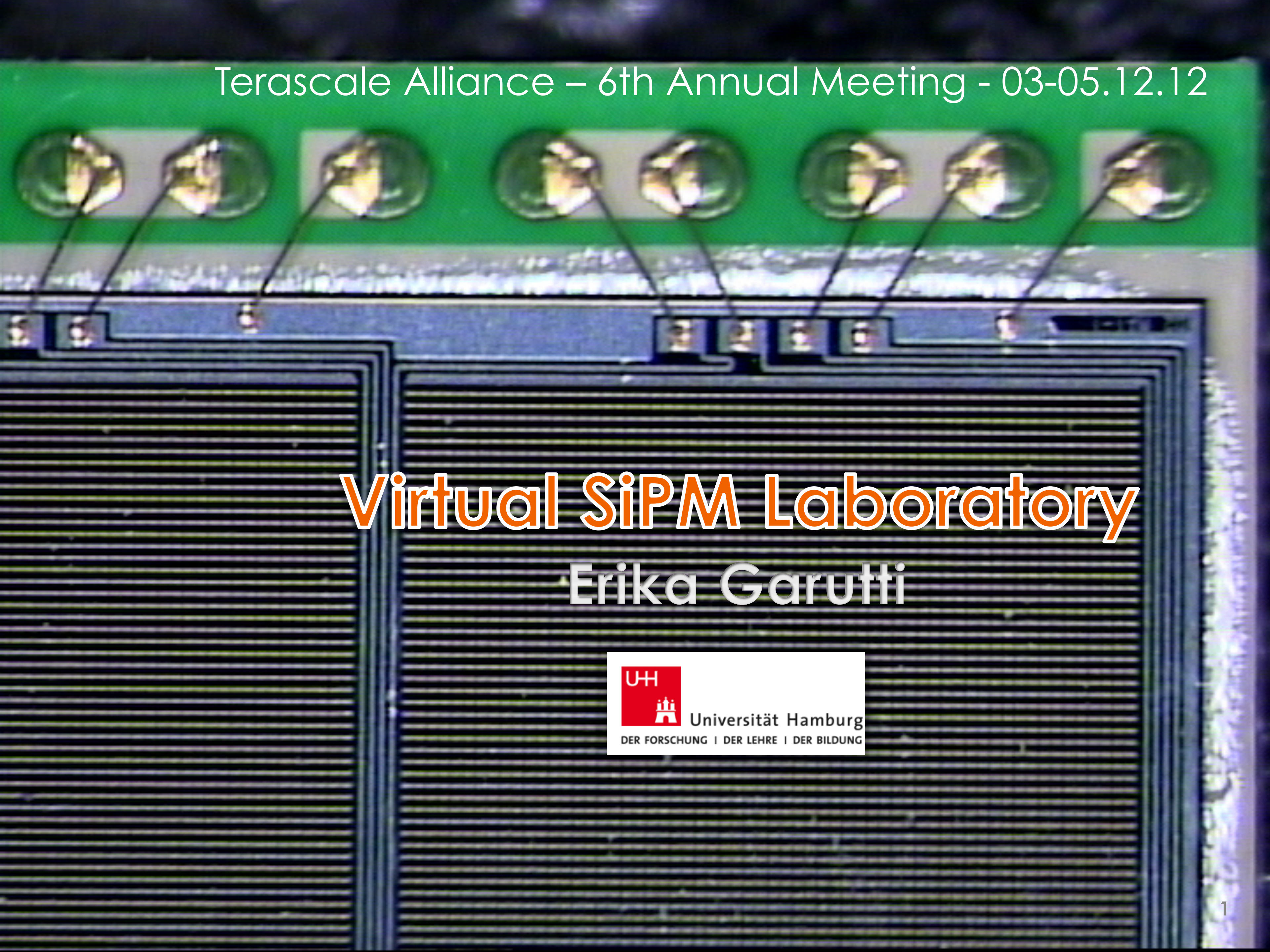
Terascale Alliance – 6th Annual Meeting - 03-05.12.12



Virtual SiPM Laboratory

Erika Garutti

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Virtual SiPM Laboratory

Partner members:

- DESY Hamburg: Engineering prototype of the LC hadronic calorimeter
- KIP Heidelberg: Readout ASICs for SiPM applications
- MPI Munich: Improve design of calorimeter tiles + SiPM
- PI Wuppertal: Large scale LED calibration system for SiPMs
- RWTH Aachen: Model the electrical properties of SiPM

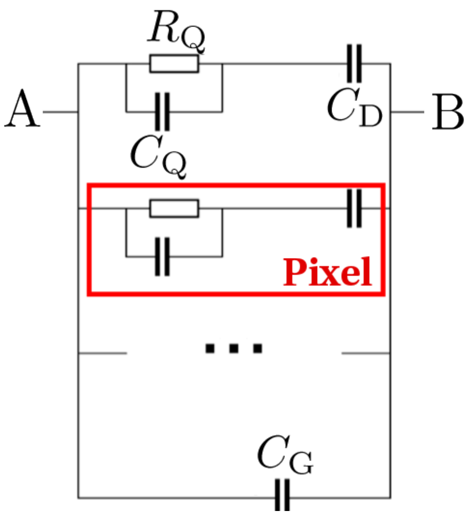
Recently extended to the universities of:

- Hamburg: DESY program + spinoff to medical imaging (dSiPM)
- Mainz: Data Acquisition for the ILD analog-HCAL with SiPM

