Study on Neutron-Rich Λ-Hypernuclei at J-PARC

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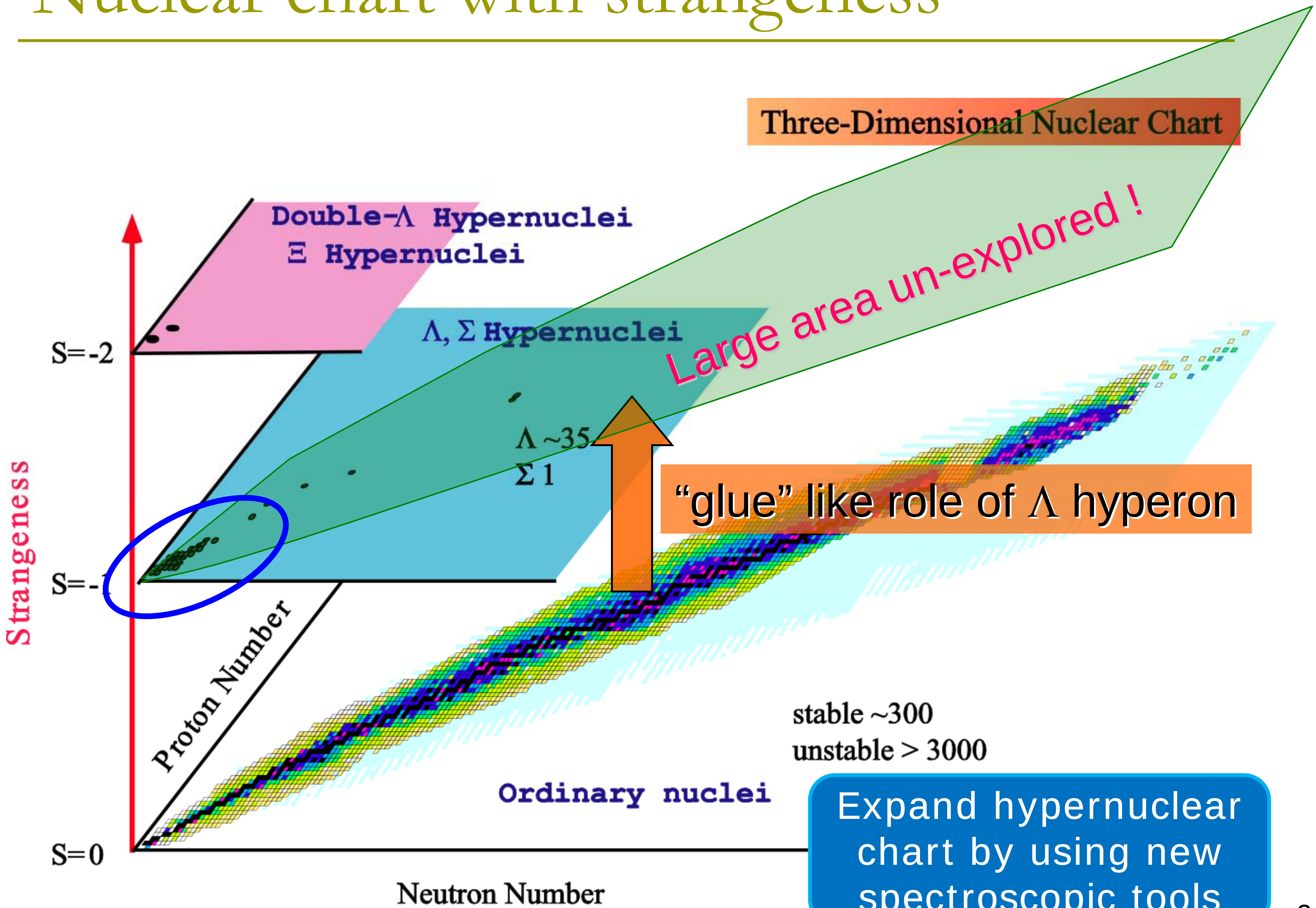
KEK, RIKEN, JAEA

