Spectroscopic study of Lambda(1405) via the (K-,n)reaction on deuteron.

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Baryons'10@Osaka.Univ 2010/12/10

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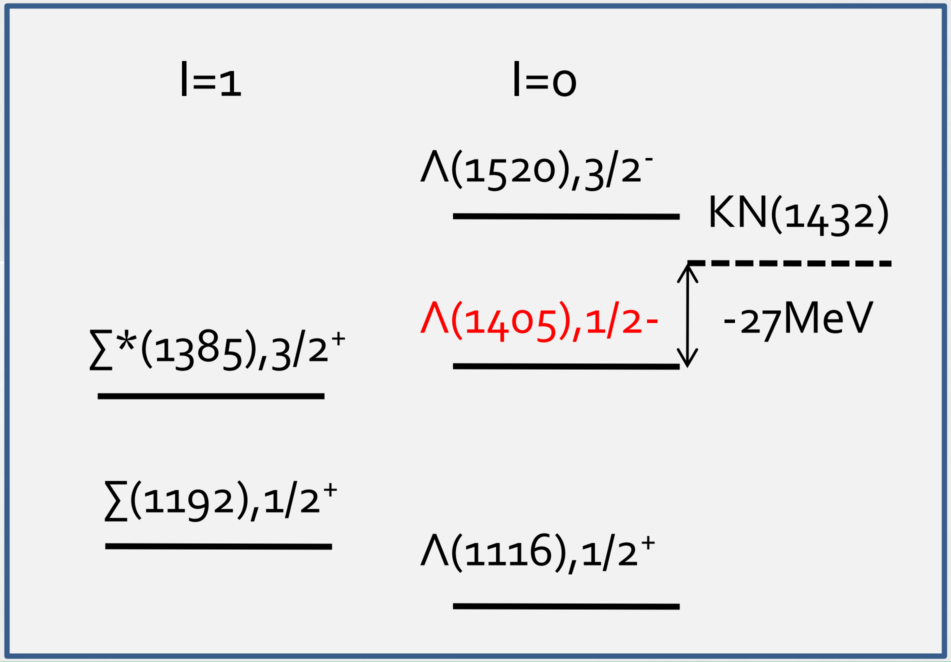
Introduction

Λ(1405)



- 3quark?5quark?

- KbarN

1406.5MeV/c²[one pole?]

Deeply bound KbarN state

A spectroscopic study of Λ(1405) directly coupled to KbarN is desired.

KbarN scattering below KbarN threthold.

→**d(K-,n)Λ* reaction**

1420MeV/c²[two pole?]

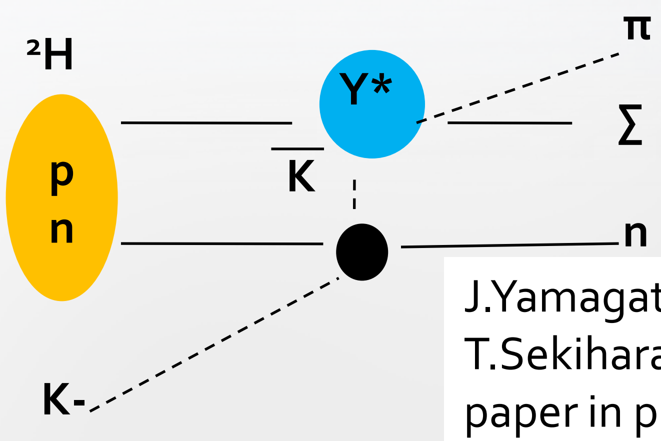
Chiral Unitary Model predicted.

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)

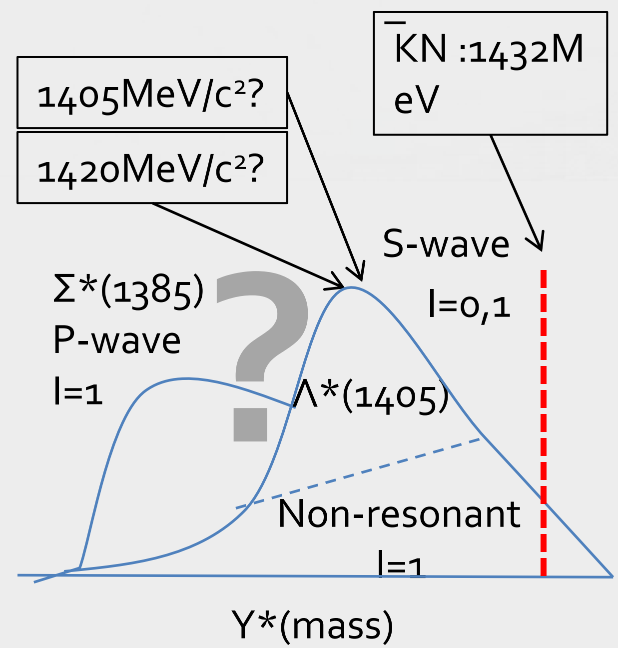
the(K-,n) reaction on Deuteron.

Motivation

- To clarify whether Λ(1405) is KbarN resonant state.



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



Purely I=0

- Λ(1405) and BG(NR/Σ*)
- S-wave,I=0 → Λ*(1405) → $\pi^0\Sigma^0$, $\pi^-\Sigma^+$, $\pi^+\Sigma^-$
- S-wave,I=1
- P-wave,I=1

Possible ID of I=0 in KbarN->πΣ
Possible decomposition of I=0 amplitude.

J-PARC E31 experiments

J-PARC E31 Collaboration

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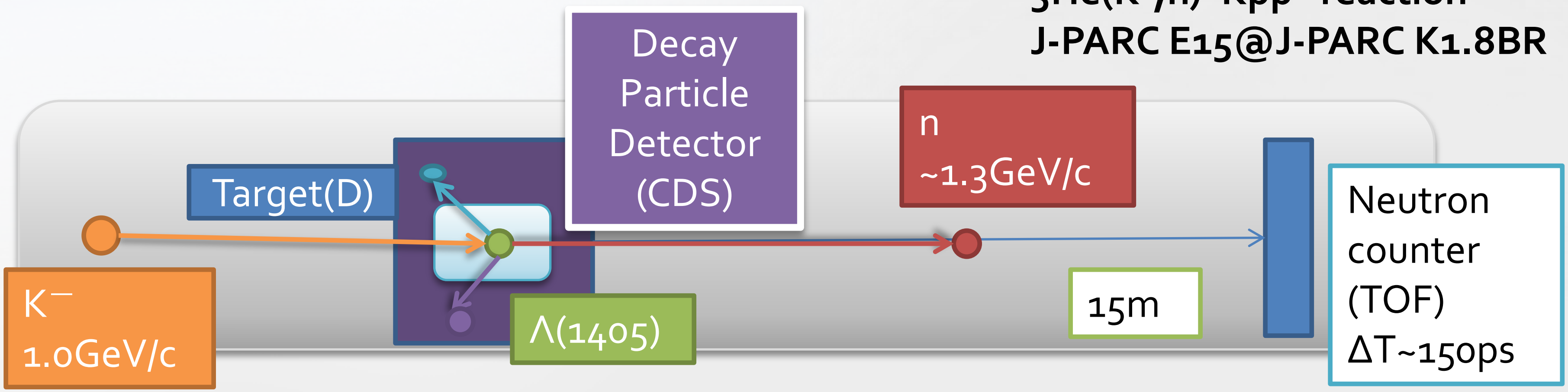
- *9. RIKEN, Japan, 10. Tokyo Institute of Technology, Japan*
- *11. Osaka Electro-Communication University, Japan, 12. University of Tokyo, Japan*
- *13. Kyoto University, Japan, 14. High Energy Accelerator Research Organization (KEK), Japan*
- *15. Technische Universitat Munchen, Germany, 16. INAF-IFSI, Sezione di Torino, Italy*
- *17. Osaka University, Japan*

J-PARC E31 Experiments

- Spectroscopic study of Hyperon Resonances below KbarN threthold via the (K⁻,n) reaction on Deuteron.

