Development of a voltage supply circuit for PMTs used in the low mass charged particle detector for the KOTO experiment

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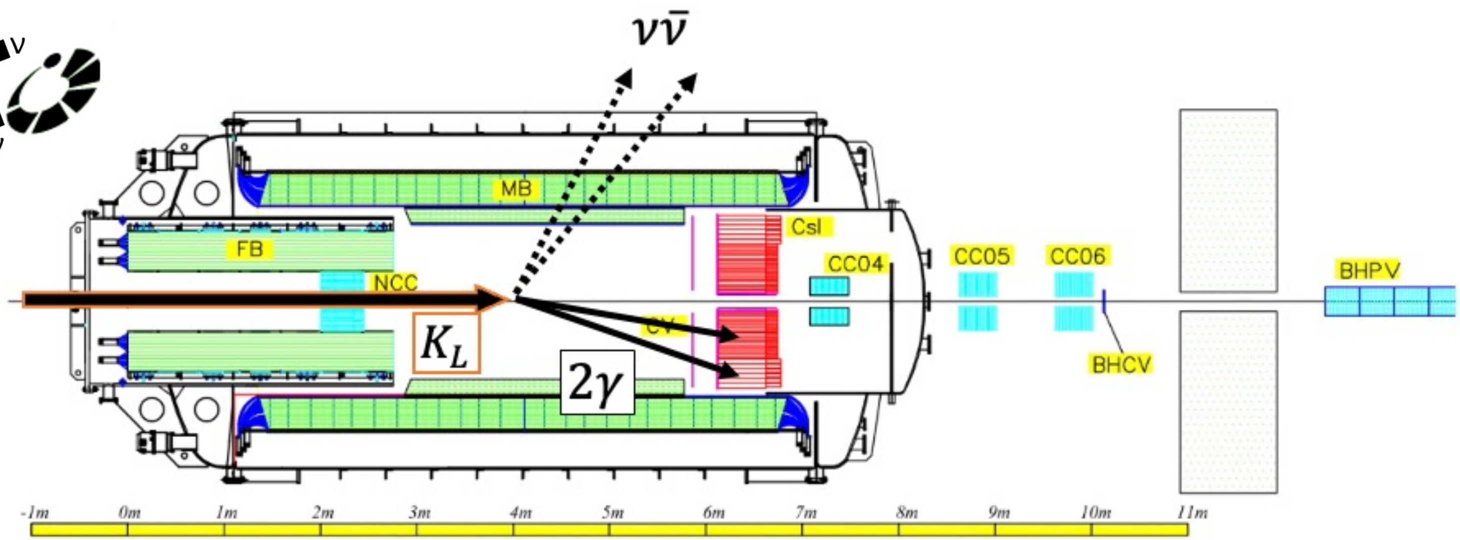
2022/12/22 Year-End meeting

KOTO experiment

- Search for ~~CP~~ rare decay $K_L \to \pi^0 \nu\bar{\nu}$ @J-PARC
  - >> Highly suppressed $\mathrm{Br(SM)} = 3.0\times10^{-11}$
  - >> Small theoretical uncertainty $\Delta\mathrm{Br}\sim2\%$
    - → Good probe for new physics!

- The signature of this decay is
  - >> $(\pi^0 \to 2\gamma)$ ⇒ CSI calorimeter
  - >> “Nothing” ⇒ No signal at the hermetic veto detectors

