Update on lifetime measurements of MCP-PMTs and status of afterglow and saturation measurements

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

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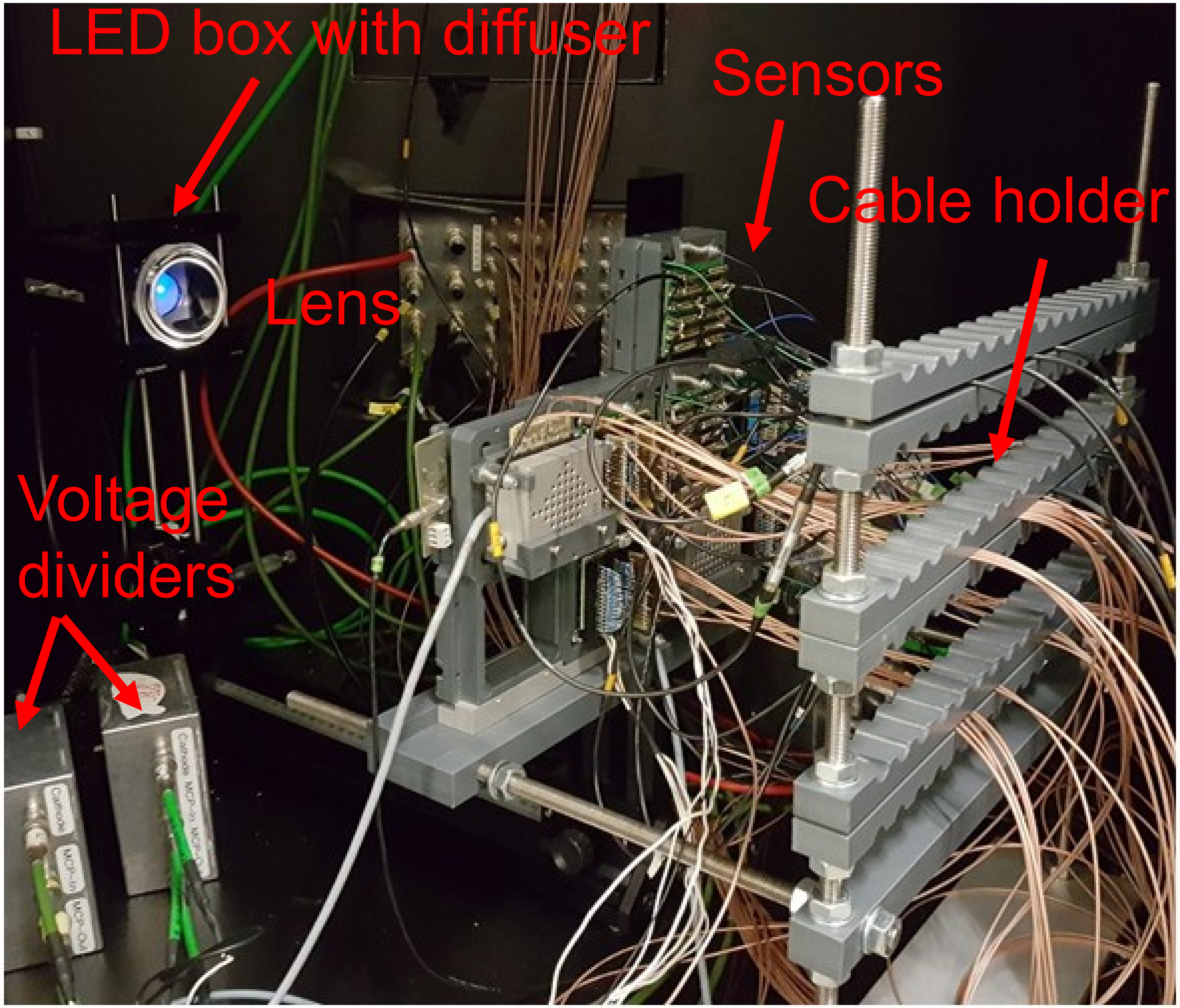
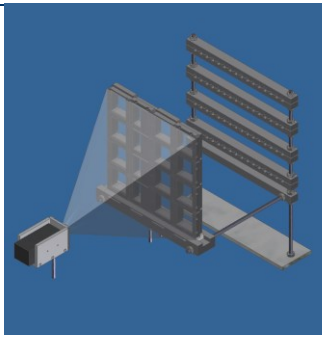
NATURWISSENSCHAFTLICHE FAKULTÄT

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 October 11, 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	25101	19.1	19.8	104
2 Inch Photonis XP85112	9002108	1678	21.7	4.9	23
2 Inch Hamamatsu R13266-07-M768 / M64	JS0035 (64 pix.)	10650	25.5	25.1	98
2 Inch Hamamatsu R13266-07-M768 / M64	JS0027 (768 pix.)	4828	24.3	23.0	95
2 Inch Hamamatsu R13266-07-M768 / M64	YH0250 (64 pix.)	8819	25.4	24.5	96

