Ξ Hypernuclear Spectroscopy

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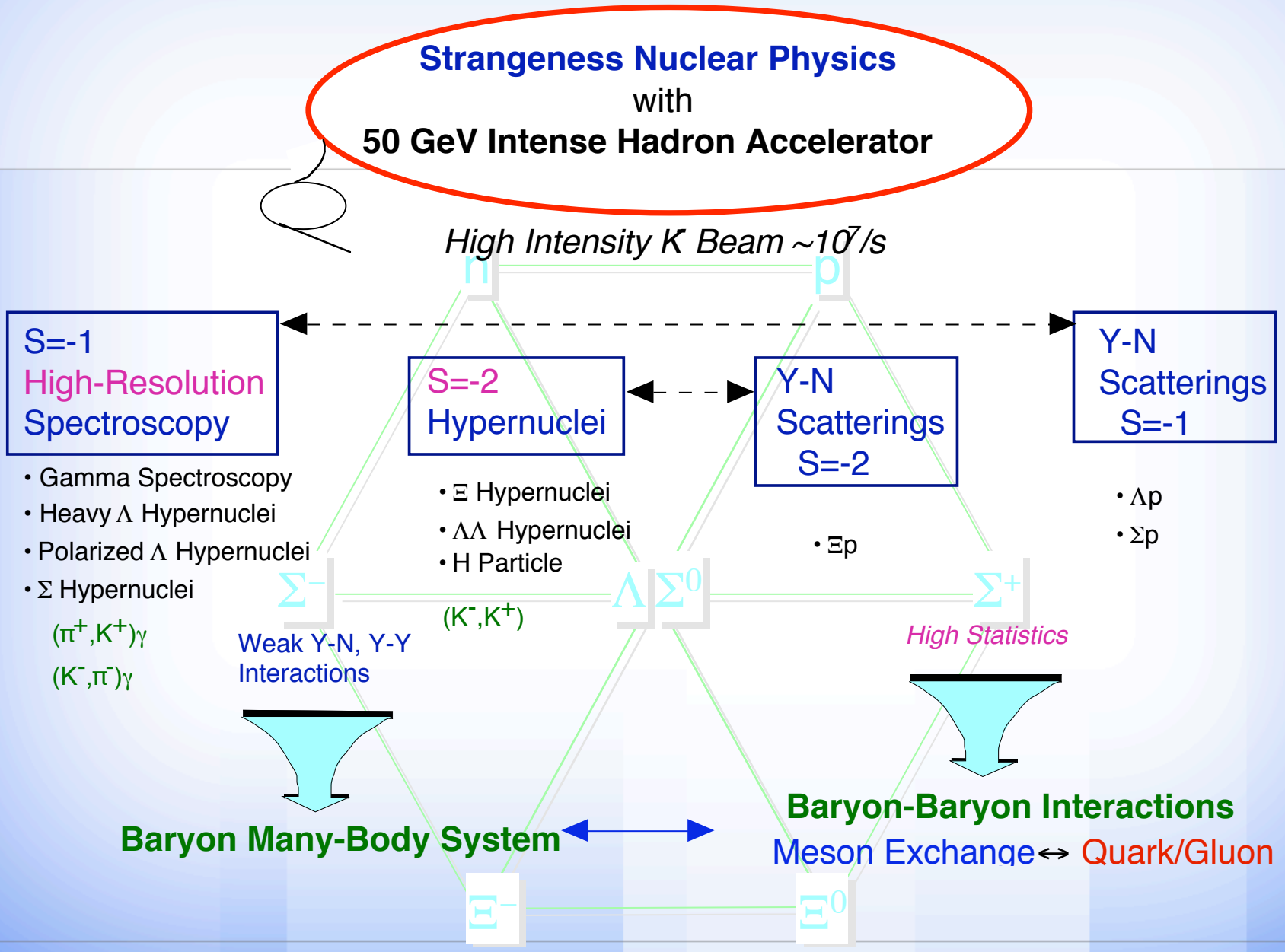
Outline -

- Introduction
- LOI for Ξ hypernuclear Spectroscopy
  - Physics motivation
  - Experimental method
  - Estimated yields
- What should be done ?
- Summary

Strangeness Nuclear Physics
with
50 GeV Intense Hadron Accelerator

High Intensity K⁻ Beam ~10⁷/s



6 LOIs in SNP and 2 Day-1 exp.

- L06: New Generation Spectroscopy of Hadron Many-Body Systems with Strageness S=-2 and -1 (K. Imai et al.)
- L07: Hyperon-Proton Scattering Experiments at the 50-GeV PS (M. Ieiri et al.)
- L08: High-Resolution Reaction Spectroscopy of S=-1 Hypernuclei (H. Noumi et al.)
- L09: Neutron-rich Λ hypernuclei by the double-charge exchange reaction (T. Fukuda et al.)
- L10: Study of Dense $\bar{K}$ Nuclear Systems (T. Nagae et al.)
- L21: Precise Measurement of the Nonmesonic Weak Decay of A=4,5 Λ Hypernuclei (S. Ajimura et al.)

