Penta-quark search via (π^-,K^-) reaction

K. Miwa (Kyoto Univ.)

E522 Collaboration

Kyoto Univ. K. Imai, N. Saito, H. Funahashi, C. J. Yoon, K. Miwa, Y. Fukao, H. Okada, K. Aoki, K. Taketani, M. Hayata, K. Shoji
KEK M. Ieiri, H. Takahashi
Gifu Univ. K. Nakazawa, T. Hibi, H. Nishikawa
Osaka Univ. T. Hayakawa
Osaka City Univ. K. Yamamoto
Pusan Univ. J. K. Ahn, S. J. Kim, B. H. Choi

Outline

- ✓ Introduction
- ✓ Experiment
- ✓ Analysis and preliminary result
- ✓ Summary

Introduction

- Report on Penta-quark Θ^+
  - Spring-8/LEPS, DIANA, CLAS, SAPHIR…….

    Exciting field to study from theoretical and experimental aspect

  - Photo-production, High energy experiment
    - Several groups report about penta-quark
  - Mesonic production
    - DIANA (K^+ beam and Xe bubble chamber)
  - Width, Spin, Parity ……not determined

    ⇒ Need more statistics
  - We propose K^+(KEK-PS E559) and π^- **(E522)** beam experiment.

Confirmation of Θ^+

Cross section with π^- reaction

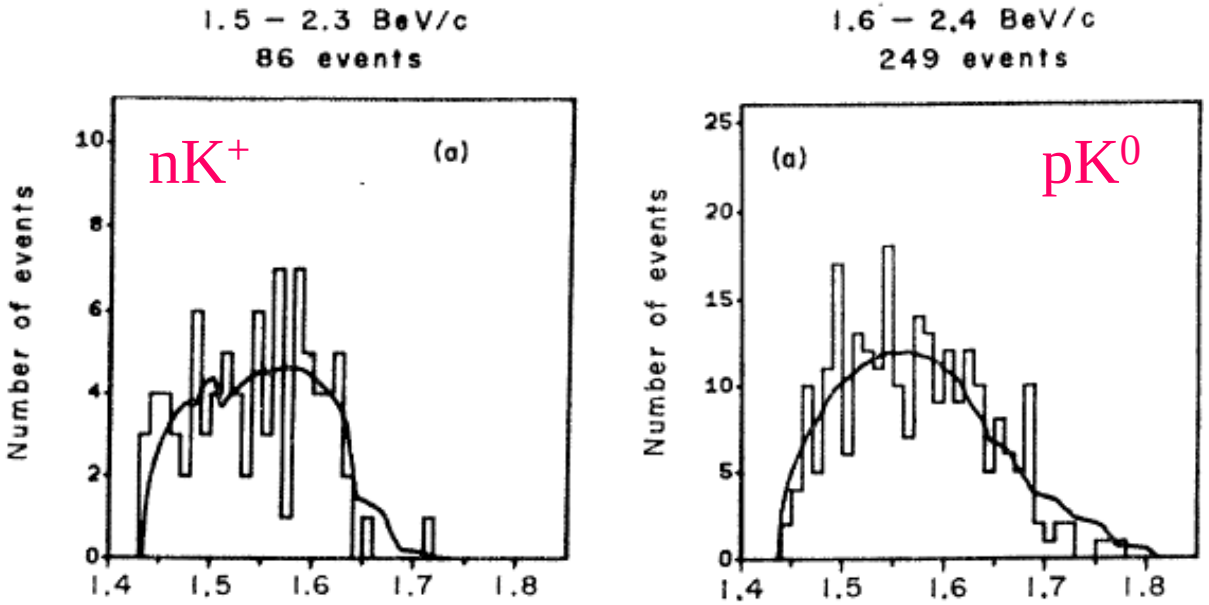
Possible (π^-,K^-) Reactions

✓	$\pi^-p \rightarrow \Theta^+K^- \rightarrow K(K^+n/K^0p)$		$@p_{th}$= 1.71 GeV/c
✓	$\pi^-p \rightarrow K^-(K^+n/pK^0)$	$\sigma \sim 26.2\mu b$	$@p_{th}$ = 1.50 GeV/c
✓	$\pi^-p \rightarrow \phi n \rightarrow K^-K^+n$	σ = 30.0 +- 8.0 μb	$@p_{th}$ = 1.56 GeV/c
✓	$\pi^-p \rightarrow \Lambda(1520)K^0 \rightarrow K^-pK^0$	σ = 20.8 +- 5.0 μb	$@p_{th}$ = 1.68 GeV/c

