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

(A possible d^* resonance)

Taya Chetry
Ken Hicks
Ohio University

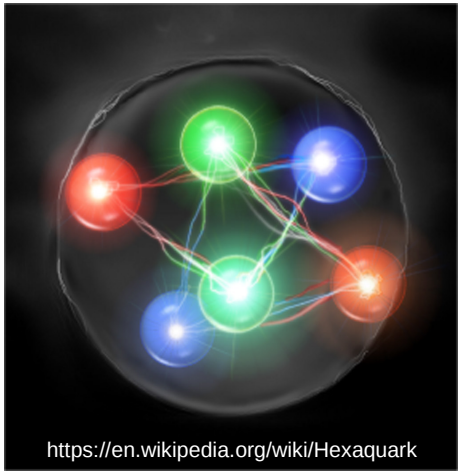
Reinhard Schumacher
Carnegie Mellon University

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.


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

dibaryon	I	S	SU(3)	legend	mass
$\mathcal{D}_{01}$	0	1	$\overline{\mathbf{10}}$	deuteron	A
$\mathcal{D}_{10}$	1	0	**27**	nn	A
$\mathcal{D}_{12}$	1	2	**27**	$N\Delta$	$A+6B$
$\mathcal{D}_{21}$	2	1	**35**	$N\Delta$	$A+6B$
$\mathcal{D}_{03}$	0	3	$\overline{\mathbf{10}}$	$\Delta\Delta$	$A+10B$
$\mathcal{D}_{30}$	3	0	**28**	$\Delta\Delta$	$A+10B$

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 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

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Dibaryonic Molecule: Physics Overview
(CLAS Coll. Meeting, June 2014)
Reinhard Schumacher

dibaryon	I	S	SU(3)	$d_1 d_2$	mass
$\mathcal{D}_{01}$	0	1	$\overline{10}$	d^*N	A
$\mathcal{D}_{10}$	1	0	27	nn	A
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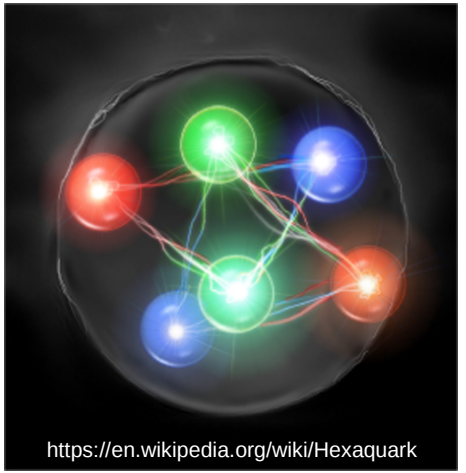
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d*(2380)

- The WASA@COSY result for ΔΔ by studying: $\mathrm{pn}\rightarrow\mathrm{d}\pi^0\pi^0$
- M ~ 2370 MeV, Γ ~ 70 MeV
- $\mathrm{I(J^P)} = 0(3^+)$: Fact arrived from the reaction is purely isoscalar.

P. Adlarson, et al., Phys. Lett. B 721 (2013) 229

P. Adlarson, et al., Phys. Lett. B 743 (2015) 325

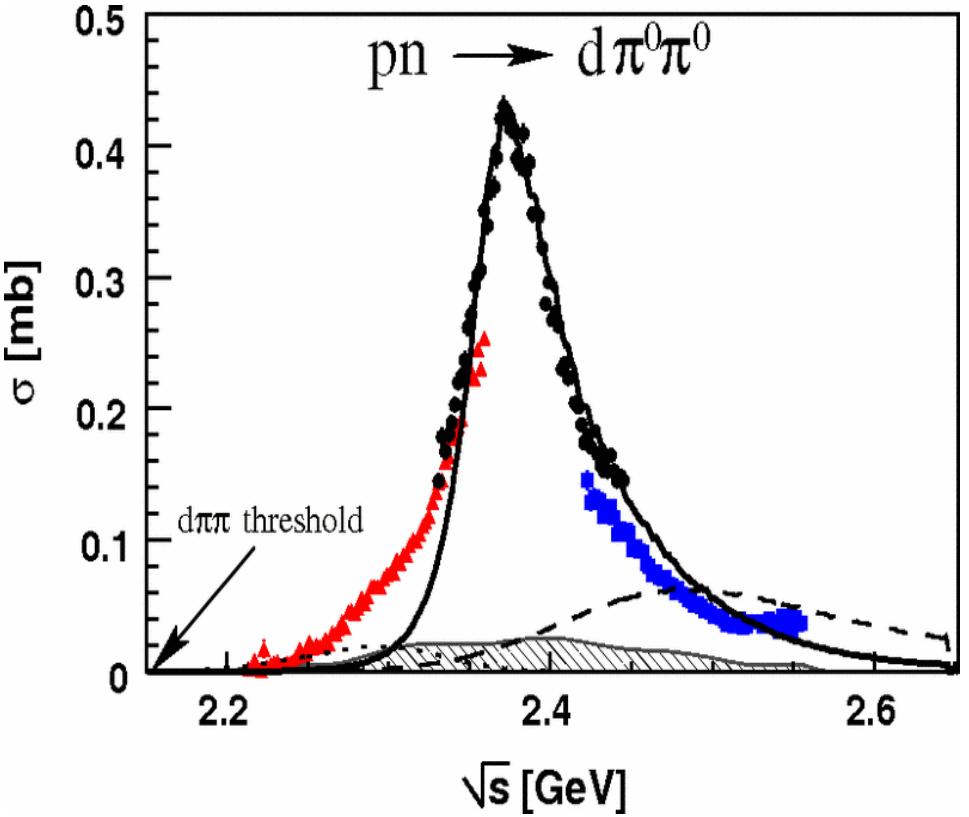
P. Adlarson, et al., Phys. Rev. Lett. 112 (2014) 202301

P. Adlarson, et al., Phys. Rev. C 90 (2014) 035204

- On the production of isotensor dibaryons: $pp \rightarrow pp\pi^+\pi^-$

arXiv:1803.03192 (18 April 2018)
arXiv:1803.03193 (18 April 2018)

D_{21} ?

