Status of the Θ^+ experiments at LEPS

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PRC paper status

- 2008.12.08 Submitted to PRC
- 2008.01.10 Comments from Referee
- 2008.02.03 Resubmitted to PRC
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3 main comments by the referee:

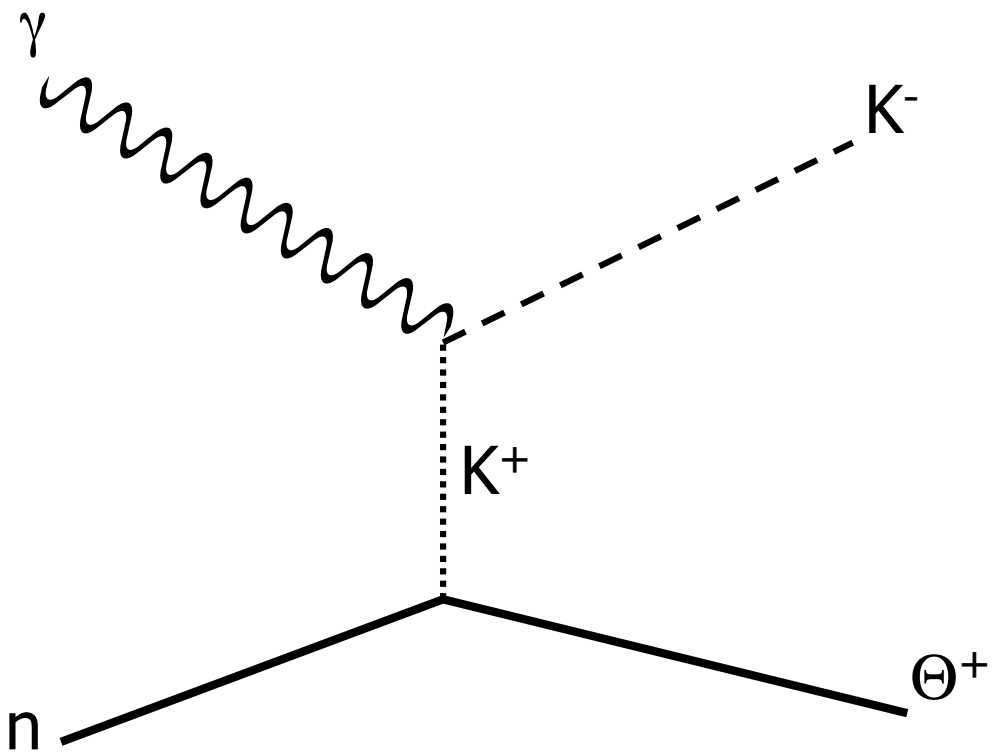
1. Change the title of the paper.
2. Give the cross section for $\Lambda(1520)$ production.
3. Restate the comments on CLAS-g10 experiment.

Preprint (arXiv:0812.1035[nucl-ex]) is available on WEB.

