June 9, 2003

Hadron-Beam Based Physics at a Neutrino Factory Complex

(Who want 10 MW class high-intensity beams other than neutrino and muon physicists?)

+

a few slides on the J-PARC Status if time allows

Shoji Nagamiya

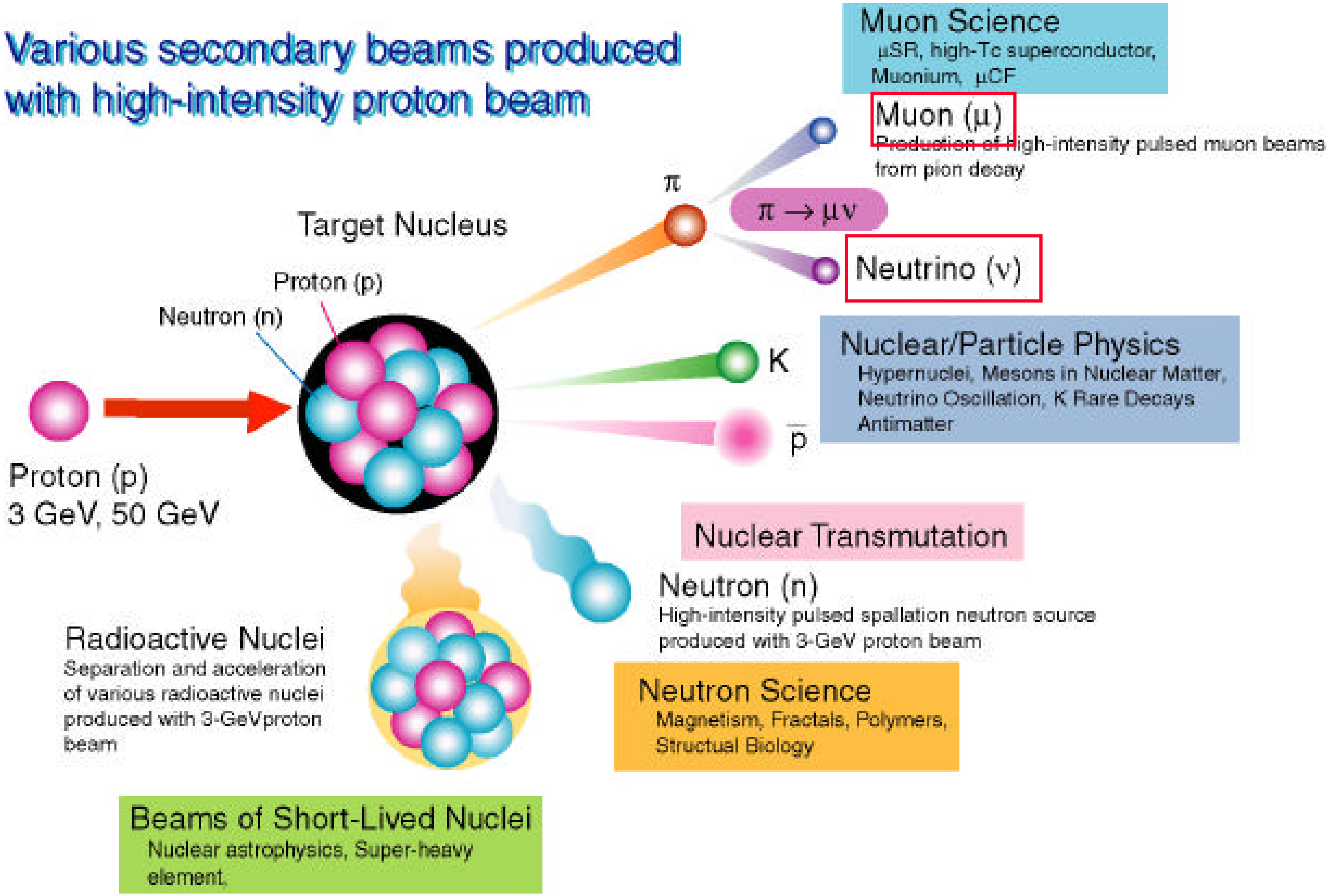
KEK

Research Areas with High Intensity Beams

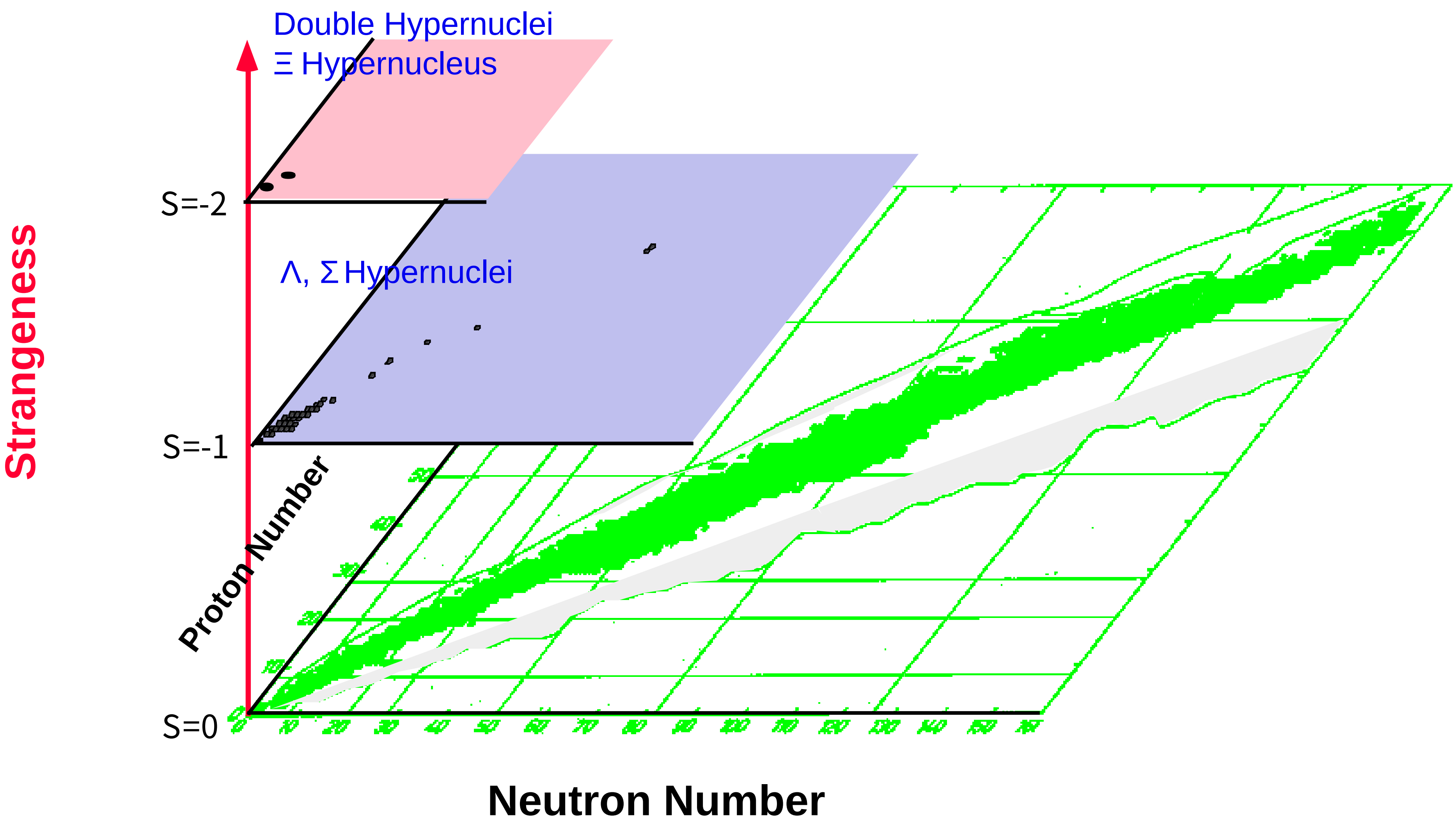
- Neutrino Physics: Already covered by many speakers
- Muon Physics: See the talks by A. Baldini and K. Ishida
- Kaon Physics:
  - Studies of double-strangeness hypernuclei, rare decays.
- Heavy-Ion Physics:
  - Search for strange matter, usage of radioactive nuclear beams far from the stability line.
- Antiproton Physics:
  - Creation of anti atoms, slow/trapped antiprotons.
- Hyperon Beam Physics:
- Physics with Other Beams such as Polarized Protons:
- Neutron Sciences:
  - Neutron scatterings to study dynamical structure of proteins and DNA, spin excitation in a magnetic alloy, etc.
- Accelerator Driven Nuclear Transmutation:
  - Usage of high-flux neutrons to change lifetimes of radioactive nuclei.

