Spectroscopic Study of Hyperon Resonances below $K^{bar}N$ Threshold via the (K^-,n) Reaction on Deuteron

H. Noumi, *Osaka Univ. RCNP*, for the E31 collaboration

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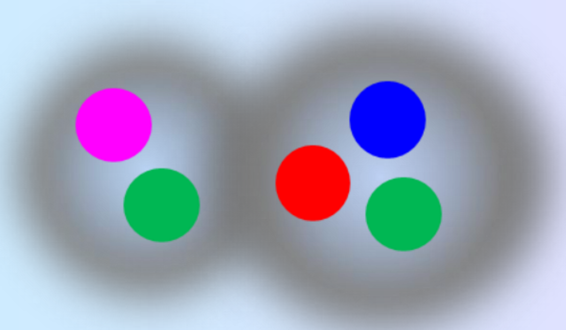
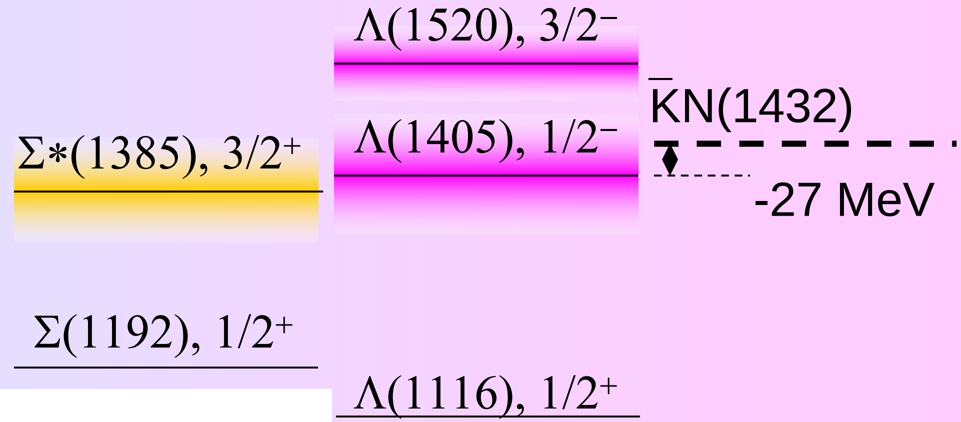
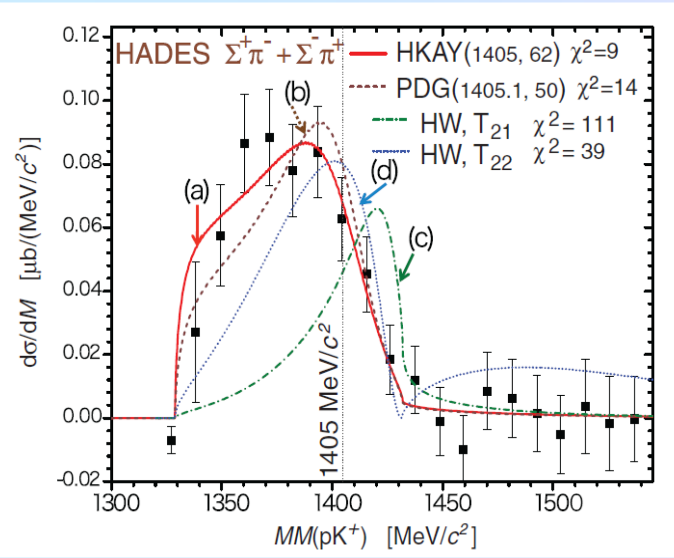
$\Lambda(1405)$: $1405.1^{+1.3}_{-0.9}$ MeV (PDG)

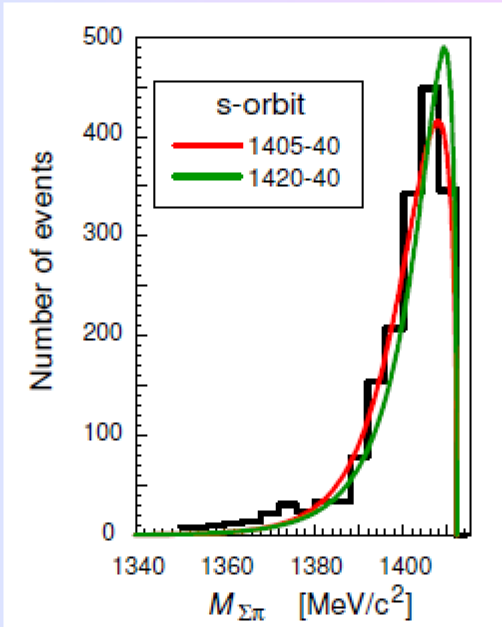
$J^P = \frac{1}{2}^-$, $I = 0$, $M_{\Lambda(1405)} < M_{\bar{K}N}$, lightest in neg. parity baryons



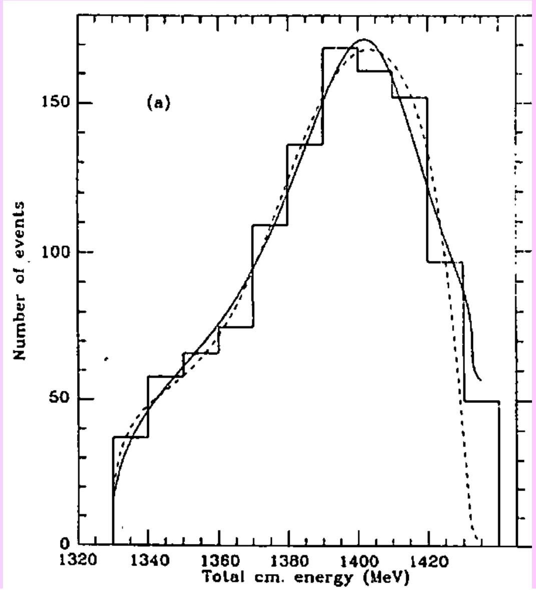




M. Hassanvand et al: $\pi\Sigma$ IM Spec. of $pp \rightarrow K^+\pi\Sigma$



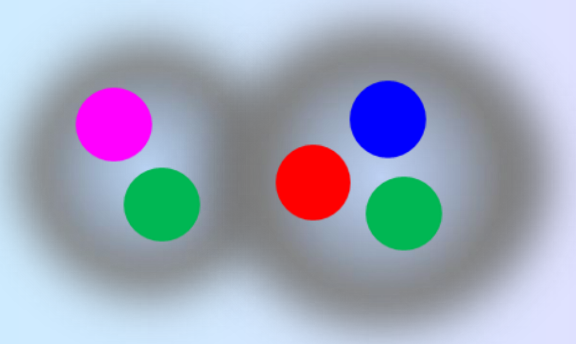
J. Esmaili et al: $\pi\Sigma$ IM Spec. of Stopped K^- on ^{4}He

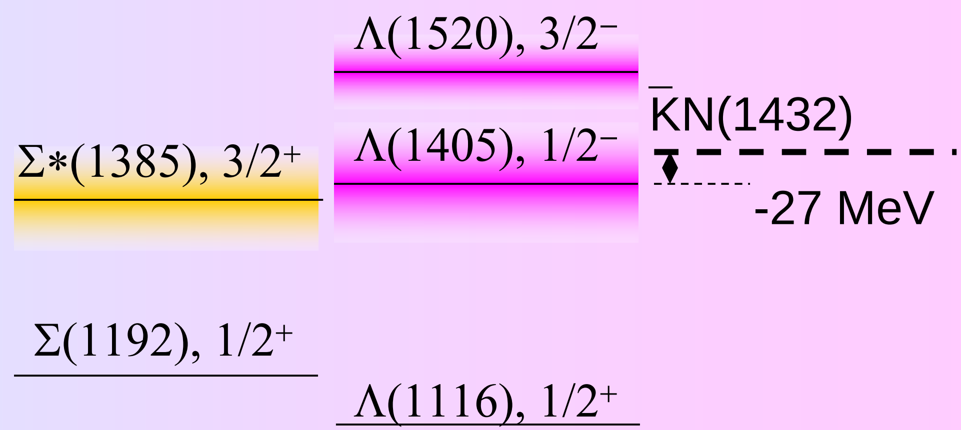


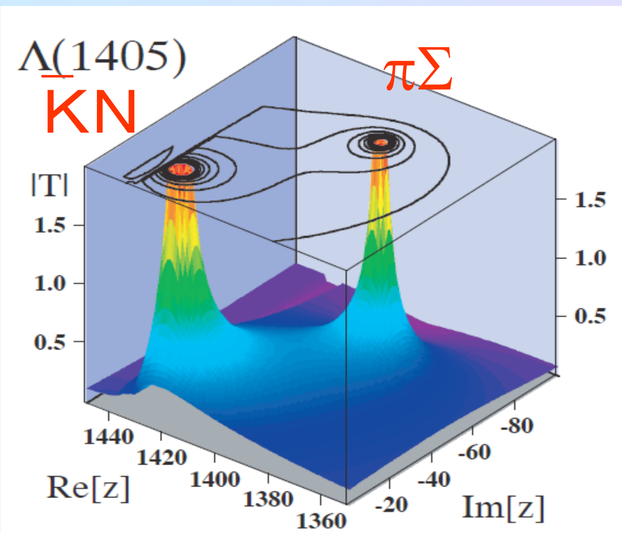
R.H. Dalitz et al: $\pi\Sigma$ IM Spec. in $K^-p \rightarrow \pi\pi\Sigma$ w/ M-matrix

Λ(1405) : Double pole?

