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

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J-PARC E31 collaboration

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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)

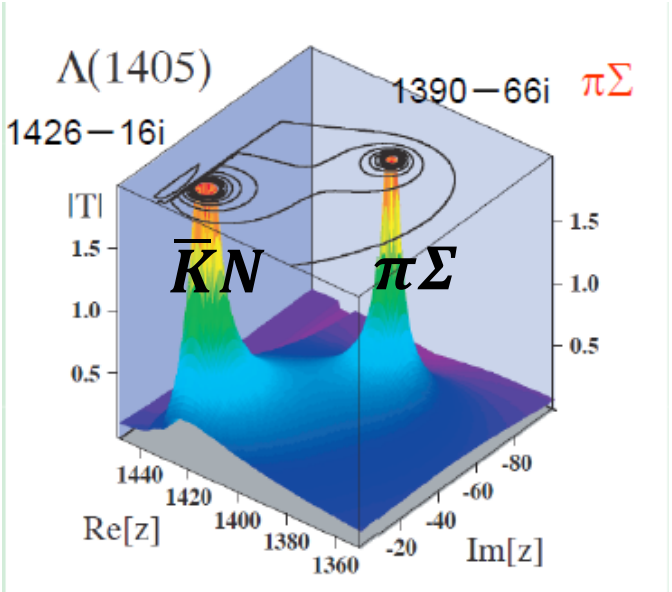
$\Gamma = 50 \pm 2$(MeV) (PDG-2012)

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

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

Λ(1405)

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

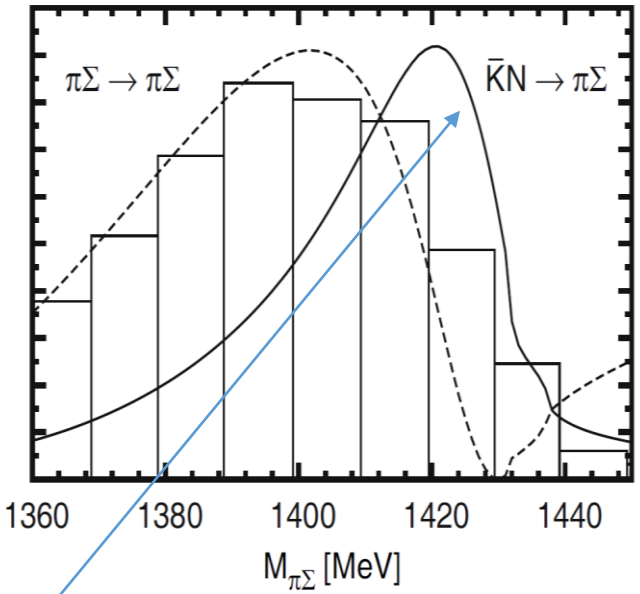


T.Hyodo and W.Weise, Phys.RevC77,035204(2008)

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

The reaction cannot occur in free space

$d(K^-, n)$ reaction

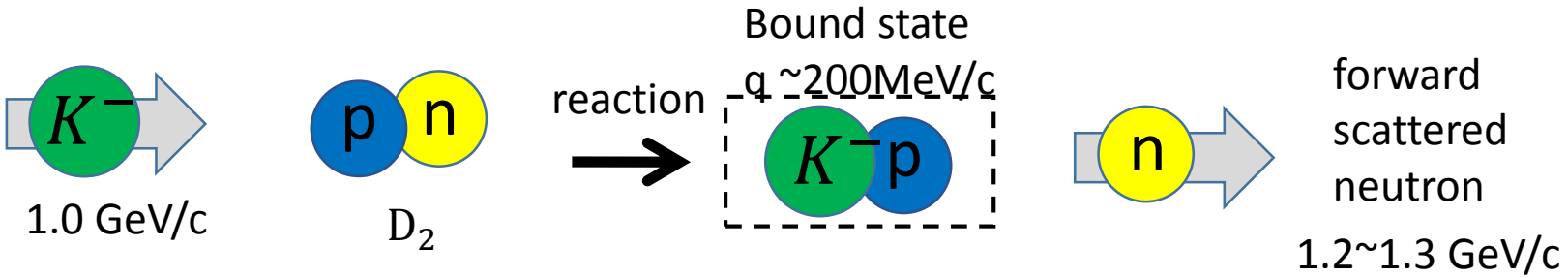


Eur. Phys. J. A42('09)257

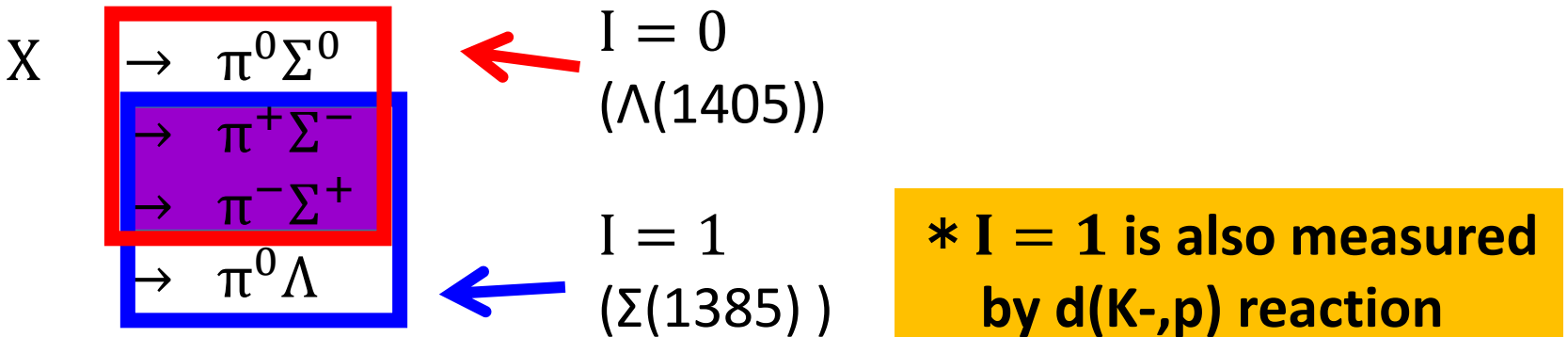
The reaction is expected to enhance the scattering

J-PARC E31 experiment

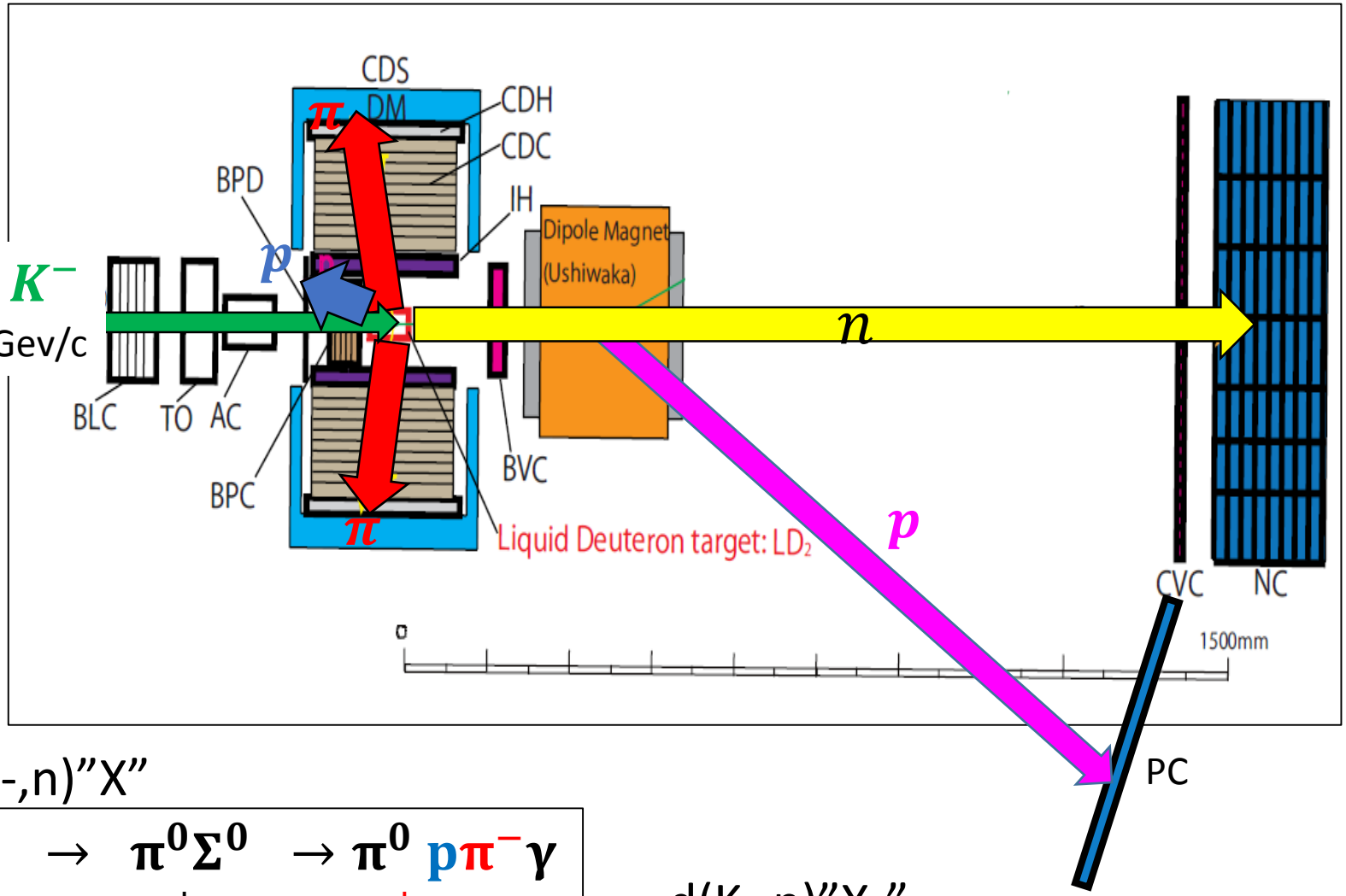
- Λ(1405) measurement via in-flight $\mathrm{d}(\mathrm{K}^-, \mathrm{n})$



