Development of Amplifier and Shaper for High-Rate MWPC

I. Kamiji[1], N. Sasao[2], T. Nomura[3], H. Nanjo[1], N. Kawasaki[1], D. Naito[1], Y. Maeda[1], S. Seki[1], K. Nakagiri[1]

[1]*Dep. of Phys., Kyoto Univ.*, [2]*Dep. of Phys., Okayama Univ.*, [3]*KEK*

J-PARC E14 (KOTO) Experiment

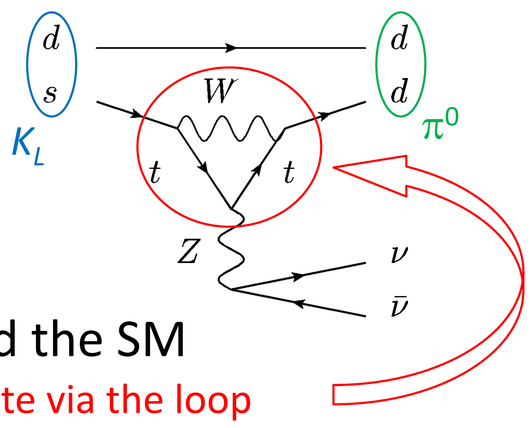
Goal of the KOTO Experiment

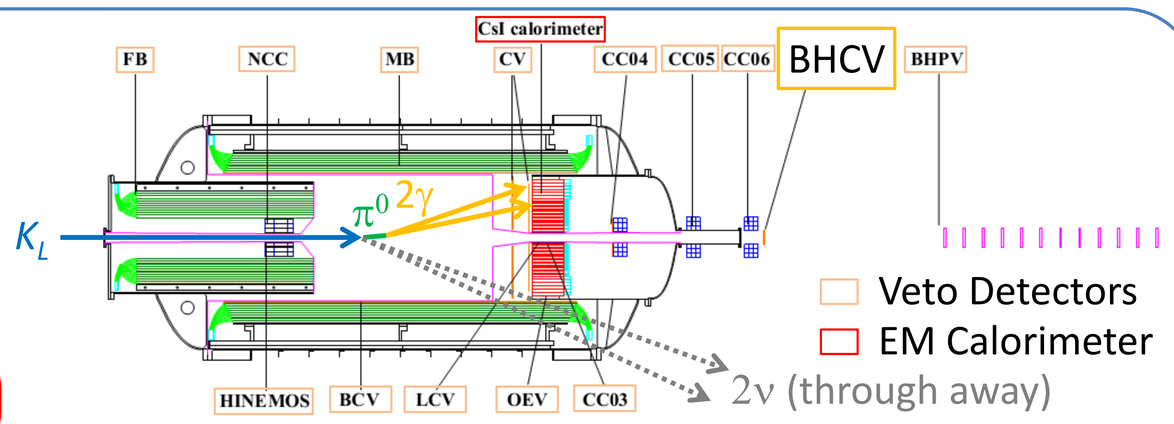
Discovery of $K_L \to \pi^0 \nu\bar{\nu}$

- Direct CP violation
- suppressed in the SM: BR = 2.4 x 10^{-11}
- Small theoretical uncertainty (2%)

→ Sensitive to new physics beyond the SM

Particles beyond the SM can contribute via the loop





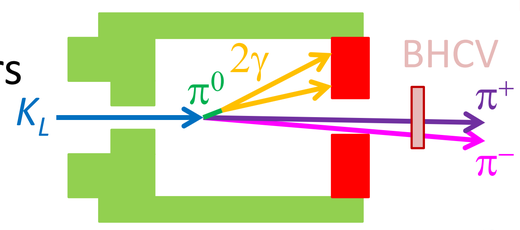
Target: 2γ ($\pi^0 \to 2\gamma$) on EMCal + "Nothing Else"

"Nothing" is assured by hermetic veto detectors

BHCV (Beam Hole Charged Veto)

