ÖAW AUSTRIAN ACADEMY OF SCIENCES

SMI – STEFAN MEYER INSTITUTE FOR SUBATOMIC PHYSICS

ALICE Fast Interaction Trigger: Comparison of Fine Mesh PMs and SiPMs

Sigrid Scherl

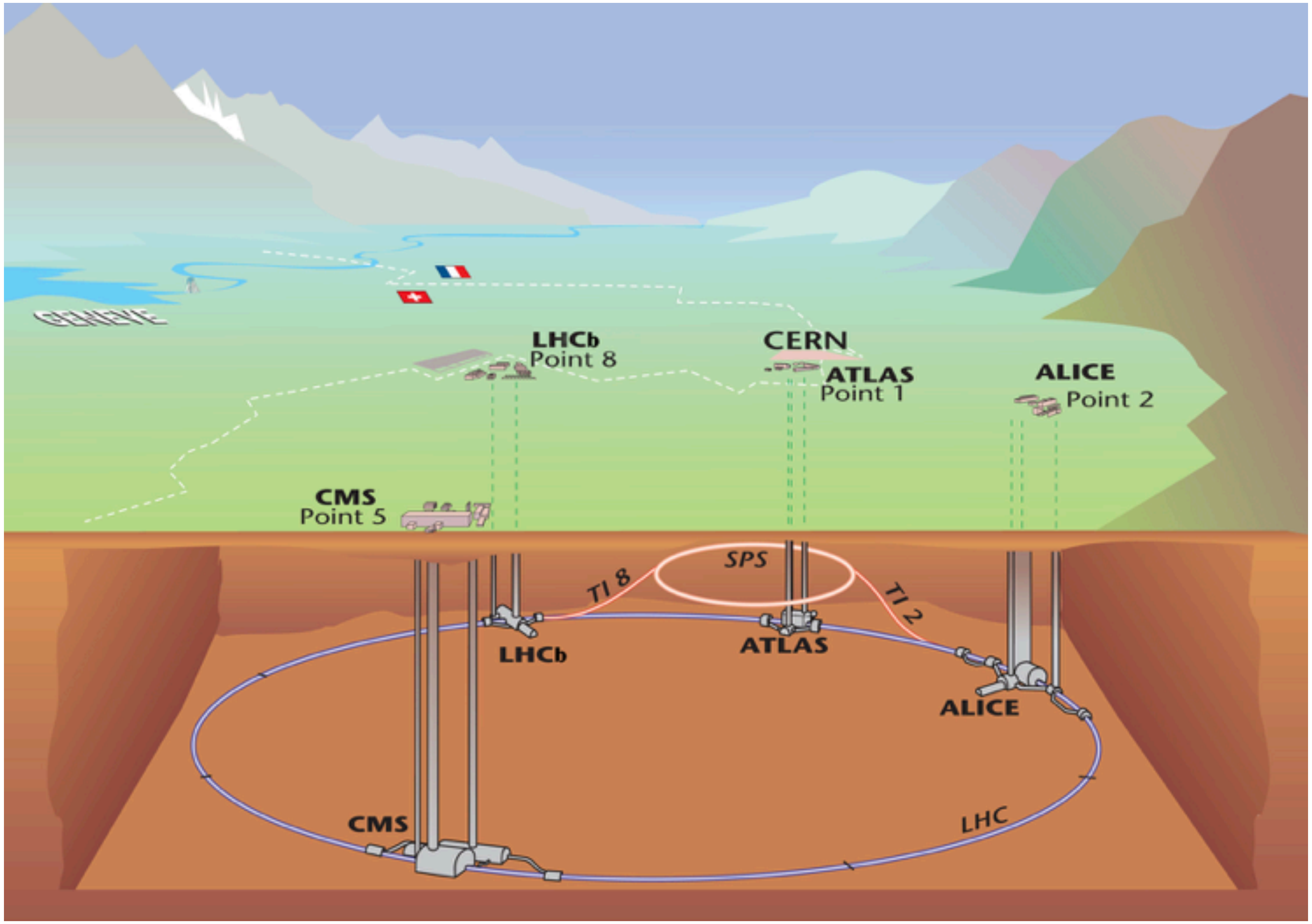
ECT* STRANEX Workshop, Trento

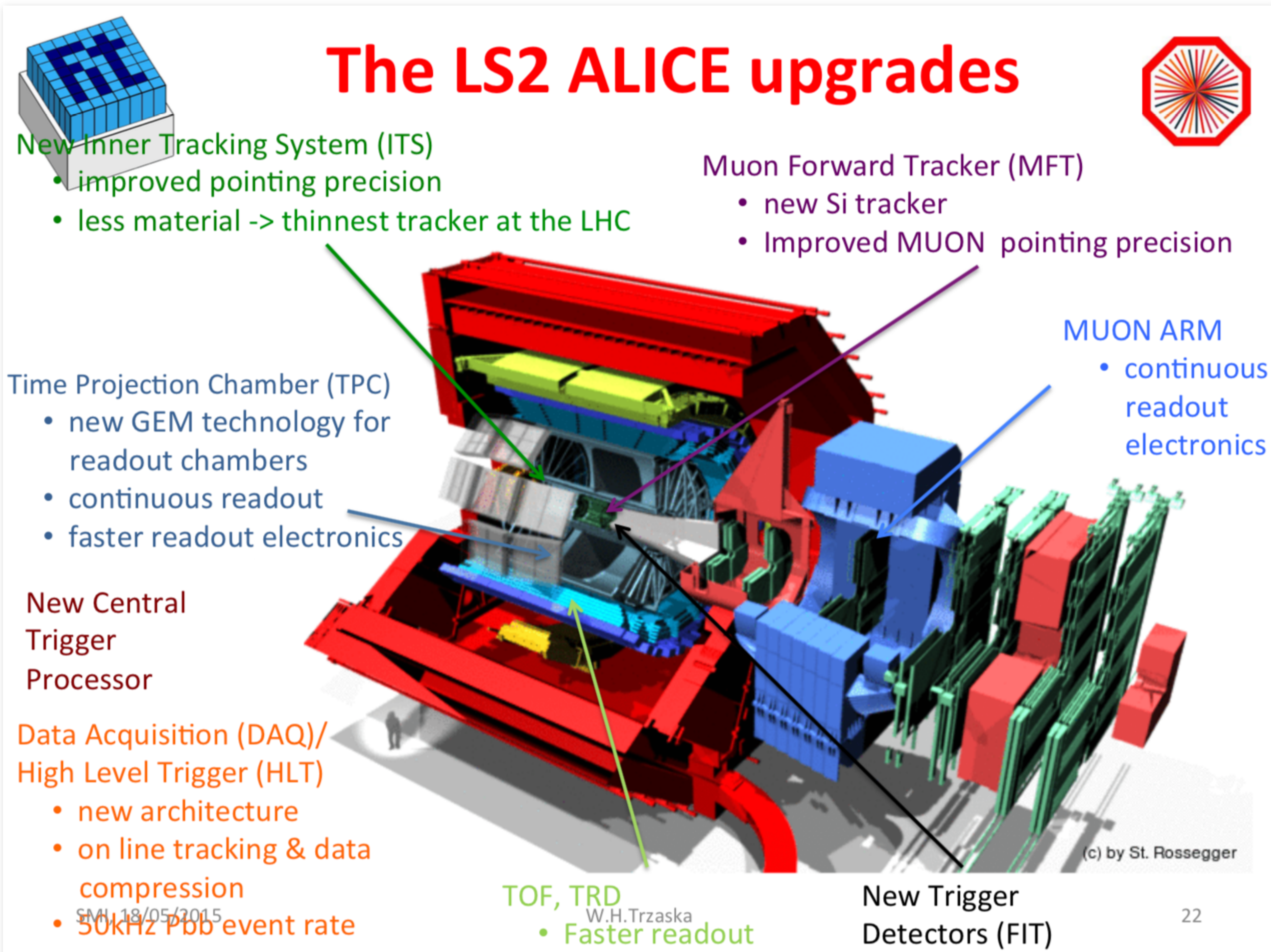
25 October, 2019

Overview

- The ALICE experiment
- Fast Interaction Trigger
- Fine Mesh PMTs and SiPMs
- The Setup
- Measurements and results
- Outlook

