Results from 6x6 cm^2 Argonne MCP photon detector tests

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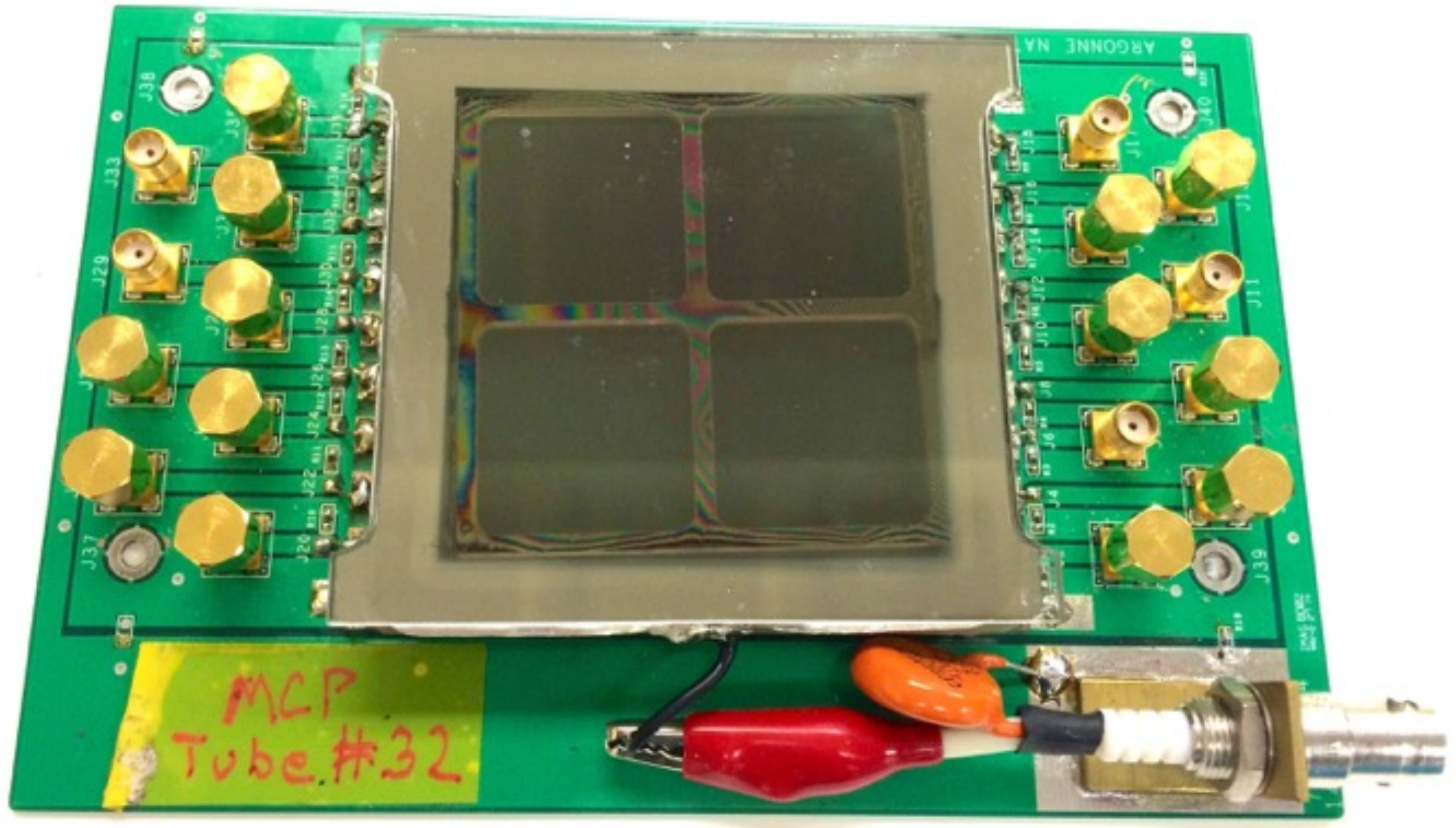
RICH 2016, 6th September

Thanks to ANL for loan of MCP tile

Overview

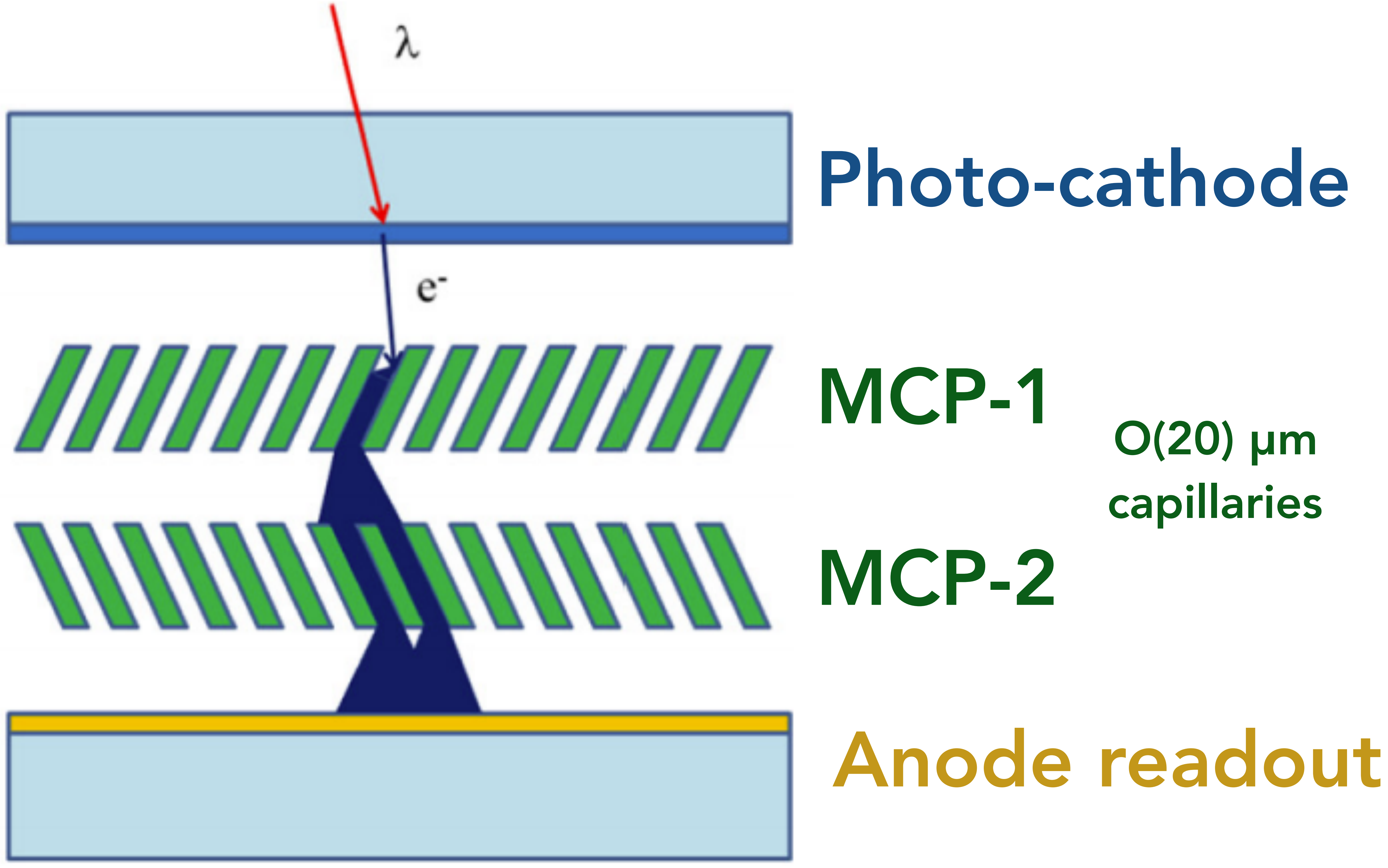
- Motivation for using MCPs (future) particle physics experiments.
- Edinburgh testing facilities.
- Test results
  - HV scans
  - Magnetic field
  - Temperature



Also see talk: "Planar microchannel plate photomultiplier with VUV-UV-Vis full range response for fast timing and imaging applications" Junqi Xie

Multi-channel plate detectors

- Sensitive to single photons
- Picosecond level time resolution
- Sub-mm level position resolution
- High gain (10^6-10^7)
- Low noise



[Nuclear Instruments and Methods in Physics Research A 804 (2015) 84–93]

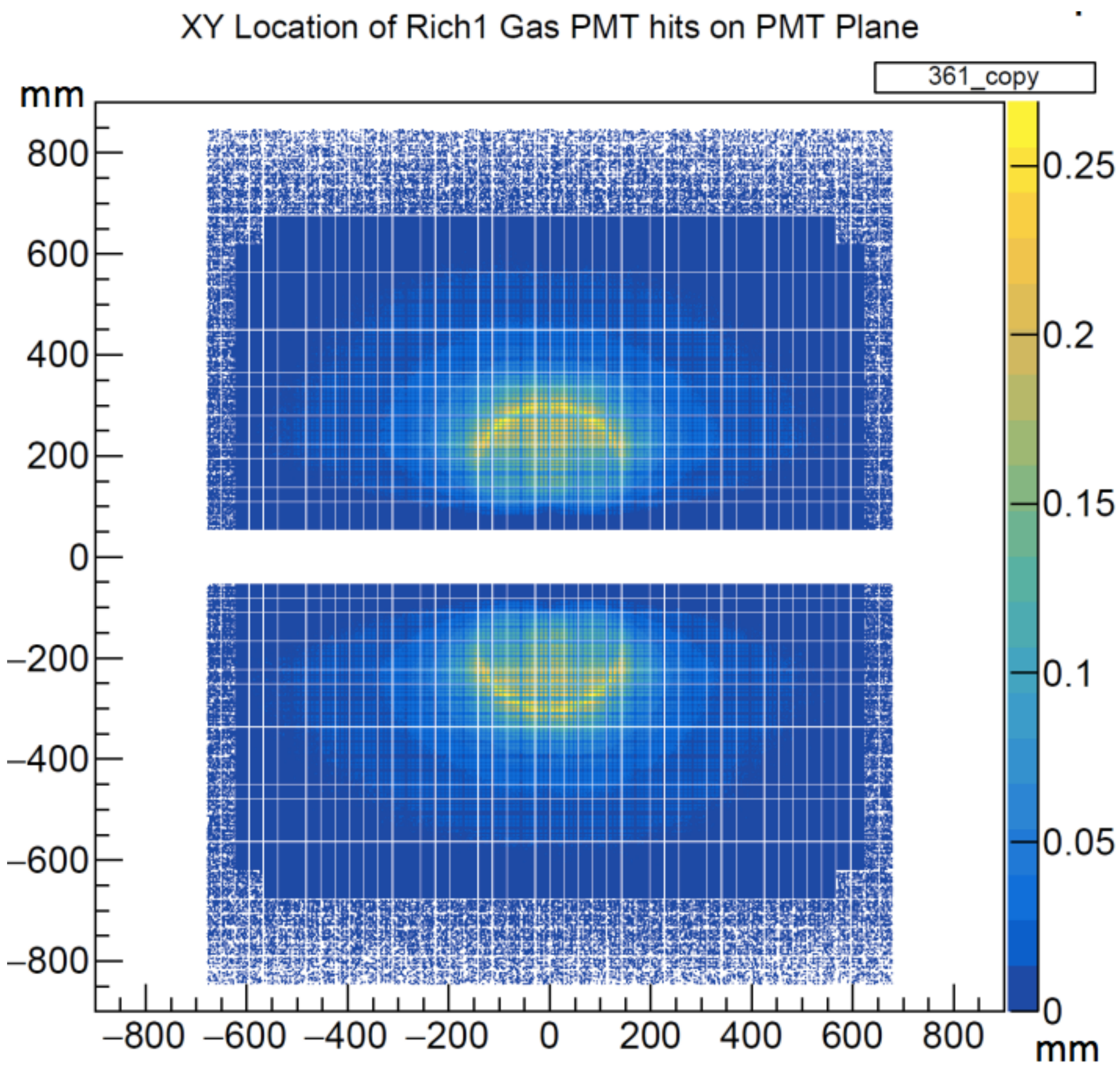
Application: LHCb upgrade

- Occupancy in RICH-1 central region for LHCb future upgrade (~10^{34} $cm^{-2}s^{-1}$ in HL-LHC era) is high (~25%)

- RICH-1 has intrinsic timing resolution of ~5 ps, which raises the possibility of timing photons.

- MCPs could provide the timing information to associate photons with individual tracks ⟹ would reduce overall occupancy.

- Need 100 6x6 cm^2 (12 20x20 cm^2) MCPs to tile RICH-1 central region.

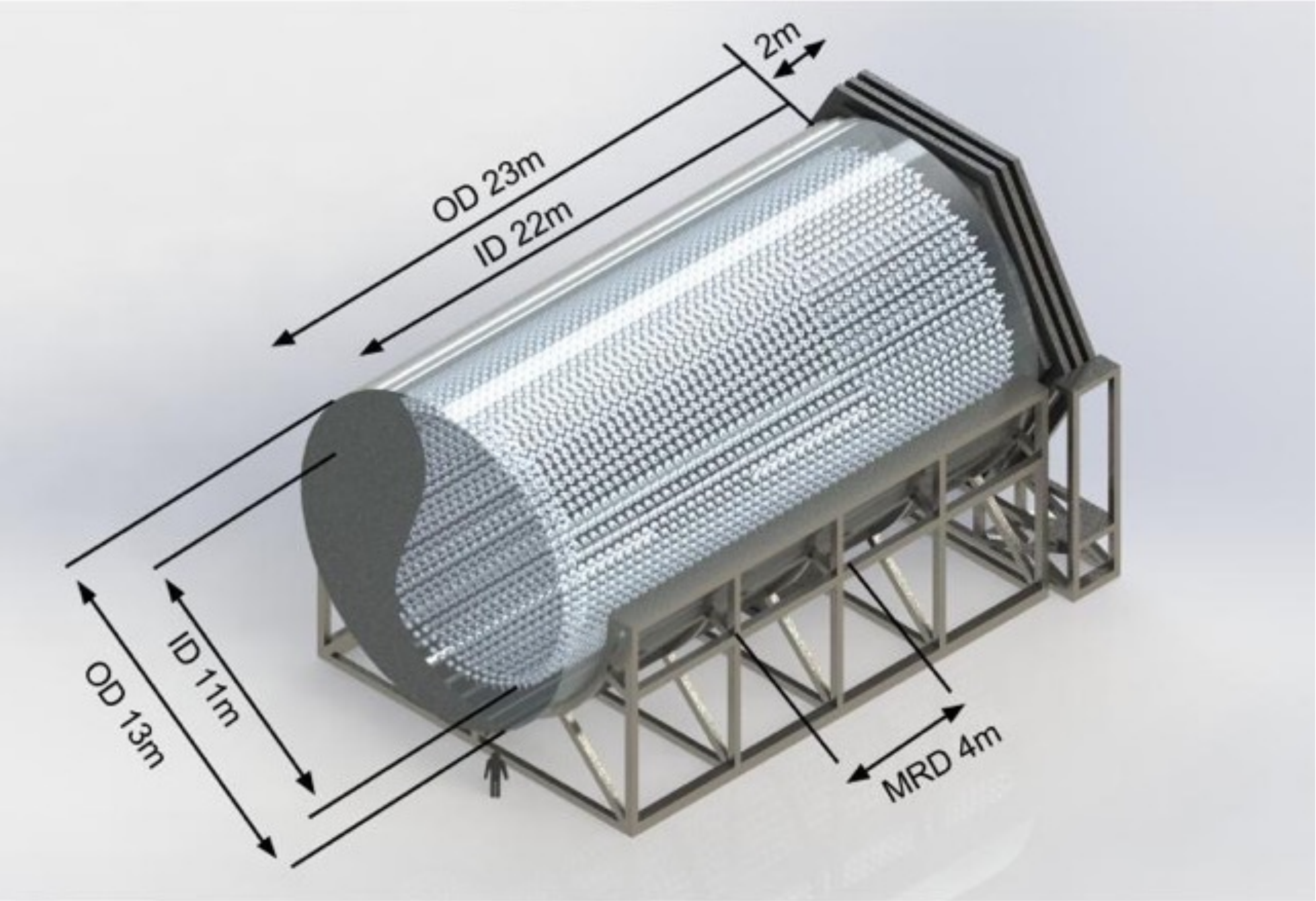


[Easo, https://indico.cern.ch/event/481359/contributions/1157547]

Application: neutrino detectors

- MCPs bring fast timing and improved spatial resolution.
- Potential to tile large surface areas at reasonable cost.
- Can lead to improved designs for future water Cherenkov or liquid Argon neutrino experiments.
  - Maximises fiducial volume of detector (get closer to the walls).
  - Better discriminate between dark noise and photons from neutron capture.
- MC shows that measuring photon arrival space-time point with resolution of 1 cm and 100 ps gives track and vertex reconstruction approaching **a few cm (and better neutrino energy resolution).**

