J-PARCにおけるΞハイパー核分光実験の実験計画

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Introduction

S = -1

- So far, we know Λ-N interaction well extracted from structure of Λ-hypernuclei, including spin component.
  - (π,K) reaction with SKS
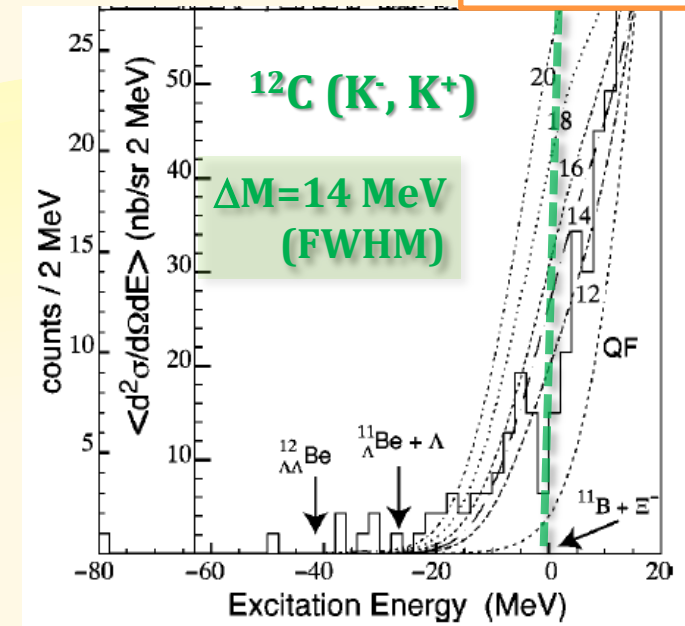 - γ-ray spectroscopy with Hyperball
- successful theoretical understanding.

S = -2

- Information is very limited.
  - ΛΛ-hypernuclei => weakly attractive Λ-Λ interaction
    - ex.) NAGARA event : unique ID of species, $^6_{\Lambda\Lambda}$He
- Ξ-hypernuclei :
  - No definite evidence for a bound state.
  - There were several experiments using (K⁻,K⁺) reaction.
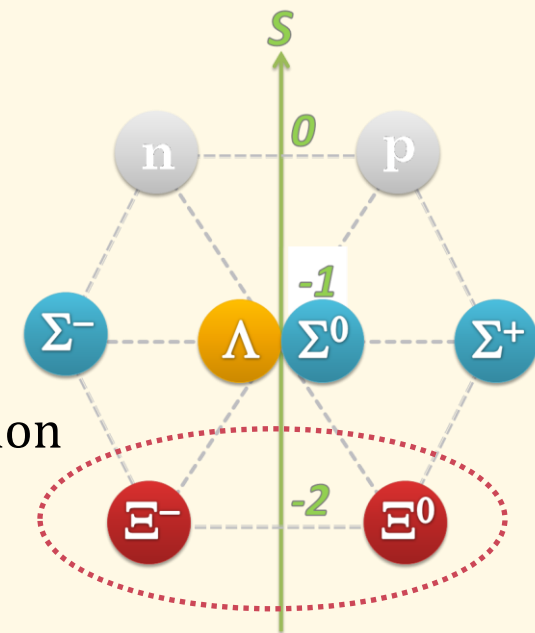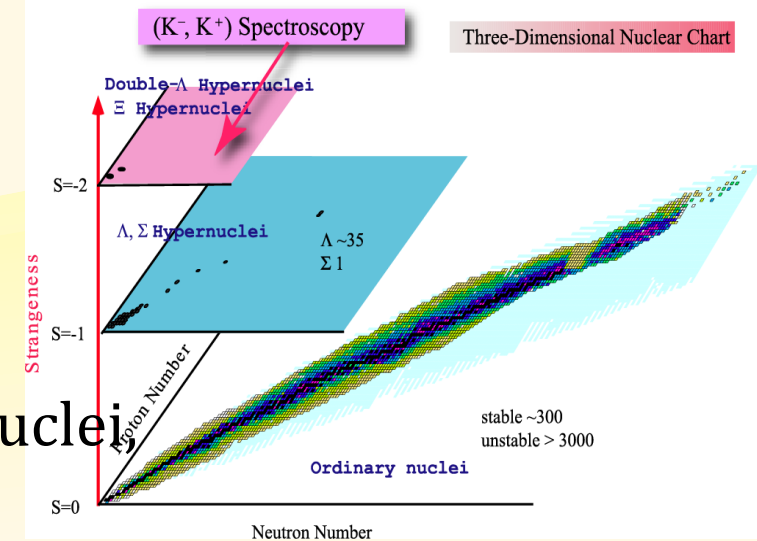
Ξ-hypernuclei : previous experiment

^{12}C (K$^-$, K$^+$)

ΔM=14 MeV (FWHM)

P.Khaustov et al., PRC61(2000)054603

◆ Previous experiment : BNL-E885

  ❖ not clear evidence of Ξ-hypernuclear bound state.

