Experimental study of a K⁻pp bound state by using the d(π⁺, K⁺) reaction.

Y. Ichikawa for the J-PARC E27 collaboration.
Kyoto University, JAEA, email: yudai@scphys.kyoto-u.ac.jp

Abstract

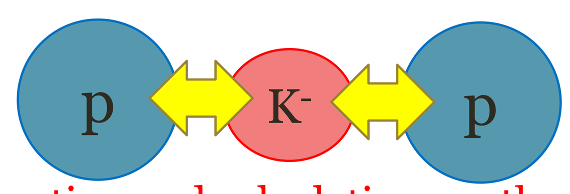
An experimental search for the K⁻pp bound state, which is considered the simplest kaonic nucleus, is performed by using the d(π⁺,K⁺) reaction at J-PARC K1.8 beam line (J-PARC E27 experiment). A pilot run was carried out in June, 2012. The missing-mass spectrum of this reaction studied of the beam momentum of 1.7 GeV/c, which allows the production of Λ(1405), has been obtained for the first time and a significant peak shift by ~40 MeV was observed in the Y* region. In a preliminary proton-coincidence analysis, a sharp spike due to the ΣN-ΛN coupling and a broad enhancement around 2.3 GeV/c², which might be attributed to the K⁻pp bound state, are clearly observed.

Physics motivation

➢ Nuclear kaon bound state

- The deeply bound state by strong interaction.
- Strong attraction of the I = 0 $\bar{K}N$ interaction （$\bar{K}N^{I=0}$） plays an important role in nuclear kaon bound state.

➢ K⁻pp nuclear bound state



- The simplest nuclear kaon bound state.
- Theoretical prediction of B.E and Γ depend on the $\bar{K}N$ interaction and calculation method.

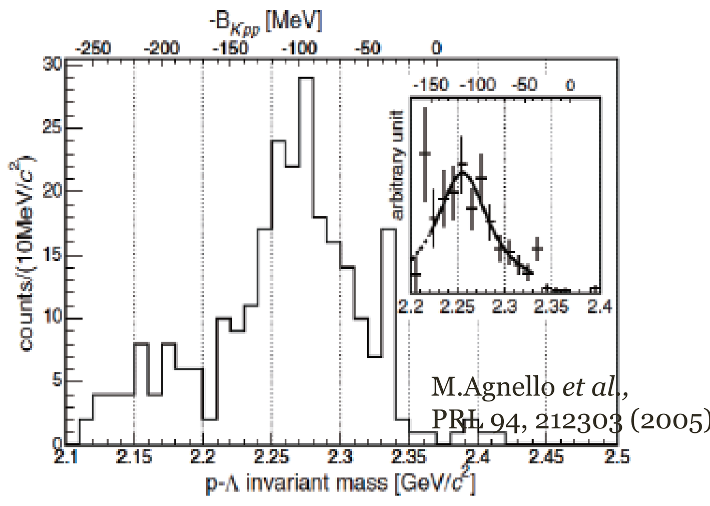
Calculated K^-pp binding energies B and widths Γ (in MeV). A. Gal/Nuclear Phys A 914 270-279(2013)

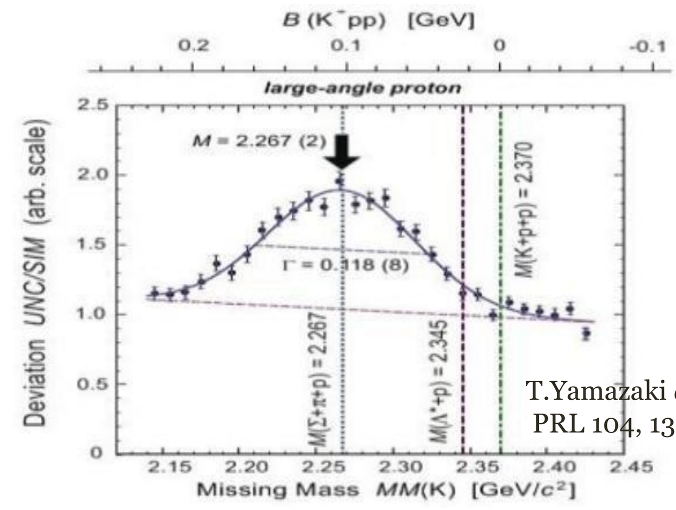
	Chiral, energy dependent			Non-chiral, static calculations			
	var. [7]	var. [8]	Fad. [9]	var. [10]	Fad [11]	Fad [12]	var. [13]
B	16	17–23	9–16	48	50–70	60–95	40–80
Γ	41	40–70	34–46	61	90–110	45–80	40–85

