Digital SiPM from PHILIPS short exploration.

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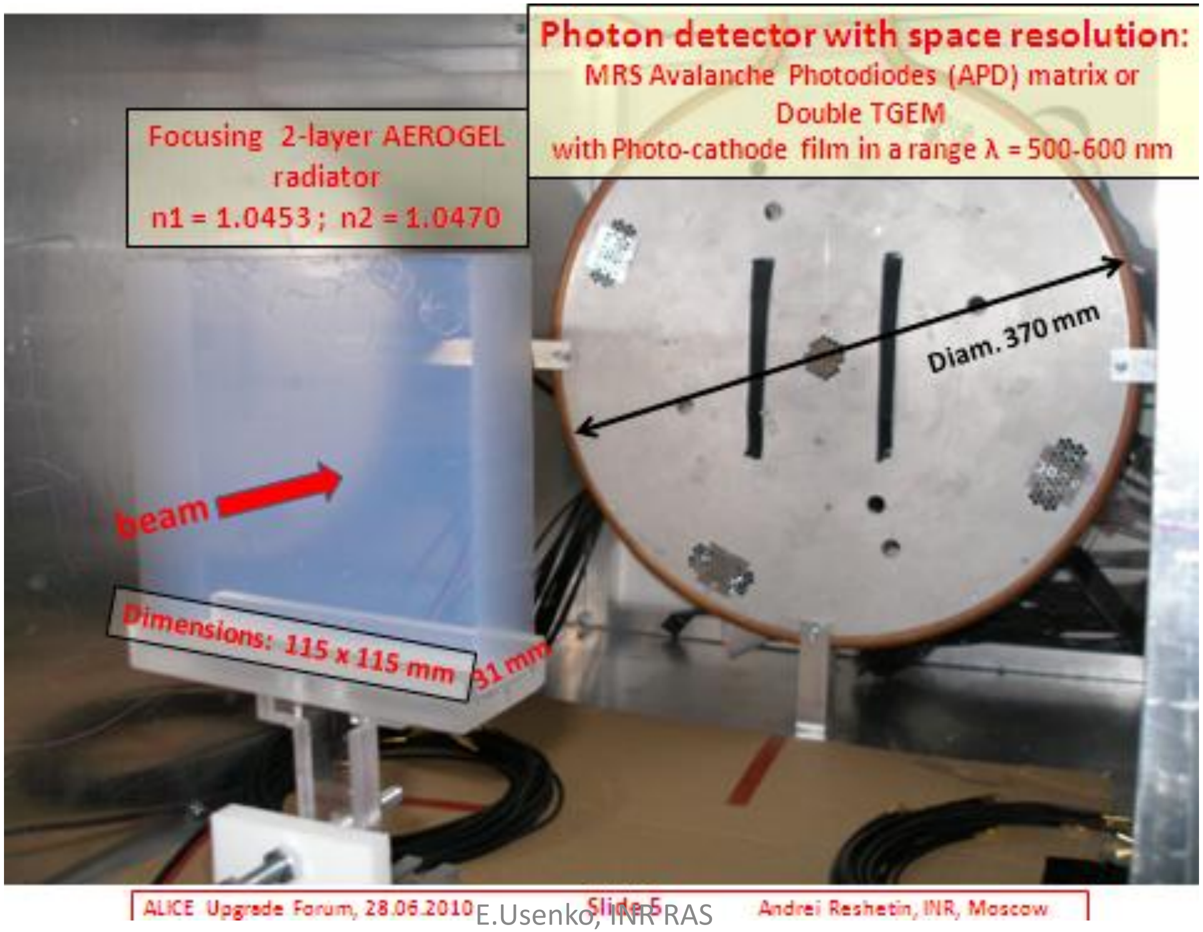
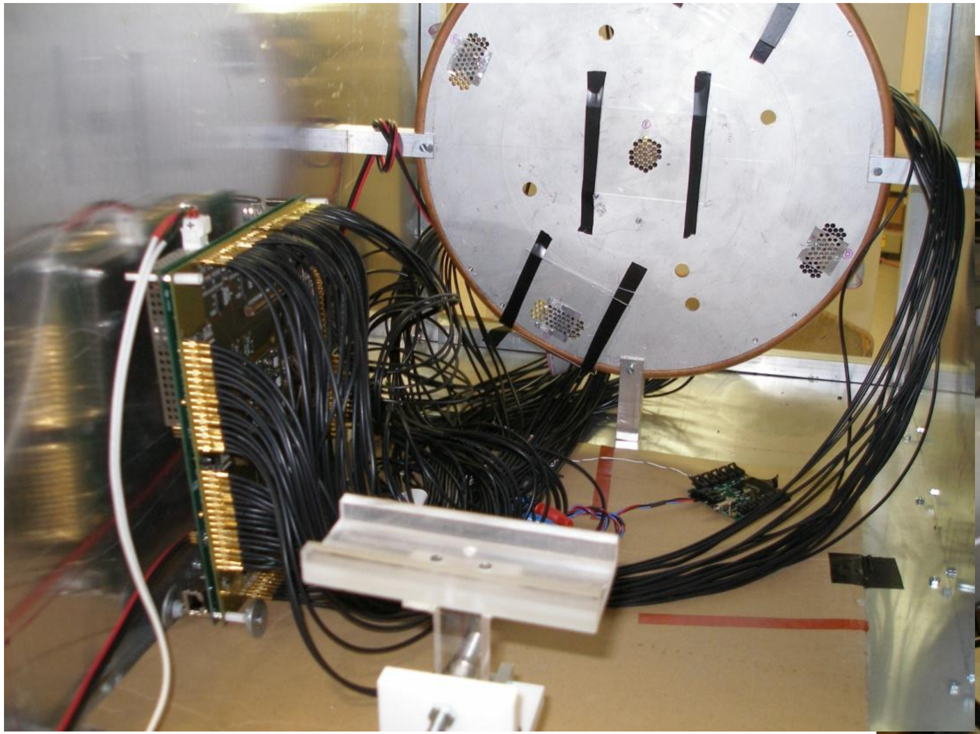
Introduction.

This proposal based on R&D of prototype FARICH which provided 2009-2012 years on CERN PS test beam for ALICE experiment.