3He(K-,n)"Kpp" reaction
J-PARC E15@J-PARC K1.8BR



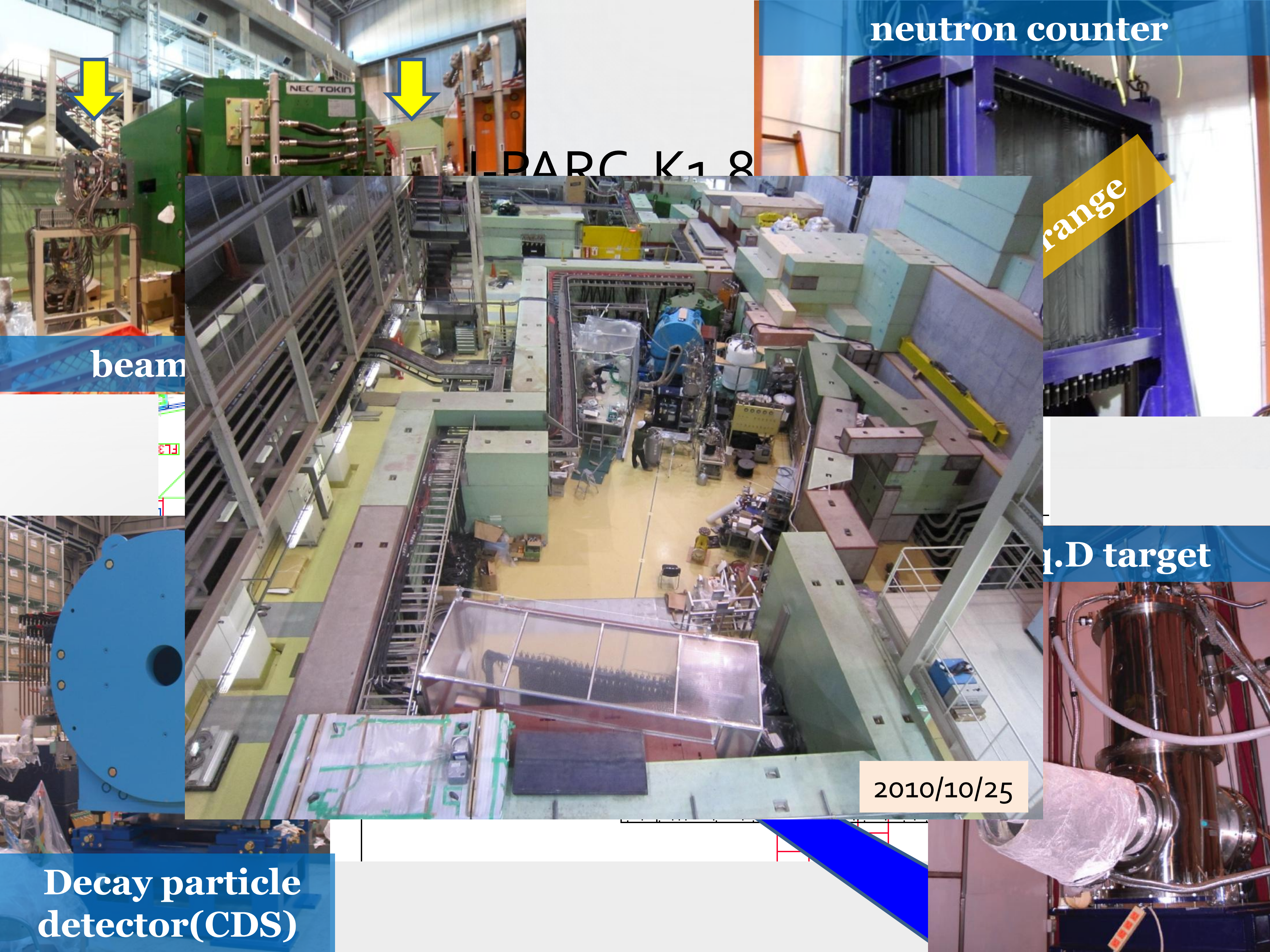
- To measure Λ* mass spectra by Missing Mass .

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

- σ_{MM}~9MeV/c² at P_{K-} = 1.0GeV/c

- To Identify Λ* decay mode by CDS

$\Sigma^-\pi^+, \Sigma^+\pi^- \rightarrow$ I=0 Λ*
I=1 NR
I=1 Σ*
$\Sigma^0\pi^0 \rightarrow$ I=0 Λ*
$\Lambda\pi^0 \rightarrow$ NR or Σ*


neutron counter
beam
NEC TOKIN
2010/10/25
Decay particle
detector(CDS)

Identification of Λ^* decay mode.

case1:

$\pi^+\Sigma^-$ and $\pi^-\Sigma^+$

$\Lambda(1405) \rightarrow \Sigma^+\pi^- \rightarrow (n\pi^+)\pi^-$

$\Sigma^-\pi^+ \rightarrow (n\pi^-)\pi^+$

case2:

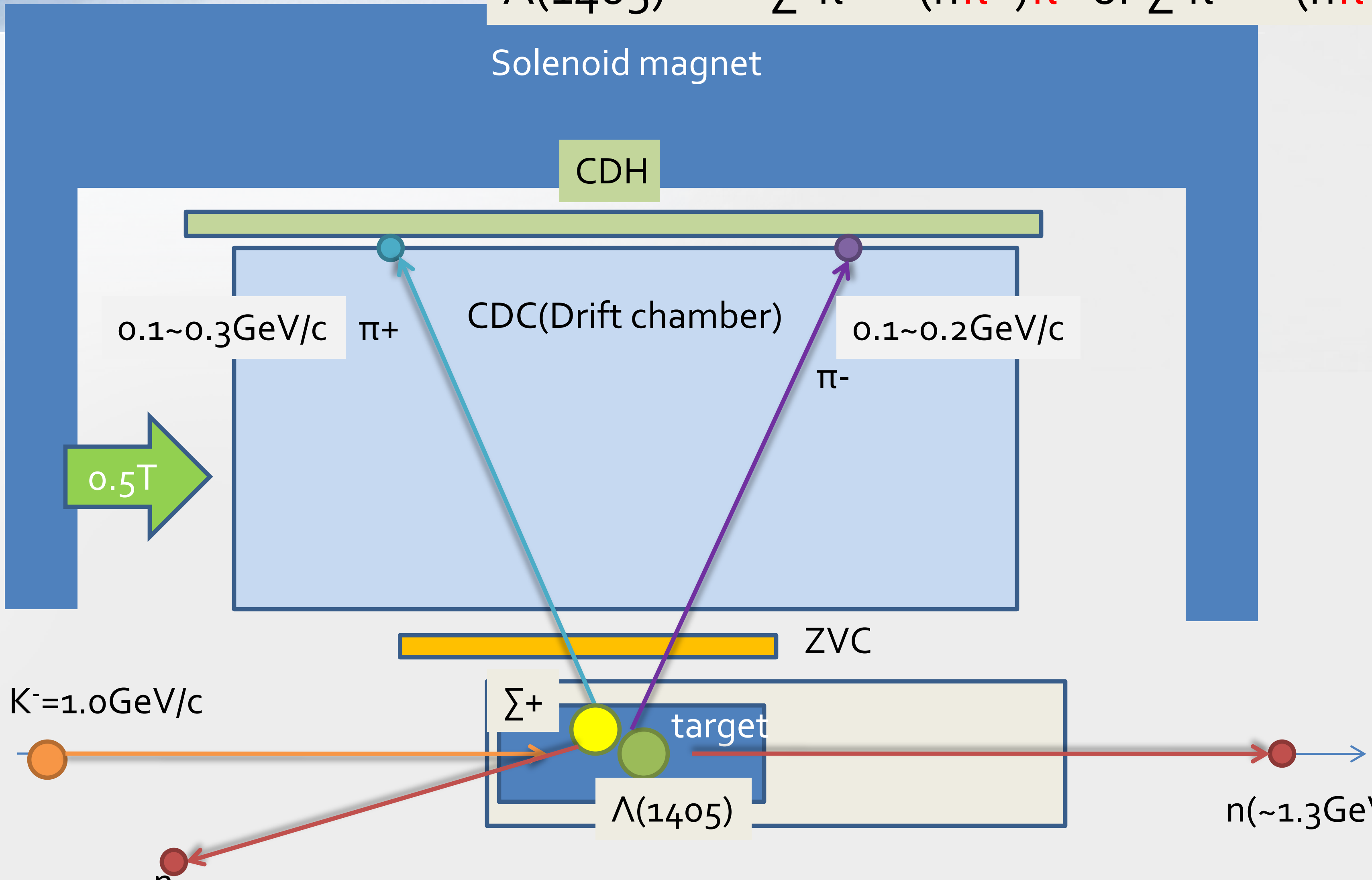
$\pi^0\Sigma^0$ and $\Lambda\pi^0(NR/\Sigma^*)$

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

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

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

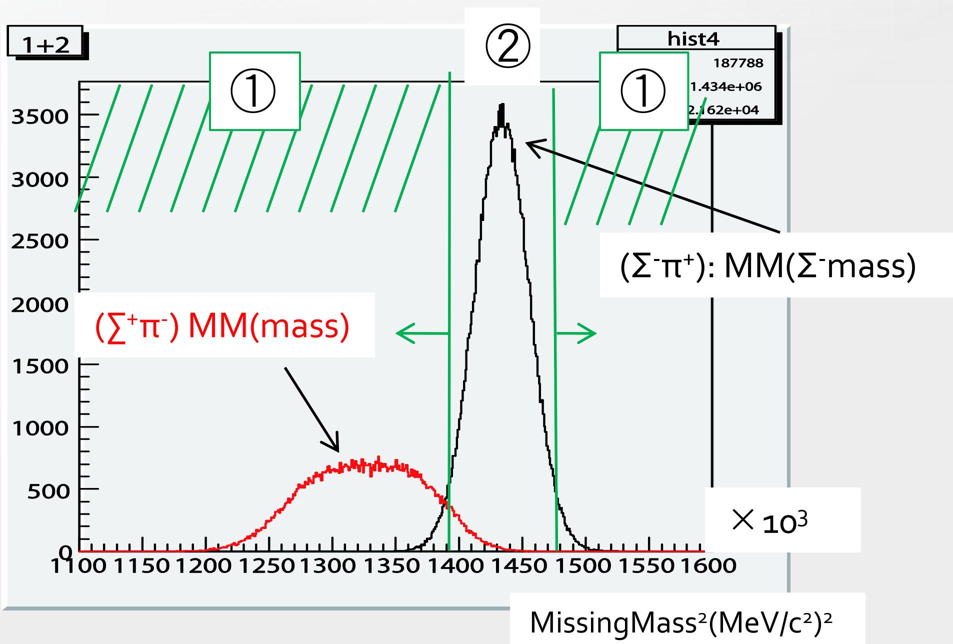
$\Lambda(1405) \to \Sigma^+\pi^- \to (n\pi^+)\pi^-$ or $\Sigma^-\pi^+ \to (n\pi^-)\ \pi^+$

