Recent result of LEPS and prospects of LEPS2

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LEPS collaboration

as substitute of Dr. Niiyama
Overview of LEPS

LEPS 2001~

LEPS2 2013~
Physics at SPring-8/LEPS

- φ-meson production
  - Reaction mechanism, φ-nucleon interaction [T. Sawada]
- Evidence for a κ meson [S.H. Hwang]
  - Reaction mechanism
- Backward meson production
  - Baryon resonance study
- Exotic baryons
  - Λ(1405) Photoproduction up to 3 GeV [Y. Nakatsugawa]
  - Θ+ Photoproduction
  - Search for KNN Bound State [A. Tokiyasu]
SPring-8 LEPS

LEPS backward compton scattering photon
- $E_\gamma \sim 2.4\text{GeV}, E_\gamma \sim 2.9\text{GeV}$ Tagged photon
- Polarization $\sim 95\%$
- $> 1\text{ Mcps}$

Physics run from 2001
Photo production experiment using charged particle spectrometer.
Pion, kaon, proton at forward angle.
**K*0Σ+ photoproduction**

- **t-channel exchange is dominant**
- **K-exchange is prohibit in K photoproduction**
- **Exchanged particle information from Decay asymmetry analysis**

Only K-exchange (natural parity exchange) or K-exchange (unnatural parity exchange) is allowed.
Parity spin asymmetry:

$$P_\sigma = 2 \rho^{1}_{1-1} - \rho^{1}_{00}$$

[Similar to photon beam asymmetry.]

- GJ frame: 0.784 $\pm$ 0.154
- Helicity frame: 0.758 $\pm$ 0.123

Dominance of natural-parity exchange is indicated at forward angles.

Consistent with $\kappa(800)$ meson exchange.
Λ(1405) production

Study for internal structure of Λ(1405)

- qqq, NK, qqqqq
- Spectrum shape
- Production mechanism
- Photon beam symmetry
- Large acceptance detector
- TPC

Previous result of LEPS (2008)
CH2 target

2012/10/18  CJJNPS2012
New result of \( \Lambda(1405) \) production

3 times higher statistic with LH2 target

\[
\Sigma^+ \pi^- \text{ mode}
\]

\[
\Sigma^- \pi^+ \text{ mode}
\]

Spectrum shape is difference in each charge mode

very preliminary

counts/0.01GeV/c^2

MM(K^+)GeV/c^2
Search for the $K^- \, pp$ bound state

- **Theoretical prediction**: $B.E. = 10 - 80 \, \text{MeV}$, $\Gamma = 30 - 110 \, \text{MeV}$
- Phys. Lett. B712, 132 etc…

- **$d(\gamma, K^+ \pi^+) K^- pp$**
- **Unique feature of $\gamma$ beam**
  - direct coupling to $K, K^*$
  - $\rightarrow$ virtual $K, K^*$ beam
  - $J=1$ (spin flip)
Search for the K⁻ pp bound state

No peak structure was observed

Upper Limit
(0.17–0.55), (0.55–1.7) (1.1–2.9) μb at 95% CL for Γ = 20, 60 , 100 MeV
\[ T = \frac{R_{Cu}^\phi / A_{Cu}}{R_C^\phi / A_C} \]

Here, the production rate of \( \phi \) mesons

\[ R_A^\phi = \frac{N_A^\phi}{N_A^{beam} N_A^{nuclei} \eta_A^{att} \eta_A^{geo} BR} \]

\[ \sigma_{\phi N} = \alpha (\text{const.}) \]

\[ \sigma_{\phi N} = \alpha \cdot p_\phi \]

\[ \sigma_{\phi N} = \alpha \cdot p_\phi^2 \]

\( \chi^2 / \text{ndf} = 6.95 / 3 \)  
(\( \chi^2 \) prob. = 7\%)

\( \chi^2 / \text{ndf} = 2.77 / 3 \)  
(\( \chi^2 \) prob. = 43\%)

\( \chi^2 / \text{ndf} = 1.32 / 3 \)  
(\( \chi^2 \) prob. = 72\%)

More Appropriate
Result of the $\Theta^+$ from LEPS

- Data from 2002-03
  - Significance 5.1\(\sigma\)
  - Shape analysis
  - $M(\Theta) =$1524 MeV

- To clarify the existence of $\Theta^+$ ....
  - Higher statistic
  - Blind analysis
  - $\rightarrow$
  - 2006-07, 2.6 times higher statistic experiment
New Result of $\Theta^+$ (blind analysis)

Same cut condition (2002-03) and better calibration in blind analysis

No strong narrow peak structure is not observed. To understand the discrepancy between two result...