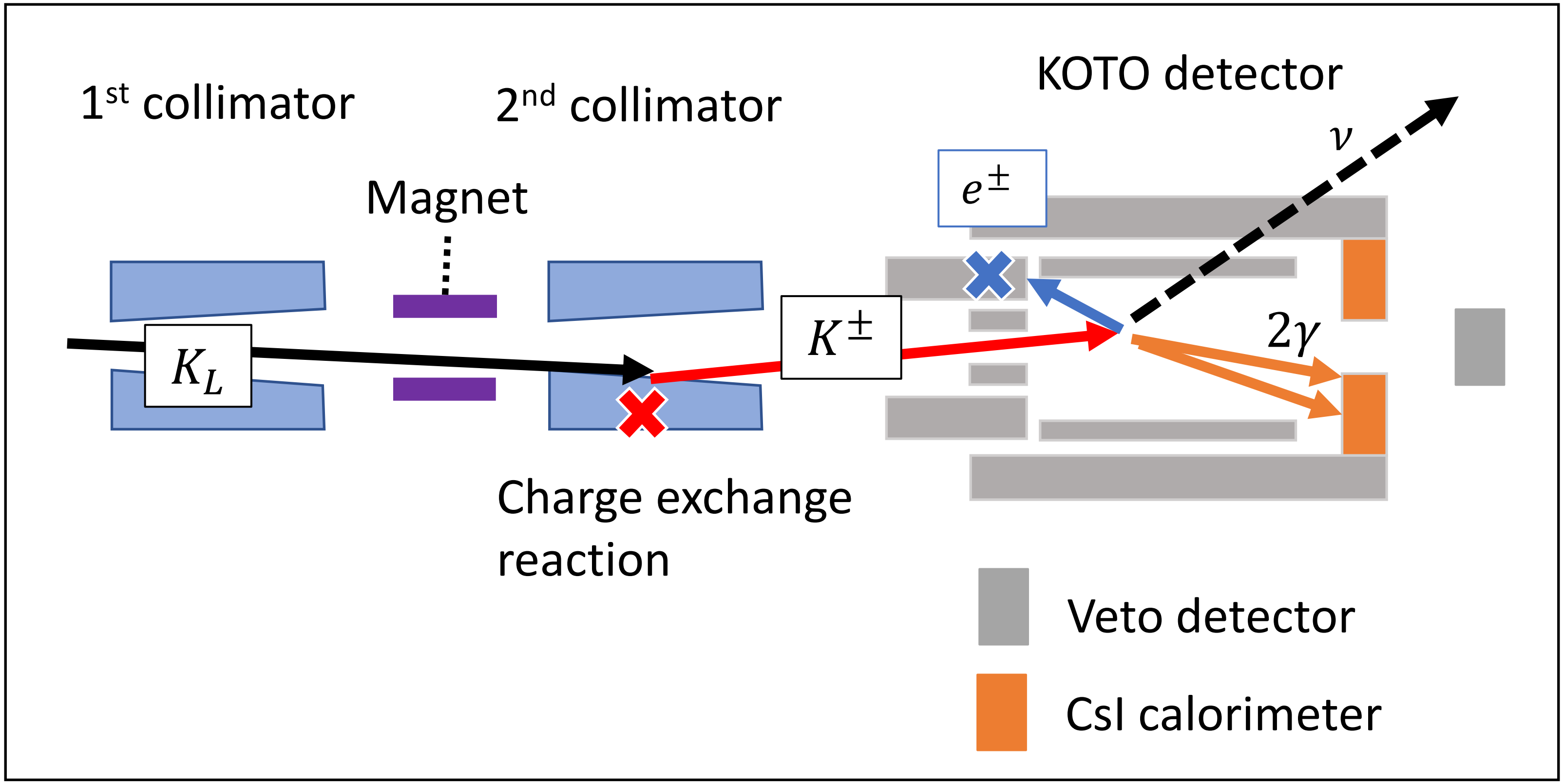


Charged K background

- Main background in the 2016-2018 data analysis

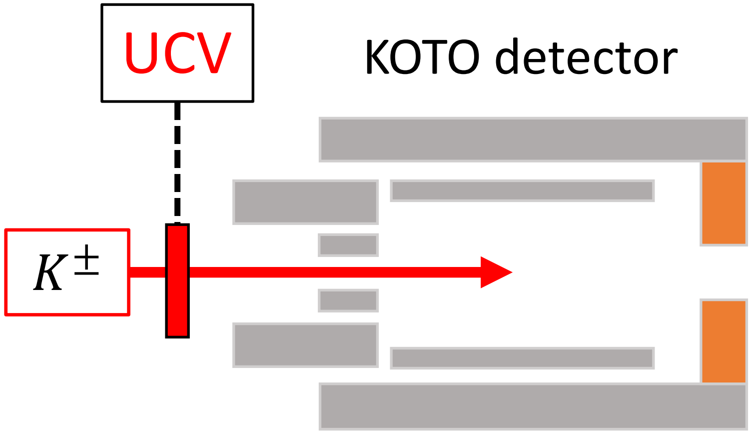
>> $K^{\pm} \rightarrow \pi^0 e^{\pm} \nu$

