

# First results of the Photek A1200107 & A3191220 2x2 inch<sup>2</sup> MCP-PMTs

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PHYSICS

ecap

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PANDA Meeting Darmstadt, March, 10, 2020

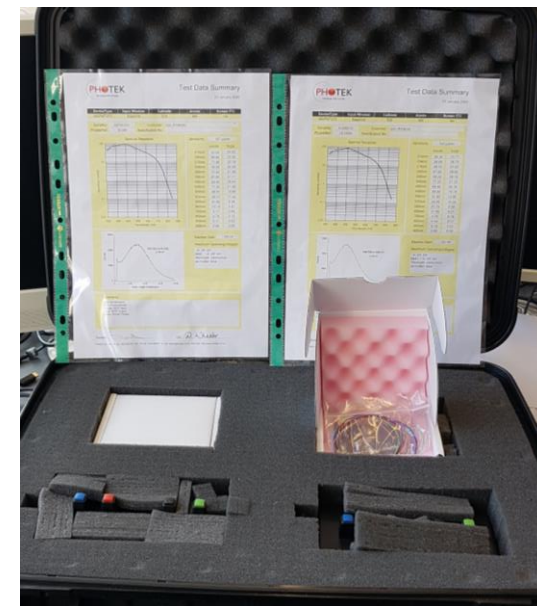
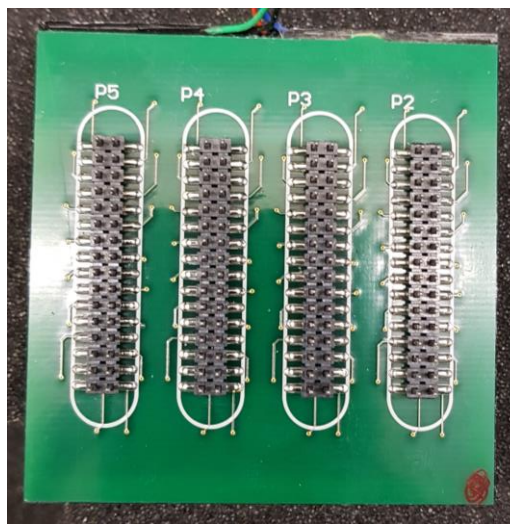
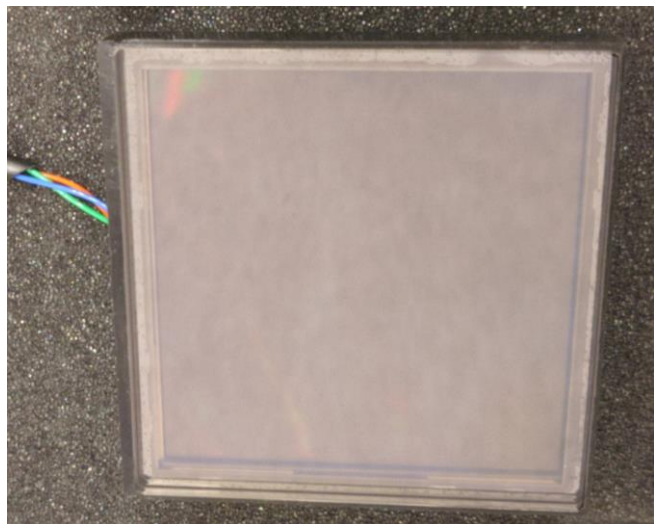


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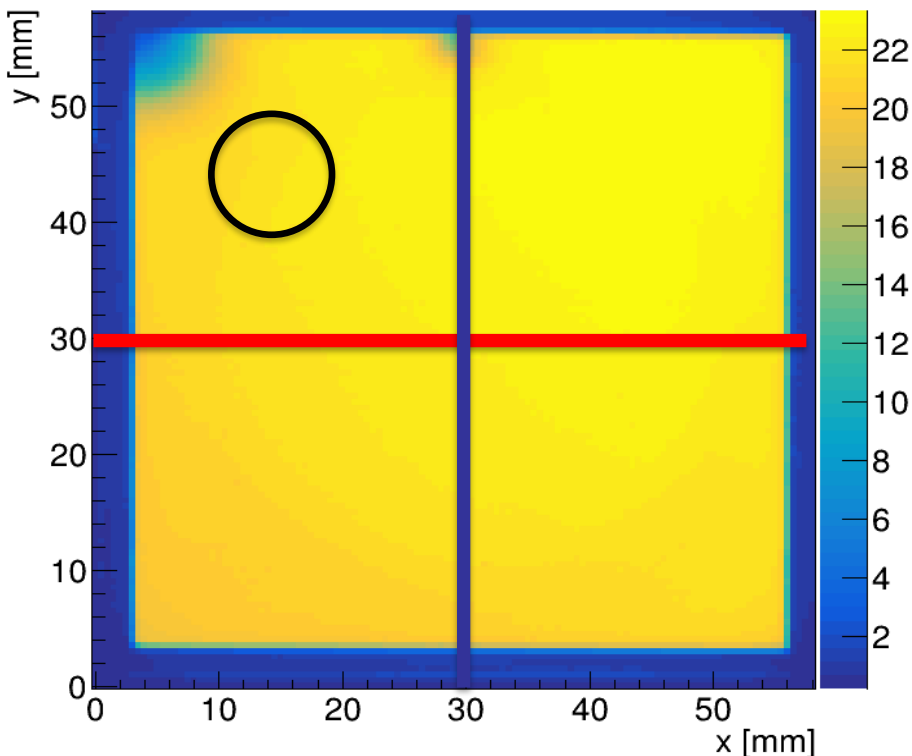
# Photek MAPMT253 A1200107 (A1) & MAPMT253 A3191220 (A3)

- 2x2 inch<sup>2</sup>, 8x8 pixels
- Comments so far:
  - not the promised Photonis backplane layout (connector spacing)
  - PC current increases with voltage (current  $\sim U$ )
    - There is a high resistive connection between PC & MCP-In (confirmed by Photek)
    - anodes are floating, ground pins are not connected → caused readout issues
- received voltage divider for each MCP-PMT

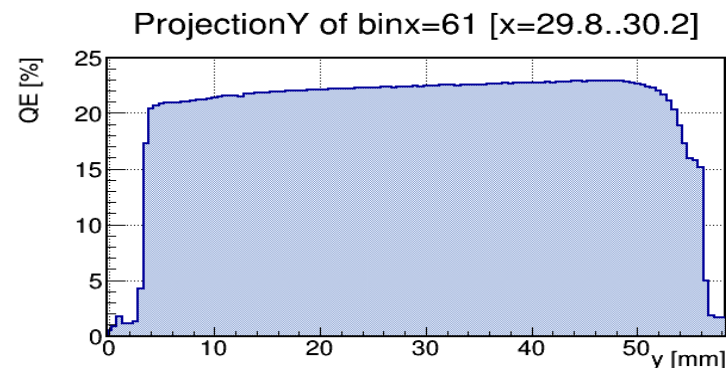
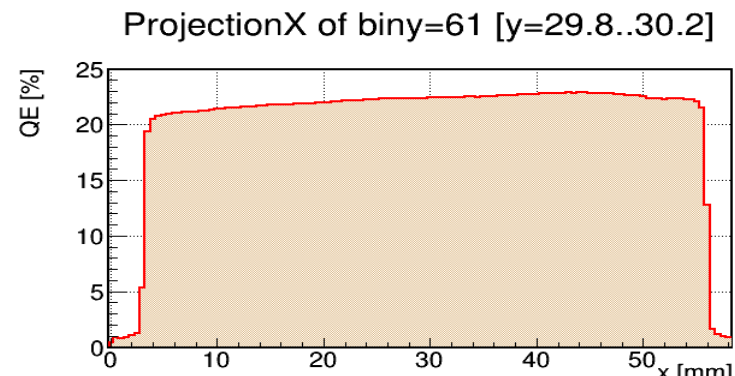


# Quantum efficiency Photek A1200107

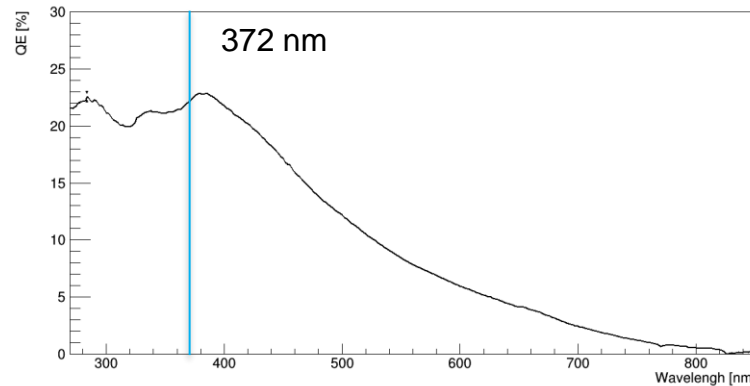
Quantum efficiency A1200107



- two holes on the top ( ~5-8% QE)
- max. QE about 23% on the top right quadrant
- bottom left quadrant around 20% QE
- overall, except holes, homogeneous distribution  $\pm 1.5\%$



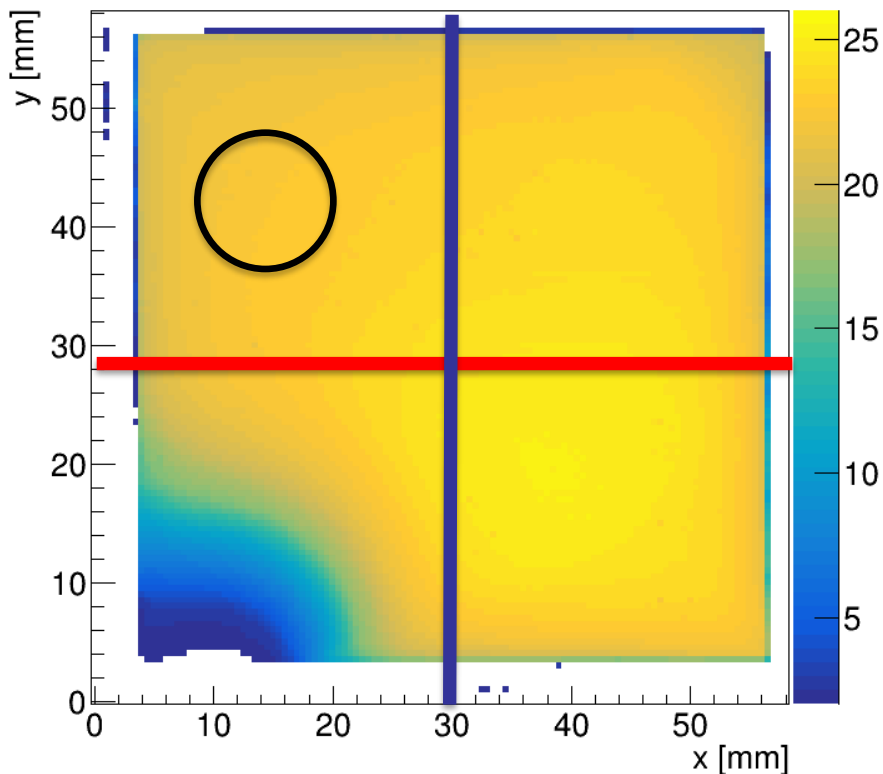
Photek 1200107 Pixel 22, 23, 32, 33



	mA/W	%QE
214nm	39.30	22.77
254nm	58.90	28.75
270nm	59.70	27.42
290nm	67.60	28.90
300nm	68.20	28.19
350nm	77.20	27.35
400nm	84.40	26.16
450nm	69.60	19.18
500nm	51.60	12.80
532nm	44.00	10.26
550nm	37.70	8.50
650nm	21.00	4.01
750nm	4.75	0.79
800nm	0.84	0.13
850nm	0.16	0.02
900nm	0.00	0.00