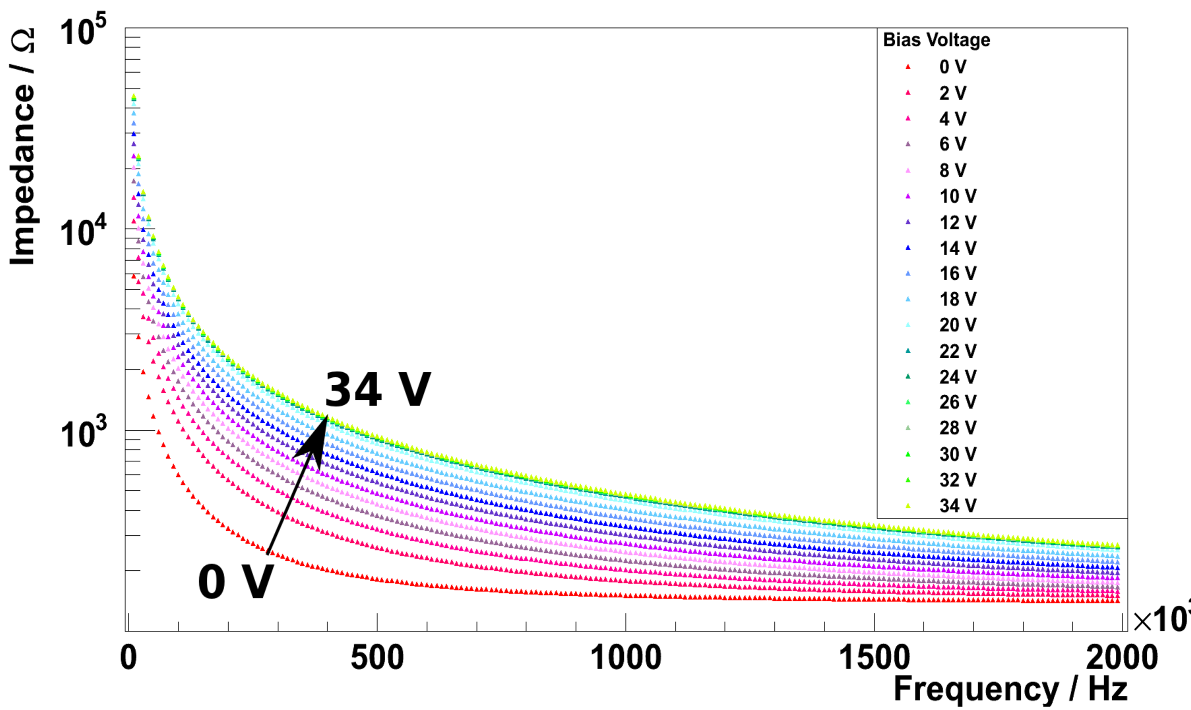
SiPM Activities in Aachen

Develop a model of the electrical properties of SiPM for GEANT4

- electrical characterization of SiPMs
  - quenching resistor
  - diode & quenching capacitances



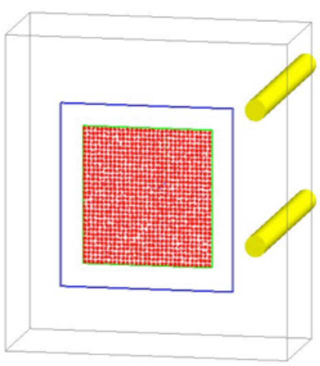
→ impedance measurements

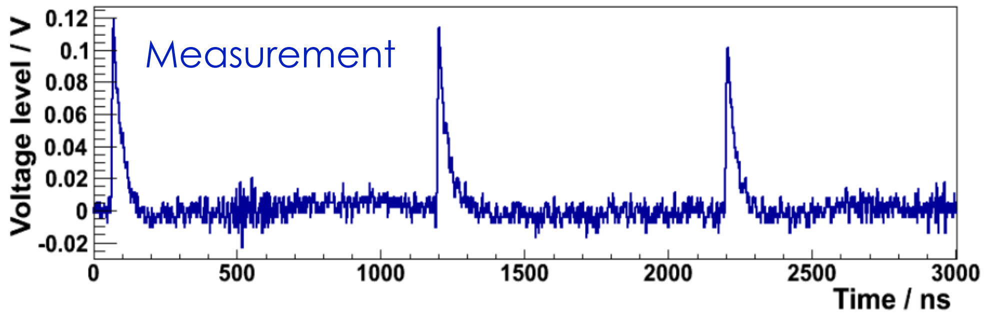


SiPM Activities in Aachen

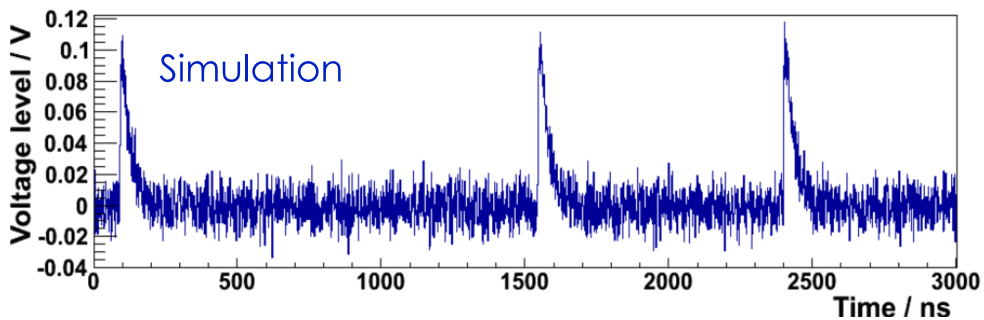
- measurements of the temperature dependence of SiPM operating parameters and noise effects
- implementation into a GEANT4 simulation of an SiPM

→ full simulation of scintillation detectors including the SiPM





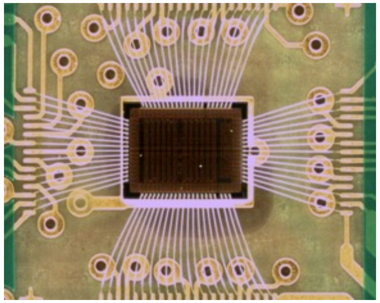
(a) Measured trace



SiPM Activities in Heidelberg

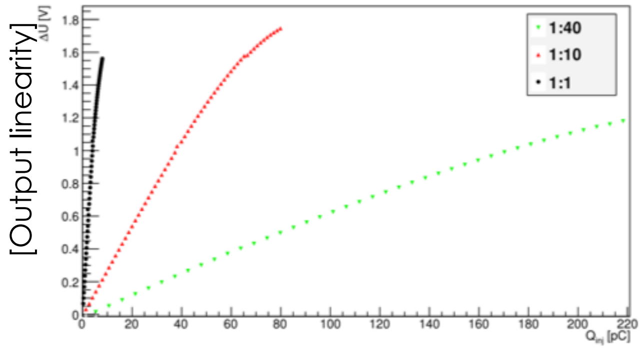
Development of custom made readout ASICs for SiPM applications in HEP and medical imaging

