Current status of spectroscopic study for the Λ(1405) via the d(K^-, n) reaction

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For the E31 Collaboration

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  - d(K$^-$, n)"X" spectrum identified $\pi^\mp \Sigma^\pm$
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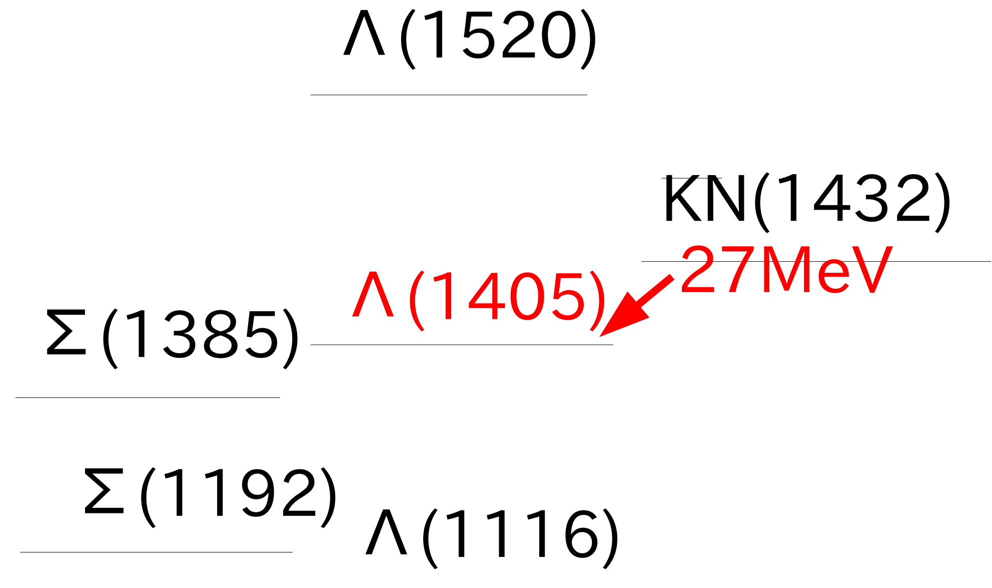
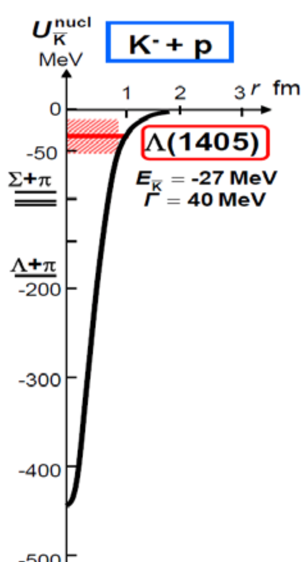
Λ(1405)



PDG

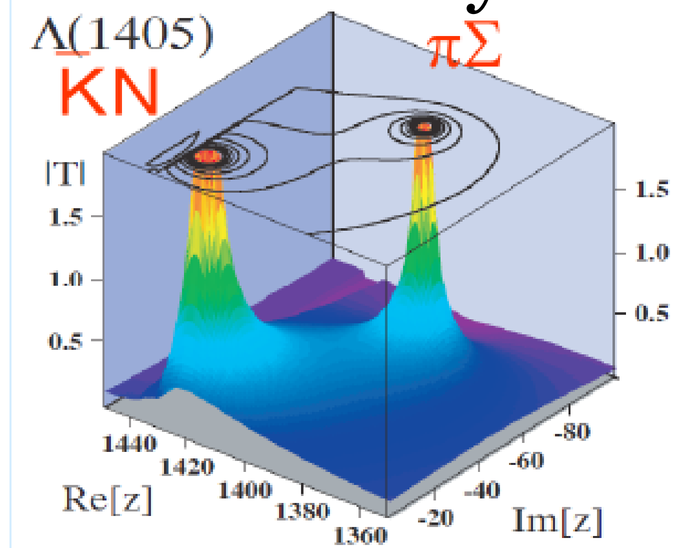
- $I(J^p)=0(\frac{1}{2}^-)$
- mass $1405.1^{+1.3}_{-1.0}$ MeV
- Width = 50.5 ± 2 MeV

$\bar{K}N$ bound state



Y.Akaishi & T.Yamazaki
PLB535, 70(2002).

Two-poles of meson-baryon



ChU model, T. Hyodo

Recent experimental study of Λ(1405)

Line shapes of Λ(1405) have been reported.

pp collision

HADES collaboration:
PRC87, 025201

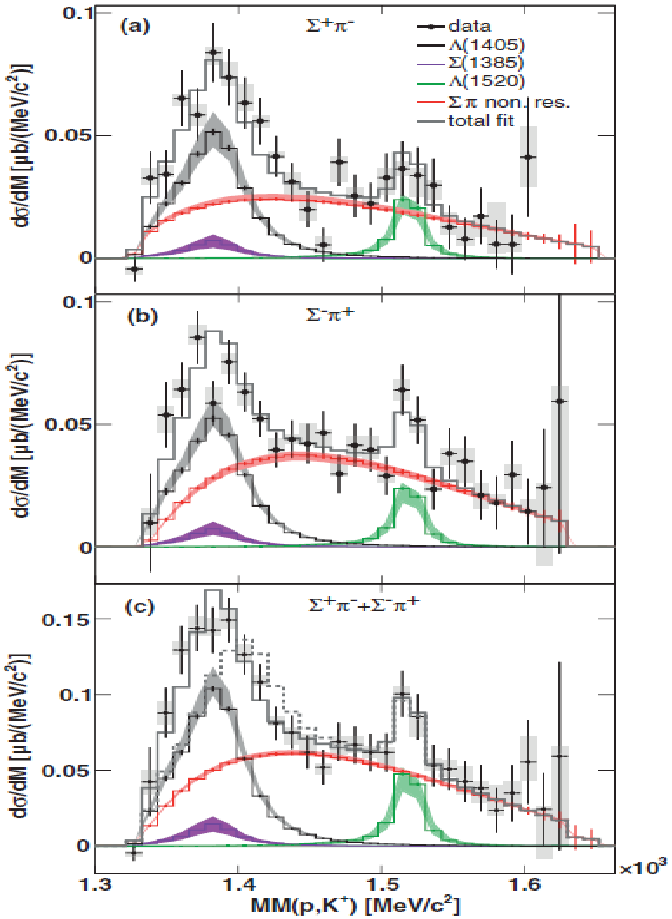
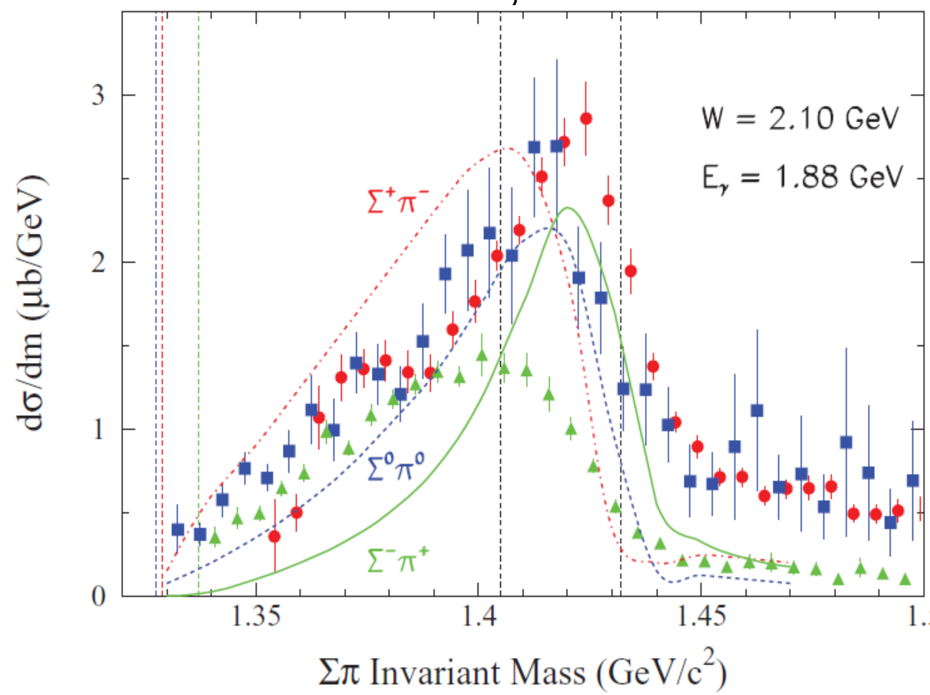


Photo-production

CLAS collaboration:
PRC87, 035206

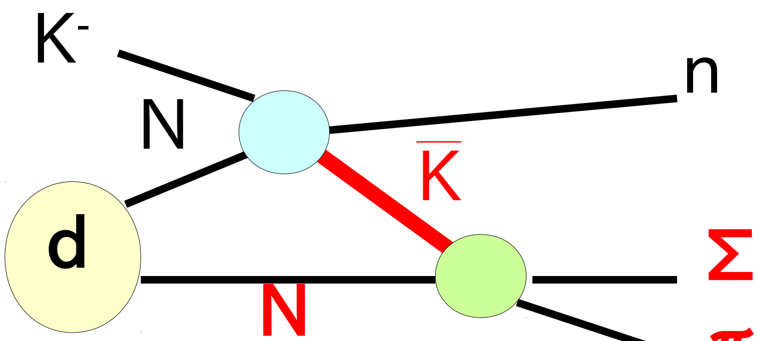


in-flight d(K⁻, n) reaction data is only $\pi^+\Sigma^-$ mode.

O. Braun et el., NPB129, 1(1977)

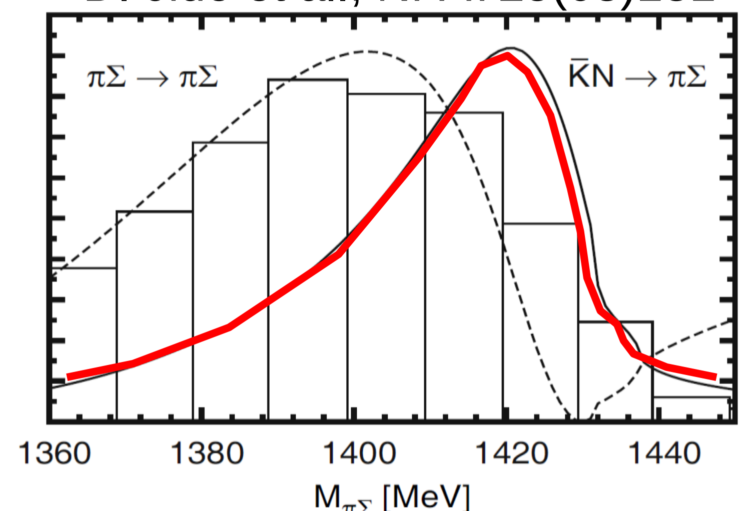
d(K^-, n) reaction

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



Chiral Unitary Model

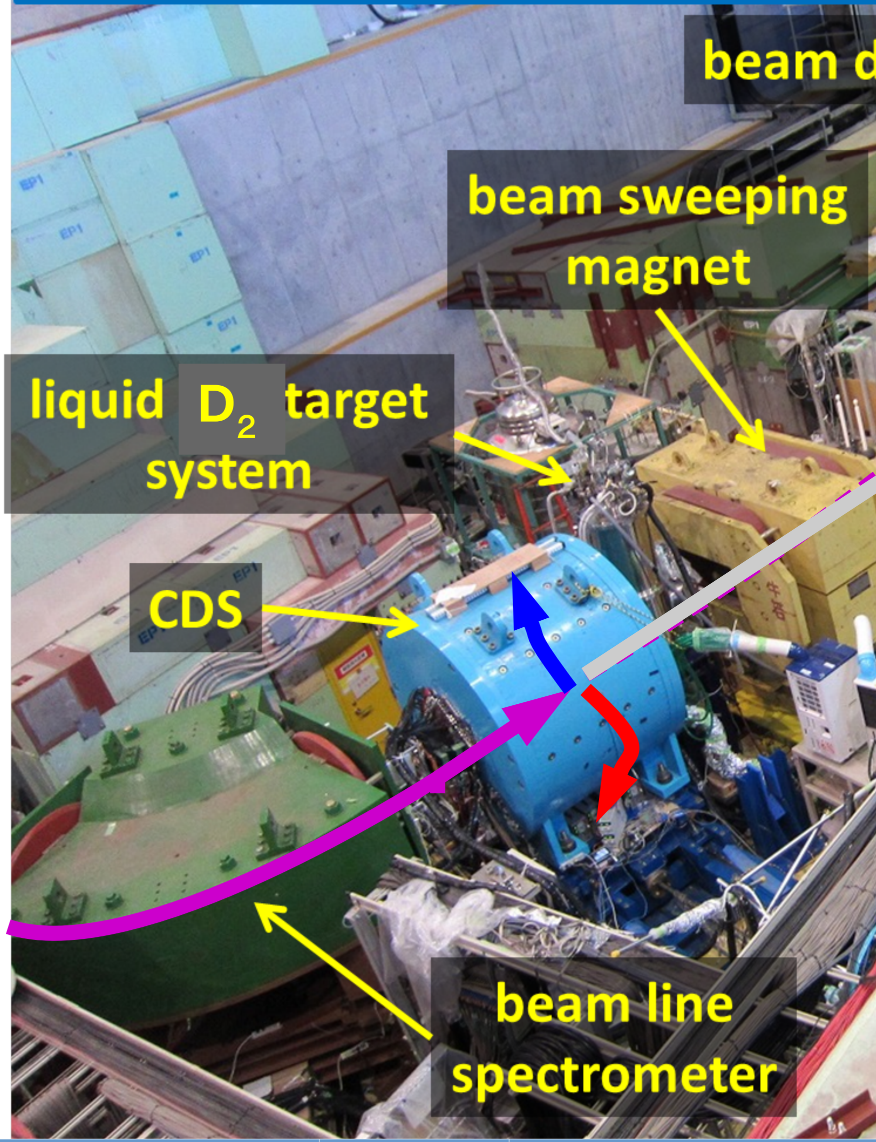
D. Jido et al., NPA725(03)181

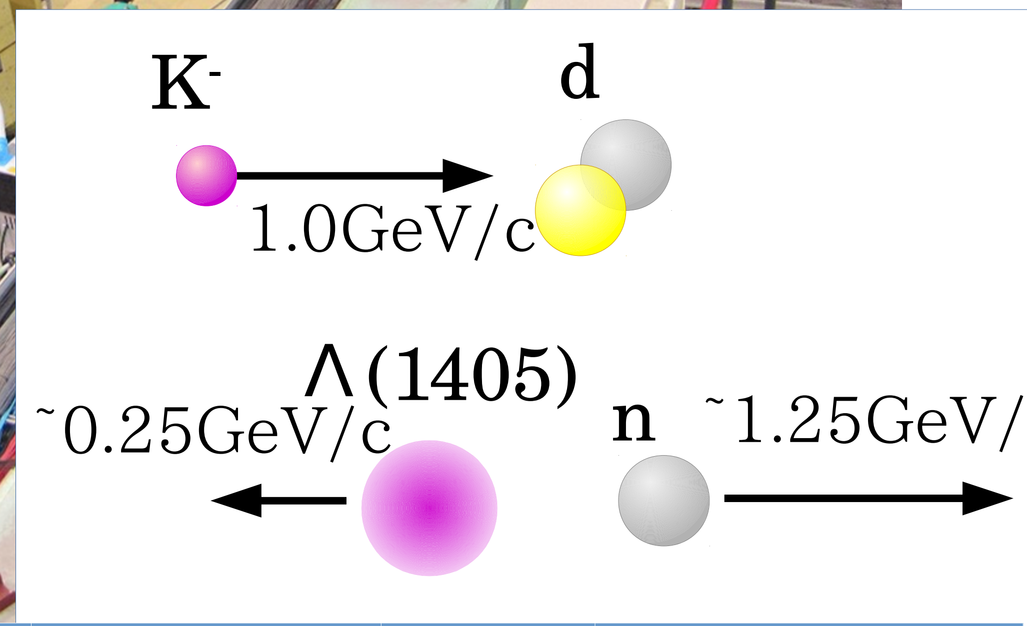


- Identify all the final states to decompose the I=0 and I=1 amplitudes.

Λ(1405)	I=0	S-wave	$\pi^{\pm}\Sigma^{\mp}$, $\pi^0\Sigma^0$
Σ(1385)	I=1	P-wave	$\pi^{\pm}\Sigma^{\mp}$, $\pi^0\Lambda$
Non-resonant	I=0,1	S,P,D・・・	

The K1.8BR spectrometer

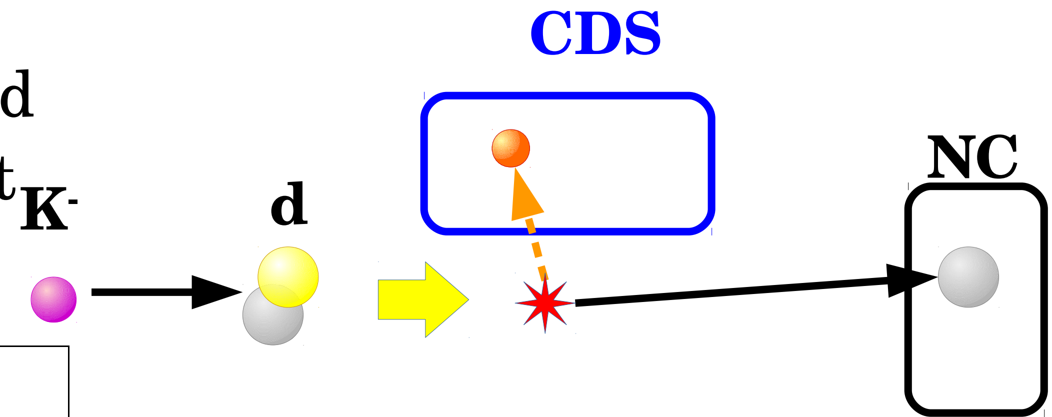


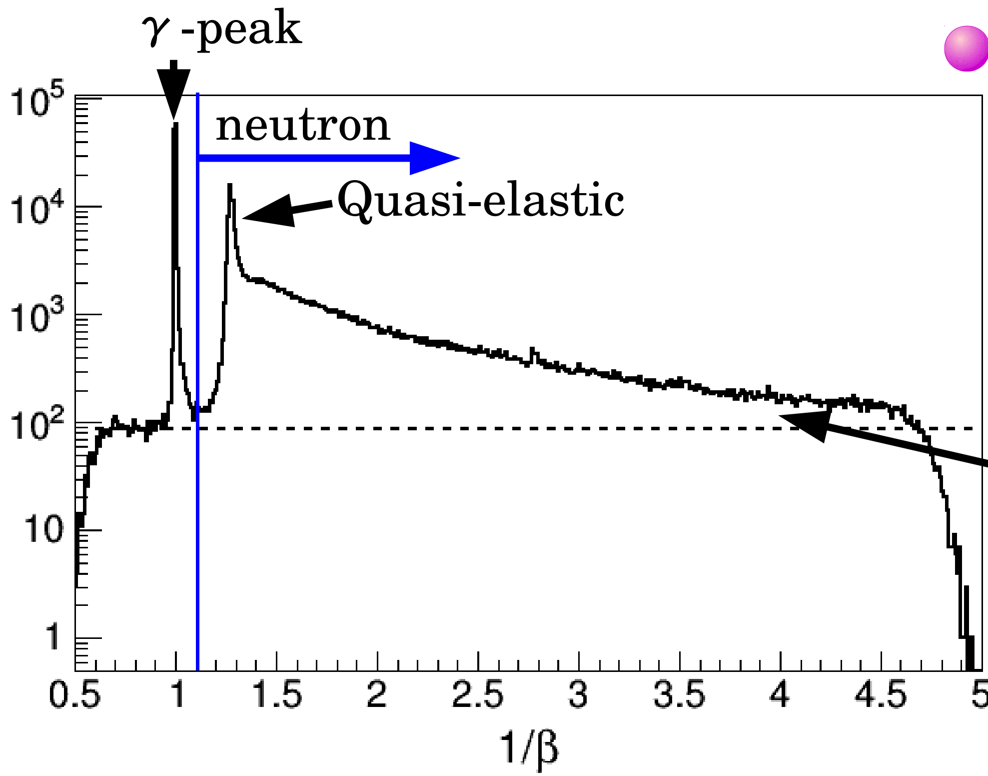


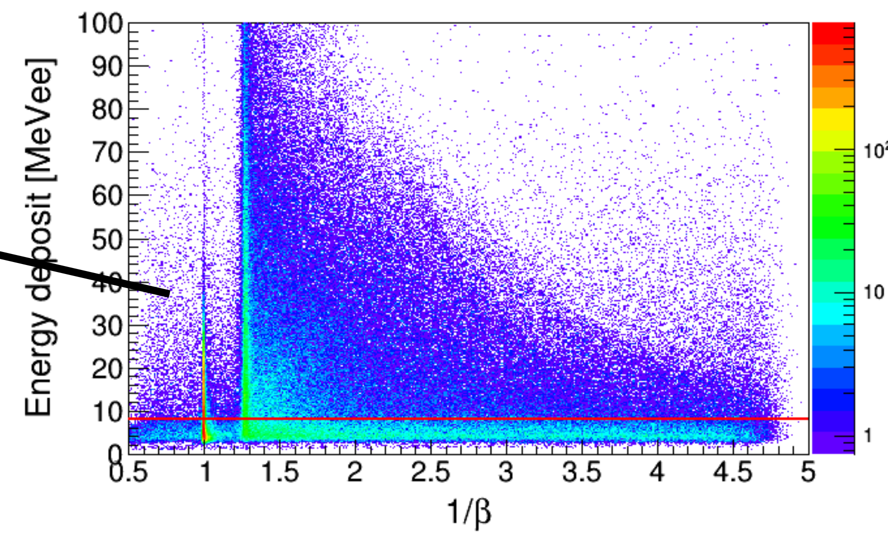
Calibration for E15	Exp Target	Primary-beam intensity	Secondary Kaon intensity	Duration	Kaon on target (w/ tgt selection)
Apr-May, 2015 (RUN#62)	D_2	26.5kW (33Tppp, 6s)	130k/spill	53h	2.8×10^9

Neutron $1/\beta$ spectrum

1 charged track in CDS is required to determine reaction vertex point





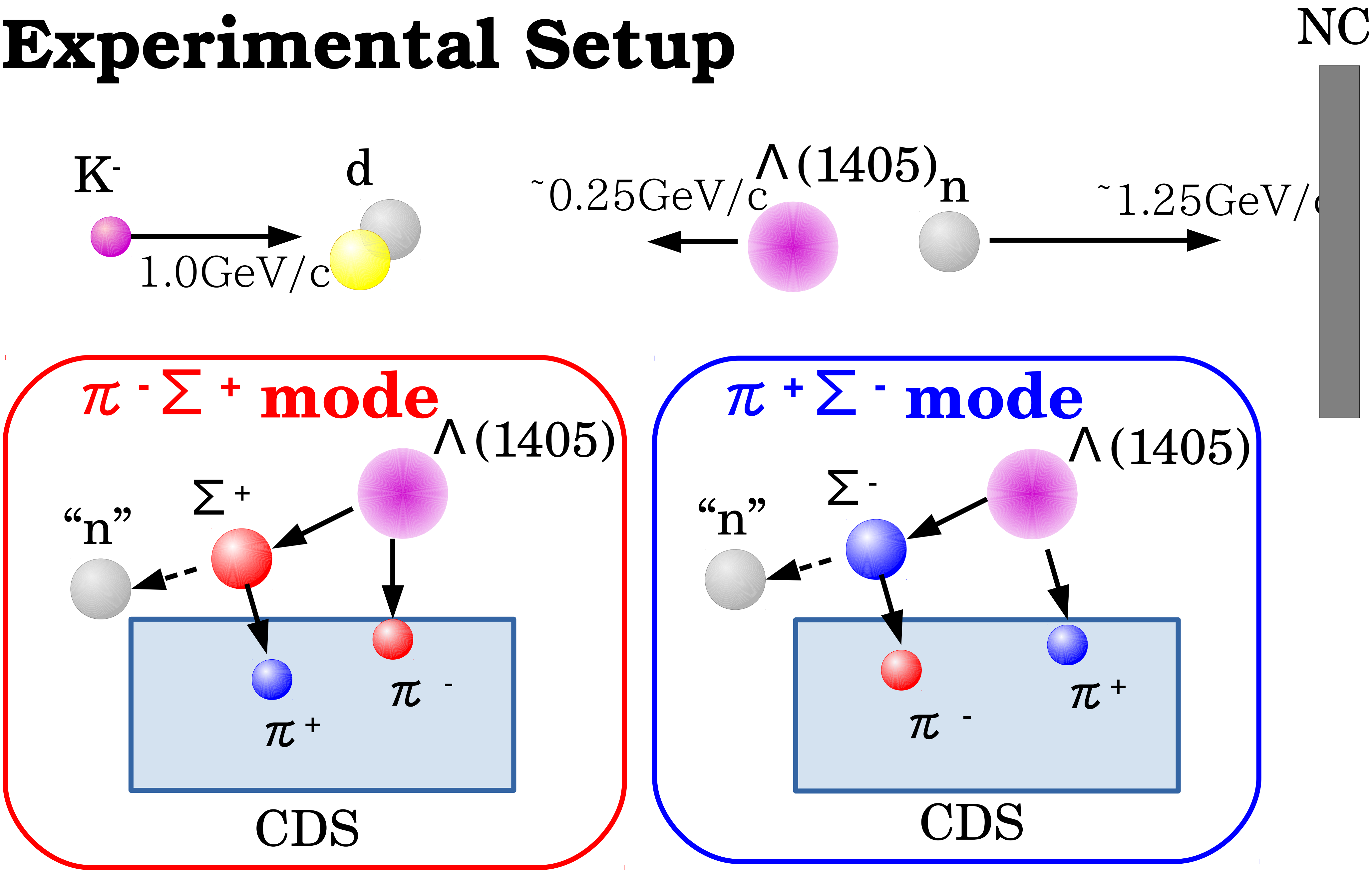


γ-peak and quasi-elastic peak are clearly seen.

TOF resolution is evaluated at 160ps by γ-peak.