My Talk

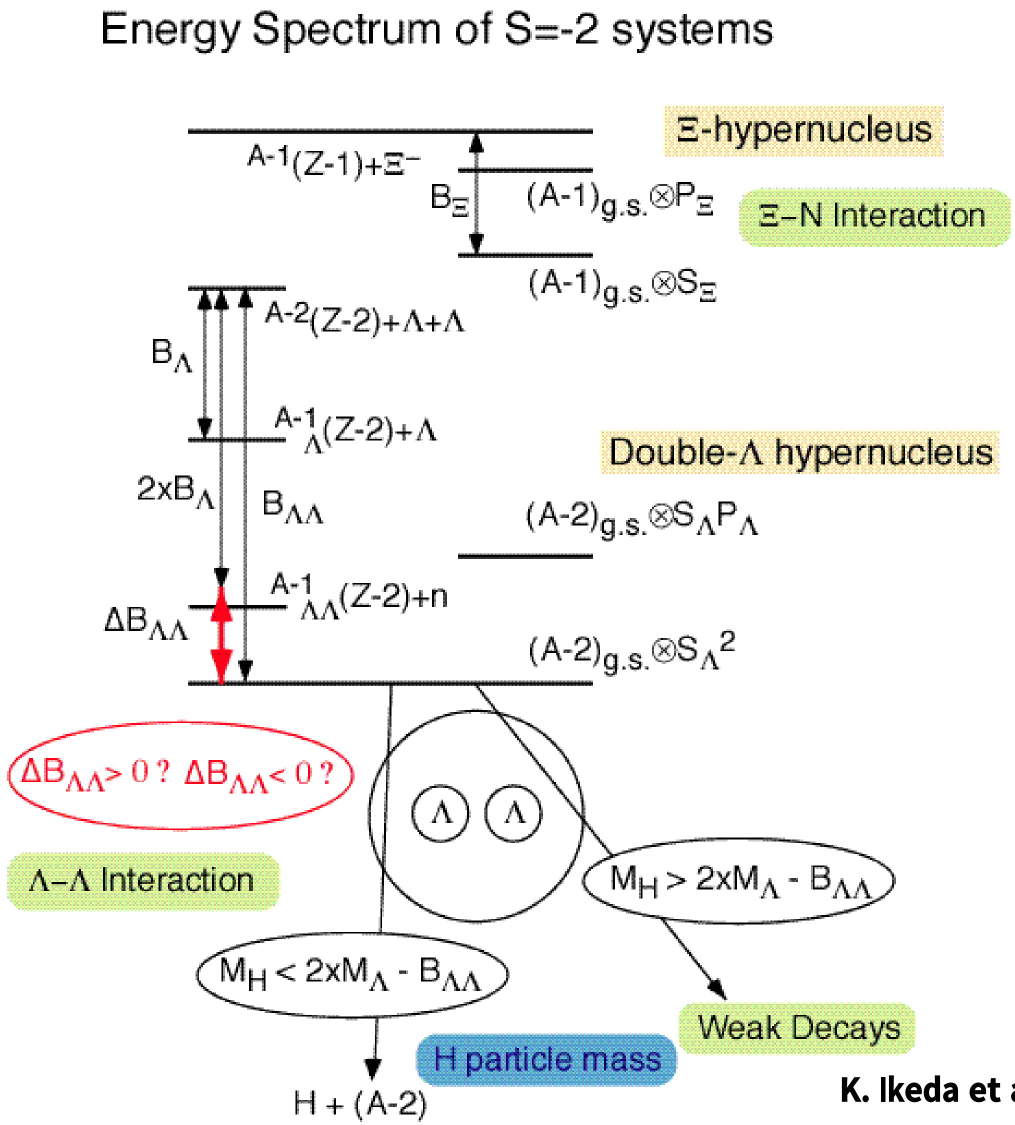
Various Beams Obtained by p+A Collisions



Three Dimensional Nuclear Chart



S = -2 Hypernuclei

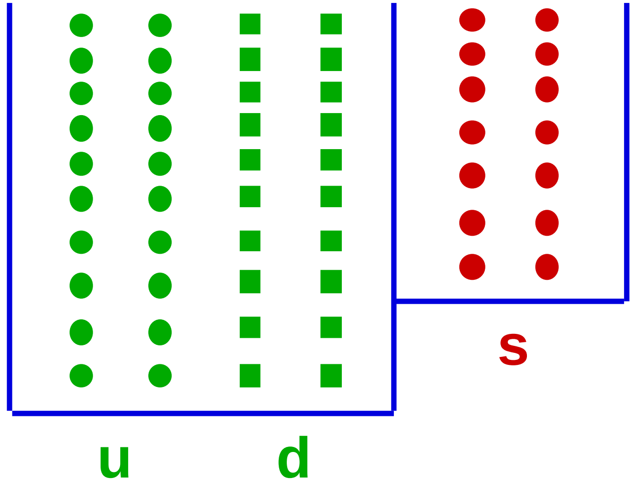


- Spectroscopic studies on S=-2 systems
  - (K⁻,K⁺): Ξ-hypernuclei
    - » SKS ~ 6 events/MeV/day
    - » for 1 MW beams
  - (K⁻,K⁺) π π : Double-Λ hypernuclei (g.s.) CDS
  - (K⁻,K⁺)γ: Double-Λ hypernuclei (excited sates) HyperBall
- YN(S=-2) Scattering: Ξ⁻p CDS

K. Ikeda et al., Prog. Theor. Phys. 91 (1994) 747

Strangelet and H^0

Strangelet



$Z(u) = +2/3\ e$
$Z(d) = -1/3\ e$
$Z(s) = -1/3\ e$

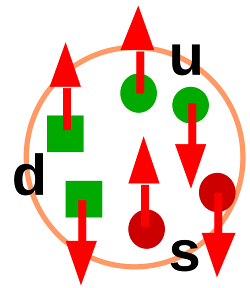
$\rightarrow Z_{strangelet} = (2n_u - n_d - n_s)/3\ e \approx (n_u - n_s)/3\ e \gtrsim 0$

$$\left(\frac{Z}{A}\right)_{strangelet} \approx \frac{(n_u - n_s)}{3(m_u + m_d + m_s)}\ e$$: small positive

Au + Au at 10 A•GeV: $n_s \approx$ a few 100 !

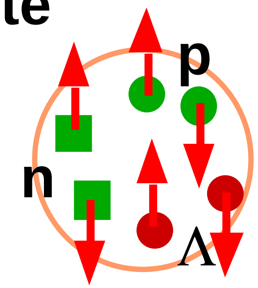
H^0

(the most simple strangelet)