Experimental status

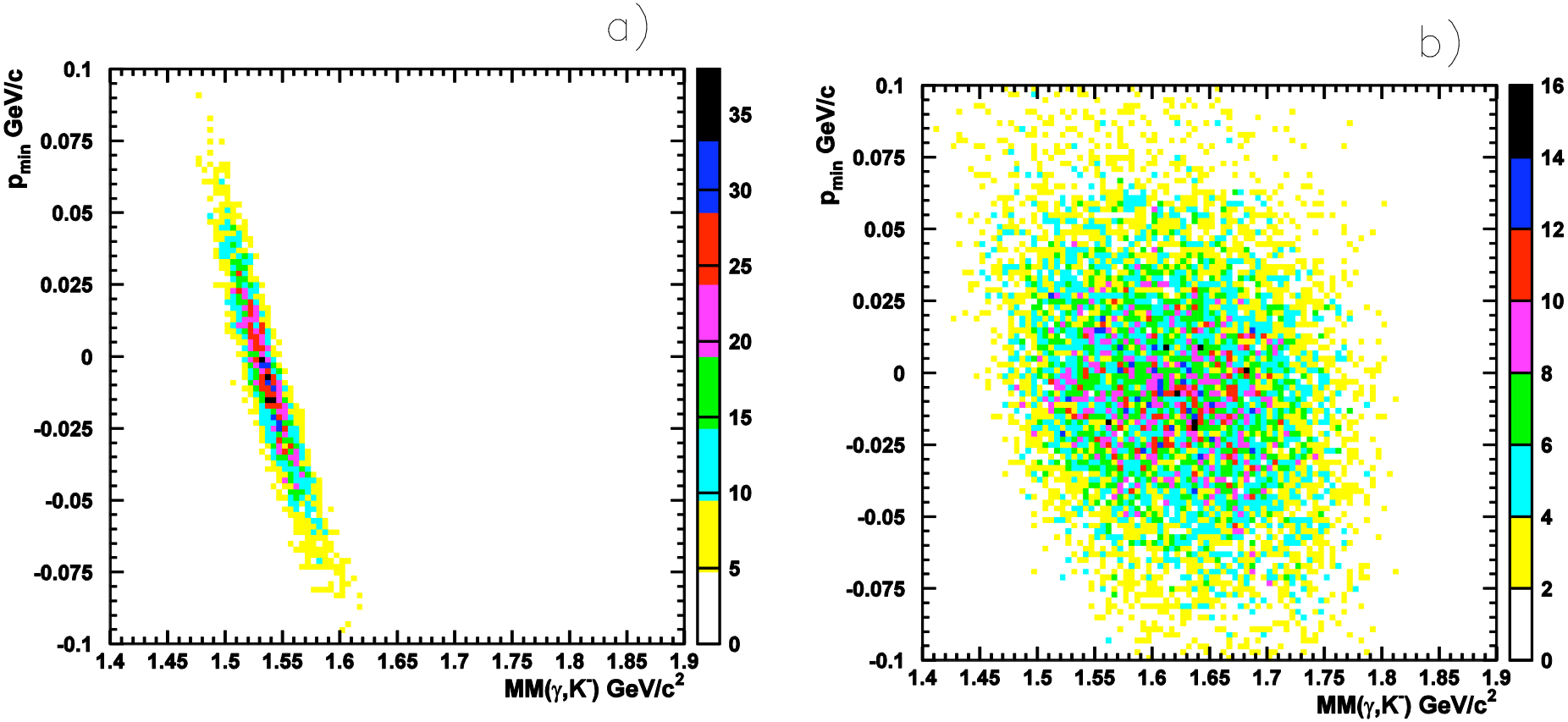
- Not seen in the most of the high energy experiments: The production rate of $\Theta^+/\Lambda(1520)$ is less than 1%.
  - Production rate depends on reaction mechanism.
- No signal observation in CLAS γp, KEK-PS (π^-,K^-), (K^+,π^+) experiments.
  - K* coupling should be VERY small.
- The width must be less than 1 MeV. (DIANA and KEK-B) reverse reaction of the Θ^+ decay: $\Theta^+ \rightarrow n\ K^+$
  - K coupling should be small.
- LEPS could be inconsistent with CLAS γd experiment (CLAS-g10).
  - Strong angle or energy dependence.

The reaction studied at LEPS



We correct and make use of Fermi motion of a neutron.

What characterize the signal and background?

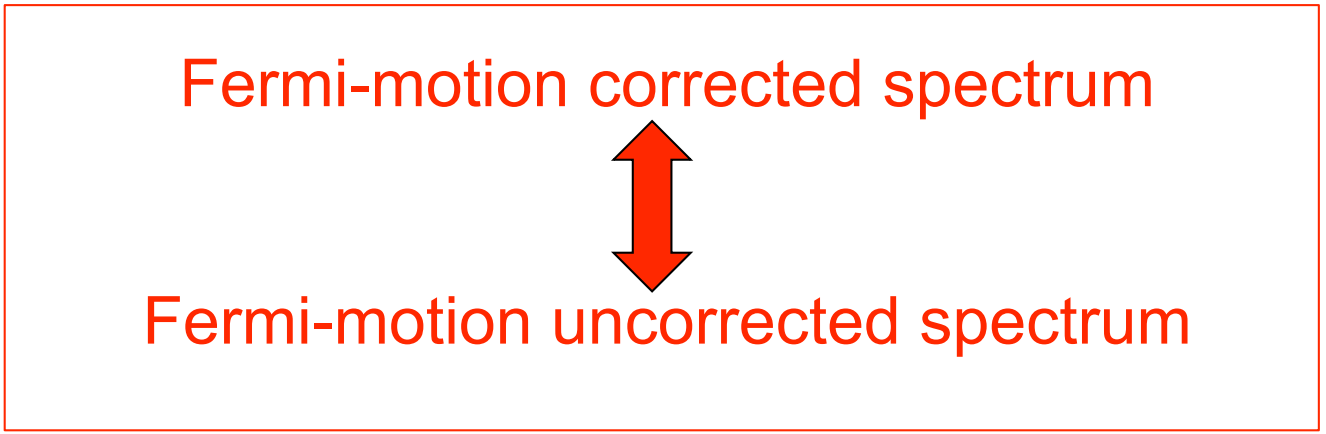


p_{min} for background events are almost determined by Fermi motion (deuteron wave function).

