K^-pp search experiment in the $d(p^+,K^+)$ reaction at J-PARC

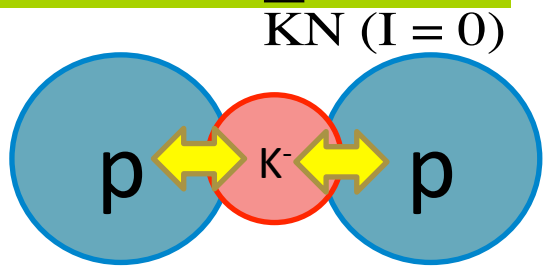
Hiroyuki Ekawa
Dept. of Phys., Kyoto Univ.

for the J-PARC E27 collaboration

YITP workshop on Hadron in Nucleus
1st Nov. 2013

Contents

K^-pp bound state

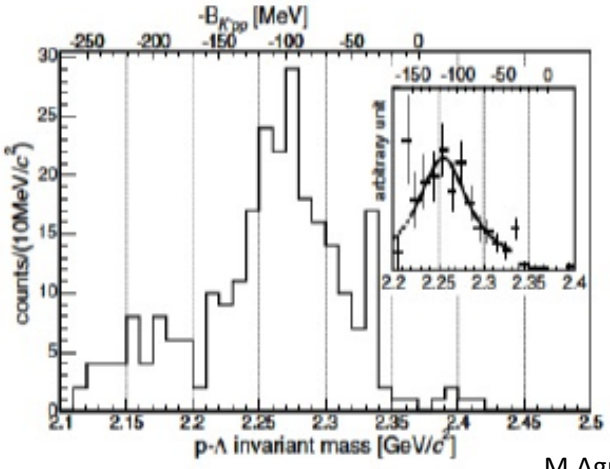


- The attractive interaction between $\overline{K}N(I = 0)$ is expected to form nuclear $\overline{K}$ bound system.
- K^-pp is the simplest nuclear $\overline{K}$ bound state.
- Theoretical prediction of B.E. and Γ depends on the $\overline{K}N$ interaction models and the calculation method .

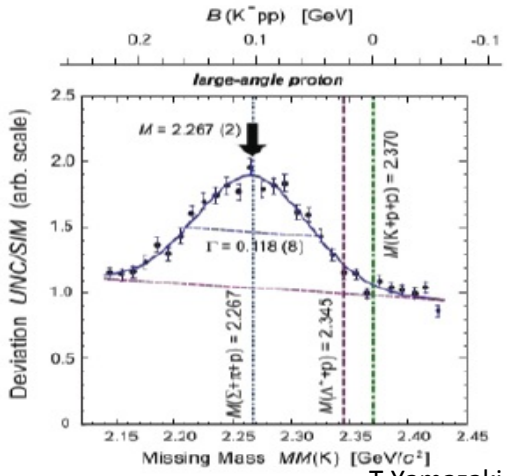
	Theoretical prediction	B.E（MeV）	Γ（MeV）
PRC76, 045201 (2002)	T. Yamazaki and Y. Akaishi	48	61
arXiv:0512037v2[nucl-th]	A. N. Ivanov, P. Kienle, J. Marton, E. Widman	118	58
PRC76, 044004 (2007)	N. V. Shevchenko, A. Gal, J. Mares, J. Revai	50 -- 70	~100
PRC76, 035203 (2007)	Y. Ikeda and T. Sato	60 -- 95	45 -- 80
NPA804, 197 (2008)	A. Dote, T. Hyodo, W. Weise	20 ±3	40 -- 70
PRC80, 045207 (2009)	S. Wycech and A. M. Green	56.5 -- 78	39 -- 60
Nucl.Phys. A914 (2013)	M. Bayar and E. Oset	15 -- 30	75 -- 80

Previous experiments

	FINUDA	DISTO
Reaction	Stopped K^- absorption on $^{6,7}Li$ + ^{12}C	p + p @ Tp=2.85GeV
Method	Invariant mass of back to back Λp pairs	$p+p \rightarrow X+K^+$ （missing mass） $X \rightarrow \Lambda+p$ （invariant mass）
B.E	$115\ ^{+6}_{-5}$ (stat) $^{+3}_{-4}$ (syst) MeV	105 ± 5 MeV
Width	$67\ ^{+14}_{-11}$ (stat) $^{+2}_{-3}$ (syst) MeV	118 ± 8 MeV



M.Agnello *et al.*,
PRL 94, 212303 (2005)



T.Yamazaki *et al.*,
PRL 104, 132502 (2010)

