Status of J-PARC and Its Scientific Application

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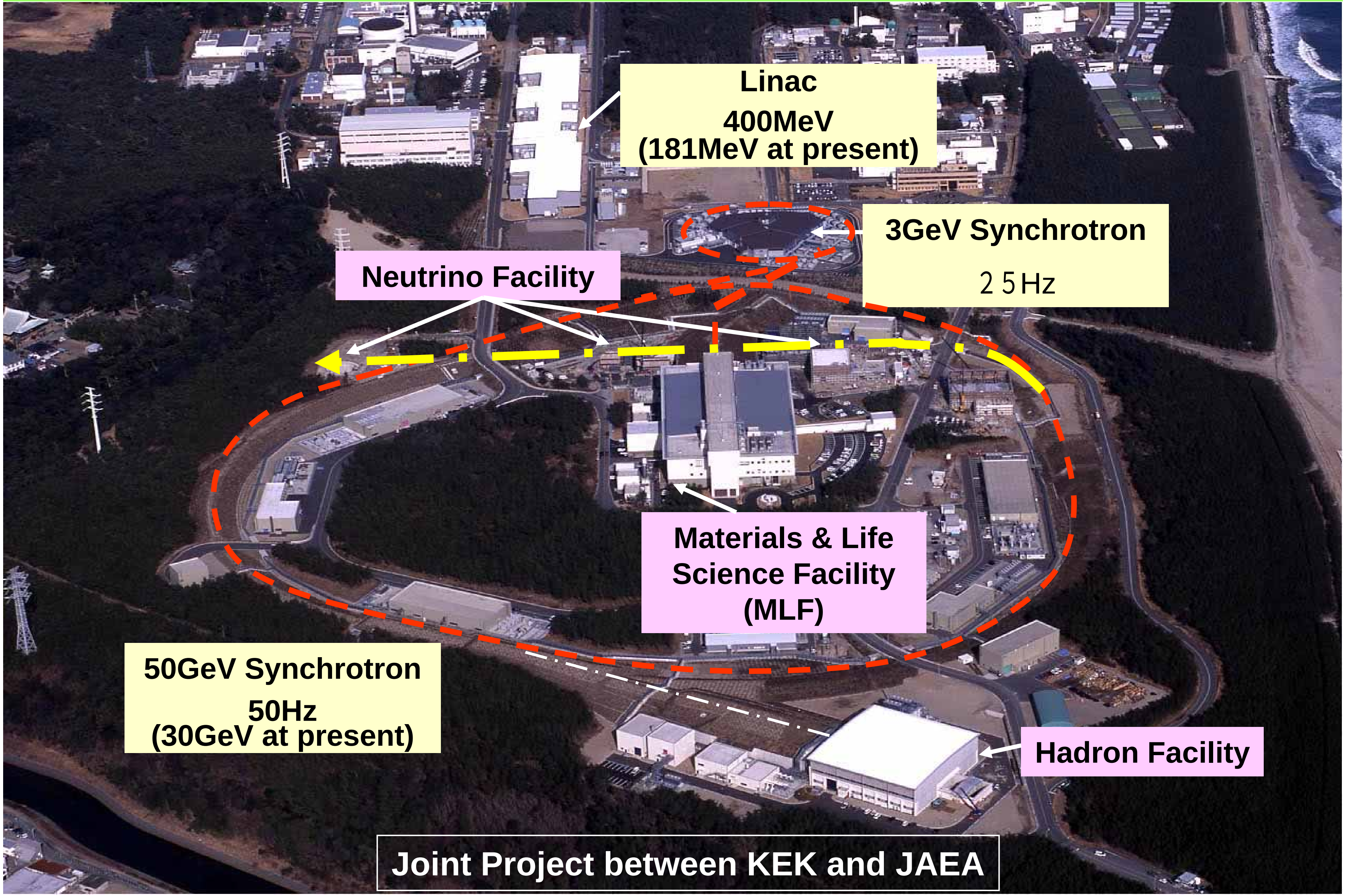
Japan Atomic Energy Agency (JAEA)

High Energy Accelerator Research Organization (KEK)

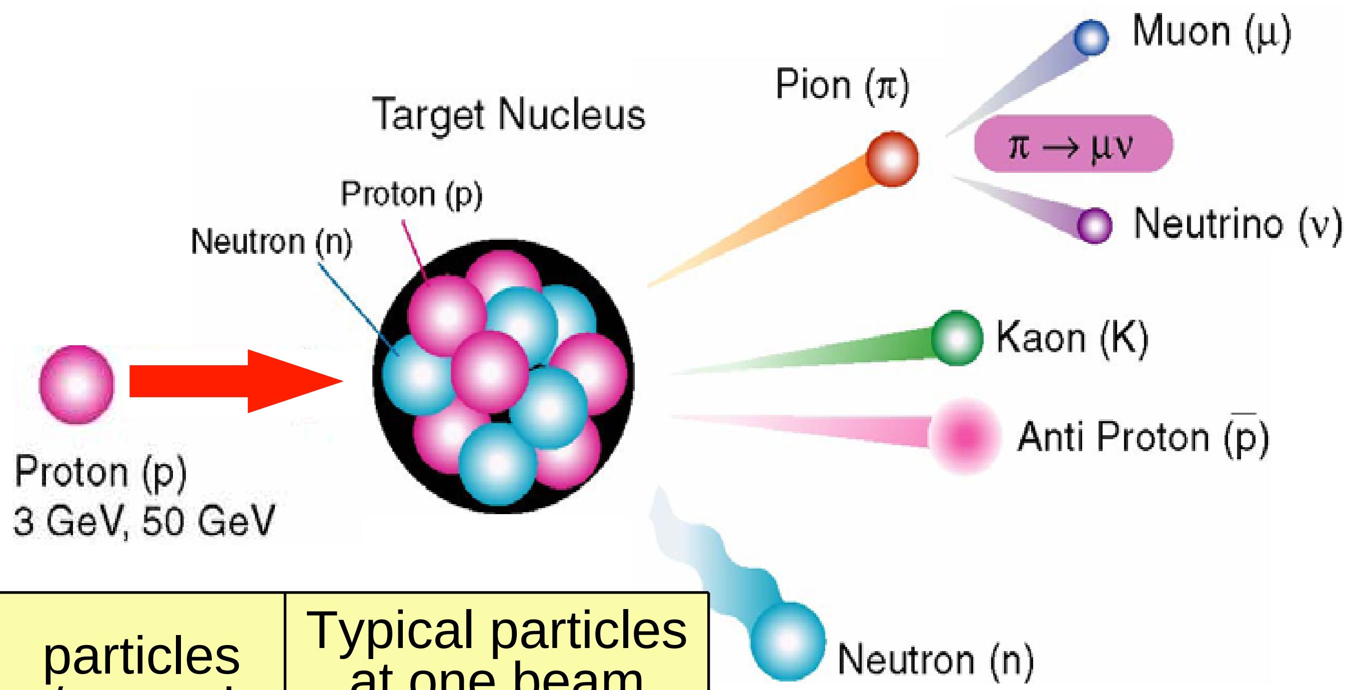
May 4, 2009 at IAEA

International Topical Meeting on Nuclear Research Applications and Utilization of Accelerators

J-PARC = Japan Proton Accelerator Research Complex



Secondary particles produced at J-PARC

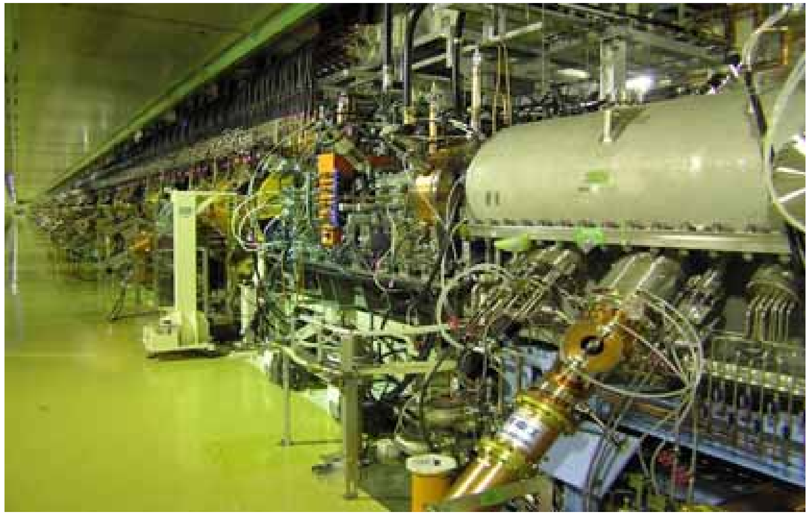


Beam Flux at the Full Power Proton Beams

	particles /one proton	particles /second	Typical particles at one beam line*)
Neutron	80	10^{17}	10^{8}
Muon	10^{-4}	10^{11}	10^{7}
Kaon	10^{-4}	10^{10}	10^{6}
Neutrino*	6	10^{15}	3×10^{7}

*) Number listed here is at Super Kamiokande.

