

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

H. Noumi, Osaka Univ. RCNP, for the P31 collaboration

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17. Osaka University, Japan

1. Introduction:

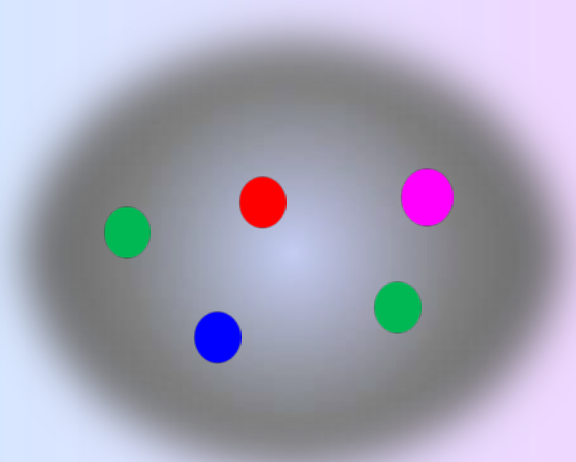
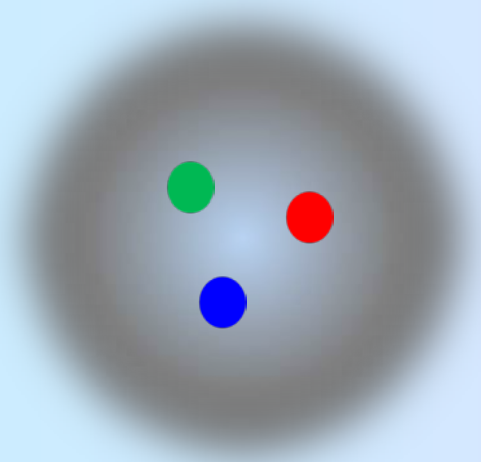
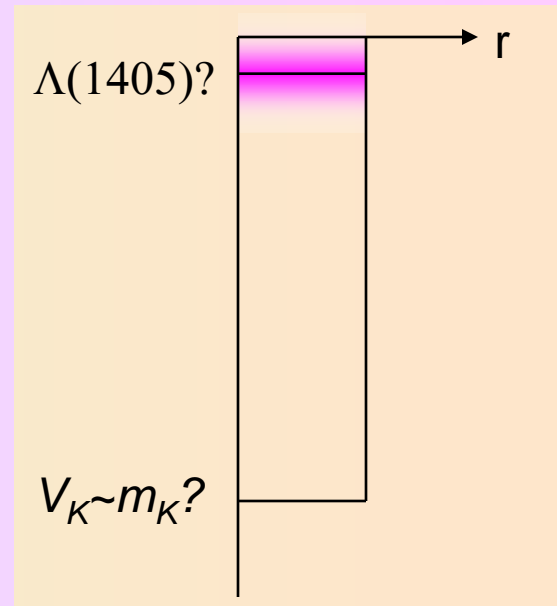
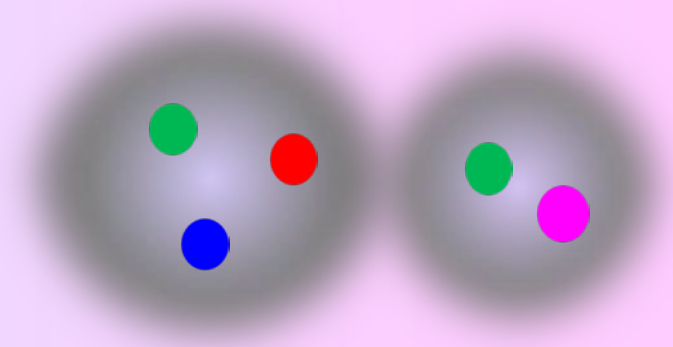
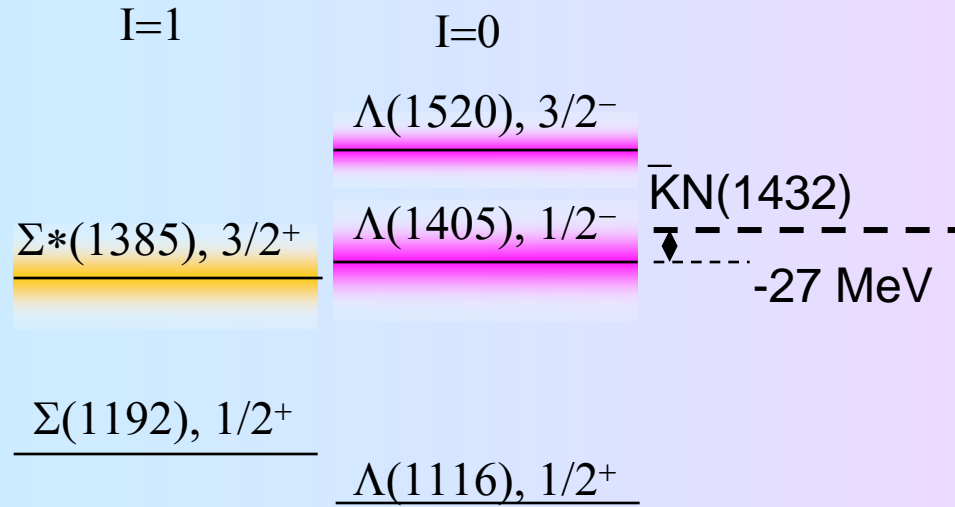
$K^{\text{bar}}N$ int. and $\Lambda(1405)$

2. Experimental Method

$d(K^-,n)\pi\Sigma$ w/ the E15 setup

3. Summary

What is $\Lambda(1405)$?



$\Lambda(1405)$ Spectroscopy via the (K^-,n) reaction on ^2H

$\Lambda(1405) S_{01}$

$$I(J^P) = 0(\frac{1}{2}^-)$$

It seems to be the universal opinion of the chiral-
nity that there are two poles in the 1400-MeV reg
discussions and earlier references, see for example
JIDO 03. ZYCHOR 08 presents experimental evide
two-pole model, but this is disputed by GENG 07A.

See also the "Note on the $\Lambda(1405)$ " in our 2000 edi
pean Physical Journal **C15** 1 (2000).

A single, ordinary three-quark $\Lambda(1405)$ fits nicely
 $1/2^-$ $SU(4) \bar{4}$ multiplet, whose other members are
 $\Xi_c(2790)^+$, and $\Xi_c(2790)^0$; see Fig. 1 of our not
Baryons."

$\Lambda(1405)$ MASS

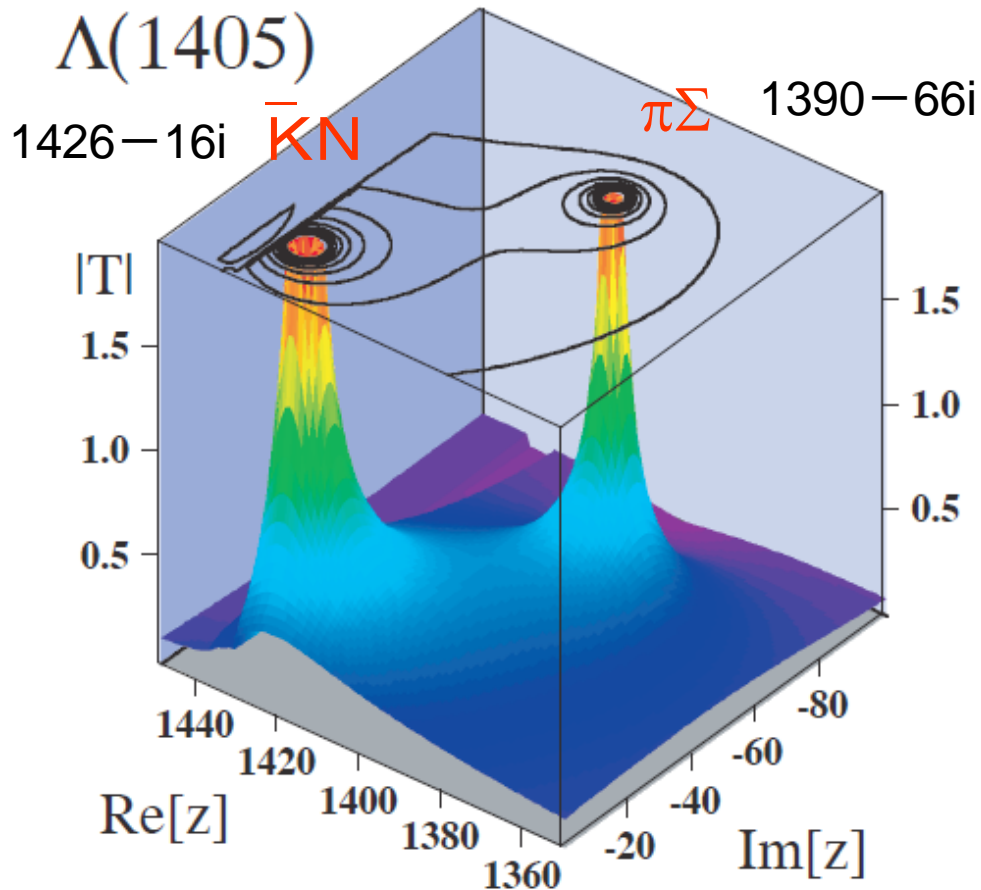
PRODUCTION EXPERIMENTS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN
<u>1406.5 ± 4.0</u>		¹ DALITZ 91	
• • • We do not use the following data for averages, fits, limits,			
1391 ± 1	700	¹ HEMINGWAY 85	HBC
~ 1405	400	² THOMAS 73	HBC
1405	120	BARBARO-... 68B	DBC
1400 ± 5	67	BIRMINGHAM 66	HBC
1382 ± 8		ENGLER 65	HDBC
1400 ± 24		MUSGRAVE 65	HBC
1410		ALEXANDER 62	HBC
1405		ALSTON 62	HBC
1405		ALSTON 61B	HBC

EXTRAPOLATIONS BELOW $N\bar{K}$ THRESHOLD

VALUE (MeV)	DOCUMENT ID	TECN
1407.56 or 1407.50	³ KIMURA 00	
• • • We do not use the following data for averages, fits, limits,		

$\Lambda(1405) : J^P = 1/2^-, I = 0$



ChU model, T. Hyodo

$\Lambda(1405)$ Spectroscopy via the (K^-,n) reaction on ${}^2\text{H}$

Motivation

- ✓ To clarify whether $\Lambda(1405)$ is a $K^{\text{bar}}\text{N}$ resonant state.

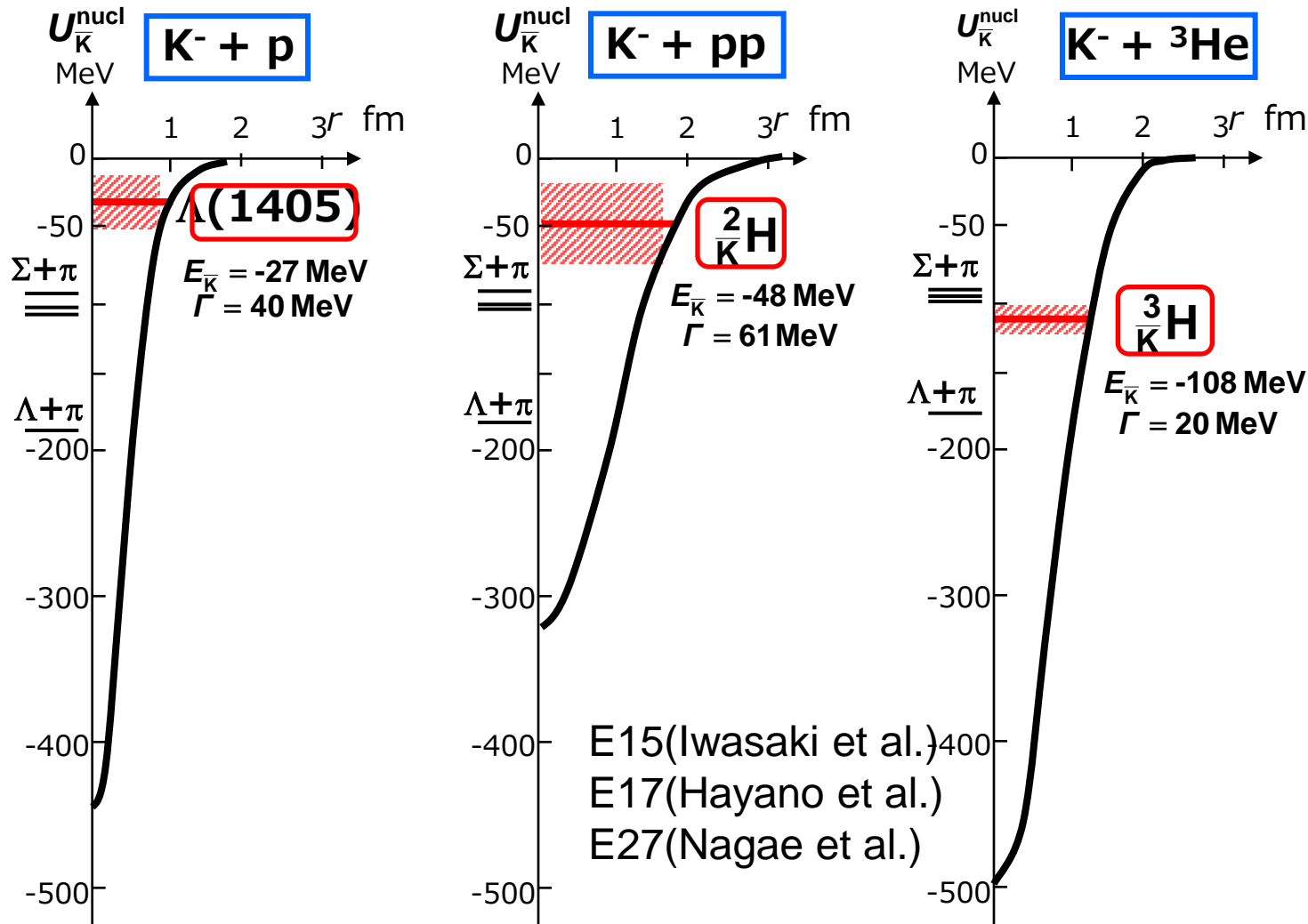
The position of Λ^* : Primary issue

~1405? as Dalitz et al. deduced.