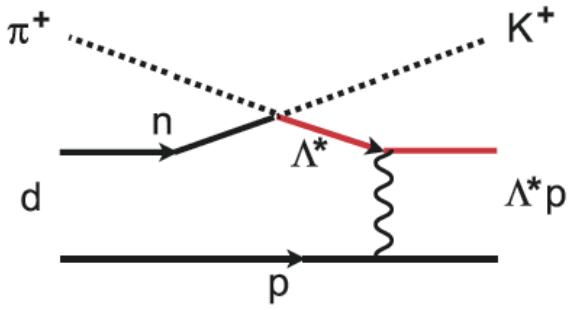
E27 experiment

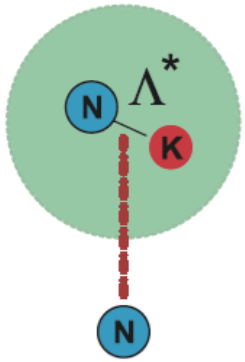
d(π⁺,K⁺) reaction

$\pi^+ + \text{"n"} \rightarrow \text{"}\Lambda^*\text{"} + K^+$

"Λ*" + "p" --> bound K^-pp *minor*

--> quasi-free Λ* *dominant*

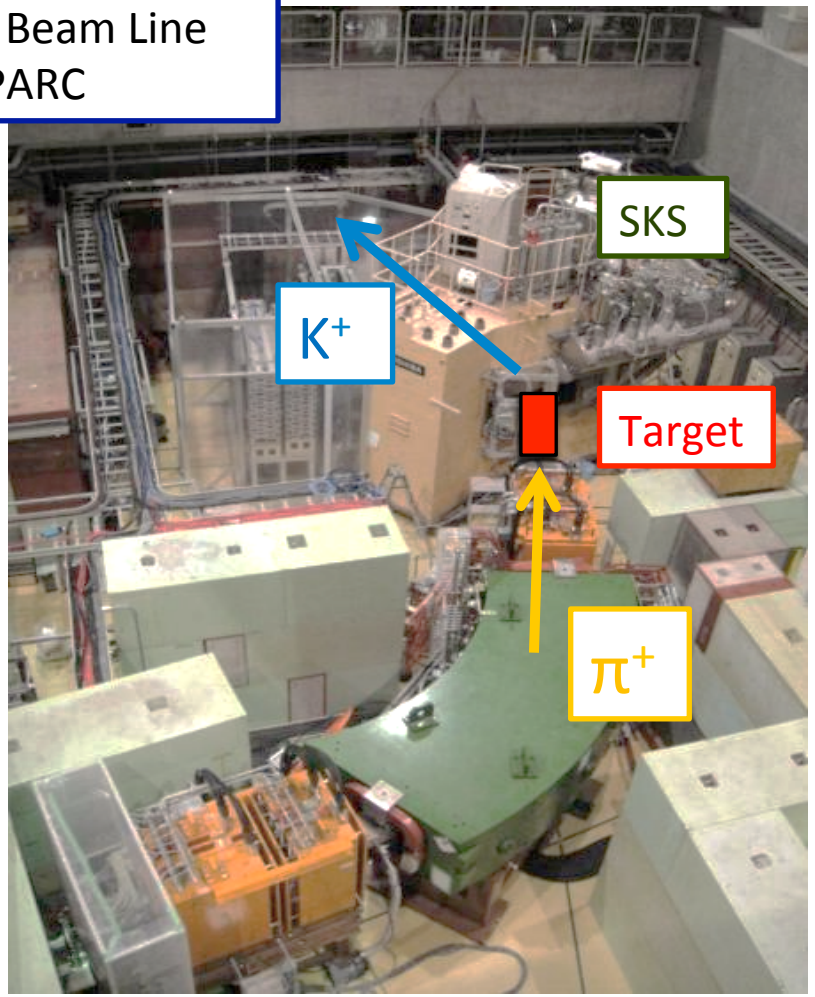




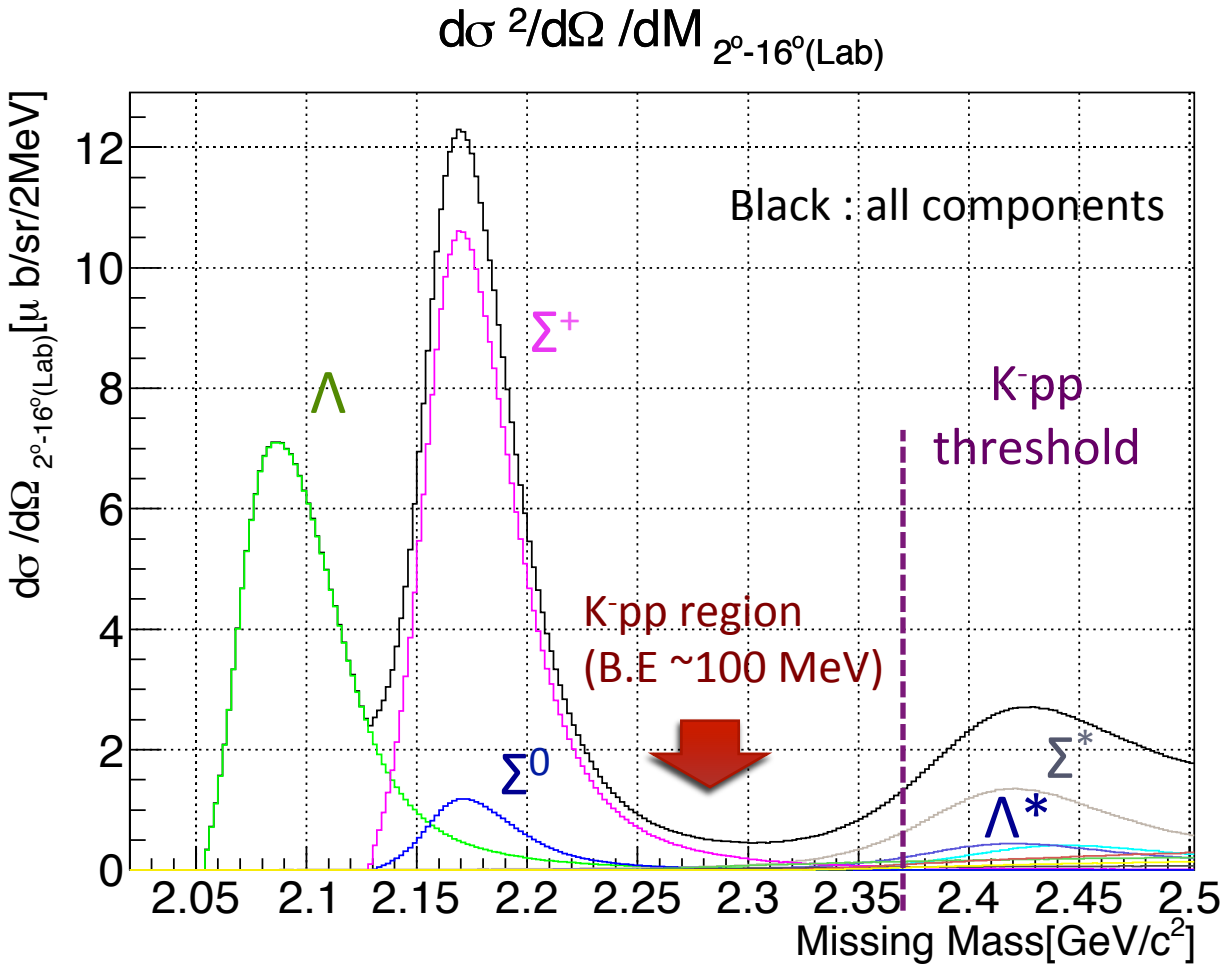
Y.Akaishi, T.Yamazaki, Phys. Rev. C 76 045201 (2007)

Λ (1405) doorway

K1.8 Beam Line
@J-PARC



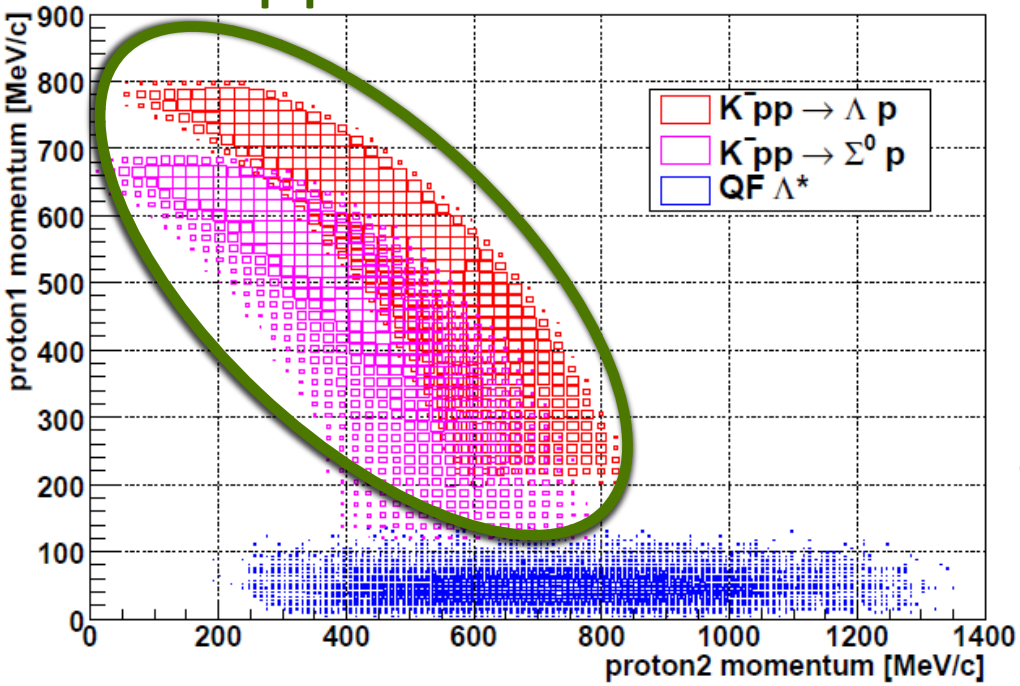
d(π⁺,K⁺) inclusive spectrum (simulation)



K⁻pp signal is hidden by other processes.

Exclusive measurement

K^-pp



- K^-pp decay (non mesonic)

$K^-pp \rightarrow \Lambda + p_1$

$\Lambda \rightarrow p_2 + \pi^-$

$K^-pp \rightarrow \Sigma^0 + p_1$

$\Sigma^0 \rightarrow (\Lambda\gamma) \rightarrow p_2 + \pi^- + \gamma$

- background

slow !

