The E31 spectroscopic experiment of Λ(1405) via in-flight d(K-,n) reaction at J-PARC K1.8BR

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Motivation

- Investigation of Λ(1405)

Λ*(1405) [uds]

$I = 0, J^p = \frac{1}{2}^-$,m=1405.1$\pm^{1.3}_{1.0}$ (MeV)<N*(1440)

$\Gamma = 50 \pm 2$(MeV) (PDG-2012)

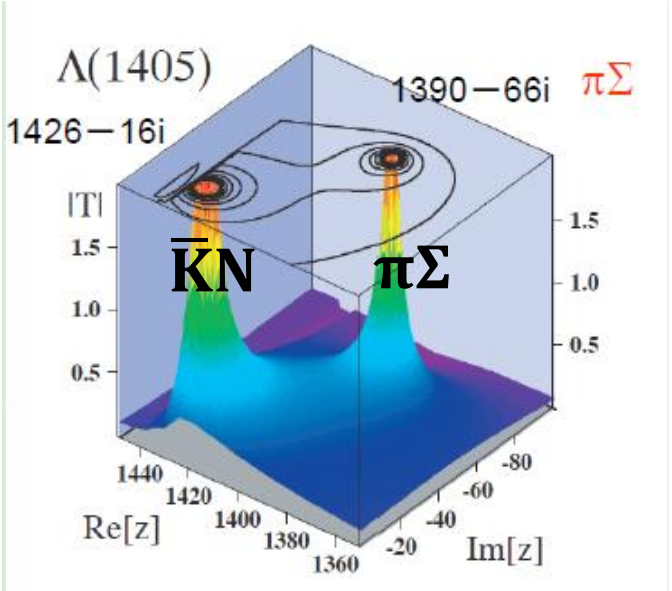
- 3 quark ? $\bar{K}N$ bound state ?

$\bar{K}N$ Thre. 1432 MeV

27 MeV

Λ(1405)

- 2 pole structure of Λ(1405) with $\bar{K}N$, πΣ resonant states by chiral unitary model



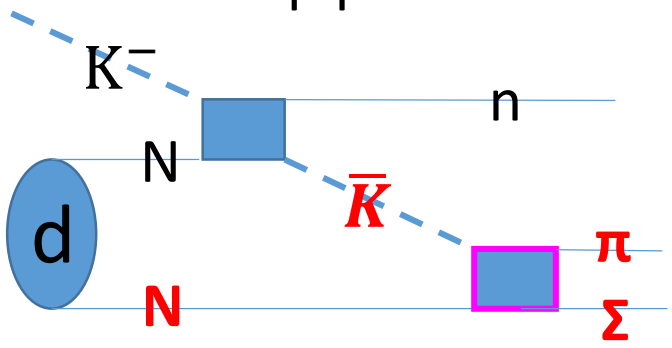
T.Hyodo and W.Weise, Phys.RevC77,035204(2008)

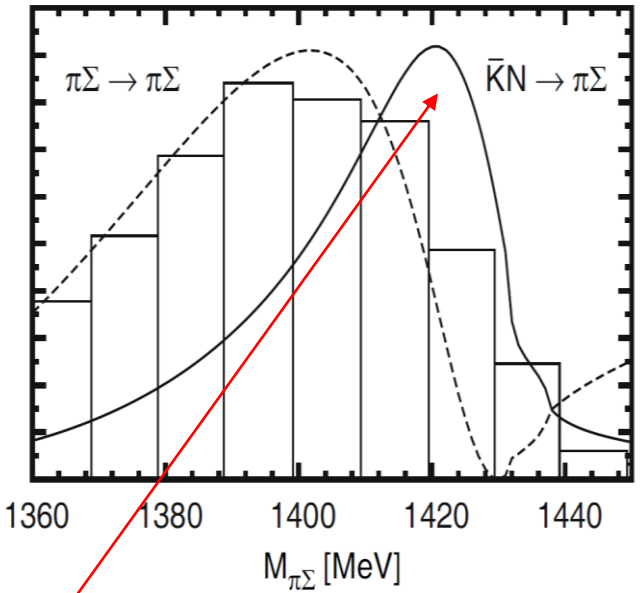
- Investigation of Λ(1405) spectrum shape in $\bar{K}N \rightarrow \pi\Sigma$

The reaction cannot occur in free space

$d(K^-, n)$ reaction

2 step process



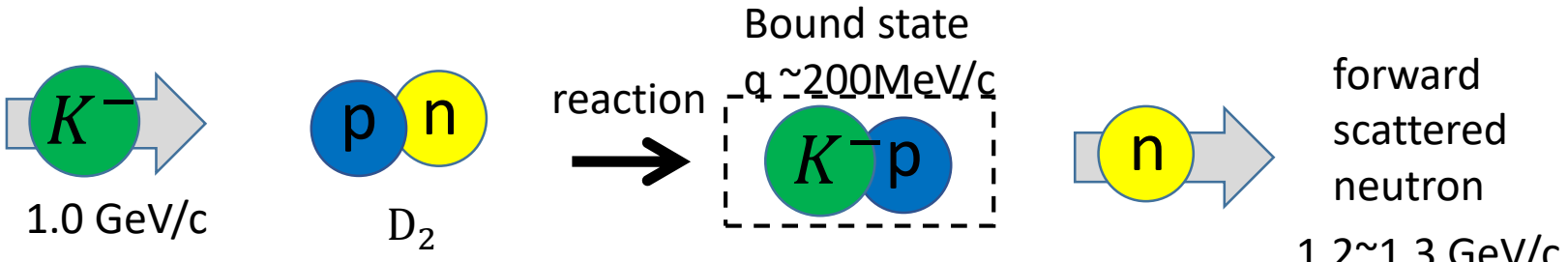


D.Jido et al,
Eur. Phys. J. A42('09)257

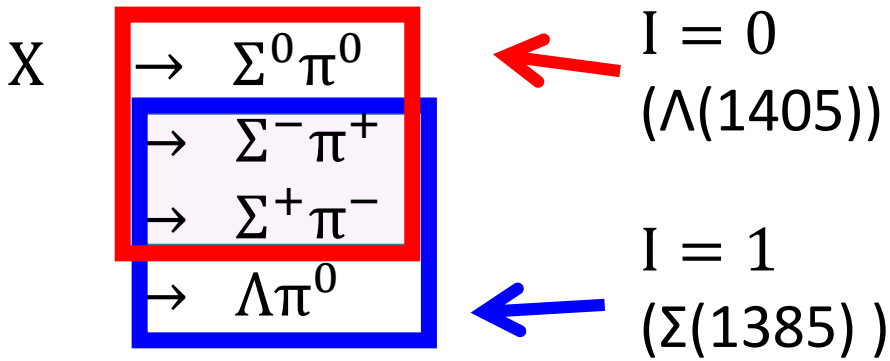
The reaction is expected to enhance the line shape at around the $\bar{K}N$ pole (~1420 MeV/c^2)

J-PARC E31 experiment

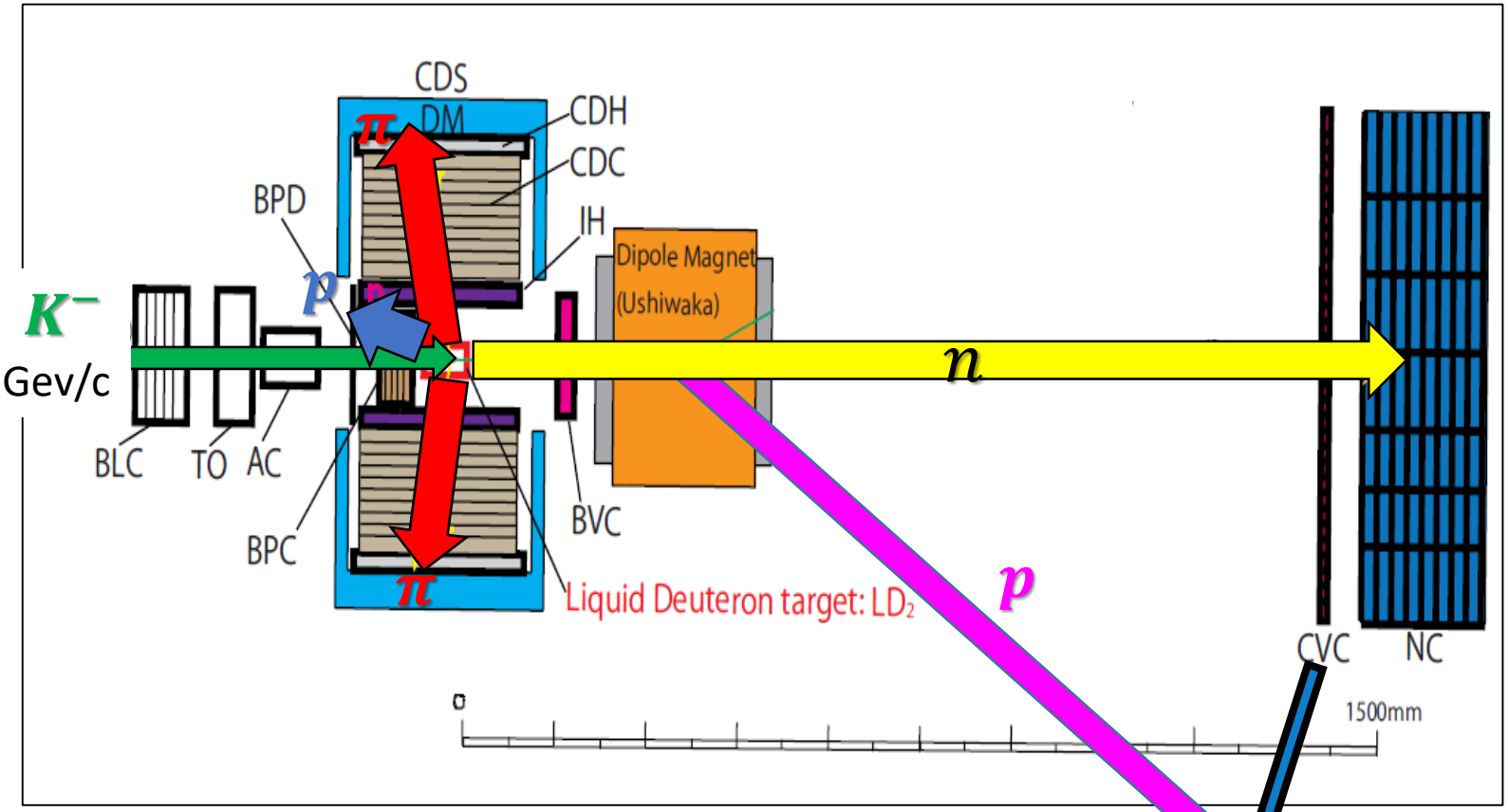
- $\Lambda(1405)$ measurement via in-flight $\mathrm{d}(\mathrm{K}^-, \mathrm{n})$