New Generation Spectroscopy of Hadron Many-Body Systems with Strangeness S=-2 and -1

- (K^-,K^+) for Ξ-hypernuclei
- $(K^-,\pi^-)\gamma$ with HyperBall-3

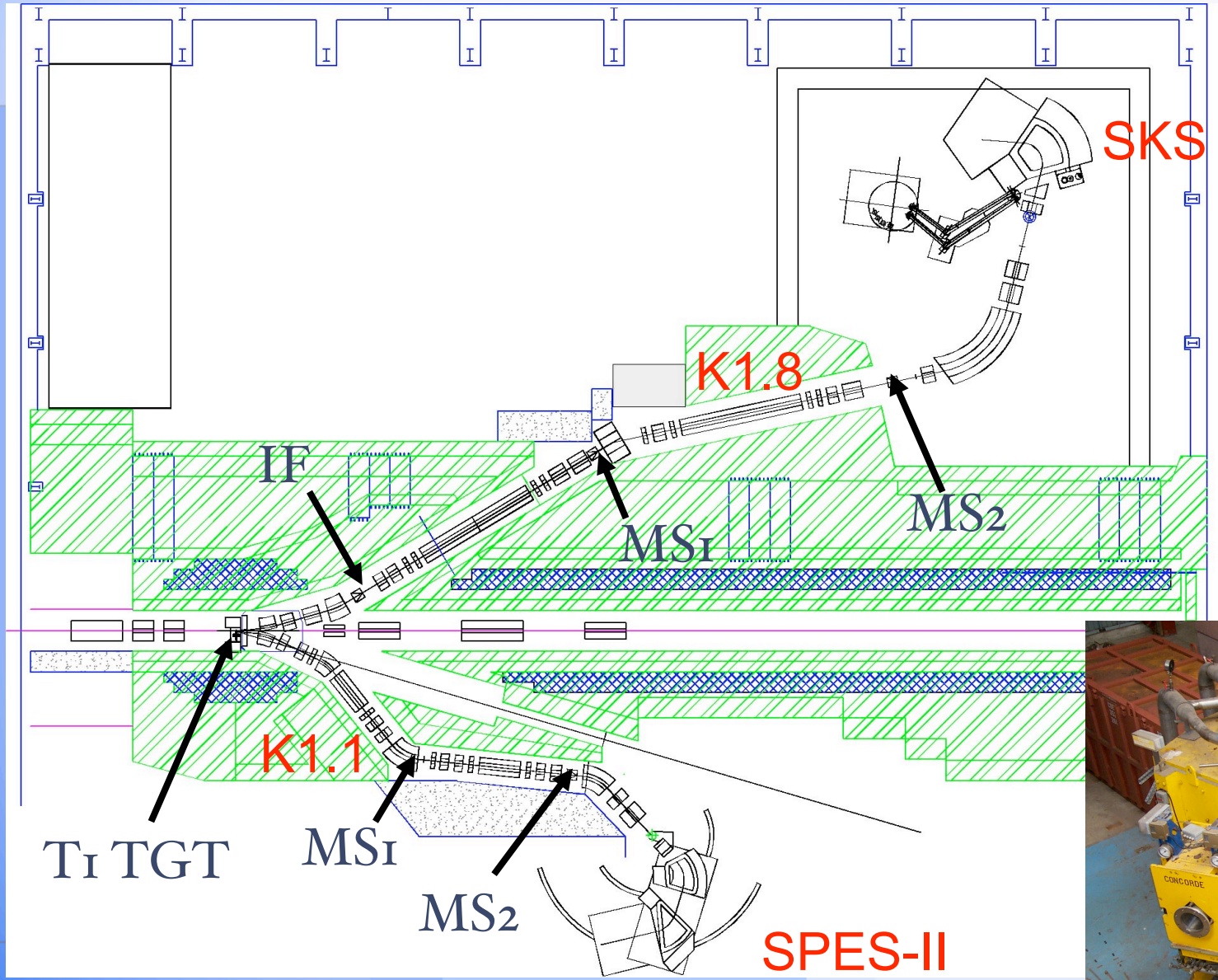
- K.Imai,M.Nakamura, H.Funahashi, M.Yosoi
- T.Nagae, M.Ieiri, H.Noumi, H.Outa, M.Sekimoto, H.Takahashi, Y.Sato, A.Toyoda
- T.Fukuda, P.K.Saha
- K.Nakazawa
- K.Yamamoto, T.Yoshida
- O.Hashimoto, K.Maeda, H.Tamura, S.N.Nakamura, T.Takahashi, Y.Fujii,H.Kanda
- T.Kishimoto, A.Sakaguchi, S.Ajimura, Y.Shimizu, S.Minami, T.Itahashi, T.Hayakawa
- M.Iwasaki, K.Itahashi, K.Tanida, Y.Matsuda
  - Japan
- J.S.Song, I.G.Park, C.S.Yoon, S.H.Kim
- J.Y.Kim
- M.Y.Pac
- J.K.Ahn, I.K.Yoo
- H.Bhang, M.Youn
  - Korea
- S.Zhou, L.Zhu
  - China
- B.Bassalleck
- L.Tang
- P.Markowitz, B.Raue, J.Reinhold
- M.May, R.E.Chrien, A.Rusek, P.H.Pile
- S.Choi
- Ed.Hungerford
- G.Franklin, R.Schumacher, B.Quinn
  - USA
- T.R.Saitoh, A.Banu
  - Germany
- J.Arvieux
  - France
- P.Kienle, M.Cargnelli, J.Marton, J.Zmeskal
  - Austria
- S.Marcello, T.Bressani
- M.Agnello
- A.Feliciello
  - Italy
- P.Tlusty
  - Czech

