Evaluation of PMT Gain Temperature Dependence via SPE Measurements

Haruka Tachibana

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FAST (Fluorescence detector Array of Single-pixel Telescopes)

Aim:

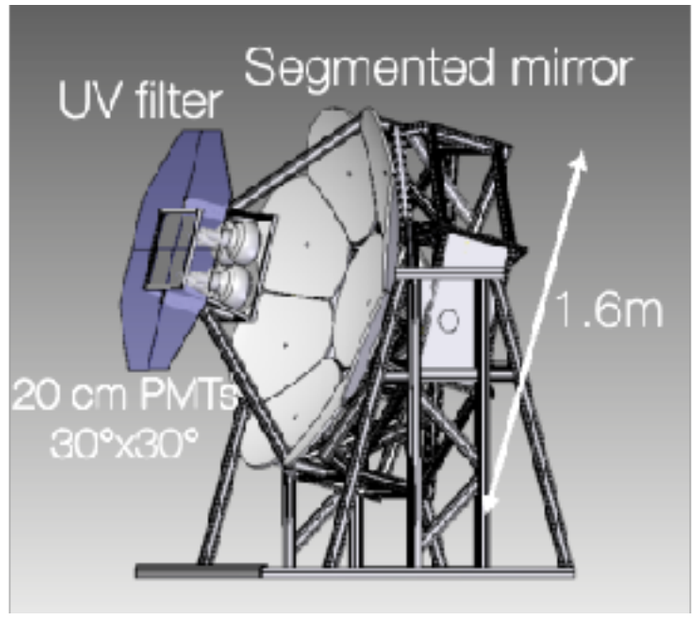
High-statistics observation of ultra-high-energy cosmic rays ($E > 10^{19}$ eV) by deploying numerous fluorescence telescopes over a wide area.

Telescope Design:

Compact structure consisting of four 8-inch Photomultiplier Tubes (PMTs), achieving low cost per unit.

Future Outlook:

Transition to autonomous operation to facilitate large-scale observation with a massive telescope array.



Current FAST Prototypes

2016~

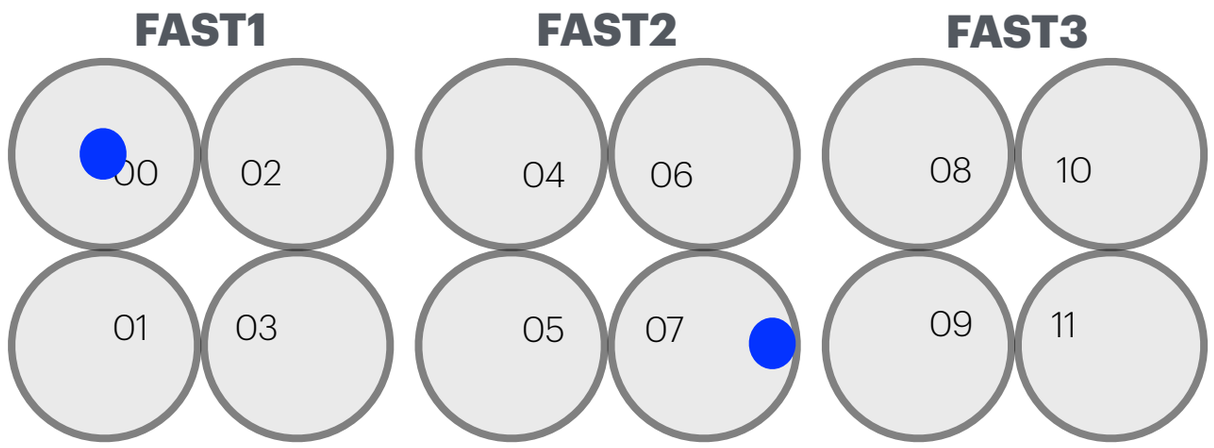
2019~

2026~

Standard Light Source: YAP

A **stable UV light source** consisting of an alpha (α) source and a scintillator.
Used to monitor the long-term stability/variation of PMT gain.

Installed on the photocathodes of PMT00 (FAST1) and PMT07 (FAST2) at FAST@TA.



sky view

Temperature dependence:

-20 ~ 10 °C : ± 1 %
10 ~ 20 °C : - 0.2 %/°C

C. Rozsa et al., (1999)

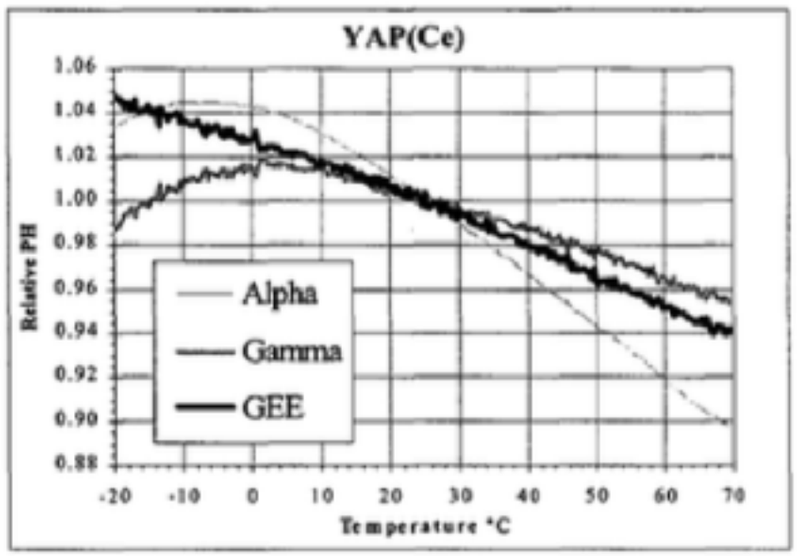


Figure 6. The normalized response of YAP(Ce) to alpha and gamma ray stimulation.