- Identification of final isospin state
  - $\Sigma^{\mp}\pi^{\pm}$have I =0 and I =1 amplitude
  - **$\Sigma^0\pi^0$is I =0 purely**
  - We will measure all the decay mode to decompose isospin amplitude



J-PARC E31 experiment set up



d(K-,n)"X"

$X \rightarrow \Sigma^0\pi^0 \rightarrow p\pi^-\gamma\pi^0$

$\rightarrow \Sigma^-\pi^+ \rightarrow n\pi^-\pi^+$

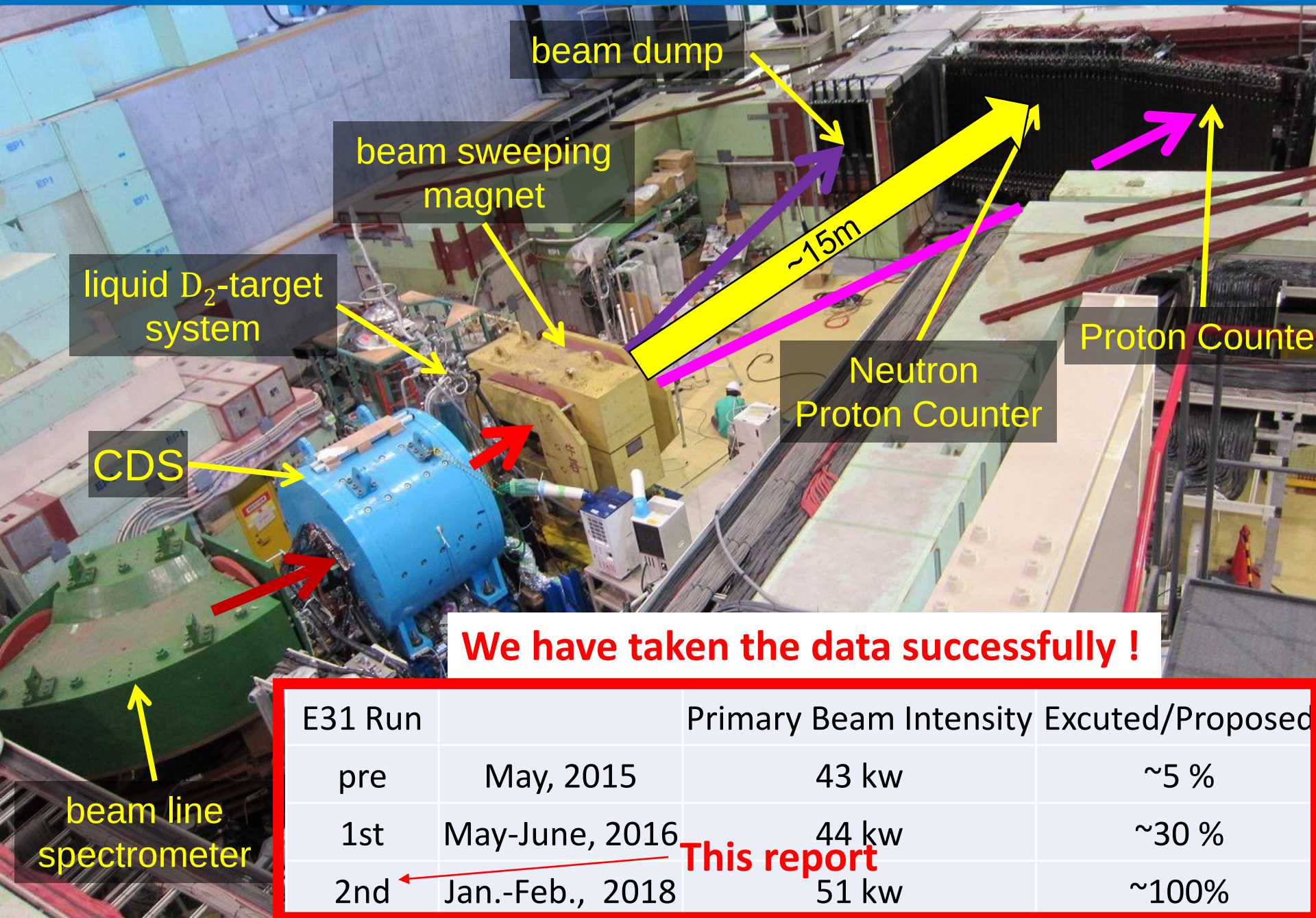
$\rightarrow \Sigma^+\pi^- \rightarrow n\pi^+\pi^-$

← This report

d(K-,p)"X-"

$X^- \rightarrow \Sigma^0\pi^- \rightarrow p\pi^-\gamma\pi^-$

K1.8BR spectrometer



We have taken the data successfully !

E31 Run		Primary Beam Intensity	Excuted/Proposed
pre	May, 2015	43 kw	~5 %
1st	May-June, 2016	44 kw	~30 %
2nd	Jan.-Feb., 2018	51 kw	~100%

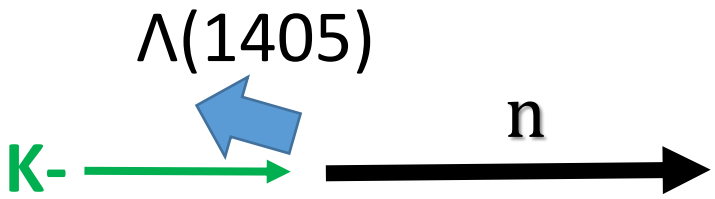
This report

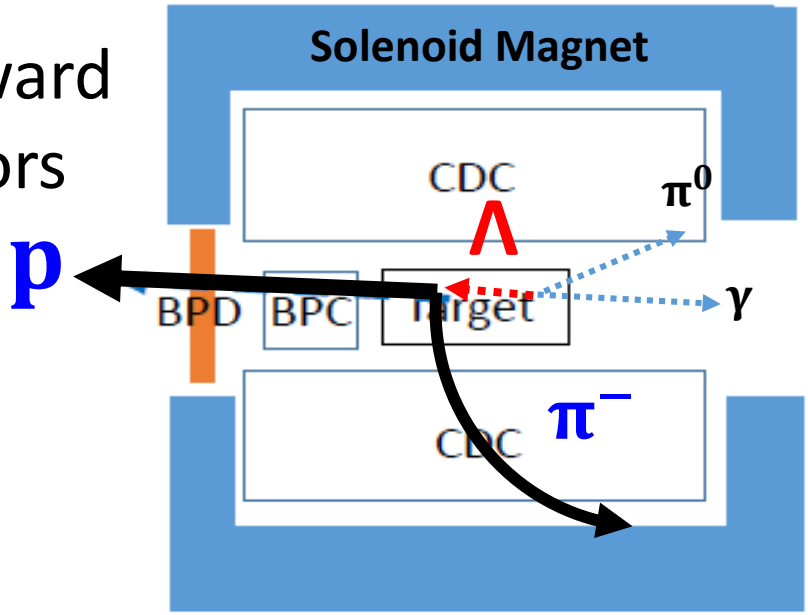
d(K-,n)"$\Sigma^0\pi^0$" analysis procedure