⇨ Not so huge back ground

Old (π^-,K^-) pK^0/nK^+ data

O. I. Dahl et al.,
Phys. Rev. 163, 1377 (1967)



There is no signal
around expected region
But low statistics

KEK-PS E522

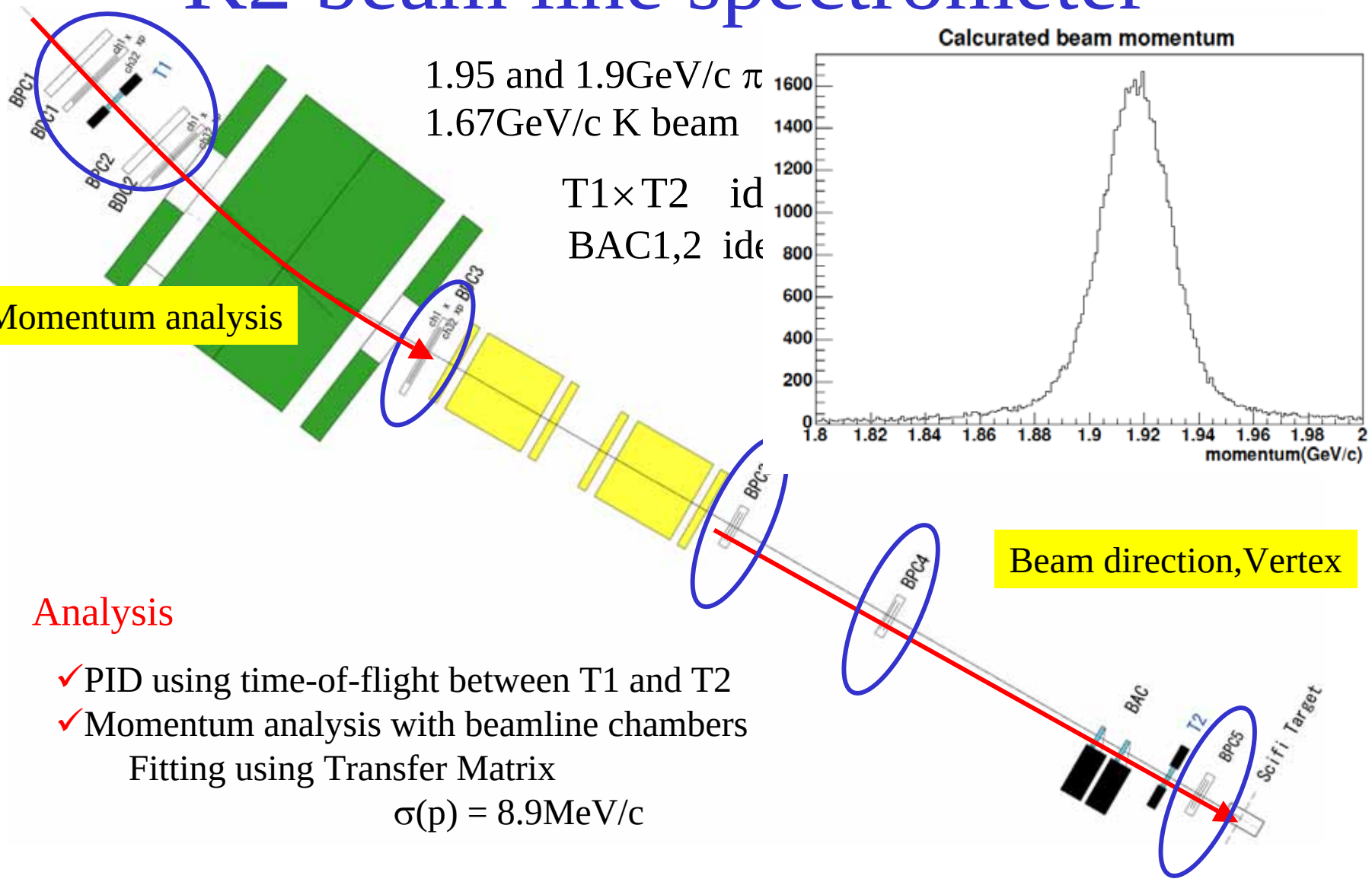
- KEK-PS K2 beam line
- Objects
  - H-dibaryon resonance search via (K^-,K^+) reaction
  - Kaonic Nuclei search via (K^-,p) reaction
  - ✓ Θ^+ search via (π^-,K^-) reaction

P_{beam}(GeV/c)	target	π^- beam	(π^-,K^-) event	comment
1.9	Scifi	2.9×10^9	17×10^3	Scifi two times thicker
1.9	CH_2	4.2×10^9	14×10^3	
1.95	CH_2	7.4×10^9	40×10^3	
1.9, 1.95	Carbon			Contribution of Carbon
1.9, 1.95 π^+	CH_2		(π^+,K^+) reaction	To check Σ^+

