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

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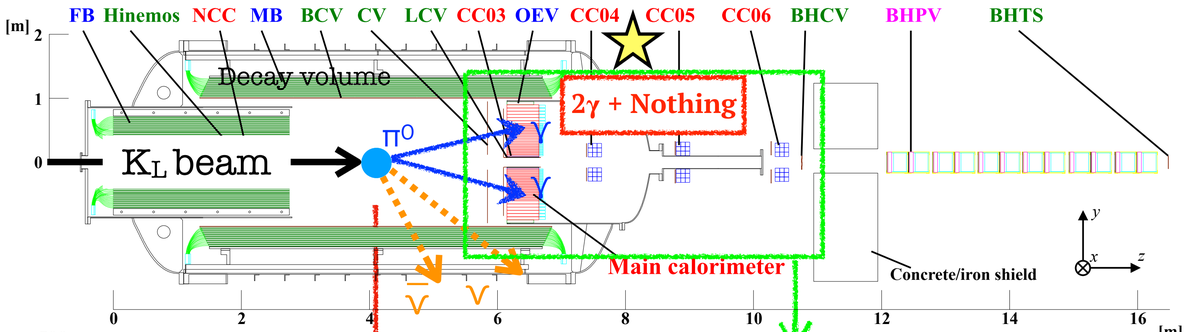
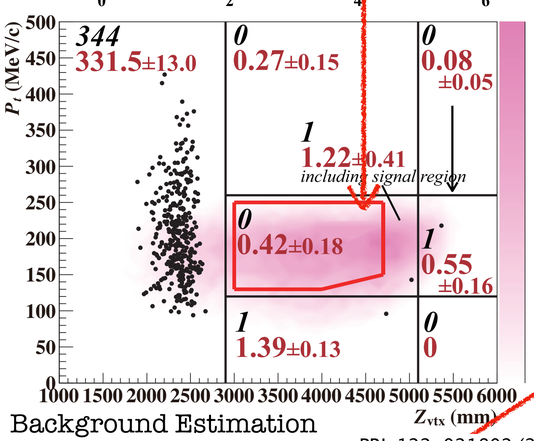
0. Motivation

- The KOTO Experiment at J-PARC is searching for the $K_L \to \pi^0\nu\bar{\nu}$ decay(Branching ratio : 3.0×10^{-11} in Standard Model).



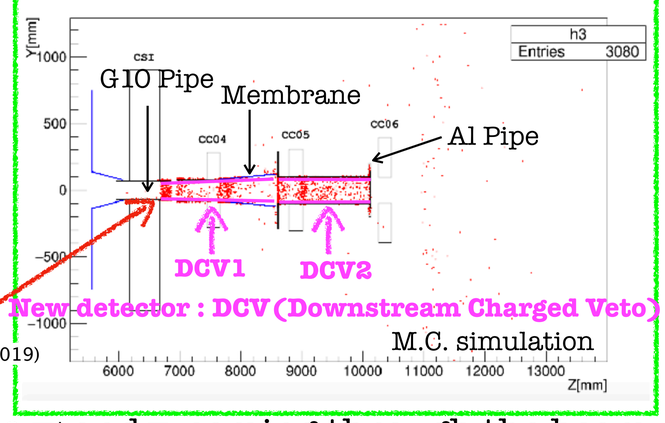


Background Estimation
(2015 data, S.E.S = 1.3×10^{-9})

PRL 122, 021802 (2019)

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

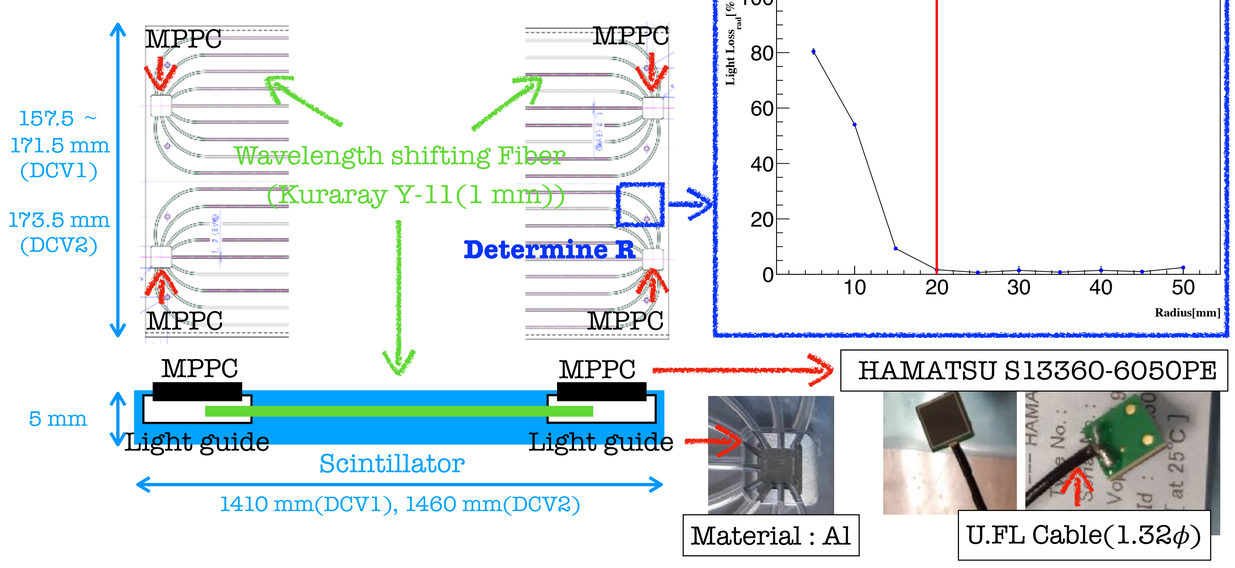
Interacting point with material for π^+, π^-