The ALICE experiment at LHC



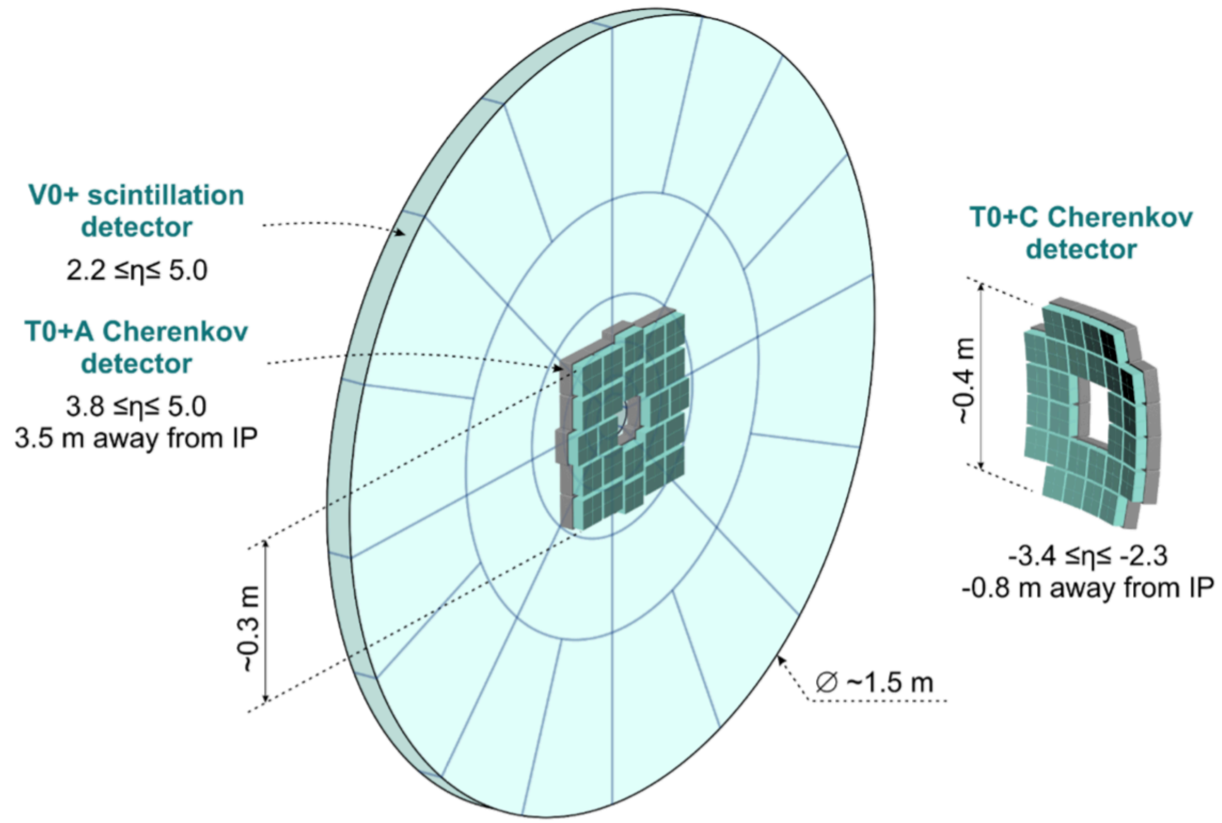

The LS2 ALICE upgrades
New Inner Tracking System (ITS)
• improved pointing precision
• less material -> thinnest tracker at the LHC
Muon Forward Tracker (MFT)
• new Si tracker
• Improved MUON pointing precision
MUON ARM
• continuous readout electronics
Time Projection Chamber (TPC)
• new GEM technology for readout chambers
• continuous readout
• faster readout electronics
New Central Trigger Processor
Data Acquisition (DAQ)/ High Level Trigger (HLT)
• new architecture
• on line tracking & data compression
• 50kHz PbPb event rate
TOF, TRD
• Faster readout
New Trigger Detectors (FIT)
(c) by St. Rossegger
SMI, 18/05/2015
W.H.Trzaska
22

Upgrades

- LHC Upgrade: Increased luminosity
- FIT:
  - Determination of collision time (over 50 ps)
  - Event multiplicity
  - Centrality
  - Reaction plane

The Fast Interaction Trigger (FIT)

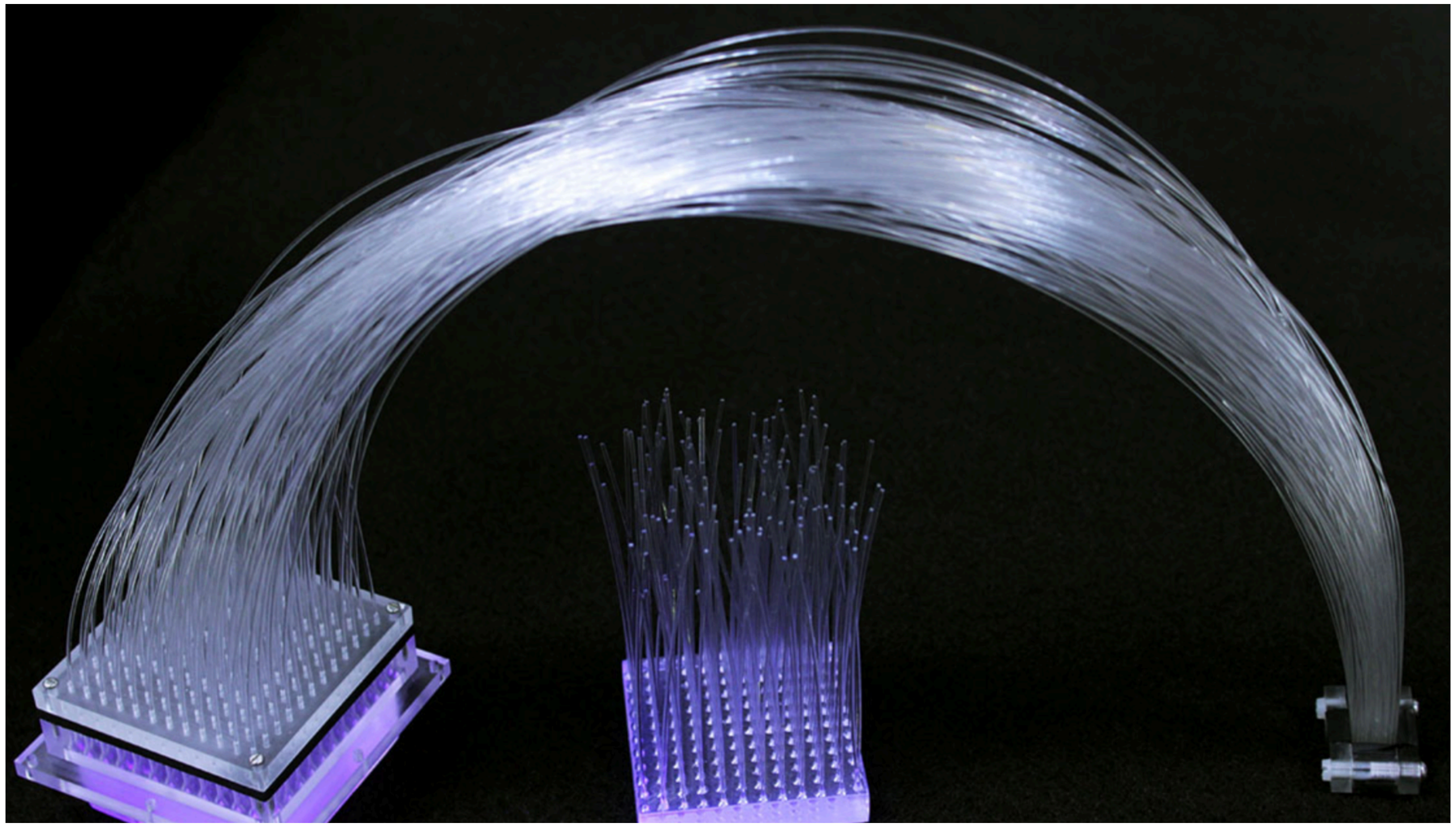
- Two arrays of Cherenkov quartz radiatiors coupled to fast MCP-PMTs (T0A+ and T0C+)
- Large, segmented scintillator ring (V0+)



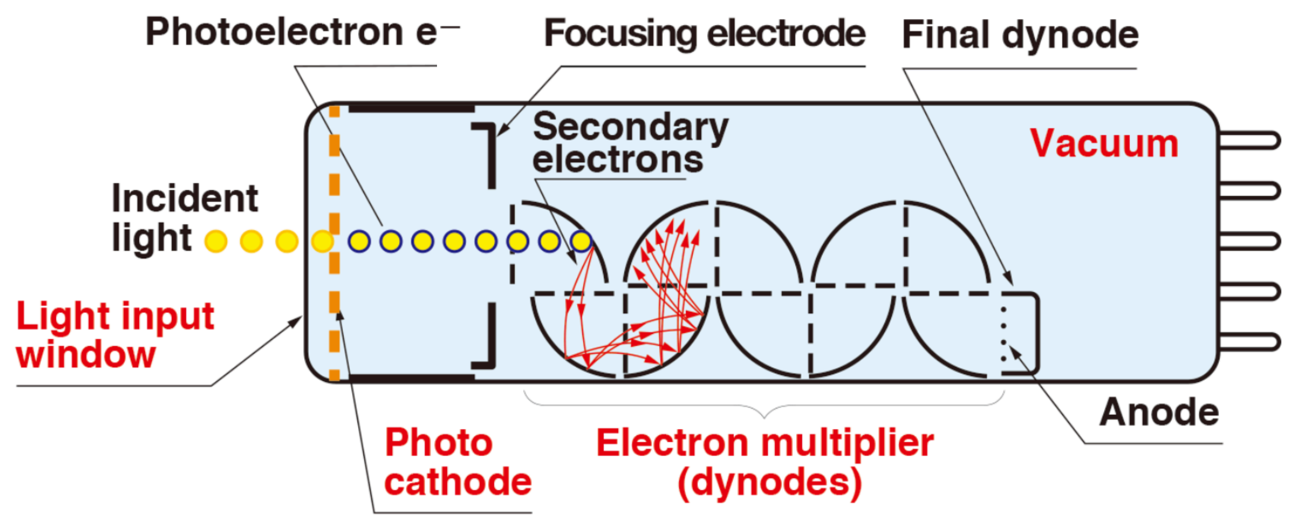
The Fast Interaction Trigger (FIT)

- V0+ forms flat disc with outer diameter of 148 cm and inner diameter of 8 cm (sufficient to pass beam line through)

- Active part of V0+ made of 4 cm thick plastic scintillators coupled to grid of fibres transmitting light to Hamamatsu fine mesh PMTs