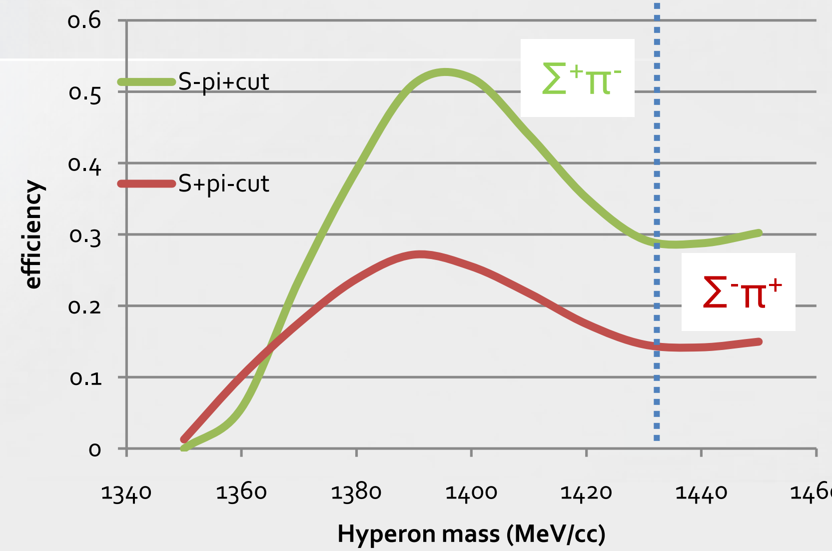


The J-PARC E15 setup is quite suitable to detect π.

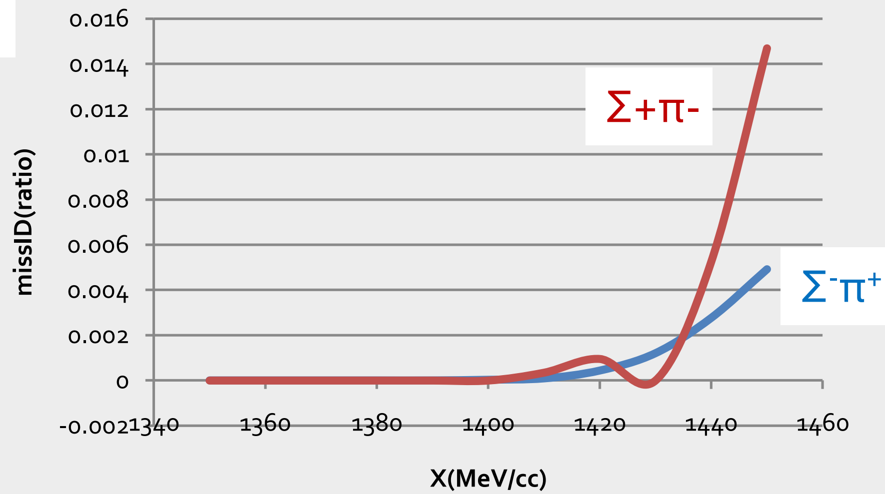
Identification of the decay modes: $\Lambda^* \to \Sigma^-\pi^+$ or $\Sigma^+\pi^-$

$$MM_{\Sigma^{\pm}}{}^2 = (\vec{P}_K + \vec{P}_d - \vec{P}_n - \vec{P}_{\pi^{\mp}})^2$$





$\Gamma(\Lambda^* \to \Sigma^+\pi^-)/\Gamma(\Lambda^* \to \Sigma^-\pi^+) \sim 1$

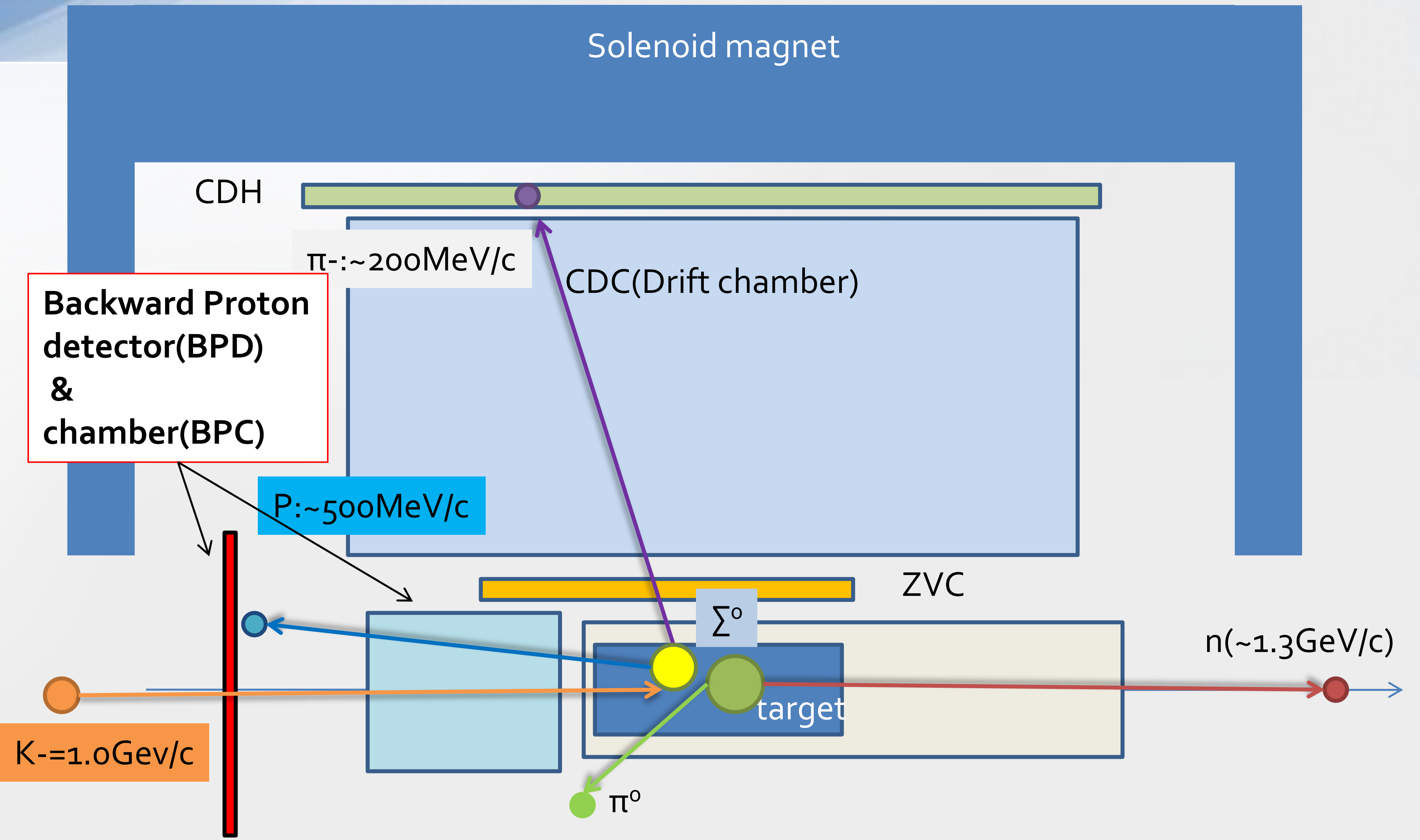


missID($\Sigma^+\pi^-$)=($\Sigma^-\pi^+$[①])/($\Sigma^+\pi^-$[②])

$\Lambda^* \to \Sigma^0\pi^0, (\Sigma^* \to \Lambda\pi^0)$

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

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



BPD measures to momentum of proton TOF methods.

