

Progress in Developing a Spiral Fiber Tracker for the J-PARC E36 Experiment

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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.

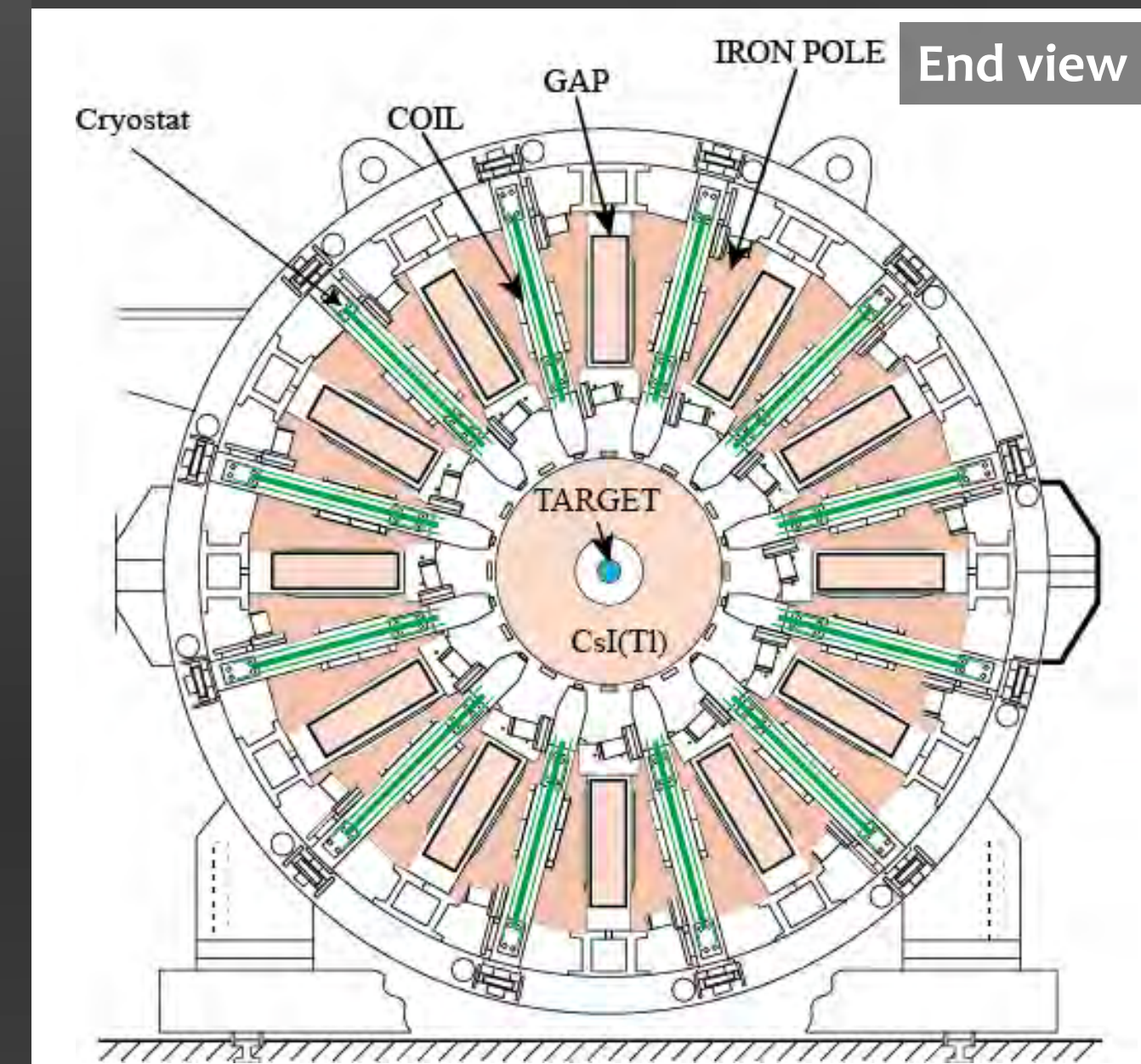
Introduction

- TREK/E36 experiment at the Proton Synchrotron of the J-PARC center, Japan
 - Test of **lepton flavor universality**
 - Precise measurement of $R_K = \Gamma(K^+ \rightarrow e^+ \nu) / \Gamma(K^+ \rightarrow \mu^+ \nu)$ 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)