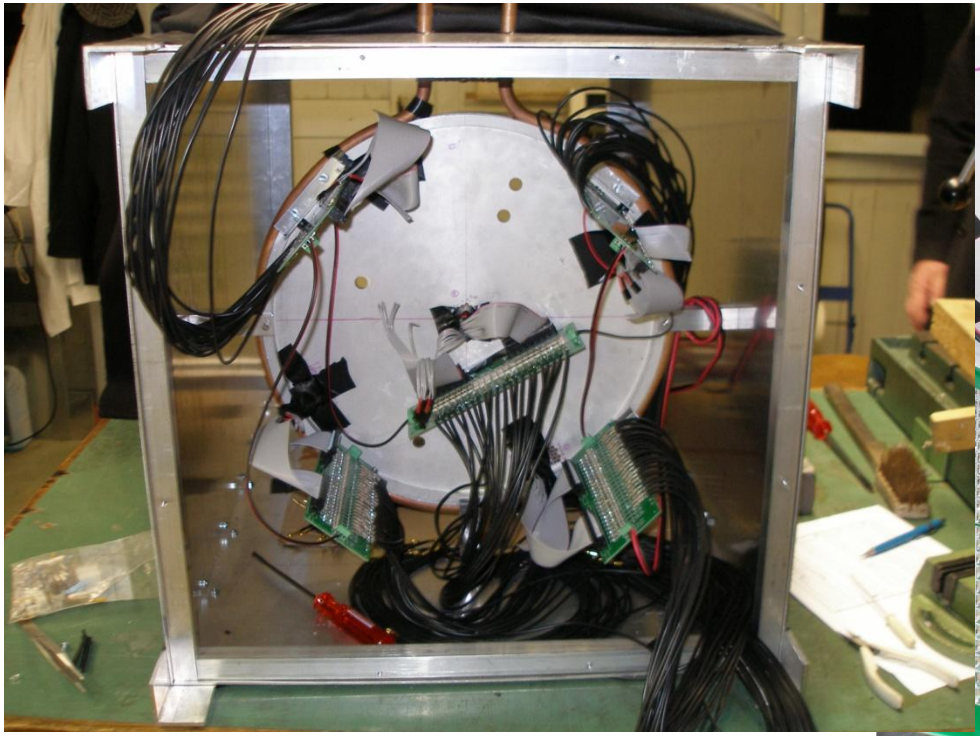
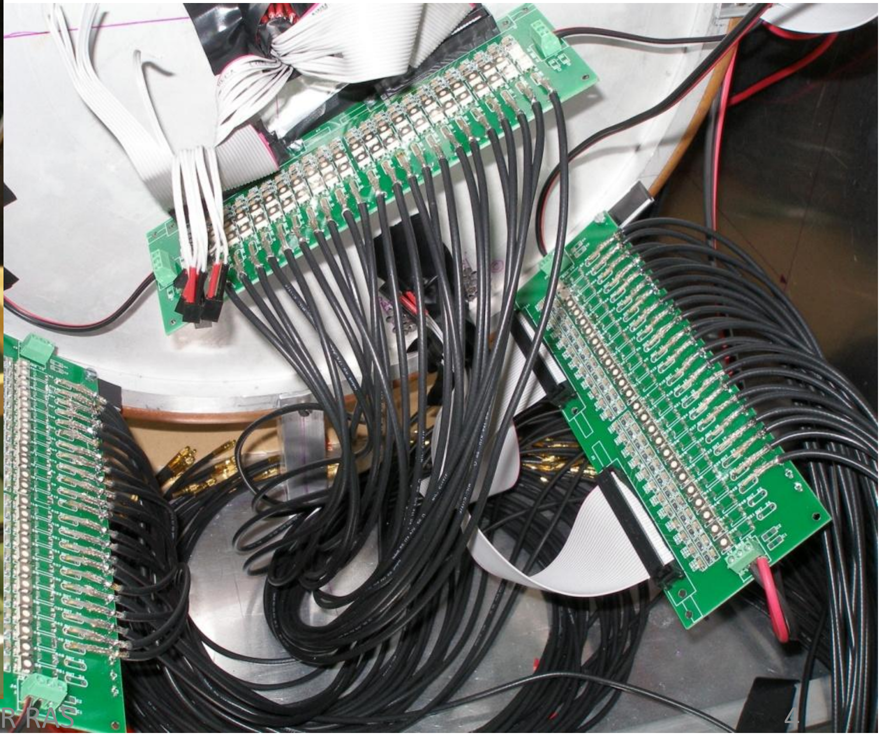
The first phase of FARICH-Prototype test on the CERN PS T10.

- First prototype of light sensitive array for Cherenkov rings was design by analog SiPM 1x1mm and consists of 108 single analog SiPM combined to four groups for 27 channels.
- Light sensitive array as a first prototype was consisting of four segments by total numbers of 27x4=108 SiPMs 1mm^2 size by one.



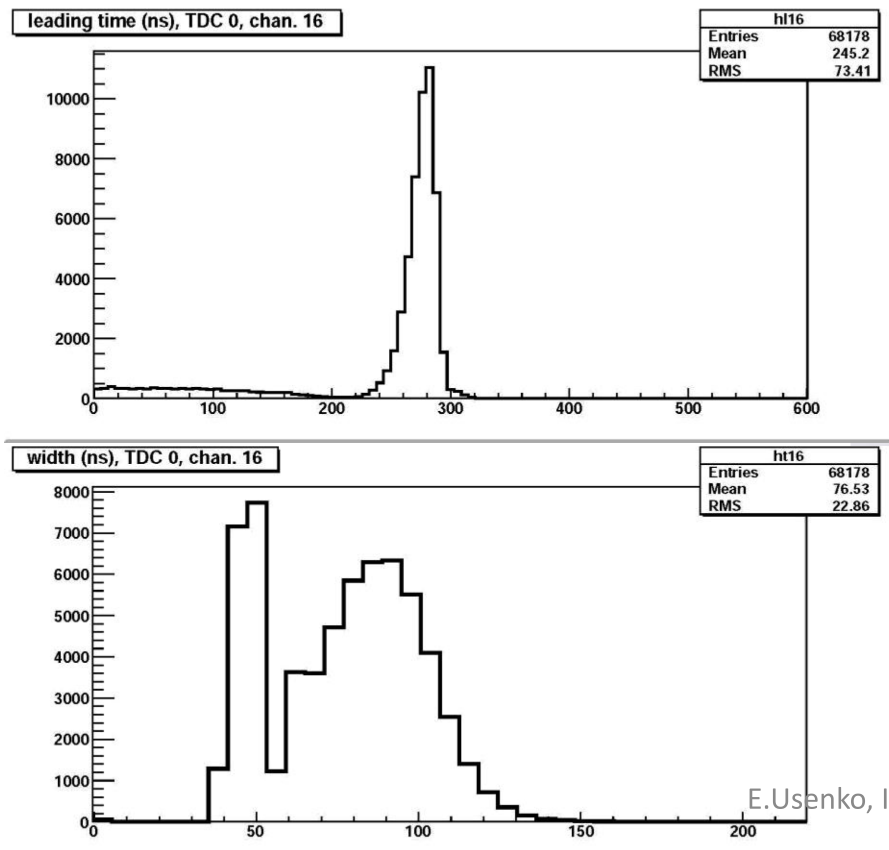
The first phase of FARICH-Prototype test on the CERN PS T10.