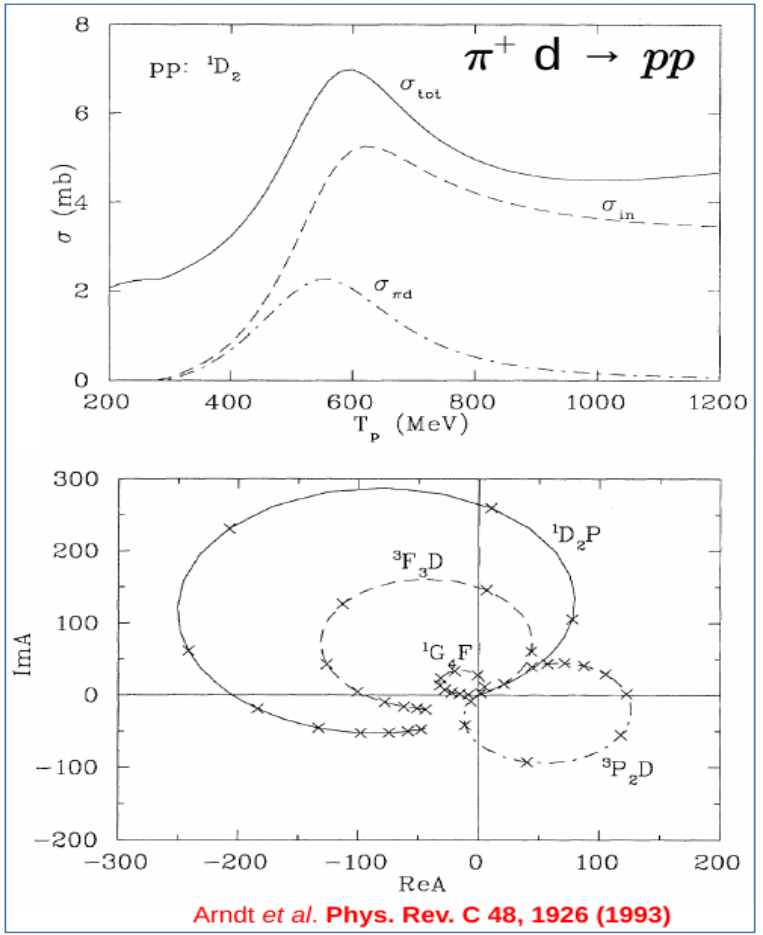


P. Adlarson *et al*
Phys Rev Lett 106, 242302 (2011)

pp Elastic Scattering

- Partial Wave Analysis.
- $^1D_2$ wave in pp elastic scattering:

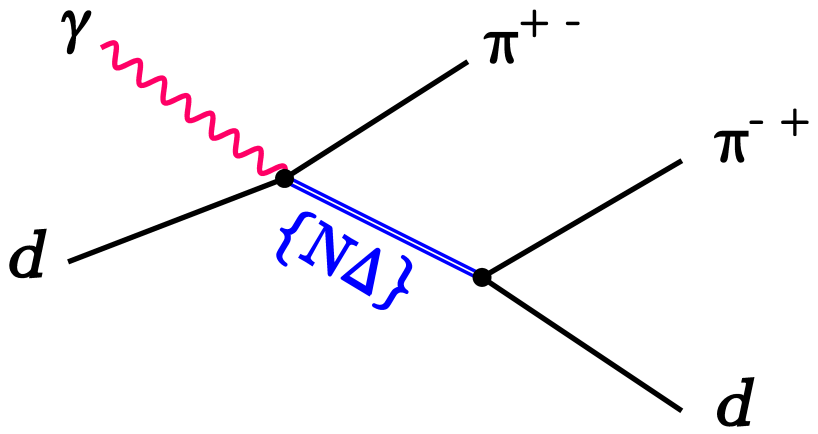
  structure at 2148 – i 63 MeV.
- Prominent "resonance pole" seen in the SAID analysis.
- The total partial wave strength is consistent with the sum of its parts



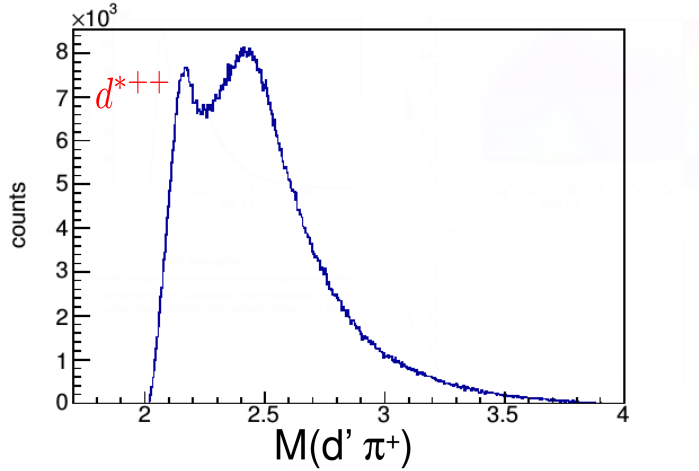
- Photons on deuteron target
- Spin:

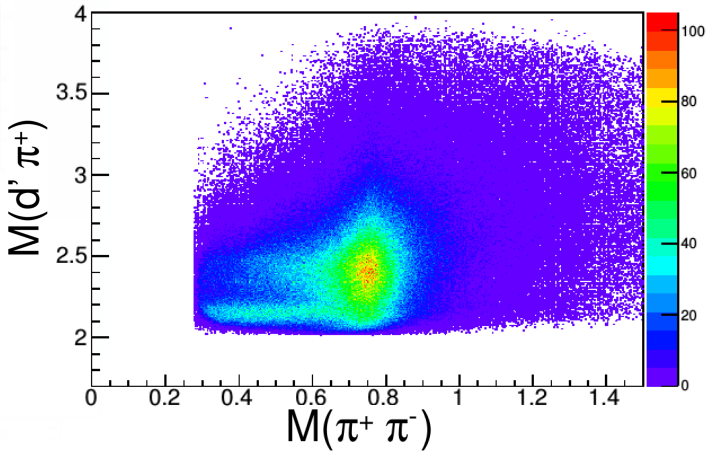
  1 + 1 → J = {0, 1, 2}
- Isospin:

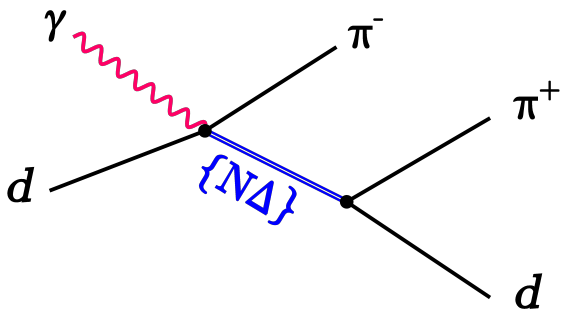
  {0, 1} + 0 → {0, 1}
- Coherent production removes complicated partial waves for nucleon mixtures.

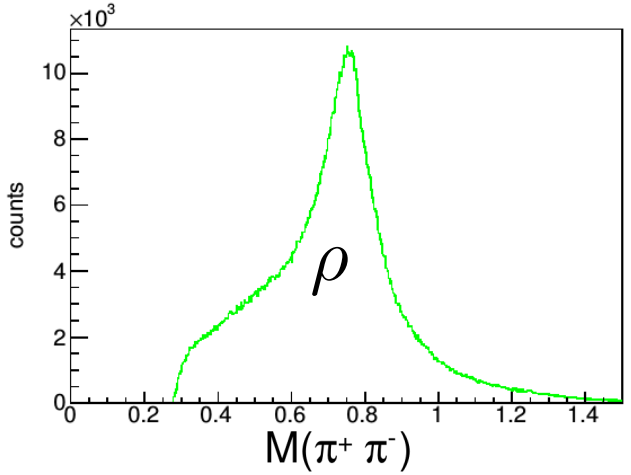


What we see?



