Pentaquark Θ^+ search experiment at J-PARC

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for the J-PARC E19 collaboration

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J-PARC E19 Collaboration

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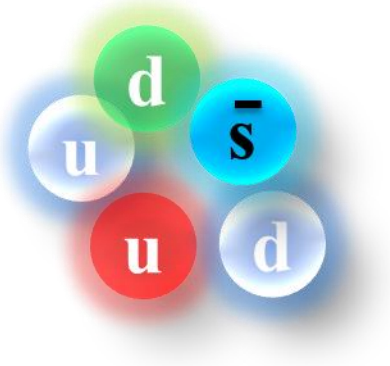
Pentaquark search

Pentaquark Θ^+



- Genuine exotic hadron (*uudd*s^{bar})
- M = ~1540 MeV/c^2 (decay $\Theta^+ \rightarrow$ KN)

Historical background

- Θ^+ pentaquark was first predicted by Diakonov et al. in 1997.
- SPring8/LEPS group reported the evidence for Θ^+ in 2003.
- Dozen experimental groups published supporting evidence for the Θ^+,
- followed by a number of experiments with no evidence.

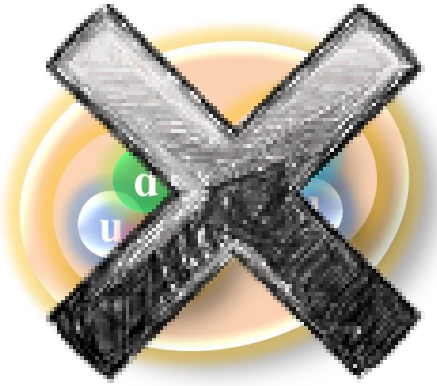
Situation is still controversial ...

Physics Motivation

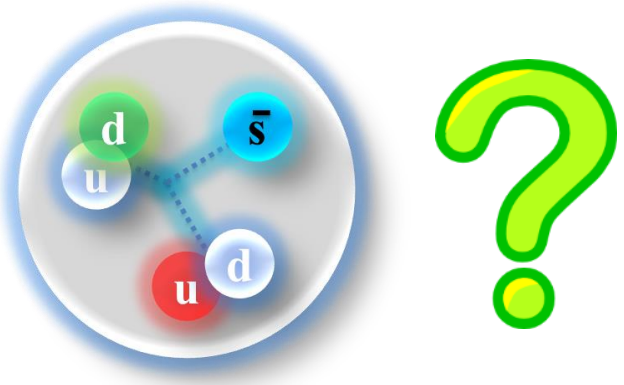
- **Distinctive feature of Θ^+ pentaquark**

Narrow Width **(< a few MeV)**

  - **Need some mechanism to suppress decay.**



Meson-Baryon molecule



Diquark structure
(Need quark rearrangement for KN decay)
R.Jaffe, F.Wilczek (2003)

Useful tool to understand low energy QCD dynamics !!

Our Approach (J-PARC E19)

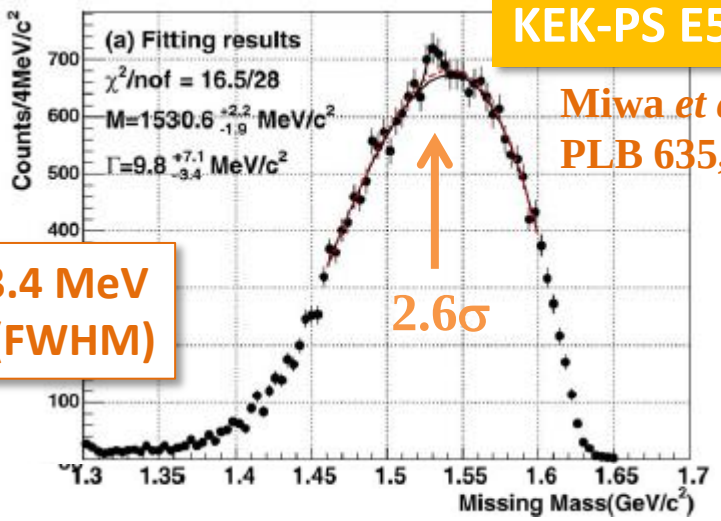
1. **Pion induced reaction** $\pi^- + p \rightarrow K^- + \Theta^+$
   - Complementary to photo-production (LEPS/CLAS).
   - Expect sizable production cross section. => High statistics

2. **High resolution missing ma**
   - K1.8 beam line & SKS = ΔM <

Previous experiment

KEK-PS E522

Miwa *et al.*, PLB 635, 72.

