Monitoring and control system for MPPCs for the upgraded koto CsI calorimeter

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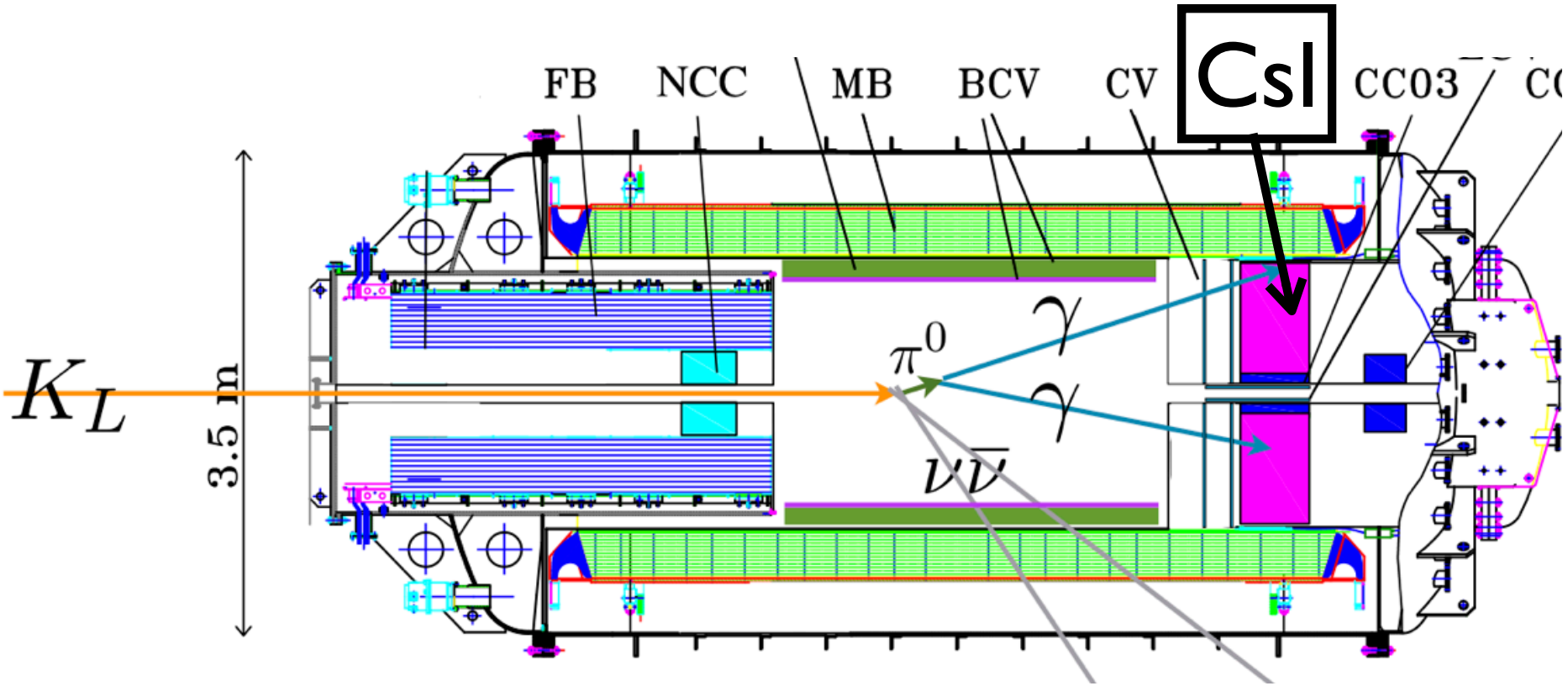
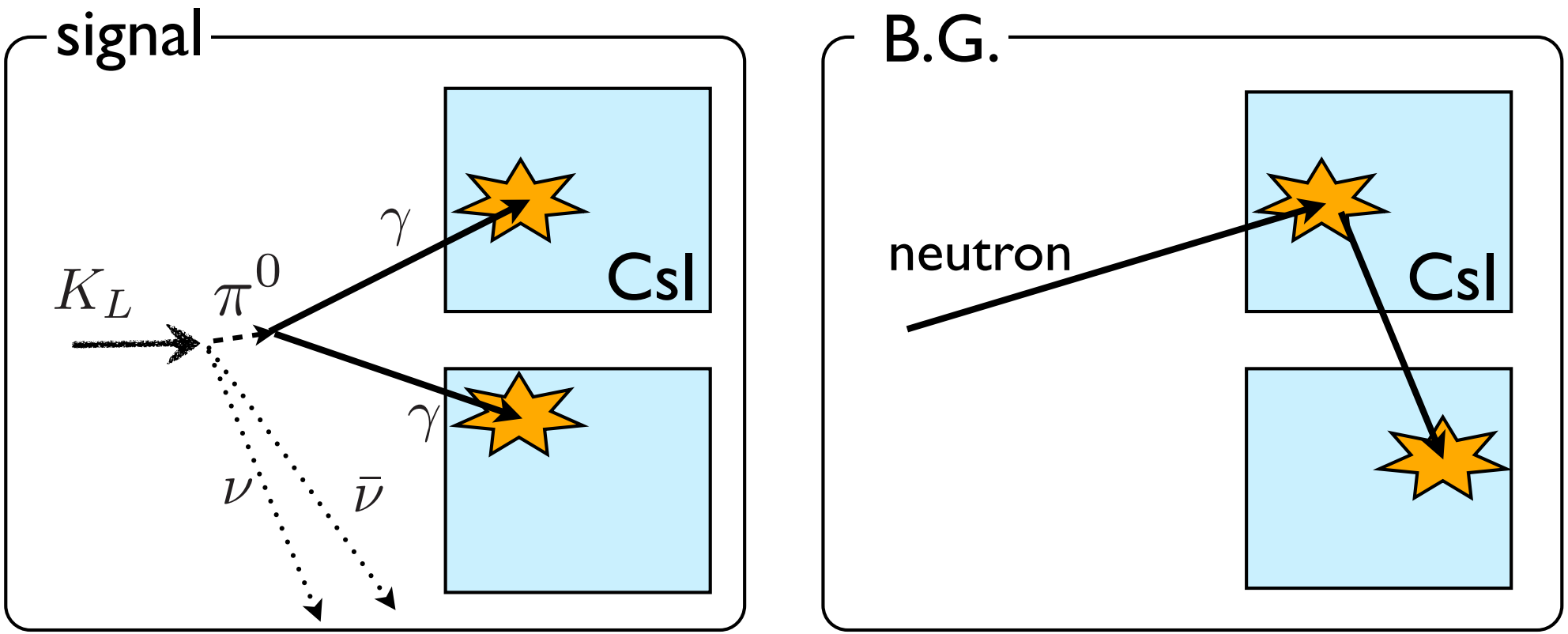
2017/12/28 Kuno and Yamanaka Group Year-End Presentation

KOTO EXPERIMENT



- Search for the rare decay $K_L \to \pi^0 \nu\bar{\nu}$ (BR~3×10^{-11} @SM)
- Signal – 2γ@CsI + nothing@other detectors

