J-PARC Project and Its Science

Shoji Nagamiya

J-PARC Center

Japan Atomic Energy Agency (JAEA)
High Energy Accelerator Research Organization (KEK)
J-PARC
Nuclear Transmutation (Phase 2)

Materials and Life Science Experimental Facility

Joint Project between KEK and JAEA

Hadron Beam Facility

Neutrino to Kamiokande

Linac (330m)

3 GeV Synchrotron (25 Hz, 1MW)

50 GeV Synchrotron (0.75 MW)

J-PARC = Japan Proton Accelerator Research Complex
Goals at J-PARC

Need to have high-power proton beams

→ MW-class proton accelerator (current frontier is about 0.1 MW)

Materials & Life Sciences at 3 GeV
Nuclear & Particle Physics at 50 GeV
R&D toward Transmutation at 0.6 GeV
- Phase 1 + Phase 2 = 1,890 Oku Yen (= $1.89 billions if $1 = 100 Yen).
- Phase 1 = 1,527 Oku Yen (= $1.5 billions) for 8 years.
- JAEA: 860 Oku Yen (56%), KEK: 667 Oku Yen (44%).
Status (before the Earthquake)
Power Capability

Linac Energy Recovery

Previous Estimate Nov. 2003

Big Earthquake

Present Estimate for 3 GeV

KEK PS 3 kW

Power Expectation [MW]

For short period

Training

Present Estimate for MR at 30 GeV

120 kW steady

115 kW steady

145 kW

200 kW steady

300 kW 1 hour

Neutrino Oscillation (T2K) Experiment

100 times sensitivity as compared with K2K

For example

- 100 neutrinos
- Disappearance of neutrinos
- Finite Mass

Electron neutrinos

\[ \theta_{13} \]
Mixing between the 1st and 3rd generation

CP violation experiment later by increasing intensity

Competition with Double Chooz, FNAL, etc.

Electron Neutrino
Mu Neutrino

(295km)

J-PARC

Super Kamiokande

神岡町
（岐阜県）

東海村
（茨城県）

タウニュートリノ
ミューニュートリノ

(295km)

J-PARC
大強度陽子加速器

神岡町
（岐阜県）

東海村
（茨城県）

タウニュートリノ ミューニュートリノ

100 neutrinos

150 neutrinos

Kamioka, K2K, MINOS, etc.

KamLAND, SNO

Solar Neutrino

Reactor Neutrino

Accelerator Neutrino

Atmospheric Neutrino
Neutrino beamline

Neutrino monitor build.

UA1 magnet donated from CERN installed in Apr-Jun, 2008 on schedule

Confirmation of $\nu$ production

On-site detector

Focusing

 Electromagnetic horn

Decay volume completed

Target station completed

Production of $\pi$

Graphite target

Primary proton beam line completed

$\pi \rightarrow \mu + \nu$

Beam dump completed

Confirmation of $\nu$ production

On-site detector
The first neutrino event detected at Super Kamiokande.
Indication of $\nu_e$ appearance (non-zero $\theta_{13}$)

6 $\nu_e$ candidates found!

Expected BG $1.5 \pm 0.3$ evts

- Prob. of 6 are all BG: 0.7% (2.5$\sigma$ equiv)
  
  $(\Delta m^2_{23} > 0)$
  
  $0.03 < \sin^2 2\theta_{13} < 0.28$
  
  90%CL range
  
  $\sin^2 2\theta_{13} = 0.11$
  
  Central value
  
  $(\Delta m^2_{23} < 0)$
  
  $0.04 < \sin^2 2\theta_{13} < 0.34$
  
  $\sin^2 2\theta_{13} = 0.14$
Measurement of $\nu_\mu$ disappearance $(\Delta m_{23}^2, \sin^2 2\theta_{23})$

Reconstructed $\nu$ energy

<table>
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<tr>
<th>$\Delta m^2$ (eV$^2$)</th>
<th>$\sin^2 2\theta$</th>
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<tr>
<td>2.1 $\sim$ 3.1 x 10^{-3}</td>
<td>&gt; 0.85</td>
</tr>
<tr>
<td>2.1 $\sim$ 3.2 x 10^{-3}</td>
<td>&gt; 0.84</td>
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</table>

Consistent with MINOS/SK results

Clear disappearance and oscillation pattern observed!!

