J-PARC E19
High-resolution Search for Θ^+ Pentaquark in $\pi^-p \rightarrow K^-X$ Reaction

M. Naruki, KEK

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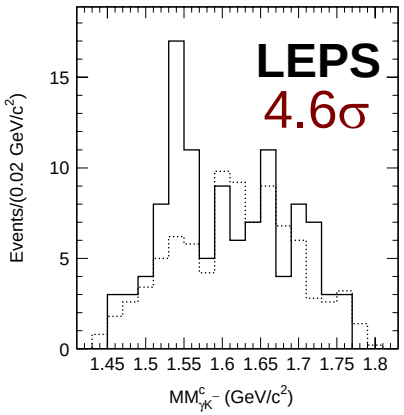
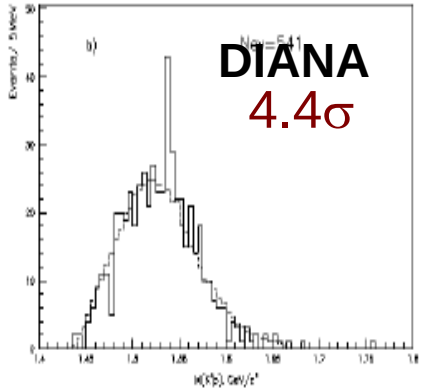
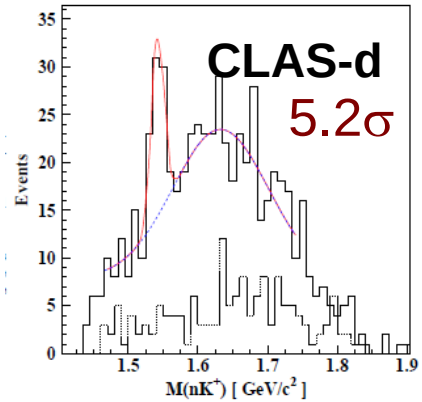
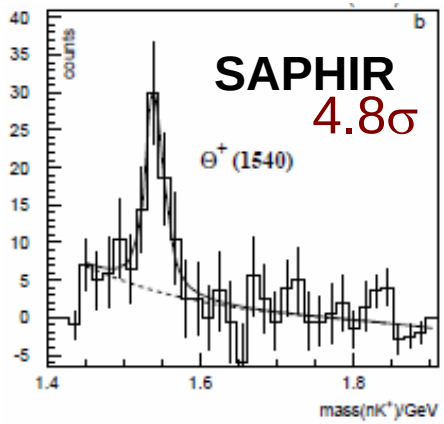
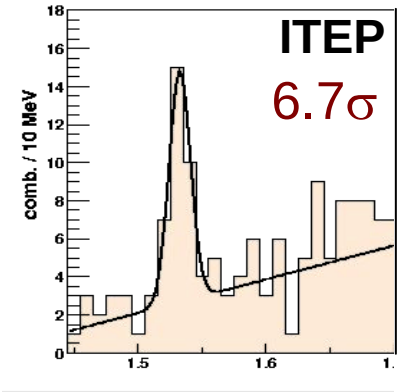
Positive Results

