

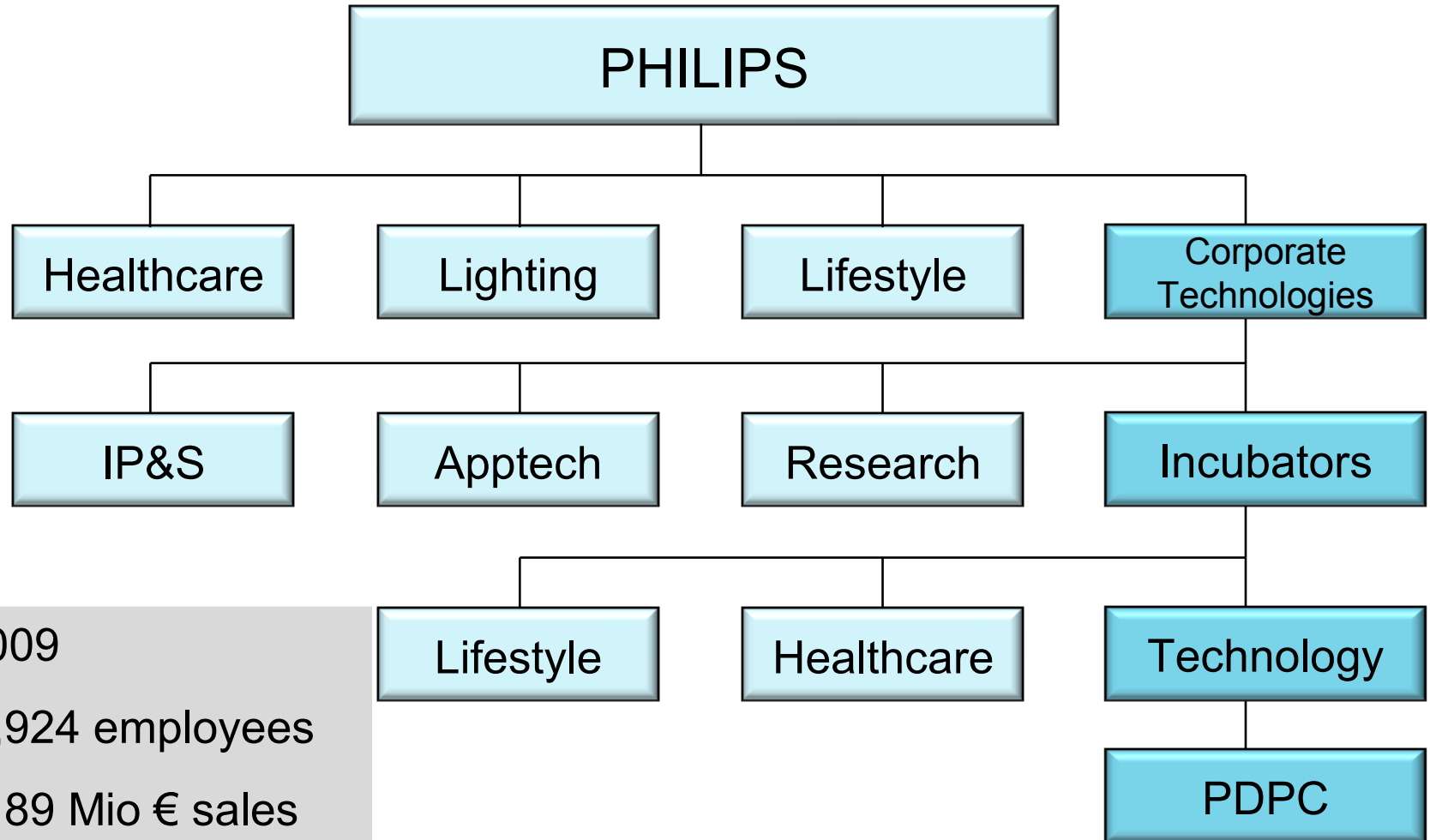
# PHILIPS

sense and simplicity

## Digital Silicon Photomultiplier

Philips Digital Photon Counting

