PMT Characterization for FlashCam

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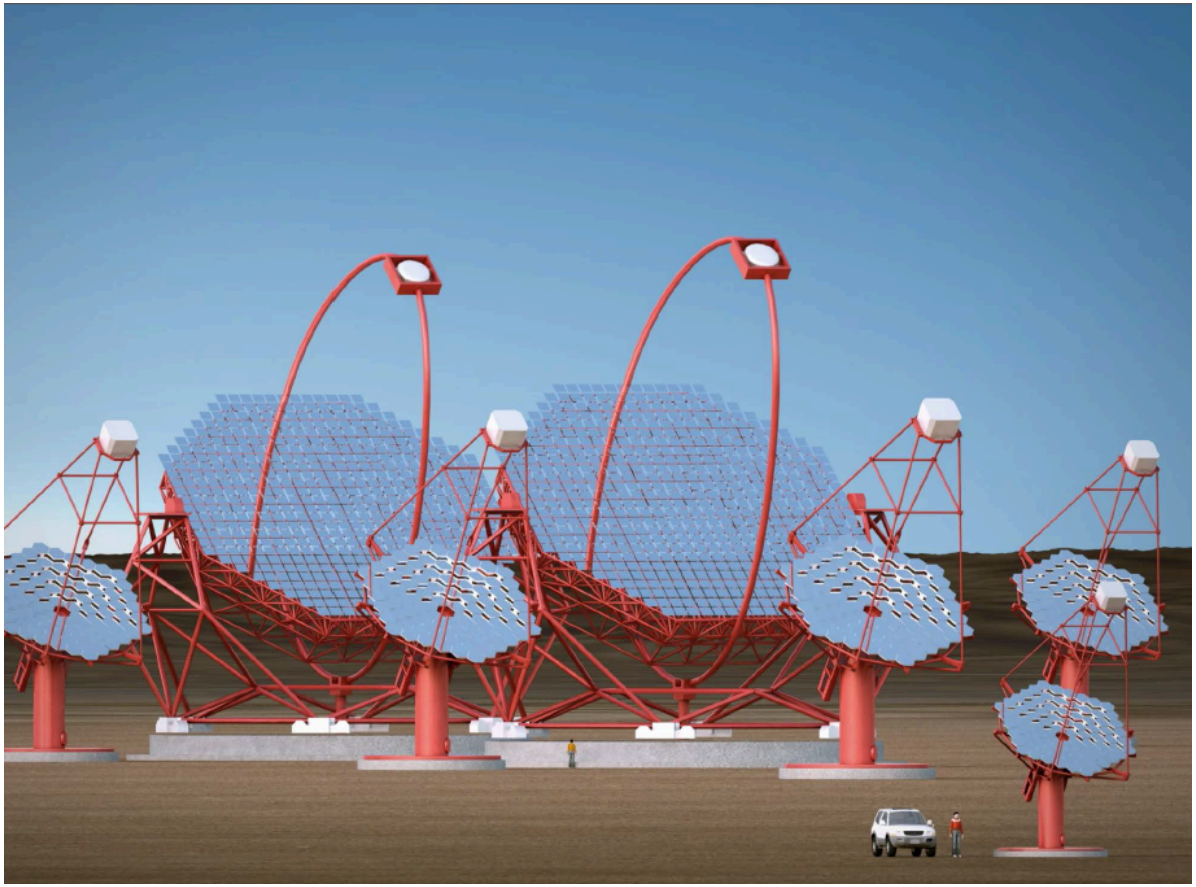
cta cherenkov telescope array

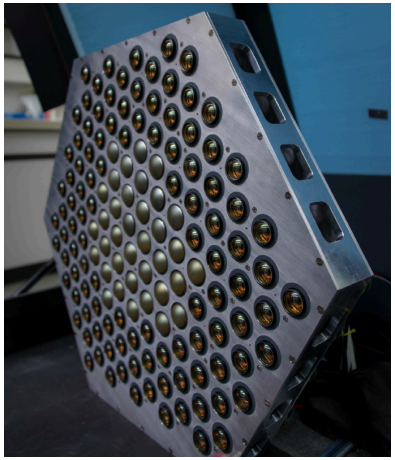
ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

The Cherenkov Telescope Array (CTA)



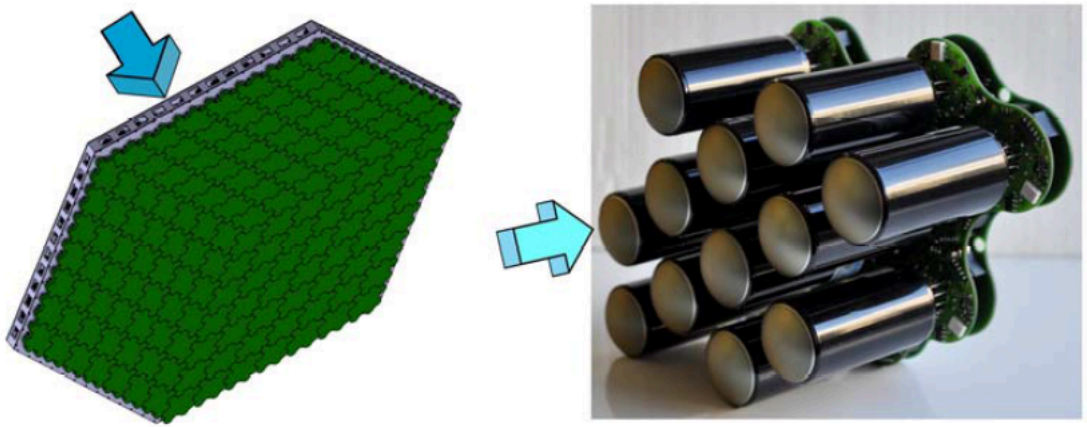
Camera for MSTs:

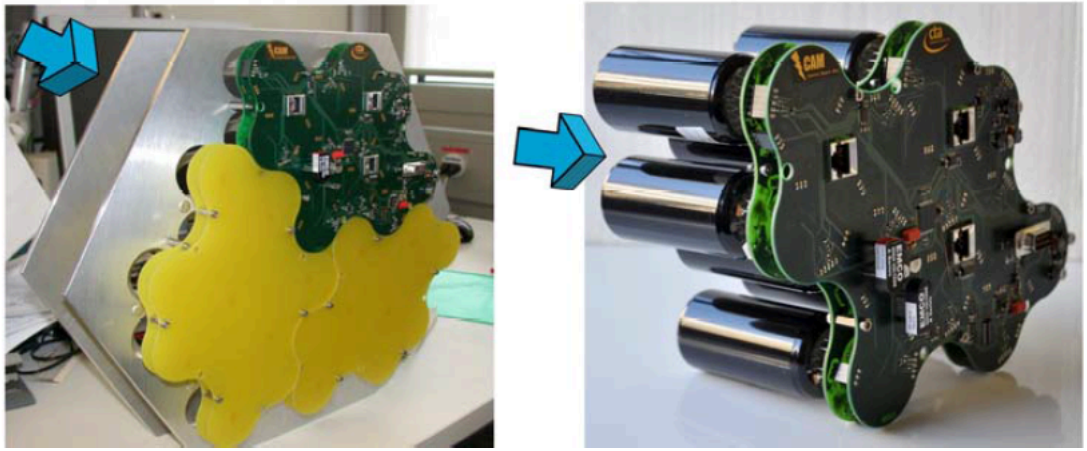


FlashCam

(144 pixel PDP test setup)

FlashCam





Complete camera:

- 147 modules
- 12 PMTs per module

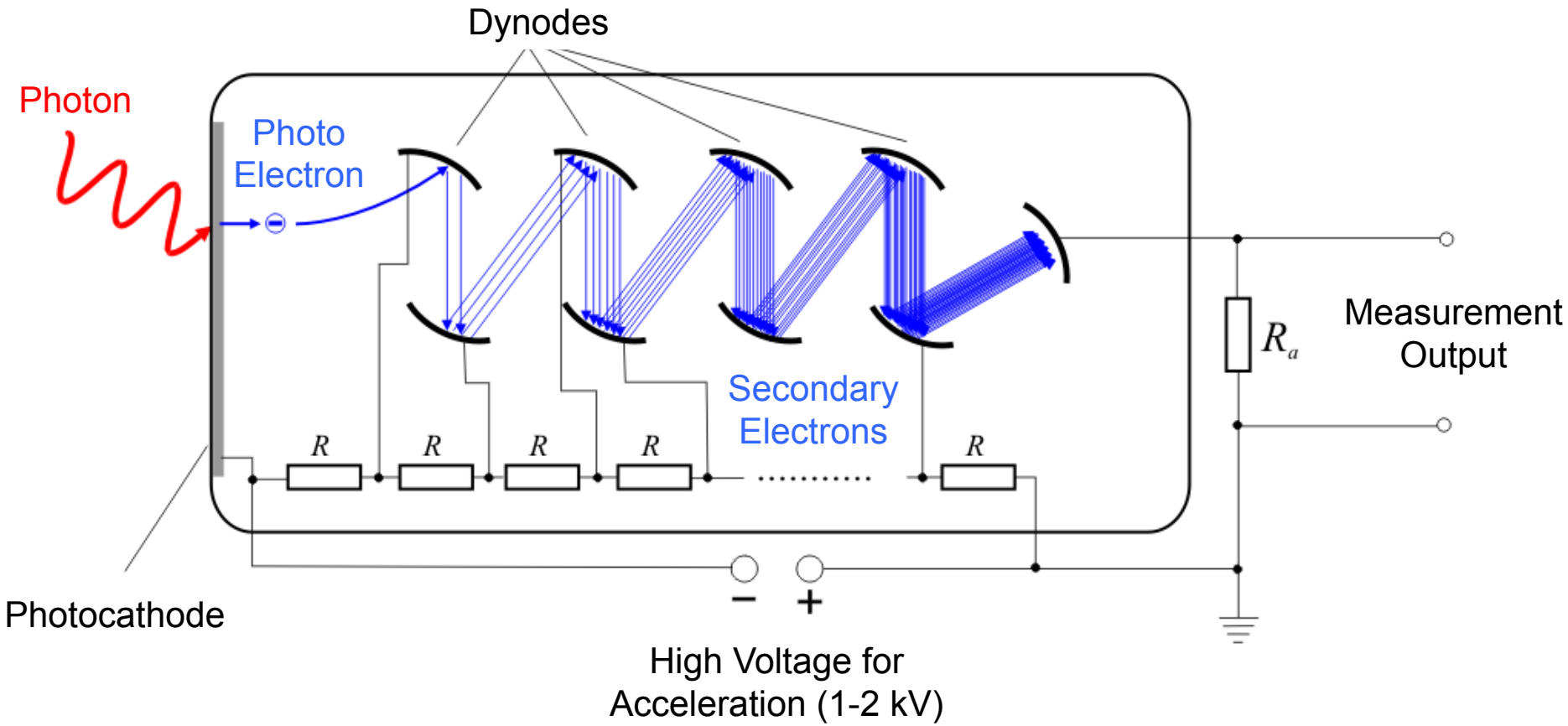
→ 1764 pixels (=PMTs)

PMTs produced by Hamamatsu (Japan)

Characterization of PMTs in Erlangen!

Which are the important parameters of a PMT to be measured?

