Development of gas wire chambers for in-beam charged particle detector in the KOTO experiment

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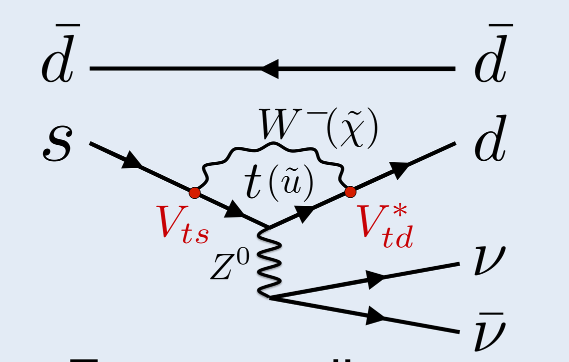
Introduction to the KOTO experiment

Goal of the KOTO experiment

= Discovery of $K_L \to \pi^0 \nu \bar{\nu}$

- direct CP-violating rare dicay
- loop-induced decay
  - ➡ BSM particles can contribute
- suppressed decay in the SM (2x10^{-11})
- small theoretical uncertainty (2%)

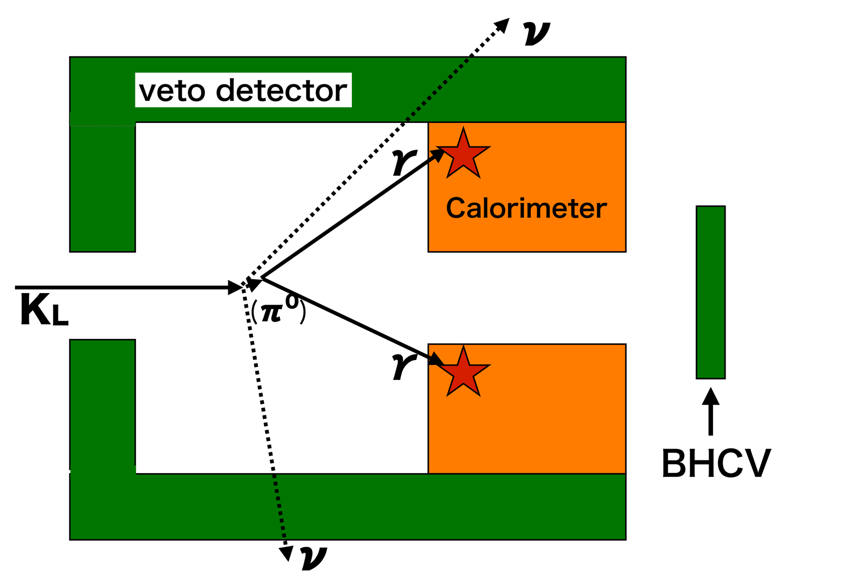
➡ Good Probe for New Physics !



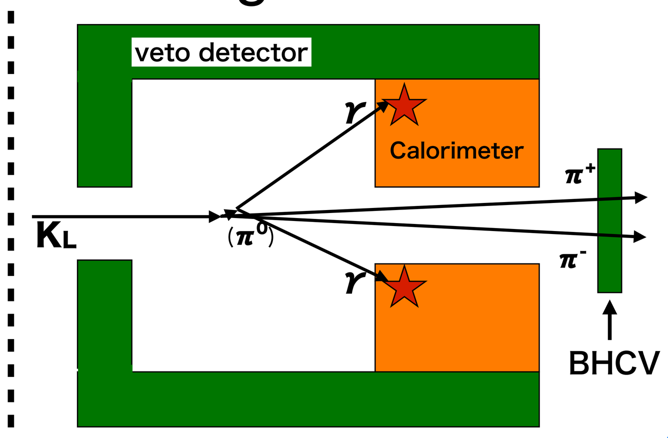
Feynman diagram

Principle of the experiment

$K_L \to \pi^0 \nu \bar{\nu}$ = 2γ (Calorimeter) + nothing (hermetic veto)



back ground event



Beam Hole Charged Veto(BHCV)

BHCV is ...

- in-beam charged particle veto counter (efficiency > 99.5% is required)
  - ➡ cover downstream in-beam area
- exposed to a high flux of photons and neutrons (0.6GHz/20x20cm² @300kW)
  - ➡ generate accidental veto signals → high counting rate

- BHCV in 2013(old BHCV): 3-mm-thick plastic scintillator + PMT
  - ➡ a significant acceptance loss is expected for the planned increase of the beam intensity

➡ upgrade of BHCV is required !