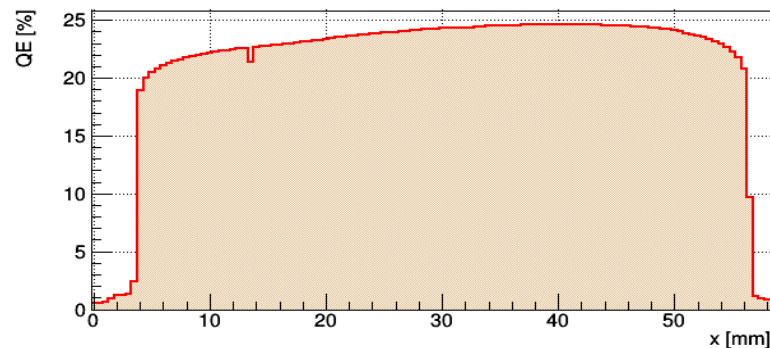
# Quantum efficiency Photek A3191220

Quantum efficiency A3191220

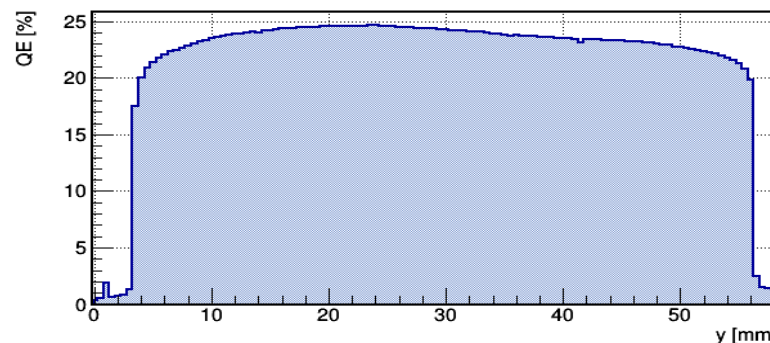


- big hole on bottom left corner ( ~0 – 5 % QE)
- max. QE about 25% in the bottom/middle right
- top left quadrant around 21% QE
- overall, except hole, homogeneous distribution  $\pm 2\%$

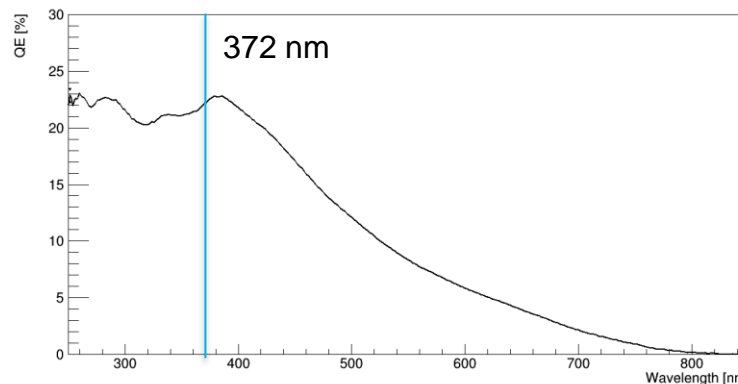
ProjectionX of biny=61 [y=29.8..30.3]



ProjectionY of binx=61 [x=29.8..30.3]



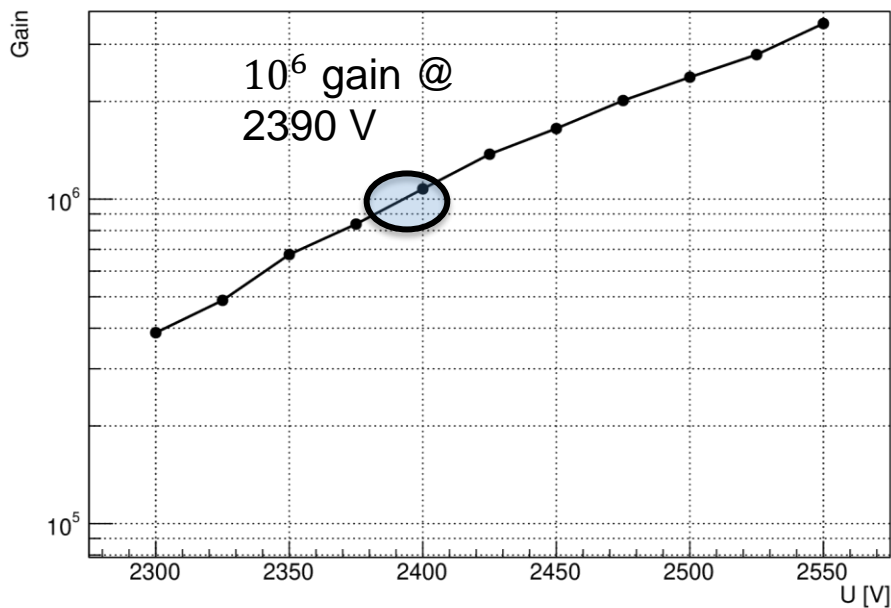
Photek 3191220 Pixel 22, 23, 32, 33



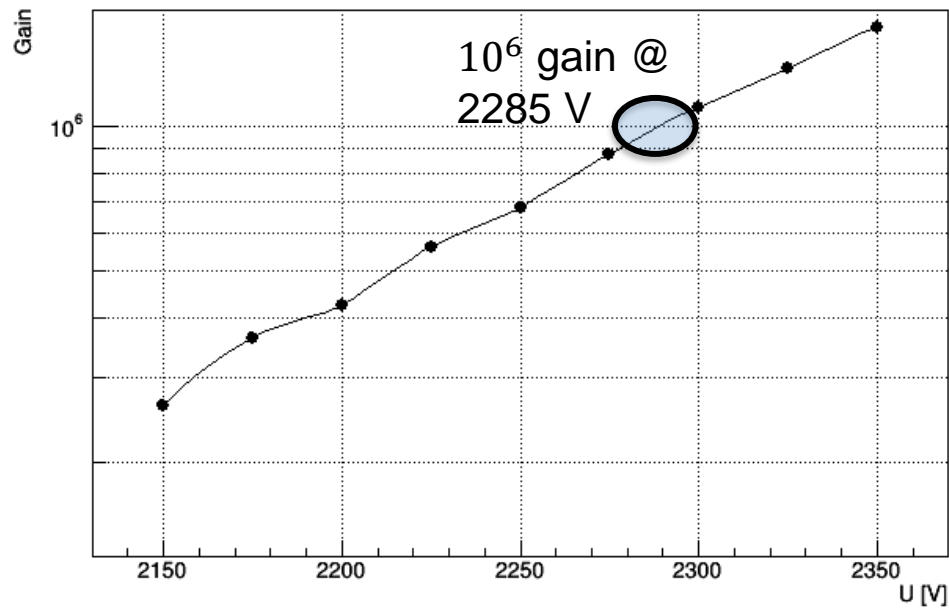
Wavelength [nm]	mA/W	%QE
214nm	43.00	24.92
254nm	68.80	33.59
270nm	71.40	32.79
290nm	76.20	32.58
300nm	77.40	31.99
350nm	87.80	31.11
400nm	92.40	28.64
450nm	77.50	21.36
500nm	56.40	13.99
532nm	49.10	11.44
550nm	41.60	9.38
650nm	23.10	4.41
750nm	5.11	0.84
800nm	0.79	0.12
850nm	0.11	0.02
900nm	0.00	0.00

# Gain curves Photek A1200107 & A3191220 for pixel x5 y4

gaincurve A1200107

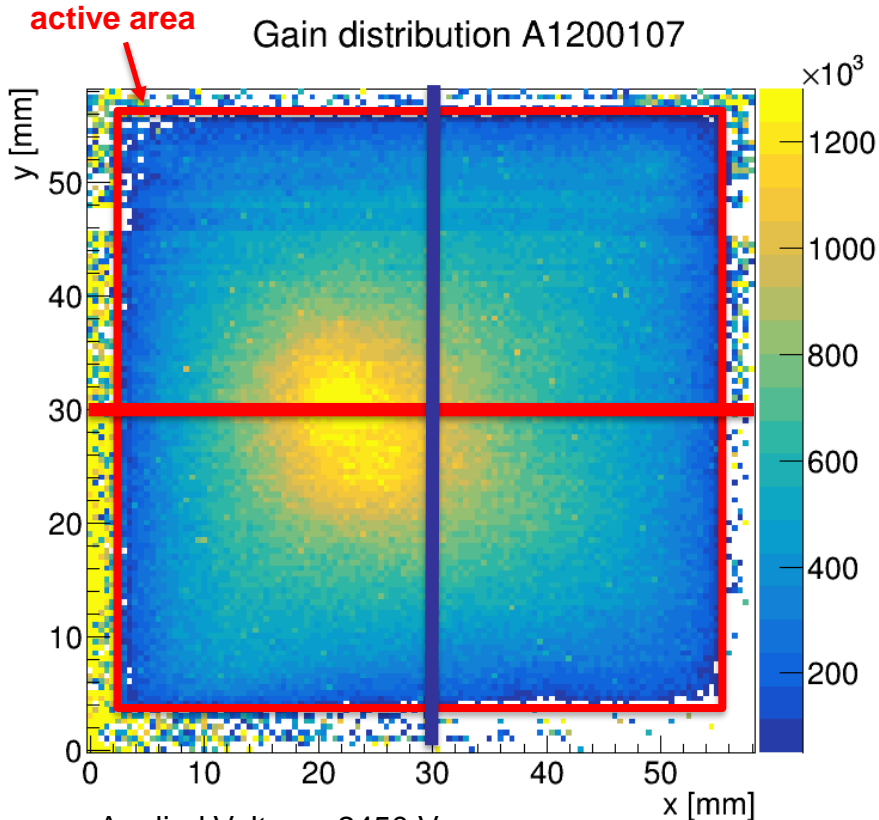


gaincurve A3191220

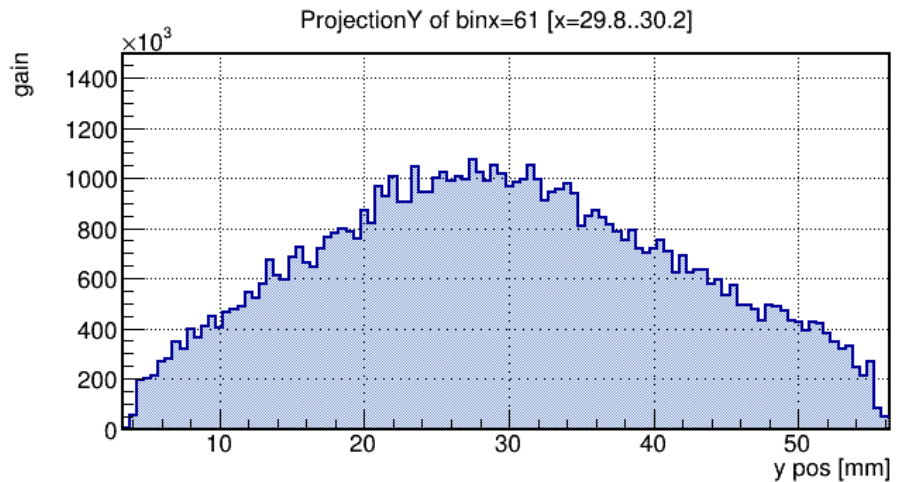
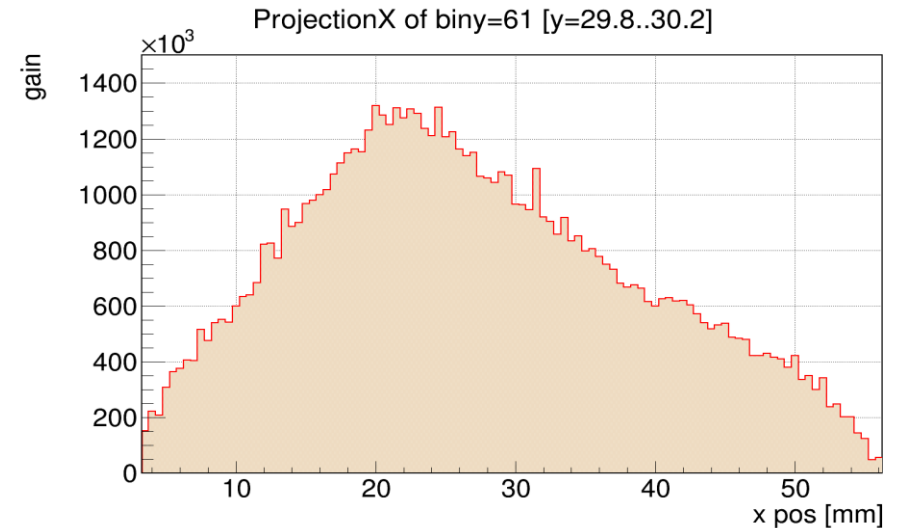


