Target Design and R&D of J-PARC E06 TREK experiment

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J-PARC E06 TREK experiment

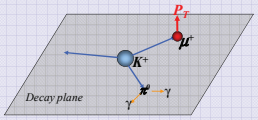
Time Reversal Experiment with Kaons

TREK is a experiment to measure the time reversal invariance precisely using $K^+ \to \pi^0 \mu^+ \nu$ decay.

Time reversal violation search by the P_T measurement

$K^+ \to \pi^0 \mu^+ \nu$ decay

$$P_T = \frac{\sigma_\mu \cdot (p_{e^+\gamma} \times p_{\mu^+})}{|(p_{e^+\gamma} \times p_{\mu^+})|}$$



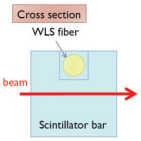
- P_T is T-odd, and spurious effects from final state interaction are small: P_T(FSI) < 10^{-5}
  Non-zero P_T is a signature of T violation.
- Standard Model (SM) contribution to P_T : P_T(SM) < 10^{-7}
  PT in the region 10^{-3}~10^{-4} is a sensitive probe of CP violation beyond the SM.
- There are theoretical models of new physics which allow a sizable P_T without conflicting with other experimental constraints.

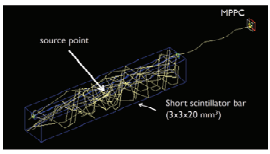
TREK experiment aims for a sensitivity of 10^{-4}

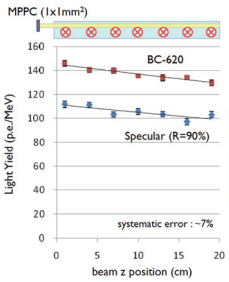
Optical simulation study based on Geant4

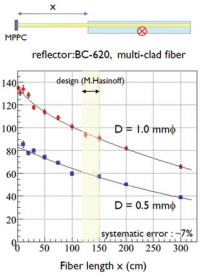
Incident μ^+ beam

- Ekine = 80 MeV (mean energy of muons from the $K_{\mu 3}$ decay)
- Position: center of the detector
- Direction: perpendicular to the fiber direction
- Energy deposit: typically 0.6 ~ 0.7 MeV









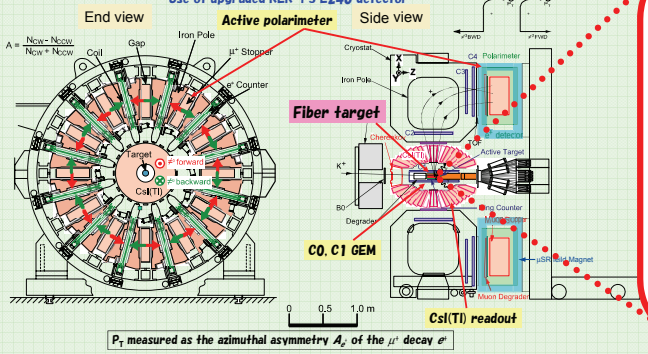
Results

- **Single-clad or multi-clad ?**
  - Light yield for multi-clad fiber is 35% better than single-clad.
- **Fiber diameter ?**
  - LY_{1mm} : $LY_{0.8mm}$: $LY_{0.5mm}$
    - 1 : 0.85 : 0.54 (for the specular reflector)
    - 1 : 0.90 : 0.65 (for the diffuse reflector)
    - The difference would be attributed to the better reflectivity of the diffuse reflector.
- **Z dependence of light yield**
  - at most 10 %
- **Attenuation length of the WLS fiber + MPPC readout**
  - ~ 400 cm

Active fiber target current baseline design

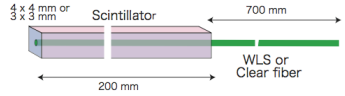
TREK detector

Use of upgraded KEK-PS E246 detector

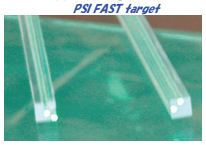


P_T measured as the azimuthal asymmetry A_ϕ of the μ^+ decay e^+

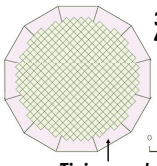
One element



c.f. E246 Ring counters
PSI FAST target



Cross section



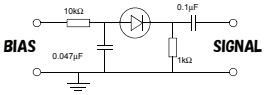
- **Light guide candidates :**
  - Bicron 692 WLS
  - Kuraray Y11 WLS
  - Clear optical fiber
- **Readout candidates :**
  - SiPMT (HPK MPPC) or
  - MA-PMT
- **Estimated hit in the photon sensor :**
  - ~10^7 particle/year/mm²

MPPC radiation hardness test in TRIUMF

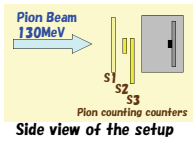
We expose MPPC to the pion beam to test the radiation hardness of MPPC.