Design of new BHCV

use thin gap chamber
- → low mass
- → high rate tolerance

Feature 1: thin cathode film

low mass ➡ reduce photon/neutron hits

use graphite-coated polyimide film as a cathode plane

Feature 2: fast gas

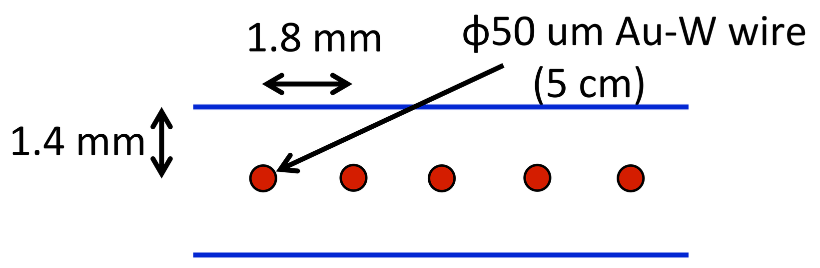
short e⁻ drift time ➡ short time jitter

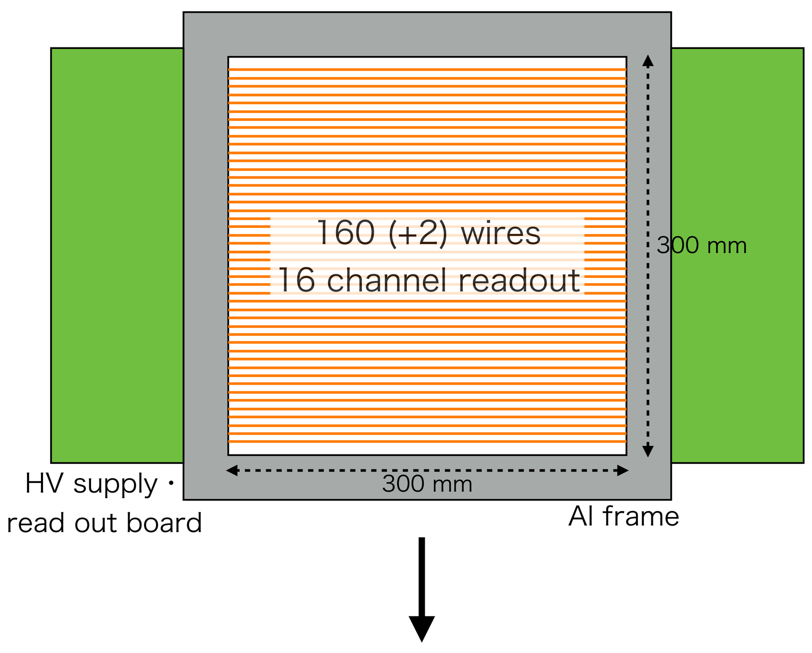
➡ veto time window can be shortened

➡ the probability of detecting an accidental veto signal is reduced

➡ acceptance loss is reduced

➡ CF_4 + n-Pentane gas mixture (n-Pentane: quench gas)

