# Characteristics of 700 HAMAMATSU H12700 MAPMTs*

*Supported by BMBF 05P15PXFCA and GSI

- Introduction
  - Why do we need MAPMTs
  - Which MAPMT was chosen
  - The test bench working principle
  - The final build
- Measurement of ~750 MAPMTs
  - Gain
  - Efficiency
  - Dark rate
  - Efficiency Artifacts

DPG Frühjahrstagung 2017 Münster
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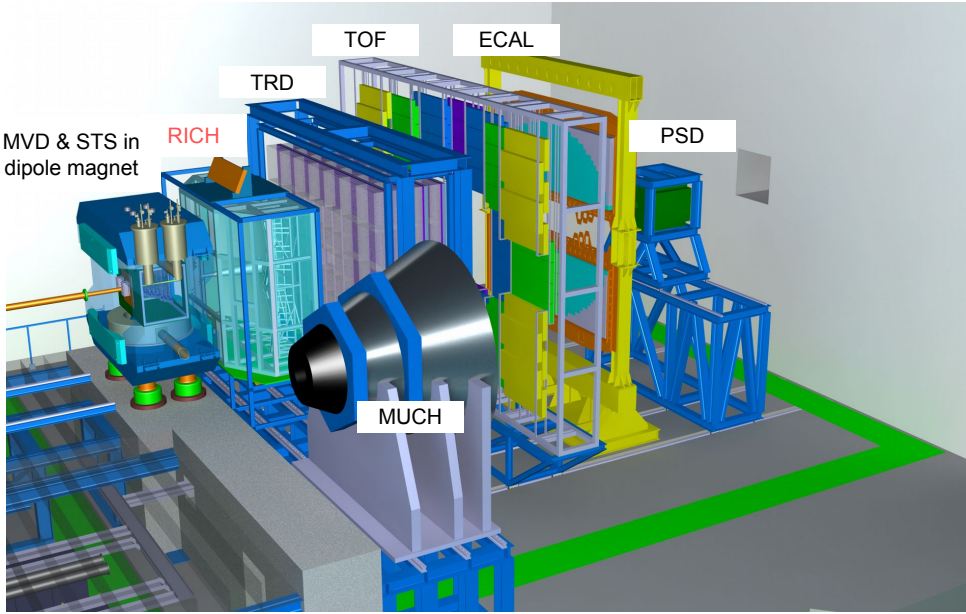
BERGISCHE UNIVERSITÄT WUPPERTAL

# Why do we need MAPMTs?

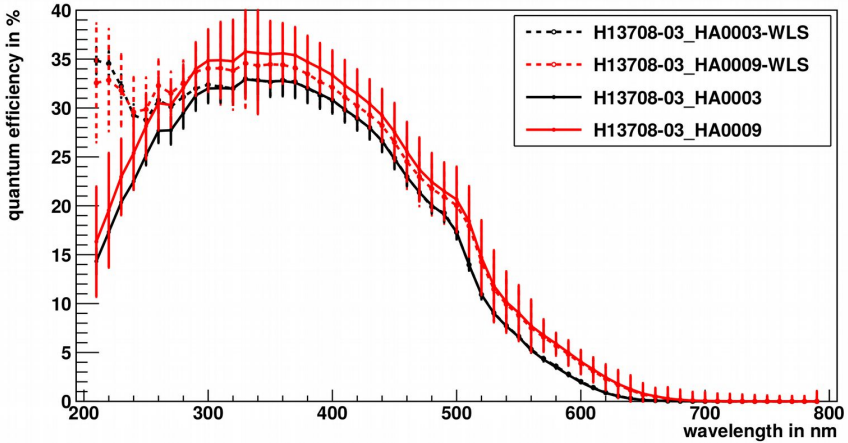
- CBM: Compressed Baryonic Matter Experiment
- Explore QCD phase diagram in the region of high net baryon densities at moderate temperatures using heavy ion collisions
- Energy range from 2 to 11 AGeV (Au + Au) at SIS100
- Electromagnetic probes providing information about:
  - Temperature of the fireball
  - Hadron dynamics
  - Thermal radiation of the fireball
- RICH:
  - Vertical splitted gaseous detector ($CO_2$)
  - Spherical mirror (Al+$MgF_2$-coated) to project rings onto photodetection plane
  - ~850 HAMAMATSU H12700 MAPMTs



# Which MAPMT was chosen

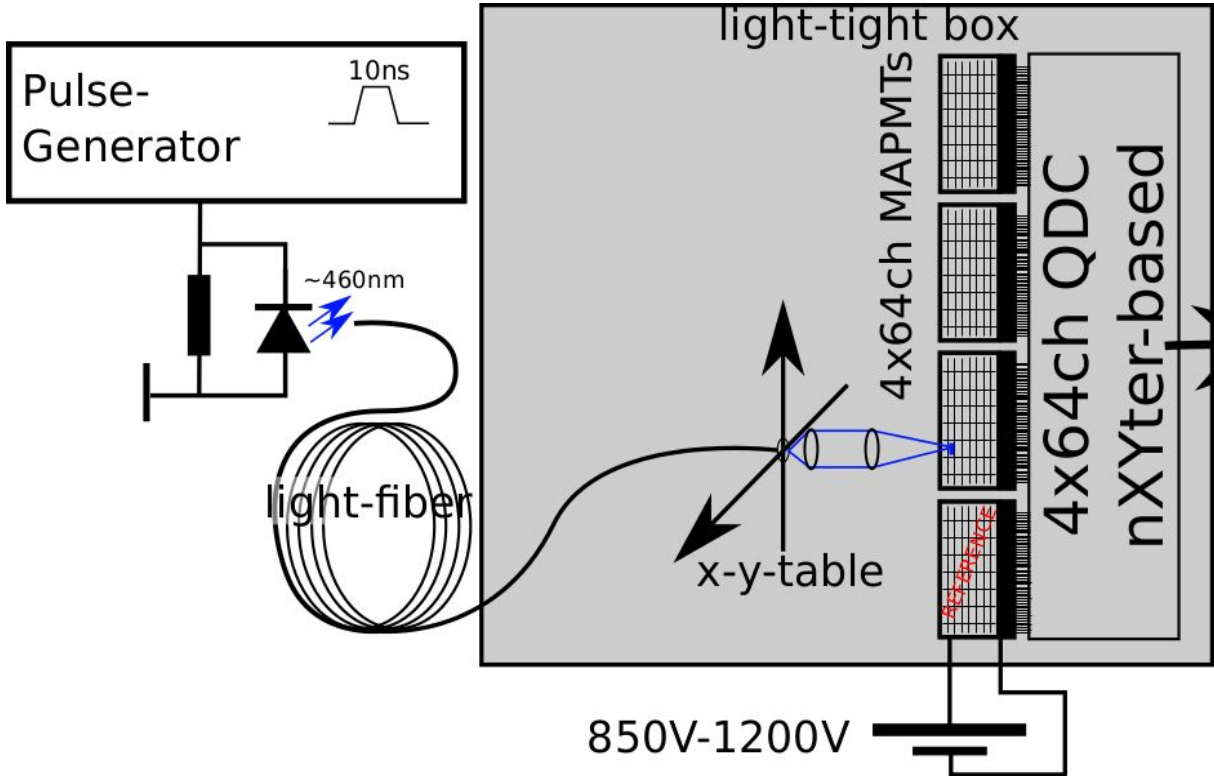
- Hamamatsu H12700 squared 52×52 $mm^2$ MAPMT
  - Combining the outer shape of the H8500 with the single photon response of the R11265
  - Clear separable single photon peak at large charges (∼1.5×$10^6$ e, 0.24 pC) using 10 dynodes
  - Blue enhanced “SBA”-cathode with high quantum efficiency
  - High collection efficiency (∼90%)
  - Large effective area featuring a high pixel resolution (64ch @ 48.5×48.5 $mm^2$)
  - Low dark rate

- Ordered 1100 HAMAMATSU H12700 MAPMTs
  - 50 being delivered each month since October 2015
- The test bench needs to be able to characterize every single MAPMT soon after delivery

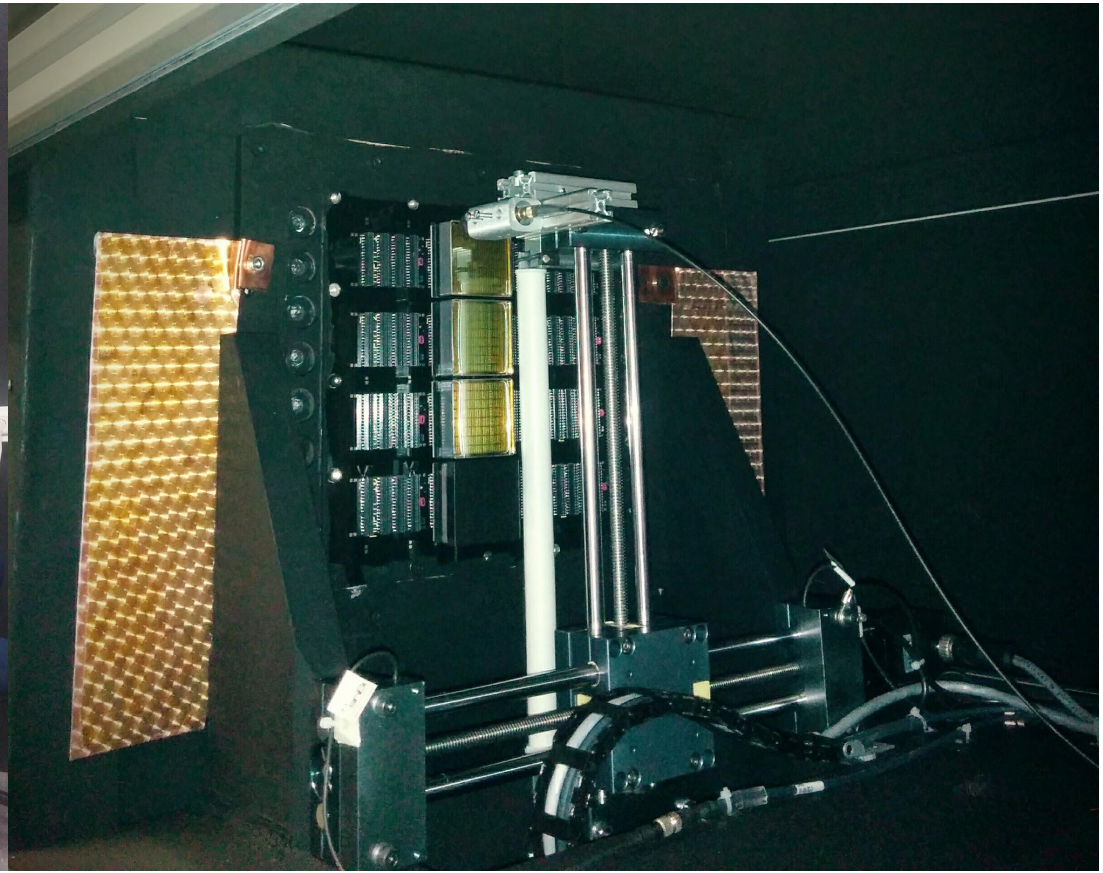


# The test bench working principle

- Triggered light-source emitting "single" photons (~1$\gamma$ / 10 pulses)
- Leading photons to single point on MAPMT
  - Optical fiber + focussing optic (~0.5 mm)
- Checking for pulses in each MAPMT channel
  - Self-triggered readout-scheme based on n-XYTER-ASIC
- Reference PMT needed