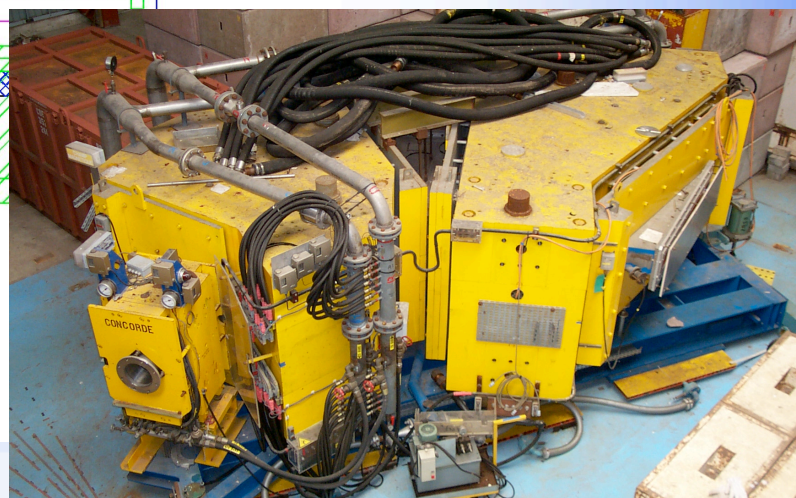
Information on S=-2

- Double Λ hypernuclei
  - Two old emulsion events(1963,1966)
  - One recent event in KEK E176(1991)
  - Nagara event in KEK E373(2001)
    - Binding energy of ${}^{6}_{\Lambda\Lambda}\mathrm{He}$
    - $m_H > 2223.7\ \mathrm{MeV}/c^2$
- Ξ hypernuclei ?

