Pixel-by-Pixel Calibration for the Auger Fluorescence Detectors

L. Niemietz, K.-H. Becker,
K.-H. Kampert, J. Rautenberg

K. Daumiller, D. Gonzalez,
A. Menshikov, H. Klages

PIERRE AUGER OBSERVATORY

BERGISCHE UNIVERSITÄT WUPPERTAL

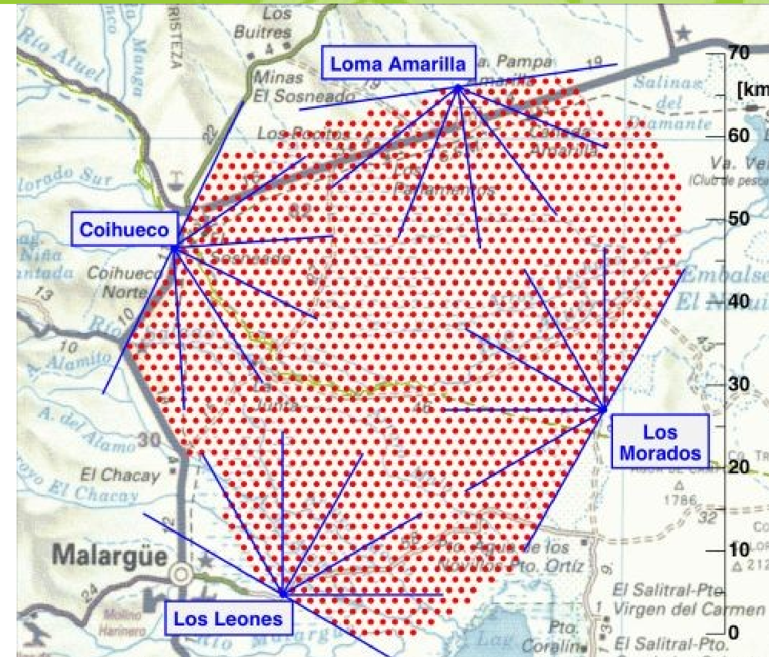
KIT Karlsruhe Institute of Technology

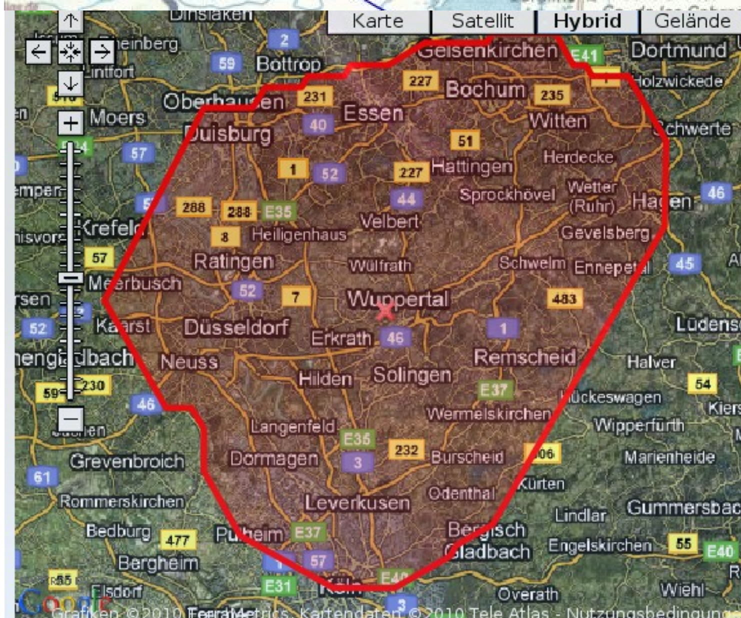
- Pierre Auger Observatory
- Motivation
- Hardware and set-up
- Data analysis
- Summary

bmb+f - Förderschwerpunkt
Astroteilchenphysik
Großgeräte der physikalischen Grundlagenforschung

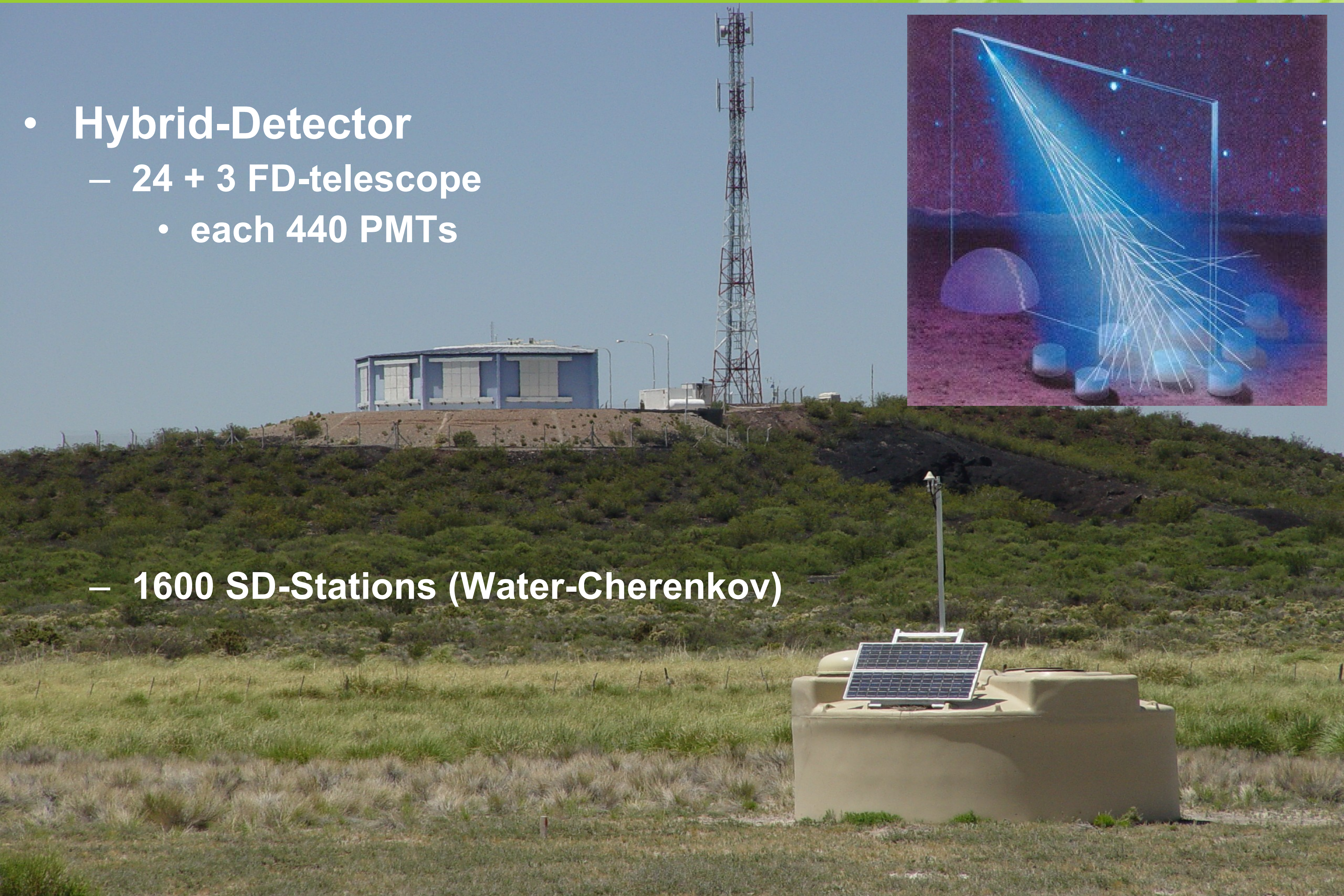
Pierre Auger Observatory

35° 28' 0'' S
69° 18' 41''W
1400 m a.s.l.



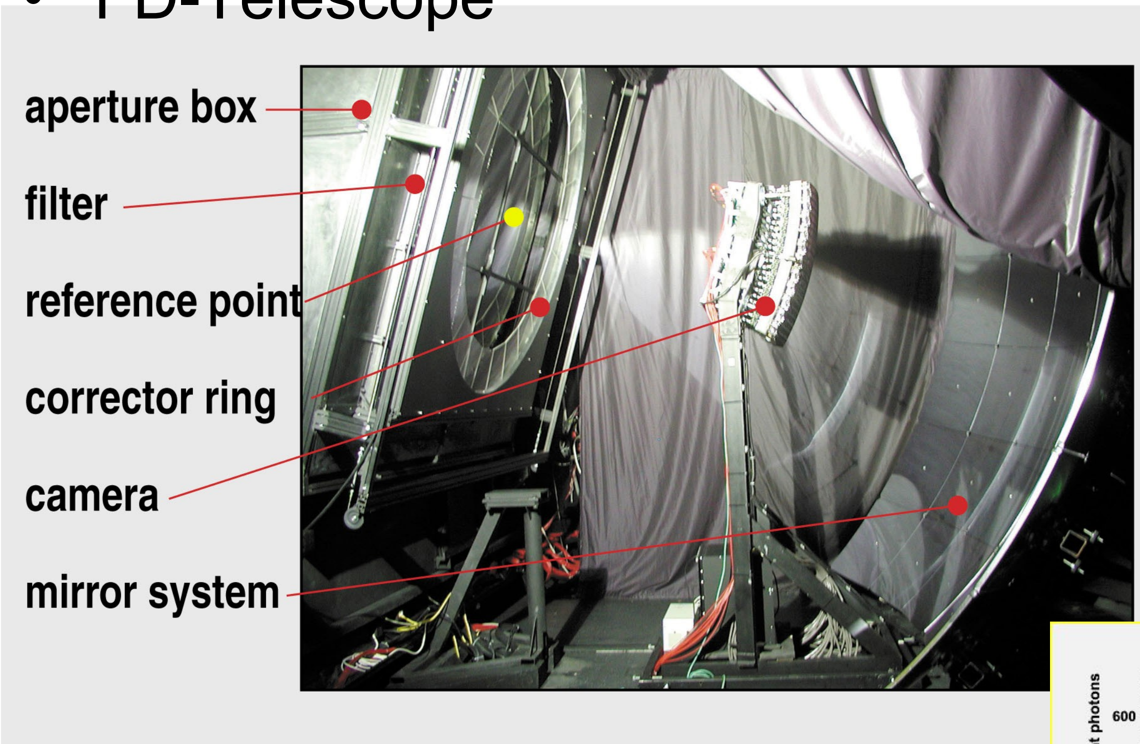


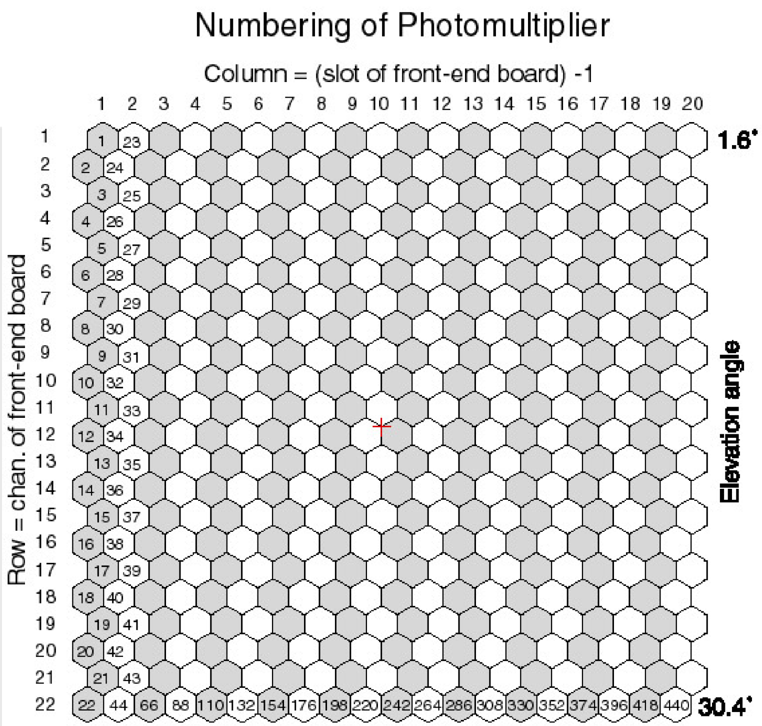
Pierre Auger Observatory



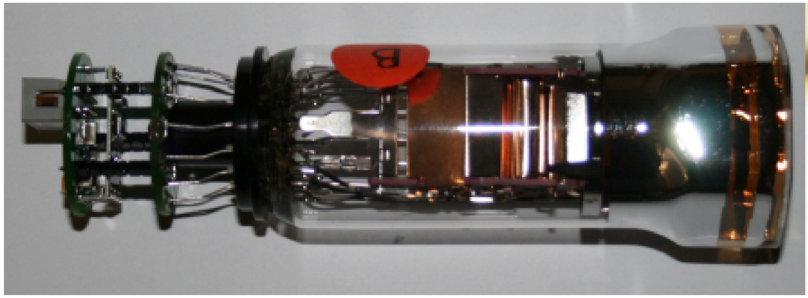
- **Hybrid-Detector**
  - **24 + 3 FD-telescope**
    - **each 440 PMTs**
  - **1600 SD-Stations (Water-Cherenkov)**

