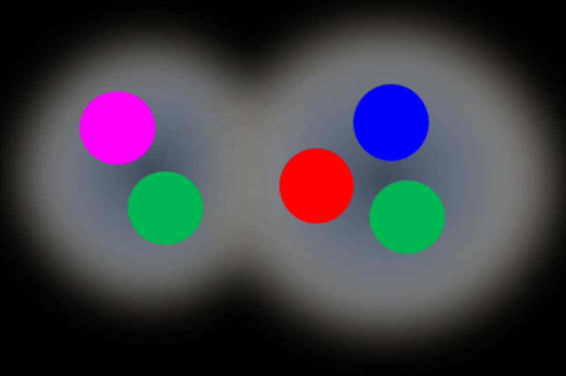
5th Joint Meeting of NPDs of APS and JPS@Hawaii
October 23-27, 2018

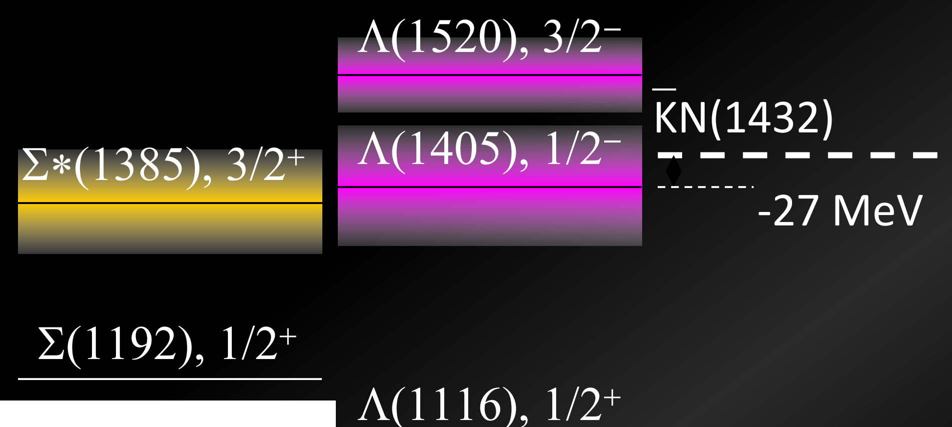
$\pi\Sigma$ spectra in the Kaon-Induced Reaction on Deuteron

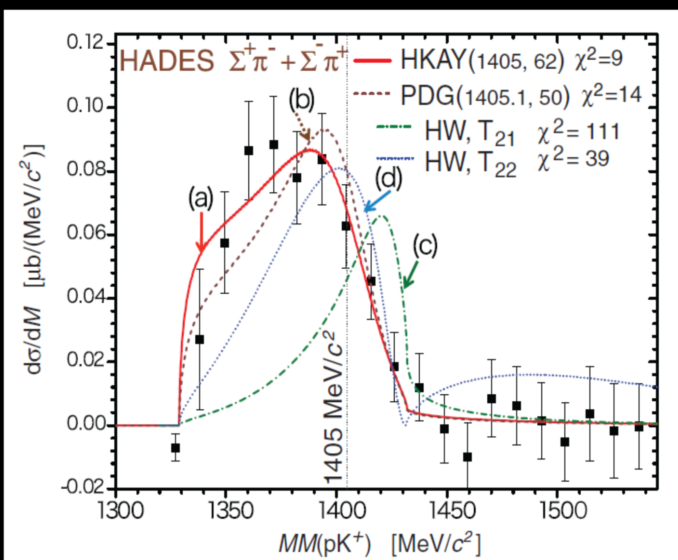
Hiroyuki Noumi
RCNP, Osaka Univ./IPNS, KEK
for the E31 collaboration

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

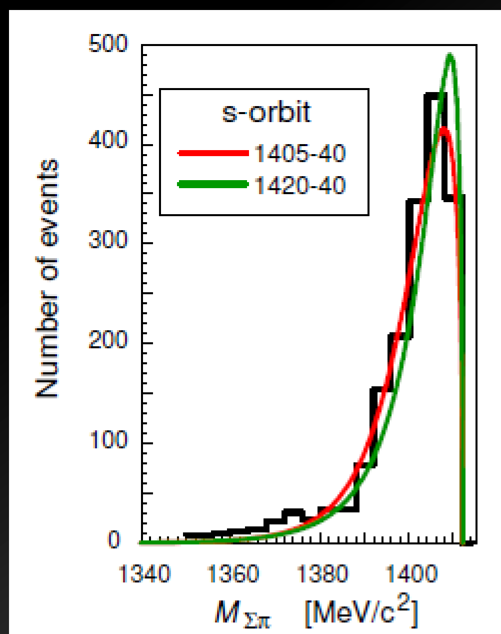
$J^P = \frac{1}{2}^-$, $I = 0$, $M_{\Lambda(1405)} < M_{\bar{K}N}$, lightest in neg. parity baryons



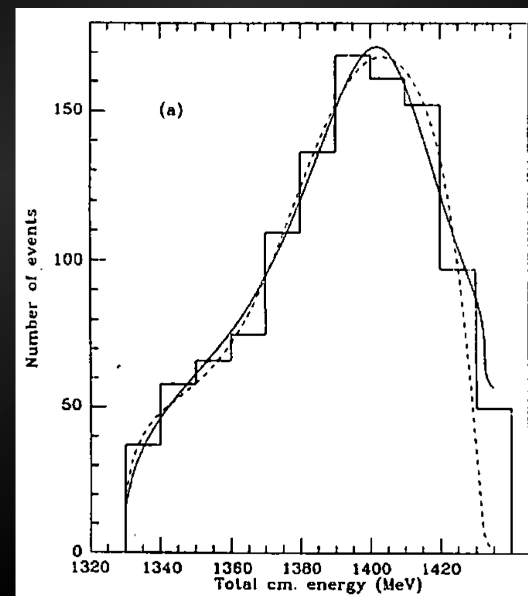




M. Hassanvand et al: πΣ IM Spec. of pp→K⁺πΣ



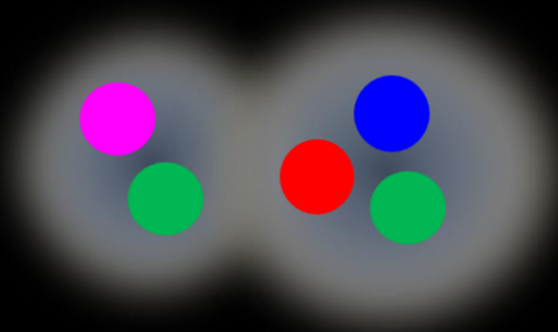
J. Esmaili et al: πΣ IM Spec. of Stopped K⁻ on ⁴He

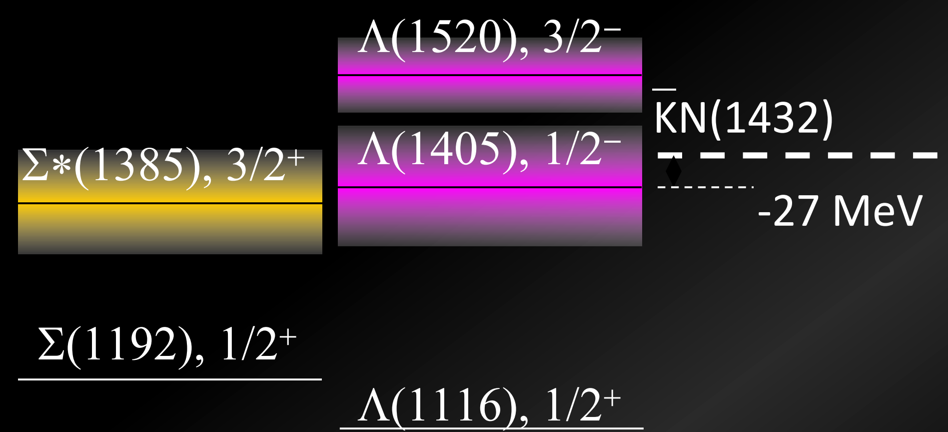


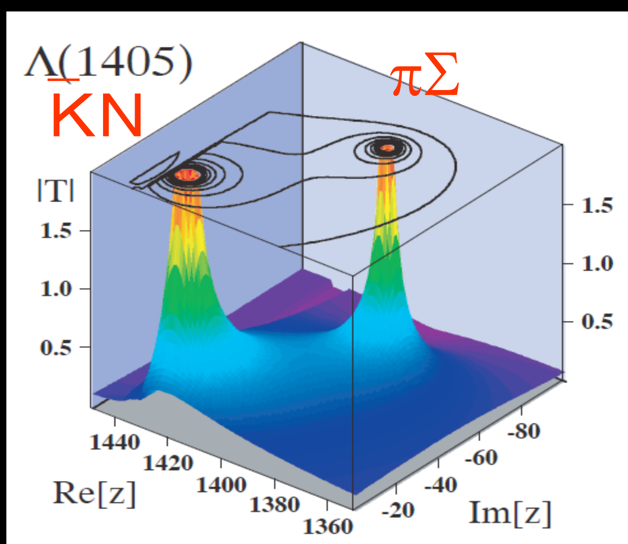
R.H. Dalitz et al: πΣ IM Spec. in K-p→ππΣ w/ M-matrix

Λ(1405) : Double pole?

