Spectroscopic study of Λ(1405) via the in-flight (K^-,n) reaction on deuteron.

SHUN Enomoto

RCNP, Osaka Univ.

For J-PARC E31 collaboration

HYP2012@Barcelona

Oct. 4, 2012

J-PARC E31 Collaboration

- S. Ajimura[1], G. Beer[2], H. Bhang[3], M.Bragadireanu[8],P. Buehler[4], L. Busso[5,6], M. Cargnelli[4], S. Choi[3], C. Curceanu[8], S. Enomoto[1], D. Faso[5], H. Fujioka[13], Y. Fujiwara[12], T. Fukuda[11], C. Guaraldo[8], T. Hashimoto[12],R. Hayano[12], T. Hiraiwa [13], M. Iio[9],K. Inoue[1], N. Ishibashi[17], T. Ishikawa[12], S. Ishimoto[14], T. Ishiwatari[4], K. Itahashi[9], M. Iwai[14], M. Iwasaki[9,10],S. Kawasaki[1], P. Kienle[15], H. Kou[10],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],Y. Sada[13],K. Shirotori[1], A. Sakaguchi[17], F. Sakuma[9], M. Sato[12], M. Sekimoto[14],H. Shi[12], 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]

- *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*
- *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*

Contents

1:Introduction

– Λ(1405)

– The(K^-,n) reaction on deuteron.

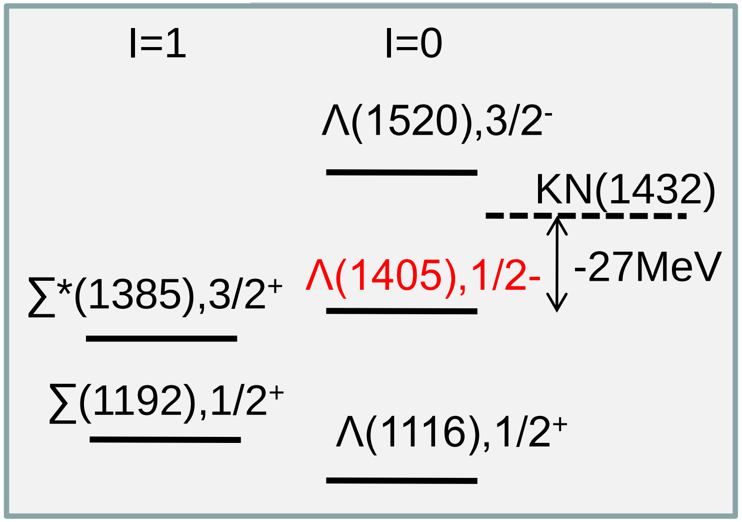
2:J-PARC E31 experiment

– Status

– Future plan & schedule

3:Summary

Is Λ(1405) KbarN bound state ?



1406MeV/c^2[one pole?]

Deeply bound KbarN state.

Y. Akaishi & T. Yamazaki, Phys. Rev. C65, 04405 (2002).

Y. Akaishi & T. Yamazaki, Phys. Lett. B535, 70 (2002)

1420MeV/c^2[two pole?]

Chiral Unitary Model predicted.

T. Hyodo, D. Jido, and A. Hosaka, Phys. Rev. Lett. 97, 192002(2006);

T. Hyodo, D. Jido and A. Hosaka, Phys. Rev. D75, 034002(2007).

T. Hyodo and A. Weise, Phys. Rev. C77, 035204(2008)

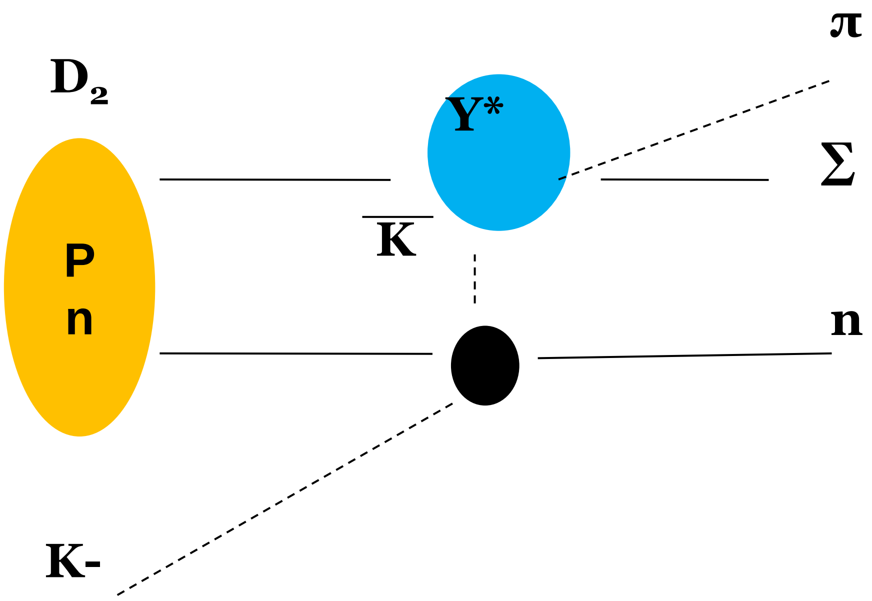
Recently Experiment data
pp➔pK$^+$π^{0}Σ^0, πΣ MM spec., Zychor et al, PLB660(08)167
γp➔K$^+$πΣ, πΣ MM spec., M. Niiyama et al, PRC78(08)035202
γp➔K$^+$πΣ, πΣ IM spec., K. Moriya et al, PTPS186(10)234

Direct KbarN scattering to form Λ(1405) below KbarN threshold must be investigated.

the (K^-,n) reaction on deuteron.

d(K-,n) is KbarN direct reaction.

(Λ(1405) can not couple to KbarN in a free space.)