- measuring gain by 50 V steps with scope by subtracting mean pedestal charge and mean single photon signal charge
- measured at a center pixel (x5 y4), near area of gain maximum
- $10^6$  gain @ 2390 V
- maximum operating voltage: 2550 V
- $10^6$  gain @ 2285 V
- maximum operating voltage: 2350 V
- $10^6$  cannot be reached at the edges

# Gain distribution Photek A1200107



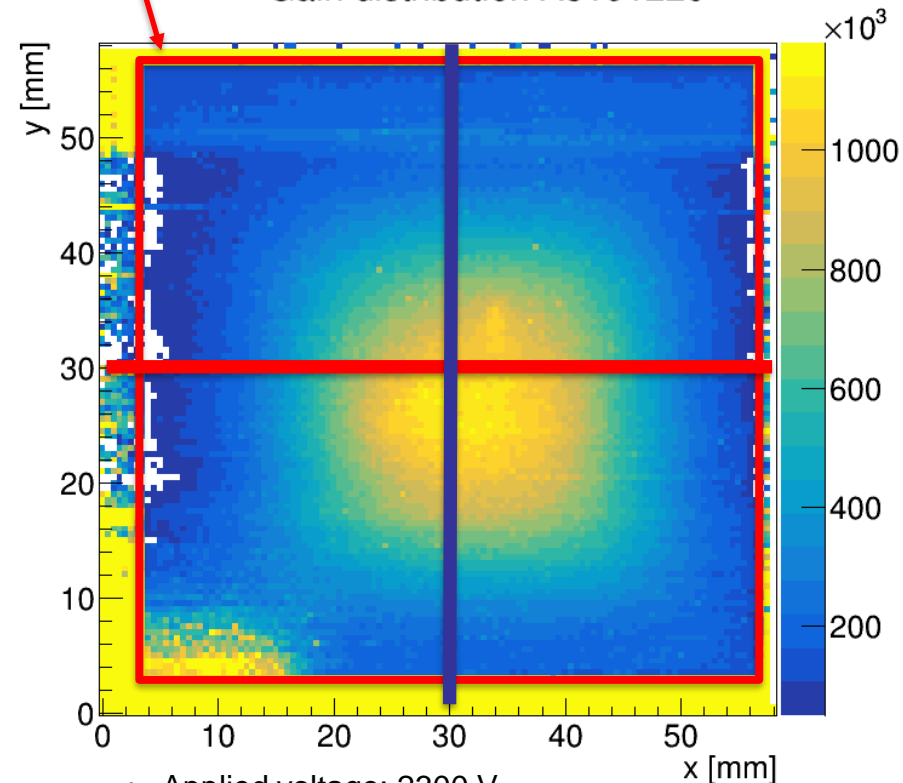
- Applied Voltage: 2450 V
- QE corrected
- reference pixel x5 y4 for scaling
- maximum:  $1.3 \times 10^6$  in the left middle
- towards edges gain drops to  $\sim 2 \times 10^5$
- poor gain homogeneity



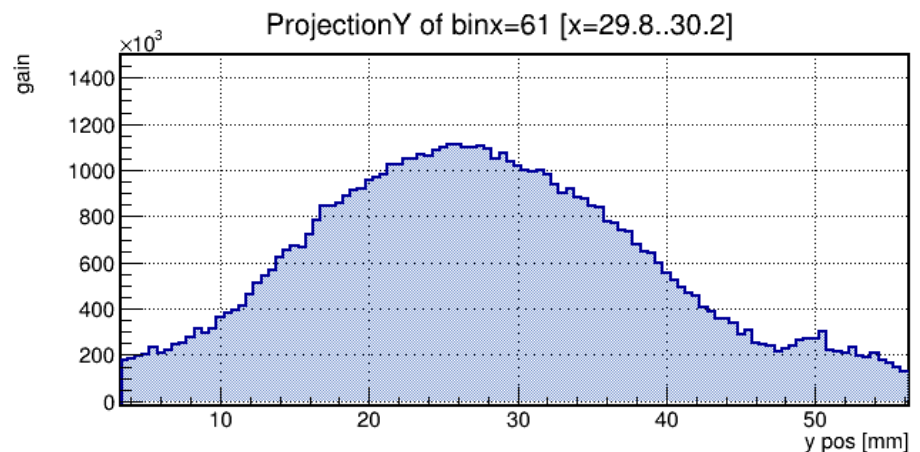
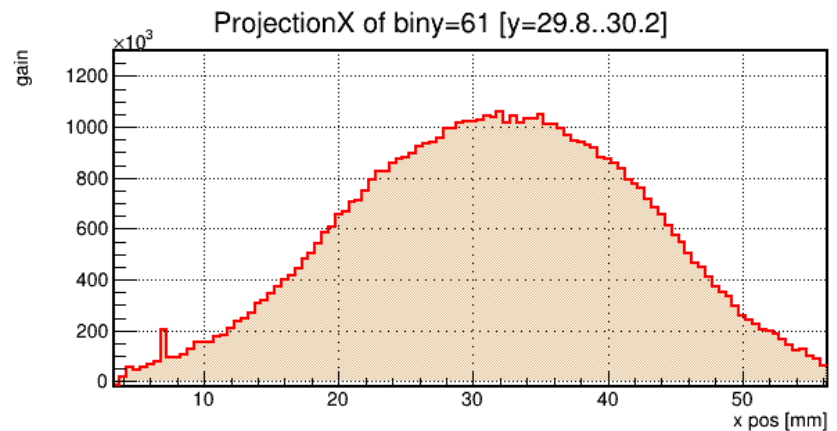
# Gain distribution Photek A3191220

active area

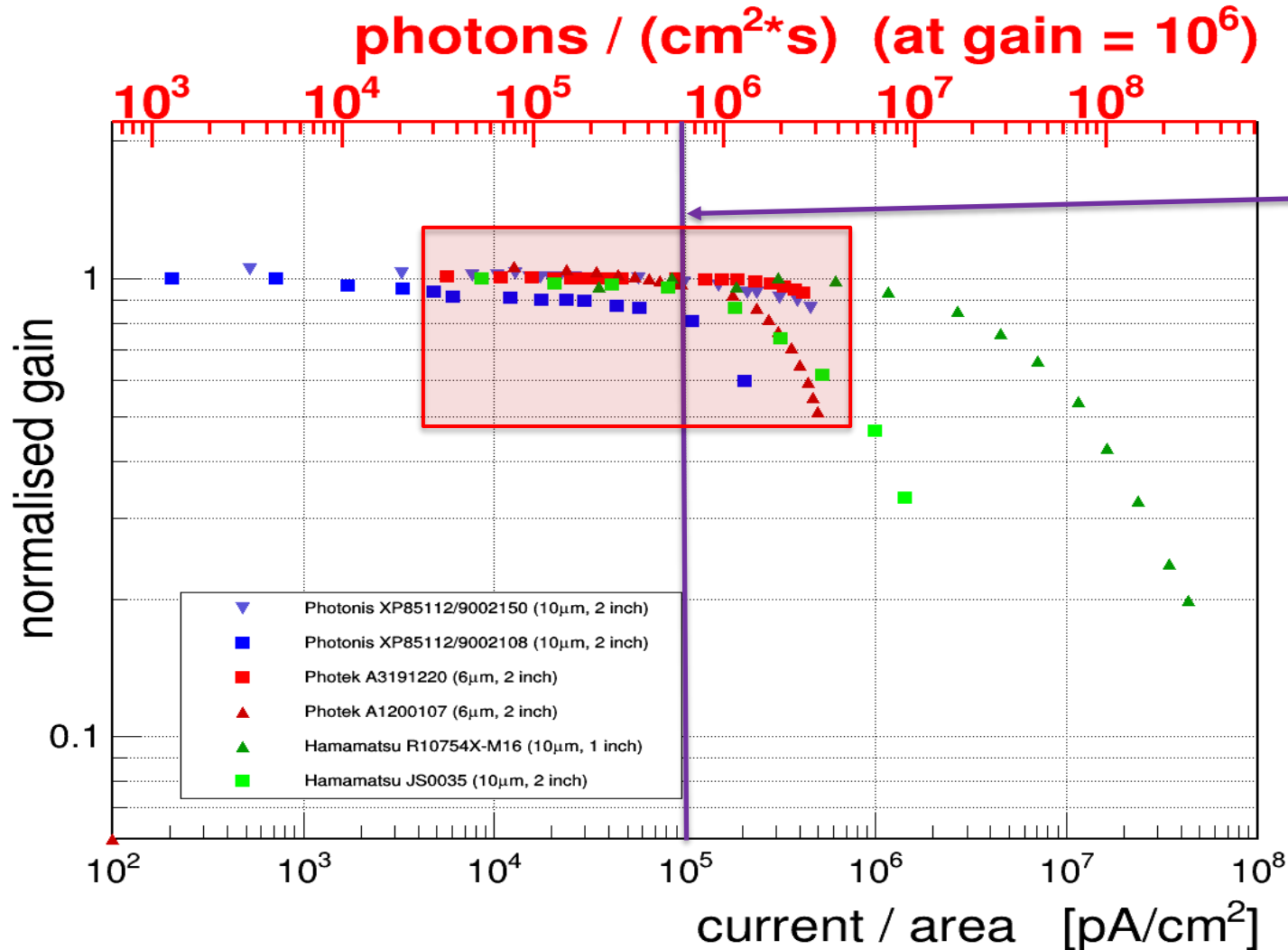
Gain distribution A3191220



- Applied voltage: 2300 V
- QE corrected
- reference pixel x5 y4 for scaling
- maximum:  $1.2 \times 10^6$  in the middle
- edges have gain drop of factor 8 – 10
- bottom left corner the QE hole visible
- bad gain homogeneity