Effect of Fermi motion correction

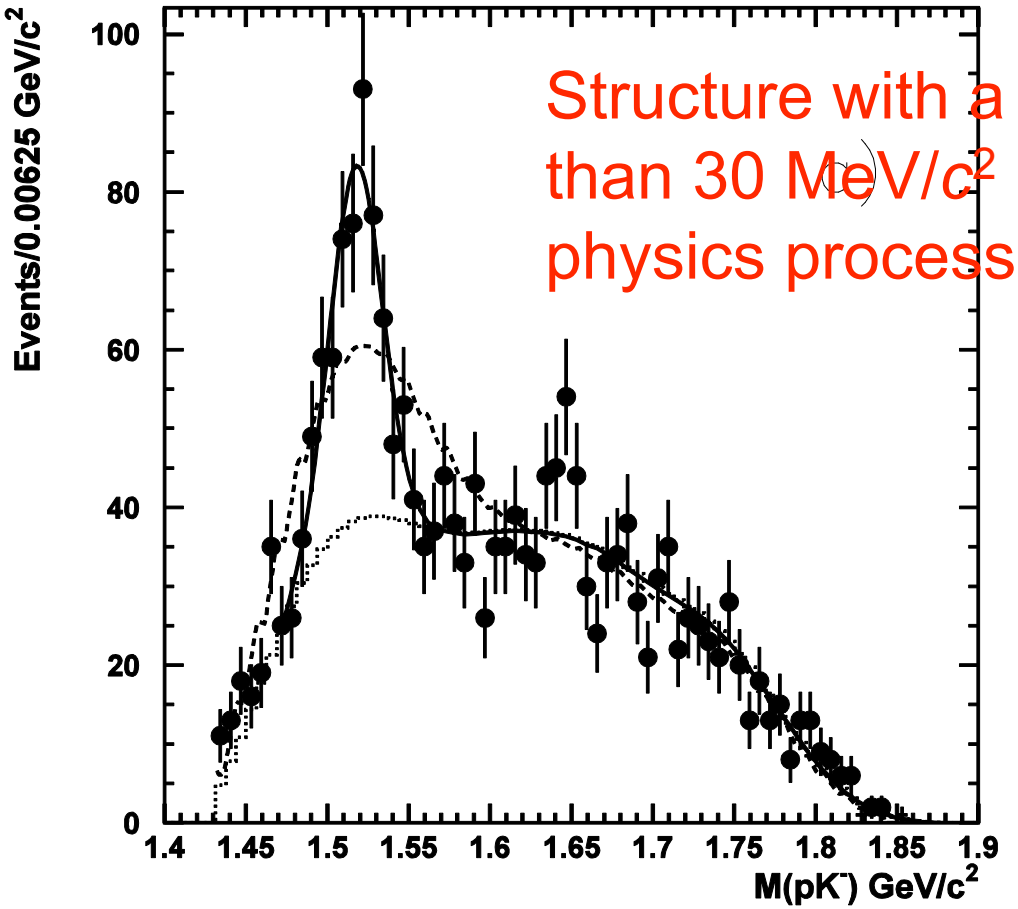
Signal: Restoration of narrow peak
Background: Shift and smearing

RMM for background spectrum:



Results of Λ(1520) analysis

Σ⁺ pK⁻ invariant mass with MMSA: Fermi motion effect corrected.