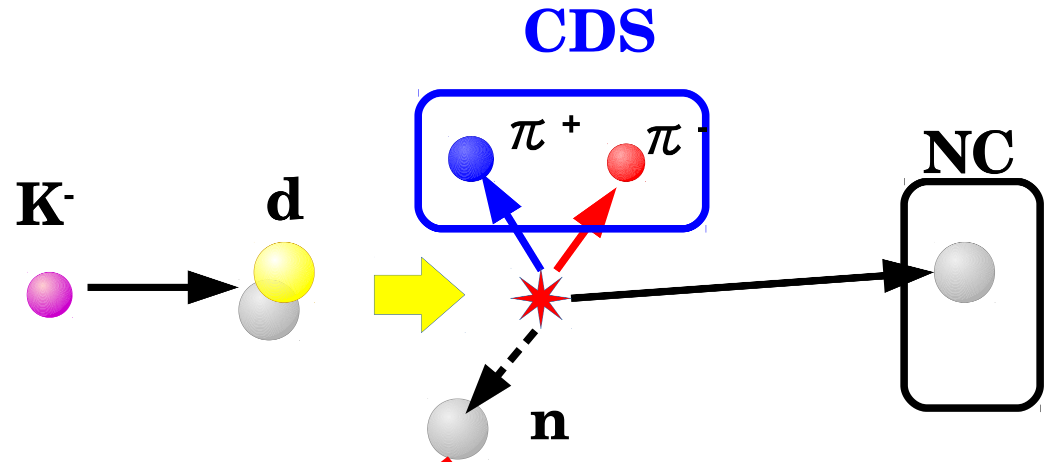
Contribution of TOF resolution to missing mass is about 8MeV/c^2 at $\bar{K}N$ threshold.

Experimental Setup

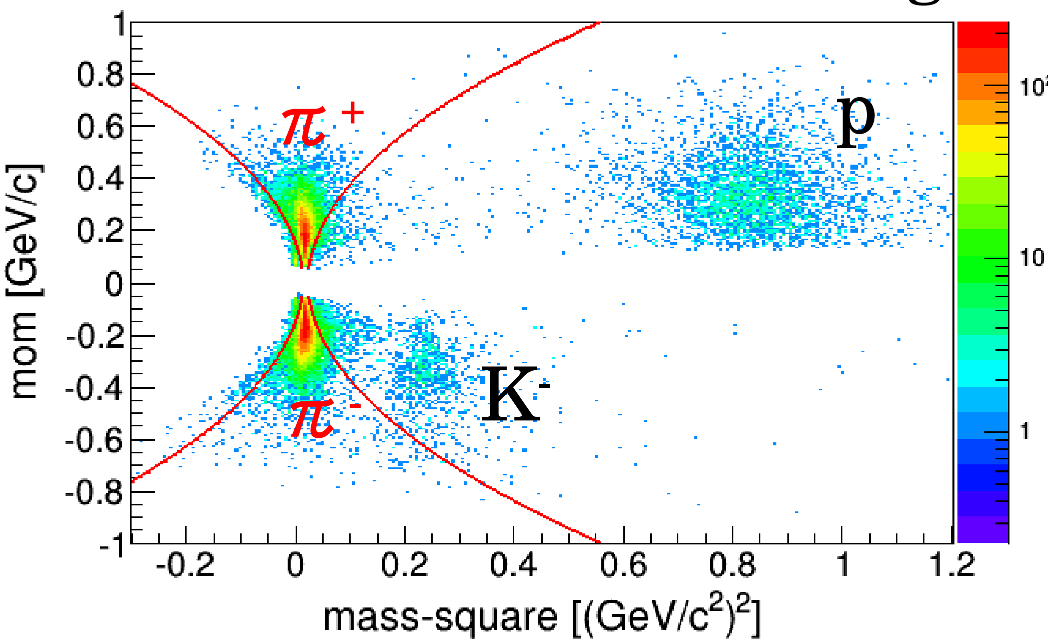


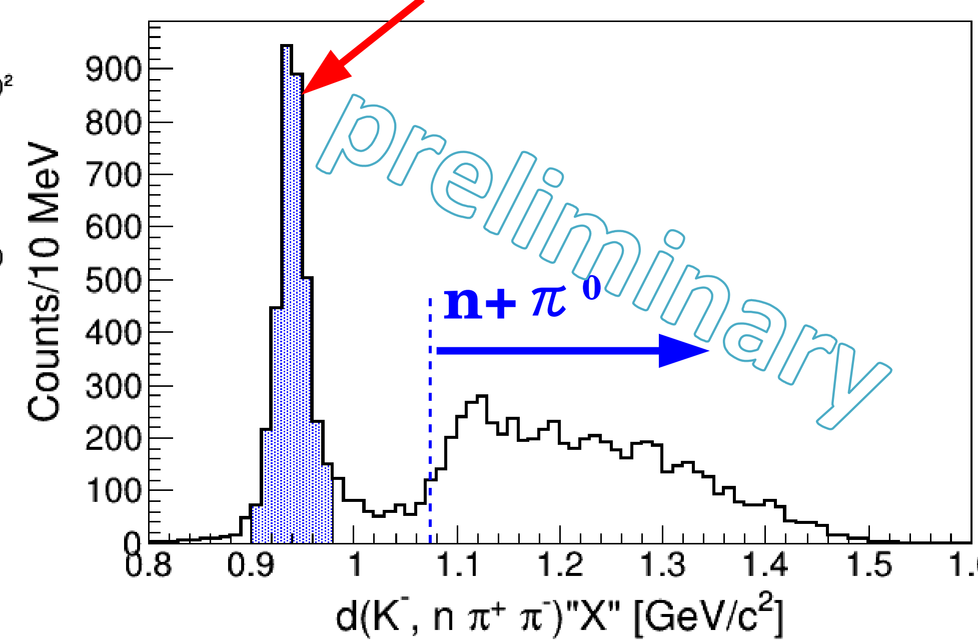
We will identify $K^- d \rightarrow n\ \pi^+\ \pi^-$ "n" events.

$K^- d \rightarrow n\ \pi^+ \pi^-$ "n" event identification



Forward n & CDS ± charge



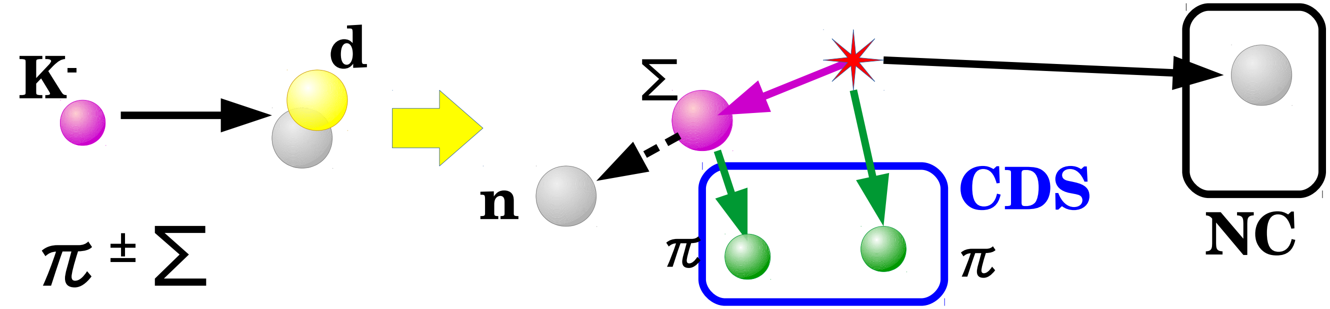


π^+ and π^- are clearly seen, we select 2.5 σ region.

A missing "n" is clearly identified.

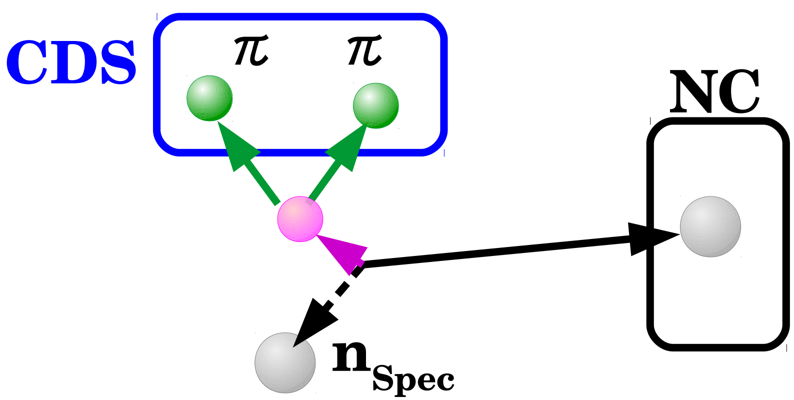
n π^+ π^- "n" final state consists of …

Signal

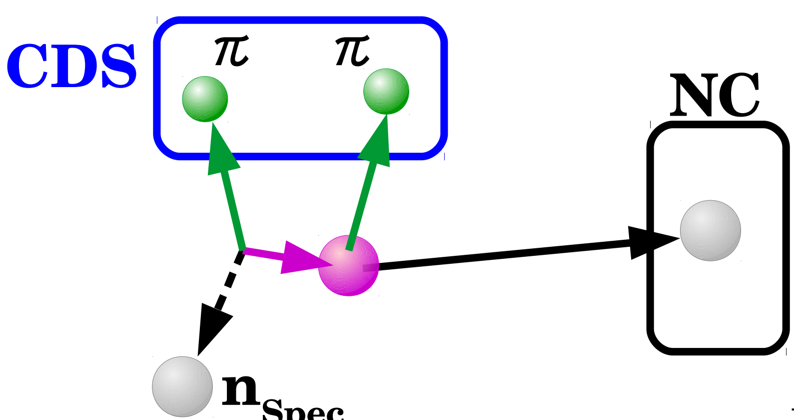


Backward $\pi^\pm\Sigma$

K^0 production



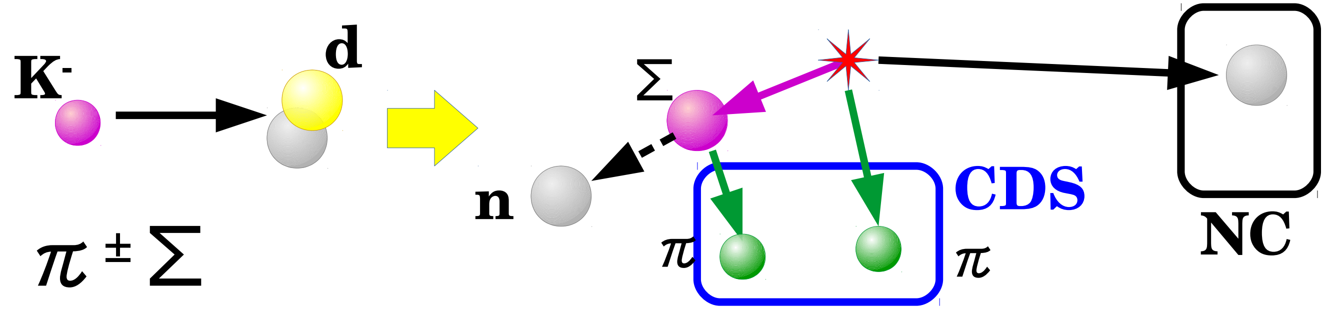
Forward Σ production



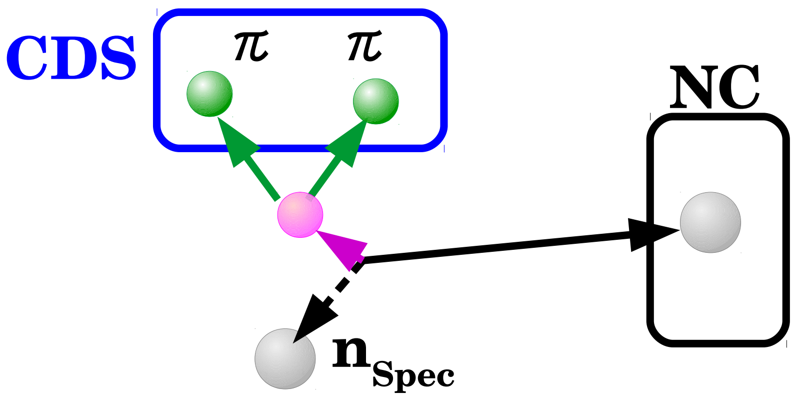
n $\pi^+ \pi^-$ "n" final state consists of ...

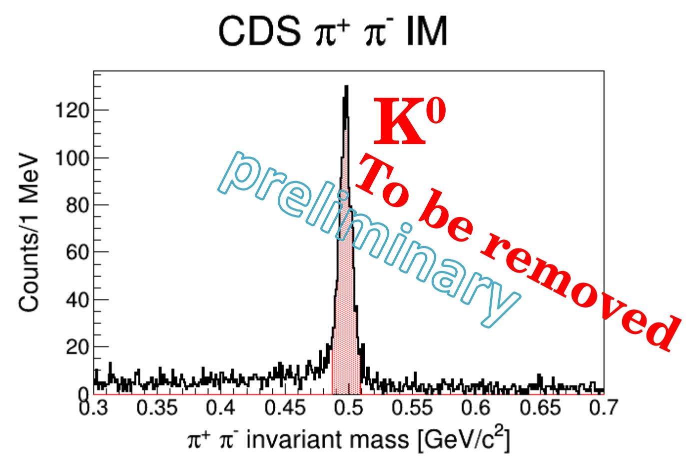
Signal

Backward $\pi^\pm\Sigma$

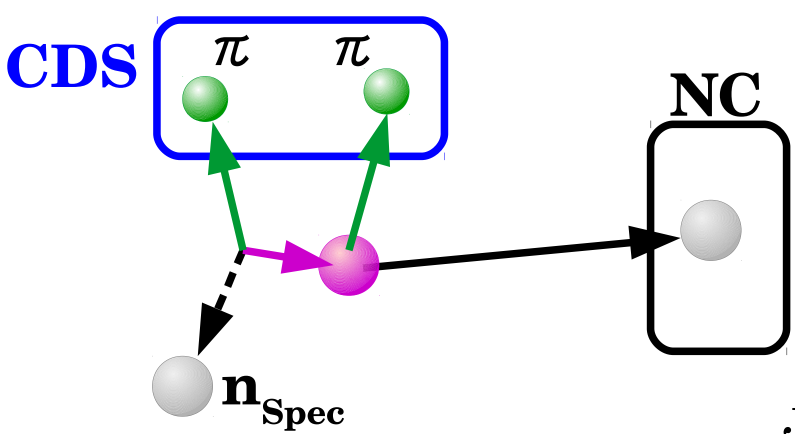


K^0 production





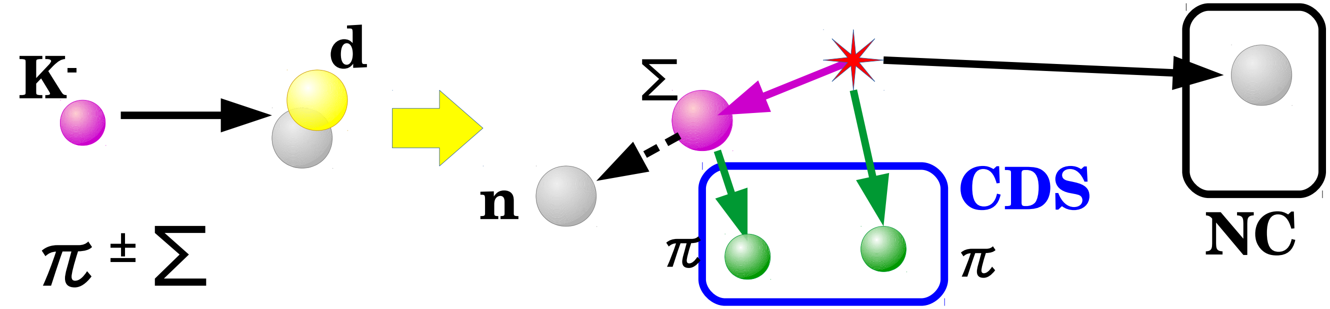
Forward Σ production



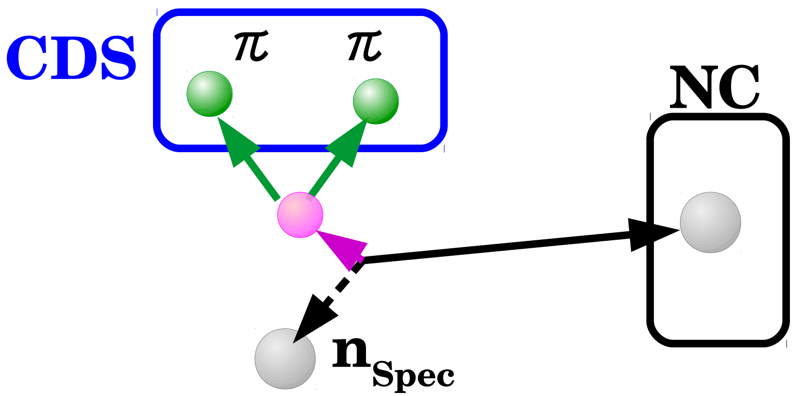
n $\pi^+ \pi^-$ "n" final state consists of ...

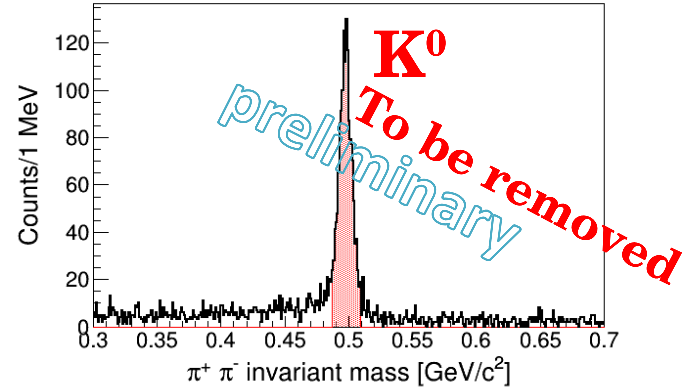
Signal

Backward $\pi^\pm \Sigma$

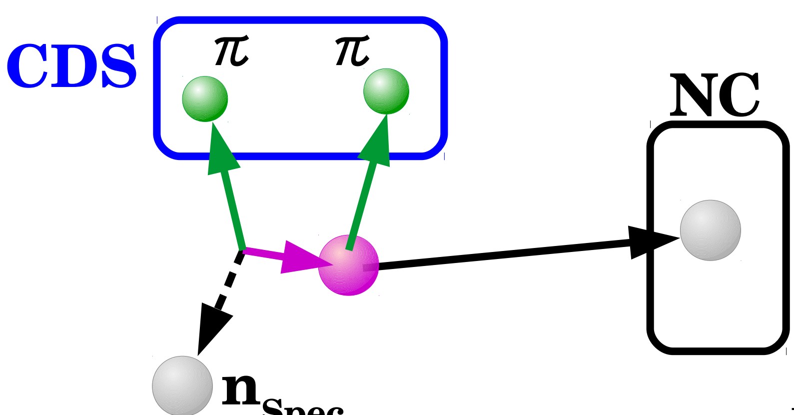


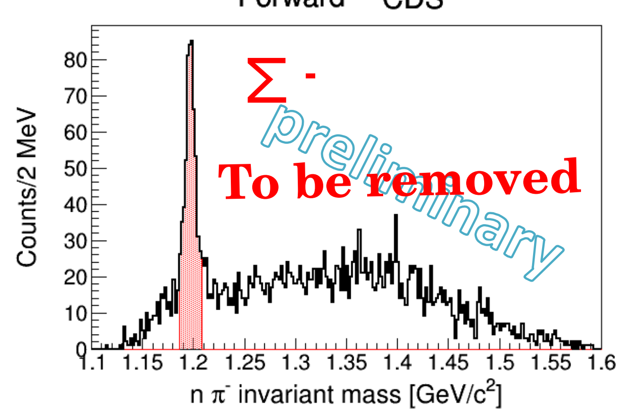
K^0 production





Forward Σ production

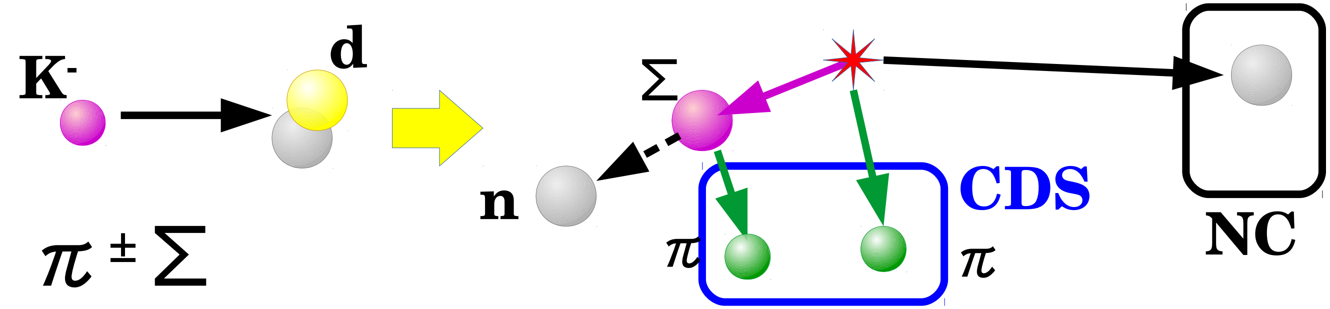




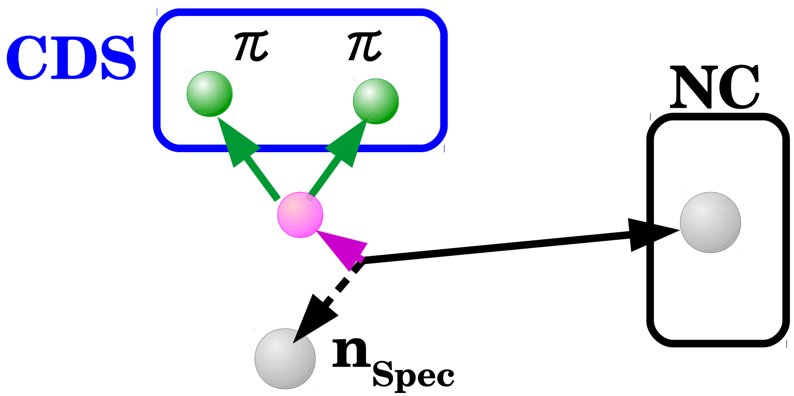
n $\pi^+\pi^-$ "n" final state consists of …

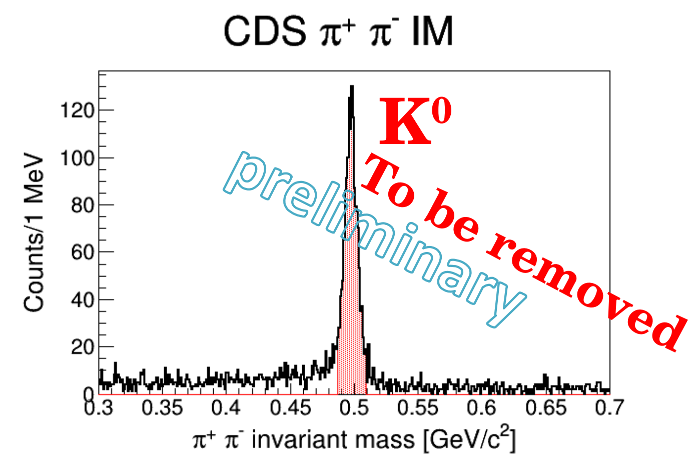
Signal

Backward $\pi^\pm\Sigma$

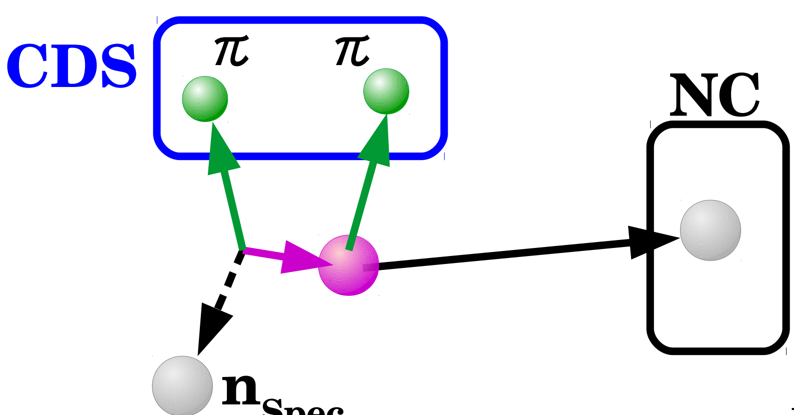


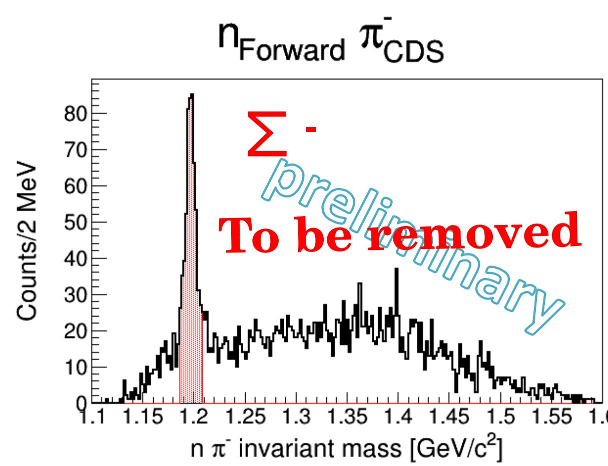
K⁰ production

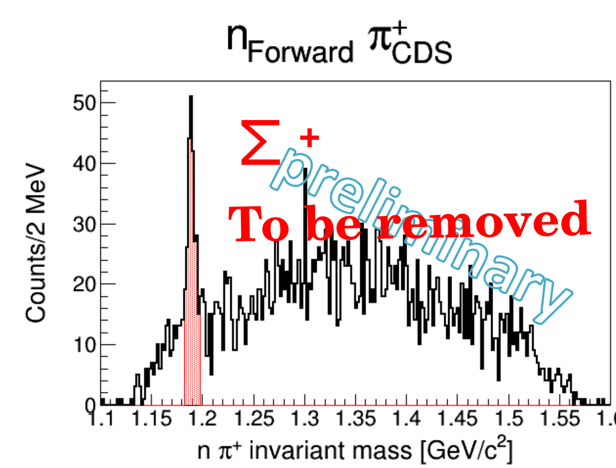




Forward Σ production



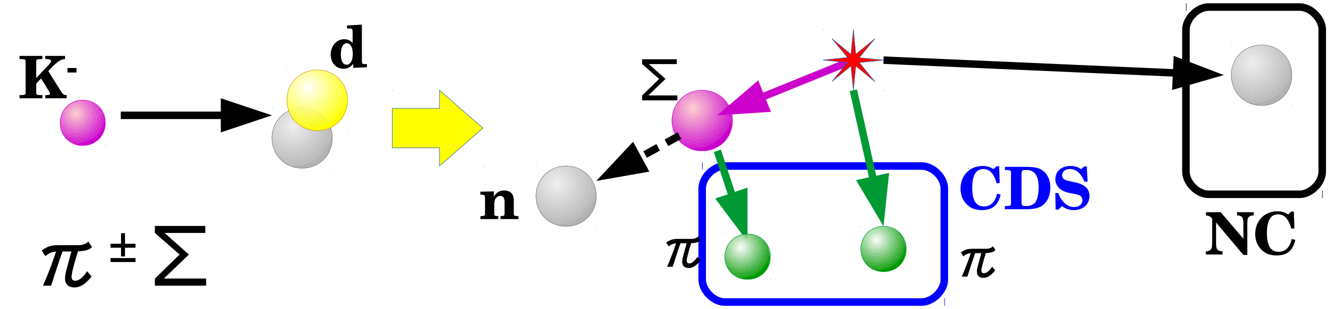




n $\pi^+ \pi^-$ “n” final state consists of ...