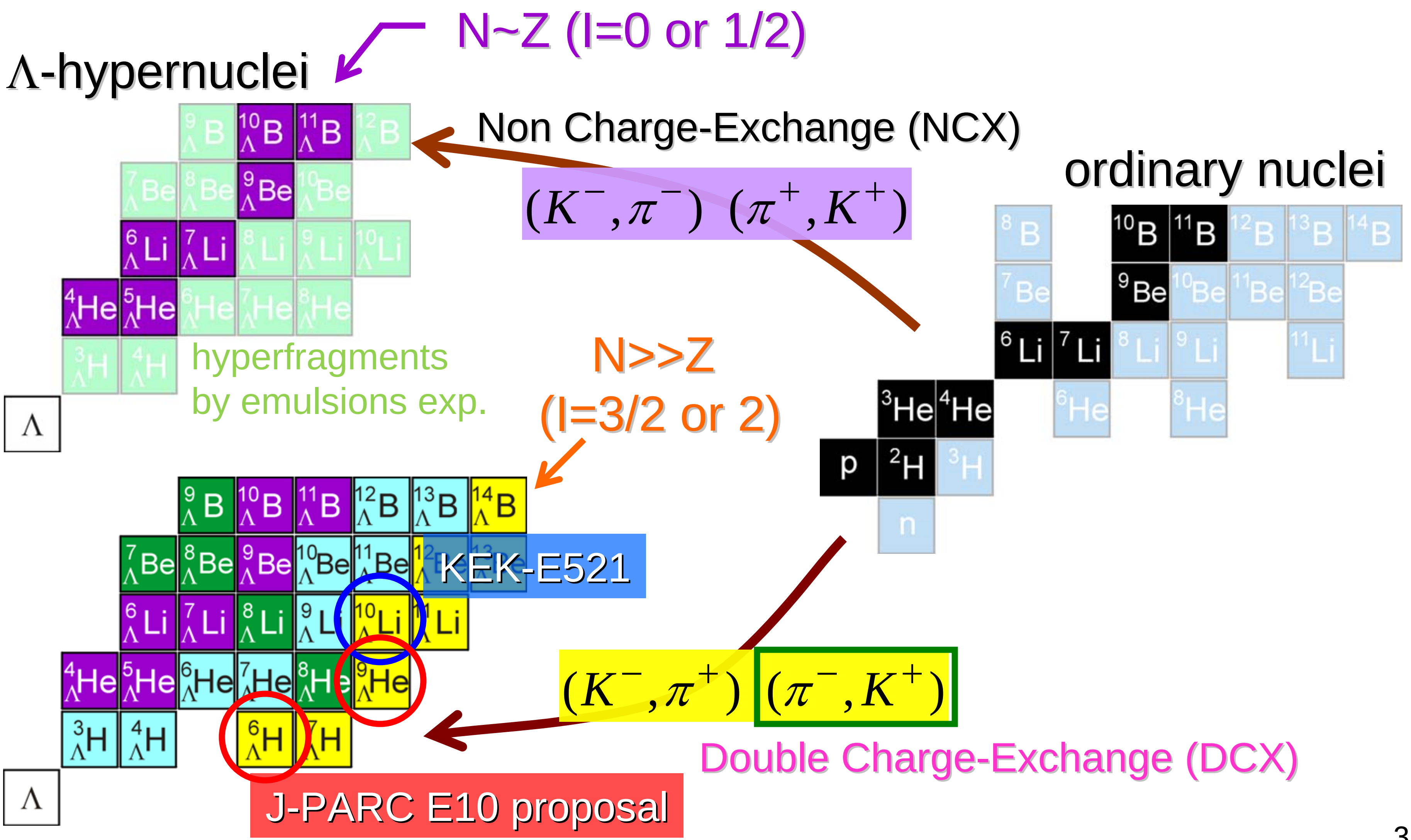
Nuclear chart with strangeness



Expand hypernuclear chart by using new spectroscopic tools

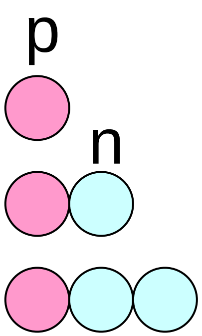
How we can expand hypernuclear chart

- Production of neutron-rich hypernuclei



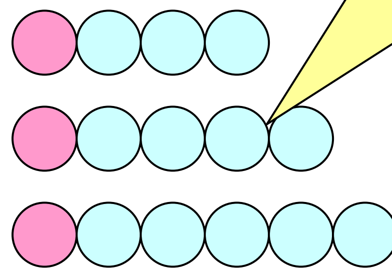
Exotic n-rich Λ-hypernuclei

- Example of "Hydrogen"