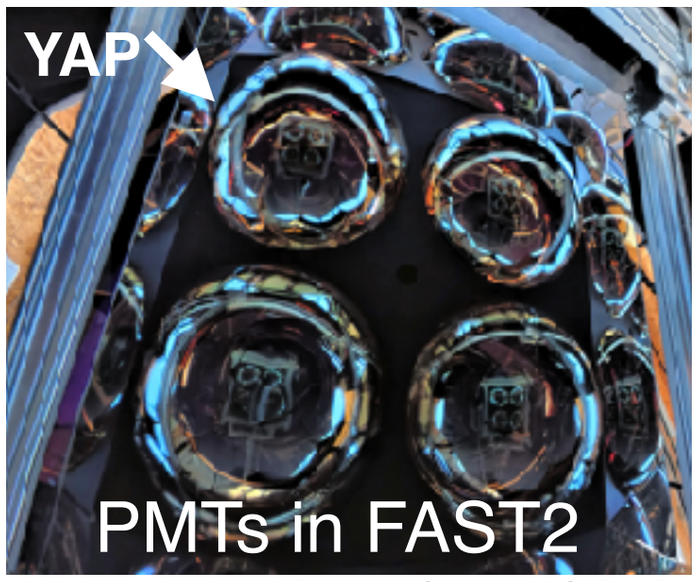


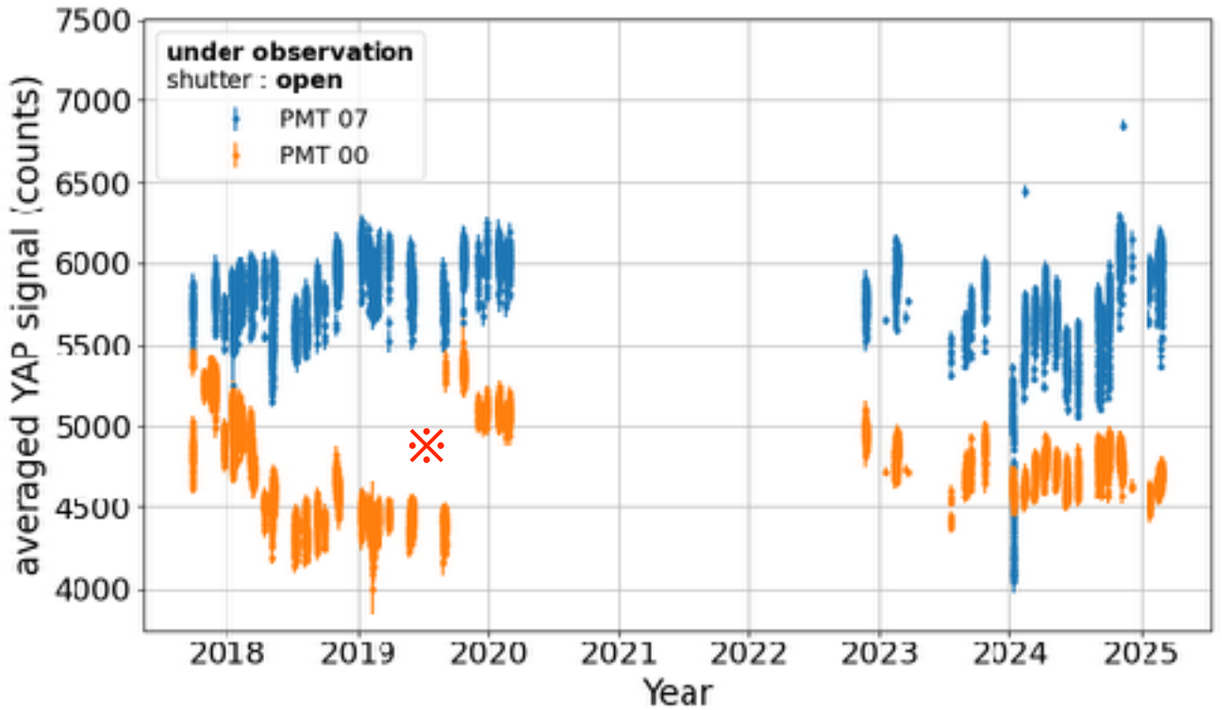
Photo by Shunsuke Sakurai

Temperature Dependence of YAP Signals

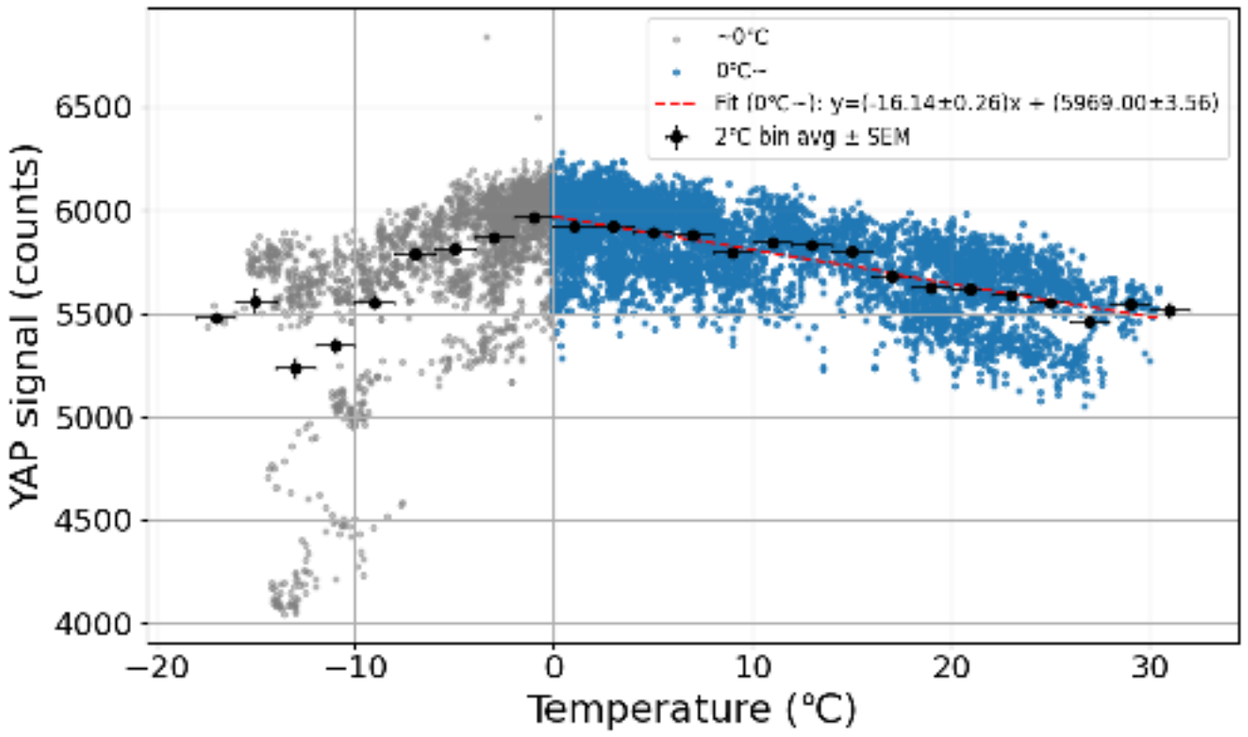
YAP signal measured with FAST@TA PMTs

※ **PMT00**
The effect of fixing the loose YAP on PMT00 2019 is visible in the graph.
→Use **PMT07** data

→ Signal shift due to temperature variation is observed.