[KLauS2v0]



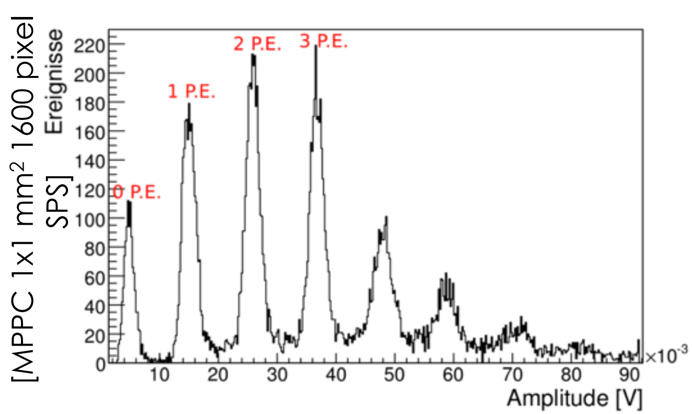
Kanäle zur **L**adungs**au**slese von **S**iPMs (KLauS):

- High precision charge measurements
- Low power design (+ power gating)
- Future version with digital output planned



Characterization results:

- SiPM bias tuneable within 2 V
- Linear range > 200 pC (smallest gain)
- S/N> 10 for single pixel signals
- Trigger jitter < 60 ps for 15 pixel signals
- Power consumption < 2.5 mW / channel
- Power gating functional

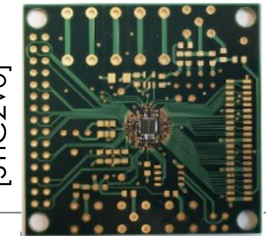


SiPM Activities in Heidelberg

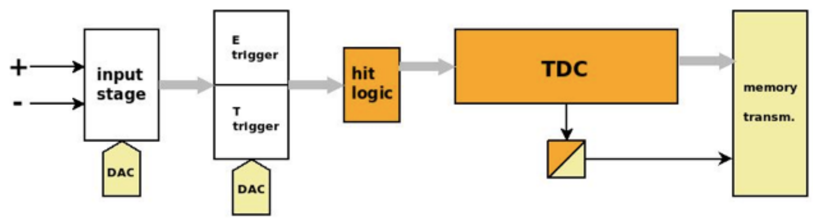
Silicon Photomultiplier Timing Chip:

- Designed for ToF applications
- 16 channels prototype designed in UMC 0.18um CMOS
- 64 channel version under development

[STiC2v0]



[STiC Channel]



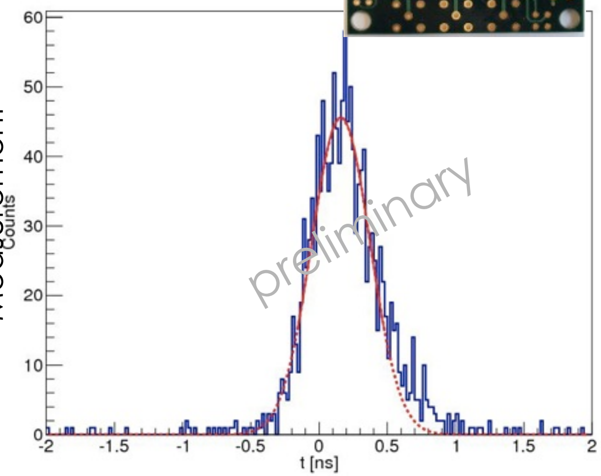
Design features:

- Differential SiPM readout possible
- SiPM bias voltage tunable within 0.5 V
- Integrated TDC with 50 ps bin width
- 160 MBit/s serial data transmission

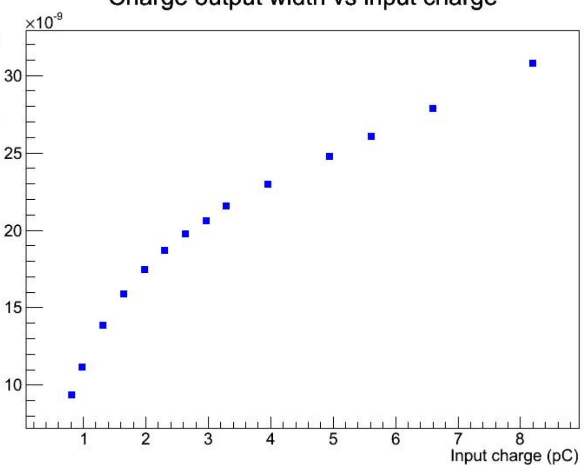
Measurement results:

- Perliminary SPTR: σ =180 ps
- Linearized ToT method preserves energy resolution: pulse width linear w.r.t input charge from 3 pC on

SPTR Measurement



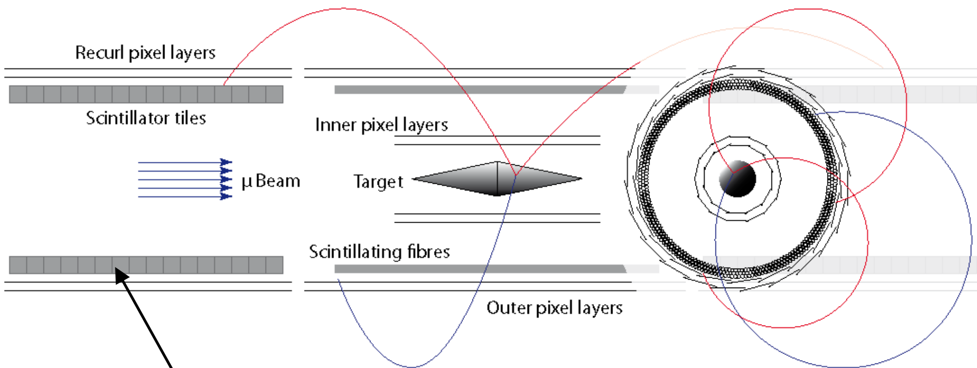
Linearized ToT Measurement



ToF Detector for Mu3e

Mu3e Experiment:

- Searching for LFV decay $\mu \rightarrow eee$
- Aimed sensitivity BR≈10^{-16}



ToF tile detector:

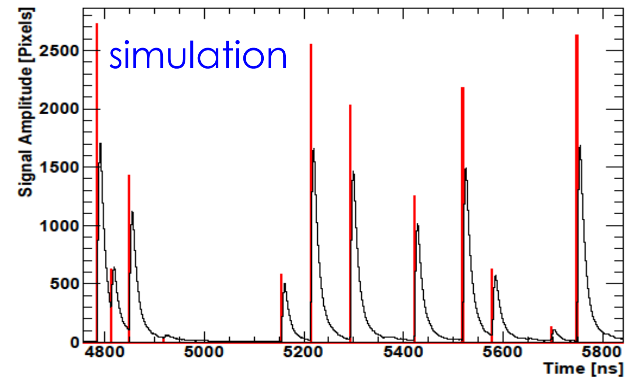
- Ca. 7000 scintillator + SiPMs
- STiC2.0 Readout
- Time-resolution <100ps
- High efficiency (>97%)
- High rates O(MHz/channel)

➔ First tests w/o STiC r/o

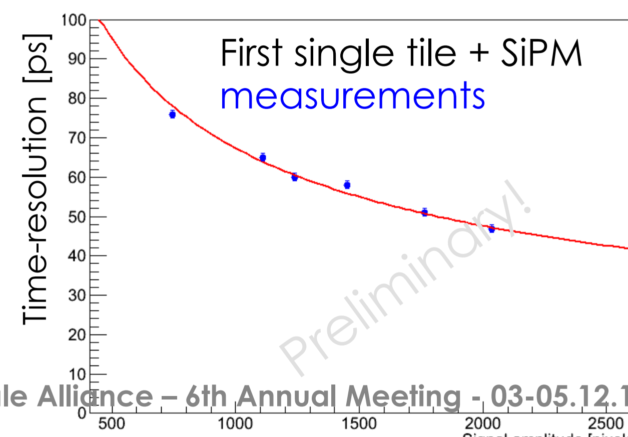
➔ Time resolution < 80ps achieved

Detector + SiPM Simulation:

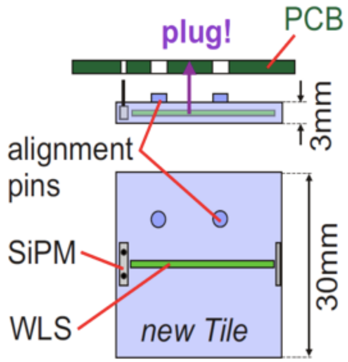
- Geant4 detector simulation + SiPM simulation (GosSiP)*
- Performance & optimization studies

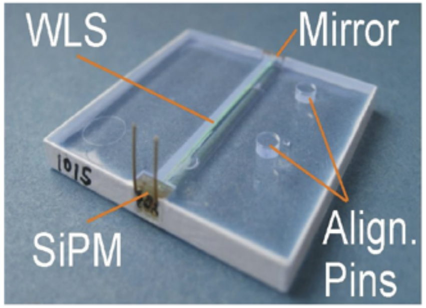


*[Patrick Eckert et al., "Study of the Response and Photon-Counting Resolution of Silicon Photomultipliers Using a Generic Simulation Framework", 2012 JINST 7 P08011]



SiPM Activities at DESY & UniHH

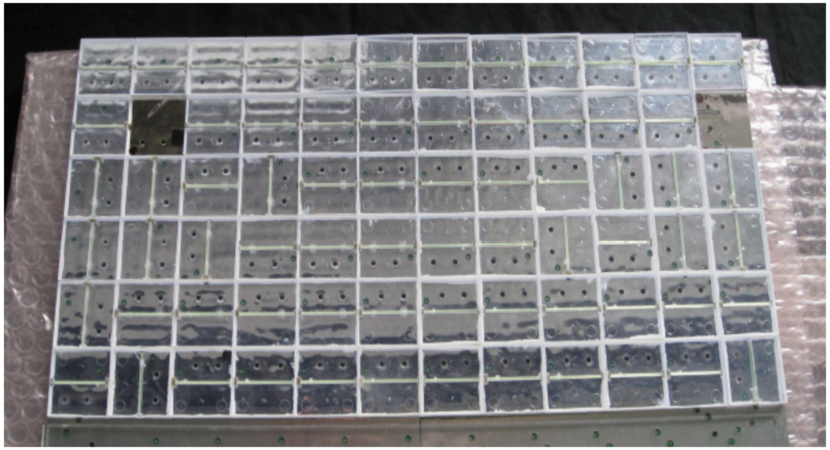


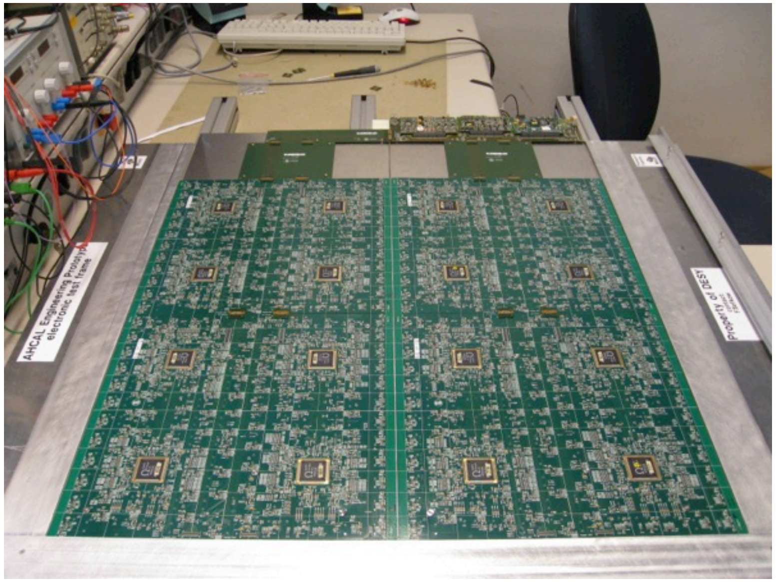


Development & test of a engineering prototype of the Linear Collider hadronic calorimeter

