Results of the Photonis XP85112 9002192 & 9002193 2x2 inch² MCP-PMTs

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

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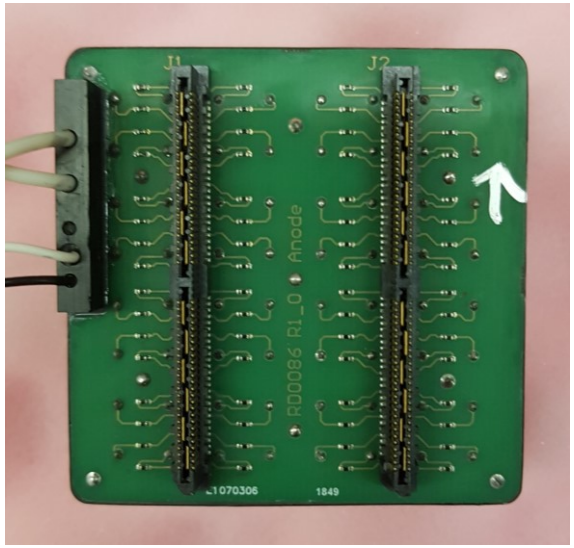
ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

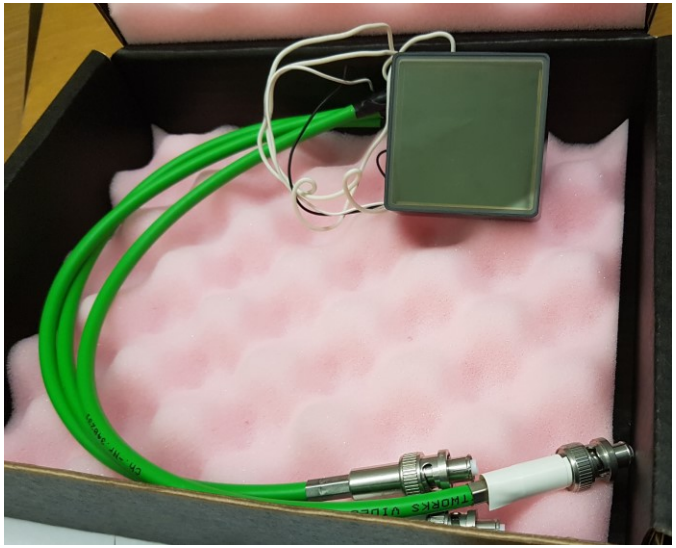
FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

NATURWISSENSCHAFTLICHE FAKULTÄT

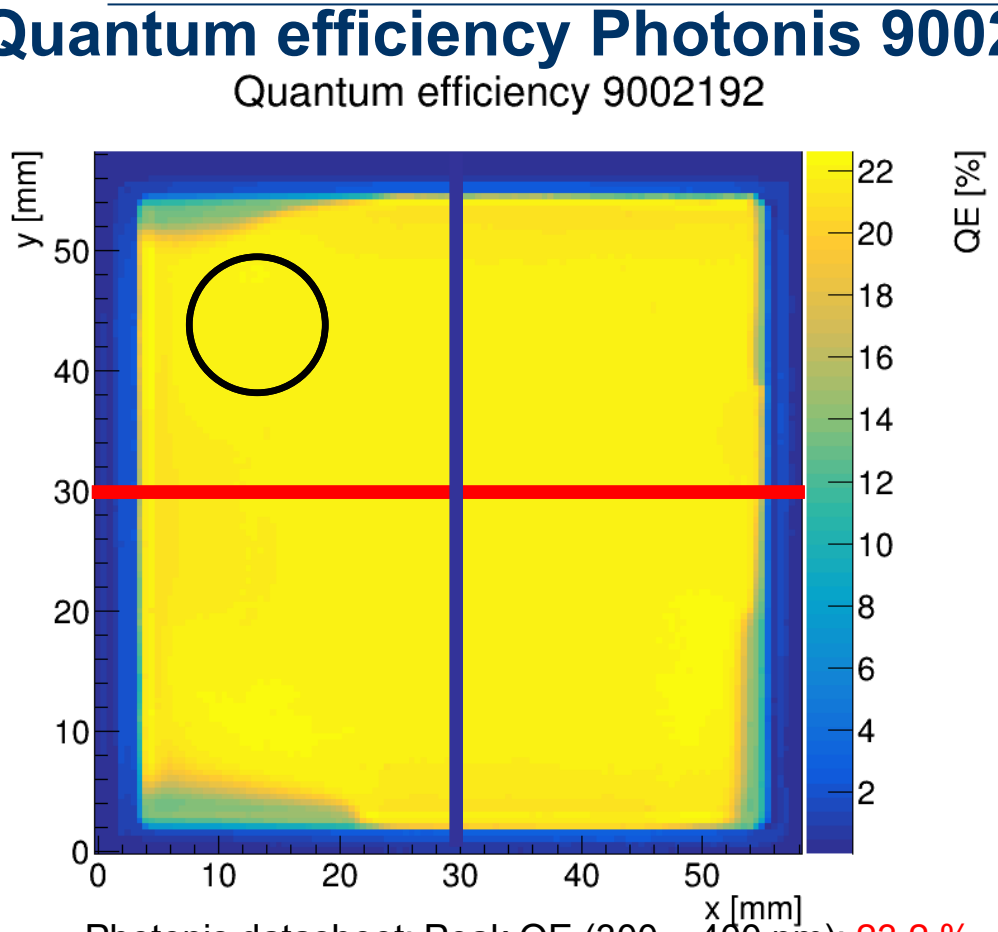
Photonis XP85112 9002192 (2192) & XP85112 9002193 (2193)

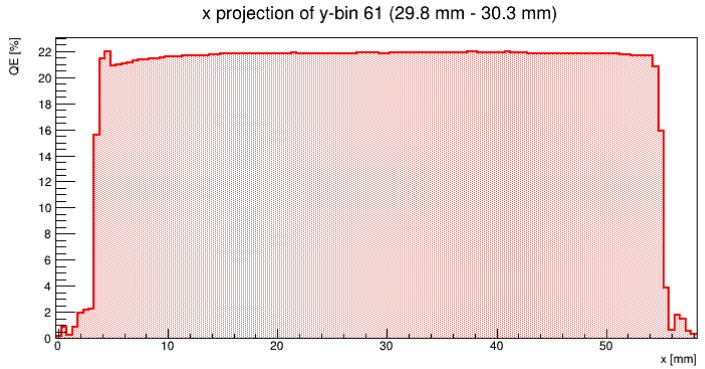
- 2x2 inch², 8x8 pixels, 10 µm MCP
- Comments so far:
  - tubes arrived in Erlangen: June 2nd, 2020
  - 10 µm MCP diameter
  - backplane layout like Photonis 9002150 (no pins out, left picture)
  - high collection efficiency tubes (Photonis comment, not measured yet)
  - recommended voltage divider: 1:10:1 (0.5 MΩ - 5 MΩ – 0.5 MΩ), but changeable up to a PC voltage of 800 V