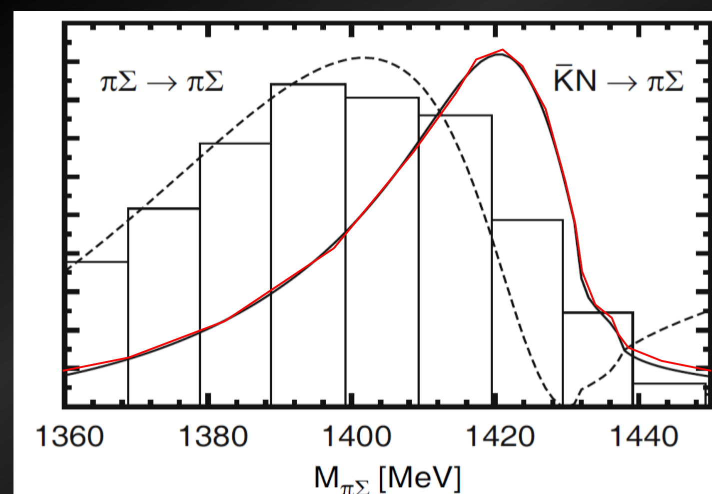
$J^P = \frac{1}{2}^-$, $I = 0$, $M_{\Lambda(1405)} < M_{KbarN}$, lightest in neg. parity baryons





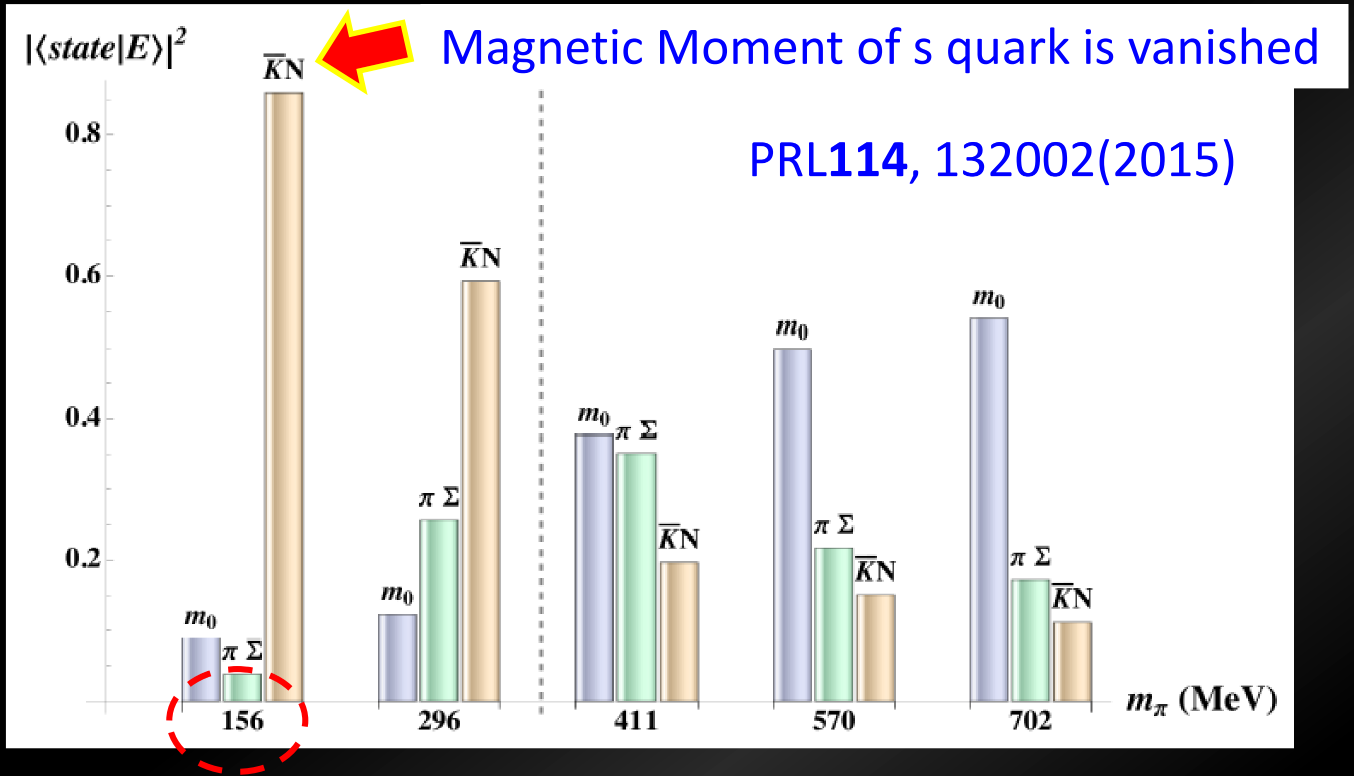


ChU model, T. Hyodo



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

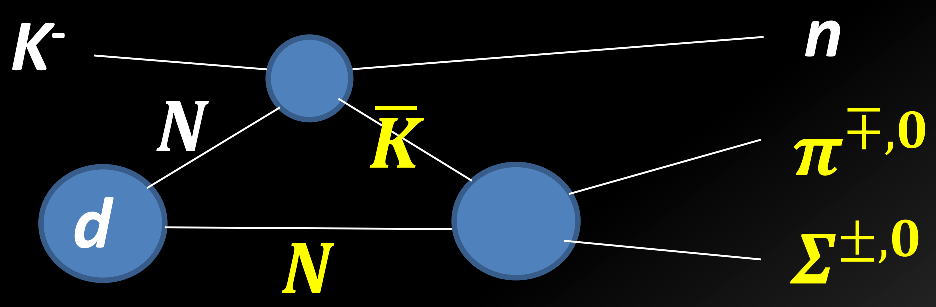
LQCD Evidence that Λ(1405) is a $K^{bar}N$ molecule!



- Study of $K^{bar}N$ scattering below the $K^{bar}N$ thres. are important.

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*.

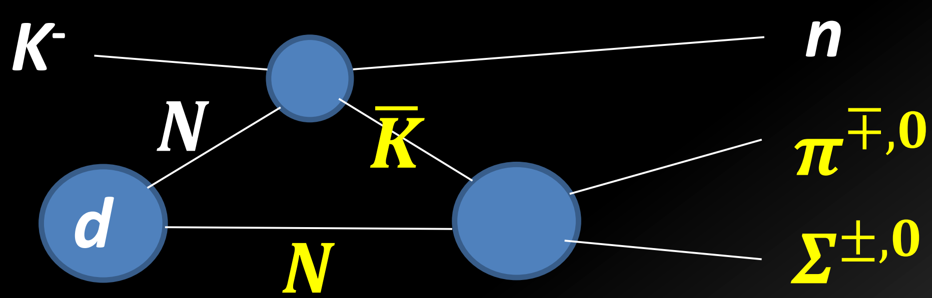


- ID's all the final states to decompose the I=0 and 1 ampl's.

$\pi^{\pm}\Sigma^{\mp}$	**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

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*.



