

Results of QA Measurements of MCP-PMTs 9002225 – 9002231

ERLANGEN CENTRE
FOR ASTROPARTICLE
PHYSICS

ecap

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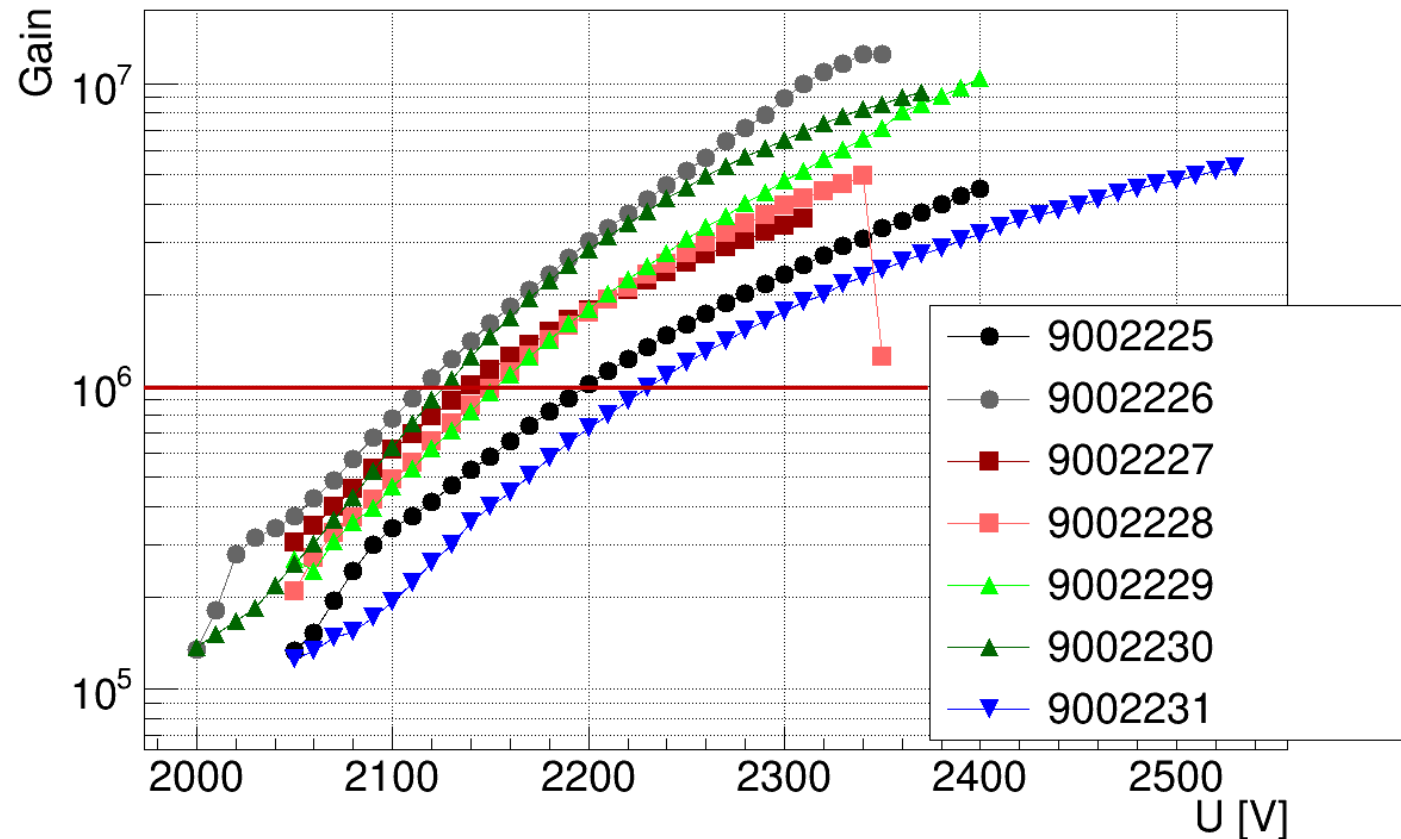
PANDA Meeting, March 9th, 2023



Gain vs voltage

- Measurements with 4:10:1 voltage divider
- Gain of 10^6 safely reached by all tubes, for some even $> 10^7$
- Escalation still occurring at high gains

Sensor	MCP-resistance at 0V [MΩ]
9002225	16
9002226	20
9002227	53
9002228	59
9002229	20
9002230	64
9002231	24

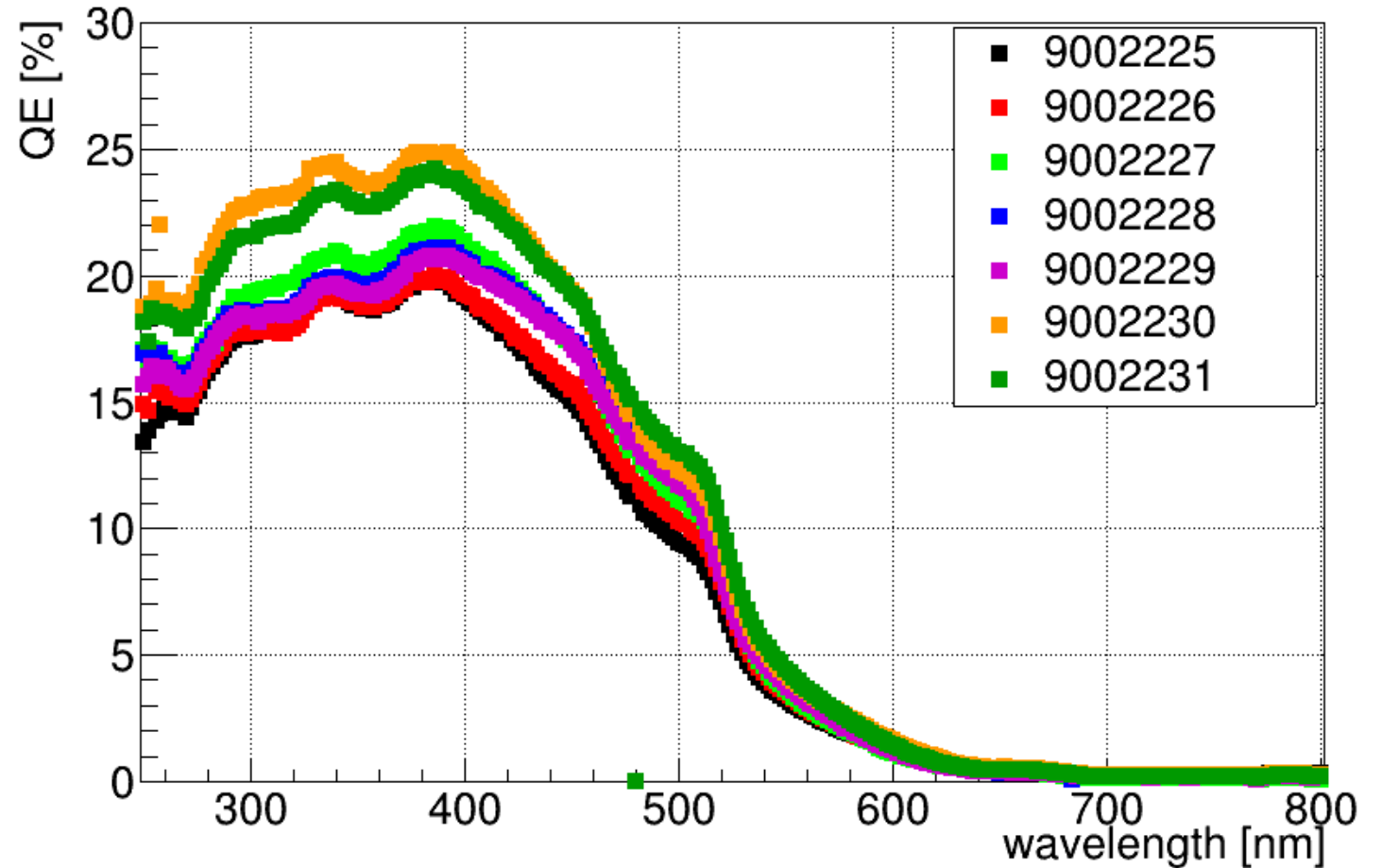


In the beginning problems measuring resistance of 9002227
 → loose connection?
 Moving cables → no effect → not reproducible