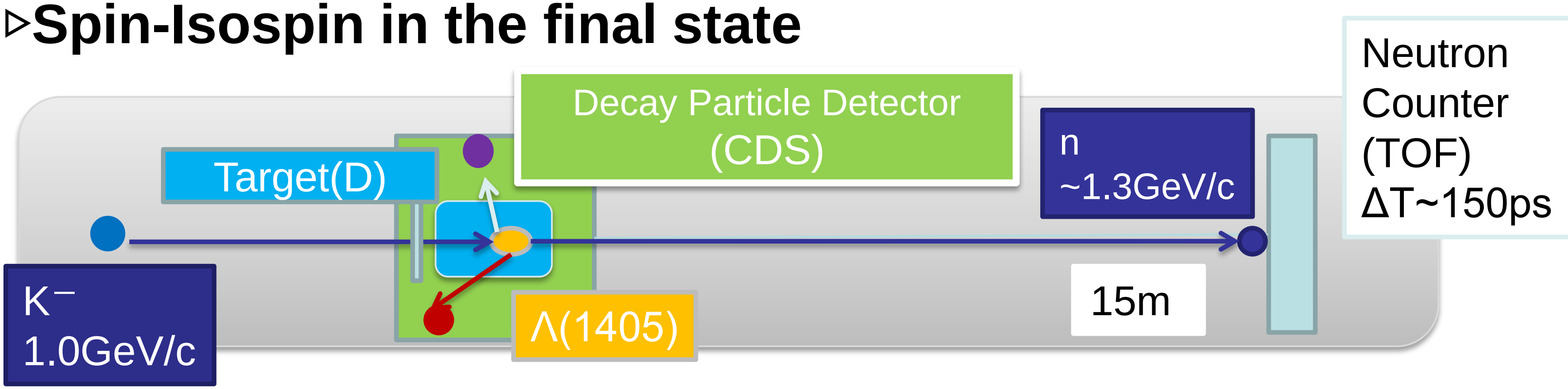


d(K-,n) may enhance the S-wave scattering at Θ_n = 0 degree.

J-PARC E31 Experiments

³He(K⁻,n)"Kpp" reaction
J-PARC E15

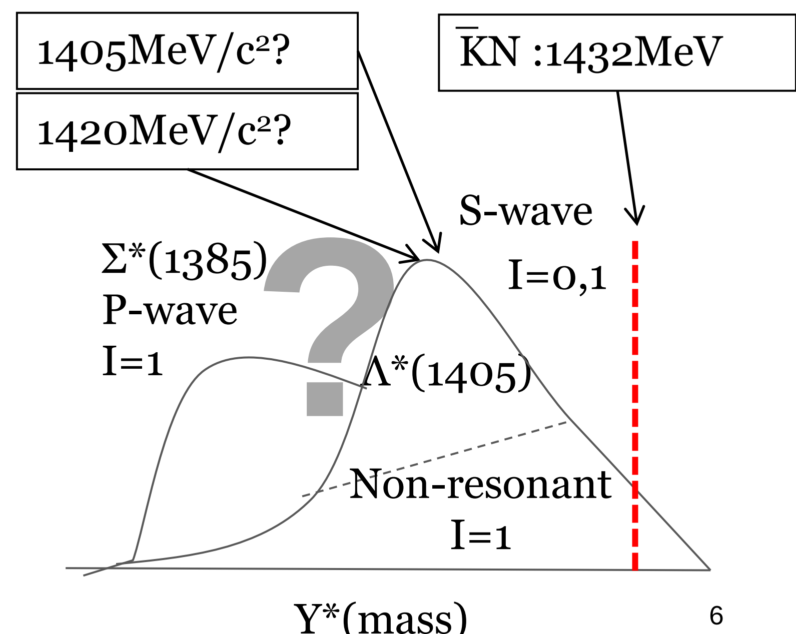
- d(K-,n) missing mass
- Spin-Isospin in the final state



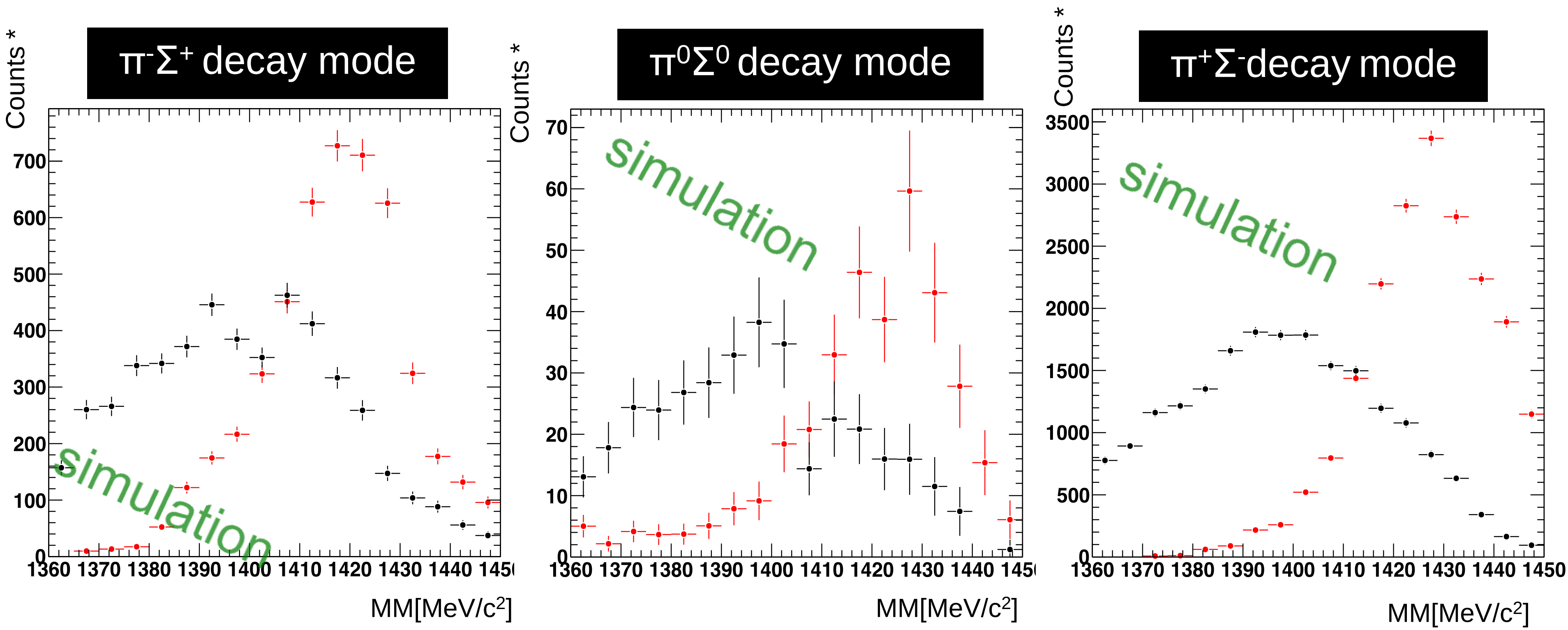
Purely I=0

Λ(1405) and BG(NR/∑*)

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



Expected missing mass spectra in d(K⁻,n)

