Light Emission from Light Detectors

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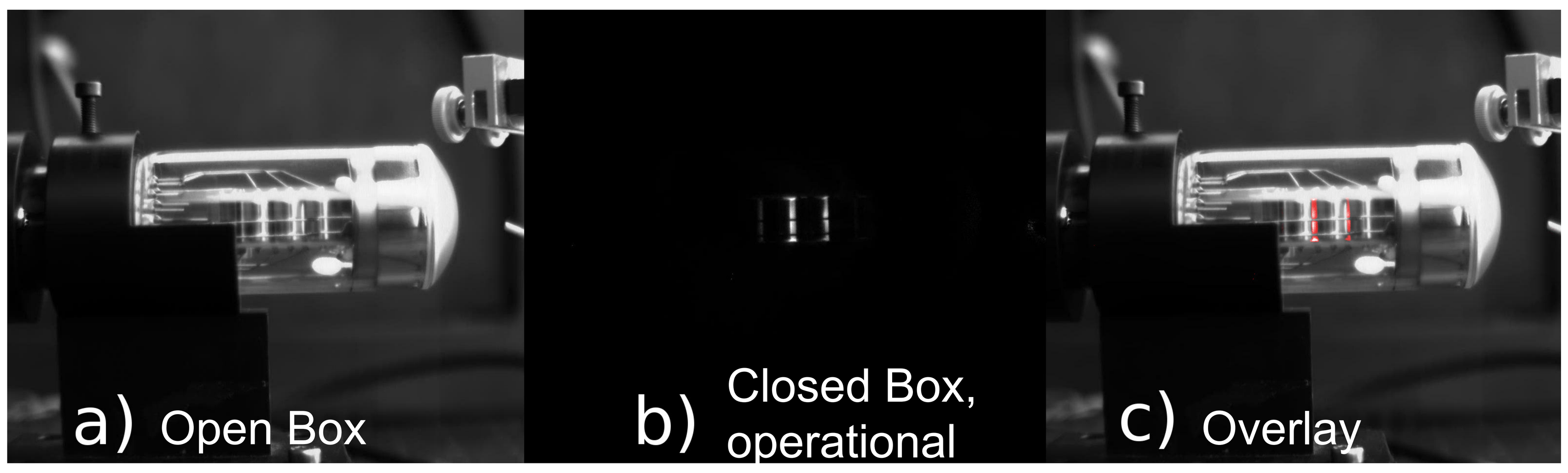
Light emission from photomultipliers (PMT) and from silicon photomultipliers (SiPM) is known to have a feedback on the respective sensor. If the emitted light in a PMT finds its way back to the photocathode, it can cause afterpulses. In SiPM light emission causes optical crosstalk between cells.

The light emission can also be used for studying the detectors. We apply light emission microscopy to SiPM and suggest to use it as precise visual method for measuring the cross-talk. Also, we have measured the transverse size of avalanches in a SiPM cell. This turned out to be significantly smaller than the usually used cell sizes. We want to dwell on implications of this fact, e.g. a lower limit for the time resolution. Our approach to study light-induced afterpulses in PMTs is to image the wavelength dependent light emission with a sensitive CCD camera and a fast gated image intensifier. We show how the electrons interact with the dynode material, time resolved on the nanosecond scale. Wavelength dependent light emission proves that not only the dynodes, but also their support structure emits light. The performed experiments help to understand the fundamental effects of light emission in PMTs and in SiPMs.

