9th J-PARC PAC Jan 16, 2010

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

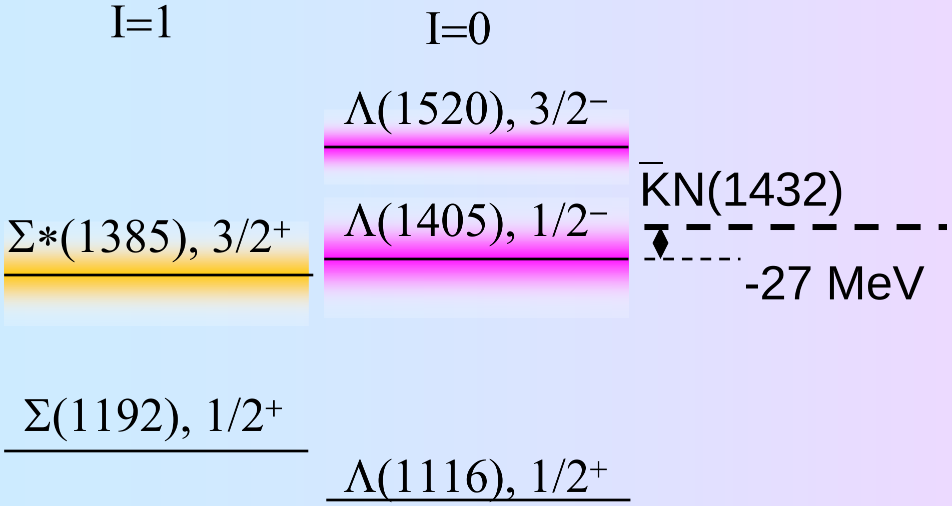
H. Noumi, *Osaka Univ. RCNP*, for the P31 collaboration

S. Ajimura[1], G. Beer[2], H. Bhang[3], P. Buehler[4], L. Busso[5,6], M. Cargnelli[4], J. Chiba[7], S. Choi[3], C. Curceanu[8], S. Enomoto[1], D. Faso[5], H. Fujioka[13], Y. Fujiwara[12], T. Fukuda[11], Y. Fukuda[10], C. Guaraldo[8], T. Hanaki[7], R. S. Hayano[12], T. Hiraiwa [13], A. Hirtl[4], M. Iio[9], N. Ishibashi[17], T. Ishikawa[12], S. Ishimoto[14], T. Ishiwatari[4], K. Itahashi[9], M. Iwai[14], M. Iwasaki[9,10], P. Kienle[15], J. Marton[4], Y. Matsuda[12], Y. Mizoi [10], O. Morra[5], T. Nagae[13], H. Noumi [1], H. Ohnishi[9], S. Okada[8], H. Outa[9], D. Pietreanu[8], A. Sakaguchi[17], F. Sakuma[9], M. Sato[12], M. Sekimoto[14], D. Sirghi[8], F. Sirghi[8], S. Suzuki[14], T. Suzuki[12], H. Tatsuno[12], M. Tokuda[10], D. Tomono[9], A. Toyoda[14], K. Tsukada[9], E. Widmann[4], T. Yamazaki[9,12], K. Yoshida[17], H. Yim[3], B. Wünschek[4], J. Zmeskal[4] + some new comers.

1. Research Center for Nuclear Physics, Osaka University, Japan
2. University of Victoria, Canada, 3. Seoul National University, South Korea
4. Stefan Meyer Institut fur subatomare Physik, Austria,
5. INFN Sezione di Torino, Italy , 6.Universita' di Torino, Italy
7. Tokyo University of Science, Japan, 8. Laboratori Nazionali di Frascati dell' INFN, Italy
9. RIKEN, Japan, 10. Tokyo Institute of Technology, Japan
11. Osaka Electro-Communication University, Japan, 12. University of Tokyo, Japan
13. Kyoto University, Japan, 14. High Energy Accelerator Research Organization (KEK), Japan
15. Technische Universitat Munchen, Germany, 16. INAF-IFSI, Sezione di Torino, Italy
17. Osaka University, Japan

1. Introduction:
   $K^{bar}N$ int. and $\Lambda(1405)$
2. Experimental Method
   $d(K-,n)\pi\Sigma$ w/ the E15 setup
3. Summary

What is $\Lambda(1405)$?



I=1

I=0

$\Lambda(1520), 3/2^-$

$\bar{K}N(1432)$

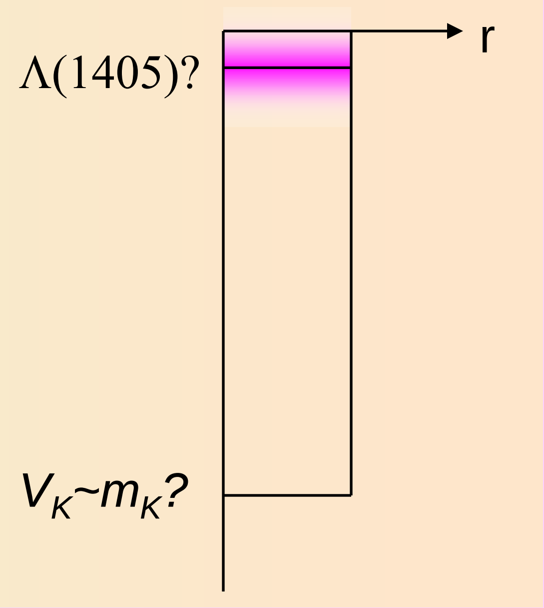
$\Sigma^*(1385), 3/2^+$

$\Lambda(1405), 1/2^-$

-27 MeV

$\Sigma(1192), 1/2^+$

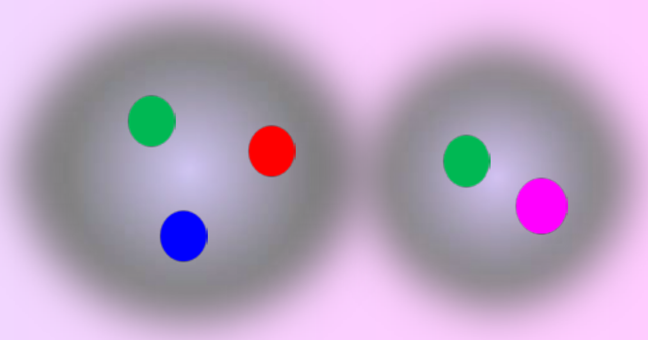
$\Lambda(1116), 1/2^+$

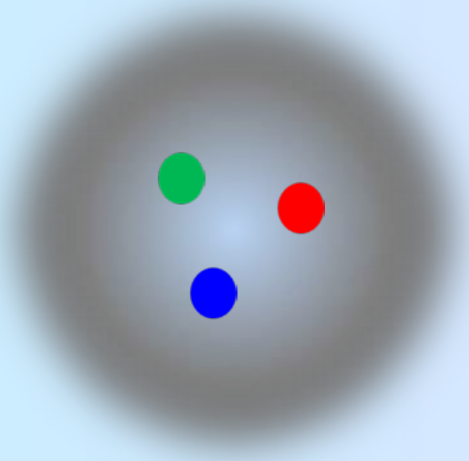


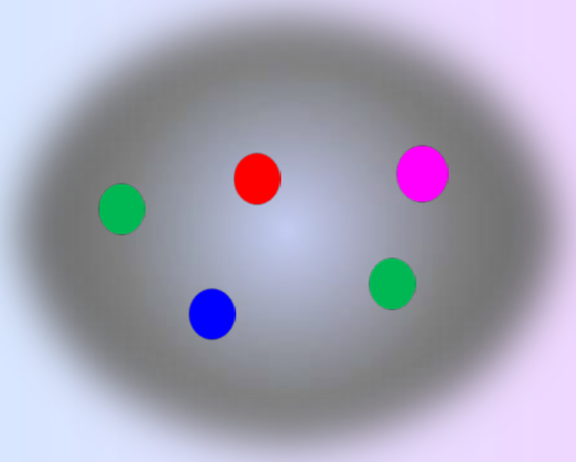
$\Lambda(1405)$?

r

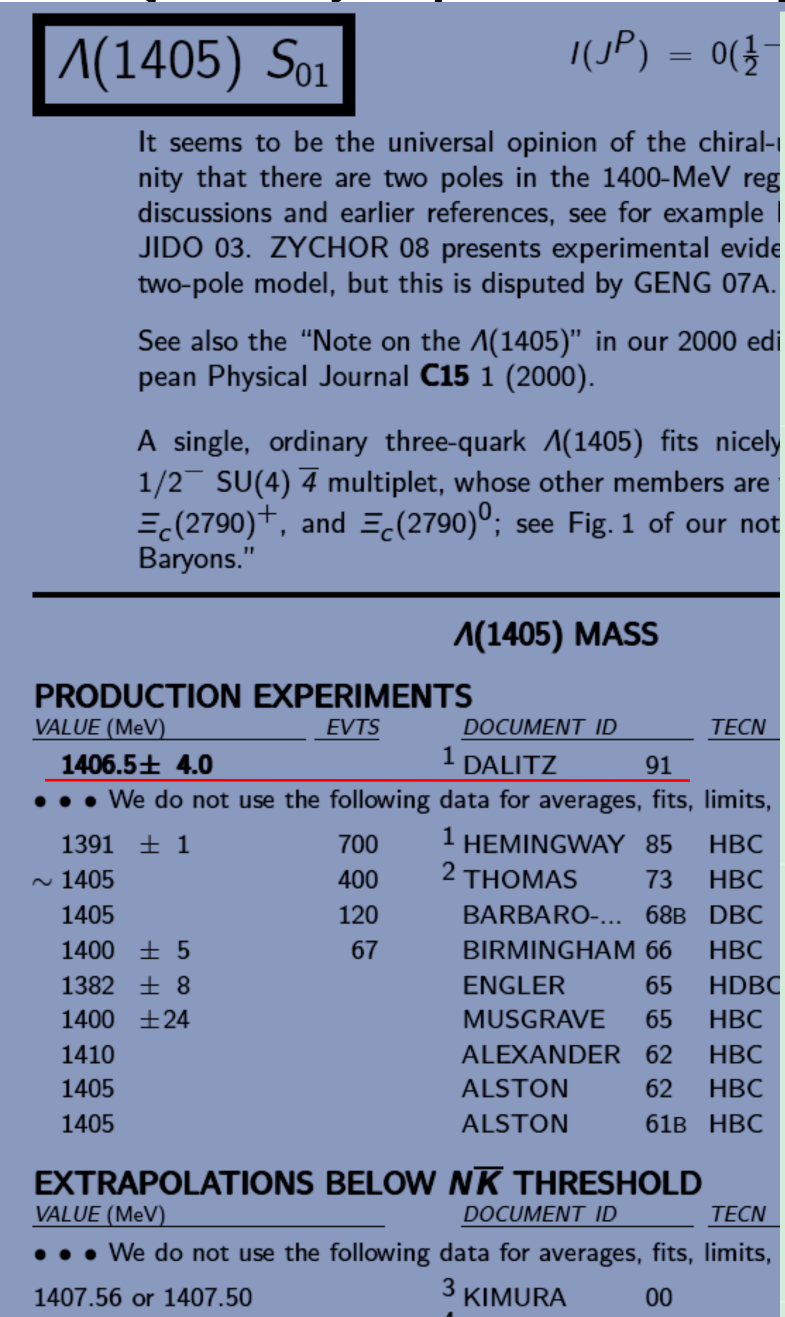
$V_K \sim m_K$?