spin = isospin = charge = 0

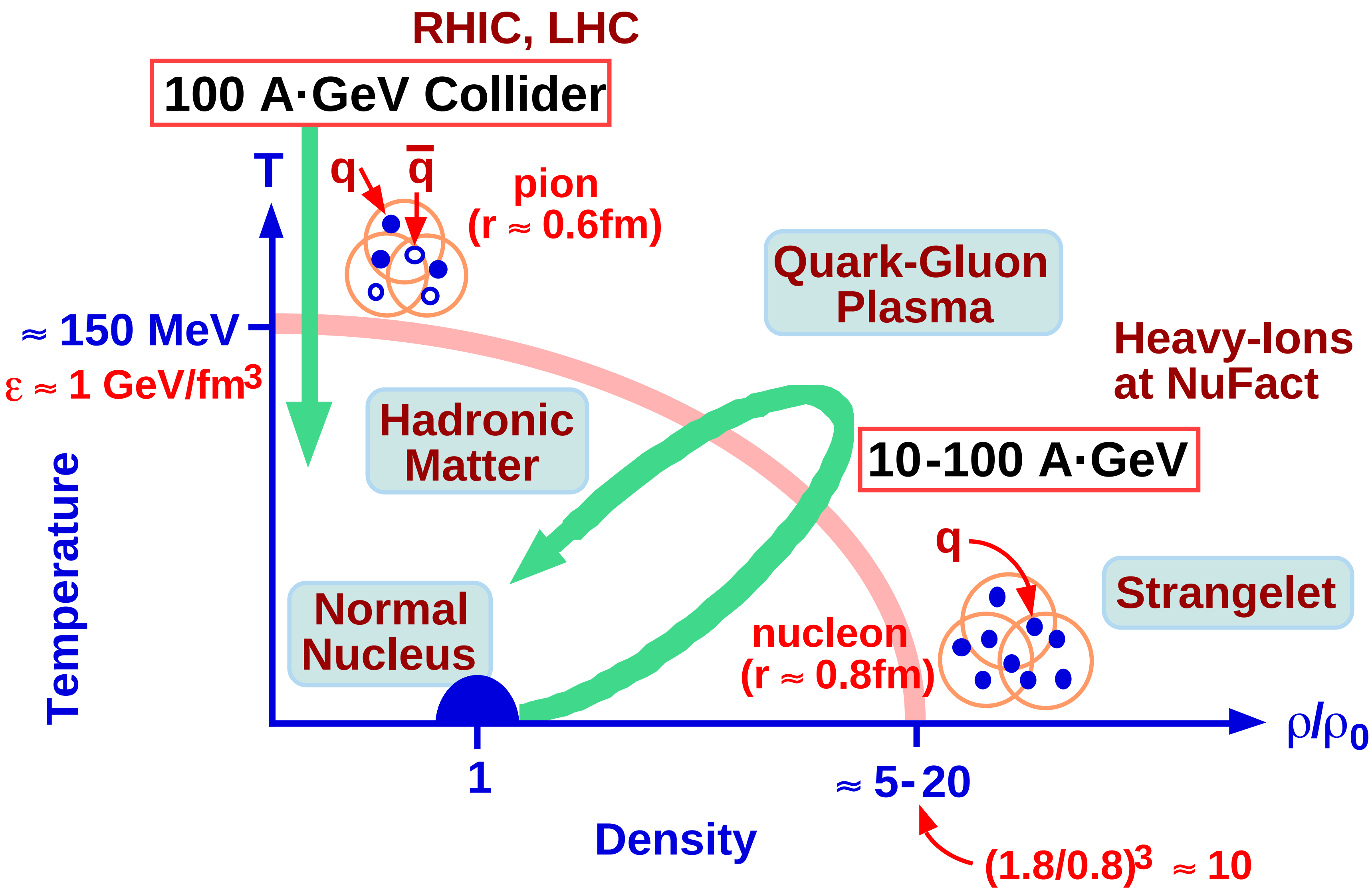
Note



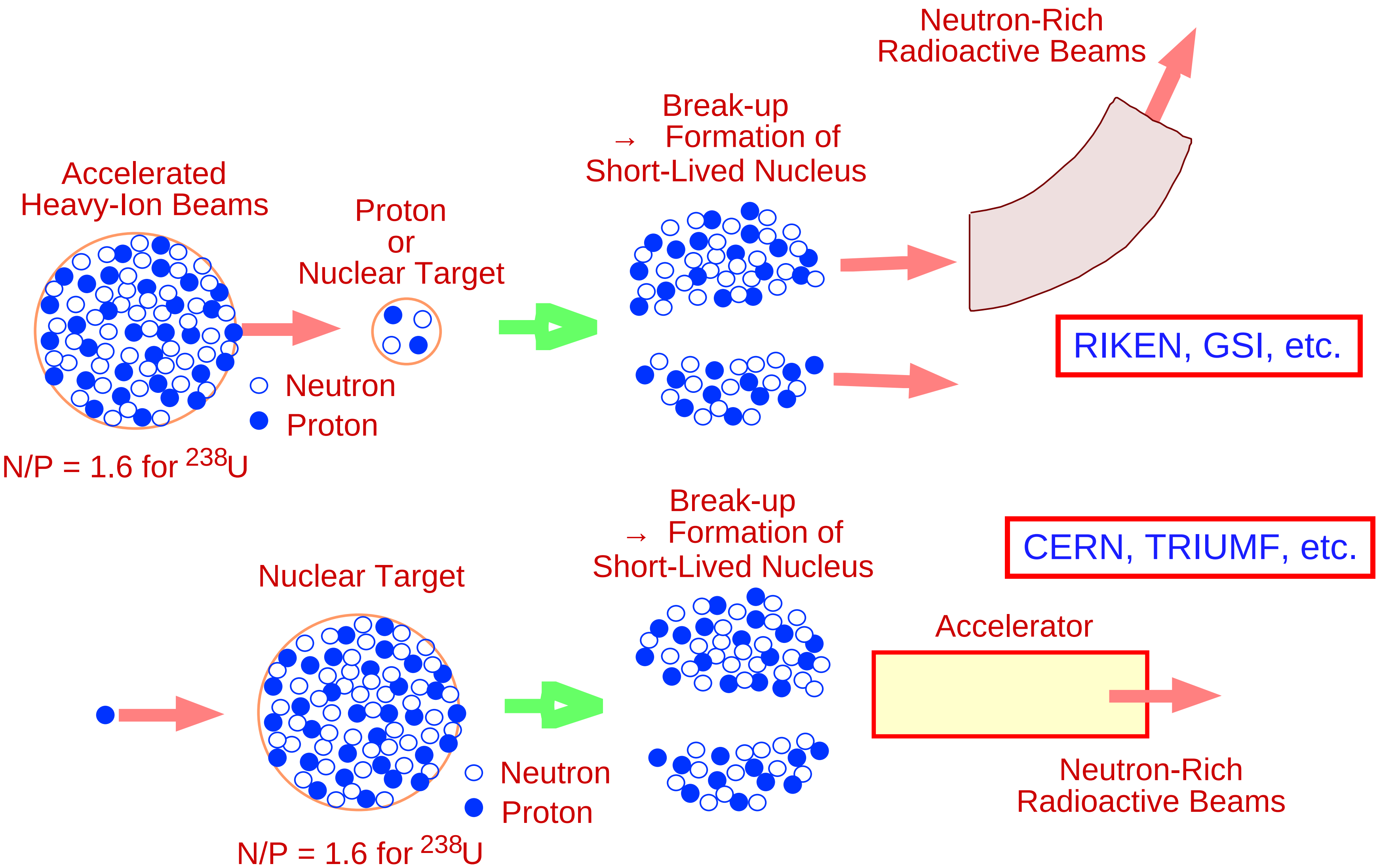
$= {}^{\Lambda\Lambda}He$

If $m_{\Lambda\Lambda} > m_{H0} \rightarrow H^0$ stable
If $m_{\Lambda\Lambda} < m_{H0} \rightarrow {}^{\Lambda\Lambda}He$ stable

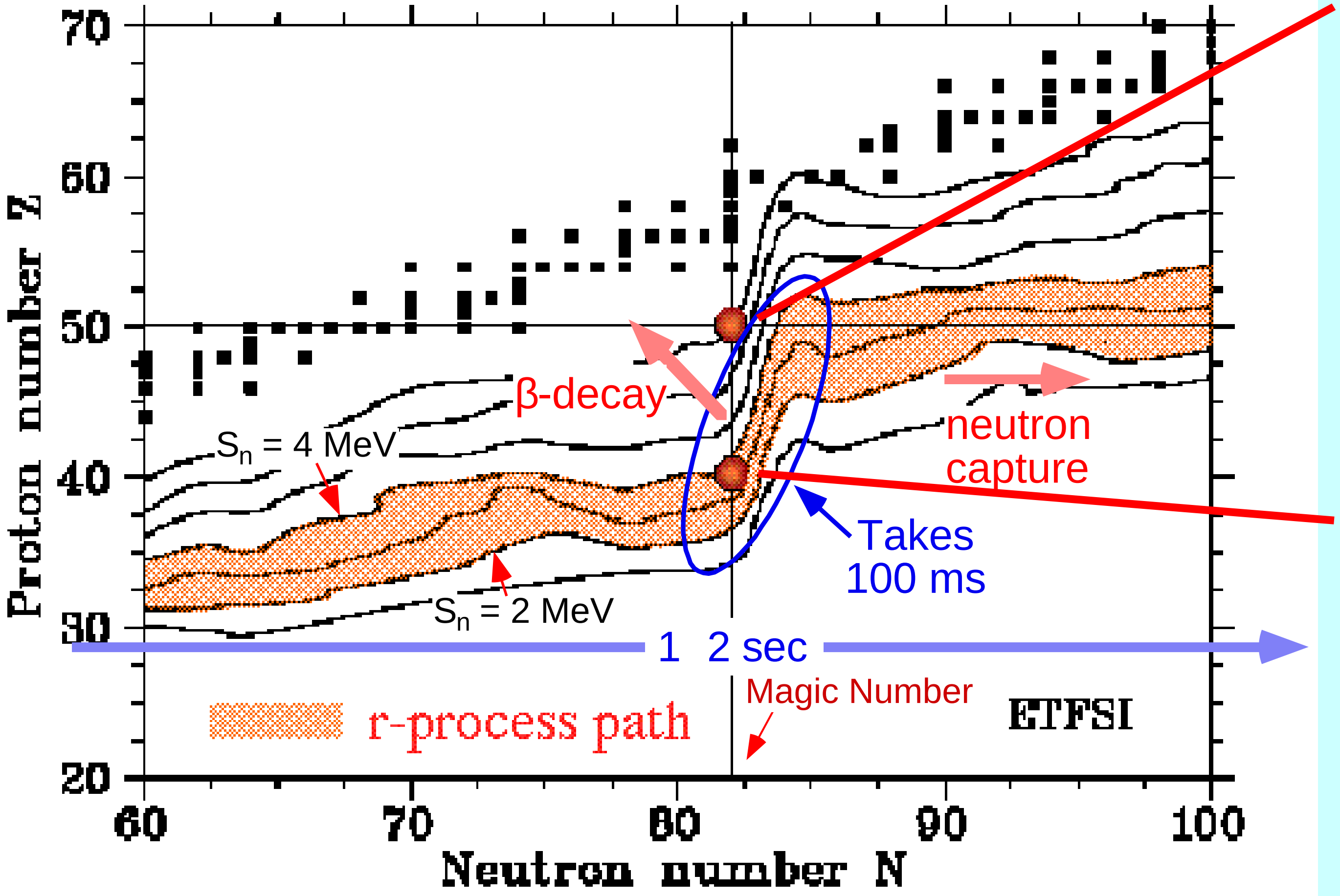
Strangelet and Heavy-Ion Collisions



Creation of Radioactive Isotope (RI) Beams



Nuclei on the r-Process Path



C. Freiburghaus. et al., Astrophys. J. 516('99)381.

^{132}Sn

Γ_β must be < $\Gamma(n,\gamma)$

Need precise measurement of σ(n,γ) with UCN

(L > 10^{27} s^{-1}•cm^{-2})

^{122}Zr

gnd st. roperty

Γ_β, $I_{delayed\ neutron}$, S_n, etc.