TITUS

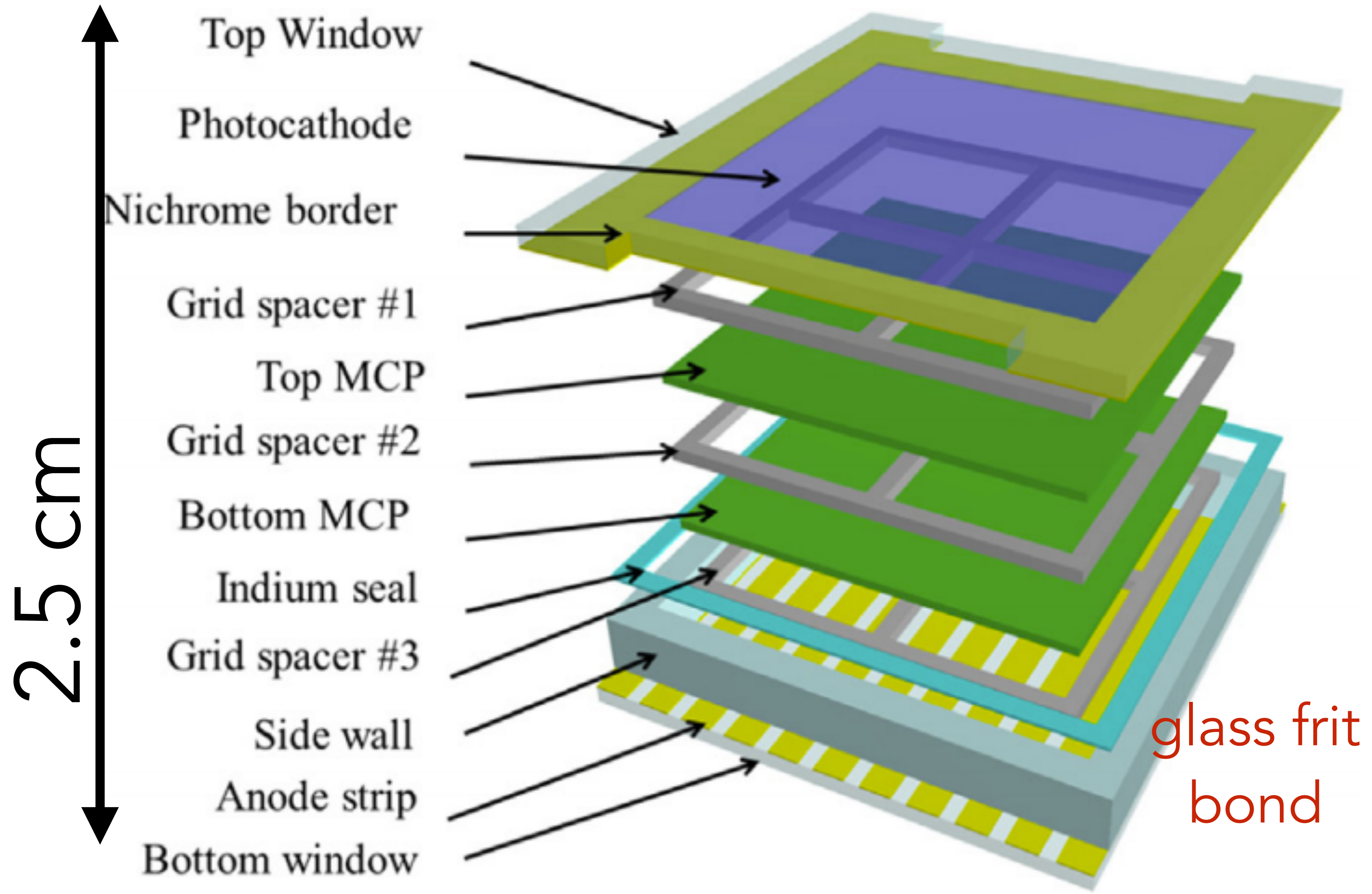


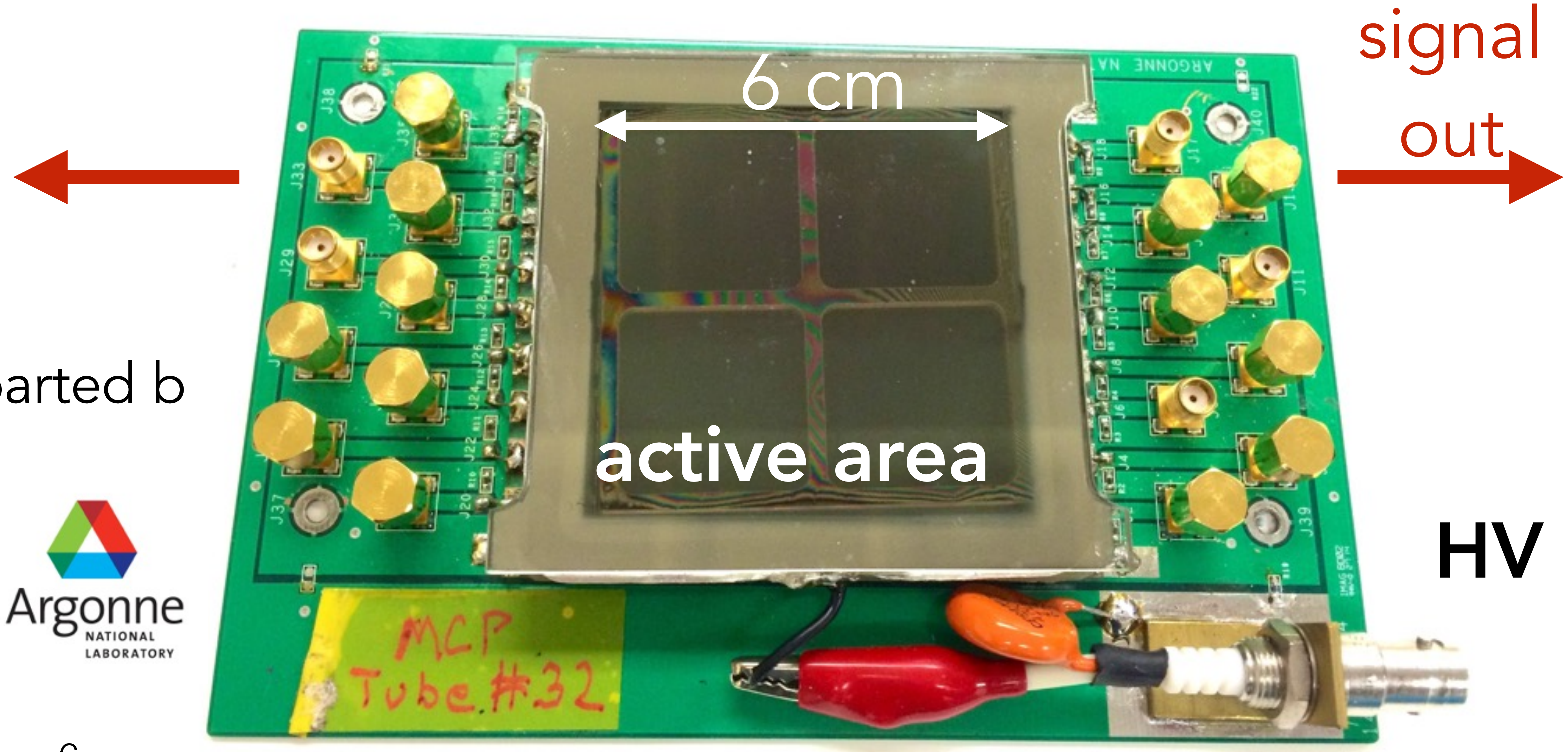
[Angel arXiv:1310.2654] [ANNIE LoI arXiv:1504.01480]
[TITUS intermediate detector for Hyper-K arXiv:1606.08114]

6x6 cm^2 prototype

- LAPPD: goal is 20x20 cm^2 tubes. [http://psec.uchicago.edu]
- "Tube 32": **one of the first prototypes** manufactured by Argonne National Laboratory.
- MCP borosilicate glass substrates made by Incom Inc.
- Bialkali photocathode (QE ~ 15%).
- 9 **strip-line anodes** (read out on both sides).
- All glass, hermetically sealed ⟹ lower cost.
- Resistive and secondary emission properties imparted b Atomic Layer Deposition.
- Resolutions: ~57 ps, < 0.8 mm

[NIM in Physics Research A 804 (2015) 84–93]

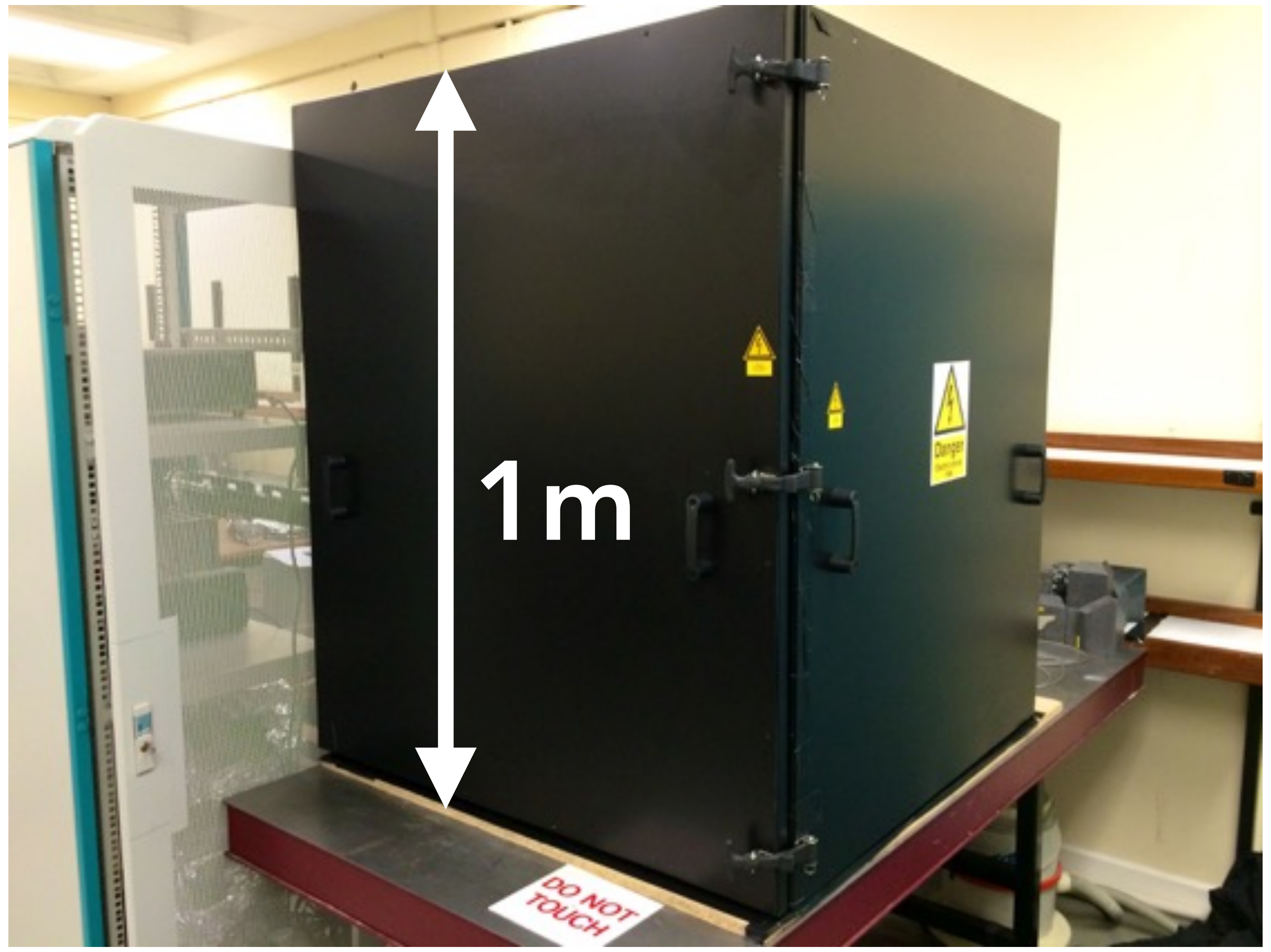


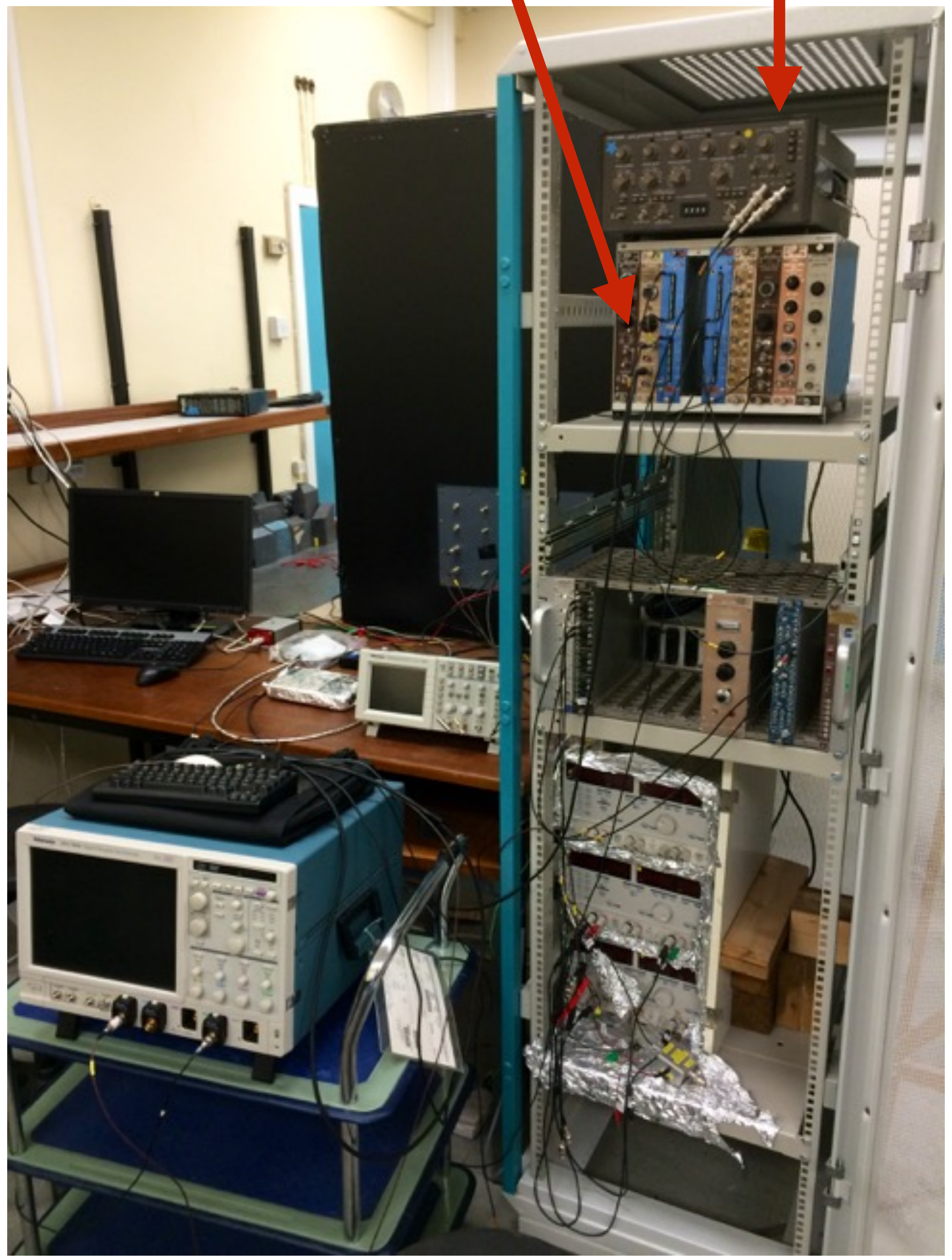


Argonne NATIONAL LABORATORY

Edinburgh test facility

- Pulse generator (100 kHz) used to pulse Edinburgh 470 nm **LED system**
  - **10 ns wide pulses**
  - Operate in single or multi-photon mode
  - Fed into box with optical fibre (12°). Not focussed.
- NIM modules for trigger
- Tektronix (6 GHz, 25 GS/s, currently broken…)
- LeCroy WavePro 960 (1 GHz, 4 GS/s quad)
- Custom LabView for DAQ + offline processing using custom python code

