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

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Collaboration

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Proposed Exp. – Abstract –

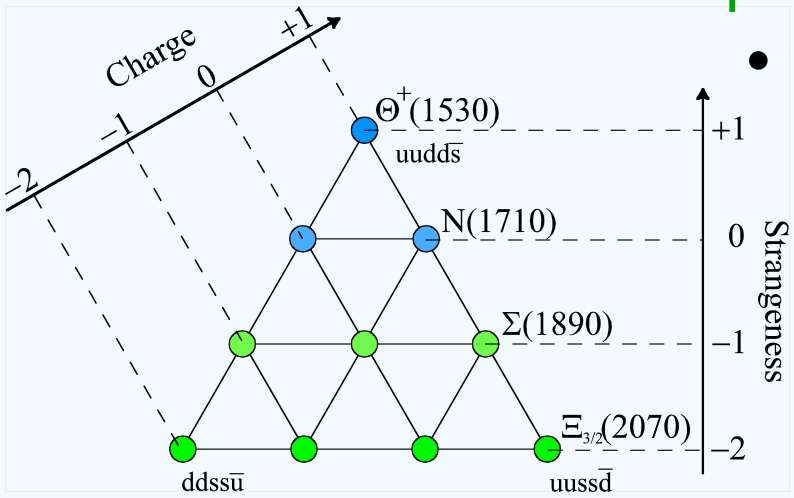
- natural expansion of E522 (πp→KX@K2)
- ~5 times better resolution : ~ 2.5MeV FWHM with SKS
  - 10 times better S/N
- 100 times larger yield : 1.2 X 10^4 Θ^+ with 20 shifts

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

- Goal -
  confirm Θ^+ existence with high statistics

The Θ^+ baryon

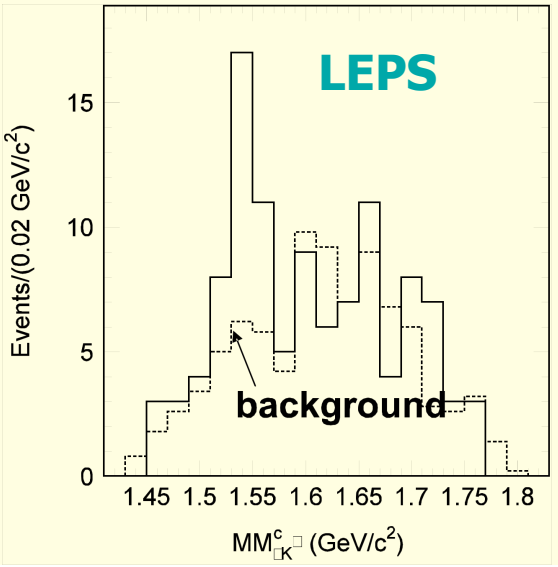
Theoretical prediction



- Diakonov et al. (’97)
  - Chiral soliton model
  - Anti-decuplet
  - M=1530 MeV, Γ< 15MeV
- irreducible 5 quark(uudds̄) state