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



J-PARC E31 experiment set up



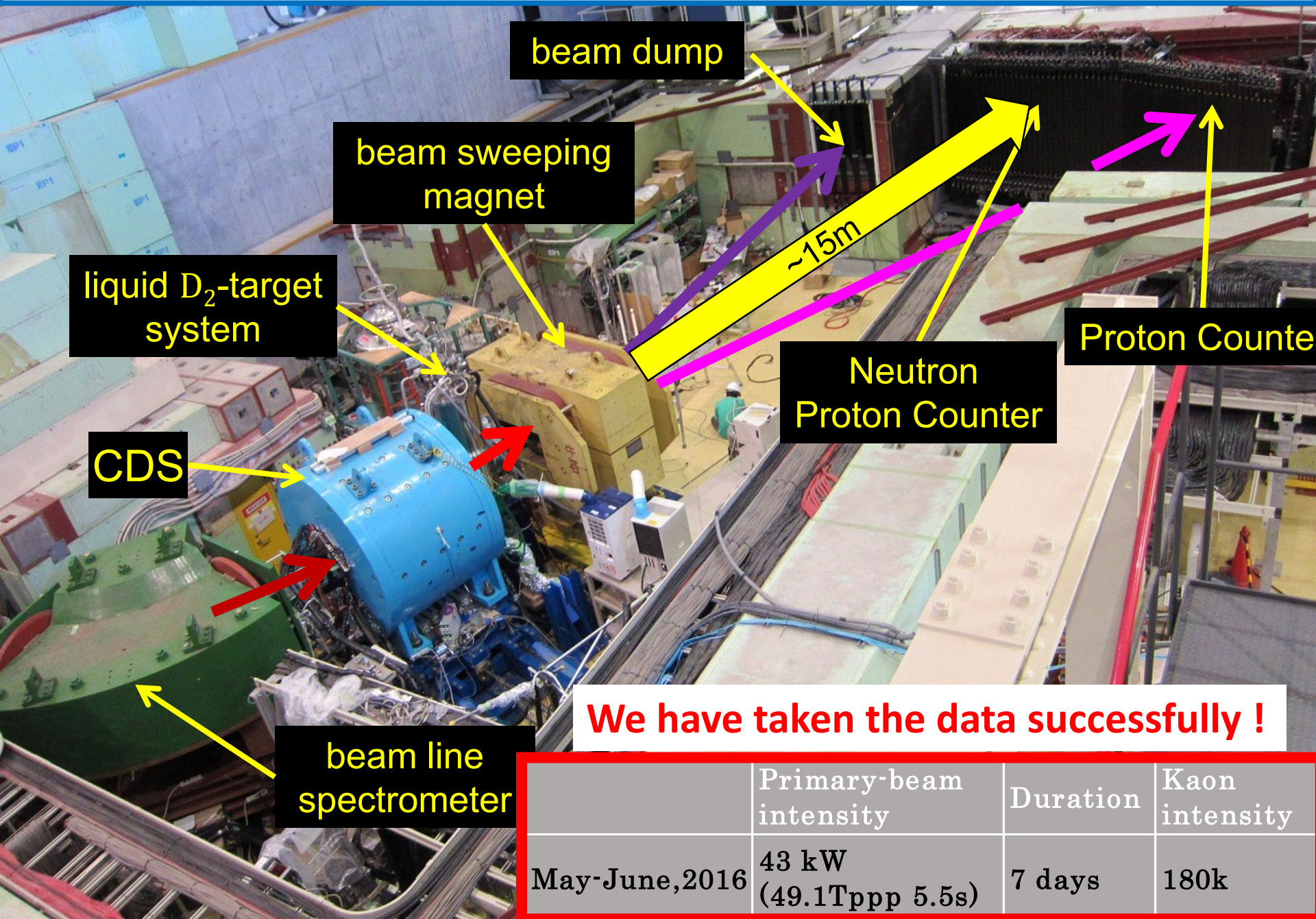
d(K-,n)"X"

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

d(K-,p)"X-"

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

K1.8BR spectrometer

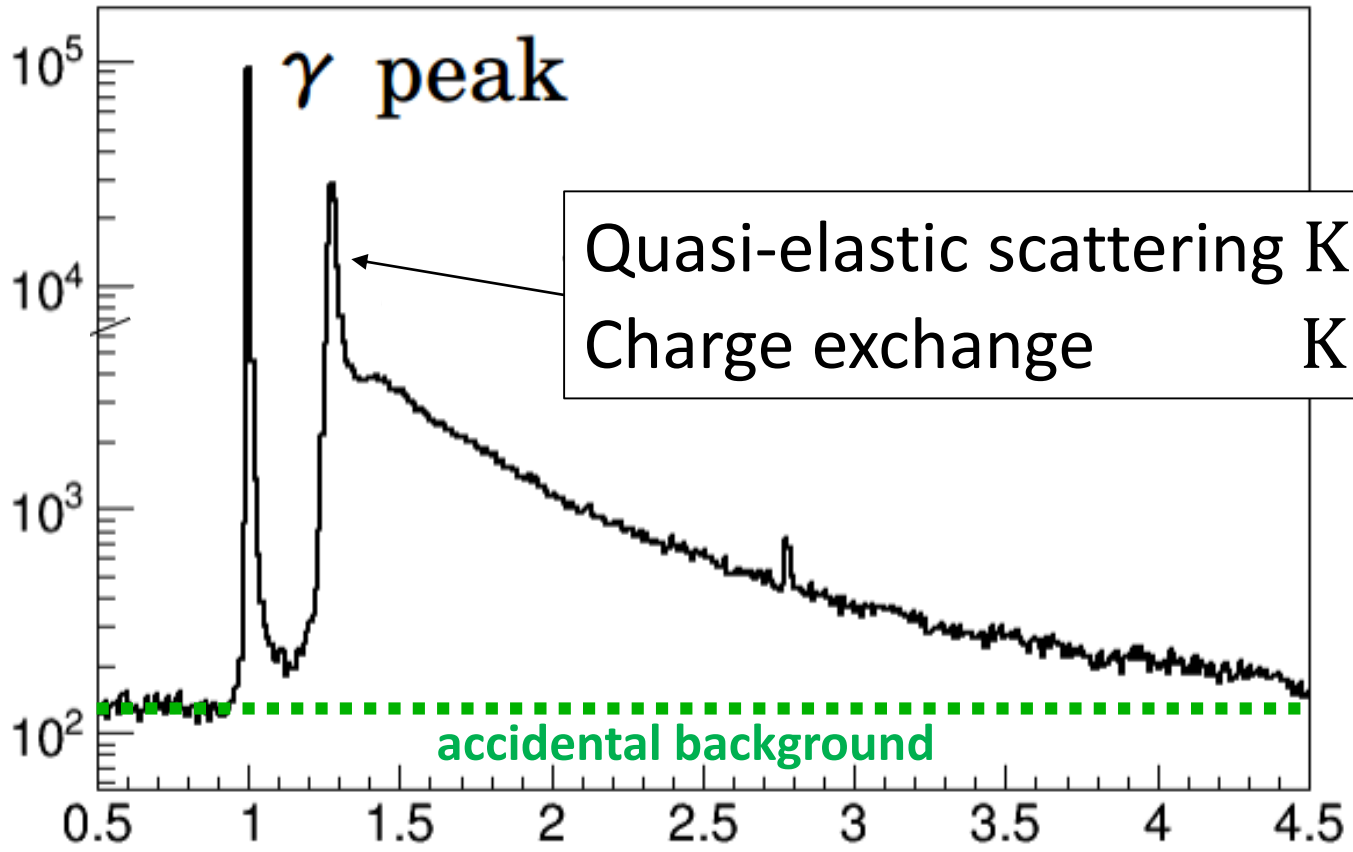


We have taken the data successfully !

	Primary-beam intensity	Duration	Kaon intensity
May-June,2016	43 kW (49.1Tppp 5.5s)	7 days	180k

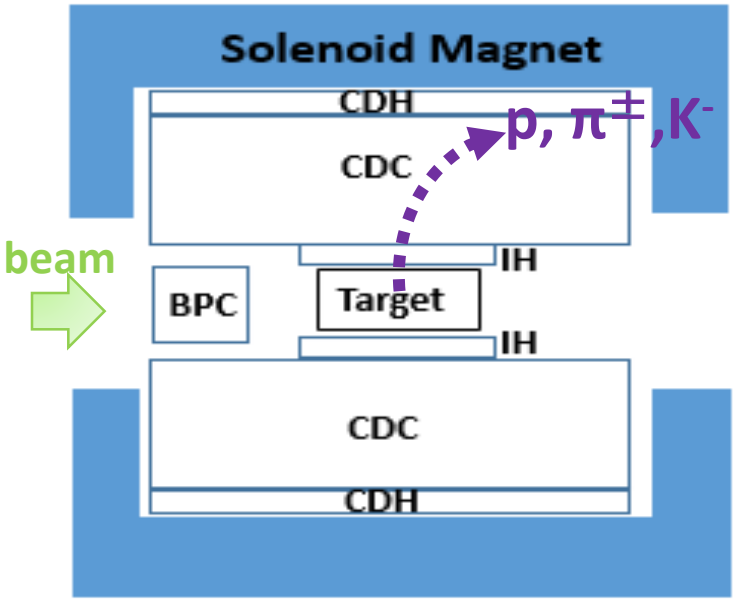
Detector performance

- Neutron Counter

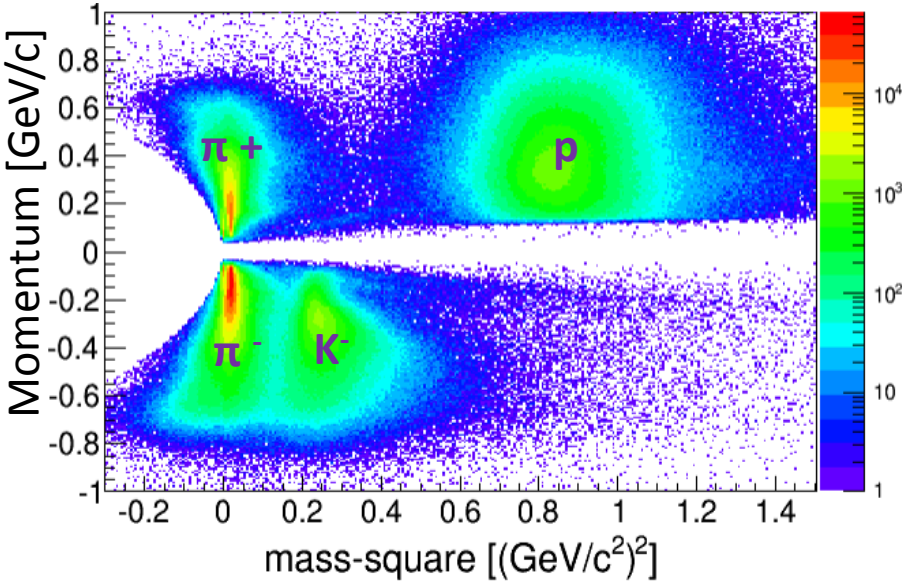


- Cylindrical detector system (CDS)