     ❖ because of limited mass resolution

  ❖ suggest weakly attractive potential of -14 MeV depth.

     ❖ by shape analysis of QF-tail

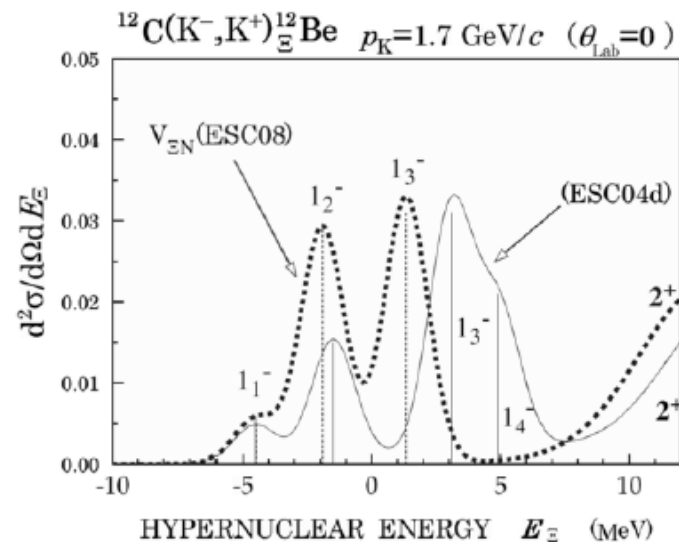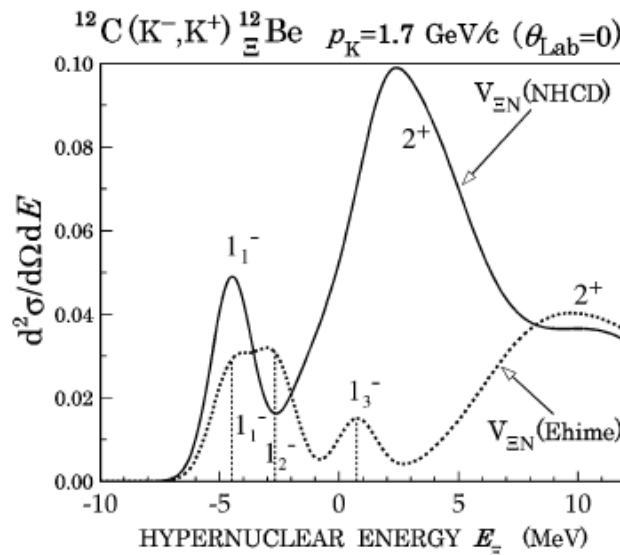   ❖ almost unique information on Ξ-hypernuclei up to now

Ξ-hypernuclei : theoretical models

- Various *B-B* interaction models exist.
  - Their predictions are quite different for Ξ-N int.

Experimental information is strongly awaited.

