Measurement of the Neutrino Beam Quality with the Muon Monitor "MUMON" in the T2K Experiment

Kento Suzuki (Kyoto University) for T2K Collaboration

T2K Experiment

Purpose

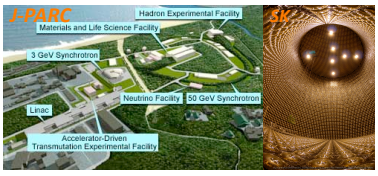
Precision measurement of θ_{23}, Δm_{23}^2 by ν_μ disappearance

First measurement of θ_{13} by ν_e appearance

$$P(\nu_\mu \to \nu_\mu) \approx 1 - \sin^2 2\theta_{23} \sin^2\left(\frac{1.27\Delta m_{23}^2 E}{L}\right)$$

$$P(\nu_\mu \to \nu_e) \approx \sin^2 2\theta_{13} \sin^2\theta_{23} \sin^2\left(\frac{1.27\Delta m_{23}^2 E}{L}\right)$$

In T2K Experiment, L=295km, E~0.6GeV



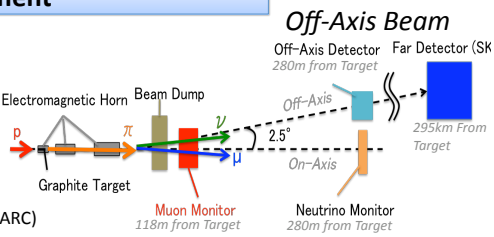
Japan Proton Accelerator Research Complex (J-PARC)

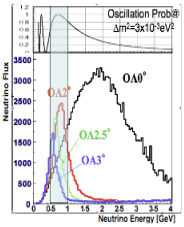
- Located at Tokai in Ibaraki prefecture.
- 30GeV proton synchrotron
- High intensity proton beam (Design Value:750kW)
- Physics data taking started from 2010 Jan. (20kW~)
- Current beam intensity is ~50kW. (~June 1st)

Super Kamiokande (SK)

- Located at Kamioka in Gifu prefecture.
- 50kt water cherenkov detector (22.5kt fiducial volume)

Off-Axis Beam





Novel Off-Axis (2.5°) method

- Make a narrower energy spectrum at SK than on-axis.
- Enhanced oscillation probability. ($\nu_\mu \to \nu_x$)
- Lower energy peak reduces non-oscillated backgrounds.

It is necessary for tuning well the beam direction to On-Axis (0°).

We must monitor the beam direction precisely (<1mrad) and in real time

Muon Monitor "MUMON"

Overview

MUMON

- Located at 118m downstream from the target (behind the beam dump).
- Detects the muons (>~5GeV/c) which go through the beam dump.
- **Can measure the profile center and the intensity of the muon beam in real time**

Need to be tolerant for high radiation area

- 100kGy for 100 days operation at 750kW.

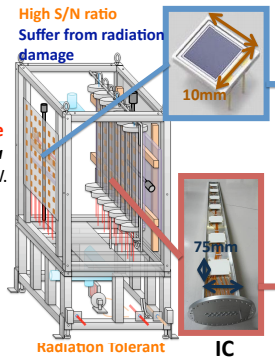
Consist of two arrays of detectors (7×7=49channels respectively)

- **Si PIN Photodiode**
  - 10mm×10mm×300μm(depth)
  - Will be exchanged for other detector in preparation for 750kW operation.
- **Ionization chamber (IC)**
  - 75mm×75mm×3mm(depth)
  - Ar+N_2(2%) (lower intensity:<200kW)
  - He+N_2(1%) (higher intensity:>200kW)

Si PIN Photodiode

High S/N ratio

Suffer from radiation damage

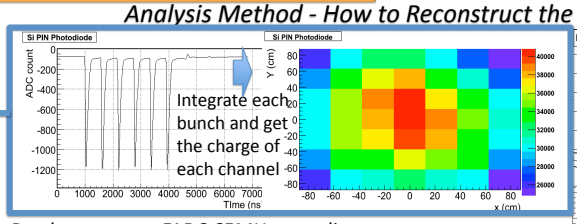


Radiation Tolerant

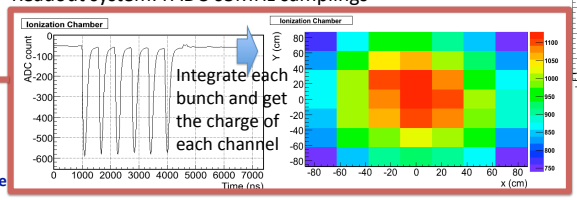
have to Keep an appropriate condition (Peressure, Temperature and O_2 level)