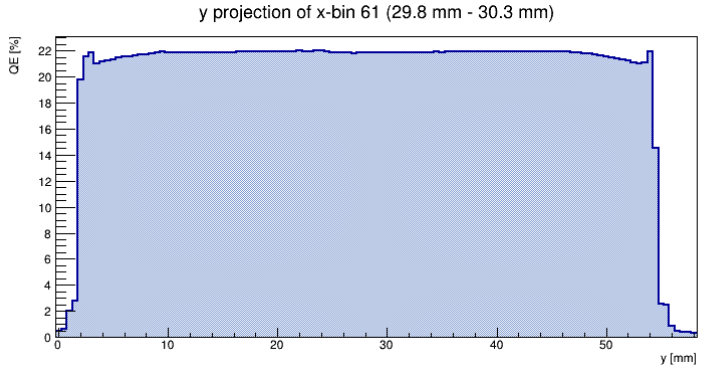


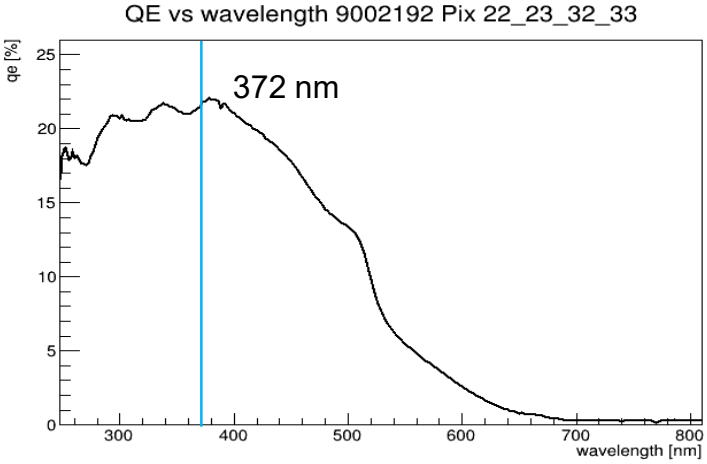


Quantum efficiency Photonis 9002192



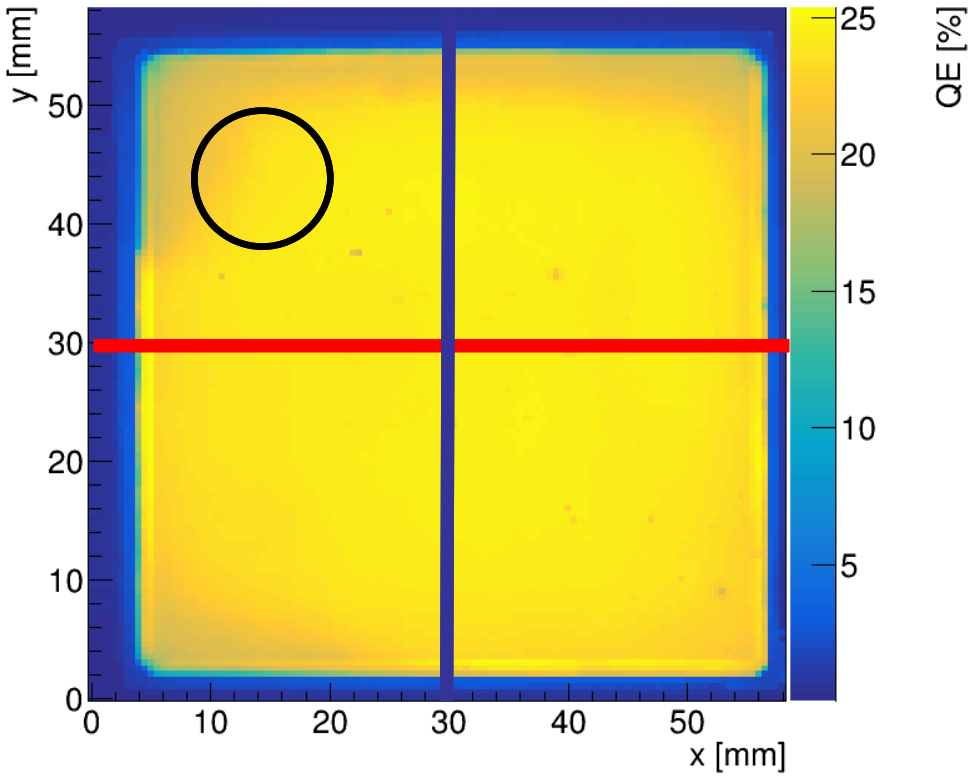


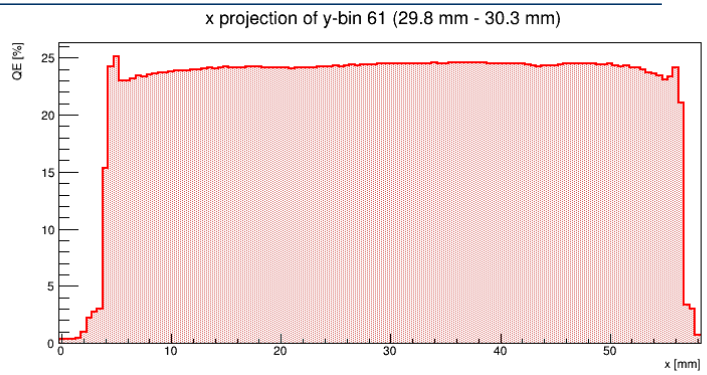


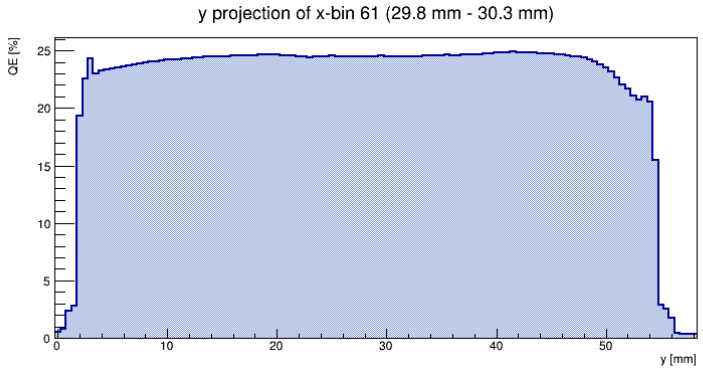


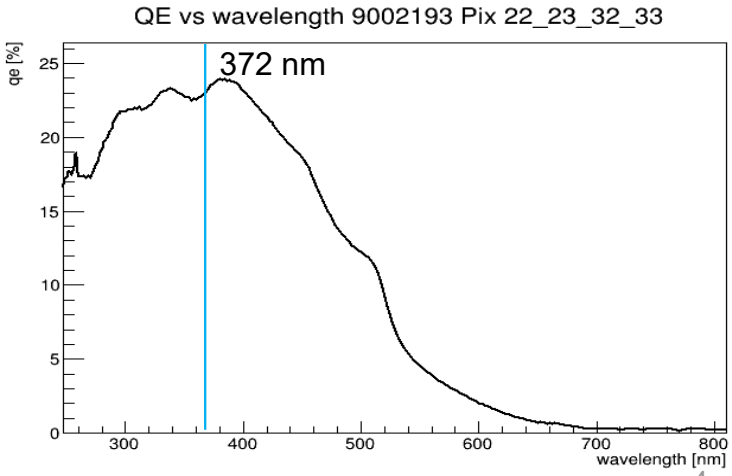
- Photonis datasheet: Peak QE (300 – 400 nm): 23.2 %
- overall QE about 21 – 22 %, except small areas at the corners top left, bottom left and bottom right to 12 – 14 % QE
- wavelength QE in important area over 20 %, fits with Photonis datasheet, own measurements a bit lower (~ 1% absolute)

Quantum efficiency Photonis 9002193





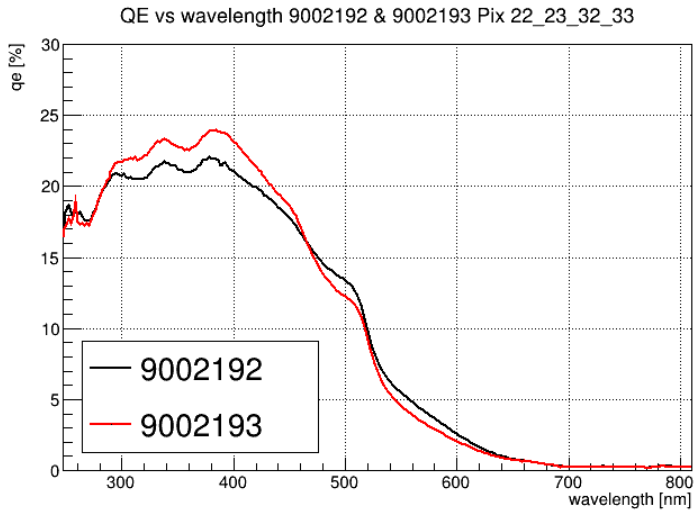




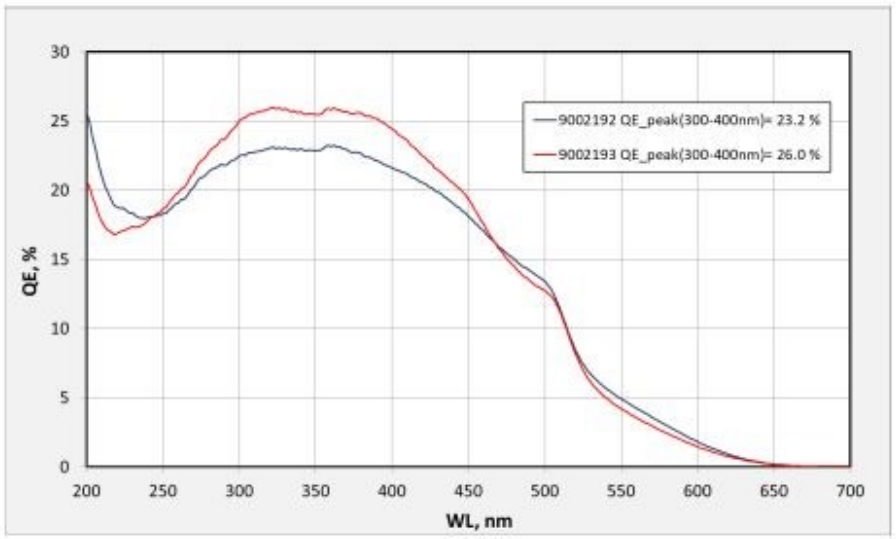
- Photonis datasheet: Peak QE (300 – 400 nm): 26 %
- overall QE about 23 – 24 %, except small areas at the corners top left, bottom left and top right to 19 – 20 % QE
- wavelength QE in important area over 20 %, fits with Photonis datasheet, own measurements a bit lower (~ 2 % absolute)