Single–$\mu$ ring events
- 104 events expected w/o osc
- 31 events detected

90% C.L. allowed region

Single-$\mu$ ring events

- 104 events expected w/o osc
- 31 events detected

Analysis A
- Best-fit $(\Delta m^2, \sin^2 2\theta)$
  - Ana. A $\sim$ (2.6 x 10^{-3} eV$^2$, 0.99)

Analysis B
- Best-fit $(\Delta m^2, \sin^2 2\theta)$
  - Ana. B $\sim$ (2.6 x 10^{-3} eV$^2$, 0.98)
Tokai, Japan
J-PARC
(Japan Proton Accelerator Research Complex)

Material and Biological Science Facility

50 GeV Synchrotron (15 μA)

3 GeV Synchrotron (333 μA)

400 MeV Linac (350m)

Neutrino Facility

Nuclear and particle physics experimental facility (Hadron Hall)

Meson (K±, K0_L, π±) beams of world highest intensity (x10 of BNL-AGS, x100 of KEK-PS)

Launched in 2009, Beam intensity and quality being improved
Nuclear & Hadron Physics at J-PARC

Hypernuclei

$\Lambda\Lambda, \Xi$ Hypernuclei

$\Lambda, \Sigma$ Hypernuclei

$K_{1.8}$

K1.8BR

KL

K1.1

High p

$K^0_\Lambda \to \pi^0 \nu \bar{\nu}$

Implantation of Kaon and the nuclear shrinkage

Bound quarks

Free quarks

Why are bound quarks heavier?

