In-beam charged particle detector using 0.2-mm thick plastic scintillator for the J-PARC KOTO experiment

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On behalf of the KOTO experiment

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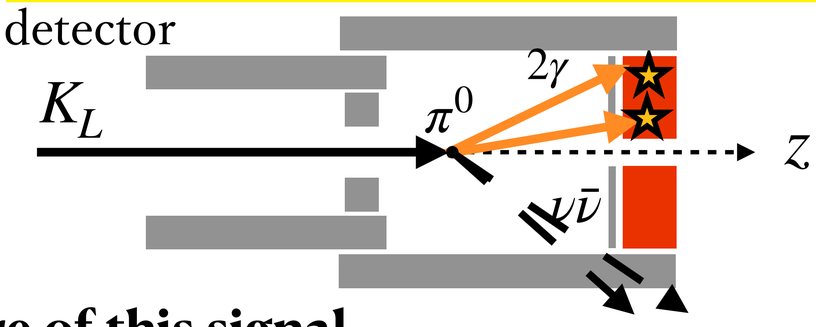
1. KOTO experiment

KOTO aims to search for $K_L \to \pi^0\nu\bar{\nu}$ decay at J-PARC

Direct CP-violating process
Rare : $\mathcal{B}_{\mathrm{SM}}(K_L \to \pi^0\nu\bar{\nu}) = 3 \times 10^{-11}$
Clean : Theoretical uncertainty ~ 2%

→ **Good probe to search for New Physics**

KOTO detector



Signature of this signal

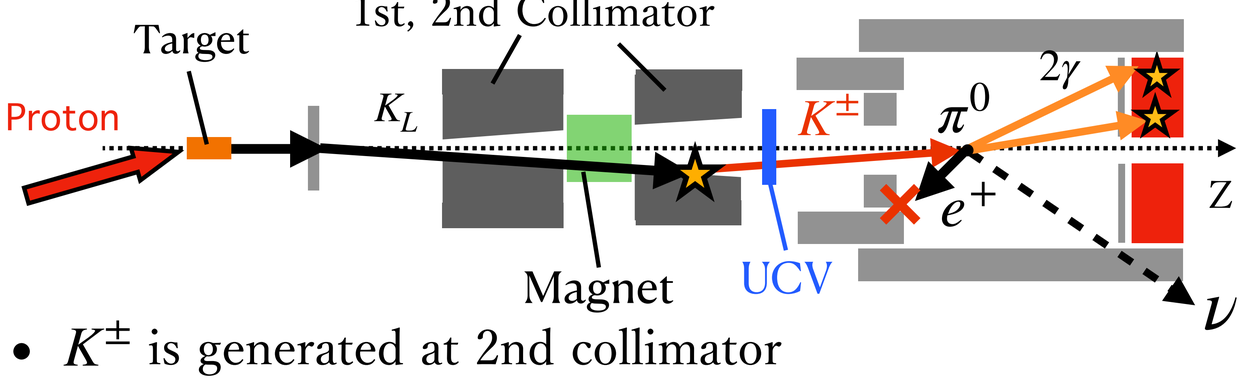
$(\pi^0 \to)\, 2\gamma$ in CsI calorimeter
+
Nothing in Veto detectors

- Latest result (KOTO2021): Best upper limit
  $\mathcal{B}_{\mathrm{KOTO2021}} < 2.1 \times 10^{-9}$ at 90% C.L.(Preliminary)
  See the slides by J. Redeker (18th July)

2. K+ background and reduction method

Rare decay search = Fight against background

- One of main backgrounds : $K^{\pm}$ decay
  $K^{\pm} \to \pi^0 e^{\pm} \nu$ $\quad \mathrm{Flux}_{K^{\pm}}/\mathrm{Flux}_{K_L} = \mathcal{O}(10^{-5})$

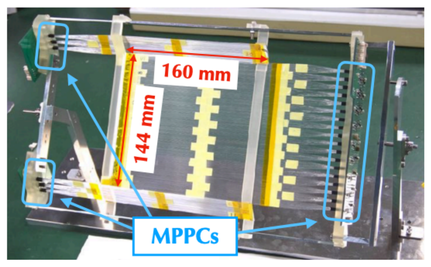
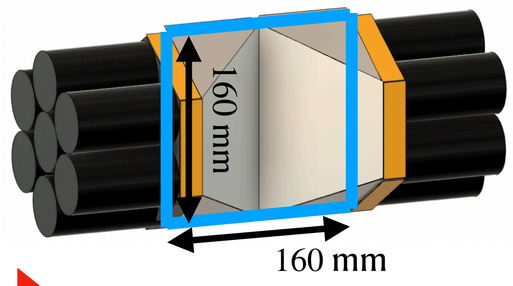


- $K^{\pm}$ is generated at 2nd collimator with charge exchange interaction
- It will mimic $K_L \to \pi^0\nu\bar{\nu}$ signal if $e^+$is not detected
- Installed a charged particle detector (Upstream Charged Veto (UCV)) in the beam