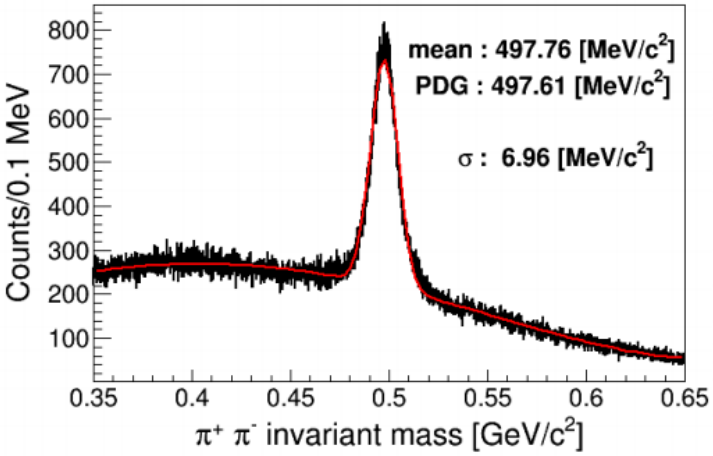
CDS



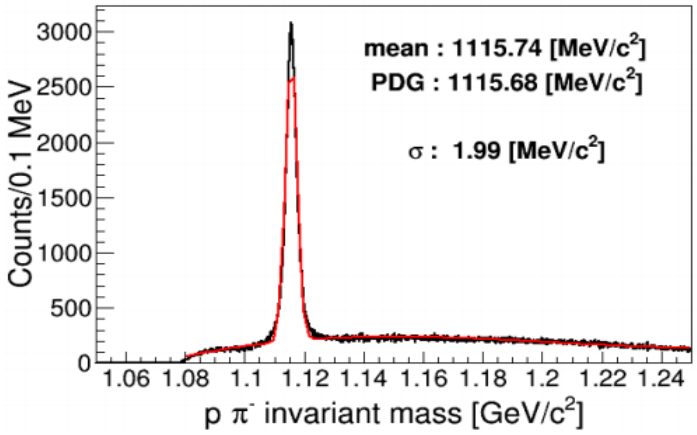
Particle identification



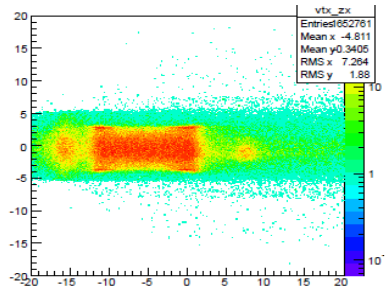
K⁰s reconstruction



Λ reconstruction



Vertex position

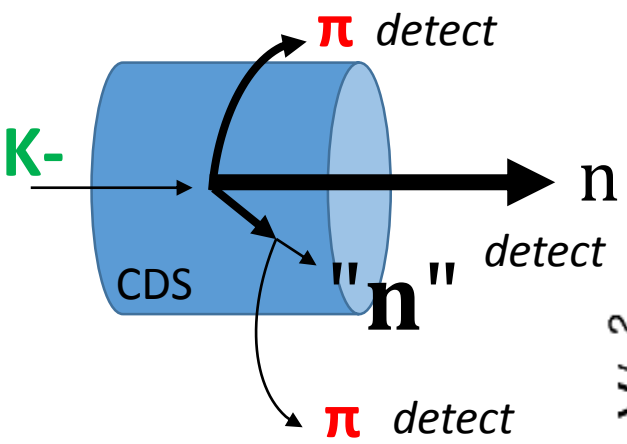


Analysis of $d(K^-, n)\pi^{\pm}\Sigma^{\mp}$ spectrum

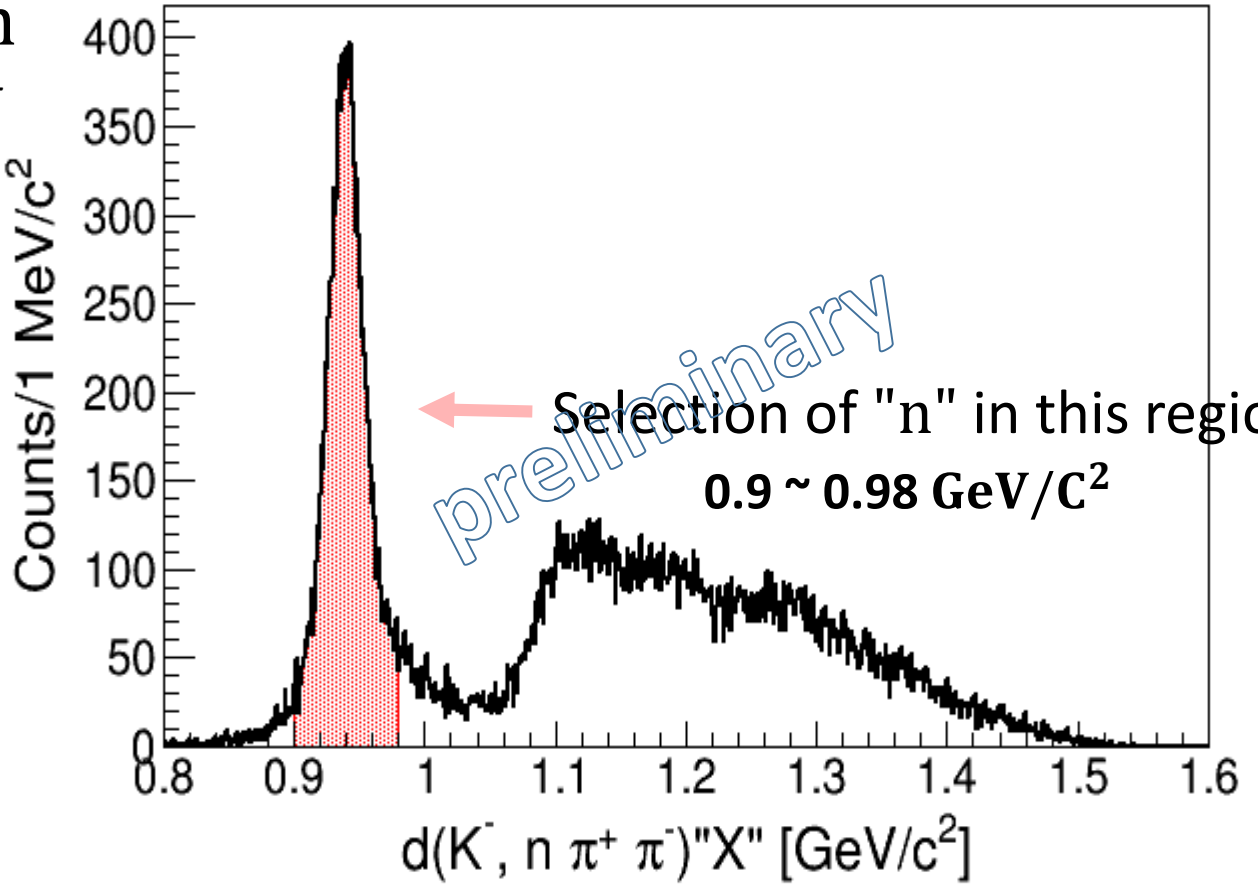
$$\begin{aligned} Y &\rightarrow \pi^+, \Sigma^- \rightarrow \pi^+\pi^- n \\ &\rightarrow \pi^-, \Sigma^+ \rightarrow \pi^-\pi^+ n \end{aligned}$$

- Analysis procedure
  - $d(K^-, n)\pi^{\mp}\pi^{\pm}$"n"
    - n -> NC
    - $\pi^{\mp}\pi^{\pm}$ -> CDS
    - $d(K^-, \pi^{\mp}\pi^{\pm}n)$"n" identification
  - BG rejection in the $d(K^-, n)\pi^{\mp}\pi^{\pm}$"n"
    1. $K^-d \rightarrow (\pi\Sigma)_{backward}\ nfo_{rward}$ → Signal
    2. $K^-d \rightarrow K^0n\ nsp_{ectator}$ → K^0 production (BG)
    3. $K^-d \rightarrow (\pi\Sigma)_{forward}\ n_{spectator}$ → Forward Σ production (BG)
  - $d(K^-, n)\pi^{\pm}\Sigma^{\mp}$ spectrum after the BG rejection
  - Decompose of $\Sigma^-\pi^+$ and $\Sigma^+\pi^-$

$d(K^-, \pi^{\mp}\pi^{\pm}n)$"n" identification

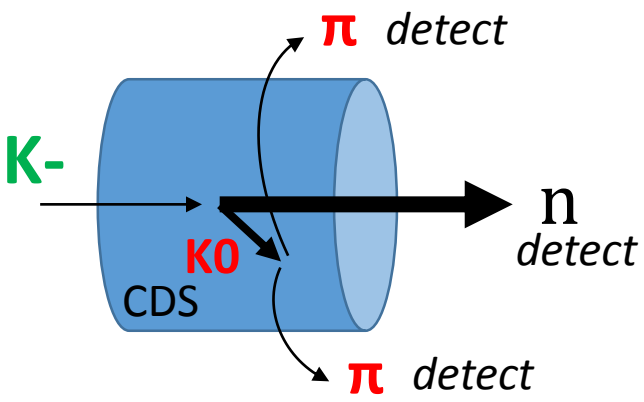


$d(K^-, \pi^{\mp}\pi^{\pm}n)$"X" missing mass

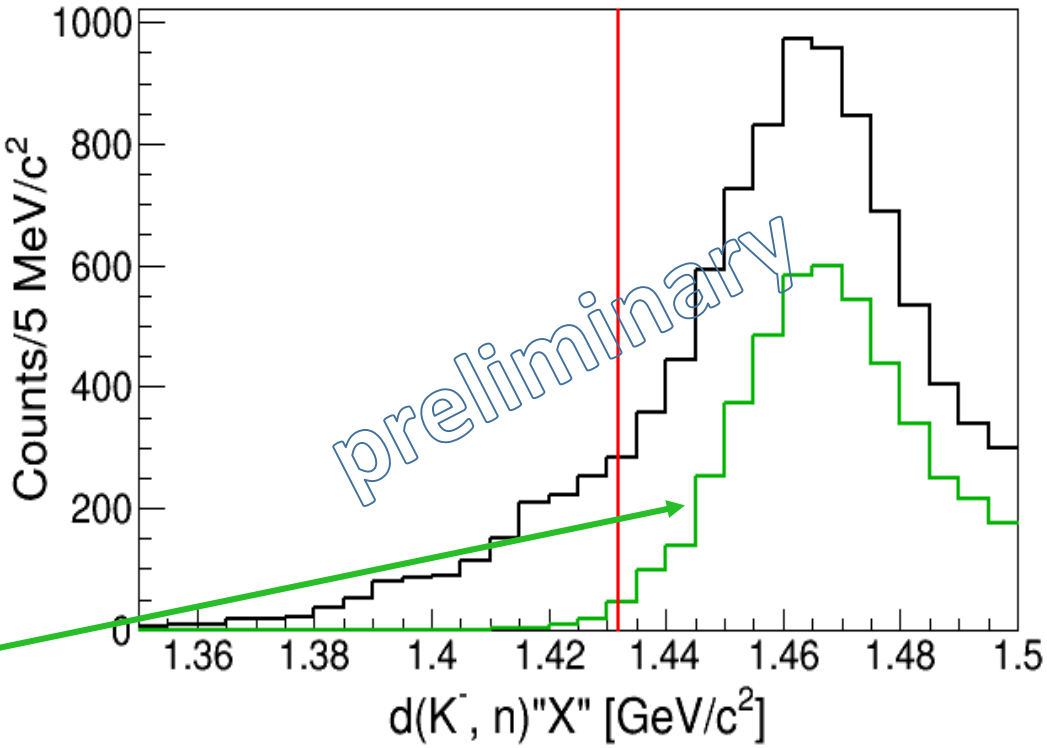


BG : $K^- d \rightarrow K^0 n\, n_{spectator}$

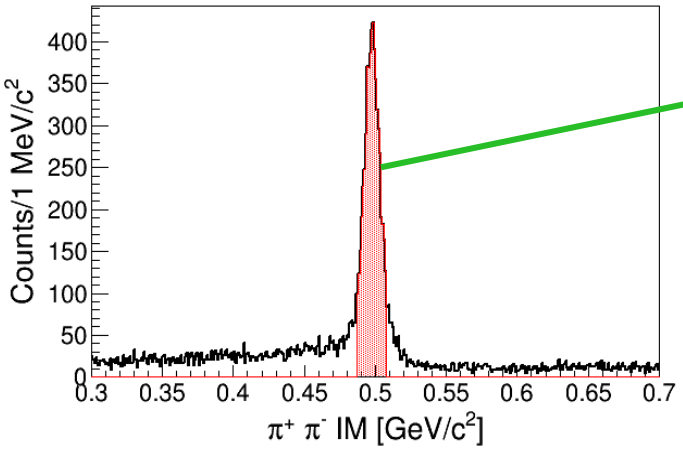
Charge exchange : $K^- p \rightarrow \overline{K^0} n$