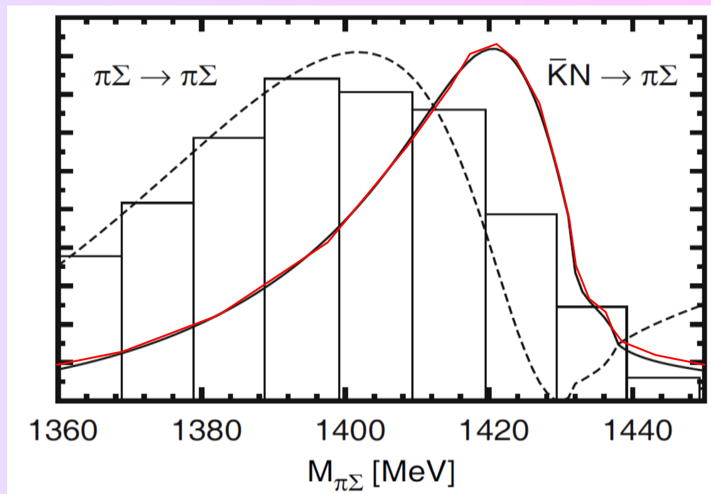
$J^P = \frac{1}{2}^-$, $I = 0$, $M_{\Lambda(1405)} < M_{\bar{K}N}$, lightest in neg. parity baryons







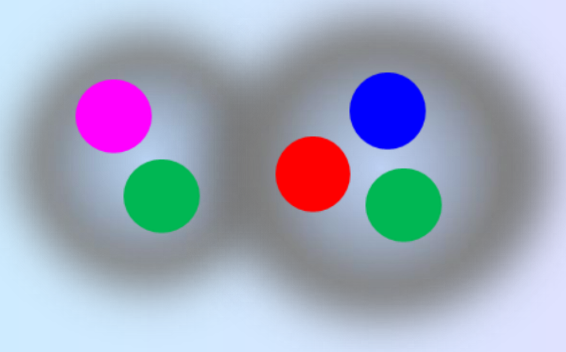
ChU model, T. Hyodo

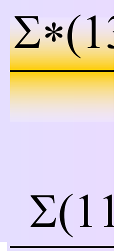


Chiral Unitary Model:
D. Jido et al., NPA725(03)181

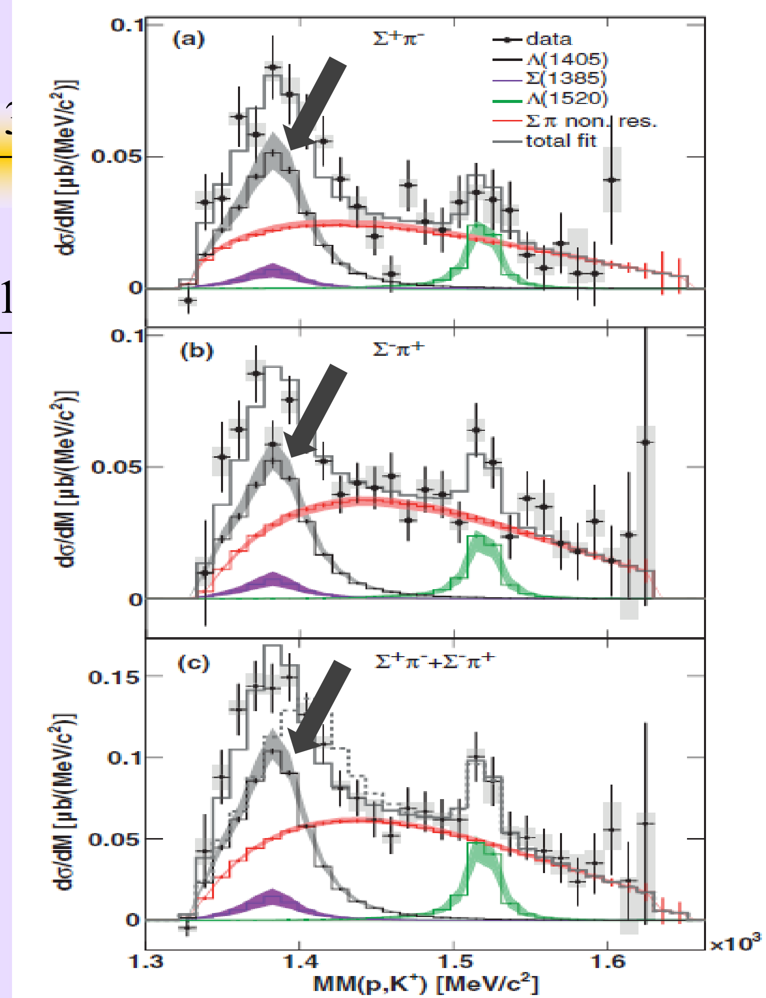
$\Lambda(1405)$: Controversial Experimental Data?

$J^P = \frac{1}{2}^-$, $I = 0$, $M_{\Lambda(1405)} < M_{\bar{K}N}$, lightest in neg. parity baryons

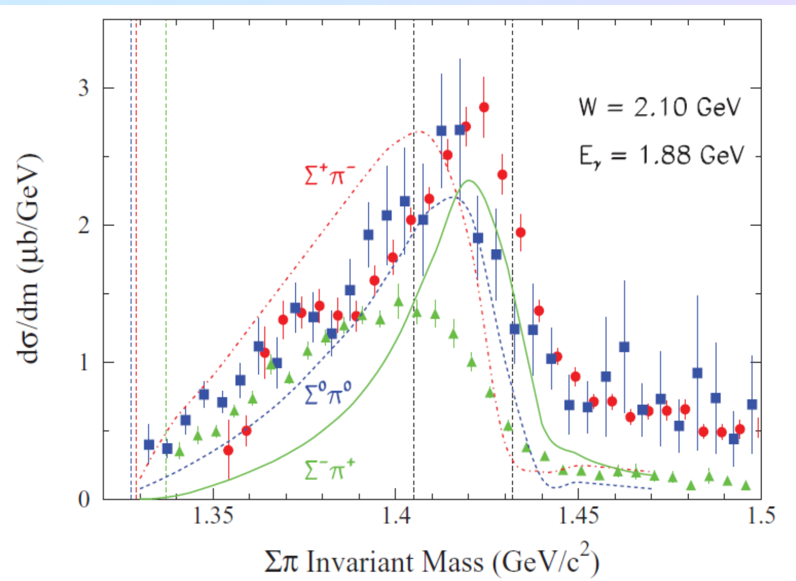




$pp \to K^+ p \pi^- \Sigma^+, K^+ p \pi^+ \Sigma^-$



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



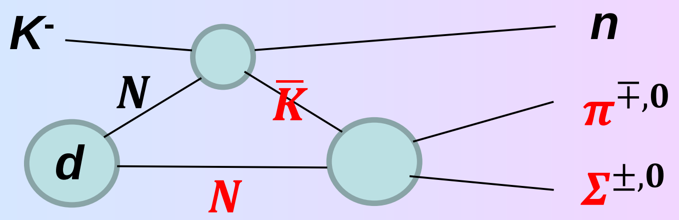
CLAS collaboration: PRC87, 035206

HADES collaboration: PRC87, 025201

E31:

- aims to conclude if $\Lambda(1405)$ appears at ~1405 MeV or ~1420 MeV in a $\bar{K}N \rightarrow \pi\Sigma$ scattering.
  - ✓ This provides basic information on a longstanding argument on a deeply bound kaonic nuclei.

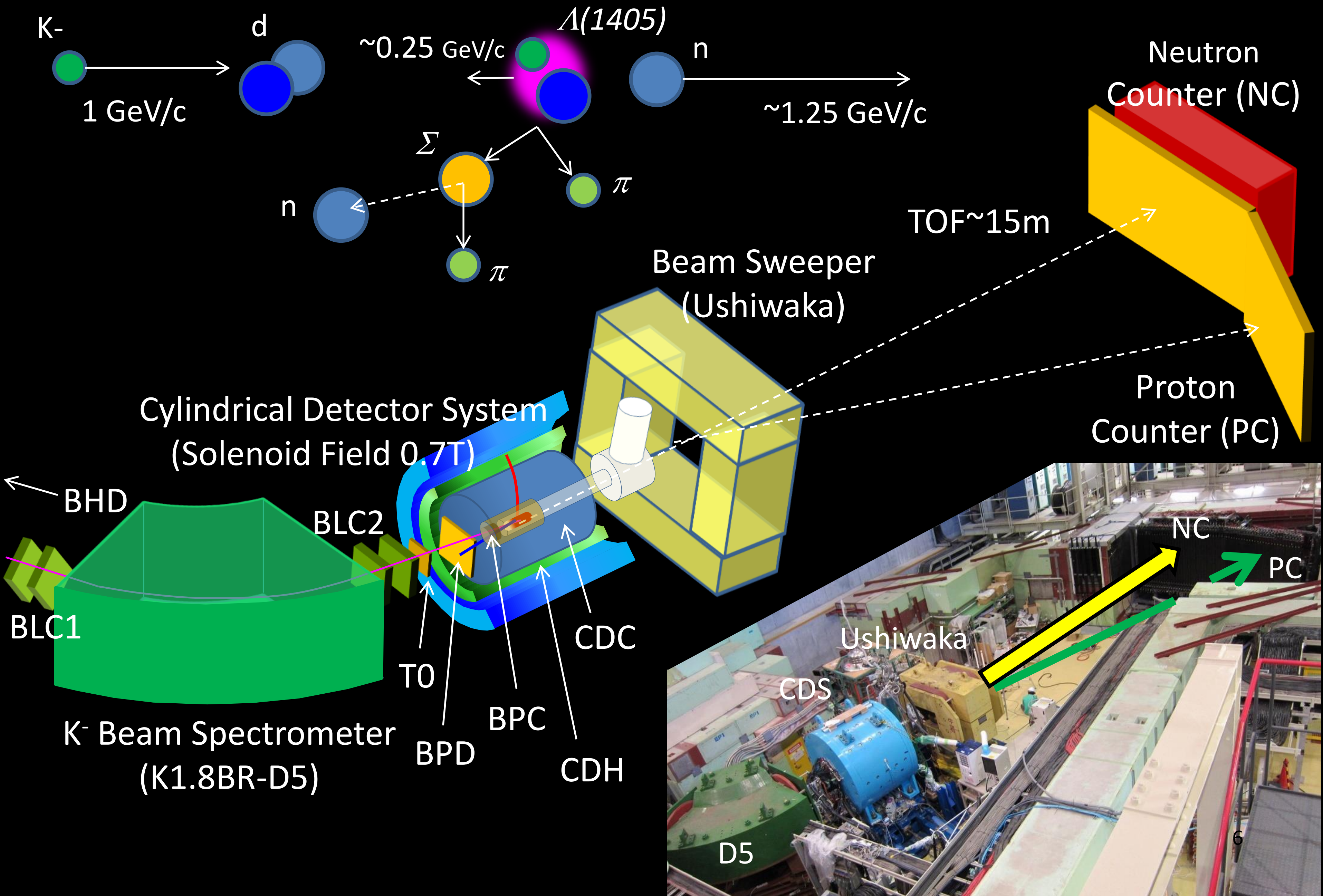
- employs $d(K^-,n)\pi\Sigma$ reactions at θ_n~0 deg., which is expected to enhance an S-wave $\bar{K}N \rightarrow \pi\Sigma$ scattering even below the $\bar{K}N$ threshold to form $\Lambda(1405)$.