K2 beam line spectrometer

1.95 and 1.9GeV/c π
1.67GeV/c K beam

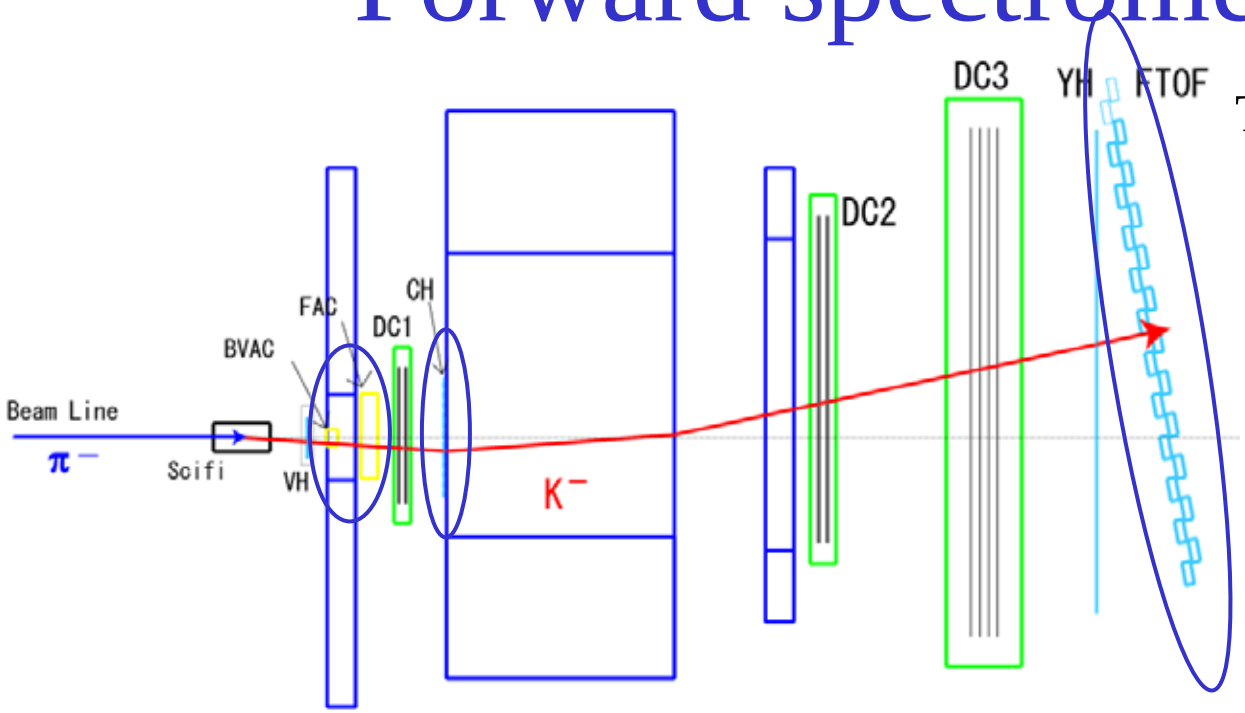
T1×T2 id
BAC1,2 ide



Analysis

- ✓PID using time-of-flight between T1 and T2
- ✓Momentum analysis with beamline chambers
  Fitting using Transfer Matrix
  σ(p) = 8.9MeV/c

Forward spectrometer



Trigger

1st level

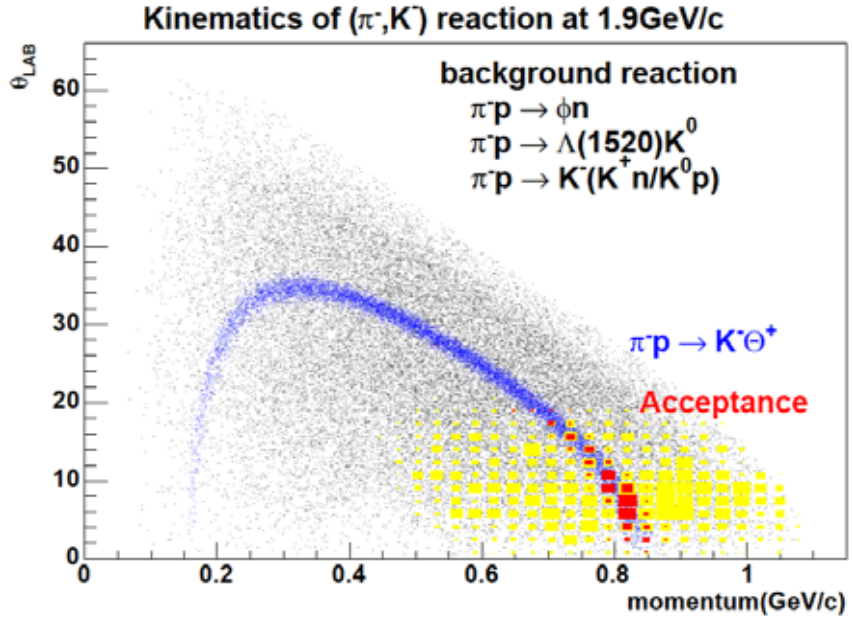
$$\overline{\mathrm{BVAC}} \times \overline{\mathrm{FAC}} \times \mathrm{CT} \times \mathrm{YH}$$

2nd level

mass trigger

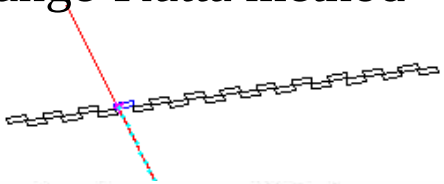
VH coincidence

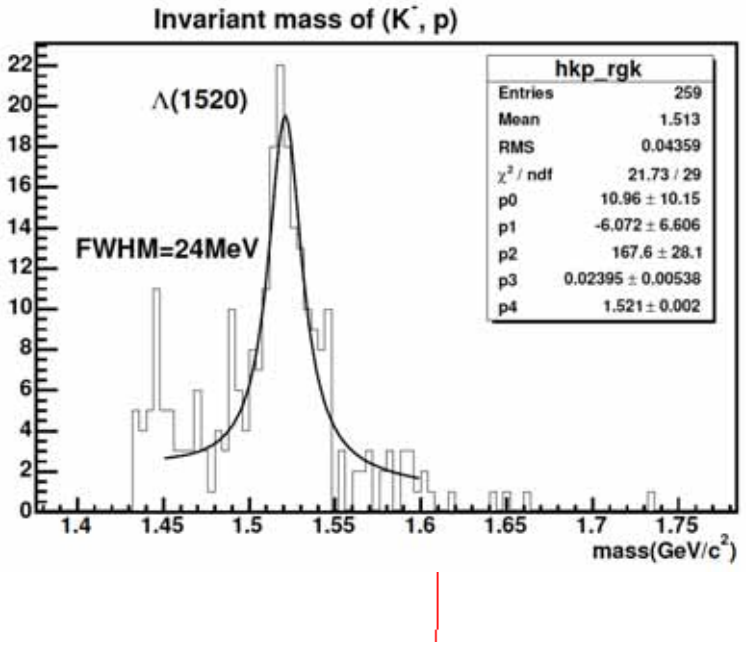
FAC for veto of π^-
eff for π --- 95%
BVAC for veto of π^-
eff for π --- 99.5%