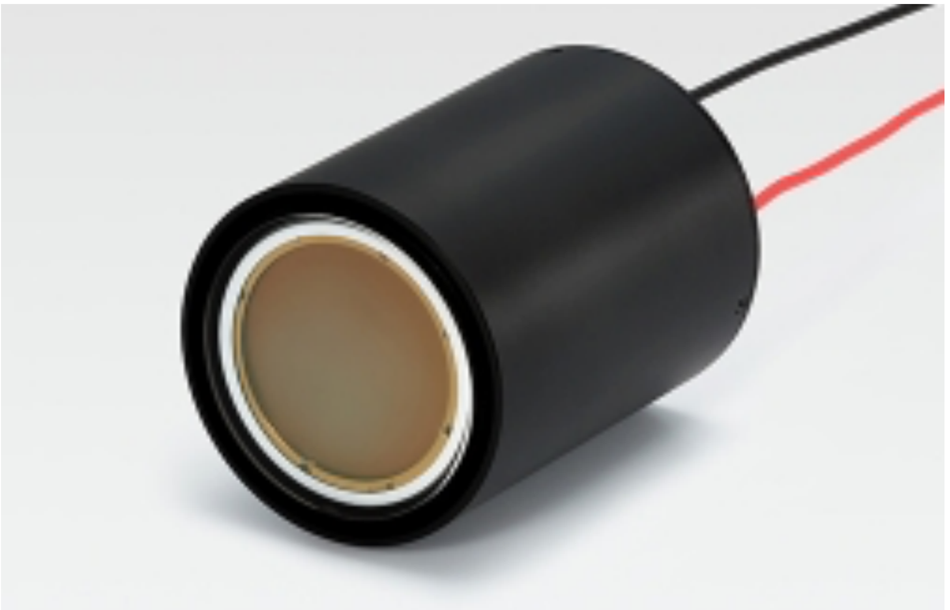
Photomultiplier Tubes

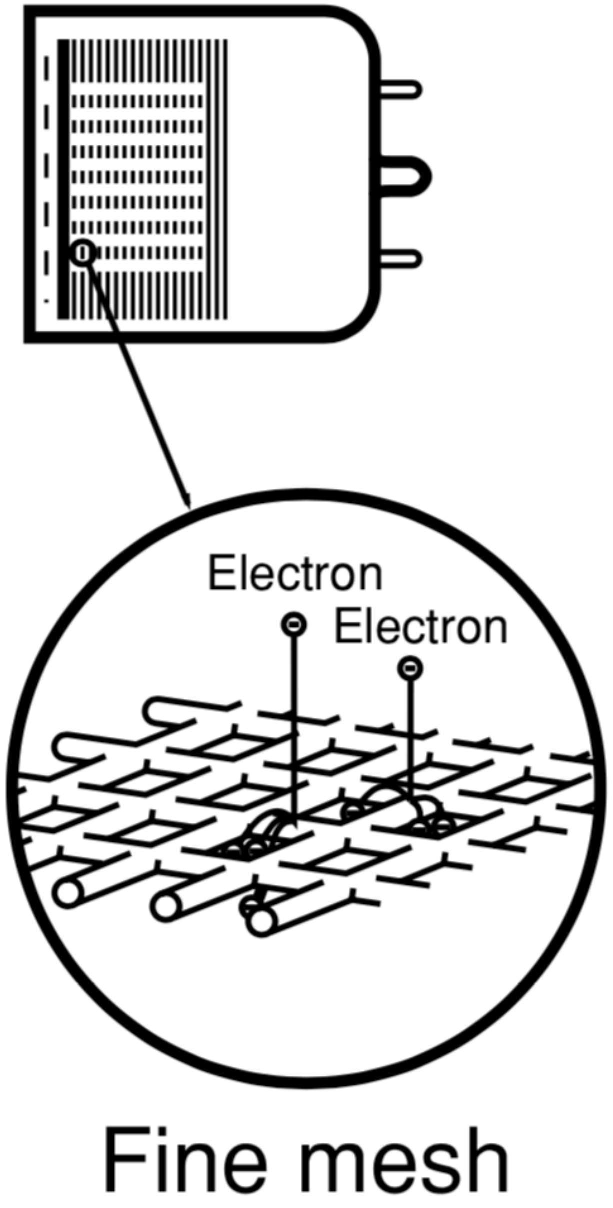


- Photon detection
- Light passes through input window
- Excites electrons in photocathode, photoelectrons emitted with certain probability (quantum efficiency)
- Accelerated and focused by focusing electrode
- Multiplied by dynodes
- Secondary electrons collected by anode

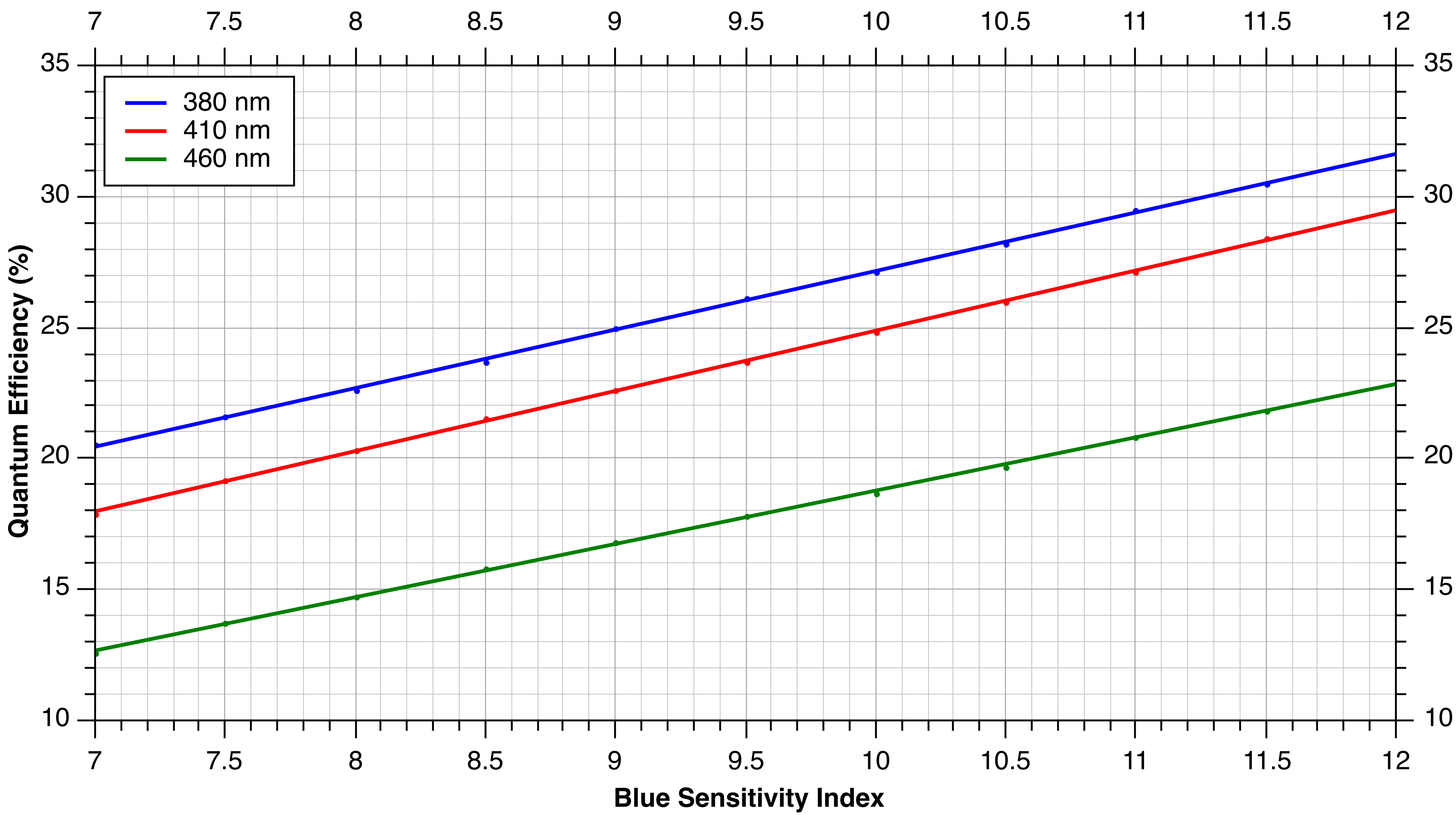
Fine Mesh PMTs

- Hamamatsu H6614
- Fine mesh electrodes for dynodes
- Works in magnetic fields
- Higher radiation resistance

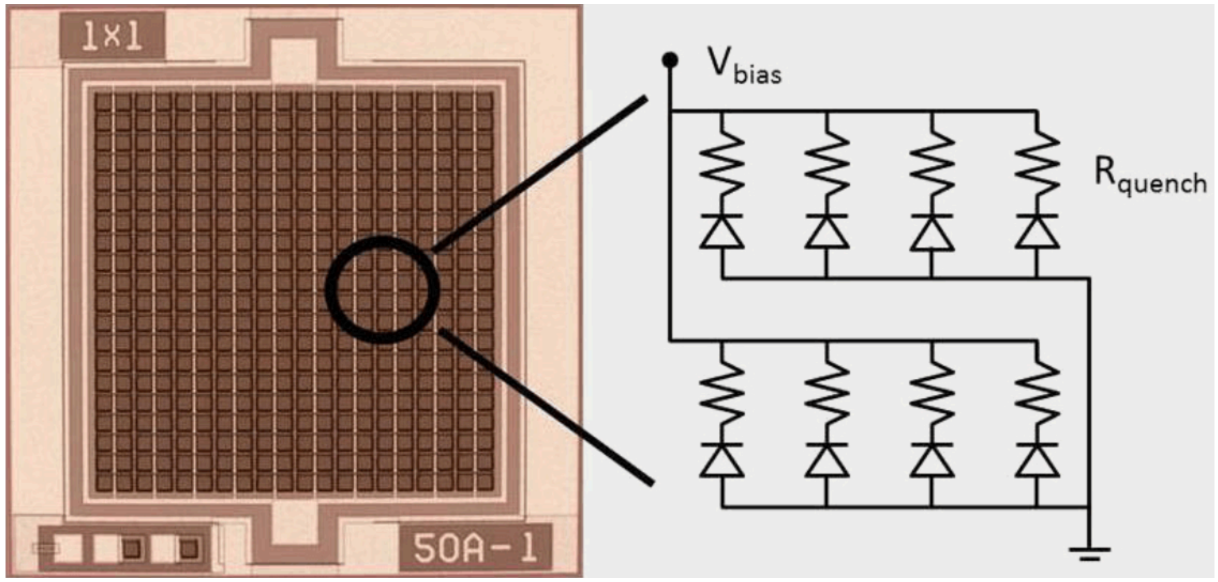




Quantum Efficiency



Silicon Photomultipliers



- Array of silicon avalanche photodiodes operated in Geiger-mode
- Microcell consisting of photodiode and quenching resistor
- Quenching resistor enables operation above breakdown voltage
- One common cathode and anode output for all microcells
- SiPM signal is sum of all microcell signals