$$\Sigma^0\pi^0 \rightarrow \Lambda\gamma\pi^0 \rightarrow p\pi^-\gamma\pi^0$$

- Λ(1405) is recoiled backward

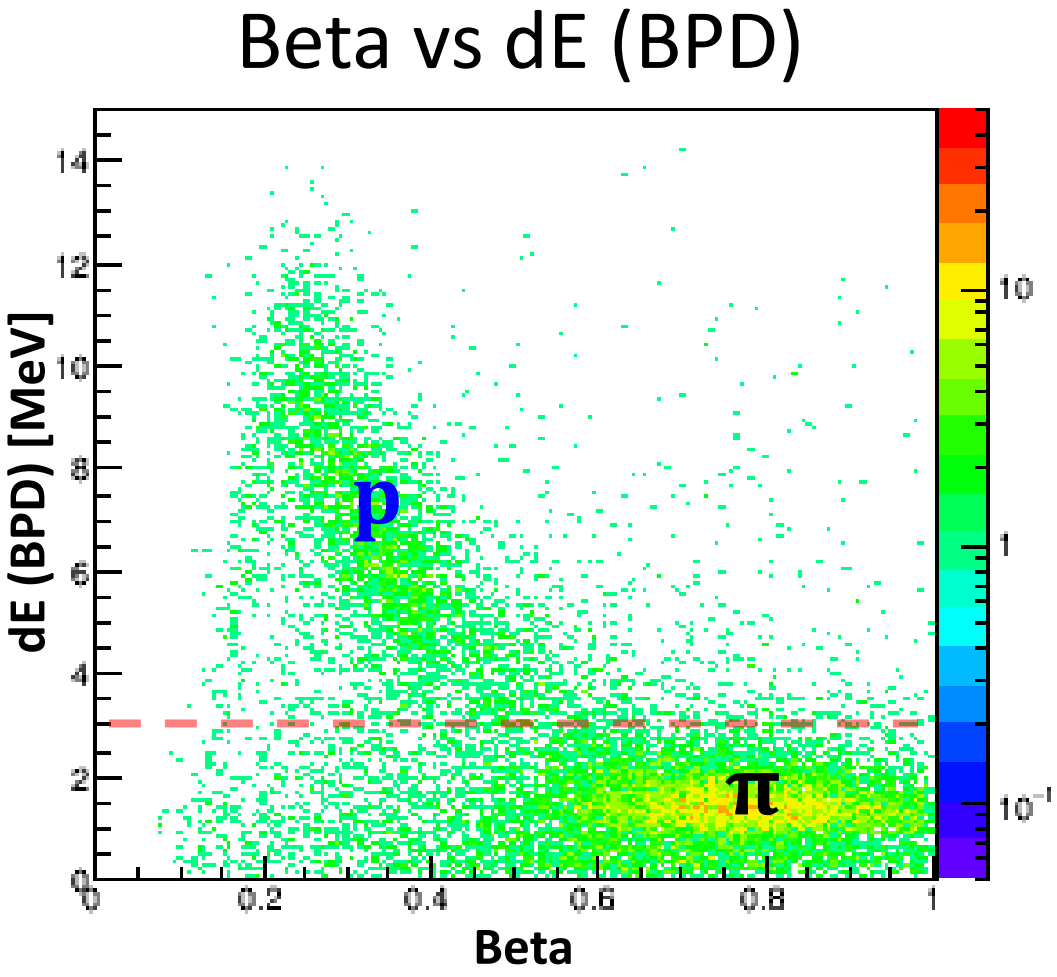
→ the decay proton emitted backward is detected by backward detectors

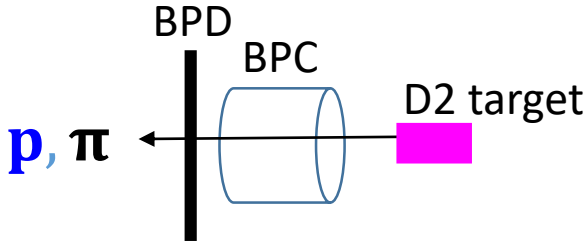




- **Reconstruction of Λ from p π^-**
- **Identify $d(K^-, n\,\Lambda)$"$\pi^0\gamma$" missing mass**

Identification of backward proton

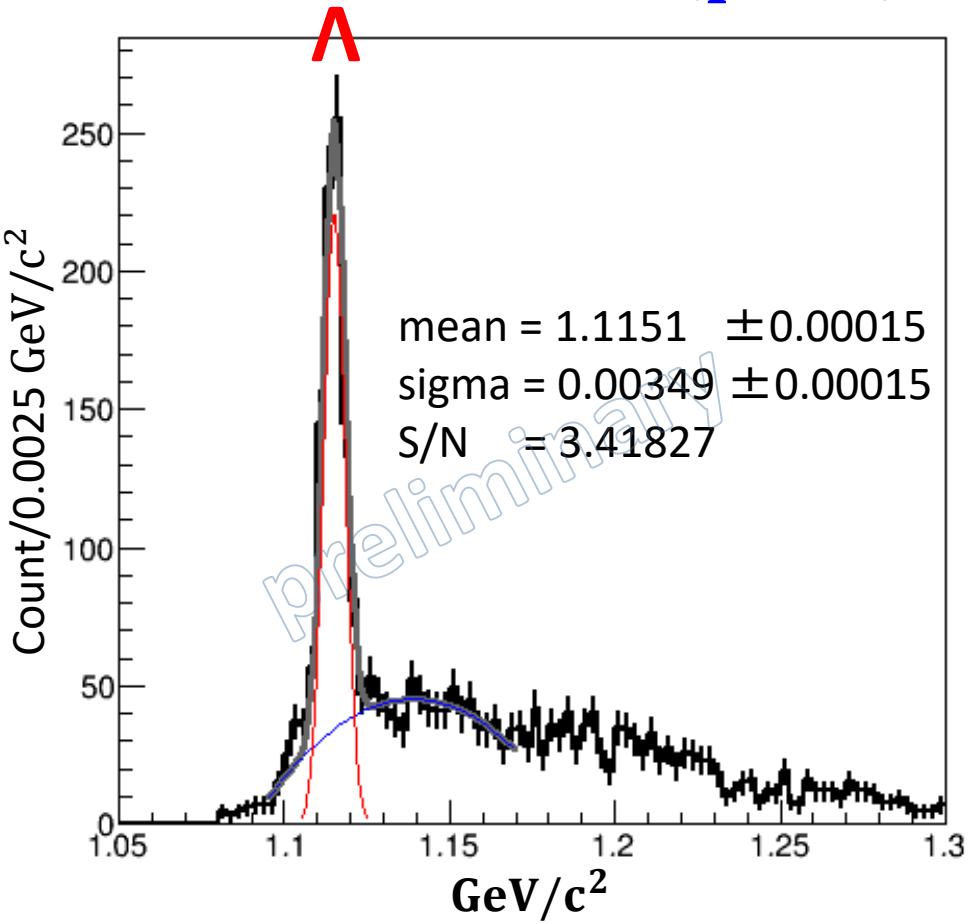




- Backward particles can be identified by dE of BPD
- Backward proton threshold - 3 MeV

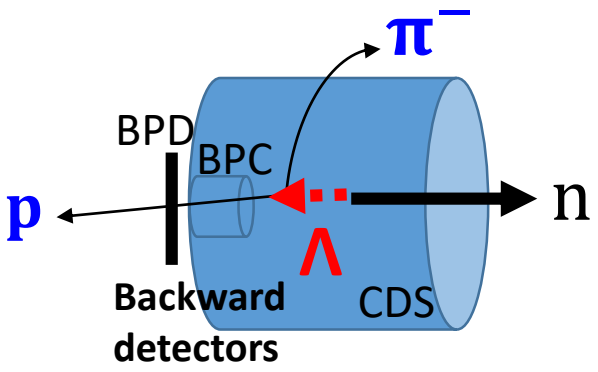
Identification of Λ

Invariant mass (p, π^-)