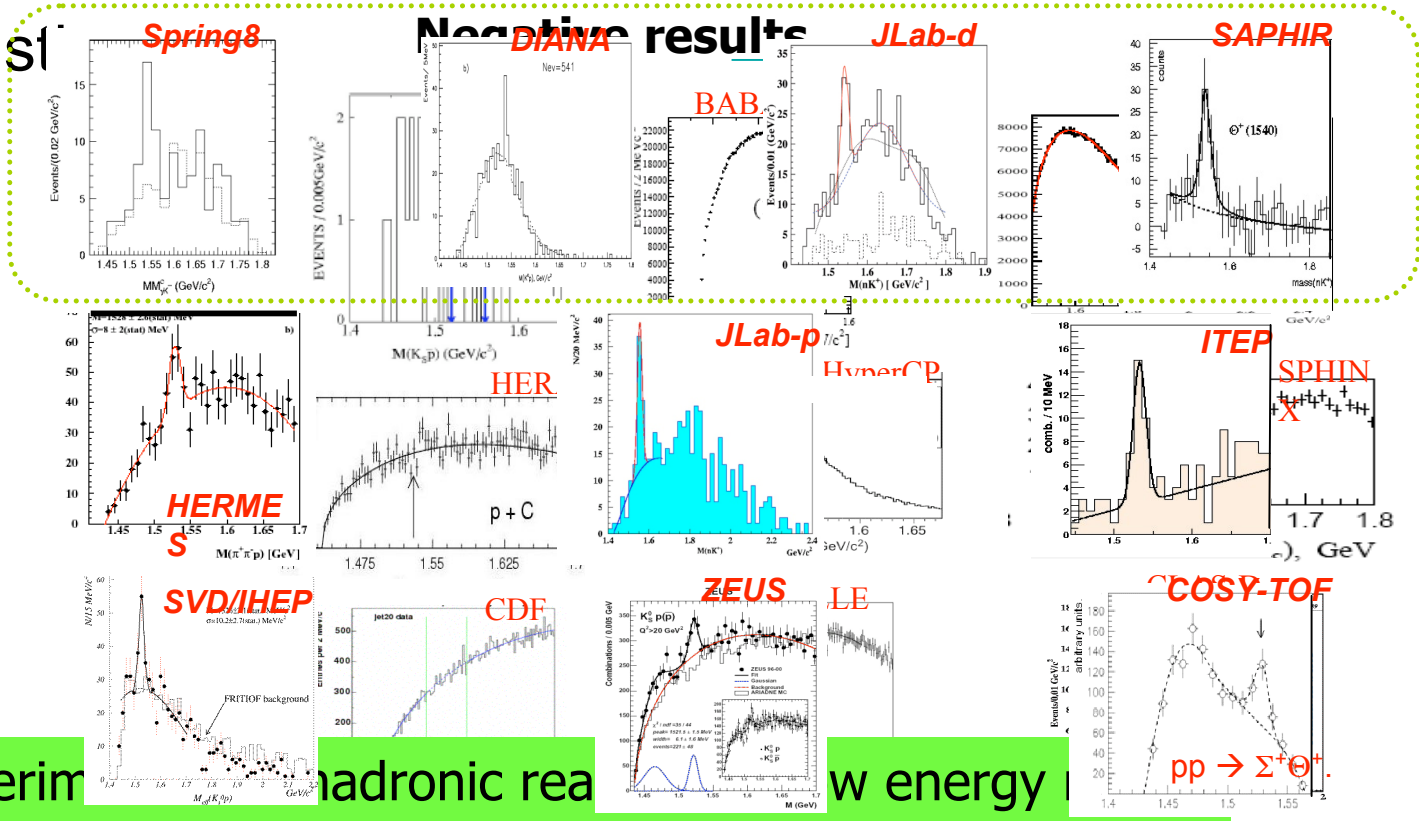
Experiment

- LEPS at Spring-8 (’03)
  - $\gamma n \rightarrow K^- \Theta^+ \rightarrow K^- K^+ n$
  - M=1540±10 MeV
  - Γ<25 MeV



Controversial status

- Experiments with positive evidence
  - Better statistics is needed (significance ~ 5σ)
- Experiments with negative results
  - High statist



High statistics experim[illegible]adronic rea[illegible]w energy

Θ^+ search via hadronic reaction

- multiquark system : to test the QCD in non perturbative regime.
  - how tightly are they bound?
  - qqqqq → qqq + qq : wide width?
- the narrow width (< 1 MeV) is remarkable characteristic.
  - What is the reason of this suppression?
  - ex. diquark model by Jaffe & Wilczek
    - -- exchange of quark combination
    - -- excitation of orbital angular momentum
  - effective forces between quarks

- To show the narrow pentaquark really exist (or not).
- We search for Θ^+ via hadronic reaction
  - high statistics
  - less ambiguity

