Update on lifetime measurements of MCP-PMTs and results of Photonis 9002150

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

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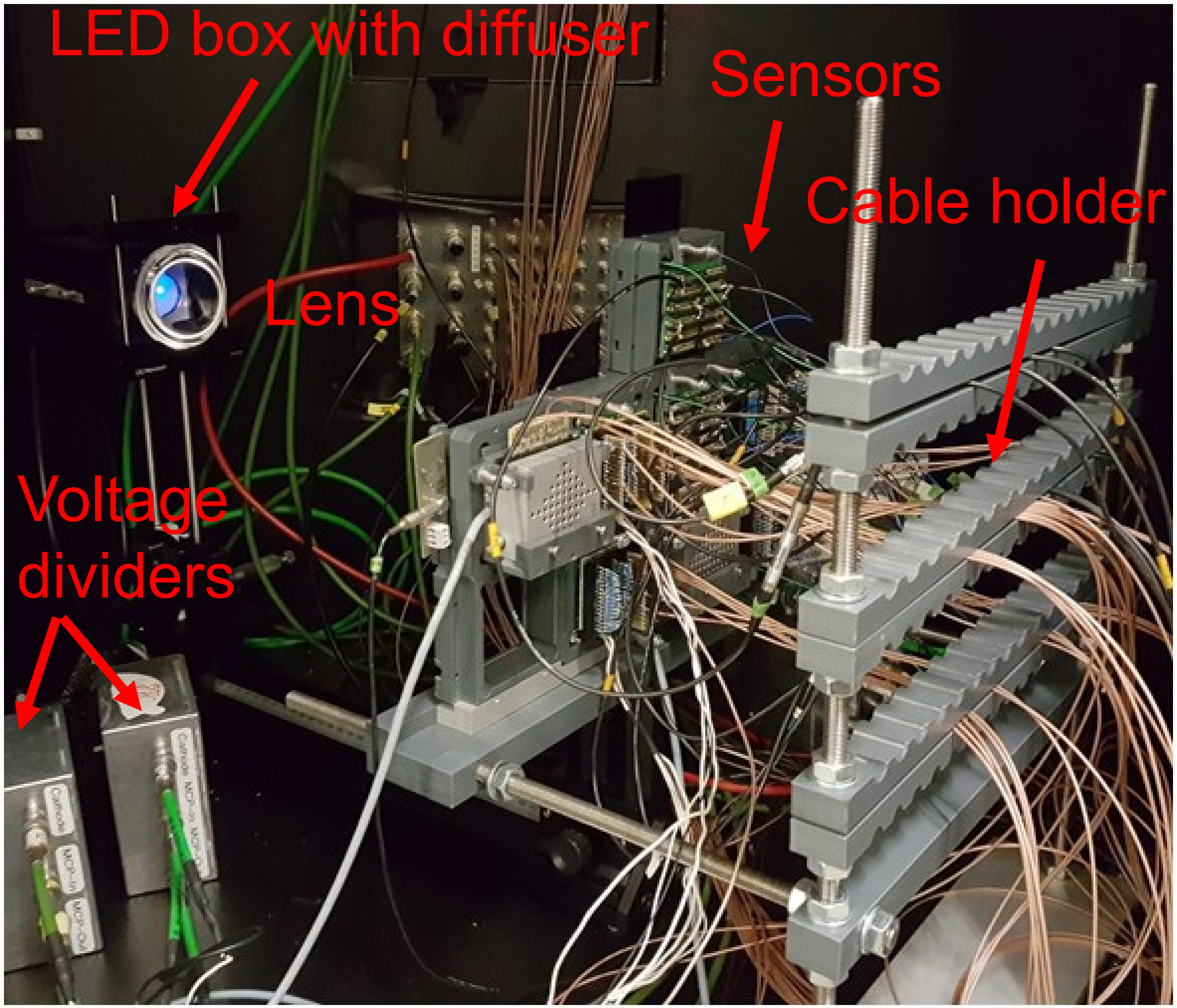
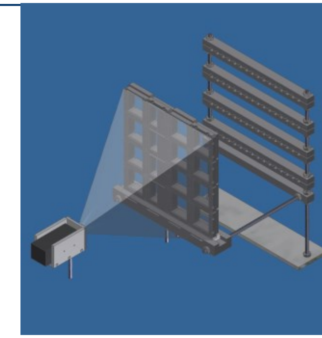
Parameters of lifetime measurements

- Goal: Simultaneous measurement of different MCP-PMTs under similar conditions as in the PANDA-DIRCs
- Constant illumination with 1 MHz single photons
  - All MCP-PMTs in same light spot
  - Permanent monitoring of integrated anode charge
- QE measurement:
  - Every few weeks:
    - Wavelength spectrum with Xenon arc lamp (75 W) and a monochromator ($\Delta\lambda$ = 2 nm, 250 nm - 800 nm)
    - Also measuring gain and dark counts
  - Every several months:
    - Surface scans with picosecond laser (372 nm, spot size: ø~0.5-1 mm)

Lifetime setup





- Pulsed LED inside aluminum Box
- Thorlabs engineered diffuser
  - In front of LED to get homogeneous light spot on sensors
- Holding construction for up to 16 sensors all illuminated by same LED
- Cable management behind sensors

Data from June 24, 2019

Illumination Overview QE (all sensors with ALD)

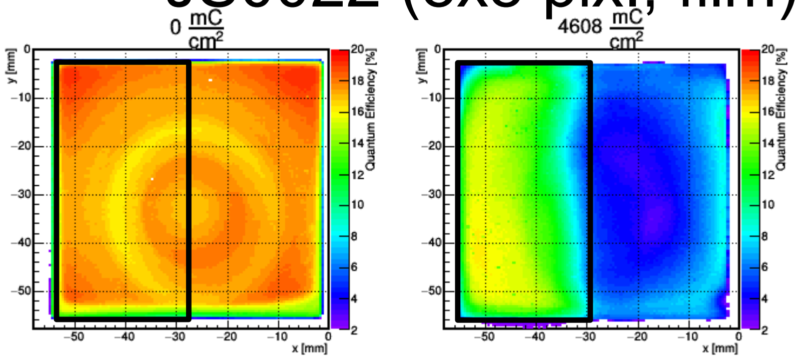
Two ALD layers

Film in front of first MCP

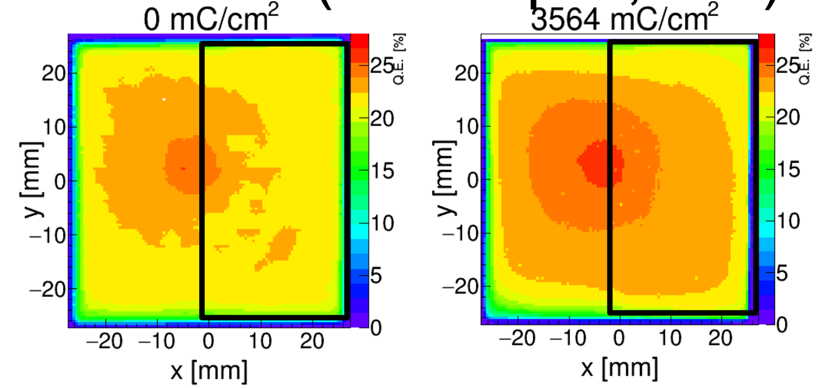
	Manufacturer	Senor ID	IAC [mC/cm²]	QE start [%]	QE latest [%]	QE latest/QE start [%]
2 Inch	Photonis XP85112	9001393	23938	19.1	19.6	103
		9002108	1534	21.7	10.7	49
2 Inch	Hamamatsu R13266-07-M768 / M64	JS0035 (64 pix.)	9911	25.5	25.4	100
		JS0027 (768 pix.)	4182	24.3	23.3	96
		YH0250 (64 pix.)	6151	25.4	25.2	99

