Measurement of the Photon Detection Efficiency of SiPMs and MPPCs

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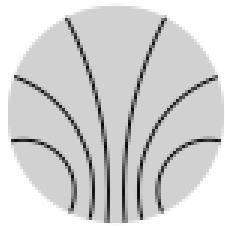


KIRCHHOFF-
INSTITUT
FÜR PHYSIK

CALICE Collaboration Meeting Manchester
08-10.September 2008

Outline

- Overview of Characterisation Measurements
- Measurement of the Photon Detection Efficiency (PDE)
- Measurement of the device uniformity
- Summary and Outlook

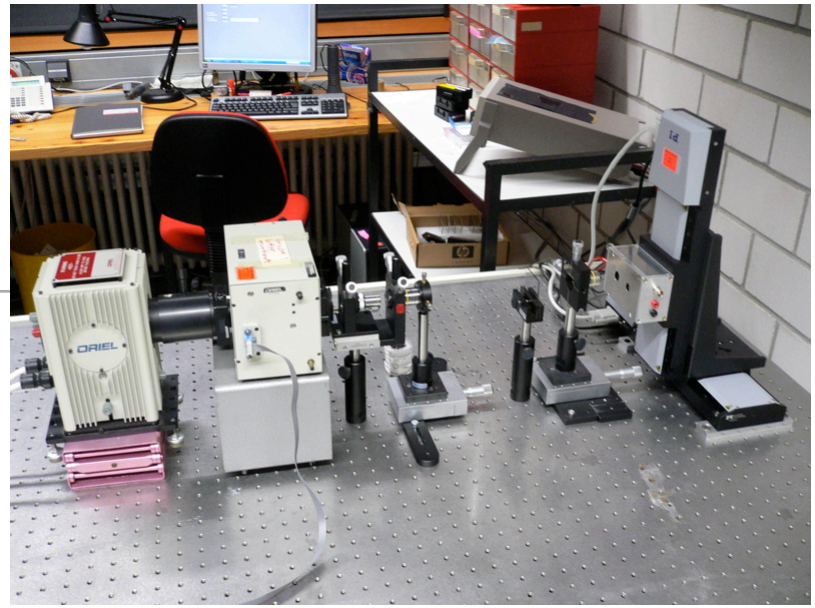
Measurement Summary

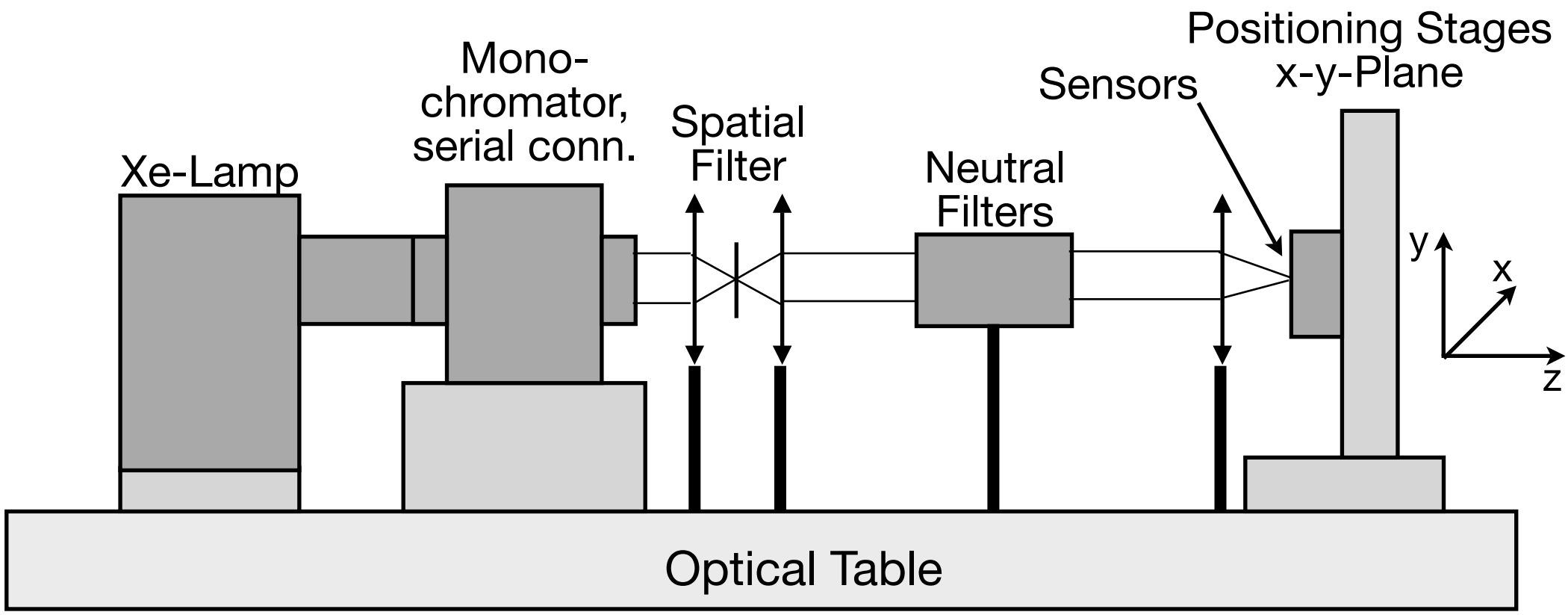
This Talk

Producer / SN	No. Pixels	I-V Char.	Dark-rate Char.	Gain Char.	PDE Char.	Surface/ Uniformity tests
Hamamatsu S10362-11-xxxC 	100	✔	✔	✔		In Progress
	400	✔	✔	✔	✔	
	1600	✔	✔	✔	✔	
SensL SPMScint 	1144	✔	✔	✔	✔	
MEPHI-PULSAR (HCAL)	1156					

