July 31, 2004
νFact04@Osaka

Science with High Intensity Hadron Machines

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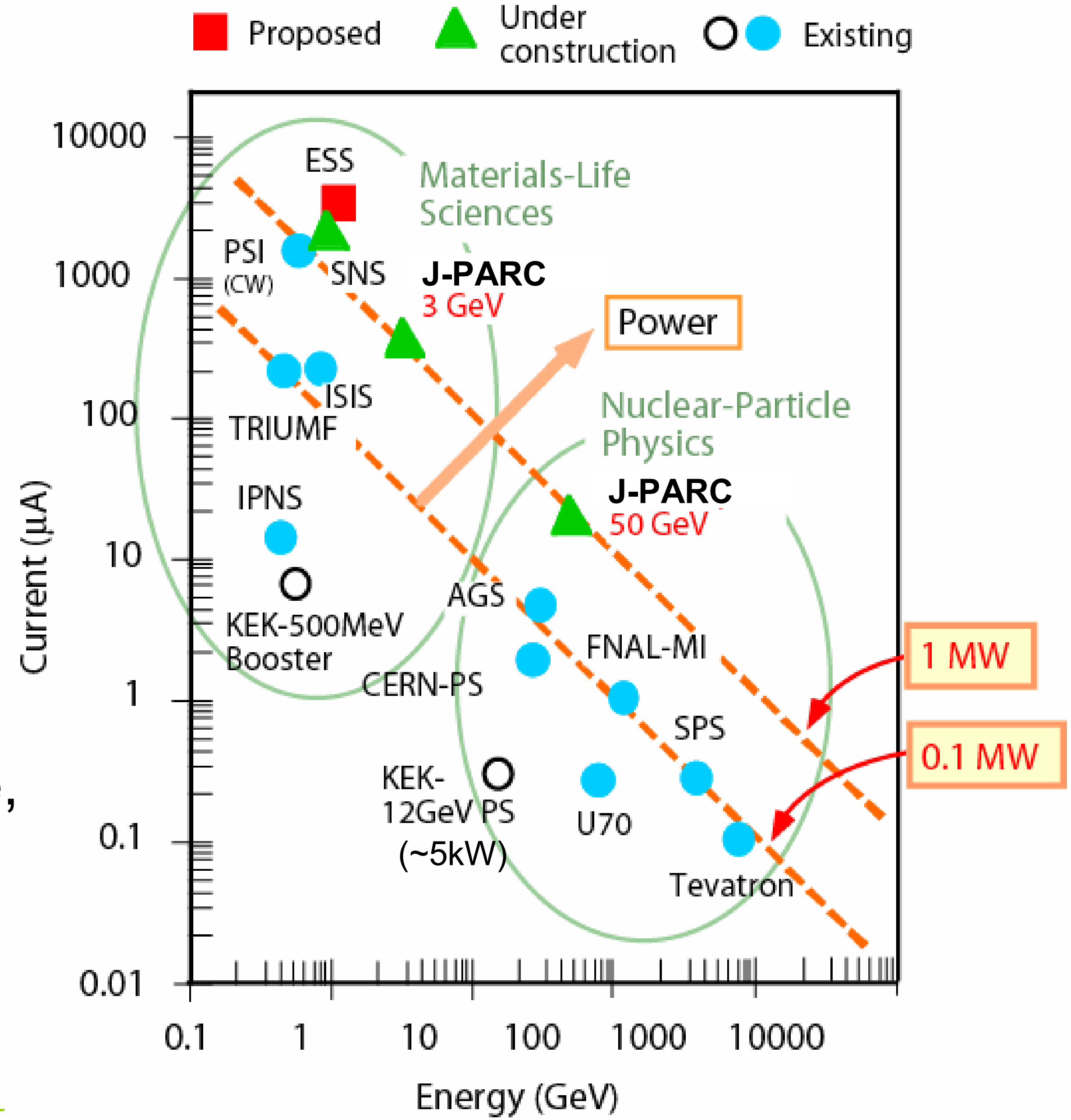
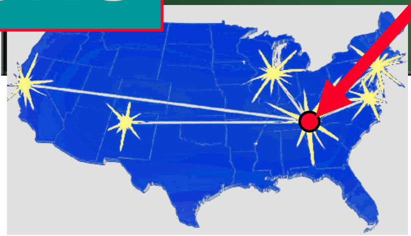
World's Proton Accelerators

- High energy frontier has been extending our views in particle physics
- **High intensity frontier**
  - 0.1MW → 1MW
  - Mult-MW in the future
  - Gives many precise, detailed knowledge on nature in many fields

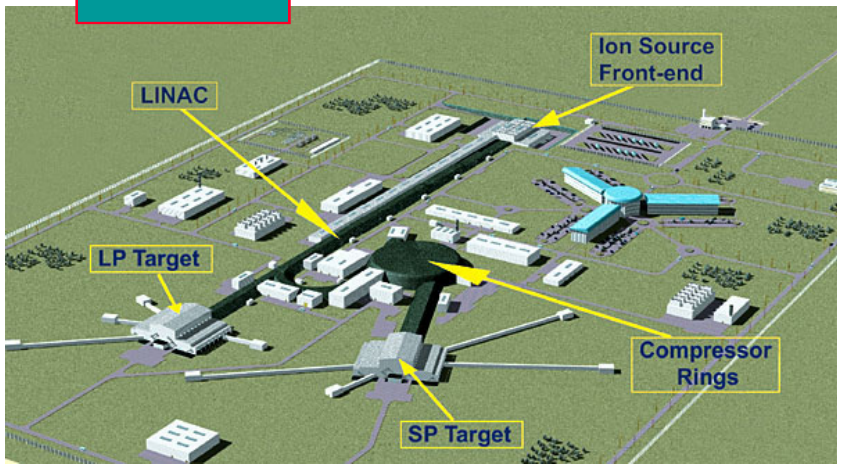


World's Future MW Proton Facilities

SNS



ESS



The Spallation Neutron Source (SNS)

- 1GeV 1.4MW Linac
- Accum. ring
- 60Hz pulsed beam
- Neutron science
- Constructing (~2006)

ESS - European Spallation Source

- 1.33GeV 10MW LINAC
- Compressor ring
- 2 target stations
- Proposed.