New detector : DCV (Downstream Charged Veto)
M.C. simulation

- π^+ and π^- 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 reach approximately 2 at SM sensitivity.
- Two new Downstream Charged Veto(DCV) counters (DCV1 and DCV2) were installed inside the vacuum beam pipe.
- Due to very limited space, a new scheme of light collection has been implemented.

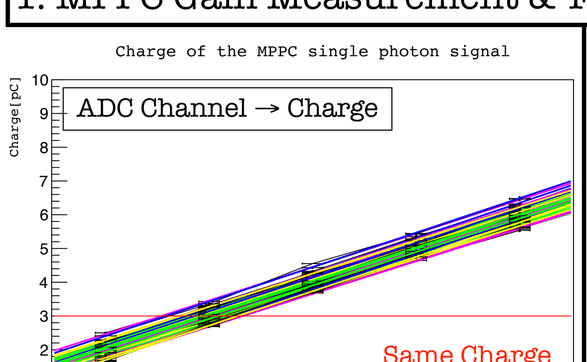
1. Scheme of DCV



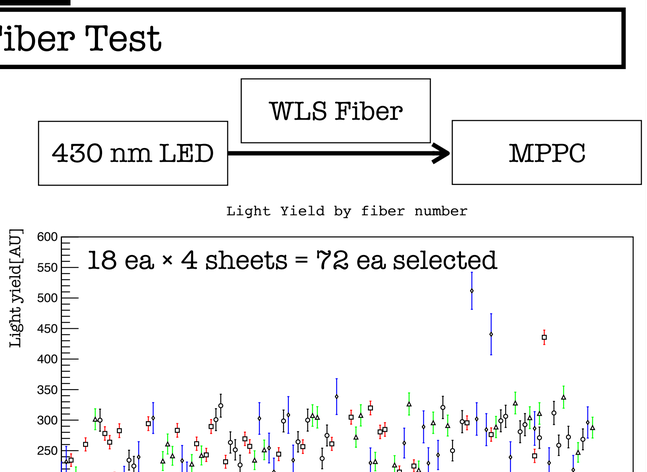
- The minimum radius of 20 mm was determined to bend the fiber.
- The fiber goes side by side into the light guide.
- MPPCs are attached to the surface of the scintillator.
- Two pipes(DCV1 and DCV2), total 8 sheets of scintillators.

2. Fabrication Process

1. MPPC Gain Measurement & Fiber Test



- MPPCs are grouped into four similar gain sets at a given operating voltage after measuring the single gain of MPPCs using 430 nm LED.



- We chose the fiber from the highest value of light yield.