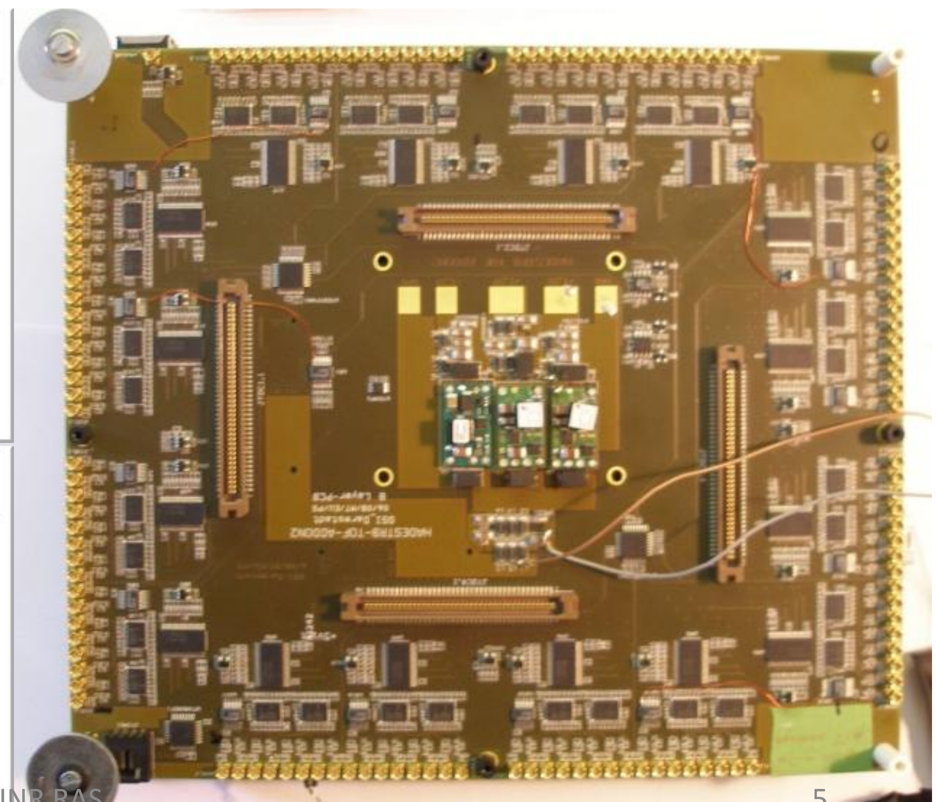
- Interconnection included SiPM biasing,
- Cabling to front-end electronics.

The first phase of FARICH-Prototype test on the CERN PS T10.

- 128-channel TRB2 based DAQ and front-end electronics especially modified for low threshold application – APD signals by ~ 1mV amplitudes for 50 Ohm load.
- Digitizing by TDC, 100ps/bin.



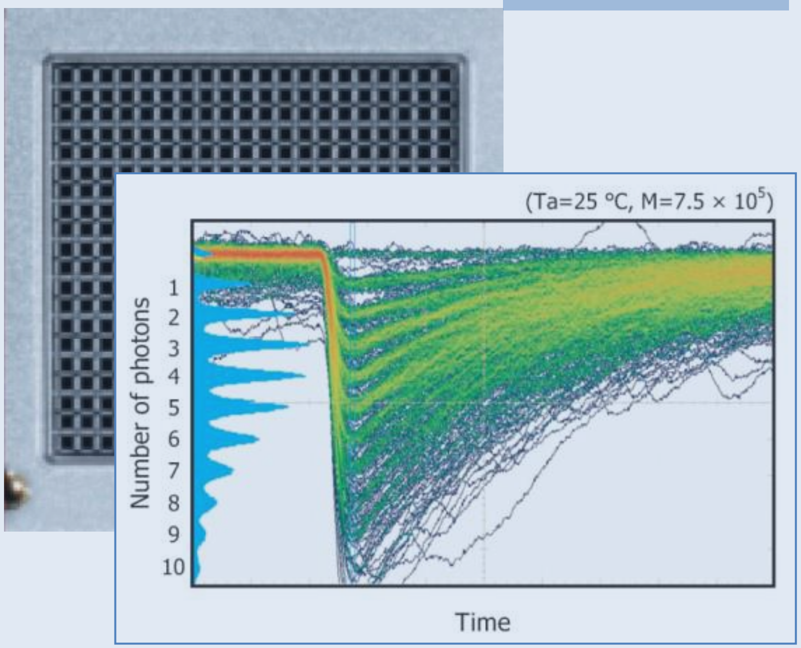


The first phase of FARICH-Prototype test on the CERN PS T10. Conclusion.

- Single SiPM could be use for build array only for low number of channels.
- Parasitic interconnect capacitance and coupled transmittion lines reduce detector quality more than array size.
- The price of of Front-end electronics and DAQ is higher than the detector itself and further increases with the size of the array increase.

Digital SiPM – New Type of Silicon Photomultiplier.