# Rate stability Photek A1200107 & A3191220

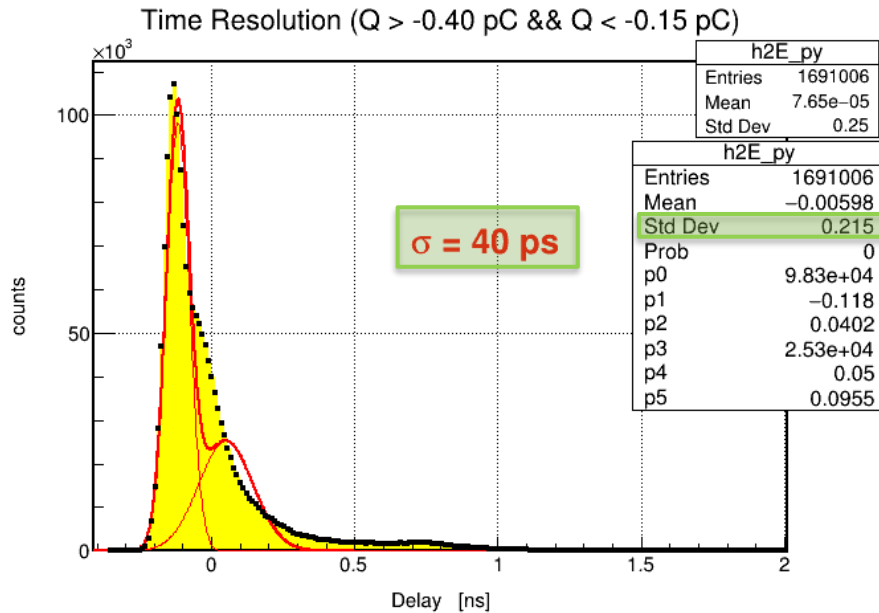


Barrel DIRC  
 requirement:  
 600 kHz per  
 cm<sup>2</sup>

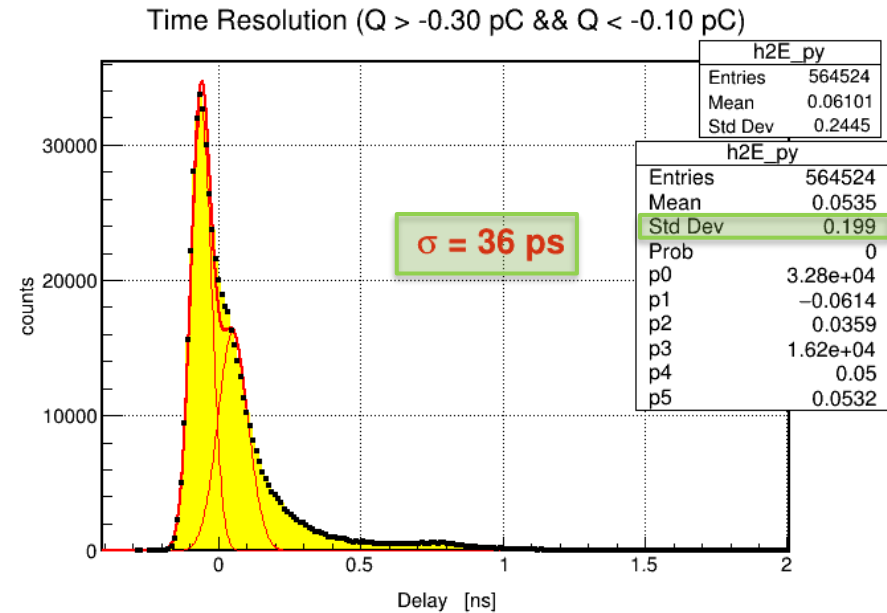


# Time resolution Photek A1200107 & A3191220 pixel x4 y5 (scope)

A1:

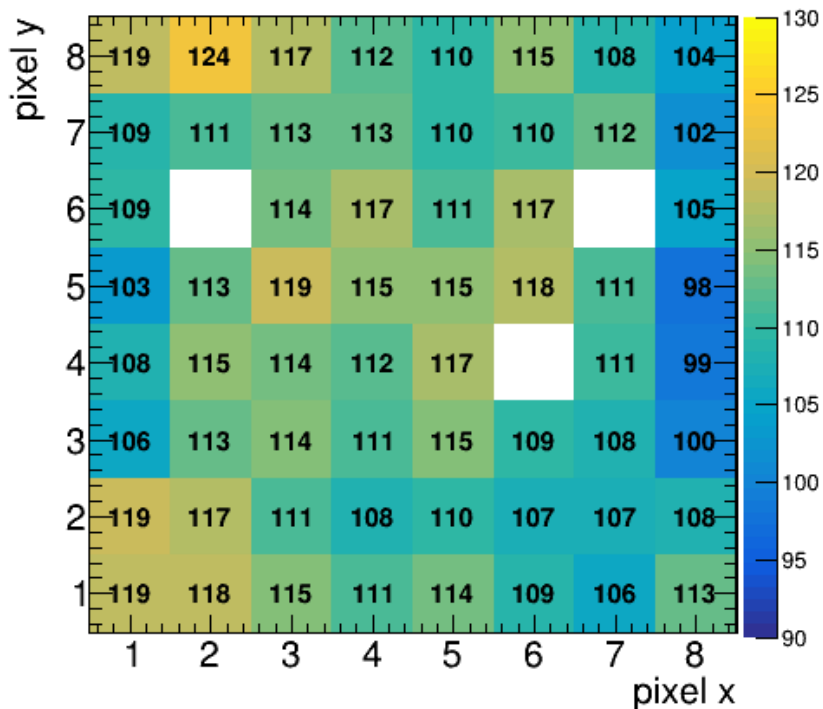


A3:

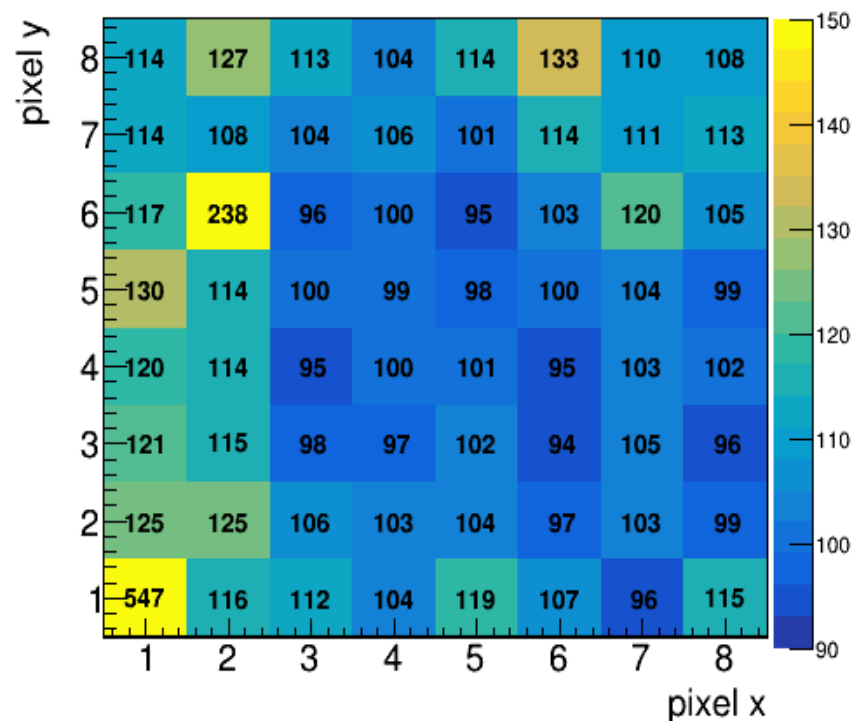


# Photek A1200107 & A3191220 DiRICH scans – time resolution

(corrected, pixel cut) Sigma2 (ps)



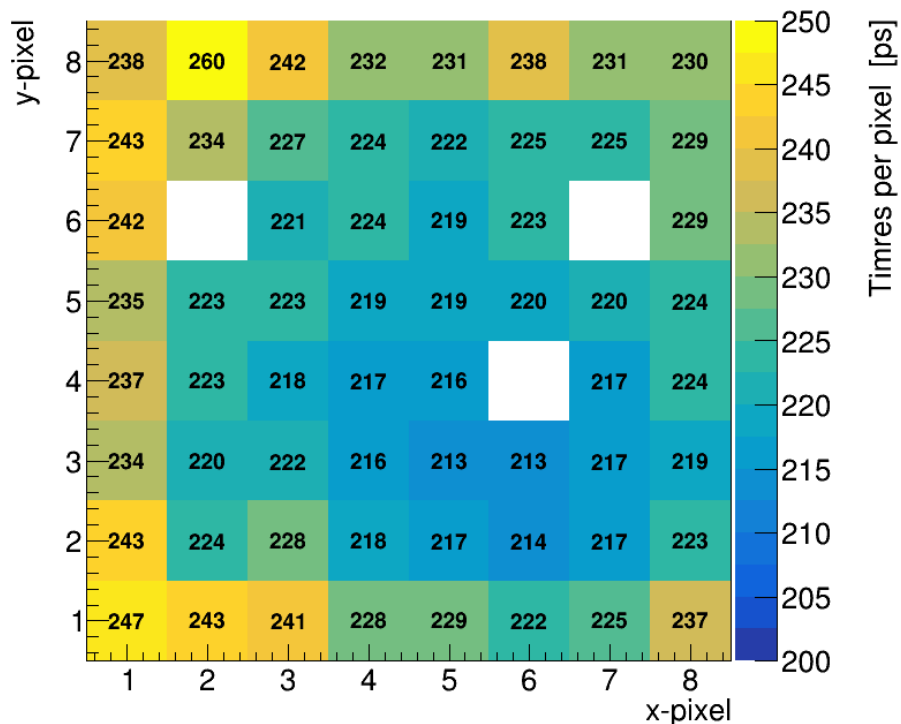
(corrected, pixel cut) Sigma2 (ps)



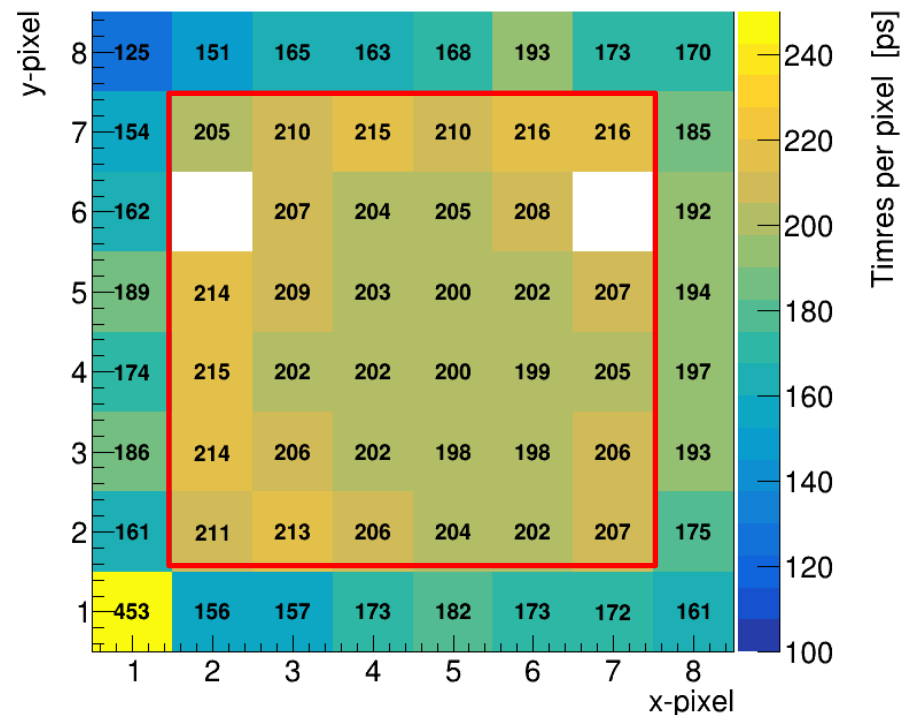
- white spots → dead pixels
- applied voltages → A1: 2400 V, A3: 2300 V
- threshold 1000, about 50% of single photon peak
- peak time resolution per pixel, timewalk corrected