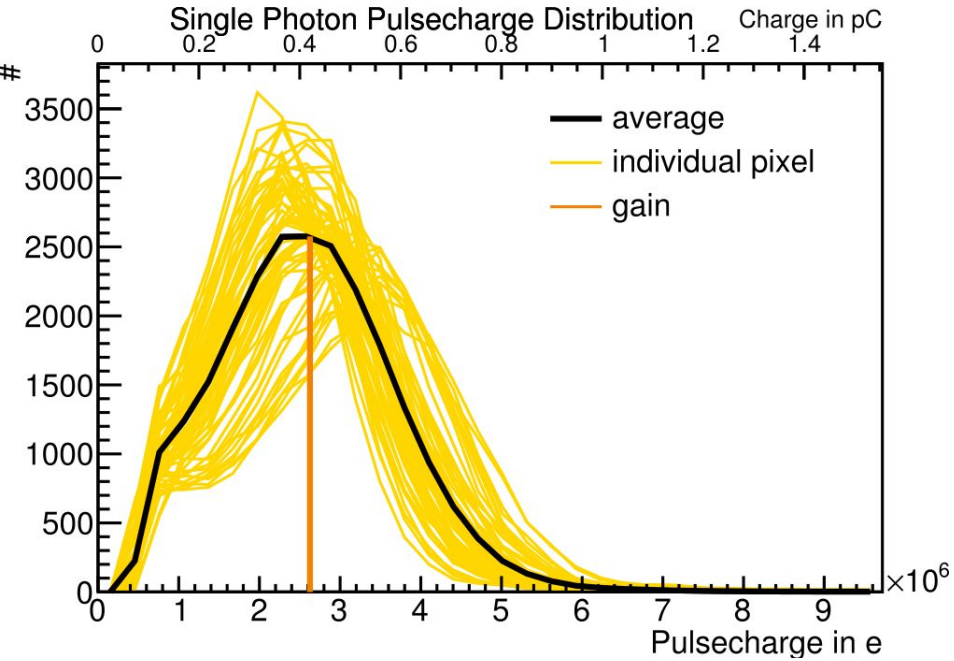


# The final build

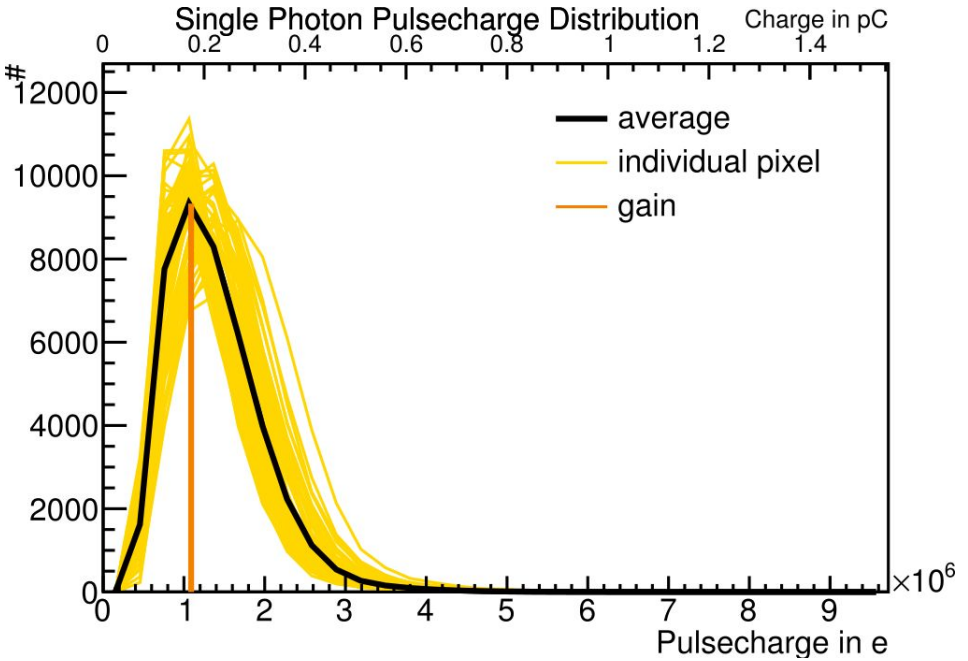


# Gain (I)

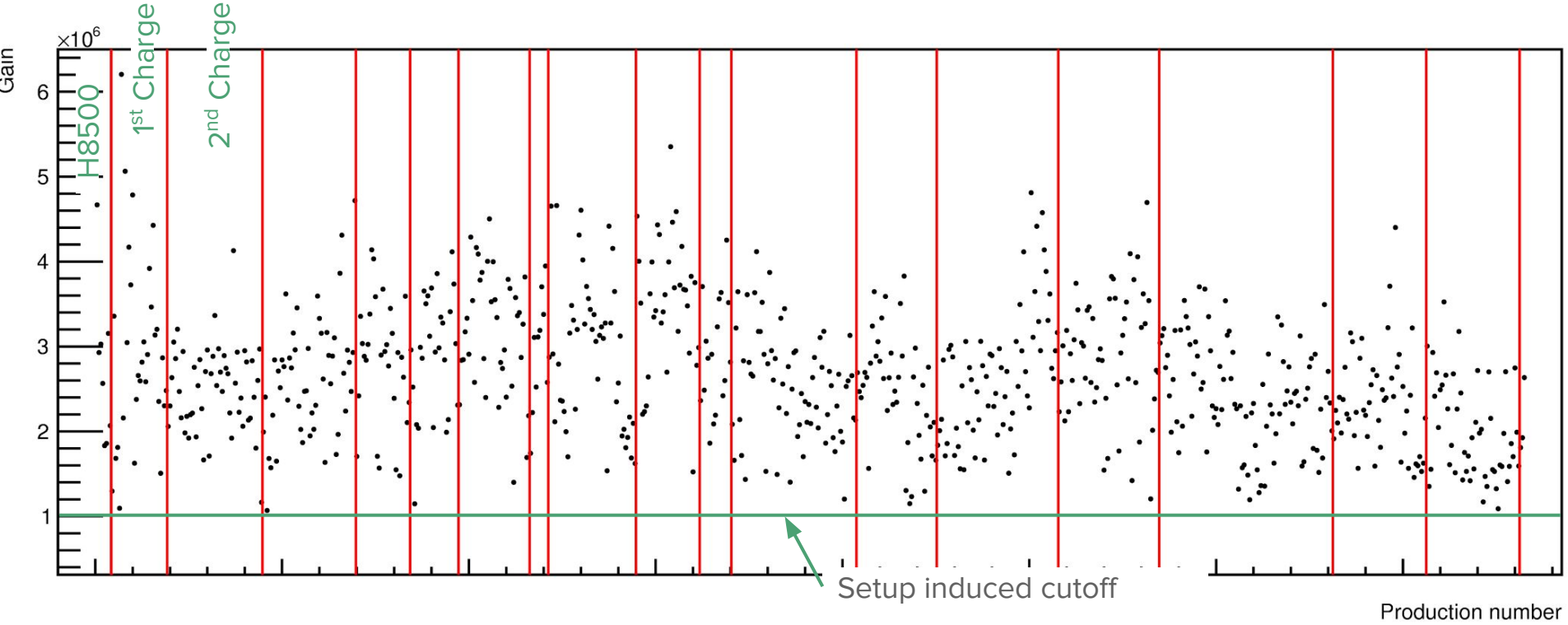
Normal Gain




Low Gain



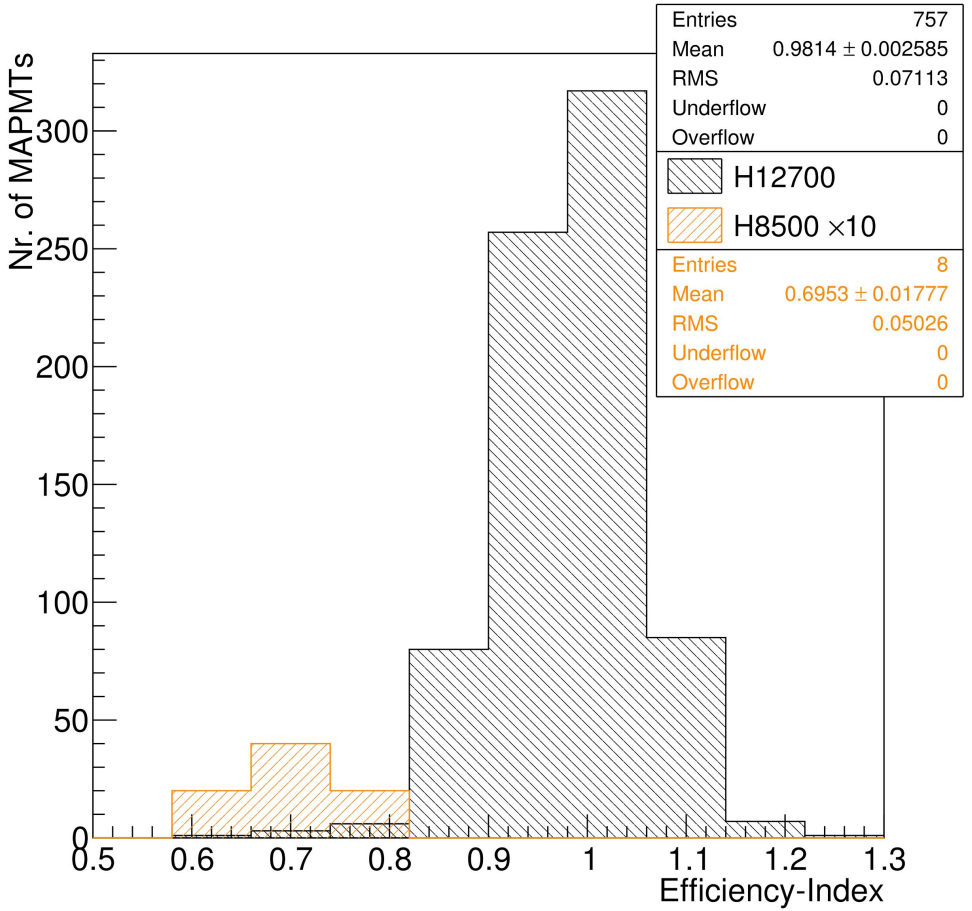
# Gain (II)



