# A new charged particle detector for KOTO experiment at J-PARC

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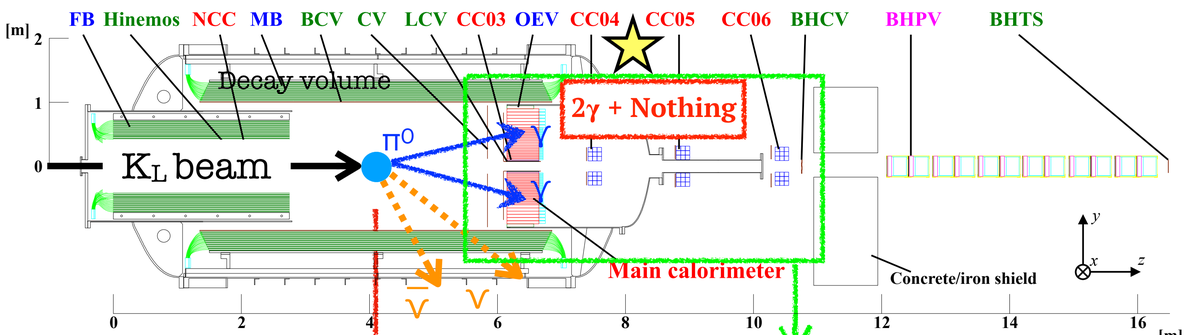
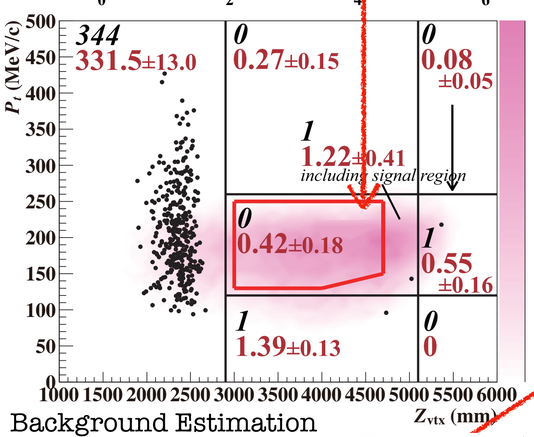
## 0. Motivation

- The KOTO Experiment at J-PARC is searching for the $K_L \to \pi^0\nu\bar{\nu}$ decay(Branching ratio : $3.0\times10^{-11}$ in Standard Model).




Background Estimation
(2015 data, S.E.S = $1.3\times10^{-9}$)