[7] N. Barnea, A. Gal, E.Z. Liverts, Phys. Lett. B 712 (2012) 132.
[8] A. Doté, T. Hyodo, W. Weise, Nucl. Phys. A 804 (2008) 197; A. Doté, T. Hyodo, W. Weise, Phys. Rev. C 79 (2009) 014003.
[9] Y. Ikeda, H. Kamano, T. Sato, Prog. Theor. Phys. 124 (2010) 533.
[10] T. Yamazaki, Y. Akaishi, Phys. Lett. B 535 (2002) 70.
[11] N.V. Shevchenko, A. Gal, J. Mareš, Phys. Rev. Lett. 98 (2007) 082301; N.V. Shevchenko, A. Gal, J. Mareš, J. Revai, Phys. Rev. C 76 (2007) 044004.
[12] Y. Ikeda, T. Sato, Phys. Rev. C 76 (2007) 035203; Y. Ikeda, T. Sato, Phys. Rev. C 79 (2009) 035201.
[13] S. Wycech, A.M. Green, Phys. Rev. C 79 (2009) 014001.

➢ Previous experiment of K⁻pp bound state

	FINUDA experiment	DISTO experiment
Reaction	Stopped K⁻ on ^{6,7}Li and ^{12}C	p + p @ T_p = 2.85 GeV
B.E	$115^{+6}_{-5}(stat)^{+3}_{-4}(syst)$MeV	103±3(stat)±5(sys)MeV
Width	$64^{+14}_{-11}(stat)^{+2}_{-3}(syst)$MeV	118±8(stat)±10(sys)MeV

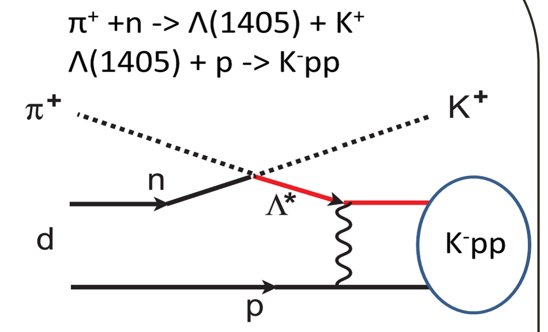




J-PARC E27 experiment

➢ d(π⁺, K⁺)X reaction at p_π = 1.7 GeV/c

- K⁻pp bound state is produced through the Λ(1405) as a doorway.
- The binding energy and decay width of K⁻pp is measured in the missing mass spectroscopy at J-PARC K1.8 beam line.
- There are many background from quasi-free hyperon production.
- The production cross section of K⁻pp will be small.