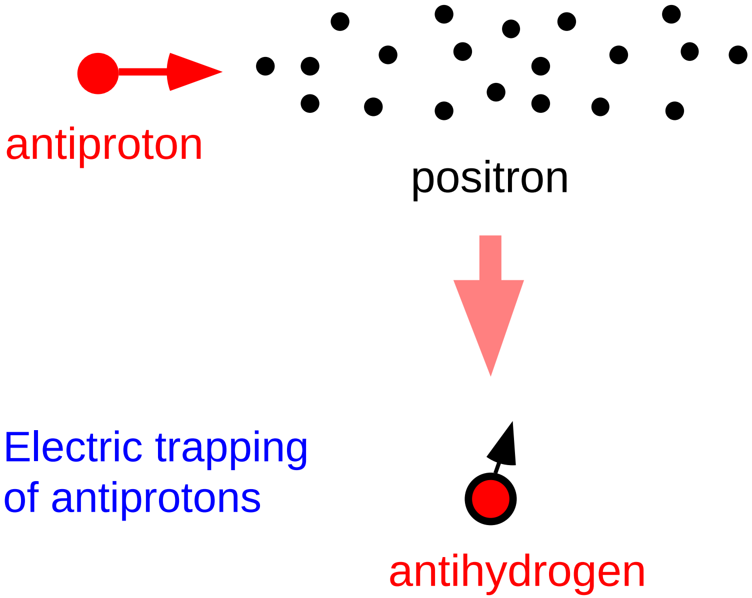
Creation of ^{122}Zr via fragmentation reaction with ^{132}Sn-Radioactive Beams

(I(^{132}Sn) > 10^{11} pps)

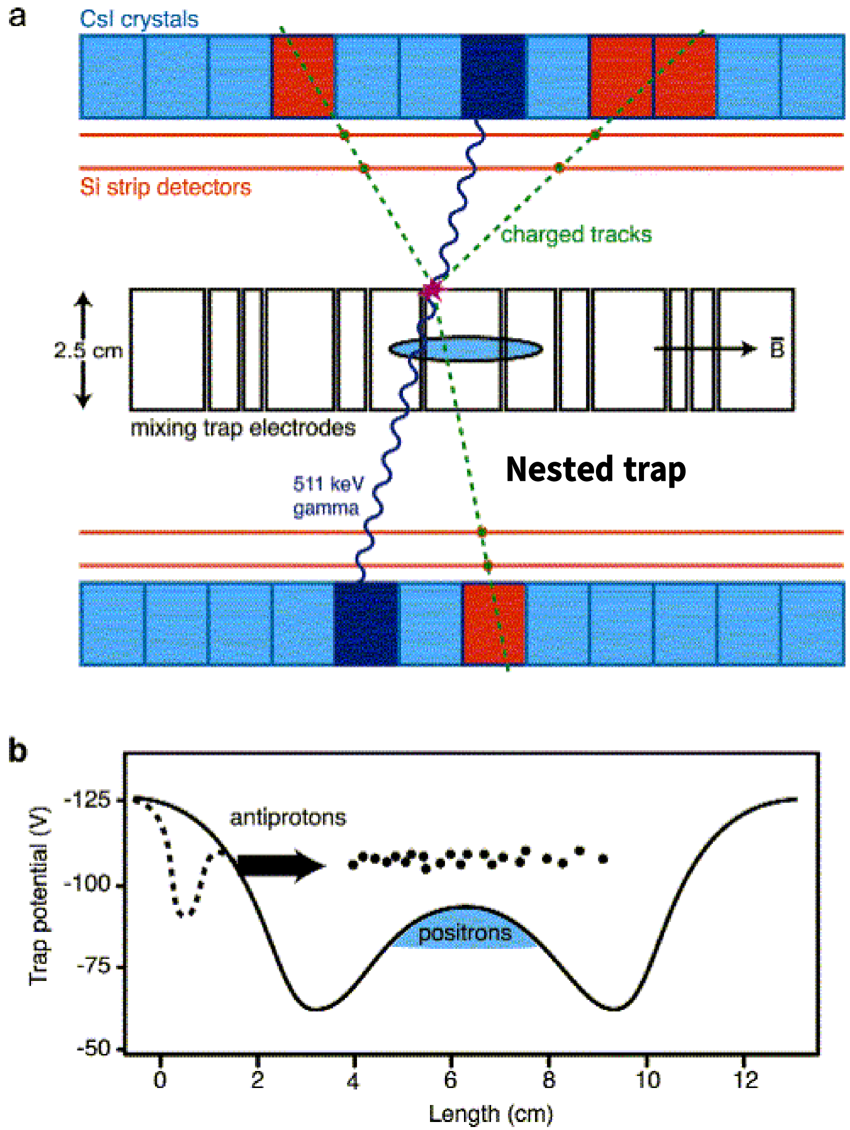
10 MW proton beams

K. Miyatake, et al.

ATHENA Experiment at CERN



Electric trapping of antiprotons



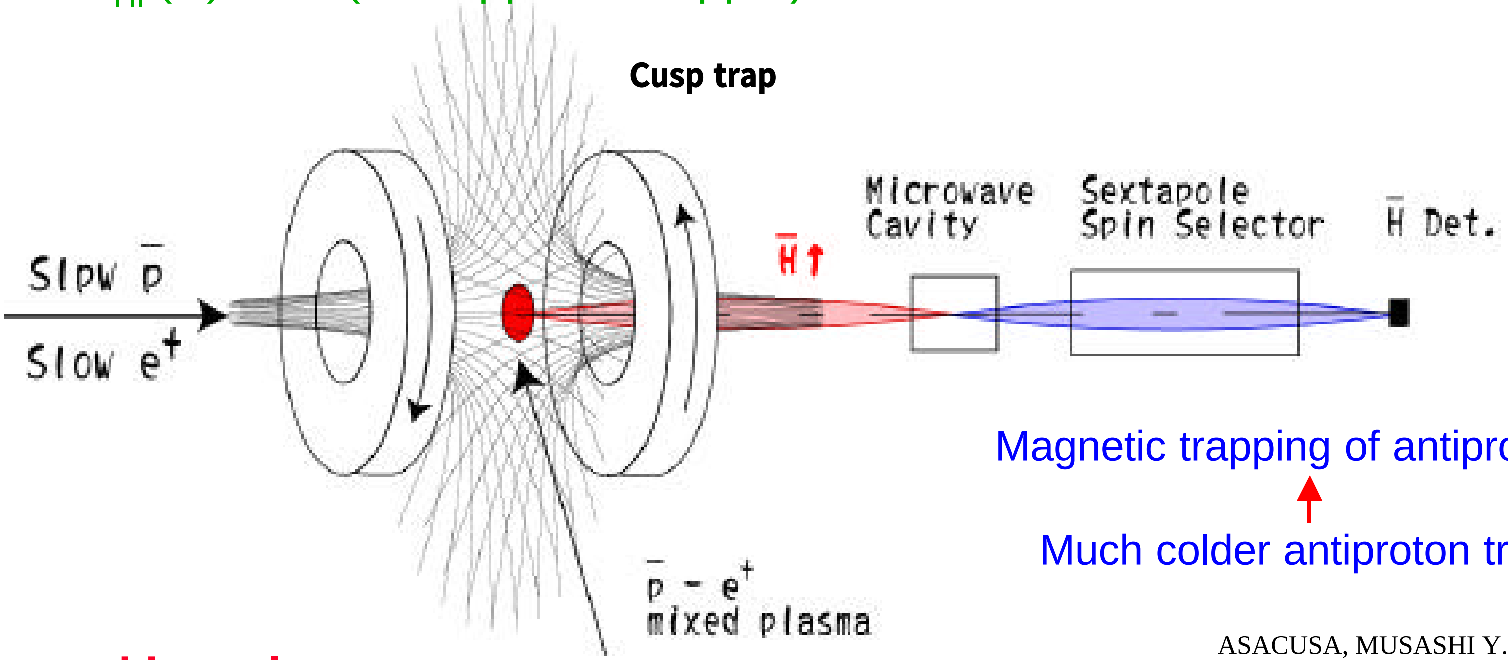
M. Amoretti, et al., Nature 419 (2002) 456.