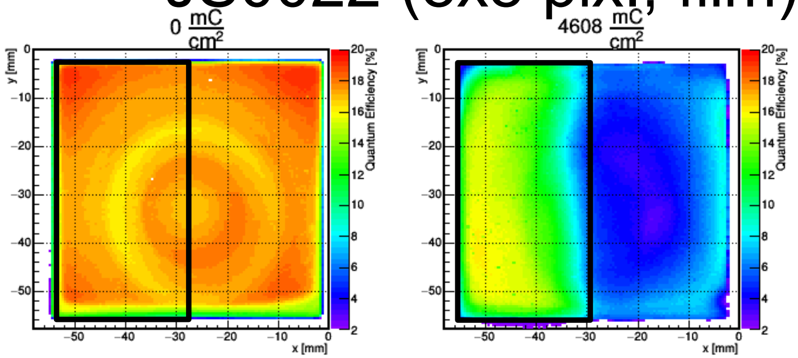
Two ALD layers: 9001393

Film in front of first MCP: JS0035, JS0027

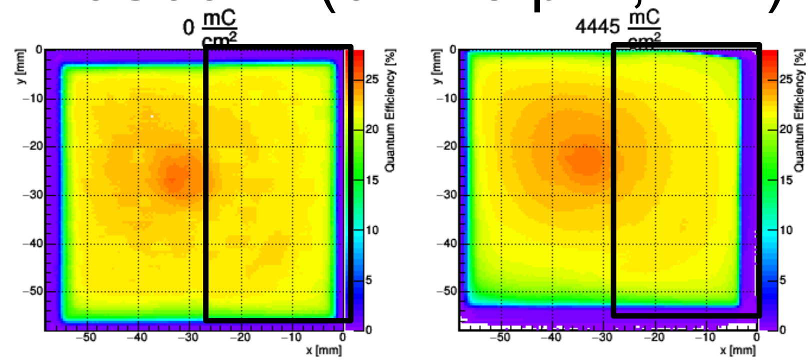
9002108 removed on October 11 2019

QE scans of new Hamamatsu 2 inch ALD devices

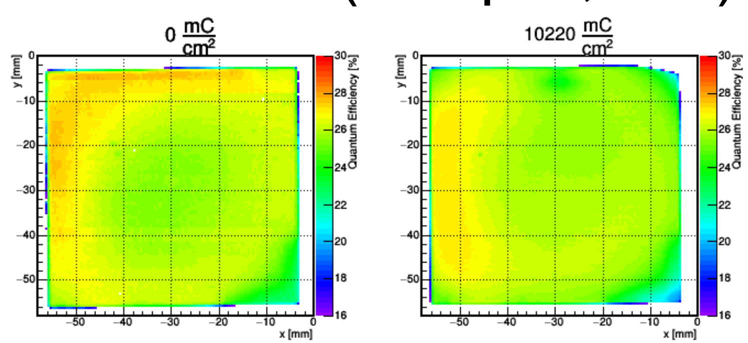
JS0022 (8x8 pix., film)



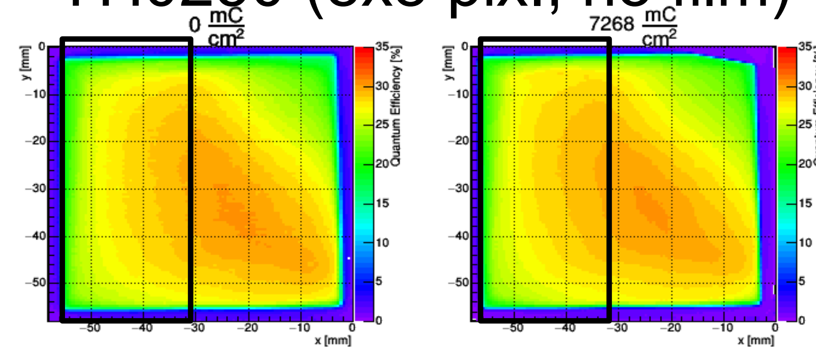
JS0027 (6x128 pix., film)



JS0035 (8x8 pix., film)



YH0250 (8x8 pix., no film)