MW Proton Facilitiy in Japan
J-PARC

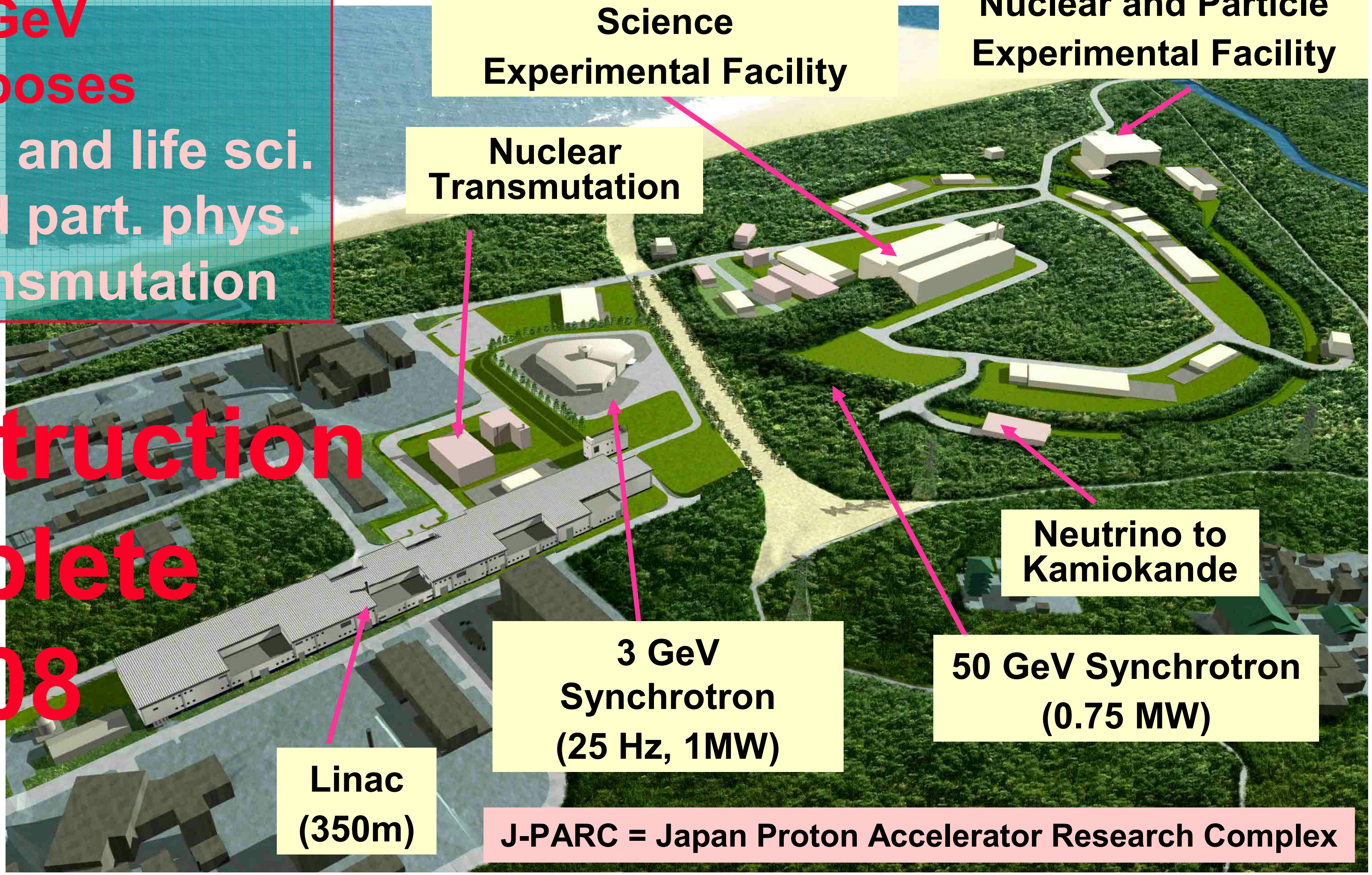
Unique facility

3GeV+50GeV

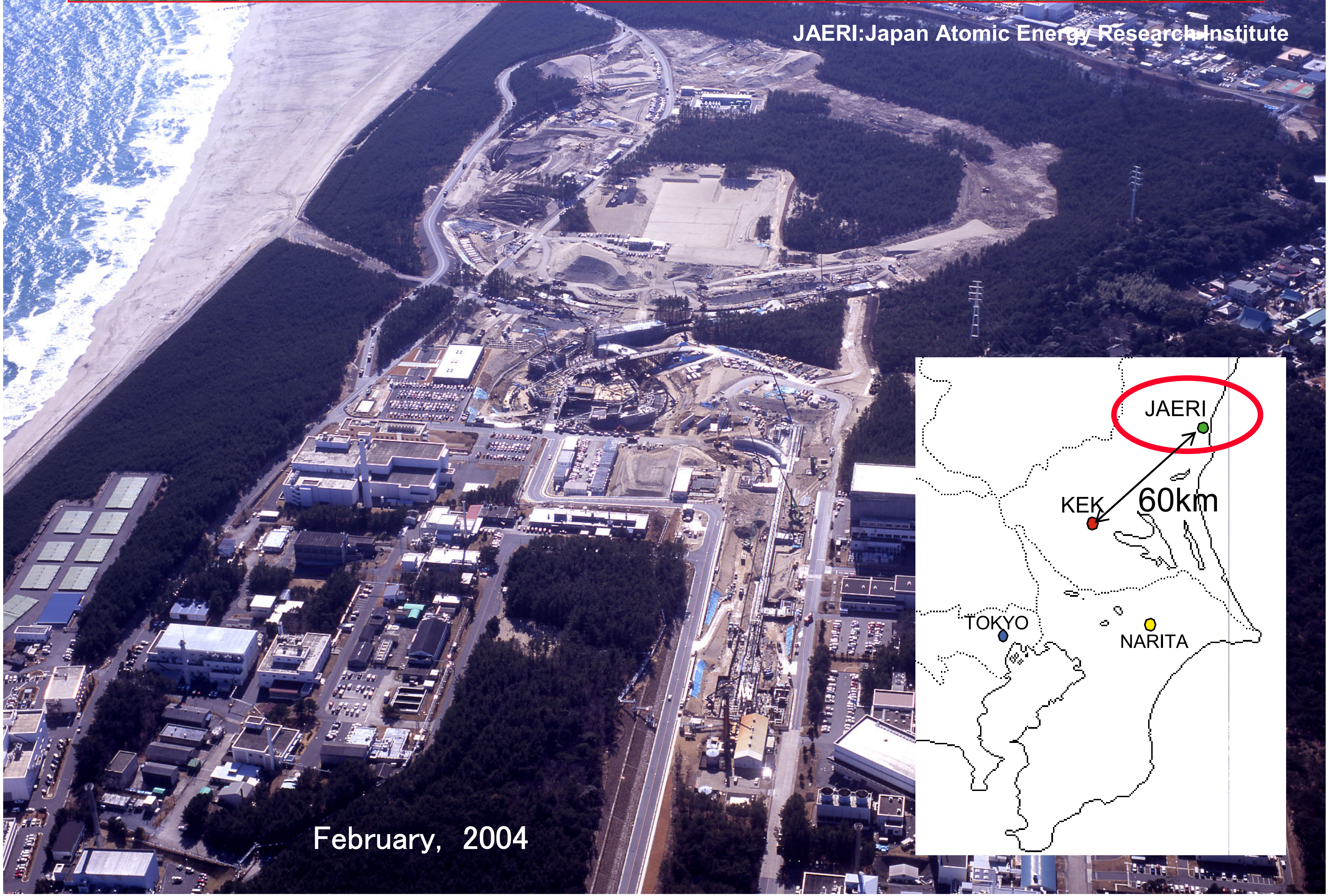
Multi-purposes

- Materials and life sci.
- Nucl. and part. phys.
- Nucl. transmutation

Construction Complete in 2008



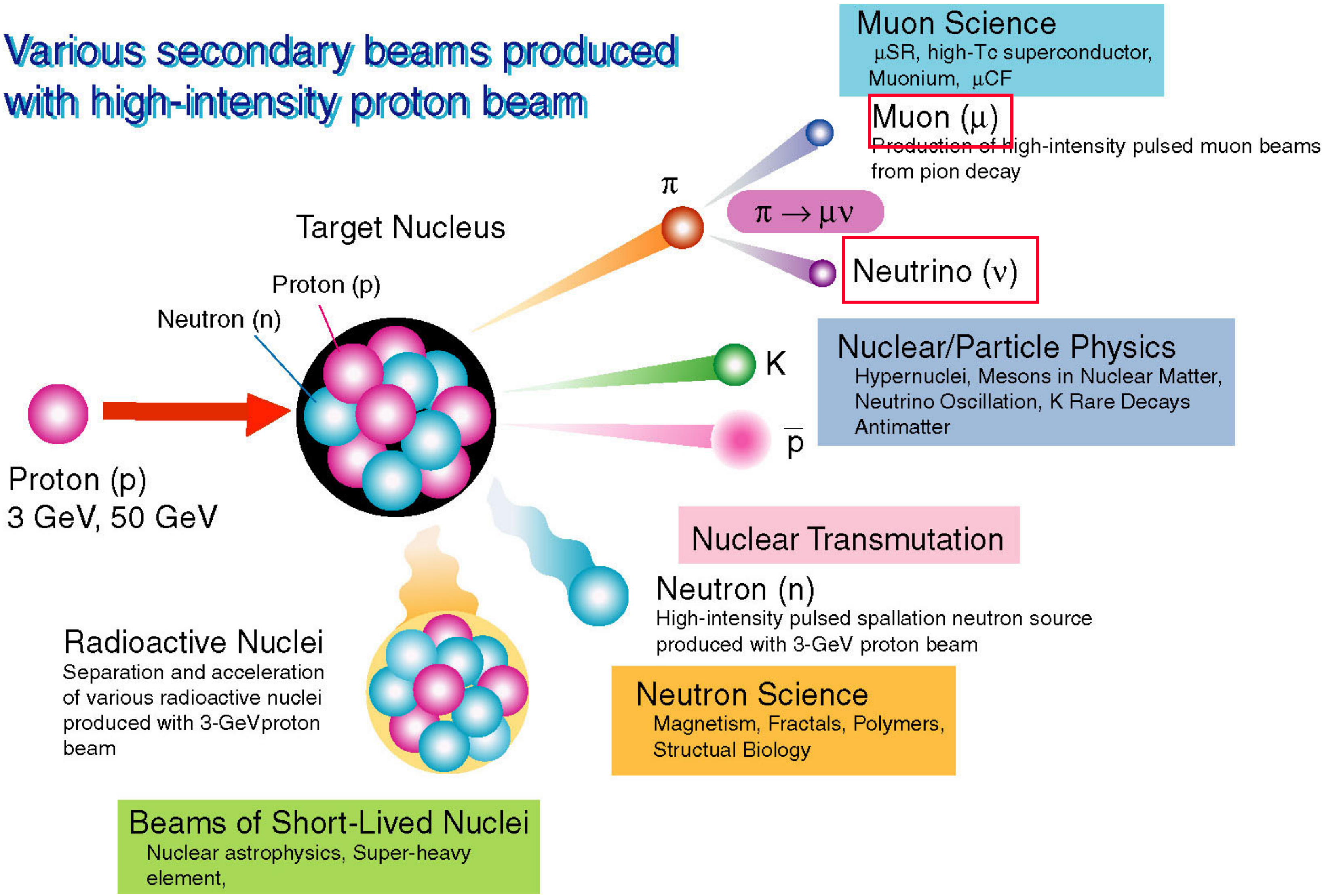
J-PARC In JAERI Tokai-site



Ground breaking of of ν facility @ J-PARC

- Decay volume part
- July, 2004

Various Beams Obtained by p+A Collisions

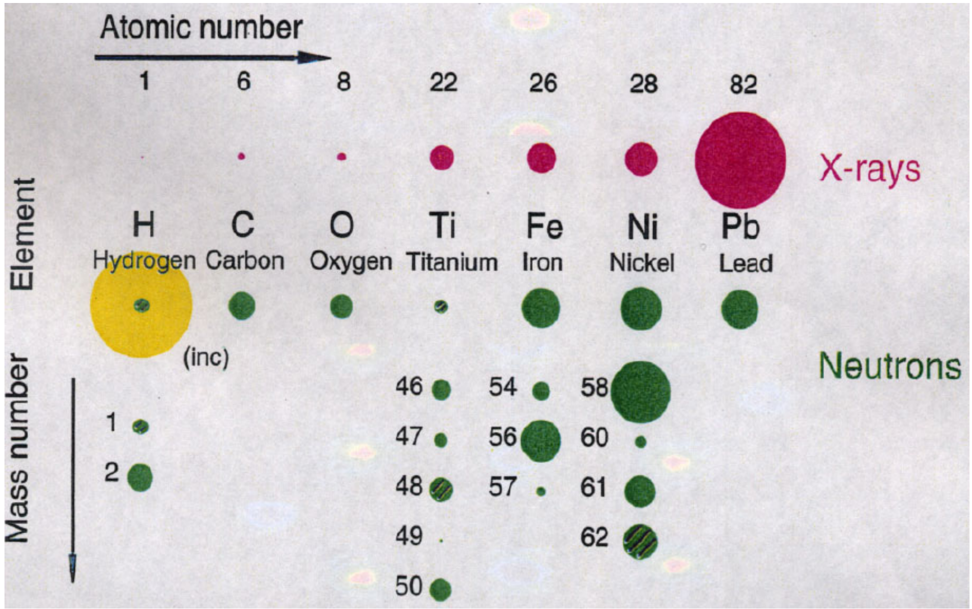


Neutron science highlight

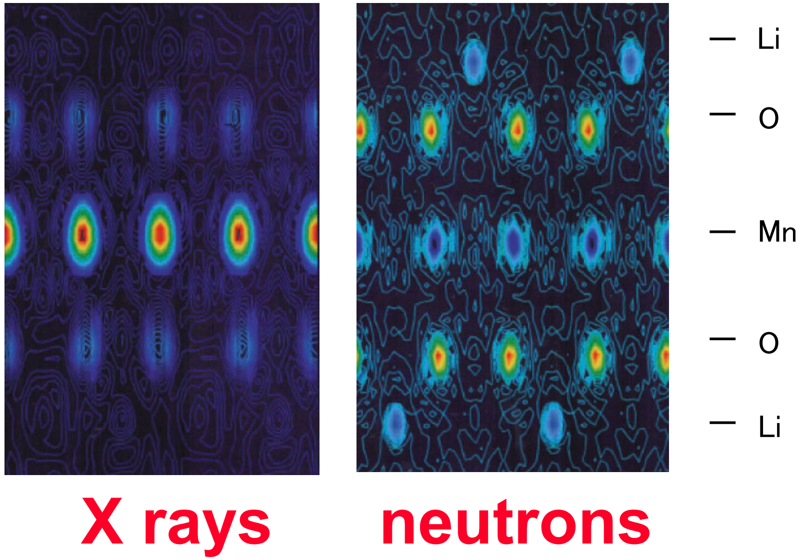
- Solid state physics: Observation of quantum effect
  (Understanding function and property of materials)
- Understanding precise atomic structure of materials
  (Indispensable base of materials science)
- Biomolecular science (Understanding life)
- Structure and dynamics of surface and interface
- Neutron imaging for industrial application and versatile researches
- High pressure and high temperature: Earth science

