Assembly and Bench Testing of a Spiral Fiber Tracker for the J-PARC TREK/E36 Experiment

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On behalf of the J-PARC TREK/E36 Collaboration

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Highlights

- We are developing a spiral fiber tracker based on plastic scintillating fibers for the J-PARC E36 experiment.
- The actual spiral fiber tracker was successfully assembled around a K^+ stopping active target holder.
- In a bench test, we confirmed that the spiral fiber tracker had no dead fibers in a total of 128 channels.

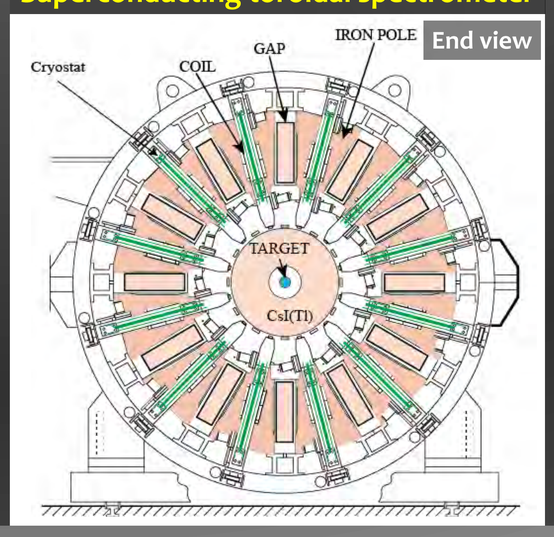
References

- TREK Collaboration, J-PARC E36 Proposal.
- J.A. Macdonald, *et al.*, *Nucl. Instrum. Methods A* 506 (2003) 60.

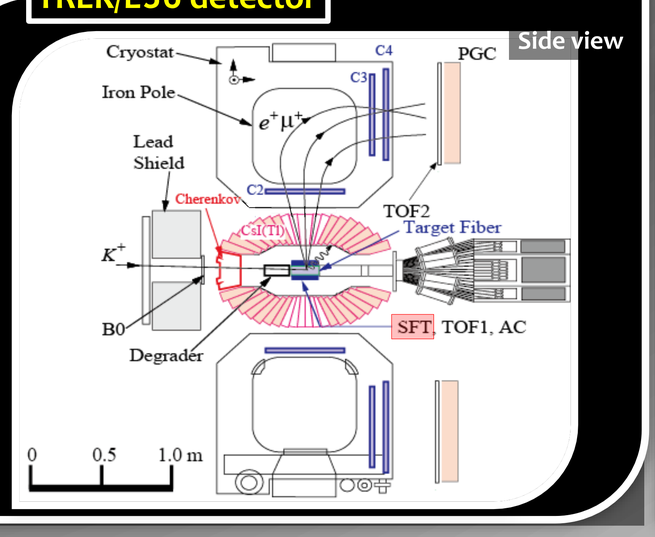
Introduction

- TREK/E36 experiment at the Proton Synchrotron of the J-PARC center, Japan
  - Test of lepton flavor universality
    - Precise measurement of $R_K = \Gamma(K^+ \to e^+\nu)/\Gamma(K^+ \to \mu^+\nu)$ using stopped K^+
  - Search for heavy sterile neutrino
  - Search for light U(1) gauge boson (dark photon)
- Charged decay particle detection
  - Momentum measurement (tracking) and efficiency control
    - Spiral fiber tracker (SFT)
    - 3 layers of multiwire proportional chambers (C2, C3, and C4)
  - Particle identification
    - Threshold aerogel Cherenkov counters (AC) with n = 1.08, TOF counters, and Pb-glass Cherenkov counters (PGC)

