Readout of PANDA MCP-PMTs

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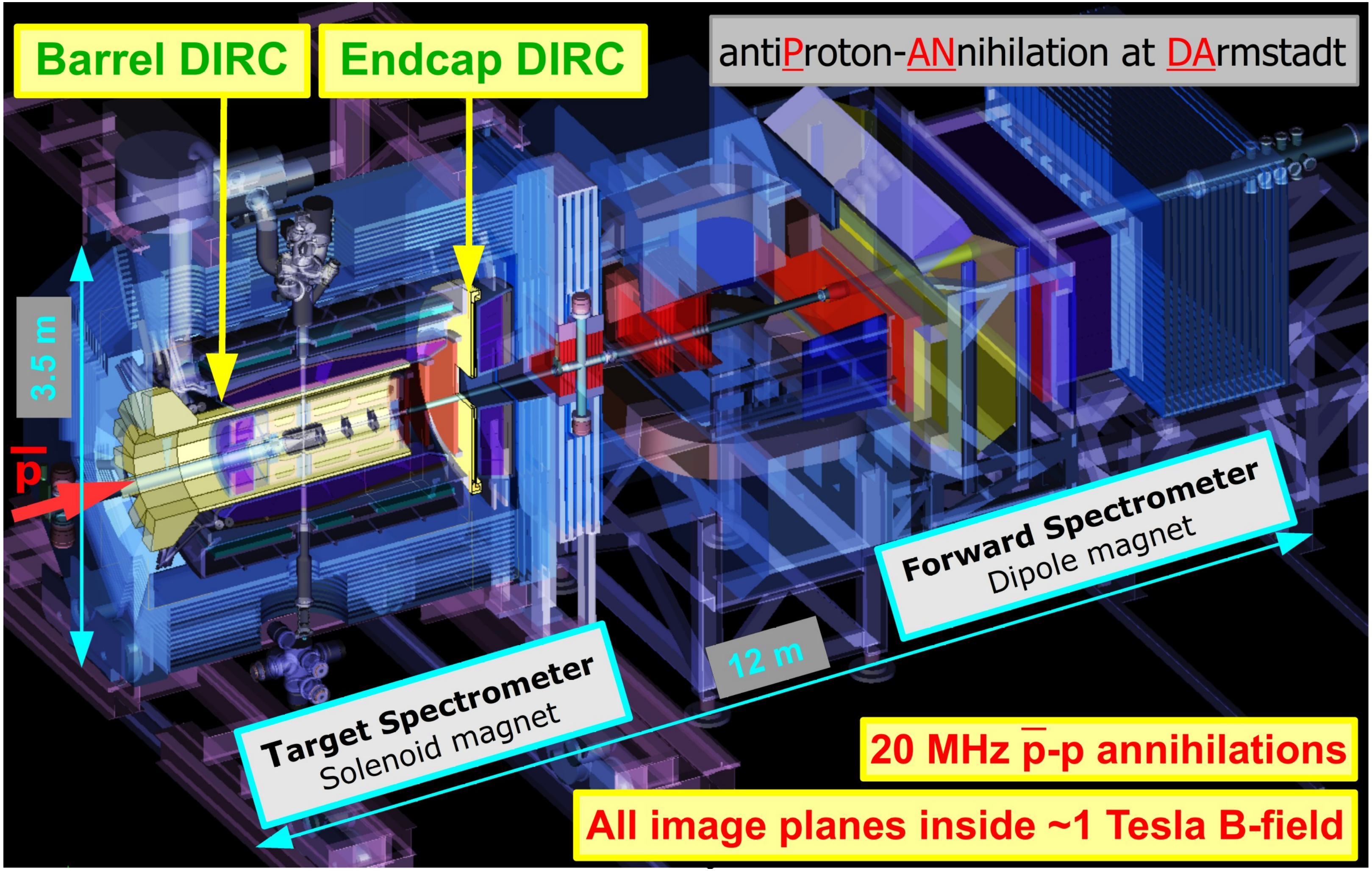
- Oscillation problems of former Photonis Planacon MCP-PMTs
- New Photonis Planacon MCP-PMTs with modified backplane
- DiRICH/TRB3 data acquisition system
- Application of DiRICH/TRB3 DAQ for quality control measurements of Photonis MCP-PMTs
- Summary

$\overline{\text{P}}$ANDA Detector at FAIR

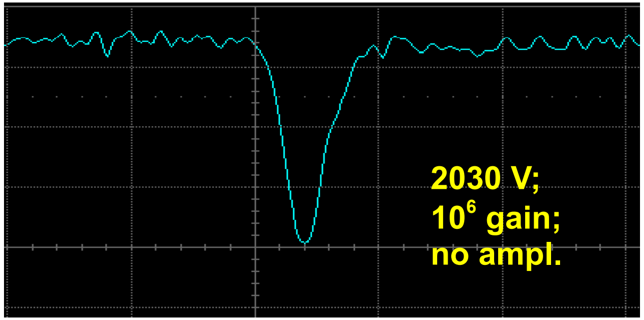


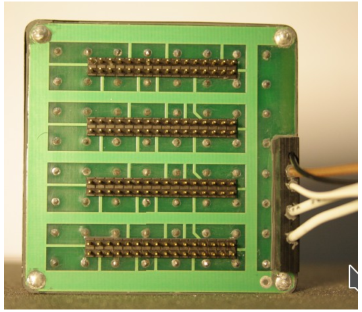
Photonis 2-inch Multi-Anode MCP-PMTs

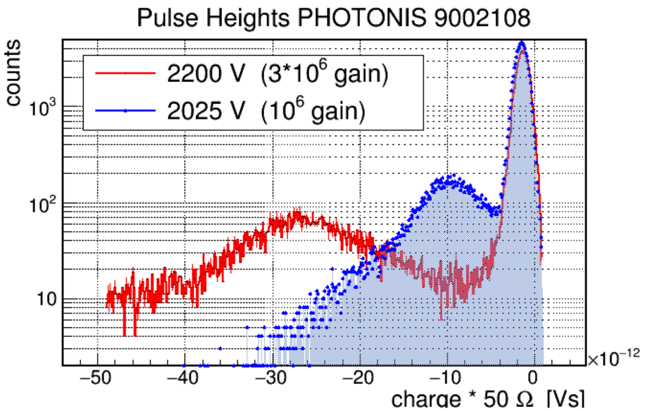
- **Photonis XP85112 (until ~2018)**
  - Burle Planacon layout
  - 8x8 pixel anode grid
  - 1-layer ALD coating (since ~2011)
  - Active/total size: 53x53/59x59 mm^2
  - **81% fill factor (active area ratio)**
  - Pore size: **10 µm** (and **25 µm**)
  - **Normal QE (20 - 25%) and CE (~65%)**
  - **Backplane with four 32-pin connectors (2 mm pitch)**
  - FEE usually connected by custom-built adapter boards and/or cables