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

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

Experimental Setup for E31

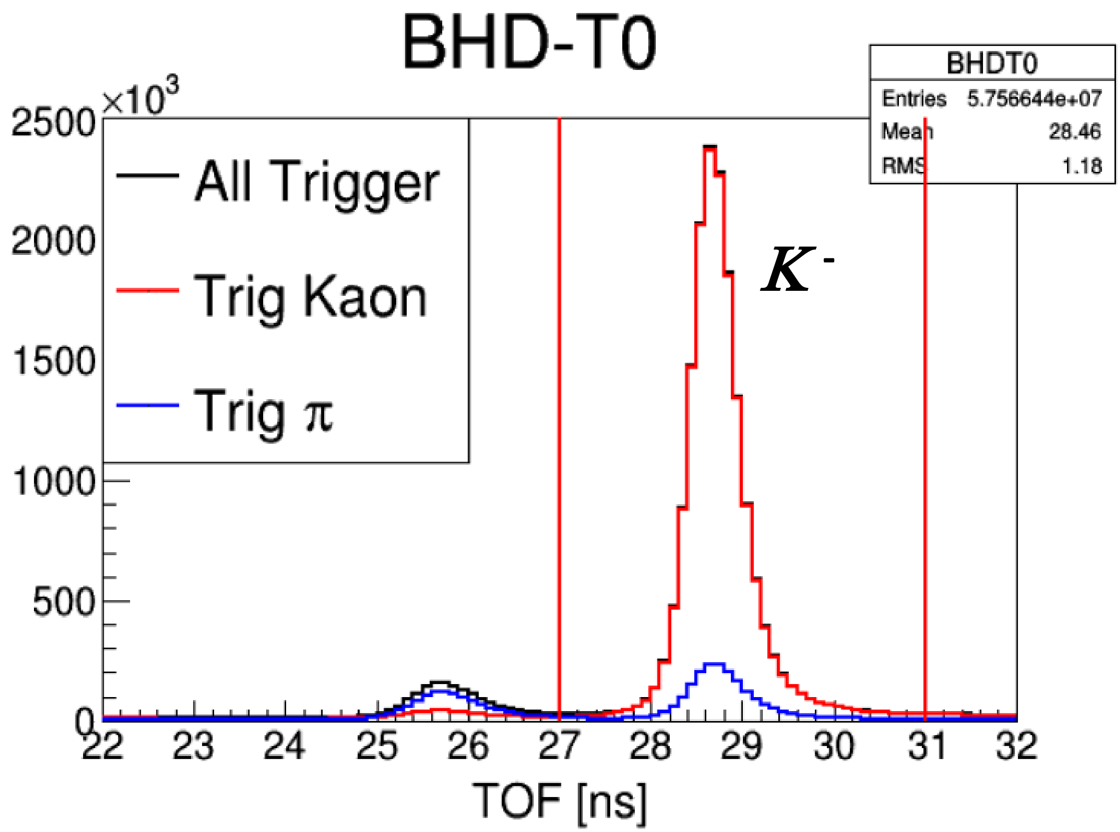


Run 62 (April-May, 2015)

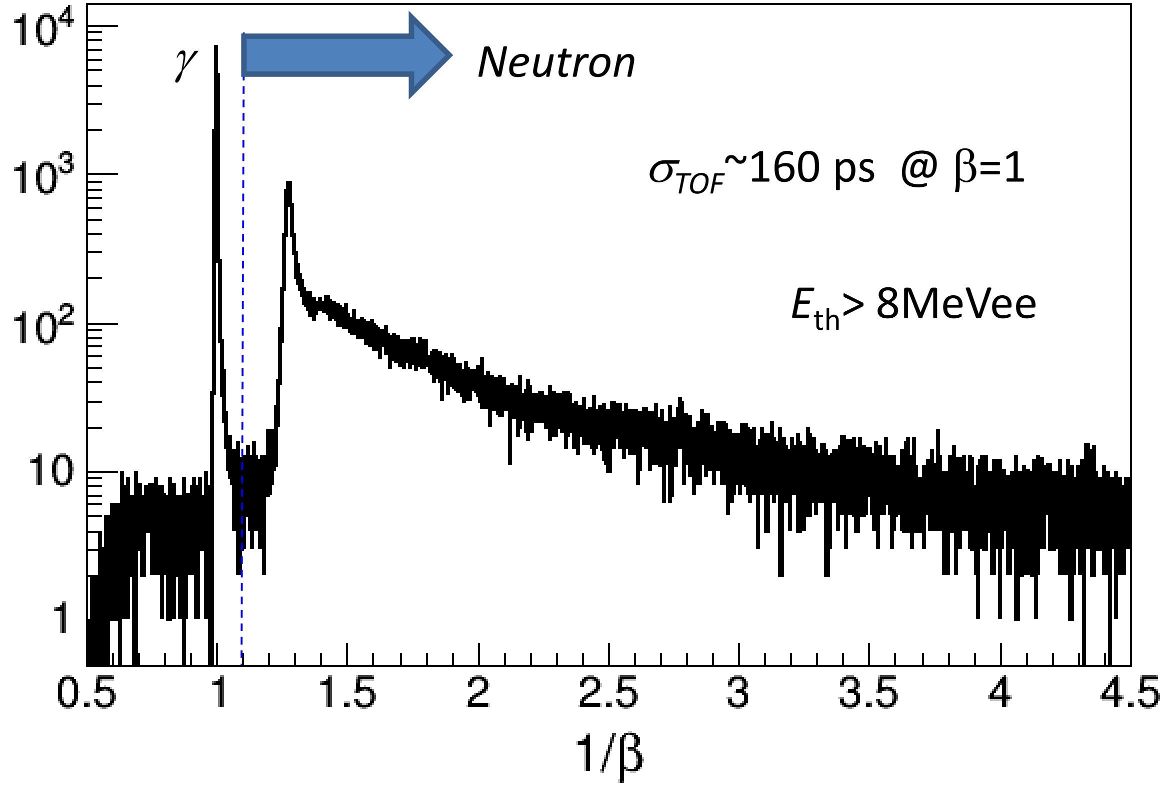
- Beam time for E15 was allocated in order to take calibration data of elementary $K^{-}p \rightarrow K^{0}n$ and $K^{-}n \rightarrow K^{-}n$ reactions using H_2 and D_2 targets.
- This provided a good opportunity to evaluate feasibility for E31.
- We demonstrate the $d(K^{-},n)X_{\pi\Sigma}$ spectrum, based on the D_2 data for 2.2 days (58 kW*days).