QE scans of new Hamamatsu 2 inch ALD devices

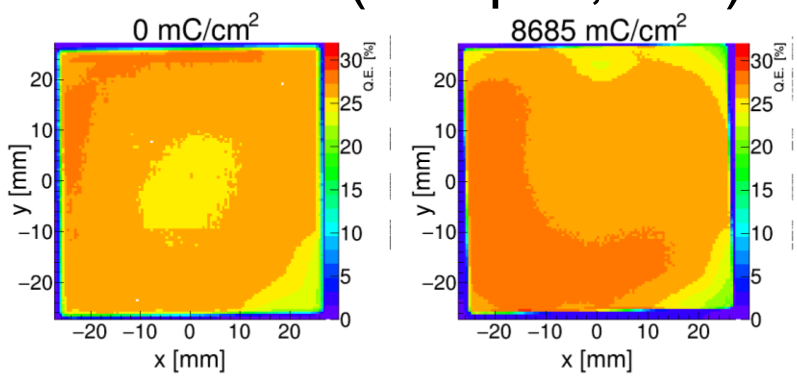
JS0022 (8x8 pix., film)



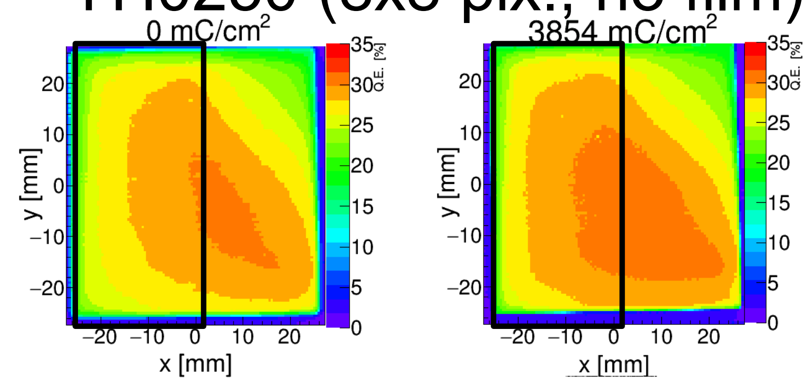
JS0027 (6x128 pix., film)



JS0035 (8x8 pix., film)



YH0250 (8x8 pix., no film)



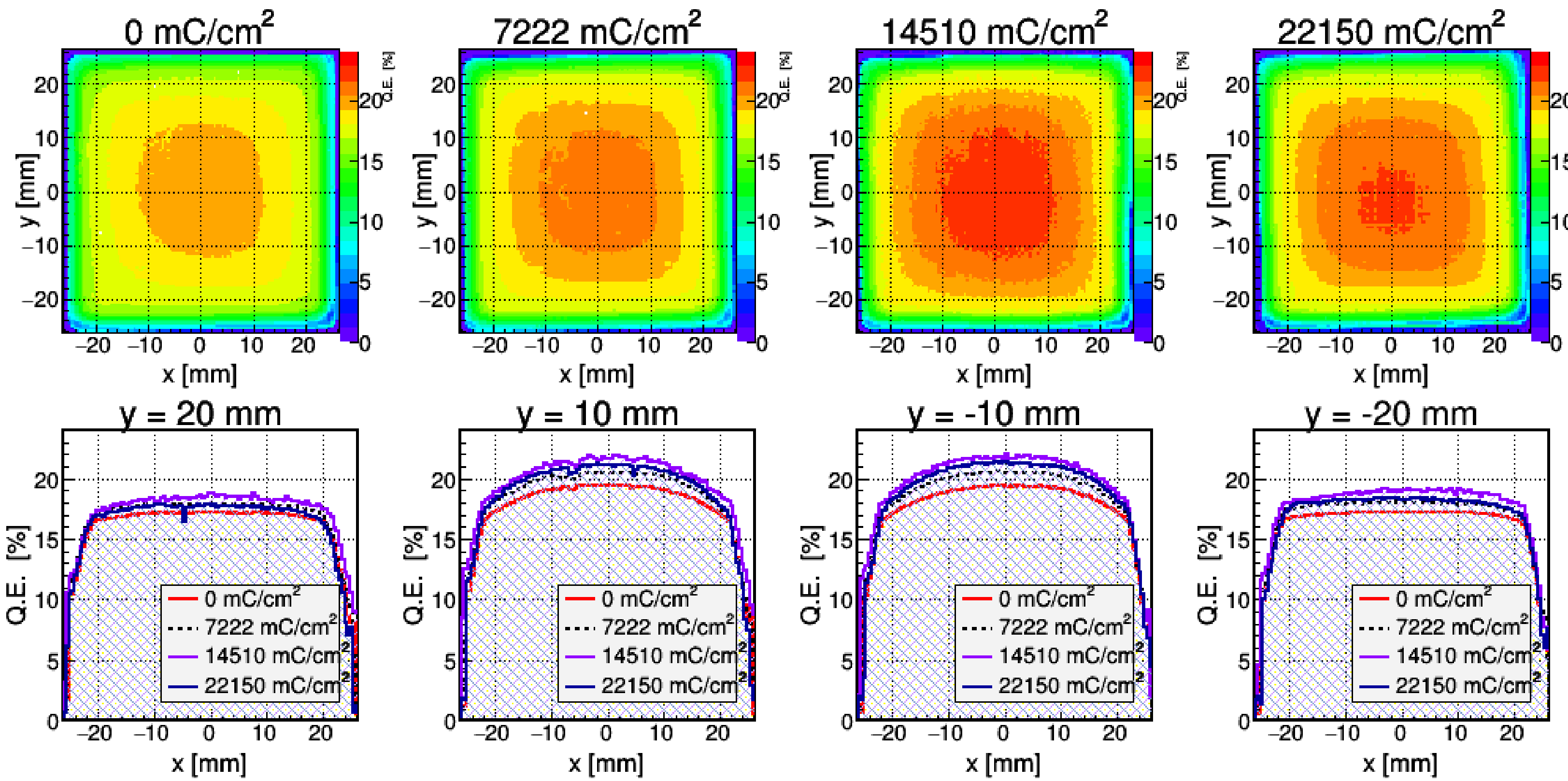
- later prototypes tend to show better performance
- measurement still ongoing

Covered

QE scans of Photonis 9001393-URD (2 ALD layers)