$d(K^-, n)\pi^{\mp}\pi^{\pm}$"n" **missing mass**



Invariant mass ($\pi^-\pi^+$)

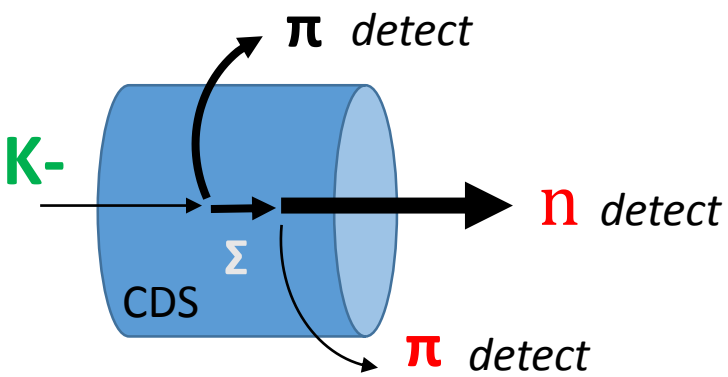


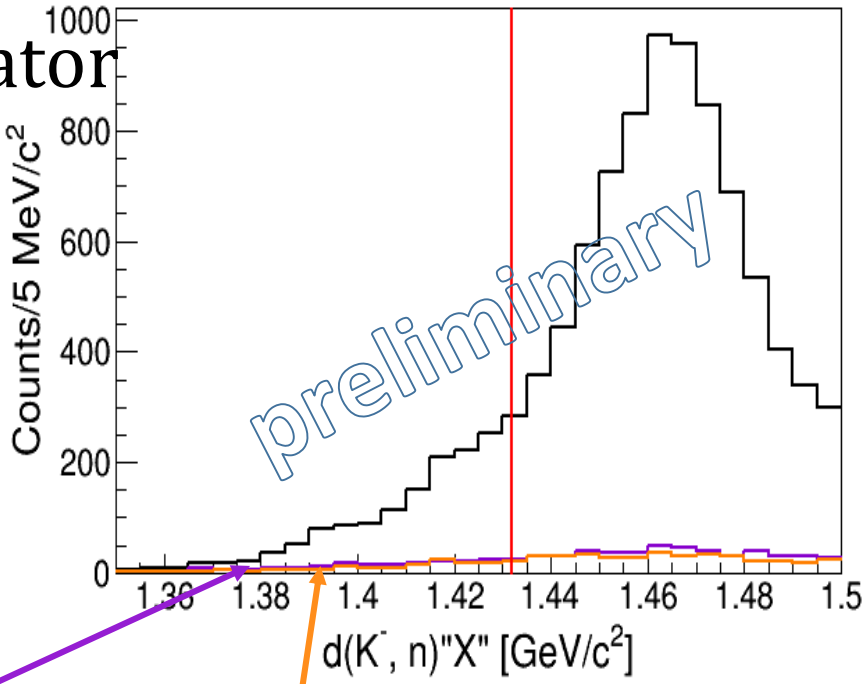
K0 event is reconstructed

- **Missing mass resolution ~ 10 MeV/c^2 at KN threshold**
- **the tail below threshold cannot be explained by detector resolution**

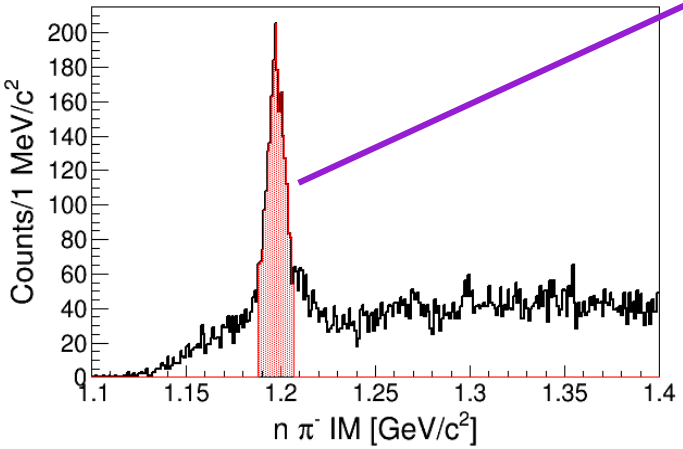
BG : $K^- d \rightarrow \pi \Sigma\, n_{spectator}$

$d(K^-, n)\pi^{\mp}\pi^{\pm}$"n" **missing mass**

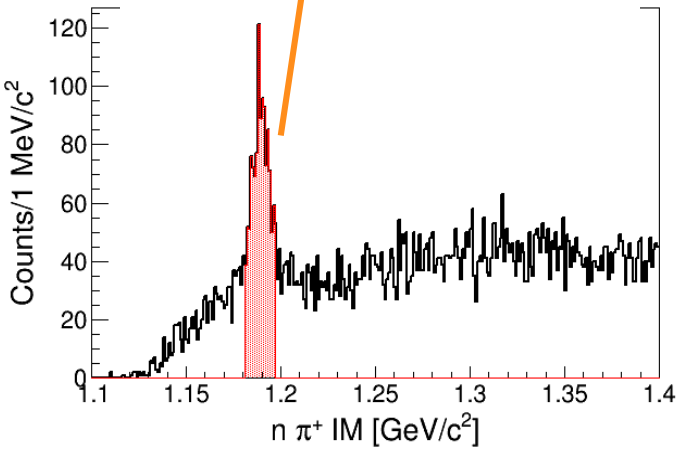




Invariant mass ($\pi^- n$)

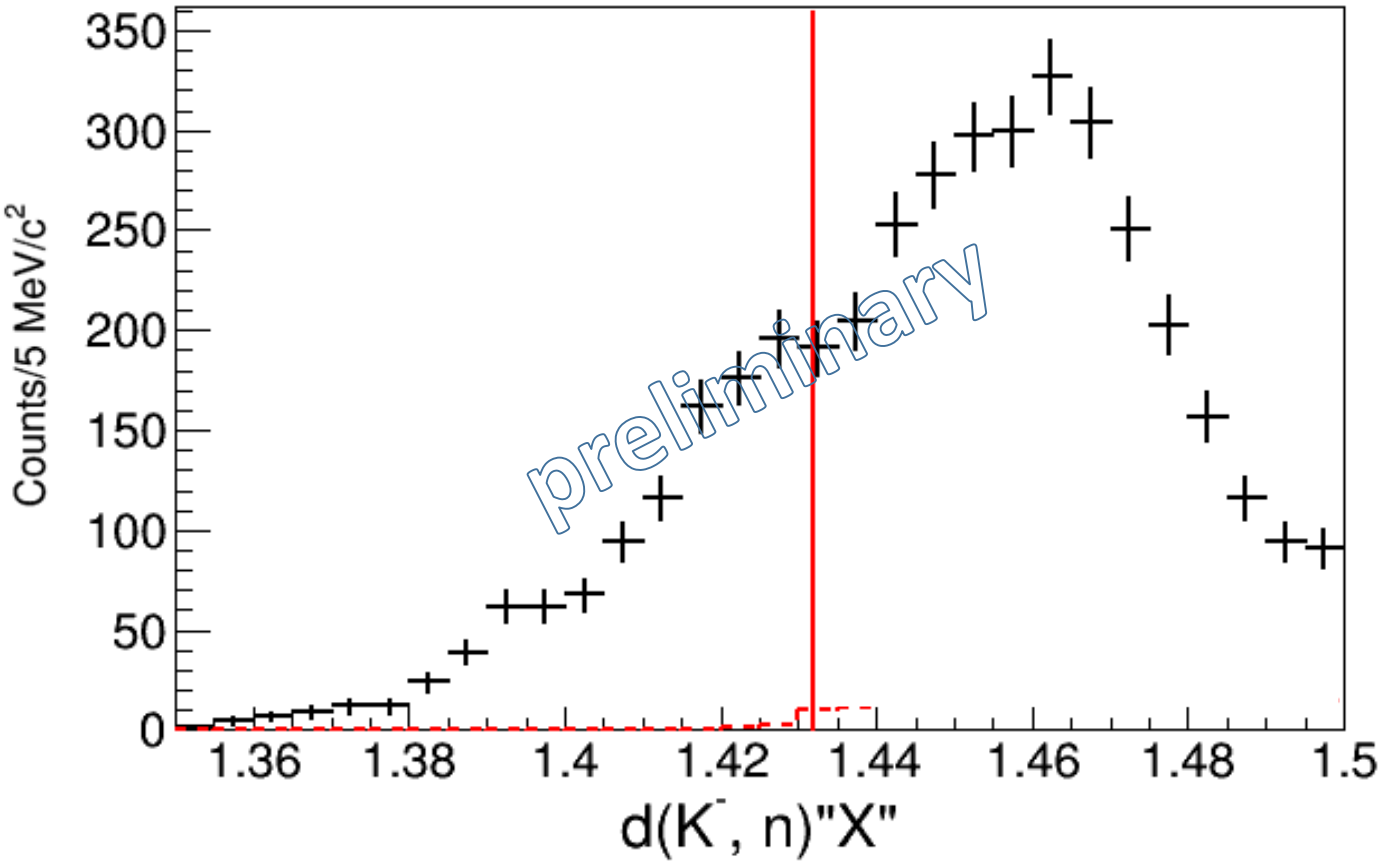


Invariant mass ($\pi^+ n$)



- **Neutron from Σ event is reconstructed**
- **The contribution of this reaction is small**

