SiPM TIME RESOLUTION: FROM SINGLE PHOTON TO SATURATION

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INTRODUCTION

The time resolution of photon detection systems is important for a wide range of applications in physics and chemistry. It impacts on the quality of time-resolved spectroscopy of ultrafast processes and has a direct influence on the highest achievable time resolution of time-of-flight detectors in high-energy and medical physics. For the characterization of photon detectors, it is important to measure their exact timing properties as a function of the photon flux and the operational parameters of the photodetector and its accompanying electronics.

We focus our studies on different types of SiPMs (Hamamatsu MPPC S10931-025P, S10931-050P and S10931-100P) with different SPAD sizes (25μm, 50μm and 100μm) coupled to the ultrafast discriminator amplifier NINO [1, 2].**For single photon time resoluton we achieve values of approximately 80ps (sigma).** In addition we show that for higher photon fluxes, an optimum in the time resolution with respect to bias and threshold settings can be reached.

SETUP

The tests comprised a series of systematic studies in terms of:

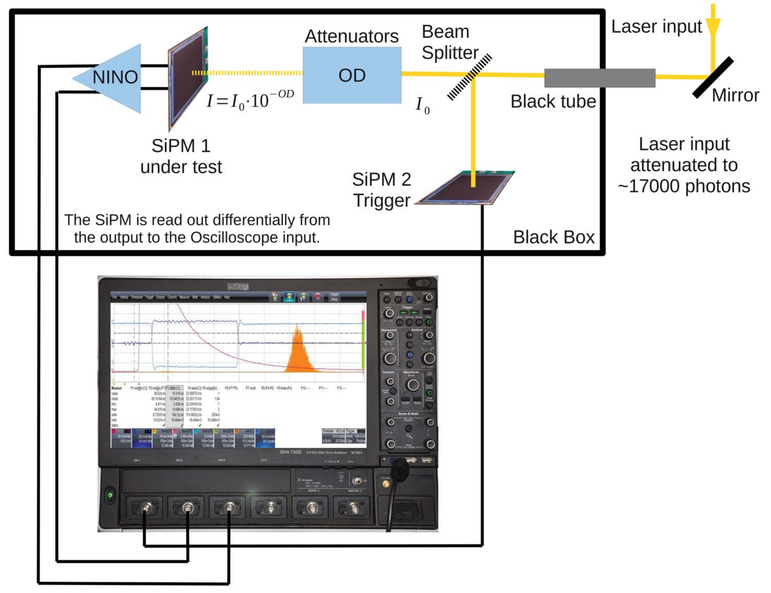
- **SiPM fill factor or SPAD size, i.e. 25, 50 and 100 μm**
- **SiPM bias voltage**
- **Discriminator (NINO) threshold**
- **Optical density (OD) of the light attenuators**

Type: S10931	SPAD size (μm^2)	Number of Cells	Fill Factor (%)	break down (V)	opt. Bias for PET [3] (V)
-100P	100x100	900	78.5	69.3	70.3
-050P	50x50	3'600	61.5	70.5	72.4
-025P	25x25	14'400	30.8	69.2	73

Tab. 1: Properties of the three different photodetectors, HAMAMATSU with 3x3mm^2 active area

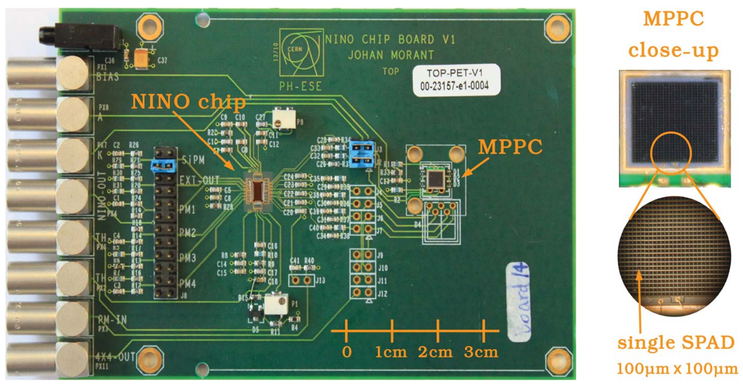
In our investigations we used:

- SiPMs (MPPCs) with an active area of 3x3mm^2 produced by Hamamatsu Photonics
- a fast LeCroy Oscilloscope DDA 735Zi 40Gs/s (with interpolation, ~1ps time resolution)
- a femtosecond laser (400nm) with 200fs pulse width.