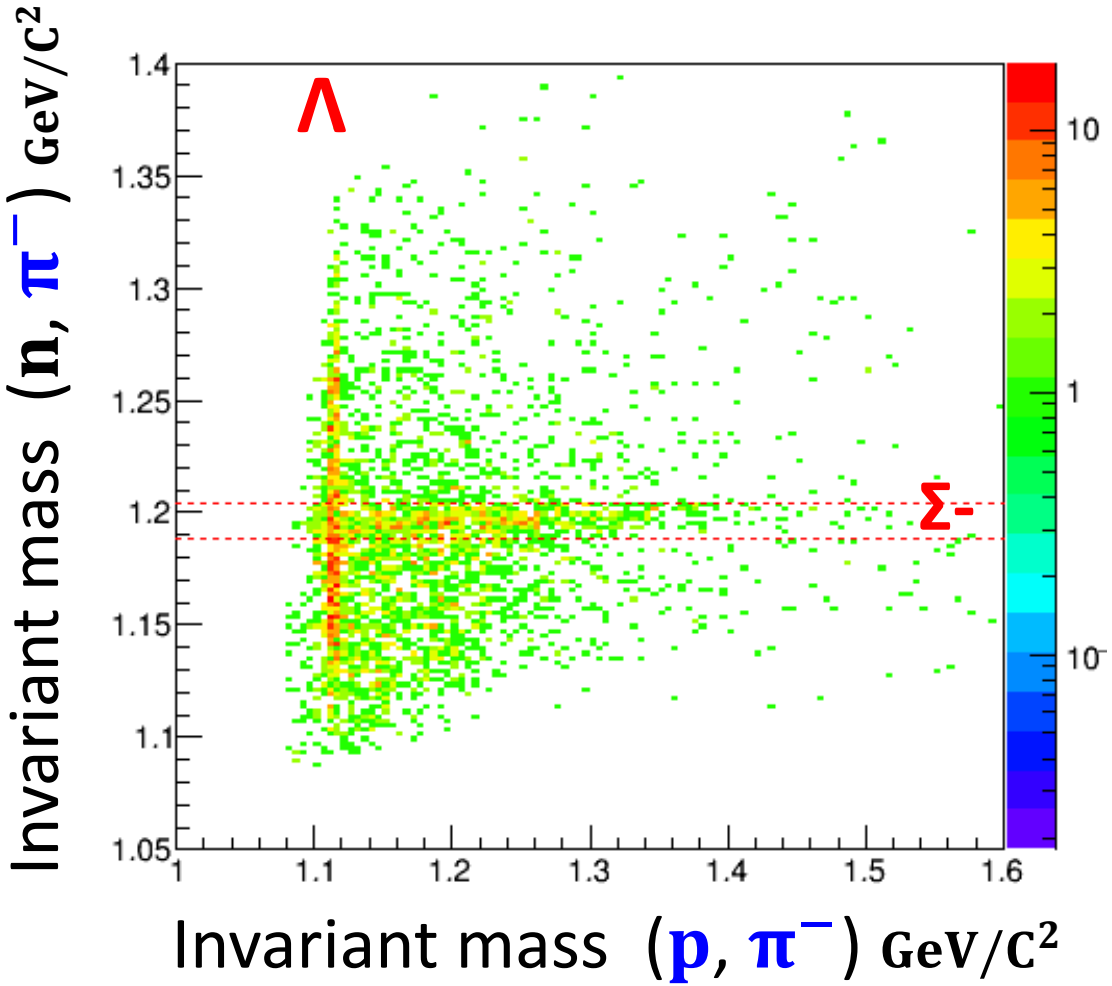
K- d → n Σ0 π0

Λ π0 γ



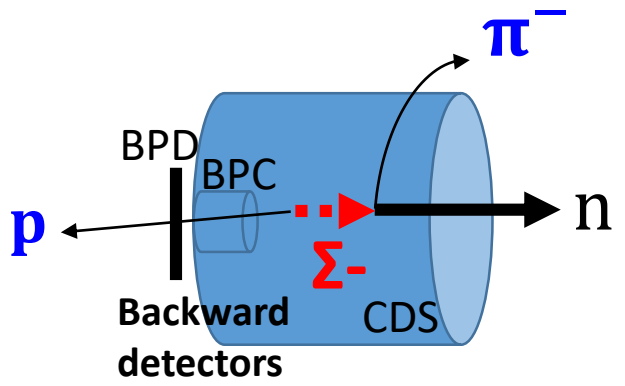
- Reconstruction of Λ is a success

BG cut from Forward Σ-



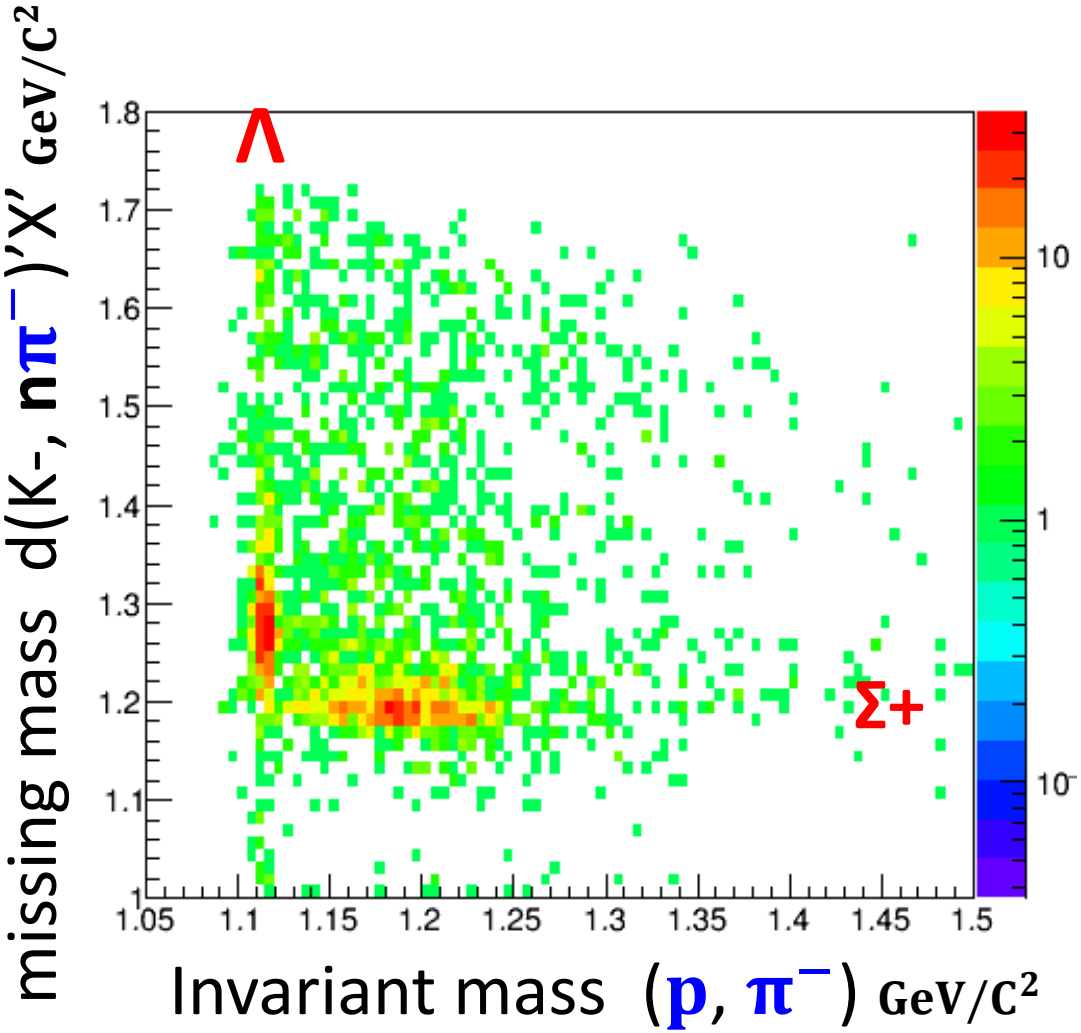
BG : $K^- d \rightarrow \Sigma^- p$

$\pi^- n$



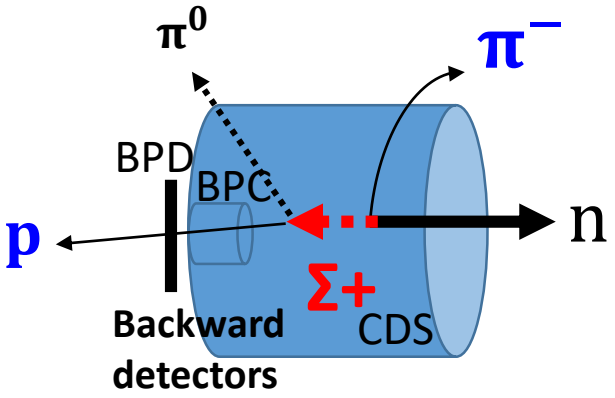
- Neutron from Σ- event is reconstructed in backward proton event
- This region is cut