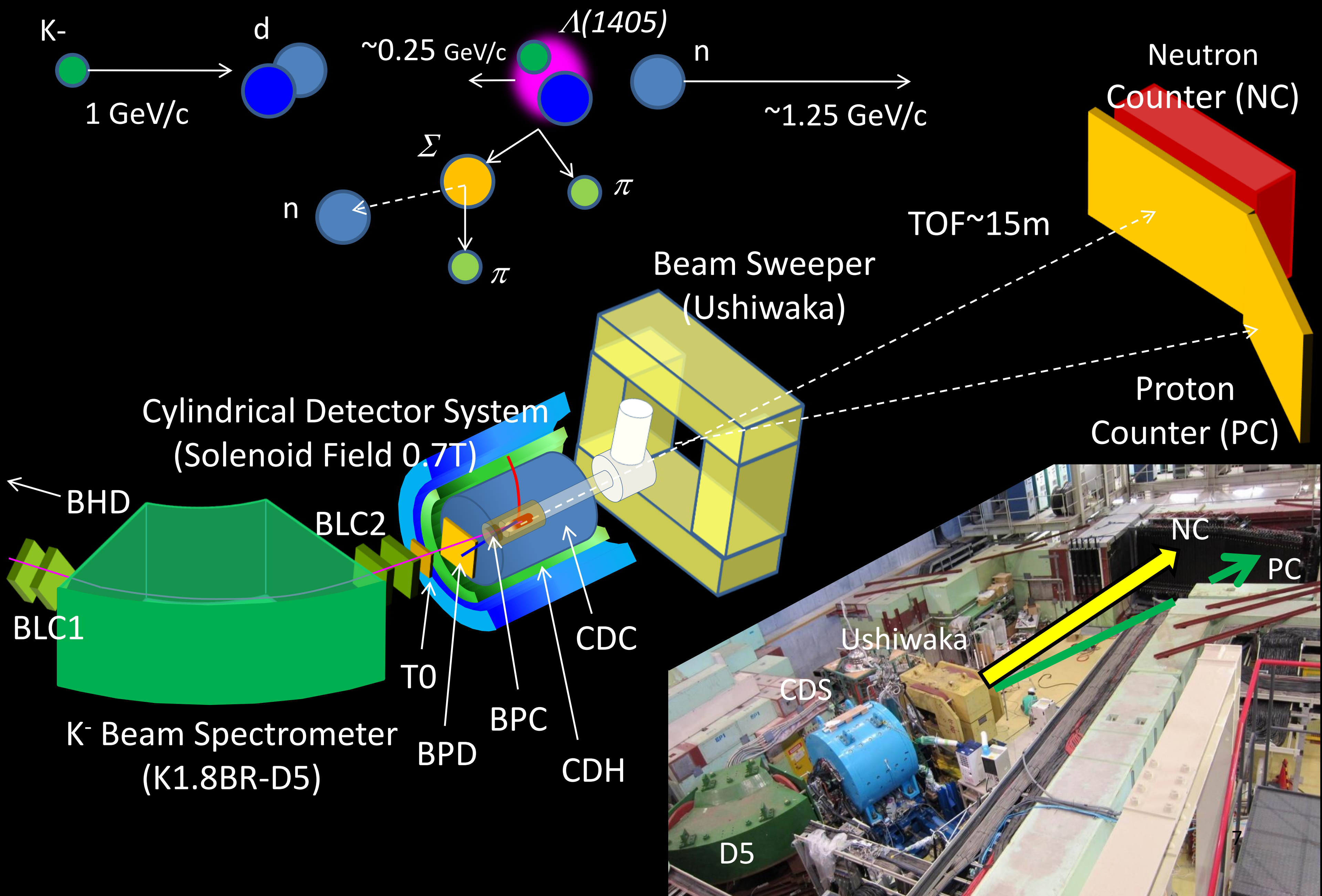
- ID's all the final states to decompose the I=0 and 1 ampl's.

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

} K. Inoue

S. Kawasaki

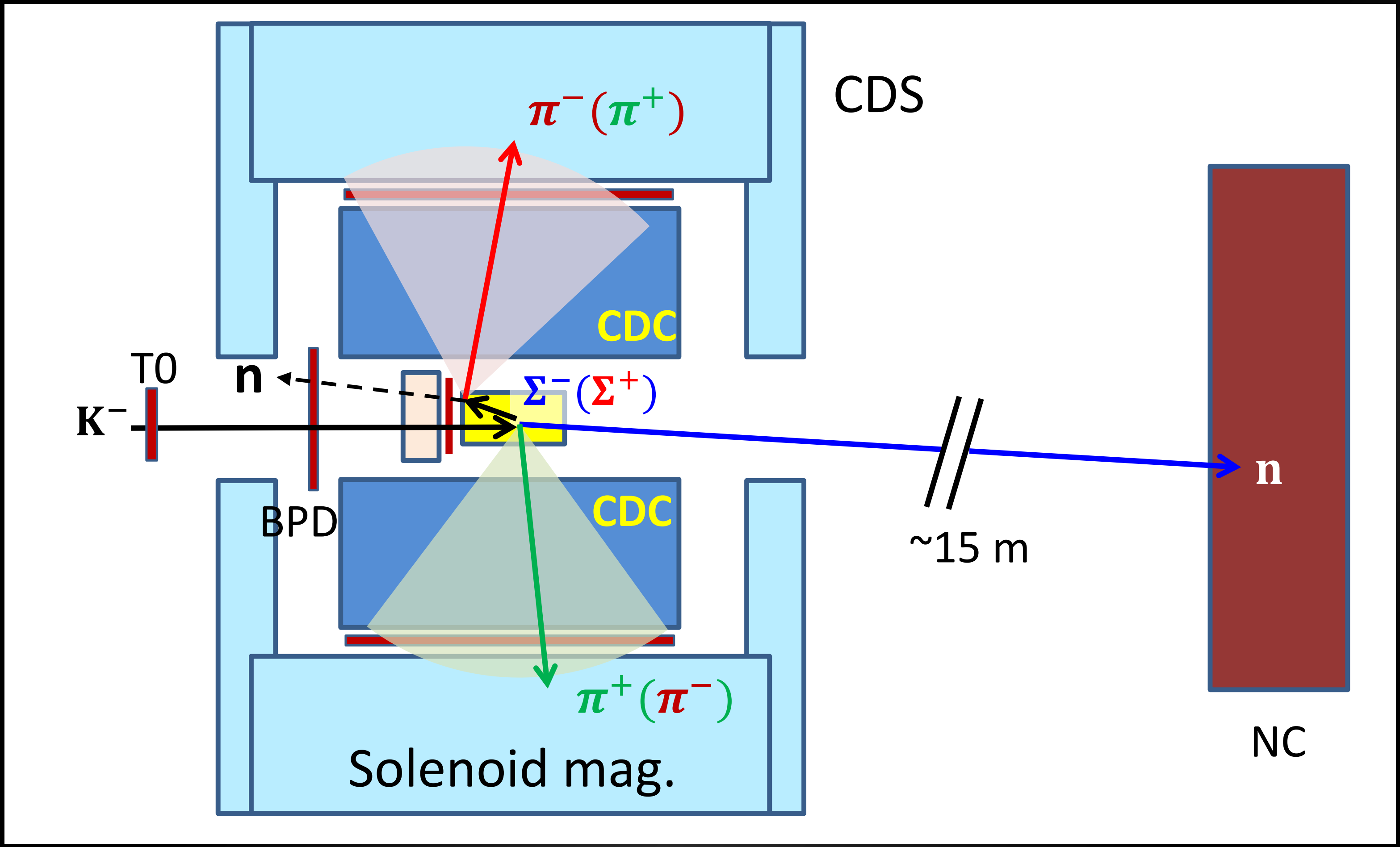
Exp. Setup for E31 at the J-PARC K1.8BR B.L.



E31 Run History

E31 run		Beam Power	Beam Time (# of Kaons)	Executed/ Proposed
pre	May 2015	27 kW	2.2d	~5%
1^{st}	May-June 2016	43 kW	~7d (14.5 G)	~30%
2^{nd}	Apr.2017	44 kW	0.5d(start up)	~30%
$2^{nd'}$	**Jan.-Feb. 2018**	**51 kW**	**~21.5d (39.2 G)**	**100%**