Fine Mesh PMT vs. SiPM

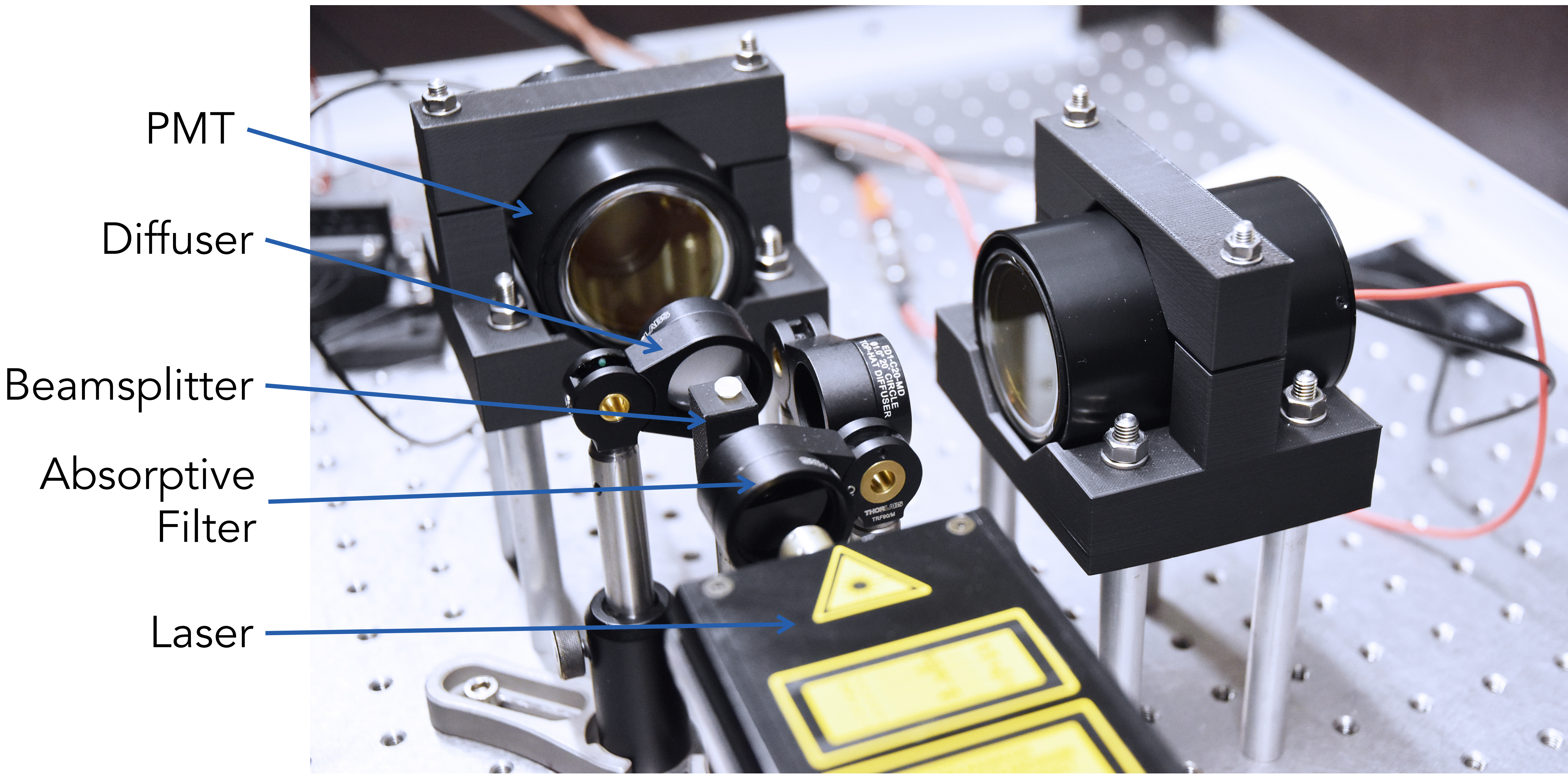
- SiPMs
  - Work in high magnetic field
  - More sensitive to radiation damage
  - Dark noise in SiPMs significantly increases due to radiation → bad timing resolution

- Fine Mesh PMTs
  - Work in magnetic fields
  - **More resistant against radiation damage than SiPMs**

Measurements

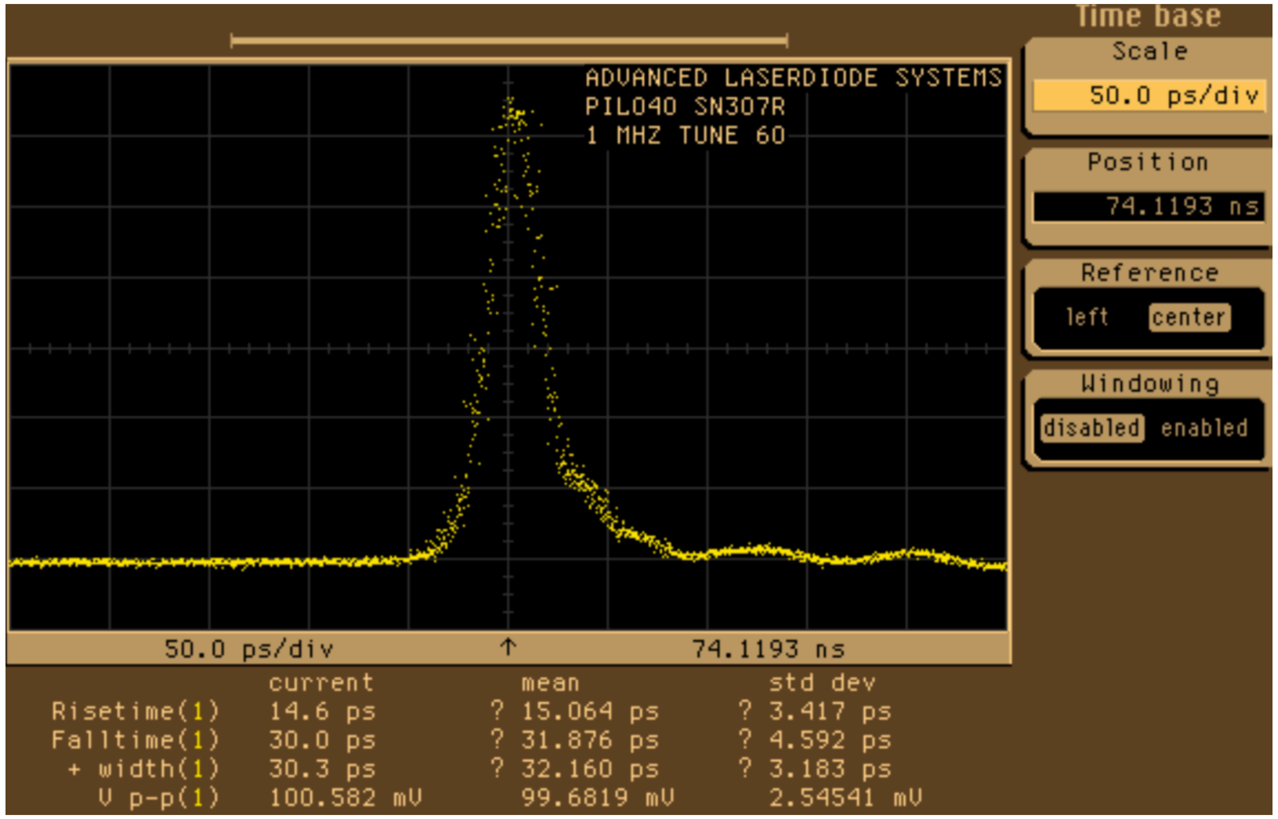
- Setup 1:
  - Anode Pulse Rise Time
  - Determination of the gain
  - Electron Transit Time
  - Electron Spread
  - Stability over time
- Setup 2:
  - Pulse Linearity
- Setup 3:
  - Anode Uniformity