- In-beam veto detector for charged particles at the downstream part of the KOTO detectors
- Incident rate of in-beam neutral particles (γ and neutron) is up to a few GHz

→ Signal loss due to fake vetoes

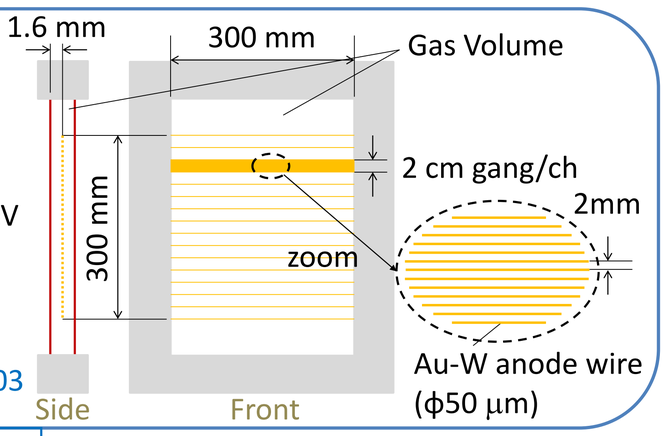


Ex.) KL → $\pi^+\pi^-\pi^0$ background

BHCV Upgrade
3mm thick MWPC

- Gas: CF_4:n-Pentane (55:45)
- Mean Energy Deposit: 1.4 keV
- High Voltage: 3000 V
- Capacitance: 50pF/ch
- Hit Rate: 800kHz (Max.)

Detail discussion -> poster No.P-603

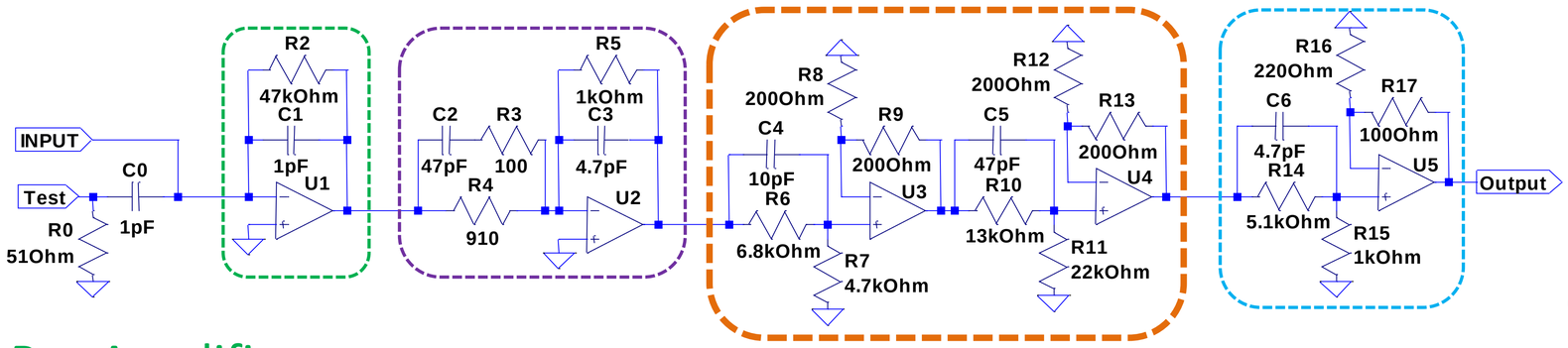


Prototype Amplifier for the New BHCV

Requirement for BHCV
- Efficiency: 99.5%
- High rate operation

Schematic Diagram

* PZC = Pole-Zero Cancellation
* Ux (x = 1 – 5): ADA4817 (Op-Amp)



Requirement & Solution

✓ Good S/N for ¼ MIP peak events
-> Charge Sensitive Amp. w/ Low Noise Op-amp

✓ Capability for high-rate operation up to 800 kHz w/o baseline shift
-> 1/t tail Cancellation Circuit