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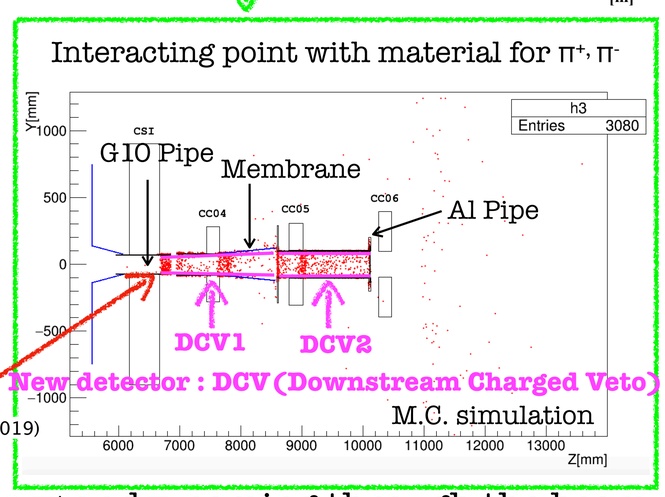
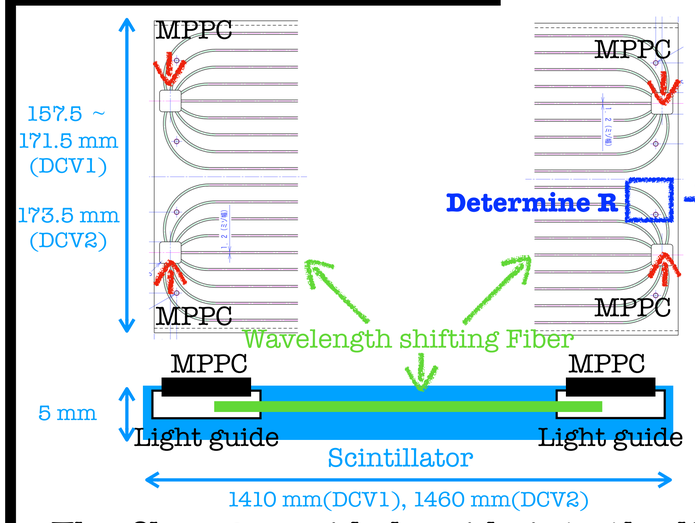
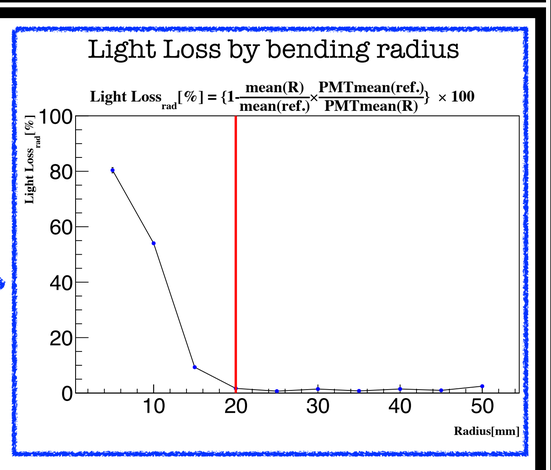



| source | | Number of events |
|---|---|---|
| $K_L$ decay | $K_L \to \pi^+\pi^-\pi^0$ | $0.05 \pm 0.02$ |
| | $K_L \to 2\pi^0$ | $0.02 \pm 0.02$ |
| | other $K_L$ decays | $0.03 \pm 0.01$ |
| neutron-induced | hadron-cluster | $0.24 \pm 0.17$ |
| | upstream-$\pi^0$ | $0.04 \pm 0.03$ |
| | CV-$\eta$ | $0.04 \pm 0.02$ |
| total | | $0.42 \pm 0.18$ |

- $\pi^+$ and $\pi^-$ coming through the beam pipe could interact with non-active materials such as G10 pipe, membrane and Al pipe.
- The number of $K_L \to \pi^+\pi^-\pi^0$ events can reached approximately 2 at SM sensitivity.
- Two new Downstream Charged Veto(DCV) counters (DCV1 and DCV2) were installed in the downstream beam pipe section.
- Due to very limited space, a new scheme of light collection has been implemented.

## 1. Scheme of DCV

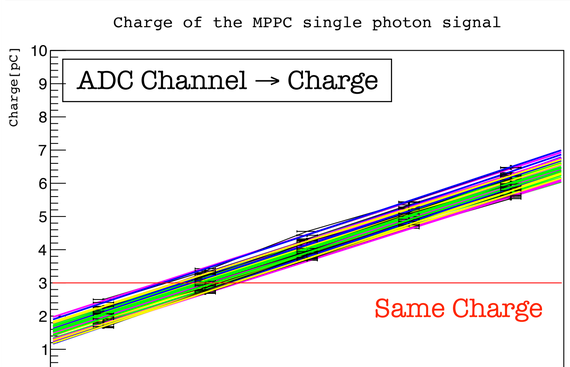


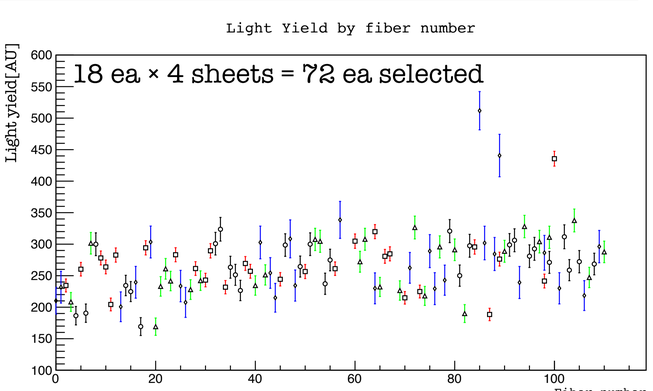




- The minimum radius of 20 mm was determined to bend the fiber.
- The fiber goes side by side into the light guide.
- MPPCs are attached to the surface of the scintillator.
- Two pipes(DCV1 and DCV2), total 8 sheets of scintillators.