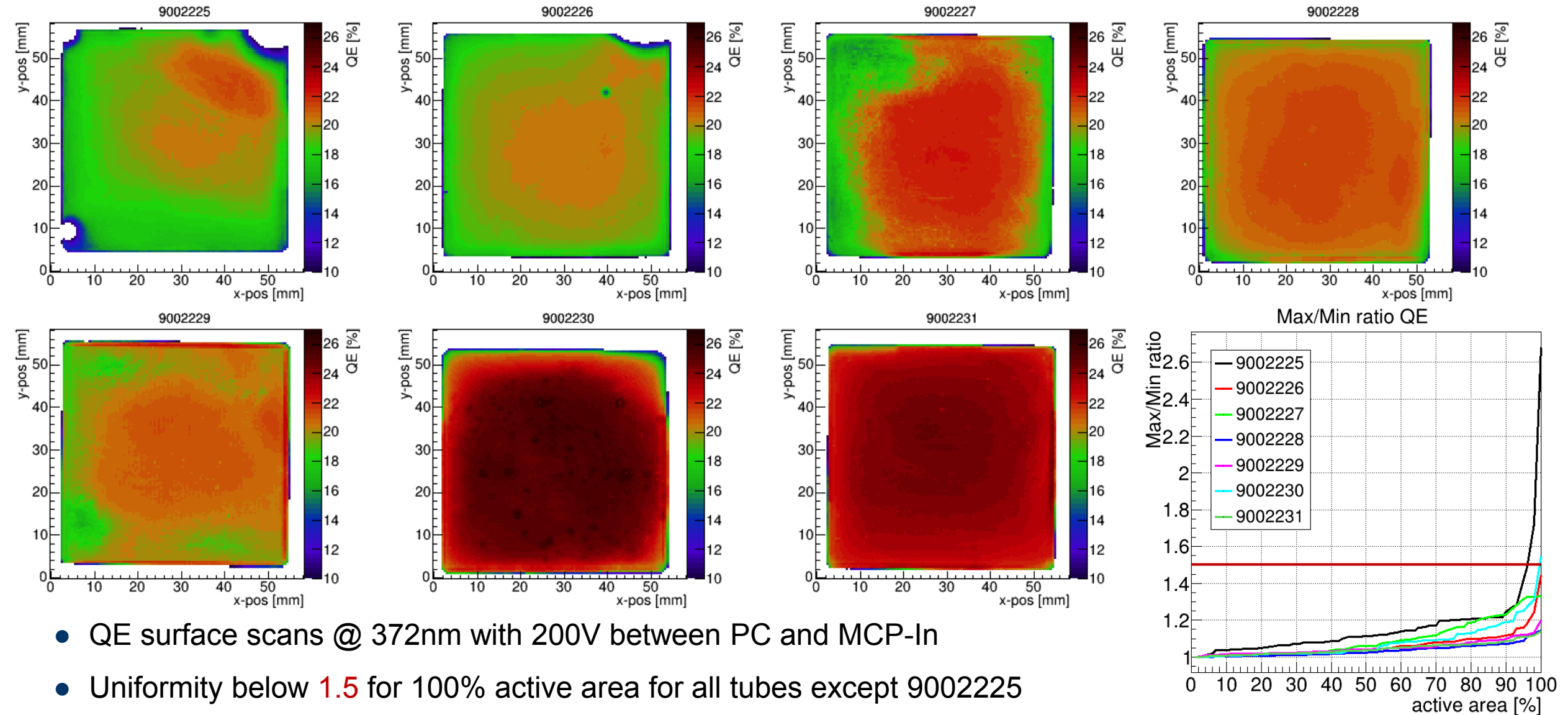
QE vs wavelength

- QE vs wavelength @ central PC position (x4 y5, ~5 mm spot)
- Peak QE of ~20% at ~390 nm
- 9002230 and 9002231 a little higher QE

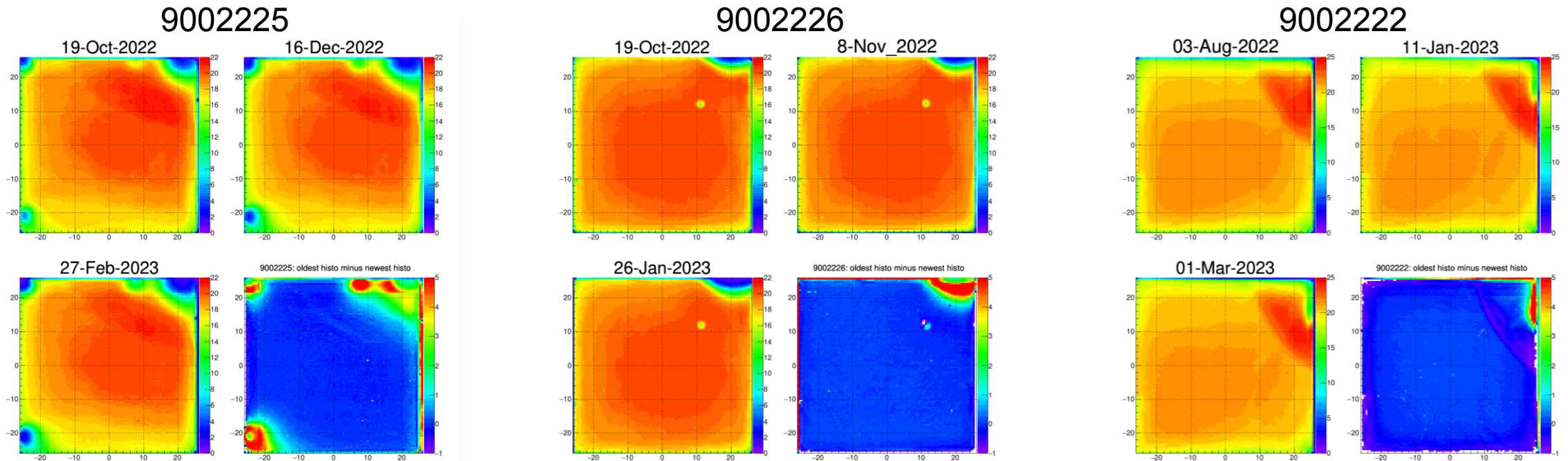
Sensor	Peak QE [%]
9002225	19.9
9002226	20.0
9002227	21.5
9002228	21.1
9002229	20.8
9002230	24.9
9002231	24.2



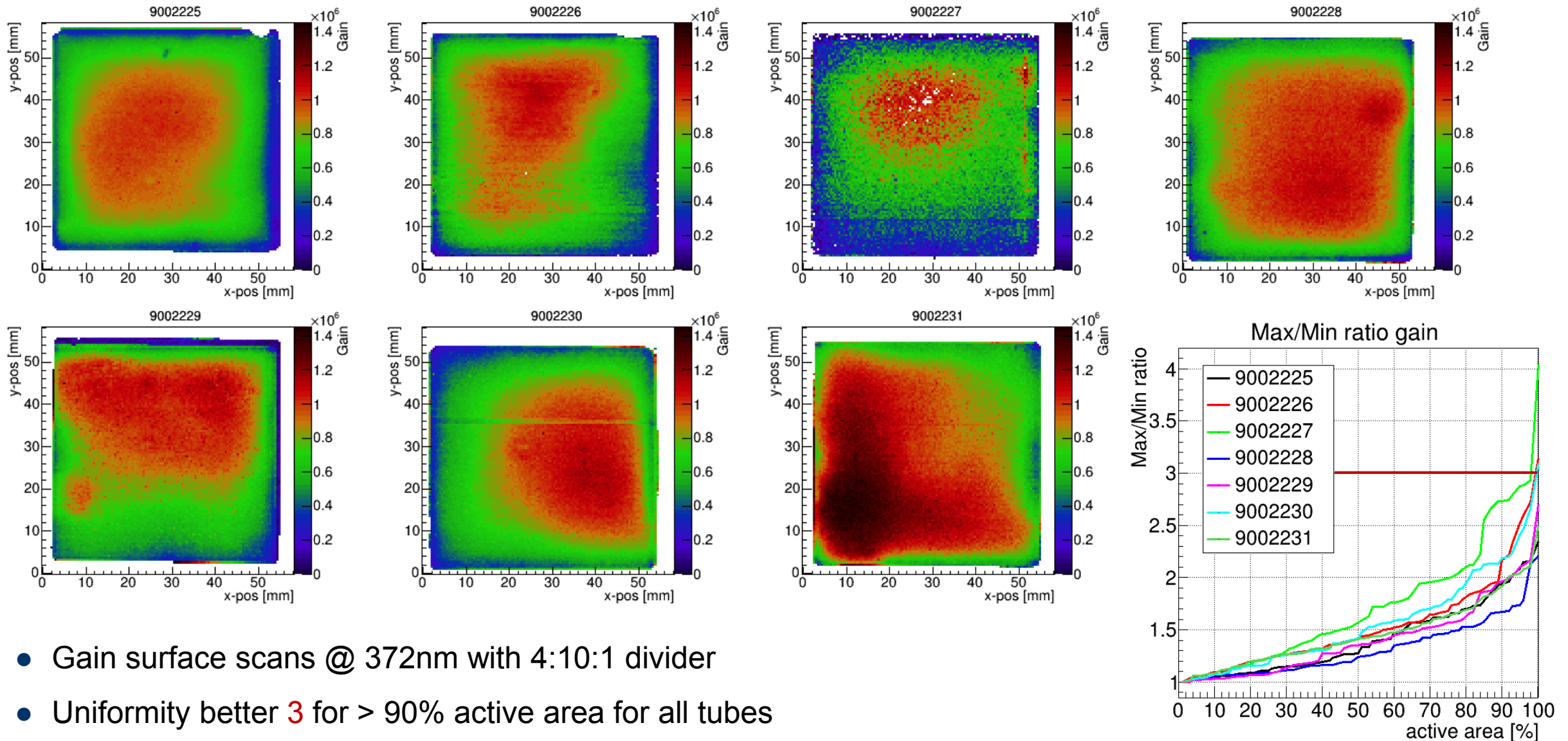
QE uniformity



- QE scans of 9002222, 9002225 and 9002226 at different times
- 9002225 and 9002226 had bad spots from the beginning
- Lower right corner: subtraction of newest to oldest scan \rightarrow bad spots increase
- Reason: imperfect sealing of PMT bodies (according to Photonis: problems with bracing furnace) \rightarrow micro leaks
- 9002225 and 9002226 will be returned to Photonis
- No QE loss observed for later sensors \rightarrow Problem solved



Gain uniformity



- Gain surface scans @ 372nm with 4:10:1 divider
- Uniformity better 3 for > 90% active area for all tubes

	9002225	9002226	9002227	9002228	9002229	9002230	9002231
QE @ 372nm & x4 y5 [%]	20.2	20.4	22.1	21.3	21.1	25.4	24.6
CE [%] (1:10:1)	91.8	90.5	89.5	91.9	93.0	95.1	
CE [%] (4:10:1)			91.4	98.7	98.4	96.3	99.6
DQE [%]	18.5 (1:10:1)	18.5 (1:10:1)	20.2 (4:10:1)	21.0 (4:10:1)	20.8 (4:10:1)	24.5 (4:10:1)	24.5 (4:10:1)