Pre-Amplifier

Charge sensitive amplifier
- Time constant: 47 ns

Low noise, high speed op-amp
- 4nV/√Hz, 2.5fA/√Hz
- Gain-Bandwidth: 410 MHz

1st Pole-Zero Cancellation

Inverting polarity of output signal
Change time constant
- 47 ns -> 4.7 ns

1/t tail cancellation (Double PZC network)

Output signal of MWPC

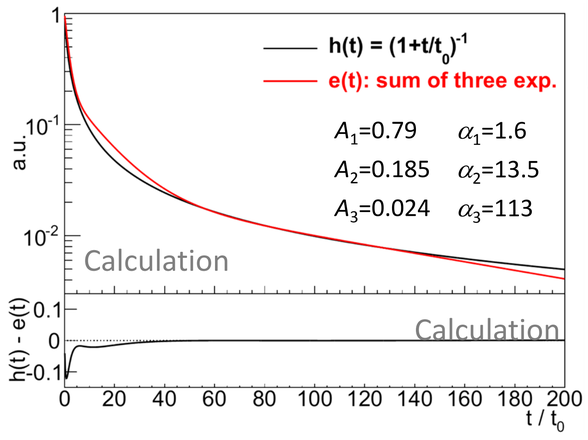
$$i(t) \propto (1 + t/t_0)^{-1} \quad t_0 = \frac{\pi\varepsilon_0 a^2}{\mu_p C V_0} = 5\text{ns}$$

$$\approx \sum_{i=1}^{3} A_i \exp(-t/\alpha_i t_0)$$

⇩ Double Pole-Zero Cancellation Network

$$A_1 \exp(-t/\alpha_1 t_0)$$

Pulse Width: O(10 μs) -> 100 ns



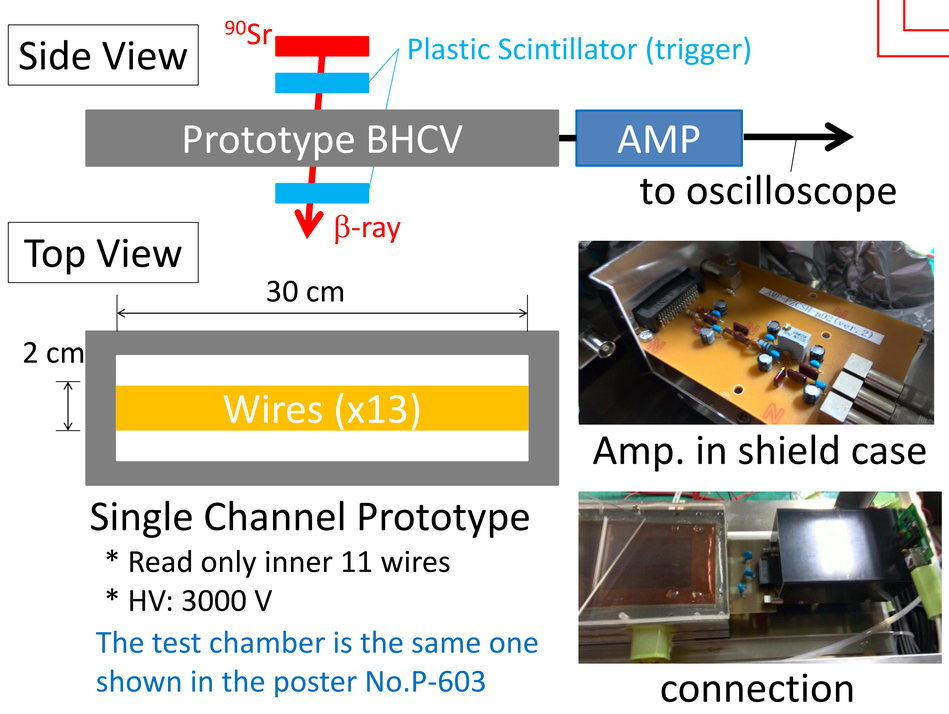
Additional PZC

change the time constant:
- αt_0 -> 4.7 ns (time constant of 1st PZC)