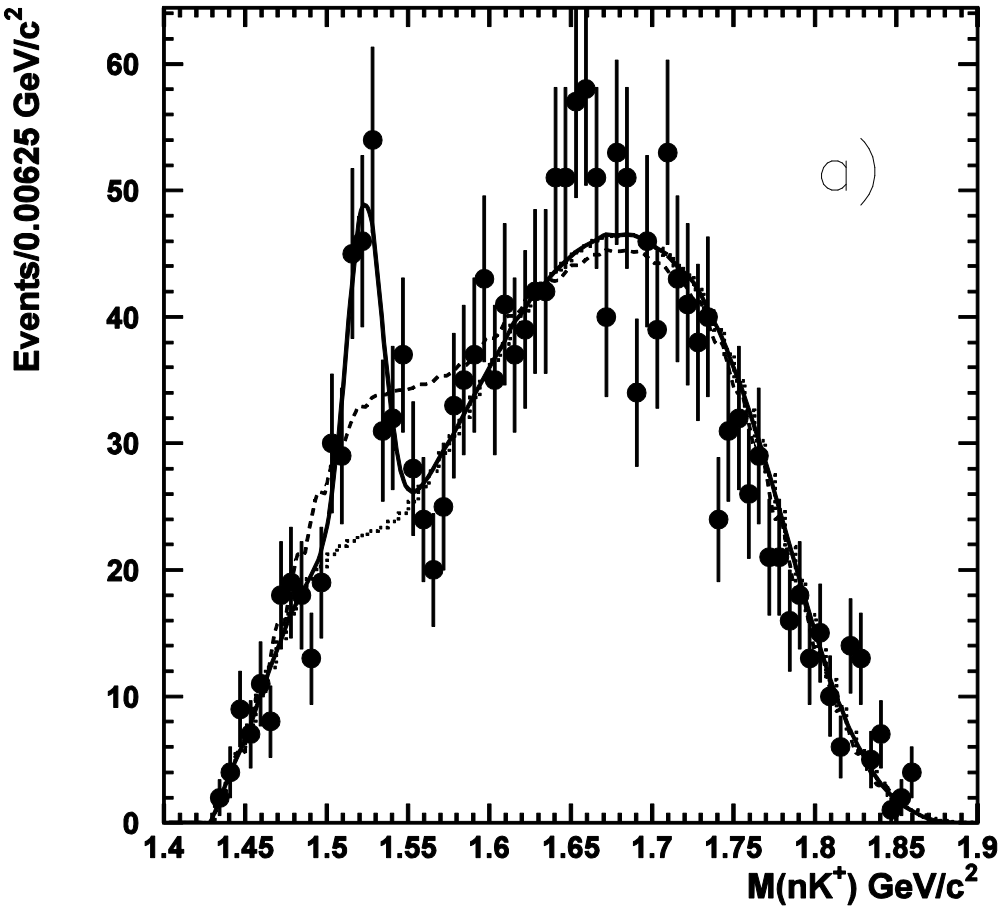
Structure with a width less than 30 MeV/c^2 requires a physics process or fluctuation.

$\Delta(-2\ln L) = 55.1$ for $\Delta ndf = 2$ $\longrightarrow$ 7.1σ

$$\mathrm{Prob}(7.1\sigma) = 1.2\times10^{-10}$$

Results of Θ^+ analysis

nK^+ invariant mass with MMSA: Fermi motion effect corrected.



$\Delta(-2\ln L) = 31.1$ for $\Delta ndf = 2 \longrightarrow 5.2\sigma$

$$\mathrm{Prob}(5.2\sigma) = 2\times10^{-7}$$

Summary of Θ^+ analysis

Peak position: 1.527 ± 0.002 GeV/c^2

Signal yeild: 116 ± 21 events

Differential cross-section: 12 ± 2 nb/sr

$\Theta^+ / \Lambda(1520)$ ratio: 0.16

Statistical significance: 5.1 σ

"The narrow peak appears only after Fermi motion correction."

Difference between LEPS and CLAS for $\gamma n \rightarrow K^- \Theta^+$ study

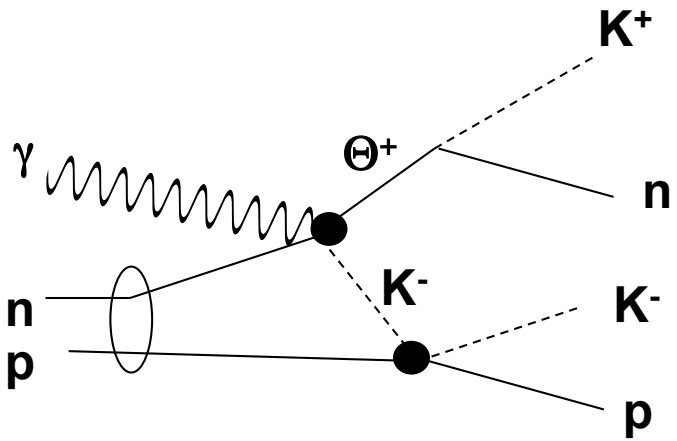
LEPS		CLAS
Good forward angle coverage	⟷	Poor forward angle coverage
Poor wide angle coverage	⟷	Good wide angle coverage
Low energy	⟷	Medium energy
Symmetric acceptance for K^+ and K^-	⟷	Asymmetric acceptance
$M_{KK} \gtrsim 1.04$ GeV/c^2	⟷	$M_{KK} > 1.07$ GeV/c^2
Select quasi-free process	⟷	Require re-scattering or large Fermi momentum of a spectator