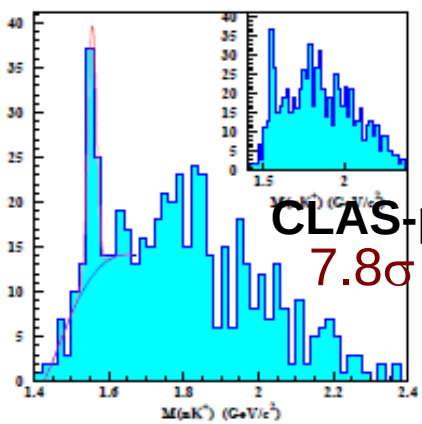


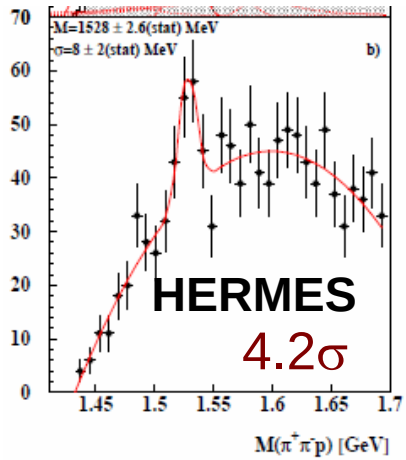


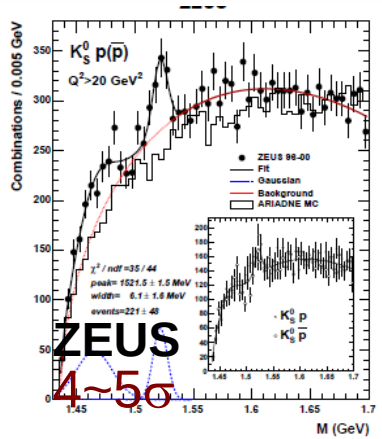


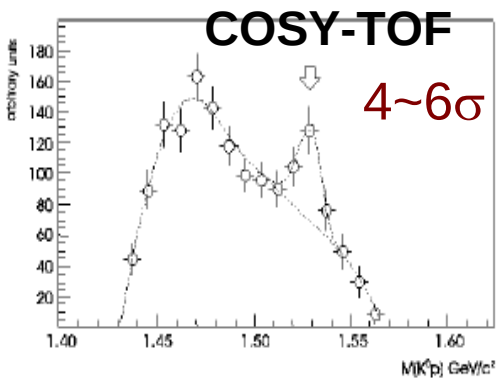


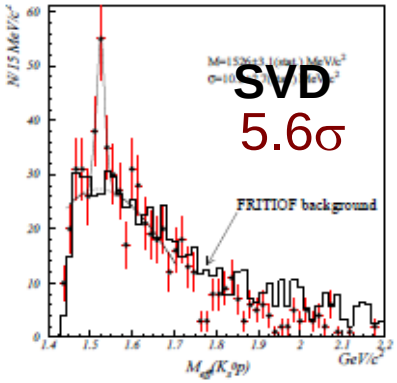










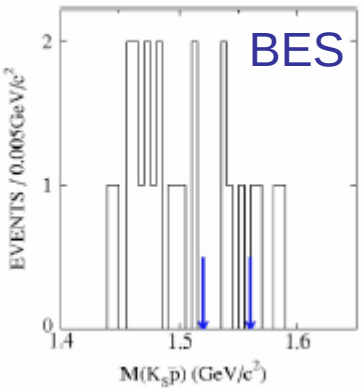


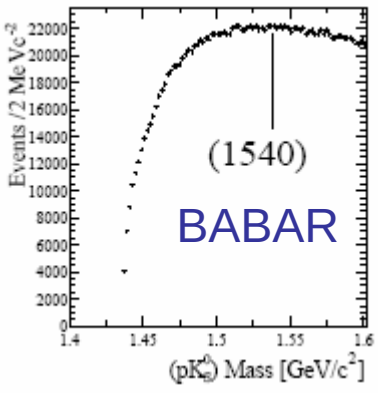
Experiments with positive evidence

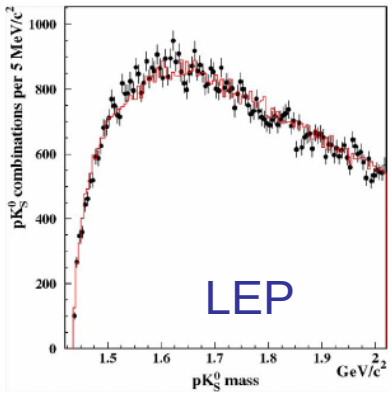
Better statistics is needed

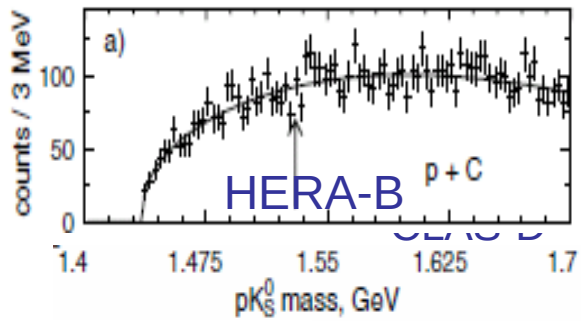
(significance ~ 5σ)