NEUTRON BACKGROUND



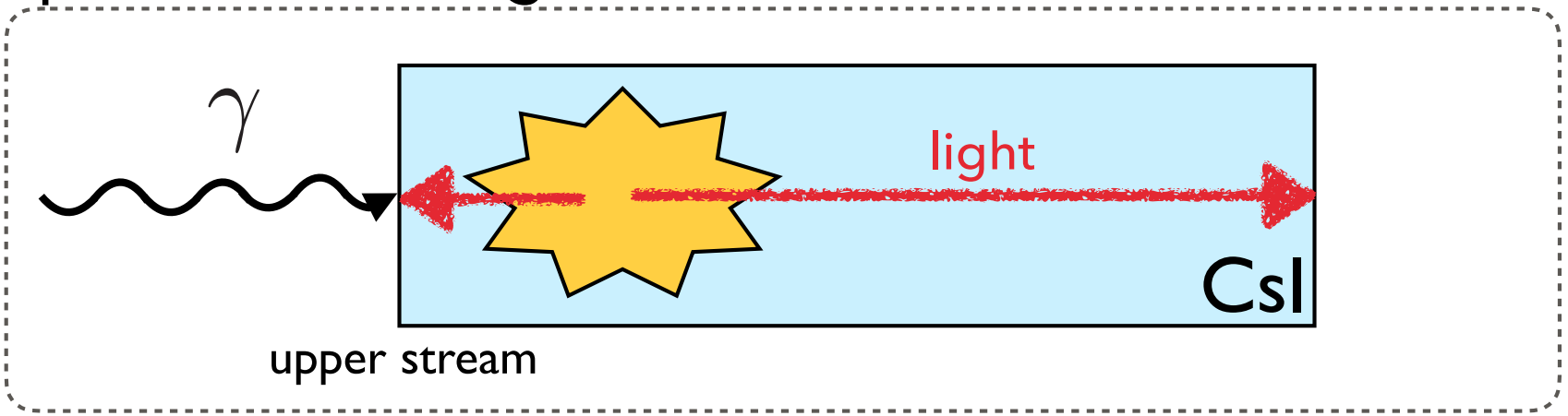
- Misidentify neutrons as photons.
  - That B.G. was already reduced to 1/100 the Pulse shape cut.
  - Furthermore, we need to reduce that B.G. by a factor 10.

BOTH-END READOUT SYSTEM

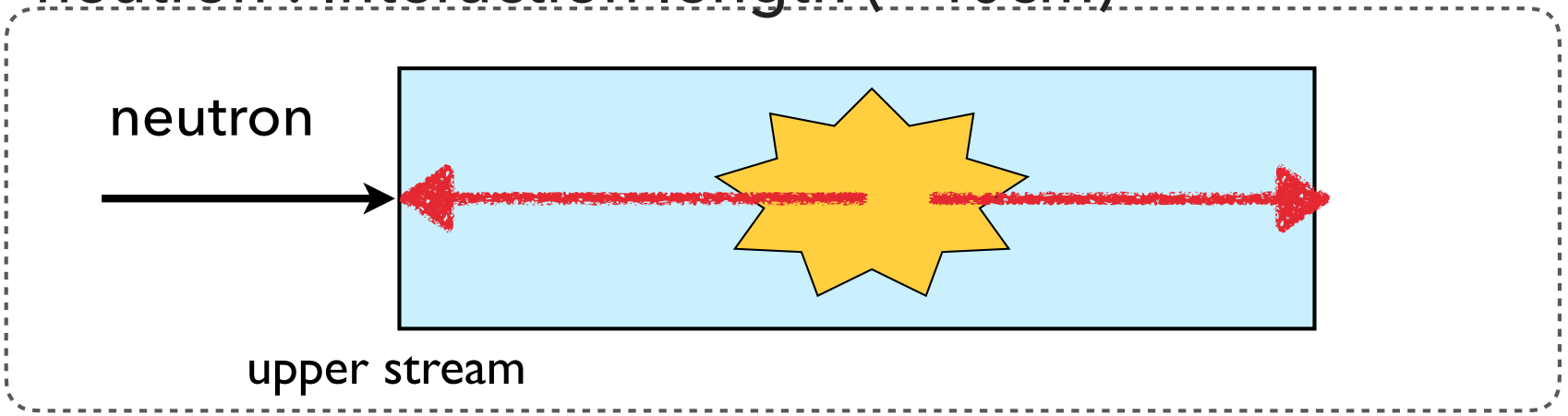
- **Timing difference**

  →discriminate b/w photons and neutrons

γ : Radiation length (~2cm)

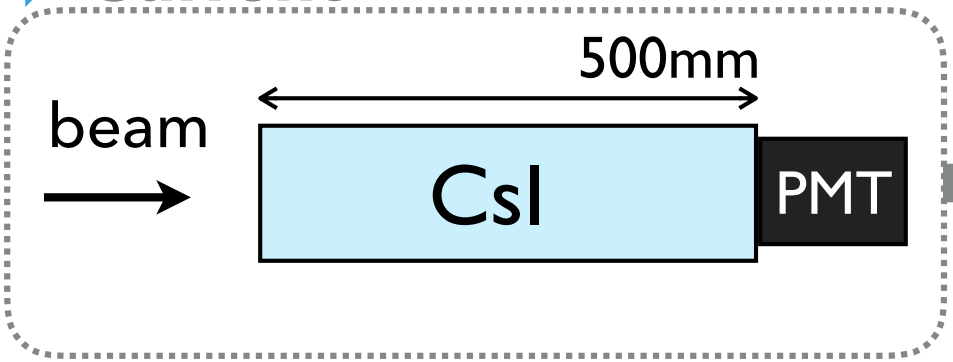


neutron : Interaction length (~40cm)