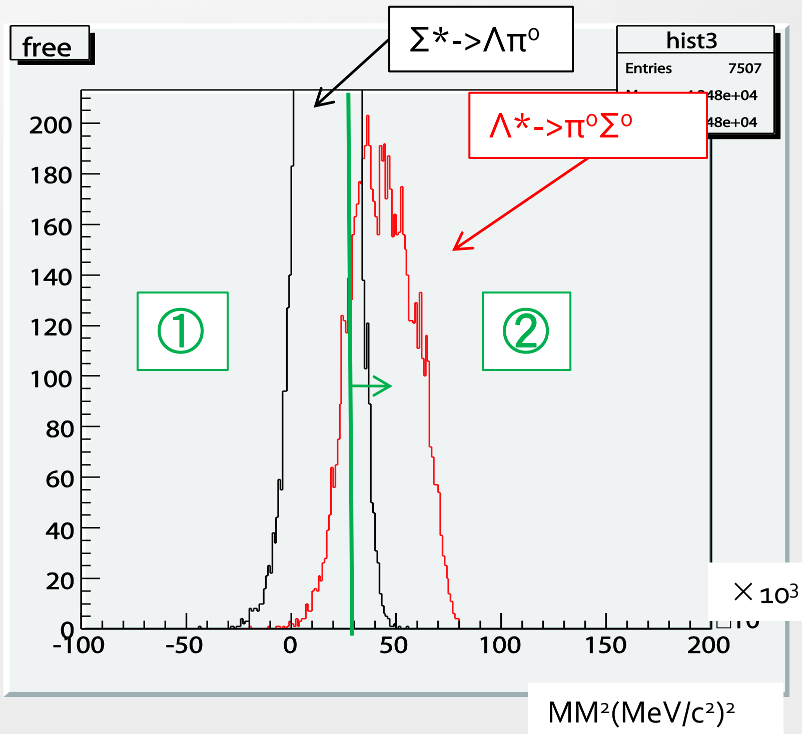
ID & Efficiency for Λ*->π⁰Σ⁰

Λ(1405)⟶∑⁰ π⁰⟶Λγπ⁰⟶(p π⁻)γ π⁰

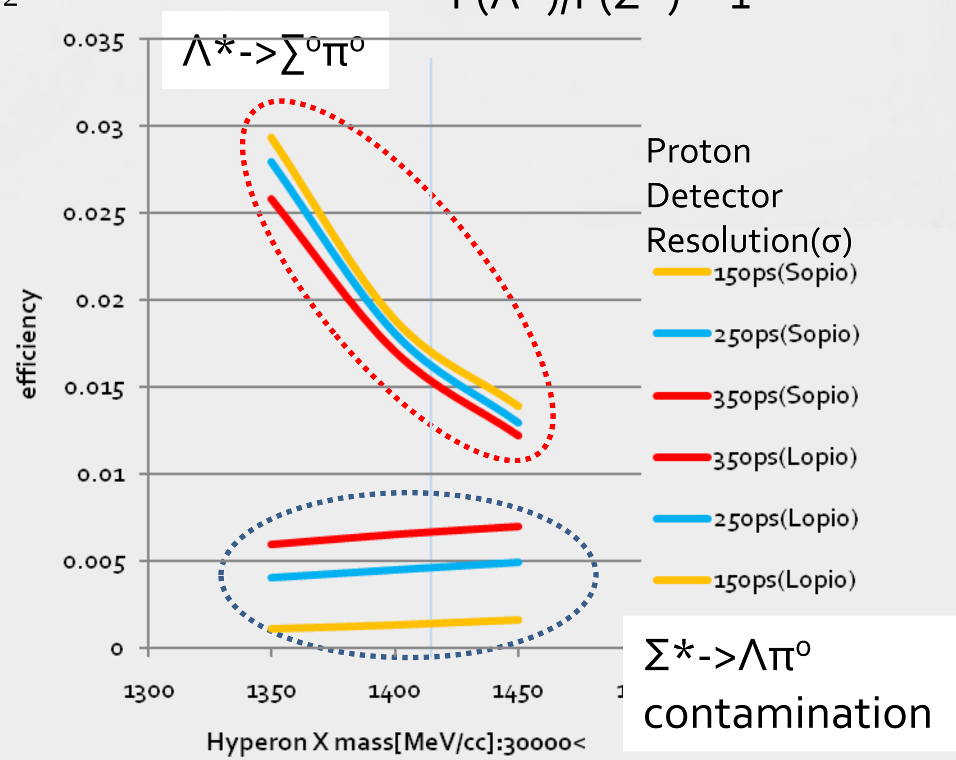
NR/∑(1385)⟶Λπ⁰⟶pπ⁻π⁰

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

P:fourth momentum



Γ(Λ*)/Γ(Σ*)~1

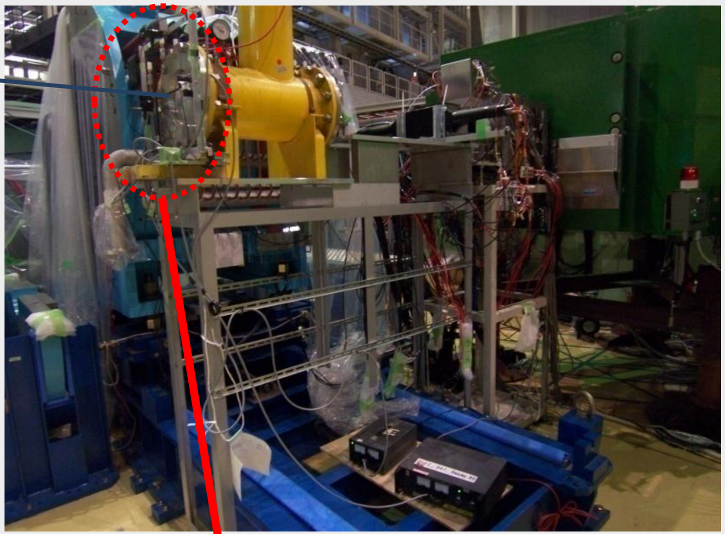


Λπ⁰(contamination)=(Λπ [②])/(Λπ)

Backward Proton Detector(BPD)

- TOF for proton

->Scintillation Hodoscopes with MPPC.

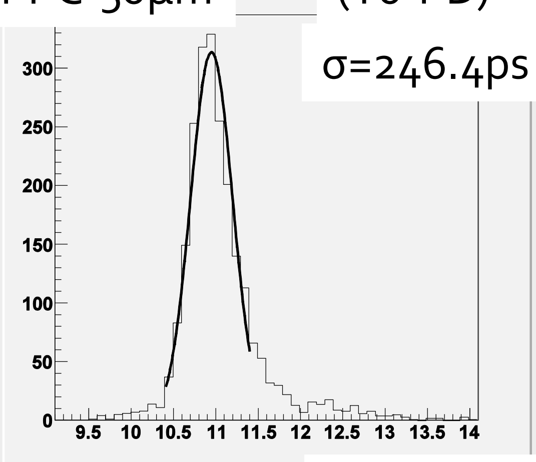


Beam test:

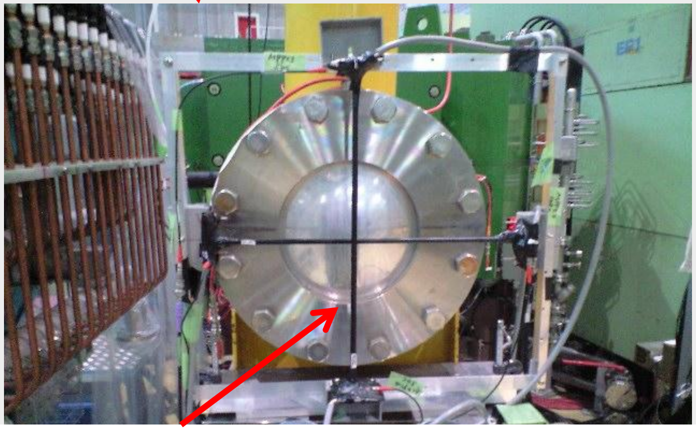
Time Resolution(BPD-T0) σ~250ps

MPPC-50μm (T0-PD)

σ=246.4ps



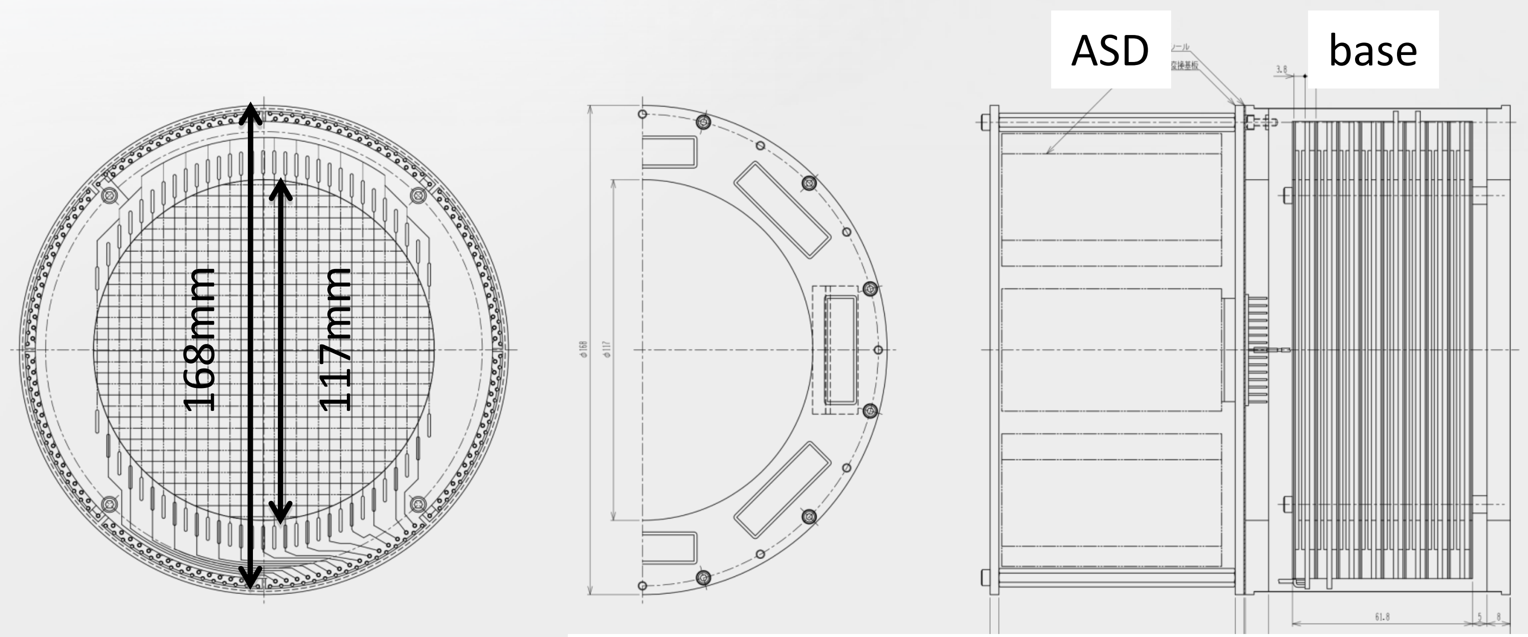
Meantime[ns]



Prototype(BPD):
5mm² × 400mm Scintillator with MPPC-50μm

Backward Proton Chamber(BPC)

Vertex Detector for Λ->pπ$^-$
-> determine the reaction point(z vertex)
for better P_n measurement in Λ*-> π^{0}Σ^0



- Wire gap 3.6mm(xx'yy'xx'yy':8layers)
- Active area ϕ111.6mm(readout:15ch(1layer))
- Outside diameter ϕ=168mm(z-TPC inside diameter ϕ=170mm)

Summary

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

  →To investigate Λ(1405) in the coupled channel KbarN->πΣ system.