Temperature coefficients from long-term data
-20 ~ 10 °C : ± 10 %
10 ~ 20 °C : **-0.47 ± 0.02 %/°C**
0 °C ~ : **-0.278 ± 0.004 %/°C**
→ Combined temperature dependence of YAP and PMT



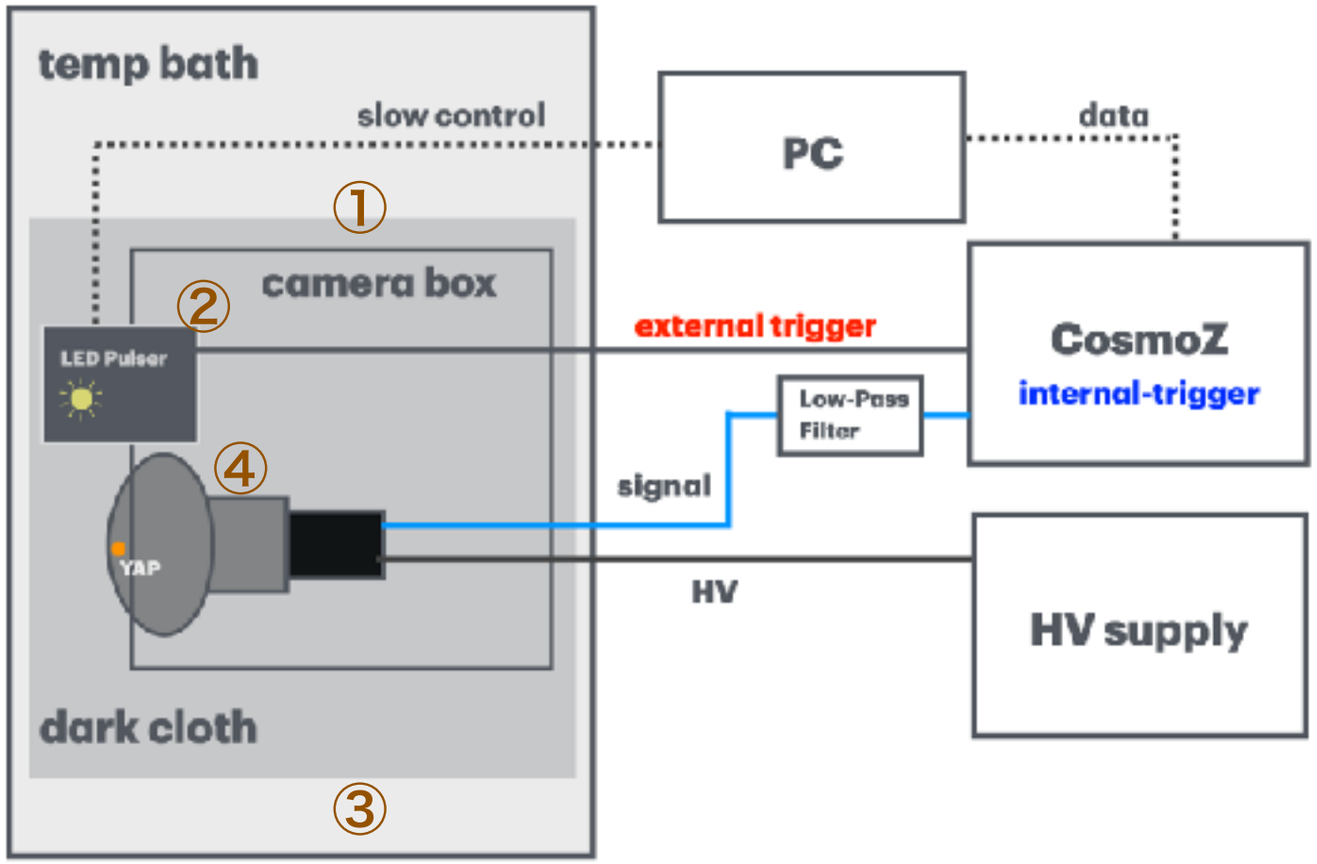
PMT Single Photoelectron measurement

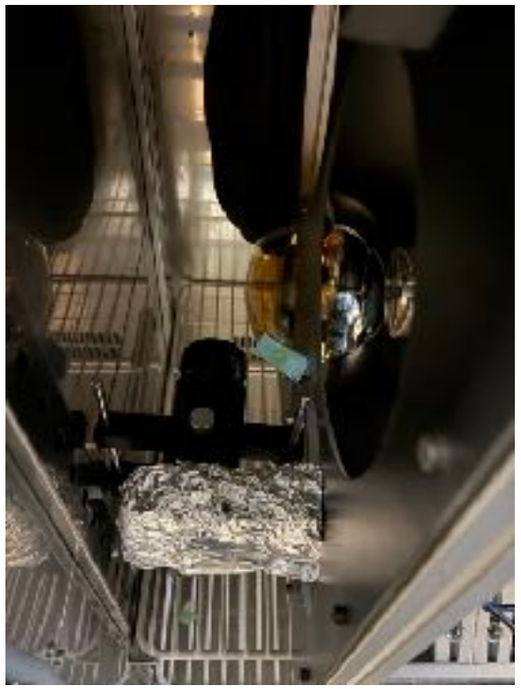
- **Problem**
  Observed YAP signal contains:
  • PMT gain
  • YAP light yield
  • QE effects ...
  → Their temperature dependences are mixed

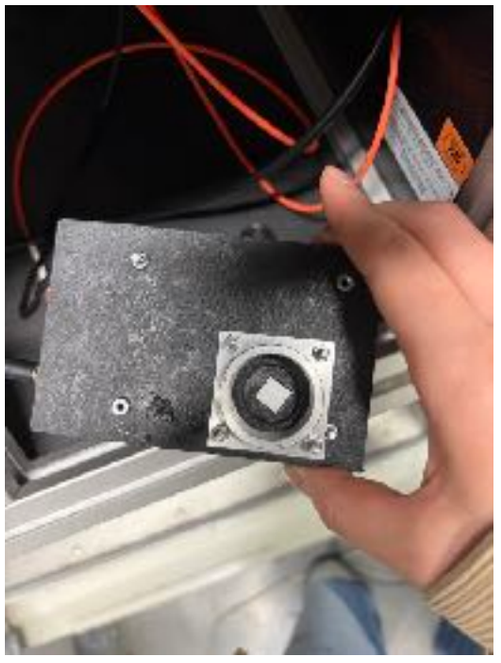
- **Measuring Single-Photoelectron (SPE) signals**
  → absolute PMT gain

- **SPE + YAP measurements**
  → decouple temperature dependences

SPE Measurement Setup







PMT: R14688 ZC2969
LPF: 15MHz
temp bath: -10 ~ 60 °C
CosmoZ: 80MHz
LED pulser (developed by Czech): Max 20mW

