Search for Θ^+ via $K^+p \rightarrow \pi^+X$ reaction at KEK-PS E559

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for the E559 collaboration

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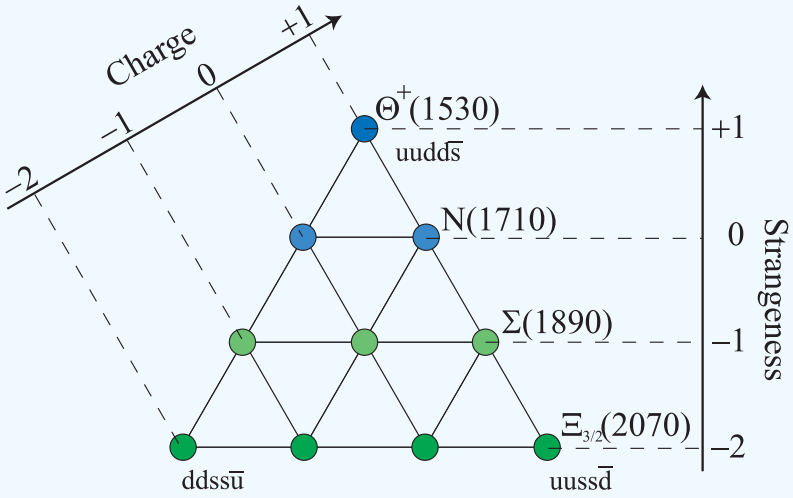
We thanks to RIKEN radiation laboratory for usage of RIKEN-CCJ for analysis

The Θ^+ baryon

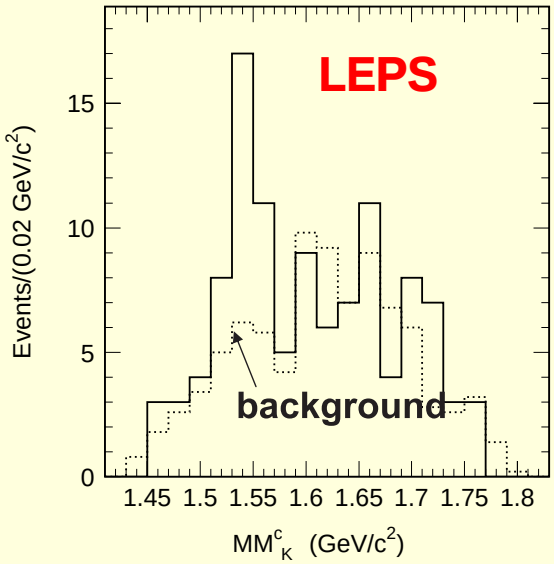


Theoretical prediction

- Diakonov et al.
  - Chiral soliton model
  - Anti-decuplet
  - M=1530 MeV, Γ< 15MeV

Experiment

- LEPS at Spring-8
  - $\gamma n \rightarrow K^- \Theta^+ \rightarrow K^- K^+ n$
  - M=1540±10 MeV
  - Γ<25 MeV