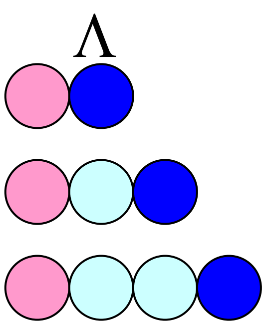
^{1}H Stable
^{2}H Stable
^{3}H Stable

Super Heavy Hydrogen

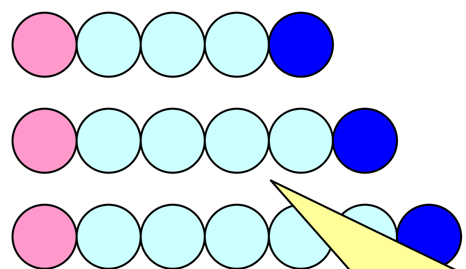


^{4}H No evidence
^{5}H Resonance
^{6}H No evidence

glue like role of Λ



$^{2}_{\Lambda}H$ Not bound
$^{3}_{\Lambda}H$ Stable
$^{4}_{\Lambda}H$ Stable

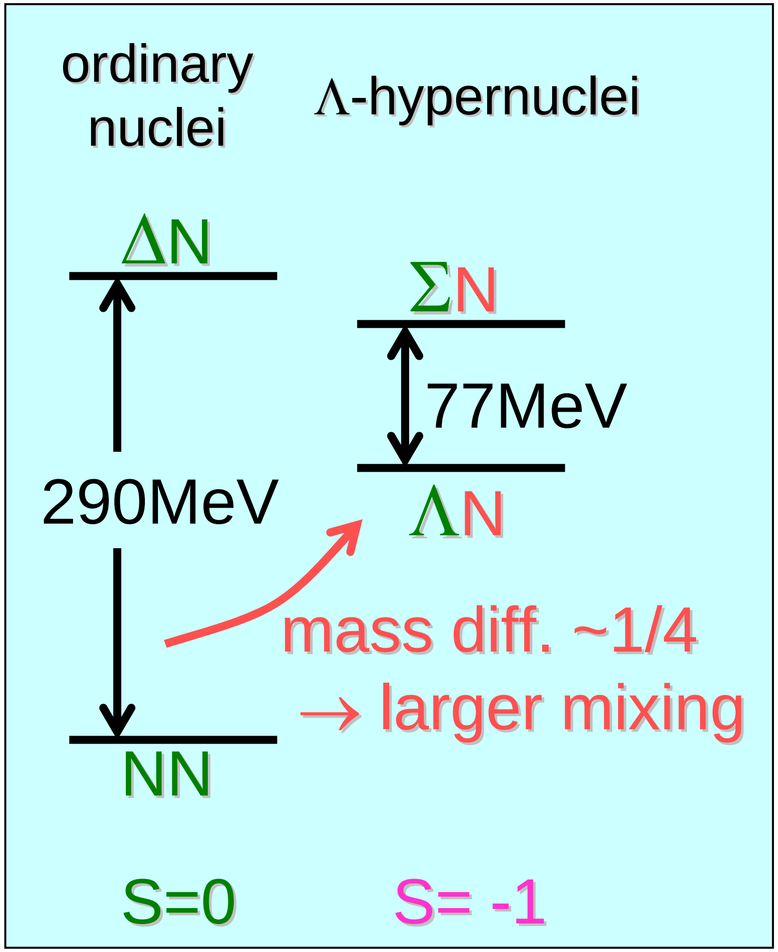


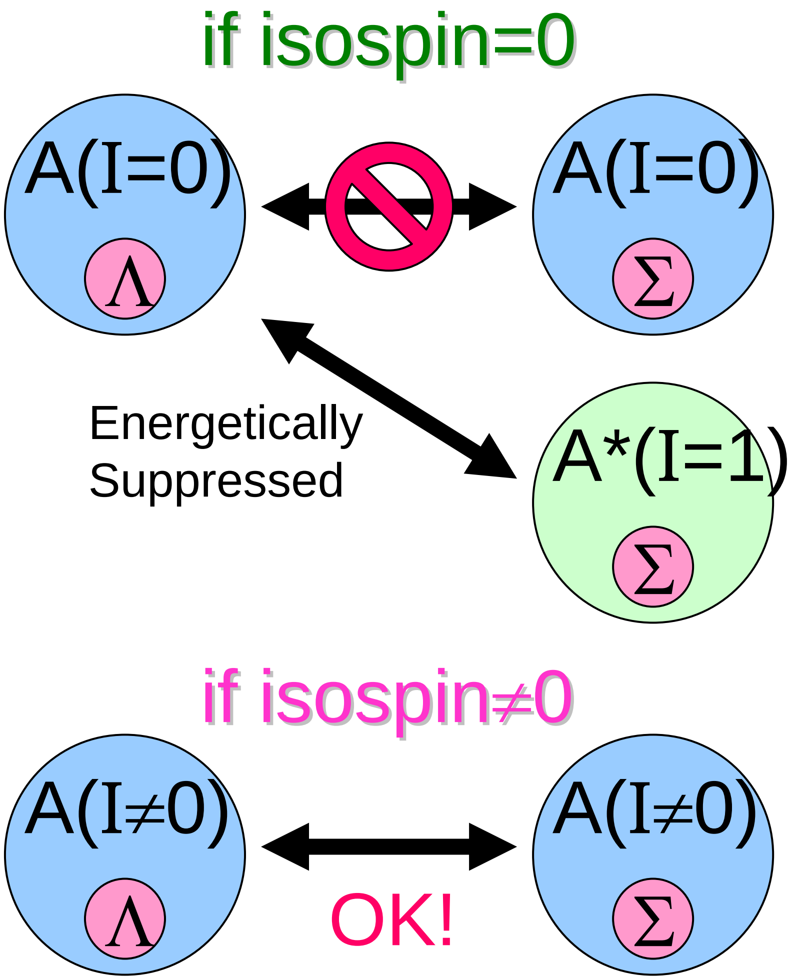
$^{5}_{\Lambda}H$ No evidence
$^{6}_{\Lambda}H$ Stable ?
$^{7}_{\Lambda}H$ Stable ?

We can produce at J-PARC

Hyper Heavy Hydrogen

ΛN-ΣN Mixing

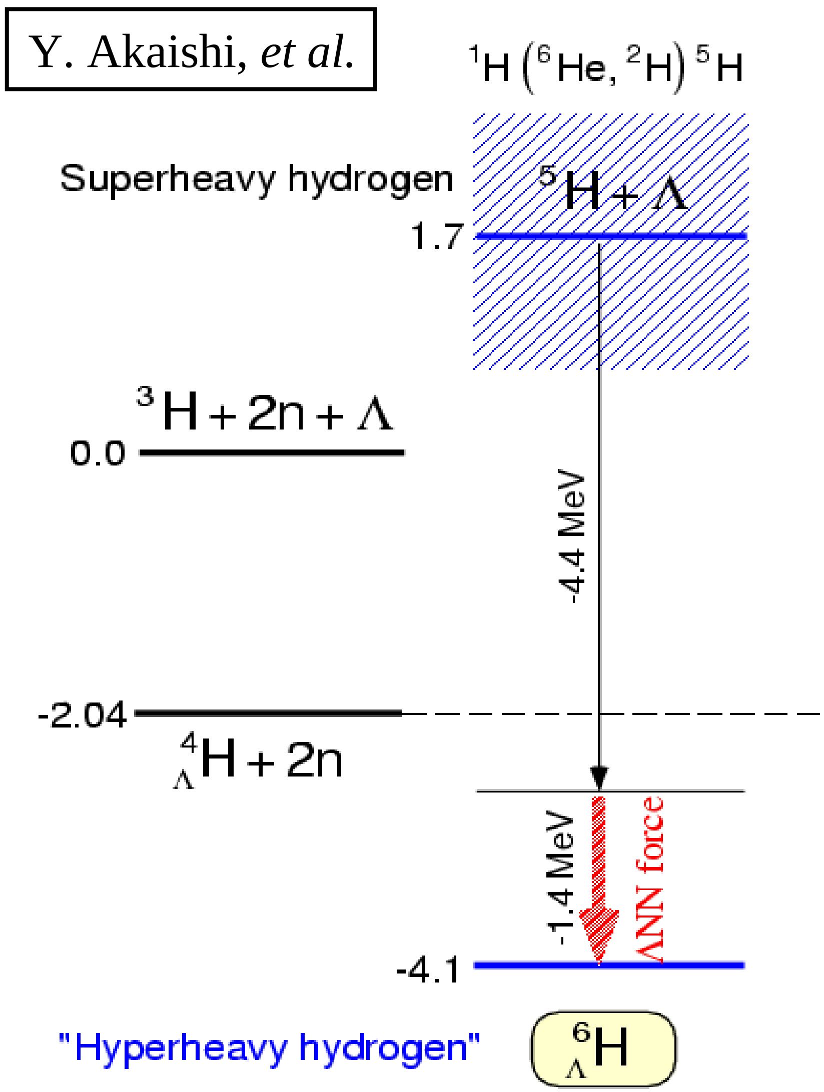




important in neutron-rich Λ-hypernuclei (large isospin)