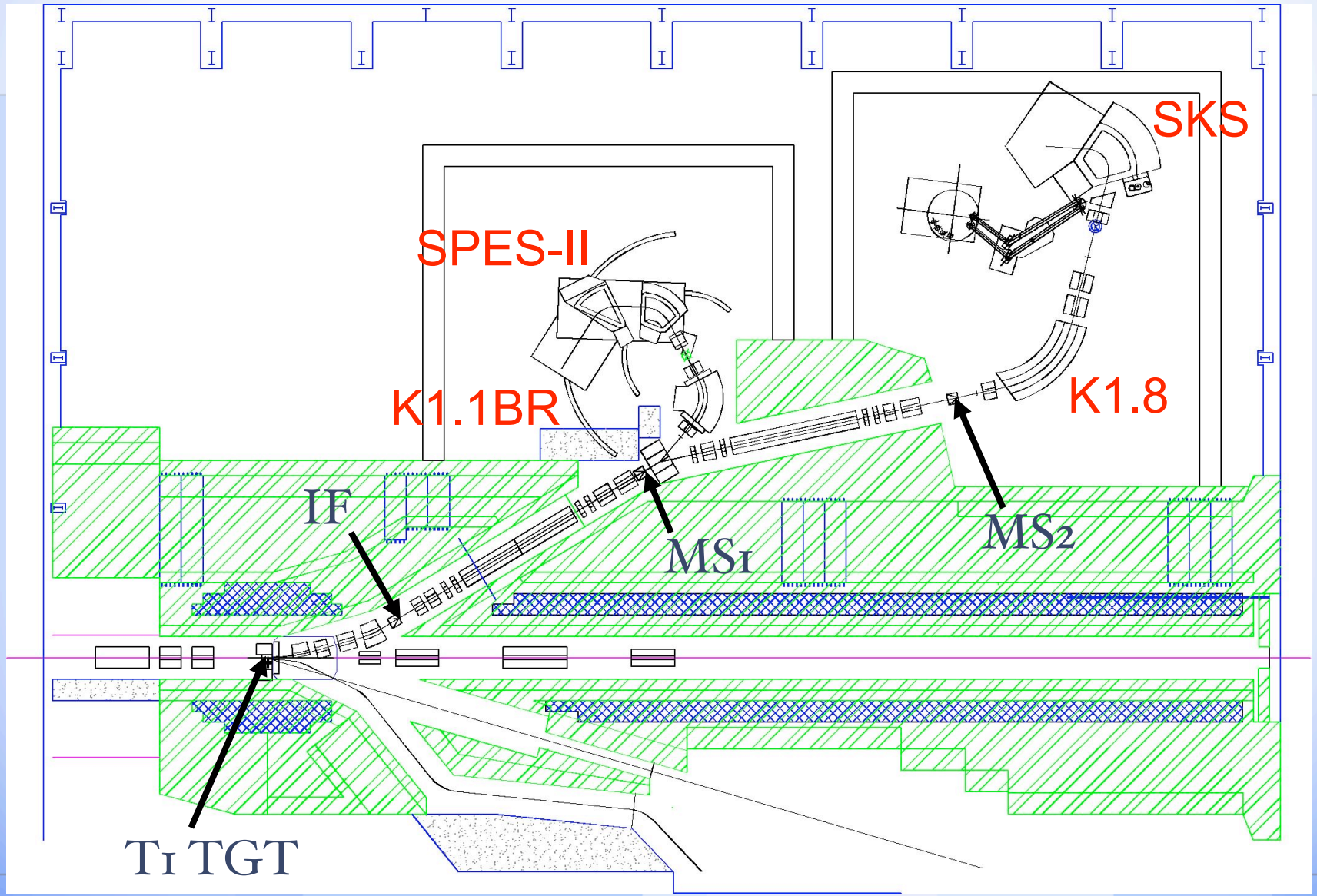
Very limited spectroscopic information

Layout Option - K1.8 and K1.1





Layout Option - K1.8+K1.1BR



Beam Line Specification

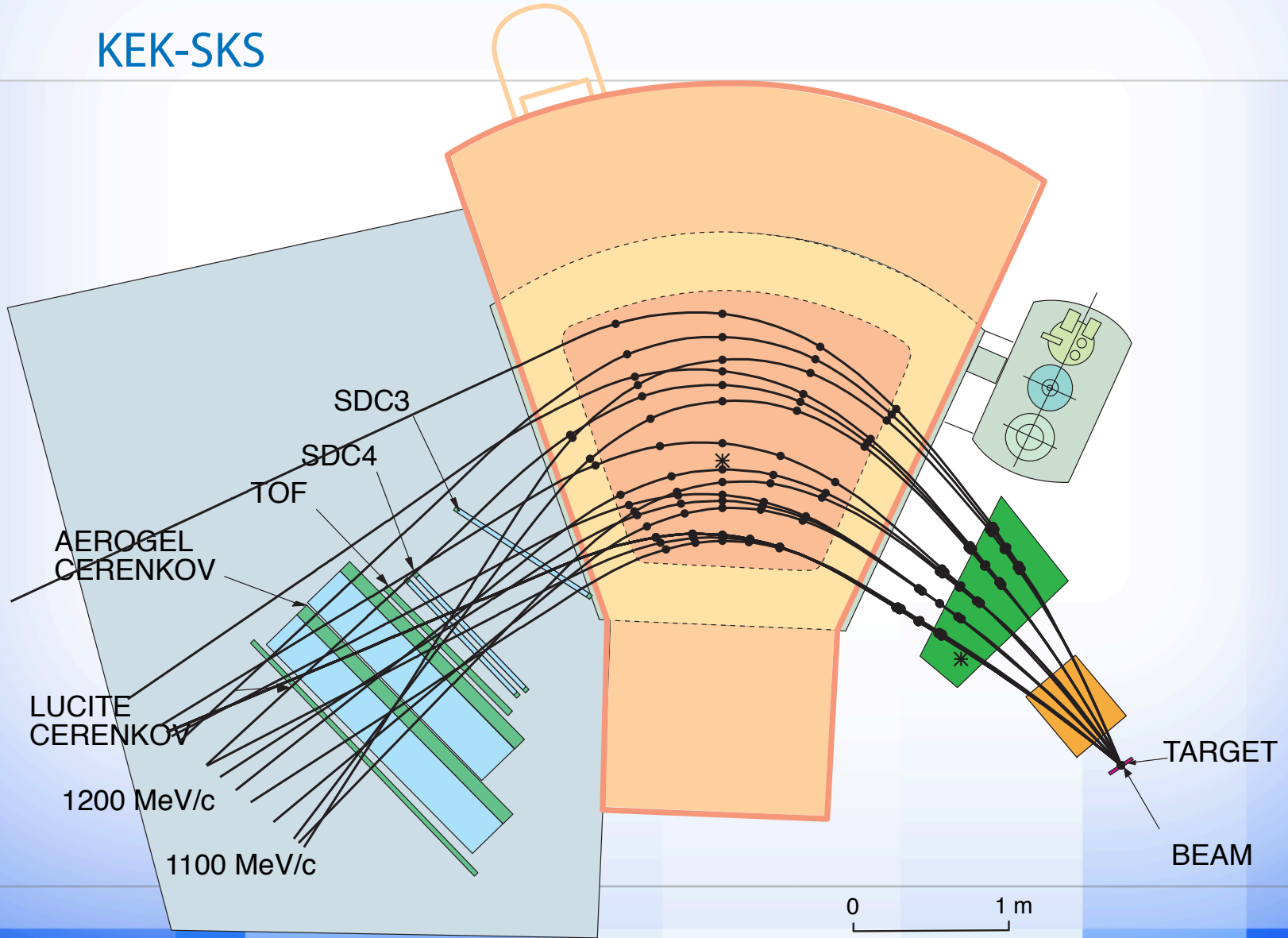
by H. Noumi

	K1.8	K1.1	K1.1BR
Length (m)	46.4	24	26.9
Acceptance (msr.%)	2.7	16.5	4.9
