23nd J-PARC PAC Jan 11-13, 2017

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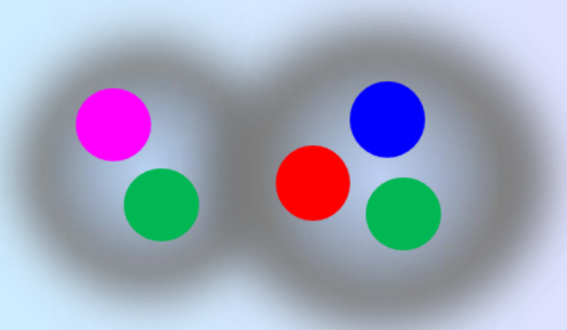
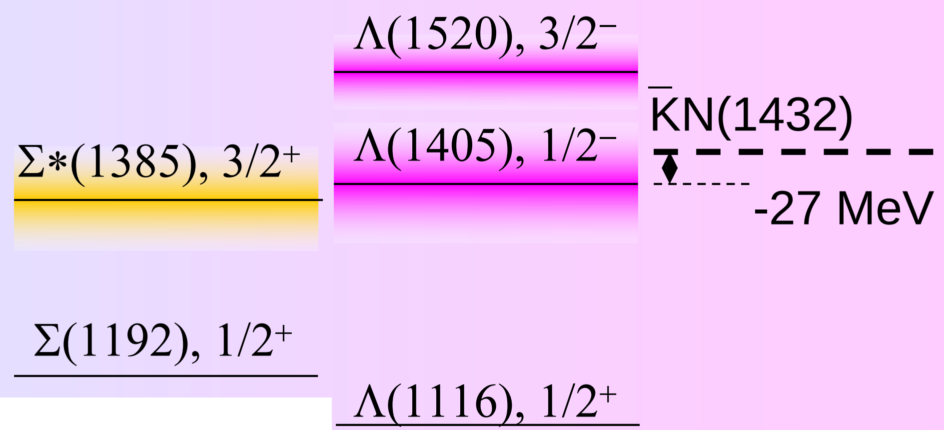
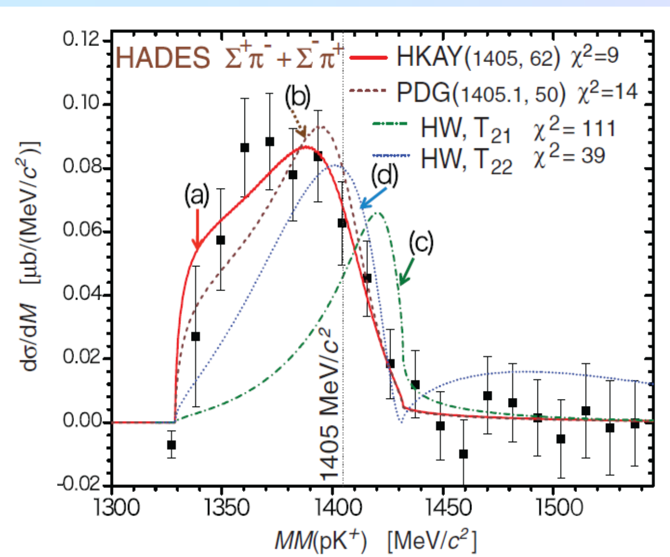
$\Lambda(1405)$: $1405.1^{+1.3}_{-0.9}$ MeV (PDG)

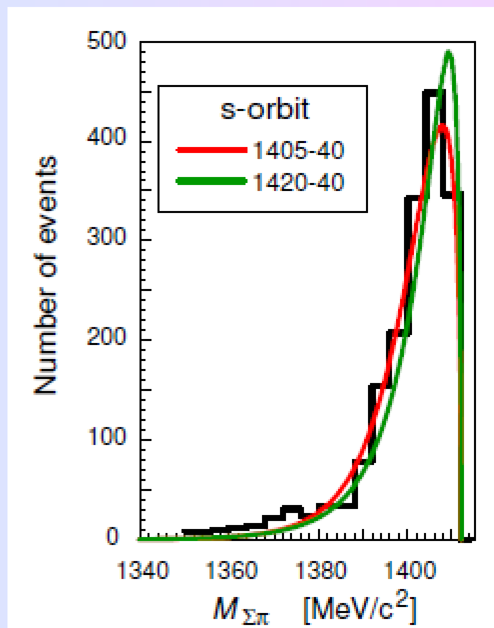
$J^P = \frac{1}{2}^-$, $I = 0$, $M_{\Lambda(1405)} < M_{\bar{K}N}$, lightest in neg. parity baryons



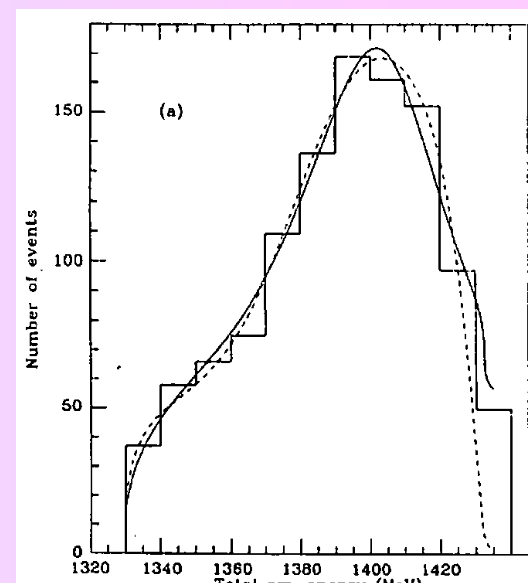




M. Hassanvand et al: $\pi\Sigma$ IM Spec. of $pp \rightarrow K^+\pi\Sigma$



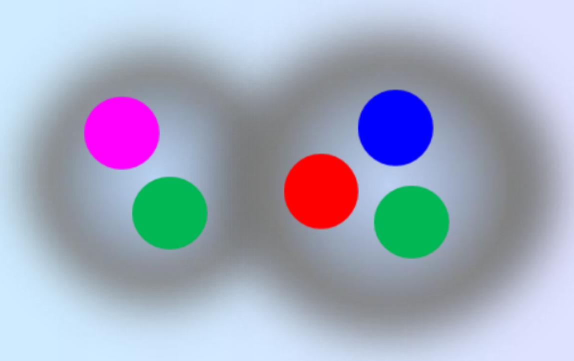
J. Esmaili et al: $\pi\Sigma$ IM Spec. of Stopped K^- on ^{4}He

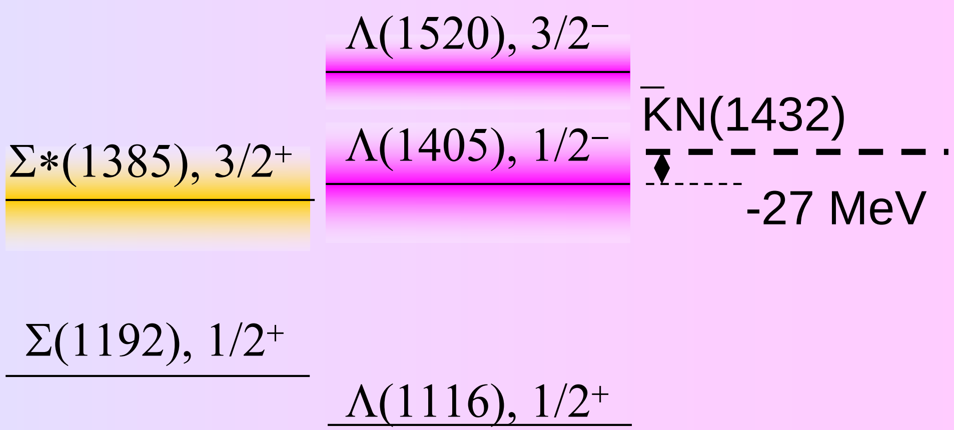


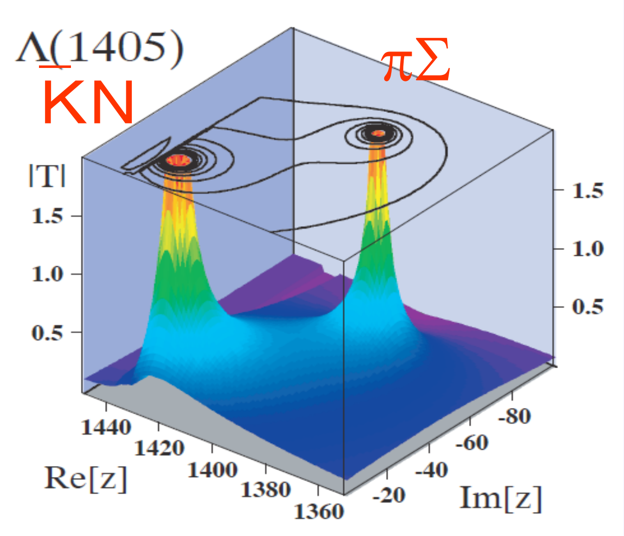
R.H. Dalitz et al: $\pi\Sigma$ IM Spec. in K-$p \rightarrow \pi\pi\Sigma$ w/ M-matrix

Λ(1405) : Double pole?