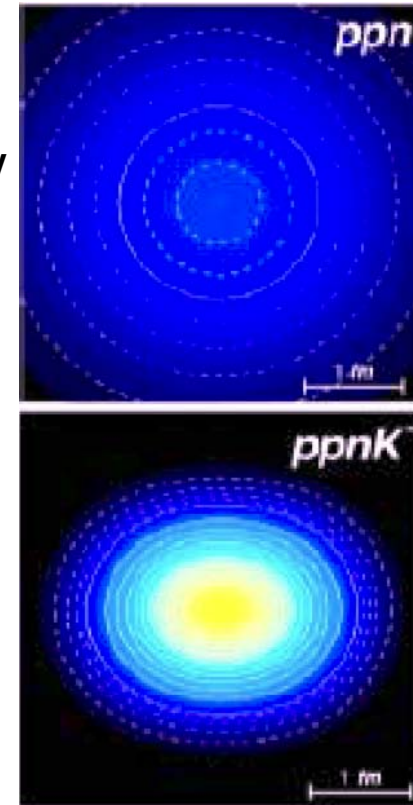
~1420? as Chiral Unitary Model predicted.

Provide the most fundamental information
on a K^{bar} -Nucleus deeply bound state.

Deeply Bound K-Nucleus System ?



Dote et al.



Y. Akaishi & T. Yamazaki, Phys. Rev. C **65** (2002) 044005.

Y. Akaishi & T. Yamazaki, Phys. Lett. B **535** (2002)

70.

8th PAC Recommendation for P31

The PAC recognizes the importance of the physics of the proposed measurements. However, there are important questions which remain to be addressed by the proponent. The PAC recommends that this proposal be deferred and reconsidered after the following questions are answered:

- How are the additional data going to accomplish the stated goals of the proposal?
Can an $I = 0$ component of the spectra be extracted unambiguously?
- Is the experimental setup suitable for the measurement of the $\Sigma^0 \pi^0$ decay channel?
Is it possible to discriminate the background of $\Sigma^*(1385) \rightarrow \Lambda \pi^0$?

$\Lambda(1405)$ Spectroscopy via the (K^-,n) reaction on ${}^2\text{H}$

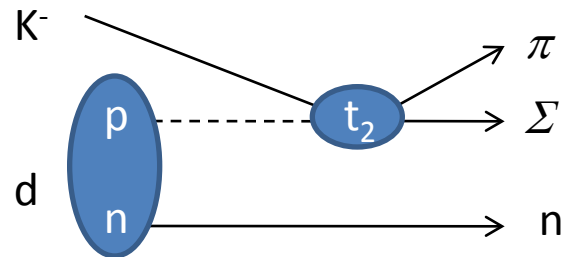
What do we measure?

✓ $K^{\text{bar}}\text{N}$ scattering below $K^{\text{bar}}\text{N}$ threshold

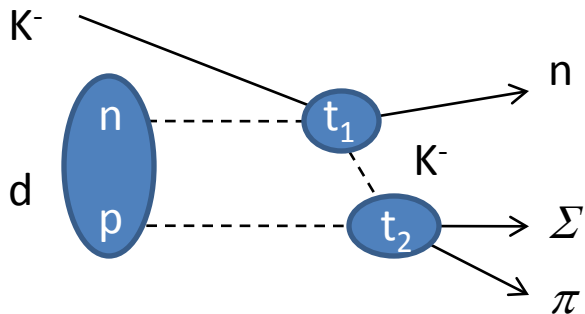
Employ $d(K^-,n)\Lambda^*$

Ideal to form the Λ^* directly coupled to $K^{\text{bar}}\text{N}$.

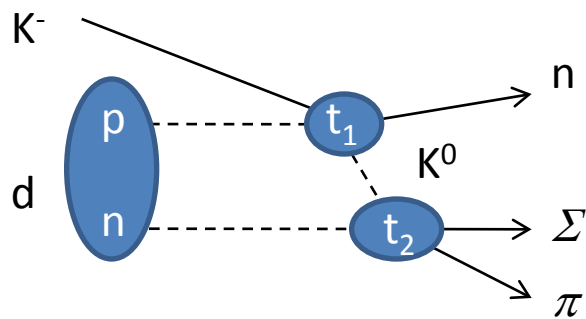
Reaction Diagram



dia.1:small

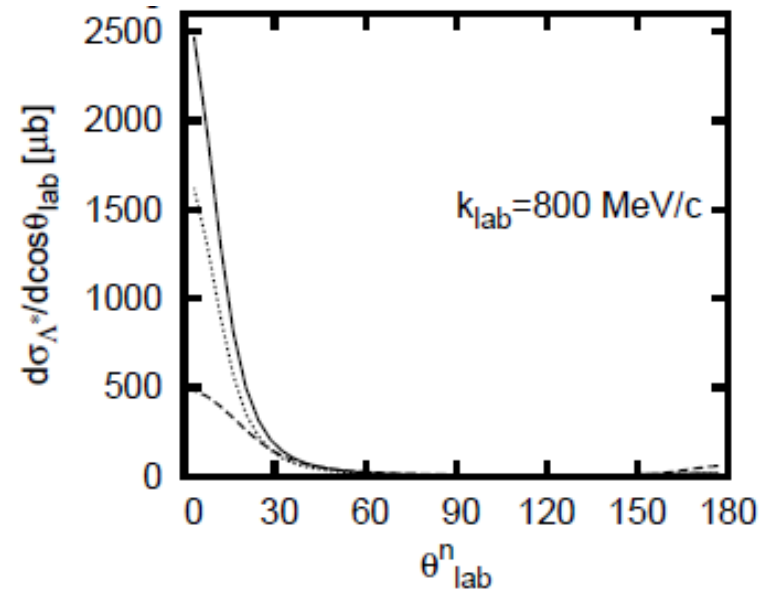
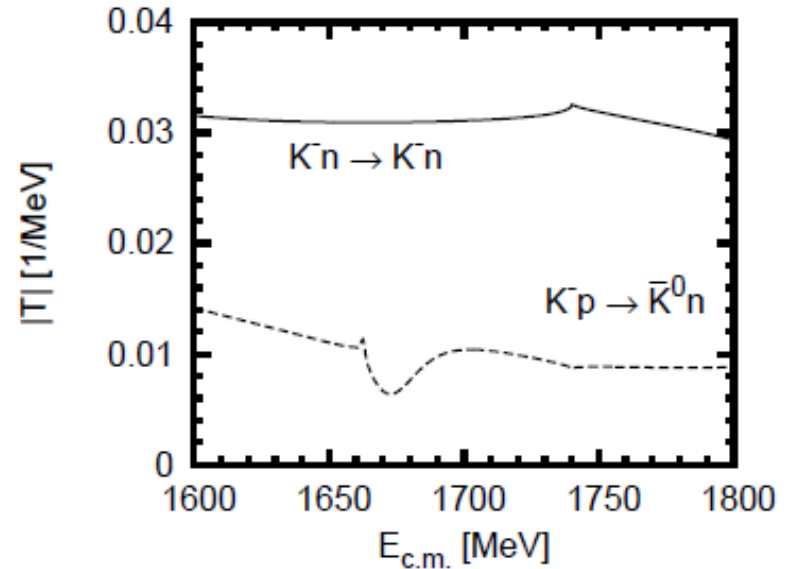


dia.2:dominant



dia.3:Interference

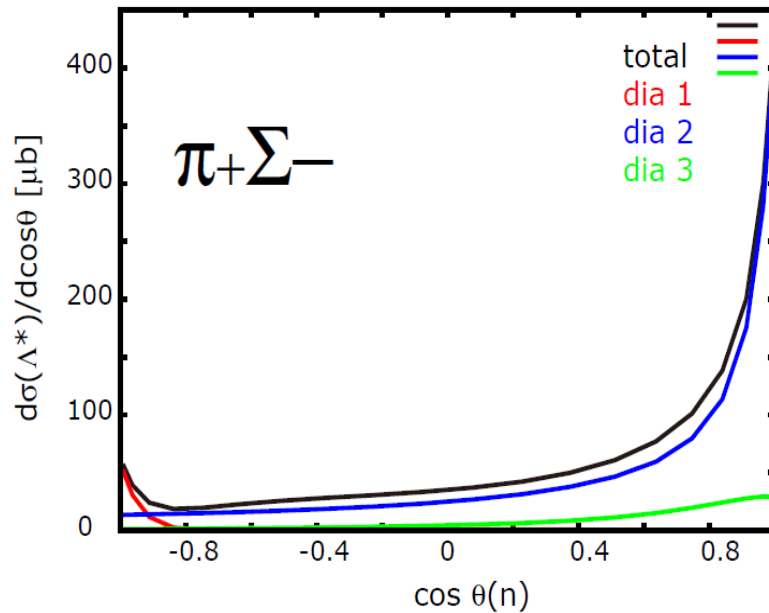
D. Jido, E. Oset, and T. Sekihara, arXiv:0904.3410



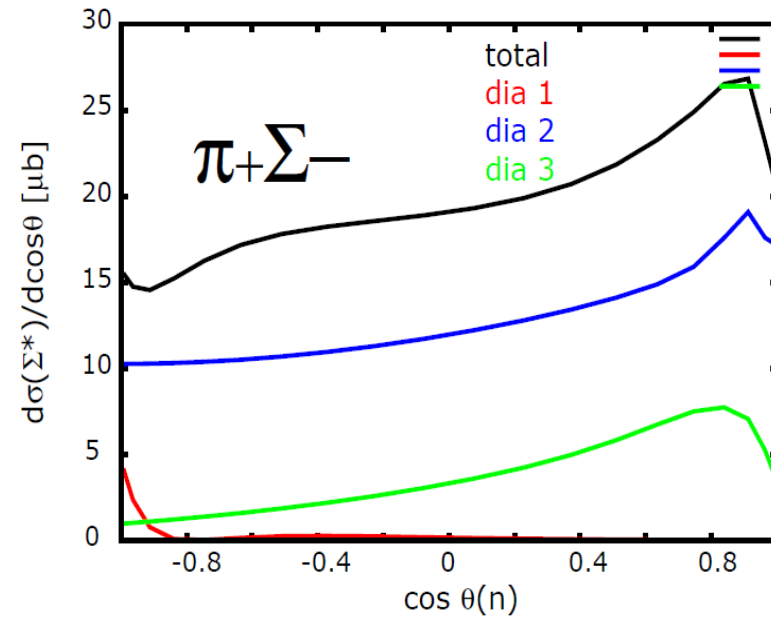
S-wave $K^{\text{bar}}N$ scattering is dominant at $\theta_n = 0$ degree.