The Setup

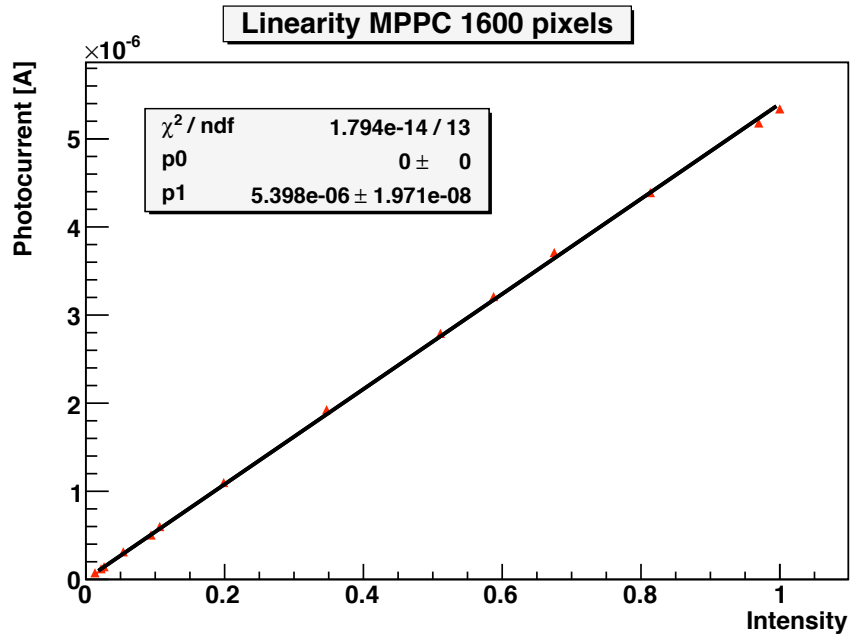
- Automated wavelength scan
- Calibrated PIN diode used as reference (NIST traceable)
- Photocurrent measured with Pico-Amperemeter