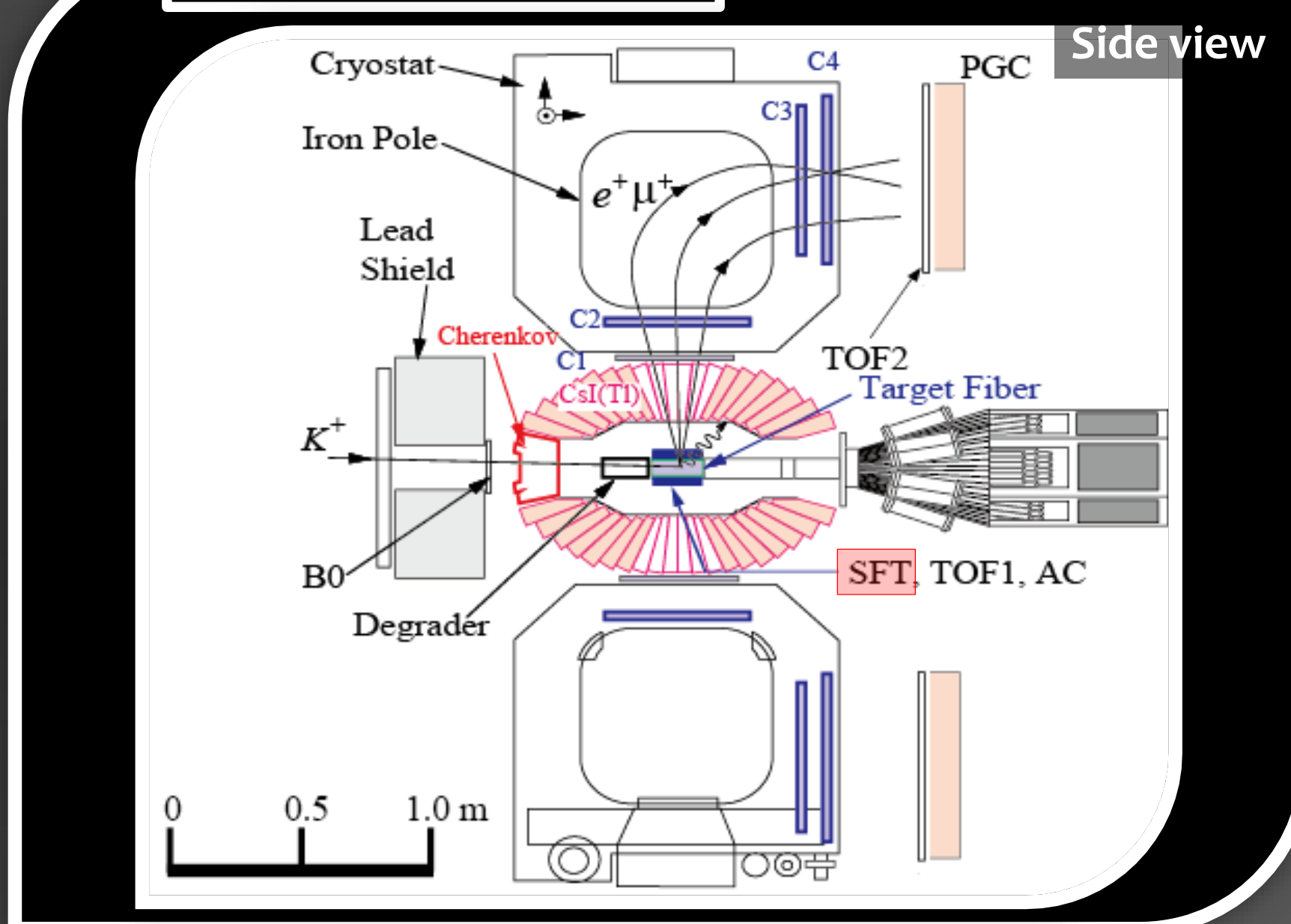
Design of the Spiral Fiber Tracker

- ϕ 1-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 \times 2 ends \times 2 layers + 17 fibers \times 2 ends \times 2 layers
- Using tracking information by an active scintillation K^+ stopping target