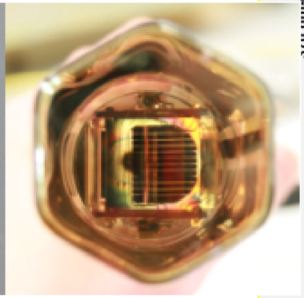
- FD-Telescope

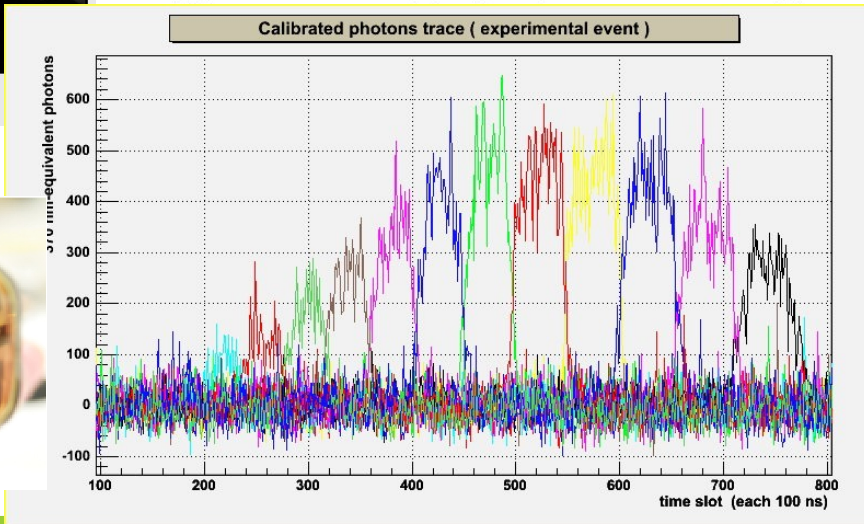




  - 440 PMTs

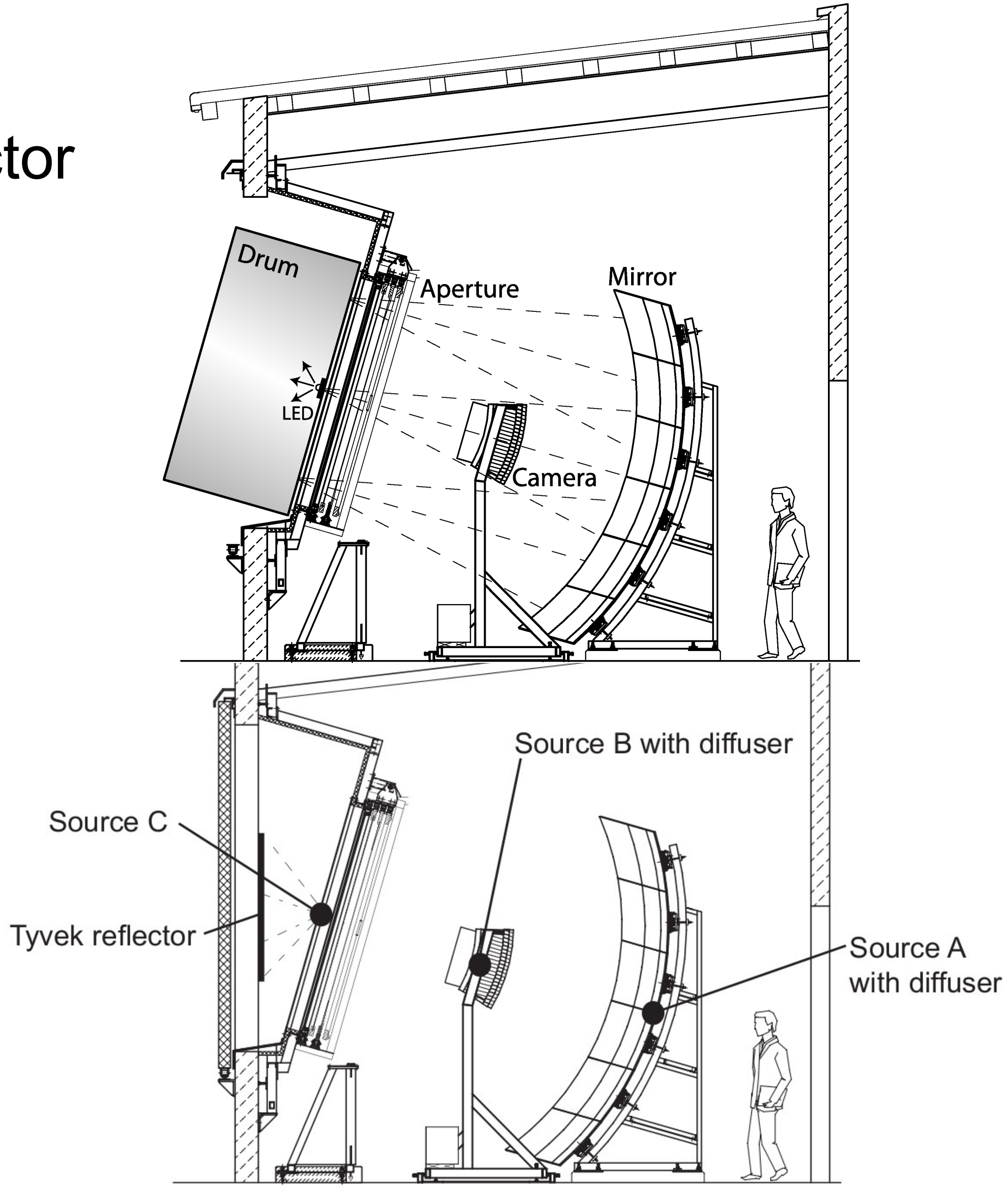






Pierre Auger Observatory

- Auger Fluorescence Detector
  - absolute Calibration
    - drum (light source with known intensity)
    - very complex
  - relative Calibration
    - compare signal of PMTs
    - 2x per night

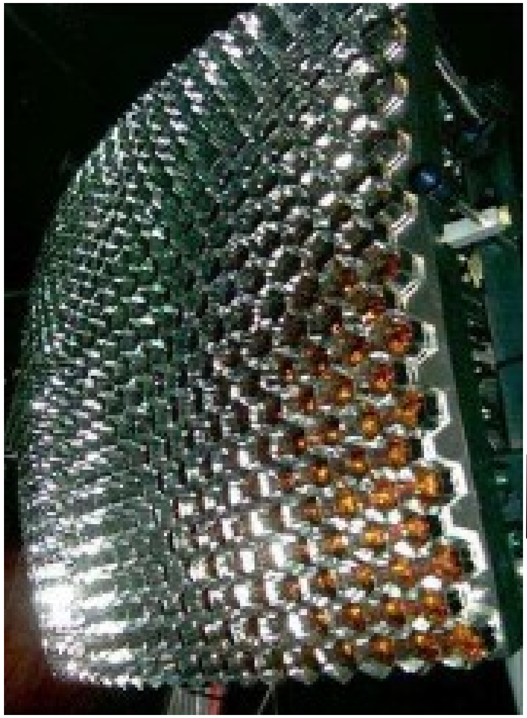


Motivation

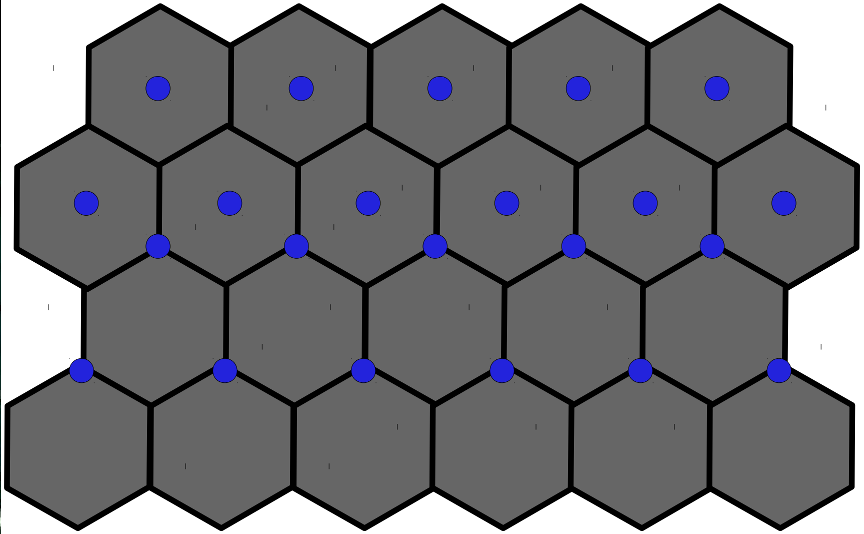
- Auger Fluorescence Detector (FD) -Calibration done by illuminating the whole camera

- Insensitive to effects:
  - mis-cablings
  - cross-talk
  - reflective effects
  - other effects, like cumulative effects

- Shoot with focused light spot at **single** PMTs
- Target on:
  - different positions on cathode-surface
  - Mercedes collectors