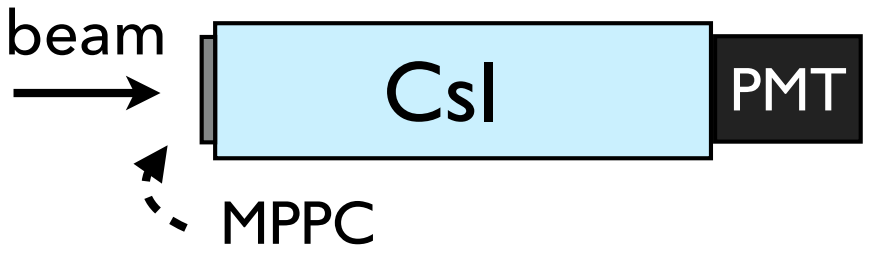


BOTH-END READOUT SYSTEM

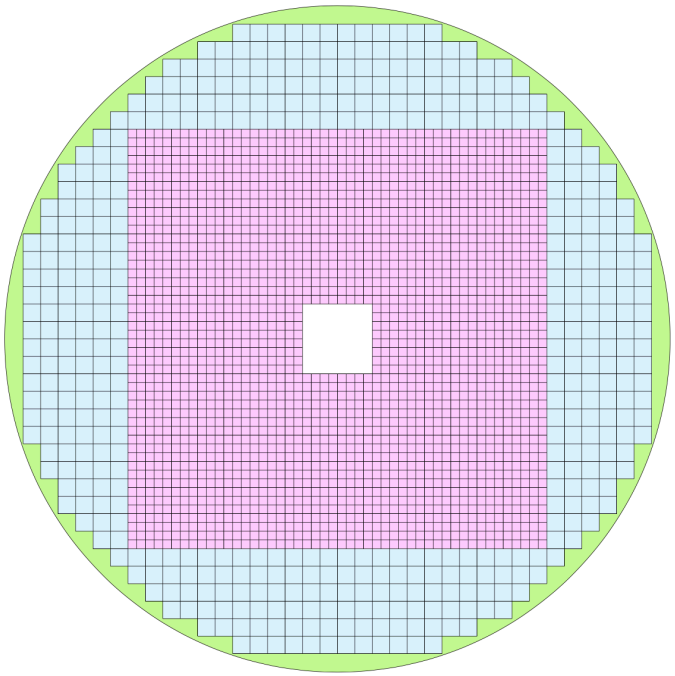
- **Current**



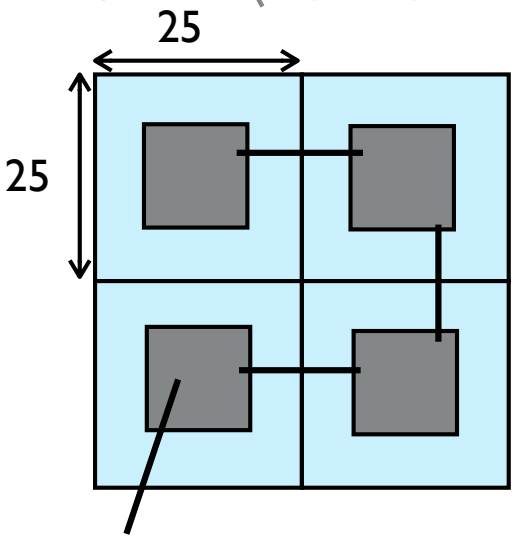
- **Both-end readout**



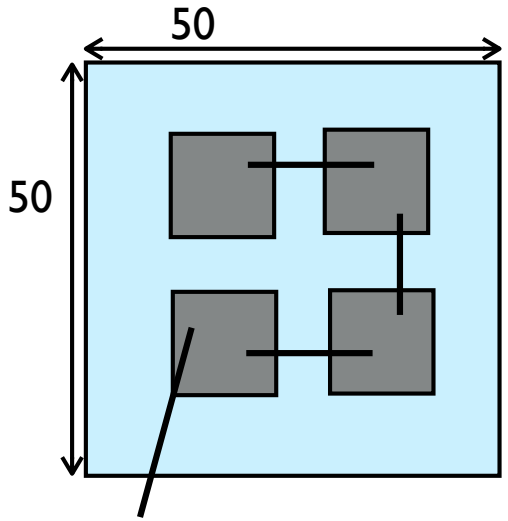
KOTO CsI calorimeter



Small (25×25mm)



Large (50×50mm)



➡ Total 4096 MPPCs

4 MPPCs are connected → 1024ch

MONITORING & CONTROL SYSTEM

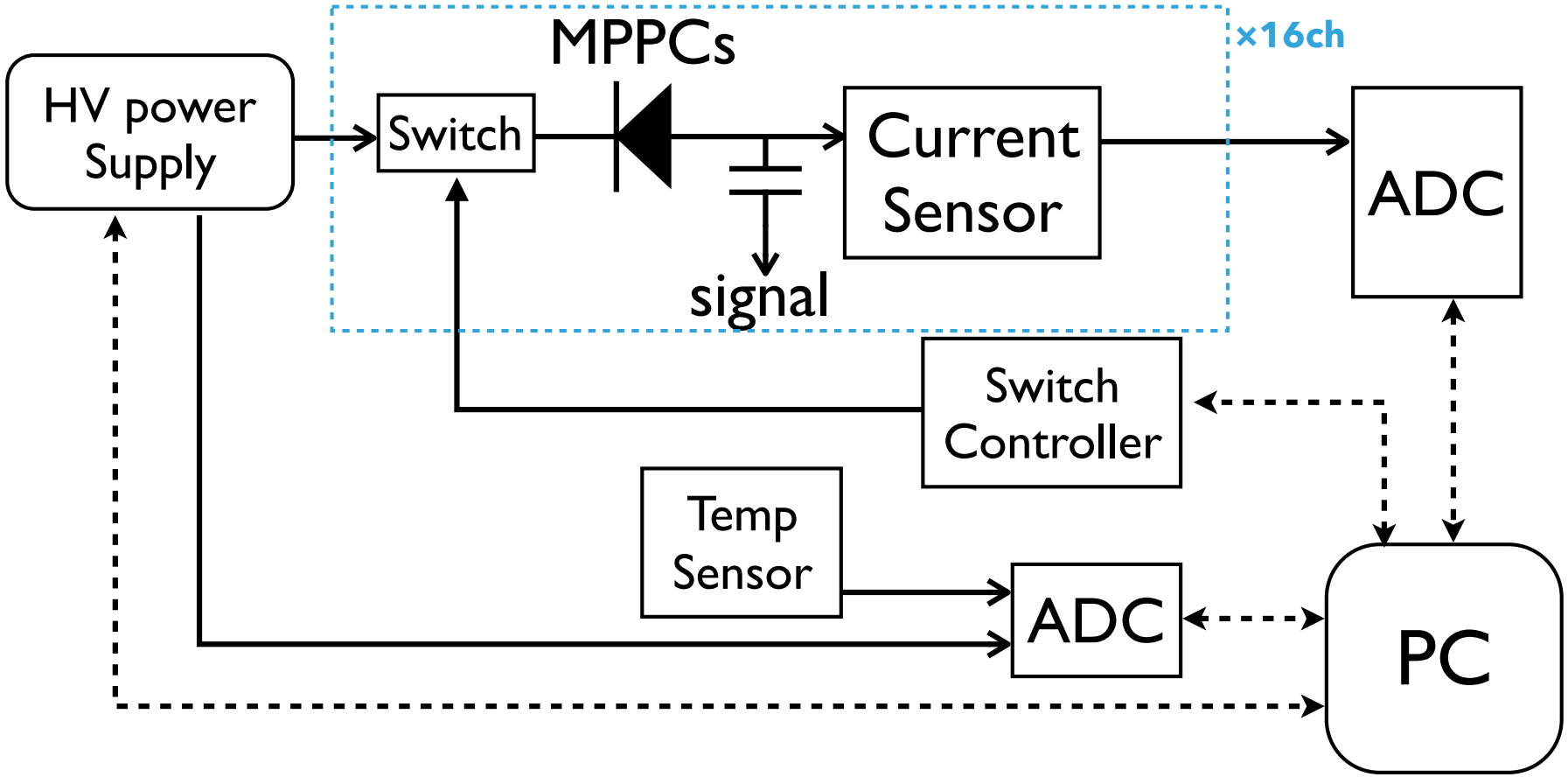
- We need the system that monitor and control 1024ch MPPCs.

  - Necessary function

    - ✓ **Monitor dark current of MPPCs (to check that MPPCs are working normally & to monitor the amount of radiation damage)**
    - ✓ Monitor & control high-voltage supplied to MPPCs
    - ✓ Monitor temperature of the board
    - ✓ Low power consumption

