The J-PARC Linac
Initial Results
Status
Upgrade Plan

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For J-PARC Accelerator Group

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J-PARC Contributions to LINAC04 (2)

Introduction

Asian Map

Beijing

Seoul

JAERI

Kamioka
Introduction

Location of JAERI at Tokai

Tokai

Tsukuba

Tokyo

Narita

Kamioka
Introduction

Nuclear and Particle Experimental Facility (NPF)
Materials and Life Science Experimental Facility (MLF)
Linac (350m)
3 GeV Synchrotron (25 Hz, 1MW)
50 GeV Synchrotron (0.75 MW)
Neutrino to Kamiokande
Nuclear Transmutation

Site View of the Project

J-PARC = Japan Proton Accelerator Research Complex
Introduction

Present Status of the J-PARC

December 2003
Linac Scheme

Accelerated particles: H⁻
Energy: 181 MeV (400 MeV for ACS, 600 MeV for SCC)
Peak current: 30 mA (50 mA@ 400 MeV for 1MW at 3GeV)
Repetition: 25 Hz (additional 25 Hz for ADS application)
Beam Pulse Length: 500 µs
Average Current: 200 µA (333 µA @ 400 MeV for 1MW at 3GeV)
(Chopped to 53 %)

Block Diagram of the Linac
Initial Results

Drift-Tube Linac (DTL)

Inside of DTL

DTL by Mitsubishi

Klystrons by Toshiba
Power Supplies by Hitachi

Beam Test: 6 mA (20 MeV) on Oct. 30, 03
30 mA on Nov. 7, 03

RFQ by Hitachi and partly by Toshiba
Initial Results  Overview of the experimental apparatus

- The first cavity DTL1 (19.7MeV) is under beam commissioning, among three DTL cavities (50MeV).
- DTL1: 76 cells (77 Q-magnets)
- The beam test stand is located at the exit of the DTL1.
- Typical Beams:  
  - 5mA, 50μsec, 5 ~ 25Hz (monitor study)  
  - 30mA, 50μsec, 5Hz (DTL study)  
  - 30mA, 250μsec, 25Hz (MEBT study)  
  cf. J-PARC Linac phase1 requirement:  
    - 30mA, 500μsec, 25Hz
Coil of Electromagnet in 324-MHz Drift Tube

The coil is electroformed and wire-cutted.
**Initial Results**

- The Slow Current Transformer (SCT) and Faraday Cup (FC) were used to measure the beam currents.
- The Time of Flight from the FCS and BPM2 was used to measure the beam energy.
- The BPM1 and BPM2 were used to measure the beam position and angle.
- The double slit type emittance monitor was used to measure the emittances.
Linac Status  Emittance Comparison at MEBT

Measured emittances

Simulation results (IMPACT by LBNL)
Linac Status

Profile Measurement and Simulation

(a) Measured vs. Simulated

(b) Measured vs. Simulated

Beam density (arb.) vs. Horizontal position (mm)

Beam density (arb.) vs. Vertical position (mm)
Initial Results  Wave Forms of Chopped Beam
Initial Results

DTL1 under commissioning
Q magnet excitation currents in the MEBT(8) and in the DTL(77) are determined by the TRACE-3D estimation. All the Q magnets are excited in DC mode. Beam transmission of 100%(a few % accuracy) has been successfully achieved with no adjustments of the Q magnet currents.

Waveforms at the entrance of the DTL(a) and at the exit of the DTL(b). Beam Pulse length = 20μsec, Repetition = 12.5Hz(duty 0.025%)
**Initial Results**

**Emittance measurement (horizontal)**

Horizontal emittance of DTL1

\[ \varepsilon = 0.39 \pi \text{mm} \cdot \text{mrad} \] (normalized rms.)

Design emittance:
0.25 \( \pi \) mm \cdot mrad (normalized rms.)

Measured at MEBT exit:
0.25 \( \pi \) mm \cdot mrad (normalized rms.)
**Initial Results**

**Emittance measurement (vertical)**

\[ \varepsilon = 0.49 \, \pi \, \text{mm} \cdot \text{mrad} \]  
(normalized rms.)

Design emittance:  
\[ 0.27 \, \pi \, \text{mm} \cdot \text{mrad} \]  
(normalized rms.)

Measured at MEBT exit:  
\[ 0.21 \, \pi \, \text{mm} \cdot \text{mrad} \]  
(normalized rms.)
Initial Results  Summary of emittance measurements

<table>
<thead>
<tr>
<th></th>
<th>Horizontal</th>
<th>Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td>After MEBT$^a$ (Measured at 29 mA)</td>
<td>0.25</td>
<td>0.21</td>
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<tr>
<td>After DTL1 (Measured at 30 mA)</td>
<td>0.39</td>
<td>0.49</td>
</tr>
<tr>
<td>After DTL1 (calculated)</td>
<td>0.25</td>
<td>0.27</td>
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<tr>
<td>After DTL1 (Measured at 5 mA)</td>
<td>0.26</td>
<td>0.37</td>
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</tbody>
</table>

a) This is in reasonable agreement with the simulation result by IMPACT.

