Recent results from LEPS and prospects of LEPS II at SPring-8

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for the LEPS collaboration

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κ meson search in $K(890)\Sigma^+$ photoproduction
Additional evidence is needed to establish $\kappa$. 

Born terms of $K(890)\Sigma^+$ photoproduction

K* exchange (spin non-flip) is suppressed.

(a) $t$-channel

(b) $s$-channel

(c) $u$-channel
K(890)\Sigma^+ photoproduction

t-channel: forward region polarization measurement is needed

CLAS, PRC75(042201)

CBELSA/TAPS
Hyperon production with $K^*(892)$

- $\gamma p \rightarrow K(890)\Sigma^+$
- **Parity filter with linearly polarized photon**

Unnatural parity ex.
$P = (-1)^J$

pseudo-scalar: kaons
Hyperon production with $K^*(892)$

- $\gamma p \rightarrow K(890)\Sigma^+$
- **Parity filter** with linearly polarized photon

Spin density matrix → Parity spin asymmetry

natural parity ex. $P = (-1)^J$

scalar: $\kappa$
Setup of LEPS I

- SVTX
- DC1
- TOF
- AC(n=1.03)
- Target
- Dipole Magnet 0.7 Tesla
- Start Counter
- DC2
- DC3
K/π selection and IM(K⁺π⁻) vs MM(γ,K⁺π⁻)
Decay angular distribution

(a) GJ frame

(b) helicity frame

Acceptance corrected data (red), Monte-carlo data (dashed), hyperon production (black histogram)
Parity spin asymmetry

\[ P_\sigma = 2\rho_{1-1}^1 - \rho_{00}^1 \]

\( \rho \): Spin density matrix elements

Consistent with model w/ \( \kappa \)-exchange by Y. Oh & H. Kim (PRC74,015208)

γ d →K⁺K⁻pn

- Data taken in 2002-2003.
- 2.0<E_{γ}<2.4 GeV.
- Significance of 5.1σ from shape analysis.
  (Δ(-2lnL) with/without signal)
- Mass=1524±2 ± 3MeV/c².

To confirm the result..

- New data was taken in 2006-2007 with almost the same setup.
- Blind analysis was applied to check the previous result.
  (Selection cut is not changed from previous analysis. Calibration is fixed before opening the box)
Search for $\Theta^+$ in Fermi-motion corrected $K^-$ missing mass

$\Theta^+$: $\gamma\ n \rightarrow K^-\ \Theta^+$
$\Lambda(1520)$: $\gamma\ p \rightarrow K^+\ \Lambda(1520)$

Previous analysis: $p/n$ unseparated
Inclusive analysis

Improve S/N

After box open: $p/n$ separated
Exclusive analysis

Separation of the two types of $K^+K^-$ events from neutron and proton largely improves the signal sensitivity.

Minimum Momentum Spectator Approximation (MMSA):
Assume possible minimum momentum configuration for the spectator.

simple MMn($\gamma,K^-$)$X$: 30 MeV/$c^2$
$M(nK^+)$ by MMSA: 11 MeV/$c^2$
(16 MeV/$c^2$ for $\Lambda(1520)$)
Results of Inclusive Analysis

New data contains 2.6 times more statistics than the previous data.

<table>
<thead>
<tr>
<th>ID</th>
<th>Entries</th>
<th>Mean</th>
<th>RMS</th>
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<td>100</td>
<td>1.639</td>
<td>0.91485d01</td>
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</tbody>
</table>

New data previous data

\( \chi^2/\text{ndf}=56.4/66 \)

K.S test 58.8%

• Blind analysis: Cuts are pre-determined.
• Narrow strong structure is not seen in the signal region.
• The significance is less than 2\( \sigma \) if we perform the same shape analysis as the previous analysis.

• Two data sets are normalized by the entry.
• In total, two data sets are consistent.

Fluctuation? Human bias? Over/under-estimation?  

Exclusive analysis
Proton detection by using $dE/dx$ in Start Counter

Proton not tagged (Proton rejected):
- KKn and part of KKp

Proton tagged ($\varepsilon \sim 60\%$)
- KKp only

Signal enhancement is seen in proton rejected events.
→ should be associated with $\gamma n$ reaction.

$p/n$ ratio:
- 1.6 before proton rejection
- 0.6 after proton rejection
M(NK⁺) for exclusive samples for each data set

- Peak is seen in tagged events for the previous data while not seen in the new data.
- An enhancement is seen in proton rejected events in the both data.
dE/dx based exclusive analysis

Proton rejection efficiency becomes 60%→90% by selecting downstream of target

"leaked" proton BG

\[ M(nK^+) \]
To check the enhancement in the exclusive sample

The model independent rejection of proton events using SC. However, acceptance of the vertex cut is only $\sim 40\%$.