Not covered

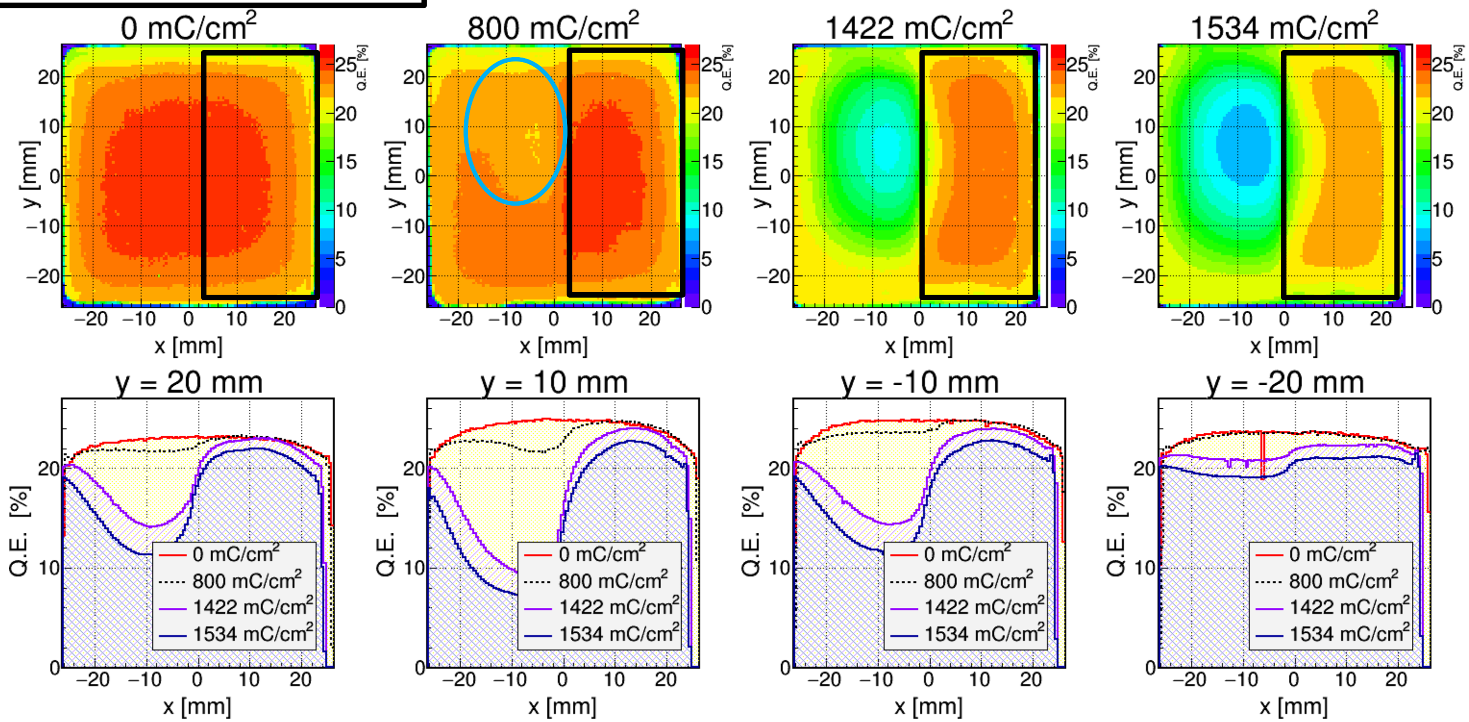
- 2 ALD layers
- No damage visible @24 C/cm² (~48 years of PANDA)



QE scans of Photonis 9002108 (ALD)

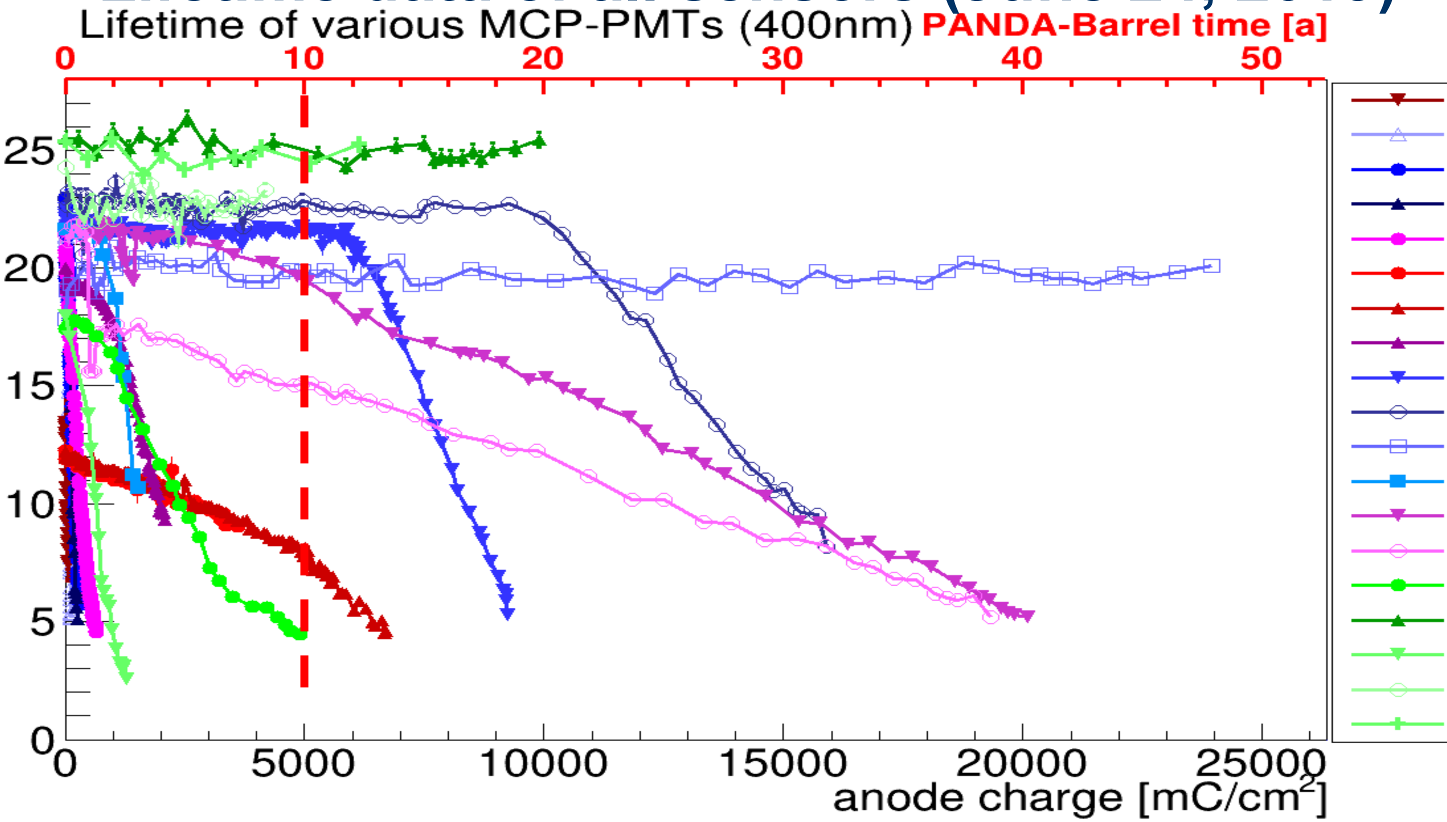
Covered (not illuminated)

Clear sign of Cathode damage



- Aging starting from the center
- Not illuminated side less and later damaged
- Probably caused by feedback ions
- ALD-coating by Photonis (and not Arradiance) →

Lifetime data of all sensors (June 24, 2019)



- Most sensors with ALD coated MCPs have lifetime > 5 C/cm²
- devices with no countermeasures have a lifetime of < 200mC/cm²
- Measurements are taking a long time

Summary

- Requirements: > 5 C/cm² at 10^6 gain (50% duty cycle, 10 years)
- lifetime increased by a factor of 50-100 with ALD coating
- Photonis
  - Best sensor at 24C/cm² without any sign of cathode damage
  - New sensor already damaged at 1.2C/cm²
- Hamamatsu:
  - Later produced (higher serial number) 2 inch tubes tend to have better performance
  - JS0035 reached 5 C/cm² as first 2 inch tube (now at almost 10C/cm²)

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Results of Photonis 9002150 (Part 1)