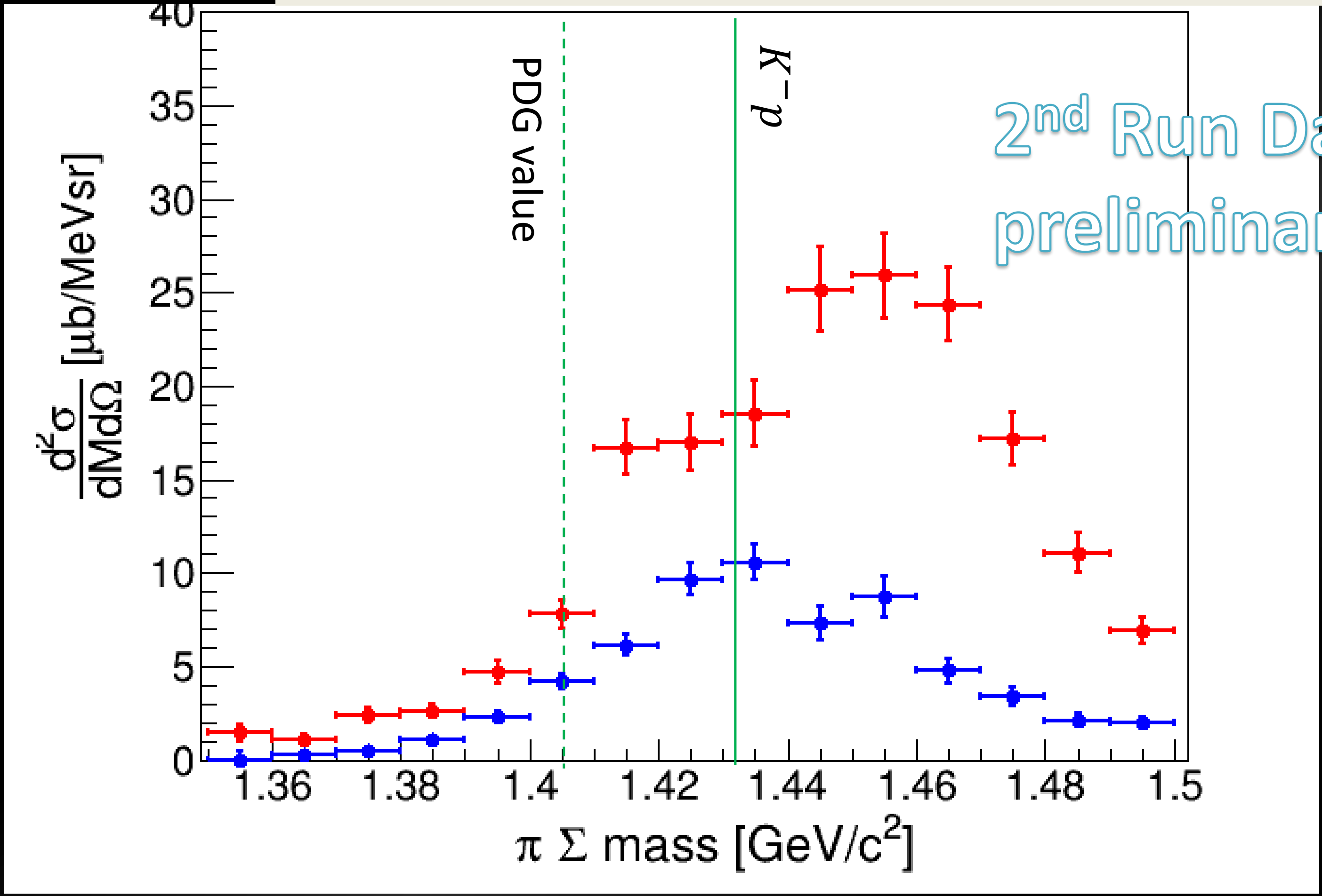
Event topology of $d(K^-, n)X_{\pi^\pm\Sigma^\mp}$



BG Process: $d(K^-, nK^0)"n"$, $d(K^-, \Sigma^\pm\pi^\mp)"n"$

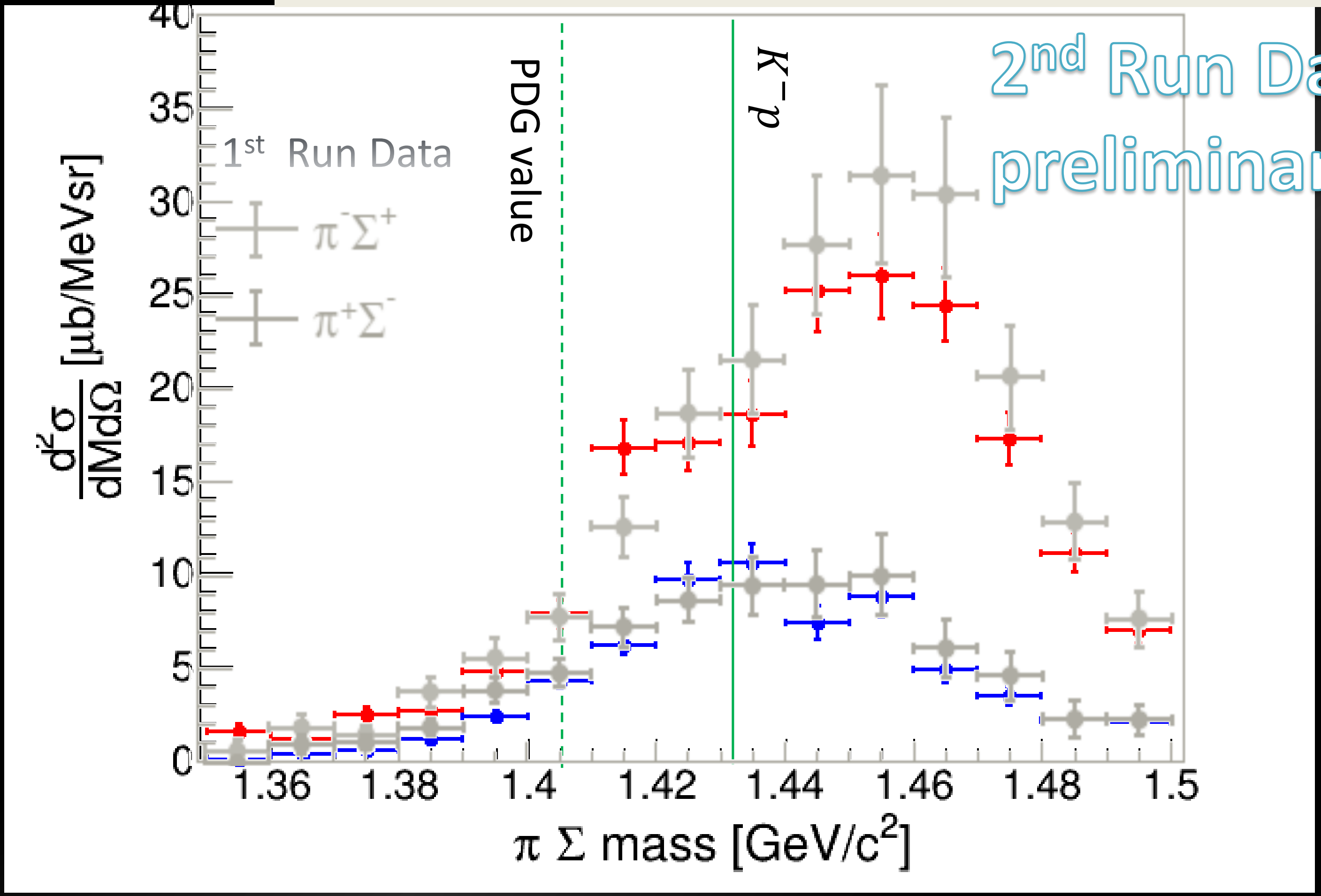
$\pi^+\Sigma^-/\pi^-\Sigma^+$ Mode ($I = 0, 1$)

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



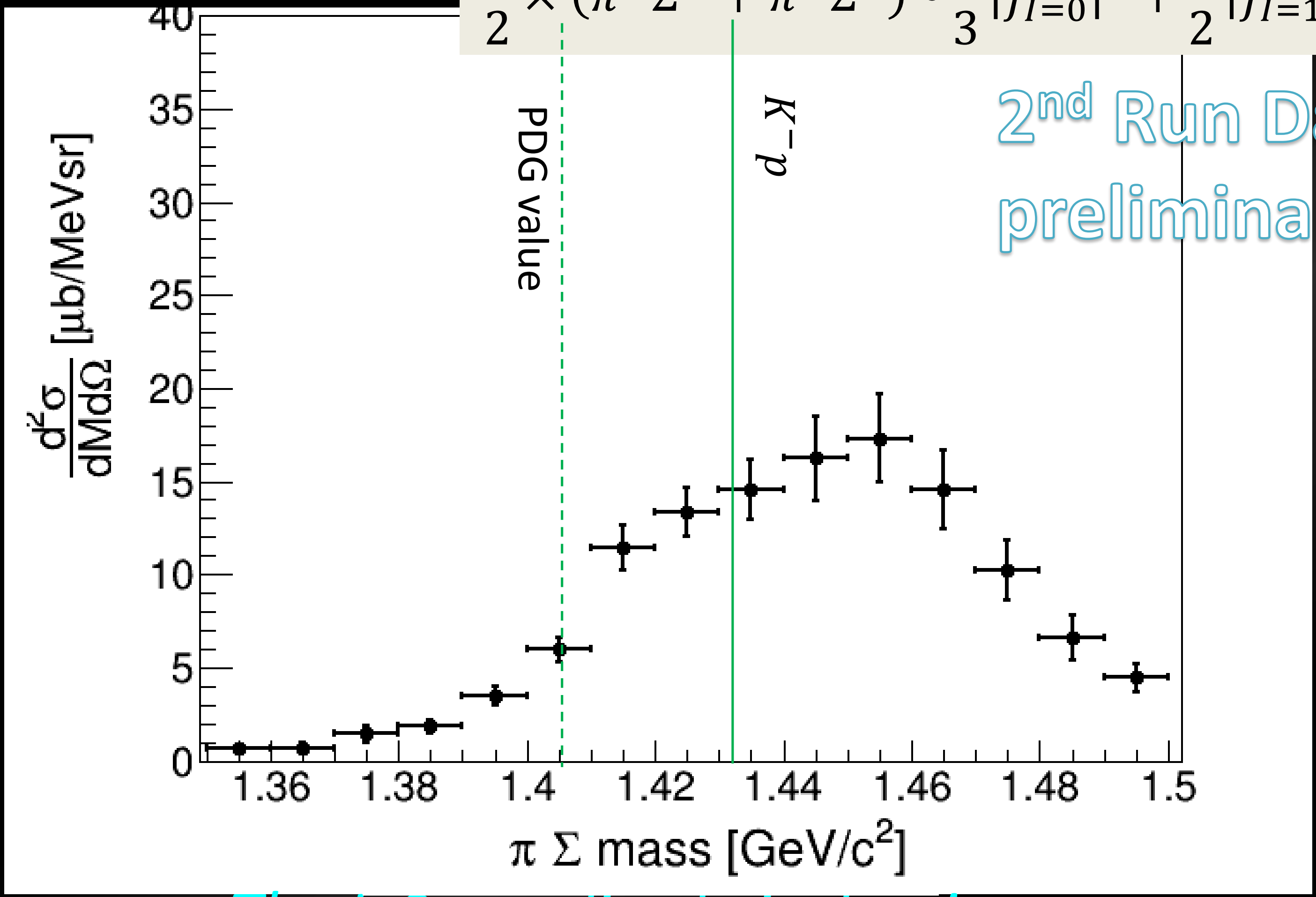
$\pi^+\Sigma^-/\pi^-\Sigma^+$ Mode ($I = 0, 1$)