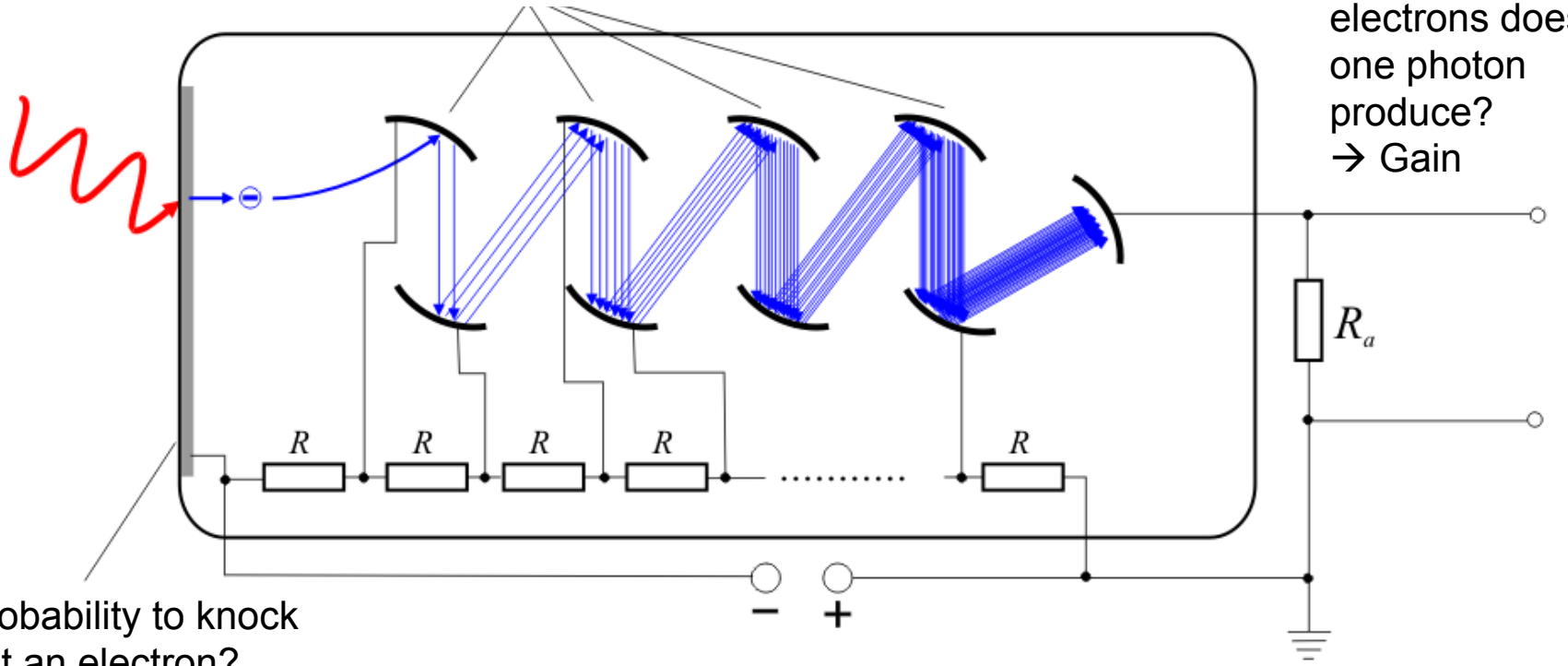
PMT Functionality



PMT Parameters

How long does it take from photon to anode-current?
→ Transit Time

How many electrons does one photon produce?
→ Gain

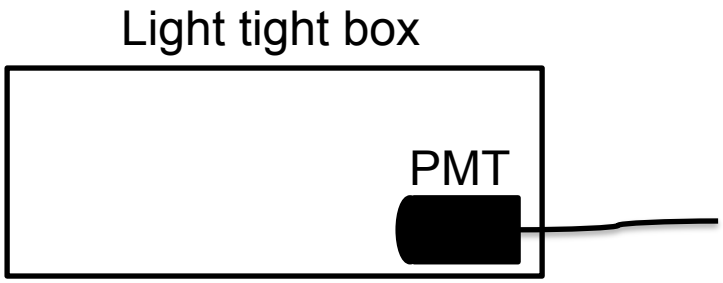


Probability to knock out an electron?
→ Quantum Efficiency

And many other Parameters…

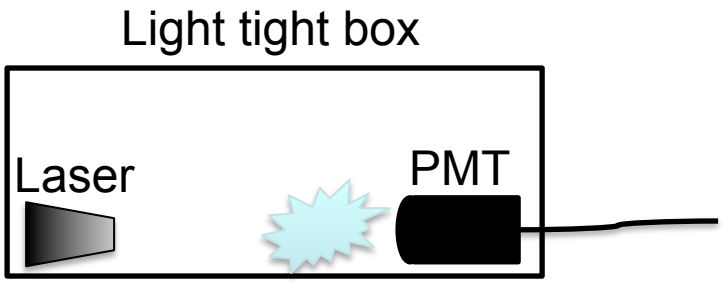
Measurement Setup

Measurement Setup



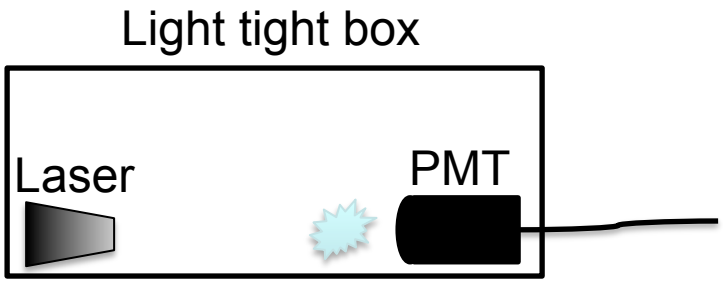
- Put PMT in a light tight box

Measurement Setup



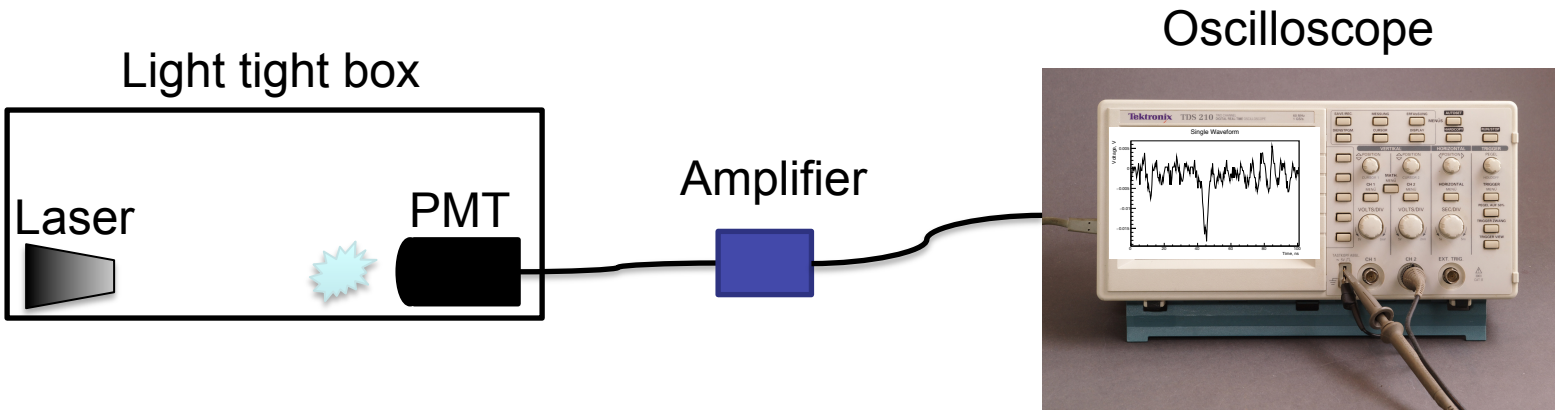
- Put PMT in a light tight box
- Shoot laser pulses at it

Measurement Setup



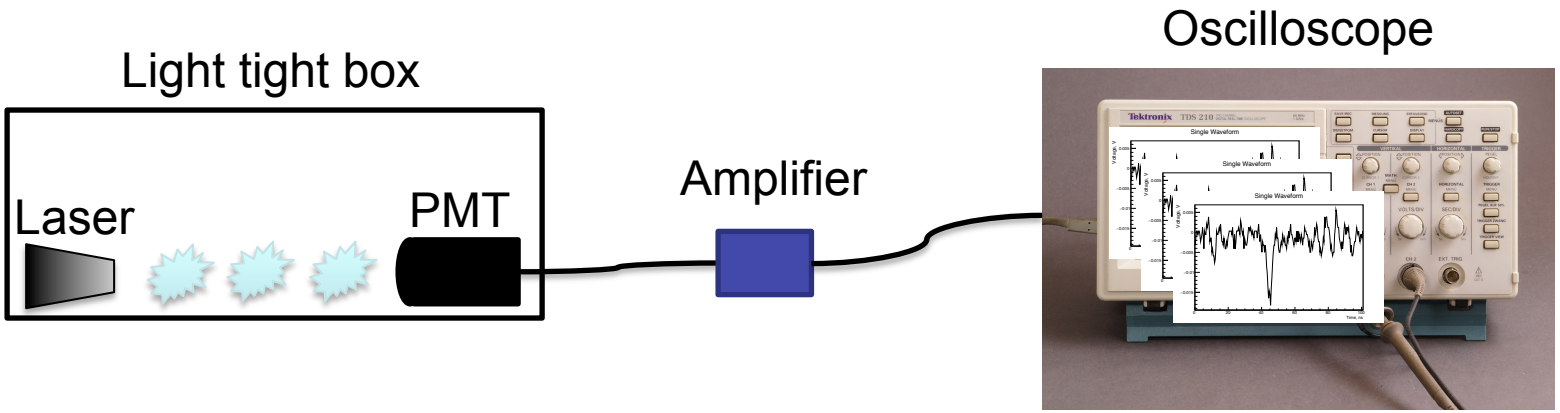
- Put PMT in a light tight box
- Shoot laser pulses at it
- Use low laser intensity to get single photo electron (SPE) pulses

Measurement Setup



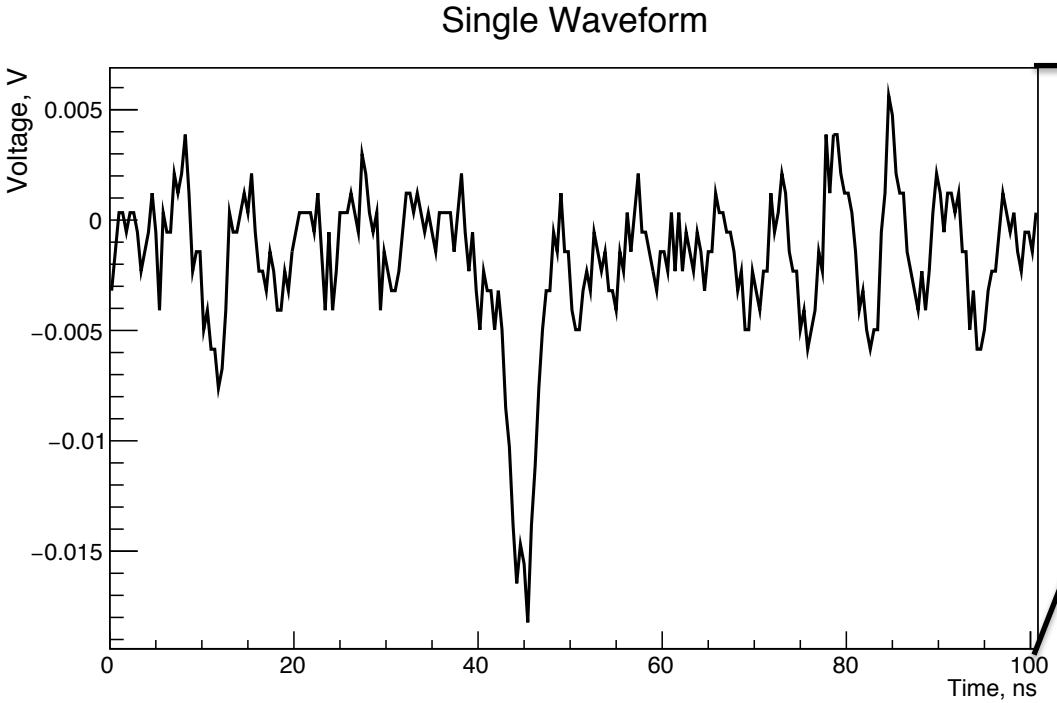
- Put PMT in a light tight box
- Shoot laser pulses at it
- Use low laser intensity to get single photo electron (SPE) pulses
- Measure waveforms with Osci (amplifier needed)

Measurement Setup

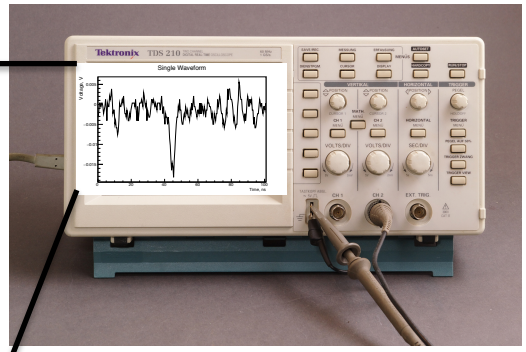


- Put PMT in a light tight box
- Shoot laser pulses at it
- Use low laser intensity to get single photo electron (SPE) pulses
- Measure waveforms with Osci (amplifier needed)
- Repeat 50 000 times!