Mixing effect in n-rich hypernuclei

- Binding energy info is important



Coherent ΛN-ΣN mixing
originally introduced to explain A=3-5 hypernuclei

Normal ΛN interaction
$B_{\Lambda} \sim 4.4$ MeV

ΛN-ΣN mixing effect
$B_{\Lambda} \sim 4.4 + 1.4$ MeV

Precise measurement of B.E.
→ Estimation of mixing effect

Production by DCX reaction

- KEK-E521 experiment established
  - $^{10}B\left(\pi^{-},K^{+}\right)^{10}_{\Lambda}Li$ reaction
  - Clean reaction

K6 beam line @KEK-PS

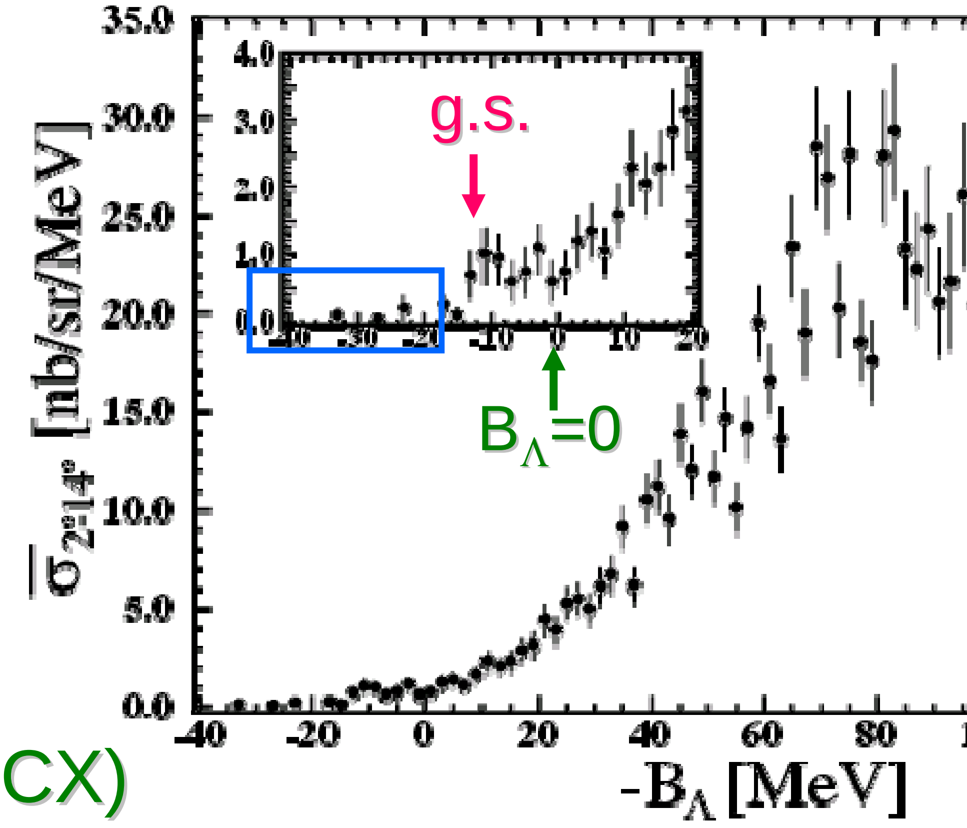
SKS spectrometer

good energy resolution

ΔB_{Λ} = 2.5MeV (FWHM)

