$d(K^-, N)"\pi Y"$ Analysis

Kentaro Inoue

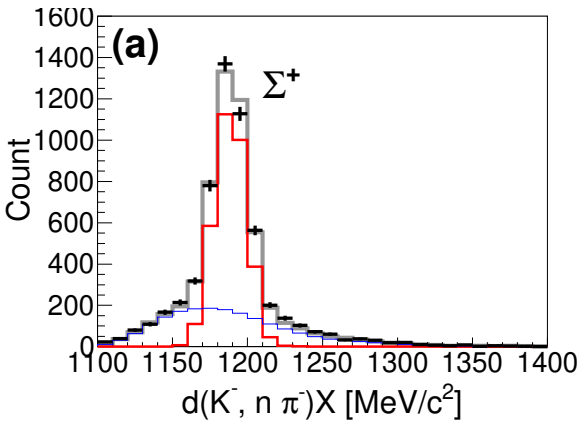
August 27, 2019

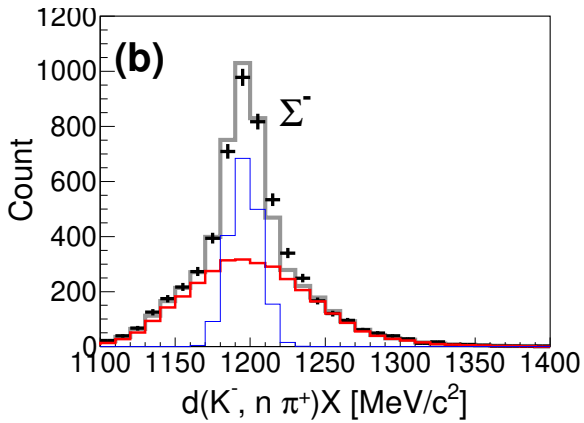
Current status

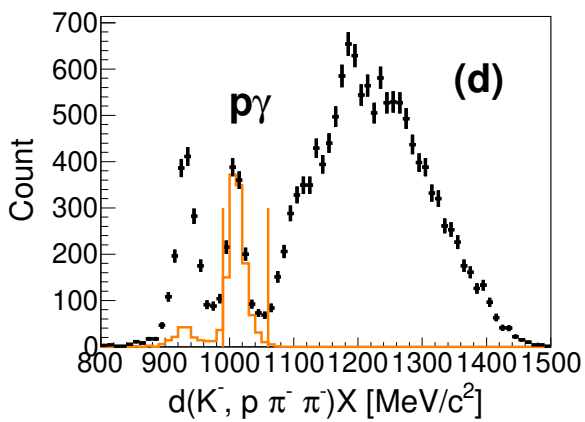
- Asano-san was updated knucl and k18ana for more realistic CDS geometory.
  $\rightarrow$ Low dE due to n/γ will be inproved.
  No, affect to my analysis because I selected in off-line analysis (software-selection)
  $\rightarrow$ I will not make new MC data sets.
- I submitted some request from Noumi-san.
  $\rightarrow$ I shows these figures

Figer for letter paper

- Change unit $[GeV/c^2] \rightarrow [MeV/c^2]$
- $\pi^-\Sigma^+$ and $\pi^-\Sigma^0$ LineStyle=2
- $\pi^+\Sigma^-$ and $\pi^-\Lambda$ LineStyle=3

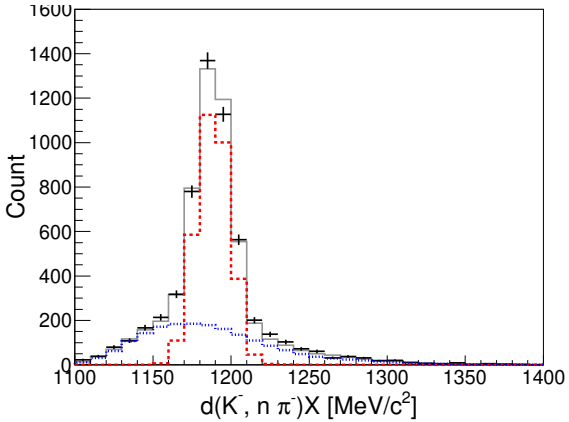


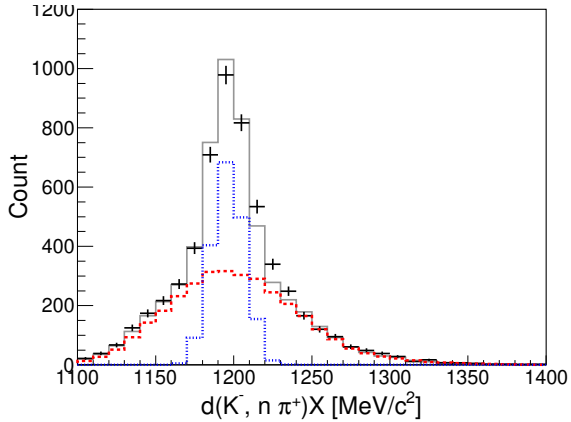


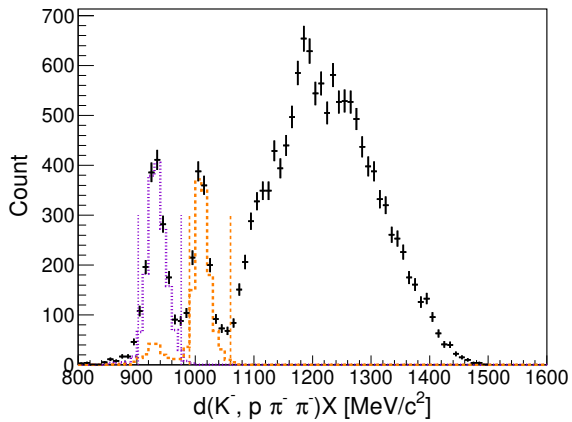


Figer for letter paper

- Change unit $[GeV/c^2] \rightarrow [MeV/c^2]$
- $\pi^-\Sigma^+$ and $\pi^-\Sigma^0$ LineStyle=2
- $\pi^+\Sigma^-$ and $\pi^-\Lambda$ LineStyle=3

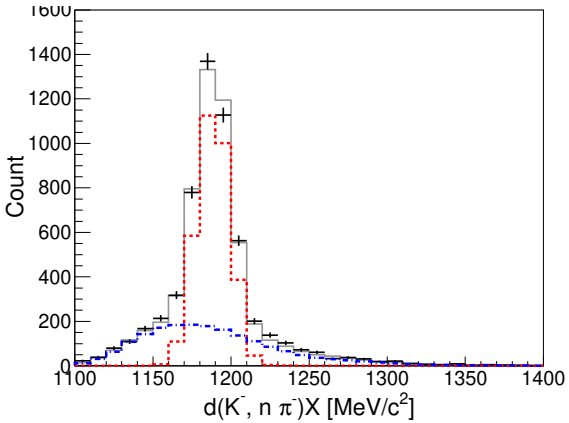


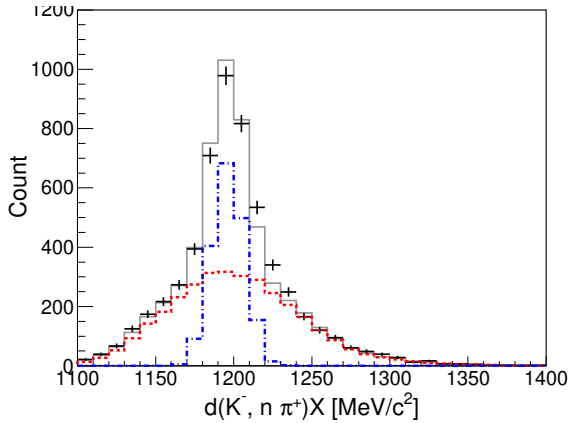


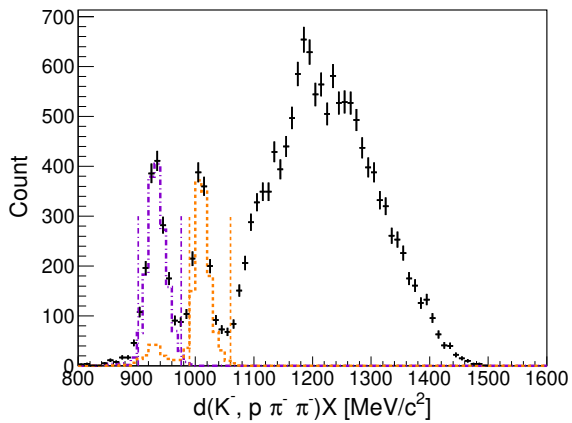


Figer for letter paper

- Change unit $[GeV/c^2] \rightarrow [MeV/c^2]$
- $\pi^-\Sigma^+$ and $\pi^-\Sigma^0$ LineStyle=2
- $\pi^+\Sigma^-$ and $\pi^-\Lambda$ LineStyle=5

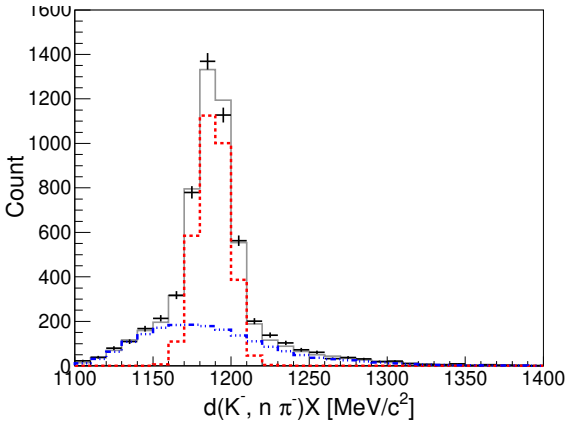


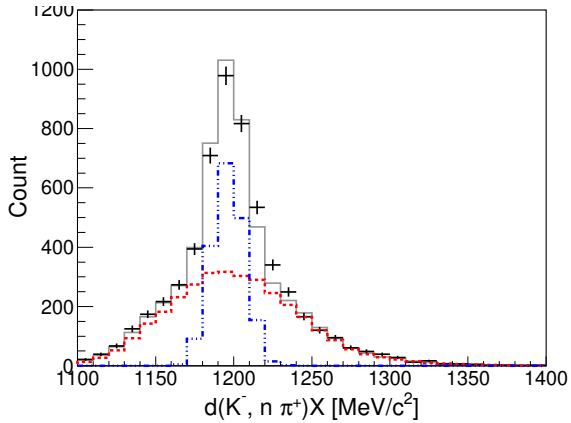


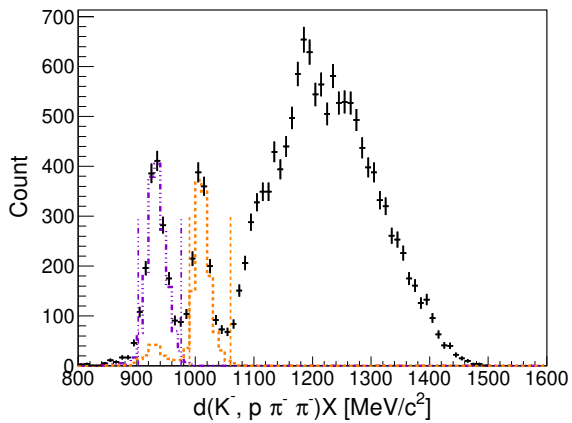


Figer for letter paper

- Change unit $[GeV/c^2] \rightarrow [MeV/c^2]$
- $\pi^-\Sigma^+$ and $\pi^-\Sigma^0$ LineStyle=2
- $\pi^+\Sigma^-$ and $\pi^-\Lambda$ LineStyle=6