Setup 1



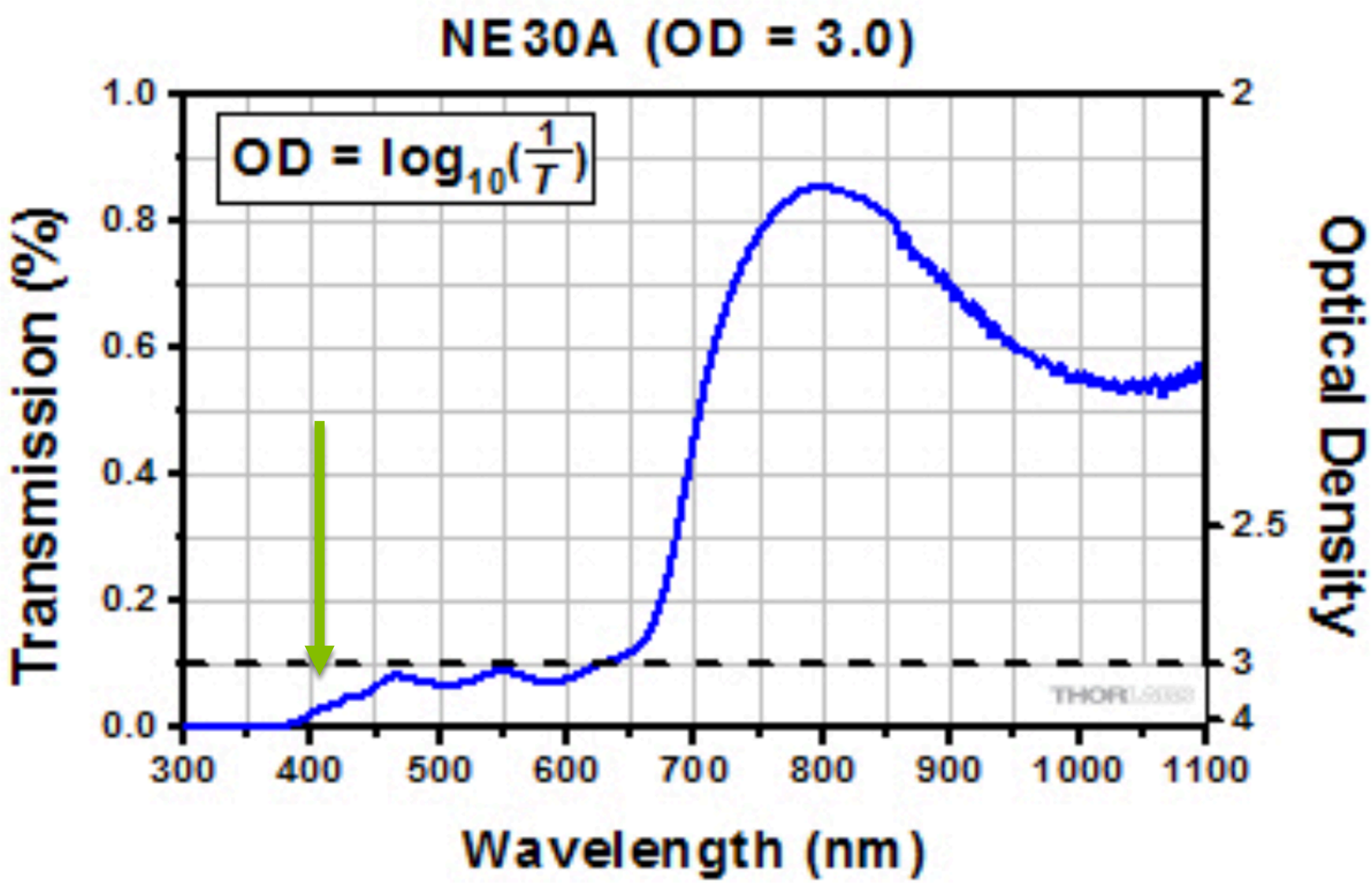
Laser

- Picosecond Injection Laser (PiLas)
- Wavelength: 404 nm
- Spectral width: 1.7 nm
- Beam diameter (0.5 m): 1.8 mm x 0.8 mm
- Pulse energy at 60% tune: 34 pJ
- Pulse width: 32 ps



Filter

- 25 mm Absorptive Neutral Density Filter *(NE30A)* by Thorlabs
- Optical Density: 3.0
  → T = 0.1%
- 404 nm: T = 0.024%