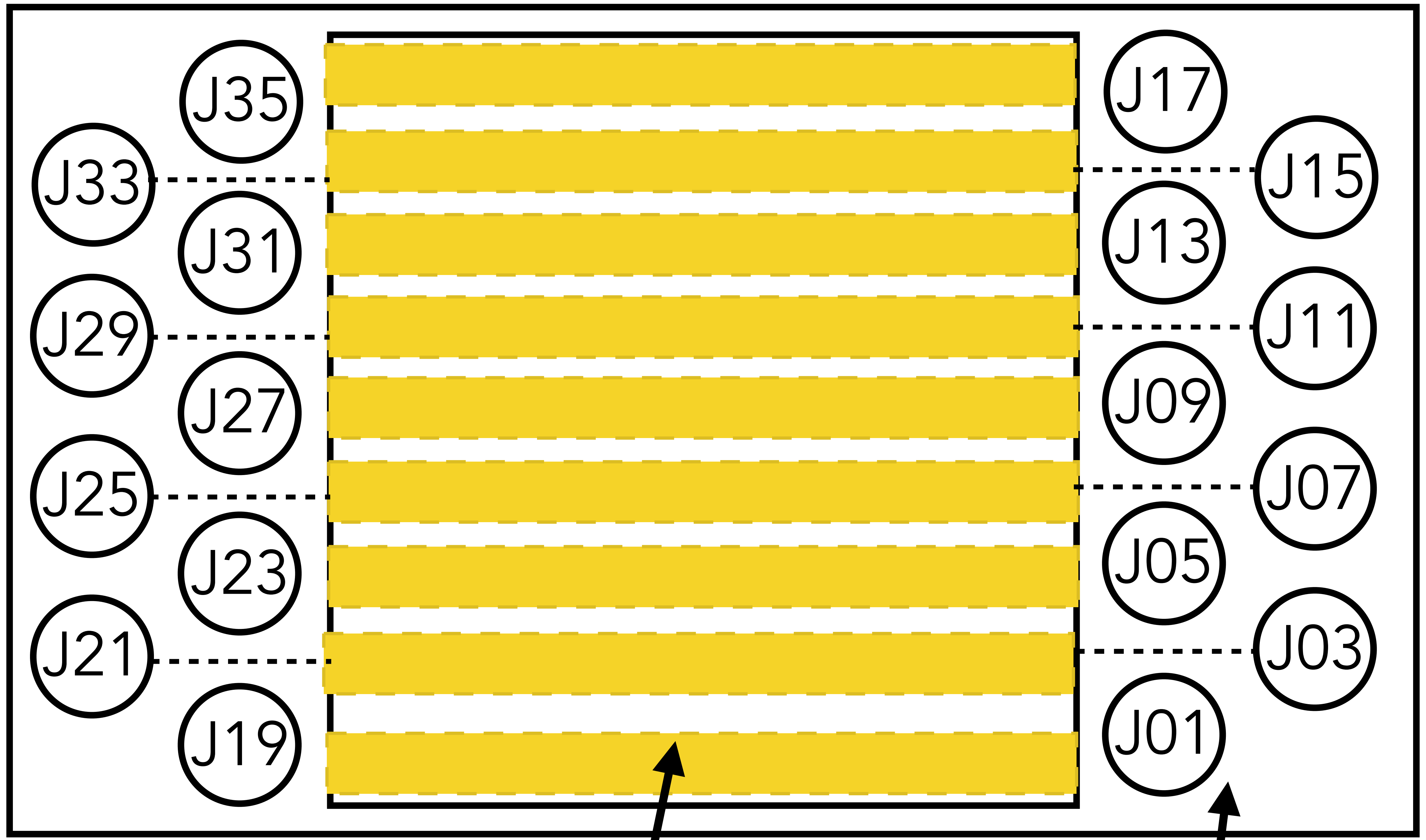




https://github.com/gcowan/hyperk/tree/master/lappd/spectra

MCP operation

Cartoon

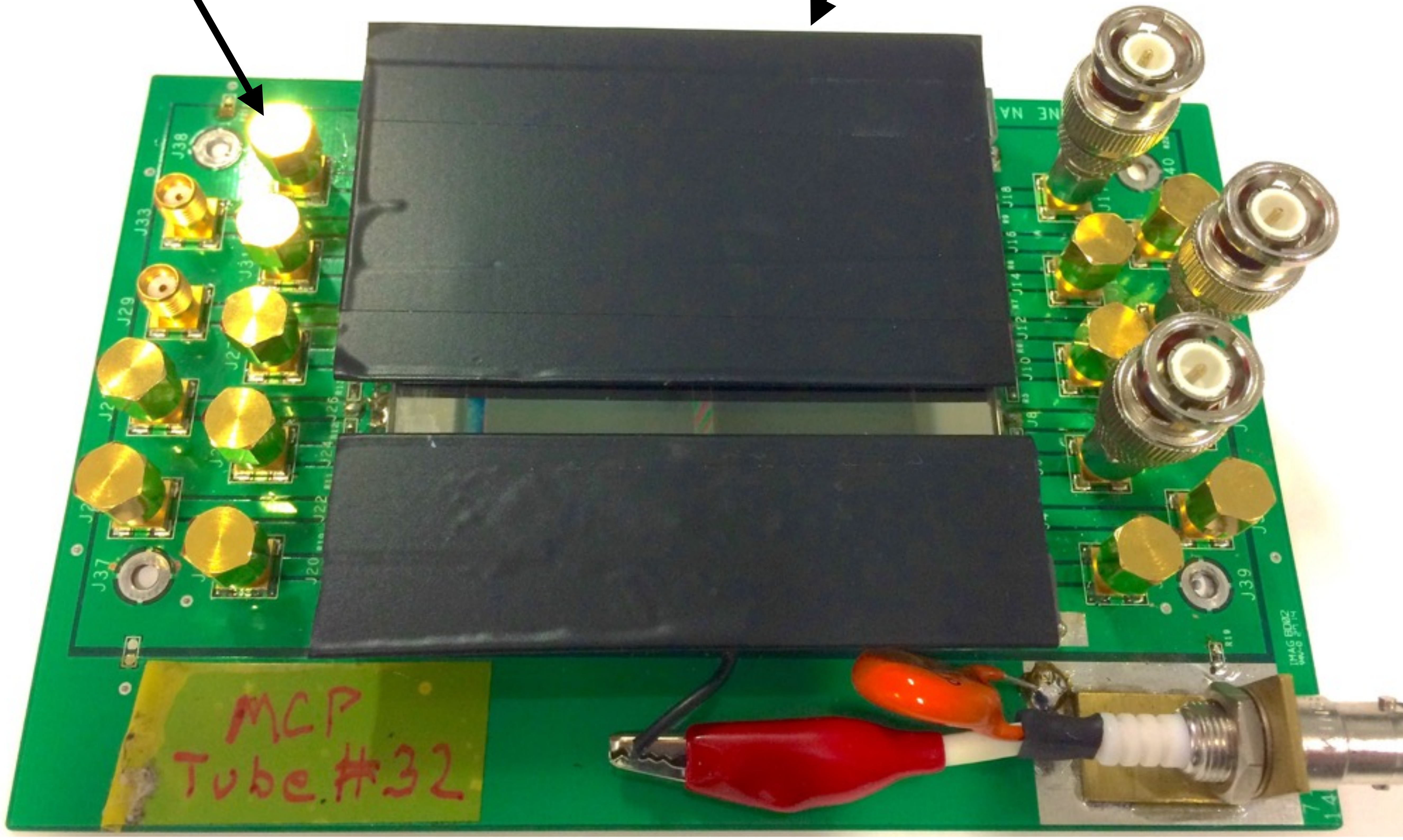


Anode strips

Channel numbers

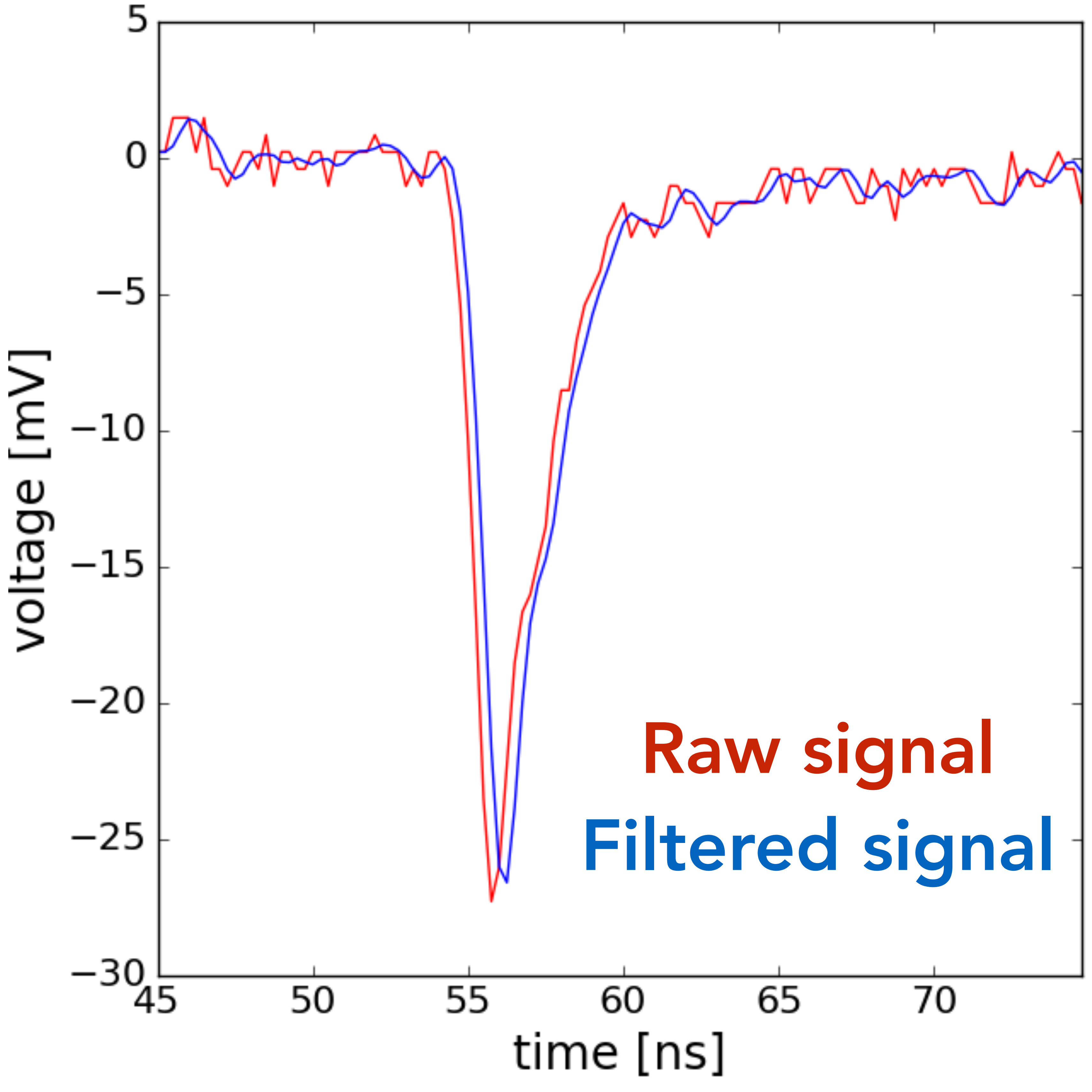
50Ω termination

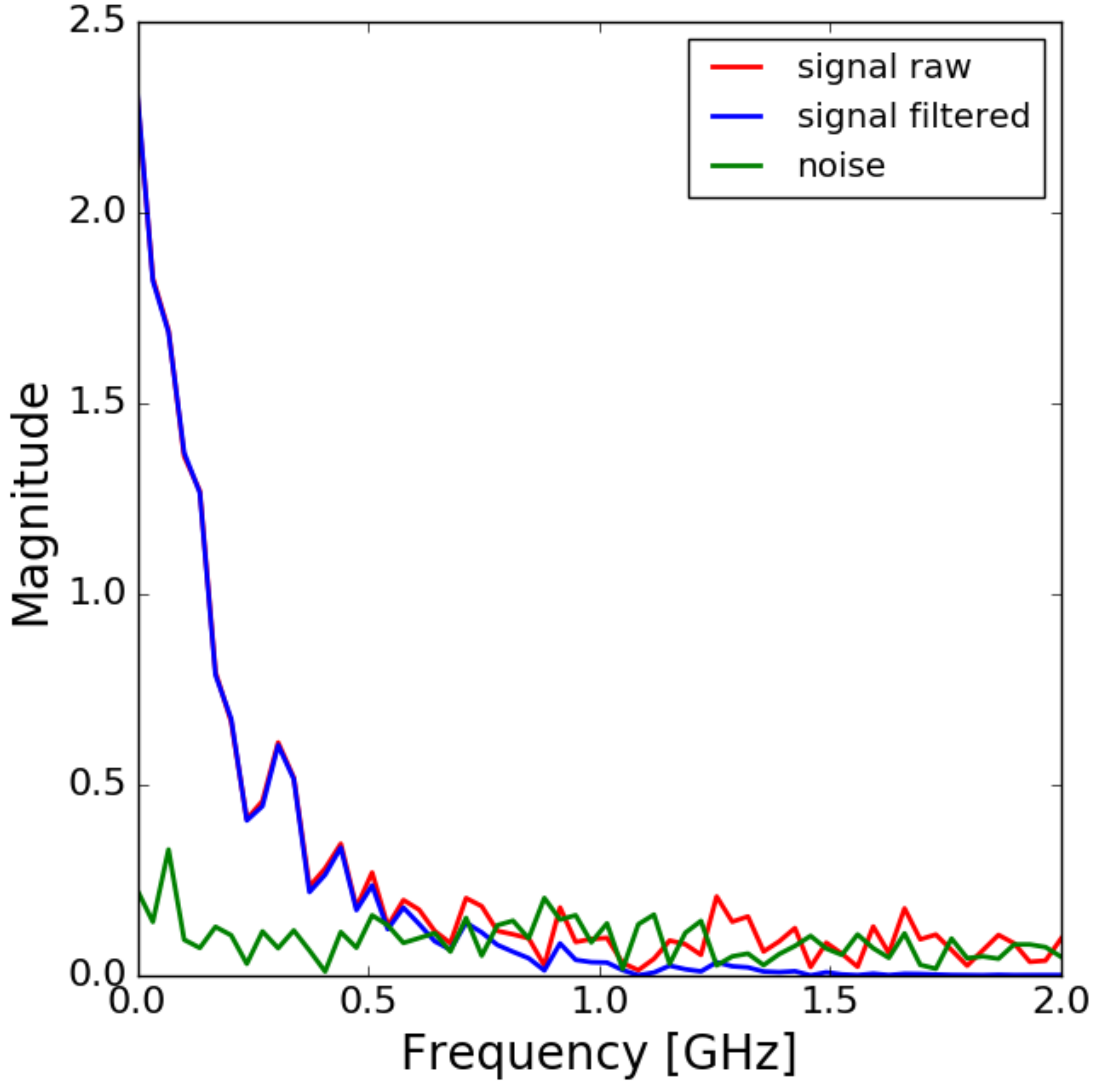
Mask



Pulse shape

- MCP has a ~5 ns pulse width @10% of max.
- The rise time is ~0.5 ns.
- Transit time spread of 0.06 ns for single photons. [NIM in PRA 804 (2015) 84–93]