Mass without Mass Puzzle

Kaonic atom

Kaonic nucleus

Strange

K meson
Hadron Hall as of 2008.10
Hadron Hall as of 2008.10

SKS spectrometer

K1.8 line

proton beam

production target

1.8 line

KL line
<table>
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<th>Stage</th>
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<td>E03</td>
<td>K.Tanida</td>
<td>SNU</td>
<td>Measurement of X rays from X-Atom Spectroscopic Study of X-Hypernucleus, $^{12}X\text{Be}$, via the $^{12}\text{C}(K^-, K^+)\text{Reactions}$</td>
<td>Stage 2</td>
<td>K1.8 preparation</td>
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<td>E05</td>
<td>T.Nagae</td>
<td>Kyoto U</td>
<td>Measurement of T-violating Transverse Muon Polarization in $K^+ \rightarrow \pi^0\mu^+\nu$ Decays</td>
<td>Stage 2 Day1 1</td>
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<td>E06</td>
<td>J.Imazato</td>
<td>KEK</td>
<td>Spectroscopic Study of X-Hypernucleus, $^{12}X\text{Be}$, via the $^{12}\text{C}(K^-, K^+)\text{Reactions}$</td>
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<td>E08</td>
<td>A.Krutenkova</td>
<td>ITEP</td>
<td>Pion double charge exchange on oxygen at J-PARC</td>
<td>Stage 1</td>
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<td>E10</td>
<td>A.Sakaguchi, T.Fukuda</td>
<td>Osaka U</td>
<td>Production of Neutron-Rich $\Lambda$-Hypernuclei with the Double Charge-Exchange Reactions</td>
<td>Stage 2</td>
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<td>E11</td>
<td>T.Kobayashi</td>
<td>KEK</td>
<td>Tokai-to-Kamioka (T2K) Long Baseline Neutrino Oscillation Experimental Proposal</td>
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<td>E13</td>
<td>T.Tamura</td>
<td>Tohoku U</td>
<td>Gamma-ray spectroscopy of light hypernuclei</td>
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<td>E14</td>
<td>T.Yamanaka</td>
<td>Osaka U</td>
<td>Proposal for $K_L \rightarrow p^0\nu n$-bar Experiment at J-PARC</td>
<td>Stage 2</td>
<td>KL beamline tuning</td>
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<td>E15</td>
<td>M.Iwasaki, T.Nagae</td>
<td>RIKEN, Kyoto U</td>
<td>A Search for deeply-bound kaonic nuclear states by in-flight $3\text{He}(K^-, n)$ reaction</td>
<td>Stage 2 Day1 1</td>
<td>K1.8BR preparation</td>
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<td>E16</td>
<td>S.Yokkaichi</td>
<td>RIKEN</td>
<td>Electron pair spectrometer at the J-PARC 50-GeV PS to explore the chiral symmetry in QCD</td>
<td>Stage 1</td>
<td>high p</td>
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<td>E17</td>
<td>R.Hayano, H.Outa</td>
<td>U Tokyo, RIKEN</td>
<td>Precision spectroscopy of Kaonic $^3\text{He}$ 3d-&gt;2p X-rays</td>
<td>Stage 2 Day1</td>
<td>K1.8BR beamline tuning</td>
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<td>E18</td>
<td>H.Bhang, H.Outa, H.Park</td>
<td>SNU, RIKEN, KRISS</td>
<td>Coincidence Measurement of the Weak Decay of $^{12}\text{C}$ and the three-body weak interaction process</td>
<td>Stage 2</td>
<td>K1.8 preparation</td>
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<td>E19</td>
<td>M.Naruki</td>
<td>KEK</td>
<td>High-resolution Search for $Q^+$ Pentaquark in $pp \rightarrow K'X$ Reactions</td>
<td>Stage 2 Day1</td>
<td>K1.8 data taking</td>
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<td>E21</td>
<td>Y.Kuno</td>
<td>Osaka U</td>
<td>An Experimental Search for Lepton Flavor Violating $\mu^-\epsilon^-$ Conversion at Sensitivity of $10^{-16}$ with a Slow-Extracted Bunched Proton Beam</td>
<td>Stage 1</td>
<td>new beamline</td>
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Note: The term `K1.8` refers to a specific priority level, and `Stage` indicates the phase of the experiment.
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<td>E22</td>
<td>S. Ajimura, A. Sakaguchi</td>
<td>Osaka U</td>
<td>Exclusive Study on the Lambda-N Weak Interaction in A=4 Lambda-Hypernuclei (Revised from Initial P10)</td>
<td>Stage 1</td>
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<td>E26</td>
<td>K. Ozawa</td>
<td>KEK</td>
<td>Search for $\omega$-meson nuclear bound states in the $\pi^{-}+^{4}\text{Z} \rightarrow n^{+}(^{4}\text{Z}-1)$ $\omega$ reaction, and for $\omega$ mass modification in the in-medium $\omega \rightarrow \pi^{0}\gamma$ decay.</td>
<td>Stage 1</td>
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<td>E27</td>
<td>T. Nagae</td>
<td>Kyoto U</td>
<td>Search for a nuclear Kbar bound state $K^{-}p$ in the $d(\pi^{+},K^{+})$ reaction</td>
<td>Stage 2</td>
<td>K1.8 preparation</td>
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<td>P28</td>
<td>H. Fujioka</td>
<td>Kyoto U</td>
<td>Study of isospin dependence of kaon-nucleus interaction by in-flight $3\text{He}(K^{-},n/p)$ reactions</td>
<td>approved as apart of E15</td>
<td>K1.8BR</td>
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<td>E29</td>
<td>H. Ohnishi</td>
<td>RKEN</td>
<td>Search for $\phi$-meson nuclear bound states in the $p^\bar{\text{b}} + Z \rightarrow \phi + \phi(Z-1)$ reaction</td>
<td>Stage 1</td>
<td>K1.1</td>
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<td>E31</td>
<td>H. Noumi</td>
<td>RCNP, Osaka U</td>
<td>Spectroscopic study of hyperon resonances below KN threshold via the $(K^{-},n)$ reaction on Deuteron</td>
<td>Stage 1</td>
<td>K1.8BR</td>
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<td>E40</td>
<td>K. Miwa</td>
<td>Tohoku U</td>
<td>Measurement of the cross sections of $\Sigma p$ scatterings</td>
<td>Stage 1</td>
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<td>T25</td>
<td>S. Mihara</td>
<td>KEK</td>
<td>Extinction Measurement of J-PARC Proton Beam at K1.8BR</td>
<td>Test experiment</td>
<td>K1.1BR data taking</td>
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<td>T32</td>
<td>A. Rubba</td>
<td>ETH, Zurich</td>
<td>Towards a Long Baseline Neutrino and Nucleon Decay Experiment with a next-generation 100 kton Liquid Argon TPC detector at Okinoshima and an intensity upgraded J-PARC Neutrino beam</td>
<td>Test experiment</td>
<td>K1.1BR data taking</td>
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<td>P35</td>
<td>T. Kajita</td>
<td>ICRR, Tokyo</td>
<td>A test experiment to measure sub-GeV flux in the on-axis direction at the J-PARC neutrino beam to be decided by E11 &amp; Lab</td>
<td>neutrino</td>
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<td>T37</td>
<td>K. Inami</td>
<td>Nagoya U</td>
<td>Test of TOP counter for B-factory upgrade</td>
<td>Test experiment</td>
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<td>T38</td>
<td>T. Nanjo</td>
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<td>Proposal for Measuring Hadron Response at K1.1BR for KOTO Experiment</td>
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<td>P39</td>
<td>K. Sakashita</td>
<td>KEK</td>
<td>A study of water Cherenkov detector for counting the number of neutrino at Near detector hall of J-PARC neutrino beam-line to be decided by E11 &amp; Lab</td>
<td>neutrino</td>
<td></td>
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E19 (Naruki et al.)
Search for Pentaquark $\Theta^+$ in $\pi^- p \rightarrow K^- X$ reaction