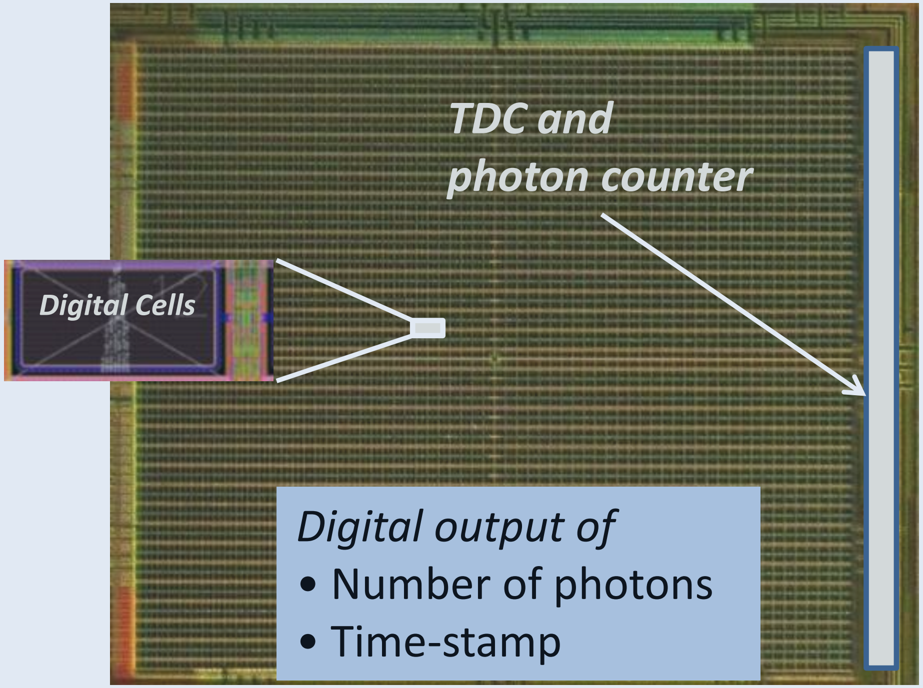
Analog SiPM



Cells connected to common readout

- Analog sum of charge pulses
- Analog output signal

Digital SiPM



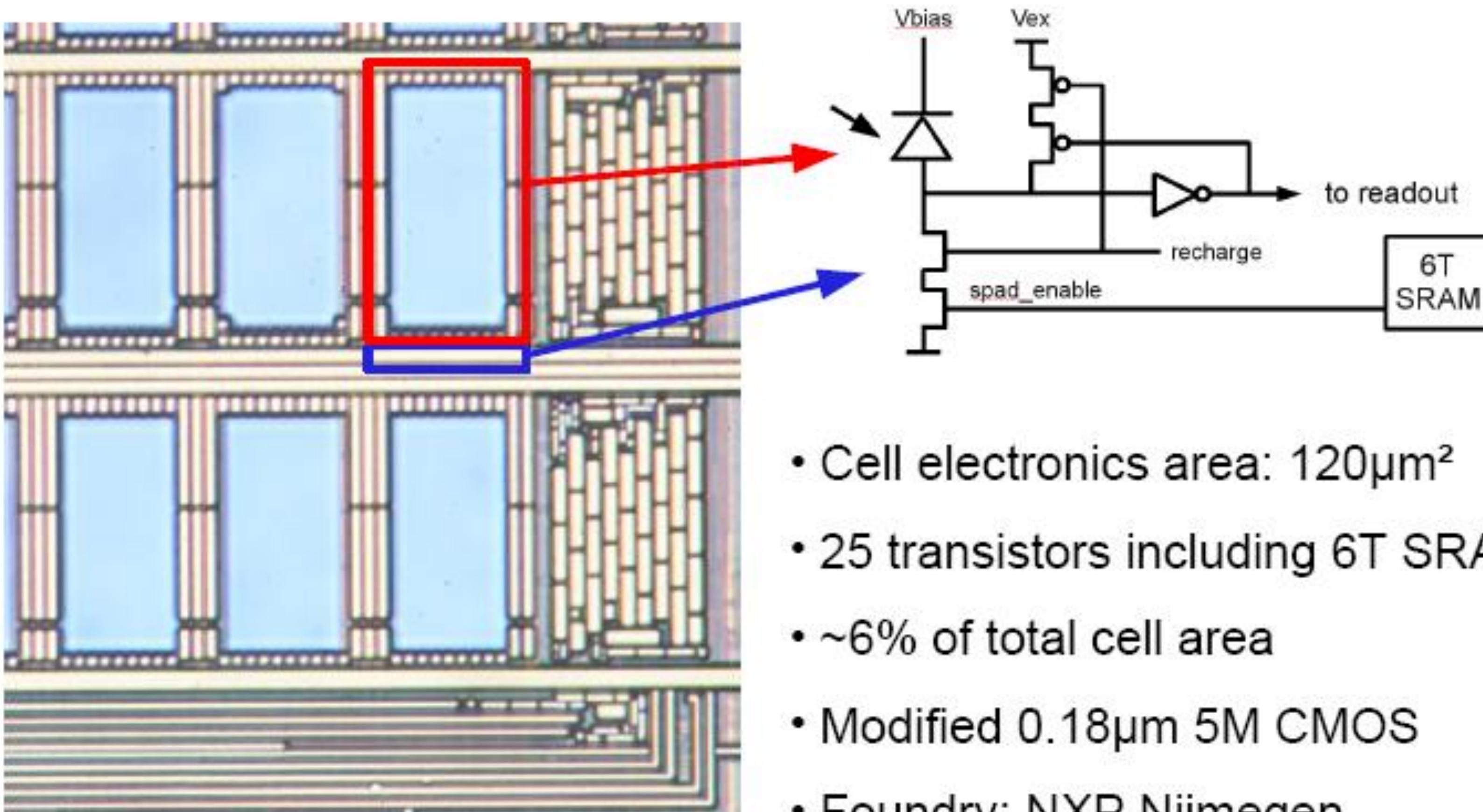
Digital output of

- Number of photons
- Time-stamp

Each diode is a digital switch

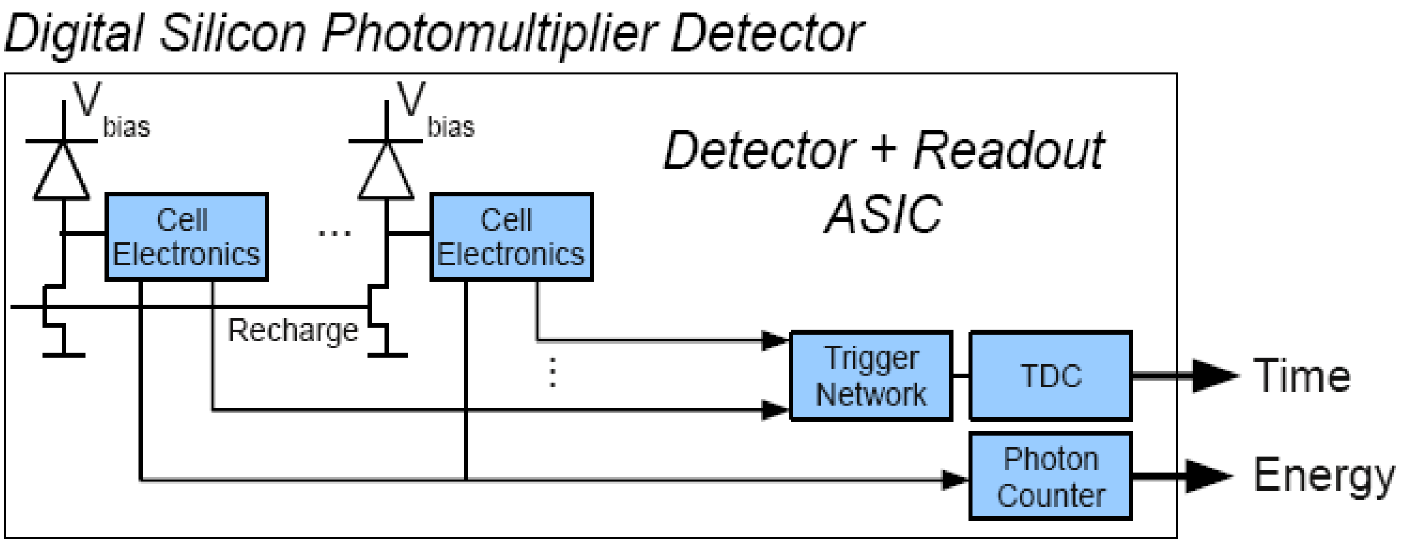
- Digital sum of detected photons
- Digital data output

Digital SiPM – Cell Electronics



- Cell electronics area: 120μm²
- 25 transistors including 6T SRAM
- ~6% of total cell area
- Modified 0.18μm 5M CMOS
- Foundry: NXP Nijmegen

Digital SiPM from Philips.
SiPM plus readout electronics structure.