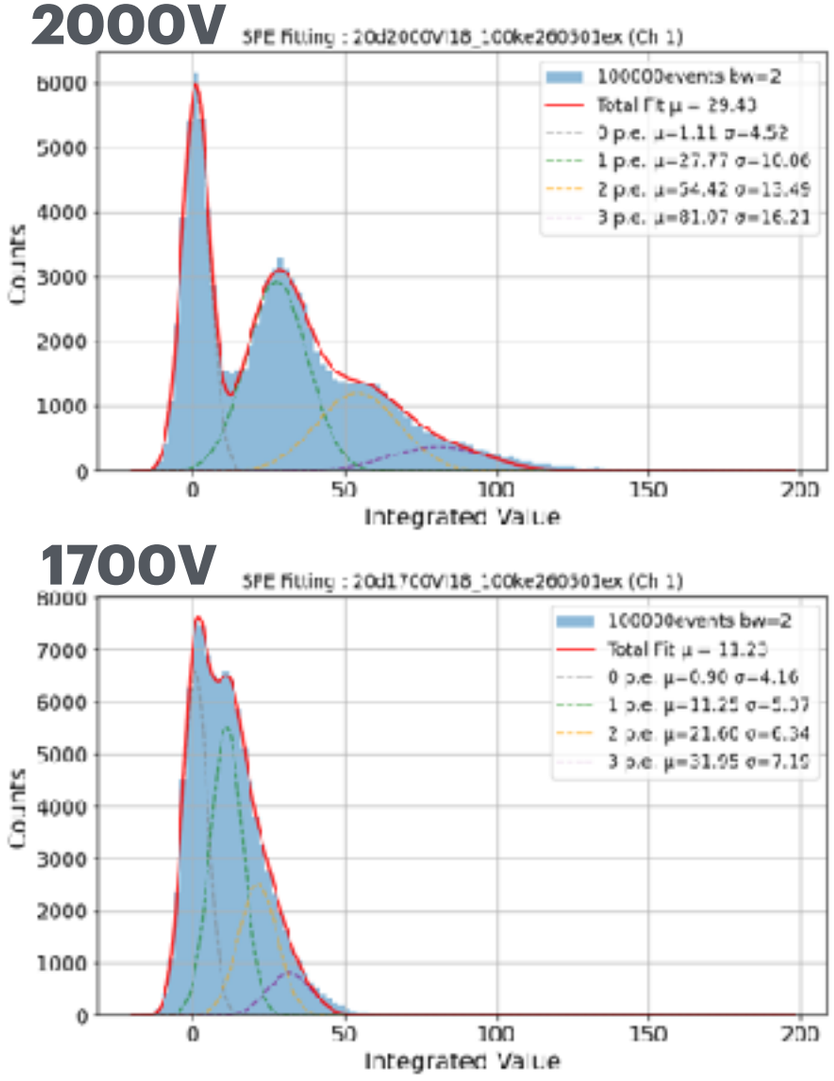
The light source is a temperature and light output stabilized LED with peak wavelength of 365 nm (+-5 nm). There is a feedback loop with a photodiode to stabilize the light output.