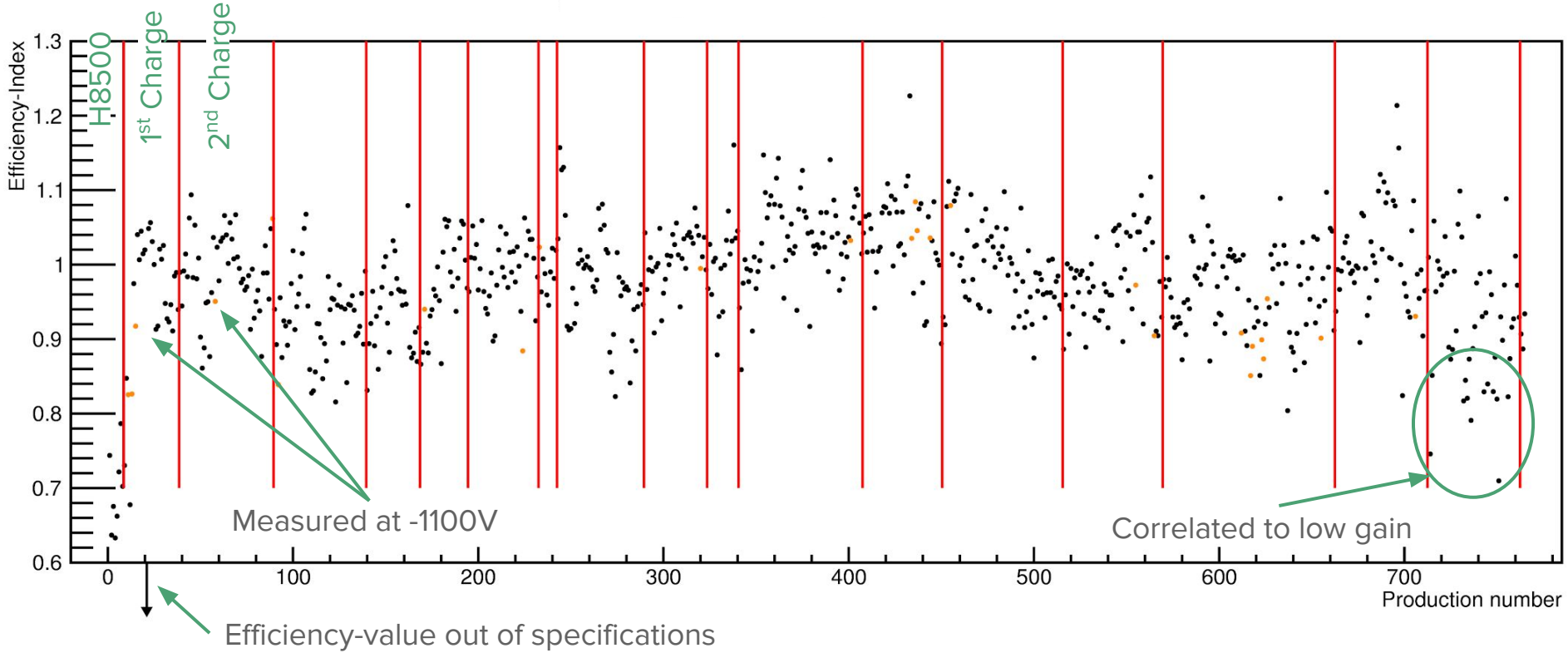

- Up to now: Low gain MAPMTs measured again with higher voltage
- Soon: Change attenuator and recalibrate test bench accordingly

# Efficiency-Index (I)

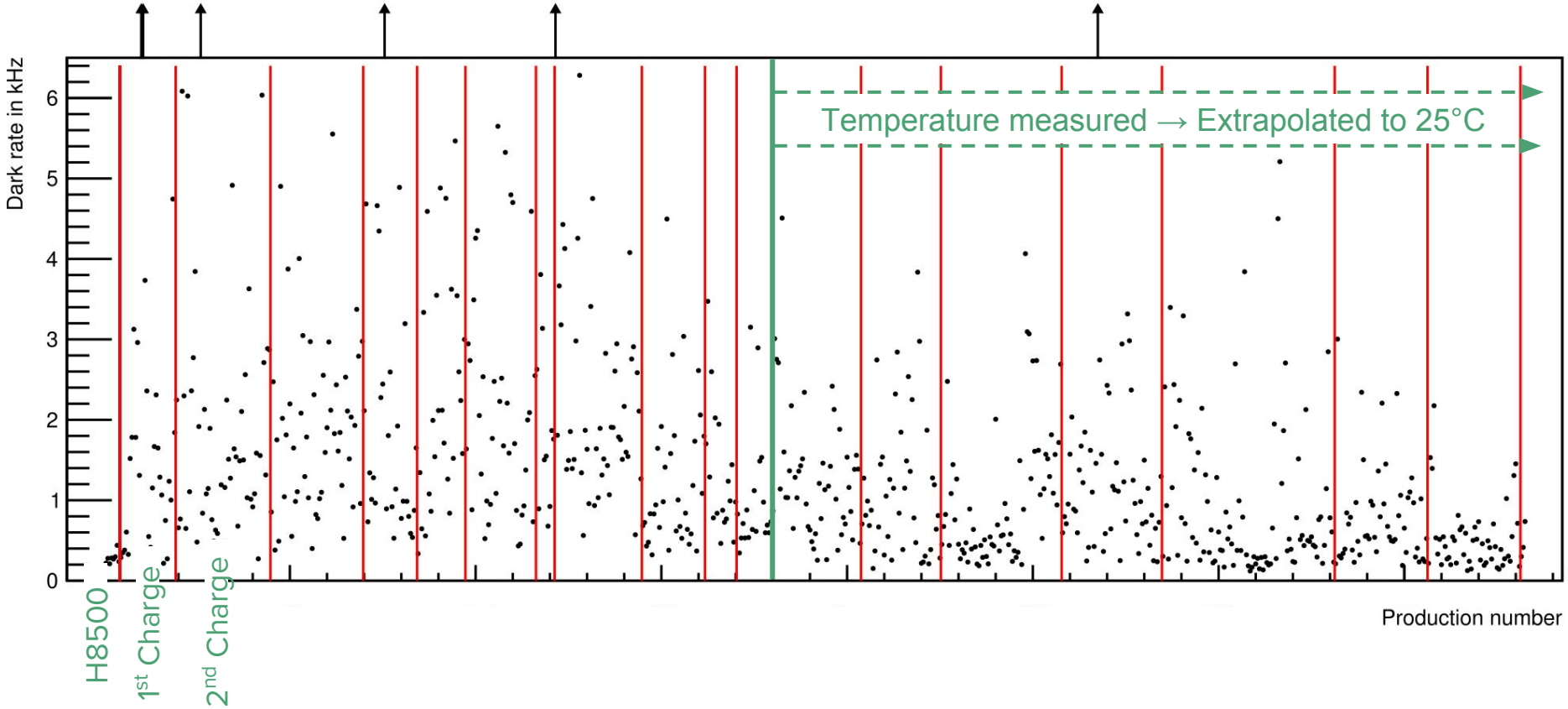
- Efficiency:
  - Detected photons divided by trigger pulses
- Efficiency-Index:
  - Average efficiency over the PMT-surface
  - Scaled to “Efficiency-Index” of the reference MAPMT
- Efficiency of H12700 higher than that of the H8500
  - Not only explainable by increased QE



# Efficiency-Index (II)



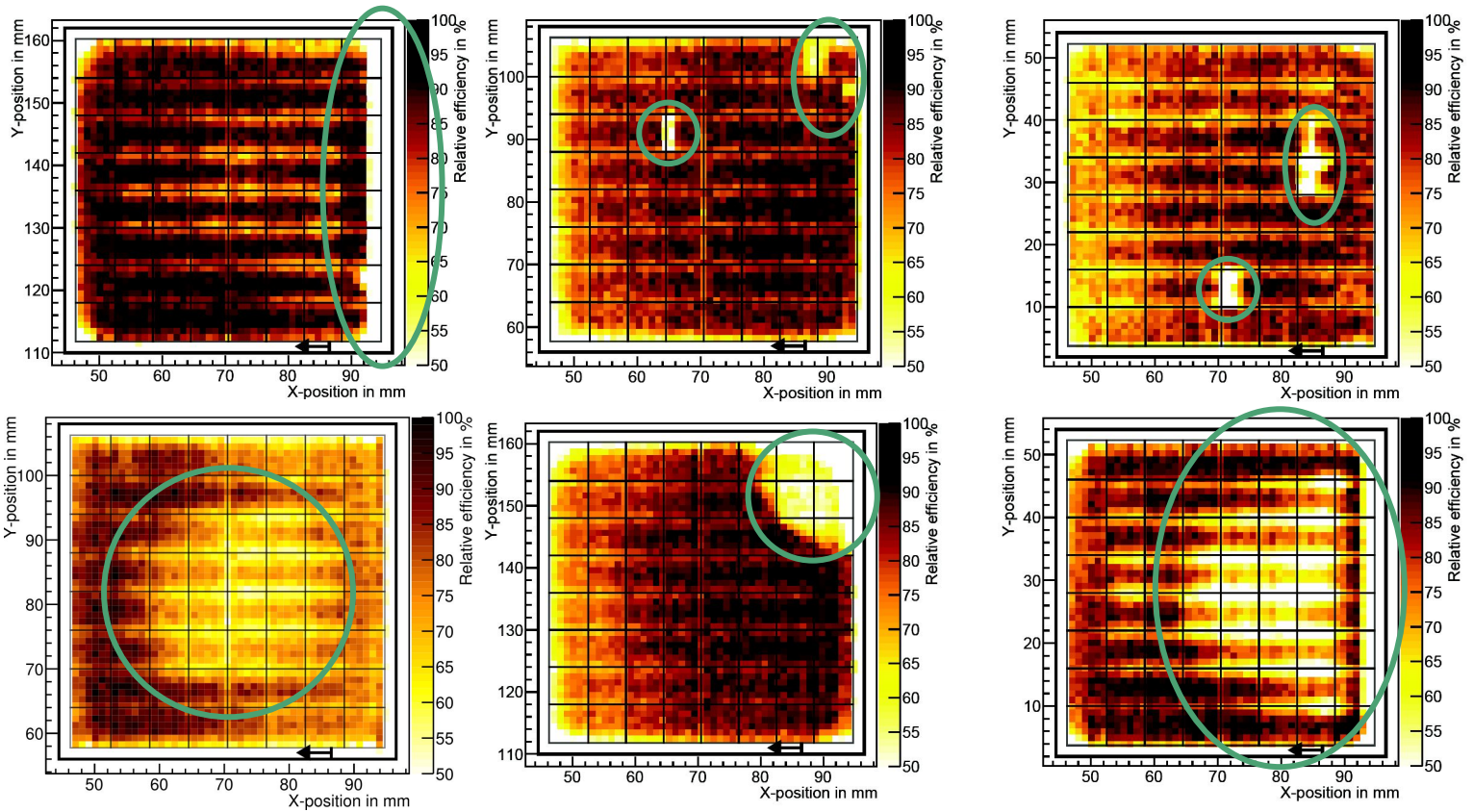
# Dark rate


Dark rate in kHz
0
1
2
3
4
5
6
Temperature measured → Extrapolated to 25°C
Production number
H8500
1st Charge
2nd Charge

# Efficiency artifacts (I)

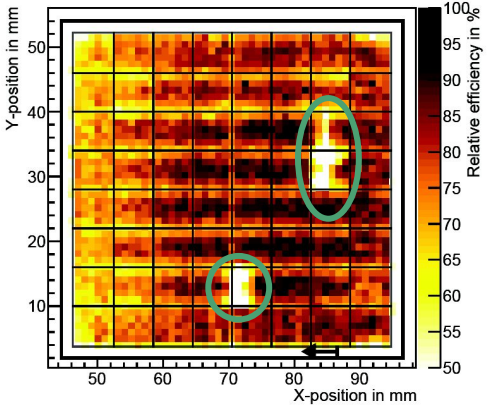
CE/Dynode-Related

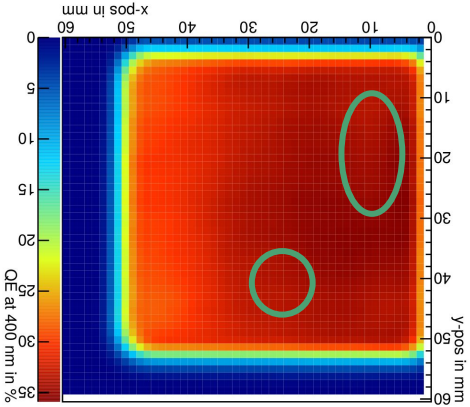
QE-Related



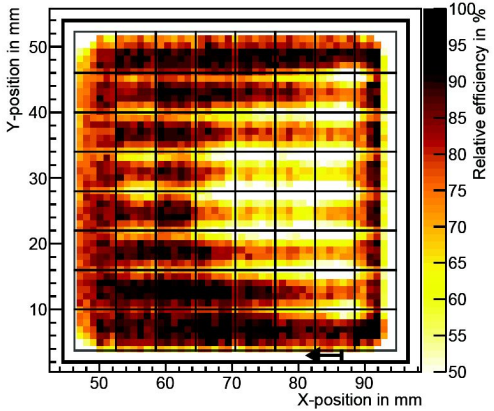
# Efficiency artifacts (II)

