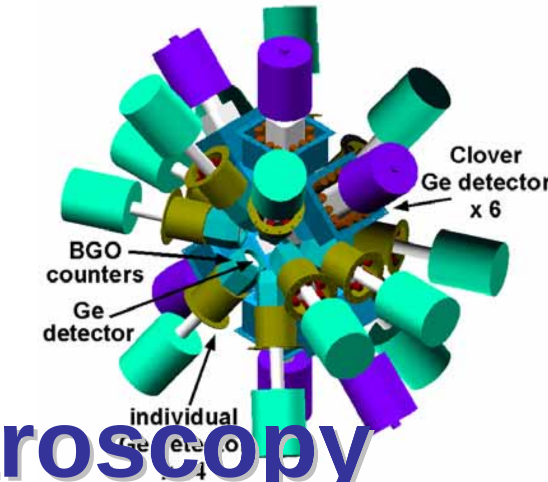

Hypernuclear γ-ray spectroscopy via Hyperball2 array

Department of Physics, Tohoku University

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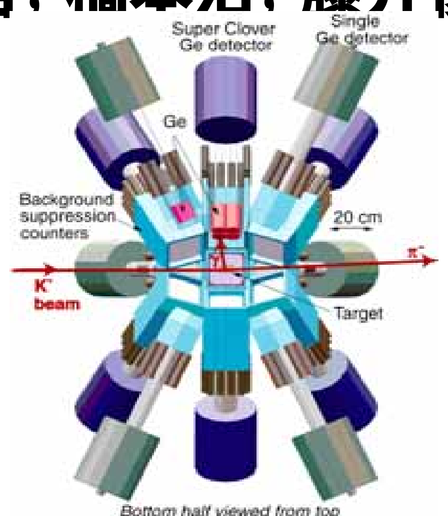
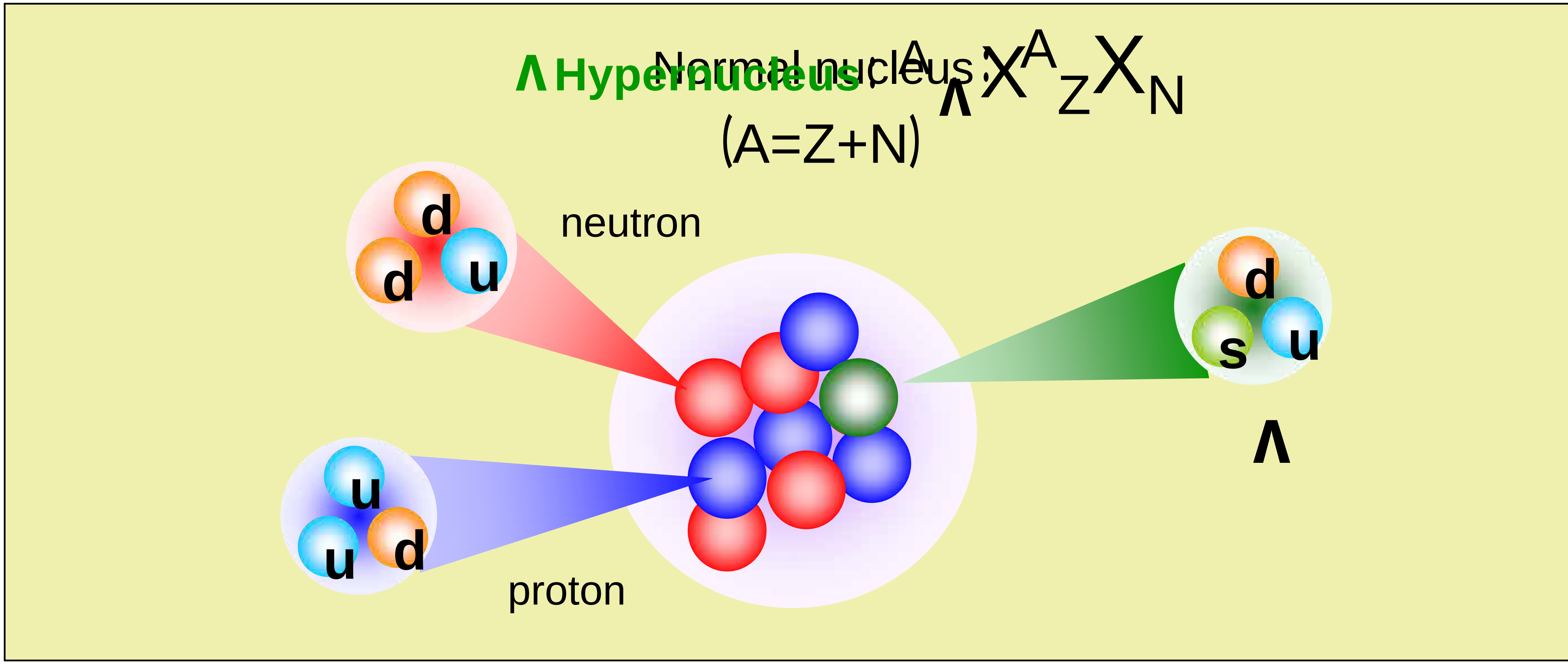
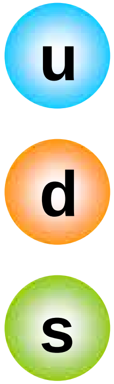


Outline

- Why study hypernuclei ?
- Why hypernuclear γ–ray spectroscopy ?
- Recent progress
- Planned experiment with Hyperball2
- Future and possibility with J-PARC
- Summary

Nuclei with strangeness：Hypernuclei





Up quark

Down quark

Strange quark

Baryons with strangeness ＝**Hyperon**

(Λ, Σ^0, Σ^+, Σ^-, Ξ^0, Ξ^-)