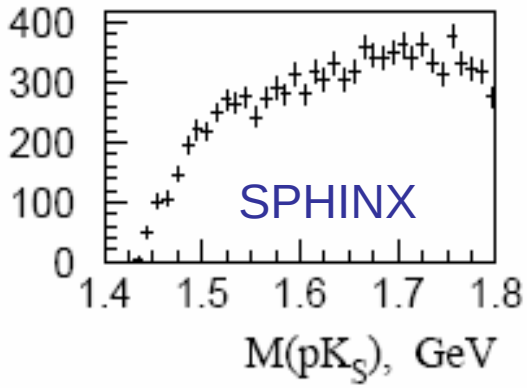
Negative Results

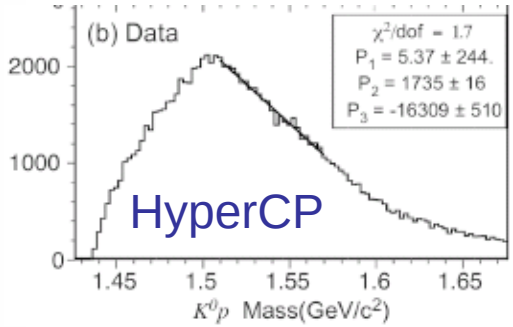


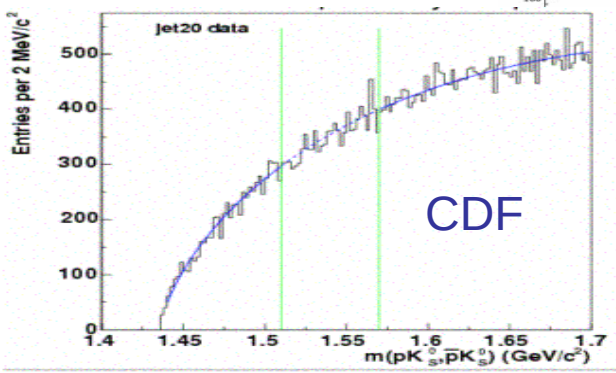


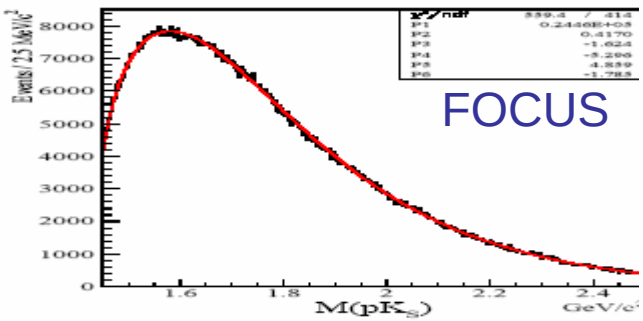


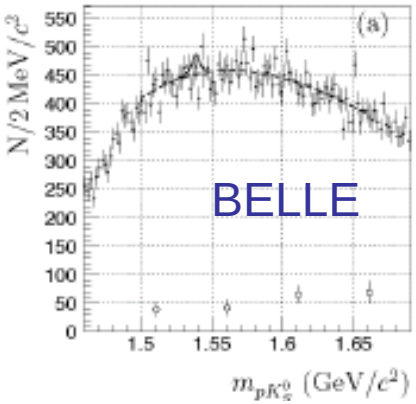


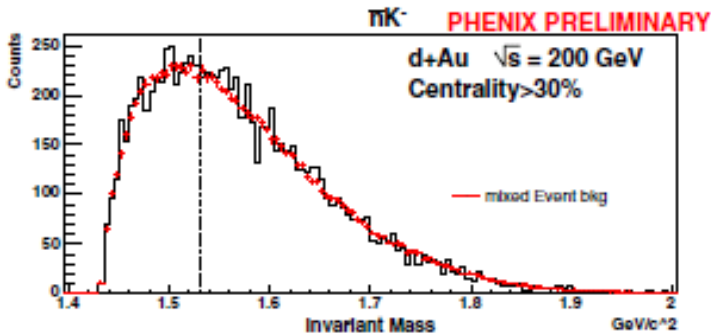












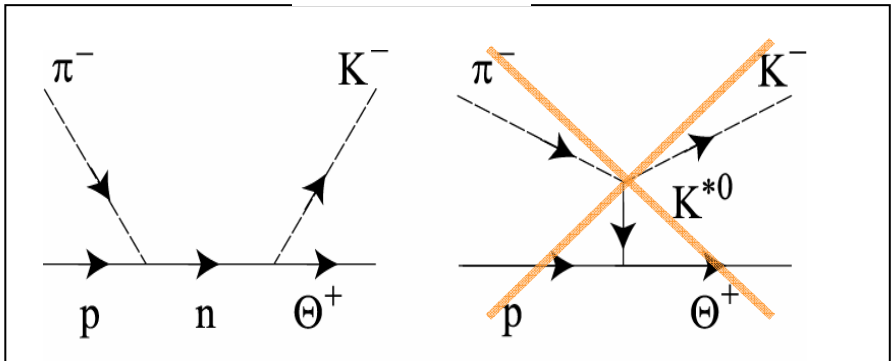
Θ^+ Search in meson-induced reactions

- ✓ Can the "positive" low energy results be reproduced?
  - – better statistics is needed.
- ✓ How far can we restrict the width to?
  - • the width appears to be very narrow. ~ 1MeV.
- ✓ Spin and Parity → width

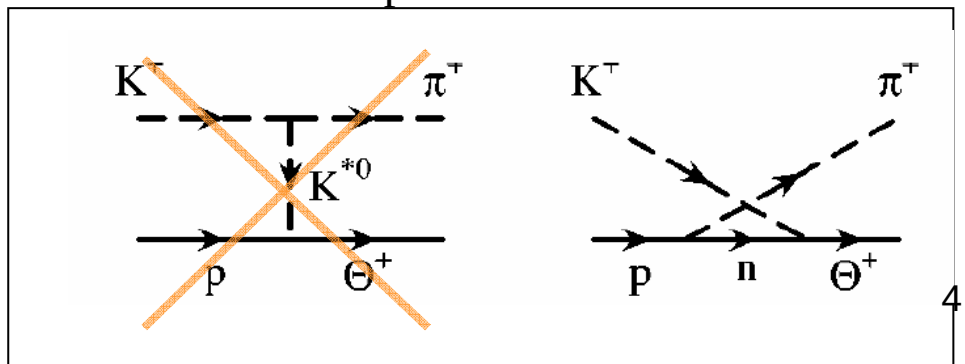
hadronic reaction

Since we already know that the K* coupling is small,
the possible production mechanism will be clarified in the following meson induced reactions.