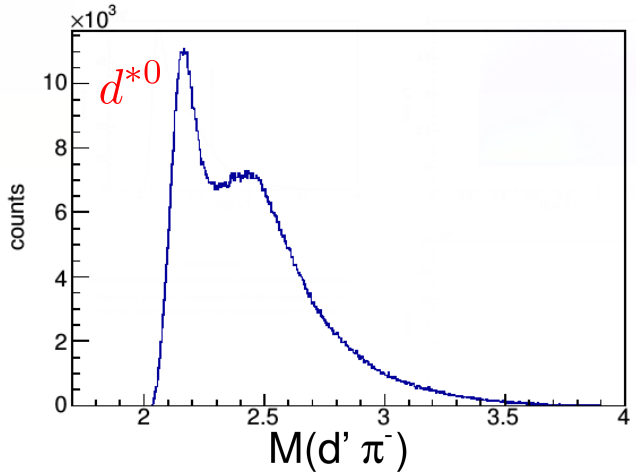


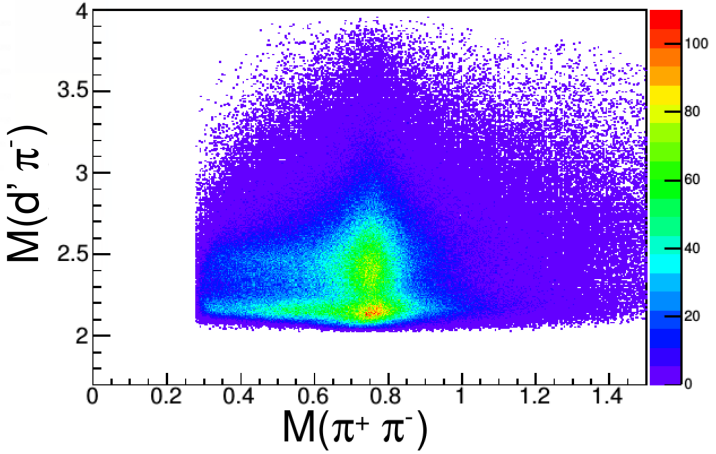


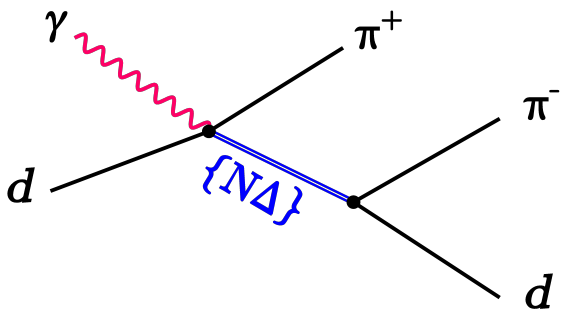


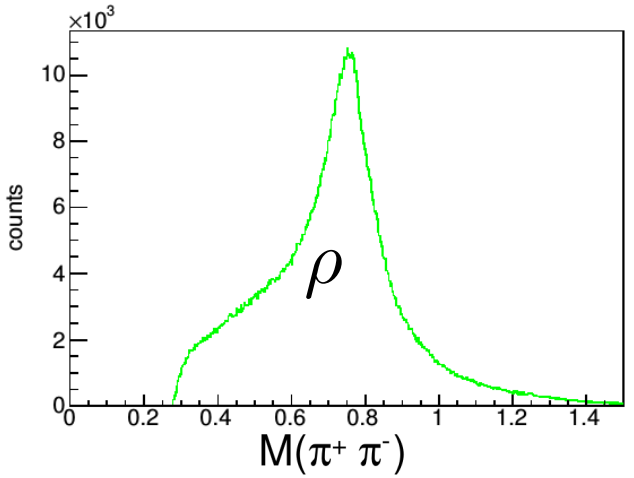
- $d\pi^+$ mass distribution.
- Basic cuts applied.
- Structure at about 2150 MeV.

What we see?



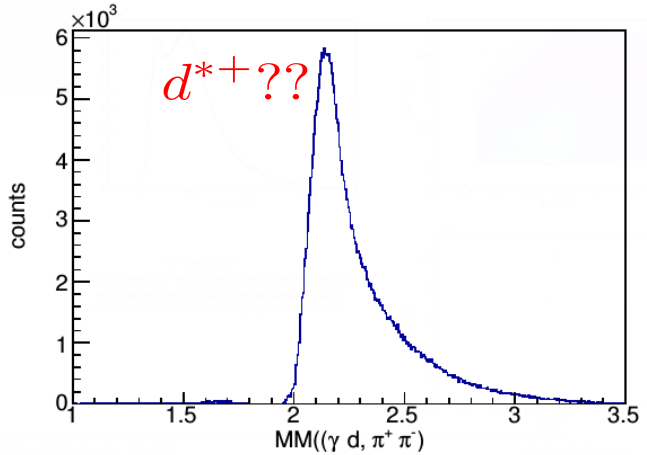


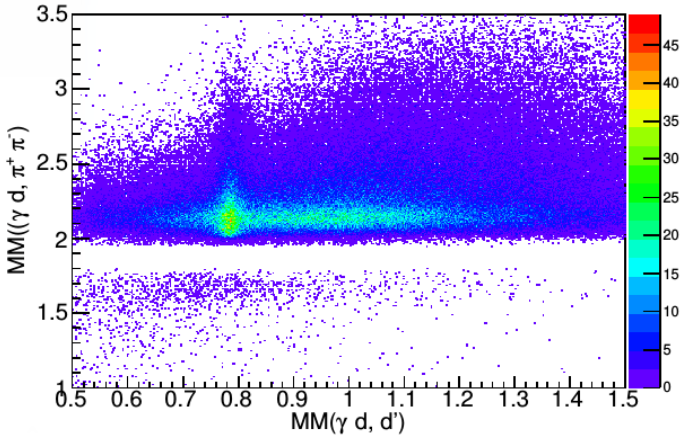




- $d\pi^-$ mass distribution.
- Basic cuts applied.
- Structure at about 2150 MeV.
- $d\pi^-$ distribution has prominent peak than $d\pi^+$ mass distribution.

What we see?