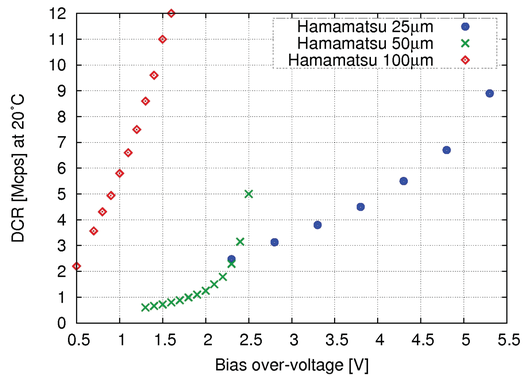


The SiPM signals are fed differentially into the ultra-fast discriminator-amplifier NINO. A fast oscilloscope measures the time delay between the differential NINO output and the trigger.

THE NINO BOARD

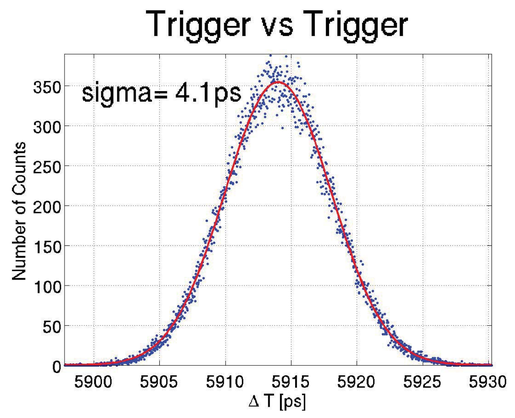


SIPM'S DARK COUNT



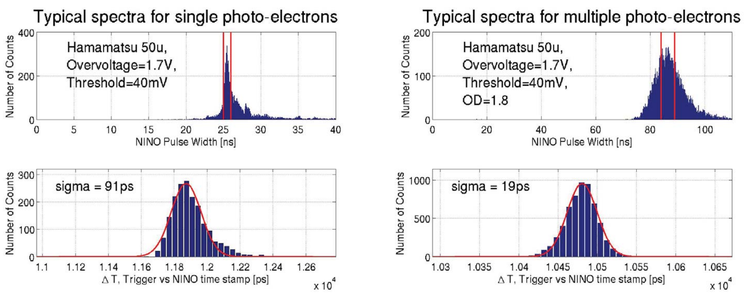
TIME REFERENCE

- To establish a precise trigger we split the beam into two beams, where one illuminated a 25μm - SiPM with aprox. 8000 photons.
- The performance of the trigger was then tested by illuminating at the same light intensity (8000 photons/pulse) two similar 25μm - SiPM and measure the time delay. We obtained a coincidence time resolution of $\sigma = 4.1ps$. **Thus the trigger jitter is about σ=2.9ps**.



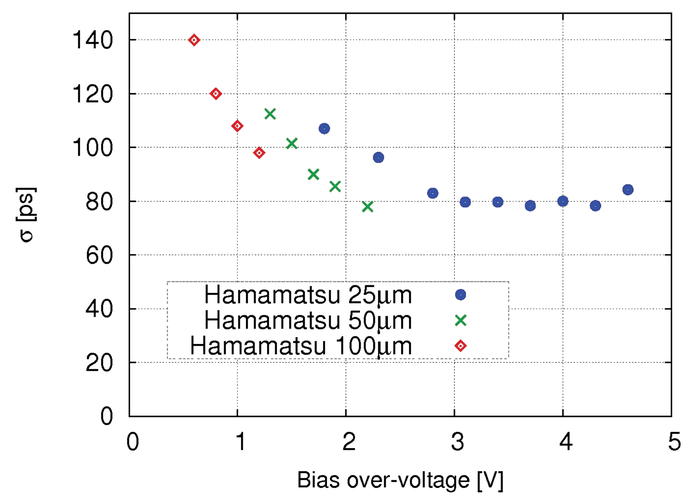
DATA ANALYSIS

- NINO employs the time-over-threshold method and produces a square pulse. The leading edge gives the time information, and the pulse width is proportional to the input charge.