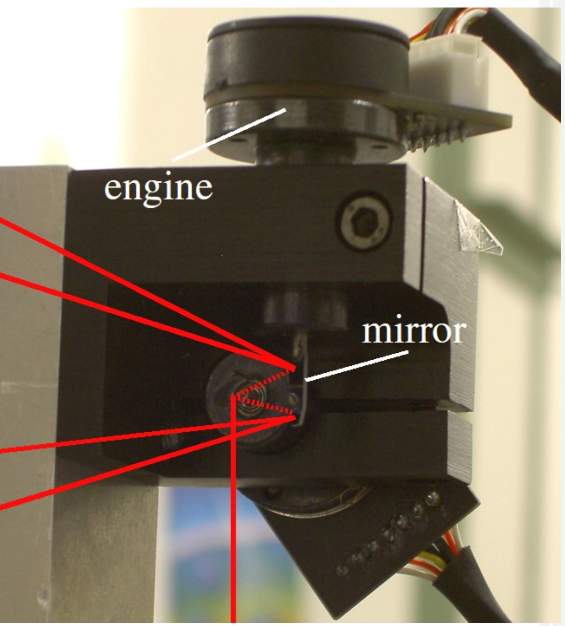
20x22 PMTs

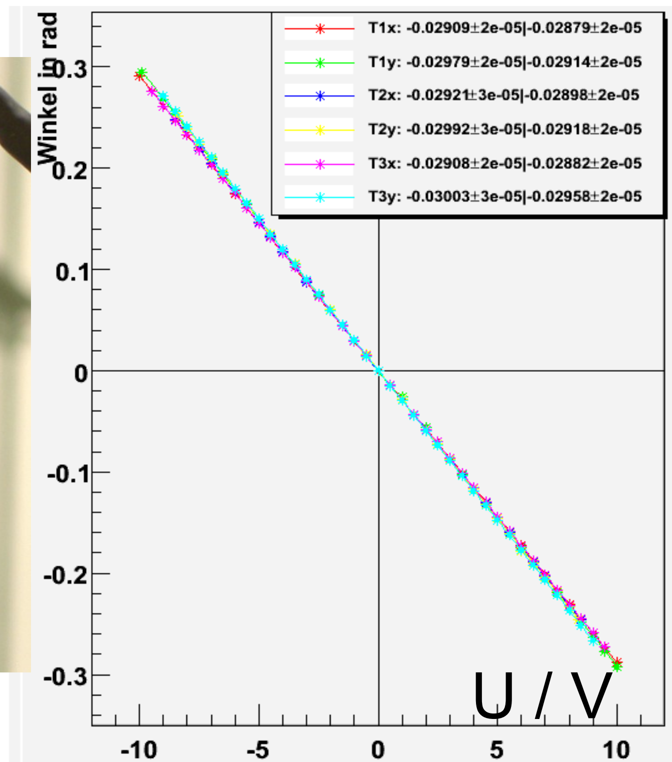


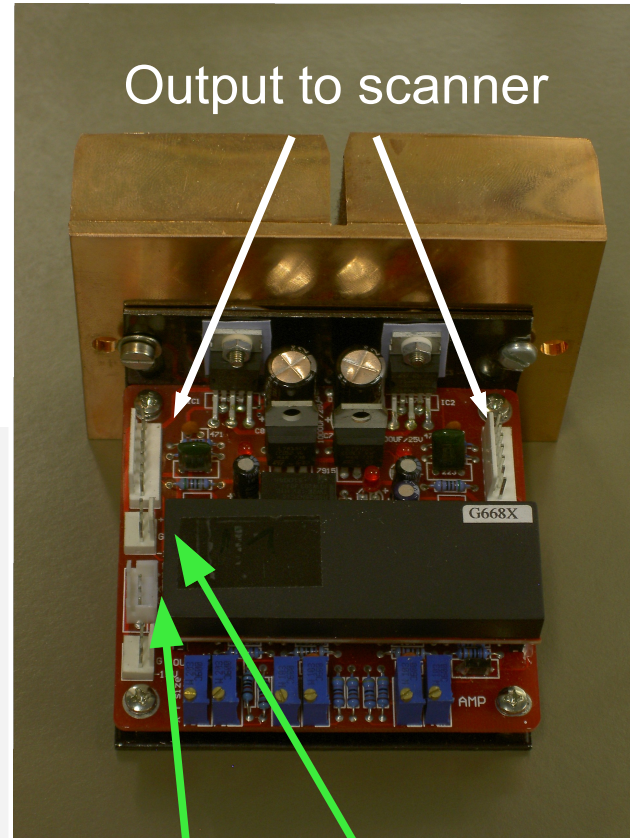
PMTs of FD-Camera

Mirror Unit

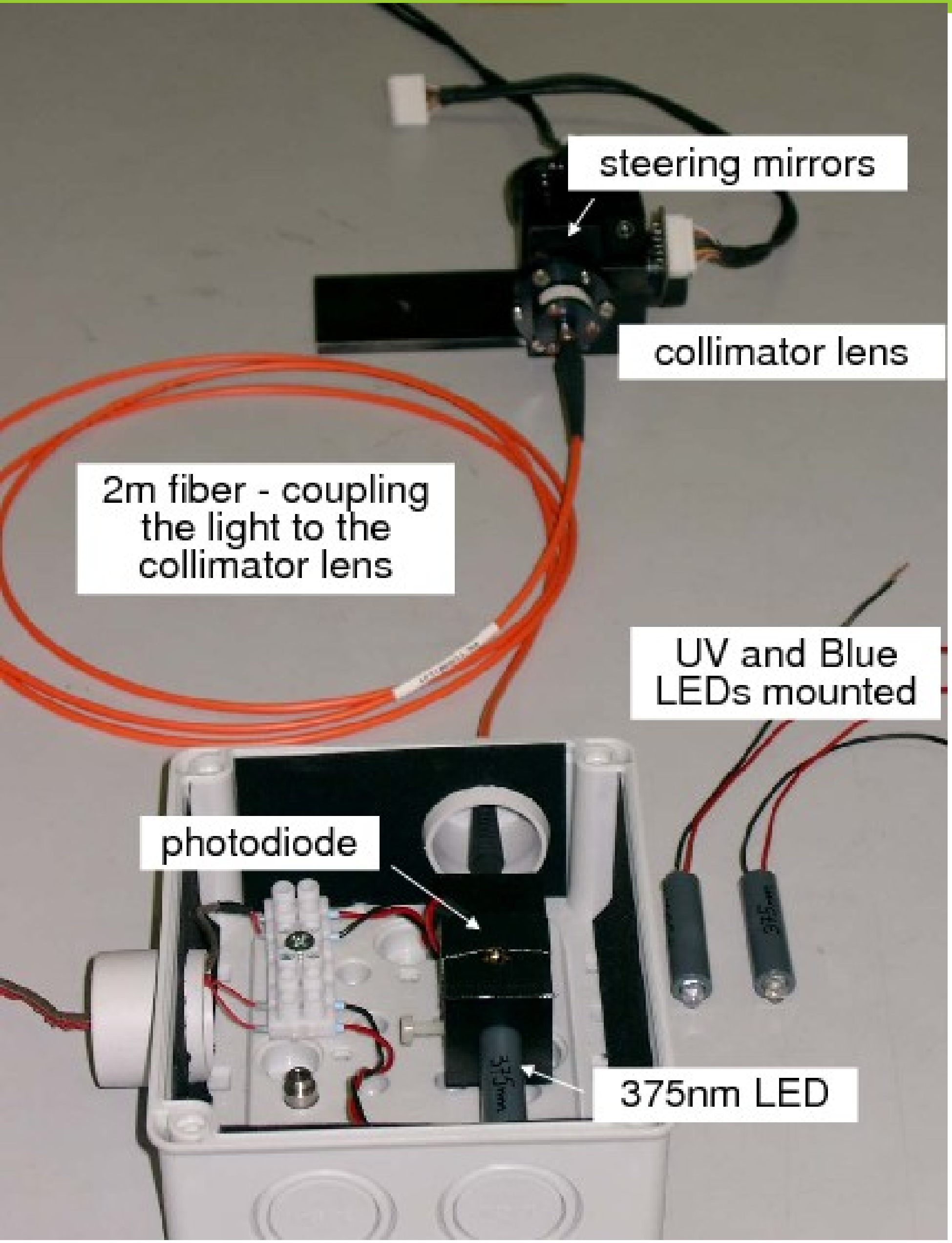
- two mirrors, one for displacement in x- one for y-axis
- analog steering of mirrors by input voltage to driver board
- angular displacement proportional to input voltage



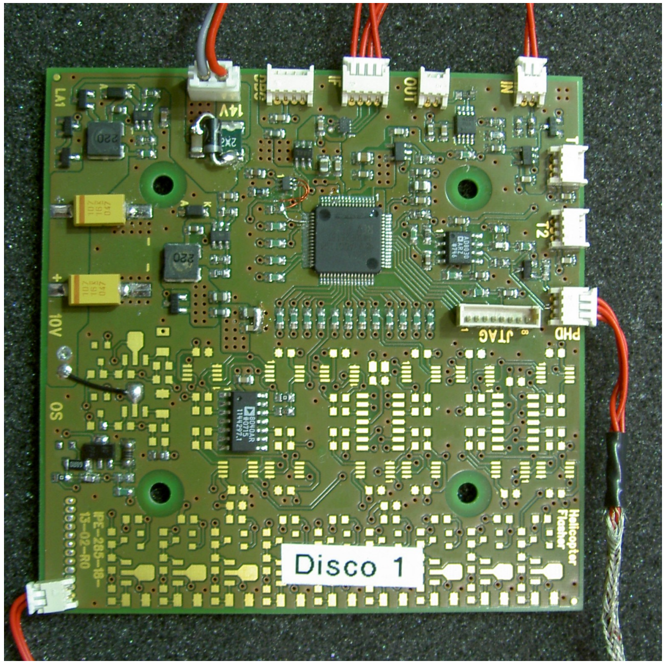




Hardware: Light-Source

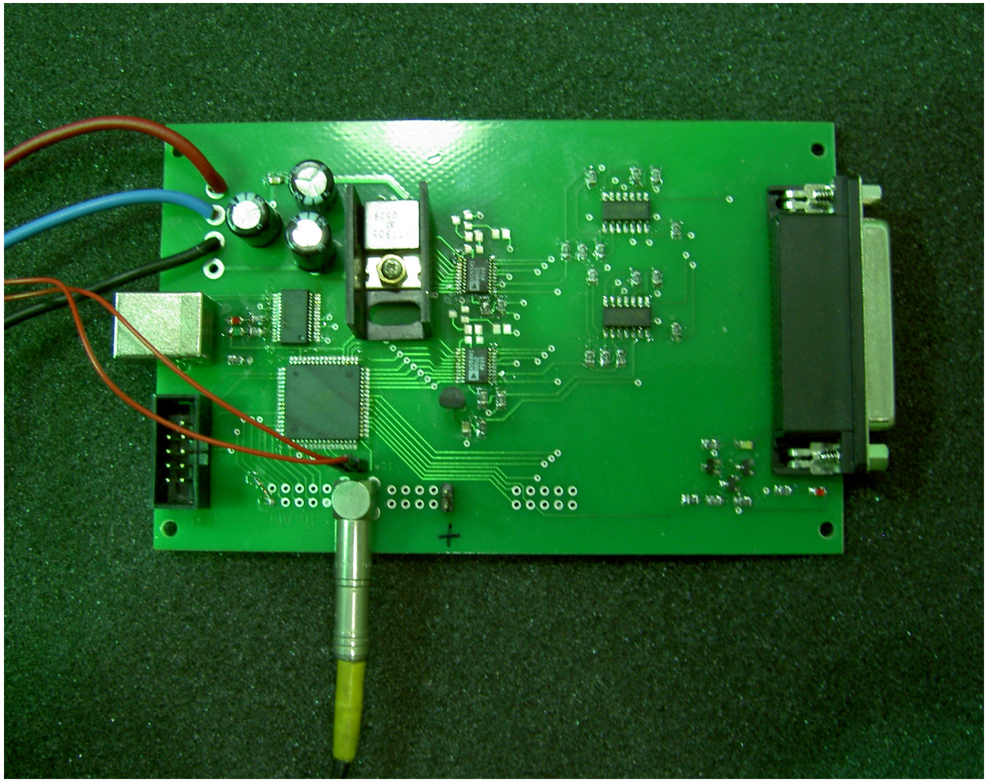


- UV and blue LED (blue for adjustment)
- photo diode to measure intensity
- collimator lens to get small spot
- light source driver board
  - control shot parameter