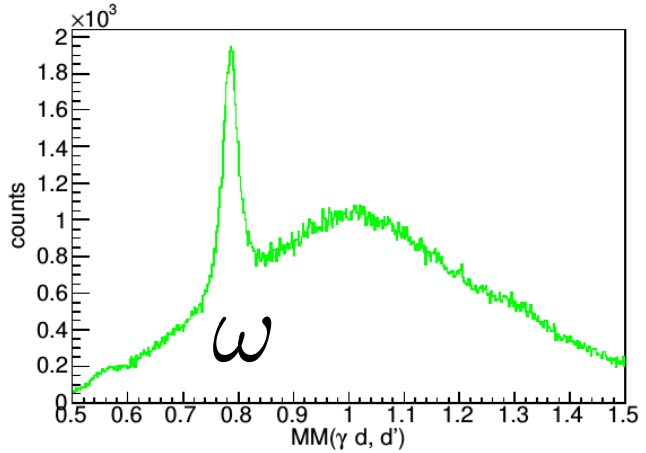


Plot Description

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

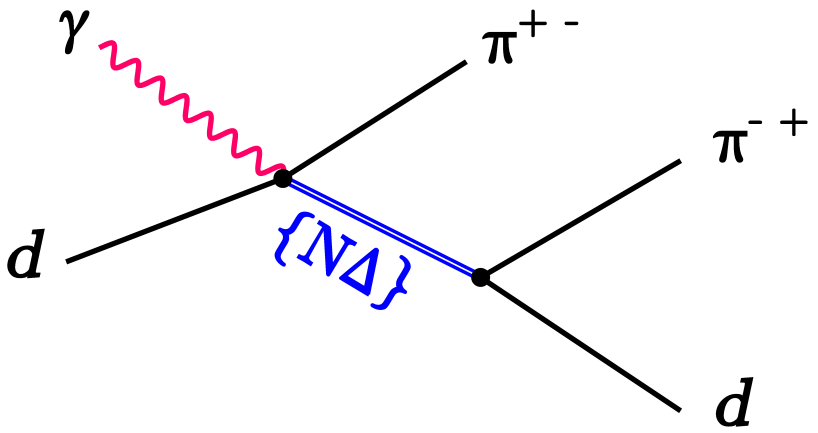
Plot on the left is the y-projection of the 2D histogram. It is the mass distribution for the π^0 and the outgoing d.

Plot on the right is the x-projection of the 2D histogram. It is the mass distribution for $\pi^+ \pi^- \pi^0$ or the ω-meson distribution.



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

Goal



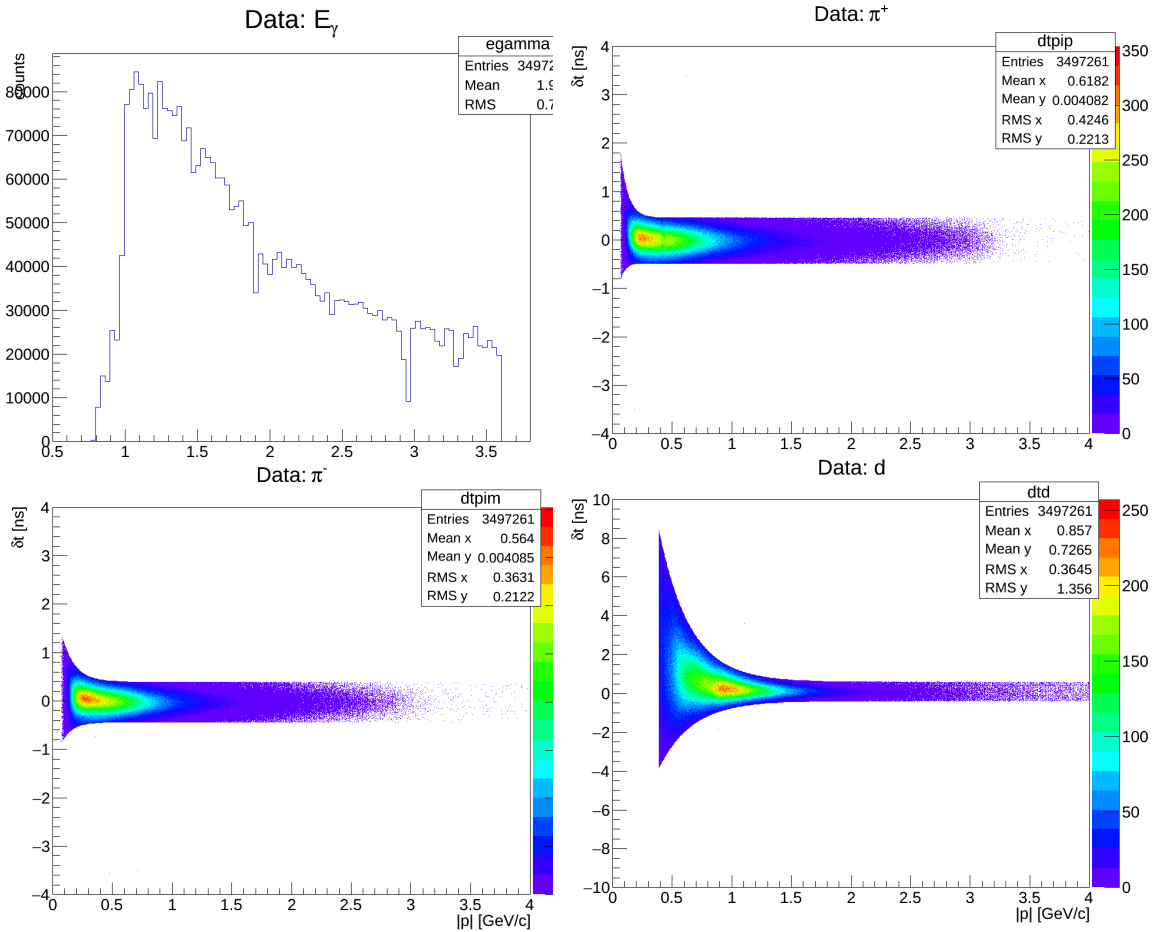
- Spin:
  1 + 1 → J = {0, 1, 2}
- Isospin:
  {0, 1} + 0 → {0, 1}

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

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

Verify the resonance and extract the differential cross section.