# Photek A1200107 & A3191220 DiRICH scans – time resolution

timeresolution rms corrected A1200107



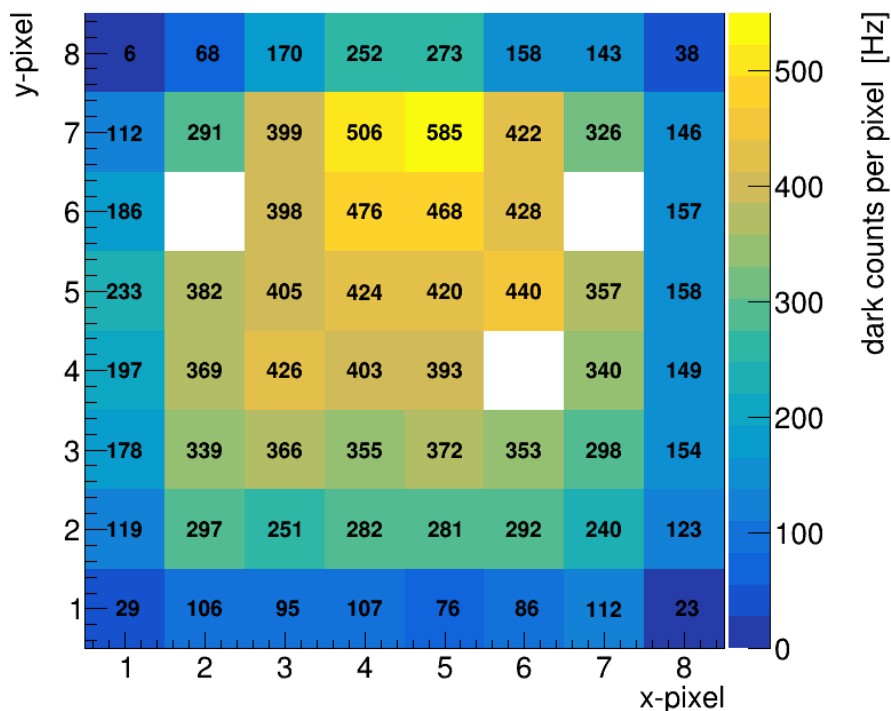
timeresolution rms corrected A3191220



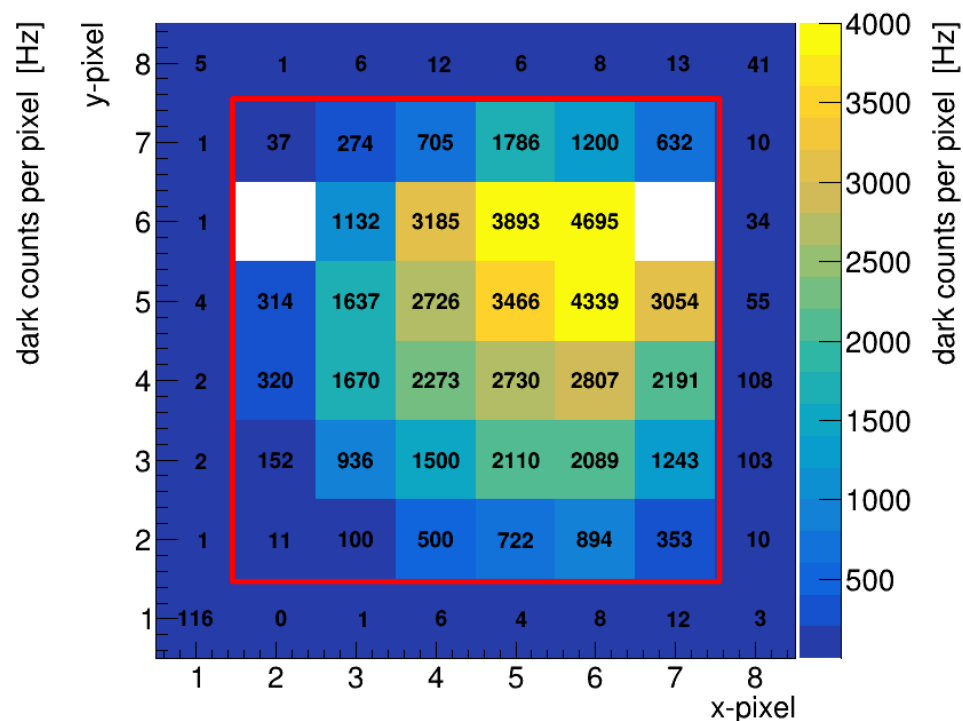
- white spots → dead pixels
- rms time resolution per pixel, timewalk corrected
- A3 two different regions remarkable, inner and outer pixels

# Photek A1200107 & A3191220 DiRICH scans – darkcount distributions

darkcount pixel map A1200107



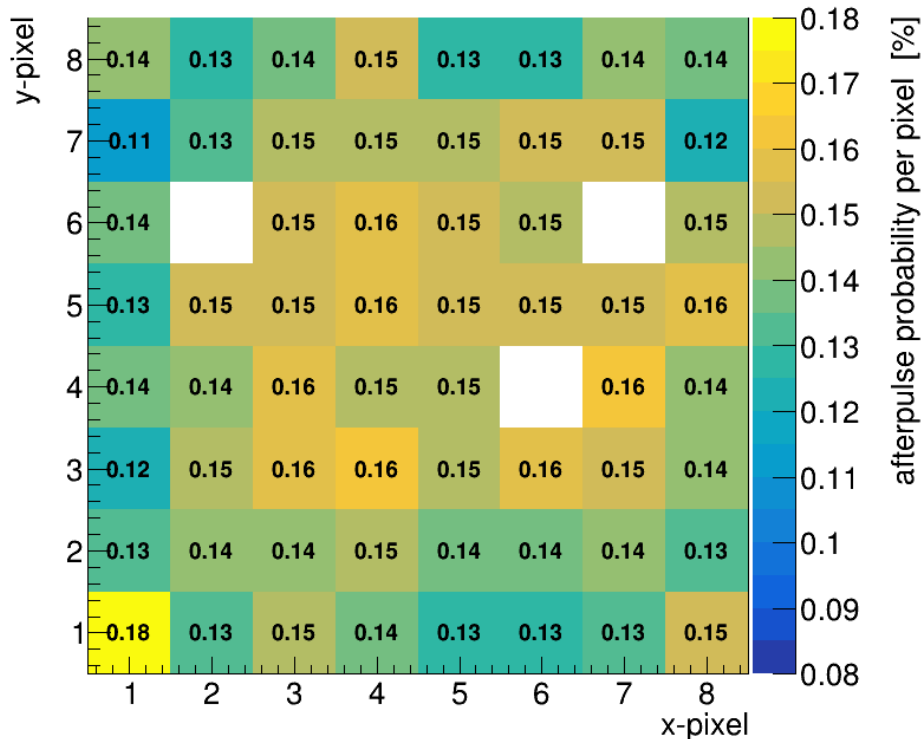
darkcount pixel map A3191220



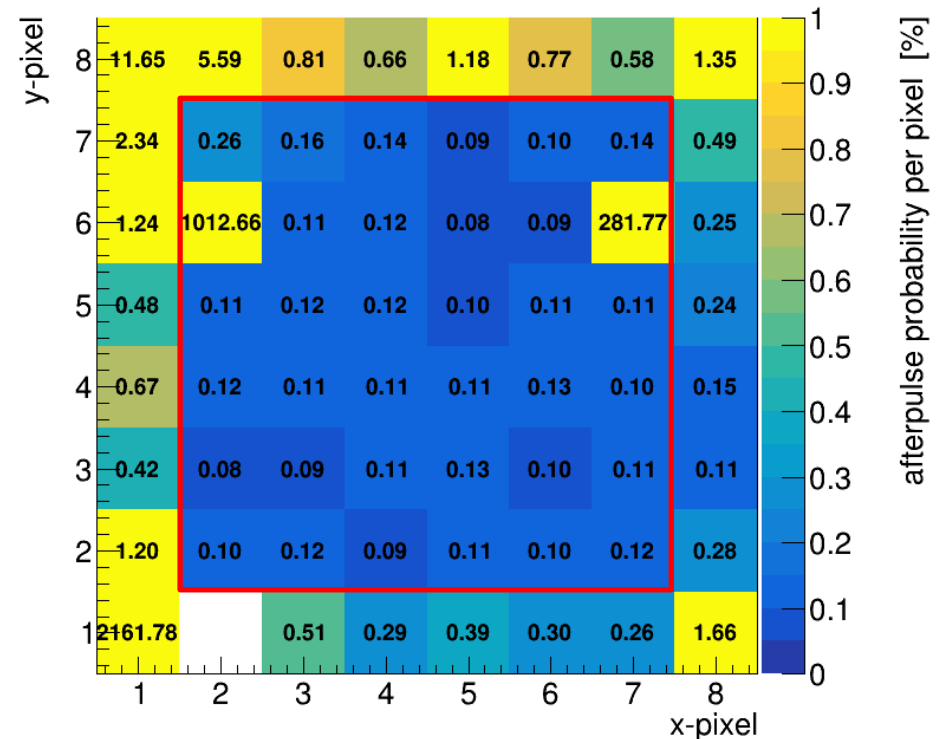
- darkcount rate per pixel
- A3 two different regions remarkable, inner and outer pixels (due to lower gain)
- same effect for A1, but on smaller scale

