Status of J-PARC and Its Scientific Application

Yukio Oyama
Japan Atomic Energy Agency (JAEA)
High Energy Accelerator Research Organization (KEK)

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J-PARC = Japan Proton Accelerator Research Complex

Materials & Life Science Facility (MLF)

3GeV Synchrotron
2.5Hz

Hadron Facility

50GeV Synchrotron
50Hz
(30GeV at present)

Linac
400MeV
(181MeV at present)

Neutrino Facility

Joint Project between KEK and JAEA

50GeV Synchrotron
(30GeV at present)
Secondary particles produced at J-PARC

Beam Flux at the Full Power Proton Beams

<table>
<thead>
<tr>
<th></th>
<th>particles /one proton</th>
<th>particles /second</th>
<th>Typical particles at one beam line*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutron</td>
<td>80</td>
<td>$10^{17}$</td>
<td>$10^{8}$</td>
</tr>
<tr>
<td>Muon</td>
<td>$10^{-4}$</td>
<td>$10^{11}$</td>
<td>$10^{7}$</td>
</tr>
<tr>
<td>Kaon</td>
<td>$10^{-4}$</td>
<td>$10^{10}$</td>
<td>$10^{6}$</td>
</tr>
<tr>
<td>Neutrino*</td>
<td>6</td>
<td>$10^{15}$</td>
<td>$3 \times 10^{7}$</td>
</tr>
</tbody>
</table>

*) 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

- Neutron Beam Lines (23 total)
- Neutron Scattering Area
- Muon Experimental Area
- Target Station
- Scattered Neutrons
- Experimental Devices
- Proton Beam
1st Experimental Hall (East Hall)

BL#01 NOBORU
New Techniques Development

BL#04 NNRI
Nuclear Data for ADS

BL#08 SHRPD
Super High Resolution
Powder Defractometor
New functional materials

BL#03 iBIX
Structural analysis of bio-materials
Development of protein, medicine, food, plastics, organic display, etc.

neutron source side

BL#01 Four SEASONS
High Tc superconductivity
Development of magnetic memory, cosmetics, steel, synthetic fiber
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

- 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

1) Structure analysis by neutron crystallography

2) Understanding of the principle of protein architecture

3) Drug design at more refined level

Information of MD results

Information of electron states

Phenylalanine
Tyrosine
Tryptophan

Hydration structure

Hydrogen bond

$\text{H}_2\text{O}$
Tc Property Change Dependent on Stress of Tape of High-Tc Super-Conducting Materials

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

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

News from J-PARC
Demonstration of Pulsed Neutron Radiography

News from J-PARC (BL#10 NOBORU)

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

Obtained Imaging

Test sample

- Gold
- Indium
- Cobalt
- Tantalum

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.

Time scales of various magnetic probes

- $10^2$
- $10^1$
- $10^{-2}$
- $10^{-4}$
- $10^{-6}$
- $10^{-8}$
- $10^{-10}$
- $10^{-12}$

Observation of muon rotation inside high Tc superconducting materials.

Application:
- Magnetism, High Tc superconductivity
- Hydrogen dynamics
Muon Beam Facility MUSE

Muon detector

Muon target position

proton

muon
Hadron Facility and Its Science

Hyper Nuclei

Kaonic Nuclei

Rare Decay

Meson Mass / Time Reversal

K1.8

K1.8BR

K1.1

K1.1BR

KL

Protons

60m
Proposals were reviewed by PAC.

- Fast extraction beam is for neutrino experiment
- Slow extraction beam is for many proposals using Kaon beams.
Nu ~ Nd ~ Ns

“Stable”

Strangeness in neutron stars ($\rho > 3 - 4 \rho_0$)
Strange hadronic matter ($A \Xi \bar{\Xi}$)

Higher density

$\Lambda\Lambda, \Xi$ Hypernuclei
$\Lambda, \Sigma$ Hypernuclei

Physics of baryon-in-nuclei system
Strange Meson Implantation

**Meson in Nuclei**

K\(^{-}\) + \(^{4}\)He → “K\(^{-}\)ppn” + n

**Bryon in Nuclei**

Nuclear shrinkage is also observed for \(\Lambda\) implantation inside the nucleus → K. Tanida, et al. 2001

**Experiment by M. Iwasaki, et al.** 2004

**Theory by Y. Akaishi, et al.** 2002

At Frascatti, a bound state of K\(^{-}\) in \(^{3}\)He was discovered recently.

M. Agnello, et al. (2005)
Meson mass change by high quark density

Nambu Theory
Spontaneous breaking of chiral symmetry creates hadron mass

$\Phi$ meson results (KEK2006)

Meson mass decreases in high density quarks?

$\Phi$ meson decaying in nuclei
Heavy nuclei (Cu) is used

$\Phi$ meson decaying in vacuum
Light nuclei (C) is used

mass distribution of $\phi$ meson in vacuum
Measured mass distribution

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

K meson is expected to have more effect.
Neutrino Facility

- Neutrino monitor building
- Horn Magnet
- Graphite Rod Target
- UA1 magnet donated from CERN
- Beam dump
- Target station
- Decay Volume
- Primary proton line
Neutrino Oscillation (T2K) Experiment

100 neutrinos
Disappearance of neutrinos
Finite Mass

150 neutrinos

Electron neutrinos
Mu neutrinos

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