$\phi$-meson Photoproduction by Using a Beam of Linearly-Polarized Photons

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Outline

- **Motivation**
  - OZI evading/respecting
  - VMD (Vector Meson Dominance)
  - Spin Density Matrix Elements

- **φ-meson Photoproduction**
  - CEBAF (Continuous Electron Beam Accelerator Facility)
  - Coherent Bremsstrahlung Facility at CLAS (CEBAF Large Acceptance Spectrometer)
  - Event Selection
OZI evading/respecting process

- Okubo Zweig Iizuka rule: In strong interaction processes where final states can only be reached via quark-antiquark annihilation are suppressed. You cannot cut gluon lines in the OZI picture.

- Experimentally this decay mode is: \((15.3 \pm 0.4)\%\)

\[\Phi \rightarrow \pi^+ \pi^0 \pi^-\]

- \(\Phi \rightarrow K^-\bar{K}^0\)

- \(\Phi \rightarrow K^+\bar{K}^0\)

\(~84\% \text{ of the } \Phi \text{ decay is OZI respecting.}\)
FIG. 29. Reaction $\gamma p \rightarrow p\phi$ at 2.8, 4.7, and 9.3 GeV. Decay angular distribution of $K\bar{K}$ pairs in the helicity system in the $\phi$ mass region $1.00 \leq M_{K\bar{K}} \leq 1.04$ GeV and in the momentum-transfer interval $0.02 \leq |t| \leq 0.8$ GeV$^2$. The curves are calculated for an $s$-channel helicity-conserving $\phi$ production amplitude.

Previous Measurements:
Spring-8 used a beam of linearly polarized photons (forward direction \(|t|<0.4 \text{ GeV}^2\))


FIG. 4: Decay angular distributions for \(-0.2 < t + |t|_{\text{min}}\) in the Gottfried-Jackson frame. The solid curves are the fit to the data. The hatched histograms are systematic errors.
VMD

Low $|t|$ regime (Spring-8 + SLAC) Forward Direction

Central region Non VMD?

High $|t|$ regime g8b Central Region

FIG. 20. Reaction $\gamma \rho \rightarrow \rho \phi$ at 2.8, 4.7, and 9.3 GeV. Decay angular distribution of KE, $\rho$ in the helicity system in the $\phi$-mass region 1.00 < $M_{\phi}$ < 1.04 GeV and in the momentum-transfer interval 0.02 < $|t|$ < 0.5 GeV$^2$. The curves are calculated for an s-channel helicity-conserving $\phi$ production amplitude.
The Decay Angular Distribution
Spin Density Matrix Elements

\[ W(\cos \theta, \phi, \Phi) = W^0(\cos \theta, \phi, \rho^0_{\alpha\beta}) - P_\gamma \cos 2\Phi W^1(\cos \theta, \phi, \rho^1_{\alpha\beta}) - P_\gamma \sin 2\Phi W^2(\cos \theta, \phi, \rho^2_{\alpha\beta}) \]

where

\[ W^0(\cos \theta, \phi, \rho^0_{\alpha\beta}) = \frac{3}{4\pi} \left[ \frac{1}{2} \sin^2 \theta + \frac{1}{2} (3 \cos^2 \theta - 1) \rho^0_{00} - \sqrt{2} \text{Re} \rho^0_{10} \sin 2\theta \cos \phi - \rho^0_{1-1} \sin^2 \theta \cos 2\phi \right] \]

\[ W^1(\cos \theta, \phi, \rho^1_{\alpha\beta}) = \frac{3}{4\pi} \left[ \rho^1_{11} \sin^2 \theta + \rho^1_{00} \cos^2 \theta - \sqrt{2} \text{Re} \rho^1_{10} \sin 2\theta \cos \phi - \rho^1_{1-1} \sin^2 \theta \cos 2\phi \right] \]

\[ W^2(\cos \theta, \phi, \rho^2_{\alpha\beta}) = \frac{3}{4\pi} \left[ \sqrt{2} \text{Im} \rho^2_{10} \sin 2\theta \sin \phi + \text{Im} \rho^2_{1-1} \sin^2 \theta \sin 2\phi \right] \]

