Setup and first results of quality assurance measurements with MCP-PMTs

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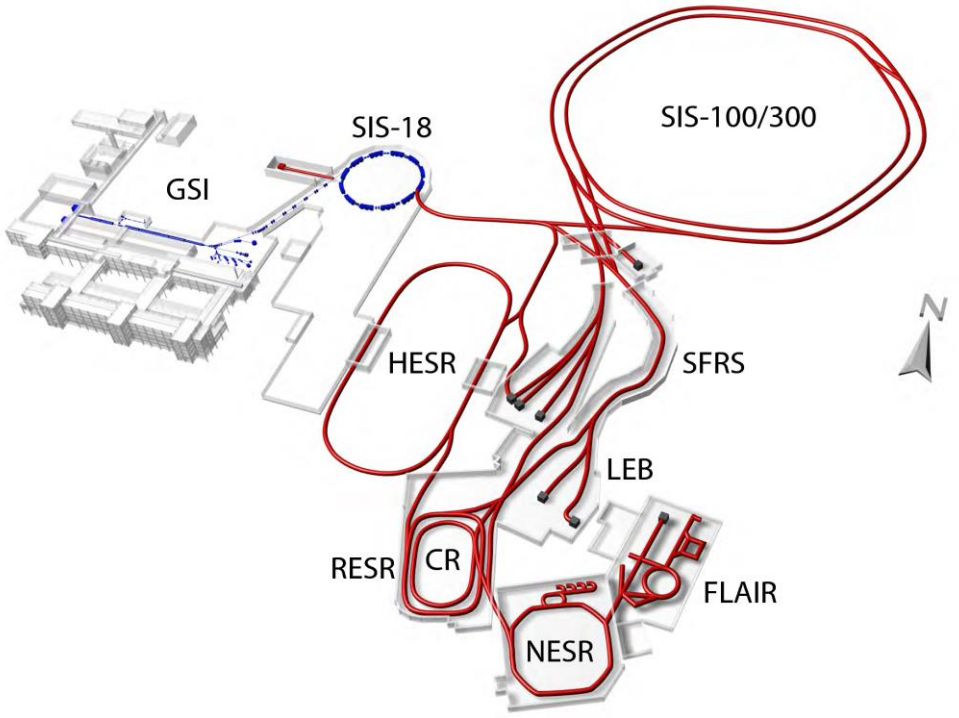
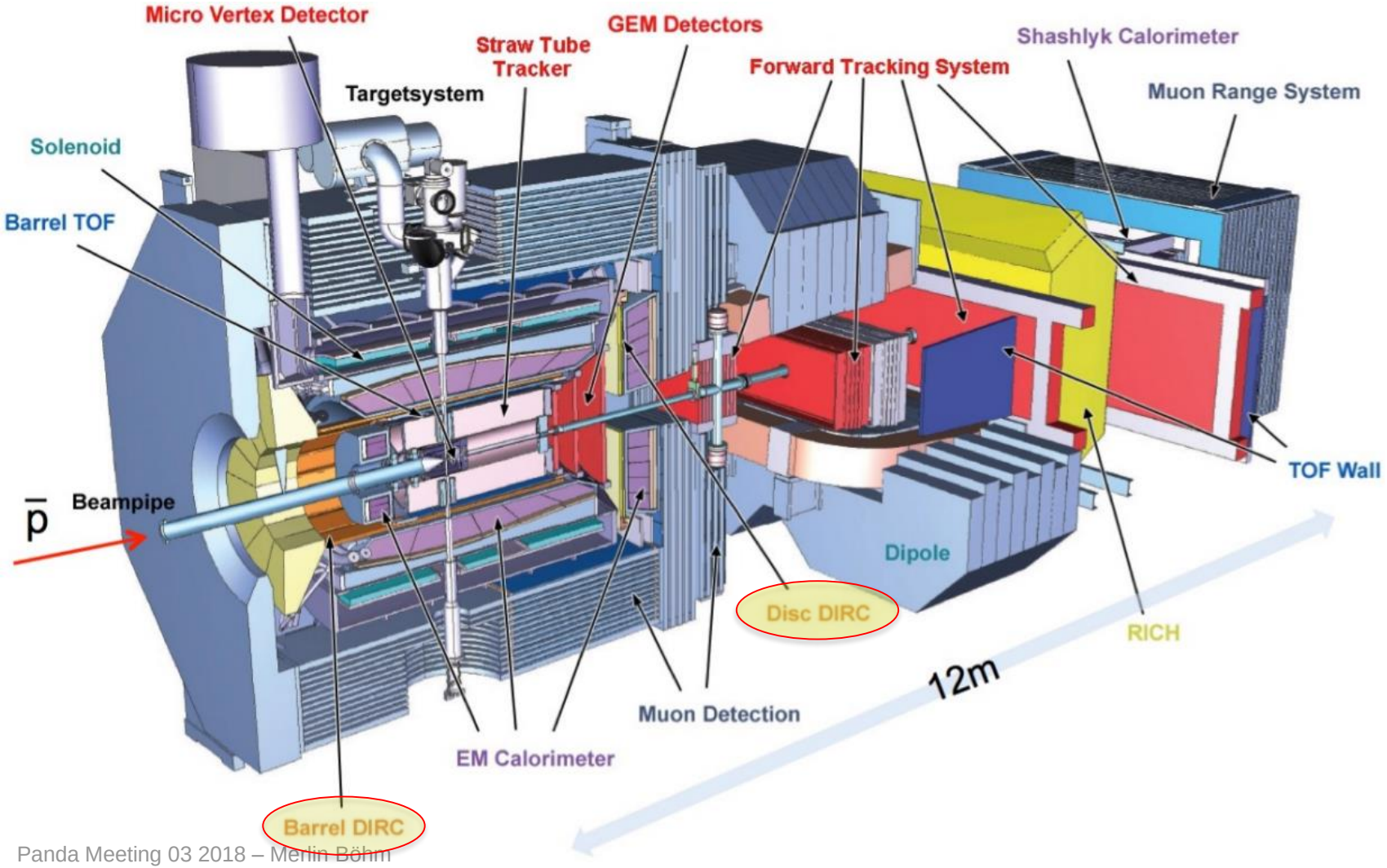
The PANDA Experiment

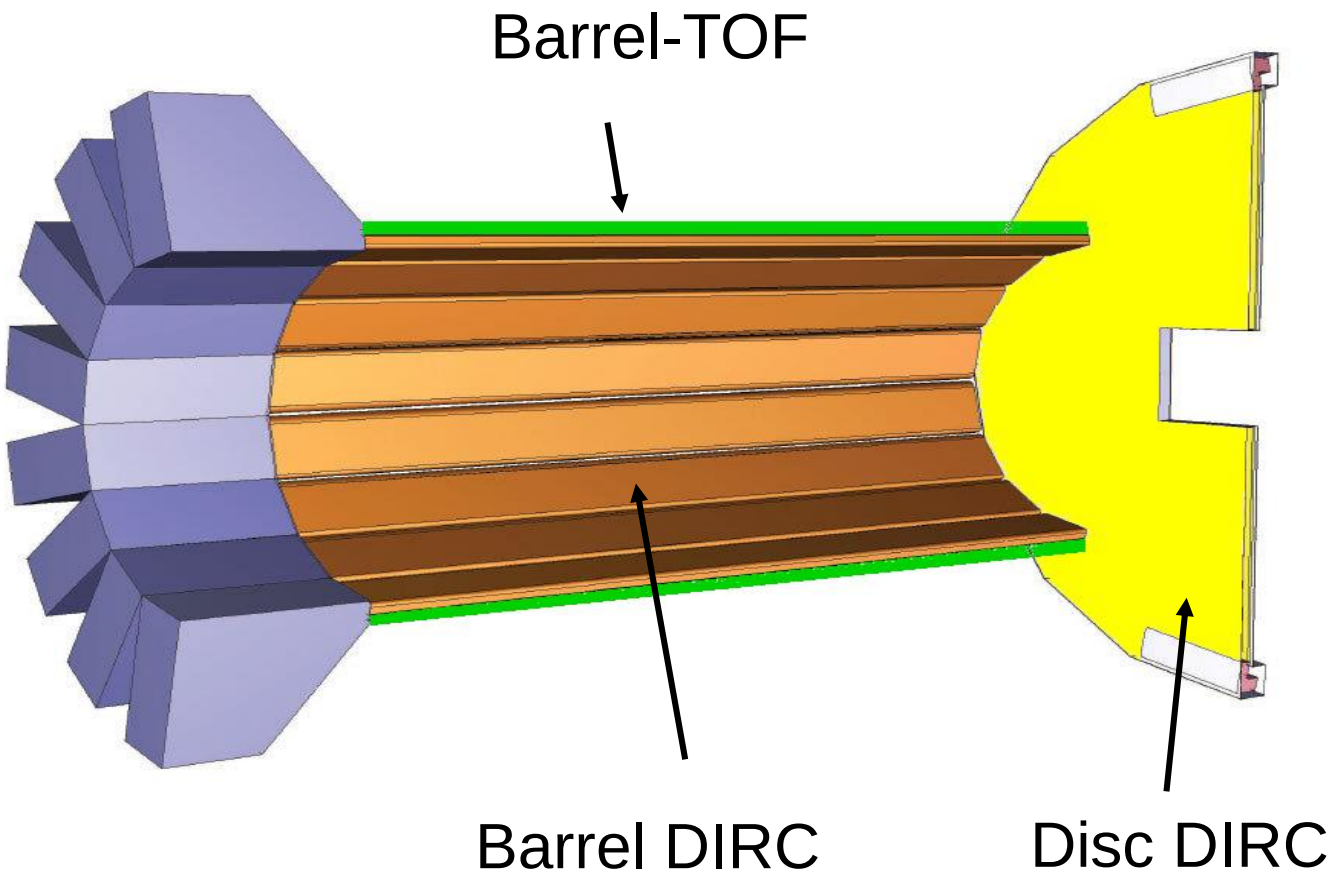
- One of the flagship experiments at FAIR
- Fixed target experiment with accelerated antiprotons on protons
  - Momentum range of 1.5 GeV/c to 15 GeV/c
- Two operation modes of the High Energy Storage Ring (HESR):
  - High resolution mode ($\Delta p/p \leq 4 \cdot 10^{-5}$, 2 MHz) electron cooling
  - High luminosity mode ($2 \cdot 10^{32}$ $cm^{-2}s^{-1}$, 20 MHz)



