Analysis status of $d(K^-, N)"\pi\Sigma"$ at J-PARC K1.8BR beam line

Kentaro Inoue

Resarch Center for Nuclear Physics

March 13, 2017

Content

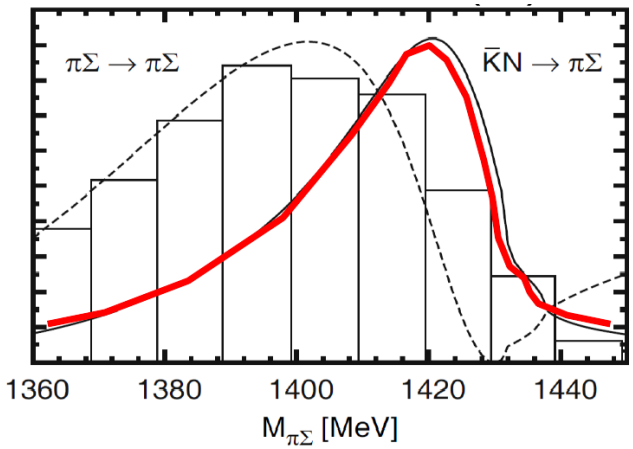
- Introduction
- K1.8BR experiemtnal setup
- Preliminary result of E31 1st physics run
  - $d(K^-, n)"\pi^{\pm}\Sigma^{\mp}"(I = 0, 1)$ mode analysis
  - $d(K^-, p)"\pi^-\Sigma^0"(I = 1)$ mode analysis
  - $d(K^-, n)"\pi^0\Sigma^0"(I = 0)$ mode analysis
- Summary

Nature of $\Lambda(1405)$

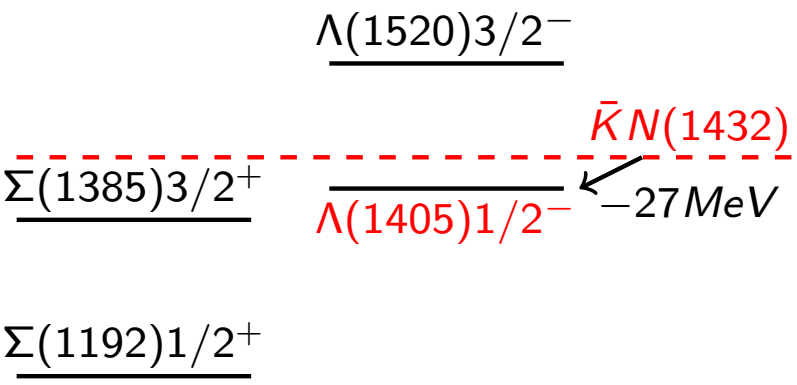
$\Lambda(1405)$

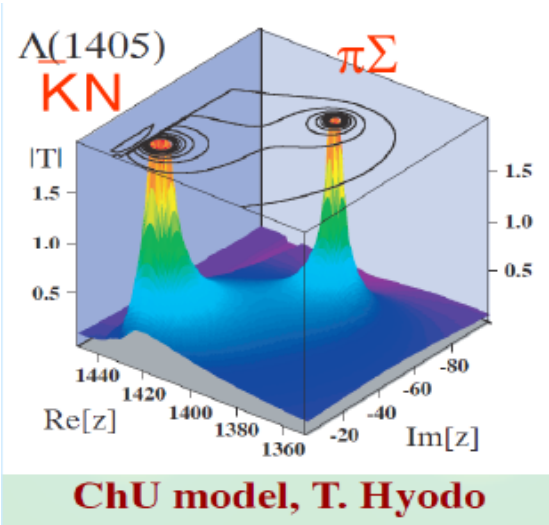
- $I(J^P) = 0\left(\frac{1}{2}^-\right)$
- $mass = 1405.1^{+1.3}_{-1.0} MeV$
- $\Gamma = 50.5 \pm 2.0 MeV$

C. Patrignani et al.(PDG), Chin. Phys. C, 40, 100001 (2016).



D. jido et el. Nucl Phys A725(2003), 181

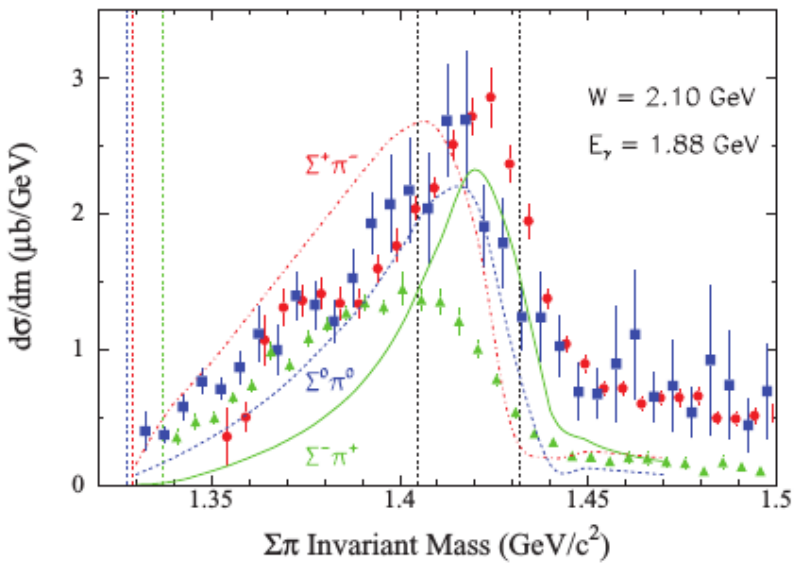




Recent experimental studies

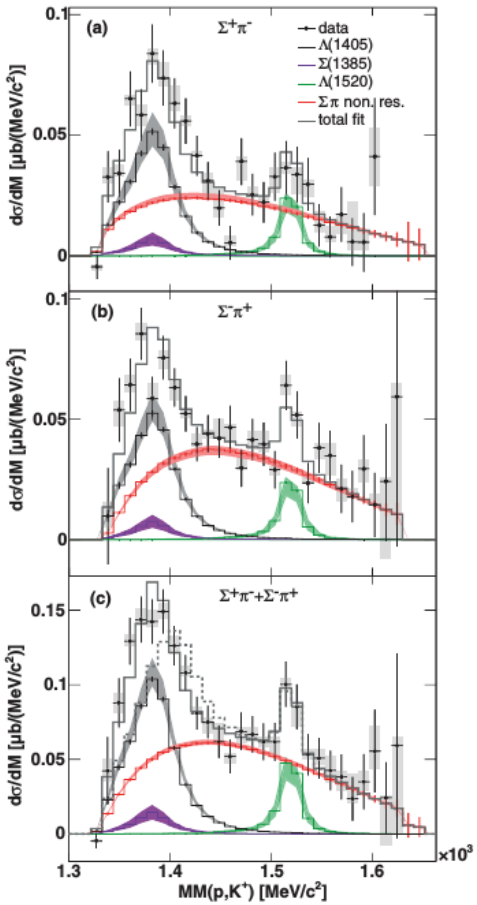
- p/γ induced experiments
  How these spectra couple to the $\bar{K}N$ pole or the $\pi\Sigma$ pole is still controversial.