MPPC dark box

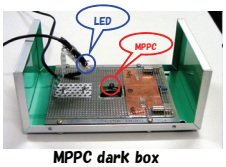
- MPPC : S10362-11-050C
  - 400pixel
  - Sample #813
  - Standard operation voltage : 69.74 V
  - Signals were amplified by the PMT amplifier.
    - PHILLIPS SCIENTIFIC Model 777
- Front read out circuit
- Blue LED
  - Using handmade LED pulser
    - under 10 nsec sharp light
- Thermo sensor



The exposure had done at TRIUMF meson hall M13 beam line.



Side view of the setup

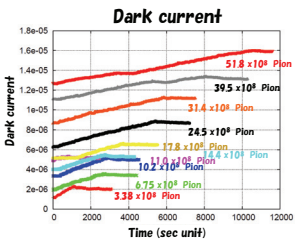


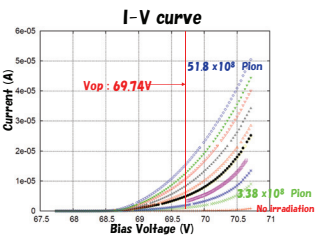
MPPC dark box

End view of the setup

Exposure table

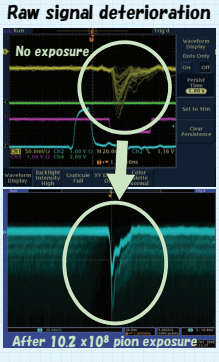
	Integral S2×S3 (×10⁸)	Accumulate Pion ×10⁸
1	126	1.70
2	125	3.38
3	250	6.75
4	259	10.2
5	53	11.0
Beam stop	-	
6	253	14.4
7	252	17.8
8	503	24.5
9	512	31.4
10	604	39.5
11	907	51.8



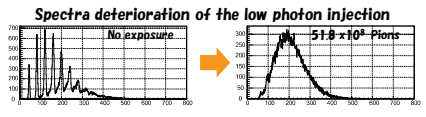


Radiation damage effects

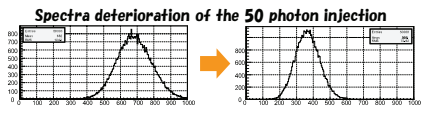
Raw signal deterioration



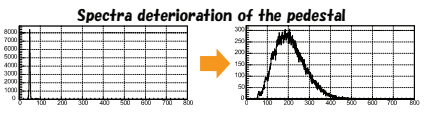
Spectra deterioration of the low photon injection



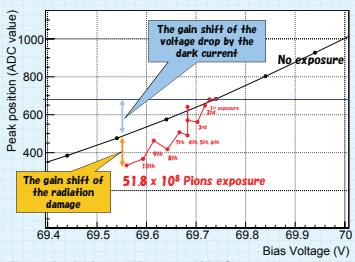
Spectra deterioration of the 50 photon injection



Spectra deterioration of the pedestal



The bias dependency of the peak of the spectrum at the 50 photon measurements



The actual bias voltage of MPPC was drop down by the dark current live in the readout circuit registers.

MPPC radiation hardness test Summary

- A 400 pixel MPPC sample was exposed 5.18x10⁹ 130 MeV/c pions (141 Gy).
  (The estimation of the number of mesons near the TREK target is 10^7 /year/mm²)
  - The figures show the deterioration of signals and spectra with increasing exposure.
- The peak of the 50 photons measurements shift to low direction.
  → 53% of the peak shift have roots in the voltage drop by the register of the noise filter.
  → 47% of the peak shift have roots in the radiation damage.
- Dark current measurements indicate the number of hot pixels increase with radiation damage.

→ MPPC can be used the readout of the TREK target.