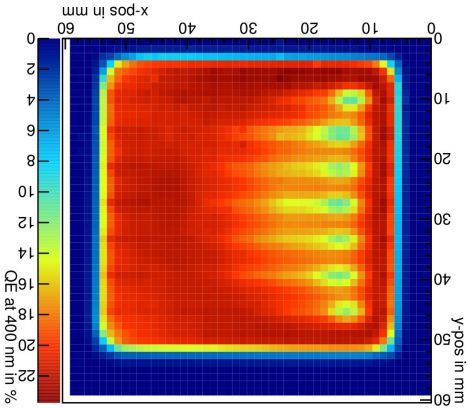
CE/Dynode-Related




QE-Related



# Summary

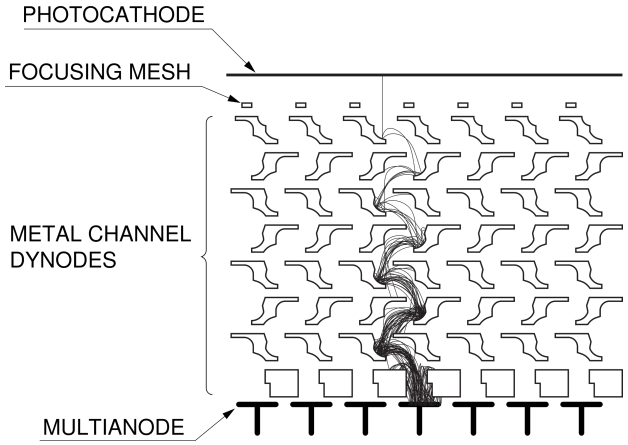
- Currently 757 HAMAMATSU H12700 MAPMTs measured
- Valuable results obtained by test bench to cross-check the distributors QA
- MAPMT Efficiency-artifacts could were observed
- High gain for nearly all H12700 ($>1.5\times10^6$)
- Higher efficiency than predecessor H8500 but also higher dark rate
- Modificate test bench to better cross check the gain requirements

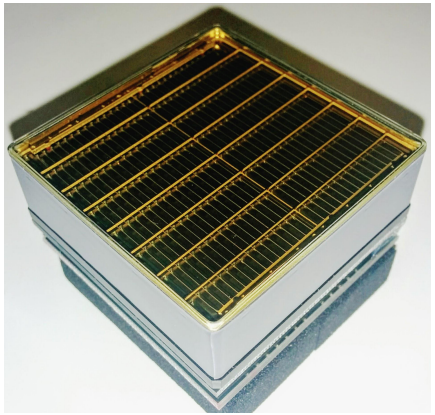
# Thank you for your attention

# Backup

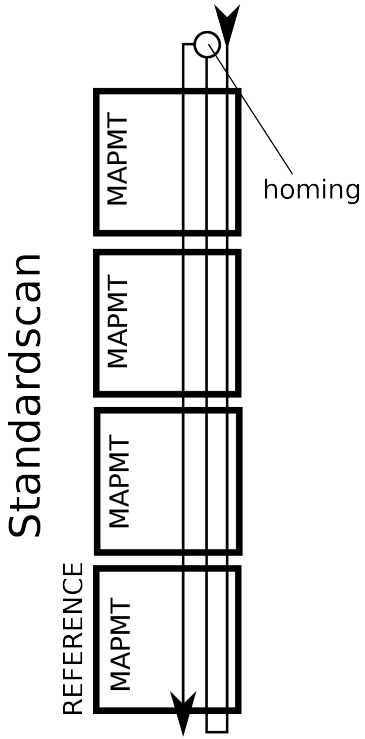
# What is a MAPMT?

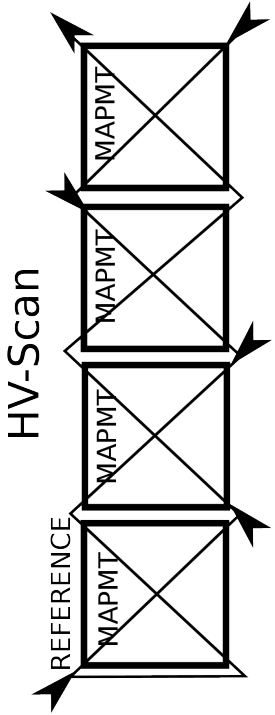
- **M**ulti**A**node-**P**hoto**M**ultiplier-**T**ube
- Device to measure photons spatially resolved
- One or more dynode-channels per anode-pad



# Standard-Measurement



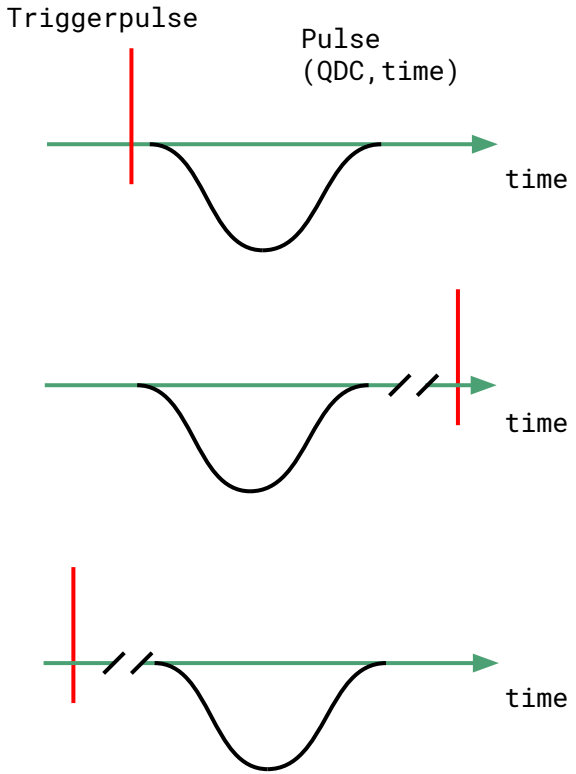




- Meander-shaped scan measuring every mm for 3.8 sec
- Homing every second row to diminish any step-losses
- HV-scan after normal scan
  - Cross shaped scan-movement
  - Measuring only 16 pixel per MAPMT
- One Scan takes 1h+7h+0.5h

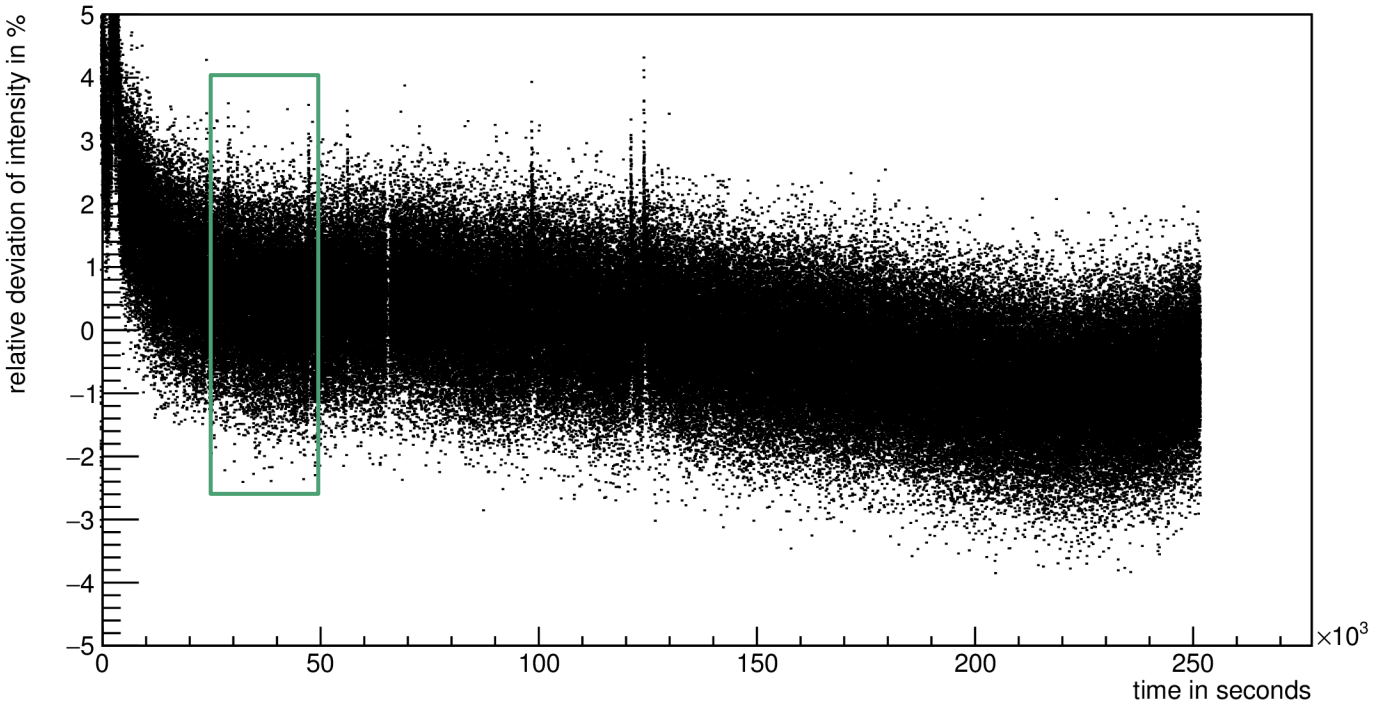
- Precision of minimum ±0.5mm over one scan

# Data-Analysis

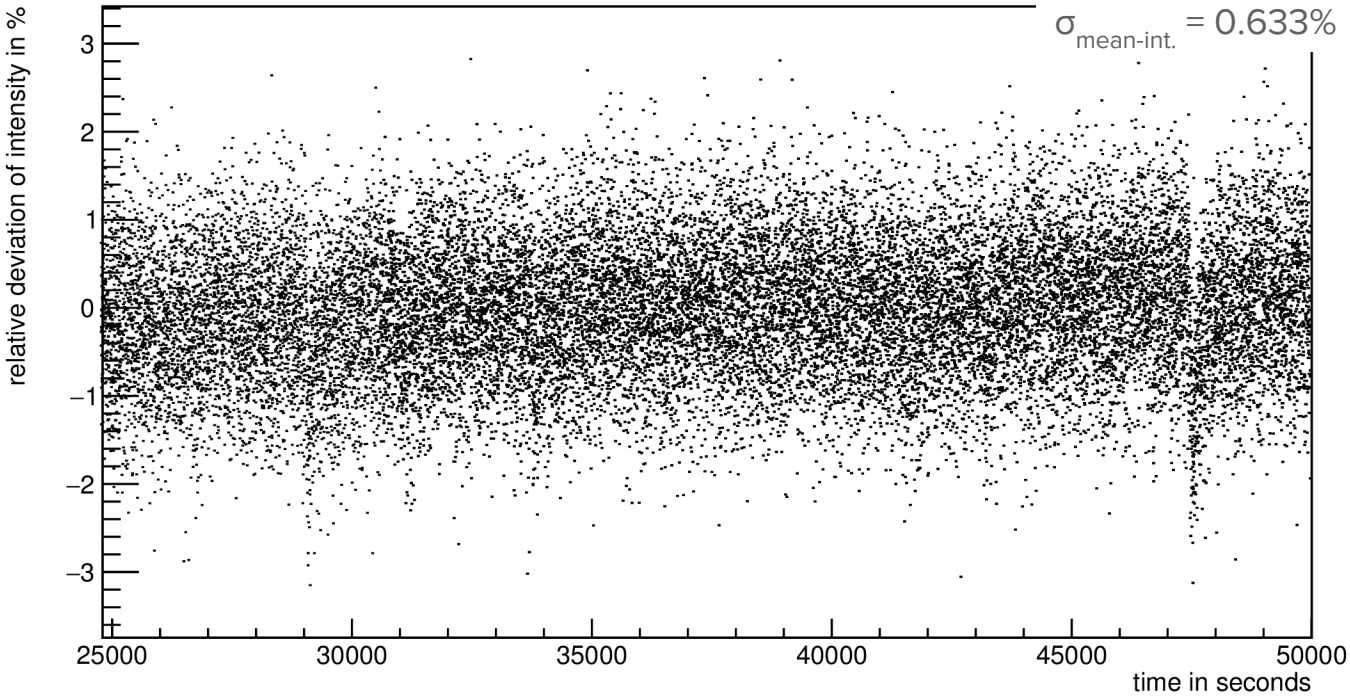
- Real Hits
  - Relative efficiency
  - ADC-spectra
    - Gain per pixel
    - Gain for diff. HV
  - Double Hit probability
- Uncorrelated Hits
  - Dark rate vs. time
  - Dark rate per pixel
- “Afterpulse” Hits
  - Afterpulse probability
  - Timedifference distribution



