Spectroscopy of Ξ hypernucleus, $^{12}_{\Xi}$Be, via the ^{12}C(K^-,K^+) reaction at J-PARC (J-PARC 50GeV-PS E05)

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on behalf of AXiS Collaboration

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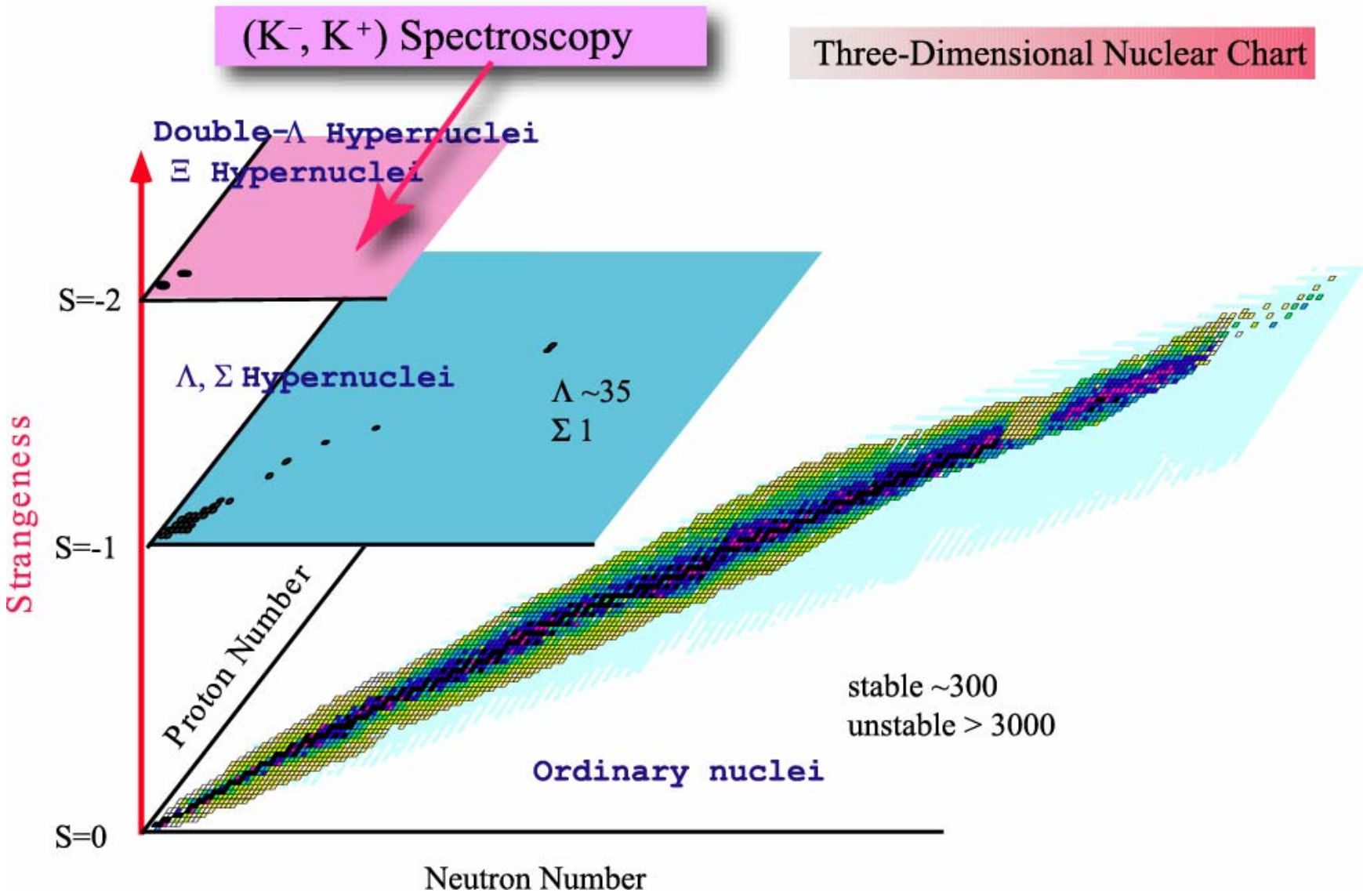
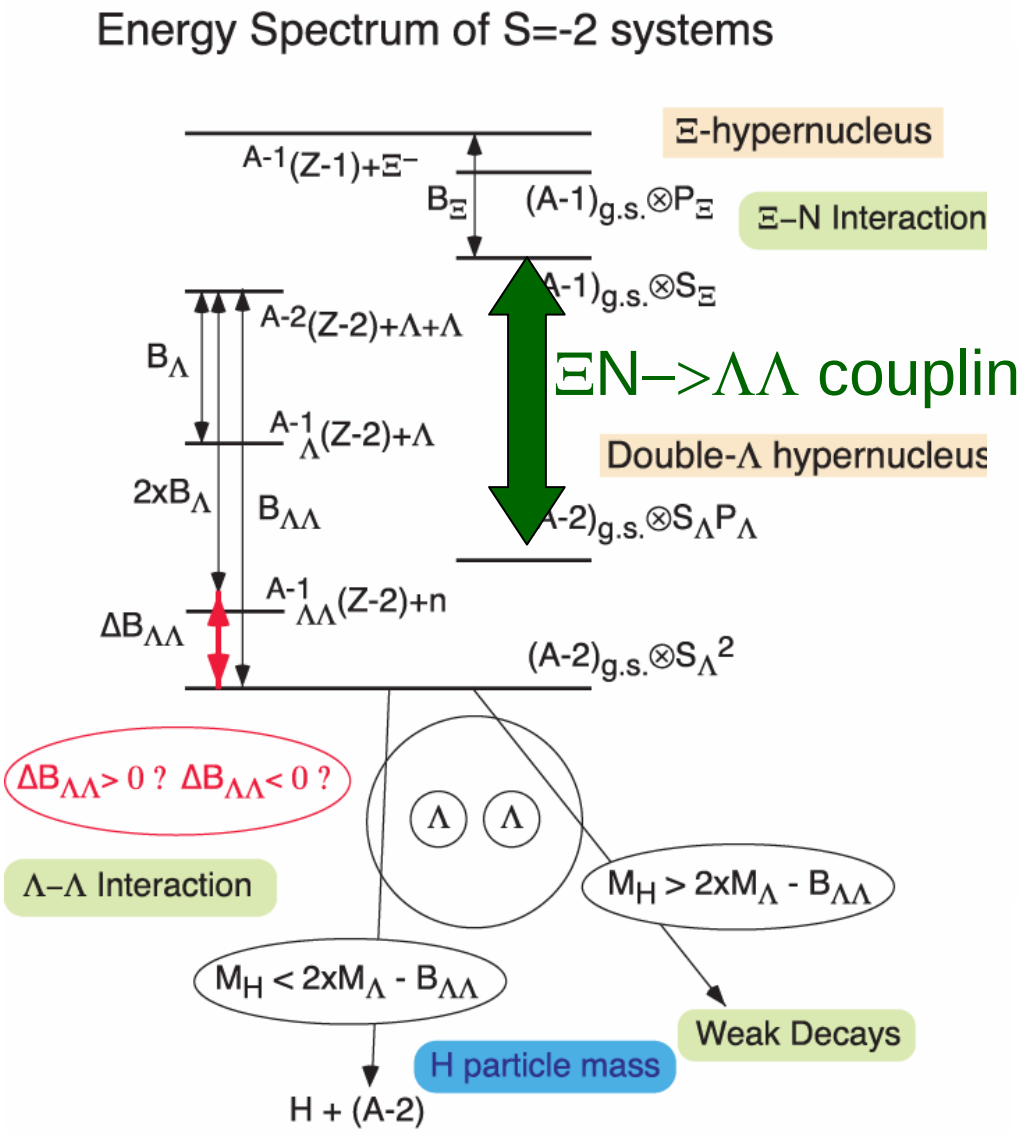
from 21 institutes