Λ(1405) Spectroscopy via the (K^-,n) reaction on ^{2}H



Λ(1405) S_{01}

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

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

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

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

Λ(1405) MASS

PRODUCTION EXPERIMENTS

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*
1406.5± 4.0		[1] DALITZ	91	

• • • We do not use the following data for averages, fits, limits,

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*
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

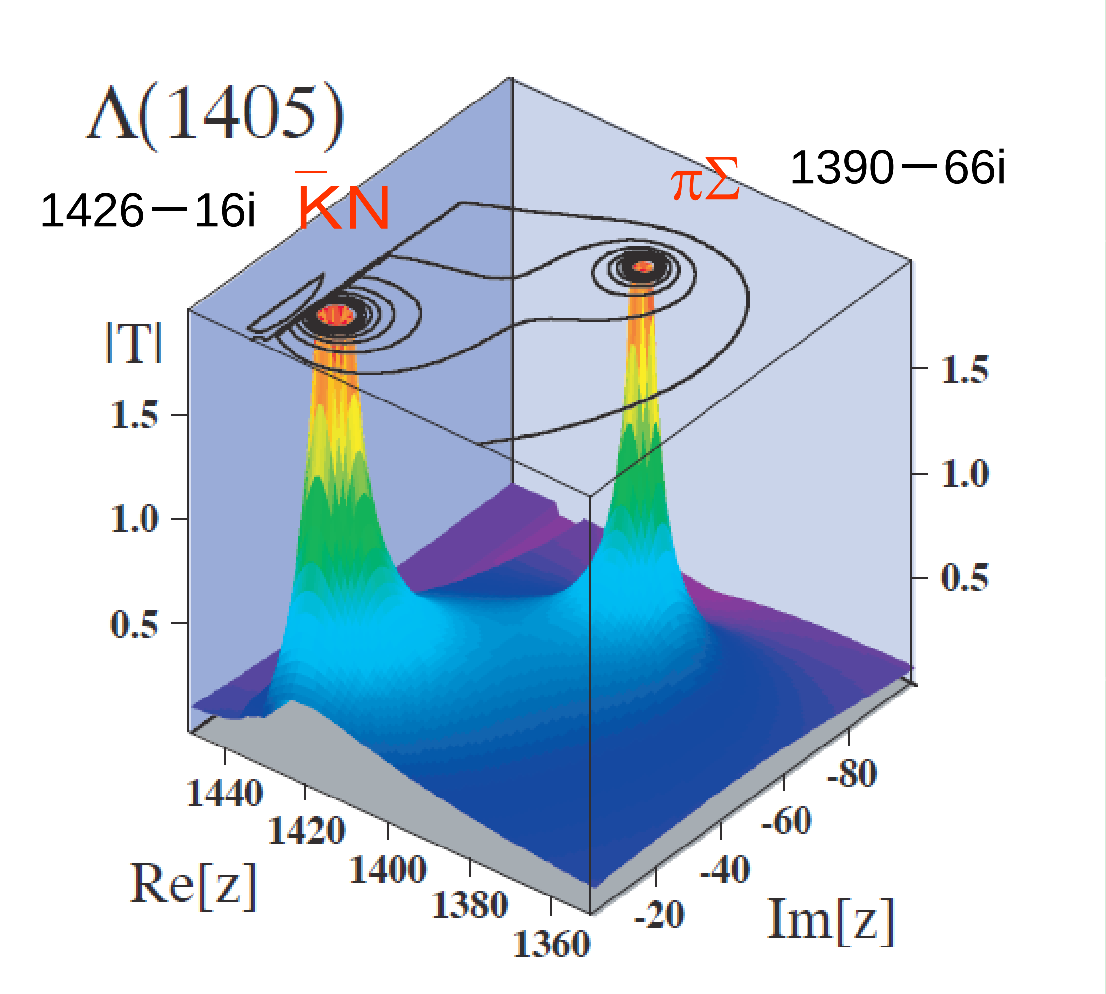
EXTRAPOLATIONS BELOW $N\overline{K}$ THRESHOLD

VALUE (MeV)	*DOCUMENT ID*		*TECN*

• • • We do not use the following data for averages, fits, limits,

VALUE (MeV)	*DOCUMENT ID*		*TECN*
1407.56 or 1407.50	[3] KIMURA	00	

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



ChU model, T. Hyodo

Λ(1405) Spectroscopy via the (K^-,n) reaction on ^{2}H

Motivation

✓To clarify whether Λ(1405) is a K^{bar}N resonant state.

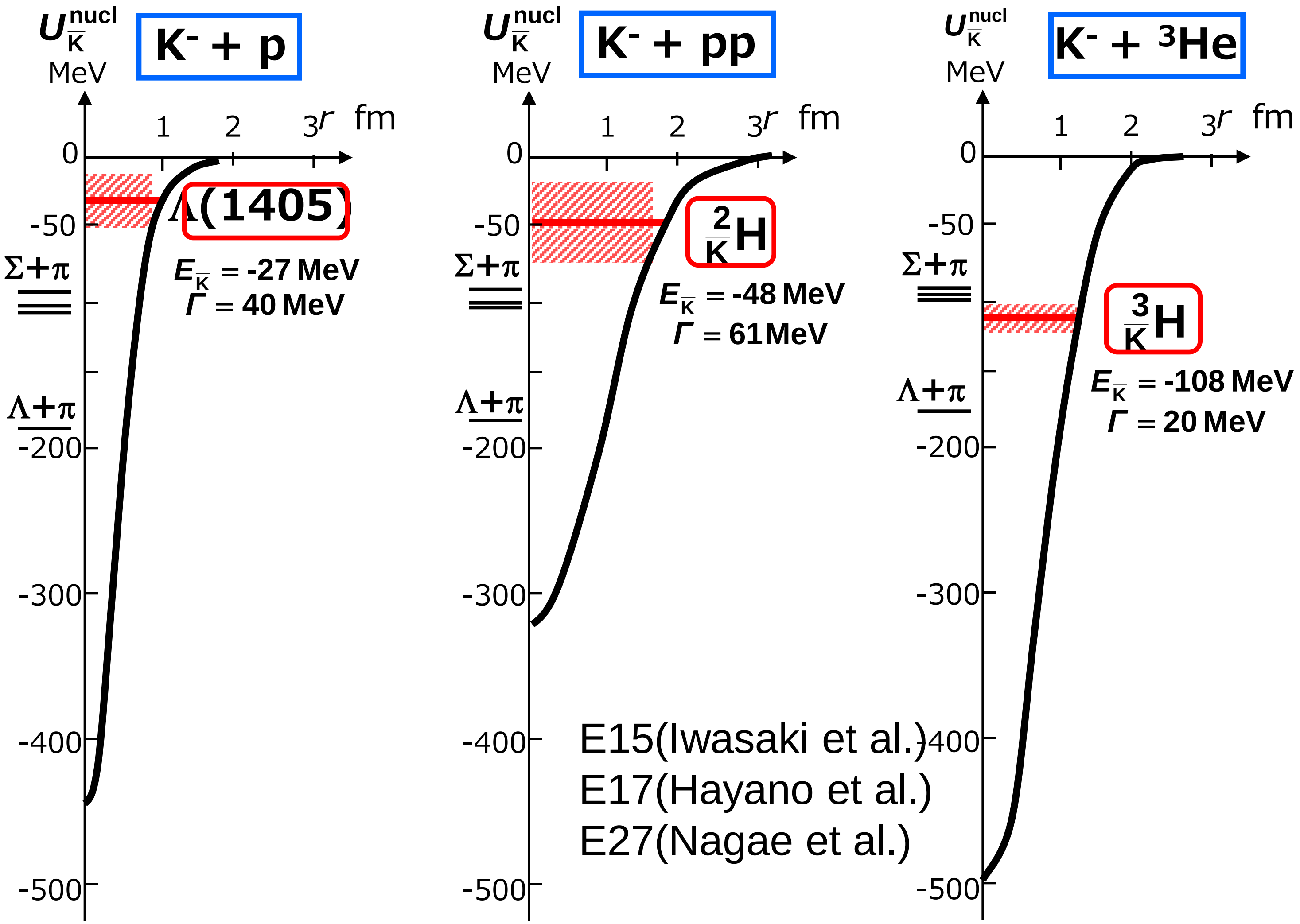
The position of Λ^* : Primary issue

~1405? as Dalitz et al. deduced.

~1420? as Chiral Unitary Model predicted.

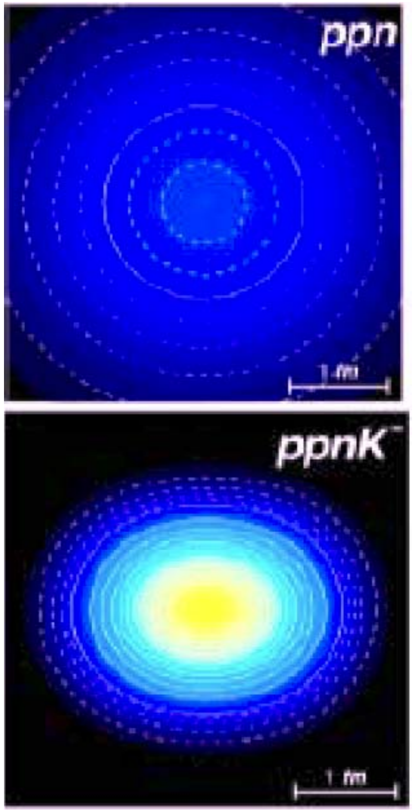
Provide the most fundamental information
on a K^{bar}-Nucleus deeply bound state.

Deeply Bound K$^-$-Nucleus System ?



E15(Iwasaki et al.)
E17(Hayano et al.)
E27(Nagae et al.)

Dote et al.



Y. Akaishi & T. Yamazaki, Phys. Rev. C65 (2002) 044005.

Y. Akaishi & T. Yamazaki, Phys. Lett. B535 (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 Sigma0pi0 decay channel? Is it possible to discriminate the background of Sigma*(1385)–>Lambda pi0?

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

What do we measure?

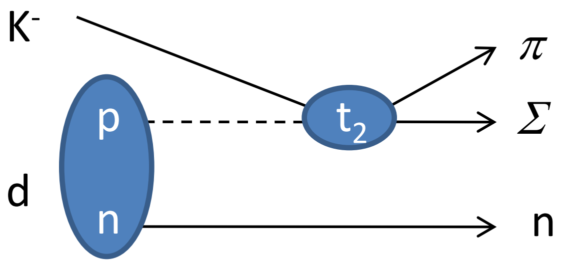
✓$K^{bar}N$ scattering below $K^{bar}N$ threshold

Employ d(K^-,n)Λ^*

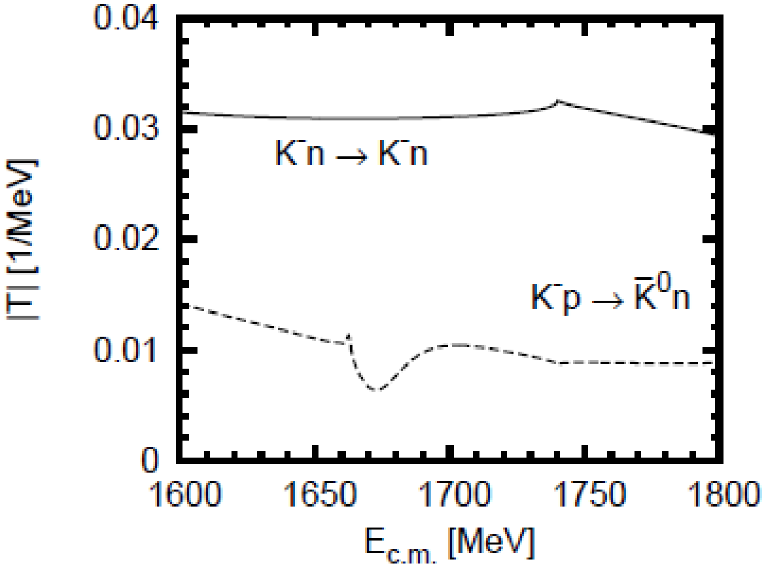
Ideal to form the Λ^* directly coupled to $K^{bar}N$.