SPE Measurement at 20°C

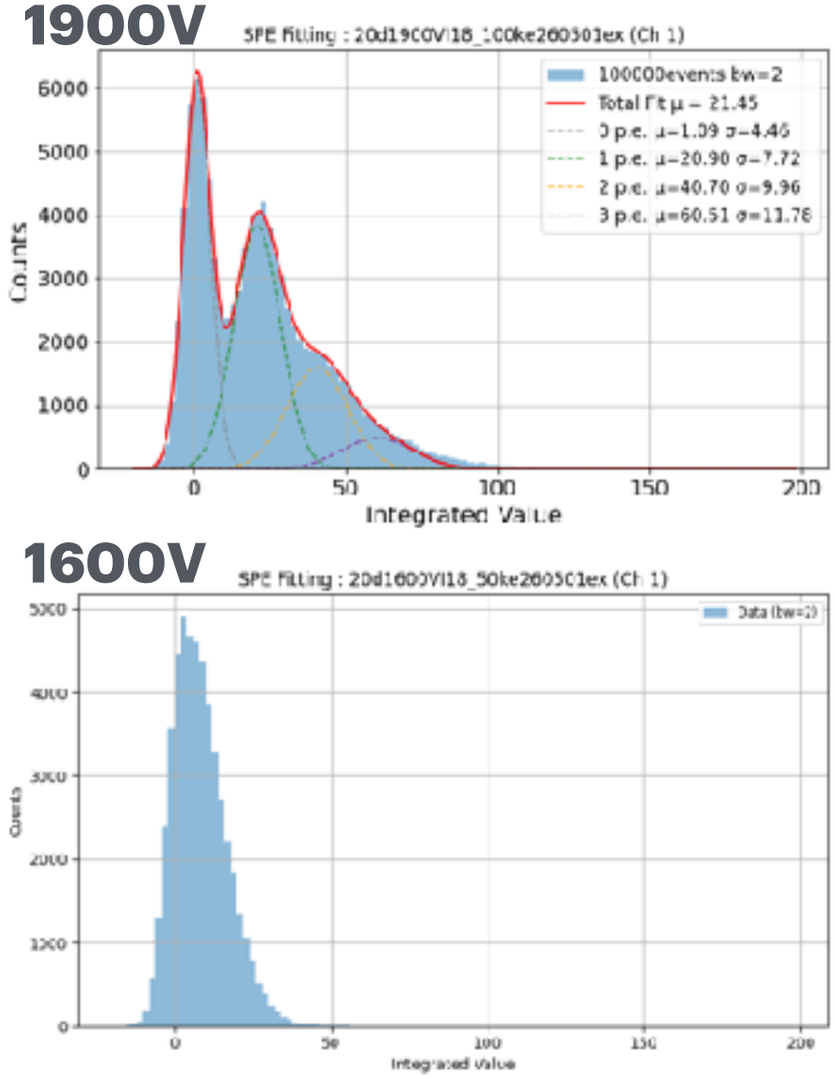
Fitting

$$S(x) = A \sum_{n=0}^{\infty} P(n;\mu) \cdot G_n(x)$$

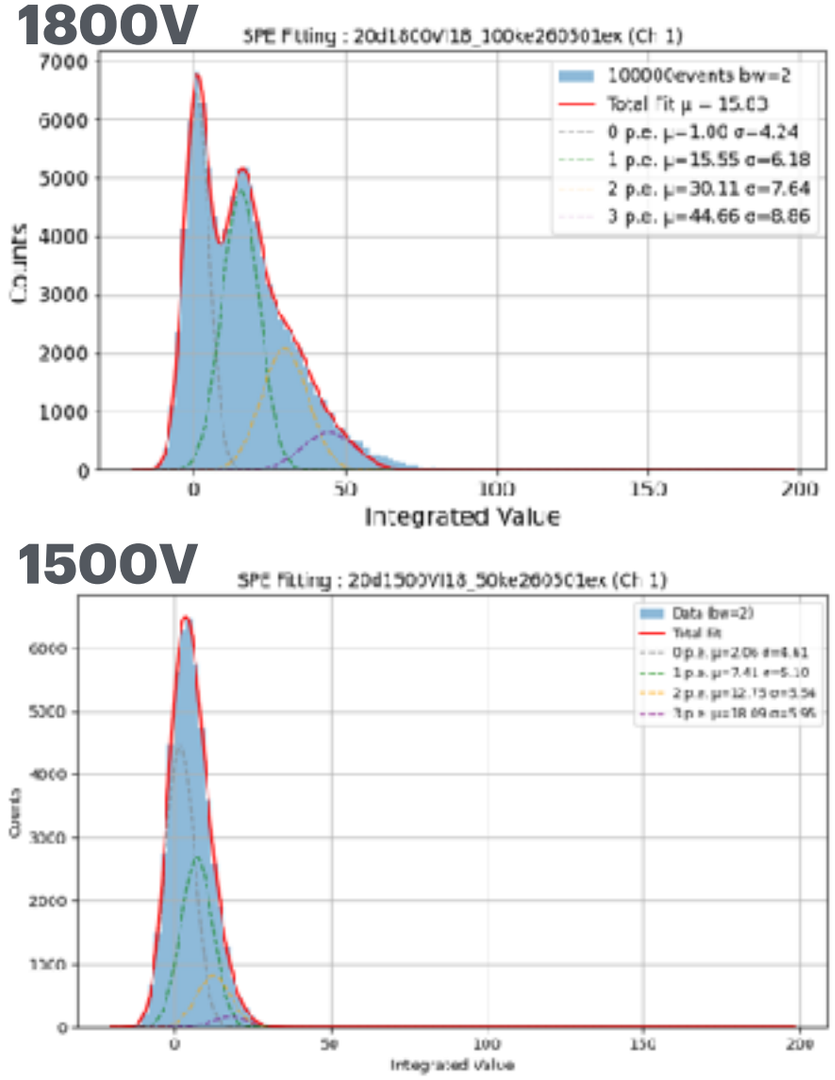
2000V



1900V



1800V



1700V

1600V

1500V

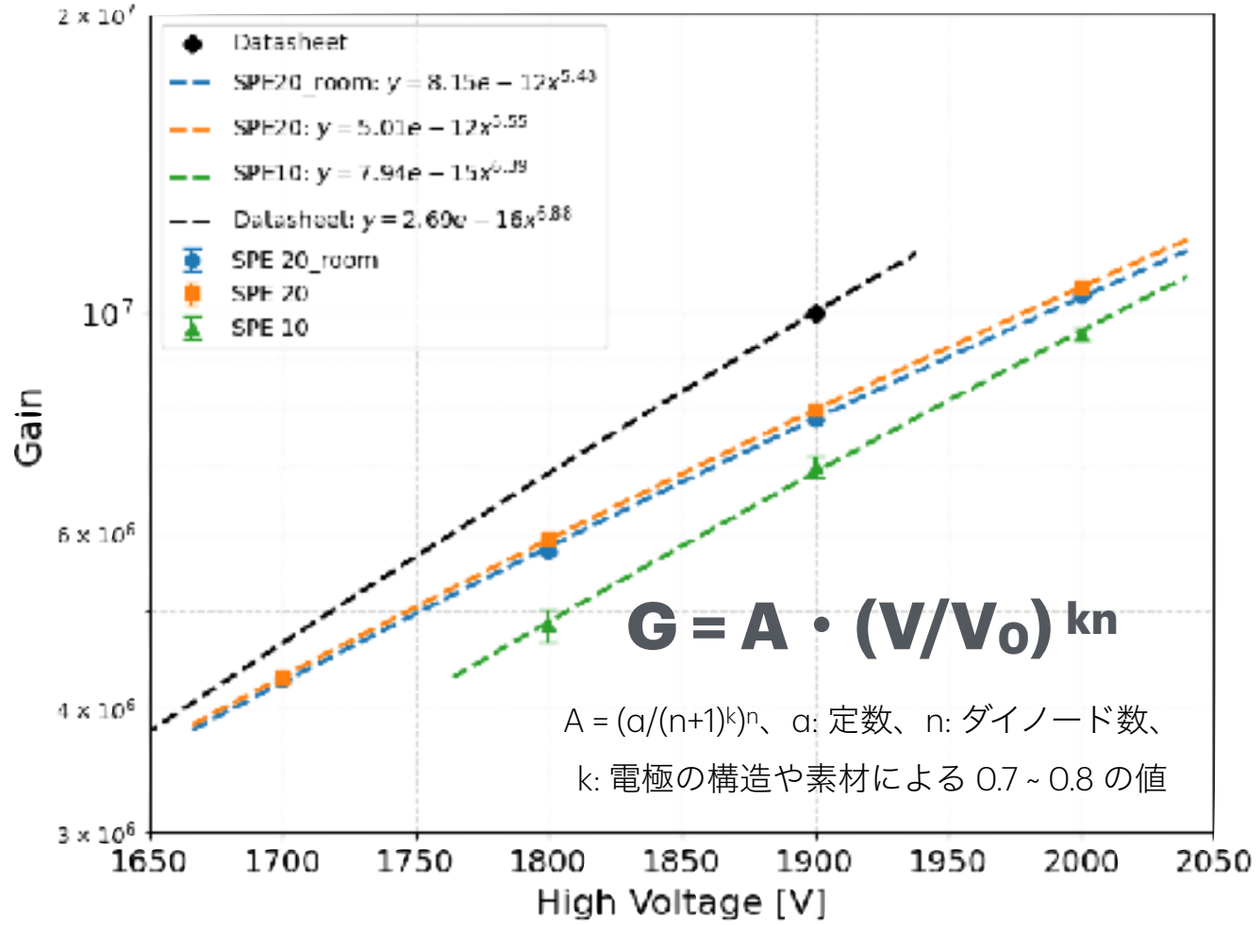
Note: SPE measurement below 1600V is challenging in the current setup due to low signal-to-noise ratio.