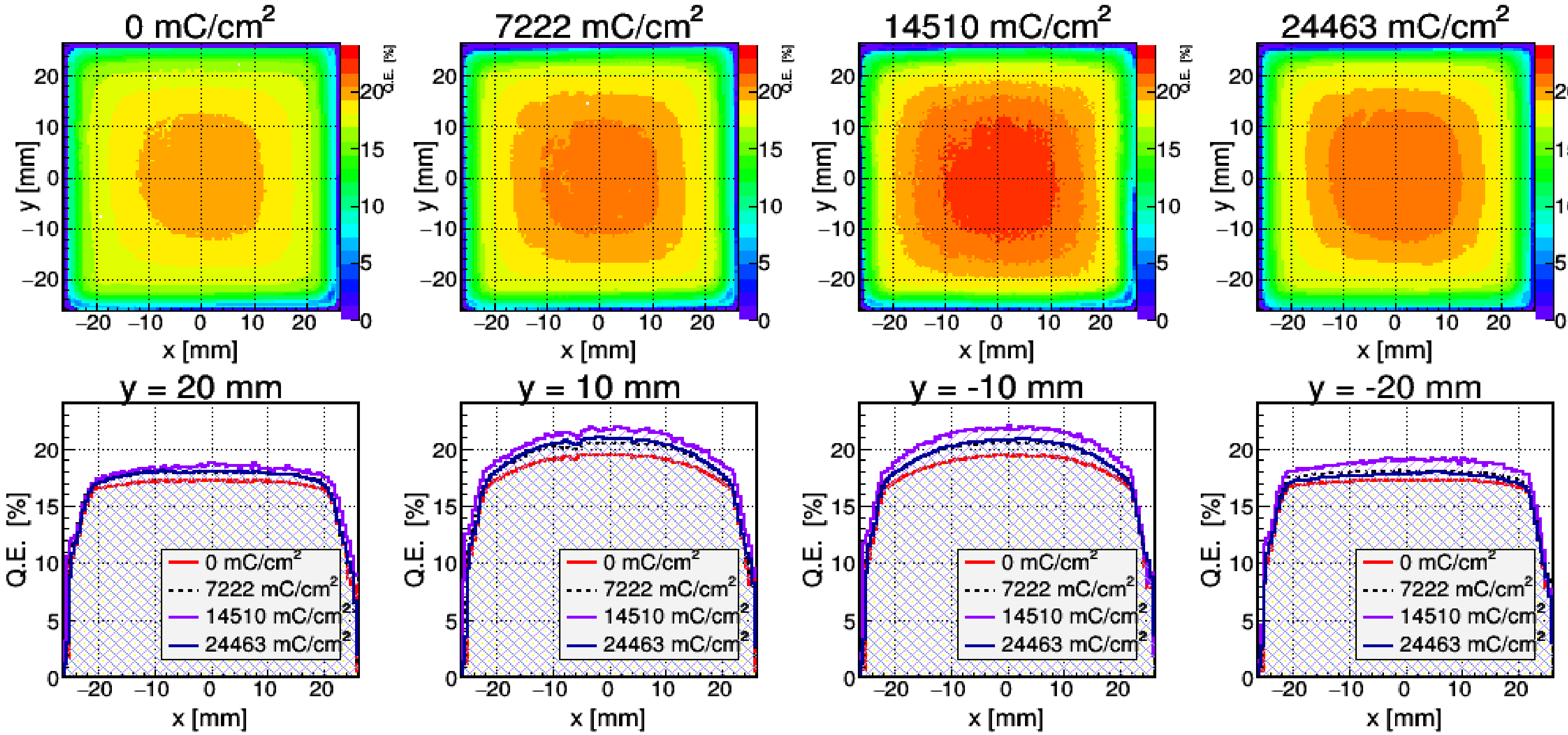
- later prototypes tend to show better performance
- measurement still ongoing

Covered

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

Not covered

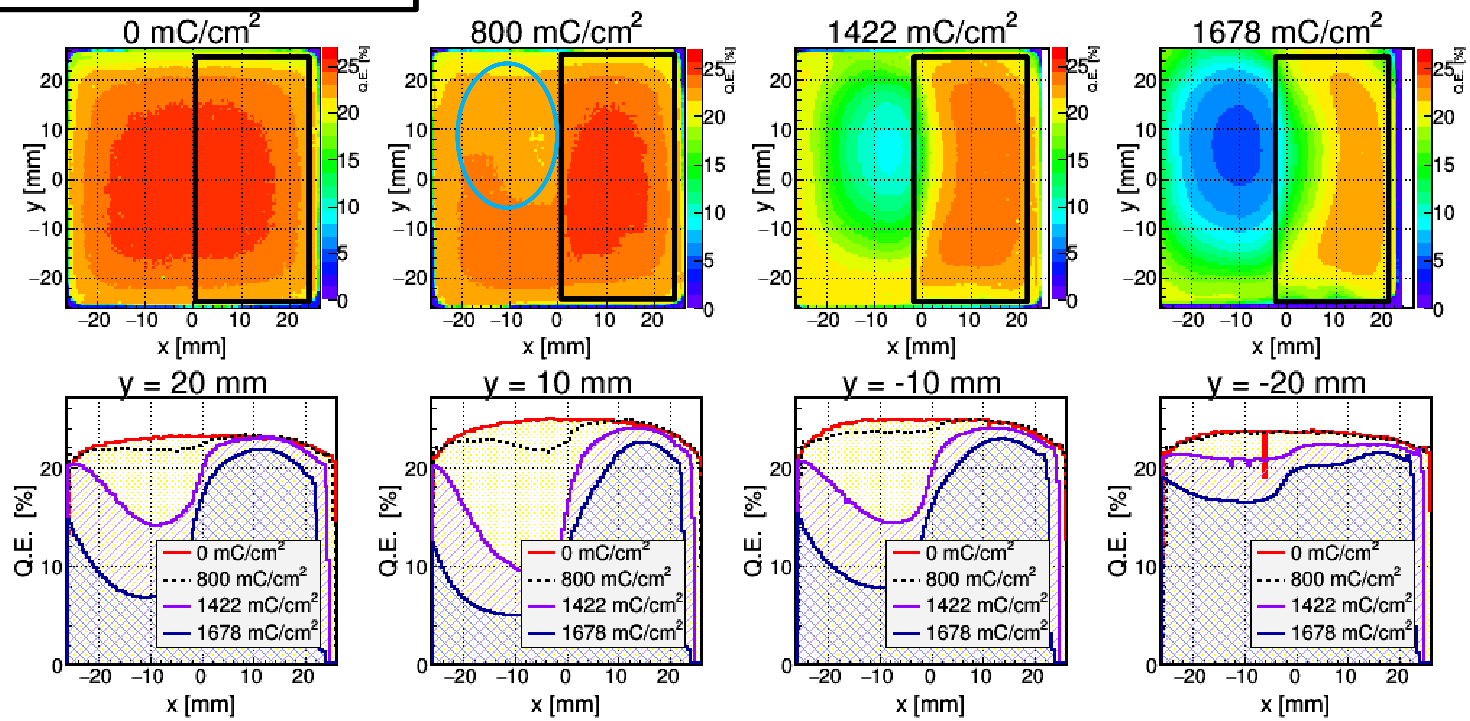
- 2 ALD layers
- No damage visible @25 C/cm² (~50 years of PANDA)