$\pi^- p \to K^- X$



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



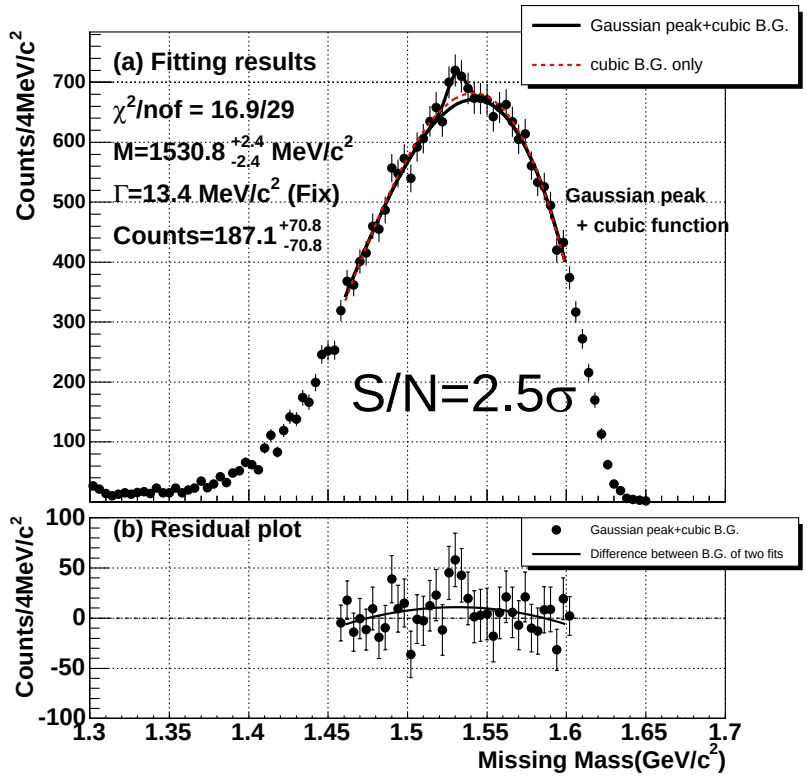
E522 experiment @ KEK-PS K2

- Θ^+ search via $\pi^- p \rightarrow K^- X$ reaction
- beam momentum : 1.87, 1.92 GeV/c
- target : Polyethylene
- intensity : 3.3 X 10^5 π^- /spill
- net beam time : 32 hours for each momentum → ~ 7 X 10^9 π^-

a bump was observed
at M =1530.8MeV/c2
at p_π=1.92 GeV/c
but : S/N = 2.5σ
upper limit : σ_{tot} = 3.9μb

if exist

p_π=1.92 GeV/c



$d\sigma/d\Omega$ = 1.9 μb/sr
→ σ_{tot} = 2.9 μb

J-PARC E19 experiment

- natural expansion of E522 ($\pi p \rightarrow KX$@K2)
- ~5 times better resolution : ~ 2.5MeV FWHM with SKS
  - 10 times better S/N
- 100 times larger yield : 1.2 X 10^4 Θ^+ with 20 shifts

- expected sensitivity (lab) 75nb/sr $\Gamma <$ 2 MeV $\rightarrow$ σ_{tot} ~112nb
  150nb/sr Γ = 10 MeV
- momentum dependence of cross section :
  p_π=(1.87,1.92,1.97GeV/c)

confirm Θ^+ existence with high statistics

Collaboration

KEK	M. Naruki, S. Ishimoto, N. Saito, Y. Sato, S. Sawada and M. Sekimoto
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Osaka Univ.	S. Ajimura
RIKEN	M. Niiyama
Tohoku Univ.	T. Maruta, K. Miwa, H. Tamura
Univ. of Tokyo	H. Fujioka, D. Nakajima and T.N. Takahashi