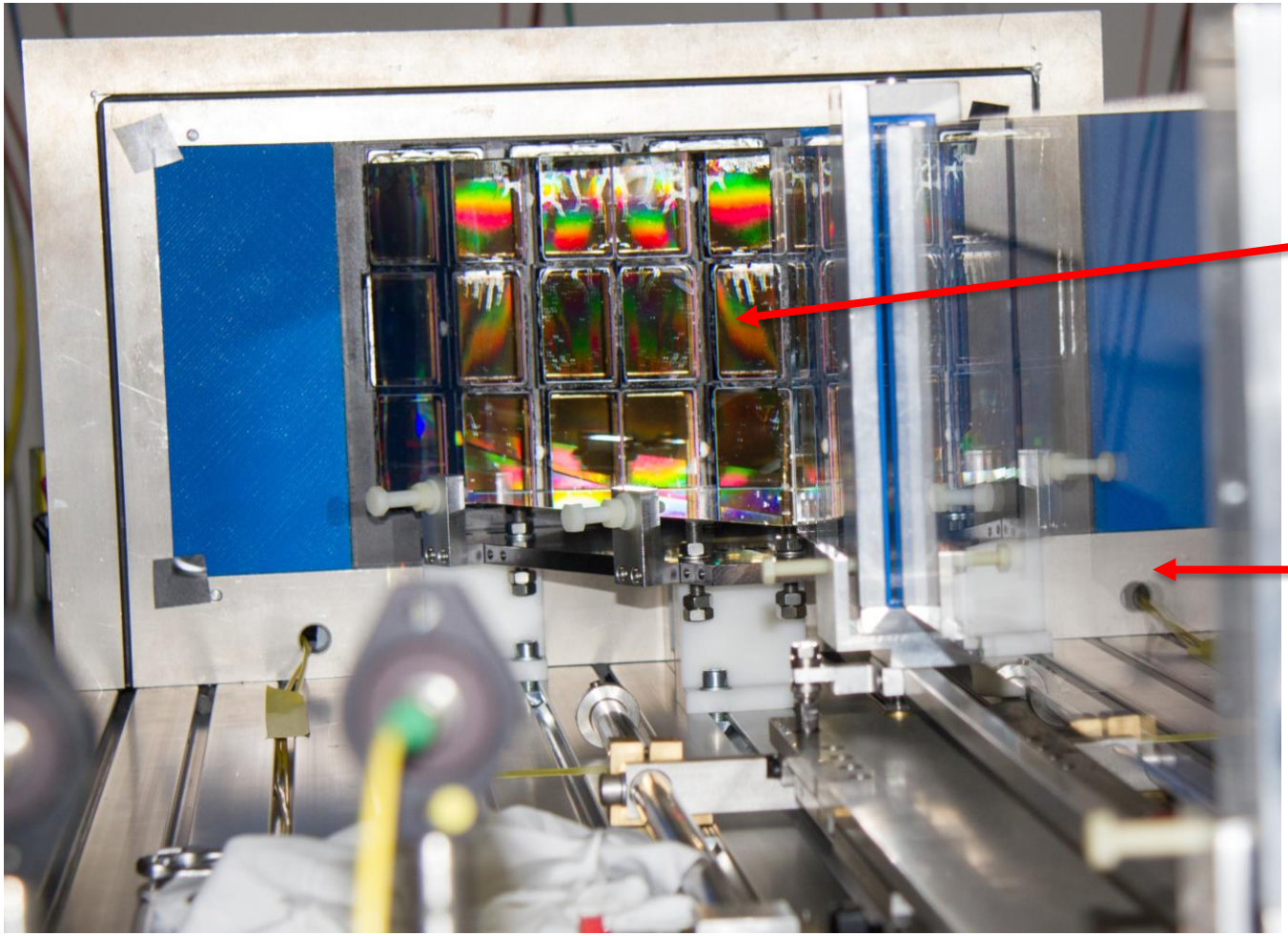
Panda Detector - Overview



Panda Detector –DIRC and TOF



Barrel DIRC – Prototype of one segment



Quality assurance for MCP-PMTs – Goals

- Need quality assurance (QA) of the ~300 MCP-PMTs for the DIRC detectors
- Efficient and semiautomatic measurement of:
  - Time resolution
  - Crosstalk
  - Darkcount rate
  - Afterpulsing
  - 2D quantum efficiency (QE)
  - QE vs. wavelength
  - 2D gain
  - Gain vs. Voltage
- For selected tubes further measurement of B-field behavior

Quality assurance for MCP-PMTs – Measurement Setup

- Surface scans using a 3-axis stepper with a PILAS Laser
- Using TRBv3 and PadiwaAmp2: time resolution, crosstalk, darkcount rate and afterpulsing, hopefully also gain
- Using Keithley 6487 picoamp: QE 2D
- Fallback solution for gain measurements using the picoamp

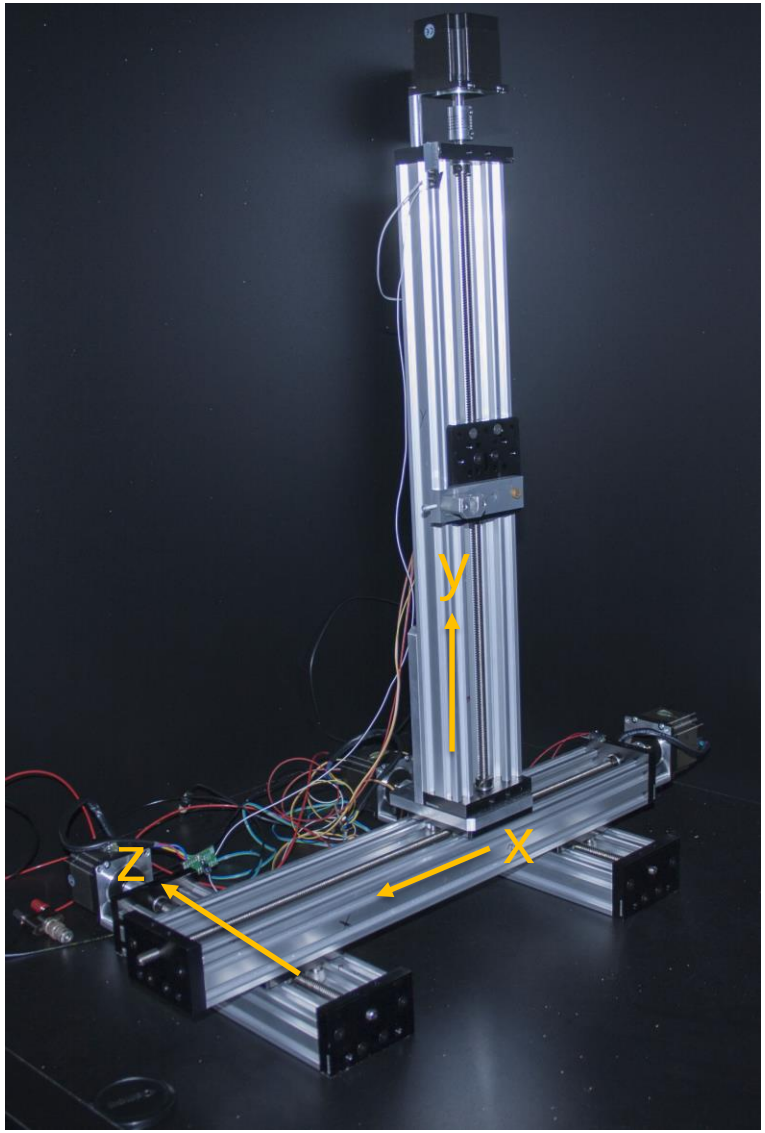
- TRB and Padiwa is a FPGA based DAQ
  - Padiwa FEE for discrimination
  - TRB for time and TOT measurement
  - DAQ is multihit capable