**Physics Motivation**

- Positive evidences at low energy (LEPS, etc.)
- Very narrow width $\sim 1$ MeV. Why?
- Negative results at high energy

**J-PARC E19**

- Hadronic “direct reaction” $\pi^- + p \rightarrow K^+ + X$
- Previous ($\pi^-, K^-$) missing mass spectrum shows a hint of $2.6\sigma$.

12\(\pm\)2 nb

$\gamma d \rightarrow K^+ K^- p n$

\[ p(\pi^-, K^-) \]

K$^+$+n Experiment to produce directly $\Theta^+$ must be done.

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*T. Nakano et al., PRC79 (2009) 025210*
Hyperball

Hypernuclear $\gamma$-ray data

$^7\text{Li} (\pi^+, K^+\gamma)$ KEK E419
$^9\text{Be} (K^-, \pi^+\gamma)$ BNL E930('98)
$^{10}\text{B} (K^-, \pi^+\gamma)$ BNL E930('01)

$^6\text{Li}$

$^{\Lambda_\Lambda}\text{B}$

$^{12}\text{C} (\pi^+, K^+\gamma)$ KEK E566

$^{13}\text{C} (K^-, \pi^+\gamma)$ BNL E929 (Nal)

$^{16}\text{O} (K^-, \pi^+\gamma)$ BNL E930('01)

$^7\Lambda\text{Li}$

$^{\Lambda\Lambda}\text{B}$

$^{11}\Lambda\text{B}$

$^{12}\Lambda\text{C}$

$^{15}\Lambda\text{N}$

$^{16}\Lambda\text{O}$

References:
- PRL 84 (2000) 5963
- PLB 579 (2004) 258
- PRC 73 (2006) 012501
- PRL 88 (2002) 082501
- NPA 754 (2005) 58c
- EPJ A33 (2007) 243
- PRL 86 (2001) 4255
- PRC 65 (2002) 034607
- PRC 77 (2008) 054315
- PRL 93 (2004) 232501
- EPJ A33 (2007) 247
ΛN spin-dependent interaction strengths determined:

\[ \Delta = 0.3 \sim 0.4, \ S_\Lambda = -0.01, \ S_N = -0.4, \ T = 0.03 \text{ MeV} \]