# Philips Organization

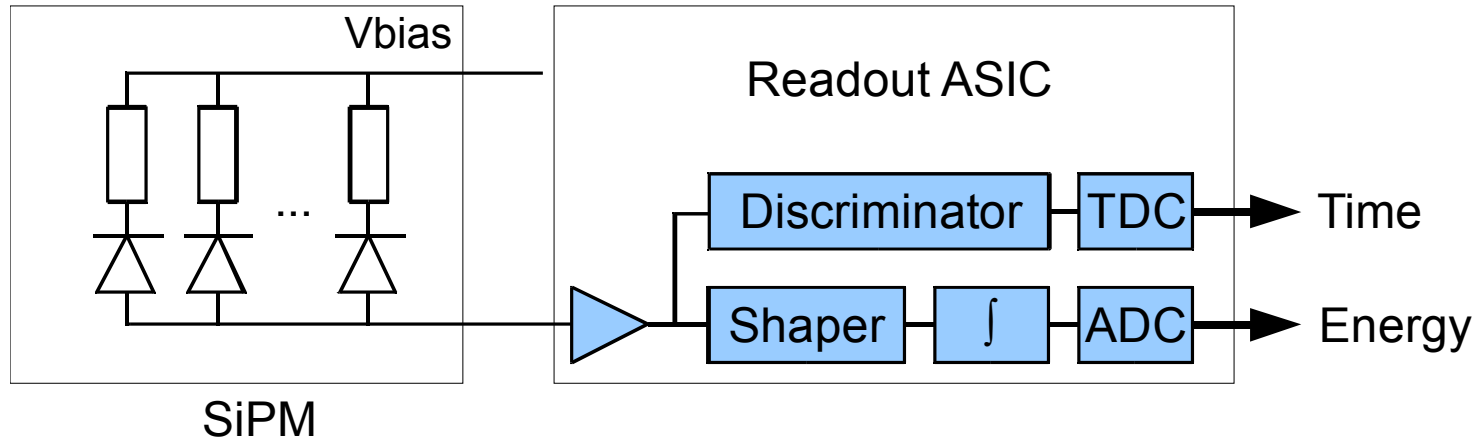


FY 2009

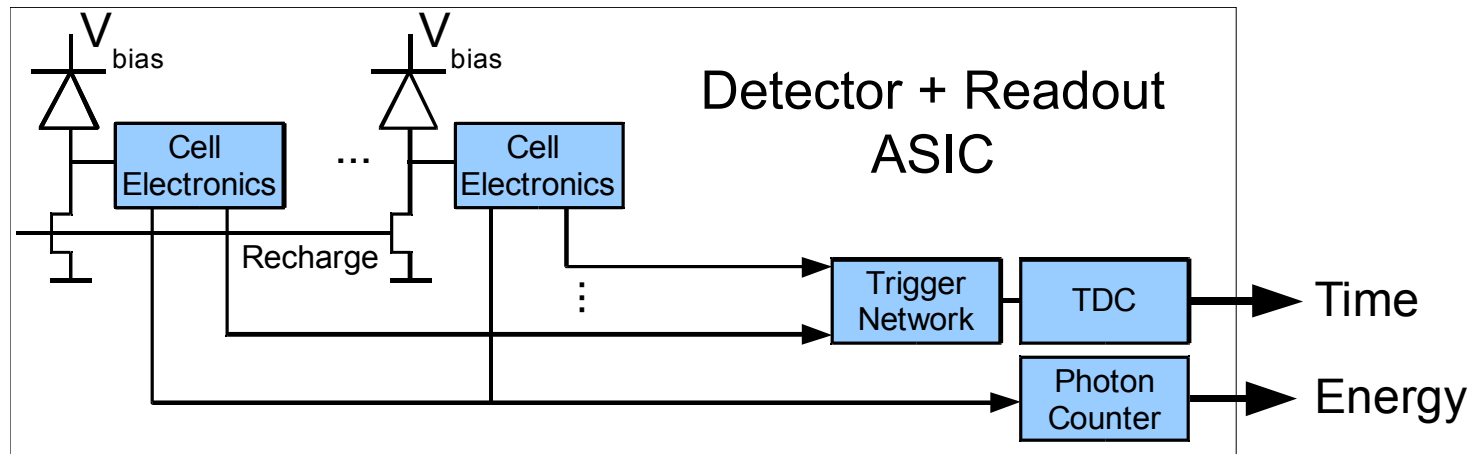
- 115,924 employees
- 23,189 Mio € sales
- 424 Mio € profit