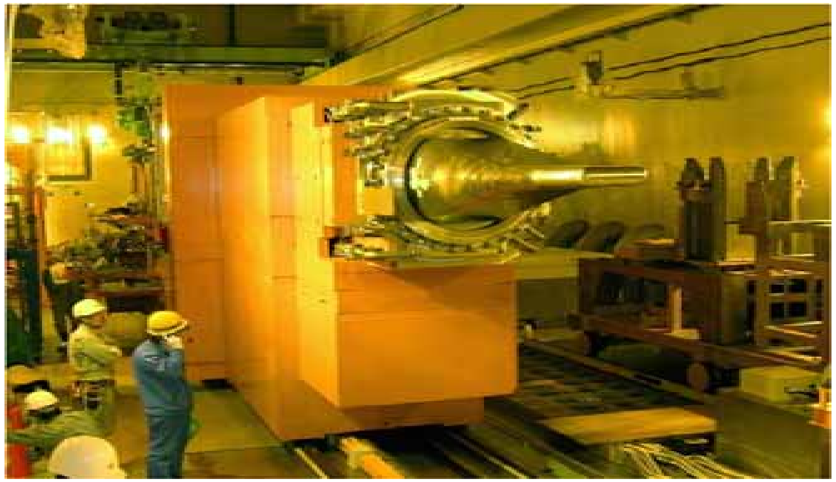
Accelerators and Neutron Target are ready



Linac (181MeV Operation on Jan. 2007, 400MeV upgrade on-going)

3GeV Synchroron (25Hz 210kW operation on Sep. 2008)

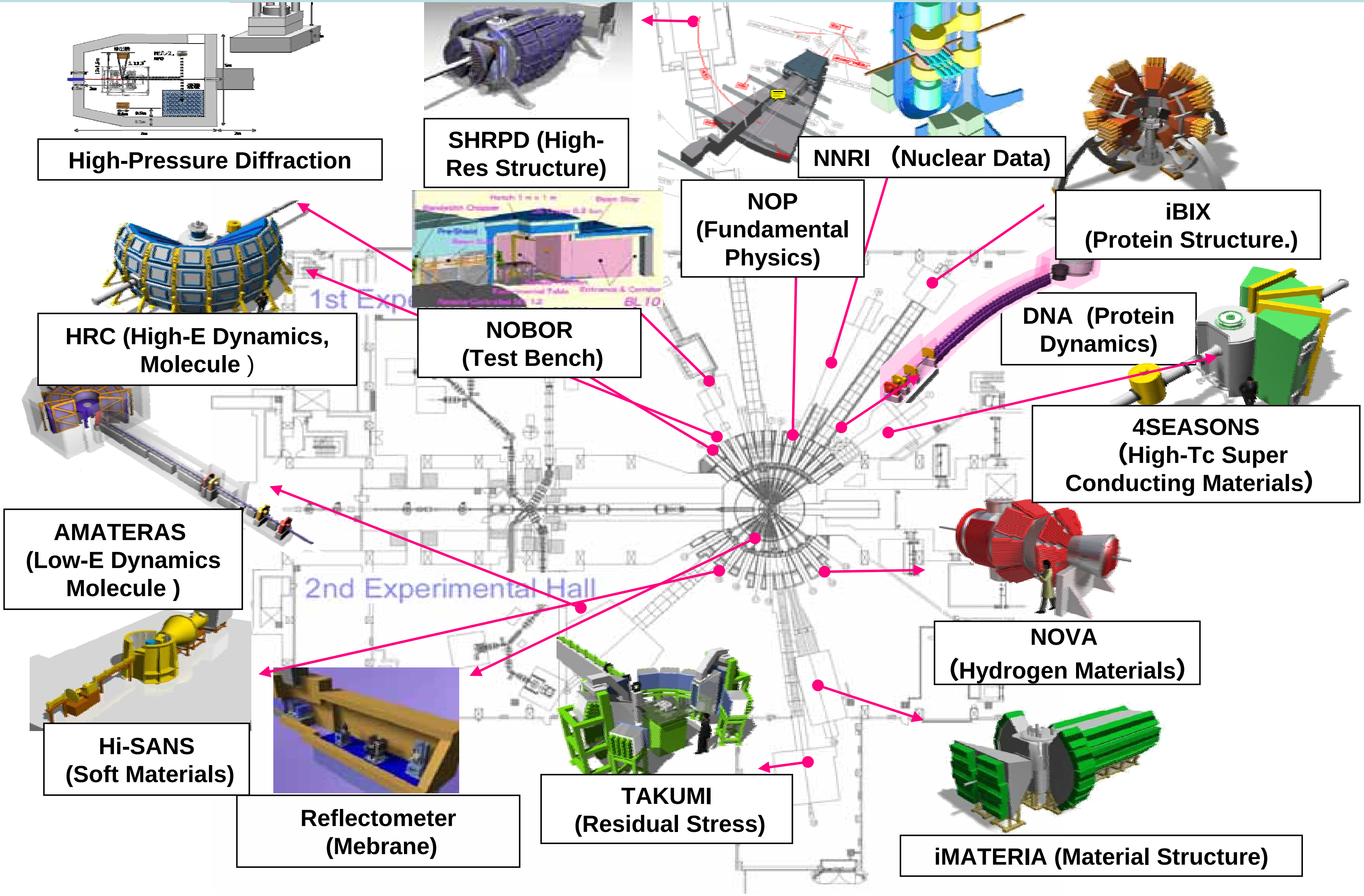
50GeV Synchrotron (Slow and fast extraction to Hadron and Neutrino Facilities 2009)



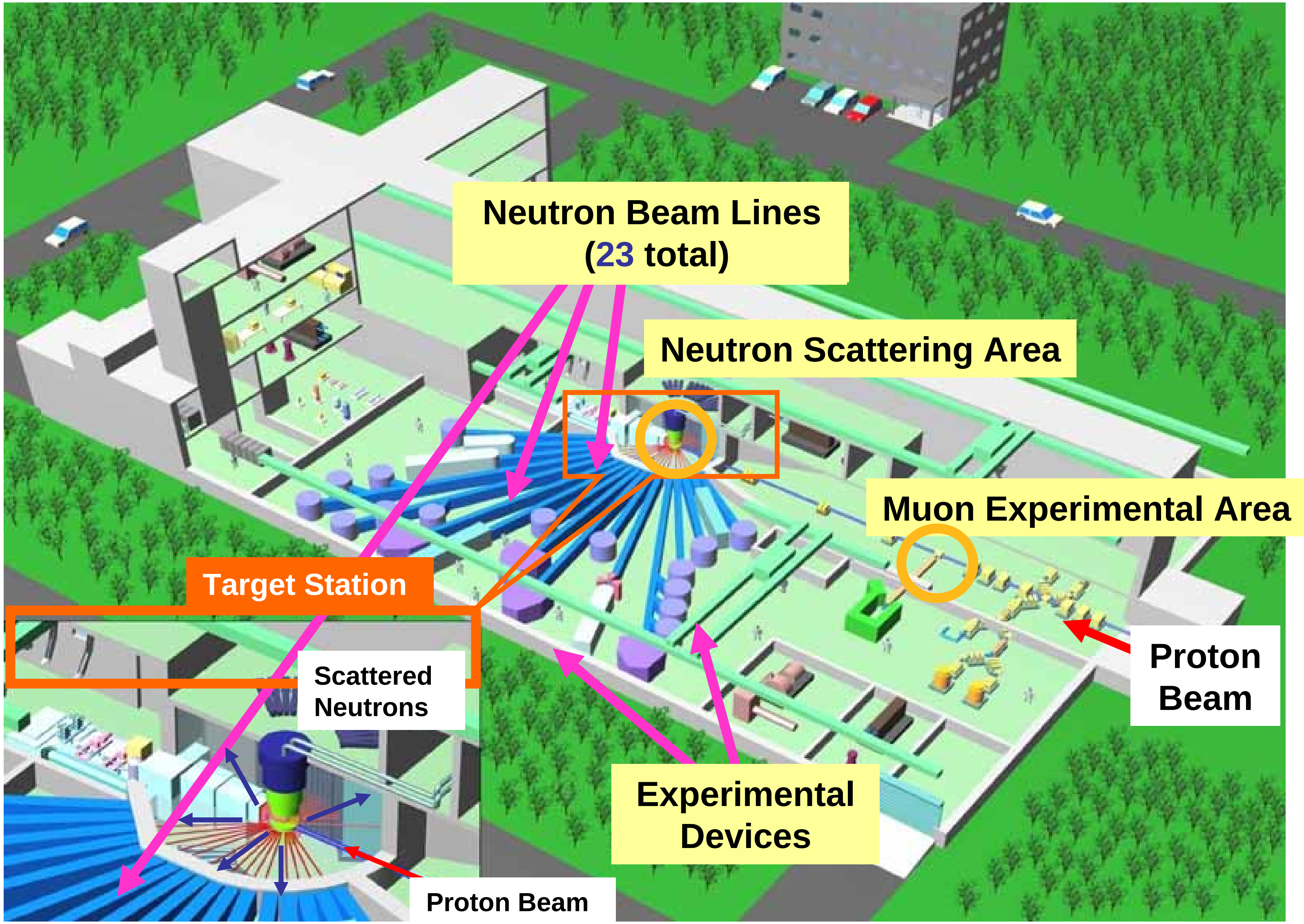
Mercury Target for Neutron (First neutrons on May 2008)

Neutron Instruments and Their Applications

- 15 Instruments are prepared for Day-one Experiments
- Now 8 Instruments are in operation

