Update on the most recent Photonis MCP-PMTs for the PANDA Barrel DIRC

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

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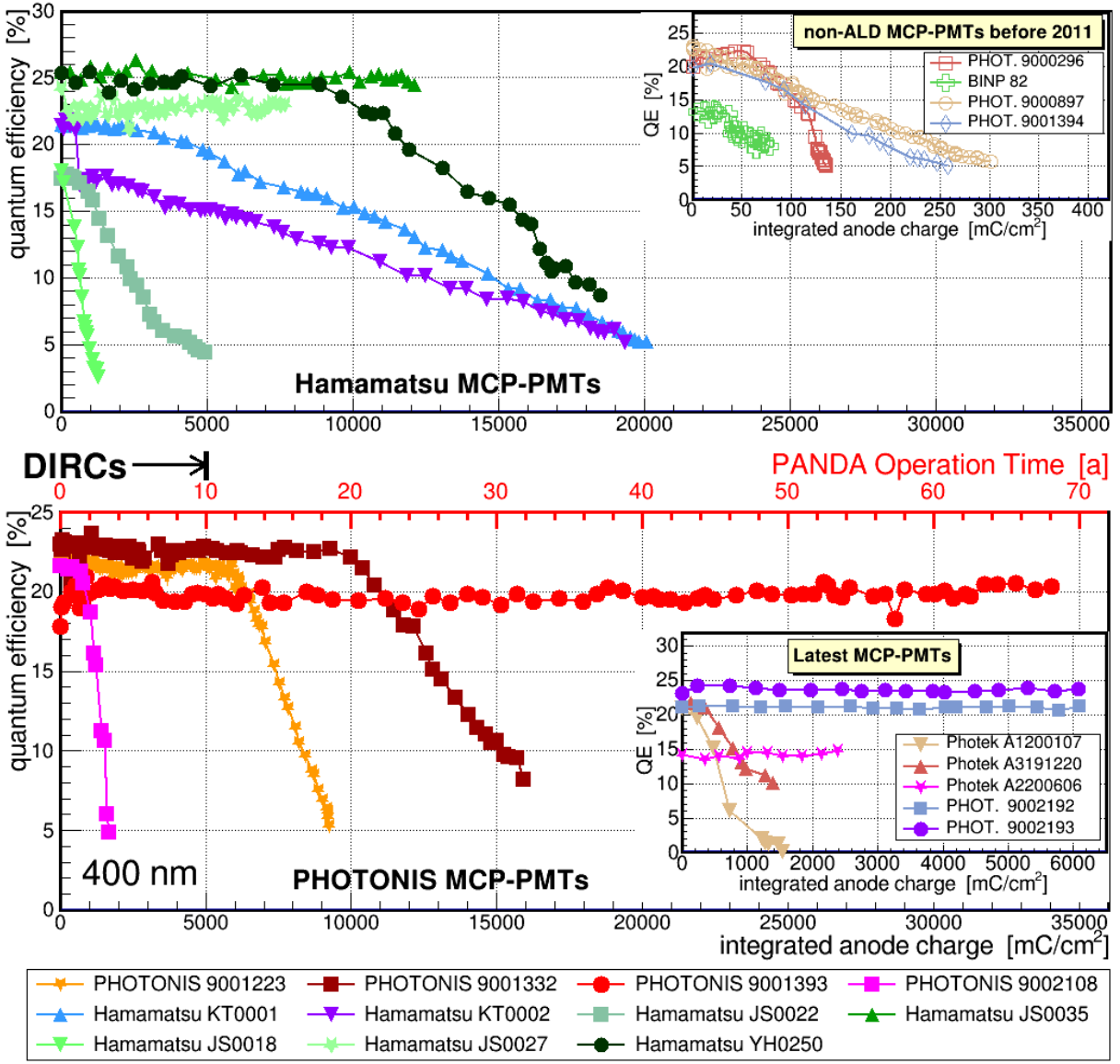
FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
NATURWISSENSCHAFTLICHE FAKULTÄT

Status of lifetime measurements

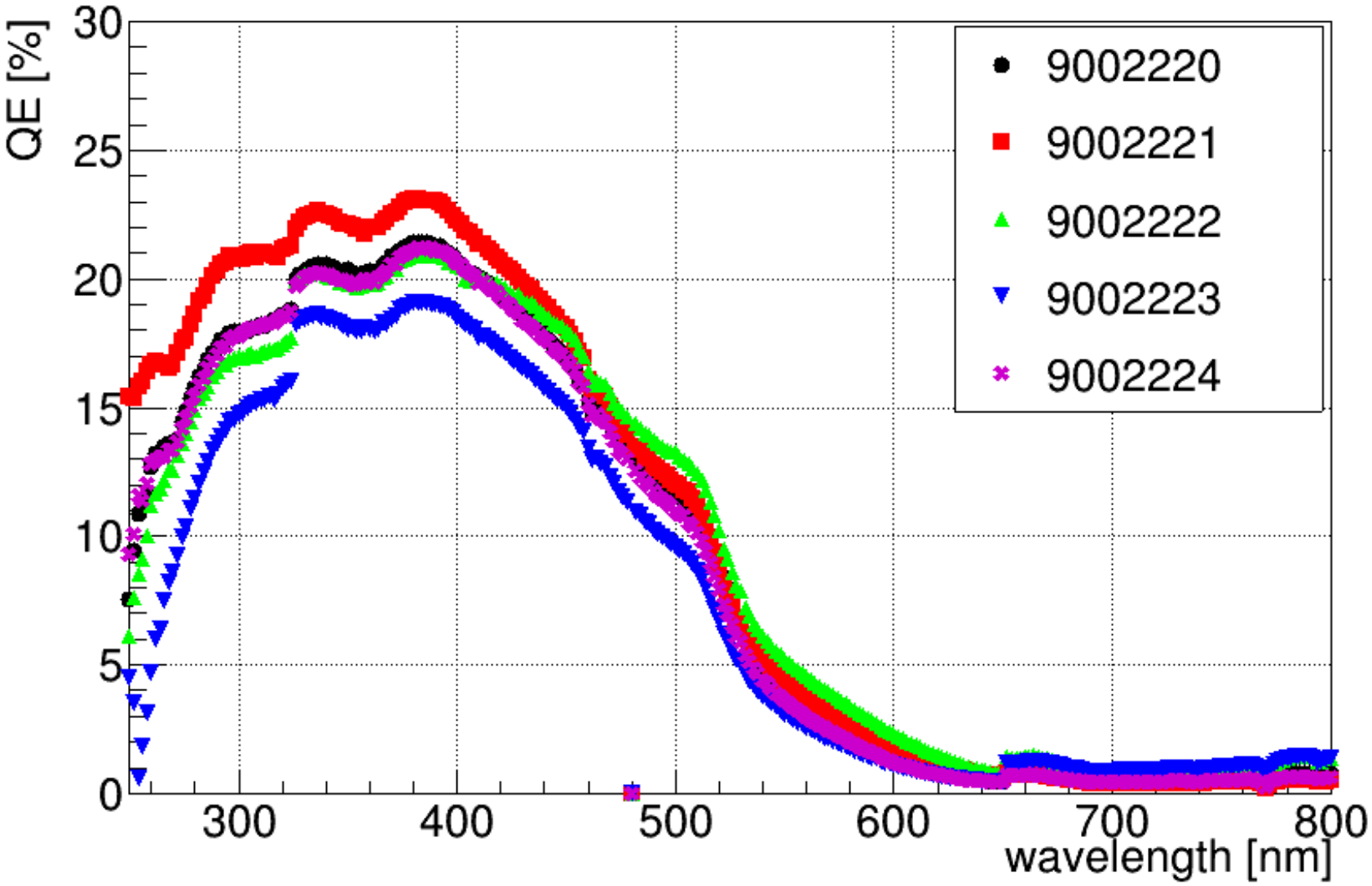
- **Required spec:** 5 C/cm² IAC (10 years of PANDA) reached by most ALD-coated MCP-PMTs
- Best sensor by far: Photonis 9001393 with two ALD-layers (no QE loss up to 34 C/cm²)

- Photonis 9002108, Photek A1200107 and A3191220 had **poor lifetime**
- Photonis 9002192, 9002193 have reached **6 C/cm²** IAC without PC damage or QE loss
- Latest Photek A2200606 has no sign of QE damage up to **2.5 C/cm²**