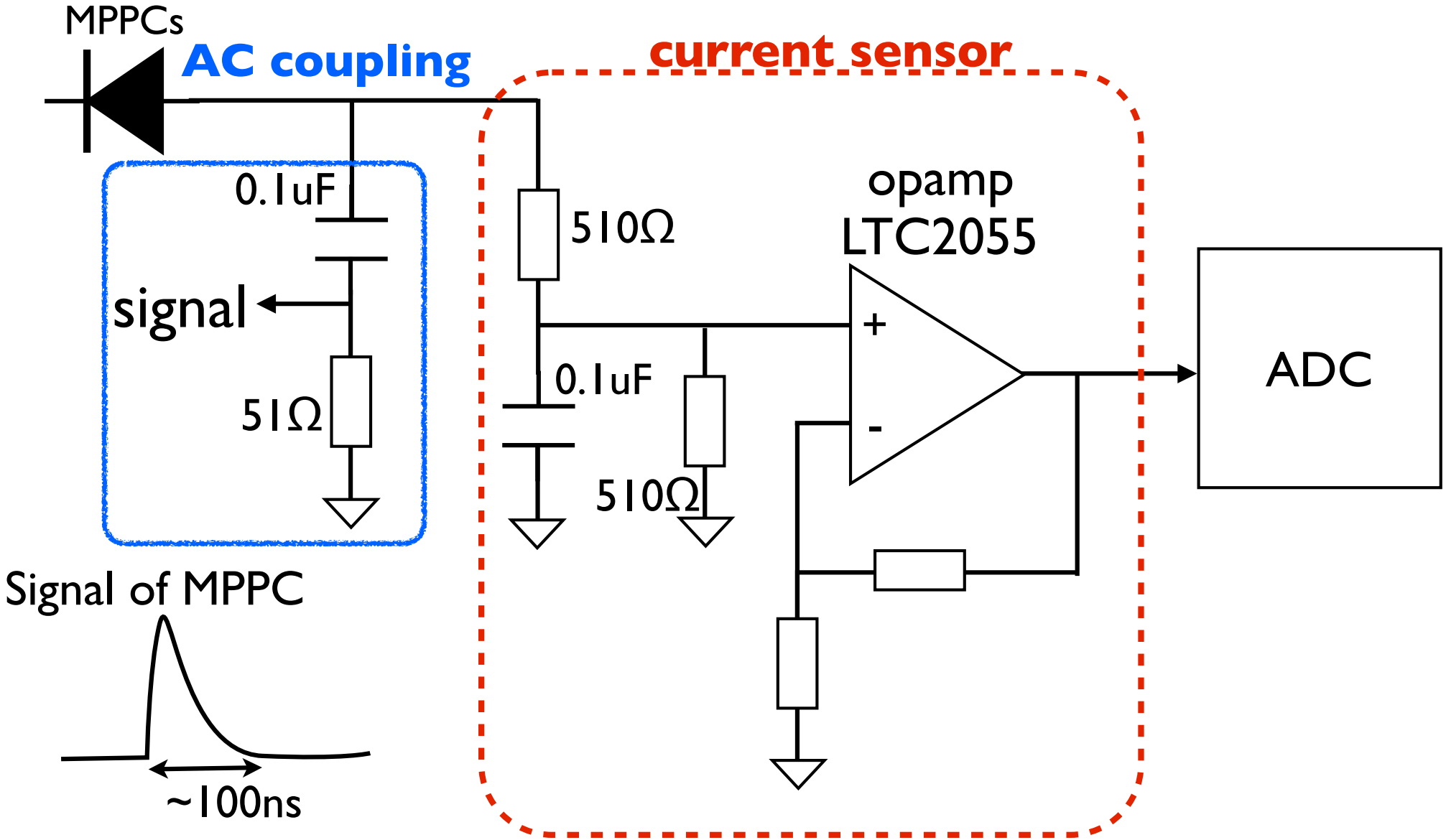
MONITORING & CONTROL SYSTEM

- Overall picture of the system



CURRENT SENSOR

- Design



MONITORING DARK CURRENT

Requirement

➡**Large dynamic range(0-200uA)**

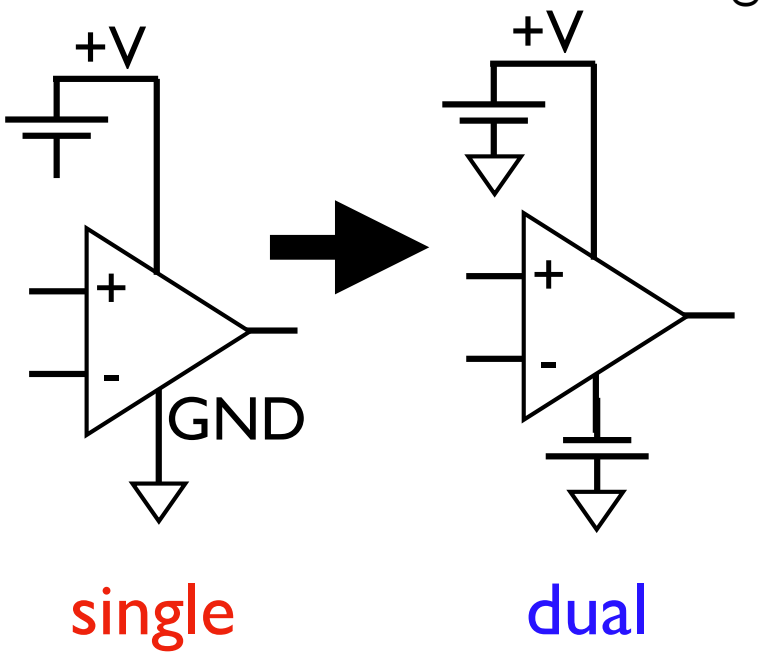
- Dark current of MPPC
  0.5uA(initially) →about 50uA(after irradiation)
  4MPPCs are connected → ~200uA

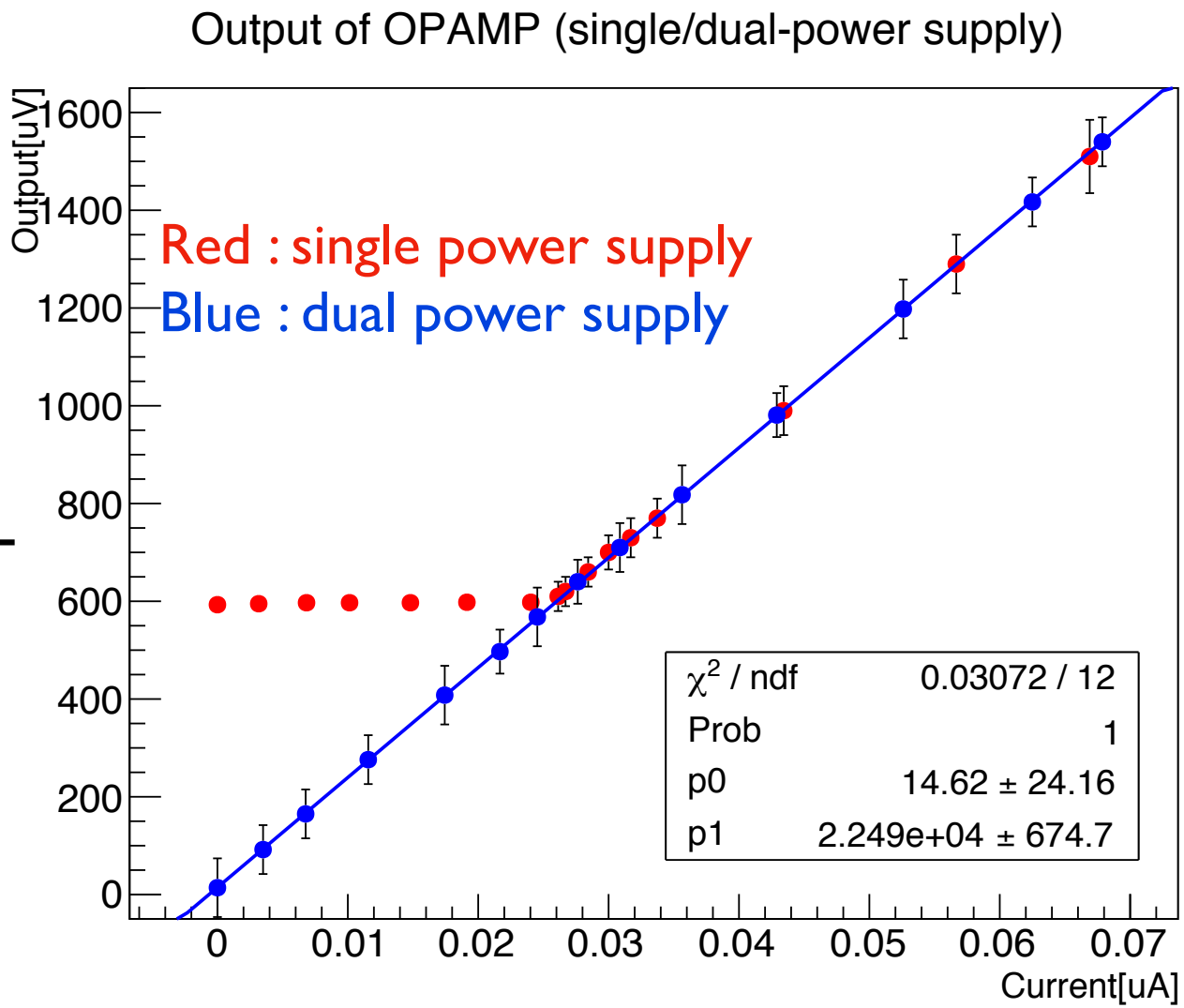
- to measure I-V curve to check MPPCs
  →need to measure small current(~0.01uA)