Goal: CPT Test down to 10^{-14}

R. Hayano, et al.

Cold Anti-hydrogen Trap

- High resolution spectroscopy of H and $\bar{H}$
  - $f_{1S-2S}(H)$ = 2 466 061 413 187 103 (46) Hz   Niering et al. PRL84(00)5496
  - $f_{1S-2S}(\bar{H})$ = ?
- Hyperfine transition: magnetic moment
  - $f_{HF}(H)$ = 1.42 040 575 176 67 GHz (hydrogen maser)
  - $f_{HF}(\bar{H})$ = ?   (1000 ppm --> 1 ppm)



Magnetic trapping of antiprotons

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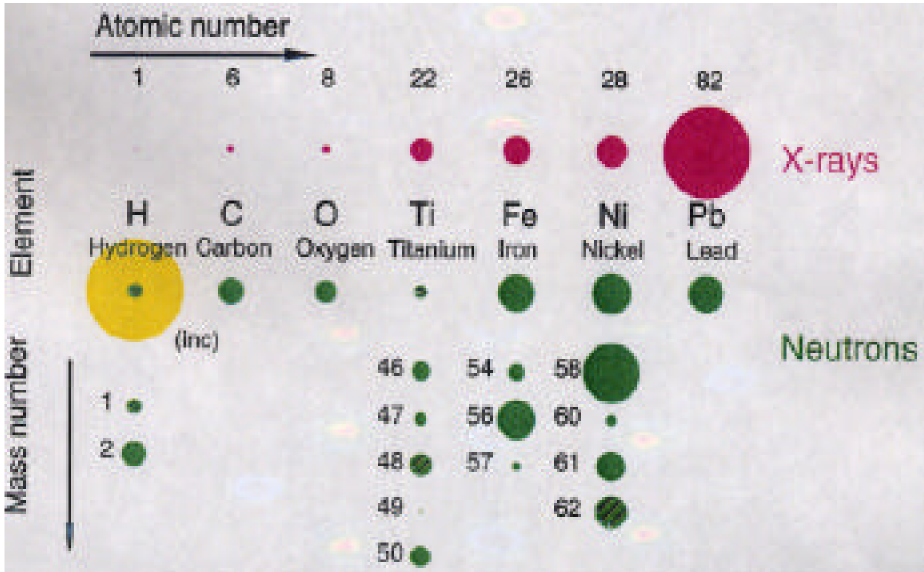
Much colder antiproton trap

Y. Yamazaki, et al.

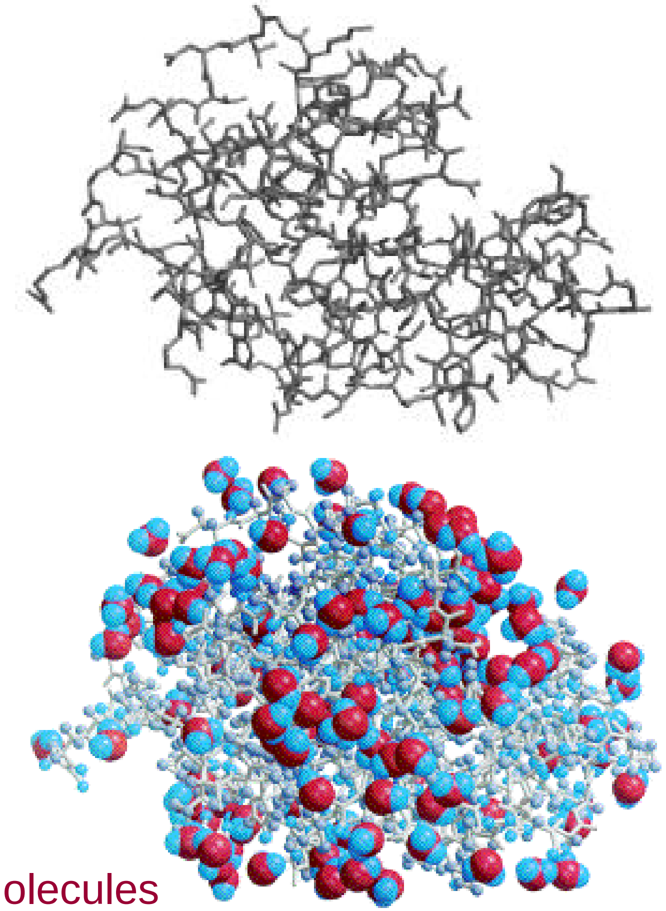
Uniqueness of Neutron Scattering

Neutron Scattering



X-rays interact with electrons.
→ X-rays see high-Z atoms.
Neutrons interact with nuclei.
→ Neutrons see low-Z atoms.

Hen Egg-White Lysozyme



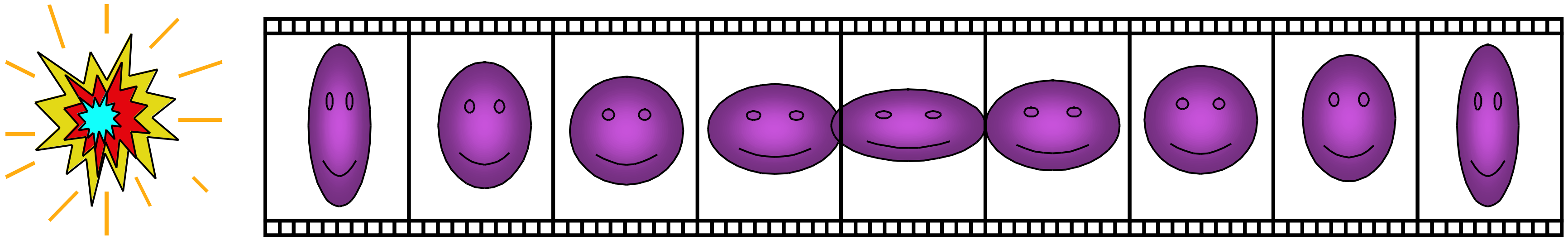
X-rays

Neutrons

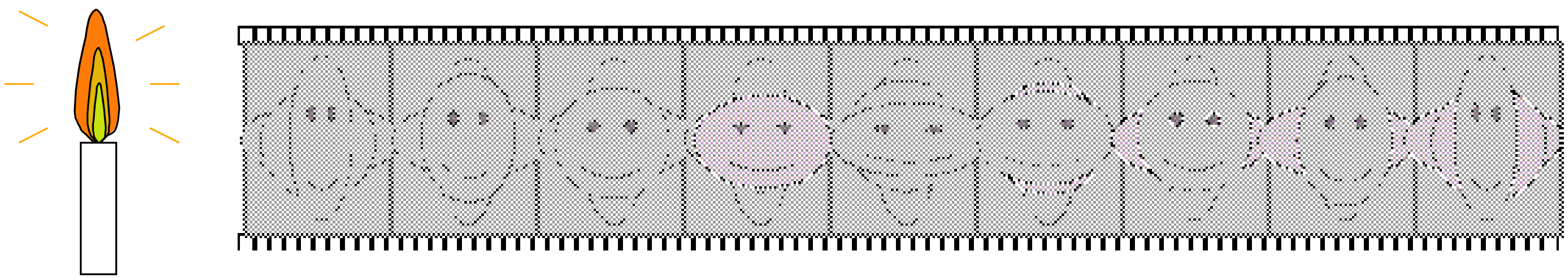
Water molecules
Observed with
neutrons

N. Niimura, et al.

Movement of H atoms



High-intensity
pulse neutrons

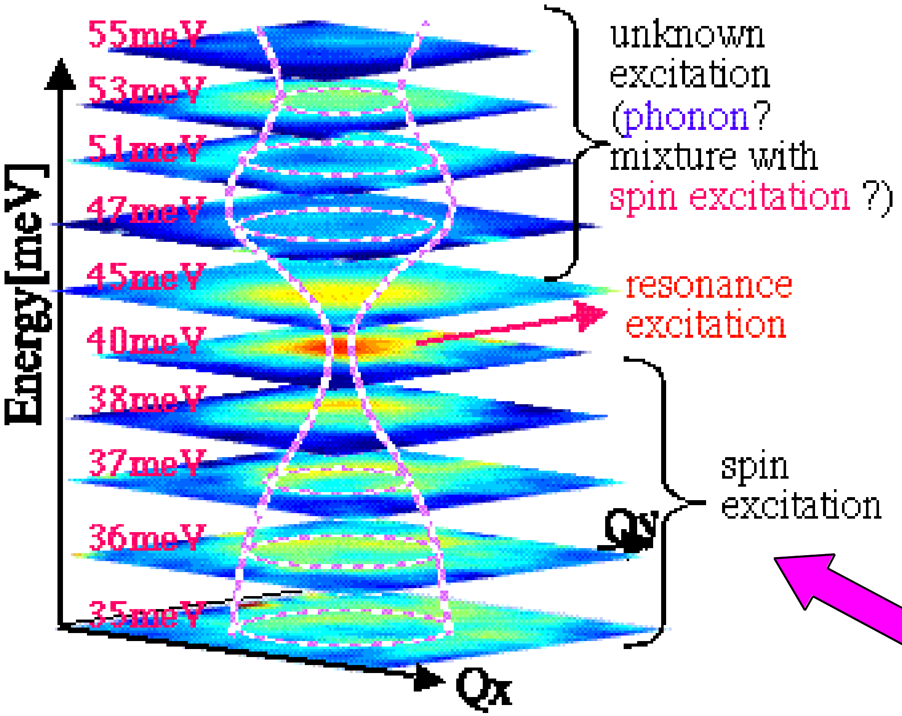


Low-intensity pulse neutrons   or   Reactor neutrons

Spin Excitation with Polarized Neutrons

One of unsolved issues in the 20th Century …

Mechanism of High-Tc S.C.
Spin-mechanism (New scenario) or
phonon-mechanism (BCS) ?