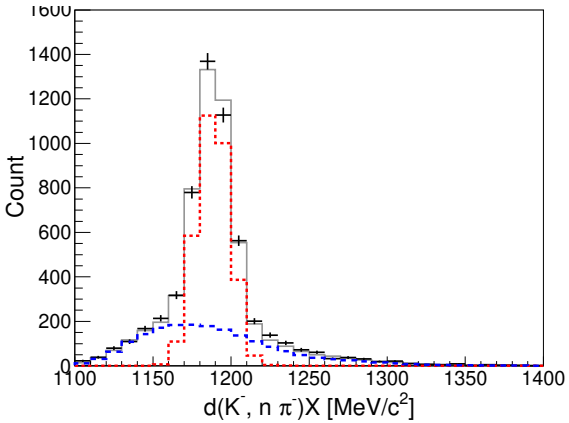


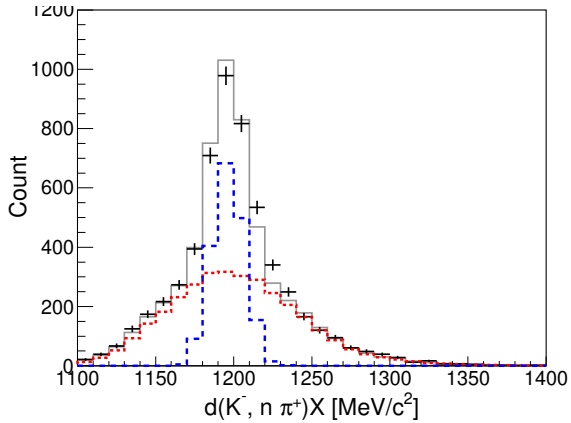


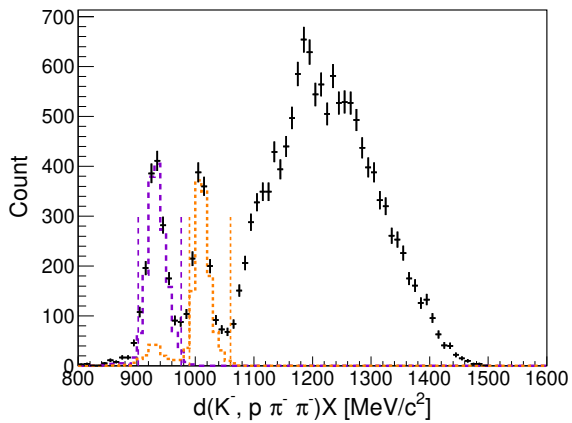


Figer for letter paper

- Change unit $[GeV/c^2] \rightarrow [MeV/c^2]$
- $\pi^-\Sigma^+$ and $\pi^-\Sigma^0$ LineStyle=2
- $\pi^+\Sigma^-$ and $\pi^-\Lambda$ LineStyle=7

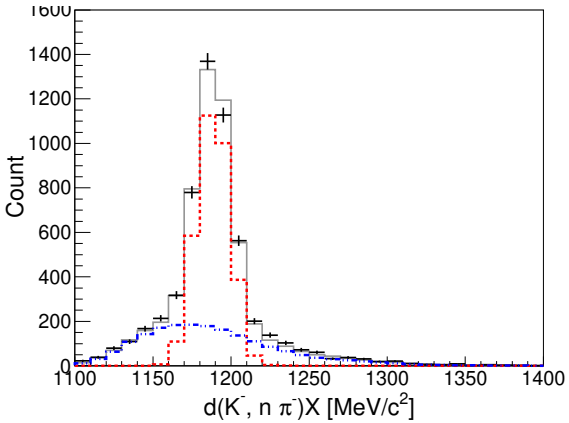


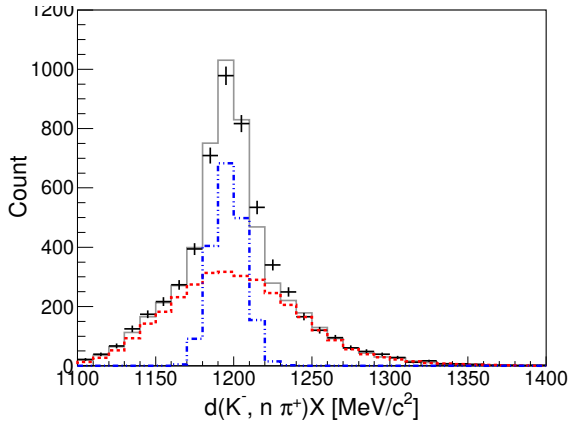


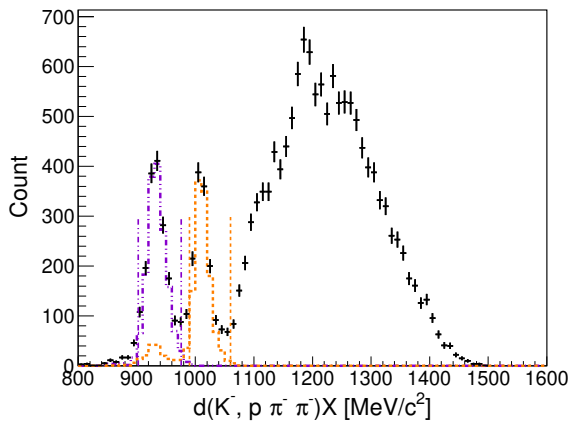


Figer for letter paper

- Change unit $[GeV/c^2] \rightarrow [MeV/c^2]$
- $\pi^-\Sigma^+$ and $\pi^-\Sigma^0$ LineStyle=2
- $\pi^+\Sigma^-$ and $\pi^-\Lambda$ LineStyle=8

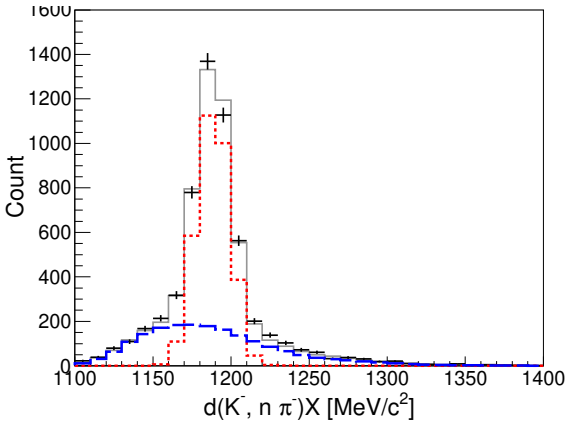


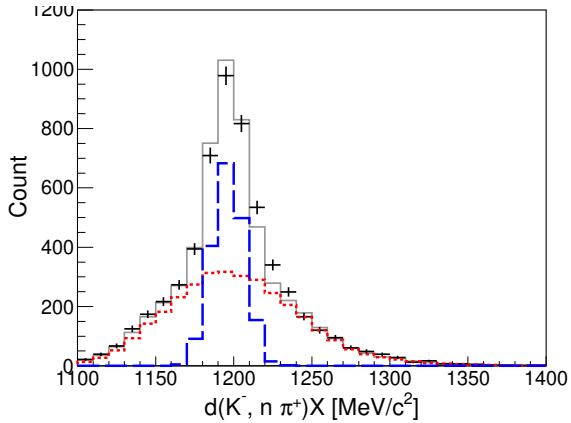


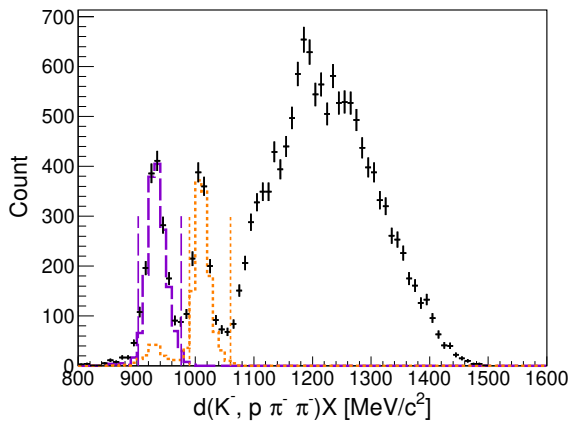


Figer for letter paper

- Change unit $[GeV/c^2] \rightarrow [MeV/c^2]$
- $\pi^-\Sigma^+$ and $\pi^-\Sigma^0$ LineStyle=2
- $\pi^+\Sigma^-$ and $\pi^-\Lambda$ LineStyle=9

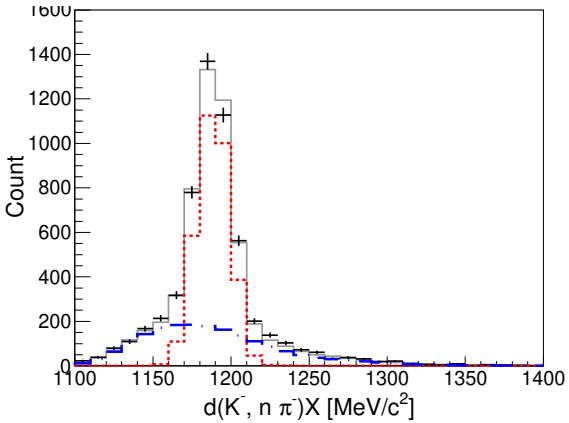


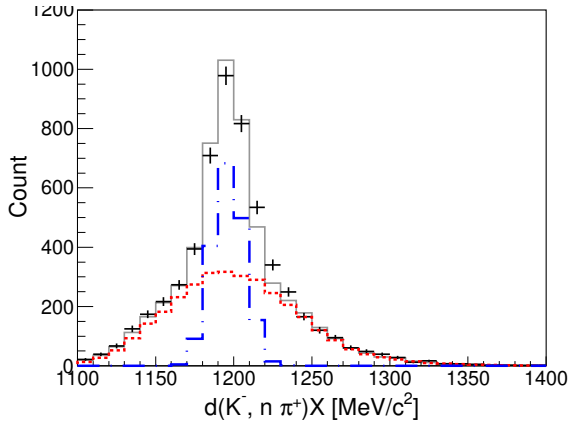


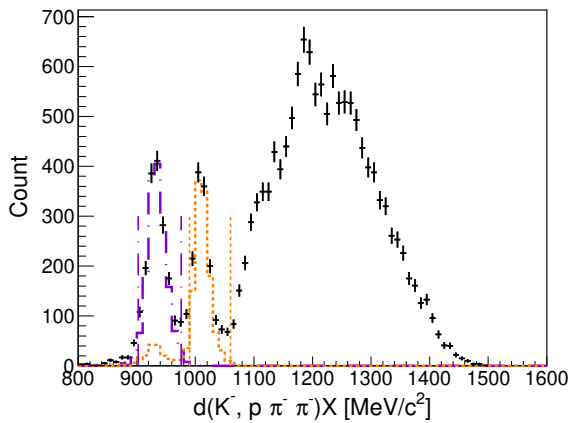


Figer for letter paper

- Change unit $[GeV/c^2] \rightarrow [MeV/c^2]$
- $\pi^-\Sigma^+$ and $\pi^-\Sigma^0$ LineStyle=2
- $\pi^+\Sigma^-$ and $\pi^-\Lambda$ LineStyle=10