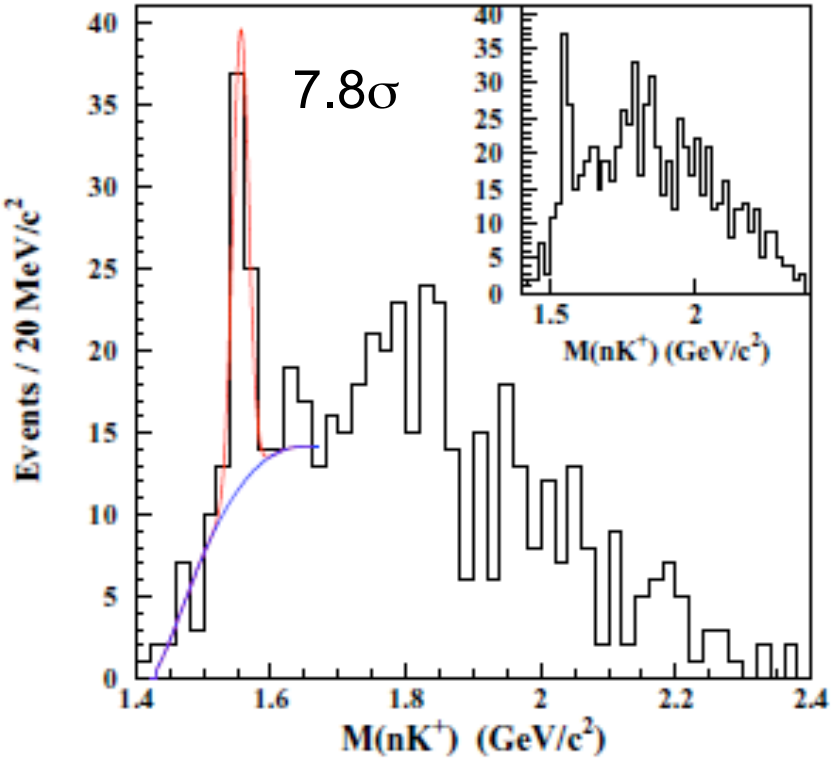
■ $\pi^- p \rightarrow K^- \Theta^+$

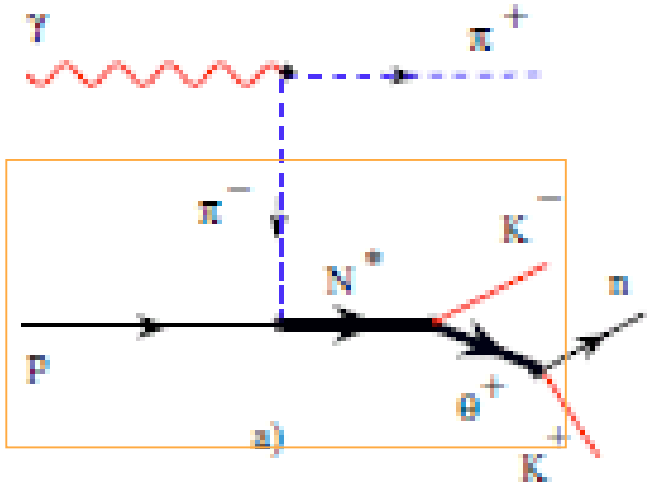
s-channel via N*

- CLAS observed Θ^+ in $\gamma p \rightarrow \pi^+ K^- K^+ n$ reaction.
- if s-channel is dominant, Θ^+ production is reduced at higher energies.

→ this process possibly exists in $\pi p \rightarrow n \rightarrow K^- \Theta^+$ reaction!