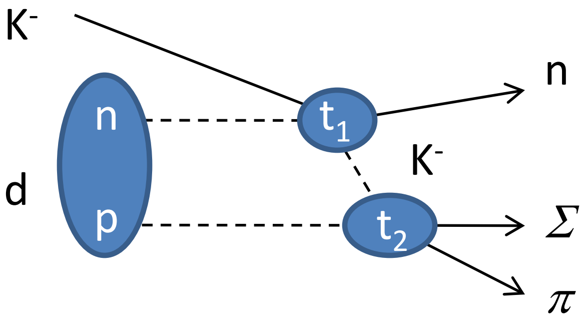
Reaction Diagram

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

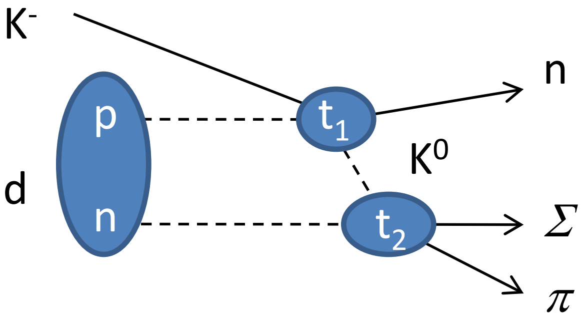


dia.1:small

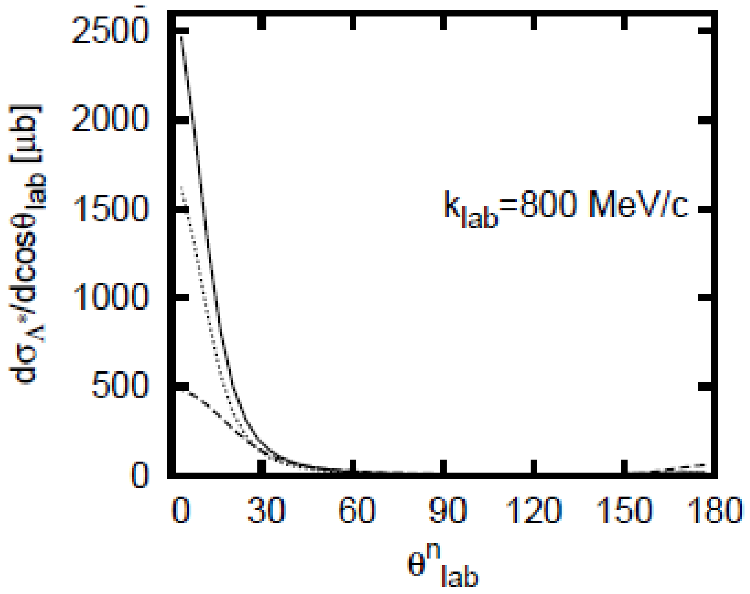




dia.2:dominant



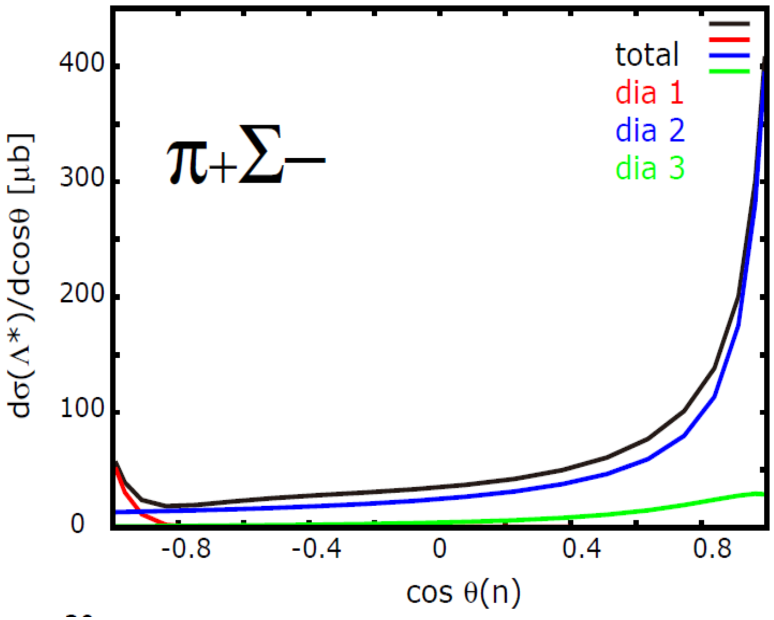
dia.3:Interference



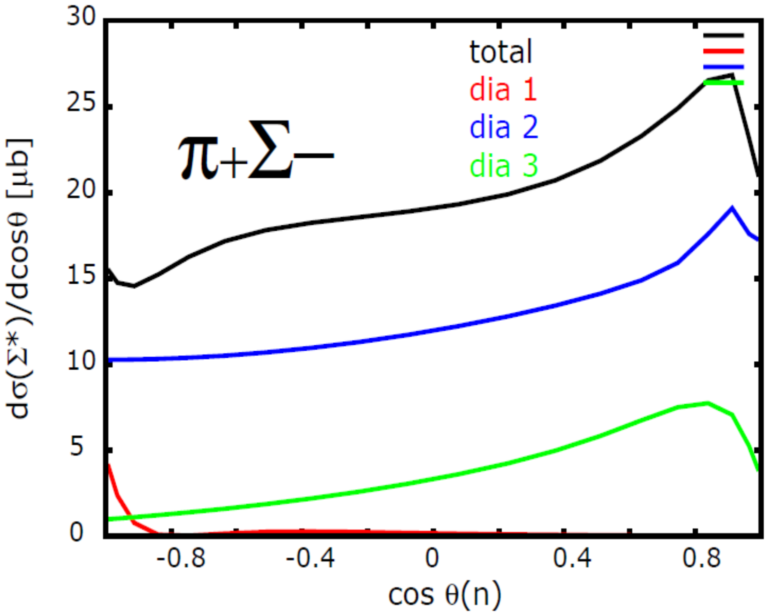
S-wave $K^{bar}N$ scattering is dominant at θ_n = 0 degree.

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

(Λ*)

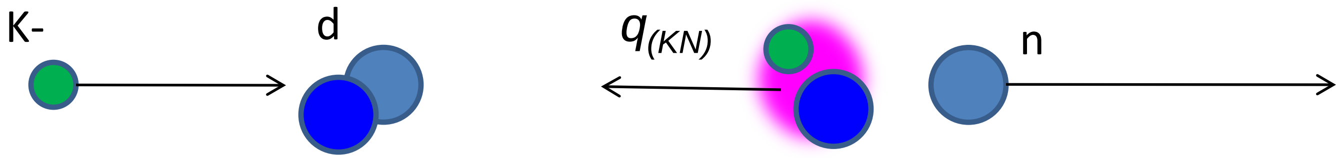


(Σ*)



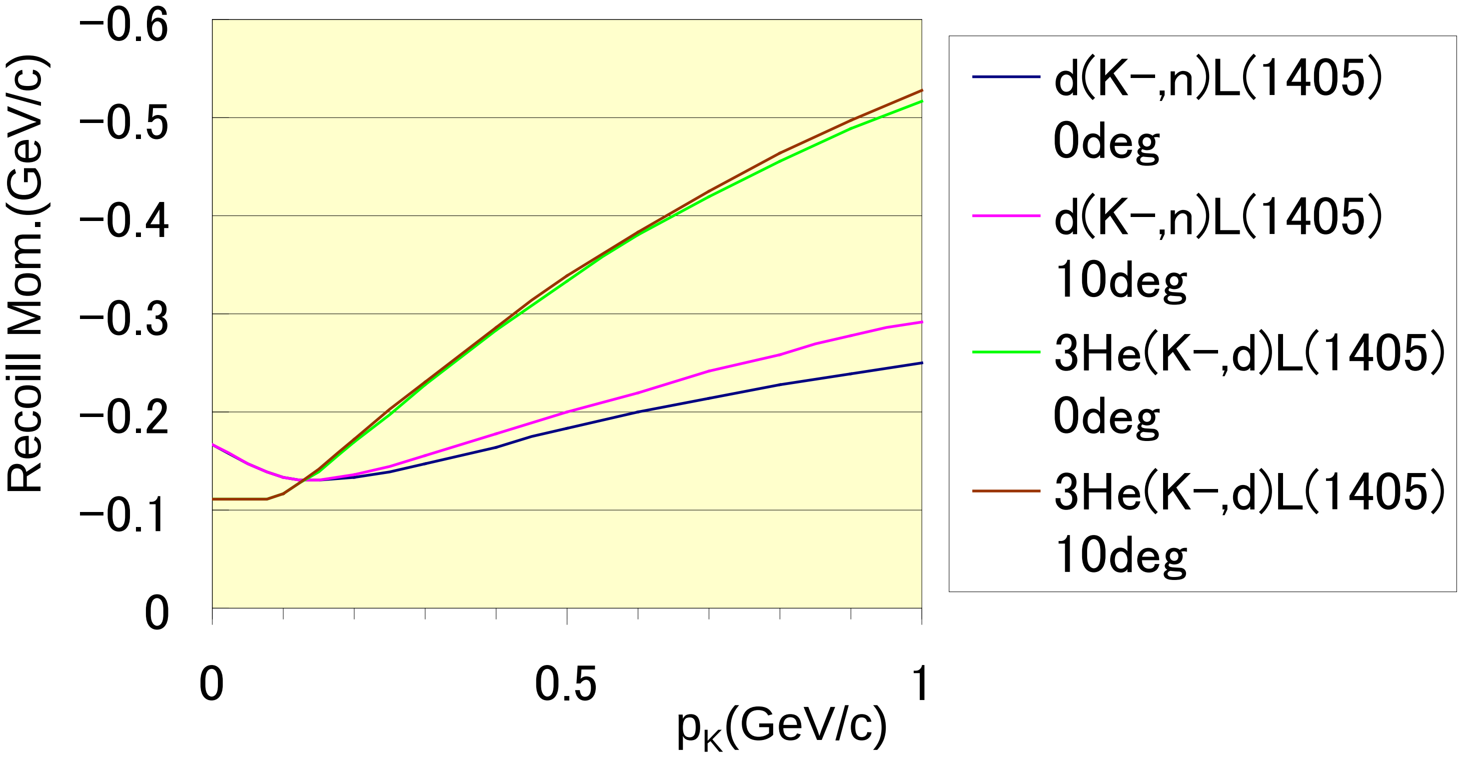
J. Yamagata-Sekihara,
T. Sekihara, and D. Jido,
paper in preparation

