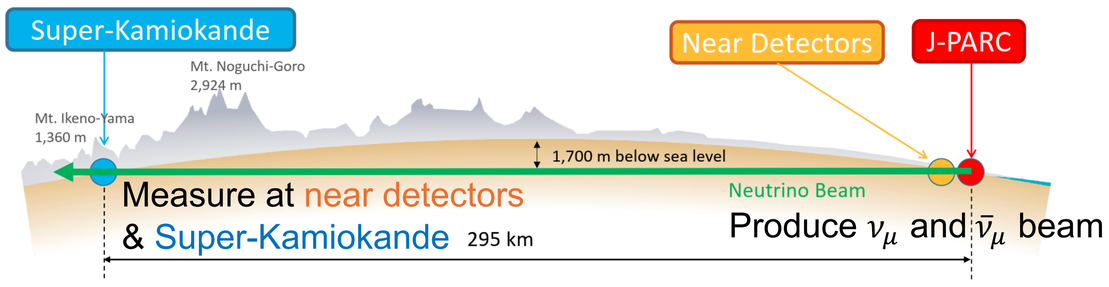
Evaluation of a new muon monitor sensor for the T2K experiment using the J-PARC neutrino beam

Yukine Sato for the T2K collaboration

1. Introduction

1.1 T2K experiment

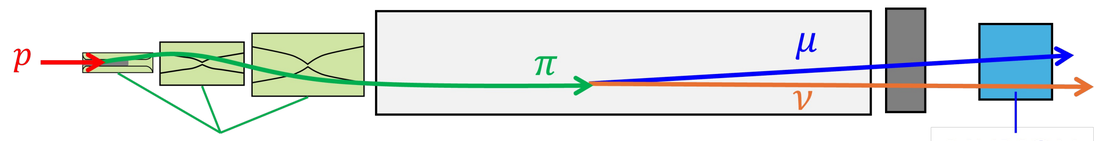
- A long-baseline neutrino oscillation experiment in Japan



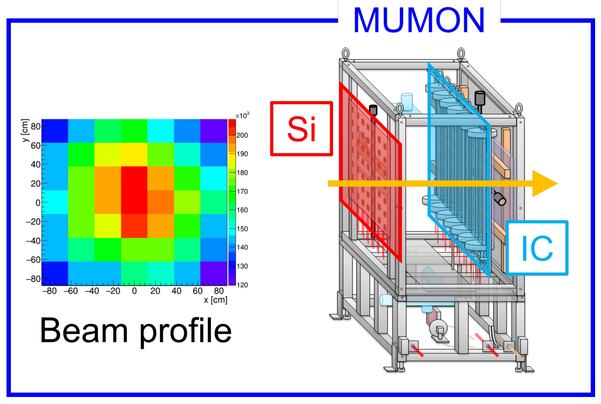
- Physics goals:
  - Precision measurement of neutrino oscillation
  - Explore CP violation in lepton sector
  - Need more statistics → upgrade the beam intensity

1.2 Muon monitor (MUMON)

- Indirectly monitors neutrino beam intensity and directions in real time

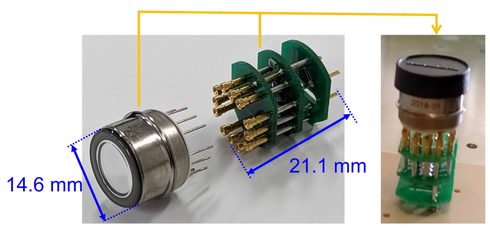


- Requirements: 0.3 mrad
- Si PIN photodiode (pad type) is main sensor for monitor
- Ionization chamber (IC) is for cross-check and backup
- Issues in future operations
  - Si: signal degradation due to radiation damage
  - IC: non-linearity due to the space charge effect