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



$$\frac{1}{2} \times (\pi^+\Sigma^- + \pi^-\Sigma^+) \ (I = 0, 1)$$

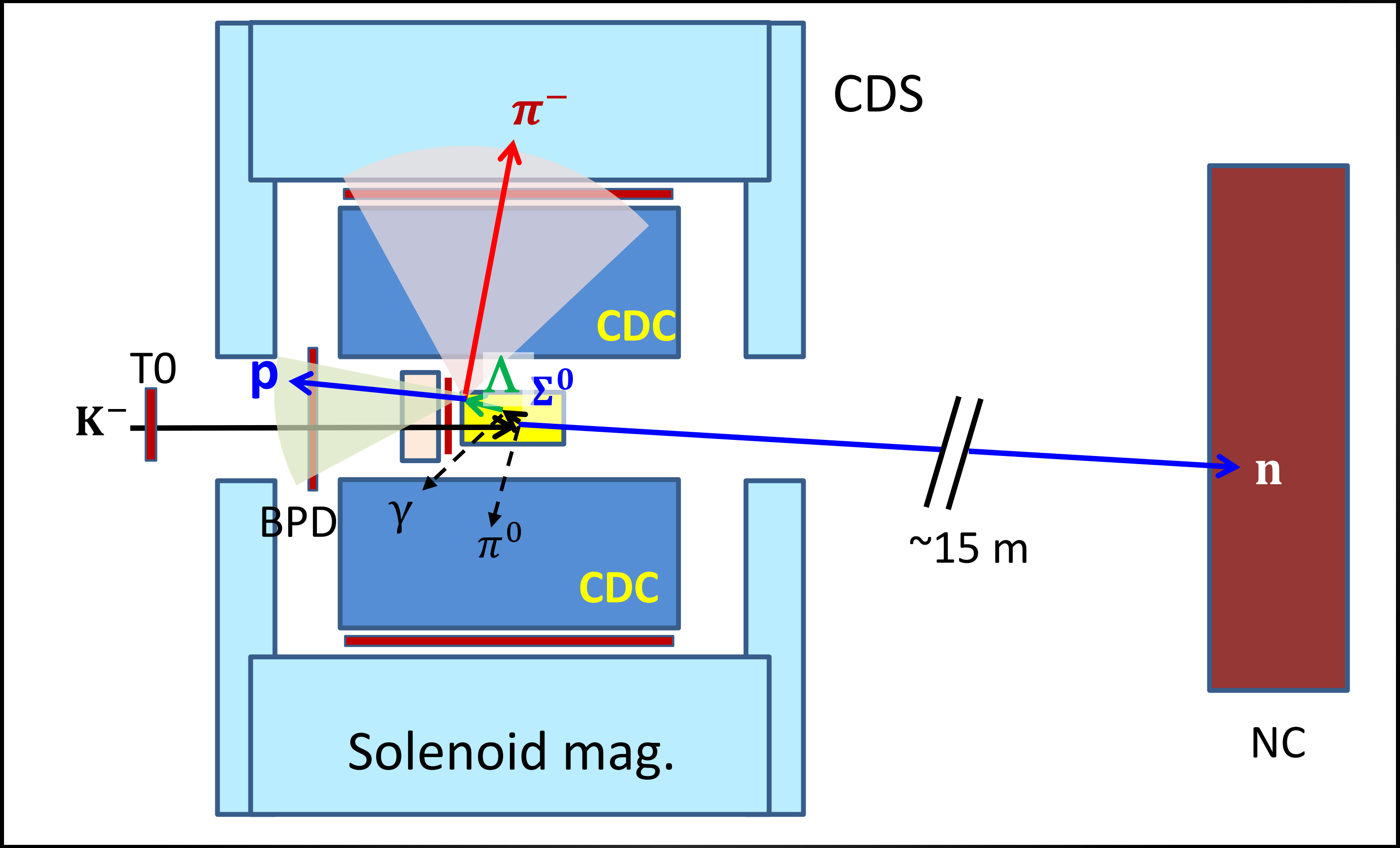
$$\frac{1}{2} \times (\pi^+\Sigma^- + \pi^-\Sigma^+) \sim \frac{1}{3}|f_{I=0}|^2 + \frac{1}{2}|f_{I=1}|^2$$