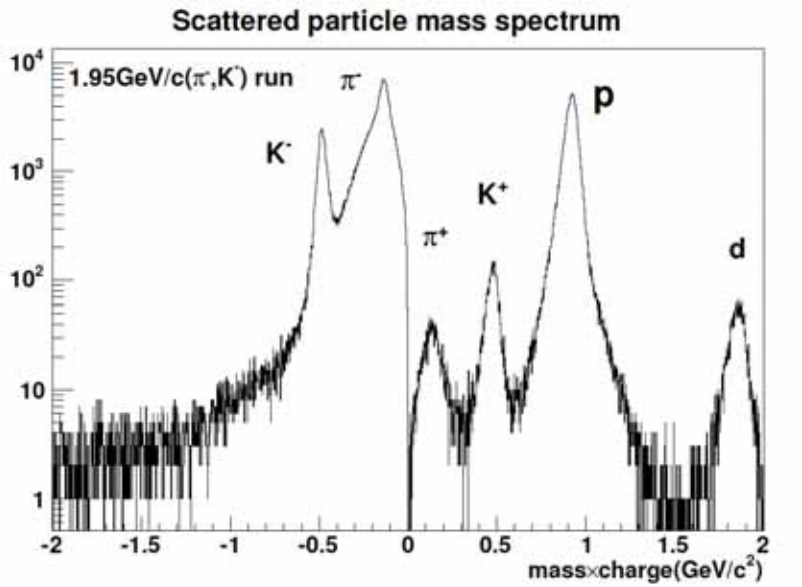


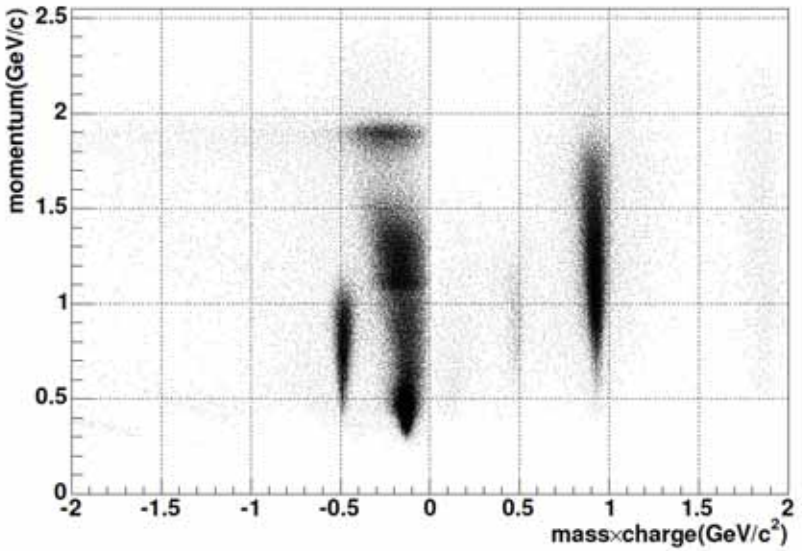
Analysis of scattered particle

- Strait tracking
  - Bending point
  - Decay reject
  - Consistency of tracks between upstream and down stream of Manget
- Use Runge-Kutta method