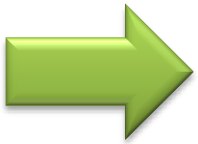


ΔM ~ 13.4 MeV (FWHM)

Our Approach (J-PARC E19)

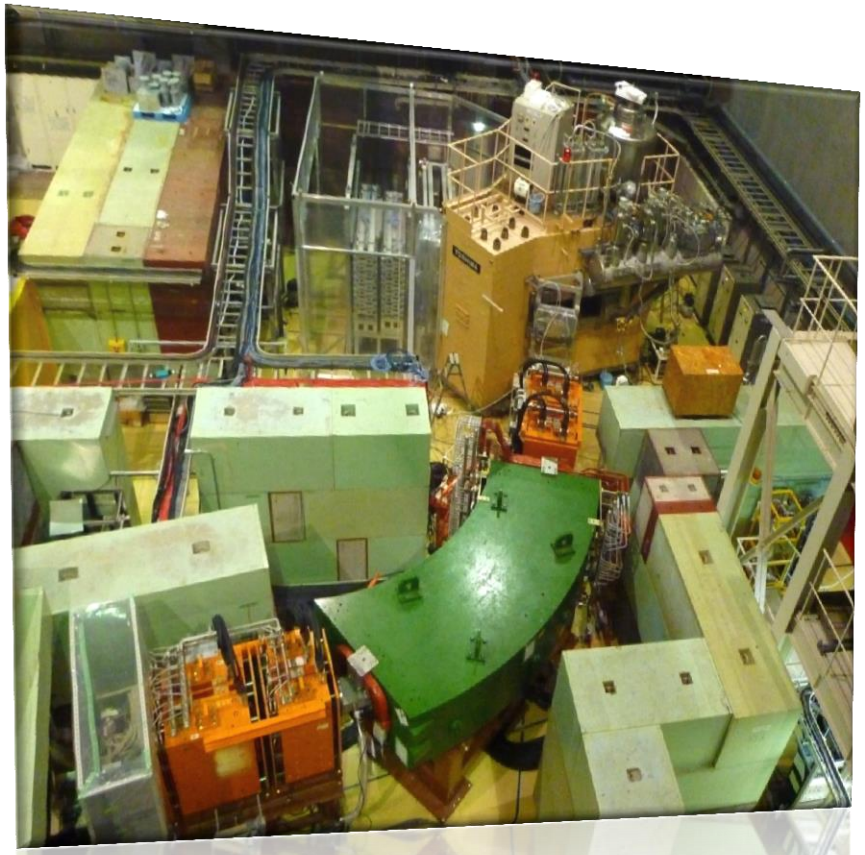
1. **Pion induced reaction** $\pi^- + p \rightarrow K^- + \Theta^+$
   - Complementary to photo-production (LEPS/CLAS).
   - Expect sizable production cross section. => High statistics