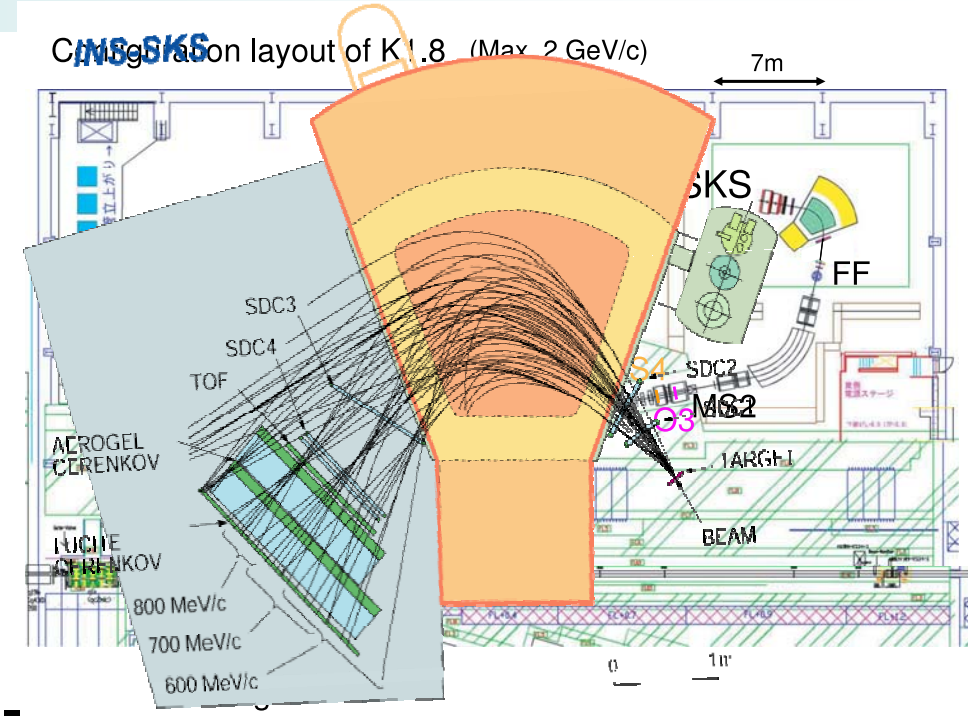
Experimental Method

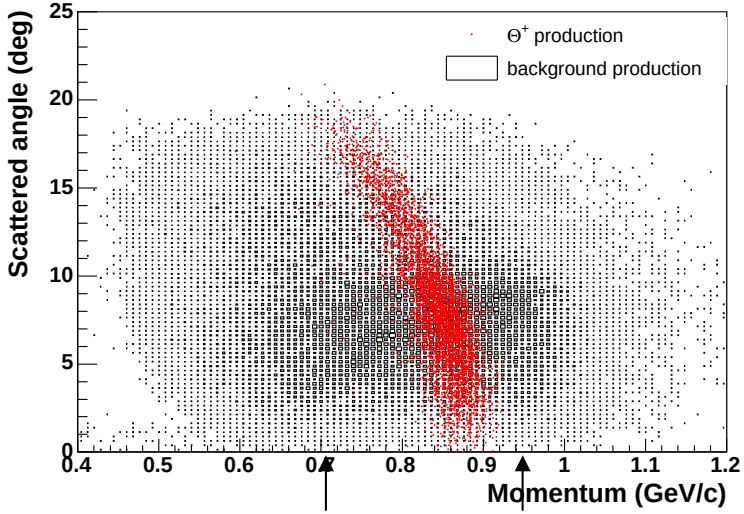
K1.8 beam line + SKS

2GeV/c $\pi^- + p \rightarrow K^- + \Theta^+$
target : liquid H_2, reuse E559's

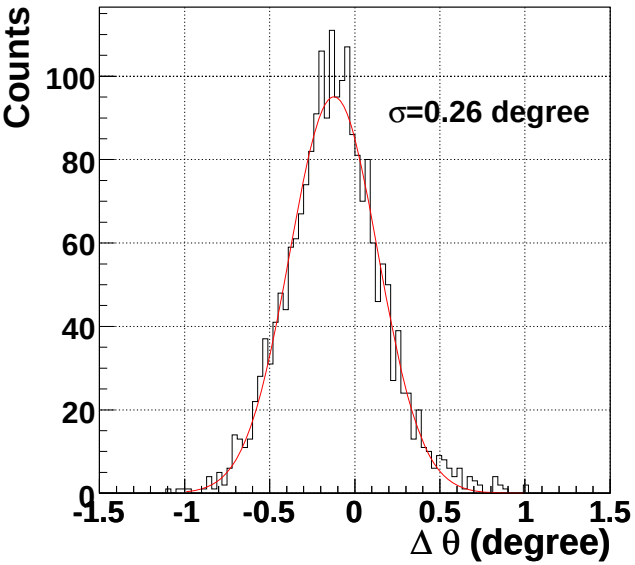
K^- : scattered angle ≤ 40°
momentum up to 0.9 GeV/c