→nuclei with strangeness＝Hypernuclei

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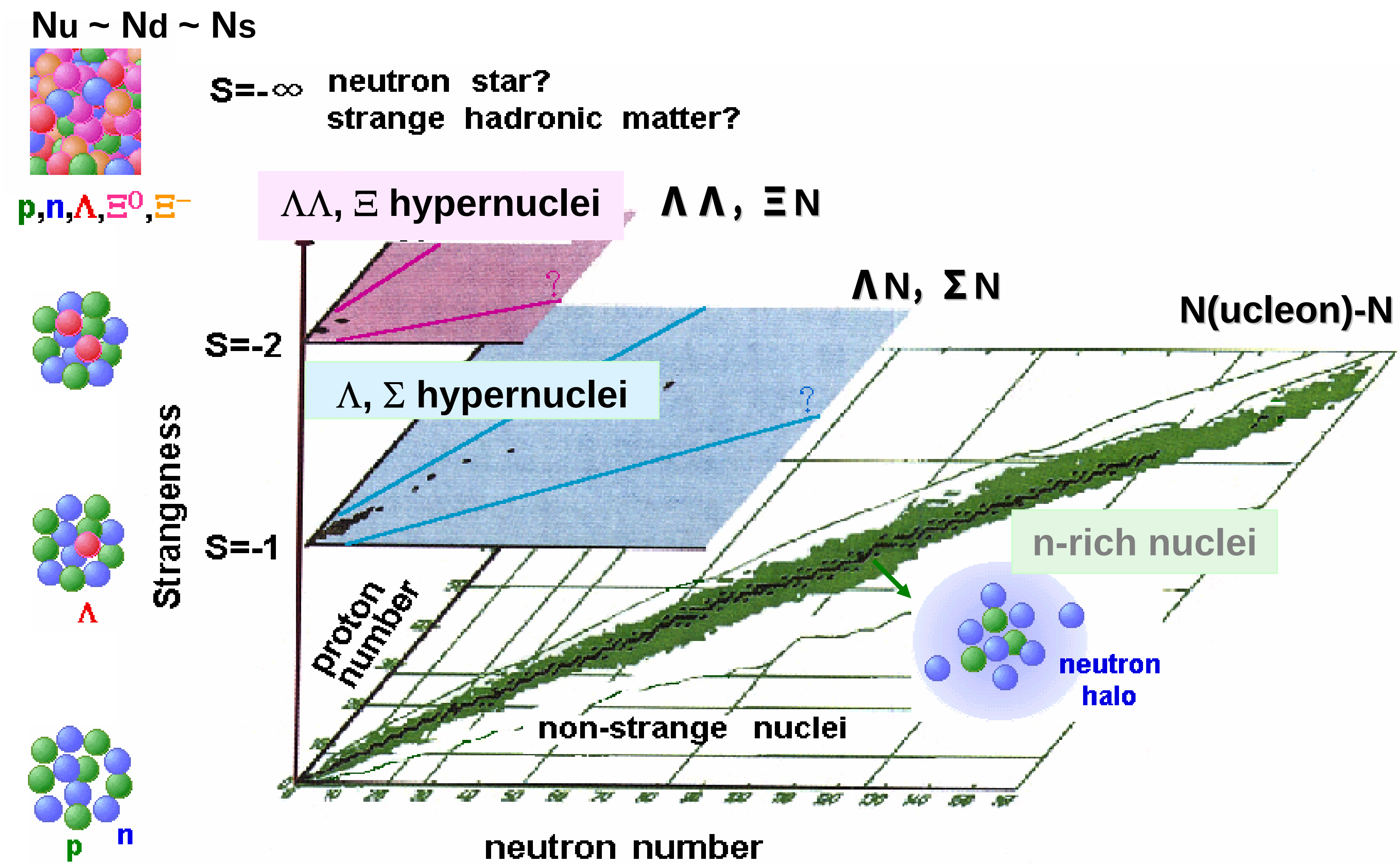
Expanding Nuclear Chart: 2D → 3D



No Pauli effect of nucleons on hyperons

Pauli principle

→ Independent particle model (shell structure)

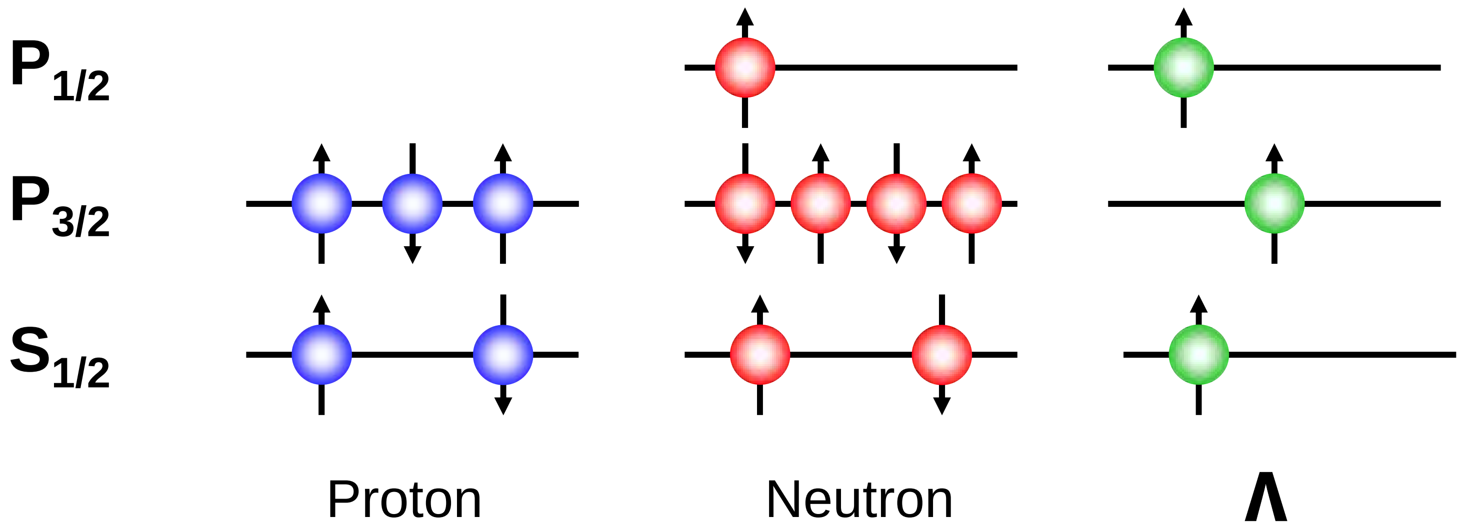
New degree of freedom

→novel types of structural change in nuclei

(size and shape changes of nuclei → shrinkage effect)

Effects of nuclear medium on baryons

(magnetic moment)