Simple understanding of the reaction mechanism

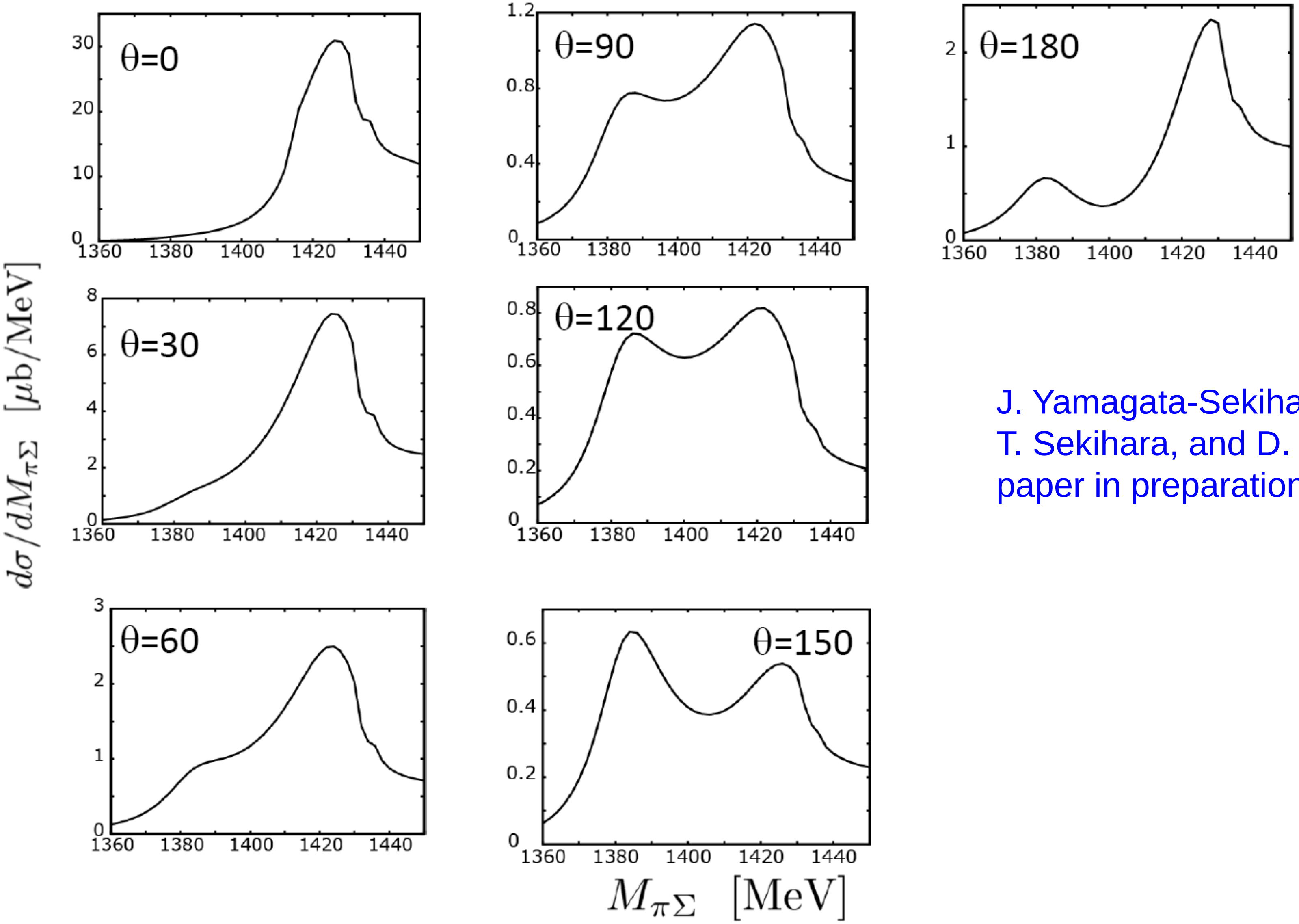


$$q^{Lab}_{\bar{K}N} \sim 250\,MeV/c, \quad p^{CM}_{\bar{K}N} \sim 160\,MeV/c$$

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

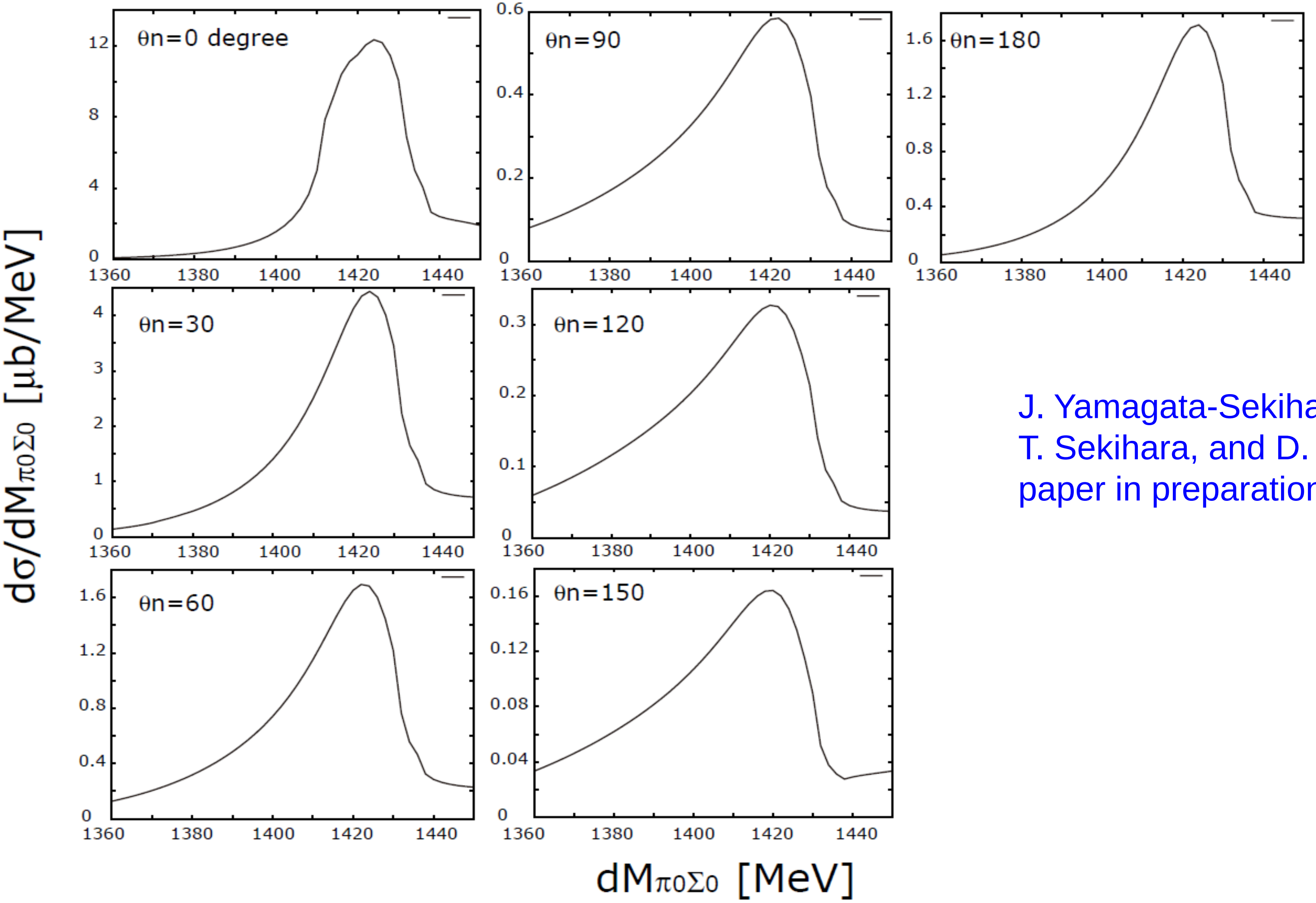


$\frac{d\sigma}{dM_{\pi\Sigma}}(\theta),\quad K^- d \to \pi^+\Sigma^- n$ at p_K=800 MeV/c



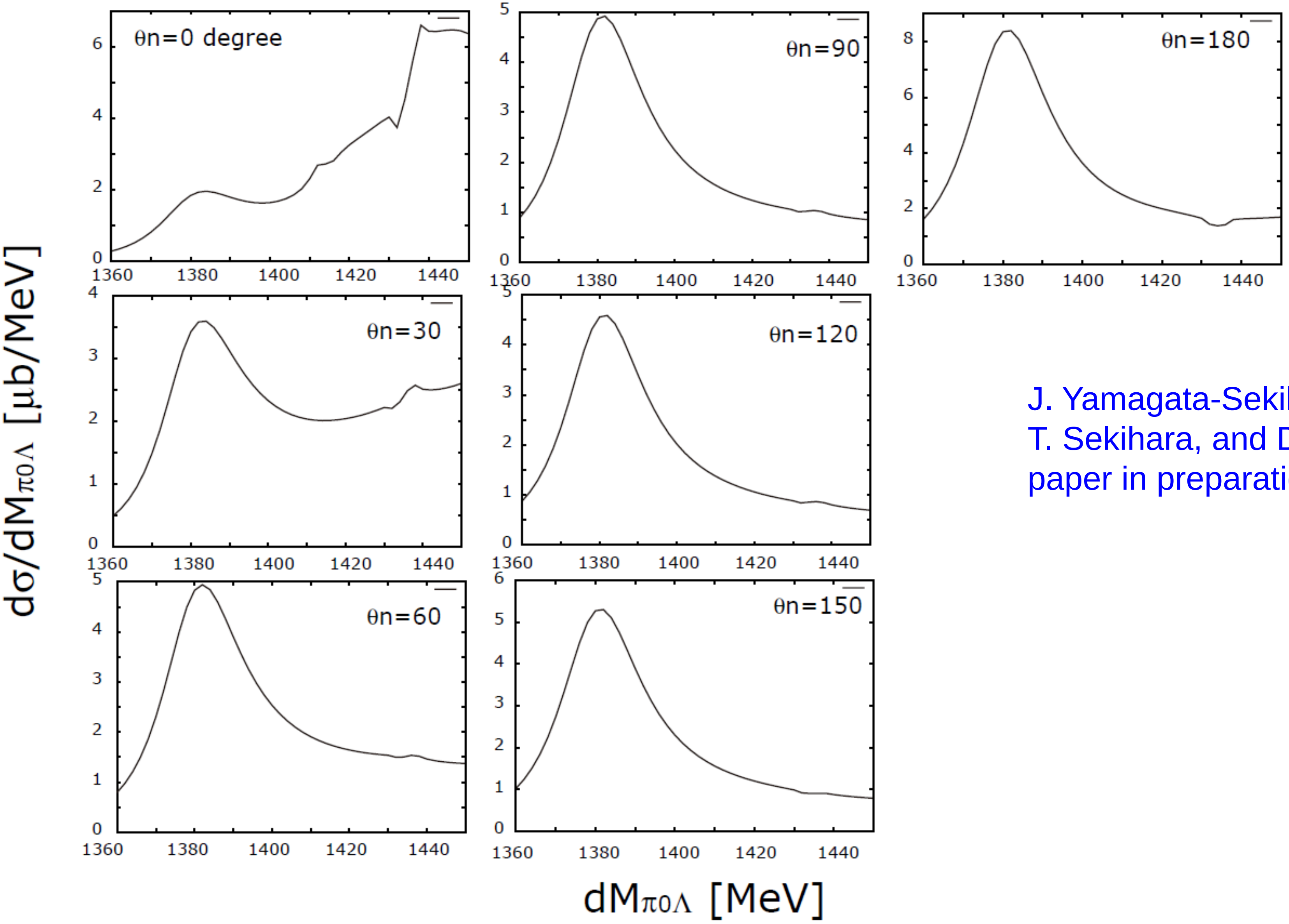
J. Yamagata-Sekihara,
T. Sekihara, and D. Jido,
paper in preparation

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



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

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



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

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

What do we measure?

✓K^{bar}N scattering below K^{bar}N threshold

Employ d(K$^-$,n)Λ^*

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

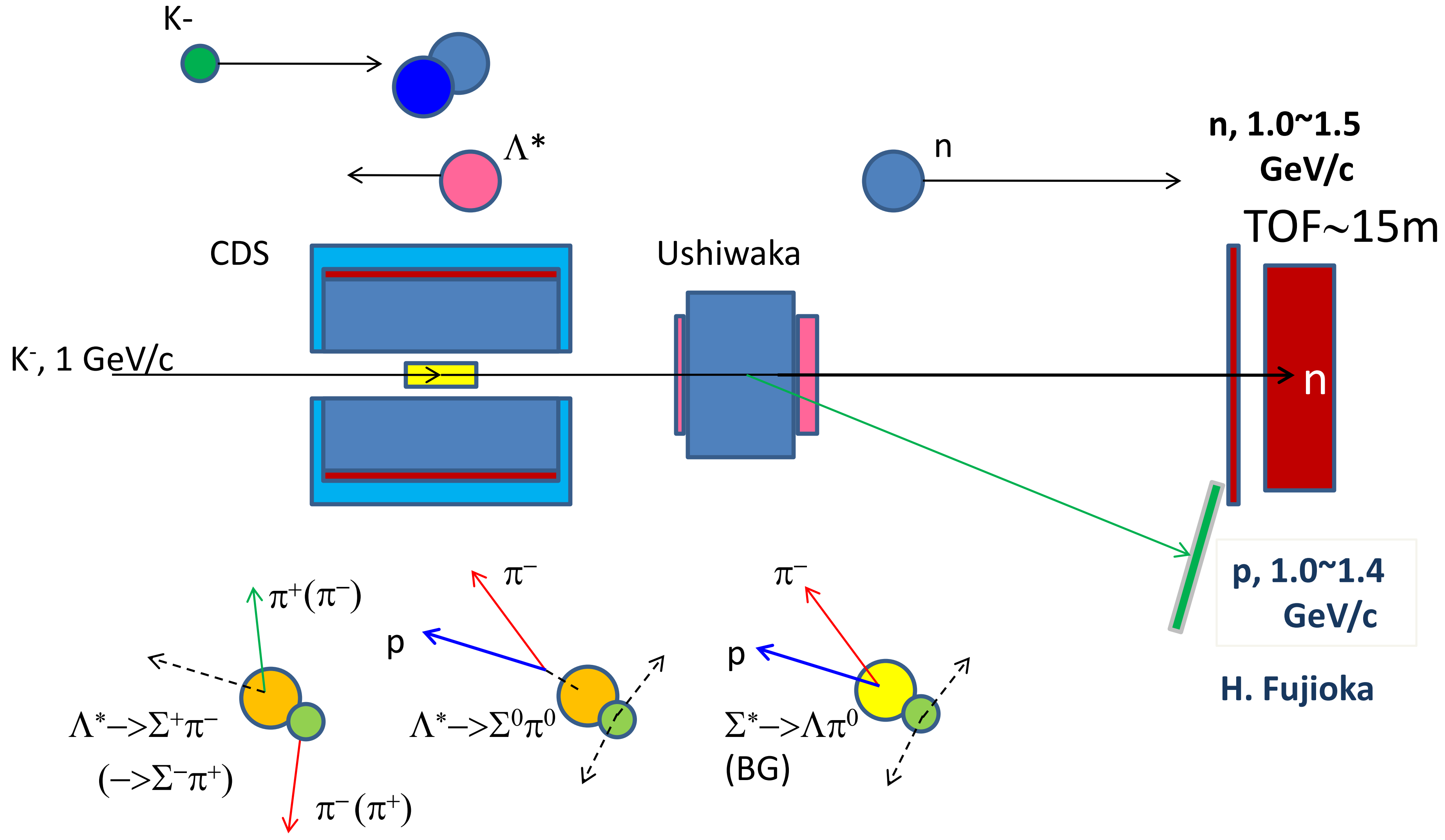
Enhancement of Λ* production at θ_n=0
BG from Σ* will be reduced.

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

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

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

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



K-

Λ*

n

n, 1.0~1.5 GeV/c

TOF~15m

CDS

Ushiwaka

K^-, 1 GeV/c

n

p, 1.0~1.4 GeV/c

$\pi^+(\pi^-)$

$\Lambda^* \text{->} \Sigma^+\pi^-$ $(\text{->}\Sigma^-\pi^+)$

$\pi^-(\pi^+)$

p

π^-

$\Lambda^* \text{->} \Sigma^0\pi^0$

p

π^-

$\Sigma^* \text{->} \Lambda\pi^0$ (BG)