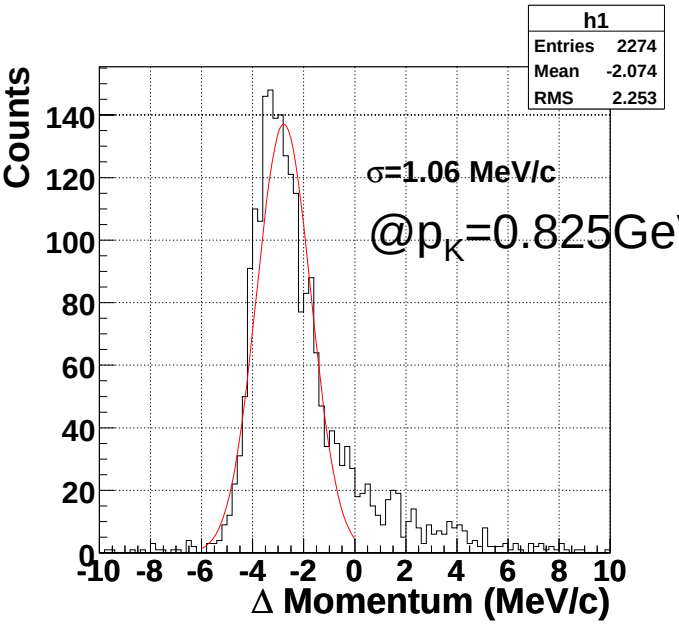
SKS : momentum coverage : 0.7-0.95GeV/c
angle coverage ≤ 20°
$p_{scattered}$ up to ~ 1.1 GeV/c
dp/p ~ 0.2% @ 1GeV/c
(~10 times better than KURAMA)
ideal for Θ^+ detection

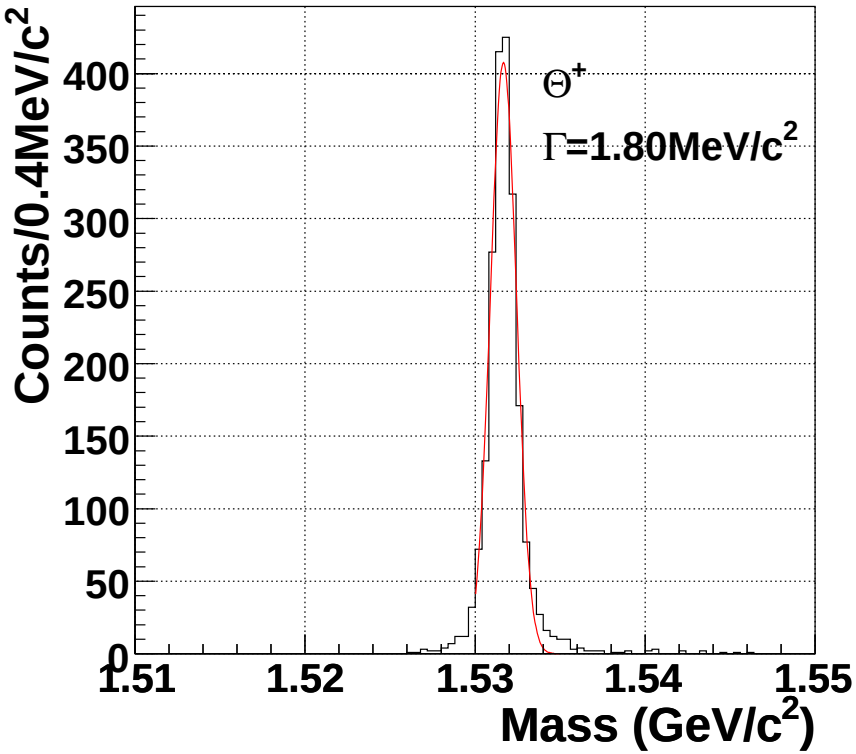




Missing Mass Resolution







ΔM = 1.8 MeV (FWHM sim.)