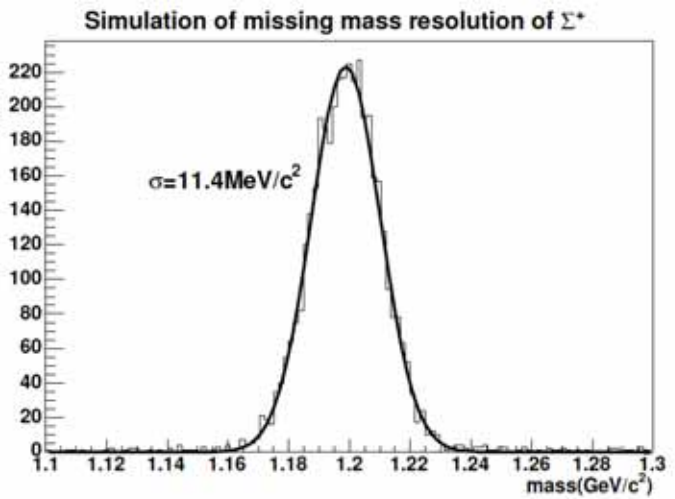


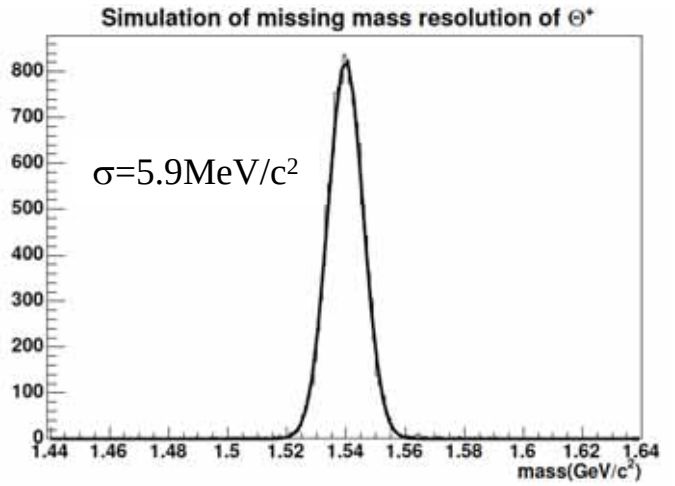




Simulation of missing mass resolution

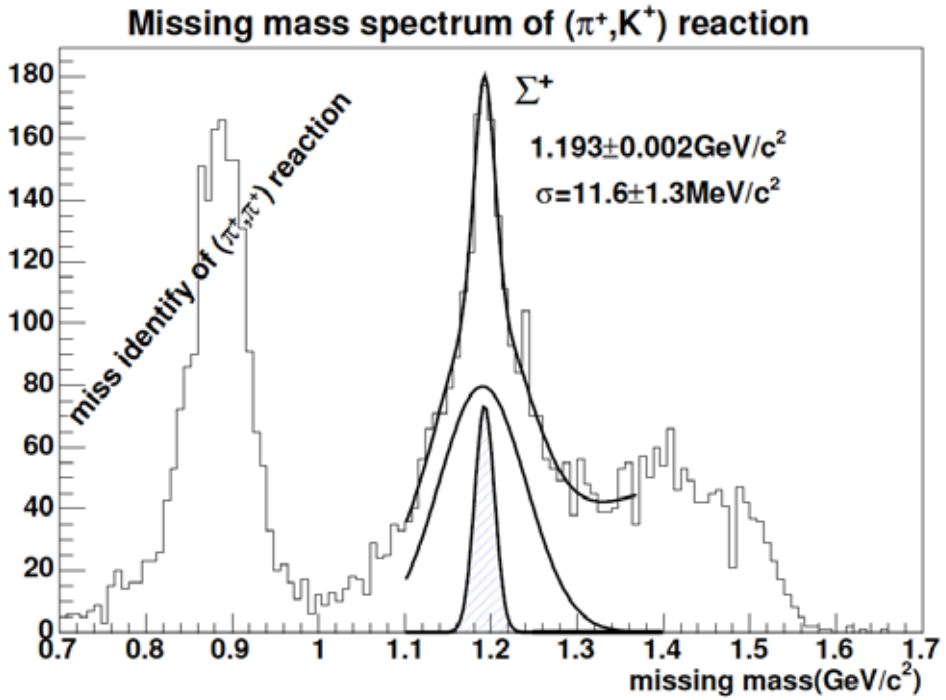
- GEANT simulation
  - Chamber resolution
  - Generate at random position inside the target
  - Include energy deposit (and decay)
  - Δp_{Beam}=8.6MeV/c
- For Θ^+ case, σ=5.94MeV/c^2
  - P_{K^-} ~= 0.85GeV/c → large bending angle





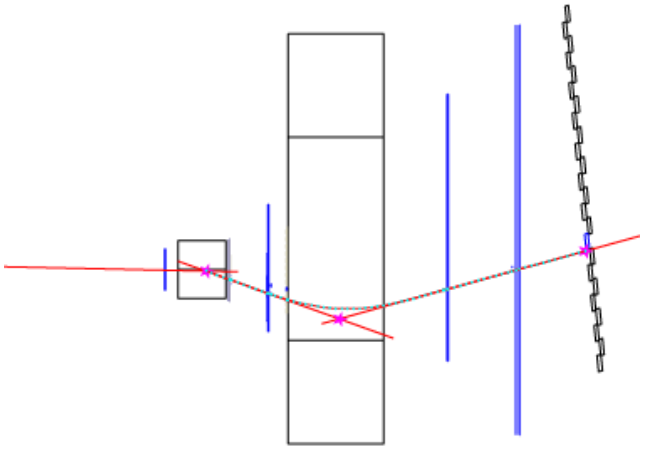
Missing mass spectrum of (π^+,K^+) reaction

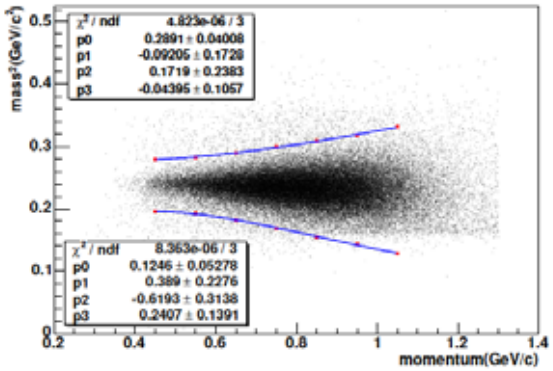
- ✓ Inverse reaction of (π^-,K^-)
- ✓ Observe Σ^+ peak

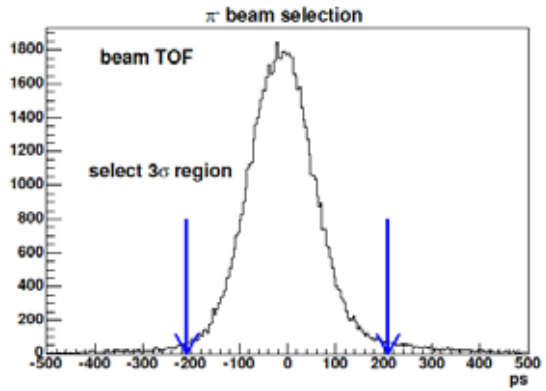


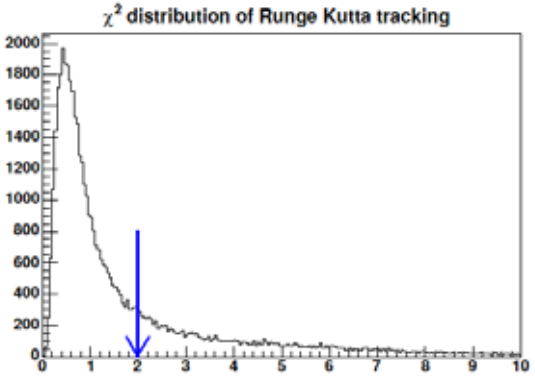
Missing mass analysis of (π^-,K^-) reaction

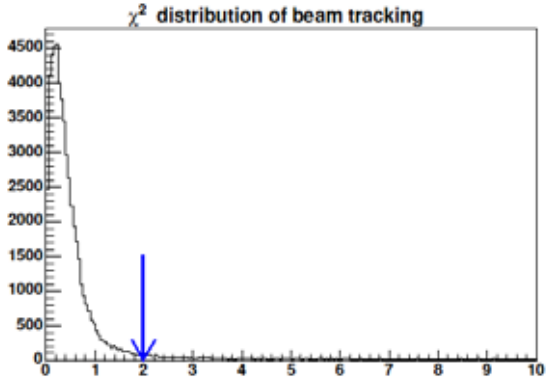
- Cut
  - Scattered particle – K^-
  - Beam particle -- π^-
  - Chi-square of runge-kutta tracking
  - Chi-square of beam tracking
  - Vertex position
  - Distance at vertex