Proton "tagged" sample

Proton "leaked" sample

Extrapolate with a help of MC

Subtract from full data sample.

$\rightarrow$ MC based exclusive analysis.
MC based exclusive analysis

- Proton contribution is estimated by fitting realistic MC distributions to proton-tagged spectra.
- The estimated proton contributions are subtracted from full data sample (without z-vertex and proton tagging cut).

\[
\chi^2/\text{ndf} = 34.4/37
\]

\[
\chi^2/\text{ndf} = 33.3/37
\]

φ and non-resonant KK, Λ(1520), Λ(1405), Summed
M(nK+) with two methods

Subtract proton contribution

MC-based exclusive events

\[ \frac{dE}{dX} \]-based exclusive events

- An enhancement is seen in proton subtracted M(nK+) spectra.
- Mass and significance estimation of the enhancement is underway.
- LEPS collaboration plans to perform new experiment with large SC (better S/N) from this October.
LEPS II project
Physics motivation for LEPS II
Pentaquark $\Theta^+$ LEPS vs CLAS

Strong angular dependence of production rate?

LEPS
forward angle

CLAS
large angle

preliminary

$P(nK^+)(\text{GeV/c}^2)$

$M(nK^+)$ (GeV/c$^2$)

Events/10 MeV/c$^2$

Counts/12.5 MeV

PRL 96, 212001(2006)
Physics motivation for LEPS II

$\Theta^+$ LEPS vs CLAS

Strong angular dependence of production rate?

After reconfirmation of $\Theta^+$ peak w/ new data → Angular dependence of production cross section.

$4\pi$ detector LEPS II.

PRC 79, 025210 (2009)
Physics motivation for LEPS II

Two pole structure of $\Lambda(1405)$

D. Jido, et al.
NPA725(2003)

Reconfirm by photoproduction.

V.K. Magas, E. Oset and A. Ramos, PRL 95
K*(890) Λ(1405) photoproduction with linearly polarized photon

High luminosity photon beam with $E_\gamma > 2.4$ GeV.
Detect $K^{*+} \rightarrow K^0 s \pi^+ \rightarrow \pi\pi\pi$
$\Lambda(1405) \rightarrow \Sigma^0 \pi^0 \rightarrow \Lambda\gamma\gamma$
$\Sigma(1385) \rightarrow \Lambda\pi^0$

Large acceptance charged / photon detector
Schematic view of the LEPS2 facility

- Backward Compton Scattering
- 8 GeV electron
- Recoil electron (Tagging)
- Laser
- 10 times high intensity:
  - Multi laser injection & Laser beam shaping
  - 2.4 GeV: 10 Mcps
  - 3 GeV: 1 Mcps

Best emittance e beam ⇒ pencil photon beam

LEP (GeV γ-ray)

BGO γ counter

Large 4π spectrometer

Beam dump
LEPS II solenoid spectrometer

Solenoid magnet was shipped from BNL
B=1 T
\[ \Delta p/p \sim 1\% \]
for \( \theta > 7 \) deg

Charged/photon detectors

Detector development is underway. Physics run will start in 2014.

\[ \gamma \text{ counter} \]
\[ \text{RPC} \]
\[ \text{TOP} \]
\[ \text{TPC} \]
\[ \text{DC} \]

\( \gamma \)

\( \sim 2m \)

\( < 2.7 \text{ GeV/c} \)
BGO-EGG $\gamma$ counter

(Tohoku Univ. group)

- BGO crystal: 1320
- Azimuthal angle: $2\pi$
- Polar angle: $24^\circ$-$146^\circ$

First $\gamma$ beam at LEPS2 in next January. Physics run from 2013 April.
Summary

LEPS

- **K*Σ+ photoproduction with evidence for κ meson exchange.** (PRL 108, 092001)
- The Θ+ is studied via γd→K+K-pn reaction with high statistics data.
  - 2.6 times higher statistics compared with previous data are collected.
- The inclusive M(nK+) spectrum for new data does not show a strong narrow peak.
  - The significance of the peak in new data is ~2σ by shape analysis.
- However, clear enhancements are seen in both new and previous data after the reduction of proton BG by exclusive analysis.
  - Mass and significance estimation of the enhancement is underway.
- **LEPS collaboration plans to perform new experiment with large SC from this October.**

LEPS II

- x10 higher intensity (2.4 GeV : 10 Mcps, 3 GeV : 1 Mcps).
- **Large acceptance detector** with solenoid magnet which cover from 7° to backward.
  - Photon and charged particle detection simultaneously.
- BGO γ counter
- **First beam in next January.**
- γ counter experiment start from next April.
- Solenoid spectrometer experiment start in 2014.