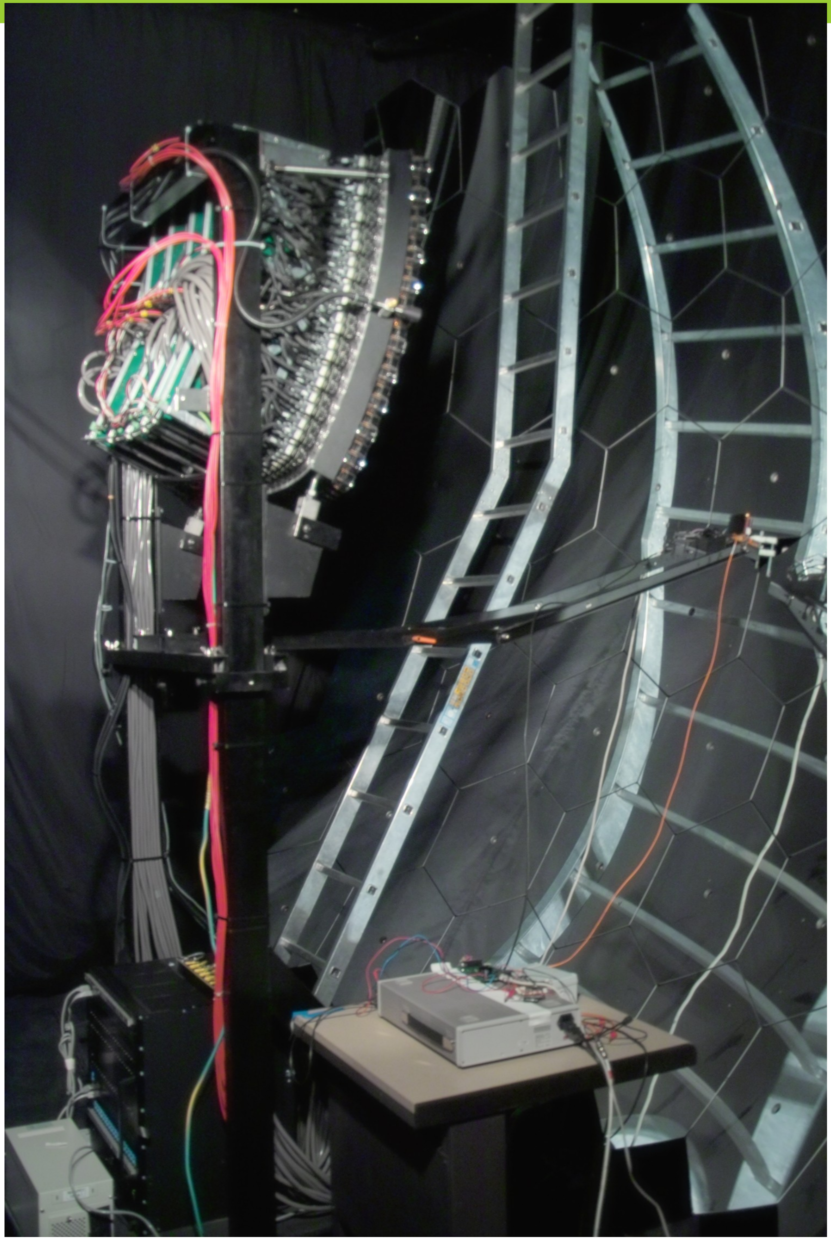


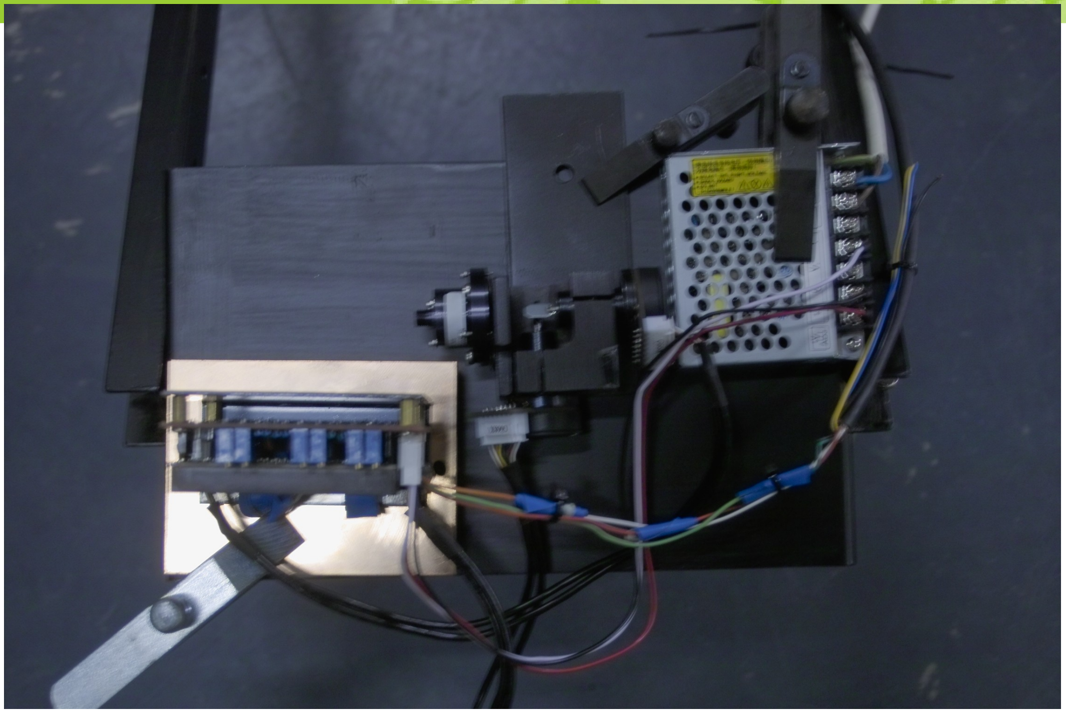
Steering board

- communicates with Laptop via USB
- communicates with light-source driver-board via I²C
- provides voltage for mirror-unit according to an DAC-count value to target at a specific position



Measurement Set-up

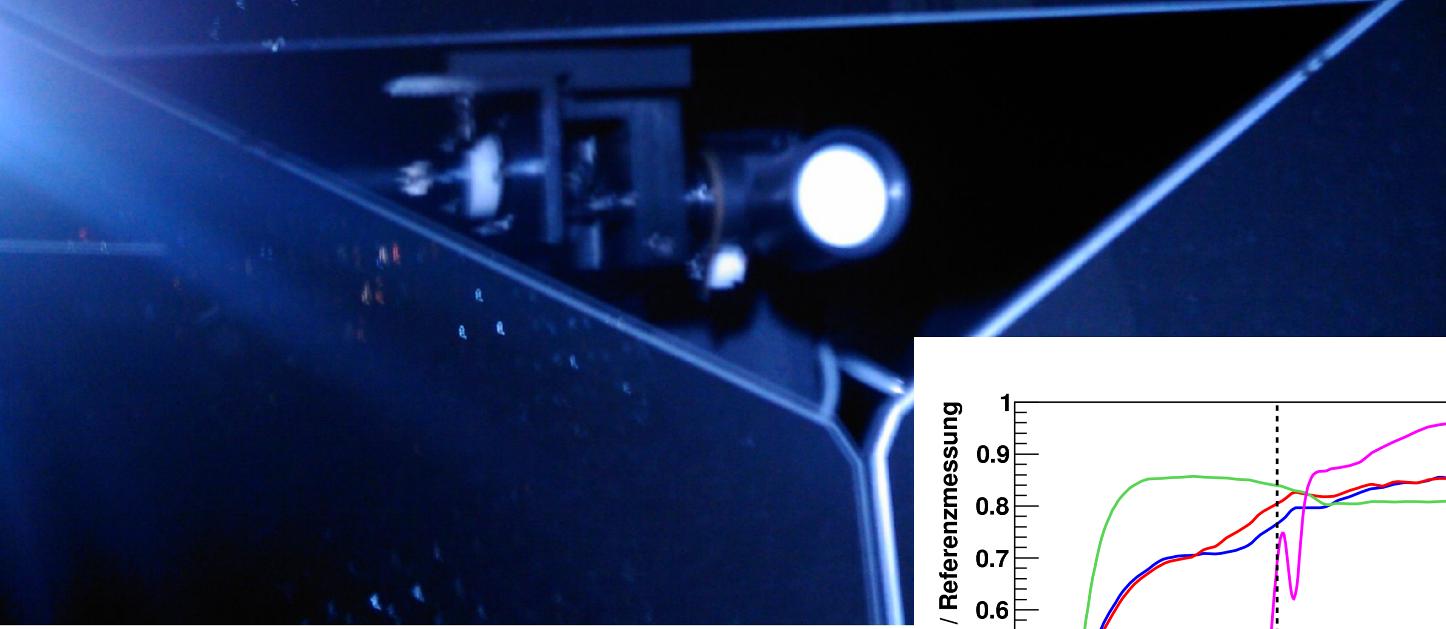


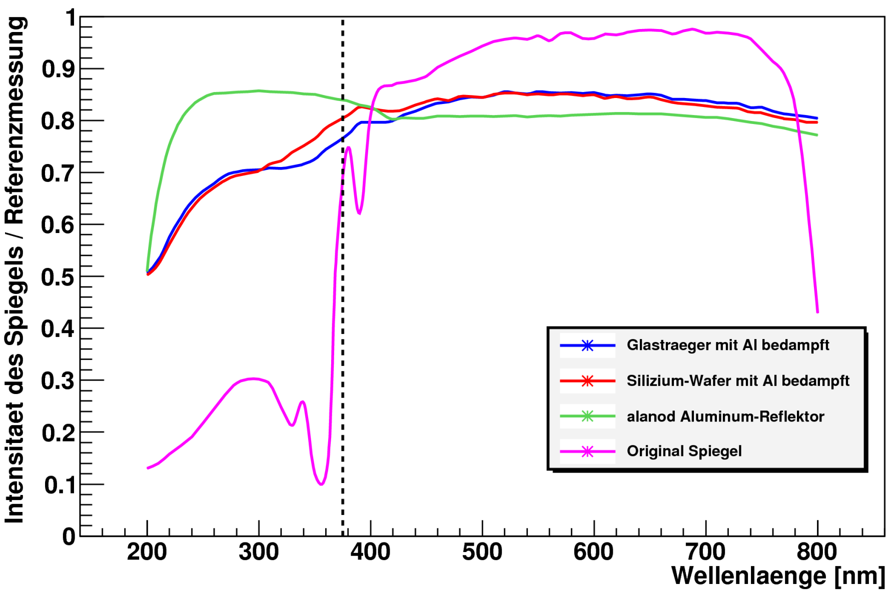


- Set-up November 2009
- Mount on camera-frame
- Mirror-unit in front of mirror center

Measurement Set-up 2

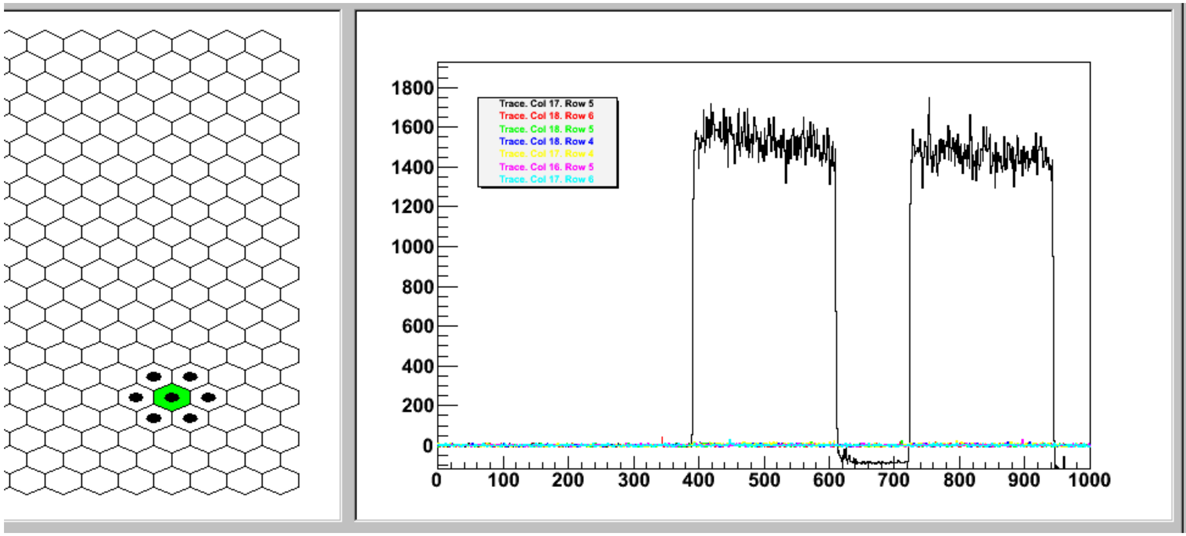
- setup March 2010
- new Frame – Mirror unit mounted beside Cal A
- new UV-reflective mirrors