- Measured with scope (LeCroy WavePro 7300, 3 GHz)
  - **Very fast and short signals**
  - Falltime ~600 ps
  - Risetime ~800 ps
  - Width ~900 ps
  - Mean pulse height at 10^6 gain: ~25 mV
- P/V ratio at 1e6 gain: ~3

x-scale = 2 ns/div; y-scale = 10 mV/div

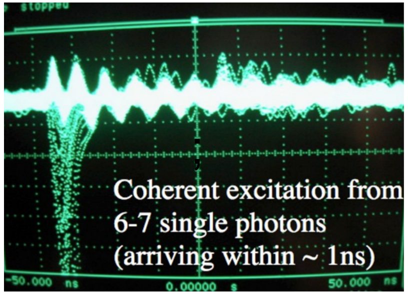




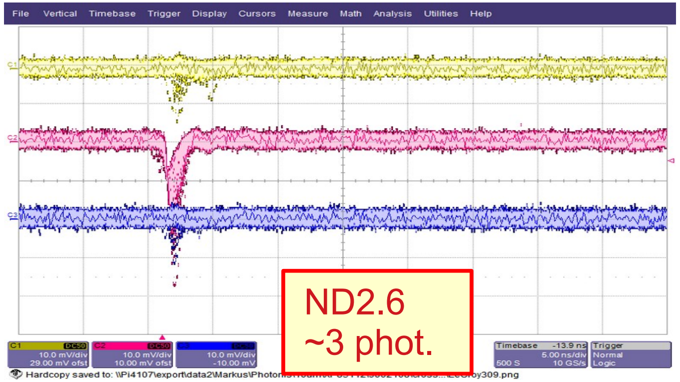


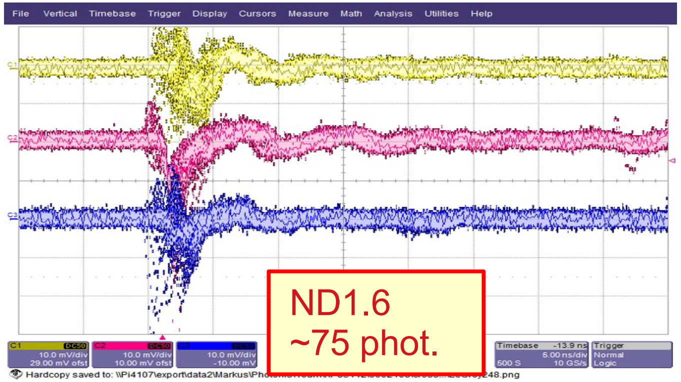
Oscillations (old)

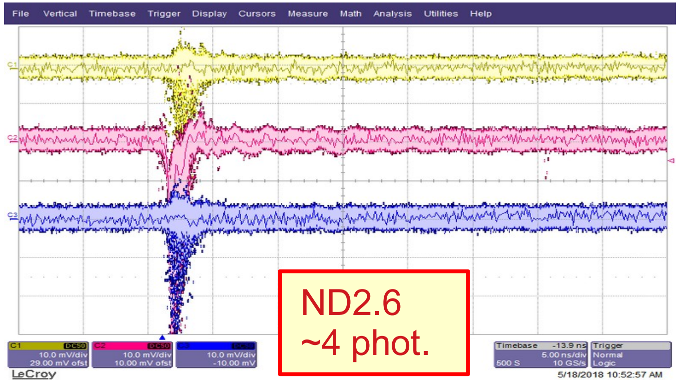
RICH 2016: J. Vav'ra, NIM A876 (2017) 185

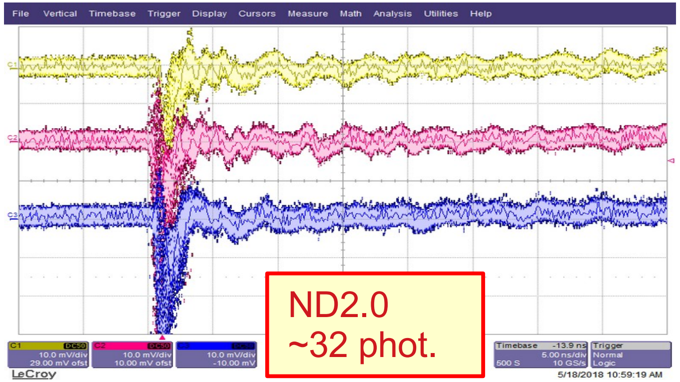


- J. Vav'ra: "coherent excitations" in old (2005) Planacon tubes
- Not seen if only one pixel illuminated; shows up when **several pixel hit** simultaneously
- Various tests: illumination of **3 to 12 pixels** (shadow mask) and **full area** at **different intensities** (neutral density filters) → **3 pixels read out** (e.g., trigger laser*px44)







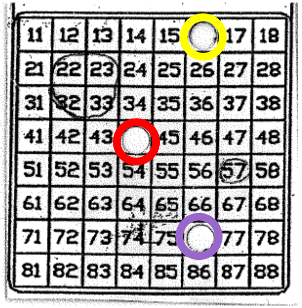


Photonis 9002108

x: 5 ns/div
y: 10 mV/div

Trigger:
Laser * px44

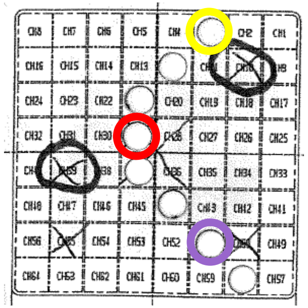
pixel's read out



Hamamatsu YH0250

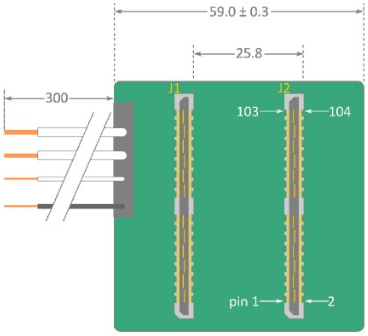
x: 5 ns/div
y: 10 mV/div

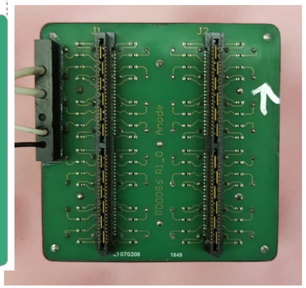
Trigger:
Laser * CH29



Photonis 2-inch Multi-Anode MCP-PMTs

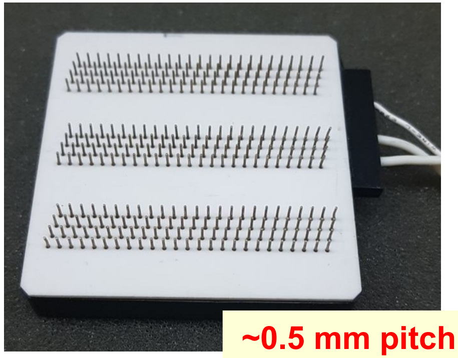
- Coherent oscillations exist in many older MCP-PMTs
  - Appear when **several photons** hit the same PMT **simultaneously** and/or at **high intensities**
  - Could lead to detection of **fake hits** in other anode pixels
- Redesign of backplane: oscillations much lower
- **Phot. XP85122-S-BA (new)**
  - Same layout as old 2'' Planacons
    - Delivery of first PMT: ~2018
    - 8x8 pixels; 81% fill factor; 10 μm pores
  - 2-layer ALD coating and high QE
  - Improvements to catch most recoil electrons of MCP-in → **CE > 90%**
    - D. Orlov et al., JINST 13 (2018) C01047





- New backplane to reduce oscillations and crosstalk
  - **Redesign of internal anode plane**
    - 75 Ohm resistor at each pad?
  - **Two 2x52-pin Samtec sockets**
    - QRM8-052-05.0-L-D-A-GP
    - Only ~**every 3rd bin connected** to anode
  - Read out by FPGA-based DiRICH/TRB3 DAQ
    - DiRICH (32 chan./board; FPGA TDC)
    - Multi-hit capable (up to 127 hits/chan/trig)
    - Provides hit time stamps (TDC) and ToT