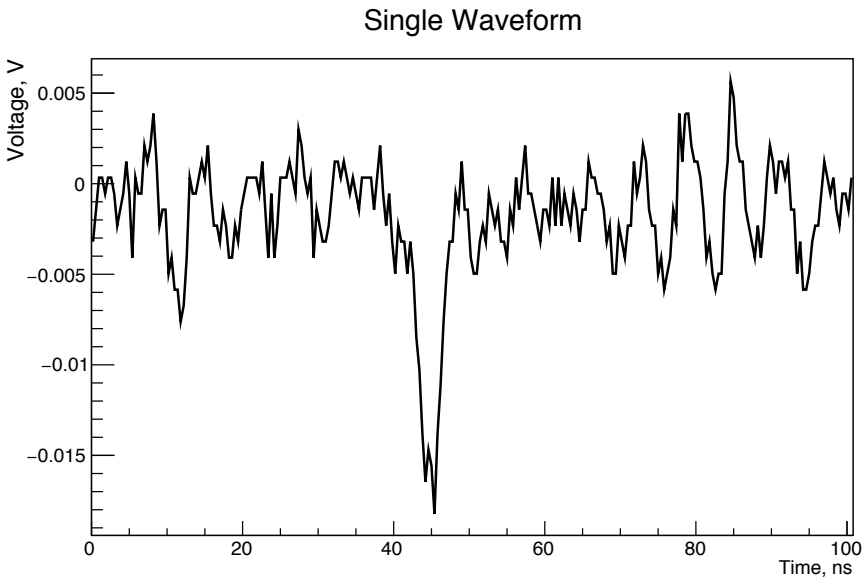
What a Waveform looks like



Oscilloscope

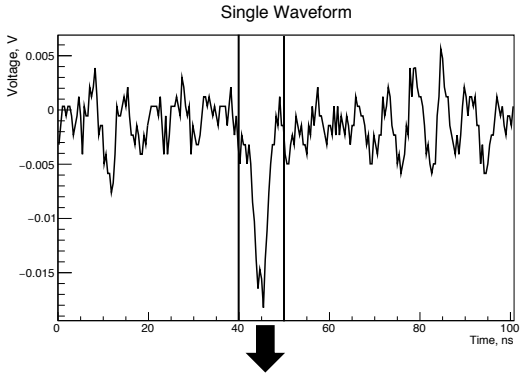


Let’s analyze it!

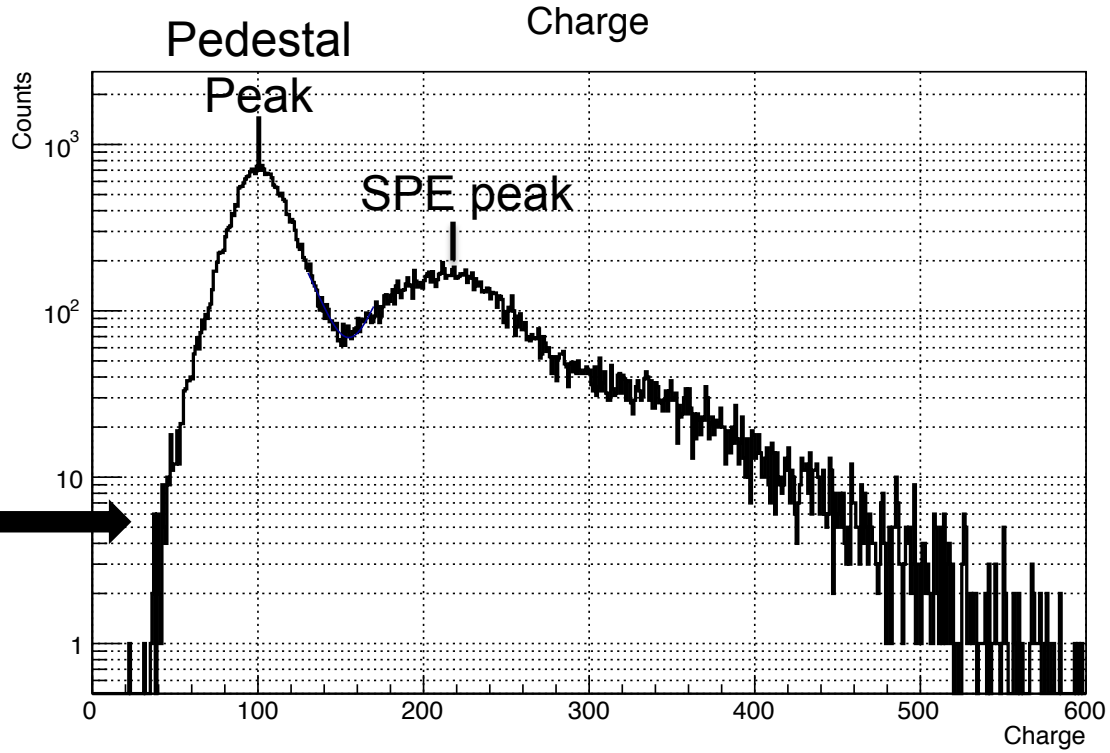


Gain

Integrate over time

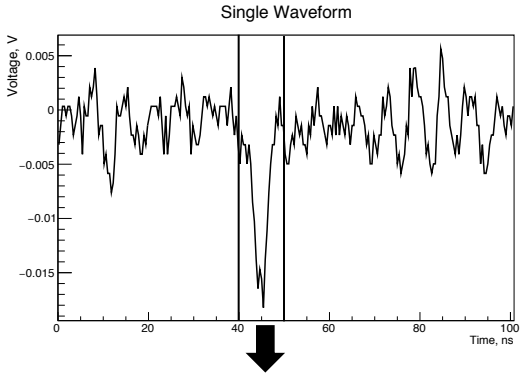


Charge

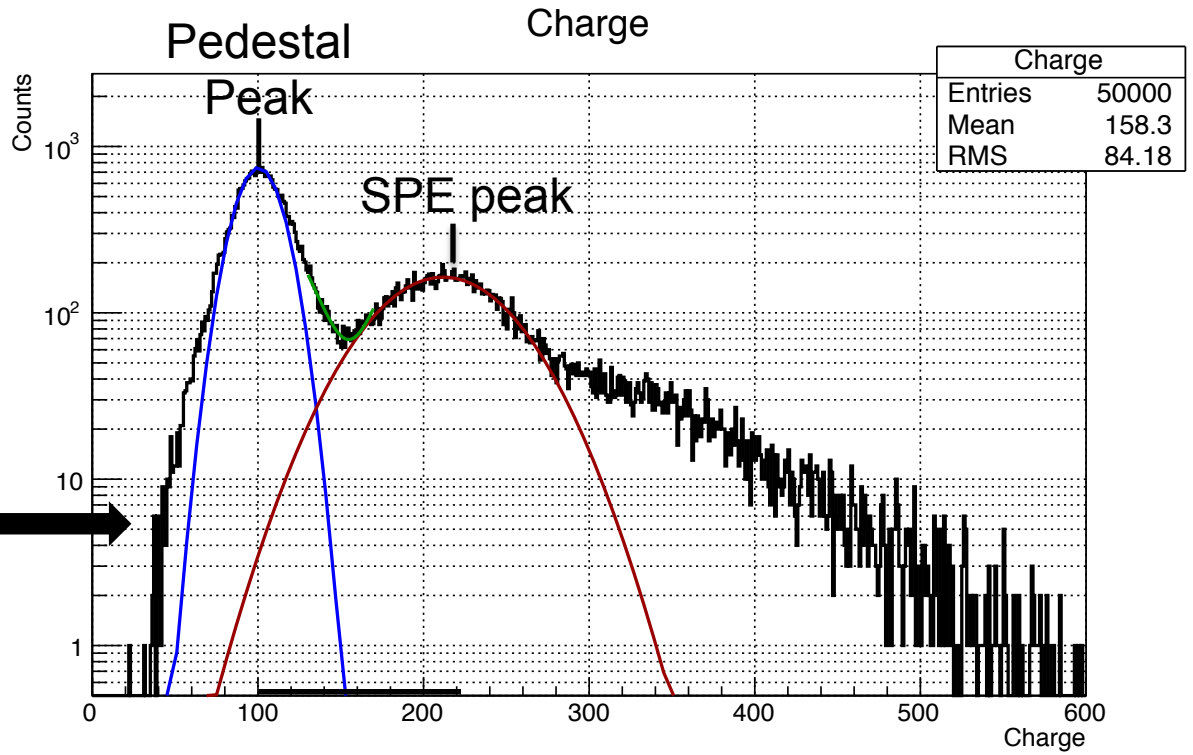


Gain

Integrate over time



Charge

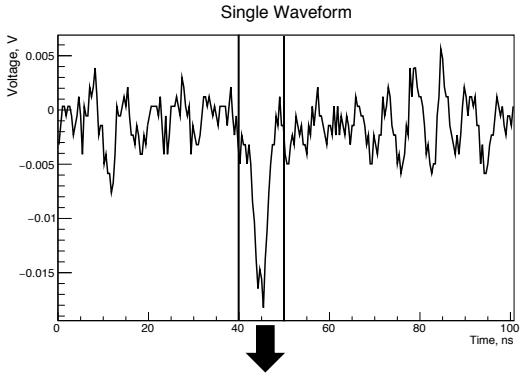


→ Gain (depends on applied Voltage!)