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

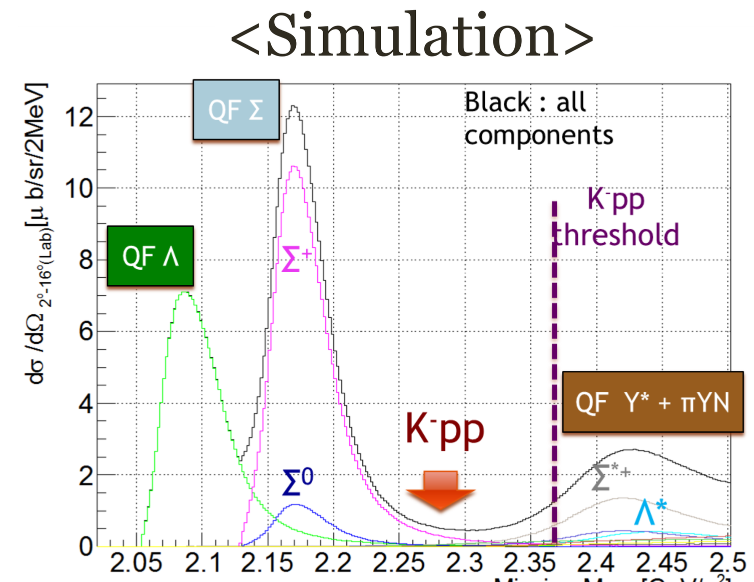
➢ J-PARC K1.8 beam line

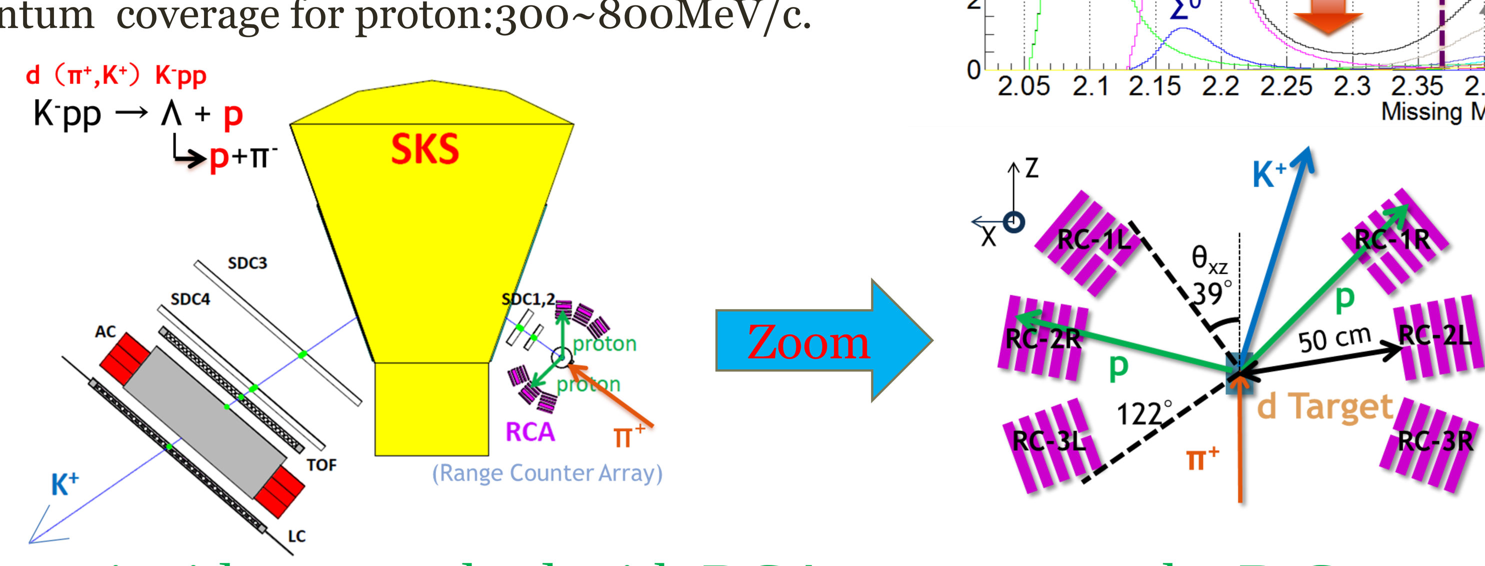
○K1.8 beam line spectrometer
- The momentum resolution is ~0.1%(FWHM).

○Superconducting Kaon Spectrometer (SKS)
- Large Acceptance ~100msr.
- Good momentum resolution ~0.2%(FWHM).

○Range counter Array (RCA)
- 6units, 5 layers (1+2+2+5+2cm) of plastic scintillator.
- TOF: 50cm, coverage angle is 39° to 122° .
- Geometrical coverage ~26%.
- Momentum coverage for proton:300~800MeV/c.

<Simulation>



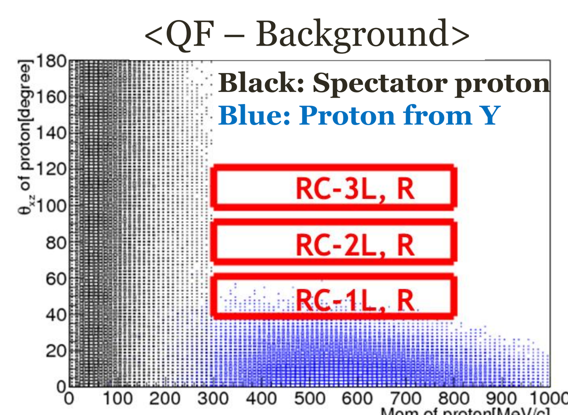


➢ Proton coincidence method with RCA to suppress the B.G.