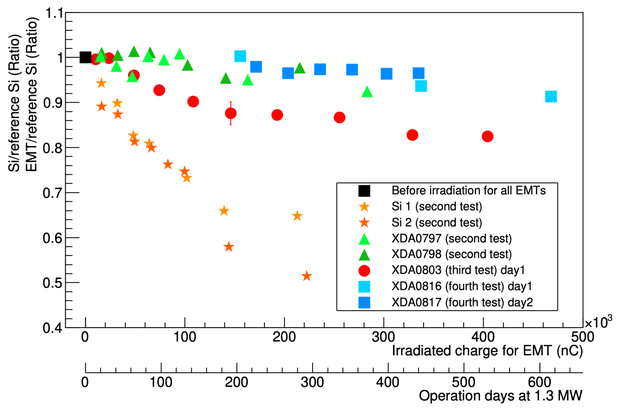
2. Electron Multiplier Tube (EMT)

- Replacement of Si and/or IC is considered for upgrade of beam intensity
- One possible replacement: **Electron Multiplier Tube (EMT)**



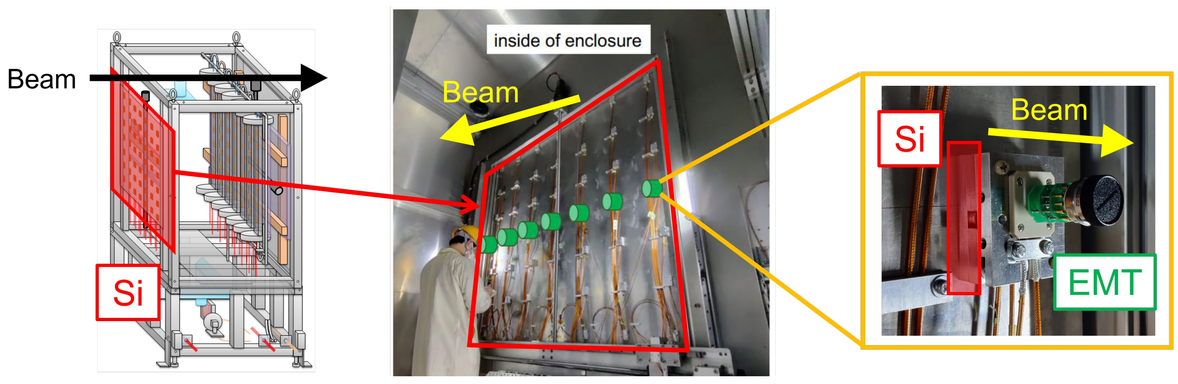
- Based on the same technology as Photomultiplier Tube (PMT)
- Photocathode is replaced with aluminum deposited glass

2.1 Beam test results[1]



- Conducted beam tests to investigate EMT performance
- The radiation tolerance of EMT is significantly better than that of Si
  → Candidates of the new MUMON detector

2.2 Installation of EMT



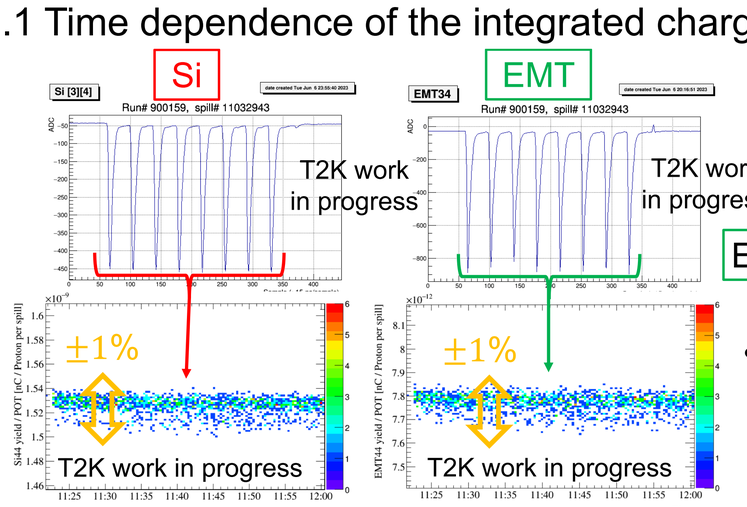
- Installed 7 EMTs inside MUMON in January 2023 for
  - Acquisition of horizontal muon profile
  - Comparison with Si detector measurements
  - Verification of signal stability under real measurement conditions