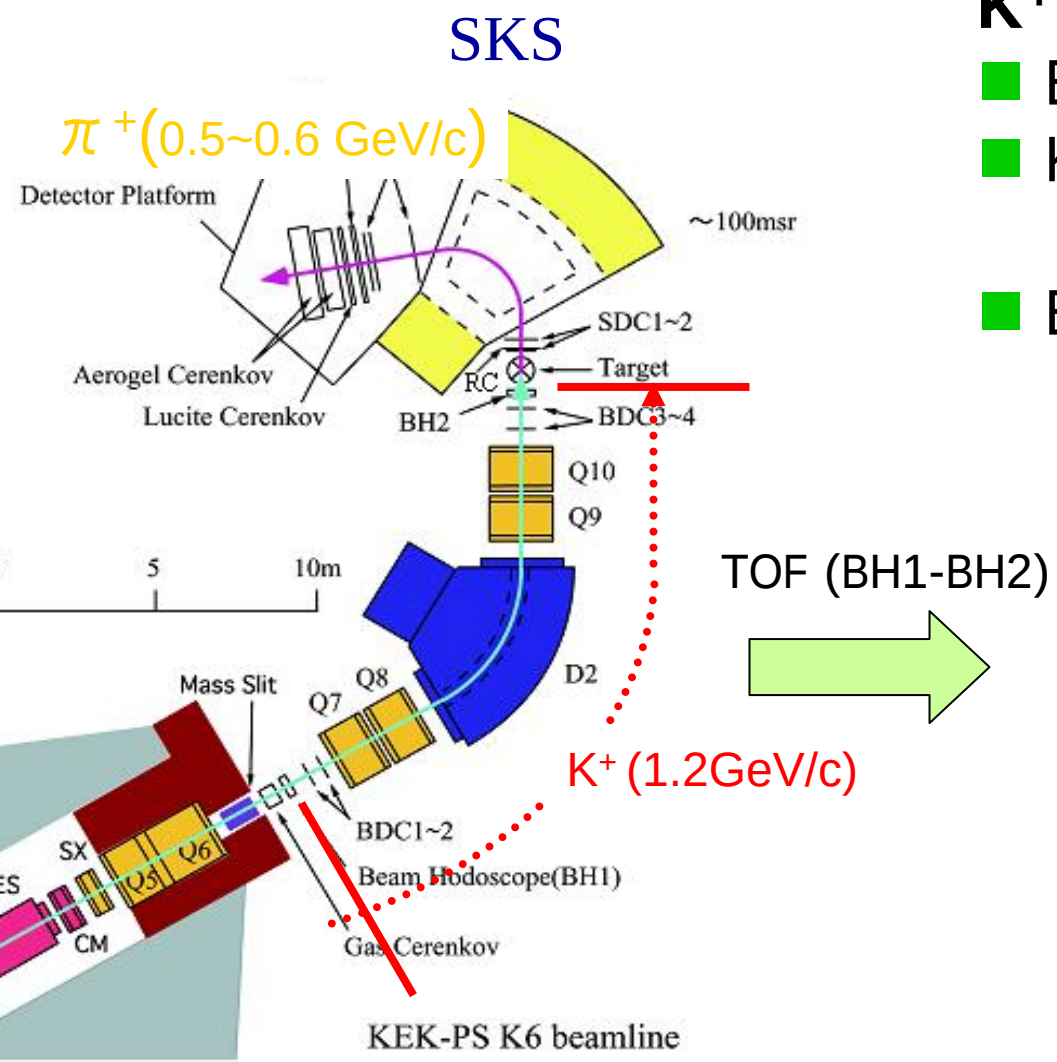


$K^+p \rightarrow \pi^+\Theta^+$ E559

- High statistics
  - Θ^+ search via $K^+p \rightarrow \pi^+X$ reaction
- High resoluiton
  - K6 beam line + SKS spectrometer
  - 2.4MeV (FWHM) expected
- Production mechanism
  - Deduction of production cross section

KEK-PS E559 @ K6 beam line
Θ^+ search via $K^+p \rightarrow \pi^+\Theta^+$ reaction
1st run 2005 June~
2nd run 2005 December~

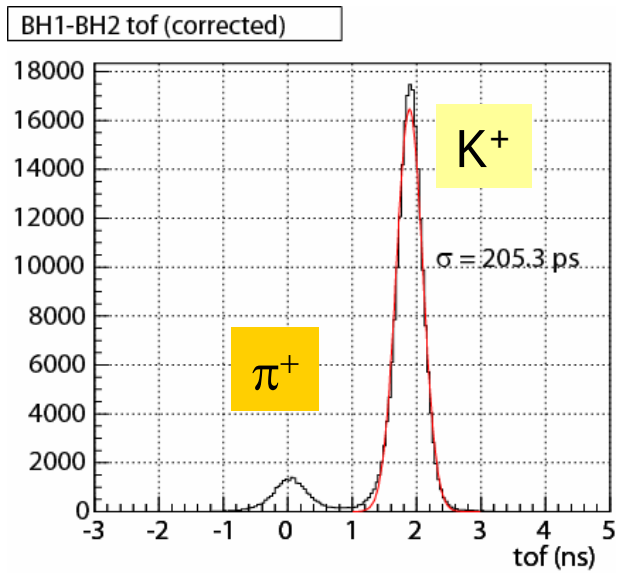
Experimental set up



TOF (BH1-BH2)

K^+ beam

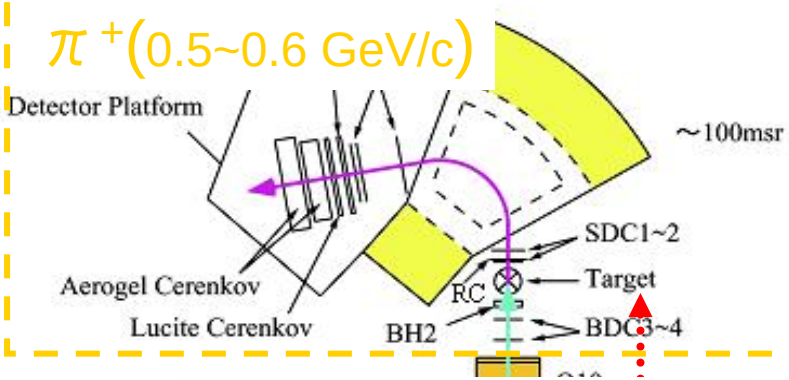
- Beam momentum 1.2 GeV/c
- K^+ identification
  TOF between BH1 – BH2
- Beam momentum resolution
  $\Delta p/p$ = 0.047%