$YBa_2Cu_3O_7$

Magnetic excitation for high T_C superconductivity

Polarized neutrons can separate spin excitations from phonon excitations !

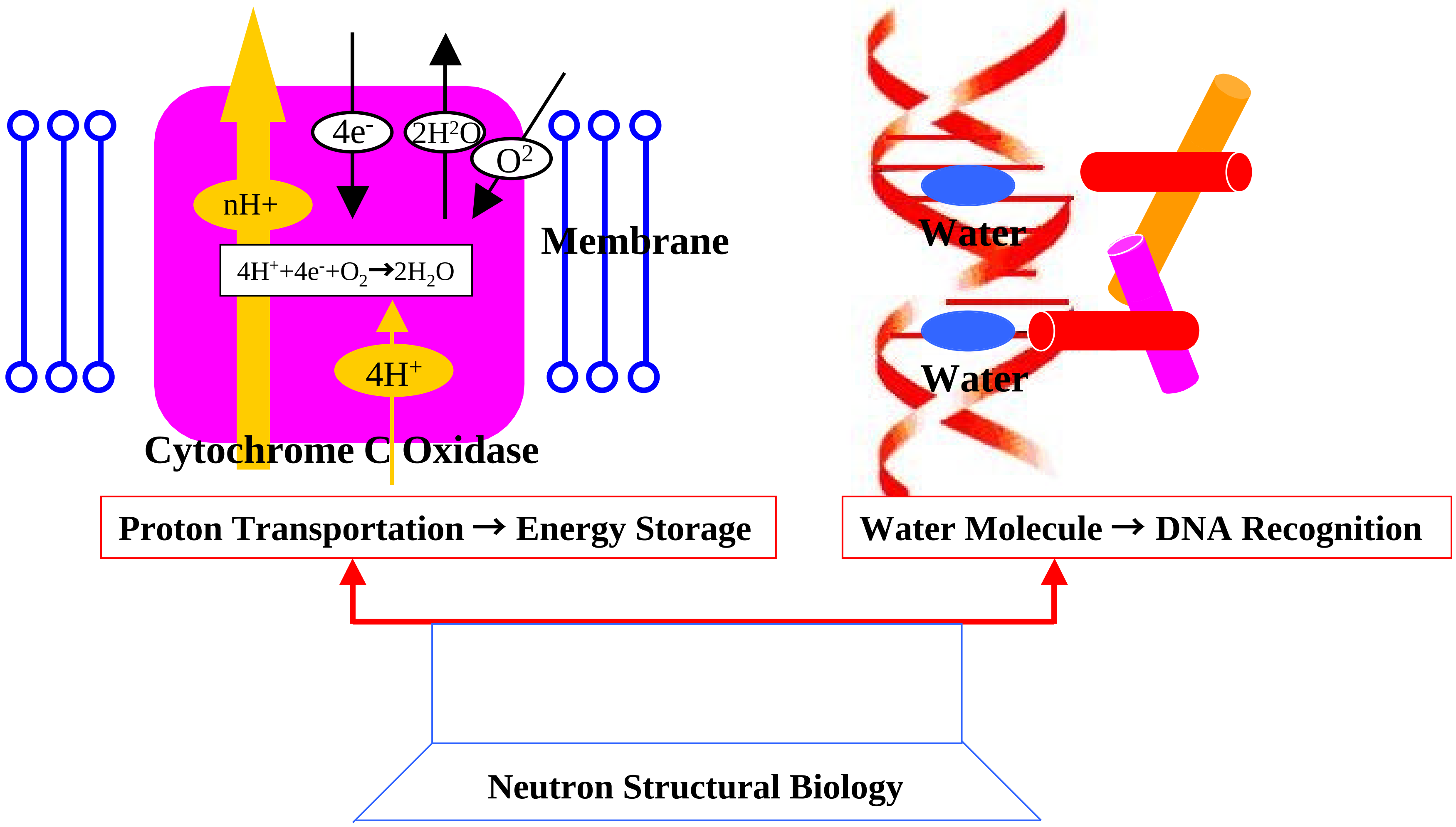
Intensity for polarized protons
< 10% of intensity for unpolarized neutrons

High intensity protons (10 MW) are needed !!!

A strange excitation mode is observed in the high-T_C Superconducitng phase.

M. Arai, et al.

Biological Examples of Neutron Scatterings



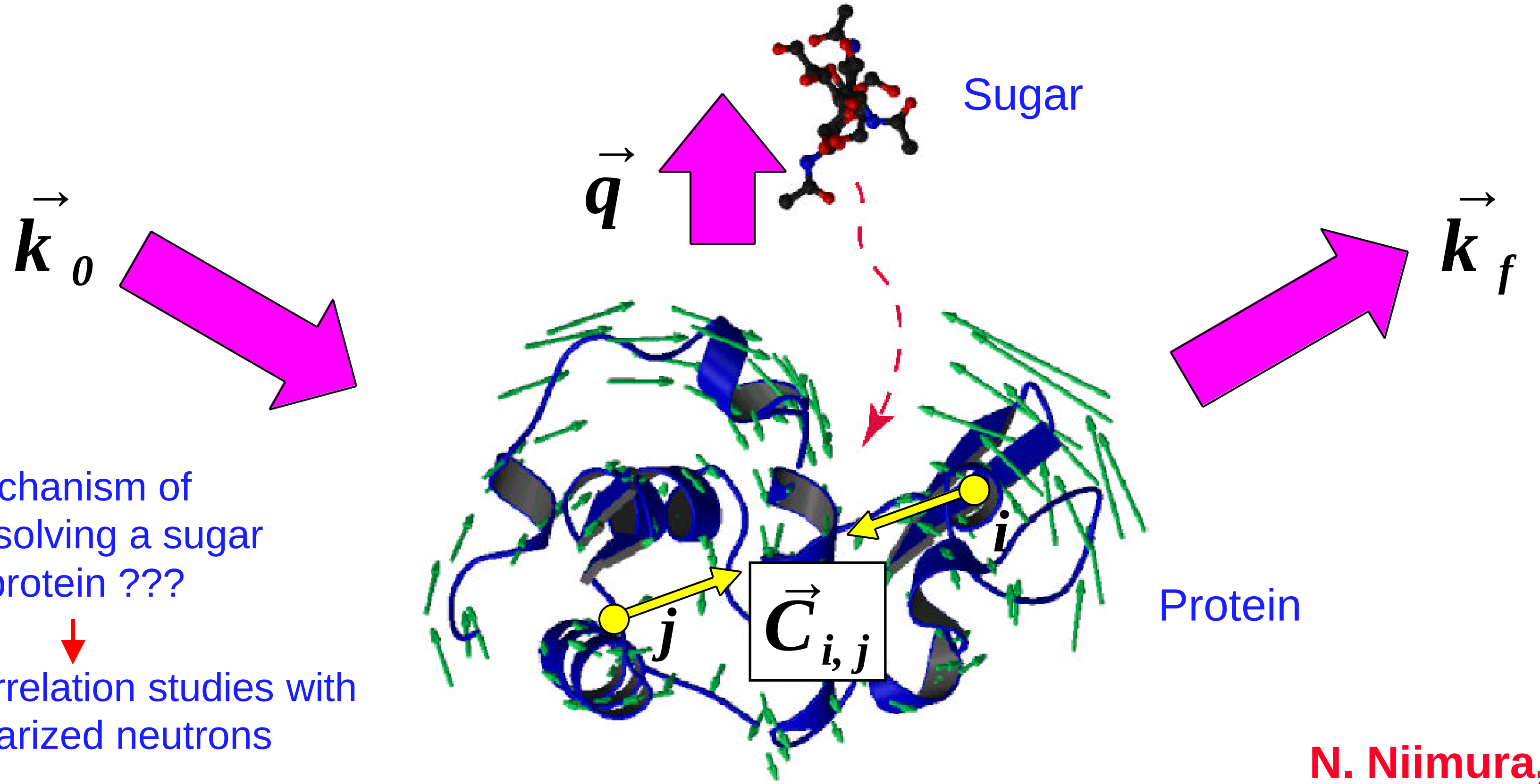
Coherent Structure Function with Pol. n

$$S(\vec{q},\omega) \qquad \left|\vec{q}\ \ \vec{C}_{i,j}\right|^2$$

where

$\vec{q}$: Scattering Vector

$\vec{C}_{i,j}$: Oscillation Amplitude Vector between *i*-th and *j*-th atoms



Mechanism of dissolving a sugar in protein ???