Basic Performance

Charge Gain	7.6 V/pC
Charge Gain (Pre-Amp)	680 mV/pC
Std. Dev. of Output Noise	5 mV
Equivalent Noise Charge	4000 e

Performance Test w/ Single-Channel Prototype of the New BHCV



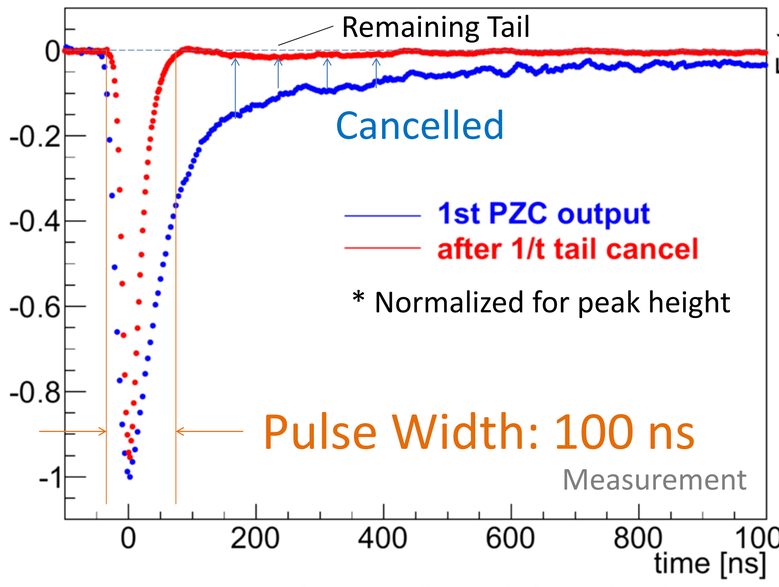
Single Channel Prototype
* Read only inner 11 wires
* HV: 3000 V

The test chamber is the same one shown in the poster No.P-603

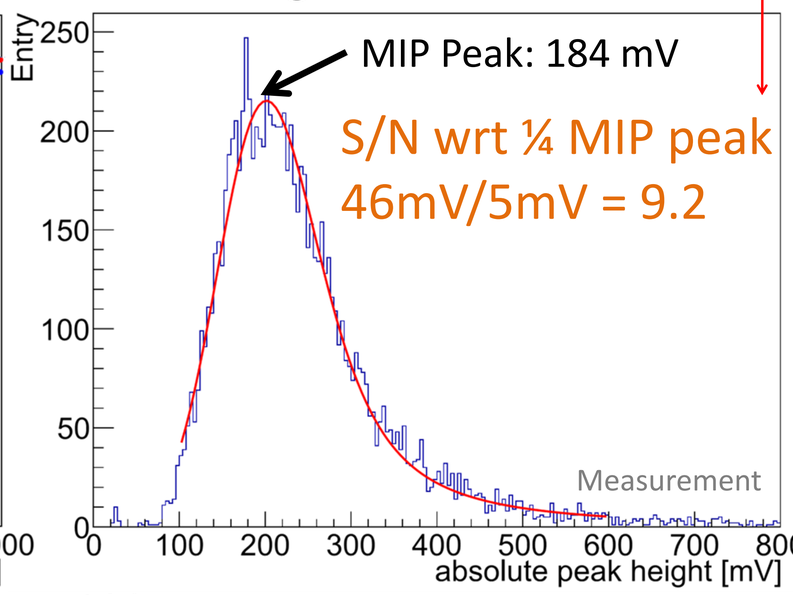
Amp. in shield case

connection

Effect of 1/t tail Cancellation



Peak Height Distribution



Remaining tail: 1% of peak height & 400 ns width

Conclusion

The prototype amplifier and shaper for high-rate MWPC have been developed

- Good S/N for ¼ MIP peak events
- Narrow pulse width (100 ns)

➡ Efficiency of BHCV: 99.5%
800 kHz operation w/ little baseline shift
} are expected

Next Steps:
- **Finalize multi-channel amp. and shaper**
- **Install and Operate BHCV for KOTO**