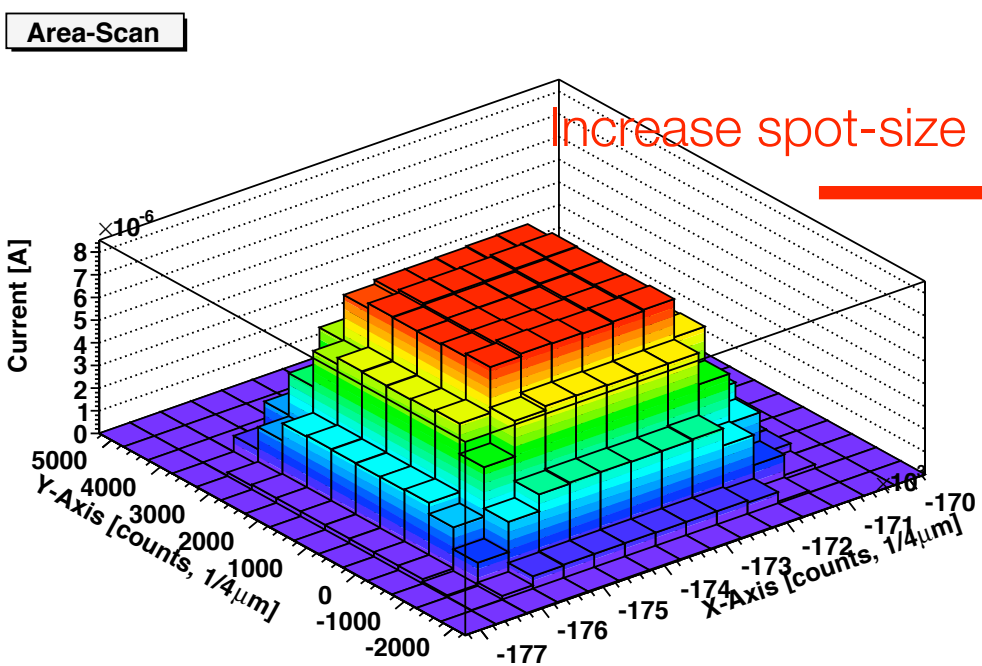




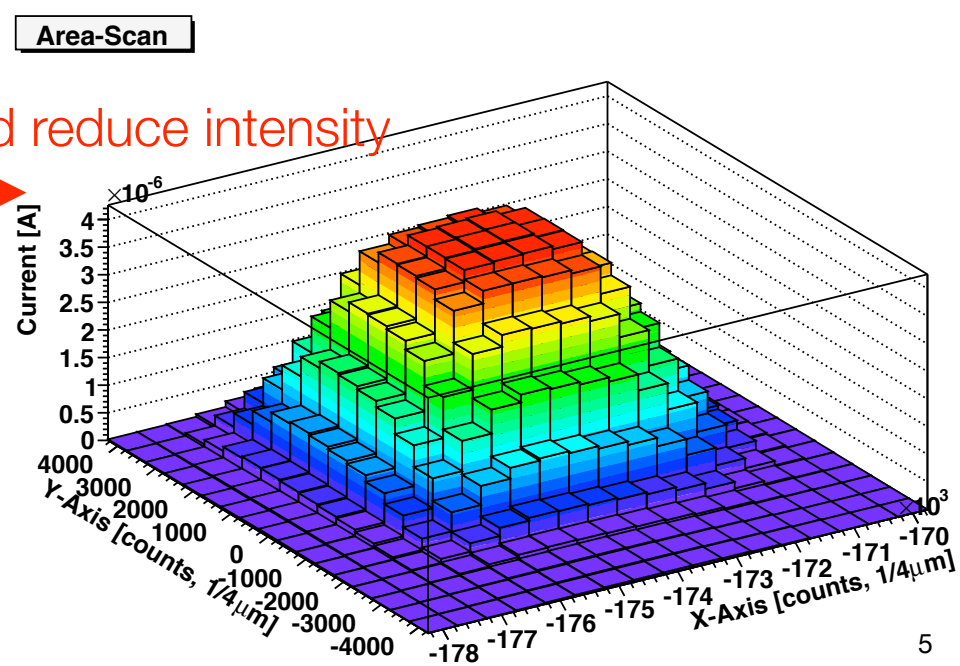
Optical Alignment

- We want to place a preferably large light spot at the centre of the MPPC/SiPM (linearity)
- Scan the sensor along x and y-axis
- Adjust spot size (focus)
- Take care that light spot isn‘t oversized (total width of scan < 2mm)
- Modify light Intensity to ensure linear response!





Increase spot-size and reduce intensity



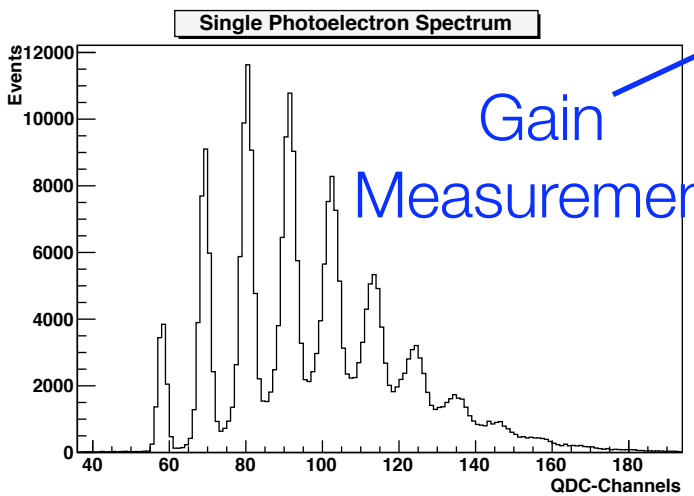
PDE-calculation

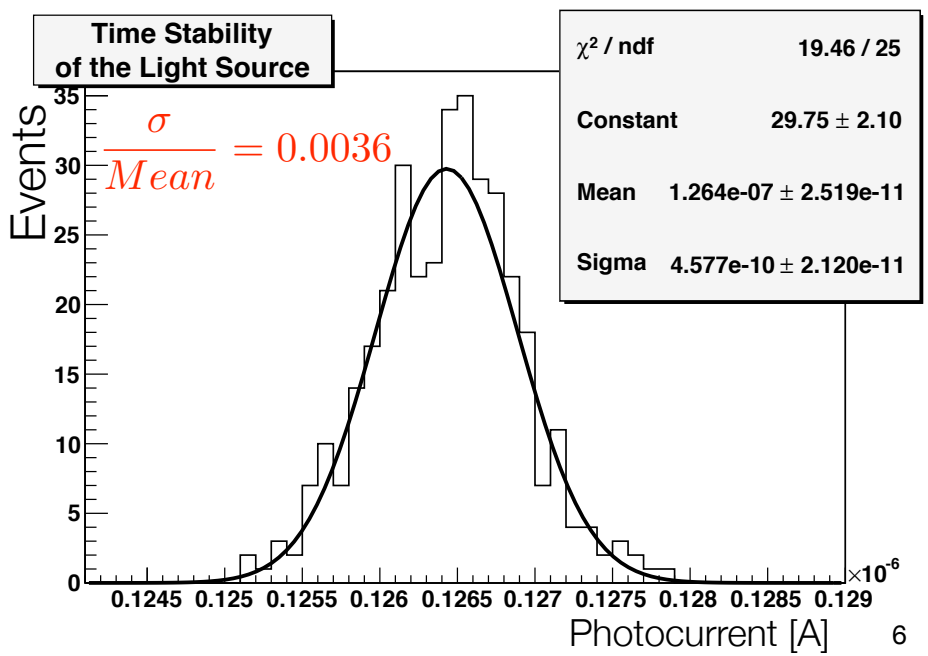
PIN-diode Calibration Data-set

$$PDE = \frac{n_{pe}}{n_p} = \frac{I_{SiPM}}{M \cdot q_e \cdot n_p} = \frac{I_{SiPM} \cdot hc \cdot R}{M \cdot q_e \cdot I_{pin} \cdot \lambda}$$