HV dependence

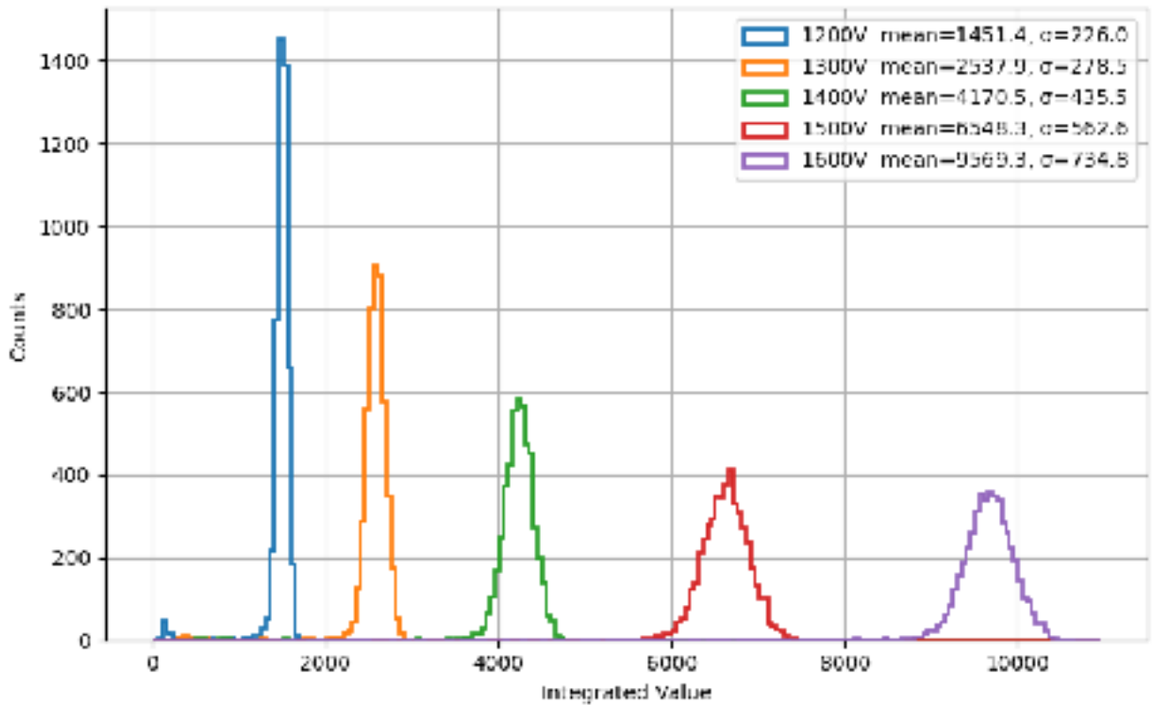
① temp bath: off
Room temperature ~ 20°C

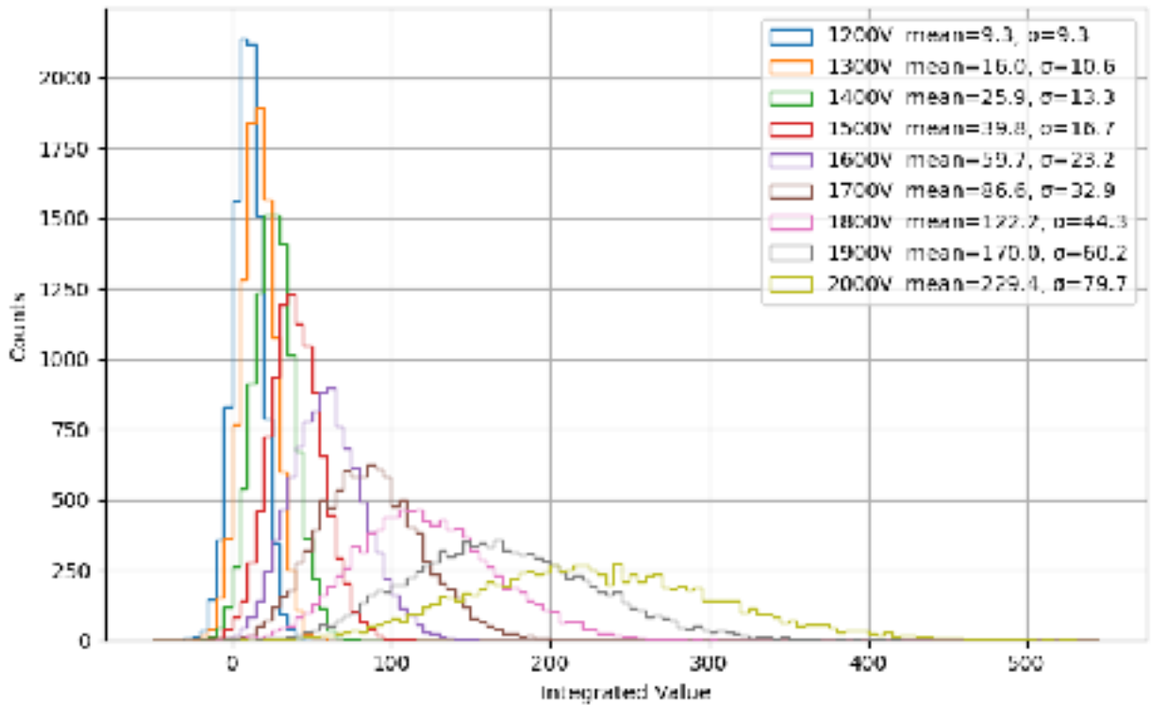
② Temp bath: on, 20°C

③ Incubator: on 10°C
※ Without LPF



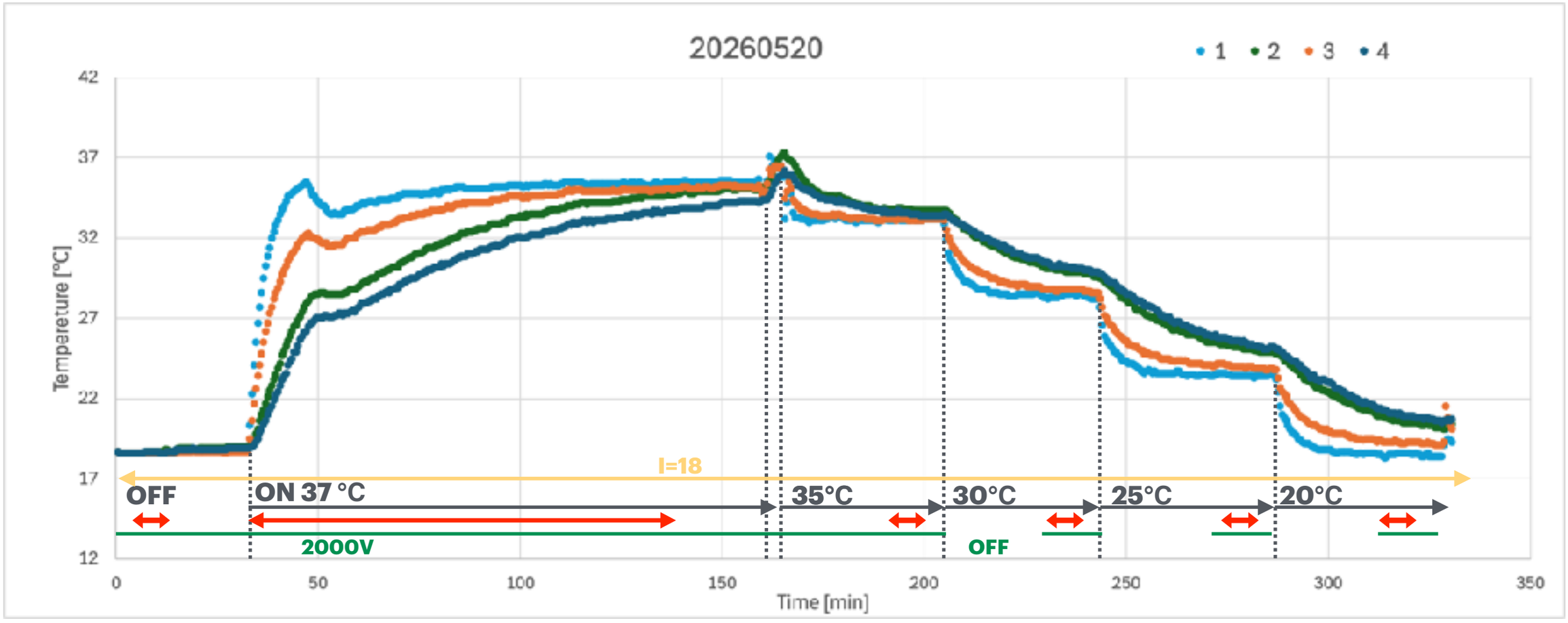
With YAP and I＝900 (50 times the light intensity of SPE)measurement