$\rightarrow e^{\pm}(missing) + 2\gamma$



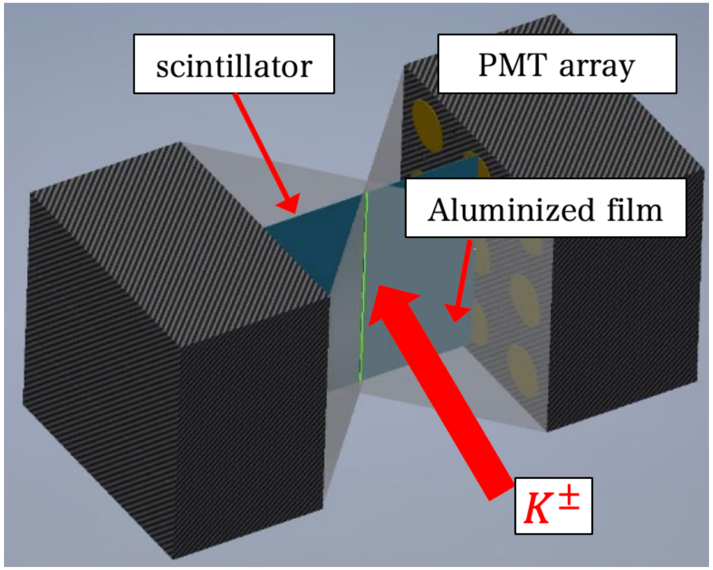
UCV

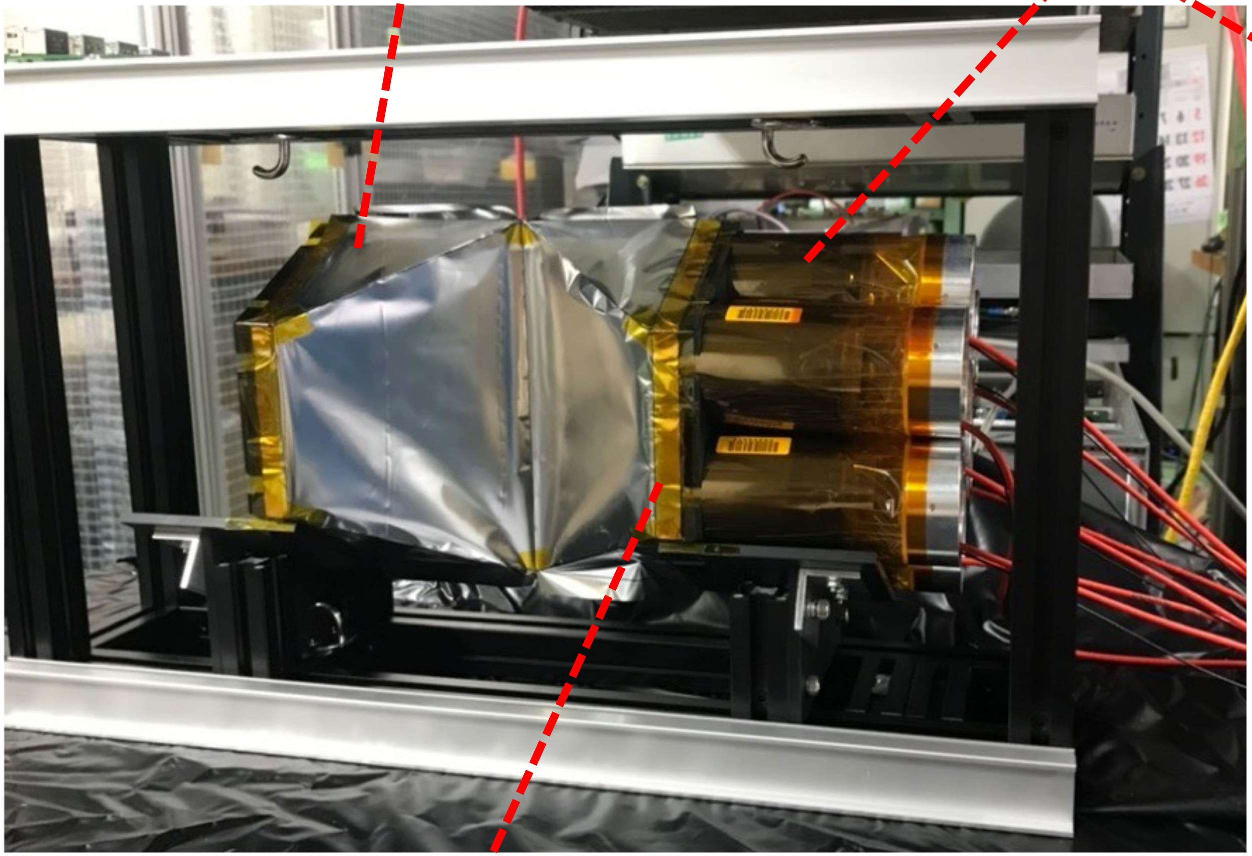
- Upstream Charged Veto counter
  - >> In-beam detector at the upstream of the KOTO detector
  - >> Veto charged particles
  - >> **Goal : 99% reduction**



- **UCV design**
  - >> Thin film scintillator
    - – 0.2mm thick
    - – 160 × 160mm^2
  - >> Collect escaped light with 12µm-thick aluminized mylar
  - >> Read out with PMTs