Compared wavelength QE with Photonis datasheet

own measurements

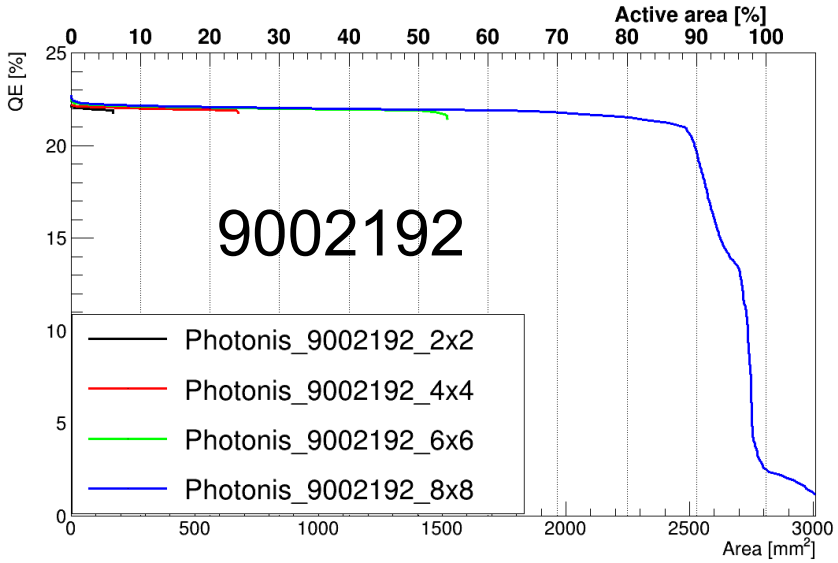


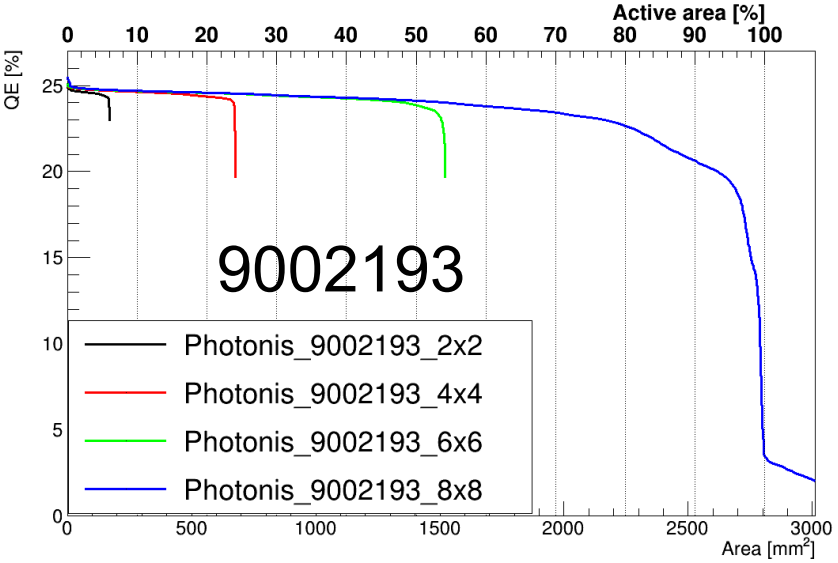
Photonis datasheet

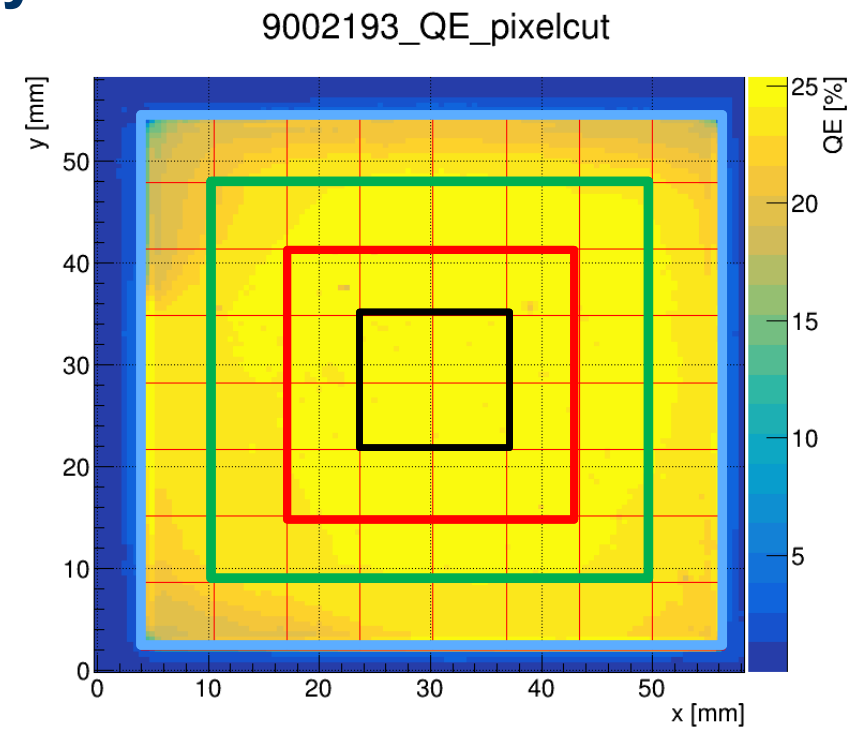


Photonis illumination: 2mm spot
Erlangen: 4 pixel (8 mm spot)

QE homogeneity compared by active area

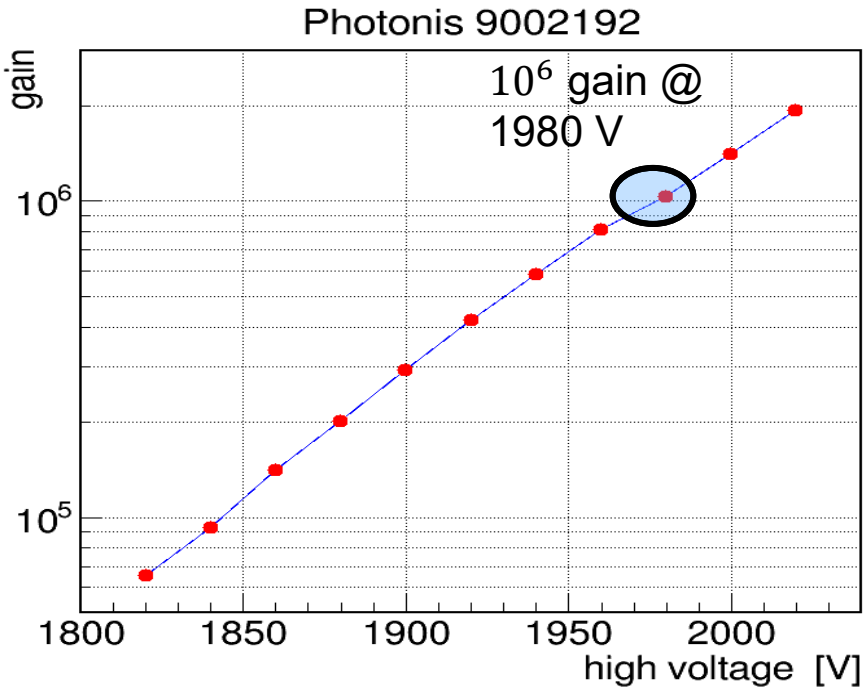


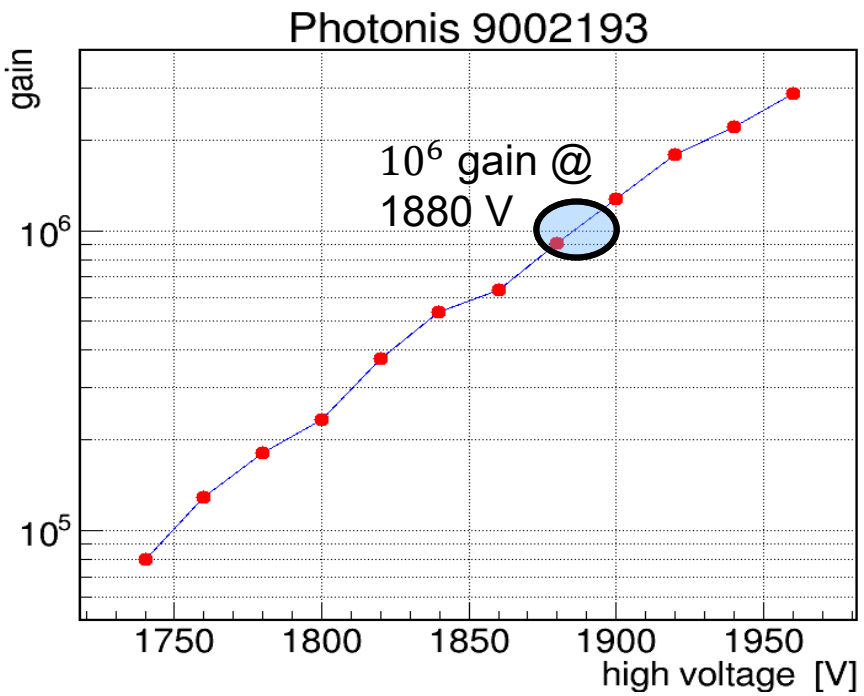




- plotted QE distribution for different sensor areas (2x2, 4x4, 6x6 pixels and whole area)
- both tubes show very good homogeneity up to 6x6 pixel area
- rapid decrease at the end of QE for 2193 due to analysis or defect bins (maybe caused by dust particles at the sensor while measurement)

Gain curves Photonis 9002192 & 9002193 for pixel x5 y5



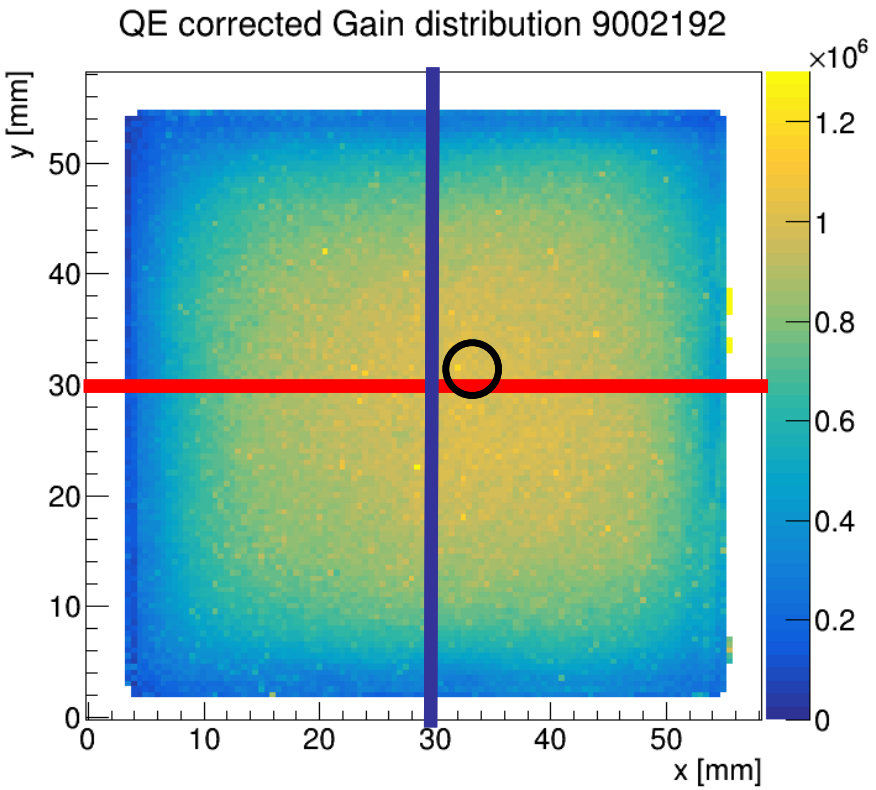


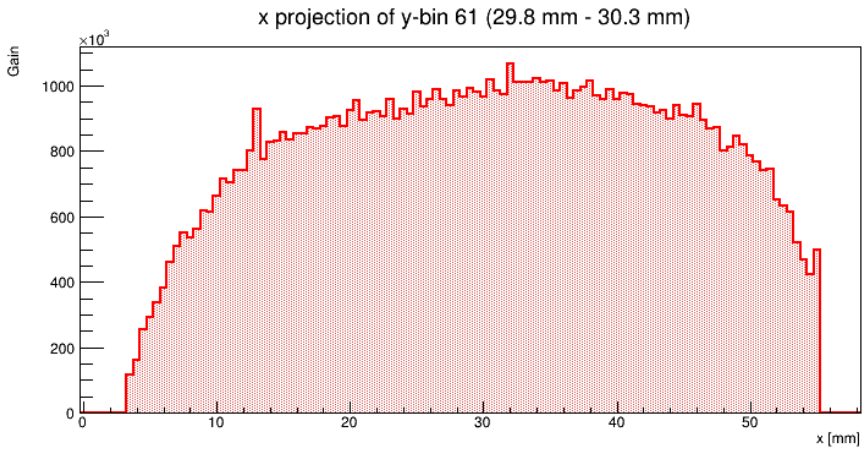
- measuring gain by 20 V steps with scope by fitting a poisson distributionon the whole signal height distribution
- measured at a center pixel (x5 y5)