2nd Run Data preliminary

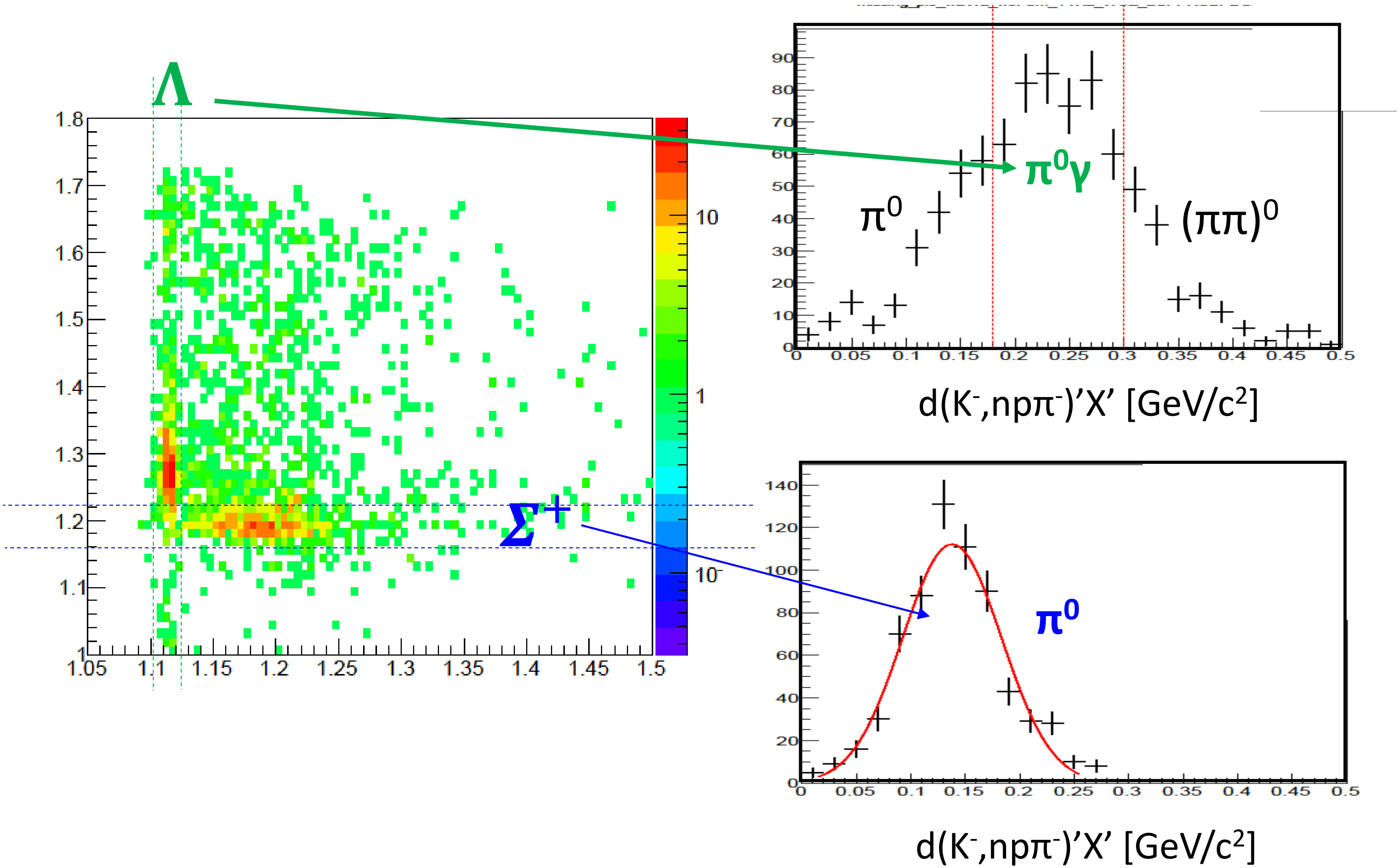
- *The I=0 amplitude is dominant.*

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



BG Process: $d(K^-, n\,)X_{\pi^0\Lambda}$, $d(K^-, n\,)X_{\pi^0\pi^0\Lambda}$,
$d(K^-, n\,)X_{\pi^-\Sigma^+}$, $d(K^-, \Sigma^- p\,)X$

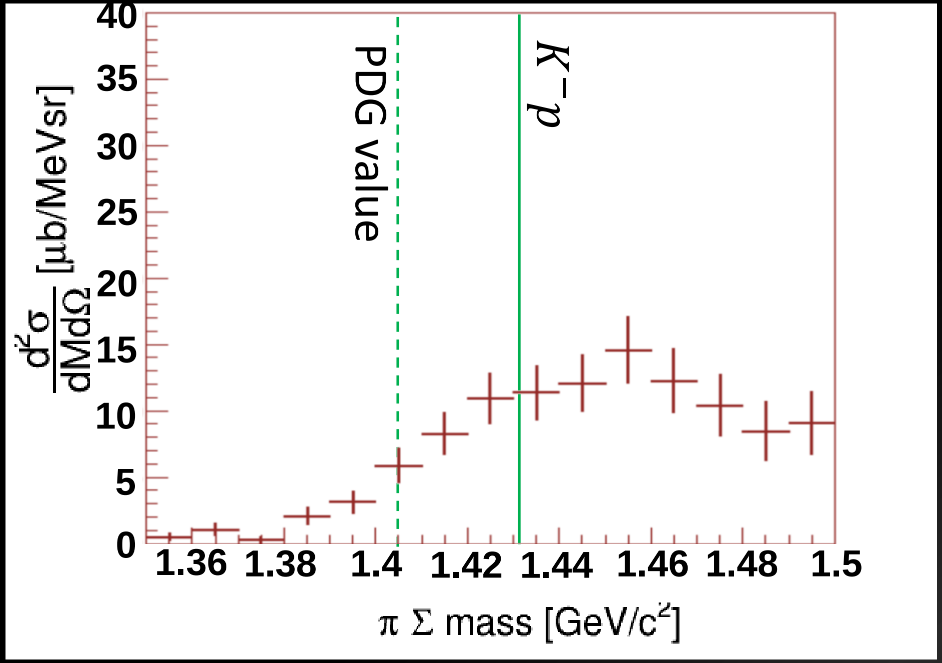
$d(K^-,n)\pi^0\Sigma^0$ vs $d(K^-,n)\pi^-\Sigma^+$

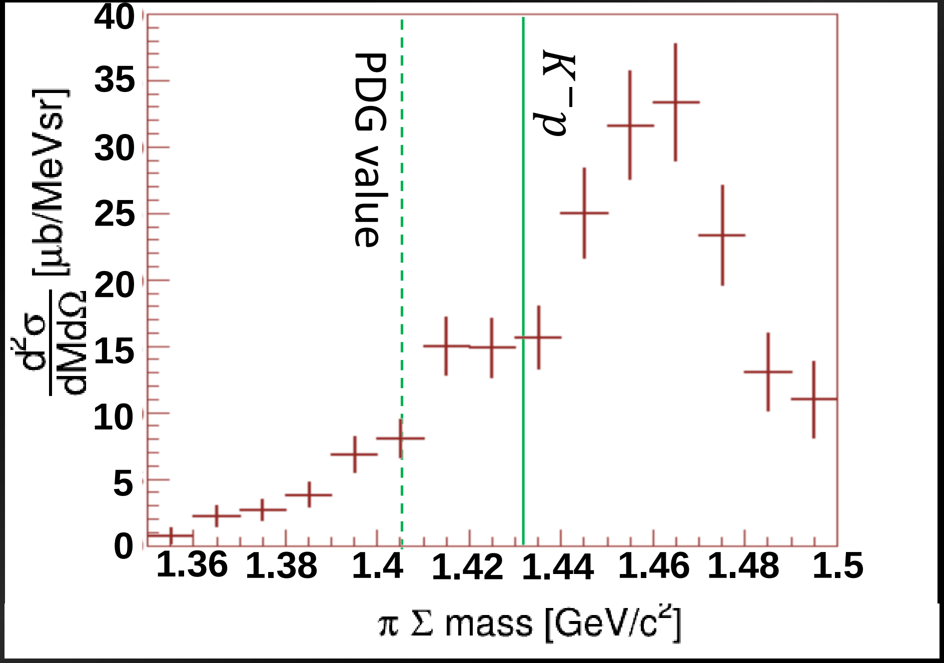


$\pi^0\Sigma^0(I=0)$

$\pi^-\Sigma^+$ Mode

2nd Run Data preliminary



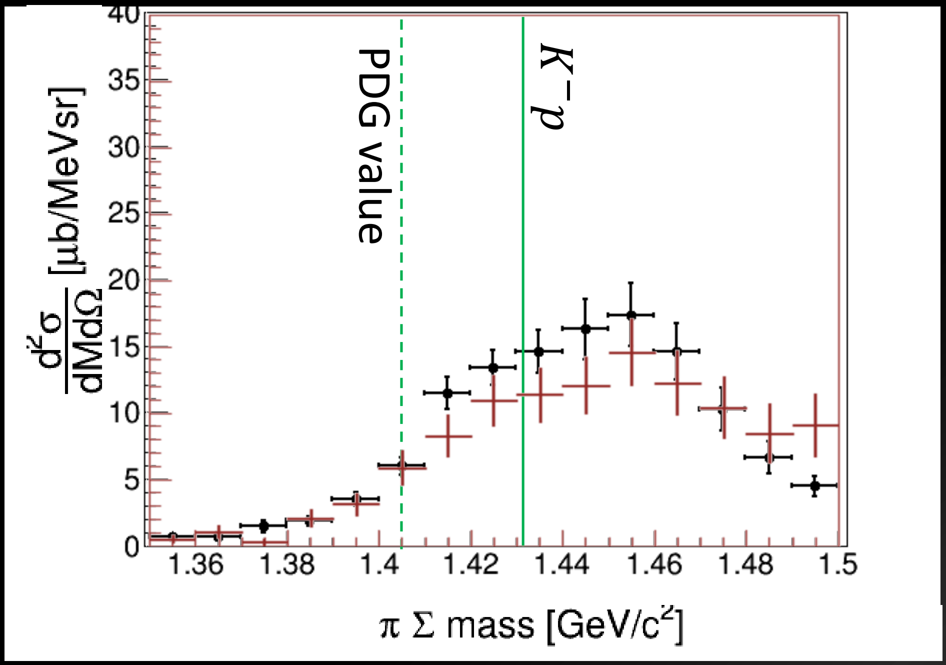


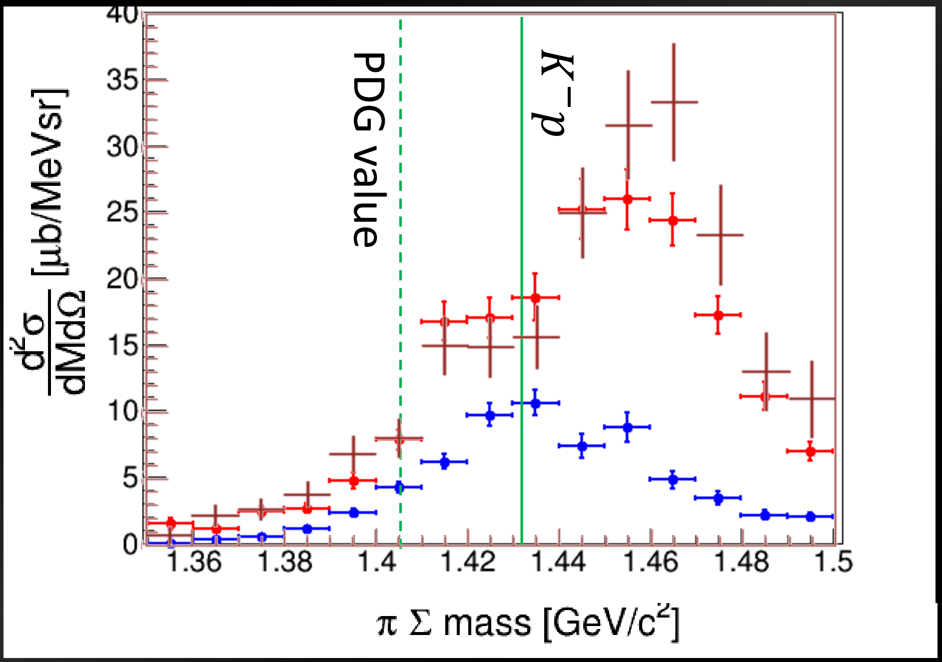
$$\frac{d\sigma}{d\Omega}(\pi^0\Sigma^0)\sim\frac{1}{3}|f_{I=0}|^2$$