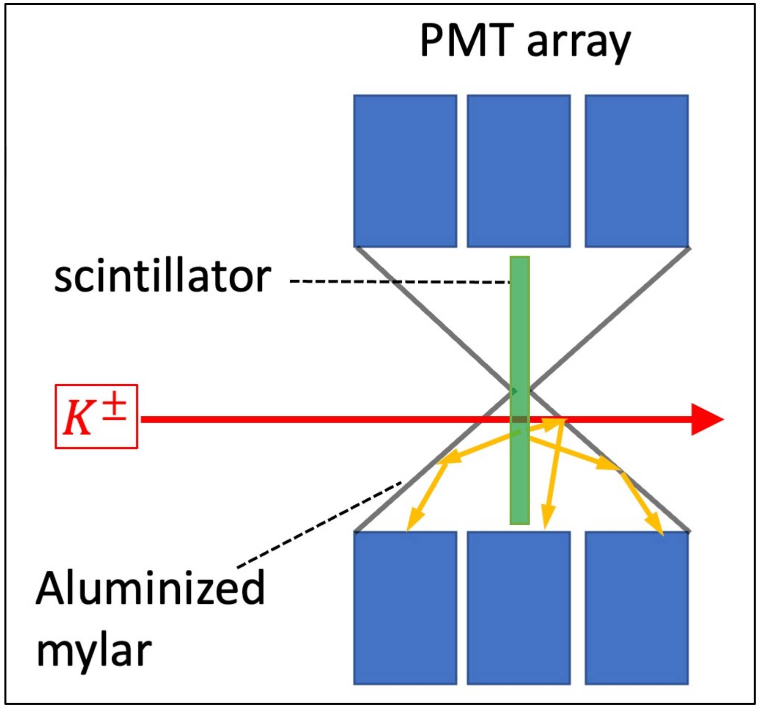
UCV design




Aluminized mylar
PMT
PMT holder

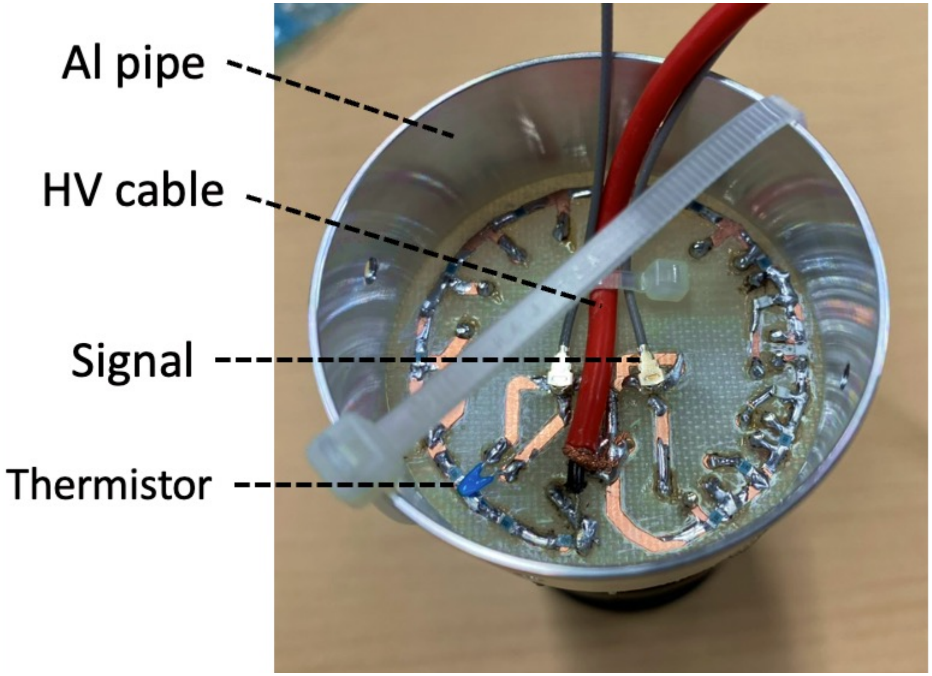

Requirements for PMT

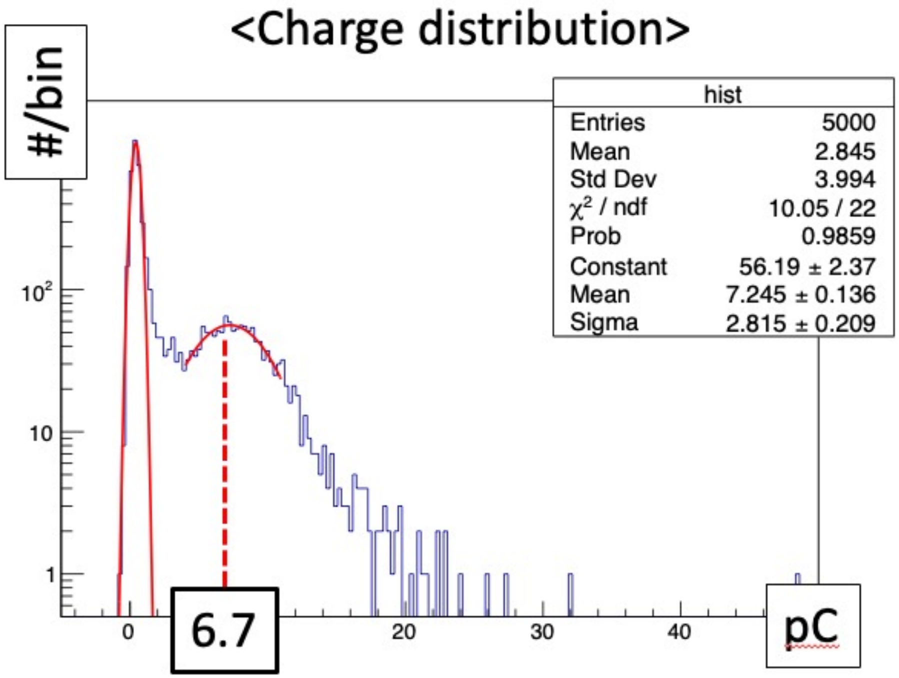
- Vacuum operation
- Readout ～20 p.e. / (1 Charged particle) by 14 PMTs
  >> Light uniformly enters each PMT
  >> Single p.e. counting
- High-rate tolerance
  >> 1 p.e. enters each PMT at **2MHz** in physics run



Base part of the PMT

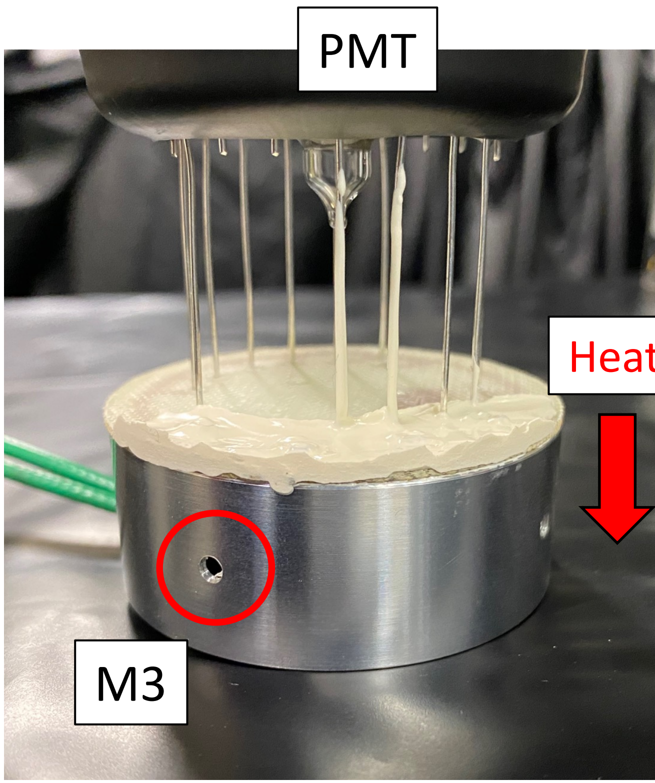
- Developed voltage divider circuit for PMT
- Read out signals with a thin coaxial cable (ϕ=1.1mm)
- Typical gain at 1.25kV : 2×10^7
- 1 p.e. peak is clear