# Analog vs. Digital Photon Counting Detector

## Analog Silicon Photomultiplier Detector

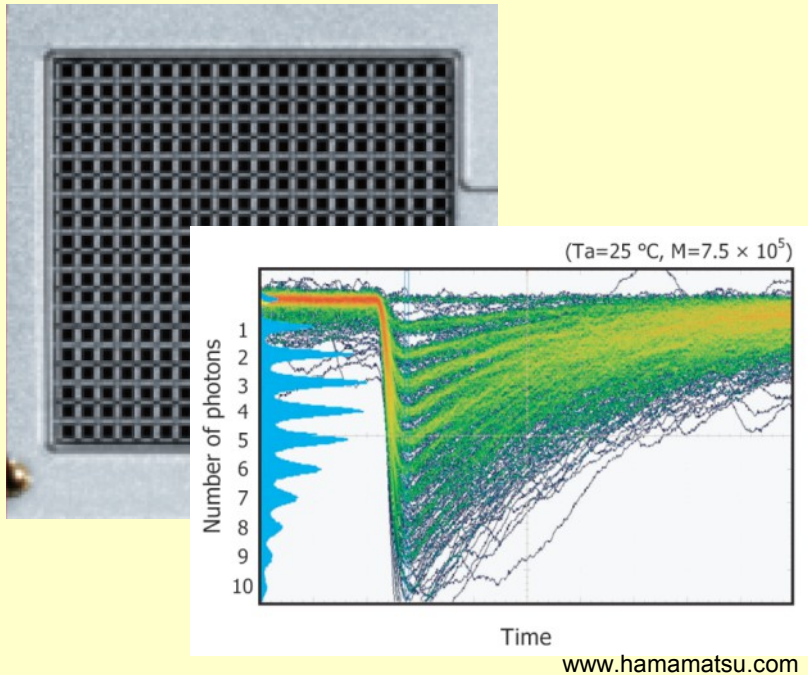


## Digital Silicon Photomultiplier Detector



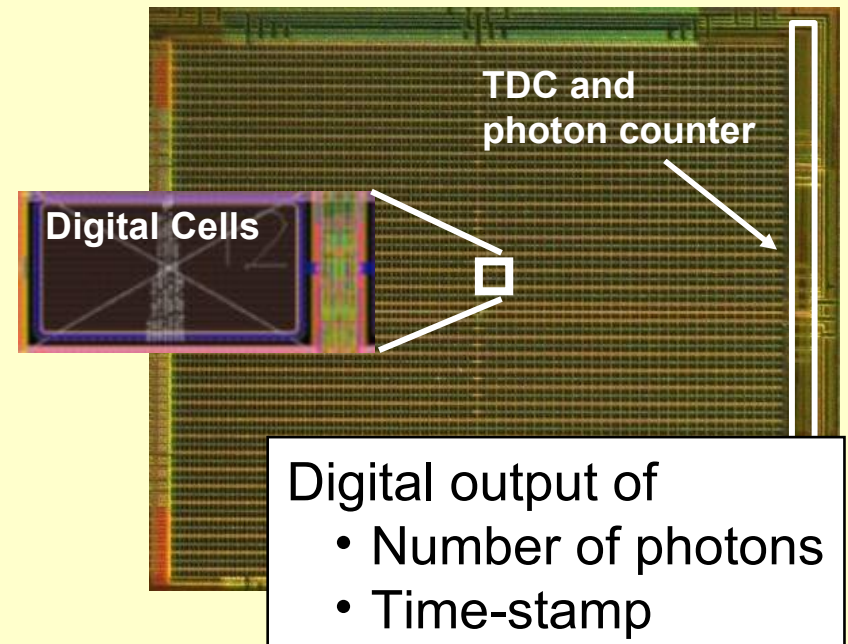
# Analog vs. Digital Silicon Photomultiplier

## Analog Silicon Photomultiplier



Summing all cell outputs leads to an analog output signal comparable to that of the PMT

## Digital Silicon Photomultiplier



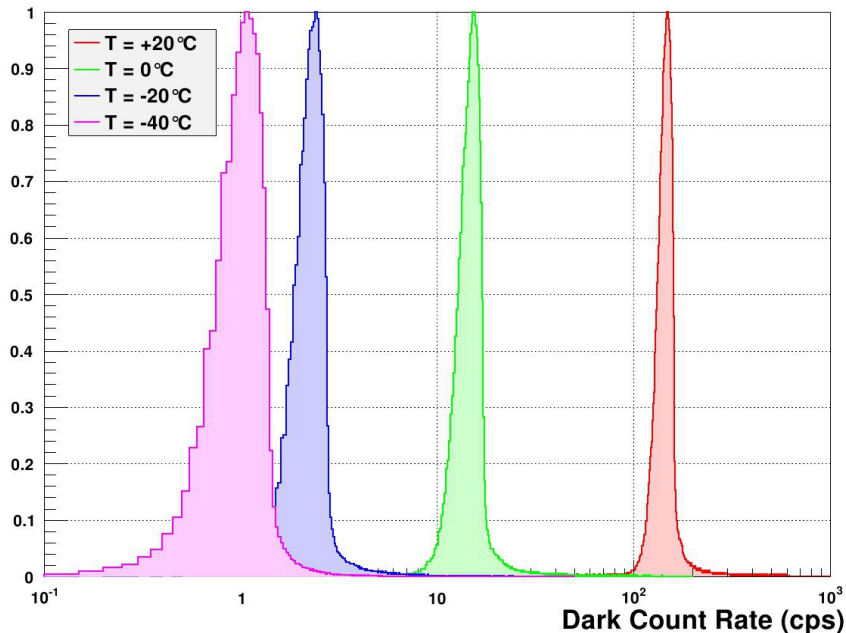
Integrated readout electronics is the key element to improved detector performance

