Detection of Optical Photons with the Timepix in an HPD Set-up

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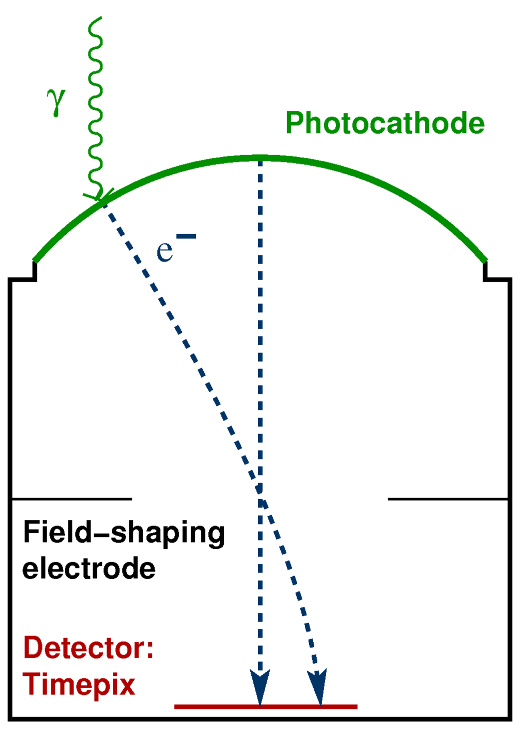
Introduction

Optical photon detection is a critical issue for neutrino telescopes like ANTARES [1]. To increase the detection efficiency for the next generation detectors like KM3NeT it is essential to improve the existing photo multiplier tubes. For example one should be able to distinguish between noise, one and two or more photo electrons. This can not easily be done with the current ANTARES PMTs but is provided by the Timepix in an HPD set-up [2], [3]. The proof of principle is given by measurements with a test set-up. Other advantages of the Timepix are the possibility to suppress electronic noise by setting a threshold, its ability to deal with high dark rates because of the huge number of pixels and the fact that the electronics is located directly in the detector.

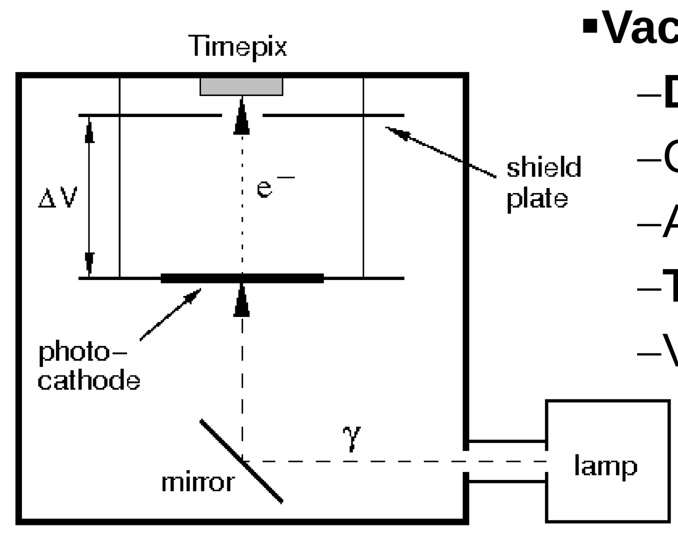
HPD Principle of Operation



Photocathode: Photon absorption and electron emission
Electric field: Electron transport (cross-focusing optics)
Sensor layer: Energy deposition
Electronics: Event detection, processing and readout

Objective: Measure time, number and position of photons

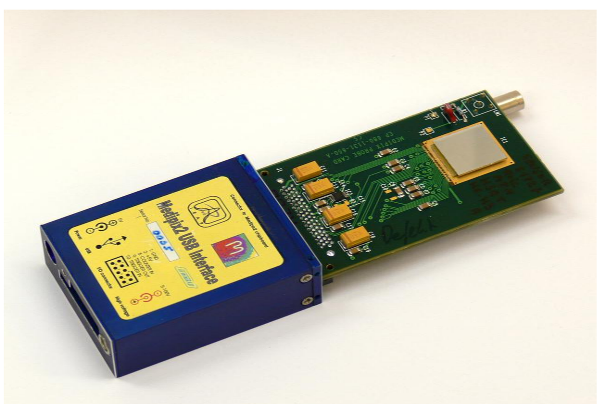
Measurements with an HPD Test Set-up at CERN