Setup in CERN test beam:

- 1 layer, 72 x 72 cm^2 active area
- 576 tiles with SiPMs read out by 16 chips



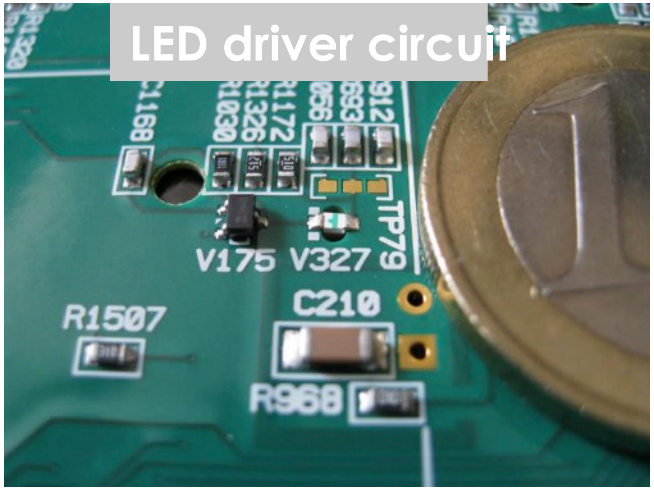


Scintillator tiles:

- 3 x 3 x 0.3 cm^3
- individual SiPMs with 796 pixels
- assembled tiles with SiPMs from ITEP, bias adjusted to 15 pixels/MIP

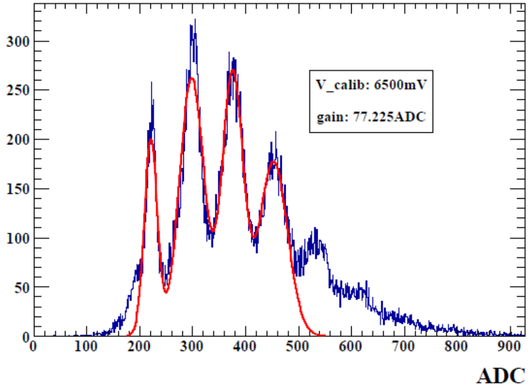
Activities in Wuppertal

Development and characterization of a SiPM calibration system for large number of channels

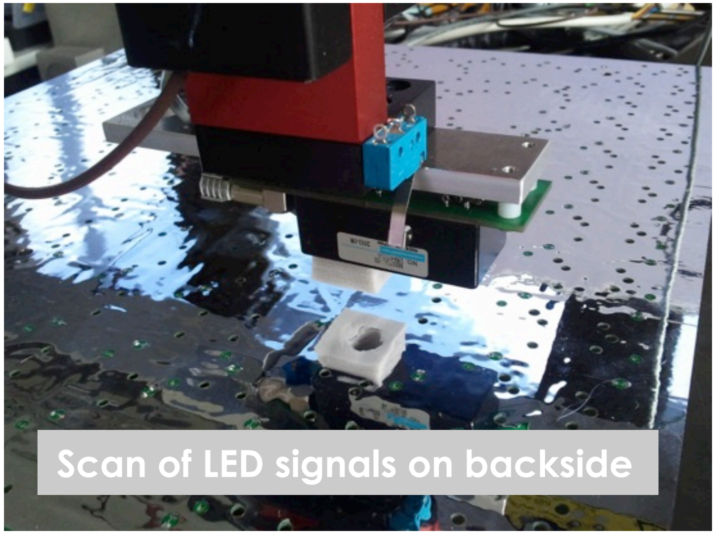


SiPM Gain Calibration with UV LEDs:

- Very short light pulse (< 10 ns)
- Scaling to large number of channels (144 / module) done
- Crucial for calibration: equalize all LED light outputs



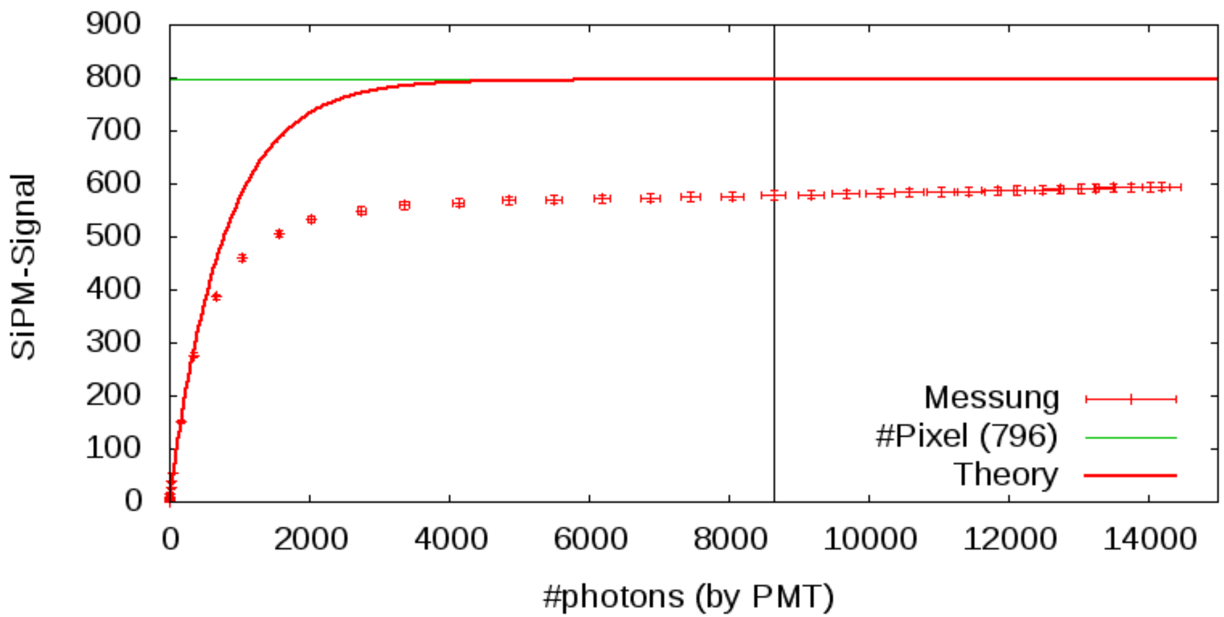
Signal distortions observed with LED scanner ➔
due to reflections on PCB and long signal delays