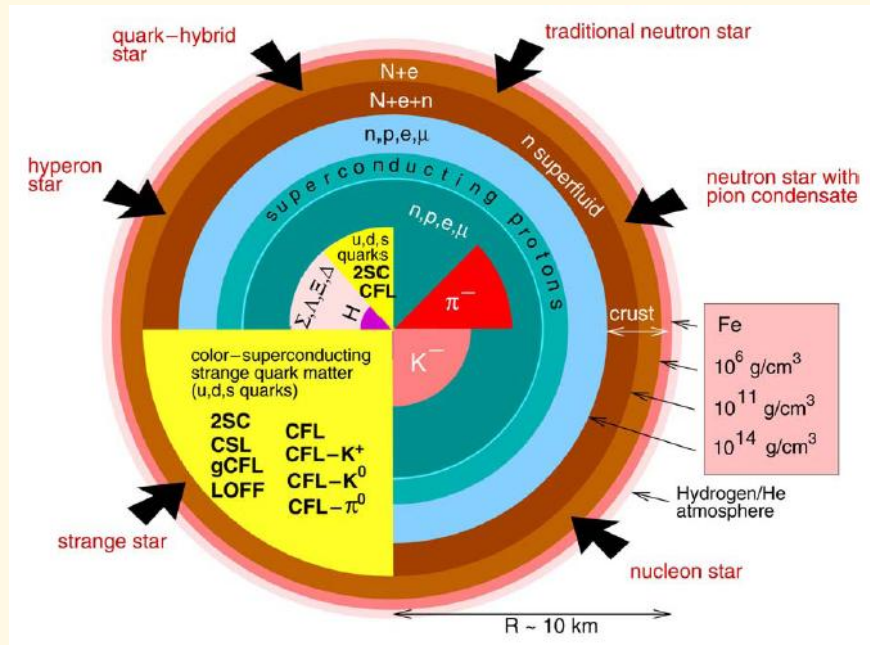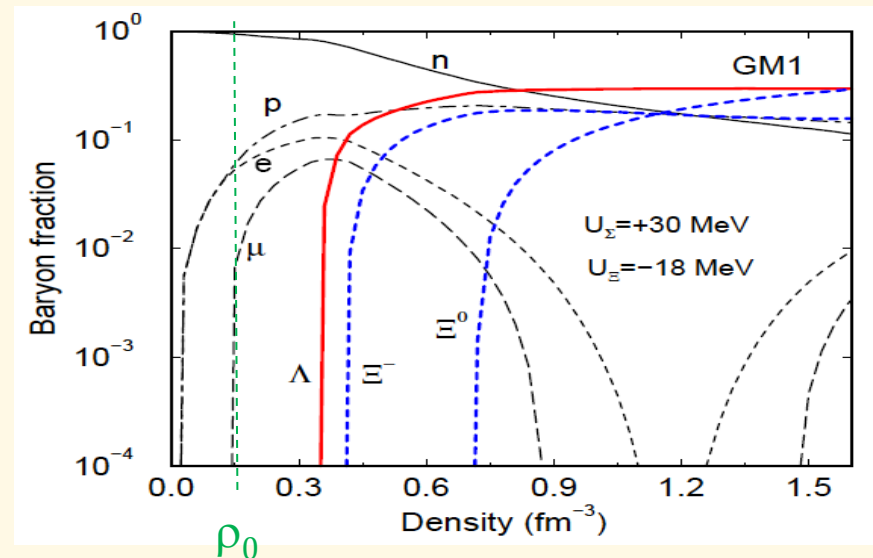DWIA spectra with various int. (*T=1*)   T.Motoba et al., NPA835(2010)223

Ξ-hypernuclei : appearance in N.S ?

- **Strangeness in dense nuclear matter**
  - Inspect into the core of neutron stars
  - Strangeness will take the key role

If Ξ-N is attractive ($U_\Xi \sim -18MeV$),
Ξ will appear next to Λ in neutron stars.