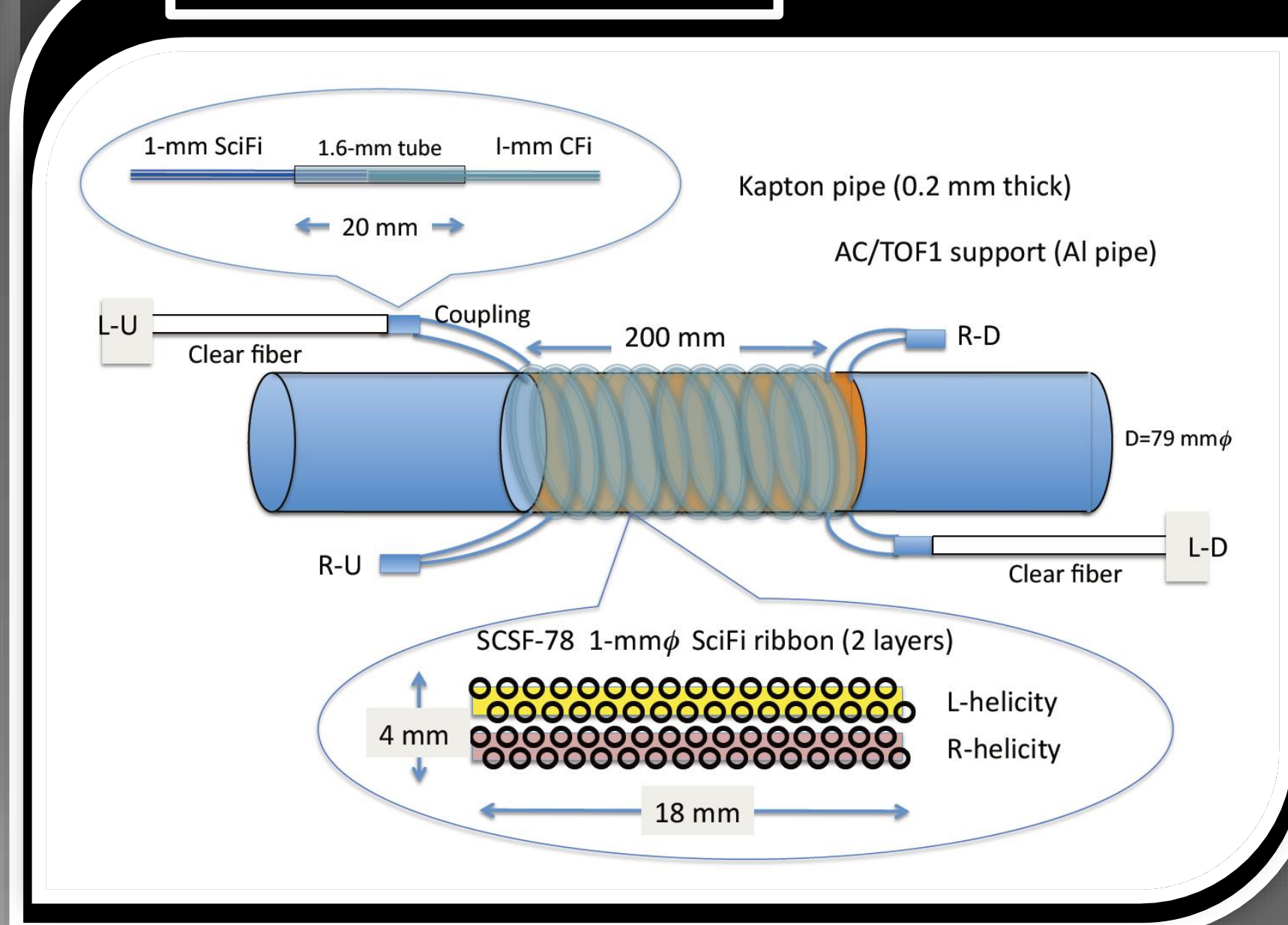
Superconducting toroidal spectrometer



TREK/E36 detector



Schematic of the SFT

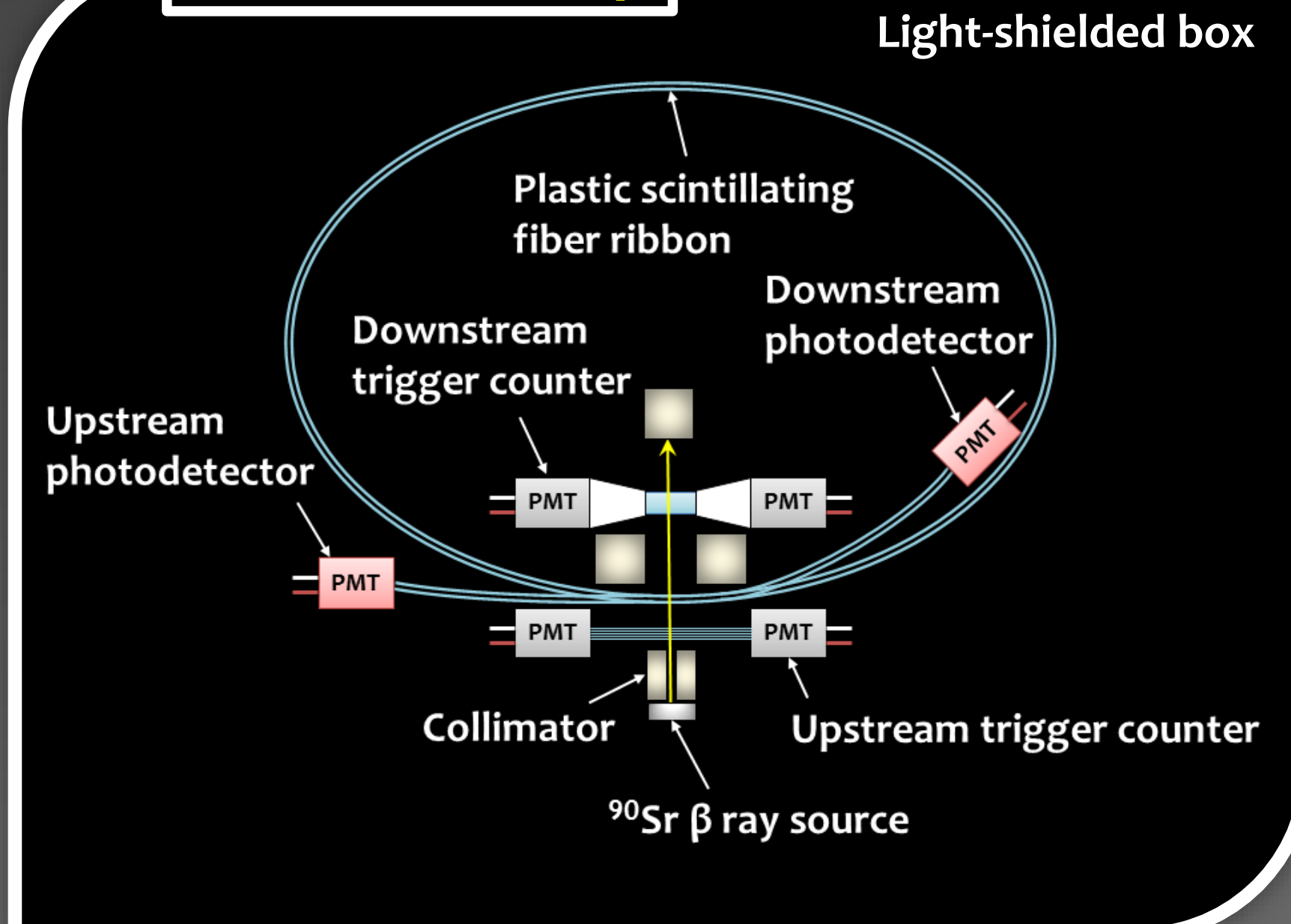


- Redundant tracking configuration
 - Reliable momentum determination
- At least 4-point tracking for robust analysis
 - Track segments before and after magnetic field
- At least 3-of-4 point tracking for efficiency control, 4-of-5 point tracking desirable for better accuracy (additional C1 tracker)