- We found that the J-PARC E15 setup has sufficient detection efficiency to identify Λ*->$\pi^+\Sigma^-$ and Λ*->$\pi^-\Sigma^+$ clearly.

- We introduce BPD & BPC to identify Λ*->πoΣo clearly .

Finish

Thank you for listening.

Back up

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

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

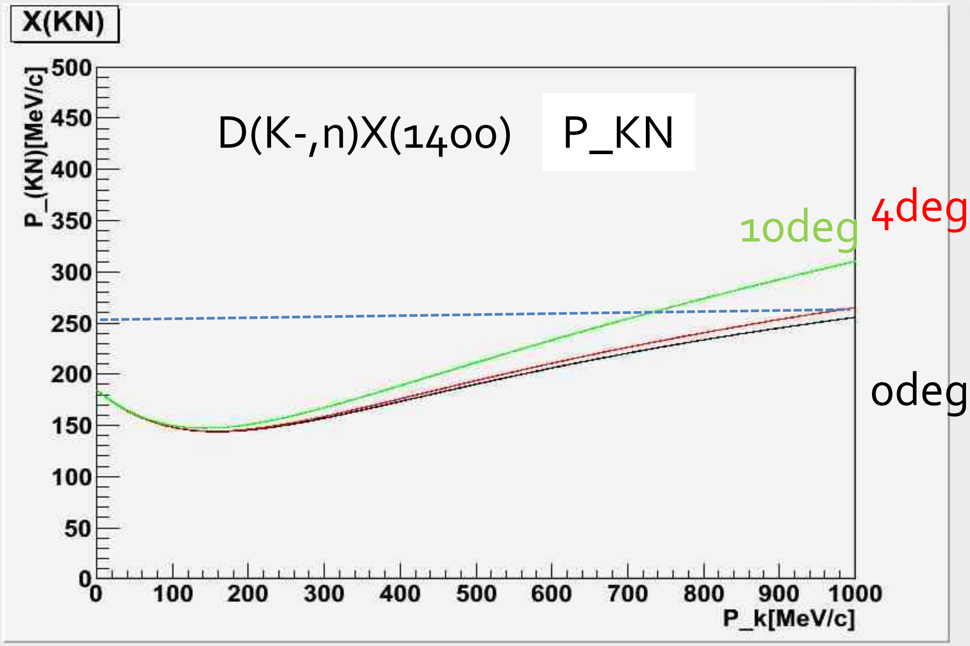
R:reconstruction(0.24)A:analysis(0.9)

- Simple the reaction mechanism.

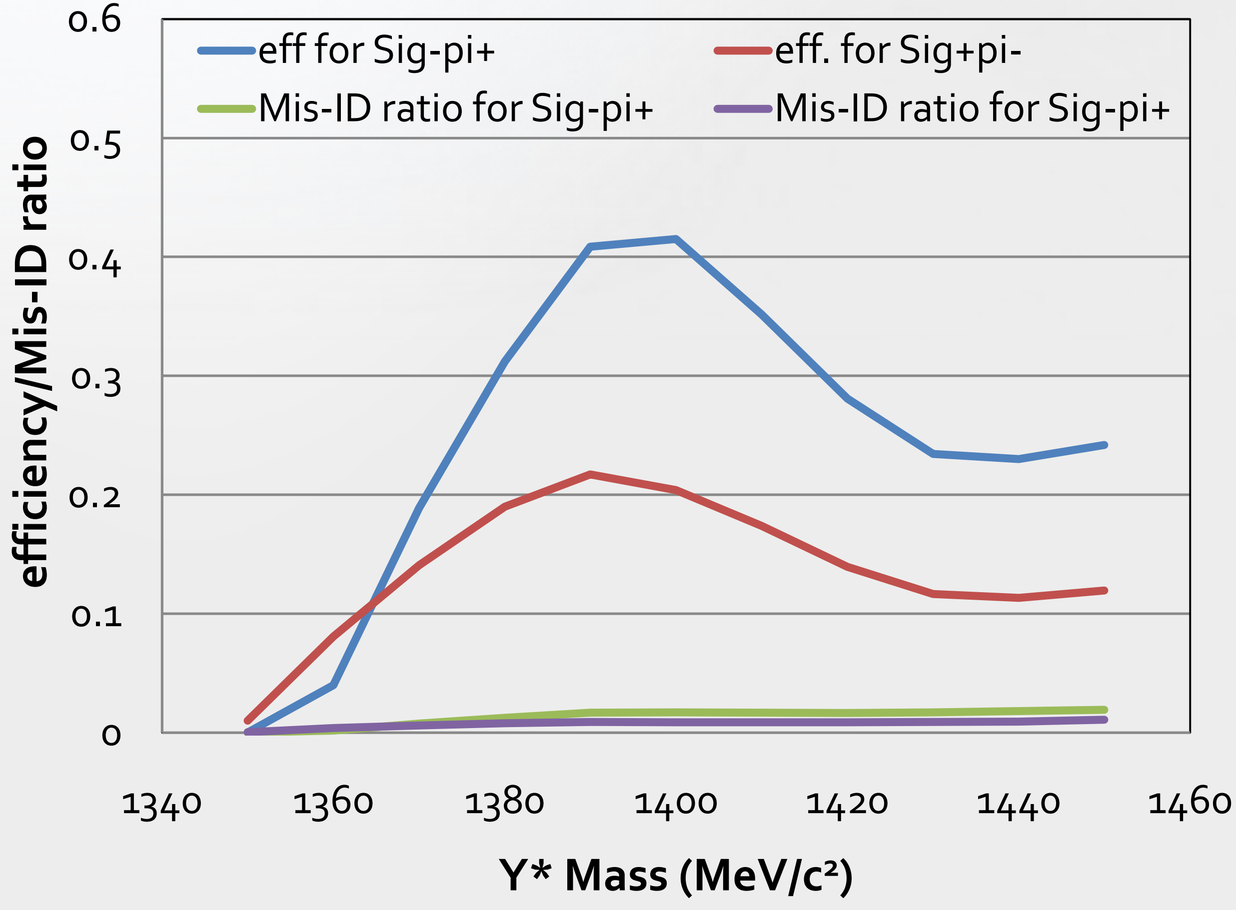
->$d(K^-,n)\pi^+\Sigma^-$ at P_{K-}=800MeV/c

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

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



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



Contamination(Mis-identification) ~a few%

Λ(1405)/Σ(1385)_1

- Clebsch-Gordan coeficients

$$\left| J, M \right\rangle = \Sigma C^{J,M}_{j_1 m_1, j_2 m_2} \left| j_1, m_1 \right\rangle \left| j_2, m_2 \right\rangle$$

$$\Sigma^+, \Sigma^0, \Sigma^- = (1,1), (1,0), (1,-1)$$

$$\pi^+, \pi^0, \pi^- = (1,1), (1,0), (1,-1)$$

$$\left|2,0\right\rangle = \sqrt{\frac{1}{6}}\pi^-\Sigma^+ \quad \sqrt{\frac{2}{3}}\pi^0\Sigma^0 \quad \sqrt{\frac{1}{6}}\pi^+\Sigma^-$$