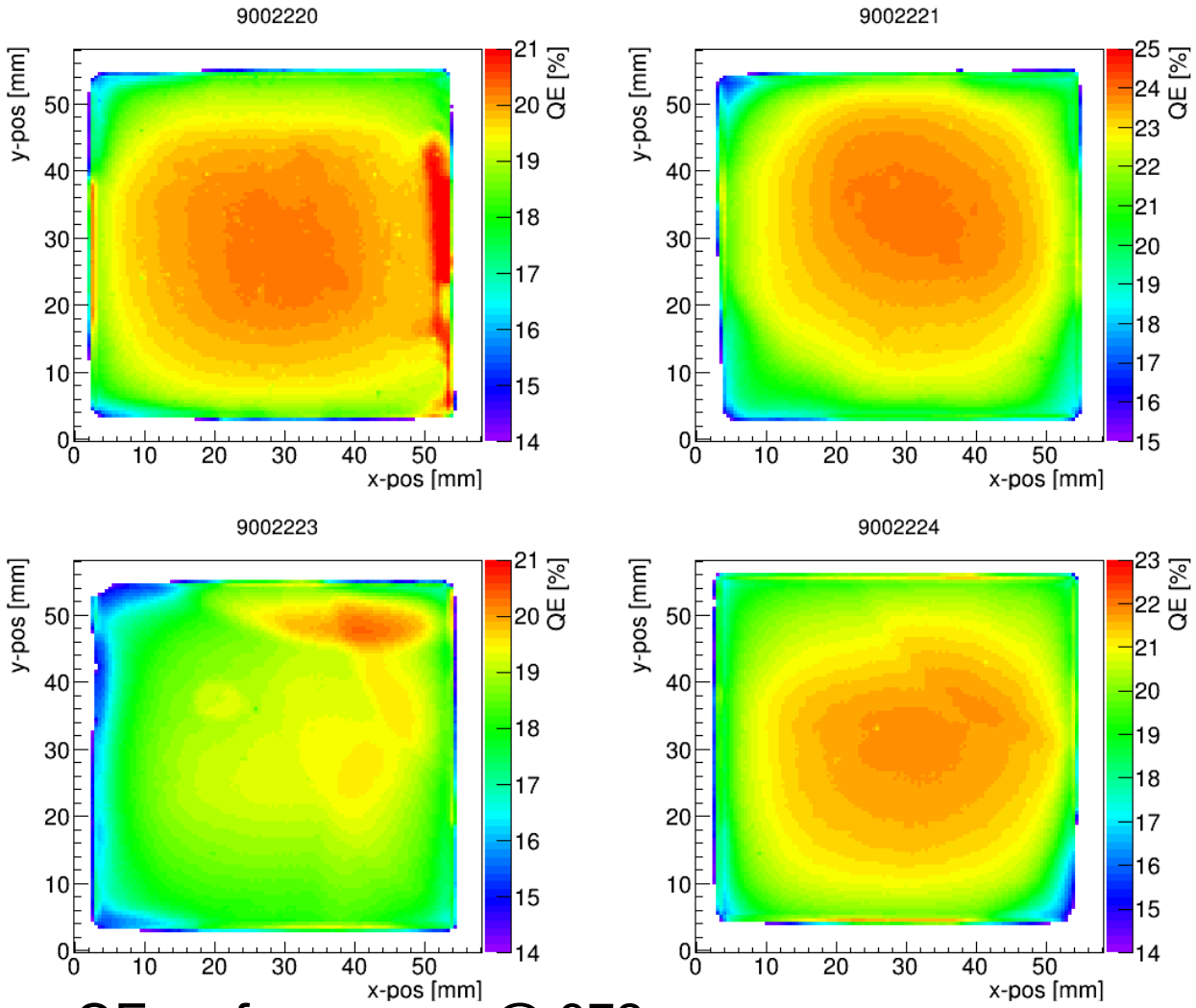


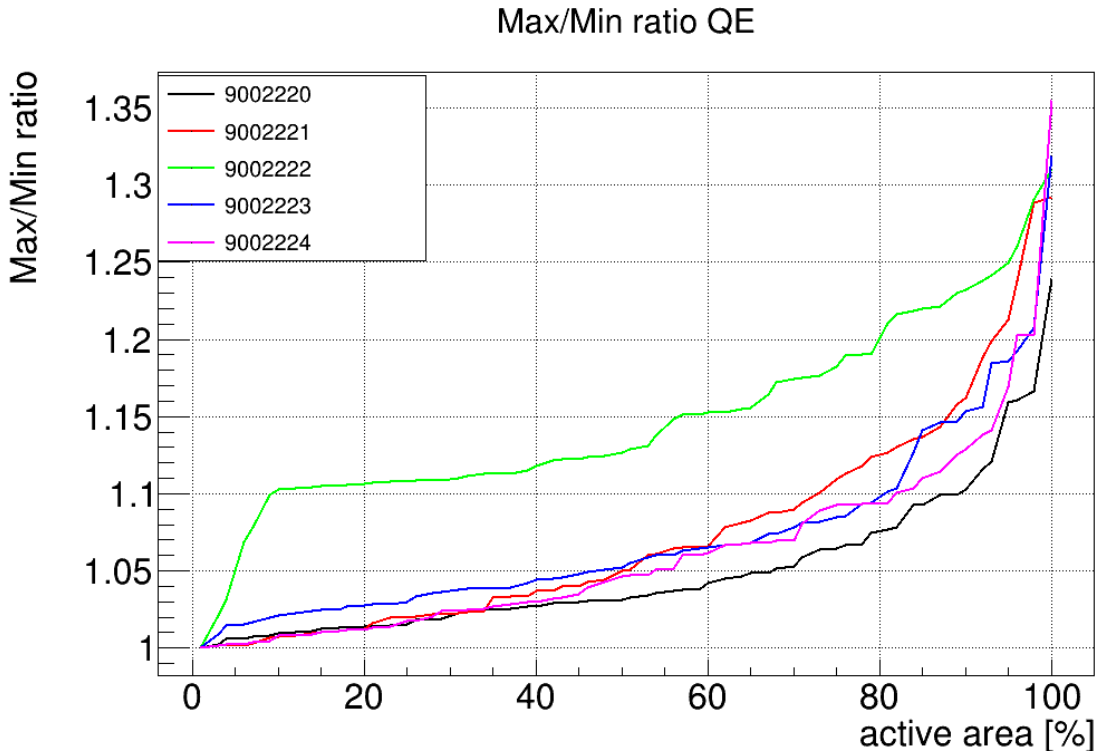
QE vs wavelength

- QE vs wavelength @ center point (x4 y5, ~5 mm spot)
- Jump @ 330 nm not real
  → DAQ related
  → Just visible for high dark currents



QE uniformity

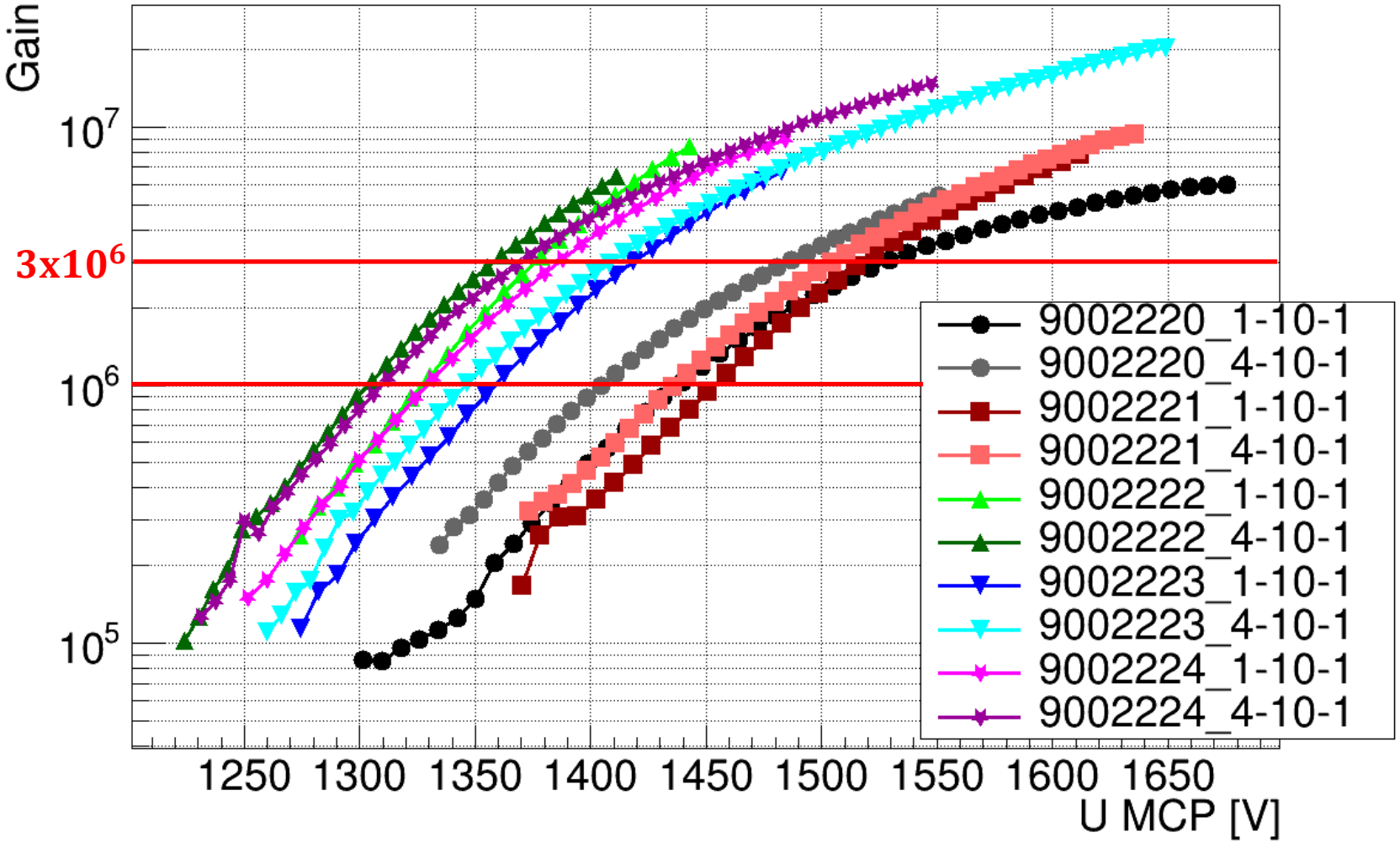




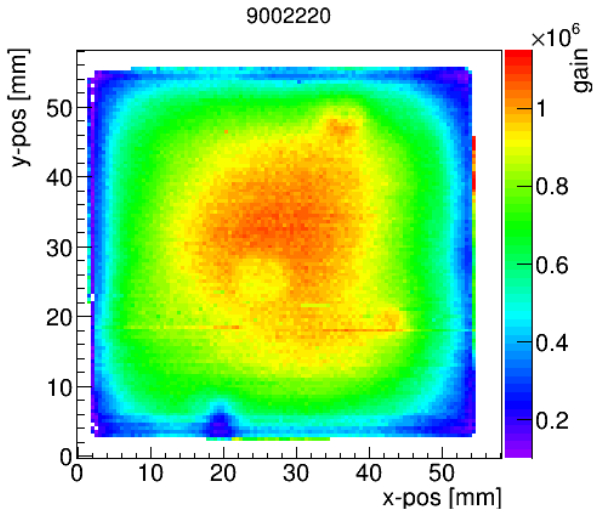
- QE surface scans @ 372nm
- Uniformity below 1.4 for all tubes for 100% active area