Measurement box

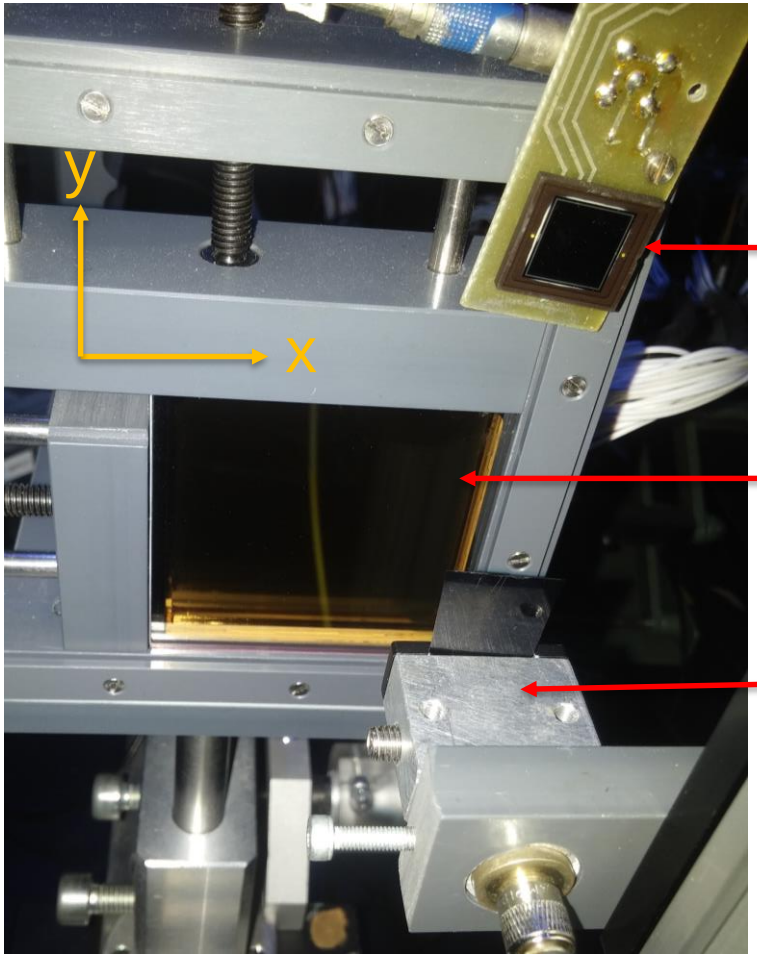
- Shielded with copper to block EMI

Stepper

- Total cost <500 €
- 3 axis stepper build from 4 linear actuators
- X and Y axis for sensor scanning, ~40 cm to drive
- Z axis for focusing the laser, ~15 cm to drive
- Position repetition accuracy below 5 µm
- Laser with microfocus and variable ND filter attached
- Spot size FWHM in focus <20 µm



Measurement setup



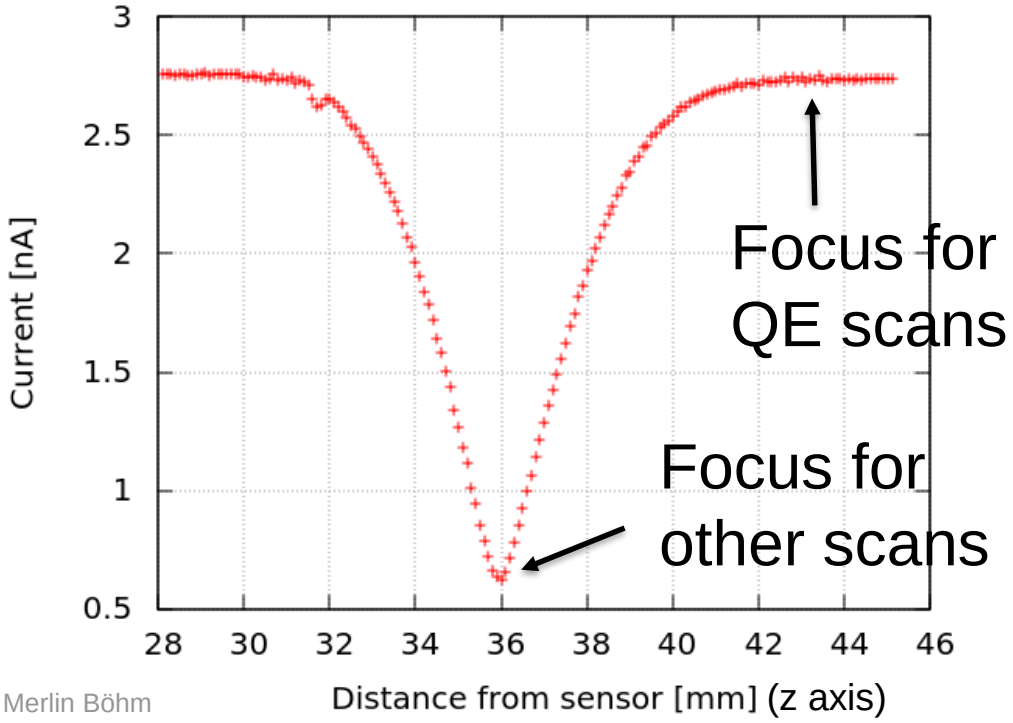
Photodiode

MCP-PMT

Laser with ND-Filter

Determination of laser focus

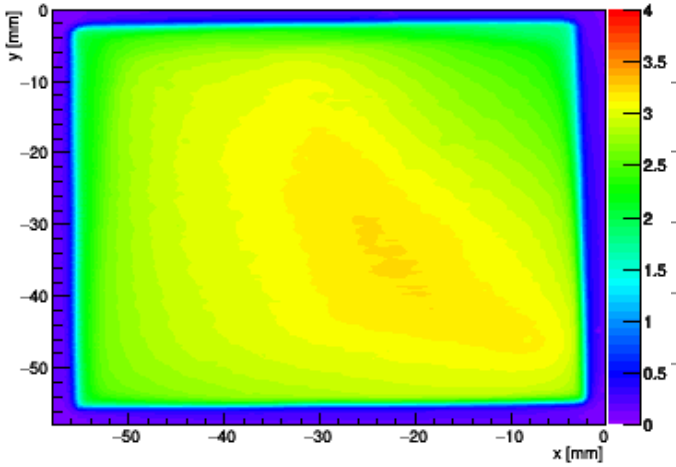
- Position dependent QE measurement (multi photon): Laser must not be focussed at the sensor because photo cathode saturates, spot size 0.5-1 mm
- All other scans (TRB,… single photon): laser must be focussed to minimize laser induced crosstalk



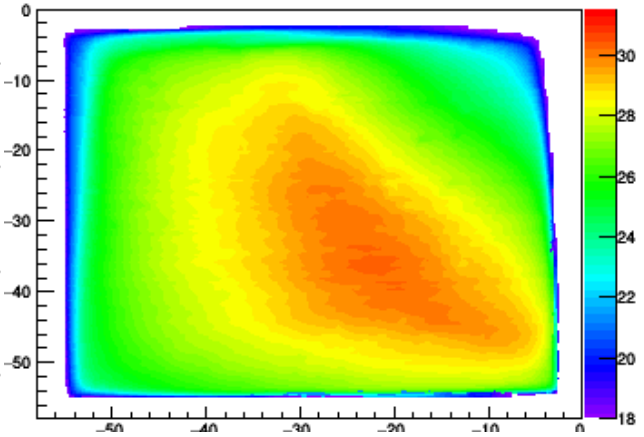
QE surface scans

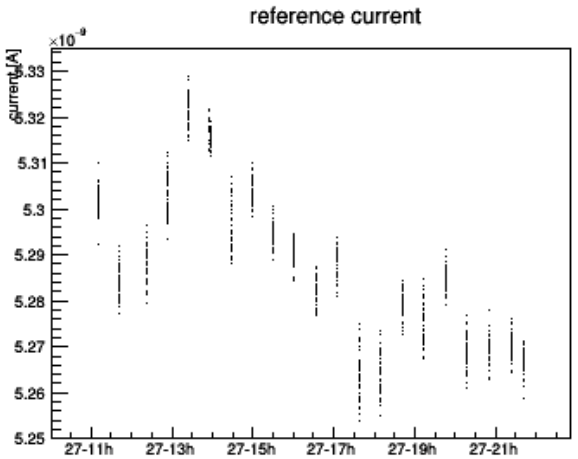
- Applying ~200 V between photo cathode and MCP-In
- Measuring the current at the photocathode or MCP-In
- Need continuous monitoring of the laser output and sensor dark current

MCP current [nA]



QE [%]