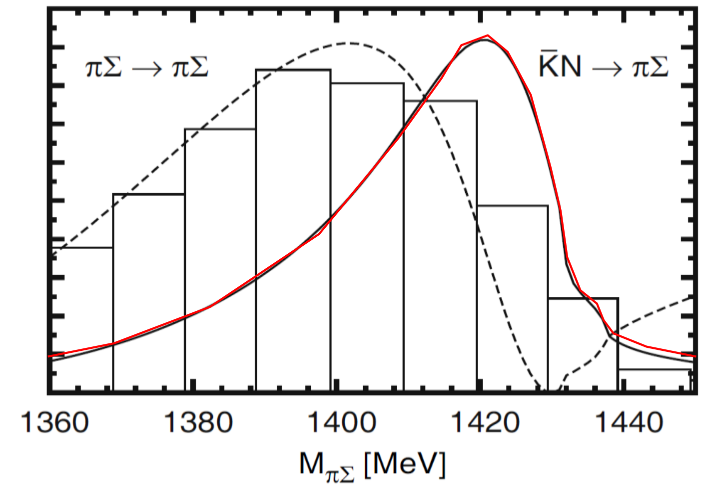
$J^P = \frac{1}{2}^-$, $I = 0$, $M_{\Lambda(1405)} < M_{\bar{K}N}$, lightest in neg. parity baryons







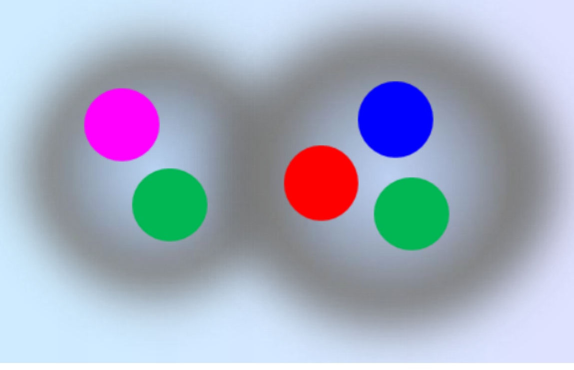
ChU model, T. Hyodo

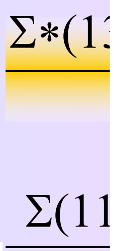


Chiral Unitary Model:
D. Jido et al., NPA725(03)181

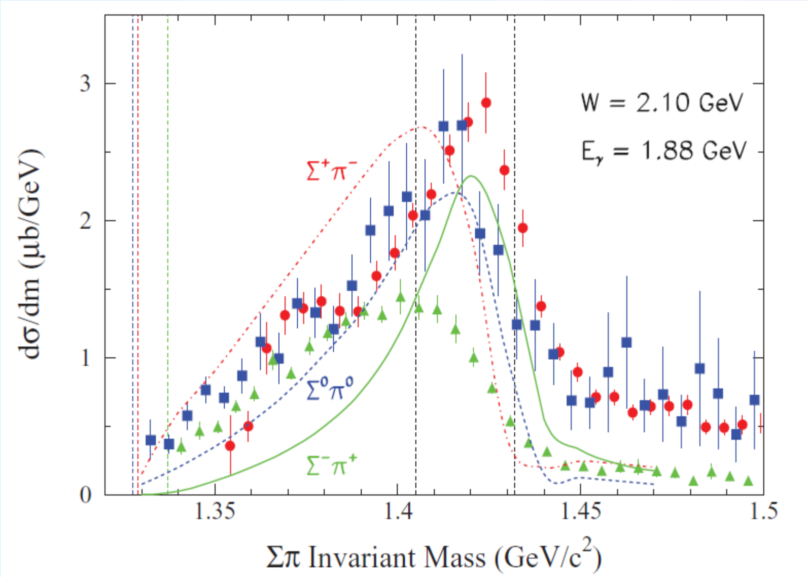
Λ(1405) : Controversial Experimental Data?

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



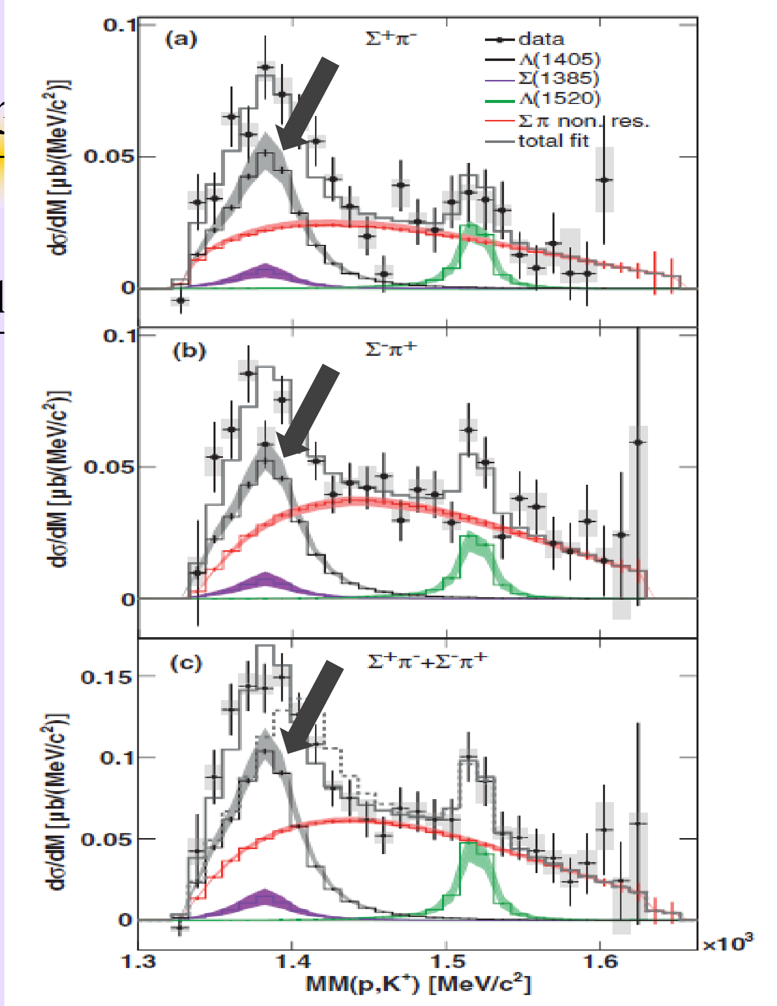


$\gamma p \rightarrow K^+\pi^-\Sigma^+, K^+\pi^0\Sigma^0, K^+\pi^+\Sigma^-$



CLAS collaboration: PRC87, 035206

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



HADES collaboration: PRC87, 025201

$\Lambda(1405)$: $1405.1^{+1.3}_{-1.0}$ MeV (PDG Part. List'gs)

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

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

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

Pole Structure of the Lambda(1405) Region

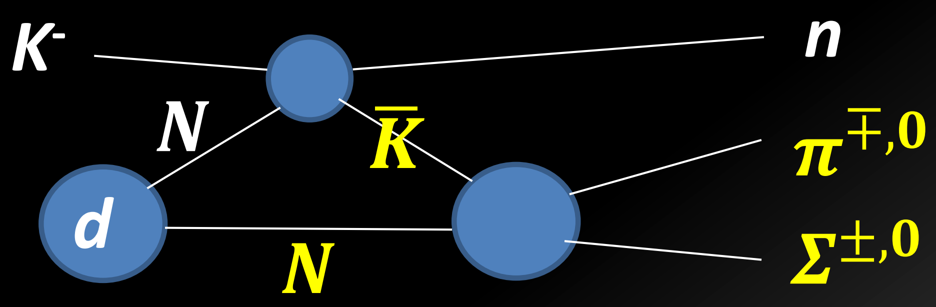
PDG Reviews: Ulf-G. Meissner and T. Hyodo (Nov. 2015)

Table 1: Comparison of the pole positions of $\Lambda(1405)$ in the complex energy plane from next-to-leading order chiral unitary coupled-channel approaches including the SIDDHARTA constraint.