Event Selection

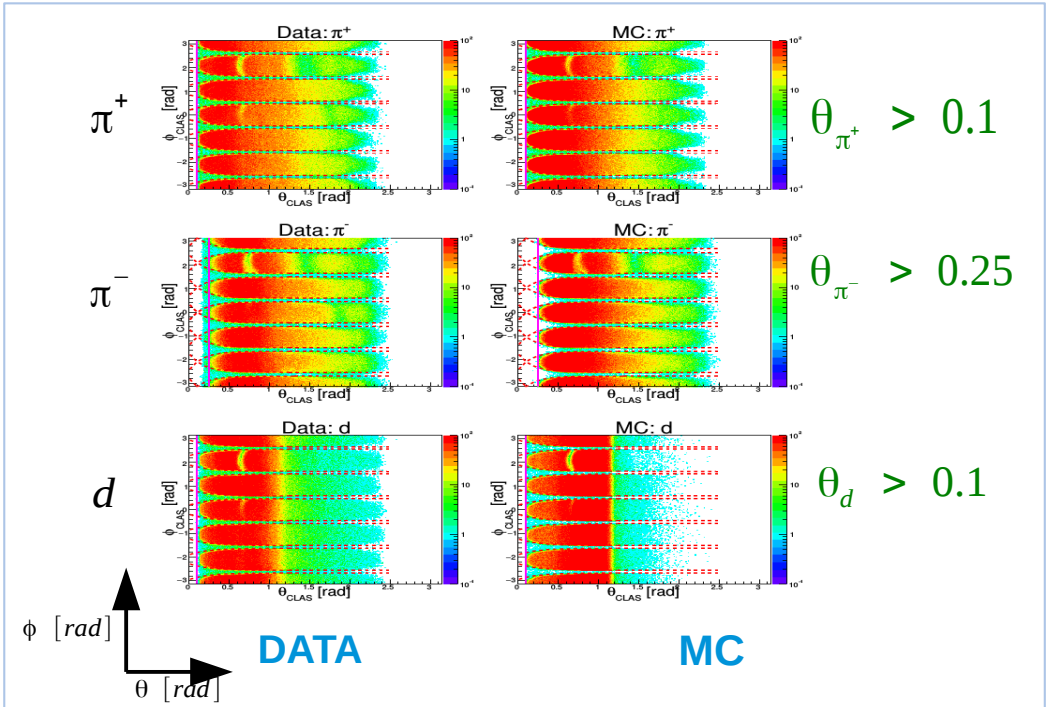


- Final state particles detected: two charged pions and a coherent deuteron.
- Particle identification is done based on momentum-dependent timing analysis.

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.

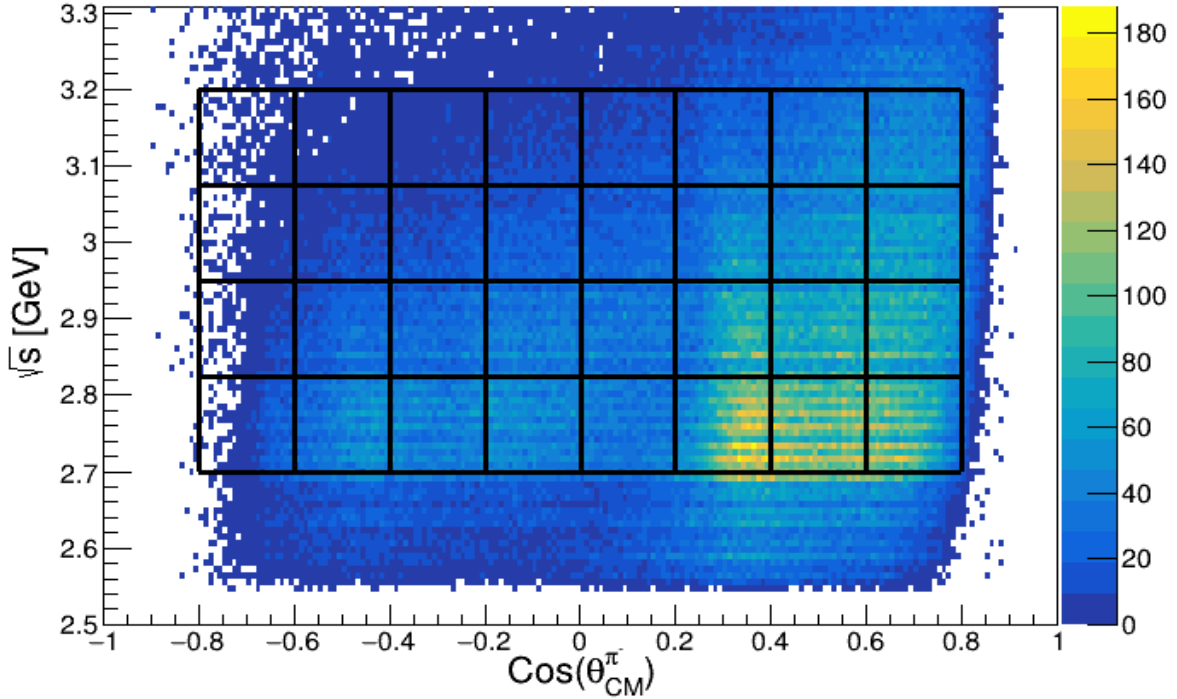
Particle	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6
π^+	23, 27 ≥ 43	≥ 45	11, 13, 23, 31 ≥ 40	23, 33, 35 ≥ 46	23, 29 ≥ 46	23 ≥ 45
π^-	23, 27 ≥ 41	≥ 41	11, 15, 16, 23, 31 34-36, ≥ 41	23, 27, 35 ≥ 43	20, 23, 29 ≥ 43	23 ≥ 42
d	23, 27 ≥ 35	23 ≥ 35	11, 22, 23, 31 ≥ 35	23 ≥ 35	23, 29 ≥ 35	23 ≥ 35