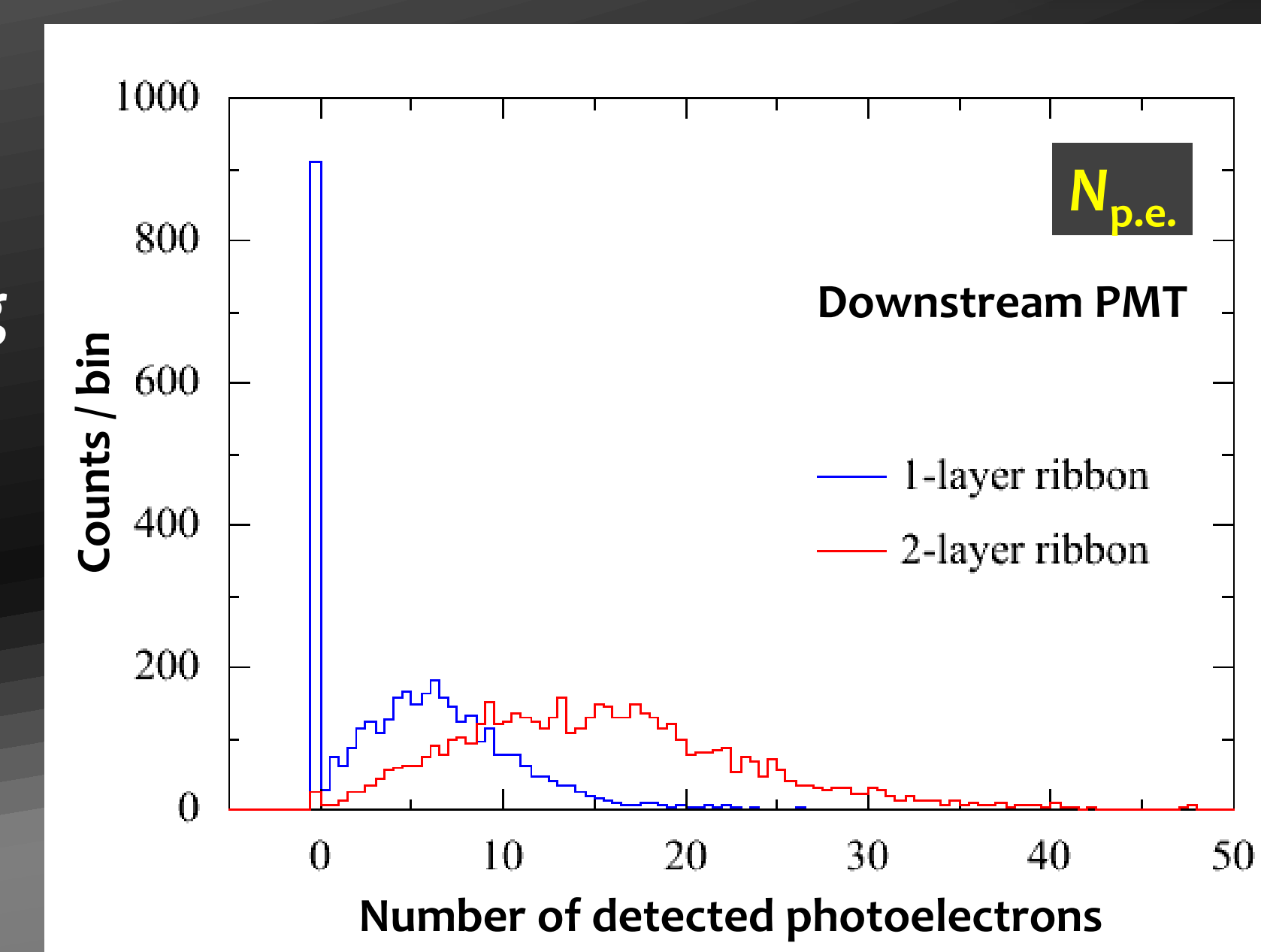
Bench Test

- **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 ϕ 0.2-mm plastic scintillating fibers
 - Downstream trigger counter based on a plastic scintillating block (H5:W10:T5 mm³)
- **Results**
 - **Detection efficiency**
 - **2-layer ribbon (staggered configuration)**
 - **99.8%** (1 p.e. threshold)
 - cf. 1-layer ribbon
 - 78.3%