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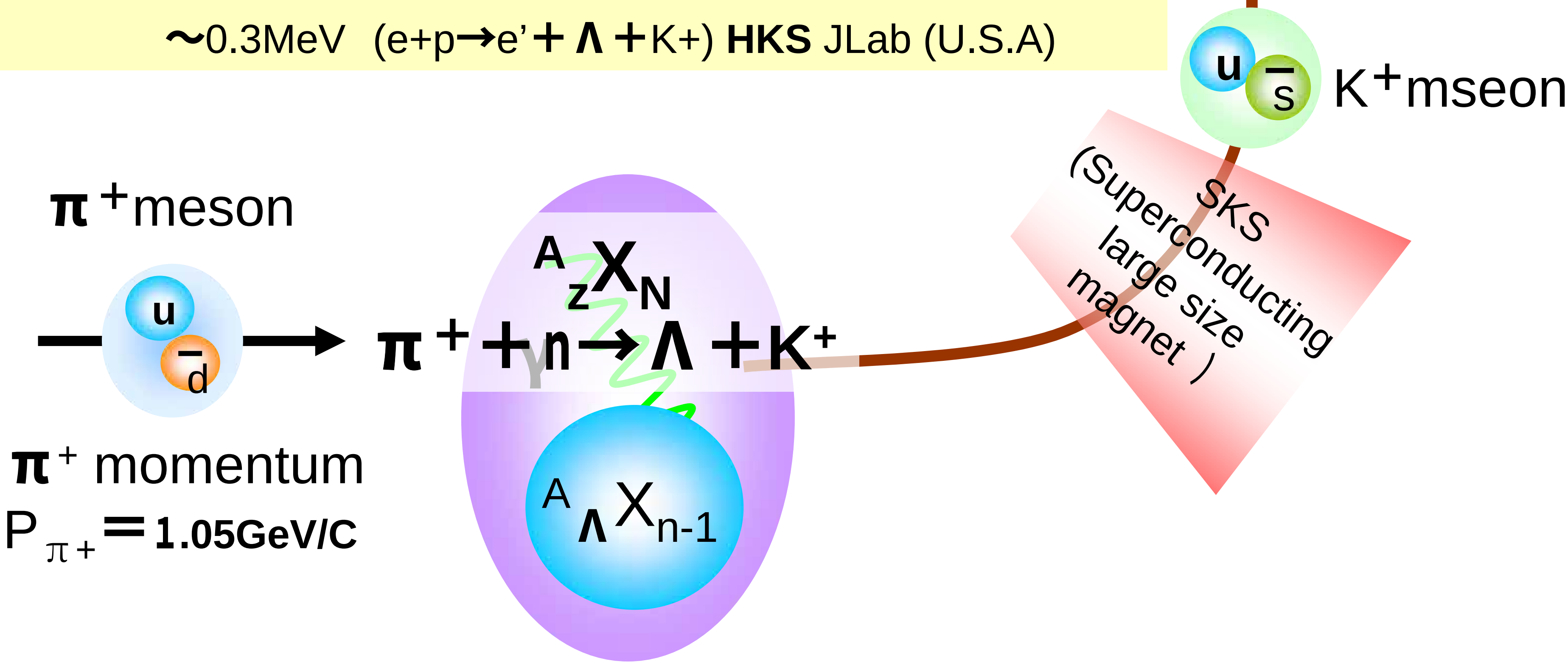
Reaction spectroscopy :

Resolution: ~**2**MeV ($\pi^+ + n \rightarrow \Lambda + K^+$, $K^- + n \rightarrow \Lambda + \pi^-$)

～0.3MeV (e+p→e'＋Λ＋K+) **HKS** JLab (U.S.A)

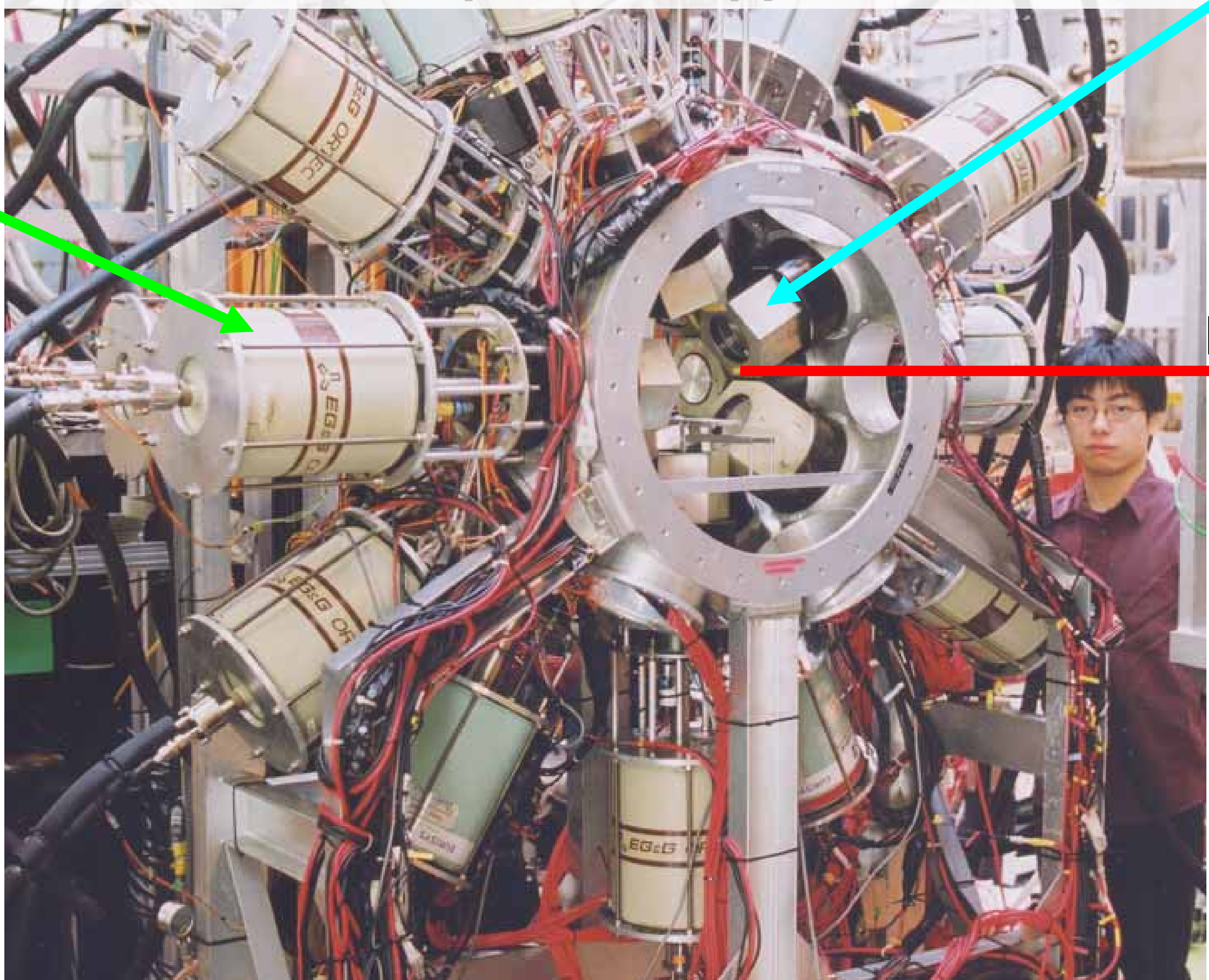


γ -ray spectroscopy with Germanium detectors

Resolution:～**0.002**MeV

Hyperball Ge array (Tohoku, Kyoto, KEK, 1998)