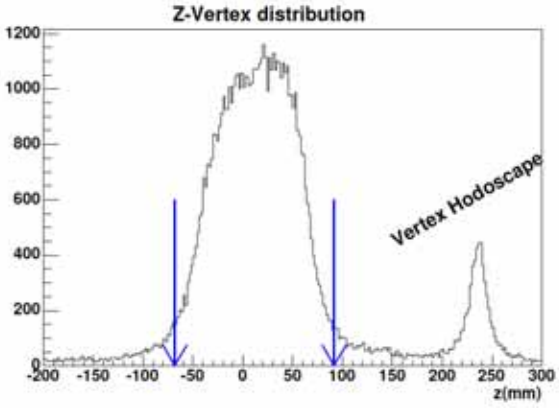


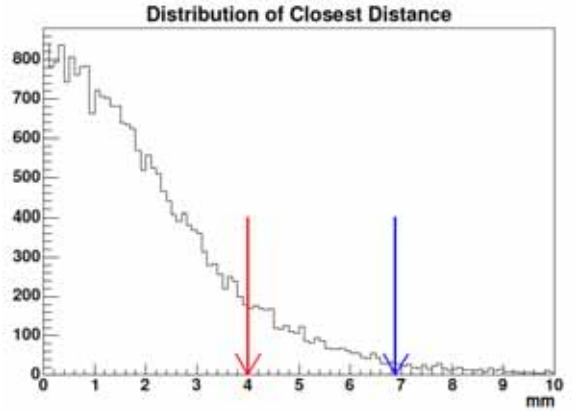






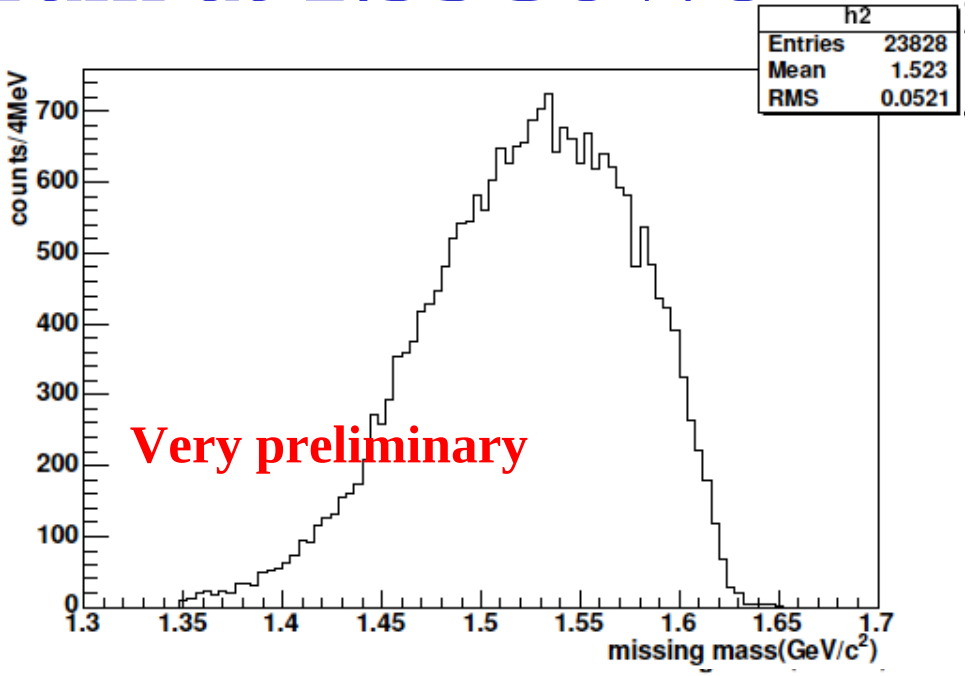


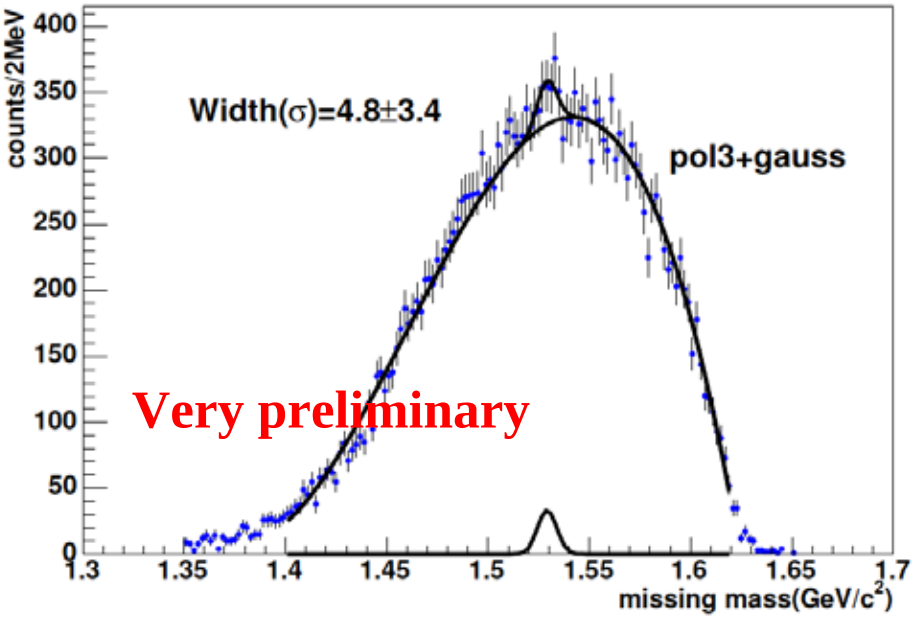




Missing mass spectrum at 1.95GeV/c

- Obtained missing mass spectrum
- We did not apply any strict cut
- There is structure around 1.53GeV/c^2
  - Statistical fluctuation?
- We need study of background