- **Photonis XP85132**
  - PANDA Endcap DIRC
  - 3x100 pixel anode grid
  - 1- (or 2-)layer ALD coatings
  - Active/total size: 53x53/59x59 mm^2
  - **81% fill factor**
  - Pore size: **10 μm**
  - **High QE (~30%) and CE > 90%**
  - Readout: taylored TOFPET ASIC
    [M.D. Rolo et al. JINST, 8 (2013) C02050]



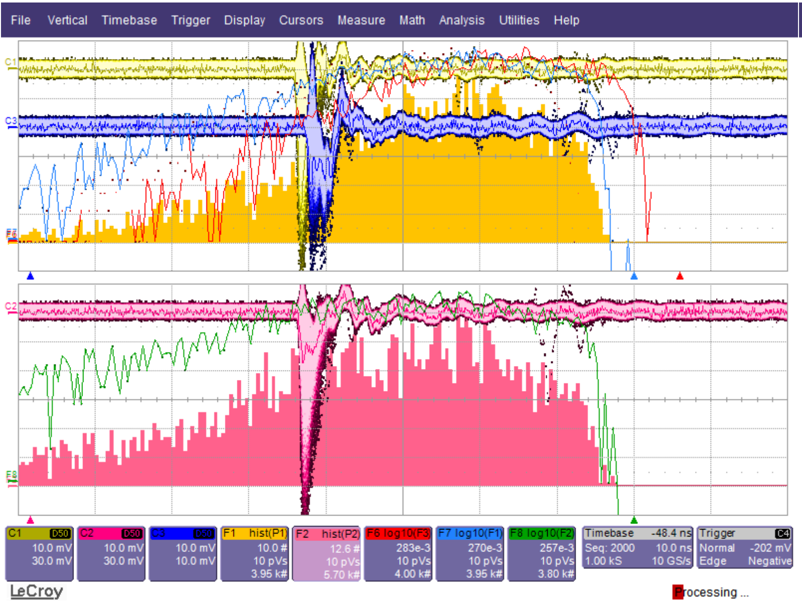
~0.5 mm pitch

Oscillations (new)

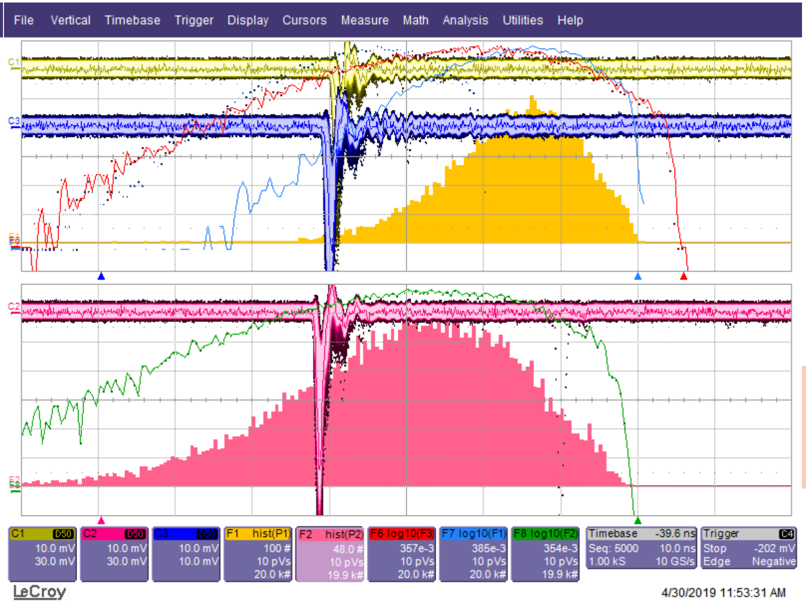
x: 10 ns/div
y: 10 mV/div

Trigger:
Laser pulse

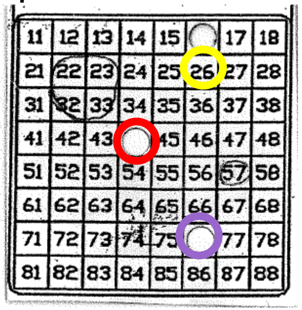
9002108 (old backplane)
64 Pixels * 3 Photons/Pulse ≈ 200 Photons



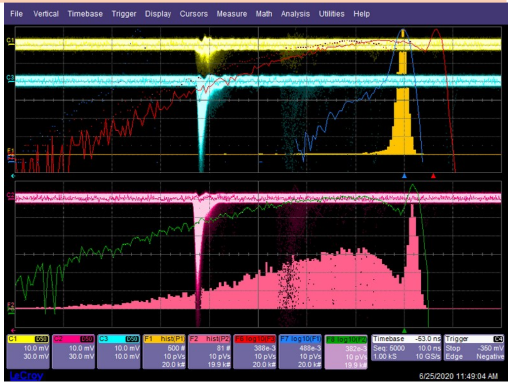
9002150 (new backplane)
64 Pixels * 4 Photons/Pulse ≈ 250 Photons



pixel's read out



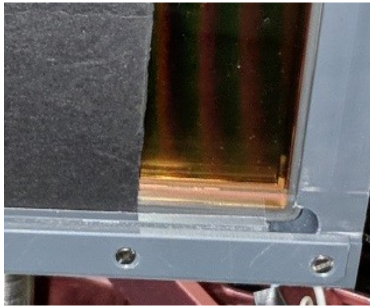
Latest Photonis **9002192**
with new backplane:
12 pixels * 2 phot./pulse = 24 phot.