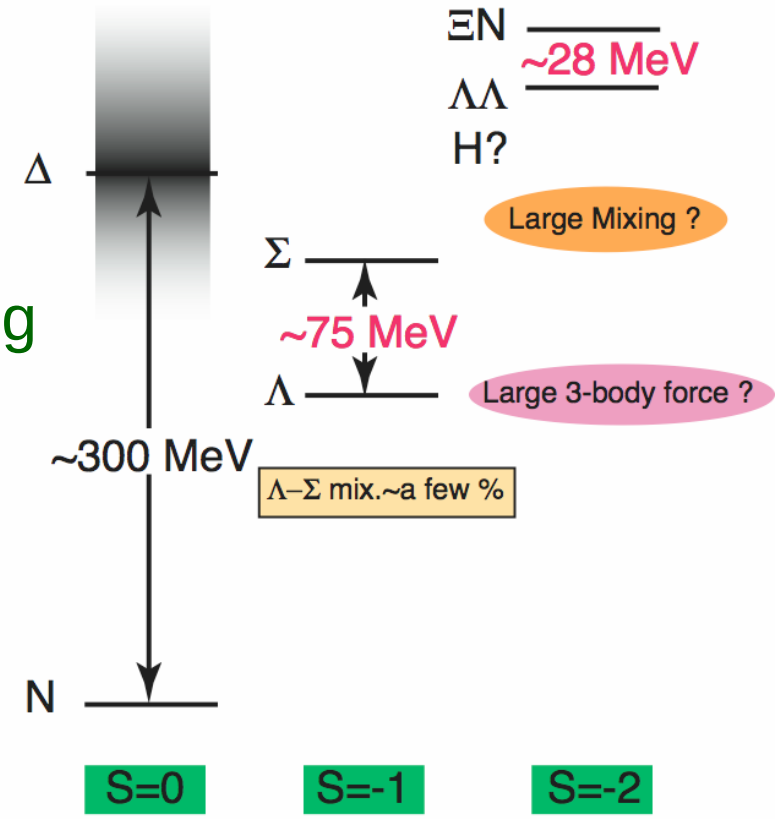
Purpose of the Experiment

- The first spectroscopic study of S=–2 system in the (K^-, K^+) reaction
  - Ξ hypernuclei, $\Lambda\Lambda$ hypernuclei
  - ΞN–>$\Lambda\Lambda$ couping
  - The first step towards multi-strangeness baryon systems


(K⁻, K⁺) Spectroscopy
Three-Dimensional Nuclear Chart
Double-Λ Hypernuclei
Ξ Hypernuclei
S=-2
Λ, Σ Hypernuclei
Λ ~35
Σ 1
S=-1
Strangeness
Proton Number
stable ~300
unstable > 3000
Ordinary nuclei
S=0
Neutron Number

S=–2 Baryon Systems



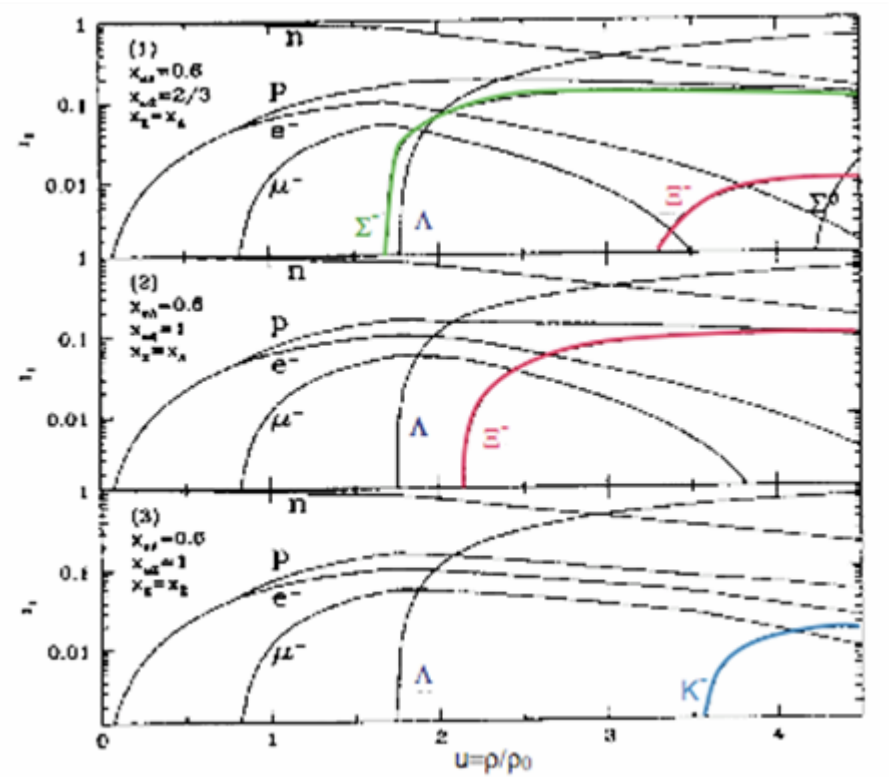


Mixing effect is more significant in S=–2 system

Ξ-Nucleus Potential & High Density Nuclear Matter

Λ, Σ^-, Ξ^-, K^- in Core of Neutron Star

chemical potential $\mu_B = m_B + \frac{{k_F}^2}{2m_B} + U(k_F)$



~~$U_\Sigma < 0$~~, $U_\Xi < 0$

$U_\Sigma > 0$, $U_\Xi < 0$

$U_\Sigma > 0$, $U_\Xi > 0$

Purpose of the Experiment

- The first spectroscopic study of S=–2 system in the (K^-, K^+) reaction
  - Ξ hypernuclei, $\Lambda\Lambda$ hypernuclei
  - ΞN–>$\Lambda\Lambda$ couping
  - The first step towards multi-strangeness baryon systems
- ΞN interaction – almost no information
  - atractive or repulsive ? Potential depth
  - ΞN–>$\Lambda\Lambda$ conversion ? Width
  - Isospin dependence ?