~45 events in bound region

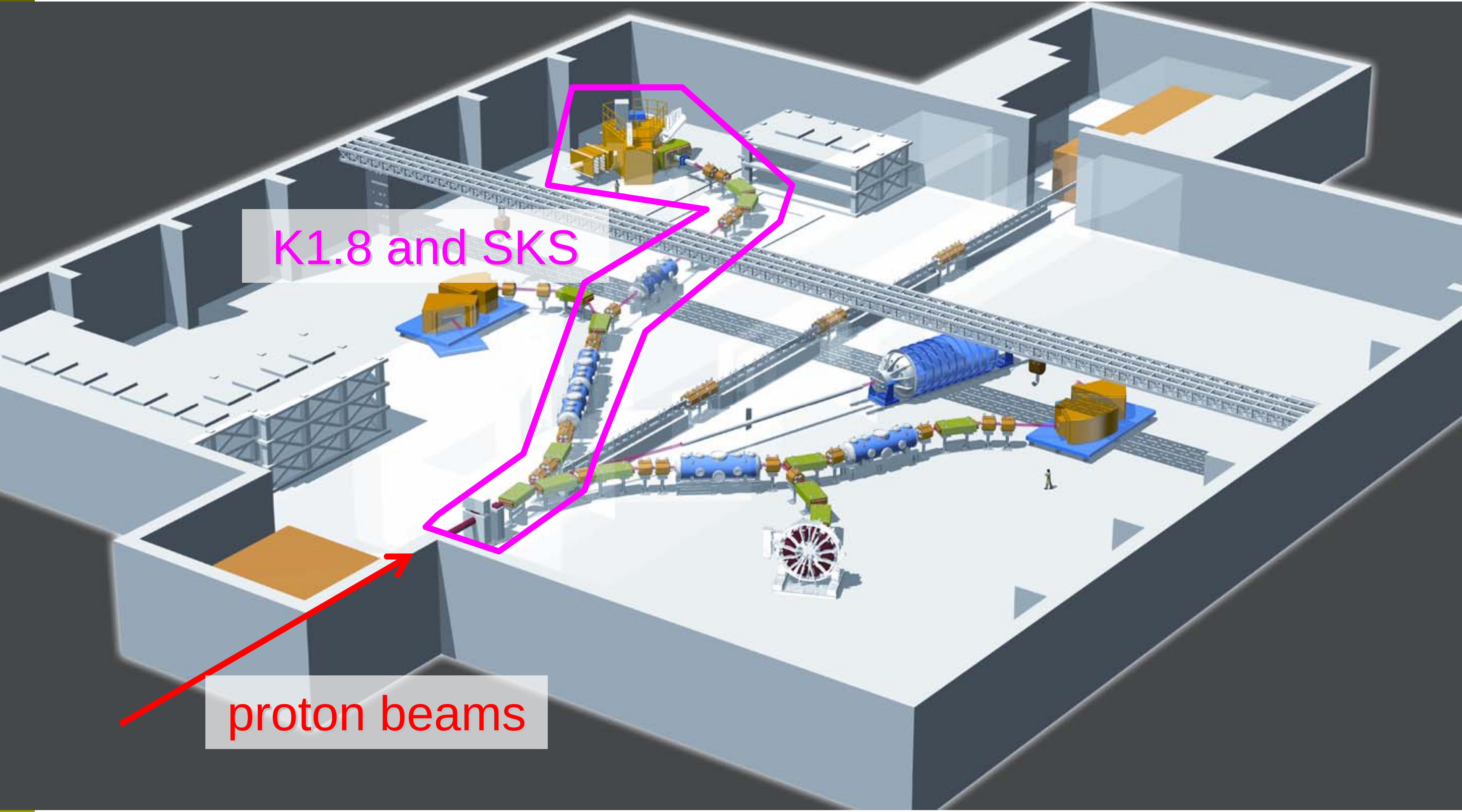
dσ/dΩ~10nb/sr (1/1000 of NCX)