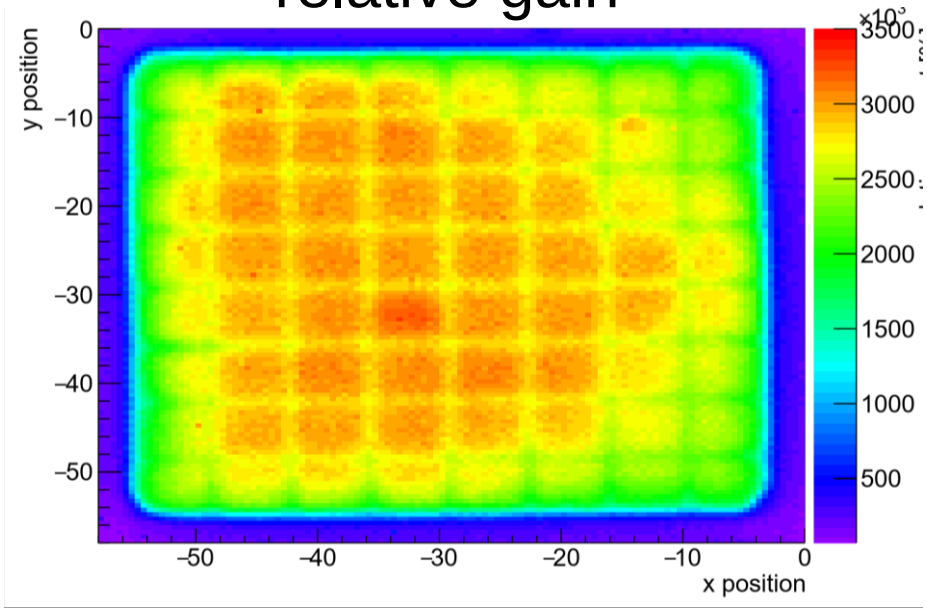


Hamamatsu R13266-07-M64 M YH0250

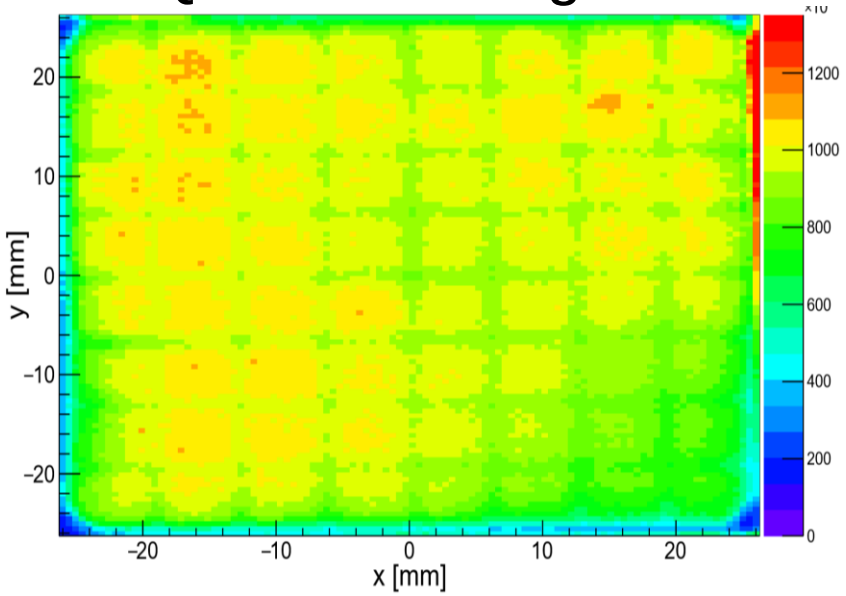
Gain surface scans (fallback solution)

- Applying full voltage to sensor
- Shorting all pixels and measuring the combined current
- Dividing the measured gain by QE