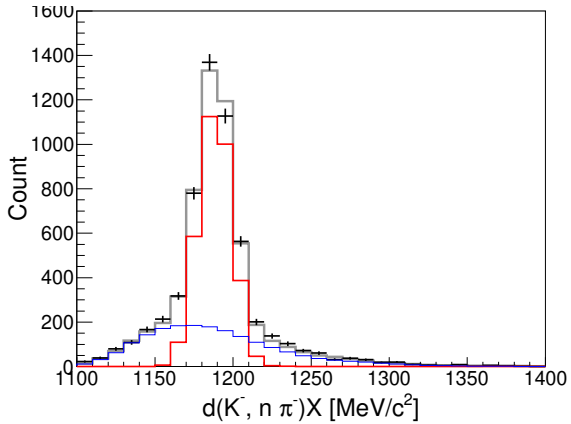


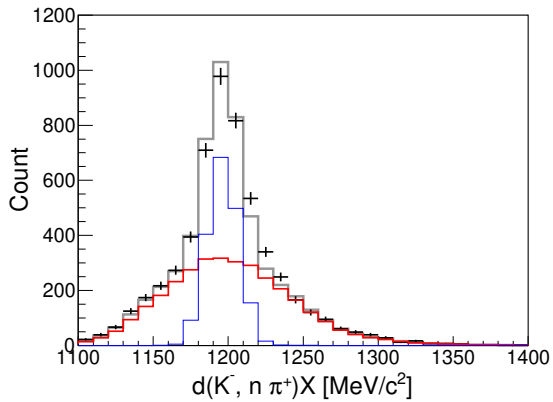


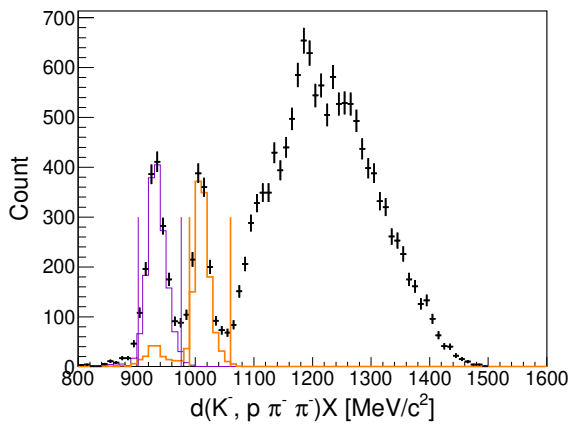


Figer for letter paper

- Change unit $[GeV/c^2] \rightarrow [MeV/c^2]$
- MC Sum : LineWidth=3
- $\pi^-\Sigma^+$ and $\pi^-\Sigma^0$ LineWidth=2
- $\pi^+\Sigma^-$ and $\pi^-\Lambda$ LineWidth=1







Summary

- I will not update final spectra.
- I make some figures with some pattern
  $\rightarrow$ I will refrect comments and send modified figures as sonn as.

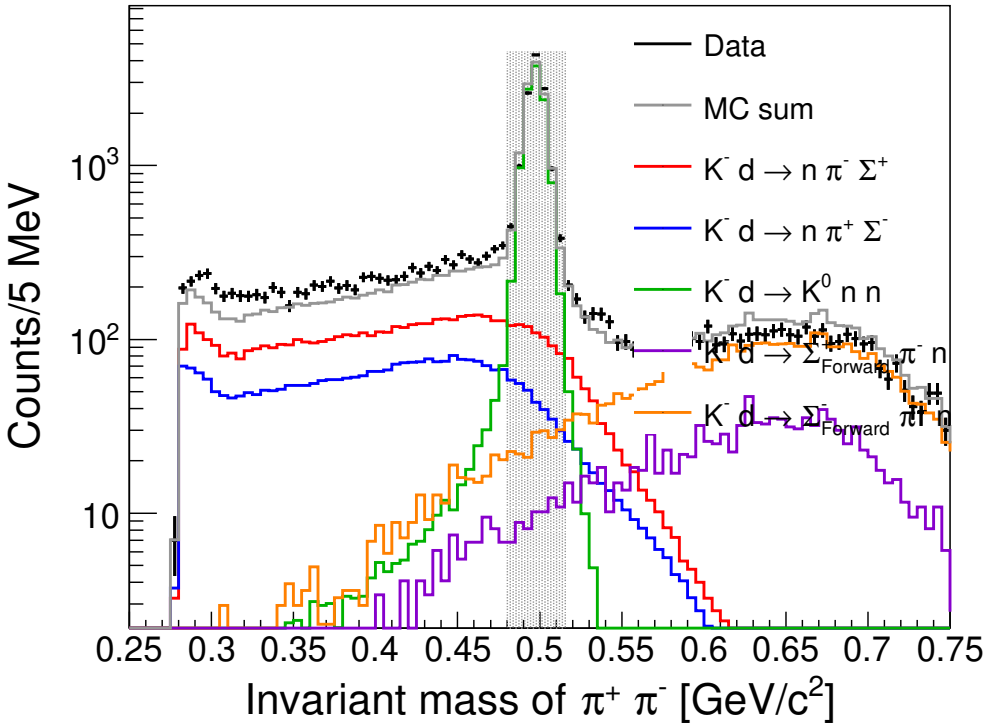
CS links $d(K^-, p)"\pi^-\Lambda/\Sigma^0"$ and $d(K^-, n)"nK^0"$

- $d(K^-, p)"\pi^-\Sigma^0"$
  `http://ag.riken.jp/J-PARC/inoue/kd_ana/txt/Run68/pimS0_CS.txt`
- $d(K^-, p)"\pi^-\Lambda"$
  `http://ag.riken.jp/J-PARC/inoue/kd_ana/txt/Run68/pimL_CS.txt`
- $d(K^-, n)"nK^0"$
  `http://ag.riken.jp/J-PARC/inoue/kd_ana/txt/Run78/K0_CS_subBG.txt`

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

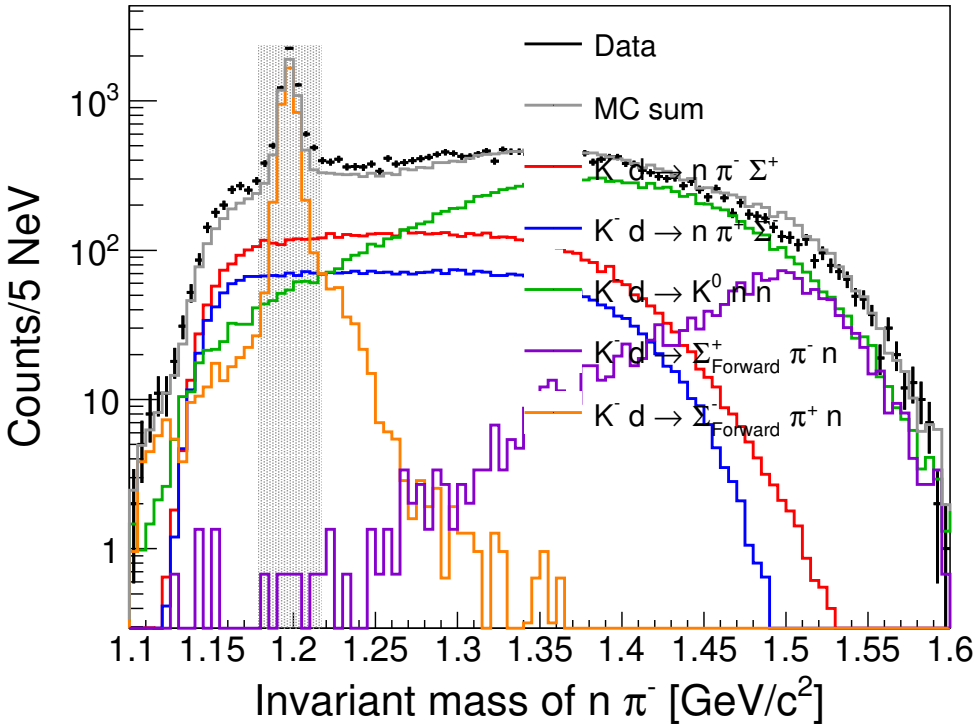
- $d(K^-, n)"\pi^-\Sigma^+"$
  Before K^0 2-step fitting
  `http://ag.riken.jp/J-PARC/inoue/kd_ana/txt/Run78/pimSp_CS_NC170_2sigma.txt`
  After K^0 2-step fitting
  `http://ag.riken.jp/J-PARC/inoue/kd_ana/txt/Run78/pimSp_CS_NC170_2sigma_after_K0_ts.txt`
- $d(K^-, n)"\pi^+\Sigma^-"$
  Before K^0 2-step fitting
  `http://ag.riken.jp/J-PARC/inoue/kd_ana/txt/Run78/pipSm_CS_NC170_2sigma.txt`
  After K^0 2-step fitting
  `http://ag.riken.jp/J-PARC/inoue/kd_ana/txt/Run78/pipSm_CS_NC170_2sigma_after_K0_ts.txt`
- $d(K^-, n)"\pi^{\mp}\Sigma^{\pm}"$ Average
  Before K^0 2-step fitting
  `http://ag.riken.jp/J-PARC/inoue/kd_ana/txt/Run78/pimSp_pipSm_ave_CS_NC170_2sigma.txt`
  After K^0 2-step fitting
  `http://ag.riken.jp/J-PARC/inoue/kd_ana/txt/Run78/pimSp_pipSm_ave_CS_NC170_2sigma_after_K0_ts.txt`

K^0 IM fitting log scale



Backward $\pi^{\mp}\Sigma^{\pm}$ was distributed at low IM.
Forward $\pi^{\mp}\Sigma^{\pm}$ was distributed at high IM.