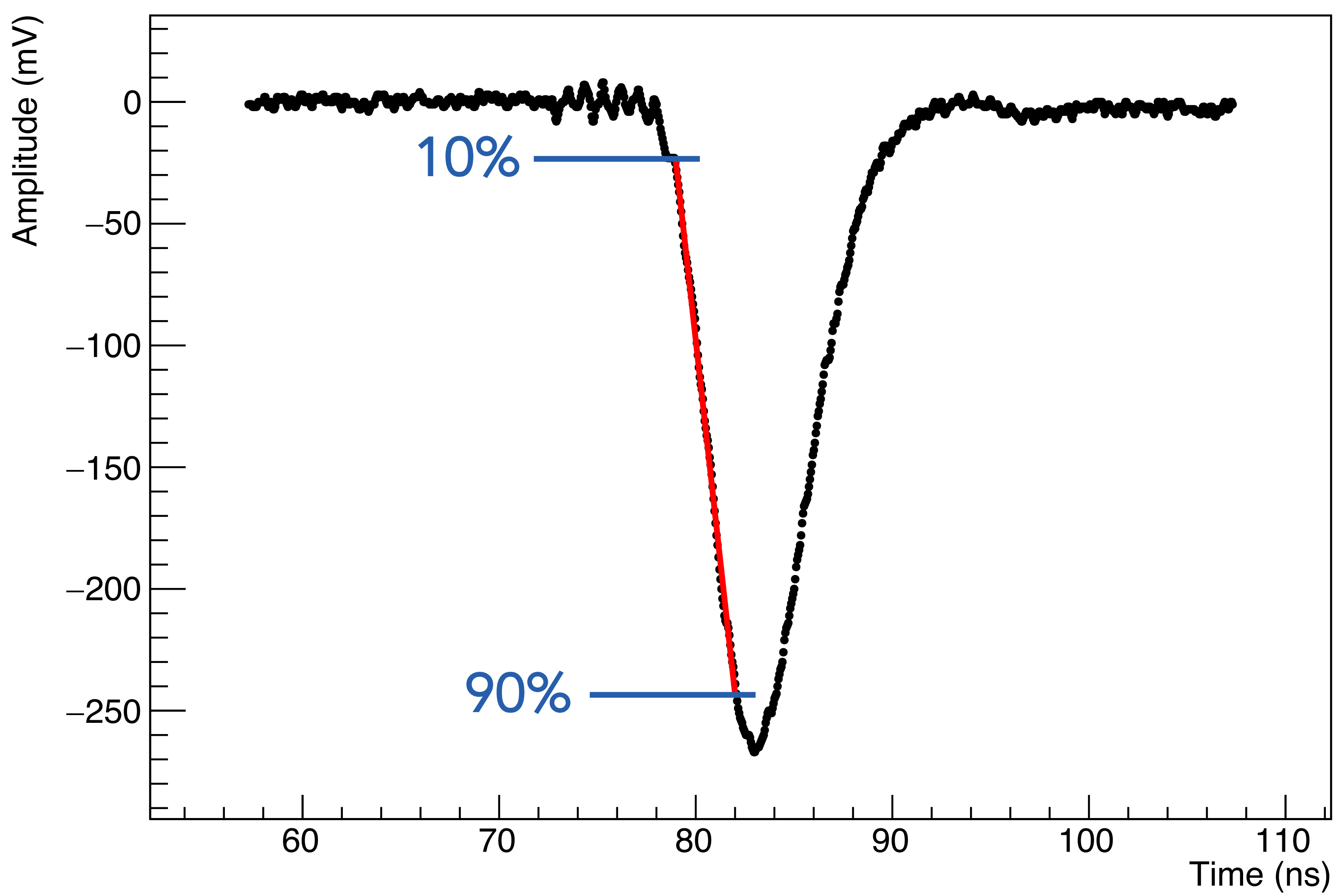


Anode Pulse Rise Time

- HV = 1.15 kV
- f = 200 Hz
- Tune = 60%

- Rise Time = (2.938 ± 0.007) ns

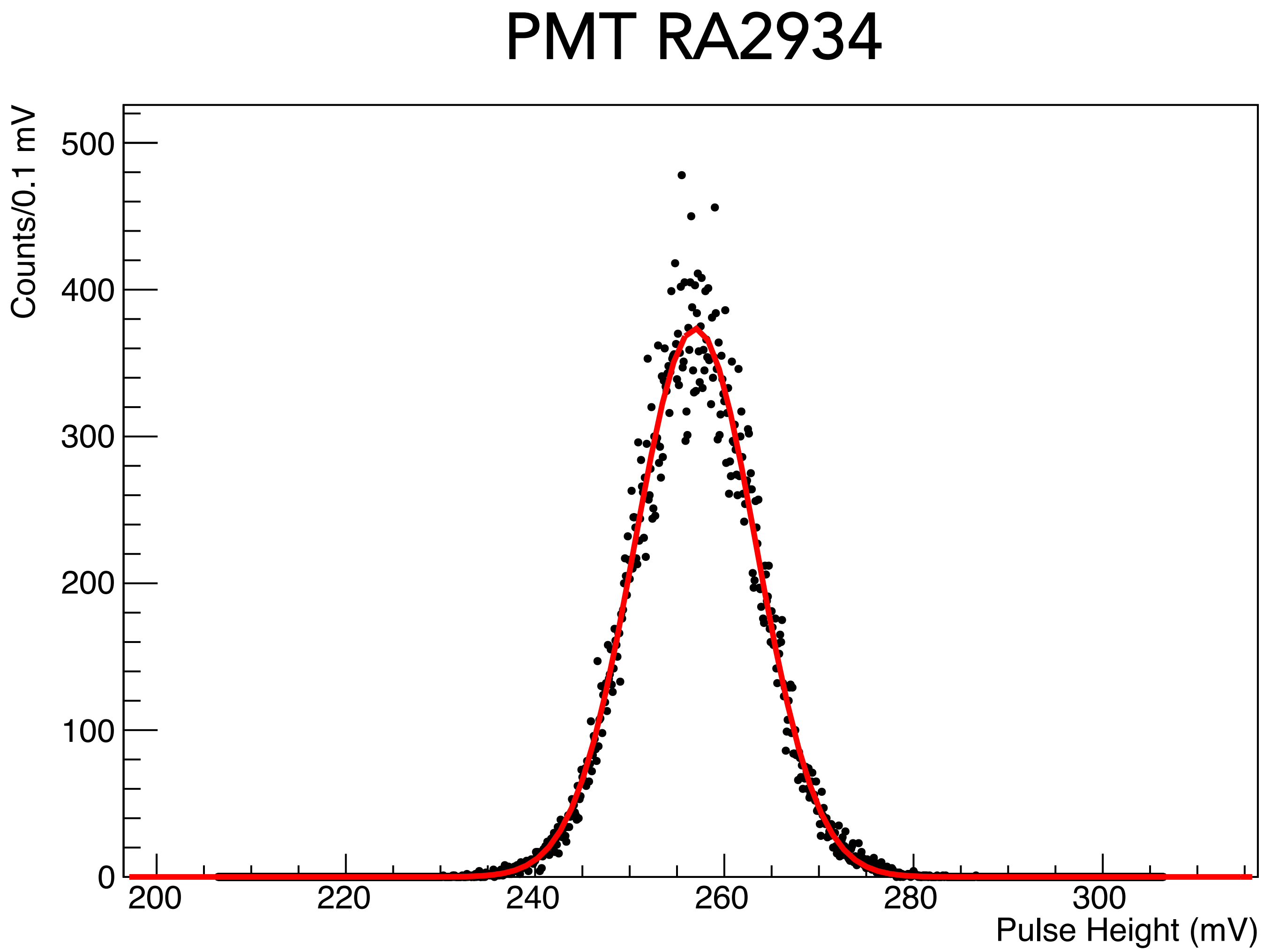
PMT RA2934



Gain Determination

- HV = 1.15 kV
- f = 200 Hz
- Tune = 60%

- Amplitude = 257 mV
- FWHM = 15 mV
- Gain ~ 0.8 x 10^5



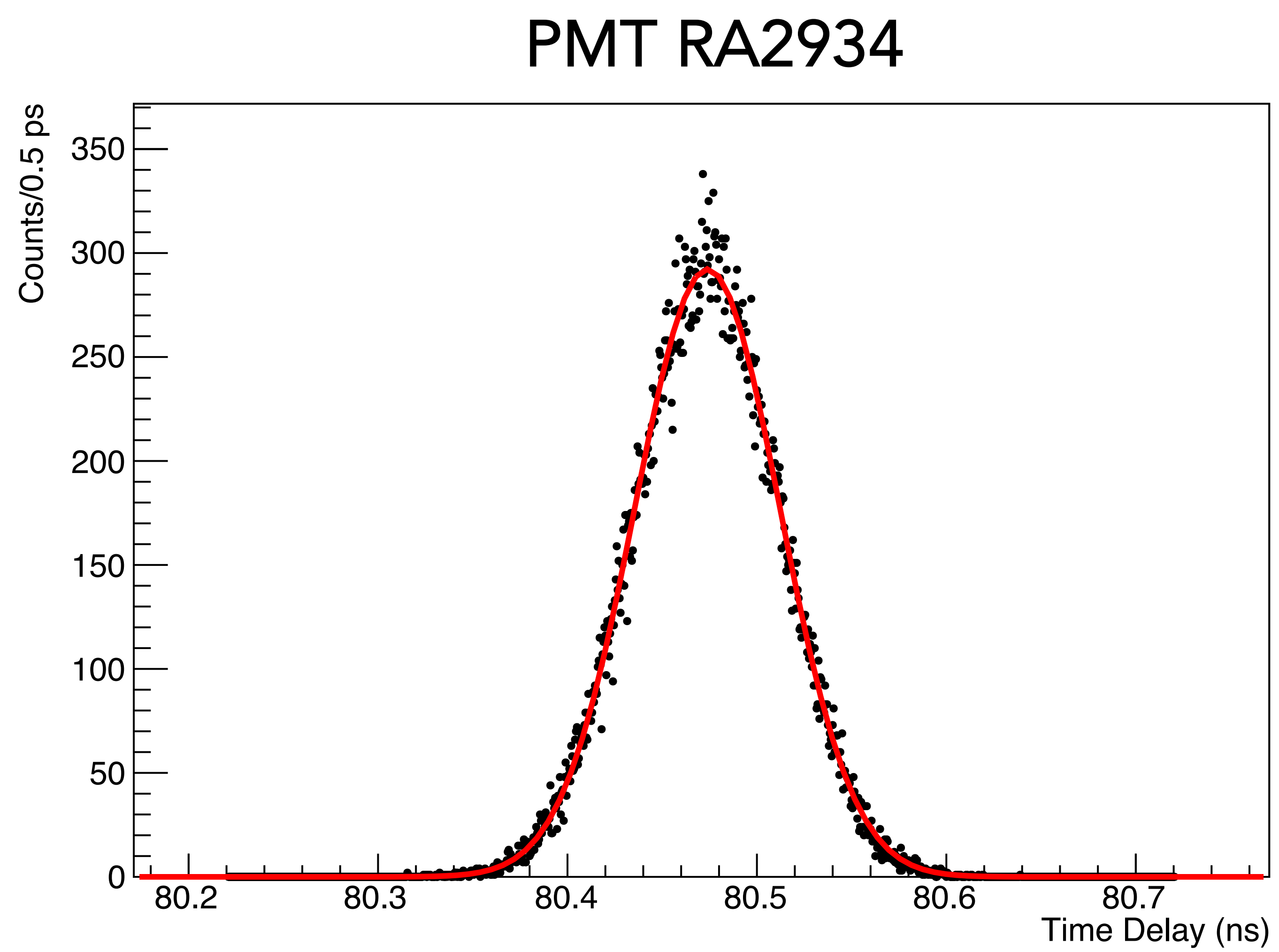
Electron Transit Time & Transit Time Spread