-> Exclusive analysis (proton/neutron identification)
Proton detection by using dE/dx in Start Counter

Proton not tagged (Proton rejected)

KKn and part of KKp

Proton tagged (ε ~60%)

KKp only

Signal enhancement is seen in proton rejected events.

→ should be associated with γn reaction.

p/n ratio:
1.6 before proton rejection
0.6 after proton rejection
M(NK\(^{+}\)) for exclusive samples for each data

- 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.
Z-Vertex cut

Proton rejection efficiency becomes large by selecting downstream

Enhance the Neutron event

Clearly observed enhancement $M(nK^+)\ (GeV/c^2)\ $
MC based exclusive analysis

- Important to estimate the proton contribution
- The estimated proton contributions are subtracted from full data sample (without z-vertex and proton tagging cut) using MC.

Unbinned fit for $M(pK^-)$ with MC simulation

$M(pK^-)$

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

$M(pK^+)$

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

$\phi$ and non-resonant KK, $\Lambda(1520)$, $\Lambda(1405)$
An enhancement is seen both in the exclusive analysis.
Mass and significance estimation is underway.
-> New experiment with large SC from this October.
New experiment setup

Start counter ( ~ 2007) 

New Start counter (2012~)
Improvement of proton tagging

Future prospect
LEPS2

BGOEGG EM-calorimeter
(neutral meson detection experiment)

BNL-E949 base detector
Θ+ search, Λ(1405)
Expansion of LEPS experiment
LEPS2 Project at SPring-8

Backward Compton Scattering

Higher intensity:
- Multi (ex. 4) laser injection w/ large aperture beam-line
- & Laser beam shaping
  ~10^7 photons/s (LEPS ~10^6)

High energy: Re-injection of X-ray from undulator
  E_γ < 7.5 GeV (LEPS < 3 GeV)

Better divergence beam
⇒ collimated photon beam
⇒ better tagger resolution
Different focus points for multi CW laser injection

Large acceptance EM calorimeter BGO/EGG.

Large 4π spectrometer based on BNL-E949 detector system.
Physics at LEPS2

- BNL-E949 base detector
  - $\Theta^+, \Lambda(1405)$
  - Expansion of LEPS experiment
- BGOEGG detector
  - $\eta'$ mesic nulei
  - Baryon resonance study with multi meson production
E949 based spectrometer

Under construction! (2014)
LEPS2 laser system

- simultaneous 4-laser injection

- Increase the laser power
  - $8 \text{ W} \rightarrow 16 \text{ W or 24W}$

- Smaller beam size
  - Lower $\sigma_x$: $58 \ \mu\text{m} \rightarrow 14 \ \mu\text{m}$

Multi laser injection system
First beam observation at LEPS3
beam profile is well collimated
consistent with the expectation

Energy spectrum with large BGO crystal (φ 8 cm x L 30cm)
Photon beam intensity ~ 7 MHz (for 0<Eγ<2.4 GeV) @ 3-(355nm) laser
η′(958) and UA(1) anomaly

- The experimental mass of η′ is more than 2 times larger than expected value.
- UA(1) anomaly effect.
- Origin of large η′ mass
- Chiral symmetry breaking
- UA(1) anomaly

Daisuke Jido, Hideko Nagahiro, and Satoru Hiren

No experimental information for UA(1) anomaly effect
Mass modification in finite density

Mass of $\eta'$ is possibly modified under the finite density compared with the vacuum

- $\Delta m_{\eta'} \sim -150\text{MeV} @\rho_0$
- $\Delta m_\eta \sim +20\text{MeV} @\rho_0$

- H. Nagahiro, M Takizawa, S. Hirenzaki
Measurement of $\eta'$ in finite density

- Large mass reduction (150 MeV) of the $\eta'$ meson in the normal nuclear density
- Existence of a bound state with a nucleus ($\eta'$-mesic nuclei)
- If we observe the $\eta'$ bound state, we achieve the information for UA(1) anomaly effect.
η’-mesic nuclei

- Strong attractive force and small absorption
  - Attractive force
  - $U_A(1)$ anomaly effect
  - Absorption
    - $\text{Re}W_0 \sim 7.5-12.5\text{MeV}$ (CB-ELSA)
    - M. Nanova et al., PLB 710, 600 (2012)
- Experimental results
  - $\text{Re} a_{\eta'N} < 0.8\text{fm}$
  - $|a_{\eta'N}| < 0.1\text{fm}$
- Optical potential with Chiral unitary model
  - $\text{Re}V \gg \text{Im}V$ (possible)
  - → more detailed experiment!