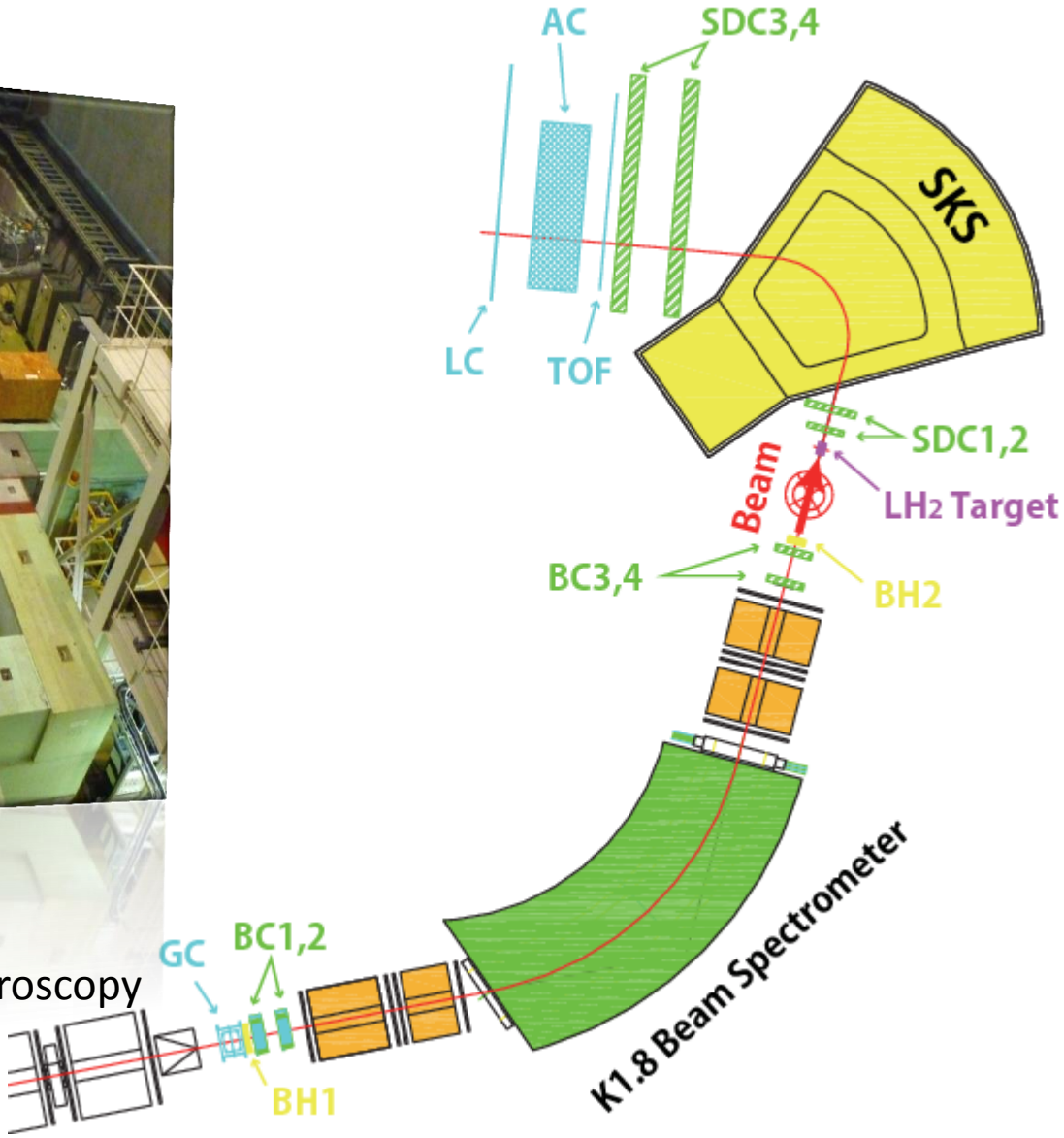
2. **High resolution missing mass spectroscopy**
   - K1.8 beam line & SKS = $\Delta M < 2$ MeV (FWHM)



Conclusive result by higher sensitivity !!

Experimental setup





J-PARC K1.8

Dedicated to the (π,K) reaction spectroscopy

π^- beam
1.92/2.00 GeV/c

History of E19

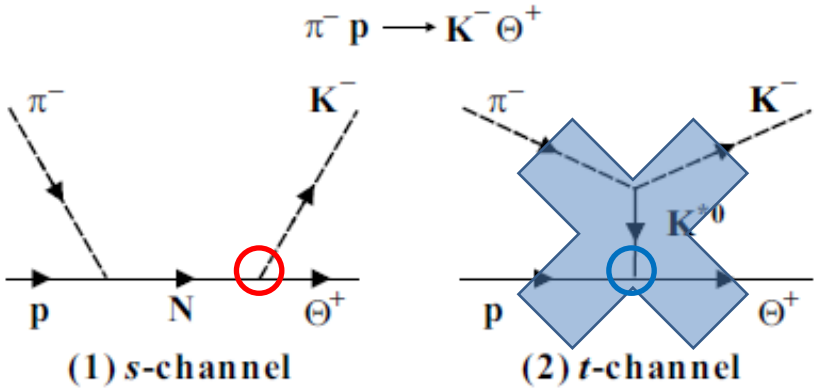
	Comment	Beam Momentum	Beam intensity	π's on Target
2009/10 ~	K1.8 beam line & detector commissioning start			
2010/10-11 **1st RUN**	examine the 2.6σ bump structure observed in E522	1.92 GeV/c	1.0 M /spill	7.8×10^{10}
2012/02 **2nd RUN**	new data at the highest beam momentum at K1.8	2.00 GeV/c	1.7 M /spill	8.7×10^{10}

This presentation

Shirotori et al., PRL 109, 132002 (2012).

- Θ^+ Peak was not observed.
- We concluded that E522 bump was not the signal by 10 times higher sensitivity.