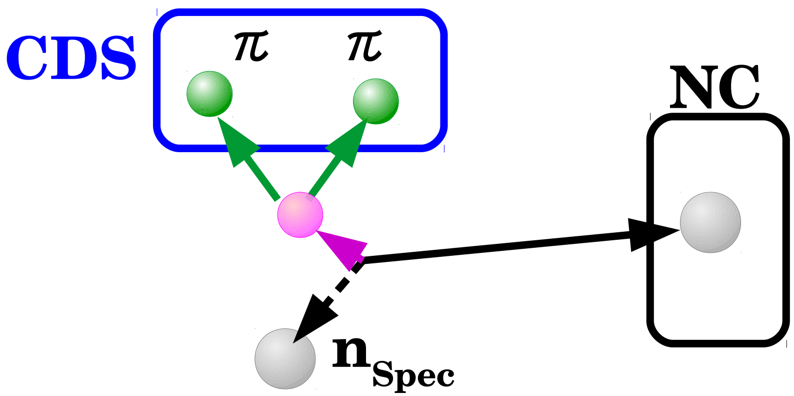
Signal

Backward $\pi^\pm\Sigma$



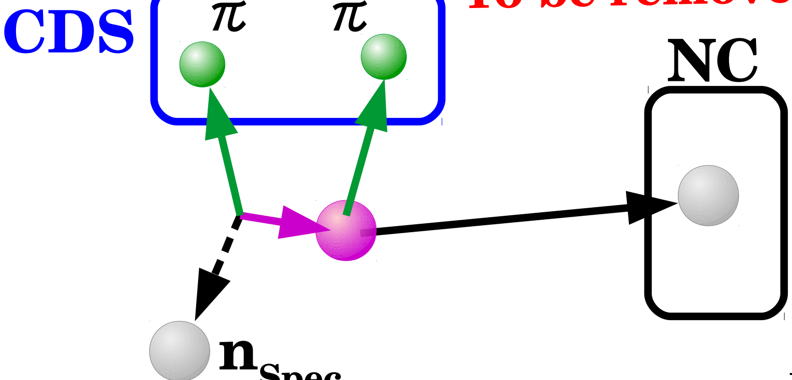
K^0 production

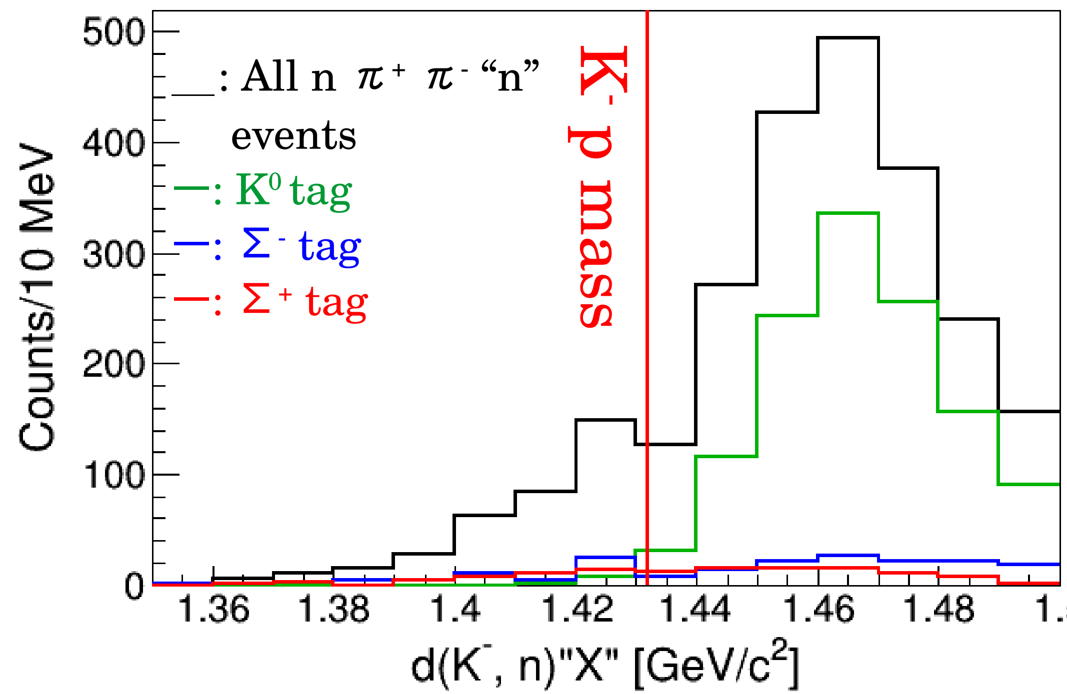
To be removed



Forward Σ production

To be removed

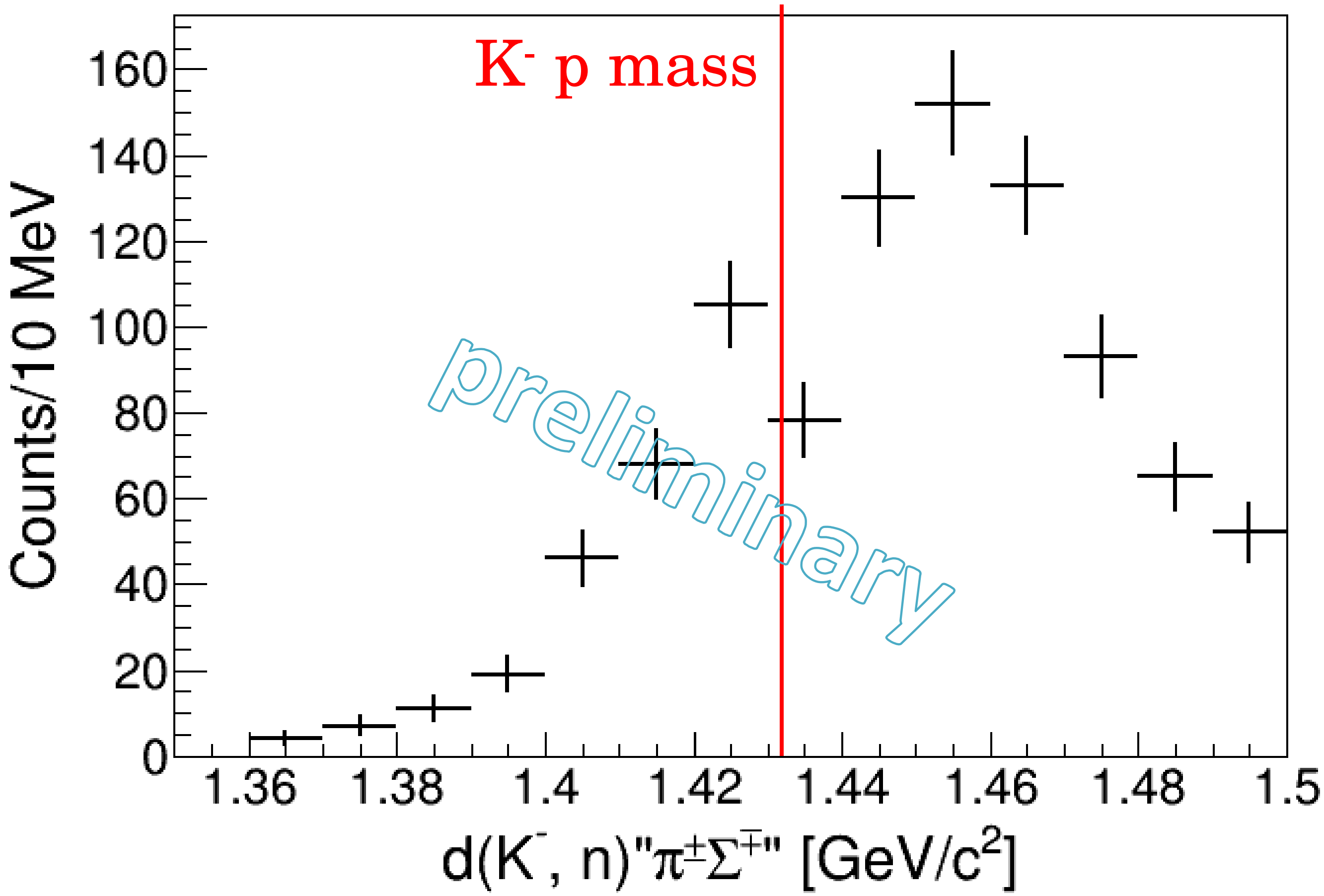




K^0 and $\Sigma_{\mathrm{Forward}}$ should be removed

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

(K^0 and Σ_{Forward} production events are removed)



This contains both $\pi^\pm\Sigma^\mp$ modes.

→ to be decomposed

How to decompose $\pi^-\Sigma^+$ and $\pi^+\Sigma^-$

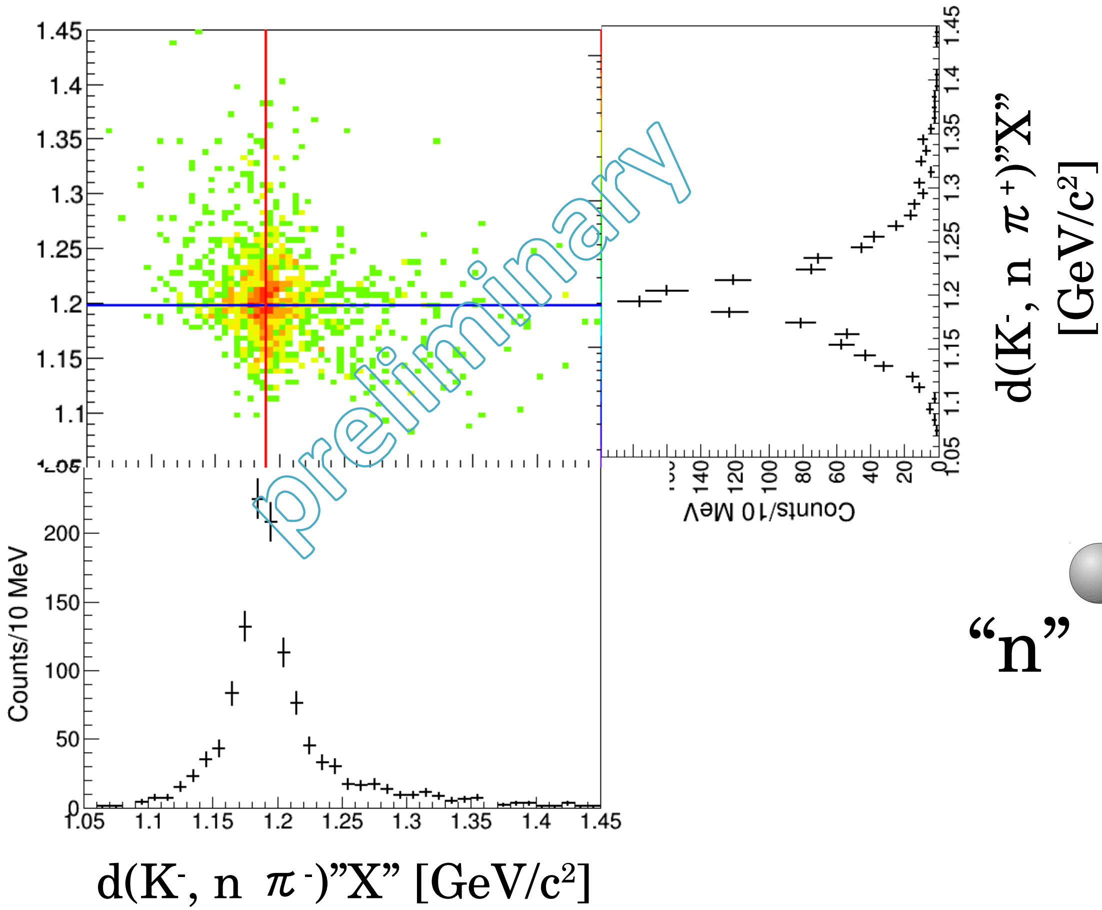
Step.1 We made two missing mass spectra of d(K$^-$, n π^-)"X" and d(K$^-$, n π^+)"X" from selected K$^-$ d→n π^+ π^- "n" events K^0 and Σ_{Forward} removed.

- In d(K$^-$, n π^-)"X"
  - $\pi^-\Sigma^+$ mode makes a peak, $\pi^+\Sigma^-$ mode does not.
- In d(K$^-$, n π^+)"X", vice versa.

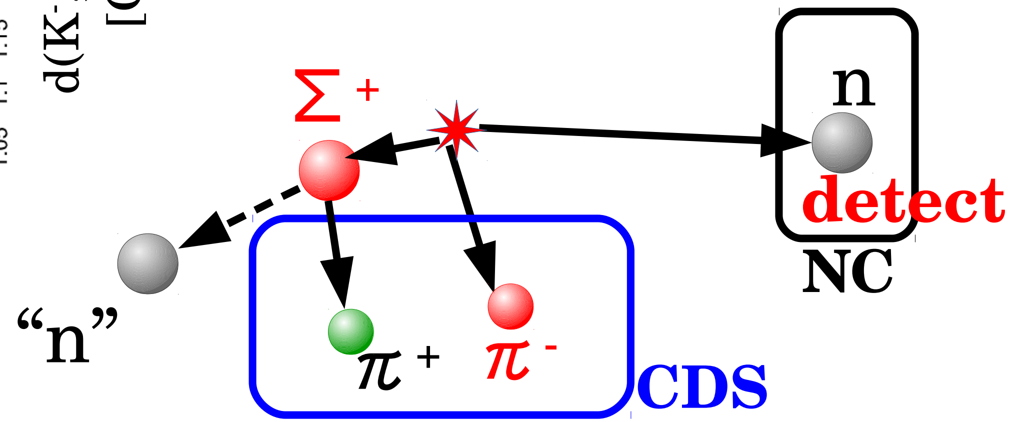
Step. 2 We evaluate number of each mode by fitting the both d(K$^-$, n $\pi^\pm$)"X" spectra.

- Spectrum shapes for each decay modes estimated by Monte Carlo simulation are employed for the fitting.
- A fitting constraint was made so that the number of each mode is same in both fitting.

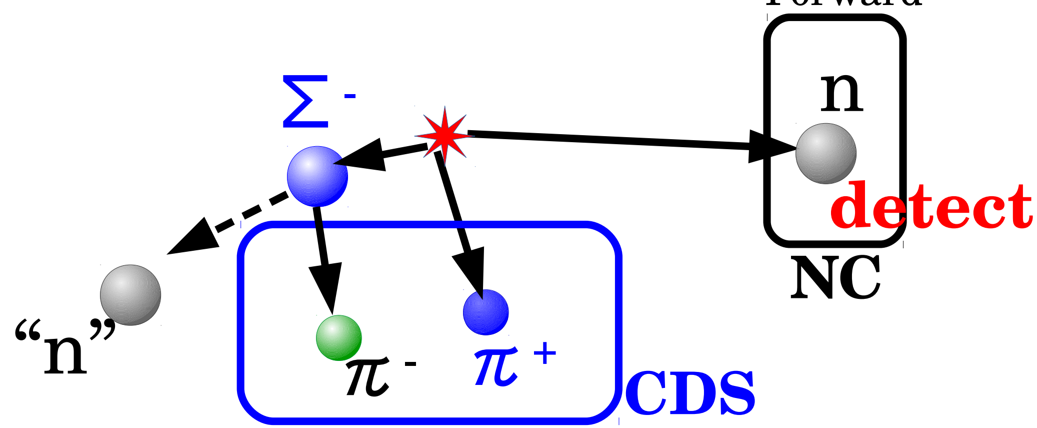
How to decompose $\pi^-\Sigma^+$ and $\pi^+\Sigma^-$



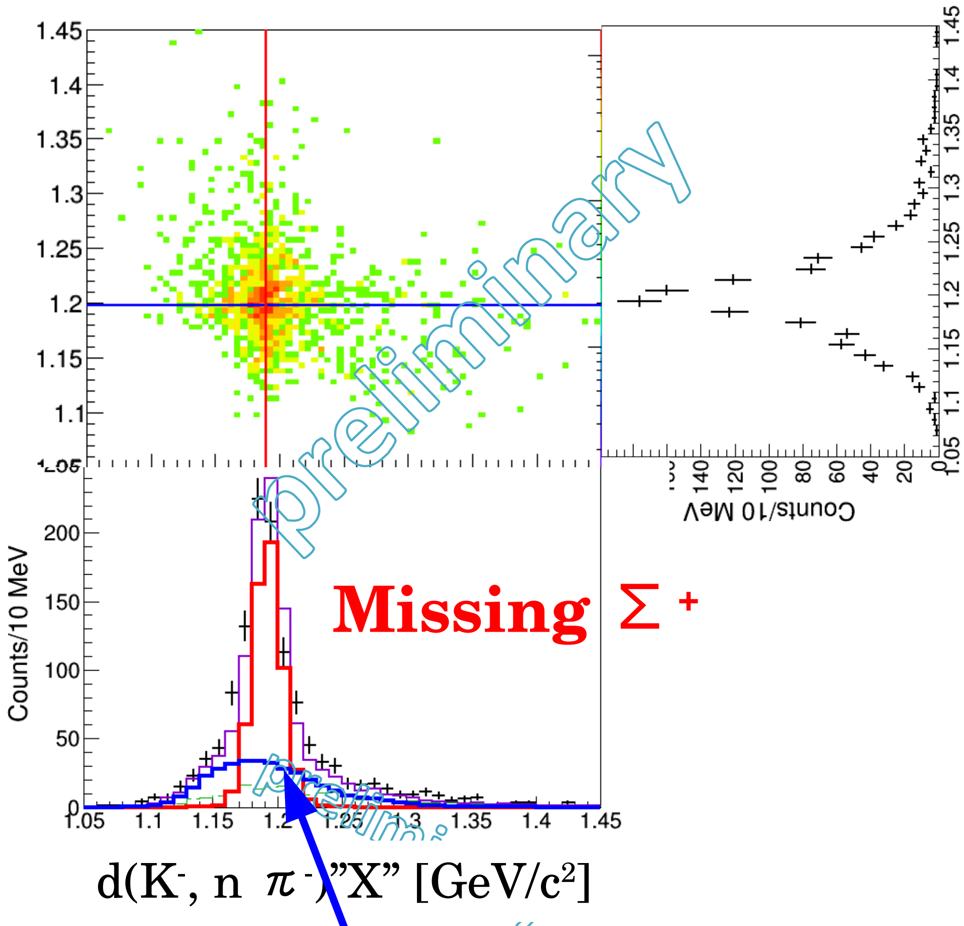
1) K$^-$ d→($\pi^-\Sigma^+$) n$_{\text{Forward}}$



2) K$^-$ d→($\pi^+\Sigma^-$) n$_{\text{Forward}}$

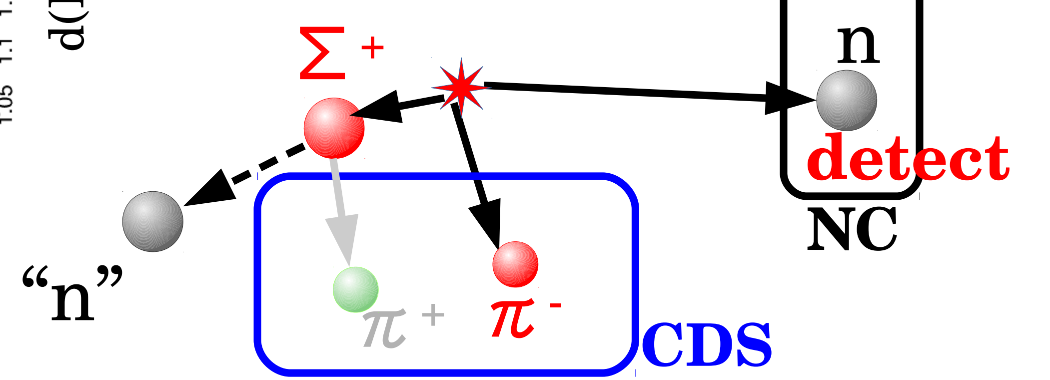


How to decompose $\pi^-\Sigma^+$ and $\pi^+\Sigma^-$

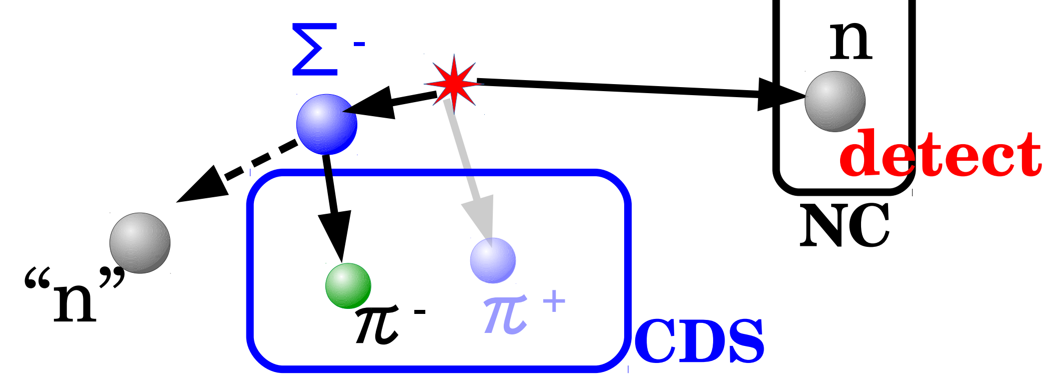


Broad distribution of π n

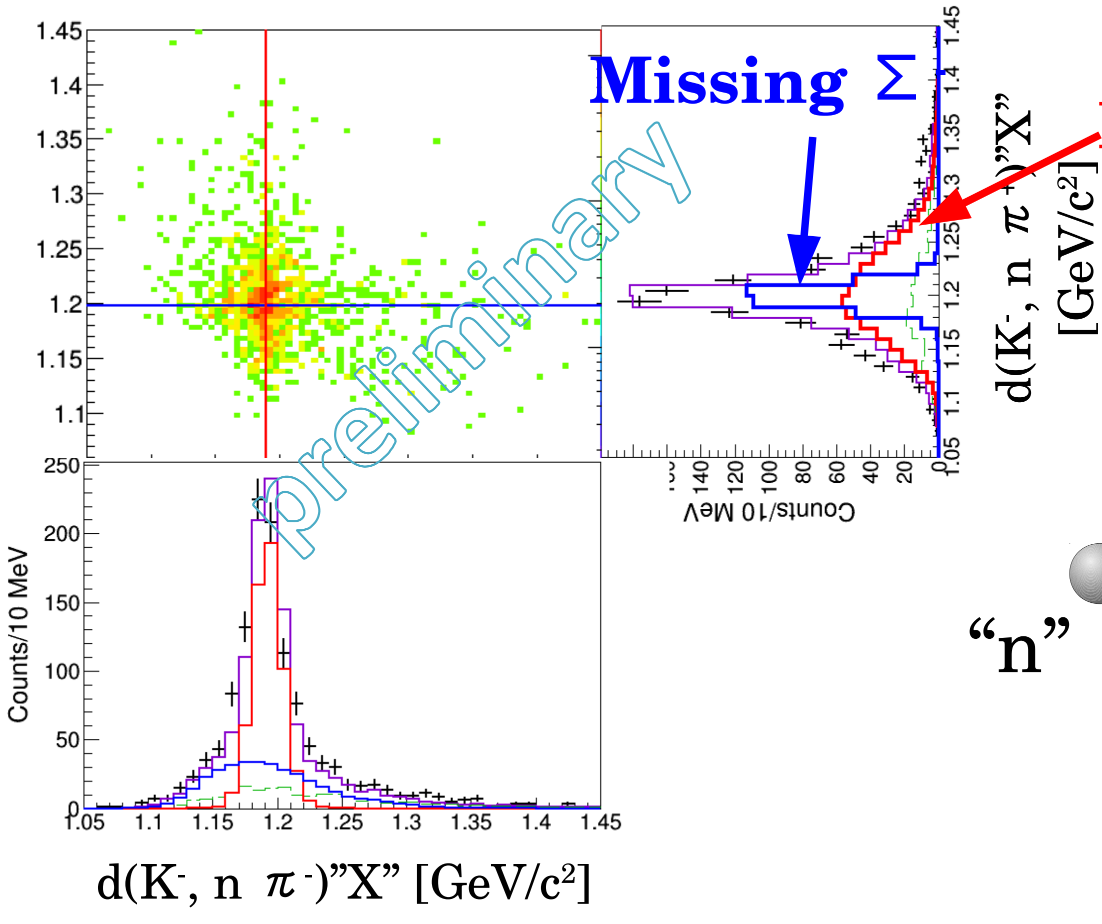
1) $K^-\ d \rightarrow (\pi^-\Sigma^+)\ n_{Forward}$