Σ^- IM fitting log scale

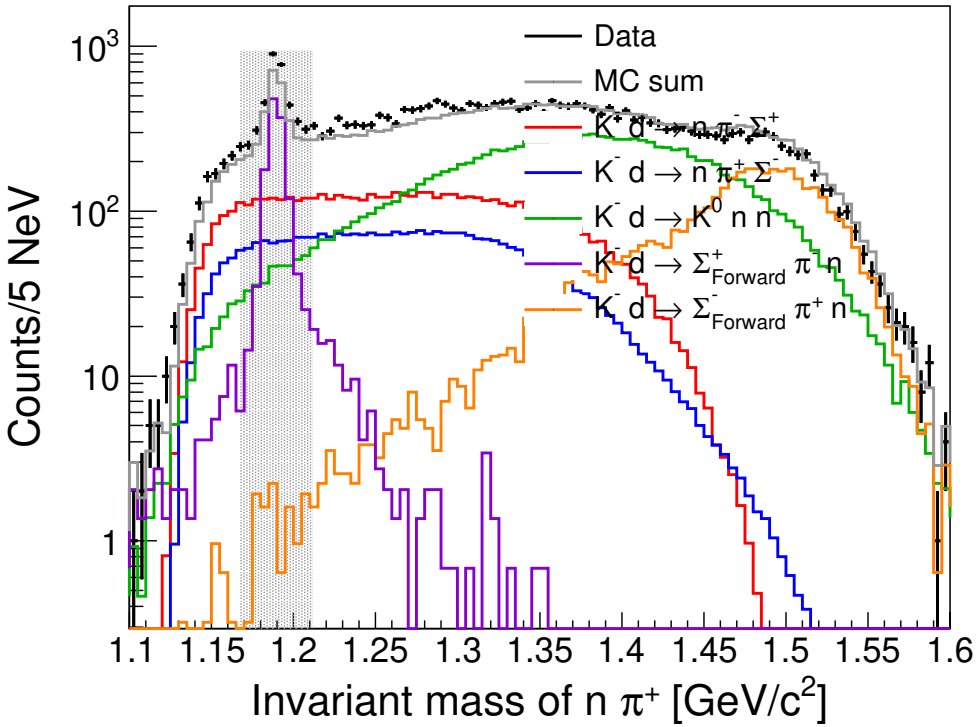


K^0 was widely distributed.

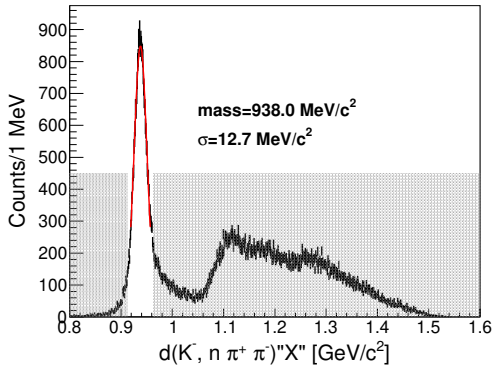
Opsit Σ_{forwad} was distributed at high IM.

Backward $\pi^{\mp}\Sigma^{\pm}$ was distributed uniformaly.

Σ^+ IM fitting log scale

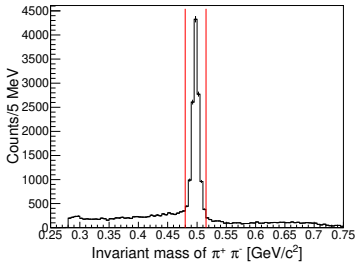


$d(K^-, n\pi^+\pi^-)"n"$ event number

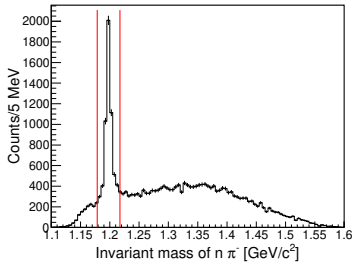


Good beam
$\pi^+ == 1$ & $\pi^- == 1$ & CDH 2hit.
(Off-line selection)
Trigger: $K \otimes$ CDH1 $\otimes$ *Neutral*
Number of Event : 98490
$d(K^-, n\pi^+\pi^+)"n"$: 25709

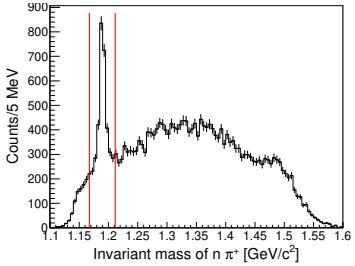
K^0 selection



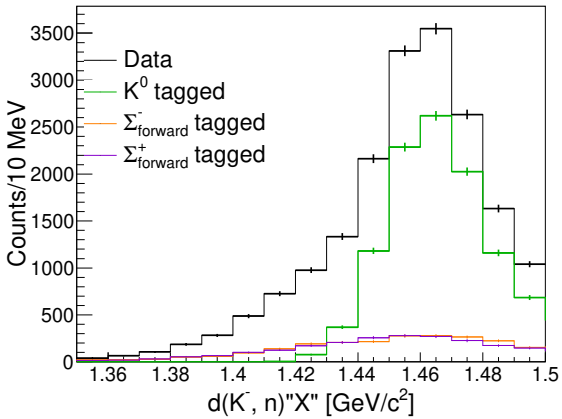
Σ^- selection



Σ^+ selection



K^0 tagged	12263
$\Sigma^-_{forward}$ tagged	5895
$\Sigma^+_{forward}$ tagged	3599
$d(K^-, n\pi^+\pi^-)"\pi^\mp\Sigma^\pm"$	5900
$K^0\&\Sigma^-$ tagged	889
$K^0\&\Sigma^+$ tagged	735
$\Sigma^-\&\Sigma^+$ tagged	334
$K^0\&\Sigma^-\&\Sigma^+$ tagged	10



Kentaro's analysis library @ ag

- Directory : /w/e15/inoue/knpipi_ev/
- Sample : macro/readKNpipi_ev.C
  macro/dumpScale.C
- Classes : src/XXXInfo.h
- ~~Data : root/readAna.root~~
- MC Data
  - $K^- d \to n_{forward} \pi^{\mp} \Sigma^{\pm}$ $m_{\pi^{\pm}\Sigma^{\mp}}$: $N\bar{K} \sim 1.8[GeV/c^2]$ flat $\theta_{n_{forward}} \sim 8^\circ$
    root/sim/kd_nL1405_pimSp:kd_nL1405_pipSm/readAna.root
  - $K^- d \to n_{spec} \pi^{\mp} \Sigma^{\pm}$ (1-step) :
    root/sim/kd_pimSp_ns:kd_pipSm_ns/readAna.root
  - $K^- d \to n_{forward} K^0 n_{spec}$ (1-step) : root/sim/kd_k0n_ns/readAna.root
  - $K^- d \to n_{forward} K^0 n$ (2-step) : root/sim/kd_k0n_2step/readAna.root
  - $K^- d \to n\Lambda(1520)$ (isotropic) : root/sim/kd_nL1520_iso/readAna.root
- Library : macro/lib/scale.C (ROOT Macro)
  ../k18ana/lib/libAll.so (Shared Library)

BACK UP

Contents

- Forward proton (I=1) Run68 Analysis
  $d(K^-, p)"\pi^-\Sigma^0$ & $d(K^-, p)"\pi^-\Lambda"$

  Suppression of $d(K^-, p)"\pi^-\Sigma^0/\Lambda"$ strength was observed.
- Forward neutron : $K^- + d \to n_{detect} + \pi^+ + \pi^- + "n"$
  1. $K^- + d \to \Sigma^{\pm}_{forward} + \pi^{\mp} + "n"$
  2. $K^- + d \to n_{detect} + K^0 + "n"$
  3. $K^- + d \to n_{detect} + \pi^{\mp} + \Sigma^{\pm}$

  K^0 & $\Sigma^{\pm}_{forward}$ were identified by invariant mass fitting of $\pi^+\pi^-$ and $n\pi^{\pm}$.
  Backward $\Sigma^{\pm}\pi^{\mp}$ were separate by $d(K^-, n\pi^{\mp})"\Sigma^{\pm}"$ fitting,
  which was performed bin-by-bin of $d(K^-, n)"X"$

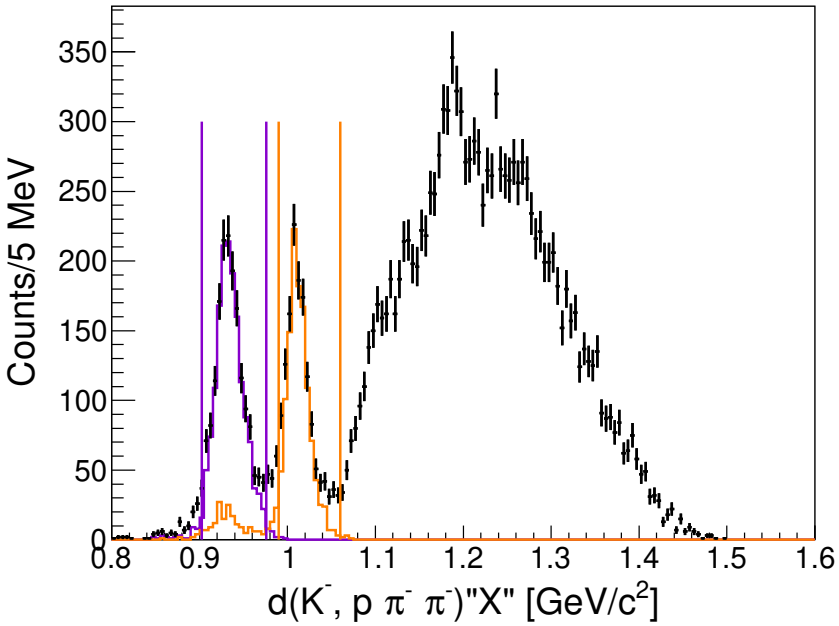
  2 step like reaction was observed in $d(K^-, nK^0)"n"$ events.
  $d(K^-, n)"\pi^{\mp}\Sigma^{\pm}$ strength was observed in the below $\bar{K}N$ threshold.