Transparency ratio

Search the η’ mesic nuclei using nuclear target.
η’ mesic nuclei in \((\gamma, p)\) reaction

- Lower Recoil momentum of η’ than hadron beam
- Experimental parameters
  - \(E_\gamma\) 1.6~2.9 GeV
  - Target C
- Forward proton detection

Numerical results: \(^{12}\text{C}(\gamma, p)^{11}\text{B}_{\eta',\omega,\eta'}\)

- \(g_D = -12.36/A^5\)
- Quasi-free

\(^{12}\text{C}(\gamma, p)^{11}\text{B}_{\eta',\omega,\eta'}\) missing mass reduction due to the medium effect through anomalous term

Hirenzaki@ELPH 201
**LEPS2 BGOEGG project**

- Egg shape EM detector
- Total volume 264L
- Total weight 1.9t (crystal)
- 2-type PMT
  - H11334 (Metal package)
  - H6524 (head-on type)
- Very fewInsensitive regeon
- Without housing material
- Only reflector 3M-ESR film (200µm)
- Energy resolution
  - 1.3 % for 1GeV e^+
- Position resolution
  - 3mm
Peripheral detectors

- Time of flight counter
- RPC
- Charge identification detector
- Charged particle tracker chambers
- CDC, DC

![Diagram of LEPS2 experiment hatch with BGO EGG, Charge ID, CDC, E949 Solenoid, and RPC labeled.]
Resistive Plate Chamber (RPC)

- Focus on mesic nuclei search
- 12 MeV forward proton momentum resolution
  - 50 psec time resolution at 12 m flight length

32 modules in wall
Charge identification detector

- Place at inside of BGOEGG
- 30 scintillators with overlap.
- Scintillator size
  - $5 \times 26 \times 413$
  - $50\text{um} \times 50\text{um}$
- Multi Pixel Photon Counter (MPPC) readout
  - Effective area $3\text{mm} \times 3\text{mm}$
  - Pixel size $50\text{um} \times 50\text{um}$
Charged particle tracker chambers

- Charged particle positions/angles at forward angle (θ<24°)
- 6 planes (XX'UU'VV')
- 80 sense wires / plane
- Effective area: φ1280mm
- 16 mm square cell

σ = 130 µm

~1.5m
Yield estimation $\eta'$ mesic nuclei by $\eta$ tagging at BGOEGG

- Dominant conversion from $\eta'$
  - $\eta' p \rightarrow \eta p$
  - $\eta \rightarrow \gamma\gamma (39.3\%)$
  - $\eta \rightarrow \pi^0\pi^0\pi^0 \rightarrow 6\gamma (33\%)$

Multi meson production background will be suppressed by $\eta$ tag at BGOEGG!

Expected yield

- $d^2\sigma/dE d\Omega \sim 2\text{nb/sr/MeV}$
- Target $\sim$ Carbon 20mm
- Beam intensity $\sim 2\text{Mcps (Tag. Eff\(\sim 50\%)$}
- Forward proton with RPC(2x4m) $\rightarrow 70000\text{ event / month}$
- With $\eta$ tag at BGOEGG $\rightarrow 2\sim 3000\text{ event / month}$
  ($\eta'N \rightarrow \eta N : 50\% \text{ from bound state}$)
η’ meson production

Geant4 simulation

- 44.3% η’ → π⁺π⁻η
- 29.5% η’ → ργ
- 20.9% η’ → π⁰π⁰η→6γ
- 2.1% η’ → γγ

@ proton target (40mm)

η’ mass resolution

~2.8%

1,1000 η’ event @ LEPS2 per 1-month
First experiment in 2013
Summary

**LEPS** project are collaborating toward next generation experiments **LEPS2** at SPring-8 with RIKEN and KEK.

**LEPS**
- $K^*\Sigma^+$ photoproduction with evidence for $\kappa$ meson exchange. (PRL108,092001)
- $\Lambda(1520)$ mass spectrum shape shows different in each charge mode.
- KNN bound state search (will be publish soon [PLB, arXiv.1306.5320])
- The $\Theta^+$ is studied via $\gamma d \to K^+K^\pi n$ 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 $\sim 2\sigma$ by shape analysis.
  - The exclusive analysis

**LEPS2**
- SPring-8 LEPS2 facility just started
- LEPS2 has one order of magnitude higher intensity beam and large acceptance coverage.
  - BGOEGG, E949 based detectors.
- BGOEGG calorimeter experiments started in this winter.
  - $\eta'$ mesic nuclei, baryon resonance, etc
- Thanks!

2012/10/18  CJJNPS2012

Thanks!