Progress in Developing a Spiral Fiber Tracker for the J-PARC 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.
- In a bench test, we obtained a charged particle detection efficiency of 99.8% in a prototype 2-layer fiber ribbon.
- The actual spiral fiber tracker was successfully assembled around a K^+ stopping active target holder.

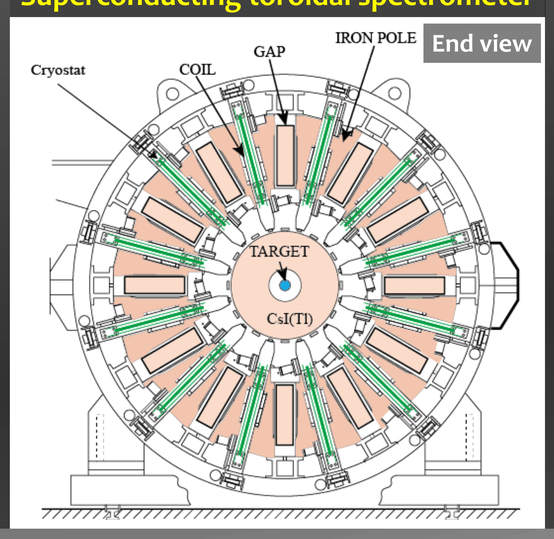
References

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

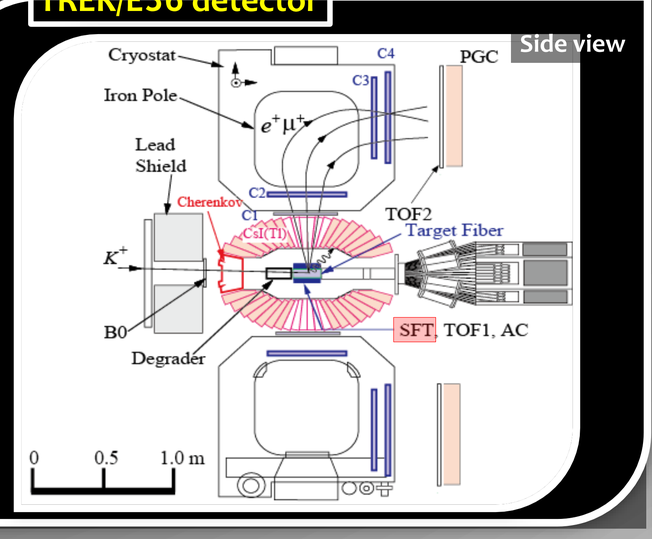
Introduction

- 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



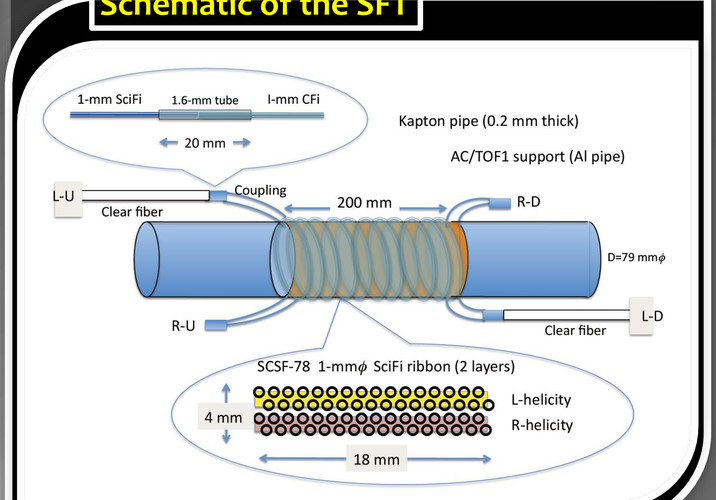
TREK/E36 detector



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)
- 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

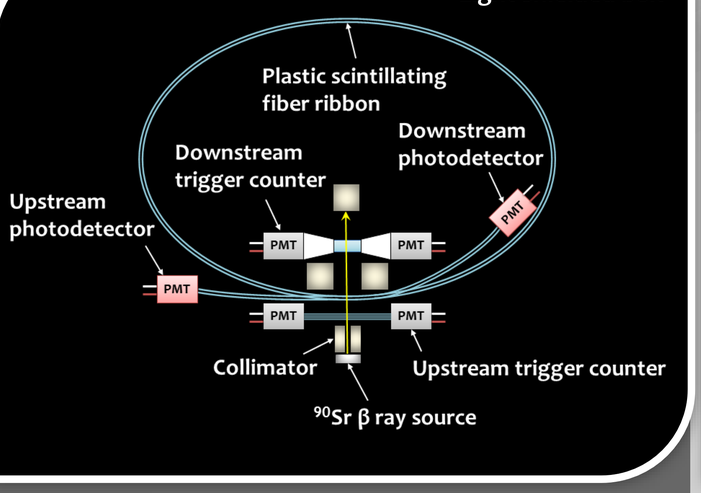


- Redundant tracking configuration
  - Reliable momentum determination
- At least 4-point tracking for robust analysis
  - Track segments before and after magnetic field
- At least 3-of-4 point tracking for efficiency control, 4-of-5 point tracking desirable for better accuracy (additional C1 tracker)