relative gain



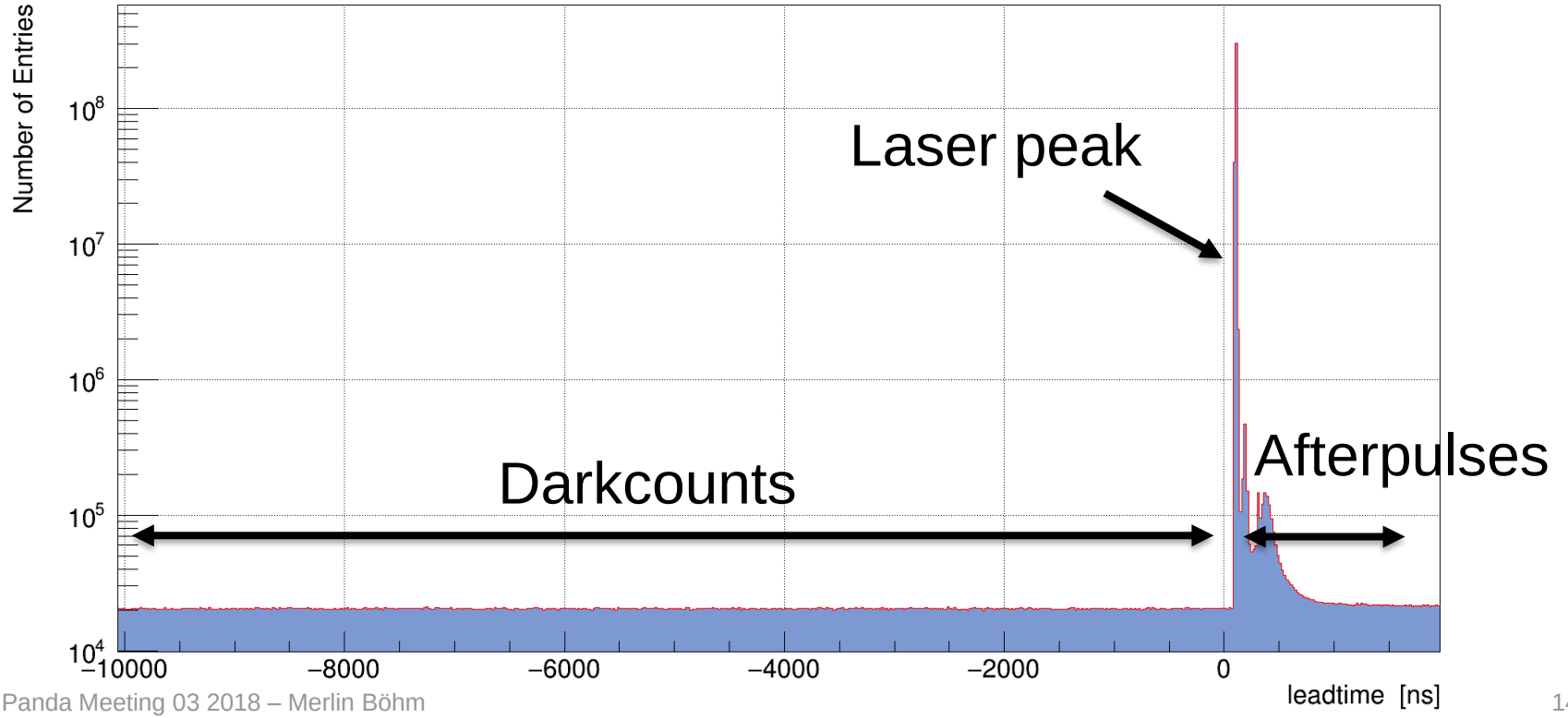
QE corrected gain



Hamamatsu R13266-07-M64 M YH0250

TRB Scans

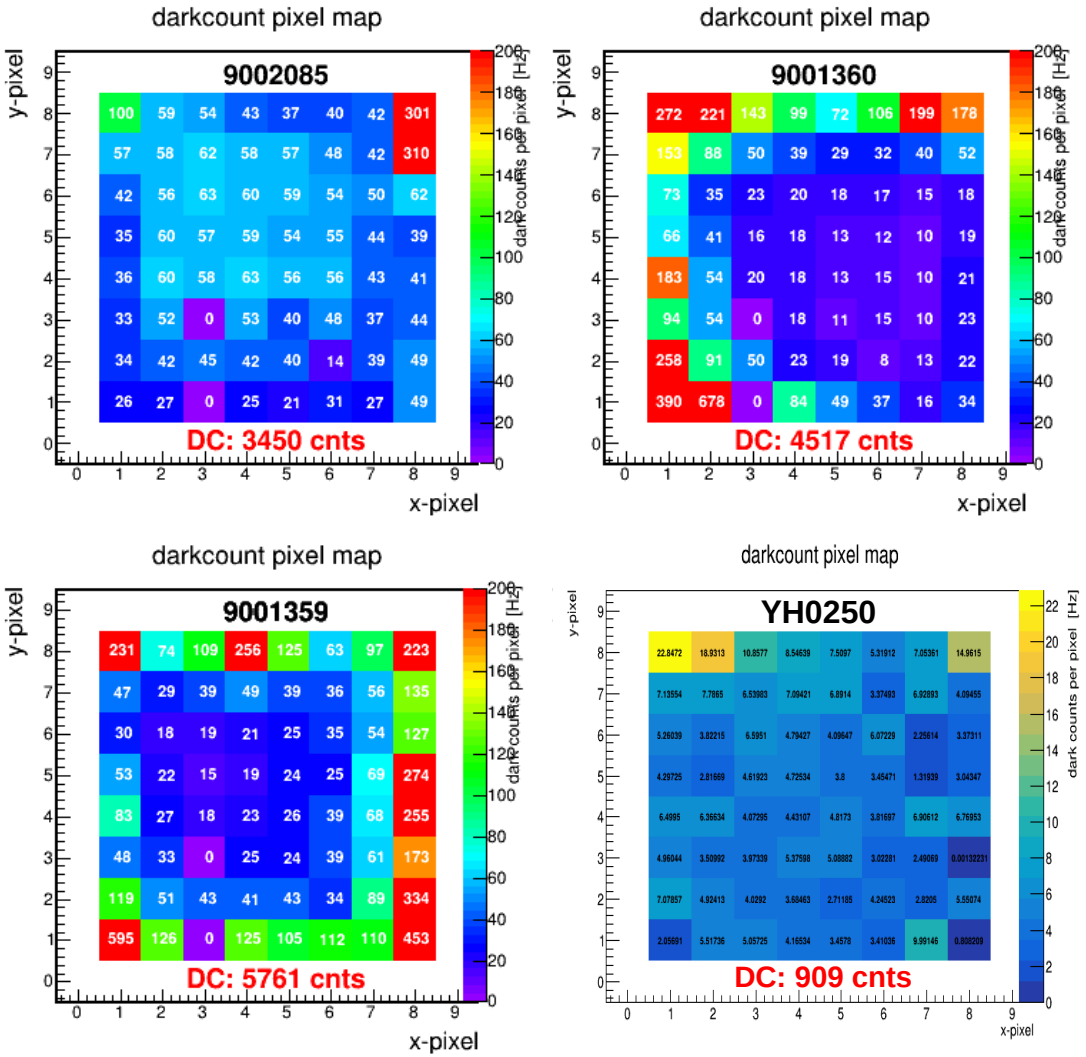
- Scanning the sensor across the surface in 0.5 or 1 mm steps with blue Laser
- Laser rate: 10 kHz or 20 kHz



TRB Scans – Darkcount rate

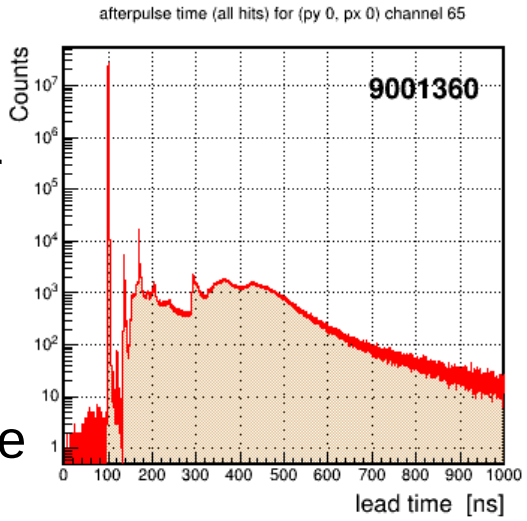
- Measurement time window ~10 µs
- Darkcounts: 400 or 900 ns before Laser pulse
- No dead time correction

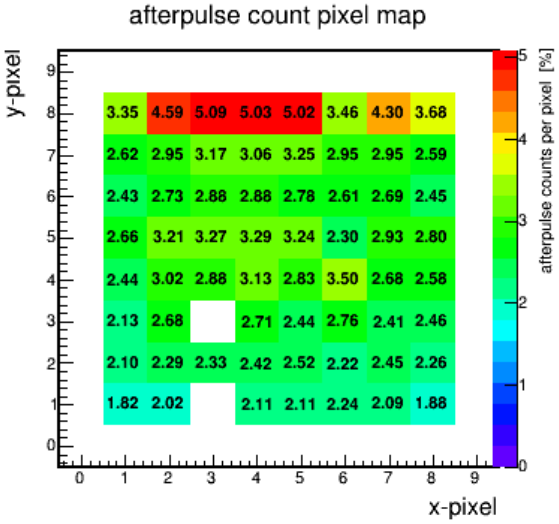
Photonis XP85012 or Hamamatsu R13266-07-M64 M

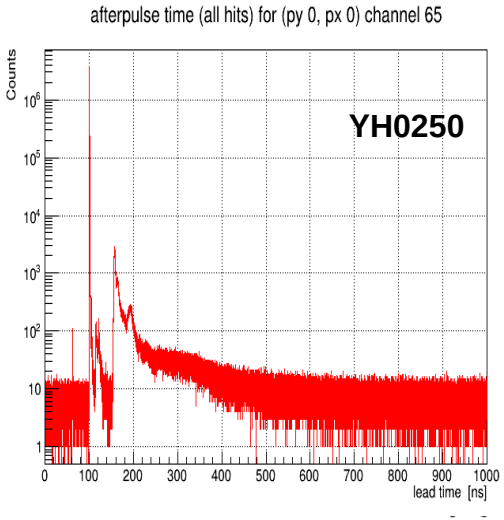


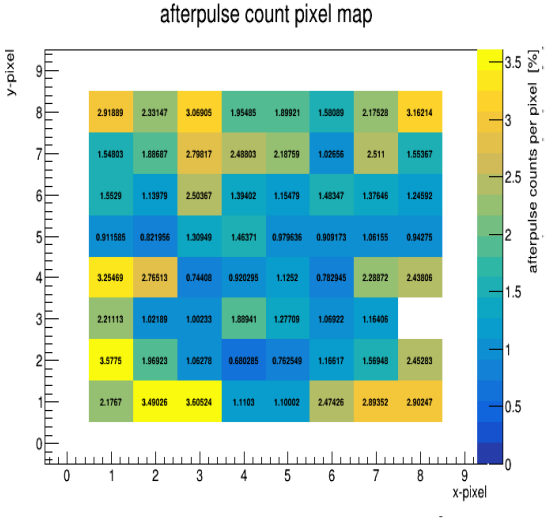
TRB Scans – Afterpulsing

- MCP signals artificially shifted for easier analysis to 100 ns
- Spectra have been verified by our scope
- Possible identification of feedback ions
- Afterpulse fraction depends on HV and/or gain





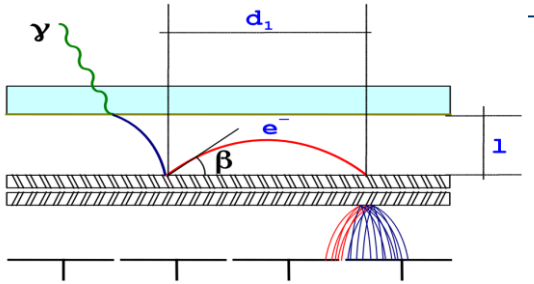




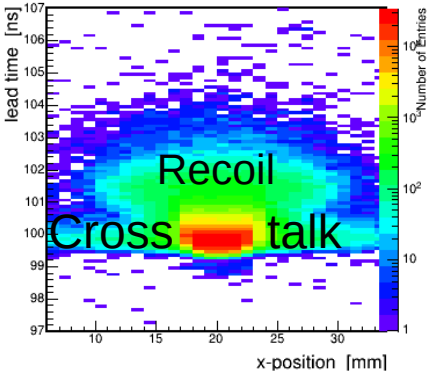
Photonis XP85012

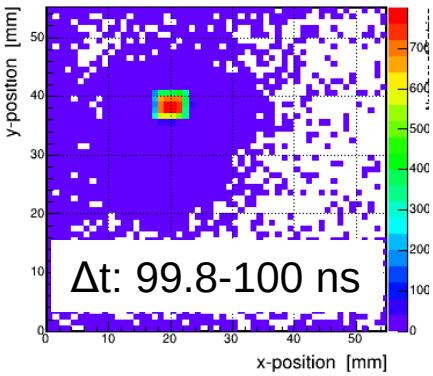
Hamamatsu

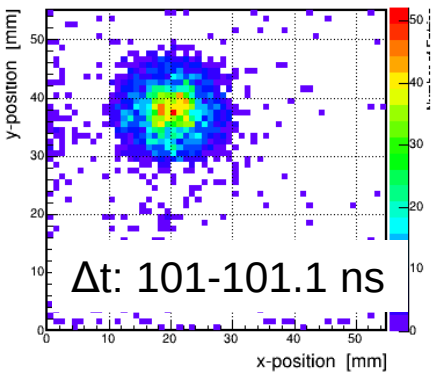
TRB Scans – Time spectrum

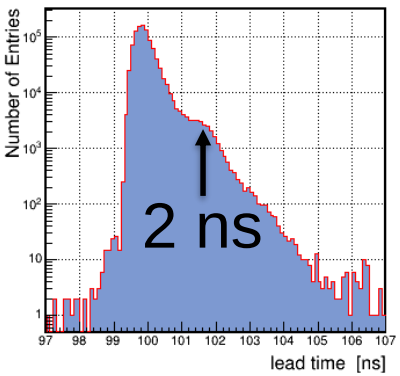


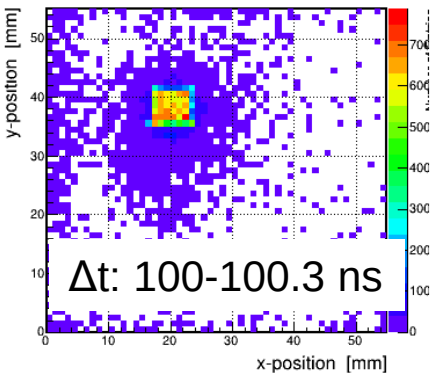
- MCP signals shifted to 100 ns for better analysis
- Delayed events → backbouncing electrons?
- Time resolution ~150-200 ps
- Time resolution measured with scope below 50 ps