# Digital SiPM Parameters

Control over individual SPADs enables detailed analysis (and optimization) of:

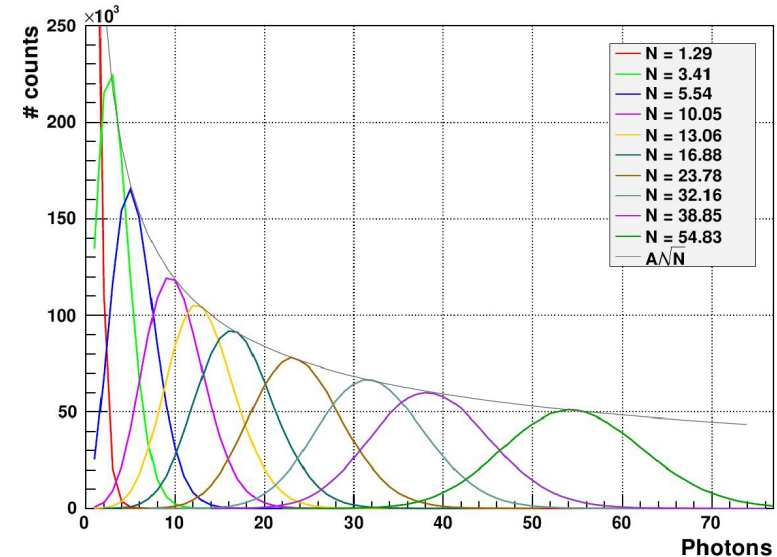
- Dark count rate of each diode
- Skew and jitter of the trigger network
- Time jitter of the SPAD and the TDC
- Breakdown voltage variation
- Afterpulsing, optical crosstalk, ...