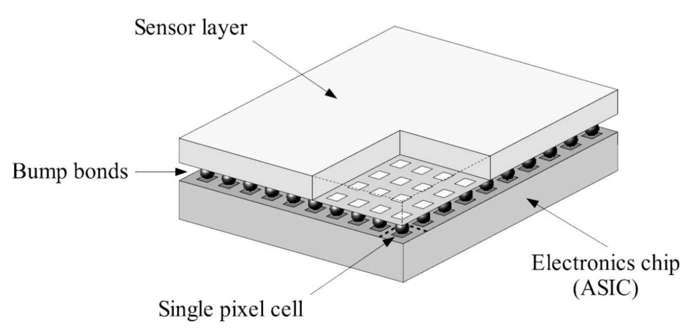


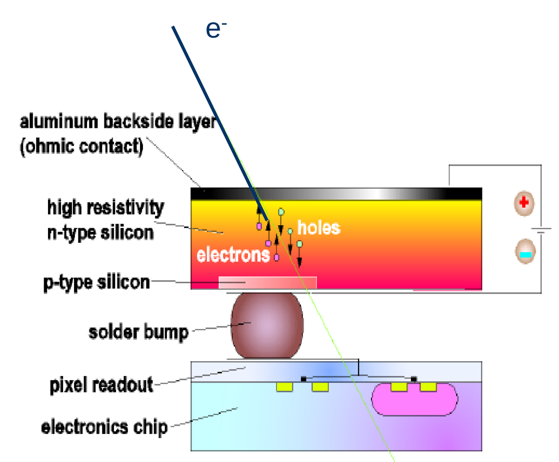
- High voltage **discharge lamp**
- **Vacuum vessel** with
  - **Deflection mirror** (position adjustable)
  - CsI **photocathode**
  - Accelerating **electric field** (U ≤ 25 kV)
  - **Timepix** chipboard (mounted upside down)
  - Vacuum: about 10^{-5} mbar

Due to the statistically light flashes of the lamp:
Trigger the end of the acquisition 3µs after the lamp flash

The Timepix Detector







Semiconductor sensor layer:
- Material: 300 µm silicon
- Filling factor 100%

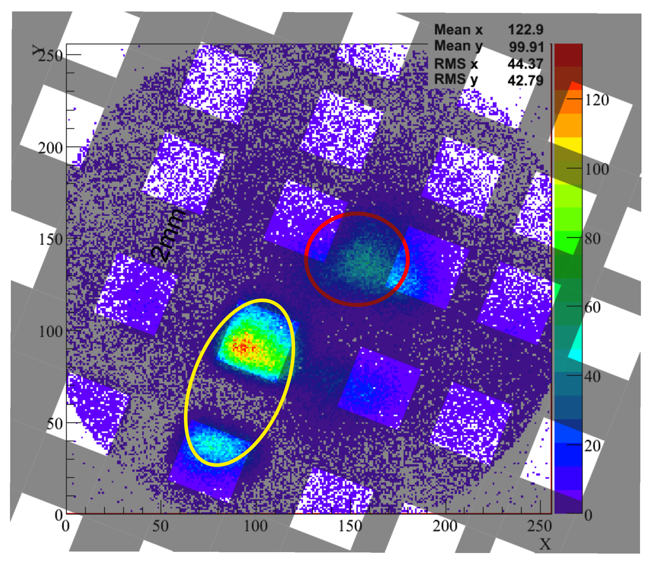
ASIC/Sensor parameters:
- Hybrid design with Pb/Sn bump-bonds
- Total sensor area: 14 x 14 mm²
- 256 rows, 256 columns
- Pixel pitch: 55 µm (square)
- 1 counter per pixel, depth of 14 bits
- 100 MHz clock frequency

Position Resolution of the Test Set-up

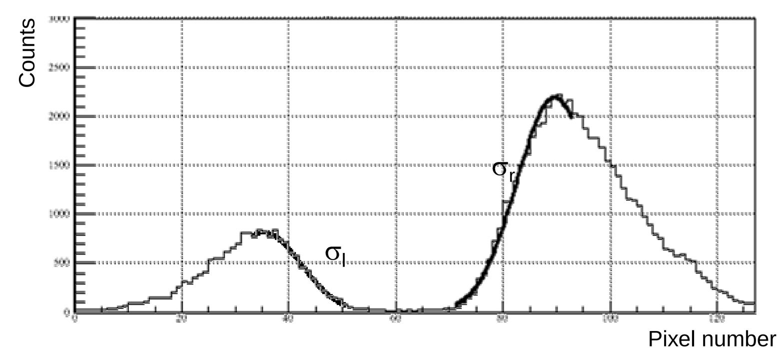
gray: absorption pattern in front of photo cathode