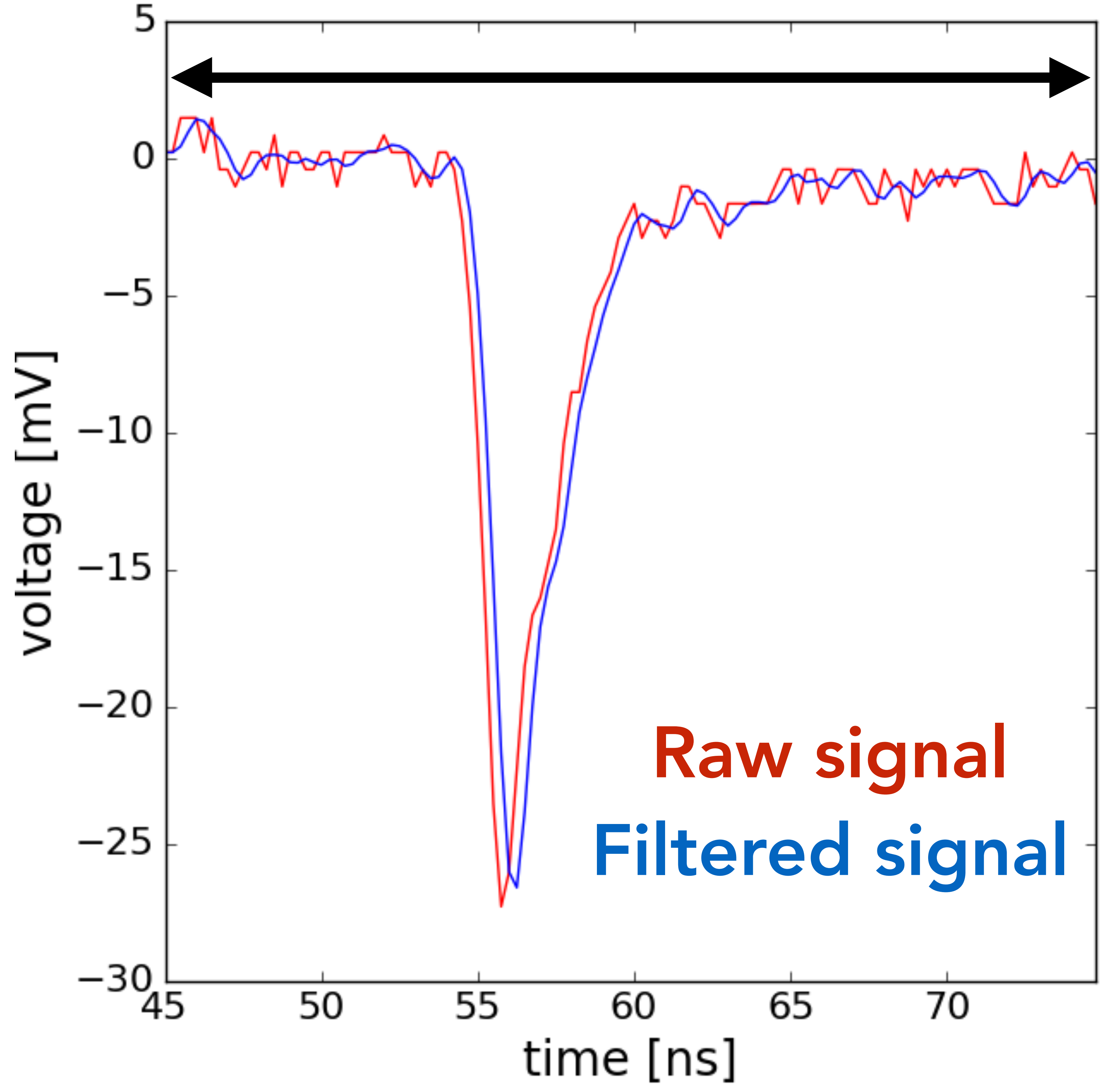


Apply Butterworth low bandpass filter (700 MHz) to remove noise

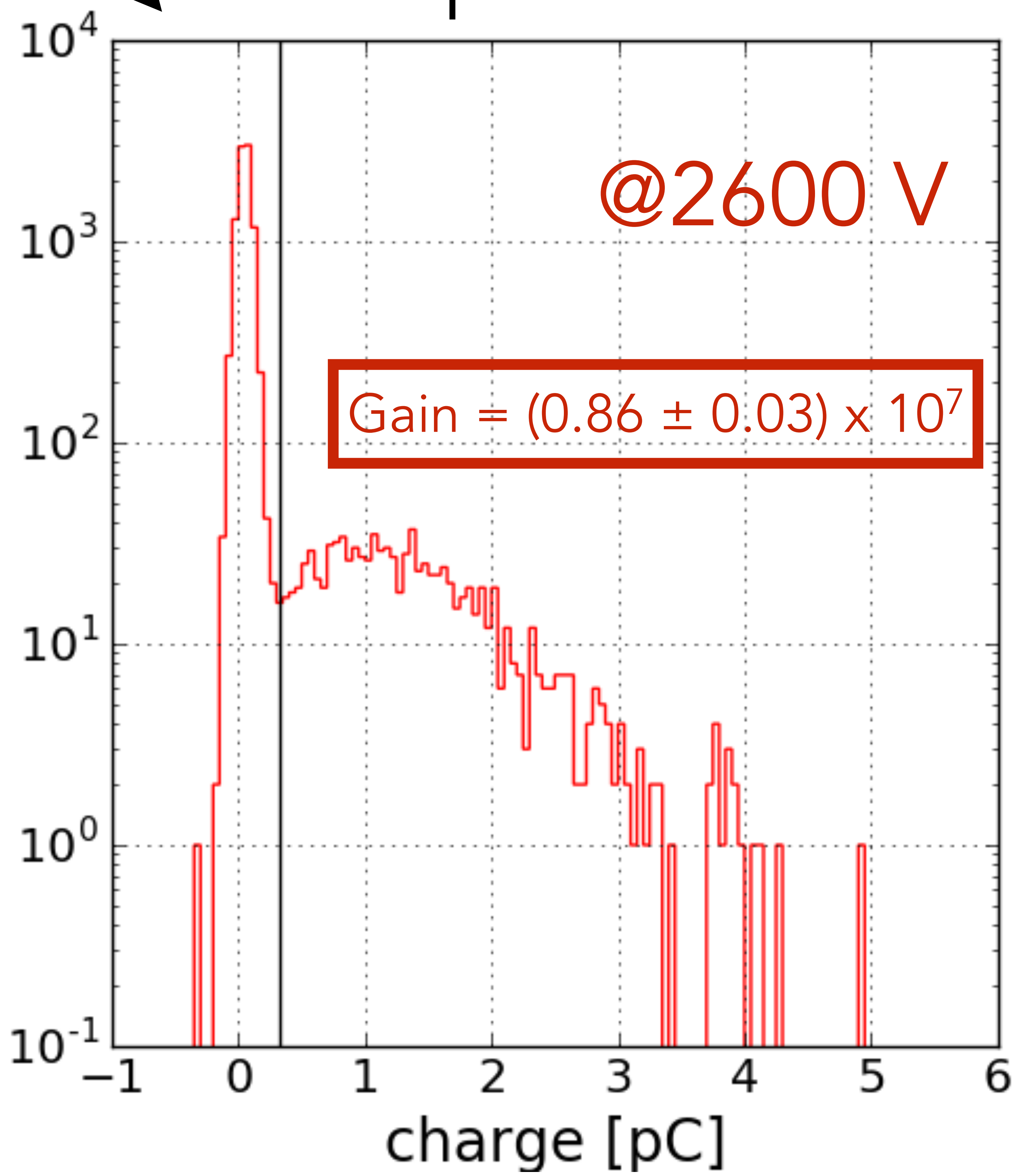
Charge spectra

Gain computed from mean of events above threshold

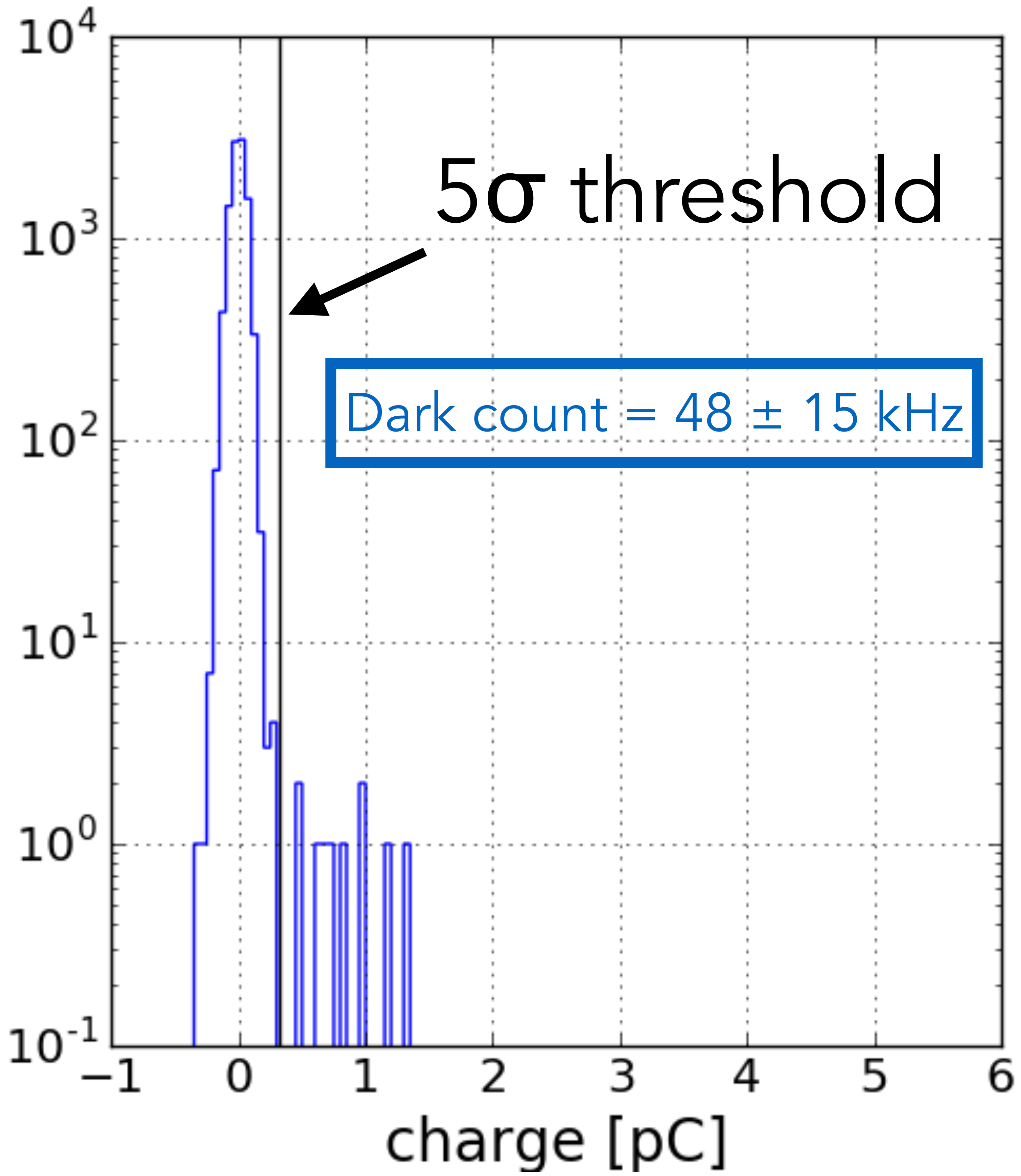
Integrate filtered signal for each event



Single photon spectrum



Pedestal

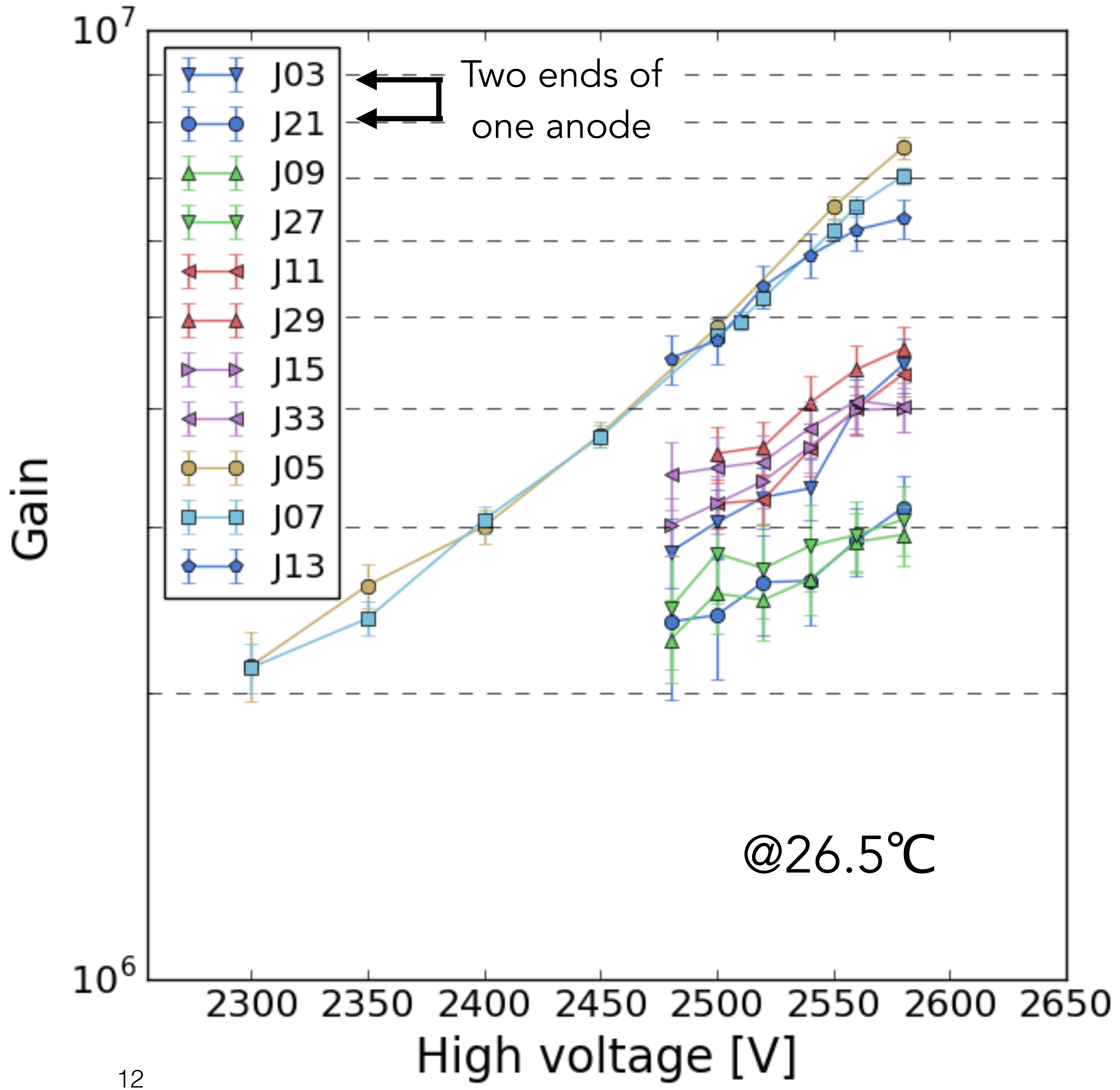


Variation between channels

Separation between pedestal and single photon peak varies between channels (see backup for more examples)

Gain curves

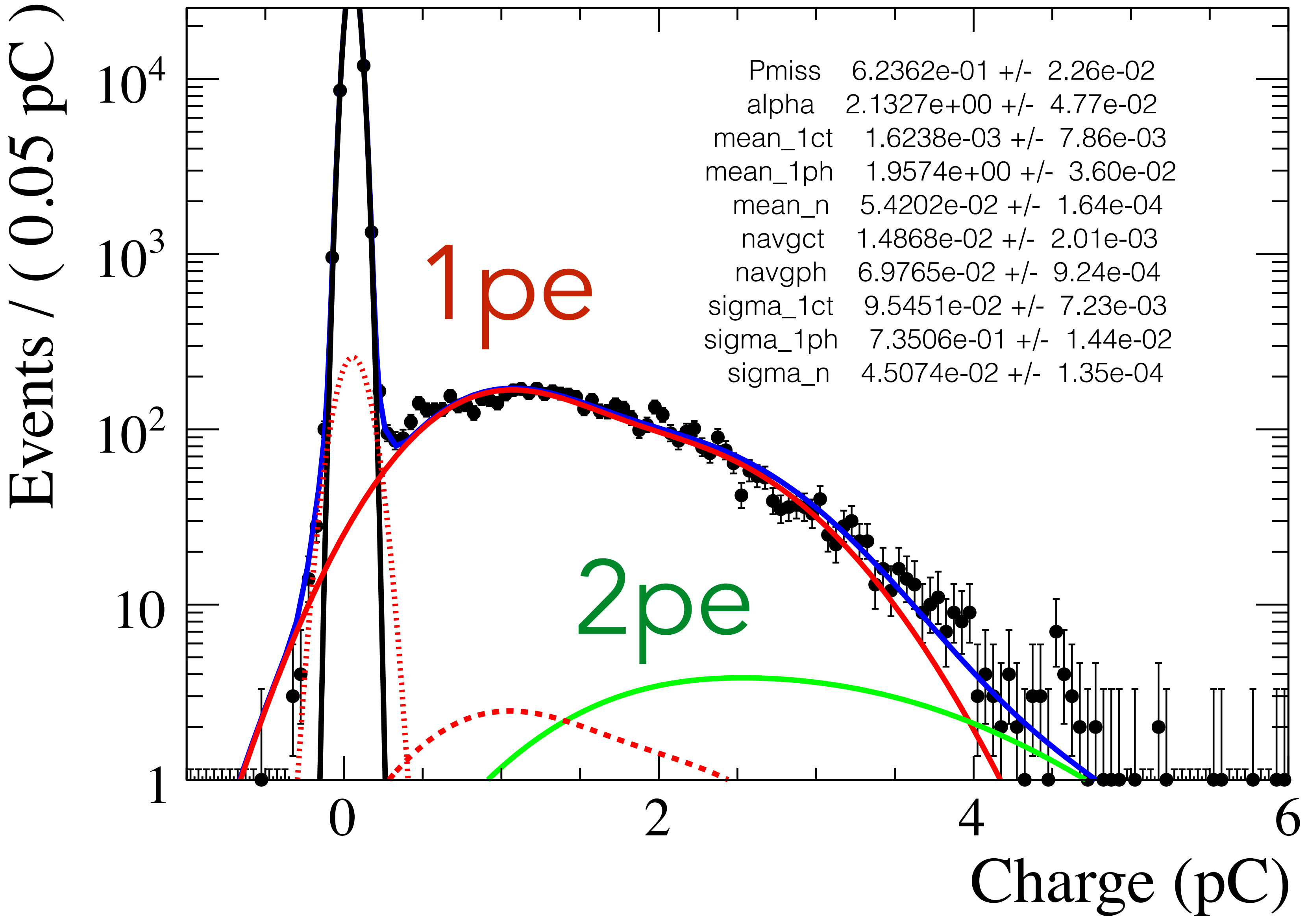
- Gains of 10^6-10^7
- Quite some variation in gain between channels.
- Saturation of gain towards 2600V?
- Below ~2450 V the single photon peak is small.
- J23, J25 (opposite J05, J07) not operational.

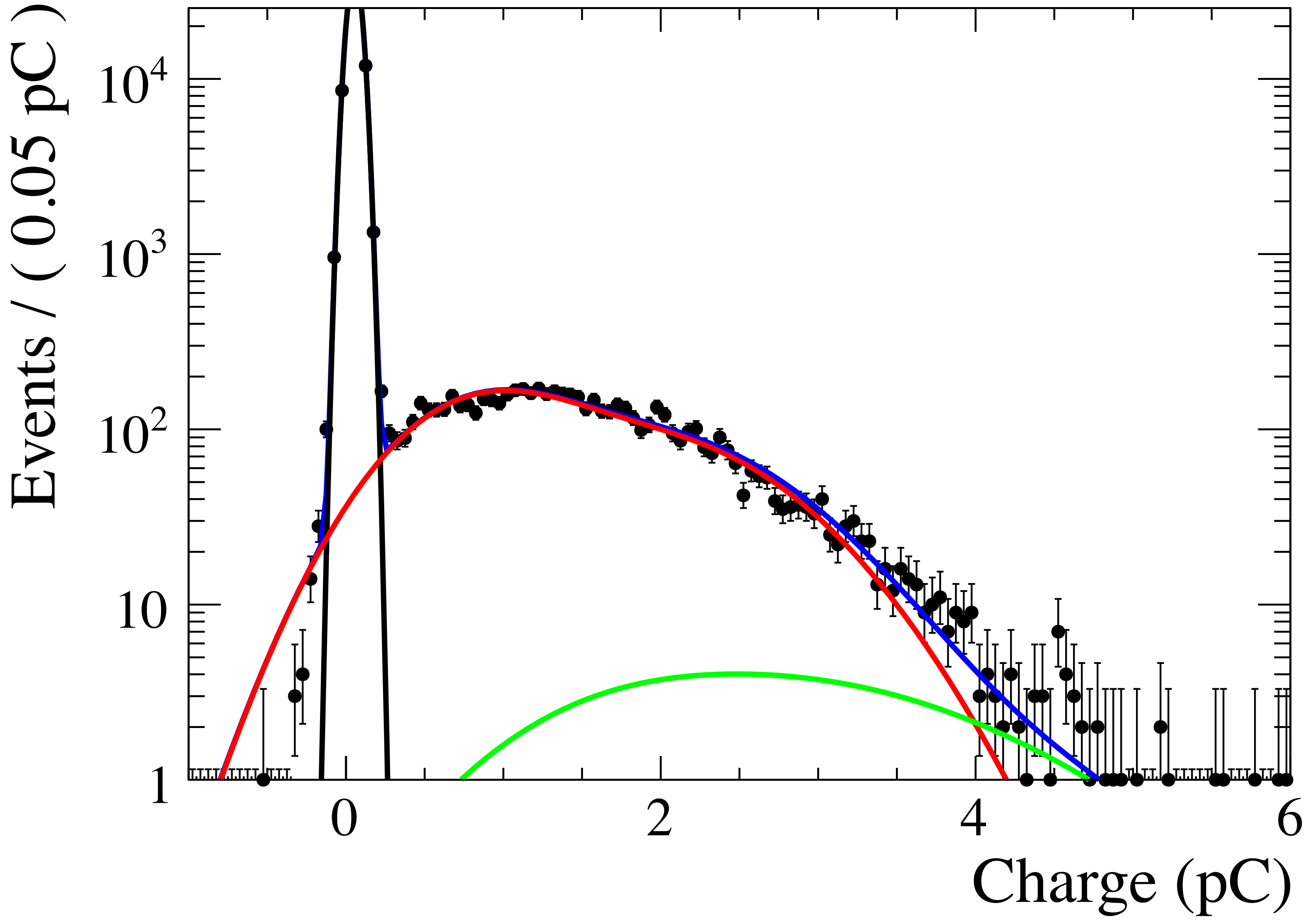


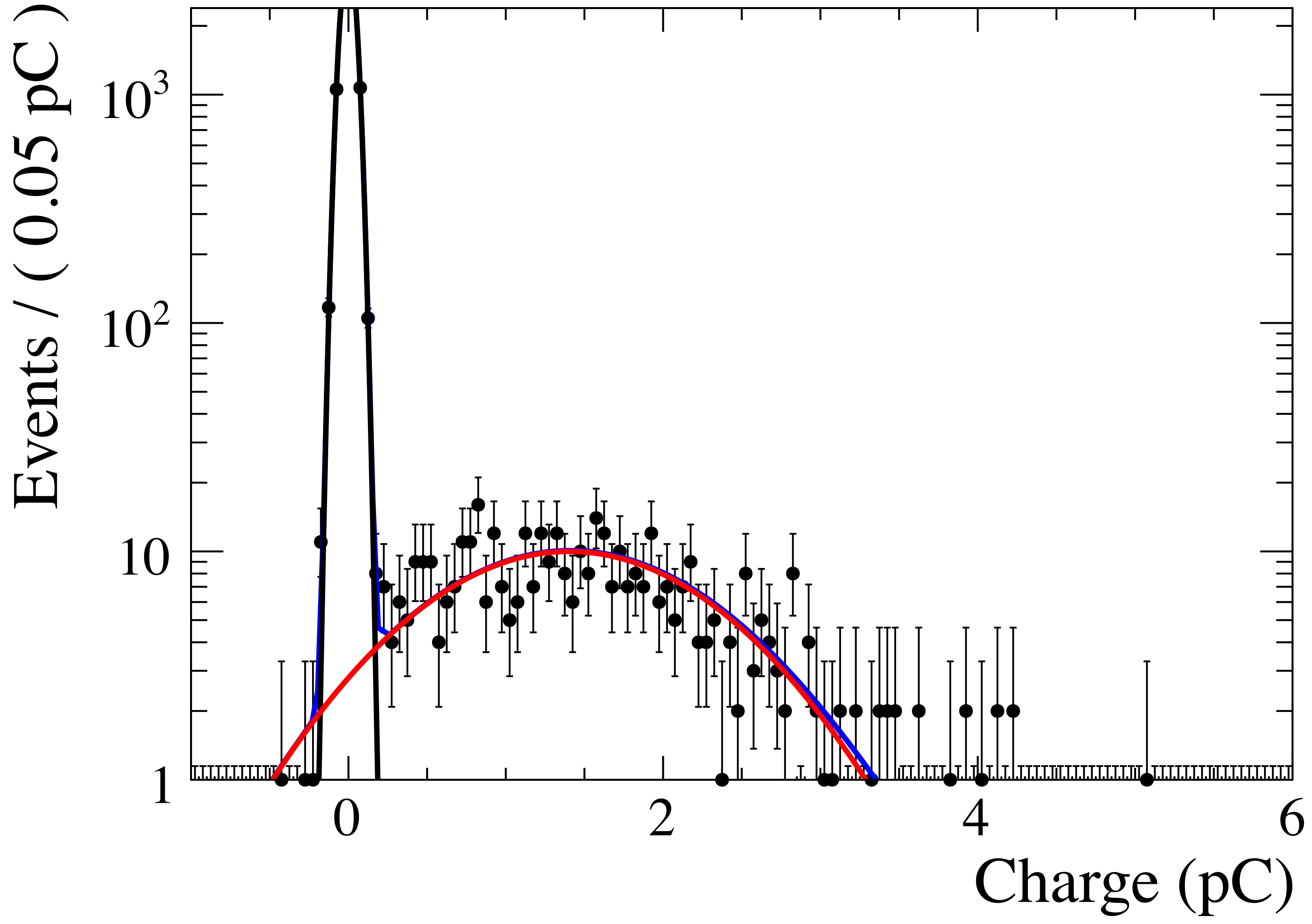
Signal fits

- Developing a fit model to describe the charge spectrum.
- Based upon existing code for LHCb MaPMT R&D
- Will allow for better estimate of the gain.
- Gaussian pedestal, Poisson sum of Gaussians for 1pe, 2pe… signals, plus contribution from "missing dynode" stages