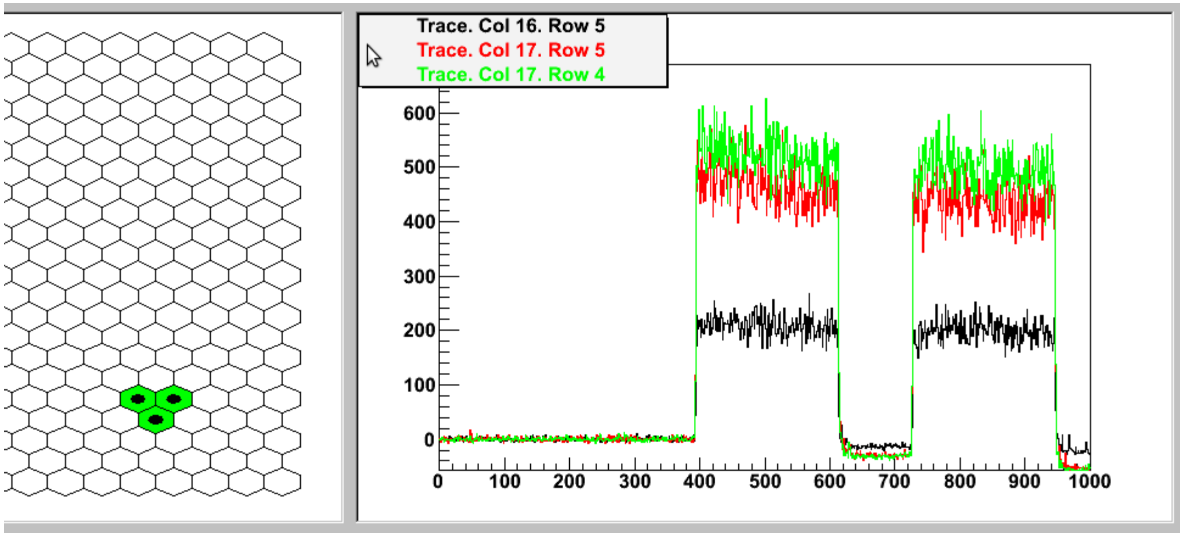


Measurement

- light-spot is small enough to hit only one PMT



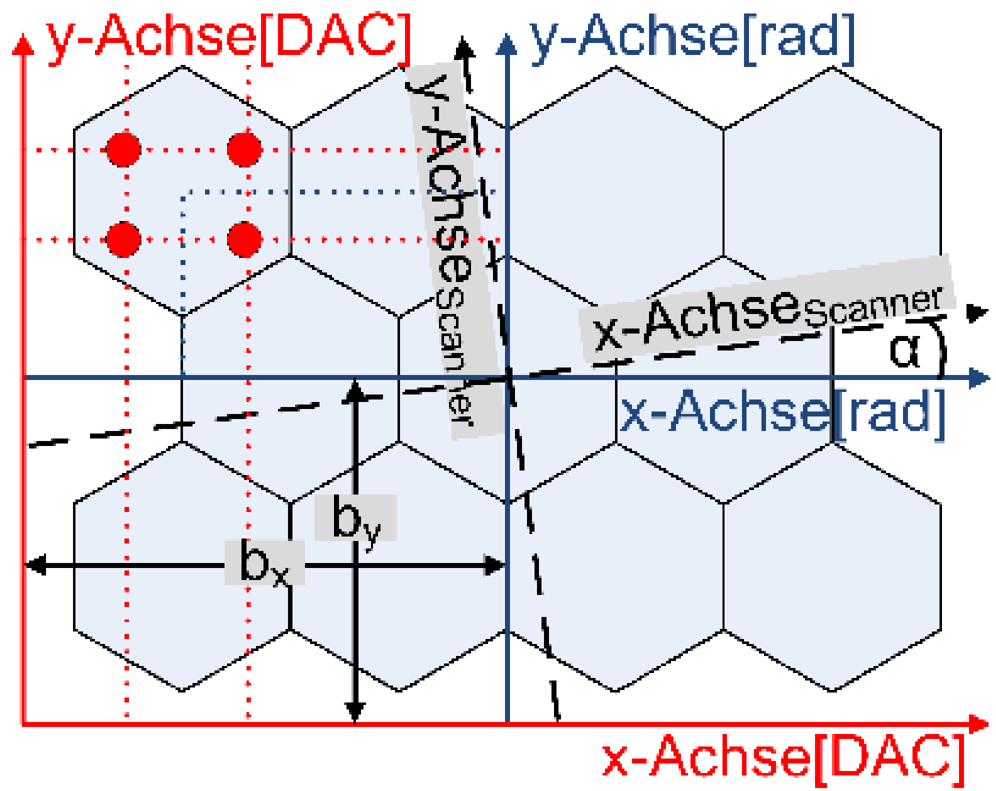
- shot on Mercedes splits signal



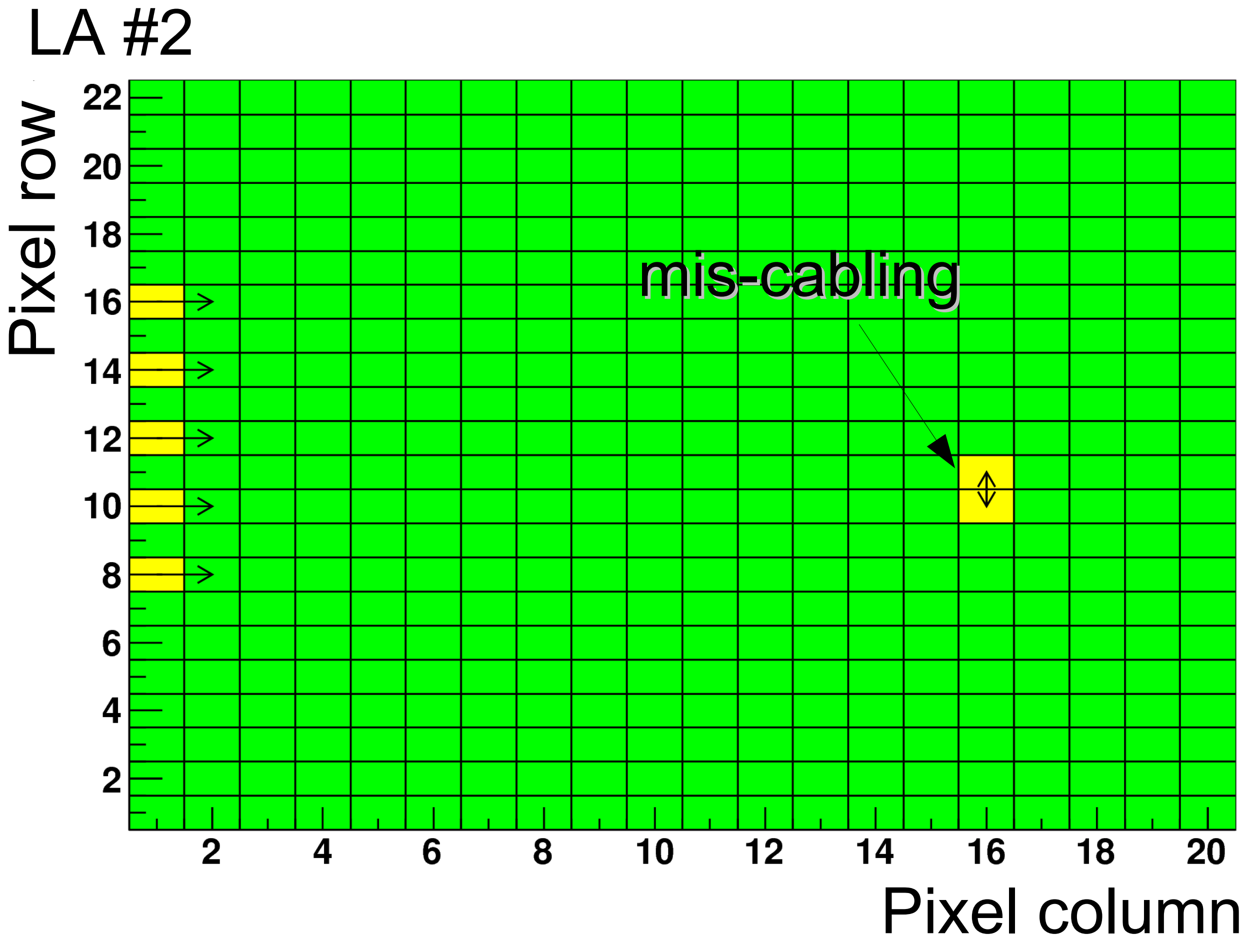
Alignment

- alignment is preciser than calibrating by hand before measurement
- convert DA counts input of mirror unit to shot position on camera
- calculate PMT position

  X_{rad} , Y_{rad} in view of mirror-unit
- shot-coordinates X_{DAC} , Y_{DAC} are known



