EXPERIMENTAL PLAN FOR E-HYPERSONAR SPECTROSCOPY

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Introduction

$S = -1$
- So far: $\Lambda, \Sigma$-hypernuclei
- successful theoretical understanding.

$S = -2$
- From now at J-PARC
- $\Lambda\Lambda$-hypernuclei, $\Xi$-hypernuclei

(K$^-$, K$^+$) Spectroscopy

Three-Dimensional Nuclear Chart

Double-$\Lambda$ Hypernuclei
$\Xi$ Hypernuclei

$\Lambda, \Sigma$ Hypernuclei

$\Lambda \sim 35$

$\Sigma 1$

stable $\sim 300$
unstable $> 3000$

Ordinary nuclei

Neutron Number

Proton Number

S=0

S=1

S=2

Strangeness
S = -2
- From now at J-PARC
- \(\Lambda\Lambda\)-hypernuclei, \(\Xi\)-hypernuclei

S = -1
- No definite evidence for a bound state.
- Strangeness in dense nuclear matter, (ex. core of N.S.)
- Theoretical predictions are quite different for \(\Xi\)-N int

F.Waber, PPNP54(2005)193

Experimental information is strongly awaited.
Previous experiment: BNL-E885

- not clear evidence of $\Xi$-hypernuclear bound state.
- because of limited mass resolution
- suggest weakly attractive potential of -14 MeV depth.
- by shape analysis and counts in bound region, compared with DWIA calc.
Spectroscopic study of $\Xi$-hypernucleus using $^{12}\text{C}(K^-, K^+)$ reaction ; $\rightarrow ^{12}\Xi\text{Be}$

Missing mass spectroscopy
- high-resolution (~3MeV)
- enough statistics

Only J-PARC can do this experiment.
- $\leq 1.4 \times 10^6$ K$^-$/spill @ 270kW
SksPlus

- outgoing $K^+$: 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)

K1.8 beam line

- incident $K^-$: 1.8 GeV/c
- Beam Spectrometer ($\Delta p/p \sim 10^{-4}$)
Constraint...

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

Modified plan, we have.

Intensity is gradually upgraded by a factor of a few year by year.
modified SKS

- Original SKS is not suited for analyzing high momentum K+.
- Modification of configuration is needed.

Recently, SKS was a little rotated.
## E05 (low intensity beam version)

<table>
<thead>
<tr>
<th></th>
<th>SksPlus</th>
<th>Sks0v2</th>
<th>SksMinus</th>
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<tbody>
<tr>
<td>Acceptance [msr]</td>
<td>40</td>
<td>80</td>
<td>100</td>
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<tr>
<td>$K^+$ Survival Rate</td>
<td>0.5</td>
<td>0.6</td>
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<tr>
<td>dp/p [%]</td>
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<td>0.24</td>
<td>0.27</td>
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<tr>
<td>$\Delta M$ [MeV]</td>
<td>3.3</td>
<td>3.7</td>
<td>4.0</td>
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<td>$Y(^{12}\Xi_{\Xi}Be)$ [/month]</td>
<td>30</td>
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Momentum Acceptance

SksZero2

SksMinus

SksPlus

\(\Sigma\)-hyp.
E05 (low intensity beam version)

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**Momentum Resolution**

![Graph showing dP vs P for different SKS configurations](image)

- SksMinus
- SksZero2
- SksPlus
### E05 (low intensity beam version)

#### mod. SKS

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Supposition

- $4.5 \times 10^5$ K$^-$/spill @ 30kW
E05 (low intensity beam version) : Yield Estimation @ 30kW

Supposition
• $4.5 \times 10^5$ K$^{-}$/spill @ 30kW
• modified SKS: 100msr

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

$= 4.5 \times 10^5 [/\text{spill}] \times 24 \times 3600 / 6 [\text{spill/day}]$
$\times 5.4 \times 6.02 \times 10^{-7} / 12 [\mu b]$
$\times 0.042 [\mu b/sr] \times 0.1 [sr] \times 0.6 \times 0.5$

$= 2.3 \text{ events/day}$
$= 70 \text{ events/month}$

We can take ~70/month statistics at 30kW as the first step of E05.

40% statistics of proposal one
Expected $^{12}_\Xi$Be Spectrum

$\Delta E_{\text{exp}} = 4 \text{ MeV}$

$V_0 = 20 \text{MeV}$

$V_0 = 14 \text{MeV}$

✓ can identify bound state.

simple peak structure

DWIA spectra from P.Khaustov et al., PRC 61 (2000) 054603
E05 (low intensity beam version) : Expected Spectrum 2

Expected $^{12}_{\Xi}Be$ Spectrum

$\Delta E_{\text{exp}} = 4$ MeV

- difficult to separate 2 peaks.
- lack of resolution

FWIA spectrum from
T. Motoba and S. Sugimoto,

* QF is not concerned.
Resolution dependence

higher-resolution system (< 2MeV) is indispensable.

=> Mid-term plan


T = 1
Theoretical Calculation for $^{16}_{\Lambda\Lambda}C$, via $\Xi^-$ doorways in the $^{16}O(K^-,K^+)$ reaction at 1.8 GeV/c

Two-step process

One-step process

$\Xi N\text{-}\Lambda\Lambda$ coupling strength: $5 \sim 10$ nb/sr

$V_{\Xi} = -14$ MeV, $\Delta E_{\text{EXP.}} = 1.5$ MeV (FWHM) included

Theoretical Calculation for $^{16}_{\Lambda\Lambda}C$, via $\Xi^-$ doorways in the $^{16}O(K^-,K^+)$ reaction at 1.8 GeV/c.

Beyond E05
- Statistical study is possible. c.f.) emulsion
- can observe excited states of double-$\Lambda$ hyp.
- sensitive to $\Xi N$-$\Lambda\Lambda$ coupling strength.

$V_\Xi = -14$ MeV, $\Delta E_{\text{exp.}} = 1.5$ MeV (FWHM) included

$5 \sim 10$ nb/sr

Requirements for the Spectrometer

- Especially for \((K^-, K^+)\) reaction @ 1.8 GeV/c
  Double-\(\Lambda\) hypernuclei
  and \(\Xi\)-hypernuclei
- High-Resolution: \(~ 5 \times 10^{-4}\)
  (corresponds to \(\Delta M_{\text{FWHM}} < 1.5\) MeV)
- Large Acceptance: \(> 60\) mrand
  (as large as possible)
- Path Length:
  as short as possible
  ex. \(K_{\text{survive}} = 50\% \rightarrow 6.8\) m
  @1.3 GeV/c

S-2S under designing
Strangeness -2 Spectrometer
S-2S under designing

**Horizontal Focus**
- \( B = 1.15 \text{ T} \) @pole
- half-aperture = 18 cm

**Vertical Focus**
- \( B = 1.6 \text{ T} \) @pole
- half-aperture = 16 cm

\( p_0 = 1.3 \text{ GeV/c} \)

**Tentative Schematic View**
J-PARC E05 is planned to observe $\Xi$-hypernuclei via $(K^-,K^+)$ missing mass spectroscopy.

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

We are preparing modified experimental plan.

i. Near future plan = low intensity version.
   - Larger acceptance
   - Tolerable resolution
   - Modest yield $\rightarrow$ Expected spectrum
   - Possibility to start exp. at $\sim$30kW as the first step.

ii. Mid-term plan
   - new higher-resolution spectrometer ($S-2S$) is under designing.
   - $\Xi$-hypernuclei and double-$\Lambda$ hypernuclei.