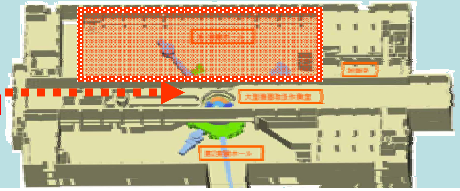


Materials & Life Experimental Facility

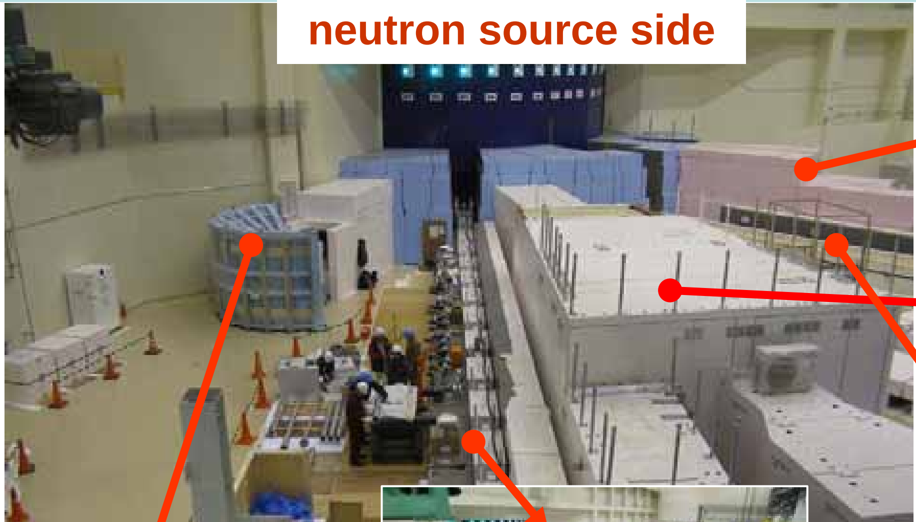


1st Experimental Hall (East Hall)

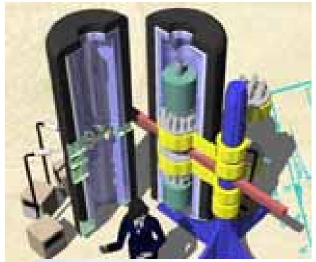
Beam



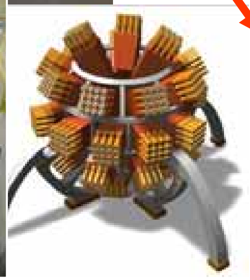
neutron source side

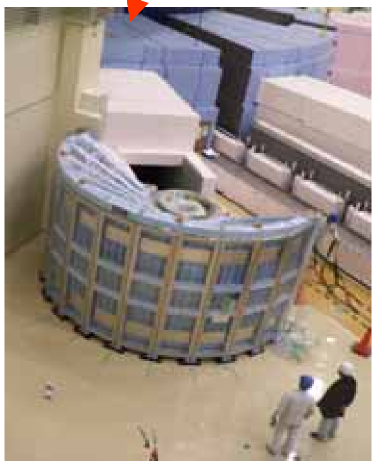


BL#10 NOBORU
New Techniques Development



BL#04 NNRI
Nuclear Data for ADS





BL#01 Four SEASONS

High Tc super-conductivity

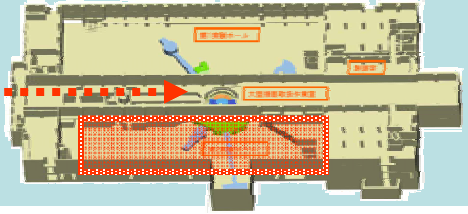
BL#03 iBIX
Structural analysis of bio-materials

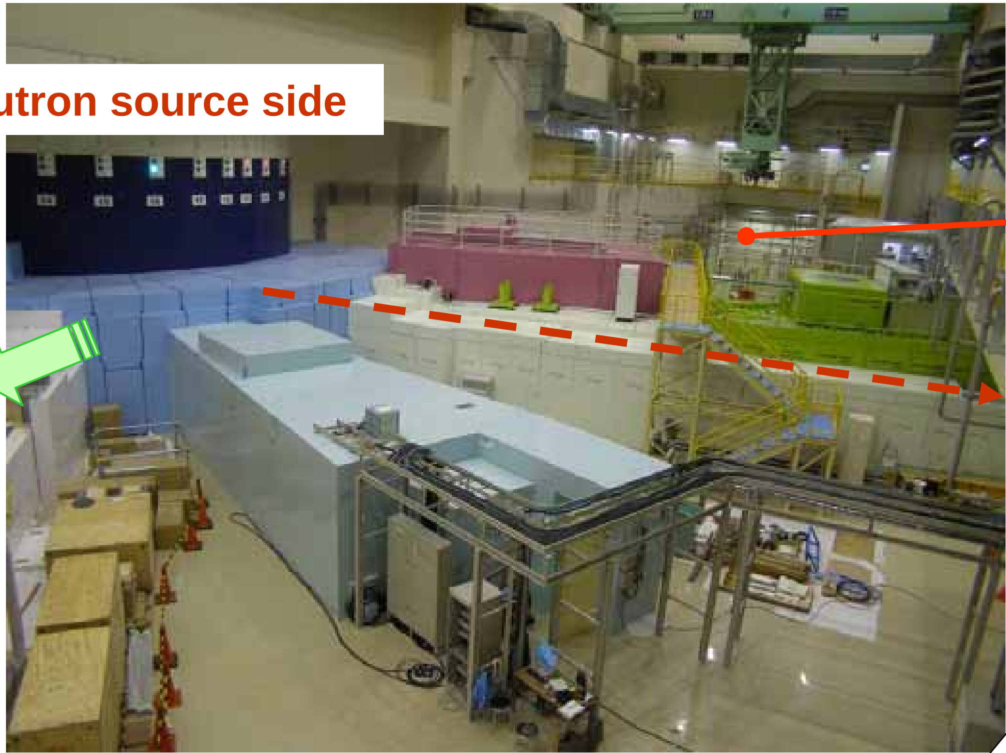
Development of protein, medicine, food, plastics, organic display, etc.

BL#08 SHRPD
Super High Resolution Powder Defractometor

New functional materials

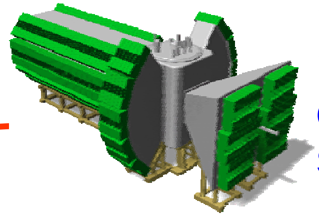
2nd Experimental Hall (West Hall)

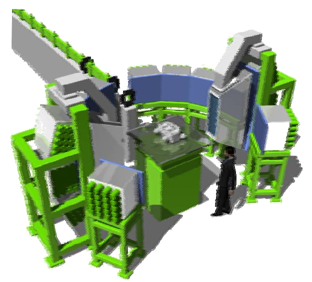




BL#20 iMATERIA

Development of magnetic memory, cosmetics, steel, synthetic fiber



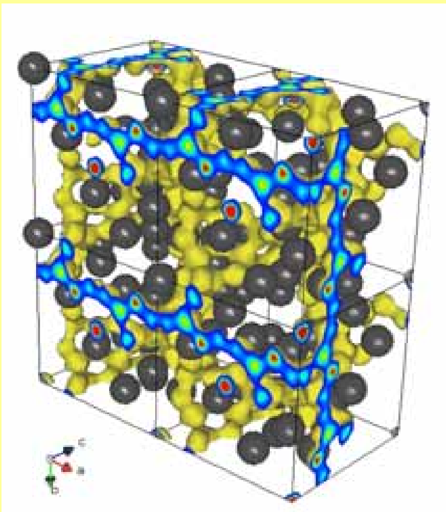


BL#19 TAKUMI

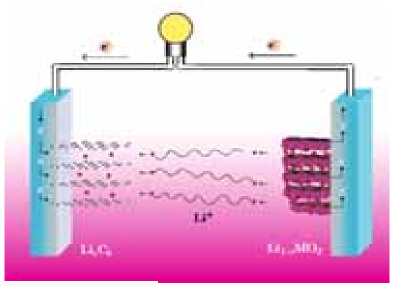
Internal residual stress measurement (Evaluation of industrial fabrication process)

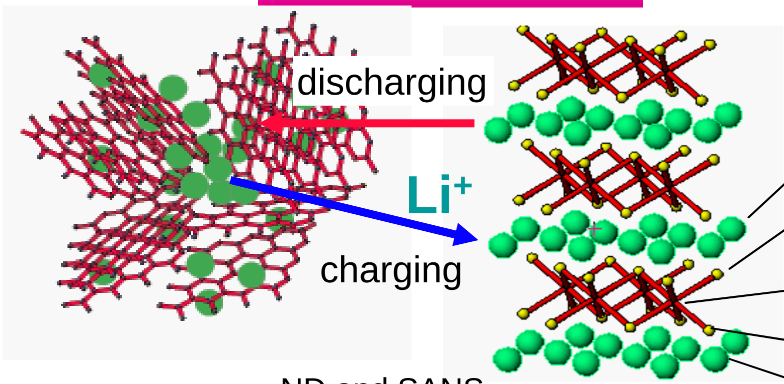
Development for high-performance battery materials

- Observe atomic / ionic structure in various scale
  (Local environment around H^+, Li^+)
- Understanding the mechanism of charge / discharge process
  => high performance



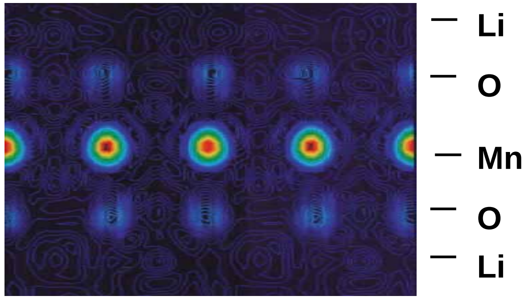
Visualization for diffusion path of Li ions