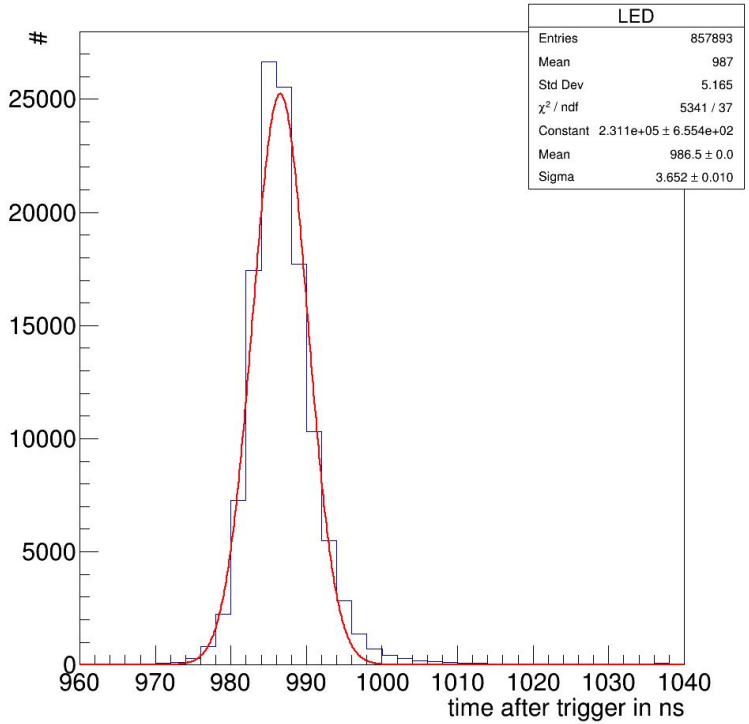
# LED intensity deviation over 70h

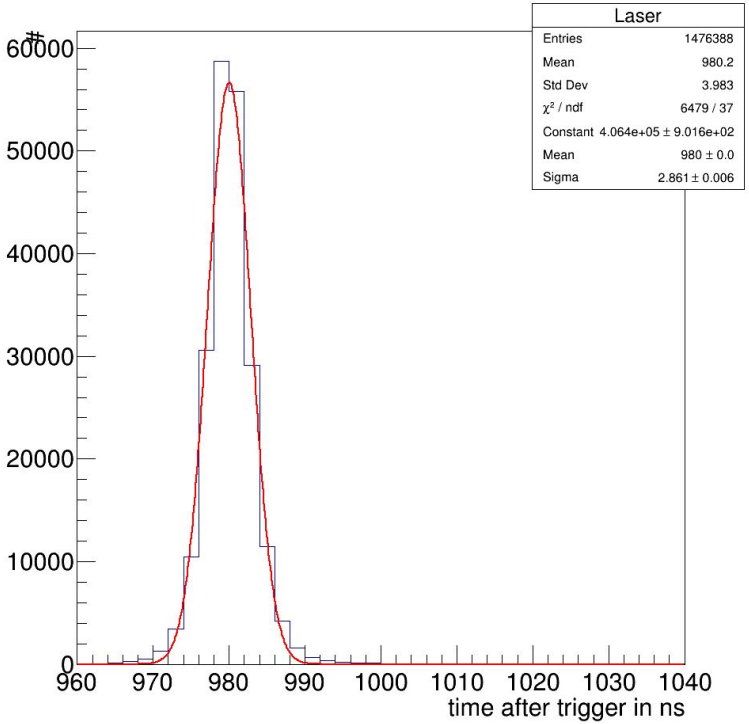


# LED intensity deviation over 7h

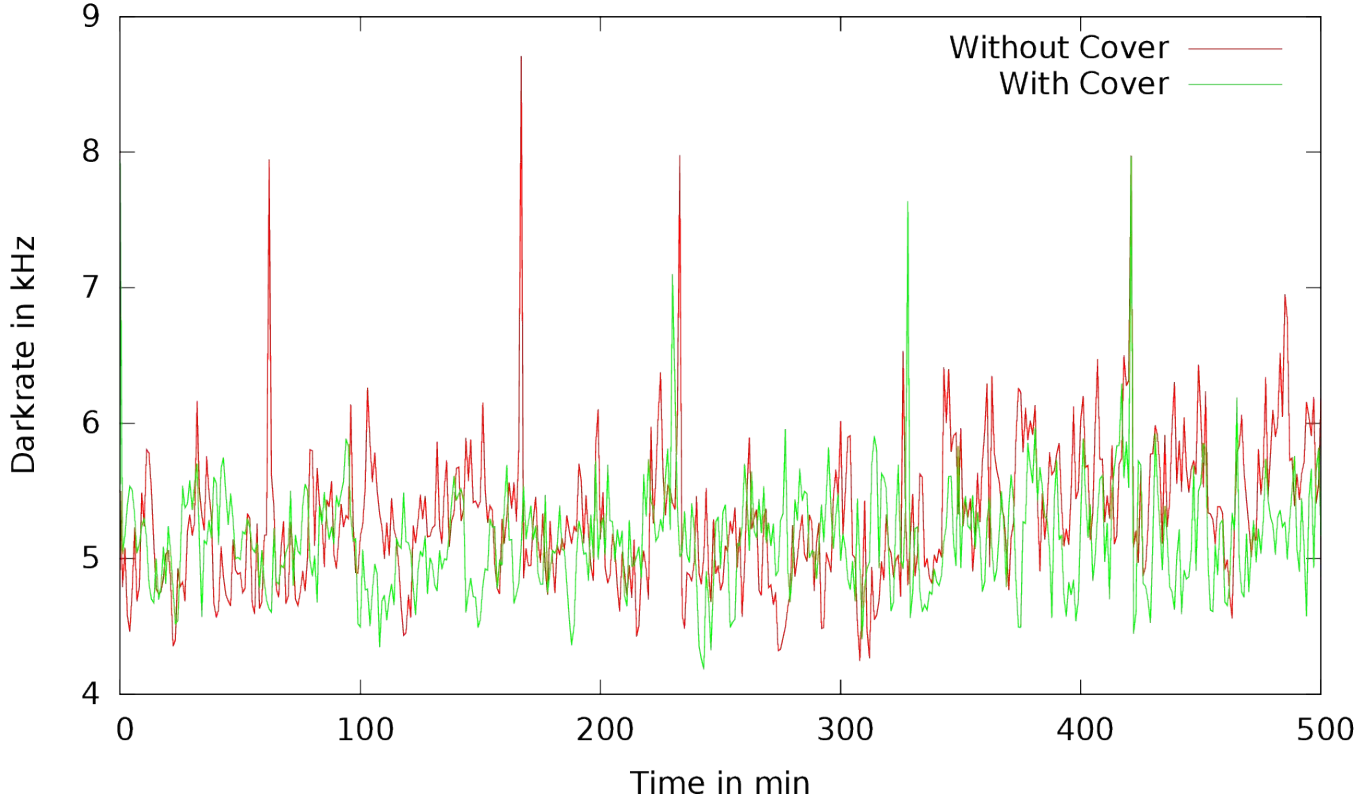


# LED-timespread

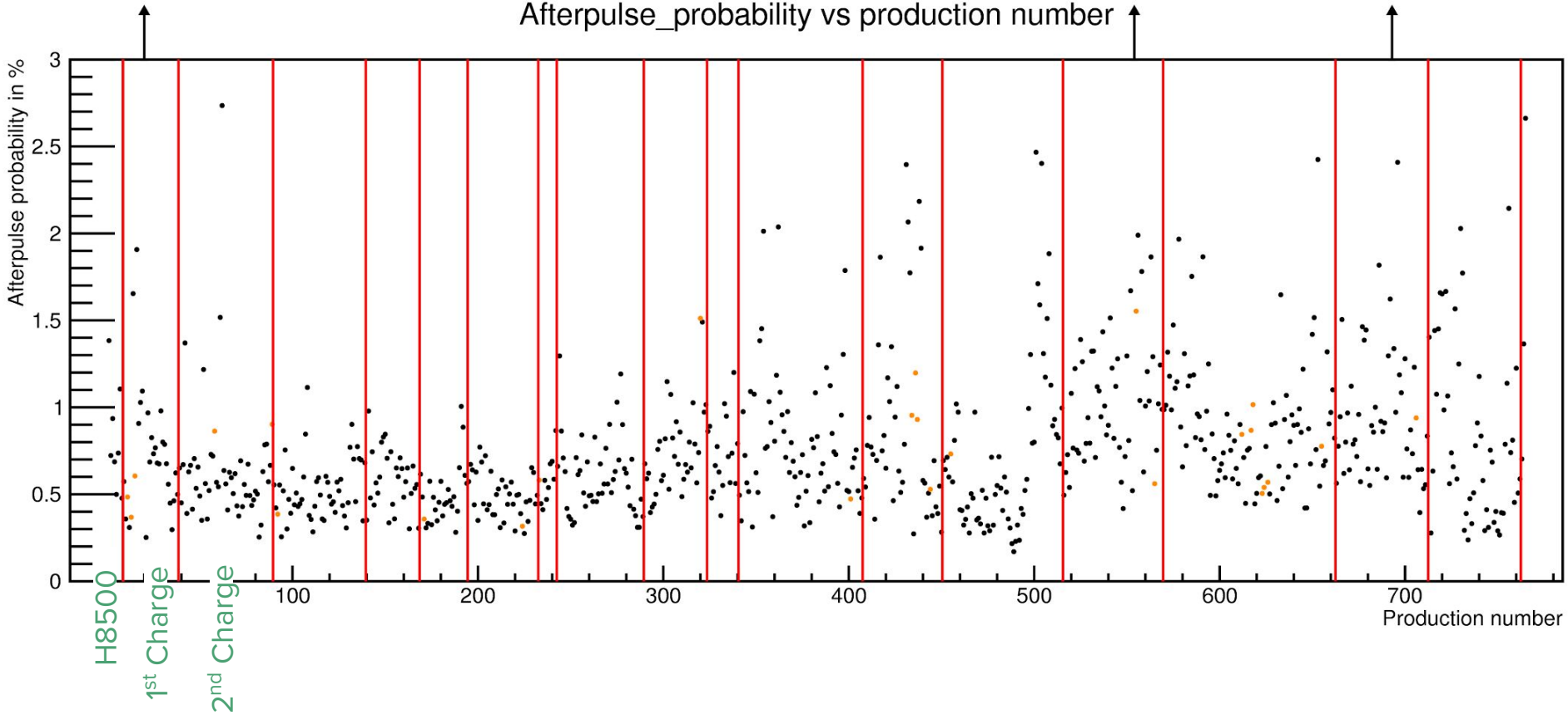


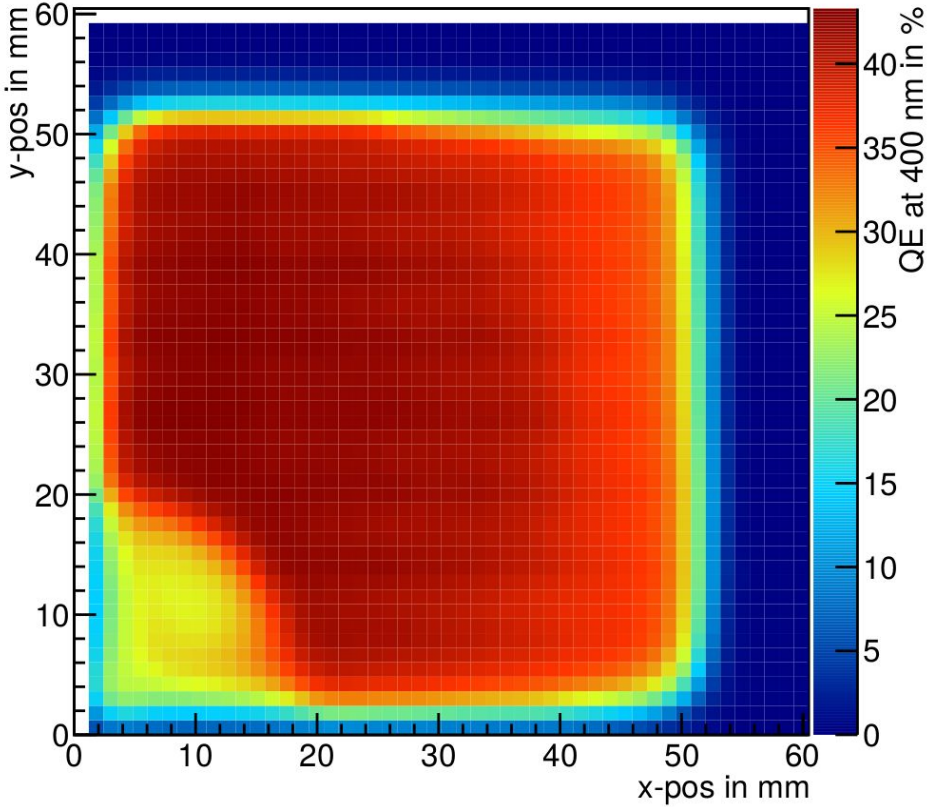
# Light tightness

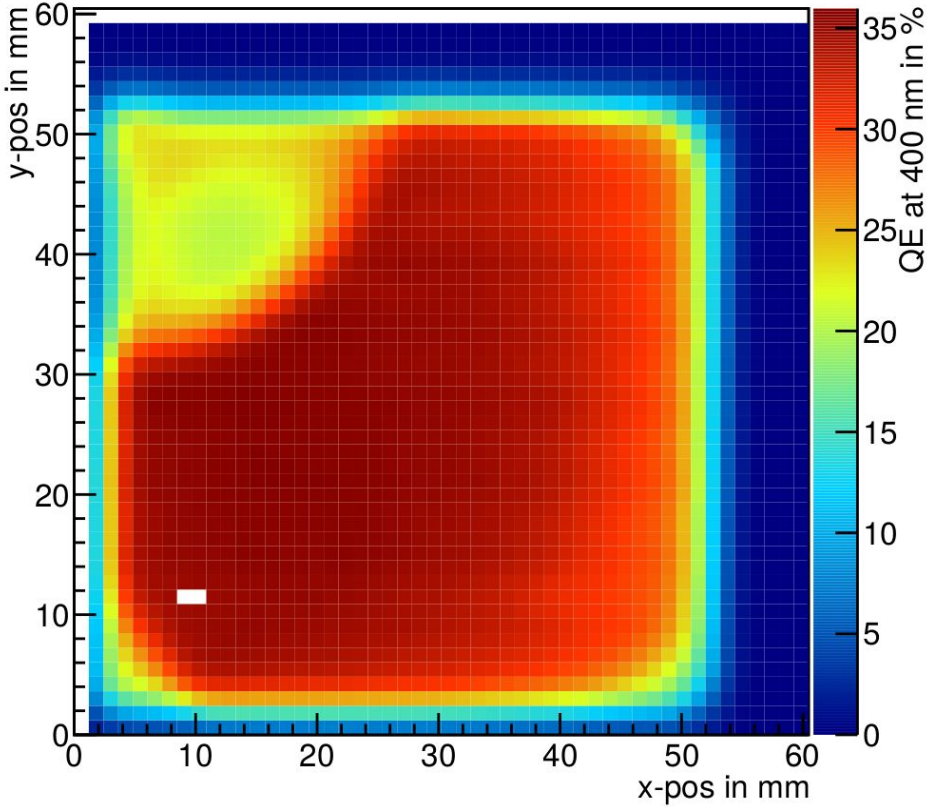


# Afterpulse probability

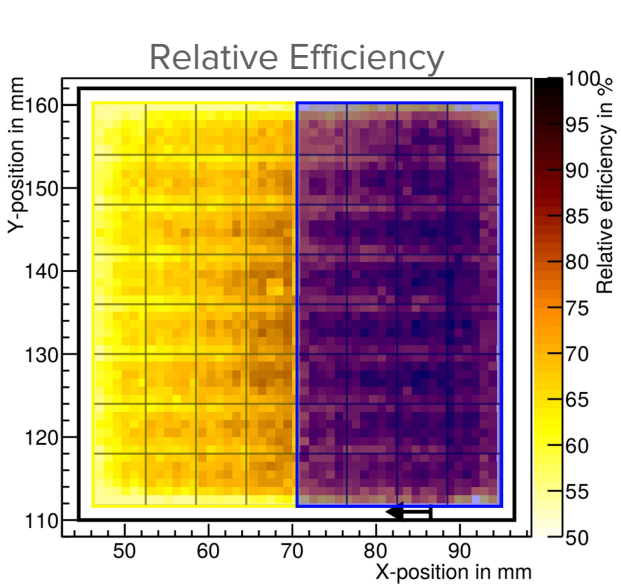