$\pi^+ + d \rightarrow \Lambda^* + K^+ + p_{1s}$

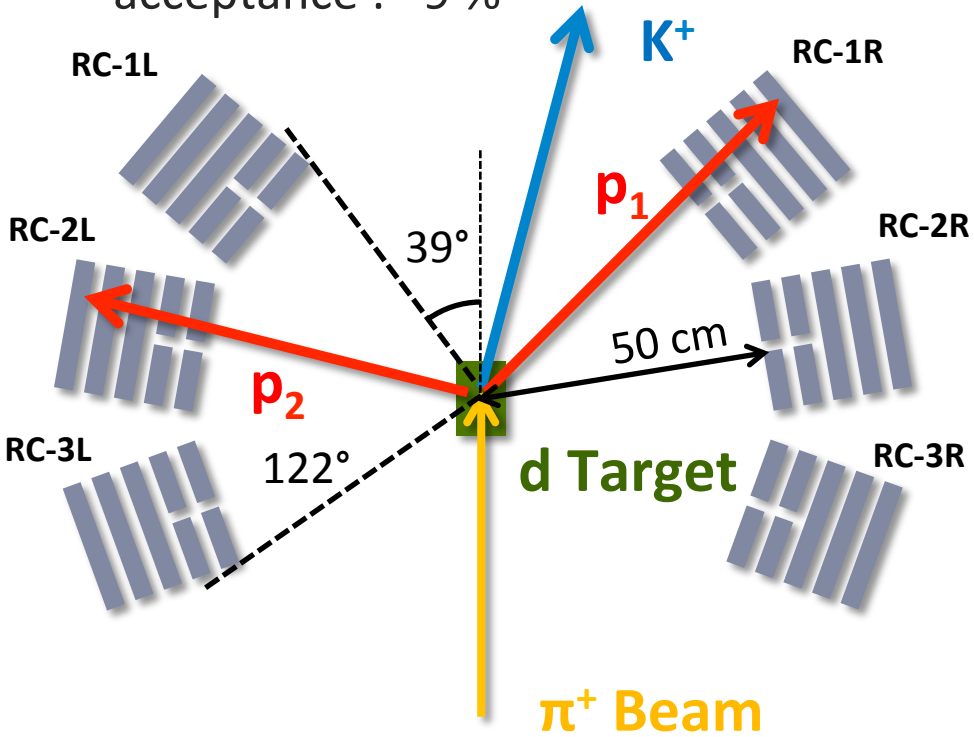
$\Lambda^* \rightarrow \Sigma + \pi$

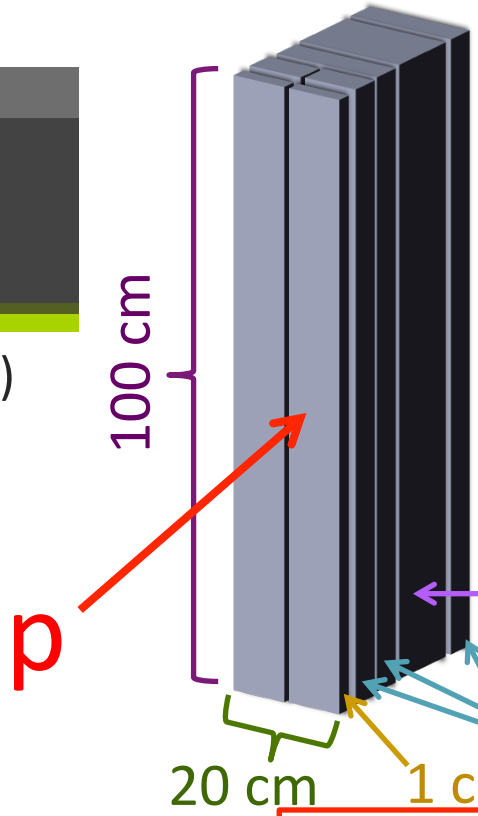
$\Sigma^+ \rightarrow p_2 + \pi^0$

We can suppress quasi-free B.G.
by requiring 2 high momentum protons.

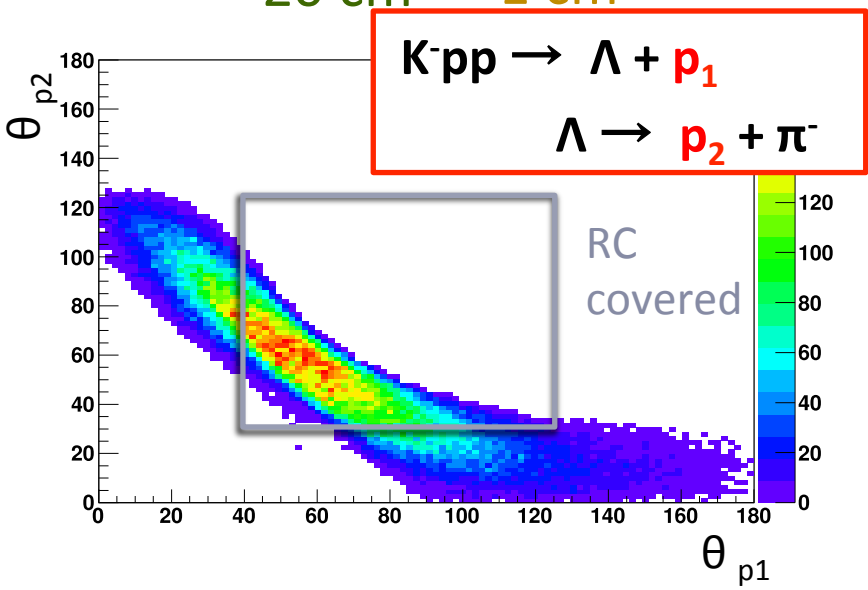
Range counter

- identify high momentum protons (>250 Mev/c)
- made by 5 layers of plastic scintillators
- covered angle : 39° -- 122° (6 units)
- acceptance : ~9 %





PID
- range
- dE
- TOF



Data taking

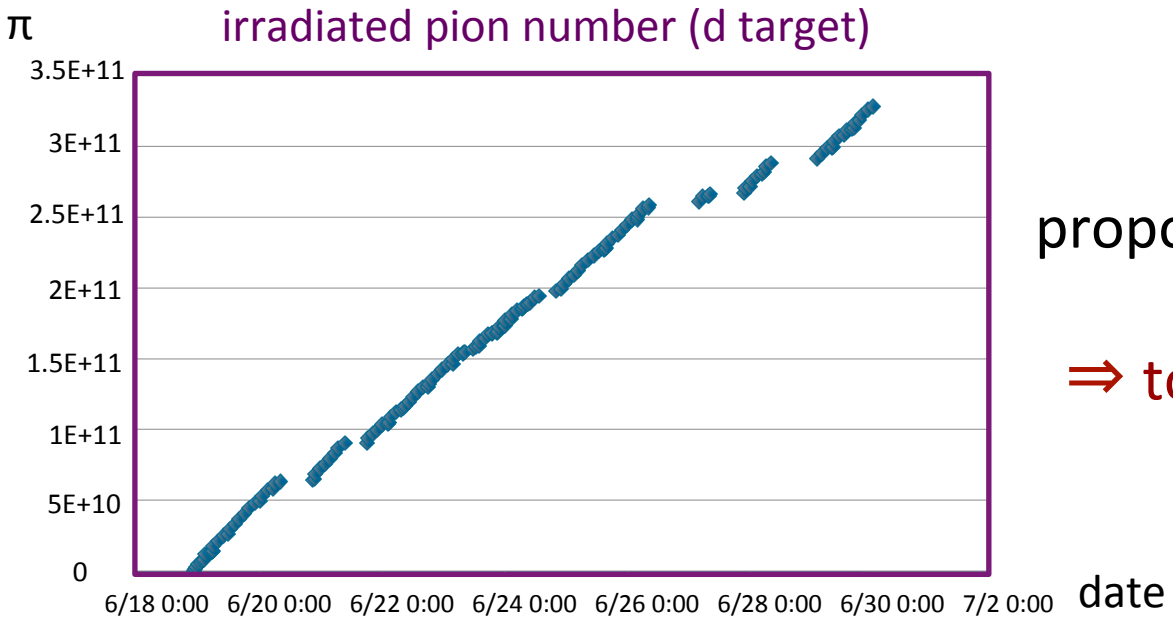
We performed data taking in June 2012.