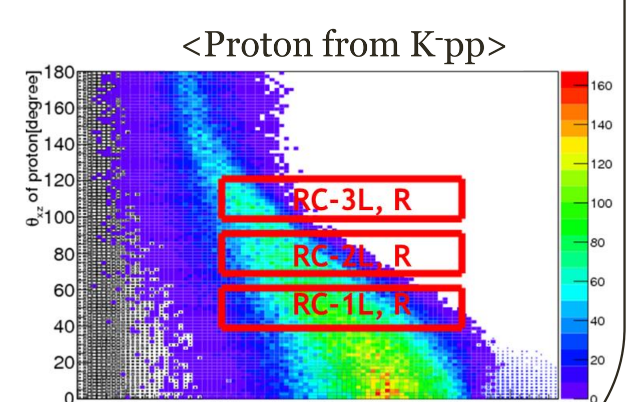
	QF - Background		Proton from K⁻pp non mesonic decay
	Proton from Y decay	Spectator proton	
Momentum	250~800MeV/c	<250MeV/c	250~800MeV/c
Emission angle	Forward angle (<60°)	All angel (0~180°)	All angle (0~180°)

- If we detect a proton at >60° (RC-2L, R), quasi-free B.G. are eliminated and the signal is enhanced!!
- If we detect two protons, QF B.G are eliminated more strongly!!

<QF – Background>



<Proton from K⁻pp>



Result of pilot experiment

➢ Run summary

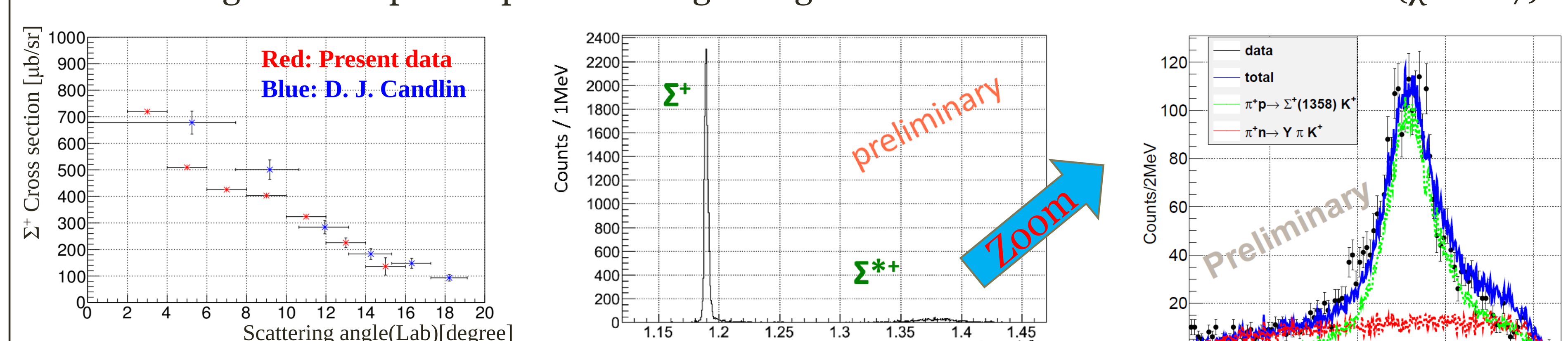
- Typical beam intensity of secondary pion beam was 3.0×10⁶ per pulse(1.7s).

○ p(π⁺, K⁺)X run at 1.7 GeV/c
- 0.6 day; #(π⁺) ~ 7.6×10⁹

○ d(π⁺, K⁺)X run at 1.7 GeV/c
- 7.6 days; #(π⁺) ~ 3.3×10¹¹

➢ p(π⁺, K⁺)X at 1.7 GeV/c data

- To check the contribution of proton in deuterium target.
- Σ⁺, Σ(1385)⁺ and Yπ are produced and these cross sections are consistent with old data.
- Missing mass shape and position are good agreement between data and simulation(χ^2=2.27).