Note on Θ^+ decay width



✓ **s-channel dominance**

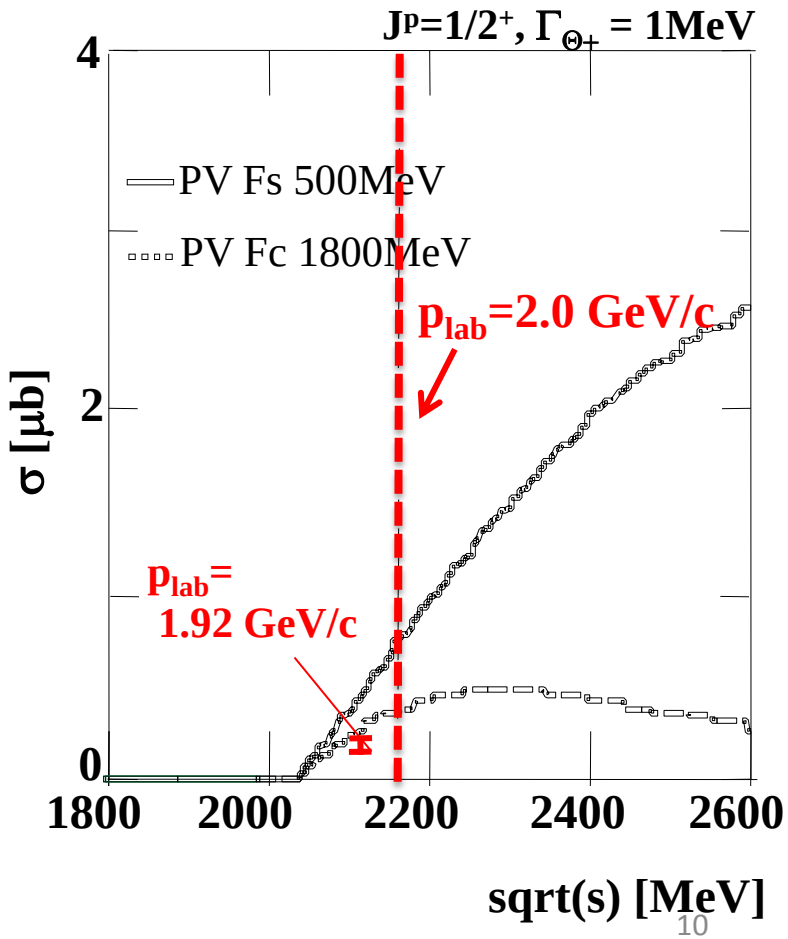
➢ $\Gamma_\Theta \propto g^2_{KN\Theta} \propto \sigma$

- **Higher beam momentum provides higher sensitivity.**

➢ **2.0 GeV/c**
(= Max. of K1.8 B.L.)

✓ **Even if no peak, stronger constraint on the Θ^+ decay width will be obtained.**

Theoretical calculations :
T. Hyodo et al., PRC 72, 055202 (2005),
PTP 128, 523 (2012).