[1] Takashi Honjo *et al.* arXiv: 2405.05877 **[physics.ins-det]**

3. Results

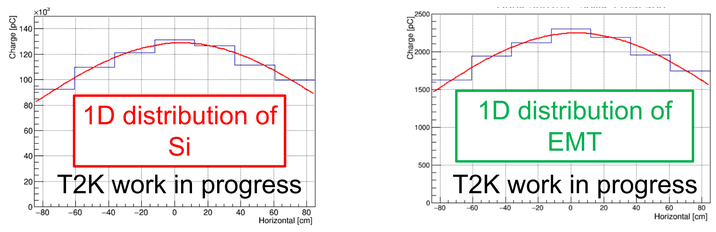
3.1 EMT at high intensity beam

3.1.1 Time dependence of the integrated charge



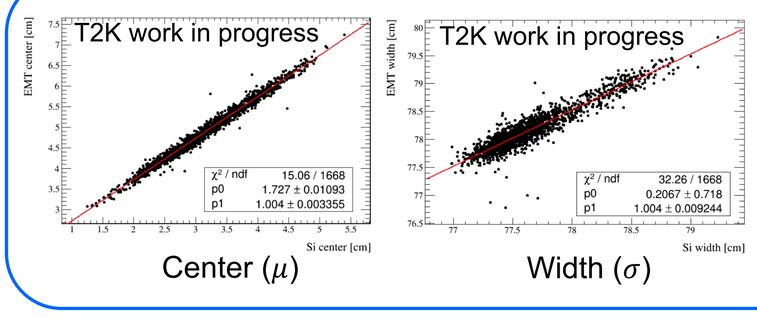
- EMTs provide as stable measurements as Si detectors

3.1.2 1D beam direction measurements



- Muon profile was successfully measured by EMT

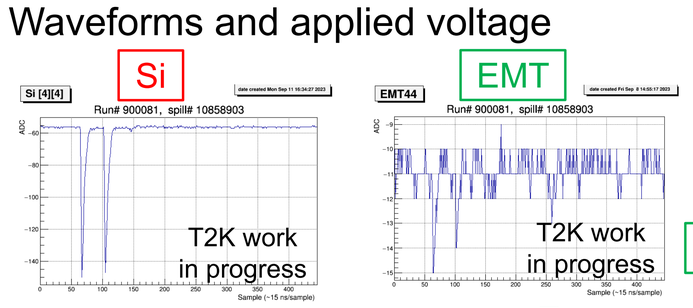
Correlation of Si and EMT beam measurements



- Beam center measurements by EMTs are systematically misaligned by 1.7 cm
  → Currently under investigation

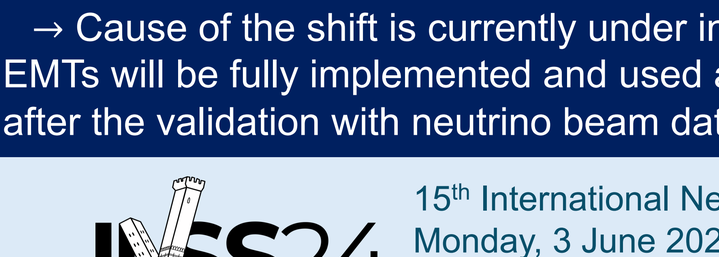
3.2 EMT at low intensity beam

3.2.1 Waveforms and applied voltage



- Gain variations are different for 7 EMTs
- EMTs need to be re-calibrated to operate at different voltages

3.2.2 1D beam direction measurements



- 1D profiles of the integrated charge at low intensity were obtained in the same way as for Si

Summary and prospects

- T2K beam direction and intensity are indirectly monitored by muons (MUMON)
- EMTs (new candidate sensors) were installed at MUMON in J-PARC
  - EMT response has been stable within ±1% during beam operation
  - Muon profile was measured by 7 EMTs at high and low intensity beam
  - Beam center measured by EMTs was misaligned by 1.7cm w.r.t. Si measurement
    → Cause of the shift is currently under investigation
- EMTs will be fully implemented and used as the primary monitors after the validation with neutrino beam data

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