**SPAD Dark Count Rate Distribution**

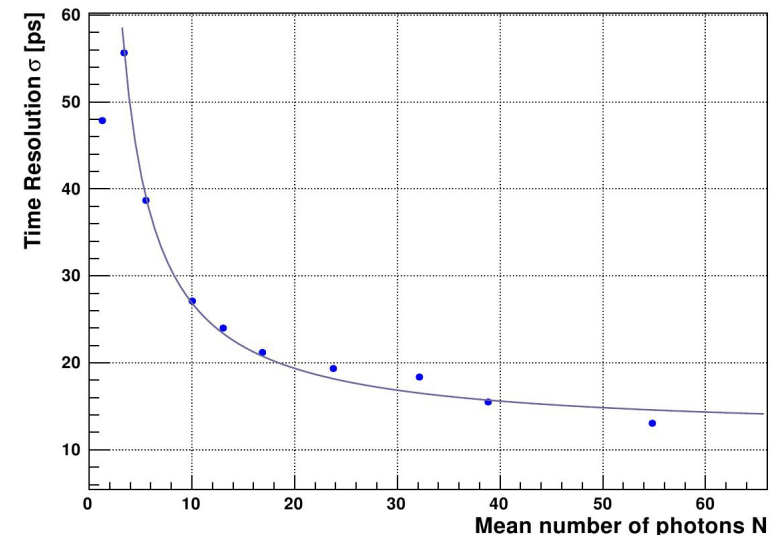


## Picosecond-Laser:

**Photon Resolution**

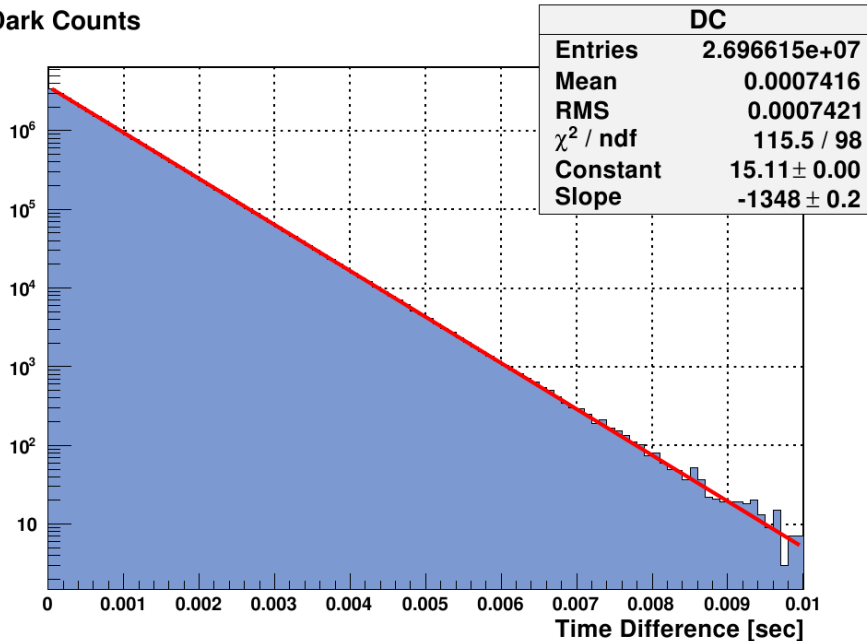


**Time Resolution**

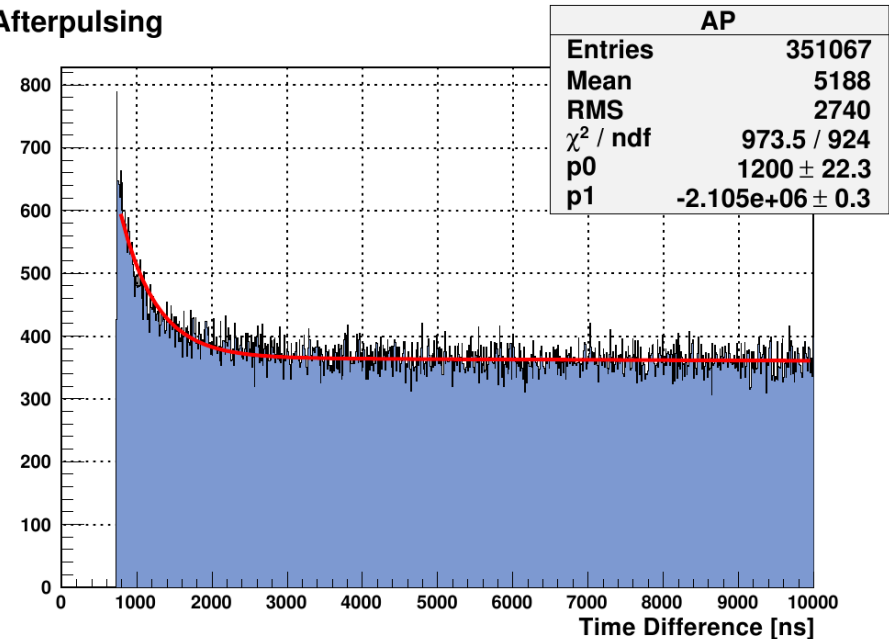


# Digital SiPM: Afterpulsing

Dark Counts



Afterpulsing



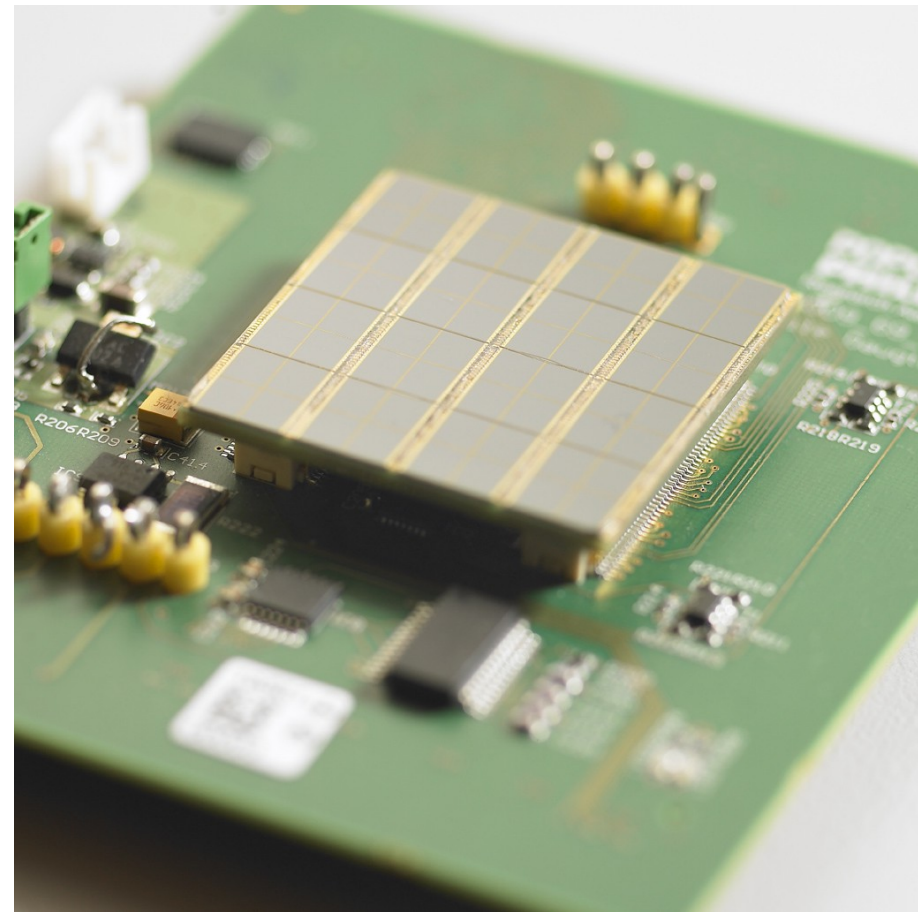
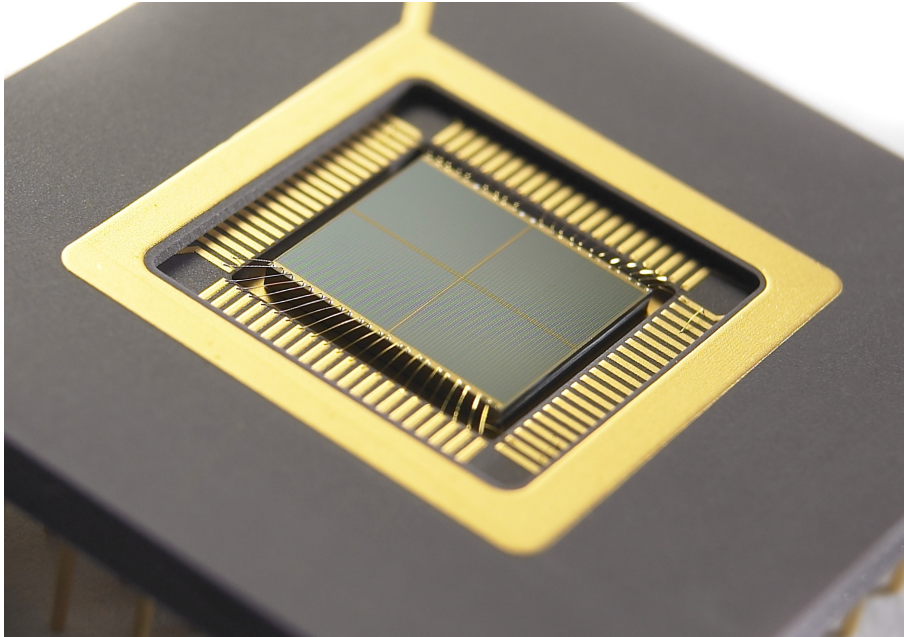
Time differences of two consecutive dark counts in a single diode.