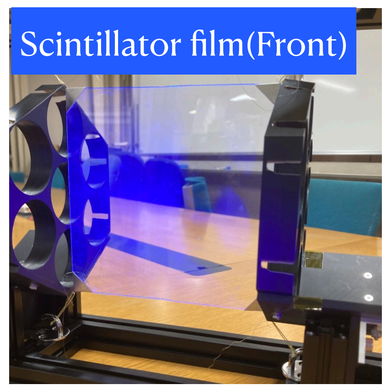
Suppress K+ background by directly detecting K+

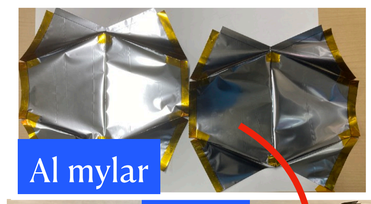
3. Upgrade of UCV

- Installed NewUCV in 2023

	UCV (2021)		NewUCV
			
Material	0.5 mmT scintillating fiber	Thinner	0.2 mmT scinti. film + 12 μmT Al mylar
Readout	MPPCs	More Radiation tolerant	PMTs
Inefficiency	7.8 %	More sensitive	< 1 %

- Photograph of NewUCV
  - Scintillator film was covered with Al mylar
  - Used 14PMTs





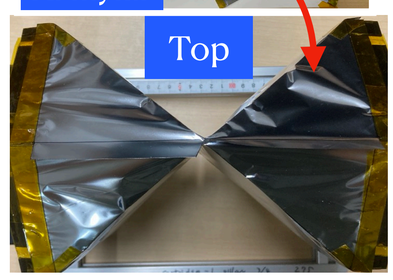
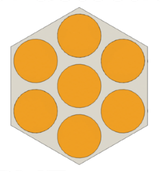
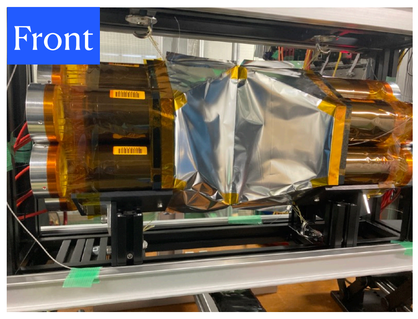


Image of detection area

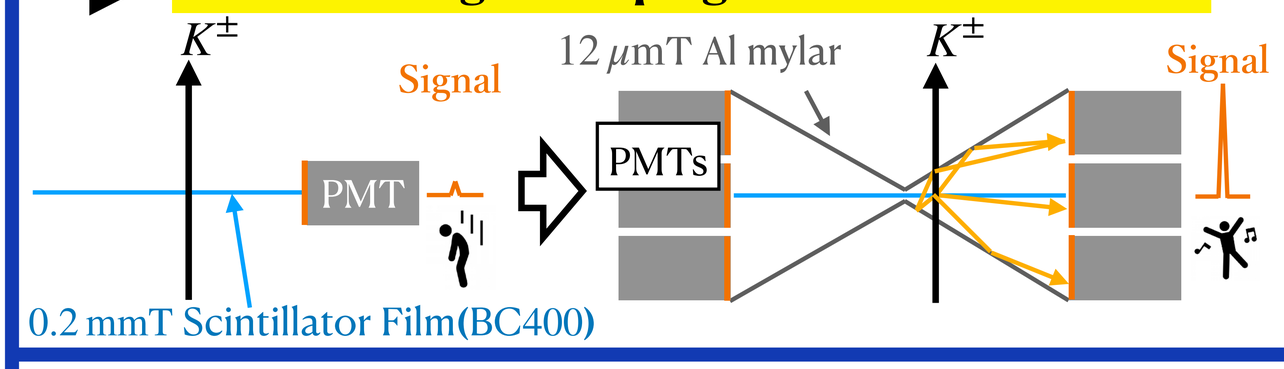


(7 PMTs per side)



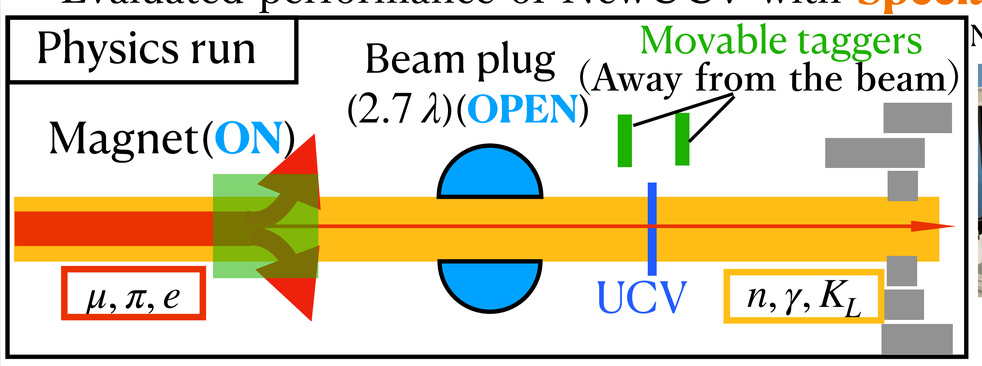
- Due to large attenuation of the light propagating inside 0.2-mmT scintillator, it's hard to get enough light yield