- $\Delta t = t_{laser\ pulse} - t_{trigger\ signal} = 73$ ns

- HV = 1.15 kV
- f = 200 Hz
- Tune = 60%

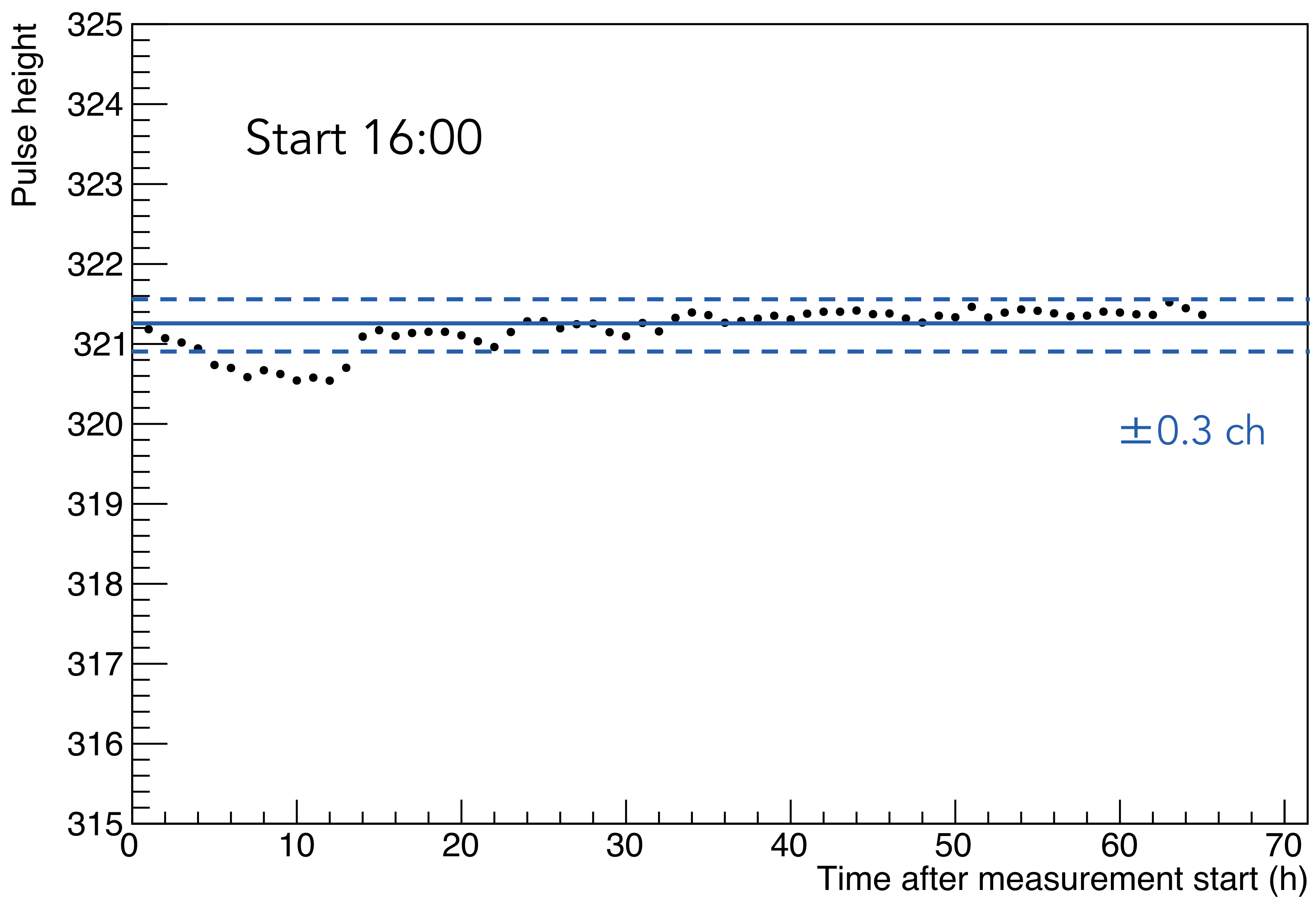
- Time delay = 80.5 ns
- FWHM = 90 ps

- Transit time = 7.5 ns
- Transit time spread = 90 ps



Stability over time

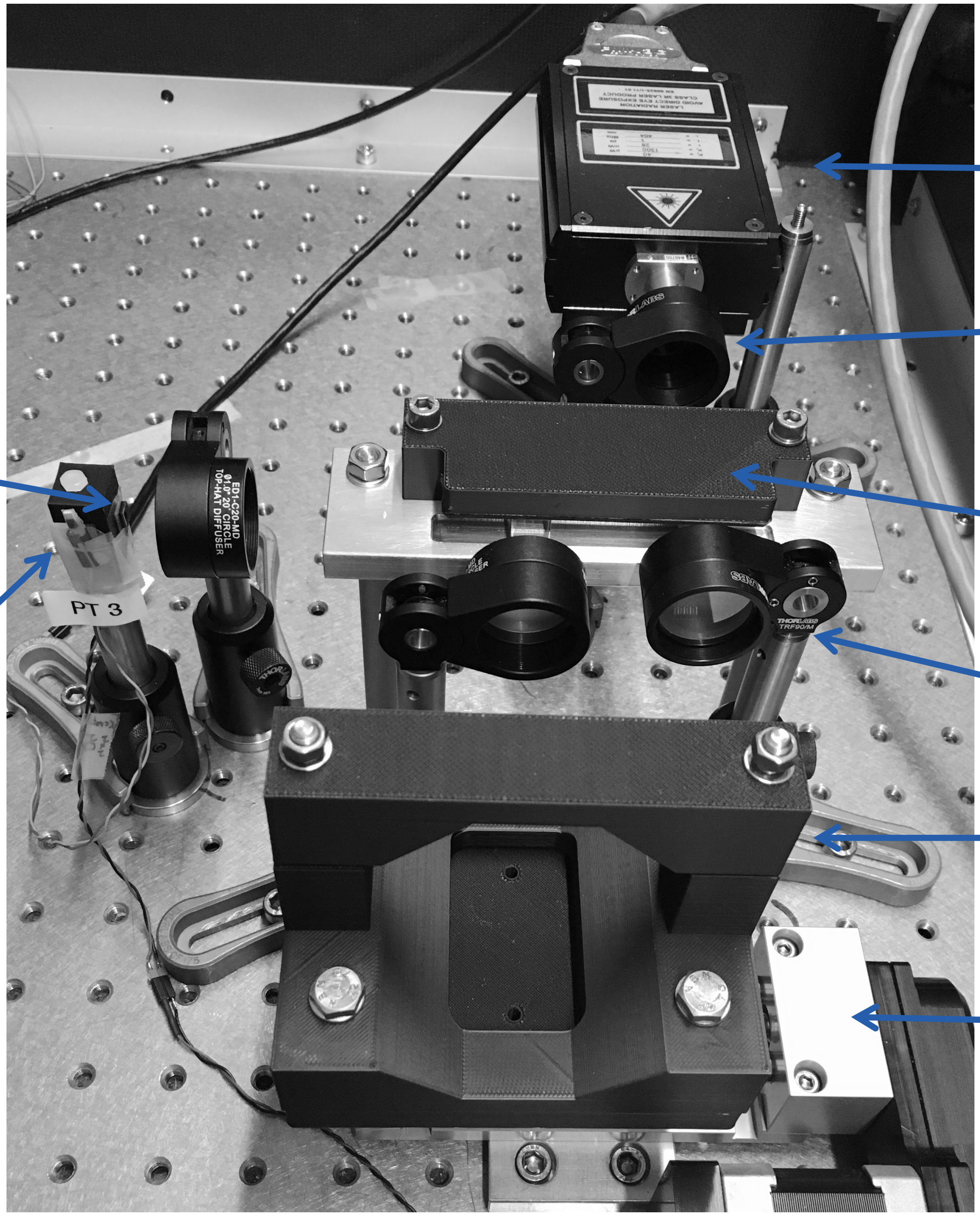
- PMT RA2908
- HV = 1050 V
- f = 50 Hz
- Tune = 50%



Comparison of PMTs

PMT Nr.	HV [kV]	Anode Pulse Rise Time [ns]	Amplitude [mV]	FWHM [mV]	ETT [ns]	TTS [ps]
RA2965	1.05	3.39	85	5	7.7	68
	1.15	3.32	181	12	7.5	79
	1.25	2.86	362	26	7.1	159
RA2918	1.05	3.10	201	14	7.5	54
	1.15	2.99	436	25	7.3	45
	1.25	2.86	887	48	7.0	67
RA2934	1.05	2.99	115	6	7.9	91
	1.15	2.94	257	15	7.5	90
	1.25	2.89	521	31	7.1	78