Photomultiplier

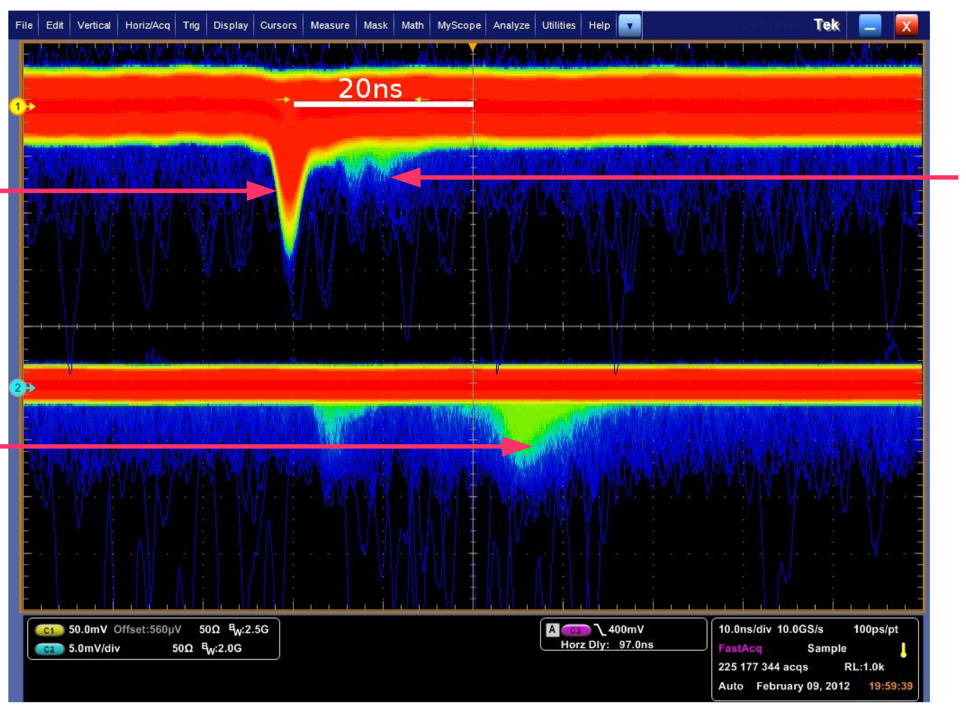
Problem: Optical afterpulses

The Sample: Hamamatsu R11920-100, Cherenkov Telescope Array Prototype



Method: PMT signals, interference filter imaging, spectroscopy, fast image intensifier camera (~ns)