QE scans of Photonis 9002108 (ALD)

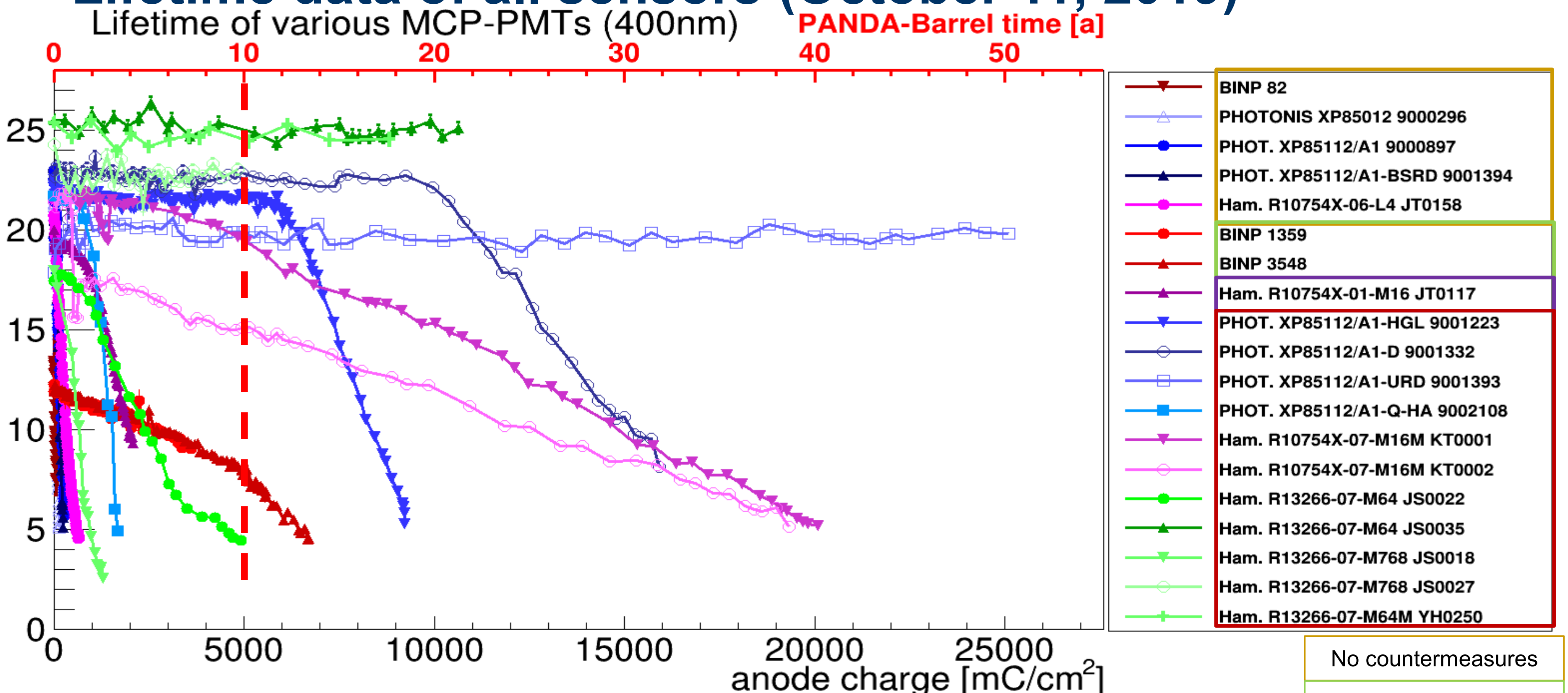
Covered (not illuminated)