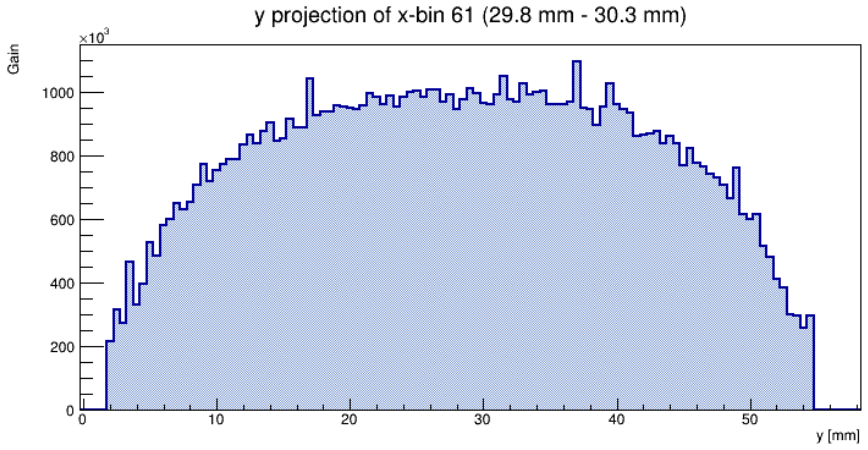
- datasheet: 10^6 gain @ 1980 V
- measured: 10^6 gain @ 1980 V
- maximum operating voltage: 2200 V

- datasheet: 10^6 gain @ 1850 V
- measured: 10^6 gain @ 1880 V
- maximum operating voltage: 2200 V

QE corrected Gain distribution Photonis 9002192

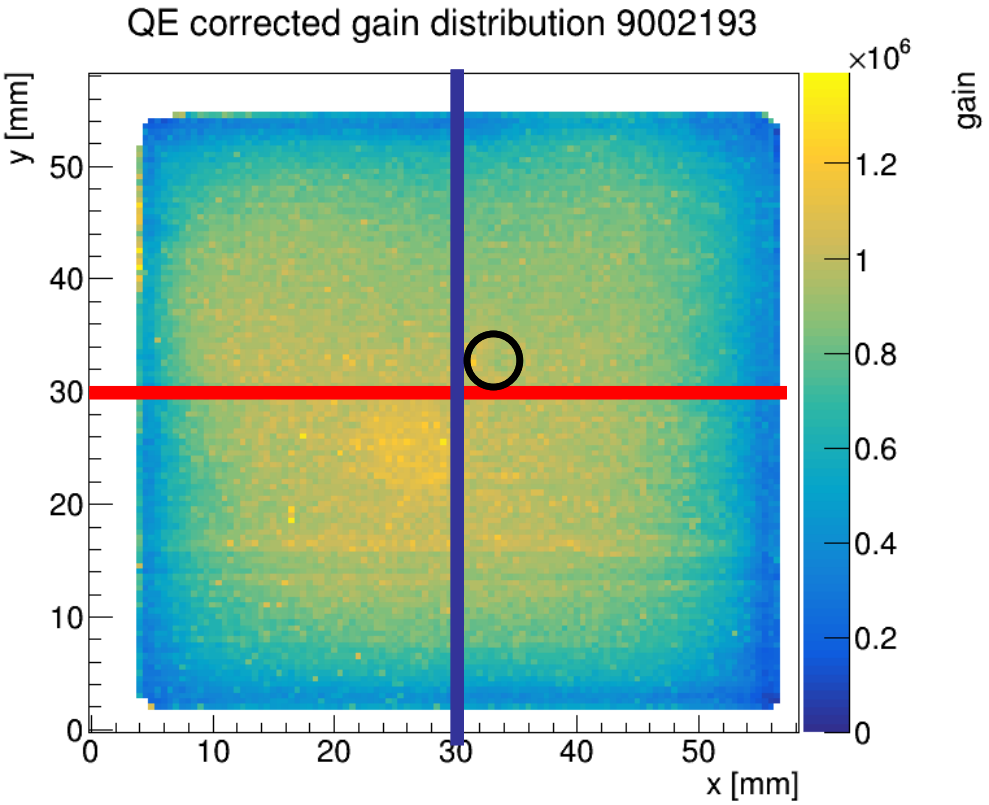


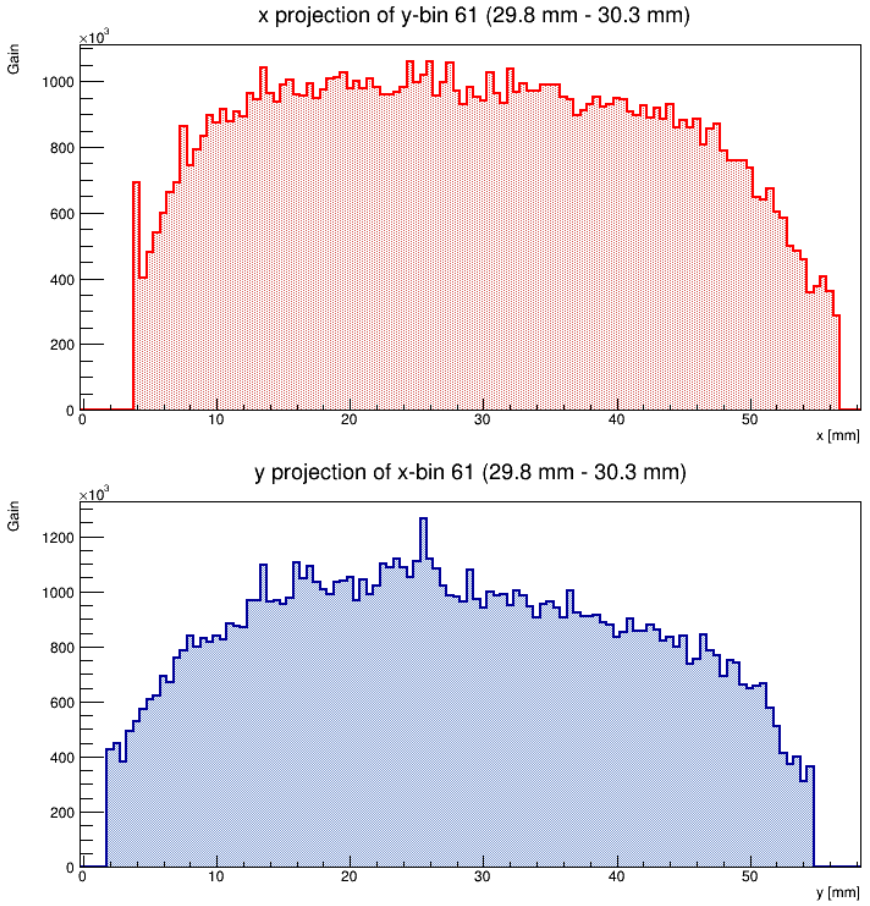




- Applied voltage: 1970 V
- reference position for scaling: x: 33 mm, y: 31 mm (black circle)
- maximum: 1.1×10^6 in the middle area
- towards edges gain drops to ~ 3×10^5

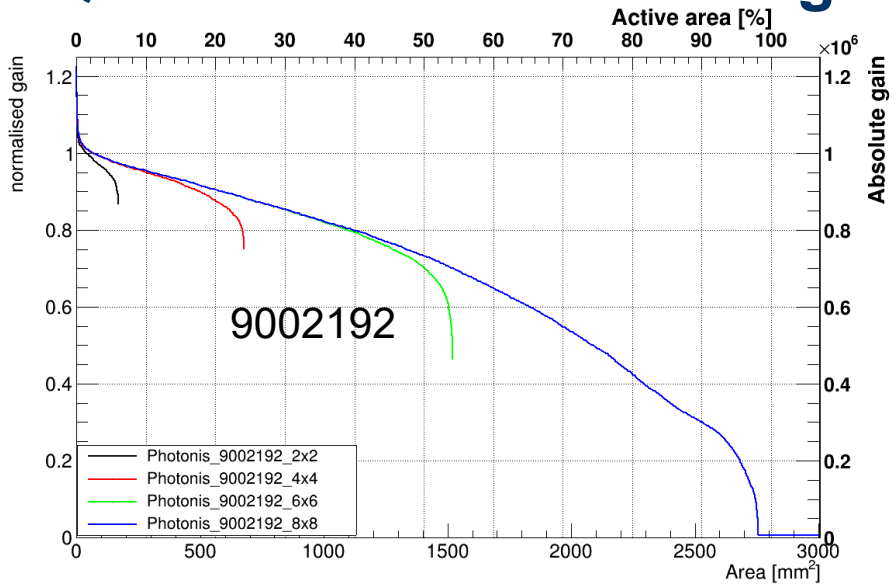
QE corrected Gain distribution Photonis 9002193