Light elements

Z dependence of sensitivity compared with X ray



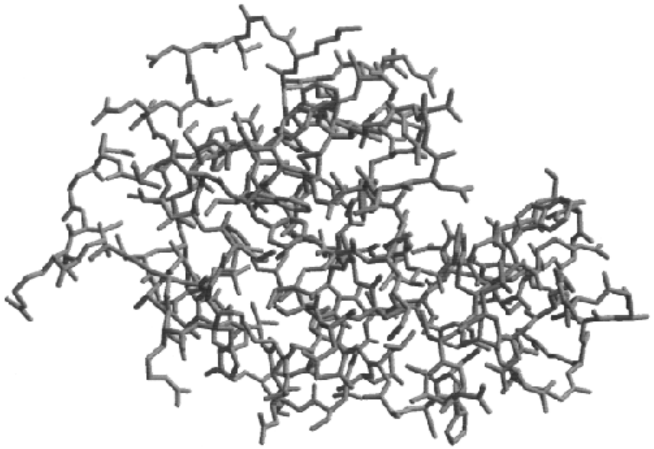
An example:
Behavior of Li in Li battery



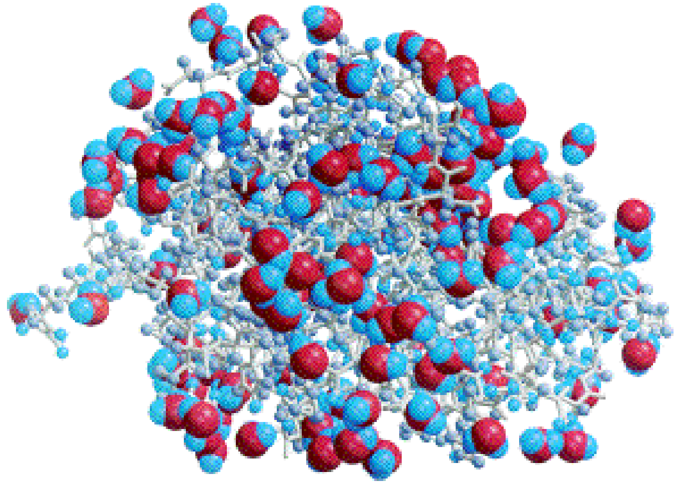
X-rays interact with electrons.
→ X-rays see high-Z atoms.
Neutrons interact with nuclei.
→ Neutrons see low-Z atoms.

Protein

Hen Egg-White Lysozyme



X-rays

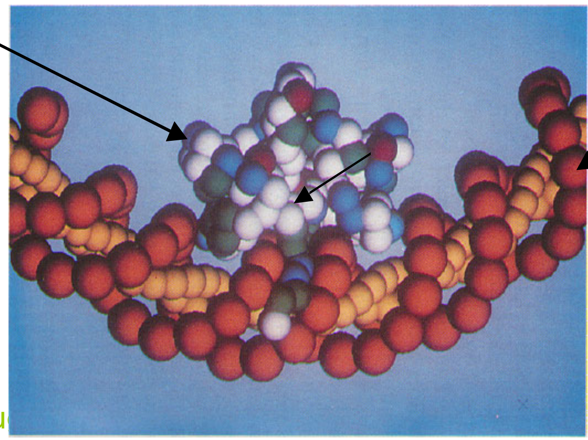


Neutrons

Water molecules Observed with neutrons

- Hydrogen (H)
- Oxygen (O)

Protein



DNA

A protein molecule moving along the DNA chain

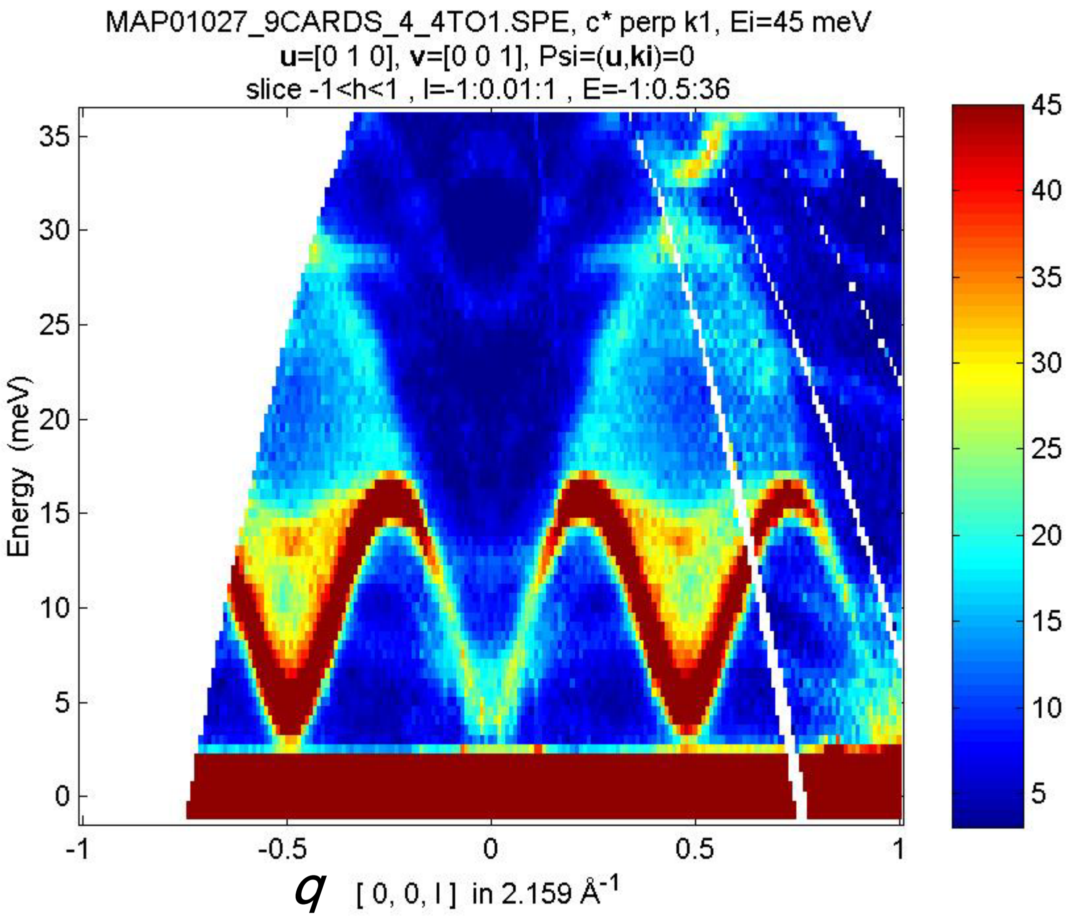
From structure to function

Quantum effect in spin excitation

$CuGeO_3$

- Spin dynamics of low–dimension system
- Magnetic scattering
- Similar study of
  - lattice dymanics
  - electron dynamics
  - orbital dynamics

⇨ understanding of High T_c SC *etc.*

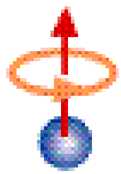


Muon science

Refer talks in WG4

Muon

Two charge states, +e and -e
Muon mass ≈ (1/10)×(proton mass)
200×(electron mass)
Finate magnetic moment