Afterpulsing: deviation from the Poisson distribution in the first few  $\mu\text{s}$ .

Many diodes show afterpulsing probabilities of less than 0.1%, few are in the 2-3% range.



# Current Status

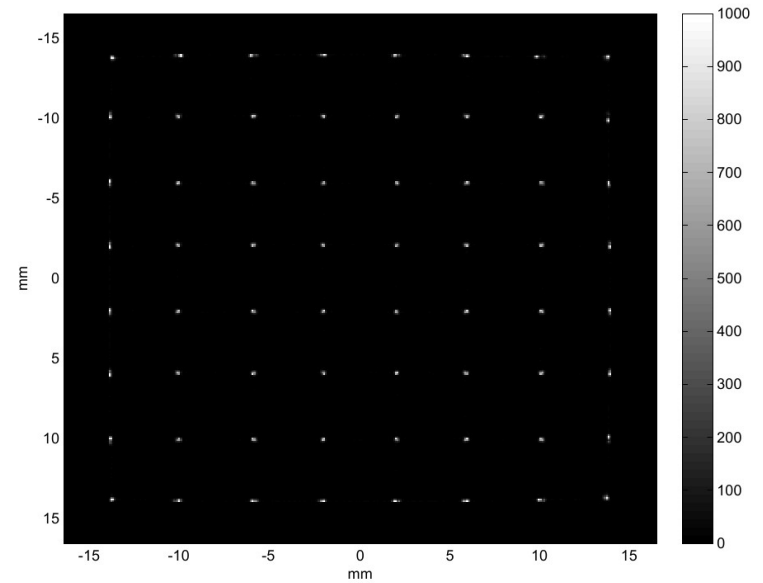


- 2x2 pixel SiPM sensor fully operational
- 8x8 pixel SiPM arrays tested and working
- Lot of work done on process optimization and yield learning
- Industrialization phase ongoing
- Re-design planned for early next year (fill factor, trigger network)