Reference of template fitting

R. Barlow and C. Beeston, Comp. Phys. Comm. 77 (1993) 219-228, "Fitting using finite Monte Carlo samples"
A.Nappi, Comp Phys. Comm. 180 (2009) 269-275

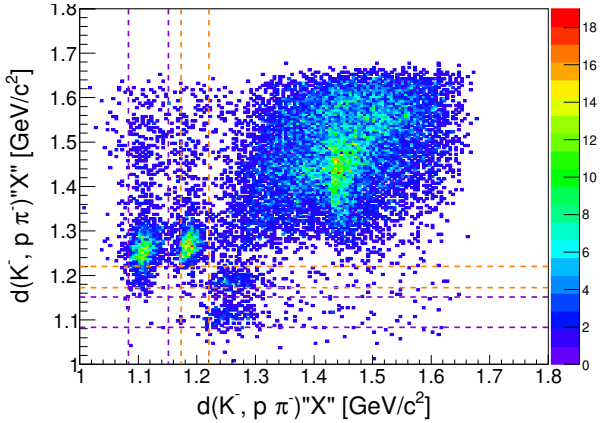
"A pitfall in the use of extended likelihood for fitting fractions of pure samples in a mixed sample"

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

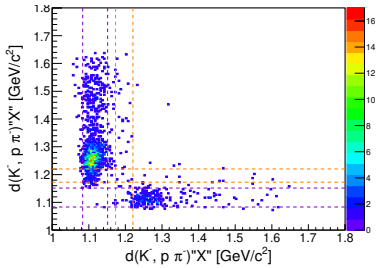


This figure shows $d(K^-, p\pi^-\pi^-)"X"$. Orange and purple plots represent $d(K^-, p\pi^-)"\Lambda"$ & $d(K^-, p\pi^-)"\Sigma^0"$. Orange and purple lines shows $d(K^-, p\pi^-)"\Lambda"$ & $d(K^-, p\pi^-)"\Sigma^0"$ selection.

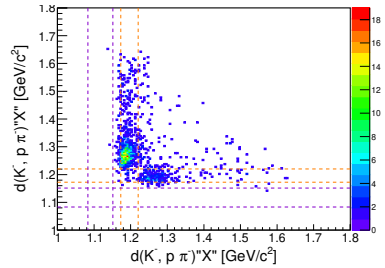
No Selection



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

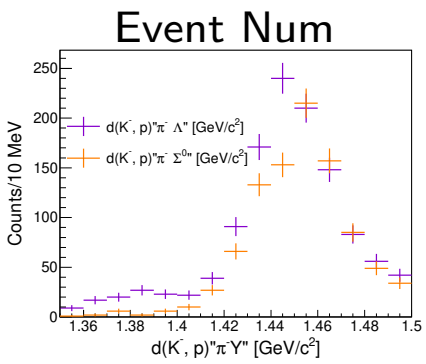


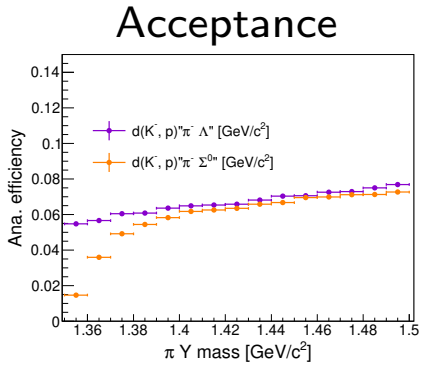
$d(K^-, p\pi^-\pi^-)"p\gamma"$ tagged



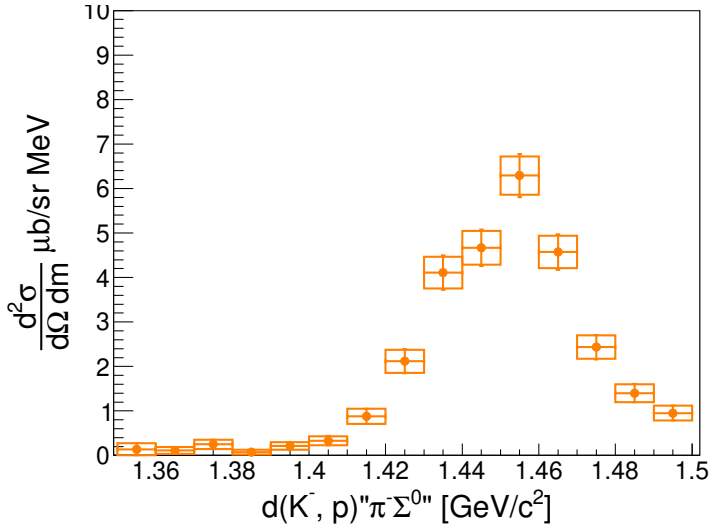
$d(K^-, p)"\pi^-\Sigma^0"$ events were selected by $d(K^-, p\pi^-)"\Sigma^0"$ & $d(K^-, p\pi^-\pi^-)"p\gamma"$.
$d(K^-, p)"\pi^-\Lambda"$ events were selected by $d(K^-, p\pi^-)"\Lambda"$ & $d(K^-, p\pi^-\pi^-)"p"$.

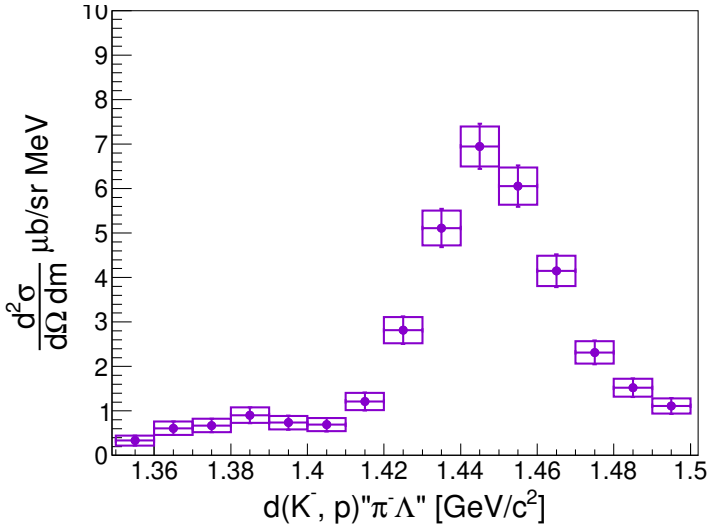
$d(K^-, p)"\pi^-\Lambda"$ and $d(K^-, p)"\Sigma^0"$ Cross Section





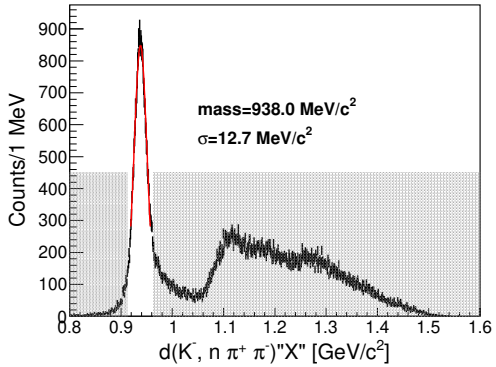
Left figure shows event number selected by before page.
Down two figure represent converted CS.
Boxes indicate statisical error.
Error bar includes scaling factor error.





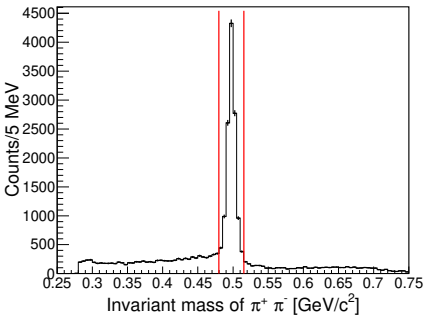
I=1 scattering amplitude was suppressed below the $\bar{K}N$ threshold.

$d(K^-, n\pi^+\pi^-)"n"$ event idetification

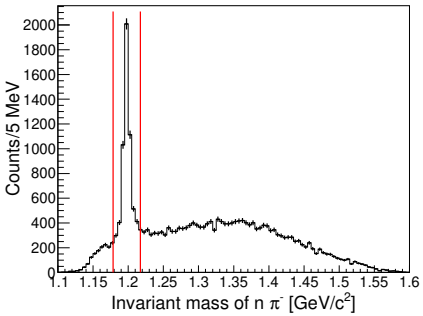


Missing neutron was selected by right figure

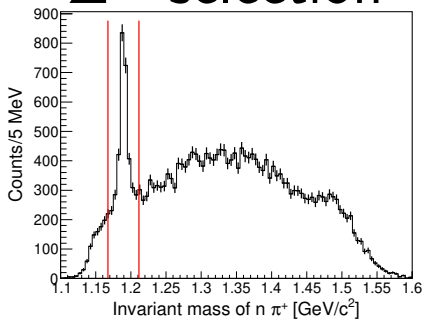
K^0 selection



Σ^- selection

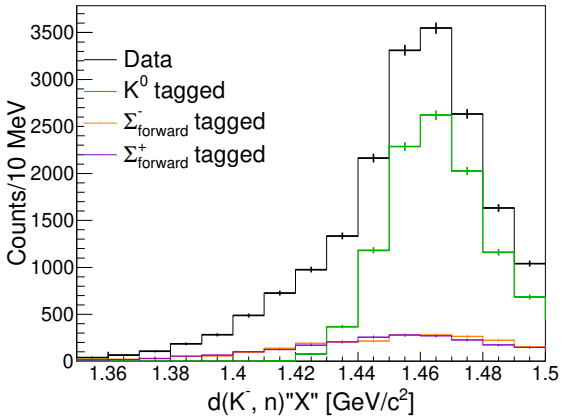


Σ^+ selection



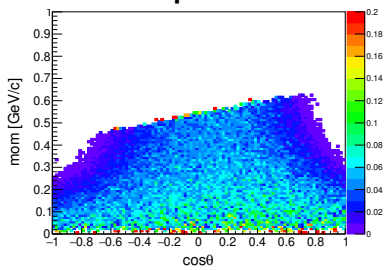
These event were identified above figures.