Event selection for the (K^-, n) reaction

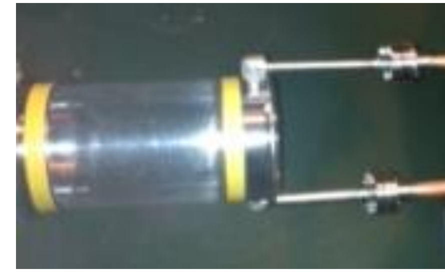
Kaon Beam Selection

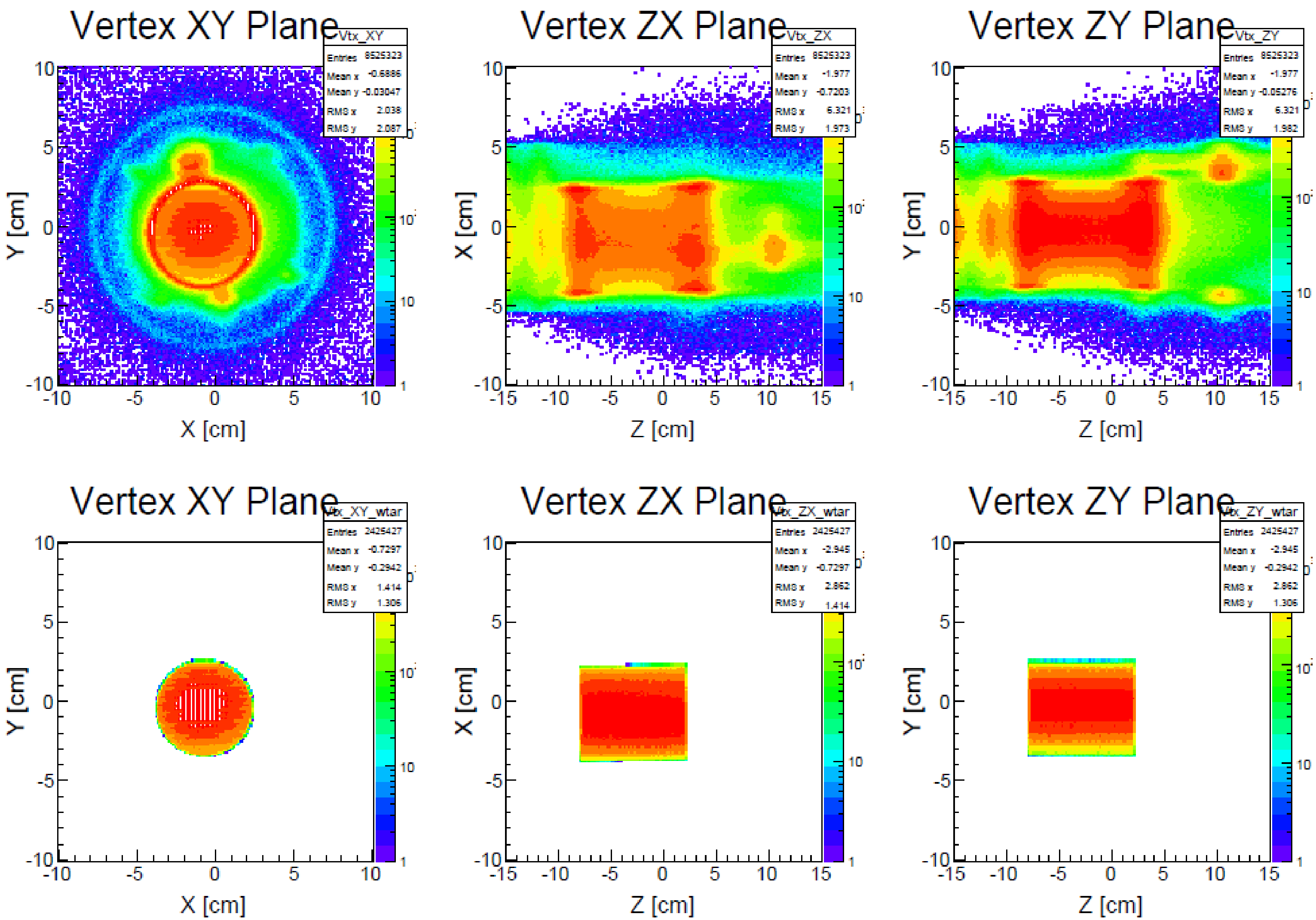


Neutron 1/β spectrum

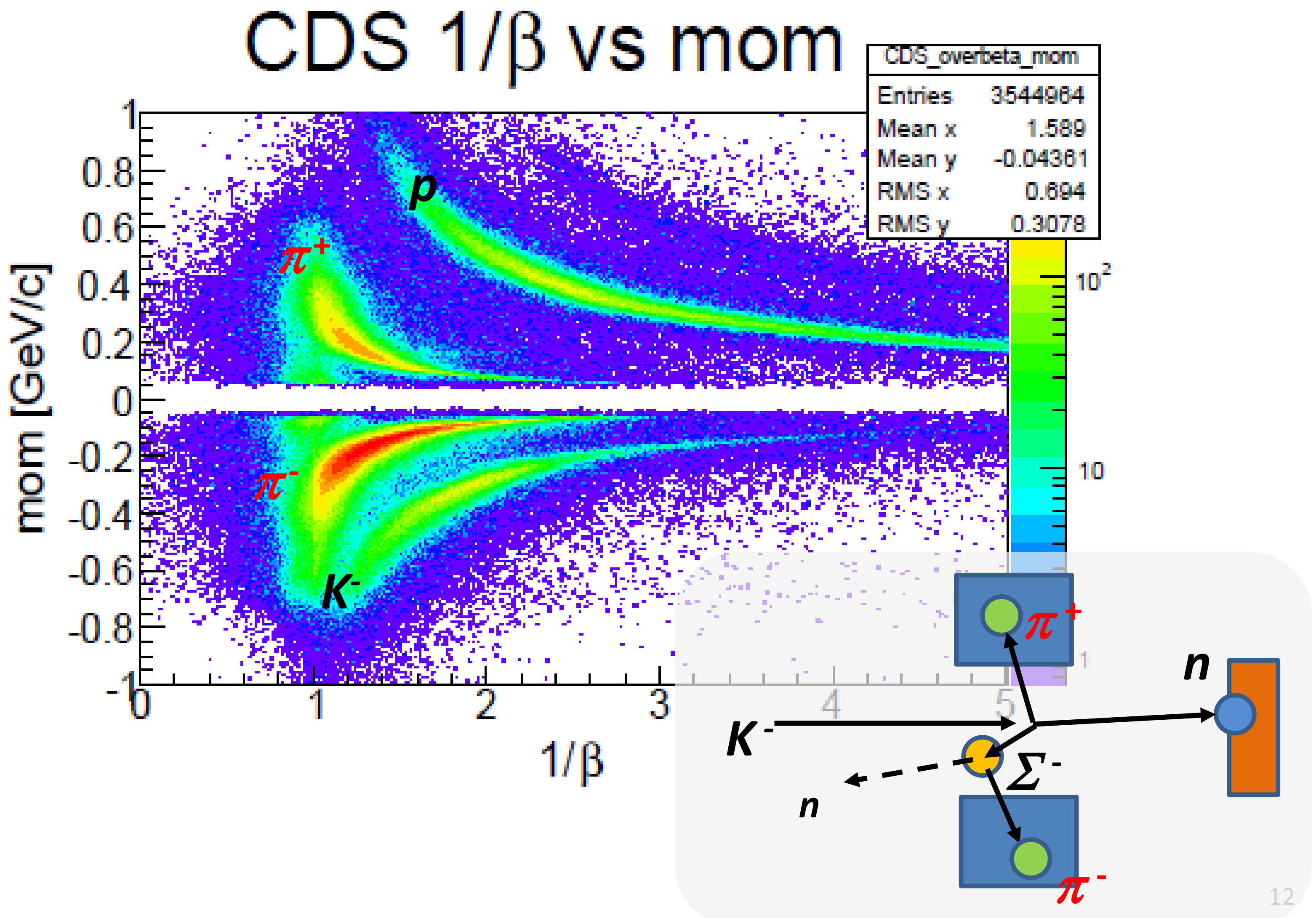


Reaction Vertex Selection