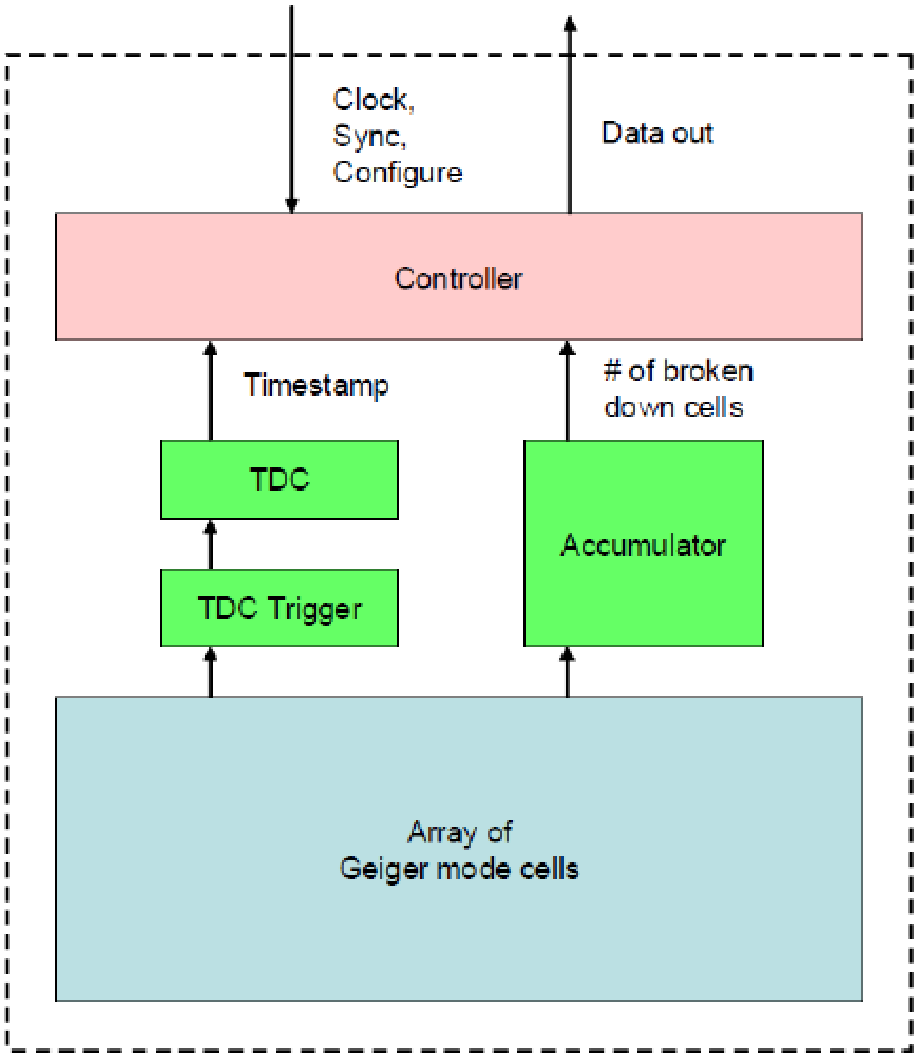


Digital SiPM is contain of 3200/6400 cells:

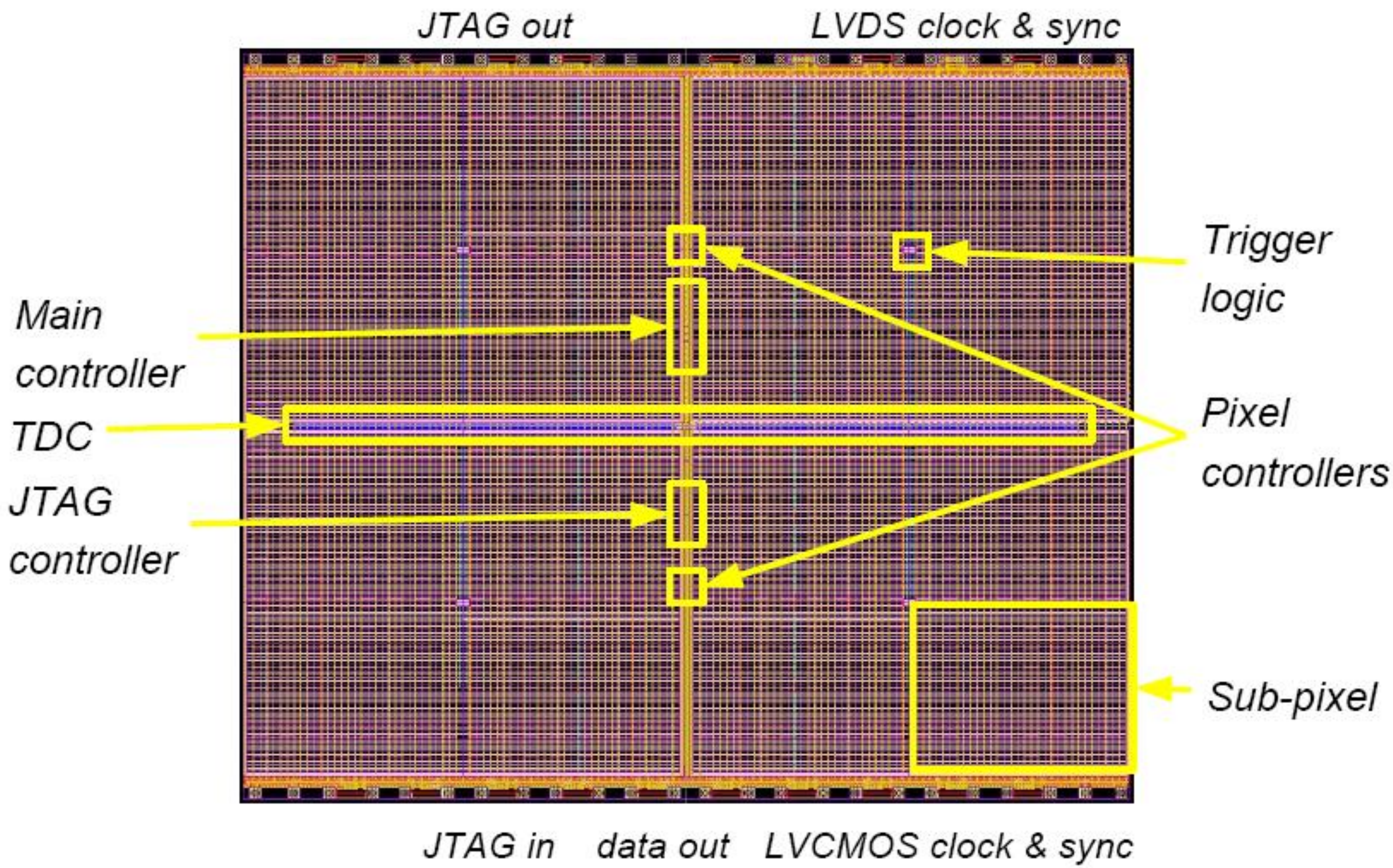
- All cells outputs are connect by OR (AND) - function to one channel TDC (20ps/bin),
- Individual cell noise counting available,