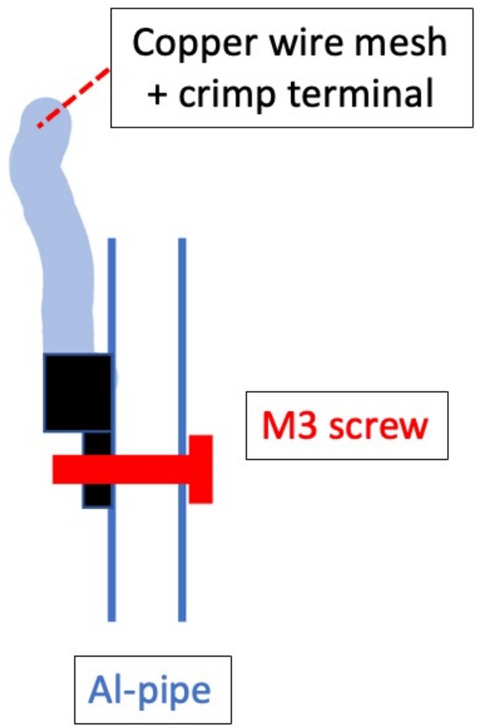


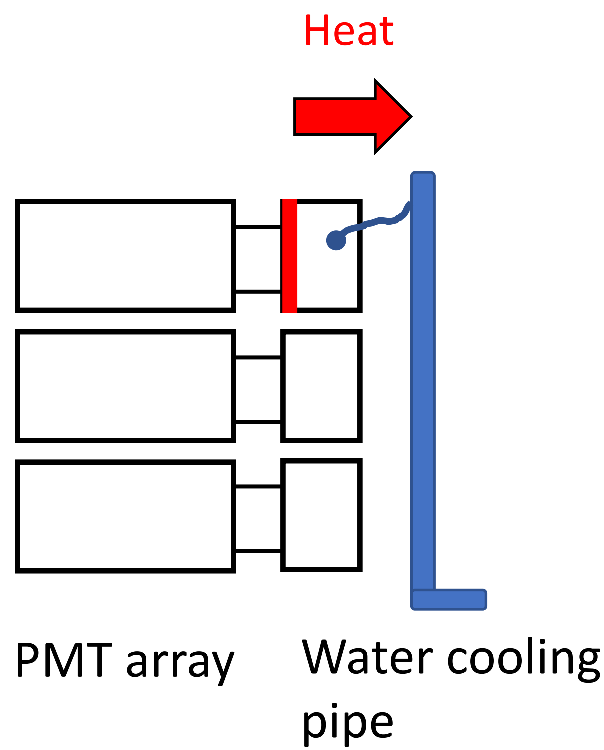


Cooling mechanism

- Heat consumption = 1.5W / PMT
- Dissipate heat by Al-pipe and ϕ1/4−inch cooling water Cu pipe
  >> Copper net wire between pipe and tube
- Monitor the temperature of each PMT base with thermistors