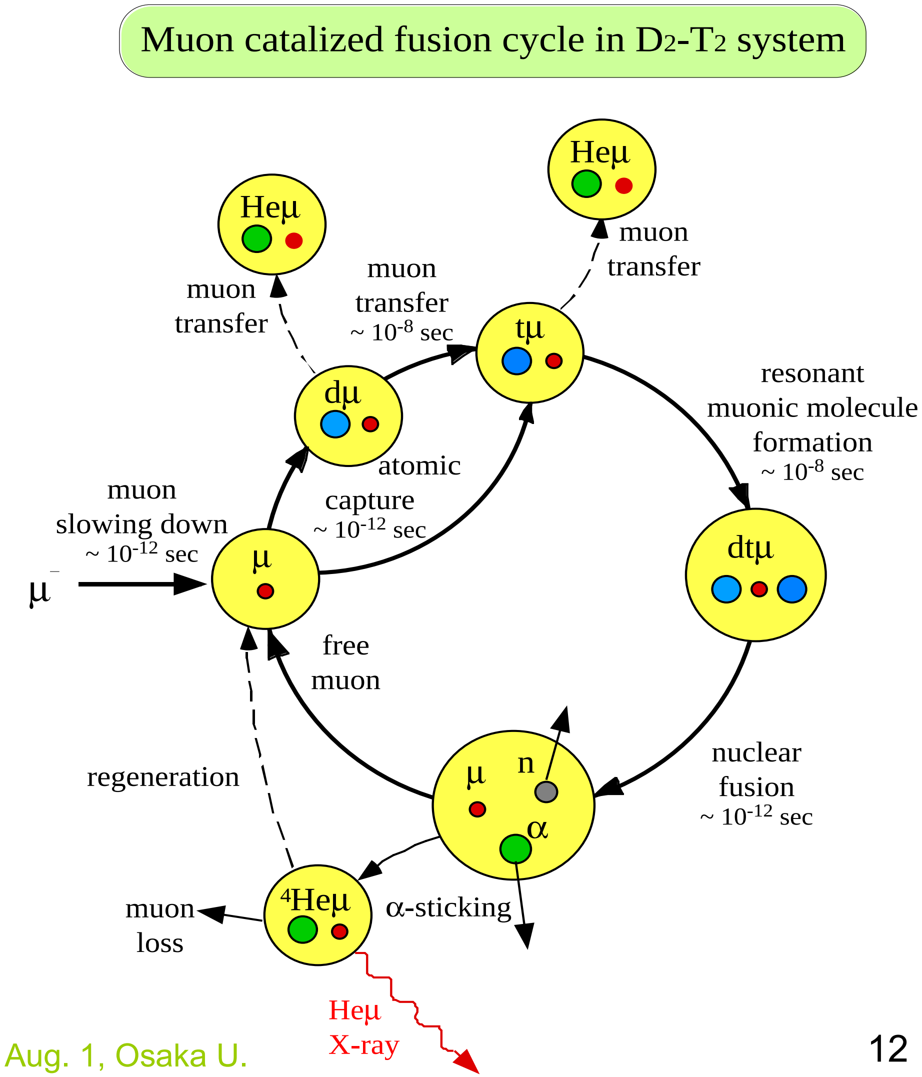
Muonic atom

Muonium

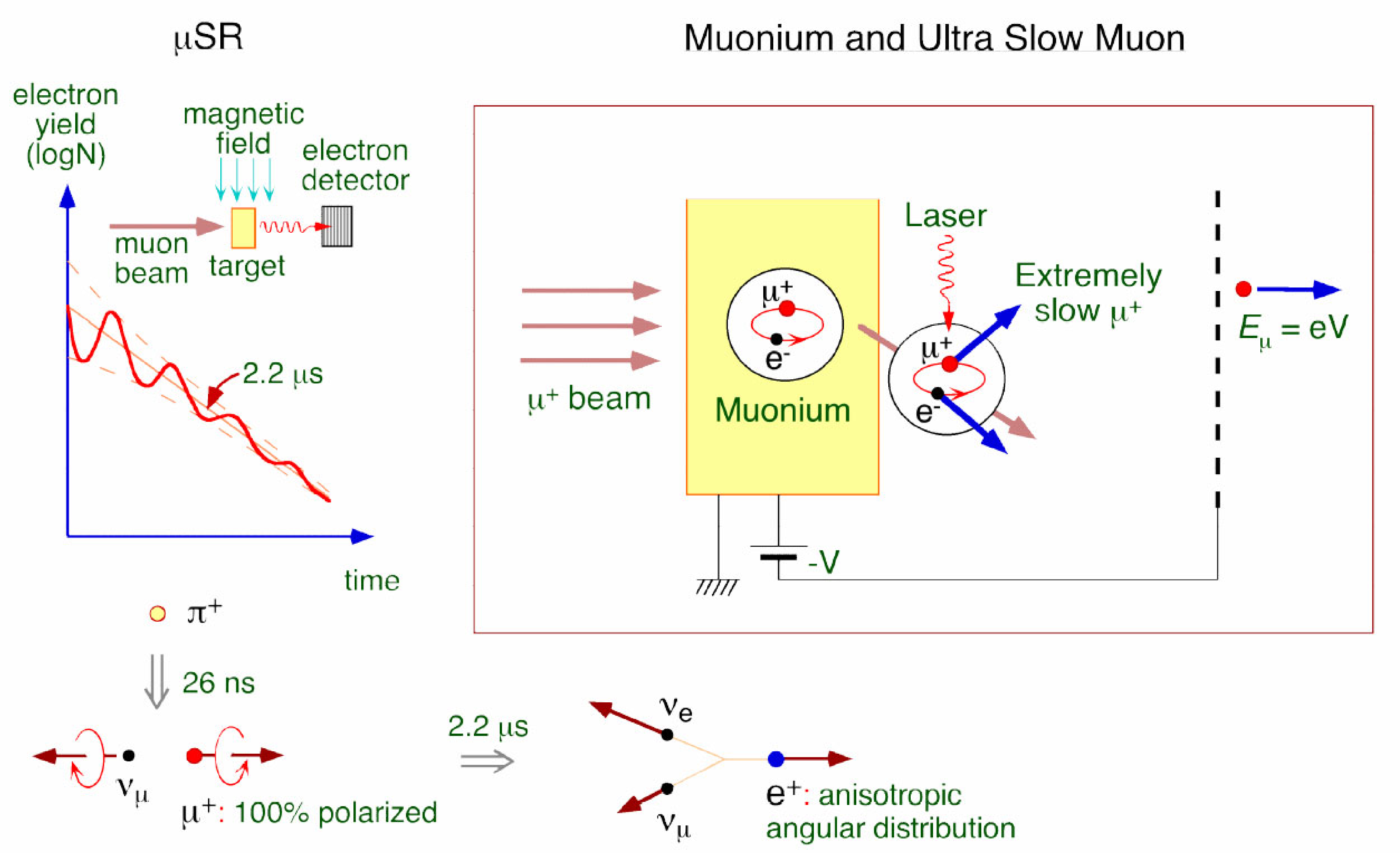
Radius is by 1/200 smaller than the normal atomic size.

T normal atomic size.

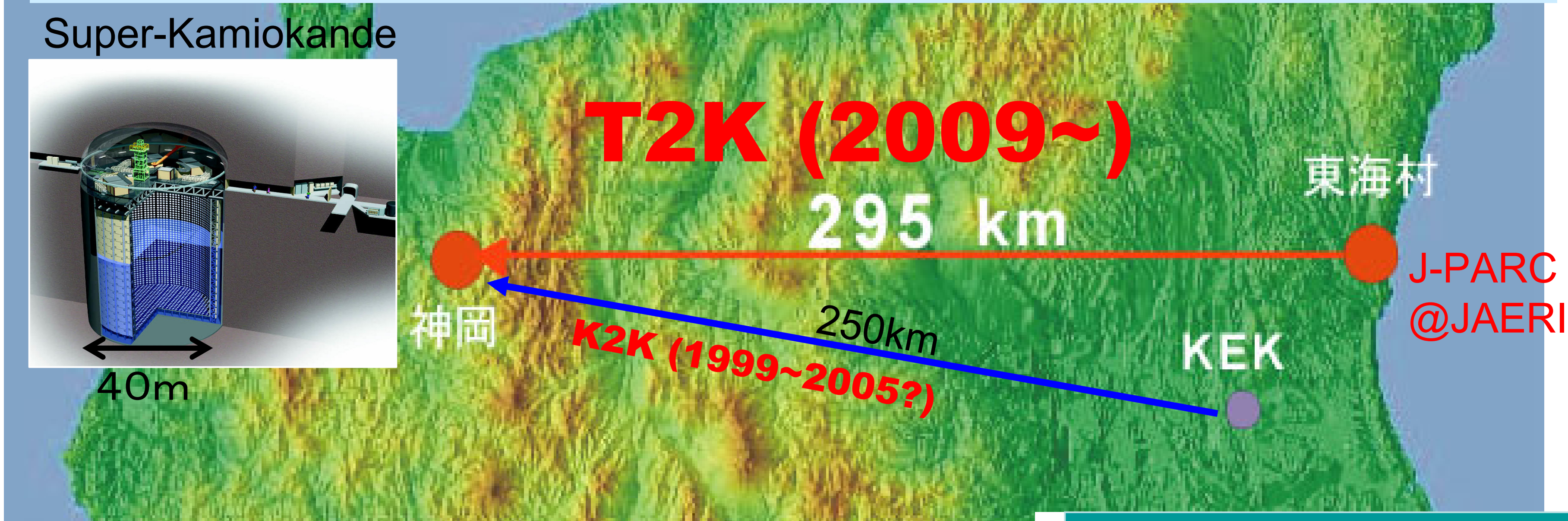
Muon catalized fusion



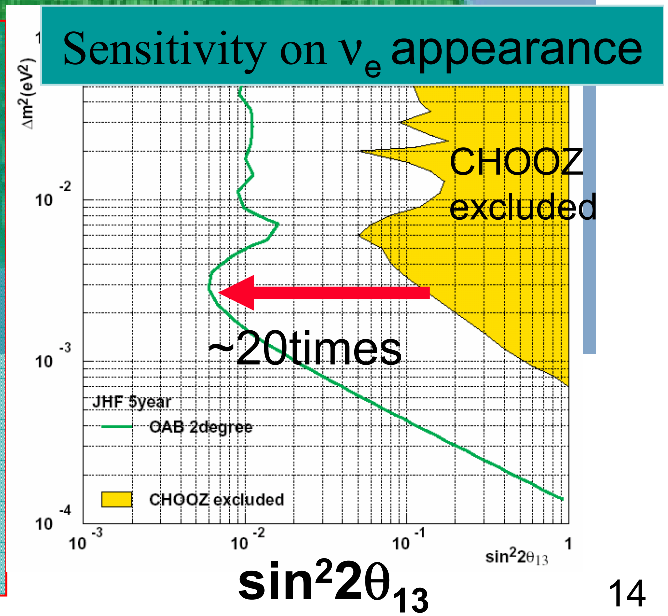
μSR and ultra slow muon



Neutrino physics at J-PARC
Tokai-to-Kamioka (T2K) LBL ν experiment



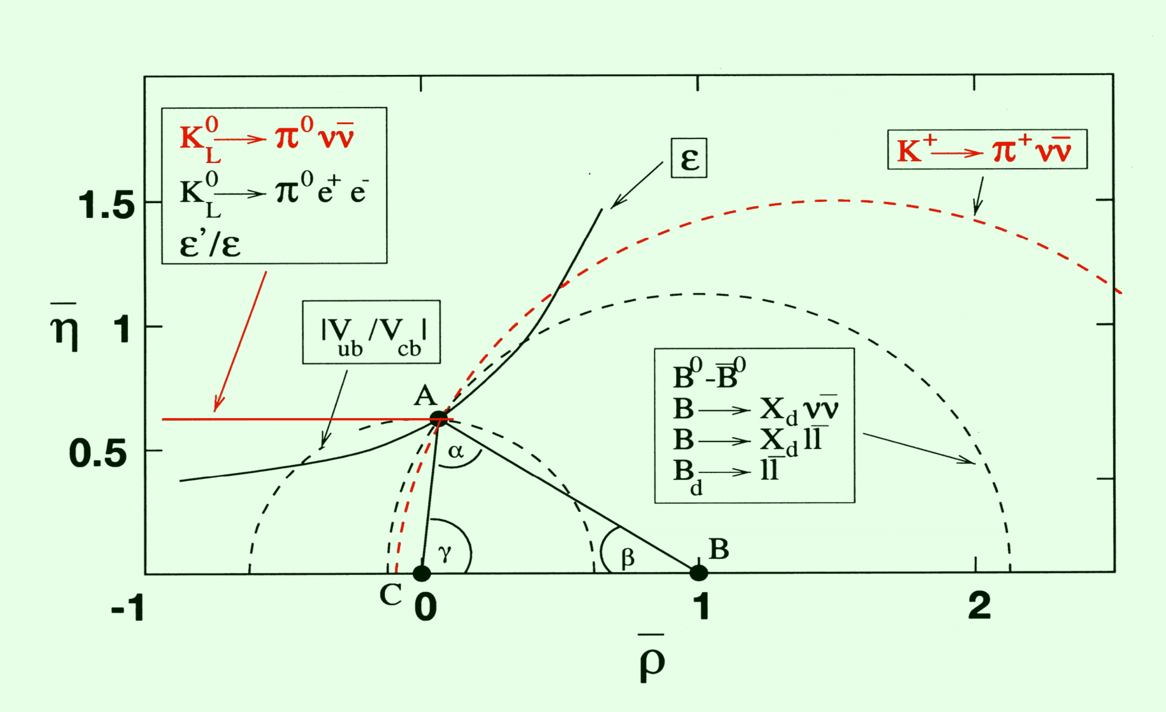
- Off-axis sub-GeV ν_μ beam from J-PARC 50GeV-PS
- ~3000 ν_μ CC int./yr (w/o osc.)
  ν_e appearance discovery
  ν_μ disapp. presice meas.
- Experiment approved.
- 5 year const. Start exp. in 2009