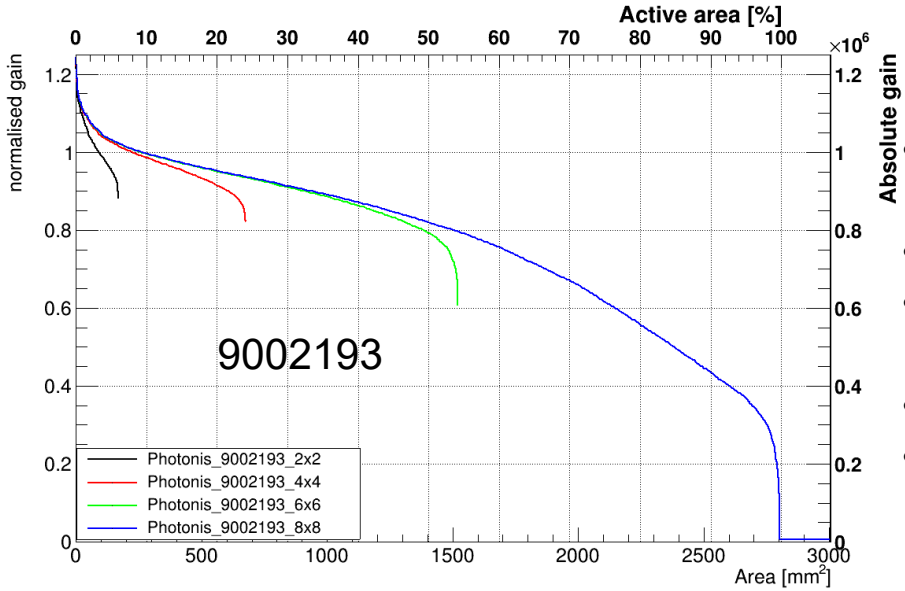


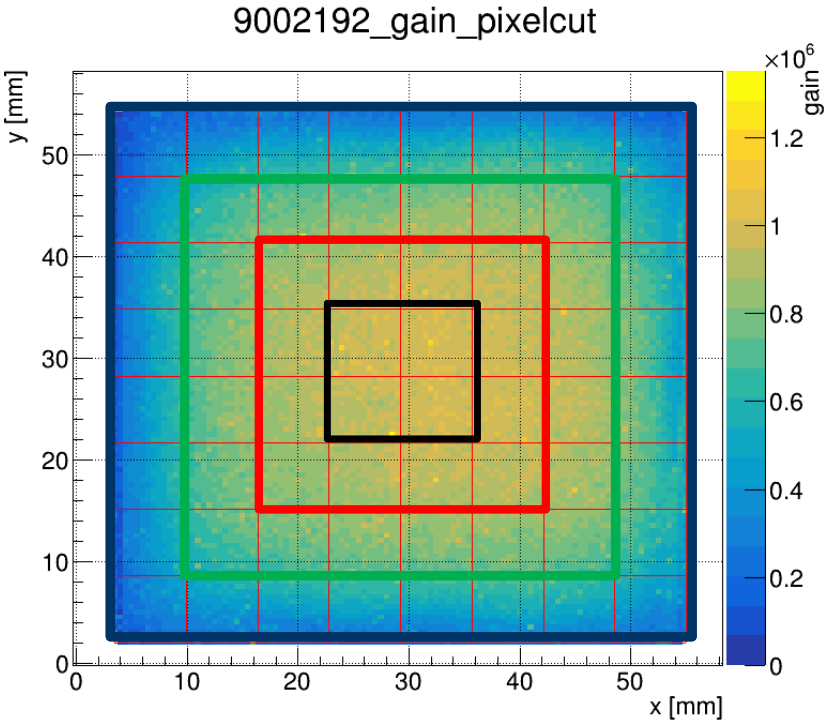


- Applied voltage: 1880 V
- reference position for scaling: x: 33 mm, y: 31 mm (black circle)
- maximum: 1.1×10^6 in the middle area
- towards edges gain drops to ~ 4×10^5

QE corrected Gain homogeneity compared by active area

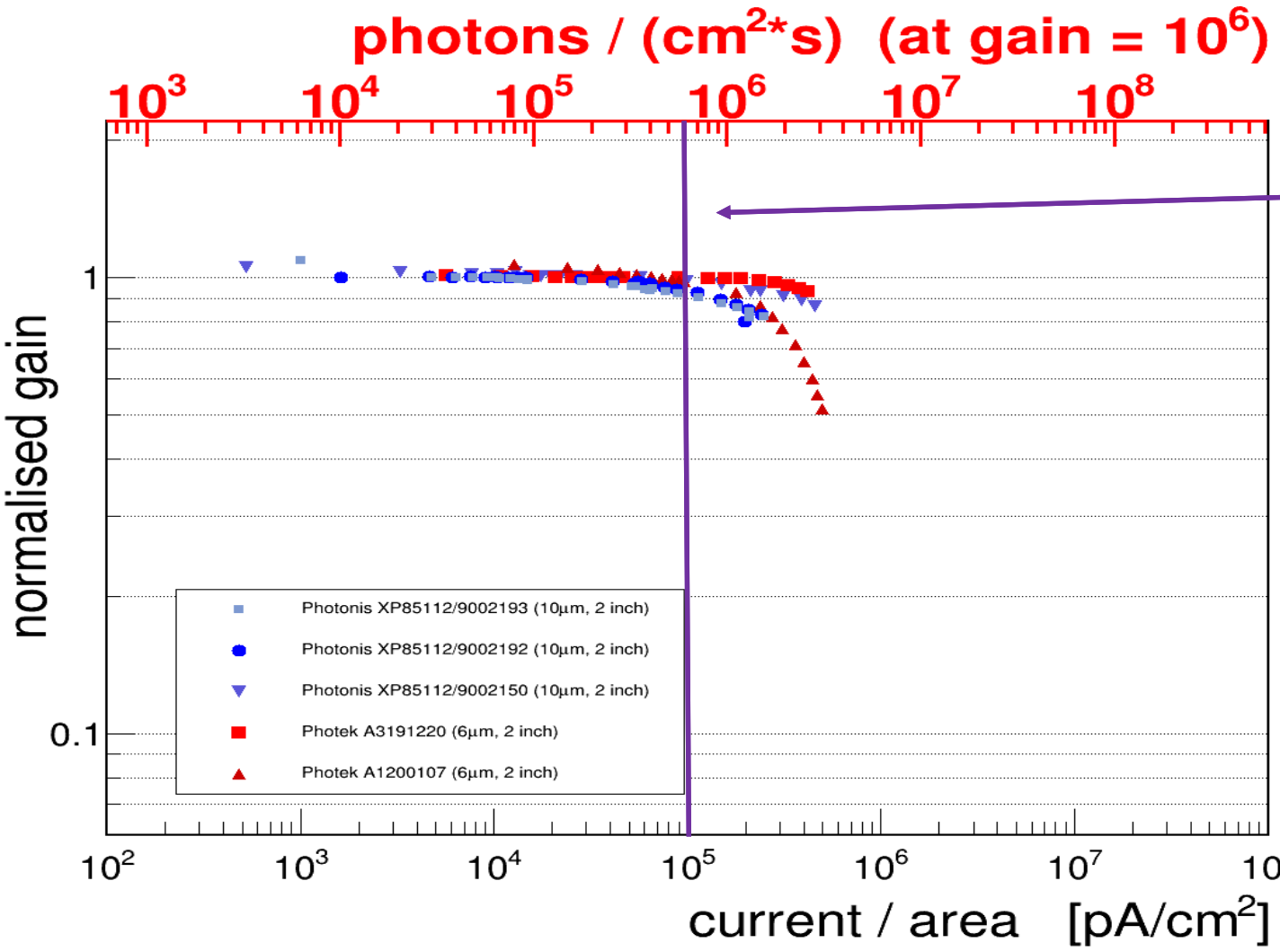






- plotted gain distribution for different sensor areas (2x2, 4x4, 6x6 pixels and whole area)
- x axis: top → active area [%], bottom → area[mm]
- y axis: left → normalised gain, right → absolute gain
- scaling value: $1 \cdot 10^6$
- both tubes have average gain distribution

Rate stability Photonis 9002192 & 9002193



Barrel DIRC requirement: 600 kHz per cm^2

Photonis 9002192 & 9002193 different voltage divider

- for datasheet voltage divider (0.5 : 5 : 0.5) [MΩ] time resolution increases, so taking measurements with different dividers → changing PC voltage
- for scope time resolution 4 dividers used (0.5 – 2 : 5 : 0.5)
- for DiRICH measurement two divider (0.5 : 5 : 0.5 & 2 : 5 : 0.5) and threshold of about 25% of single photon peak (~ 2 - 3 mV), same threshold for both configurations, so 2 : 5 : 0.5 threshold may be a bit lower due to higher signals

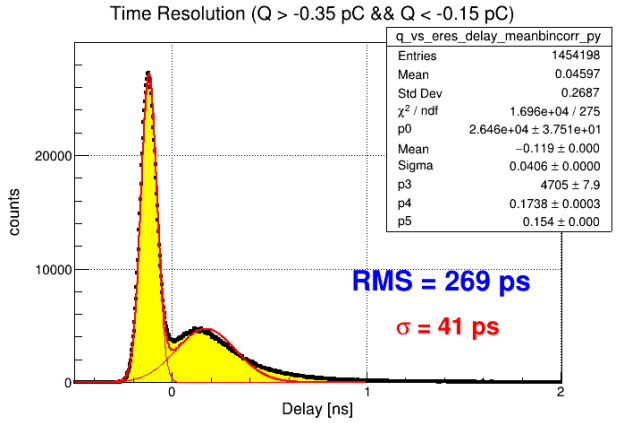
9002192

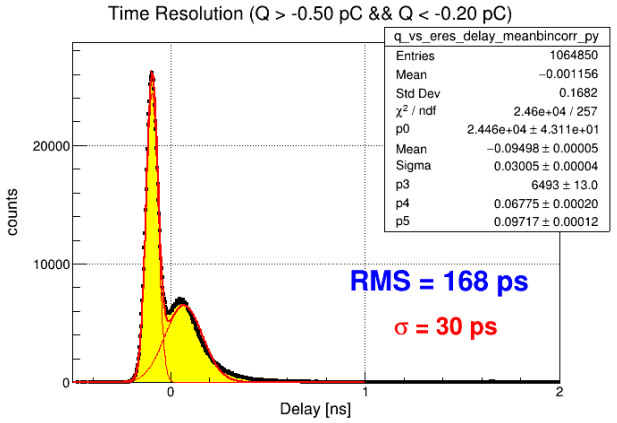
Divider [MΩ]	voltage (PC-MCP) [V]	used gain
0.5 : 5 : 0.5	182	$9.5 \cdot 10^5$
1 : 5 : 0.5	364	$1.5 \cdot 10^6$
1.5 : 5 : 0.5	547	$1.5 \cdot 10^6$
2 : 5 : 0.5	729	$1.45 \cdot 10^6$