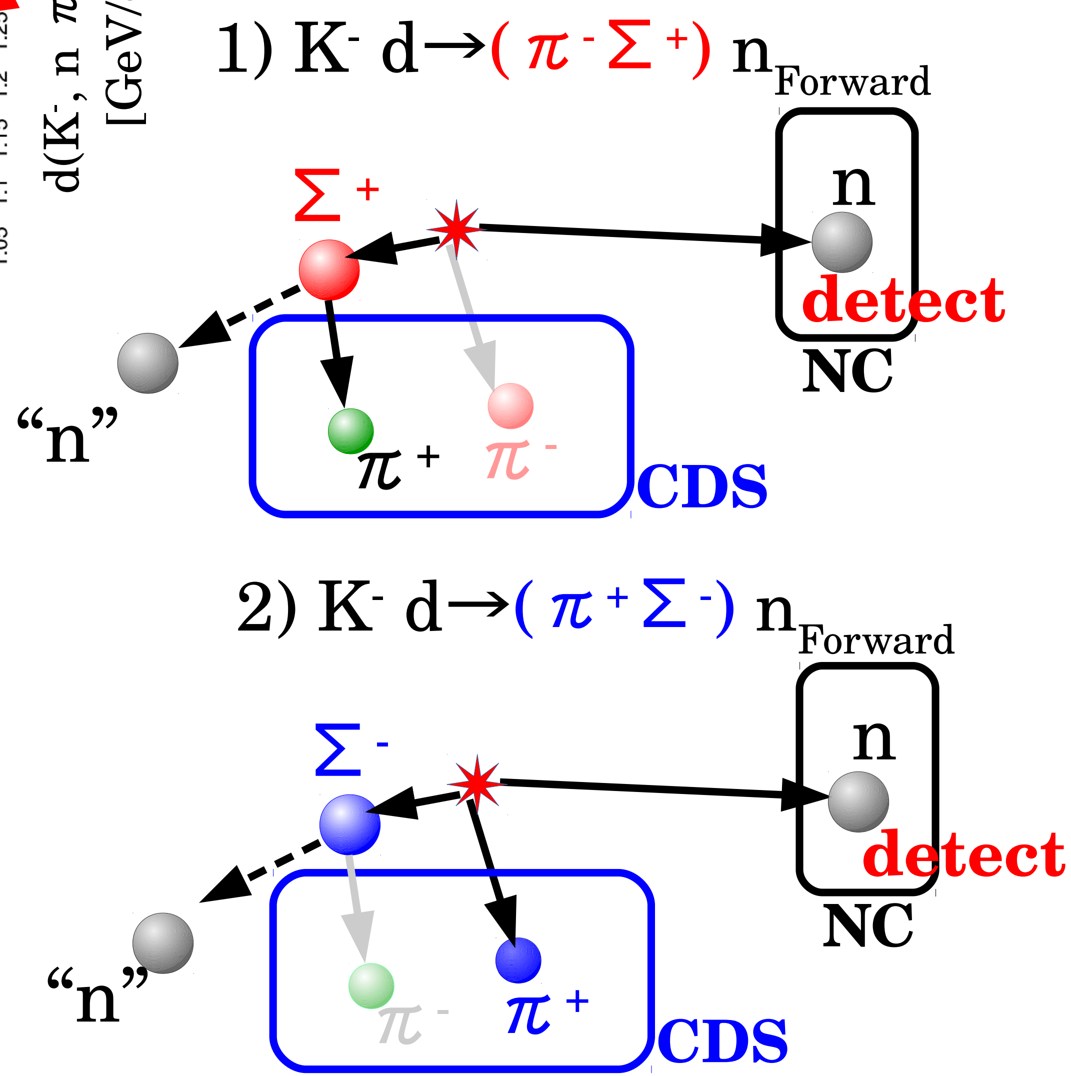


2) $K^-\ d \rightarrow (\pi^+\Sigma^-)\ n_{Forward}$

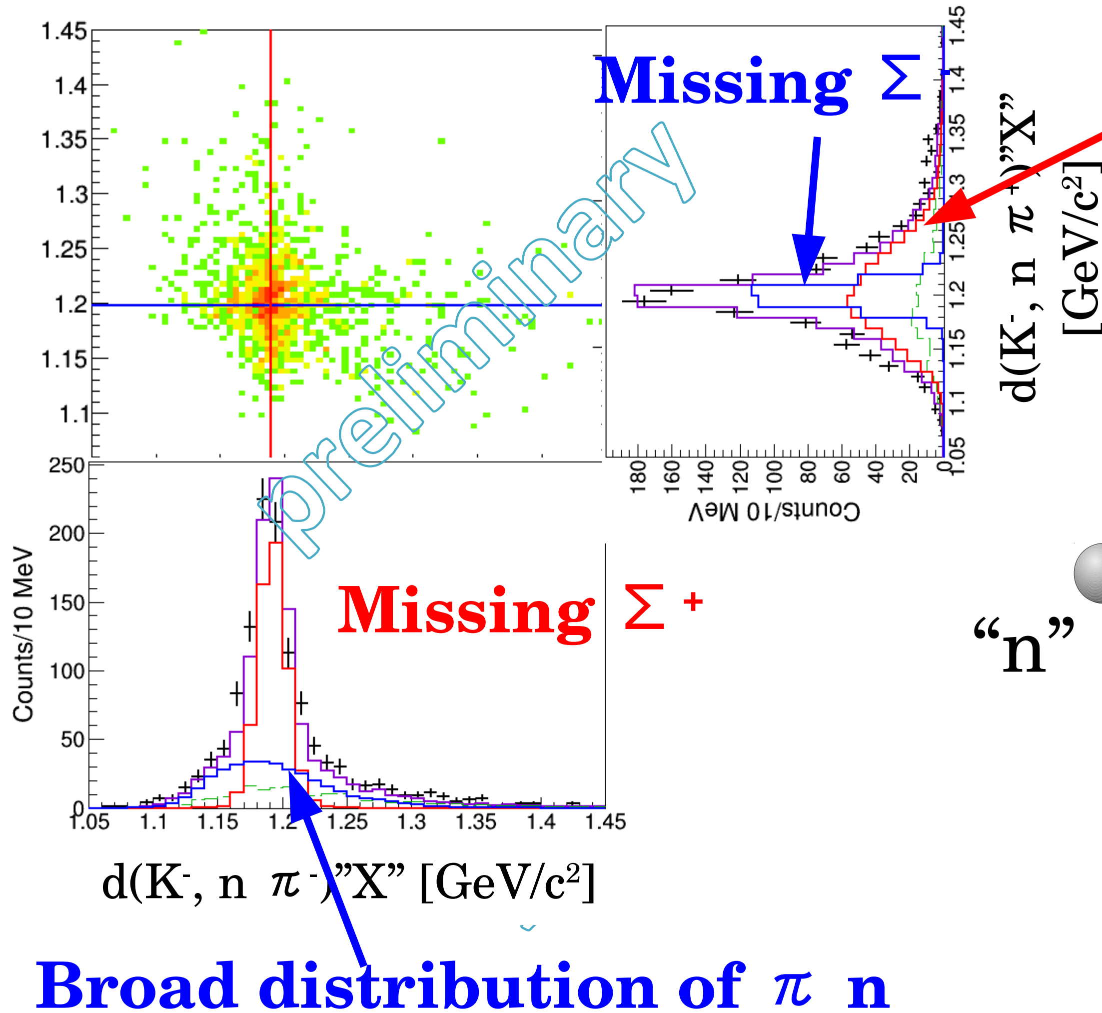


How to decompose $\pi^-\Sigma^+$ and $\pi^+\Sigma^-$

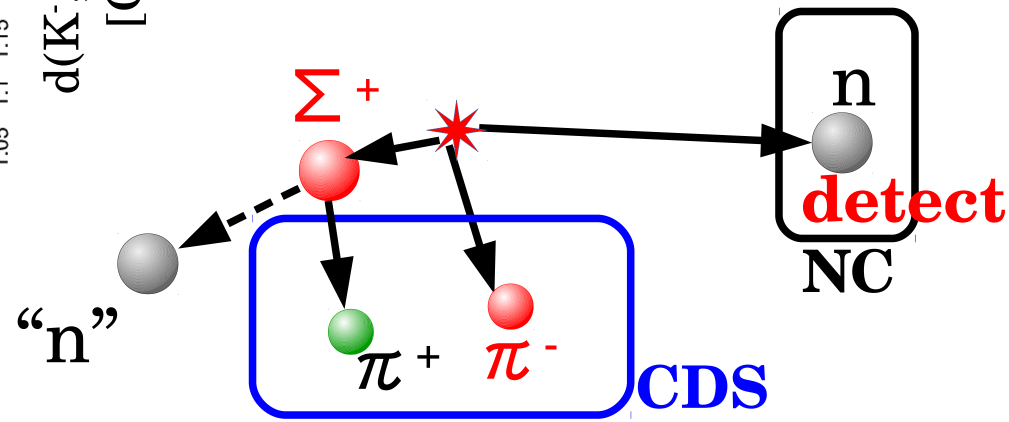




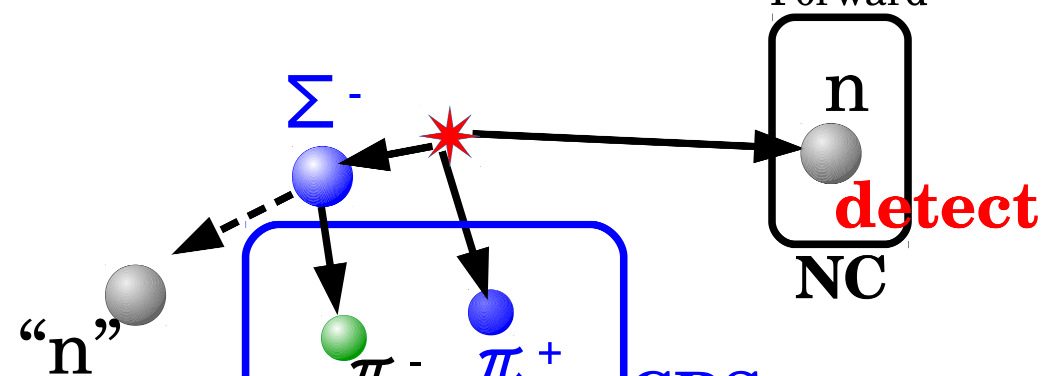
How to decompose $\pi^-\Sigma^+$ and $\pi^+\Sigma^-$



1) K$^-$ d→($\pi^-\Sigma^+$) $n_{Forward}$

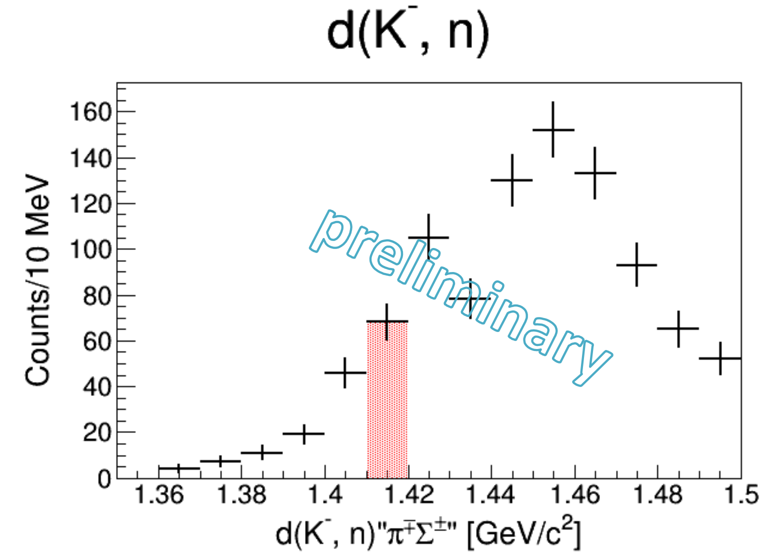


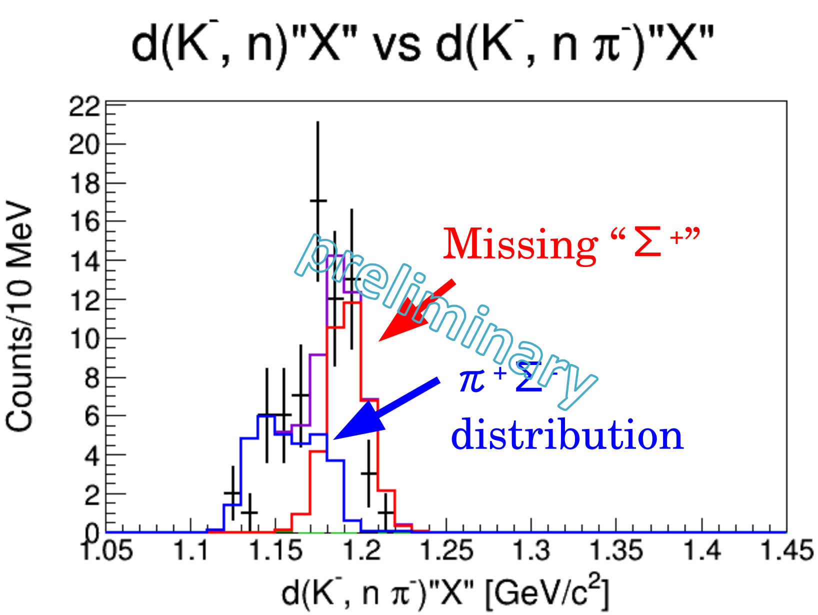
2) K$^-$ d→($\pi^+\Sigma^-$) $n_{Forward}$

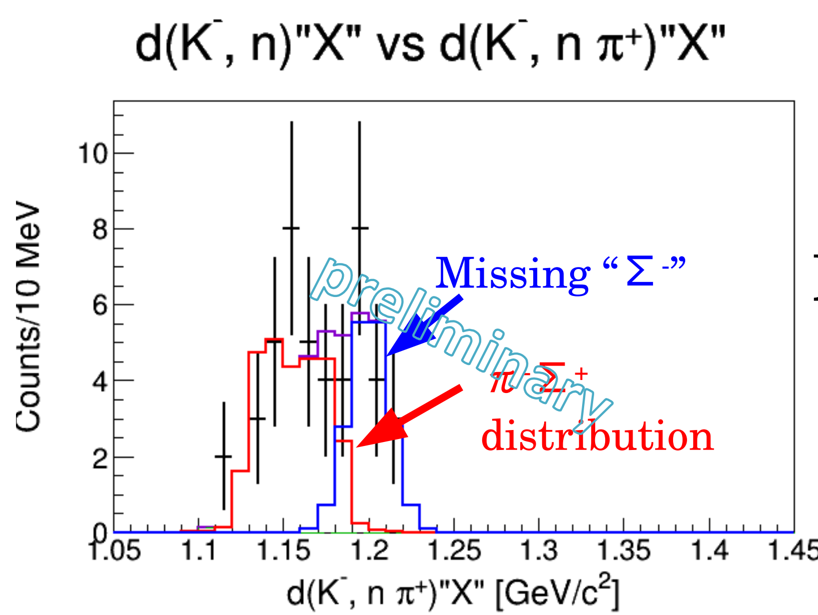


Decomposition of $\pi^-\Sigma^+$ and $\pi^+\Sigma^-$

The fitting is done
bin by bin of d(K$^-$, n)"X"





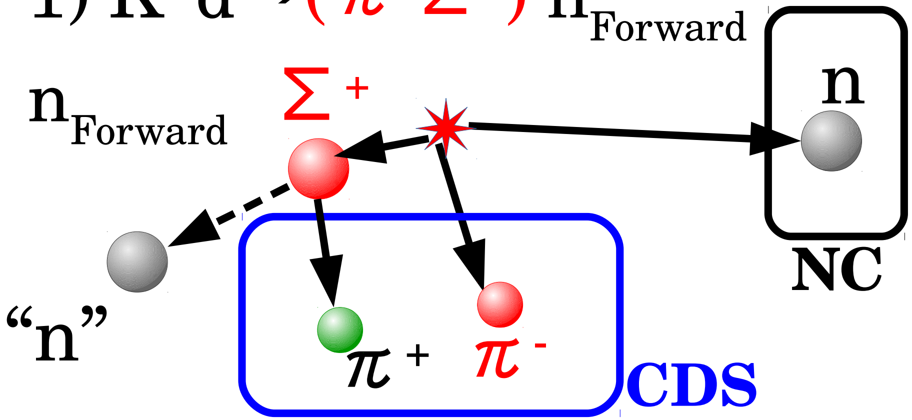


χ^2 : 25.5
NDF : 19
χ^2/NDF
~1.34

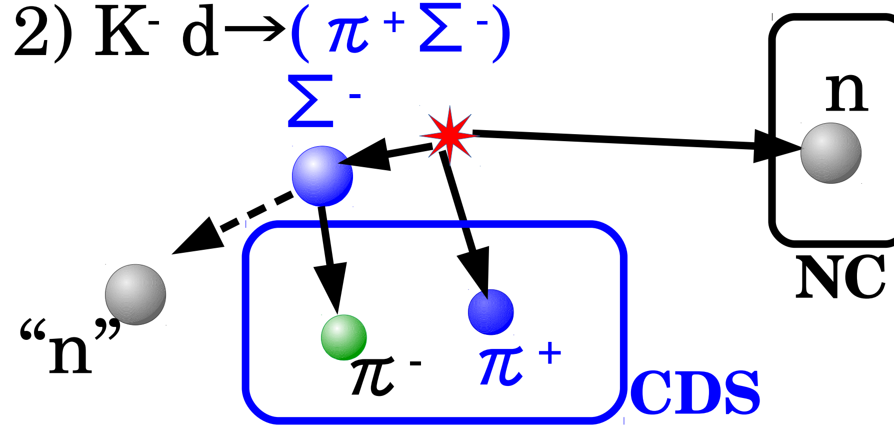
CDS reconstruction efficiency correction

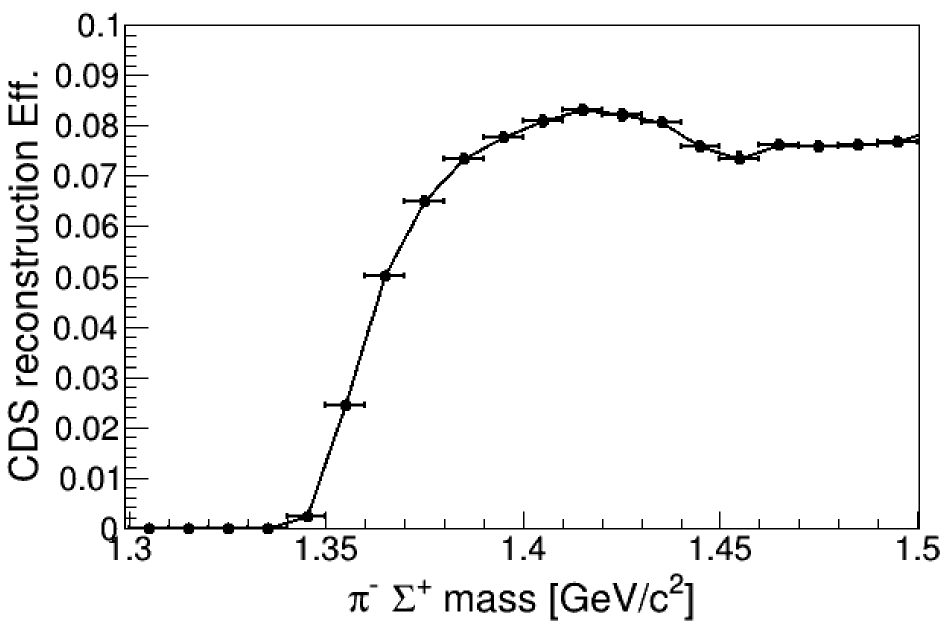
Simulated reaction

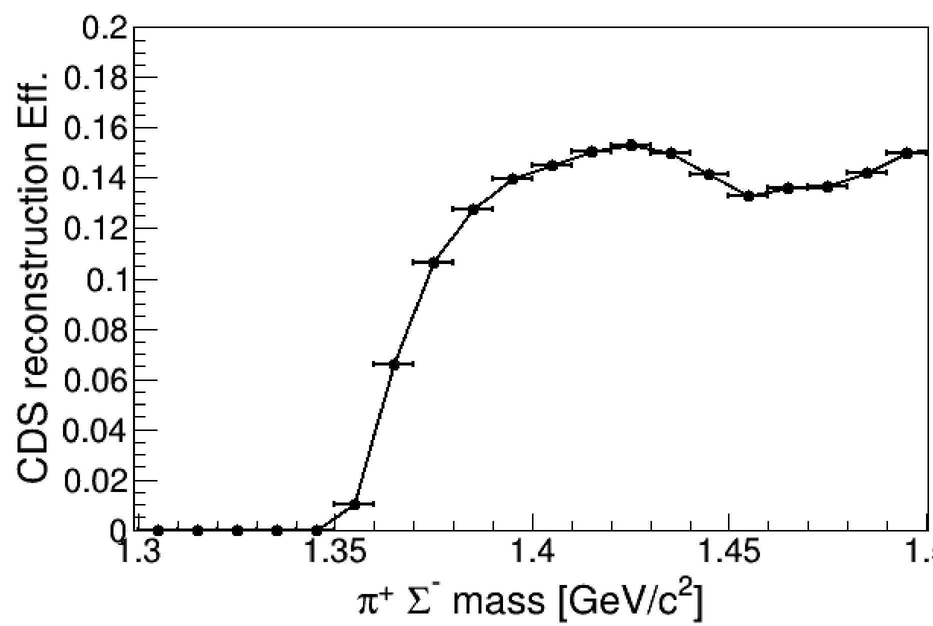
1) $K^- d \rightarrow (\pi^- \Sigma^+)\, n_{Forward}$



2) $K^- d \rightarrow (\pi^+ \Sigma^-)$

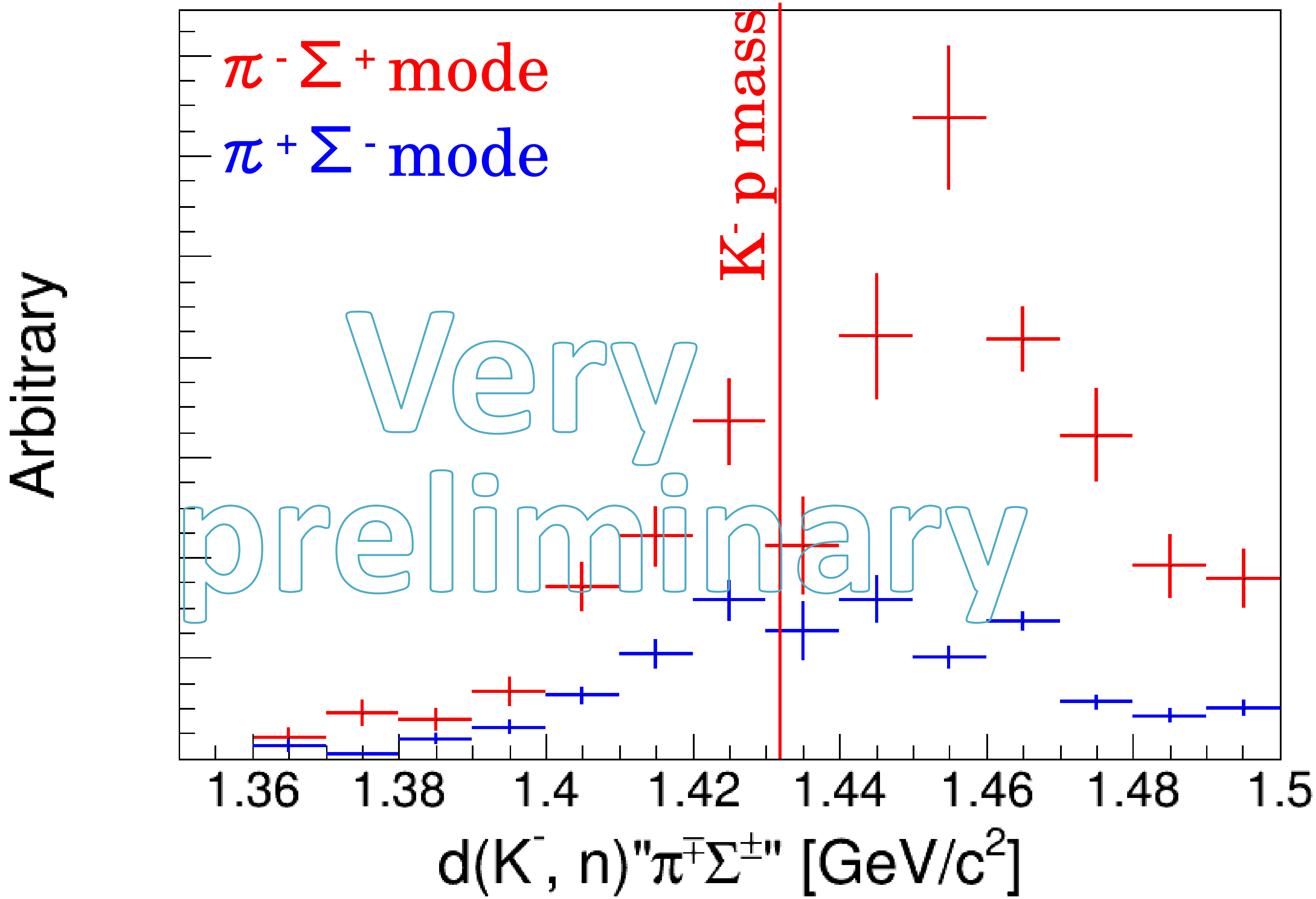






We correct $\pi^{\pm}\Sigma^{\mp}$ spectra by CDS reconstruction efficiency.

Decomposed d(K$^-$, n)“$\pi^{\pm}\Sigma^{\mp}$” spectra



We found $\pi^-\Sigma^+$ mode is dominant.

We will confirm this structure in much higher statistics.

Summary and future plan

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

→We found the $\pi^-\Sigma^+$ mode is dominant.

→A structure is observed below the $\bar{K}N$ threshold.

E31 will start in this May.

- We will collect 20 times more statistics than present data.
- We expect to identify all final states and decompose I=0 and I=1 amplitudes.

The J-PARC E31 Collaboration

S. Ajimura[1], G. Beer[2], M. Bragadireanu[4], P. Buehler[4], L. Busso[5], M. Cargnelli[4], S. Choi[3], C. Curceanu[8], S. Enomoto[14], D. Faso[5], H. Fujioka[13], Y. Fujiwara[12], T. Fukuda[11], C. Guaraldo[8], R. S. Hayano[12], T. Hashimoto[9], T. Hiraiwa[1], M. Iio[14], M. Iliescu[8], K. Inoue[1], N. Ishibashi[7], Y. Ishiguro[13], T. Ishikawa[12], S. Ishimoto[14], T. Ishiwatari[4], K. Itahashi[9], M. Iwai[14], M. Iwasaki[9,10], S. Kawasaki[1], P. Kienle[15], H. Kou[10], Y. Ma[9], J. Marton[4], Y. Matsuda[12], Y. Mizoi[11], O. Morra[5], T. Nagae[13], H. Noumi[1], H. Ohnishi[9], S. Okada[9], H. Outa[9], K. Piscicchia[8], L. PoliLener[8], A. Romero Vidal[8], Y. Sada[1], A. Sakaguchi[7], F. Sakuma[9], M. Sato[9], M. Sekimoto[14], H. Shi[12], K. Shirotori[1], D. Sirghi[8], F. Sirghi[8], S. Suzuki[14], T. Suzuki[12], H. Tatsuno[8], M. Tokuda[10], D. Tomono[9], A. Toyoda[14], K. Tsukada[16], E. Widmann[4], O. Vazquez Doce[8], T. Yamaga[1], T. Yamazaki[9,12], K. Yoshida[7], H. Yim[3], J. Zmeskal[4].