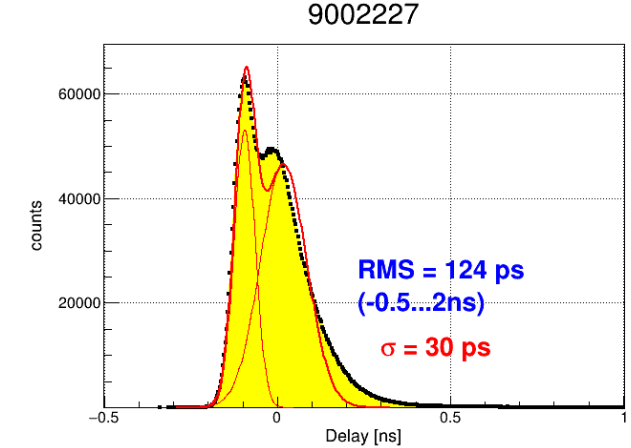
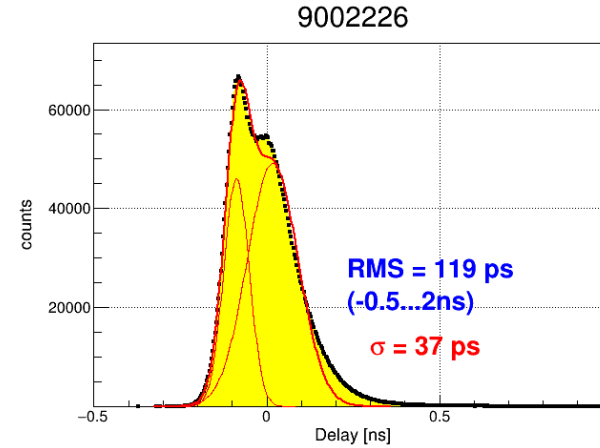
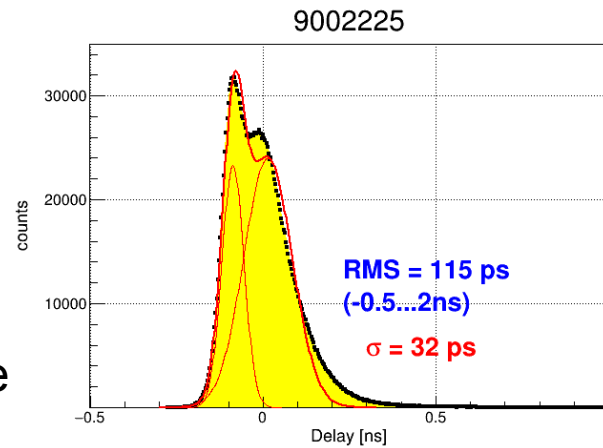
- CE > 90% for all tubes
- CE higher for 4:10:1 divider
- DQE ~20%, highest for 9002230 and 9002231 due to their high QE

Time resolution measured with oscilloscope

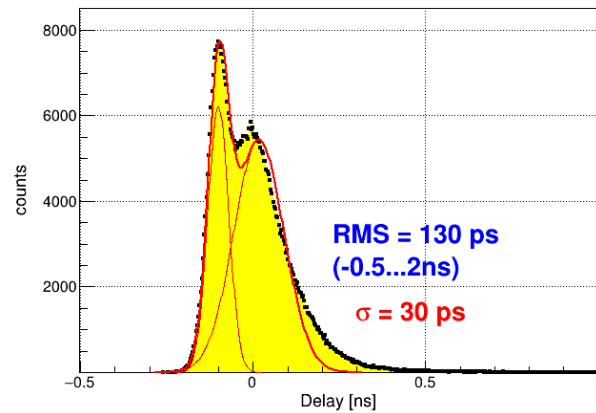


	9002225	9002226	9002227	9002228	9002229	9002230	9002231
RMS [ps] (-0.5...2ns)	115	119	124	130	130	130	120
Sigma [ps]	32	37	30	30	30	29	34

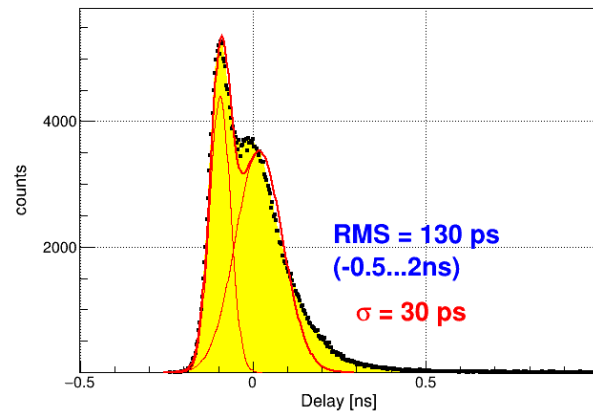
- 4:10:1 divider
- RMS < 130ps
- Sigma ~30ps
- Fits not perfect
- Increased speed of measurement → possible for all sensors



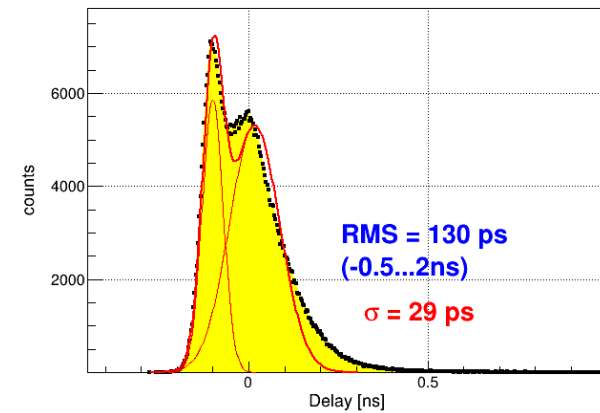
9002228



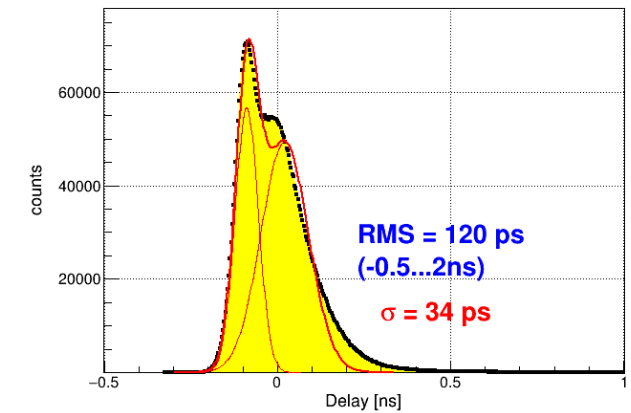
9002229



9002230

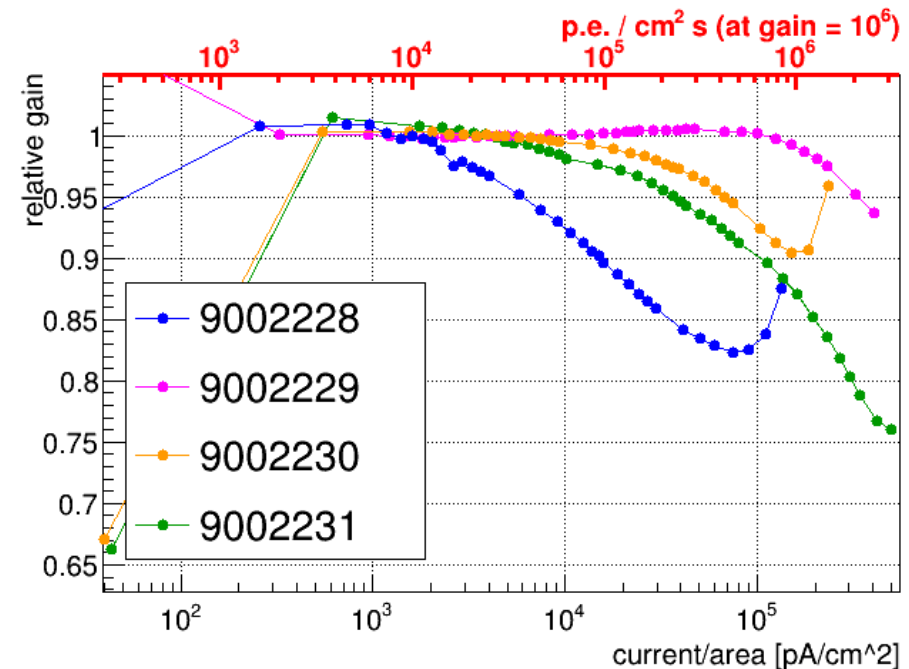
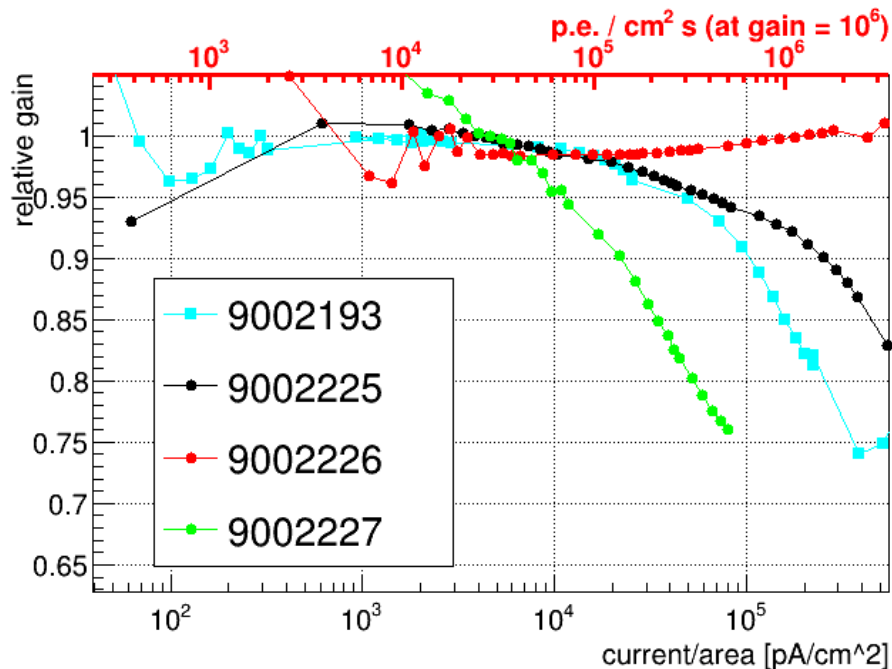


