Differences between standard analog SiPM readout and our new, more digital-like SiPM readout

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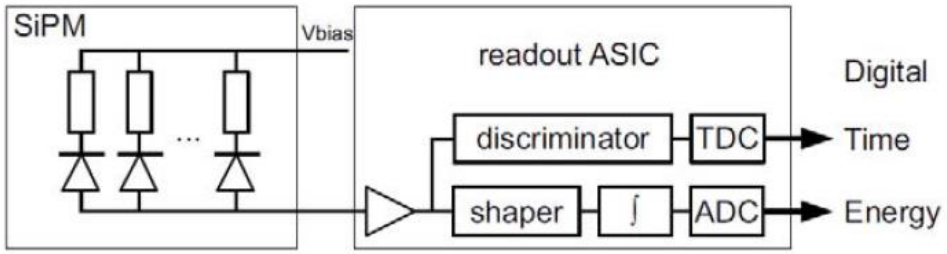
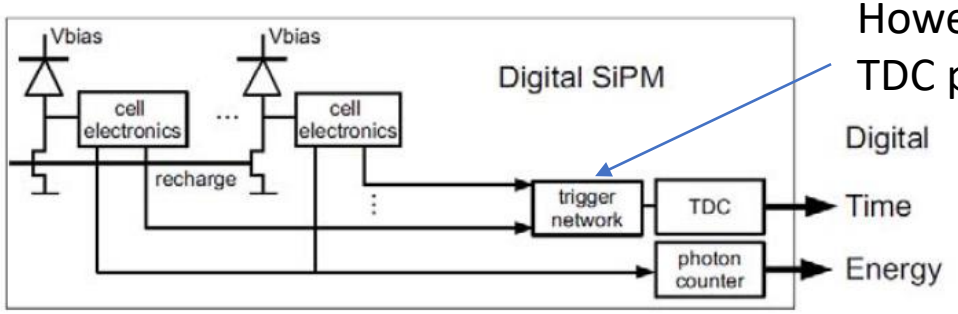
Analog vs. Digital SiPM

In our case one CITIROC Channel



However we will consider one TDC per SPAD



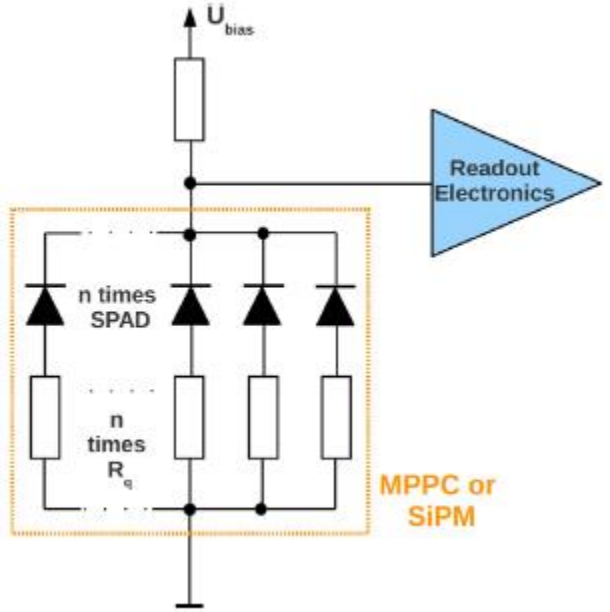
Robert Joppe: Preparation and first applications of a digital SiPM https://web.physik.rwth-aachen.de/~hebbeker/theses/joppe_bachelor.pdf

Different Noise Mechanisms in SiPMs

- 1. thermally generated electrons in the high-field region (dark counts)
- 2. trapped and delayed re-emitted electrons in the high-field region (afterpulses)
- 3. secondary photons, generated in the Geiger discharge (optical crosstalk)

Source: Ch. Dietzinger, P. Iskra, Thomas Ganka, T. Eggert, Lothar Höllt, A. Pahlke, N. Miyakawa, M. Fraczek, J. Knobloch, F. Wiest, W. Hansch, R. Fojt, "Reduction of optical crosstalk in silicon photomultipliers," Proc. SPIE 8460, Biosensing and Nanomedicine V, 84601L (10 October 2012); https://doi.org/10.1117/12.930473