Digital SiPM – Sensor Architecture

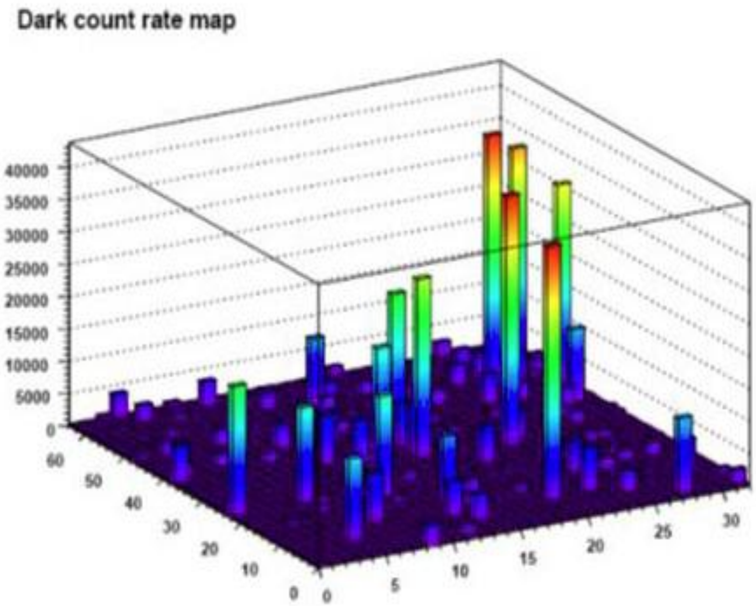
- Operating frequency: 200MHz
- 2 x TDC (bin width 23ps, 9bit)
- Configurable trigger network
- Validation logic to reduce sensor dead time due to dark counts
- JTAG for configuration and scan test
- Electrical trigger input for test and TDC calibration

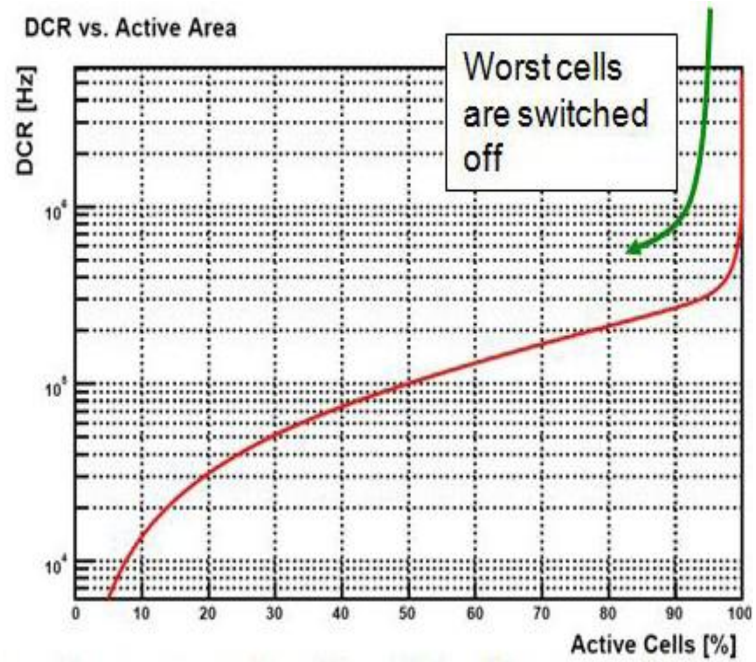


Digital SiPM – Sensor Architecture



Digital SiPM from Philips. Noise reduction.



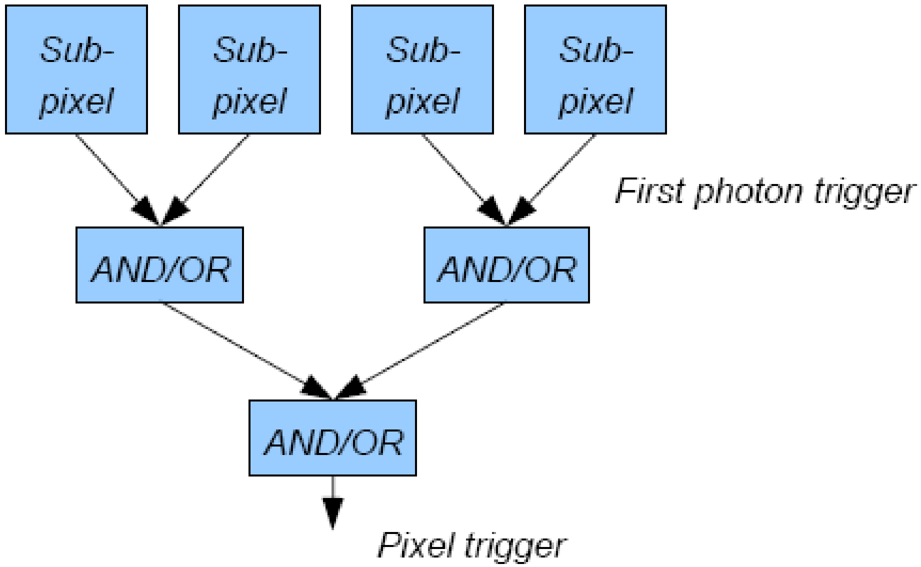


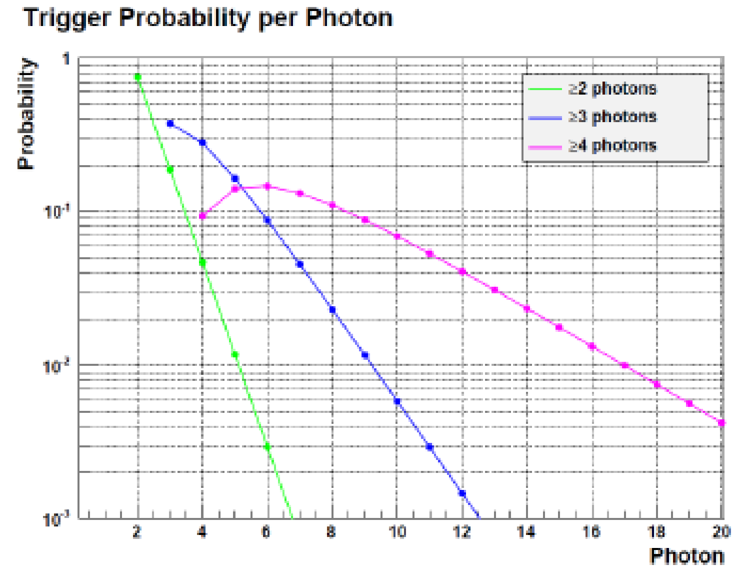
Option to physically disable arbitrary.