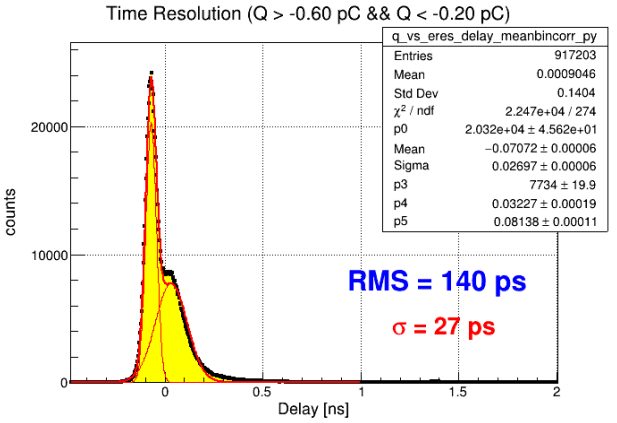
9002193

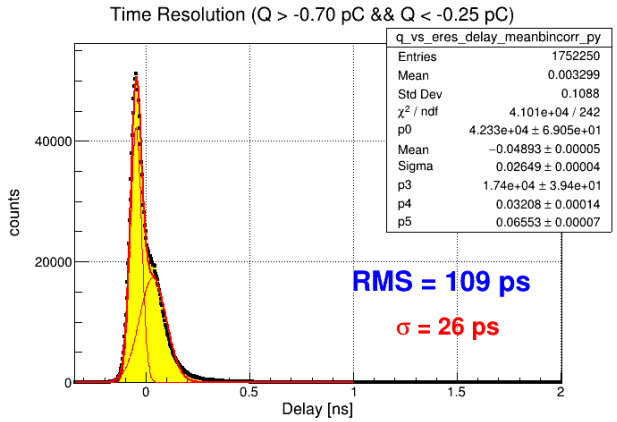
Divider [MΩ]	voltage (PC-MCP) [V]	used gain
0.5 : 5 : 0.5	173	$9.3 \cdot 10^5$
1 : 5 : 0.5	346	$1.5 \cdot 10^6$
1.5 : 5 : 0.5	519	$1.65 \cdot 10^6$
2 : 5 : 0.5	692	$1.4 \cdot 10^6$

Time resolution Photonis 9002192, pixel x5 y5 (scope)





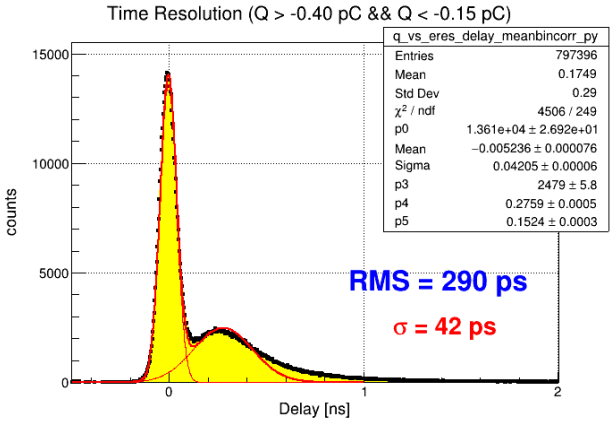


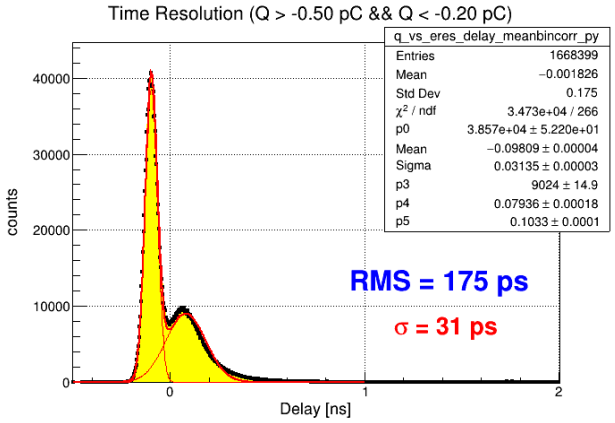


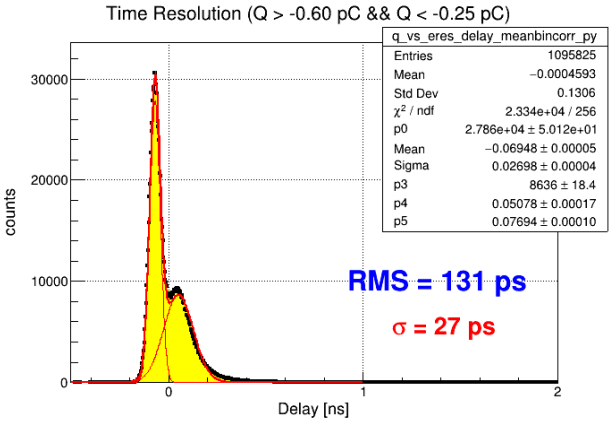
Divider [MΩ]	PC - MCP [V]	σ [ps]	RMS [ps]	$T_{signal} - T_{recoil}$ [ps]
0.5 : 5 : 0.5	182	41	269	293
1 : 5 : 0.5	364	30	168	163
1.5 : 5 : 0.5	547	27	140	104
2 : 5 : 0.5	729	26	109	81

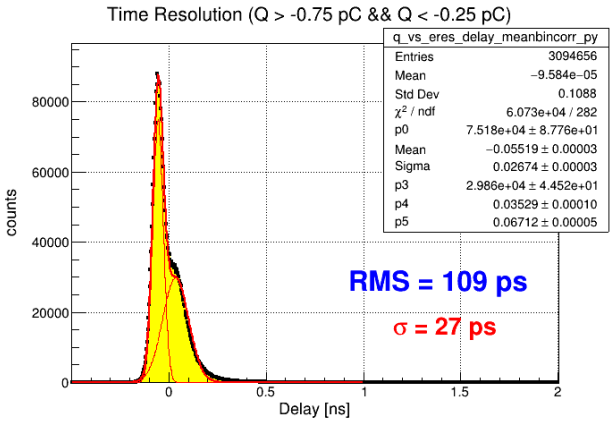
- RMS time resolution displayed for -0.5 ns to 2 ns range
- increasing of PC voltage improves RMS of a factor up to 2.4

Time resolution Photonis 9002193, pixel x5 y5 (scope)









Divider [MΩ]	PC - MCP [V]	σ [ps]	RMS [ps]	$T_{signal} - T_{recoil}$ [ps]
0.5 : 5 : 0.5	173	42	290	281
1 : 5 : 0.5	346	31	175	168
1.5 : 5 : 0.5	519	27	131	120
2 : 5 : 0.5	692	27	109	90

- RMS time resolution displayed for -0.5 ns to 2 ns range
- increasing of PC voltage improves RMS of a factor up to 2.6

➢ Both tubes: with increasing PC voltage recoil peak moves into main signal peak → better RMS & σ

Compared timeresolution with Photonis measurements

PC - MCP [V]	σ [ps]	RMS 1ns	RMS 2ns
182	41	225	269
364	30	131	168
547	27	105	140
729	26	84	109

9002192, measured data, 9002193

PC - MCP [V]	σ [ps]	RMS 1ns	RMS 2ns
173	42	237	290
346	31	143	175
519	27	103	131
692	27	85	109

PK, V	Peak Time Resolution (σ), ps	RMS (<1ns), ps	RMS (<2ns), ps
200	34	199	265
400	29	118	178
600	28	90	123
800	25	75	100

Photonis measurements

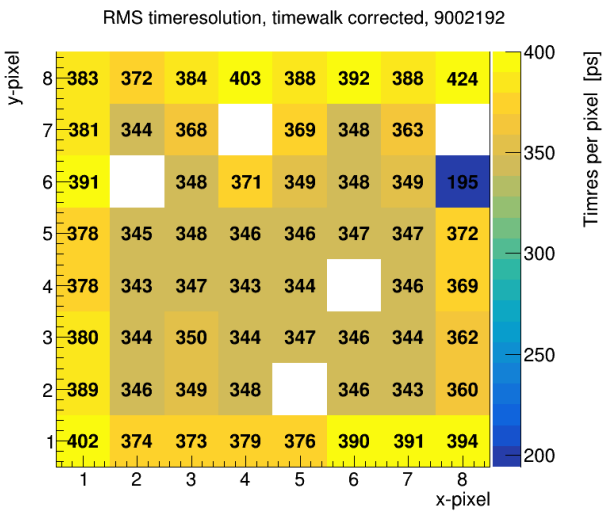
PK, V	Peak Time Resolution (σ), ps	RMS (<1ns), ps	RMS (<2ns), ps
200	40	207	264
400	25	125	180
800	25	76	96

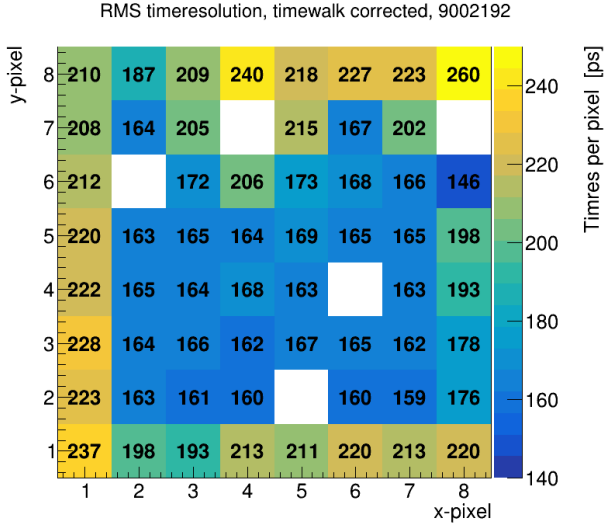
Photonis 9002192 & 9002193 RMS resolution (DiRICH)