F.Waber, PPNP54(2005)193

J.Schaffner-Bielich, NPA804(2008)309

Experiment

J-PARC E05: Ξ-Hypernuclear Spectroscopy
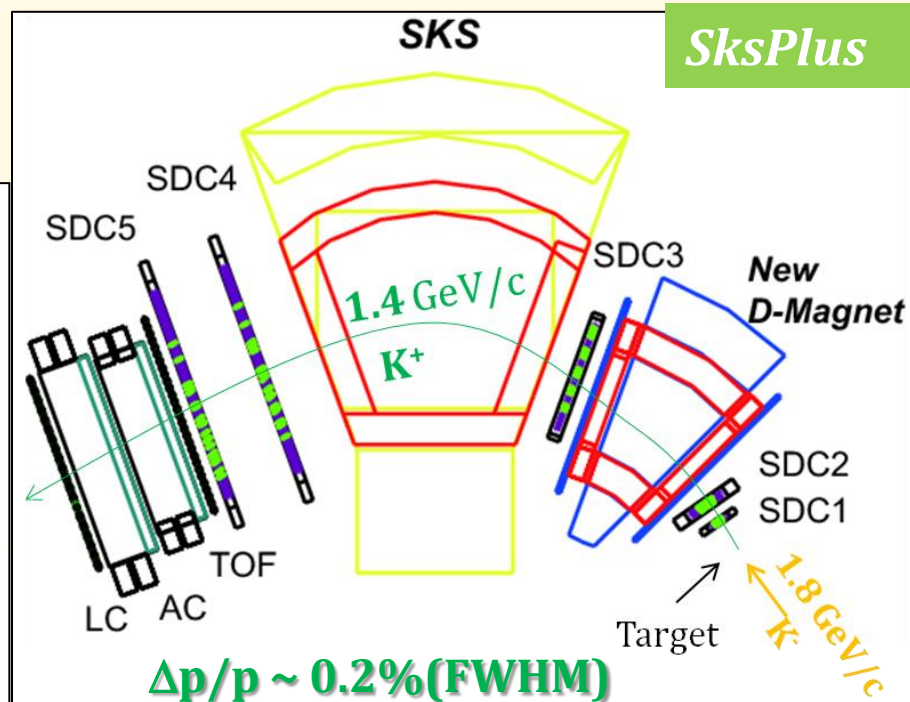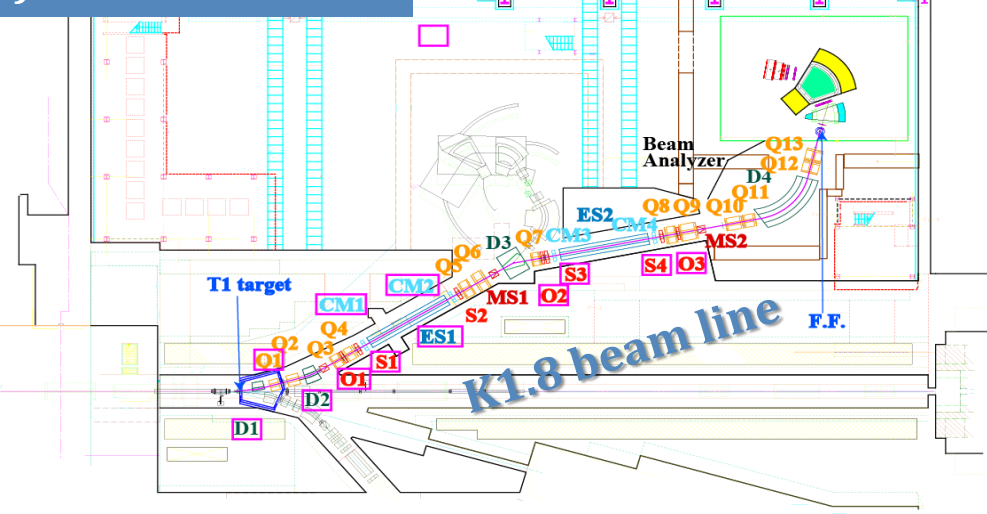
- Spectroscopic study of Ξ-hypernucleus
- using $^{12}C(K^-, K^+)$ reaction ; -> $^{12}_{\Xi}Be$
- Missing mass spectroscopy
  - measure momentum of both incident K^- and outgoing K^+
  - with **high-resolution (~3MeV)** and **enough statistics**
- Only J-PARC can do this experiment. <= 1.4×10^6 K^-/spill

- Goal
  - observe peaks of Ξ-hypernuclei for the first time.
  - Binding energy   => potential depth (real part)
  - Width   => ΞN->ΛΛ conversion width (imaginary part)

Experimental Setup

- **K1.8 beam line + SksPlus**

  - **K⁻ : 1.8 GeV/c, Beam Spectrometer ($\Delta p/p \sim 10^{-4}$)**

  - **K⁺ : 1.3~1.4 GeV/c, SksPlus ($\Delta p/p \sim 2 \times 10^{-3}$)**

    - **New D-mag. is added to obtain stronger mag. field.**

    - **prior momentum resolution than acceptance(40msr)**

J-PARC Hadron Hall

K1.8 beam line

SksPlus

SKS

SDC4

SDC5

SDC3

New D-Magnet

1.4 GeV/c

K⁺

SDC2

SDC1

TOF

LC   AC

Target

1.8 GeV/c
K⁻

$\Delta p/p \sim 0.2\%$(FWHM)