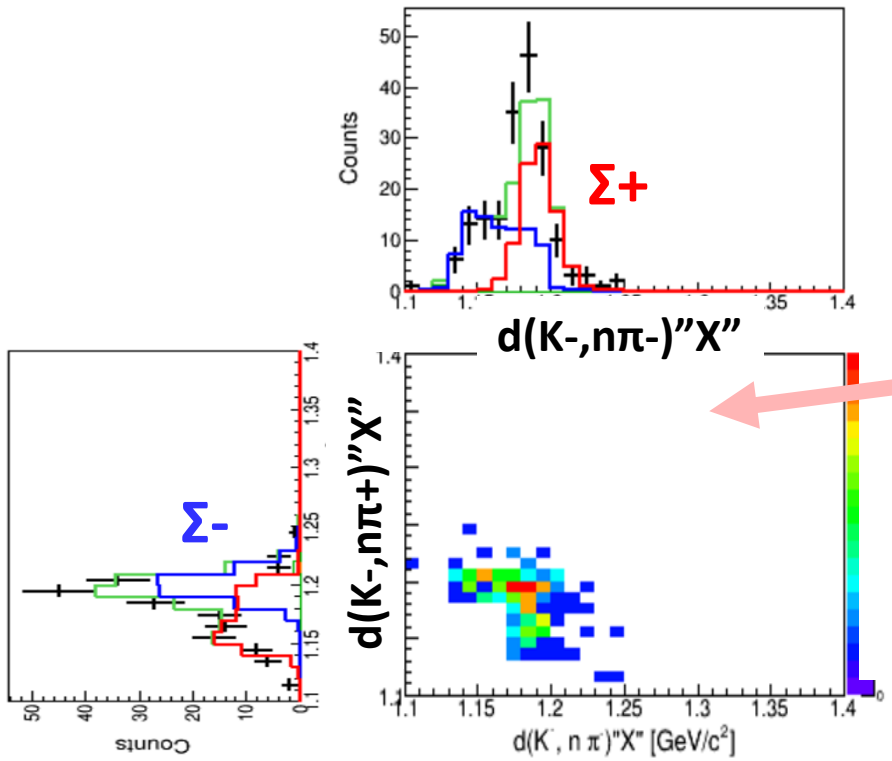
$d(K^-, n)\pi^{\pm}\Sigma^{\mp}$ spectrum

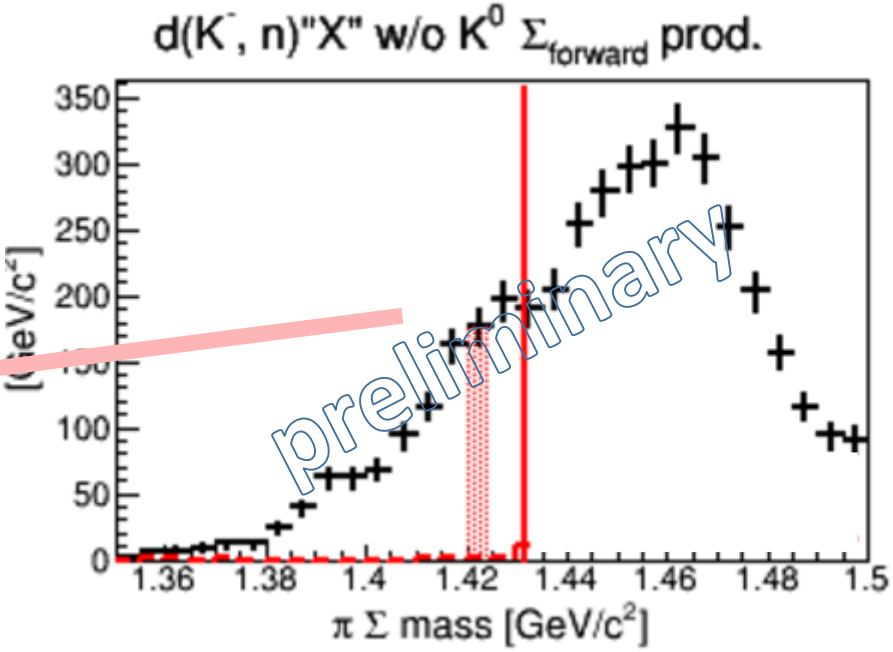


- The structures below and above the threshold

Decomposition into $\Sigma^-\pi^+$ and $\Sigma^+\pi^-$

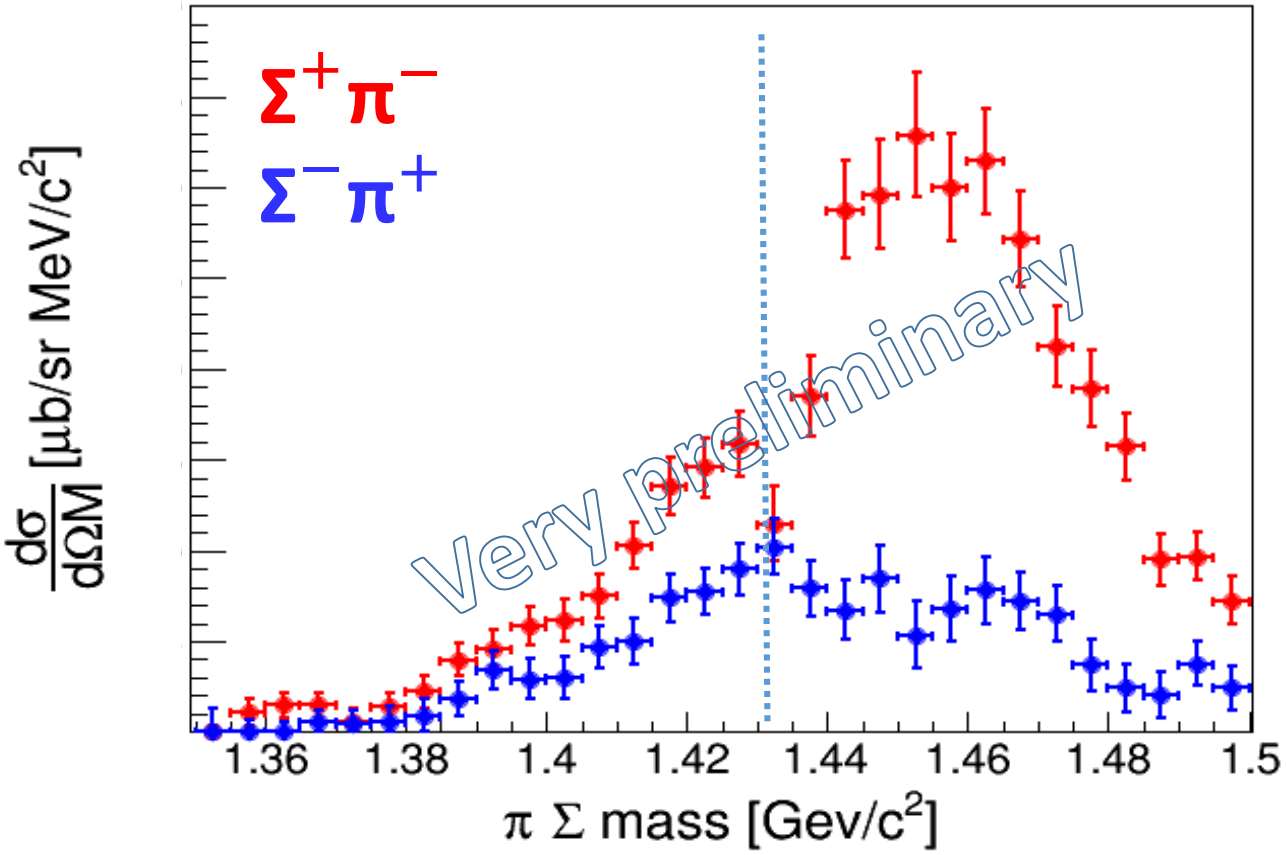
- The d(K-,nπ)"X" distribution's are fitted with the distribution of Σ+ and Σ- estimated by MC SIM (Template fitting)
  - Fitted bin by bin of the d(K-,n)"X"





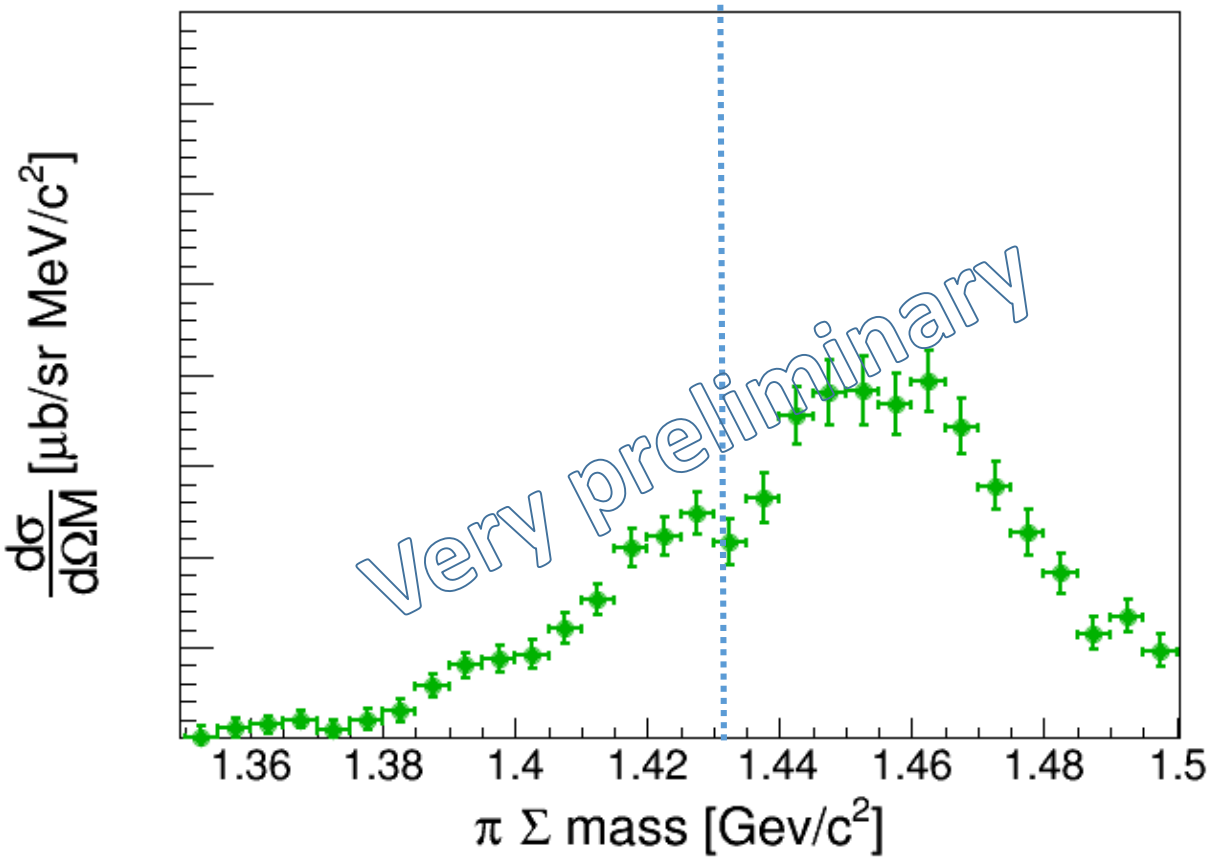
Decomposed spectrum of $\Sigma^-\pi^+$ and $\Sigma^+\pi^-$

- w/ acceptance correction



- **The difference between two mode is due to the interference term of I =0 and I =1**

