E10 status

Atsushi Sakaguchi (Osaka University) for the E10 Collaboration
Hypernuclei and issues of studies

- **What is Hypernuclei?**
  - Hypernucleus is a new category of “nucleus” which contains hyperons as new ingredients
  - Candidate hyperons are $\Lambda$, $\Sigma$, $\Xi$ and $\Omega$

- $\Lambda$ hypernuclei
  - Have very clear “nuclear” structure as normal nuclei
  - Many studies and interesting phenomena

- “glue-like role” of $\Lambda$ hyperon
  - $\Lambda$ hyperon resides deep inside nucleus
  - Additional attractive $\Lambda$-$N$ interaction
  - Glue effect may extend boundary of stability of “nuclei”
• $\Lambda N-\Sigma N$ mixing in hypernuclei
  • Strong mixing of $\Lambda N$ and $\Sigma N$ pairs both have $I=1/2$

BB spectra

ordinary nuclei

$\Delta N$

$\Delta m \sim 300$ MeV

$\Sigma N$

$\Delta m \sim 80$ MeV

$\Lambda N$

$S=-1$

$S=-2$

hypernuclei

$\overline{K}NN$

$\Sigma*N$

$\Sigma \Lambda$

$\Xi N$

$\Lambda \Lambda$

$\Sigma \Sigma$

overall conservation of isospin is required

$I=0$

$I=1$

$I_A \neq 0$

$I_A \neq 0$

larger mixing expected in nuclei with larger $I_A$

How large is mixing in neutron-rich hypernuclei?
Aims of E10 experiment

- **Aim 1**: production of $\Lambda$ hypernuclei close to the neutron drip-line, $^6\Lambda H$ and $^9\Lambda He$
  - E10 may produce highly neutron-rich $\Lambda$ hypernuclei
    - $^6\Lambda H$ (1p, 4n and 1$\Lambda$), $^9\Lambda He$ (2p, 6n and 1$\Lambda$)
    - These are exotic hypernuclei we have never seen clearly
  - “glue like role” of $\Lambda$ hyperon is critical in such loosely bound hypernuclei

- **Aim 2**: $\Lambda$-N interaction at the extreme condition
  - The $\Lambda N\Sigma N$ mixing effect may be observed in the hypernuclear structures
  - Neutron-rich $\Lambda$ hypernuclei are good laboratories to study the $\Lambda N\Sigma N$ mixing
ΛN-ΣN mixing effects in $^6_{\Lambda}H$

- **Structure and cross section** of neutron-rich hypernuclei may give us information of the ΛN-ΣN mixing

K. Swe Myint and Y. Akaishi, PTP Supplement 146 (2002) 599

E10 provides decisive conclusion

M. Agnello et al., FINUDA Collaboration, PRL 108 (2012) 042501

3 events of $^6_{\Lambda}H$ candidates

FINUDA Collab. $^6Li$(stopped-$K^-,\pi^+$)
Method of production of n-rich $\Lambda$ hypernuclei

- How to produce?
  - Use Double Charge-eXchange (DCX) reaction

$$\pi^- + p + p \rightarrow K^+ + \Lambda + n$$

$^6\text{Li} \left(\pi^-, K^+\right) ^6\Lambda\text{H}$

$Z=3$  $Z=1$

Challenge is the tiny production cross section about 1/1000 of Non-CX

$^6\Lambda\text{H}$ as 1st phase of E10
E10 run plan written in proposal

- High intensity pion beams are necessary
  - to override the tiny production cross section
- **10M/spill** pion beams, 3 weeks beamtime → 3T pions

### Parameters and Values

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pion beam momentum</td>
<td>1.2 GeV/c</td>
</tr>
<tr>
<td>Pion beam intensity</td>
<td>10M/spill</td>
</tr>
<tr>
<td>Total number of pions (6 s acc. cycle)</td>
<td>3T pions</td>
</tr>
<tr>
<td>Target thickness ((^6)Li)</td>
<td>3.5 g/cm(^2)</td>
</tr>
<tr>
<td>DCX cross section (assumed)</td>
<td>10 nb/sr</td>
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<tr>
<td>SKS acceptance</td>
<td>100 msr</td>
</tr>
<tr>
<td>Spectrometer efficiency (due to K decay)</td>
<td>0.5</td>
</tr>
<tr>
<td>Analysis efficiency</td>
<td>0.5</td>
</tr>
<tr>
<td>Estimated (^6)Λ(^\Lambda) H yield</td>
<td>265</td>
</tr>
</tbody>
</table>