$d(K^-,n)\pi^+\Sigma^-$ at $p_K=800$ MeV/c

(Λ^*)

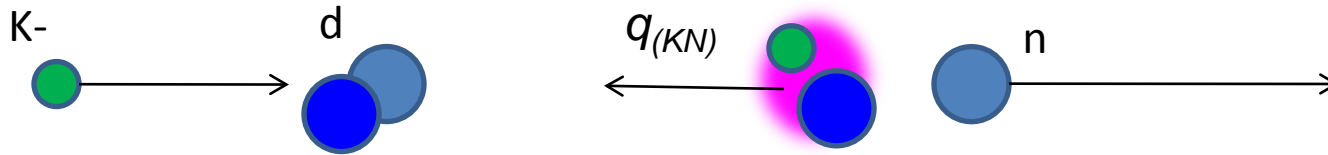


(Σ^*)



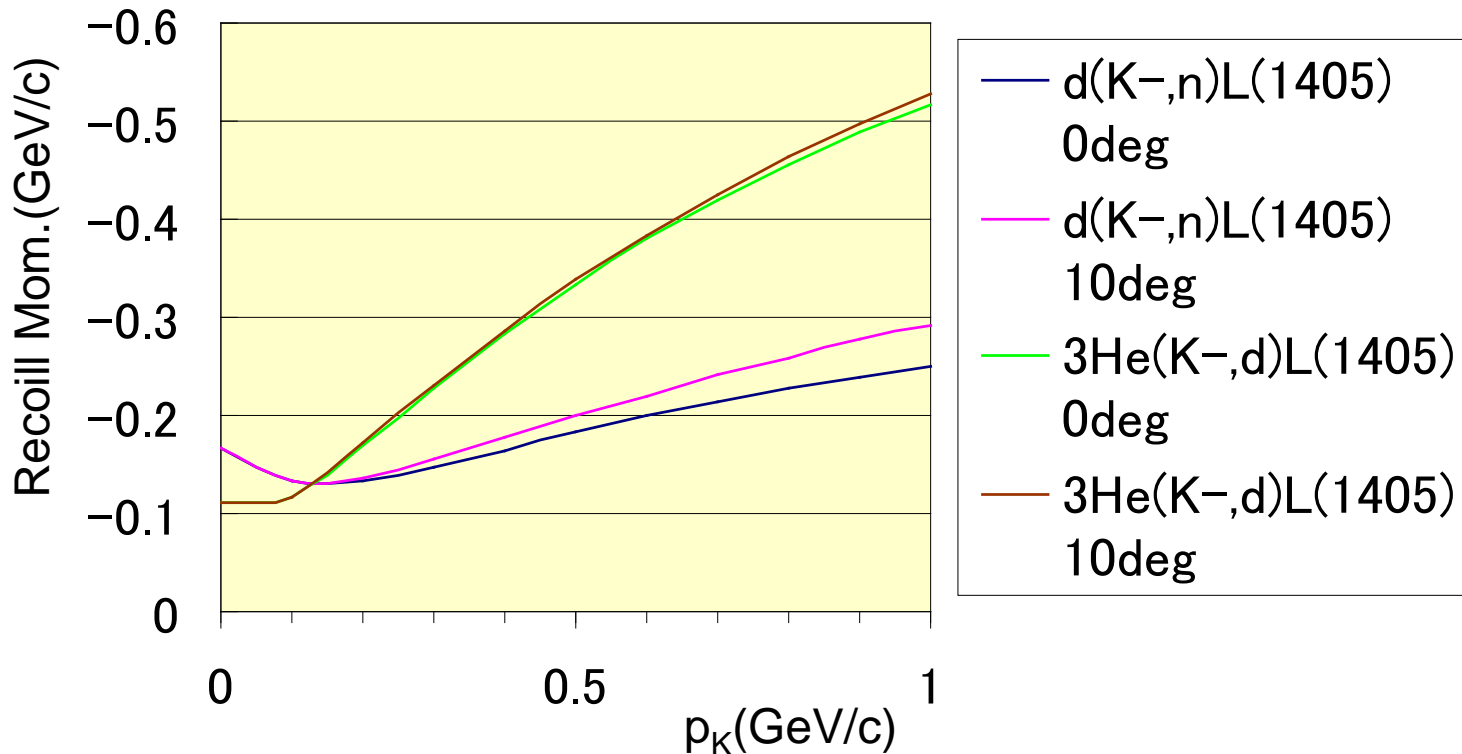
J. Yamagata-Sekihara,
T. Sekihara, and D. Jido,
paper in preparation

Simple understanding of the reaction mechanism

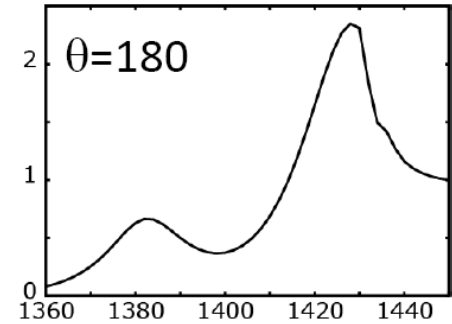
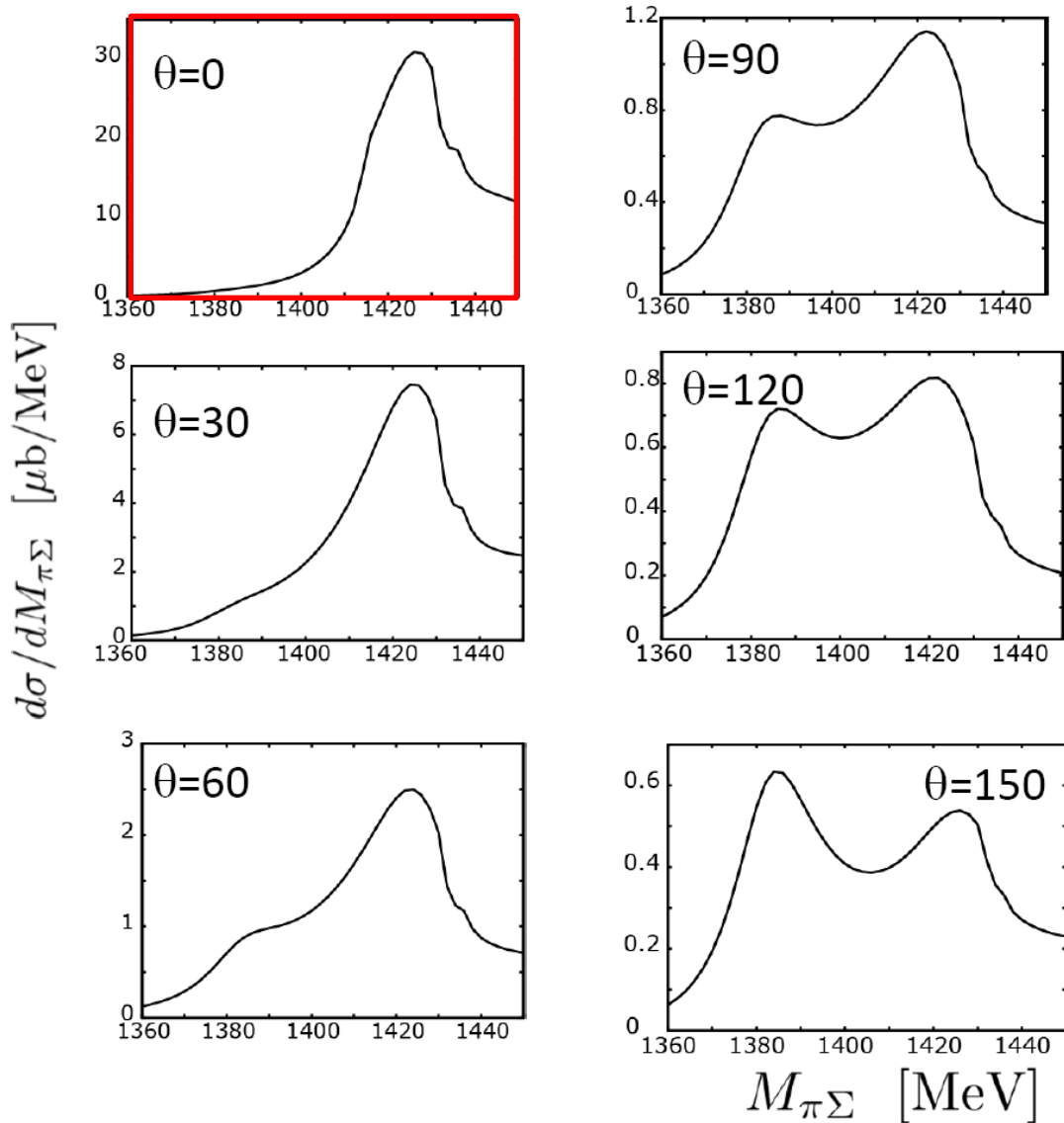


$$q_{\bar{K}N}^{Lab} \sim 250 \text{ MeV} / c, \quad p_{\bar{K}N}^{CM} \sim 160 \text{ MeV} / c$$

$$L = \frac{\vec{r} \times \vec{p}}{\hbar} < 1, \quad \text{for } r \sim 1 \text{ fm}$$

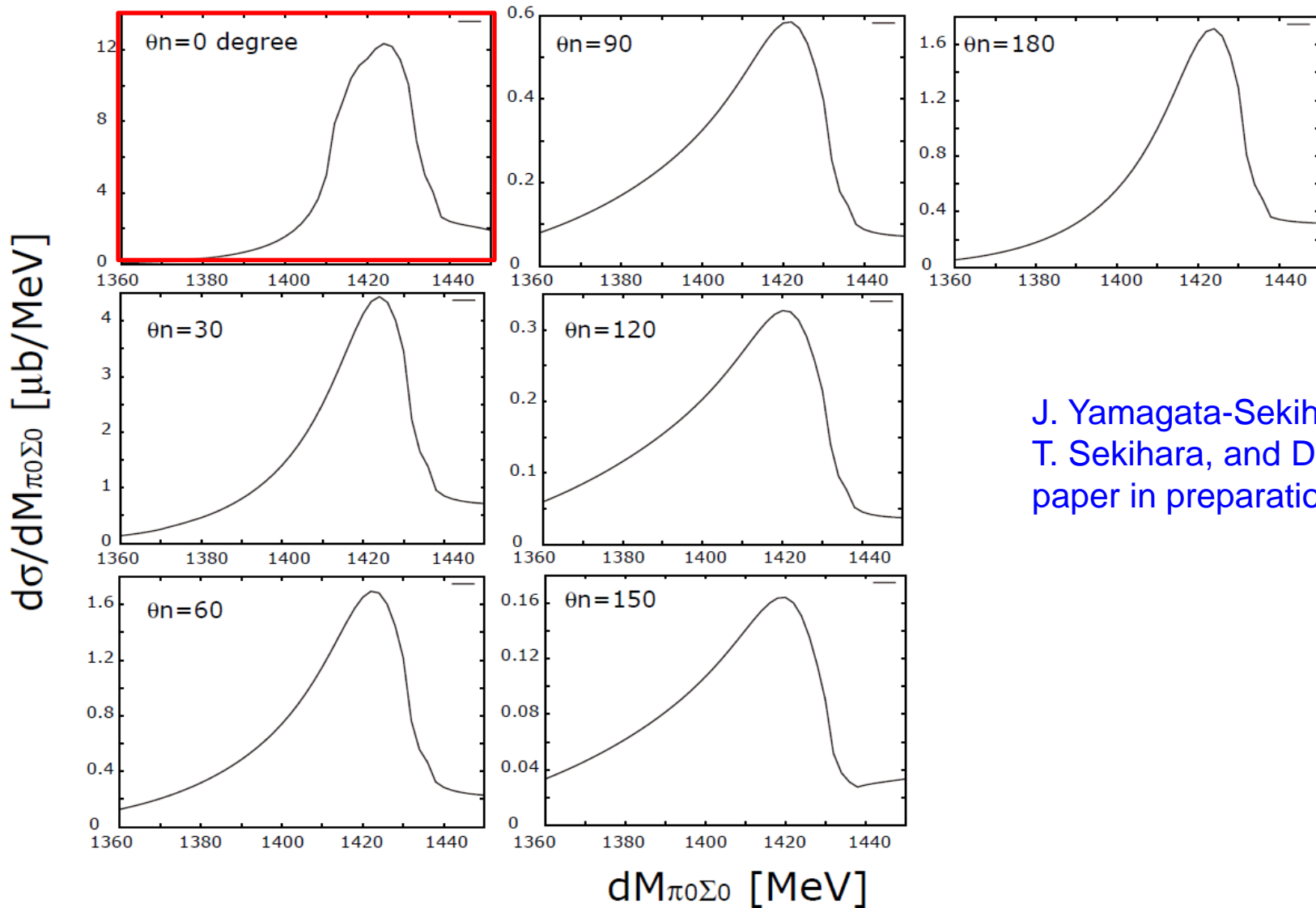


$$\frac{d\sigma}{dM_{\pi\Sigma}}(\theta), \quad K^- d \rightarrow \pi^+ \Sigma^- n \quad \text{at } p_K=800 \text{ MeV}/c$$