The speaker is allowed by his young colleagues to report the above data by adding a word “preliminary.”
**Project Status**  
**Phase 1 and Phase 2 (as of 2001)**

- **Phase 1**
  - Linac (Normal Conducting)
  - 50 GeV PS
  - Neutrinos to SuperKamiokande

- **Phase 2**
  - Linac (Superconducting)
  - 3 GeV PS (25Hz)
  - R&D for Nuclear Transmutation

**KEK Budget**
- 50 GeV PS
- Experimental Area

**JAERI Budget**
- Linac (Normal Conducting)
- R&D for Nuclear Transmutation
The long-base line neutrino experiment project from J-PARC to Super Kamiokande (T2K) was approved for construction starting from April, 2004 to be completed by March, 2008.
Neutrino physics at J-PARC

Tokai-to-Kamioka (T2K) LBL ν experiment

- Off-axis sub-GeV νµ beam from J-PARC 50GeV-PS
- ~3000 νµ CC int./yr (w/o osc.)
- νe appearance discovery
- νµ disapp. presice meas.
- 5 year const. Start exp. in 2009.
2) The funding to the linac and the RCS was delayed by one year. The schedule for the MR building had been delayed by more than one year for the archaeological investigation of the ancient salt pans. However, the delay in the beam commissioning schedule was managed to decrease to half a year.

Construction Schedule (as of Oct., 2003)
3) The linac energy was decreased from 400 MeV to 181 MeV in order to compensate the budget overflow in the linac and RCS. The RCS beam power is reduced from 1 MW to 0.6 MW by this.

The RCS collimation system can stand the 10 % beam loss at the 181 MeV injection for the 0.6-MW beam power.

The simulation results depend on the number of macro particles.

Injection energy: 181 MeV
Beam Power: 0.6 MW at Ext.
No error, realistic aperture
**Project Status**

*Injection Scheme to the 50 GeV MR*

Although the RCS beam power is reduced from 1 MW to 0.6 MW, the beam power of the MR may be kept as original by increasing the time duration of the injection from the RCS to the MR.

**181 MeV linac**
Injection/Fast Extraction Scheme for the 50 GeV Ring

- Injection time: 560 ms
- RF frequency: 3.34-3.44 MHz
- Injection kicker flat top: 130 ns
- Pulse bending magnet flat top: 600 ms
- Injection kicker rise time: 170 ns

**400 MeV linac**
Injection/Fast Extraction Scheme for the 50 GeV Ring

- Injection time: 560 ms, 120 ms
- RF frequency: 1.67-1.72 MHz
- Injection kicker flat top: 900 ns, longer PFN cable
- Pulse bending magnet flat top: 120 ms, only pattern change
- Injection kicker rise time: <300 ns, no change
Project Status  Expected Beam Power (not guaranteed)

Expected Beam Power at 3 GeV

200 MeV on Day 1

400 MeV on Day 1

400 MeV installation in 2008-2010

3 GeV Neutron and Muon Construction

Completion of 200 MeV Linac

Completion of T2K

400 MeV Linac Construction

<table>
<thead>
<tr>
<th>Year</th>
<th>3 GeV Neutron and Muon</th>
<th>50 GeV Nuclear - Particle</th>
<th>T 2 K Experiment</th>
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</thead>
<tbody>
<tr>
<td>JFY2007</td>
<td>Construction</td>
<td>Beam Test</td>
<td>Usage for Experiments</td>
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<tr>
<td>JFY2008</td>
<td>Construction</td>
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<td>Usage for Experiments</td>
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<td>JFY2010</td>
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<td>JFY2011</td>
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<td>JFY2012</td>
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平成19年度  平成20年度  平成21年度  平成22年度  平成23年度  平成24年度
Project Status

IAC, March 2004
Project Status

• Ancient Salt Farm

February, 2004
Project Status

3 GeV Area
Project Status

50 GeV Area
The commissioning schedule will be 0.5 year behind the original schedule, although the budget profile will be extended by 1 year.