9002231



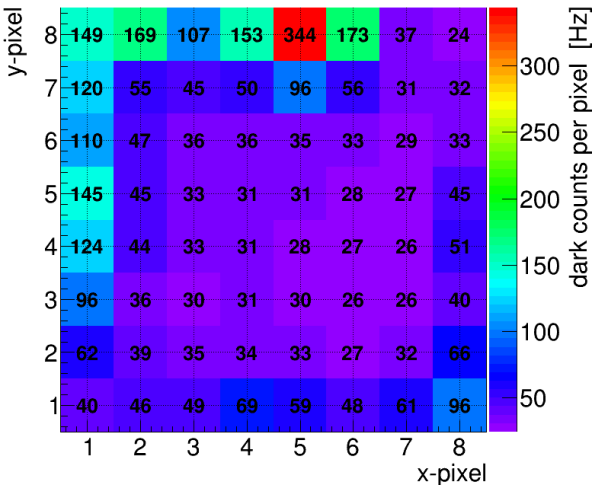
Rate capability in current mode

- Illumination of whole sensor surface, measurement of anode current of all shorted pixels
- 9002225, 9002230, 9002231: similar behaviour to older sensors (9002193)
- 9002226, 9002229: high rate capability
- 9002227, 9002228: decreasing gain from the beginning → poor rate capability
- Very different behaviours → not understood yet
- Increase of gain at high frequencies due to entering the escalation mode

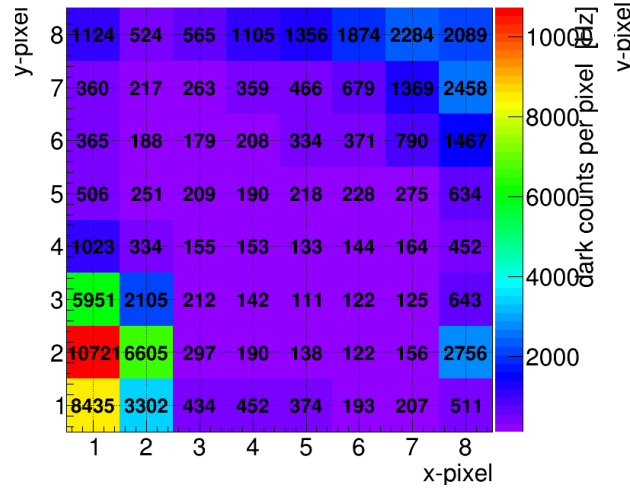


Dark count rates

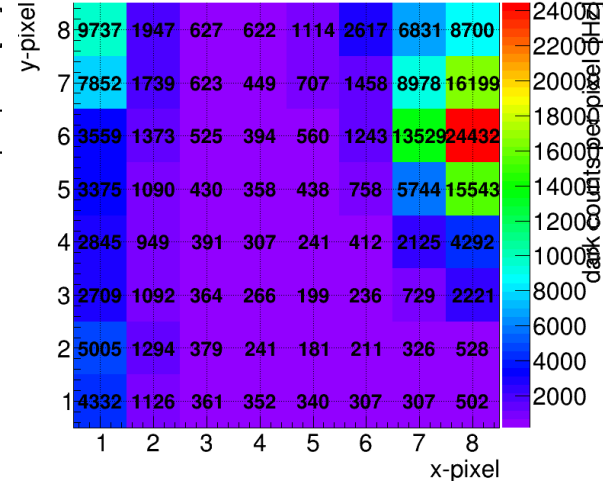
9002225



9002226

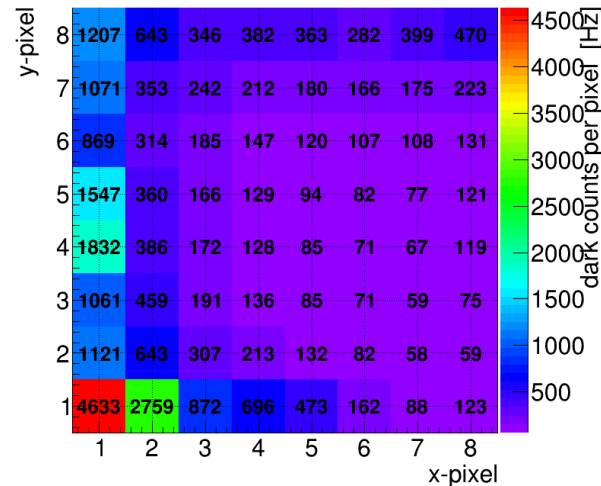


9002227

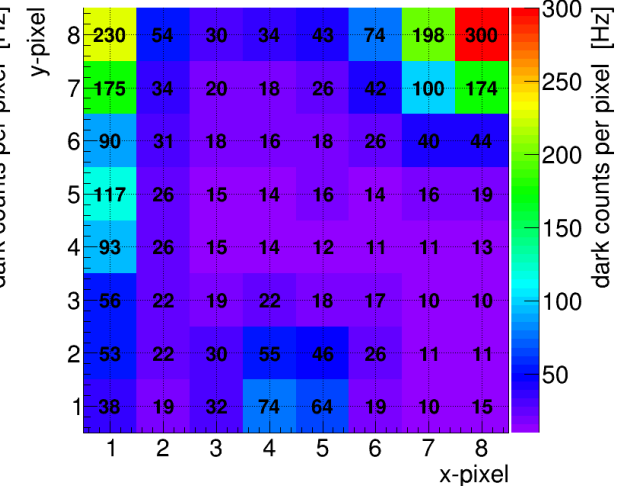


- 4:10:1 divider
- Dark count rates measured with TRB/DiRICH DAQ
- **Important: different scales in z axis!**
- Typical hot pixels at rims

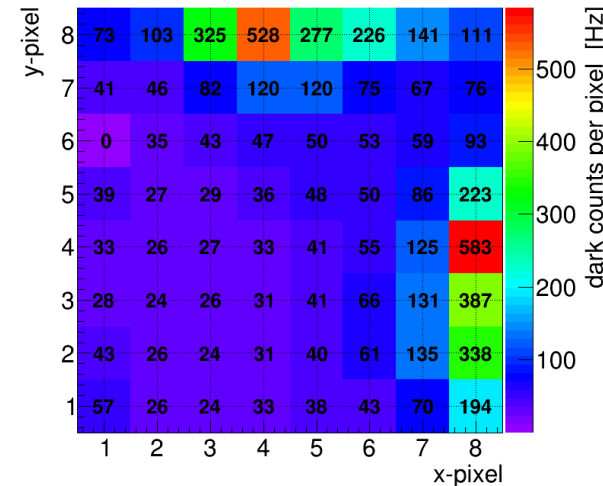
9002228



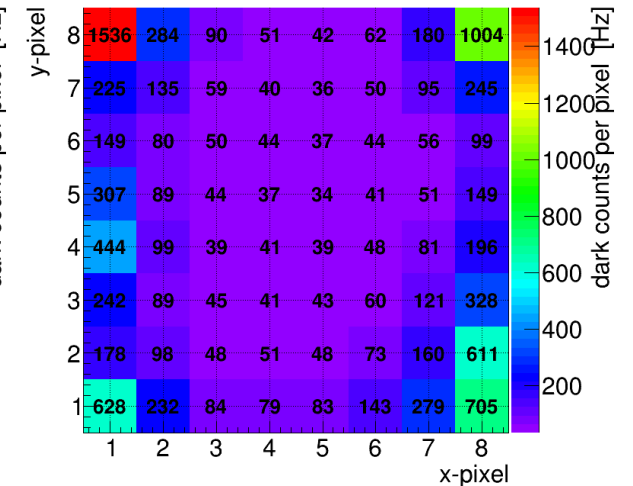
9002229



9002230



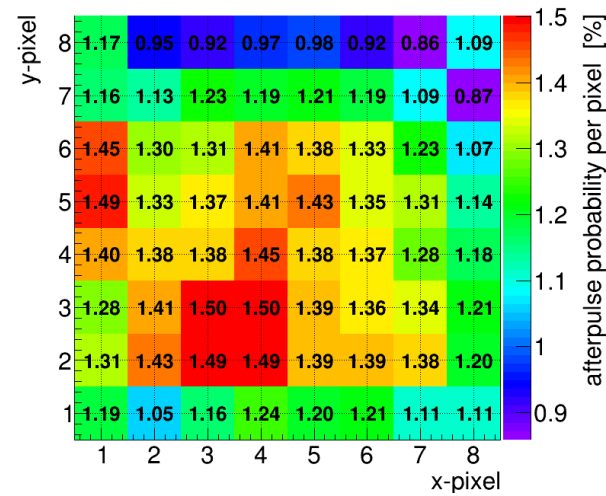
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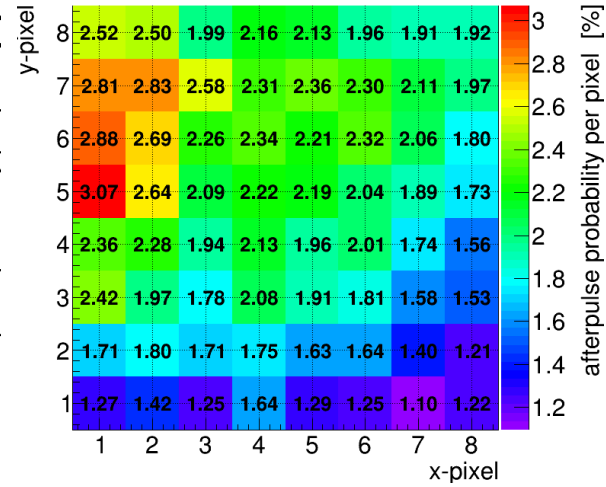
Afterpulse ratio

- 4:10:1 divider
- Afterpulse probability measured with TRB/DiRICH DAQ
- **Important: different scales in z axis!**
- **9002227**: very high AP ratio (~40%)
- **9002228**: high AP ratio (~7.4%)