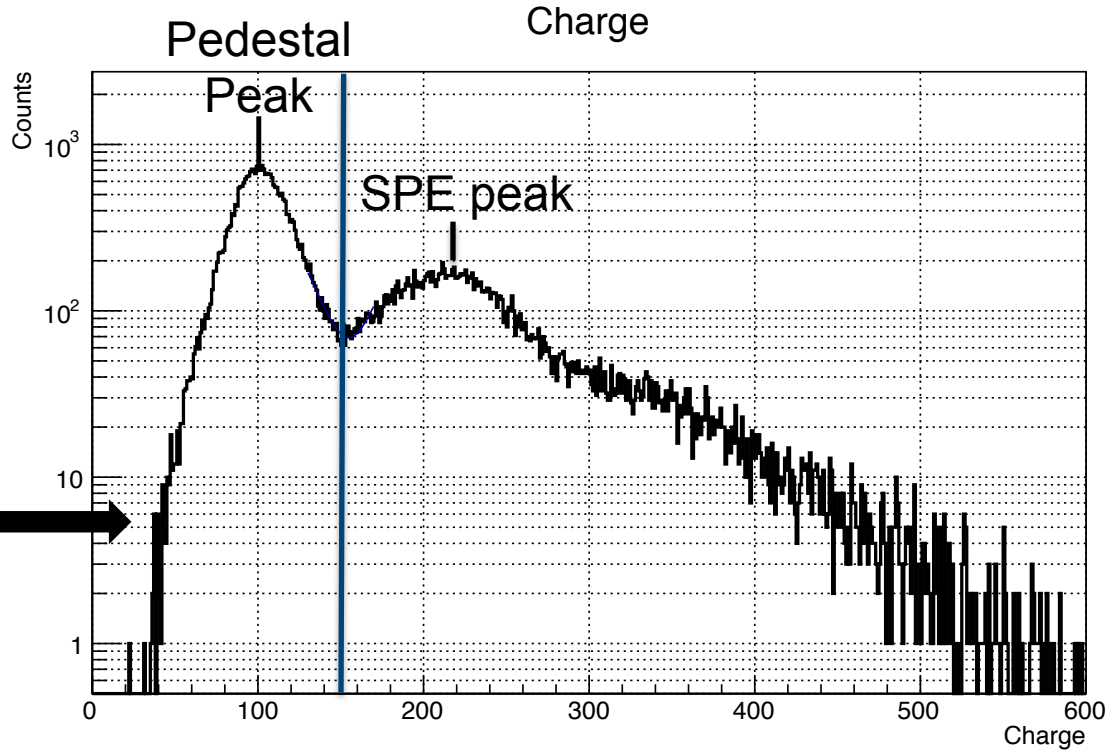
here: ~5*10^5 @ 1200 V

Number of Photoelectrons per Pulse

Integrate over time



Charge

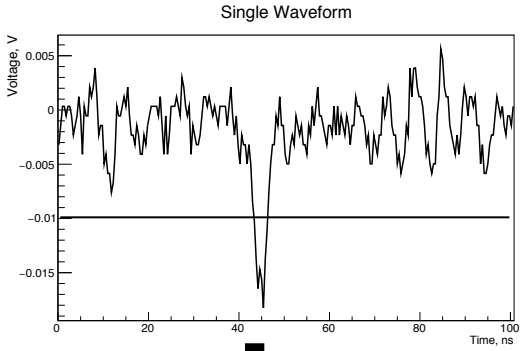


→ Number of Photoelectrons

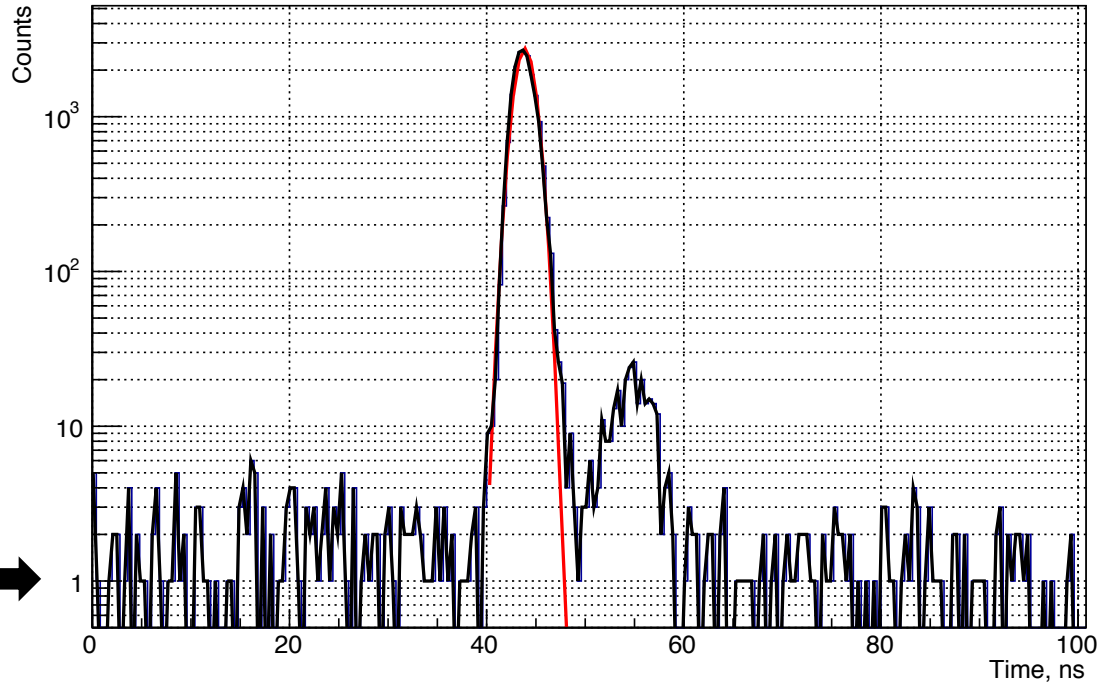
here: ~0.49 per Laser Pulse

Transit Time

Amplitude threshold

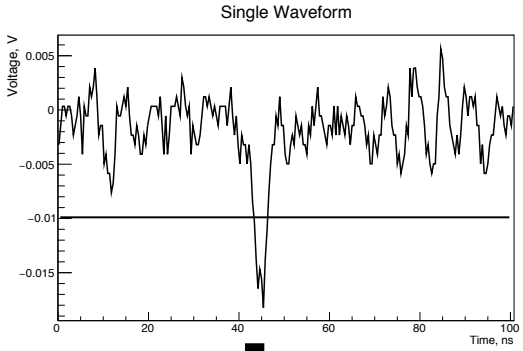


Time when signal first exceeds threshold



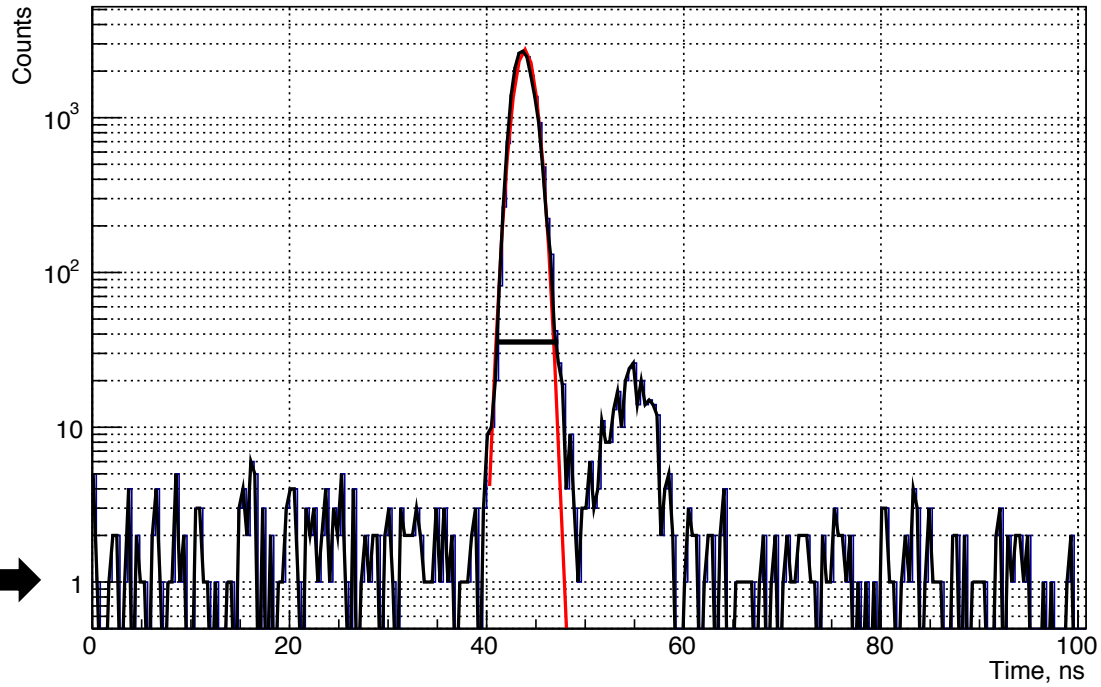
Transit Time Spread

Amplitude threshold



Time when signal first exceeds threshold

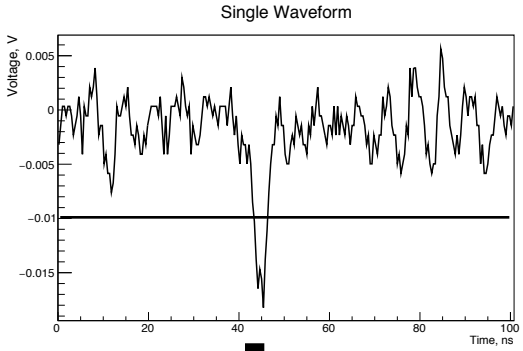
Transit time spread