A dawn of high resolution hypernuclear γ–ray spectroscopy



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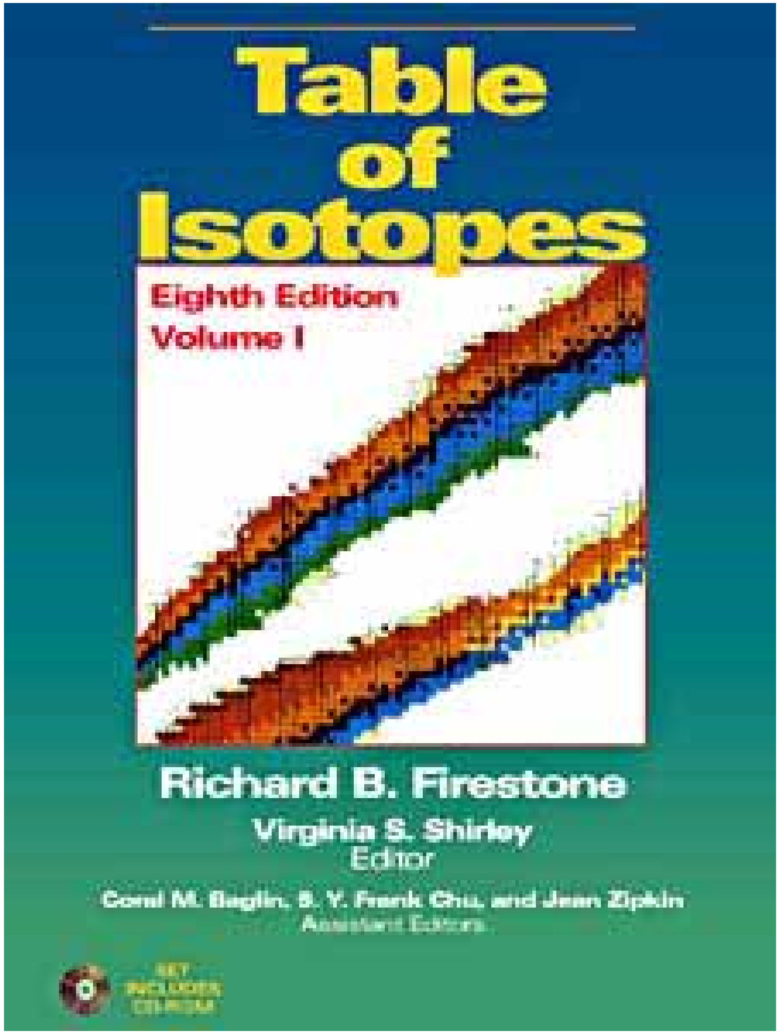
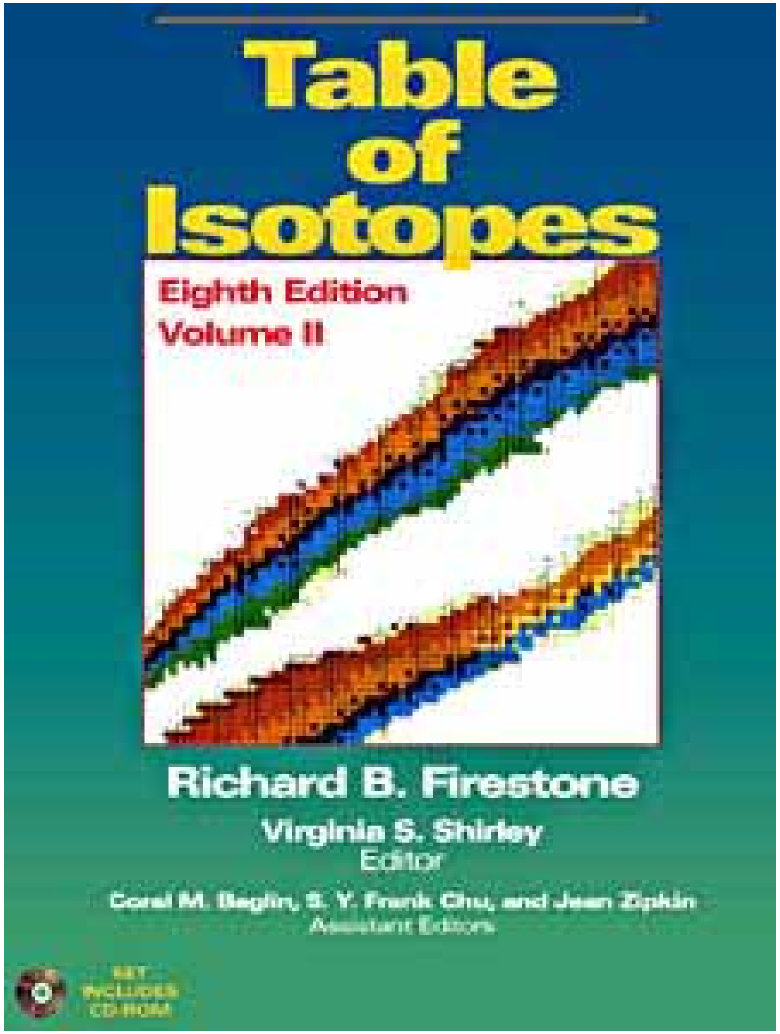
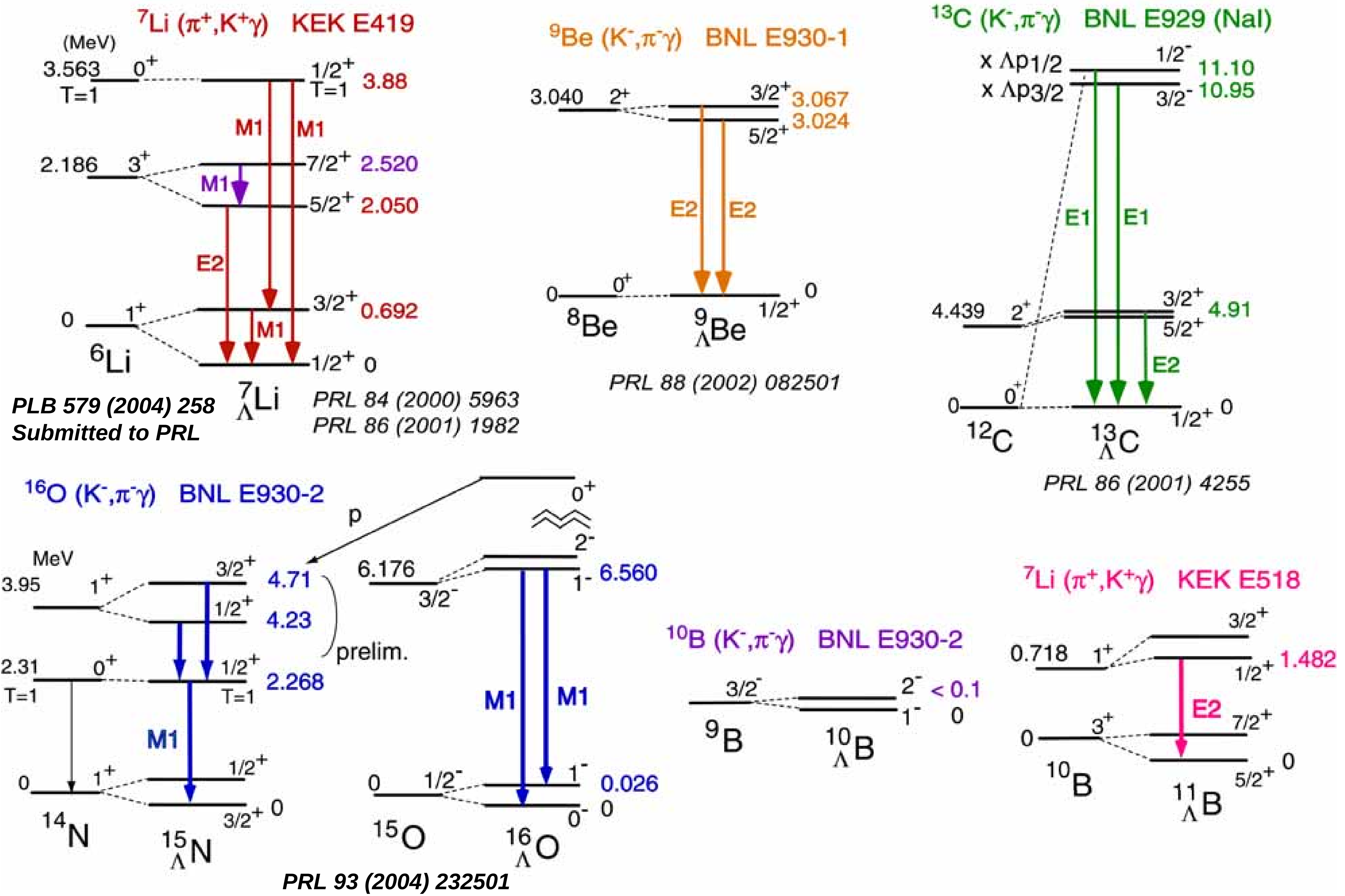
Contains nuclear structure and decay data for over **3,100** isotopes and isomers