MONITORING DARK CURRENT

- OPAMP(single power supply) can't work well @ small current region

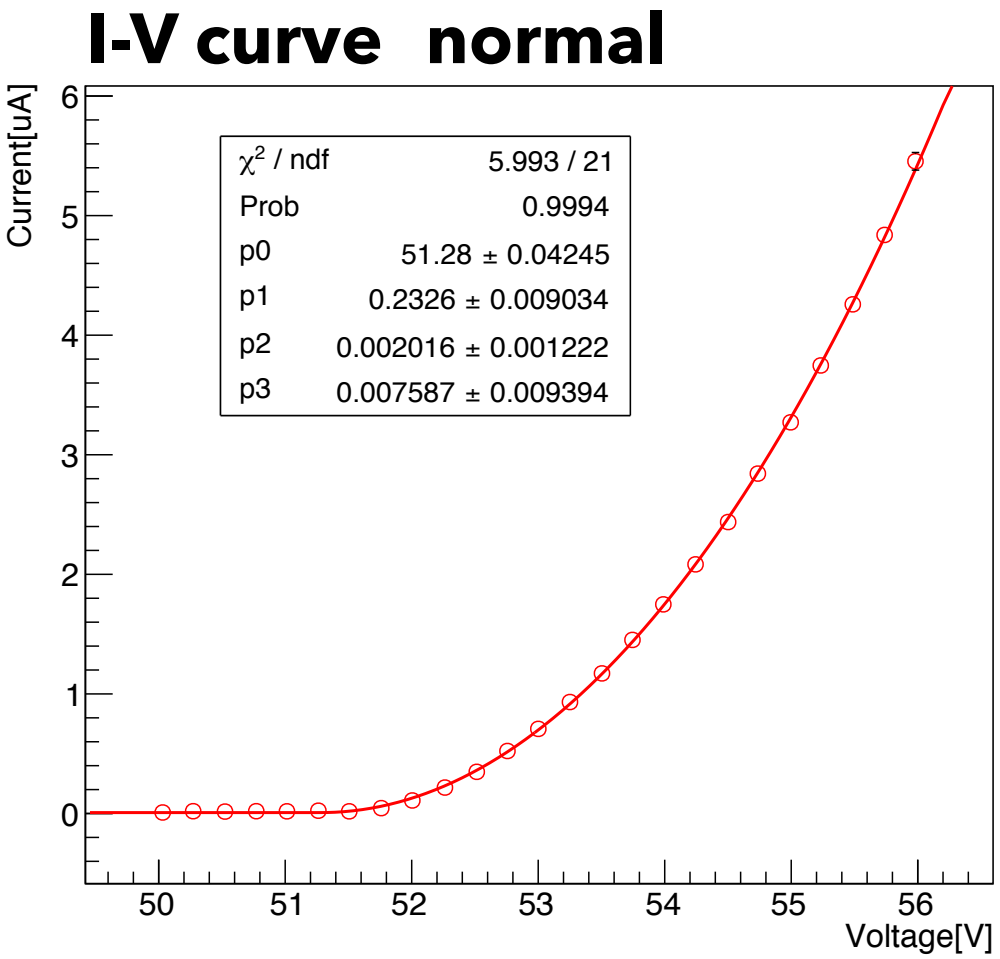
➡ **Change to dual power supply**

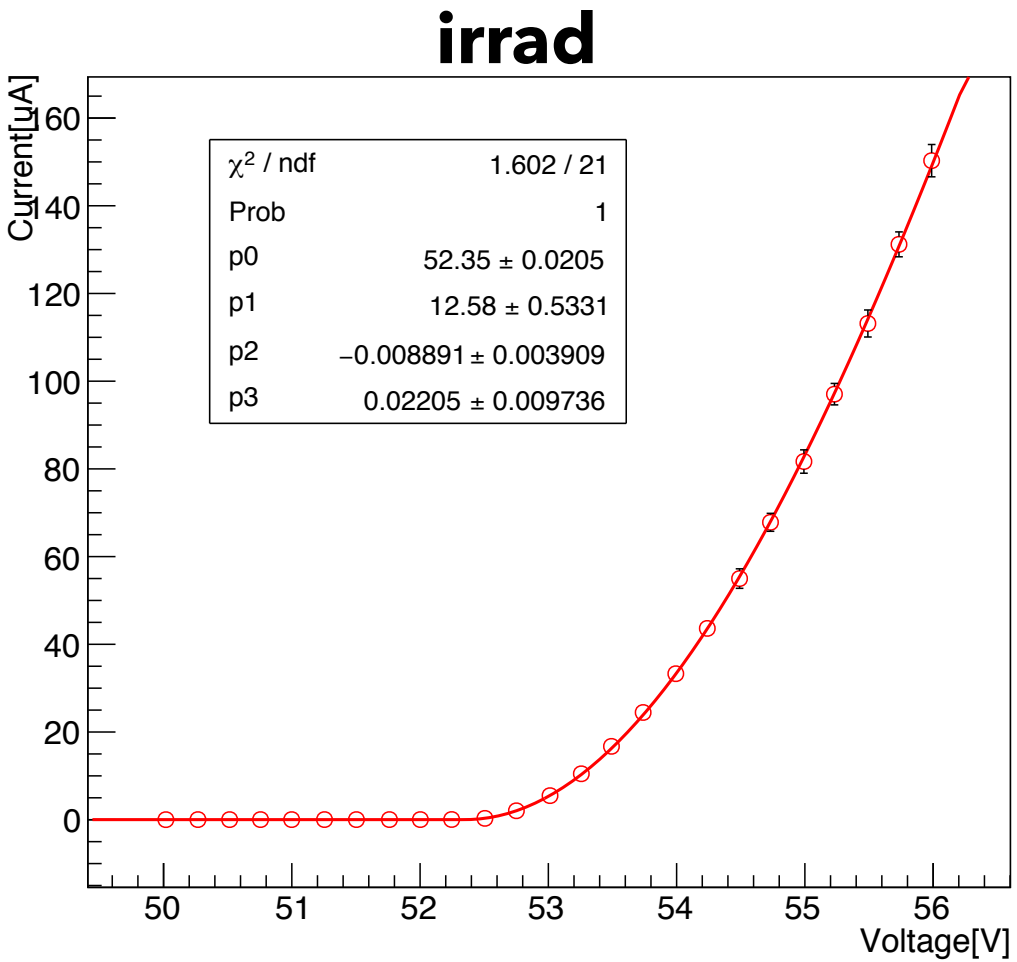




MONITORING DARK CURRENT

- I-V curve of normal MPPCs & irrad MPPCs





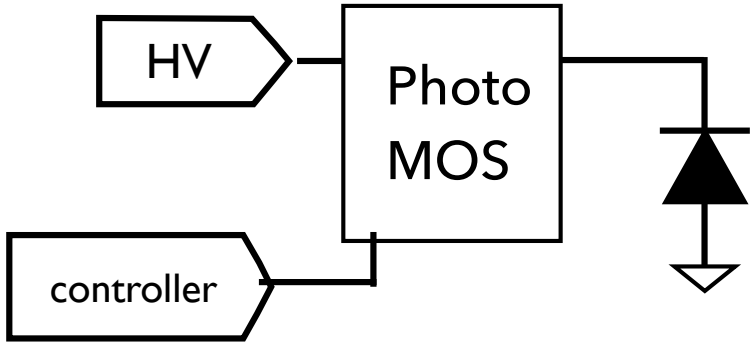
SUMMARY

- We will install 4096 MPPCs to reduce the neutron B.G. .
- I developed the control & monitoring system for MPPCs.
  - That system has some functions.
    Monitor MPPCs, measure temperature, etc..
- I will solve some problem and improve the system.