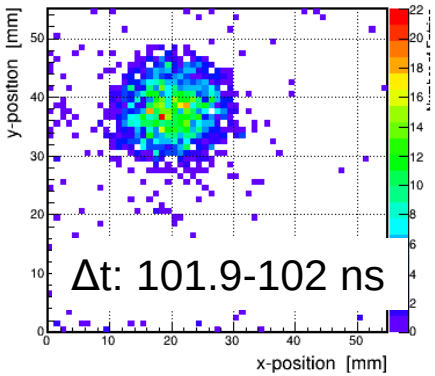










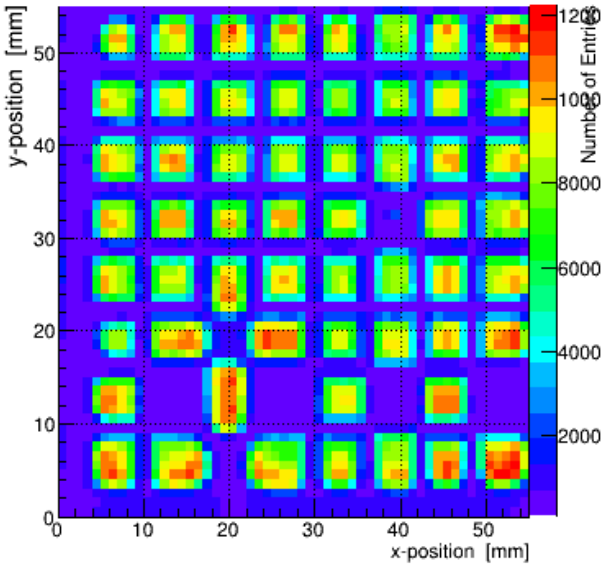


Photonis XP85012 9001360

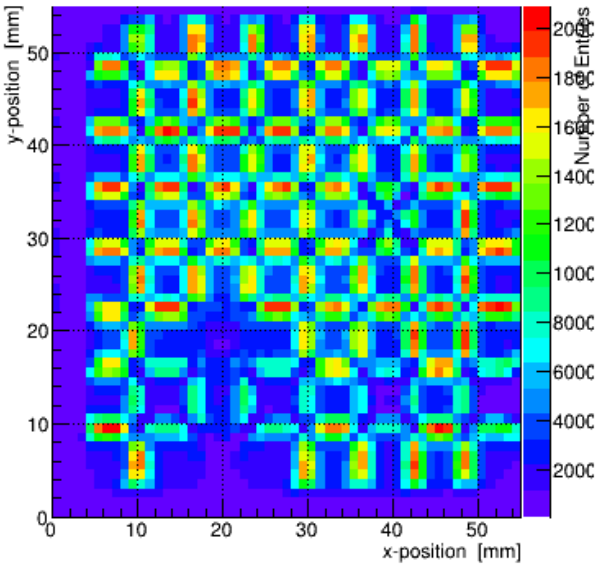
TRB Scans – Charge sharing

- Cut to only 1 hit on the MCP per Laser pulse: pixels, 2 hits: borders, >2 hits: edges
- Crosstalk due to charge sharing visible
- Cut on narrow time window at first peak