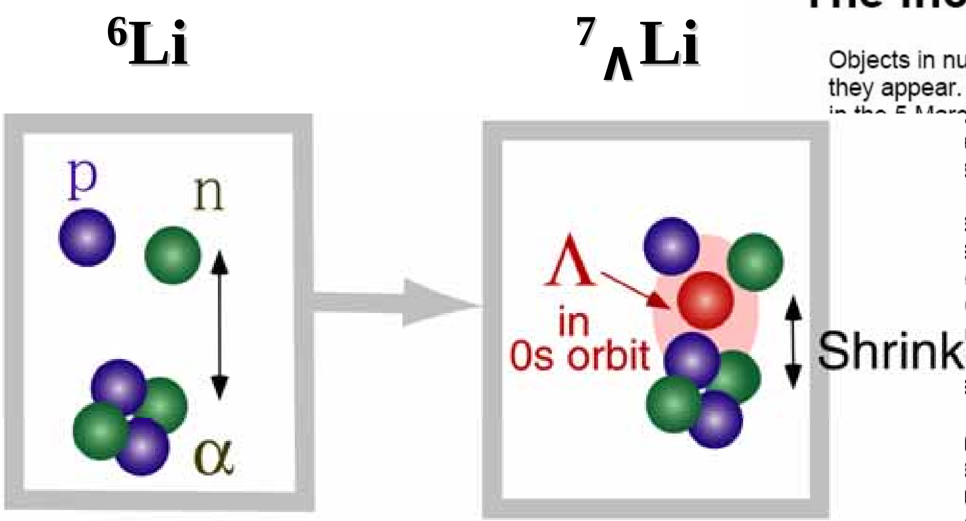




A road to *Table of Hyper-isotopes*



Structural change in nucleus with a presence of Λ



B(E2) [e^2 fm^4] $10.9 \pm 0.9 \longrightarrow 3.6 \pm 0.5 \pm^{0.5}_{0.4}$

⇒ 19±4% Shrinkage by Λ

Physical Review Focus

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Phys. Rev. Lett. 86, 1982
(issue of 5 March 2001)
Title and Authors

1 March 2001

The Incredible Shrinking Nucleus

Objects in nucleus may be smaller than they appear. At least, that's what a paper in the 5 March *PRL* suggests. The authors ...e decay of a lithium isotope ...s core a lambda particle--a ...one of its two down quarks ...a strange quark--and found ...eus had shrunk. The lambda ...ls to the center of the nucleus ...ind it more tightly together. ...ent is one of the first to give ...ook at interactions of such ...eons inside the nucleus.

H. Tamura/Tohoku Univ.

Eyes on the nucleus. Researchers used Hyperball's 14 sensitive detectors to show that a strange quark dramatically shrinks the size of a nucleus..