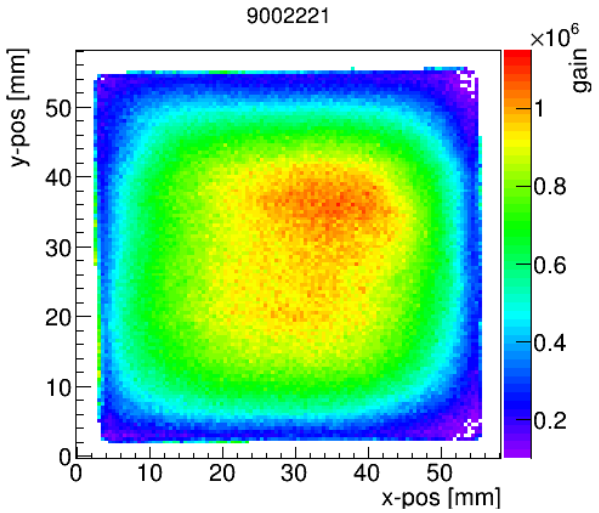
Gain vs voltage

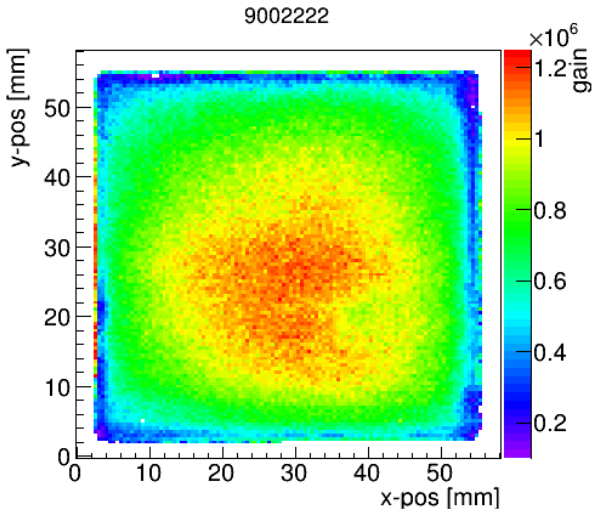
- Measurements with two different voltage dividers taken for each tube
  - 1-10-1: 200 V PC - MCPin
  - 4-10-1: 800 V PC - MCPin
- All 4-10-1 curves at slightly higher gain than other curves because of higher initial energy of photo electron
- Gain of 10^6 safely reached by all tubes, for some even > 10^7
- **$3x10^6$** to obtain at every pixel $1x10^6$ gain due to max/min ratio of 3

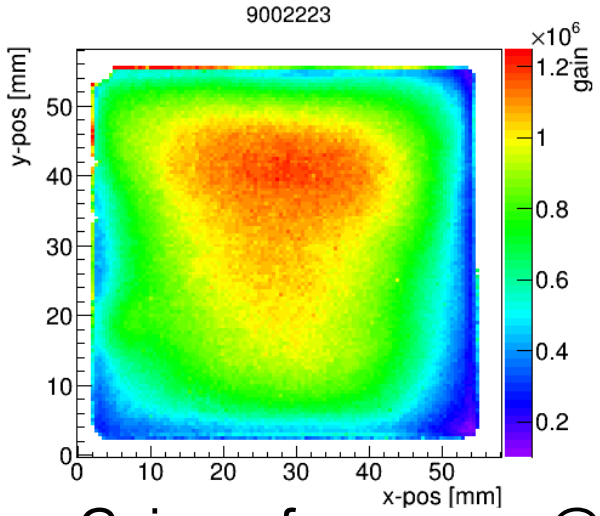


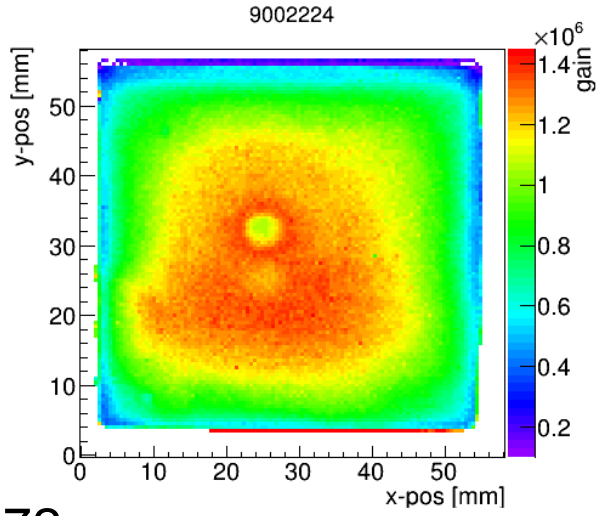
Gain uniformity



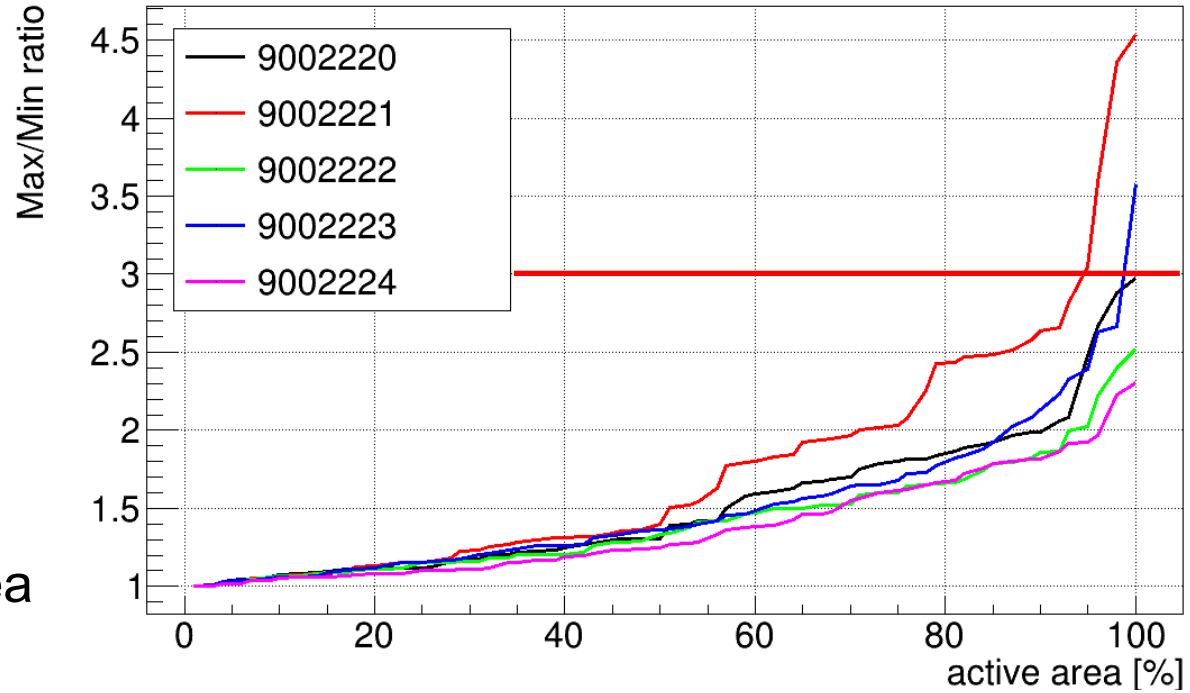








Bad spots come from PCBs (very annoying because no systematic failure!)



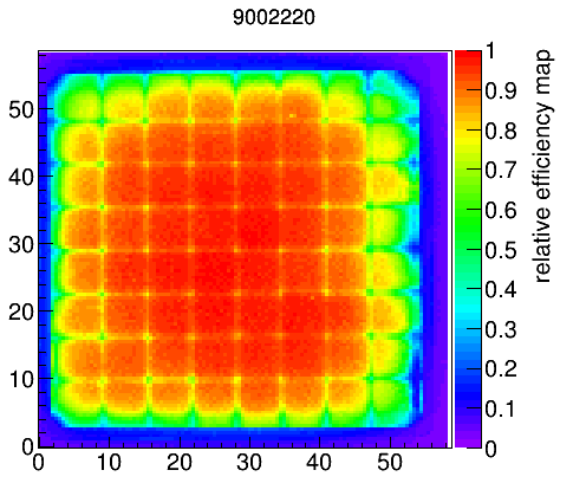
- Gain surface scans @ 372nm
- Uniformity better 3 for all tubes for > 90% active area

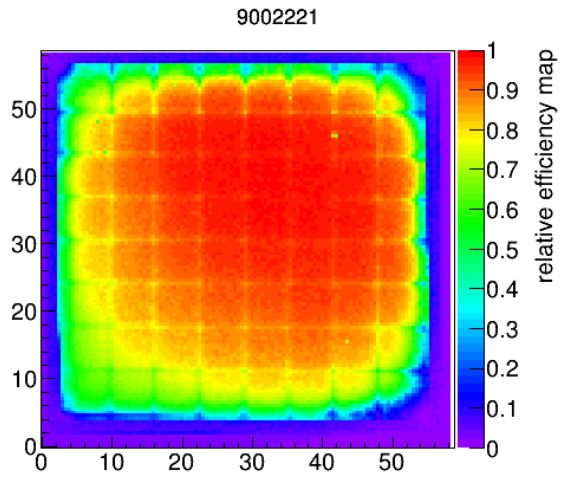
Efficiency plots with TRB/DiRICH DAQ

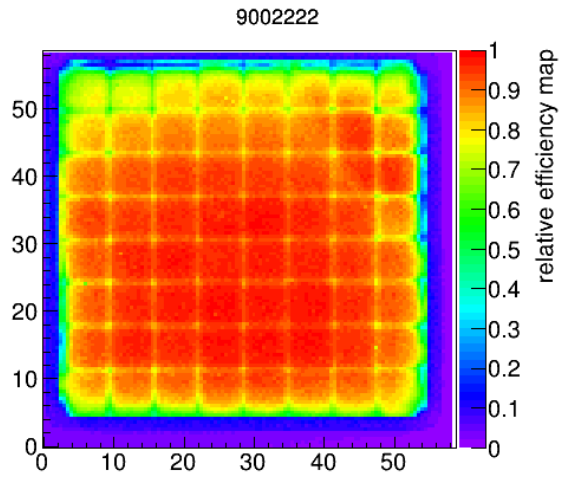
- Normalized number of main peak events at every position
- Threshold: ~20-30% of single photon peak