*Linearly polarization gives access to six more density matrix elements

*Those are calculated in \( \phi \) rest frame (Helicity Frame)
Spin Density Matrix Elements

IF VMD:

- Density matrix elements should be equal to ZERO but \( \rho^{1,1} \) and \( \text{Im}\{\rho^{2,1}\} \)
- \( \rho^{1,1} , \text{Im}\{\rho^{2,1}\} = (1/2, 1/2 : \text{Pomeron}) \)
- \( \rho^{1,1} , \text{Im}\{\rho^{2,1}\} = (-1/2, 1/2 : \text{Meson}) \)

If not:
- Knockout processes take place
- Interesting physics beyond VMD
$\phi$–Photoproduction: g8b experiment

Linearly Polarized Photon Beam

$p(\pi, \eta, \eta', \rho, \omega, \phi, K, \Lambda)$

Target: Hydrogen
The Coherent Bremsstrahlung Facility at CLAS

Requirements for Coherent Bremsstrahlung

- Low emittance, stable beam
- High quality thin crystal
- Collimation < 0.5 characteristic angle
Experiments with Linearly Polarized Photons at CLAS

The Coherent Bremsstrahlung Facility at CLAS

Diamond

Goniometer, G.W. University
Linearly Polarized Photons

- Mean polarization estimated to be ~70%, from comparison with the coherent bremsstrahlung calculation.

i.e. Coherent Peak at 2.1GeV
Event Selection

\[ \bar{\gamma} p \rightarrow p\phi \rightarrow pK^+K^- \]
Mode: (pK^+)K^−

Before K^- missing mass cut

\[ \phi \rightarrow K^+K^- \text{ Invariant mass (before)} \]
Event Selection

\[ \gamma \vec{p} \rightarrow p\phi \rightarrow pK^+K^- \]

Mode: \((pK^+)K^-\)

After \(\pi^+X\) vs \(K^+X\) cut, timing cuts and \(K^-\) missing mass cut

All this is just for 5 runs. All this is just for 5 runs.

We have 400 runs in total.

\(\phi \rightarrow K^+K^-\) invariant mass

(after cuts)
Signal to background ratio: 4.18
Events Signal: 502
Events Background: 120

Event Selection

$\bar{\gamma}p \rightarrow p\phi \rightarrow pK^+K^-$
Mode: $(pK^+)K^-$
Conclusions

- Polarization 70%
- Over 500 $\phi$-meson were found for 5 runs$^*$ in g8b data.
- We predict over 7500 events from 1.9 to 2.1 GeV.
- We are working on optimizing the $\phi$-meson signal through direct $pK^+K^-$ measurement and missing mass ($p,K^-)K^+$

$^*$ This represents ~5% of data
g8 history so far…
Tagged and Collimated $\gamma$ beam in Hall B for beam-asymmetry studies for the reactions:

$$\gamma p \rightarrow p(\pi, \eta, \rho, \omega, \phi), K\Lambda$$

<table>
<thead>
<tr>
<th>Coh. Peak</th>
<th>good evts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.3 GeV</td>
<td>(1.4 Billion)</td>
</tr>
<tr>
<td>1.5 GeV</td>
<td>(2.0 Billion)</td>
</tr>
<tr>
<td>1.7 GeV</td>
<td>(1.8 Billion)</td>
</tr>
<tr>
<td>1.9 GeV</td>
<td>(1.2 Billion)</td>
</tr>
<tr>
<td>2.1 GeV</td>
<td>(0.9 Billion)</td>
</tr>
<tr>
<td>Amorphous</td>
<td>(1.8 Billion)</td>
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</tbody>
</table>

Photon Polarization exceeds 90% in the peak

$\rho^0$ at low $|t|$ (< 0.30 GeV$^2$)

Thanks!!!