ペンタクォーク探索実験 J-PARC E19: 2nd Run Result (3)

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for the J-PARC E19 collaboration

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日本物理学会2013年秋季大会@高知大学
2013/09/20
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   – On \( \Xi^+ \) decay width

4. Summary
# History of E19

<table>
<thead>
<tr>
<th>Comment</th>
<th>Beam Momentum</th>
<th>Beam intensity</th>
<th>π’s on Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009/10 ~ K1.8 beam line &amp; detector commissioning start</td>
<td></td>
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</tr>
<tr>
<td>2010/10-11 1st RUN examine the 2.6σ bump structure observed in E522</td>
<td>1.92 GeV/c</td>
<td>1.0 M /spill</td>
<td>7.8 x 10^{10}</td>
</tr>
<tr>
<td>2012/02 2nd RUN new data at the highest beam momentum at K1.8</td>
<td>2.00 GeV/c</td>
<td>1.7 M /spill</td>
<td>8.7 x 10^{10}</td>
</tr>
</tbody>
</table>
Aim of the 2nd run

- s-channel dominance
- $\Gamma_\Theta \propto g_{K N \Theta}^2 \propto \sigma$

- Higher beam momentum provides higher sensitivity.

- 2.0 GeV/c
  - (= Max. of K1.8 B.L.)
  - Even if no peak, stronger constraint on the $\Theta^+$ decay width will be obtained.

Theoretical calculations:
T. Hyodo et al., PRC 72, 055202 (2005), PTP 128, 523 (2012).
Result from the 2nd run
Missing Mass of $\Xi^+$ run

$\pi^- + p \rightarrow K^- + X \; @ \; p_\pi = 2.00 \text{ GeV/c}$

Yes, no peak structure was observed in $\Xi^+$ run.

E19-2\textsuperscript{nd} Preliminary

Counts / 1.0 MeV/c\textsuperscript{2}
Comparison with BG simulation

BG processes
① \( \pi^- p \rightarrow \phi n \rightarrow K^- K^+ n \)
② \( \pi^- p \rightarrow \Lambda(1520) K^0 \rightarrow K^- K^0 p \)
③ \( \pi^- p \rightarrow K^- K^+ n \) (nonresonant)
④ \( \pi^- p \rightarrow K^- K^0 p \) (nonresonant)

Cross sections and angular distributions are referred from precedent exp.
Scale was normalized to exp. data.

O.I. Dahl et al., PR 163, 1377 (1967)
H. Courant et al., PRD 16, 1 (1977)

Data can be reproduced by BG simulation.
BG distribution has no structure in \( \Theta^+ \) sensitive region: 1.50—1.56 GeV.
[Note] This BG shape is not used in estimation of upper limit because of large uncertainty of the referred data.
Upper limit for \( \Theta^+ \) production cross section

An example of fitting result @ 1.535 GeV/c²

- **Signal:** Gaussian with fixed width of 1.74 MeV
- **B.G.:** 3rd order polynomial

**Fitting results of each mass**

Upper Limit (90% C.L.)

- \( \chi^2 / \text{ndf} = 72.7 / 65 \)
- \( M = 1.535 \text{ GeV/c}^2 \) (fixed)
- \( \Gamma = 1.74 \text{ MeV/c}^2 \) (fixed)
- Area = 0.177 ± 0.077 \( \mu \text{b/sr} \)

- Upper limit for differential cross section averaged from 2 to 15 deg:
  - \( < 0.28 \mu \text{b/sr} @ 1.50 - 1.56 \text{ GeV/c}^2 \)

**Cf.)** E19-1st: \( < 0.26 \mu \text{b/sr} @ 1.51 - 1.55 \text{ GeV/c}^2 \)

- Difference comes mainly from evaluated M.M.Resol. (1.44 → 1.74 MeV)
Upper limit for $\Theta^+$ decay width

We can obtain U.L. of decay width, in the same way of the 1$^{st}$ run.

\[ \Gamma_\Theta \propto g_{KNO}^2 \propto \sigma \]

- 0.61 MeV for $\frac{1}{2}^+$
- 3.7 MeV for $\frac{1}{2}^-$

Cf.) E19-1st: 0.72 MeV for $\frac{1}{2}^+$, 3.1 MeV for $\frac{1}{2}^-$
- For $\frac{1}{2}^+$ case, U.L. was improved because of larger cross section of theor. calc.
- For $\frac{1}{2}^-$ case, U.L. was not updated since cross section become smaller.