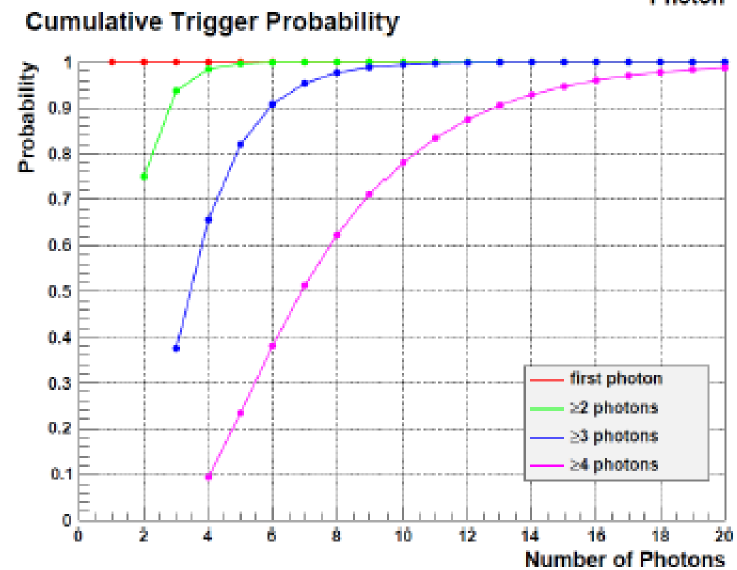
User selectable cells on the sector.

10-times reduce noise after 10% noisy cells disabled.

Digital SiPM – Trigger Logic

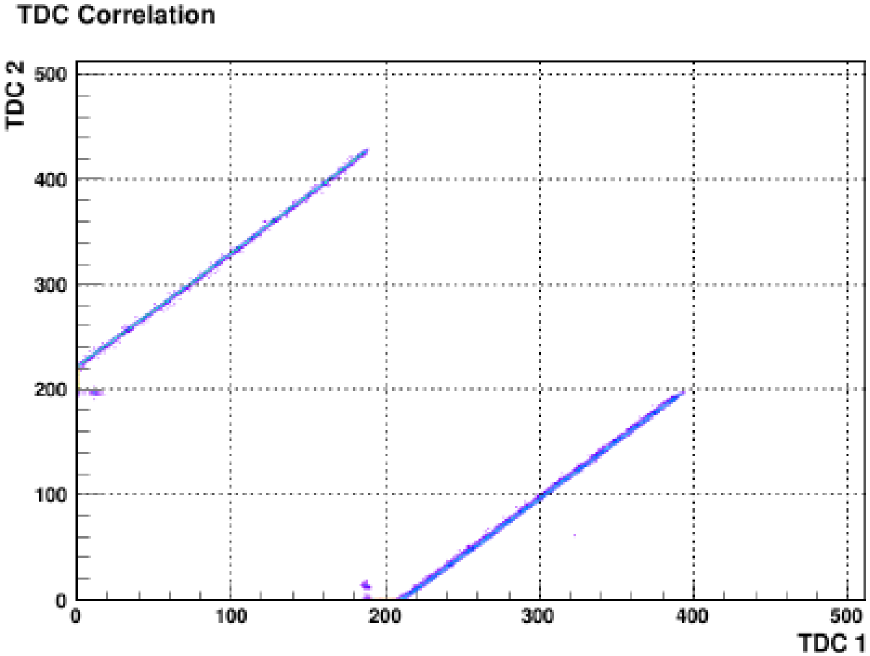


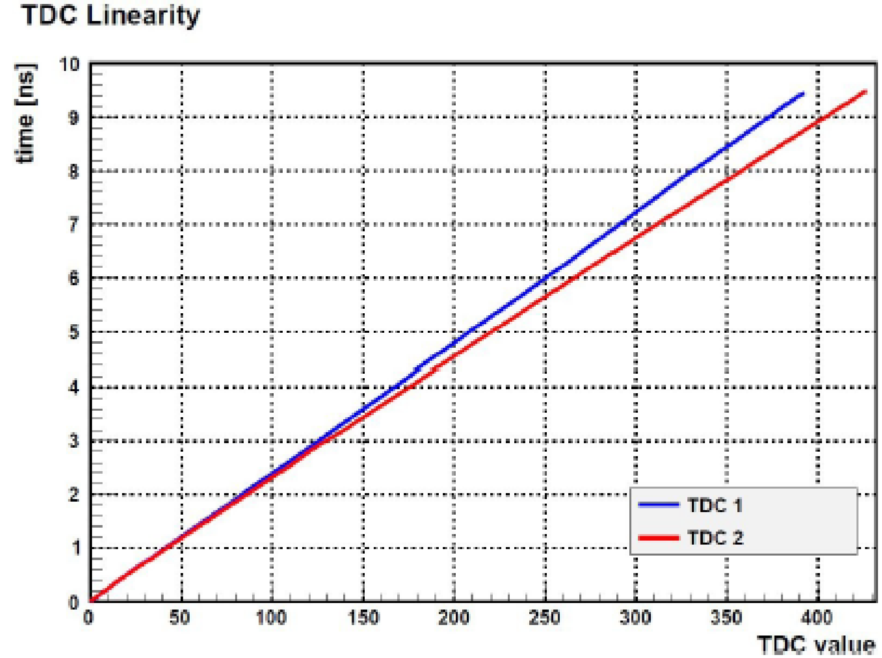




- *Each sub-pixel triggers at first photon*
- *Sub-pixel trigger can be OR-ed or AND-ed to generate probabilistic trigger thresholds*
- *Higher trigger threshold decreases system dead-time at high dark count rates at the cost of time resolution*

