J-PARC Accelerators

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• Outline, Status, Schedule of J-PARC accelerator
• MR Beam Power Upgrade
J-PARC Facility

Materials and Life Science Experimental Facility

Hadron Beam Facility

Nuclear Transmutation Facility

Neutrino to Kamiokande

Linac (350m)

3 GeV Synchrotron (RCS)

50 GeV Synchrotron (MR)
Linac structures and parameters

- Ion Source: Volume Production Type
- RFQ: Stabilized Loop
- DTL: Electro-Quad in DT, 3 tanks
- Separated DTL(SDTL): no quad in DT, short tank(5cells), 32 tanks
- Annular Coupled Structure (ACS): axial symmetric
- Super Conducting Linac (SCL): wide aperture, high acceleration gradient

- particles: H⁻
- Energy: 181 MeV (RCS injection)
  400 MeV (RCS injection)
  600 MeV (to ADS)
- Peak current: 30 mA @181 MeV
  50 mA @400 MeV
- Repetition: 25 Hz (RCS Injection)
  50 Hz(RCS Injection + ADS application)
- Pulse width: 0.5 msec
3GeV Synchrotron (RCS)

- Rapid Cycle (25Hz)
- Ceramics vacuum chamber
- stranded conductor coil for D,Q magnets
- High field MA loaded cavity
- long lived carbon foil for charge exchange injection

- Circumference 348.3m
- Repetition 25Hz(40ms)
- Injection Energy 180/400 MeV
- Output Energy 3GeV
- Beam Power 0.6/1MW
- particles 0.50/0.83 \times 10^{14} ppp
- Harmonic 2
- Bunch Number 2
- Nominal Tune (6.72, 6.35)
- Transition $\gamma_t$ 9.14
- S.C. Tune Shift -0.2
50GeV Synchrotron (Main Ring)

- Imaginary Transition $\gamma$
- High Gradient Magnetic Alloy loaded RF cavity
- Small Loss Slow Extraction Scheme
- Both Side Fast Extraction for Neutrino and Abort line
- hands on maintenance scheme for small radiation exposure

Circumference: 1567.5m
Injection Energy: 3GeV
Output Energy: 30GeV (slow)
40GeV (fast)
50GeV (Phase II)
Beam Power: 0.75MW (Phase II)
Particles: $3.3 \times 10^{14}$ ppp
Repetition: 0.3Hz
Harmonic: 9
Bunch Number: 8
Nominal Tune: (22.4, 20.8)
**Phase I**

- **day-1 stage**
  - Linac: $180\text{MeV}$, $30\text{mA}$, $25\text{Hz}$
  - RCS: $3\text{GeV}$, $0.6\text{MW}$
  - MR: $40\text{GeV}$, $400\text{kW}$

- **Next Stage**
  - Linac: $400\text{MeV}$, $50\text{mA}$, $25\text{Hz}$
  - RCS: $3\text{GeV}$, $1.0\text{MW}$
  - MR: $40\text{GeV}$, $670\text{kW}$

**Phase II**

- Nuclear Transmutation Facility (ADS)
  - Linac: $600\text{MeV}$, $50\text{Hz}$
- Extension of Hadron and Neutron Facility
- MR: $50\text{GeV}$, $750\text{kW}$

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From the diagram:

- Linac (Superconducting) $600\text{MeV}$
- Linac (Normal Conducting) $400\text{MeV}$
- $3\text{GeV}$ Synchrotron (25Hz)
- Neutrinos to SuperKamiokande
- Hadron Experimental Facility
- Materials and Life Experimental Facility
- Neutrinos to SuperKamiokande
## Accelerator Schedule

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<td>• beam commissioning</td>
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<td>• slow beam commissioning</td>
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<td>• Neutrino commissioning</td>
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MR injection

RCS h=2, 2 bunches
MR h=9, 8 bunches

3 GeV Ring
2 Buckets

25 Hz
(40msec/cycle)

Injection at 3GeV

Fast Extraction at 50GeV

50 GeV Ring
9 Buckets

beam current: 15μA
beam power: 750kW
(400MeV Linac)

50GeV original pattern
(PhaseII)

50GeV extraction

0.7s
0.17s
1.9s
0.87s

total 3.64s

Magnet power supply upgrade
Electric power storage system
(fly wheel generator, SMES)
Beam Power \[ [kW] = \text{energy} \ [\text{GeV}] \times \text{beam current} \ [\mu\text{A}] \]

Beam current \( \propto \text{number of particles} \times \text{repetition} \)

Lower energy + higher repetition \( \longrightarrow \) same beam power
High Rep. Beam power 2MW

Bdot: 2.3 × 50GeV original pattern (3.64s repetition)
RF voltage: 2.3 × present voltage
electric storage system is necessary

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Graph: Dipole and quadrupole magnets

Electric Power (MW)

Energy (GeV)

- 50GeV 750kW original pattern
- 50GeV, 750kW original pattern

Repetition: 0.54s, 0.81s, 1.08s, 1.35s
Eddy current of dipole chamber

**SUS316L, 2mm thick**

**Bdot:** $2.3 \times 50\text{GeV}$ original pattern

**$\Delta B/B @\text{effective region} < 8.1 \times 10^{-4}$**

**Heat:** 100W/chamber

----> acceptable
Present Fast Extraction Scheme
designed to extract 50GeV beam

Acceptance 19.5π

Emittance
3GeV  81π (54π ×1.5)
20GeV  14.4π
30GeV  10π
40GeV  7.6π
50GeV  6.1π
Larger acceptance orbit <30GeV (no thin septa)

Extracted orbit acceptance $38\pi$

Kicker $L=2.43\text{m}$

Large aperture and compact kicker using lumped capacitance proposed
Low energy high rep. scheme can give same high power beam as high energy scheme at the same Bdot.

Merit:
1. Has low average and peak electric power
   ----> saves operation cost and power supply cost drastically
2. Damage due to accidental one shot beam loss is small.
   • Beam power/pulse is small
   • Beam size is large
   ----> Heat deposit /volume is small, thermal stress is small

1. Extracted beam emittance is larger
   --> Extraction orbit with large acceptance has been designed.
   --> Kicker development with large aperture has started.
2. Sextupole field and heat due to dipole chamber eddy current is acceptable
3. High rep. -->
   Injected beam power is higher
   --> Upgrade of the transport and ring collimators may be necessary
For 4MW Beam Power

$p p p \times 2-3$ in addition to 2MW scheme

- RCS $h=1$, MR $h=9$, 8 batches injection, $p p p \times 2$, $t_{inj} \times 2$
- barrier bucket injection, $p p p \times 2-3$, $t_{inj} \times 2-3$

Injection time is not negligible for high repetition

- 50GeV, RCS $h=1$, MR $h=9$, 8 batches, $Bdot \times 2.7$
  --> $p p p \times 2$
  space charge tune shift $0.16 \times 2$

- 50GeV, $Bdot \times 1.9$
  barrier bucket injection, 12 batches
  --> $p p p \times 3$
  space charge tune shift $0.16$

- 20GeV, $Bdot \times 2.8$
  barrier bucket injection, 12 batches
  --> $p p p \times 3$
  space charge tune shift $0.16$
For 4MW Beam Power

- add an accumulator ring (A. R.) in the MR tunnel
  RCS -> A. R. -> MR

save injection time to MR

Lower energy and higher repetition of MR can be possible.