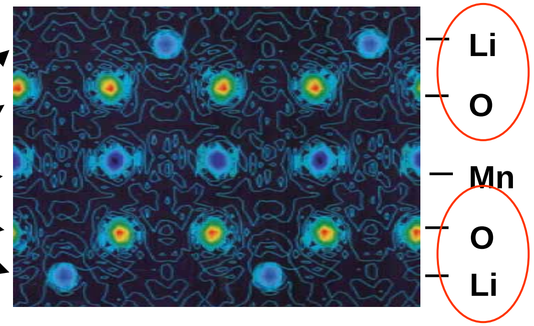
ND and SANS

X-ray



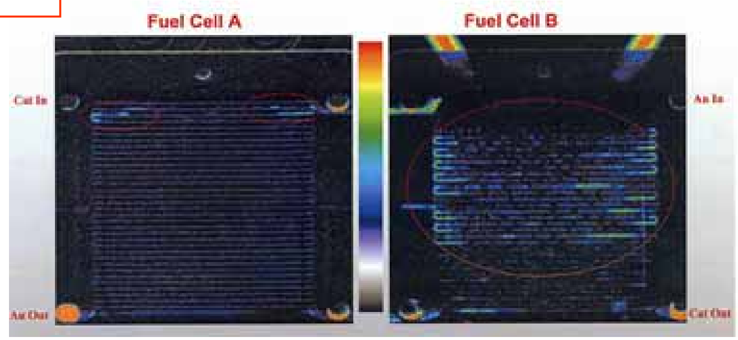
($LiMn_2O_4$)

neutron

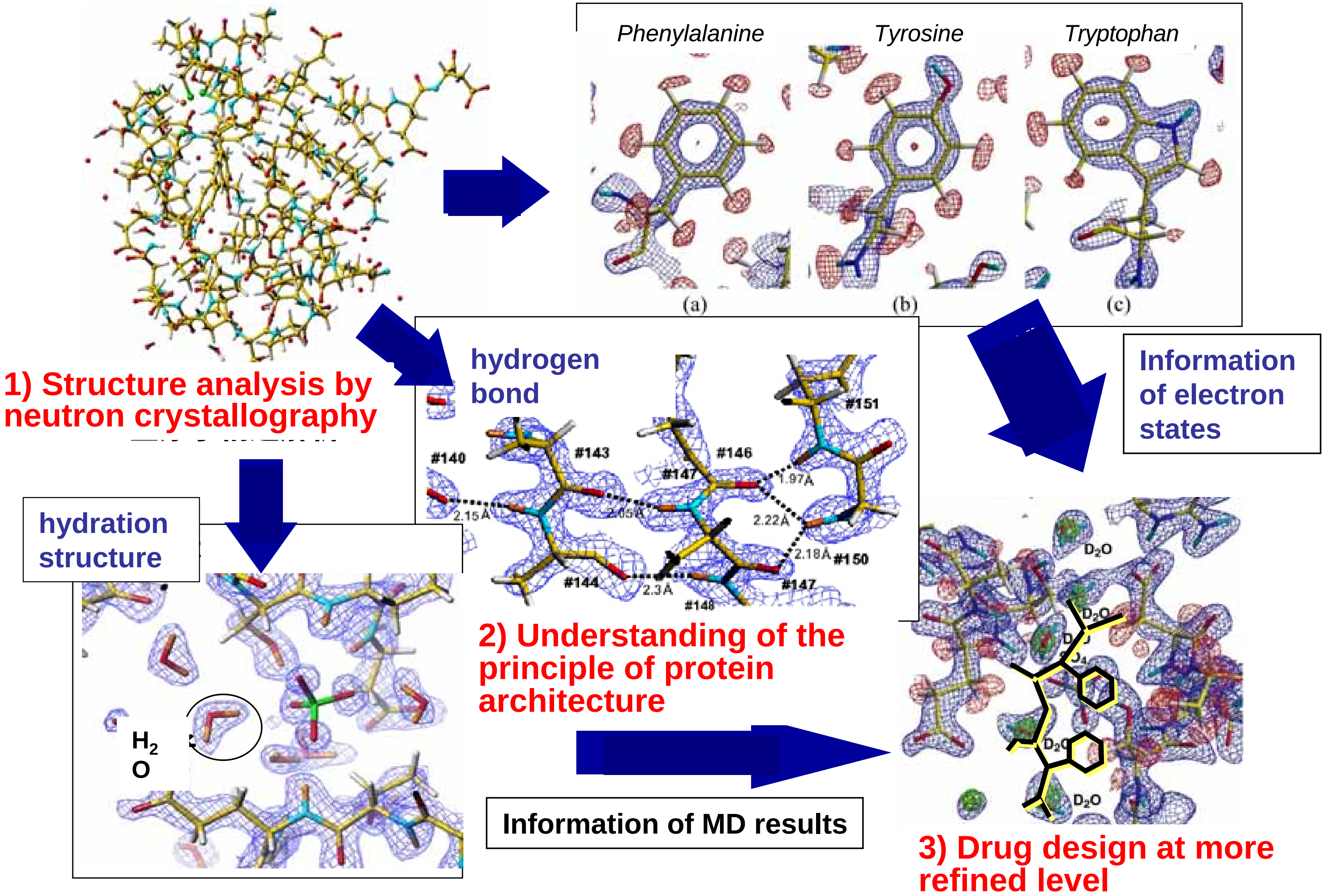


Hydrogen Fuel Cell

- In-situ evaluation of the structure of separator of fuel cell by neutron radiography.
- The water, produced by reaction, flow smoothly can be seen in Cell A. On the other hand, the water was stagnant at the corner in Cell B. This suggested that the structure of separator in Cell B is not optimal. (NIST)



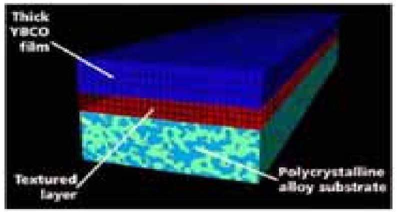
Protein Structure and Drug Design

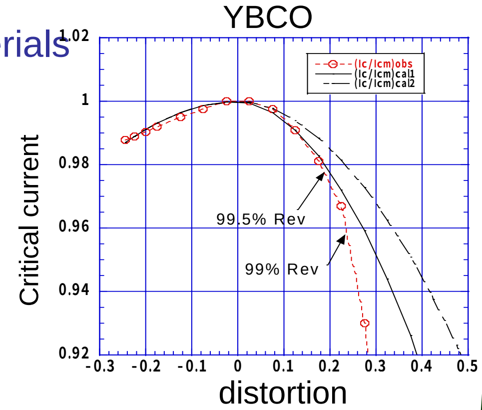


Tc Property Change Dependent on Stress of Tape of High-Tc Super-Conducting Materials

News from J-PARC

Tape of superconducting materials
$YBa_2Cu_3O_7$ (YBCO)

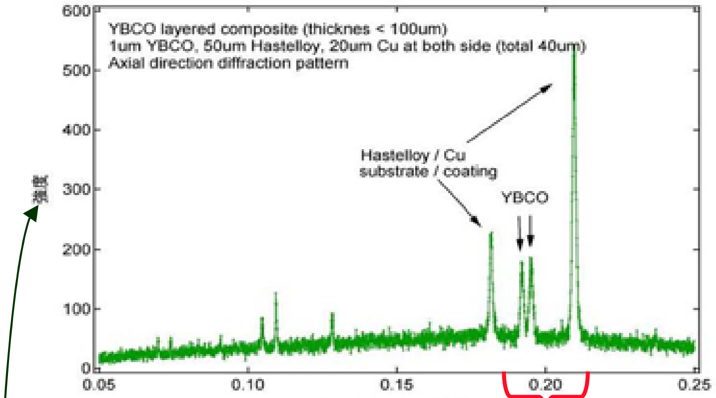


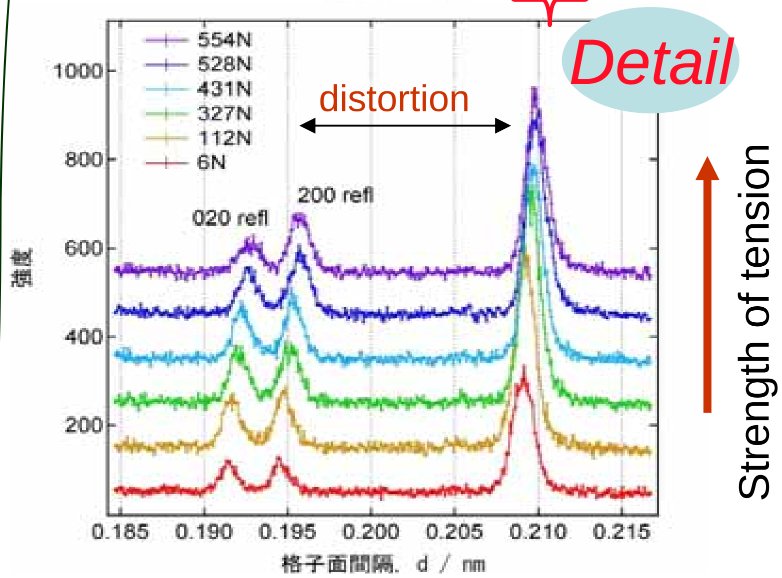


Property of super conductivity depends on internal distortion produce during fabrication or usage.
→very important to clarify the mechanism

Distortion test under tension applied to 100 μm-thick tape

BL#19 TAKUMI



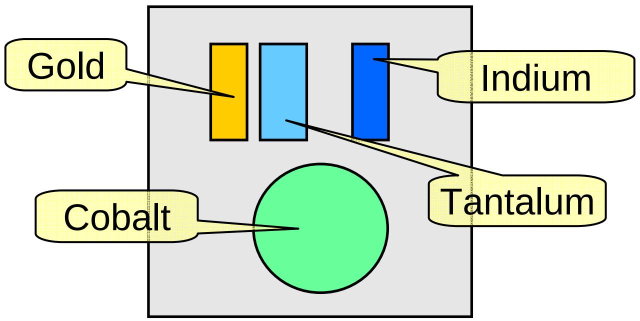


Analysis of distortion of YBCO lattice distance by tension strength
→Mechanism of distortion

Demonstration of Pulsed Neutron Radiography
(BL#10 NOBORU)