approach	pole 1 [MeV]	pole 2 [MeV]
Refs. 11,12, NLO	$1424^{+7}_{-23} - i\,26^{+3}_{-14}$	$1381^{+18}_{-6} - i\,81^{+19}_{-8}$
Ref. 14, Fit II	$1421^{+3}_{-2} - i\,19^{+8}_{-5}$	$1388^{+9}_{-9} - i\,114^{+24}_{-25}$
Ref. 15, solution #2	$1434^{+2}_{-2} - i\,10^{+2}_{-1}$	$1330^{+4}_{-5} - i\,56^{+17}_{-11}$
Ref. 15, solution #4	$1429^{+8}_{-7} - i\,12^{+2}_{-3}$	$1325^{+15}_{-15} - i\,90^{+12}_{-18}$

E31 aims at:

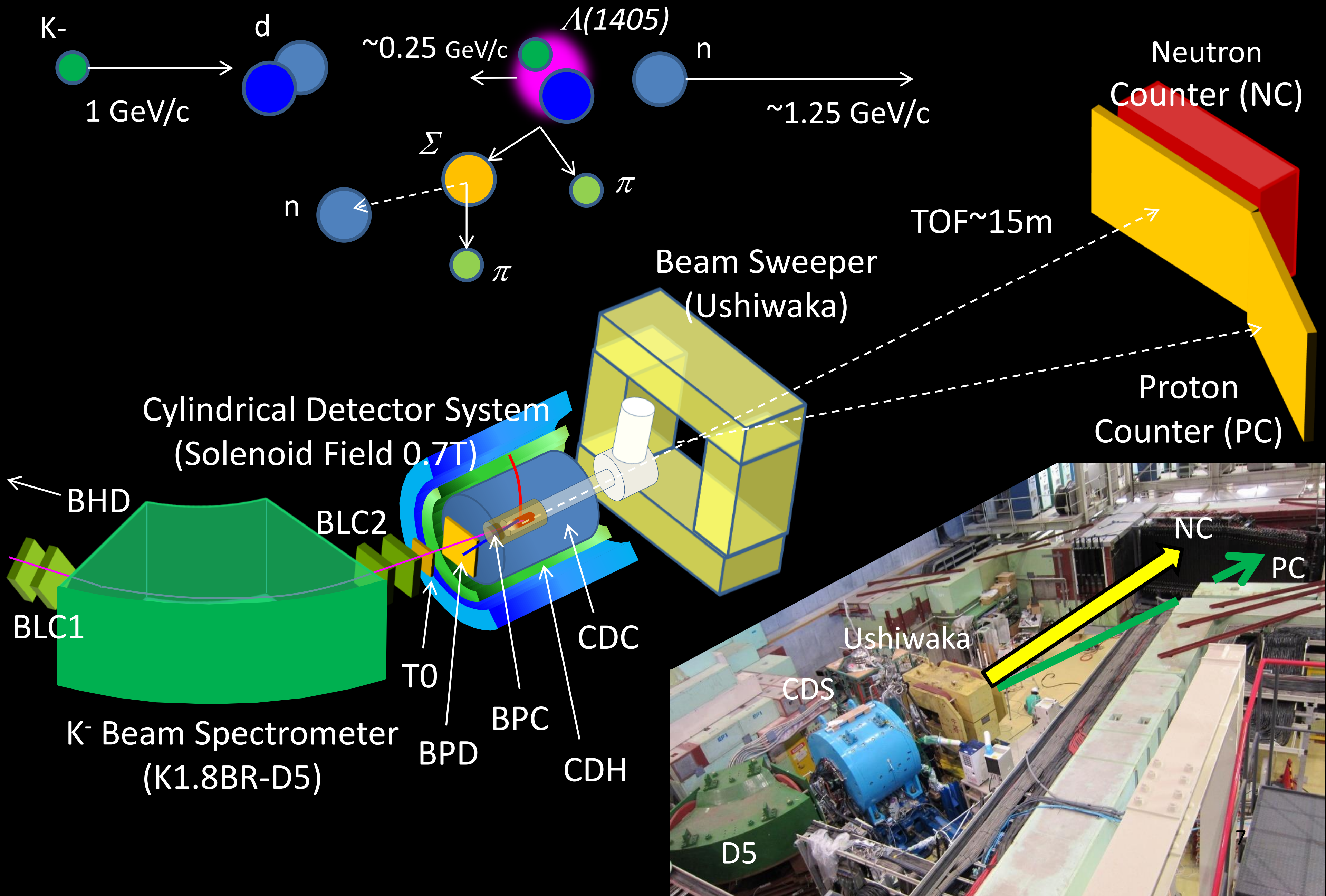
- measuring an *S*-wave $\bar{K}N \rightarrow \pi\Sigma$ scattering below the $\bar{K}N$ threshold in the $d(K^-,n)\pi\Sigma$ reactions at a forward angle of *n*.



- ID's all the final states to decompose the I=0 and 1 ampl's.

$\pi^{\pm}\Sigma^{\mp}$	**I=0, 1**	**Λ(1405) (I=0, S wave), non-resonant[I=0/1] (Σ(1385) (I=1, P wave) to be suppressed)**
$\pi^-\Sigma^0$ [$\pi^-\Lambda$]	I=1	non-resonant (Σ(1385) to be suppressed) $d(K^-,p)\pi^-\Sigma^0$ [$\pi^-\Lambda$]
$\pi^0\Sigma^0$	I=0	Λ(1405) (I=0, S wave), non-resonant

Experimental Setup for E31

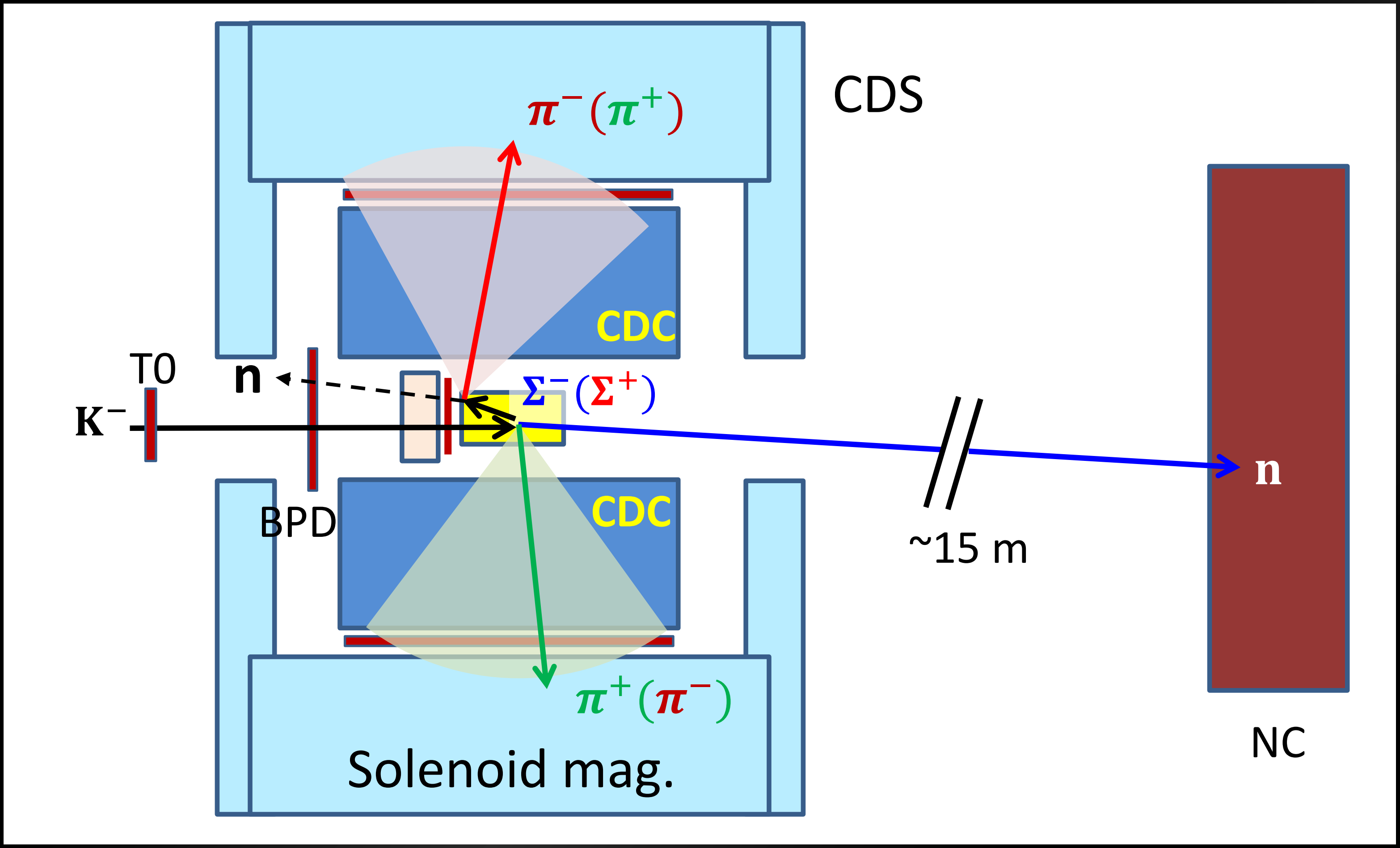


E31 Run Summary

E31 run		Beam Power	Beam Time	Executed/ Proposed
pre	May 2015	27 kW	2.2d	~5%
1st	May-June 2016	43 kW	~7d	~30%
2nd	Spring 2017	45 kW (Expected)	~20(+2)d (request)	100%