0.5 : 5 : 0.5 divider

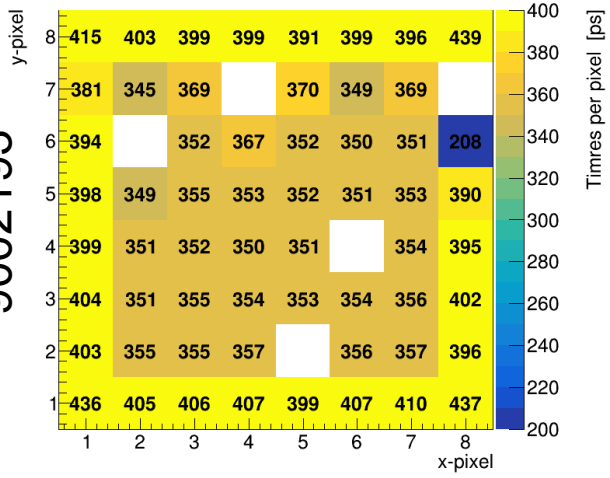
2 : 5 : 0.5 divider

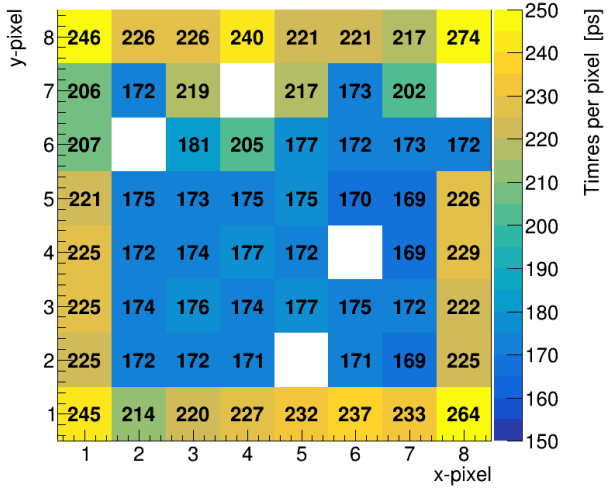
9002192





9002193



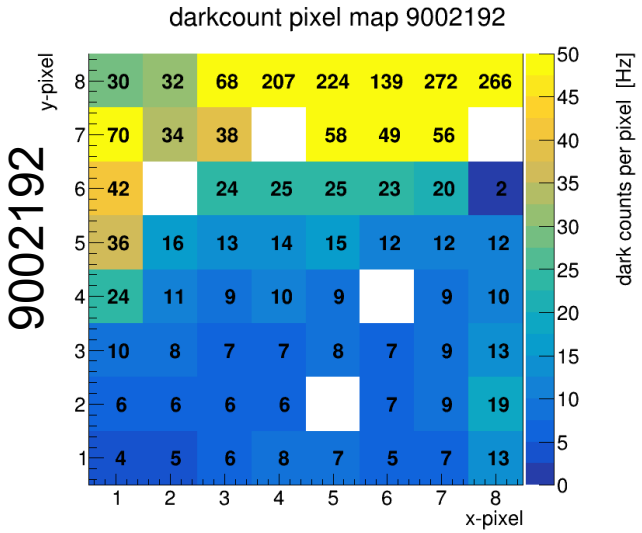


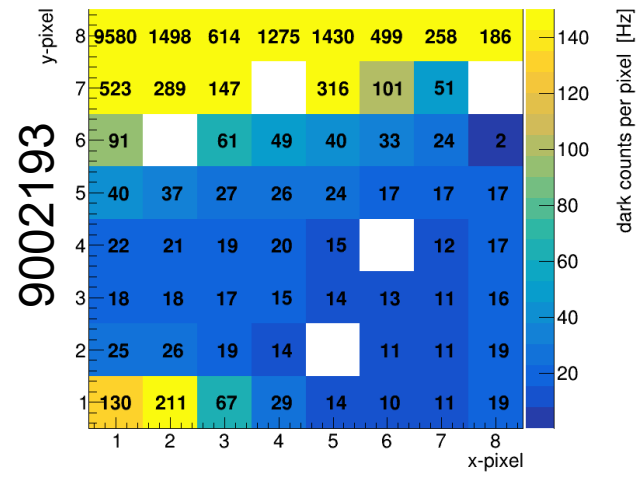
- after taking the DiRICH time resolution (~ 90 ps) into account → comparable results of RMS resolutions
- goal → better DiRICH resolution of 20 – 30 ps (more information → ask Merlin)

- mean of inner 6x6 pixels:
  - 0.5 : 5 : 0.5, 9002192:
  - ➢ **349 ps**
  - 2 : 5 : 0.5, 9002192:
  - ➢ **170 ps**
  - 0.5 : 5 : 0.5, 9002193:
  - ➢ **355 ps**
  - 2 : 5 : 0.5, 9002192:
  - ➢ **178 ps**

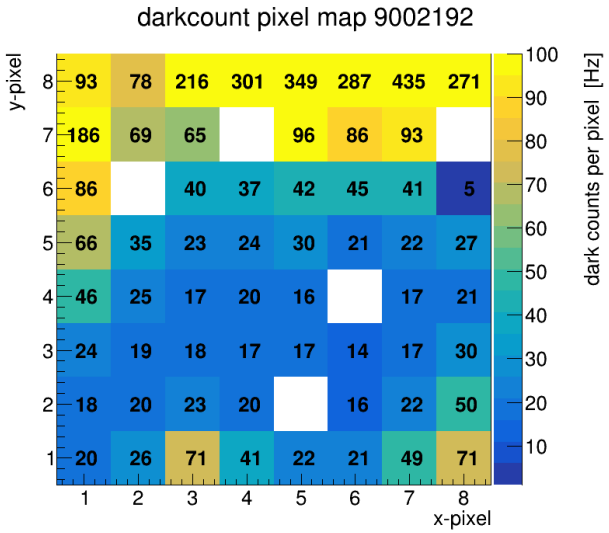
Photonis 9002192 & 9002193 darkcount distribution (DiRICH)

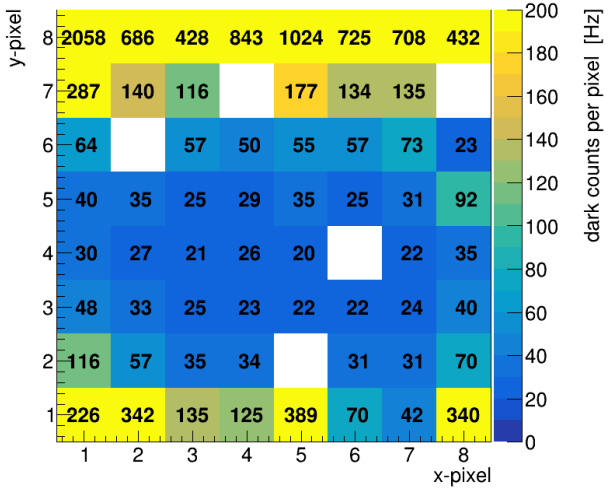
0.5 : 5 : 0.5 divider





2 : 5 : 0.5 divider





- mean of inner 6x6 pixels (per pixel):
  - 0.5 : 5 : 0.5, 9002192:
  - ➢ **17 Hz**
  - 2 : 5 : 0.5, 9002192:
  - ➢ **33 Hz**
  - 0.5 : 5 : 0.5, 9002193:
  - ➢ **47 Hz**
  - 2 : 5 : 0.5, 9002192:
  - ➢ **51 Hz**

- top pixel row higher darkcount rate than rest of tube

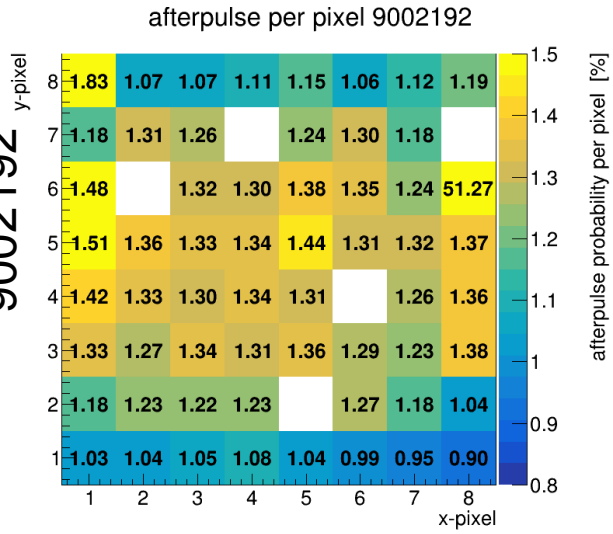
➢ not clear, if property of tube or caused by measurement environment

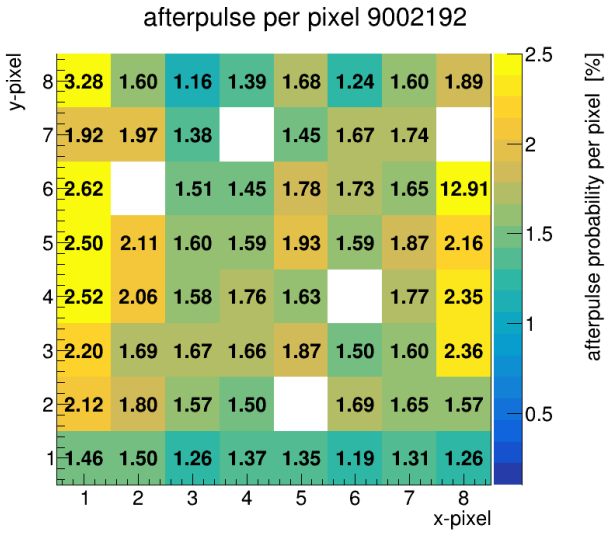
Photonis 9002192 & 9002193 afterpulsing (DiRICH)