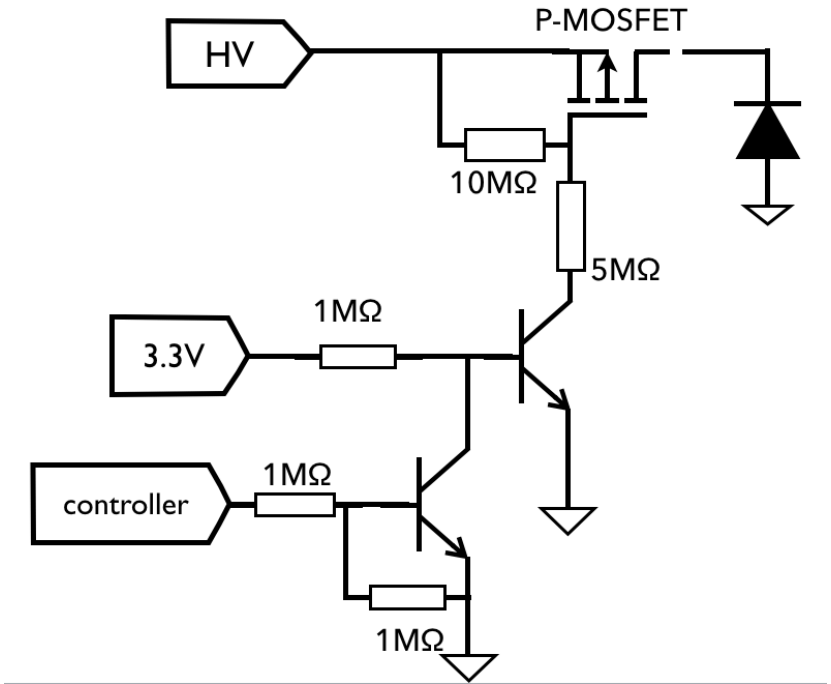
BACKUP

SWITCH

Plan A : PhotoMOS relay

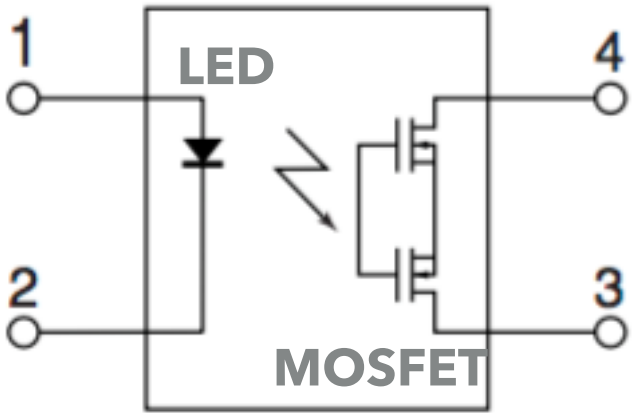


Plan B : Transistor



	PhotoMOS	Transistor
Power consumption (HV on)	~0W	300uW/ch
Power consumption (HV off)	10~ 30mW/ch	~0W
speed of switching	~0.1ms	~1ms
on-resistonce	25Ω	<1Ω
leak current	< 1μA	< 1μA

PHOTOMOS RELAY



- Turn on/off MOSFET(switch) by LED

- High insulation (>200MΩ)
- Low power consumption ~10mW (other relays ~ 1W)
- Normally close type → simple circuit
- reduce #parts used in the switch

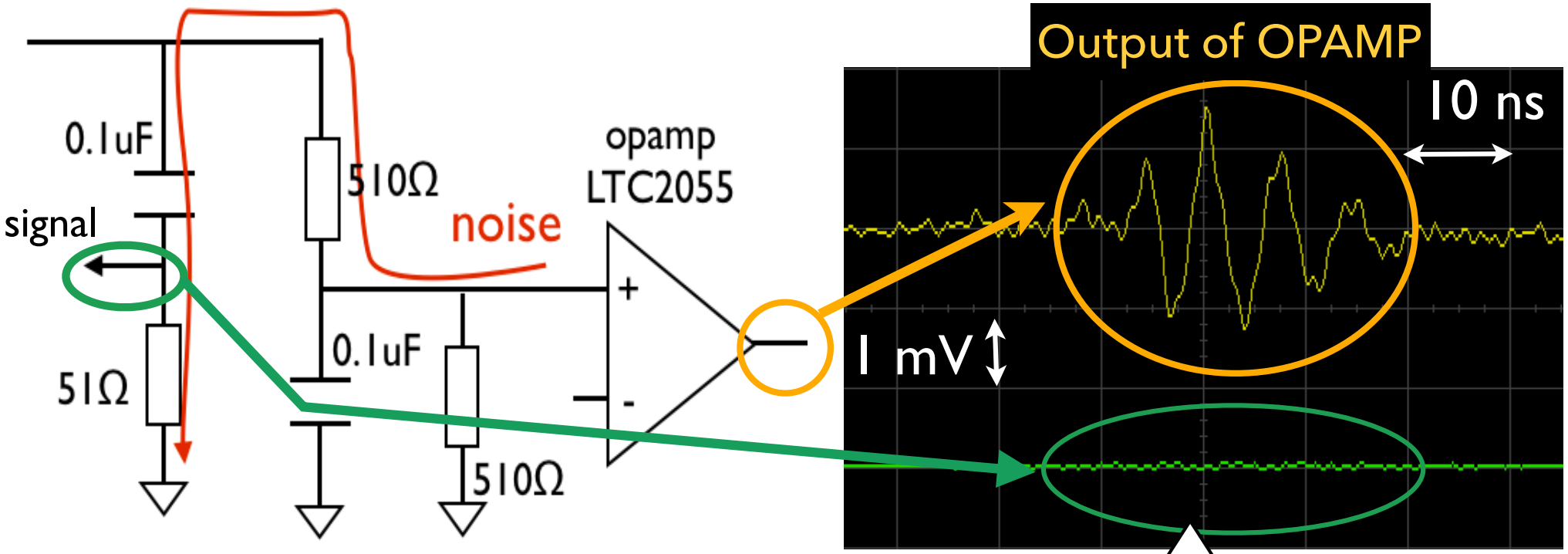
MONITORING DARK CURRENT

- **Requirement**
  - **No effect to the signal readout**
  - **Large dynamic range**
    - Dark current of MPPC
      0.5uA(initially)
      →about 50uA(after 1.5×10^9 n/cm^2 irradiation)
      4MPPCs are connected → 2~200uA
  - **Resolution (~0.01uA)**
    - to measure the I-V curve to check MPPCs

MONITORING DARK CURRENT

- Noise from OPAMP → affect the signal readout

➡ checked the Noise

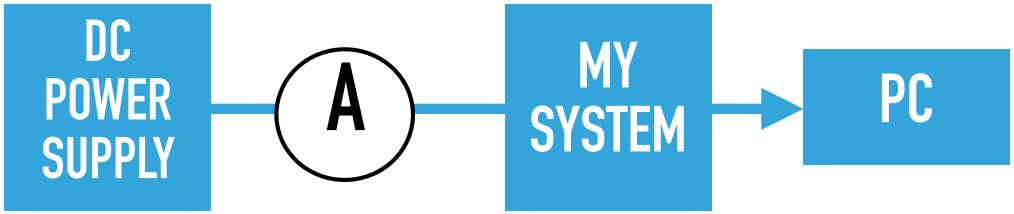


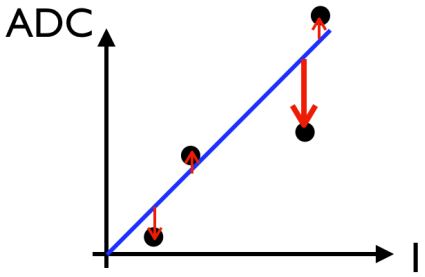
noise < 100uV

→No effect to the signal(~100mV)