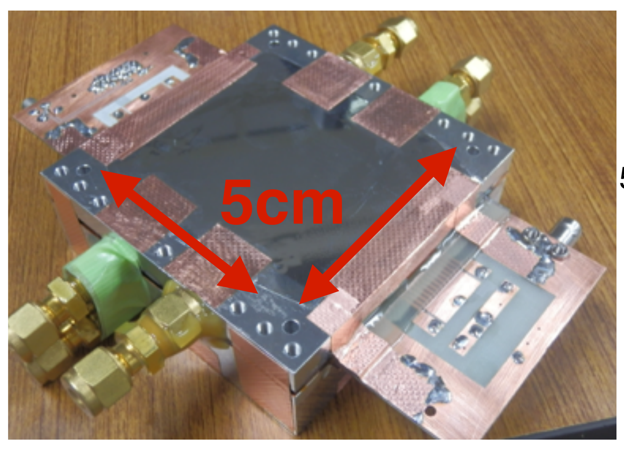


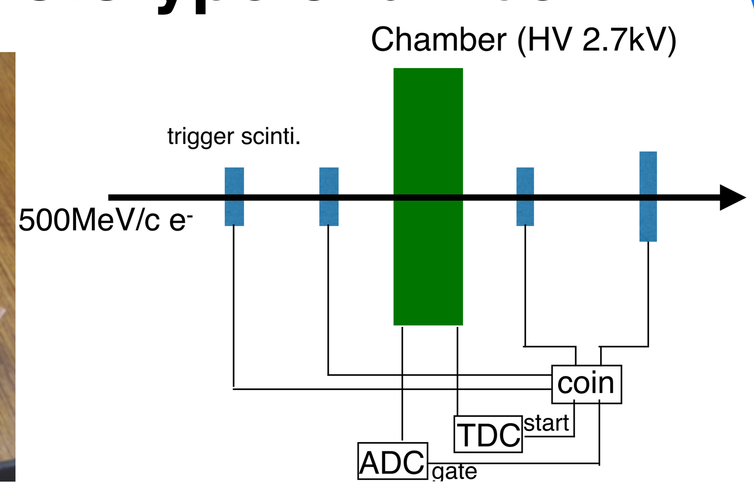


install 3 modules in line along beam axis
➡ 2-out-of-3 logic

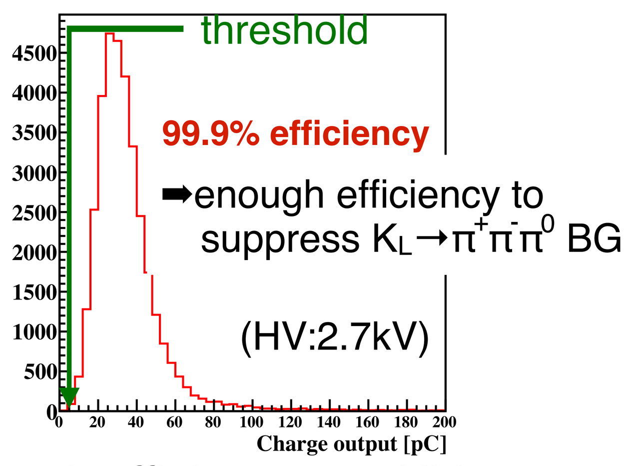
- Efficiency(ε=1-η) becomes better ($\eta_{tot} = 3\eta^3 + 3\eta^2(1-\eta) < \eta$)
- time jitter becomes short by defining detect time as the fastest hit time in 3 modules