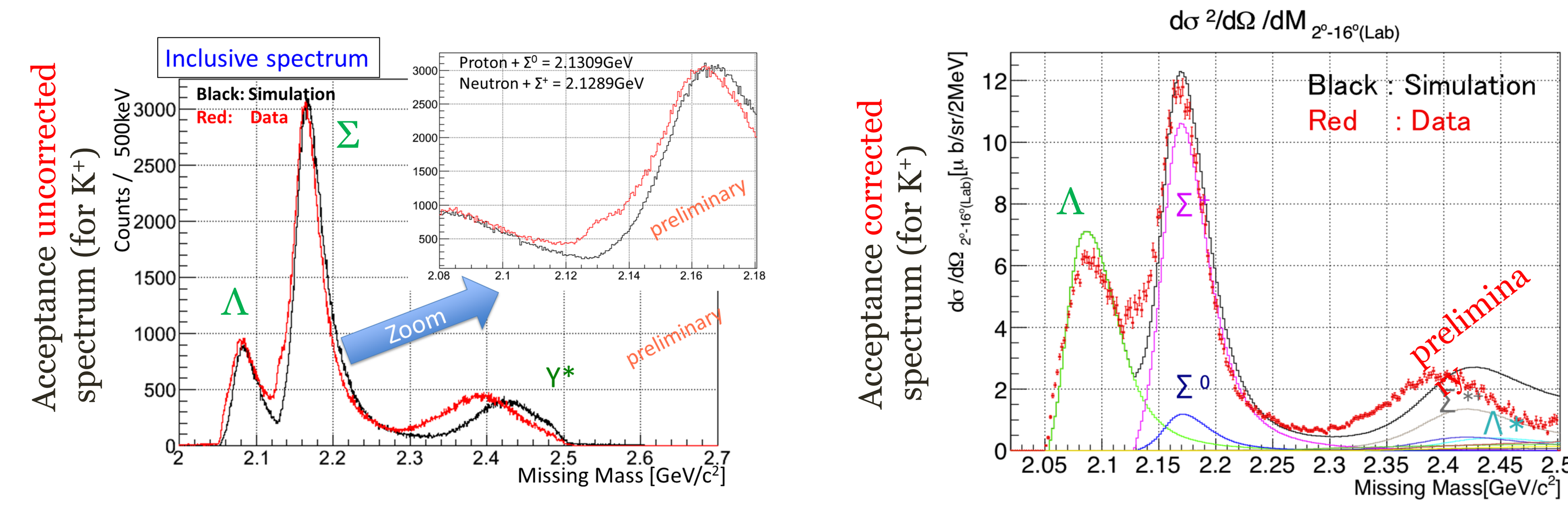


➢ d(π⁺, K⁺)X at 1.7 GeV/c data

- The missing mass spectrum of this reaction is measured for the first time.

＜Inclusive analysis＞

- In the quasi-free Λ / Σ⁰/⁺ region, the simulation almost reproduced the experimental spectrum, except for an enhancement around 2.13GeV/c².
  ->It can be attributed to a cusp structure due to ΣN-ΛN (I=1/2) coupling.
- There is a significant (~40 MeV) shift in the Y* region compared with a simulation.