**Key Dates**

- **April, 2005**  Start installation for main components
- **Sept., 2006**  Start linac beam test
- **May, 2007**   Start RCS beam test

### Schedule

<table>
<thead>
<tr>
<th>Linac Components</th>
<th>2003(J15)</th>
<th>2004(J16)</th>
<th>2005(J17)</th>
<th>2006(J18)</th>
<th>2007(J19)</th>
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<tbody>
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<td><strong>Linac</strong></td>
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<tr>
<td>DTL Beam Test at KEK</td>
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<td>Beam Test</td>
<td>Cooling, Preparation</td>
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<td>Building, Utilities</td>
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<td>Construction</td>
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<td>Transfer to Tokai</td>
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<td>Linac Components</td>
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<td>Fabrication, Test</td>
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<td>Installation, Commission</td>
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<td>LLRF</td>
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<td>Klystron: Test and Installation</td>
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<td>RFQ, DTL, SDL Installation</td>
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<td>Final Alignment</td>
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<td>Conditioning</td>
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<tr>
<td>Beam Test</td>
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<td>RCS Beam Test</td>
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</table>

*March, 2004*
Plan view of the linac building
(W:47.5m, L:330m, H:15.3m)

Cross sectional view at the SDTL part
Linac tunnel (floor level -13.5m), sub- tunnel, klystron gallery, rooms for power supply and cooling water system.
Linac Status

Cut-away View of the Linac Building
Linac Status

Status of the DTL#2,#3 Cavities

The tuning of the #2 cavity has been finished, while that of the #3 cavity is under way.

Installation of the drift tubes in the cavity.
Linac Status

Fabrication of 22 cavities out of 32 has already been completed as planned. Fabrication will be finished by this October. The next major step is assembling.

Some of the cavities are stored at KEK.

Status of the SDTL Cavities

Some cavities are under the electro-forming process.

The seven cavities have been assembled, while the three were power-tested.
Linac Status

Status of the Other Components

- **RF Power Sources**
  
  Among twenty klystrons for RFQ, DTL and SDTL’s the sixteen have been assembled, while the seven were power-tested. All the twenty anode-modulators and the five cathode power supplies were ready.

- **BT to RCS**
  
  Most of the Beam Transport (BT) components from the linac to the RCS will be completed by March, 2005, while some will be finished one year later.
The future upgrade plans are divided into three categories.  
1) Linac energy recovery, which will start immediately after the Phase I completion.  
2) The Phase II of the J-PARC project, which has been already agreed between the two institutes.  
3) The facilities proposed by the J-PARC users as extensions of the present J-PARC facilities.
1) Linac Energy Recovery

- The Annular-ring Coupled Structure is geometrically an axial symmetric version of the Side-Coupled Structure (SCS).
- The two ACS cavities are already under construction.
- The two ACS bunchers are also under production for the beam transport from the 190-MeV SDTL to the ACS.
- The three klystrons have been ordered, while the two is under power test.
- The ACS first appeared in famous Andreev’s paper[1972] had been long useless for its Q degradation, although its advantage regarding the axial symmetry has been realized. The 1300-MHz ACS was developed for JHP in KEK, with deep insight to the RF characteristics of the structure. The prototype of the ACS with two five-cell cavities bridged by a five-cell bridge coupler was first power-tested up to more than designed field with a pulse length of 600 µs and a repetition of 50 Hz [1990]. Afterwards a few ACS cavities were fabricated and power-tested with different β values and different coupling slots.
- After the J-PARC project started, the new 972-MHz ACS cavity was developed in order to keep the same size as that of 1300-MHz ACS in close collaboration with Institute for Nuclear Research (INR), Moscow, and Tokyo Institute of Technology. One disadvantage of the ACS cavity is its big size, since the ACS can be formed by rotating the side-coupled structure around the beam axis, geometrically speaking. This disadvantage is partly compensated by this new structure. The present version of the ACS is the one thus developed.
1) Linac Energy Recovery  