Recent discussion on experimental plan

Setup modification for low intensity beam

- Accelerator intensity is very limited.
  - **now, ~% of design value (270kW)**
- In original E05 plan, statistics are miserable. => not realistic
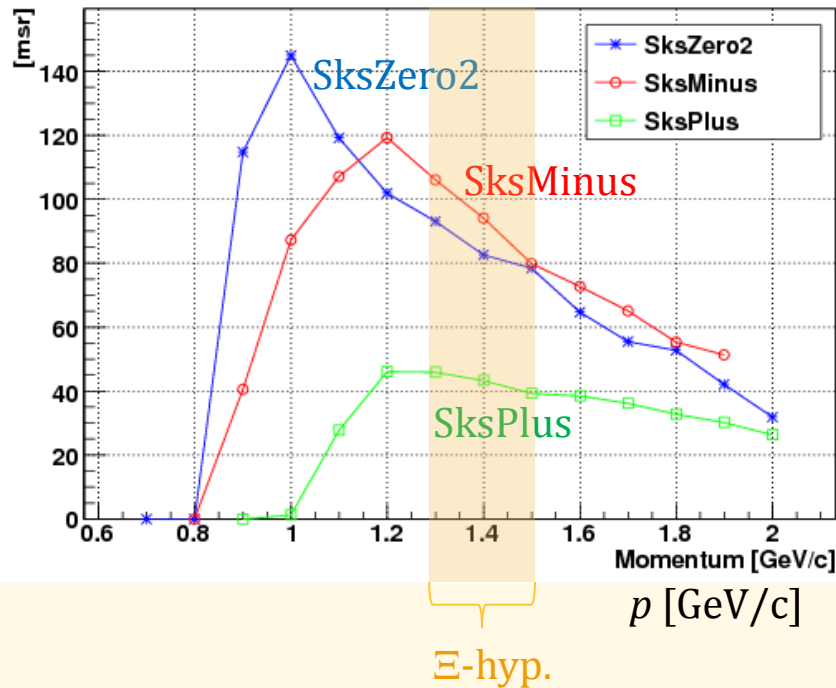- **need more acceptance**

- **modify SKS configuration**
- *SksZero → SksZero2*
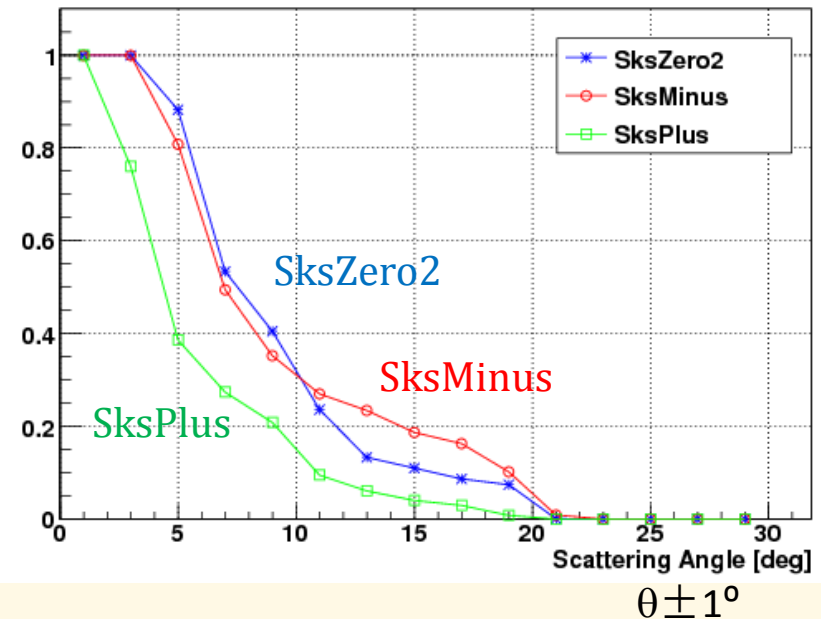 - only move normal SKS downstream detectors to high-momentum side

SksZero2

1.5 GeV/c
1.4 GeV/c
1.3 GeV/c
1.2 GeV/c
1.1 GeV/c
1.0 GeV/c

$\theta = 0^{o}$
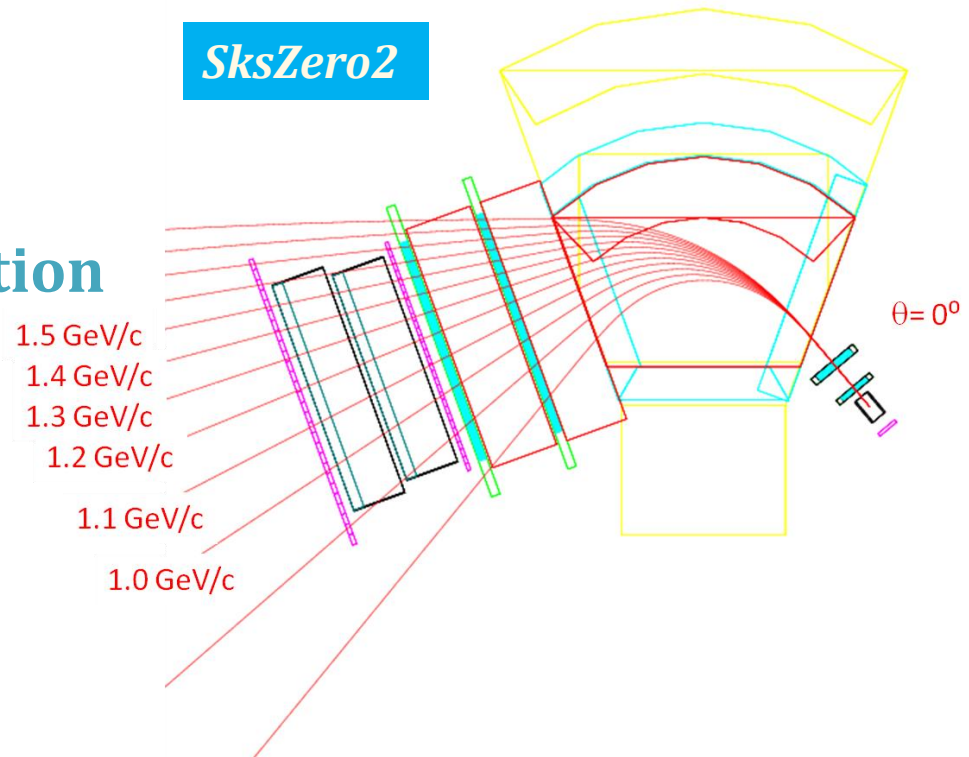
E05 (low intensity beam version) : Acceptance