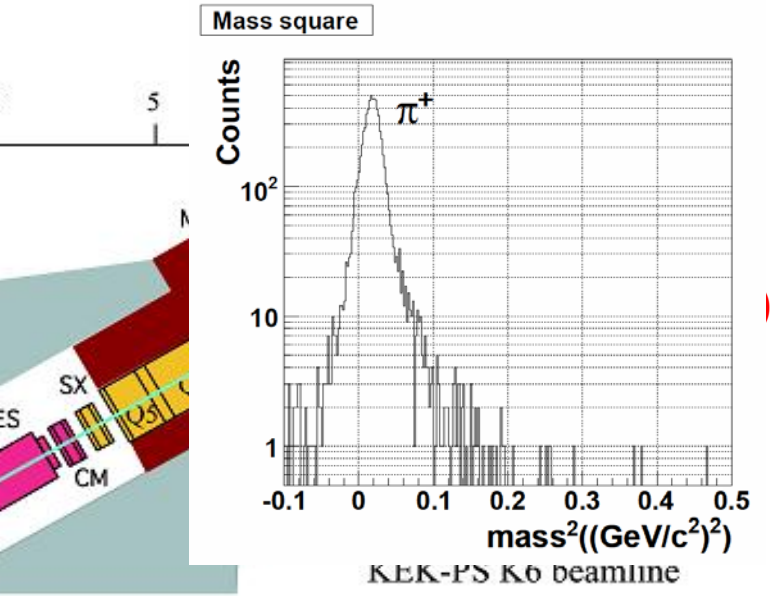


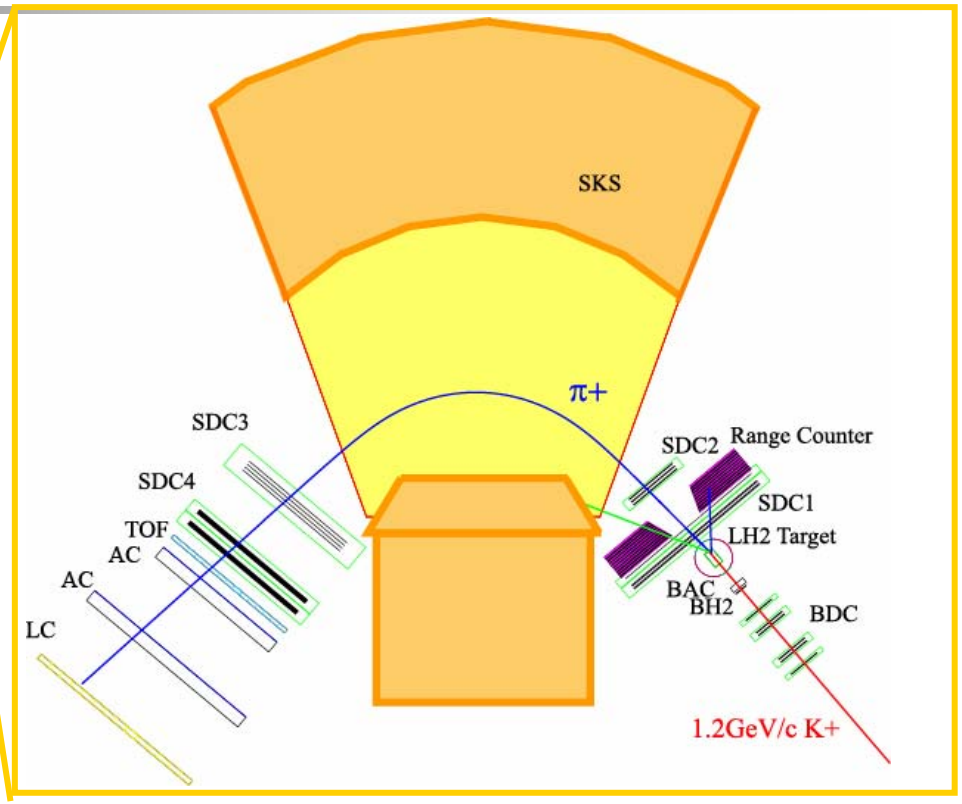
Experimental set up

SKS

π^+(0.5~0.6 GeV/c)







- SKS
  - Detect scattered π+
  - Momentum resolution $\Delta p/p$=0.42% (FWHM)
  - π^+ identification
    mass reconstruction