Setting up to measure the Frequency of ACS
**1) Linac Energy Recovery**

**Schedule Proposed**

<table>
<thead>
<tr>
<th>LINAC 400 MeV Recovery Schedule</th>
<th>2003.2.18</th>
</tr>
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<tbody>
<tr>
<td>Shut Down</td>
<td></td>
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<tr>
<td>The First Year</td>
<td></td>
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<tr>
<td>July, Aug.</td>
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<tr>
<td>The 2-nd Year</td>
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<tr>
<td>July-Sept.</td>
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<tr>
<td>The 3-rd Year</td>
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<tr>
<td>July-Sept.</td>
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<tr>
<td>The 4-th Year</td>
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<tr>
<td>July-Sept.</td>
<td></td>
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<tr>
<td>The 5-th Year</td>
<td></td>
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<tr>
<td>July-Dec.</td>
<td></td>
</tr>
<tr>
<td>Operation</td>
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<td>Scheduled Operation</td>
<td></td>
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<tr>
<td>Electricity</td>
<td></td>
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<tr>
<td>Distribution Step up</td>
<td></td>
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<td>Wiring</td>
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<td>Control</td>
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<td>Test Run</td>
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<td>Control</td>
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<td>Device Control Program</td>
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<tr>
<td>Wiring</td>
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<tr>
<td>Commissioning Program</td>
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<tr>
<td>ACS Assembly</td>
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<tr>
<td>Test Area Set up</td>
<td></td>
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<tr>
<td>RF System Set up</td>
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<tr>
<td>ACS Cavity Production</td>
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<td>Q-Mag Beam Monitor Production</td>
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<td>Kly, PS</td>
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<tr>
<td>Set up</td>
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<tr>
<td>Wiring</td>
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<tr>
<td>ACS System Test, Tuning</td>
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<td>RFQ Debuncher Replace</td>
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<td>Tunnel</td>
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<td>WQ Set up</td>
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<td>LINAC Commissioning</td>
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<td>Buncher(MEBT2) Installation</td>
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</tr>
<tr>
<td>RF System Tuning</td>
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<tr>
<td>3 GeV Commissioning</td>
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</table>
Energy spread of the beam, passing through the idle detuned accelerating structure (without transient effects)

Energy spread is 0.615 MeV at 2.04 MeV detuned, while it should be less than 0.4 MeV.

We have to give up the installation of the 200-400 MeV high-energy structures on beam line, detuned and being idle.

The structures should be installed to the beam line, followed by the beam commissioning.

This will increase the period of the beam shut down in the final year by one month or more.
**Future Upgrade Plan 2, 3)  Two Types of Letters of Intent (LoI’s)**

### Neutron Scatterings
- Call for LoI’s: Once a year.
- Fall of 2002: Accepted 18 LoI’s.
- Recommended 9 LoI’s into the next detailed proposals.
- Additional LoI’s came in.
- Approved LoI’s need to proceed into the funding request.

### Nuclear Particle Experiments
- Call for LoI’s: June, 2002.
- Early 2003: Accepted 30 LoI’s.
- Committee for Nuclear and Particle Experimental Facilities
- Discussions on \( \nu \) experiment, Day-1 experiments with K-beams, Phase-1 experiments, and Phase 2+ experiments.
- Need on redesign of experimental area, etc. to allow high priority experiments.
Future Upgrade Plan 2)  

23 neutron beam lines

- Stress Analysis diffractometer  
  A. Morii (JAERI)

- Bio-molecular spectrometer  
  K. Shibata (JAERI)

- Chopper Inst. (high reso.)  
  S. Itoh (KEK)

- Small angle diff. (high intensity)  
  K. Alzawa (JAERI)

- Reflectometer (horizontal)  
  N. Torikai (KEK)

- Powder diffractometer (versatile)  
  T. Ishigaki (Muroran Inst Tech)

- Bio-molecular X-tal diff. (versatile)  
  I. Tanaka (JAERI)

- High energy chopper instrument  
  K. Nakajima (JAERI)

- Total Scattering Inst. (amorphous)  
  T. Otomo (KEK)

- Powder diffractometers (high resolution)  
  T. Kamiyama (KEK)
Future Upgrade Plan 2, 3) Letters of Intent for 50-GeV MR

- Announce of LoI call: July 2002
- Thirty LoI’s were submitted by early 2003
  - Strangeness nuclear physics 7
  - Nuclear/hadron physics 7
  - Kaon decay physics 4
  - Muon physics 3
  - Neutrino physics 1
  - Future facilities 8
- 478 physicists with 2/3 from outside Japan. Asian participation is still few.
- Call for proposals: Most likely, within a year, if no further delay is observed for the 50-GeV MR construction.
Future Upgrade Plan 3) Neutrino factory with J-PARC proton driver
Future Upgrade Plan 3) Severeal-MW Neutron Source

The 2nd MLF
The 2nd RCS
GeV-class linac
The 2nd MLF
Future Upgrade Plan 3) Arrangements Made for the Future

- Reserved area for an additional fast extraction
- Fast extraction for neutrinos
- Tunnel for a future linac
- 50-GeV MR tunnel
- 50 GeV main ring

Plan view

Vertical View from the left
Summary

- In general, the construction of the J-PARC accelerator is on schedule for starting the linac beam commissioning in mid-2006 and extracting the 40-GeV beam by the end of JFY2007 (a half year later than original schedule), although the funding was stretched by one year.
- The linac front end was beam-commissioned for DTL1 up to 20 MeV. More tuning is necessary to obtain the satisfactory emittances.
- The further effort is necessary for reducing the shut down period of the final year of the linac energy recovery, since the high-energy structure cannot be located on beam line.
- Future upgrade plans beyond the Phase II were proposed by both the neutron and particle physics communities.