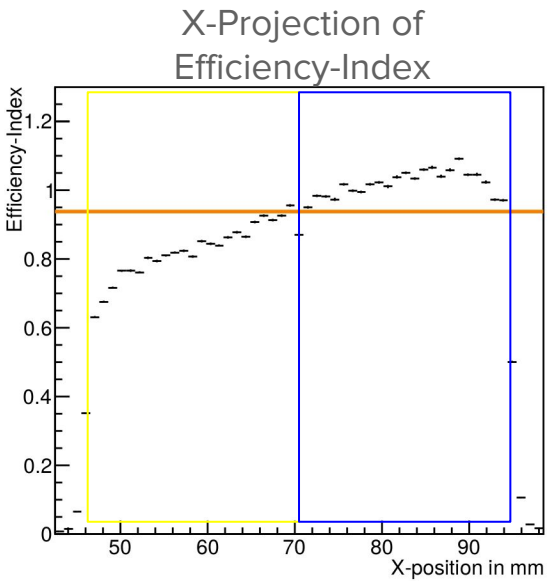
# QE-Artifacts

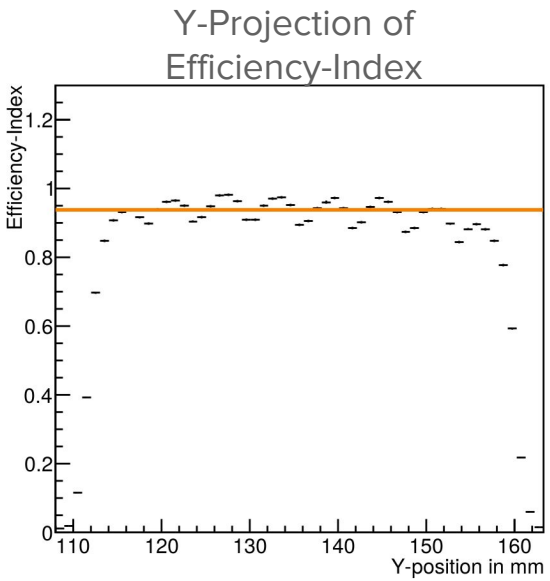


# 2D-Efficiency and Projections

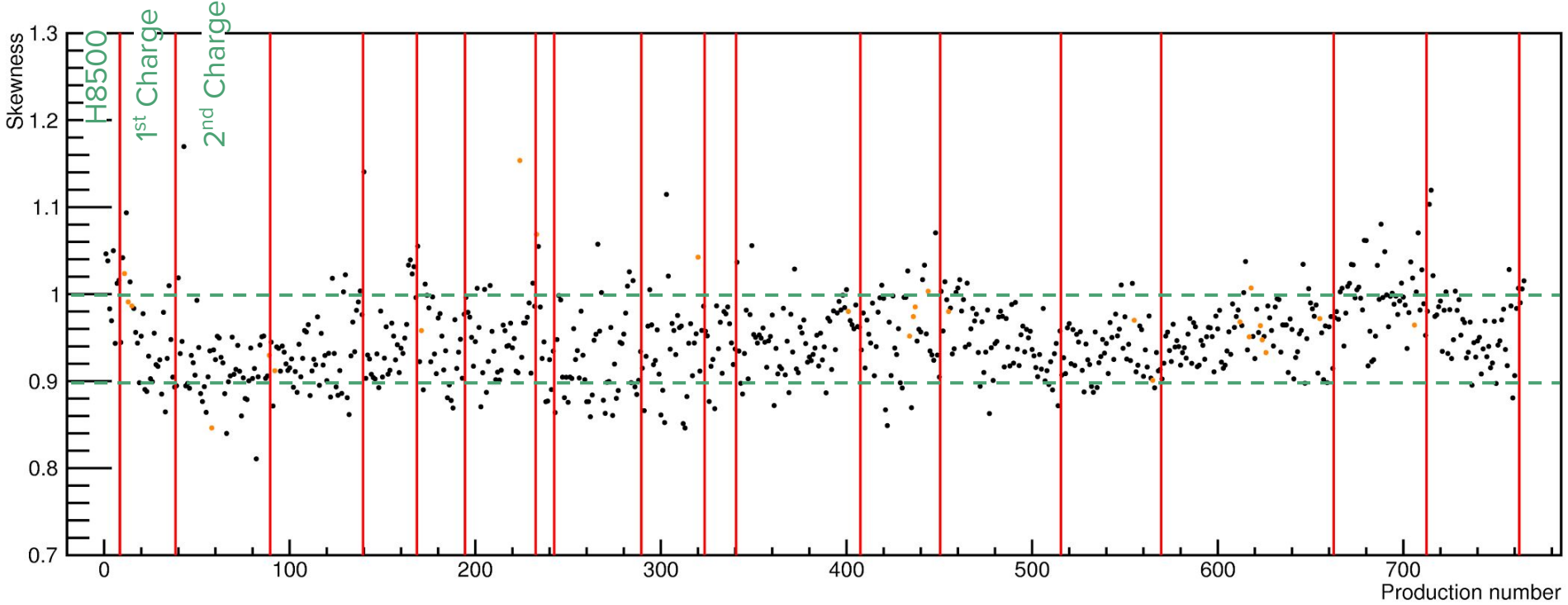


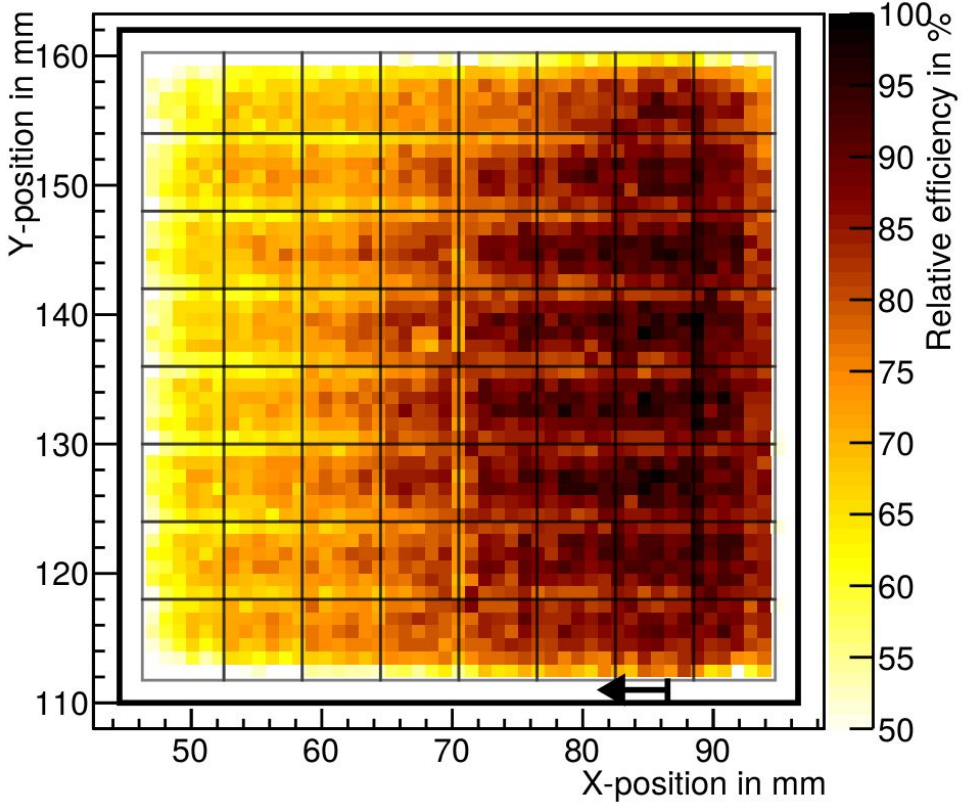



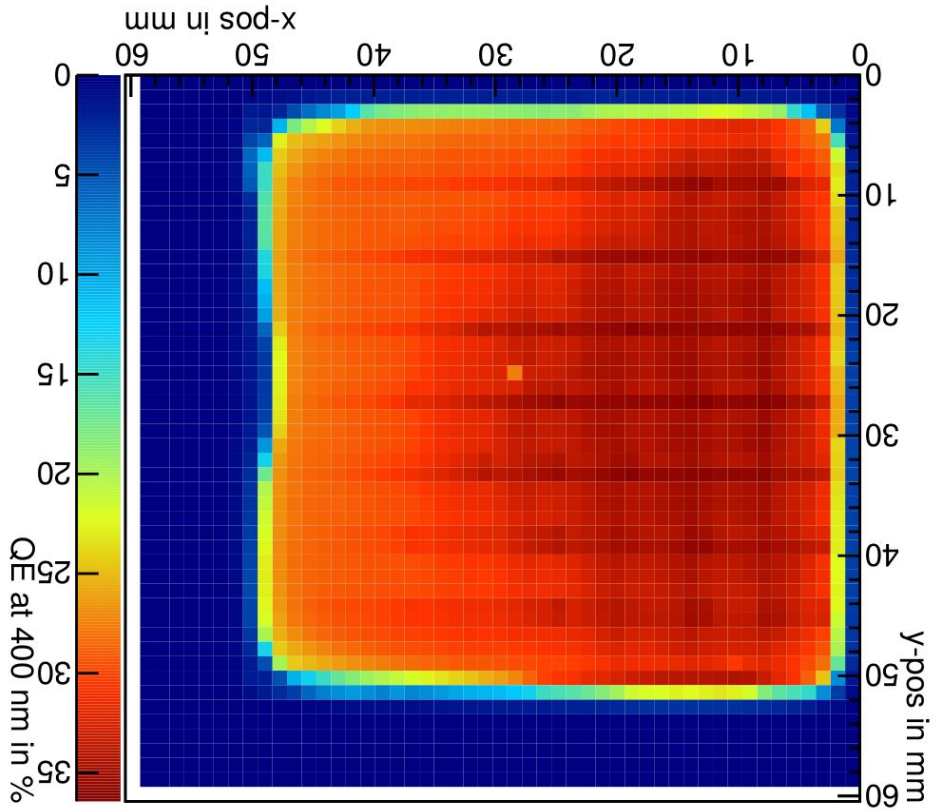

Skewness = ■ / ■

# Skewness

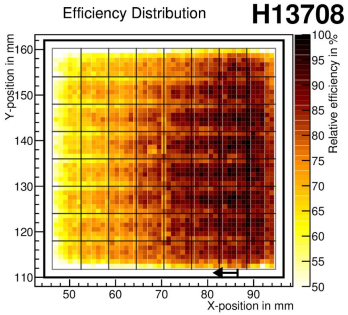

H8500
1st Charge
2nd Charge
Skewness
1.3
1.2
1.1
1
0.9
0.8
0.7
0
100
200
300
400
500
600
700
Production number

# QE-Skewness

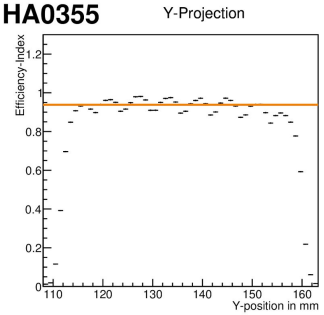

Y-position in mm
160
150
140
130
120
110
50
60
70
80
90
X-position in mm
Relative efficiency in %
100
95
90
85
80
75
70
65
60
55
50

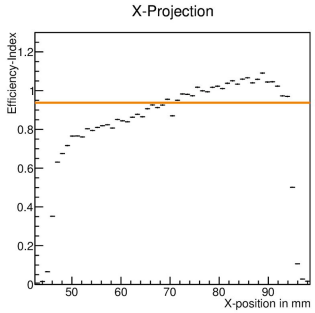

x-pos in mm
0
10
20
30
40
50
60
QE at 400 nm in %
0
5
10
15
20
25
30
35
y-pos in mm
0
10
20
30
40
50
60