Background

3-body decay of K^+

1 or 3 charged particle

$K^+ \to \pi^+\pi^+\pi^-$

$K^+ \to \pi^+\pi^0\pi^0$

$K^+ \to \mu^+\pi^0\nu_\mu$

$K^+ \to e^+\pi^0\nu_e$

2 or 4 charged particle

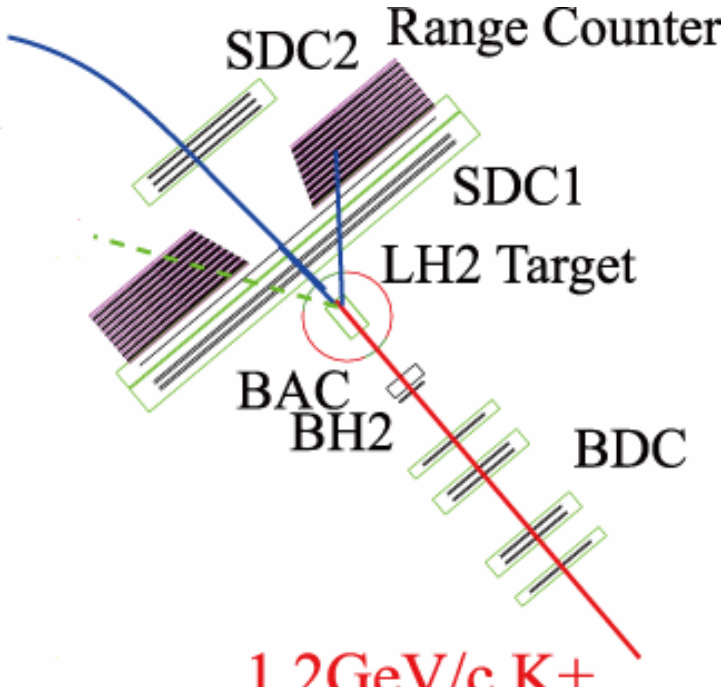
K^+p reaction

$K^+p \to \Delta K \to \pi^+ n K^+$

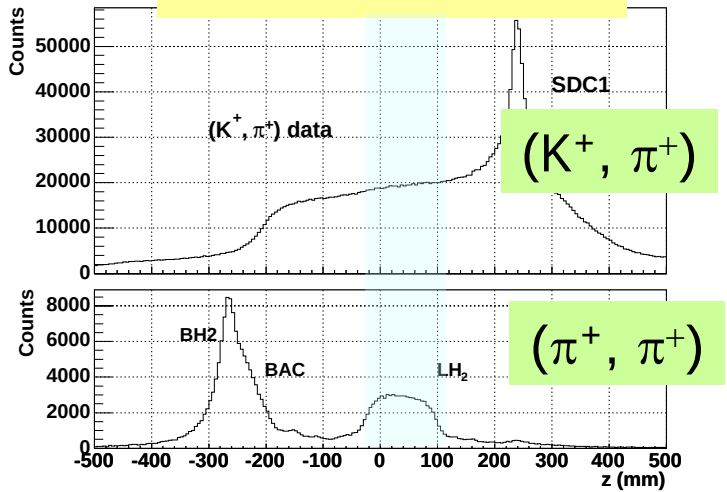
$K^+p \to \Delta K \to \pi^+ p K^0$

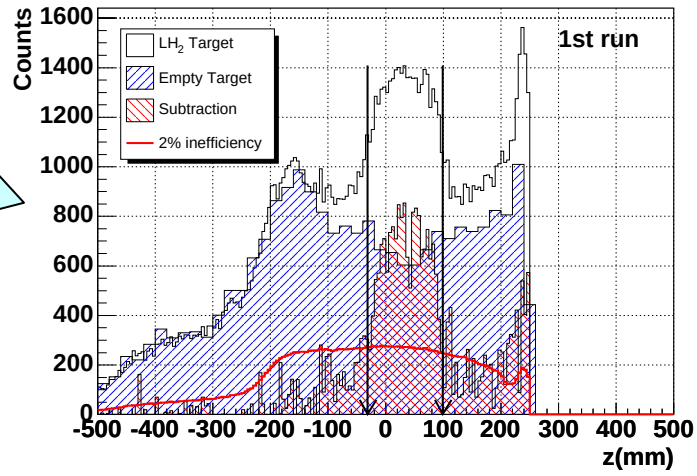
$K^+p \to NK^* \to \pi^+ n K^+$

$K^+p \to NK^* \to \pi^+ p K^0$

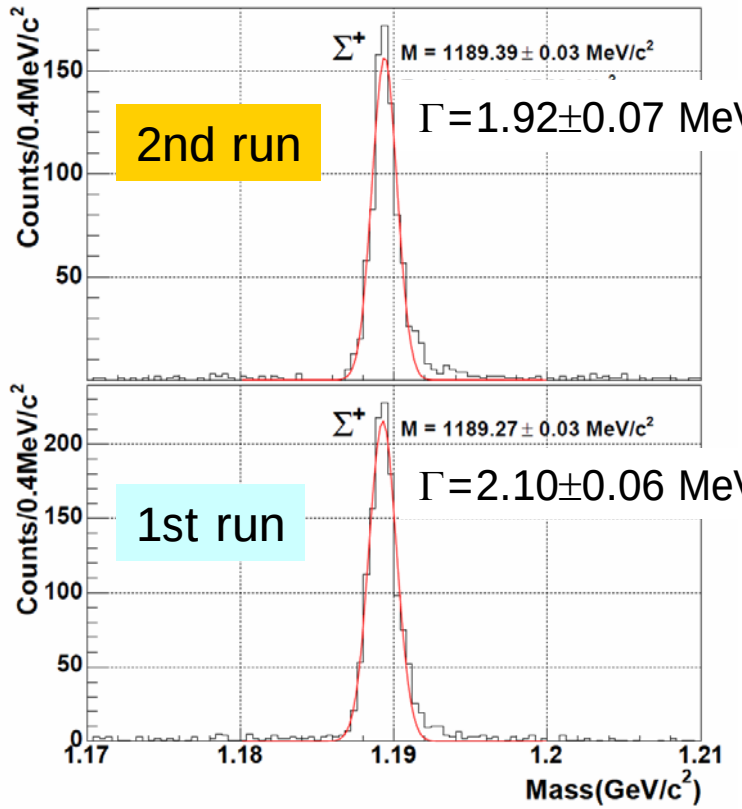


Vertex distribution





Analysis of $\pi^+p \rightarrow K^+\Sigma^+$



Resolution : consistent with simulation

K6 : $\Delta p/p$ = 0.047% (FWHM)
SKS : $\Delta p/p$ = 0.43% (FWHM)

Resolution 1.98 MeV/c² (FWHM)

For Θ^+ 2.4 MeV/c² is expected

Yield

2nd run : 1200 event

σ=144±10μb

$$N_\Sigma = \sigma \times N_{tgt} \times N_{\pi+} \times (survival) \times (\text{acceptance})$$