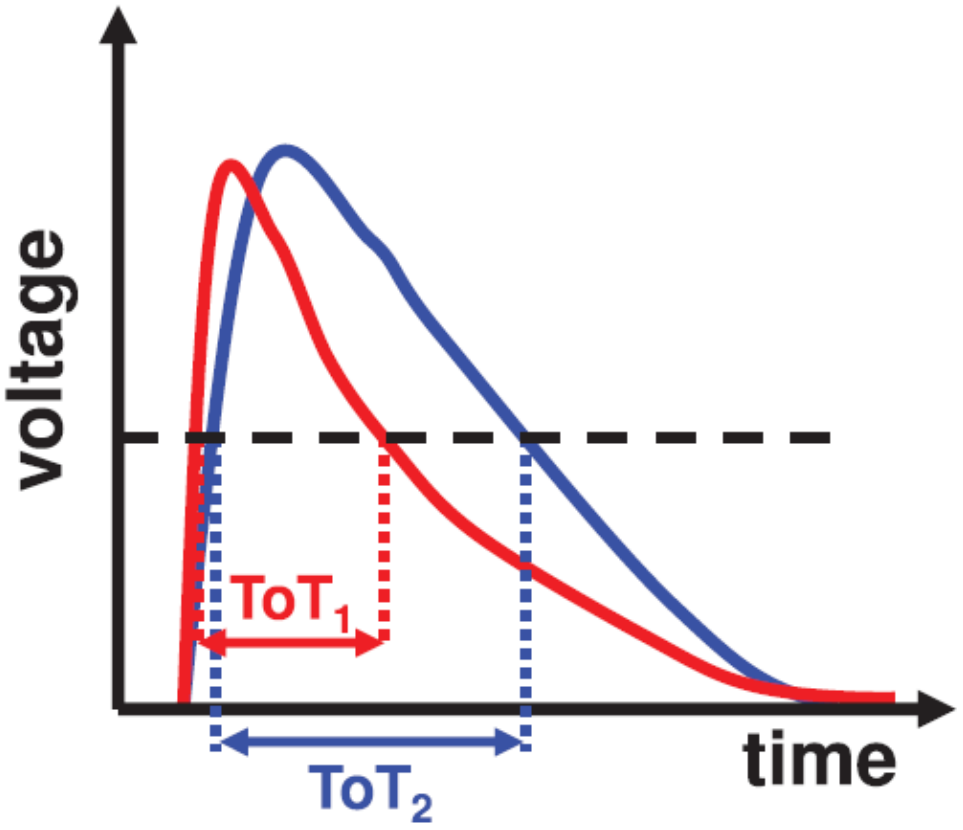
Current Setup: Analog SiPM



S. Gundacker, E. Auffray, P. Jarron, T. Meyer, P. Lecoq,
On the comparison of analog and digital SiPM readout in terms of expected timing performance,
Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 787, 2015, Pages 6-11, ISSN 0168-9002, https://doi.org/10.1016/j.nima.2014.10.020.
(https://www.sciencedirect.com/science/article/pii/S016890021401167X)

Signal

- Amplitude is sum of firing microcells
- Timing of single photons has to be determined by very fast shaper and discriminator
- Time over Threshold (ToT) can be used to determine signal amplitude but can be disturbed by noise



Chen-Ming Chang *et al* 2017 *Phys. Med. Biol.* **62** 258

Our SiPM is more a digital SiPM

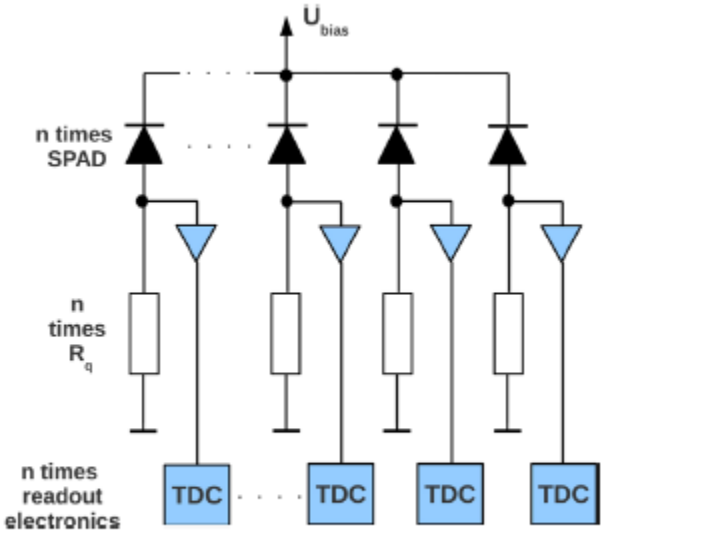


Fig. 2. In the multi-digital SiPM the timestamp of every photon detected is recorded with its own time to digital converter (TDC).