Possible contamination from $\Sigma^+\pi^-$



BG : $K^- d \rightarrow \Sigma^+ \pi^-$

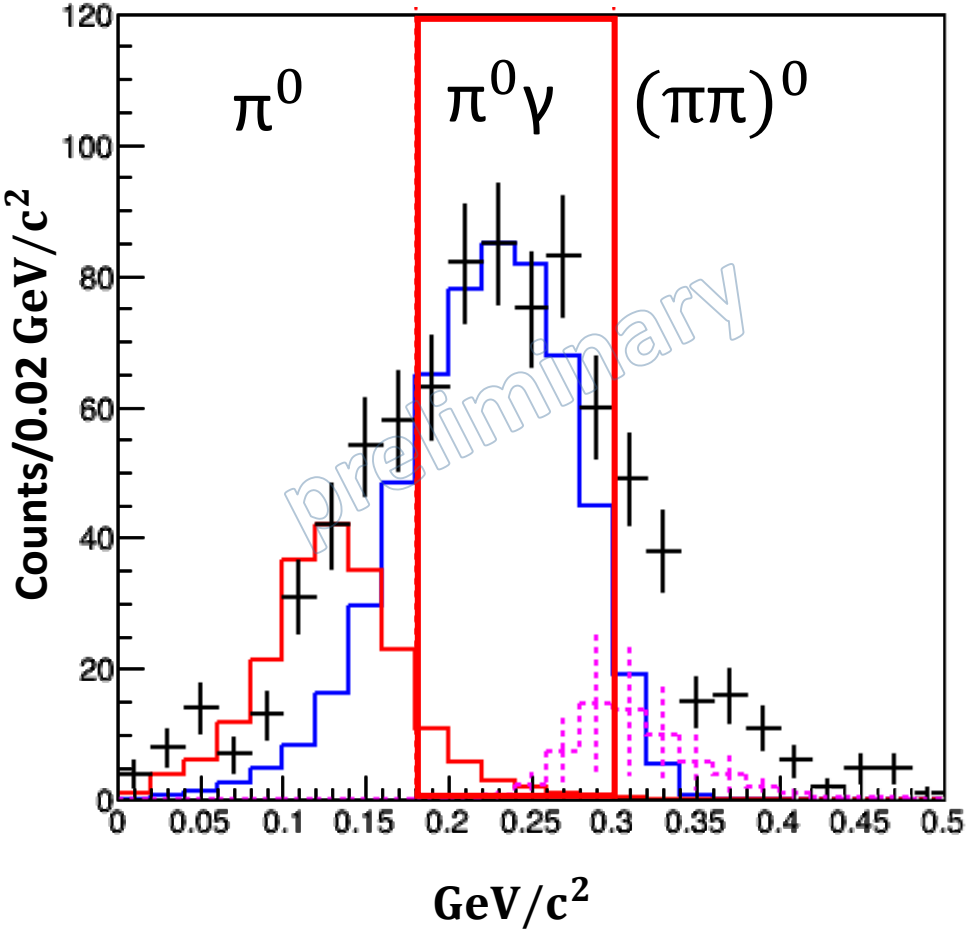
$\rightarrow p\ \pi^0$



- $\Sigma^+\pi^-$ event is reconstructed in backward proton event
- $\Sigma^+\pi^-$ event is separated from Λ event

Selection of $\pi^0\gamma$ region

d(K-,nΛ)'X' missing mass



+ (Data)

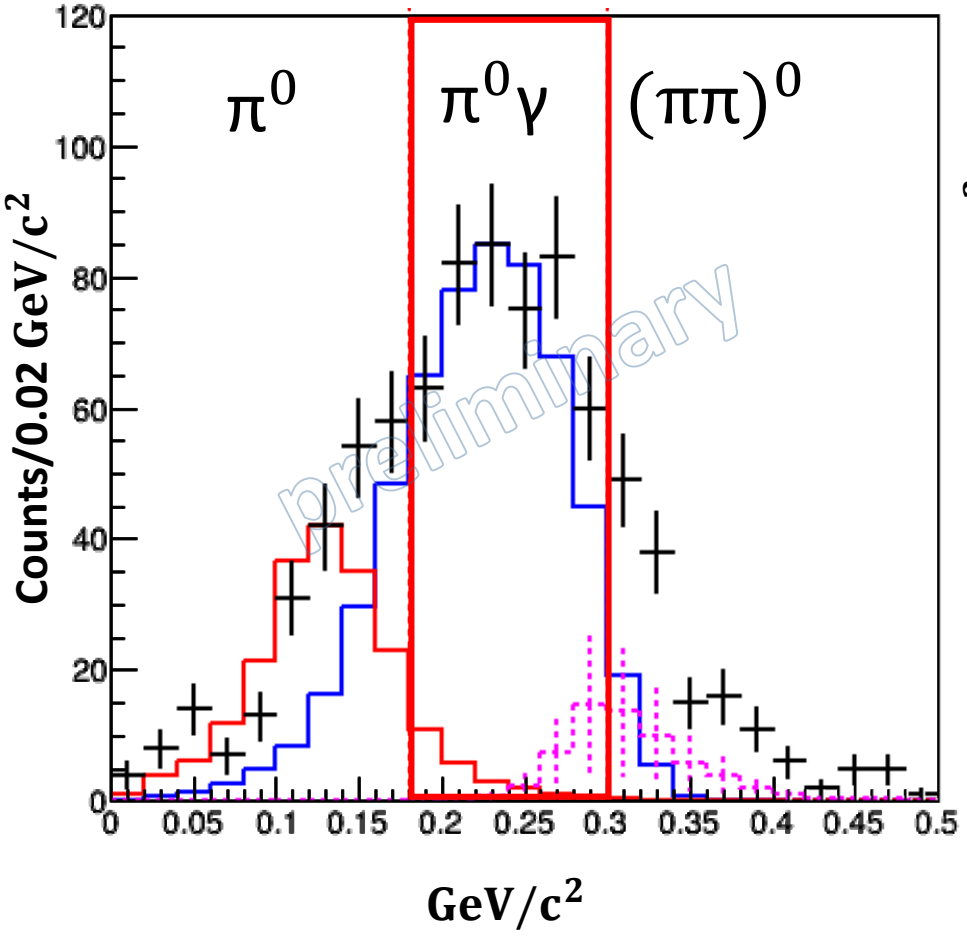
Hist(SIM)

- $K^-d \rightarrow n\,\Lambda\,\pi^0$
- $K^-d \rightarrow n\,\Sigma^0\,\pi^0$
- $K^-d \rightarrow n\,\Lambda\,(\pi\pi)^0$

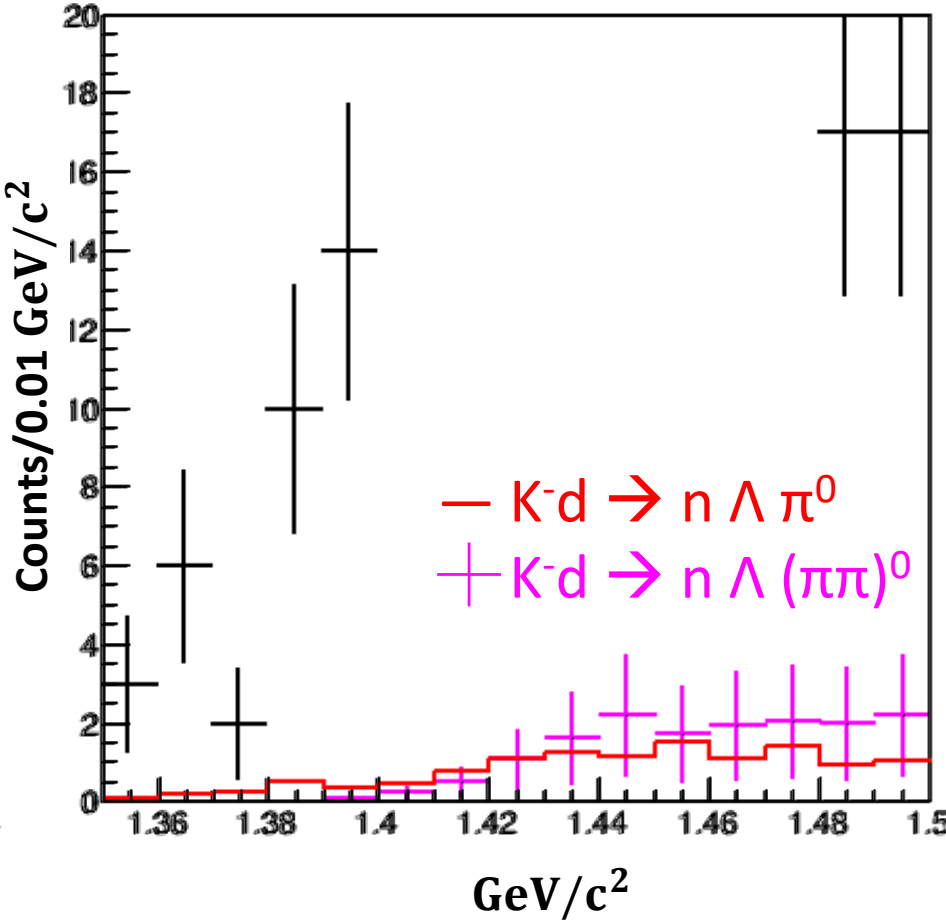
Selection of $\pi^0\gamma$ $0.18 < d(K^-,n\Lambda) < 0.3$ [GeV/c2]