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)
- removed on October 11 2019

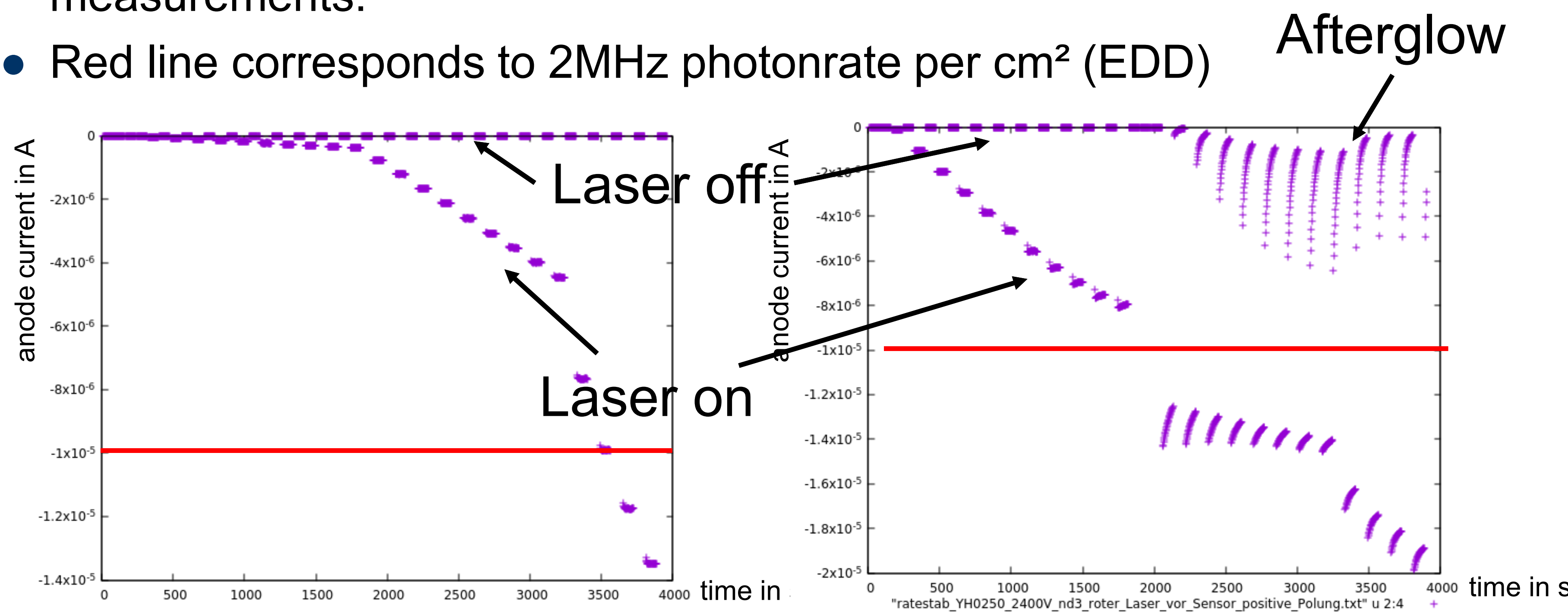
Lifetime data of all sensors (October 11, 2019)



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

Reminder: Afterglow

- After illuminating MCP-PMTs with high intensity light the darkcount rate is significantly increased
- The count rate decays within several seconds - minutes
- This effect can also be observed during our rate stability measurements:
- Red line corresponds to 2MHz photonrate per cm² (EDD)



Photonis 9001393 URD

Hamamatsu YH0250

Afterglow

- Afterglow comes from photons from the MCP itself after high illumination
- Afterglow depends on duration and intensity of illumination and gain of the MCP-PMT
- → for more information see Merlins talk at DIRC2019