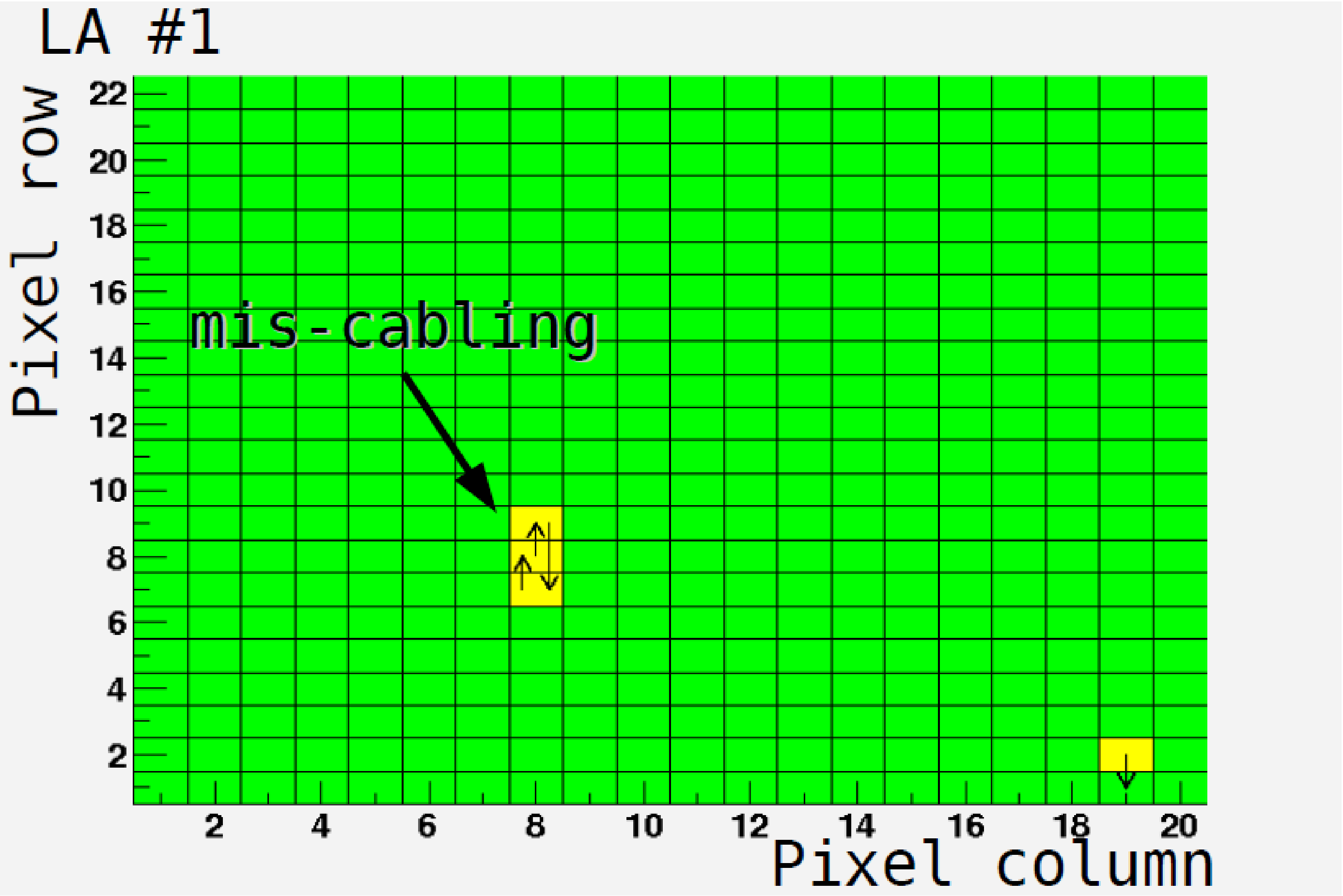
Data analysis



correct hit PMT   incorrect hit PMT

expected position ——> observed position

Data analysis



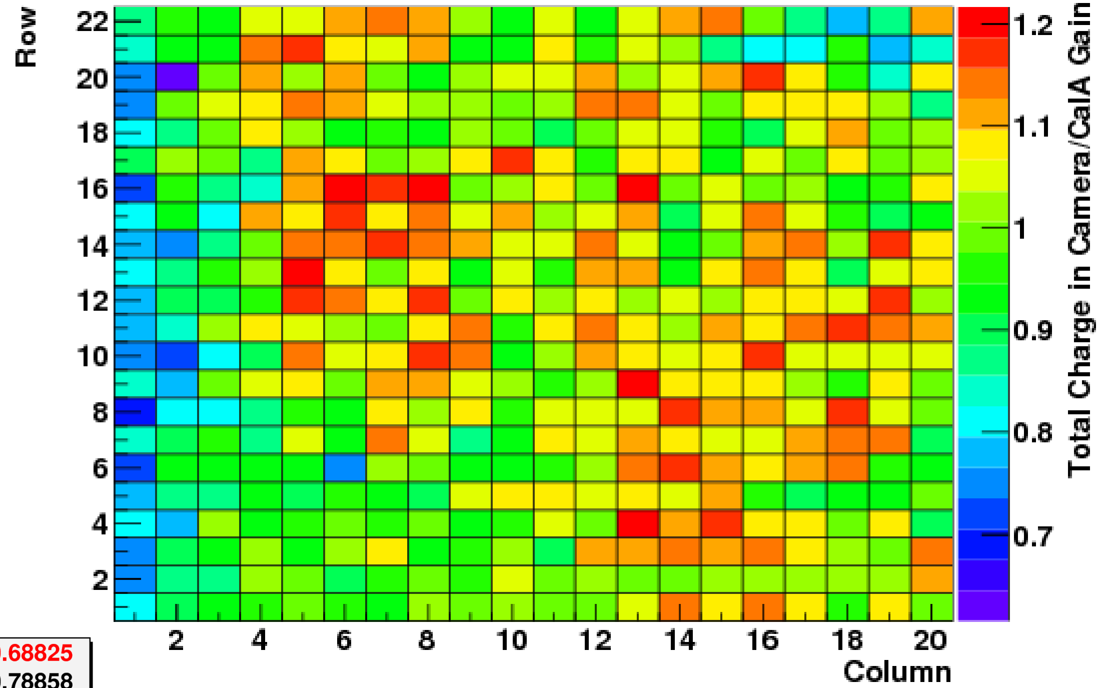
correct hit PMT

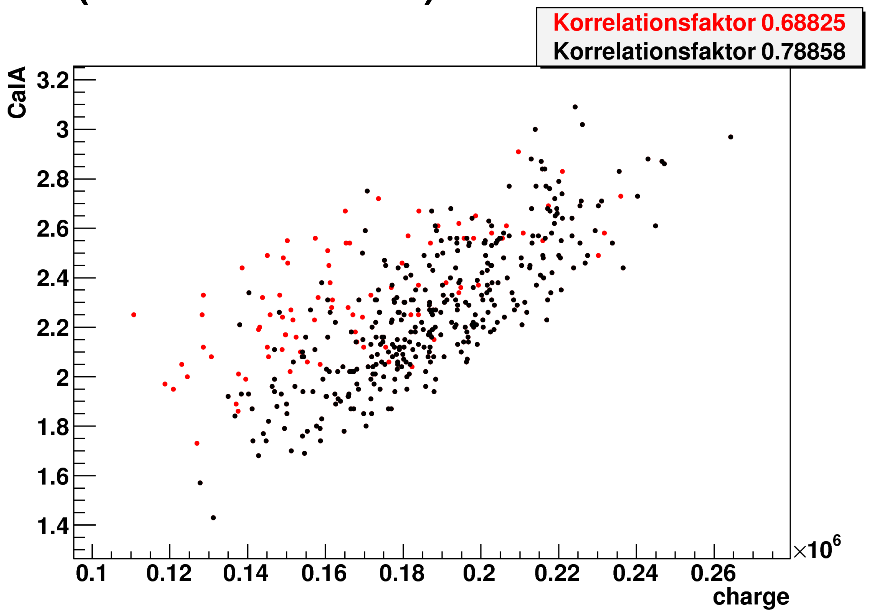
incorrect hit PMT

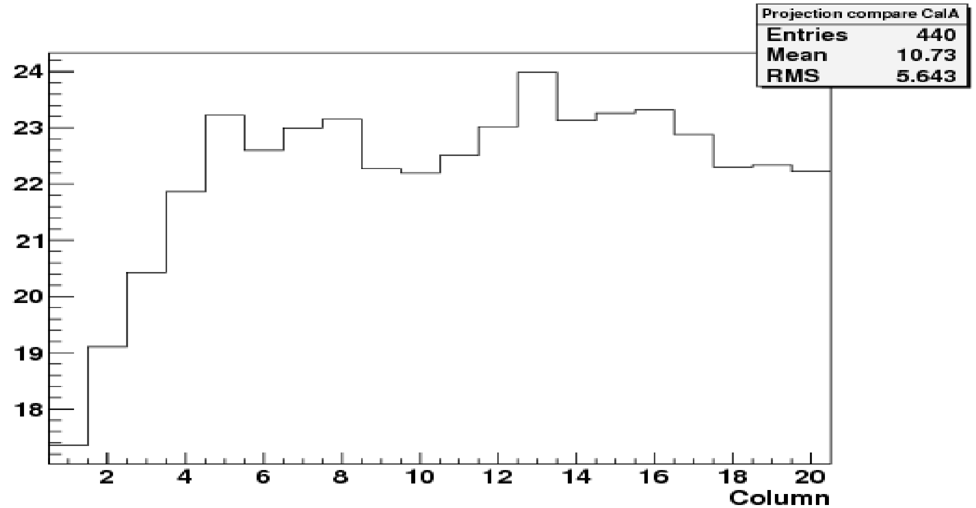
expected position ⟶ observed position

Comparison to calibration

- compare Pixel-by-Pixel scan with Cal A gain measurement
- good correlation, but strange drop-off on the right caused by scanner (… see later)