PMT measures laser

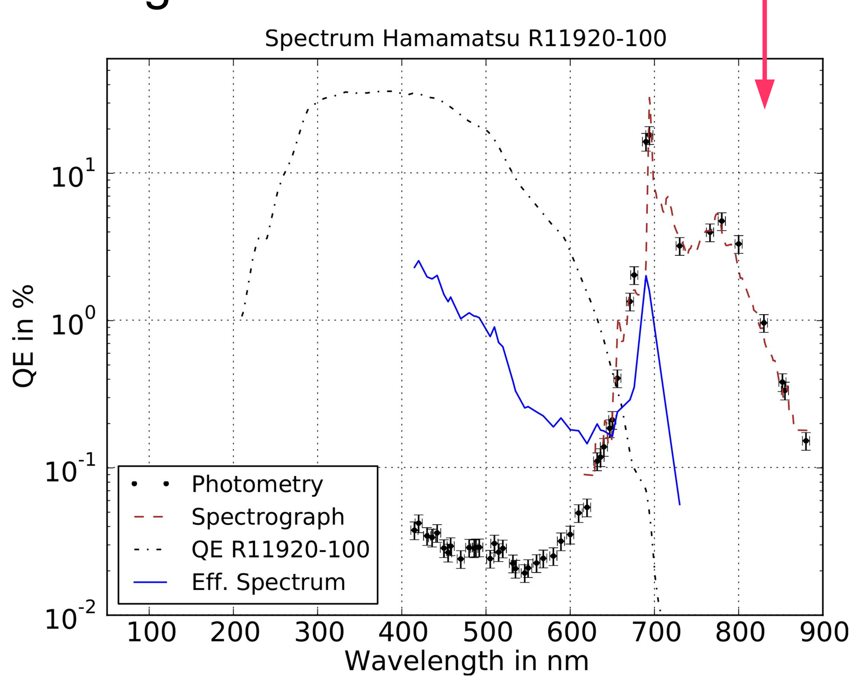


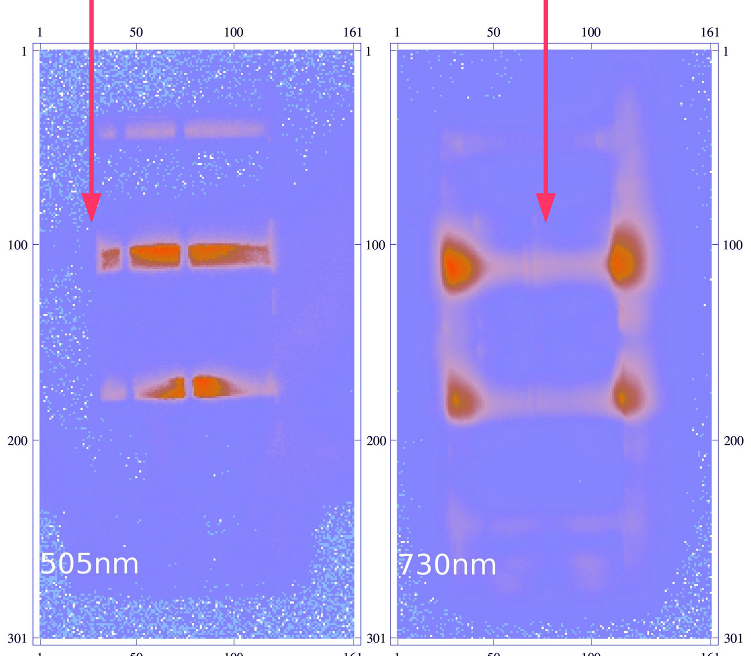
And fast afterpulses appear

A PMT from the side sees light emission from the dynodes

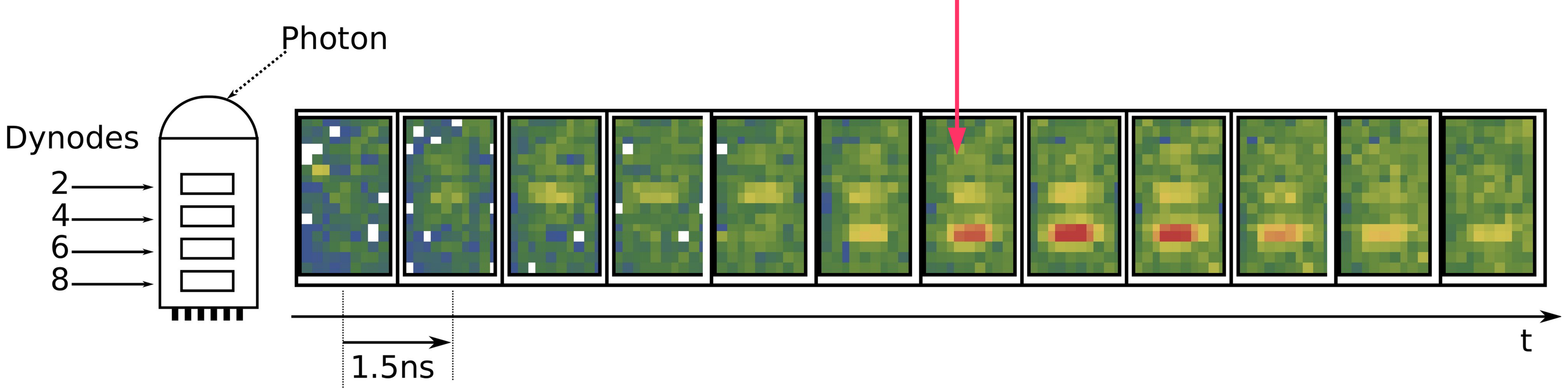
Results:

Spectral Properties: Line Emission, dynode light emission and dynode holding material fluorescence