$\gamma p \to K^+\pi^-\Sigma^+, K^+\pi^0\Sigma^0, K^+\pi^+\Sigma^-$



CLAS collaboration: Phys Rev C87, 035206

$pp \to K^+p\pi^-\Sigma^+, K^+p\pi^+\Sigma^-$

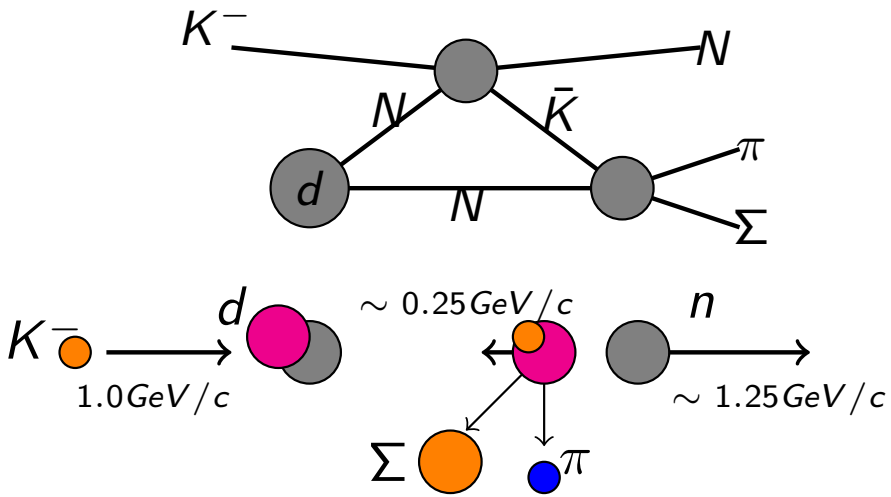


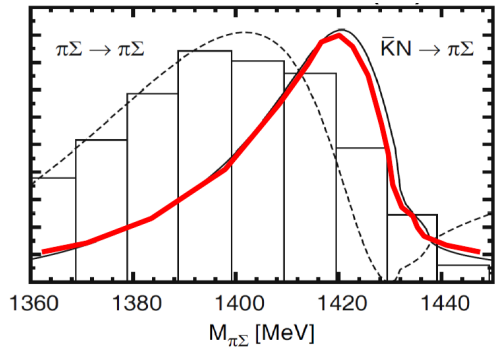
HADES collaboration:
Phys Rev C87, 025201

Kaon induced reaction is desired.

$d(K^-, N)$ reaction

- The $d(K^-, N)$ reaction measrued at $\theta_N = 0$ is expected to enhance an **S-wave** $\bar{K}N \to \pi\Sigma$ scattering even **below the $\bar{K}N$ threshold**.

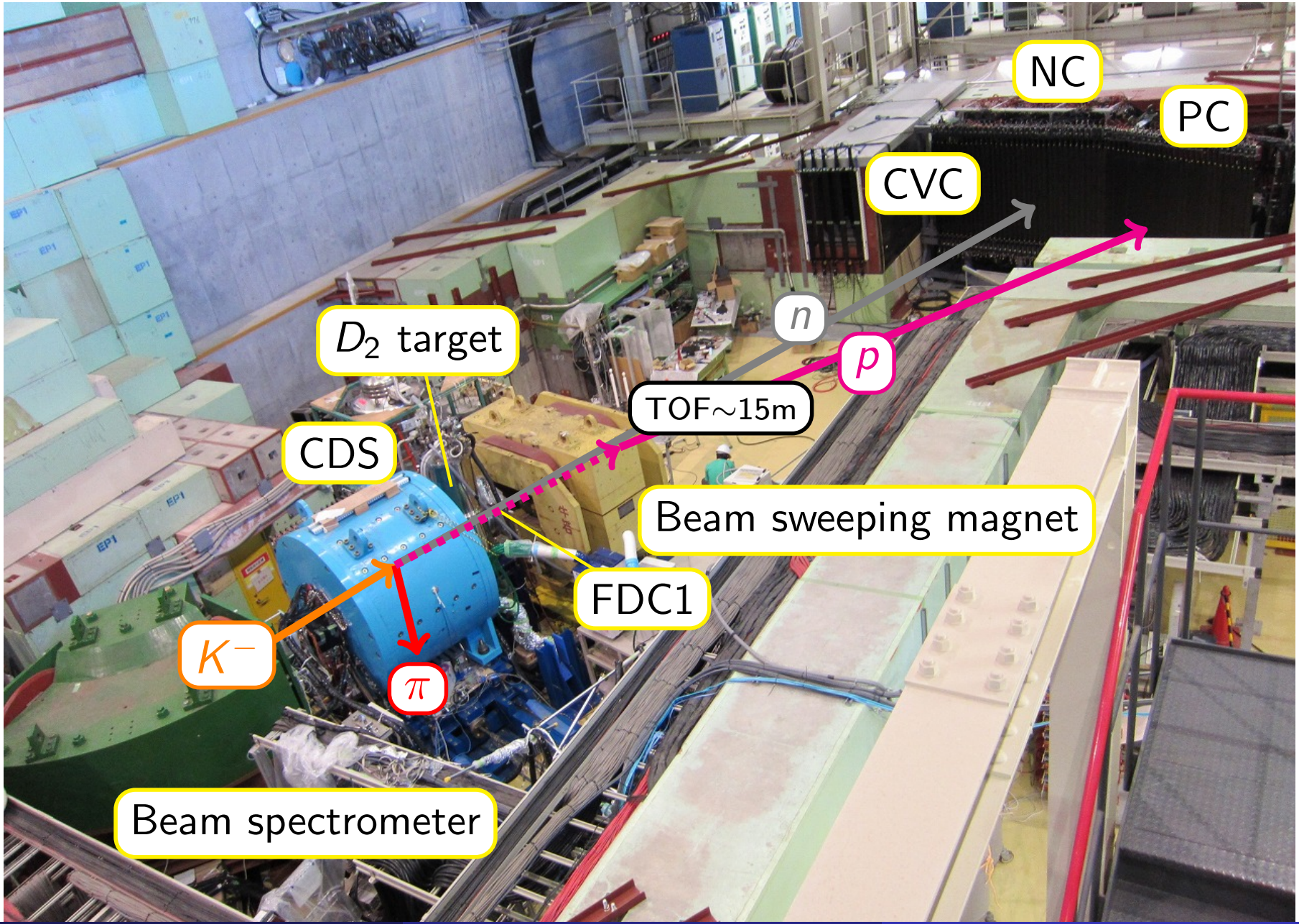




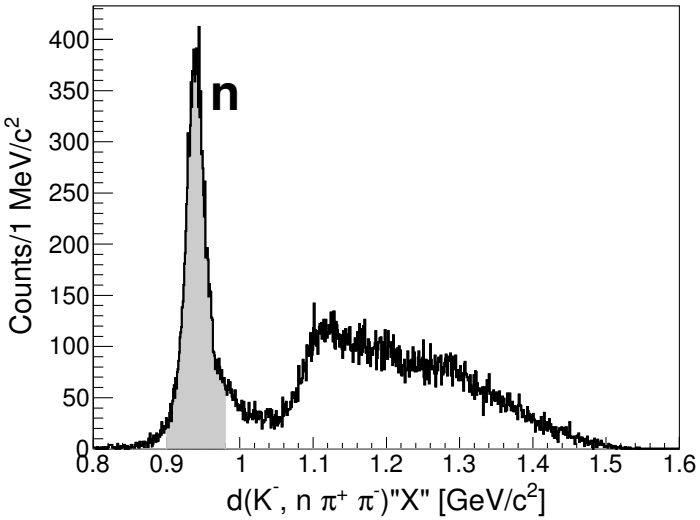
- All final states are identified to decompose the $I = 0$ and the $I = 1$ amplitudes.