SiPM Activities in Wuppertal

Measurement of SiPM saturation point:

- Single Tile and SiPM with 796 pixels
  - Light guided to SiPM by fiber
- Light monitored by PMT (calibrated to „pixels“)
- LED calibration circuit utilized to measure saturation point
- Observe reduced dynamic range due to inhomogeneity of light in the fiber, hence on SiPM front face



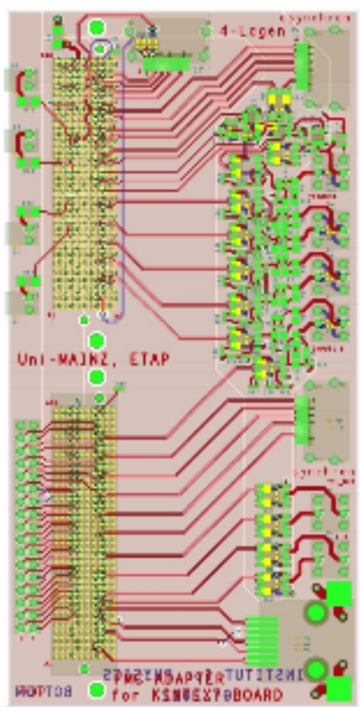
SiPM Activities in Mainz

Data Acquisition development for the ILD analog hadronic calorimeter with SiPM readout.

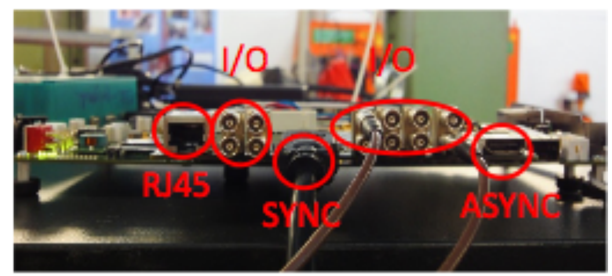
AHCAL read-out:

- New **Clock & Control card (CCC)** developed and build.
- New interface for configuration and control.
- Very high stability, successfully employed in 2012 test beams.

CCC mezzanine from Mainz:



CCC at the testbeam (front):

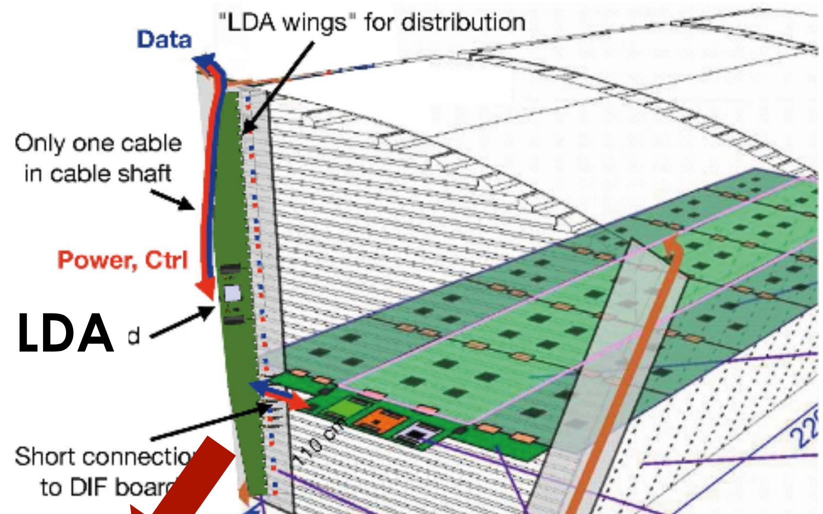


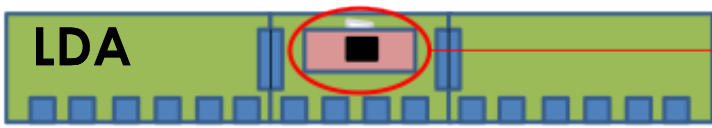
CCC at the testbeam (top):

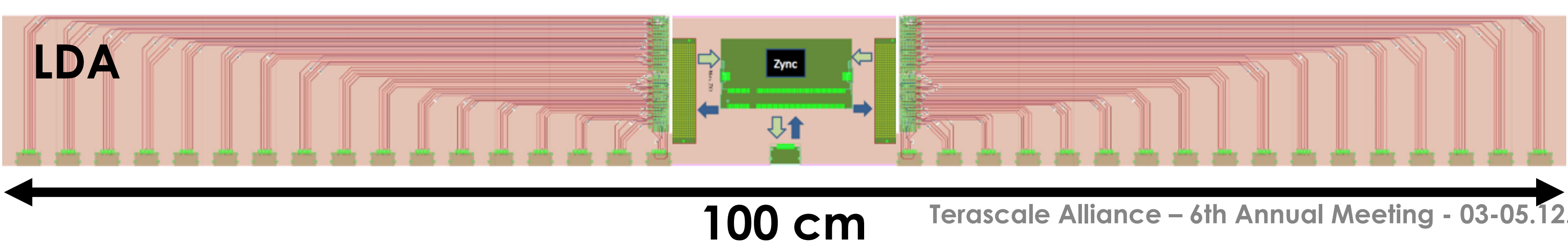
SiPM Activities in Mainz

AHCAL read-out:

- Development of **digital read-out board (LDA)** for 2013 test beams.
- Final & full-scale design for ILD detector
  ⟹ each board reads out all 48 scintillator layers of one AHCAL octant



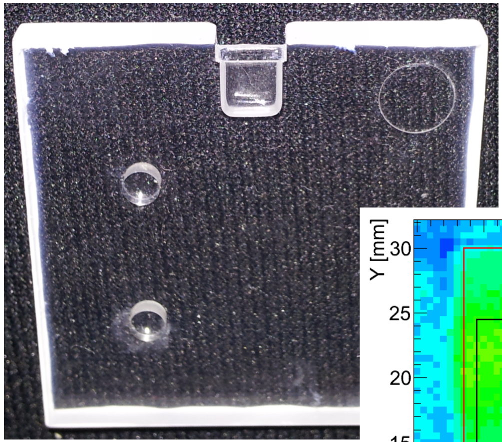


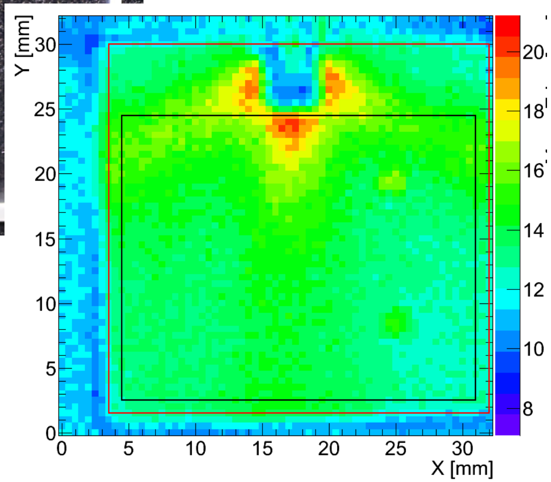


SiPM Activities at DESY/UniHH/MPI

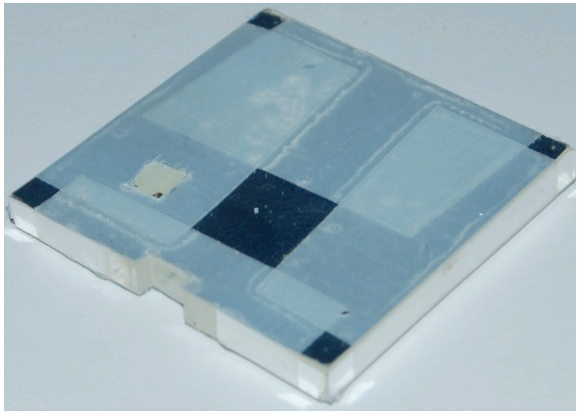
Improve on the tile design in terms of light yield uniformity, reproducibility, production time and cost

Compare:
- molded vs machined scintillator tiles
- chemically matted sides vs fully wrapped tiles
- different types of SiPMs from various producers