Momentum Acceptance

SksZero2
SksMinus
SksPlus

Ξ-hyp.

p [GeV/c]

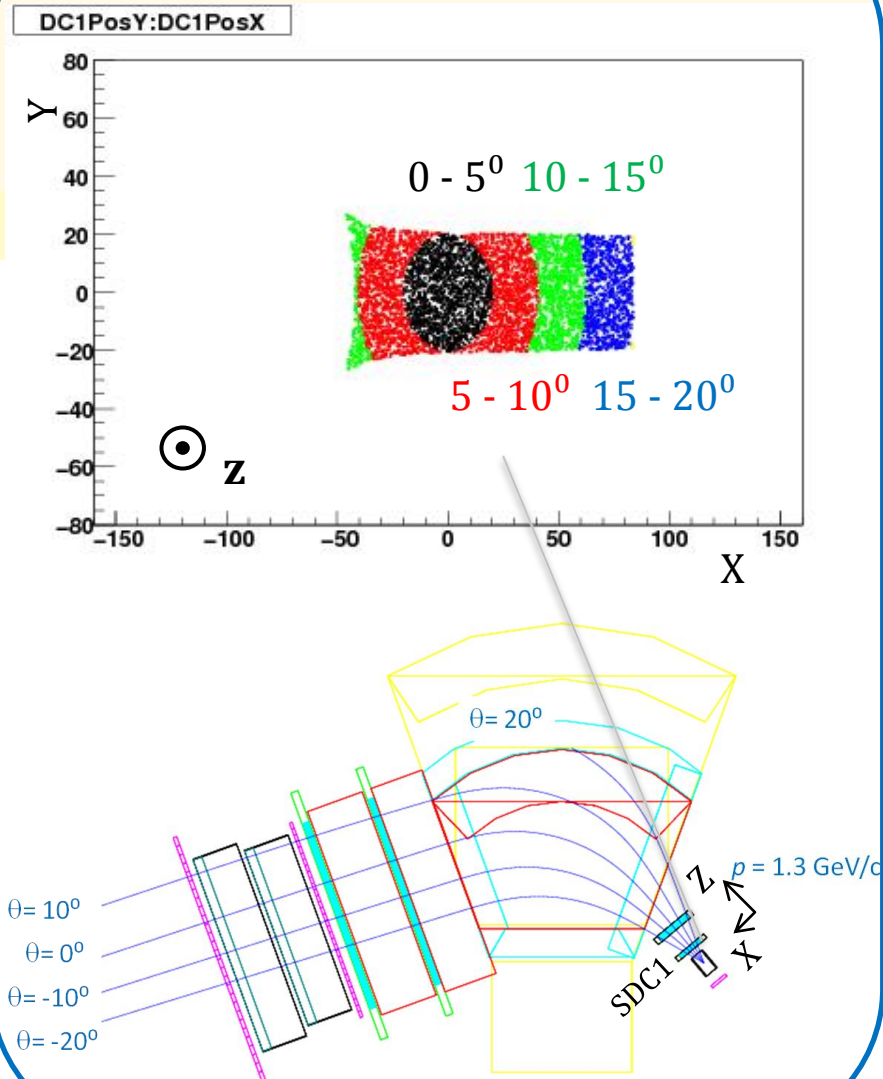**Angular Acceptance** p = 1.3 GeV/c

SksZero2
SksMinus
SksPlus

$\theta \pm 1°$

◆ Acceptance is larger.
- SksZero2 > SksPlus

    80 msr   40 msr @1.4GeV/c

◆ 100%-coverage angle
- SksZero2 < 5°
- SksPlus   < 3°

Triggered scattering particle profile @ SDC1