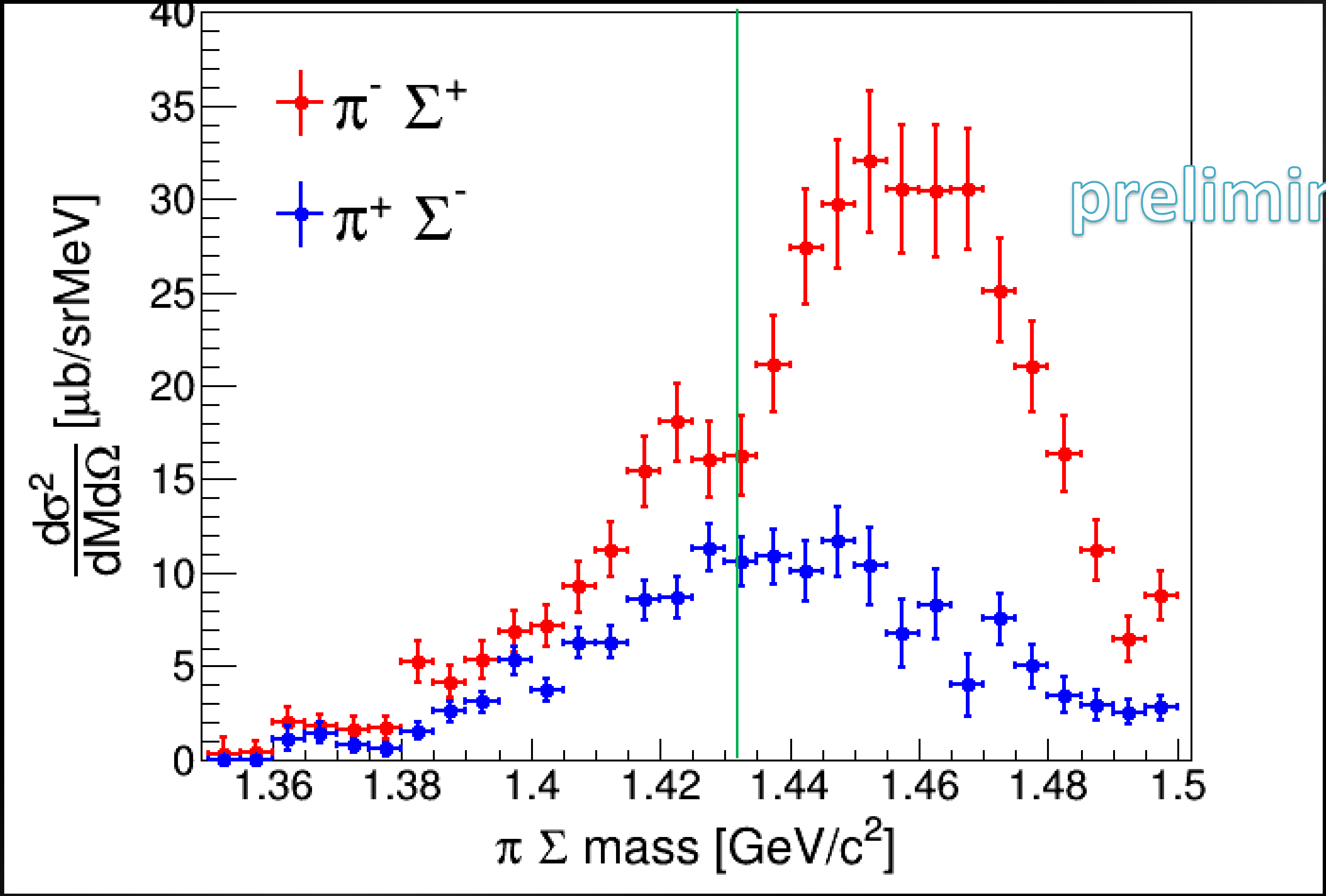
Event topology of $d(K^-, n)X_{\pi^\pm\Sigma^\mp}$

- I=0 and 1 mode



$\pi^+\Sigma^-/\pi^-\Sigma^+$ Mode ($I = 0, 1$)

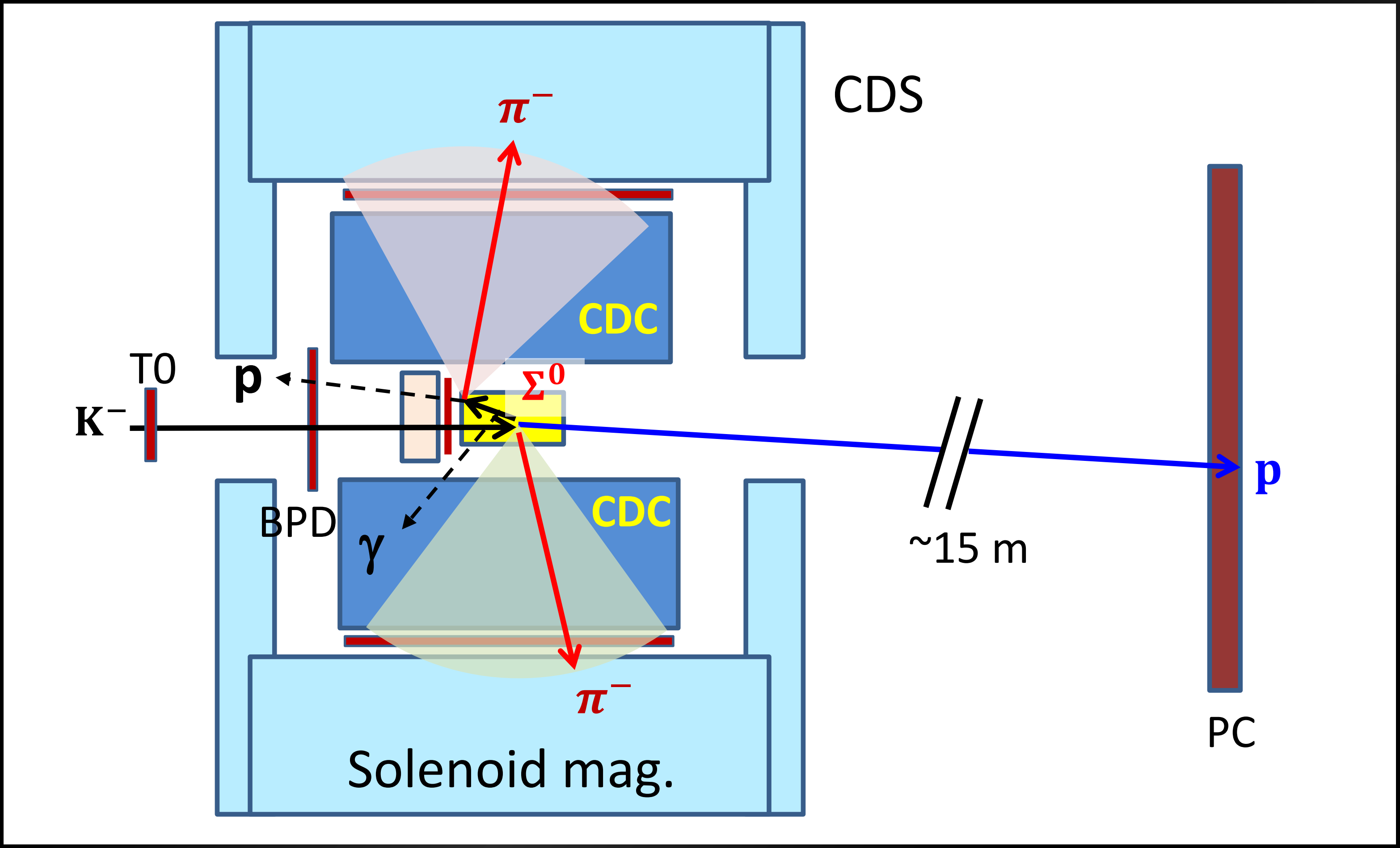
$$\frac{d\sigma}{d\Omega}(\pi^\pm\Sigma^\mp) = \frac{1}{3}|f_{I=0}|^2 + \frac{1}{2}|f_{I=1}|^2 \pm \frac{\sqrt{6}}{3} Re(f_{I=0}f^*_{I=1})$$