# Photek A1200107 & A3191220 DiRICH scans – afterpulse distributions

afterpulse per pixel A1200107

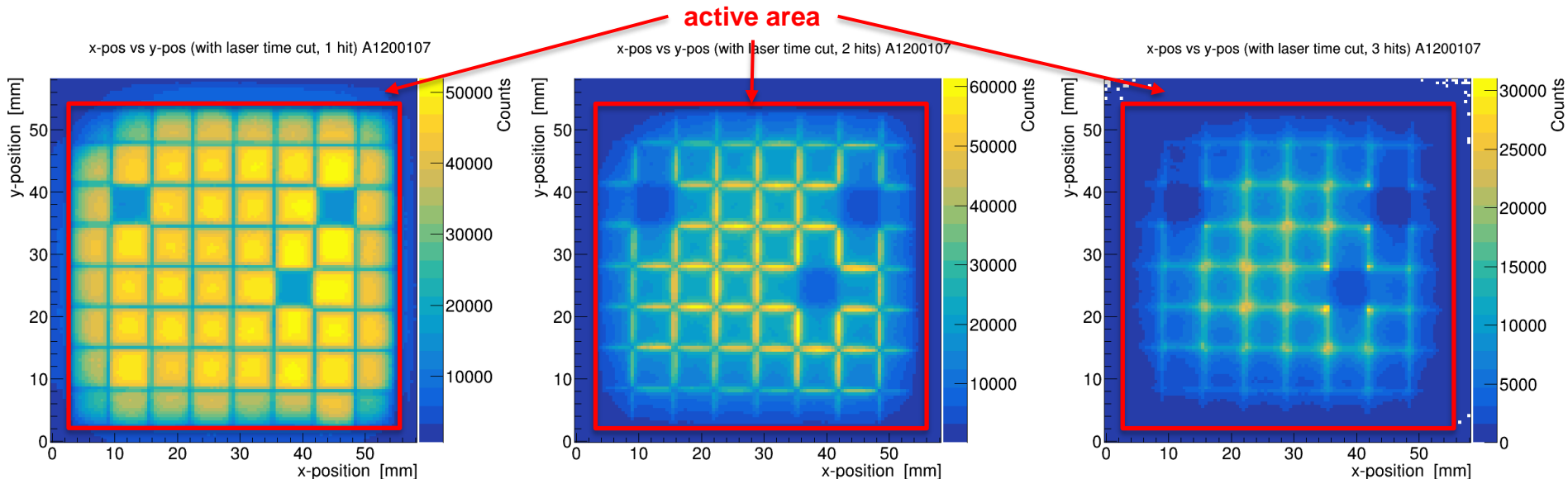


afterpulse per pixel A3191220



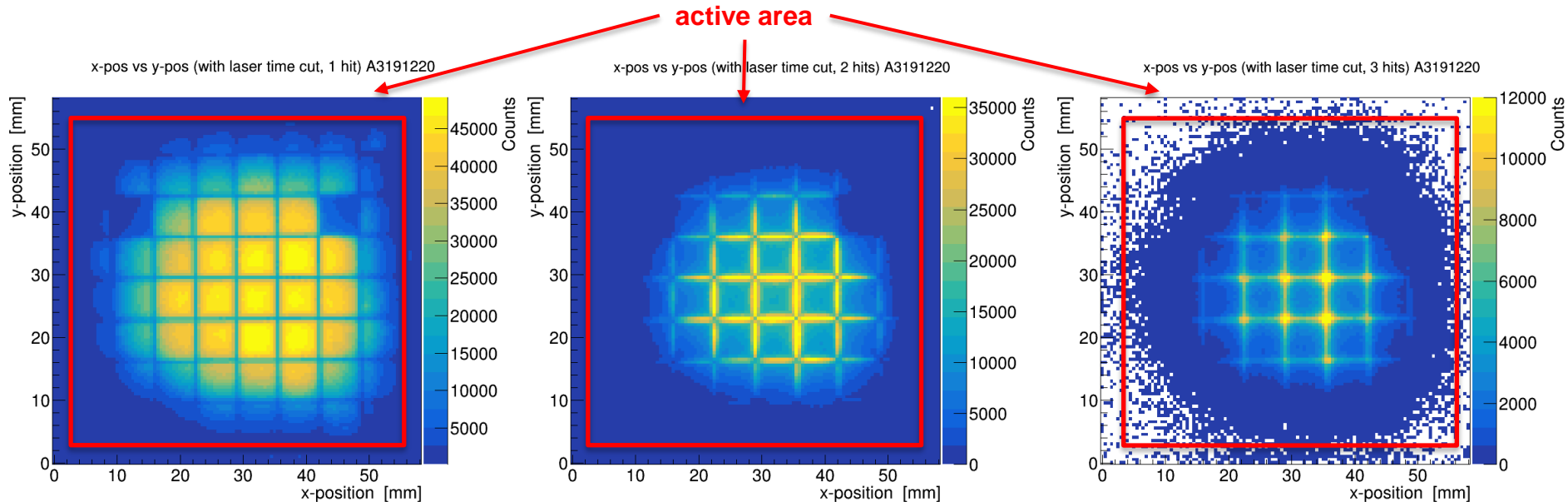
- afterpulse probability per pixel usually 0.15 %
- A1 very homogeneous
- A3 two different regions remarkable, inner and outer pixels (due to lower gain)

# Photek A1200107 & A3191220 DiRICH scans – A1 crosstalk behaviour



- 1 hit per laser pulse → pixel structure, all pixels visible
- 2 hits per laser pulse → expected pixel grid measured
- 3 hits per laser pulse → corner spots
- expected behaviour for whole active area measured
- charge cloud width  $\sim 0.5$  mm

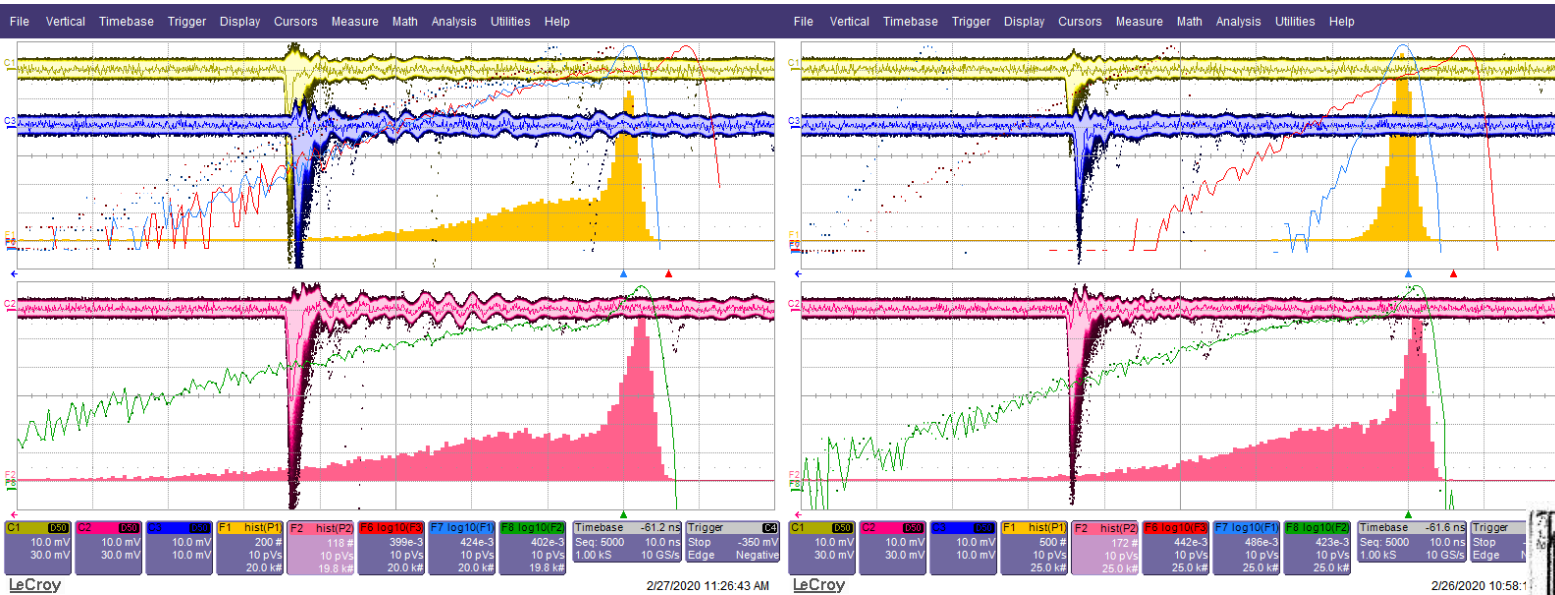
# Photek A1200107 & A3191220 DiRICH scans – A3 crosstalk behaviour



- 1 hit per laser pulse → pixel structure
- top and bottom left corners no pixels visible → gain too low for threshold
- 2 hits per laser pulse → edges
- charge cloud width ~ 0.3 mm
- 3 hits per laser pulse → corners
- hits just 4 by 4 center pixels visible

# Photek A1200107 & A3191220 – oscillation measurements

- 2x2 inch<sup>2</sup>, 8x8 pixels, 6 μm pores with ALD coating, 10<sup>6</sup> gain
- Red (632 nm) PiLas, 10 kHz, illumination of **full sensor**



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

Trigger:  
 Laser pulse

A1200107, ND 3.6  
 all pixels \* 1 = 64 p.e.

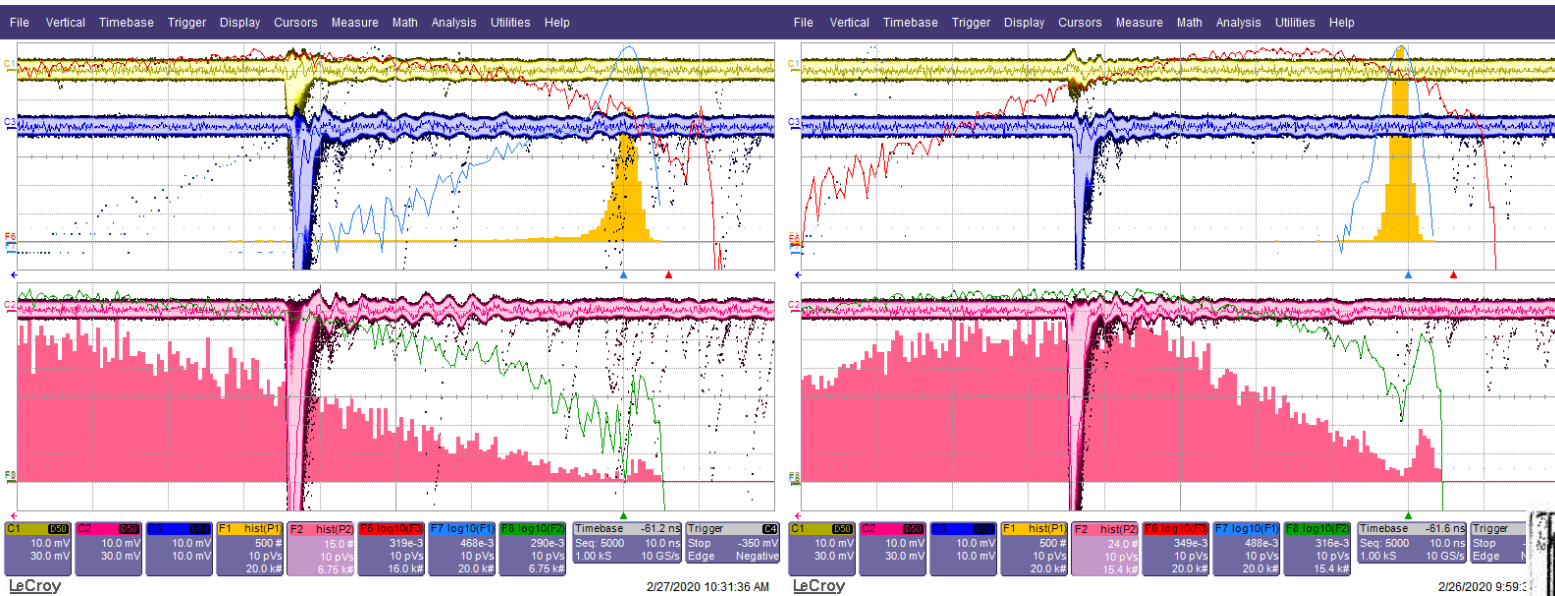
A3191220, ND 3.6  
 all pixels \* 1 = 64 p.e.