- Tagger energy corrections
- Momentum corrections

Binning

Distribution



2.7 < W < 3.2 GeV

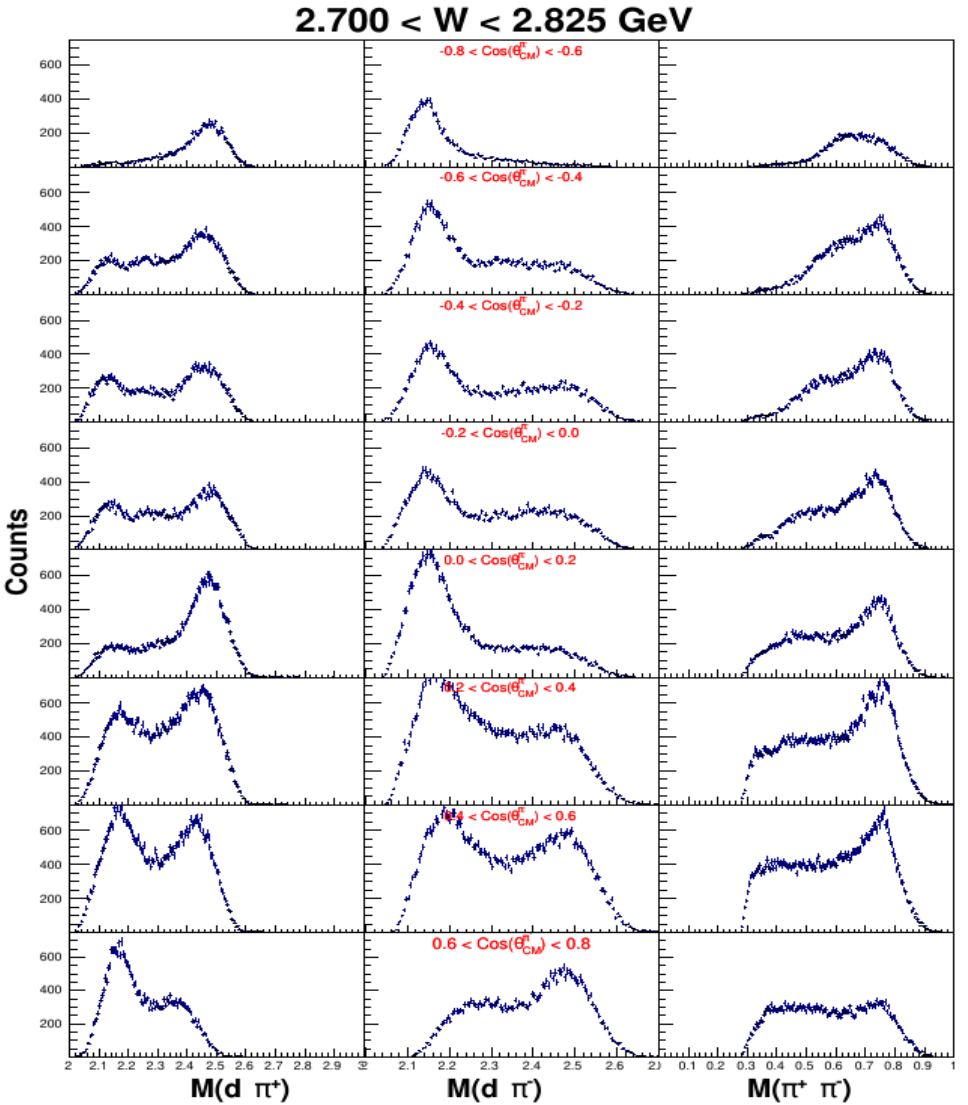
Backgrounds

- Major Backgrounds:
  - Phase Space:

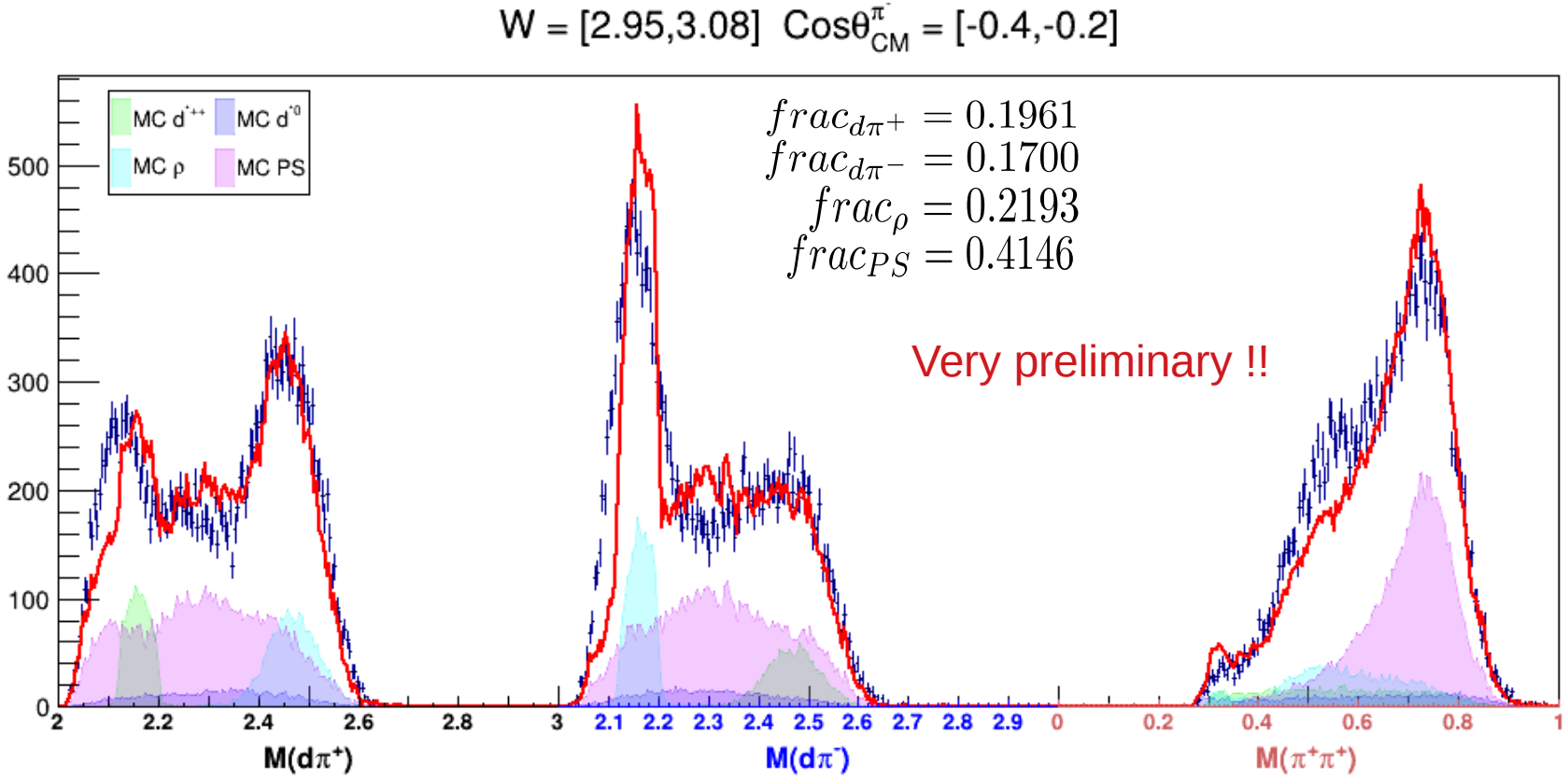
    $d\pi^+\pi^-$
  - Rho meson

    $\pi^+\pi^-$
  - Other resonance/reflection

    $d\pi^+/d\pi^-$
  - Other??
- MC generated for each case



Yield Extraction



Diff. Cross Section

Working formula for DCS :

$$\frac{d\sigma}{d\cos\theta^{\pi^-}_{CM}}(W) = \frac{Yield}{\delta(\cos\theta^{\pi^-}_{CM})A\mathcal{L}(W)}$$

$A \equiv$ *Detector Acceptance*

Luminosity,

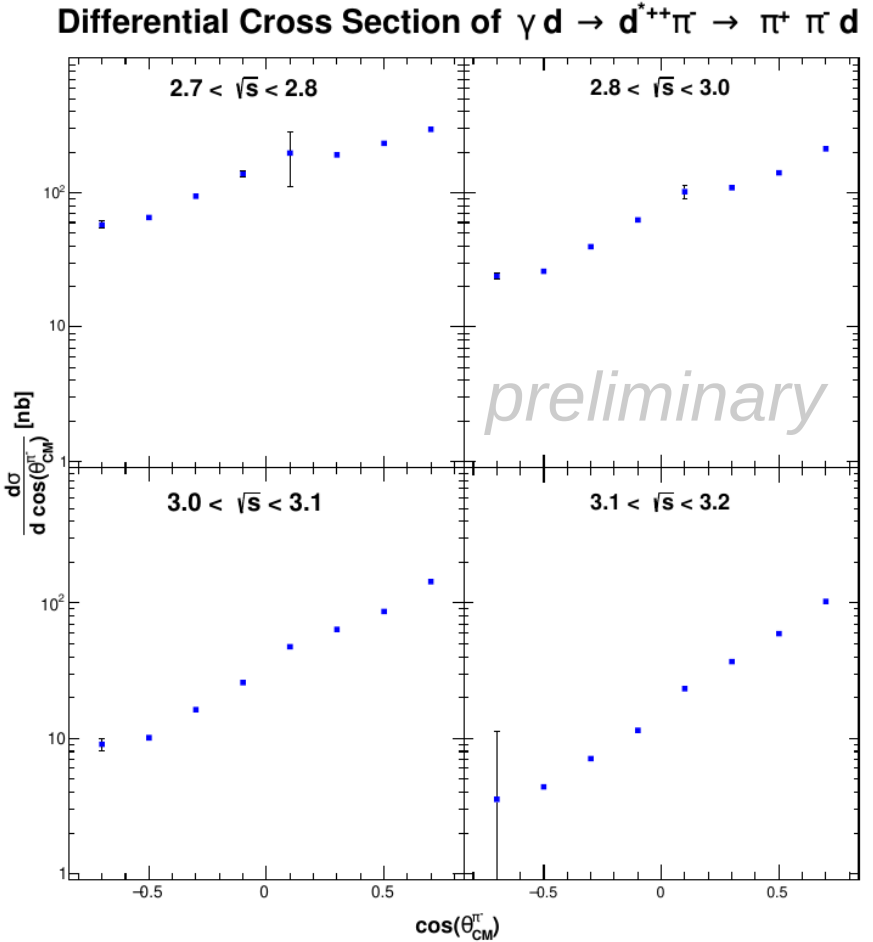
$$\mathcal{L} = \frac{\rho_d N_A l_d}{M_d} N_\gamma$$

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

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

$l_d = 24\ cm$

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



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.