preliminary

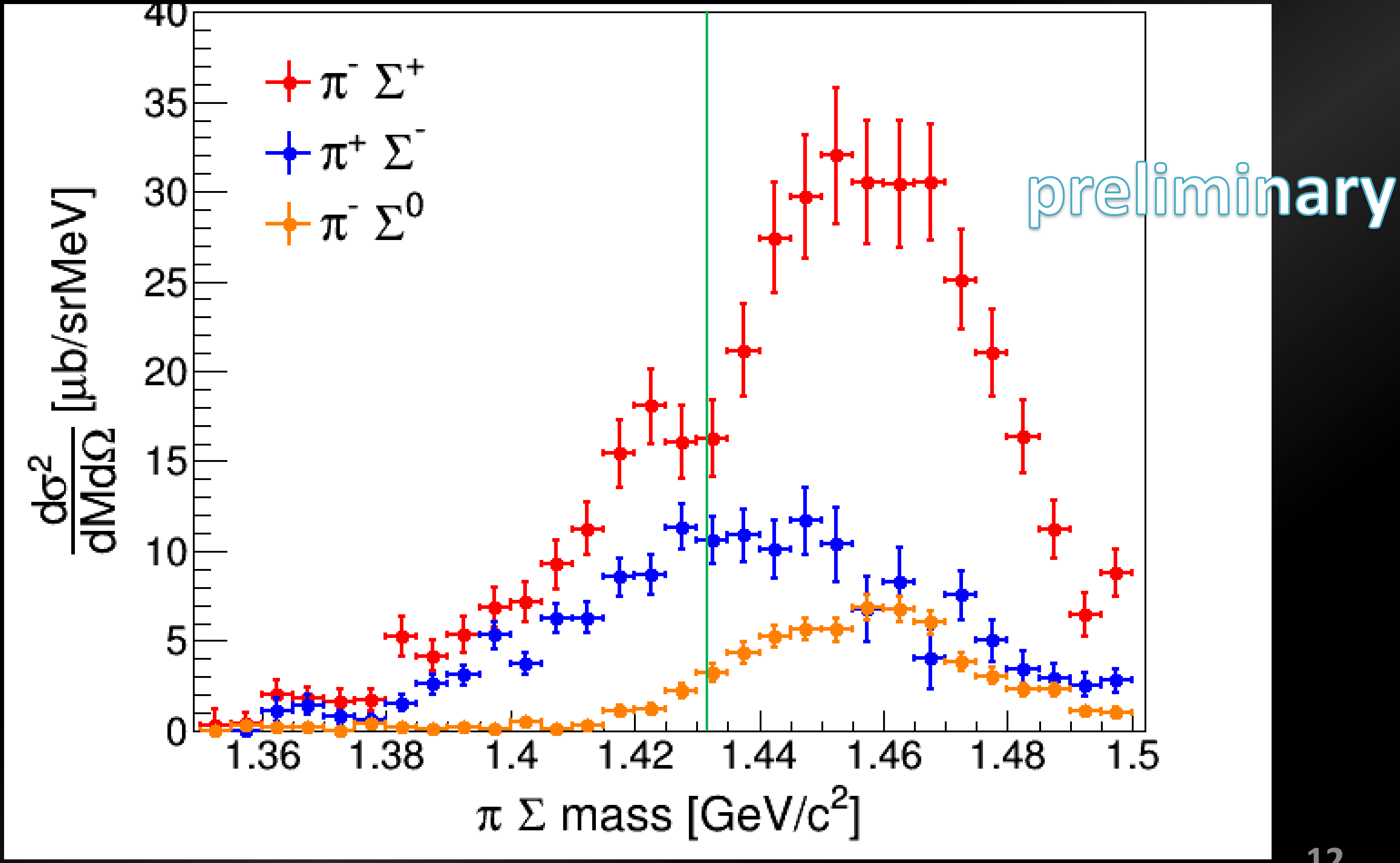
Event topology of $d(K^-, p)X_{\pi^-\Sigma^0}$

- Pure I=1 mode

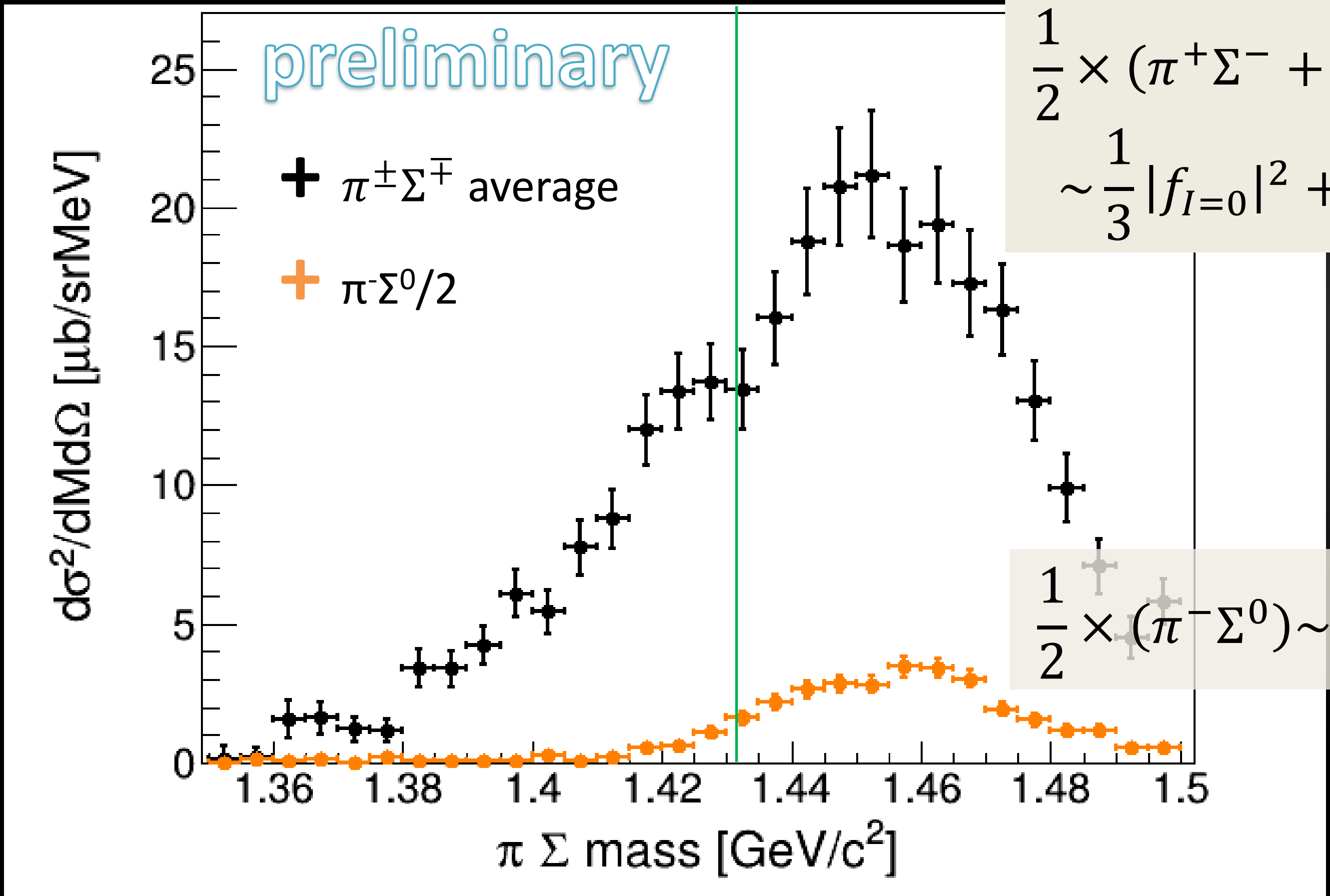


$\pi^-\Sigma^0$ Mode ($I = 1$)