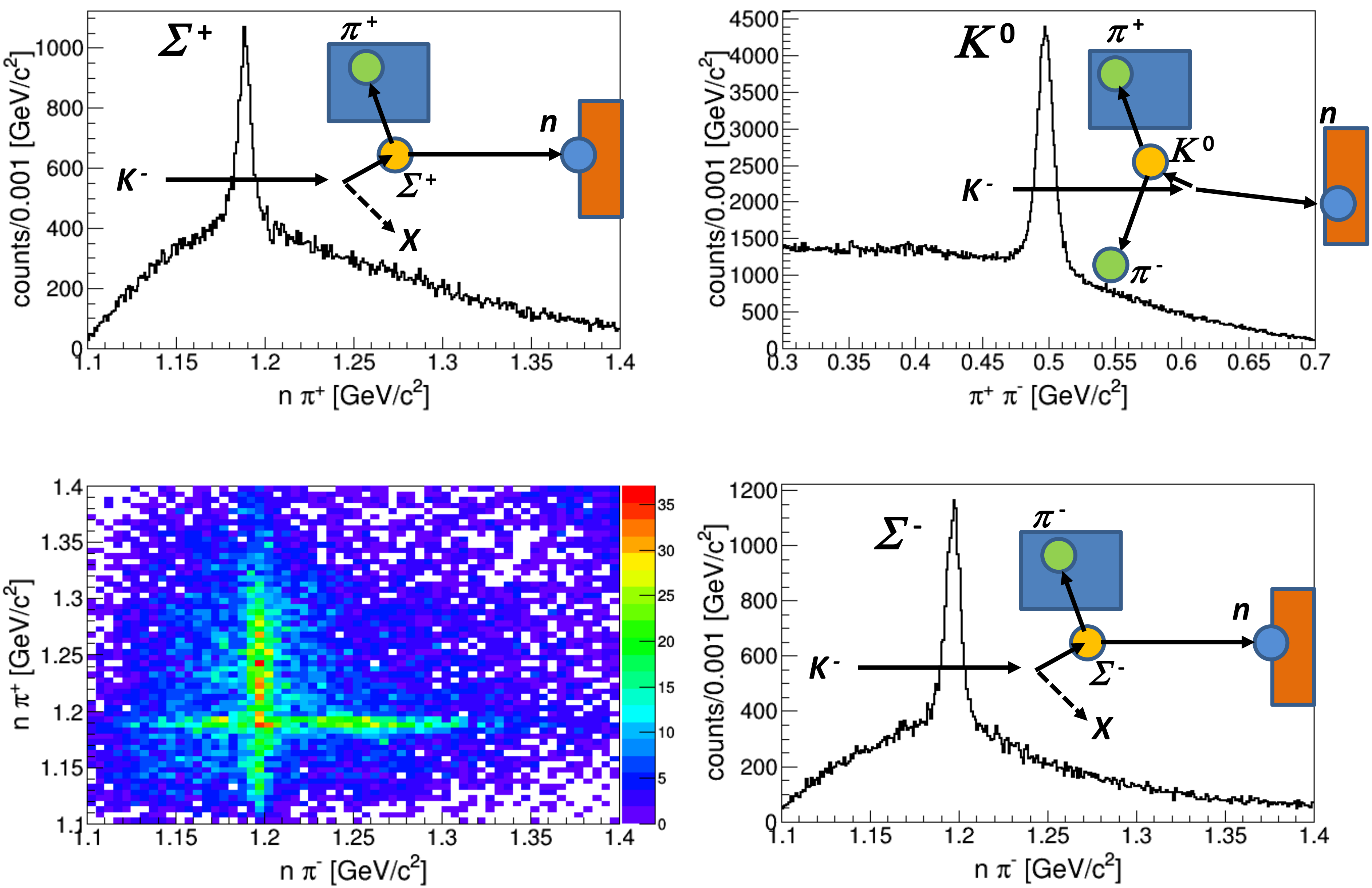




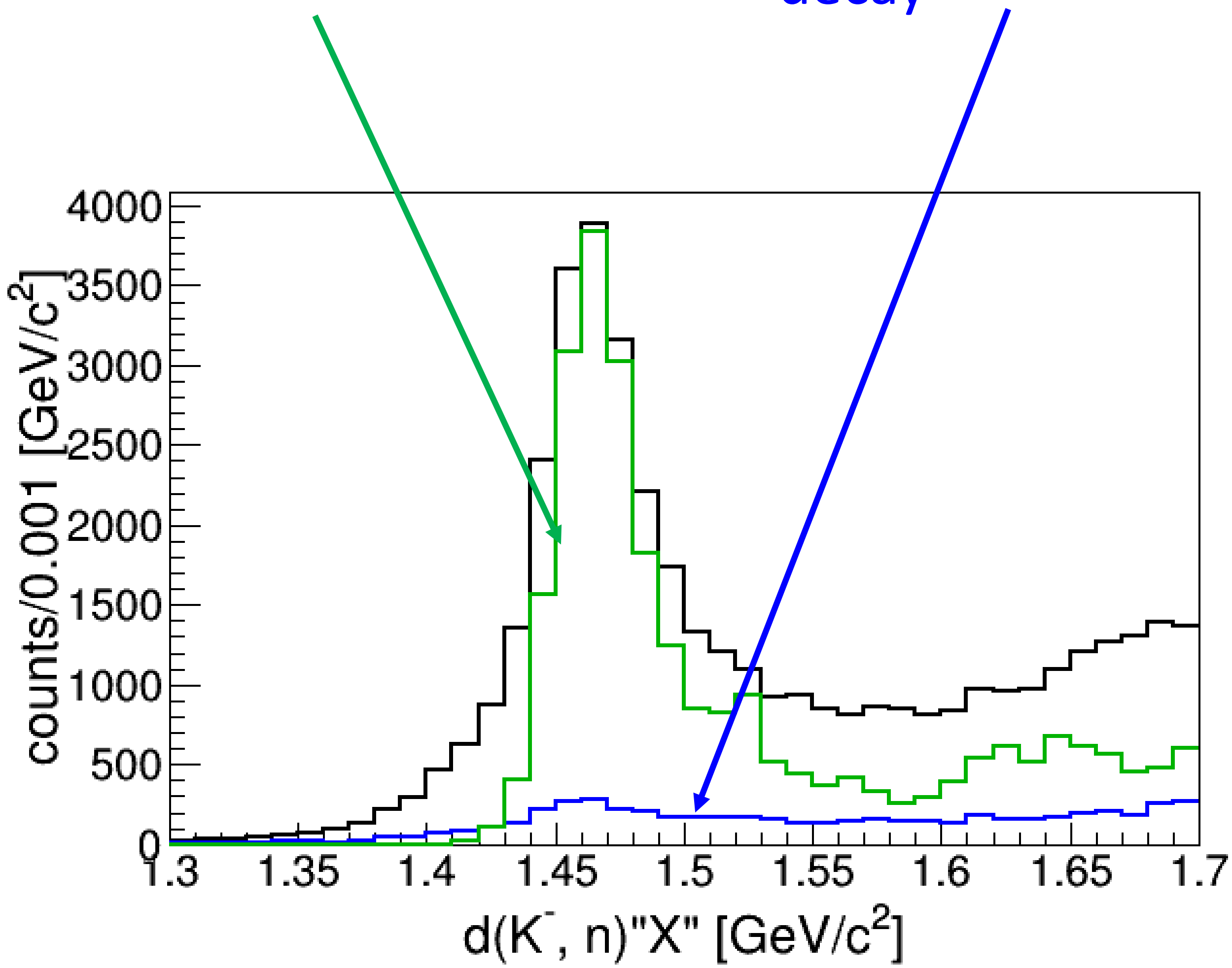
π^+ and π^- detection in CDS



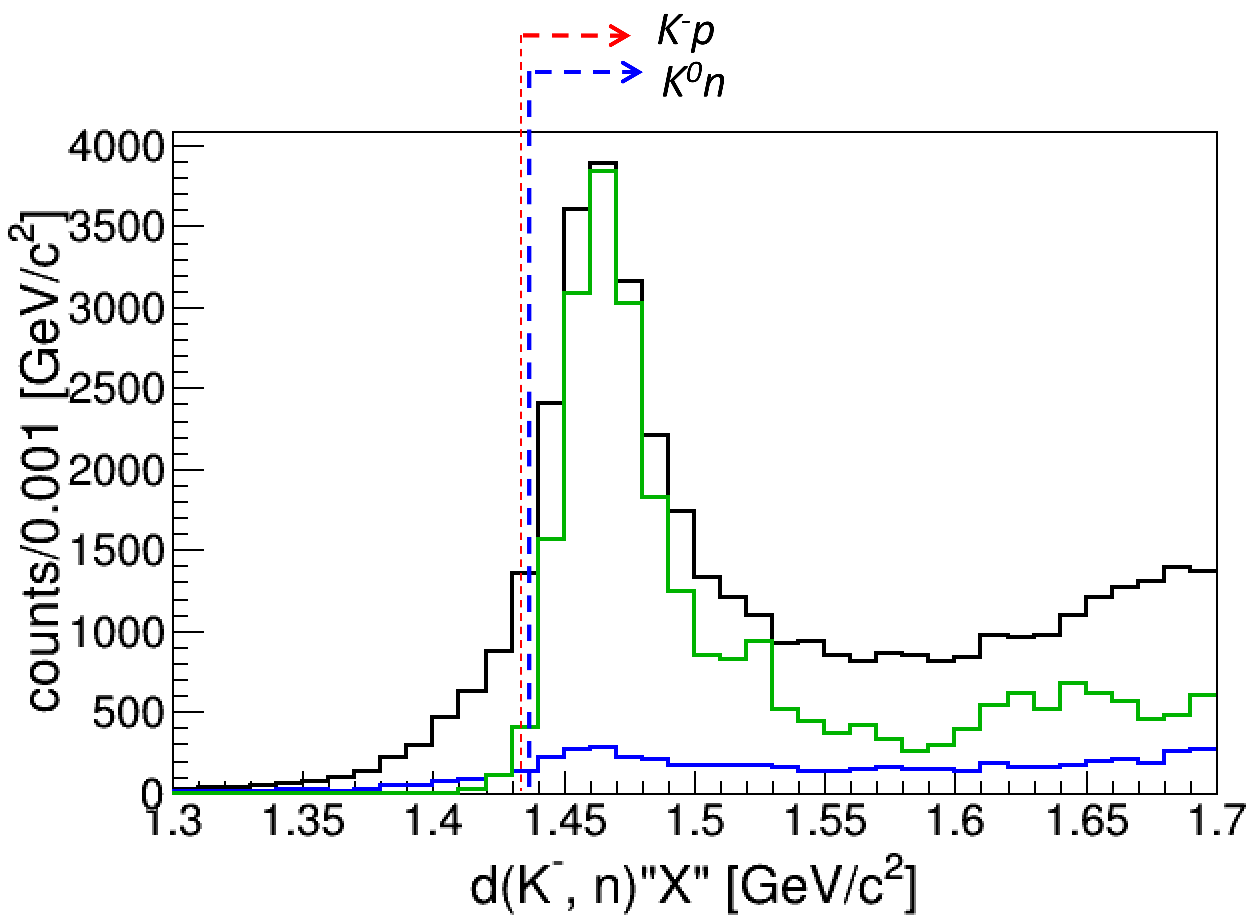
K^0 and Σ_{decay} reconstructions



Semi-inclusive d(K^-,*n*)*X* spectra, K^0 selected (x10) , and Σ_{decay} selected (x10)