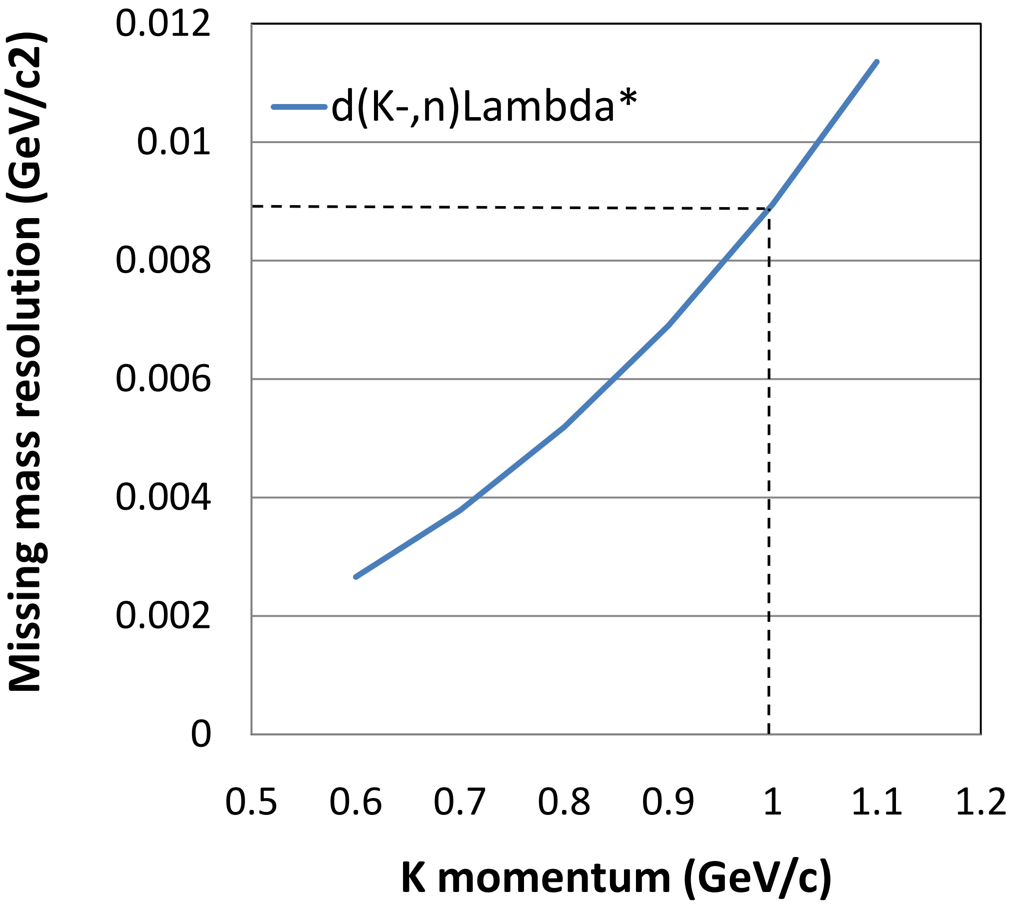
H. Fujioka

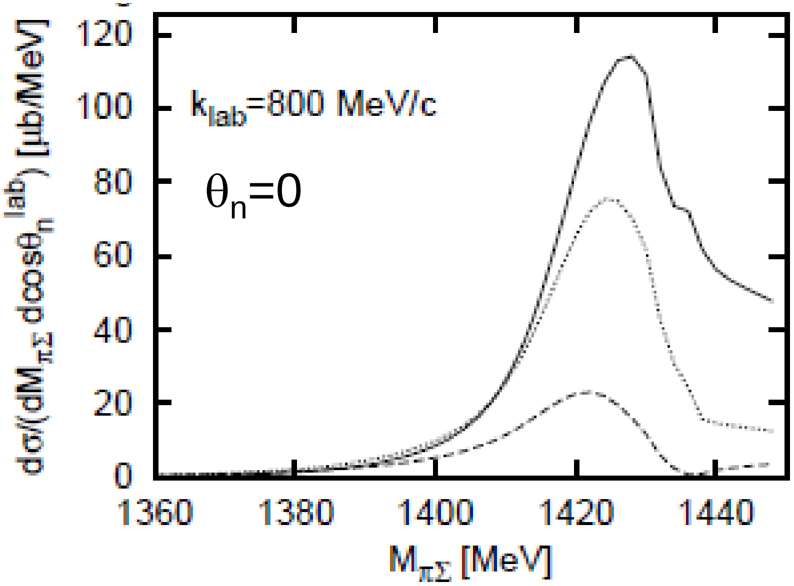
Missing Mass Resolution in the d(K^-, n)X reaction

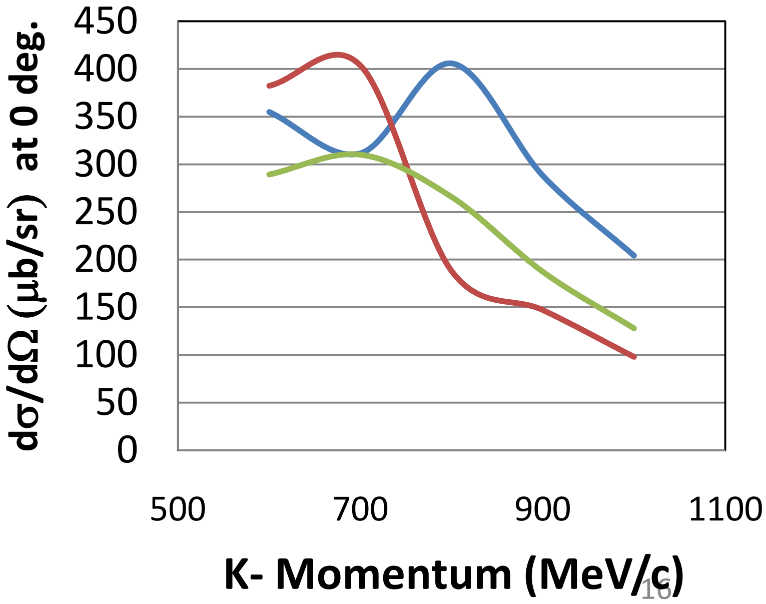
Dominant sources of ambiguity…

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

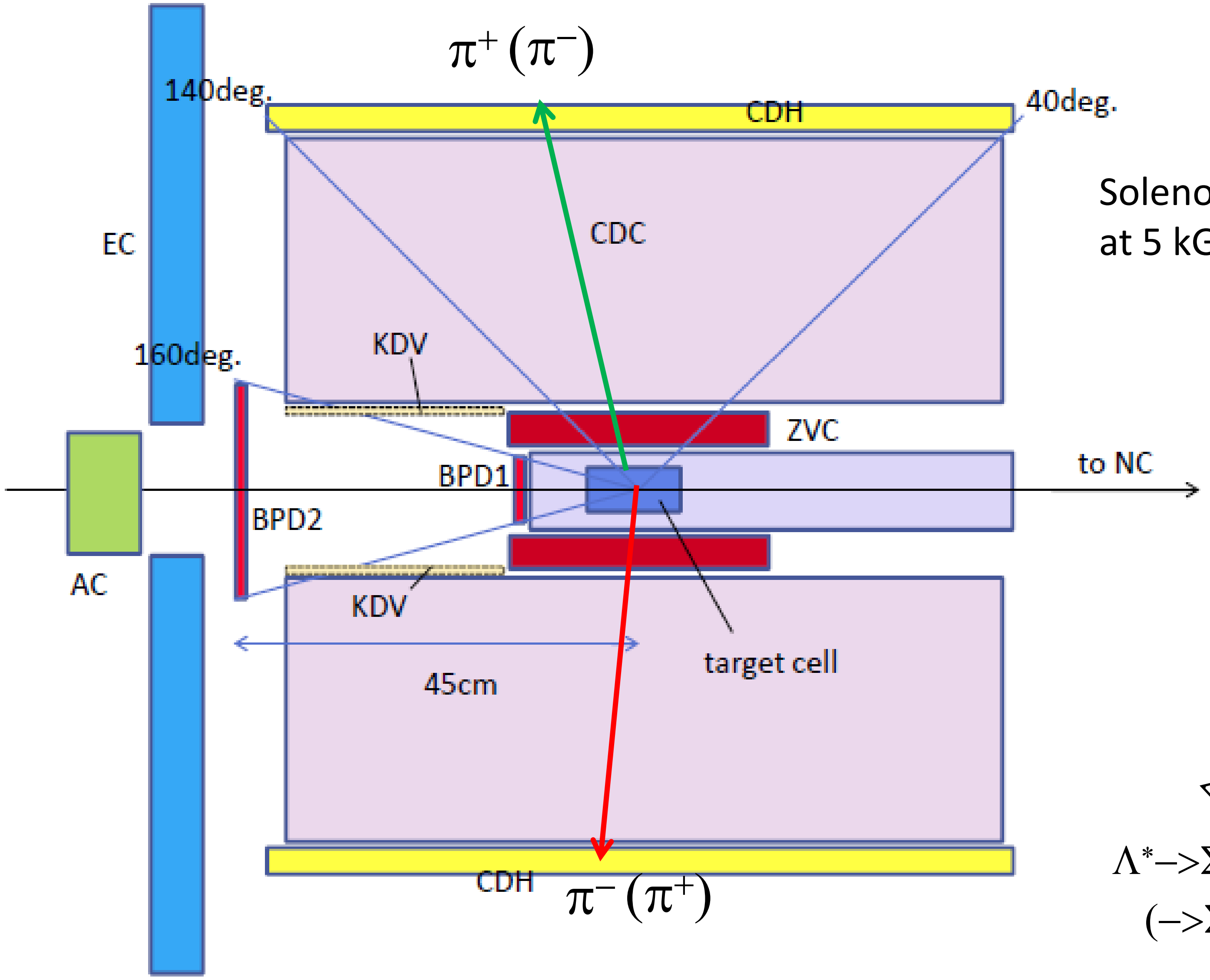
σ_{MM} ~ 9 MeV/c at p_{K-}=1 GeV/c



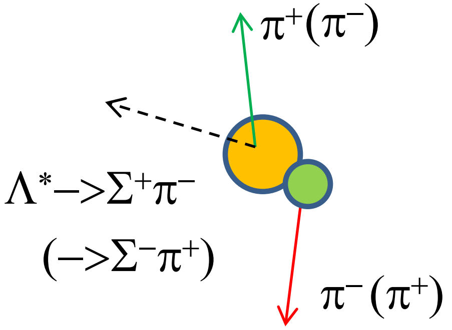




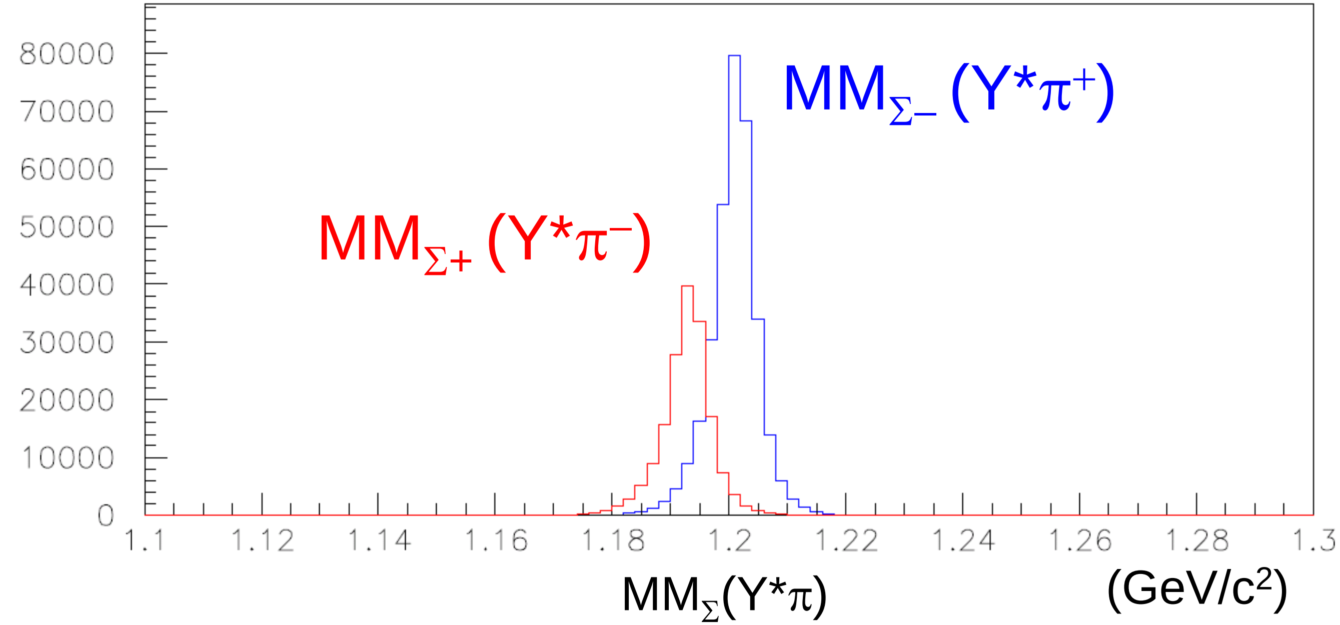
Detection of the Λ^* -> $\pi^-\Sigma^+$ and $\pi^+\Sigma^-$ modes