Consistency in the $\pi^{\pm}\Sigma^{\mp}/\pi^{0}\Sigma^{0}$ Mode

2nd Run Data preliminary

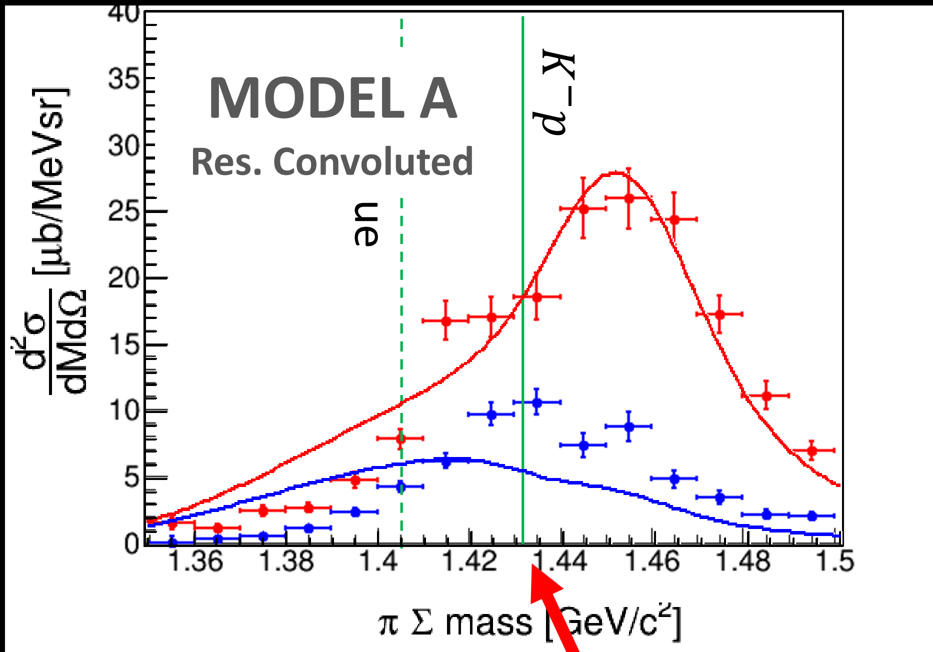
$$\frac{1}{2}\times(\pi^{+}\Sigma^{-}+\pi^{-}\Sigma^{+})\sim\frac{1}{3}|f_{I=0}|^{2}+\frac{1}{2}|f_{I=1}|^{2}$$