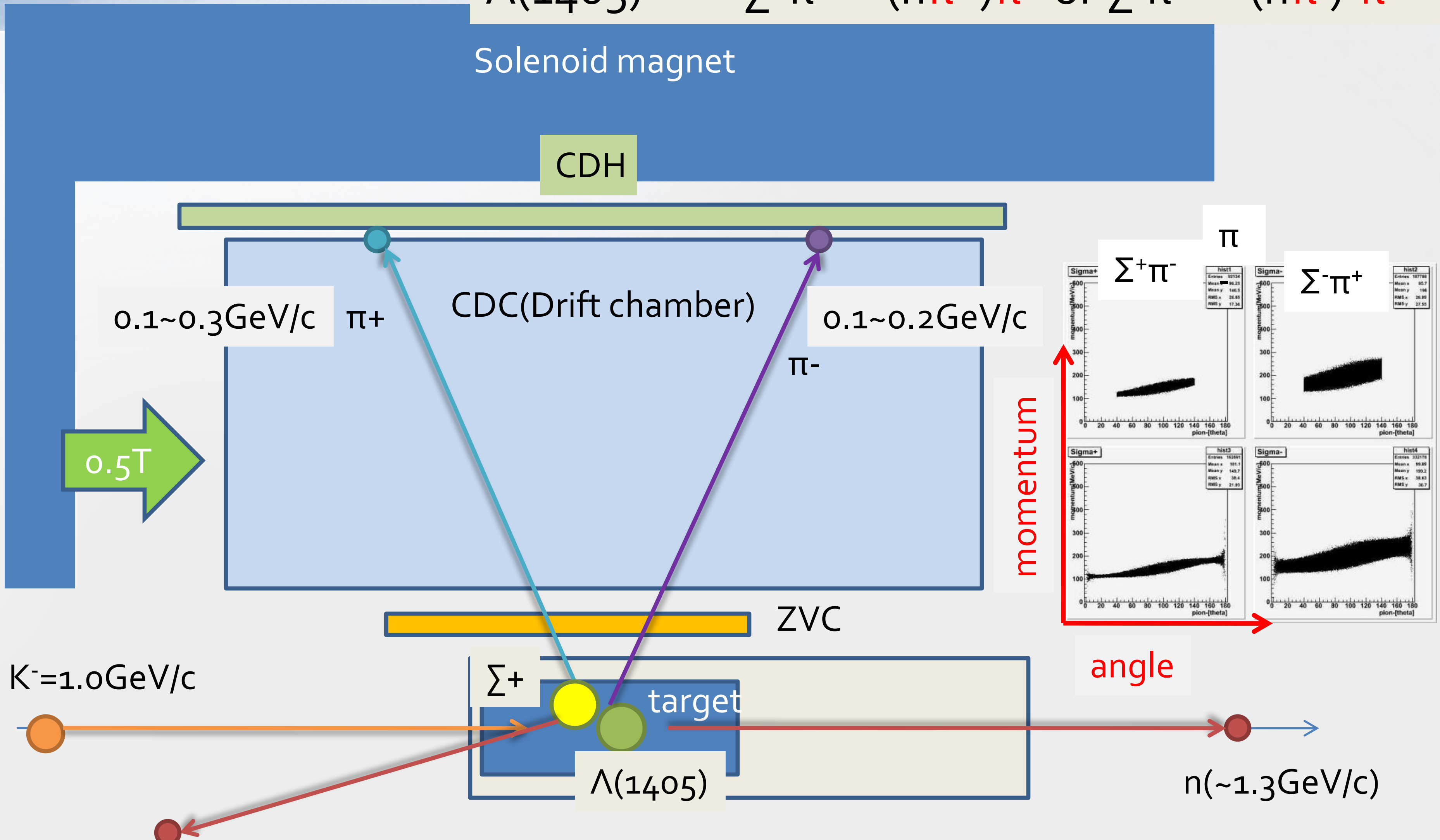
$$\left|1,0\right\rangle = -\sqrt{\frac{1}{2}}\pi^-\Sigma^+ \quad 0 \quad \sqrt{\frac{1}{2}}\pi^+\Sigma^-$$

$$\left|0,0\right\rangle = \sqrt{\frac{1}{2}}\pi^-\Sigma^+ \quad -\sqrt{\frac{2}{3}}\pi^0\Sigma^0 \quad \sqrt{\frac{1}{3}}\pi^+\Sigma^-$$

- Σ(1385)[I=1] can not decay $\pi^0\Sigma^0$.

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

$\Lambda(1405) \rightarrow \Sigma^+\pi^- \rightarrow (n\pi^+)\pi^-$ or $\Sigma^-\pi^+ \rightarrow (n\pi^-)\ \pi^+$

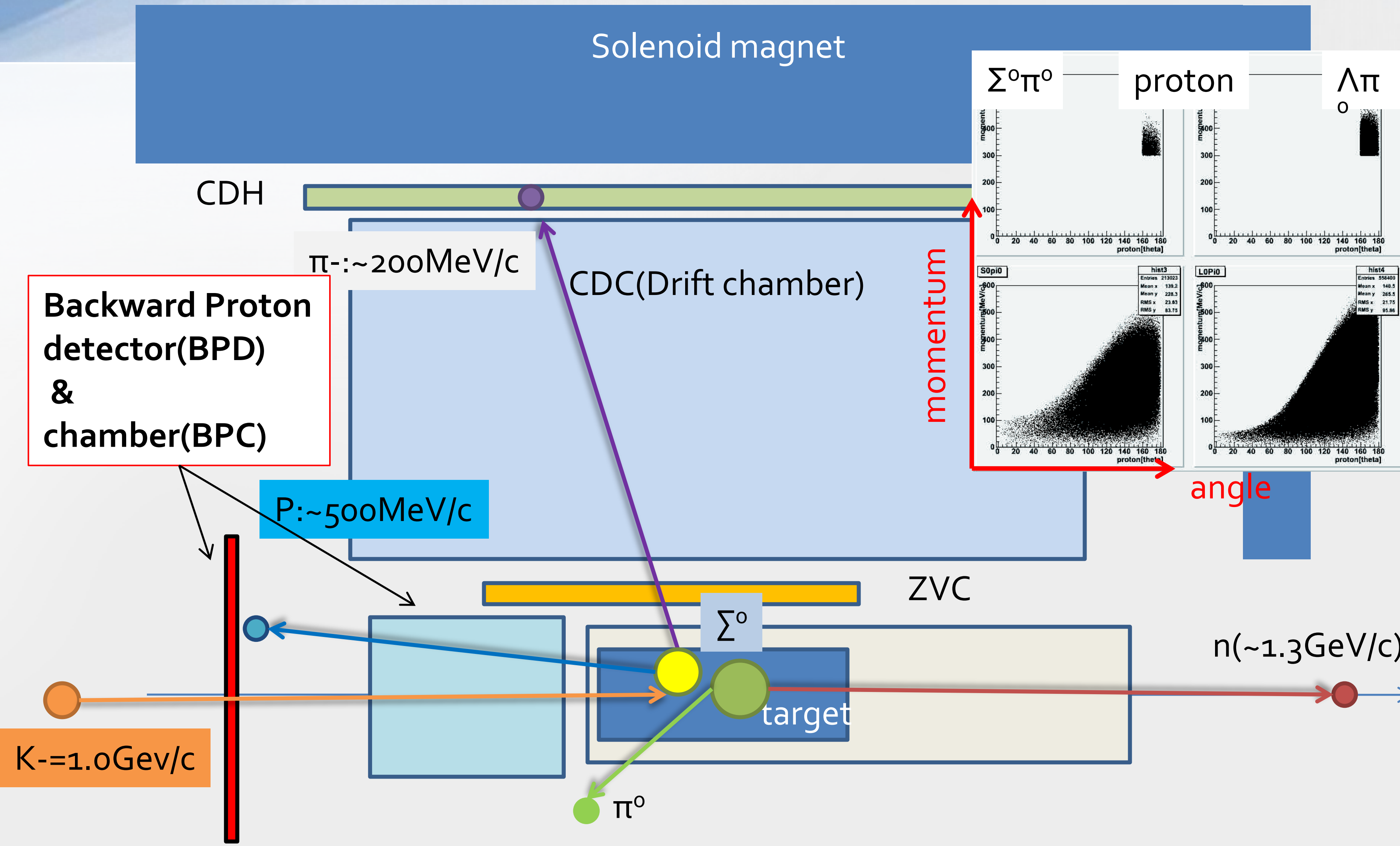


The J-PARC E15 setup is quite suitable to detect π.

$\Lambda^* \rightarrow \Sigma^0\pi^0, (\Sigma^* \rightarrow \Lambda\pi^0)$

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

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



BPD measure s to momentum of proton TOF methods.

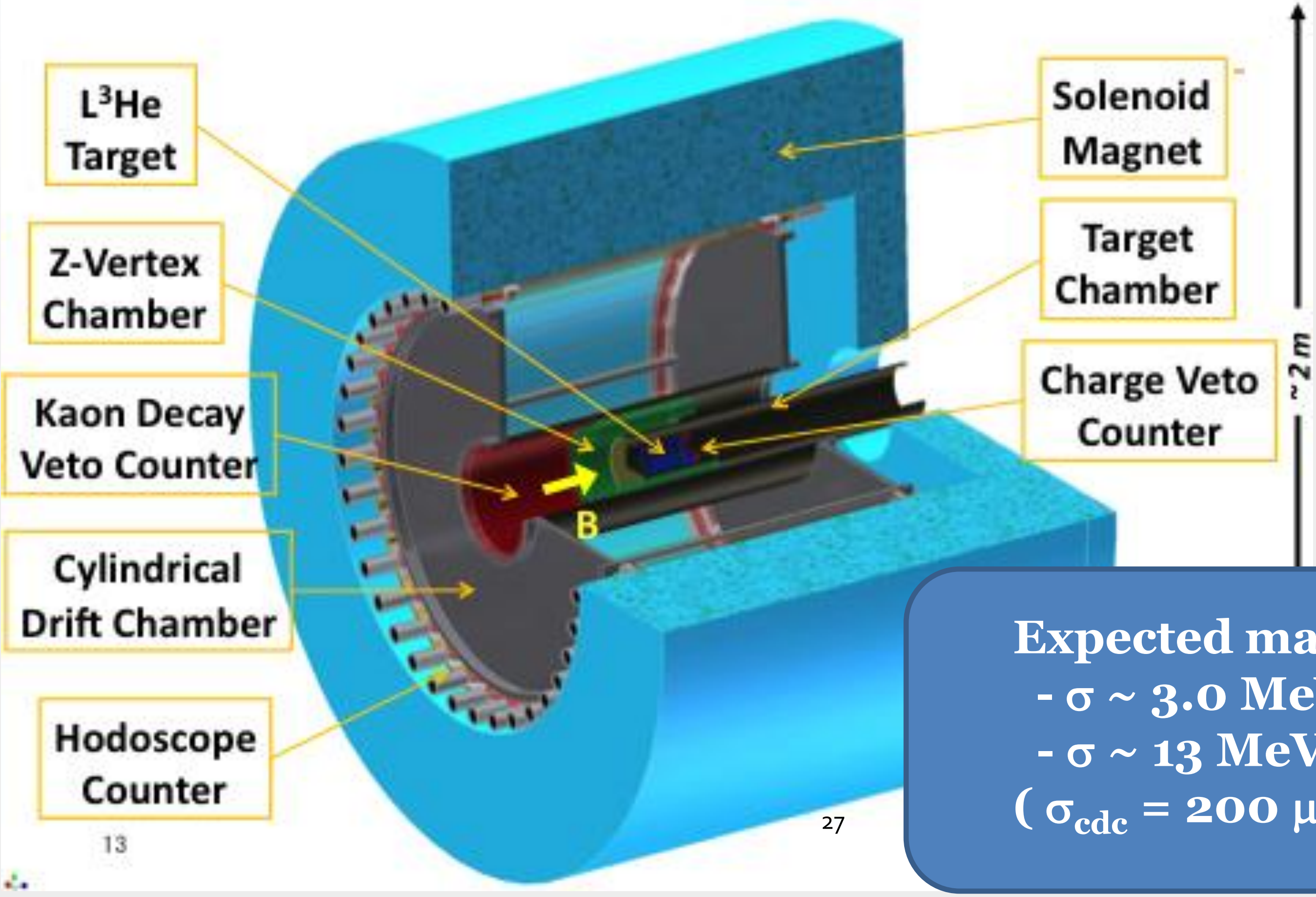
Decay mode[$\Lambda(1405)/\Sigma(1385)$]