Kaon decay physics

- High precision frontier using high-intensity beams
- Test of the Standard Model and search for new physics
- Complementary to *B* physics and to the energy frontier

CKM matrix determination and test of unitary triangle



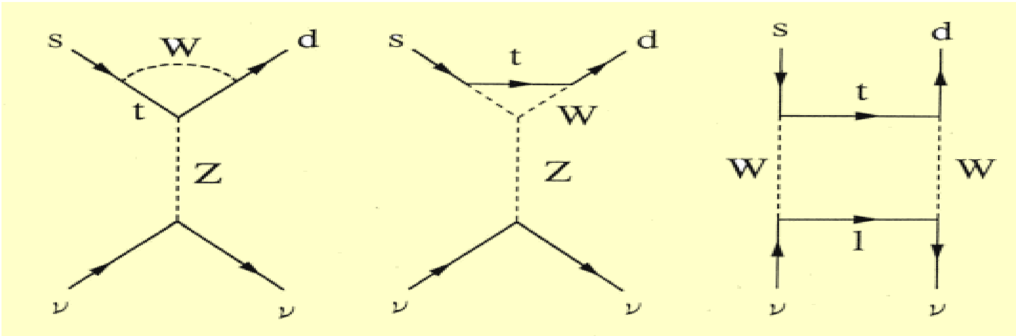
- Usefullness of FCNC decays

$K^0{}_L \to \pi^0 \nu\bar{\nu}$

$K^+ \to \pi^+ \nu\bar{\nu}$

CP violation in $K_L \to \pi^0 \nu \bar{\nu}$

Direct CP Violating Process

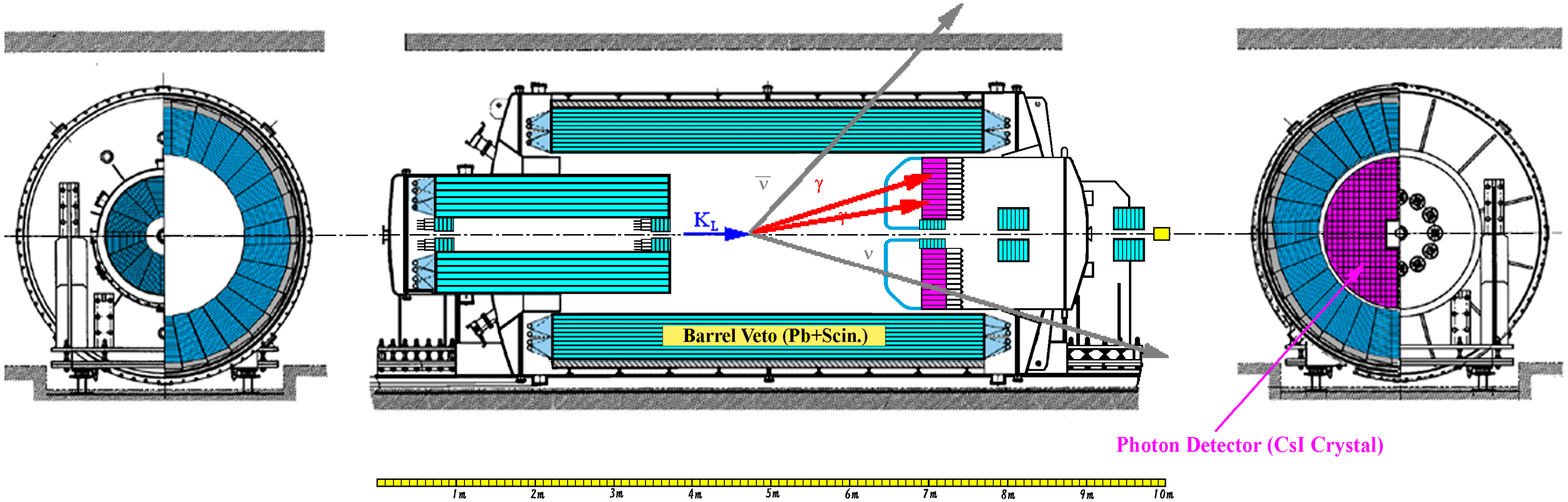


Standard Model prediction

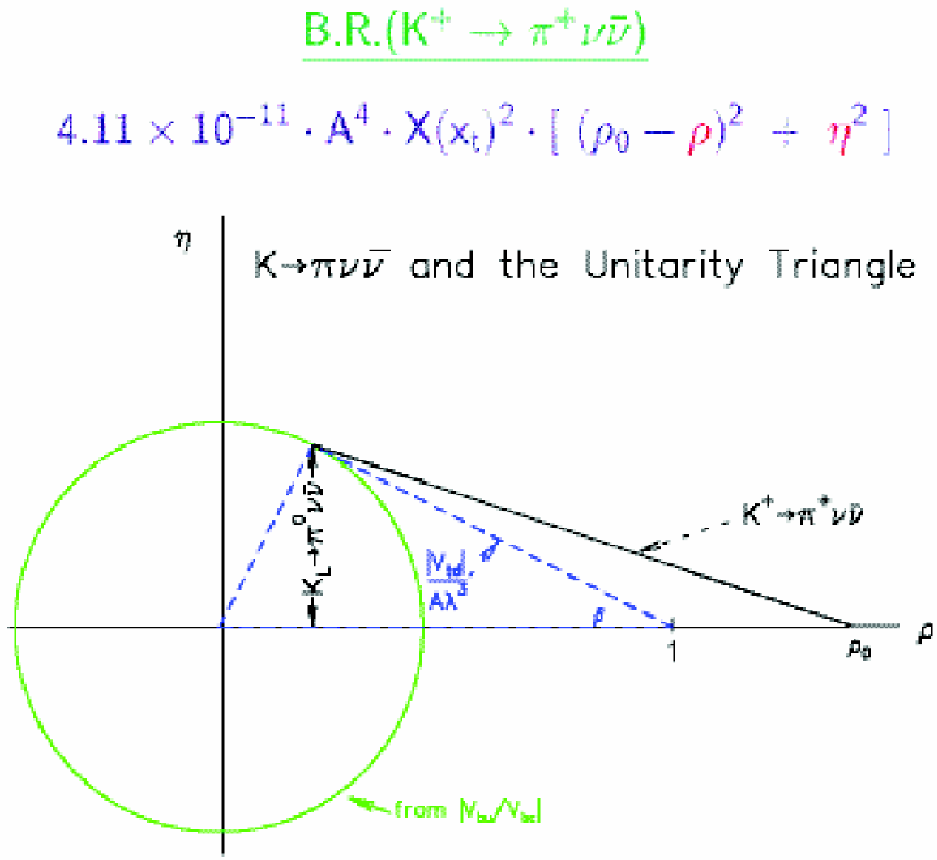
$BR(K_L \to \pi^0 \nu \bar{\nu})$
$= 6 \kappa_1 \cdot Im(V_{td} V_{ts})^2 X^2(x_t)$
$= 1.94 \cdot 10^{-10} \eta^2 A^4 X^2$
$\sim 3 \times 10^{-11}$

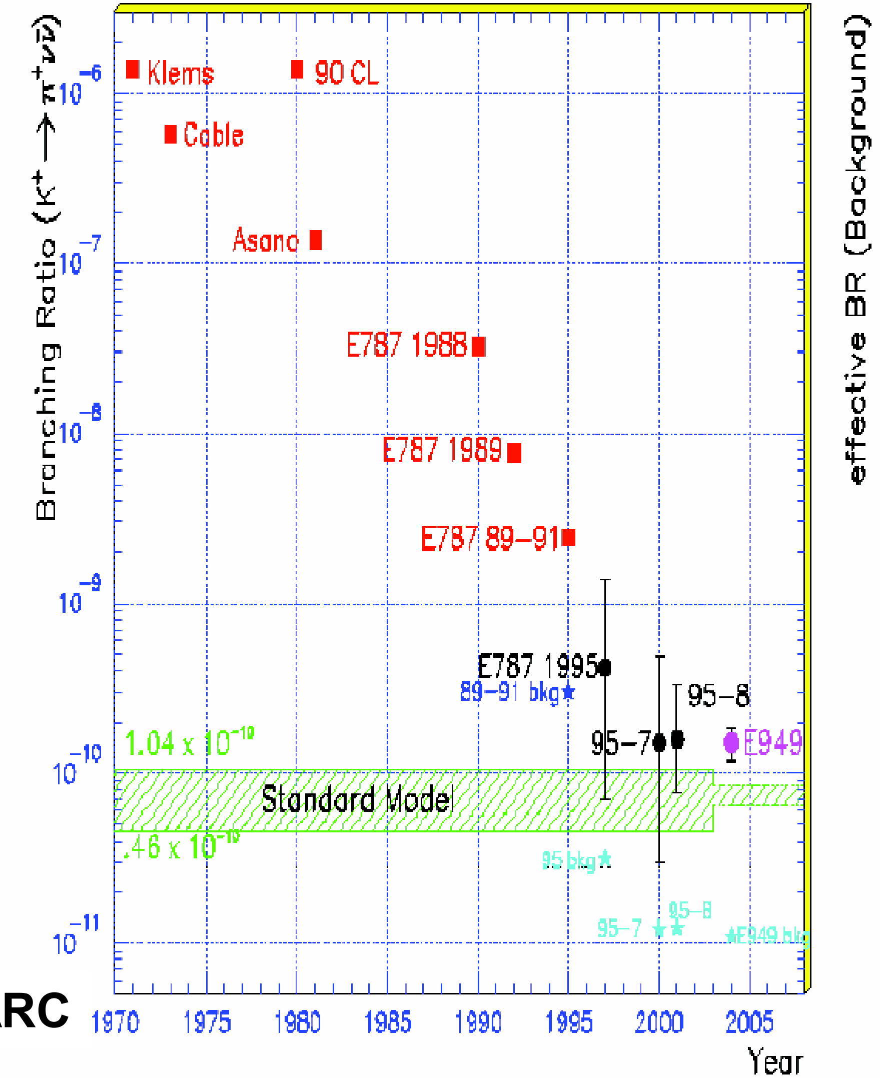
Determination of η with 10% precision

- E391a : $10^{-9} - 10^{-10}$
- KOPIO : 10^{-12} (50 events)
- J-PARC : < 10^{-13} (1000 events)