News from J-PARC

Test sample

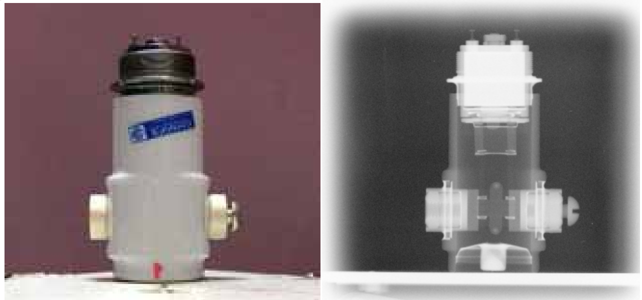


50mm×50mm

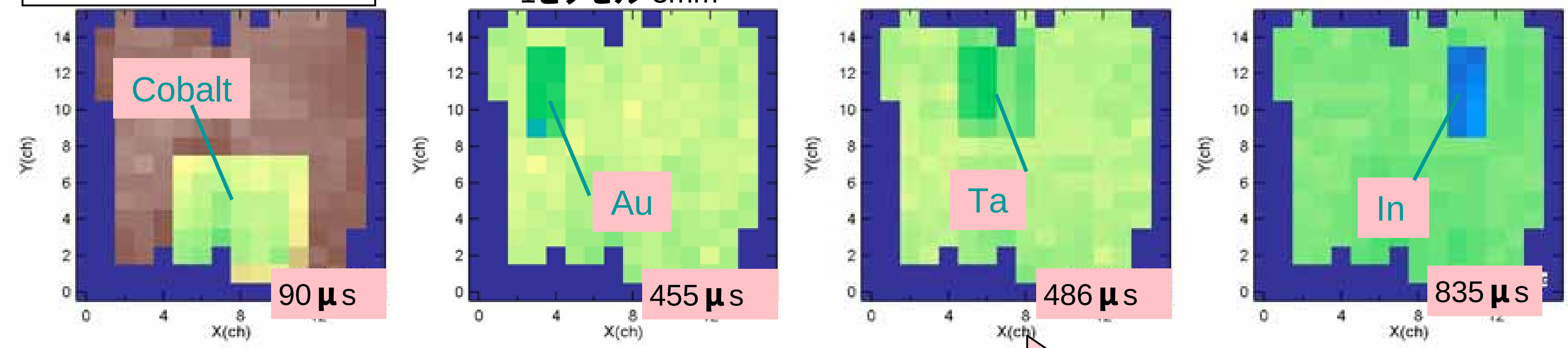
1ピクセル 3mm

Conventional neutron radiography

Difference of neutron transmission is observed, but material difference can not be distinguished.



Obtained Imaging



Time after pulse neutron production

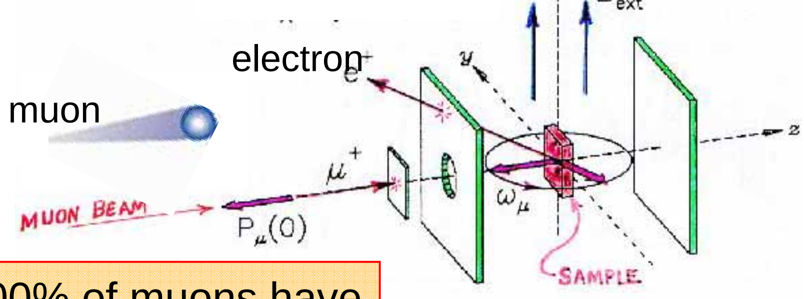
- Demonstration of material analysis by non-destructive method utilizing Brugg edge scattering.
  Applicable elements: Au, Ag, Cu, Mn, Mo, Zn, Co, Ta, In, W, Hg, etc.
- Further study: spatial resolution, quantitative accuracy

Muon Application

Muon has a mass of 100 times as electron mass and has spin & charge

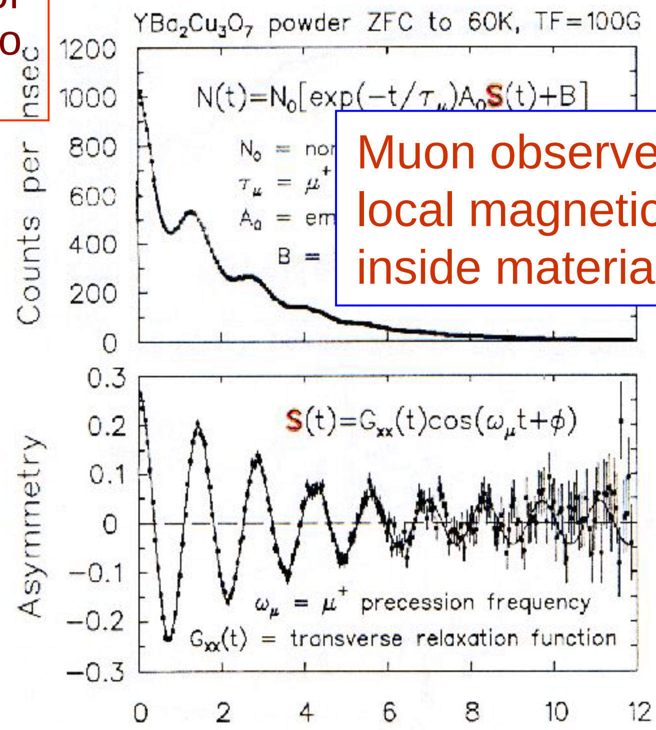
Muon spin rotates in magnetic field

Angular distribution of emitted electrons also rotates.



A 100% of muons have the same spin direction.

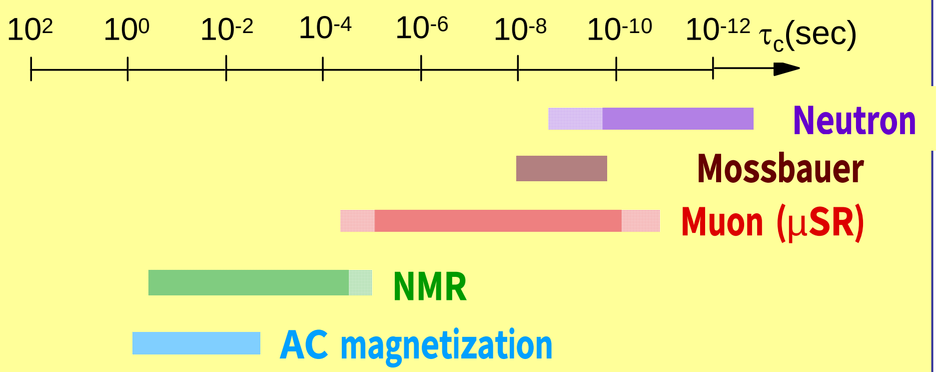
Most of electron are emitted to spin direction.



Muon observes local magnetic field inside materials

Observation of muon rotation inside high Tc superconducting materials.