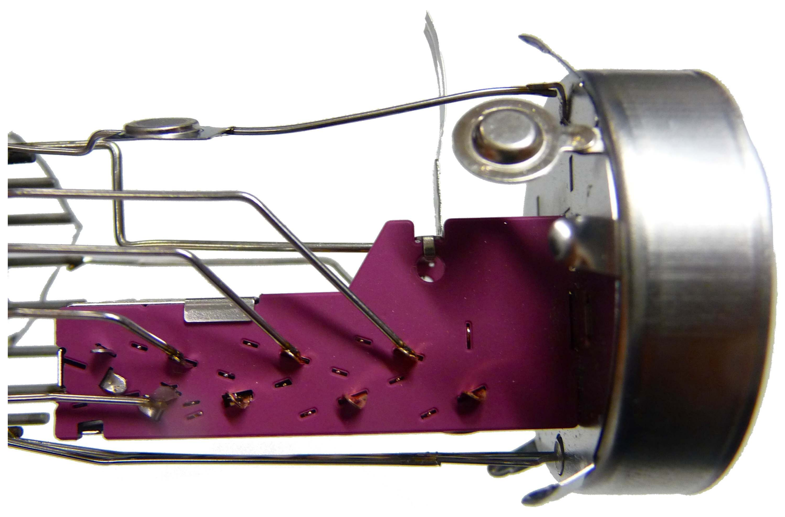


Time resolved imaging of the multiplication process



Implications:

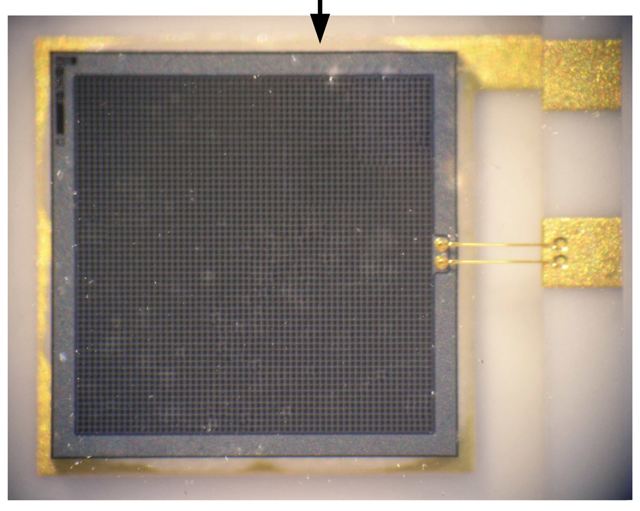
Dynode holding material recipe optimisation → quenching of the fluorescence light will improve the design of photomultipliers