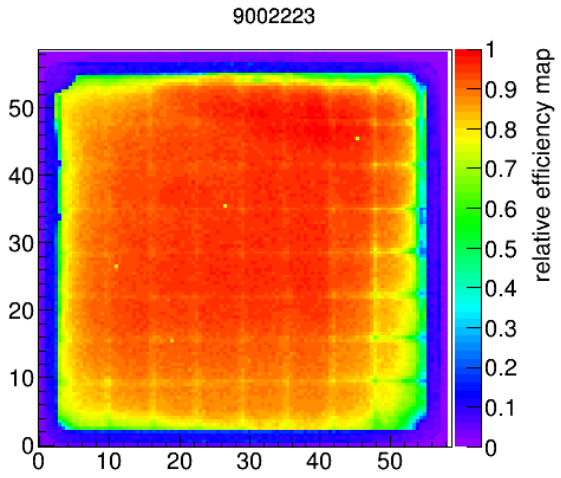
- Important for experimental setup

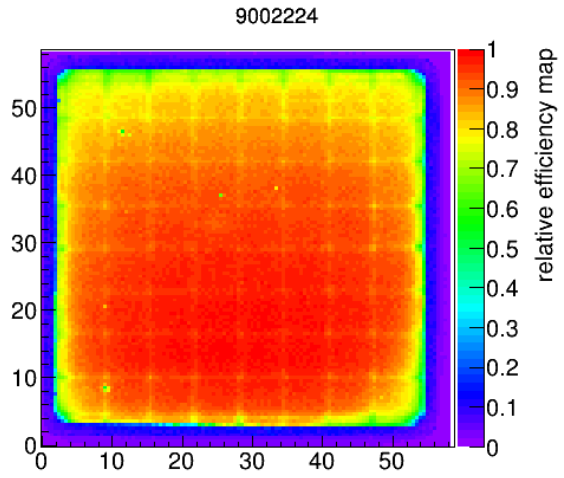
➢ Combined information of gain, QE & CE





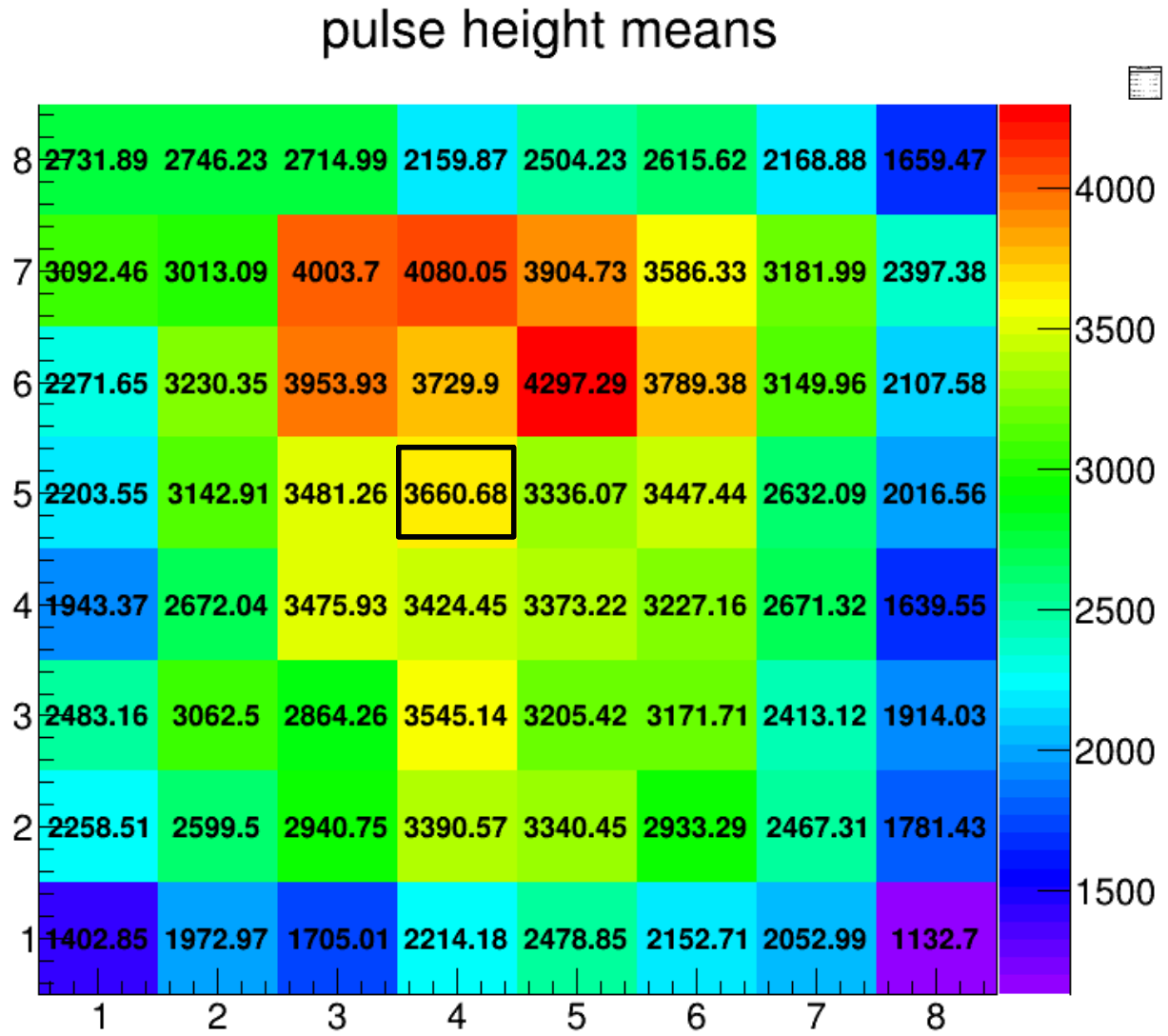






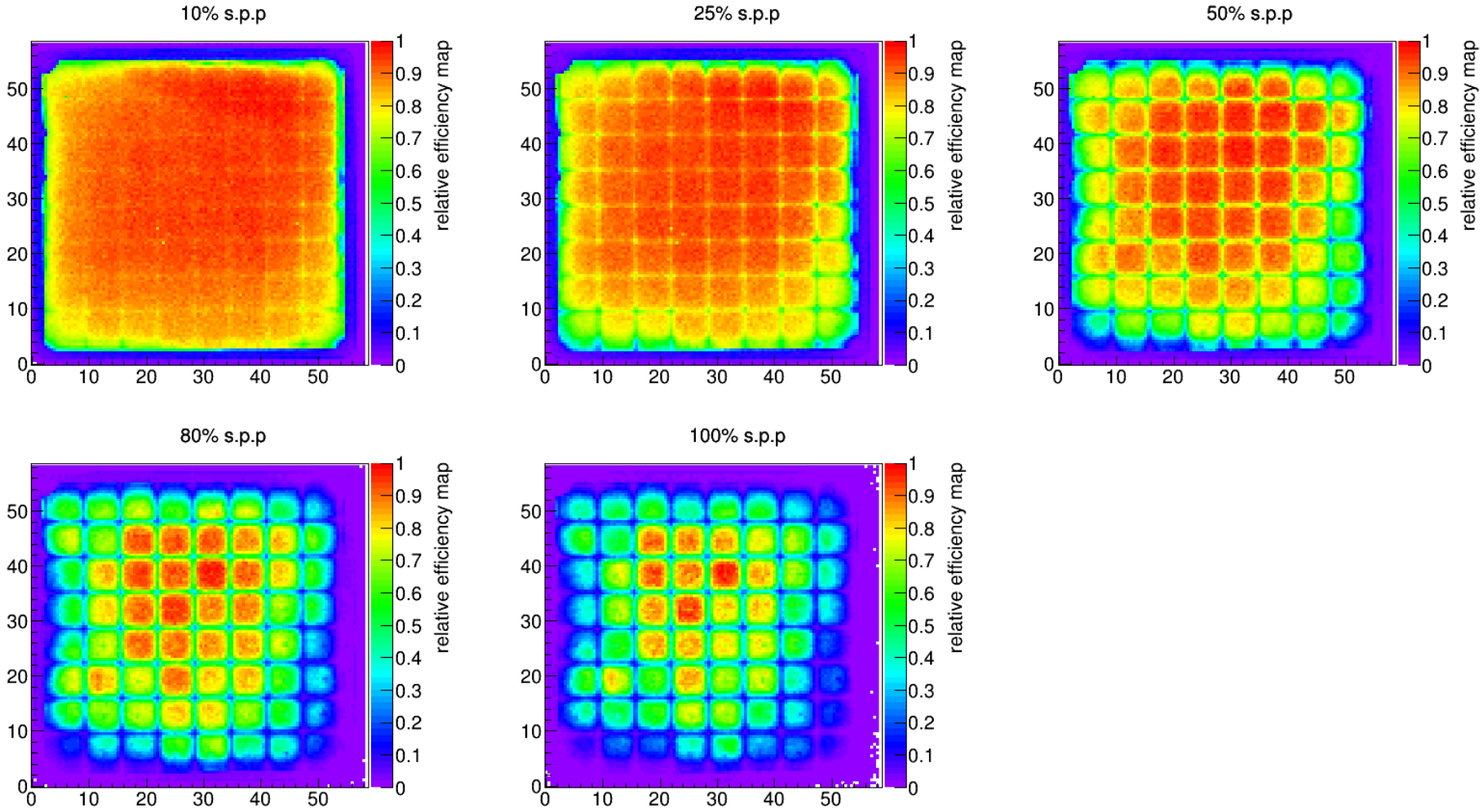
Threshold scan with TRB/DiRICH DAQ

- Calculated threshold for single photon peak for every pixel
- S.p.p of pixel **x4 y5** taken for following surface scans on next slide
- S.p.p behaviour strongly correlated to gain distribution