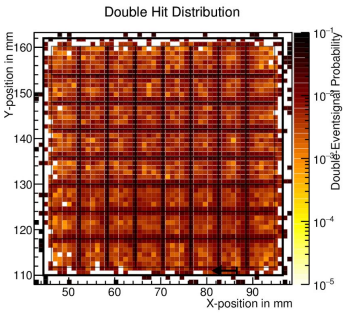
# Datasheet

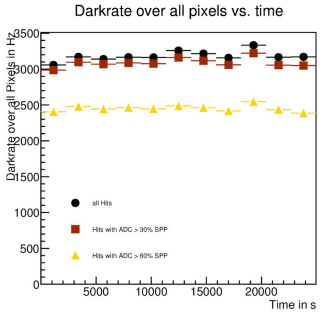


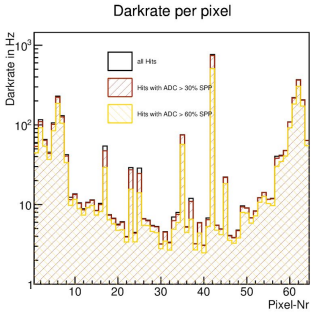

**H13708 HA0355**

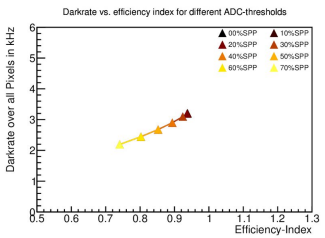


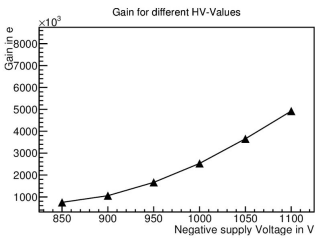



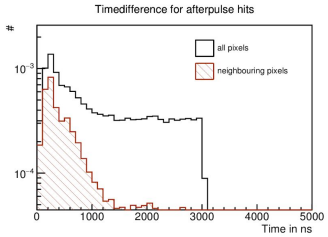



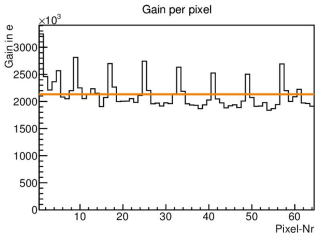



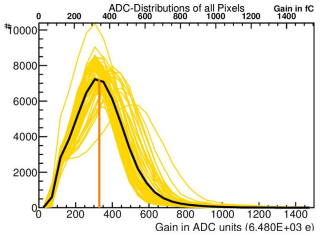



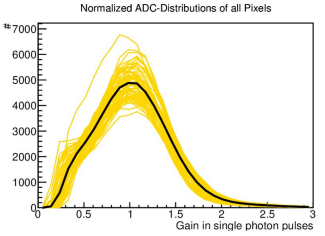



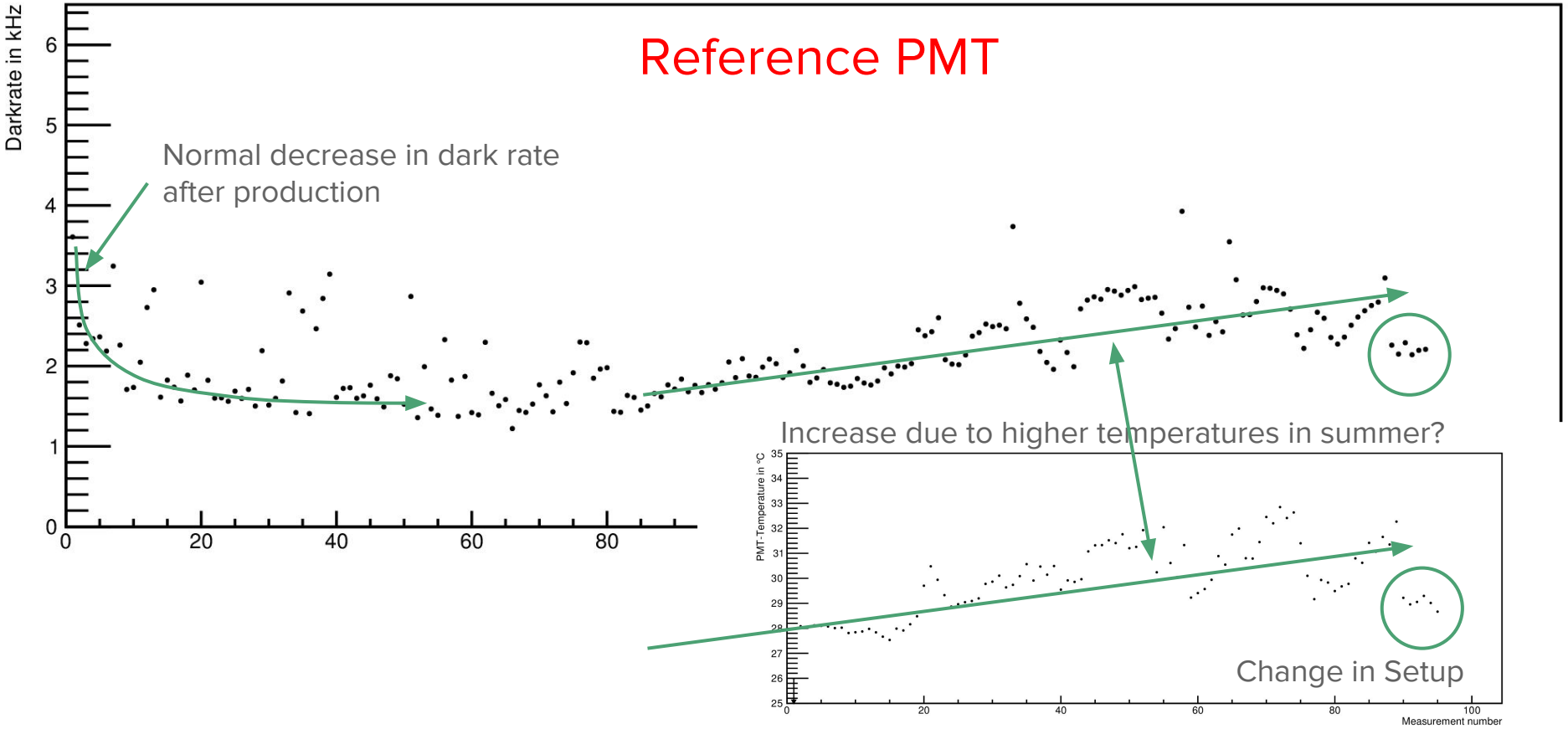



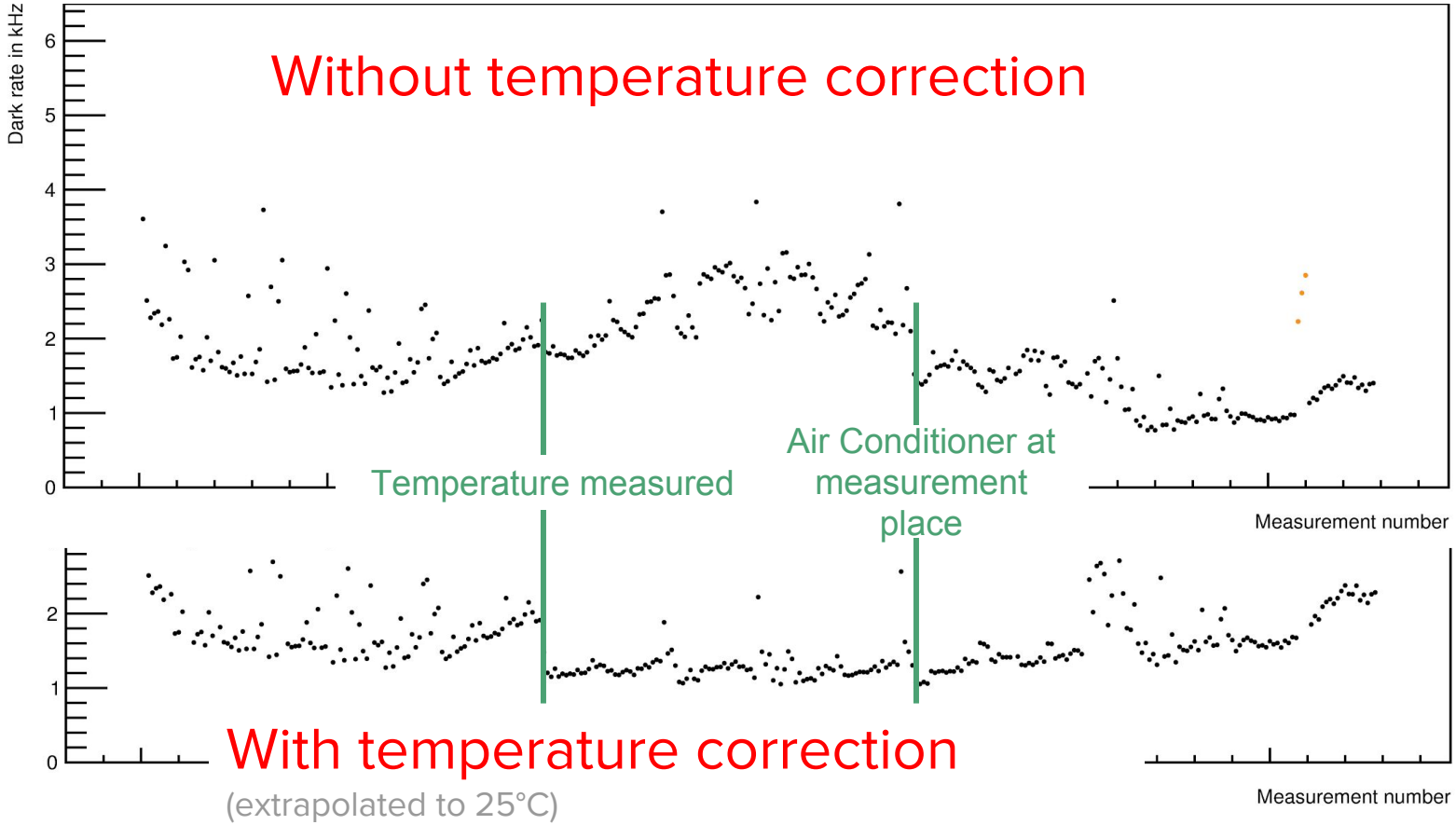




| | |
|---|---|
| **H13708 HA0355 / meas.-date: 160623_0946 / meas.** | **-pos: 3 / extrapolated meas.-points: 0** |
| **Efficiency Index:** | **0.938** |
| **Effective Area (Area w. rel. Eff.>60%):** | **78.90%** |
| **Efficiency Skewness in X-direction:** | **0.811** |
| **Afterpulse Probability:** | **0.433%** |
| **Average Double-Eventsignal Probability:** | **0.939%** |
| **Average Gain at -1000 V over all Pixels:** | **2.133E+06 e (ADC-shift:118.01/91.05)** |
| **Gain reduction for decreasing HV:** | **1.487E+04 e/V** |
| **Darknoise of all Pixels:** | **3206.262 Hz @ 29.70 deg.C(PMT)/22.02 deg.C(FEE** |
| **Average Darknoise over the 3 noisiest Pixels:** | **454.162 Hz** |

# Dark rate variance due to temperature variance



# Dark rate of reference PMT



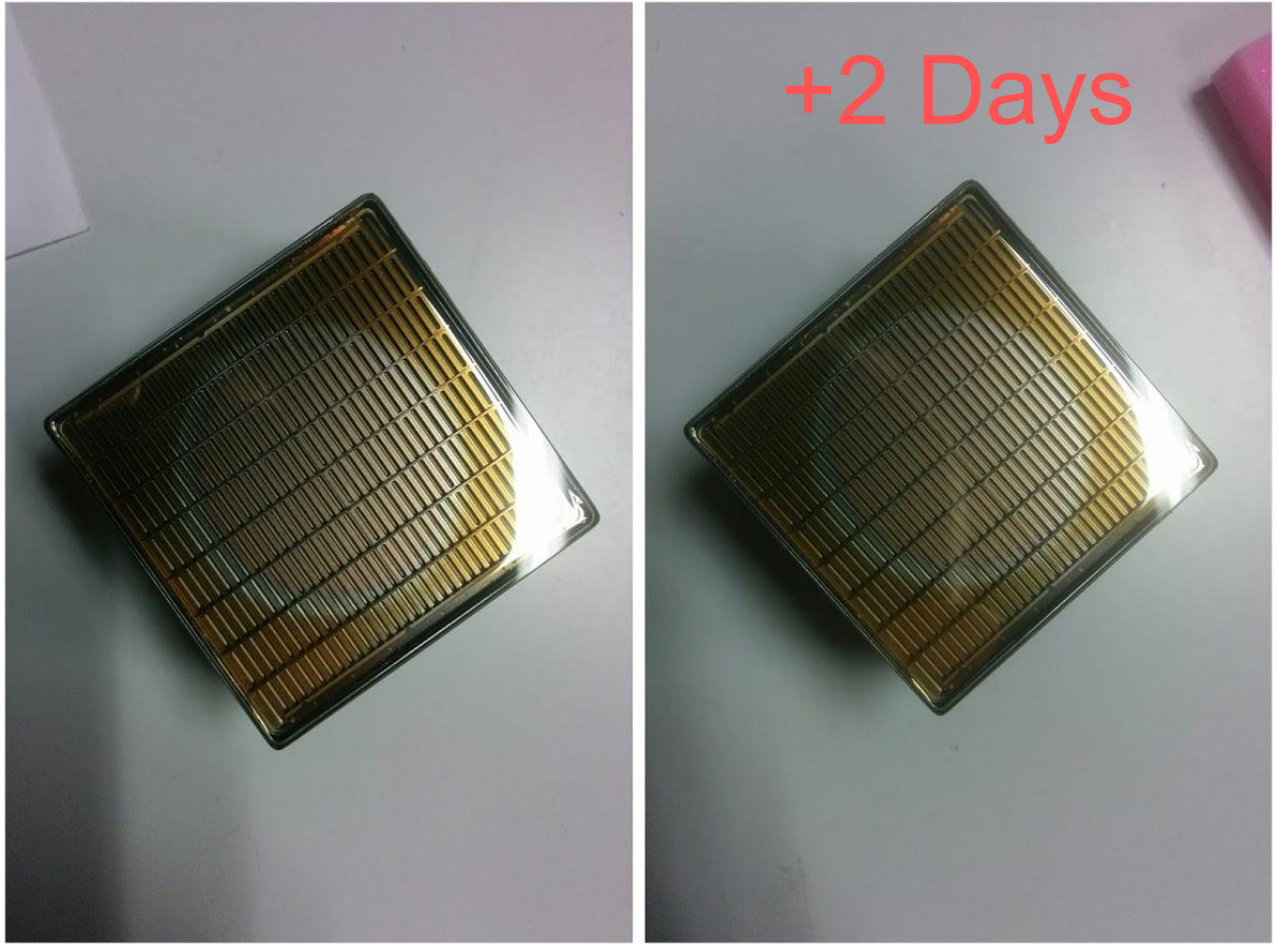
# “Reclamation” Status

- Based on a subsample of 550 fully examined MAPMTs

- 27 MAPMTs returned to HAMAMATSU due to non-fulfillment of buying-specs.
  - High noise (one pixel >1 kHz / all pixels >6.4 kHz) : 12-times
  - Efficiency-Artifacts in QE (e.g. inefficient corners, skewed efficiency plane): 9-times
  - Efficiency-Artifacts not visible in QE (e.g. inefficient pixel parts): 7-times
  - High afterpulse rate: 1 PMT (2.7%)
  - Inoperative photocathode due to broken vacuum(?): 1 PMT

- 7 MAPMTs disapproved by HAMAMATSU
  - Mainly those with minor efficiency artefacts (CE-related / Dynode-defect related)
  - Overall low efficient PMTs were also rejected

- 7 MAPMTs are still under investigation


+2 Days