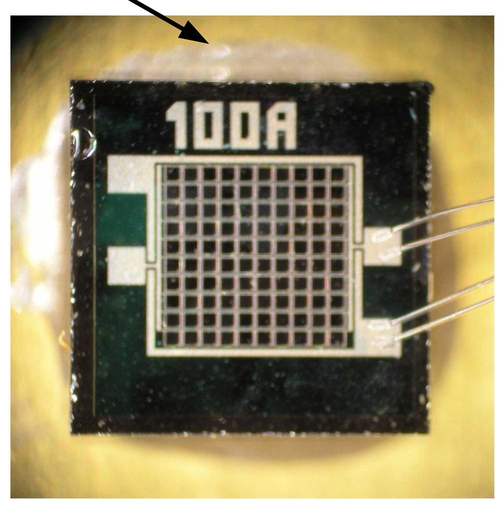


Silicon Photomultiplier

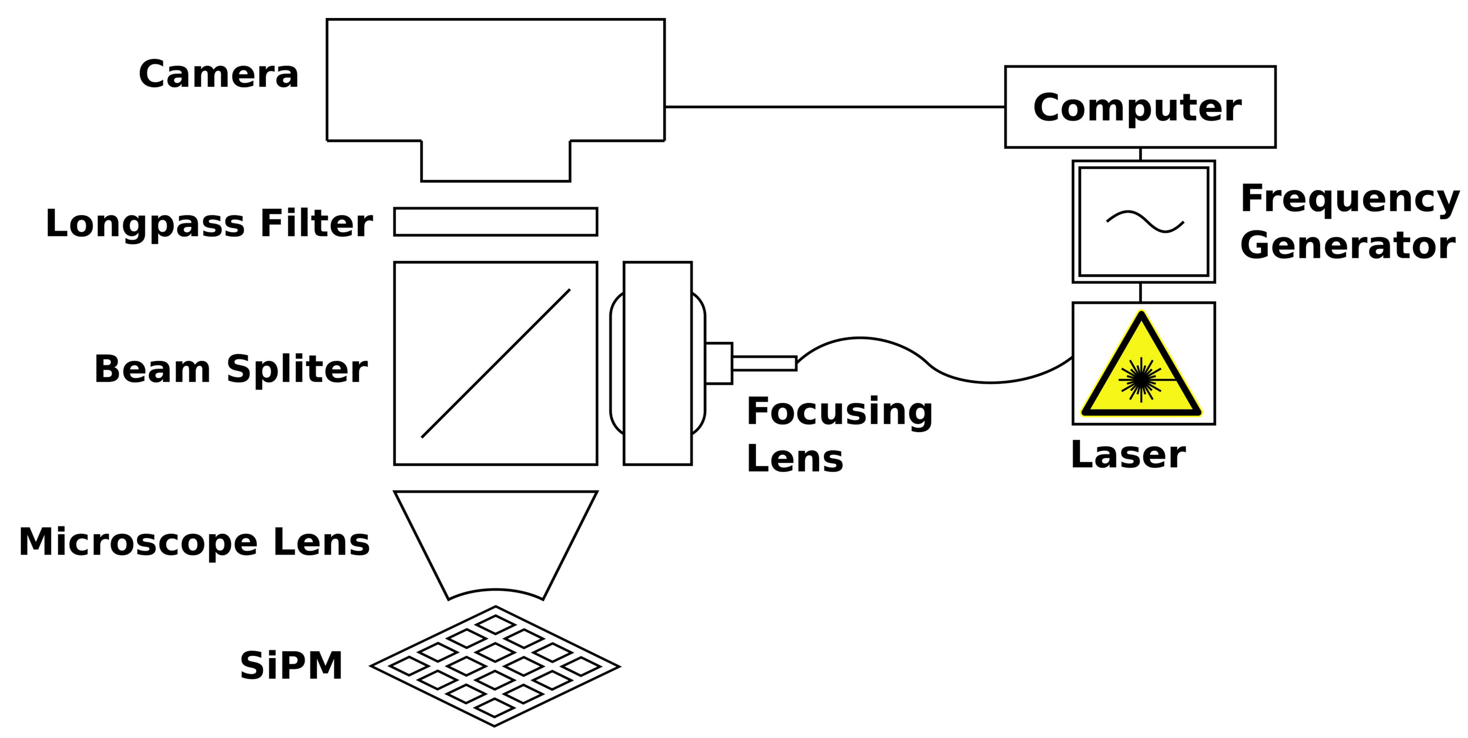
Problem: Optical cross-talk between cells