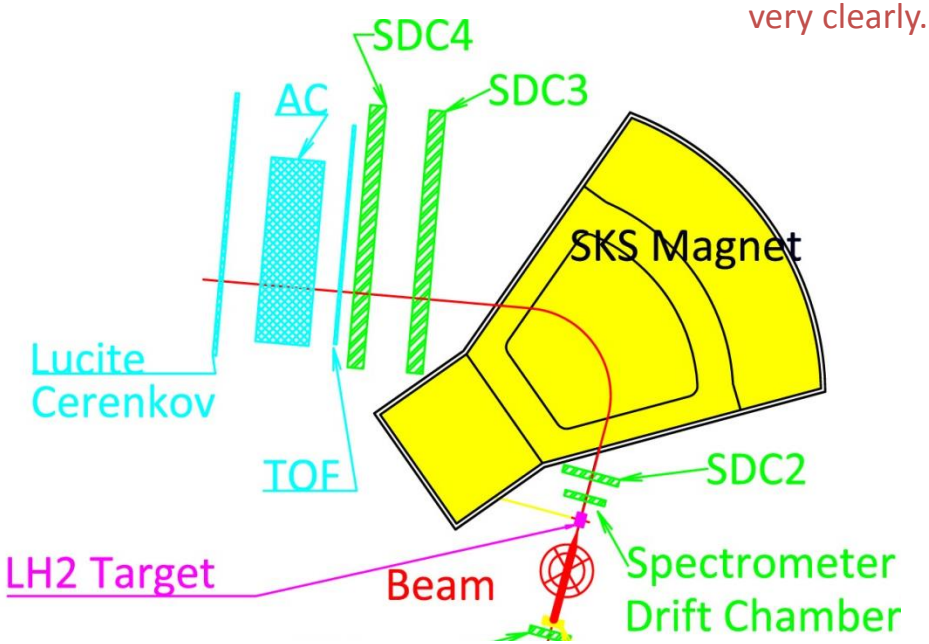
Result of the E19-2nd run

SKS spectrometer

- **SKS system : p_K**

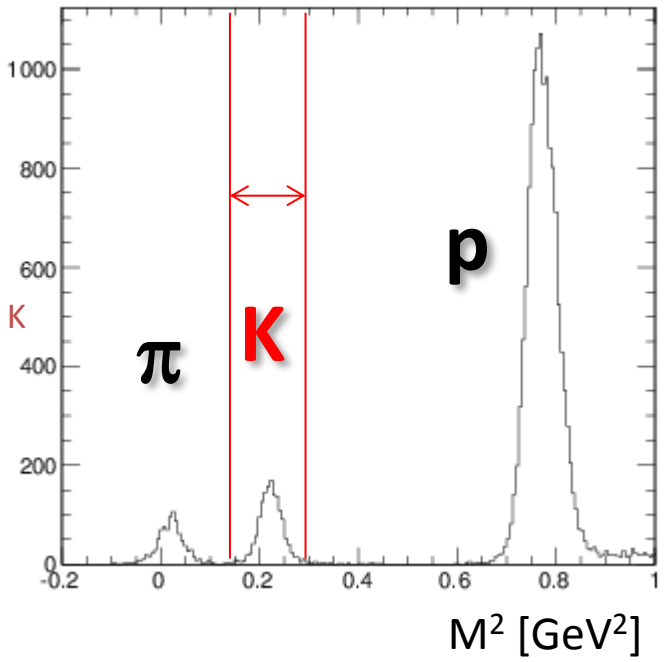
  PID counters
  - Timing counter
  - Aerogel Cherenkov (K/π) : n=1.05
  - Lucite Cherenkov (K/p) : n=1.49

  Tracking
  - MWDCs : 3 mm pitch
  - DCs : 10 mm pitch, 2m × 1m size



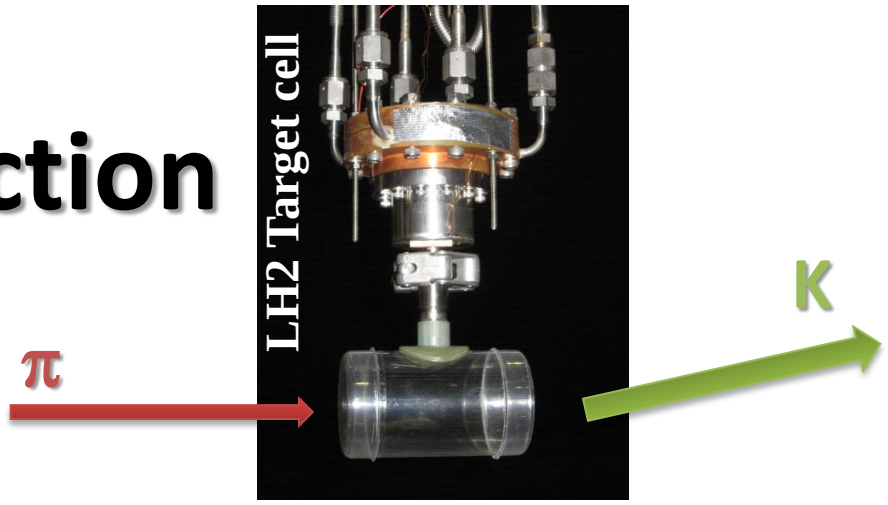
We can separate only K very clearly.

Scattered particle M^2



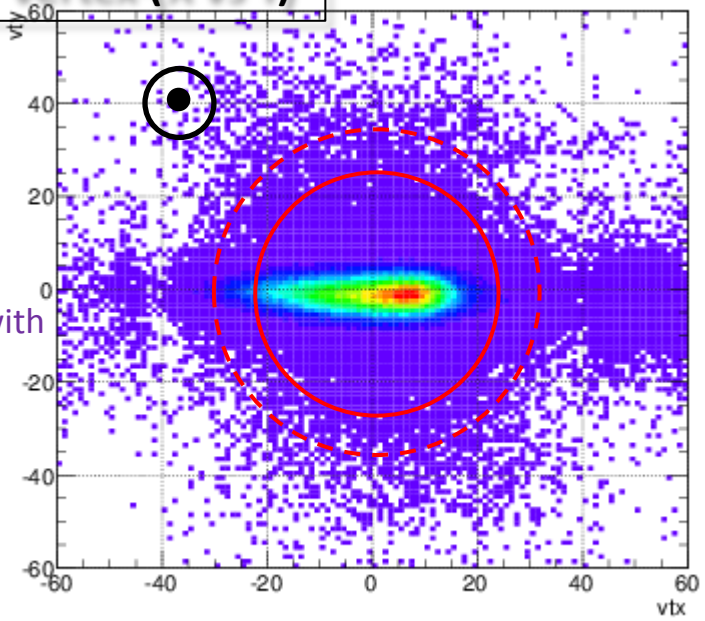
Good momentum reconstruction and PID !!