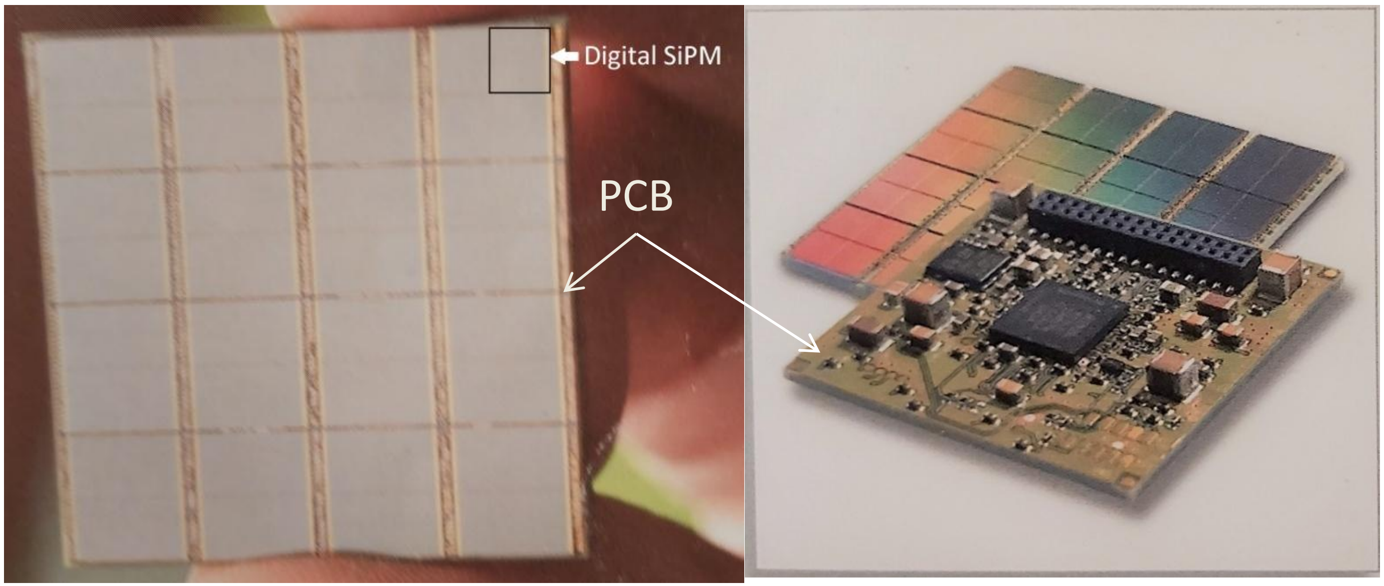
Digital SiPM – Time-to-Digital Converter





- Two identical 9 bit TDCs running with 180° phase-shifted clocks
- 100MHz reference clock generated from 200MHz system clock
- Each TDC has ~0.5ns wide 'blind spot' close to clock edge → bin 0
- Two-phase clock guarantees at least one valid TDC value for any event
- For ~90% of the events, both TDC values can be used to increase accuracy
- TDC calibration using dark counts or randomly distributed events

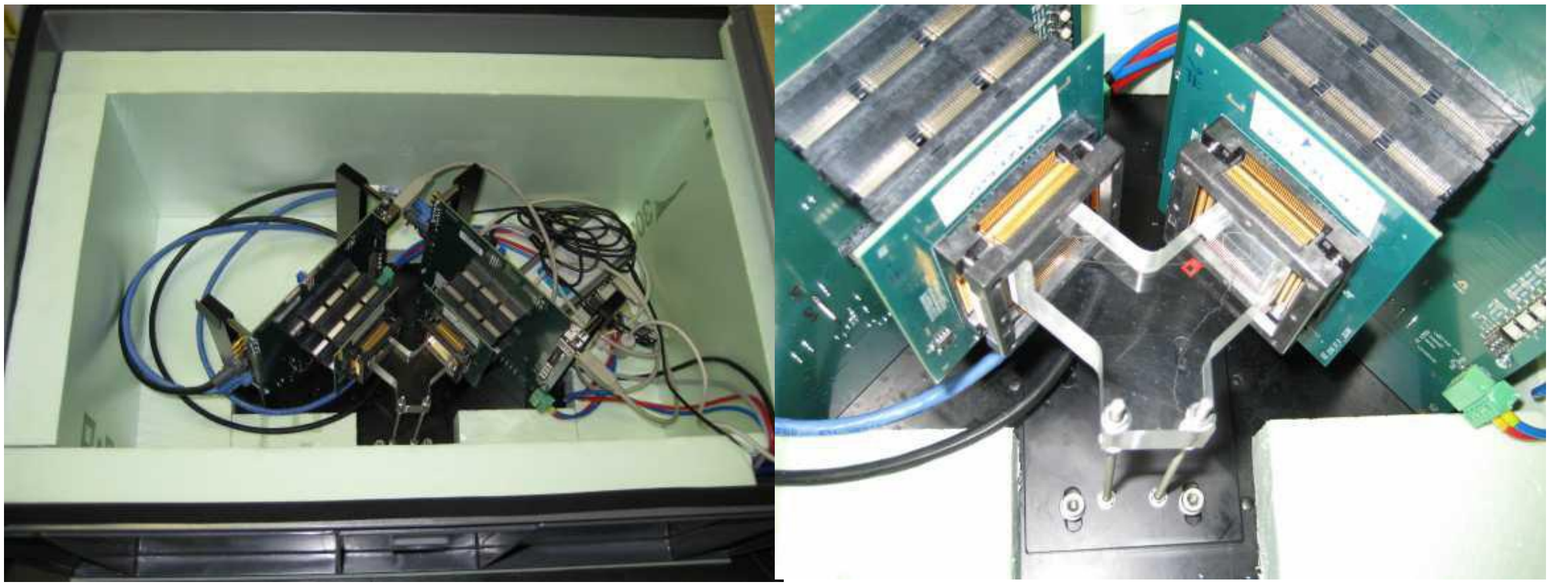
Digital SiPM from Philips.



Digital SiPM array cluster based on 32x32mm PCB:

- On top side is mounted 8x8 (DPC 3200-22) DSiPMs,
- On bottom side – interface electronics cluster.
- Integrated readout electronics is the key element to superior detector performance

Cherenkov Detector: Experimental Setup. CERN PS & SPS beam test.



- PMMA radiator coupled via air gap to two digital SiPMs in coincidence
- Sensors used: DLD8K (technology demonstrator), 8188 diodes each
- Box isolated and temperature-controlled with a TEC to 2-3°C

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Future Extensions & New Applications

- Current dSiPM is best suited for scintillator readout:
  - Relatively large dead time when used for single photon detection
  - Loss of useful information (i.e. photon position, pulse shape)
  - Suboptimal use of real-estate when used for other applications
- Extension/modification of the digital SiPM architecture:
  - Cost-effective way of adding new features
  - But: any change in the present design means NRE (new mask set, test wafers)
  - Typically, any change means large design effort (full custom design)
  - Physical dimensions (chip size, diode size, bond pads) must not change
- There is much more:
  - Focal plane computing
  - Integration of data processing/reduction, image processing, etc.
  - But: is there enough volume to justify the NRE?
- Philips/NXP could offer access to Multi-Project Wafer runs to test new ideas
  - contact us if you are interested