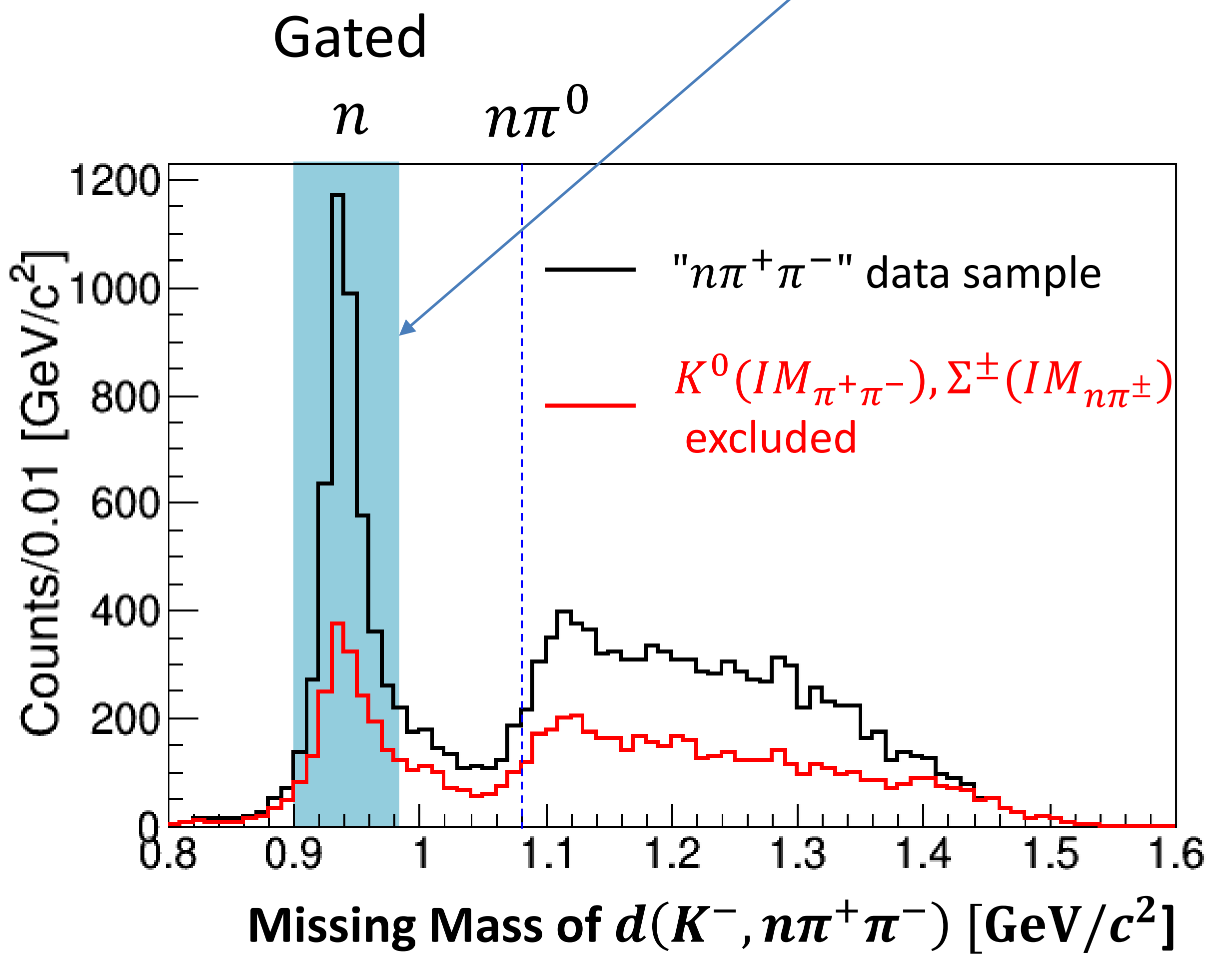


Semi-inclusive d(K^-,*n*)*X* spectra, K^0 selected (x10) , and Σ_{decay} selected (x10)

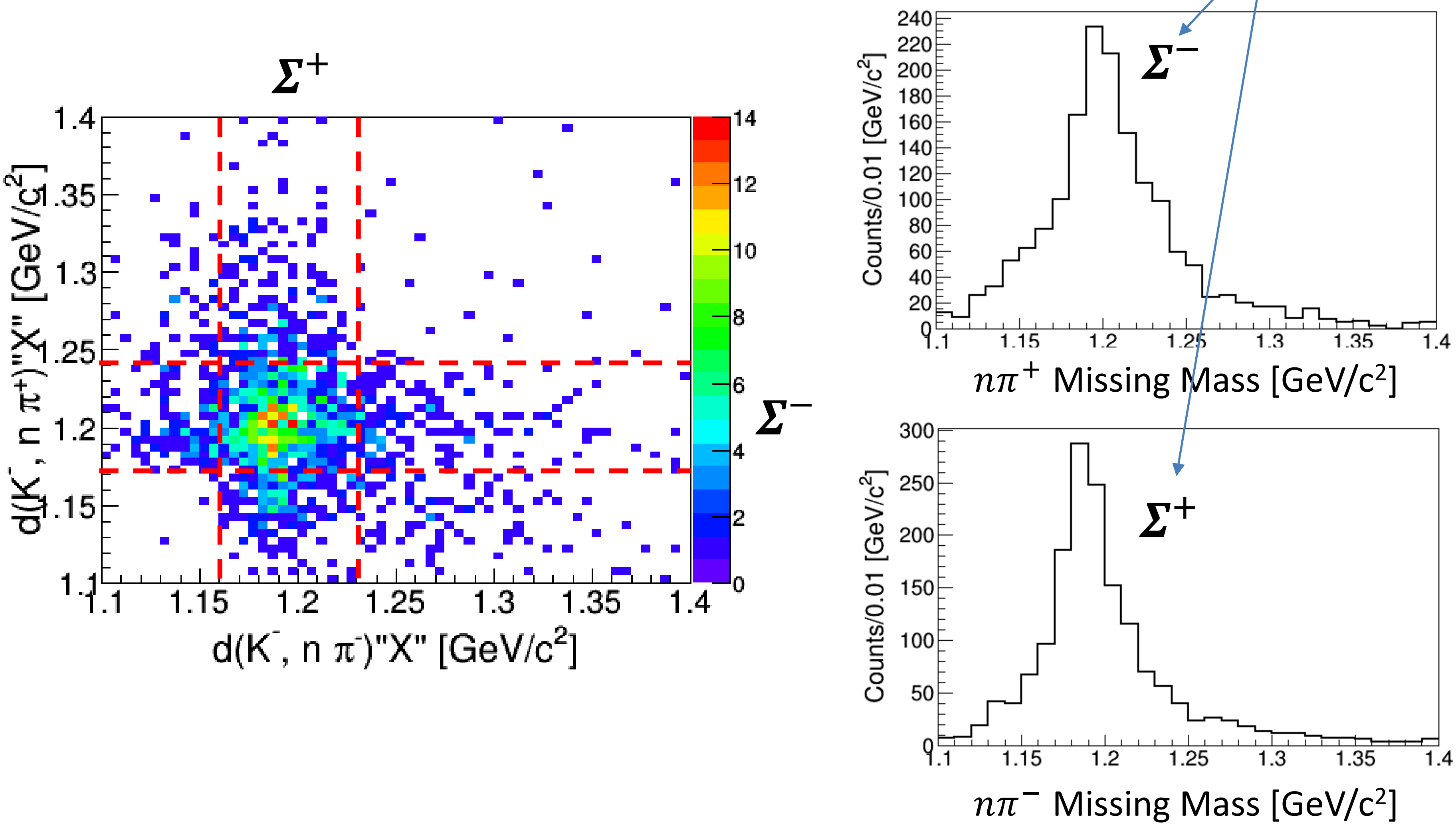


Event selection for exclusive $d(K^{-},n)\pi^{\pm}\Sigma^{\mp}$ reactions

$$d(K^-, n\pi^+\pi^-)n_{missing}$$



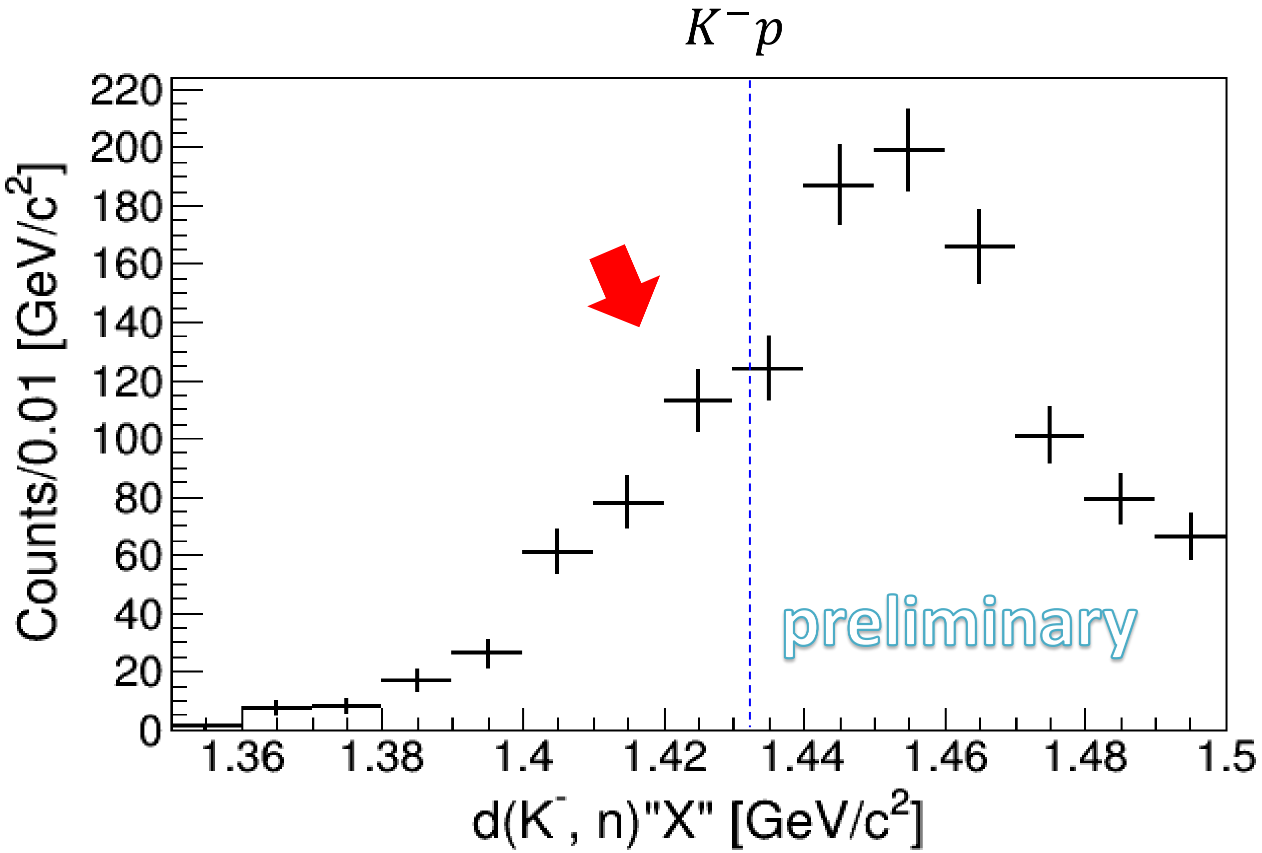
Missing $\Sigma^{\mp}$ in $d(K^-, n\pi^{\pm})X_{\pi^{\mp}n}$



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

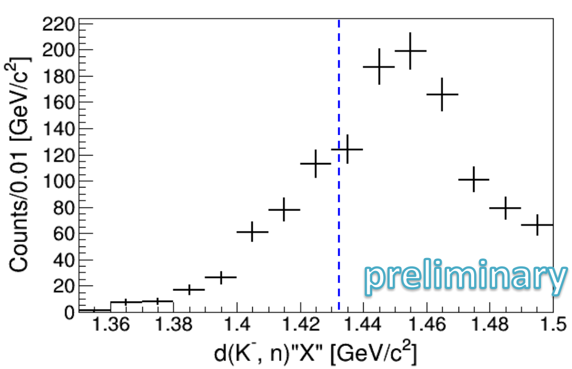
$d(K^-, n)X_{\pi^\pm\Sigma^\mp}$ Spectrum

Missing mass spectrum of the $d(K^-, n)X_{\pi^\pm\Sigma^\mp}$ reaction
K^0 and Σ_{decay} events have been excluded.