U_Ξ , Γ_Ξ and Partial Wave Contributions in Nuclear Matter

(MeV)

Model	T	$^1S_0$	$^3S_1$	$^1P_1$	$^3P_0$	$^3P_1$	$^3P_2$	U_Ξ	Γ_Ξ
NHC-D	0	–2.6	0.1	–2.1	–0.2	–0.7	–1.9		
	1	–3.2	–2.3	–3.0	–0.0	–3.1	–6.3	–25.2	0.9
Ehime	0	–0.9	–0.5	–1.0	0.3	–2.4	–0.7		
	1	–1.3	–8.6	–0.8	–0.4	–1.7	–4.2	–22.3	0.5
ESC04d*	0	6.3	–18.4	1.2	1.5	–1.3	–1.9		
	1	7.2	–1.7	–0.8	–0.5	–1.2	–2.8	–12.1	12.7

- OBE (NHC-D, Ehime)
  - no t-channel meson exchange
  - odd-state attraction
  - strong A-dependence of V_Ξ
  - small width
- ESC04d*
  - strong attraction of $^3S_1$(T=0)
  - large width

Previous Studies on Ξ-Hypernuclei and Ξ Potential

- Dover & Gal; Analysis of old emulsion data

$$U_{\Xi} = -24 \pm 4\ \mathrm{MeV}$$ Ann. of Phys. 146 (1983) 309

- Ξ-Captured events at KEK E176

Prog. Thoer.Phys. 89 (1993) 493

$$\Xi^- + {}^{12}\mathrm{C} \rightarrow {}^{4}_{\Lambda}\mathrm{H} + {}^{9}_{\Lambda}\mathrm{Be}\ (0.54 \pm 0.20\mathrm{MeV})$$
$$\Xi^- + {}^{14}\mathrm{N} \rightarrow {}^{4}_{\Lambda}\mathrm{H} + {}^{11}_{\Lambda}\mathrm{B}\ (0.35 \pm 0.20\mathrm{MeV})$$
$$\Xi^- + {}^{16}\mathrm{O} \rightarrow {}^{4}_{\Lambda}\mathrm{H} + {}^{13}_{\Lambda}\mathrm{C}\ (6.62^{+0.22}_{-0.23}\ \mathrm{MeV})$$

Phys. Lett. B355 (1995) 45

$$\Xi^- + {}^{12}\mathrm{C} \rightarrow {}^{4}_{\Lambda}\mathrm{H} + {}^{9}_{\Lambda}\mathrm{Be}\ \ (3.70^{+0.18}_{-0.19}\ \mathrm{MeV})$$
$$\rightarrow {}^{4}_{\Lambda}\mathrm{H} + {}^{9}_{\Lambda}\mathrm{Be}^{*}\ (0.62^{+0.18}_{-0.19}\ \mathrm{MeV})$$
$$\rightarrow {}^{4}_{\Lambda}\mathrm{H}^{*} + {}^{9}_{\Lambda}\mathrm{Be}\ (2.66^{+0.18}_{-0.19}\ \mathrm{MeV})$$