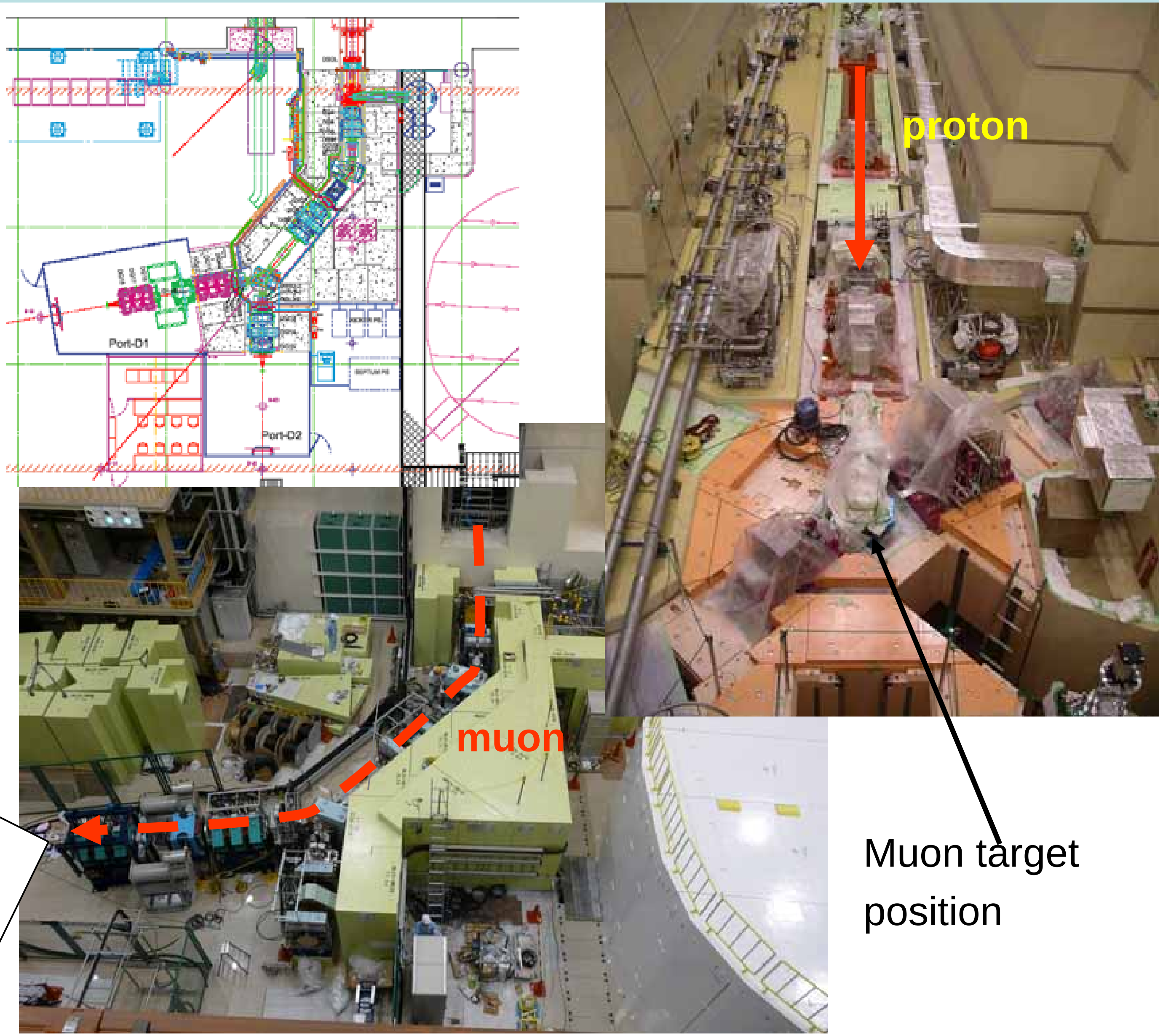
Time scales of various magnetic probes



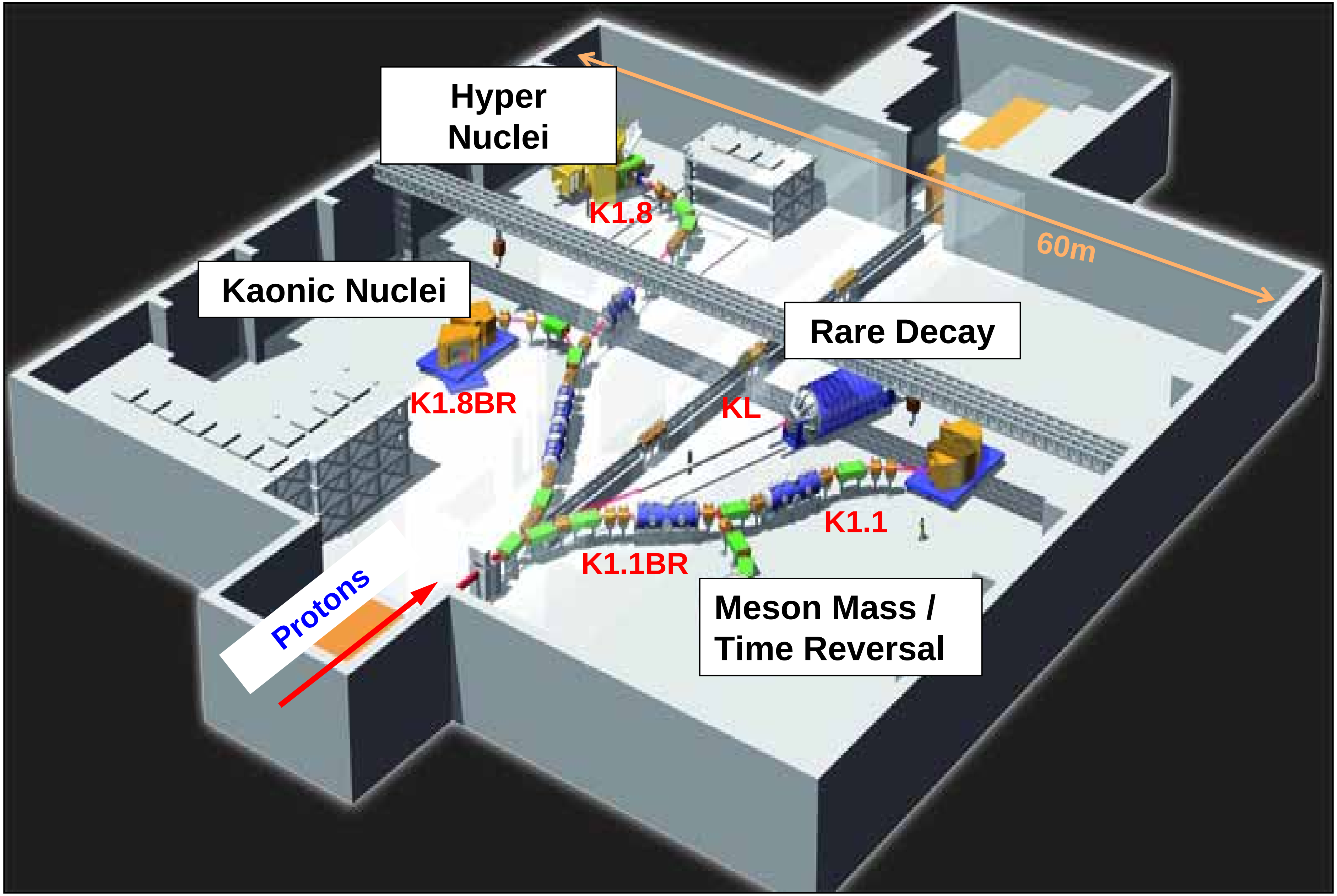
Application:
- Magnetism, High Tc superconductivity
- Hydrogen dynamics

Muon Beam Facility MUSE

Muon detector



Hadron Facility and Its Science



Proposals were reviewed by PAC.

- Fast extraction beam is for neutrino experiment
- Slow extraction beam is for many proposals using Kaon beams.

		(Co-)Spokespersons	Affiliation(*)	Title of the experiment	1st PAC status	Time Day1?	prior Prior	2nd PAC status	3rd PAC status
P01		V. Sumachev	Petersburg Nulear Physics Institute	Proposal on measurements of the spin rotation parameters A and R at the J-PARC in the resonance region of π-N elastic scattering	Rejected				
P02	LoI	P. Aslanyan	Laboratory for High Energy, JINR	Study of Exotic Multiquark States with Λ-Hyperons and K^0_s Meson Systems at JPARC	–			–	–
E03		K. Tanida	Kyoto U	Measurement of X rays from Ξ^- Atom	Stage 1			–	–
P04		J. C. Peng; S. Sawada	U. of Illinois at Urbana-Champaign; KEK	Measurement of High-Mass Dimuon Production at the 50-GeV Proton Synchrotron	Deferred			–	–
E05		T. Nagae	KEK	Spectroscopic Study of Ξ-Hypernucleus, $^{12}_{\Xi}Be$, via the $^{12}C(K^-, K^+)$ Reaction	Stage 2	Day1	1	–	–
E06		J. Imazato	KEK	Measurement of T-violating Transverse Muon Polarization in $K^+ \to \pi^0 \mu^+ \nu$ Decays	Stage 1			–	–
E07		K. Imai, K. Nakazawa, H. Tamura	Kyoto U., Gifu U., Tohoku U.	Systematic Study of Double Strangeness System with an Emulsion-counter Hybrid Method	Stage 1			Stage 2	–
E08		A. Krutenkova	ITEP	Pion double charge exchange on oxygen at J-PARC	–			Stage 1	–
P09	LoI	T. Nakano	RCNP, Osaka U	Study of Exotic Hadrons with S=+1 and Rare Decay $K^+ \to \pi^+ \nu \nu$-bar with Low-momentum Kaon Beam at J-PARC	–			–	–
E10		A. Sakaguchi	Osaka U	Study on Λ-Hypernuclei with the Charge-Exchange Reactions	Deferred			Stage 1	Stage 2
E11		K. Nishikawa	KEK	Tokai-to-Kamioka (T2K) Long Baseline Neutrino Oscillation Experimental Proposal	Stage 2			–	–
P12	LoI	S. Choi	Seoul National University	Study of Parton Distribution Function of Mesons via Drell-Yan Process at J-PARC at High-p beamline	–			–	–
E13		H. Tamura	Tohoku U	Gamma-ray spectroscopy of light hypernuclei	Stage 2	Day1	2	–	–
E14		T. Yamanaka		... $\pi^0 \nu\nu$-bar Experiment at J-PARC	Stage 1			–	Stage 2 PAC recommenation
E15		M. Iwasaki, T...		...ly-bound kaonic nuclear states by in-flight 3He(K−, n) reaction	Stage 1	Day1		Stage 2	–
E16		S. Yokkaichi		...ctrometer at the J-PARC 50-GeV PS to explore the chiral symmetry in ...	Deferred			Stage 1	–
E17		R. Hayano, H. Outa	U. Tokyo, R...		Stage 1	Day1		Stage 2	–
E18		H. Bhang, H. Outa, H. Park	SNU, RIKEN, ...	...tion	Deferred			Stage 1	–
E19		M. Naruki	RIKEN		Stage1	Day1		Stage 2	–
P20	LoI	Y. Kuno	Osaka U	... Intense Muon Source, PRISM	–			–	–
P21		Y. Kuno	Osaka U	An Experimental Search for Lepton Flavor Violating $\mu^- - e^-$ Conversion at Sensitivity of 10^{-16} with a Slow-Extracted Bunched Proton Beam					
E22		S. Ajimura, A. Sakaguchi	Osaka U	Exclusive Study on the Lambda-N Weak Interaction in A=4 Lambda-Hypernuclei (Revised from Initial P10)				Stage 1	–
P23		A. D. Krisch	U. of MICHIGAN	Analyzing power A_n and A_{nn} in 30-50 GeV very-high-$P_\perp^2$ proton-proton elastic scattering					
P24		Y. Goto, H. Sato	RIKEN, KEK	Polarized Proton Acceleration at J-PARC					

:Stage2 approval
:Stage2 PAC recommendation
:Stage1 approval
:Rejected
:LoI
(*) : Affiliation of the spokespersons