Setup 2



Pulse Linearity

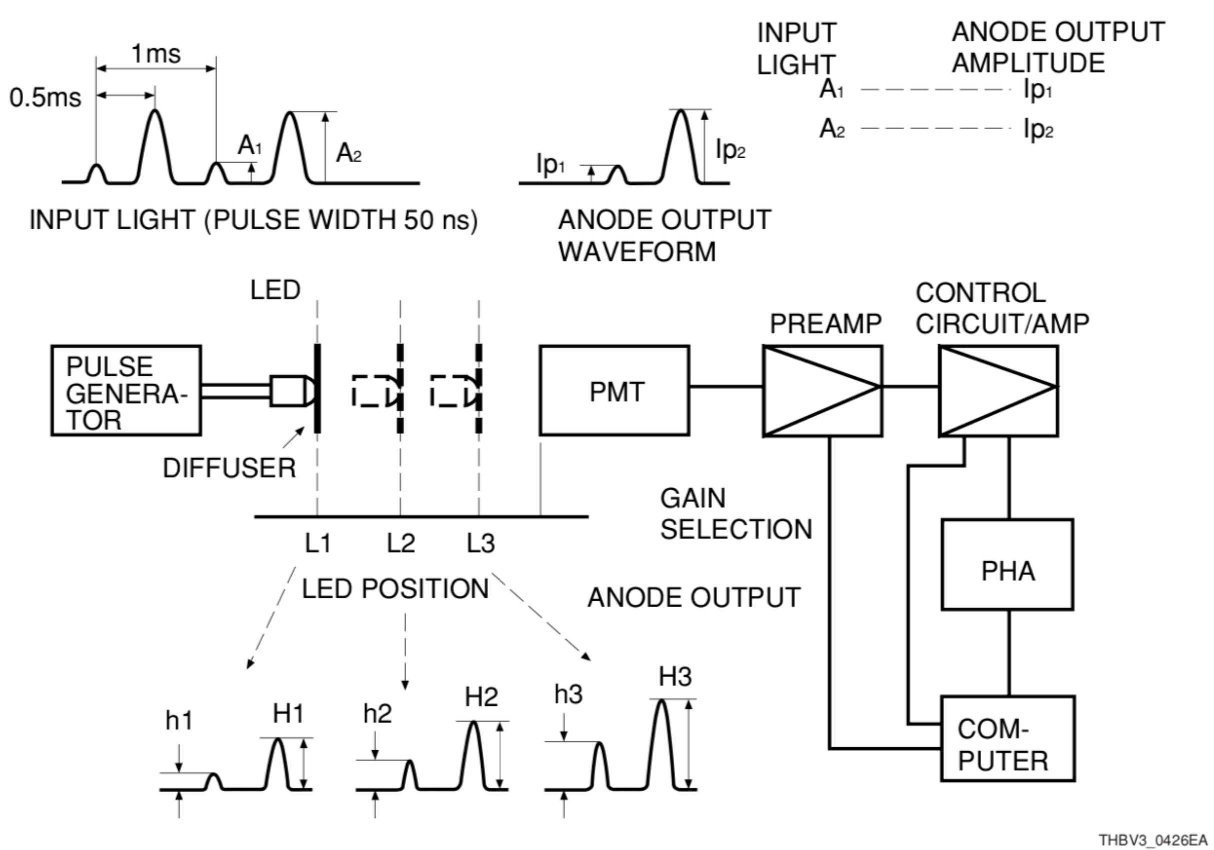


Figure 4-26: Block diagram for pulse mode linearity measurement

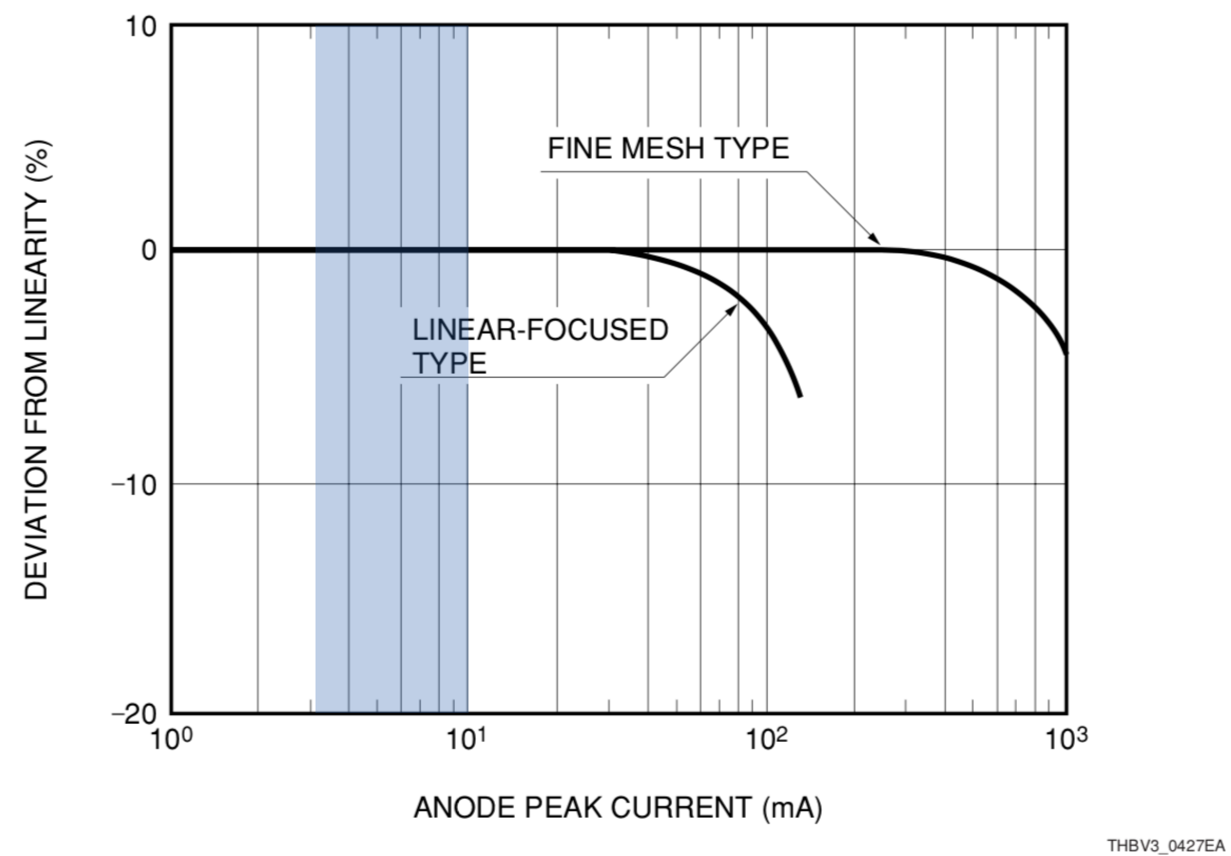
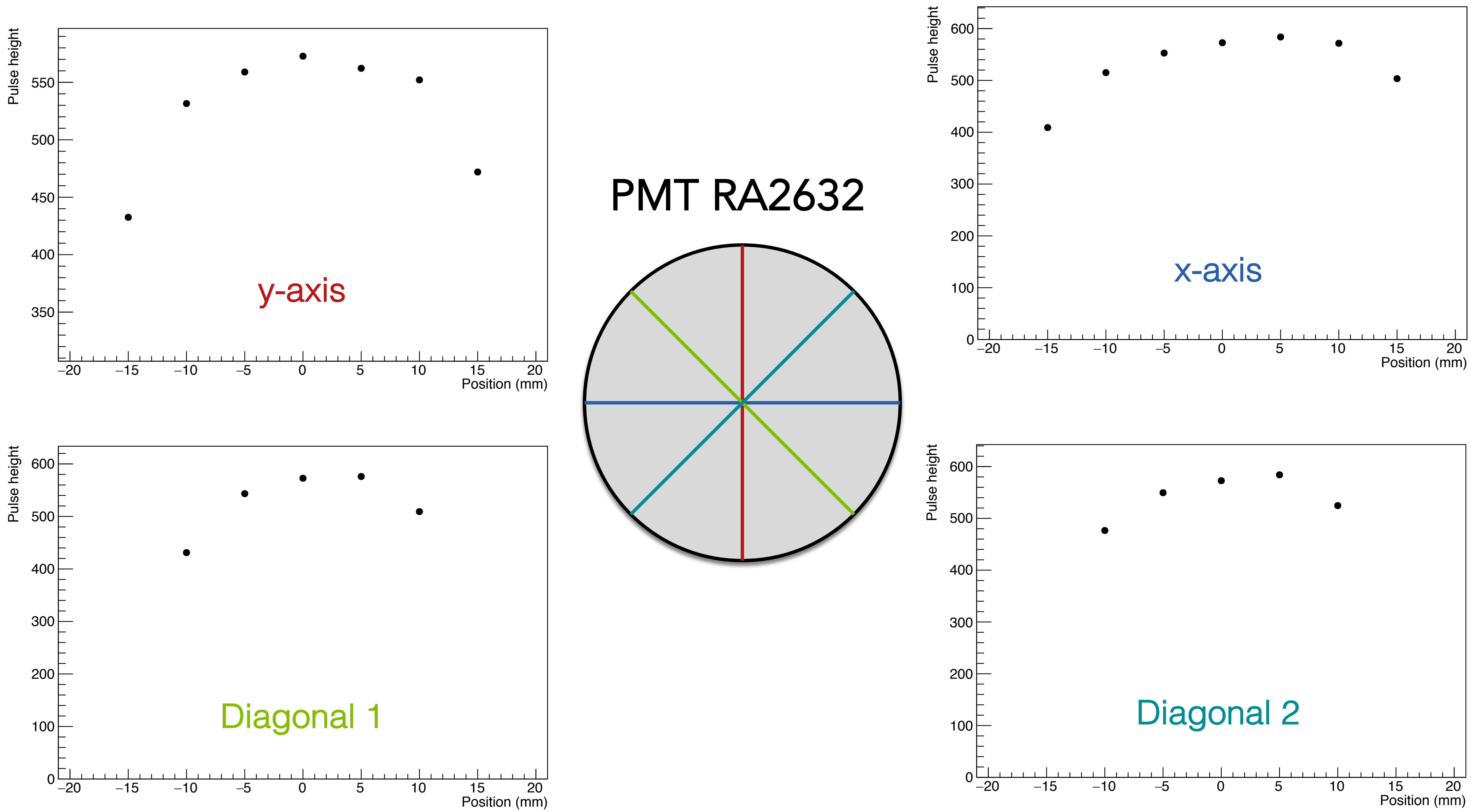


Figure 4-27: Pulse linearity

→ within measurement presicion results in agreement with theory

Anode Uniformity



Summary and Outlook

- Returned all PMTs to Hamamatsu for inspection because signal output resistor was faulty in three PMTs
- Measurements show all parameters are within specifications
- Still to do:
  - Continuation of anode uniformity measurements
  - Measurement of single after pulses
- Assembly will start middle of November

Sources

- Slide 3: cds.cern.ch/record/1125888/files/bul-pho-2008-078.jpg
- Slide 4: Wladyslaw H. Trzaska
- Slide 6: arXiv:1812.00594 [physics.ins-det]
- Slide 7: Wladyslaw H. Trzaska
- Slide 8: hamamatsu.com/eu/en/product/optical-sensors/pmt/about_pmts/index.html
- Slide 9: hamamatsu.com/eu/en/product/type/H6614-70/index.html
  hamamatsu.com/resources/pdf/etd/PMT_handbook_v3aE.pdf
- Slide 10: Hamamatsu
- Slide 11: ketek.net/sipm/technology/working-principle/
- Slide 12: Varlen Grabski
- Slide 14: Stefan Meyer Institute
- Slide 15: Advanced Laser Diode Systems – PiLas Test Report
- Slide 16: thorlabs.com/newgrouppage9.cfm?objectgroup_id=266&pn=NE30A#811
- Slide 23: hamamatsu.com/resources/pdf/etd/PMT_handbook_v3aE.pdf

Beamsplitters

- 50:50 Non-Polarizing Beamsplitter Cube (*BS010*) by Thorlabs
- Wavelength: 400 – 700 nm
- Side: 10 mm

- 30:70 Non-Polarizing Beamsplitter Cube *(BS049)* by Thorlabs
- Wavelength: 400 – 700 nm
- Side: 10 mm

Diffuser

- Thorlabs 1" 20° Circle Top-Hat Diffuser (*ED1-C20-MD*)
- Transmission: 90%

Calculation of photon number and pulse height

Pulse energy at 60% tune value: $34 \text{ pJ} = 34 \cdot 10^{-12} \cdot 6.2 \cdot 10^{18} \text{ eV} = 2.11 \cdot 10^{8} \text{ eV}$

Number of photons: $\dfrac{2.11 \cdot 10^{8} \text{ eV}}{3.07 \text{ eV}} = 6.87 \cdot 10^{7}\ \gamma$

Photons after diffuser: $0.9 \cdot 6.87 \cdot 10^{7}\ \gamma = 6.18 \cdot 10^{7}\ \gamma$

Photons after beamsplitter (0°): $0.474 \cdot 6.18 \cdot 10^{7}\ \gamma = 2.93 \cdot 10^{7}\ \gamma$

Photons after NE30A filter: $2.42 \cdot 10^{-4} \cdot 2.93 \cdot 10^{7}\ \gamma = 7077.02\ \gamma$

Quantum efficiency: $0.3 \cdot 7077.02\ \gamma = 2123.11 \text{ p.e.}$

In PMT with gain of 1×10^{5}: $10^{5} \cdot 2123.11 = 2.12 \cdot 10^{8} \text{ p.e.}$

Charge in PMT: $1.602 \cdot 10^{-19} \text{ As} \cdot 2.12 \cdot 10^{8} \text{ p.e.} = 2.25 \cdot 10^{-11} \text{ As}$

Resulting current: $\dfrac{2 \cdot 2.25 \cdot 10^{-11} \text{ As}}{10 \text{ ns}} = 0.0045 \text{ A}$

Measured pulse height: $0.0045 \text{ A} \cdot 50\ \Omega = 225 \text{ mV}$

Blue Sensitivity

- Like luminous sensitivity measurement, only with blue filter placed infront of PMT → cannot be directly represented by lumens
- Blue filter: Corning Cs No. 5-58
- Luminous sensitivity: output current obtained from cathode or anode divided by the incident luminous flux