d(π^+,K^+) @1.7 GeV/c : 7.6 days, 3.3×10^{11} π

p(π^+,K^+) @1.7 GeV/c : 0.6 days, 7.6×10^{9} π

calibration : 2 days

3M π^+/spill (6s cycle)



proposal : 40 days, 5M π^+/ spill

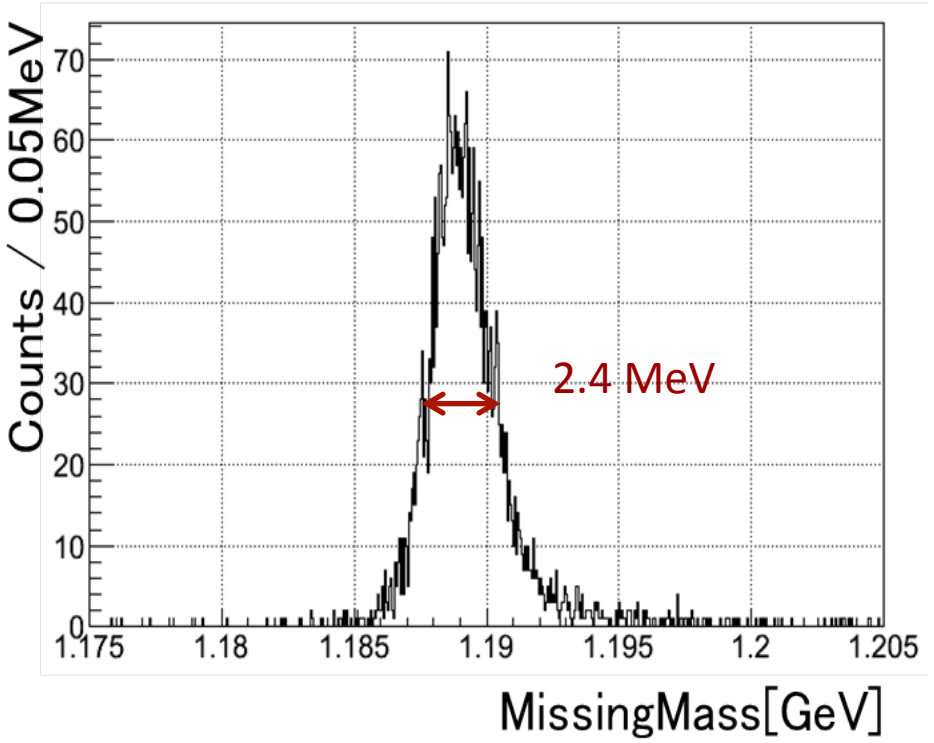
⇒ token data : ~10 %

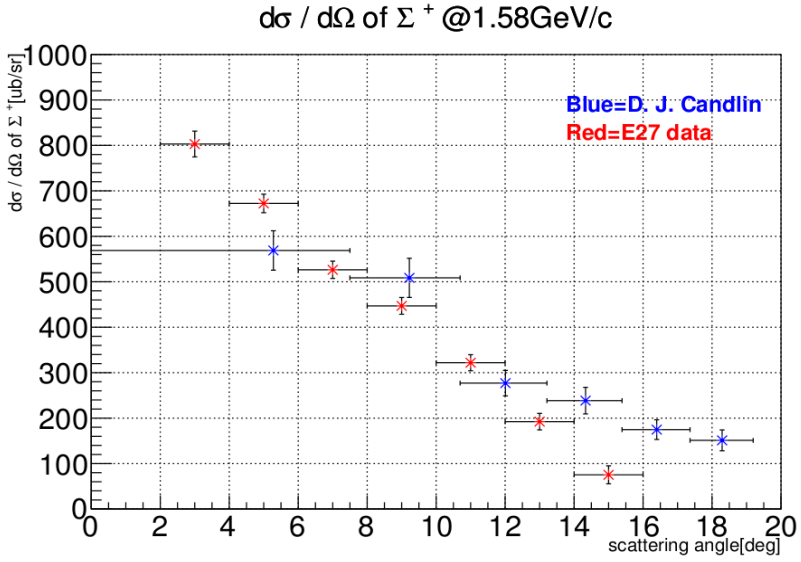
Performance of spectrometer

$p(\pi^+,K^+)\Sigma$ @1.58 GeV/c (calibration run)

Missing mass resolution
- 2.41 MeV (FWHM)

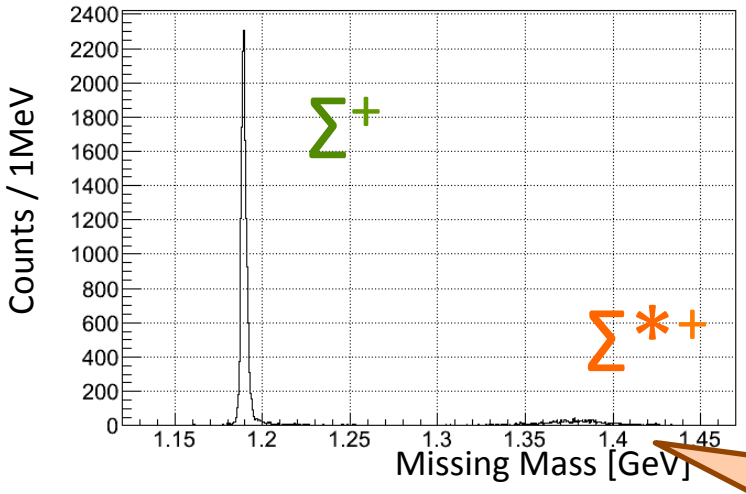
Mass
- 1188.98 ± 0.03 MeV (PDG : 1189.37 MeV)





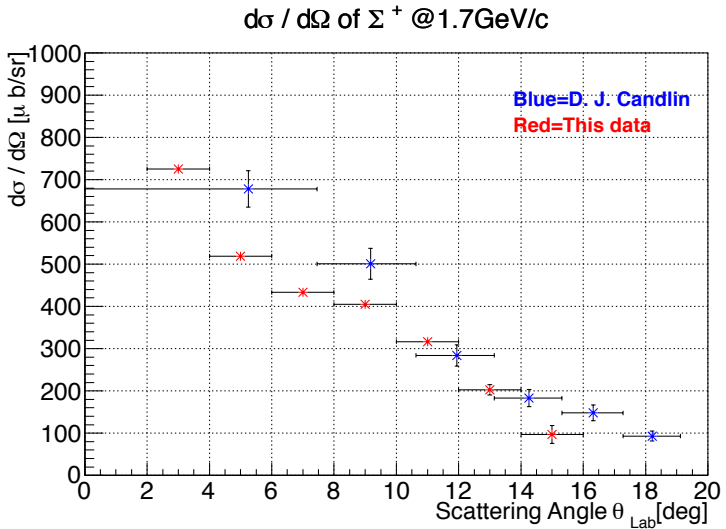
cross section is consistent with old data
(D.J.Candlin et al.)