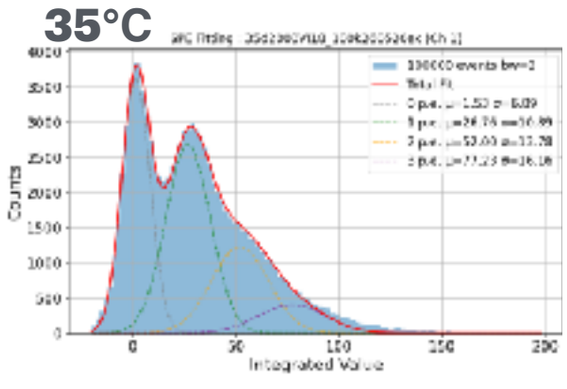


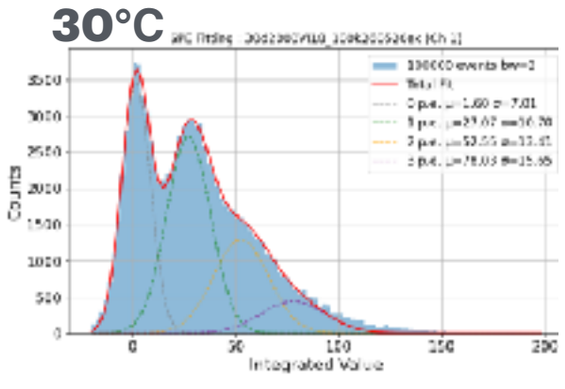


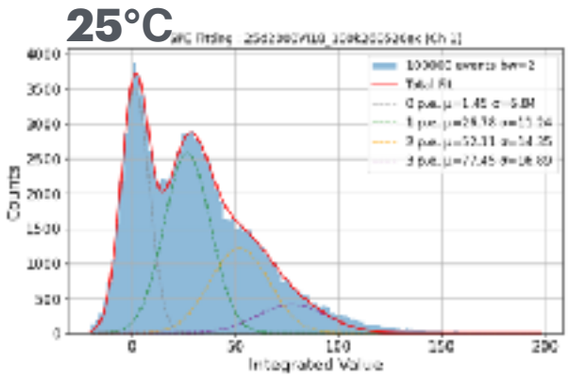
Measurement ④

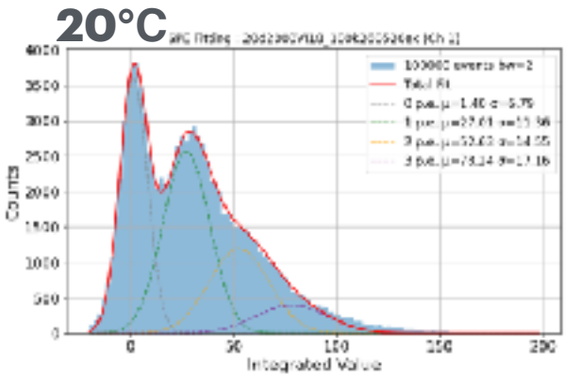
T = 35, 30, 25, 20 °C, HV = 2000V, I=18, SPE measurement