Intensity (ppp)			
1.8 GeV/c	1.0E+07		
1.1 GeV/c	4.9E+05	4.1E+07	1.0E+07
Electro-static Separator	6m-7.5MV/m ×2	2m-7.5MV/m ×2	6m-5MV/m ×1
Separation/Size(rms)	10.8	4.2	6.5
Beam Mom.Resol.(%)	0.07	-	0.05

Highest beam intensity in the world !

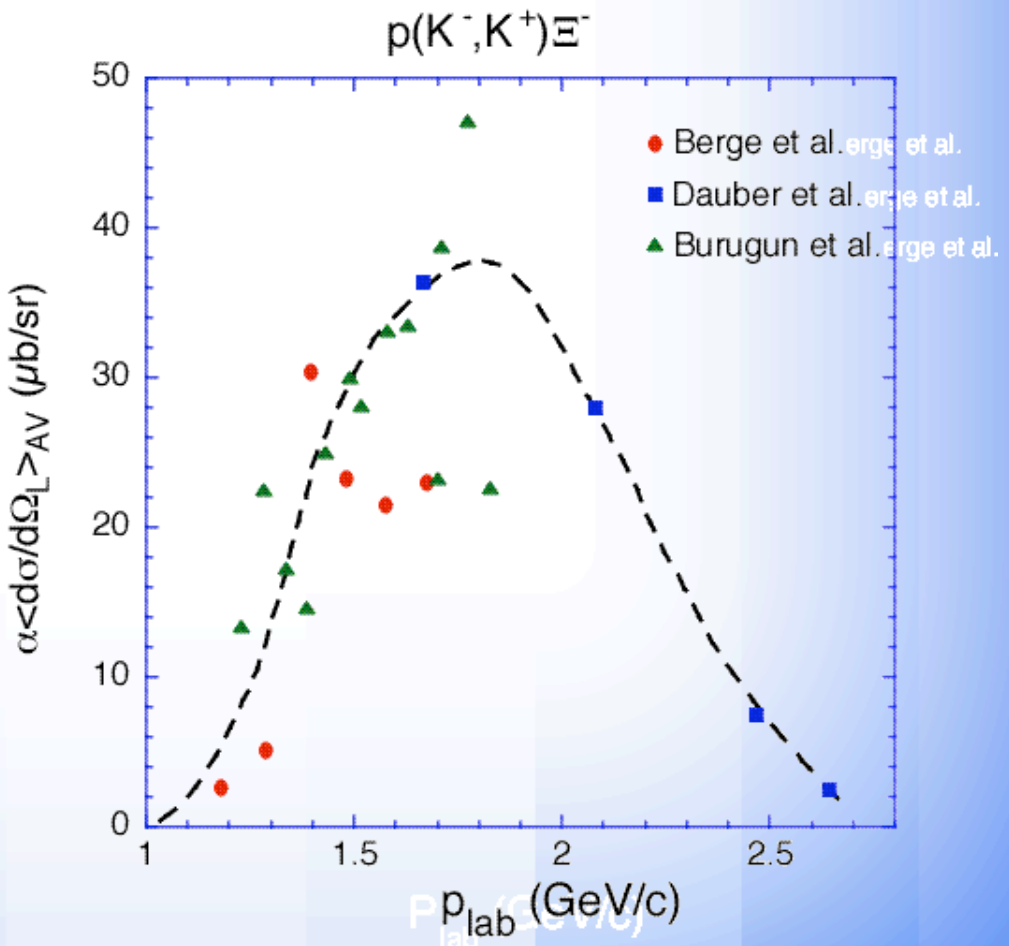
ΞHypernuclei with (K^-,K^+)