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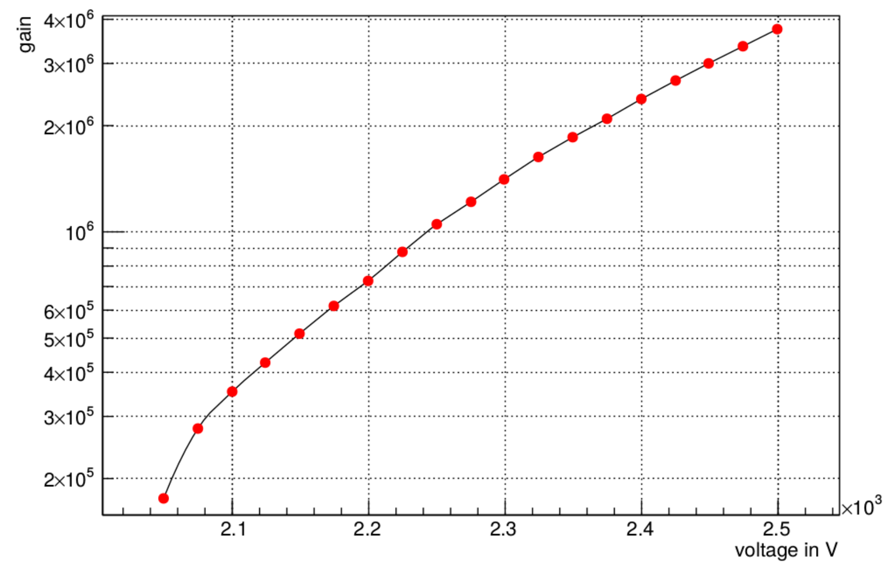
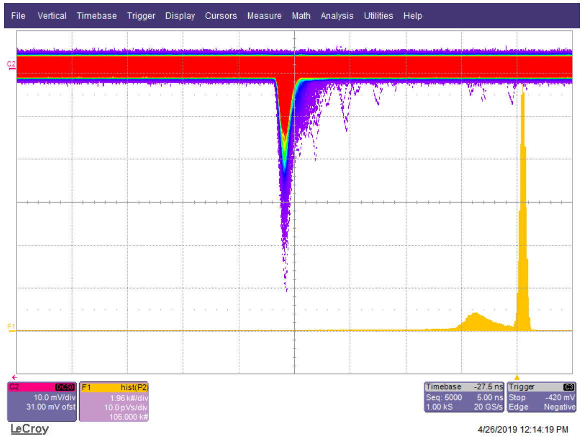
Gain vs voltage

- Measured with scope
- Signal not amplified
- Gain calculated with gauss fit in histogram data (pedestal and signal)
- 10^6 gain at 2250V (with 250kΩ:1MΩ:125kΩ divider!) ~ 1650V MCP voltage
- datasheet: 1725V MCP voltage

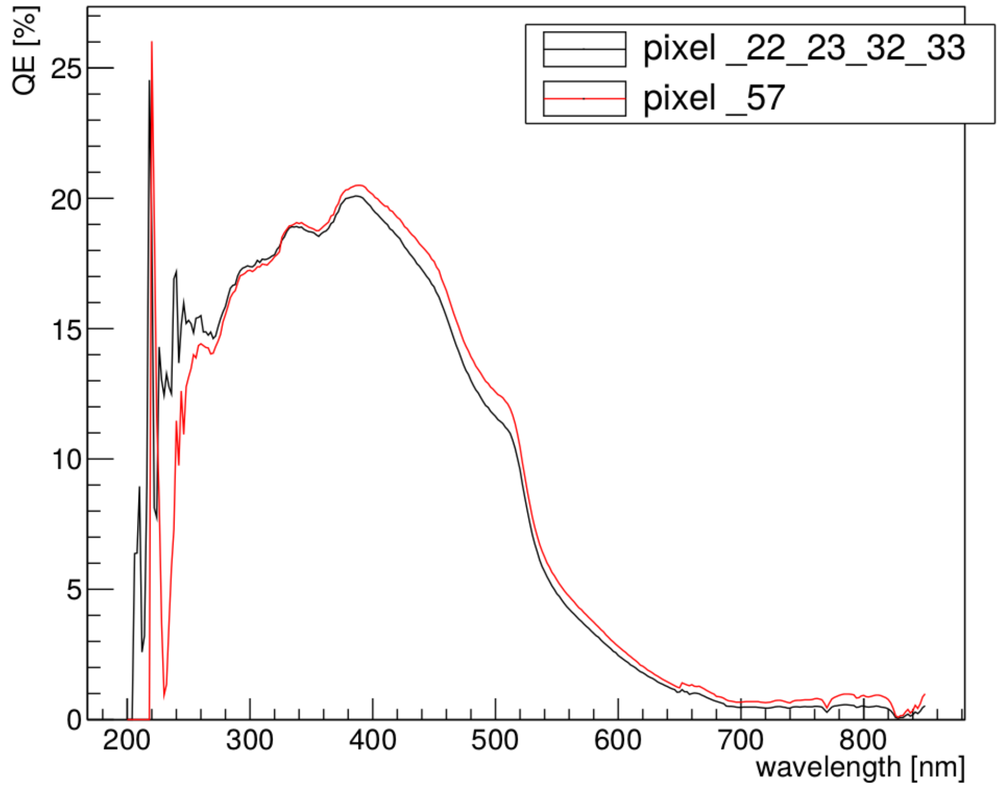


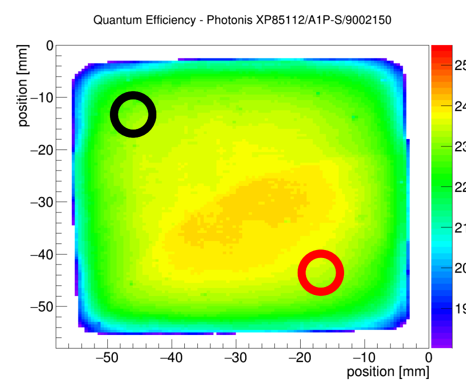


charge/gain spectrum and signals at 2250V

QE vs wavelength

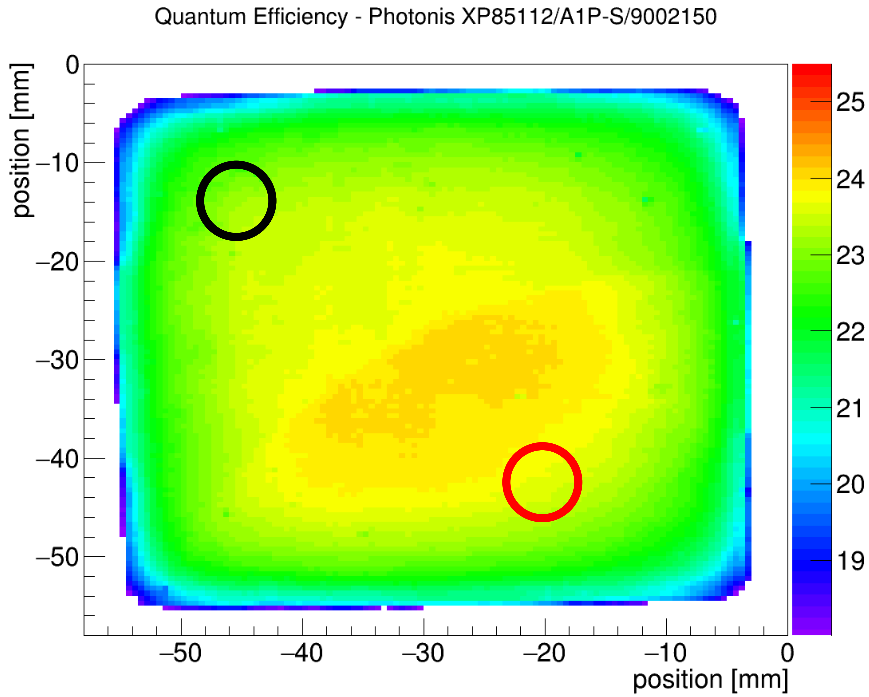
- -200 V at cathode, ground at MCP-in
- Current measured at MCP-in
- Calculated in reference to photo diode current (known QE for each wavelength)
- Data below 280nm and above 650nm not very reliable → light source
- Max QE ~20% at 400nm