→ **Collect the light escaping from the scintillator**

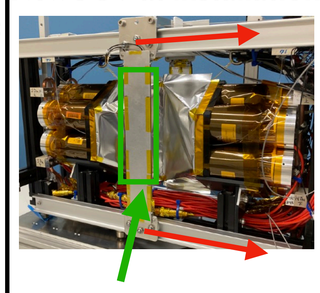


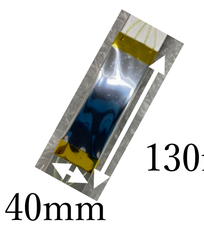
4. Performance evaluation

- Evaluated performance of NewUCV with **Special Data** in 2024



NewUCV at installation



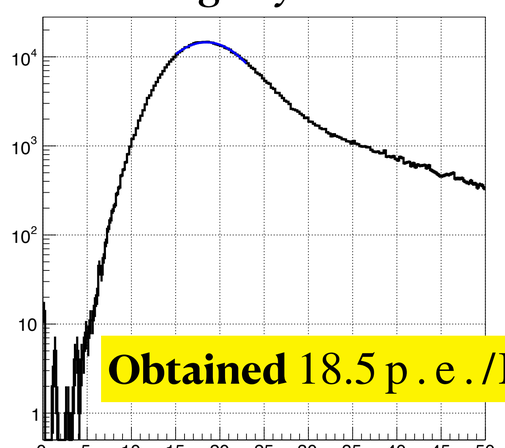


Movable taggers

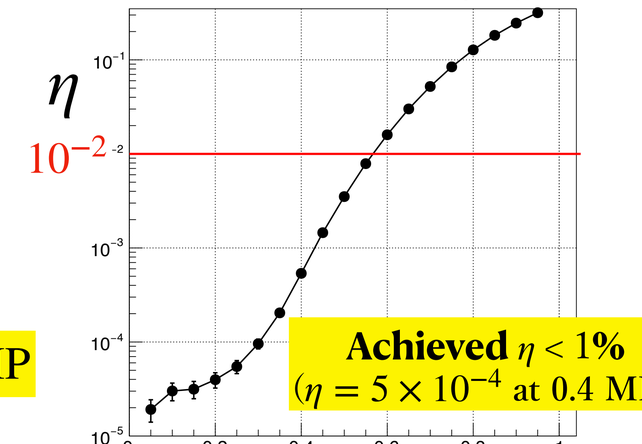
- Magnet OFF + Plug CLOSED -> **Enhance** μ, π, e
- Trigger : coincidence of taggers -> **Tag MIPs**

5. Result (2024 data)

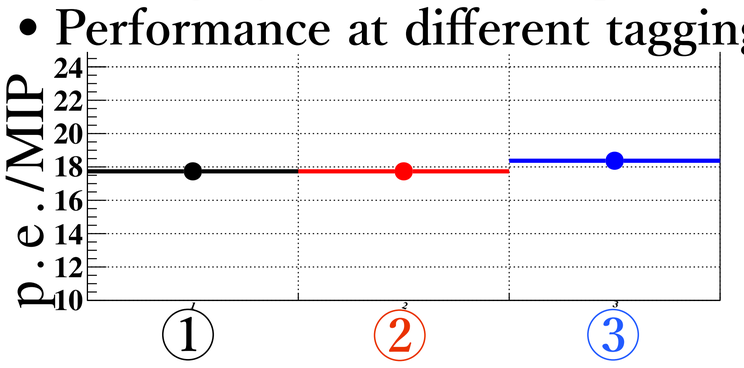
- Light yield

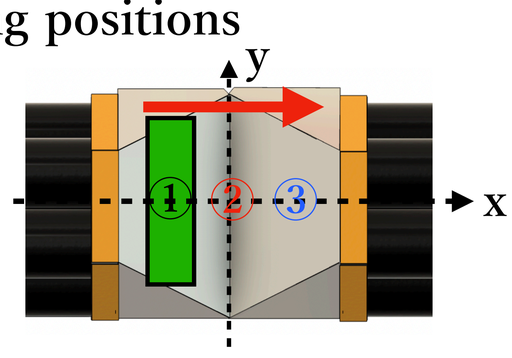


- Inefficiency η



- Performance at different tagging positions





→ **Confirmed the uniformity of performance**

6. Conclusion

- Installed new version of UCV in 2023
- Evaluated the performance using 2024 beam data
  -> Achieved 5×10^{-4} inefficiency (<<1%)
- Expect to eliminate K+ background