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



$\pi^+\Sigma^-/\pi^-\Sigma^+$ Average $(I=0,1)$ v.s. $\frac{1}{2}\times\pi^-\Sigma^0$ Mode $(I=1)$



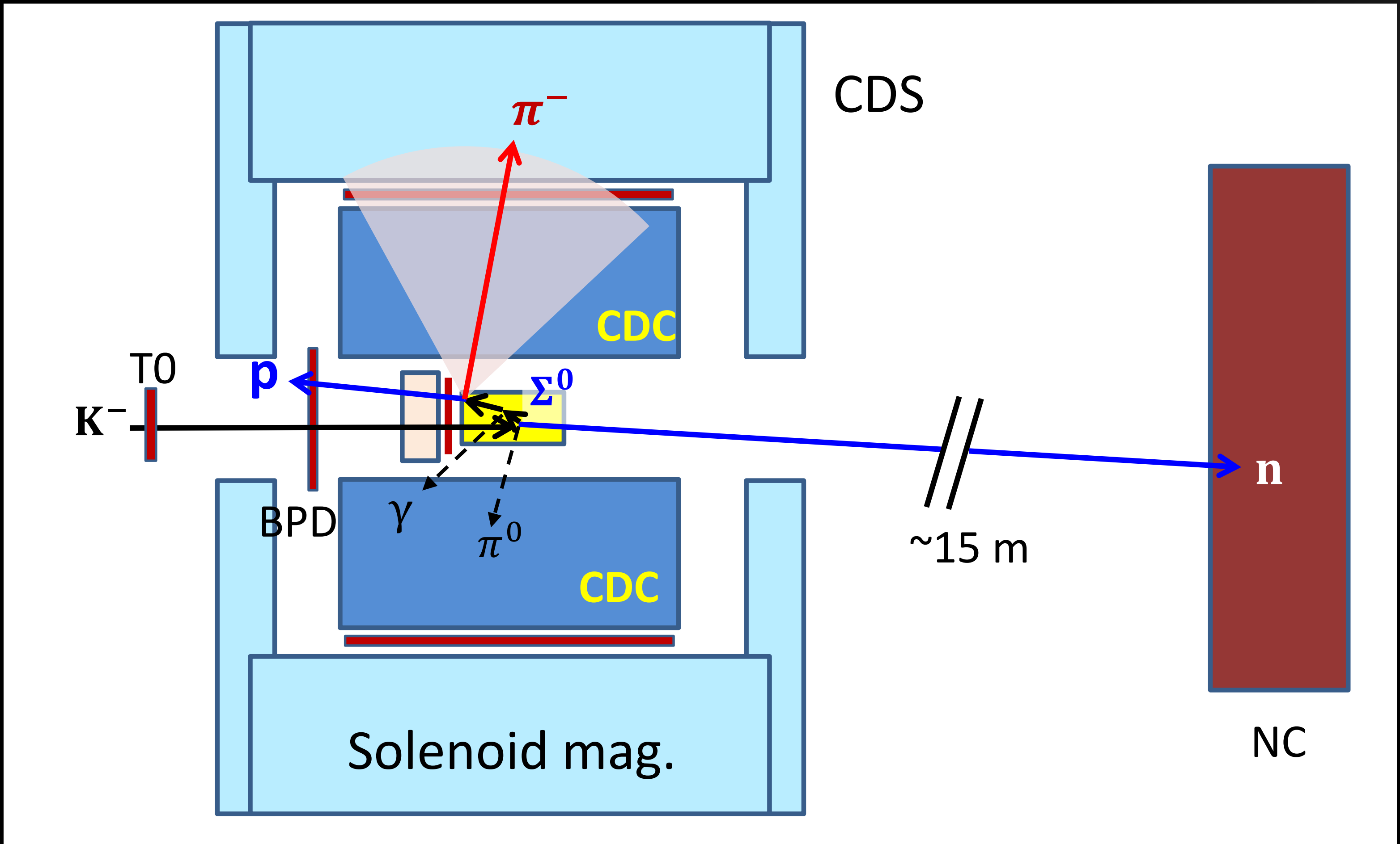
$$\frac{1}{2}\times(\pi^+\Sigma^- + \pi^-\Sigma^+) \sim \frac{1}{3}|f_{I=0}|^2 + \frac{1}{2}|f_{I=1}|^2$$