$\gamma p \rightarrow \pi^+ K^- K^+ (n)$





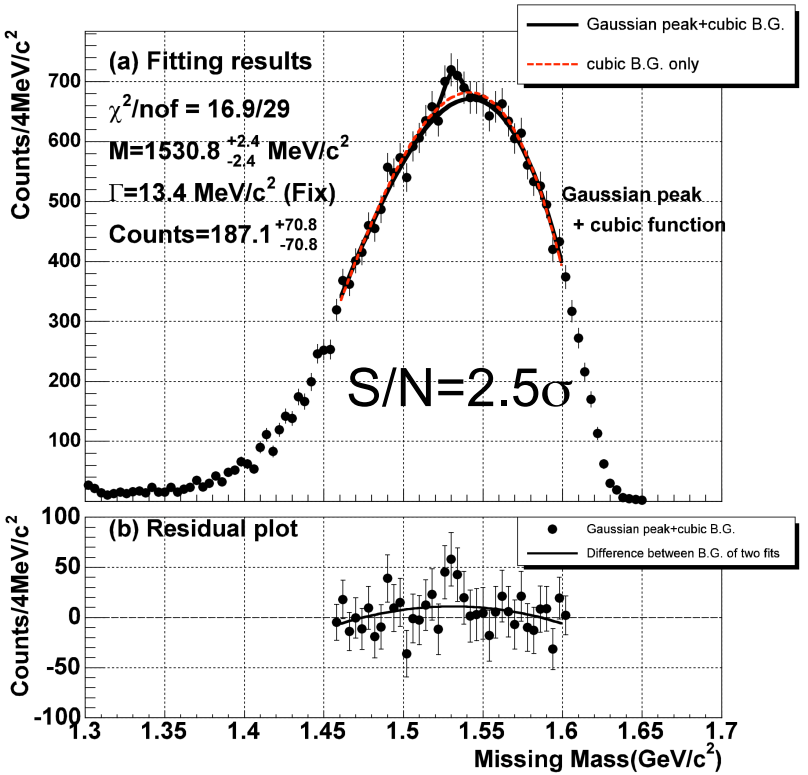
E522 experiment @ KEK-PS K2

- 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

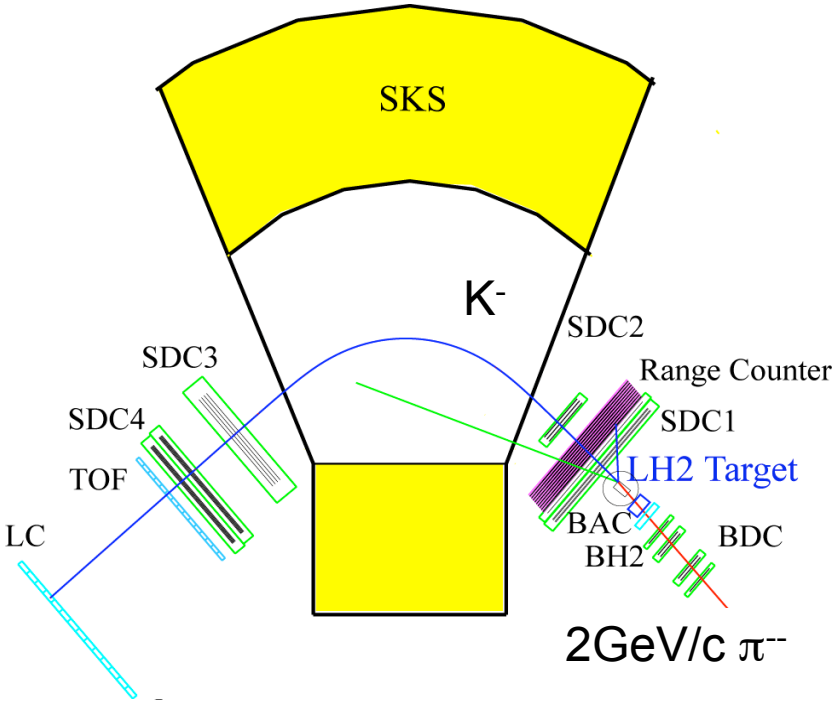
Experimental Method

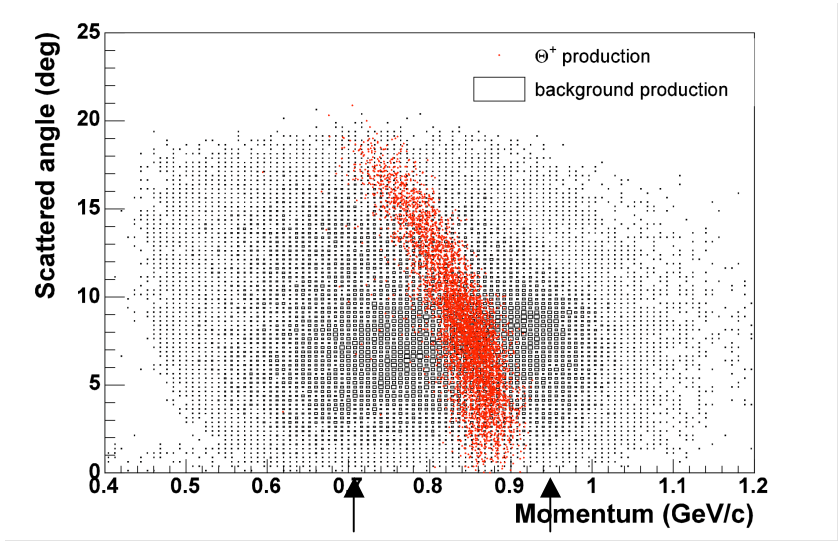
K1.8 beam line + SKS

2GeV/c π^- + p → K^- + Θ^+
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





Rate Estimation

acceptable beam intensity is limited to
rate capability of the beam line chamber

- tracking chambers @PS K6 : 5mm pitch
  - stands up to
    $4 \times 10^6 \times 1.1$(protons) /1.8sec = $5 \times 10^6\ \pi^-$ /sec
- new tracking chambers; 1mm pitch MWPC
  - 5×10^6 /sec X 5 / 1 mm = 1.3×10^7 /sec