11	12	13	14	15	16	17	18
21	22	23	24	25	26	27	28
31	32	33	34	35	36	37	38
41	42	43	44	45	46	47	48
51	52	53	54	55	56	57	58
61	62	63	64	65	66	67	68
71	72	73	74	75	76	77	78
81	82	83	84	85	86	87	88



# Photek A1200107 & A3191220 – oscillation measurements

- 2x2 inch<sup>2</sup>, 8x8 pixels, 6 μm pores with ALD coating, 10<sup>6</sup> gain
- Red (632 nm) PiLas, 10 kHz, illumination of 12 pixels



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

Trigger:  
 Laser pulse

A1200107, ND 2.6  
 $12 * 3.5 = 42$  p.e.

A3191220, ND 2.6  
 $12 * 3.5 = 42$  p.e.

11	12	13	14	15	16	17	18
21	22	23	24	25	26	27	28
31	32	33	34	35	36	37	38
41	42	43	44	45	46	47	48
51	52	53	54	55	56	57	58
61	62	63	64	65	66	67	68
71	72	73	74	75	76	77	78
81	82	83	84	85	86	87	88

**Photek 1200116, not  
relevant for tendering!**



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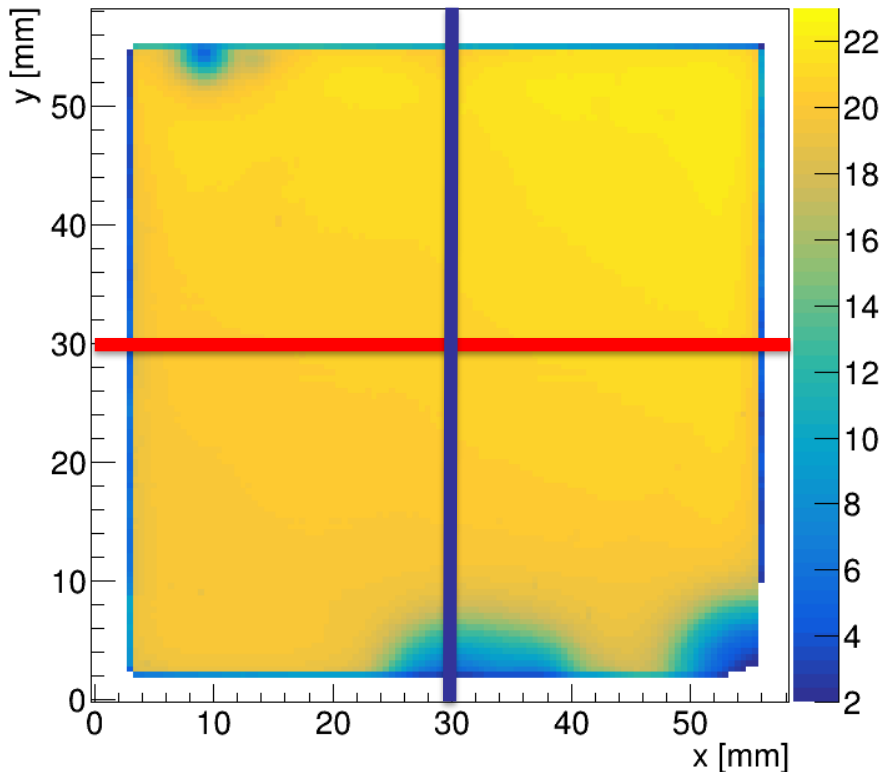


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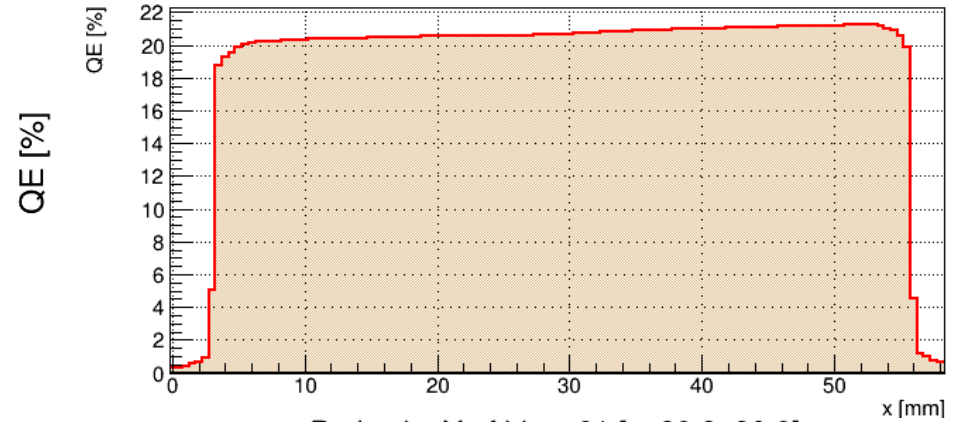
# Quantum efficiency Photek A1200116

Quantum efficiency A1200116

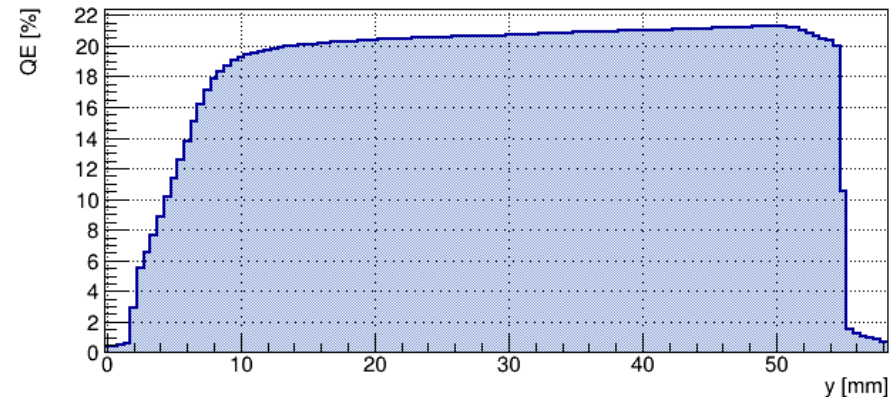


- some small damages at top & bottom
- max. QE about 22% in the top right quadrant
- bottom left quadrant around 19% QE
- overall, except hole, homogenous distribution  $\pm 1.5\%$

ProjectionX of biny=61 [y=29.8..30.2]



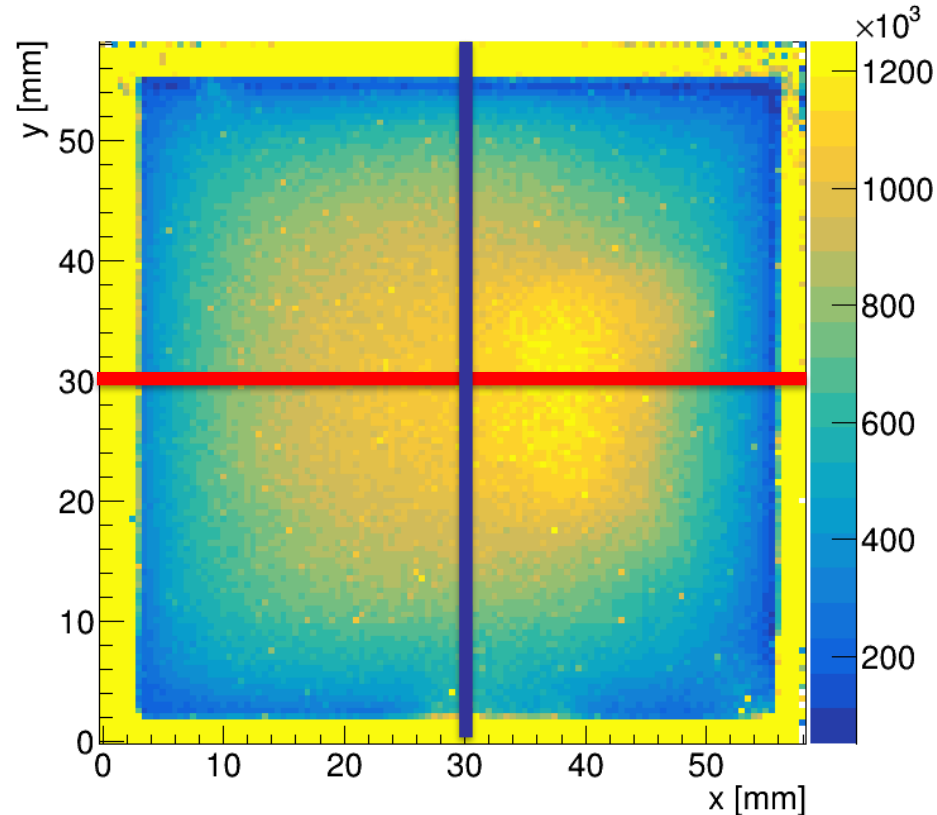
ProjectionY of binx=61 [x=29.8..30.2]



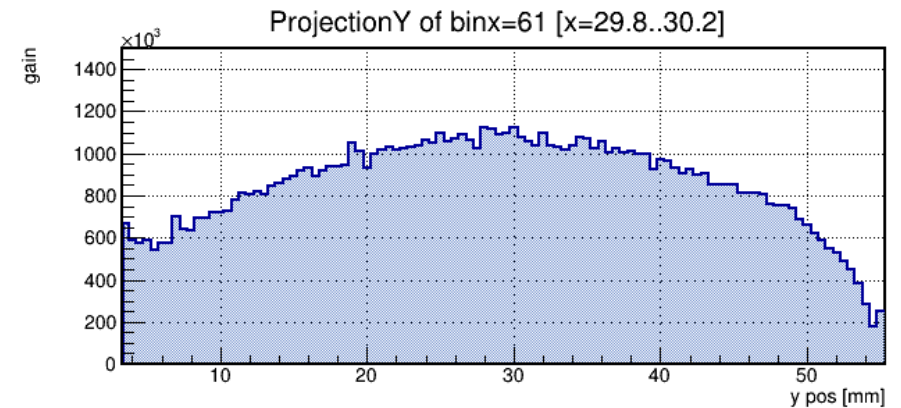
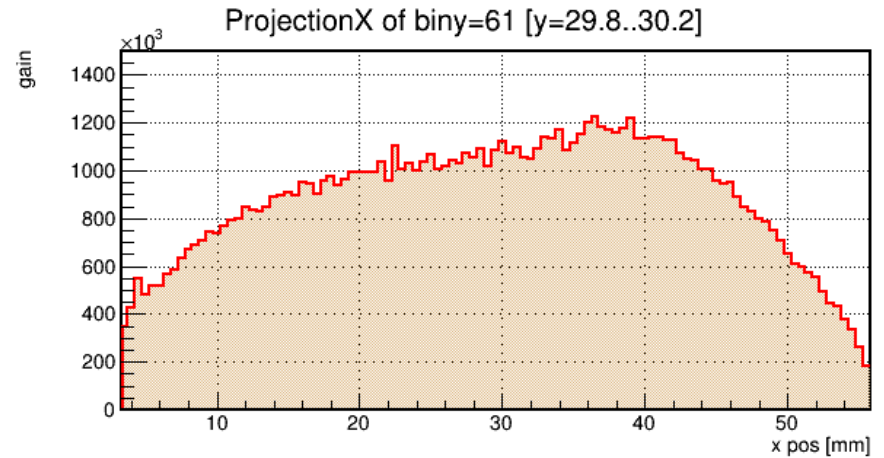
350nm	78.50	27.81
400nm	82.60	25.61