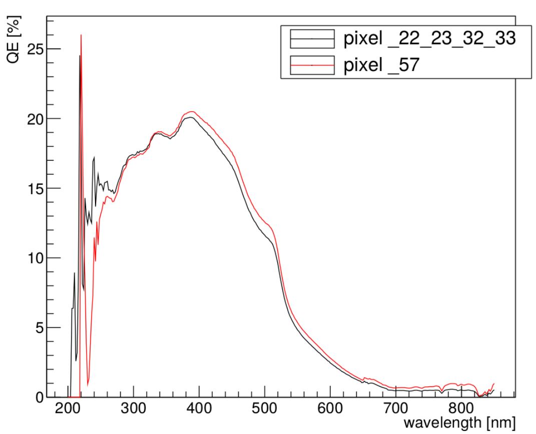




QE surface scan

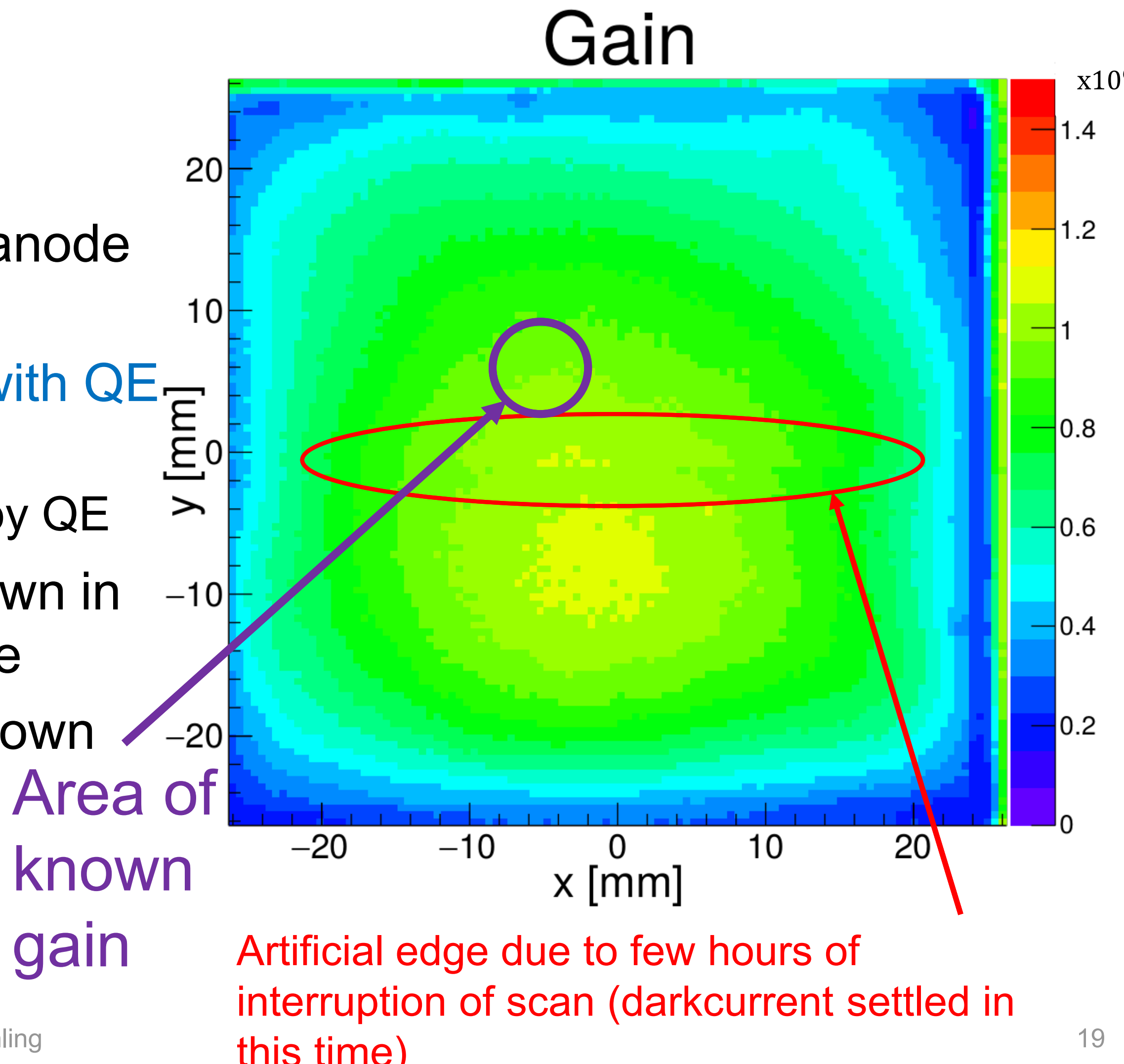
- -200 V at cathode
- Current measured at MCP-in
- Calculated in reference to photo diode current (known QE for wavelength)
- Scanned with 372 nm (blue)
- 0.5 mm steps across surface





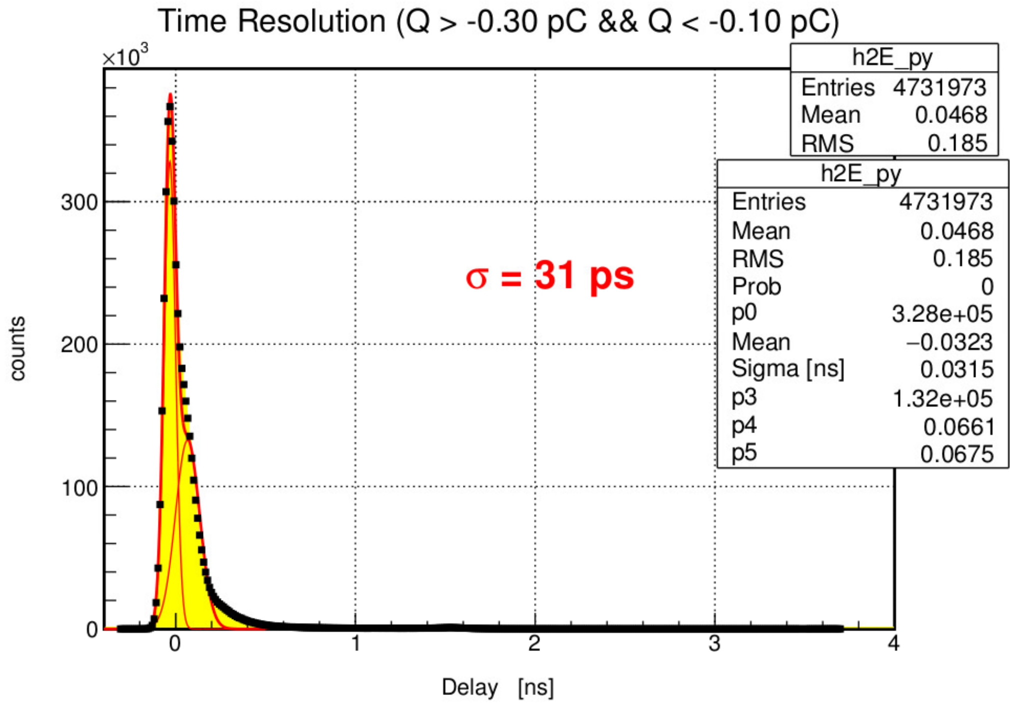
Current gain scan

- Scanning 2200 V ($\sim 1 * 10^6$ gain)
- Measuring shortened anode current
- Scan data are folded with QE of the sensor
  - Have to be divided by QE
- QE corrected gain shown in picture on the right side
- Gain then scaled to known value of one pixel