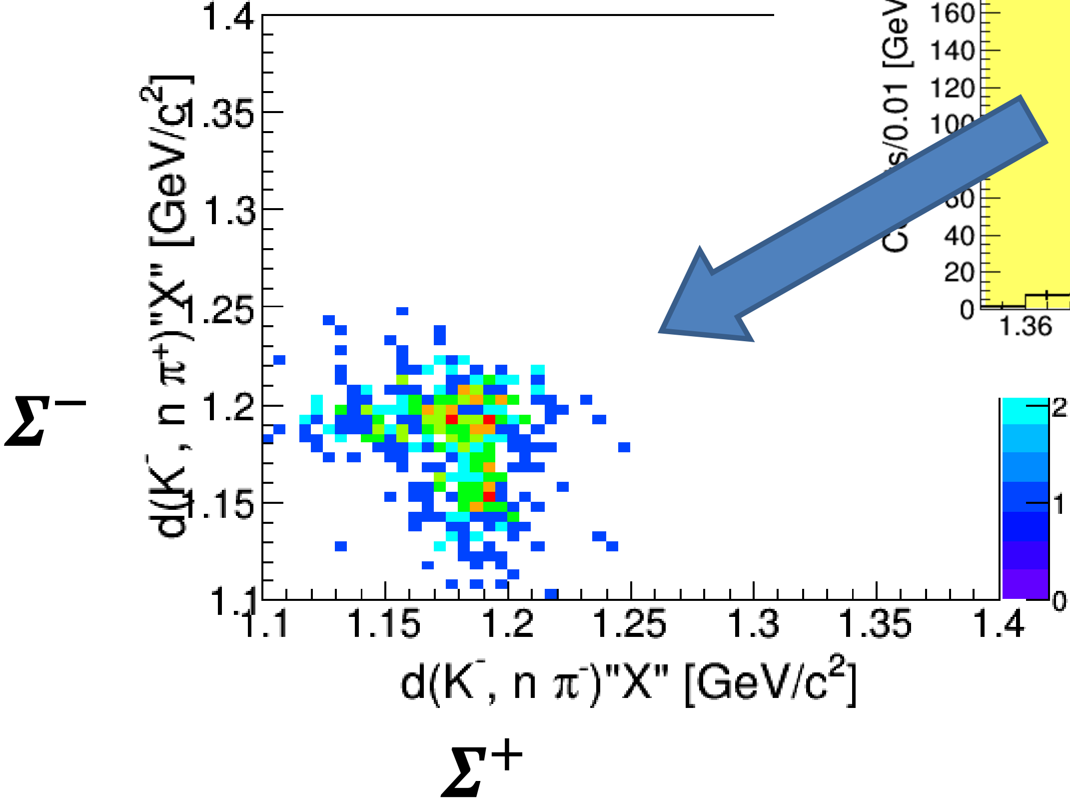
Remarks

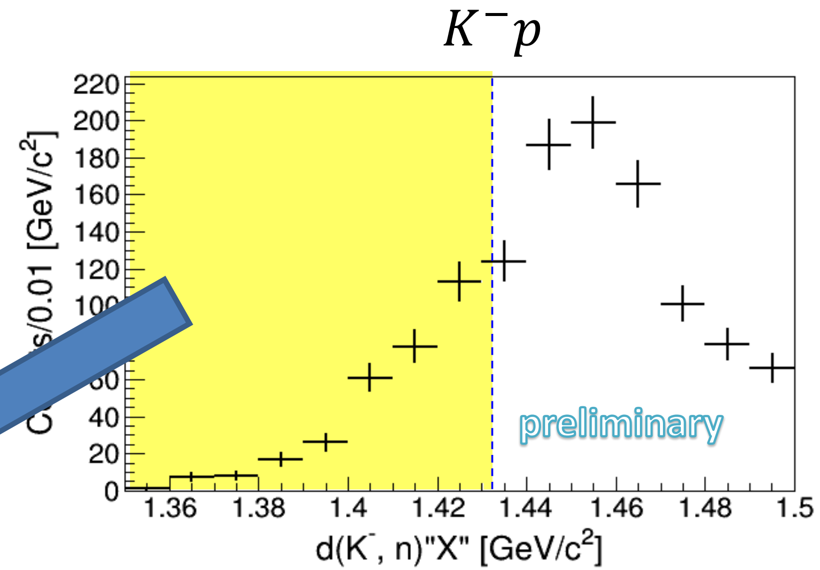
- The $d(K^{-},n)X_{\pi^{\pm}\Sigma^{\mp}}$ spectrum at θ_n=0 deg for the first time.
  - provides a $\bar{K}N \rightarrow \pi\Sigma$ scattering data below the $\bar{K}N$ threshold.
- A bump structure at ~1420 MeV has been observed.
  - To be identify $\pi^{\pm}\Sigma^{\mp}$ separately
  - Analysis of $\pi^{0}\Sigma^{0}$ in progress



$\pi^{\pm}\Sigma^{\mp}$ mode ID

Need more statistics…





Request

- We request beam time allocation at the earliest occasion.
  - We could accumulate ~19 times more statistics for the proposed beam time of 154 kW*week (~27 days, 40 kW).
- We expect:
  - $\pi^{\pm}\Sigma^{\mp}$ mode ID separately for >5 days(*)
  - $\pi^{0}\Sigma^{0}$ yield to be confirmed for >10 days(*)
  - Line shape for the $\pi^{0}\Sigma^{0}$ mode for >20 days(*)

(*) A primary beam power of 40 kW is assumed.
BT allocation should be multiply 1.1 for beam availability and add 1 day for start-up.

Backup

Beam Time Request for E31

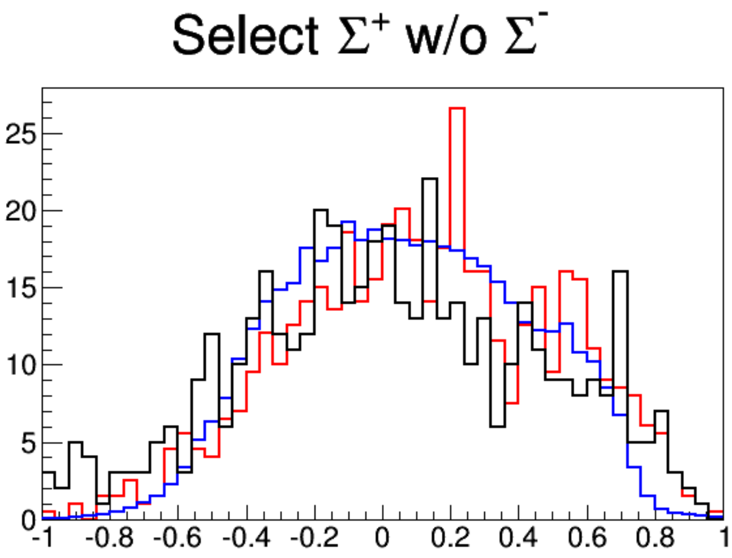
※E31 requests beam time allocation at the earliest opportunity, even if it is intermittently because E31 is always ready to run when the D_2 TGT is placed.

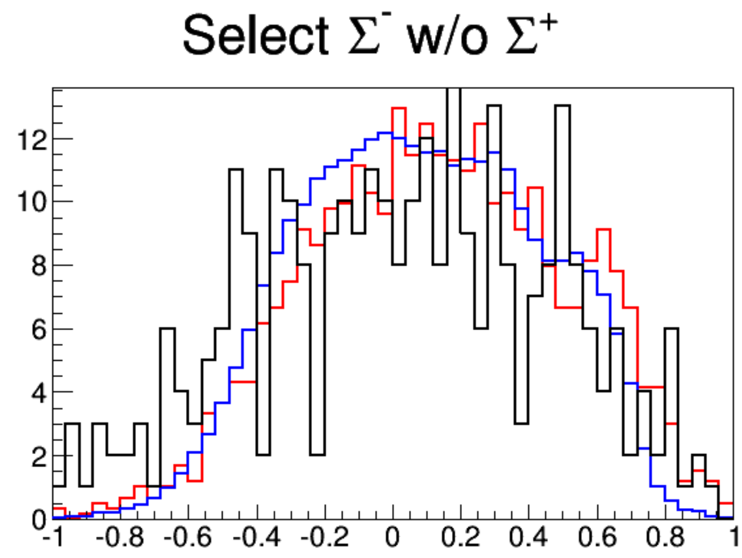
	Power (Beam Time)*	Yield (1.4~1.43 GeV/c^2)		Experimental Achievement expected
		$\pi^{\pm}\Sigma^{\mp}$ mode	$\pi^0\Sigma^0$ mode	
May, 2015 (run#62)	26.5 kW 2.2 days	250	TBA	180 was expected in the $\pi^{\pm}\Sigma^{\mp}$ modes
Autumn, 2015 Case I	40 kW 5 days	870	30	$\pi^{\pm}\Sigma^{\mp}$ mode ID separately
Autumn, 2015~ Case II	40 kW 10 days	1700	60	Yield of the $\pi^0\Sigma^0$ mode be confirmed
Autumn, 2015~ Case III	40 kW 20 days	3400	130	$\pi^0\Sigma^0$ mode line shape?
Autumn, 2015~ Case IV	40 kW 27 days	4700	180	Proposed beam time

* BT allocation should be multiply 1.1 for beam availability and add 1 day for start-up.