$K^+ \to \pi^+\nu\bar{\nu}$ at J-PARC

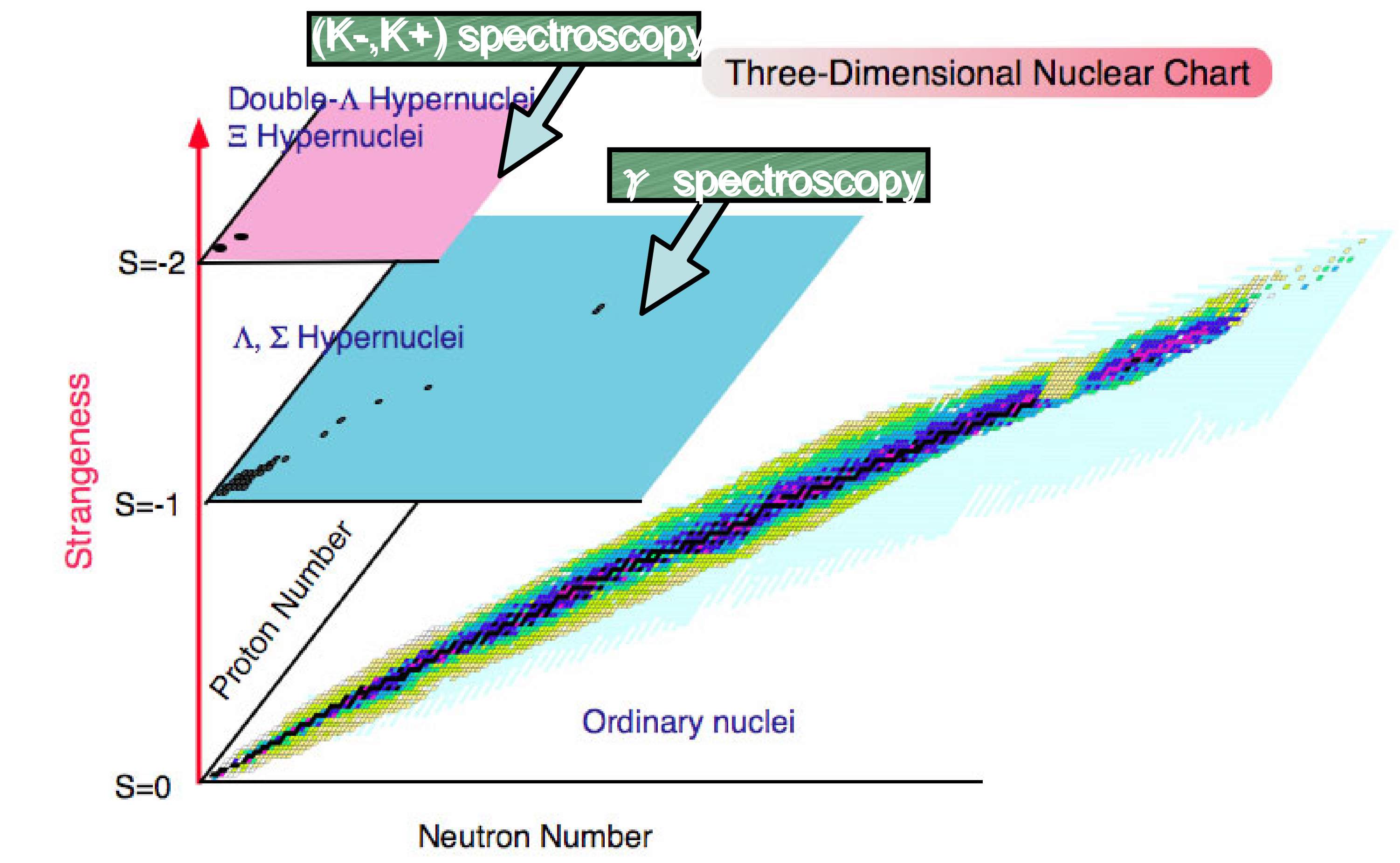




- Standard model prediction: $(0.75 \pm 0.29) \times 10^{-10}$
- Expected number of events at **J-PARC** ~100

Strangeness Nuclear Physics

New Hadron Many-Body Systems with Strangeness



T.Kobayashi (KEK)

Spectroscopy of S=-2 systems

Ξ hypernuclei/ $\Lambda\Lambda$ hypernuclei

- only a few events of $\Lambda\Lambda$ hypernuclei reported
- Ξ hypernuclear spectroscopy ?
- mixed states of Ξ, $\Lambda\Lambda$, and *H* exist ?
  - » K. Ikeda et al., Prog. Theor. Phys. 91 (1994) 747

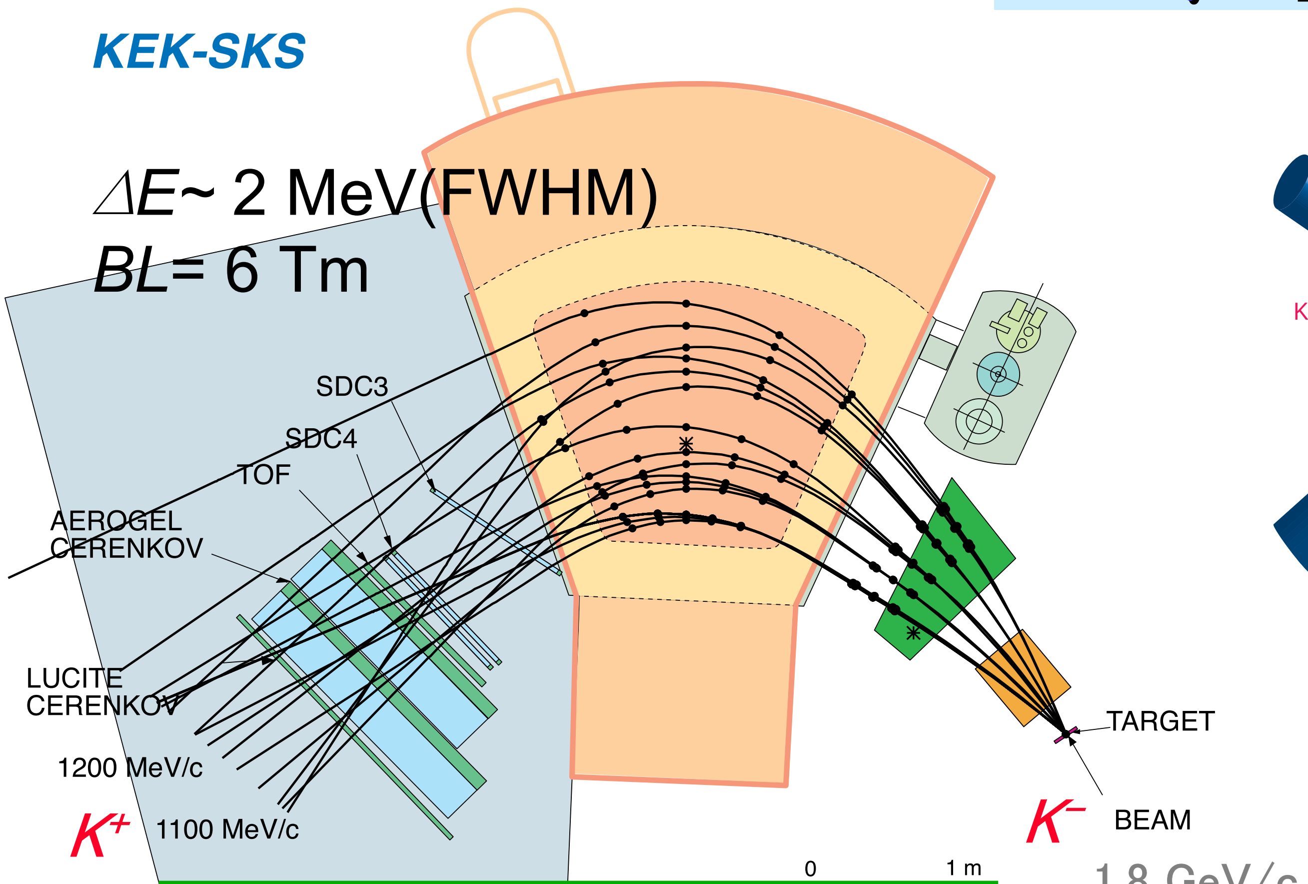
- need high intensity beams
  - (K^-,K^+) reaction at 1.8 GeV/c
    ex. ^{208}Pb(K^-,K^+) with 2 g/cm^2 thick target
    $\rightarrow$ ~6 events/MeV/day
- *H* dibaryon (*ssuudd*, I=J=0)
  - no evidence so far
  - m_H>2223.7 MeV(~6 MeV below 2m_Λ)
- S=-3 Ω^- nuclei, charm-hypernuclei *etc*.

(K^-,K^+) spectroscopy of Ξ^- hypernuclei

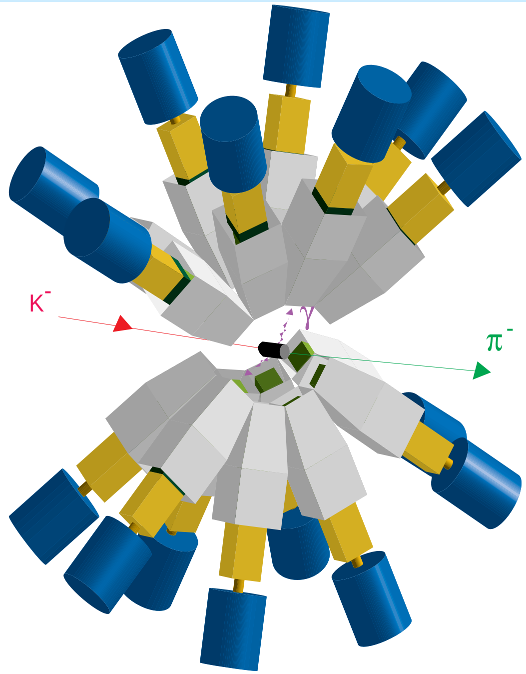
Ge detector system "HyperBall" for γ spectroscopy