LEPS: $\theta_{LAB} < 20$ degree $\quad |t| < 0.6$ GeV^2

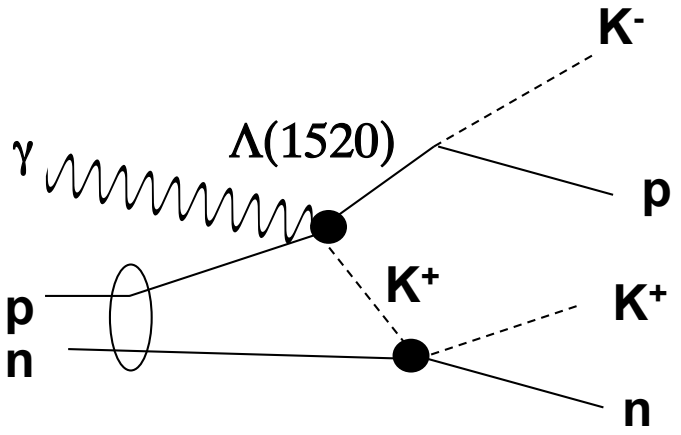
CLAS: $\theta_{LAB} > 20$ degree

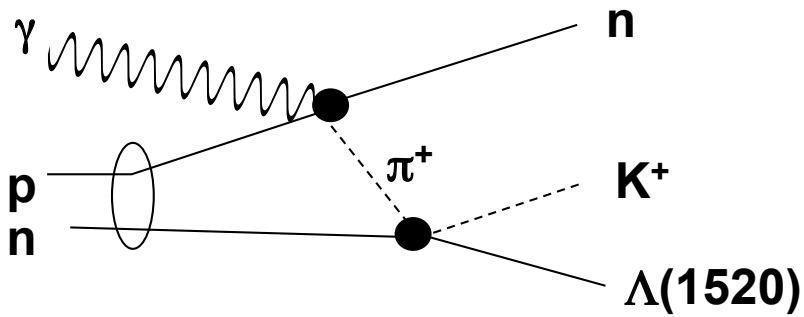
Θ^+ might be a soft object.

The reaction studied at CLAS



Re-scattering is necessary for all charged particles to be detected.