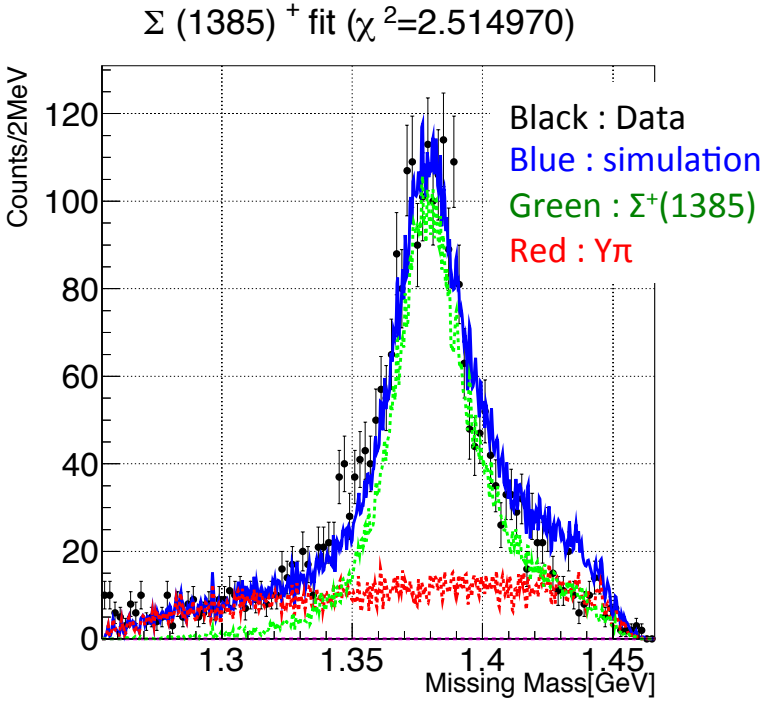
p(π⁺,K⁺) @1.7 GeV/c



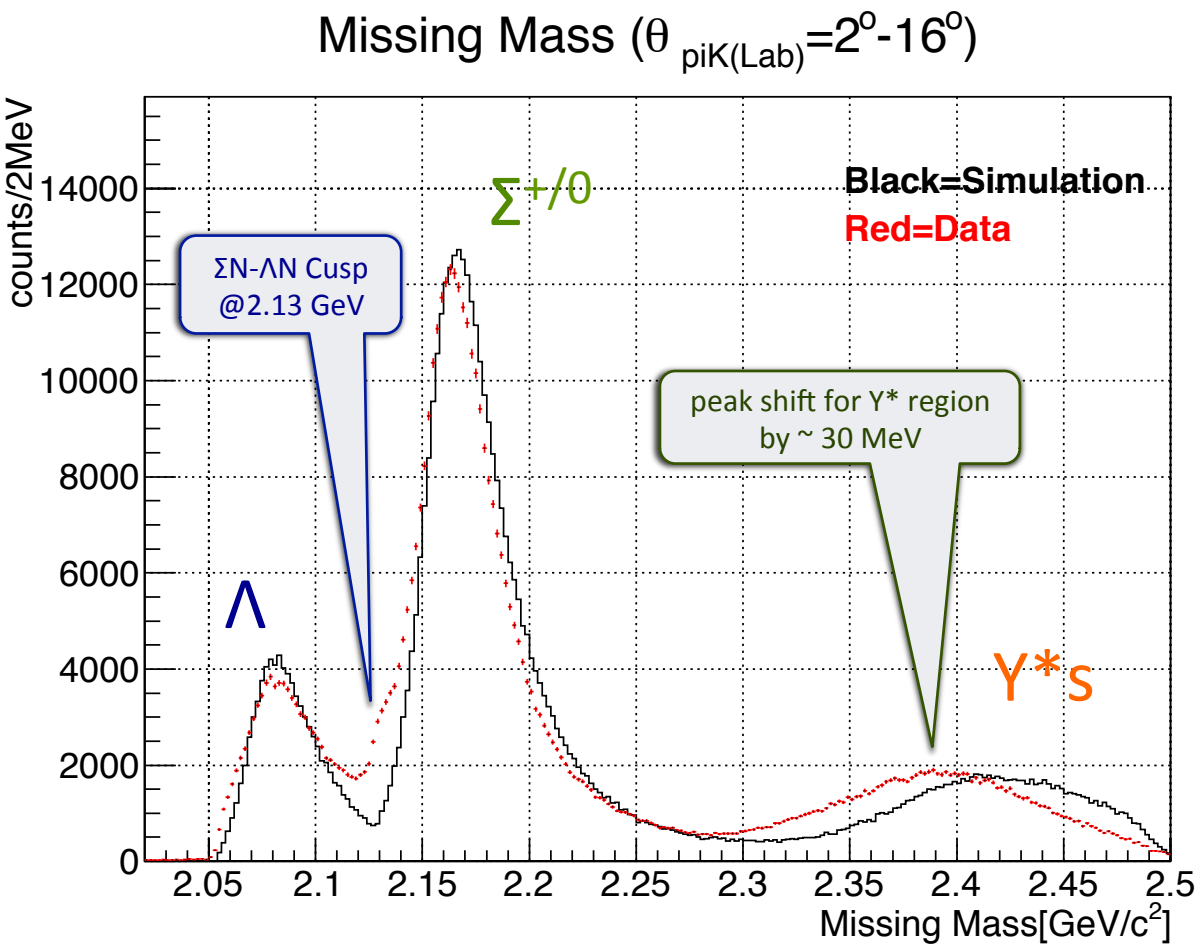
components

- Σ⁺ production
  - ΔM = 3.2 MeV (FWHM)
  - Mass = 1188.92 MeV
- Σ⁺ (1385) production
- Yπ production





d(π⁺,K⁺) @1.7 GeV/c



Main components

- Λ production
- Σ production
- Y* : Σ (1385), Λ (1405) production

Overall shape is consistent with simulation.