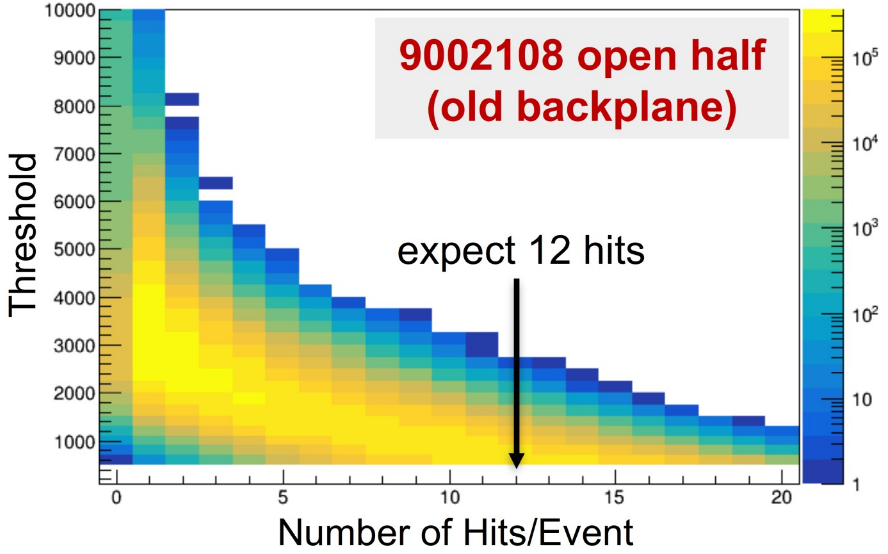


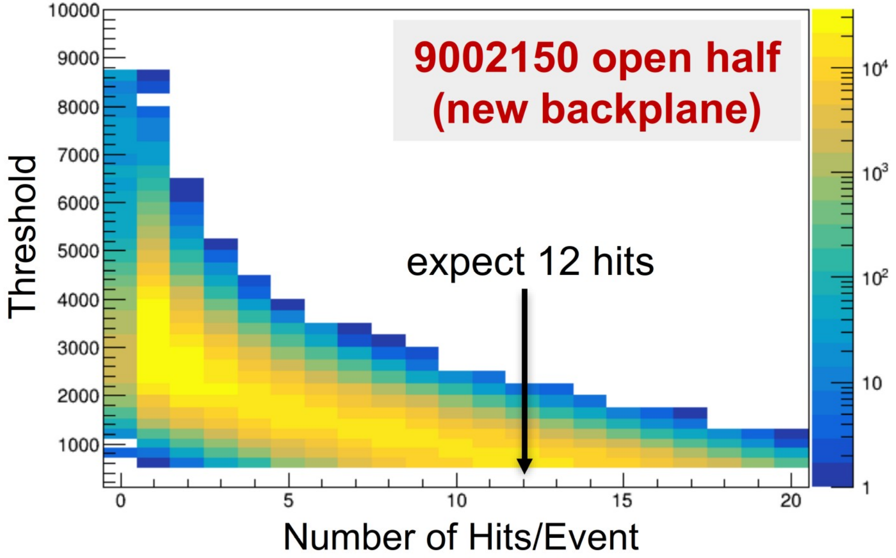
- Red (632 nm) PiLas, 10 kHz, ALD coating, 1e6 gain, illumination of full sensor
- **Oscillations clearly lower after backplane redesign**
- 9002192 (masked): -- almost no signal at covered pixel (lower right, yellow trace)
  -- clean signals at the 12 illuminated pixels (blue and red trace)

Crosstalk seen with DiRICH/TRB3 DAQ (A)

- Cover half of the MCP-PMT and read out only the 3 most left and right rows
- **At different threshold:** count the **number of simultaneous hits** in a 15 ns window around the laser peak on the covered and open side (24 pixels each)
- ND-Filter to get ~1 p.e./pixel ($\overline{n}_{pe}$), adjust HV for similar pulse height distribution in both MCP-PMTs
- Illuminated (open) half: **~12 hits expected** [24 pixels * (1- exp(-$\overline{n}_{pe}$) with $\overline{n}_{pe}$ ~ 0.7]
  Covered half: only crosstalk ("fake") hits from oscillation should be seen

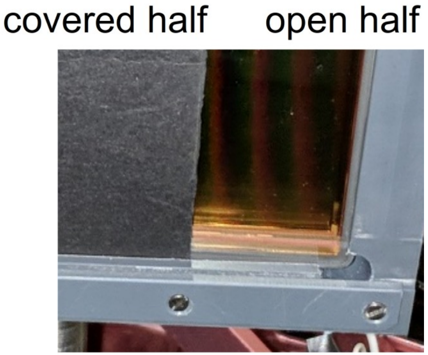


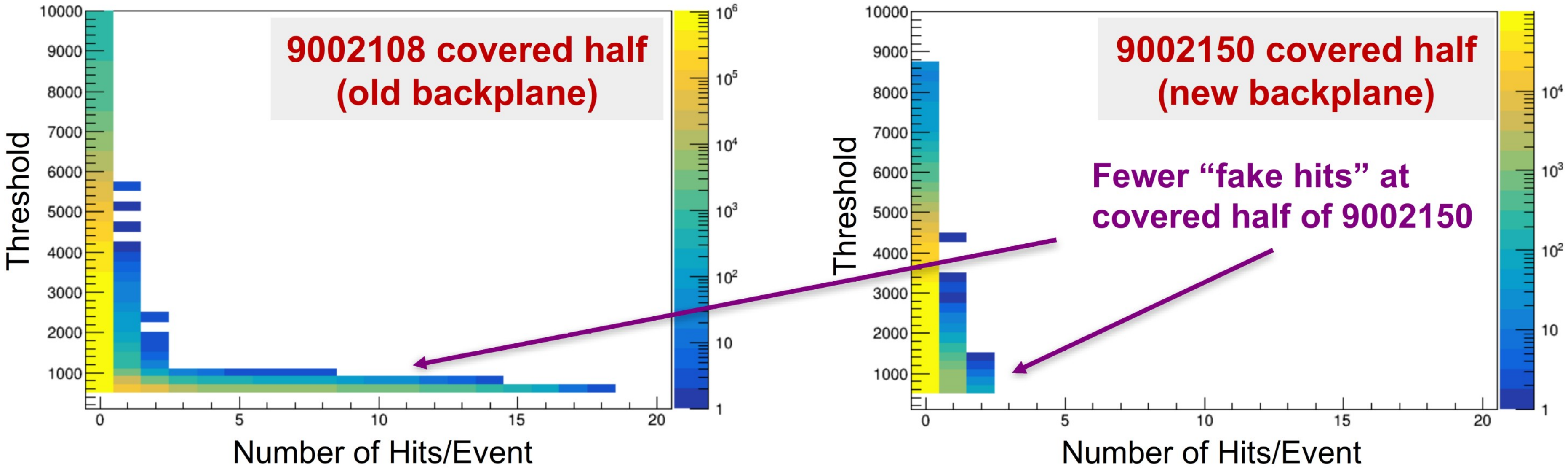




Crosstalk seen with DiRICH/TRB3 DAQ (B)

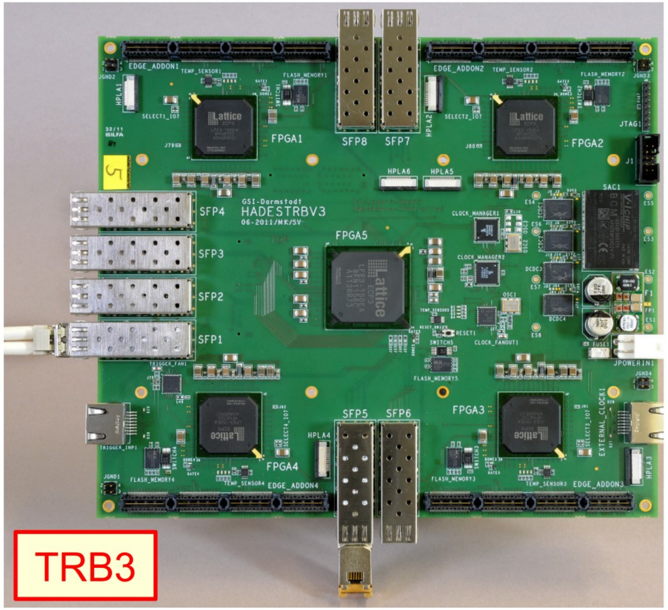
- 9002108: at low threshold crosstalk of **up to 18 hits/laser pulse** are observed
  9002150: only **up to 2 hits/laser pulse** seen
- 9002150 also shows 25% lower crosstalk pulse height compared to 9002108
- New backplane of Photonis MCP-PMT reduced ringing and crosstalk
- **Important lesson:** **careful backplane design is essential to avoid fake hits**





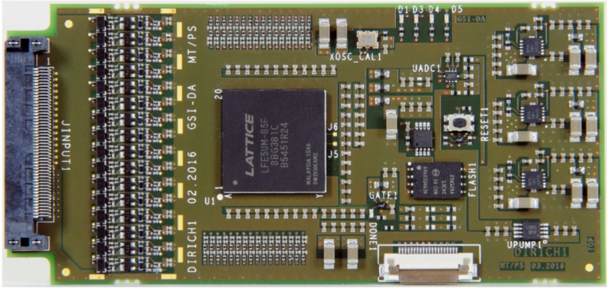
DiRICH/TRB3 DAQ

- FPGA based DAQ: TRB3, DiRICH, 4 PMTs/backplane
  - Developed at GSI for HADES and CBM
  - **32 chan. DiRICH FEE boards**: amplification, discrimination, TDC, ToT
  - **256 chan. TRB3**: distribution of trigger signals and accumulation of data
  - Power supply and data concentrator card at each backplane
  - < 20 ps RMS; 700 kHz max. trigger rate