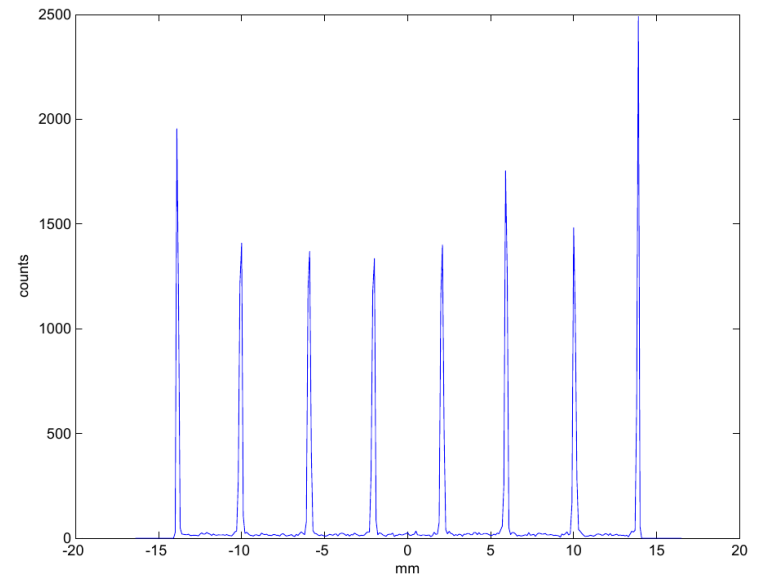
# Crystal Measurements



8x8 array of LYSO crystals coupled to one tile, illuminated by a  $^{22}\text{Na}$  source



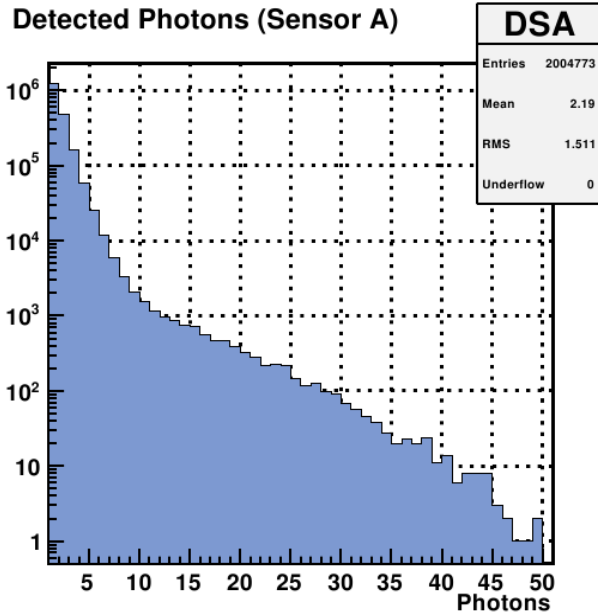
Floodmap



Cross-section



# Čerenkov Light Detection

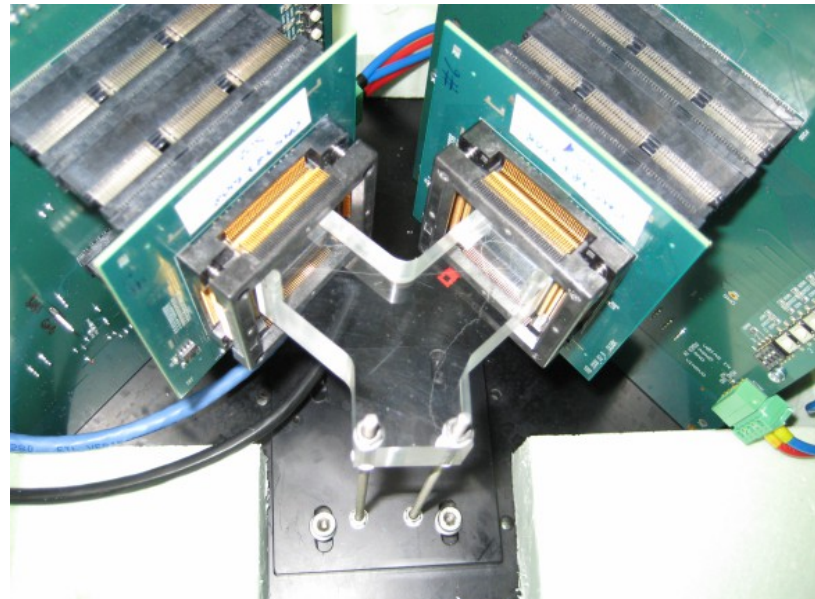
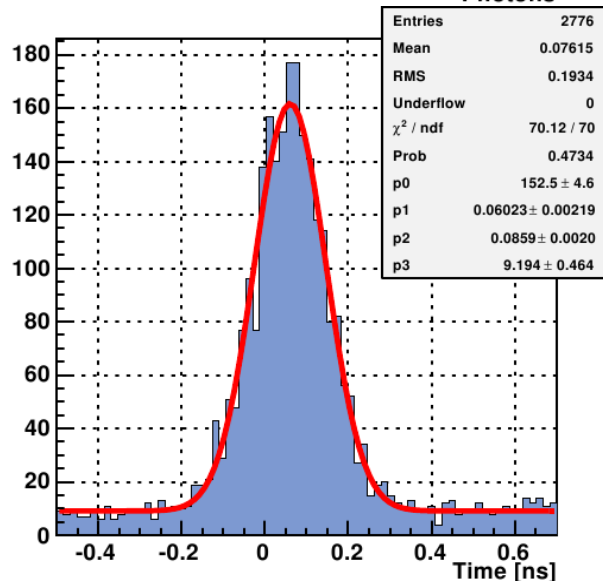