→ Transit Time Spread FWHM ~2.45 ns

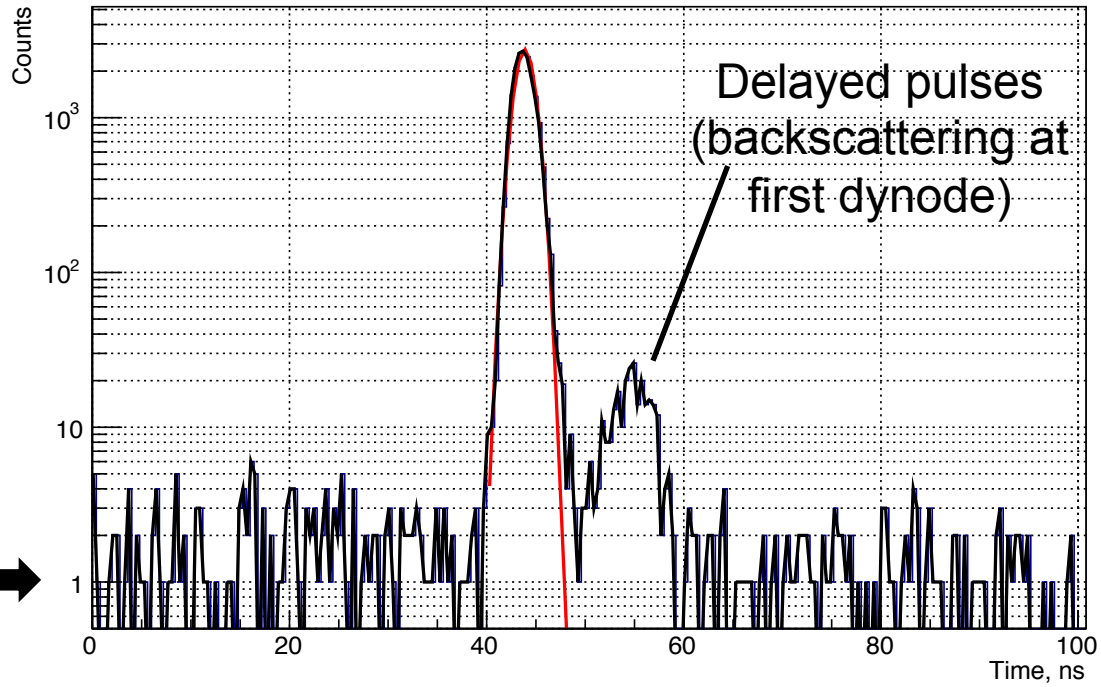
Delayed Pulses

Amplitude threshold



Time when signal first exceeds threshold

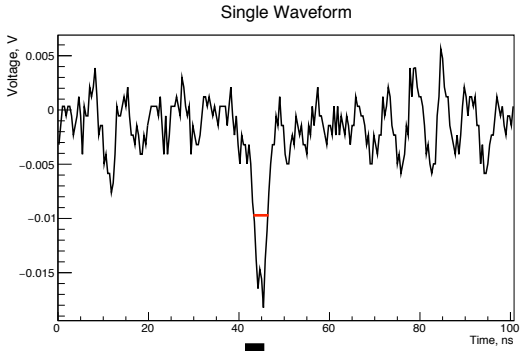
Transit time spread



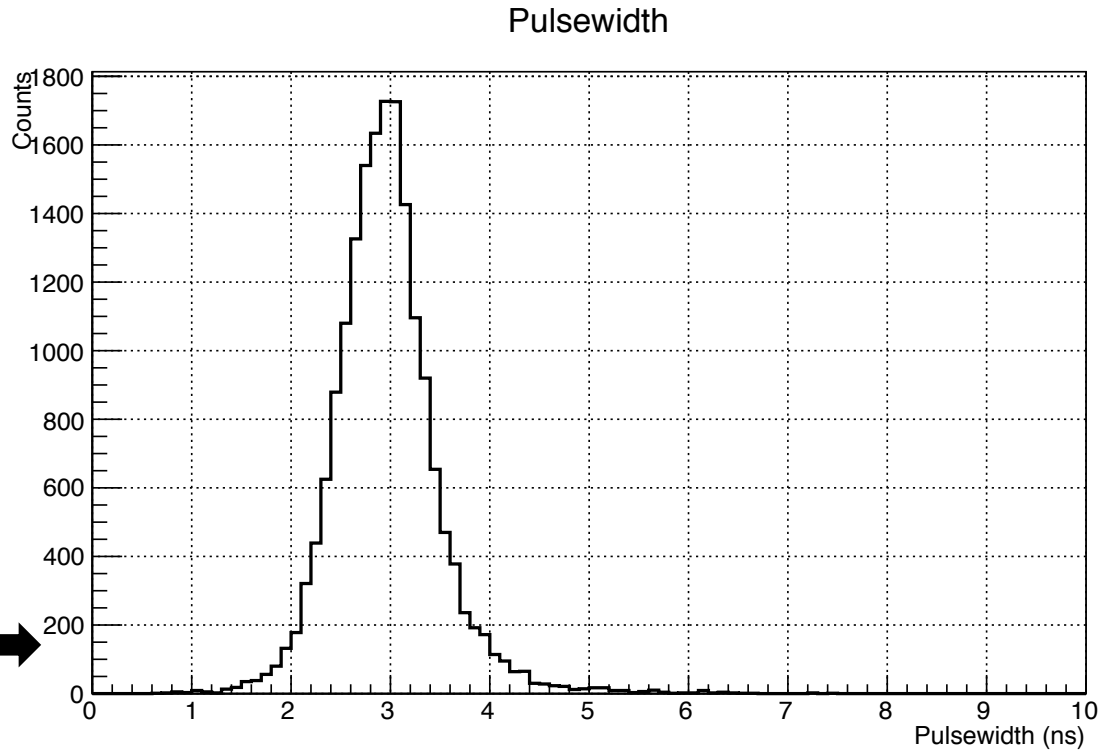
→ Delayed pulses ~1.4%

Pulse Width

Search in every WF



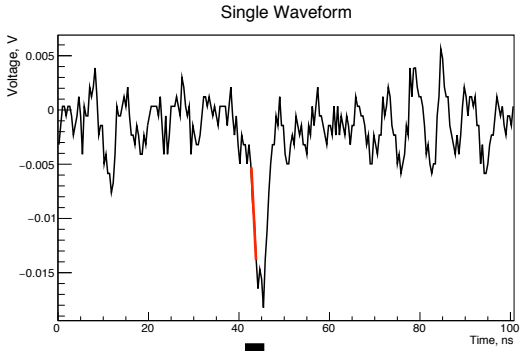
Pulsewidth
FWHM



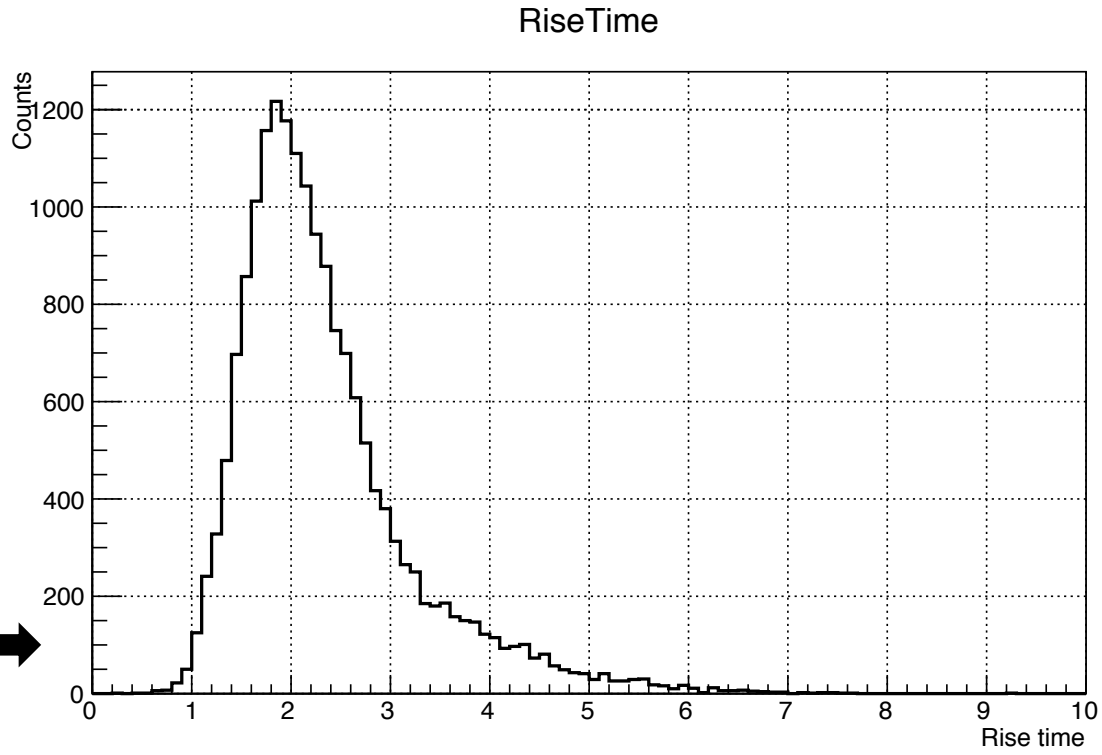
→ Mean 2.96 ns

Risetime

Amplitude threshold



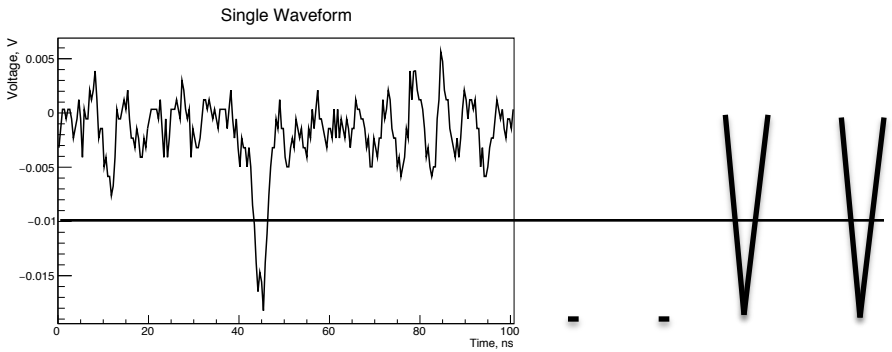
Time to get from 10% Peak to 90% Peak



→ Mean 2.34 ns

Afterpulsing

Longer observation time window



