Analysis of the Radiative Decay of Eta in CLAS

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On behalf of the CLAS Collaboration
Light Meson Decay Program at CLAS

- Access to multiple light meson decays via

\[ \gamma + p \rightarrow p + X \]

where

\[ X = \pi^0, \eta, \omega, \rho, \eta', \text{and } \phi \]

<table>
<thead>
<tr>
<th>Dalitz decays</th>
<th>( \pi^0, \eta, \eta' \rightarrow e^+e^-\gamma )</th>
<th>Transition form factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiative decays</td>
<td>( \eta, \eta' \rightarrow \pi^+\pi^-\gamma )</td>
<td>Box anomalies, FSI</td>
</tr>
<tr>
<td>Hadronic decays</td>
<td>( \eta, \eta' \rightarrow \pi^+\pi^-\pi^0 )</td>
<td>Dalitz plot analysis, quark mass ratio,</td>
</tr>
<tr>
<td></td>
<td>( \eta' \rightarrow \pi^+\pi^-\eta )</td>
<td></td>
</tr>
</tbody>
</table>
Eta Meson Properties

\[ M_\eta = 547.862 \pm 0.017 \text{MeV} \]
\[ \tau = 5 \cdot 10^{-19} \text{s} \]
\[ \Gamma = 1.31 \pm 0.05 \text{keV} \]

<table>
<thead>
<tr>
<th>Decay</th>
<th>Branching Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \eta \to \pi^+\pi^-\pi^0 )</td>
<td>(22.92 ± 0.34)%</td>
</tr>
<tr>
<td>( \eta \to \pi^+\pi^-\gamma )</td>
<td>(4.22 ± 0.08)%</td>
</tr>
<tr>
<td>( \eta \to e^+e^-\gamma )</td>
<td>(6.9 ± 0.4) x 10^{-3}</td>
</tr>
<tr>
<td>( \eta \to \mu^+\mu^-\gamma )</td>
<td>(3.1 ± 0.4) x 10^{-4}</td>
</tr>
</tbody>
</table>
Triangle and Box anomalies

• At the chiral limit, all decays are determined by Wess-Zumino-Witten Lagrangian

\[
A_{\eta \to \pi^+\pi^-\gamma} \propto \frac{e}{4\sqrt{3}\pi^2F_\pi^3} \left( \frac{F_\pi}{F_8} \cos \theta - \sqrt{2} \frac{F_\pi}{F_0} \sin \theta \right)
\]

• Amplitude is sensitive to box anomaly and predicts decay width of 35.7 eV\(^{(1)}\)
The Box Anomaly

- Must properly include momentum dependence to describe experimental data

\[ \Gamma^{exp}(\eta \rightarrow \pi^+ \pi^- \gamma) = 55.3 \pm 2.4 \text{eV} \]

- Modify amplitude by reaction specific polynomial and pion vector form factor\(^{(4)}\)

\[ A_{\eta \rightarrow \pi^+ \pi^- \gamma} \times \left[ F_{PV}(s_{\pi\pi}) \cdot (1 + \alpha s_{\pi\pi}) \right] \]

- Want to measure alpha parameter for decay:

\[ \eta \rightarrow \pi^+ \pi^- \gamma \]
Previous measurements of alpha parameter

\[ \alpha = 1.8 \pm 0.04 \]

Gormley, et. al.

<table>
<thead>
<tr>
<th>Experiments</th>
<th>( \alpha ) parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>WASA-at-COSY</td>
<td>1.89 ± 0.86</td>
</tr>
<tr>
<td>KLOE</td>
<td>1.32 ± 0.08</td>
</tr>
<tr>
<td>CLAS</td>
<td>ongoing</td>
</tr>
<tr>
<td>BESIII</td>
<td>ongoing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Theoretical Models</th>
<th>( \alpha ) parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/D</td>
<td>0.64 ± 0.02</td>
</tr>
<tr>
<td>HLS</td>
<td>0.23 ± 0.01</td>
</tr>
<tr>
<td>((O(p^6) + 1 \text{- loop}))</td>
<td>-0.7 ± 0.1</td>
</tr>
<tr>
<td>Box anomaly</td>
<td>-1.7 ± 0.02</td>
</tr>
</tbody>
</table>
The g11 experiment with CLAS at JLAB

• May 17, 2004 - July 29, 2004
• Beam energy: 4 GeV
• Photon beam energy: 1.5-3.5 GeV
• Liquid H2 target
• 21 TB of raw data collected
Event Selection and Particle ID

- Trigger required two charged tracks in different sectors
- Required events with three charged tracks corresponding to
- Required events to have at least one photon
- Time of Flight (TOF) was used for particle identification
- Detect all final state particles
Data Cuts

\[ \gamma \text{ Momentum [GeV]} \]

\[ (\text{me}_{PP\pi\pi-P\gamma}) \text{ [GeV]} \]
Data Cuts

\[ mx2_{PPipPimGam} \text{ [GeV}^2\text{]} \]

\[ \eta' \]

\[ \rho/\omega \]

\[ 0.2 \quad 0.4 \quad 0.6 \quad 0.8 \quad 1 \quad 1.2 \quad 1.4 \]

\[ 0 \quad 2000 \quad 4000 \quad 6000 \quad 8000 \quad 10000 \quad 12000 \quad 14000 \quad 16000 \quad 18000 \quad 20000 \]
Analysis

Not acceptance corrected
Simulations

1. Simulate IM($\pi^+\pi^-$) from 0.30 GeV to 0.50 GeV

2. GSIM: generated events were passed through GEANT software in CLAS

3. GPP: GSIM Post Processor is used for smearing due to detector response

4. RECIS: Reconstruction program to analyze GSIM output in same manner as raw data
MC and Data Comparison

h_{Pp} [Entries 64597, Mean 1.07, Std Dev 0.3452]

h_{Ppip} [Entries 64597, Mean 0.513, Std Dev 0.2787]

h_{Ppim} [Entries 64597, Mean 0.6351, Std Dev 0.3188]

h_{Pgam} [Entries 64597, Mean 0.2948, Std Dev 0.1329]
MC + Data Comparison II

\( \theta_P \) [deg]

\( \theta_{\pi^+} \) [deg]

\( \theta_{\pi^-} \) [GeV]

\( \theta_{\gamma} \) [deg]

Data

recMC
MC + Data Comparison III

\( \phi_P \) [deg]

Entries: 11898
Mean: 3.128
Std Dev: 104.5

\( \phi_{\pi^+} \) [deg]

Entries: 11898
Mean: 3.708
Std Dev: 104.4

\( \phi_{\pi^-} \) [deg]

Entries: 11898
Mean: 3.389
Std Dev: 105.6

\( \phi_\gamma \) [deg]

Entries: 11898
Mean: 2.793
Std Dev: 105
Summary and Future Work

• Box anomaly is important to describe experimental distributions

• Alpha parameter has been measured previously but measurements are not consistent with theoretical descriptions

• Acceptance and systematic error calculations in progress
References


2. PDG, Chin. Phys, 090001, 2014