Superconducting toroidal spectrometer



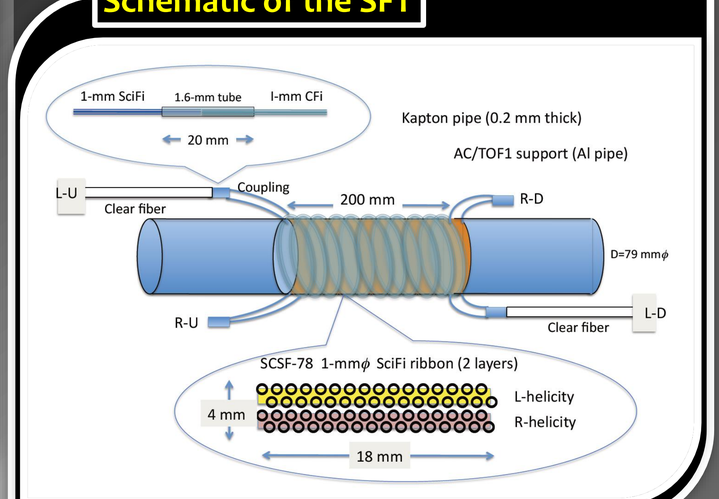
TREK/E36 detector



Design of the Spiral Fiber Tracker

- φ1-mm double-clad plastic scintillating fiber (SCSF-78, Kuraray Co., Ltd.)
  - Glueing 15 or 17 fibers to create 1-layer flat ribbon
  - ~5 m per ribbon (~attenuation length)
  - Clear fiber extension with low transmission loss (total ~11 m per ribbon)
- Coiling the ribbons around K^+ target holder (AC/TOF aluminum pipe support)
- 4 ribbon layers in 2 helicities
  - Inner (1st + 2nd) layers: 15 fibers in L-helicity
  - Outer (3rd + 4th) layers: 17 fibers in R-helicity
  - Staggered fiber configuration (1-side glueing)
- Multi-pixel photon counter (MPPC) readout with EASIROC module
  - 128 ch = 15 fibers × 2 ends × 2 layers + 17 fibers × 2 ends × 2 layers
- Using tracking information by an active scintillation K^+ stopping target

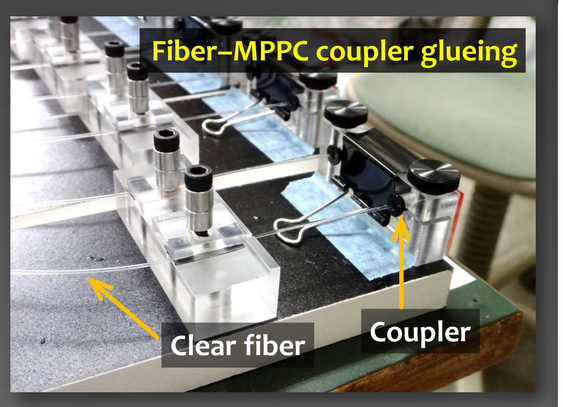
Schematic of the SFT



- Redundant tracking configuration
  - Reliable momentum determination
- At least 4-point tracking for robust analysis
  - Track segments before and after magnetic field
- At least 3-of-4 point tracking for efficiency control