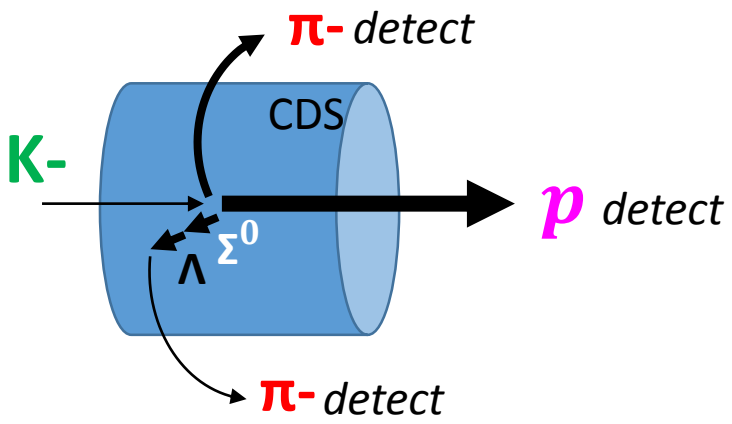
Average of $\Sigma^-\pi^+$ and $\Sigma^+\pi^-$ spectra



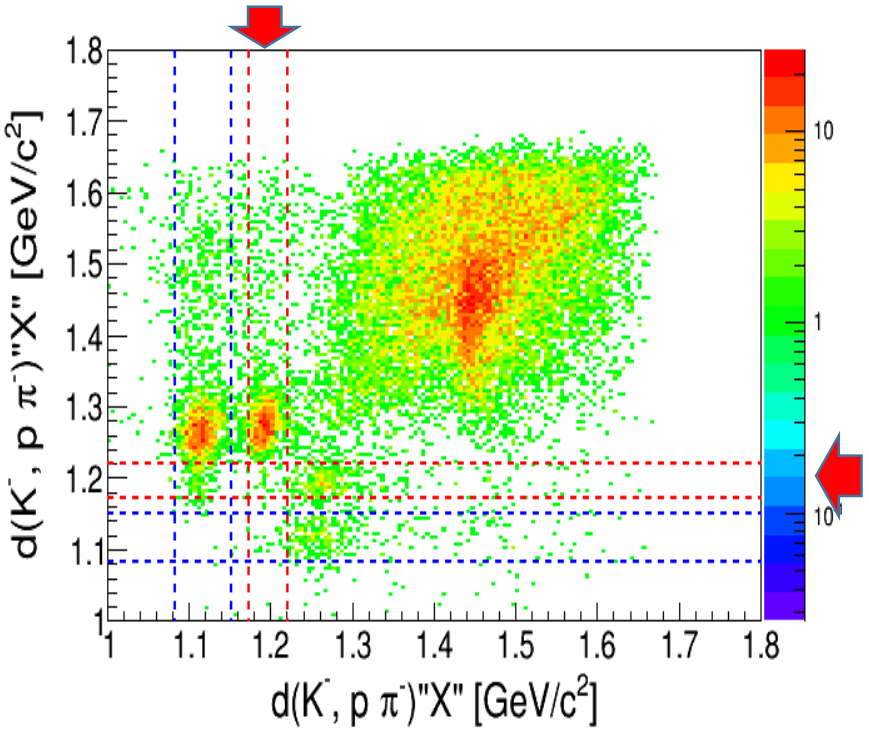
- **The interference term is expected to be canceled**

d(K-,p)"$\Sigma^0\pi^-$"

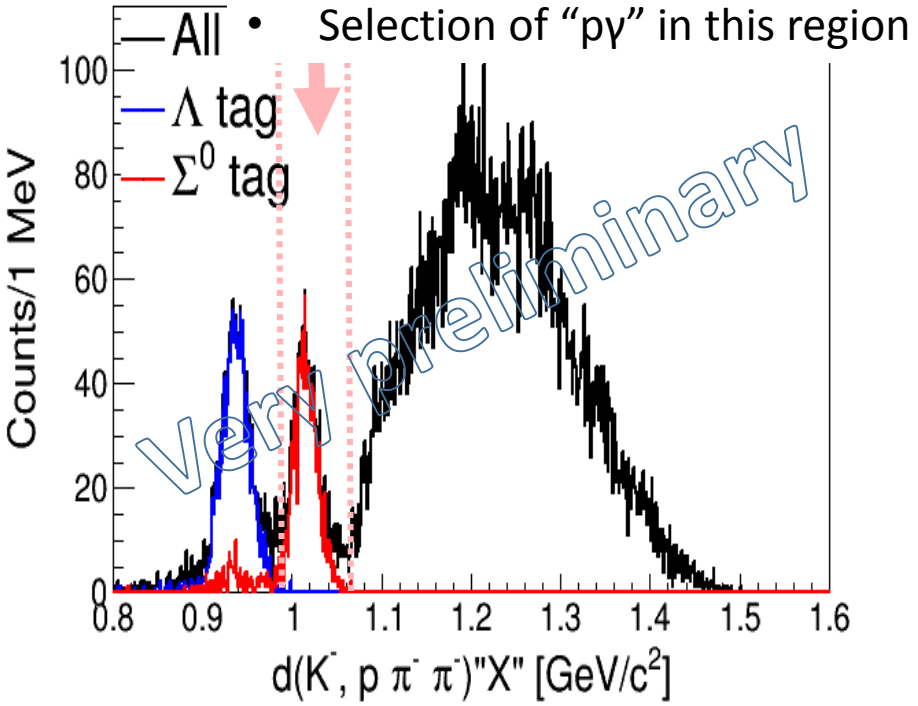
$$\pi^-\Sigma^0 \rightarrow \pi^- p\pi^-\gamma$$



Σ^0 in d(K-,pπ^-)"X"

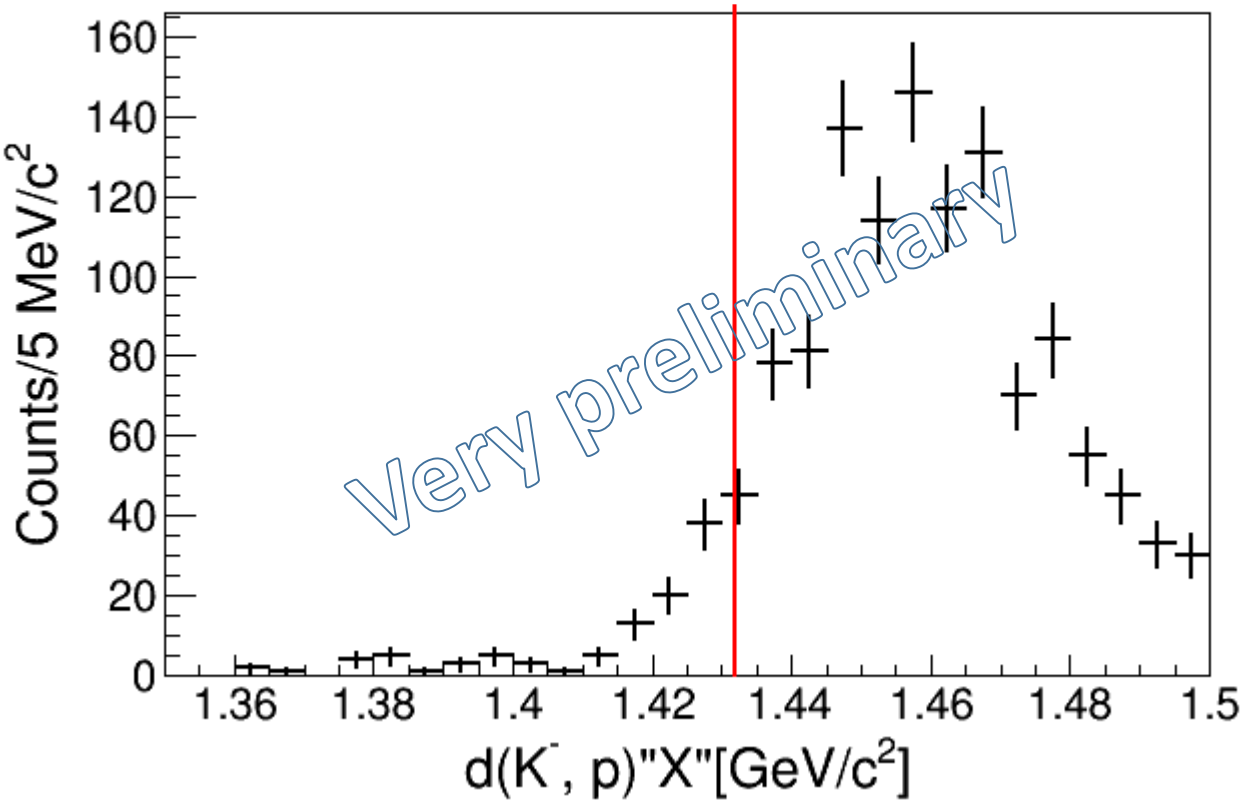


pγ in d(K-,p$\pi^-\pi^-$)"X"



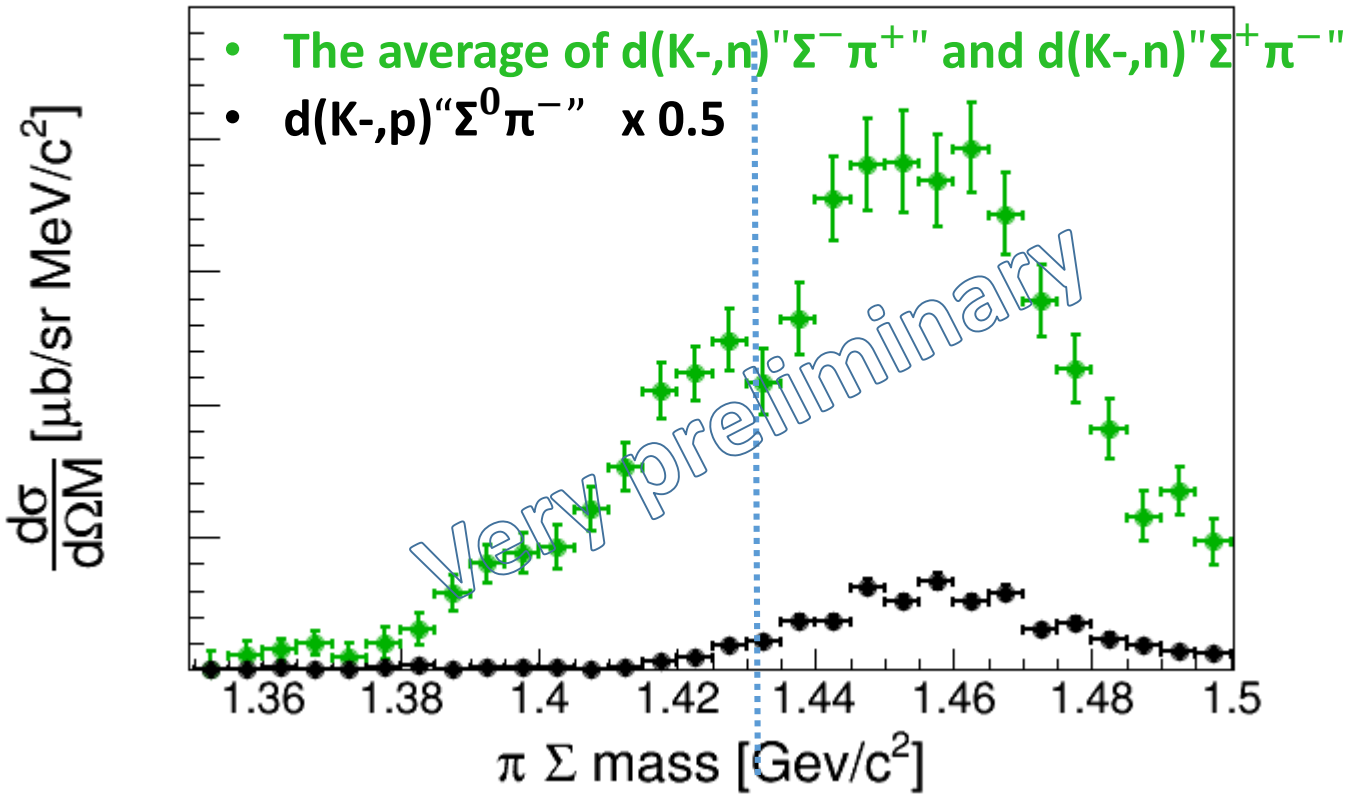
• Selection of "pγ" in this region

- d(K-,p)"$\Sigma^0\pi^-$" missing mass
  - I =1 mode



Suppression of I =0 below the threshold relatively

Suppression of I =1



$$\frac{1}{2} \times (\pi^+\Sigma^- + \pi^-\Sigma^+) \sim \frac{1}{3}|f_{I=0}|^2 + \frac{1}{2}|f_{I=1}|^2$$