29.7%

3.34%

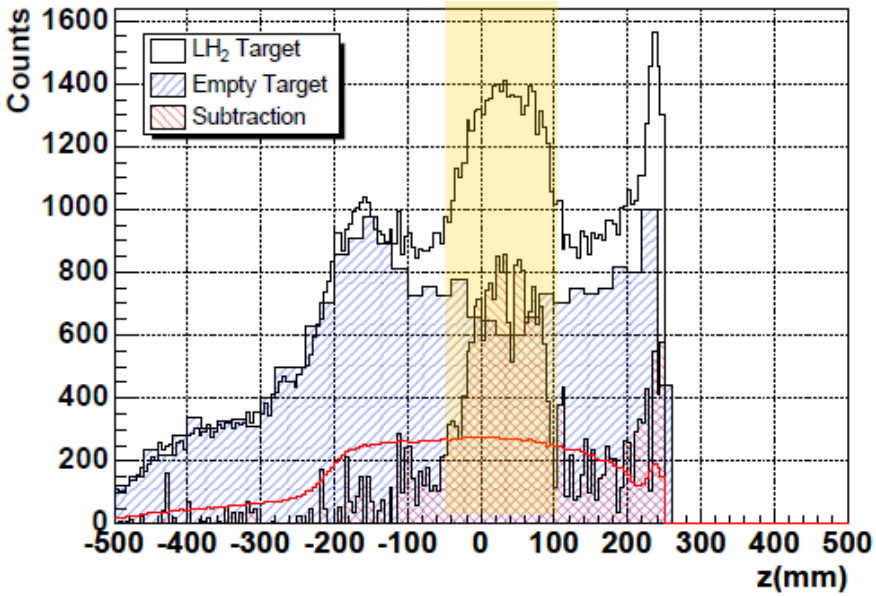
Expected event 1200

Missing mass value

Consistent between 1st run and 2nd run

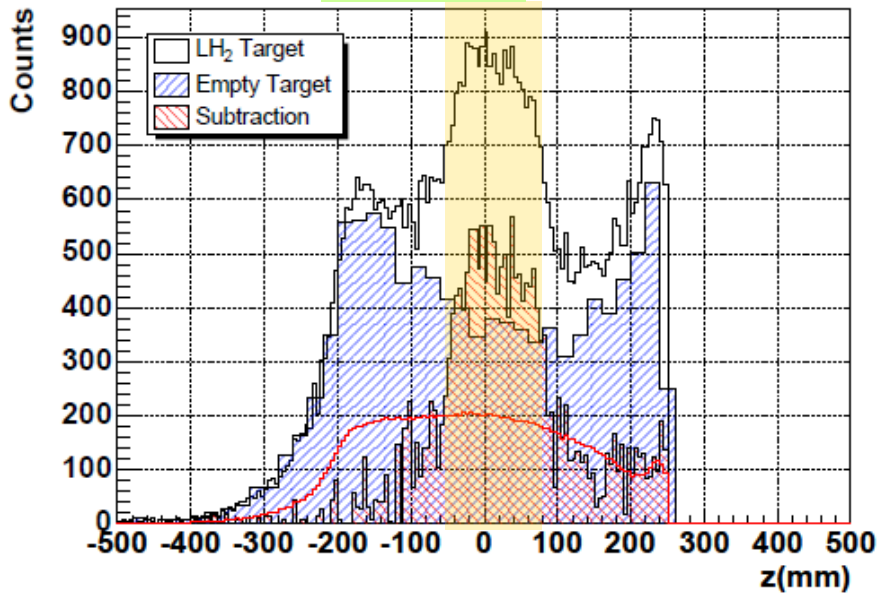
Vertex distribution of $K^+p \rightarrow \pi^+X$ reaction

1st run



17200 event (-30<vtz<100)

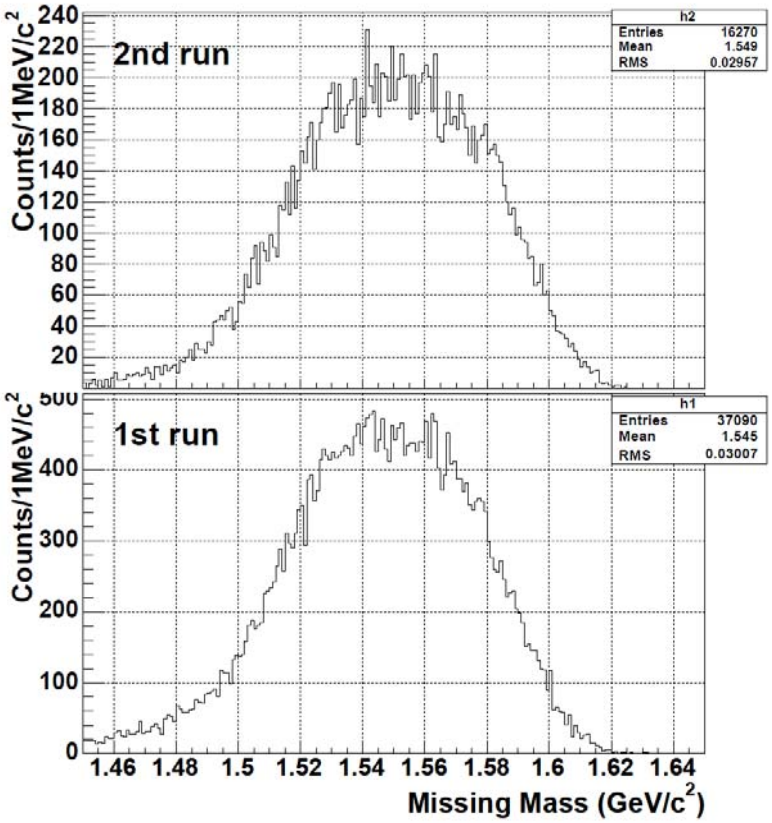
2nd run

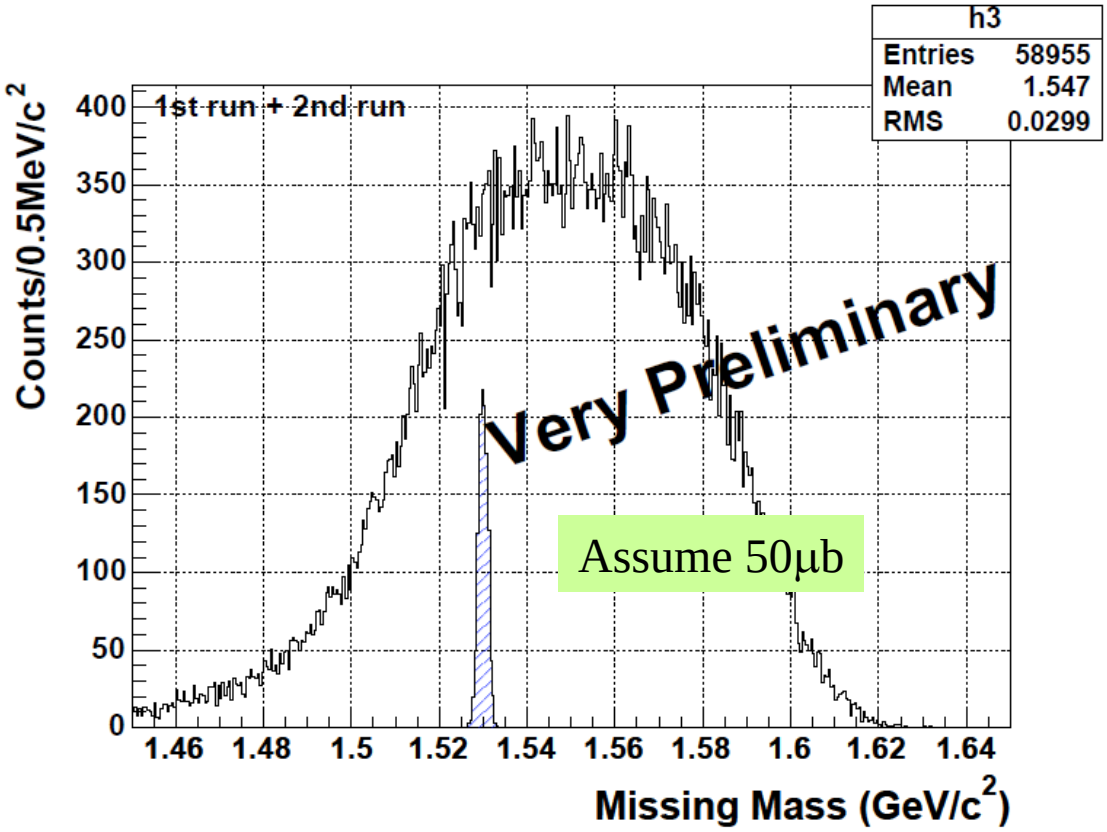


10100 event (-40<vtz<85)