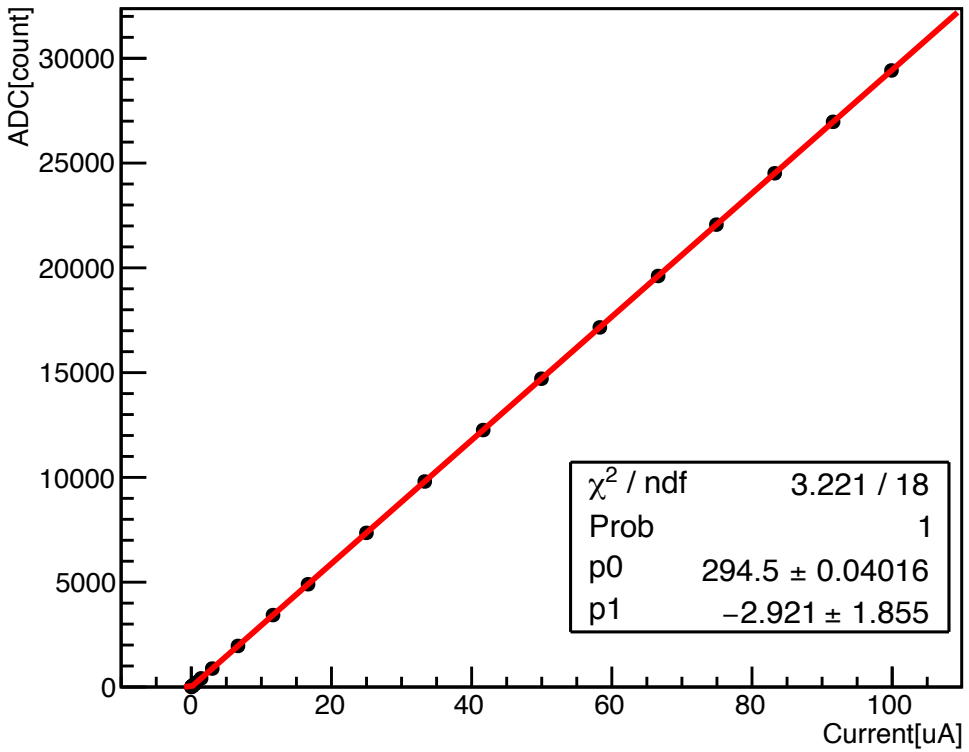
MONITORING DARK CURRENT

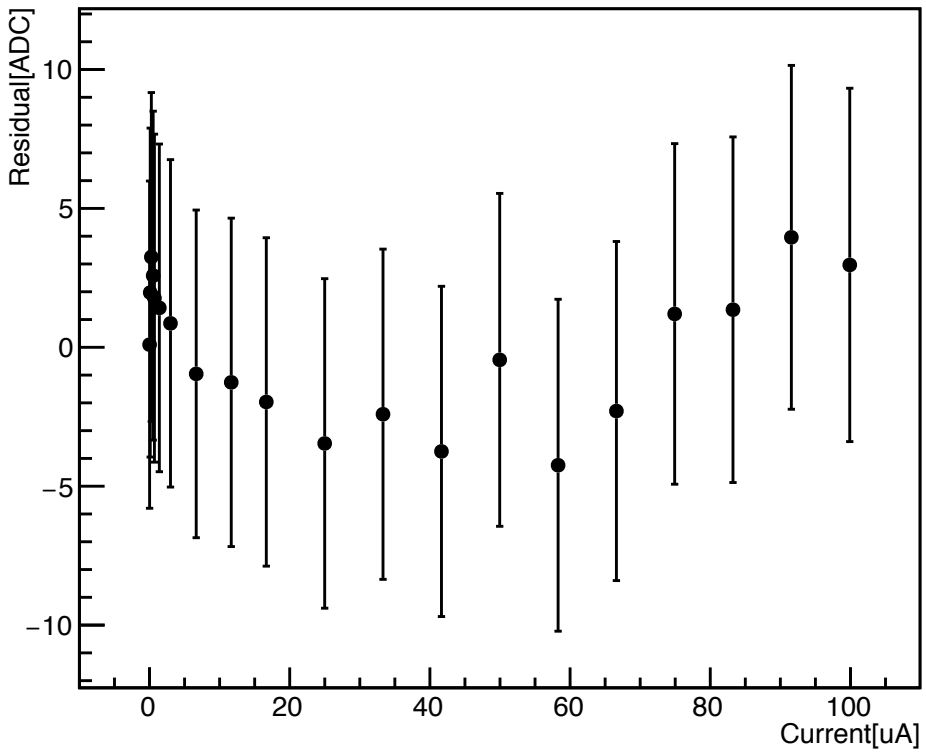
- Calibration(previous version)





Residual = ADC -(Fit)