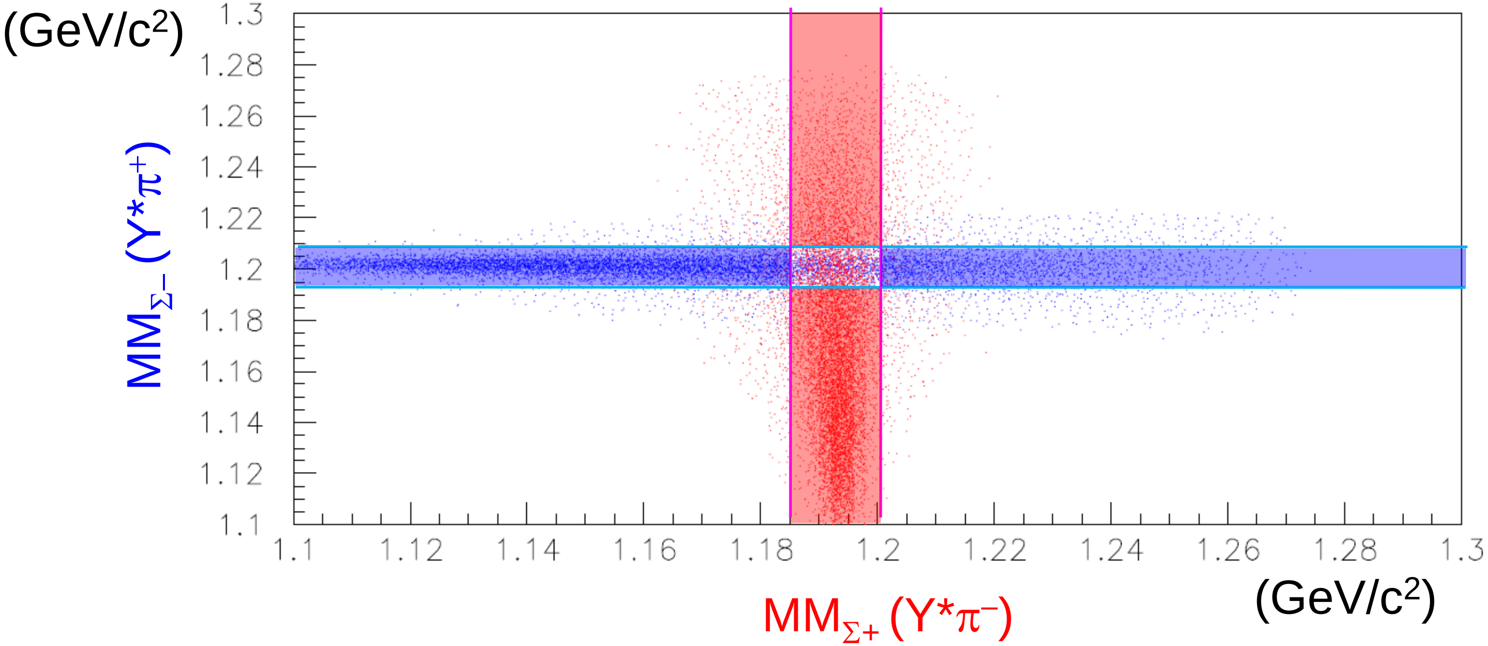


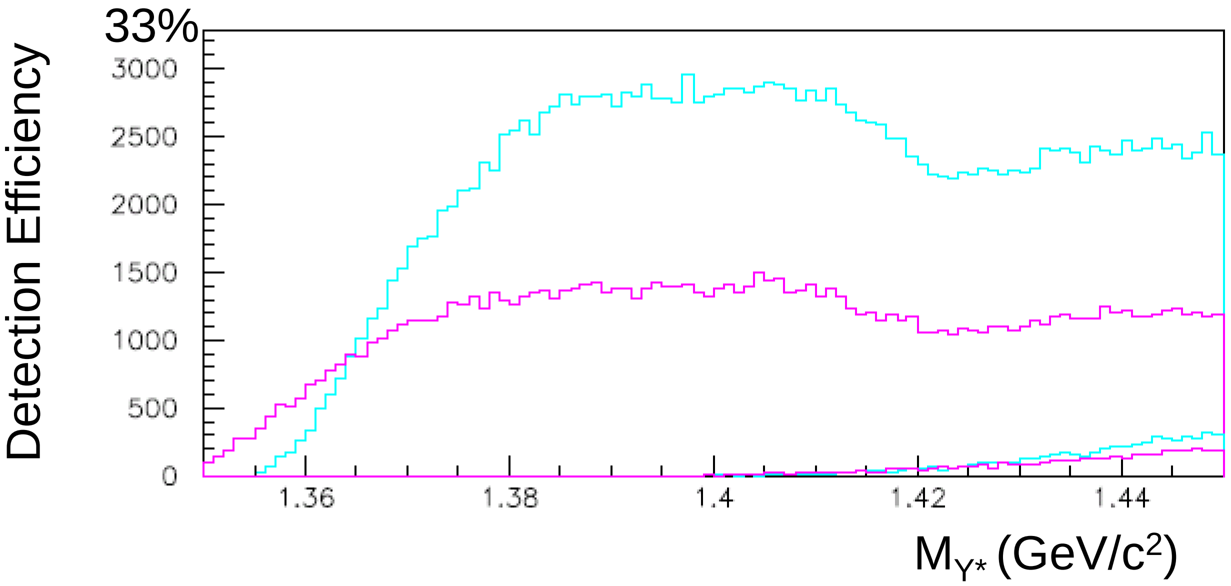
Solenoid Field
at 5 kG



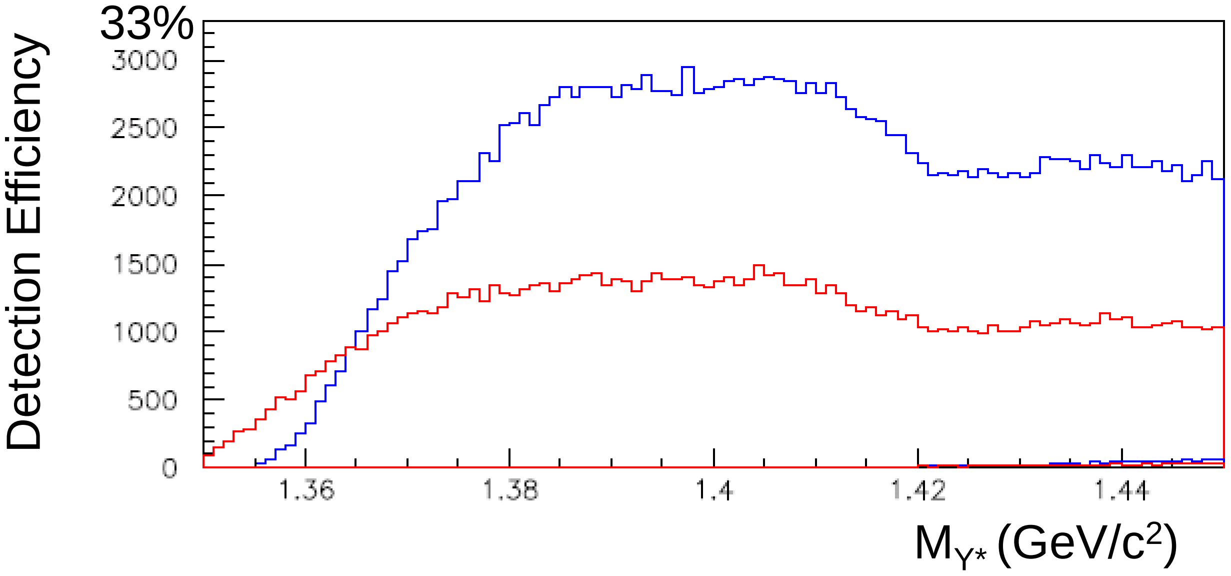
Identification of the Λ^* -> $\pi^-\Sigma^+$ and $\pi^+\Sigma^-$ modes