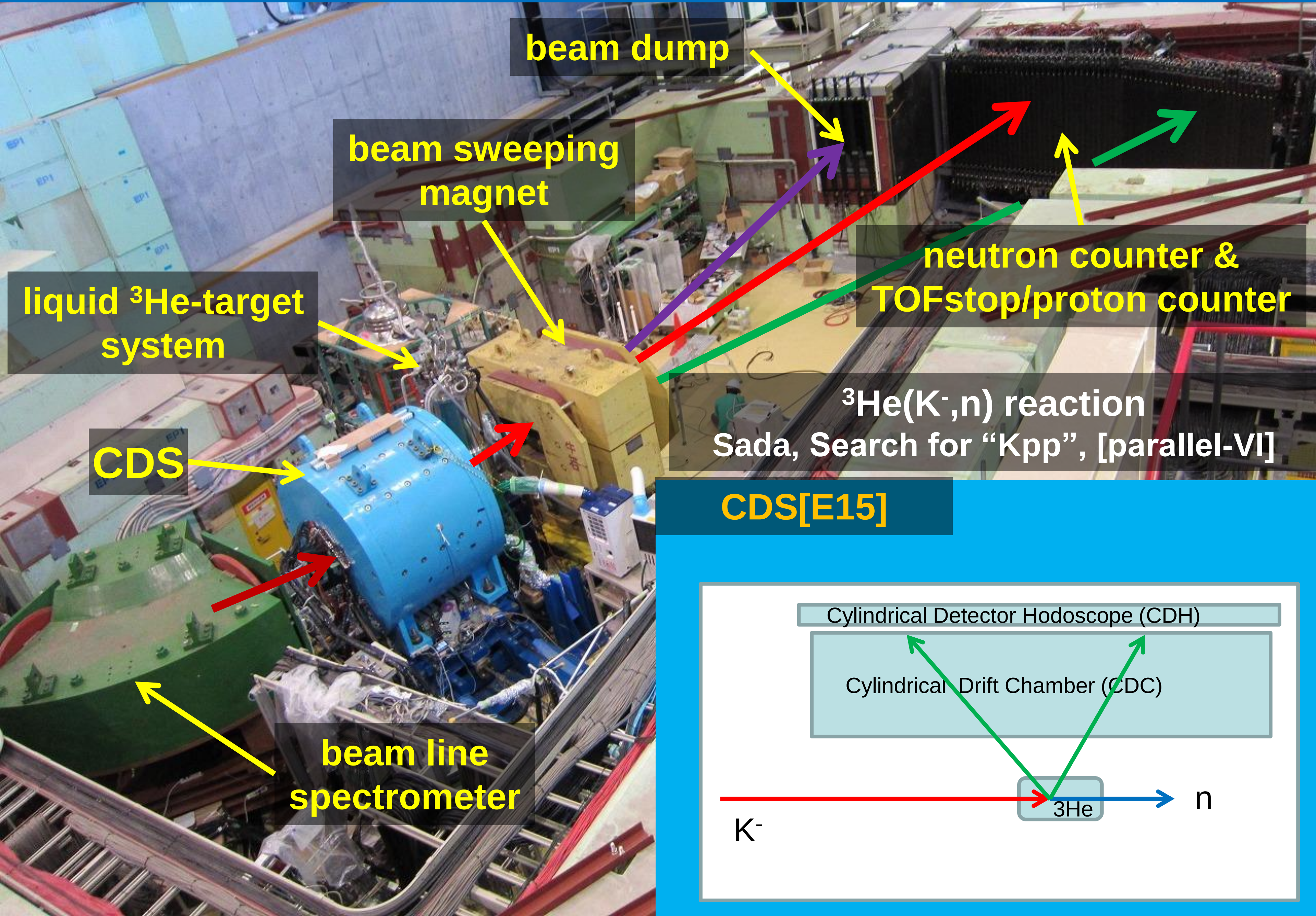


$$MM_X = \sqrt{(\vec{P}_K + \vec{P}_d - \vec{P}_n)^2}$$

Calculated by **data [1]** / **chiral unitary model [2]** .

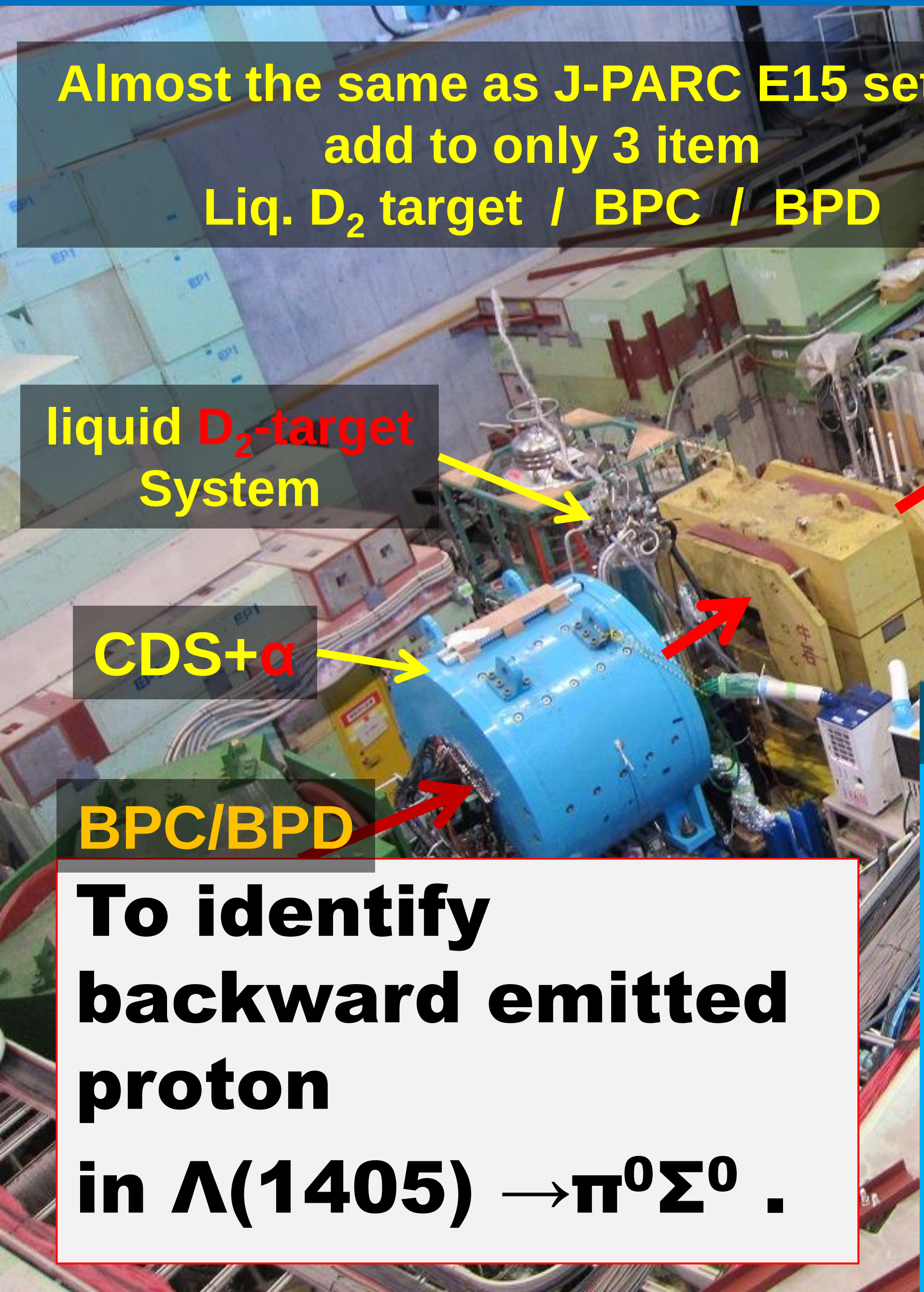
[1]R. J. Hemingway, Nucl. Phys. B 253, 742 (1985)
[2]D. jido, E. Oset and T. Sekihara, Eur. Phys. J A42(2009) 257