Gain Measurement

Current Measurement



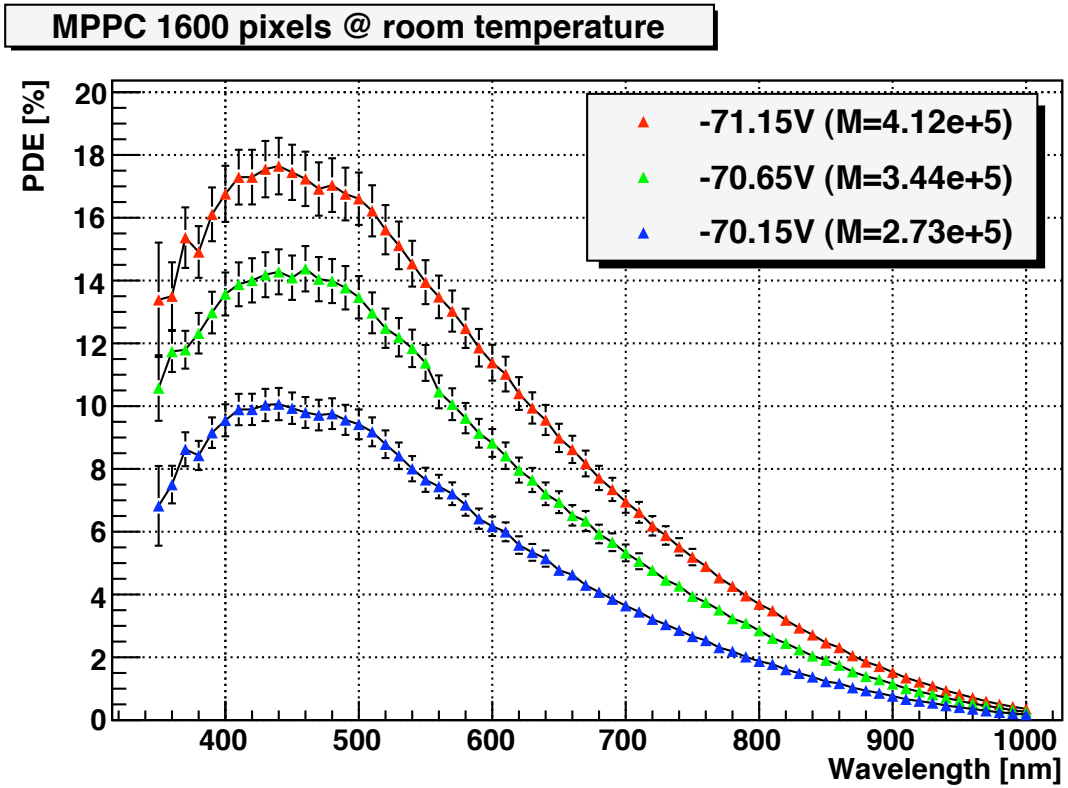


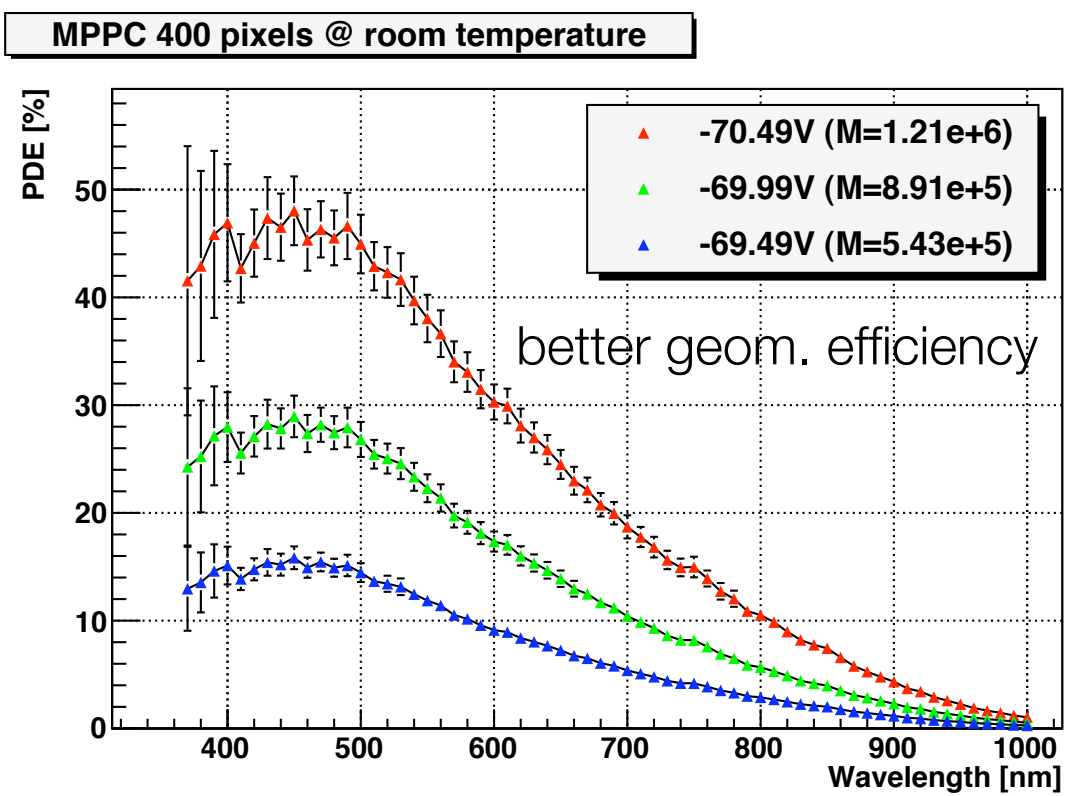
Measure I_{SiPM} and I_{pin} one after another, therefore the time stability of the light source is important.