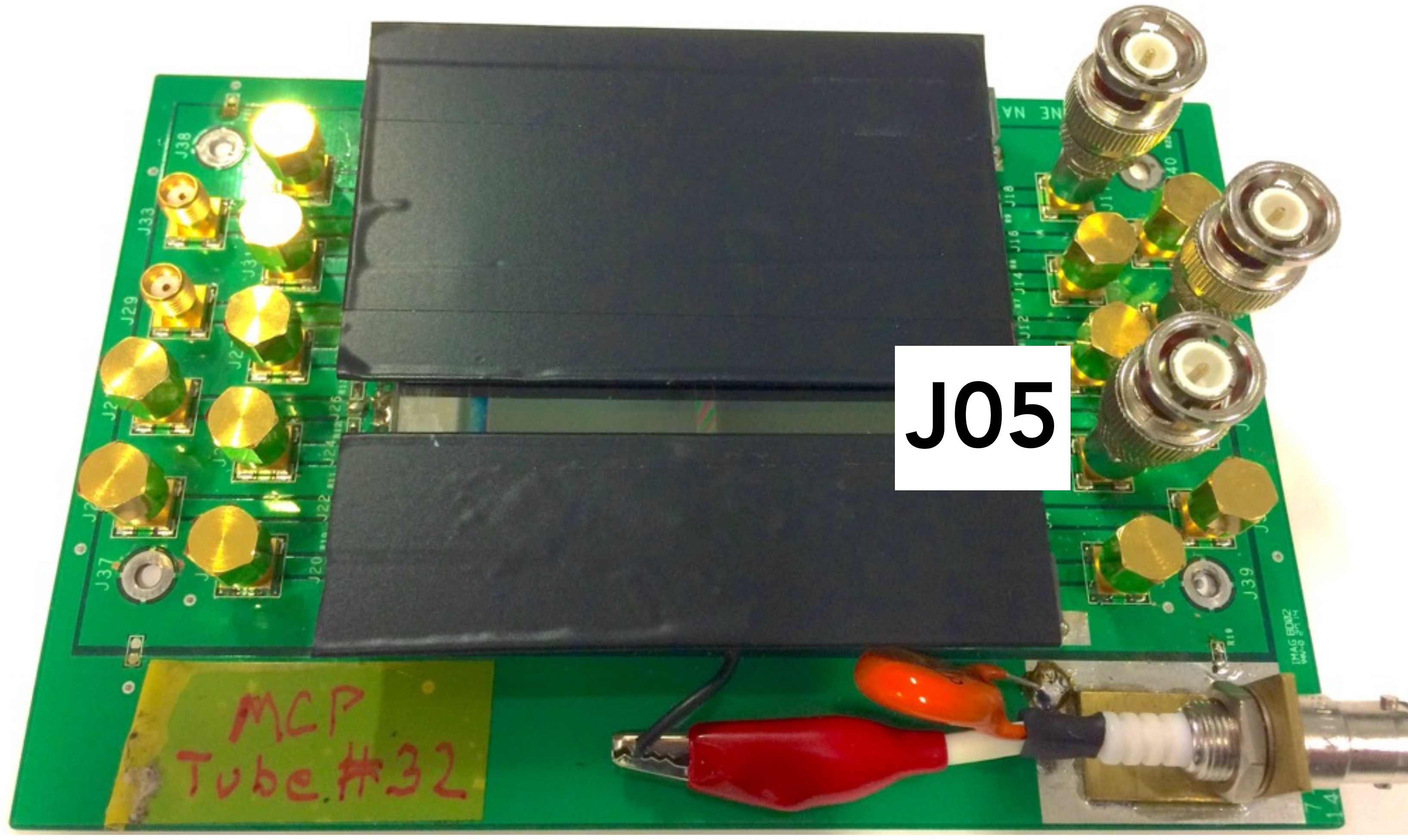
See poster: "First results from Quality Assurance Testing of MaPMTs for the LHCb RICH Upgrade" Silvia Gambetta





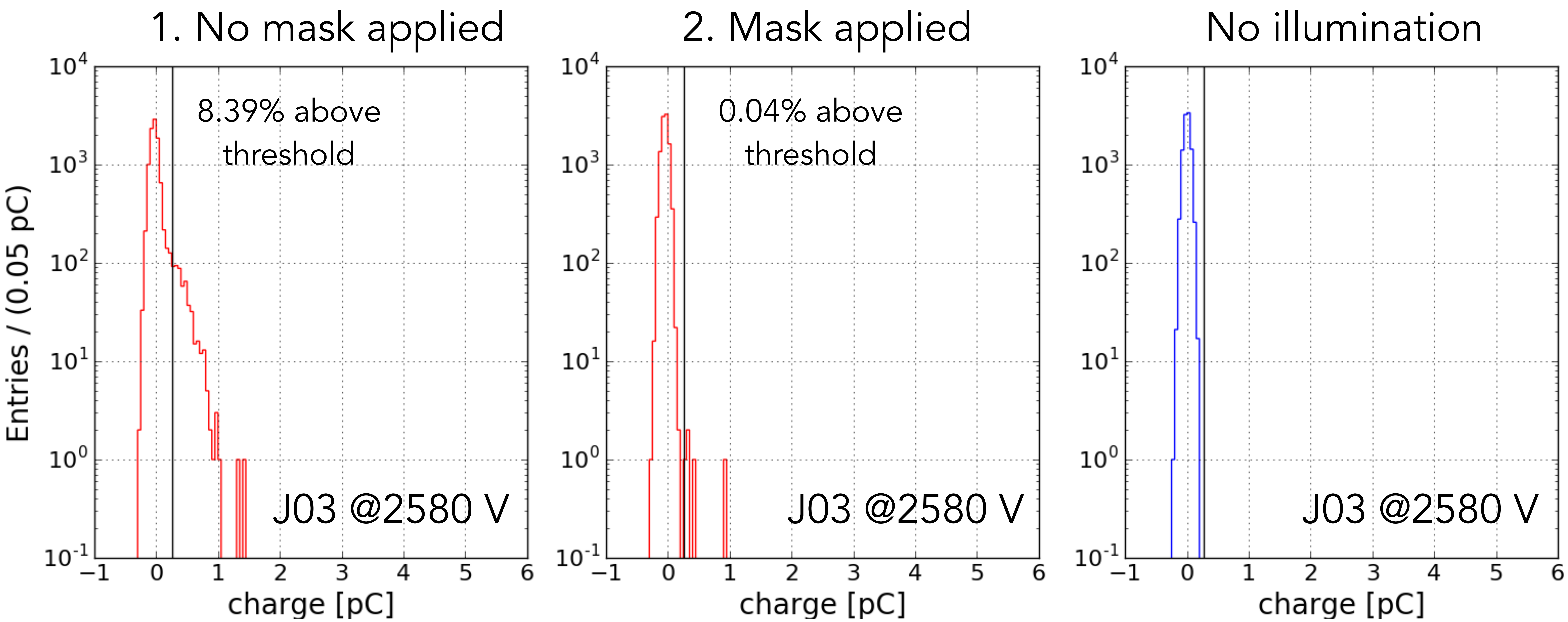


Cross-talk



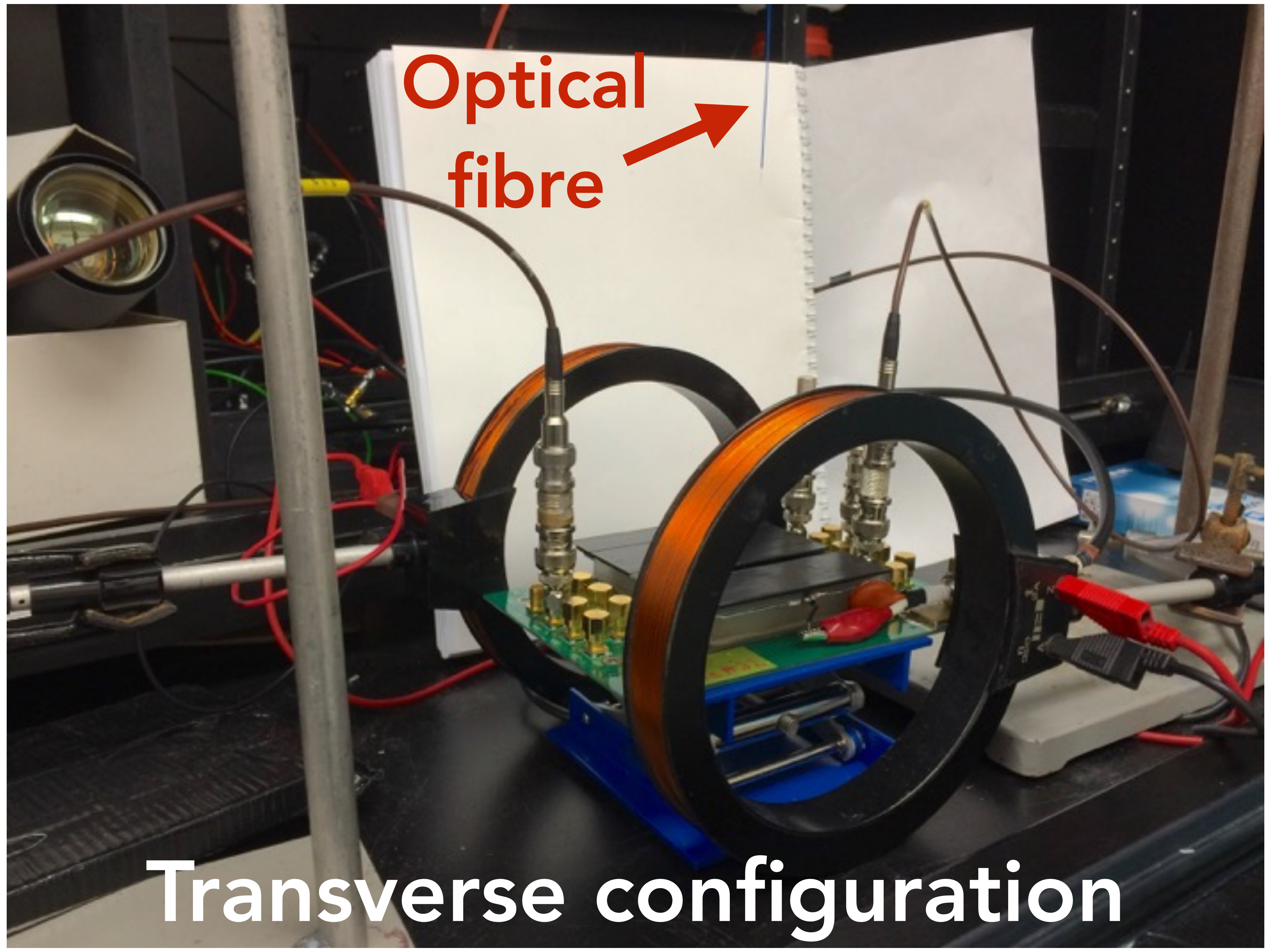
1. Obtain charge spectrum of channels J03, J05 when no mask applied
2. Obtain charge spectrum of J05, **mask all other channels**.

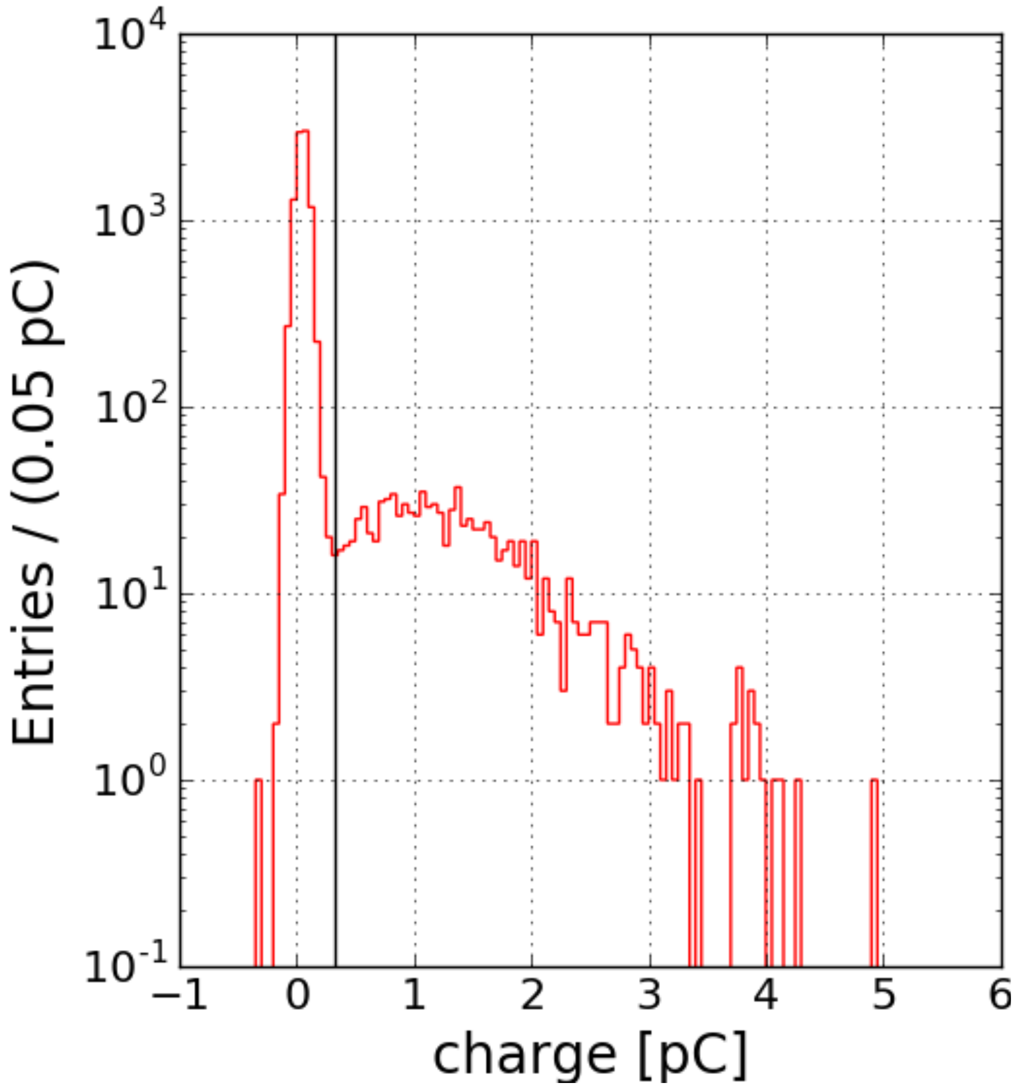
- In **<1%** of cases we see signal on J03 when there is also signal on J05.

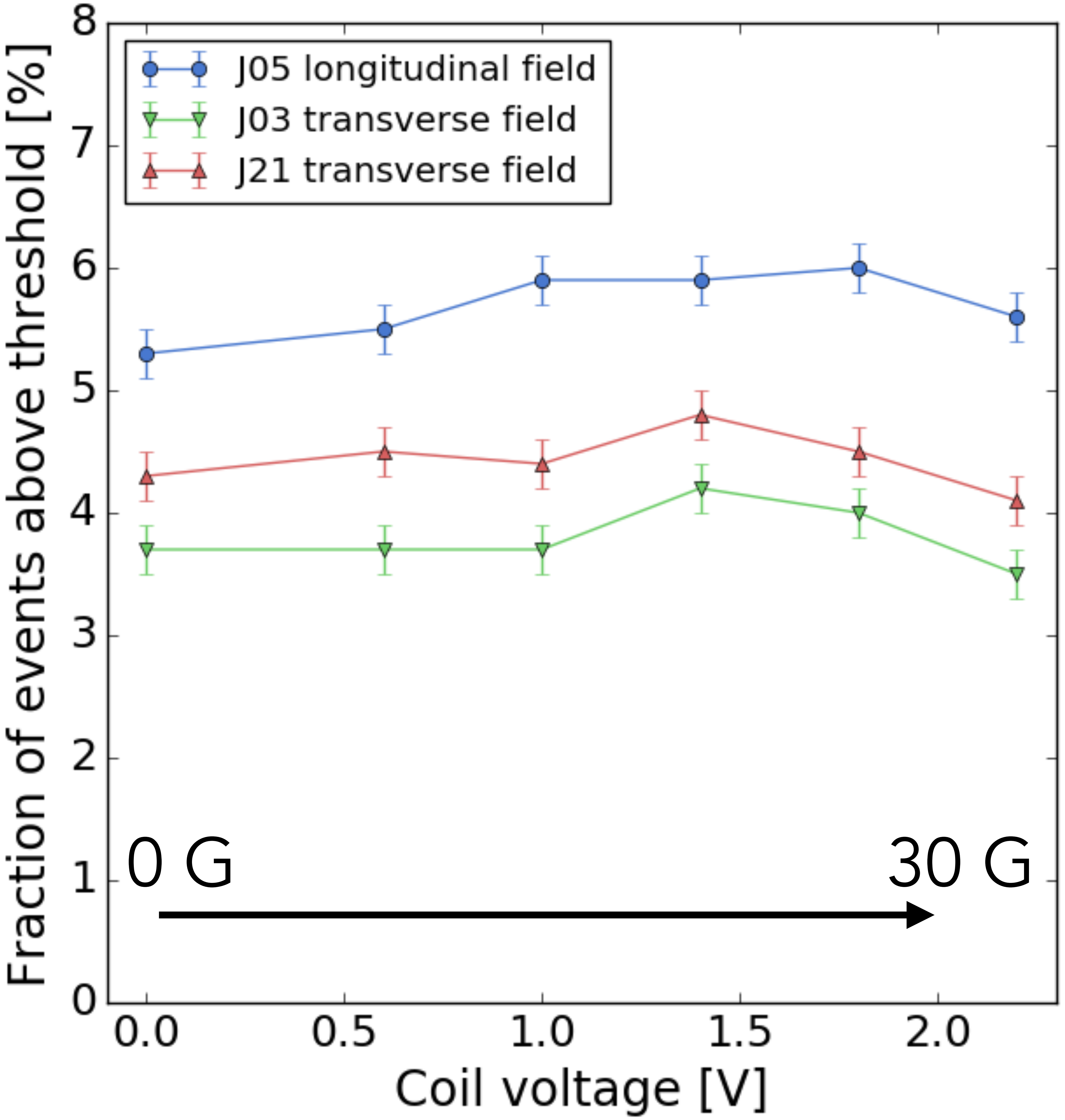


Behaviour in magnetic field

- Small Helmholtz coils generate field up to 30G.
- Transverse and longitudinal configuration.
- Device insensitive to these field levels.