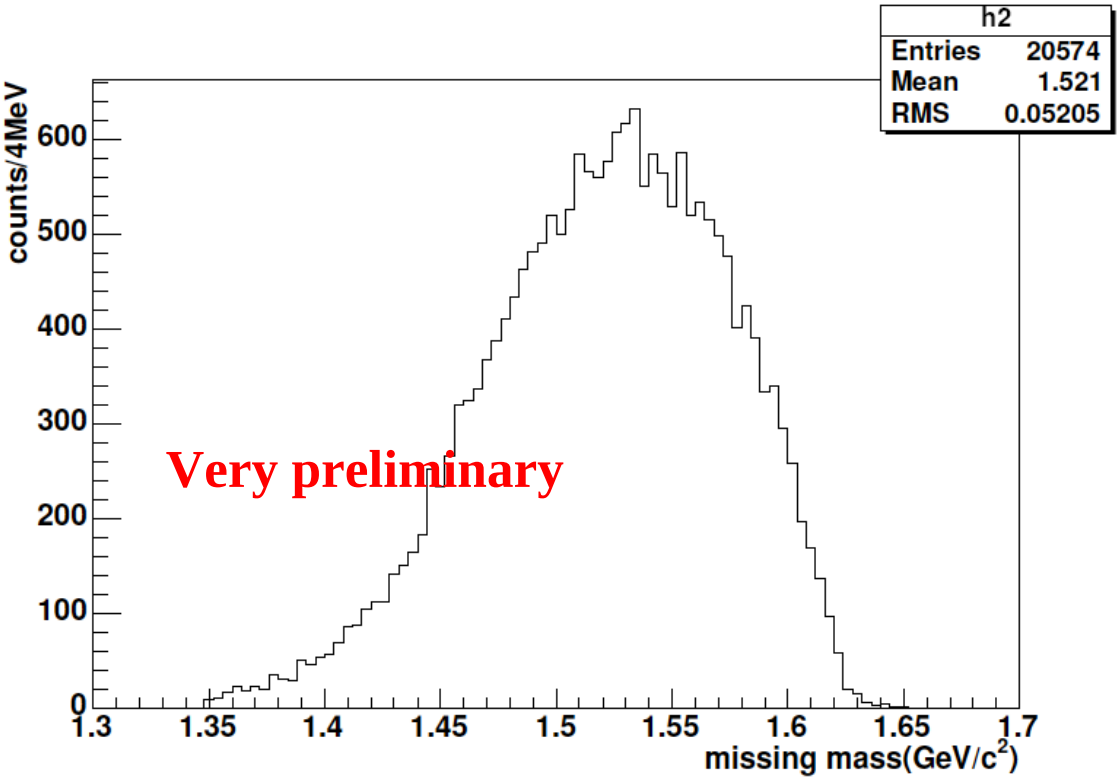


Spectrum with strict cut

Cut strictly

✓ Mass cut → 2σ

✓ closest Distance < 4mm

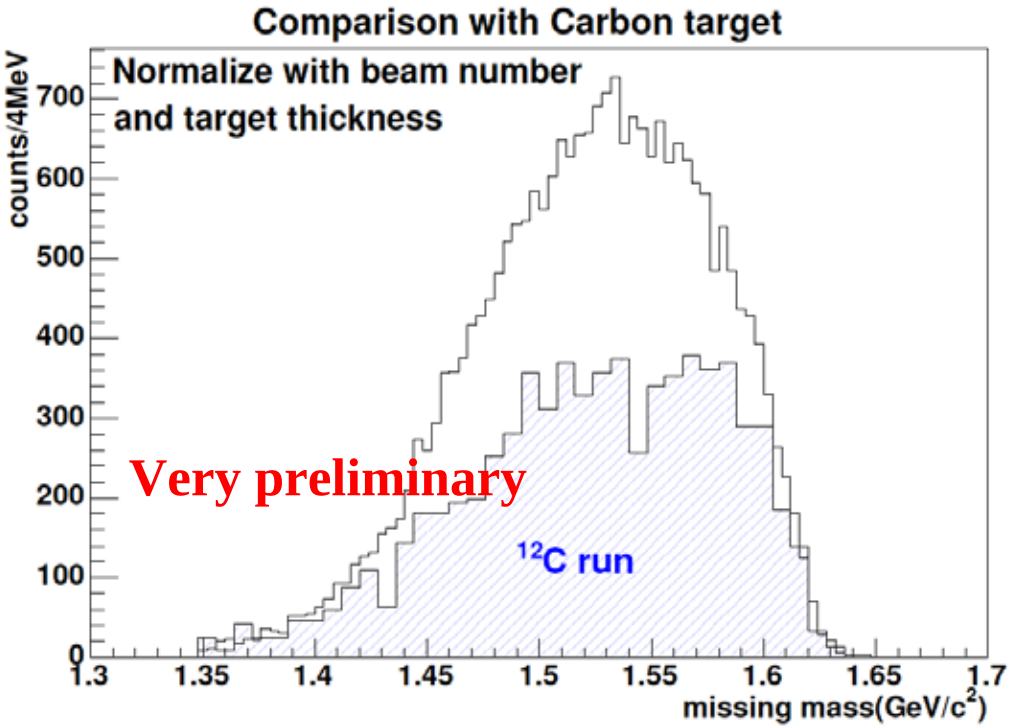


We need reasonable cut to increase S/N ratio.

Our study is still underway.