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9. RIKEN, Japan, 10. Tokyo Institute of Technology, Japan

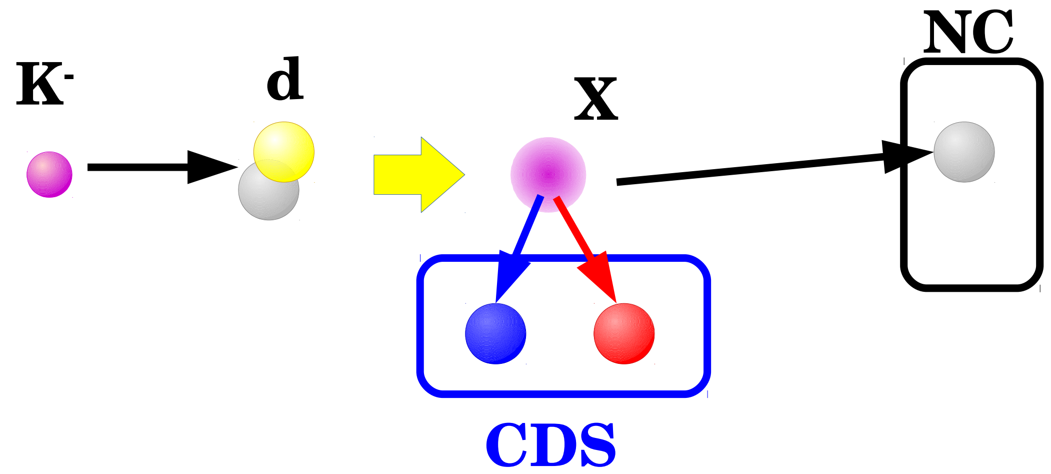
11. Osaka Electro-Communication University, Japan, 12. University of Tokyo, Japan

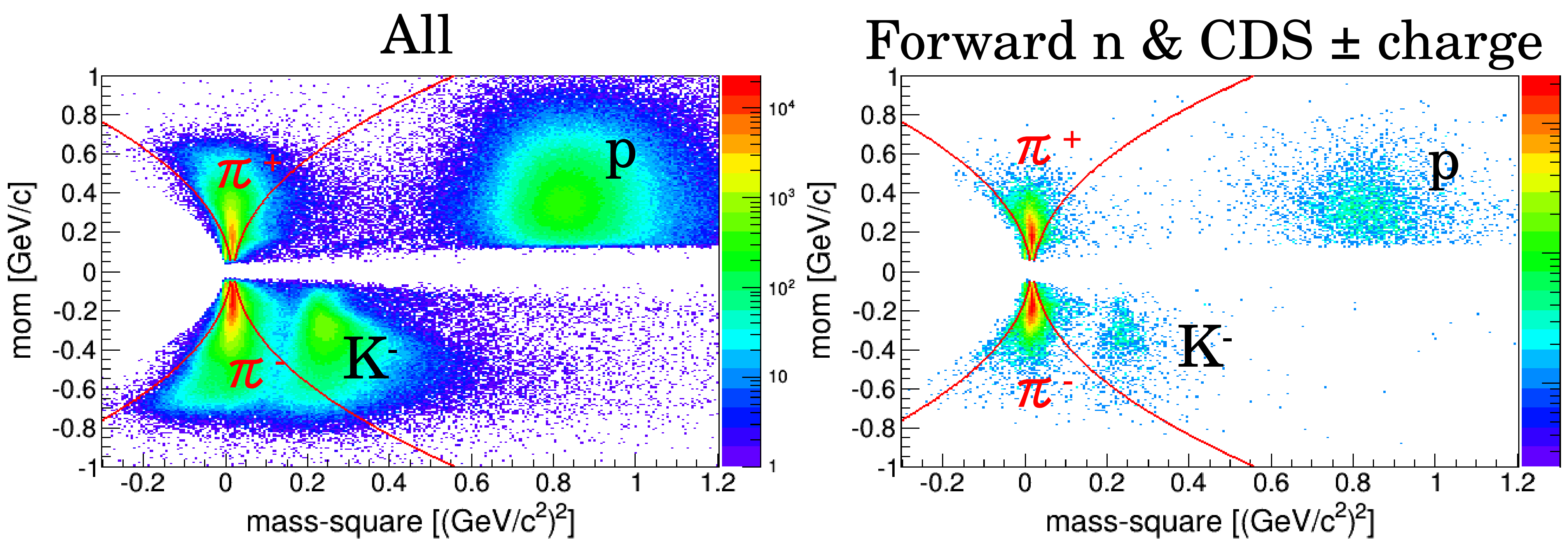
13. Kyoto University, Japan, 14. High Energy Accelerator Research Organization (KEK), Japan

15. Technische Universitat Munchen, Germany, 16. Tohoku University, Japan

Back up

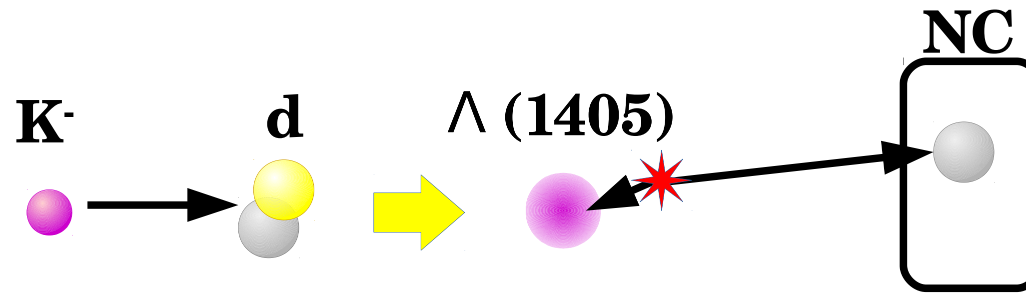
CDS particle identification

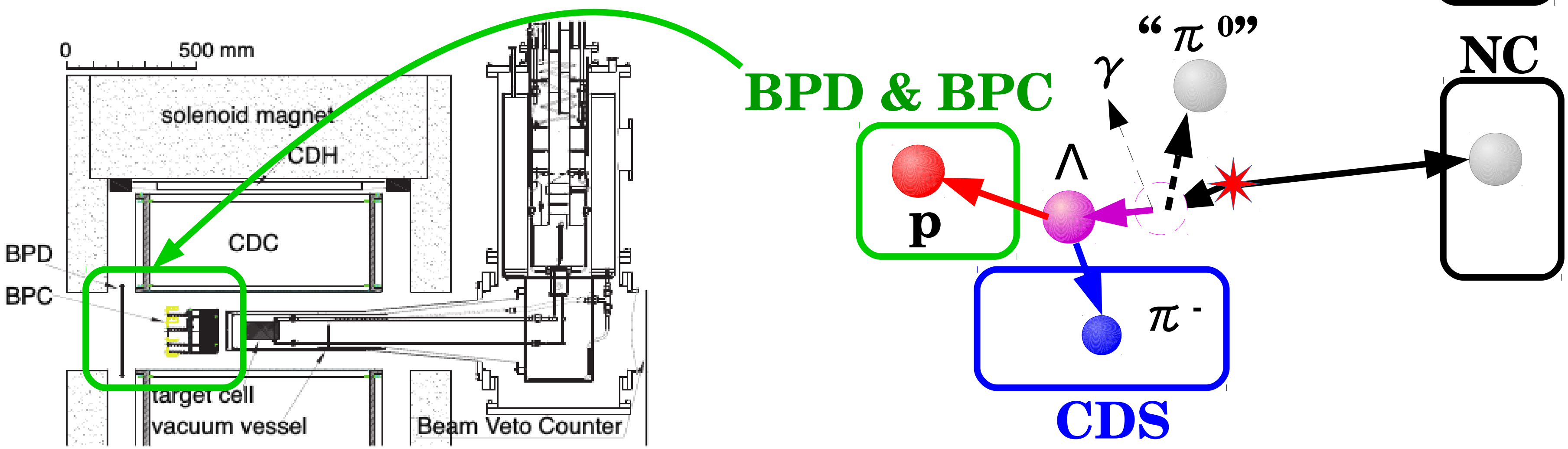




Experimental method~ $\pi^0 \Sigma^0$ mode

$\Lambda(1405)$ mass is measured by $d(K^-, n)$ missing mass.





Decay proton is emitted in a backward angle.

→proton is detected by backward detectors(BPD &BPC).

$\pi^0\Sigma^0$ and $\pi^0\Lambda$ is identified by $d(K^-, n\Lambda)$"X".

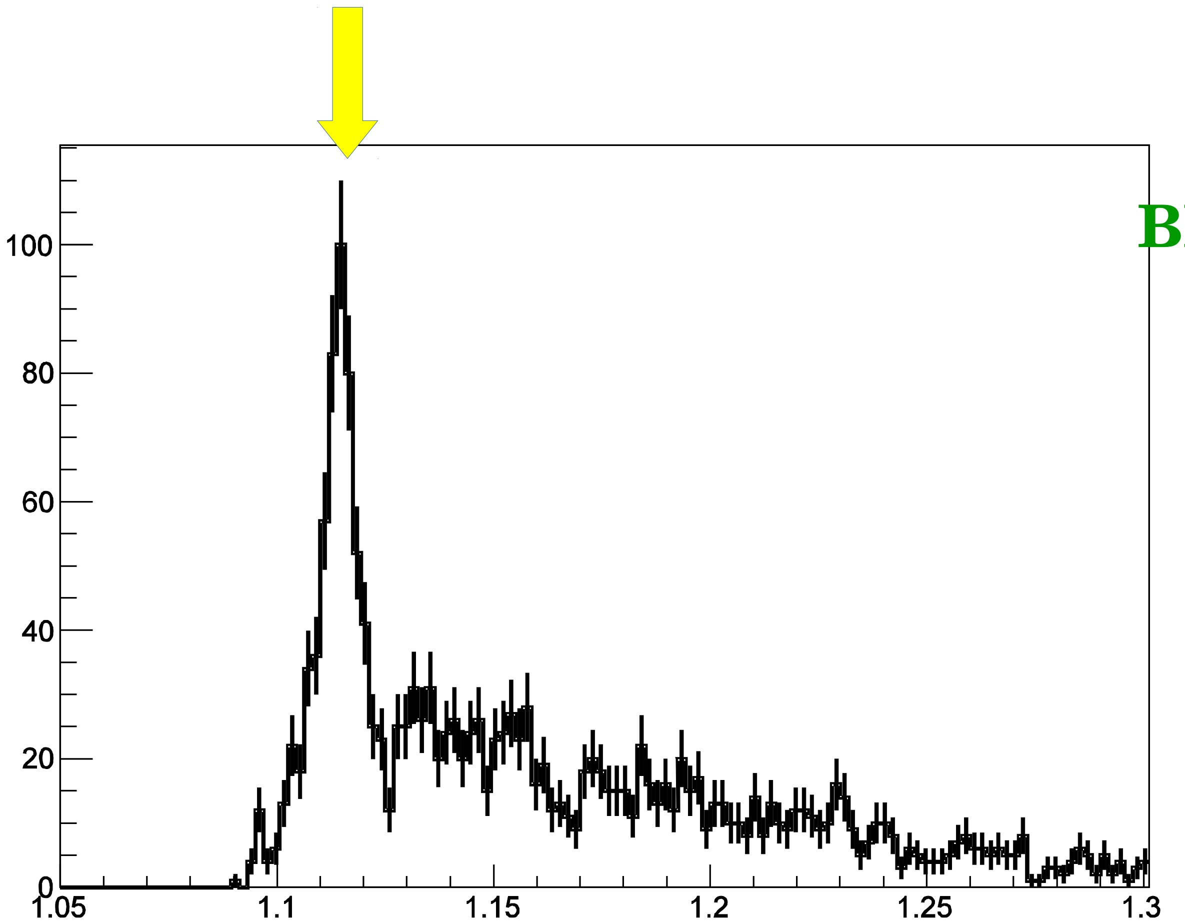
$K^- d \rightarrow \Lambda^* n \rightarrow (\pi^0 \Sigma^0) n \rightarrow \pi^0 (\gamma \Lambda) n$

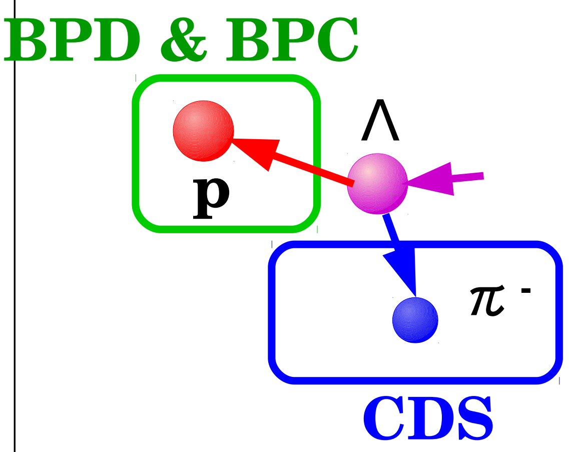
(I=0)

detect

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

Invariant mass of backward proton and π^- in CDS





Backward Λ is successfully reconstructed.

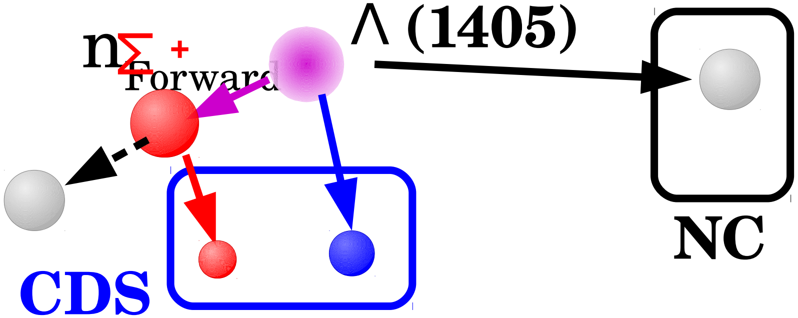
How to decompose of $\pi^-\Sigma^+$ and $\pi^+\Sigma^-$

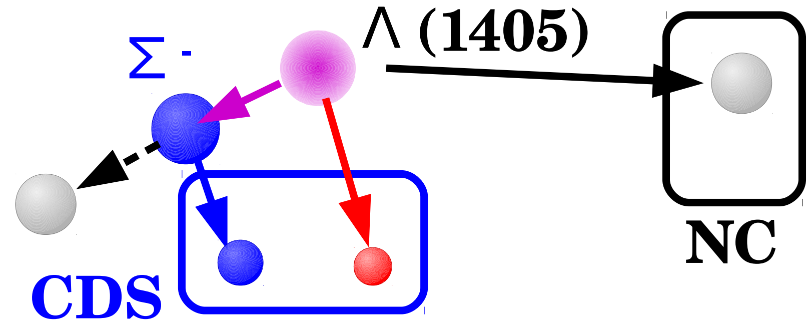
Simulated reaction

~ Sim

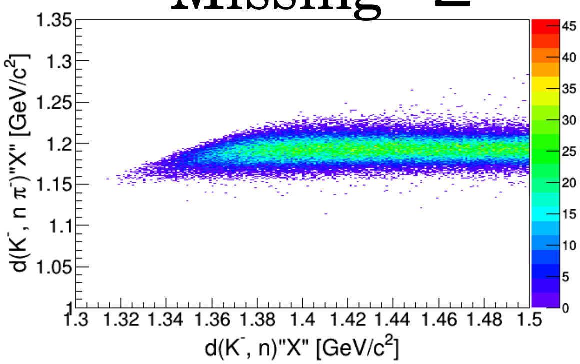
1) $K^- d \rightarrow (\pi^-\Sigma^+) n_{Forward}$

2) $K^- d \rightarrow (\pi^+\Sigma^-)$

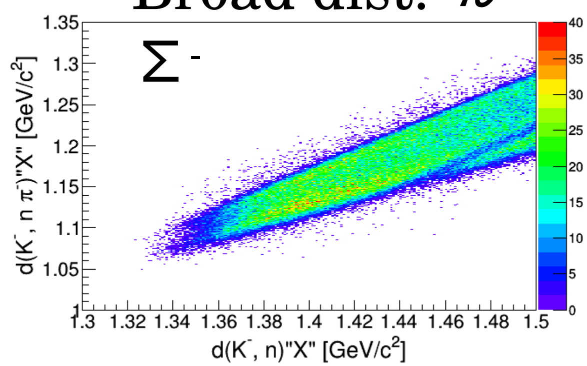




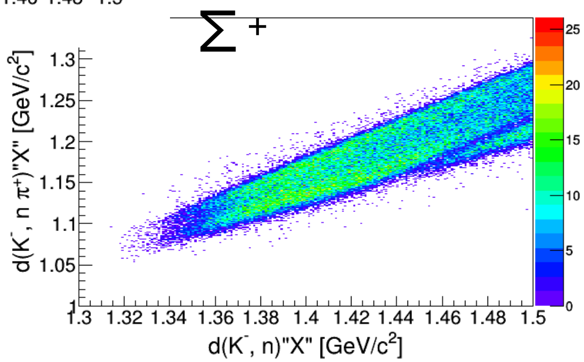
Missing "Σ^+"



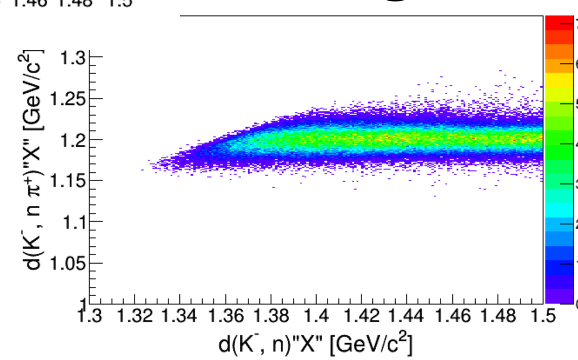
Broad dist. π^+ Σ^-



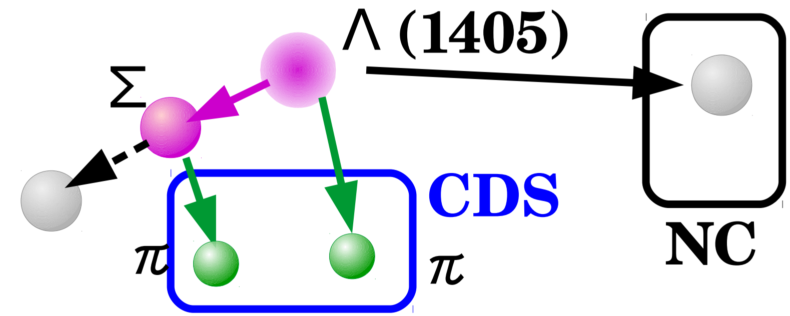
Broad dist. π^- Σ^+

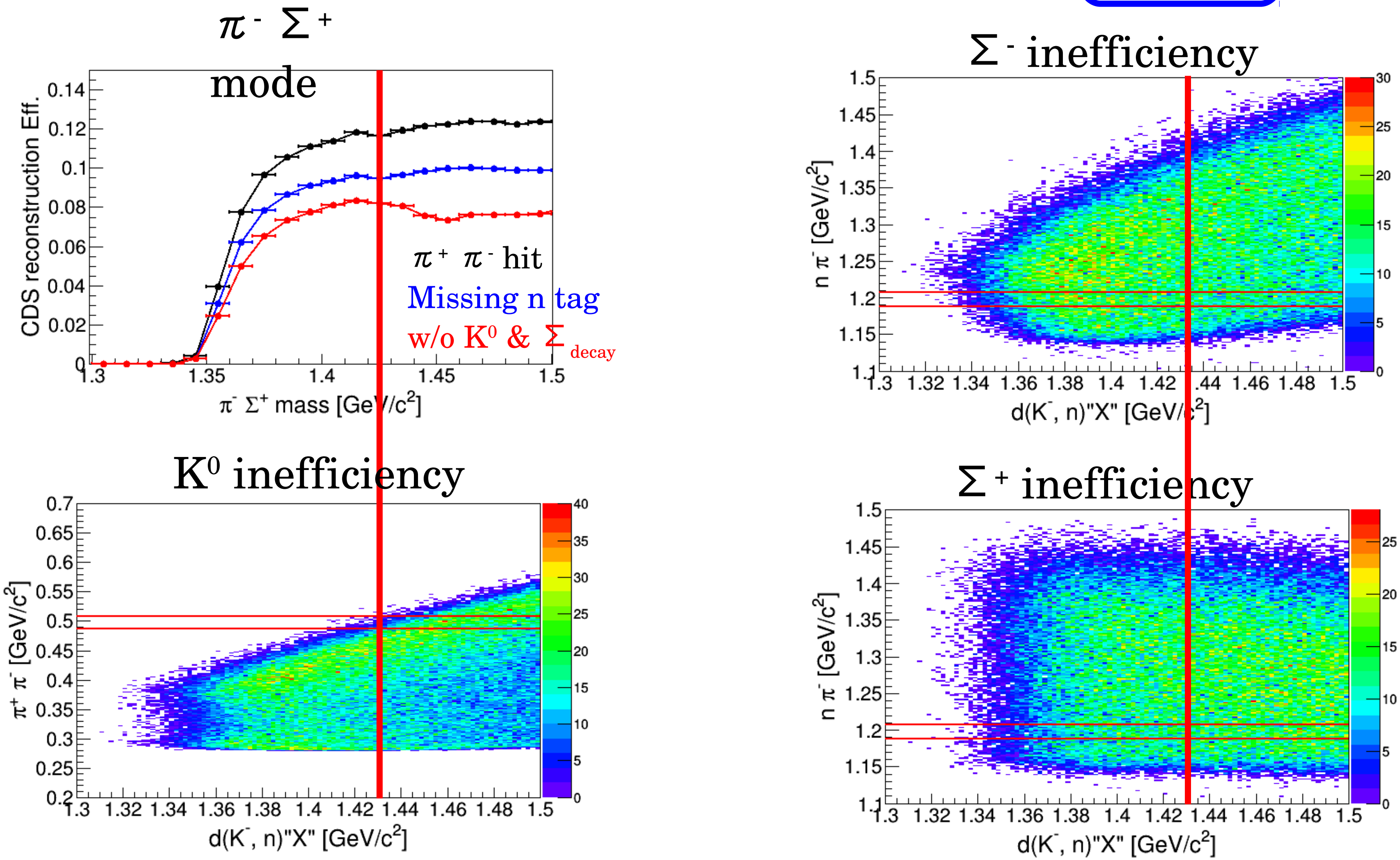


Missing "Σ^-"

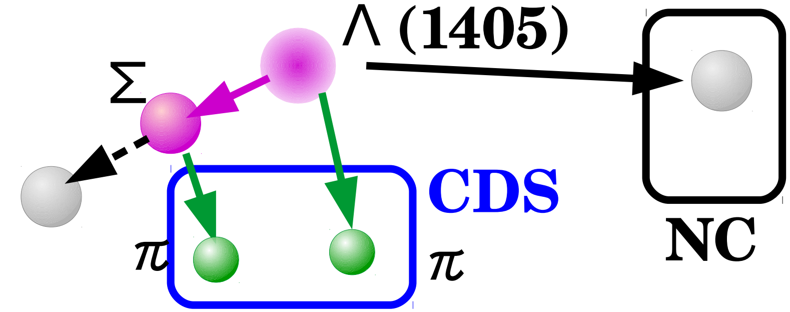


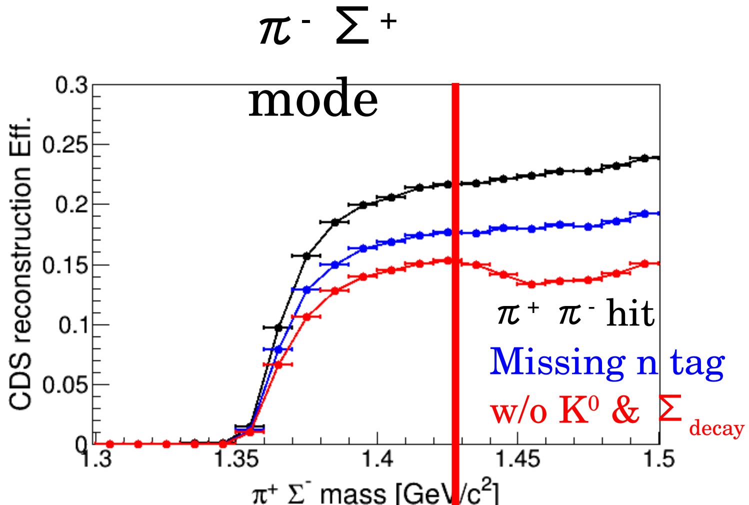
CDS reconstruction efficiency correction