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

- *The I=0 amplitude is dominant.*

Event topology of $d(K^-, n)X_{\pi^0\Sigma^0}$

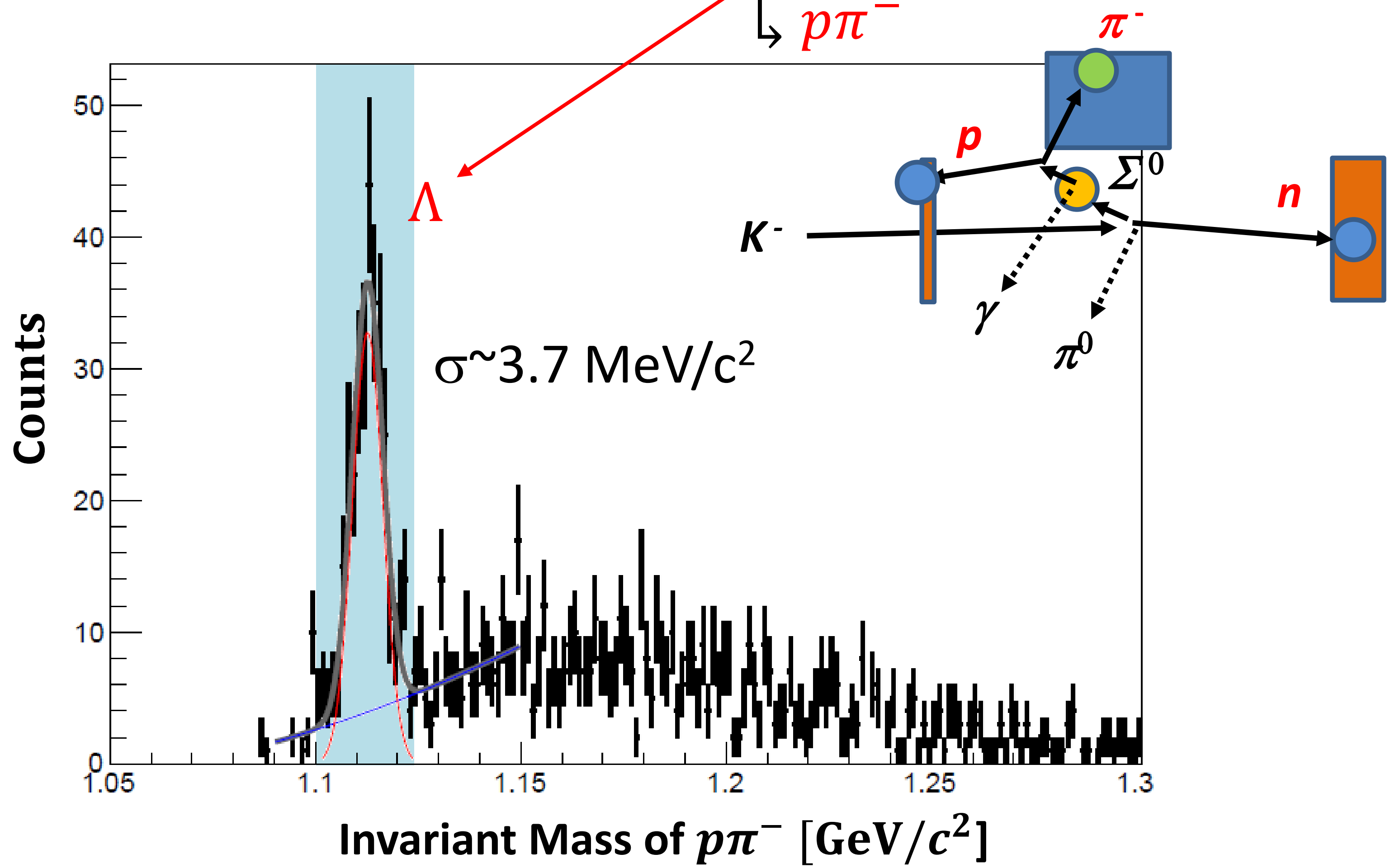
- Pure I=0 mode



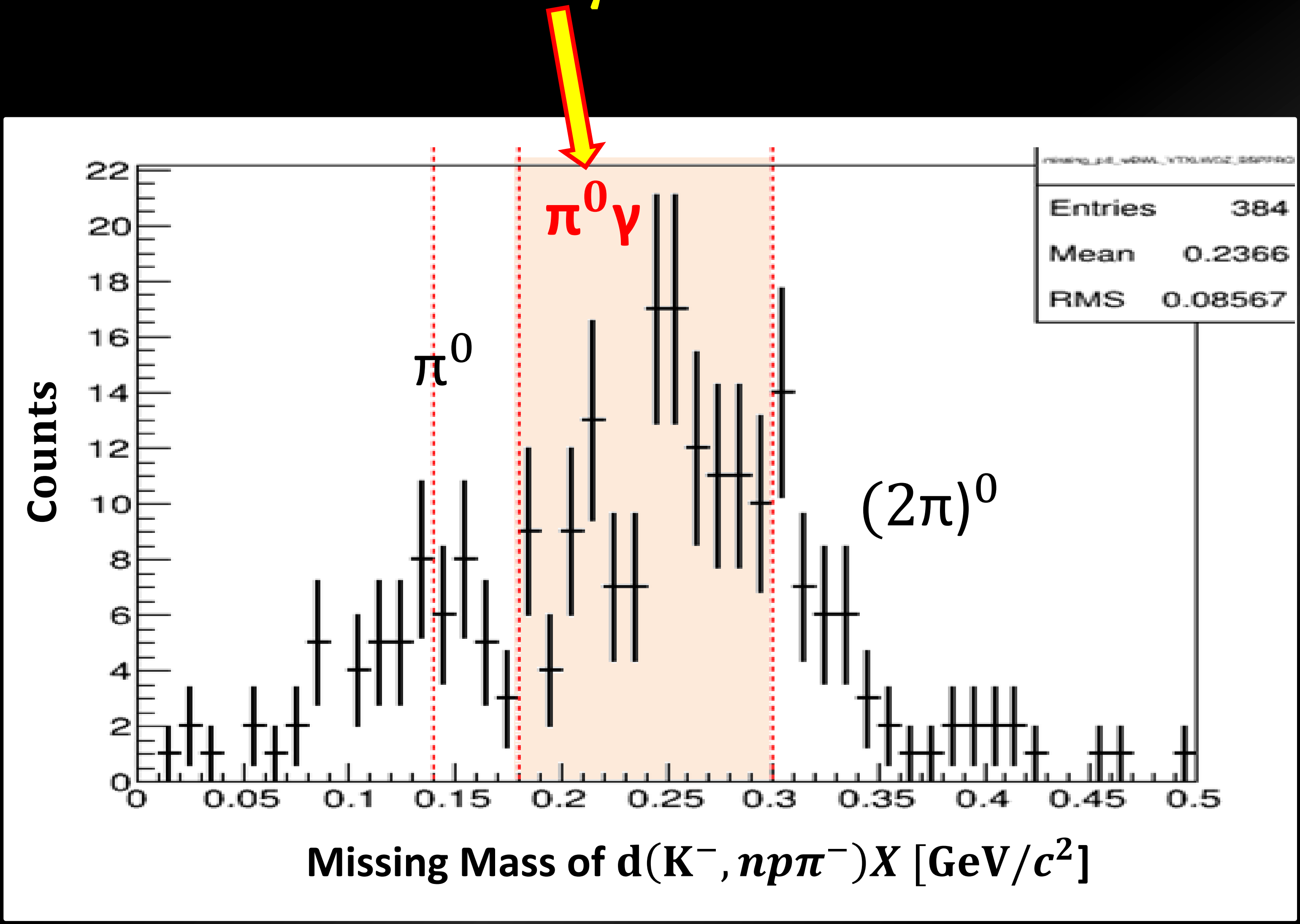
$d(K^-, n)X_{\pi^0\Sigma^0}$ mode (I=0)