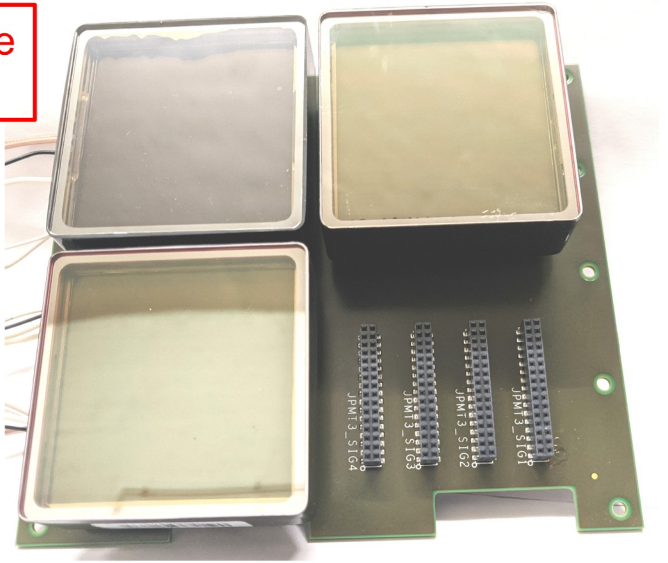


DiRICH/TRB3 DAQ-system:
A.Neiser et al., JINST 8 (2013) C12043
C. Ugur et al., JINST 11 (2016) C01046
J. Michel et al., JINST 12 (2017) C01072
A. Rost et al., JINST 12 (2017) C02047
The TRB3 website: http://trb.gsi.de