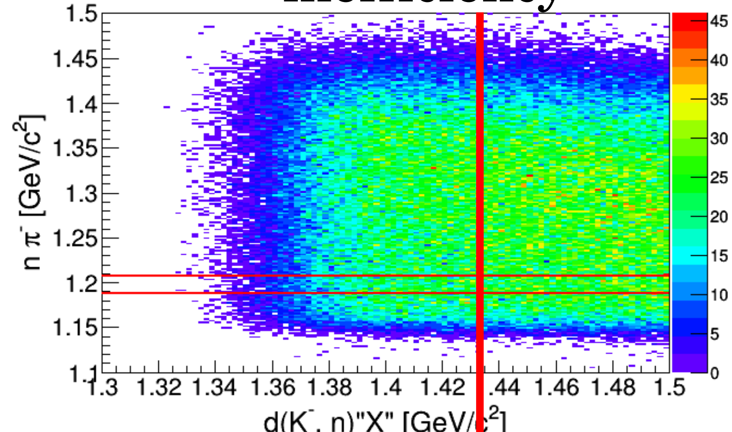


CDS reconstruction efficiency correction

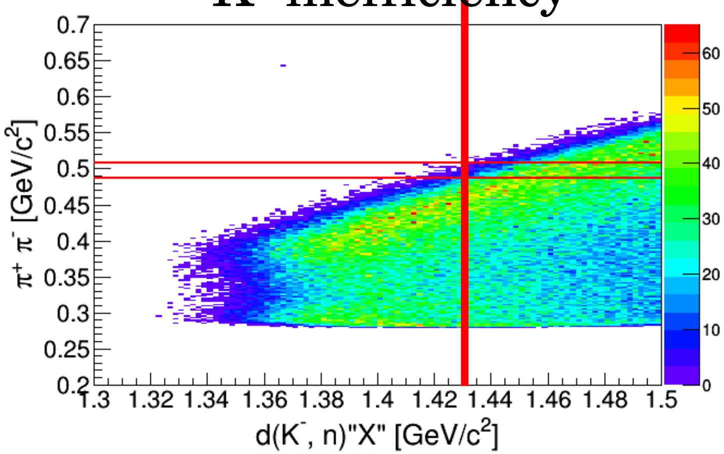




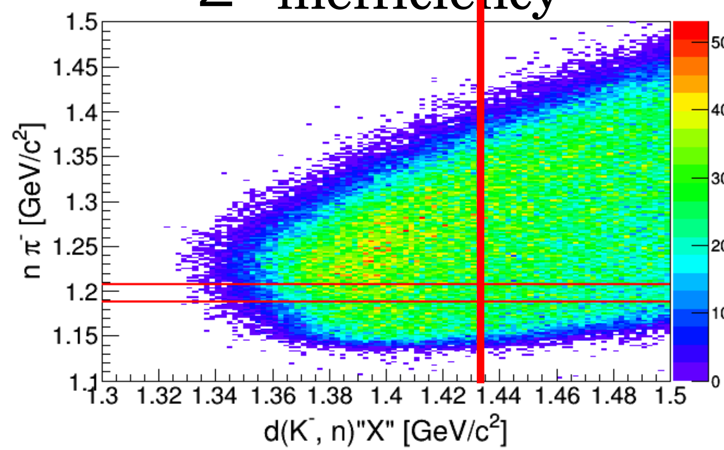
Σ^- inefficiency



K^0 inefficiency



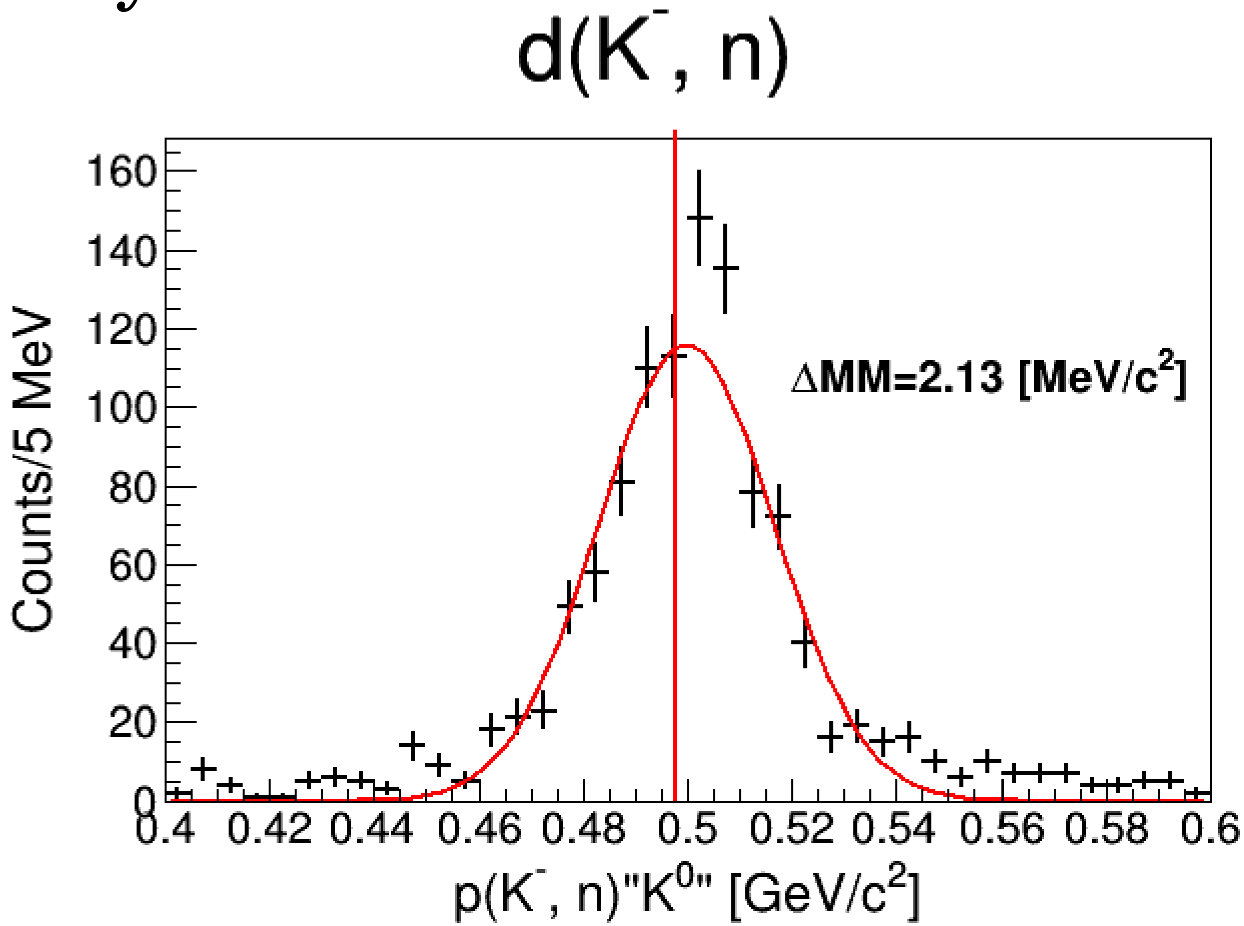
Σ^+ inefficiency



Accuracy of missing mass

Using H_2 target run.

K^0 is tagged by CDS.



Accuracy of missing mass is estimated at ~2.1 MeV/c^2 by $p(K^-, n)$"K^0" events.

Contamination of K^0 and Σ $_{\text{Forward}}$

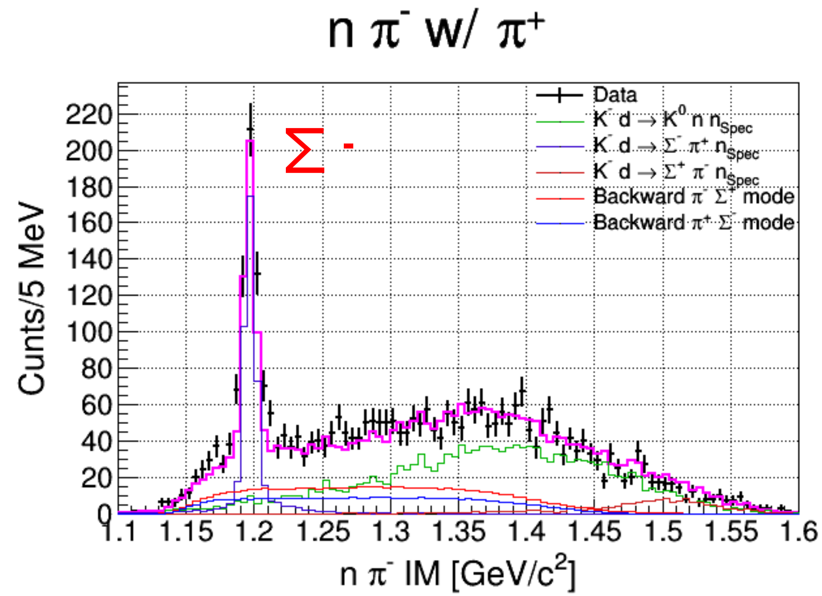
1)$K^- d \rightarrow K^0\, n\, n_{Spec}$

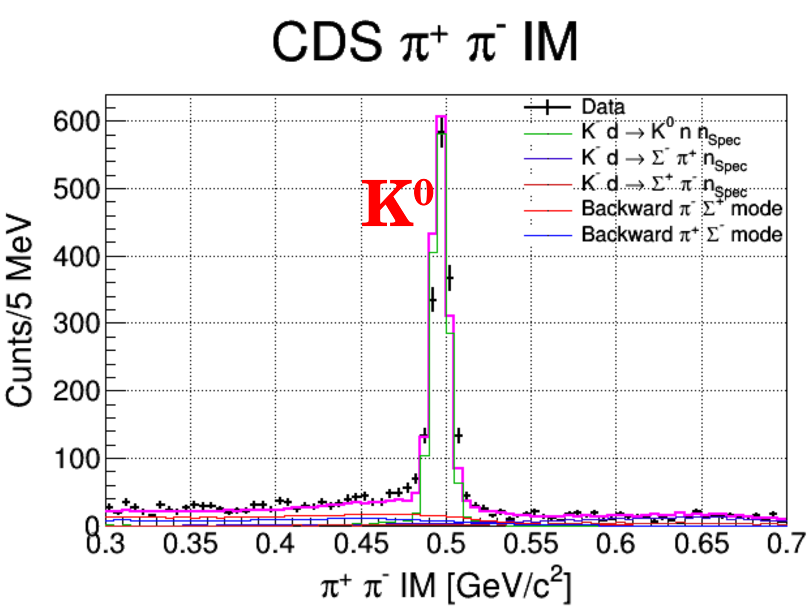
2)$K^- d \rightarrow \pi^+ \Sigma^-$ n_{Spec}

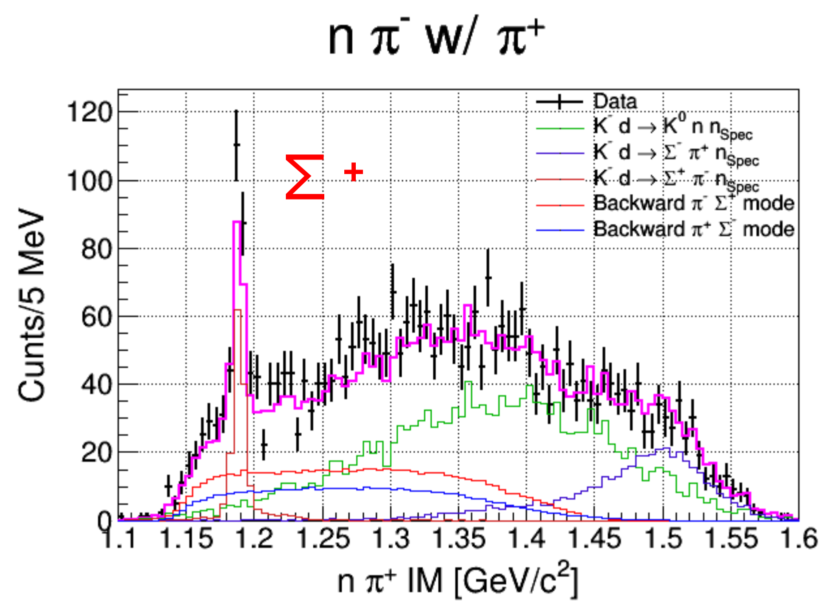
3)$K^- d \rightarrow \pi^- \Sigma^+$ n_{Spec}

Angular distribution simulates previous data of elementary process.

Contamination is evaluated by global fitting

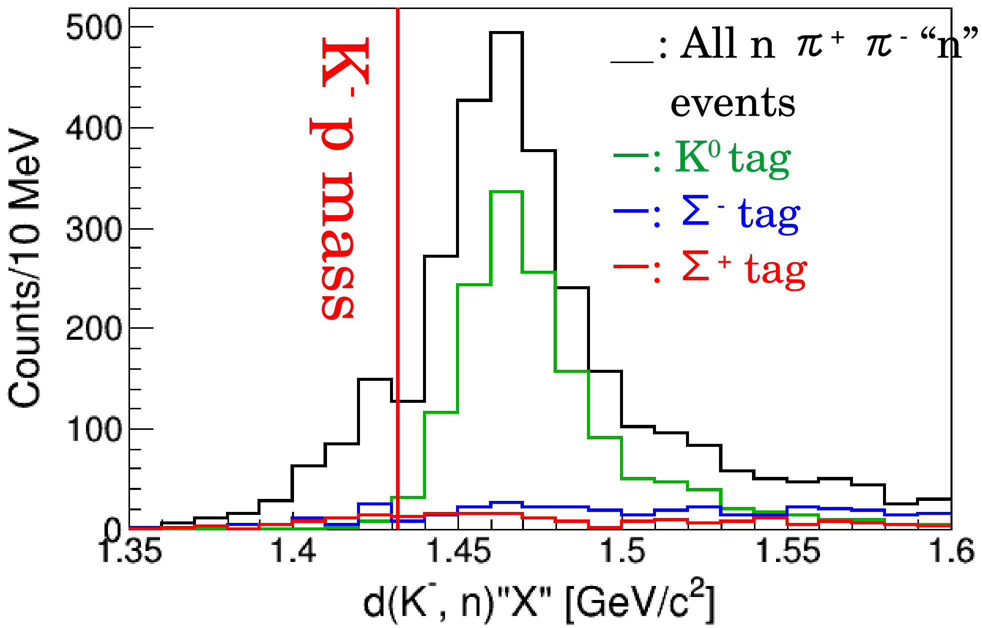


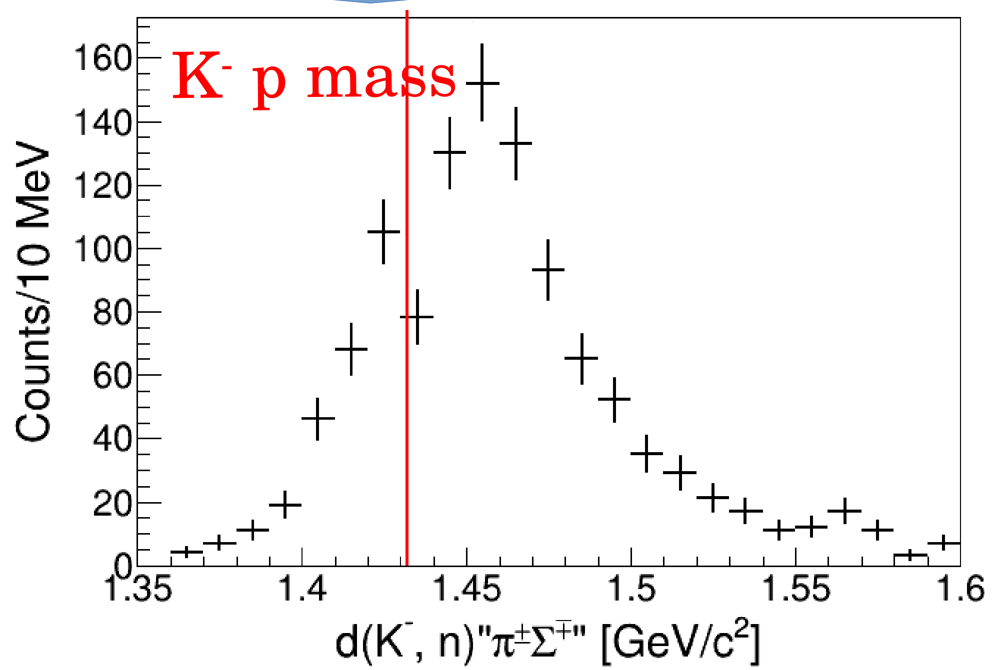




d(K$^-$, n)"X" 1.35~1.6 GeV/c^2

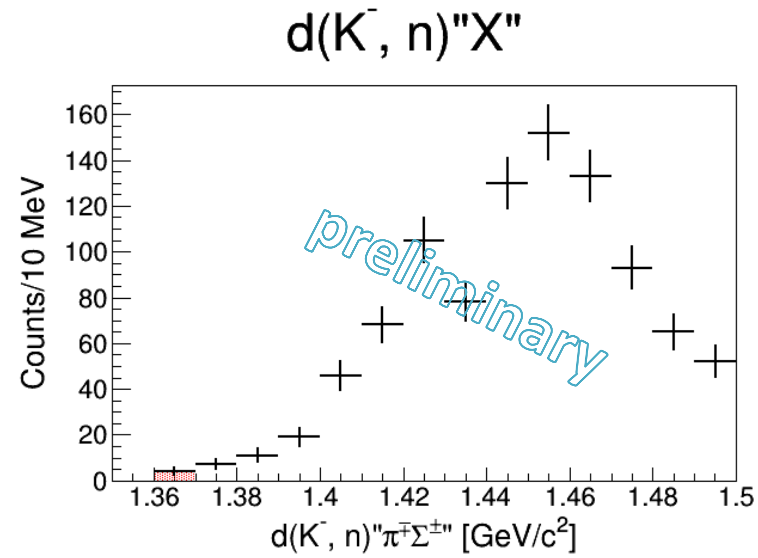
K^0 and $\Sigma_{forward}$ were removed

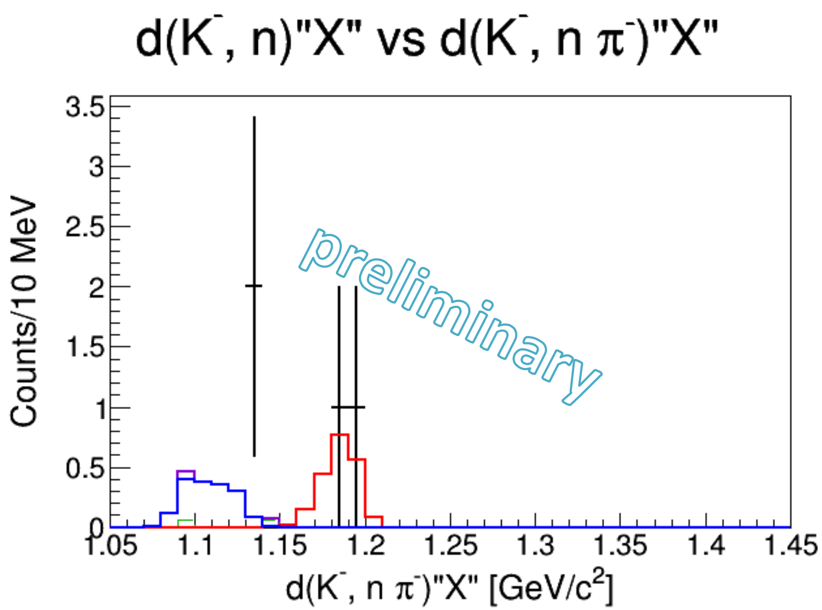


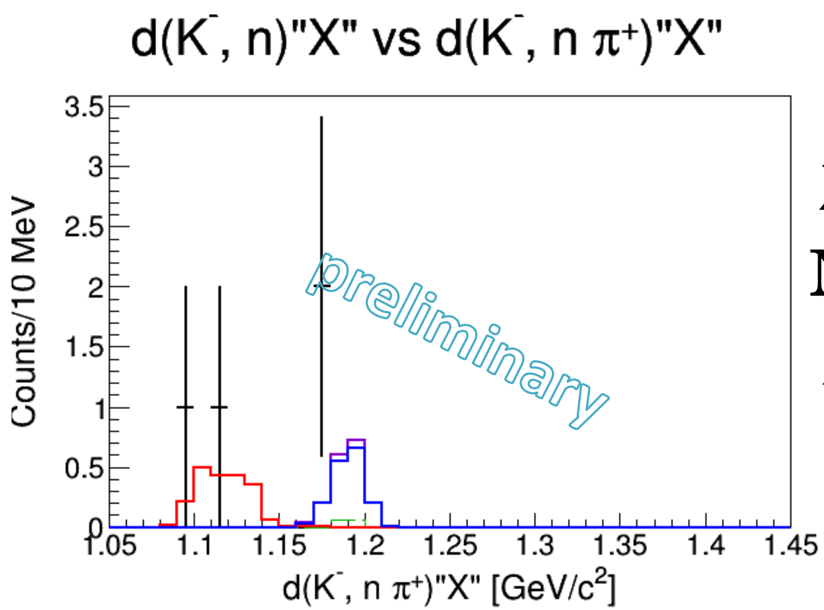


Decomposition of $\pi^-\Sigma^+$ and $\pi^+\Sigma^-$

The fitting is done
bin by bin of d(K$^-$, n)"X"



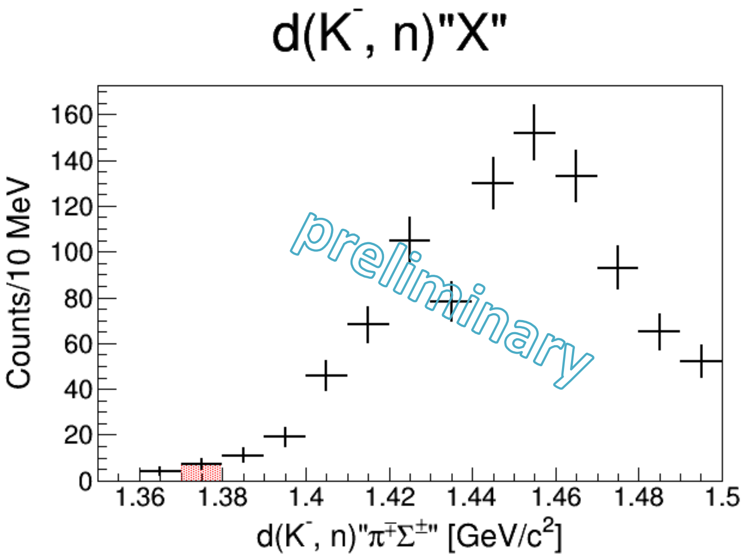


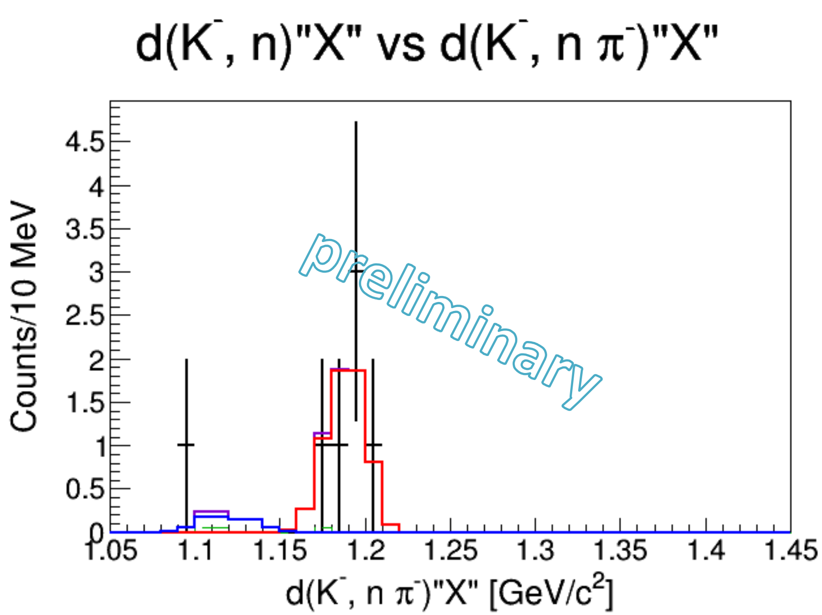


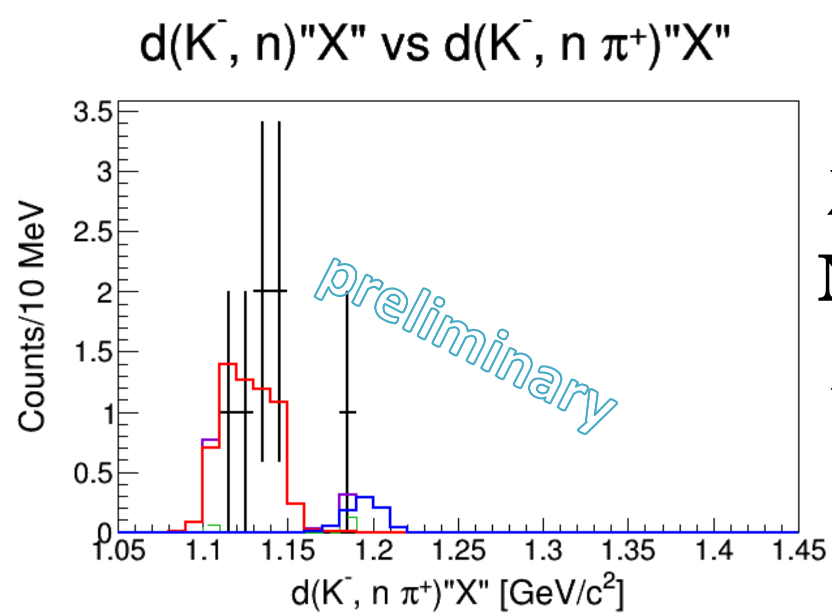
X^2 : 27.4
NDF : 4
χ^2/NDF
~6.86

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

The fitting is done
bin by bin of d(K$^-$, n)"X"



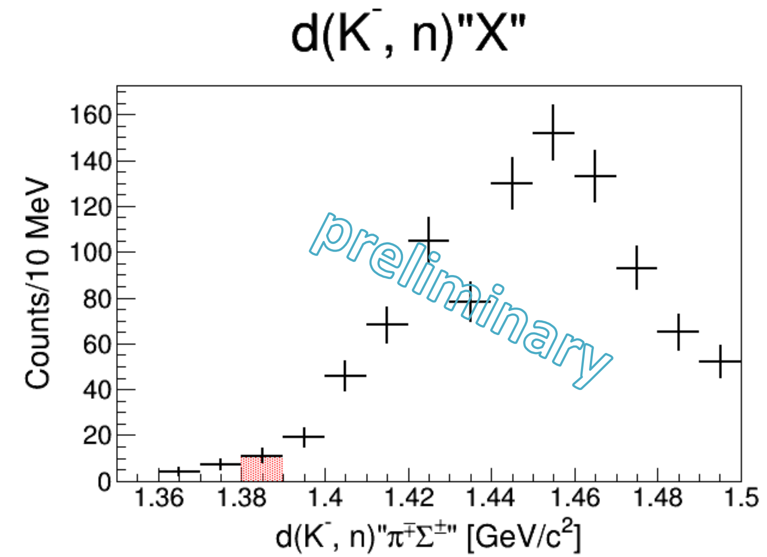


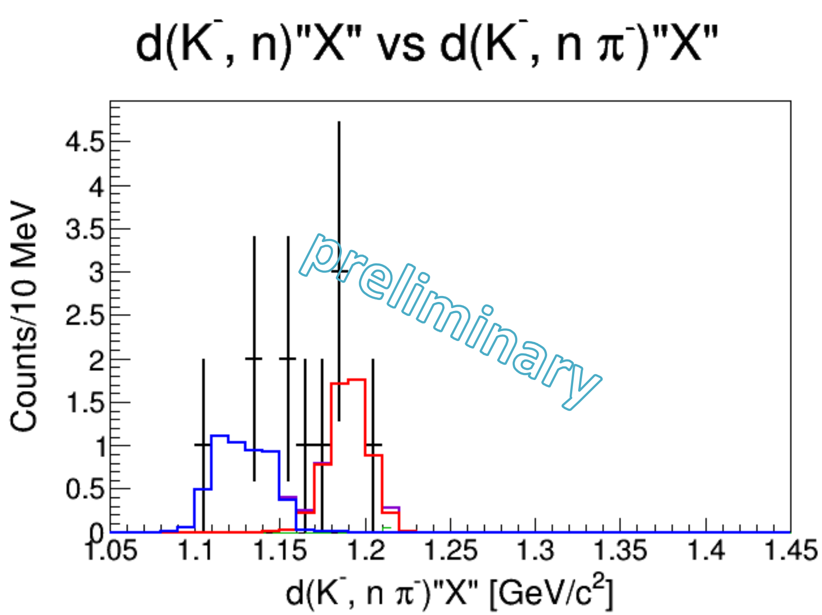


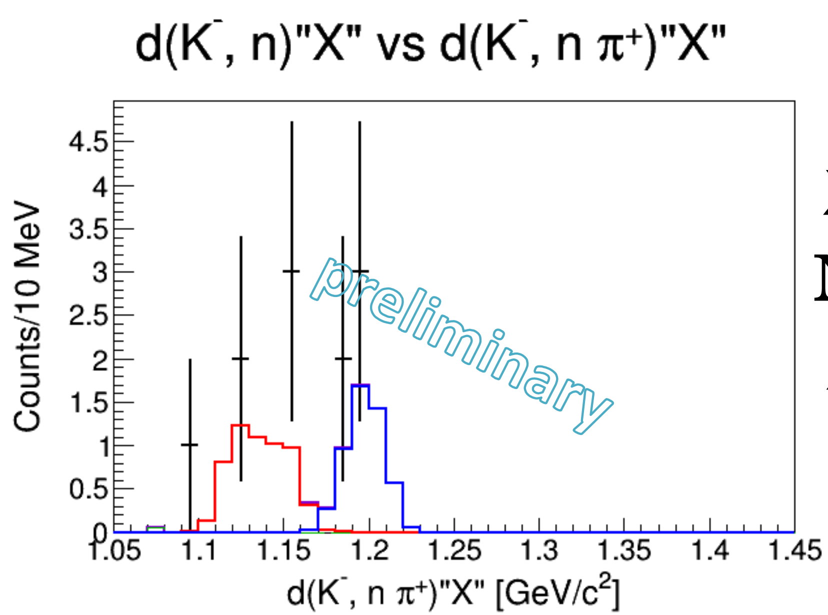
X^2 : 12.9
NDF : 8
χ^2/NDF
~1.61

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

The fitting is done
bin by bin of d(K$^-$, n)"X"