Missing mass ($K^+p \rightarrow \pi^+X$)

Sum of 1st and 2nd runs





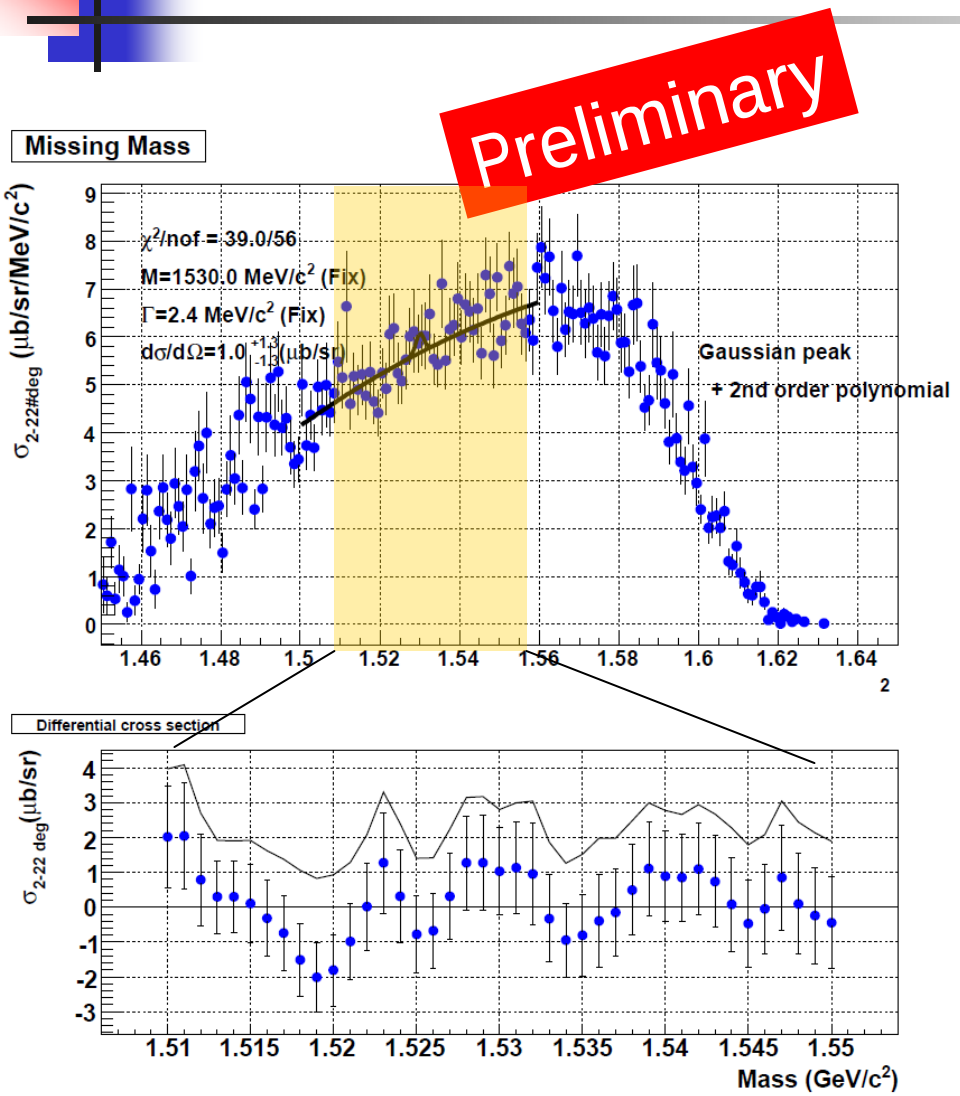
Differential cross section

$$\left(\frac{d\sigma}{d\Omega}\right) = \frac{1}{N_{target}} \cdot \frac{1}{N_{beam} \cdot f_{K+beam} \cdot \epsilon_{K6}} \cdot \frac{1}{\epsilon_{LC} \cdot \epsilon_{TOF}} \cdot \frac{1}{f_{decay} \cdot f_{\pi+int}} \cdot \frac{N_{\Theta+}}{\epsilon_{SdcIn} \cdot \epsilon_{SdcOut} \cdot \epsilon_{Sks} \cdot \epsilon_{Sdc1} \cdot \epsilon_{vtx} \cdot d\Omega}$$

Typical values of correction factors

	cut	efficiency(%) (1st run / 2nd run)
f_{K+beam}	K^+ beam on-target factor	84.5±3.5 / 96.2±1.6
ϵ_{K6}	tracking efficiency of beam particle	95.3±0.3 / 95.6±0.3
ϵ_{LC}	LC efficiency	95.5±0.2
ϵ_{TOF}	TOF efficiency	∼100.
f_{decay}	π^+ decay factor	85.2±0.2
$f_{\pi+int}$	π^+ interaction factor	94±2
ϵ_{SdcIn}	SdcIn tracking efficiency	87.5
ϵ_{SdcOut}	SdcOut tracking efficiency	92.9±0.3
ϵ_{Sks}	Sks tracking efficiency	95±0.7
ϵ_{Sdc1}	Sdc1 analysis efficiency	69.4±3.7
ϵ_{vtx}	vertex cut efficiency	$85.2^{+2.9}_{-1.3}$ / $85.0^{+0.4}_{-0.9}$
ϵ_{Bdc5}	BDC5 cut efficiency	—— / 91.60.2
$d\Omega$	acceptance at lab. frame	0.11sr.