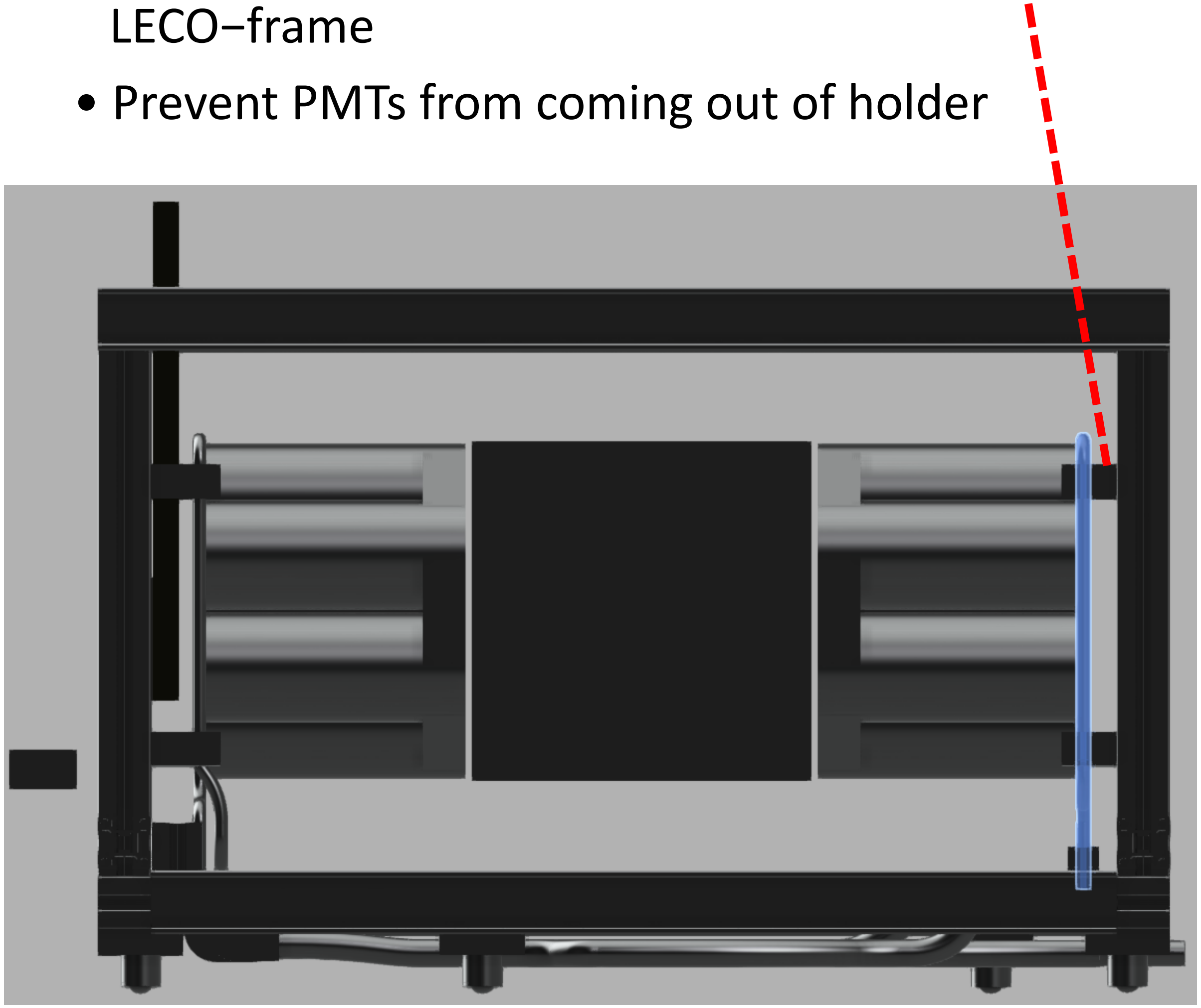


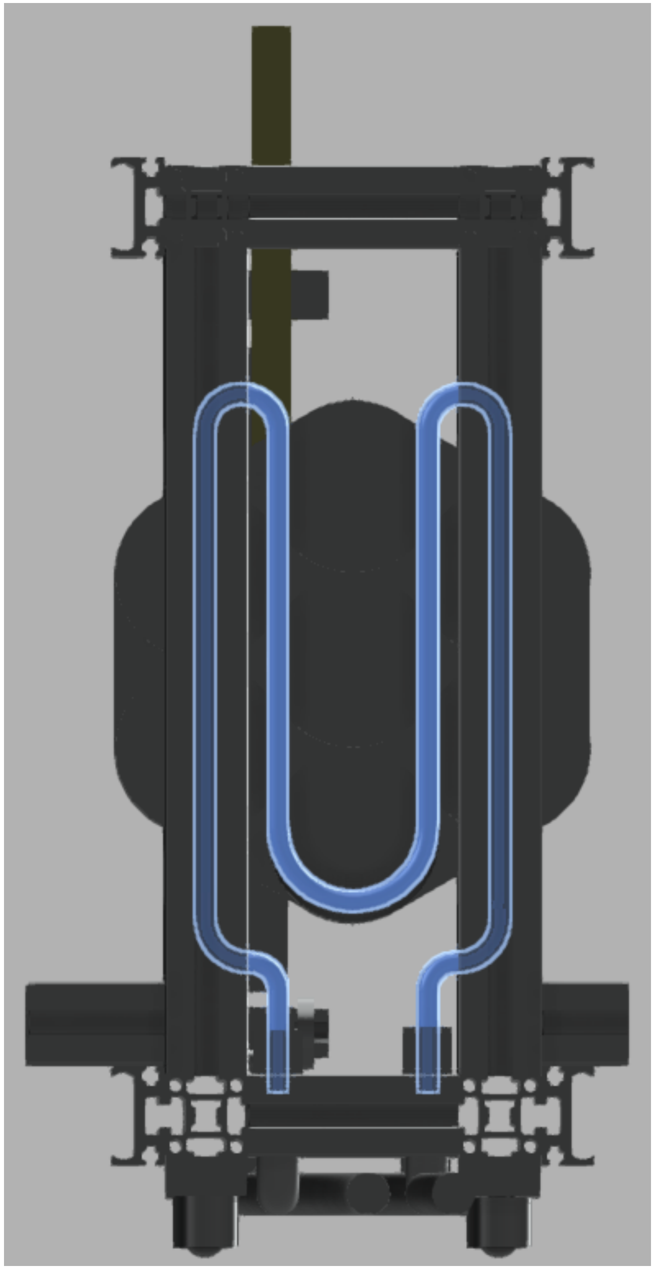




Water cooling pipe

- Cu pipe is held and thermally insulated from LECO−frame
- Prevent PMTs from coming out of holder