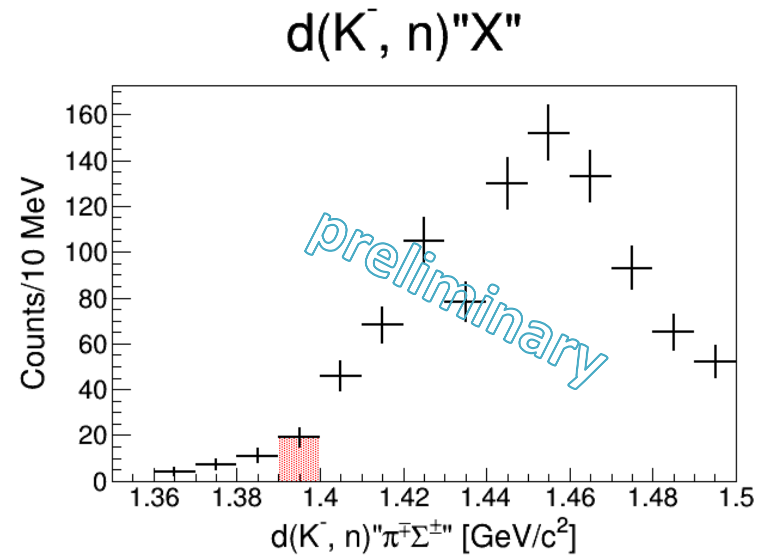


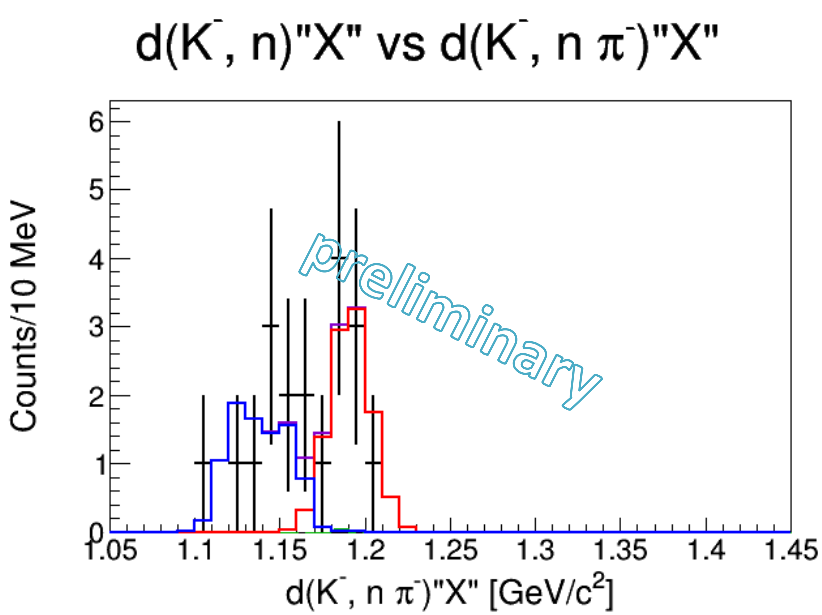


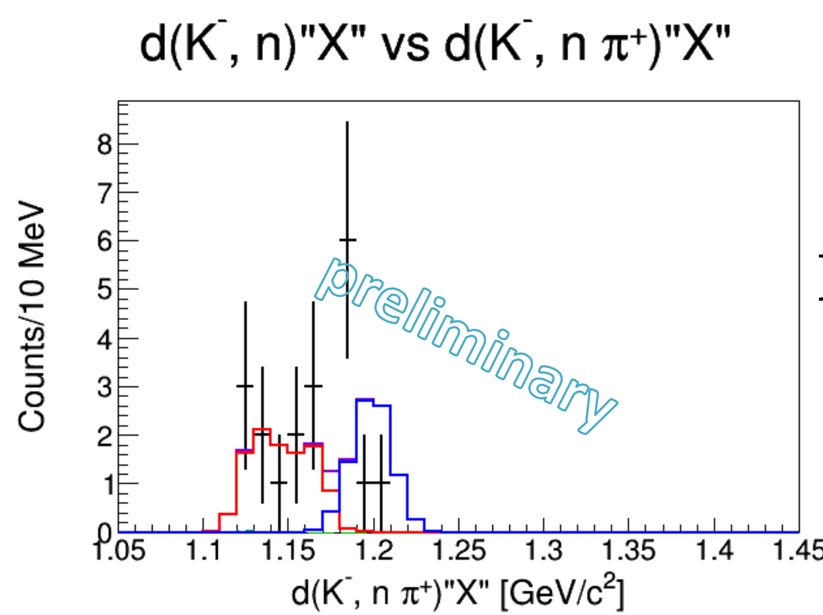
X^2 : 38.7
NDF : 10
χ^2/NDF
~3.87

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

The fitting is done
bin by bin of d(K⁻, n)"X"



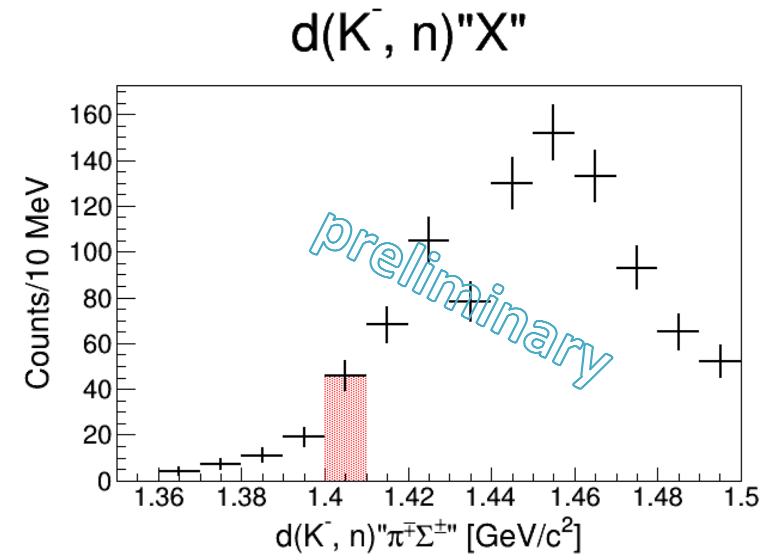


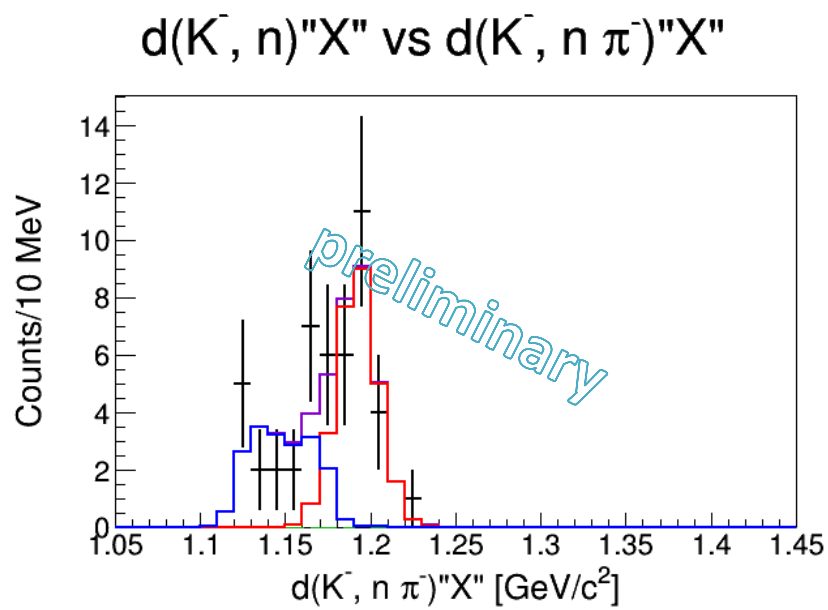


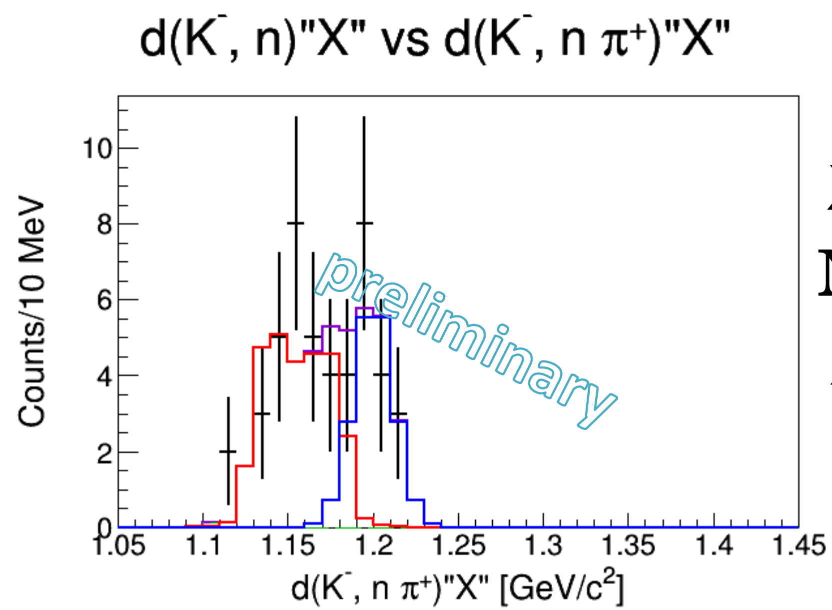
X^2 : 27.4
NDF : 16
χ^2/NDF
~1.71

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

The fitting is done
bin by bin of d(K⁻, n)"X"



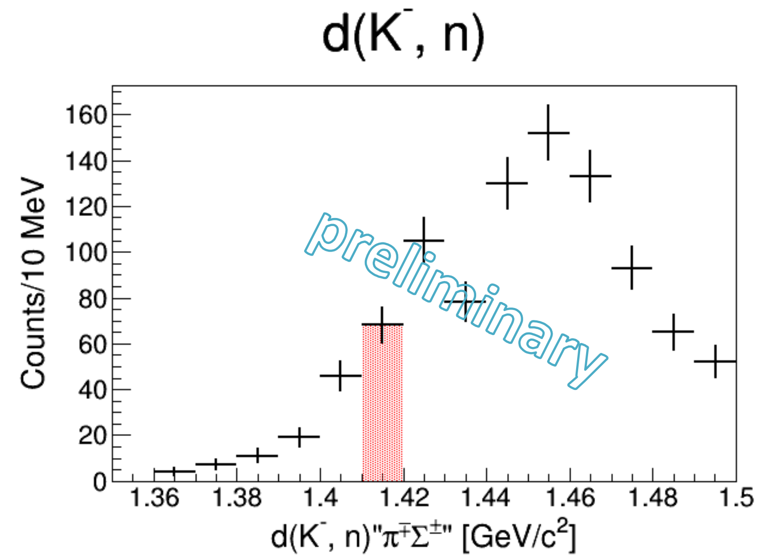


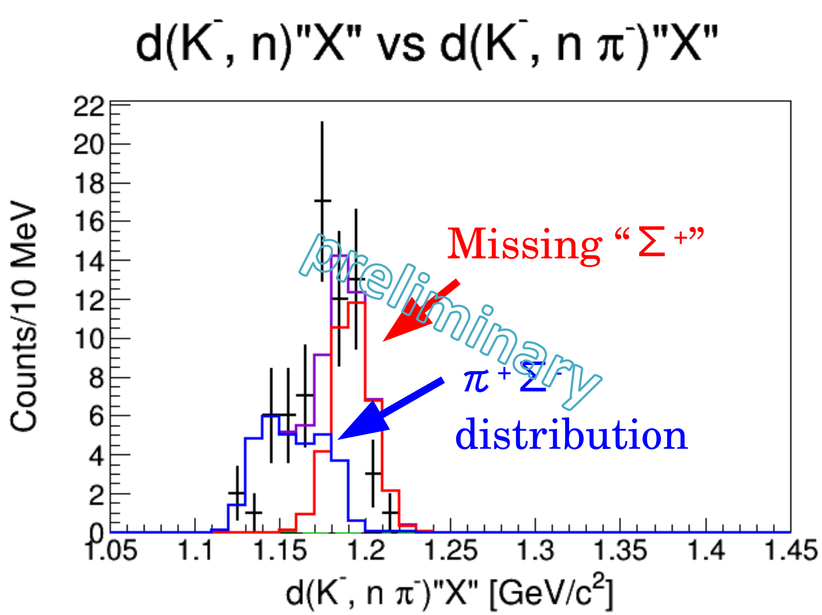


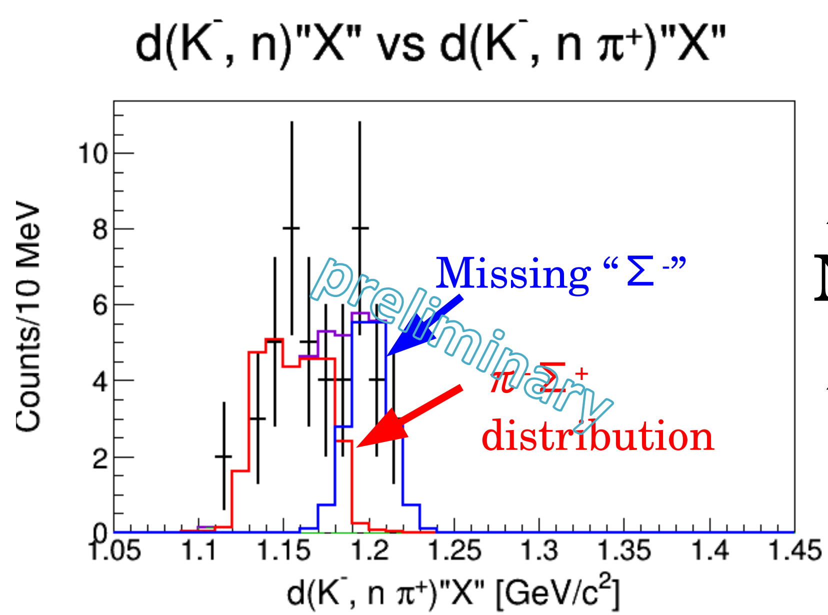
X^2 : 29.1
NDF : 18
χ^2/NDF
~1.62

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

The fitting is done
bin by bin of d(K$^-$, n)"X"



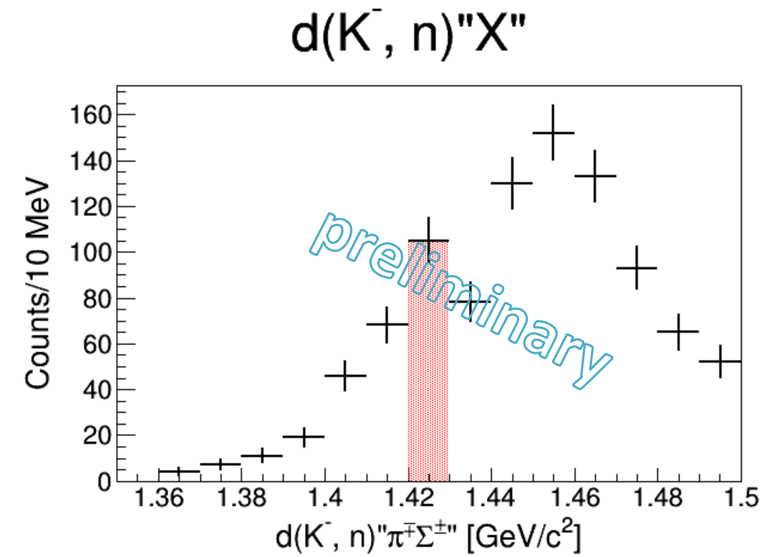


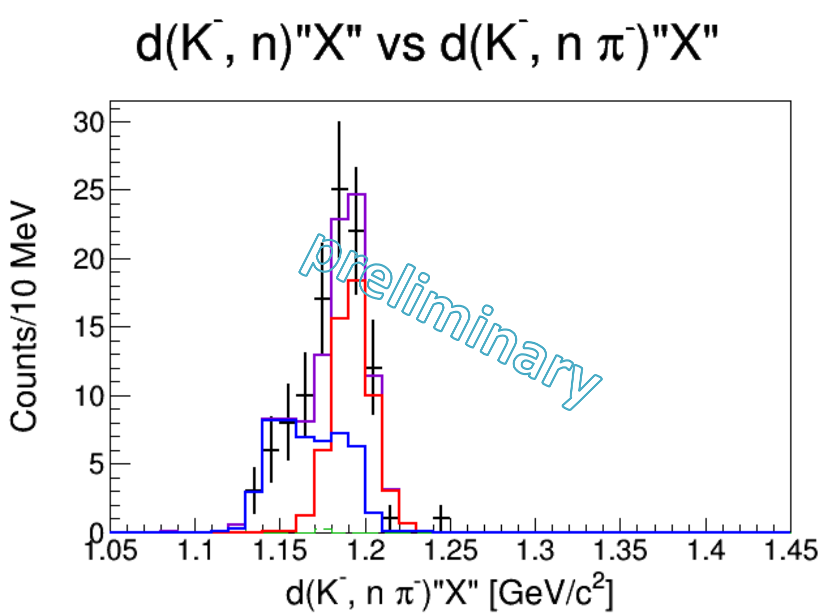


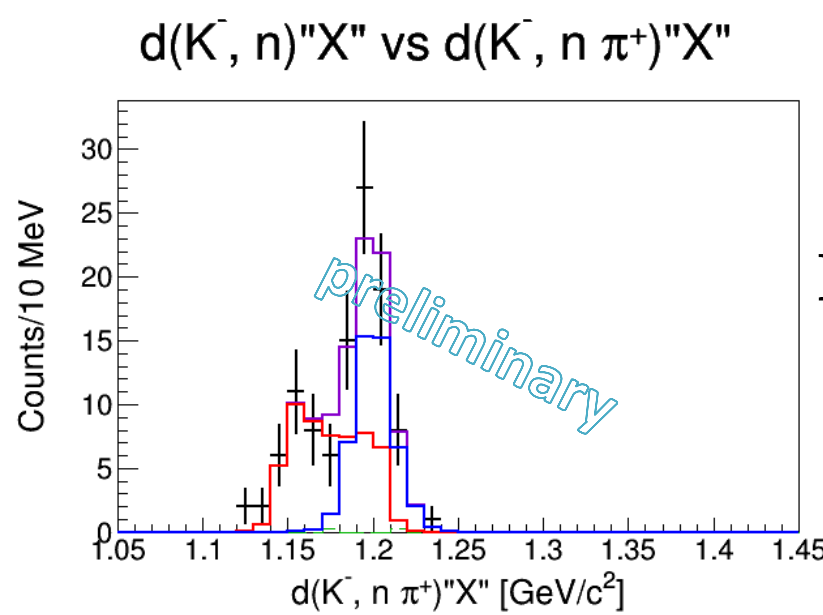
χ^2 : 25.5
NDF : 19
χ^2/NDF
~1.34

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

The fitting is done
bin by bin of d(K-, n)"X"



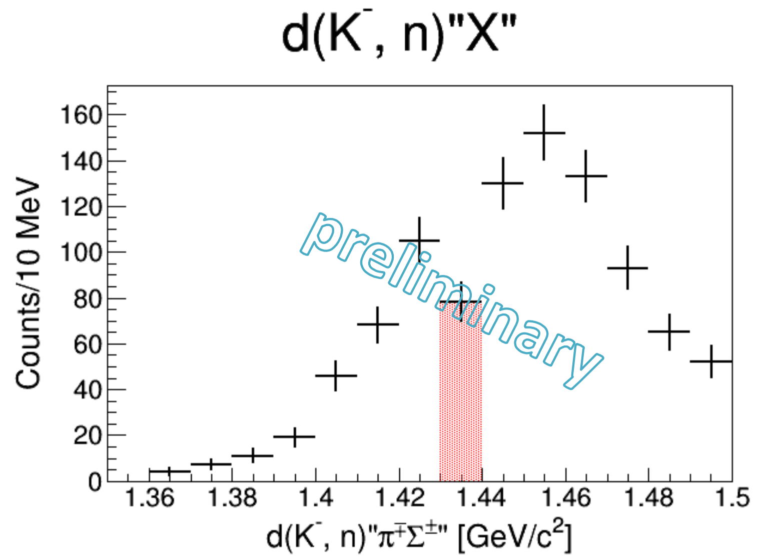


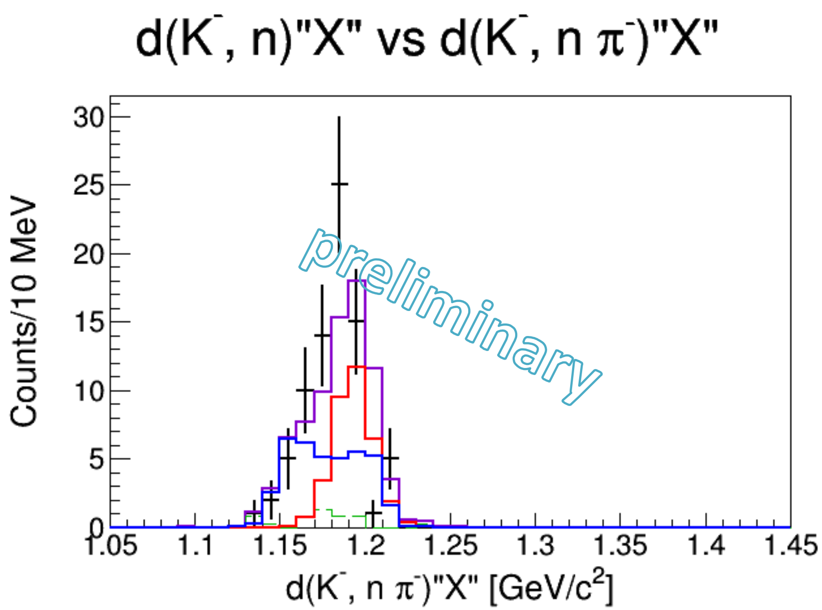


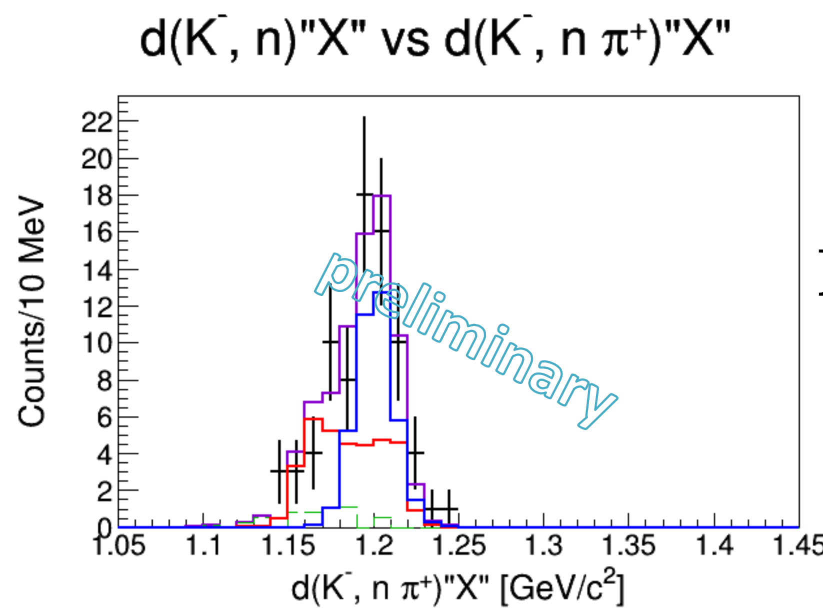
X^2 : 25.5
NDF : 19
χ^2/NDF
~1.34

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

The fitting is done
bin by bin of d(K⁻, n)"X"