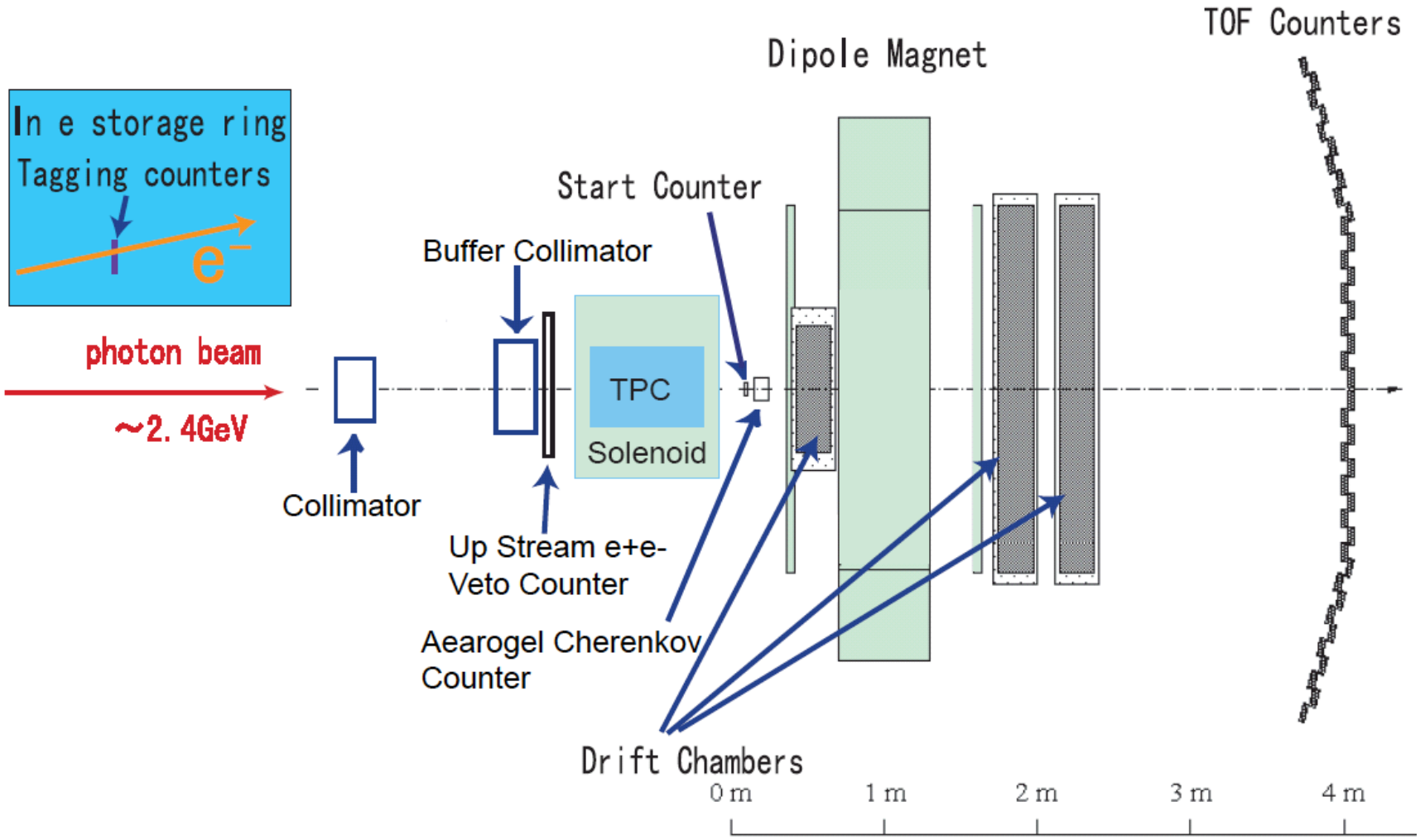


+ many others

Revised comment on CLAS-g10

There is a contradiction between the upper limit given by CLAS and the differential cross-section given here. However, there are differences between the CLAS and the LEPS measurements. For the CLAS measurement, some rescattering processes are required to give enough momentum to the spectator proton to be detected by the CLAS detector, where the rescattering probability was modeled by empirical data for the mirror reaction of $\Lambda(1520)$ production. The estimated probability was claimed to be conservative since the $K^+ n$ cross-section is smaller than that for $K^- p$. But the rescattering for the both cases could be dominated by baryon-baryon scattering (leaving the K angle largely unaffected). Therefore, if the Θ^+ is mainly produced at forward angles, it is possible that the CLAS would not see the K^- associated with Θ^+ production because the most forward angle for K^- detection is about 20 degrees for the CLAS measurement, whereas most of the LEPS acceptance is forward of 20 degrees. This speculation offers one of the possible scenarios to resolve the seeming contradiction. In the near future, the LEPS will have data with a larger acceptance analyzed, using a time-projection chamber for large angles to provide the Θ^+ angular distribution.