beam test for a prototype chamber

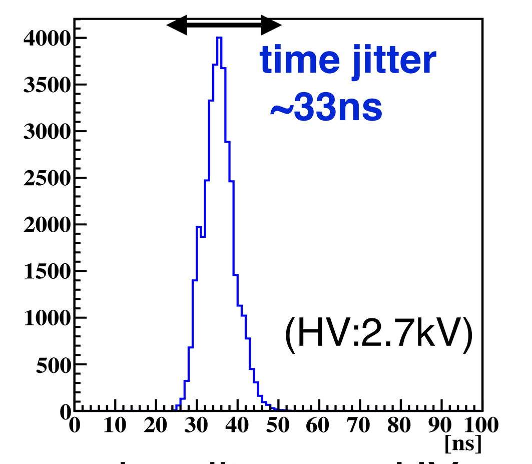




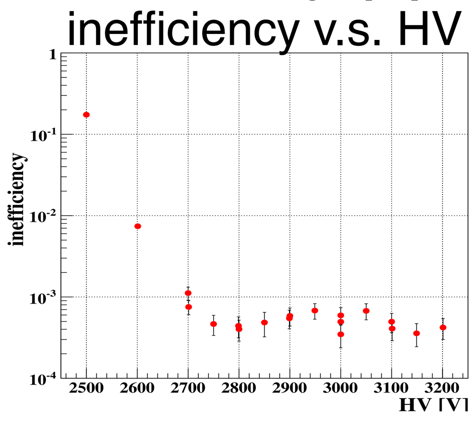
ADC distribution



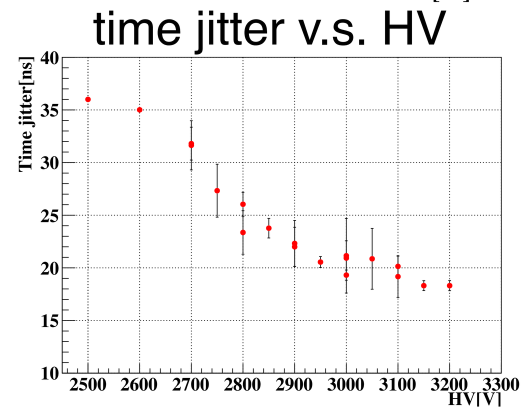
TDC distribution



inefficiency v.s. HV



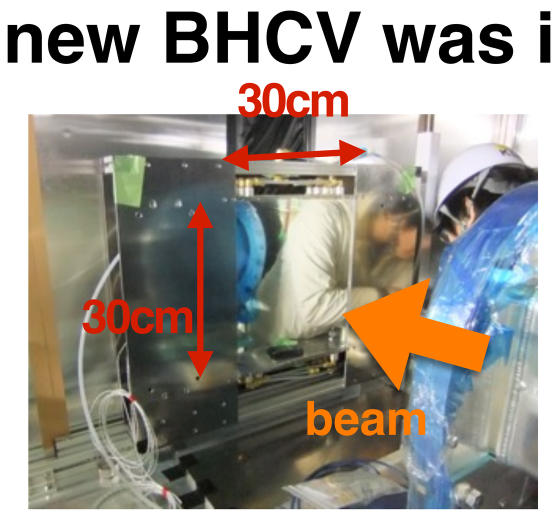
time jitter v.s. HV



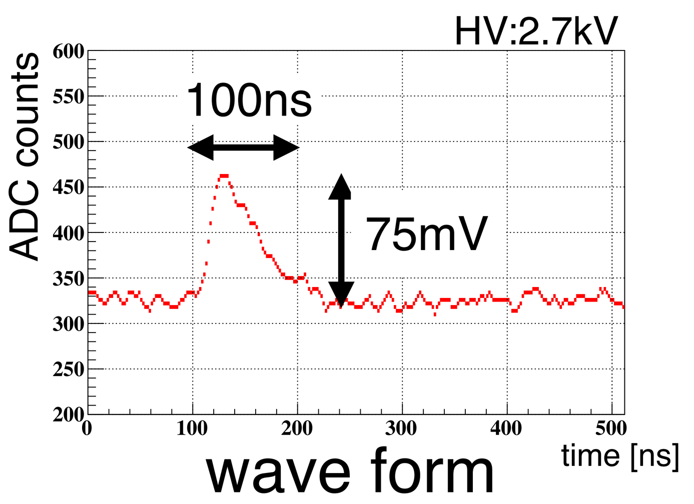
rate tolerance was also checked
➡ No gain drop at 60kHz/cm² (maximum rate expected in KOTO)

Performance of new BHCV

new BHCV was installed



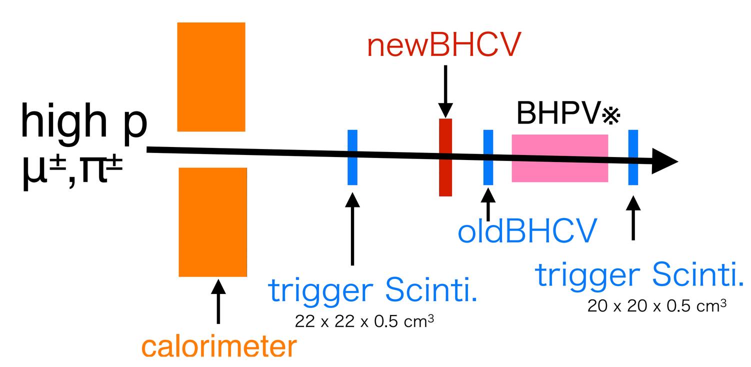
3 modules are glued and placed in line along beam axis



wave form

MIP peak ~75mV in peak height

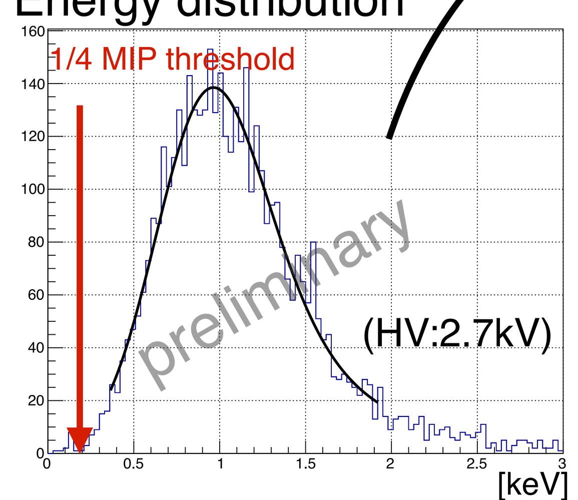
Efficiency measurement



required hits of old BHCV and 2 trigger scintillators

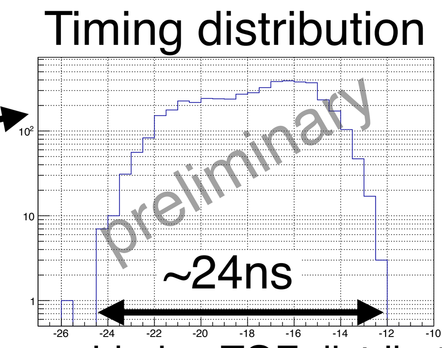
※BHPV is a photon counter made of aerogel and lead (total radiation length ~ 6.2 X_0)
➡select high momentum charged particles

Energy distribution



~99.6% efficiency (each module)
➡ 99.9% w/ 2-out-of-3 logic

Timing distribution



considering TOF distribution, veto timing window is ~ 30ns (2 times wider than old BHCV)

rate reduction

(24kW)	oldBHCV	newBHCV
rate	4.4 MHz	1.4 MHz

(threshold : 1/4 MIP peak)

counting rate of new BHCV was ~1/3 of that of old BHCV

Conclusion

BHCV was upgraded with thin gap chamber
- 99.9% efficiency was achieved
- counting rate was reduced to 1/3 of that of old BHCV
- ➡ acceptance loss: 6% → 4% @24kW beam power (23% → 15% @100kW)