Efficiency plots vs signal threshold

- Normalized number of main peak events at every position
- Different thresholds plotted for Photonis 9002223



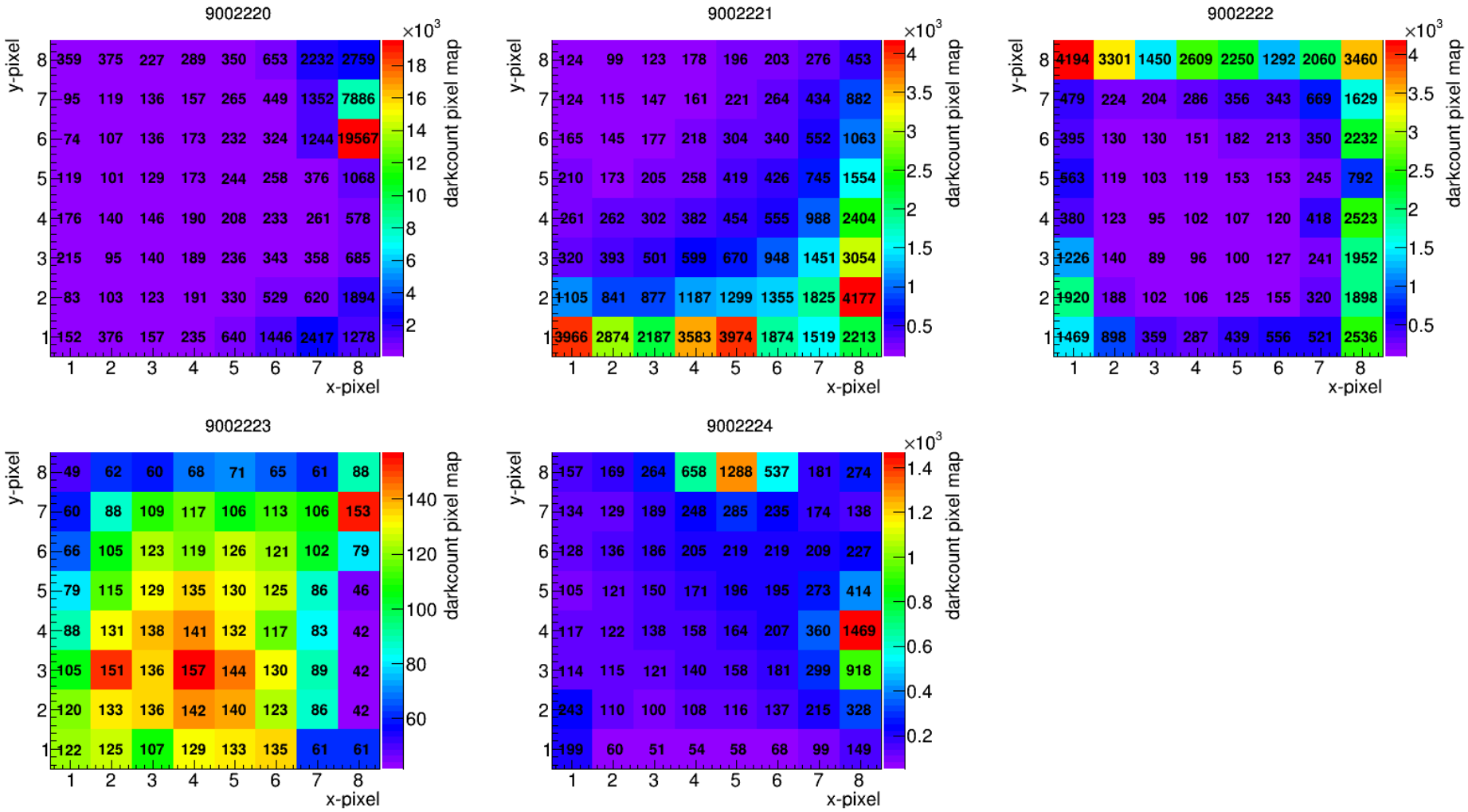
CE & DQE

	9002220	9002221	9002222	9002223	9002224
QE @ 372nm & x4 y5 [%]	20.2	23.8	21.5	19.1	21.8
CE [%]	95	80	88	87	90
DQE [%]	19.3	19.1	18.9	16.8	19.6

- 9002221 measured thrice ~80%
- 9002220 – 9002224 reach CE of 80 – 90%

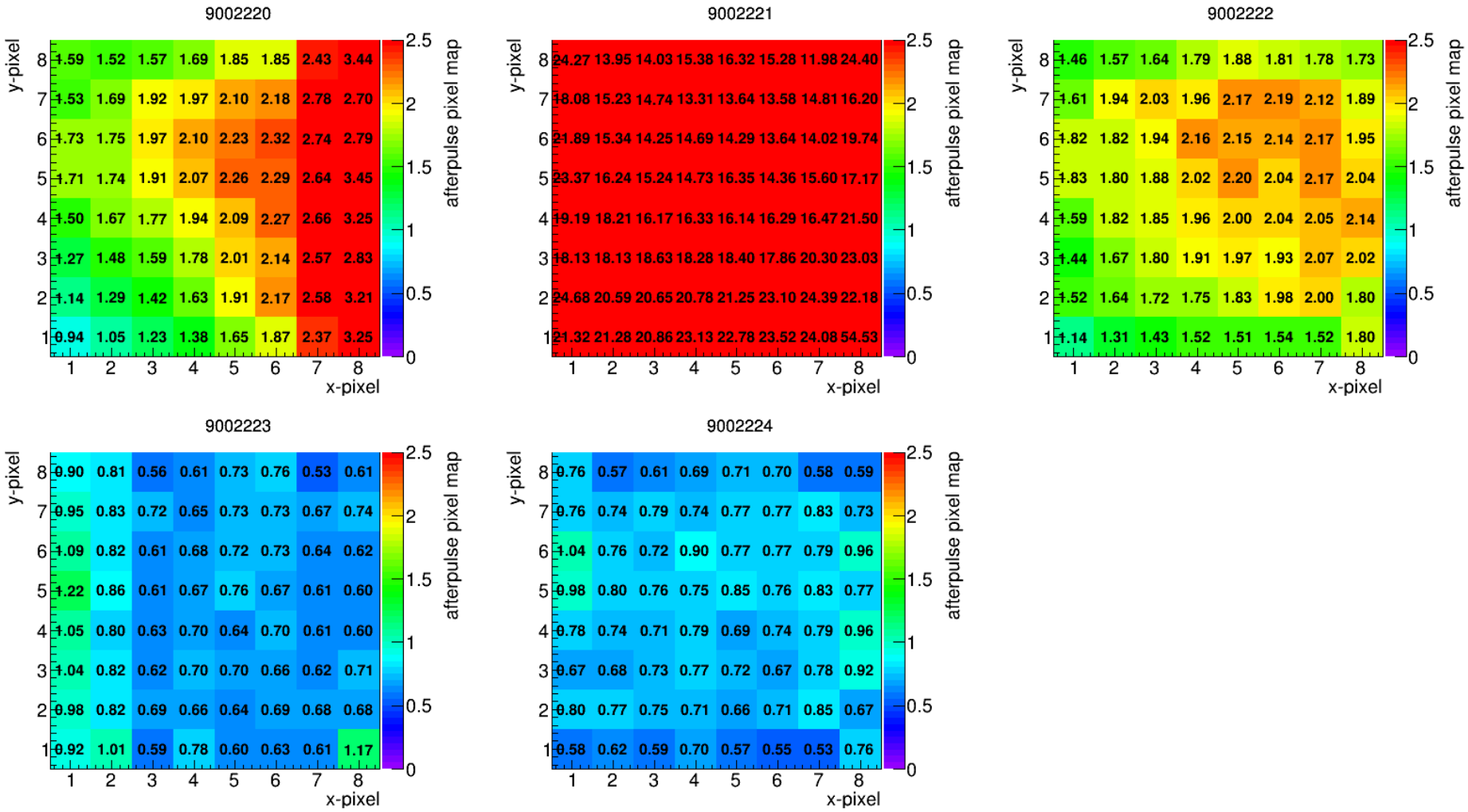
Dark count rates with high PC-MCP voltage

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



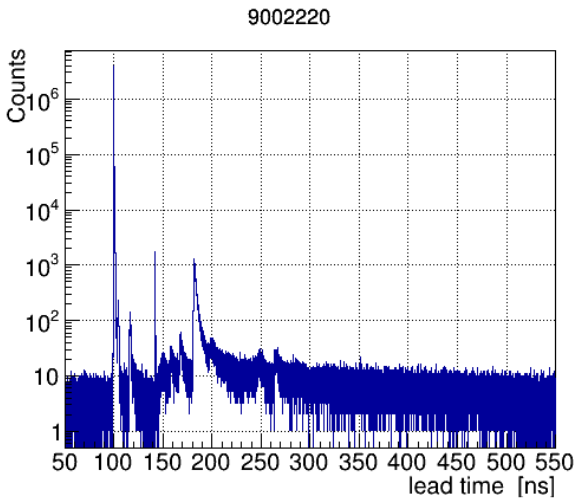
Afterpulse ratio with high PC-MCP voltage

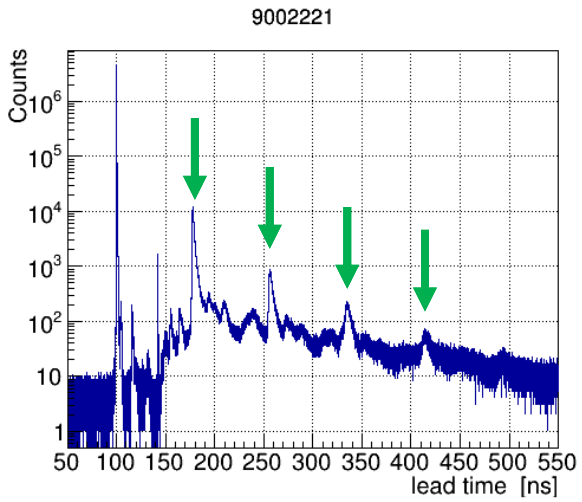
- Afterpulse probability measured with TRB/DiRICH DAQ
- Something wrong with 9002221?
  - ➢ Explanation shown on next slide