Comparison with Carbon data

- Carbon target
  - Thickness 5cm
  - Density 1.78g/cm^3
- Beam counts
  - CH_2 7.4*10^9
  - Carbon 8.5*10^8
- Normalize with beam counts and target number → 8.4
- N(proton)=9175
- N(Carbon)=14137
- N(p):N(C) = 2:3



Upper limit estimation of cross section

- ✓ $\pi^- p \rightarrow K^-(K^+ n / p K^0)$ $\sigma \sim 26.2\mu b$ @p_{th} = 1.50 GeV/c
- ✓ $\pi^- p \rightarrow \phi n \rightarrow K^- K^+ n$ σ = 30.0 +- 8.0 μb @p_{th} = 1.56 GeV/c
- ✓ $\pi^- p \rightarrow \Lambda(1520) K^0 \rightarrow K^- p K^0$ σ = 20.8 +- 5.0 μb @p_{th} = 1.68 GeV/c

Sum of background cross section = 77μb

Num of Θ < 190 (but depend on back ground)

Contribution from proton(background) --- 9175

$$\frac{N(peak)}{N(B.G)} \approx \frac{\sigma(peak)}{\sigma(B.G)}$$

$$\frac{77}{9175} \times 190 \approx 1.6\mu b$$

Very preliminary

$$\frac{d\sigma}{d\Omega} = \frac{N_\Theta \times Cor(track) \times Cor(decay) \times Cor(Analysis) \times Cor(DAQ)}{N_{Bean} \times N_{Target}}$$

- ✓Eff(track)≥0.75
- ✓Eff(analysis)≥0.56
- ✓Eff(Decay)=0.57

$$\frac{d\sigma}{d\Omega} \approx 0.2\mu b/sr$$

Assuming s-wave, about 10% of K^- go to spectrometer → σ~2μb

Very preliminary

Theoretical calculation

Cross section for $\pi^- p \rightarrow K^- \Theta^+$

Yongseok Oh et al.

Calculation with effective interaction Lagrangian

→various $g_{K^*N\Theta}$

→form factor

π Production ~100 μb

→ sensitive to $g_{K^*N\Theta}$

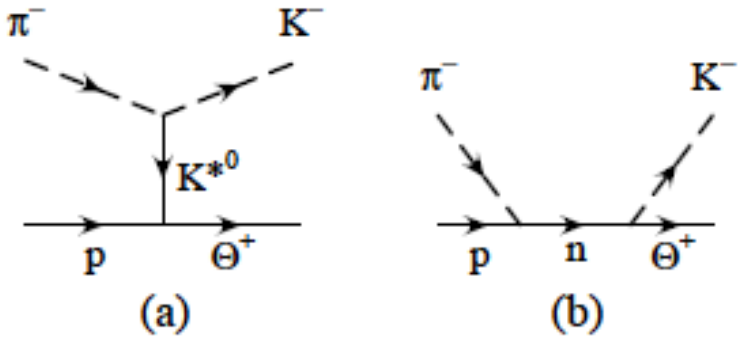
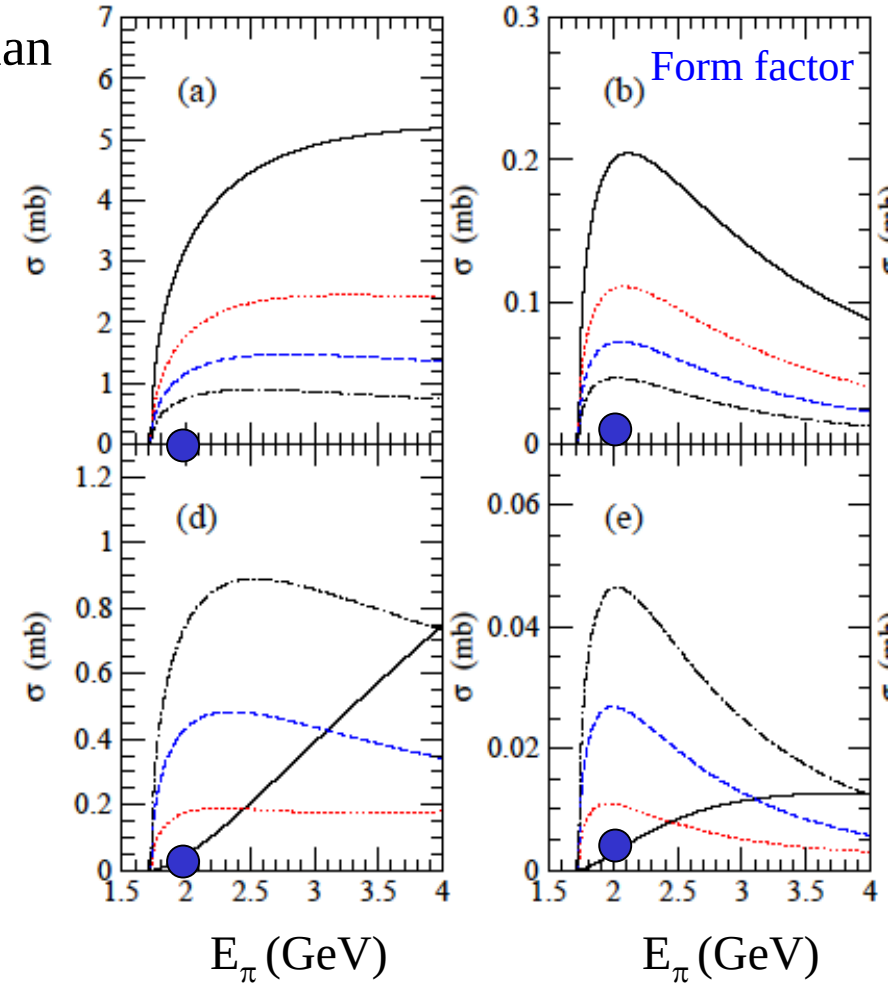


FIG. 6: Diagrams for $\pi^- p \rightarrow K^- \Theta^+$ reaction.



Yongseok Oh *et al.*, hep-ph/0310019

Summary

- We carried out E522 experiment to search Θ^+ via (π^-,K^-) reaction at KEK-PS K2 beam line.
- We used 1.95GeV/c π^- beam and CH_2 target.
- We obtained the missing mass resolution for Θ^+ to be 5.9MeV.
- In the missing mass spectrum of (π^-,K^-) reaction, there is enhancement around 1.53GeV/c^2 but not significant.
- Even if this enhancement is statistical fluctuation, we can estimate upper limit of cross section, and obtained about 2μb assuming K^- is scattered with s-wave.