2. Making the scintillator pipe

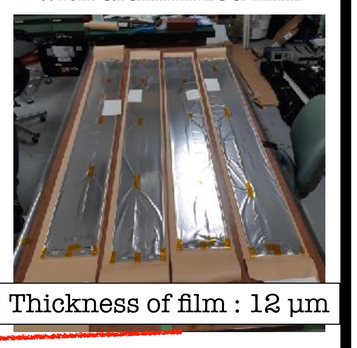
Fiber gluing with optical cement

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

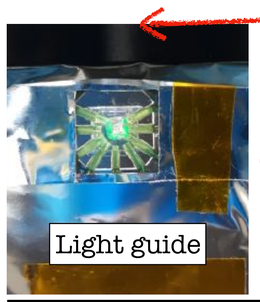
Evacuation by vacuum chamber

Less than 1 pa.
Over the 48 hr
Extracting outgas

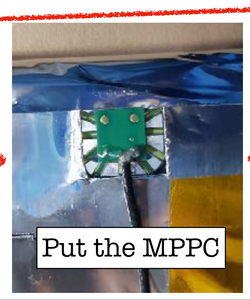
Wrapping with aluminized film



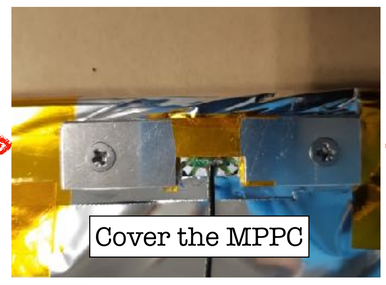
Thickness of film : 12 μm



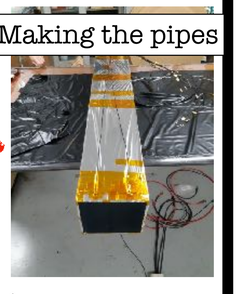
Light guide



Put the MPPC



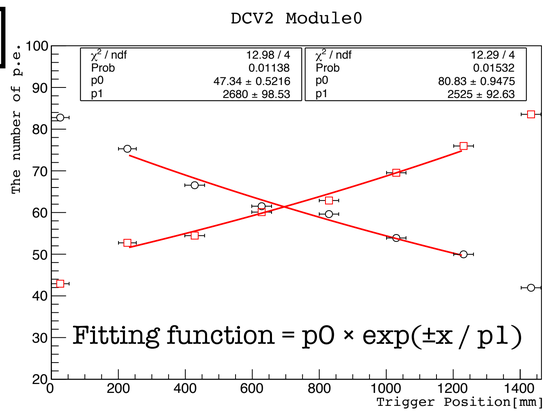
Cover the MPPC



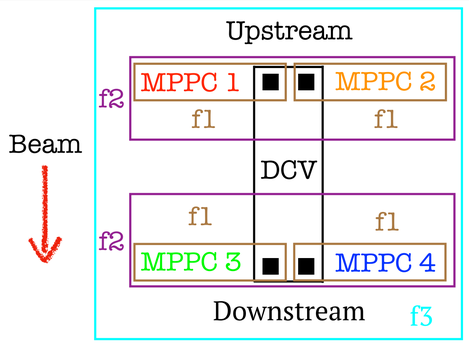
Making the pipes

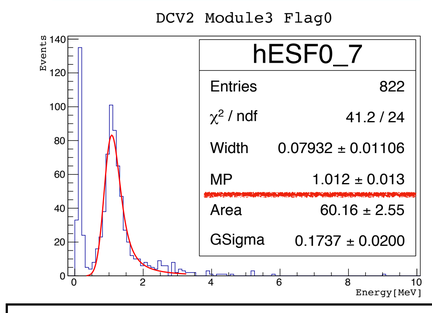
3. Cosmic ray test

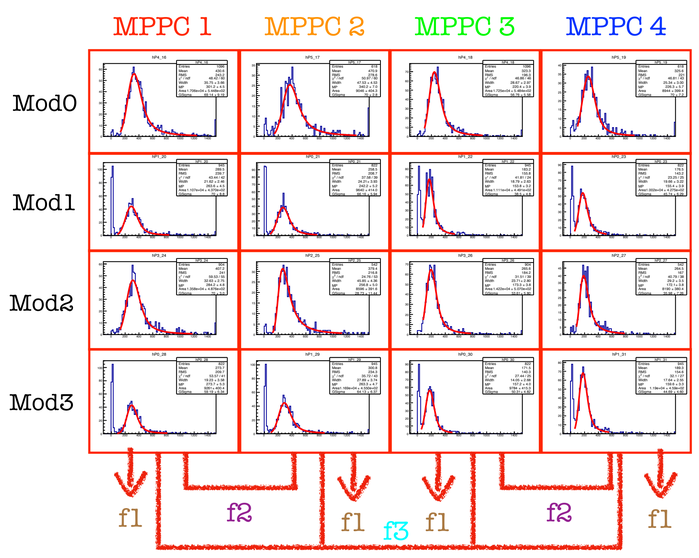
- We measured the number of photoelectrons(p.e.) using cosmic ray at 8 points.
- p.e. for 1 MeV at center point. 60.15(DCV1), 58.62(DCV2)
- Attenuation length 2469±165.1 mm(DCV1) 2566±166.0 mm(DCV2)



3. Energy Calibration







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.
- The energy response to cosmic ray of each DCV module was studied using normalized light yields for each four MPPCs, two pairs of MPPCs facing each other and all four MPPCs.

- 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.
- From the cosmic ray test, we got 60 p.e. at the center of DCV.
- Energy calibration was done with cosmic rays tagged by surrounding detectors.
- Stability of its performance during beam time is under study.

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