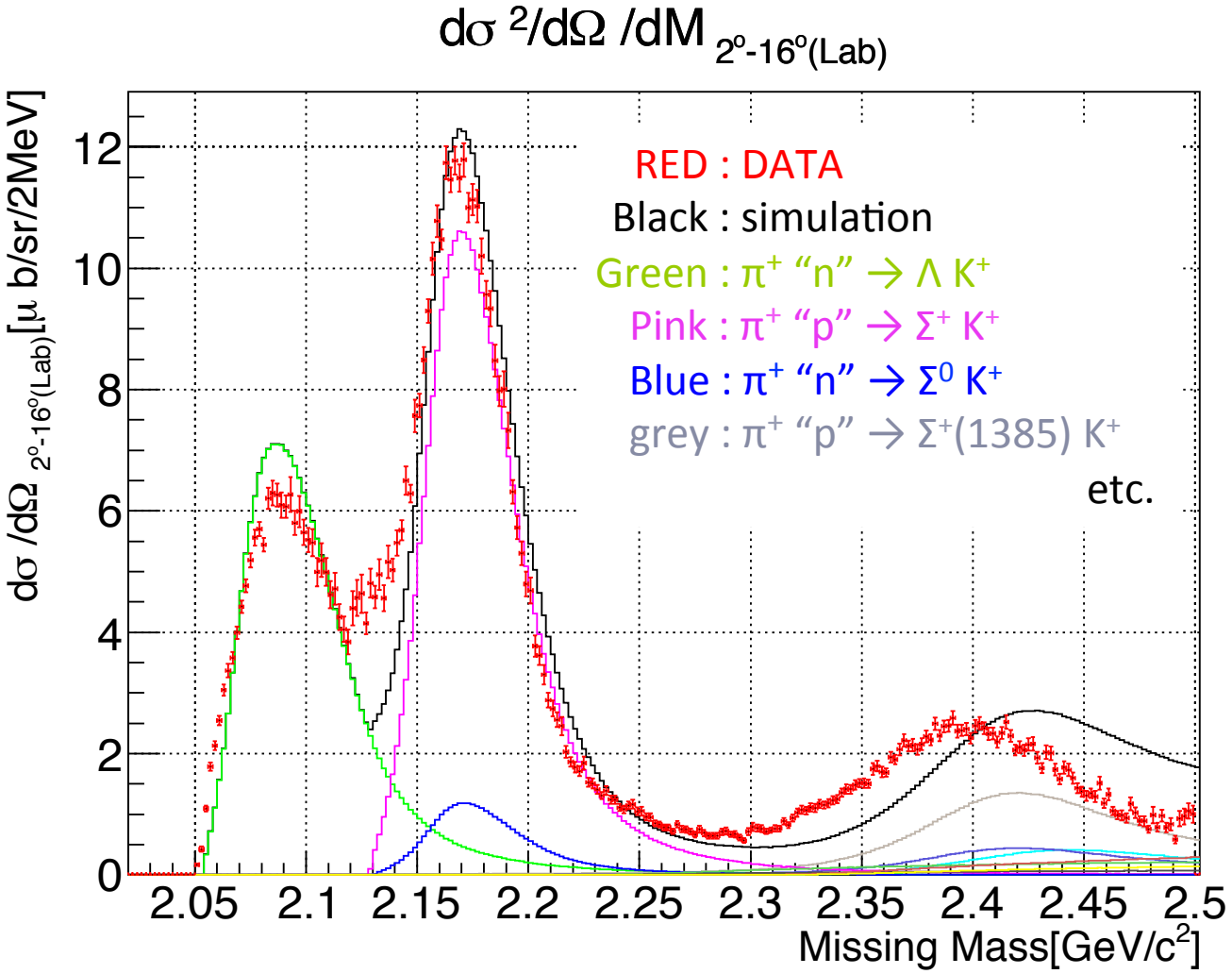
ΣN-ΛN Cusp

excess is observed at 2.13 GeV

Peak shift

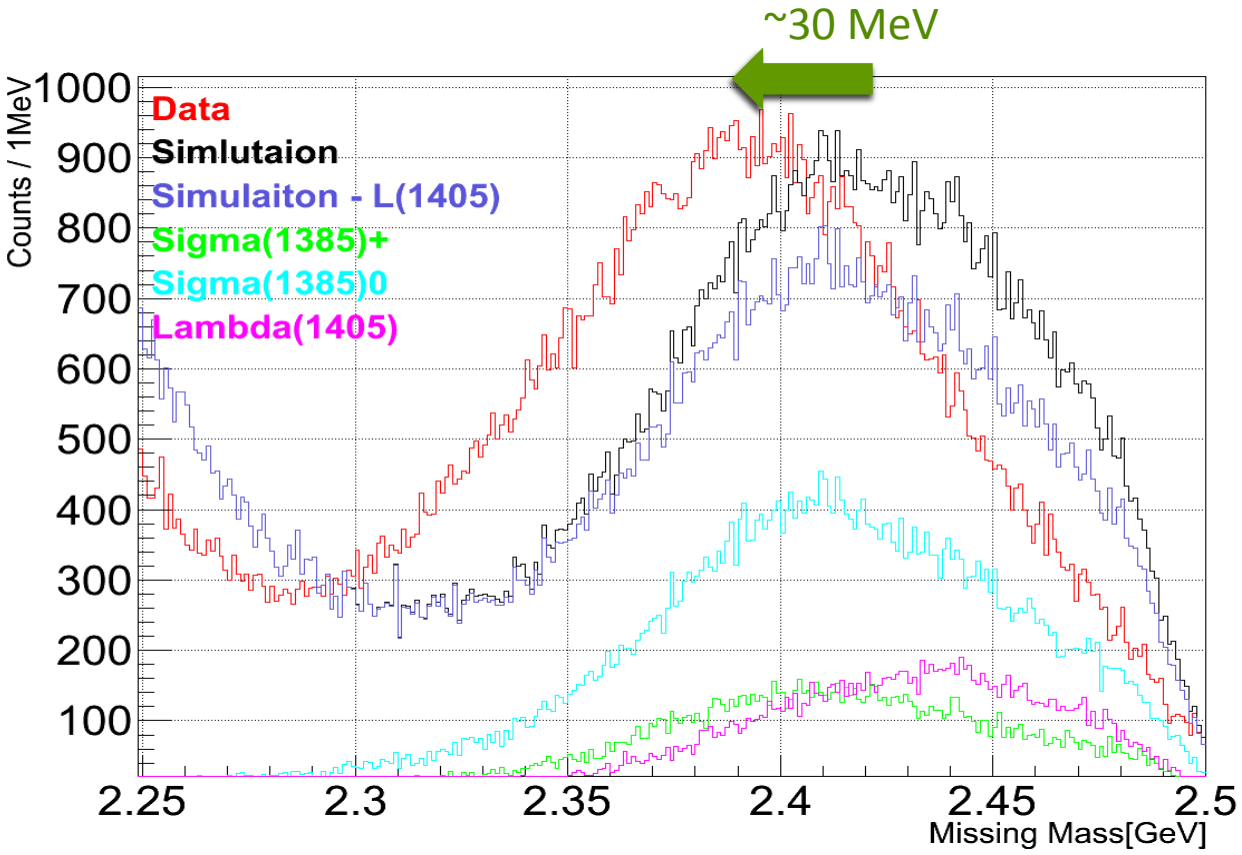
Y* mass shift lower ~ 30 MeV

Differential cross section d(π⁺,K⁺) @1.7 GeV/c



quasi-free Y* region

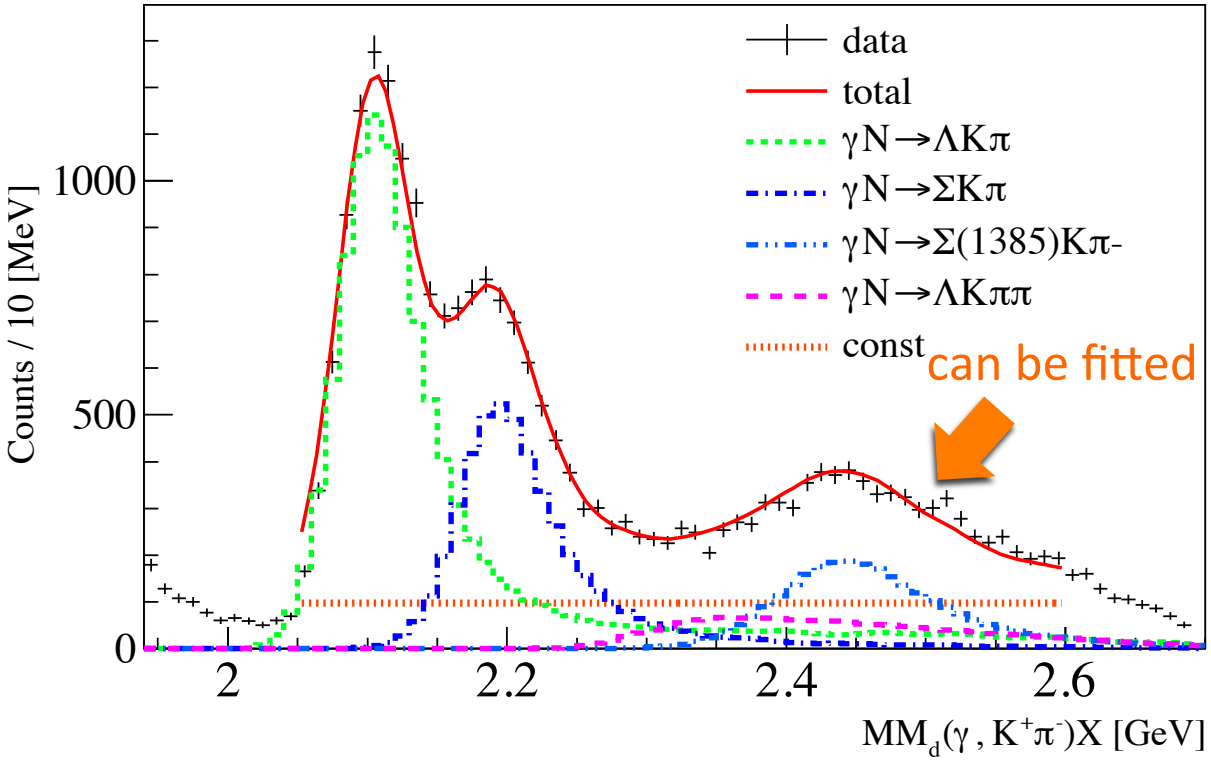
comparison between data and simulation



The discrepancy can not be interpreted by quasi-free processes .