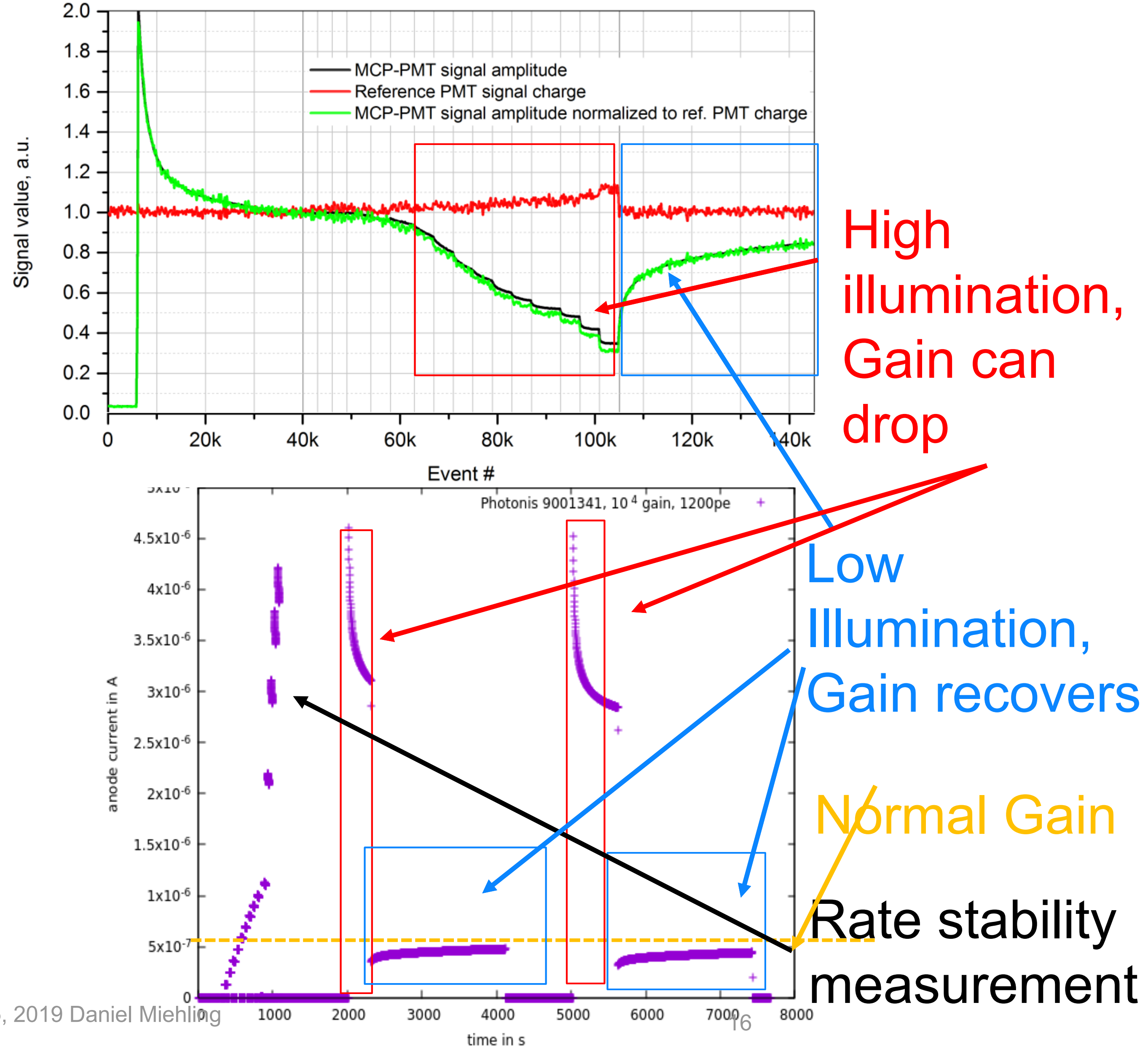
- measurements with a lot of sensors were done
- divide afterglow current (at ~ EDD rates) by anode current to get a feeling of how much the sensors shows this effect

Sensor	JS0035	YH0250	JS0027	KT0002	9001332	9001341	9001393	9001394	9002108	9002150	9001165	9001340
afterglow	3e-05	4e-03	-	<6e-06	<3e-05	1e-05	4e-05	1e-05	2e-06	1e-05	1e-04	6e-05

- good news: no problem for MCP-PMTs for the Barrel DIRC rates, only Hamamatsu YH-series for EDD could cause issues

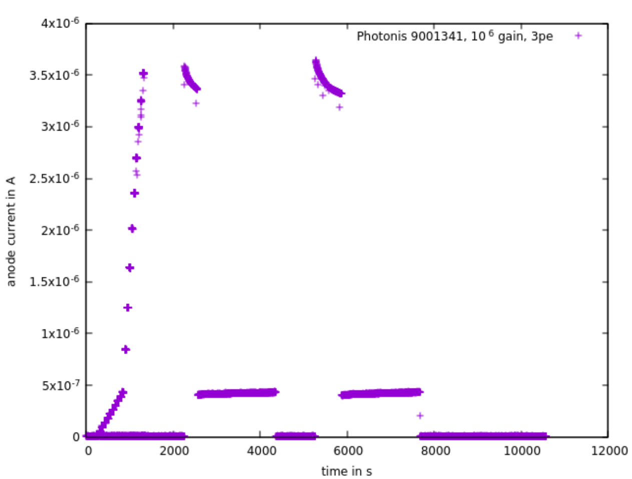
Gain recovery

- Antamanova et al. observed (2018 JINST 13 T09001)
  - After high illumination the gain is lower than before
  - Only in ALD tubes, but not in non-ALD tubes
- We can reproduce this effect for many tubes, but not for all