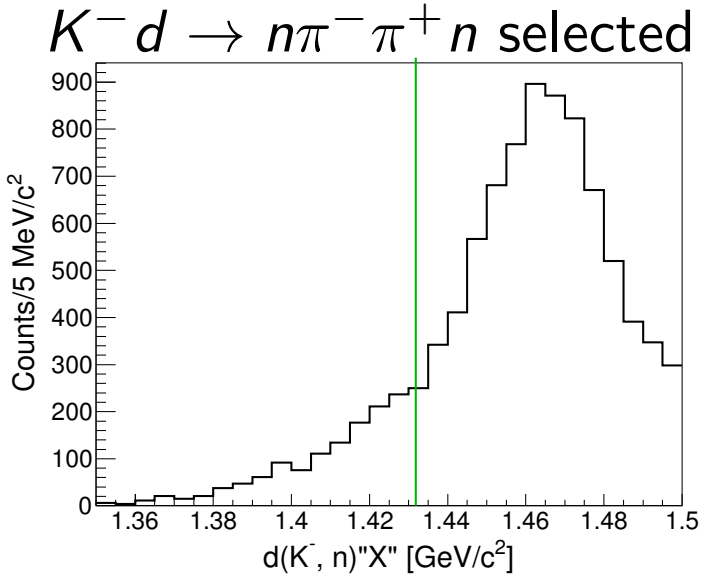
$d(K^-, n)"\pi^{\pm}\Sigma^{\mp}"$	I=0,1	$\Sigma(1385)$ (I=1, P-wave) excepted to be suppressed $\Lambda(1405)$ (I=0, S-wave) non-resonant (I=1,0) (S, P, D)
$d(K^-, n)"\pi^0\Sigma^0"$	I=0	$\Lambda(1405)$(I=0, S-wave), non-resonant (S, P, D)
$d(K^-, p)"\pi^-\Sigma^0"$	I=1	non-resonant (S, P, D) $\Sigma(1385)$ (P-wave) excepted to be suppressed

The K1.8BR experimental setup



$K^- d \to n\pi^+\pi^- n$ selection



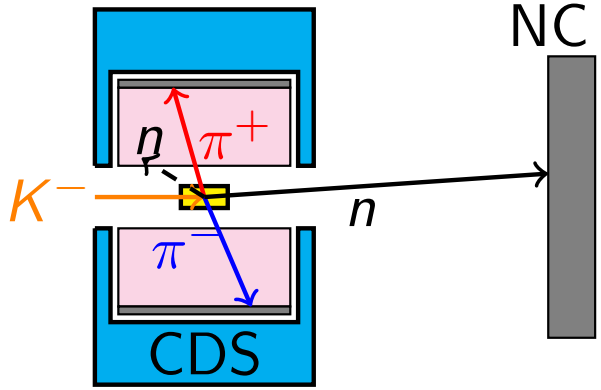


Signal

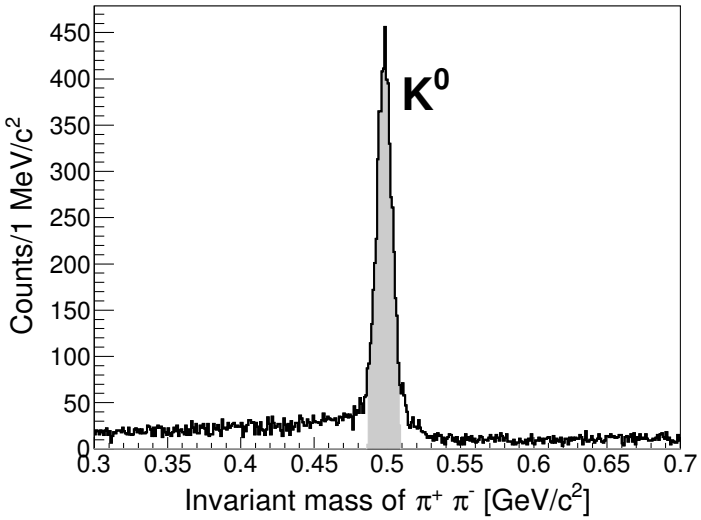
- $K^- d \to \underset{\text{detect}}{n} \ \pi^\pm \ \Sigma^\mp \to \underset{\text{detect}}{n} \ \pi^\pm\pi^\mp \underset{\text{missing}}{n}$

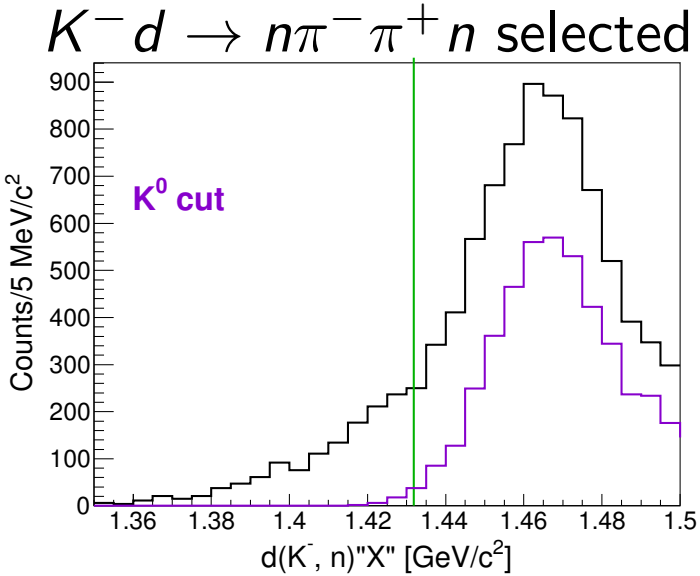
Background

- $K^- d \to \underset{\text{detect}}{n} \ K^0 \ \underset{\text{missing}}{n_{spec}} (K^0 \to \pi^+\pi^-)$
- $K^- d \to \pi^\pm \ \Sigma^\mp \ \underset{\text{missing}}{n_{spec}} \ (\Sigma^\pm \to \underset{\text{detect}}{n} \ \pi^\pm)$



$K^- d \to n K^0 n_{spec}$ rejection





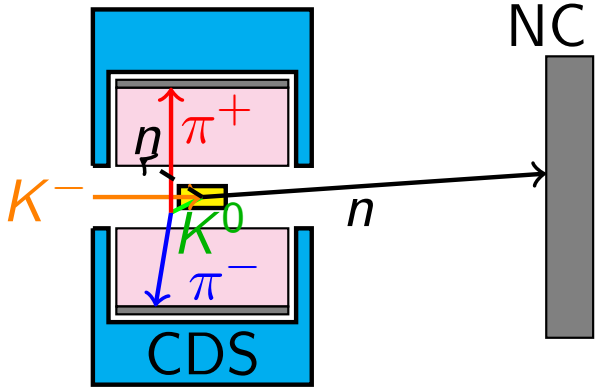
$K^- d \to n \pi^- \pi^+ n$ selected

Signal

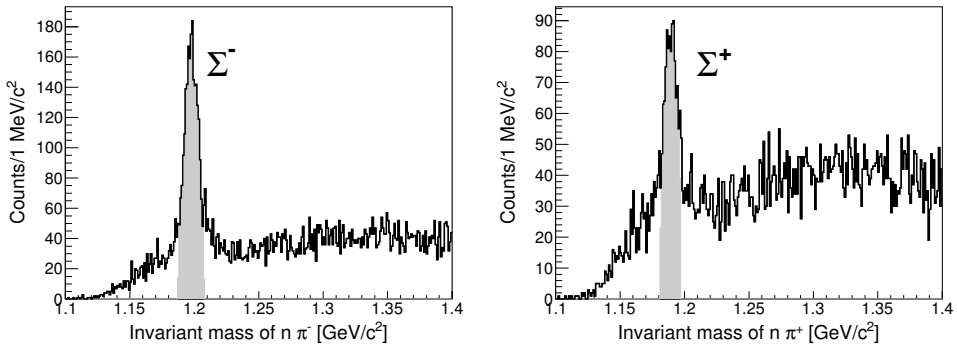
- $K^- d \to \underset{\text{detect}}{n} \ \pi^\pm \ \Sigma^\mp \to \underset{\text{detect}}{n} \ \pi^\pm \pi^\mp \underset{\text{missing}}{n}$

