CLEO-c Sensitivity to Radiative Decay of Scalar Mesons

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Discussion Points

- Scalar mesons $f_0(1370)$, $f_0(1500)$, and $f_0(1710)$
- What we know about $J/\psi \rightarrow \gamma f_0$
- What can CLEO-c add about $J/\psi \rightarrow \gamma f_0$
- Unravelling glue and $q\bar{q}$ with $f_0 \rightarrow \gamma V$

Specific example: $f_0(1710) \rightarrow \gamma \rho$ in CLEO-c
The $f_0(1370)$, $f_0(1500)$, and $f_0(1710)$

- Well established “light” scalar mesons
- All are seen in some experiments, but none of them are seen in all experiments.
- **Current best guess:** These are mixtures of isoscalar quarkonia and the lightest glueball
- The mixing remains an unknown matrix, both experimentally and theoretically
What we know about $J/\psi \rightarrow \gamma f_0$

For $f_0(1710)$:

- Clear peak in $J/\psi \rightarrow \gamma f_0 \rightarrow \gamma K^+ K^-$, etc...
- Branching ratio $10^{-3}$
- Spin well established in partial wave analysis

The $f_0(1370)$ is a broad S-wave peak in the PWA.

The $f_0(1500)$ is not (obviously) observed.
Orientation: Inclusive $J/\psi \rightarrow \gamma X$


Minimum Ionizing

$\eta(1440)$

No other prominent peaks in the inclusive spectrum.

$\eta'$

Photons Energy (MeV)
Recent results from BES

Exclusive final state shows lots of peaks.
“Partial Wave Analysis”

\[ |a_{0,0}|^2 \]

\[ |a_{2,0}|^2 \]
\[ |a_{2,1}|^2 \]
\[ |a_{2,2}|^2 \]

\( \text{K}^+ \text{K}^- \)
\( \text{K}_S \text{K}_S \)
\( \pi^+ \pi^- \)

SLAC Mark-III (Dunwoodie, et al.)
What can CLEO-c add?

• Up to $10^9 \, J/\psi \, (\approx 20 \times \text{BES})$
• High resolution photon detection
• Excellent particle identification

Obviously, CLEO-c will look for narrow structures ala $f_J(2230)$ with high sensitivity.

What other specific measurements can CLEO-c make that bear on the issue of gluonic excitations?
Unravelling glue and $q\bar{q}$ with $f_{0} \rightarrow \gamma V$

**Basic idea:** Glue component doesn’t couple to photons, and flavor component sensitive to $V=\{\rho, \omega, \varphi\}$.

*Radiative decays: A New flavor filter.*
By Close, Donnachie, and Kalashnikova.

*Radiative scalar decays in the light front quark model.*
By DeWitt, Choi, and Ji.

*Decay width calculations are basically consistent, especially in the ratios to different vector mesons.*
**Calculations from Close, et al:**

<table>
<thead>
<tr>
<th>State</th>
<th></th>
<th>Total width (MeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Radiative Decay Widths (keV)</td>
<td></td>
</tr>
<tr>
<td>f_0 → γρ(770)</td>
<td>f_0 → γφ(1020)</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>f_0(1370)</td>
<td>443</td>
<td>1121</td>
</tr>
<tr>
<td>f_0(1500)</td>
<td>2519</td>
<td>1458</td>
</tr>
<tr>
<td>f_0(1710)</td>
<td>42</td>
<td>94</td>
</tr>
</tbody>
</table>

For example, for the three different mixing scenarios, we have

\[
B[f_0(1710) → γρ] = \frac{42 \text{ to } 705}{125 \times 10^3} = (0.3 \text{ to } 5) \times 10^{-3}
\]

\[
B[f_0(1710) → γφ] = \frac{800 \text{ to } 78}{125 \times 10^3} = (6.4 \text{ to } 0.6) \times 10^{-3}
\]

\[
\frac{B[f_0(1710) → γρ]}{B[f_0(1710) → γφ]} = \frac{42}{800} \text{ to } \frac{705}{78} = \frac{1}{19} \text{ to } 9
\]
Specific example: $f_0(1710) \rightarrow \gamma \rho$ in CLEO-c

**The Challenge:** Need to extract a signal with $BR \approx 10^{-6}$

**Monte Carlo study:**

- **Signal:** Generate $J/\psi \rightarrow \gamma f_0(1710) \rightarrow \gamma \gamma \rho \rightarrow \gamma \gamma \pi^+ \pi^-$ and attempt to extract events with high efficiency

- **Background:** Generate “generic” $J/\psi$ events using best available information and apply same cuts as those used to extract the signal

*Work done by Istvan Danko (RPI)*
Signal Monte Carlo: Reconstruction efficiency

\[ f_0(1710) \rightarrow \gamma \pi^+ \pi^- \]

\[ \rho \rightarrow \pi^+ \pi^- \]

**Efficiency=65.2%**
Signal Monte Carlo:
Truth matching

\[ f_0(1710) \rightarrow \gamma \pi^+\pi^- \]

\[ \rho \rightarrow \pi^+\pi^- \]

\( \pi^+\pi^- \) correct
All correct
\( \pi^+\pi^- \) correct, \( \gamma \)'s wrong
Generic Monte Carlo: Generated $7 \times 10^6$ events

All events

Exactly two tracks w/opposite charge

Exactly two, high energy, unmatched showers in CsI

Result of imposing vertical line cut on “other” histogram
Understanding the remaining backgrounds

\( J/\psi \to \rho \pi \to \pi^0 \pi^+ \pi^- \to \gamma \gamma \pi^+ \pi^- \ (BR=1.27\%) \)

Also \( J/\psi \to \{ \rho \eta, \gamma \eta', ... \} \to \gamma \gamma \pi^+ \pi^- \)
Removing the remaining backgrounds (work in progress)

Results so far: 604 events remain \((10^{-4} \text{ rejection})\) with signal detection efficiency 39.4%. “Not bad, but more to go.”
Where we are going from here...

- Continue to study generic backgrounds and reduce them as far as possible.
- Work on a partial wave analysis technique for verifying the J/ψ→γf_0(1710)→γγρ signal
- Study J/ψ→γf_0(1710)→γγφ (in progress)
- Study J/ψ→γf_0(1710)→γγω
Summary

• The situation of glueball components in the scalar meson sector remains murky

• CLEO-c will contribute high statistics and precision techniques towards the problem

• One key problem we will attack is finding the “mass mixing matrix” elements

• Simulations are underway so that we are ready for the problem when the data arrives