- $\Lambda(1405) \to \pi^-\Sigma^+ \to \pi^-(p\pi^0)$ [51.57%] or $\pi^-(n\pi^+)$ [48.31%]
  $\pi^+\Sigma^- \to \pi^+(n\pi^-)$[99.84%]
  $\pi^0\Sigma^0 \to \pi^0\Lambda\gamma \to \pi^0(n\pi^0)$[35.8%] or $\pi^0(p\pi^-)\gamma$[63.9%]

- $\Sigma(1385) \to \pi\Lambda$[87.0%]
  $\to \pi\Sigma$[11.7%]

Cylindrical Detector System

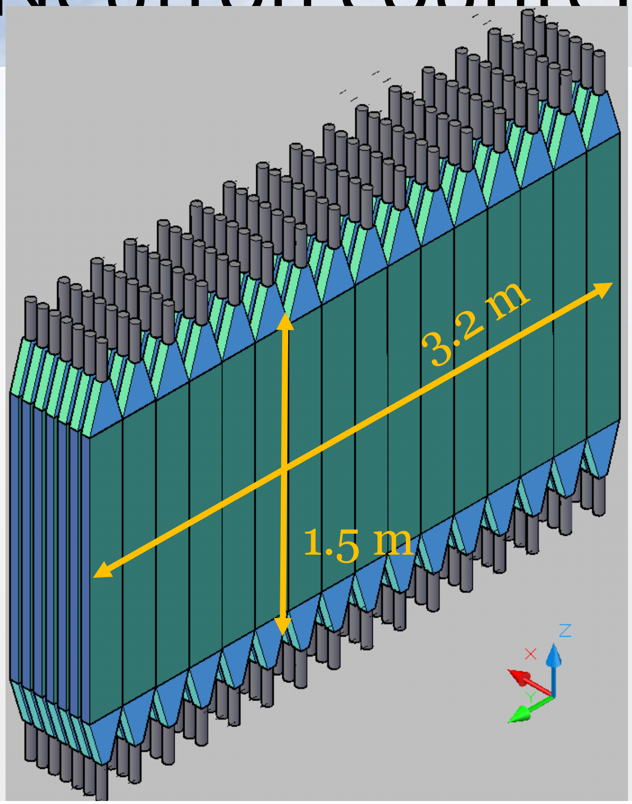
- **A newly developed system for invariant mass study**



Expected mass resolution :
- $\sigma \sim 3.0$ MeV/c² for Λ
- $\sigma \sim 13$ MeV/c² for K^-pp

(σ_{cdc} = 200 μm / Field : 0.5 T)

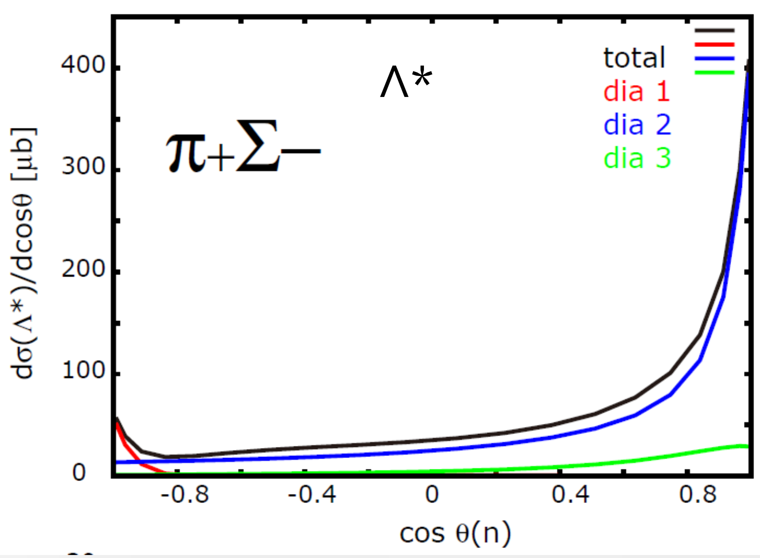
Neutron counter

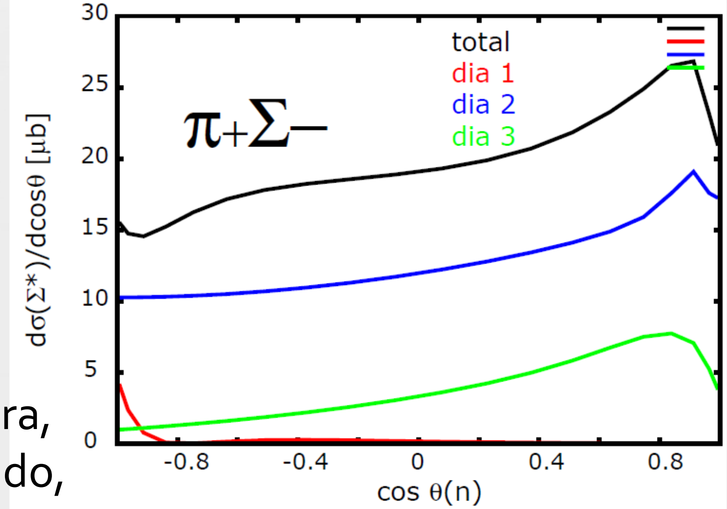


rearrange

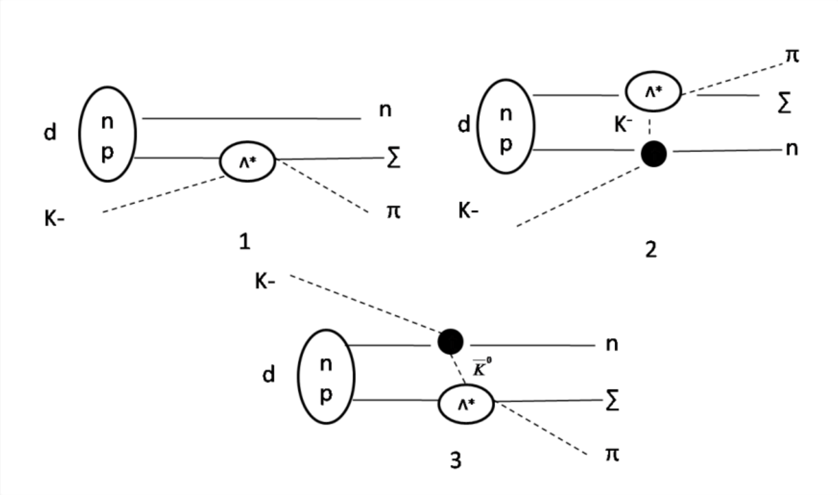
- 20 x 5 x 150 cm^3 Plastic Scintillator
- Configuration : 16 (wide) x 7 (depth)
- Surface area : 3.2m x 1.5m
- missing mass resolution for K^-pp
  σ = 9.2 MeV/c^2 (P_n=1.3 GeV/c, σ_{TOF}=150 ps)