DC-Current measurement cannot discriminate crosstalk and afterpulses -> Overestimation of the PDE-value

PDE Measurement Results MPPC

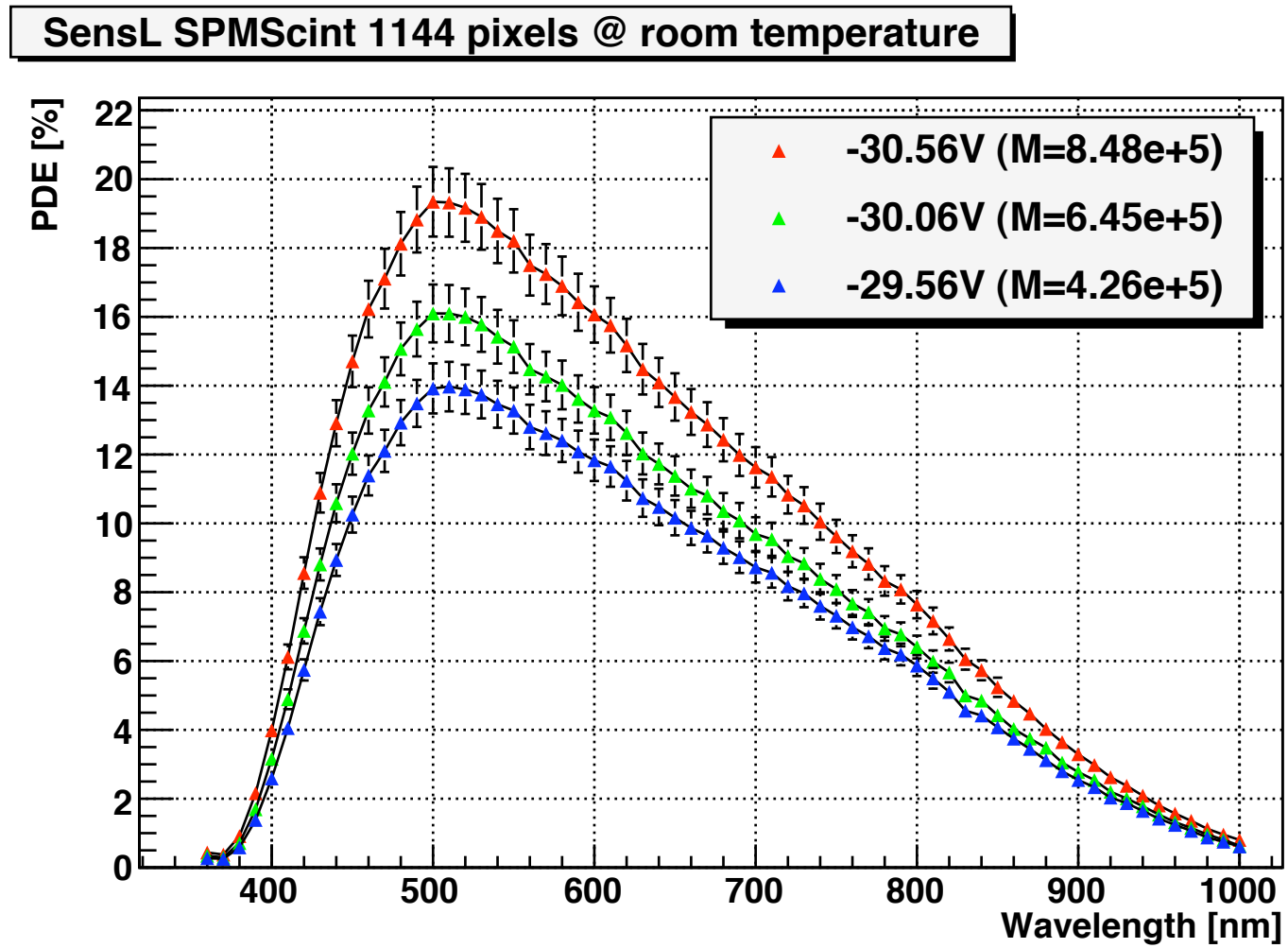
- High PDE value in the blue wavelength region
- Smaller dynamical range of the 400 pixel device makes the measurement difficult (low light intensity). S/N-ratio of the PIN-diode-signal limits the application below 400nm.
- We observe PDE values, smaller than the values quoted by HAMAMATSU (~10% at nominal voltage)
- Precise gain measurement is crucial for the PDE evaluation. Measured gain values are consistent with the quoted vales when taking into account temperature effects.





