Studies of $\eta^{(\prime)}\pi$ Final States Using GlueX Data HADRON 2019

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Indiana University on Behalf of the GlueX Collaboration Work Supported by DE-FG02-05ER41374

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Overview

1. Why $\eta^{(\prime)}\pi$?

- What we want to measure
- Status exotic hybrid meson searches in $\eta^{(')}\pi$

2. The GlueX Experiment

- Large acceptance detector
- Polarized γ beam at 8.5 GeV
- 3. Status of current analyses at GlueX
 - $\gamma p \rightarrow \eta^{(\prime)} \pi^- \Delta^{++}$
 - $\gamma p \rightarrow \eta^{(\prime)} \pi^0 p$
- 4. Challenges and Outlook

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The $\eta^{(\prime)}\pi$ System

• For orbital angular momentum L = 0, 1, 2, 3, ... of the $\eta(')\pi$ system, we gain access to J^{PC}

• $\eta\pi$ in a *P*-wave results in exotic quantum numbers (non $q\bar{q}$)

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$$\frac{L}{J^{PC}} \xrightarrow{S} P D F \dots$$

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Experiment	Beam Momentum (GeV/c)	Reaction	Claim
GAMS	32, 38, 100	$\pi^- p ightarrow \pi^0 \eta n$	$\pi_1(1400)$
KEK	6.3	$\pi^- p \rightarrow \pi^- \eta p$	$\pi_1(1400)$
E852	18	$\pi^- p ightarrow \pi^- \eta(') p$	$\pi_1(1400/1600)$
Crystal Barrel	Annihilation	$ar{p}n o \pi^0 \eta$	$\pi_1(1400)$
VES	37	$\pi^- p ightarrow \pi^- \eta(') p$	$\pi_1(1600)$
COMPASS	190	$\pi^- p ightarrow \pi^- \eta(') n$	P-wave Intensity
CLEO	-	$\chi_{c1} \to \eta^{(\prime)} \pi \pi$	$\pi_1(1600)$
CLAS	5.5	$\gamma p ightarrow \pi^{-} \eta \Delta^{++}$	(not published)

• Searches going on in other channels, but strongest evidence for exotic mesons are in $\eta'\pi$ and $\rho\pi$ final states

COMPASS Results for $\pi^- p \rightarrow \eta^{(\prime)} \pi^-$





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COMPASS Results for $\pi^- p \rightarrow \eta^{(\prime)} \pi^-$



PLB 740, 303 (2015)



• Clear *D*-wave (L = 2) structure at ≈ 1300 MeV in $\eta\pi^-$ system ($a_2(1320)$)

• Other structures around 1500-2000 MeV \rightarrow need PWA to understand

COMPASS Results for $\pi^- p \rightarrow \eta \pi^-$ and $\eta' \pi^-$





• Forward/backward asymmetry attributed to interference between odd and even waves

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COMPASS Results for $\pi^- p \rightarrow \eta \pi^-$ and $\eta' \pi^-$





- Forward/backward asymmetry attributed to interference between odd and even waves
- L=1,3,5 (exotic waves) suppressed in $\eta\pi^-$ with respect to $\eta'\pi^-$
- Only report *P*-wave intensity, do not make a claim for an exotic

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JPAC Coupled–Channel Fit to COMPASS Results (PRL 122, 042002) Joint Physics Analysis Center (JPAC)



- Coupled channel fit to both $\eta\pi$ and $\eta'\pi$ amplitudes from COMPASS PWA
- Pole positions for a_2 , a'_2 , and π_1 (exotic *P*-wave) determined
 - $\pi_1(\text{exotic})$: $M = 1564 \pm 24 \pm 86 \text{ MeV}, \Gamma = 492 \pm 54 \pm 102 \text{ MeV}$
- Single π_1 pole position describes both $\eta\pi$ and $\eta'\pi$

The GlueX Experiment



$\eta^{(')}\pi$ Systems With GlueX

The goal of this work is to study known resonances (e.g. $a_0(980)$, $a_2(1320)$) to build the foundation for hybrid meson searches at GlueX.