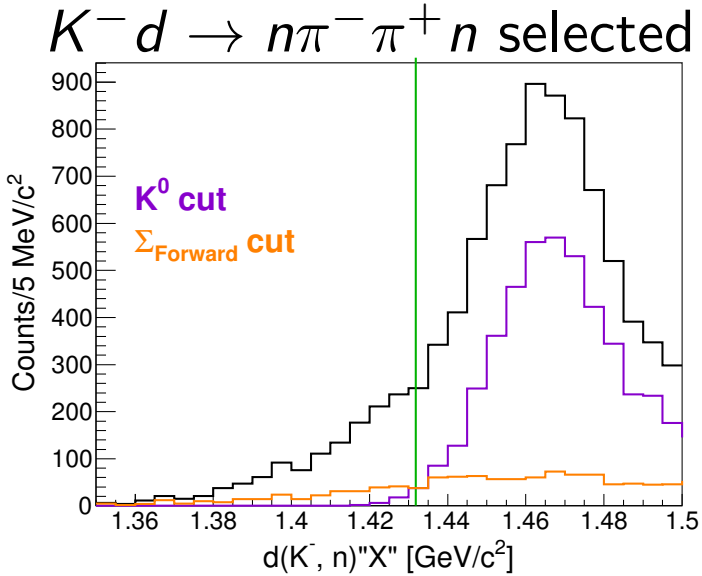
Background

- $K^- d \to \underset{\text{detect}}{n} \ K^0 \ \underset{\text{missing}}{n_{spec}} (K^0 \to \pi^+ \pi^-)$
- $K^- d \to \pi^\pm \ \Sigma^\mp \ \underset{\text{missing}}{n_{spec}} \ (\Sigma^\pm \to \underset{\text{detect}}{n} \ \pi^\pm)$



$K^- d \to \pi^{\pm} \Sigma^{\mp} n_{spec}$ rejection



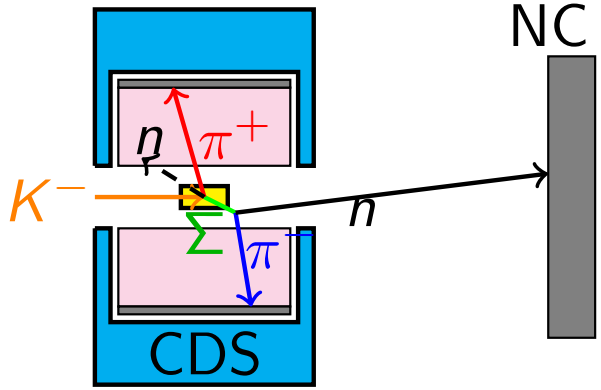


Signal

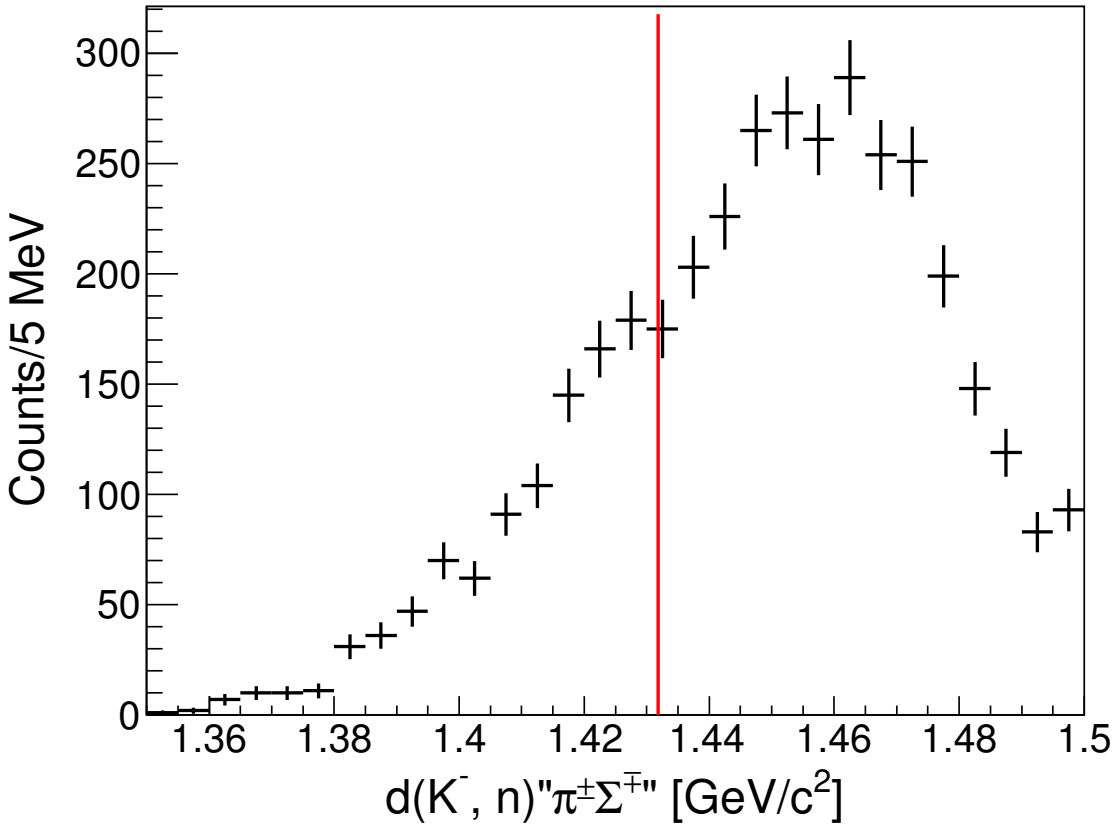
- $K^- d \to \underset{\text{detect}}{n} \ \pi^{\pm} \ \Sigma^{\mp} \to \underset{\text{detect}}{n} \ \pi^{\pm}\pi^{\mp} \underset{\text{missing}}{n}$

Background

- $K^- d \to \underset{\text{detect}}{n} \ K^0 \ \underset{\text{missing}}{n_{spec}} (K^0 \to \pi^+\pi^-)$
- $K^- d \to \pi^{\pm} \ \Sigma^{\mp} \ \underset{\text{missing}}{n_{spec}} \ (\Sigma^{\pm} \to \underset{\text{detect}}{n} \ \pi^{\pm})$