0.5 : 5 : 0.5 divider

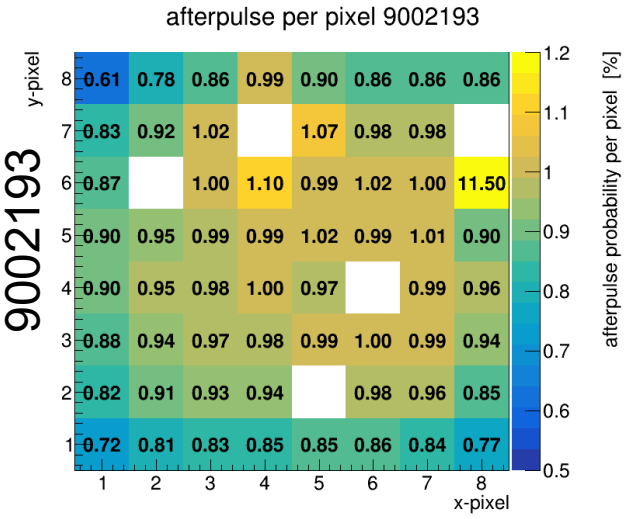
2 : 5 : 0.5 divider

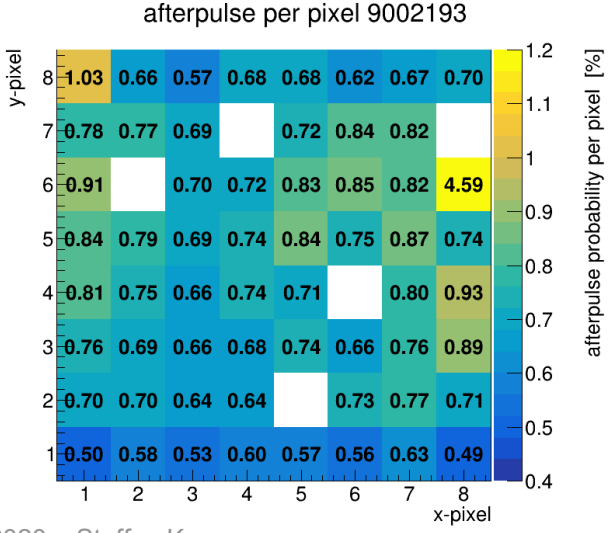
9002192





9002193

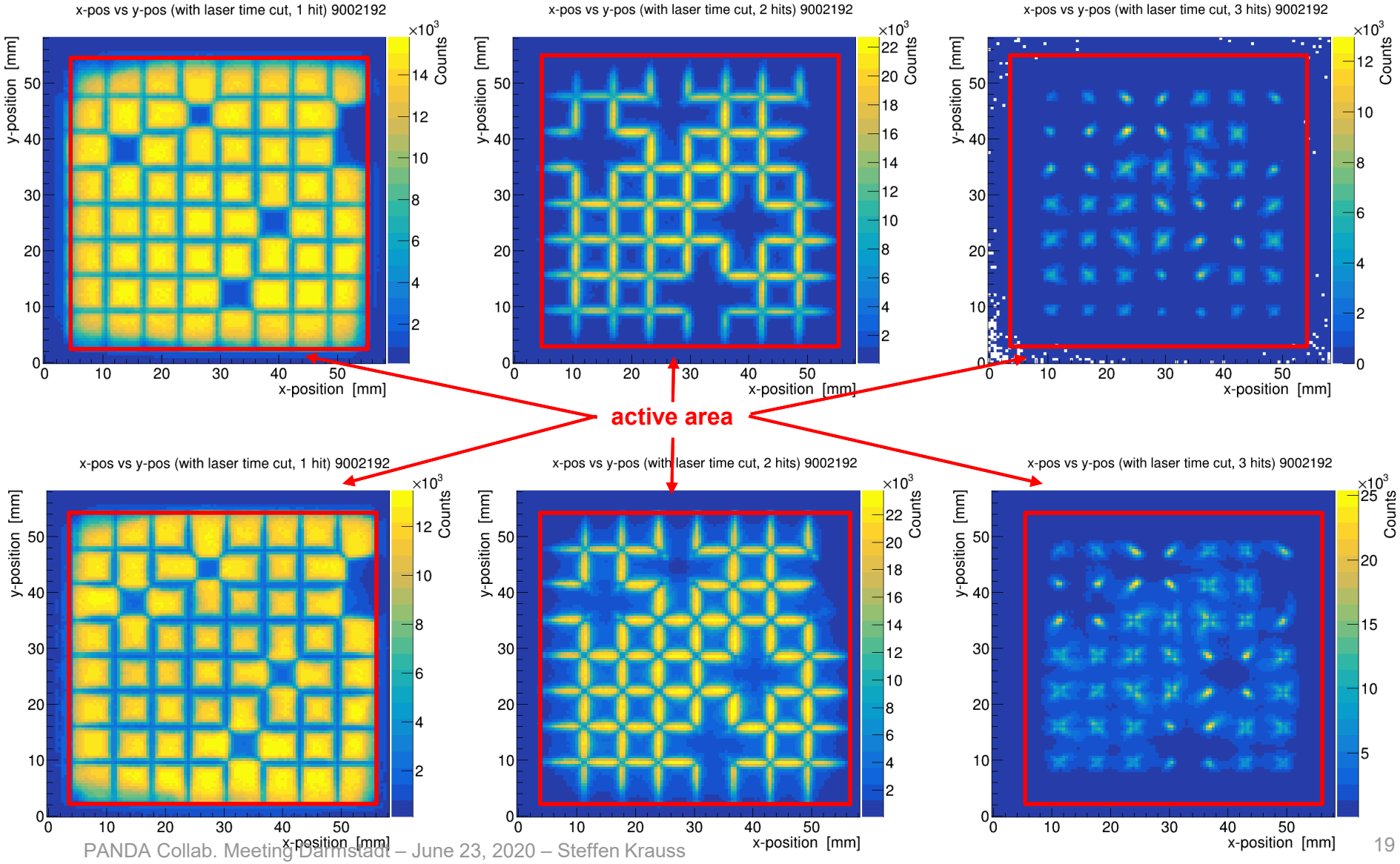




- darkcount corrected afterpulse probability in range of 5 – 500 ns after main peak
- mean of inner 6x6 pixels (per pixel):
  - 0.5 : 5 : 0.5, 9002192:
  - ➢ **1.3 %**
  - 2 : 5 : 0.5, 9002192:
  - ➢ **1.69 %**
  - 0.5 : 5 : 0.5, 9002193:
  - ➢ **0.99 %**
  - 2 : 5 : 0.5, 9002192:
  - ➢ **0.74 %**
- afterpulse probability decreases by using higher PC-MCP voltage

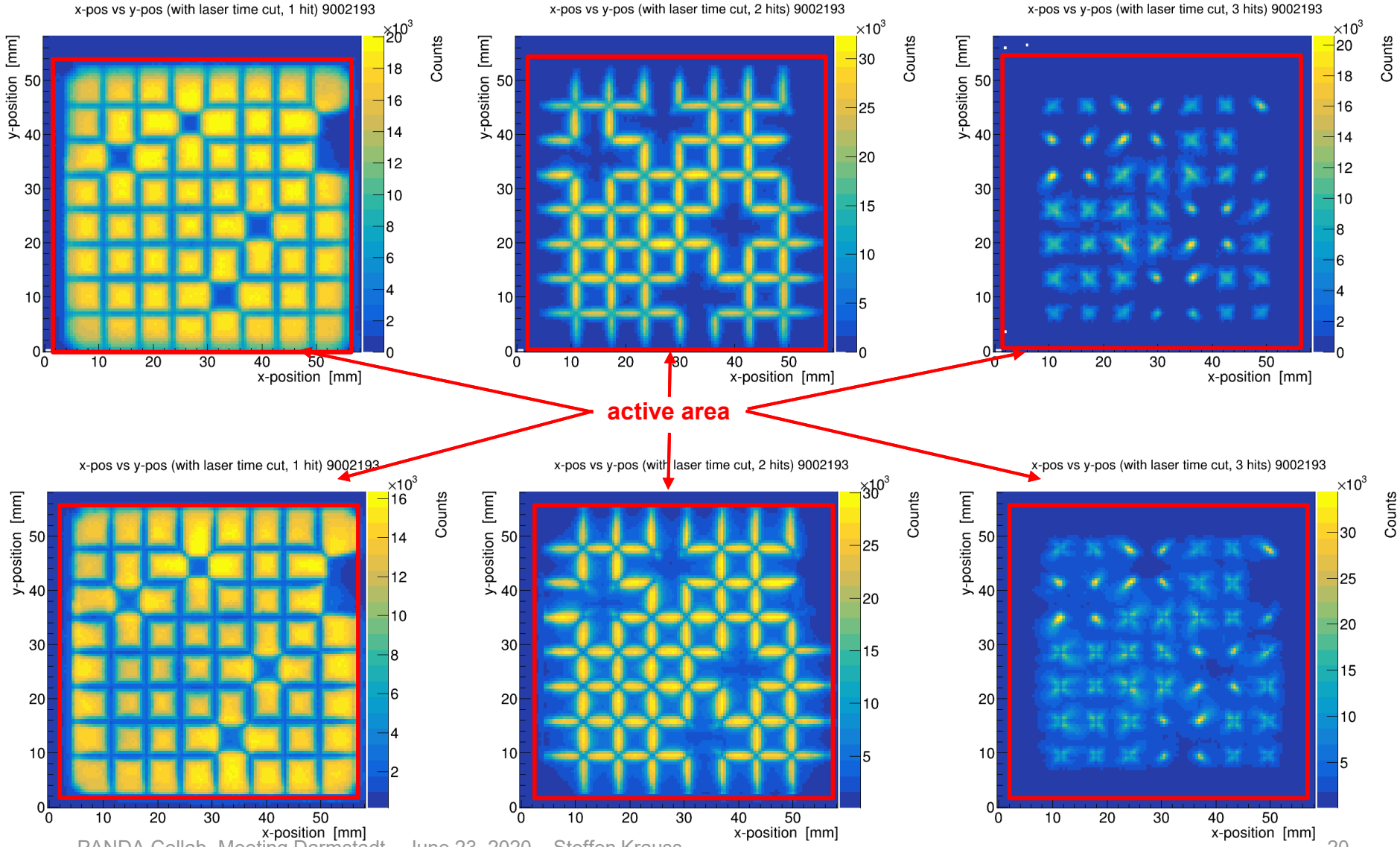
- top row: 0.5 : 5 : 0.5
- bottom row: 2 : 5 : 0.5

Photonis 9002192 crosstalk behaviour (DiRICH)



- top row: 0.5 : 5 : 0.5
- bottom row: 2 : 5 : 0.5

Photonis 9002193 crosstalk behaviour (DiRICH)



Summary

- spatial QE distributions are homogeneous over almost whole active area (~ ± 0.5 %), except corners
- gain distribution average and comparable with previous Photonis tubes
- 10^6 gain everywhere reachable, 10^6 gain voltage ~ 200 V (2192), 300 V (2193) below maximum appliable voltage → gain of up to 10^7 (in maximum area) seems to be reachable
- rate stability: both tubes reach Barrel DIRC requirement but not for EDD
- required time resolution with PC voltage modification easily reachable
- darkcount rate, afterpulse probabilities and crosstalk behaviours are moderate and viable for the PANDA-DIRCs

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Summary

- missing measurements:
  - all tubes: magnetic field, collection efficiency
  - Photonis: oscillation measurements, lifetime (will start after missing measurements, except magnetic field)
  - Photek A1200116 (not official one): rate stability, oscillation measurements wavelength QE
- due to corona pandemic, physics department was in lockdown between 18th of March until end of May → no measurements were taken
- after, reduced working possible (one person per office/laboratory), but still many restrictions
- not cleared when magnetic field measurements will take place, due to forbidden FAU business travels for an indefinite period

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