM<sup>2</sup>(π<sup>+</sup>π<sup>-</sup>d) < 0.005 [GeV<sup>2</sup>]
- Bad SC Paddles removed.

Particle	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6
$\pi^+$	23, 27		11, 13, 23, 31	23, 33, 35	23, 29	23
	$\geq 43$	$\geq 45$	$\geq 40$	$\geq 46$	$\geq 46$	$\geq 45$
$\pi^{-}$	23, 27		11, 15, 16, 23, 31	23, 27, 35	20, 23, 29	23
	$\geq 41$	$\geq 41$	$34-36, \ge 41$	$\geq 43$	$\geq 43$	$\geq 42$
d	23, 27	23	11, 22, 23, 31	23	23, 29	23
	$\geq 35$	$\geq 35$	$\geq 35$	$\geq 35$	$\geq 35$	$\geq 35$



- Tagger energy corrections
- Momentum corrections

### A study of the $\gamma d { ightarrow} \pi^+ \pi^- d$ reaction

#### T. Chetry, Ohio University

## What we see?





- $d\pi^+$  mass distribution.
- Basic cuts applied.
- Structure at about 2150 MeV.

A study of the  $\gamma d \rightarrow \pi^+ \pi^- d$  reaction

## What we see?

10

counts

d



- dπ<sup>-</sup> mass
   distribution.
- Basic cuts applied.

Hunting dibaryons

- Structure at about 2150 MeV.
- $d\pi^-$  distribution has prominent peak than  $d\pi^+$  mass distribution.

### A study of the $\gamma d \rightarrow \pi^+ \pi^- d$ reaction





2.7 < W < 3.2 GeV

A study of the  $\gamma d \rightarrow \pi^+ \pi^- d$  reaction

# Backgrounds

- Major Backgrounds:
  - Phase Space:

 $d\pi^+\pi^-$ 

- Rho meson

 $\pi^+\pi^-$ 

Other resonance

 $d\pi^+/d\pi^-$ 

- Others??
- MC generated for each case



### A study of the $\gamma d \rightarrow \pi^+ \pi^- d$ reaction

T. Chetry, Ohio University

# Yield Extraction: method

- Scale major Backgrounds to get an idea of the distribution.
- Use template functions for each distribution to fit the spectrum
- Extract yield for the peak.
- Work in progress.





- Resonance peaks seen: three charge states are possible using the same detection sample.
- Scaling backgrounds is a challenge. Full understanding would require theory input.
- Differential cross section results from the data is the next step.