π^0,$(\pi\pi)^0$ contamination in d(K-,n)$\Sigma^0\pi^0$

d(K⁻,nΛ)'X' missing mass



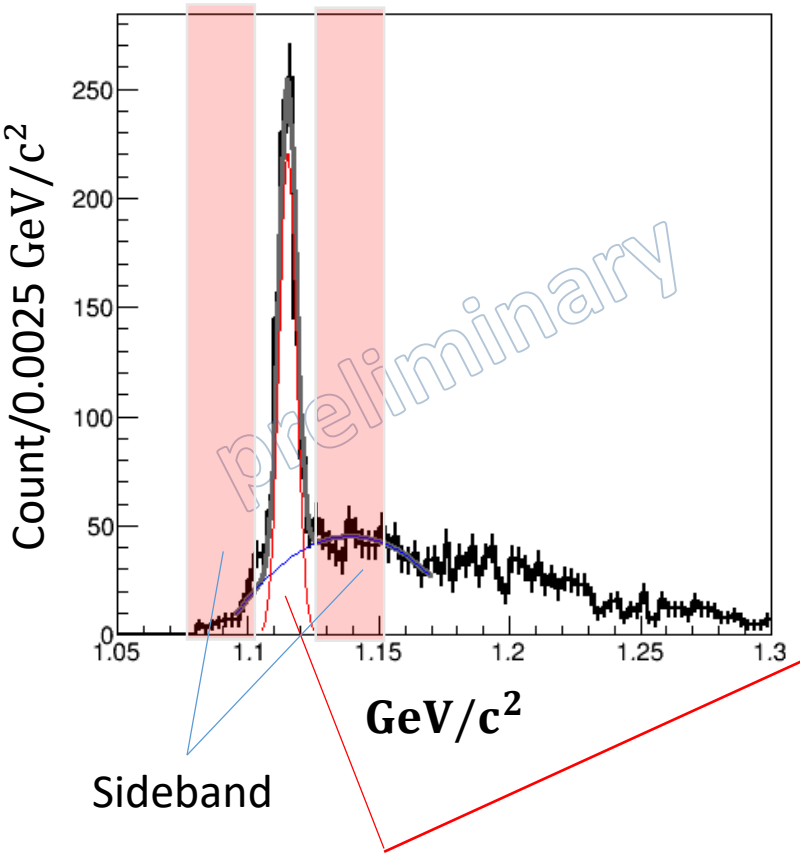
d(K-,n)$\Sigma^0\pi^0$ missing mass



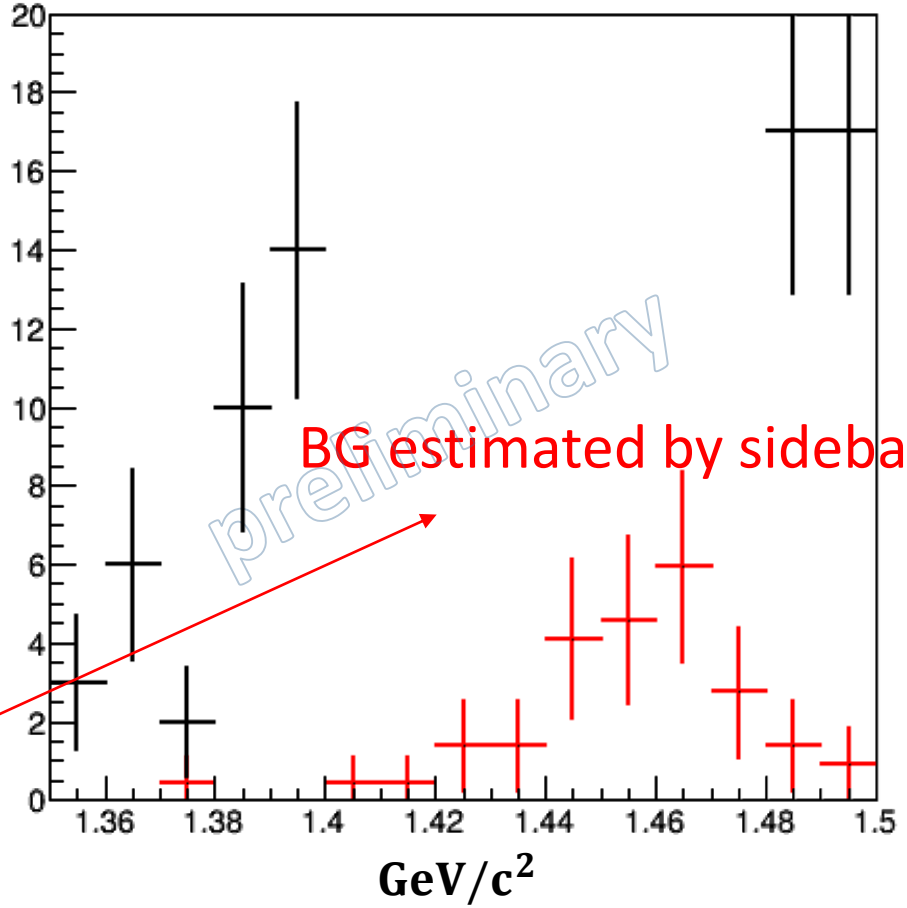
Contribution of π^0、$(\pi\pi)^0$ is small (1.35~1.5 [GeV/c2])

BG estimation from sidebands of Λ

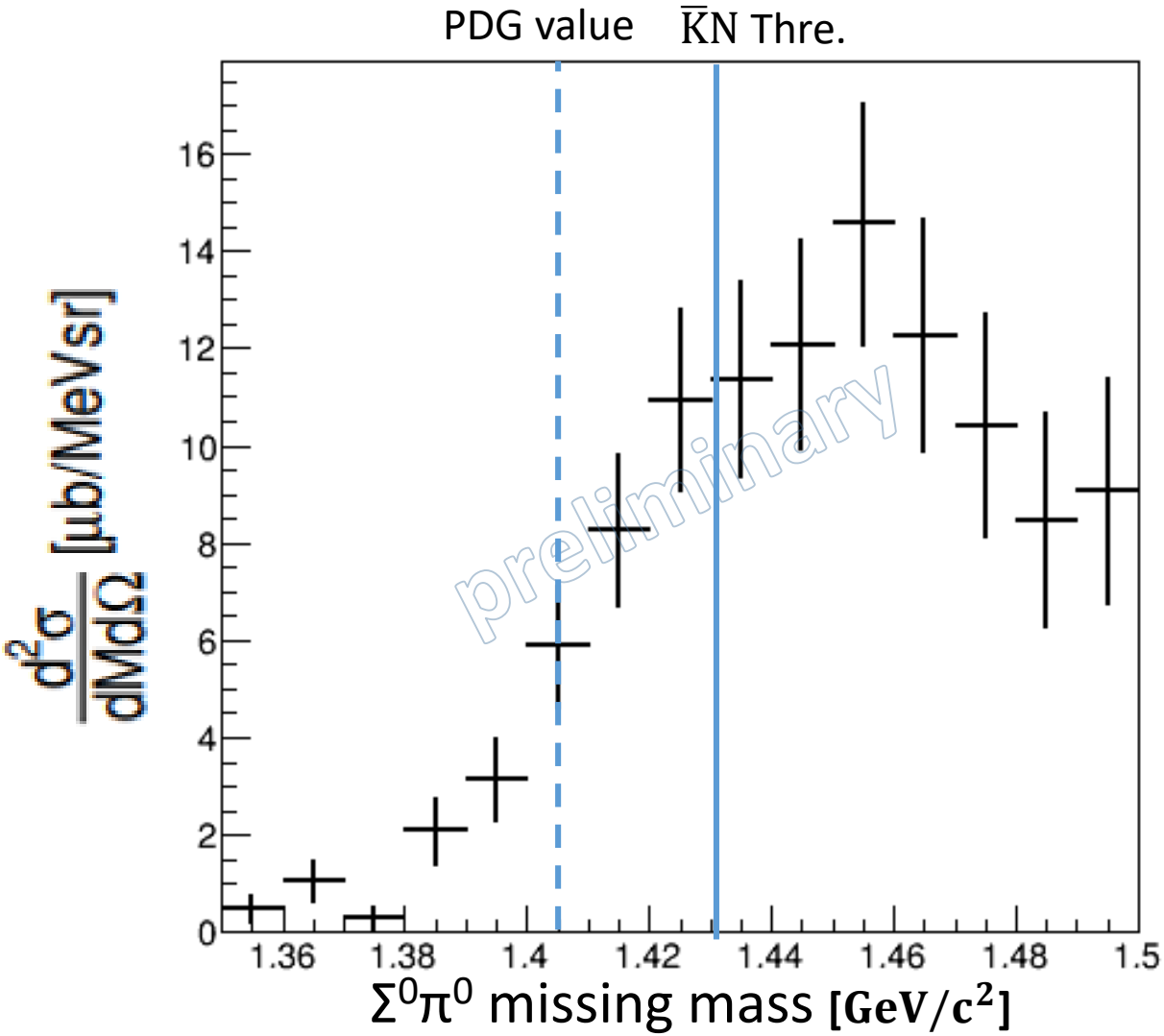
Invariant mass $(\mathbf{p}, \boldsymbol{\pi}^-)$