KEK-SKS



Entrance to the S=−2 World

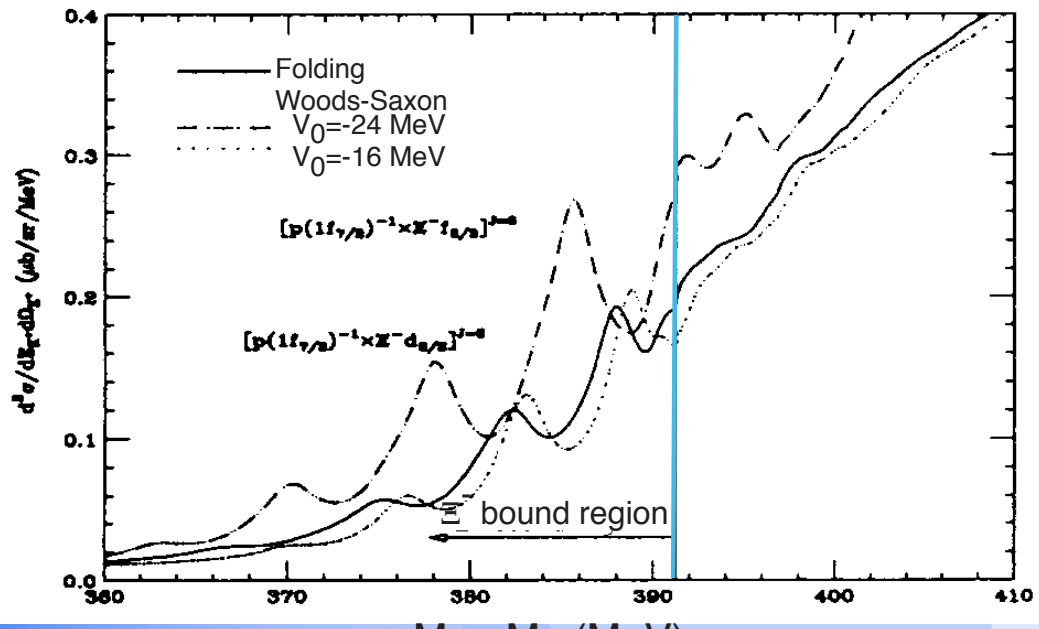
- Doorway Reaction:
  $K^- + p \rightarrow K^+ + \Xi^-$
  at 1.8 GeV/c



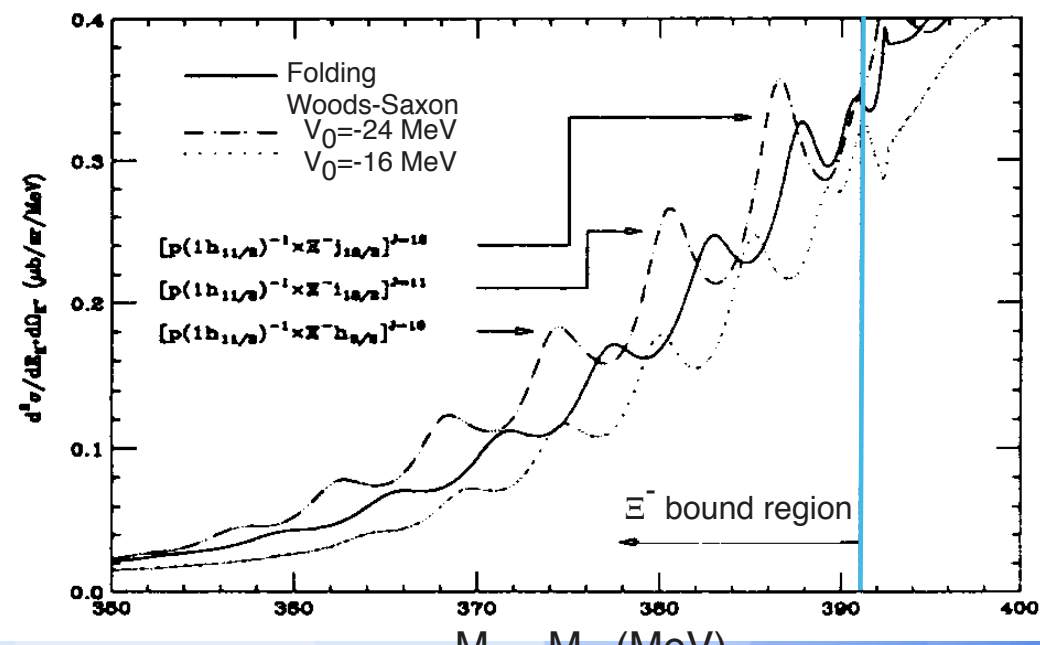
(K^-,K^+) Spectroscopy

- 2 MeV_{FWHM} resolution
- ~6 events/day/MeV for 50 msr, 2g/cm^2-thick Pb ⟶ ~20 days

$^{58}Ni(K^-,K^+)$



$^{208}Pb(K^-,K^+)$



Energy Resolution

- 2 MeV_{FWHM} resolution

$$\Delta E^2 = \beta_{K^+}^2 \times \Delta p_{K^+}{}^2 + \beta_{K^-}^2 \times \Delta p_{K^-}{}^2 + \Delta E_{straggling}^2$$

$$\Delta p / p_{K^-} = 2 \times 10^{-4}$$

$$\Delta p / p_{K^+} = (0.96 \pm 0.13) \times 10^{-4}\, p_K + (0.092 \pm 0.007)(\%)$$

$$\therefore \Delta E \sim \sqrt{1.89^2 + 0.31^2 + 0.5^2} = 2 MeV_{FWHM}$$

  - Limited by the SKS resolution
- Widths of the Ξ bound state < 1 MeV?