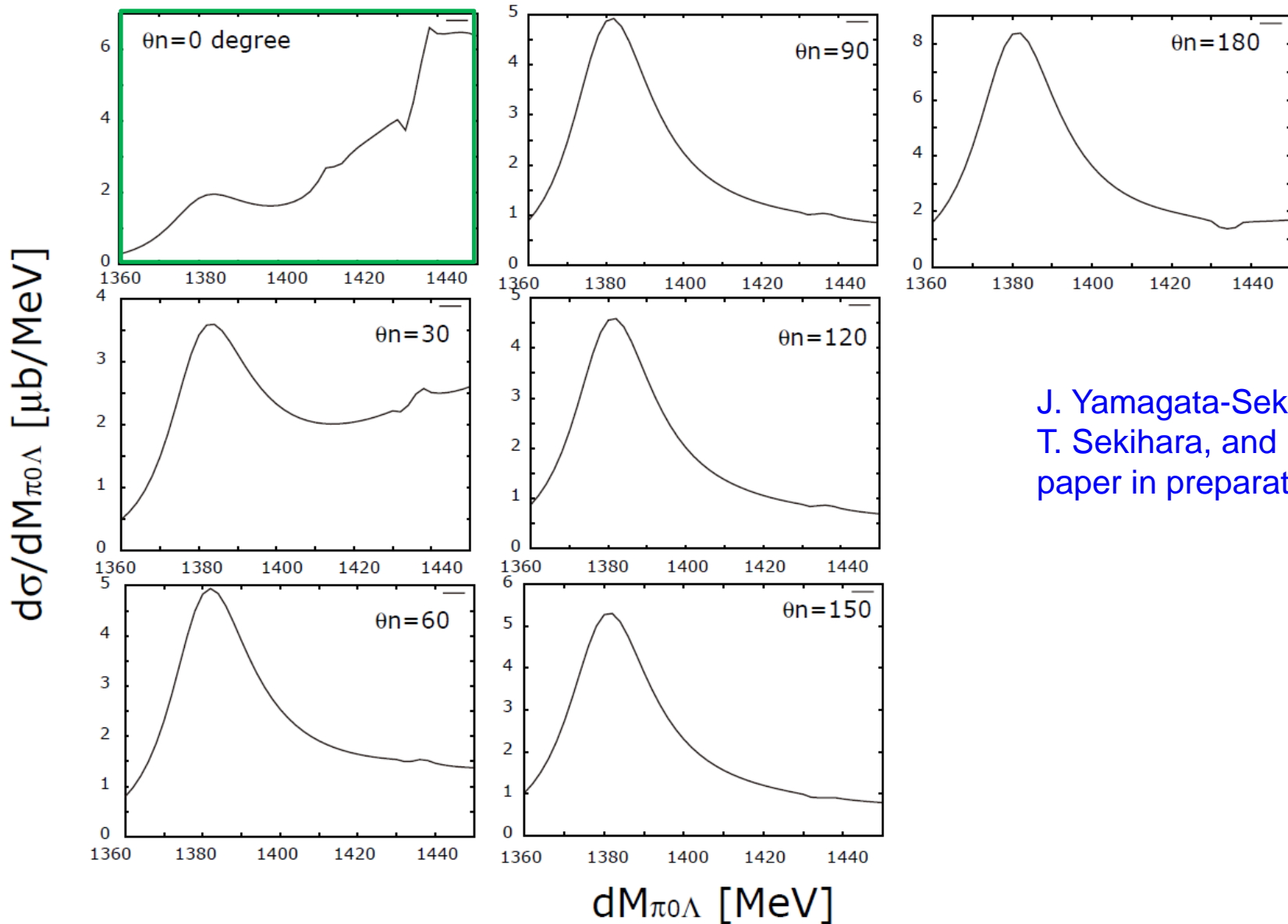
J. Yamagata-Sekihara,
T. Sekihara, and D. Jido,
paper in preparation

$$\frac{d\sigma}{dM_{\pi\Sigma}}(\theta), \quad K^- d \rightarrow \pi^0 \Sigma^0 n \quad \text{at } p_K=800 \text{ MeV}/c$$



J. Yamagata-Sekihara,
T. Sekihara, and D. Jido,
paper in preparation

$$\frac{d\sigma}{dM_{\pi\Sigma}}(\theta), \quad K^-d \rightarrow \pi^0\Lambda n \quad \text{at } p_K=800 \text{ MeV}/c$$



J. Yamagata-Sekihara,
T. Sekihara, and D. Jido,
paper in preparation

$\Lambda(1405)$ Spectroscopy via the (K^-,n) reaction on ${}^2\text{H}$

What do we measure?

- ✓ $K^{\text{bar}}\text{N}$ scattering below $K^{\text{bar}}\text{N}$ threshold

Employ $d(K^-,n)\Lambda^*$

Ideal to form the Λ^* directly coupled to $K^{\text{bar}}\text{N}$.

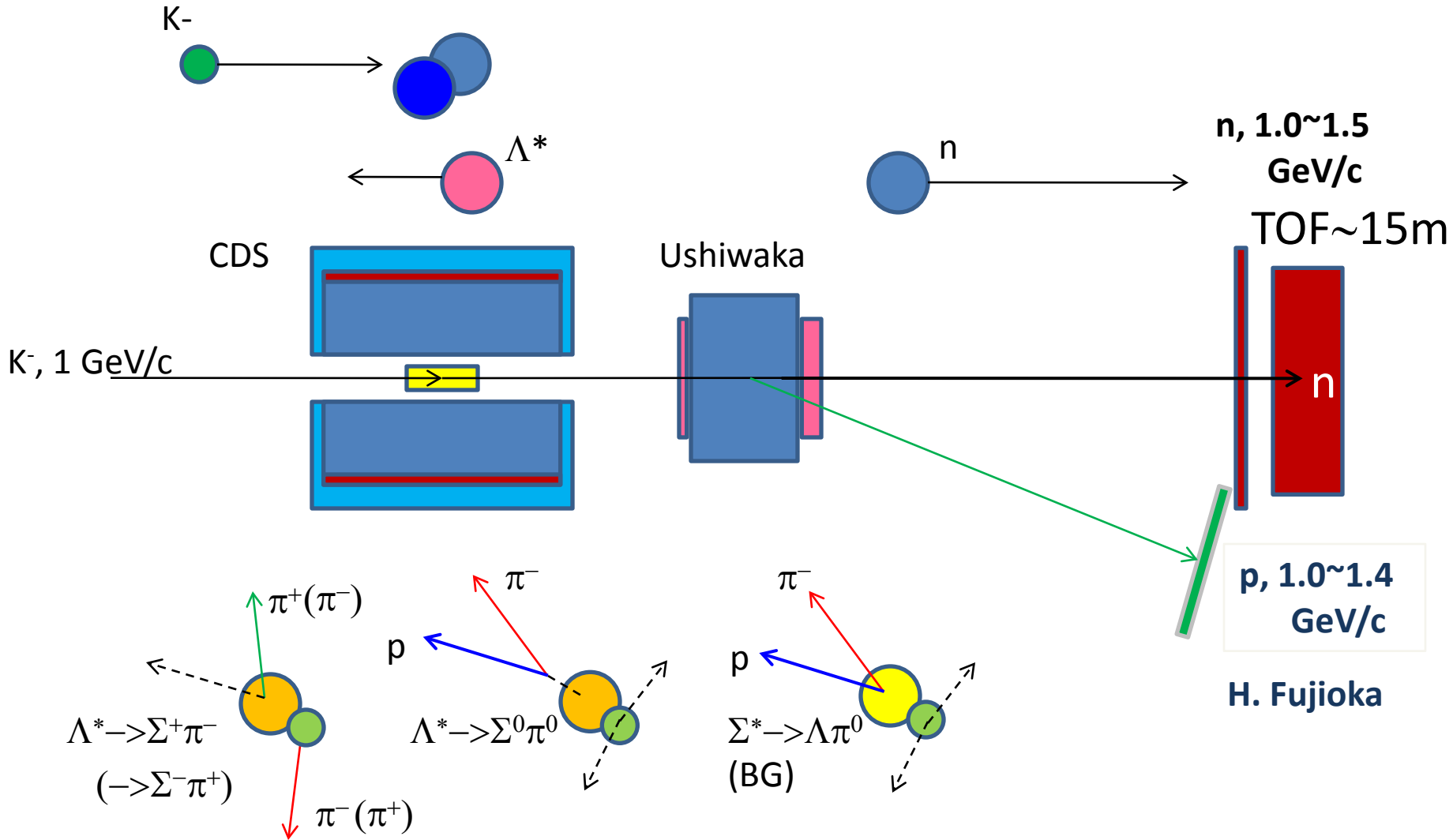
Enhancement of Λ^* production at $\theta_n=0$
BG from Σ^* will be reduced.

- ✓ Possible ID of an $I=0$ amp. in $K^{\text{bar}}\text{N} \rightarrow \pi\Sigma$

S-wave, $I=0$	$\rightarrow \Lambda^*(1405)$	$\rightarrow \pi^0\Sigma^0, \pi^{+/-}\Sigma^{-/+}$
S-wave, $I=1$	\rightarrow non-resonant	} $\rightarrow \pi^0\Lambda, \pi^{+/-}\Sigma^{-/+}$
P-wave, $I=1$	$\rightarrow \Sigma^*(1385)$	

$\Lambda(1405)$ Spectroscopy via the (K^-,n) reaction on ${}^2\text{H}$

${}^2\text{H}(K^-,p)\Sigma^{*-}$

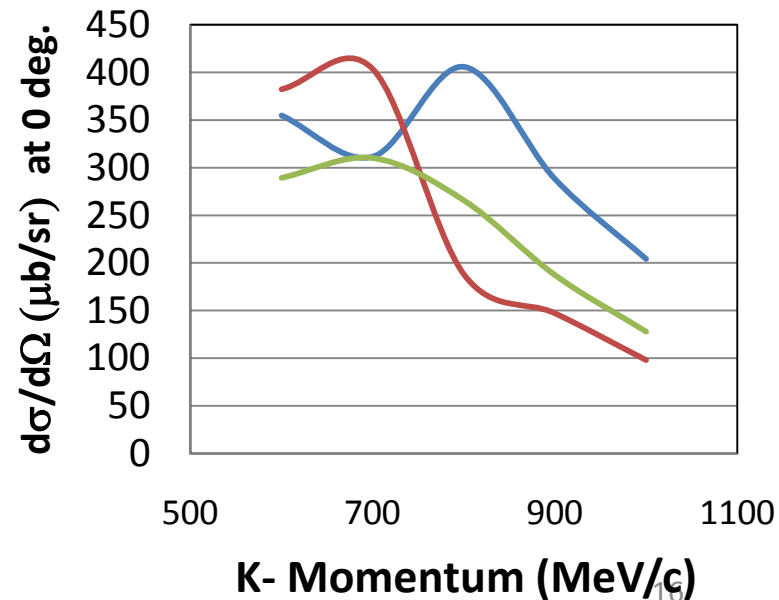
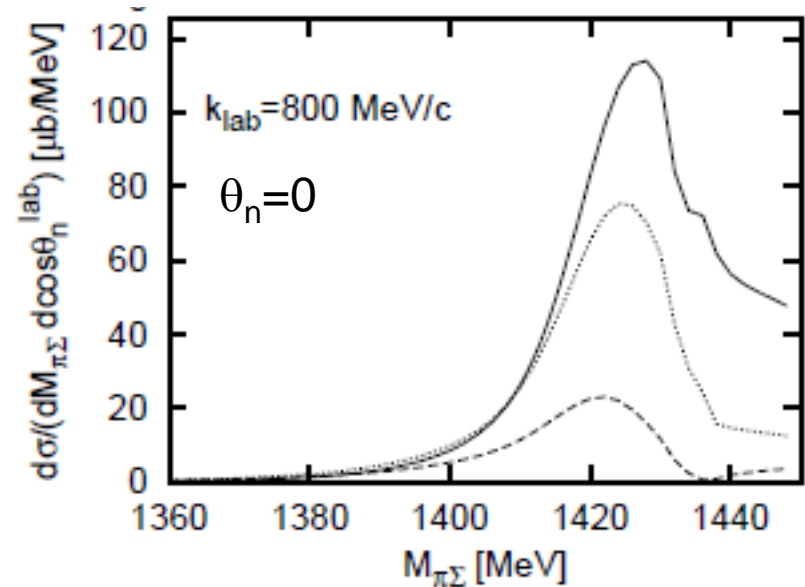
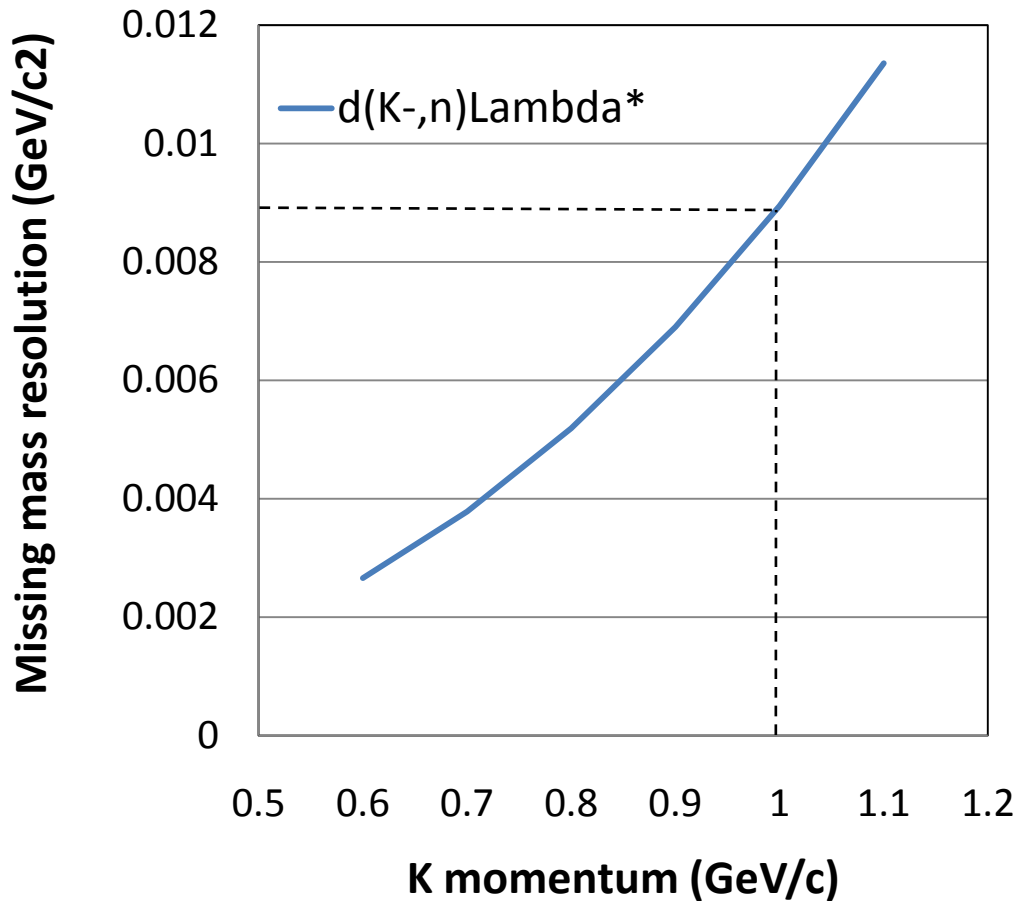