Almost all these p-shell levels are reproduced by this parameter set. (D.J. Millener)

Further: ΛN-ΣN and ΛNN force, r-dependence, charge symmetry breaking (Λp \neq Λn?), …

J-PARC E13 (Tamura et al.)
Hypernucleus

Shallow Potential

Deep potential + Heavier mass?

Small \((l \cdot s)\) Force

\((l \cdot s)_{\text{surface}} > (l \cdot s)_{\text{interior}}\)

Analyze Hypernuclear Spectroscopy with \(m_\Lambda(r), V_{l \cdot s}(r)\) as two parameters!
Implantation of Hadron in the Nucleus

- Partial deconfinement of quarks
- Mass change

\[ \Gamma(S=-1) \]

\[ \Xi(S=-2) \]

K Meson

Quark

Anti-quark

Proton or Neutron

Shrinkage? (by 20% in radius)

High Res. Exp.

Hyper nucleus

Shrinkage???
(by 50% in radius)

K: Bound State???
M. Angello, et al. PRL 94, 212303 (2005), + many others

Nucleus

Shrinkage???
Studies on Double Strange Nuclear Systems

Spectroscopy of $\Xi$ hypernuclei by ($K^-,K^+$) reaction

Possible only at J-PARC

$\Xi$-N interaction

Essential to describe neutron star matter

Precise measurement of $\Xi^-$-atomic X-rays

$\Lambda$-$\Lambda$ interaction

E03

E05

E07

Decays of $\Lambda\Lambda$ hypernuclei in emulsion

Nagara event (KEK E373)
PRL 87 (2001) 212502
A search for deeply bound kaonic nuclear states by in-flight $^3\text{He}(K^-,n)$ reaction

J-PARC E15 Experiment

prediction for nucleon density distribution by AMD

$\rho \sim 10\rho_0$: extremely dense system

Does the deeply bound state really exist?


Missing mass spectroscopy via neutron

Invariant mass reconstruction
Recent Search for Kaonic Nuclei

KEK–PS E549

KEK–PS E549

FINUDA (RUN1)
preliminary

FINUDA (RUN2)

FOPI (GSI)

CERN (OBELIX)

DISTO(SATURNE)

\[ M = 2.267 \pm 0.002 \]
Recent Search for Kaonic Nuclei

Conclusive evidence for the existence has not been obtained.
Origin of Hadron Mass - J-PARC E16 -

In Vacuum

Hadrons $\sim 1000 \text{ MeV}/c^2$
Constituent quarks $\sim 300$

Hot/Dense Matter

Current quarks $\sim 5 \text{ MeV}/c^2$

$\rightarrow$ vector meson mass in nuclear matter

proton
nuclear target

high momentum beamline + E16 Spectrometer
Electron Pair Production in PHENIX

Still a big Issue from CERN-SPS
insight into halo nuclear structure through hypernuclei

ordinary nuclei \(\Lambda\)-hypernuclei

\[ \Delta N \]

77MeV

\[ \Sigma N \]

\[ \Sigma \]

\[ \Lambda N \]

\[ \Lambda \]

\[ N \]

\[ S = -1 \]

smaller \(\Delta M\)

larger mixing

\[ \Sigma \]

\[ \Lambda \]

\[ N \]

\[ \Lambda \]

\[ N \]

contribution of \(\Sigma\) component

and many body effect

n-rich hypernucleus is a doorway to n-star

Study of Neutron-Rich Hypernuclei
J-PARC/E10

production of neutron-rich and exotic hypernuclei by the double charge-exchange (DCX) reaction