$$\frac{1}{2} \times (\pi^-\Sigma^0) \sim \frac{1}{2}|f_{I=1}|^2$$

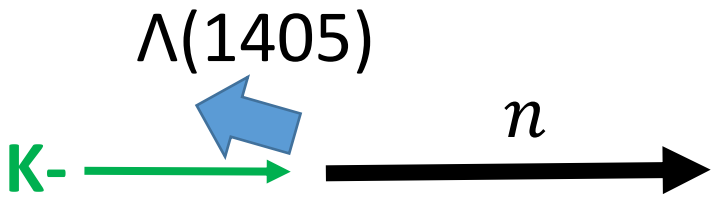
Assuming the similarity of d(K-,n) and d(K-,p),
the amplitude of I =1 in the d(K-,n) reaction is expected to be suppressed below the threshold → the measurement of I =0 is waited for strongly

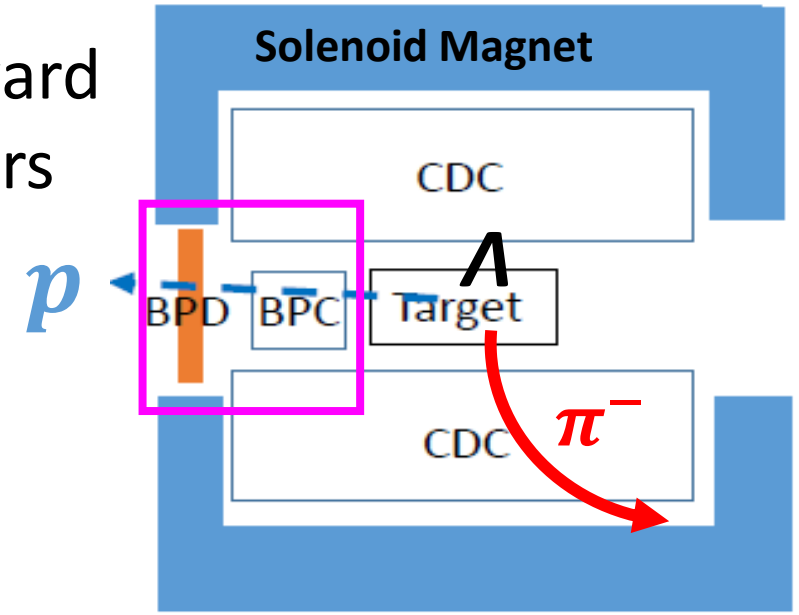
d(K-,n)"$\Sigma^0\pi^0$" analysis status

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

- Λ(1405) is recoiled backward

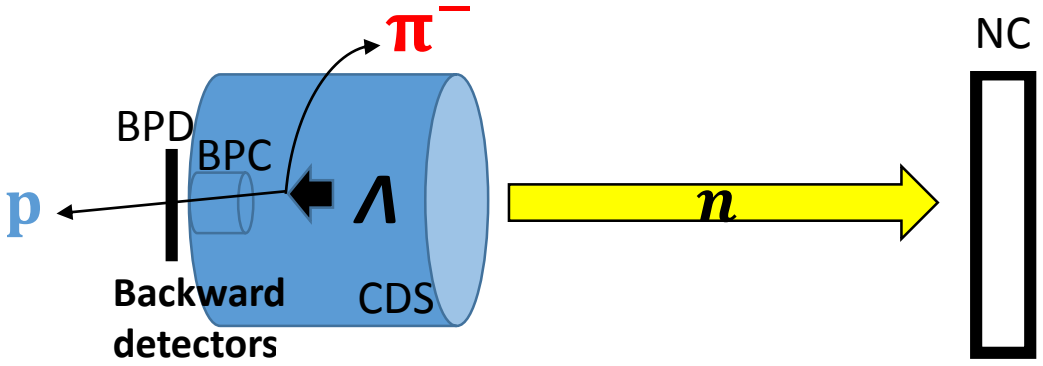
→ the decay proton emitted backward is detected by backward detectors



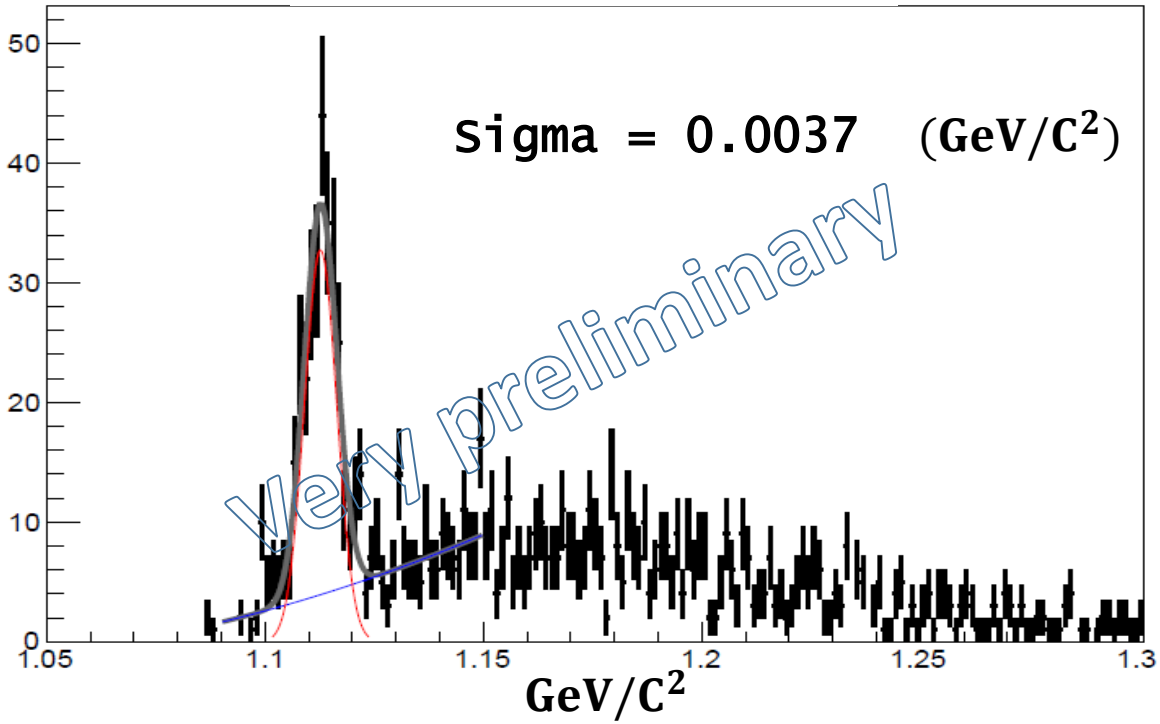


- Analysis procedure
  - **Reconstruction of Λ from p π^-**
  - **Separation of Λ $\pi^0\gamma$ by $d(K^-, n\,\Lambda)$"X" missing mass from Λπ^0 or Λ$\pi^0\pi^0$**

Backward Lambda reconstruction



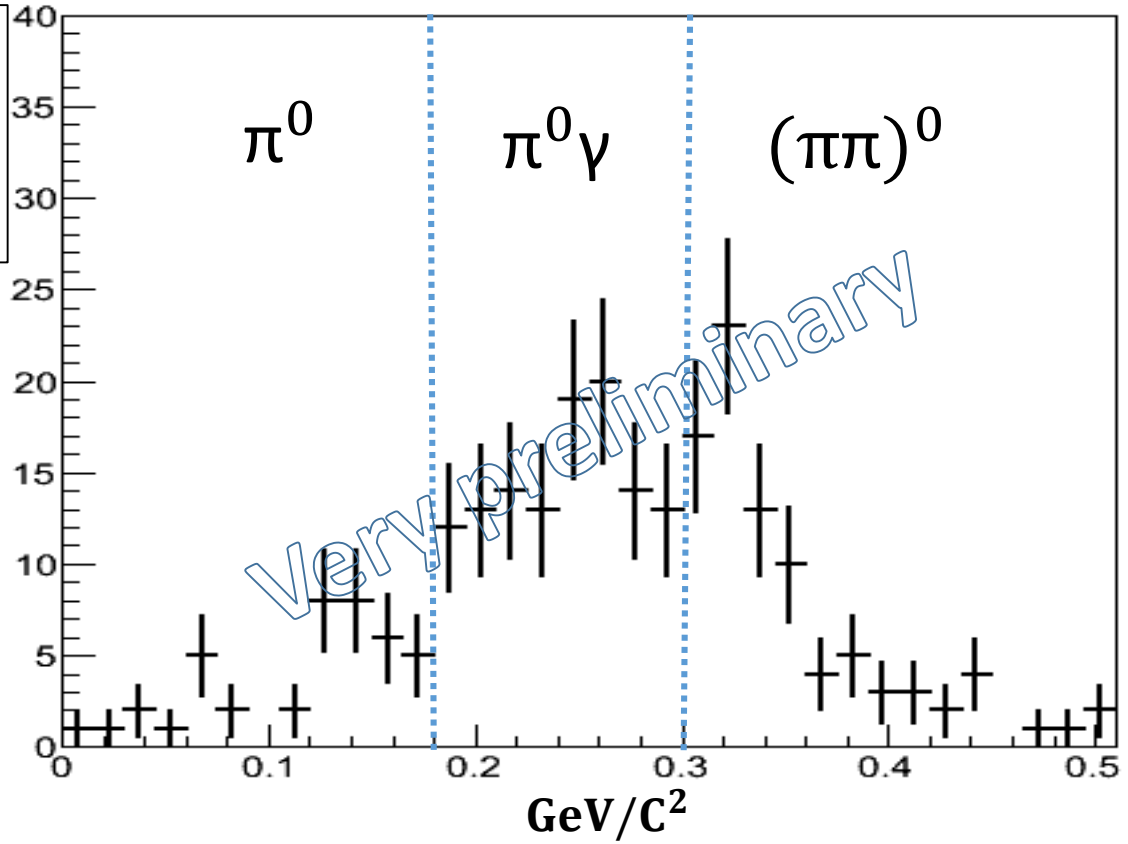
Invariant mass ($\pi^- p$)



Lambda is reconstructed as designed

d(K-,nΛ)”X” missing mass

- $\pi^0\Lambda$ (I =1)
- $\pi^0\Sigma^0$ -> $\pi^0\gamma\,\Lambda$ (I =0)
- $\pi^0\pi^0\Lambda$



- Events in the region of $\pi^0\gamma$ is confirmed
- Events in the region of π^0 (I =1) is suppressed
- However we need more data for the d(K-,n)"$\Sigma^0\pi^0$" spectrum

conclusion

- The preliminary result of the E31 1st physics run is presented
  - The d(K-,n)"$\Sigma^-\pi^+$" and "$\Sigma^+\pi^-$" spectra are observed.
    - The difference of two spectrum is clearly seen which is due to the interference term
  - The d(K-,p)"$\Sigma^0\pi^-$" spectrum (I = 1) is observed.
    - This mode is suppressed especially below the threshold .