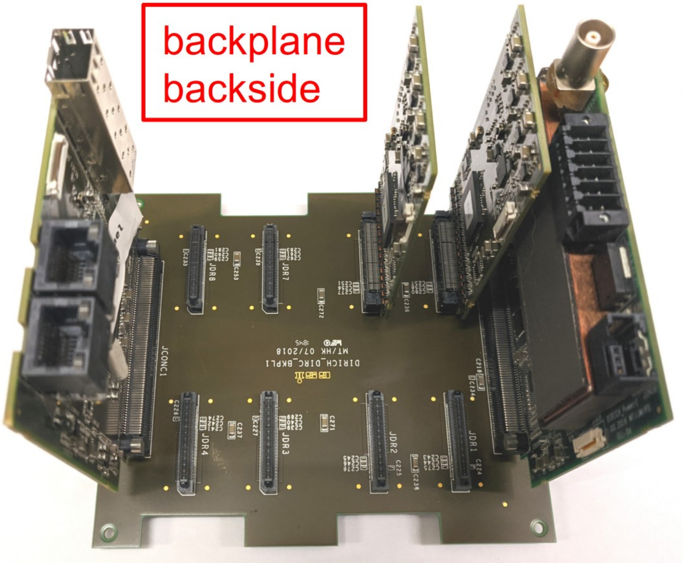
DiRICH



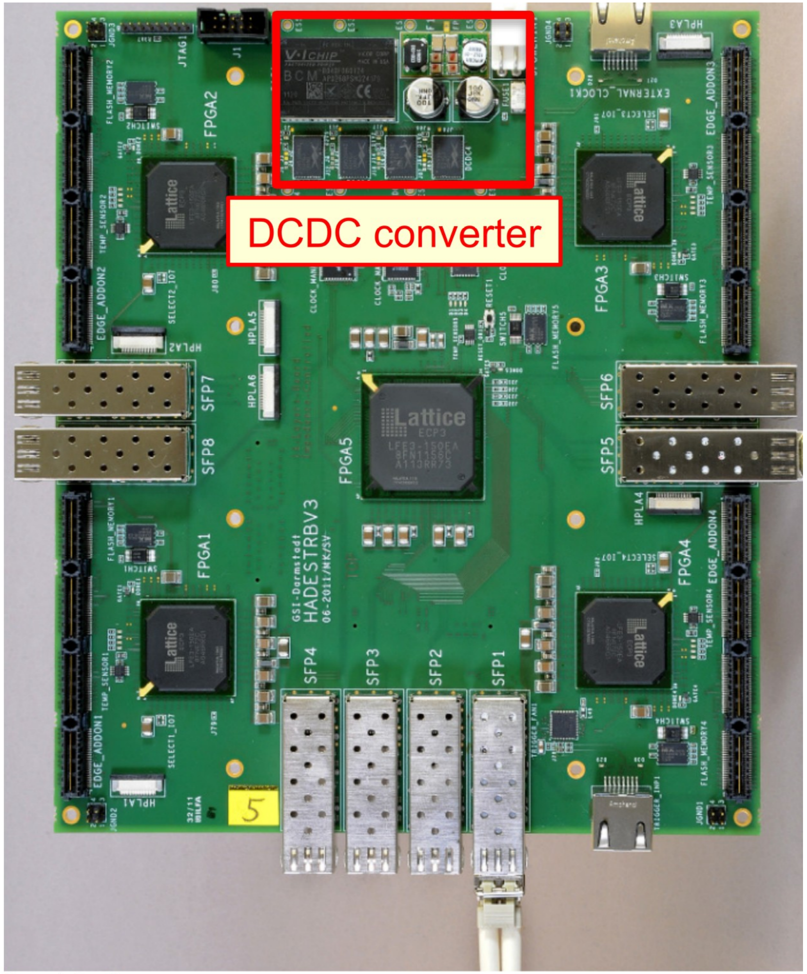
backplane frontside

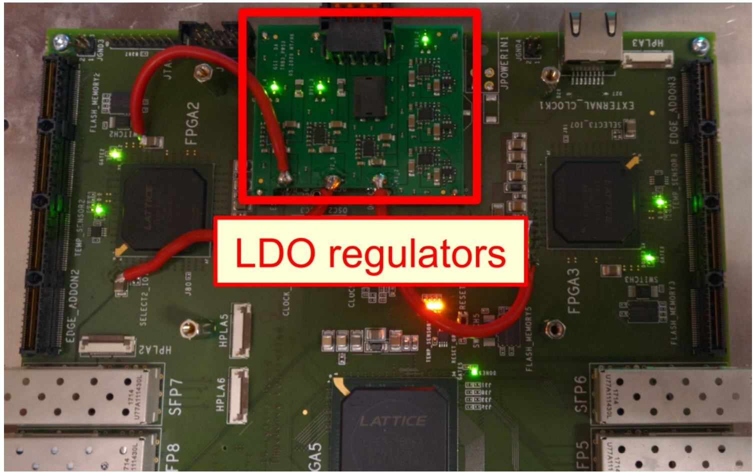


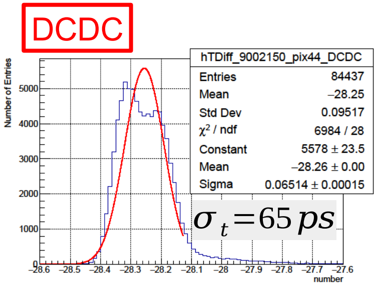
backplane backside

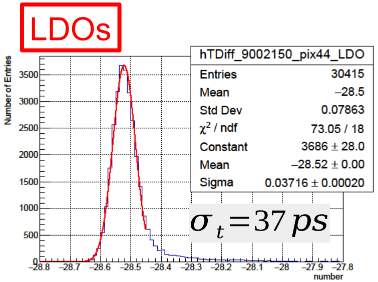


Problem with TRB3s







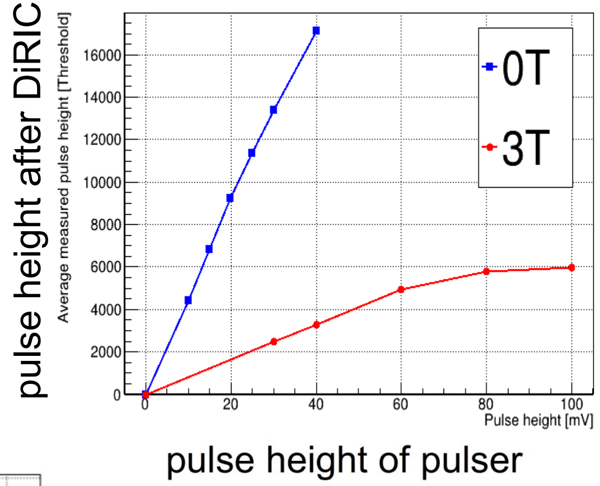


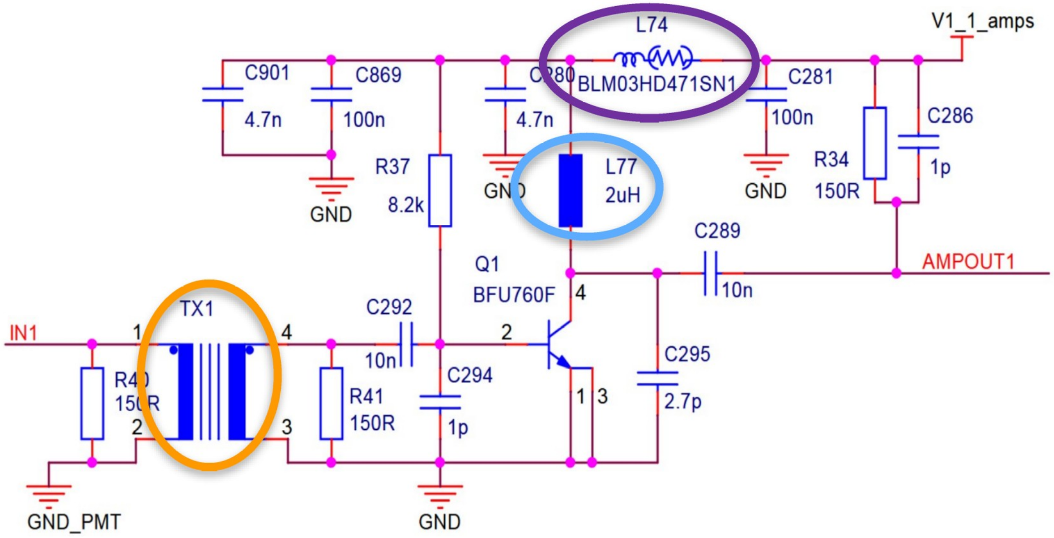
- Observation: measured time resolution is much worse than the nominal <20 ps RMS
  - TRB3 was first powered with DCDC voltage converters
    - Double peak structures seen in both Time and ToT
    - Delay lines inside FPGA highly susceptible to voltage variations → leads to worse time resolution and double peaks
  - TRB3 is now powered by LDOs (Low Dropout regulators)
    - LDOs are less noisy and deliver more stable output voltages to FPGA
    - **Much better time resolution** and no double structures seen anymore

Problem with DiRICH inside B-field

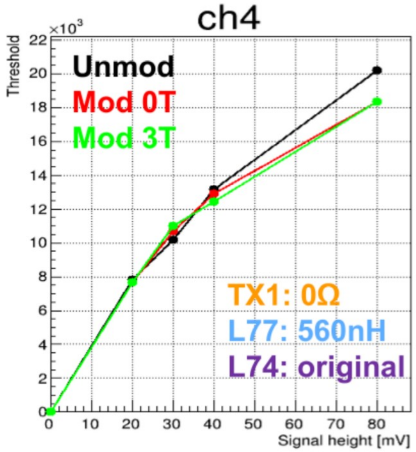
- Observation: massive signal damping inside B-field
  - Schematic shows input stage of one DiRICH input channel
    - Amplification (x25) drops by factor 5 – 6 inside 3 Tesla MRI magnet
    - **Coil** (TX1, L77, L74) **ferrites saturate** at above 0.3 – 0.7 T
  - Solution: exchange TX1 coil with 2 x 10 nF capacitors to keep the electric isolation between sensor channels and DAQ
    - **TX1 bridged and L77 without ferrite core** shows nearly **no signal drop**
    - total loss of only ~11% in 3 Tesla B-field

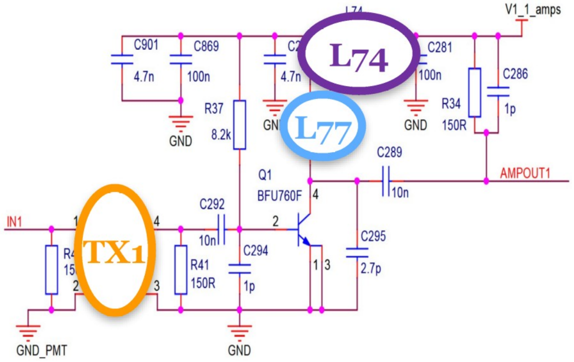
old configuration





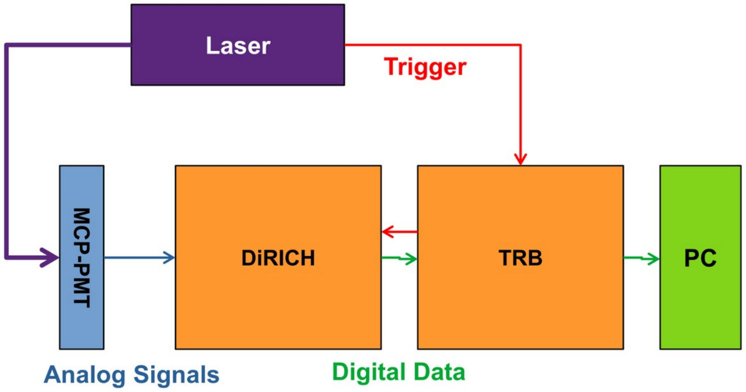
new configuration



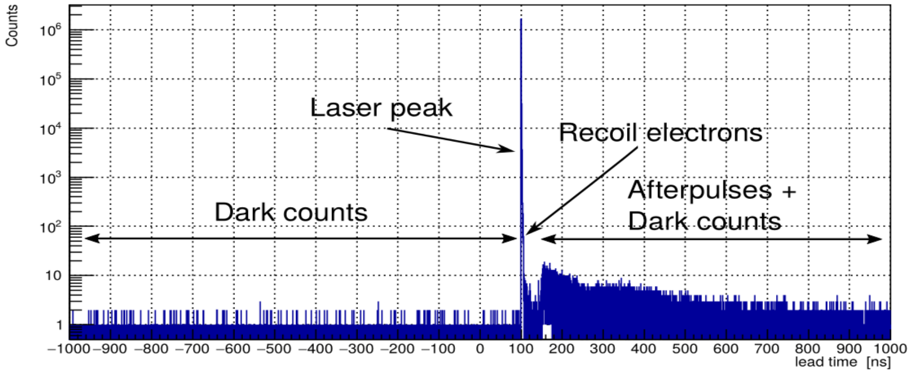


PMT Quality Control Scans with DiRICH/TRB3

- Automated quality control measurements for series production Barrel (and Endcap) DIRC MCP-PMTs