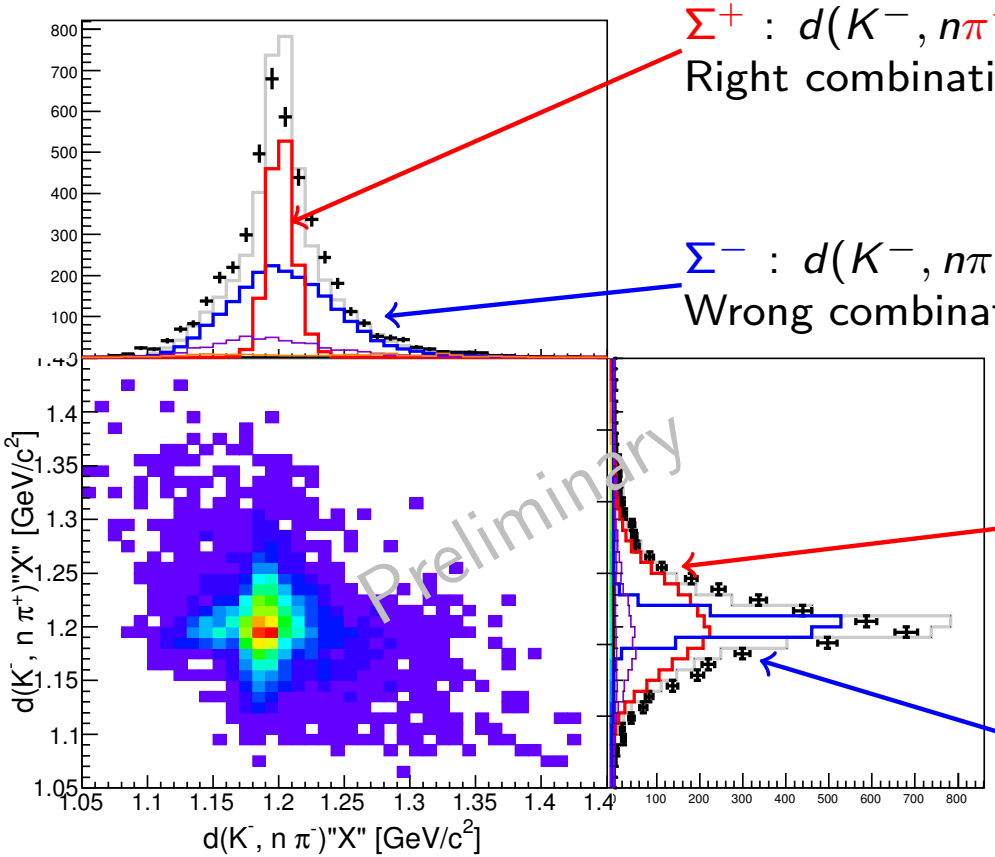
$d(K^-, n)"\pi^{\pm}\Sigma^{\mp}"$ spectrum



K^0 and forward-going Σ are removed.
This spectrum includes both $\pi^+\Sigma^-$ and $\pi^-\Sigma^+$ modes.
$\rightarrow$ These modes should be separated.

$\pi^-\Sigma^+$ and $\pi^+\Sigma^-$ identification

Missing mass distributions of $d(K^-, n\pi^\pm)$ are estimated by MC simulations in order to separate the $\pi^\pm\Sigma^\mp$ modes.



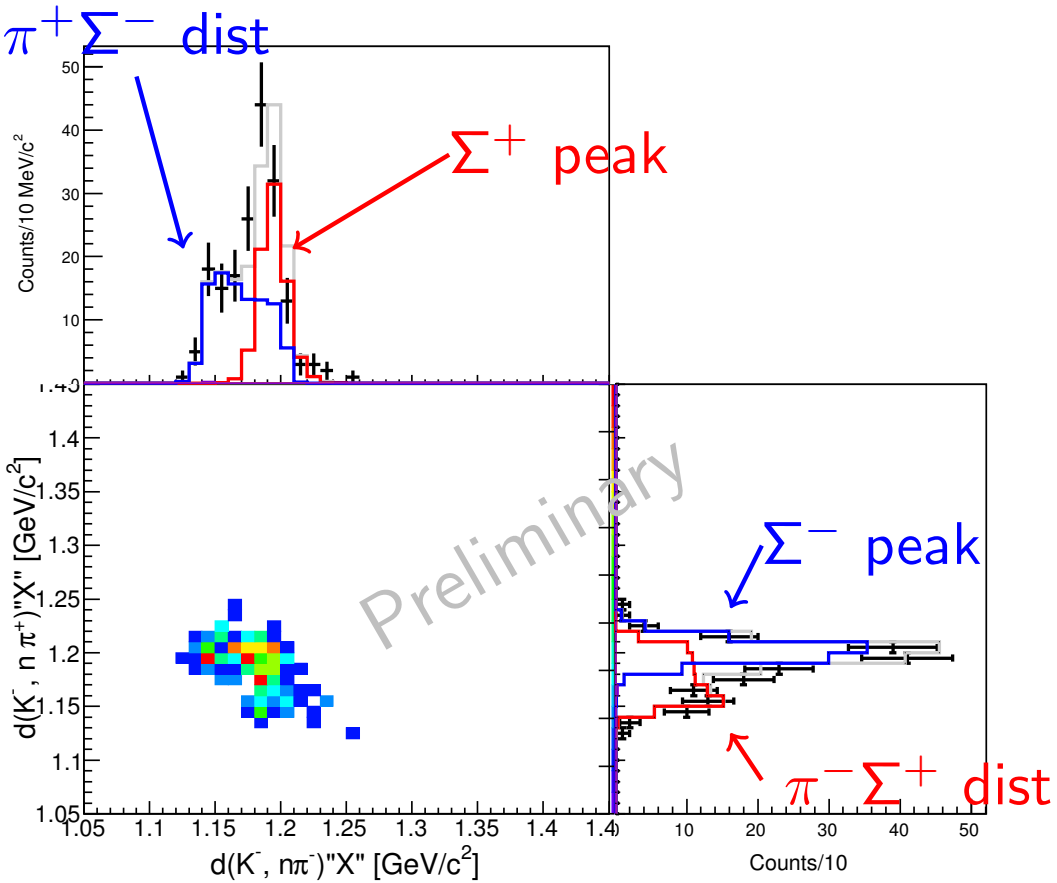
Σ^+ : $d(K^-, n\pi^-)''\pi^+ n''$
Right combination of $n\pi$

Σ^- : $d(K^-, n\pi^-)''\pi^+ n''$
Wrong combination of $n\pi$

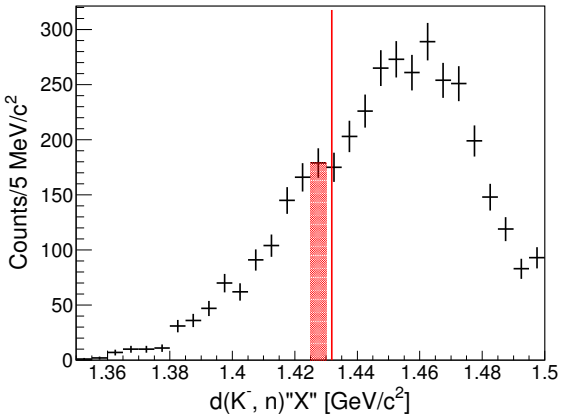
Σ^+ : $d(K^-, n\pi^+)''\pi^- n''$
Wrong combination of $n\pi$