Time resolution

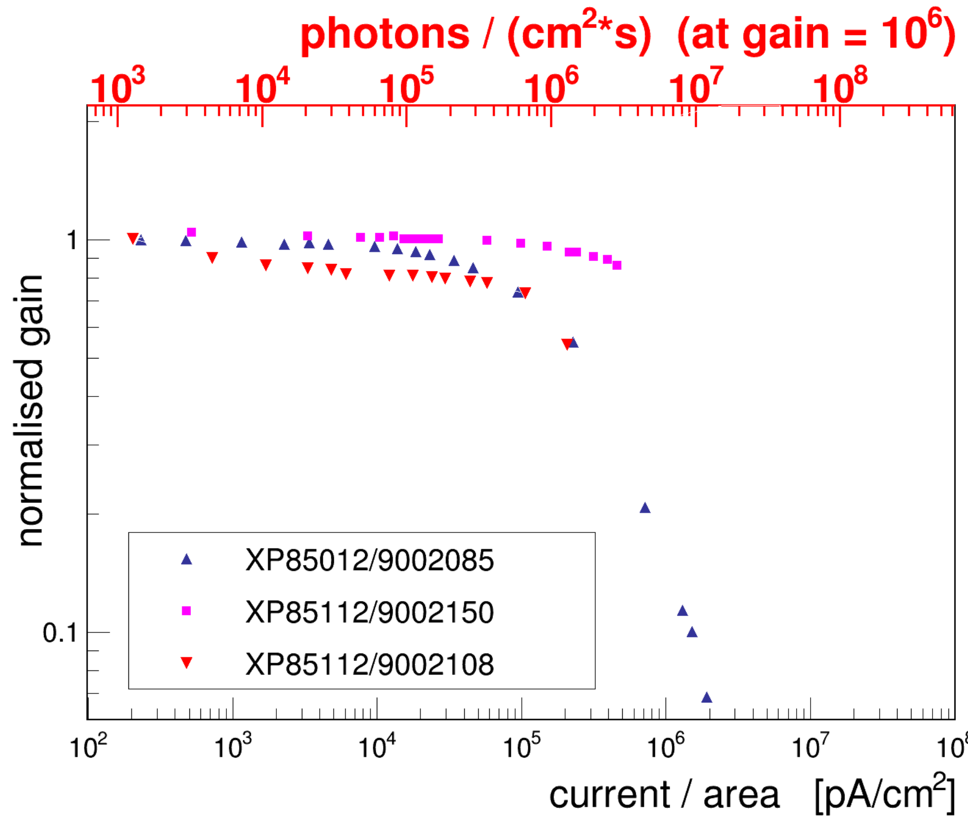
- Measured with scope at 2250V (~$1 * 10^6$ gain)
- Red PiLas at 1 kHz and 27 % tune
- 200x amplified signal, followed by impedance matched splitting
- Low discriminator threshold (30mV) (just above noise band)
- Time walk corrected spectra
- σ = 31 ps (RMS = 185 ps)



log bild bis
4ns

Rate stability

- Measured with shortened anodes at $1 * 10^6$ gain
- Full illuminated sensor and photodiode in same light spot (diffuser)
- Monitor diode and shortened anode current for different laser frequencies
- In theory, when diode current doubles anode current should double too
- Norm to first value taken:
- $y = \frac{Anodecurr\_x}{Diodecurr\_x} / \frac{Anodecurr\_1}{Diodecurr\_1}$



- y should be 1 if sensor doesn't change its gain
- Better than 9002085 and 9002108
- Higher rates were not accessible because of limitation of anode current

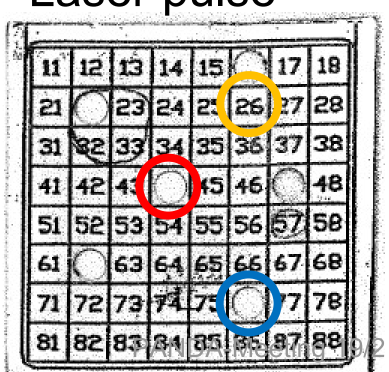
Photonis 9002150

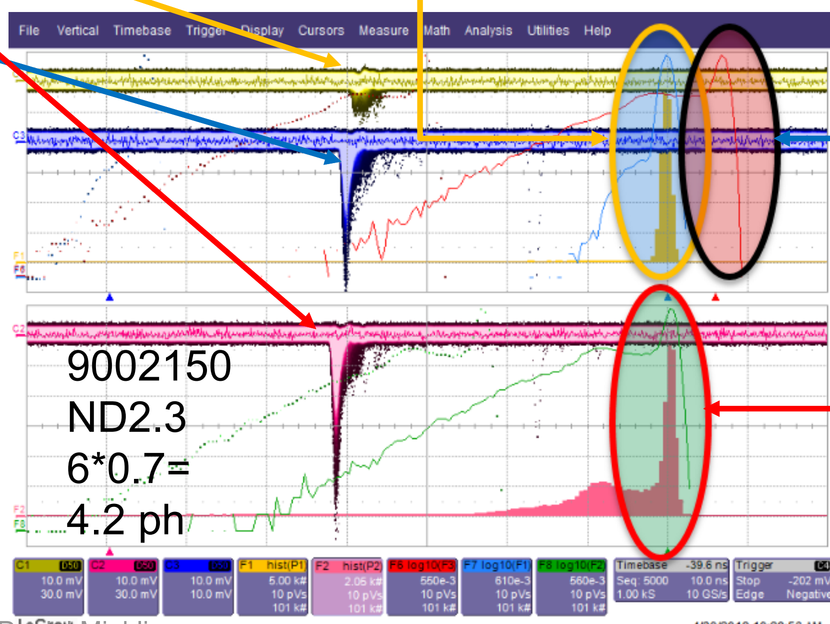
- explanation of ringing slides

signal of three different pixels (with persistence, ~5k events):
C1: pix26 (yellow)
C2: pix44 (red)
C3: pix76 (blue)

charge spectrum (histogram) + log of charge spectrum (thin line) of all events(~100k)
C1: pix26 (yellow+blue)
C2: pix44 (red+green)
C3: pix76 (missing+red)

x: 10ns/div
y: 10mV/div
Trigger:
Laser pulse





- colour of arrow → signal colour
- oval → charge spectrum
- log of charge spectrum → filling

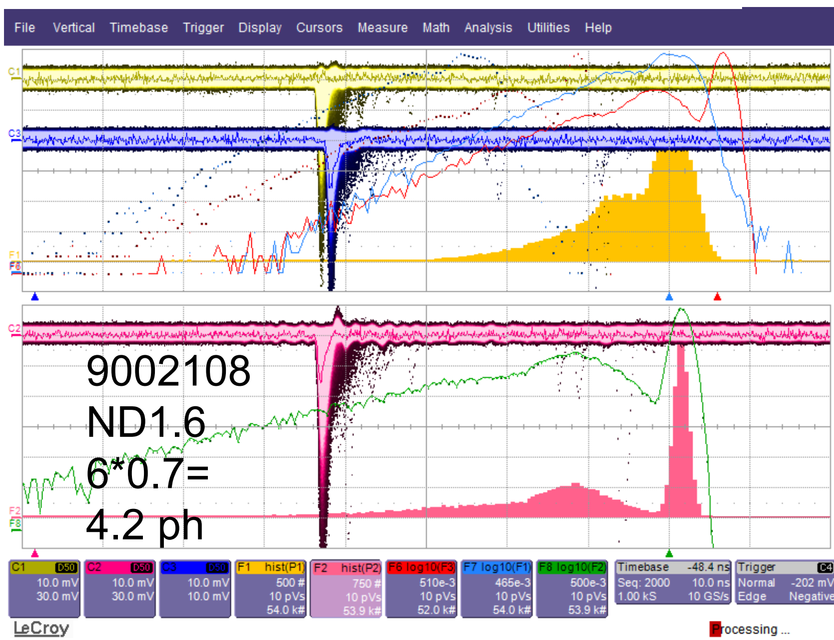
number of illuminated pixels * number of photoelectrons (determined with the charge spectrum histogram and poisson statistics) = number of photons seen by the sensor