Yield Estimation

- 50 msr, 2g/cm^2-thick Pb

$$Y = I_{Beam} \times 2g/cm^2/208g \times N_A \times \frac{d\sigma}{d\Omega} \times \Delta\Omega \times f_{decay} \times f_{eff}$$

$$= 10^7 \times (2/208) \times 6.02 \times 10^{23} \times 0.1 \times 10^{-30} \times 0.05 \times 0.5 \times 0.5 events/sec$$

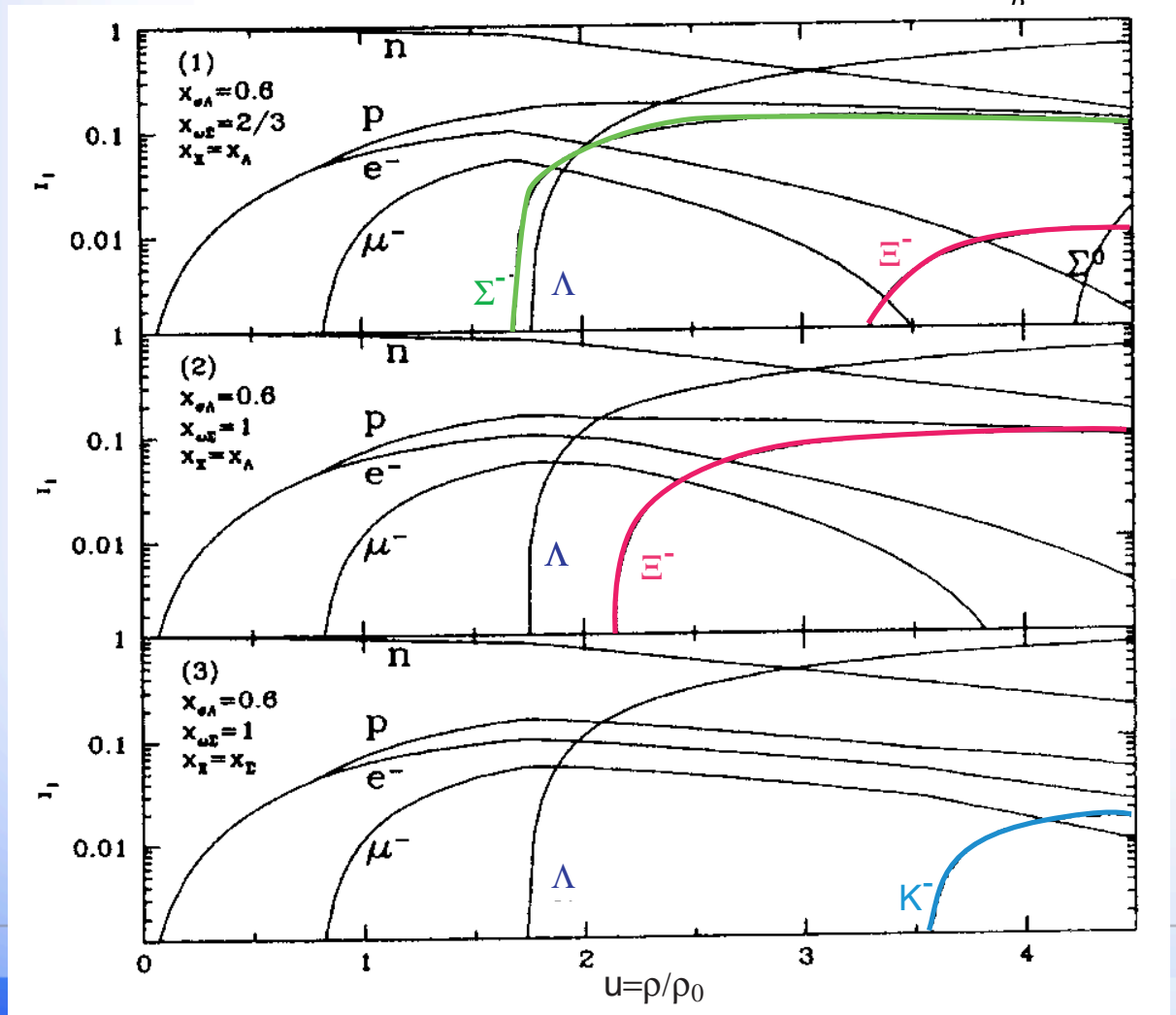
$$\cong 6 events/MeV/day$$

Issues in ΞA potential

- A-dependence of ΞA potential depth
  - Strong p-wave attraction
  - Ξ^{-}-^{207}Tl > 2x Ξ^{-}-^{11}B ?
- Isospin dependence
  - How strong is the Lane term ?
  - Ξ^{-}p-Ξ^{0}n mixing
- Width and ΞN-ΛΛ coupling

Ξ hypernuclei potential ?

