A study of the $\gamma d \rightarrow \pi^+ \pi^- d$ reaction
(A possible $d^*$ resonance)

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Ken Hicks
Ohio University

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CLAS Collaboration Meeting
12 July 2018
Dibaryons

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

<table>
<thead>
<tr>
<th>dibaryon</th>
<th>I</th>
<th>S</th>
<th>SU(3)</th>
<th>legend</th>
<th>mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mathcal{D}_{01}$</td>
<td>0</td>
<td>1</td>
<td>$\begin{array}{c}10 \ \end{array}$</td>
<td>deuteron</td>
<td>$A$</td>
</tr>
<tr>
<td>$\mathcal{D}_{10}$</td>
<td>1</td>
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<td>$nn$</td>
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<tr>
<td>$\mathcal{D}_{12}$</td>
<td>1</td>
<td>2</td>
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Freeman J. Dyson and Nguyen-Huu Xuong
Phys. Rev. Lett. 13, 815 – Published 28 December 1964

- Dyson-Xuong mass formula:
  - $M_{N\Delta} \approx 2160$ MeV
  - $M_{\Delta\Delta} \approx 2350$ MeV

- A. Gal, H Garcilazo, “3-body model calculations of N \Delta and \Delta\Delta dibaryon resonances” Nuclear Physics A 928 (2014) 73-88

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**Dibaryonic Molecule: Physics Overview**

(CLAS Coll. Meeting, June 2014)

Reinhard Schumacher

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https://en.wikipedia.org/wiki/Hexaquark

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d* (2380)

Motivation

- The WASA@COSY result for ΔΔ by studying: pn → dπ⁰π⁰
- M ~ 2370 MeV, Γ ~ 70 MeV
- I(J⁺) = 0(3⁺) : Fact arrived from the reaction is purely isoscalar.
  

- On the production of isotensor dibaryons: pp → ppπ⁺π⁻
  
arXiv:1803.03192 (18 April 2018)
arXiv:1803.03193 (18 April 2018)

A study of the γd → π⁺πd reaction

T. Chetry, Ohio University

CLAS Coll. Meeting, July 2018
Motivation

- Partial Wave Analysis.
- $^1D_2$ 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.

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

Hunting dibaryons

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

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What we see?

Hunting dibaryons

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

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What we see?

Hunting dibaryons

- $d\pi^0$ mass distribution.
- Basic cuts applied.
- Structure at about 2150 MeV.
- Will investigate this channel later!

Plot Description
The 2D histogram is made after basic cuts are applied to the data.

Plot on the left is the $\gamma$-projection of the 2D histogram. It is the mass distribution for the $\omega$ and the outgoing $d$.

Plot on the right is the $x$-projection of the 2D histogram. It is the mass distribution for $\pi^+\pi^-\omega$ or the $\omega$-meson distribution.
Goal

Investigate $N\Delta$ using $d\pi\pi$ in the final state.

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

Verify the resonance and extract the differential cross section.

- Spin: $1 + 1 \rightarrow J = \{0, 1, 2\}$
- Isospin: $\{0, 1\} + 0 \rightarrow \{0, 1\}$
Event Selection

- Final state particles detected: two charged pions and a coherent deuteron.

- Particle identification is done based on momentum-dependent timing analysis.
Cuts Applied

- Timing cuts made using momentum-dependent analysis
  - One “good photon”, |Δt|<1 ns
- -37 cm < z_{vertex} < -13 cm
- Fiducial cuts applied
  - Minimum Theta Cut
- Minimum Momentum Cuts
  - −0.01 < MM^{2}(\pi^+\pi^-d) < 0.005 [GeV^2]
- Bad SC Paddles removed.

<table>
<thead>
<tr>
<th>Particle</th>
<th>Sector 1</th>
<th>Sector 2</th>
<th>Sector 3</th>
<th>Sector 4</th>
<th>Sector 5</th>
<th>Sector 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>π^+</td>
<td>≥ 23, ≥ 27, ≥ 43</td>
<td>≥ 45</td>
<td>11, 13, 23, 31, ≥ 40</td>
<td>23, 33, 35, ≥ 46</td>
<td>23, 29, ≥ 46</td>
<td>23, ≥ 45</td>
</tr>
<tr>
<td>π^-</td>
<td>≥ 23, ≥ 27, ≥ 41</td>
<td>≥ 41</td>
<td>11, 15, 16, 23, 31, 34-36, ≥ 41</td>
<td>23, 27, 35, ≥ 43</td>
<td>20, 23, 29, ≥ 43</td>
<td>23, ≥ 42</td>
</tr>
<tr>
<td>d</td>
<td>≥ 23, ≥ 27, ≥ 35</td>
<td>≥ 35</td>
<td>11, 22, 23, 31, ≥ 35</td>
<td>23, ≥ 35</td>
<td>23, 29, ≥ 35</td>
<td>23, ≥ 35</td>
</tr>
</tbody>
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- Tagger energy corrections
- Momentum corrections
2.7 < W < 3.2 GeV
Backgrounds

- Major Backgrounds:
  - Phase Space: \(d\pi^+\pi^-\)
  - Rho meson: \(\pi^+\pi^-\)
  - Other resonance/reflection: \(d\pi^+/d\pi^-\)
  - Other??
- MC generated for each case
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Yield Extraction

$W = [2.95,3.08]$  $\cos\theta^\pi_{cm} = [-0.4,-0.2]$  

Very preliminary!!

$frac_{d\pi^+} = 0.1961$  
$frac_{d\pi^-} = 0.1700$  
$frac_\rho = 0.2193$  
$frac_{PS} = 0.4146$
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Diff. Cross Section

Working formula for DCS:

$$\frac{d\sigma}{d\cos\theta_{CM}}(W) = \frac{\text{Yield}}{\delta(\cos\theta_{CM})A\mathcal{L}(W)}$$

$A \equiv \text{Detector Acceptance}$

Luminosity,

$$\mathcal{L} = \frac{\rho_d N_A l_d}{M_d} N_{\gamma}$$

$N_{\gamma} \equiv N_{\gamma}(W)$

$\rho_d = 0.169 \text{ g cm}^{-3}$

$l_d = 24 \text{ cm}$

$M_d = 2.014 \text{ g mole}^{-1}$
Summary

- Resonance peaks seen: three charge states are possible using the same detection sample.
- Currently investigating $d^{*++}$ and $d^{*0}$.
- Scaling backgrounds is a challenge. Work in progress (Newer simulations: problem with user_ana, interactive production of files: about 1 hour for one file of 50k events).
- Full understanding would require theory input.