KEK-SKS

ΔE~ 2 MeV(FWHM)
BL= 6 Tm



6 events/MeV/day for 1 MW beams

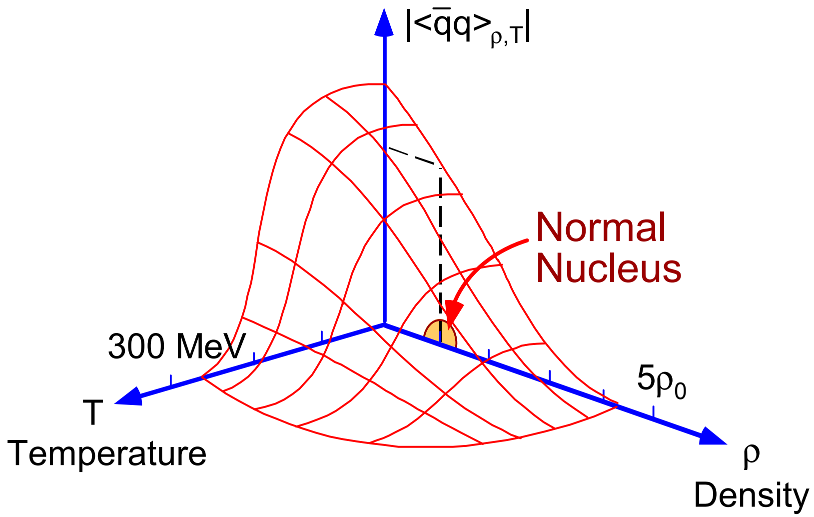


$(K^-,K^+)\gamma$: Double-Λ hypernuclei (excited sates)

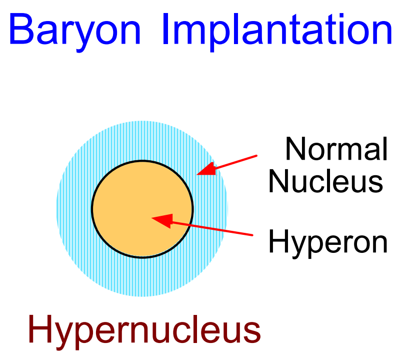
Hadrons in nuclear matter

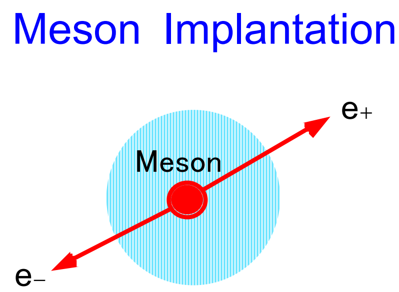
- Methods to study the origin of hadron mass:
  - Lattice QCD (theory)
  - Implantation of a hadron in nuclear matter (J-PARC)

- Change of meson mass in nuclear matter due to "partial restoration of chiral symmetry".



●T.Hatsuda and S.H.Lee, Phys.Rev. C46, R34 (1992)
●Muroya *et al.* , hep-lat/0208006

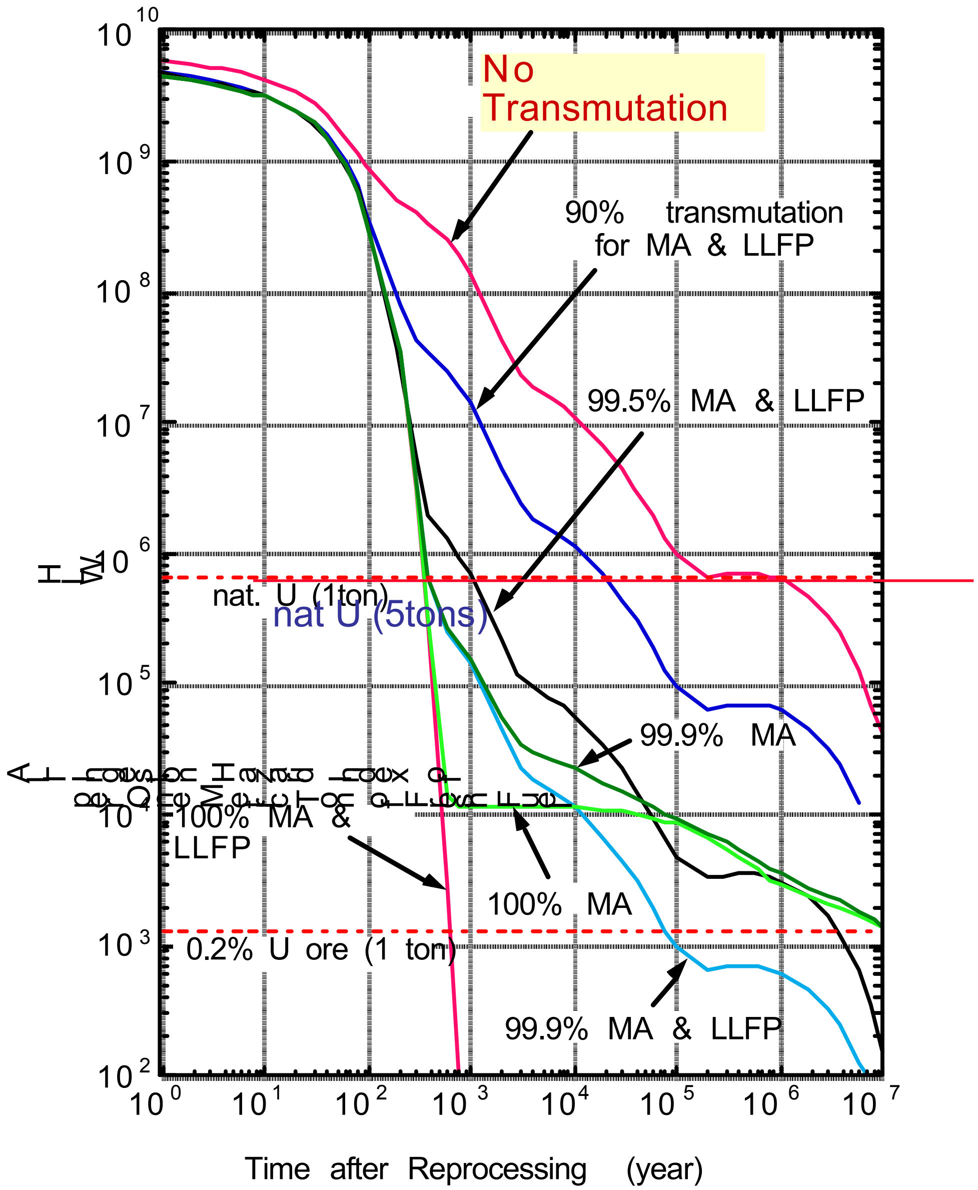




Vector meson decay
$\phi, \rho, \omega \rightarrow l^+ l^-$

KEK E325 ; K. Ozawa, *et al.*,
Phys. Rev. Lett. 86, 5019 (2001).

Necessity of nuclear transmutation

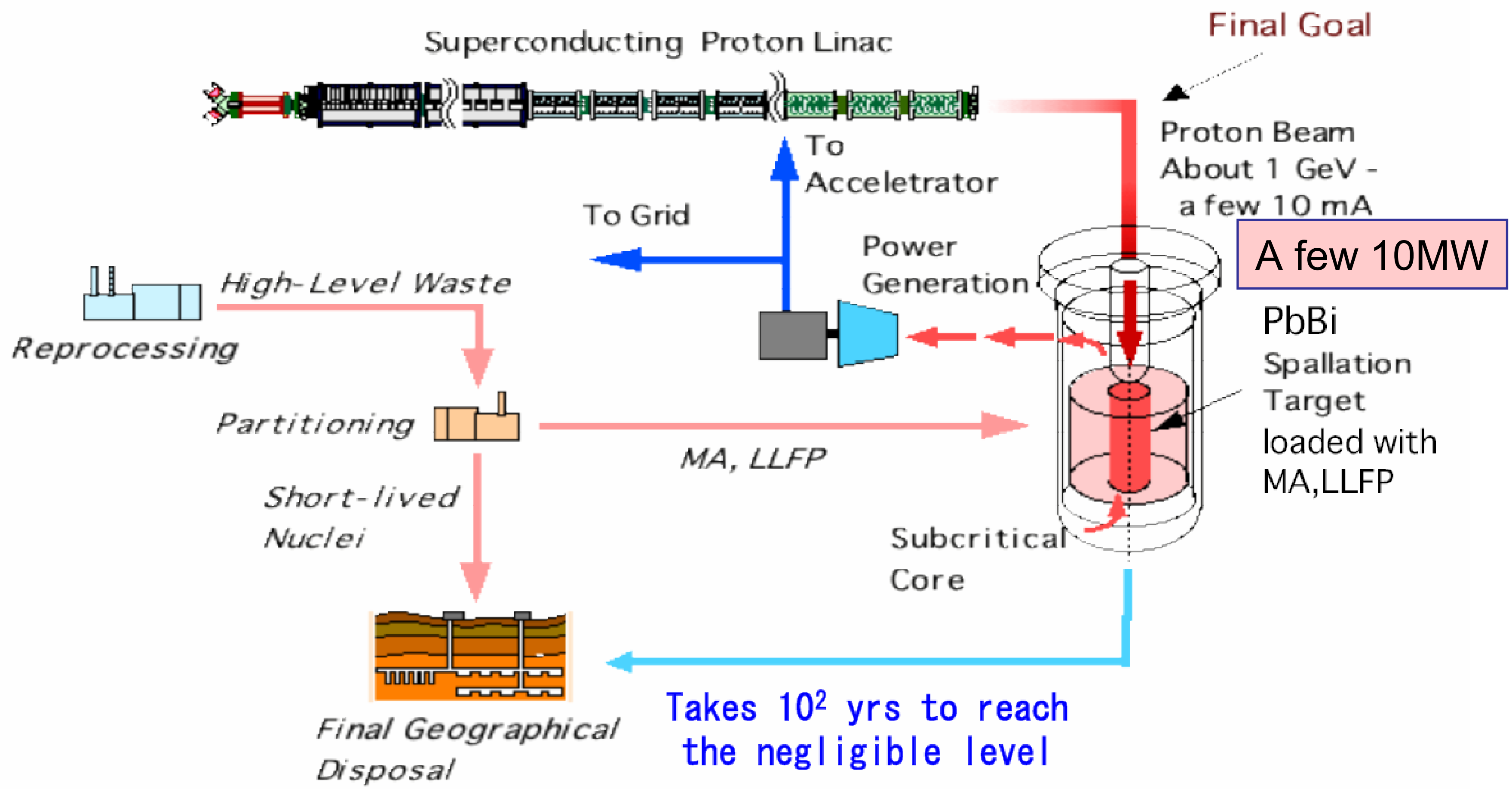


- 99.5% transmutation efficiency will reduce the radioactivity level to the natural uranium level within 500 years

- Technical feasibility is studied using 600 MeV beam at JHF

MA : Np, Am, Cm
LLFP : Tc-99, I-129

Accelerator-driven transmutation (ADS)