Vertex Reconstruction



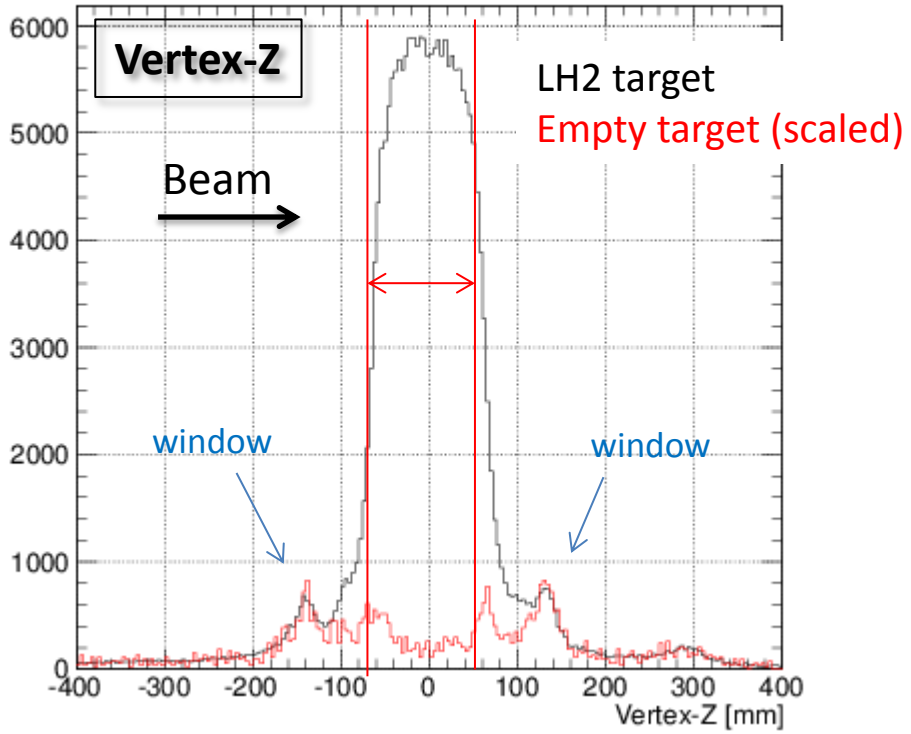
$\phi 67.8 \times 120$ mm

Vertex-(X vs Y)



Consistent with horizontally oblate beam shape.

Vertex-Z



Target cell is clearly identified !!

Consistency check with previous exp.

- ✓ $\pi^+ + p \rightarrow K^+ + \Sigma^+$ @ 1.37 GeV/c
- ✓ **Missing mass resolution:**

$\Delta M_{\Sigma} = 1.92$ MeV (FWHM)

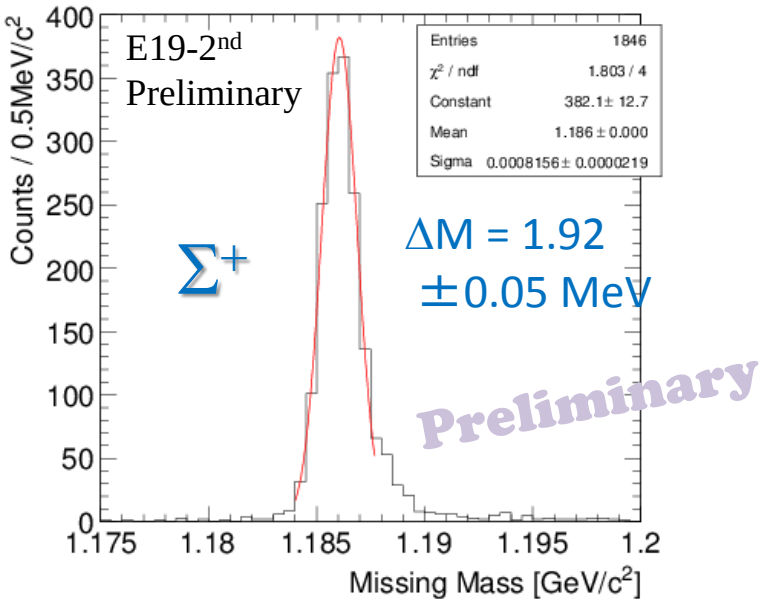
– **Equivalent to the 1st run.**

Cf.) 1.86±0.08 MeV @ E19-1st

$\Delta M_{\Theta} = 1.74$ MeV (FWHM)

Σ^+ Missing Mass

$\pi^+ + p \rightarrow K^+ + \Sigma^+$ @ 1.37 GeV/c



Consistency check with previous exp.