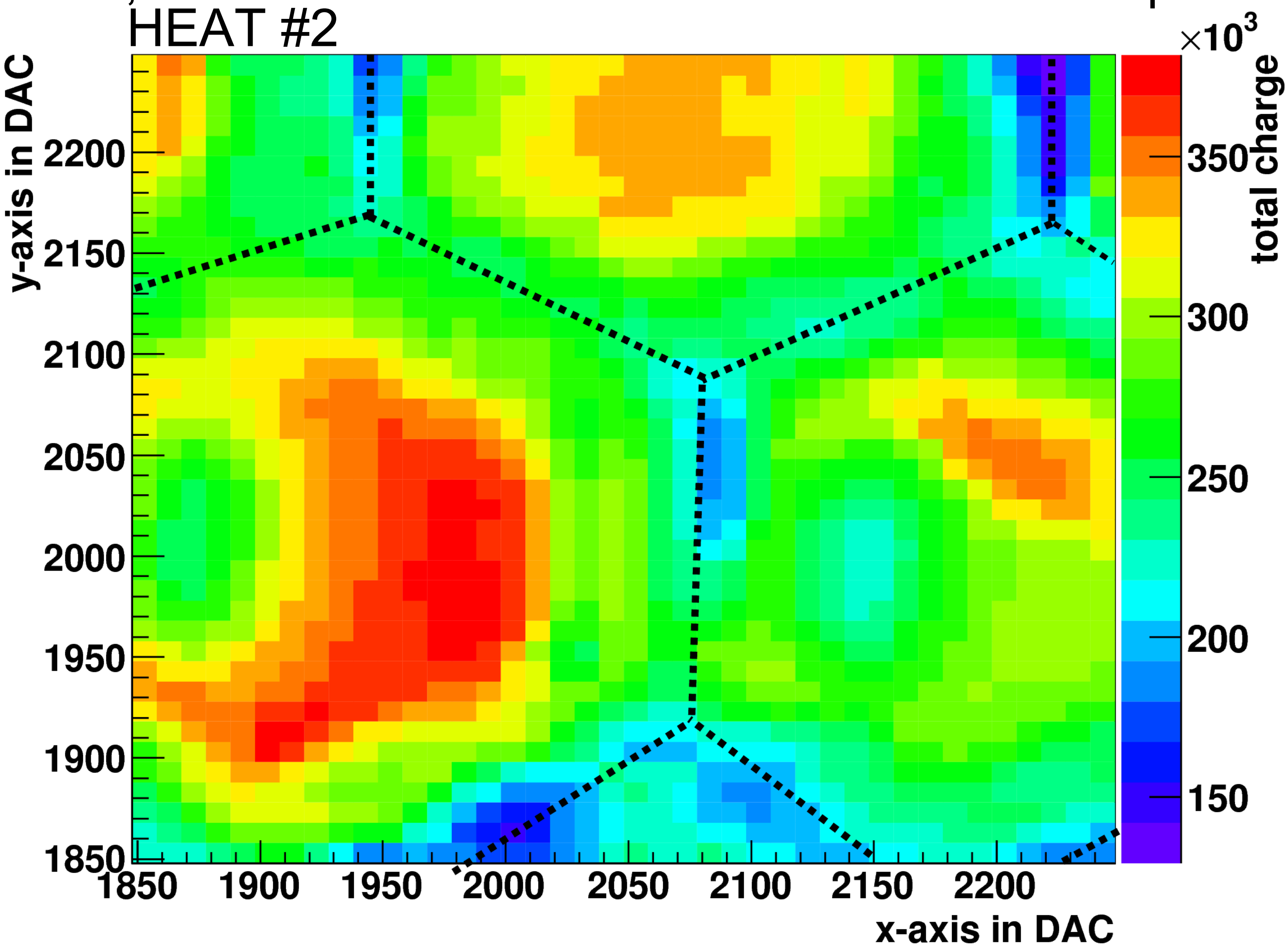






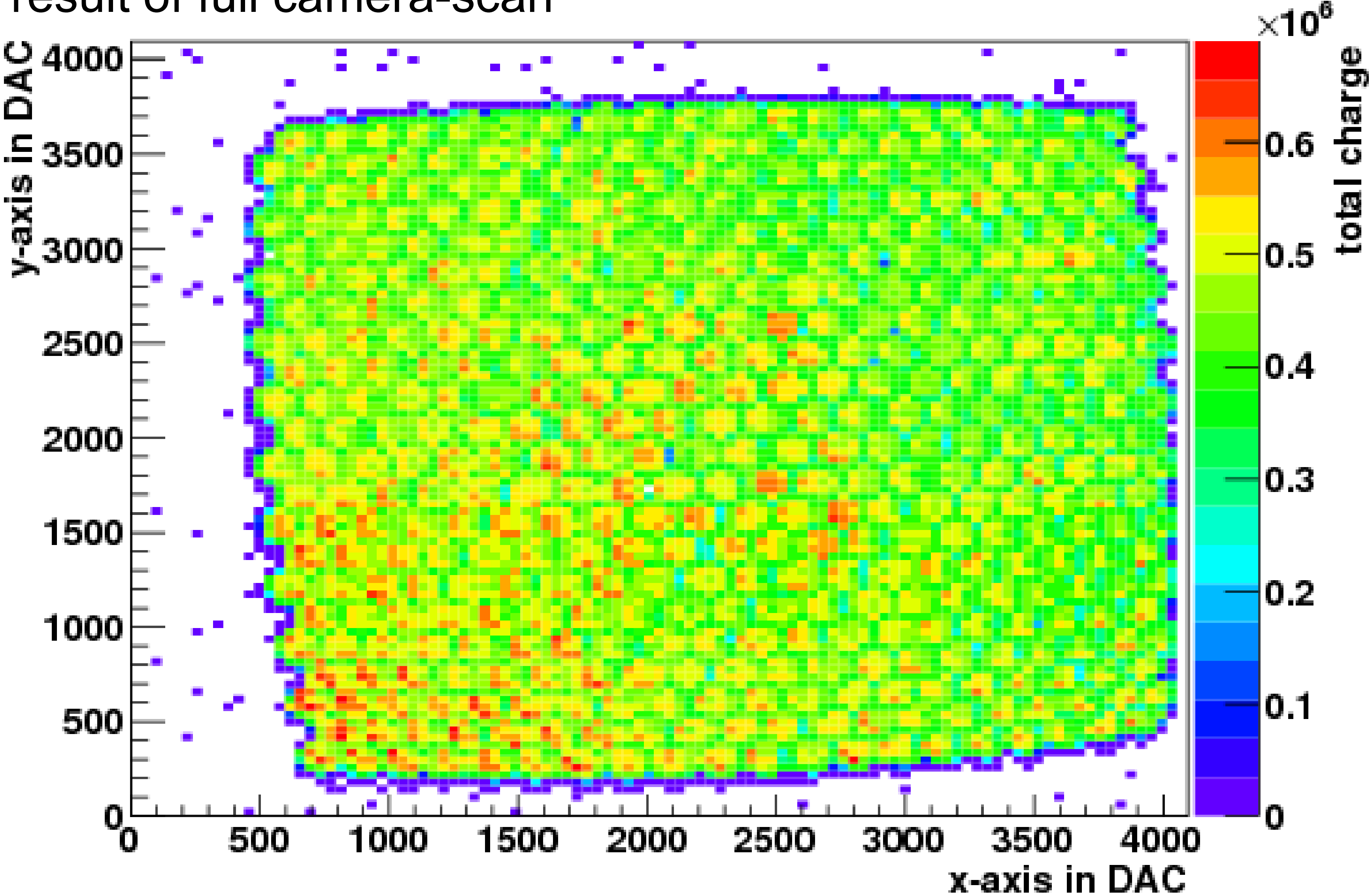
Inhomogeneity of single PMT

- first test, shoot on small area of camera with small step size

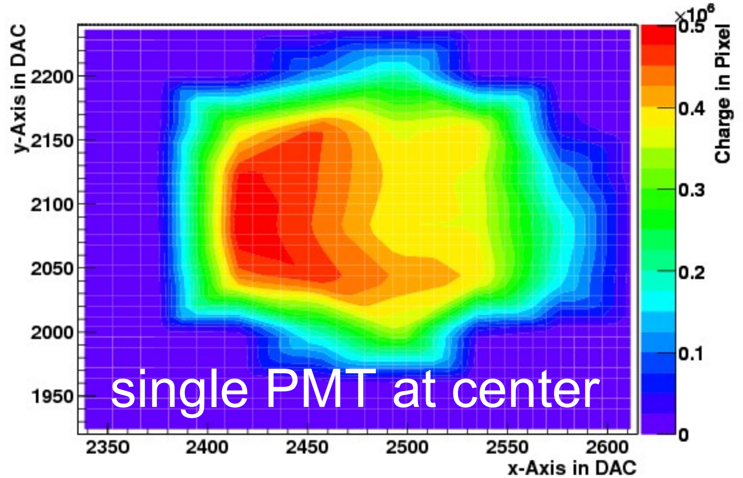


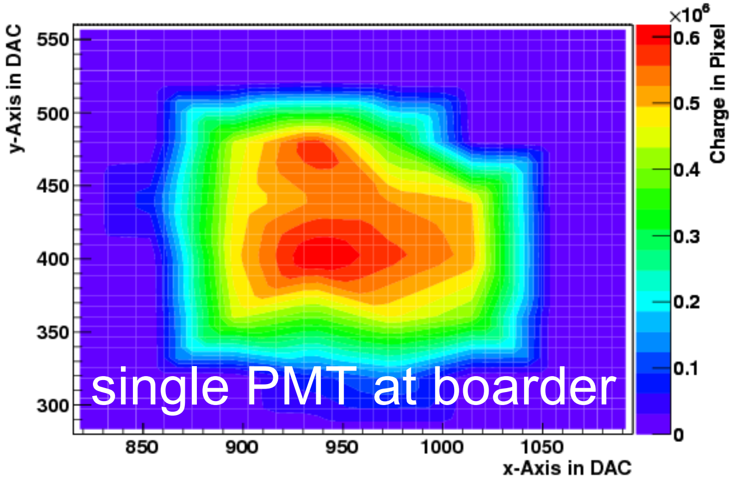
Inhomogeneity of camera

- result of full camera-scan

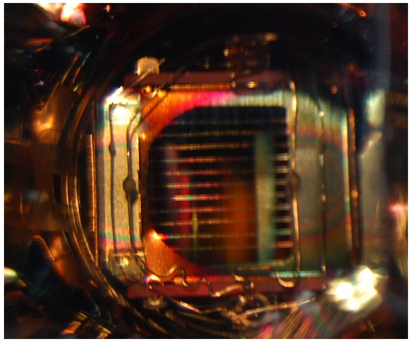


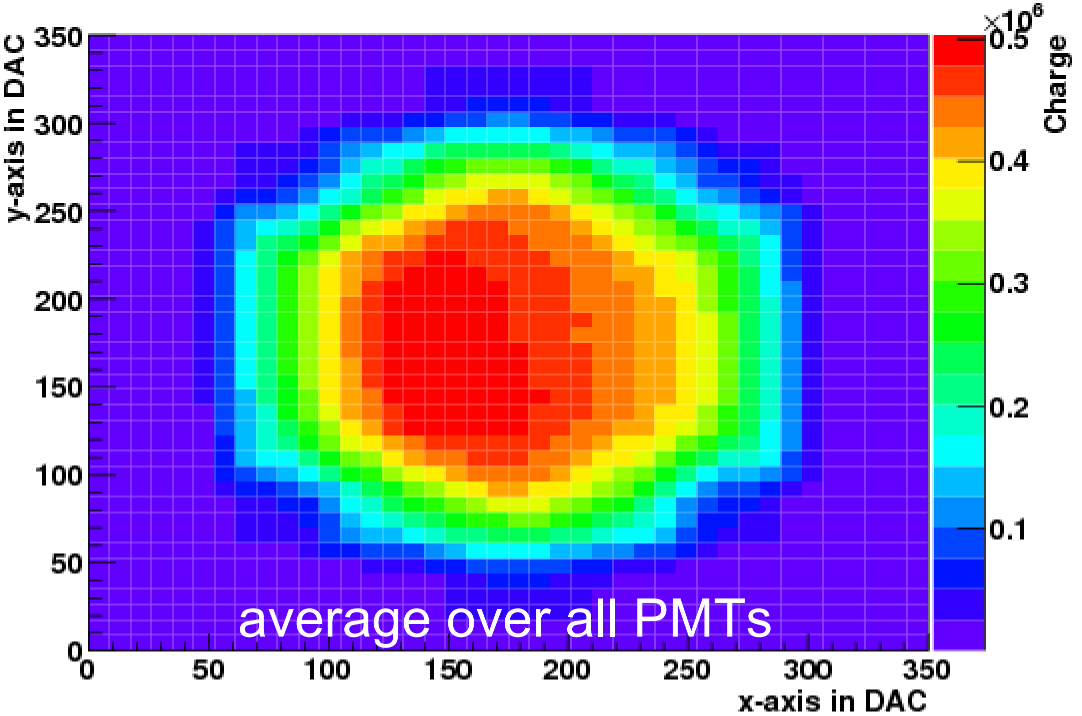
Inhomogeneity





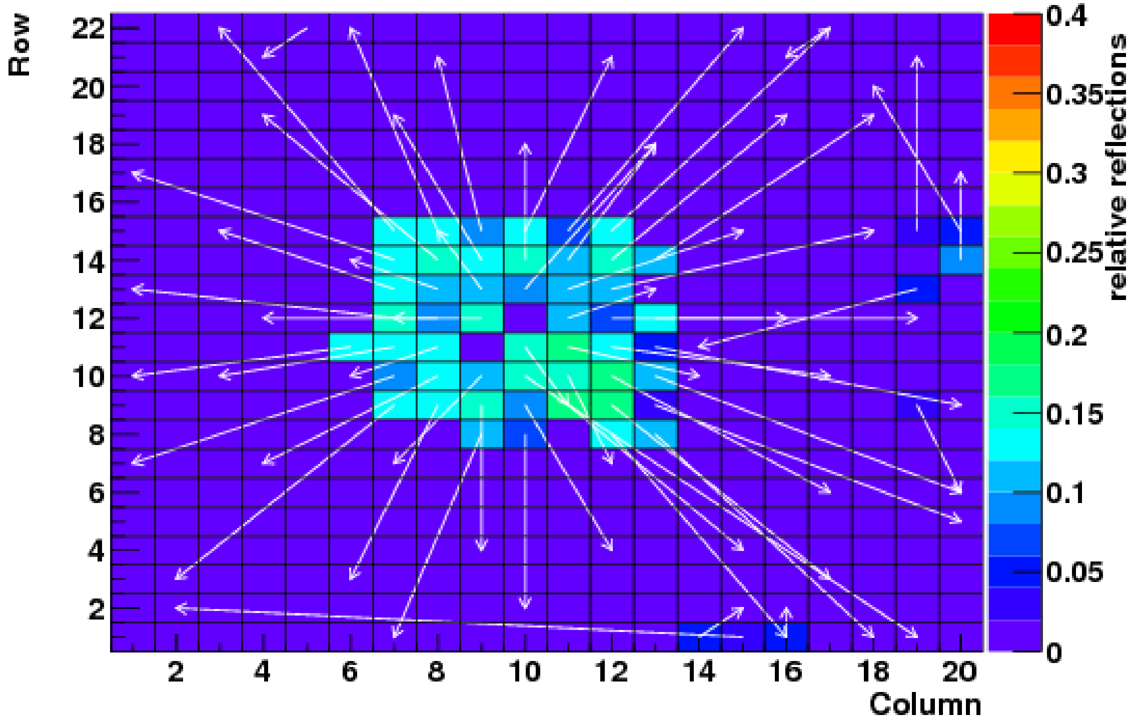
- average over all PMTs
- fit position of single PMT
- normalize total charge
- inhomogeneity about 20% due to x-axis