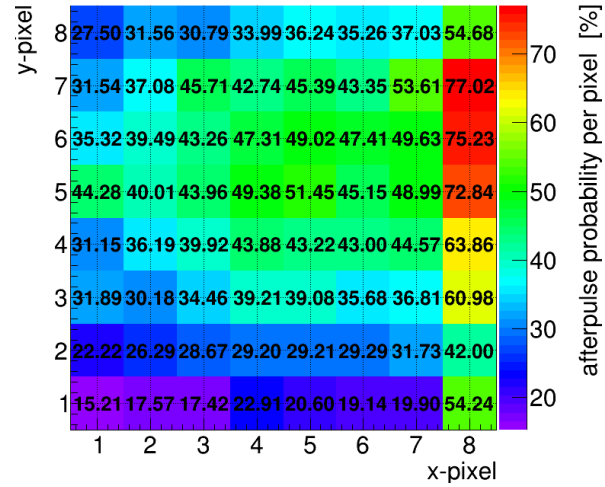
9002225



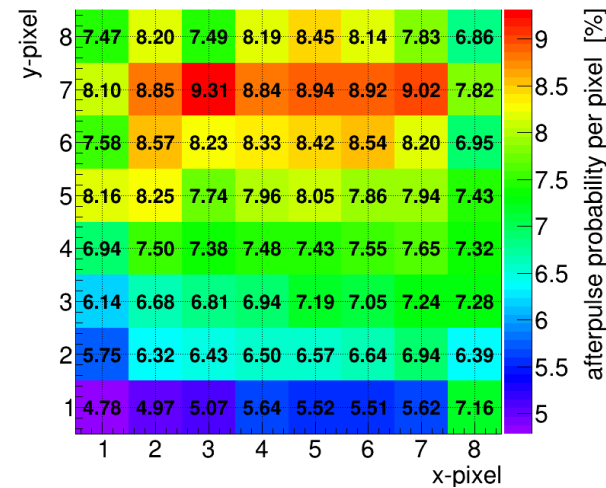
9002226



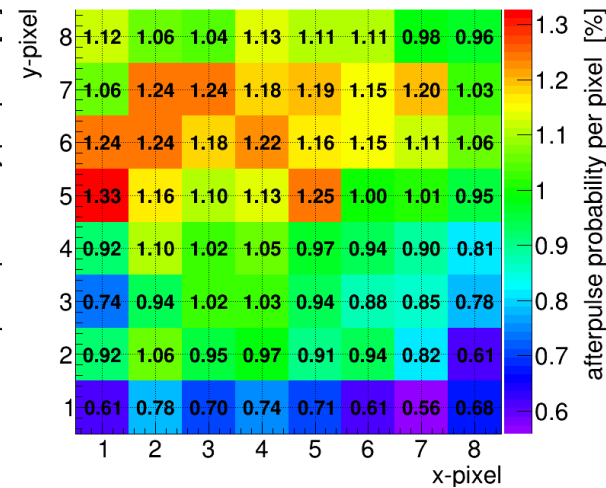
9002227



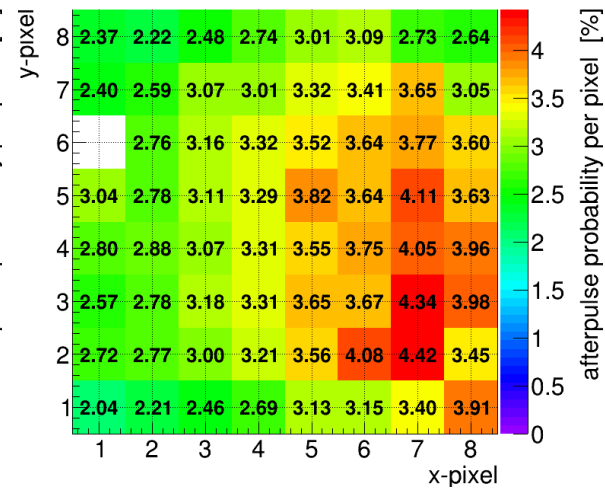
9002228



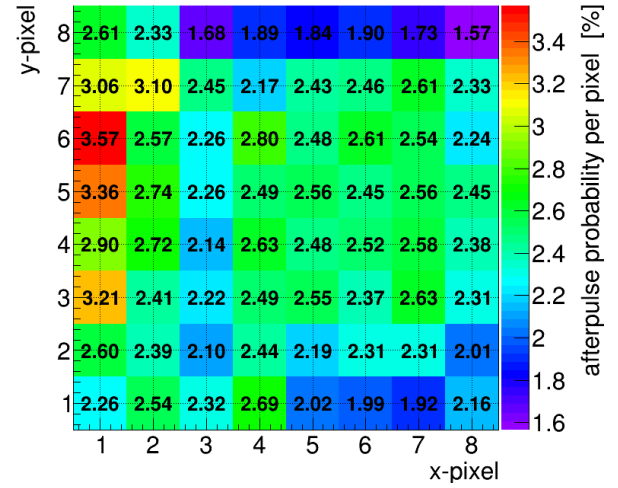
9002229



9002230

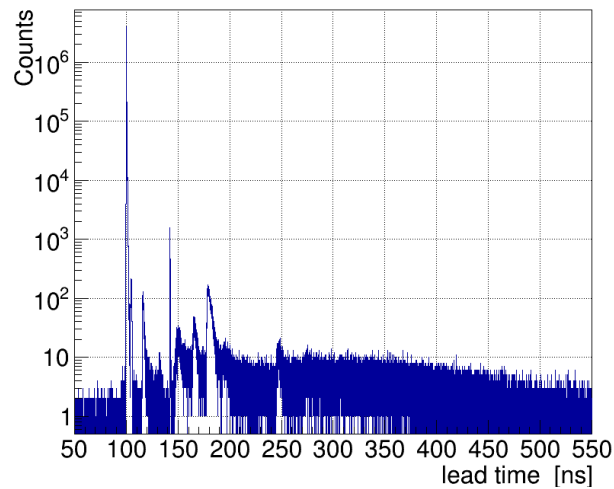


9002231

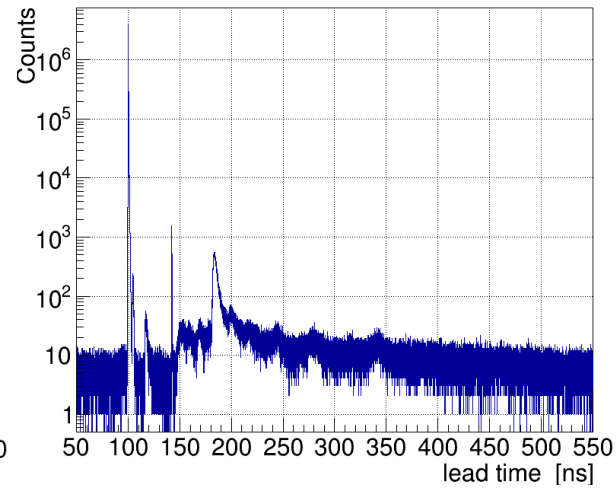


Afterpulse ratio

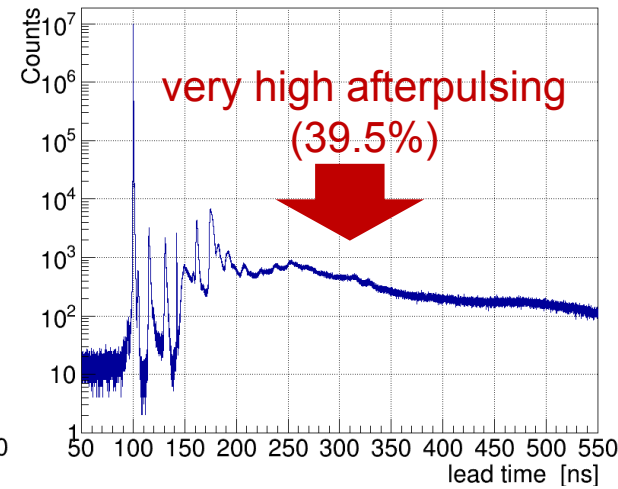
9002225



9002226



9002227

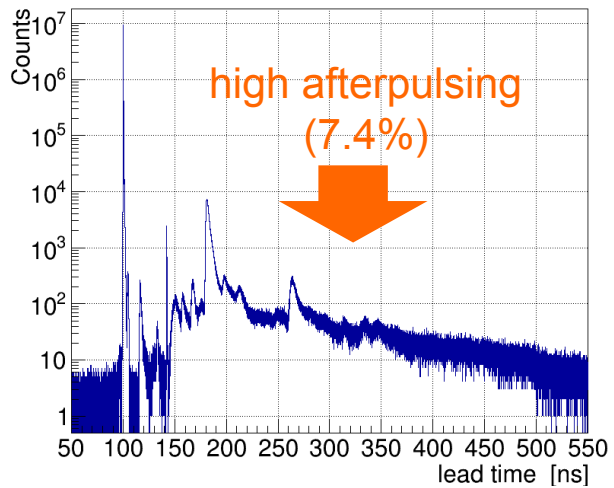


- Afterpulse probability measured with TRB/DiRICH DAQ

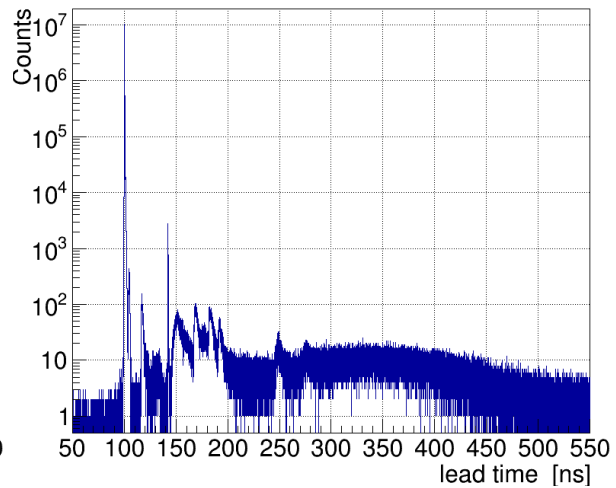
- 9002227:

- High afterpulse probability
- also seen with scope

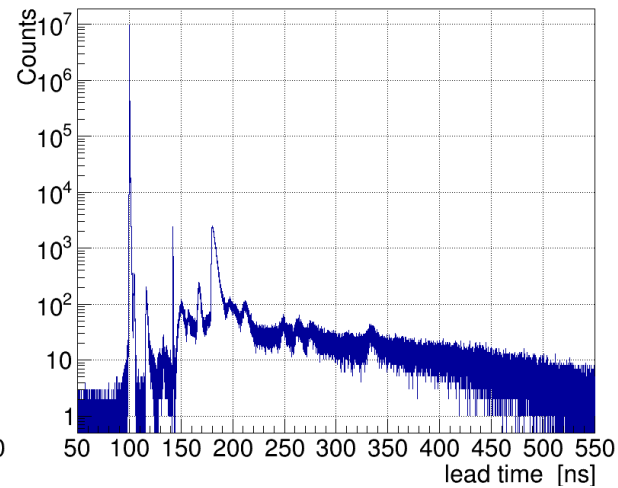
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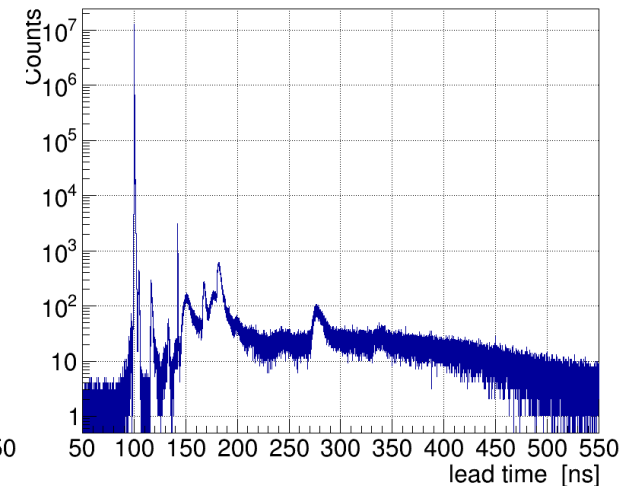
9002229



9002230

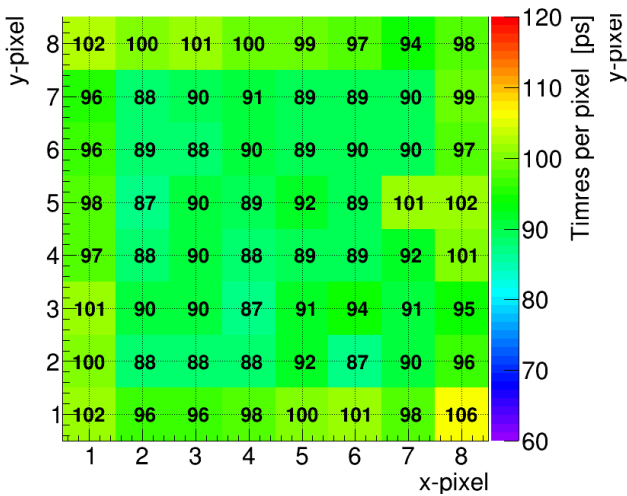


9002231

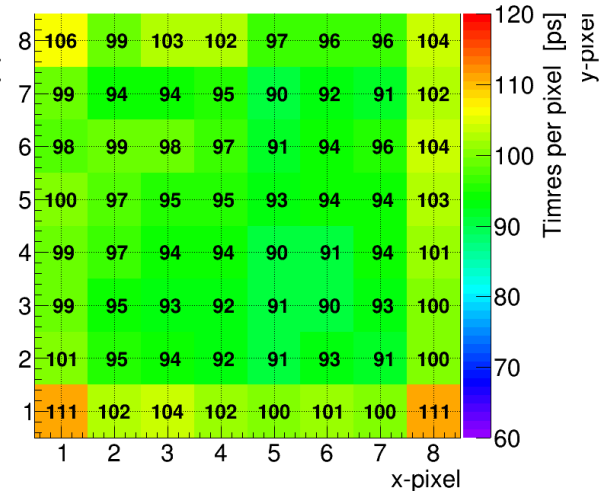


σ_{TTS} -time resolution with TRB/DiRICH DAQ

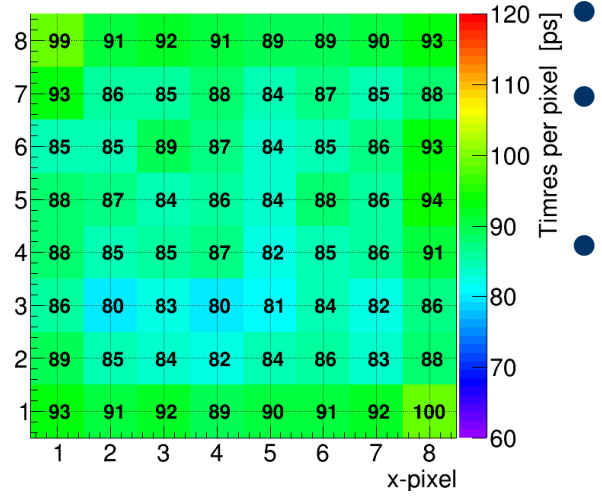
9002225



9002226

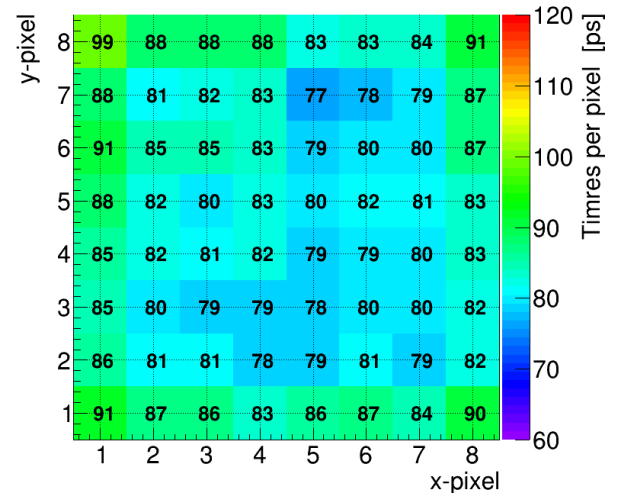


9002227

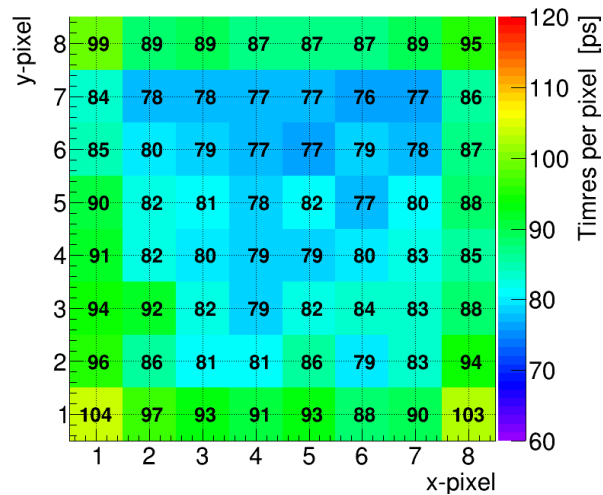


- 4:10:1 divider
- σ timing measured with TRB/DiRICH DAQ
- σ timing <100 ps for >90% of all pixels for combined tube-DAQ system and over full pixel area