Setup of TPC experiment



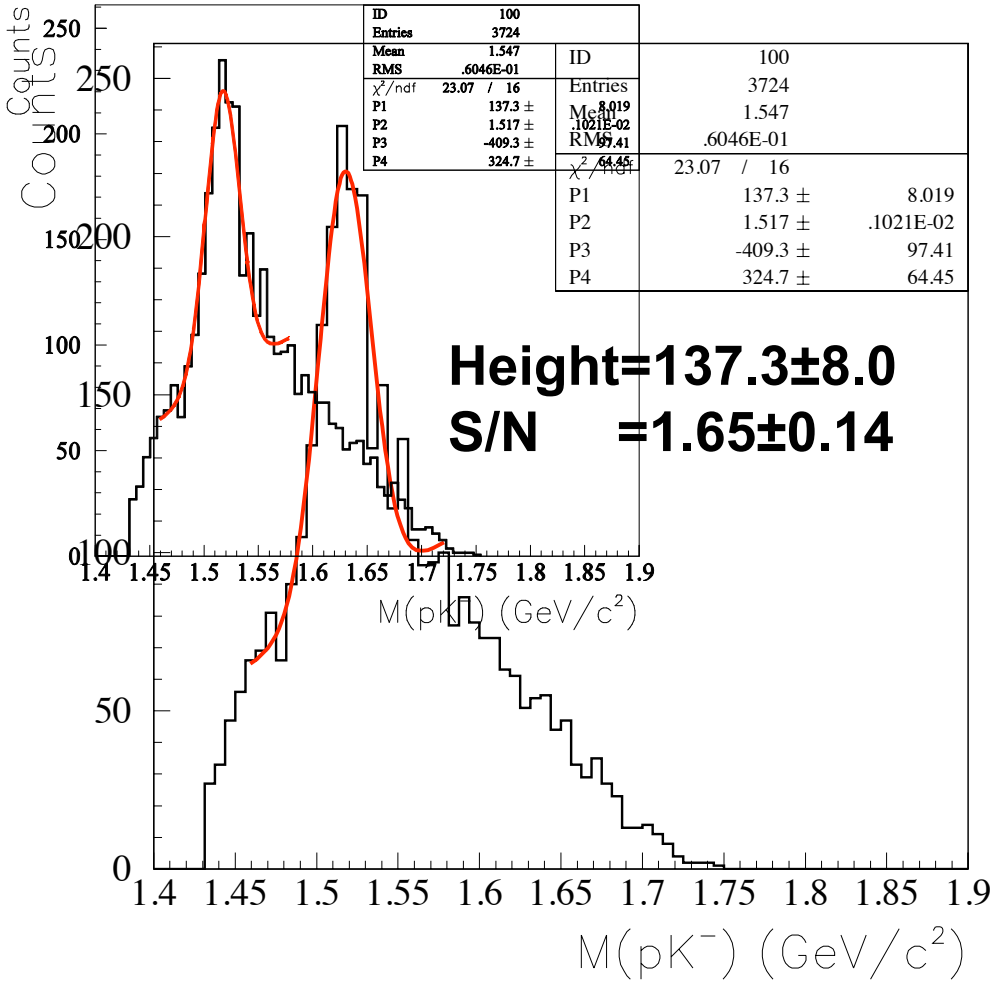
Experiment with a new TPC and a new LH2/LD2 target was started in January, 2008.

Next step

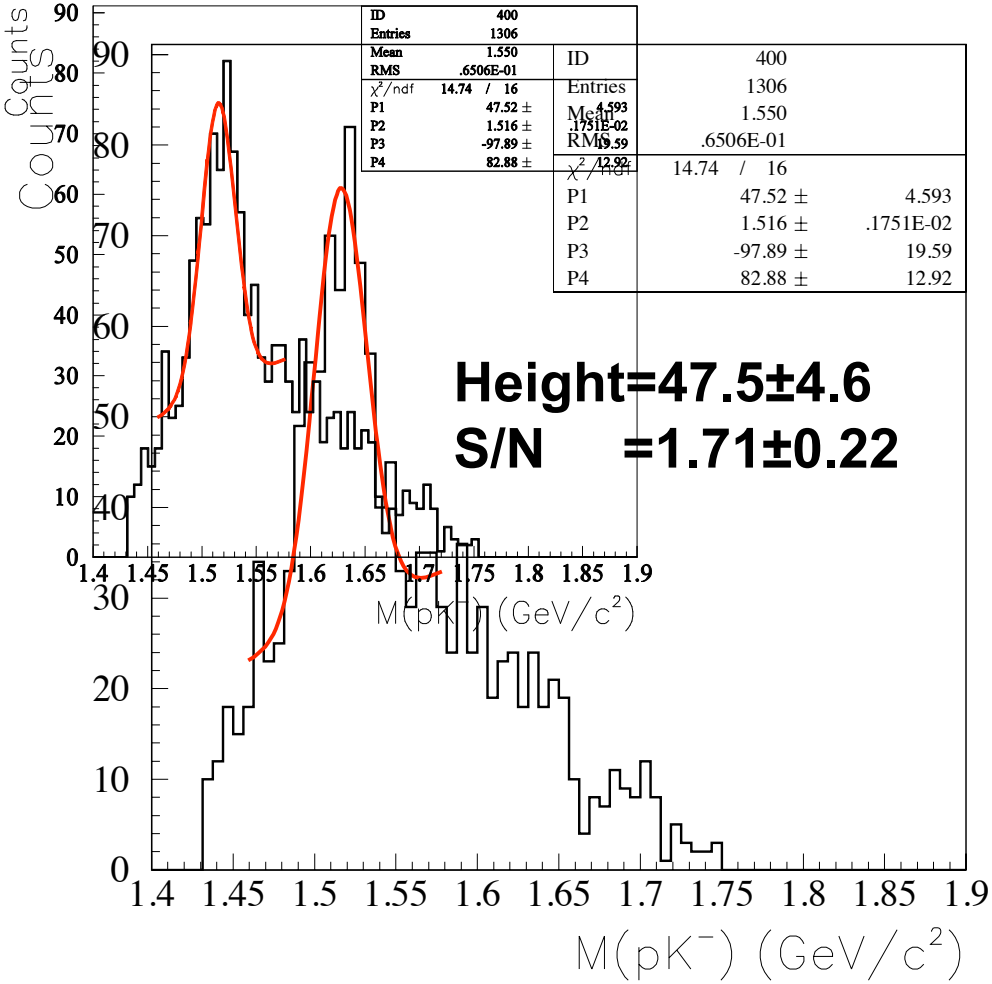
The remaining thing to check is possible bias in the analysis.
High statistics data (~3 times) was collected in 2006-2007 with the same experimental setup.
Blind analysis is under way to check the Θ^+ peak