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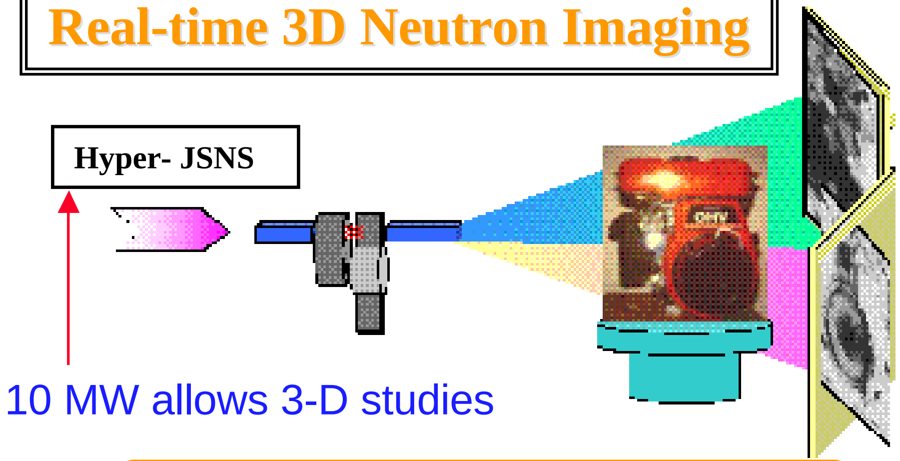
Correlation studies with polarized neutrons

N. Niimura, et al.

3 Dimensional Movie for Industrial Usage

Real-time 3D Neutron Imaging



- **Real-time 3D Imaging of Bulky Body Containing Light Elements**
- **Elements Identification in Bulk**

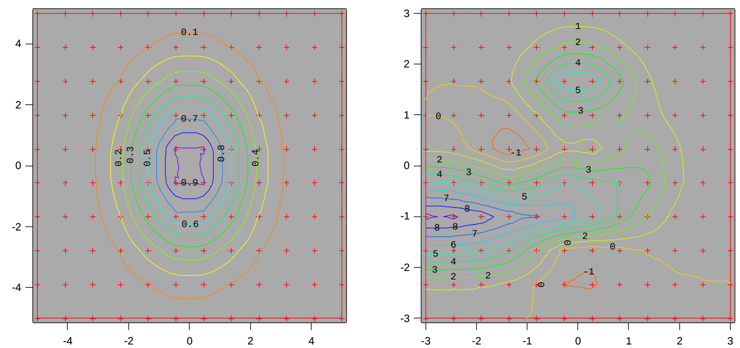
- **Industrial Application**
- **Factory Product Testing**
- **Aircraft, Aerospace Vehicle**
- **Automobile**

Y. Morii, et al.

Real-time Strain Distribution Measurement

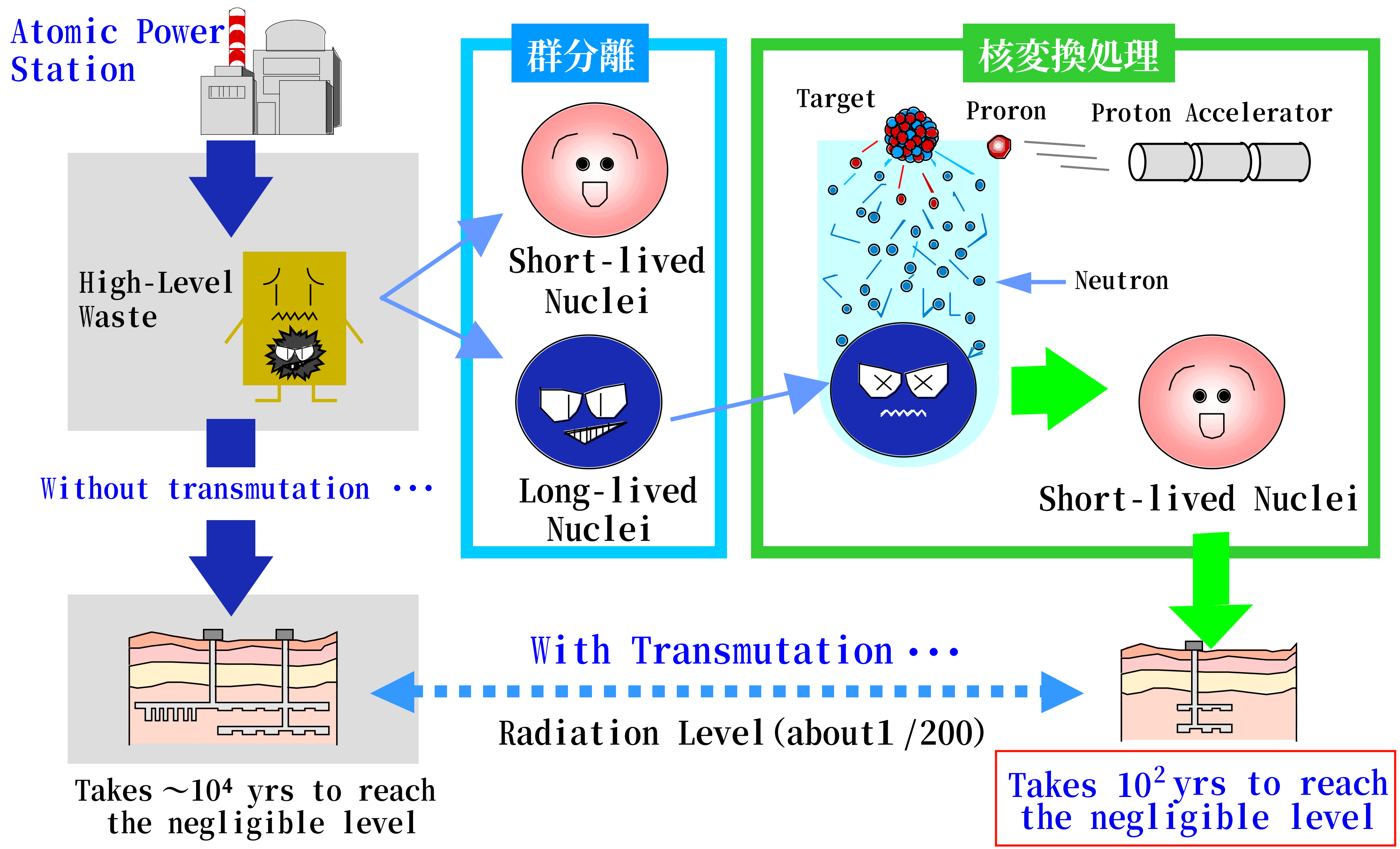
Variation of Strain Distribution

$t=t_0$(before ignition) → $t=t_1$(after ignition) → $t=t_2$…… →

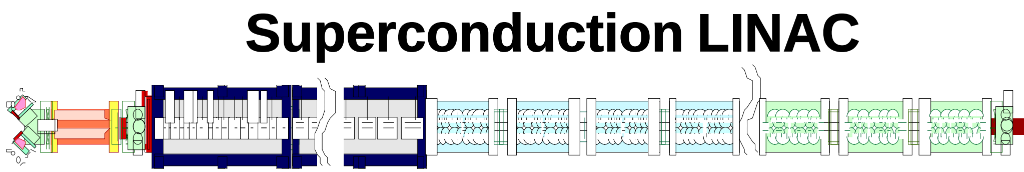


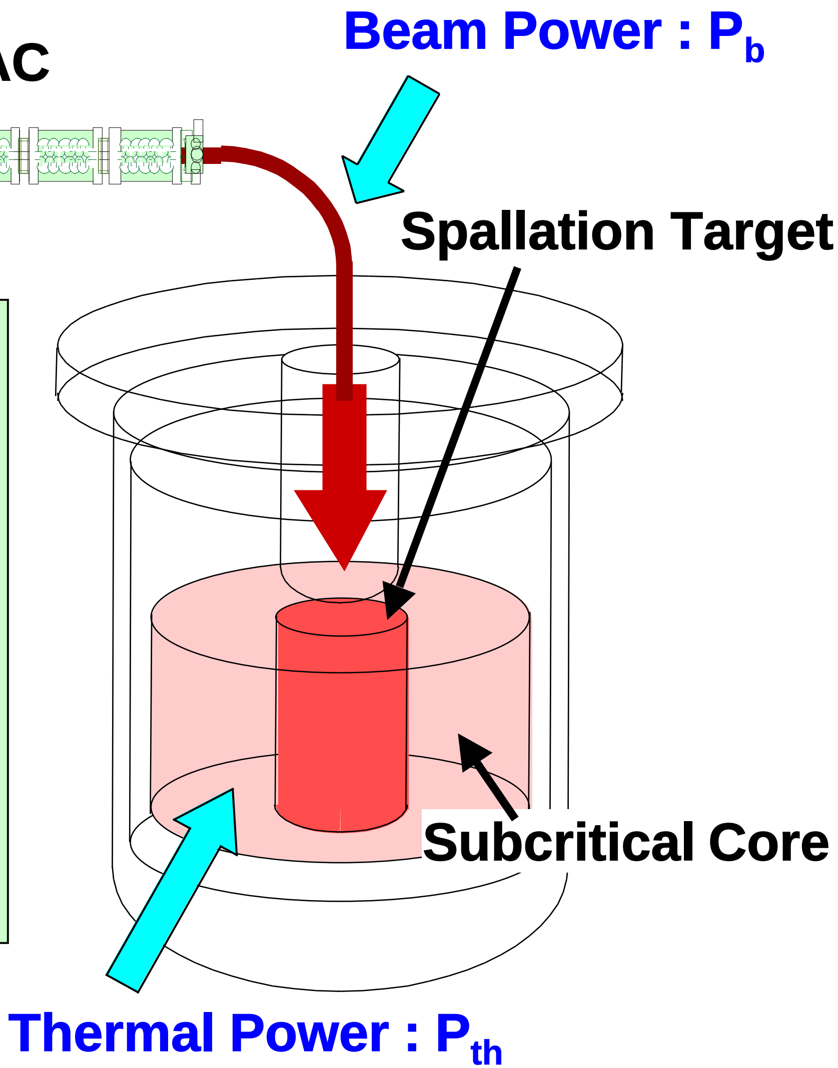
- **Large Size Components**
- **In-situ Measurement in Operating Condition**
- **Time-sliced Measurement**