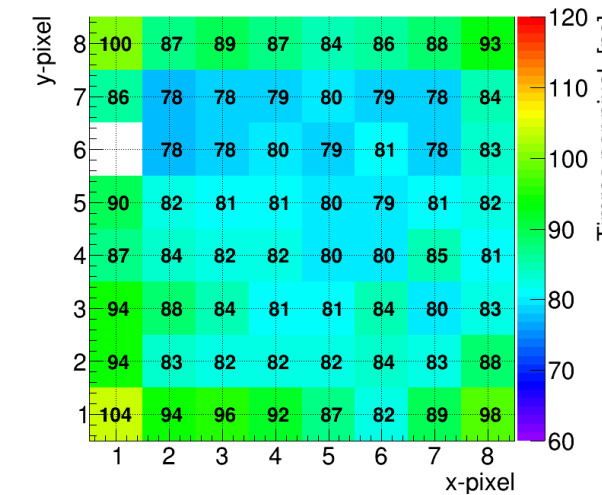
9002228



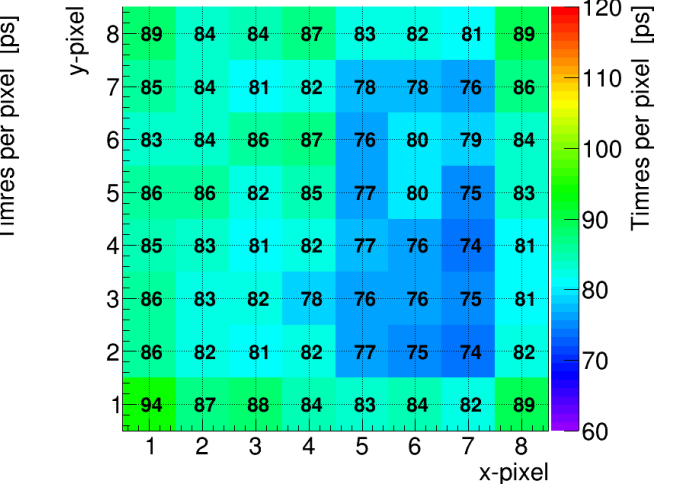
9002229



9002230



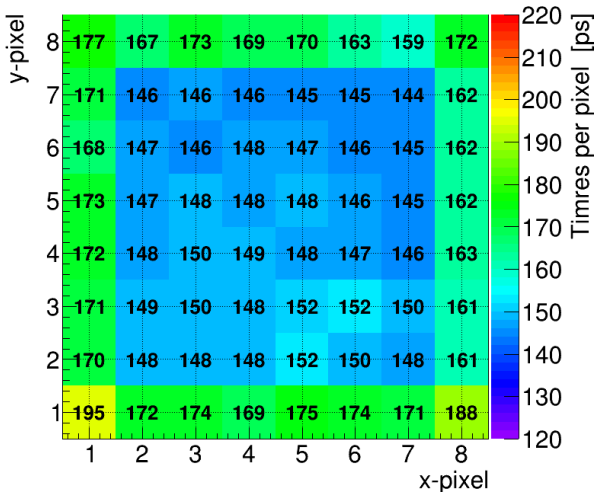
9002231



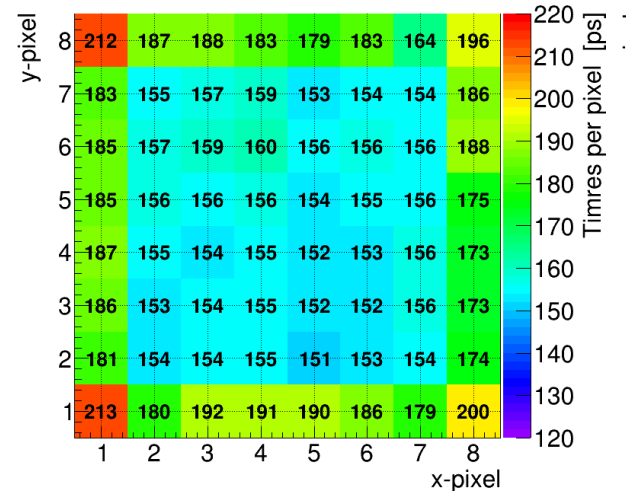
RMS timing with TRB/DiRICH DAQ

- 4:10:1 divider
- RMS timing measured with TRB/DiRICH DAQ
- Time window: -0.5 – +2 ns around main peak
- RMS timing **<200 ps** for >95% of all pixels for combined tube-DAQ system and over full pixel area

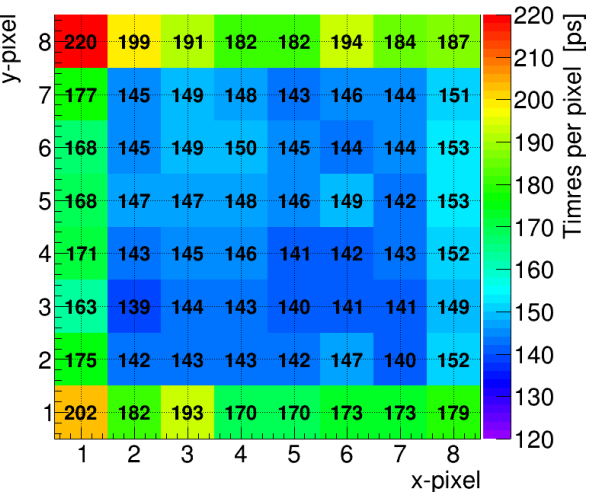
9002225



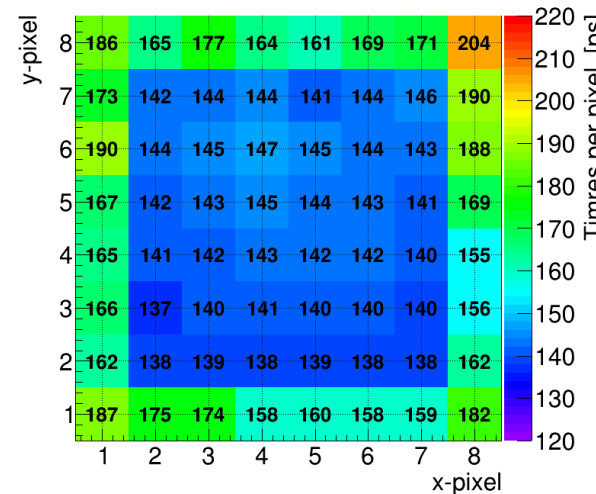
9002226



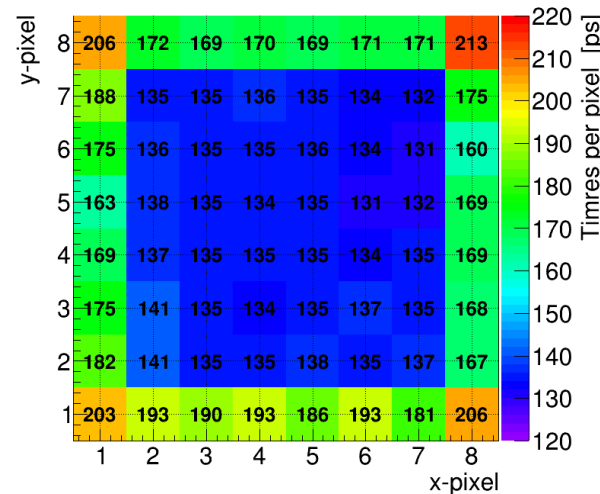
9002227



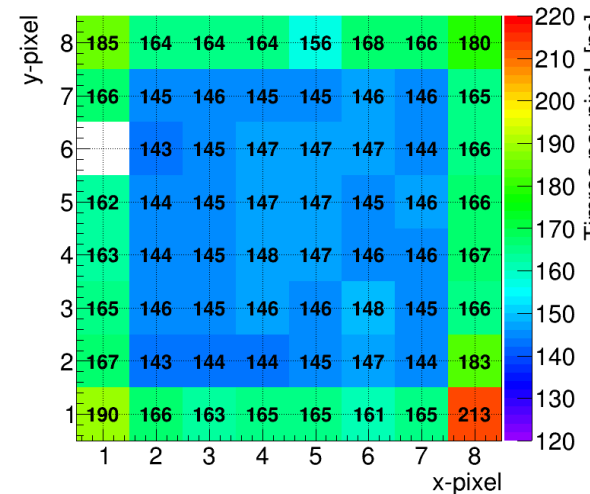
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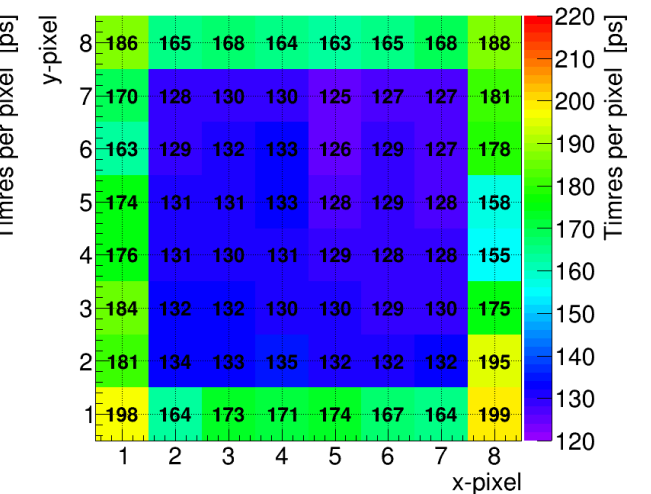
9002229