- Each Microcell has its own readout chain and TDC
- When one photon hits one microcell (SPAD) it fires and generates very large signal
- Number of photons is the sum of fired microcells
- Very easy to determine time of arrival of individual photons
- Noisy cells can be masked (disabled)
- Optical crosstalk may be detected by seeing 2D clusters

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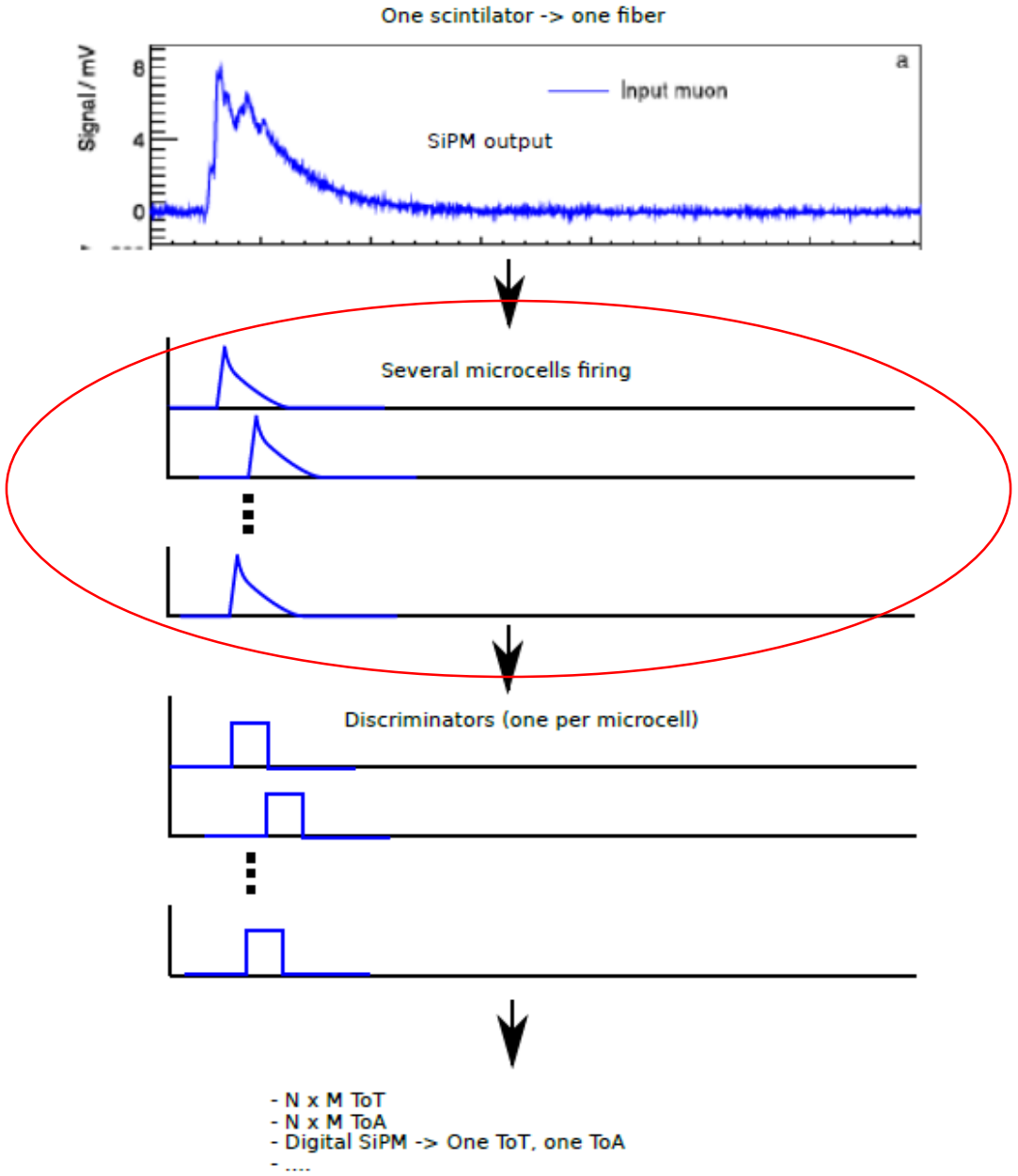
So what data can we get from a signal SPAD?

- Time of the Rising edge of the Signal:
  - Time of arrival of the photon
- Time over threshold of the signal
  - If gain of SPAD very high:
    - see if there is pileup or afterpulses
    - Dead time of SPAD
  - If gain is lower:
    - ToT needed for time walk corrections
  - -> It makes sense to measure ToT in first prototype to see if it is needed

What data can we get from the complete SiPM?

- We should be able to track each single photon with its time of arrival
  -> each photon creates its individual digital output
- No adder amplifiers are needed, we get the sum easily digitally, either by counter on chip or on FPGA
- SiPM can be used to study scintillators and fibers very precisely

Comparison of both architectures



Current AMIGA SiPM signal

Currently: microcell signals are summed up in analogue way

Both SiPMs have firing microcells

Microcell signals will be directly digitized

How would the new readout may look like?