By Kotera

High-rate stability

- Gain needs to be stable during the physics run

  >> 2 MHz hit rate on average

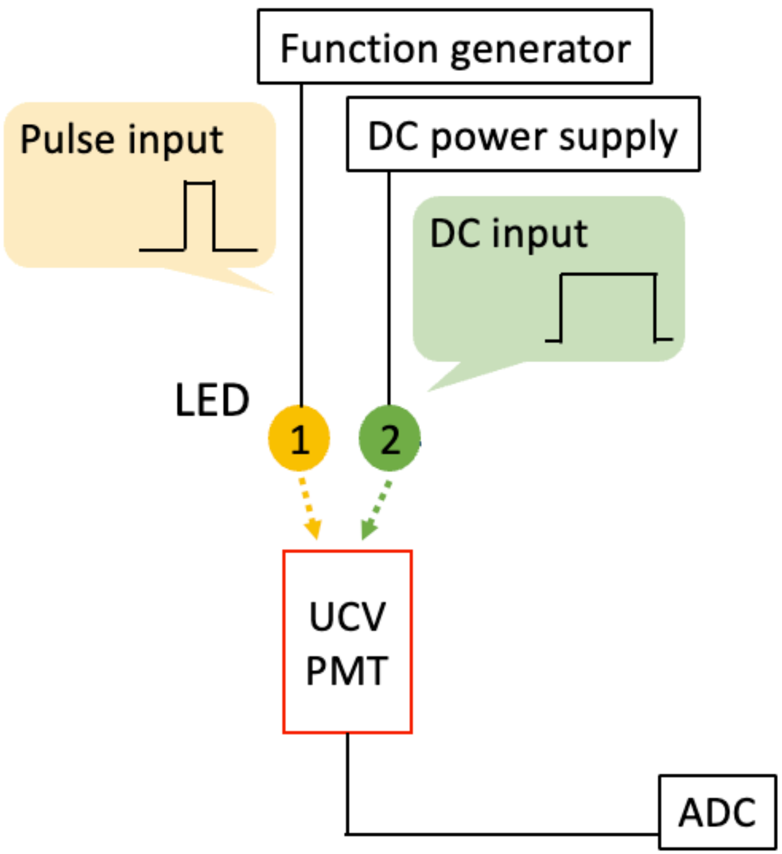
  >> Hit rate = 1 p.e. rate on each PMT

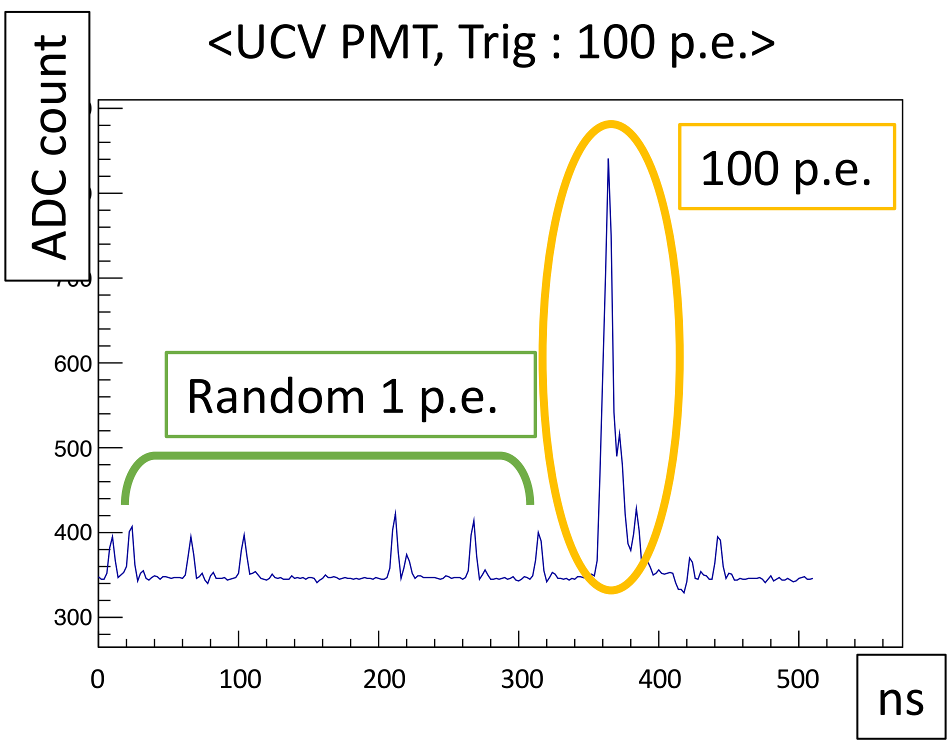
  >> Spike structure of the beam varies instantaneous rate

- Beam power will be upgraded from 64kW => 100kW (Rate will be × 1.6)

High-rate stability

- Use 2 LEDs
  - >> ① : Large pulse (～100 p.e.) to monitor gain change
  - >> ② : Random 1 p.e. signals
    - – Change 1 p.e. rate by changing DC input voltage