PDE SensI SPM

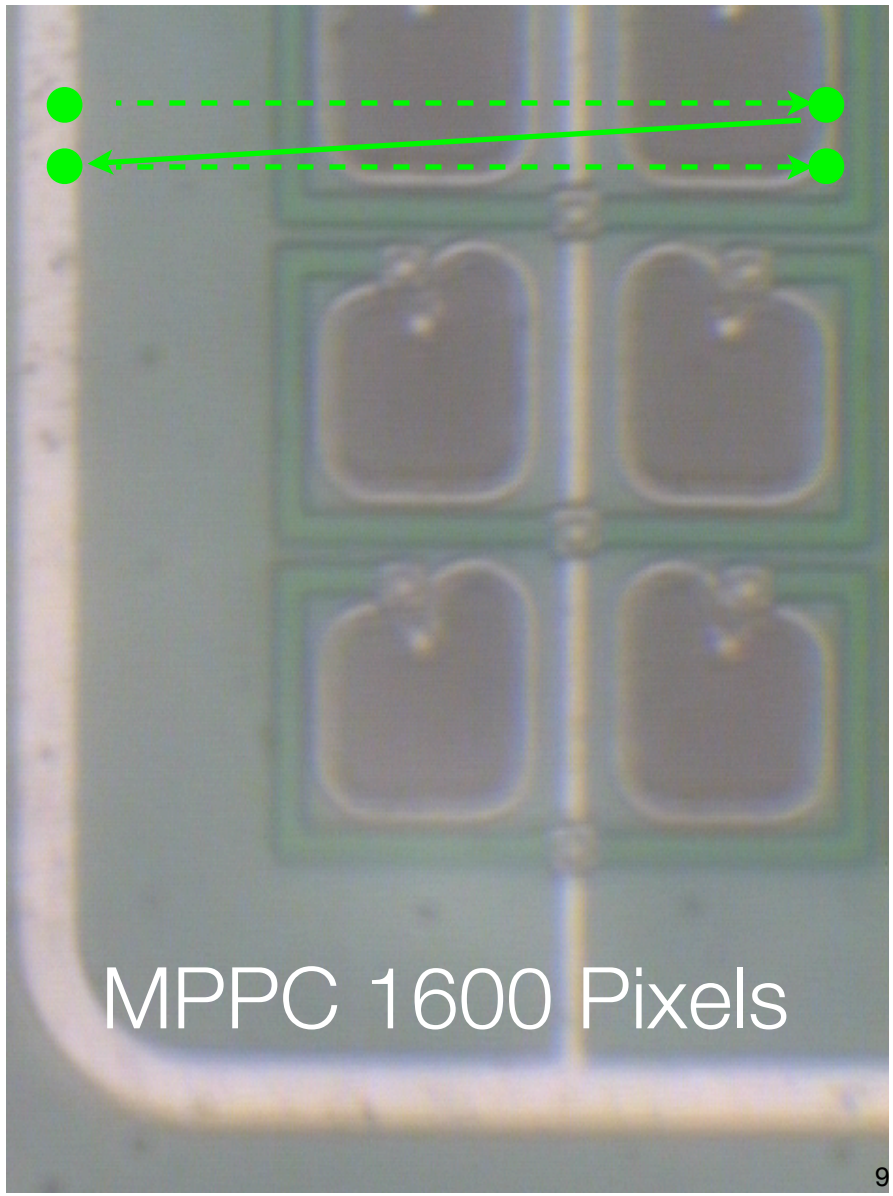
- High PDE-value in the green wavelength region. (peaks at 520nm)
- Only small PDE-value for blue light
- Slightly higher PDE peak-value than the MPPC with 1600 pixels because higher geom. efficiency