Σ^- : $d(K^-, n\pi^+)''\pi^- n''$
Right combination of $n\pi$

Fitting for $\pi^-\Sigma^+$ and $\pi^+\Sigma^-$ separation



Example $d(K^-, n)"X"$
$1.425 \sim 1.430[GeV/c^2]$

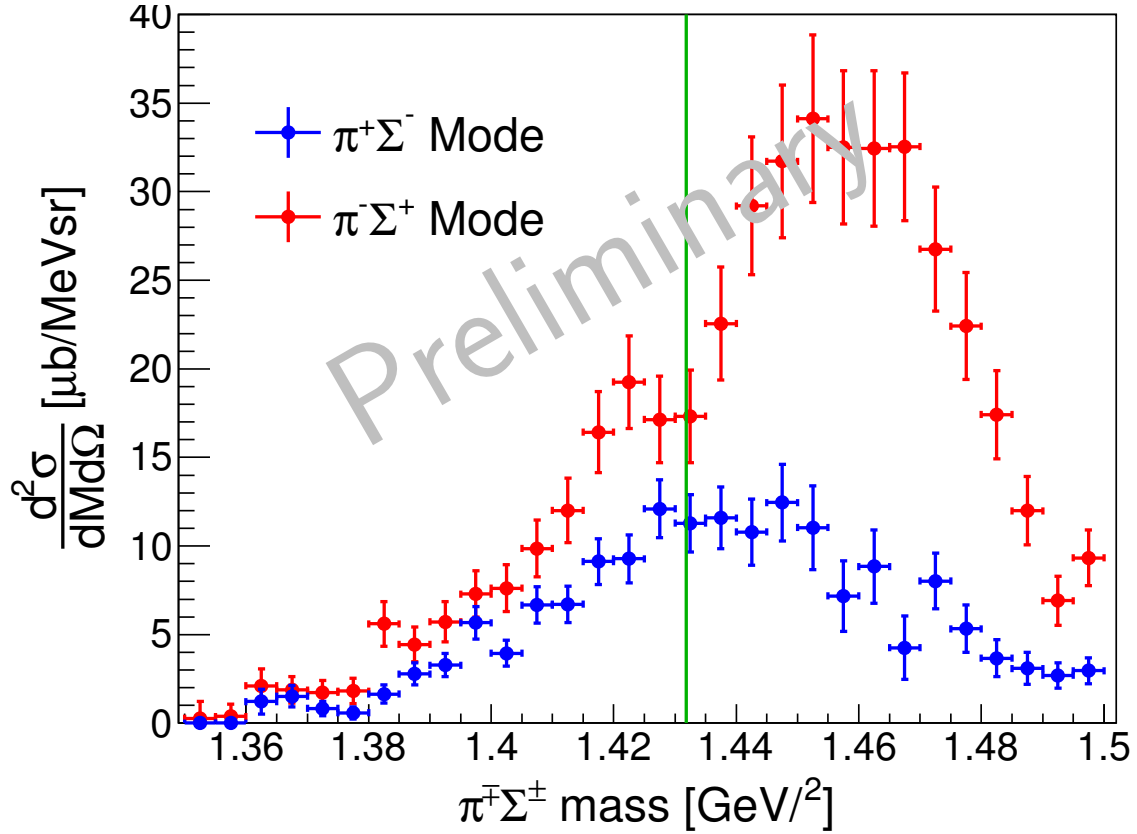


Fittings are done bin by bin
Free parameters

1. Number of $\pi^+\Sigma^-$ events.
2. Number of $\pi^-\Sigma^+$ events.

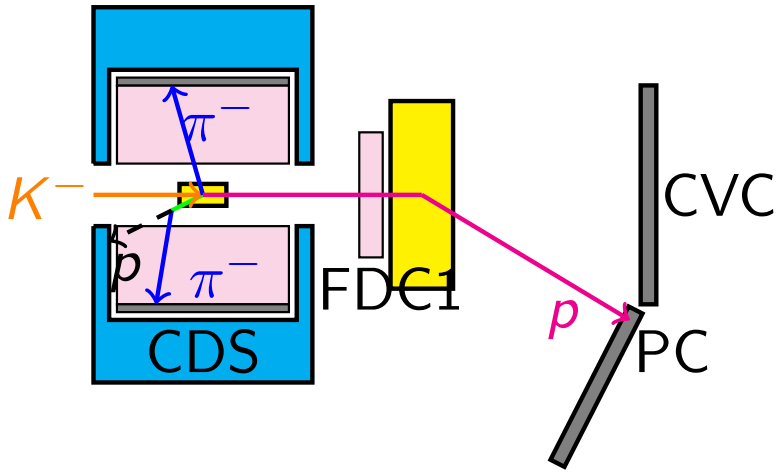
Cross section of $\pi^-\Sigma^+$ and $\pi^+\Sigma^-$

$$(\pi^{\pm}\Sigma^{\mp}) \sim \frac{1}{3}|f_{I=0}|^2 + \frac{1}{2}|f_{I=1}|^2 \pm \frac{\sqrt{6}}{3} Re(f_{I=0} f^*_{I=1})$$



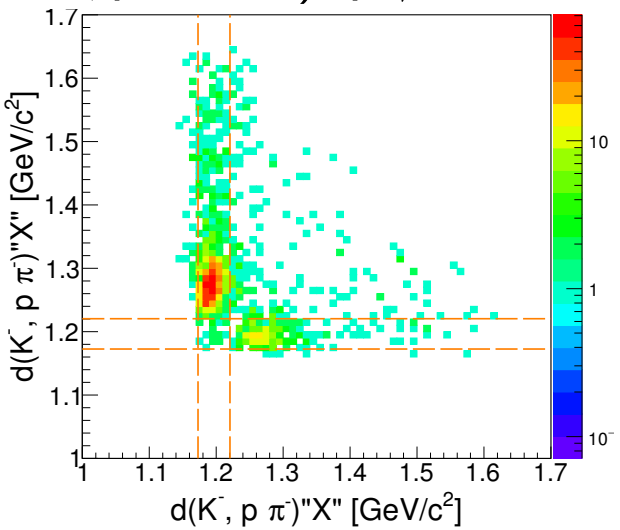
Interference between the $I = 0$ and 1 amplitudes of the $\pi\Sigma$ scattering is observed.

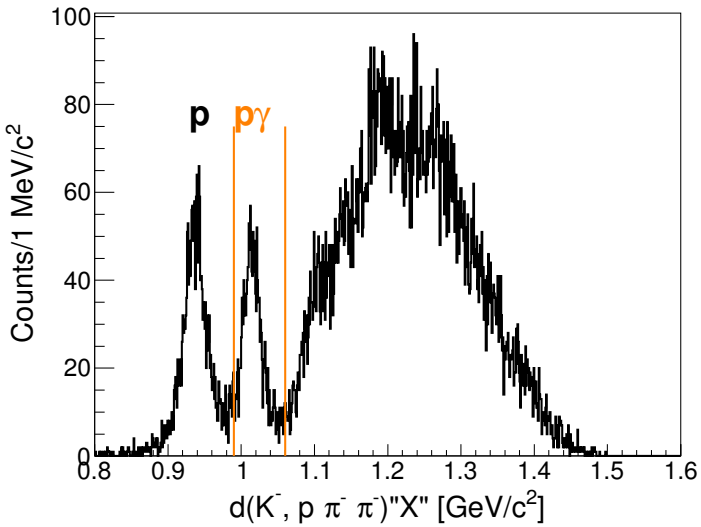
$d(K^-, p)"\pi^-\Sigma^0"$ event selection