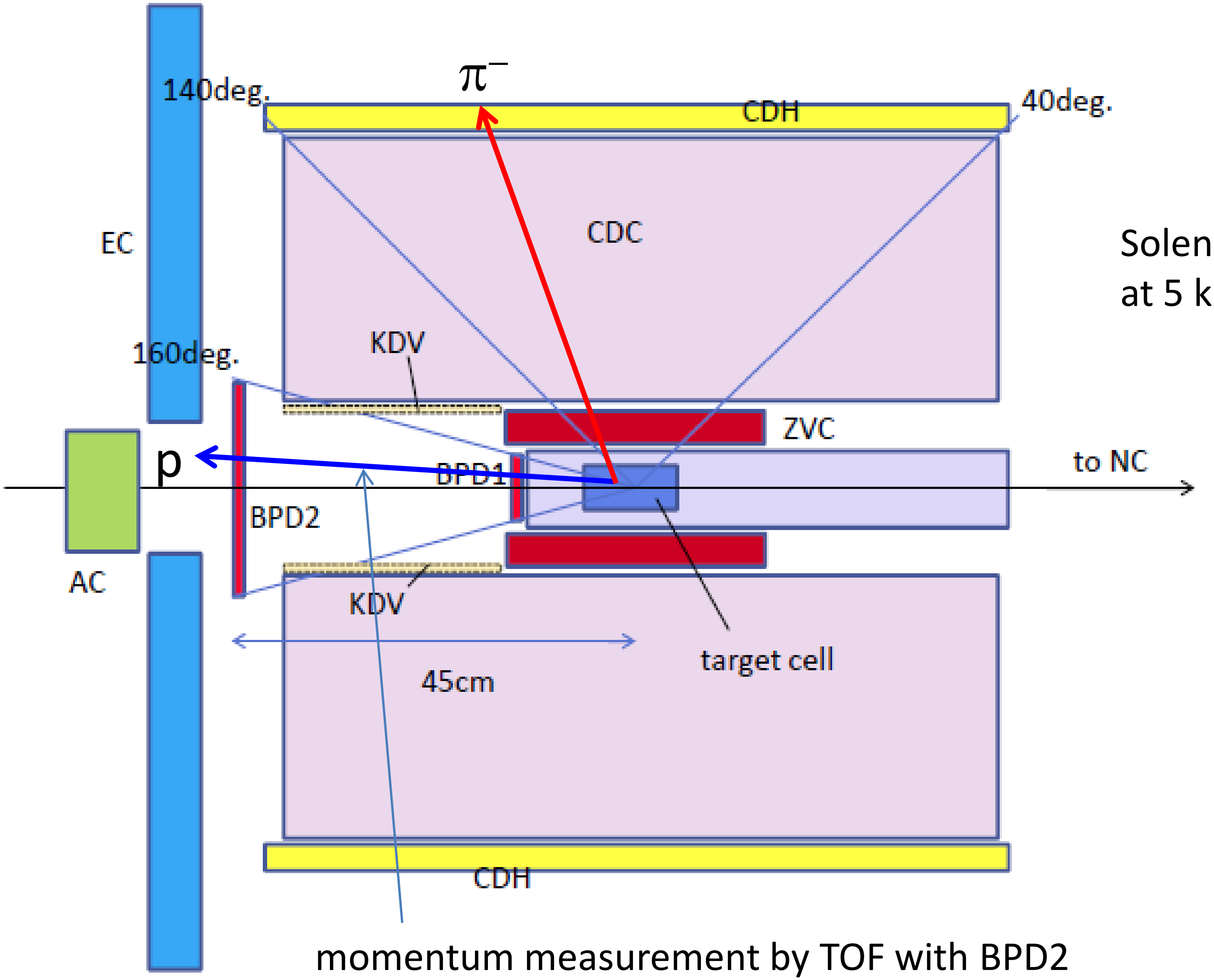


$$\frac{\pi^+\Sigma^-}{\pi^-\Sigma^+} \sim 1$$

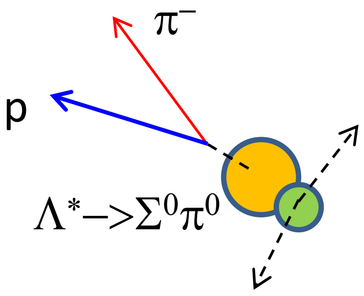


$$\frac{\pi^+\Sigma^-}{\pi^-\Sigma^+} \sim 1$$

Backward Proton Detectors for the Λ^* -> $\pi^0\Sigma^0$ mode



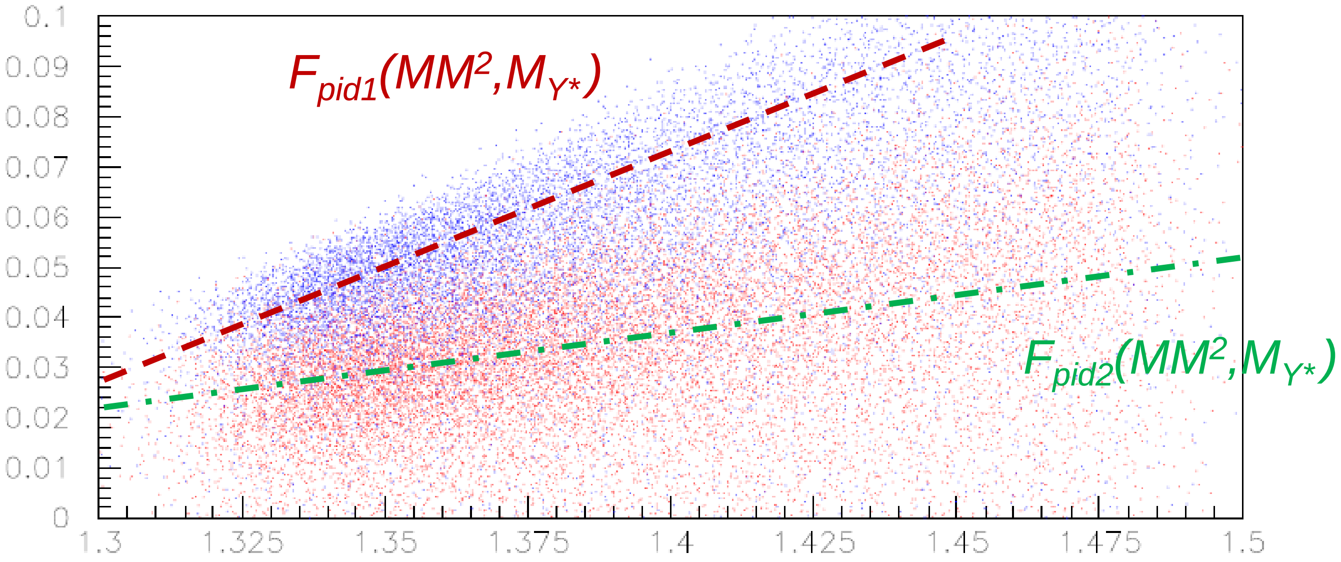
Solenoid Field
at 5 kG

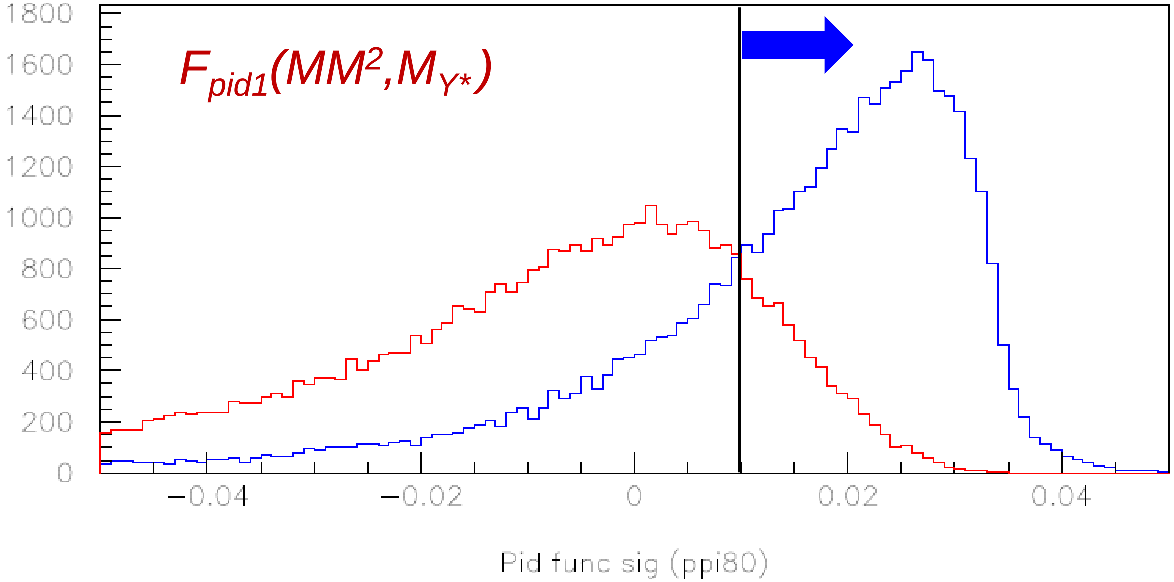


momentum measurement by TOF with BPD2

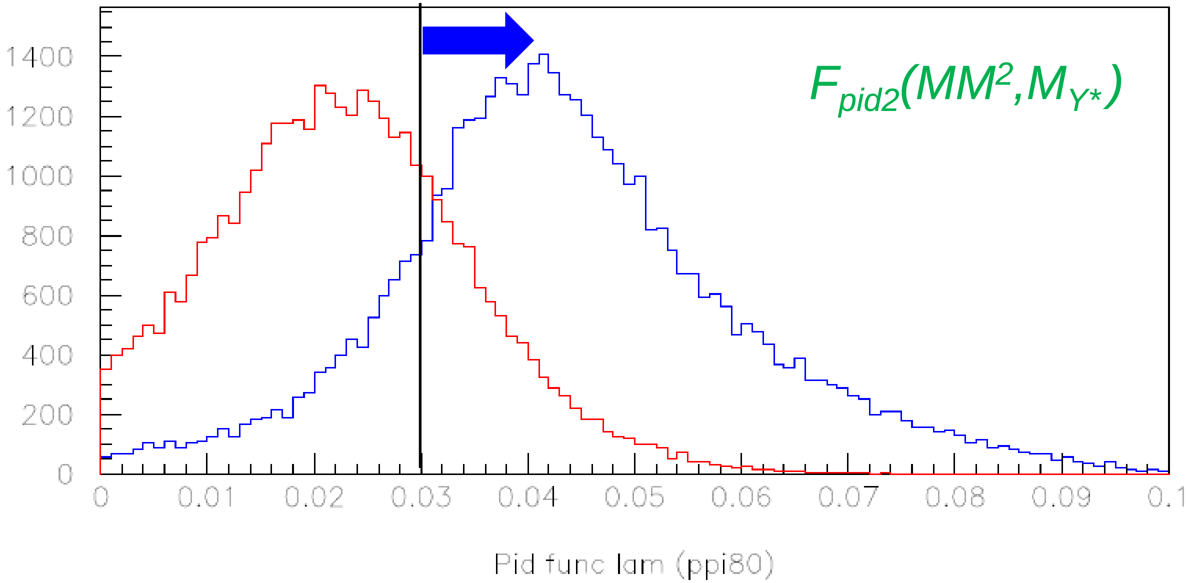
Identification of the Λ^* -> $\pi^0\Sigma^0$ mode

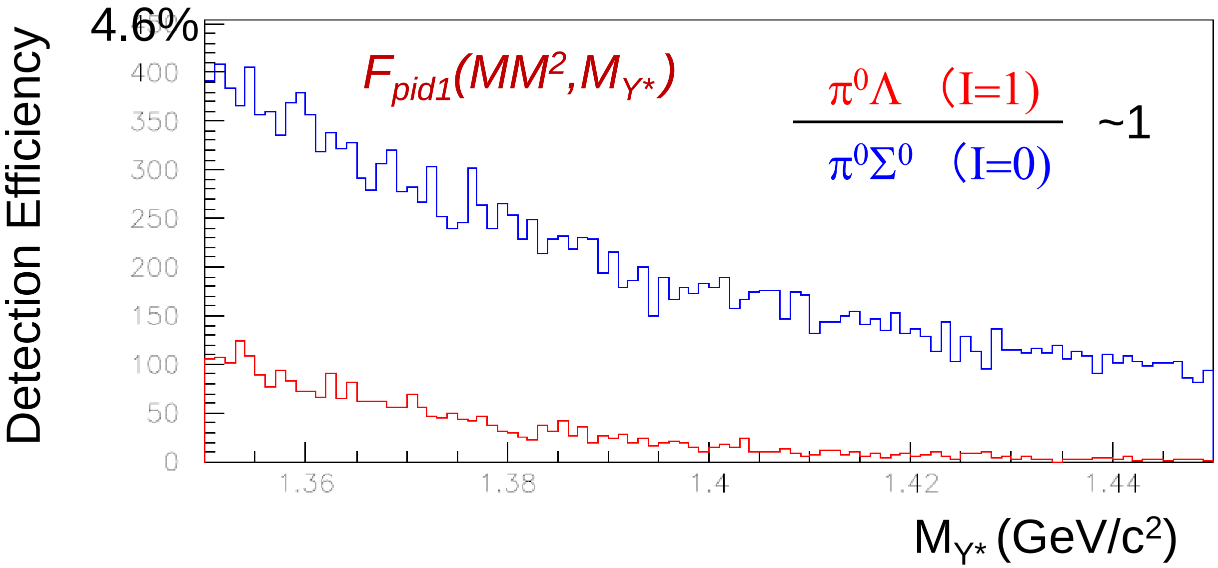
$$\frac{\pi^0\Lambda \quad (I=1)}{\pi^0\Sigma^0 \quad (I=0)} \sim 1$$



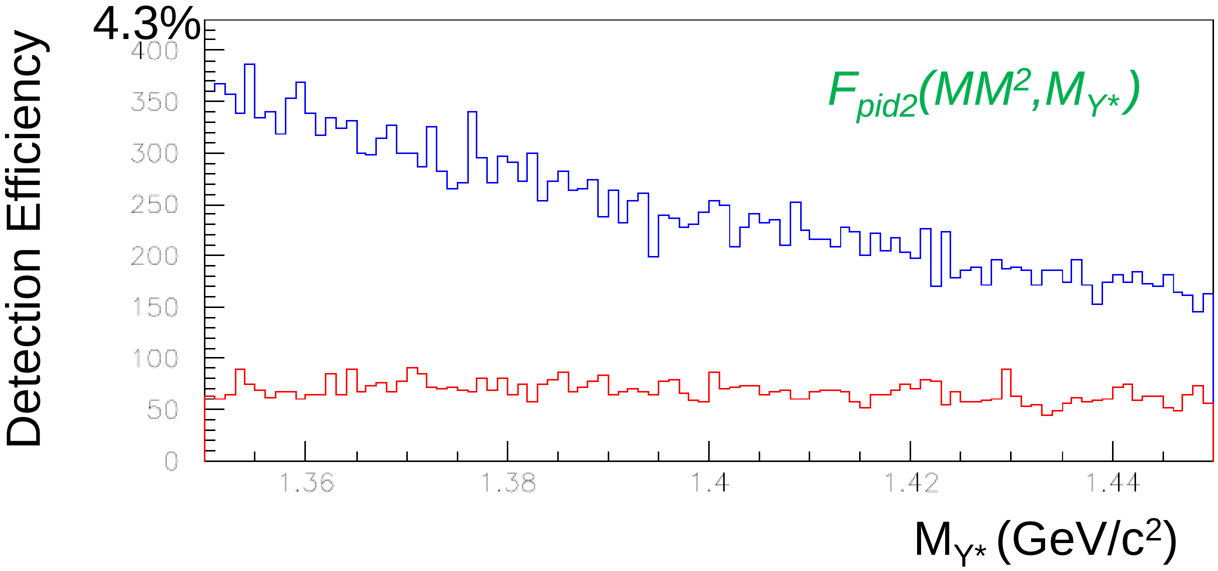


$$\frac{\pi^0\Lambda \quad (I=1)}{\pi^0\Sigma^0 \quad (I=0)} \sim 1$$





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



Summary

(1) We propose to study the d(K^-, n)$\pi\Sigma$ reactions, which is aiming primarily to clarify whether Λ(1405) is a K^{bar}N resonance as predicted by the ChUM or not.
(We fix if $\Lambda*$ appear at 1420 MeV/c^2 or 1405MeV/c^2.)

(2) We expect to reduce Σ* BG owing to S-wave dominant d(K^-,n) at θ_n=0.

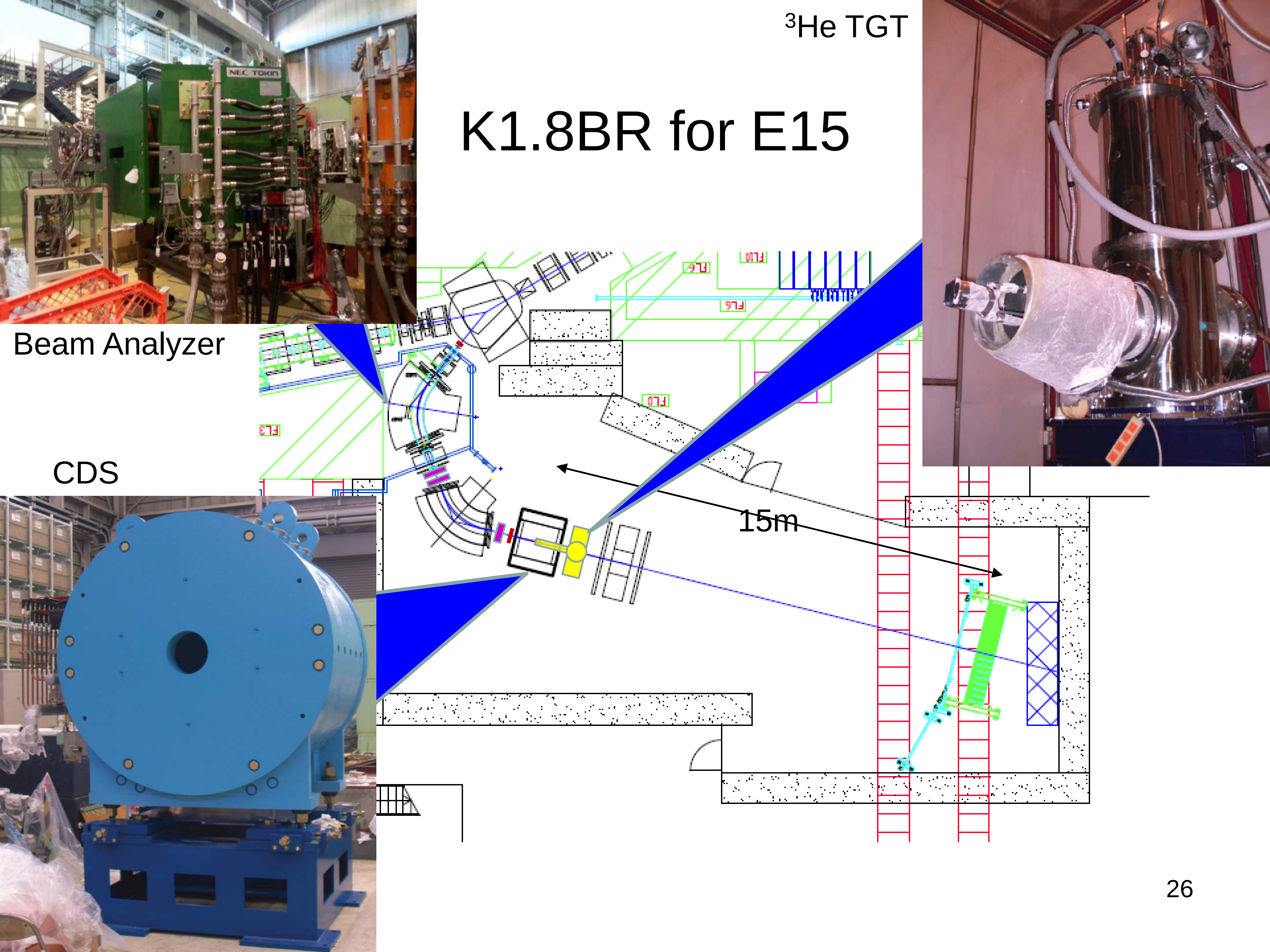
(3) We expect to identify the final $\pi^+\Sigma^-$ and $\pi^-\Sigma^+$ states clearly.
-> Primary aim can be achieved.