Increase yield ×10 at J-PARC

Design of experiment

- Beam Lines at Hadron Experimental Hall

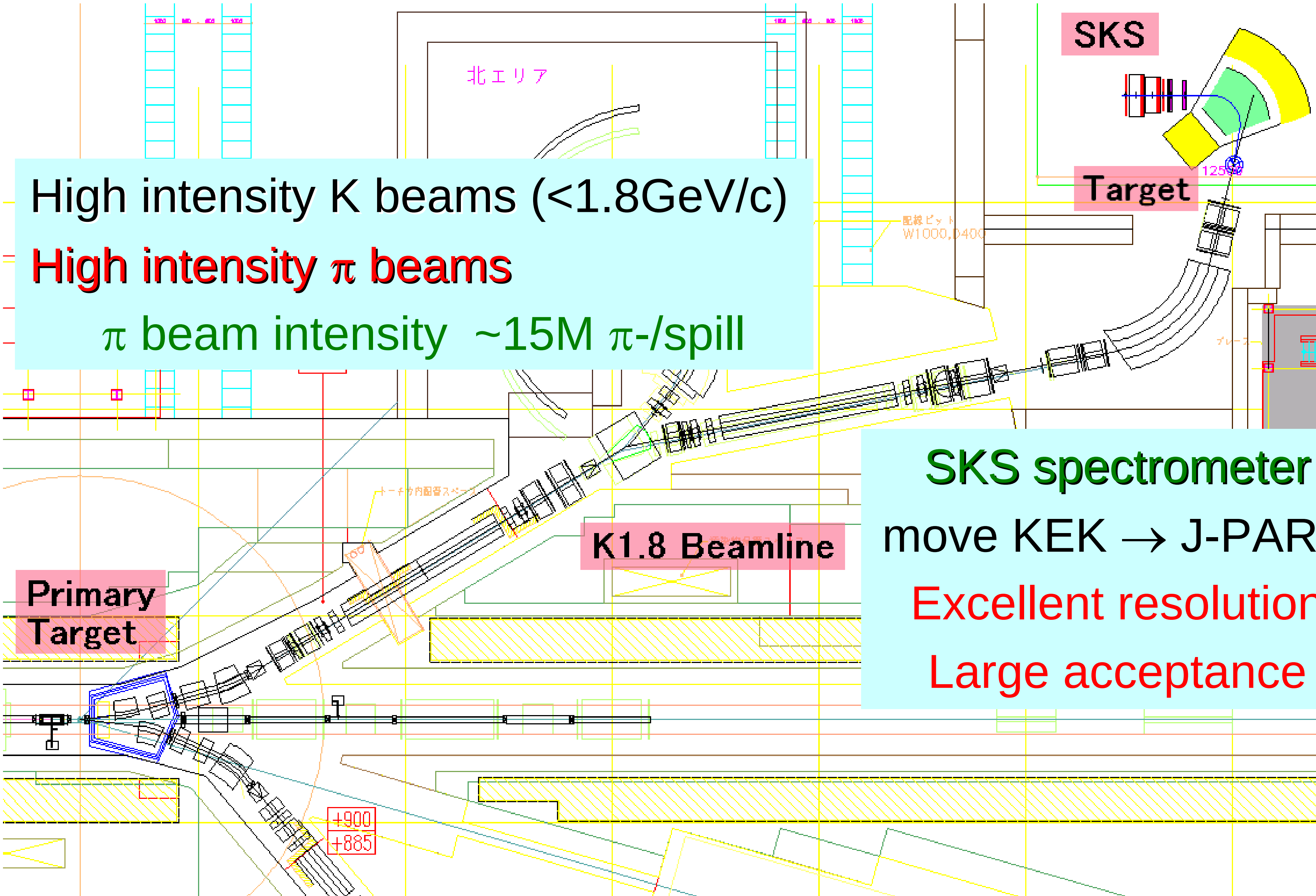


K1.8 beam line and SKS

High intensity K beams (<1.8GeV/c)

High intensity π beams

π beam intensity ~15M π-/spill



SKS spectrometer

move KEK → J-PARC

Excellent resolution

Large acceptance

Beams for DCX measurement

- Optimum π beam momentum ~ 1.2GeV/c
  - E521 experiment tells

pion beam momentum	1.05 GeV/c	1.2 GeV/c
$^{10}B(\pi^-,K^+)^{10}{}_{\Lambda}Li$ cross section	5.8 nb/sr	11.3 nb/sr

- Puzzle of reaction mechanism of DCX
  - Naïve two-step reaction

$$\pi^- + p \to K^0 + \Lambda, \quad K^0 + p \to K^+ + n$$
$$\pi^- + p \to \pi^0 + n, \quad \pi^0 + p \to K^+ + \Lambda$$