Uniformity Tests

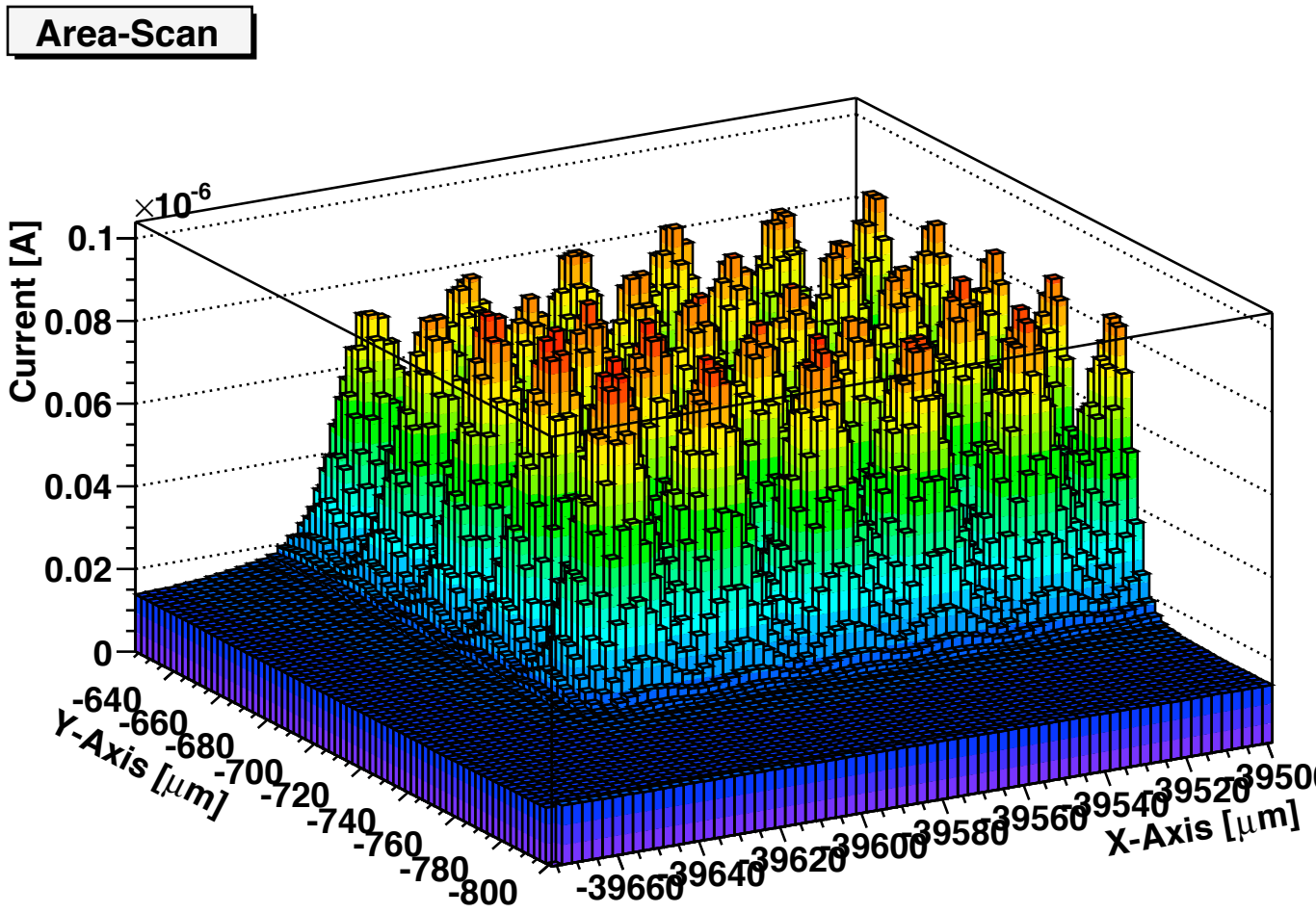
- Scan the device along small light-spot
- If the bias is switched on, the device (gain)-uniformity can be tested.
- No Bias: Structure of the device (metal tracks, quenching resistors)
- Time for single point acquisition (moving & measuring) ~3s

  → time consuming
  → Scan only „interesting“ regions



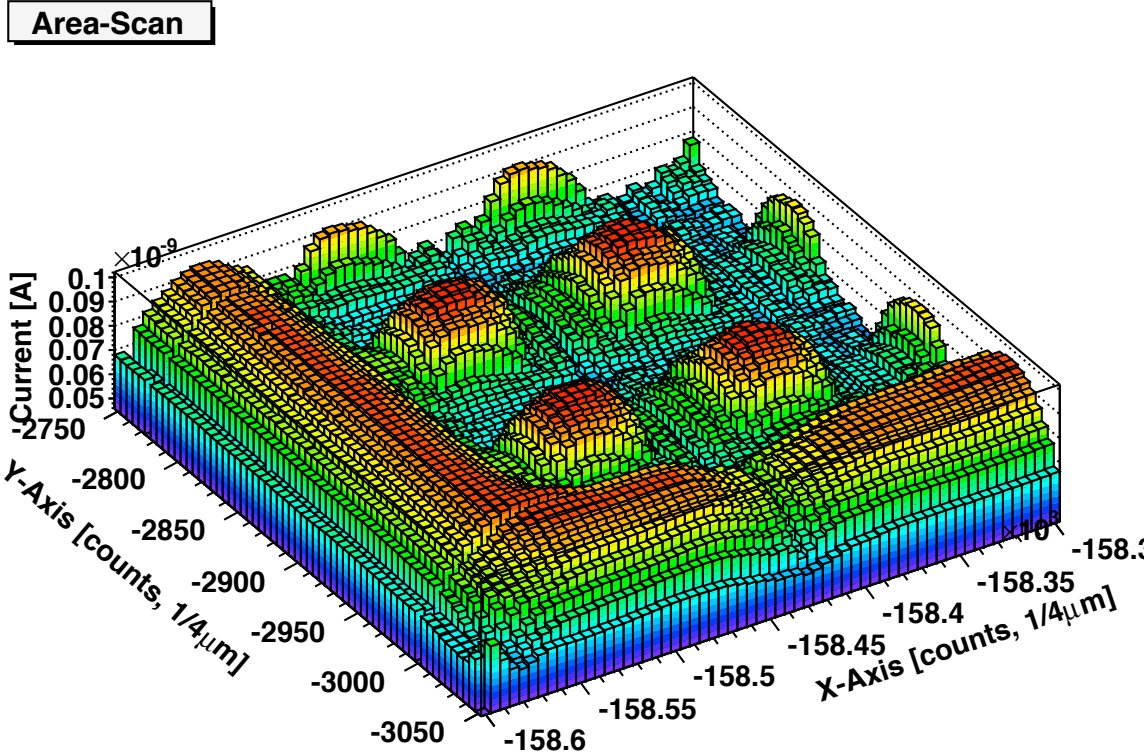
MPPC 1600 pixels (bias-voltage switched on)