yellow: lamp spot

red: reflection of photons at the sensor

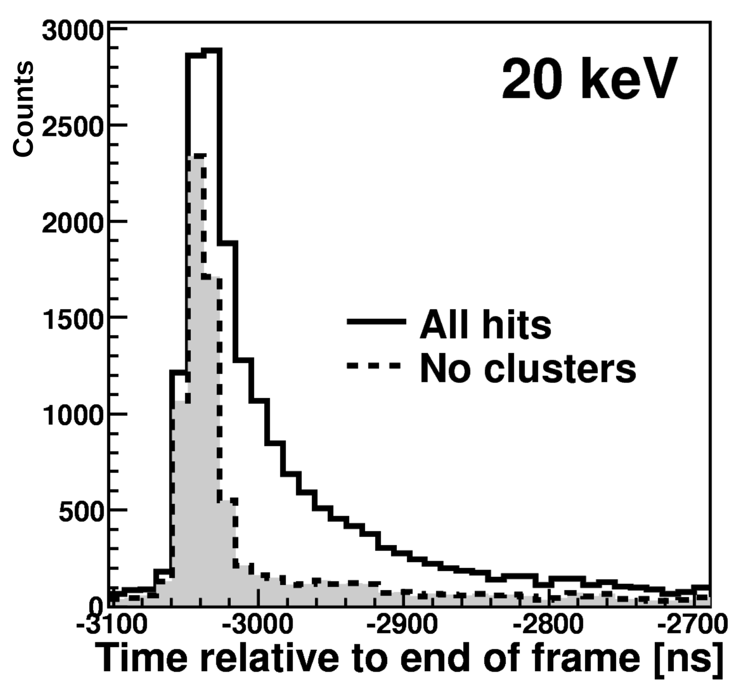


Cut through the lamp spots



Gaussian fit: σ_r = 365.8 µm
σ_l = 362.1 µm
σ_{optics} = 300 µm

Time Resolution of the Test Set-up



End of frame at time zero

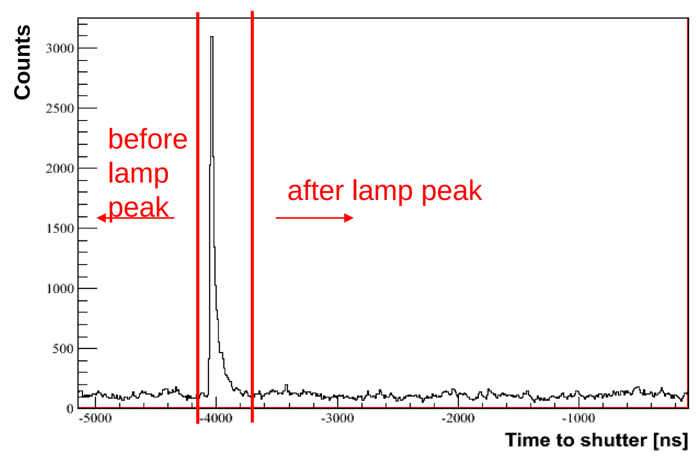
No clusters: single hits where all neighboring pixels count zero
The **broadening** of the peak (all hits) is caused by charge sharing
Charge sharing: charge from one photo electron is spread to two or more neighboring pixels

σ_{single} = 10.4 ns
(clock frequency: 100 MHz)

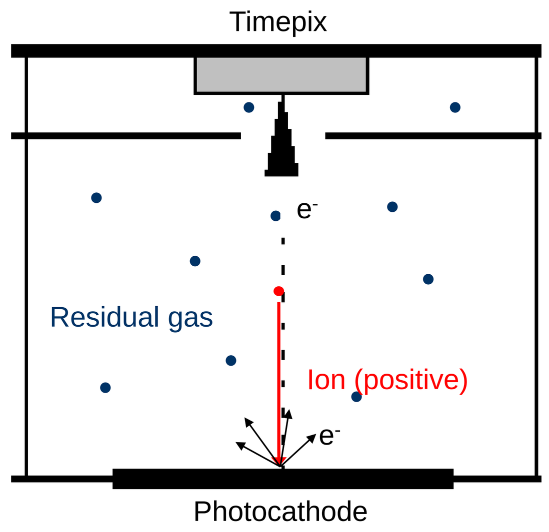
Dark Rate of Test Set-up

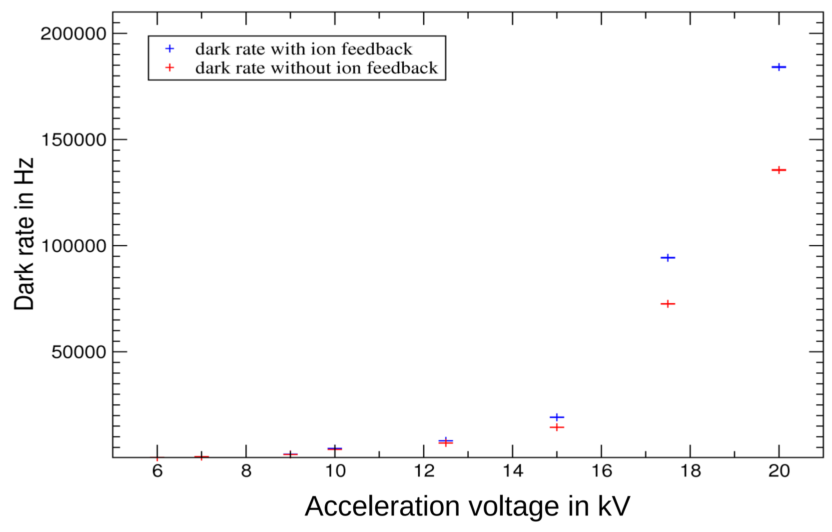
Dark rate:

- emitted electrons from the photo-cathode by thermal effects
- ionisation of residual gas



Ion feedback produces clusters of pixels in one time bin
→ identification to reduce the dark rate





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References:
[1] The ANTARES Collaboration Website: http://antares.in2p3.fr
[2] G. Anton, and T. Michel: Patent application PCT/EP 2007/005 072
[3] The Medipix Collaboration Website: http://www.cern.ch/medipix