## 2. Fabrication Process

### 1. MPPC Gain Measurement & Fiber Test

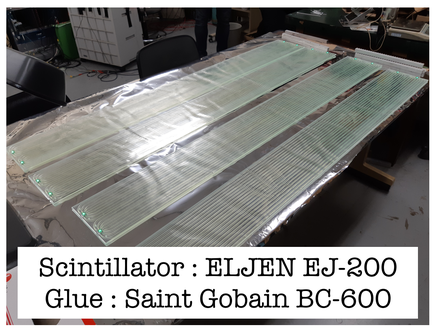



- We used the MPPCs from HAMAMATSU S13360-6050PE.
- MPPC were each connected by U.FL Cable(1.32$\phi$)
- Using 430 nm LED, we measured the MPPC single gain.
- MPPCs were grouped into four with the same operating voltage.
- We used the fiber from Kuraray Y-11(1 mm)
- LED light(430 nm) was injected from one side and the light yield was measured with MPPC from the other side.
- We chosen the fiber from the highest value of light yield.

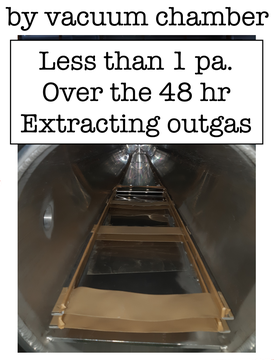
### 2. Making the scintillator pipe

Fiber gluing with optical cement



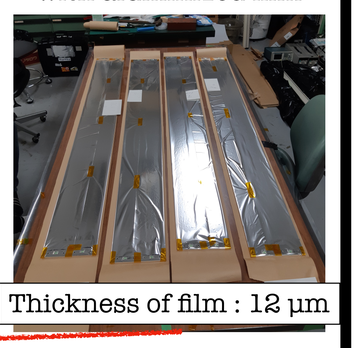
Scintillator : ELJEN EJ-200
Glue : Saint Gobain BC-600