d(γ,K⁺π⁻)Y* @1.5-2.4 GeV

- Spring-8 LEPS



arXiv:1306.5320

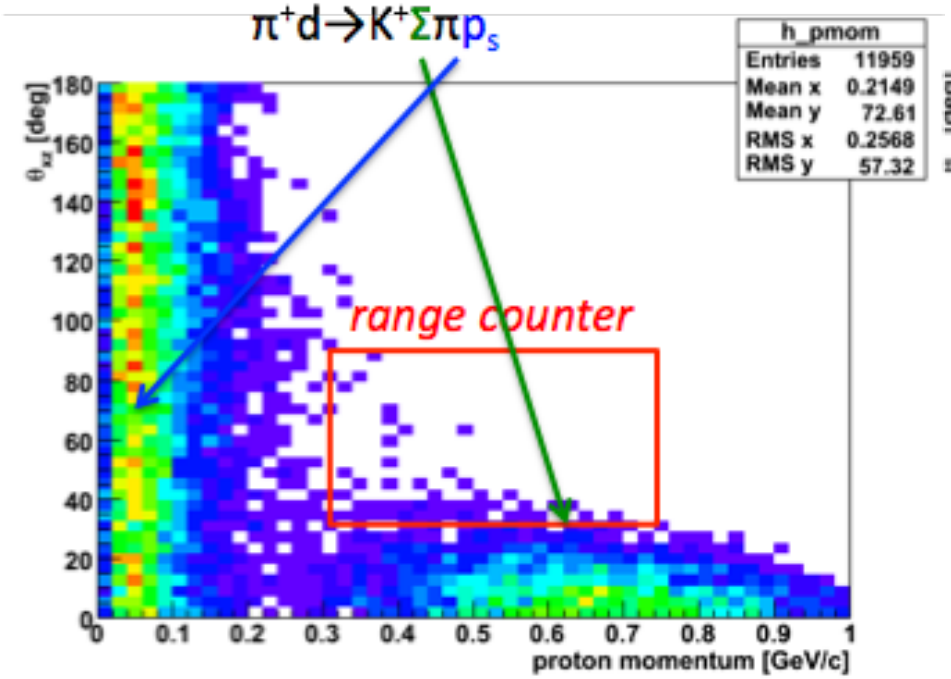
Peak shift is not observed for Σ (1385).

1 proton tagging

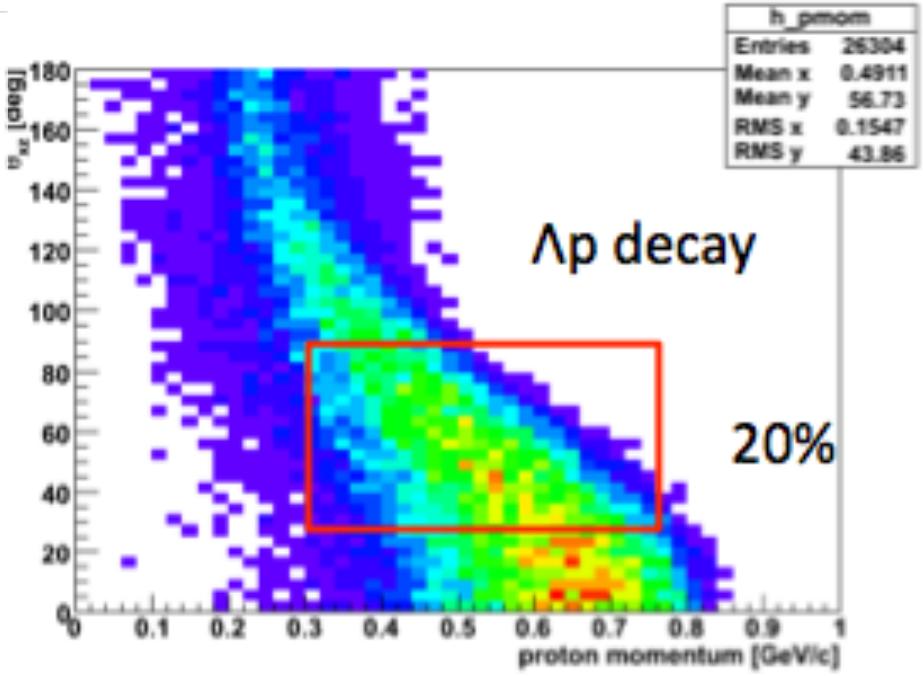
Proton distribution is different between quasi-free process and K^-pp non mesonic decay.

⇒ 1 proton tagging method will work well !!