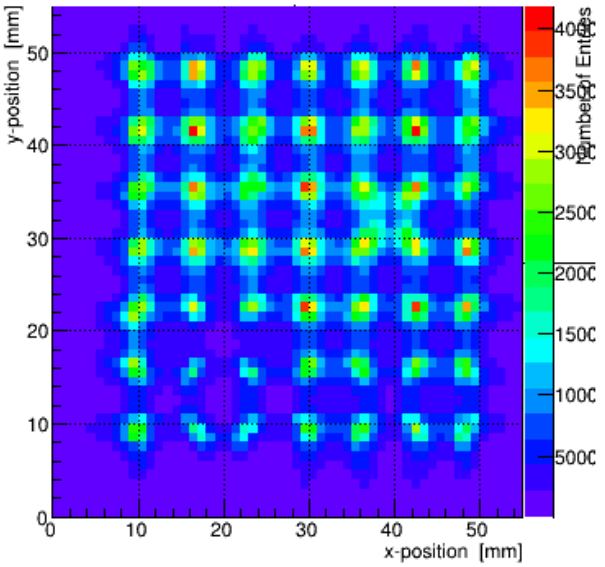
1 hit



2 hits



>2 hits

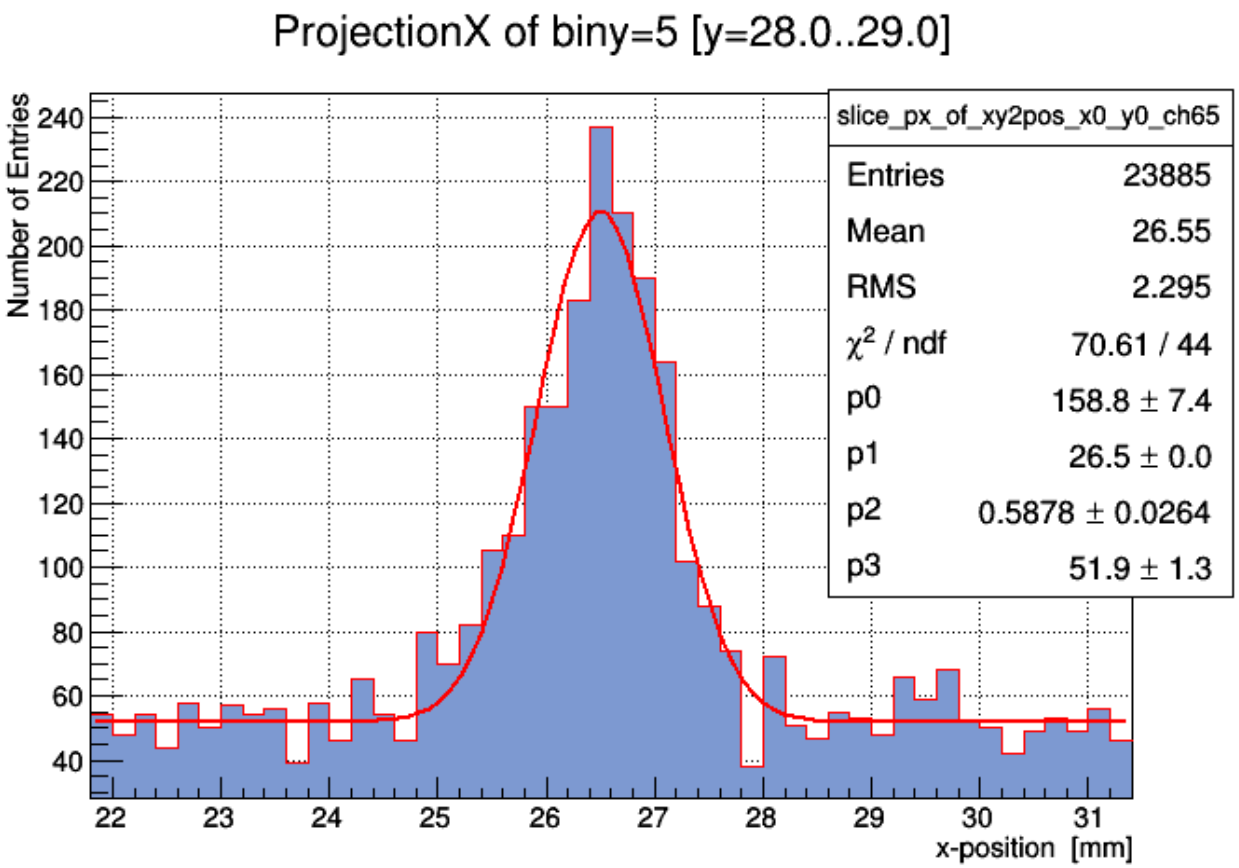


Photonis XP85012 9001360

TRB Scans – Charge sharing

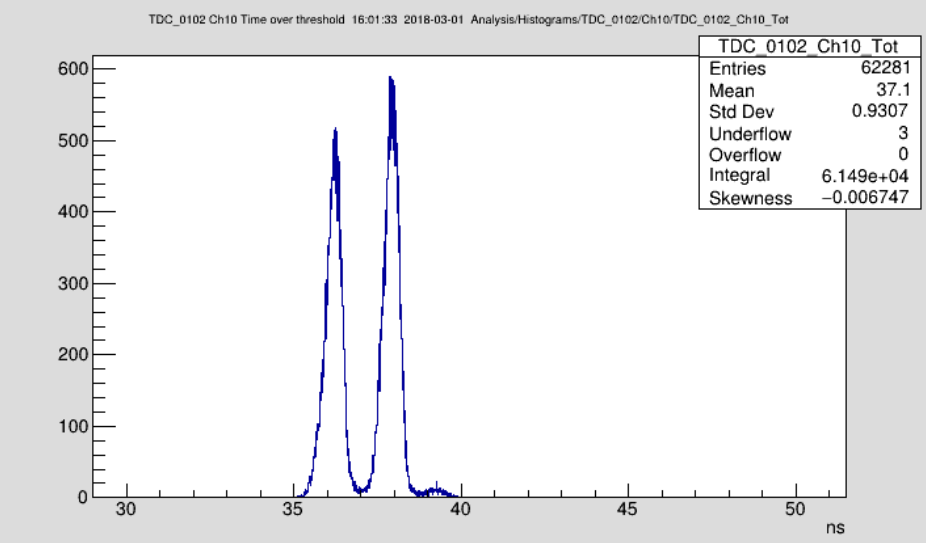
Photonis XP85012
9001360

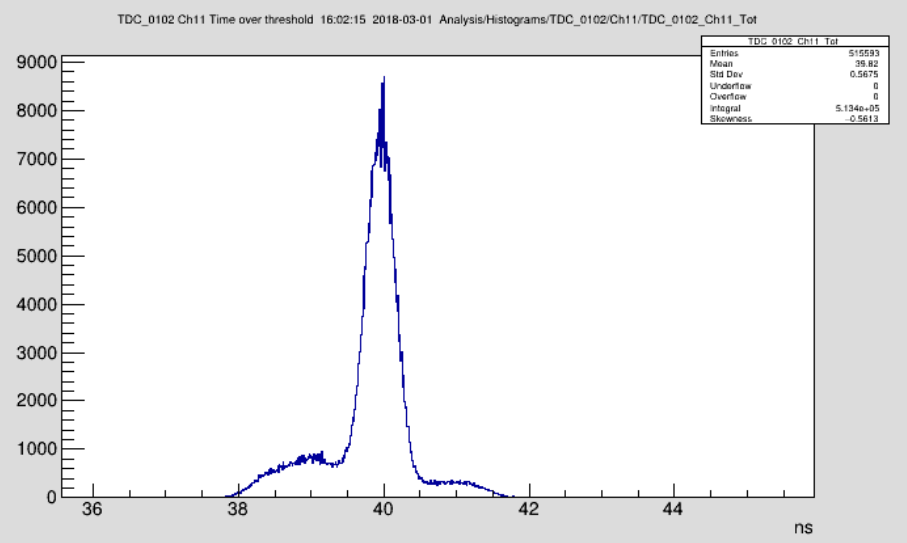
- Width of charge sharing ~0.6 mm



Current status - remaining problems

- Padiwa oscillation problems when mounted directly on the MCP-PMT
  Padiwa3 more affected than Padiwa1 (with adapterboard)
- Multiple peaks in TOT spectra, Photonis worse than Hamamtsu





Photonis XP85012 9002108

Current status - remaining problems

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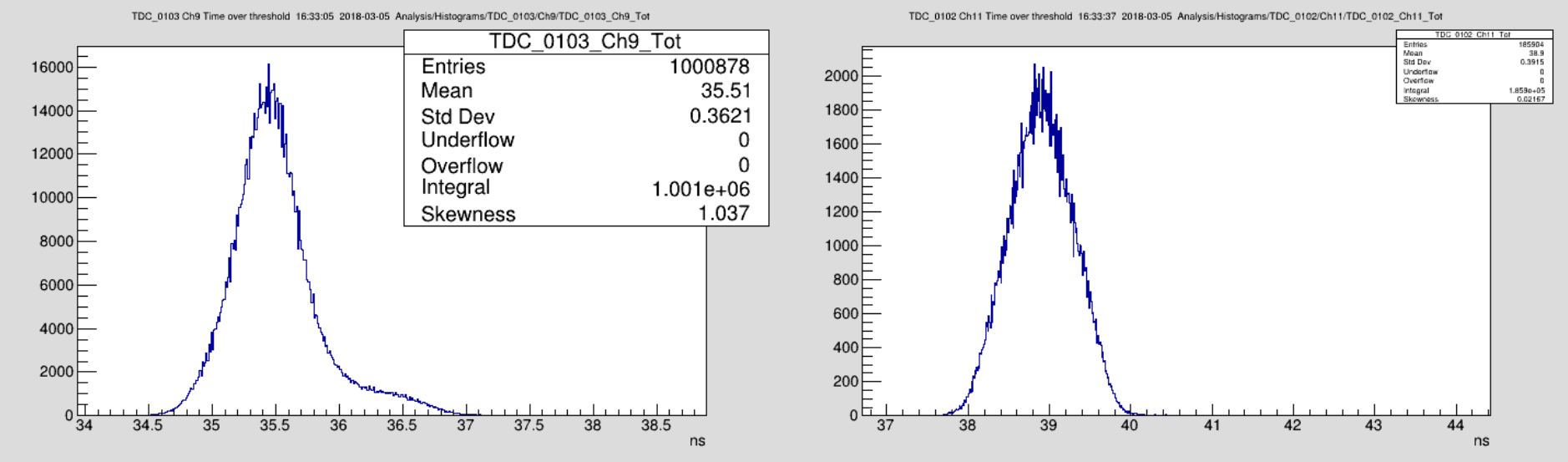
- Multiple peaks in TOT spectra, Photonis worse than Hamamtsu

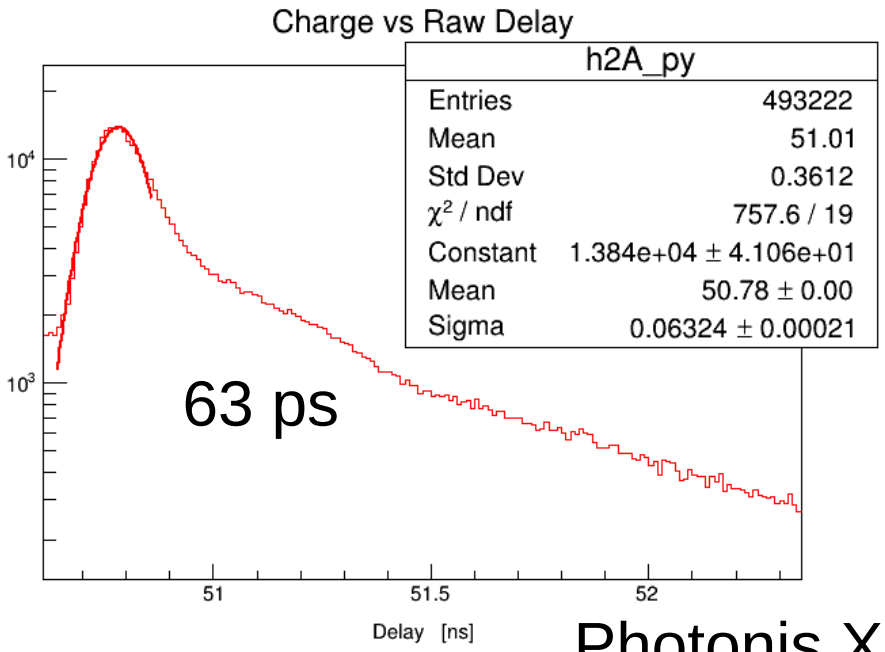


Hamamatsu R13266-07-M64 M YH0250

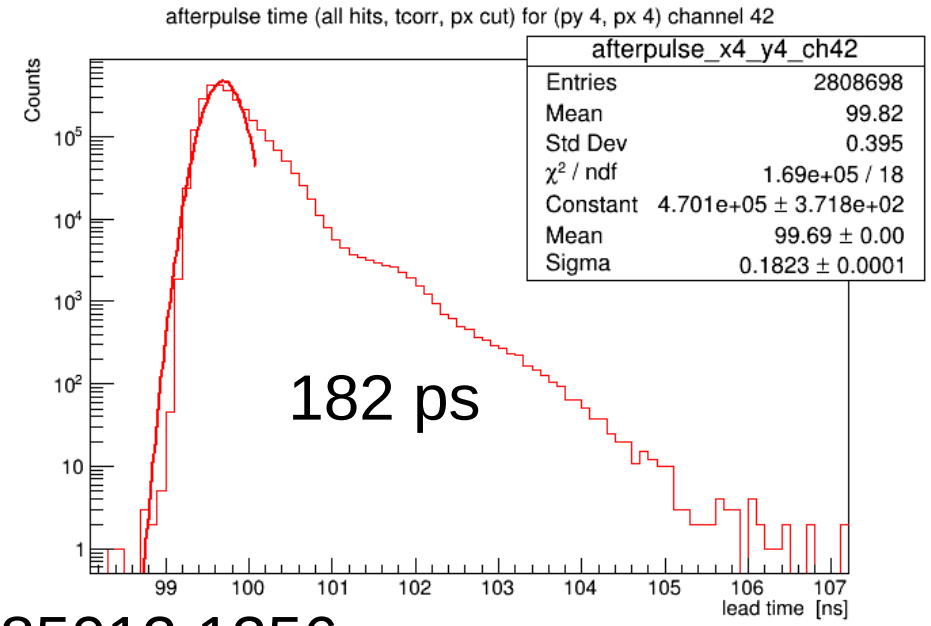
Current status - remaining problems- time resolution