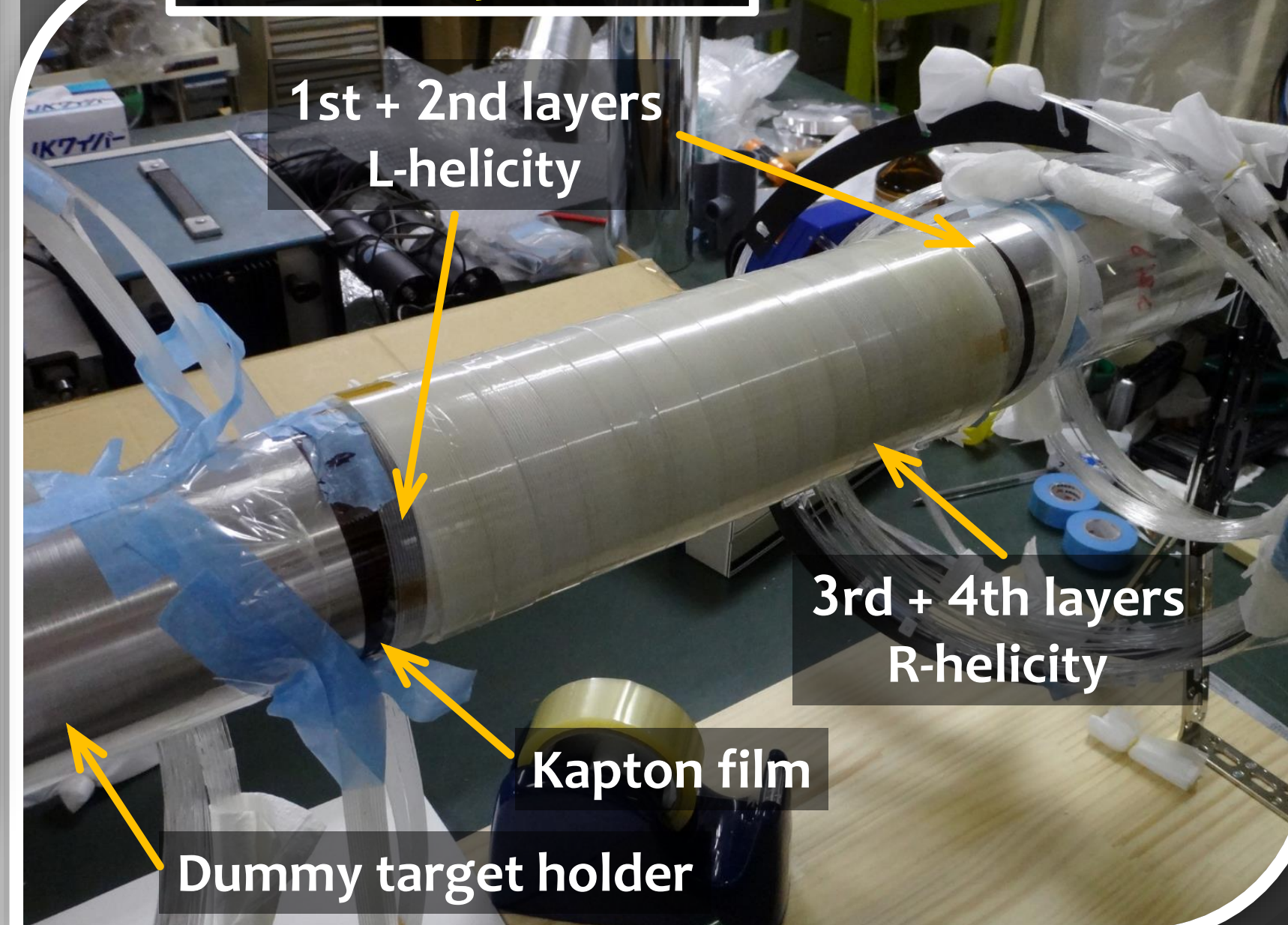
Bench test setup



Prototype fiber ribbon



Coiled 4-layer fibers

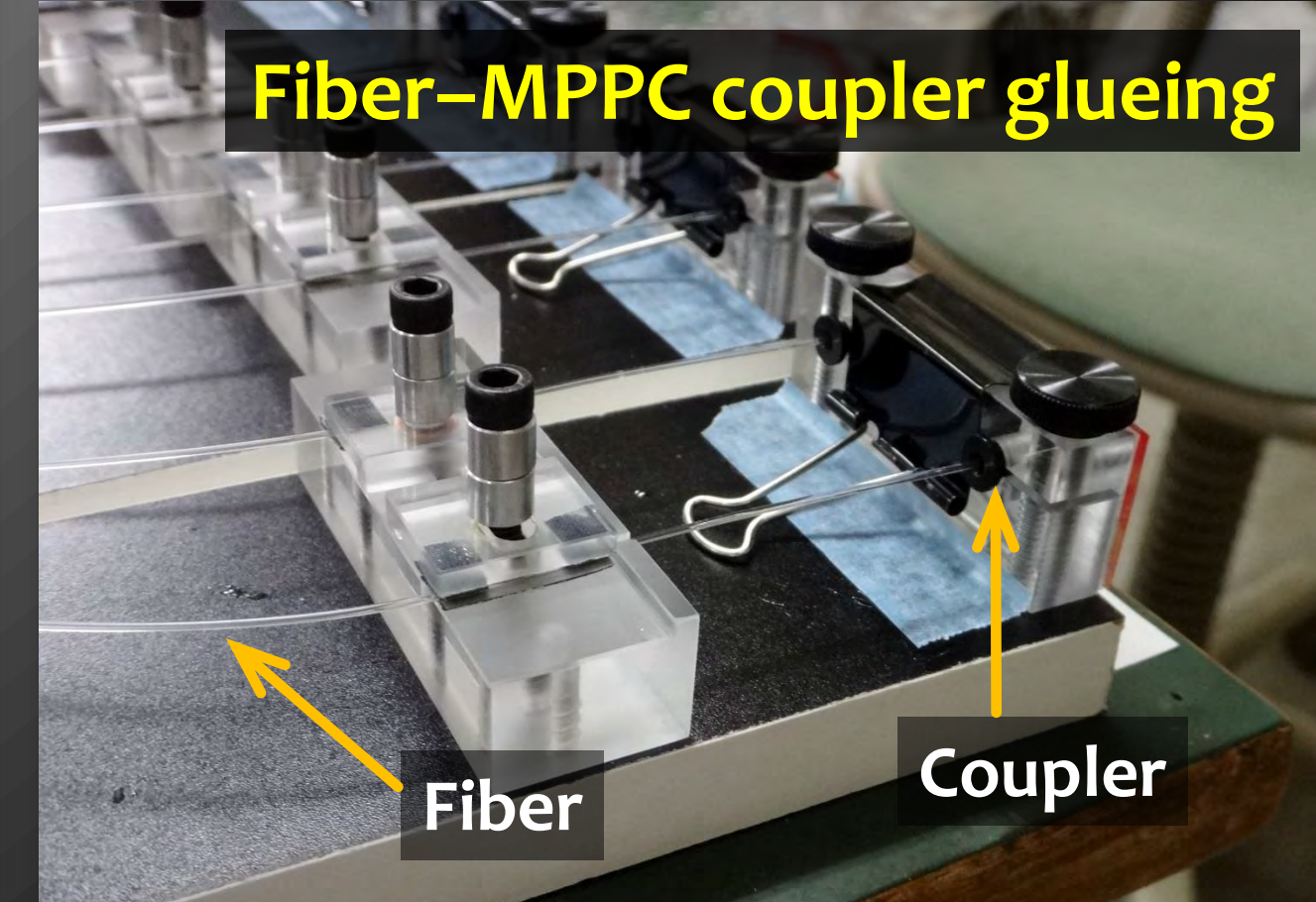


In April 2014

1. **Preparing a dummy target holder** to work on a table
 - Same diameter with an actual target holder (ϕ 79 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