$\hookrightarrow \gamma\Lambda$

$\hookrightarrow p\pi^-$

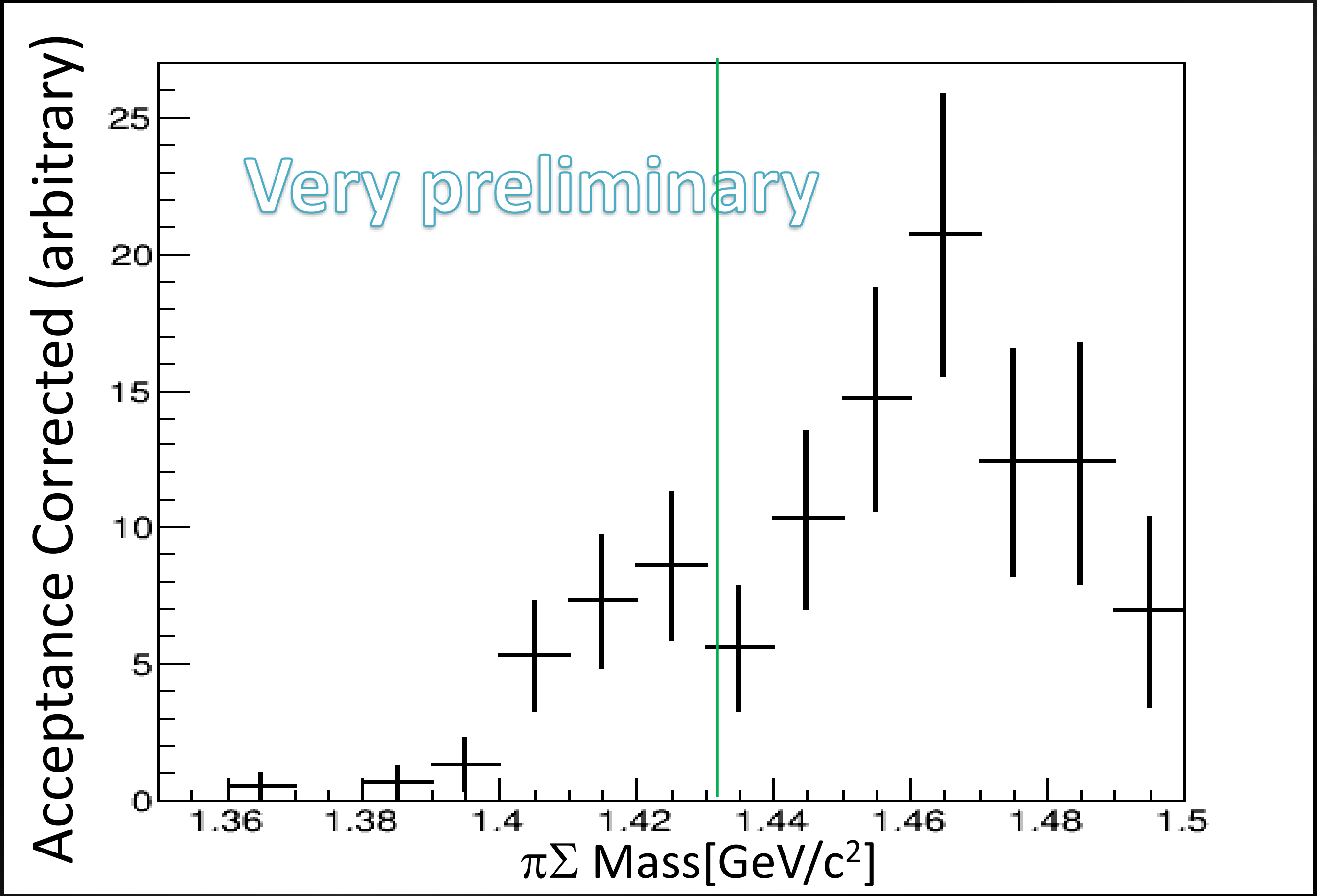


$d(K^-, n\Lambda)X_{\pi^0\gamma}$ in $d(K^-, n)X_{\pi^0\Sigma^0}$



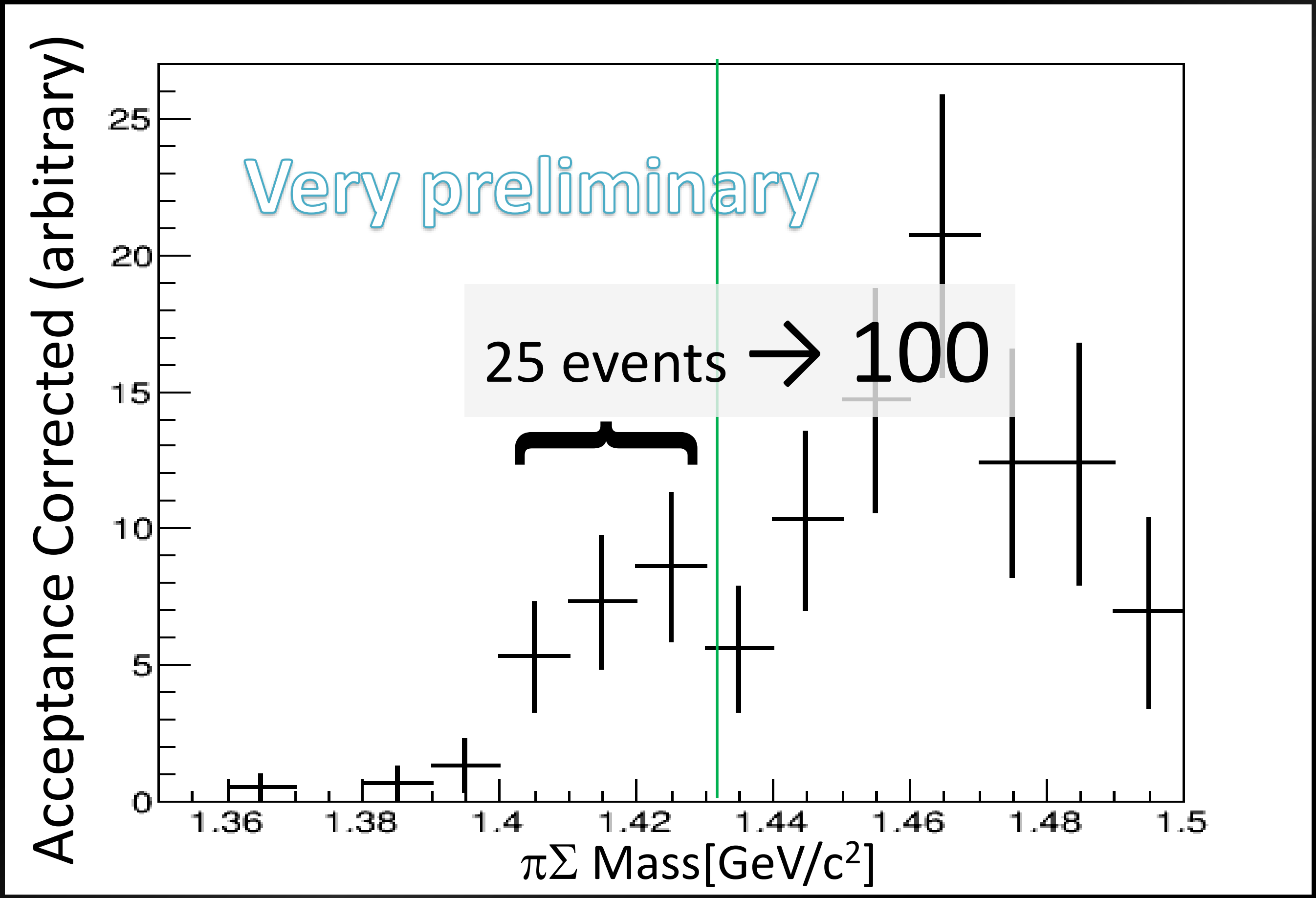
$\pi^0\Sigma^0$ Mode ($I=0$)

$$\frac{d\sigma}{d\Omega}(\pi^0\Sigma^0) \sim \frac{1}{3}|f_{I=0}|^2$$



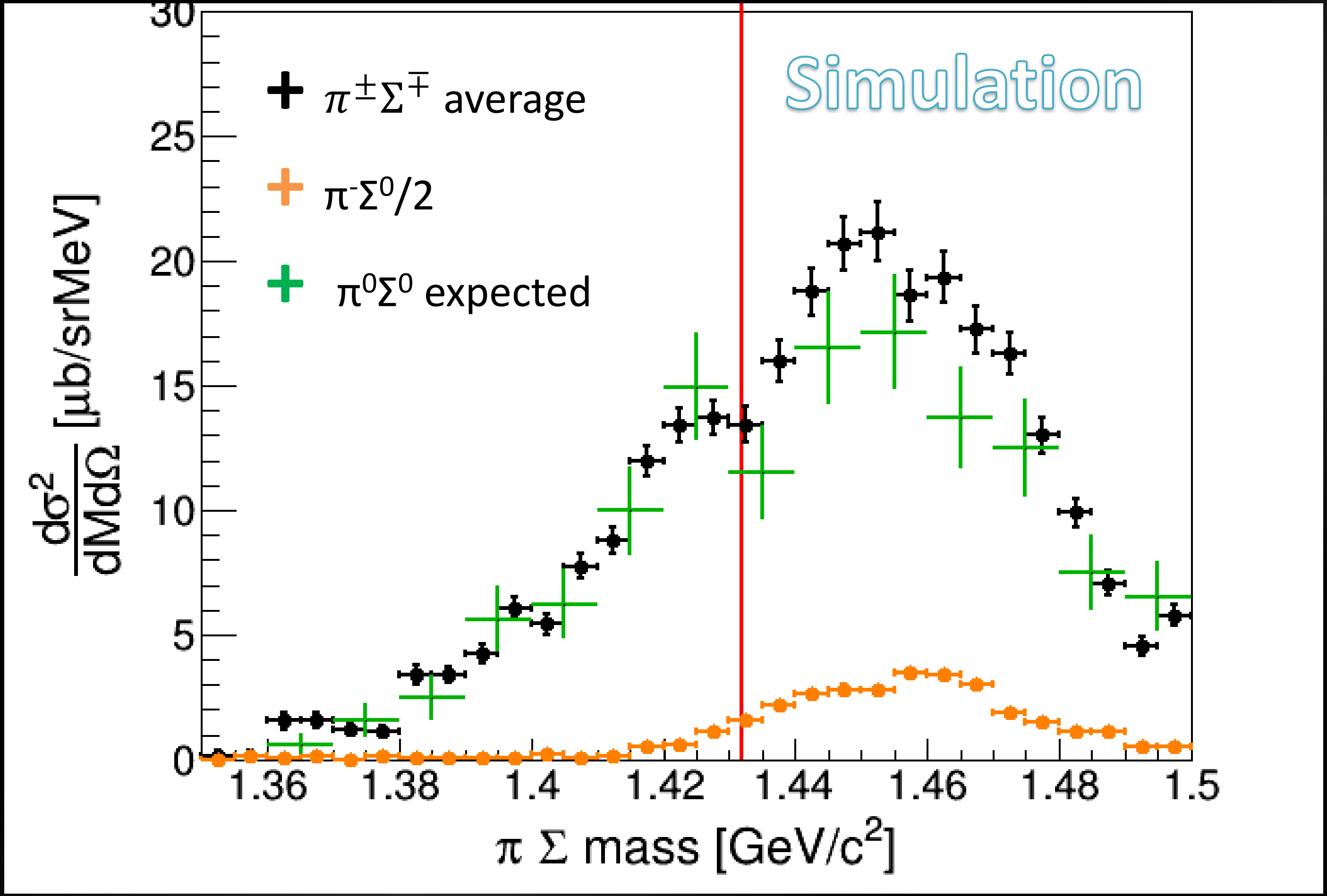
$\pi^0\Sigma^0$ Mode ($I = 0$)

$$\frac{d\sigma}{d\Omega}(\pi^0\Sigma^0) \sim \frac{1}{3}|f_{I=0}|^2$$



Expected Line shapes of all the modes

$$S(\pi^{\pm}\Sigma^{\mp}\ av.) = S(\pi^0\Sigma^0) + S(\pi^-\Sigma^0/2)\ ?$$



Remarks of E31 1st Run

- I=0, 1 modes, $d(K^-,n)X_{\pi^\pm\Sigma^\mp}$, are measured.
  - Interference btw I=0 and 1 is observed.
- Pure I=1 channel, $d(K^-,p)X_{\pi^-\Sigma^0}$, is measured.
  - I=0 amp. seems dominant in $\pi^\pm\Sigma^\mp$ modes, assuming similarity of the reaction mechanism among $d(K^-,n)X_{\pi^\pm\Sigma^\mp}$ and $d(K^-,p)X_{\pi^-\Sigma^0}$.
- Line shape of the pure I=0 channel, $d(K^-,n)X_{\pi^0\Sigma^0}$, is observed.

In the E31 2nd Run

- We would like to confirm if the line shape for $\pi^0\Sigma^0$ is identical to the $(\pi^-\Sigma^+ + \pi^+\Sigma^- - \pi^-\Sigma^0)/2$ spectrum
- At least 10% in statistical error below the K-p threshold is necessary.
  - Strength of $I = 1$ is ~10% in the $\pi^\pm\Sigma^\mp$ average spectrum.
- We request to run for 20(+2 for start up) days at 45 kW to accumulate ~100 events below the K-p threshold.
- We can finish E31 before summary shutdown.

E31 Run Summary/Request

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