Differential cross section



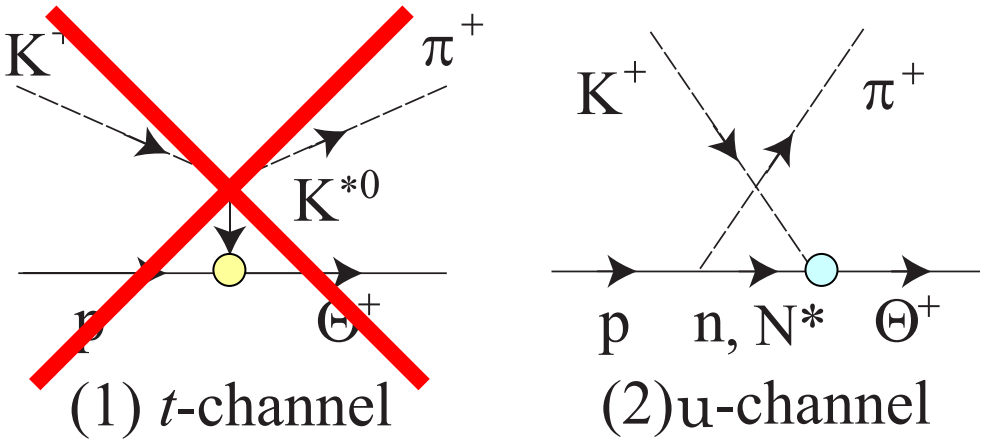
- Averaged diff. cross section
  - 2°~22° at laboratory frame

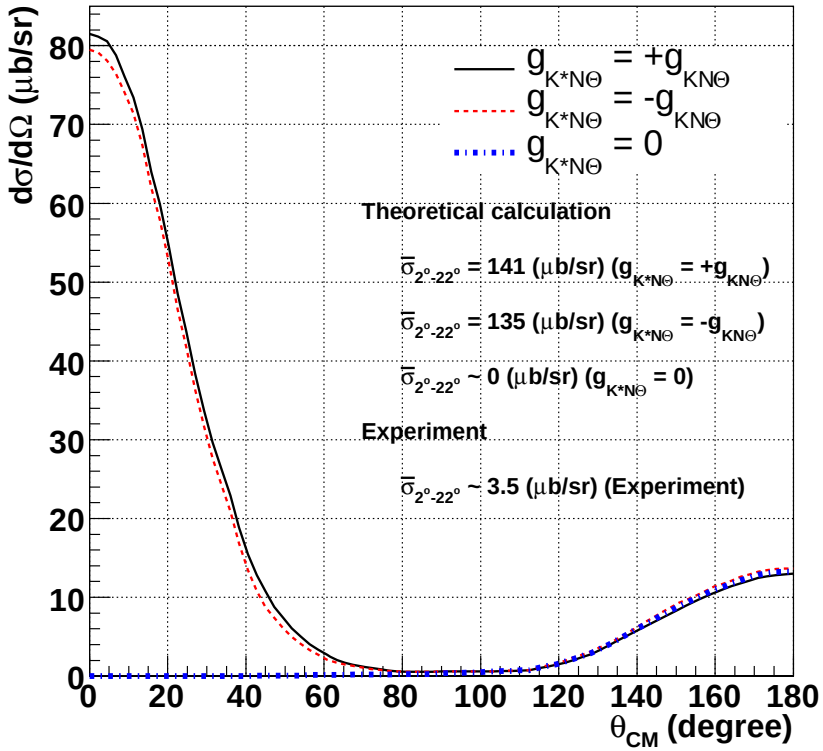
$$\bar{\sigma}_{2^\circ-22^\circ} = \int_{2^\circ}^{22^\circ} \left(\frac{d\sigma}{d\Omega}\right) d\Omega \Big/ \int_{2^\circ}^{22^\circ} d\Omega.$$

- No peak structure
- 90% C.L. Upper limit
  - Fitting
    - Gauss peak (2.4MeV/c2 Fix)
    - 2nd order polynomial B.G.
- Less than 3.5μb/sr

Discussion about production mechanism

Possible production diagram





Theoretical calculation by Y. Oh *et al.*

Controlled by two parameter

- $g_{KN\Theta}$: related to the width (~1MeV/c^2)
- $g_{K^*N\Theta}$: No experimental information

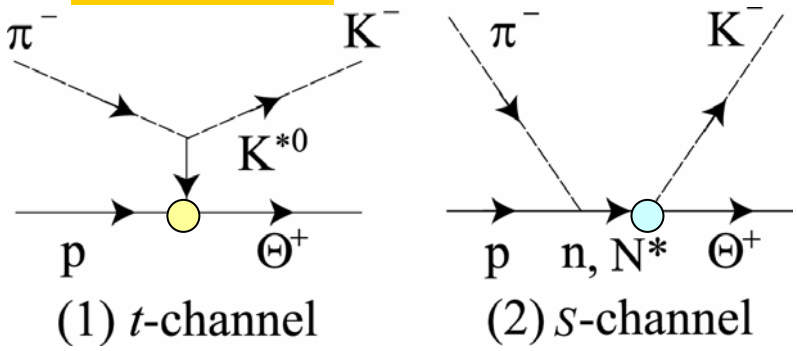
If t-channel exists → $d\sigma/d\Omega$ shows forward peak