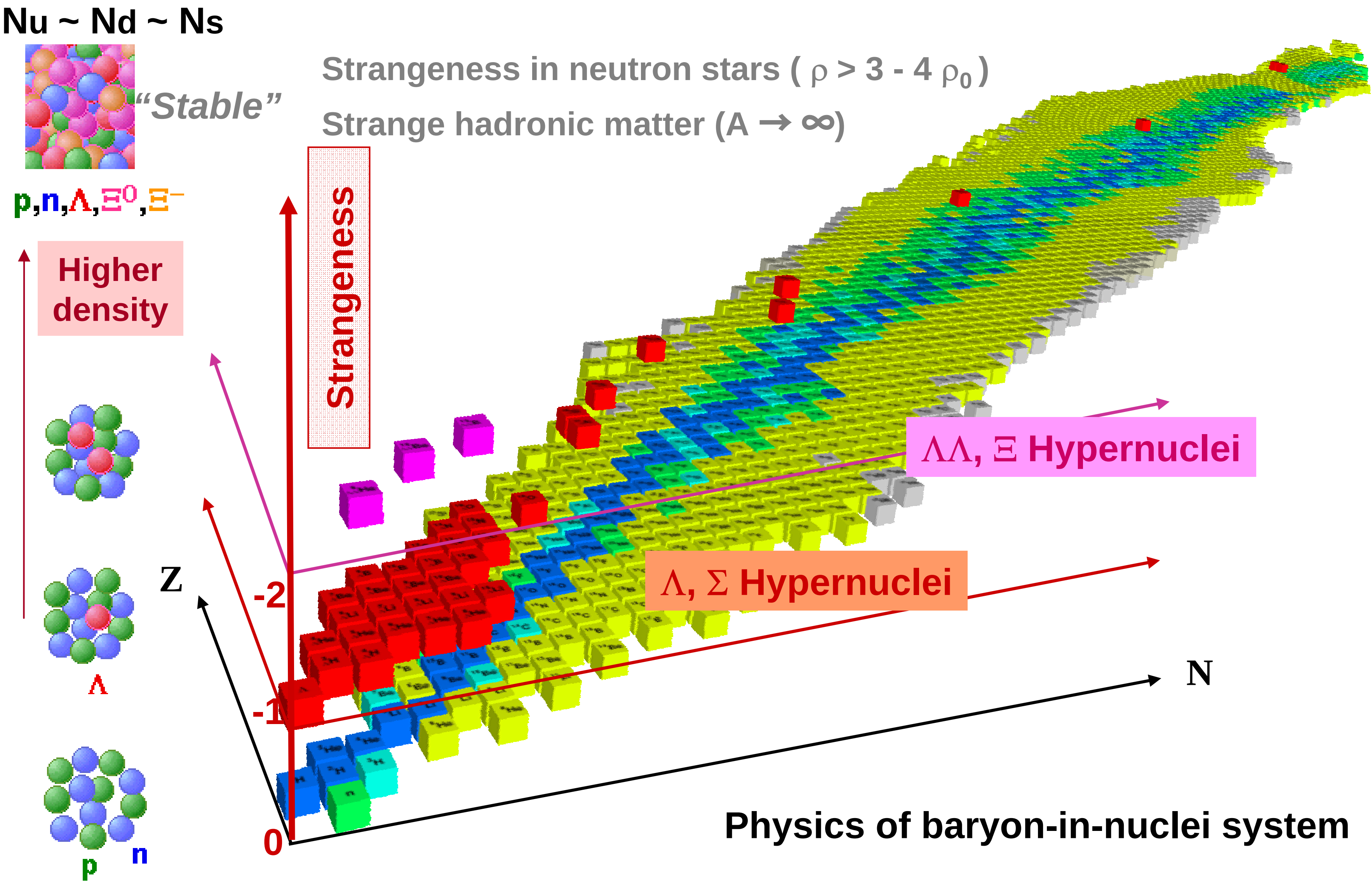
: Experiment at the fast extraction beam

Fast Extraction Beam
= Neutrino Beam

Other Proposals Use Slow Extracted Beams
Primarily Kaon Beams (Some Primary Beams)

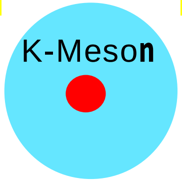
List of Proposed Experiments at Main Ring
(30 GeV Operation on Day 1)

Hyper Nuclei Physics
Three Dimensional Nuclear Chart



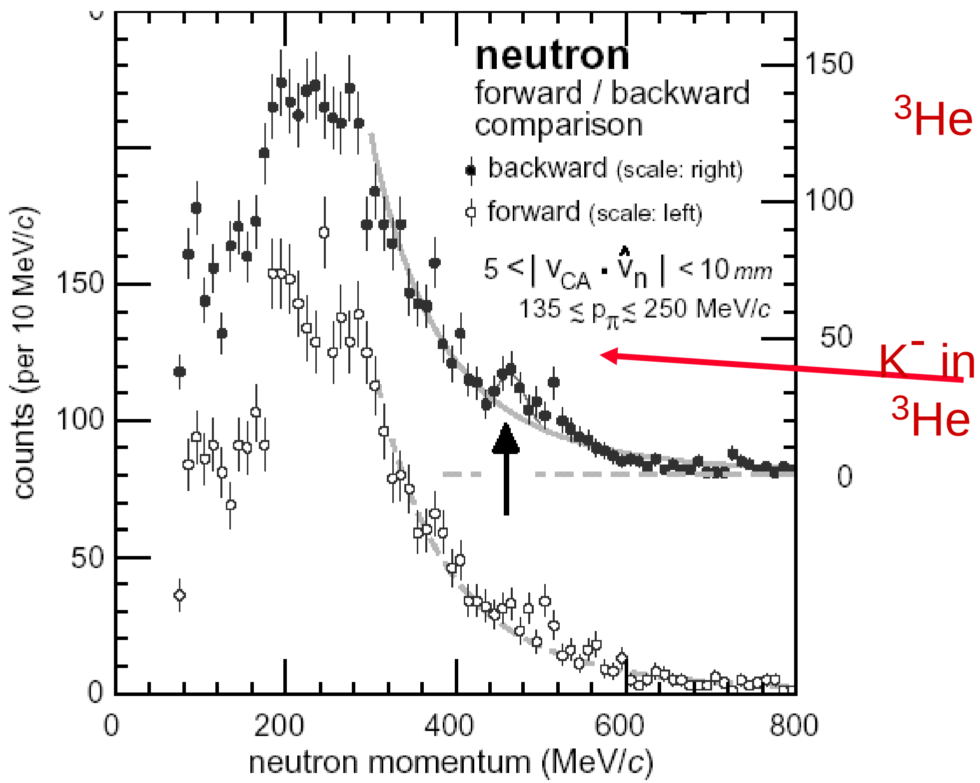
Physics of baryon-in-nuclei system

Strange Meson Implantation

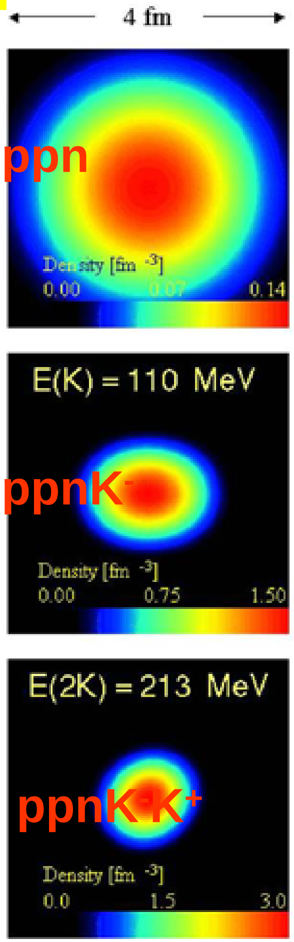


Meson in Nuclei

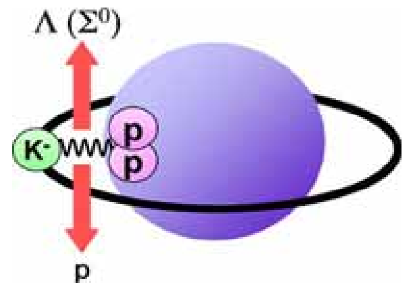
$K^- + {}^4He \rightarrow$ "K^-ppn" + n



Experiment by M. Iwasaki, et al. 2004

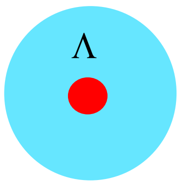


Theory by Y. Akaishi, et al. 2002



At Frascatti, a bound state of K^- in ^3He was discovered recently.

M. Agnello, et al. (2005)



Bryon in Nuclei

Nuclear shrinkage is also observed for Λ implantaion inside the nucleus ← K. Tanida, et al. 2001

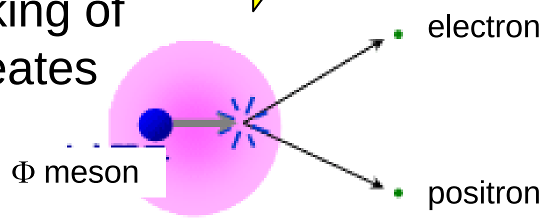
Meson mass change by high quark density

Nambu Theory

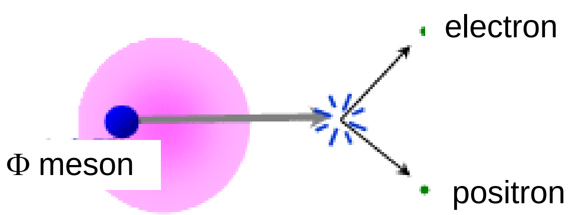
Spontaneous breaking of chiral symmetry creates hadron mass

Φ meson results (KEK2006)

Meson mass decreases in high density quarks?