- Access to multiple channels:
- 1. $\gamma p \rightarrow \eta \pi^{0} p, \eta \rightarrow \gamma \gamma$ 2. $\gamma p \rightarrow \eta \pi^{0} p, \eta \rightarrow \pi^{+} \pi^{-} \pi^{0}$ 3. $\gamma p \rightarrow \eta \pi^{-} \Delta^{++}, \eta \rightarrow \gamma \gamma$ 4. $\gamma p \rightarrow \eta \pi^{-} \Delta^{++}, \eta \rightarrow \pi^{+} \pi^{-} \pi^{0}$ 5. $\gamma p \rightarrow \eta' \pi^{0} p, \eta' \rightarrow \pi^{+} \pi^{-} \eta, \eta \rightarrow \gamma \gamma$ 6. $\gamma p \rightarrow \eta' \pi^{-} \Delta^{++}.$
 - $\eta' \to \pi^+ \pi^- \eta, \ \eta \to \gamma \gamma$

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- 6. $\gamma p \rightarrow \eta' \pi^- \Delta^{++},$ $\eta' \rightarrow \pi^+ \pi^- \eta, \ \eta \rightarrow \gamma \gamma$

- Different decay modes should contain same physics
 - \Rightarrow Understand Acceptance
 - \Rightarrow Handling of backgrounds
- Charged and neutral decays are complimentary
- Incorporation of beam polarization into Amplitude Analysis

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- $\begin{array}{ll} \mathbf{6.} & \gamma \mathbf{p} \rightarrow \eta' \pi^- \Delta^{++}, \\ & \eta' \rightarrow \pi^+ \pi^- \eta, \ \eta \rightarrow \gamma \gamma \end{array} \end{array}$

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• Potentially could look at other $\eta^{(')}$ decay modes

 $\gamma p
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ightarrow \gamma \gamma$ (pprox 80% of collected GlueX data, 8< E_{γ} <9 GeV)



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$M(\eta\pi^-)$ in t bins (pprox 80% of collected GlueX data)



- Clear t dependence of $a_{0,2}$ production
- Extracting moments (or amplitudes) as a function of t should be a short term target for early physics

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• $\frac{\sigma(a_0)}{\sigma(a_2)}$ for both neutral and charged exchanges Colin Gleason (IU)

$$\gamma m{p} o \eta \pi^- \Delta^{++}, \; \eta o \pi^+ \pi^- \pi^0$$
 ($pprox$ 20% of collected GlueX data)



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- Have $\approx \frac{1}{10}^{th}$ the statistics compared to $\eta \rightarrow \gamma \gamma$
- More background under η
- Angular distribution looks similar
- $M(\eta\pi^-)$ looks similar for $\eta \to \gamma\gamma$

$\eta\pi$ COMPASS Comparison ($\eta \rightarrow \pi^+\pi^-\pi^0$)



- Expect $\approx 120 \text{k} \ \gamma p \rightarrow \eta \pi^- \Delta^{++}$, $\eta \rightarrow \pi^+ \pi^- \pi^0$ with collected data
 - COMPASS had 116k events
- Expect ≈ 1 M events in $\eta \rightarrow \gamma \gamma$ decay with collected data

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COMPASS $\eta'\pi$ Comparison



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- Different assumptions about background (Deck vs. baryon)
 - Should be able to validate recent JPAC fit results

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COMPASS $\eta'\pi$ Comparison



M(η'π) [GeV/c²]

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Incorporation of Beam Polarization: Polarized Moments

(V. Mathieu (JPAC), arXiv:1906.04841)

• Can write the intensity as a function of the γ -beam polarization:

 $I(\Omega, \Phi) = I^0(\Omega) - P_{\gamma}I^1(\Omega)\cos 2\Phi - P_{\gamma}I^2(\Omega)\sin 2\Phi$

- Model with $a_0(980)$, $a_2(1320)$, $\pi_1(1600)$, $a_2'(1700)$ with parameters from recent JPAC fit to COMPASS data
- Different sensitivity to observables between polarized and unpolarized moments
- Polarization enhances sensitivity to the exotic P wave



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Takeaways and Outlook

- GlueX has access to multiple η and η' decay modes in both charged and neutral exchanges
 - Different acceptances and physics backgrounds
 - Allows for comparing and cross checking between decay modes
- Comparable statistics to COMPASS (\approx 120k events) in $\eta'\pi^-\Delta^{++}$ and $\eta\pi^-\Delta^{++}$, $\eta \to \pi^+\pi^-\pi^0$
 - Expect $\approx 1M$ in $\gamma p \rightarrow \eta \pi^- \Delta^{++}, \ \eta \rightarrow \gamma \gamma$
- Initial focus is on studying a_0 and a_2 production
 - 1. How do we treat the backgrounds?
 - 2. Do we trust the modeling of our acceptance?
 - 3. Is what we are extracting correct when doing the amplitude analysis?
 - 4. Will lay the foundation for exotic searches at GlueX
- Interaction with theorists (JPAC) has been and will be crucial to developing techniques and understanding our results