- Measure time delay between laser pulse and pixel response
- For easier analysis laser peak shifted to 100 ns for all channels

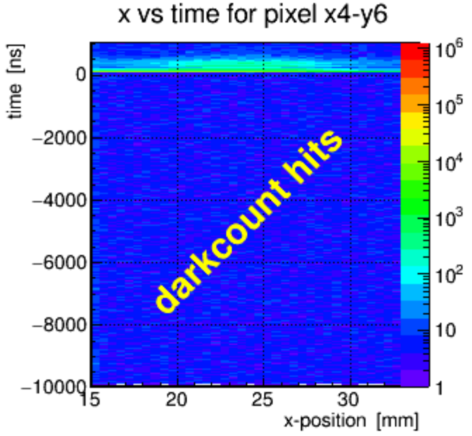


- Each channel: permanently recording time and time-over-threshold (ToT) information of all hits above a freely selectable threshold
- Record all hits in a certain time window (e.g., -10 to +1 μs) around PiLas trigger (for each pixel)
- xy-scans (½ – 1 mm steps): information per channel
  - x-, y-position, hit time, ToT, number of hits
  - **Time resolution** (TTS and RMS) per anode pixel
- Higher level information accessible:
  - **Darkcount** xy-distributions
  - Charge sharing (and electronic) **crosstalk** behavior
  - **Recoil electron** distributions (position and time)
  - **Afterpulse** distributions → TOF of feedback ions
- 3D-info (x, y, t) allows the **separation of**
  - **hits from recoil electrons**
  - **charge sharing events**
  - **afterpulse hits**