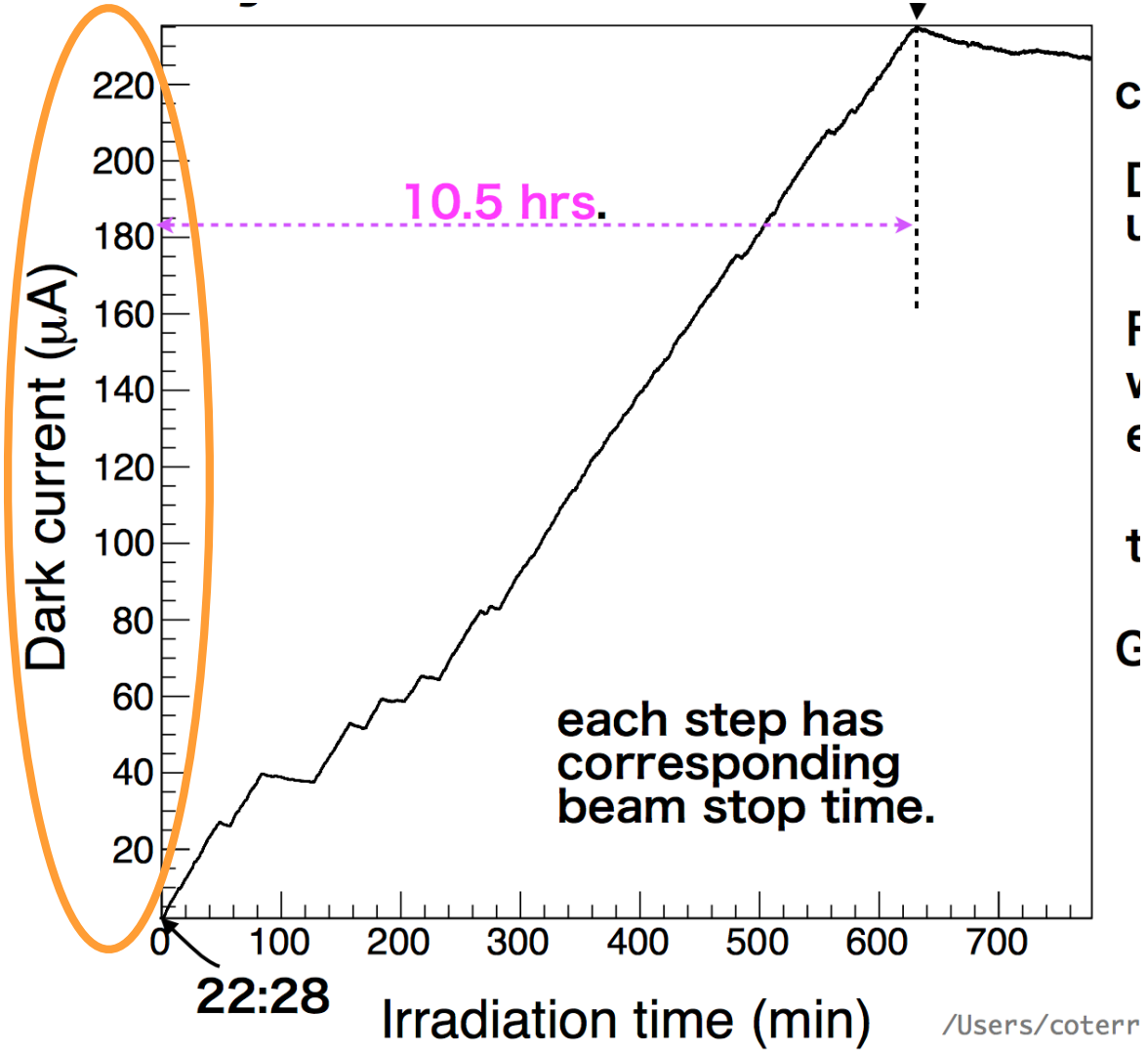




DARK CURRENT OF IRRADIATED MPPC

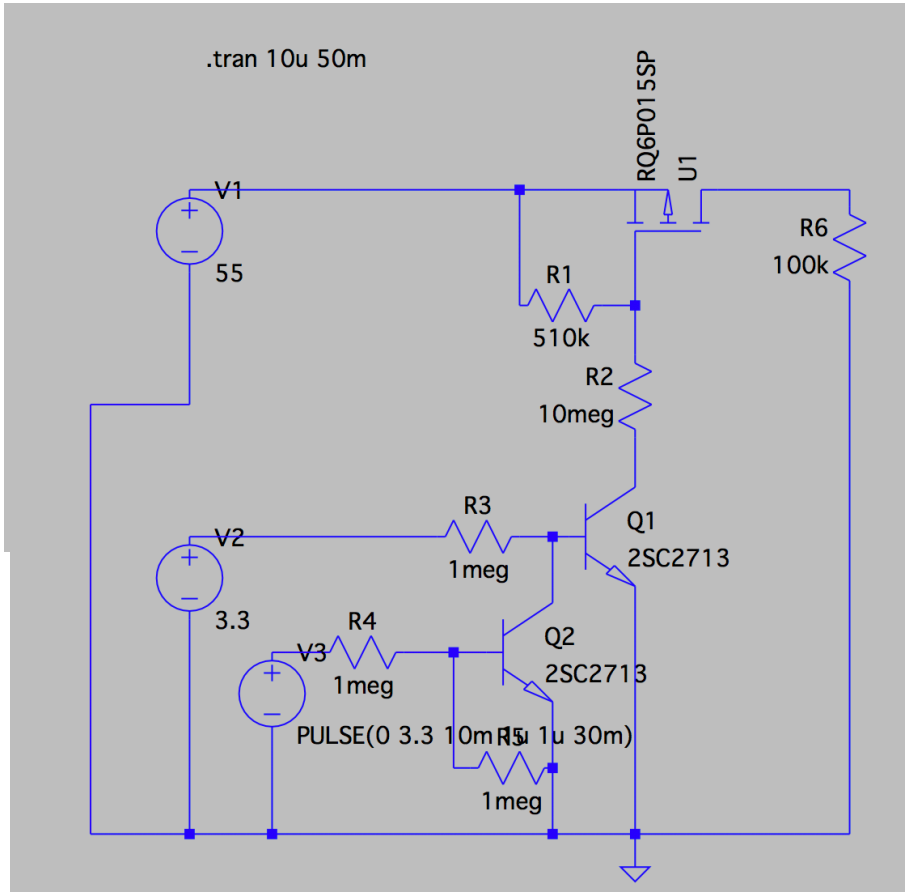
** From Kotera-san's slide
@2017July KOTO collaboration MT

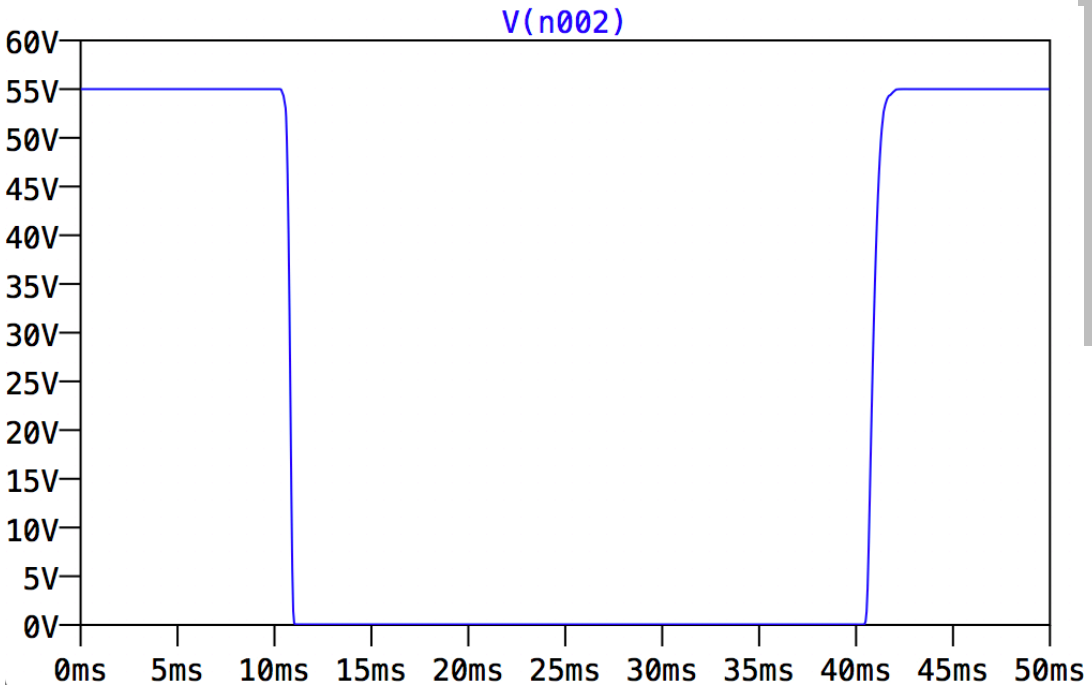
This value is the sum of 5 series connected MPPCs.



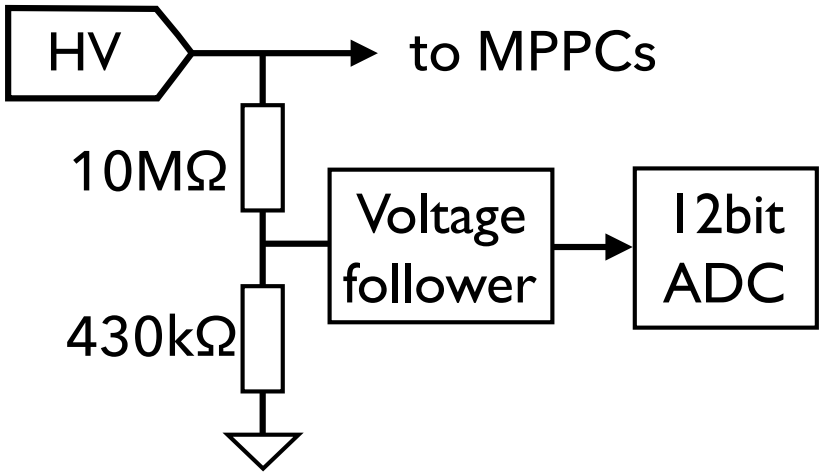
SIMULATION OF SWITCH

- Use LTSpice
- All parts are realistic one.





MONITORING HIGH VOLTAGE



- Bias voltage of MPPCs ~60V

  12bit ADC→ 1Count = 0.015V

  V_{over} =V-V_{br}~ 3 → 0.015V/3V =0.5%

  → We can observe 0.5% variation in V_{over}.

MONITORING TEMPERATURE

- temperature sensor IC
  This IC outputs voltage proportionally to the temperature.
  The voltage is converted to the digital value by a 12bit ADC.

Temperature (measured by thermocouple)	Temperature (measured by my system)
8℃	8.3±2.4 ℃
17℃	17.1±2.4 ℃
24℃	24.8±2.4 ℃
30℃	30.3±2.4 ℃

This IC can measure the temperature precisely.