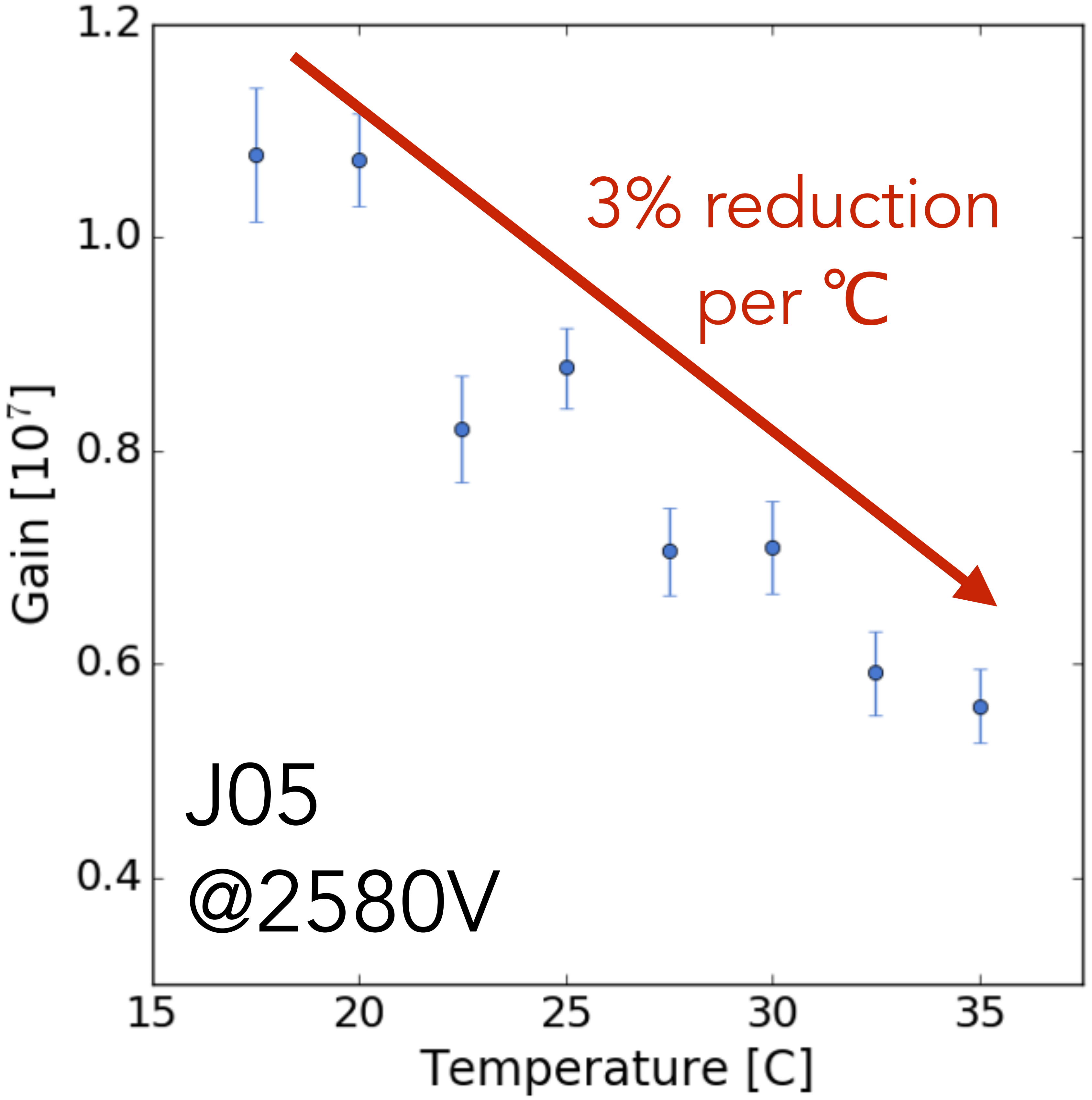


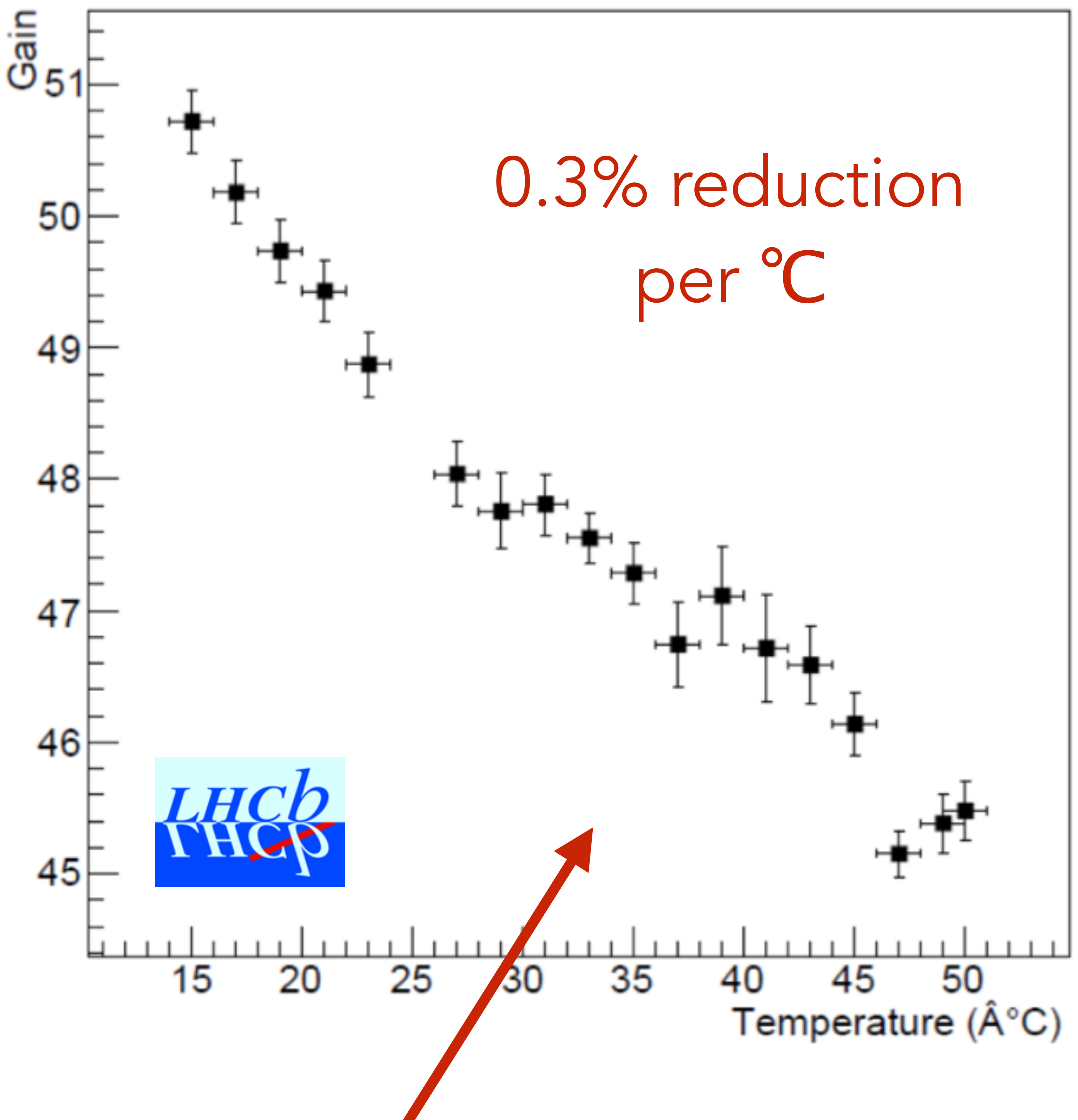




Gain as function of temperature

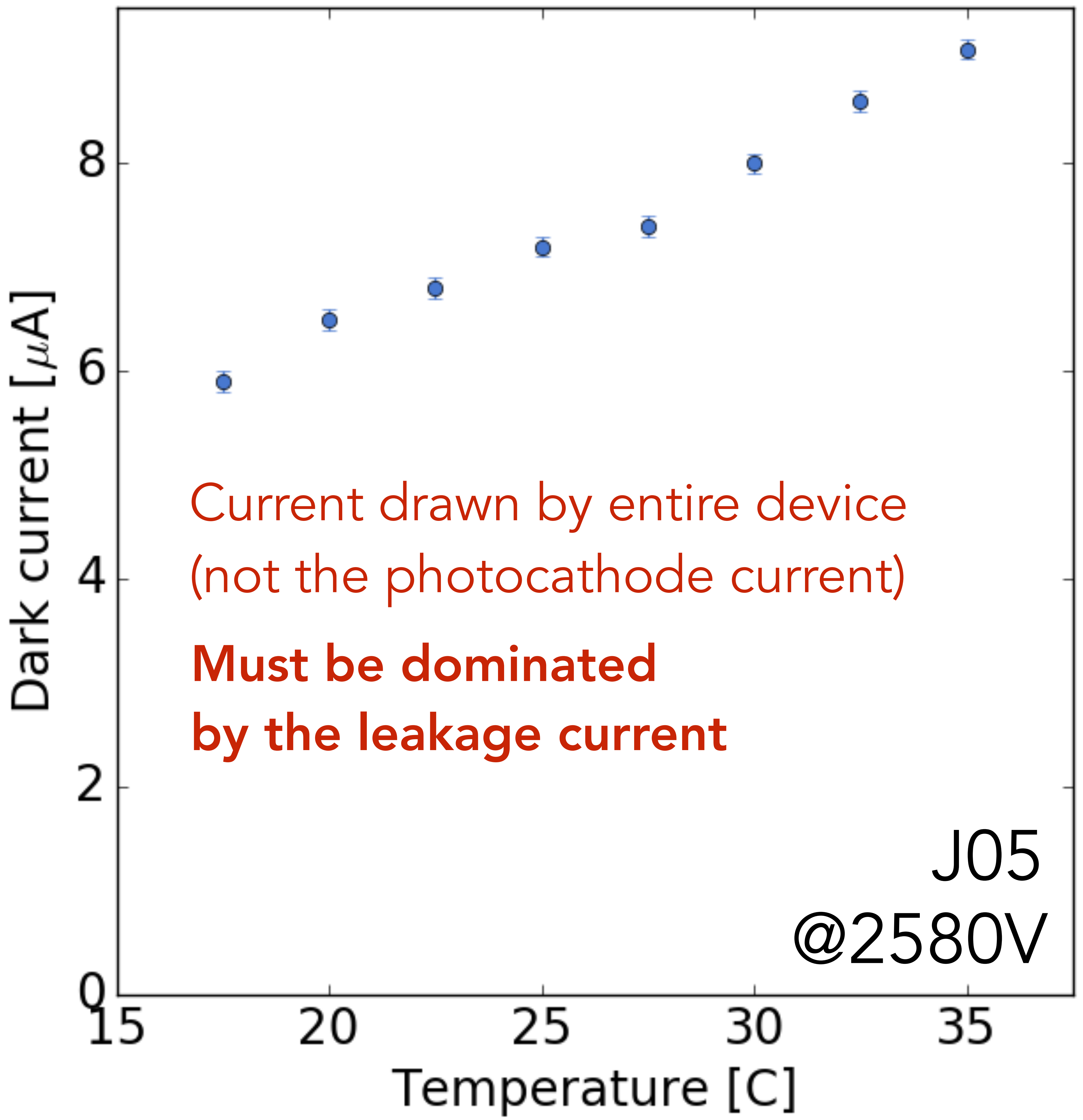
- Use (light-tight) Binder climate chamber to study gain variation with temperature.
- Temperature allowed to settle for ~20 mins at each point.