J-PARC K1.8BR beam line[Jun. 2012]



Experimental Setup for J-PARC E31

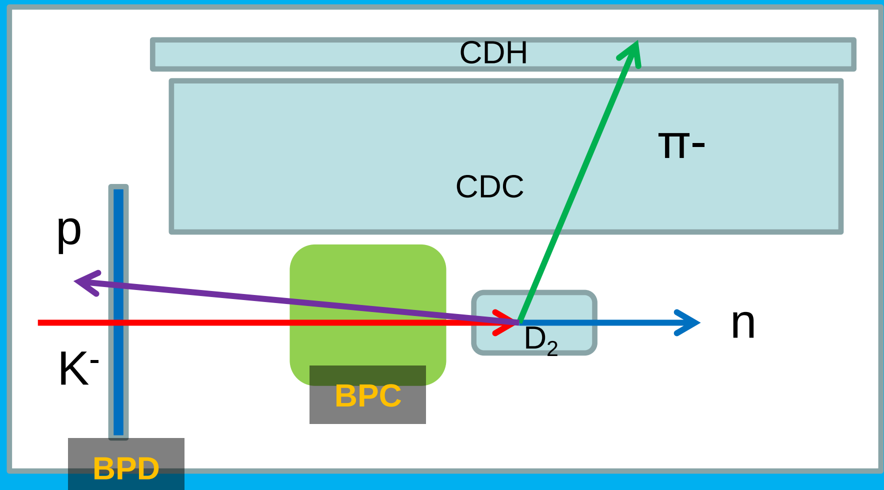
Almost the same as J-PARC E15 setup .
add to only 3 item
Liq. D_2 target / BPC / BPD



To identify backward emitted proton in Λ(1405) →$\pi^0\Sigma^0$.

$\pi^0\Sigma^0$ final state

$\Lambda(1405)\rightarrow\Sigma^0\pi^0\rightarrow\Lambda\gamma\pi^0\rightarrow(p\,\pi^-)\gamma\,\pi^0$

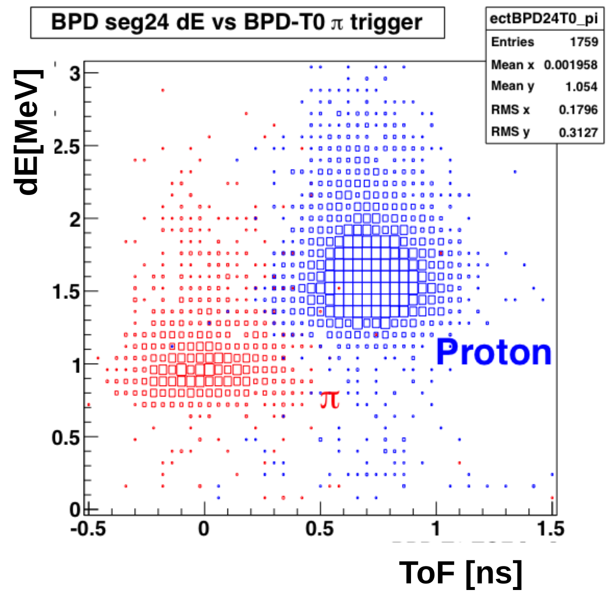


Backward Proton Detector (BPD & BPC)

BPD (Backward Proton Detector)

- ✓70 plastic scintillators
- ✓MPPC
- ✓$\sigma(TOF_{T0\text{-}BPD})$ = 160ps

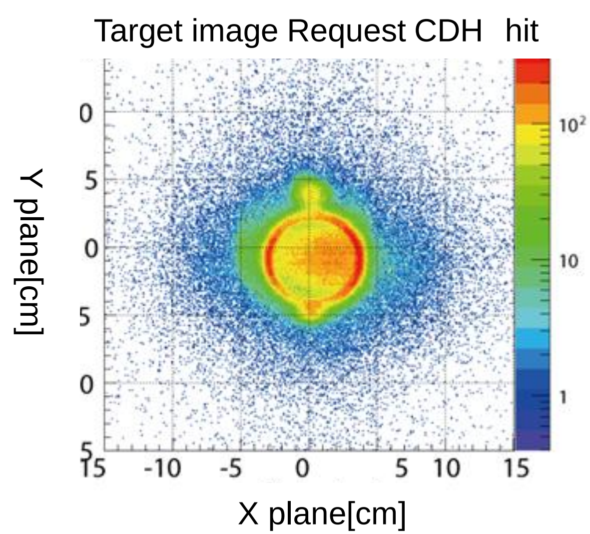
- ▷ Measure a ToF.
- ▷ Determine momentum.

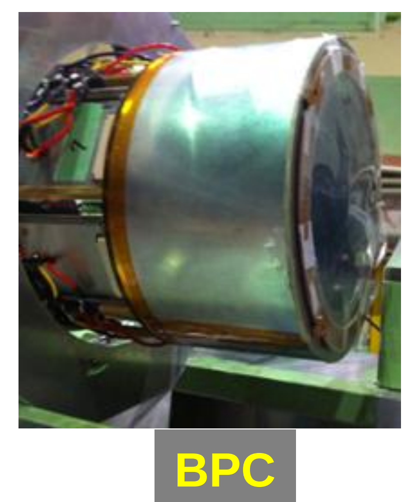


BPC (Backward Proton Chamber)

- ✓wire drift chamber
- ✓planer type, 8 layers

- ▷Track a proton trajectory
- ▷Determine a decay vertex.