- Λ, Σ^-, Ξ^-, K^- in Neutron Star Core ?
  - Chemical Potential: $\mu_B = m_B + \frac{k_F^2}{2m_B} + U(k_F)$

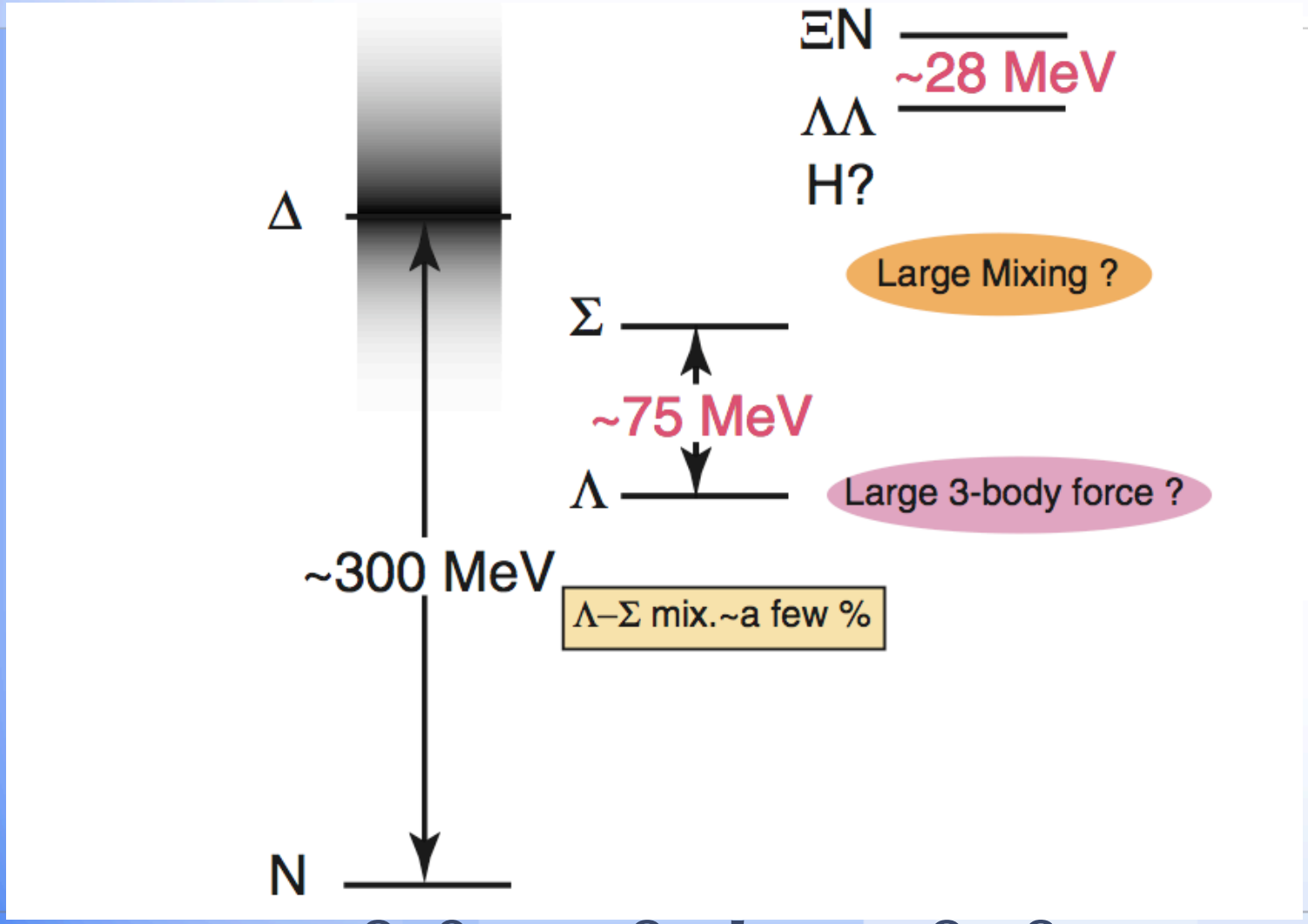


U_Σ<0, U_Ξ<0

U_Σ>0, U_Ξ<0

U_Σ>0, U_Ξ>0

Particle Mixing



What should be done ?

- Budget request for transferring the SKS to Tokai
- Optimization of the Spectrometer system: SKS, K1.8
  - energy resolution, acceptance
- R&D for High-rate detectors and Trigger system

- Preparation for Full proposal
  - collaboration

Summary

- Ξ Hypernuclear Spectroscopy will open a gate for the spectroscopic studies of S=-2 systems
  - potential depth, conversion width
- Next target: Double-Λ excited levels
  - direct population through ΞN-ΛΛ mixing
  - Gamma ray transitions with Hyperball-3