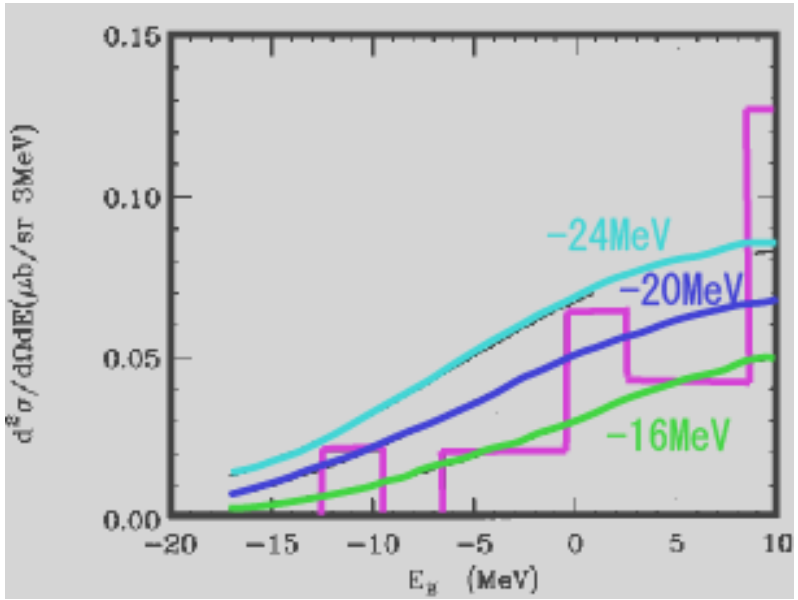
- Analysis by Yamamoto

$$U_{\Xi} = -(16 - 17)\ \mathrm{MeV}$$ Few-Body Syst. Suppl. 9 (1995) 145

Previous Studies on Ξ-Hypernuclei and Ξ Potential (2)

(K^-,K^+) Missing Mass Spectroscopy

KEK-E224



T.Fukuda et. al, PRC58(1998)1306

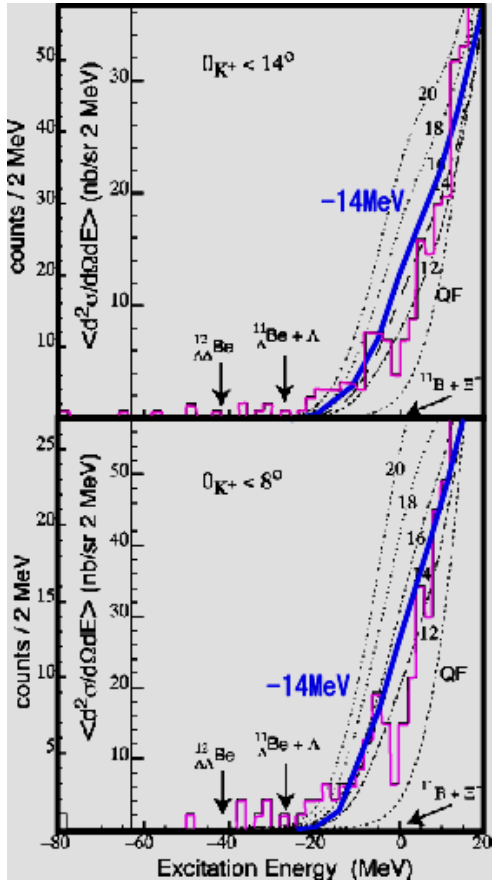
ΔM=22MeV

BNL-E885

ΔM=14MeV

Evidence !?