If t-channel does not exist
→ $d\sigma/d\Omega$ shows backward peak

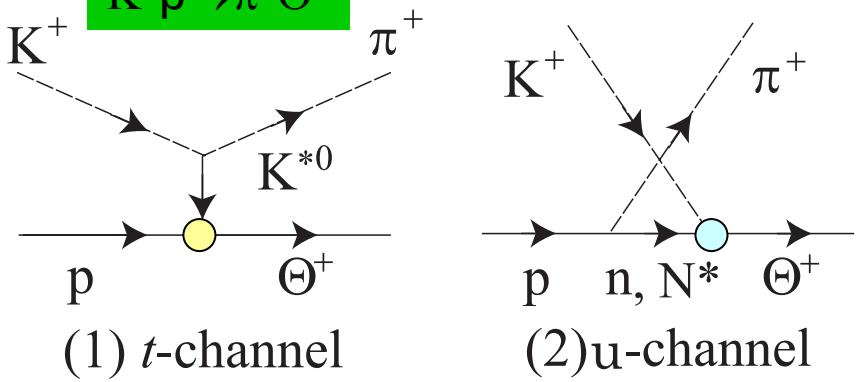
Our experimental result
$\overline{\sigma}_{2^\circ\ -22^\circ} < 3.5\mu b/sr$
t-channel process is excluded

Production mechanisms of (π^-,K^-) and (K^+,π^+)

$\pi^-p\to K^-\Theta^+$



$K^+p\to\pi^+\Theta^+$



The same coupling constants,
$g_{KN\Theta}$ and $g_{K^*N\Theta}$, are used

To explain small cross section of both reactions

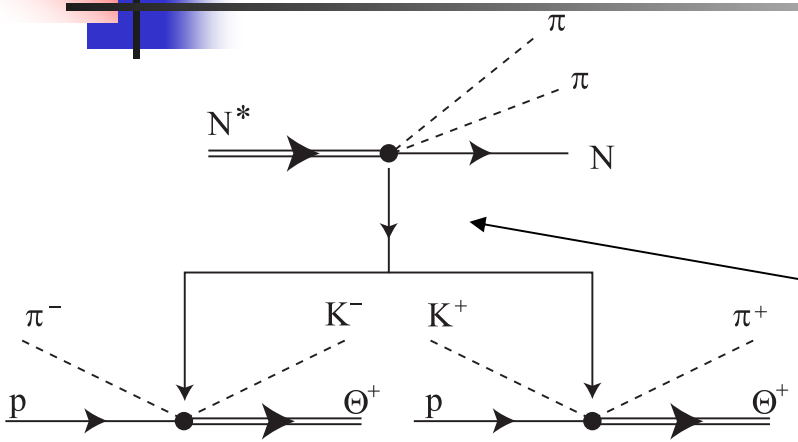
1. $g_{KN\Theta}$ is small
2. $g_{KN\Theta}$ and $g_{K^*N\Theta}$ have sizable scale.
   Destructive interference of two amplitudes

Destructive @ $\pi^-p\to K^-\Theta^+$
Constructive @ $K^+p\to\pi^+\Theta^+$
Cannot explain small cross section for both reactions

$g_{K^*N\Theta}$ should be small.
interference should be small

Therefore $g_{KN\Theta}$ should be small

Two meson couplings by Hyodo and Hosaka

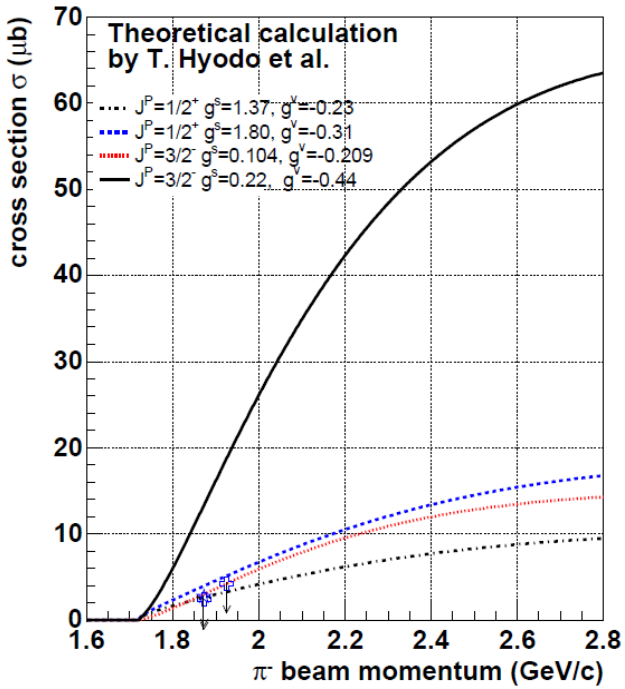


Contact term of two meson coupling

- If the width is extremely narrow, there is sizable cross section

Coupling constant (scalar and vector)
← decay width of $N^* \to \pi\pi N$

Constraint from $\pi^- p \to K^- \Theta^+$ result



For $K^+ p \to \pi^+ \Theta^+$ reaction

$\sigma_{2^\circ\ -22^\circ} \sim 600\mu b/sr\ (J^P=1/2^+)$
$\sigma_{2^\circ\ -22^\circ} \sim 50\mu b/sr\ (J^P=3/2^-)$

Destructive interference to $\pi^- p \to K^- \Theta^+$
Constructive interference to $K^+ p \to \pi^+ \Theta^+$

Cannot explain small cross section of both reactions

This production mechanism should be small.

Summary

- E559 experiment @ K6 beam line
  - Θ^+ search via $K^+p \rightarrow \pi^+X$ reaction
  - Missing mass resolution 2.4 MeV/c^2
- No peak structure from missing mass spectrum
- Differential cross section (2^o~22^o at Lab. frame)
  - Differential cross section < 3.5μb/sr (preliminary)
- Production mechanism
  - t-channel (K^{0*} exchange) → forward peak
    - Exclude by present result
  - u-channel → backward peak
    - We do not have sensitivity to exclude u-channel process