NCX: \((K^-,\pi^-), (\pi^+,K^+)\) reaction

SCX: \((K^-,\pi^0), (\pi^-,K^0)\) reaction

DCX: \((K^-,\pi^+), (\pi^-,K^+)\) reaction

We can learn
halo nuclei property
\(\Lambda N-\Sigma N\) mixing
\(\Lambda NN\) 3-body force
EOS of n-star core

ordinary nuclei

well established

\(\Lambda\)-hypernuclei

new spectroscopic tool
Particle Physics at Hadron Hall

- **KOTO**: K0 at Tokai, approved
- **TREK**: Time Reversal Experiment with Kaons, scientific approved
- **COMET**: Coherent Muon Electron Transition, scientific approved

- new proposal on neutron EDM
- new proposal on muon g-2/EDM

International Collaborations
KTeV

CsI calorimeter

dismantled by December 2008

July 2010

October 2010:
engineering run
with 1800 crystals

KOTO CsI calorimeter

completed

with 2700 crystals

2011.Feb.08 16:30

May 2011
(after the earthquake)
Necessity for Hadron Hall extension

- Too small area ⇔ KEK-PS x2.4, BNL-AGS x4.1
- Only 4 beam lines ⇔ KEK-PS ~7 lines, BNL-AGS ~15 lines

-> Ineffective operation ("output per operation cost" is bad.)

Long waiting queue of approved experiments

(At K1.8/K1.8BR lines, 6960 hours = more than 6 years)

-> Discourage users in the world. Predominance will be lost.

Extremely urgent!
First priority in nuclear physics community in Japan

RIKEN is considering its funding!
World Hadron Facilities

- Juelich
- GSI and FAIR
- DAFNE
- CERN
- FNAL
- J-Parc
- J-Lab
Highlights before March 11, 2011 (Earthquake)

- Beam power has been steadily increasing: 200 kW for 3 GeV, 145 kW for Main Ring at 30 GeV.
- 400kW long-run test completed. Goal is 1 MW.
- Neutrino Facility: Started to take data at Super Kamiokande. 6 electron-neutrino candidate events were detected. Possibility of large $\theta_{13}$. Encouragement to go to CP measurement.
- Hadron Facility: About ready to run for many experiments. First data for penta-quark search were completed.
- Materials and Life Facility: Neutron and muon beams already produced many fruitful data and the results are being published.
- Need more and serious efforts towards “international usage” and toward creating “lively academic atmosphere”.
- Also, need more effort toward “industrial usage” of J-PARC
Status (after the Earthquake)
Immediately after the Earthquake

Outside of LINAC building is heavily damaged.

We are getting water from an outside fire-hydrant, as original cooling water system has not yet been fixed.
LINAC-2

Many pipes for supplying cooling water were damaged.

Placing a temporal bridge for carrying in materials for repair.
Many piles reached to a basement rock minimized a direct damage to the tunnel. However, groundwater leaked into the tunnel and the water depth increased to 10 cm (100 tons) within two weeks after the earthquake.

Repairing water leaks in the tunnel is almost completed.
LINAC-4

- The floor level sagged 4 cm downward in the tunnel. Because accelerator cavities should be aligned within ±1 mm to each other along the beam line for the operation, they have been leveled and realigned where necessary.
- Restoration work on the cooling water system and power supply is going smoothly.

Realigned accelerator cavities of DTL and SDTL were tested for water-tightness.
3 GeV Synchrotron (RCS)-1

- There were severe damages on many facilities around the RCS building.
- The restoration work was started after repaved roads for carrying in materials and instruments for the work. The work is progressing smoothly.

The road was repaved.

Immediately after the Earthquake

The bent stage was repaired. Power has been supplied to the RCS building.
Many basements for the equipment were re-leveled.
Replacing damaged water pipes and repairing many damaged parts.

Immediately after the Earthquake

Tilted condenser transformers were straightened.