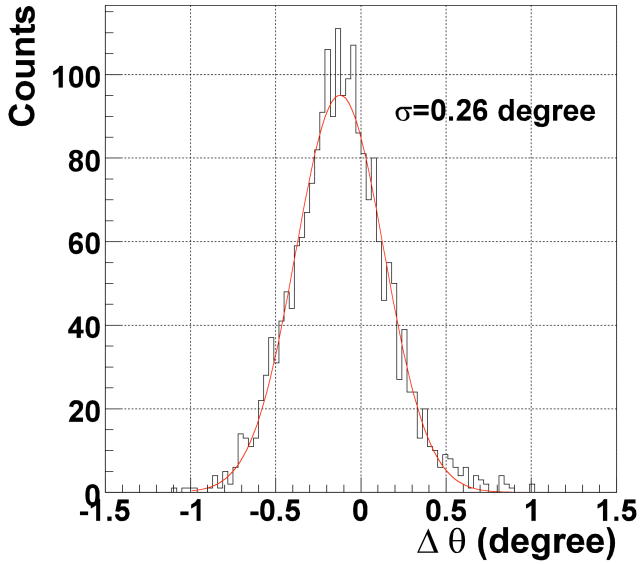
  → 1.0×10^7 /spill w/ 0.7 sec flat top

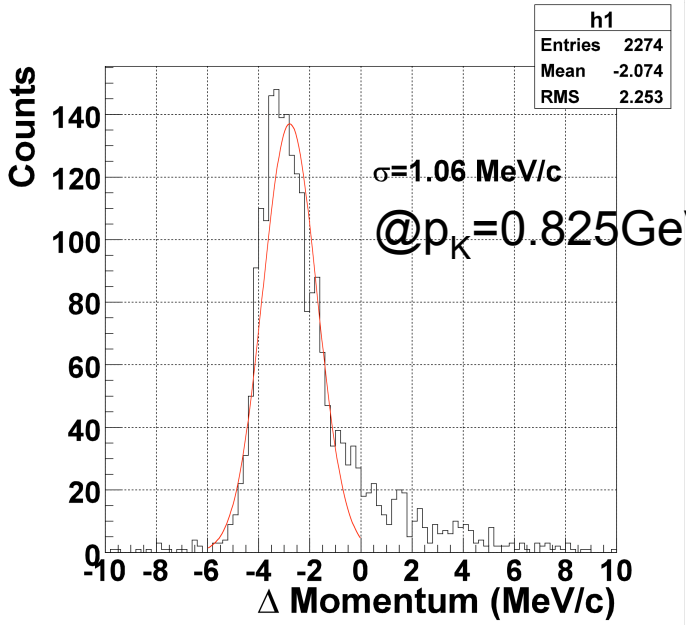
  → 1.5×10^7 /spill w/ 1.4 sec flat top

required number of protons : 4×10^{12} pps

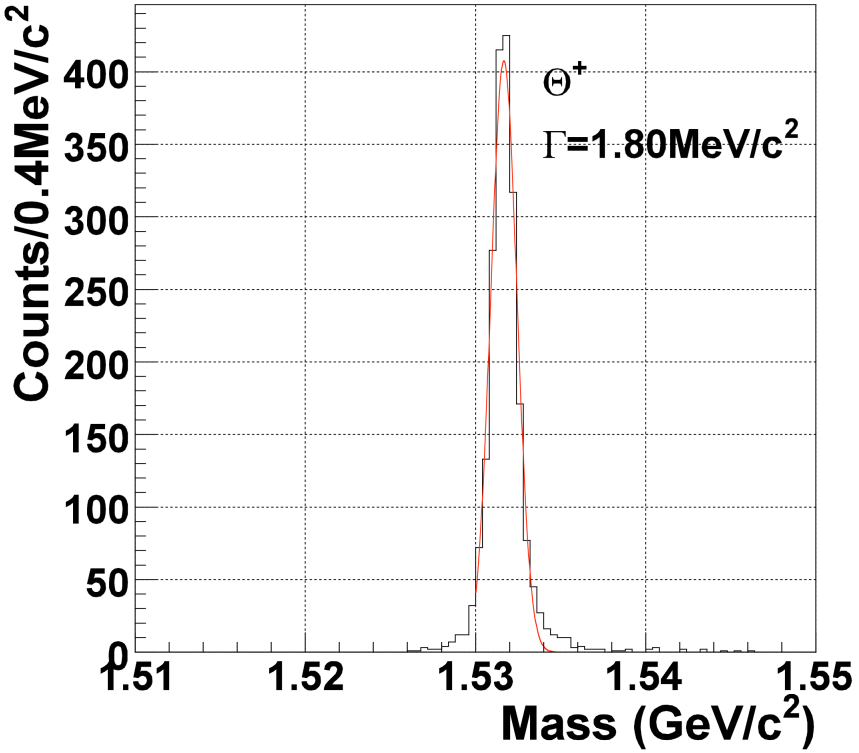
~ 1/50 of DAY-I intensity

Missing Mass Resolution





@p_K=0.825GeV/c



ΔM = 1.8 MeV (FWHM sim.)