T. Hyodo et al., PTP 128, 523 (2012).
Discussion on $\Xi^+$ decay width
Combined Analysis of 1\textsuperscript{st} and 2\textsuperscript{nd} run

- Now, we obtained results at 2 kinds of initial momentum: 1.92 and 2.00 GeV/c.
- We performed a combined analysis based on the theoretical calculation, considering about these momentum dependence.
Theoretical calculation of meson-induced $\Theta^+$ production

- Effective Lagrangian approach
- Less ambiguous than photoproduction

✓ Theoretical uncertainty
  - Coupling scheme: PS/PV
  - Form factor: static/covariant
  - Form factor cutoff value was determined by hyperon prod.
  - $\Theta^+$ mass dependence was considered; $1.510—1.550$ GeV

There are some ambiguity,
But we took all variations into account and adopted the “most conservative” case.
This is confident for “upper limit estimation”.

T. Hyodo et al., PTP 128, 523 (2012).
An example of combined fitting

Simultaneous Fit of 1st and 2nd data:
- $\sigma$ is proportional to $\Gamma_\Theta$ at each momentum.
- $\Gamma_\Theta$ is an unique parameter (except for coefficients of pol.).
Upper limit on decay width

Results of combined fitting

\[ J^P = \frac{1}{2}^+ \]

<table>
<thead>
<tr>
<th>Decay Width [MeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
</tr>
<tr>
<td>0.3</td>
</tr>
<tr>
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</tr>
<tr>
<td>0.1</td>
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<tr>
<td>-0.1</td>
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<tr>
<td>-0.2</td>
</tr>
<tr>
<td>-0.3</td>
</tr>
<tr>
<td>-0.4</td>
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</tbody>
</table>

\[ J^P = \frac{1}{2}^- \]

<table>
<thead>
<tr>
<th>Decay Width [MeV]</th>
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<tbody>
<tr>
<td>1.5</td>
</tr>
<tr>
<td>1.0</td>
</tr>
<tr>
<td>0.5</td>
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<td>-0.5</td>
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<tr>
<td>-1.0</td>
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<td>-1.5</td>
</tr>
</tbody>
</table>

Upper Limit (90% C.L.)

- In mass region 1.51—1.55 GeV/c^2
  - Upper limit on \( \Gamma_\Theta \)

- 0.39 MeV for \( \frac{1}{2}^+ \)
- 1.7 MeV for \( \frac{1}{2}^- \)

[Note]:
This limit is very conservative estimation.
Discussion (for ½+) comparison with other experiment

✓ Our U.L. overcame the U.L. from Belle ($\Gamma_\Theta < 0.64$ MeV).

For LEPS region, $\Gamma < 0.22$ MeV.

LEPS:
$M = 1524 \pm 2 \pm 3$ MeV

For DIANA region, Our U.L. is comparable to their width.

DIANA:
$M = 1538 \pm 2$ MeV
$\Gamma = 0.36 \pm 0.11$ MeV
arXiv:1307.1653

U.L. in mass region of 1.51--1.55 GeV, $\rightarrow \Gamma_\Theta < 0.39$ MeV

R.Mizuk et al., PLB 632, 173 (2006)
Summary

- E19 2nd run result was presented.
  - No peak structure was observed in MM spectrum.
  - Upper limit for $\Omega^+$ production cross section was obtained to be $0.28\, \mu b/sr$ @ $1.50 - 1.56$ GeV/c$^2$.
  - Upper limit on $\Omega^+$ decay width was derived to be $0.61 (3.7)$ MeV for $\frac{1}{2}^+$ ($\frac{1}{2}^-$).

- Combined analysis of 1$^{\text{st}}$ and 2$^{\text{nd}}$ run was also reported.
  - Based on the theoretical calculation, (conservative) upper limit on $\Gamma_{\Omega}$ was estimated to be $0.39 (1.7)$ MeV for $\frac{1}{2}^+$ ($\frac{1}{2}^-$).