Missing Mass Resolution in the $d(K^-, n)X$ reaction

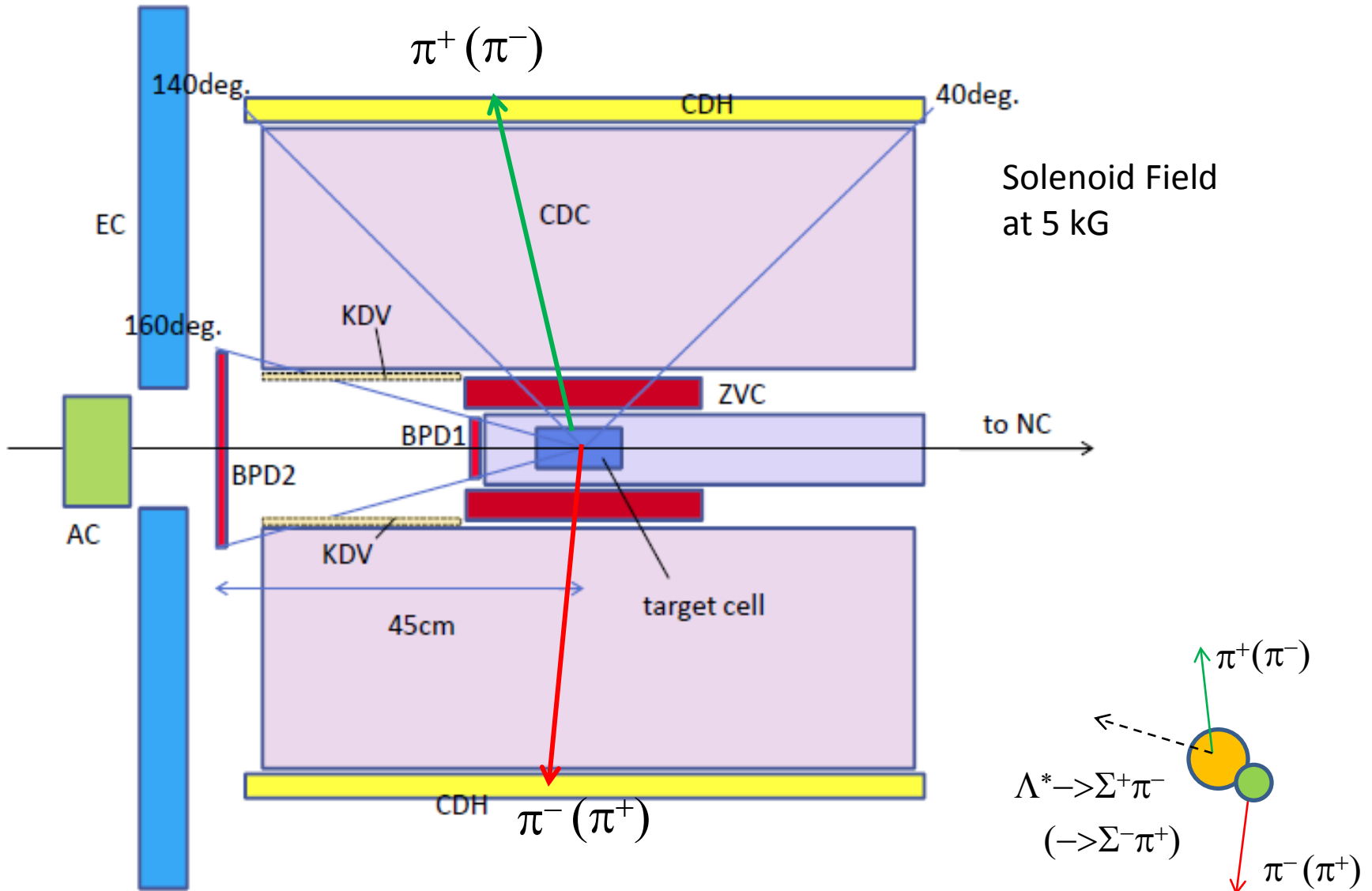
Dominant sources of ambiguity...

$dt \sim 120$ ps (NC) $dL_V \sim 2$ cm, $dL_T \sim 5$ cm, F.L. = 15 m

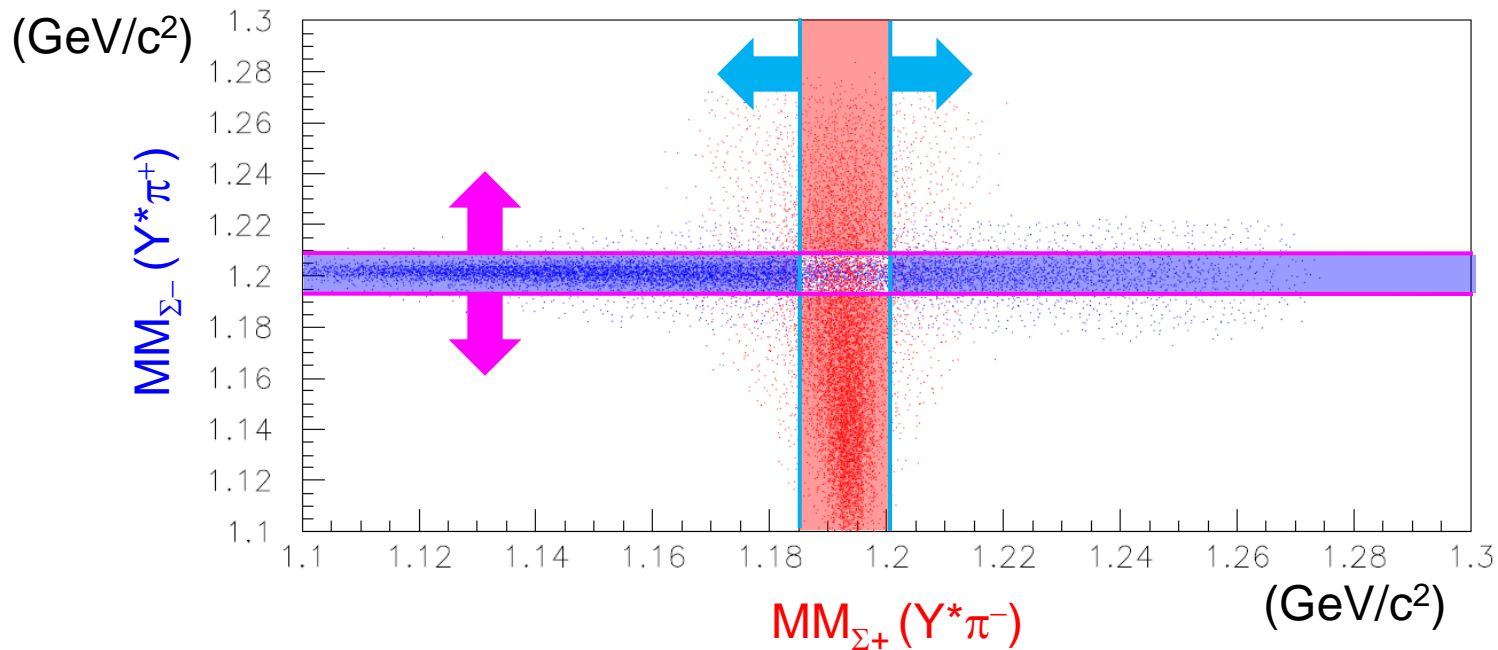
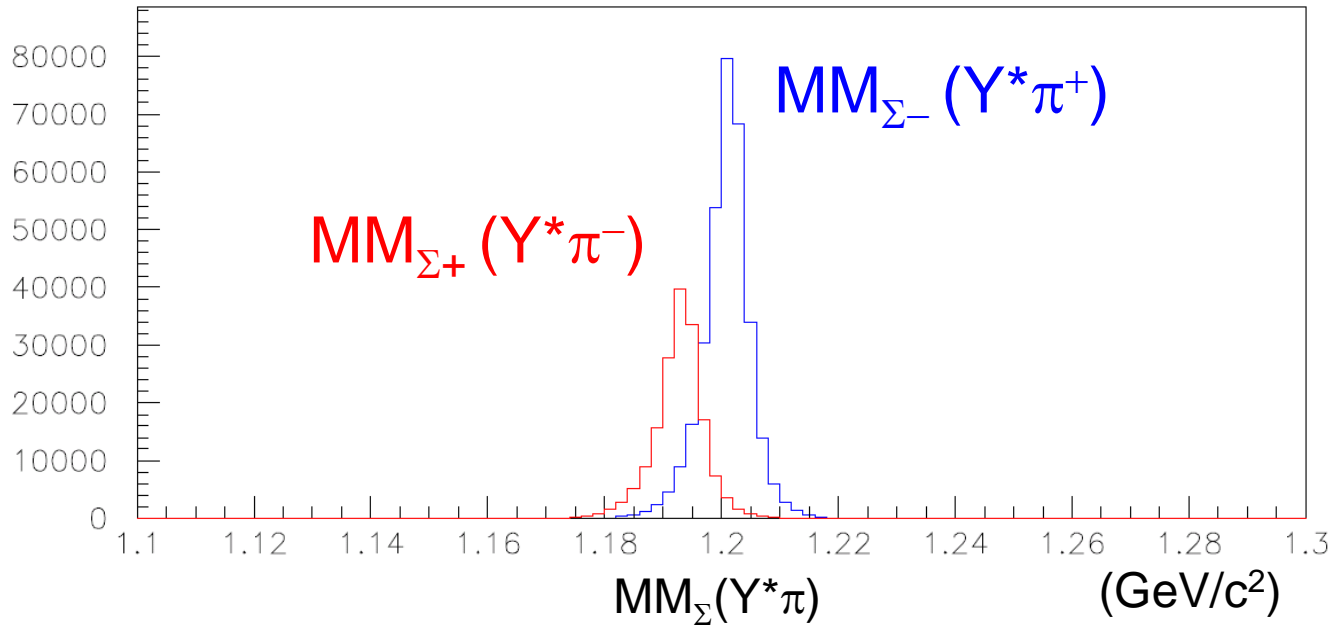
$\sigma_{MM} \sim 9$ MeV/c at $p_{K^-} = 1$ GeV/c