$V_Ξ$ = –14 MeV



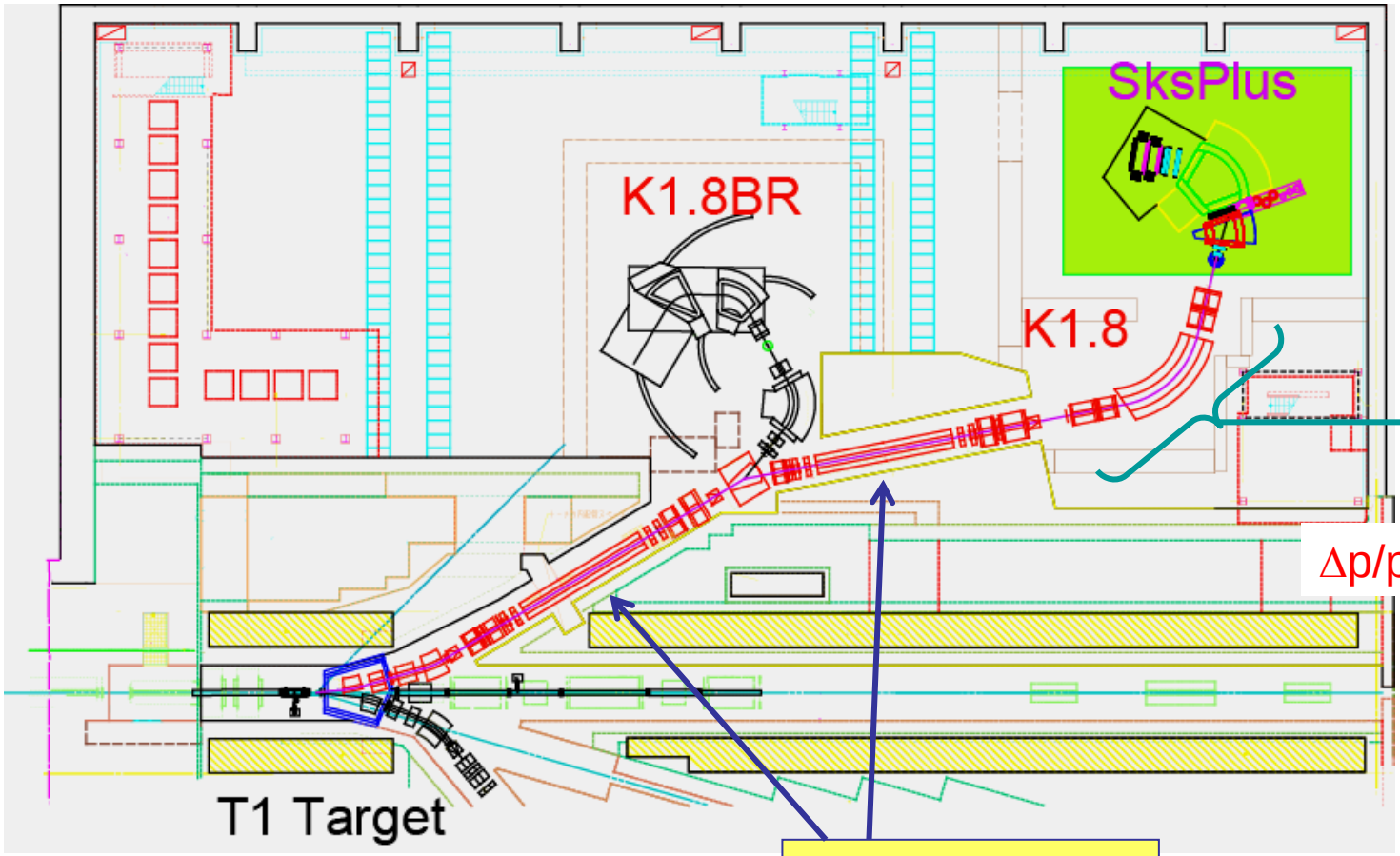
P.Khaustov et al, PRC61(2000)0546

insufficient resolution
poor statistics

Experimental Method

- (K^-,K^+) reaction at P_{K^-}=1.8 GeV/c
  - Missing mass resolution $\Delta M \sim 3$ MeV/c^2 (FWHM)
- K1.8 beamline at J-PARC
  - High intensity 1.4×10^6 /spill @ 30GeV(9μA)
  - Double-stage E.S. separators $K^-/\pi^- \sim 6.9$
  - High-resolution spectrometer $\Delta p/p = 3.3 \times 10^{-4}$(FWHM)
- SksPlus Spectrometer
  - A new dipole magnet in front of SKS
  - Acceptance: 30 msr
  - Momentum resolution: $\Delta p/p = 1.2 \times 10^{-3}$(FWHM)
  - New simple cryogenics system