1. $K^- d \to K^0 nn$
   2-step like events was observed.
2. $K^- d \to \pi^\mp \Sigma^\pm$
   Forward : Background $\to$ Negligibly small.
   Backward : Main Signal

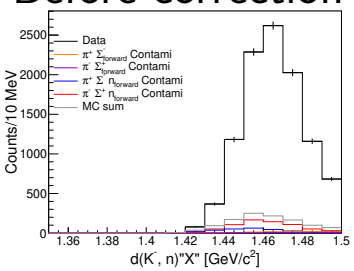


K^0 previous result

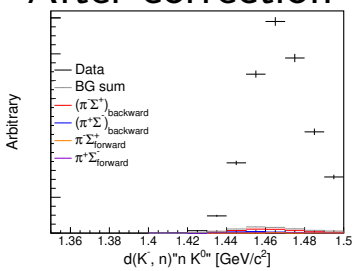
Acceptance



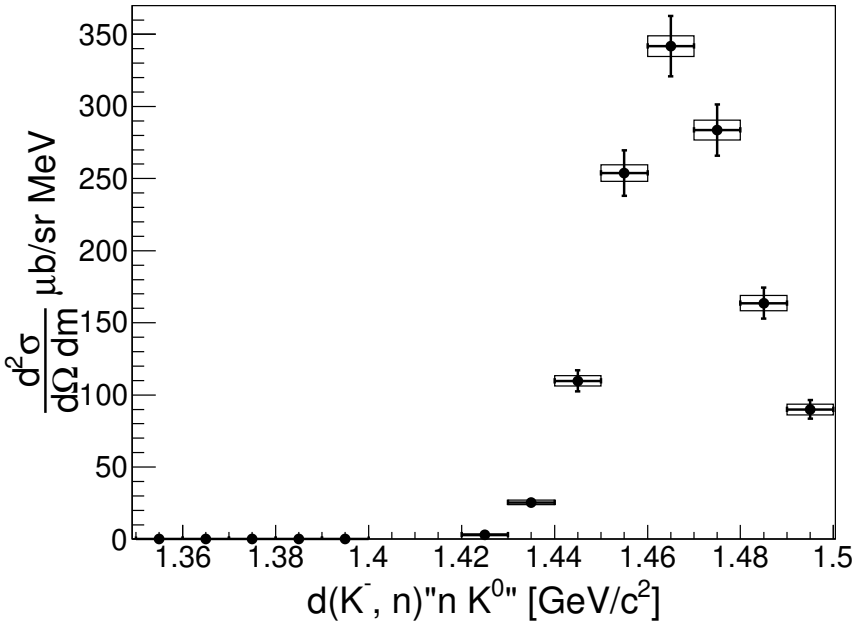
Before correction



After correction



K^0 Cross Section



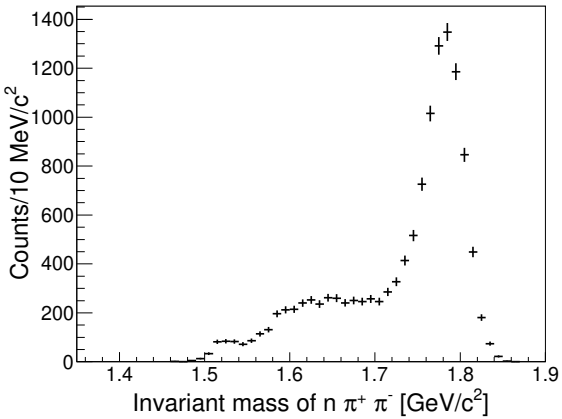
Background processes were subtracted.
Boxes indicate statisical errors.
Error bars include scaling factor.

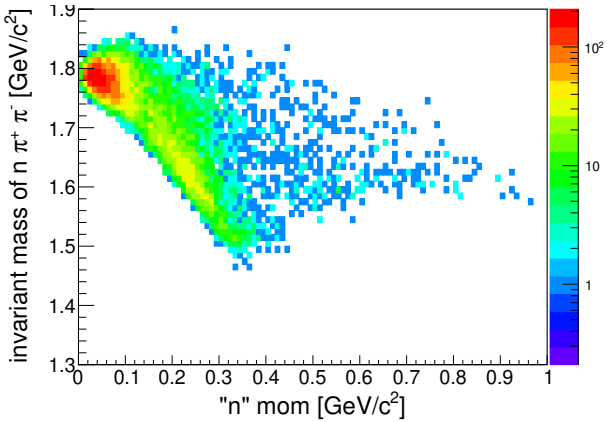
$d(K^-, n)"nK^0"$ spectrum looks like quasi-elastic (1-step).
Cross Section was converted by acceptance of $\cos\theta$ and mom of K^0.

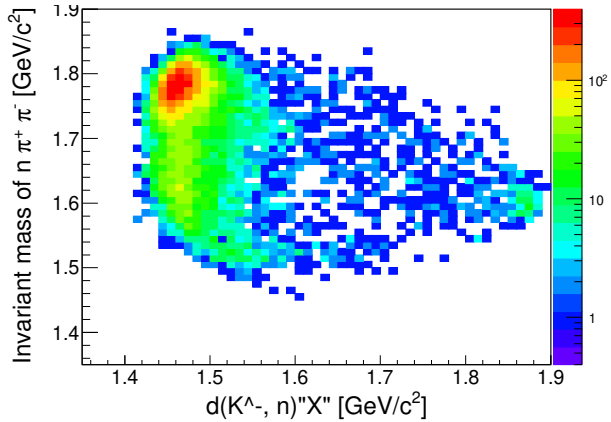
$$\frac{d^2\sigma}{d\Omega dM_{d(K^-,n)}} = F \times \sum M(\cos\theta, p) \times \frac{1}{A(\cos\theta, p)}$$

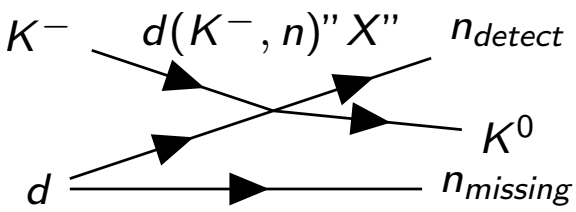
K^0 kinematical plots

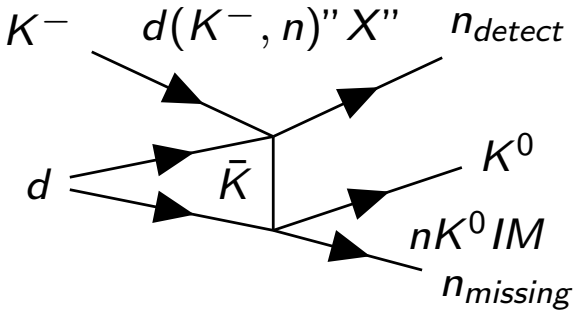
$d(K^-, n)"K^0 n"$ looked like 1-step reaction.
2-step like events were observed in IM of nK^0 and "n" momentum.

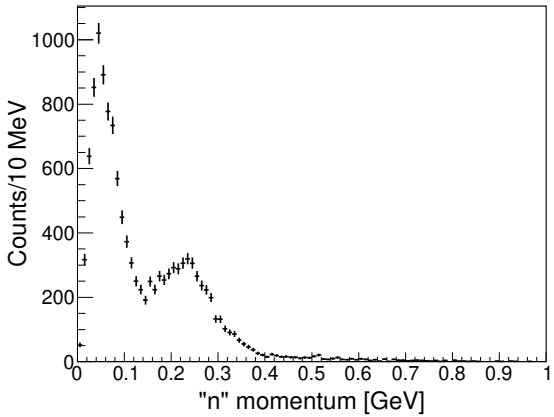


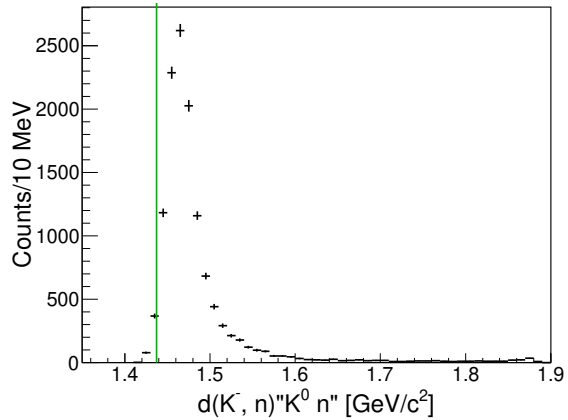








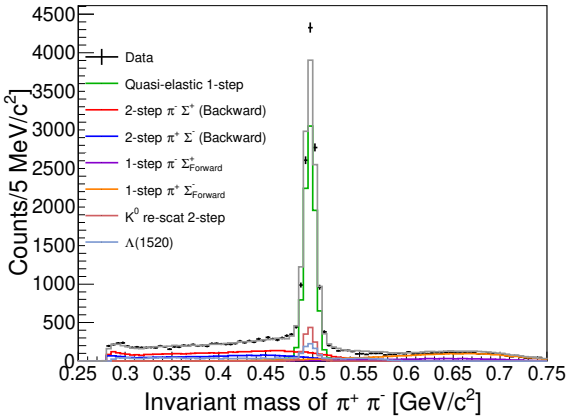


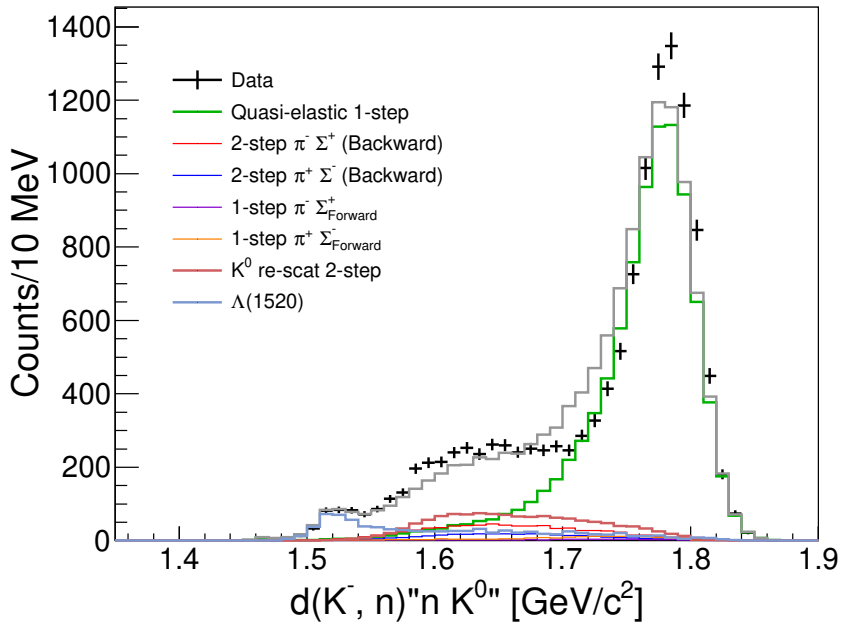


Fitting of nK^0 invariant mass

Reactions and ration of K^0 tagged events subtracted $\pi^{\mp}\Sigma^{\pm}$ BG.

1. $K^- + d \to n + K^0 + n_{spec}$ (1-step) : About 80%
2. $K^- + d \to n + K^0 + n$
   K^0 and n_{spec} was isotropic scattered (2-step) : About 12 %
3. $K^- + d \to n\Lambda(1520)$ isotropic : About 8%



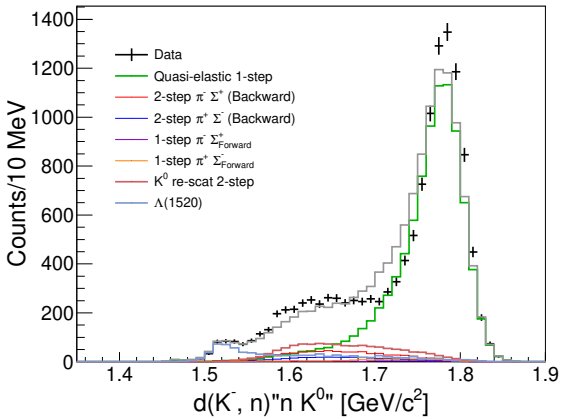


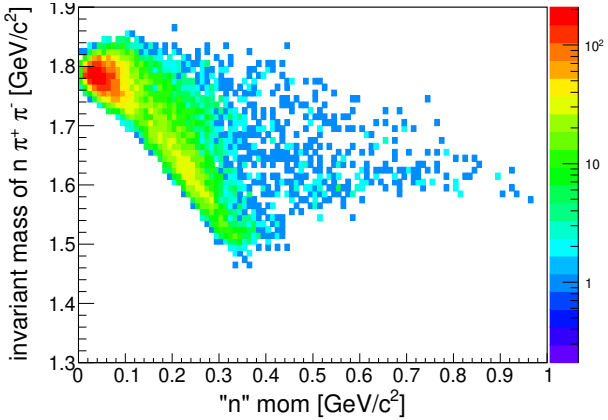
$\pi^{\mp}\Sigma^{\pm}$ events was fixed.