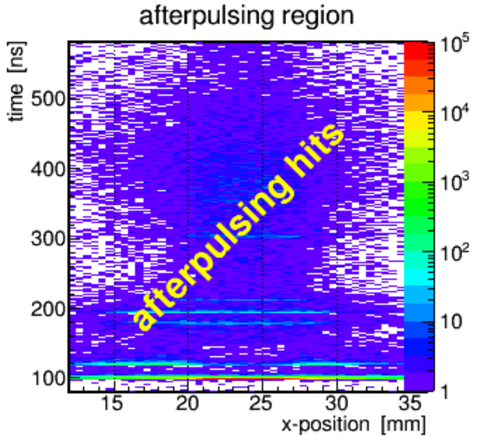
Information from DiRICH/TRB3 Scans

PHOTONIS 9002085; read out pixel: x4-y6

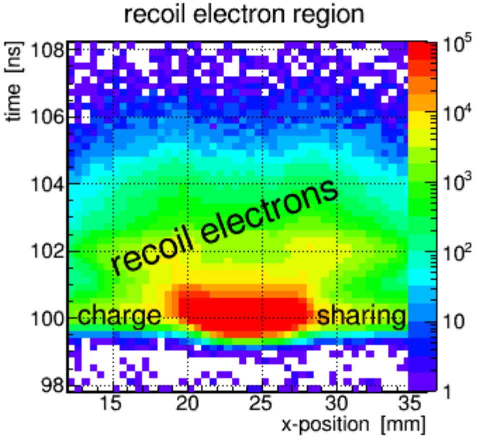
Dark counts



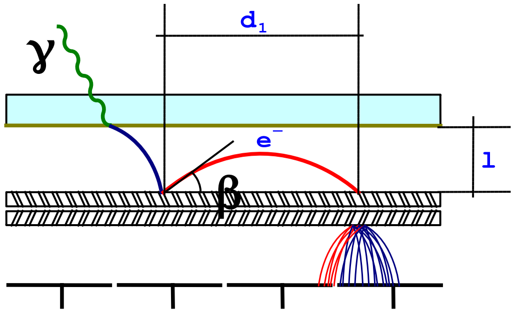
Afterpulses

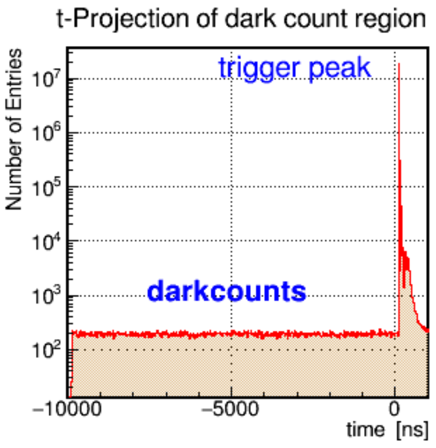


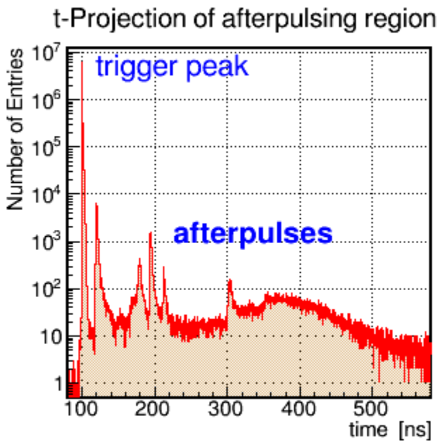
Recoil electrons

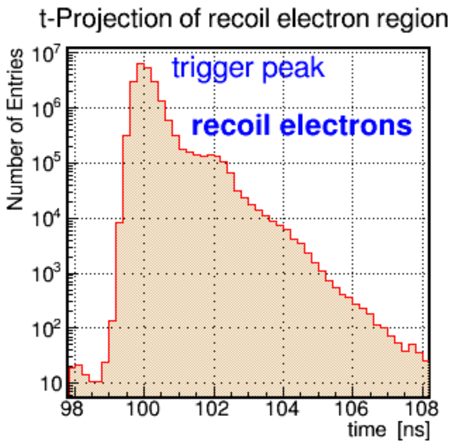


Recoil electrons

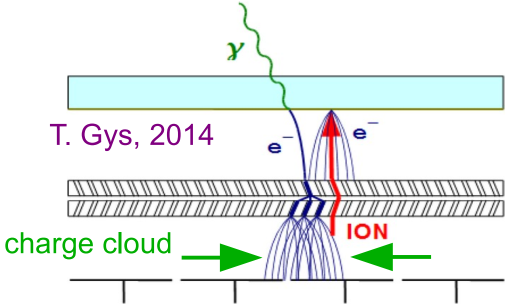








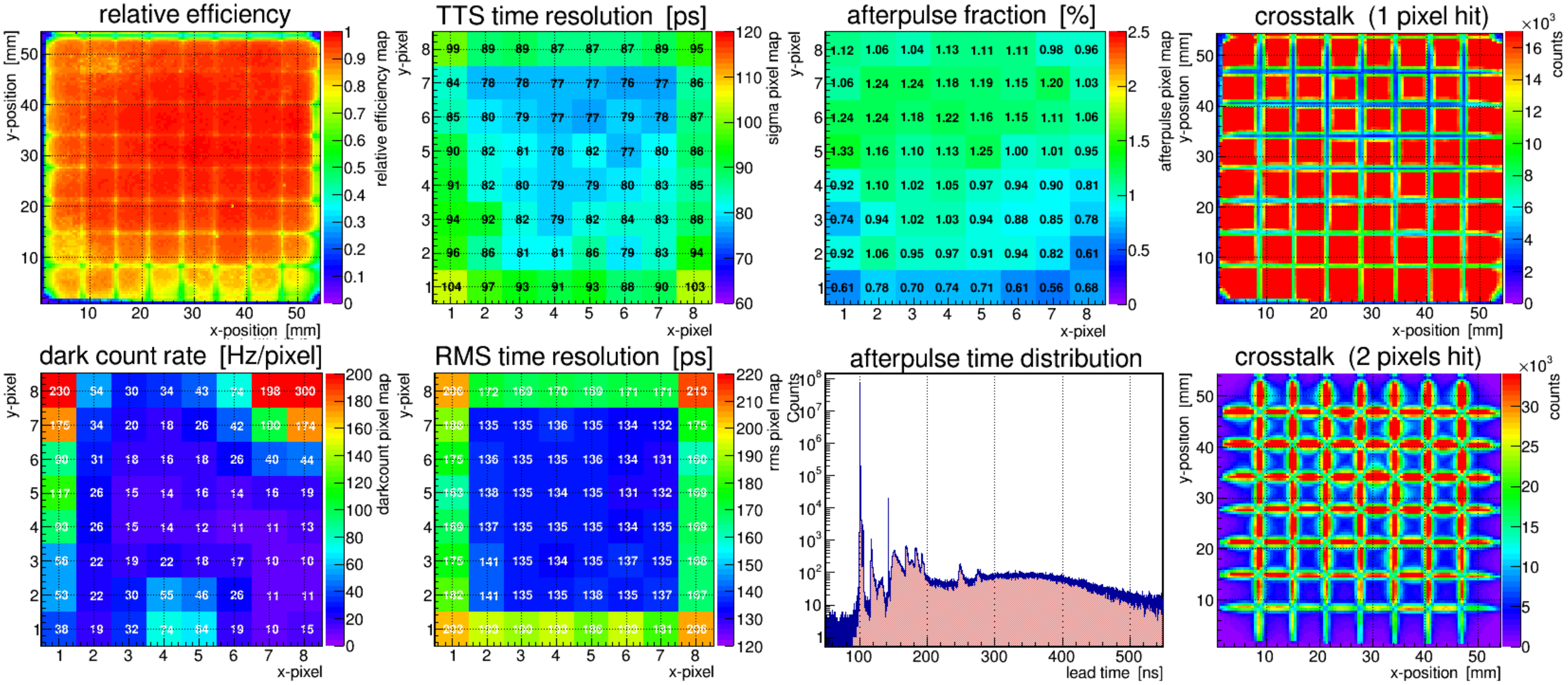
Afterpulses + Charge sharing



Example Results of xy-Scans with DiRICH/TRB

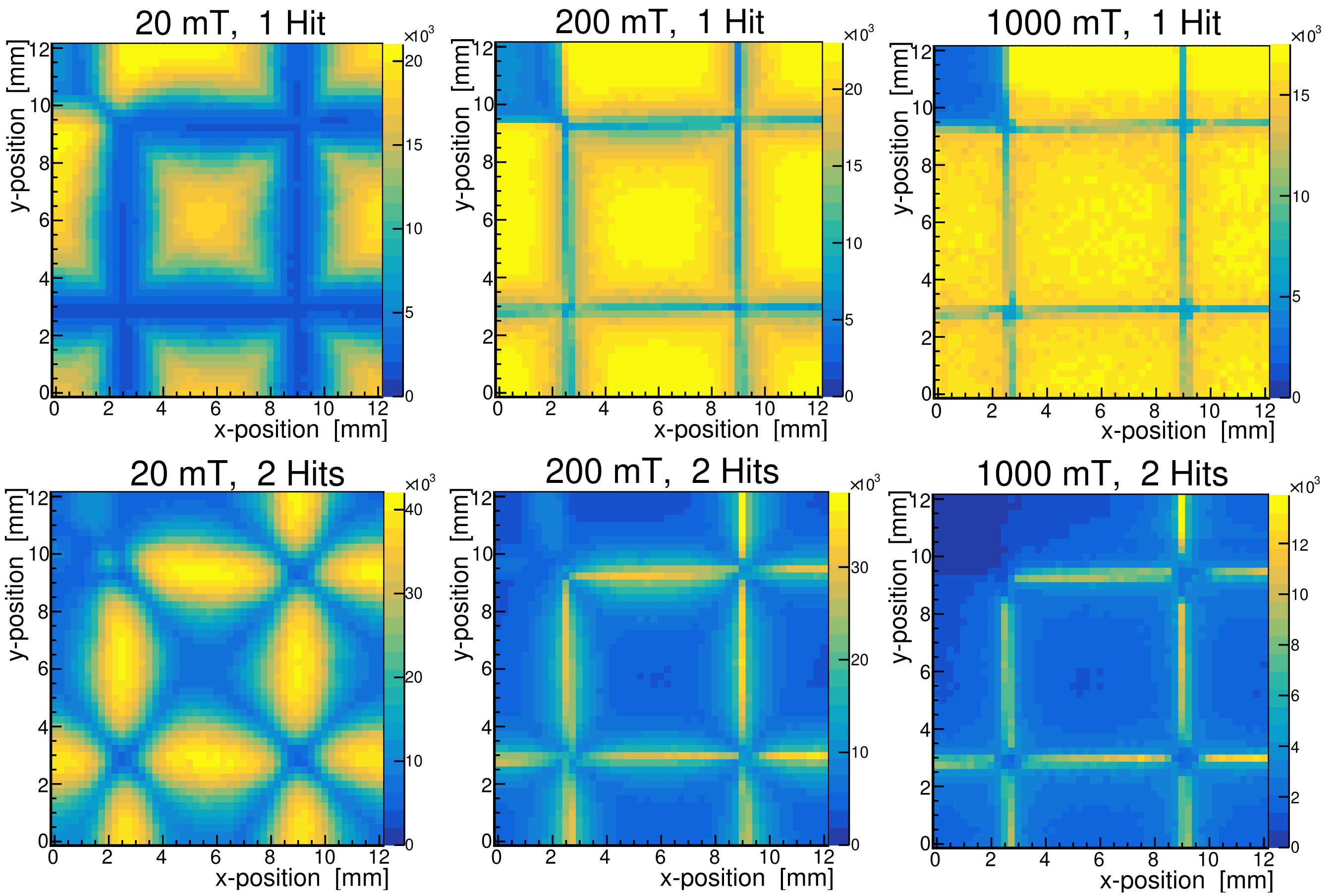
!! All results obtained with **one single xy-scan** of ~21 hours (½ mm steps; 13689 measured positions) !!

PHOTONIS 9002229



Crosstalk inside Magnetic Field

Photonis 9002192; xy-scan of 9 pixels (6x6 mm² each) read out by TRB DAQ



- Charge sharing crosstalk is clearly affected by B-field
- Pixel position is much better defined inside B-field >0.1 T
  - magnetic field forces electrons between MCP and anode to curl
  - charge cloud is less extended
  - almost no charge sharing left
- Similar studies were done with recoil electrons
  - photo electron bounces back at MCP entrance
  - due to curling in B-field these electrons fall back to the MCP at basically the same position
  - time distribution is unchanged

Summary

- Modified backplane significantly reduced the oscillations seen in former MCP-PMTs
- PANDA Barrel DIRC MCP-PMTs will be read out by GSI-designed DiRICH/TRB3 DAQ
- Application of this system for PMT quality control screenings show very good results
    - Allows fast and automated xy-scans for each PMT
    - Access to internal PMT parameters like
        - Time resolution
        - Dark count rate
        - Electronic and charge sharing crosstalk
        - Recoil electron distributions
        - Afterpulse distributions and fractions