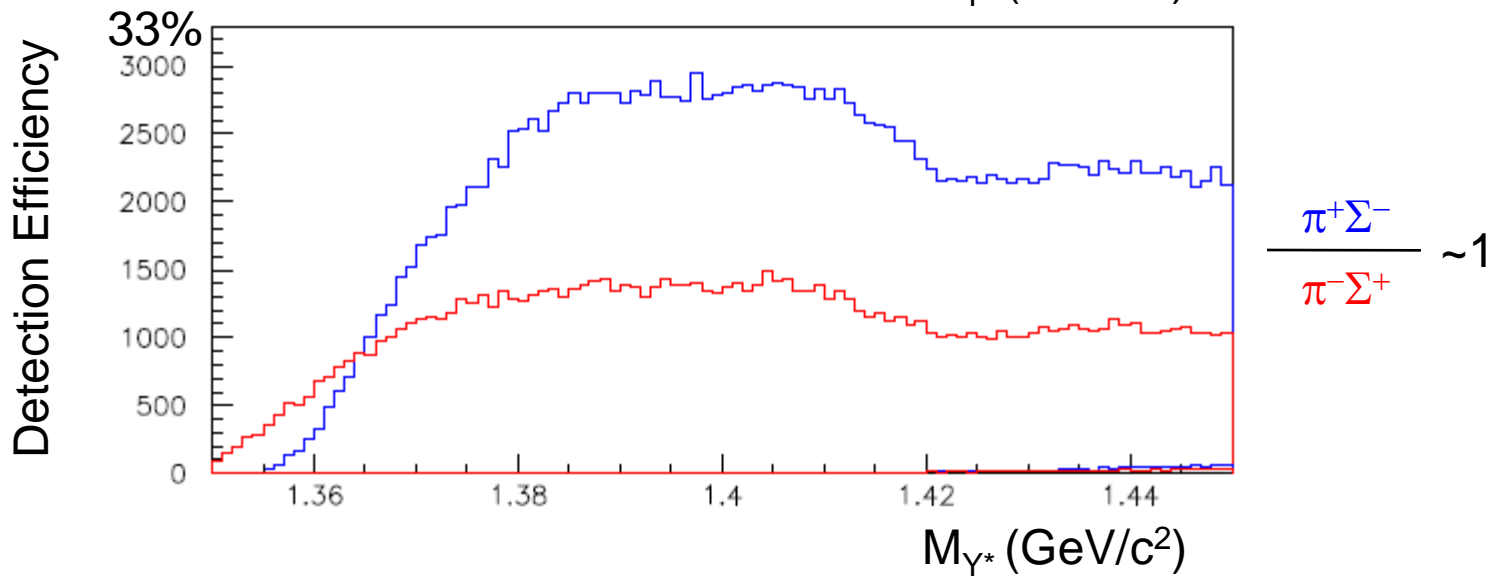
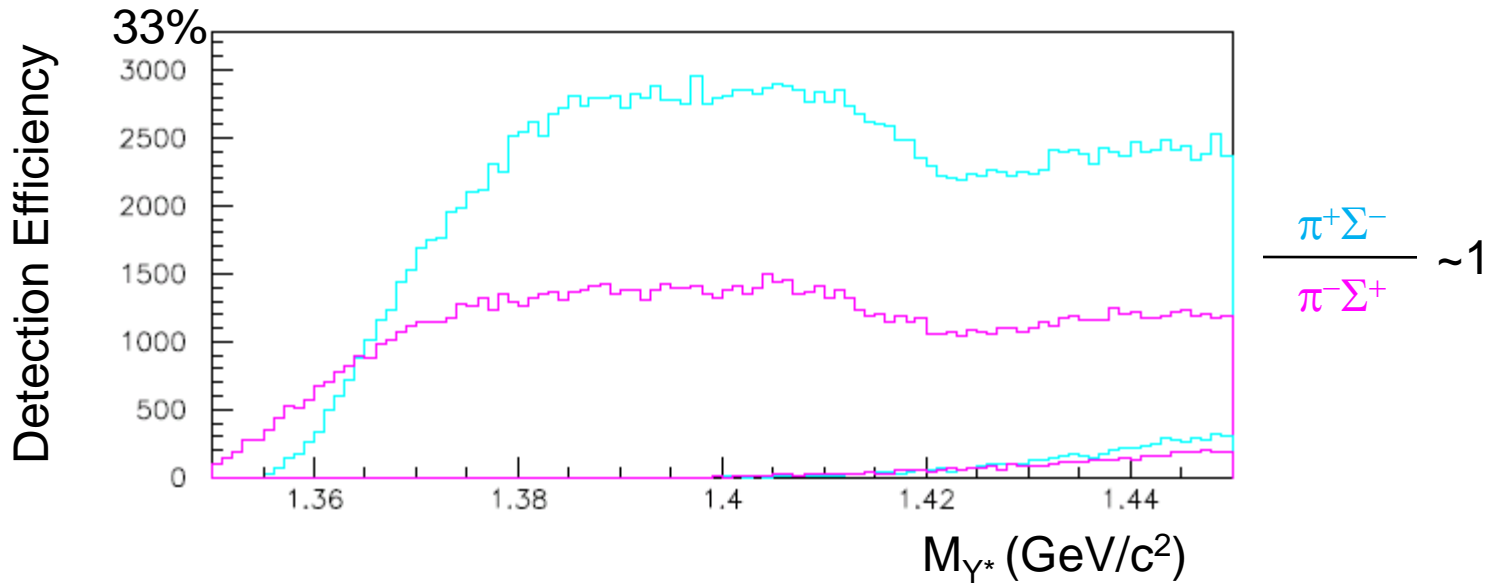


Detection of the $\Lambda^* \rightarrow \pi^- \Sigma^+$ and $\pi^+ \Sigma^-$ modes

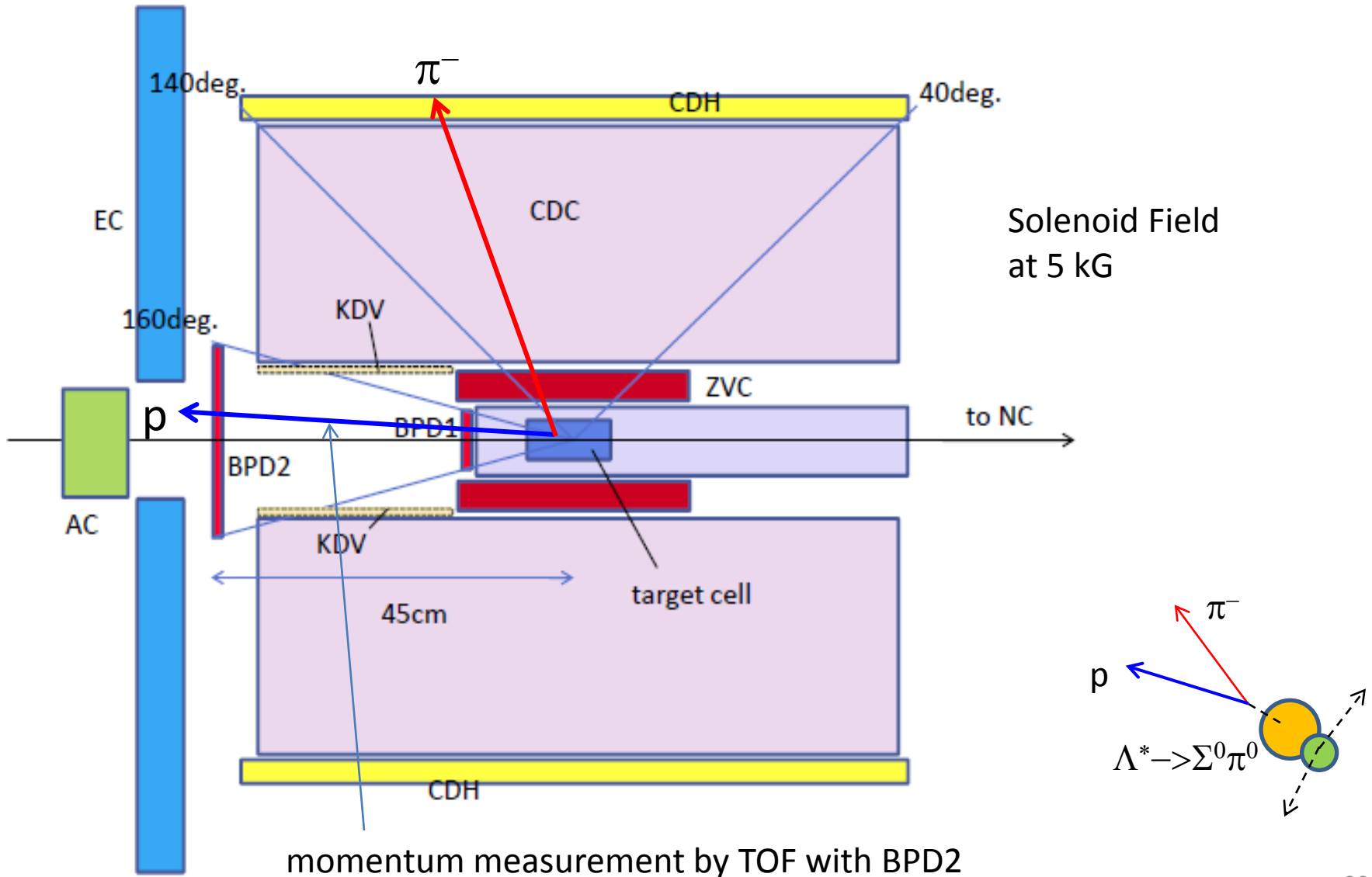


Identification of the $\Lambda^* \rightarrow \pi^- \Sigma^+$ and $\pi^+ \Sigma^-$ modes



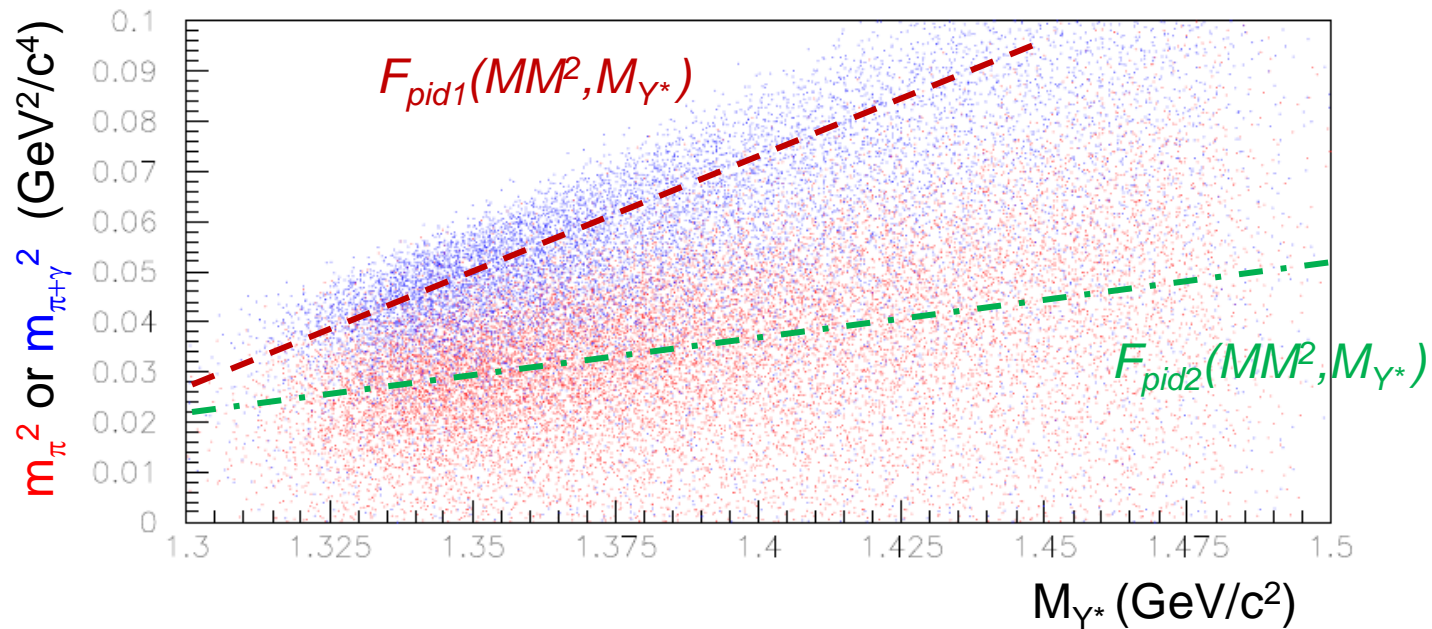


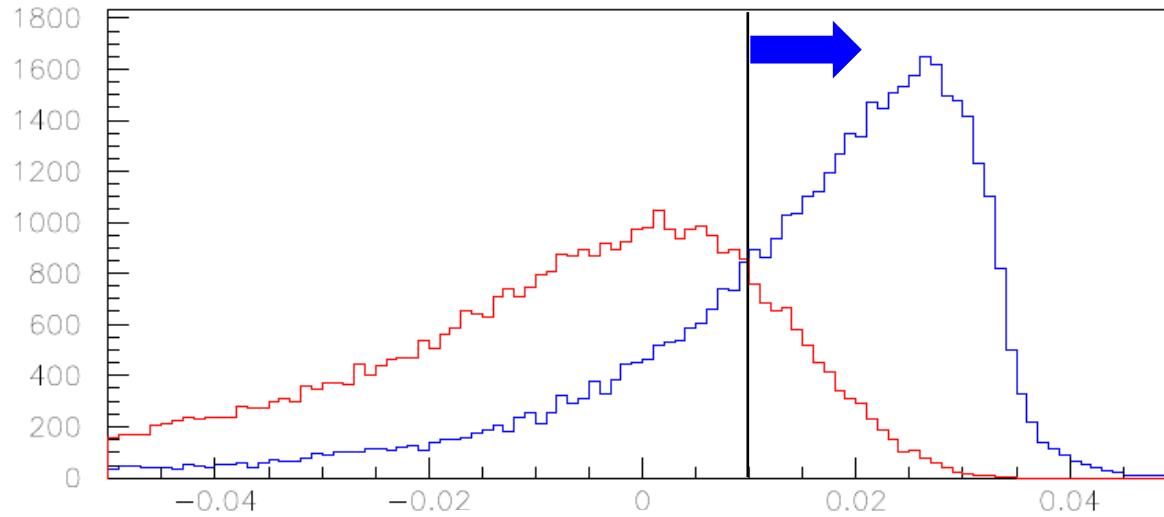
Backward Proton Detectors for the $\Lambda^* \rightarrow \pi^0 \Sigma^0$ mode