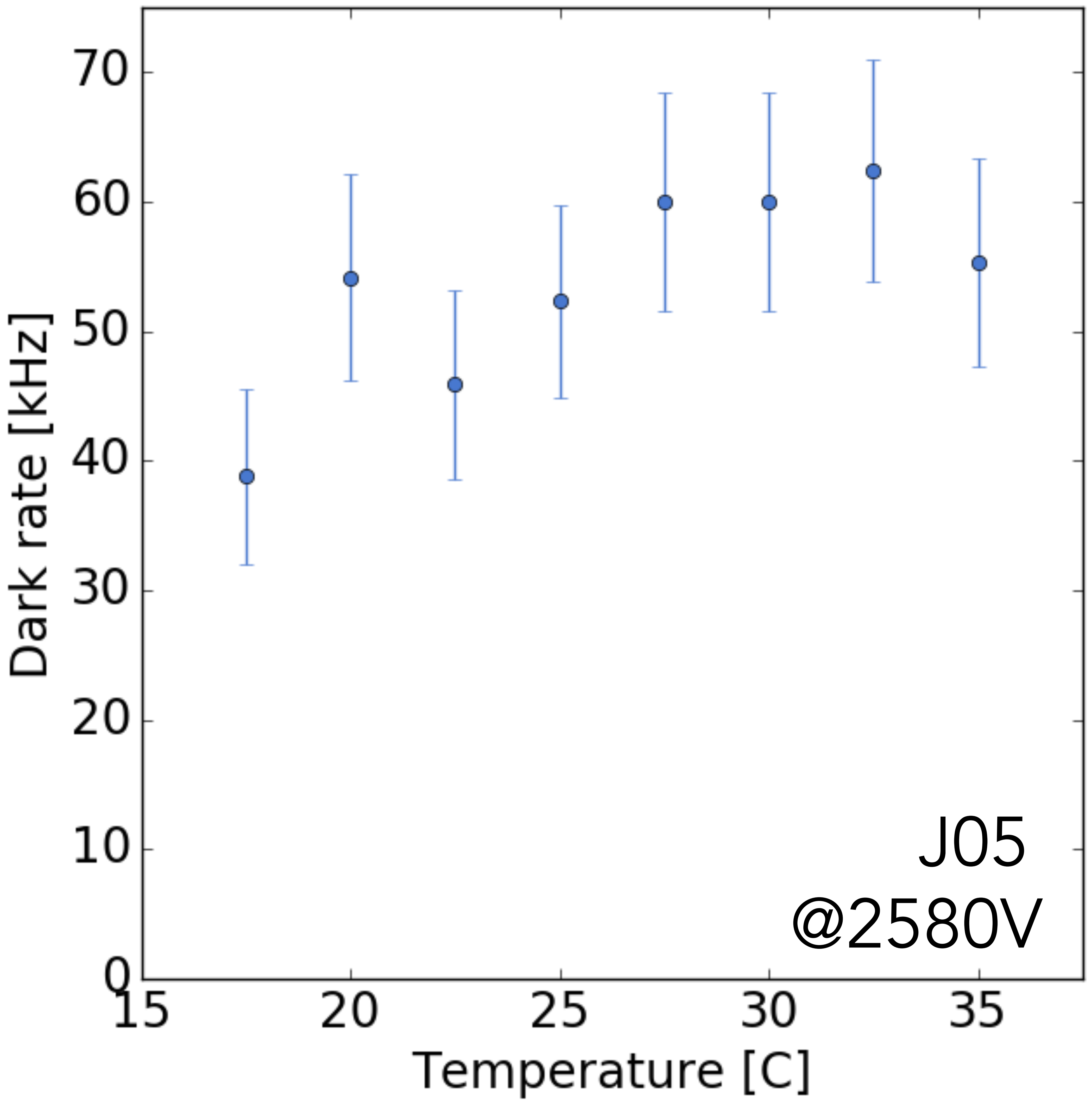




For comparison: Hamamatsu R13742 MaPMT being tested for LHCb upgrade

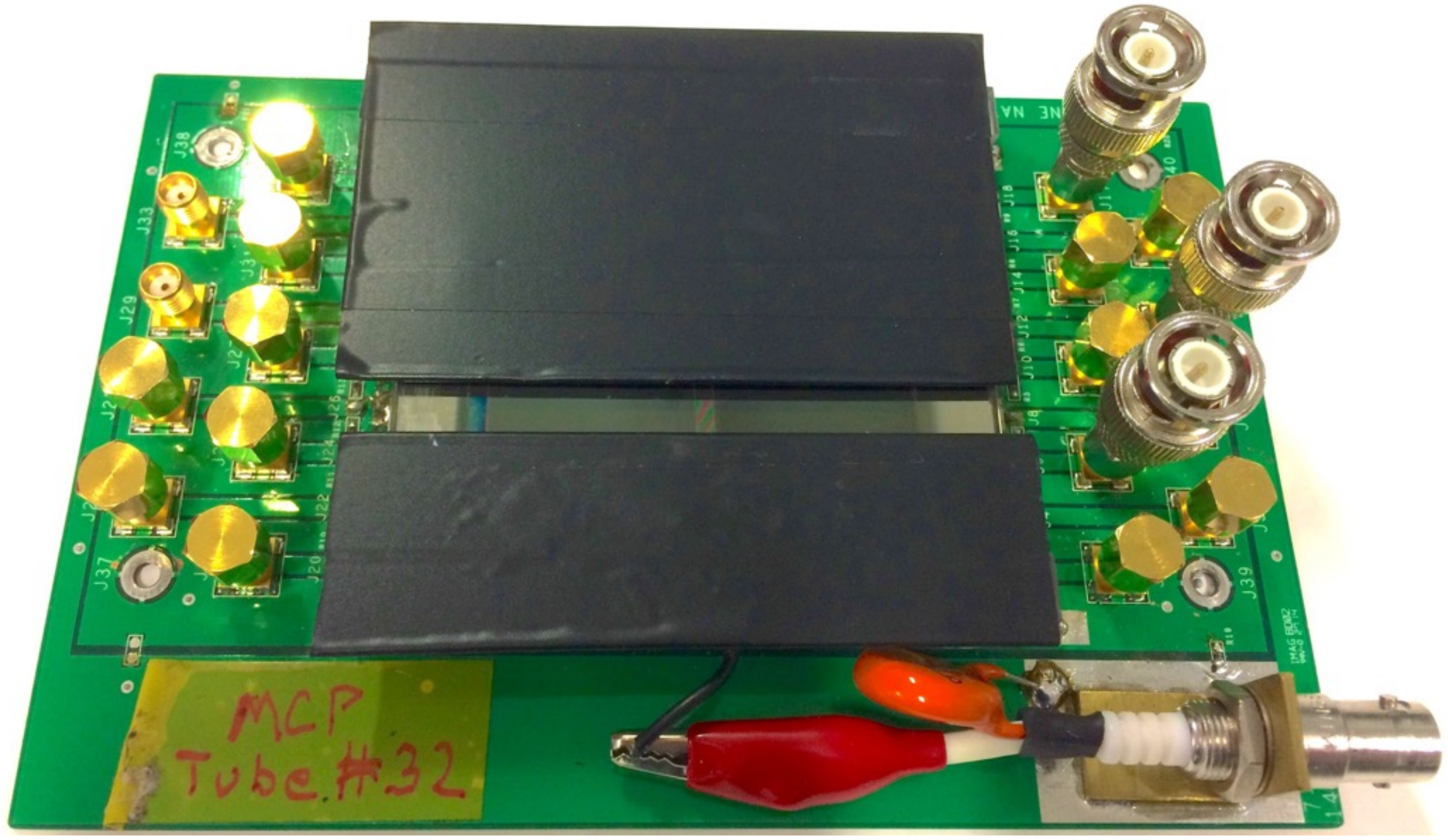
Dark rate as function of temperature

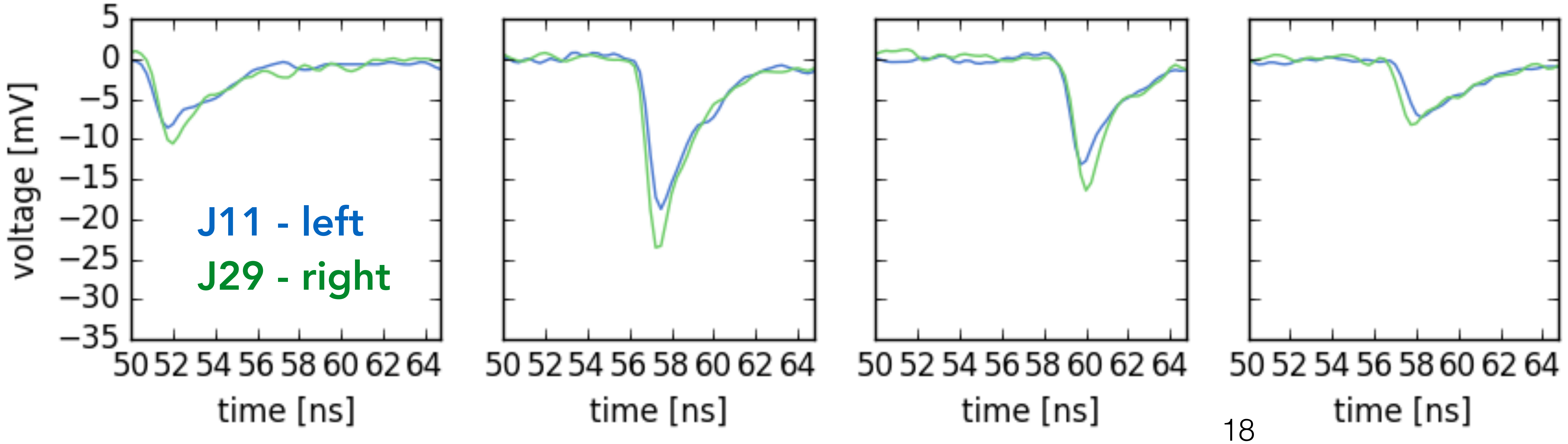


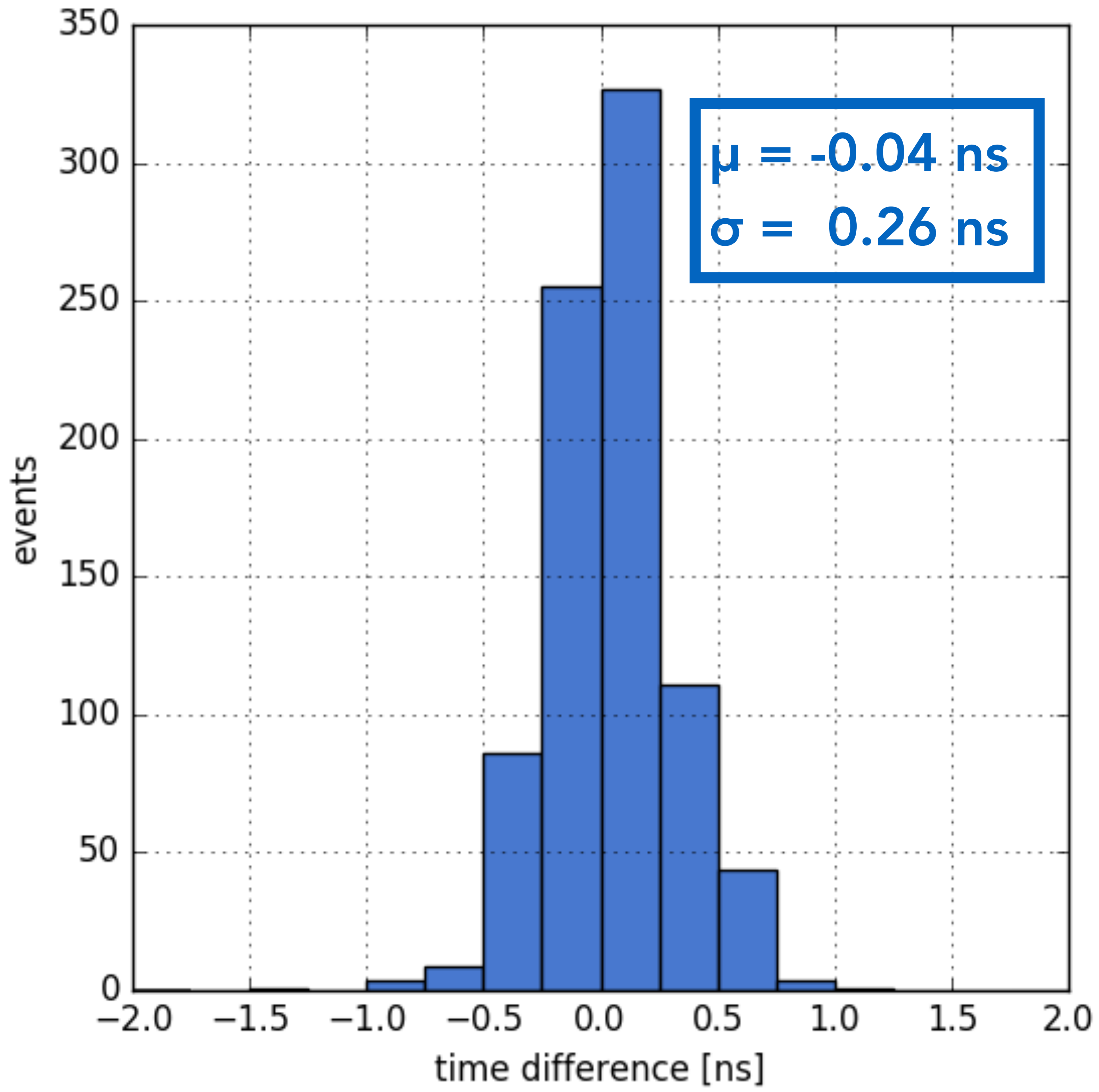


Time correlations

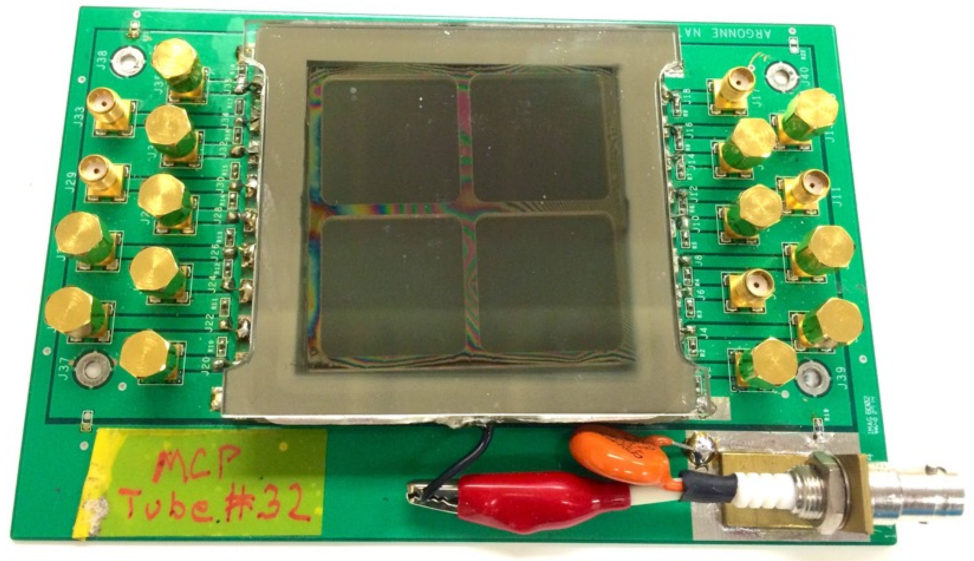
- Use time difference between signals at each end of anode to determine position of incident photon along the strip.
- We are limited by resolution of oscilloscope (4 GS/s).







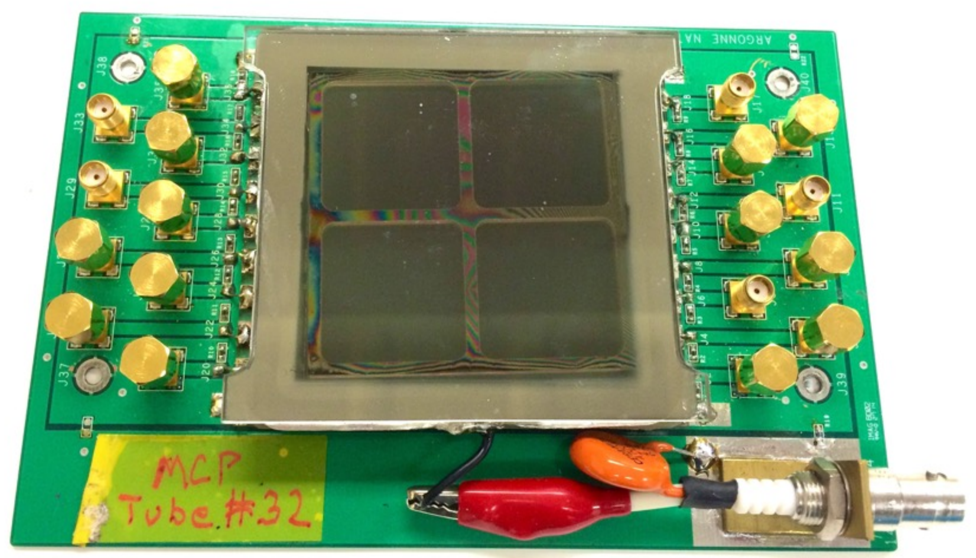
Future plans



- Tube#32 is early prototype MCP. The voltage distribution totally depends on the MCP and the spacer resistances, which are defined by the ALD, but not under control during tube processing.
    - ⟹ once sealed there is no way to individually optimise the HV for the internal stack components
- **New design**: the voltages can be independently controlled.
    - Sheffield has one of the new tubes (Tube#44) now under test.

- Use (repaired) faster scope to repeat **timing measurements**.
- Further **magnetic field** tests (including cross-talk studies in field).
- Infrastructure now commissioned and ready to test newer devices.

Summary



- Investigated properties of **early prototype 6x6 cm^2 MCP-tile from ANL** using new Edinburgh photo-detector test facilities.
- **Gains of 10^6-10^7 measured**, with some variation between channels observed.
- **No loss of gain with increase of transverse/longitudinal magnetic field** (up to 30 G).
- **Decrease in gain as temperature increases** (3% per ℃ between 17.5 - 35.0℃).
- Candidate applications for these devices discussed.

Backup

Dimensions

[Nuclear Instruments and Methods in Physics Research A 804 (2015) 84–93]

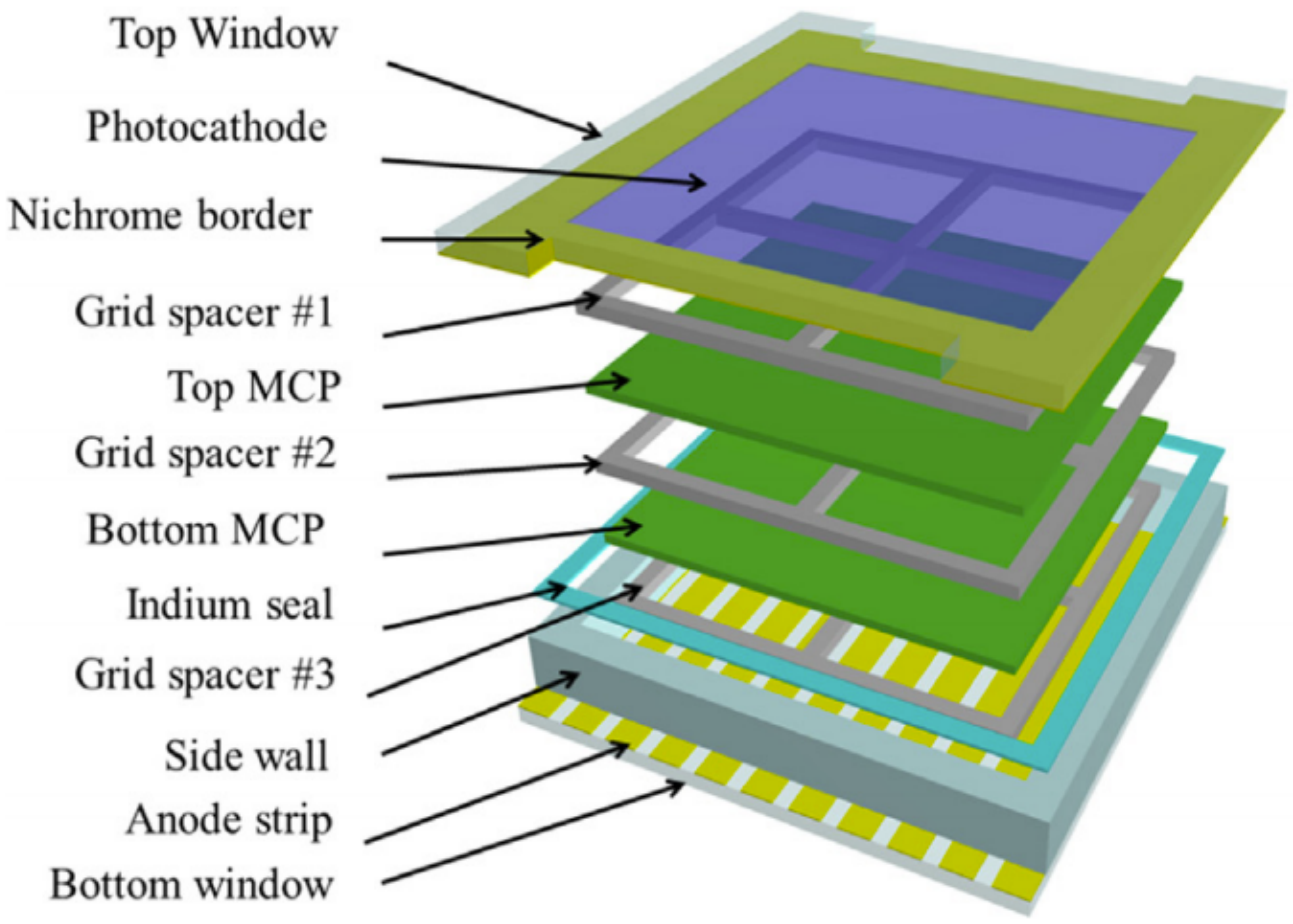
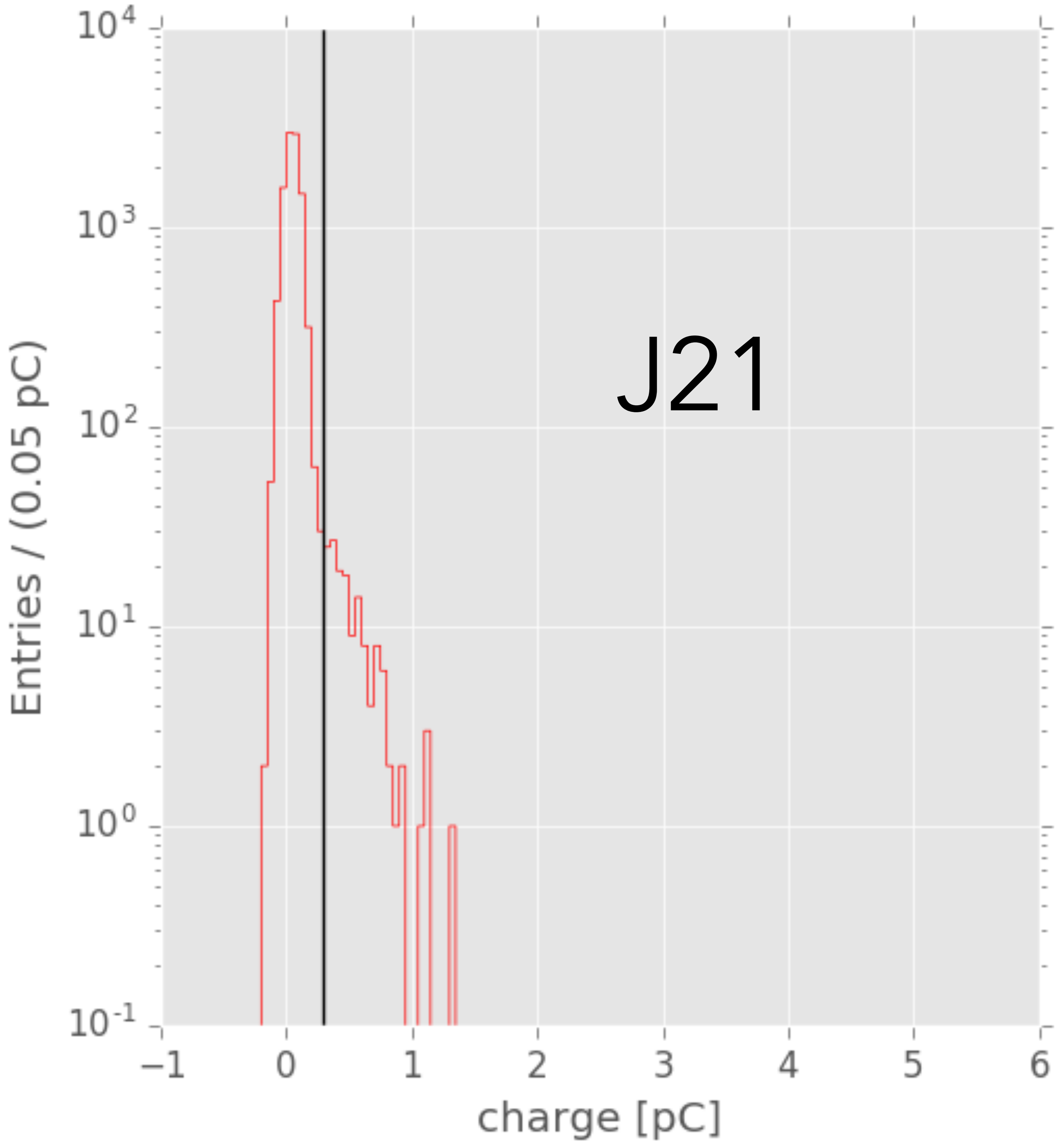