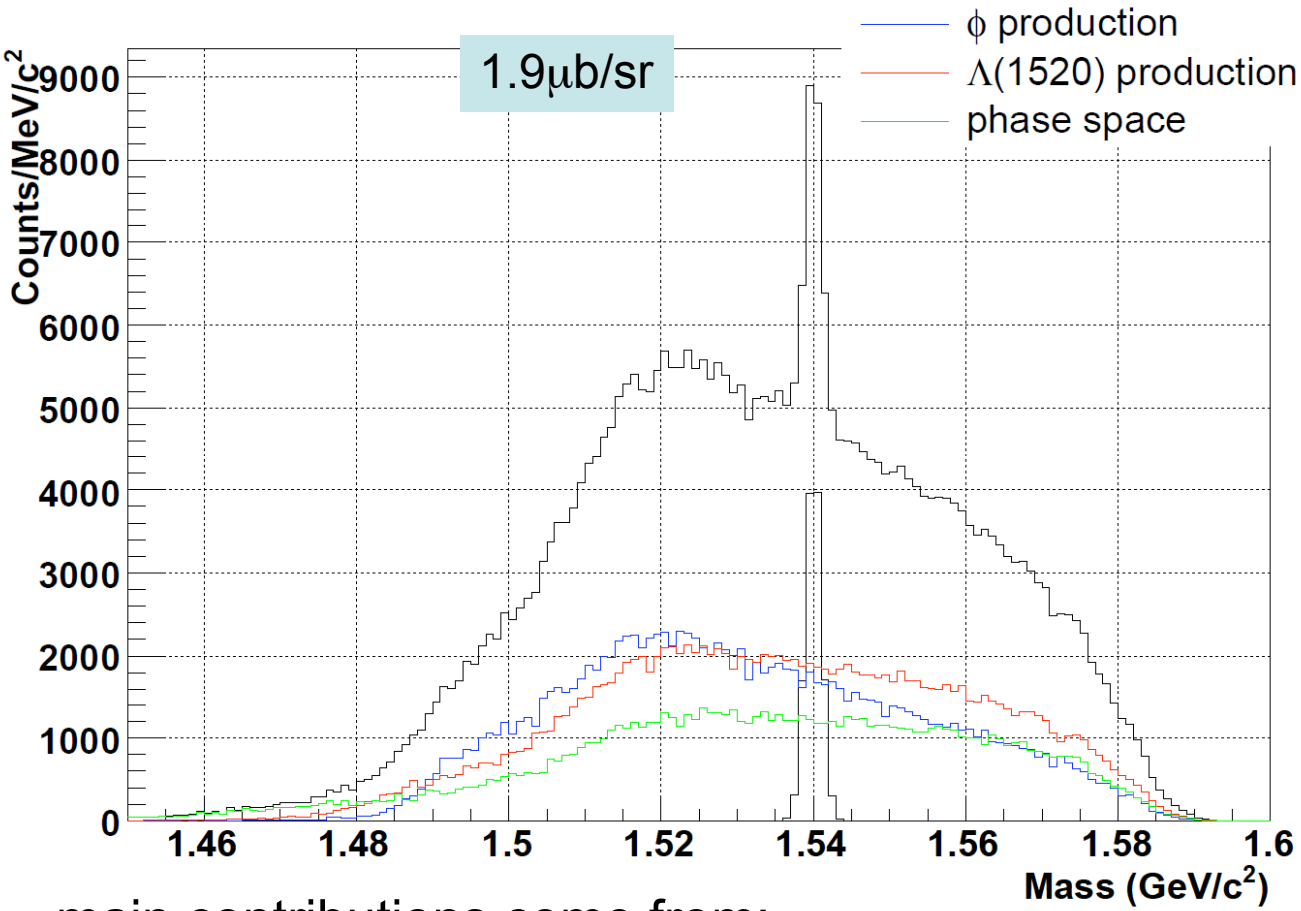
$\sigma_\theta = 0.26°$

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

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

→ ΔM = 2.5 MeV (FWHM calc.)

Missing mass simulation



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

main contributions come from;

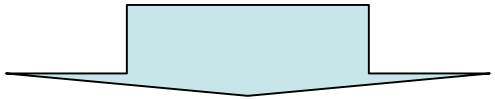
ϕ :	$\phi n \rightarrow K^+K^-n$	30.0±8.0 μb
Λ :	$\Lambda(1520)K^0 \rightarrow K^-K^0p$	20.8±5.0 μb
phase space :	K^-KN	26 μb

Expected Yield & Sensitivity

- 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 Γ < 2 MeV	75nb/sr Γ < 2 MeV
48σ Γ = 10 MeV	150nb/sr Γ = 10 MeV

Summary

- J-PARC K1.8 beam line + SKS is ideal for Θ+ production
  - at low energy
  - in hadronic reaction → high statistics
  - with high mass resolution
- If exist;
  - confirm Θ^+ existence with high-statistics.
  - production mechanism : $\pi^- p \rightarrow K^- \Theta^+$