(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 θ_n=0 is quite helpful.

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

Backup Slides

K1.8BR for E15



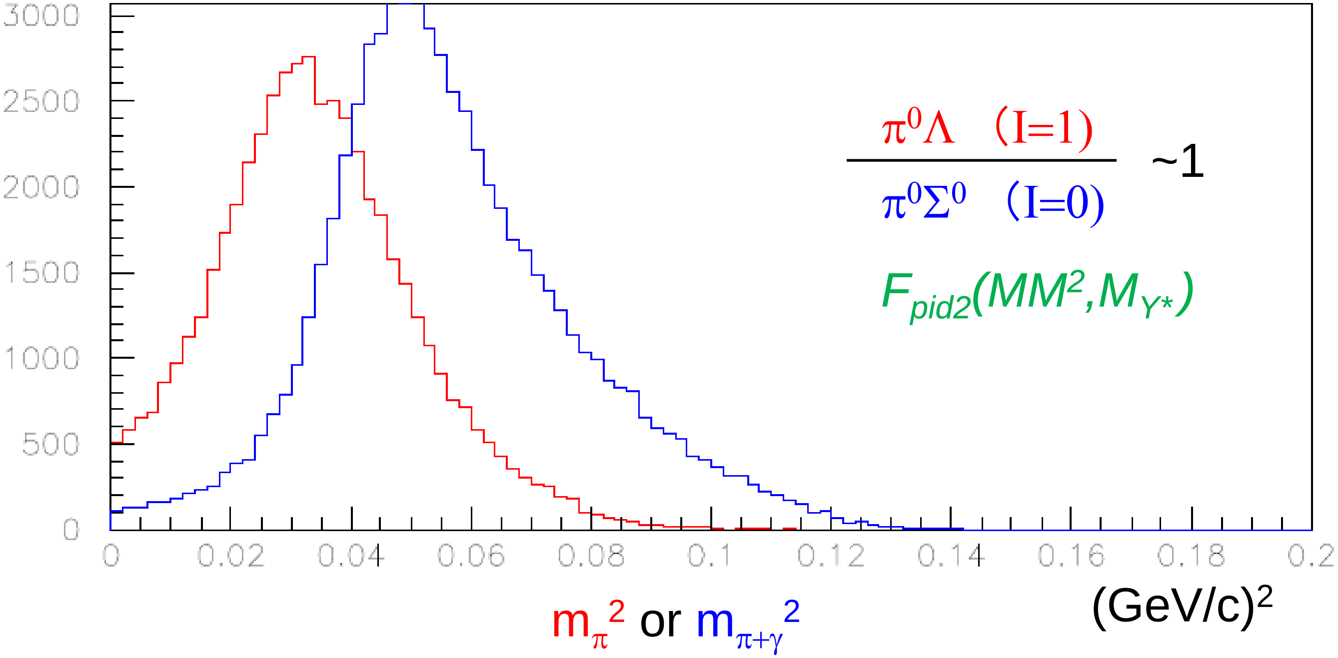
^{3}He TGT

Beam Analyzer

CDS

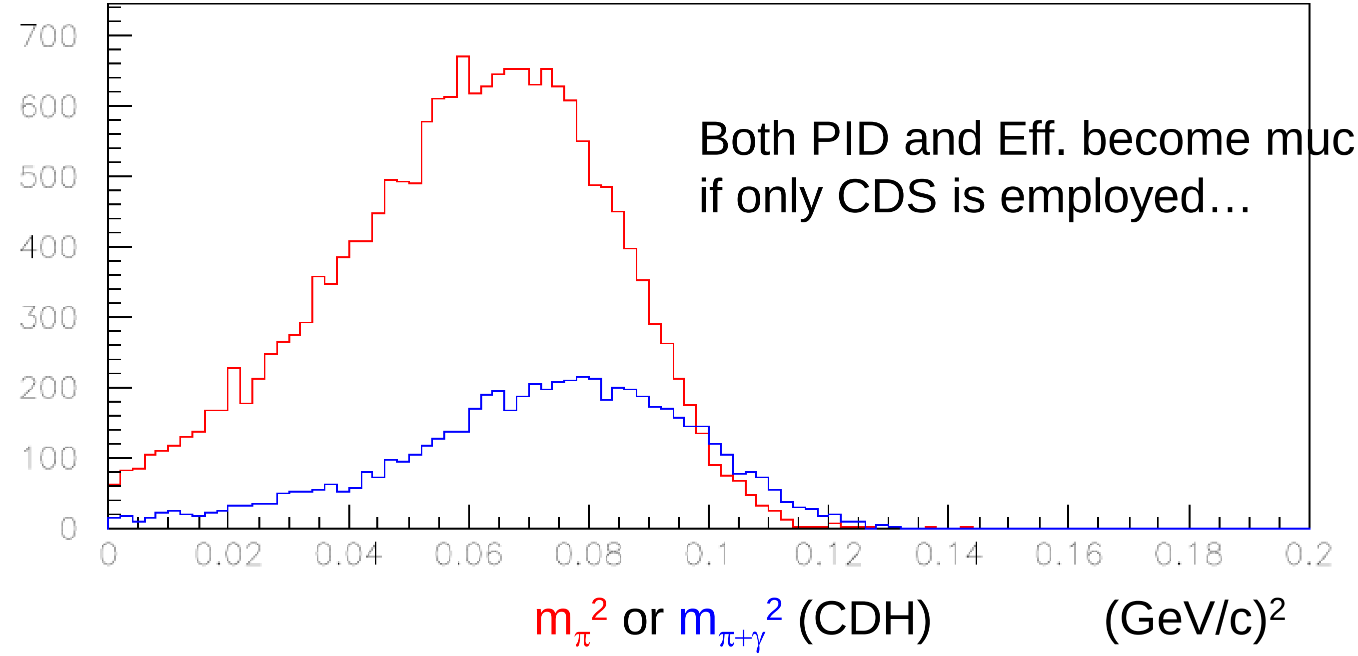
Yield Estimation

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 μb/sr	Λ^*–>$\pi^+\Sigma^-$
		97	Λ^*–>$\pi^-\Sigma^+$
		128	Λ^*–>$\pi^0\Sigma^0$
Solid angle	$\Delta\Omega$	0.020 sr	
Reconstruction eff.	ε_P	0.2	
DAQ			0.9
Beam Tracking			0.9
Neutron detection			0.3
Decay mode eff.	ε_M	0.32	Λ^*–>$\pi^+\Sigma^-$–>$\pi^+\pi^-n$
		0.16	Λ^*–>$\pi^-\Sigma^+$–>$\pi^-\pi^+n$
		0.015	Λ^*–>$\pi^0\Sigma^0$–>$\pi^0\pi^-p$
Analysis eff.	ε_A	0.8	
Yield	Y	~19200	Λ^*–>$\pi^+\pi^-n$ (120 shifts)
		~4800	Λ^*–>$\pi^-\pi^+n$ (120 shifts)
		~350	Λ^*–>$\pi^0\pi^-p$ (120 shifts)



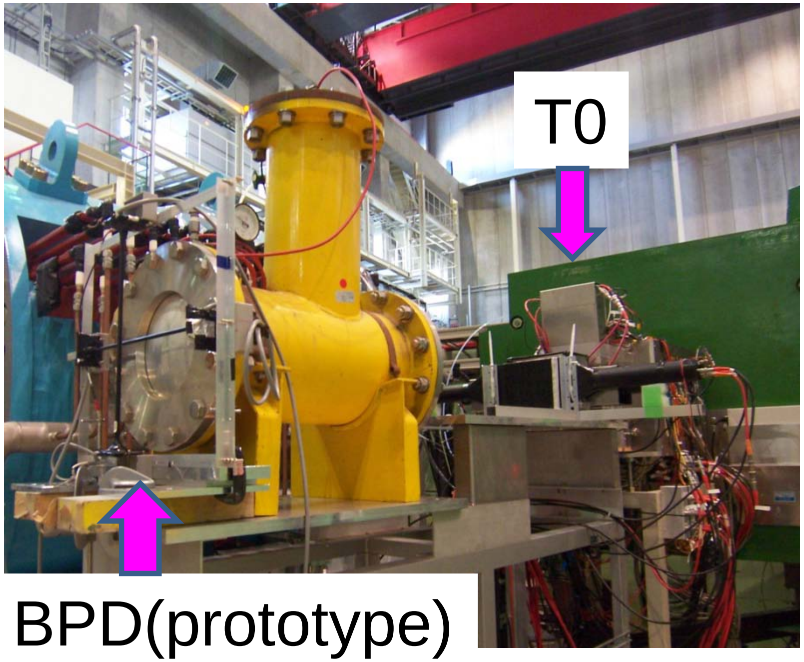
$$\frac{\pi^0\Lambda \quad (I=1)}{\pi^0\Sigma^0 \quad (I=0)} \sim 1$$

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

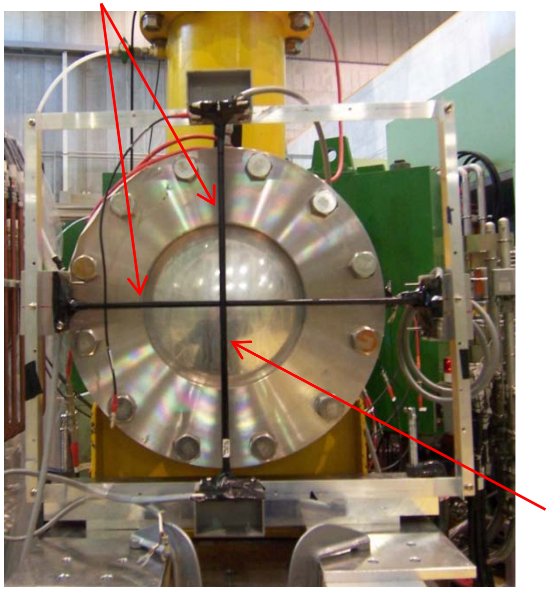


Both PID and Eff. become much worse if only CDS is employed…

MPPC test for backward proton detector (BPD)

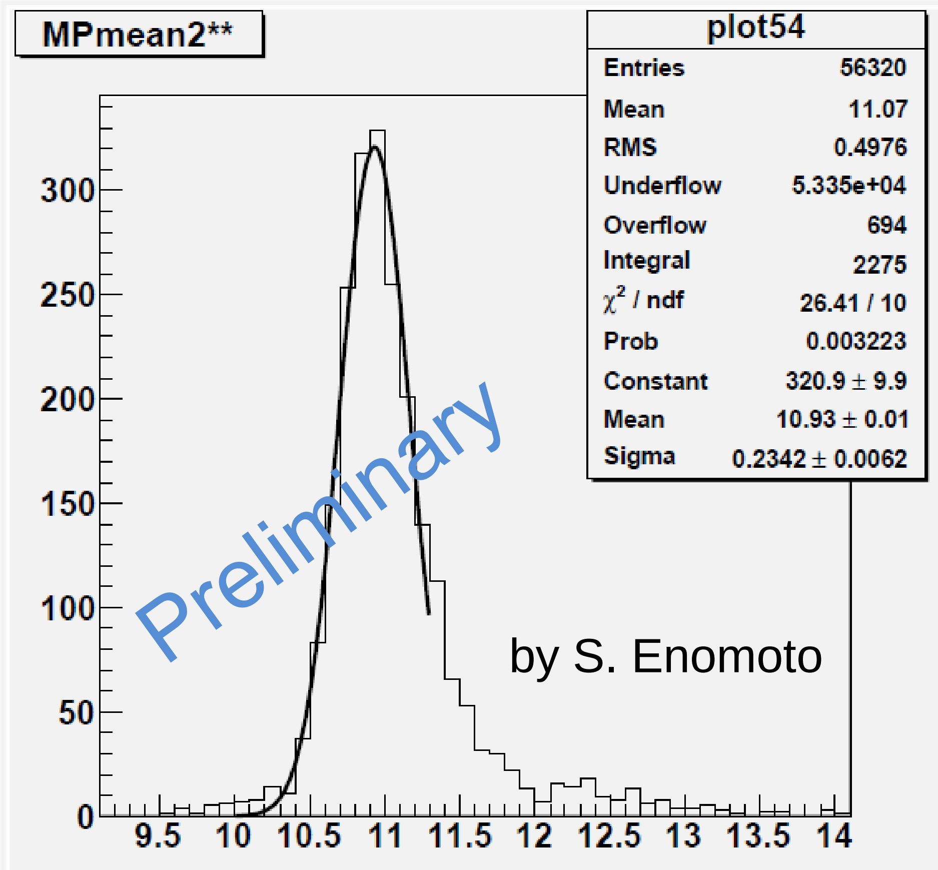


BPD(prototype)



□5mm x400mm Scintillator w/ MPPCs

Time Resolution (BPD-T0) σ~230 ps



by S. Enomoto