9002230

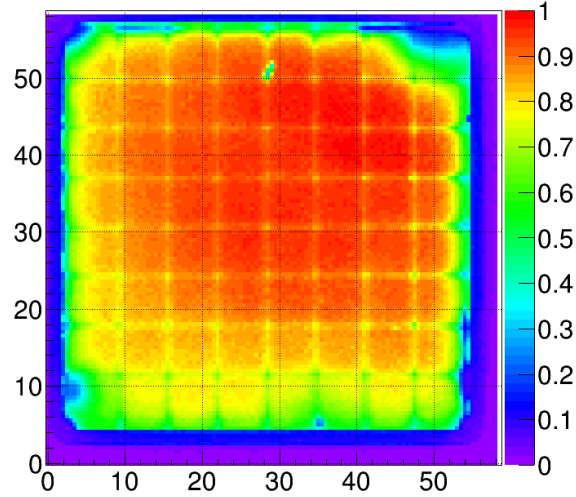


9002231

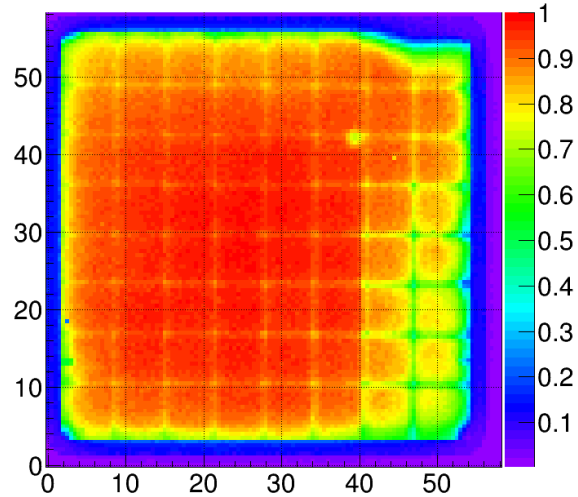


Efficiency plots with TRB/DiRICH DAQ

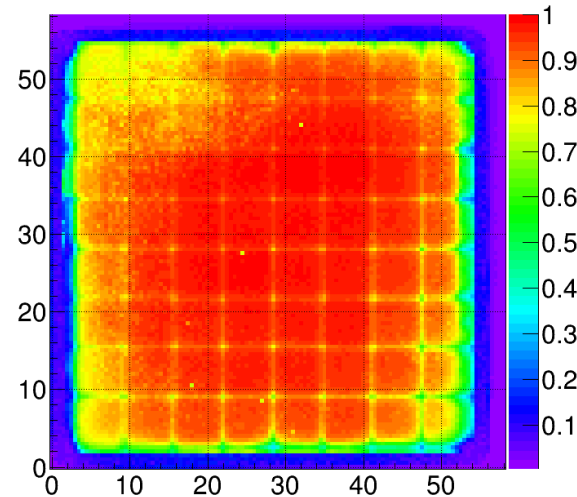
9002225



9002226

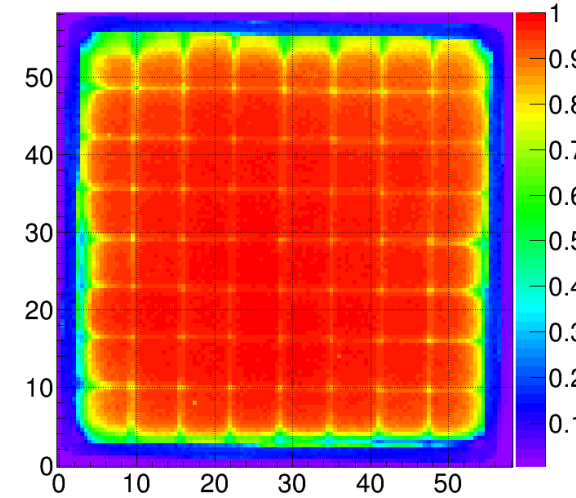


9002227

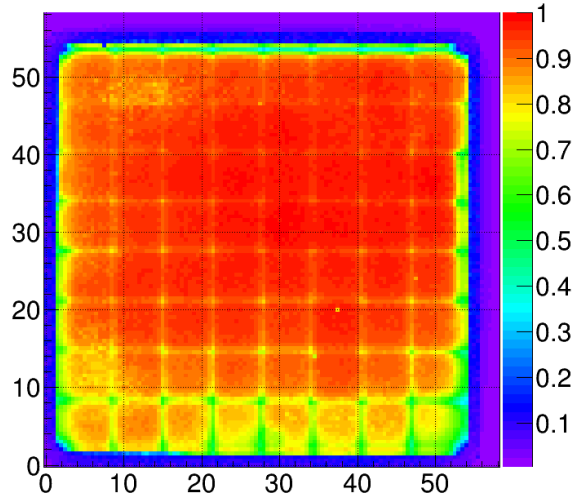


- 4:10:1 divider
- Normalized number of laser peak events at every position
- Threshold: ~20% of s.p.p at pixel x4 y5
- Important for experimental setup: combination of CE, gain and threshold
- Dead pixel of 9002230 due to adapter board

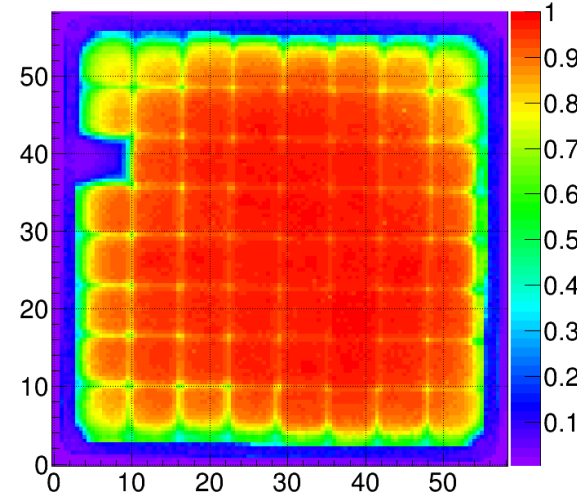
9002228



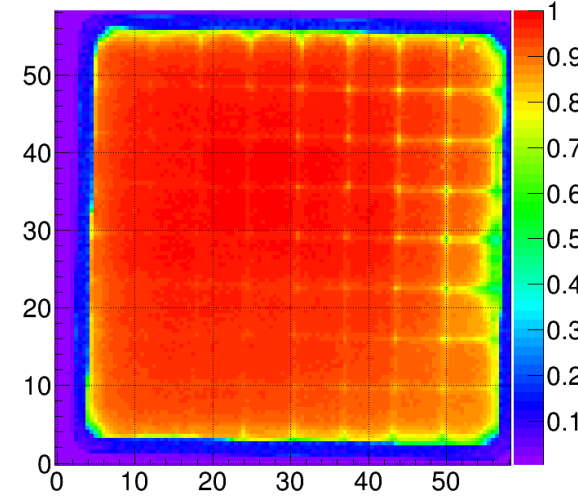
9002229



9002230



9002231



Means obtained with TRB scans



Sensor	relative efficiency [%]	DC rate [Hz/cm ²]	AP p. pixel [%]	TTS p. pixel [ps]	RMS p. pixel [ps]
9002225	80	142.9	1.3	94	158
9002226	86	2602.4	2.0	97	169
9002227	87	6609.5	39.5	87	158
9002228	88	1061.1	7.4	83	155
9002229	88	109.9	1.0	85	155
9002230	86 (w/o dead channel)	228.1	3.2	85	156
9002231	90	403.2	2.4	82	149

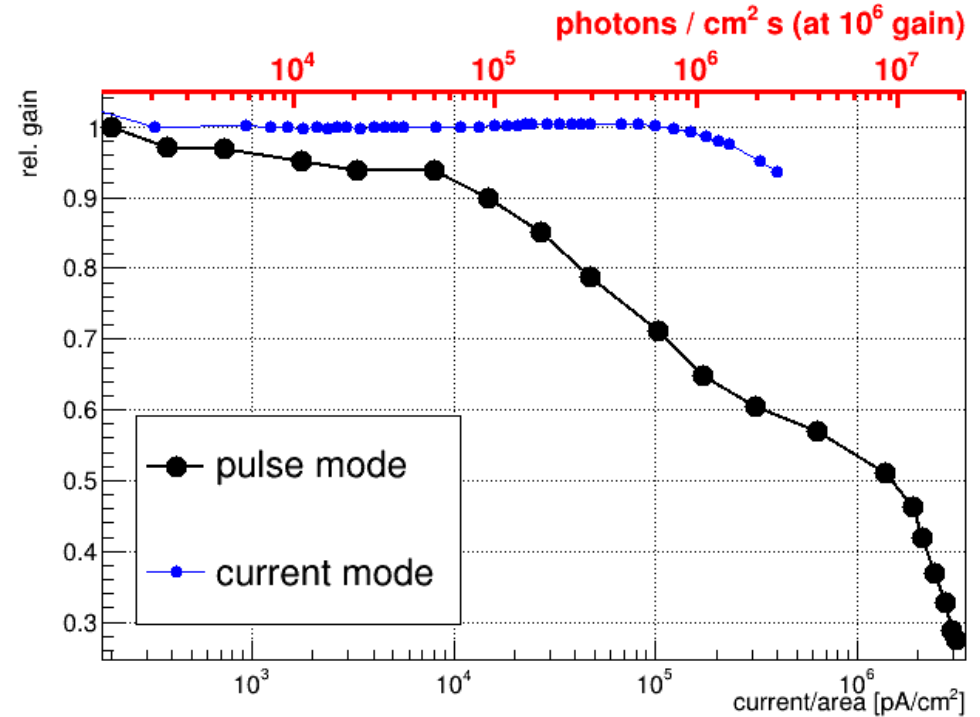
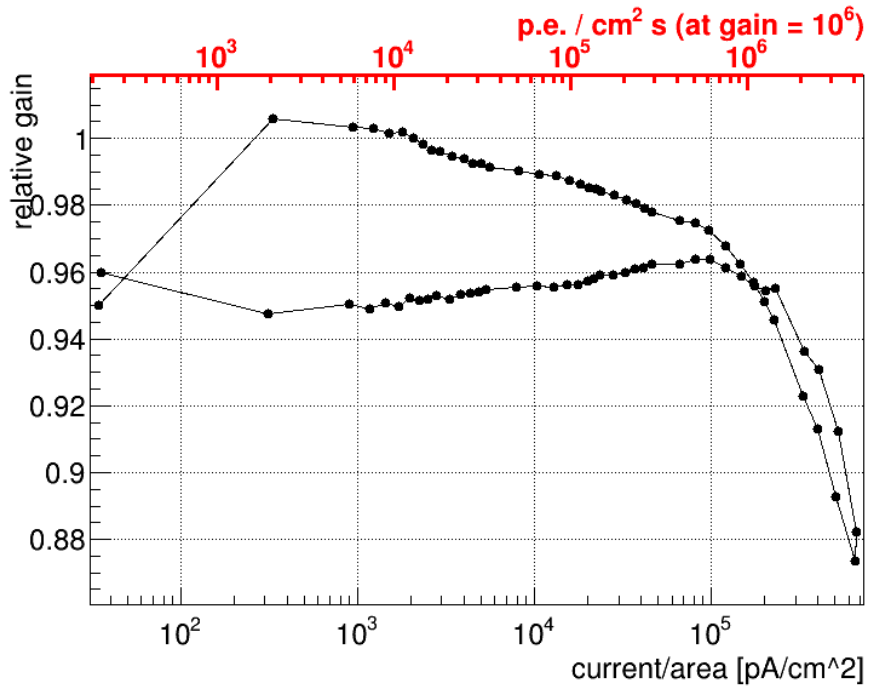
- Good QE and gain homogeneity for 9002227-9002231
- High DQE of ~20%
- Time resolution fulfills requirements

But:

- 900225 and 9002226 are losing QE → will be returned to Photonis
- 9002222 also shows slight QE loss
- 9002227 might have a loose connection and has very high afterpulse probability
- In general quite high afterpulse probability
- Inconsistent measurements of the rate capability
→ search for possible reason is ongoing

Backup

Measurements of 9002229 with 4:10:1 divider



- Measurement from low to high frequencies and back again
- ~100s illuminated and ~100s laser off
- Less hysteresis for shorter measurements
- No improvement with longer time without illumination

- Currents mode: illumination of whole sensor surface, measurement of anode current of all shortend pixels
- Pulse mode: illumination of pixel 44, measurement of pulse height spectrum
- Very different behaviours

Rate capability in pulse mode

- Pulse mode: illumination of pixel 44, measurement of pulse height spectrum