Φ meson decaying in nuclei

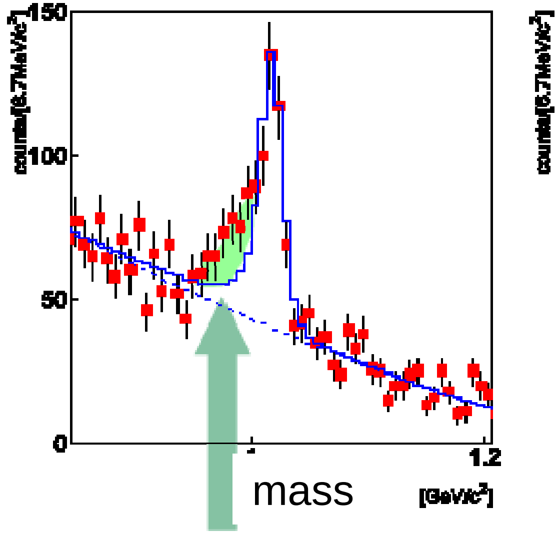


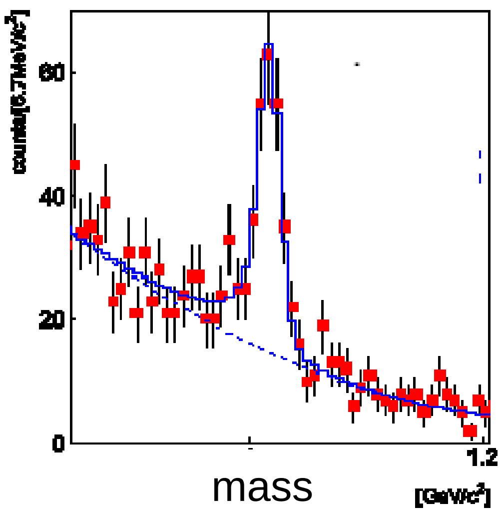
Φ meson decaying in vacuum

Heavy nuclei (Cu) is used

Light nuclei (C) is used

- mass distribution of ϕ meson in vacuum
- Measured mass distribution



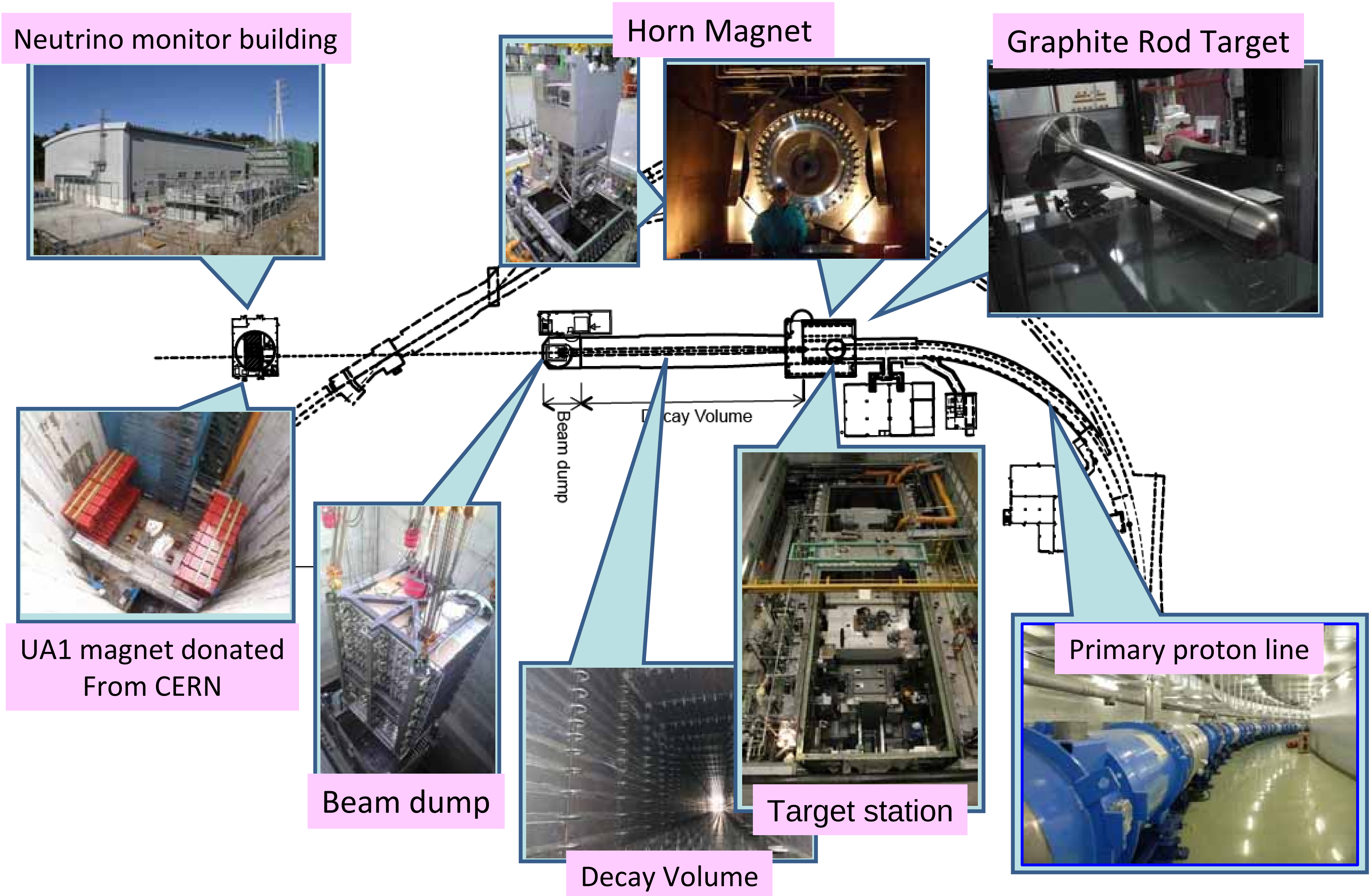


K meson is expected to have more effect.

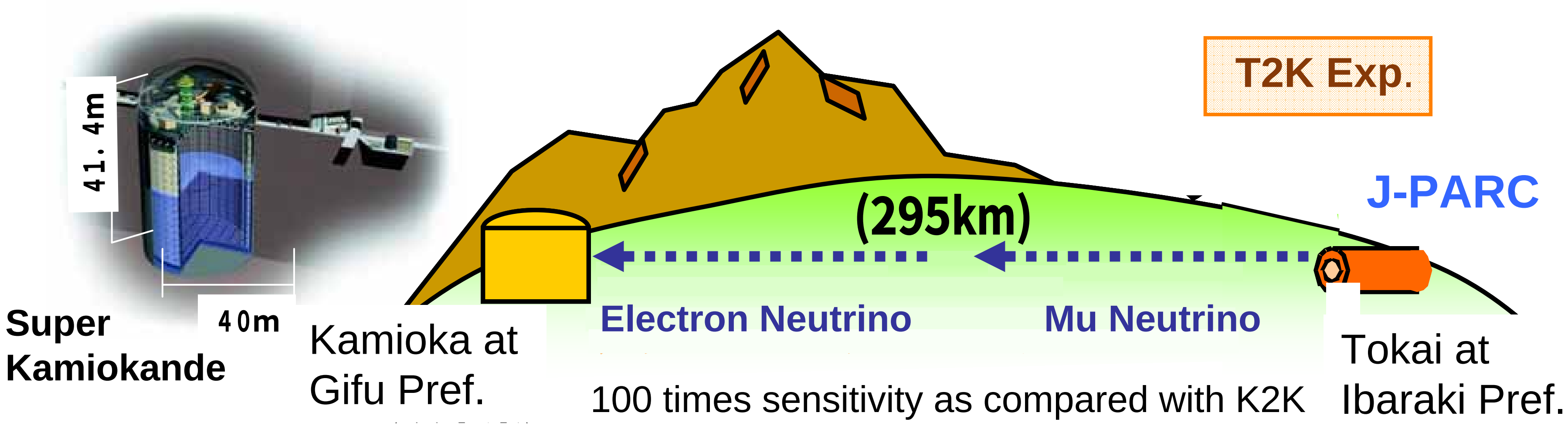
This part can not be explained by mass distribution of decay in vacuum

This can be explained by mass distribution of decay in vacuum

Neutrino Facility



Neutrino Oscillation (T2K) Experiment



T2K Exp.

100 times sensitivity as compared with K2K

For example

100 neutrinos ← **150 neutrinos**

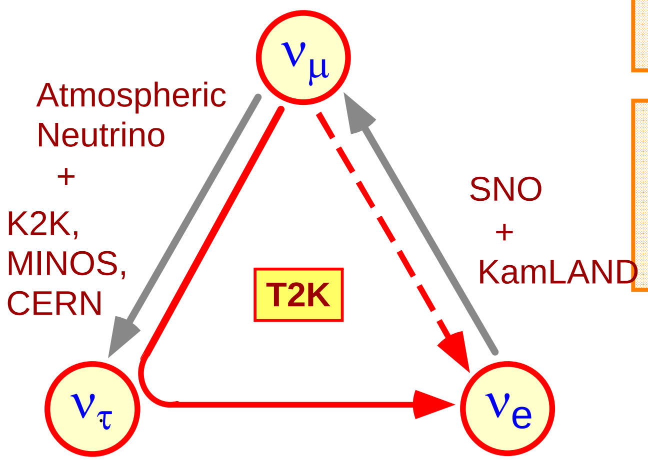
Disappearance of neutrinos ↔ **Finite Mass**

Electron neutrinos ← **Mu neutrinos**

θ_{13} ↔ **Mixing between the 1st and 3rd generation**

CP violation experiment later by increasing intensity

Competition with DiyaBay, FNAL, etc.



Summary

Status of J-PARC

- J-PARC facility construction was completed.

  User operation has been started.

Applications of J-PARC

- Neutron : **structural analysis, dynamics of materials**
- Muon : **internal magnetic field measurement**
- Hadron(Kaon) : **physics of strangeness & quark matter**
- Neutrino : **neutrino oscillation**
- Future : **ADS facility for accelerator-based nuclear system**