Plan & Schedule

- J-PARC E31 Proposed beam Time Request:

120shifts, with 27kw primary proton

~19200[$\Lambda(1405)\rightarrow\pi^+\Sigma^-$],~4800[$\Lambda(1405)\rightarrow\pi^-\Sigma^+$] ,~350[$\Lambda(1405)\rightarrow\pi^0\Sigma^0$]

- **Pilot run**(plan)
- **Wish to have a short term run before summer 2013.**
- When **1week*20kW…..**
  - Confirm that the d(K-,n) reaction really enhances an S-wave KbarN scattering to form $\Lambda(1405)$.
  - Collect **2400**$\pi^+\Sigma^-$(>old Bubble Chamber Exp.), **600**$\pi^-\Sigma^+$(new)

  →**can provide new data in a short time!!**

- **Full scale run**
  - Collect $\pi^0\Sigma^0$ mode.

  →2014 spring~ (after J-PARC long shutdown) .

Summary

▷We propose to study Λ(1405) hyperon resonance via the d(K-,n) reaction.

- KbarN→πΣ scattering below KbarN threshold
- how Λ(1405) is dynamically formed from initial KbarN state.

▷ E31 is ready to run !!

- (E15setup), D_2target, BPC and BPD are ready

▷We wish to start data acquisition before summer 2013.

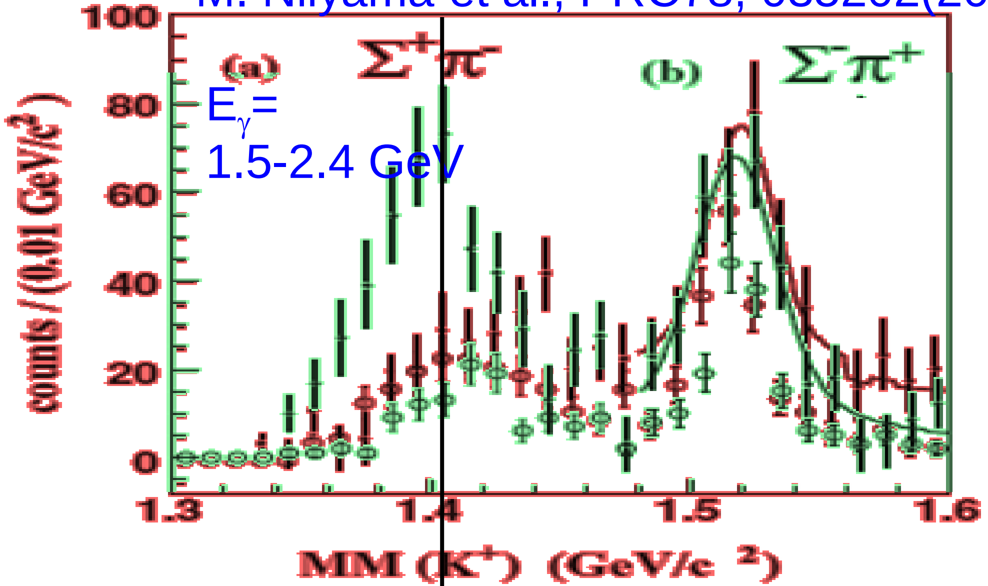
- We are sure to provide new data on Λ(1405)→$\pi^-\Sigma^+$ and $\pi^-\Sigma^+$ in a short time, and Λ(1405)→$\pi^0\Sigma^0$ finally.

Moltes gracies !

BACK UP

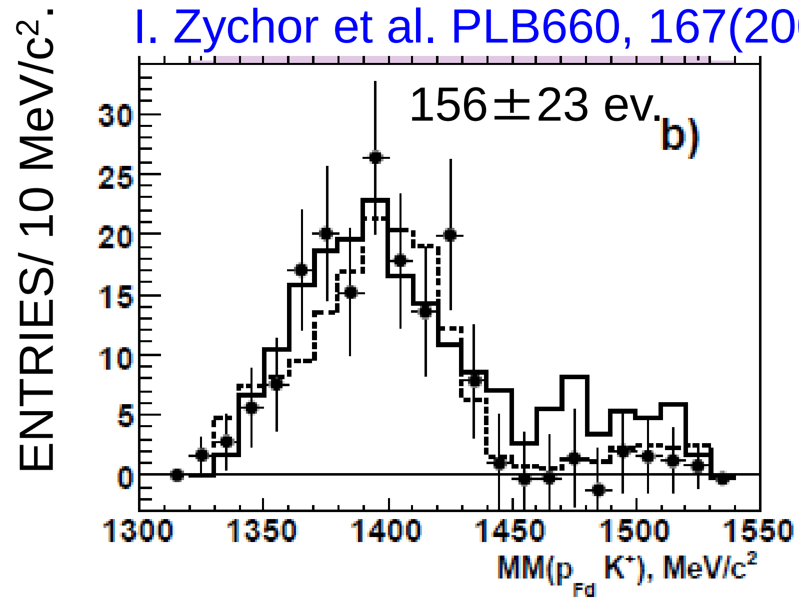
LEPS: $\gamma p \to K^+ \Sigma \pi$

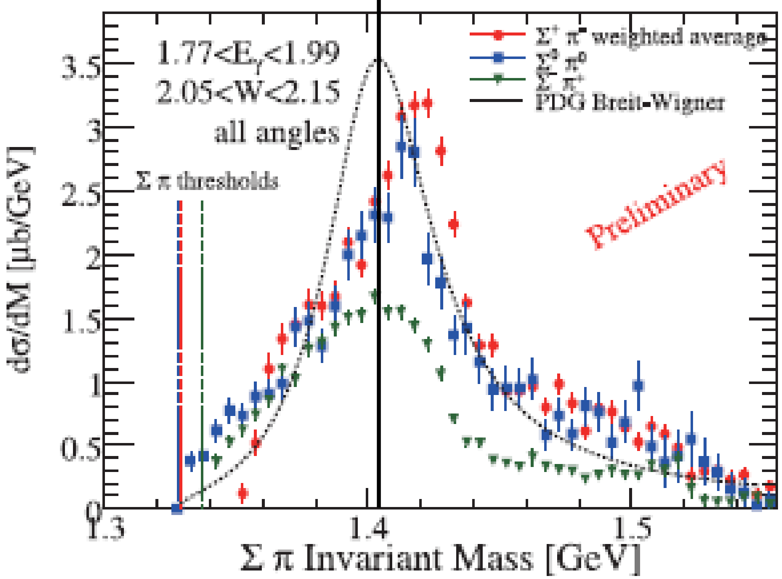
M. Niiyama et al., PRC78, 035202(2008)