SksZero2

DC1PosY:DC1PosX

0 - 5⁰ 10 - 15⁰

5 - 10⁰ 15 - 20⁰

$\odot$ z

θ = 20⁰

θ = 10⁰
θ = 0⁰
θ = -10⁰
θ = -20⁰

p = 1.3 GeV/c

SDC1

SksPlus

DC1PosY:DC1PosX

0 - 5⁰ 10 - 15⁰

5 - 10⁰ 15 - 20⁰

$\odot$ z

θ= 20⁰

θ = 10⁰

θ= 0⁰
θ= -10⁰

θ= -20⁰

p = 1.3 GeV/c

SDC1
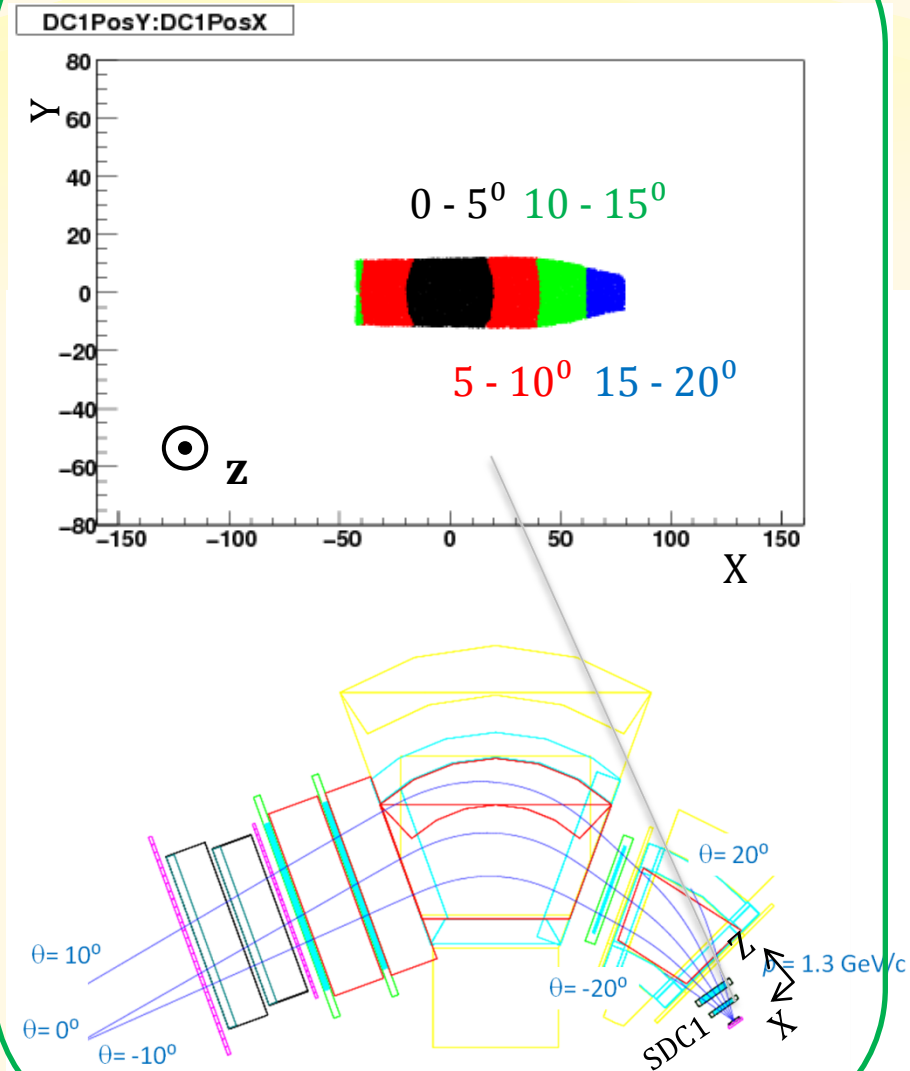
can increase vertical angular acceptance.