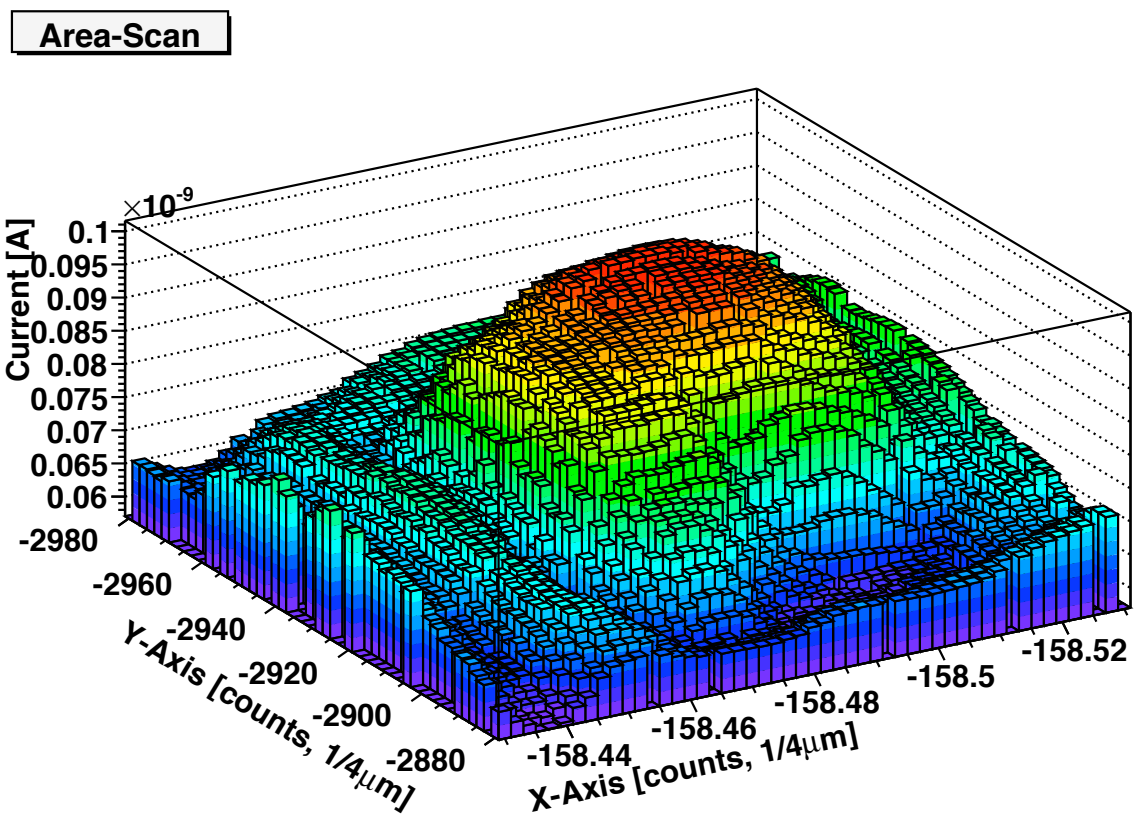
- Step-size in x and y-direction (bin-size): 2.5µm
- Edge of the device
- Individual pixels are clearly visible
- No broken pixels

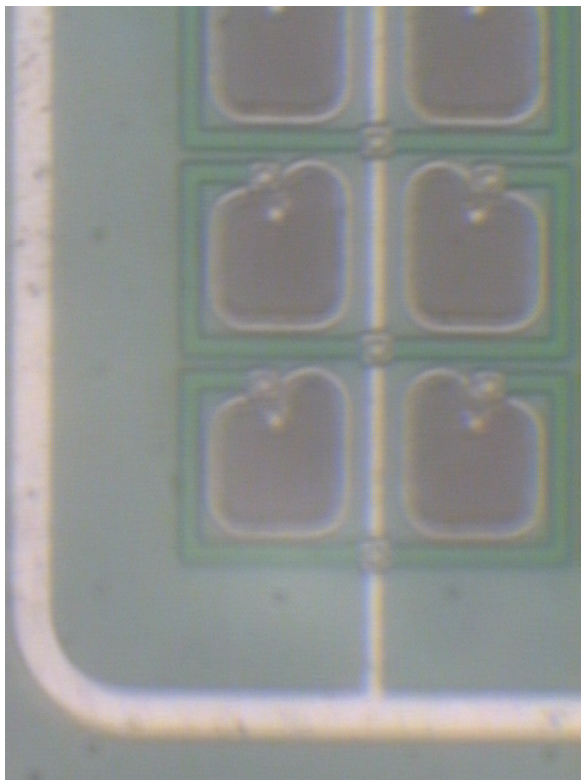


MPPC 1600 pixels (no bias-voltage)

- Device responses like a normal photodiode
- Detailed surface structure visible







Summary & Outlook

- PDE has been measured over wide spectral range (350 - 1000nm).
- Measured values for the PDE of the MPPCs are smaller than the the values quoted by HAMAMATSU.
- Device uniformity tests possible, but time consuming (3 seconds per point) Detailed scan only for „interesting“ regions.
- Apply uniformity test to MEPHI-PULSAR SiPMs (long discharge)
- Accurate positioning and small spot size allows single pixel measurements (e.g. timing, PDE without geometrical effects)

Thank you for your attention!