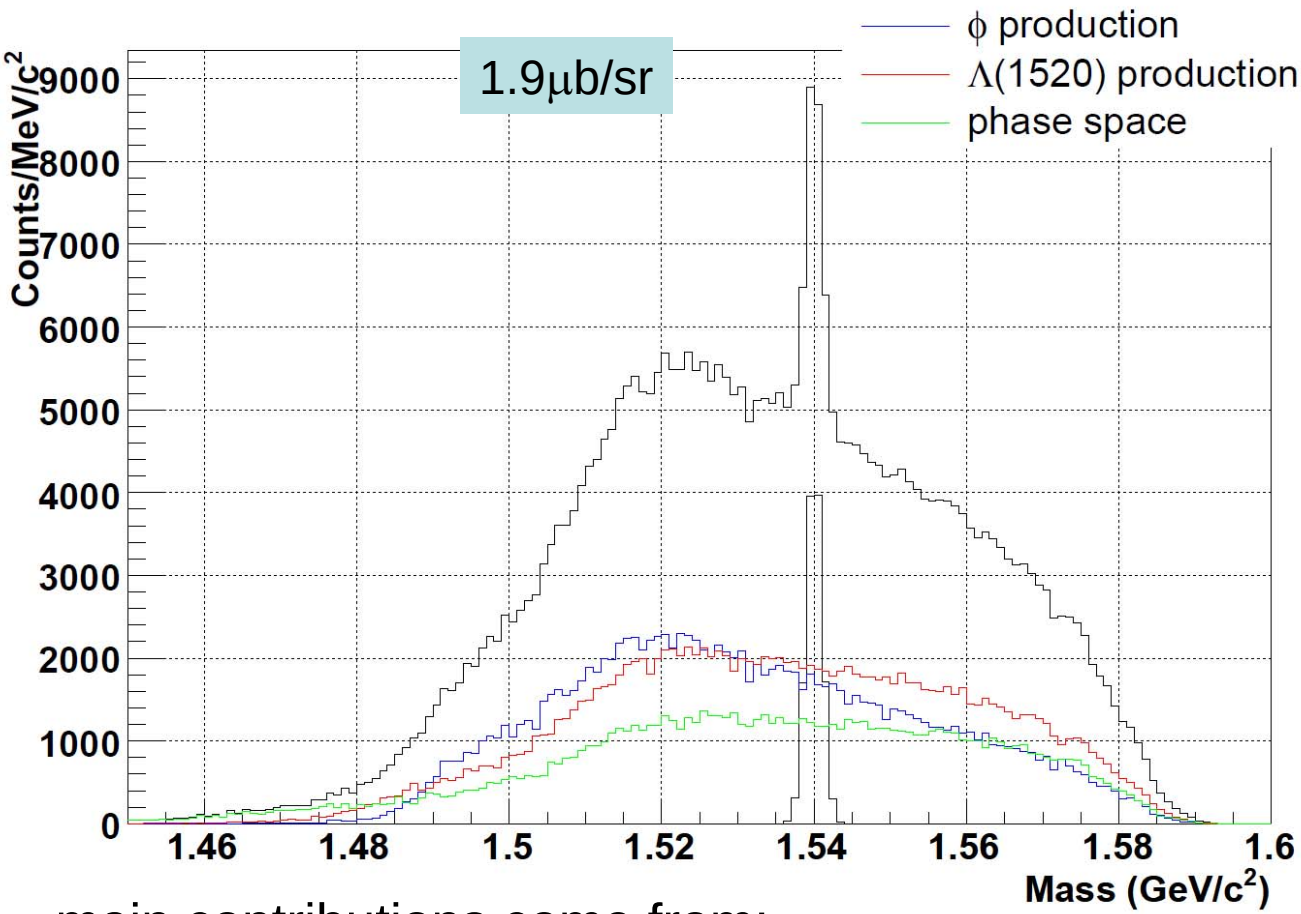
$\sigma_\theta = 0.26^\circ$

$dp_K/p_K = 0.096 \times p\% + 0.092\%$

$dp_{beam}/p_{beam} = 1.4 \times 10^{-4}$ @ 1 GeV/c

→ ΔM = 2.5 MeV (FWHM calc.)

Missing mass simulation



significance : 62σ
assuming
Γ < 2MeV
σ = 1.9μb

main contributions come from;

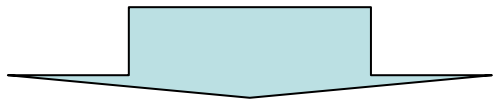
φ :	$\phi n \rightarrow K^+K^-n$	30.0±8.0 μb
Λ :	$\Lambda(1520)K^0 \rightarrow K^-pK^0$	20.8±5.0 μb
phase space :	K^-KN	26 μb

Expected Yield & Sensitivity

- Improvements
  - 5 times better resolution : ~ 2.5MeV FWHM with SKS
  - 10 times better S/N
  - 100 times larger yield : 1.2 X 104 Q+ with 20 shifts
- yield
  - beam pions :160 hours beam time → 4.8 X 10^{11} π for each p_π
  - SKS acceptance : 0.1 sr
  - analysis efficiency : 50%
  - K decay : 50% ← TOF 4.7m
  - 1.9μb/sr @ p_π=1.92GeV/c ← E522

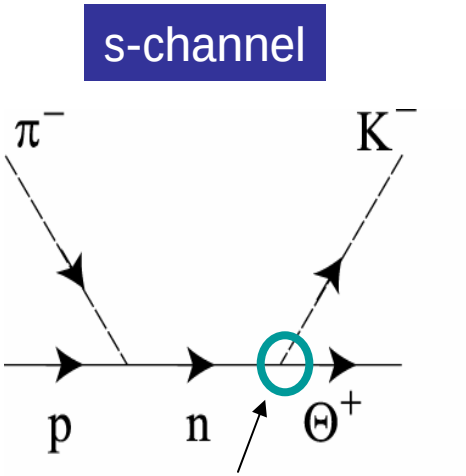
    → 1.2 X 10^4 events
- background
  - 0.8 μb/sr/MeV @ 1.530MeV for proton target ← E522
  - momentum flat