Identification of the $\Lambda^* \rightarrow \pi^0 \Sigma^0$ mode

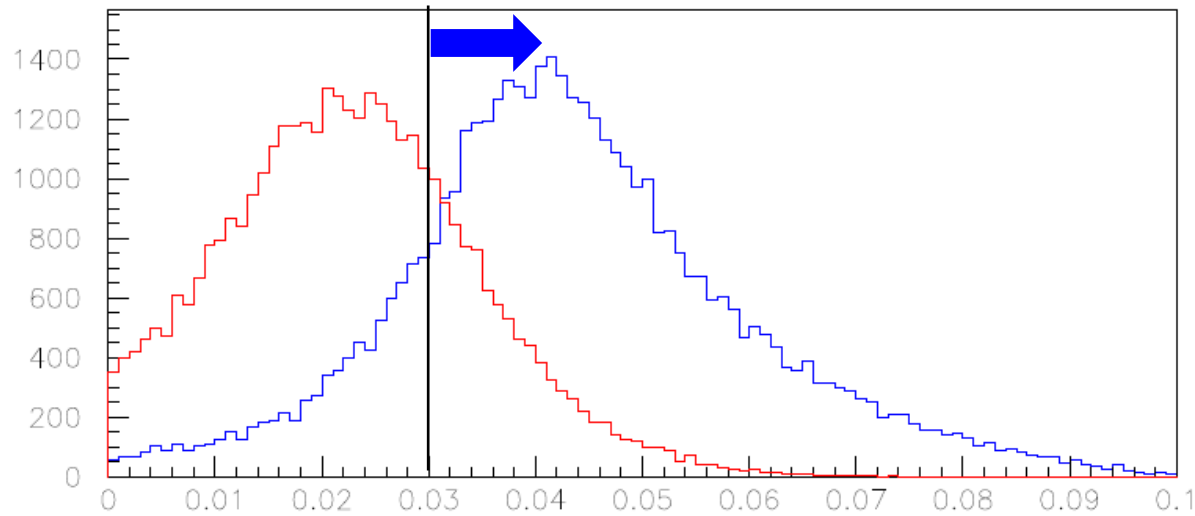
$$\frac{\pi^0 \Lambda \quad (I=1)}{\pi^0 \Sigma^0 \quad (I=0)} \sim 1$$



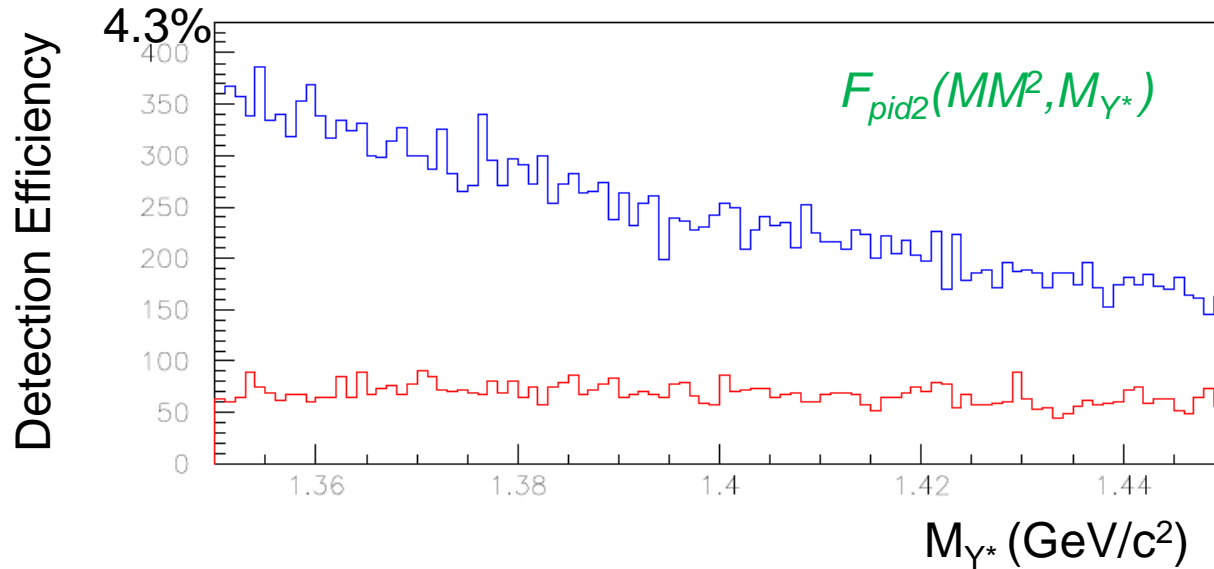
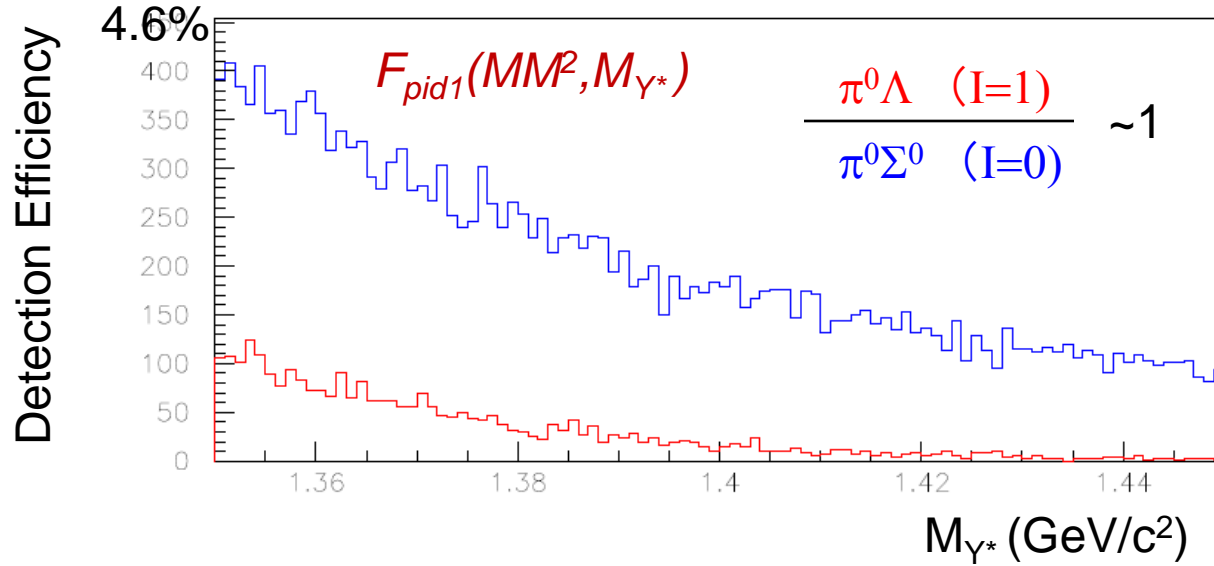


$$\frac{\pi^0 \Lambda \quad (I=1)}{\pi^0 \Sigma^0 \quad (I=0)} \sim 1$$

$F_{pid1}(MM^2, M_{\gamma^*})$



$F_{pid2}(MM^2, M_{\gamma^*})$



Summary

- (1) We propose to study the $d(K^-, n)\pi\Sigma$ reactions, which is aiming primarily to clarify whether $\Lambda(1405)$ is a $K^{\text{bar}}N$ resonance as predicted by the ChUM or not.
(We fix if Λ^* appear at $1420 \text{ MeV}/c^2$ or $1405 \text{ MeV}/c^2$.)
- (2) We expect to reduce Σ^* BG owing to S-wave dominant $d(K^-, n)$ at $\theta_n=0$.
- (3) We expect to identify the final $\pi^+\Sigma^-$ and $\pi^-\Sigma^+$ states clearly.
-> Primary aim can be achieved.
- (4) We demonstrate to identify the final $\pi^0\Sigma^0$ state.
-> Possible decomposition of $I=0$ amplitude.
S-wave dominant $d(K^-, n)$ at $\theta_n=0$ is quite helpful.

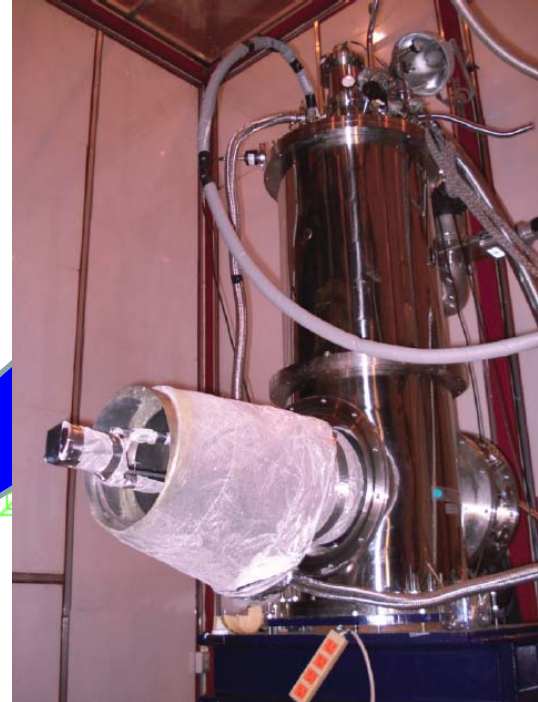
The E15 setup is quite suitable to carry out the present experiment.

Backup Slides

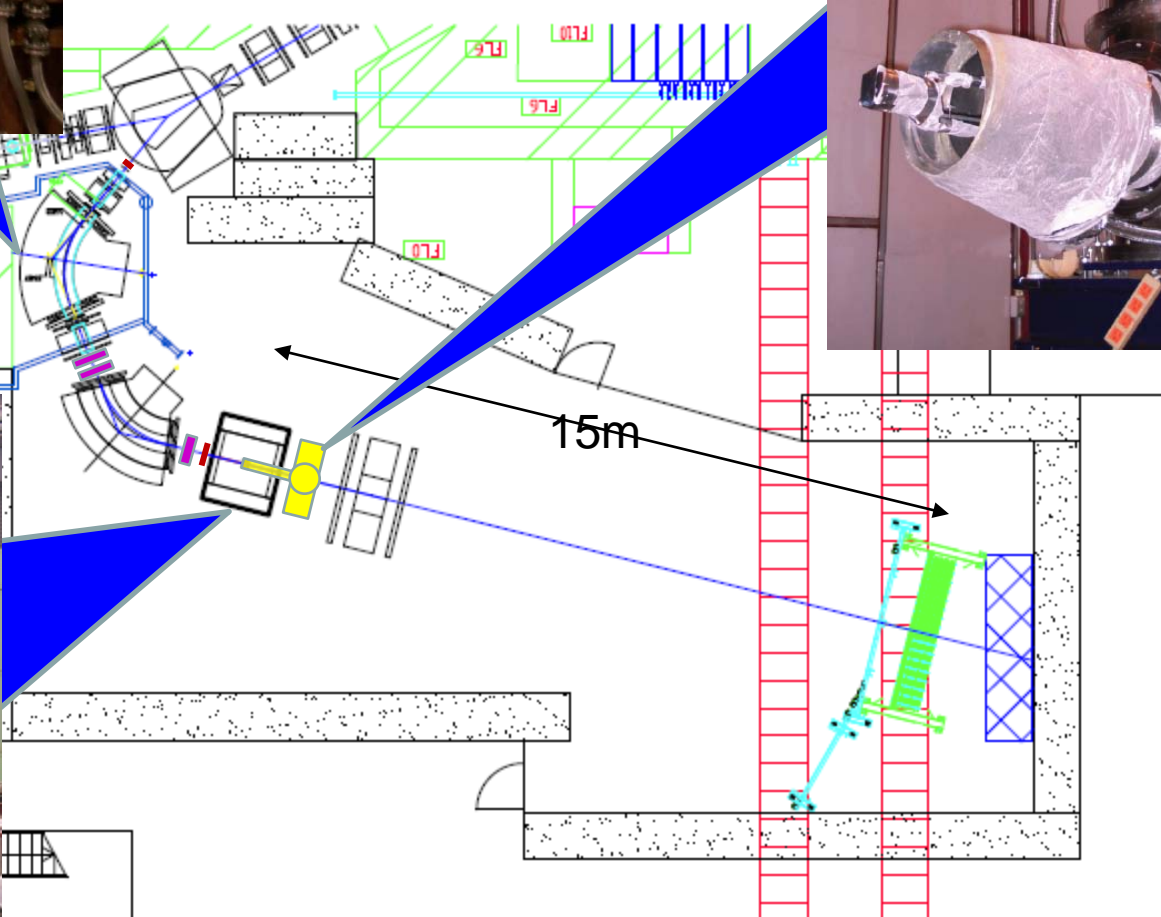
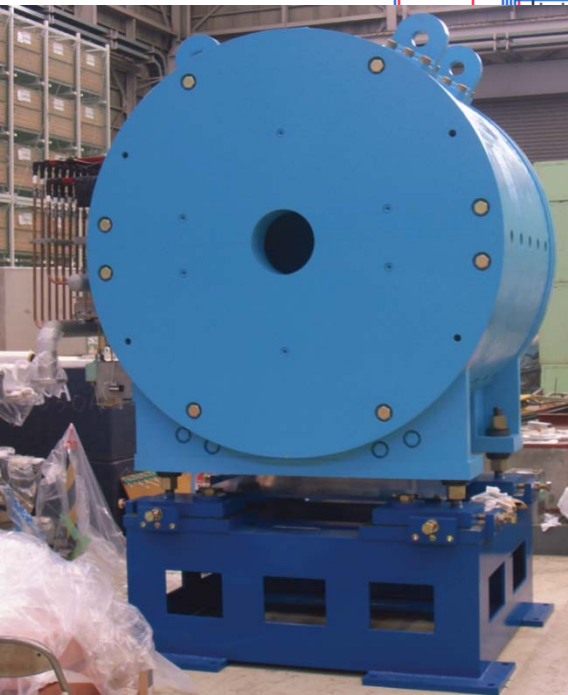
K1.8BR for E15