$$\sigma(1.05\ \mathrm{GeV/c}) > \sigma(1.2\ \mathrm{GeV/c})$$

  - One-step reaction with ΛN-ΣN mixing

$$\pi^- + p \to K^+ + \Sigma^-, \quad (\Sigma^- p) \to (\Lambda n)$$

Σ channel opens at 1.045GeV/c

$$\sigma(1.05\ \mathrm{GeV/c}) < \sigma(1.2\ \mathrm{GeV/c})$$

Yield estimation for $^{9}_{\Lambda}He$ production

- Cross section ~10nb/sr (~1/1000 of NCX)
- Major difficulty in this experiment

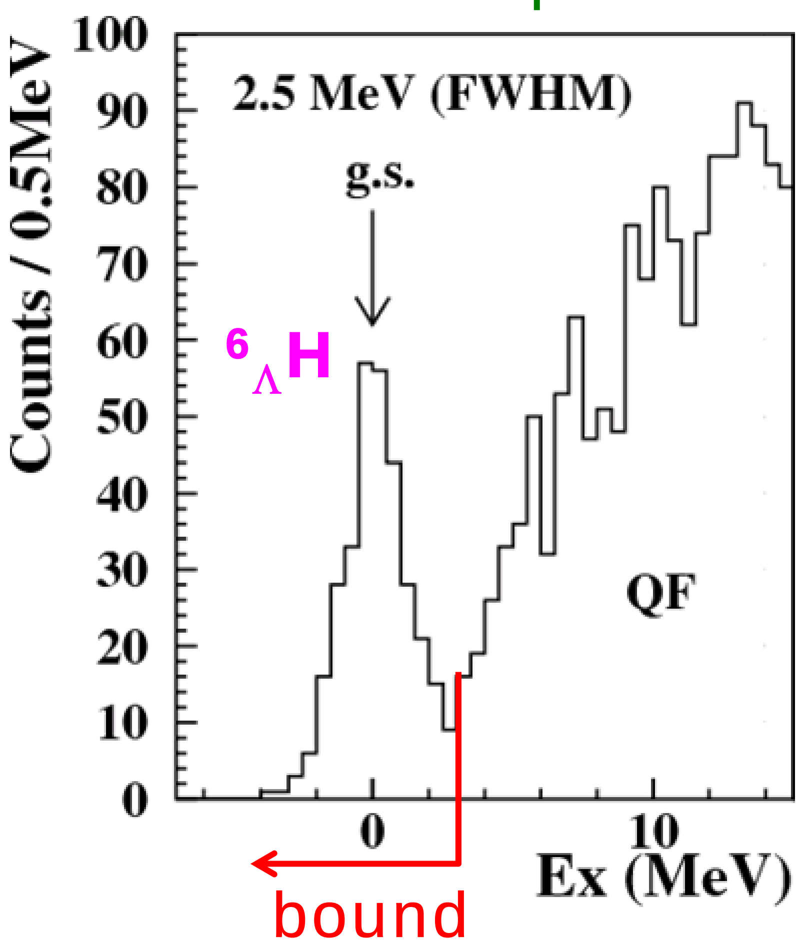
Parameters	Values	
π^- beam momentum	1.2 GeV/c	
π^- beam intensity	**1.5 x 10^7 /spill**	← High intensity beams
PS acceleration cycle	5.7 s/spill	
^{9}Be target thickness	3.5 g/cm^2	
Reaction cross section	10 nb/sr	
Spectrometer solid angle	**0.1 sr**	← Large acceptance
Spectrometer efficiency	0.5	
Analysis efficiency	0.5	

- About 300 events in 3 weeks of beamtime
  - 7 times larger ← KEK-E521 (47 events)
  - Discussion on level structure possible with new data

Prospects on B.E. measurement

- Measurement of B.E. of $^{6}_{\Lambda}$H

simulated spectrum



Assumptions

overall energy resolution

≈ 2.5 MeV(FWHM)

$^{6}_{\Lambda}$H yield

≈ 300 events

$^{6}_{\Lambda}$H/QF ratio (Ex<23MeV)

$\approx 1/10$

Well separated from QF

Statistical error of B.E. < 0.1MeV

Minimize systematic errors

Summary

- We need new spectroscopic tools to expand the hypernuclear chart
  - Further study on the S=-1 system
  - DCX reaction is a candidate and promising
- J-PARC E10 proposal
  - Produce neutron-rich Λ-hypernuclei by DCX
  - Use K1.8 beam line and SKS spectrometer
  - Study exotic hypernuclei ($^{6}_{\Lambda}$H, $^{9}_{\Lambda}$He)
  - Increase yield (×~10) from E521
  - Investigate ΛN-ΣN mixing effect by precise measurement of binding energies of neutron-rich hypernuclei