Neutrino beam line at J-PARC

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• Proton beam line
• Target & neutrino beam
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T2K project

J-PARC (Tokai)
0.75 MW  50 GeV PS

4 MW ?

Super-K: 50 kton
Water Cherenkov

Hyper-K?

νμ → νx disappearance
νμ → νe appearance
NC measurement

sin^2 2θ_{13} from ν_e appearance

T2K (Tokai To Kamioka) collaboration started
Neutrino beam facility

Approved in Dec. 2003 for 5 years construction

Components

- Primary proton beam line
  - arc section (super-conducting)
  - straight sec. (normal-conducting)
- Target/Horn system
- Decay volume (130m)
- Beam dump
- Muon monitors
- Near neutrino detector (280m)
- Second near neutrino detector (~2km): not approved yet
Proton beam line

Arc Section
84.5°, R=105m, Super conducting magnets

Final Focusing Section
Normal conducting magnets

Preparation section
Normal conducting magnets

Specification (50GeV)

- Single turn fast extraction
- 8 bunches/\sim 5\mu s
- 3.3 \times 10^{14} protons/spill
- Cycle: 3.64 second
- \varepsilon = 6\pi \text{ mm.mr}, \Delta p/p = 0.31\%

(\varepsilon = 7.5\pi \text{ mm.mr},
\Delta p/p = 0.36\% @40\text{GeV})
50GeV ring
0.5W/m

Arc Section
1W/m
to assure hands-on maintenance
and below quench limit

Preparation section
0.75kW (0.1%)
controlled by collimators

Fast extraction
(kicker, septum)
1.1kW (0.15%)

Final Focusing section
0.25kW (0.03%)

Assumed by HAND
Shielding design based on assumption
Same order as KEK-PS beam line
\( \sim 10^2 \) relative suppression required
Preparation section

- Matching beam from PS to ARC section

- Dipole(H): 2
- Quadrupole: 5
- Steering: 5
- 5 with MIC

Acceptance: $60\pi$ mm.mr

Collimators to minimize beam loss & heat load at super-conducting magnets

Top view

$\varepsilon = 6\pi$ mm.mr
Arc section

- 14 cells of “Combined Function” super-conducting magnets
- >200π mm.mr acceptance

Two magnets in one cell

Common cryostat design to LHC arc magnets
⇒ Reduce Cost & Risk
Combined function

- Combined function magnets to save space and cost
- First application for super-conducting magnet

**Combined function**

**Dipole Field:** 2.587 T
**Quad. Field:** 18.62 T/m
**Inductance:** 14mH
**Magnetic Length:** 3.3m
**Current:** 7345A
**Stored Energy:** 0.38MJ
R&D for magnet

• Cryogenic Science Center of KEK

Trial winding of coil at KEK

Trial Yoke Pack & Plastic Collar
Final focusing section

- Bending/focusing beam to target

Side view

Vertical dipole magnets to change off-axis angle (2°~3°)

σ_r~6mm at target

- Dipole(V): 2
- Quadrupole: 4
- Steering: 2
Beam monitors

Beam Monitor
• I : Intensity (CT)
• C: Center position (LPM)
• P: Profile (SSEC/RGBPM)
• Loss monitor
Off Axis Beam

(ref.: BNL-E889 Proposal)

• WBB is intentionally misaligned from detector axis
• Quasi monochromatic beam
• Off axis angle: 2°~3° tuned for oscillation maximum

Statistics at SK:
(OAB 2°,1yr,22.5kt)
• ~3000 ν_μ CC (~x100 of K2K)
• ν_e ~ 0.2% at ν_μ peak
Target

- Carbon Graphite target: 30mm(D) x 900mm(L)
- $10^{21}$ protons in a year
- Energy deposit: 58kJ/spill
- Cooled at outer surface

$10^{14}$ P/spill
$\sigma_r = 6$mm

Max. 236°C at center
Max. 85°C at surface

Water cooling
Cooling of target

Two scenarios

• Water cooling
  • Required thermal transfer (6kW/m²K) was achieved in test setup.
  • Shrink in container due to radiation damage may be a problem.
    ⇒ irradiation test at BNL

• Helium gas cooling
  • No container for graphite
  • Entrance window required
  • Under discussion

600~700°C@center
500°C@surface

600~700°C@center
500°C@surface
Horn system

- Converge secondary pions into decay volume
- 3 horn system
- Carbon target in 1st horn
- Made by Aluminum
- 320kA pulse current
- Water cooled inside
- Under design and R&D
R&D for horn

- Thermal analysis
  - 82°C at maximum
  - Cooled by water mist

- Test of Friction Stir Welding
  - HITACHI, Ltd.
  - Pulsed load Test
    - 1.1x10^7 repetition
    - No damage by repetition fatigue was found.
Decay volume

3NBT (BT between 3GeV&MLF) constructed in 2005

50m under 3NBT will be constructed in 2004

- Off axis angle: 2°~3°
- Cross section: Square box shape
  \[(2.2m(W) \times 2.8m(H)) \sim (3.0m(W) \times 4.6m(H))\]
- Consists of iron plates with water cooling channels
- Filled by 1atm Helium
- Surrounded by 6m thick concrete
Cooling of DV

- DV should work with 4MW beam
- FEM analysis for 4MW beam
  - Iron plate $< 60^\circ C$
  - Concrete $< 120^\circ C$

Production of iron plates with water-cooling plate-coils finished for 50m construction under 3NBT.
Beam dump

Cu Core 230t

Cooled at r=170cm by 30°C water

162°C at maximum

For 0.75MW beam

For 4MW beam: Aluminum core?

Iron block 660t (DURATEC?)

Concrete shield

Decay Volume

beam
- **Muon monitors @140m (dump)**
  - Fast (spill-by-spill) monitoring of beam direction / intensity
- **Near detector @280m**
  - Neutrino intensity/spectrum/direction
- **Second Near Detector @2km**
  - Almost same $E_\nu$ spectrum as for SK
  - not approved yet

⇒ Talk by Clark McGrew tomorrow
Far Detector

1st stage

Super-Kamiokande
- 50kt water Cherenkov
- 11,000 20inch PMT’s

2nd stage

Hyper-Kamiokande
- ~1Mt water Cherenkov
- ~200,000 photo-sensors

Same Off axis angle for SK and HK

⇒ Talk by Shiozawa tomorrow
Five years construction in 2004~2008
Most heavy construction in last 2 years
• Civil const.: 83.5
• Instrumentation: 76.1
• Normal cond. magnet: 10.4
• Super cond. magnet: 33.3
• Target, DV, dump: 12.6
• Cooling system: 15.2
• Detector & others: 4.4

KEK ν: 159.6 Oku Yen
KEK others: 490.1 Oku Yen
JAERI: 864.7 Oku Yen
Total: 1514.4 Oku Yen

Unit: Oku$(10^8)$ Yen ~ 1M$
• Neutrino beam facility was approved for five years construction.
• Off axis (~2.5°) experiment with SK
• 100 times larger intensity than K2K
• T2K collaboration started in 2003.
• Design and R&D are on going.
• Construction of decay volume is starting.
• Start experiment in 2009