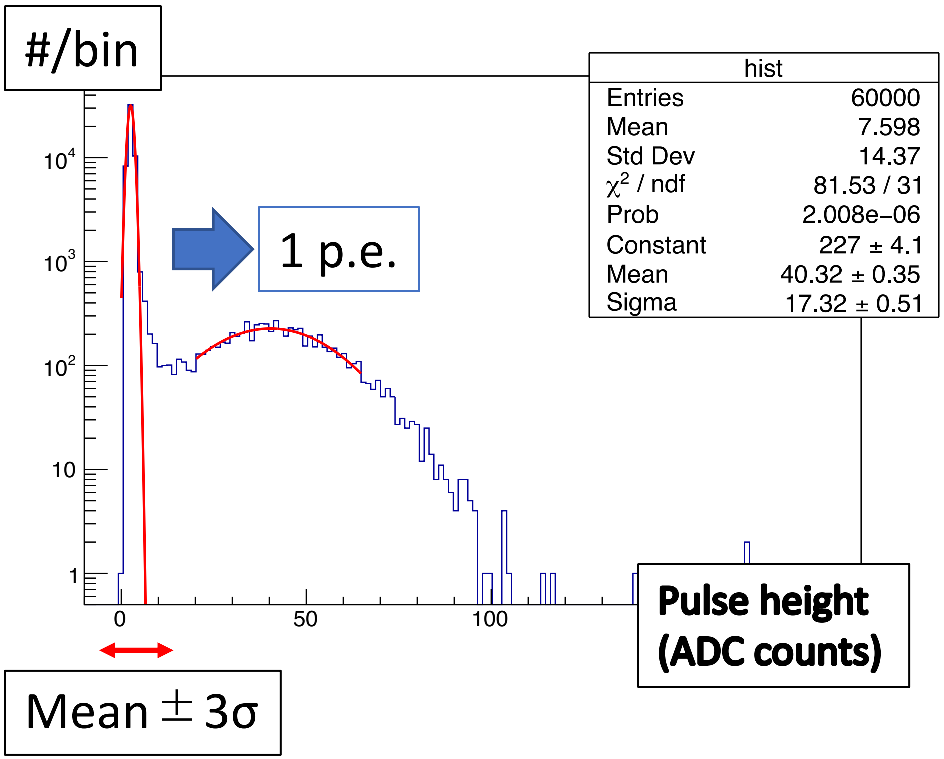
High-rate stability

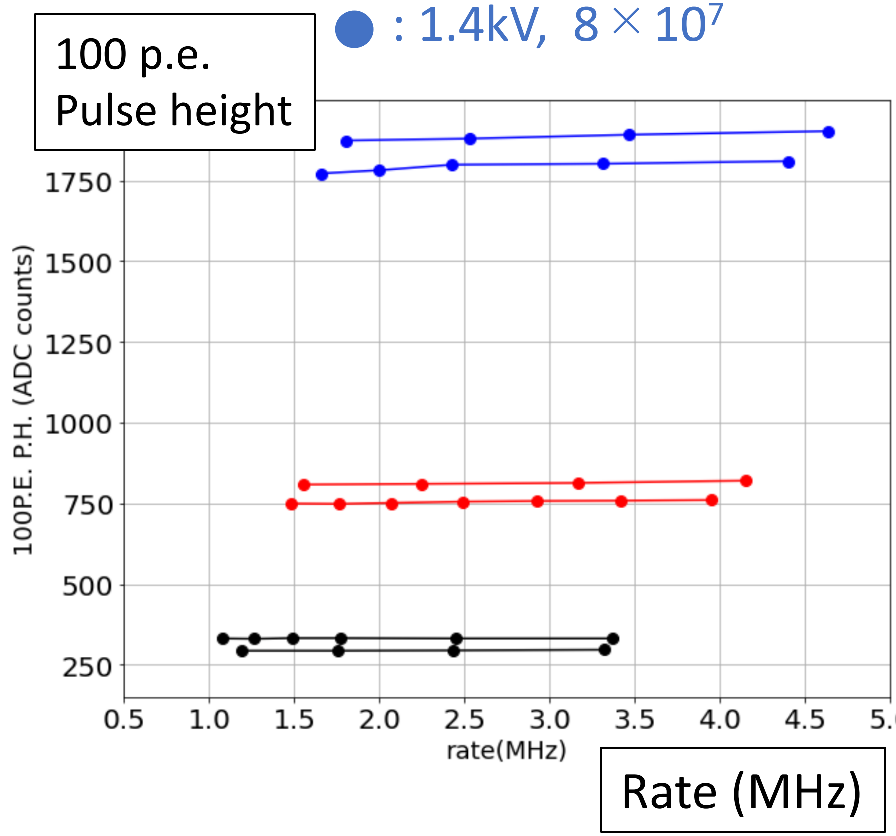
- Gain is stable within 1% below the rate of physics run
- Data taking time < 5min for each line

● : 1.1kV, Gain = 1.5×10^7

● : 1.25kV, 4×10^7

● : 1.4kV, 8×10^7





Summary

- UCV is an in-beam detector to veto upstream charged particles
- Readout signals with PMTs
- Developed PMT base part
  >> Works in vacuum
  >> Works in high-rate condition => Physics run is OK

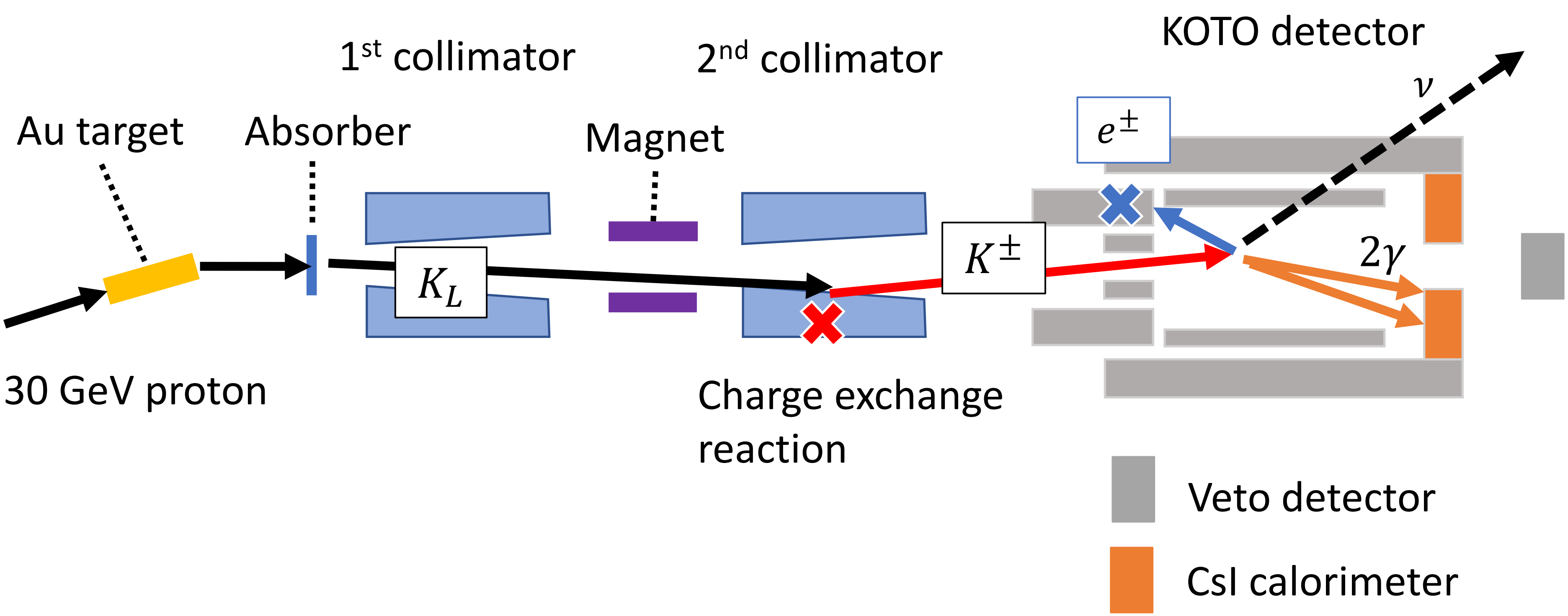
Backup slides

Charged K background

- Main background in the 2016-2018 data analysis

>> $K^{\pm} \to \pi^{0} e^{\pm} \nu$

$\to e^{\pm}(missing) + 2\gamma$



PMT to be used

- R14095

  >> Compact PMT ϕ52mm

  >> No assembly type

  >> Low noise, clear 1 p.e. signal

Hamamatsu Photonics
R14095-01