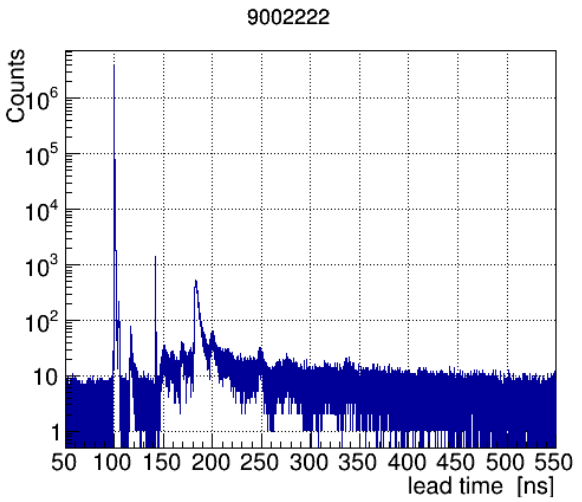


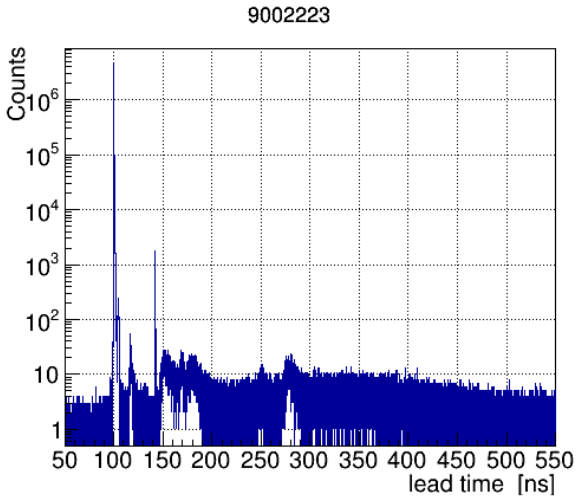
Afterpulse ratio with high PC-MCP voltage

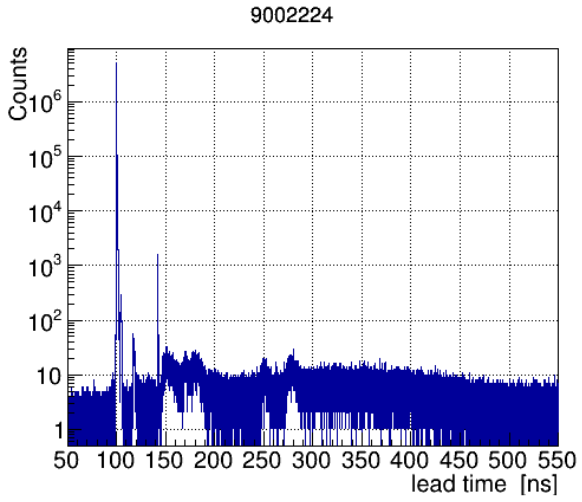
- Afterpulse probability measured with TRB/DiRICH DAQ
- Something wrong with 9002221?
- Significantly higher count rates in afterpulse timing regime
- **Additional peaks** also seen with scope with completely different setup (PCBs, cables, DAQ)
- Next step: reproduce with digitizer & use of HV without divider





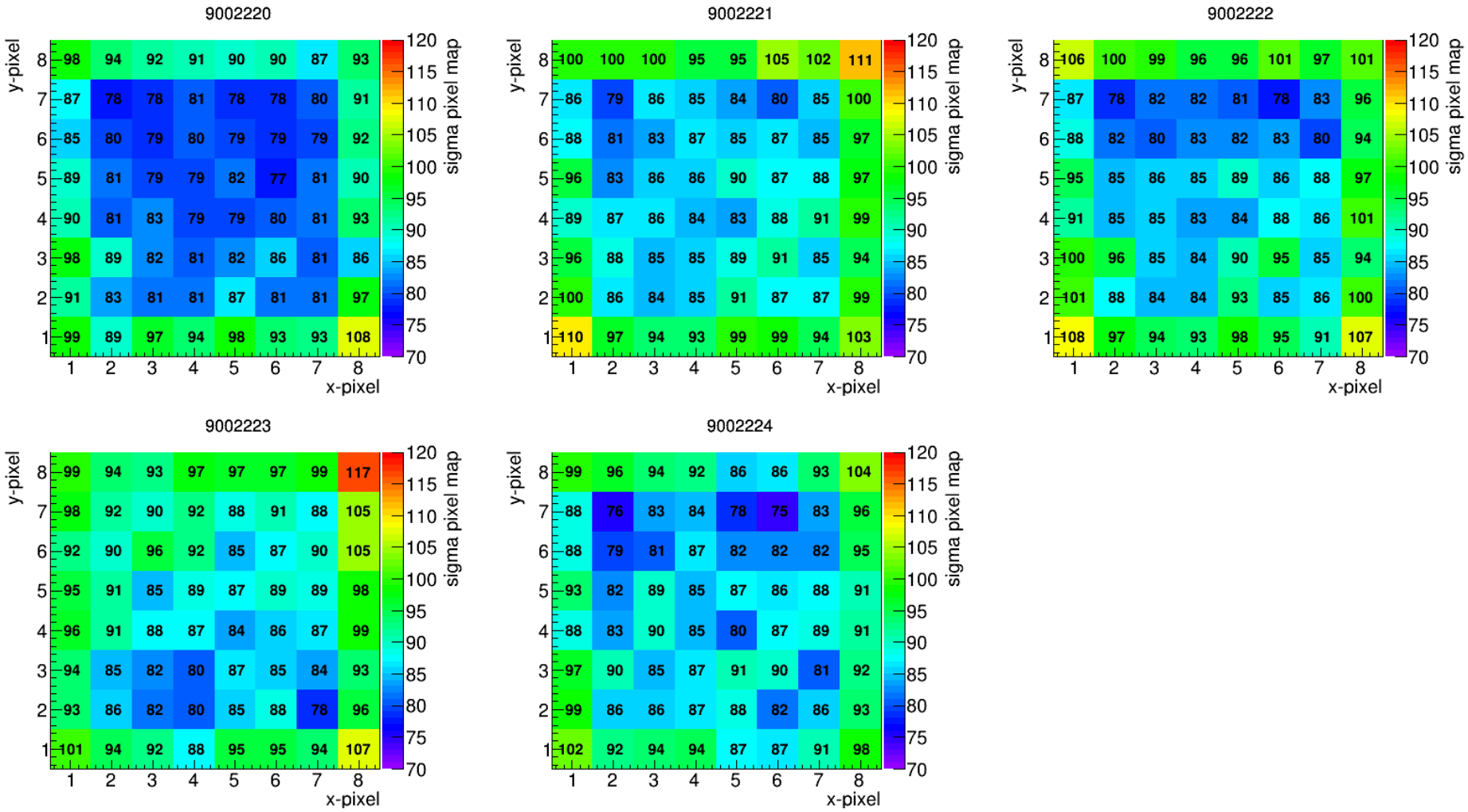






σ timing with high PC-MCP voltage

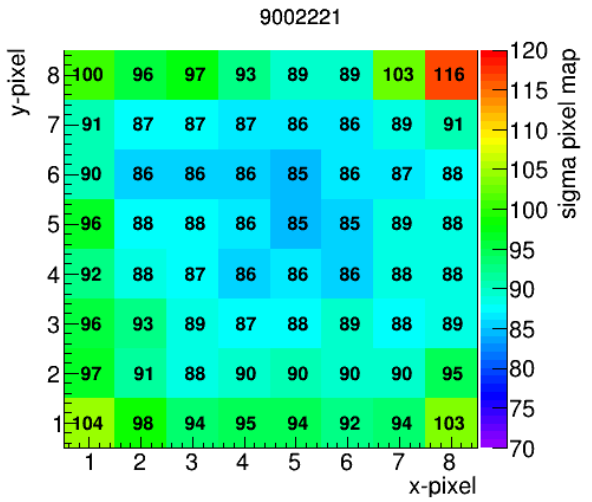
- 4:10:1 divider
- σ timing measured with TRB/DiRICH DAQ
- σ timing <100 ps for >90% of all pixels for combined tube-DAQ system and over full pixel area

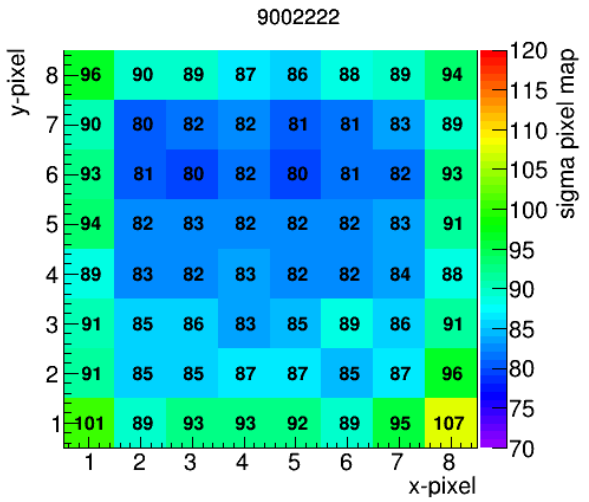


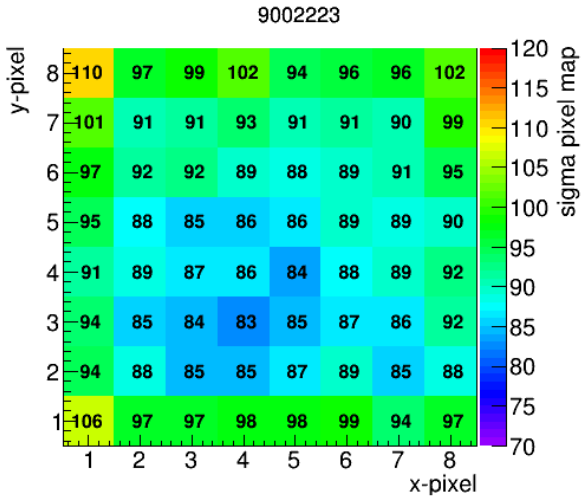
σ timing with low PC-MCP voltage as comparison