First tests at CERN SPS in August 2010 in collaboration with Prof. Düren (Univ. Gießen)

CRT  $\sigma = 85.9\text{ps} \rightarrow$  Sensor  $\sigma = 60.7\text{ps}$

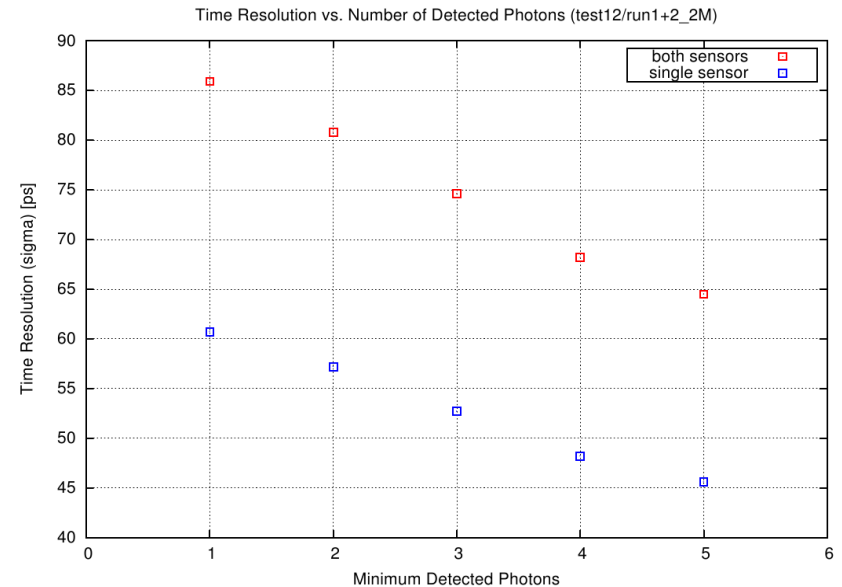
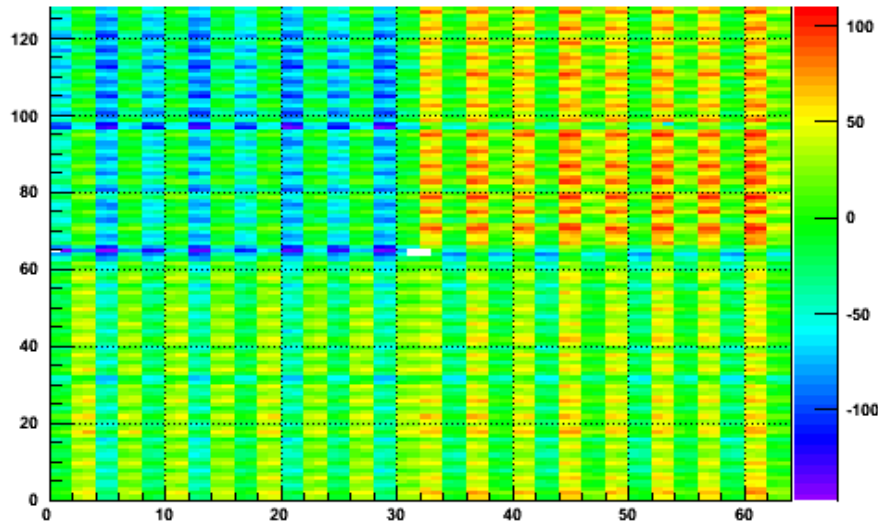
Sensor optimization could lead to  $\sigma = 30\text{-}40\text{ps}$ .

Next beam time: December 2010 at DESY



# Time Resolution vs. Detected Photons

TDC Laser Map (Skew)



Time resolution improves with the number of photons

- Sampling of the trigger network skew
- Trigger network now the main limiting factor for single photon timing
- The skew will be minimized in the next submission

Expected single photon time resolution after optimization:  $\sigma = 30\text{-}40\text{ps}$