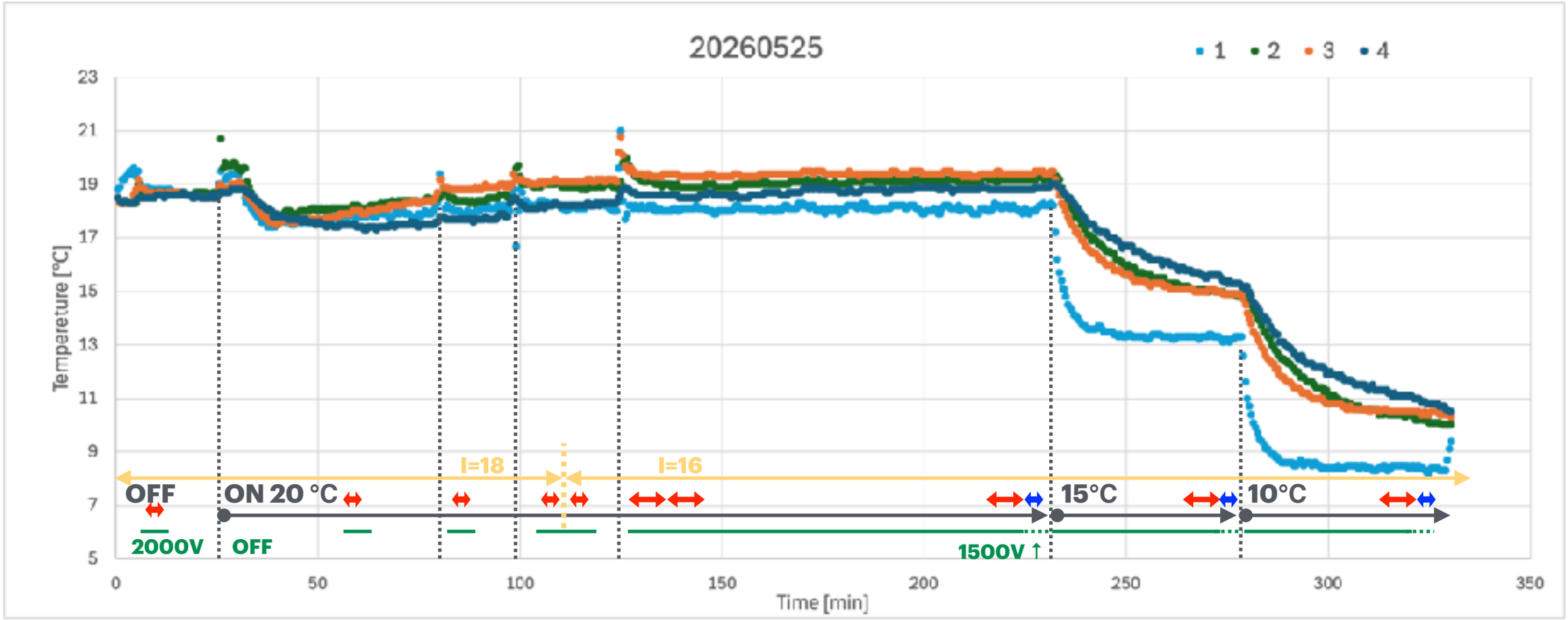




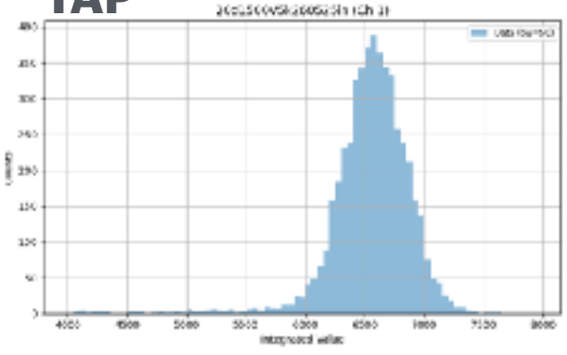


Measurement ⑤

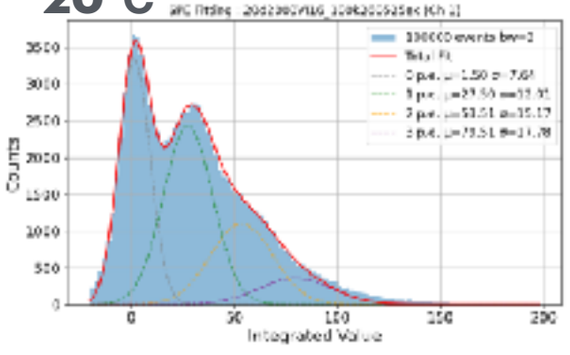
T = 20, 15, 10 °C, **HV = 2000, 1500 V**, **I=18,16**, **SPE** & **YAP** measurement



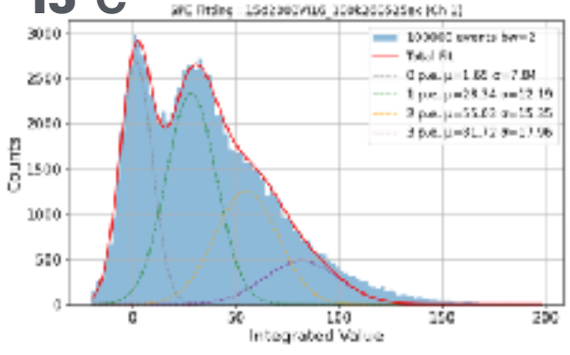
YAP



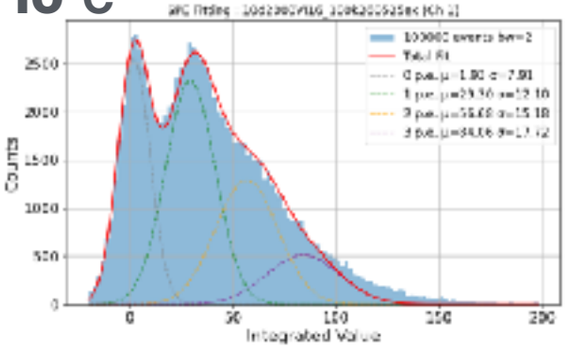
20°C



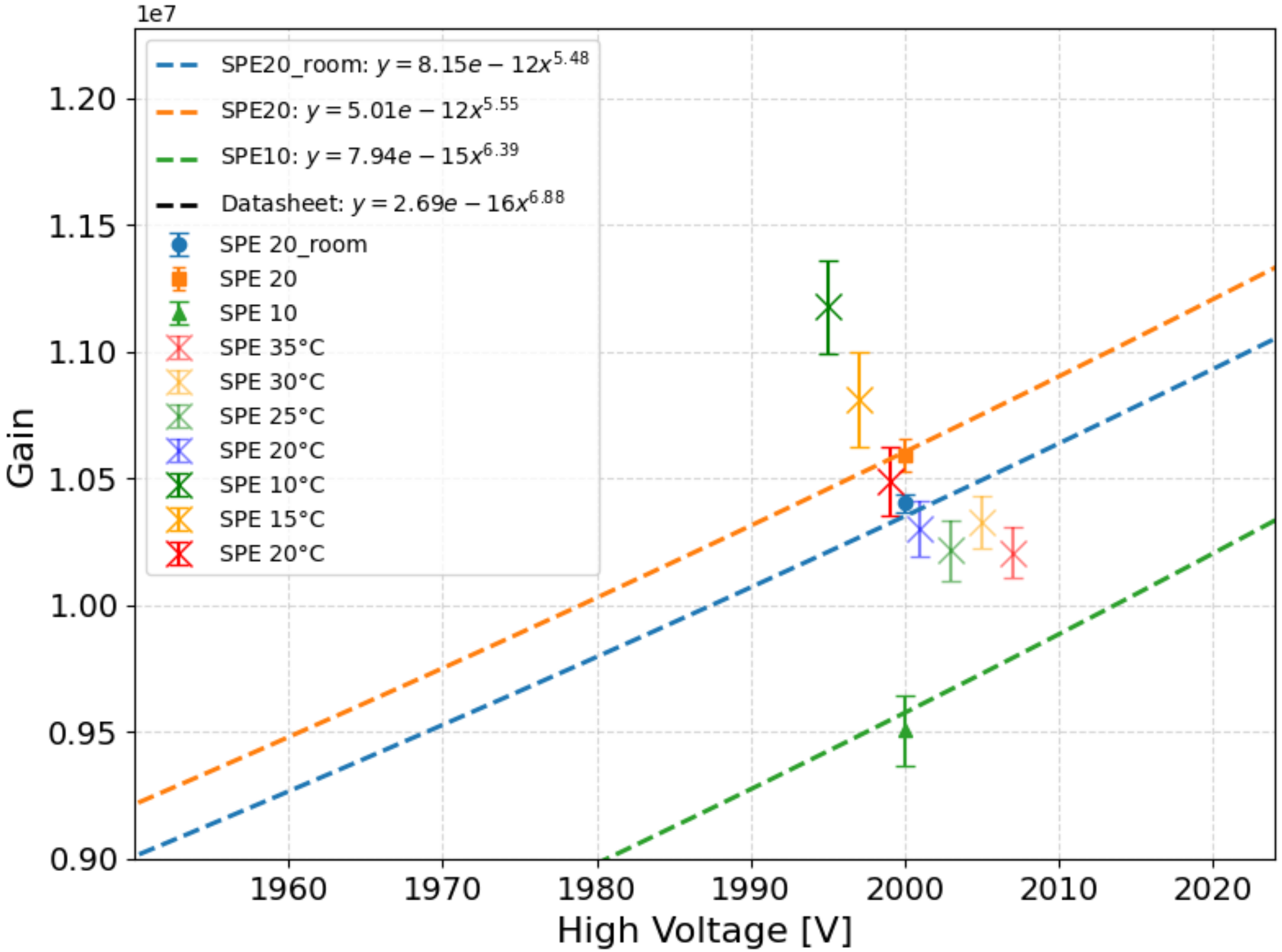
15°C



10°C



HV dependence of Gain



Temperature dependence of Gain