...rists predicted that the ...a lambda particle inside a ...us could cause it to shrink. ...da is neither a proton nor a ...not constrained by the Pauli ...nciple, which prevents ...leons from occupying the ...and defines the size of the nucleus. This property allows the ...ke up no space and to slide into the center of a nucleus, where its ...g energy pulls the other nucleons closer together. But for almost ..., there was no experiment that could confirm this prediction.

Now a collaboration led by Kiyoshi Tanida of Tokyo University has found evidence that nuclear shrinkage does exist. The team fired pions into a target of lithium to produce lithium-lambda nuclei. They found the lifetime of these excited nuclei by measuring the spectrum of gamma rays emitted when the lithium-lambdas decayed to their ground state. "The lifetime is very sensitive to the size of the nucleus," Tanida explains, so it led directly to a size estimate.

This experiment was challenging because it required an extremely accurate measurement of the gamma rays, which were emitted in every direction from the target. The team used an instrument called Hyperball, which consists of 14 high-resolution germanium detectors positioned in a spherical arrangement.

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Experiments with Hyperball2

(Being assembled)

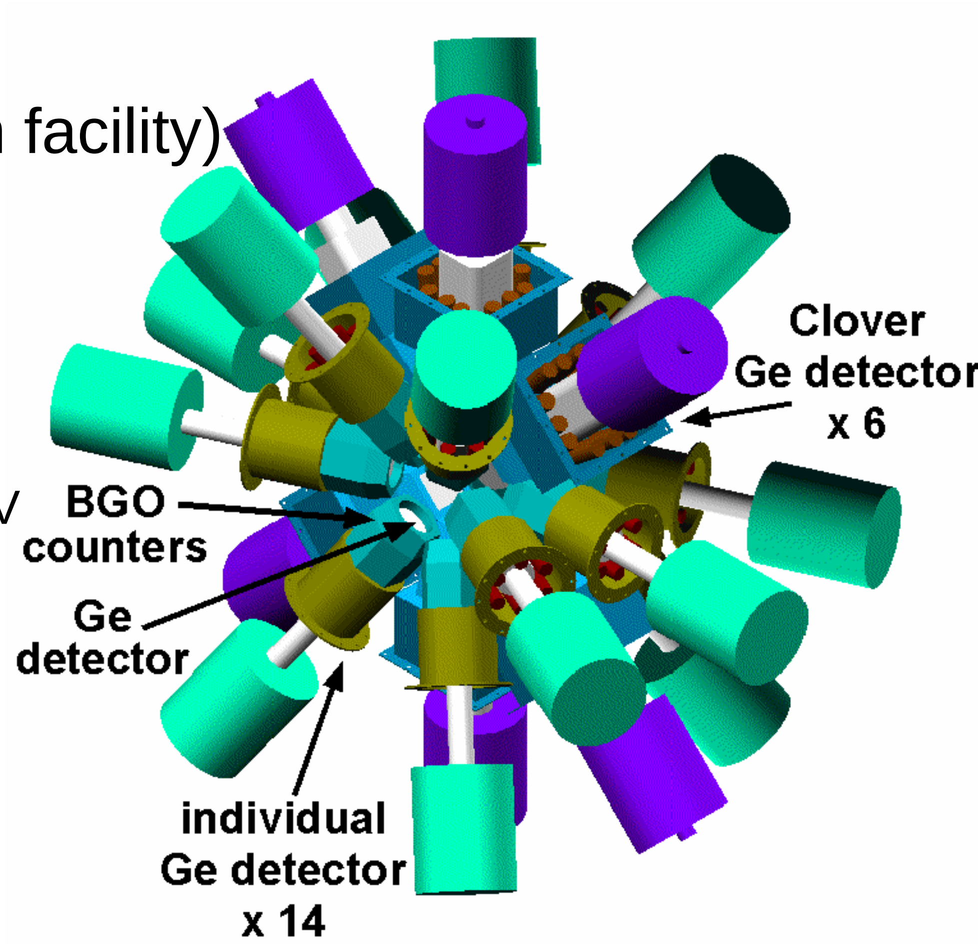
Hypernuclei γ-ray spectroscopy

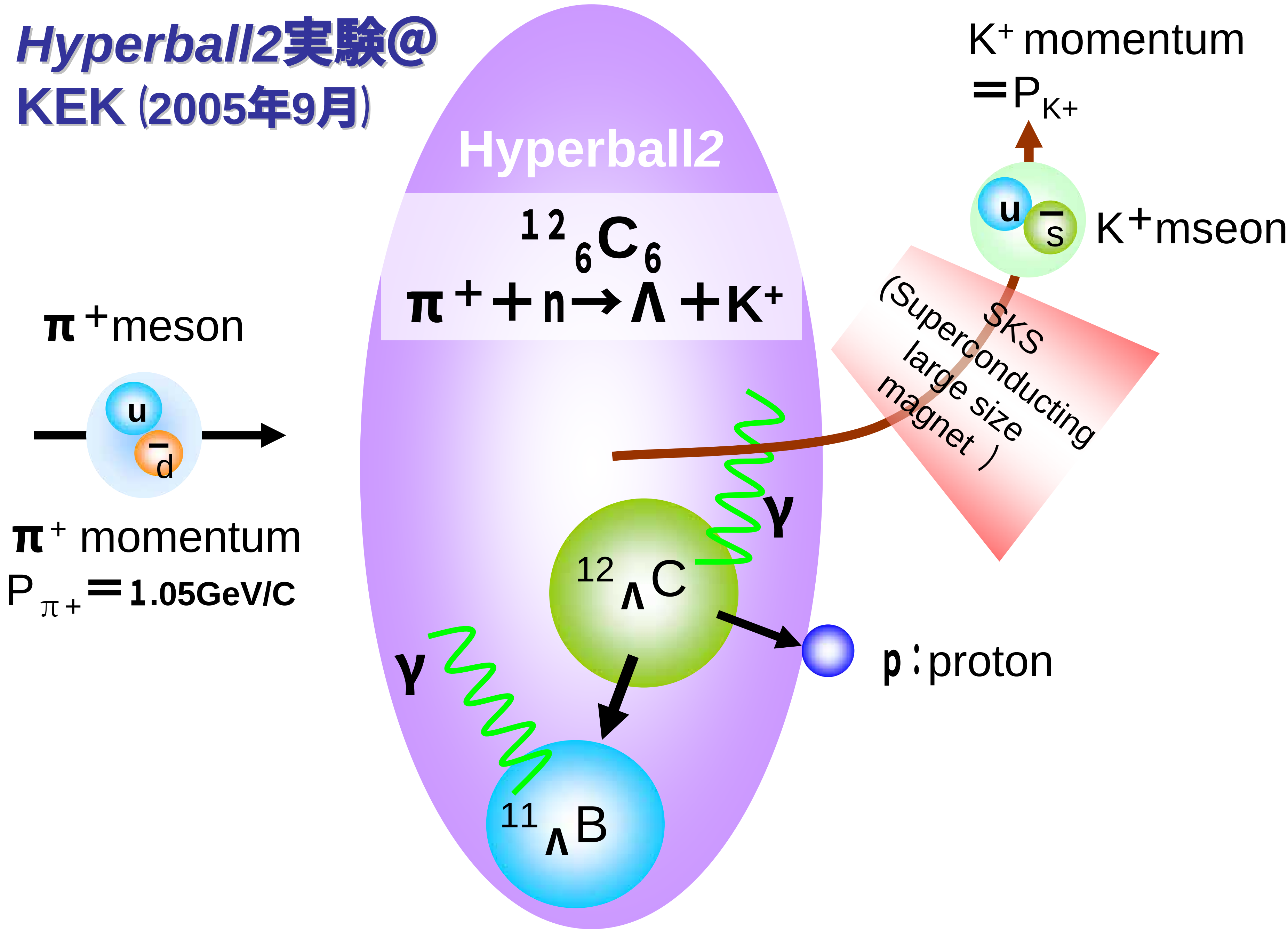
(KEK@Tsukuba/BNL@New York State)