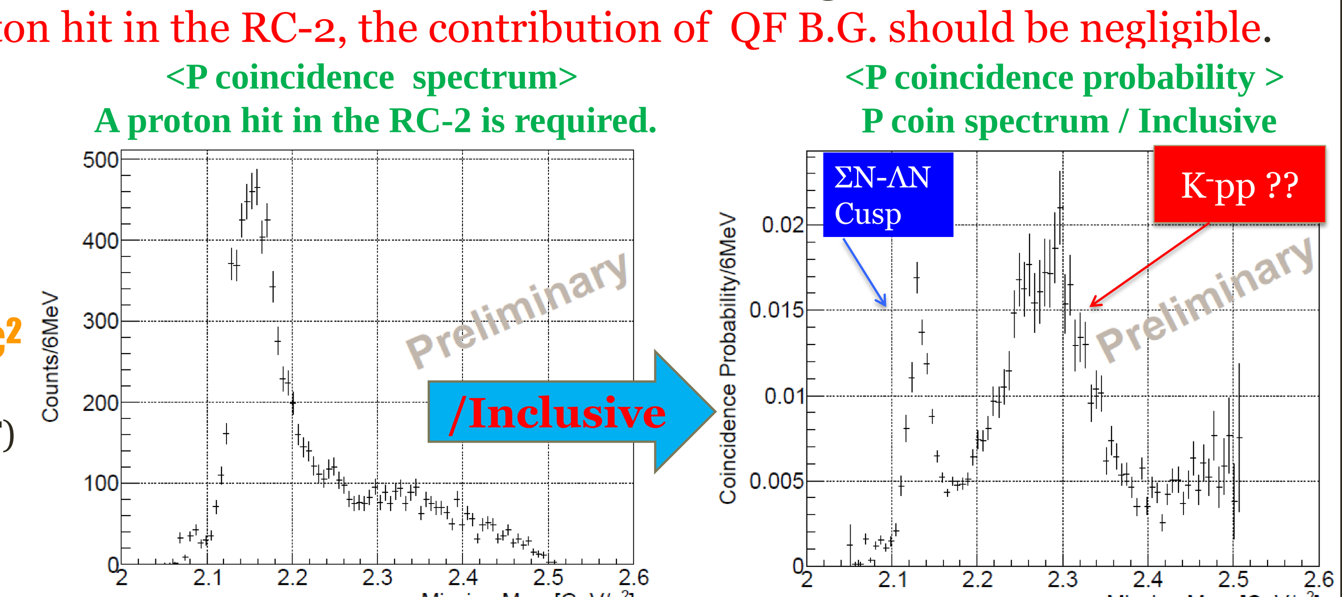
＜Coincidence analysis with RCA＞

- The obtained pion coincidence probability is almost consistent with a simulation for the quasi-free process considering the angular distributions and decay branch.
- Protons from quasi-free B.G. cannot be emitted in the side-ward angles (>60°) .
  -> By requiring the proton hit in the RC-2, the contribution of QF B.G. should be negligible.

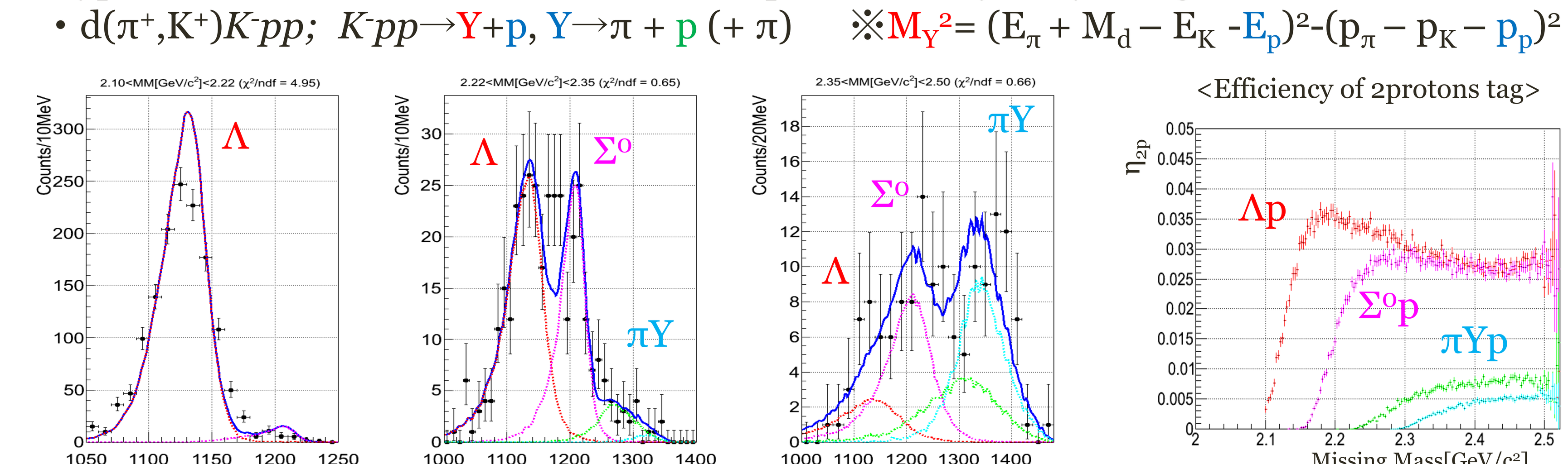
○Excess due to ΣN-ΛN cusp is clearly observed

○Broad enhancement is observed around 2.3GeV/c²

→There is a emitting source involving two nucleons (non QF) in high emission probability.
→A possible explanation is K⁻pp.



- Hyperon masses are reconstructed from 2 protons analysis by using the RCA.
  - d(π⁺,K⁺)K⁻pp; K⁻pp→Y+p, Y→π + p (+ π) ※M_Y^2= (E_π + M_d – E_K -E_p)²-(p_π – p_K – p_p)²



Summary and future work

＜Inclusive analysis＞
- We have obtained d(π⁺, K⁺) at 1.7 GeV/c for the first time.
- Together with the p(π⁺, K⁺) data, the inclusive spectra are understandable except for Y* region.
- ΣN-ΛN cusp structure and peak shift of Y* are observed.

＜Coincidence analysis＞
- π detection probability is almost consistent between data and simulation.
- In proton coincidence, the ΣN-ΛN cusp structure and an broad enhancement around 2.3 GeV/c² are clearly observed.
- → A possible explanation of the observed structure is K⁻pp.
- → The detail studies on detection efficiencies are in progress.
- Hyperon masses are reconstructed from 2 protons analysis by using the RCA.

＜Future work＞
- Apply the acceptance correction for protons which detected by RCA.