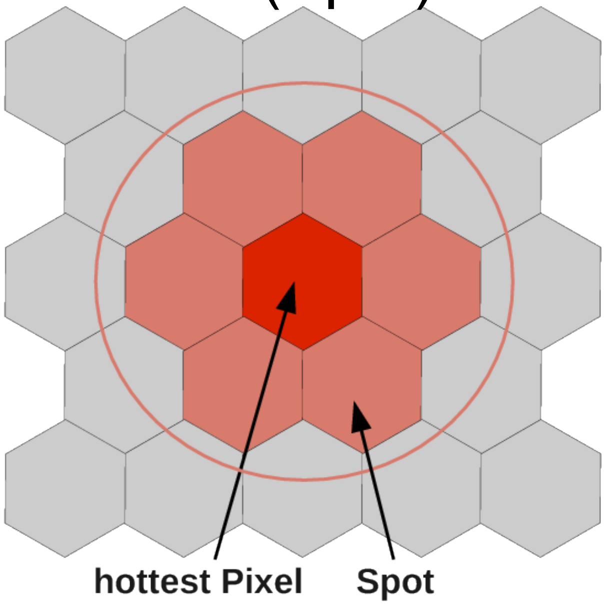


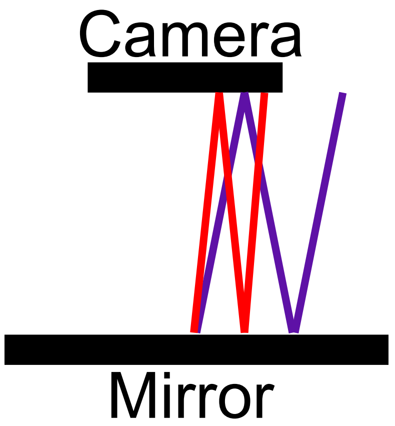


Reflections

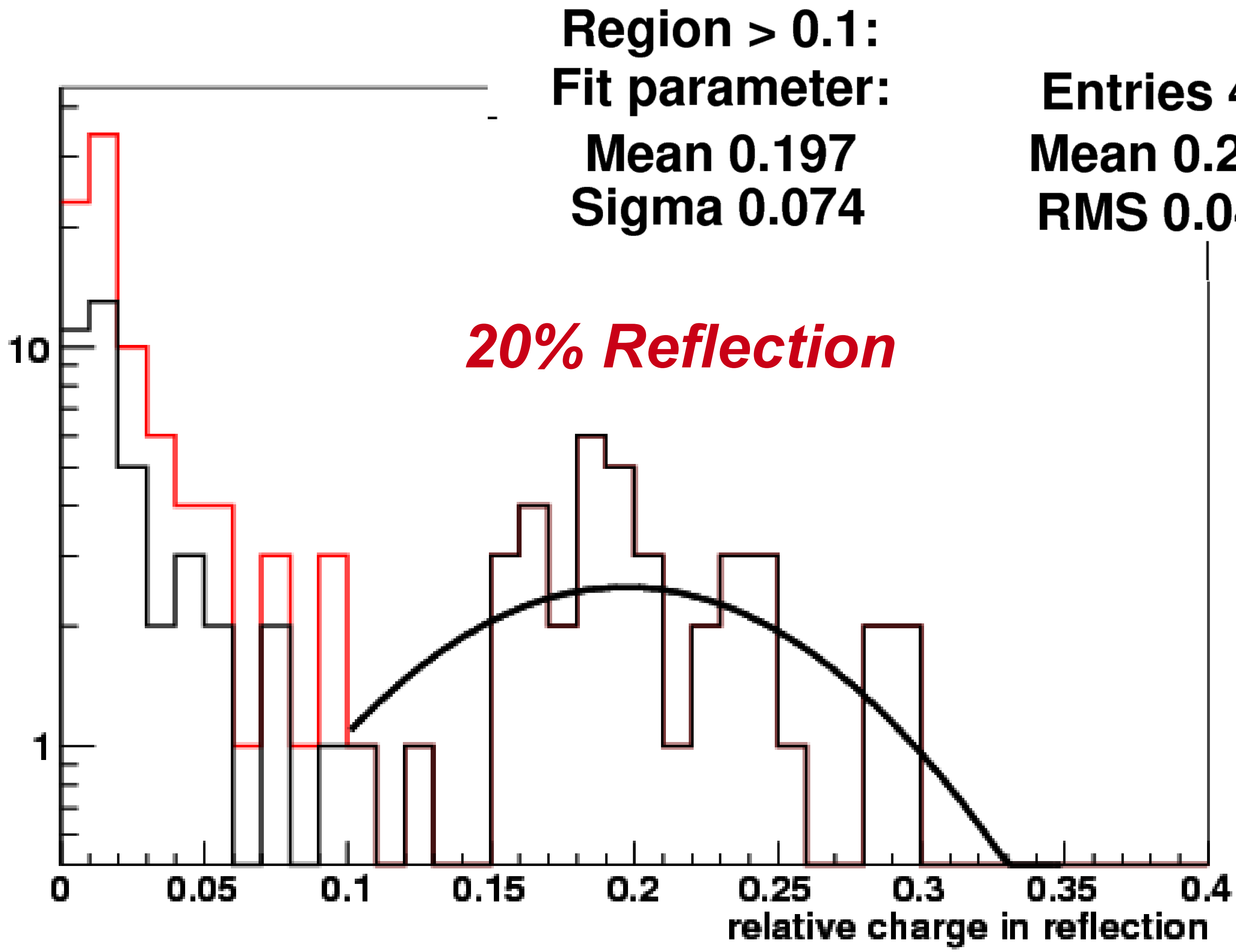
- sum up charge in hottest pixel + neighbor PMTs (Spot)
- reflections = total charge – spot
- arrow points from shot pixel to hottest pixel outside spot



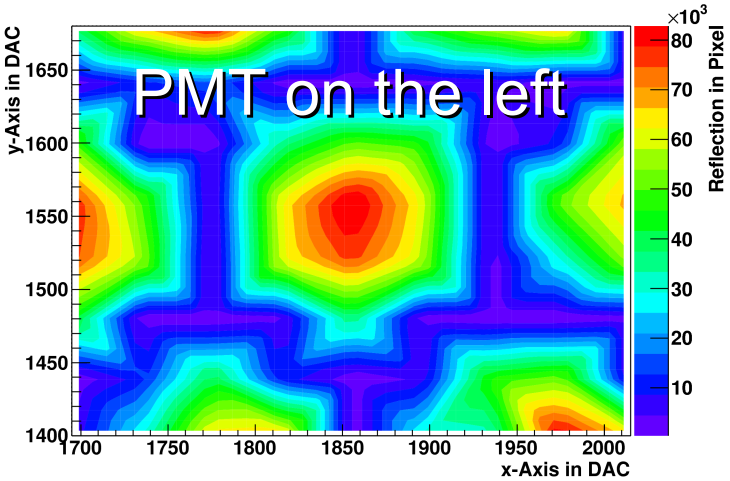


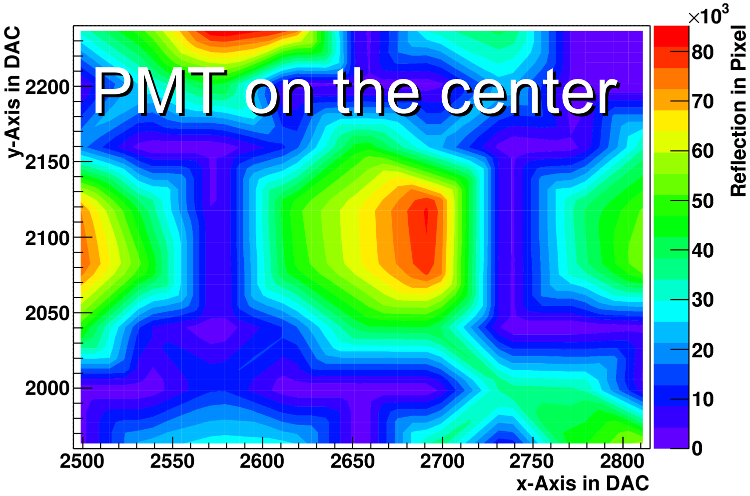


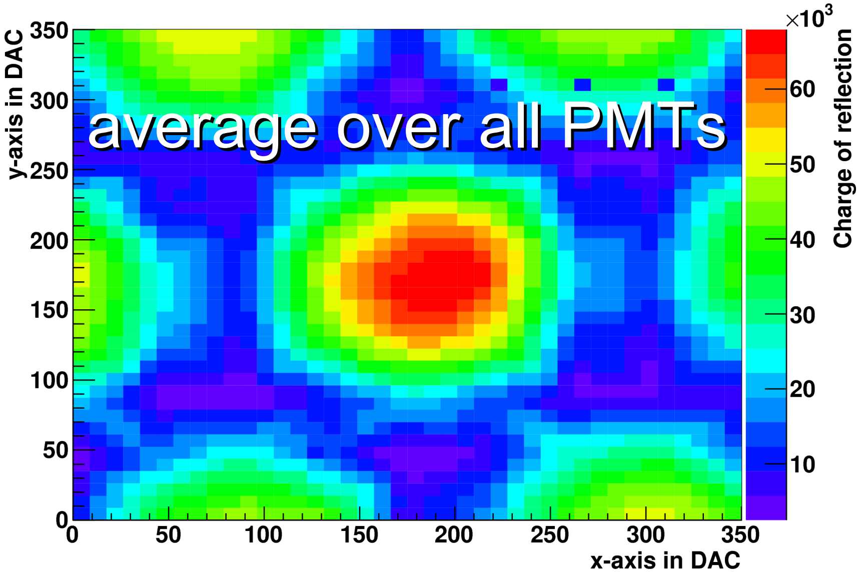
Relative Reflection

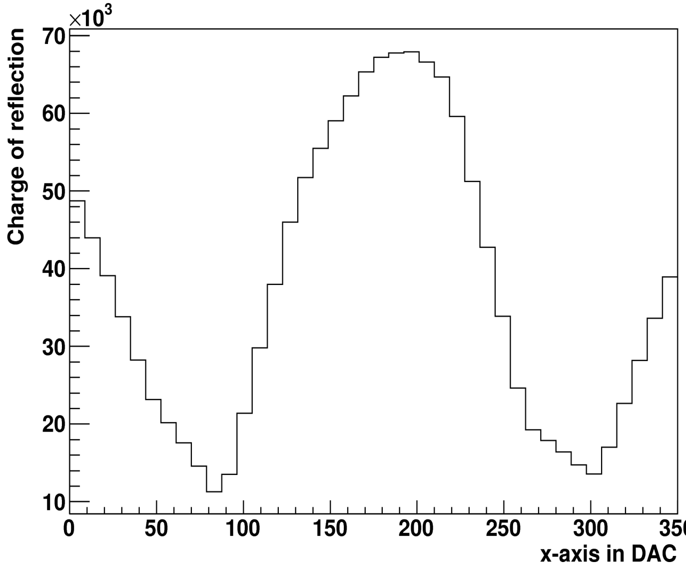


Inhomogeneity of reflections









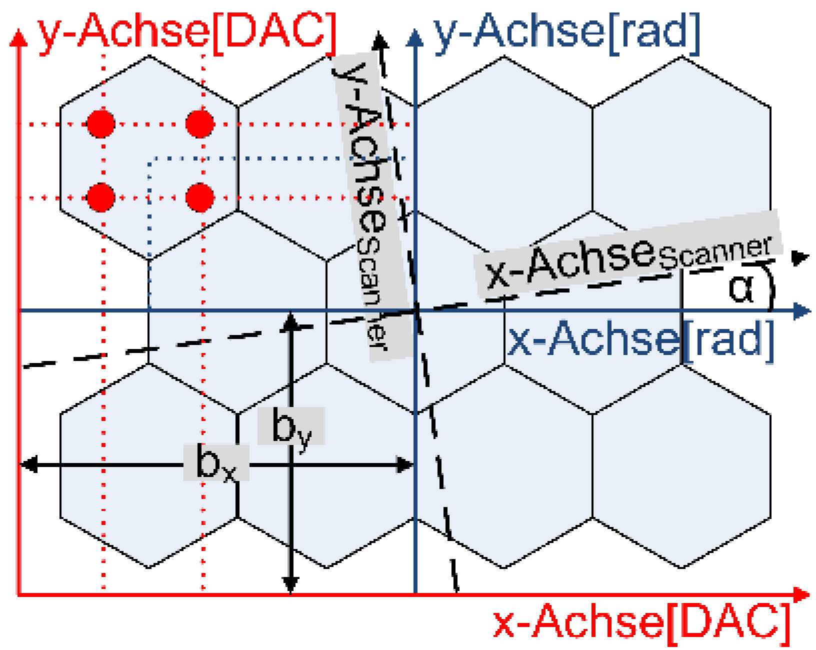
Reflection seems to depend on PMT-surface position
scattering from inside-out or Mercedes structure?

Summary and Outlook

- Pixel-by-Pixel Calibration works and provides useful data
- found mis-cablings in 5 telescopes
- promising for calibration
- study of PMT and camera inhomogeneities
- PMT-surface reflections are ca . 20% and point from the camera-center radial out

Alignment

- alignment is used to convert DAC-Input of mirror-unit to shot-position on camera
- calculate PMT position X_{rad}, Y_{rad} in view of mirror-unit
- Shot-coordinates X_{DAC}, Y_{DAC} are known
- fit-function:



$$X_{DAC} = X_{rad} \cdot a_x \cdot \sin(\alpha) - Y_{rad} \cdot a_y \cdot \sin(\alpha) + b_x + Y_{rad} \cdot a_y \cdot \sin(\beta)$$

$$Y_{DAC} = X_{rad} \cdot a_x \cdot \sin(\alpha) - Y_{rad} \cdot a_y \cdot \cos(\alpha) + b_y$$

- a_x, a_y slope; b_x, b_y axis intercept; α rotation angle of mirror-unit β difference of angle between both mirros to right angle

Reflections