    → 5.0 X 10^3 counts/MeV



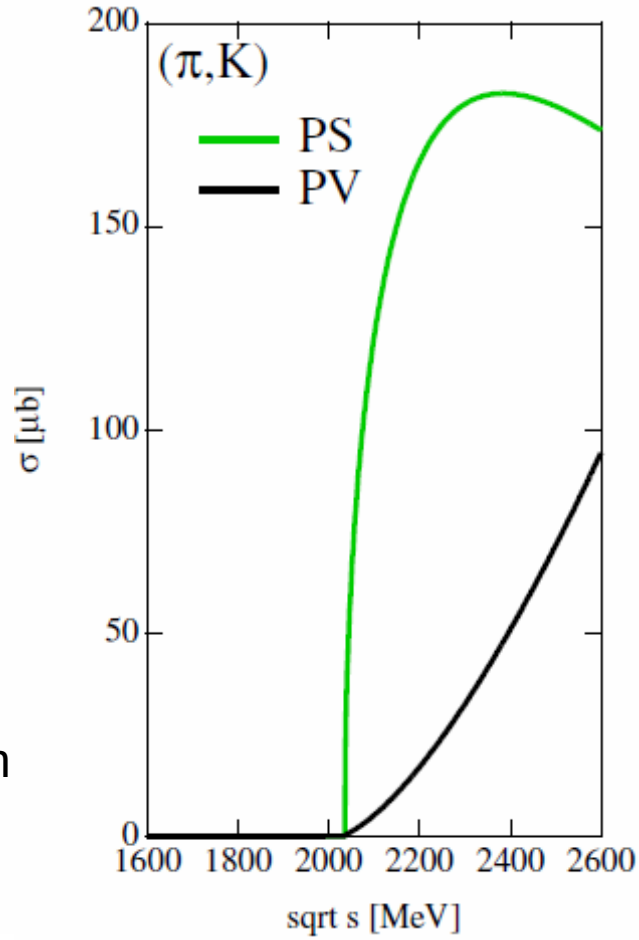
statistics	sensitivity
62σ $\Gamma <$ 2 MeV	75nb/sr $\Gamma <$ 2 MeV

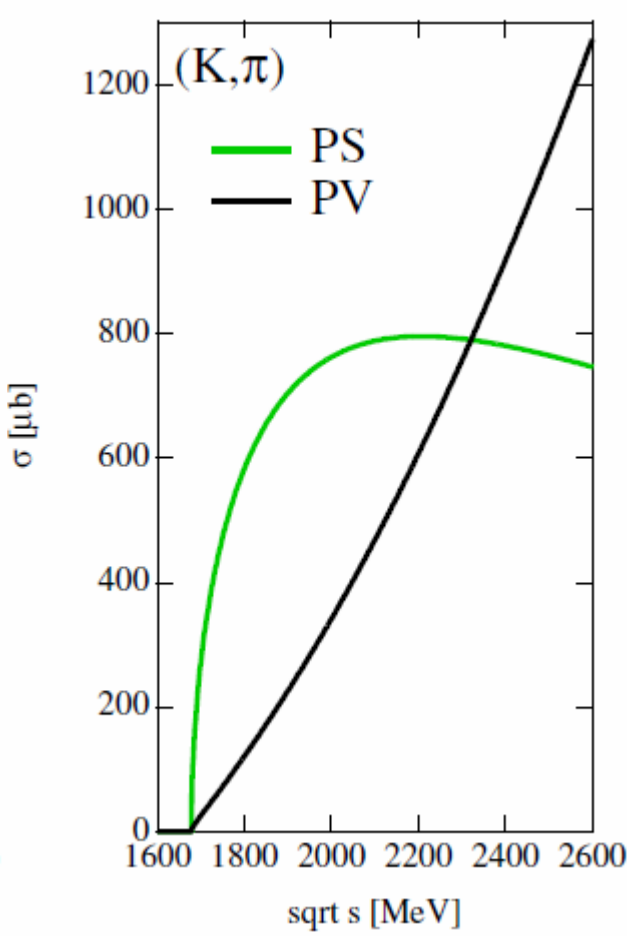
Impact on Θ^+



cross section $\propto$ width

sizable as far as the width is finite.





T. Hyodo, priv. comm.

	$P_{\rm lab} = 1.92$ GeV $\pi^- p \to K^- \Theta^+$		$P_{\rm lab} = 1.2$ GeV $K^+ p \to \pi^+ \Theta^+$	
	PS	PV	PS	PV
without form factor	63 [μb]	4.9 [μb]	55 [μb]	1.0 [μb]
F_s, $\Lambda_s = 500$ MeV	4.2 [μb]	0.33 [μb]	9.4 [μb]	0.17 [μb]
F_c, $\Lambda_c = 1800$ MeV	2.4 [μb]	0.19 [μb]	38 [μb]	0.71 [μb]

Summary

- E522 experiment searched for Θ^+ in (π^-, K^-) reaction and observed bump structure around 1.53GeV with statistical significance of 2.5σ.

- J-PARC E19 experiment searches for Θ^+ in (π^-, K^-).
  - K1.8 beam line + SKS is ideal for Θ^+ production
  - s-channel production at low energy: $\sigma \propto \Gamma$
  - hadronic reaction → high statistics
  - with high mass resolution; 2.5MeV(FWHM)