COSY-ANKE: $pp \to pK^+\Lambda^*(\to \pi^0\Sigma^0)$

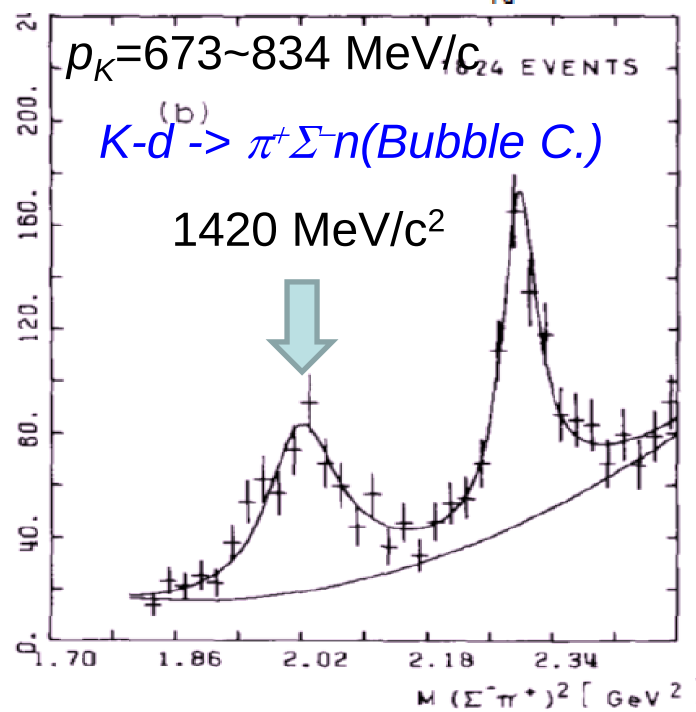
I. Zychor et al. PLB660, 167(2008





CLAS: $\gamma p \to K^+ \Sigma \pi$

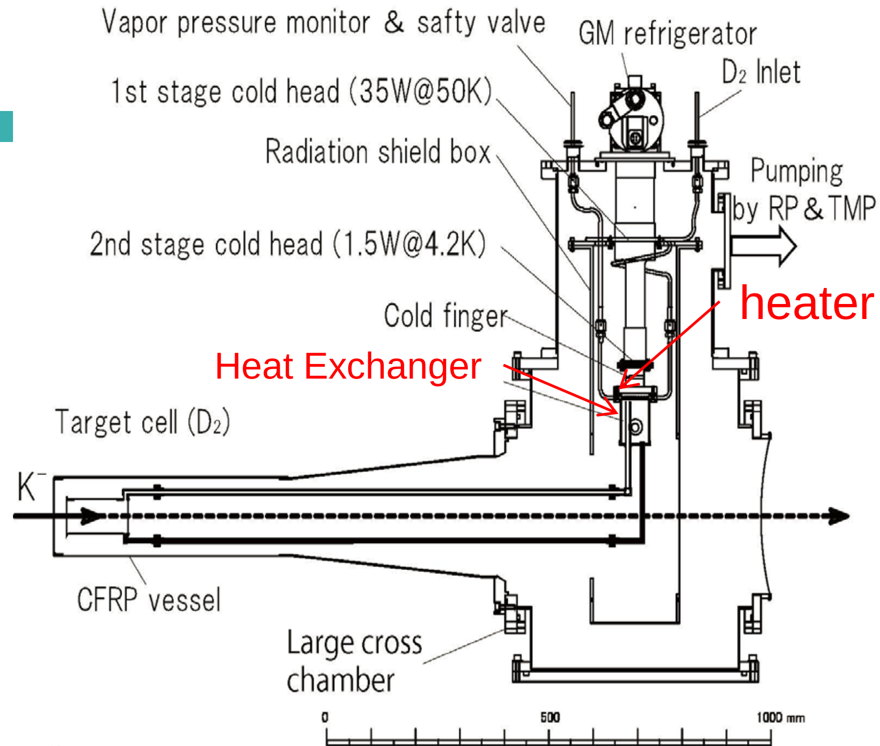
K. Moriya et al., PTP Suppl.186, 234(2010)



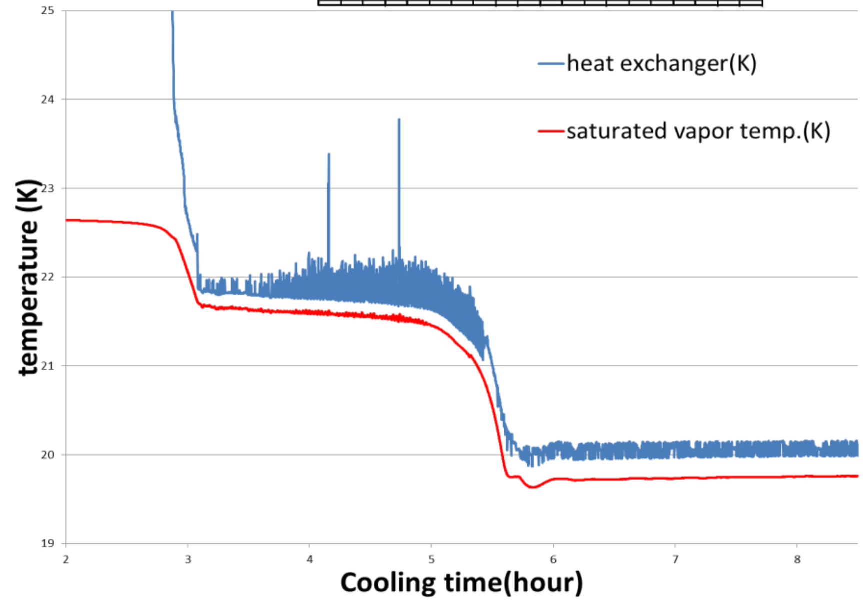
O. Braun et al., NPB129, 1(1977)

Liq. D2 target

- 4K G-M refrigerator to liquefy
  - ✔Easy to control temperature w/ heater @ H. E.



- Demonstration to liquefy Hydrogen.
  - ✔Temp. can be controlled around 20K.