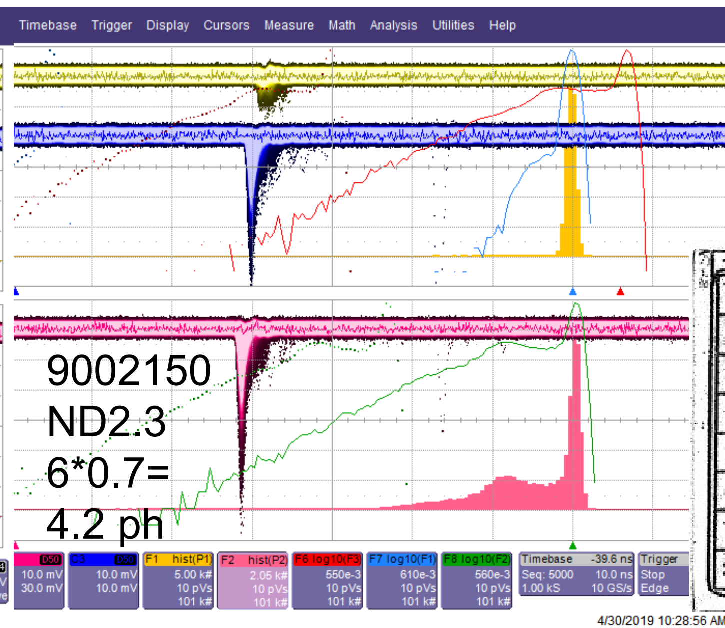
Photonis 9002108 and 9002150

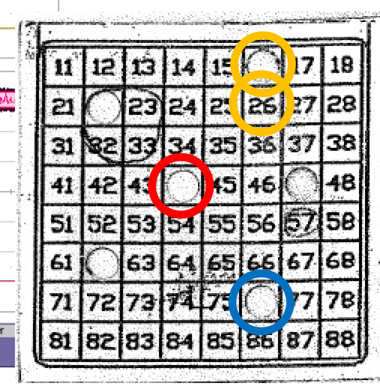
- 2 inch x 2 inch, 8 x 8 pixels, 10 µm pores with ALD coating, 10^6 gain
- Red (632 nm) PiLas, 10 kHz, illumination of 6 pixels

x: 10ns/div
y: 10mV/div

Trigger:
Laser pulse







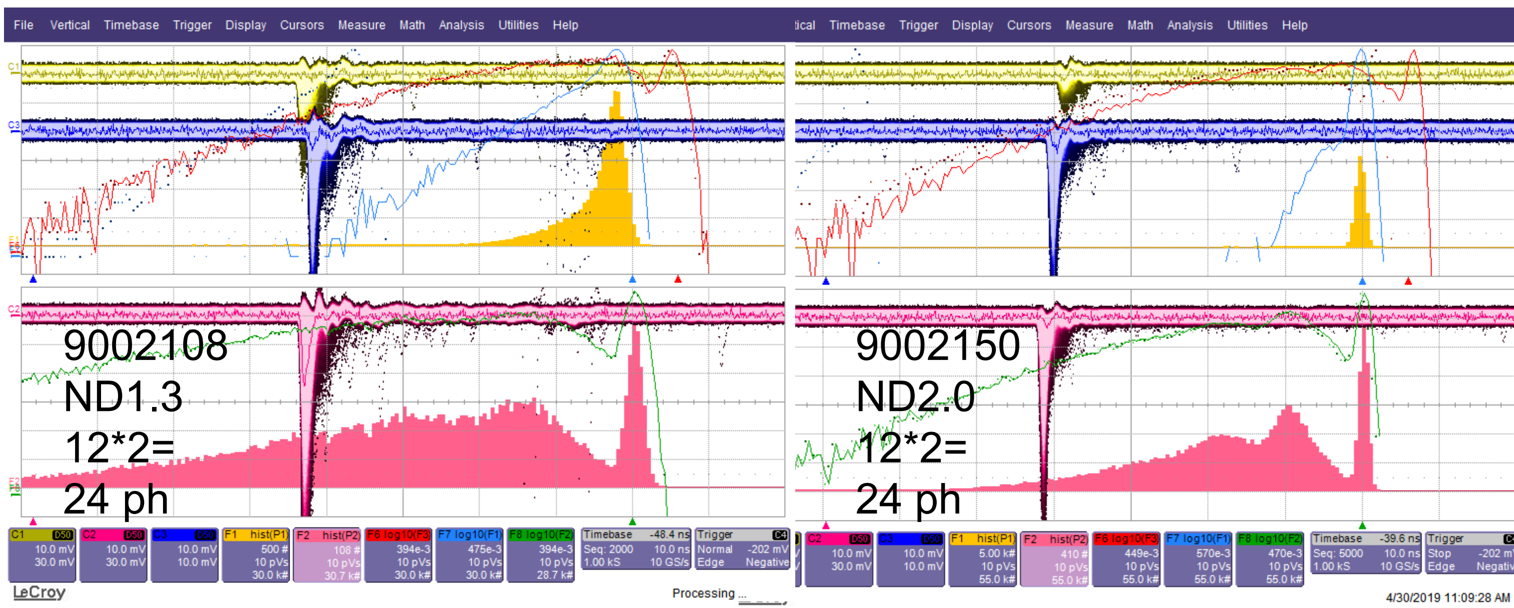
here: C1=pix16
(normal pixel)

here: C1=pix26
(crosstalk pixel)

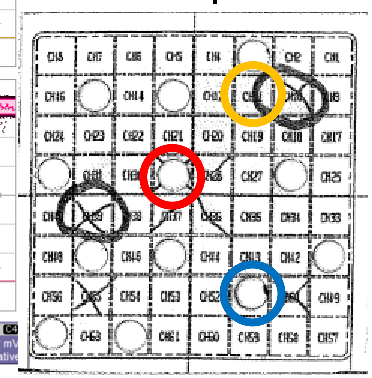
Photonis 9002108 and 9002150

- 2 inch x 2 inch, 8 x 8 pixels, 10 µm pores with ALD coating, 10^6 gain
- Red (632 nm) PiLas, 10 kHz, illumination of 12 pixels