  → The I = 0 amplitude is dominant below the KbarN threshold in the d(K-,n)"$\Sigma^-\pi^+$" and "$\Sigma^+\pi^-$" spectra

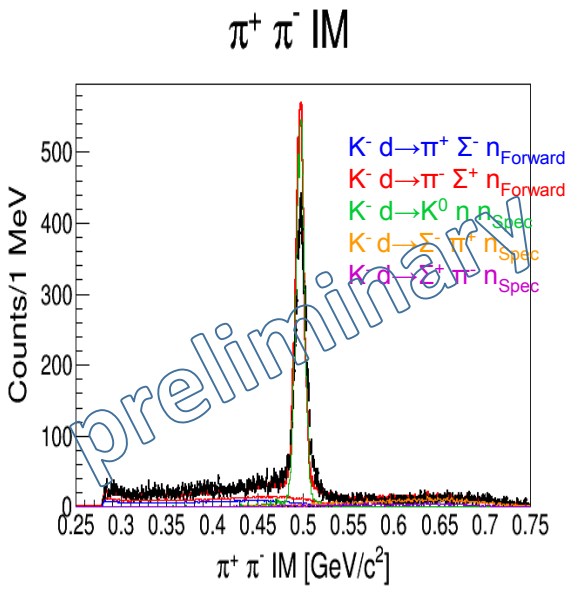
- The d(K-,n)"$\Sigma^0\pi^0$" spectrum (I = 0) is to be measured
    - Identification of this mode is succeeded.
    - We will take 2nd run data for the $\Sigma^0\pi^0$ (I=0) spectrum (in the next spr. ?).

BACK UP

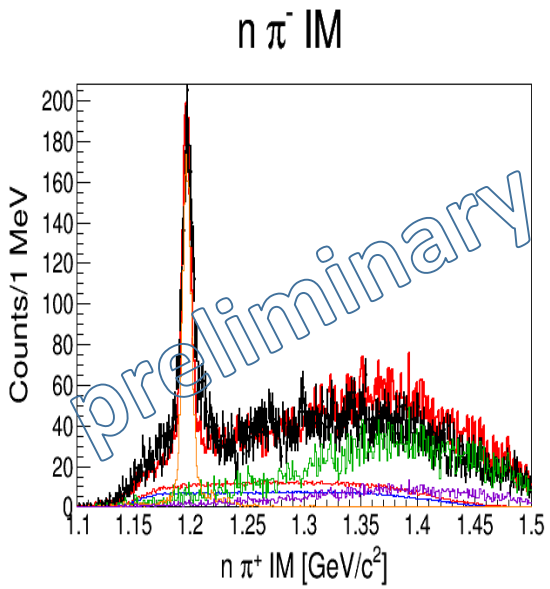
Decompose of signal and BG

- Fitting of invariant ($\pi^-\pi^+$), (n π^+) and (n π^-) by SIM

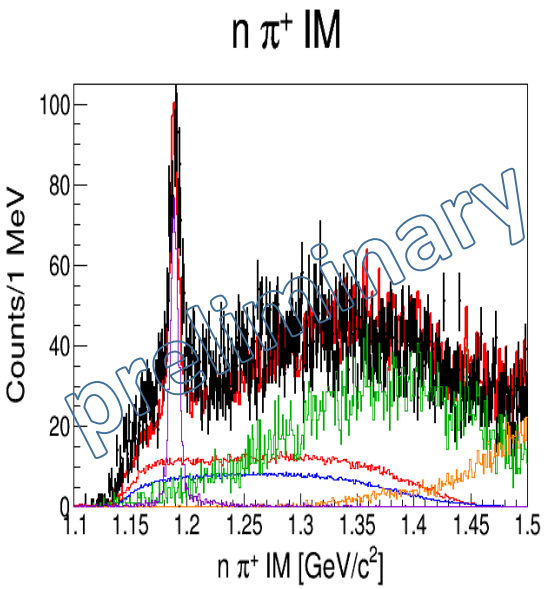
Invariant mass ($\pi^-\pi^+$)



Invariant mass (π^-n)

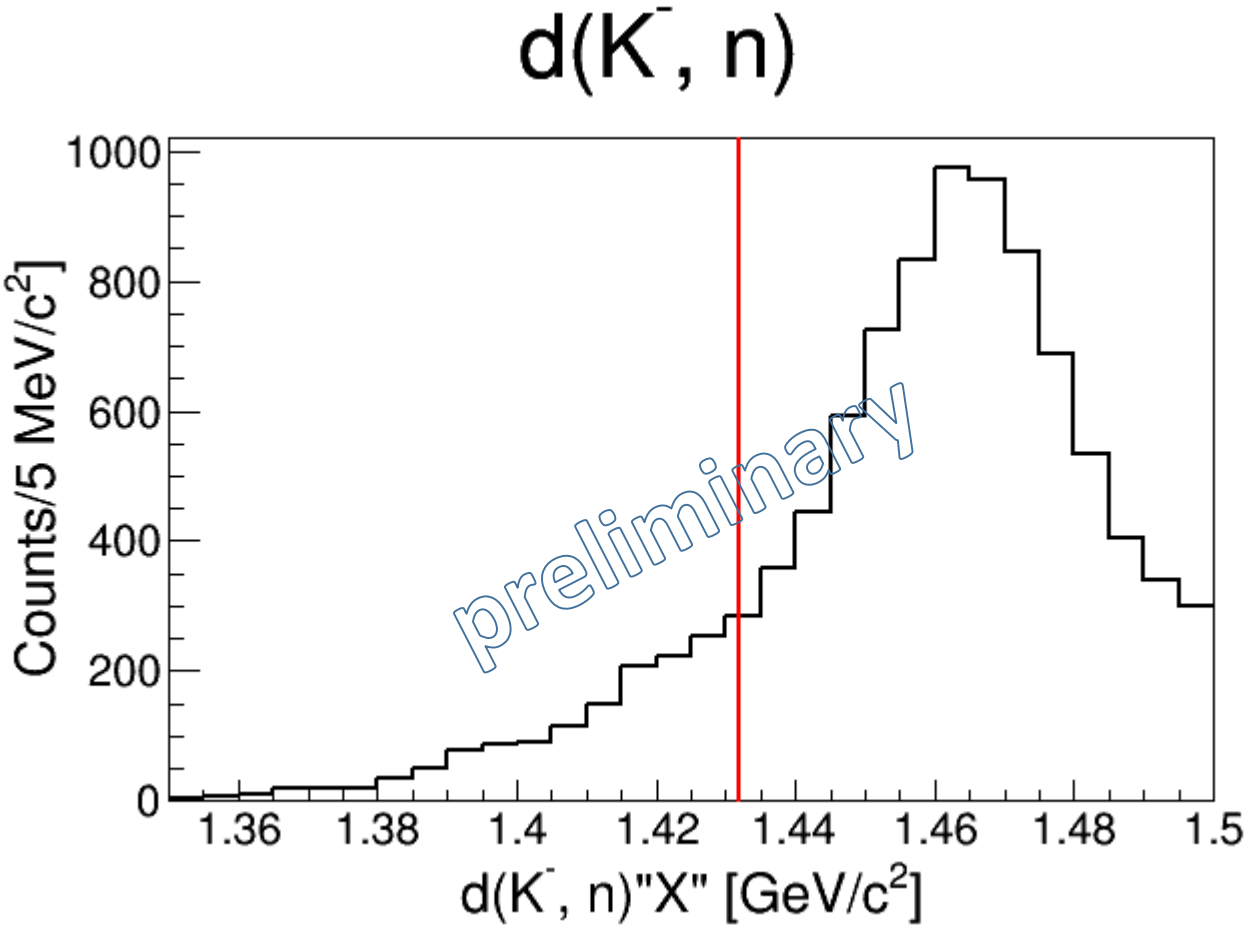


Invariant mass (π^+n)



- SIM seem to reproduce the data well

$d(K^-, n)\pi^{\mp}\pi^{\pm}$"n" spectrum

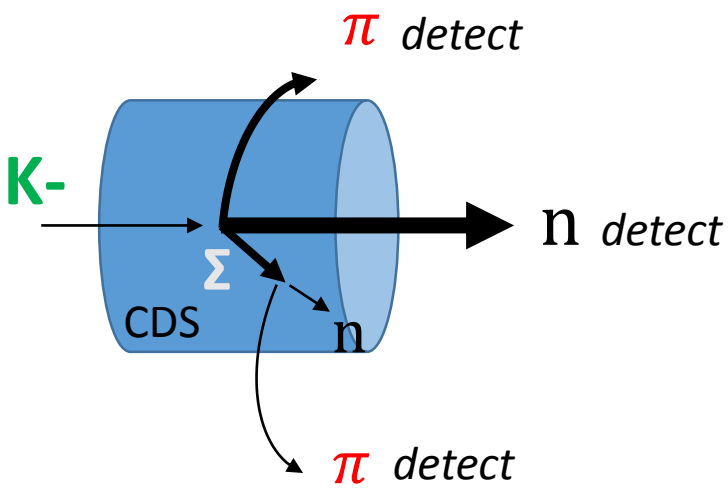


- **Charge exchange peak around 1.47 $\mathbf{GeV/C^2}$**
- **Significant yield below the $\bar{K}N$ threshold.**
- **Removal of BG →**

$d(K^-, n)"X"$ spectrum

- $\pi^-\pi^+$ is detected in CDS

$d(K^-, n)"X"$ w/$\pi^-\pi^+$ **missing mass**



- **Charge exchange peak around 1.47 GeV/C^2**
- **In this spectra, $d(K^-, n)\pi^{\mp}\pi^{\pm}"n"$ is abstracted →**