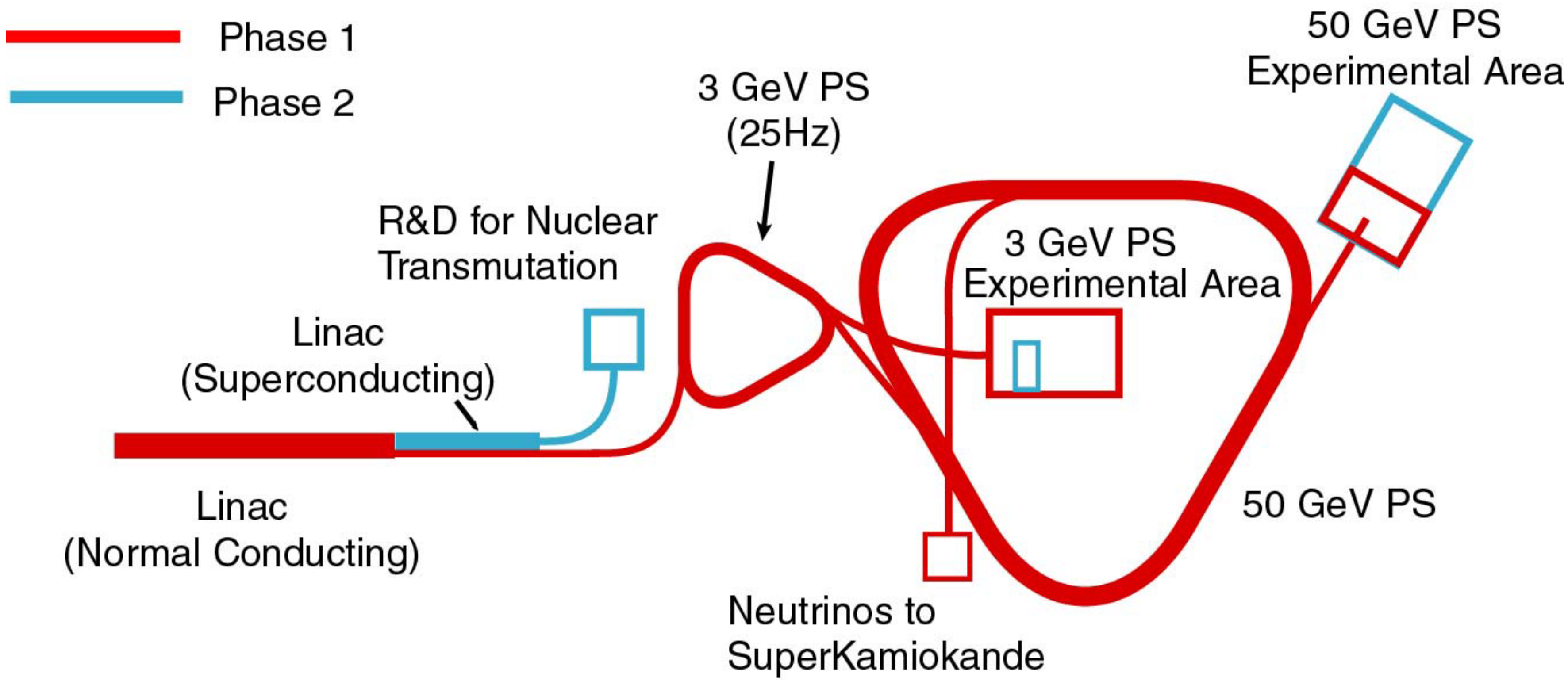


Nuclear transmutaion is an important issue for nuclear power stations. This project will explore the technical feasibility.

Summary

- High intensity hadron machines
  - MW-class facilities being constructed.
  - Multi-MW in the future.
- Provide powerful tool for extending our knowledge in wide range of fields
  - Industry (neutron,..)
  - Materials & life science (neutron, muon,..)
  - Fundamental science (n, μ, ν, K, $\bar{p}$…)
  - Nuclear power
- Unique facility in Japan covering all fields "J-PARC"
  - will soon be online in 2008

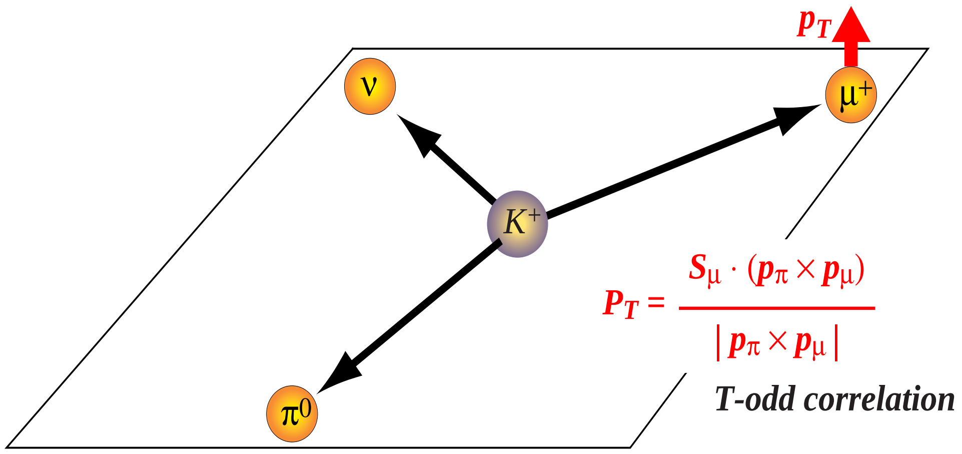
J-PARC Phase 1 and Phase 2



- Phase 1 + Phase 2 = 189 billion Yen (= $1.89 billion if $1 = 100 Yen).
- Phase 1
  - 151 billion Yen for 7 years.
  - Construction : Apr.2001~Mar.2008
  - Neutrino included: Construction Apr.2004~Mar.2009

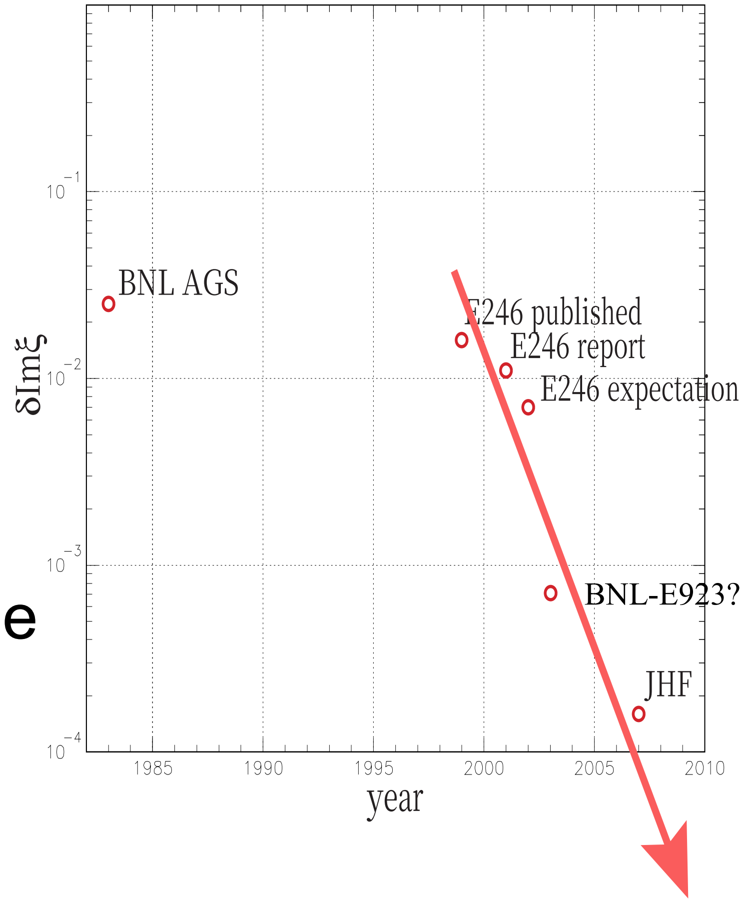
T violation in $K^+ \to \pi^0 \mu^+ \nu$ decay

■ Muon transverse polarization P_T



$P_T^{spurious}$ (Final State Interaction) ~ 10^{-6} (Zhitnitskii, 1980)

- Search for new physics beyond the SM
  - Multi-Higgs doublet model
  - Leptoquark model
  - *R* -parity violating SUSY *etc.*

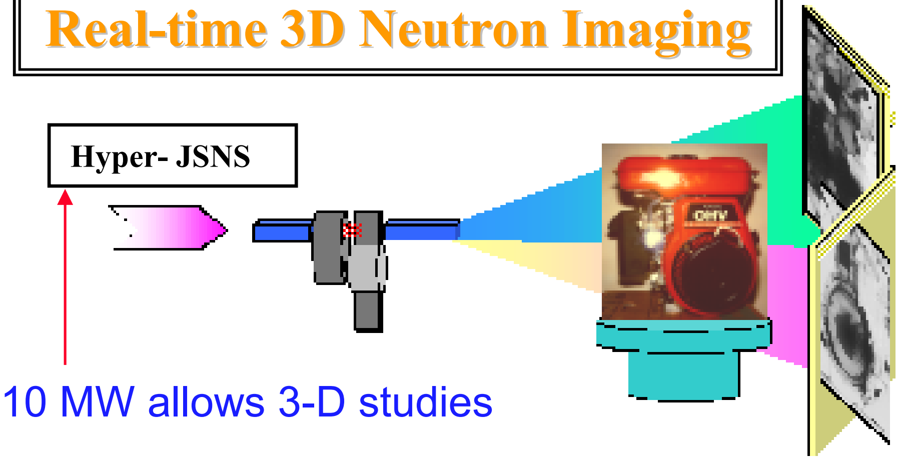


■ P_T in $K^+ \to \mu^+ \nu \gamma$ □□also measured.

- $\delta P_T \sim 10^{-4}$ at J−PARC

3 Dimensional Movie for Industrial Usage

Real-time 3D Neutron Imaging



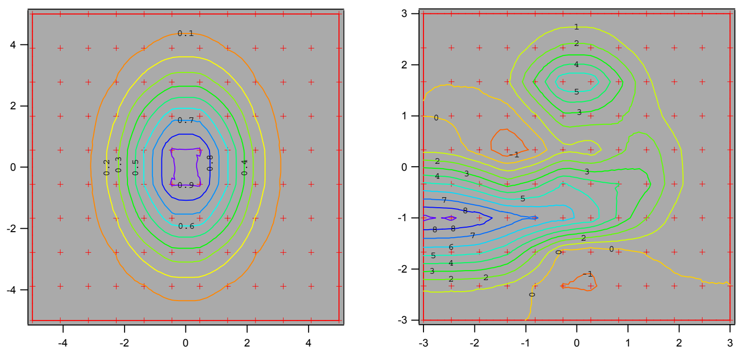
- Real-time 3D Imaging of Bulky Body Containing Light Elements
- Elements Identification in Bulk

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

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

Y. Morii, et al.