In-beam experiment

(Tohoku University Cyclotron facility)

- [Single Ge (60%) +BGO] x 14
  + [Clover type Ge (125%) +BGO] x 6
  → Photopeak efficiency ~ 5% at 1 MeV
- Super high rate electronics
  ~ 1 TeV/sec, 100 kHz
- VME-based data readout





Hyperball2実験@
KEK (2005年9月)
Hyperball2
12 6 C 6
π+ + n → Λ + K+
π+meson
u
d
π+ momentum
Pπ+ = 1.05GeV/C
K+ momentum
= PK+
u
s
K+mseon
SKS
(Superconducting
large size
magnet)
γ
12 Λ C
γ
11 Λ B
p : proton

Magnetic moment measurement in $^{11}{}_{\Lambda}B$

Does magnetic moment of Λ change in nuclear medium？

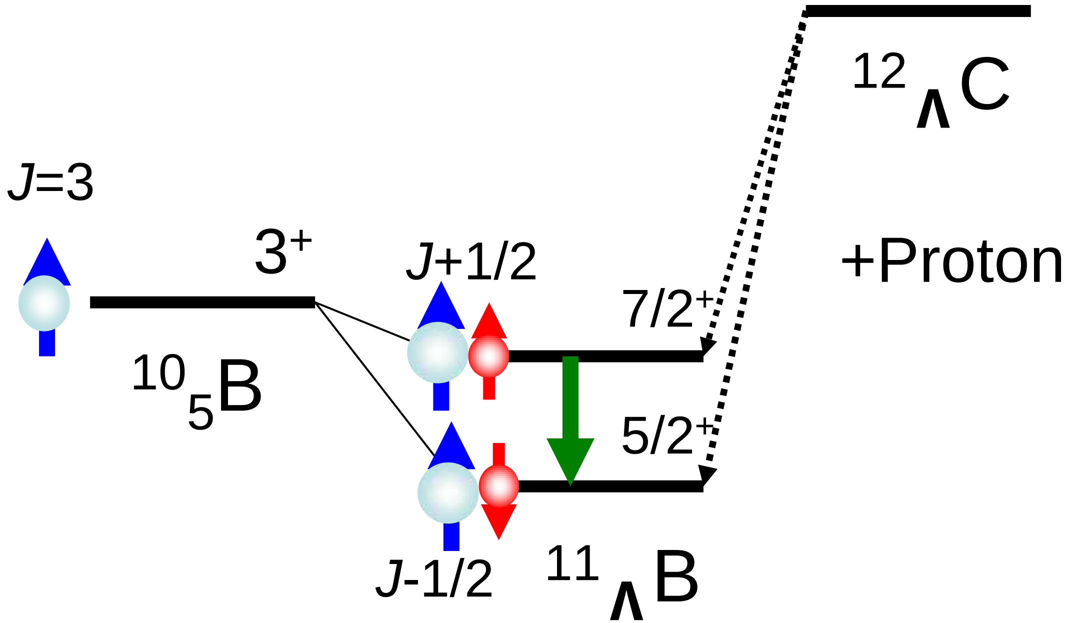
Short lifetime of hyper nuclei:１００～２００ps

→direct measurement of μ_{Λ} difficult

Measurement of Λ spin-flip transition probability

(B(M1：$7/2^{+}$→$5/2^{+}$) via Doppler shift attenuation method)