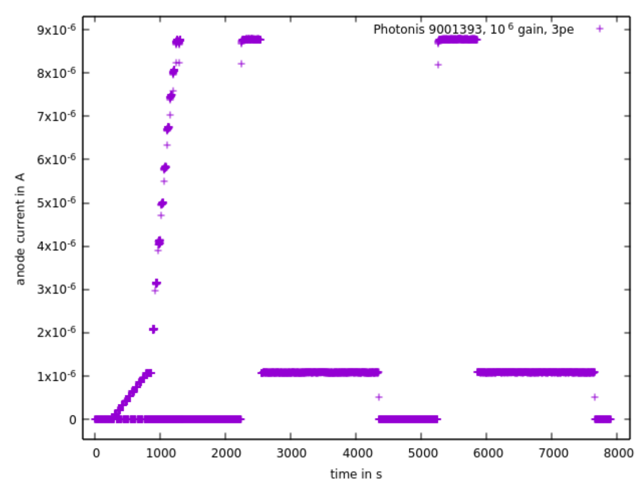


Gain saturation and recovery time

- effects seem to be correlated with ratestability, higher ratestability reduces these effects
- the effects are in the order of a few % (for example the 9001341 loses 5% gain in 5 minutes @700 kHz Photons/cm²)
- more investigations needed to determine the equilibrium
- good news again: no problem for sensors at Barrel DIRC rates, for EDD one should keep this in mind



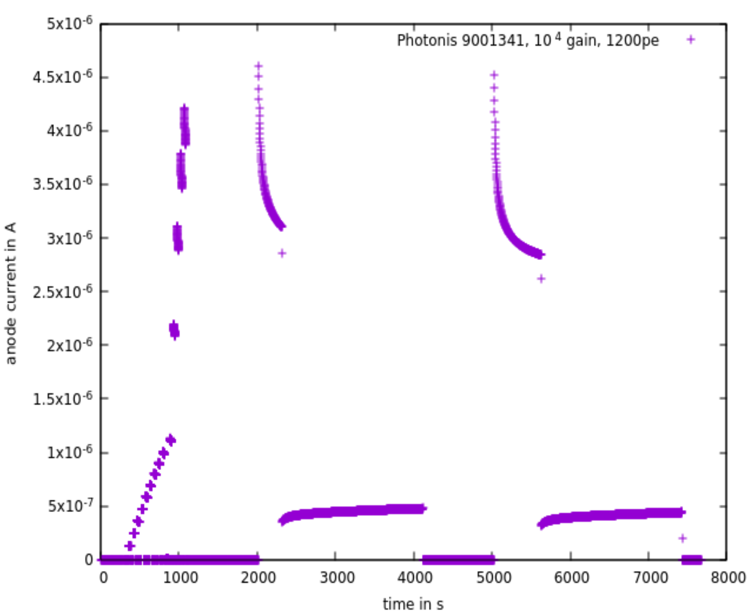
„bad“ example, 9001341

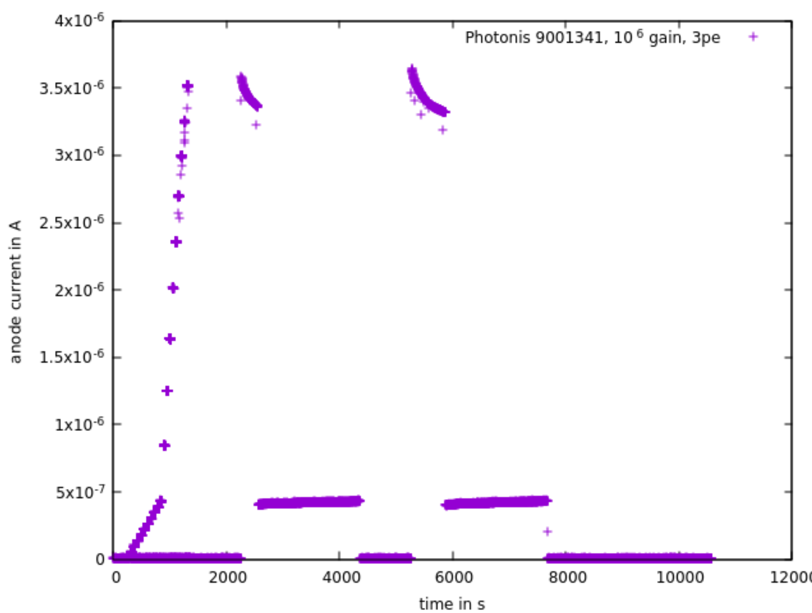


„good“ example, 9001393

Dependence on number of photoelectrons

- afterglow, ratestability, saturation and recovery time depend on the number of photoelectrons per laser pulse
- both plots with Photonis 9001341 and up to ~4µA anode current, but left with 10e4 gain and 1200 pe, right with 10e6 gain and 3pe and higher laser frequencies
- left the number of photons per time intervall is very high for a short time





Gain saturation and recovery time

- „bad“ sensors: YH0250, JS0027, 9001341, 9002108,
- „good“ sensors: JS0035, KT0002, 9002150, 9001165, 9001340
- „very good“ sensors: 9001332, 9001393, 9001394