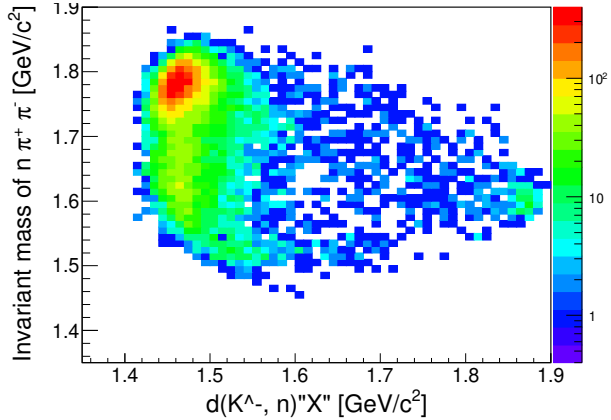
$\to K^0$ raction details in p.**??**

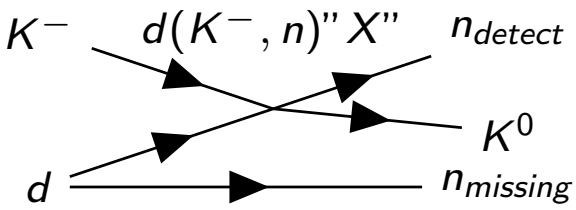
K^0 kinematical plot with fitting

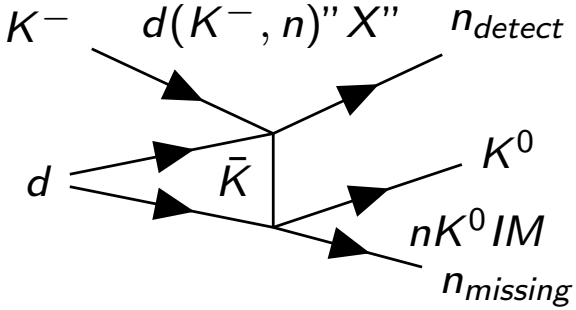
$d(K^-, n)"K^0 n"$ looked like 1-step reaction.
2-step like events were observed in IM of nK^0 and "n" momentum.

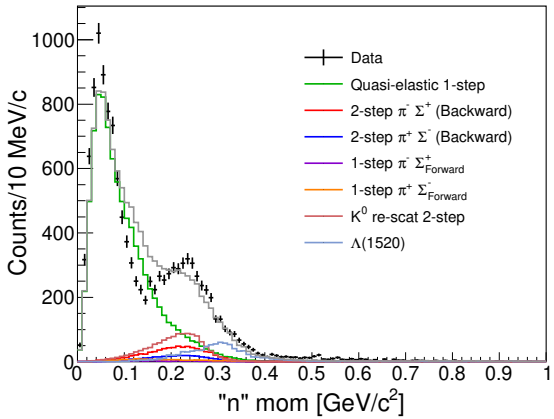


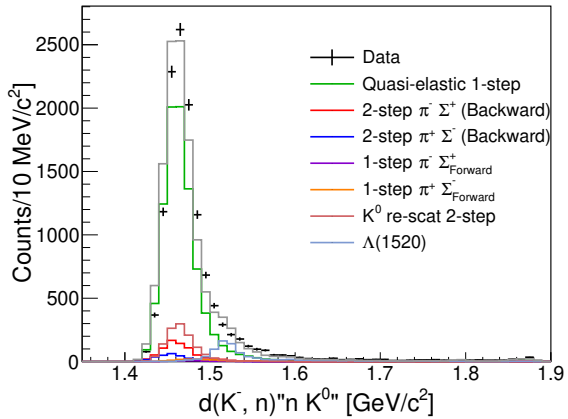






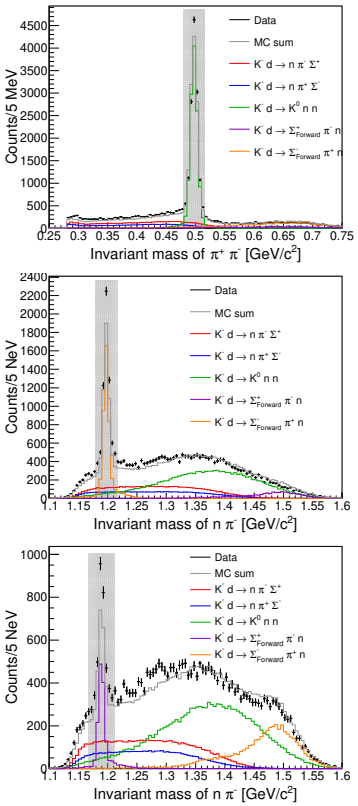


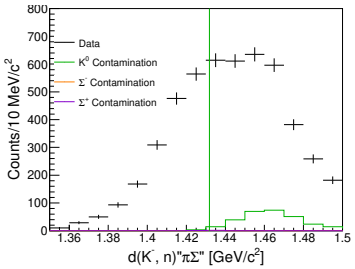




Fitting for separation of $d(K^-, n)"\pi^{\pm}\Sigma^{\mp}"$

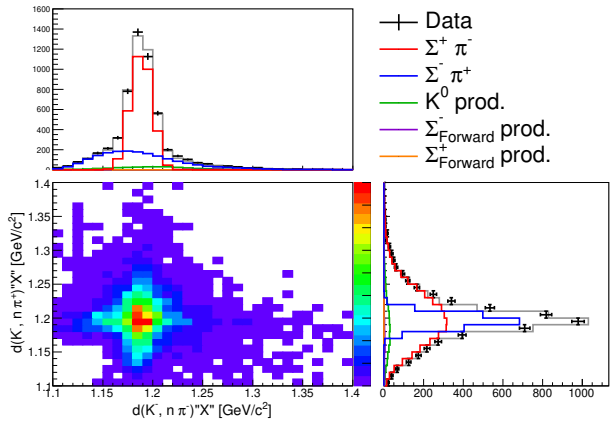
1. $K^- d \to K^0 " n " n_{detected}$
   $\to$ These events include 1-step & 2-step
2. $K^- d \to " n " \pi^{\mp} \Sigma^{\pm}_{forward}$ $\Sigma^{\pm}_{forward} \to \pi^{\pm} n_{detected}$
   $\to$ Strangeness gives forward scattering baryon
   Negligibly small in K^0 and $\Sigma_{forward}$ rejected events
3. $K^- d \to \pi^{\mp} " \Sigma^{\pm} " n_{detected}$
   Recoiled $\bar{K}$ reacts with residual nucleon.
   Strangeness gives backward particles.





Left figure indicates $d(K^-, n)"\pi^{\mp}\Sigma^{\pm}"$, which was rejected K^0 and $\Sigma^{\pm}_{forward}$

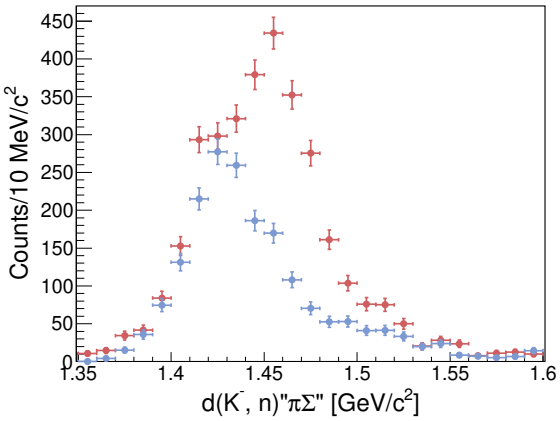
Right figure shows $d(K^-, n\pi^{\mp})"\Sigma^{\pm}"$ fitting. Above figure Σ^+ peak clearly seen. Σ^- peak seen in right projection.



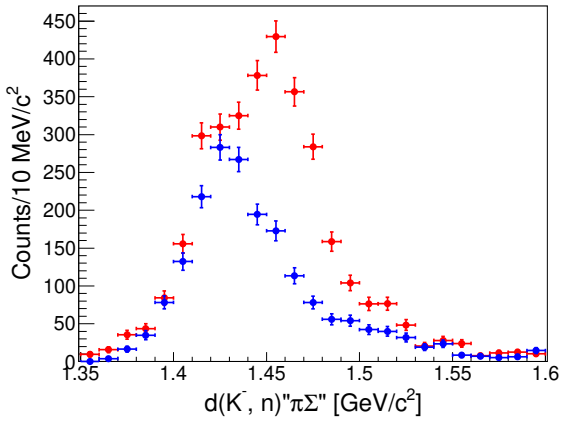
Affect of $\pi^+\Sigma^-$ and $\pi^-\Sigma^+$ separation

$\rightarrow$ Before meeting report had bug,
fix parameter readout in fitting after K^0 2-step fit.