d(K-,n)Σ0π0 missing mass

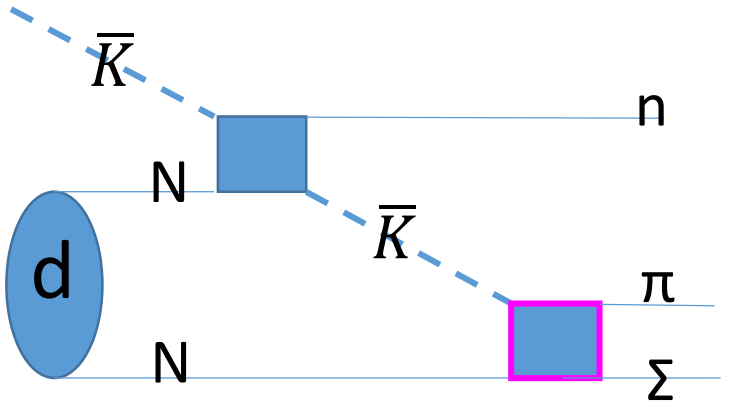


Cross Section of $d(K^-,n)\Sigma^0\pi^0$



We first observed the $d(K^-,n)\Sigma^0\pi^0$ spectrum

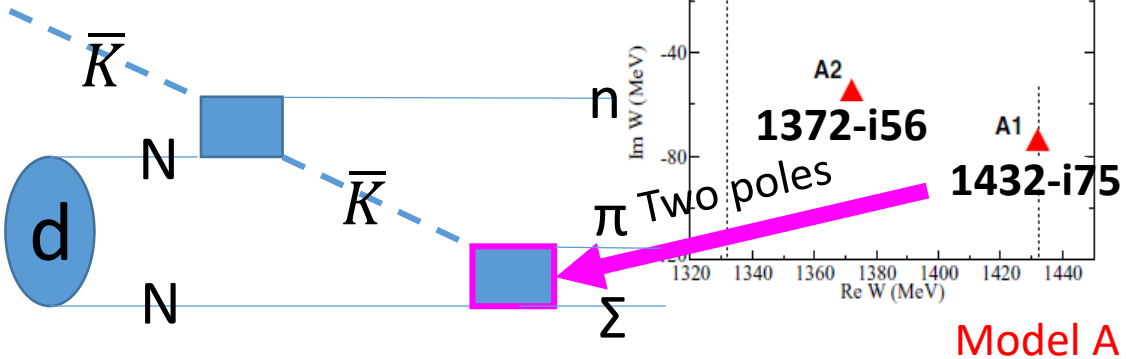
Theoretical calculation on d(K⁻,n)πΣ



- 2 step process
  - D. Jido, E. Oset, and T. Sekihara, EPJA49, 95(2013)
  - J. Yamagata-Sekihara, T. Sekihara, and D. Jido, PTEP, 2013, 043D02
  - H. Kamano and T.-S. H. Lee, PRC94, 065205(2016)
- Faddeev calculation
  - K. Miyagawa and J. Haidenbauer, PRC85,065201(2012)
  - K. Miyagawa, J. Haidenbauer, and H. Kamada, PRC97, 055209(2018)
  - S. Ohnishi, Y. Ikeda, T. Hyodo, and W. Weise, PRC93, 025202(2016)

Comparison w/ theoretical calculation

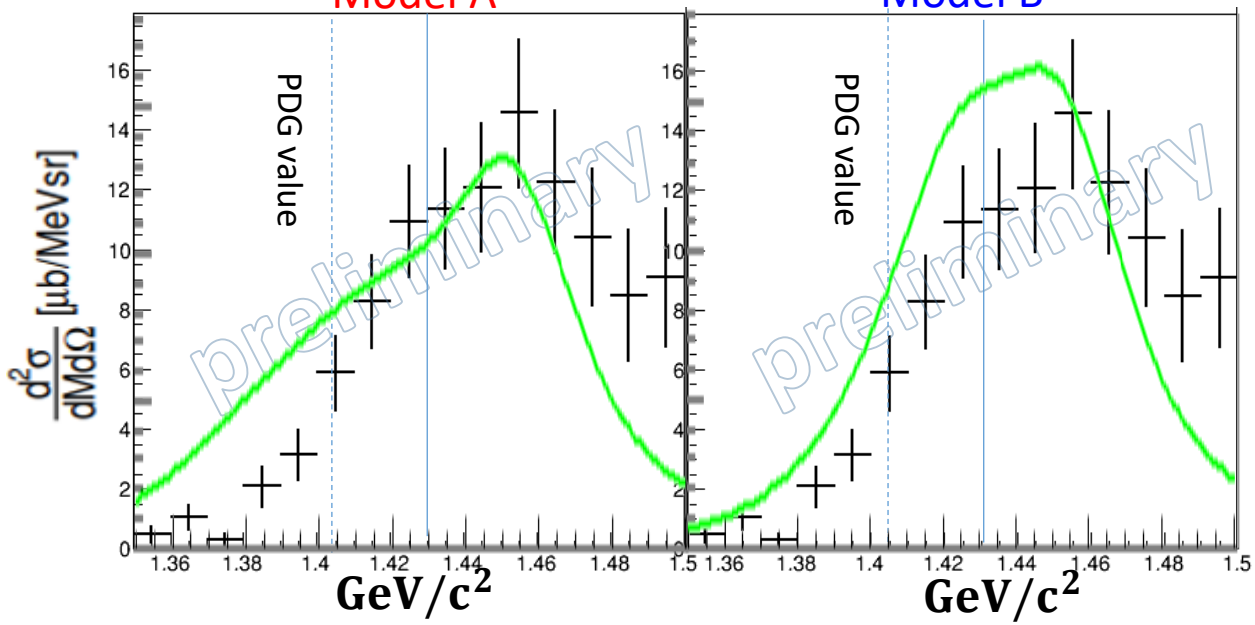
2 step process



Model A

Model A

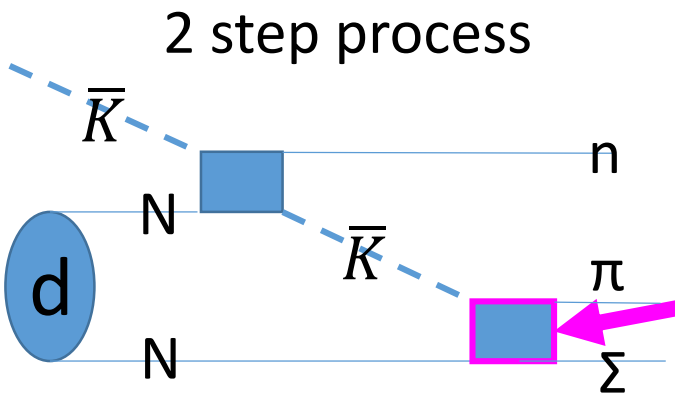
Model B



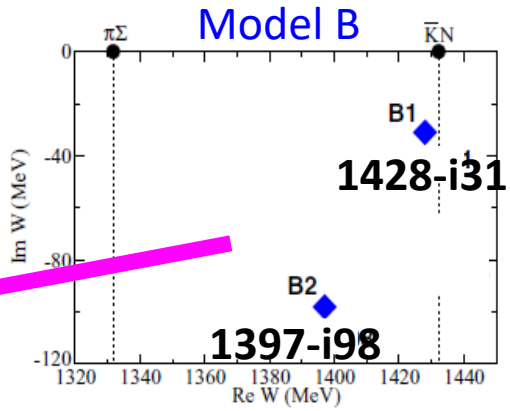
H. Kamano et al., Phys. Rev. C 94, 065205 (2016)

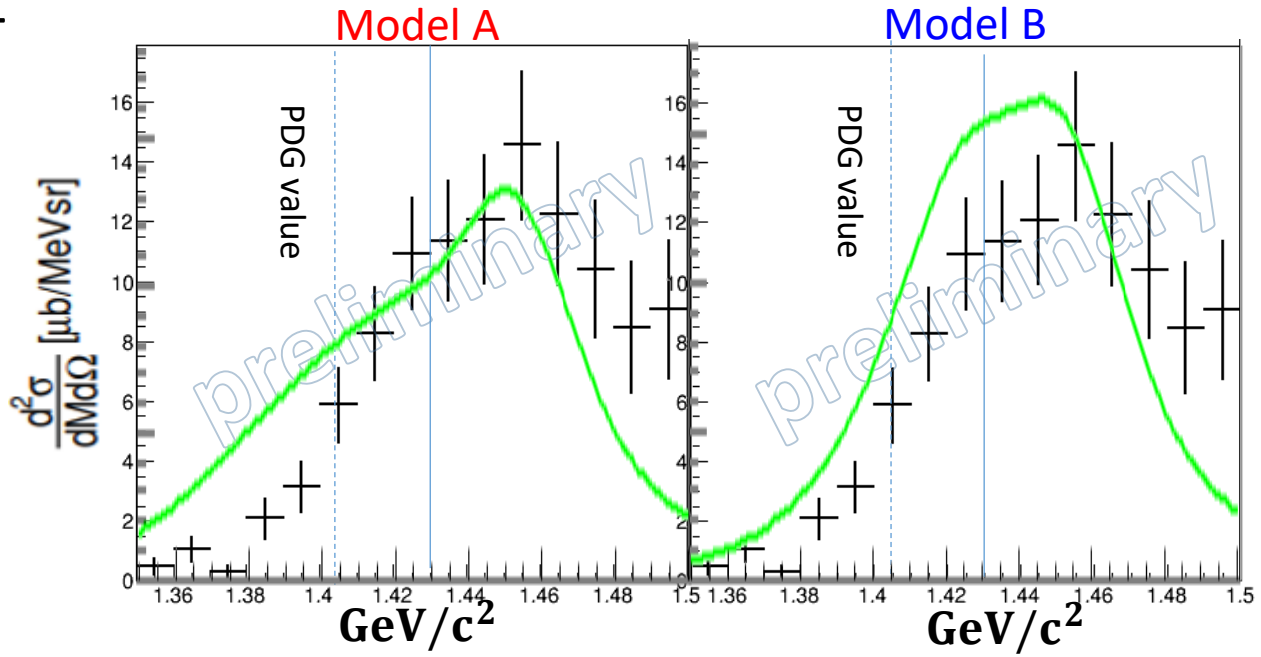
Res. convoluted

Comparison w/ theoretical calculation



Two poles





Two step process well explains the observed spectrum.