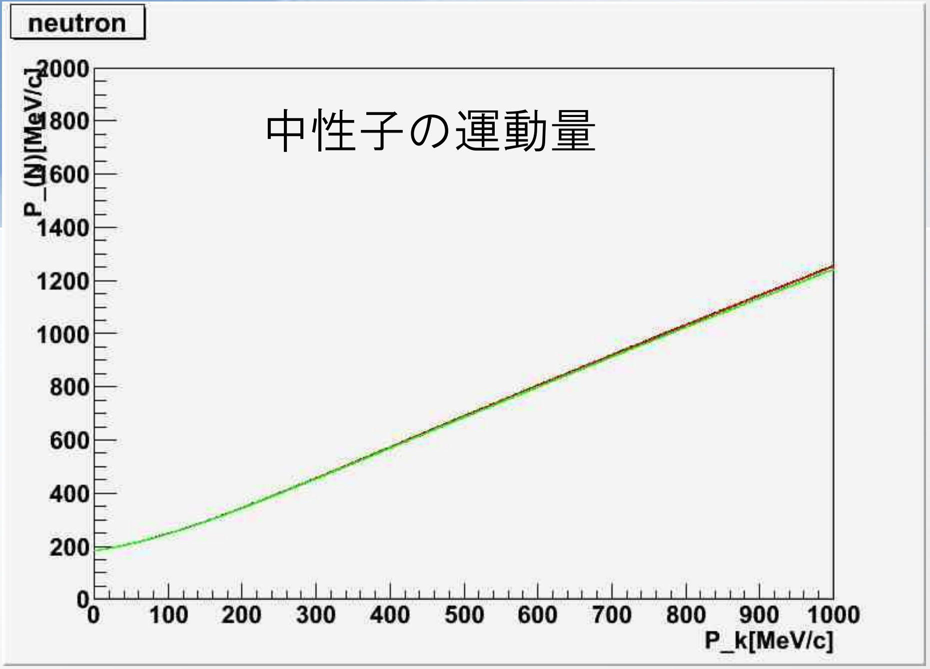
D(K$^-$,n)$\pi^+\Sigma^-$ (P_K=800MeV/c)

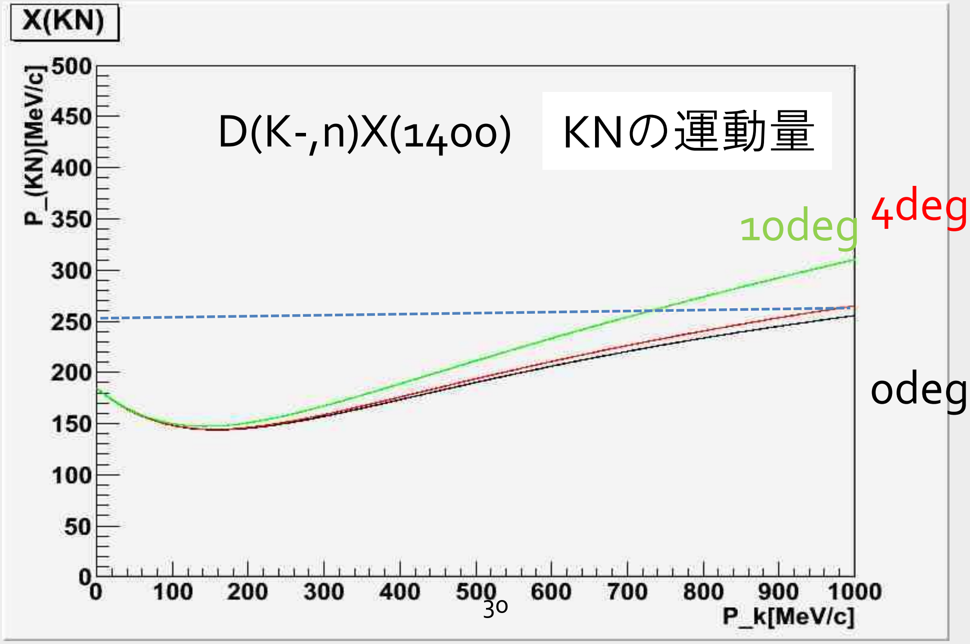




J.Yamagata-Sekihara, T.Sekihara,and D.Jido, paper in preparation







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

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

L=0,s-waveの反応断面積が大きい

the(K-,n) reaction on Deuteron.

Motivation

- To clarify whether Λ(1405) is KbarN resonant state.

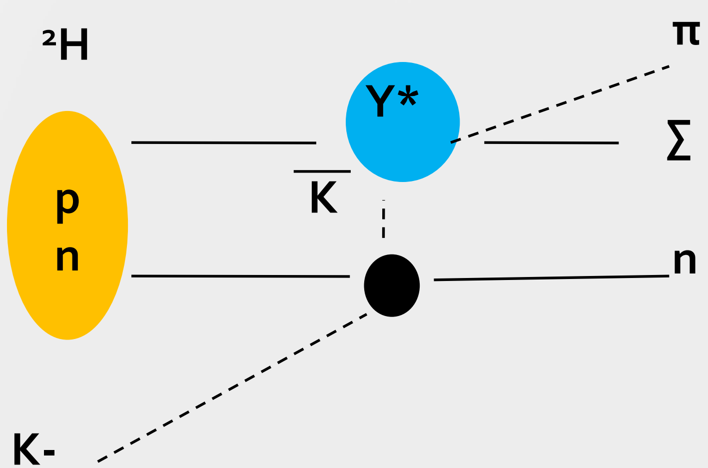
KbarN scattering below KbarN threthold.

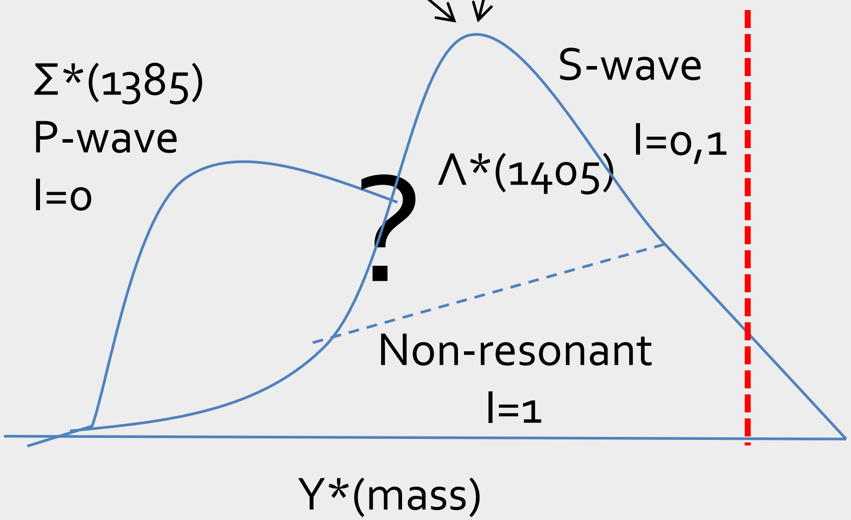
→**d(K-,n)Λ* reaction** is KbarN direct reacion.

$\bar{K}N$:1432MeV

1420MeV/c²?

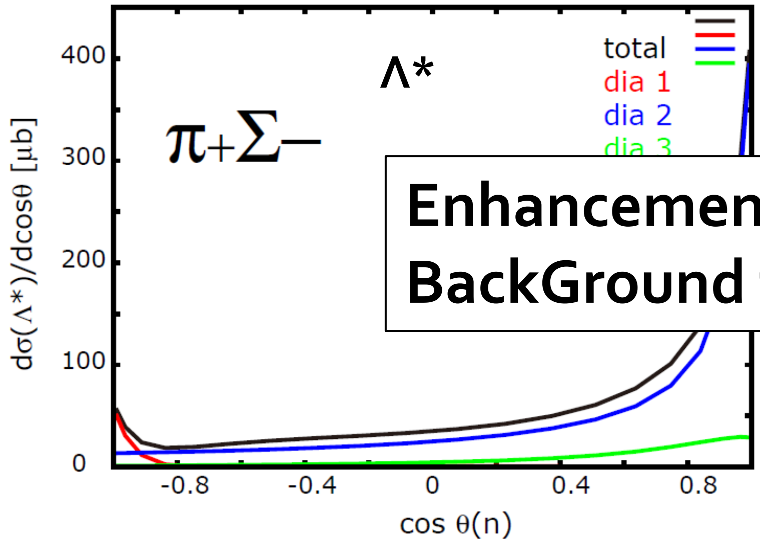
1405MeV/c²?



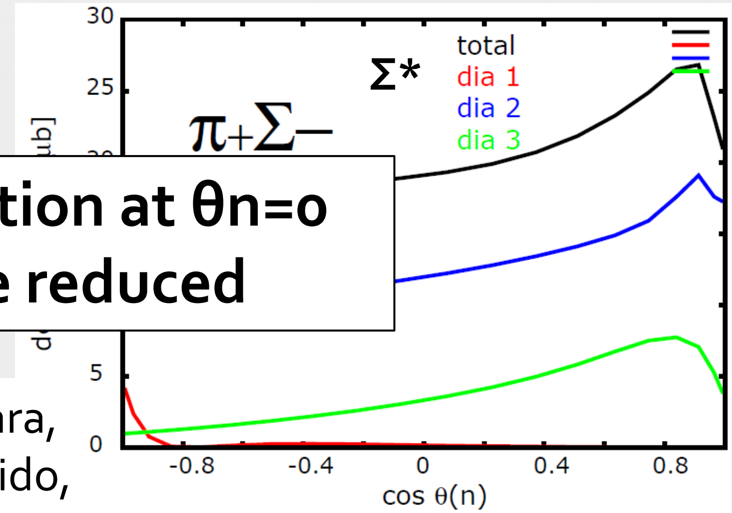


the(K-,n) reaction on Deuteron.

S-wave KbarN scattering is dominant at θ_n = o degree



D(K$^-$,n)π$^+$Σ$^-$



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

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

Purely I=o

Possible ID of I=o in KbarN->πΣ

- S-wave,I=o → Λ*(1405) → π^{0}Σ^0, πΣ$^+$, π$^+$Σ$^-$
- S-wave,I=
- P-wave,I=1 → Σ*(1385) →

Possible decomposition of I=o amplitude.