K1.8 Beamline



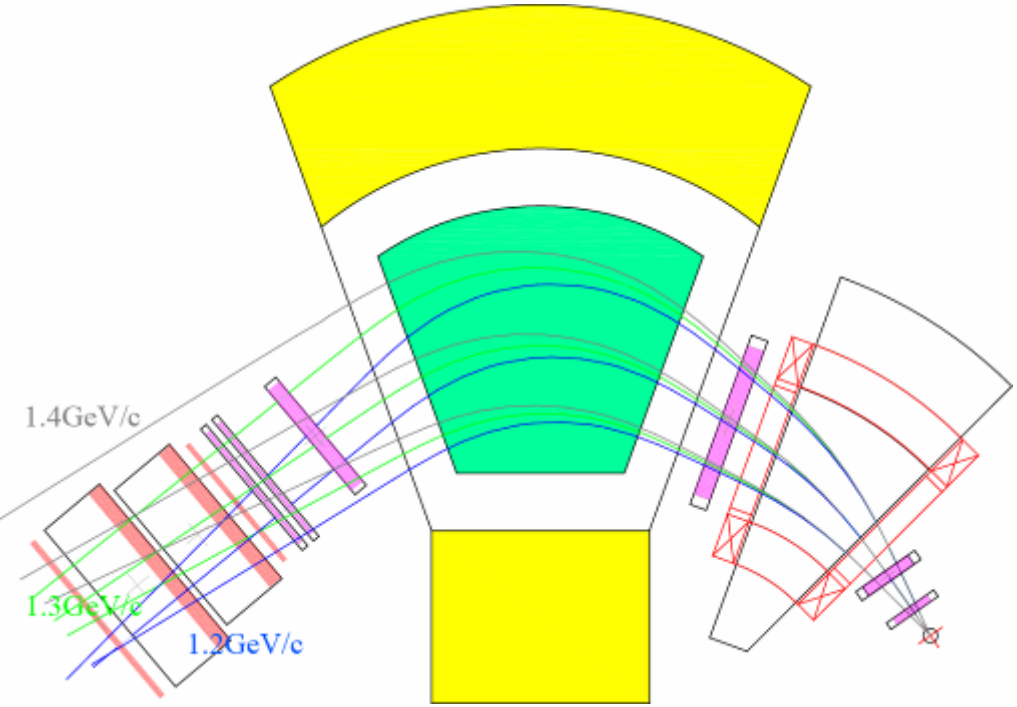
Beam Spectrometer

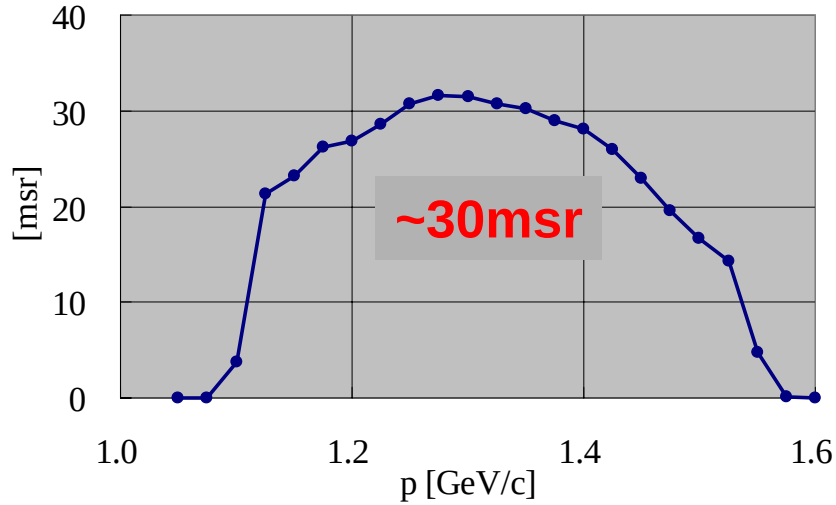
$\Delta p/p=3.3\times10^{-4}$(FWHM)