Table 1 Specifications of the stack components

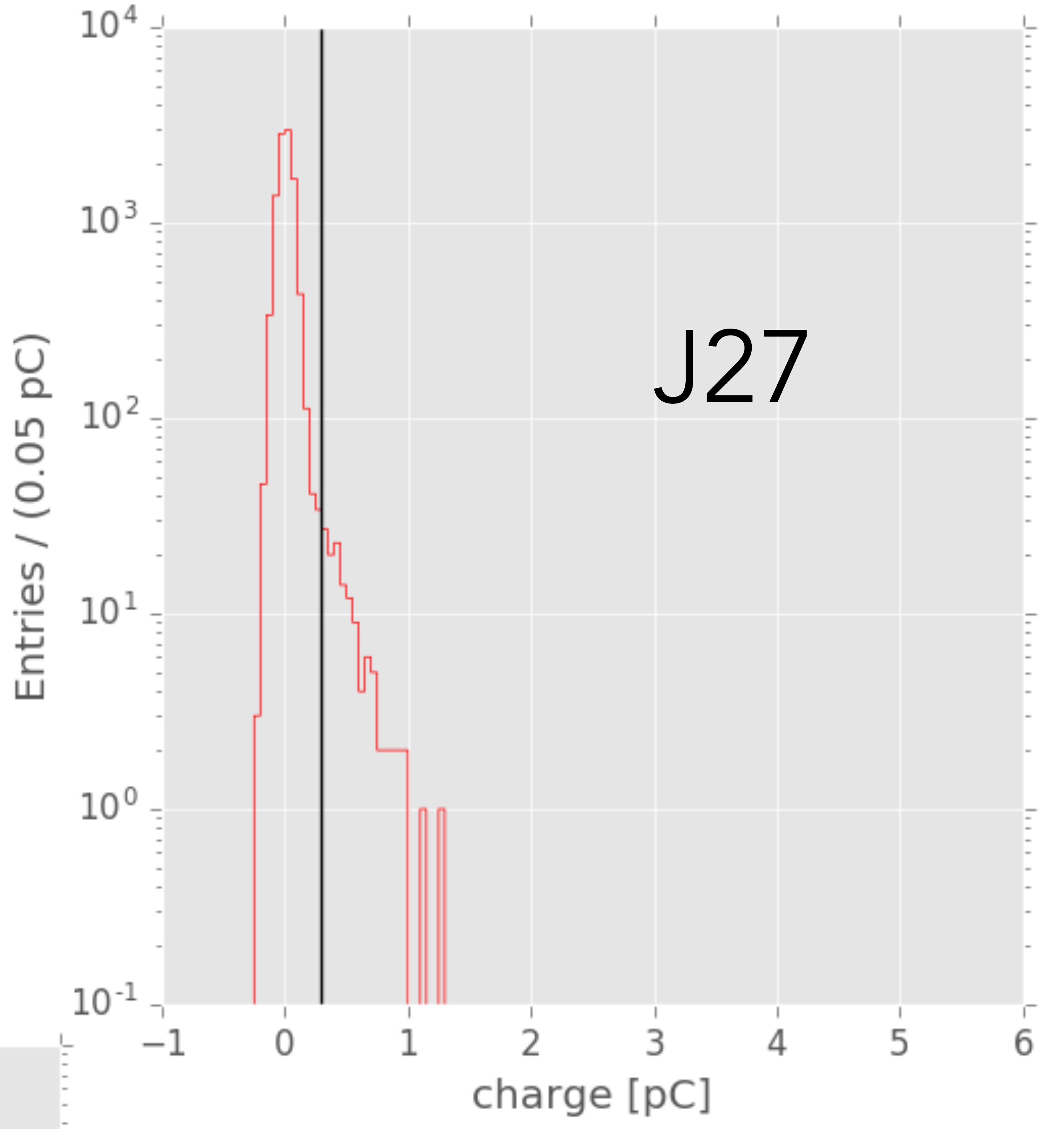
Components	Thickness (mm)	Size (mm)	Resistive coating	Desirable resistance (MΩ)
Top Window	2.75	85.3 × 85.3	Bialkali	$10^5 – 10^7$
Grid spacer #1	2	59.7 × 59.7	ALD-Spacer	40
Top MCP	1.2	59.7 × 59.7	ALD-MCP	200
Grid spacer #2	2	59.7 × 59.7	ALD-Spacer	40
Bottom MCP	1.2	59.7 × 59.7	ALD-MCP	200
Grid spacer #3	3.15	59.7 × 59.7	ALD-Spacer	60
Side wall	9	76.2 × 76.2	-	$10^5 – 10^7$
Bottom window	2.75	85.3 × 85.3	-	$10^5 – 10^7$

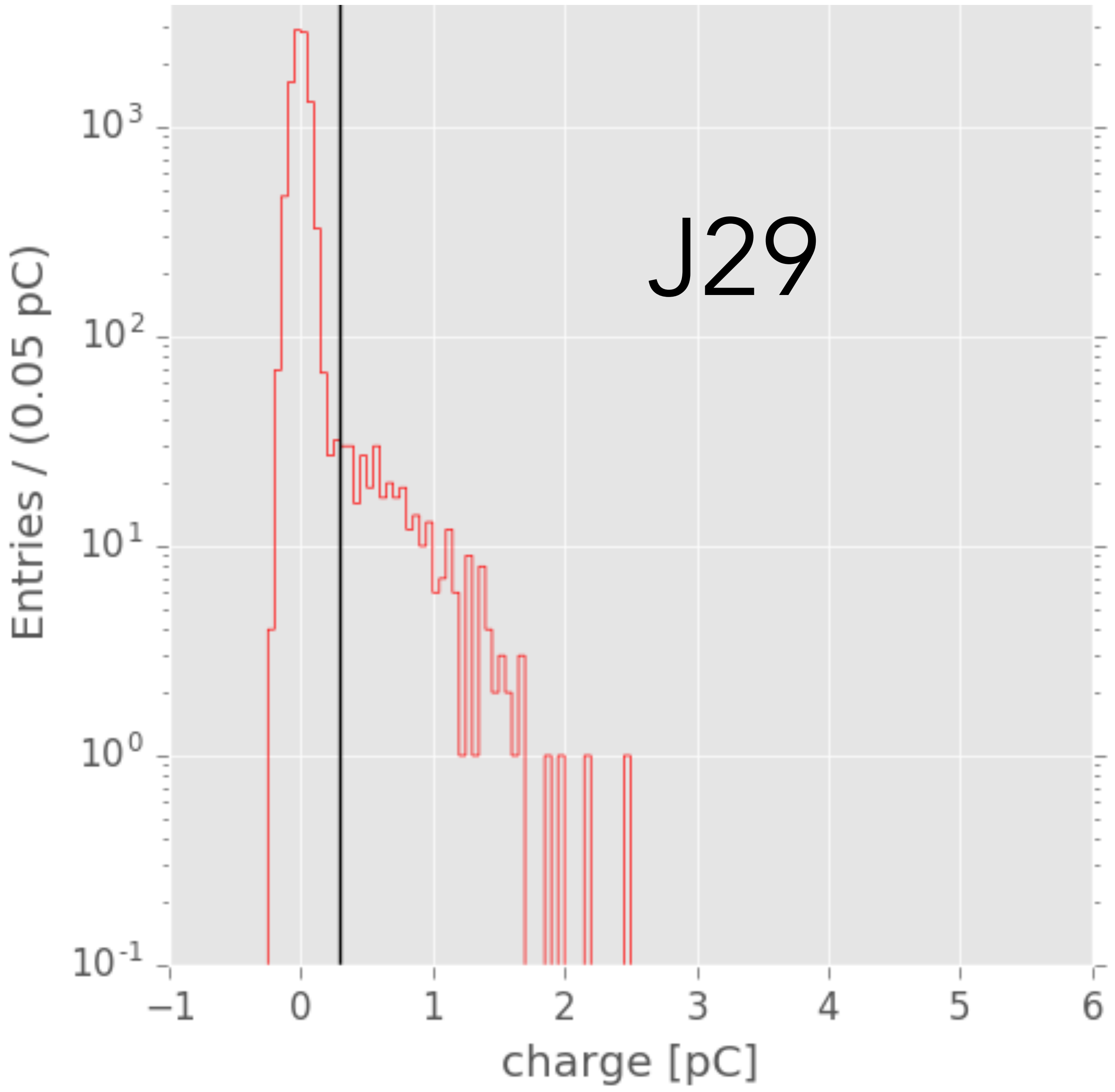

J03
@2580 V
26.5℃
J05
J07
J09
J11
J13
J15
Entries / (0.05 pC)
charge [pC]
ARGONNE NATIONAL LAB
J15
J11
J07
J03
J13
J09
J05



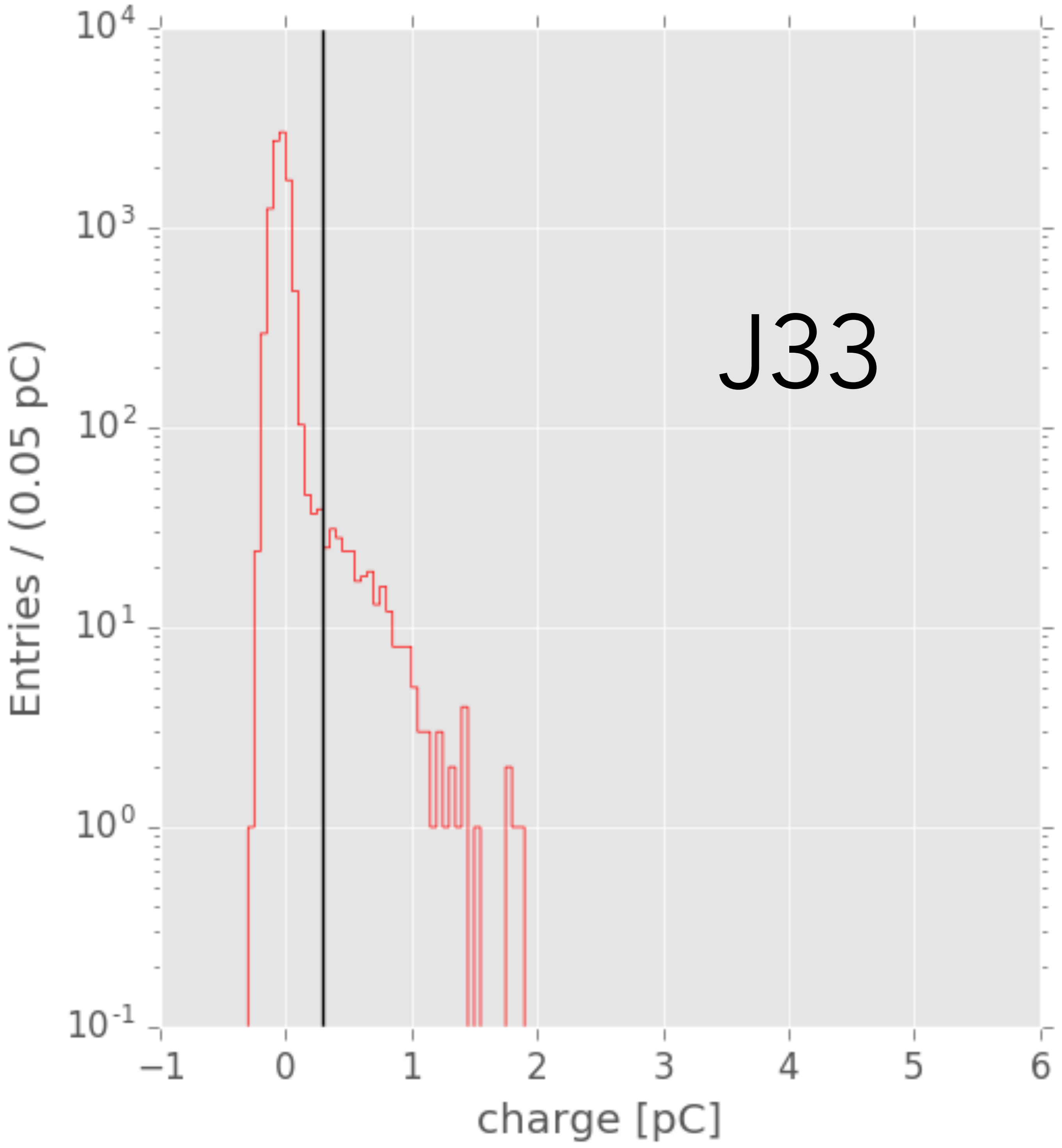
J23
not working

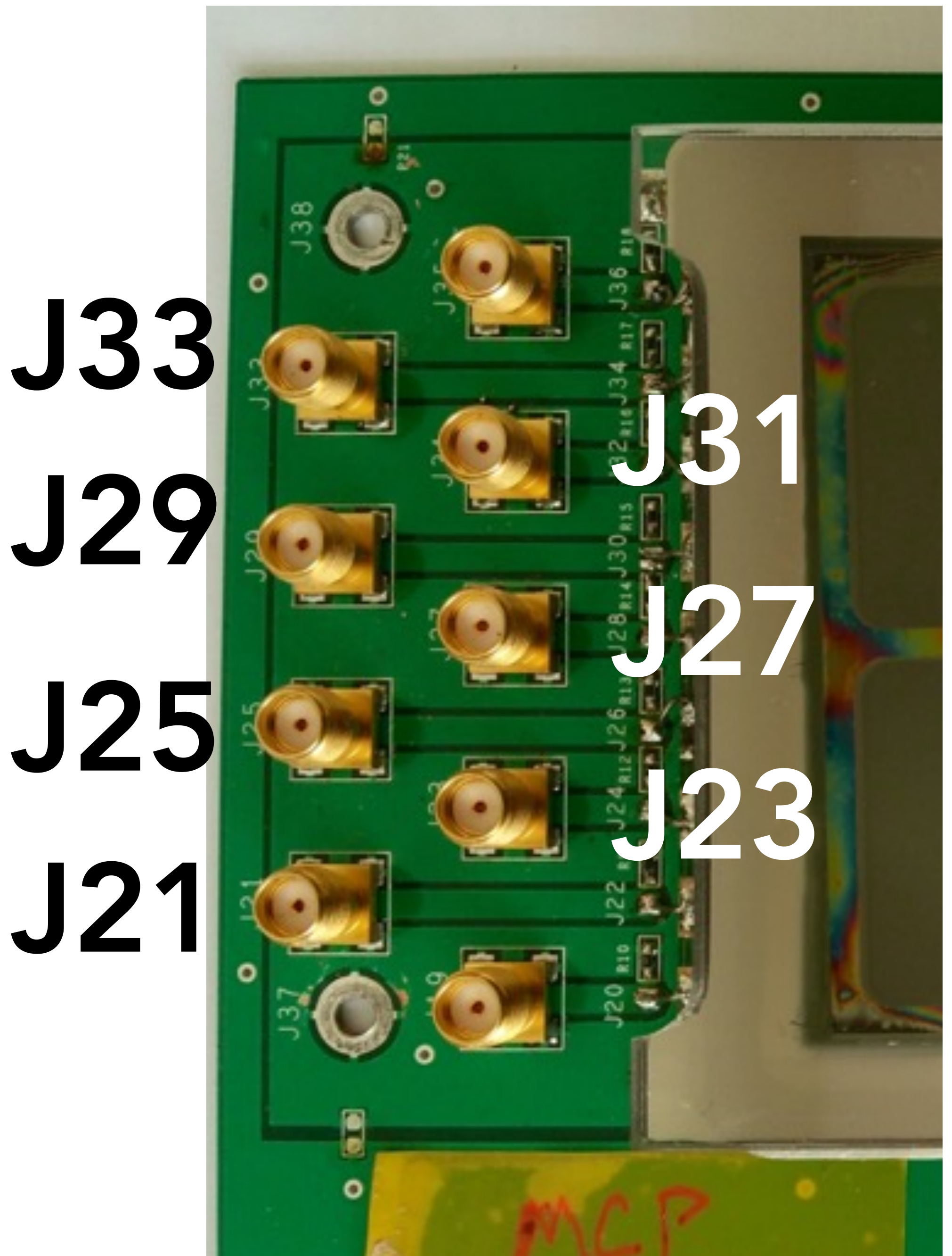
J25
not working





J31
not working





LAPPD™

http://psec.uchicago.edu

- Large area picosecond photodetector - imaging, vacuum photosensors based on MCPs.
- New fabrication techniques (ALD) for making large area ($20x20cm^2$) devices using low-cost materials and well-established industrial techniques.
- Very thin, so maximise fiducial volume.
- **Single photon timing resolution < 0.1 ns, and position resolution of O(1)mm**
  - Leads to track and vertex reconstruction of O(1)cm.
  - Can separate between space and time coordinates of individual hits ⇒ photon counting.
  - Better separation of dark noise and photons from neutron capture and better energy resolution.