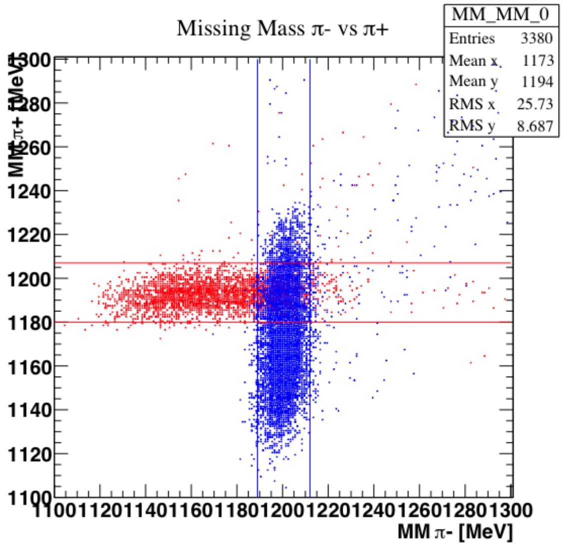


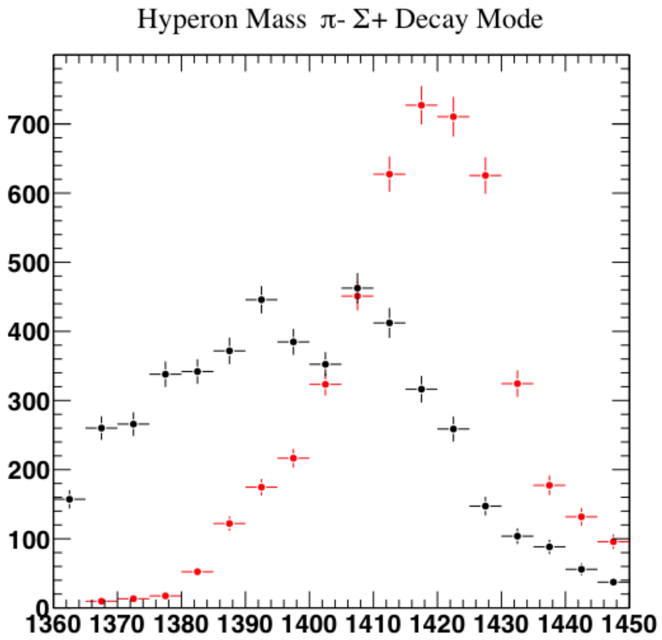
	H2	D2
BP	20.3K	23.8K
MP	14.0K	18.7K

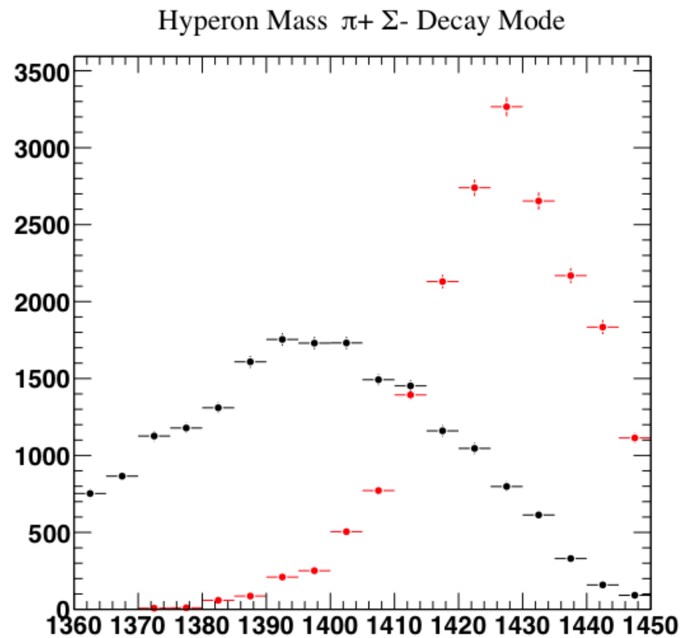
Identifying π⁻ π⁺ final state

Λ(1405), (Σ(1385)) → π⁻Σ⁺ → π⁻ n π

Λ(1405), (Σ(1385)) → π⁺Σ⁻ → π⁺ n π

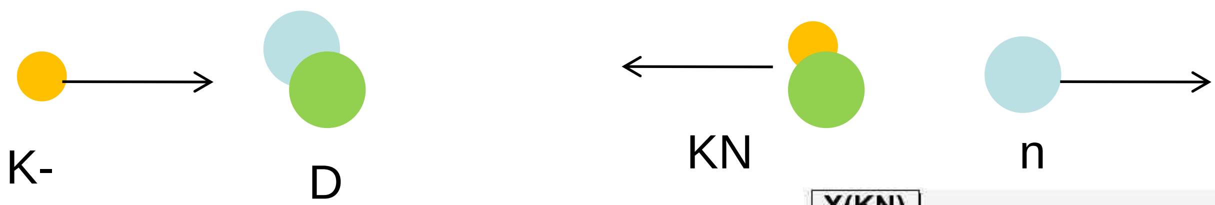






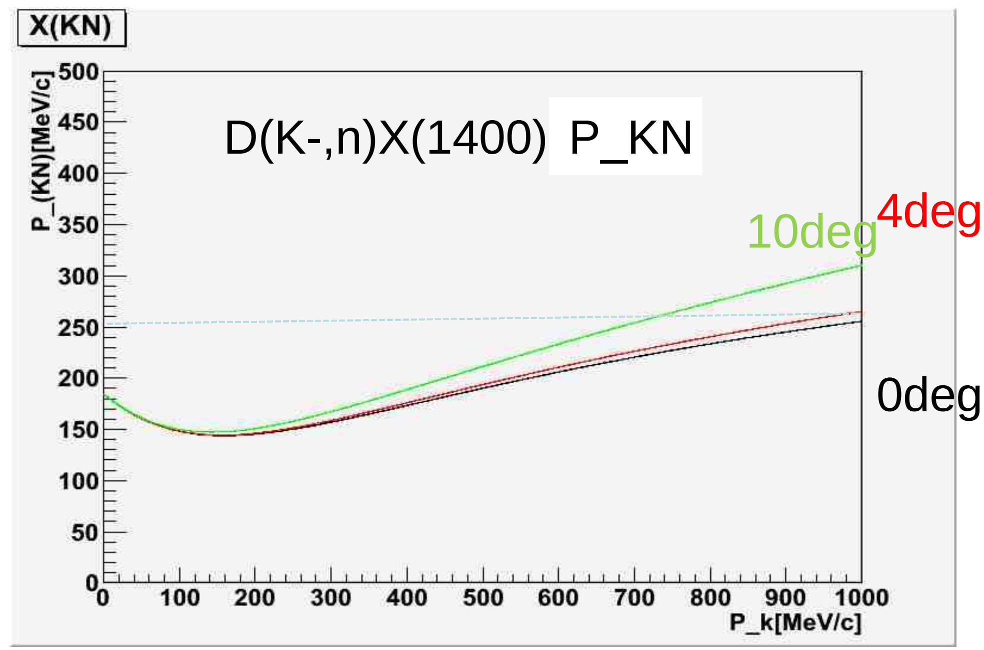
- Simple the reaction mechanism.