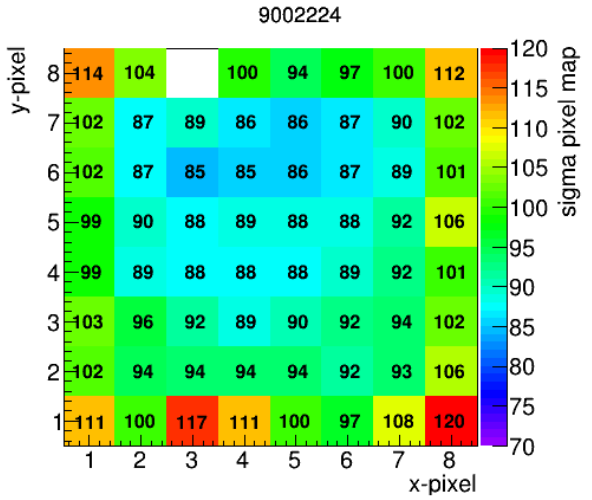
- 1:10:1 divider
- σ timing measured with TRB/DiRICH DAQ
- σ timing <100 ps for >90% of all pixels for combined tube-DAQ system and over full pixel area
- ➢ **No major changes in timing**

9002220
not measured yet



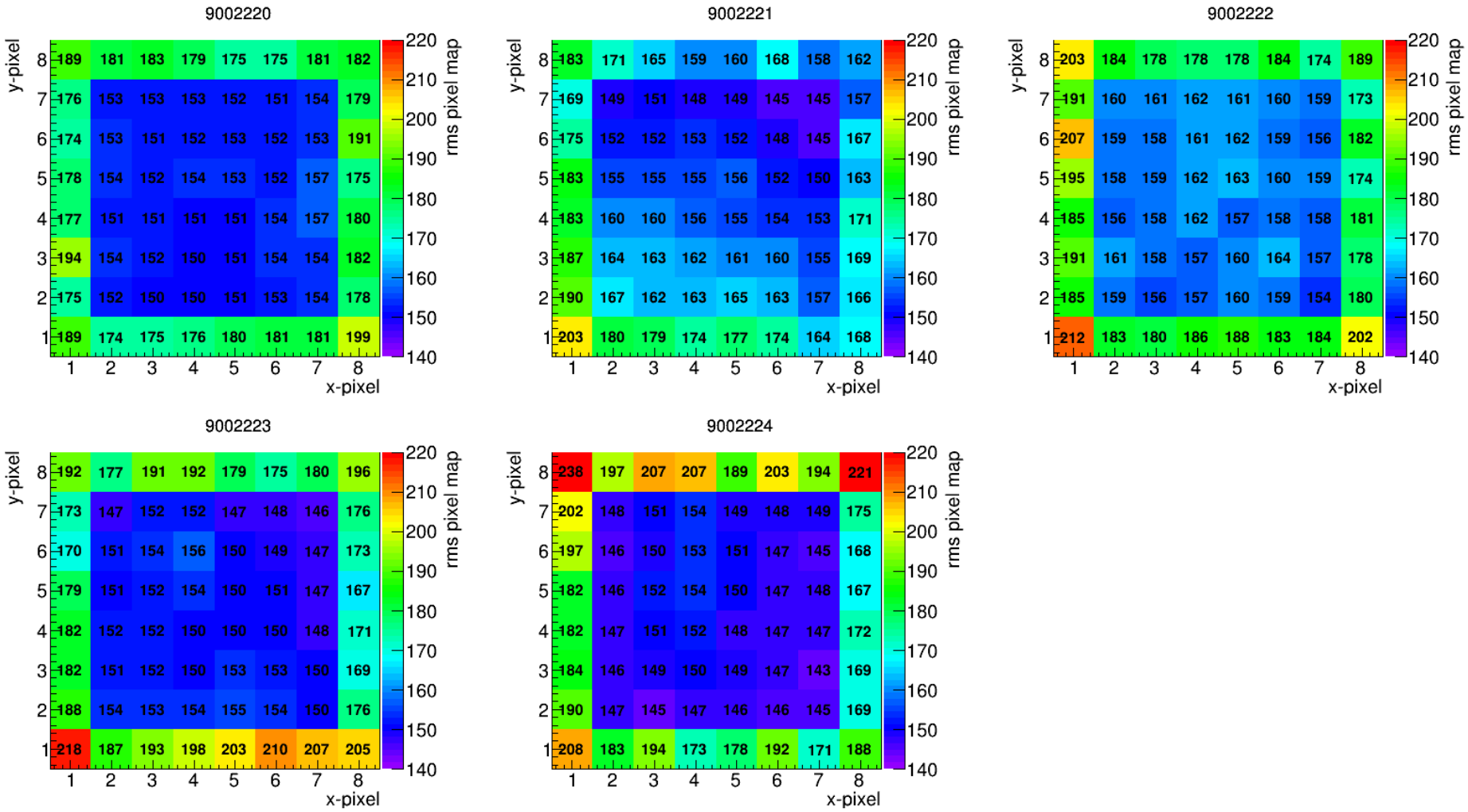






RMS timing with high PC-MCP voltage

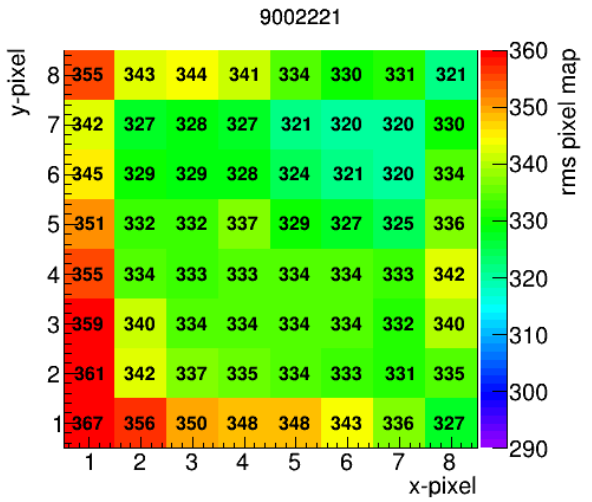
- 4:10:1 divider
- RMS timing measured with TRB/DiRICH DAQ
- Time window: -0.5 - +2 ns around main peak
- RMS timing **<200 ps** for >95% of all pixels for combined tube-DAQ system and over full pixel area

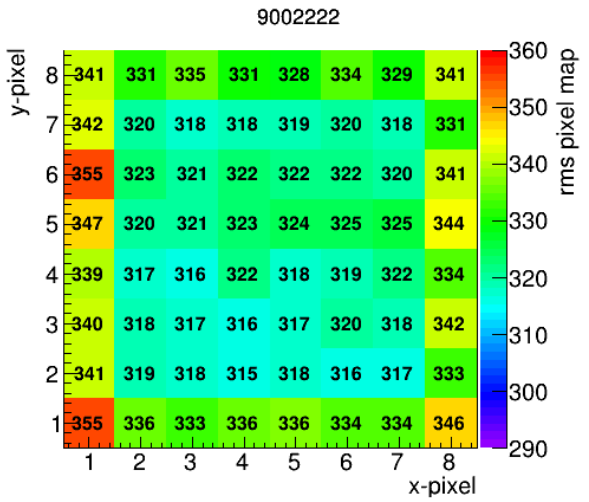


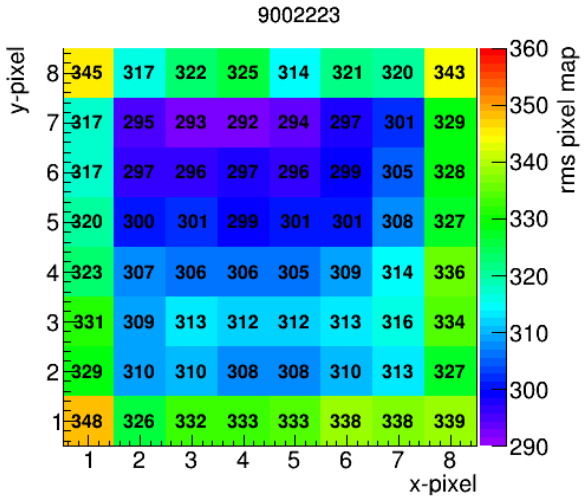
RMS timing with low PC-MCP voltage

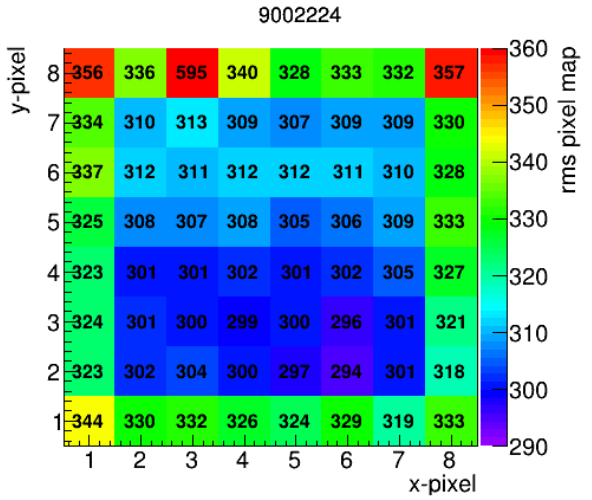
- 1:10:1 divider
- RMS timing measured with TRB/DiRICH DAQ
- Time window: -0.5 - +2 ns around main peak
- RMS timing **>300 ps** for >90% of all pixels for combined tube-DAQ system and over full pixel area
- High PC-MCP voltage reduces RMS timing by factor of **~2**