- Time resolution measured with the scope is much better
- Scope: ~65 ps
- TRB: ~180 ps

Oscilloscope



TRB

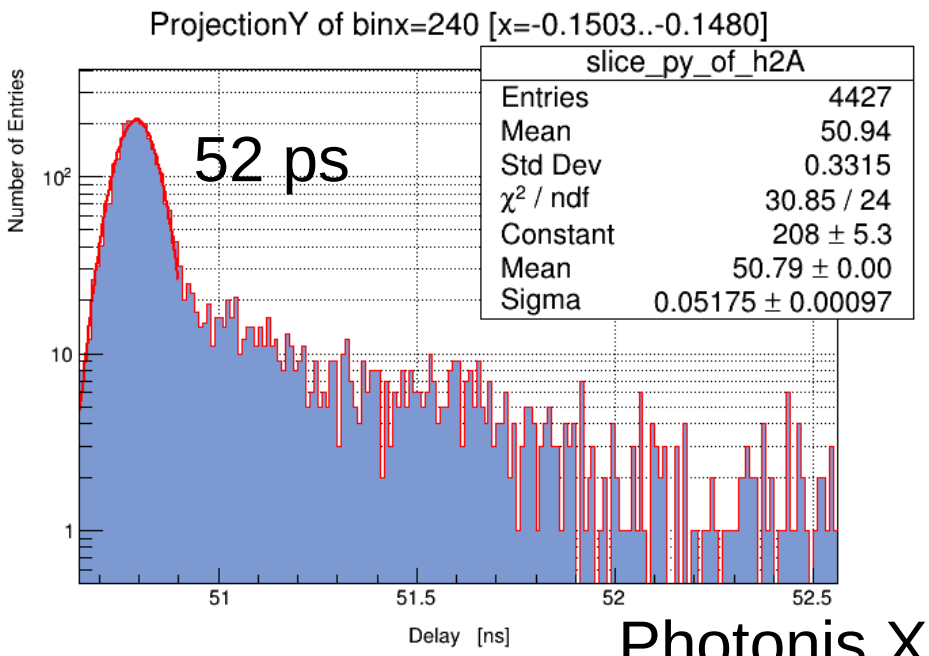


Photonis XP85012 1356

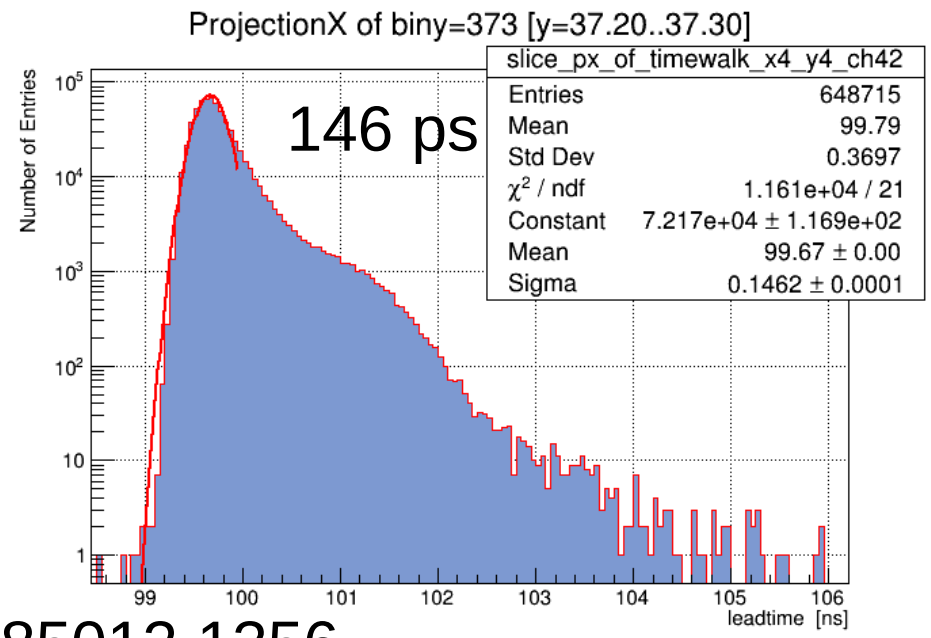
Current status - remaining problems- time resolution

- Time resolution measured with the scope is much better
- Scope: ~65 ps, timewalk corrected ~50 ps
- TRB: ~180 ps, timewalk corrected ~145 ps

Oscilloscope



TRB



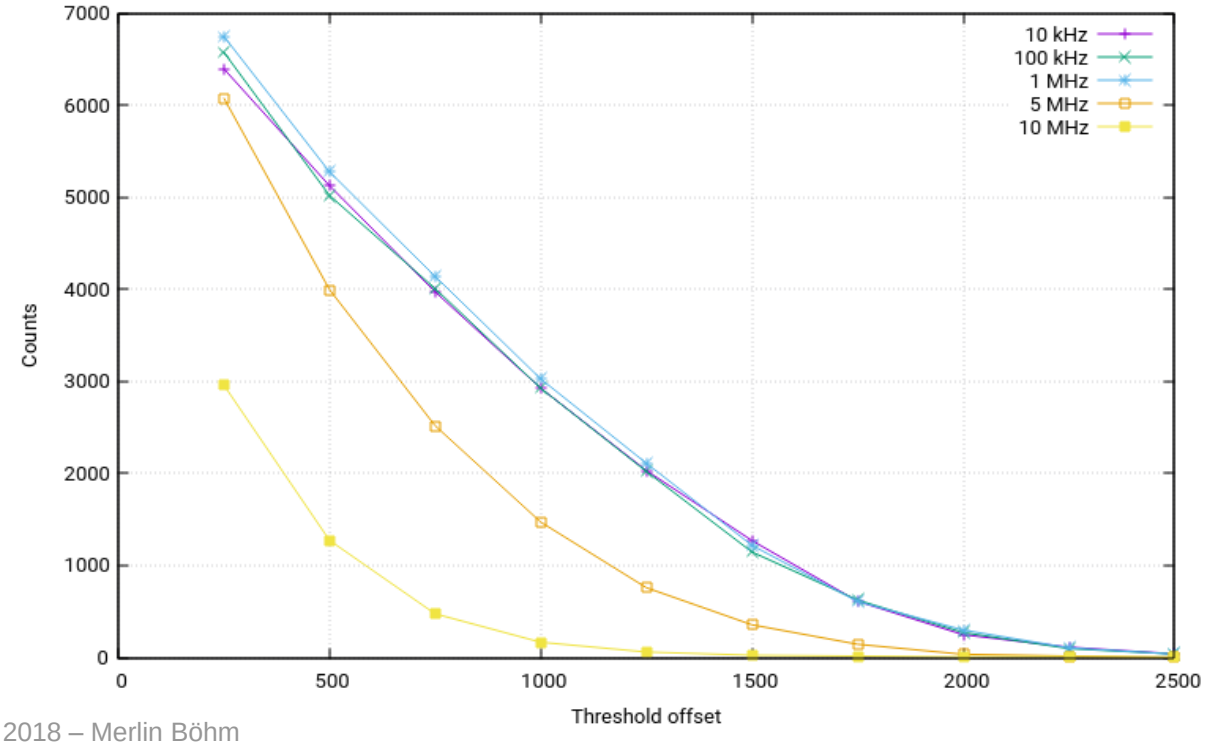
Photonis XP85012 1356

Current status - remaining problems- time resolution

Sensor	H YH0250	H JS0035	P 1332	P 1340	P 1341	P 1353	P 1393	P 1394
Threshold	500	500	500	500	500	500	500	500
Verbindung	kabel	kabel	direkt	kabel	kabel	kabel	kabel	direkt
Poren	10 µm	10 µm	10 µm	25 µm	10 µm	25 µm	10 µm	10 µm
Avg Timeres Fit 1G	147	128	201	213	149	191	197	176
Avg Timeres Fit 2G	133	107	170	196	134	147	160	139
Avg RMS	1135	172	362	465	280	351	424	320
Avg Timeres Fit 1G tot cut	120	111	182	201	138	138	153	174
Avg Timeres Fit 2G tot cut	112	95	156		121	119	129	127

Current status – measuring rate stability with TRB DAQ

- Sensor fully illuminated with single photons
- TOT does not change when MCPs saturates and the gain drops
- Measuring the count rate vs. threshold offset and laser rate



Summary and Outlook

- Summary:
  - QA setup is built and is working
  - Need to solve bad time resolution
  - Maybe include rate stability measurement for all sensors

- Outlook:
  - Still waiting for Padiwa Amps 2 boards for gain measurement
  - Still waiting for DIRICH DAQ for test measurements
  - Expand DAQ to >300 channels

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Backup – threshold offset vs. signal height