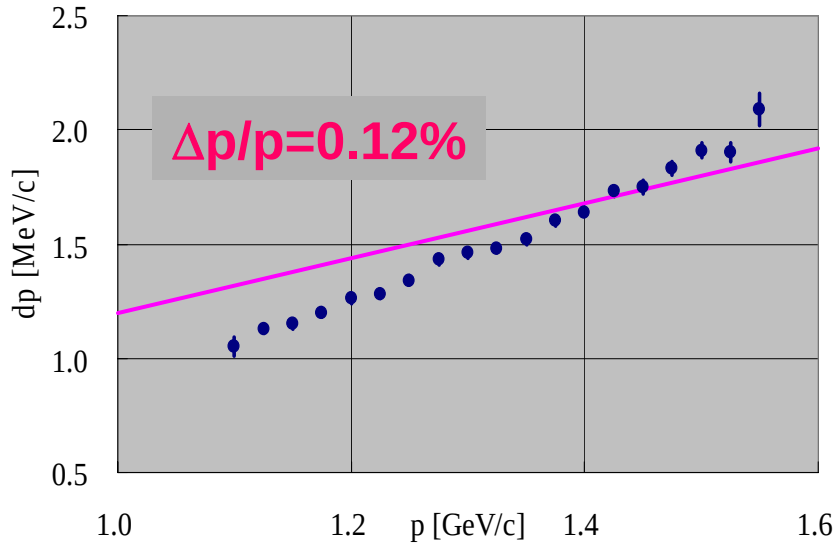
E.S. Separators

K^-/π^- ~6.9

SksPlus Spectrometer

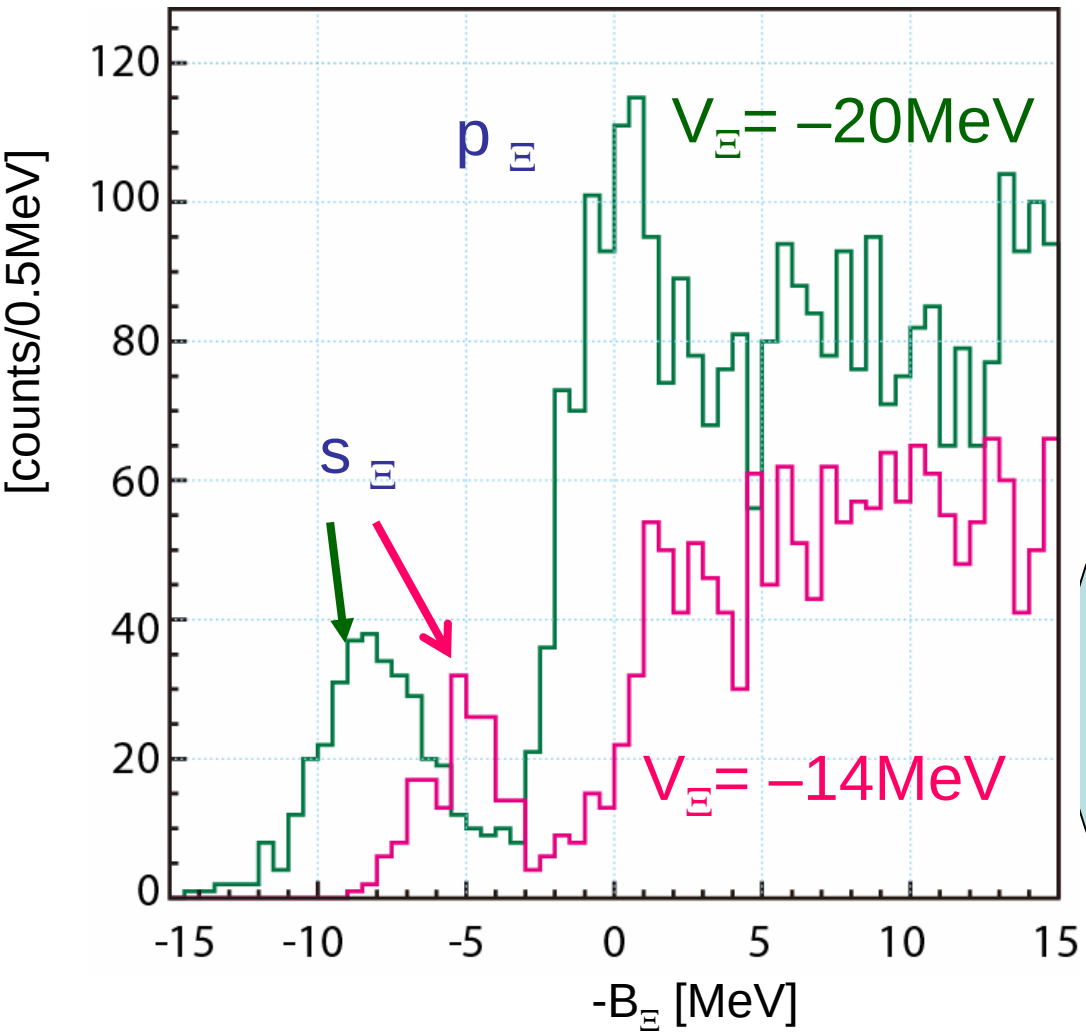






- 95° total bend
- ~7m flight path
- Δx=0.3 mm (RMS)

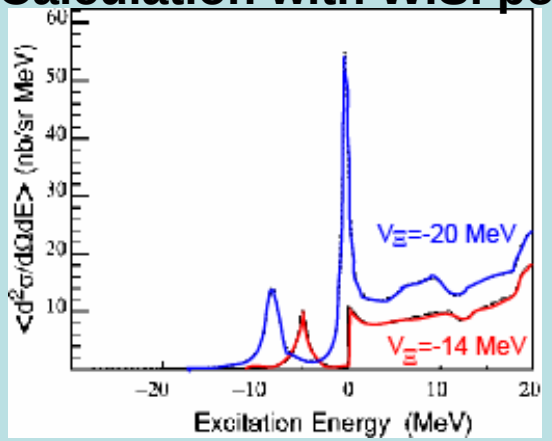
Expected $^{12}_{\Xi}$Be Spectrum



$\Delta E_{meas.} = 3\ MeV_{FWHM}$

One momth Data-taking

Calculation with W.S. pot.



P.Khaustov, et al.
Phys. Rev. C61(2000)
054603

Summary

- Rich subjects in S=–2 world
  - Ξ-hypernuclei, ΛΛ-hypernuclei
  - ΞN, ΞN–>ΛΛ interaction
  - High density nuclear matter
- K1.8 beamline at J-PARC
  - High Intensity K^- beam 1.4×10^6 /spill
  - High purity K^-/π^- ~6.9
  - High resolution spectrometers
- Ξ-hypernuclear spectroscopy via $^{12}C(K^-,K^+)$
  - ΔM ~ 3MeV
  - Stage-2 approval