E05 (low intensity beam version) : Resolution

Momentum Resolution

$$K^- + {}^{12}C \rightarrow K^+ + X$$
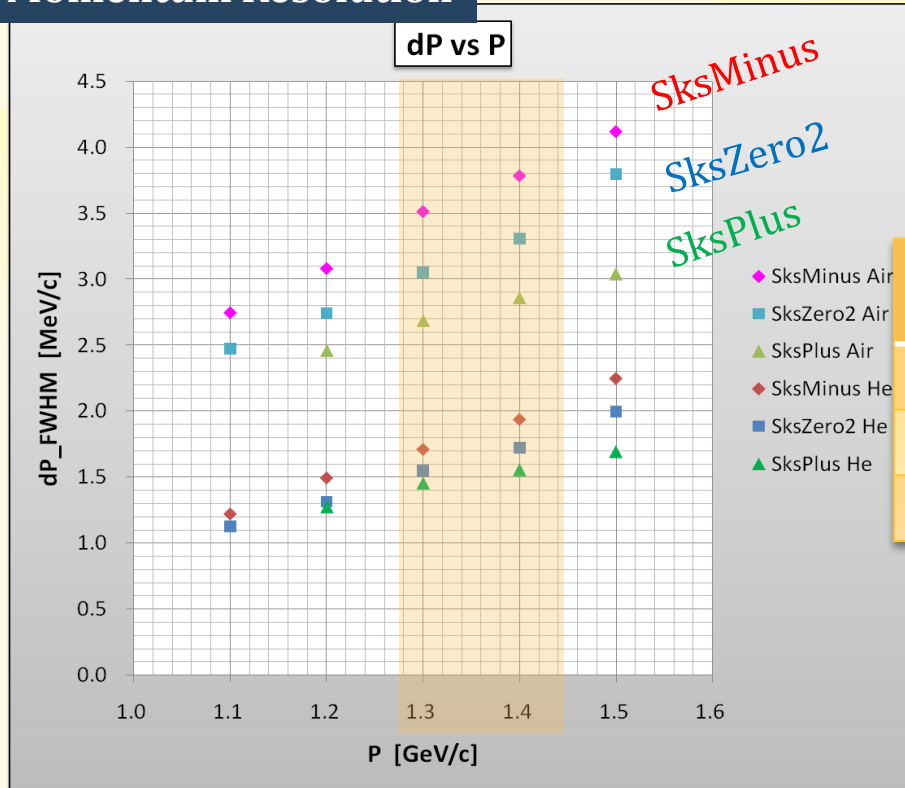
Missing Mass Resolution

in FWHM

	Δp [MeV/c]	$\Delta p/p$ [%]	ΔM [MeV]
SksPlus	2.86	0.20	3.3
SksZero2	3.31	0.24	3.7
SksMinus	3.78	0.27	4.0

ΔE_{strag}=2MeV is included.
(5.4g/cm^2 ^{12}C target)

- ◆ $\Delta p/p =$ SksZero2: 0.24 % ,   SksPlus: 0.20 %
- ◆ $\Delta M =$ SksZero2: **3.7 MeV** ,   SksPlus: 3.3 MeV

- ◆ *Resolution is just a little worse, but **acceptable level**.*

Yield Estimation (E05 original)

- $Y(^{12}_{\Xi}Be) = N_{beam} \times N_{target} \times d\sigma/d\Omega \times \Delta\Omega \times f_{decay} \times f_{analysis}$

$= 1.4 \times 10^6 [/spill] \times 2.4 \times 10^4 [spill/day] \times 5.4 \times 6.02 \times 10^{-7}/12 [/\mu b]$

$\times 0.06 [\mu b/sr] \times 0.04 [sr] \times 0.5 \times 0.7$

$= 7.6$ events/day

~ 230 events/month

Yield Estimation (30kW, w/SksZero2)

- $Y(^{12}_{\Xi}Be) = N_{beam} \times N_{target} \times d\sigma/d\Omega \times \Delta\Omega \times f_{decay} \times f_{analysis}$

$= 1.4 \times 10^6 [/spill] \times 2.4 \times 10^4 [spill/day] \times 5.4 \times 6.02 \times 10^{-7}/12 [/\mu b]$

30/270 x 5/3

$\times 0.06 [\mu b/sr] \times 0.04 [sr] \times 0.5 \times 0.7$

0.08   (in case of Pt T1-target)

$= 7.6$ events/day

2.8

~ 230 events/month

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We can take
~80/month statistics at 30kW
as the first step of E05.

Now planning....

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Summary

- J-PARC E05 is planed to observe Ξ-hypernuclei via (K^-, K^+) missing mass spectroscopy.

- It provides essential information to $S=-2$.

- Ξ-N interaction are extracted from B and Γ.

- Resolution and statistics are important at the experimental point of view.

- We are preparing modified experimental plan for low intensity version. Larger acceptance and acceptable resolution are achieved.

- We want to start exp. at 30kW as the first step.