Quasi-free Y productions

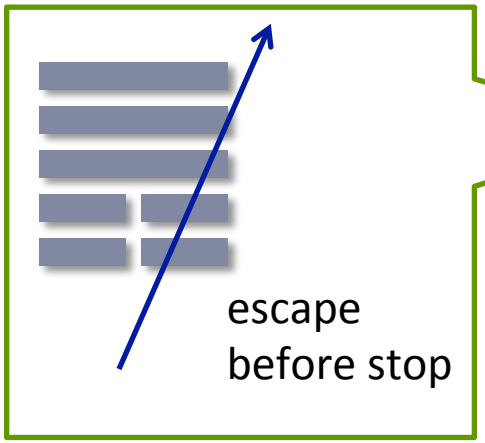


Non-mesonic decay from K^-pp

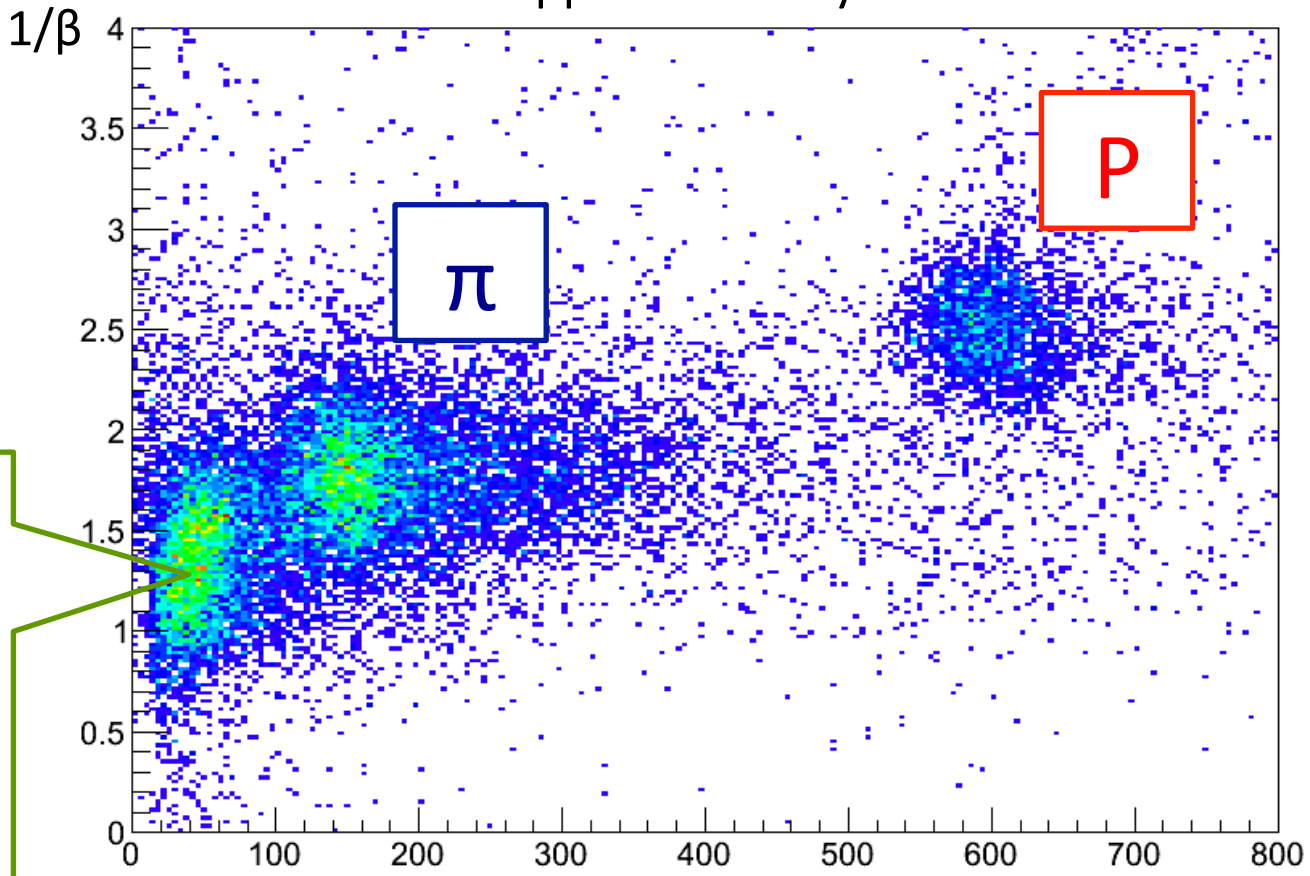


Performance of range counter

cut parameter
- stop layer
- 1/β
- PID function (dE/dx)



stopped at 4th layer

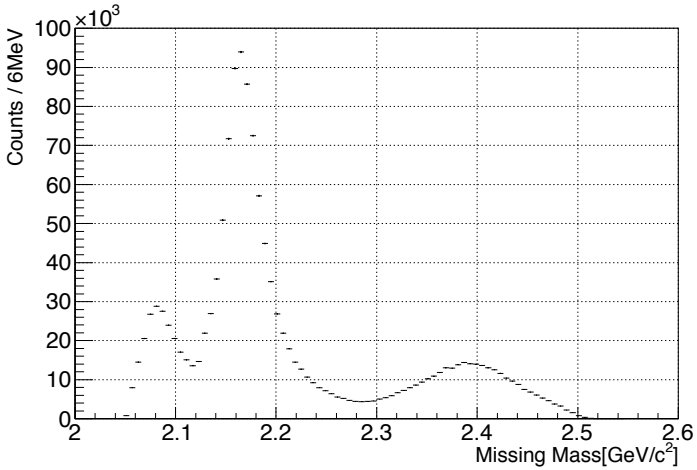


proton is well separated from pion

Coincidence study

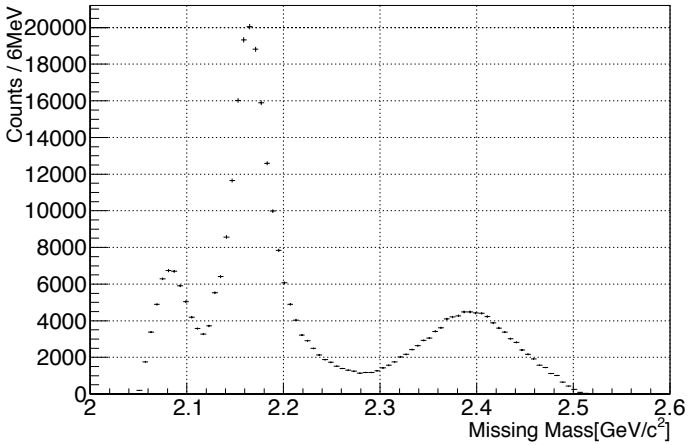
We studied coincidence data by using RC cut.

inclusive



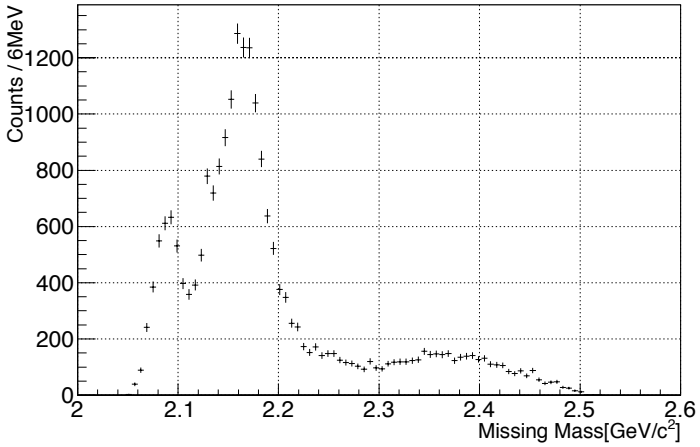
$\bar{p}$ cut

1 pion coincidence



p cut

1 proton coincidence



$\bar{p}$ cut : π or slow p

p cut : proton (p > 280 MeV/c)

1 pion tagging spectrum

R_π = (Pion coincidence spectrum) / (Inclusive spectrum)
$R_\pi \propto$ (π emission BR) x (π detection efficiency)

QFΛ and QFΣ emit 1 pion
QFY* and πYN emit 2 pions

R_π reflects π emission probability, therefore the ratio in QFY* + πYN region is higher than those in the other regions.

R_π is almost constant at each region.

1 proton tagging spectrum

ΣN-ΛN Cusp is clearly seen.

K^-pp-like bump structure is observed.

We should take account of the tagging efficiency of RC carefully.

Analysis is on going.

2 proton tagging spectrum

2 proton tagging rate is very low.
An excess seems to exist at ~2.26 GeV, but the number of events is small.

Summary

- We performed $p(\pi^+,K^+)X$ and $d(\pi^+,K^+)X$ measurement by using 1.7 GeV/c π^+ beam in June 2012.
- ΣN-ΛN cusp structure and peak shift of Y* are observed in $d(\pi^+,K^+)$ inclusive spectrum.
- K^-pp-like bump structure is observed in 1 proton tagging spectrum.
- 2 proton tagging event is too low, therefore further combined analysis is necessary.

"Study of kaonic nuclei by the d(pi+, K+) reaction at J-PARC." Yudai Ichikawa @ HADRON 2013