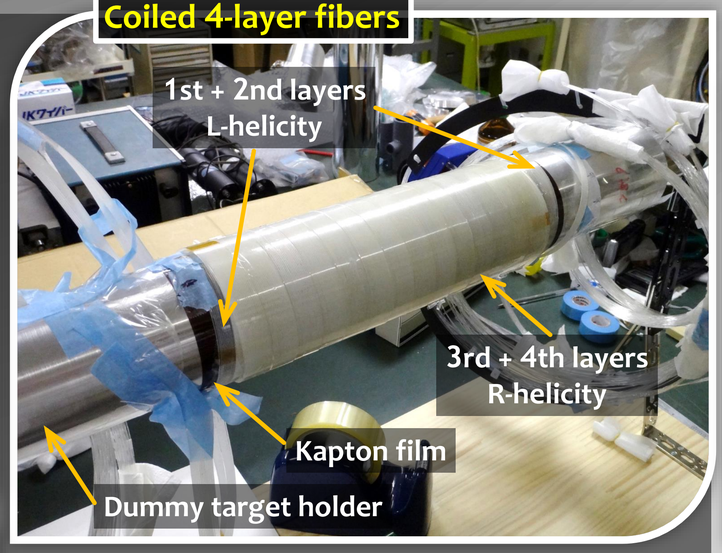
Assembly

Fiber–MPPC coupler glueing

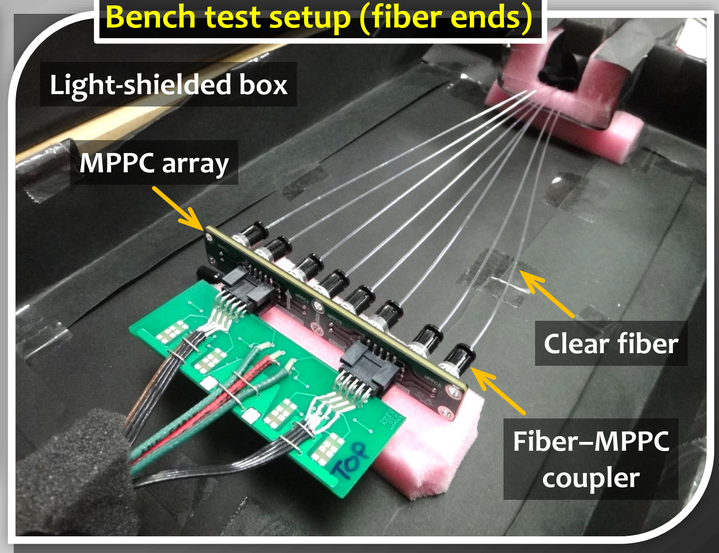


Fiber–MPPC coupler

Coiled 4-layer fibers

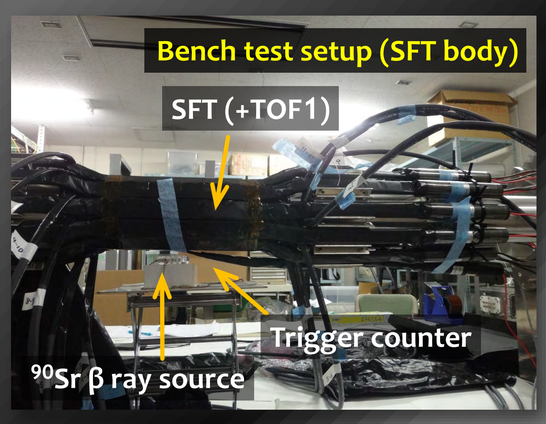


Bench test setup (fiber ends)

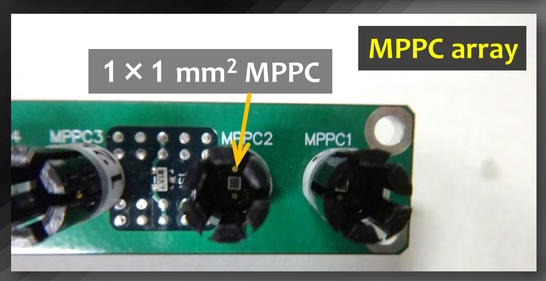


Bench Tests

Bench test setup (SFT body)

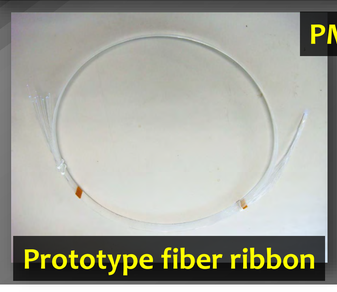


MPPC array



PMT connector

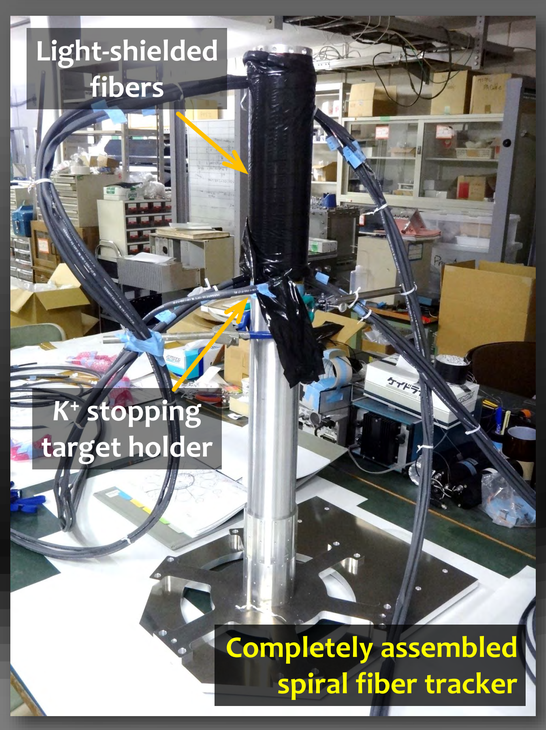
Prototype fiber ribbon



In April 2014

1. Preparing a dummy target holder to work on a table
   - Same diameter with an actual target holder (φ79 mm)
   - Wrapped by thin kapton film to easily unmount coiled fiber ribbons
2. Coiling the fiber ribbons for 1st and 2nd layers around the kapton sheet
   - L-helicity
3. Coiling the fiber ribbons for 3rd and 4th layers around the 1st–2nd layers
   - R-helicity
   - Fixed by Mylar tape
4. Light-shielding the fibers
5. Glueing a coupler to the fiber edge
   - Fiber coupler connecting a MPPC
6. Polishing the fiber terminus to remove redundant glue
7. Transferring the coiled fiber ribbons with the Kapton sheet from the dummy holder to the actual target holder

Light-shielded fibers / K^+ stopping target holder / Completely assembled spiral fiber tracker



After assembly in July 2014

- Using ^{90}Sr β ray source
- Using one scintillation trigger counter
- MPPC readout
- Results
  - Obtained signals form all fibers
    → No dead channel

Before assembly in March 2014

- One prototype scintillating fiber ribbon with a length of 1.5 m available
- Using ^{90}Sr β ray source
- Using two scintillation trigger counter
- Photomultiplier (PMT) readout
- Bundling the fiber edge to connect them with PMTs
- Results
  - Naïve detection efficiency
    - 2-layer ribbon
      - 99.8% (1 p.e. threshold)
    - *cf.* 1-layer ribbon
      - 78.3%