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- ✓ **Missing mass resolution:**

  $\Delta M_\Sigma = 1.92$ MeV (FWHM)

  – Equivalent to the 1st run.

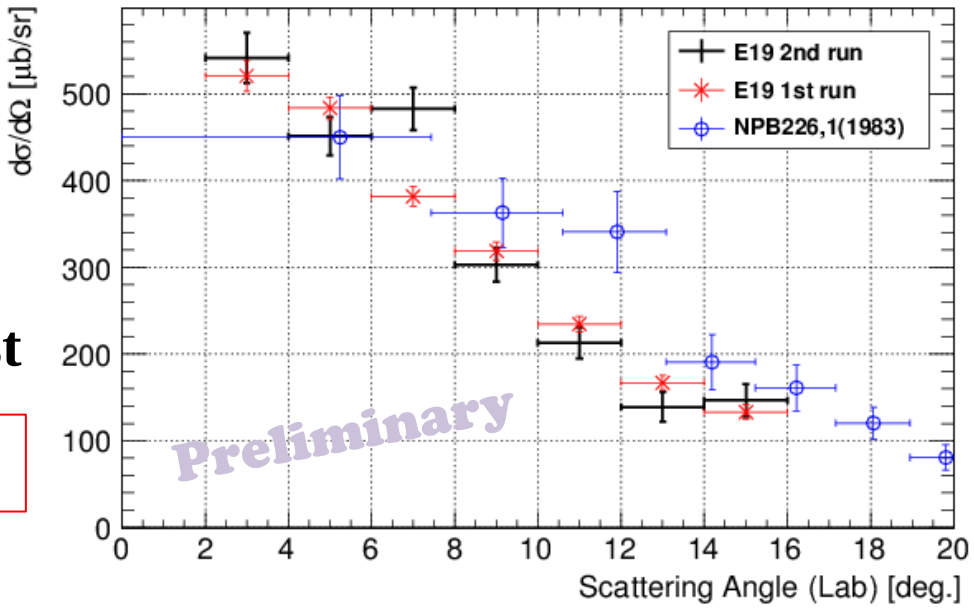
  Cf.) 1.86±0.08 MeV @ E19-1st

  $\Delta M_\Theta = 1.74$ MeV (FWHM)

- ✓ **Differential cross section**
  - – Almost consistent with 1st run and reference data.
  - – Good understanding of efficiencies and acceptance.

Σ^+ Differential Cross Section

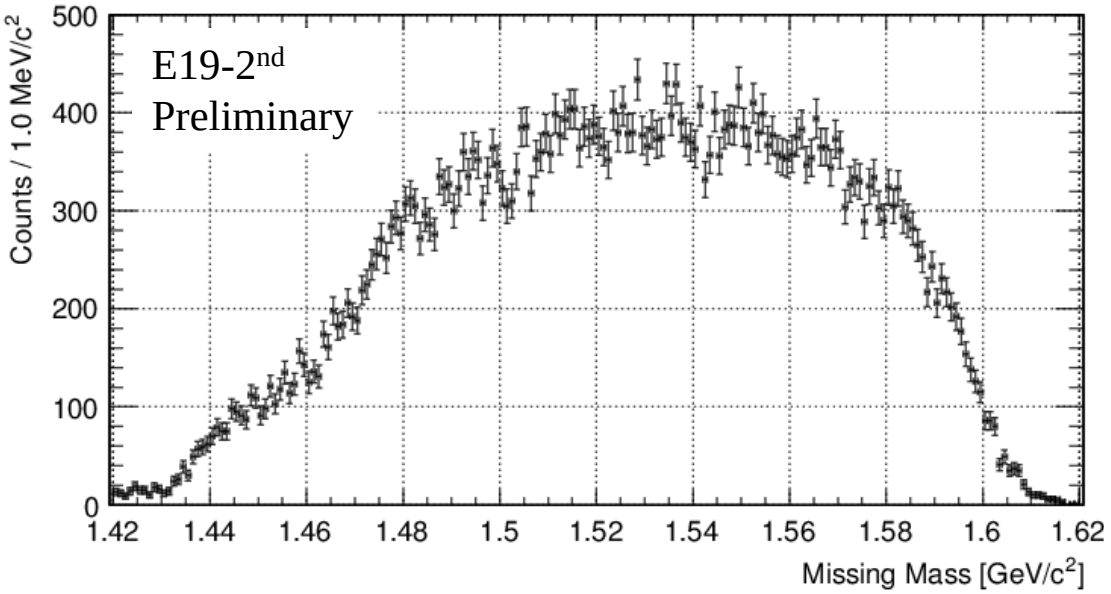
$\pi^+ + p \rightarrow K^+ + \Sigma^+$ @ 1.37 GeV/c