→Extraction of μ_{Λ} in nuclear medium



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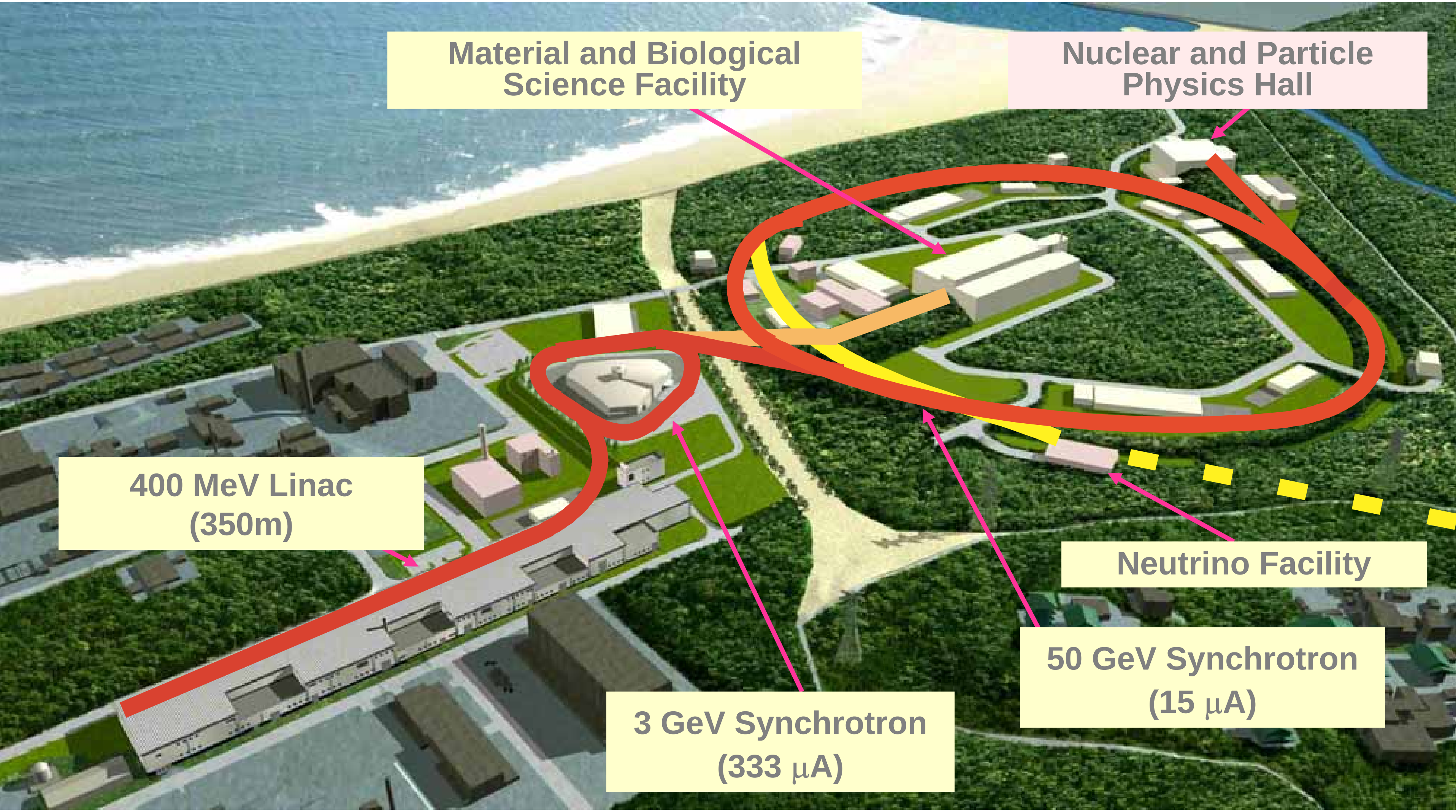
J-PARC (Japan Proton Accelerator Research Complex)

By KEK+JAERI, will be completed in 2008 at Tokai, Japan

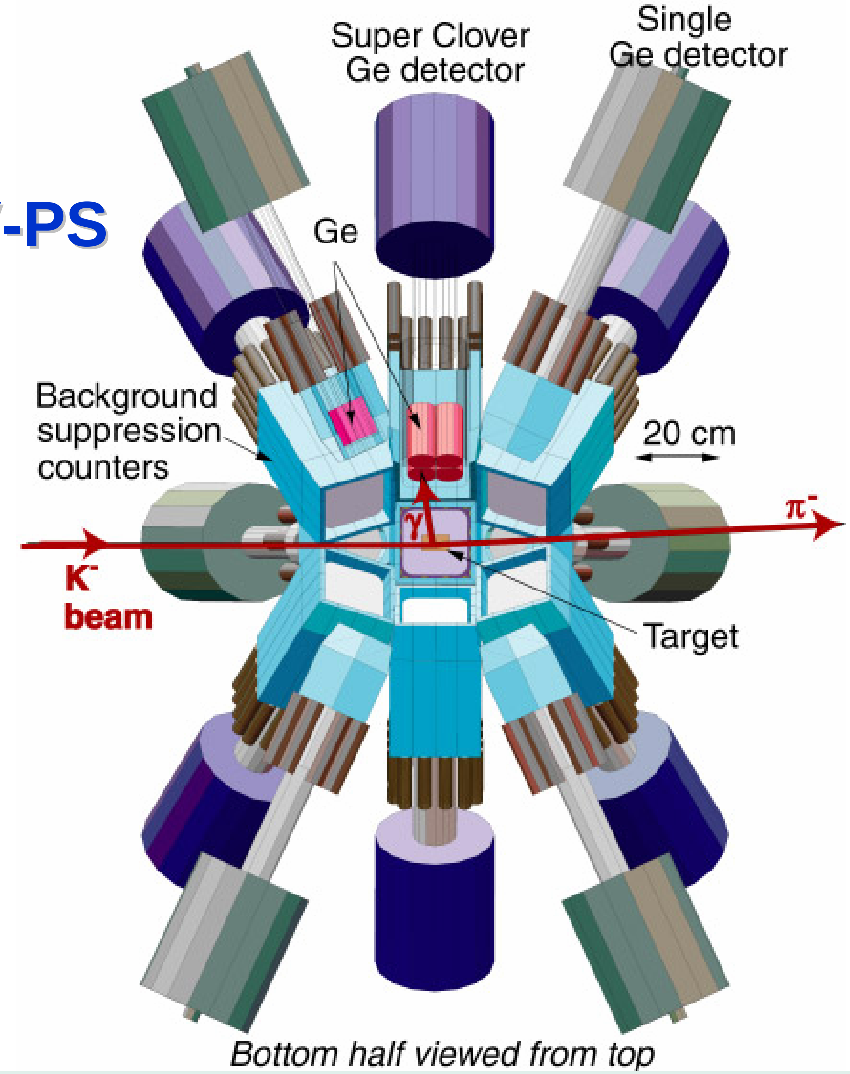


Hyperball-J

Experimental challenges with Intense beam provided by 50GeV-PS

Enormous background

Piling up of Ge signals



- ε > 10% at 1 MeV (x4 of Hyperball)
- Rate limit ~2x10^7 particles /s (x5)
- Yield: x20 for single γ
  x80 for $\gamma\gamma$

-> Systematic study of light to heavy Λ hypernuclei
B(M1)-> μ_Λ, Ξ atomic X-rays

Summary

- **Nuclear world is expanded by including hypernuclei with strangeness.**
- **Construction of *Hyperball* has realized γ-ray spectroscopy of hypernucleus for the first time with a few keV resolution.**
- **Hyperball2 is being constructed and preparation for experiments are ongoing.**
- **J-PARC provides new possibilities in hypernuclear studies.**