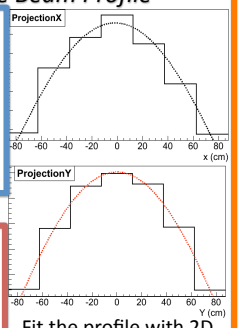
IC

Analysis Method - How to Reconstruct the Beam Profile -



Readout system: FADC 65MHz samplings

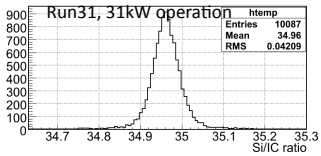




Fit the profile with 2D Gaussian then measure profile center, width and peak value.

Performance of MUMON

Intensity Measurement



Total charge (Si PIN) / Total charge (IC)

- This value insensitive to fluctuation in beam direction, horn current and beam intensity.
- Shows intrinsic resolution of MUMON in intensity measurement :

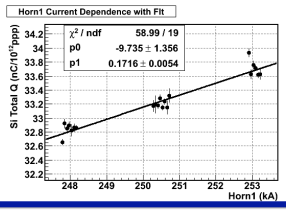
σ_{MUMON}/Q_{MUMON} <0.12% (RMS/Mean)

Resolution excellent for requirement of experiment! (Requirement is less than 3% !)

(*) total charges of all channels (49 channels). This value roughly corresponds to muon's yield.

Dependence on Horn Current

- Left fig: changed horn1 current by ± 1% from nominal value(250kA) .
- Right fig: Schematic of three horns. Pions are focused by these.
- **MUMON can monitor 0.3kA fluctuation in horn1's current ←thanks to MUMON's good resolution.**



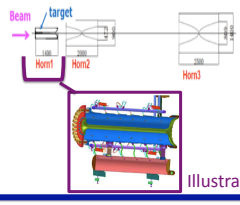
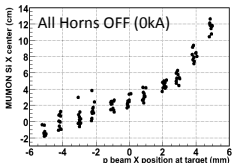
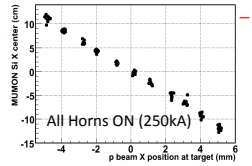


Illustration of 1st horn

Sensitivity to the Proton Beam Position at Target

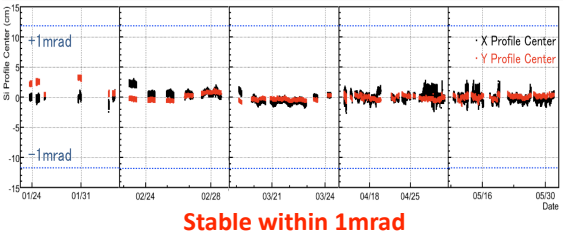


- Changed the proton beam position at target
- Beam angle is kept parallel to beam axis
- Observed inverse correlation when all horns are at 250kA.
- **MUMON can monitor 0.1mm difference of proton beam position when all horns are on (250kA).**



Achieved Beam Quality in Physics Run

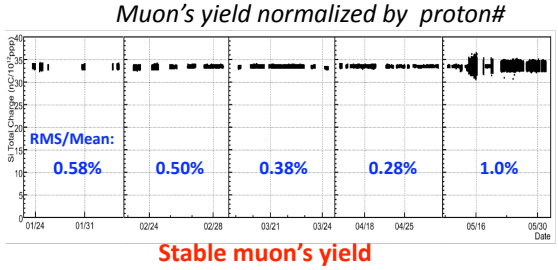
Beam direction



Stable within 1mrad

(*) Requirement is less than 1mrad (11.8cm at MUMON)

Muon's yield normalized by proton#



Stable muon's yield

(*) In last run fluctuation in this value was relatively large because condition of other beam monitor changed.

- The Beam direction on-axis is well understood thanks to MUMON measurement.
- MUMON's live time is **99.95%.**

Currently MUMON is stable and running well! MUMON and T2K are ready for more beam!