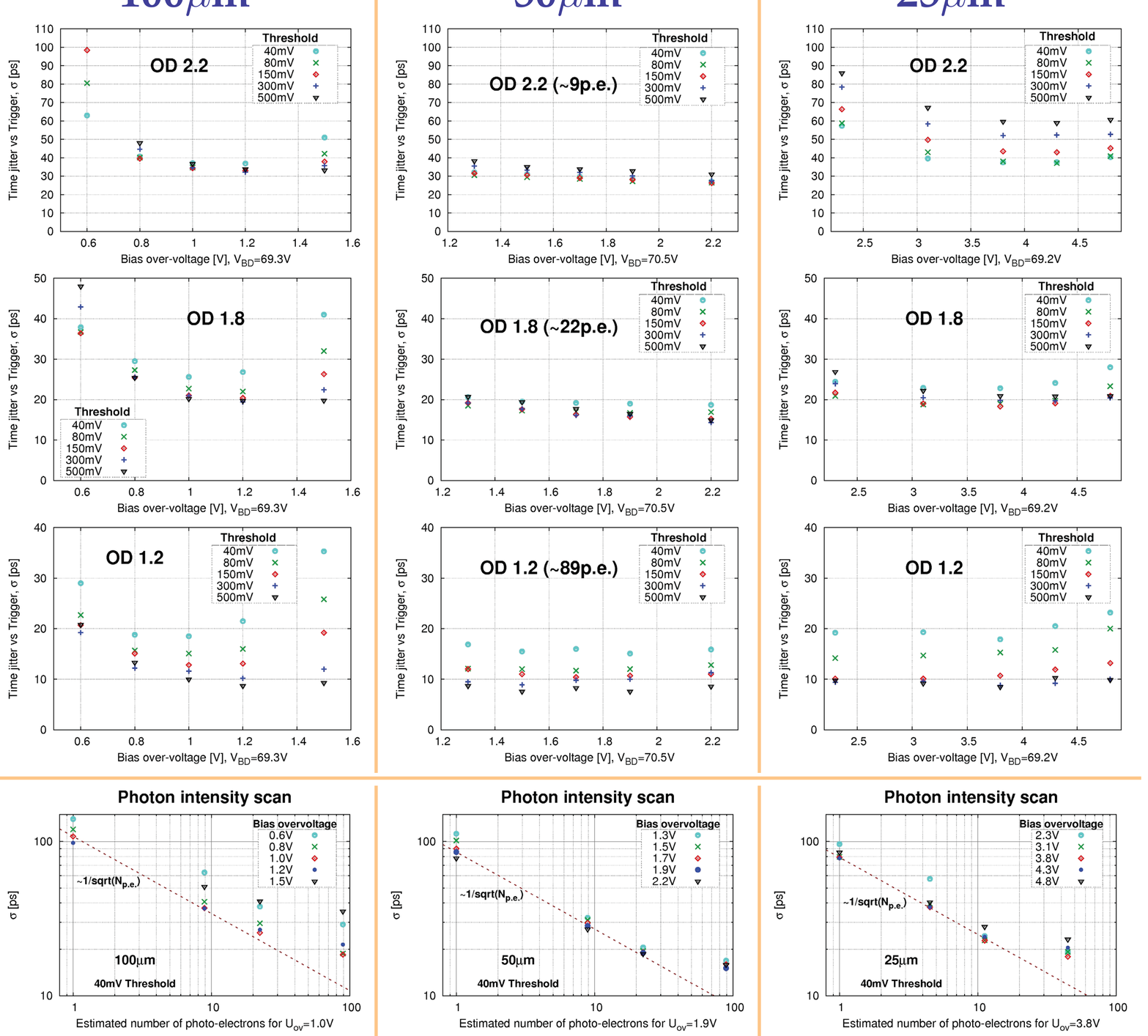
- We selected a small area around the peak of the pulse width histogram and ploted the corresponding delay time spectrum.
- With this selection we reduce the influence of time walk and the Poissonian photon flux jitter to the time distribution.

SINGLE PHOTON TIME RESOLUTION



- Single photon time resolution was measured at very low light intensities to ensure single photon hits on the detector.
- The chosen NINO threshold was 40mV. Making dark count scans, this value was found to be low enough to detect the firing of a single photon avalanche diode (SPAD).

TIME RESOLUTION VS. LIGHT INTENSITY (OD), THRESHOLD AND OVERVOLTAGE



SUMMARY AND OUTLOOK

- Using NINO, we achieved good single photon time resolutions, down to 80ps sigma. Light level scans show good $1/\sqrt{N_{p.e.}}$ agreement. At saturating photon fluxes and high threshold values we even measured a time resolution of less than 10ps sigma. This approaches the timing limitations of the electronics (NINO) and the acquisition system. At lower NINO thresholds this value is strongly deteriorated by the SiPM's dark count.
- In future tests the noise contribution to the single photon time resolution will be studied in more detail. This would include a full characterization of NINO with SiPM-like input pulses.

REFERENCES

[1] F. Anghinolfi et al. IEEE TRANS. NUCL. SCI., VOL. 51, NO. 5, PP. 1974-1978, OCT 2004

[2] P.Jarron et al. NUCLEAR SCIENCE SYMPOSIUM CONFERENCE RECOR (NSS/MIC), 2009 IEE, PP. 1212-1219,2009,JANUARY 2010

[3] S. Gundacker et al., "A SYSTEMATIC STUDY TO OPTIMIZE SIPM PHOTODETECTORS FOR HIGHEST TIME RESOLUTION IN PET", IEEE TRANSACTION ON NUCLEAR SCIENCE, RECEIVED JULY 7,2011, TO BE PUBLISHED