$$K^- d \to p\pi^-\Sigma^0 \to p\pi^-\Lambda\gamma$$
$$\to p\pi^-\pi^- p\gamma$$

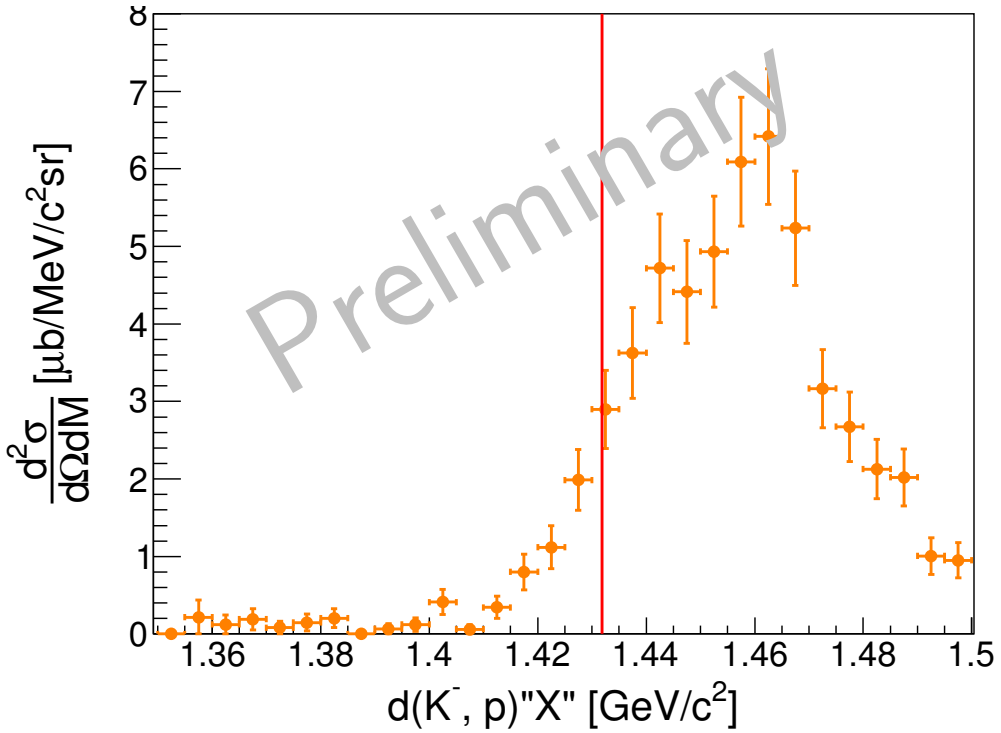
$d(K^-, p\pi^-\pi^-)"p\gamma"$ selected





$d(K^-, p)"\pi^-\Sigma^0"$ mode is clearly idendentified by selecting $d(K^-, p\pi^-\pi^-)"p\gamma"$ and $d(K^-, p\pi^-)"\Sigma^0"$.

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

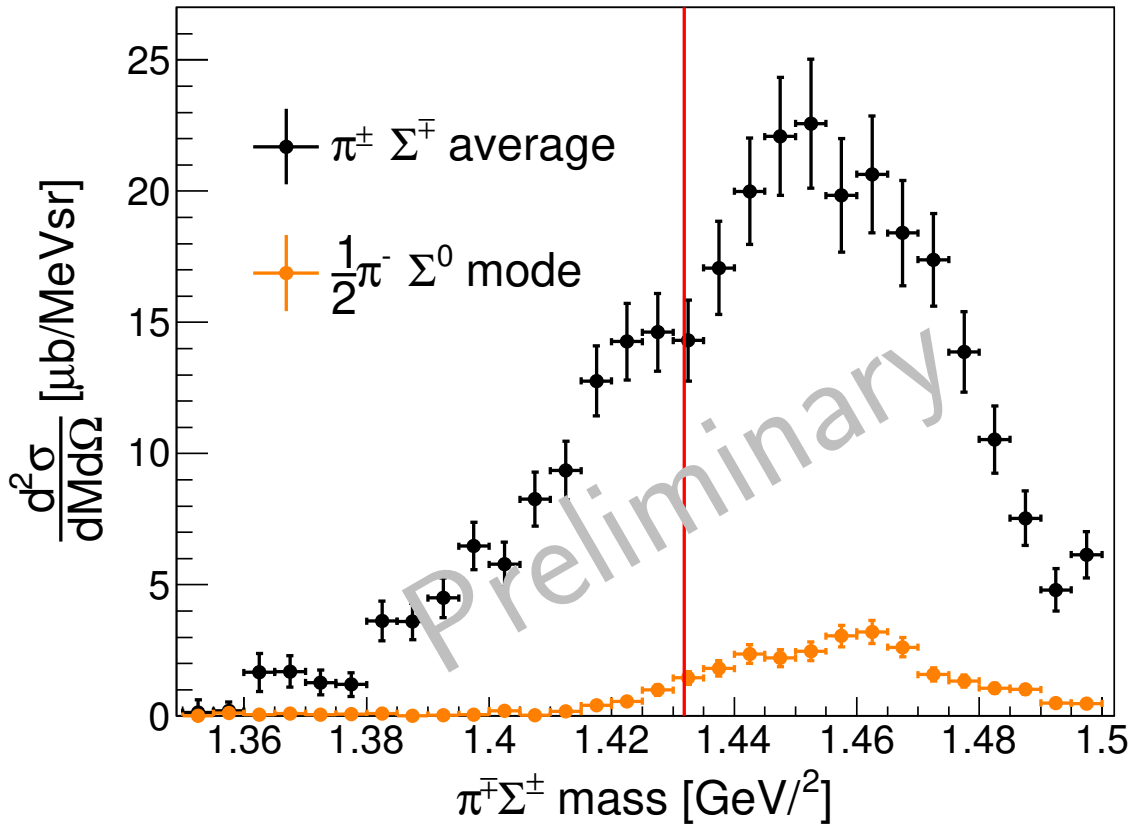


$d(K^-, p)"\pi^-\Sigma^0"$	I=1	non-resonant (S, P, D) $\Sigma(1385)$ (P-wave) to be supressed

Comparison $\pi^{\pm}\Sigma^{\mp}$ $(I = 0, 1)$ and $\pi^{-}\Sigma^{0}$ $(I = 1)$

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

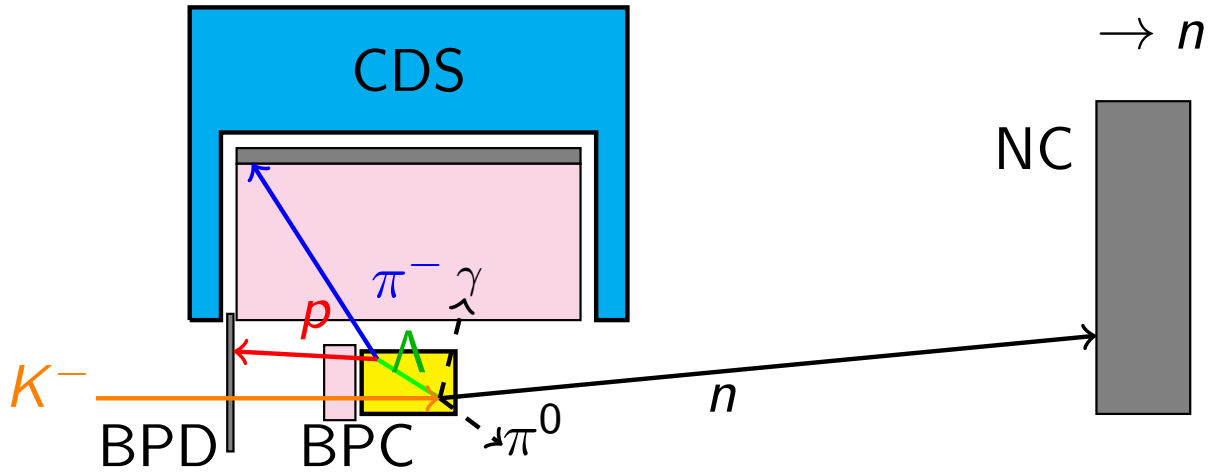
$$\frac{1}{2}\pi^{-}\Sigma^{0} \sim \frac{1}{2}|f_{I=1}|^2$$