Angular Distribution/Acceptance

d(K^-, n $\pi^{-/+}$) ("$\Sigma^{+/-}$") cosθ in $\pi\Sigma$ CM Frame





Black : Data

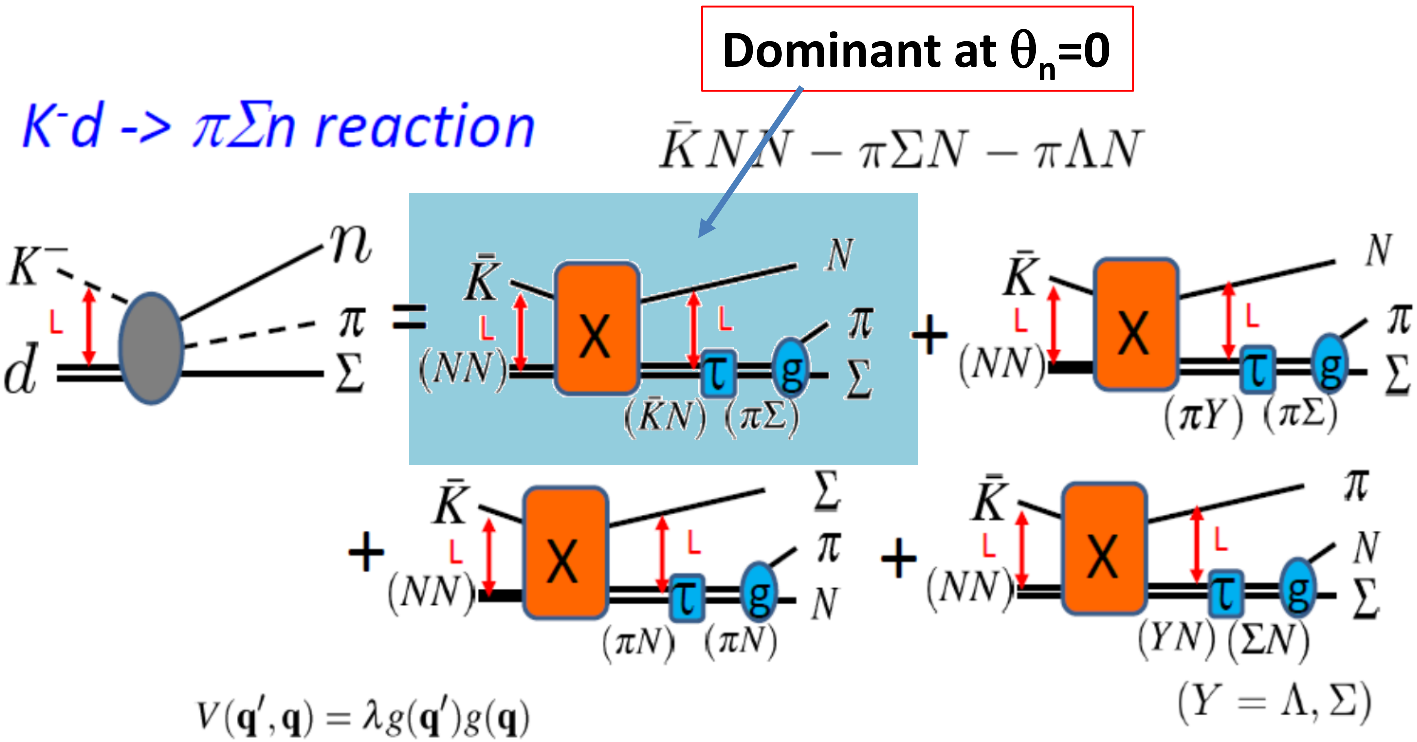
Red : MC Brit-Wigner (1.405 GeV/c^2)

Blue: MC Flat (1.34~1.60 GeV/c^2)

Faddeev Cal. (AGS)

S. Ohnishi, Y. Ikeda, T. Hyodo, E. Hiyama, and W. Weise

$K^-d \to \pi\Sigma n$ reaction



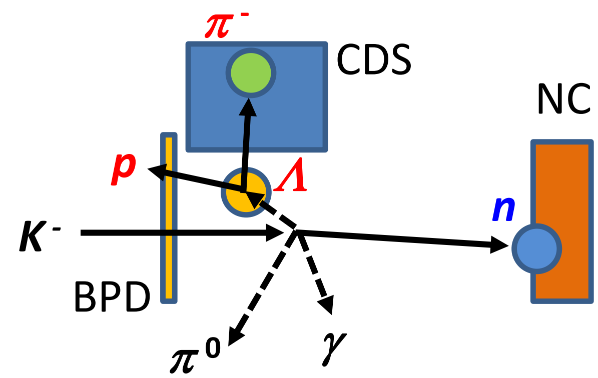
$$V(\mathbf{q}', \mathbf{q}) = \lambda g(\mathbf{q}') g(\mathbf{q})$$

$$t_i(\mathbf{q}', \mathbf{q}, W - E_i) = g(\mathbf{q}') \tau(W - E_i) g(\mathbf{q})$$

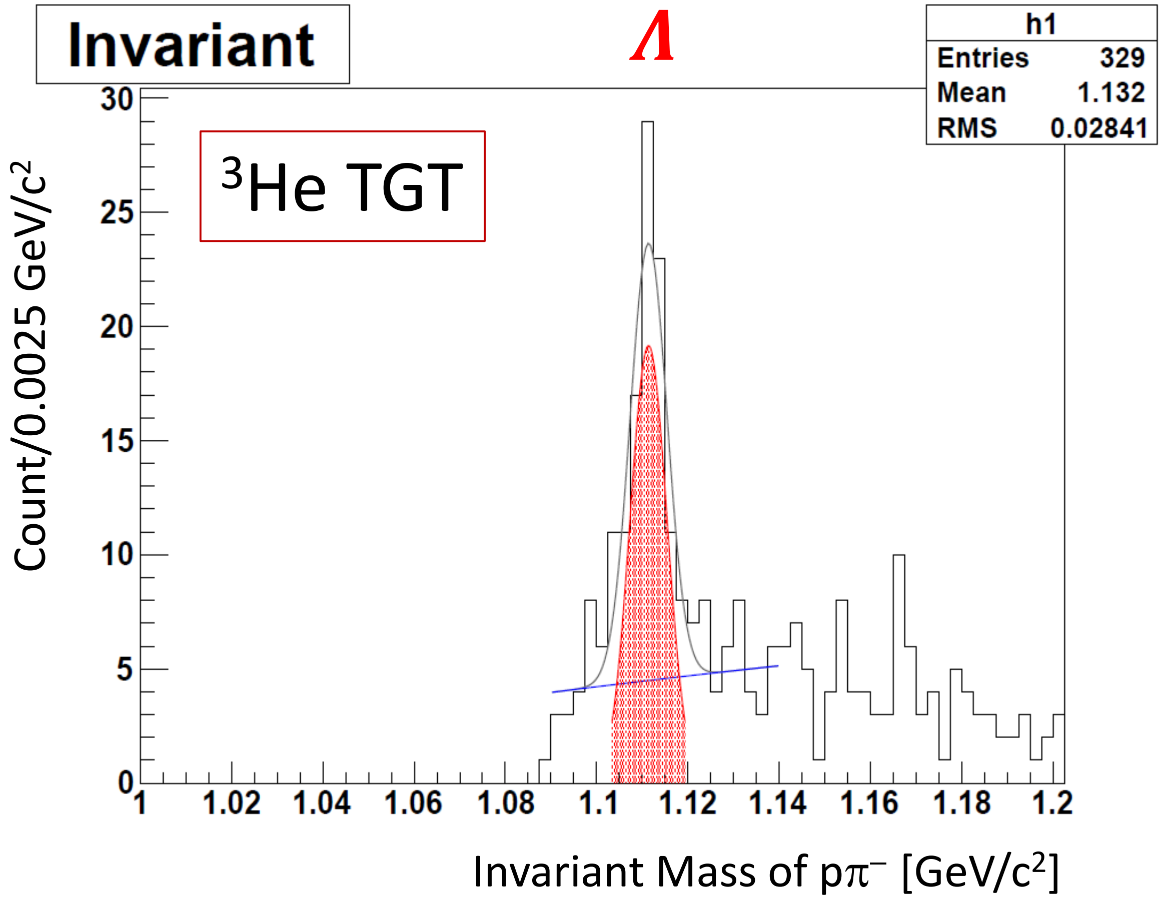
Alt-Grassberger-Sandhas(AGS) eq. : X_{ij} ; quasi two-body amplitude

$$X_{i,j}(\mathbf{p}_i, \mathbf{p}_j, W) = (1 - \delta_{i,j}) Z_{i,j}(\mathbf{p}_i, \mathbf{p}_j, W) + \sum_{n \neq i} \int d\mathbf{p}_n Z_{i,n}(\mathbf{p}_i, \mathbf{p}_n, W) \tau_n(W - E_n) X_{n,j}(\mathbf{p}_n, \mathbf{p}_j, W)$$

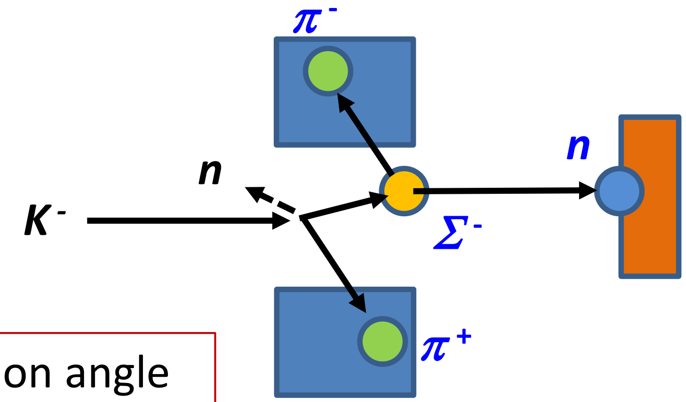
$\pi^0\Sigma^0$ mode ID (in progress)



- BPD(p)+CDS(π^-)



$\pi^{\pm}\Sigma^{\mp}$ invariant mass in $d\,(K^{-}, \pi^{\pm}\Sigma^{\mp})n_{missing}$



- Different analysis option covering wide Y* production angle is also available.