- „bad“ means one can see a effect at ~5pe per pulse and at ~1000pe per pulse
- „good“ means one can see a effect only at ~1000pe per pulse
- „very good“ means no effect even at ~1000pe per pulse

- good news: no problem for MCP-PMTs for the Barrel DIRC rates, only Hamamatsu YH-series for EDD could cause issues

Summary

- Requirements: > 5 C/cm² at 10^6 gain (50% duty cycle, 10 years)
- Photonis
  - Best sensor at 25 C/cm² without any sign of cathode damage
  - New sensor already damaged at 1.2 C/cm², now at 1.6 C/cm² only ~3% QE left in the hole
- 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 11C/cm²)
  - JS0027 (almost) reached 5 C/cm² as well
- afterglow, saturation and recovery time should be no problems for Barrel DIRC, but should be further investigated for EDD

GEFÖRDERT VOM

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Thank you for your attention!

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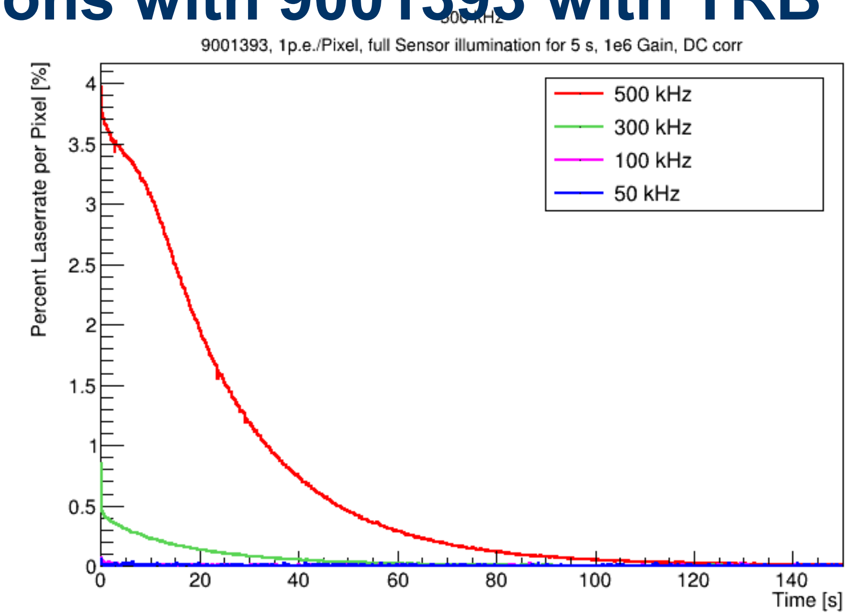
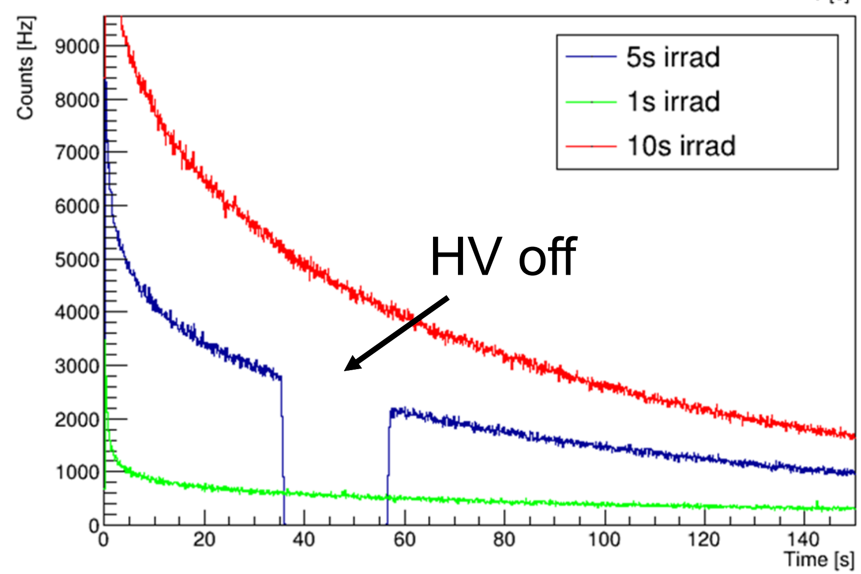
Afterglowing – further investigations with 9001393 with TRB

- Illuminating the full MCP-PMT PC several seconds with ~1 p.e./Pixel, then turn off the laser and measure the count rate for 300 s
- Higher illumination intensity (laser frequency) results in more afterglow
- Observed up to 10% afterglow events compared to the laser rate
- Longer illumination intensity results in more afterglow
- Turning off the HV during the decay has no effect on the number of afterglow events
- Amount of afterglow events depends on the voltage applied (gain) during the illumination





Afterglowing - photons or electrons?

- Measured two facing MCP-PMTs, once with the illuminated MCP-PMT turned on and once turned off
- Observe the count rates of the control MCP-PMT
- Count rates of the control MCP-PMT are higher when the illuminated MCP-PMT has been turned on
- ->Afterglow effect must be based on Photons