Λ(1520) peak for LD2 data

2006-2007 data



2002-2003 data



Fitting was carried out with fixed width(16MeV/c^2)

Ratio of height = 2.89±0.32 ← consistent with the luminosities

Θ^+ search experiment at J-PARC

- Reverse reaction of the Θ^+ decay using a low energy K^+ beam gives an unambiguous answer.

$$K^+n \rightarrow \Theta^+ \rightarrow K_S^0 p$$

- Cross-section depends on only the spin and the decay width.

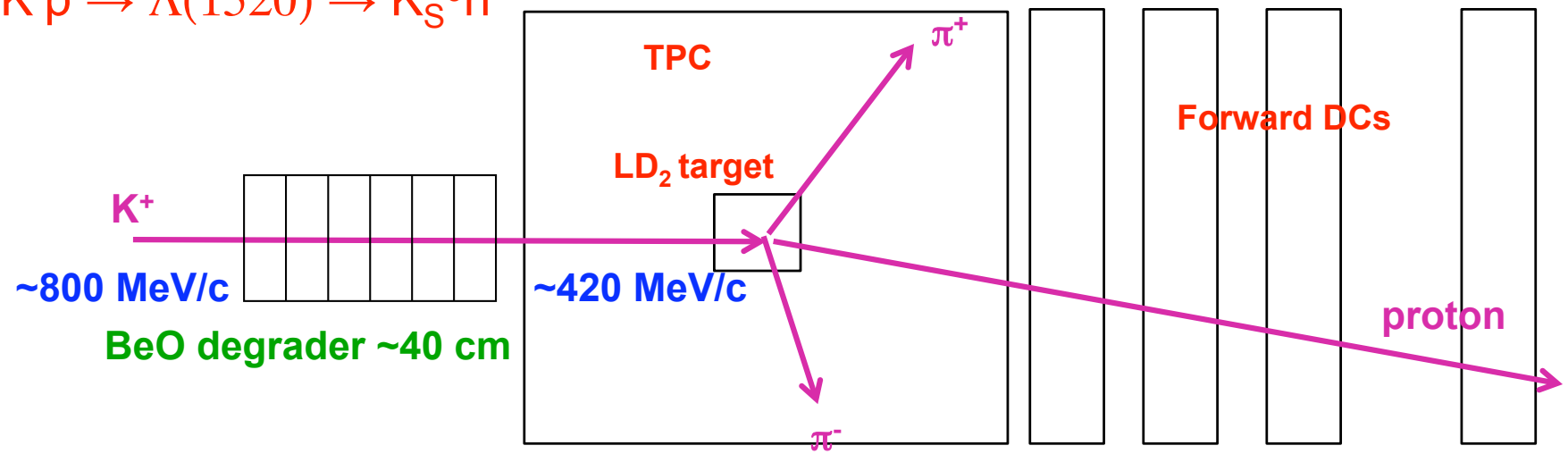
for J = ½

$$\sigma = \frac{\pi}{8k^2}(2J+1)\int \frac{\Gamma^2}{(E-M)^2+\Gamma^2/4}dE \Rightarrow 26.4\ \Gamma\ \text{mb/MeV}$$

CEX ($K^+n \rightarrow K_S^0 p$) ~7 mb

Bi-product

$K^-p \rightarrow \Lambda(1520) \rightarrow K_S^0 n$



Summary and prospects

1. The positive result from 2002-2003 data analysis is accepted for publication on PRC.
2. New data set with 3 times more statistics has been already taken.
3. Blind analysis is in under way out to check the peak (in this year).
4. If the peak is confirmed, a new experiment with a Time Projection Chamber has been carried out since Jan 2008. → wider angle coverage and Θ^+ reconstruction in pK_s decay mode.
5. If the peak is confirmed, the study will be expanded at LEPS2. We will also submit a proposal to do a complete search for Θ^+ by using a low energy K^+ beam at J-PARC.