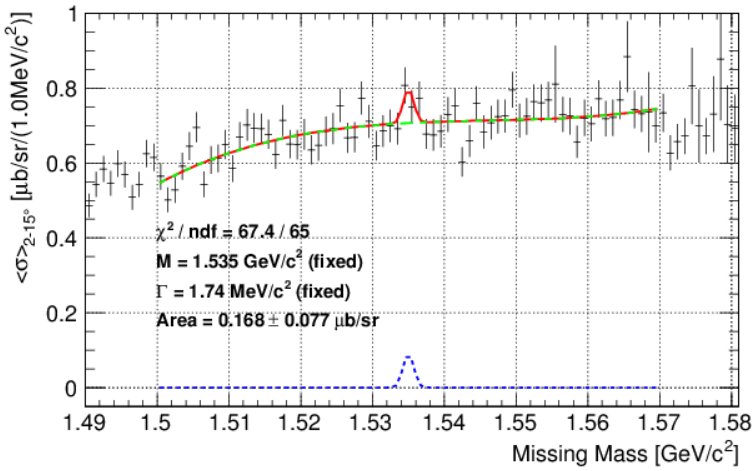
Consistency Check → OK

Analysis Result of E19-2nd run

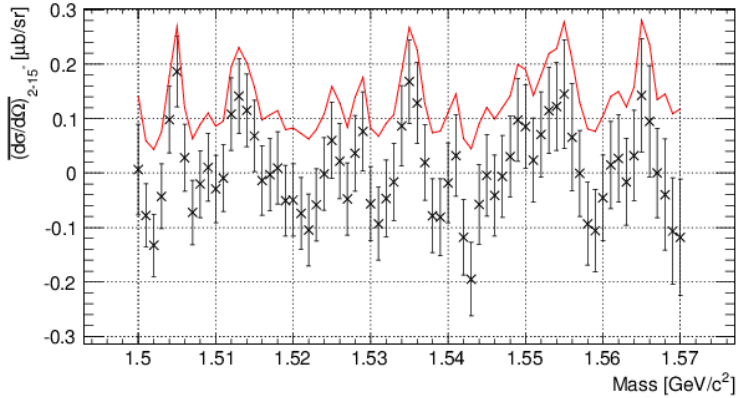
$\pi^- + p \rightarrow K^- + X$ @ p_π = 2.0 GeV/c



An example of fitting result @ 1.535 GeV/c²



Fitting results of each mass and Upper limit (90%C.L.)

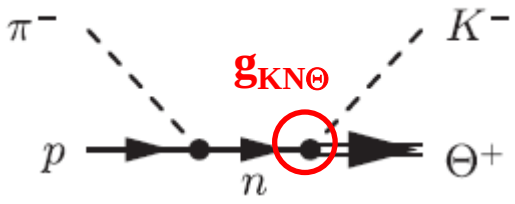


- **No peak structure was observed.**
- **Upper limit on differential cross section averaged from 2 to 15 deg:**

  < 0.28 μb/sr @ 1.50 – 1.57 GeV/c²

Upper limit on decay width

- **Considering about theoretical uncertainty (coupling scheme and form factor), we chose the most conservative case as the upper limit.**



$\Gamma_\Theta \propto g^2_{KN\Theta} \propto \sigma$

T. Hyodo et al., PTP 128, 523 (2012).

Upper Limit on Γ_Θ for J^P_Θ

- **0.61 MeV for ½+**
- **3.7 MeV for ½-**

(Preliminary)

Summary

- J-PARC E19 is a pentaquark Θ^+ search experiment with high statistics and high resolution.
  - $\pi^- p \rightarrow K^- \Theta^+$ reaction
  - J-PARC K1.8 B.S. and SKS
- New result of E19-2nd run was presented.
  - Consistency with the 1st run was checked. → O.K.
  - Θ^+ missing mass resolution of 1.74 MeV was evaluated.
  - No peak structure was observed in MM spectrum.
  - Upper limit for Θ^+ production cross section was obtained to be 0.28 μb/sr @ 1.50 – 1.57 GeV/c^2
  - This corresponds to upper limit on Θ^+ decay width of 0.61 and 3.7 MeV for J^P = ½+ and ½-, respectively.