9002220
not measured yet







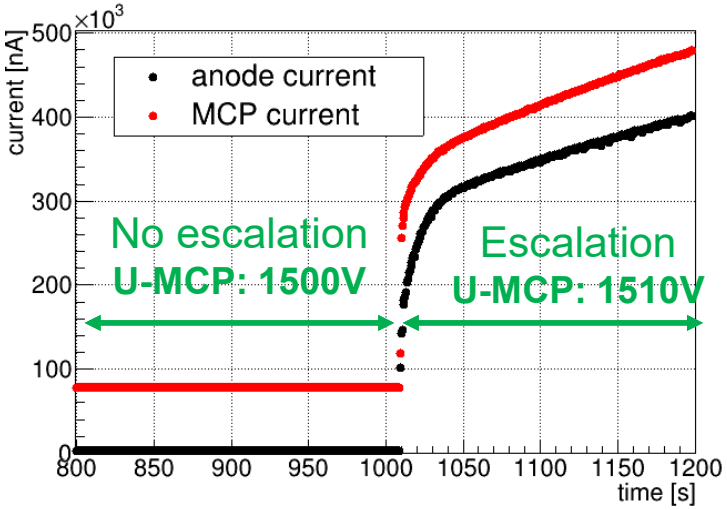


Means of TRB scans

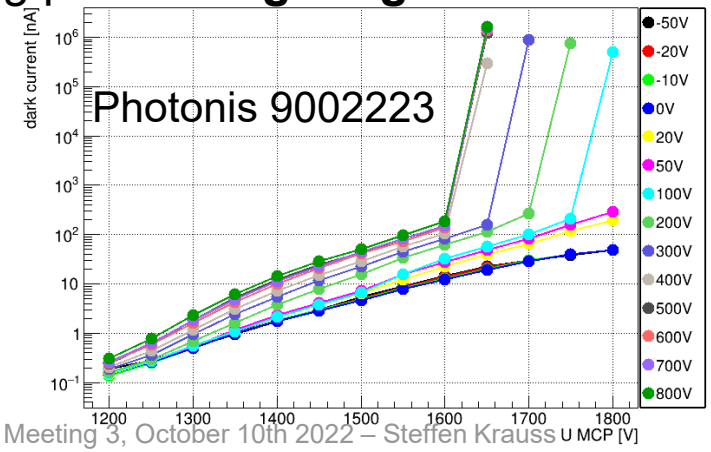
	9002220		9002221		9002222		9002223		9002224	
Dark count rate [Hz/cm²]	2100		2195		1870		247		558	
Afterpulseratio p. pixel [%]	2.0		18.8		1.8		0.7		0.7	
TTS low voltage p. pixel [ps]			91		90		92		94	
TTS high voltage p. pixel [ps]	86		91		90		92		88	
RMS low voltage p. pixel (inner/ outer area) [ps]			330	343	307	354	304	329	305	341
RMS high voltage p. pixel (inner/ outer area) [ps]	153	181	155	172	159	186	151	186	148	189

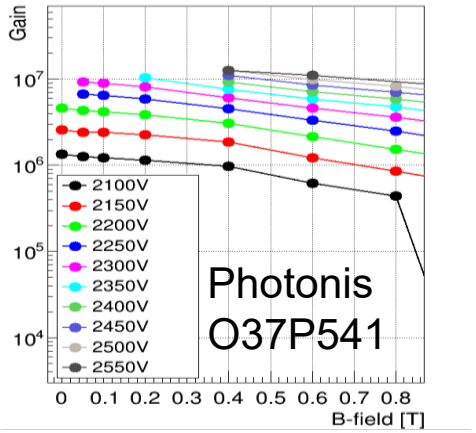
Effects seen in escalation mode summary

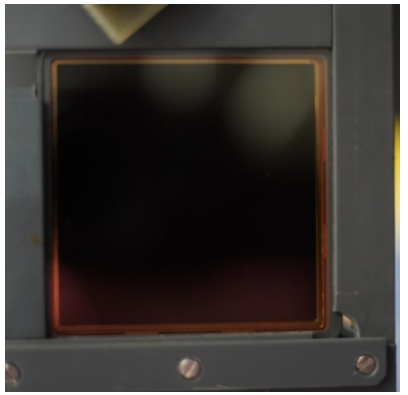
- B-field measurements showed strange effects (“escalation“) when decreasing field to 0 T, first observed in fall 2020
- Start of “escalation“ depends on gain and/or illumination conditions
- List off effects seen during “escalation“:
  - Higher current across the MCPs (factor >3) → resistivity drop
  - Seems to have no equilibrium state, steady increase of currents
  - High (dark) count rate and high anode current
  - Smaller signals → gain drop
  - **photon creation**
  - Effects appear to be less serious inside magnetic field
- Escalation behaviour only appears with latest Photonis tubes
- By optimizing the ALD process Photonis was able to **shift** the ”escalation” starting point **to higher gains for 9002221-9002224**



Reason: photon creation inside the MCP-PMT, can be seen with camera or even bare eyes







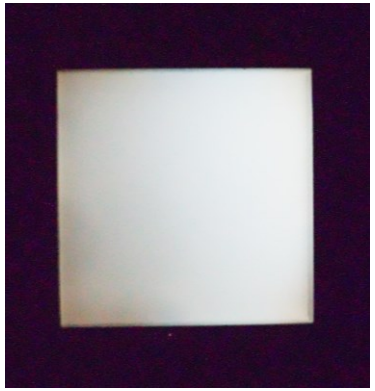


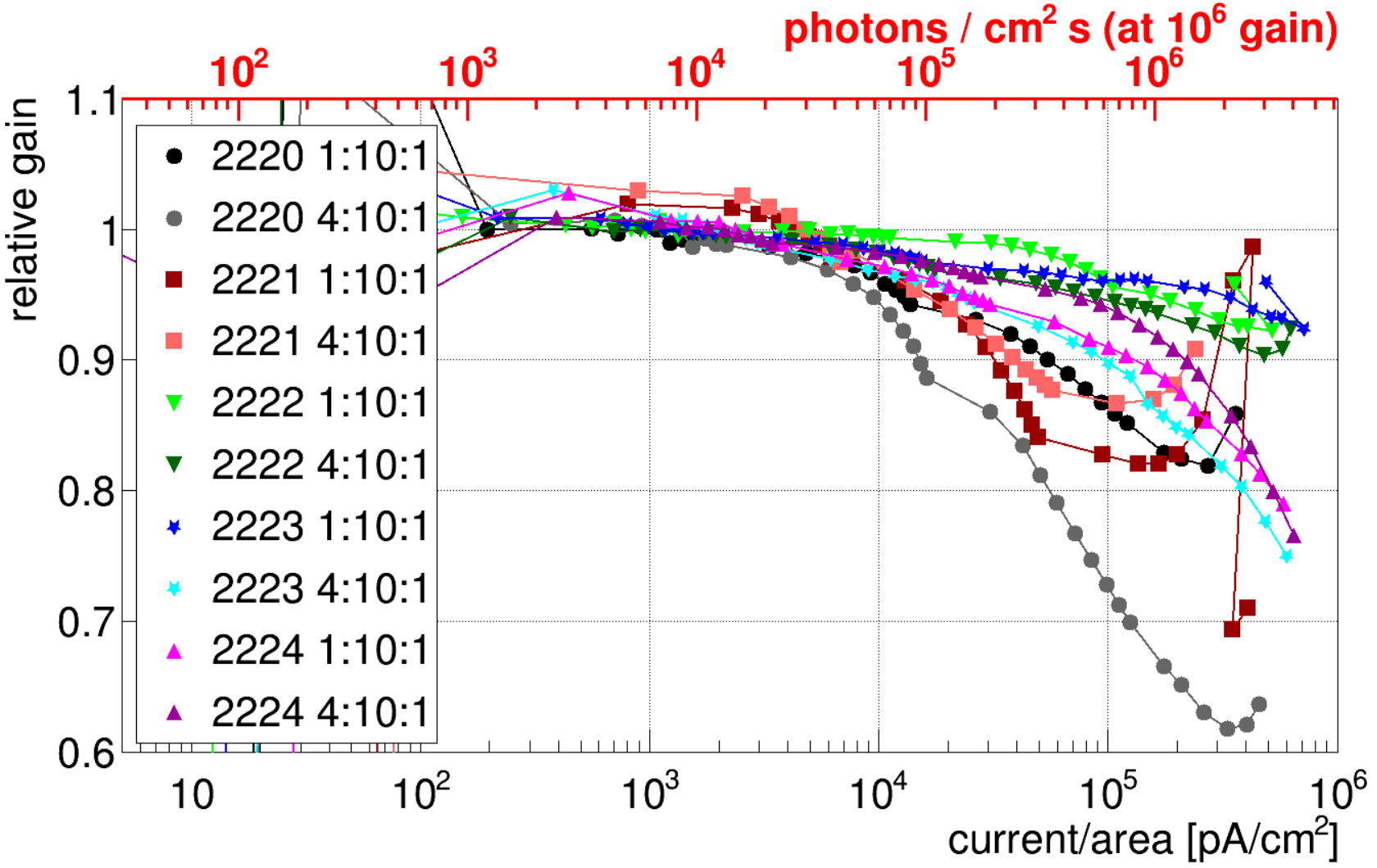
photo of PMT before operation and during escalation mode

Voltage divider discussion

GEFORDERT VOM
Bundesministerium für Bildung und Forschung

Rate capability

- Curves plotted for both voltage dividers
- Dependencies not yet visible → need to improve evaluation method
- Dips in some curves (e.g. 9002220, 4:10:1) not fully understood yet but DAQ related (about to disappear soon)



Dark currents vs voltages

- Dark current measurement for different PC & MCP voltage combinations
- At some point all tubes are switching into high dark current mode
- Further investigations ongoing