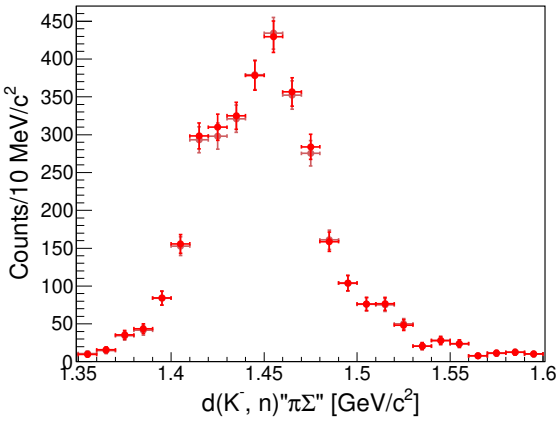
Before



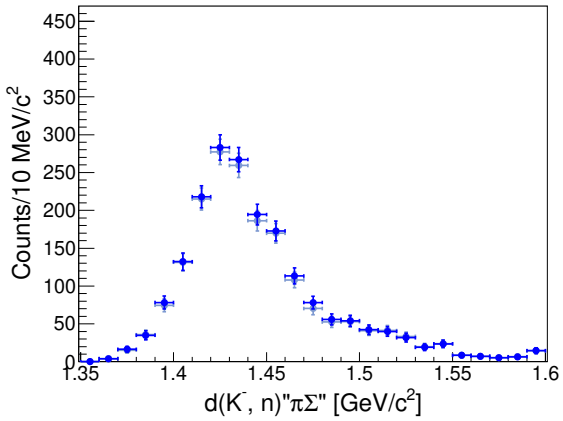
After



$\pi^-\Sigma^+$



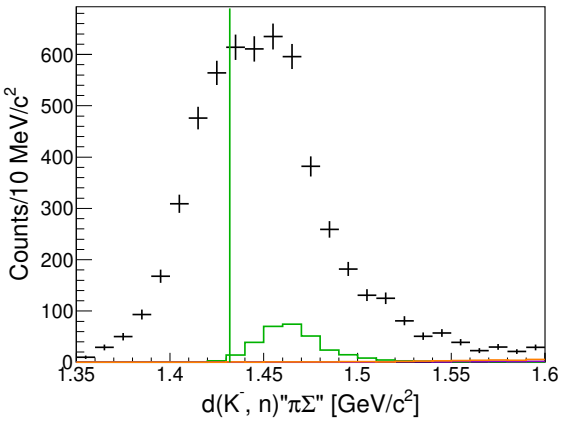
$\pi^+\Sigma^-$

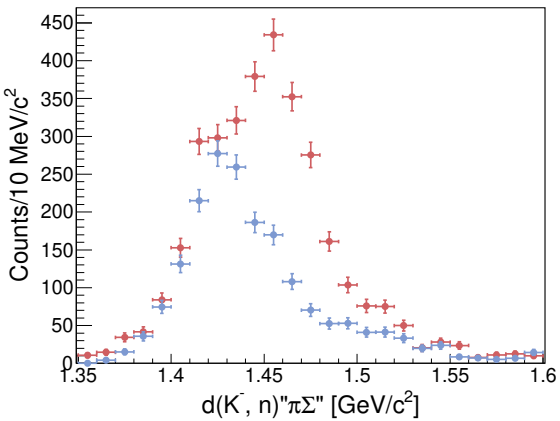


2-step affect to quasi-elastic

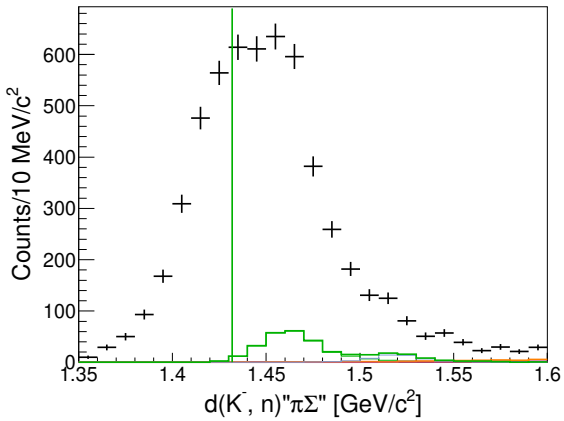
BG shape was changed by K^0 process.
This don't affects Spectra almost were not change.

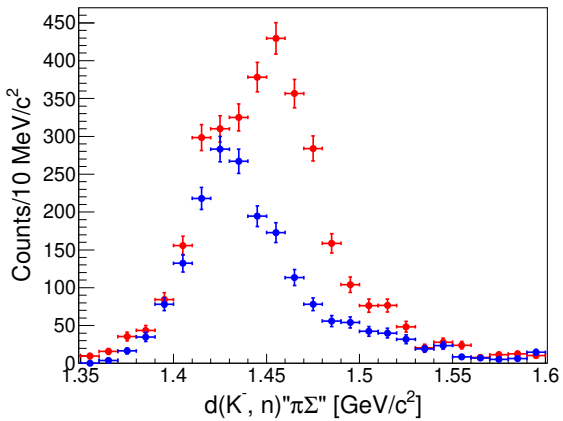
Before





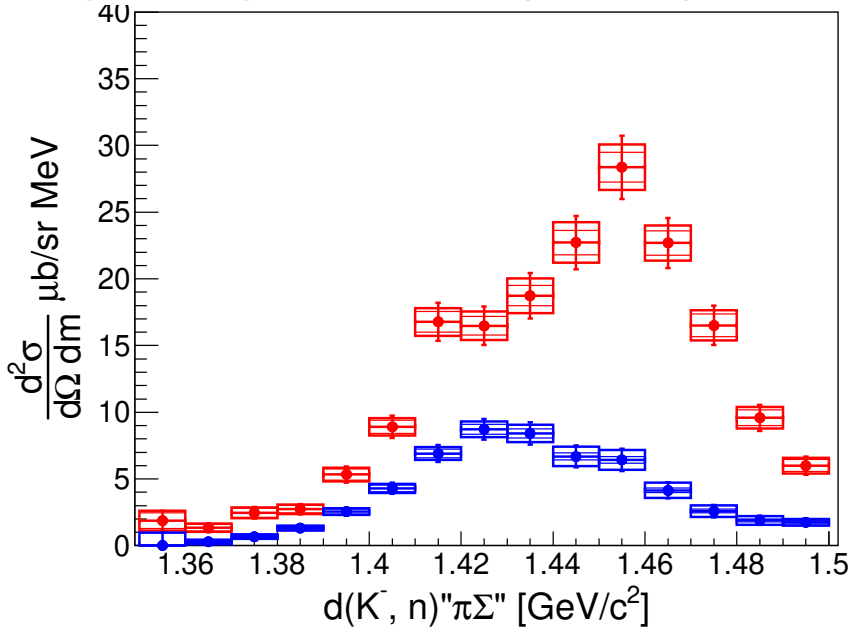
After



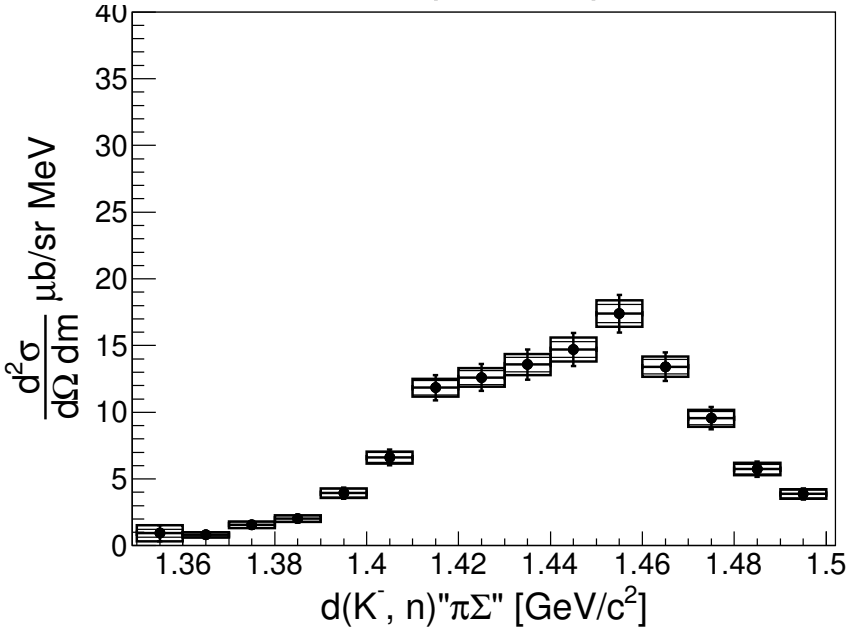


$d(K^-, n)"\pi^{\mp}\Sigma^{\pm}"$ Cross Section

$d(K^-, n)"\pi^-\Sigma^+$ $d(K^-, n)"\pi^+\Sigma^-$



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



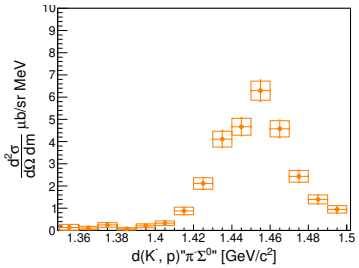
Inner boxs indicate statisical errors, outer boxs indicate statisical and fitting errors.
Error bars include scaling factor which is common weight for all bins.

Large scattering amplitude was observed even in the $\bar{K}N$ threshold.

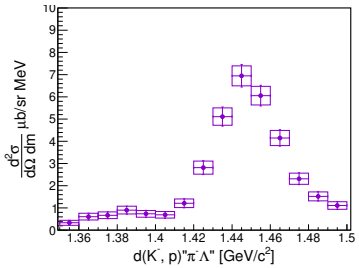
Result

$d(K^-, p)"\pi^-\Sigma^0"$ & $d(K^-, p)"\pi^-\Lambda"$ $I = 1$ channel

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



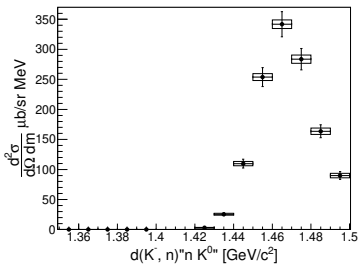
$d(K^-, p)"\pi^-\Lambda"$



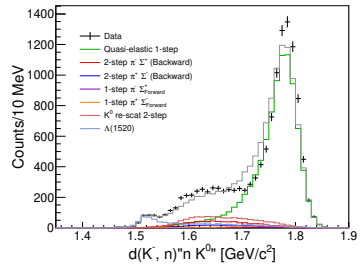
$I = 1$, $d(K^-, p)"\pi^-\Sigma^0/\Lambda"$ scattering amplitude were suppressed in the $\bar{K}N$ threshold.

$d(K^-, n)"nK^0"$ Quasi-elastic

$d(K^-, n)"nK^0"$



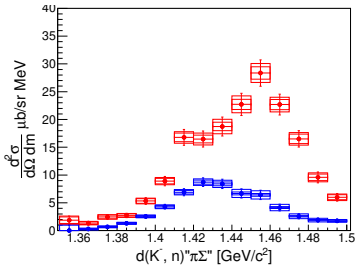
$n_{detect}K^0$ IM



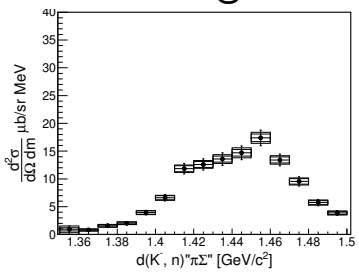
$d(K^-, n)"nK^0"$ spectrum look quasi-elastic 1-step $K^-d \to nK^0n_{spec}$ reaction.
In about 12% of them, recoiled $\bar{K}$ scatters with residual neucleon was occupied.
In about 8% of them, n $\Lambda(1520)$ production was occupied

$d(K^-, n)"\pi^\mp\Sigma^\pm"$ $I = 0, 1$ channel

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



$d(K^-, n)"\pi^\mp\Sigma^\pm"$ average



Interferance term of $d(K^-, n)"\pi^\mp\Sigma^\pm"$ was observed.
Scattering amplitude of about 5% quasi-elastic was obserbed above the $\bar{K}N$ threshold.
Large scattering amplitude was observed even in the $\bar{K}N$ threshold.