->$d(K^-,n)\pi^+\Sigma^-$ at P_{K-}=800MeV/c



$$P_{\bar{K}N(Lab)} \sim 250MeV/c, P_{\bar{K}N(CM)} \sim 160MeV/c$$

$$L = \frac{\vec{r} \times \vec{p}}{\hbar} < 1, r \sim 1fm, \hbar c \sim 200MeV \cdot fm$$



Enhancement of Λ* production at θn=0
BackGround from Σ* will be reduced

S-wave KbarN scattering is dominant at θ_n =0 degree.

ID & Efficiency for Λ*->$\pi^0\Sigma^0$

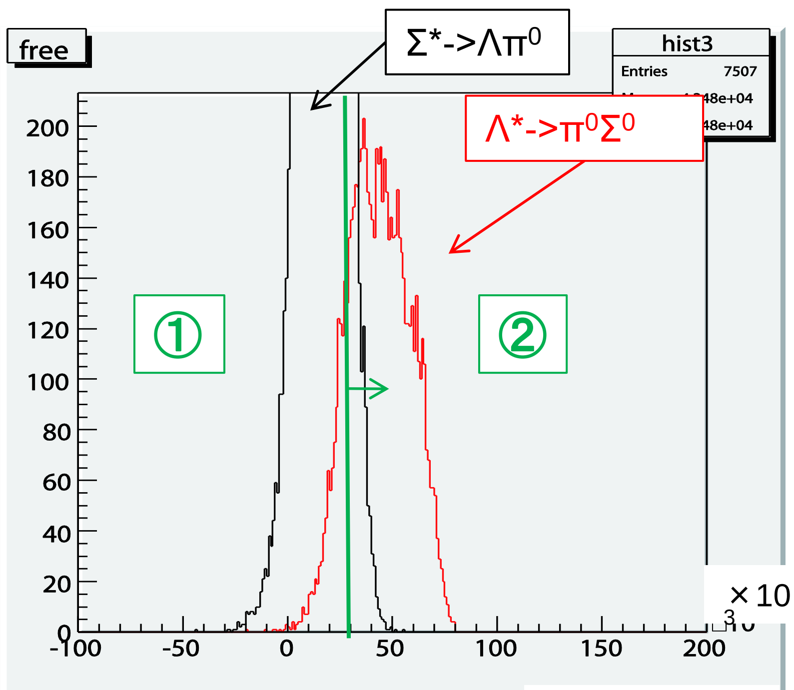
$\Lambda(1405) \to \Sigma^0 \pi^0 \to \Lambda\gamma\pi^0 \to (p\ \pi^-)\gamma\ \pi^0$

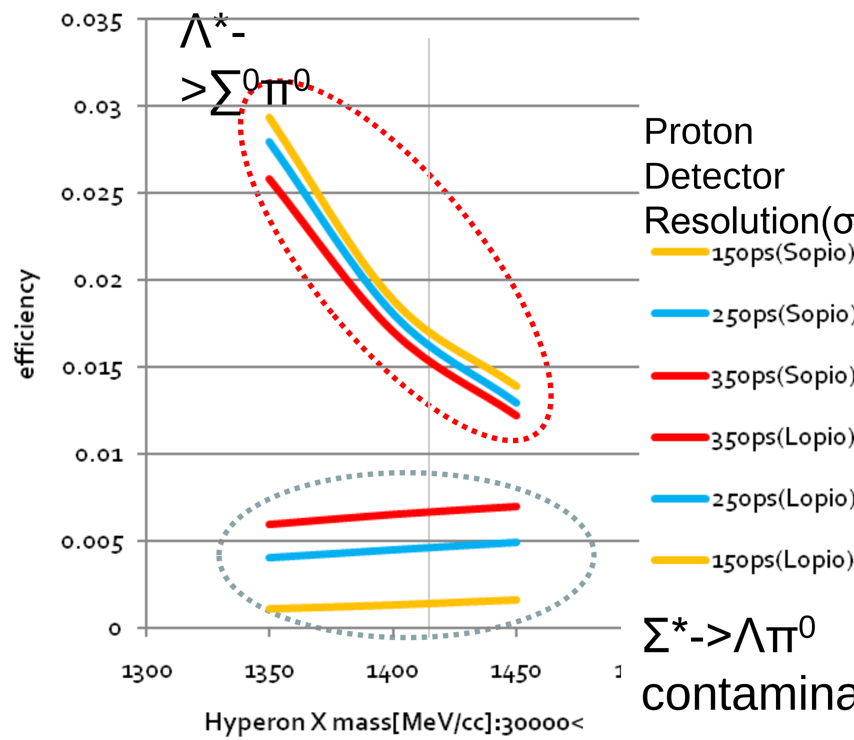
$NR/\Sigma(1385) \to \Lambda\pi^0 \to p\pi^-\pi^0$

$$MM_Y{}^2 = (\vec{P}_Y)^2 = (\vec{P}_K + \vec{P}_d - \vec{P}_n - \vec{P}_p - \vec{P}_{\pi^-})^2$$

P:fourth momentum

Γ(Λ*)/Γ(Σ*)~1





Σ*->$\Lambda\pi^0$ contamination

$\Lambda\pi^0$(contamination)=(Λπ [②])/(Λπ)

E31 experiment

Intensity	30GeV-27kW(6s)	
Secondary beam	K-:1.0GeV.c	
Beam intensity(Ib)	2.0*10^5per pulse	6s spill interval
Cross section(dσ/dΩ)	220μb/sr 97 128	Λ(1405)→π+∑-→π+π-n Λ(1405)→π-∑+→π-π+n Λ(1405)→π0∑0→π0π-p
Solid angle(ΔΩ)	0.020sr	
Decay mode efficiency(ε_M)	0.32 0.16 0.015	Λ(1405)→π+∑-→π+π-n Λ(1405)→π-∑+→π-π+n Λ(1405)→π0∑0→π0π-p
Target	4.1*10^23	Liquid deuteron(8cm)
Yield(120shift)	~19200 ~4800 ~350	Λ(1405)→π+π-n Λ(1405)→π-π+n Λ(1405)→π0π-p

$$Y = I_b \times n_t \times \frac{d\sigma}{d\Omega} \times \Delta\Omega \times \varepsilon_R \times \varepsilon_M \times \varepsilon_A$$

R:reconstruction(0.24)A:analysis(0.9)