x: 10ns/div
y: 10mV/div



Trigger:
Laser pulse

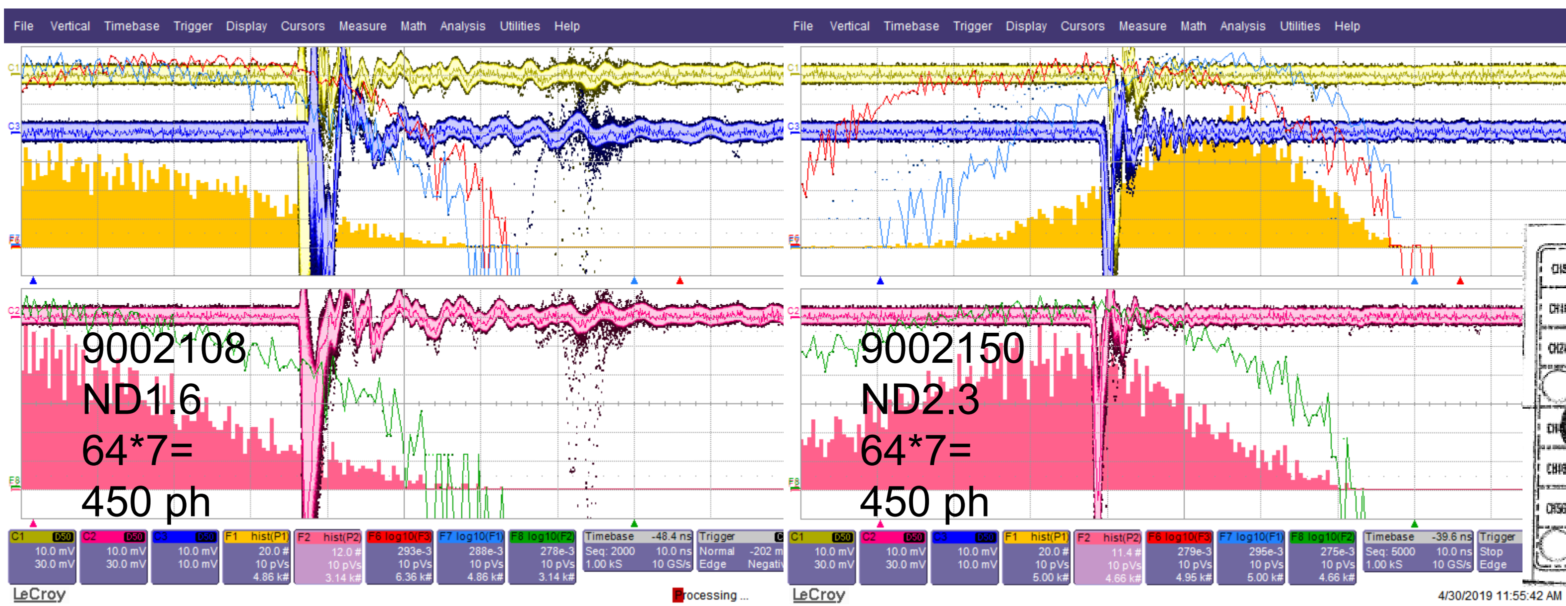


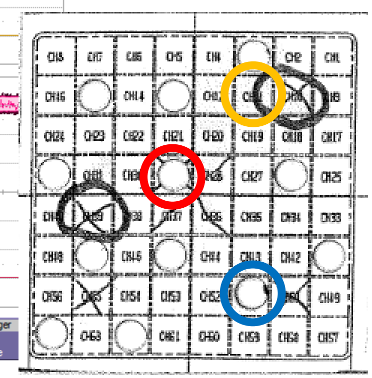
Photonis 9002108 and 9002150

- 2 inch x 2 inch, 8 x 8 pixels, 10 µm pores with ALD coating, 10^6 gain
- Red (632 nm) PiLas, 10 kHz, illumination of all pixels

x: 10ns/div
y: 10mV/div

Trigger:
Laser pulse





Thank you for your attention!

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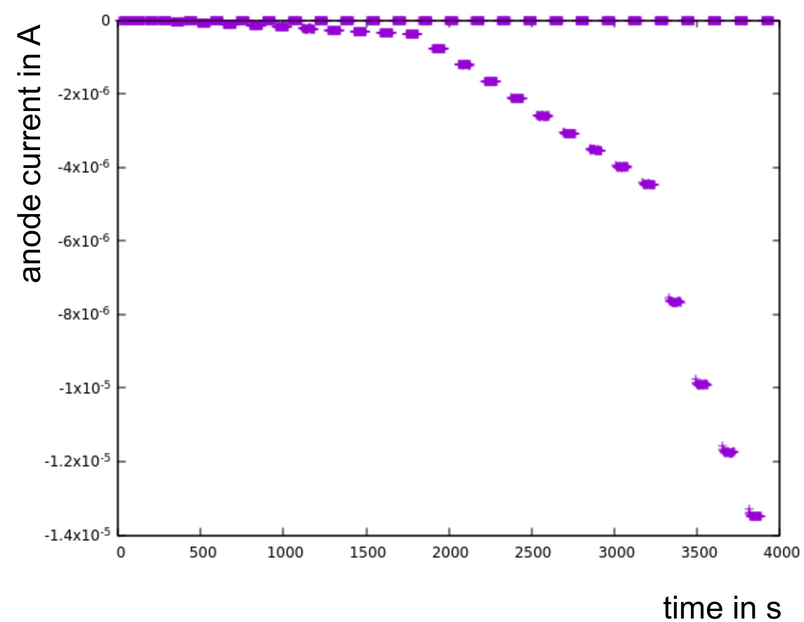
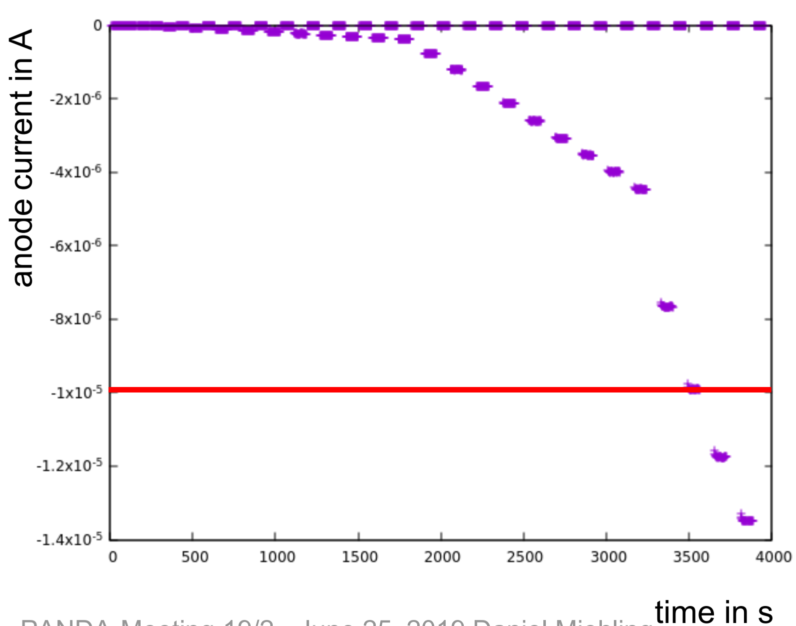
New feature: afterglowing?

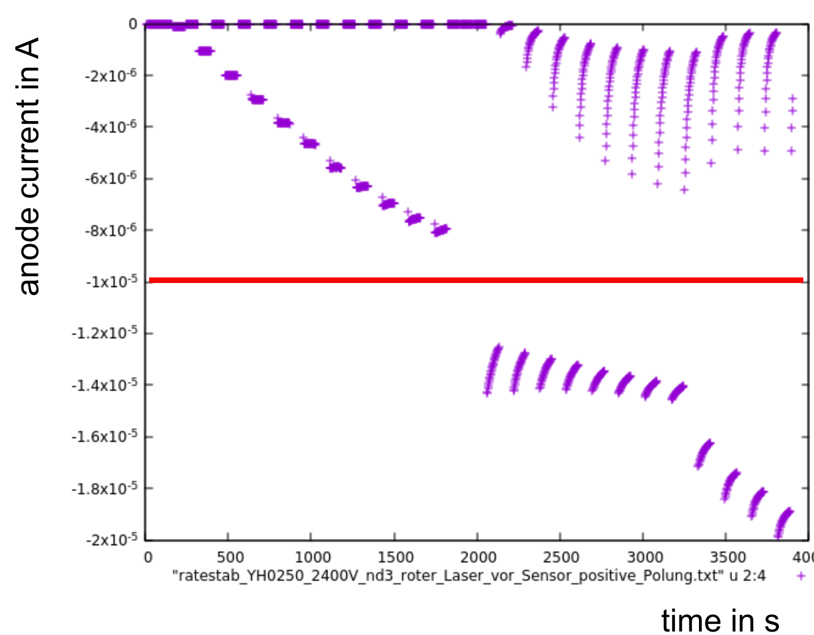
- ratestability measurement with shortenend anodes and current measurement
- turning laser on and off again with increasing light intensity
- with monitoring of light intensity → can determine ratestability



New feature: afterglowing?

- left: Photonis 9001393-URD
- right: Hamamatsu YH0250
- red line corresponds to 2MHz photonrate per cm²





New feature: afterglowing?

- this feature seems to occur with both Photonis and Hamamatsu tubes and affects only ALD-tubes

- no effect:
  Photonis 9001341 (non-ALD tube)

- almost no or a small effect:
  Photonis 9001393 (two-ALD), 9001394 (ALD), 9002108 (ALD), 9002150 (ALD);
  Hamamatsu JS0026 (ALD?, Gießen), JS0035 (ALD)

- a strong effect:
  Hamamatsu YH0245 (ALD?, Gießen), YH0250 (ALD)

New feature: afterglowing?

- comment: the summary on the last slide is preliminary since (most of) the data is from old ratestability measurements and only „bycatch“
- more investigations needed with both current measurements and PADIWA and/or DiRiCH