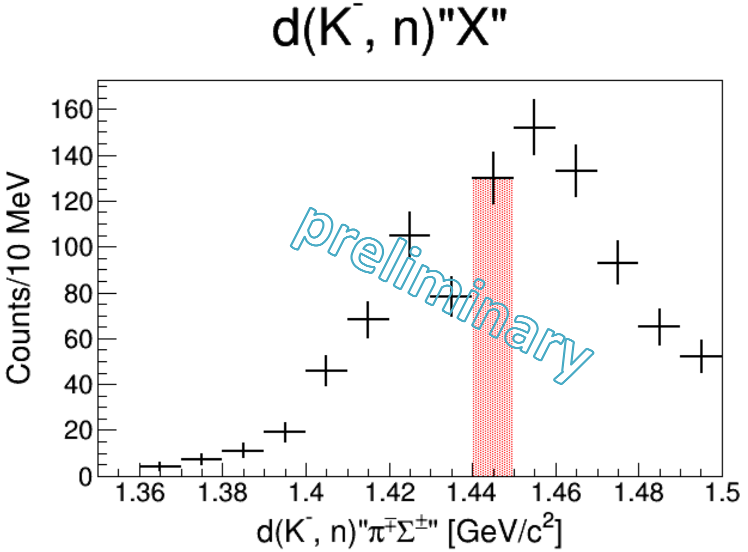


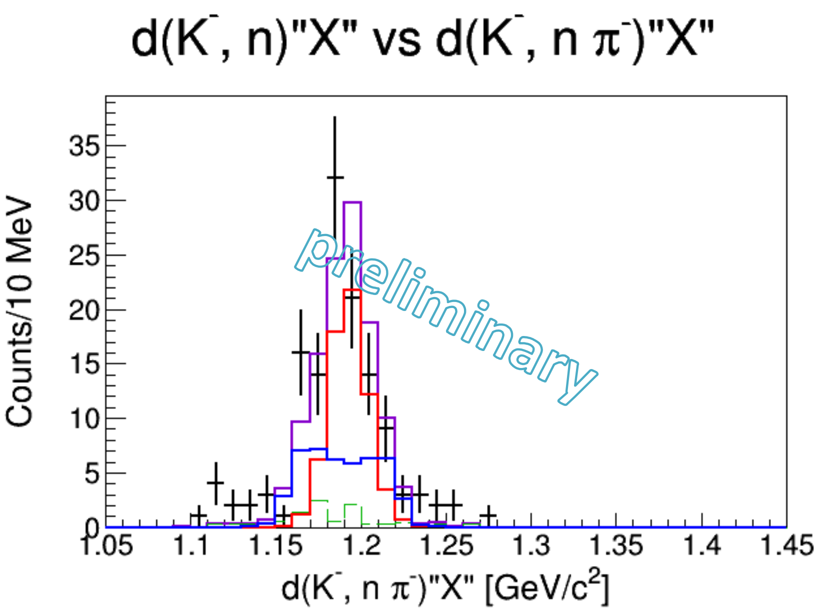


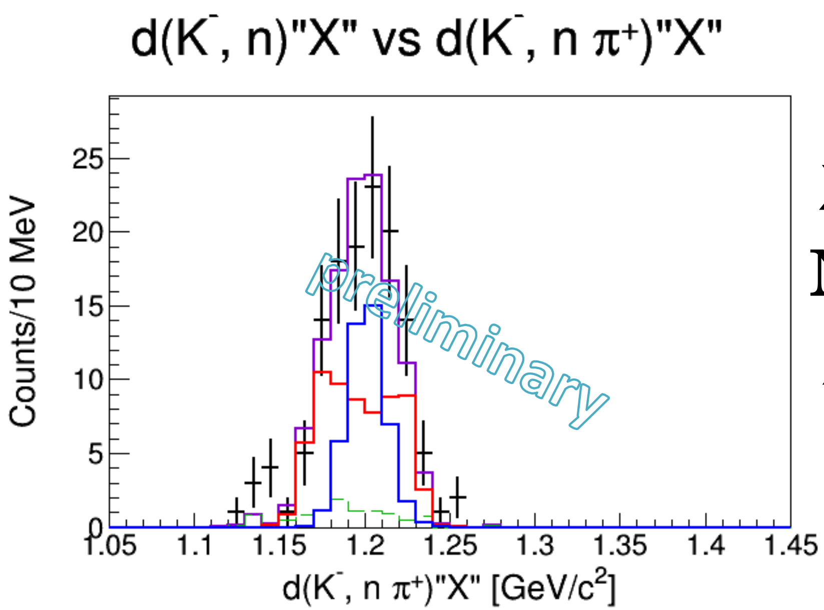
χ^2 : 42.6
NDF : 18
χ^2/NDF
~2.36

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

The fitting is done
bin by bin of d(K$^-$, n)"X"



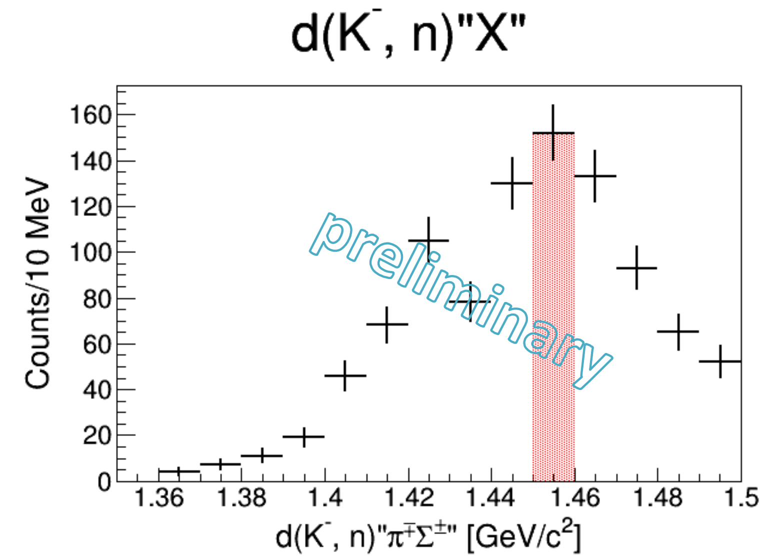


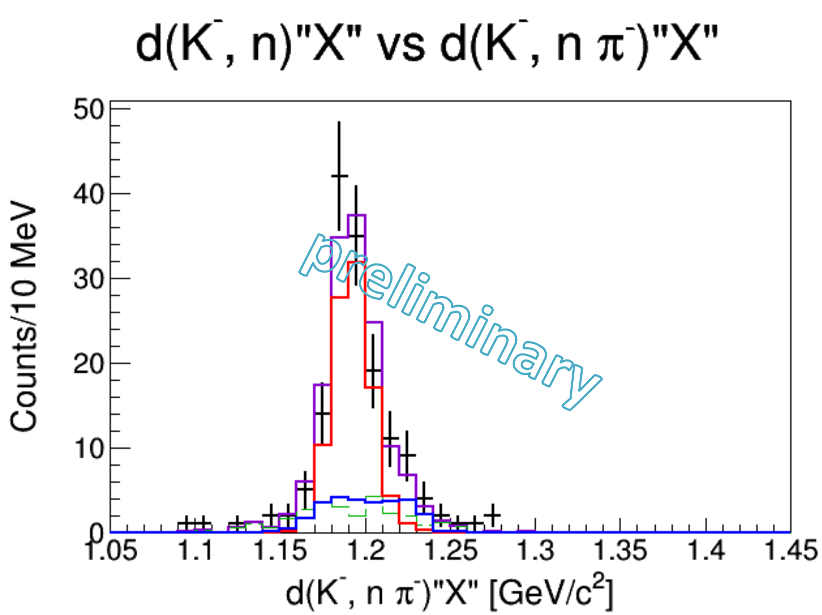


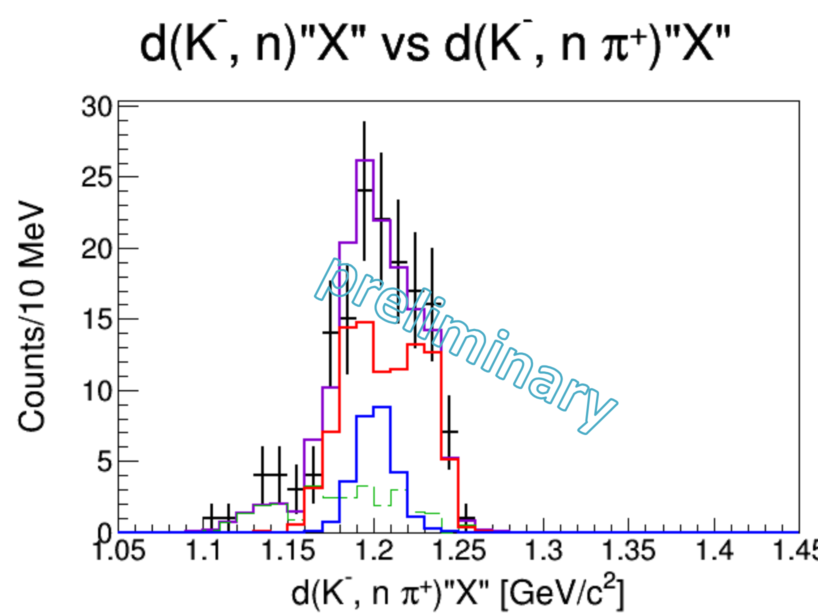
X^2 : 76.7
NDF : 29
χ^2/NDF
~2.65

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

The fitting is done
bin by bin of d(K$^-$, n)"X"



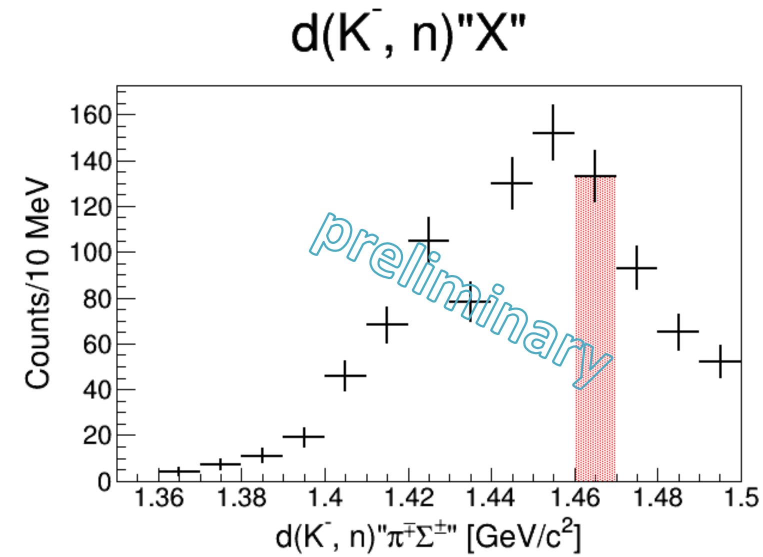


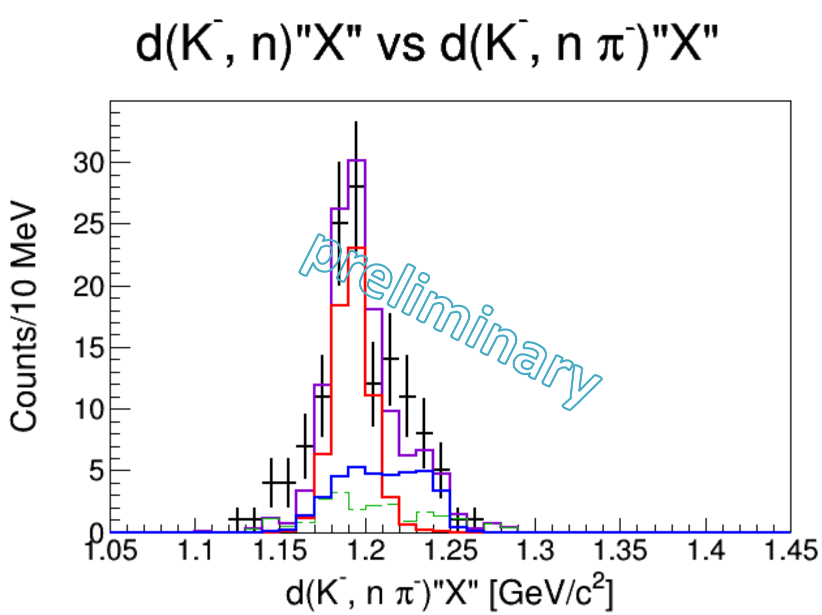


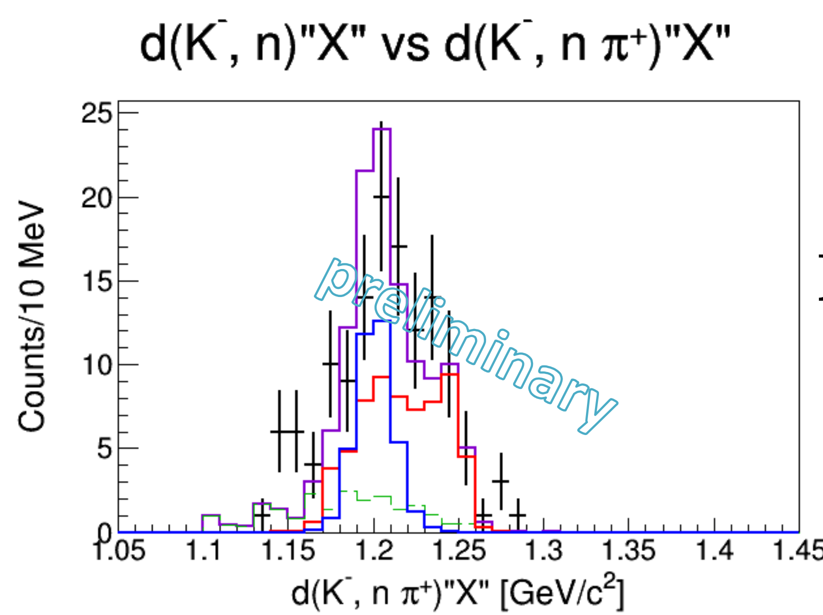
X^2 : 33.2
NDF : 30
χ^2/NDF
~1.11

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

The fitting is done
bin by bin of d(K$^-$, n)"X"



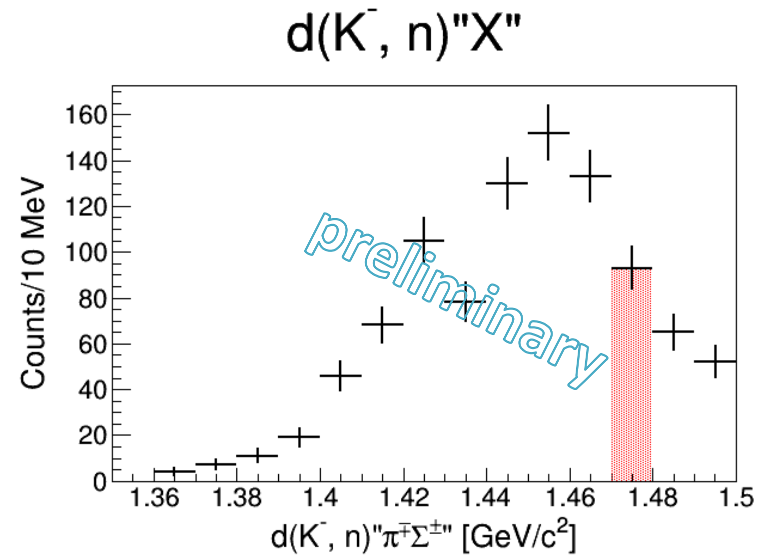


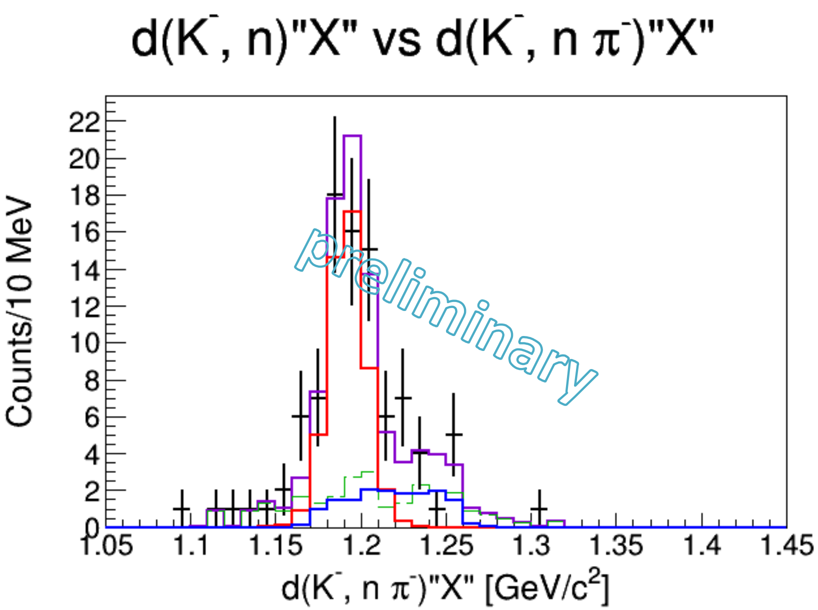


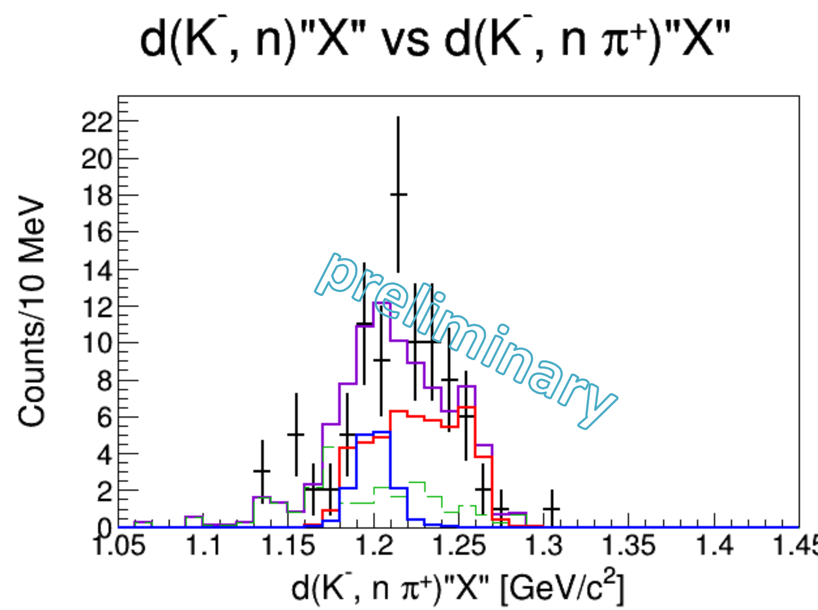
X^2 : 63.9
NDF : 29
χ^2/NDF
~2.2

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

The fitting is done
bin by bin of d(K$^-$, n)"X"



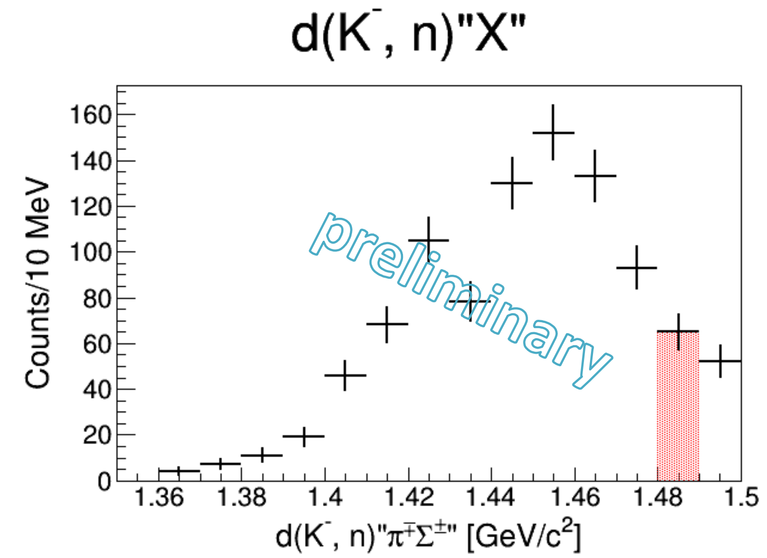


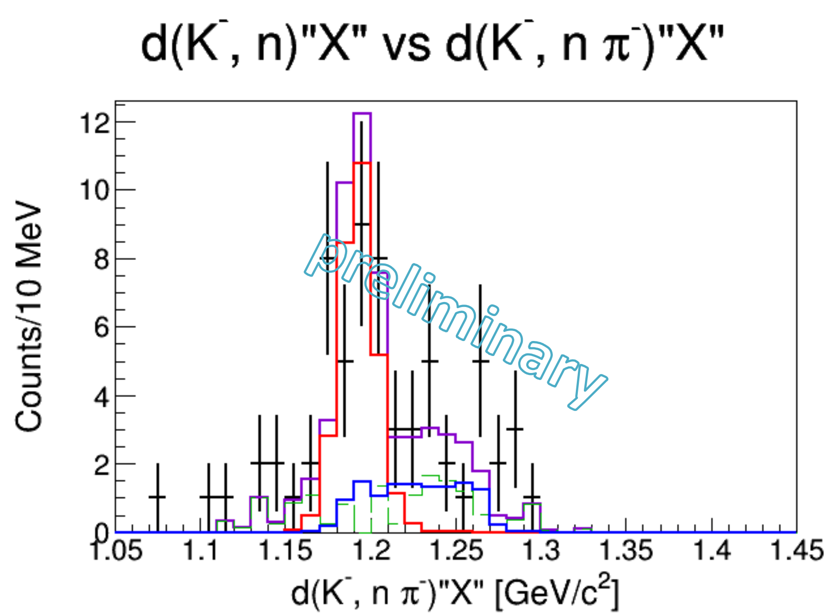


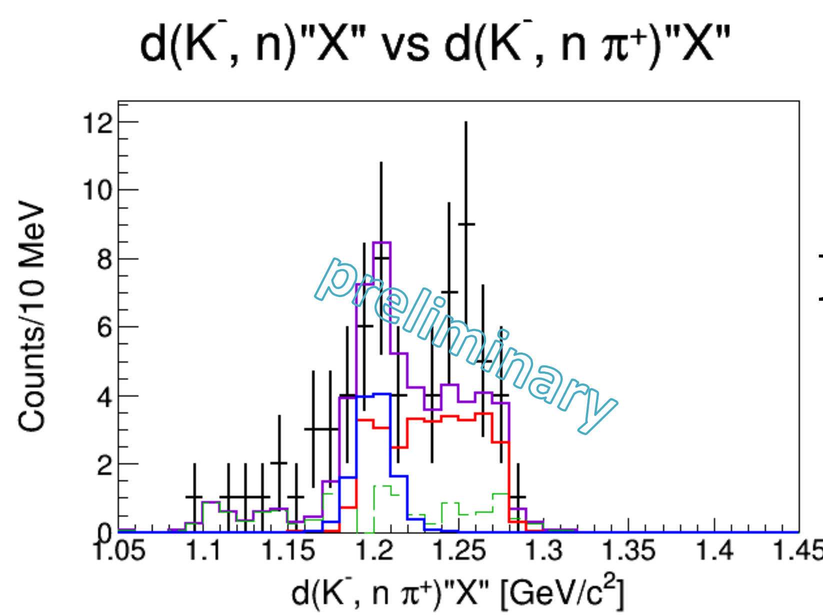
χ^2 : 53.2
NDF : 30
χ^2/NDF
~1.77

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

The fitting is done
bin by bin of d(K$^-$, n)"X"



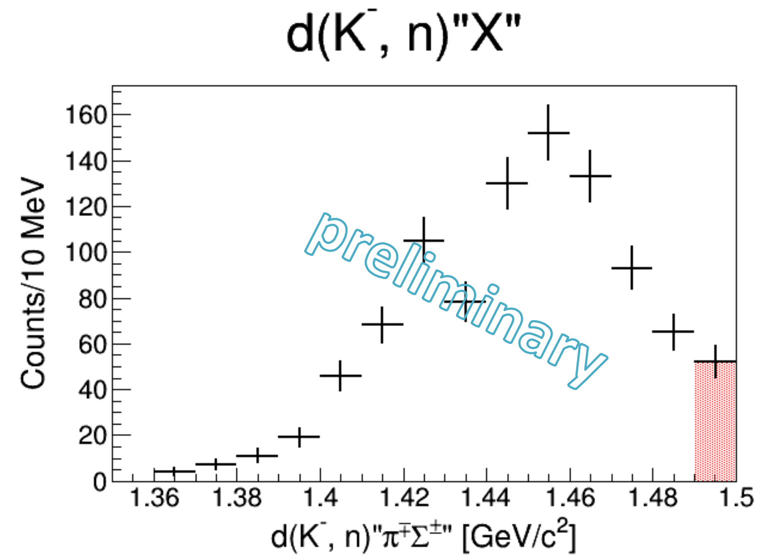


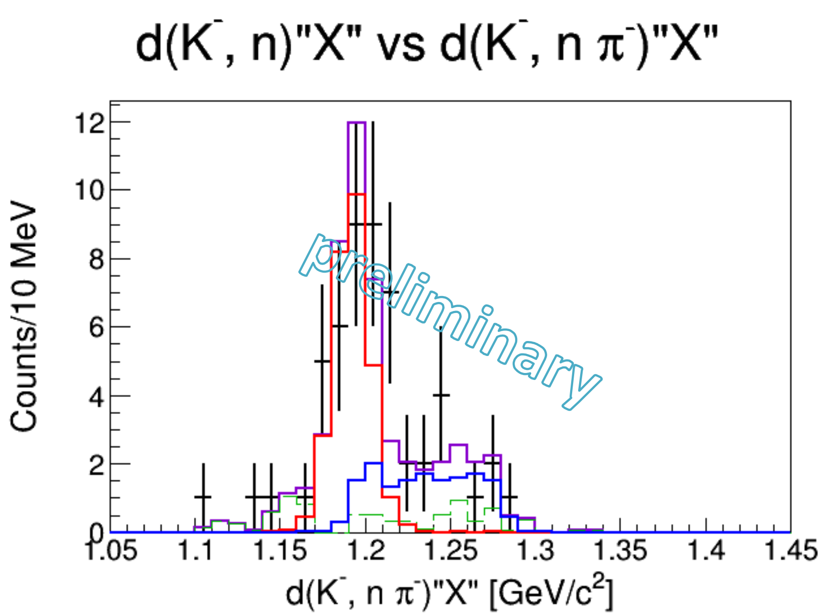


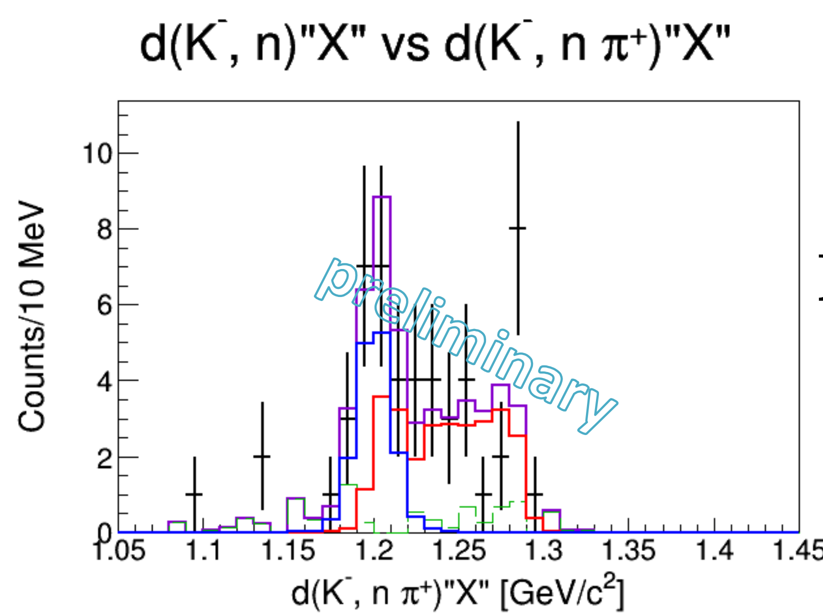
χ^2 : 59.1
NDF : 36
χ^2/NDF
~1.64

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

The fitting is done
bin by bin of d(K$^-$, n)"X"







χ^2 : 46.1
NDF : 28
χ^2/NDF
~1.65