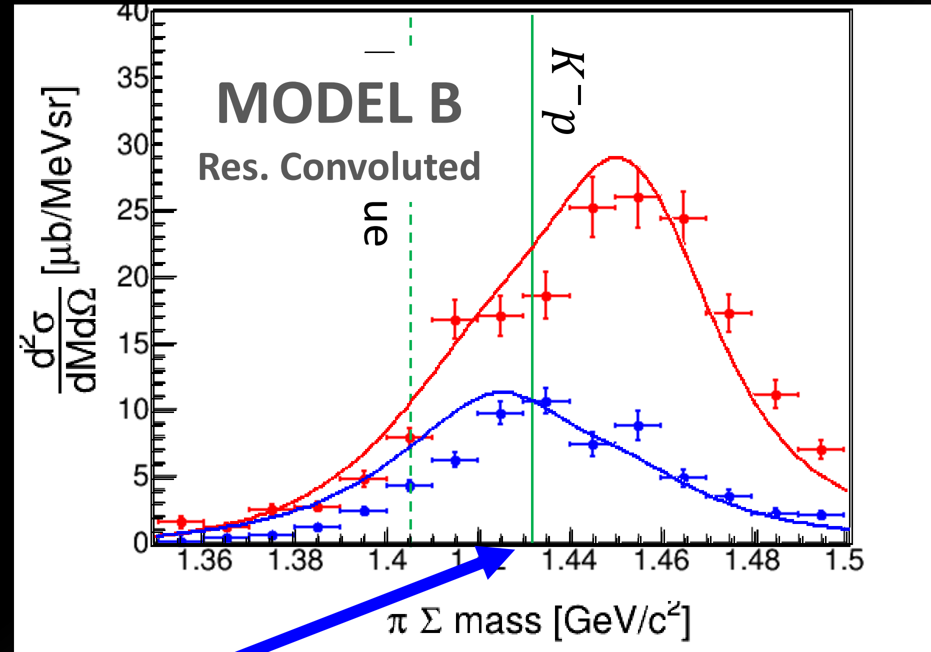


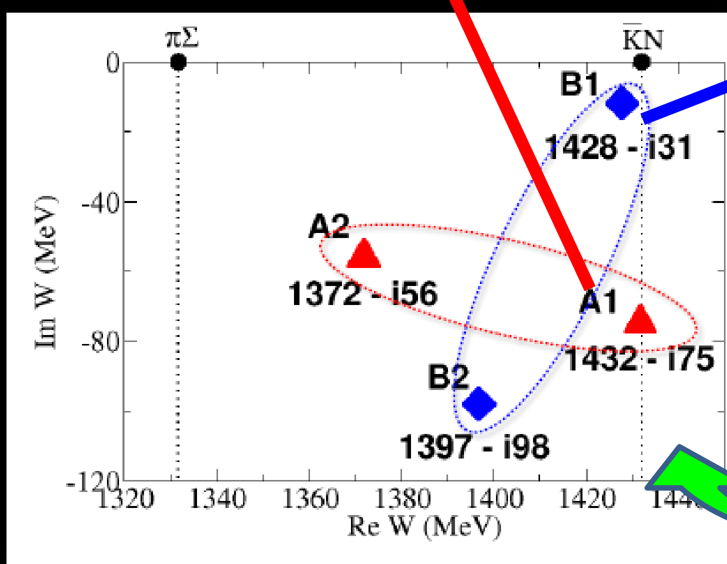


$$\frac{d\sigma}{d\Omega}(\pi^{0}\Sigma^{0})\sim\frac{1}{3}|f_{I=0}|^{2}$$

Comparison w/ theory

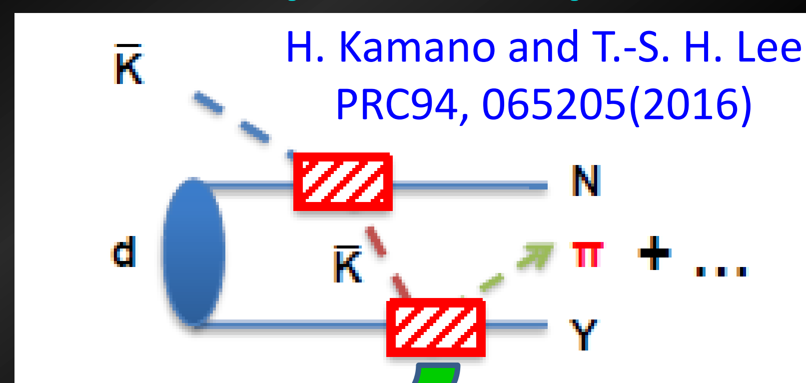






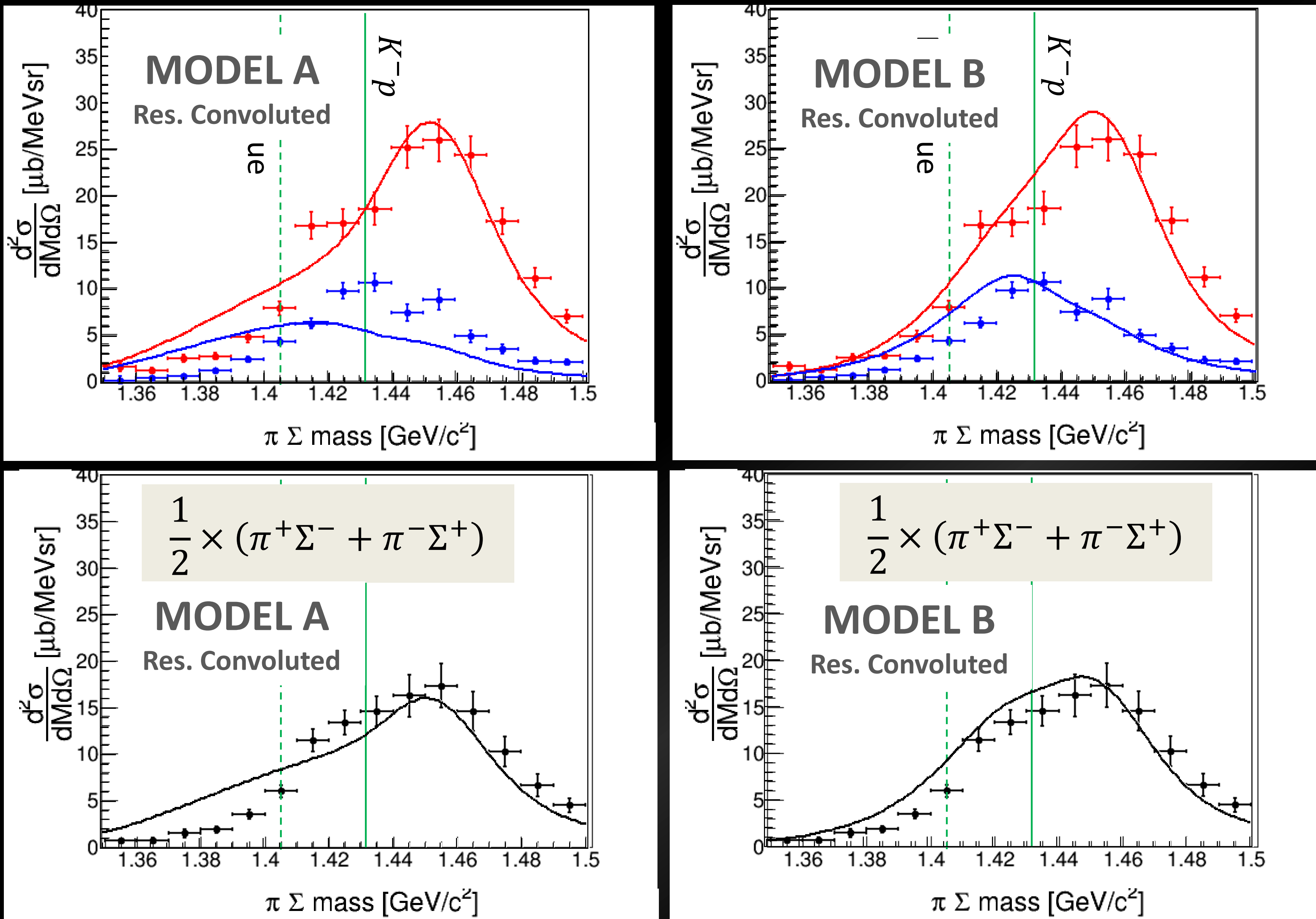
Two step reaction process

H. Kamano and T.-S. H. Lee
PRC94, 065205(2016)



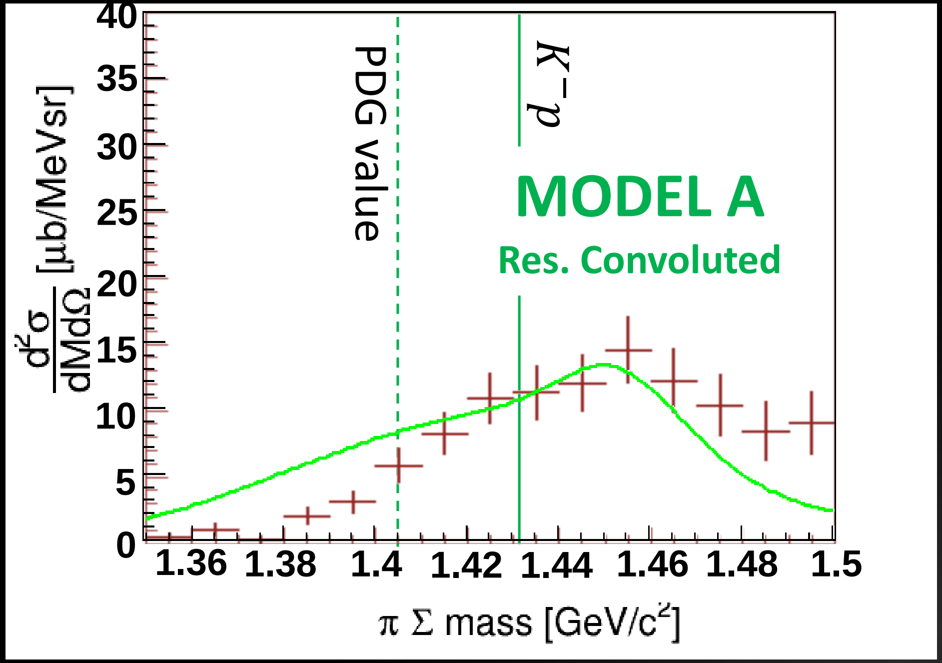
Resonance Poles

Comparison w/ theory

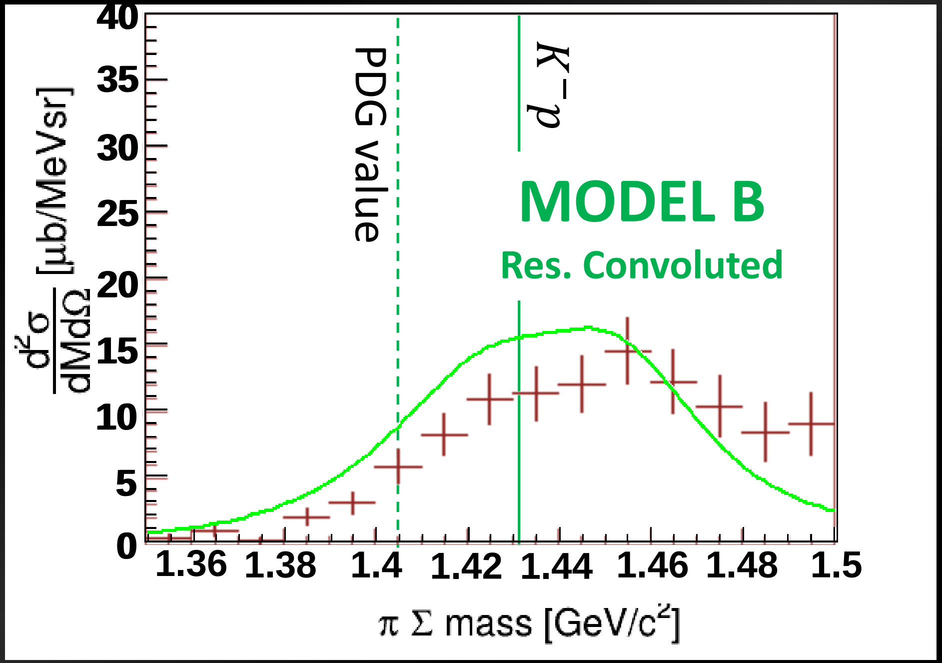


Comparison w/ theory

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



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



Summary

- Data analysis of the E31 2nd Run is in progress.
  - 39.2 G kaons were irradiated on deuteron.
- We first measured the $\pi^{\pm}\Sigma^{\mp}$ and $\pi^0\Sigma^0$ mass spectra followed by the Kaon-induced reaction on deuteron.
- We confirm
  - Interference btw I=0 and 1 amplitudes in the $\pi^{\pm}\Sigma^{\mp}$ modes
  - Dominance of I=0 amp. in the $\bar{K}N \to \pi\Sigma$ scattering.
- We compare w/ a theoretical calculation.
  - The two step process, $\bar{K}N \to \pi\Sigma$ followed by $K^-N \to n\bar{K}$ on deuteron, well explains a gross feature of observed spectra.
  - Pole positions related to $\Lambda(1405)$ MUST be extracted so as to reproduce the observed spectra further.

Backup

$\pi^+\Sigma^-/\pi^-\Sigma^+$ Mode separation (template fitting, Run78)