Accelerator-Driven Transmutation (ADS)



Needed Accelerator Power for ADS in Japan





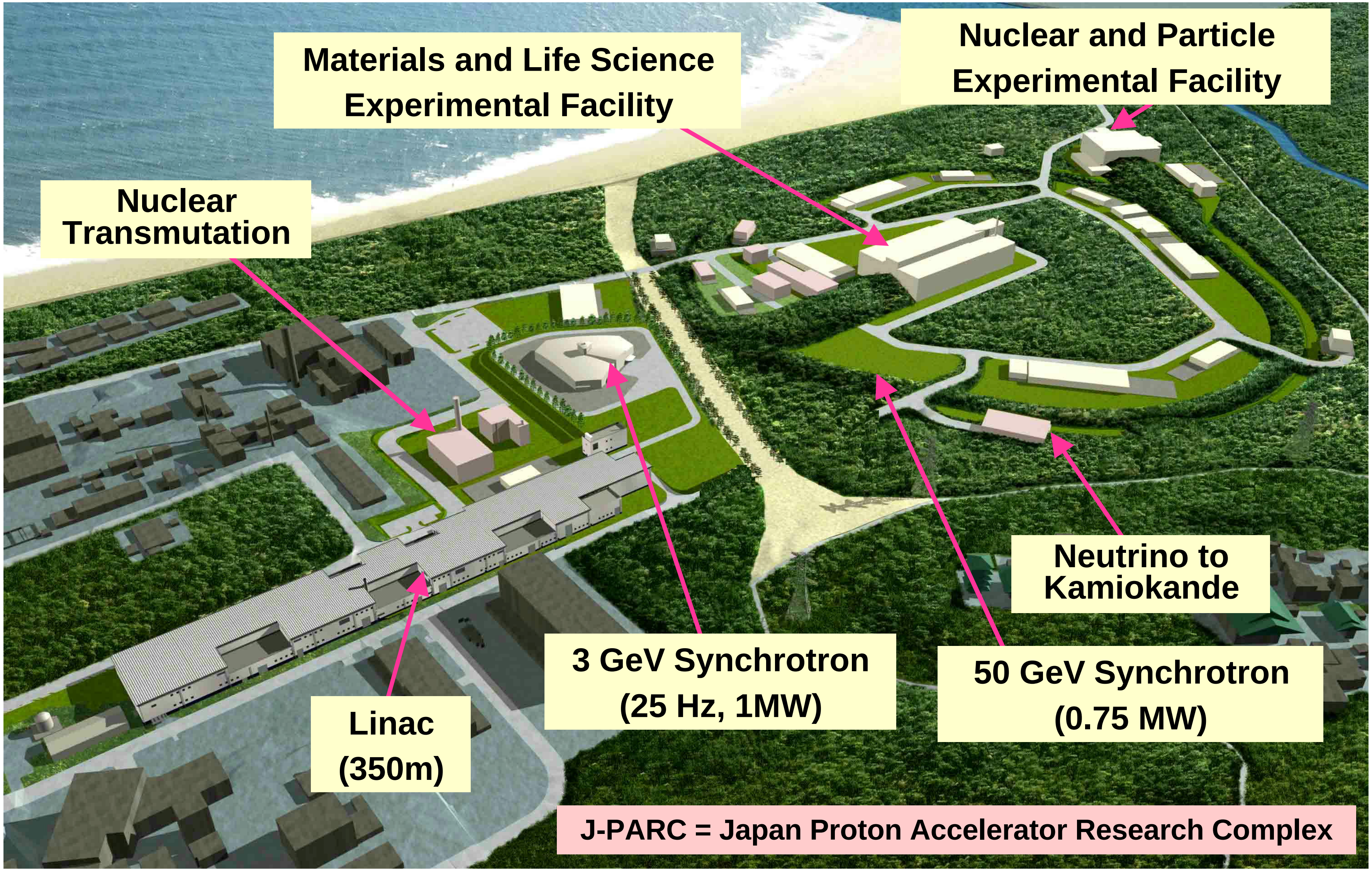
- *To transmute all MA produced in Japan, thermal power (P_{th}) of about 3200MW is necessary in ADS.*
- *When we use 1GeV proton beam, P_{th} is proportional to beam power P_b .*

$$P_{th} = P_b \times M$$

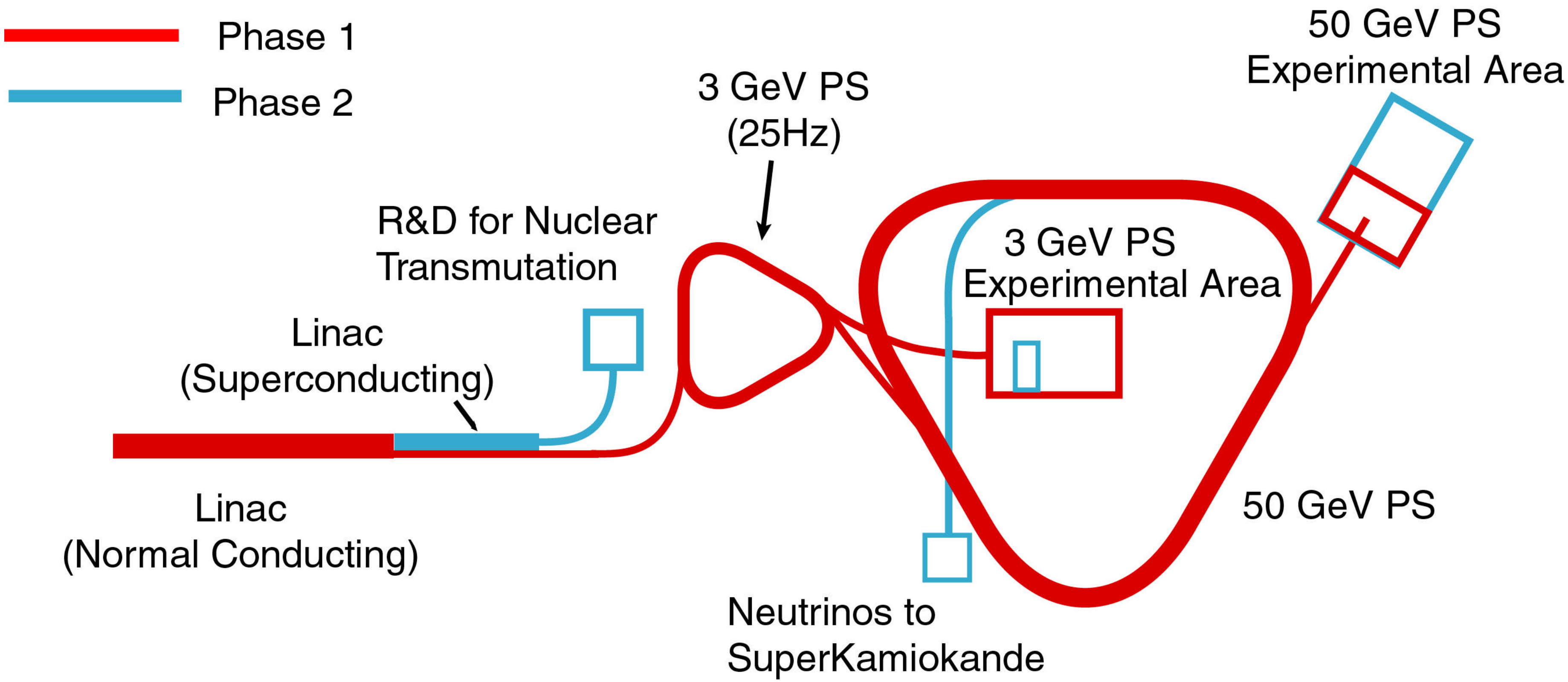
- *We usually use M = 40*
- *Therefore, P_b=80MW is necessary.*
- *"4 accelerators of P_b=20MW" is our reference case.*

H. Oigawa, et al.

J-PARC Facility



Phase 1 and Phase 2



- Phase 1 + Phase 2 = 189 billion Yen (= $1.89 billion if $1 = 100 Yen).
- Phase 1 = 133.5 billion Yen for 6 years (= 2/3 of 189 billion Yen).
- Construction budget does not include salaries.

Present Status

Construction Budget for Phase 1