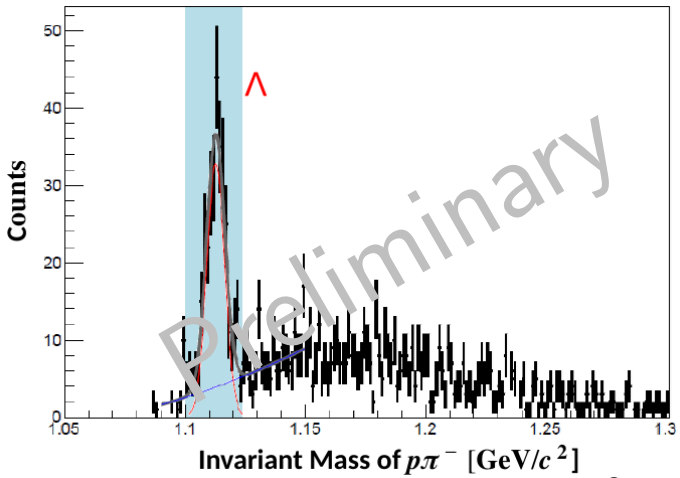


The $I = 0$ amplitude is dominant.

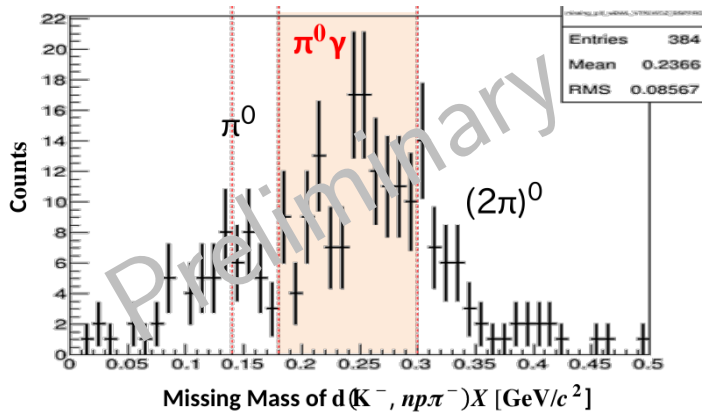
$d(K^-, n)"\pi^0\Sigma^0"\ (I = 0)$ event selection

$$K^- d \to n\Sigma^0\pi^0 \to n\Lambda\gamma\pi^0$$
$$\to np\pi^-\gamma\pi^0$$



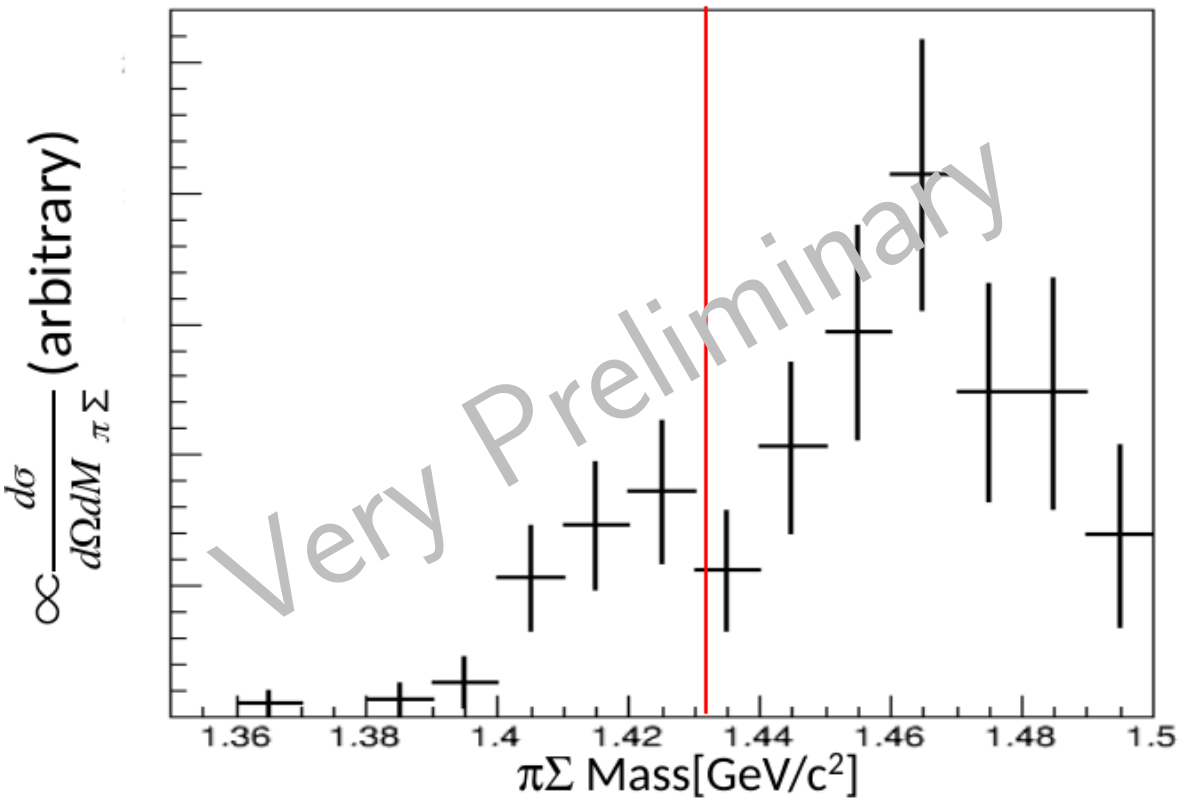


Backward Λ tagged



$d(K^-, n)"\pi^0\Sigma^0"$ mode is clearly identified by selecting Λ and $d(K^-, n\Lambda)"\pi^0\gamma"$.

$d(K^-, n)"\pi^0\Sigma^{0}"(I = 0)$ spectram



The $d(K^-, n)"\pi^0\Sigma^{0}"$ spectrum is observed, which seems similar to those obtained in the $\pi^{\pm}\Sigma^{\mp}$ modes.

Statistics will be increased further in coming beam time in June, 2017.

Summary

- The preliminary result of the E31 1st physics run is presented.
  - $d(K^-, n)"\pi^{\pm}\Sigma^{\mp}"(I = 0, 1)$ spectra is presented.
    The difference of two spectra is observed due to interference of the $I = 0$ and 1 amplitudes.
  - Comparison of $d(K^-, n)"\pi^{\pm}\Sigma^{\mp}"$ and $d(K^-, p)"\pi^-\Sigma^0"$
    The I=0 amplitude is dominant.
  - $d(K^-, n)"\pi^0\Sigma^0"(I = 0)$ spectra is presented.
    The $d(K^-, n)"\pi^0\Sigma^0"$ spectrum is observed.
- The result of the E31 1st physics run will be finalized.
  $\rightarrow$ $d(K^-, n)"\pi^{\pm}\Sigma^{\mp}"$ and $d(K^-, p)"\pi^-\Sigma^0"$.
- The E31 2nd physics run will be performed in June, 2017.
  $\rightarrow$ Statistics of $d(K^-, n)"\pi^0\Sigma^0"$ will be increased.