→ More pulses after a few 100 ns!

→ So called afterpulses

Mechanism 1:

- Photoelectron ionizes gas atom in PMT
- Acceleration to photo cathode

Mechanism 2:

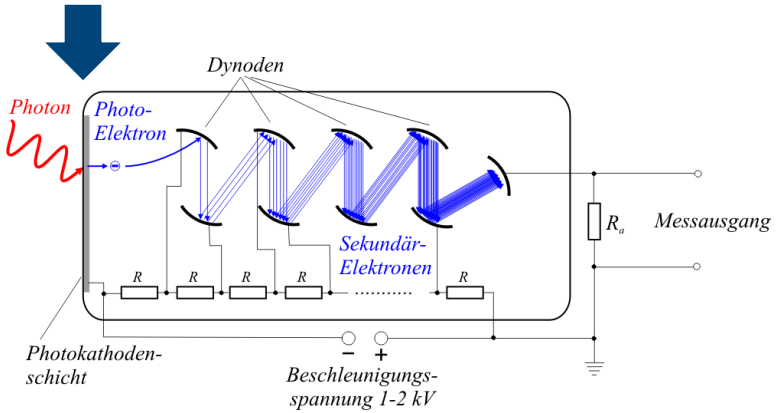
- Photoelectron produces photon at a dynode
- Photon is backscattered to photo cathode

- New photoelectron(s) produced at cathode
- Afterpulsing

Quantum Efficiency Measurement

Quantum Efficiency (QE)

(= Possibility of incoming photon to knock out an electron at the cathode)

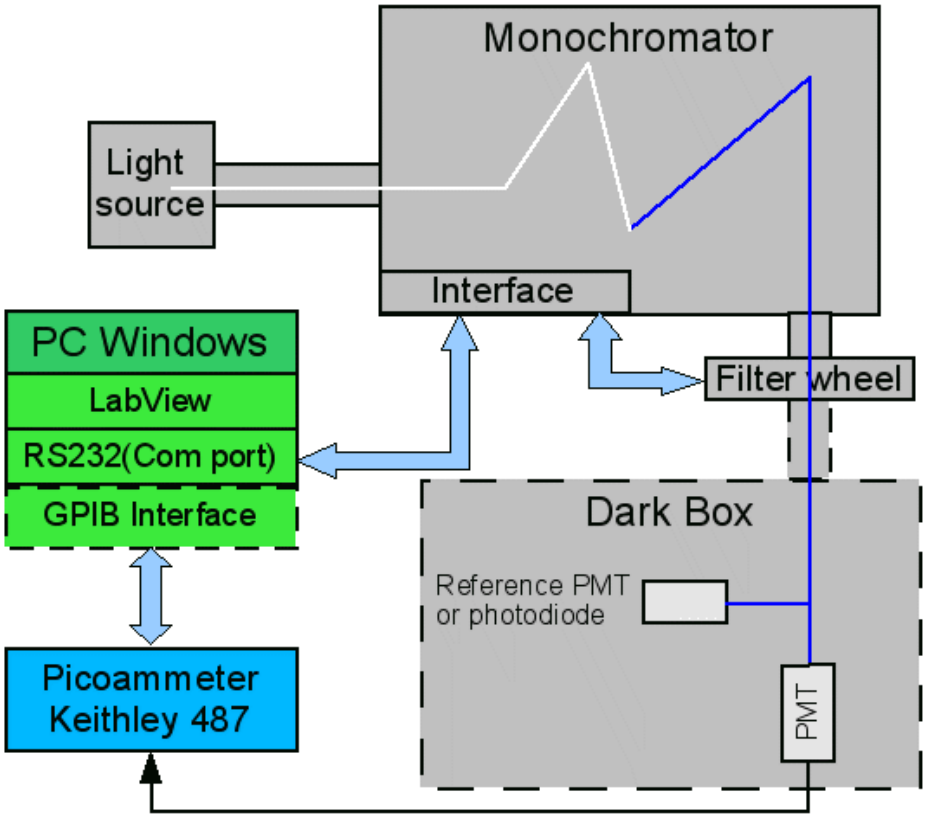


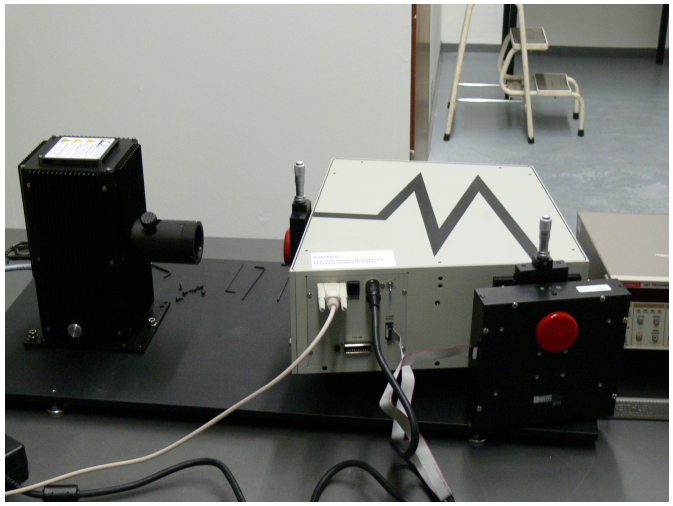
Measurement:

- All dynodes and anode connected, few hundred volts relative to cathode

  → Collection efficiency ~100%
- Monochromatic light (different wavelengths)
- Photocathode current measured (no amplification needed)
- Comparison with calibrated photodiode to know incoming light intensity

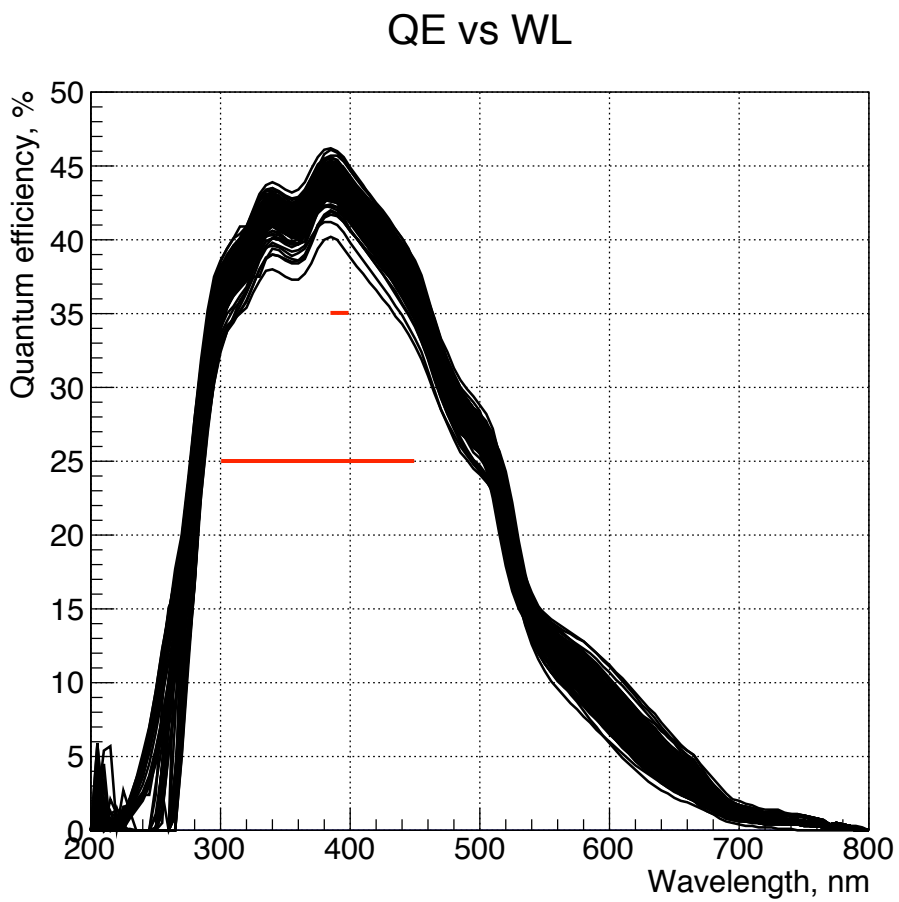
QE Measurement Setup





- Tungsten Xenon Lamp
- Monochromator LOT-Oriel MS301 fully automated 200-800 nm

QE Hamamatsu 8 dynode PMTs



- 100 PMTs measured
  - 50 in January
  - 50 in February
- Requirements fulfilled (red):
  - More than 25% between 300 nm and 450 nm
  - More than 35% at peak

Conclusion

- PMTs can be characterized by measuring certain parameters
- Different measurement setups for different parameters

- Most important parameters to characterize a PMT:
  - QE (Special base, all dynodes connected)
  - Gain (Charge parameter)
  - TTS (Time parameter)
  - Afterpulsing (Long measurement times)

- Test of Hamamatsu PMTs for FlashCam currently ongoing in Erlangen
- Measure everything (but QE) at once by measuring the waveform

Thanks for your attention!

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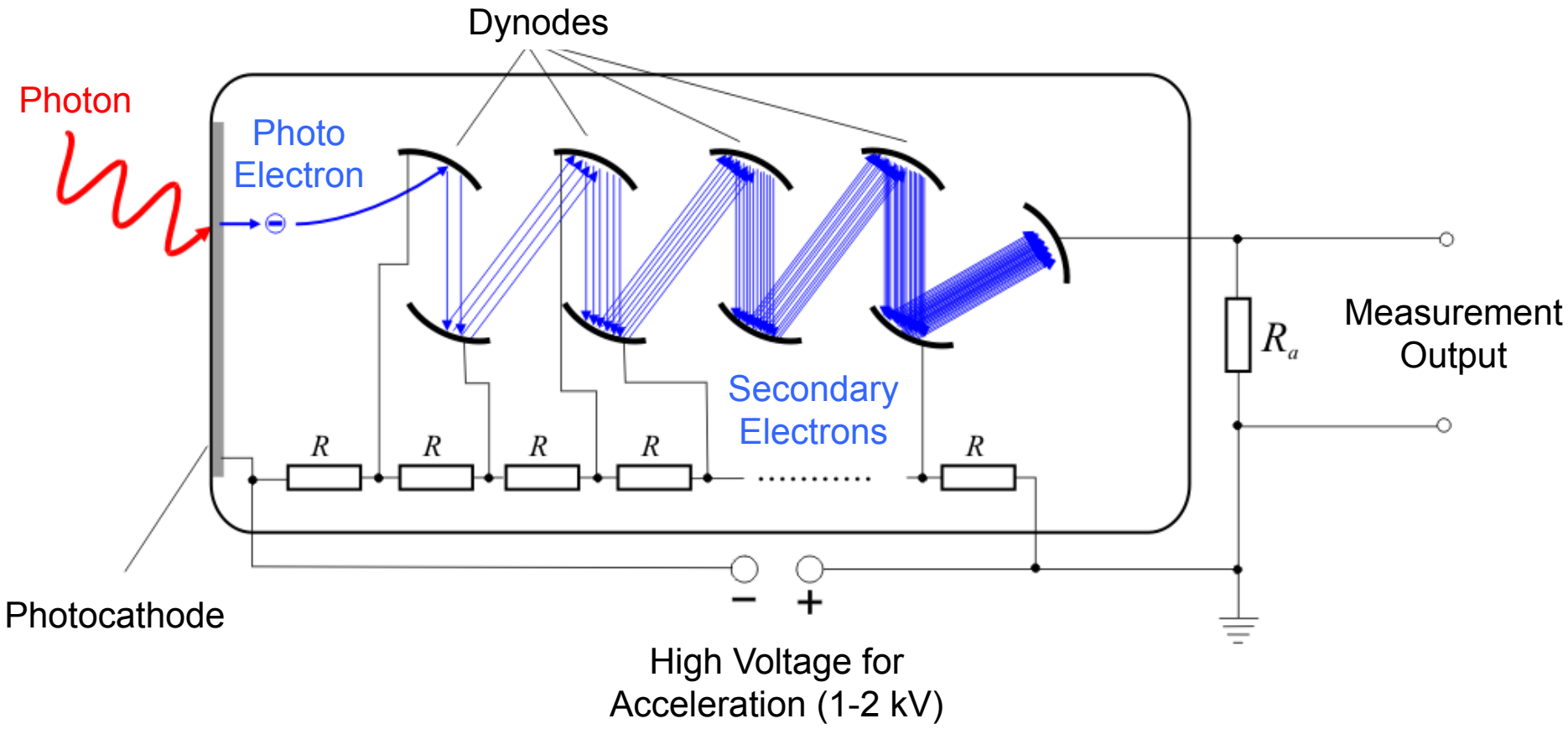
PMT Scheme


Dynodes
Photon
Photo
Electron
Secondary
Electrons
R
R
R
R
R
R_a
Measurement
Output
Photocathode
−
+
High Voltage for
Acceleration (1-2 kV)