![Simulation graph](image.png)

**2.5 MeV (FWHM)\(^6\)Λ\(^\Lambda\) H g.s.**

**Counts / 0.5 MeV**

**QF**

**Ex (MeV)**

**0**

**10**
Practical problems and current status

- Ripples of 50GeV PS magnet affect duty factor of SX
  - SX duty factor was 25-30% during beamtime in June
    - Instantaneous beam rate is 3-4 times larger than average
- Beam rate study in 2012 June beamtime
  - Confirmed tracking system was OK up to 7M/spill (reported in the last PAC meeting)
- Beam rate study in 2012 December beamtime
  - Several detector upgrades before the December beamtime (see next slide)
  - Beam rate studies done at 7, 8, 9, 10, 11 and 12M/spill
  - Production runs at 10M/spill (conservative choice)
Upgrades for higher beam intensity

- Detectors in K1.8 beam spectrometer
The 16th J-PARC PAC at IQBRC, 9 January 2013

1mm fiber tracker (ready)

fiber tracker (new)

BFT

SDC1

SDC2

SFT

BC3

1mm fiber tracker (ready)

BFT

SDC1

SDC2

SFT

BC3

SFT-UV

SFT installation
Upgrade of other detectors

- New timing-counter BH2 and tracking SSD
Summary of 2012 December beamtime (1)

- Beamtime summary (from 15/Dec to 27/Dec)

![Graph showing beamtime summary](image)

- Integrated beamtime (hour)
- Date in December 2012

- Total Allocated
- w/ Beam
- User Trouble
- Down Time

- Production runs ~ 100 h
- commissioning rate/trigger study calibration runs
- down time 2.2% (5.9%)
- down time 20% (25%)
- 144 hours
- 32 hours
Summary of 2012 December beamtime (2)

- Results of quick analyses of calibration runs
  - $\Sigma^-$ production (energy scale)
  - $^{12}_\Lambda$C production (energy scale and resolution check)

**5 hours**

$p(\pi^-, K^+)\Sigma^-$

$\Delta M_X$: 2.5 MeV (FWHM)

no $E_{\text{loss}}$ correction

**13 hours**

$^{12}_\Lambda C(\pi^+, K^+)X$

$\Delta B^\Lambda$: 3.0 MeV (FWHM)

$\text{Ex} \rightarrow \text{g.s.}$
Summary of 2012 December beamtime (3)

- Number of pion beams on target in production runs

![Graph showing the number of pions produced over the dates of December 2012.](image)

- 0.64 T pions
- 0.12 T pion/day
- 6 days of production runs in January → 0.72 T pions
- 1.36 T pions in total
- 1.5 T pions in total if accelerator is stable
Summary of 2012 December beamtime (4)

- Trigger rates and DAQ efficiency
  - 1\(^{st}\) Level trig.: 1.8k/spill, 2\(^{nd}\) Level trig.: 700/spill
  - Our goal of <1000/spill (2\(^{nd}\) Level) was achieved
  - DAQ efficiency: 80%
Summary and prospects

- December beamtime done successfully, and we continue production runs in January.
  - Obtained 0.64 T pion beams on target in December
  - Prospect of total pion beams > 1.36 T pions
- We could run at 10M/spill beam intensity on target even at the low duty factor (about 30%).
- Calibration runs were done successfully
  - Measured $\Sigma^-$ and $^{12}_\Lambda$C production reactions
  - Energy resolution was about 3 MeV (FWHM)
- Analysis of $^6_\Lambda$H production data in Dec. is in progress
  - $\Lambda$ QF production ~ 1400 events, $\Sigma$ QF ~ 16k events