Evacuation by vacuum chamber

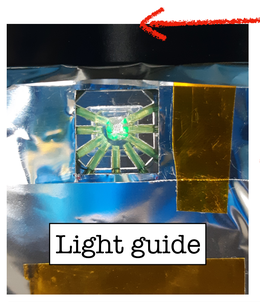


Less than 1 pa.
Over the 48 hr
Extracting outgas

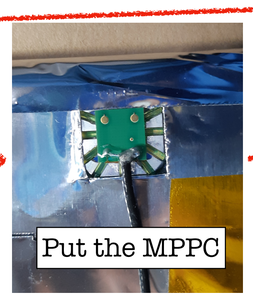
Wrapping with aluminized film



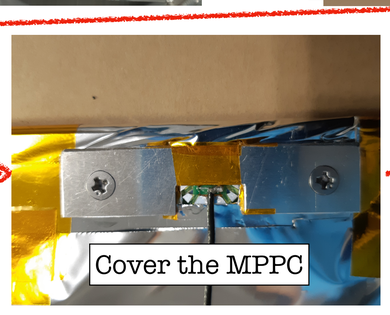
Thickness of film : 12 μm



Light guide



Put the MPPC

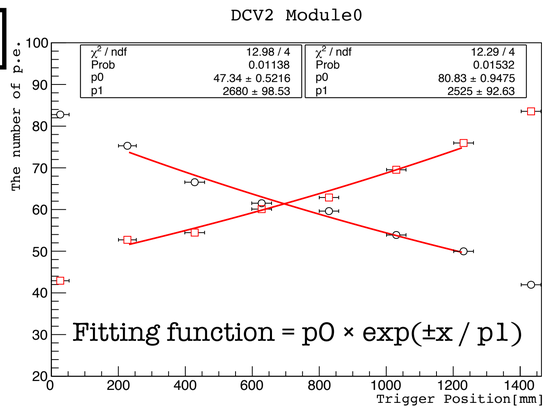


Cover the MPPC

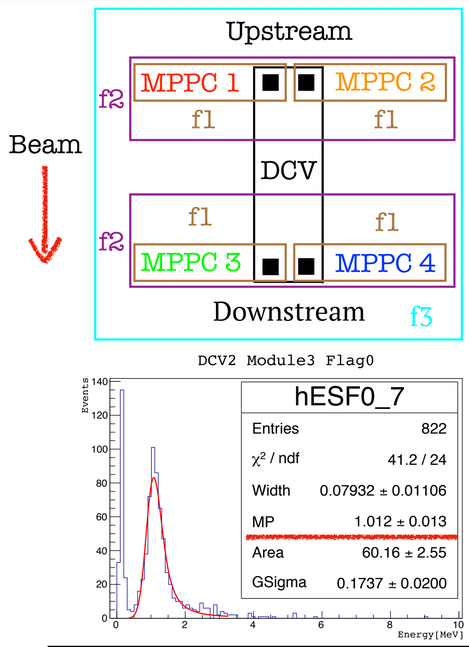
Making the pipes

### 3. Cosmic ray test

- We measured the P.E. using cosmic ray at 8 trigger positions.
- P.E. for 1 MeV at center point.
  60.15(DCV1), 58.62(DCV2)
- Attenuation length
  2469.12±165.09 mm(DCV1)
  2566.62±166.04 mm(DCV2)

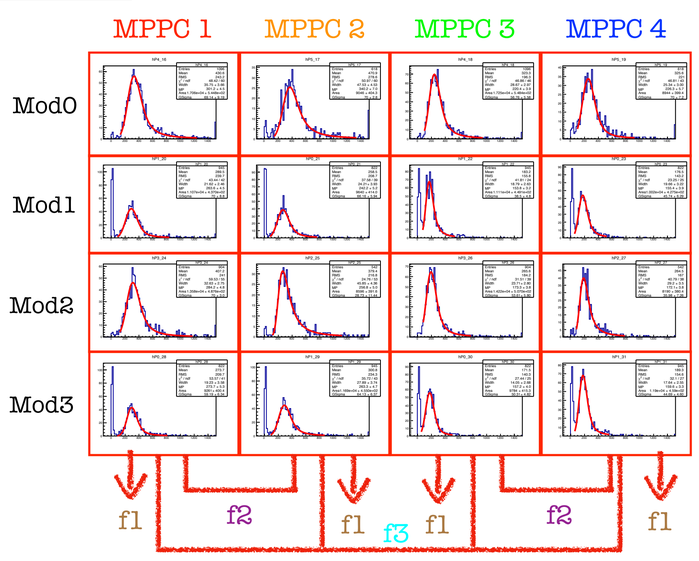



## 3. Beam Commissioning










Fitting function : Landau convoluted with Gaussian

Calibration factor = Attenuation factor / (f1 × f2 × f3 × Path length correction factor)

- CC04 and CC05(★ surrounding DCV) were used as trigger counter to calibrate with cosmic ray.
- Energy calibration was performed from the calculation of normalized factor for each MPPC to the sum of MPPC's energy.




- Analysis is underway to check the cause of the variation of the calibration factor and the stability of the DCV during the beam time.

## 4. Summary

- To reduce the $K_L \to \pi^+\pi^-\pi^0$ background, It is necessary to install a new scintillator detectors(DCV) inside the beam pipe.
- Due to limited space, a new type of light collection is adapted.
- The result of cosmic ray analysis showed DCV got about 60 p.e.
- DCV has been successfully installed at KOTO.
- The calibration of DCV was completed using the cosmic ray.
- Analysis for stability of DCV performance is ongoing.

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