# Gain distribution Photek A1200116

Gain distribution A1200116

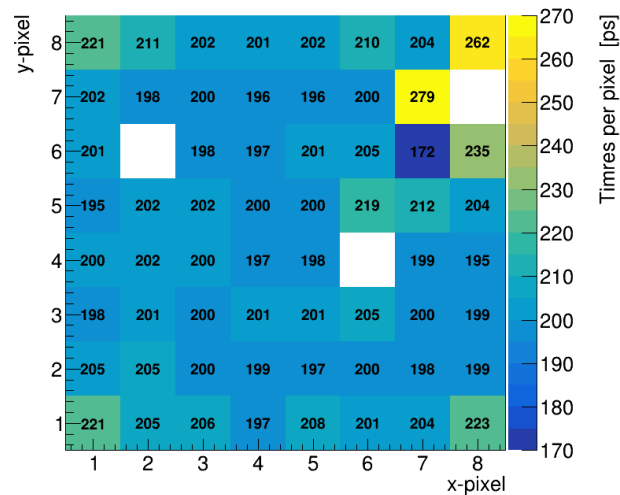


- some small damages at top & bottom
- max. QE about 22% in the bottom/middle right
- top left quadrant around 21% QE
- overall, except hole, homogenous distribution  $\pm 2\%$

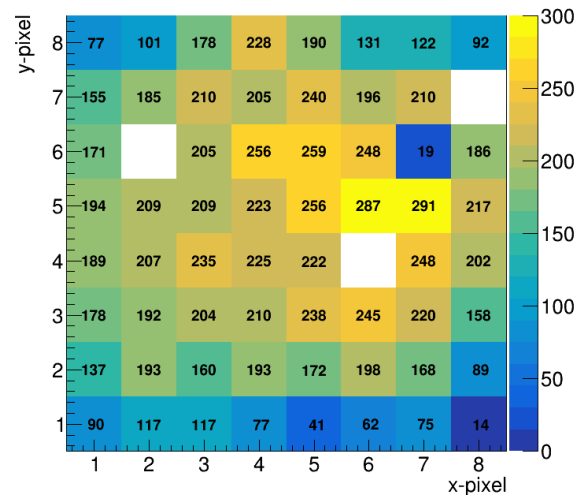


# Photek A1200116 DiRICH scan

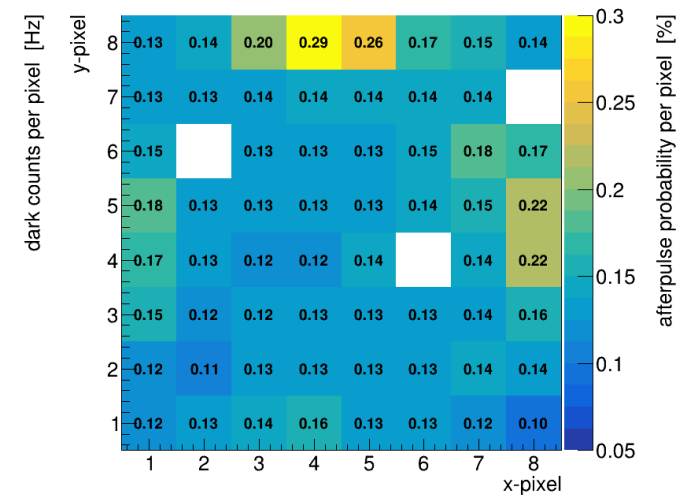
timeresolution rms corrected A1200116



darkcount pixel map A1200116



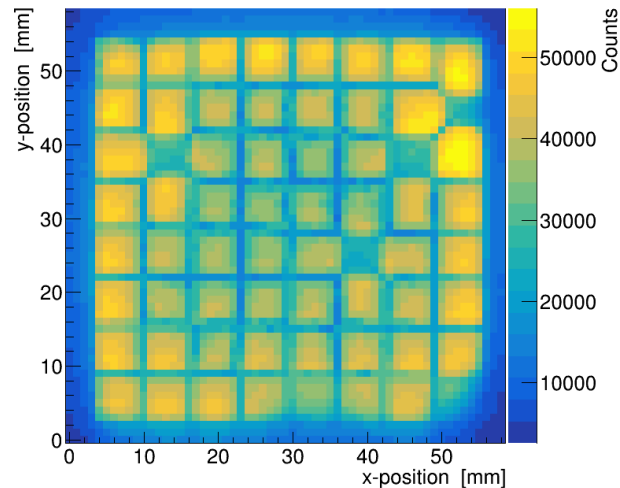
afterpulse per pixel A1200116



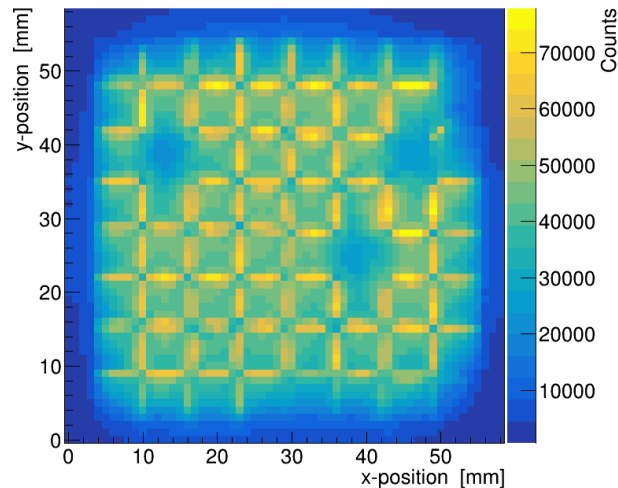
- applied voltage 2650 V
- threshold 1000, about 50% of single photon peak
- rms time resolution per pixel, timewalk corrected
- darkcounts and afterpulse probability are comparable

## Photek A1200116 DiRICH scan

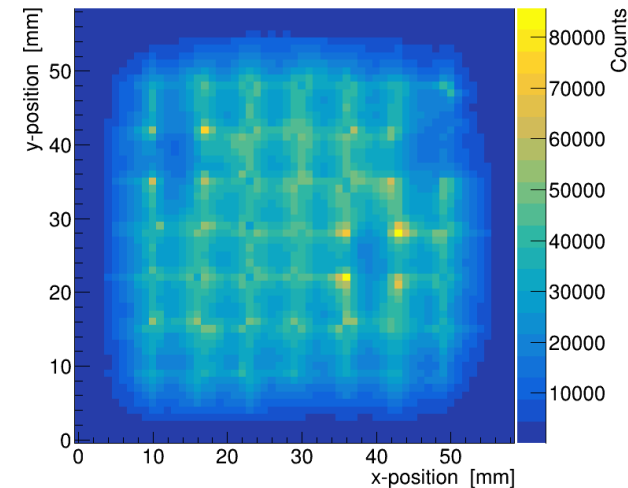
x-pos vs y-pos (with laser time cut, 1 hit) A1200116



x-pos vs y-pos (with laser time cut, 2 hits) A1200116



x-pos vs y-pos (with laser time cut, 3 hits) A1200116



- 1 hit per laser pulse → pixel structure, all pixels visible
- 2 hits per laser pulse → expected pixel grid measured
- 3 hits per laser pulse → corner spots
- expected behaviour for whole active area measured

## Summary

- good homogeneity in QE distribution for A1 & A3 (except holes at rims)
- QE spectra about 5 % (abs.) lower as written in datasheet, for 372 nm (blue)
- A1 & A3 reach  $> 10^6$  gain but only for center area
- gain for both sensors very inhomogeneous over detective area
- rms time resolution of DiRICH and scope comparable, (  $\sim 200$  ps)
- DiRICH measurement of A3 for center pixels okay, but outer pixels cannot be measured, due to low gain
- Oscillation measurements tend to be better than other MCP-PMTs (incl. Photonis 9002150, modified backplane)
- Outlook: integration into lifetime setup and magnetic field measurements, CE

GEFÖRDERT VOM



Bundesministerium  
für Bildung  
und Forschung

# Thank you for your attention

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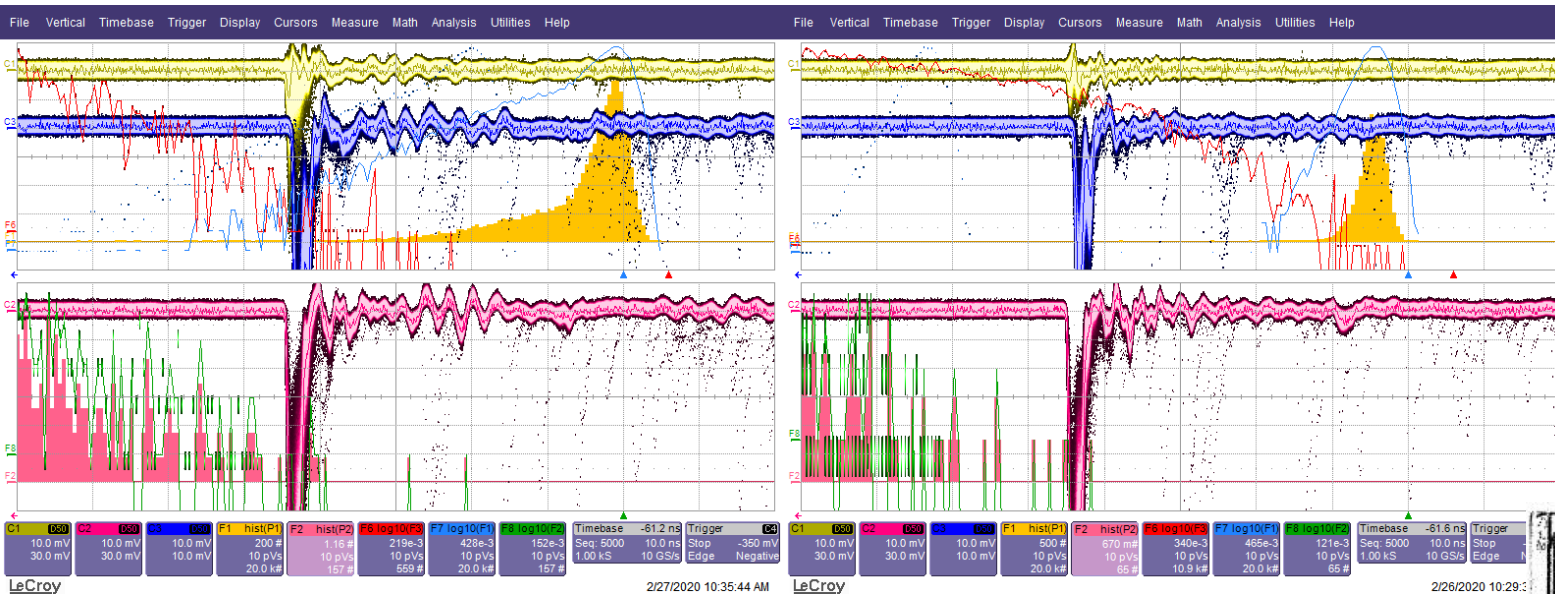
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# Photek A1200107 & A3191220 – oscillation

- 2x2 inch<sup>2</sup>, 8x8 pixels, 6 μm pores with ALD coating, 10<sup>6</sup> gain
- Red (632 nm) PiLas, 10 kHz, illumination of 6 pixels



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

Trigger:  
 Laser pulse

A1200107, ND2.0  
 6 \* 8 = 48 p.e.

A3191220, ND2.0  
 6 \* 8 = 48 p.e.

11	12	13	14	15	16	17	18
21	22	23	24	25	26	27	28
31	32	33	34	35	36	37	38
41	42	43	44	45	46	47	48
51	52	53	54	55	56	57	58
61	62	63	64	65	66	67	68
71	72	73	74	75	76	77	78
81	82	83	84	85	86	87	88