Reinforced foundation for a cooling tower (right)
Refining work of pumps and motors (left)

Water pipes were replaced, being ready for passing water.
No obvious damages were observed. (Photo taken on March 29).
J-PARC Facility

Materials and Life Science Experimental Facility

Hadron Beam Facility

Nuclear Transmutation (Phase 2)

J-PARC = Japan Proton Accelerator Research Complex

Joint Project between KEK and JAEA

Linac (330m)

3 GeV Synchrotron (25 Hz, 1MW)

50 GeV Synchrotron (0.75 MW)

Neutrino to Kamiokande

500m
50 GeV Synchrotron (MR)-1

- Repair of water leaks has been done. The facilities for electric power supply and cooling water supply have been restored as well.
- All electromagnets (~400) are being realigned at 5 magnets/day.
- Magnets moved more than 1 cm are realigned to change a stage position (Photos).

Jacking up an electromagnet to make a space between the magnet and the stage

Hanging up the magnet

Pulling out the stage to put new longer height-adjust screws

Sometimes we need to place an adapter to put a new longer anchor bolt.
50 GeV Synchrotron (MR)-2

- There were no serious damages on all MR equipment/instruments, such as electromagnets. It, however, appeared they misaligned in both vertical and horizontal directions.
- Some electromagnets that misaligned greatly are realigned with replacing a stage and/or an anchor part.
- Inspection of the high-frequency power amplifying system has been completed.

Red: Reference positions of electromagnets
Blue: Actual positions after the earthquake
(Please note the magnitude of displacement is amplified x2000.)

Electromagnet displacement in a vertical direction
50 GeV Synchrotron (MR)-3

• Not only restoration but also improvement/upgrade of the equipment/facility are conducted to increase beam intensity when the operation will be resumed.

Putting new hanging racks on ceiling for pipes for new cooling system to supply clear water
A tilted He tank was removed to repair the foundation.

The road was re-opened after filling depressions with pebbles.

Inspection by the fire department
Materials & Life Science Experimental Facility (MLF)-2

Immediately after the Earthquake

An attached building to the west side of the main MLF building sank ~20 cm. The building is jacked up with 24 hydraulic lifters (blue). Created interspace will be filled with cement injected from holes of the floor.

Repairing cracks on the floor of 3NBT tunnel (left), and repairing a joint wall with removing concrete (right).
Reassembling work of shielding blocks for neutron beams in the 2nd experimental hall (above). Inspection of the inside of the muon beam facility after removing shielding blocks (right). This area does not have any serious damage.
Immediately after the Earthquake

AC device tilted toward a depression of a road. Many pipes were damaged

Repairing roads and plumbing have been completed.

Realignement work of electromagnets (above) and superconducting magnets (below) is progressing smoothly. We also try to improve cooling power.
Neutrino Experimental Facility-2

- Inspection of highly radiated parts, such as a target station, is progressing smoothly.
- The soundness of all equipment and devices, including three horns, have been visually confirmed.

The soundness of Beam Dump and Decay Volume was visually confirmed. There were no water leaks.

The 3rd horn hung by a crane for inspection (left) and the 3rd horn in a shielding maintenance area.
Immediately after the Earthquake

Repairing roads and plumbing have been completed.
Electromagnets in the switchyard need to be realigned. The work is progressing smoothly.
Hadron Experimental Facility-3

- After removing shields temporally, the soundness of all equipment and devices have been confirmed. No realignments are required.

Inspection work in Hadron Hall

No damages in the device
Summary of Damage

- No Tsunami Effect
  - We prepared up to 8 m Tsunami.
- Main Buildings were almost OK
  - Many underpins for major buildings.
- However, many utility buildings, roads, and added buildings had significant damage.
- When to recover?
  - Aiming at recovering by the end of this year.
  - Expect to have 2 cycle (about 2 month) running this year.
- Operation of Next Fiscal Year
  - Full 9 cycle (200 day) operations for users.
Thank you!