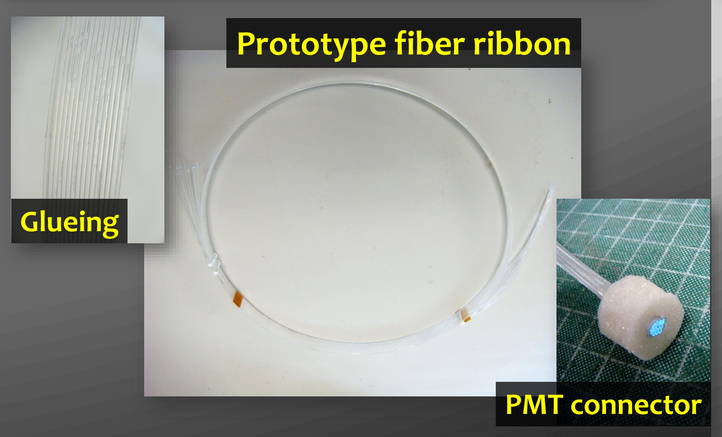
Bench Test

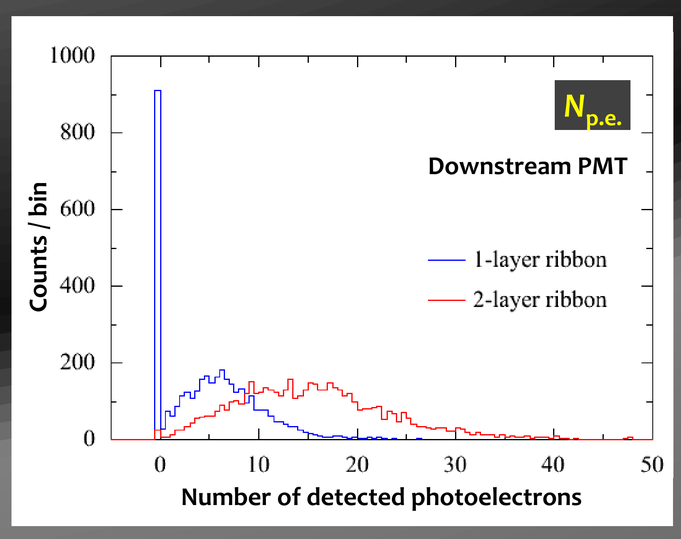
- Prototype fiber ribbon preparation
  - Glueing 16 fibers to create 1-layer ribbon by Moderation-Line Co., Ltd.
  - 1.5 m, 1 ribbon available
  - Bundling the fiber edge to connect them with photodetectors
- Bench test using ^{90}Sr β ray source in March 2014
  - Measuring minimum ionization particle detection efficiency of SFT prototype
  - Irradiating 2-layer and 1-layer ribbons
    - 2-layer ribbon formed by rounding 1 ribbon
  - Photomultiplier readout (MPPC readout not ready)
  - Upstream trigger counter based on a bundle of φ0.2-mm plastic scintillating fibers
  - Downstream trigger counter based on a plastic scintillating block (H5:W10:T5 mm^3)
- Results
  - Detection efficiency
    - 2-layer ribbon (staggered configuration)
      - 99.8% (1 p.e. threshold)
    - *cf.* 1-layer ribbon
      - 78.3%

Bench test setup

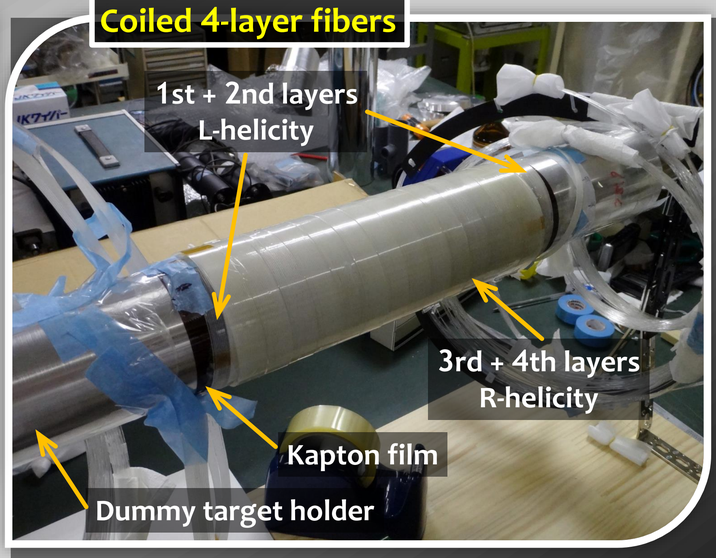


Prototype fiber ribbon





Coiled 4-layer fibers

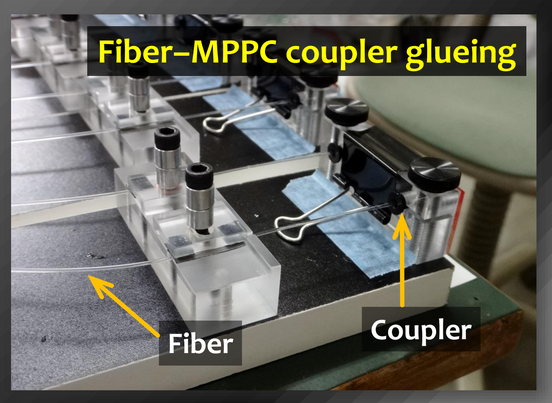


In April 2014

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

Assembly

Fiber–MPPC coupler glueing



Fiber–MPPC coupler