Beam Analyzer

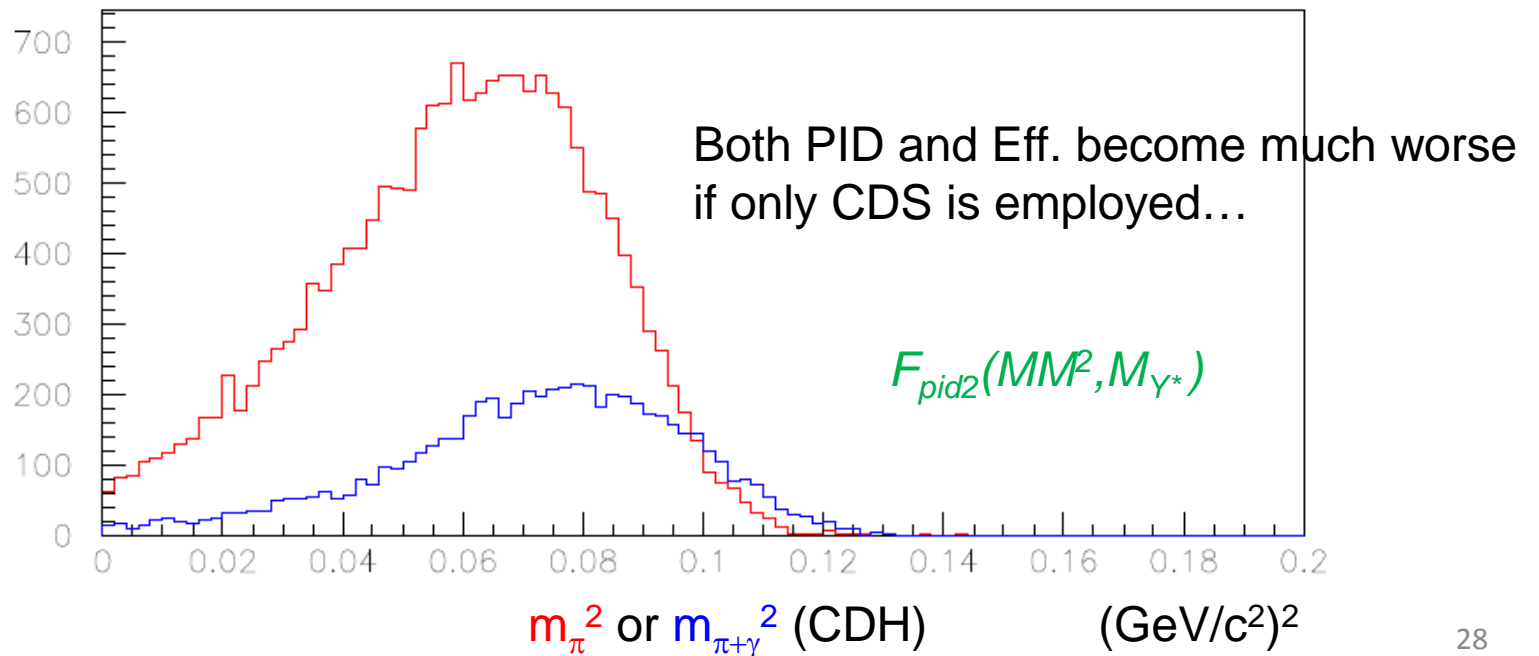
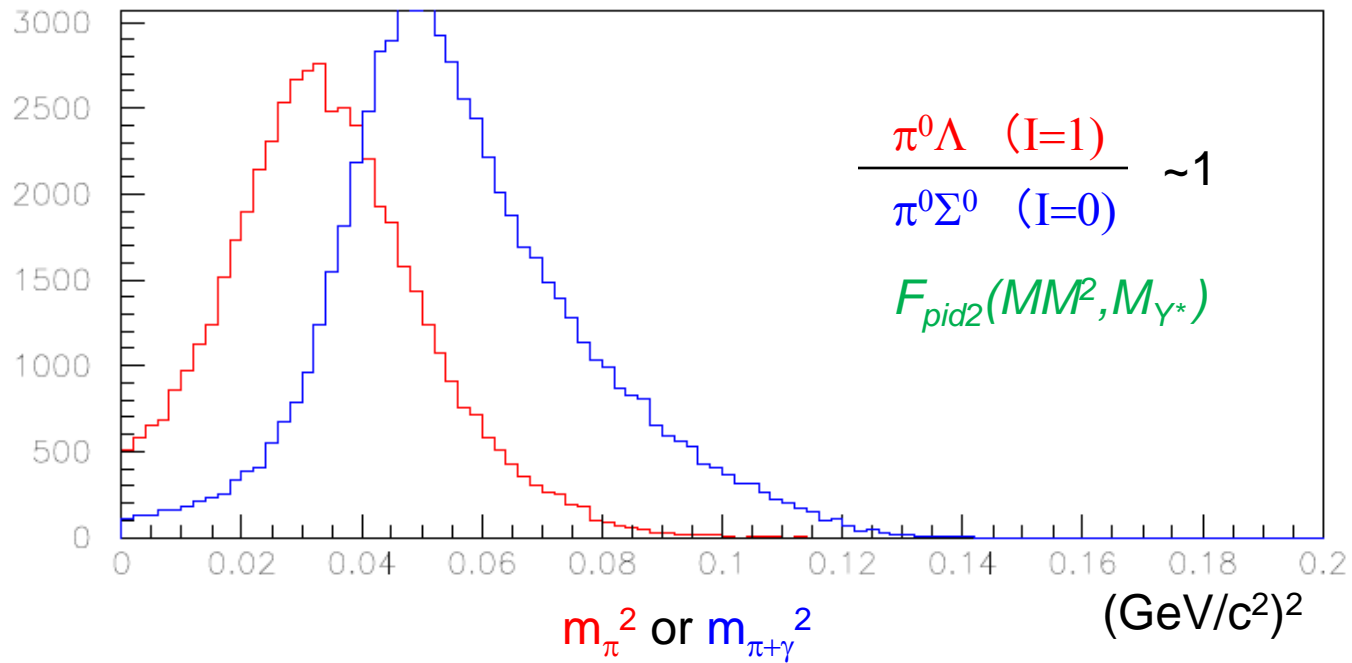


CDS

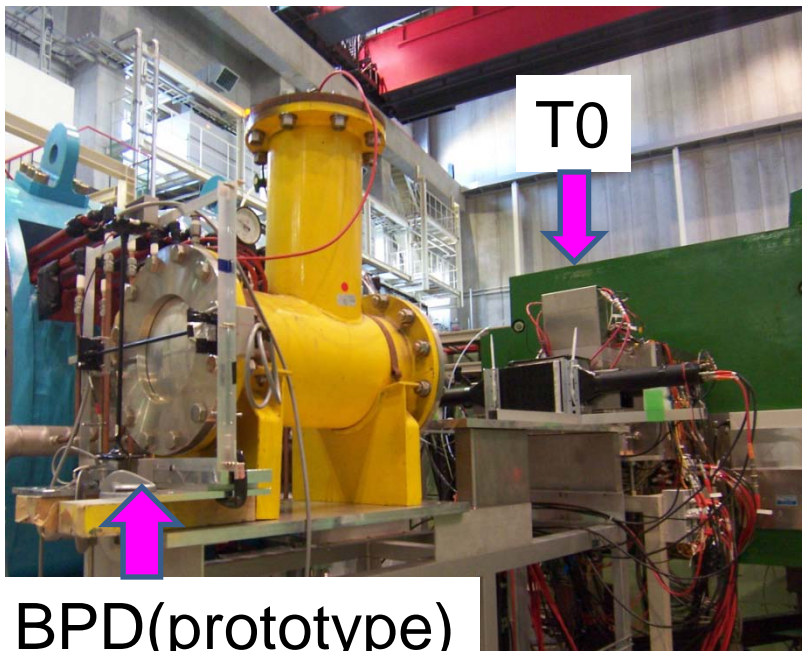


Yield Estimation

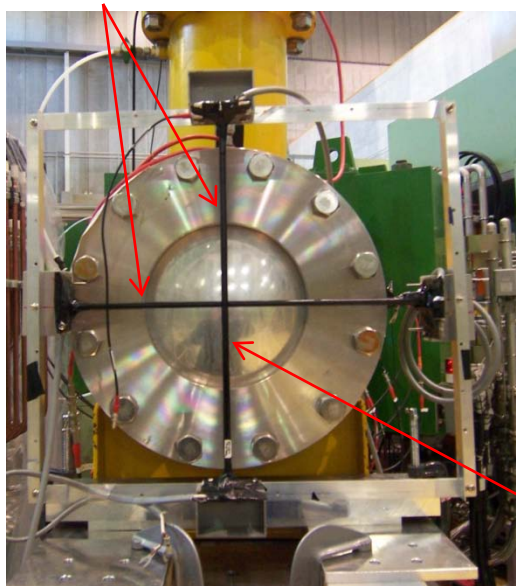
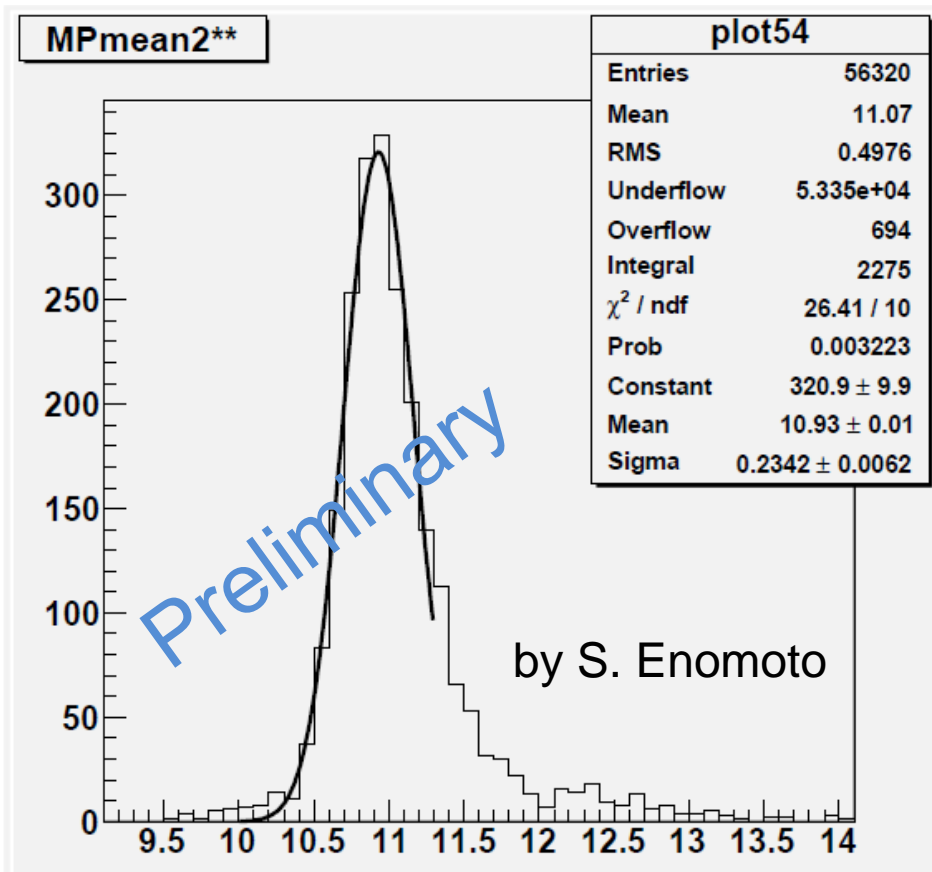
Item	Mnemonic		Comment
Intensity	I_b	2.0E+5 ppp	30GeV-27kW(6s)
# of target nuclei	n	4.1E+23	D:8cm, 0.169g/cc
Reaction X section	$d\sigma/d\Omega$	220 $\mu\text{b/sr}$ 97 128	$\Lambda^* \rightarrow \pi^+\Sigma^-$ $\Lambda^* \rightarrow \pi^-\Sigma^+$ $\Lambda^* \rightarrow \pi^0\Sigma^0$
Solid angle	$\Delta\Omega$	0.020 sr	
Reconstruction eff. DAQ Beam Tracking Neutron detection	ϵ_P	0.2	0.9 0.9 0.3
Decay mode eff.	ϵ_M	0.32 0.16 0.015	$\Lambda^* \rightarrow \pi^+\Sigma^- \rightarrow \pi^+\pi^-n$ $\Lambda^* \rightarrow \pi^-\Sigma^+ \rightarrow \pi^-\pi^+n$ $\Lambda^* \rightarrow \pi^0\Sigma^0 \rightarrow \pi^0\pi^-p$
Analysis eff.	ϵ_A	0.8	
Yield	Y	~19200 ~4800 ~350	$\Lambda^* \rightarrow \pi^+\pi^-n$ (120 shifts) $\Lambda^* \rightarrow \pi^-\pi^+n$ (120 shifts) $\Lambda^* \rightarrow \pi^0\pi^-p$ (120 shifts)



MPPC test for backward proton detector (BPD)



Time Resolution (BPD-T0) $\sigma \sim 230$ ps



□ 5mmx400mm Scintillator w/ MPPCs