H. Kamano et al., Phys. Rev. C 94, 065205 (2016)

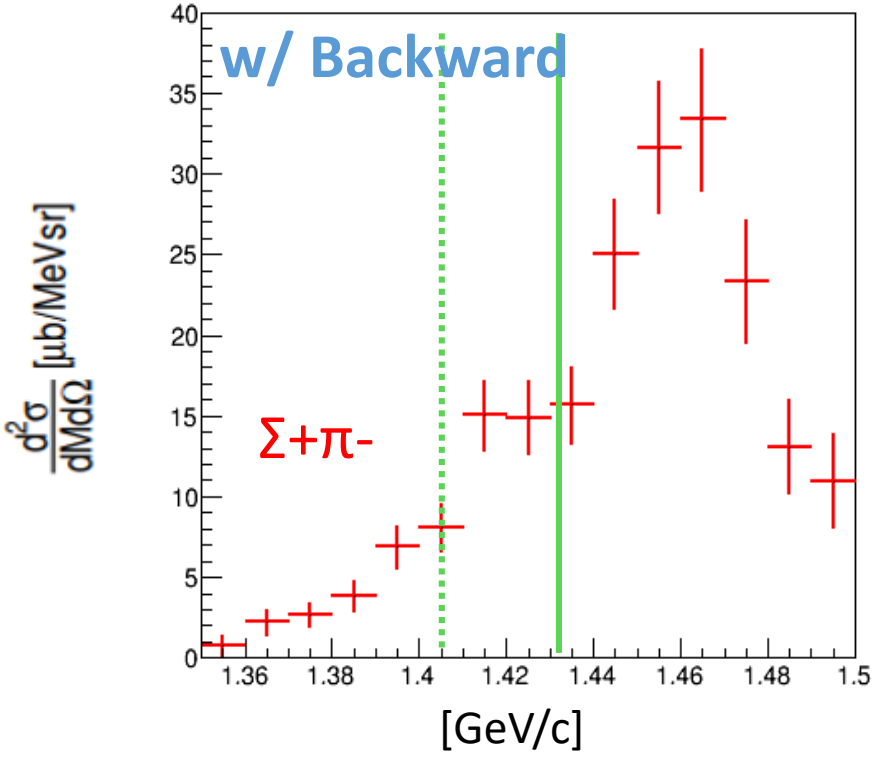
Res. convoluted

Summary

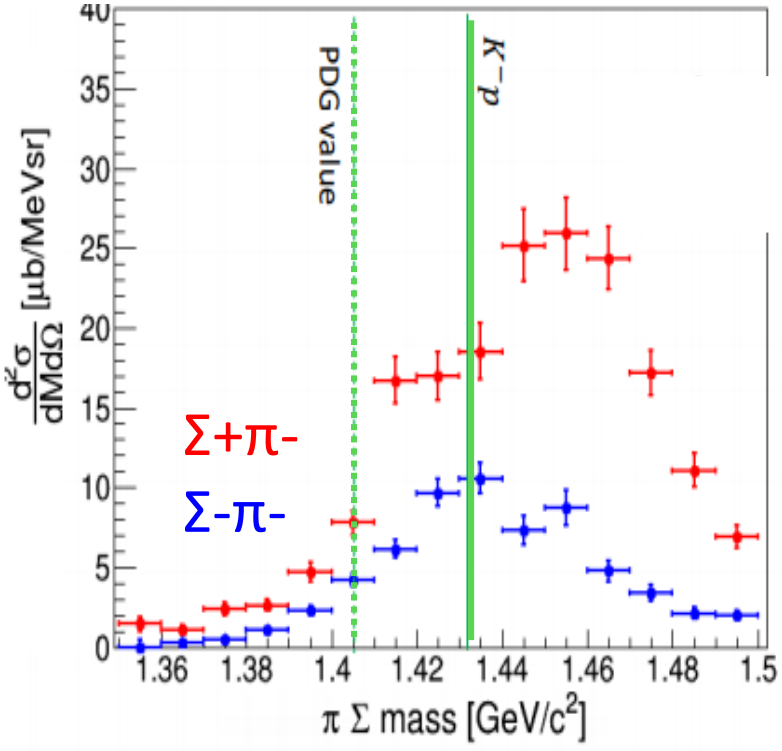
- We have performed E31-2nd, and obtained d(K-,n)Σ0π0 spectrum shape
- Overall behavior of d(K-,n)Σ0π0 spectrum seem to be explained well by the theoretical calculation w/ 2 step process.
- Λ(1405) pole information is expected to be extracted by the spectrum shape in 2 step process.

Confirmation of backward analysis w/ d(K-,n)Σ+π-

d(K-,n)Σ+π- missing mass
(Σ+ → p π0)

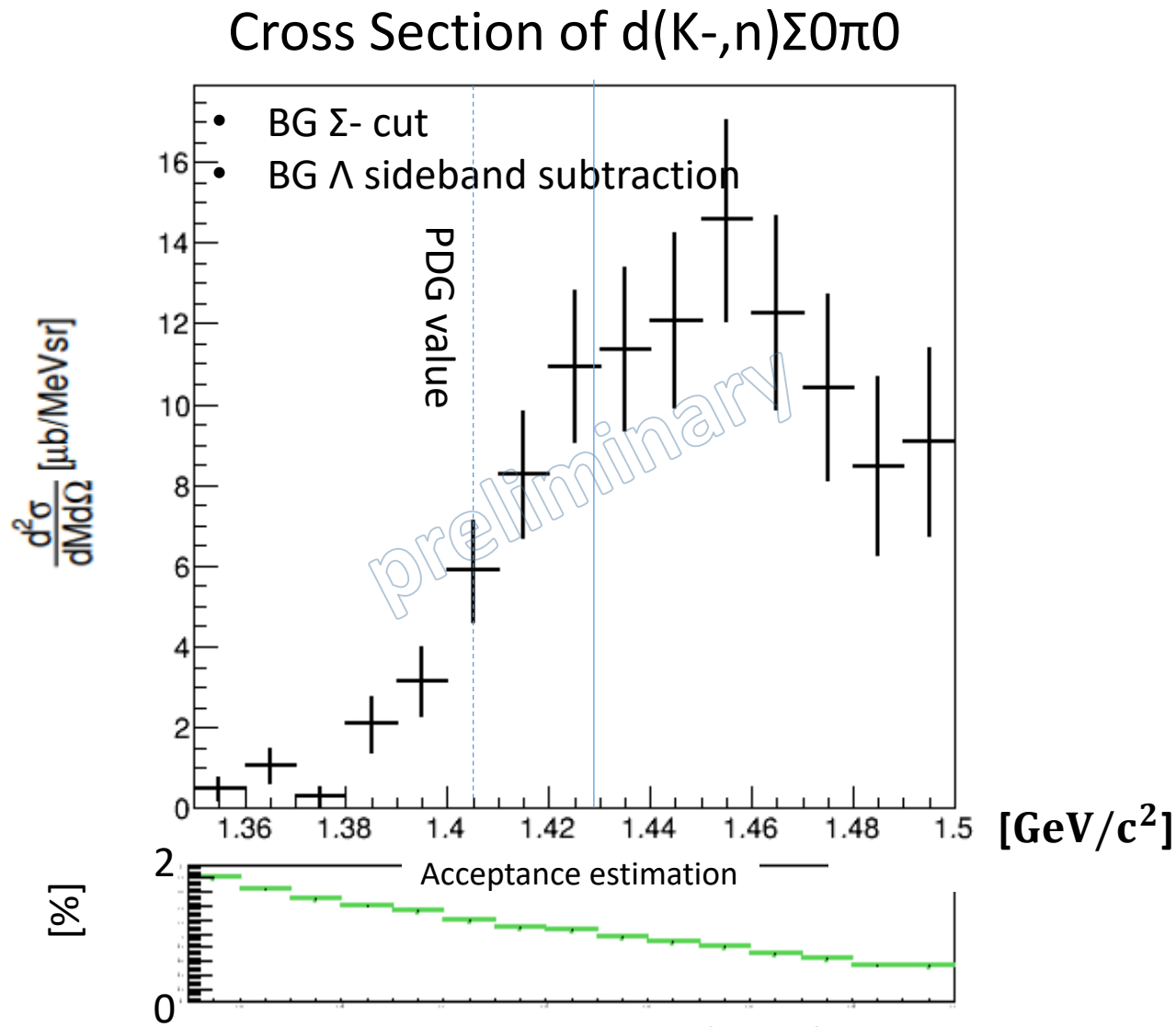


d(K-,n)Σ+π- missing mass
(Σ+ → π+ n)



- Spectrum shape of d(K-,n)Σ+π- (Σ+ → p π-) reproduce the one of d(K-,n)Σ+π- (Σ+ → π+ n) well
  → Backward analysis works well

Cross Section of d(K-,n)Σ0π0



We obtained the line shape of d(K-,n)Σ0π0 spectrum