The Sample: Hamamatsu, MEPhI Prototypes



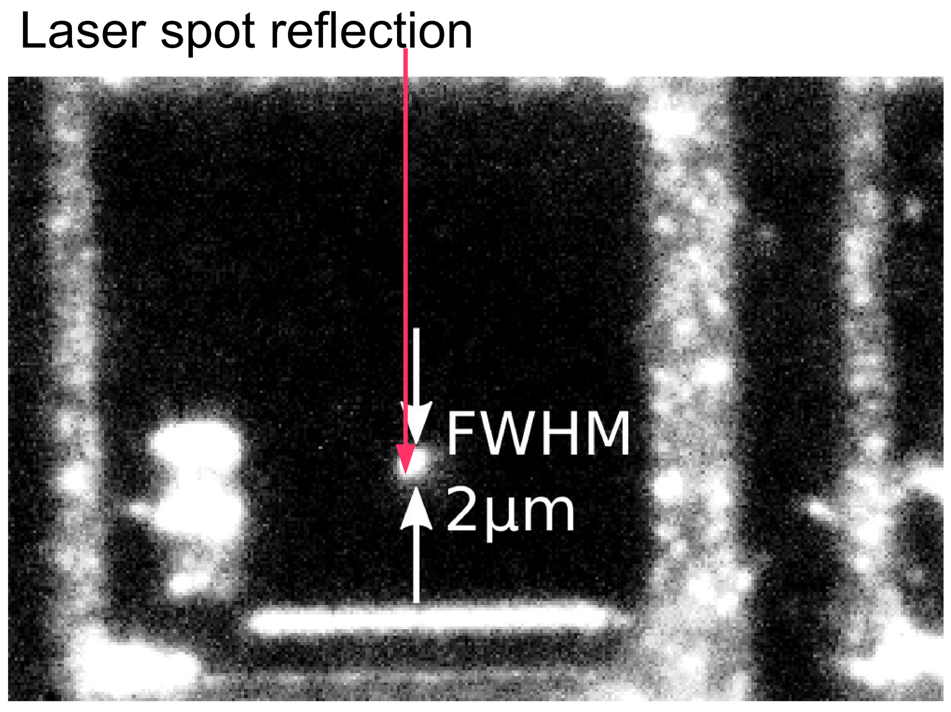


Method: Light Emission Microscopy

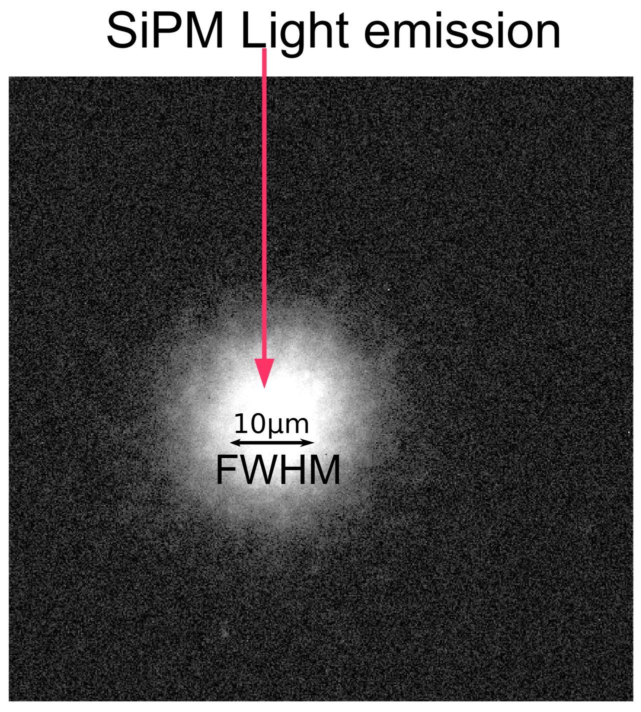


Results: Avalanche size is ~ 10 micrometer

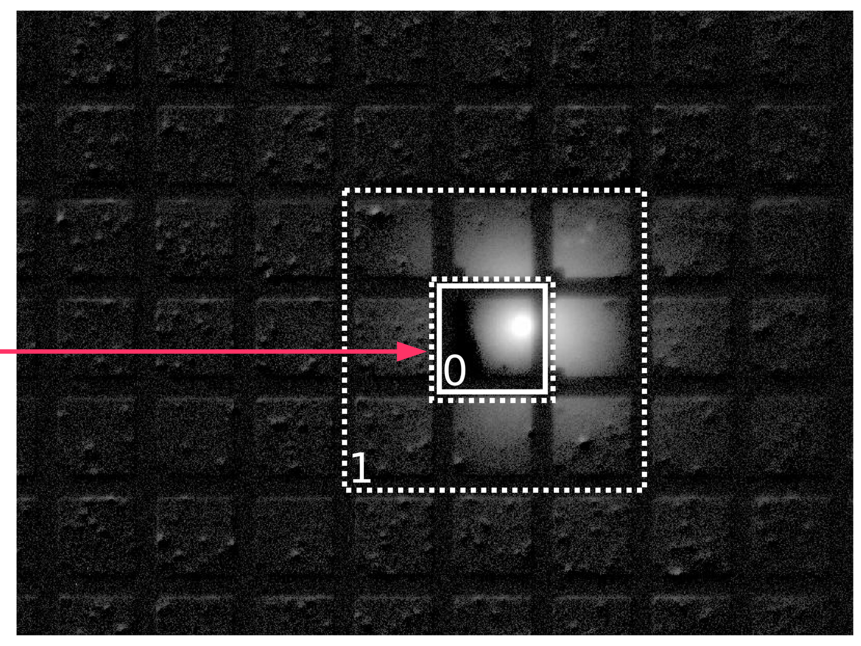
Laser spot reflection



SiPM Light emission



Direct imaging of cross-talk, precise measurement possible (0 = target, 1 = cross-talk)



Implications:

- Avalanche size sets lower limit for the size of the cell → time resolution will not improve further
- Direct proof of cross-talk
- Diffusion without light assistance (entire cell should be bright), confirms theory for shallow junctions