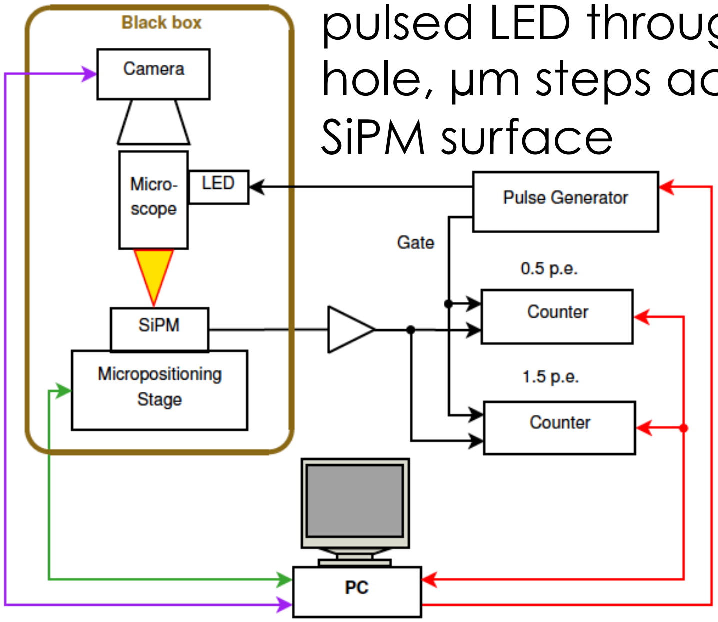
fiberless tile
MPI Munich
and ITEP



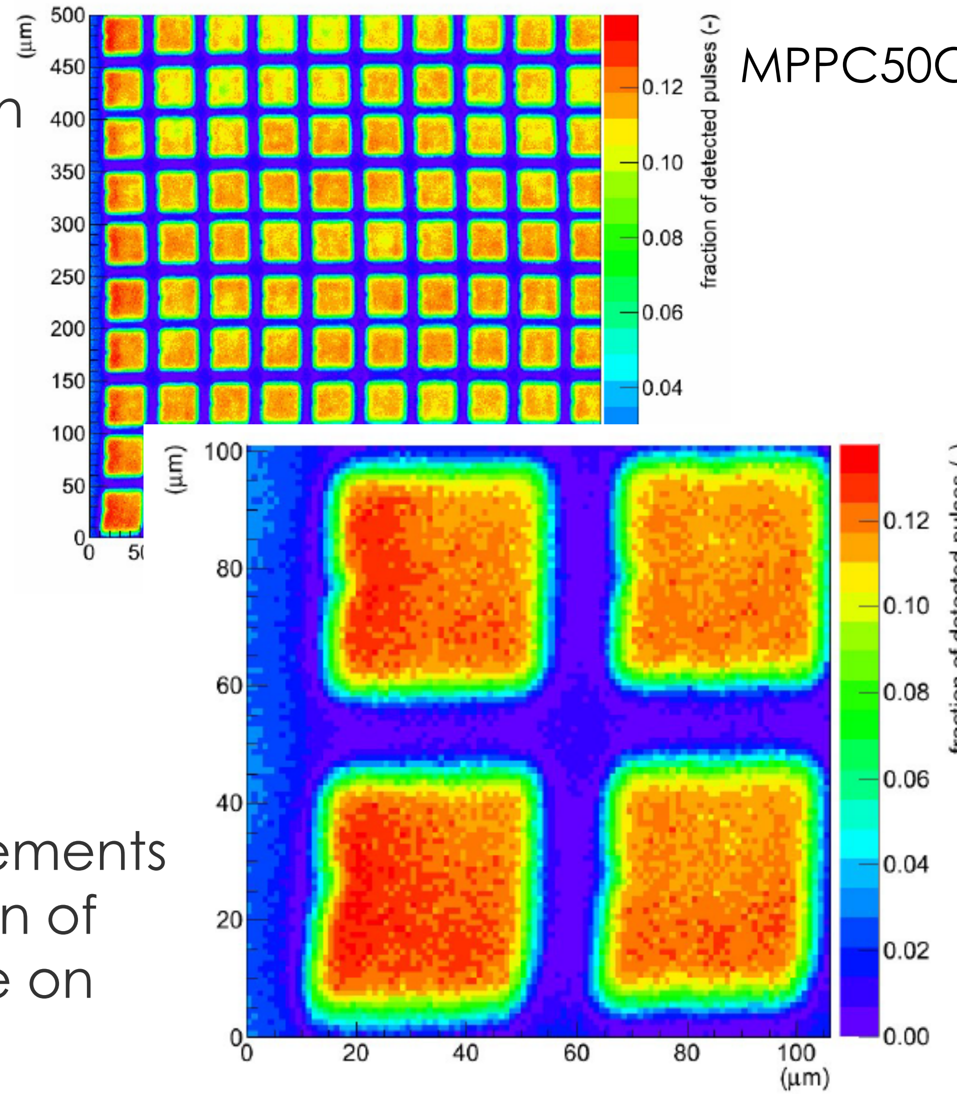
fully wrapped
Uni. Hamburg

Detailed SiPM Scans at MPI

- Developed a setup for SiPM scanning with sub-pixel resolution



pulsed LED through pin-hole, μm steps across SiPM surface

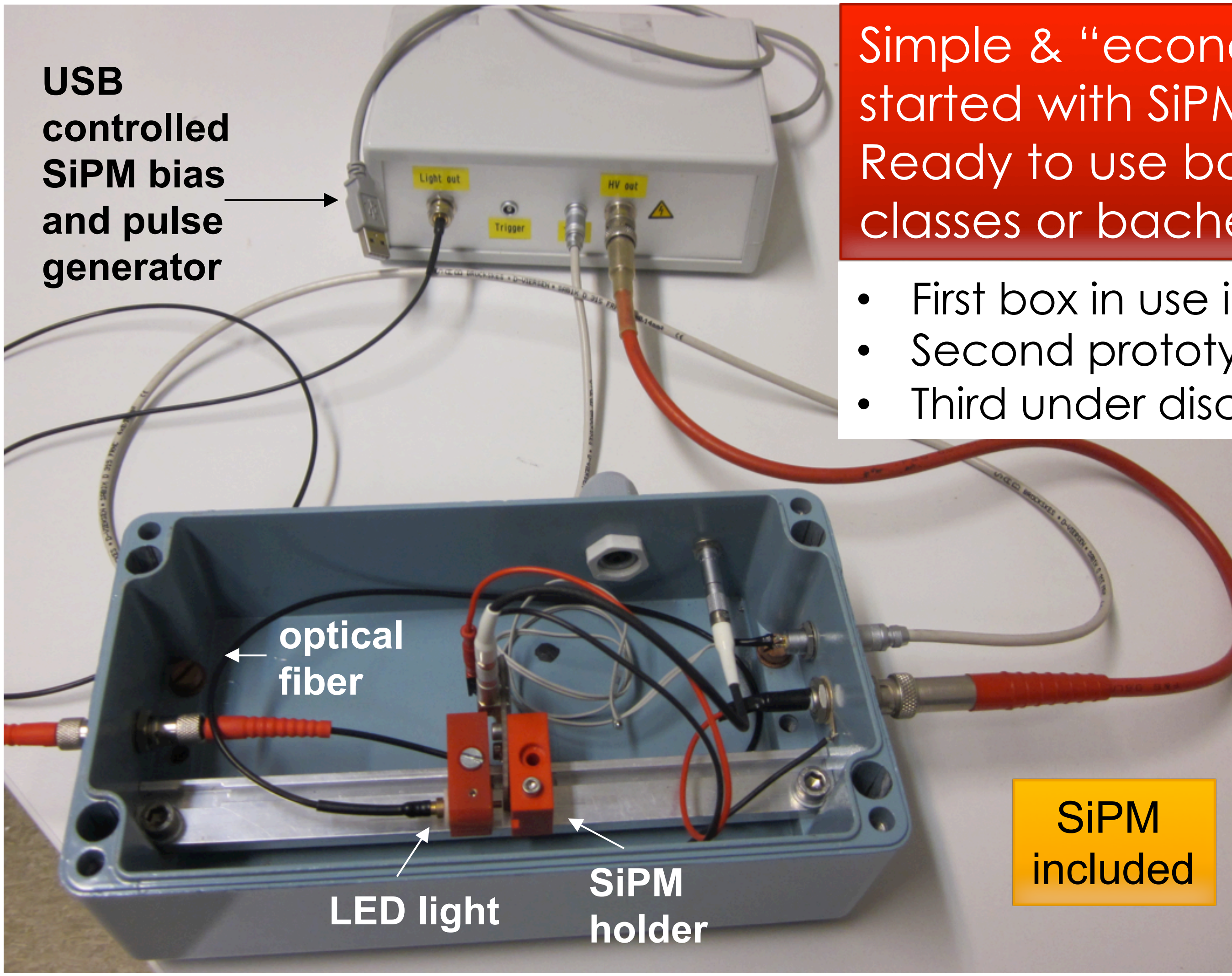


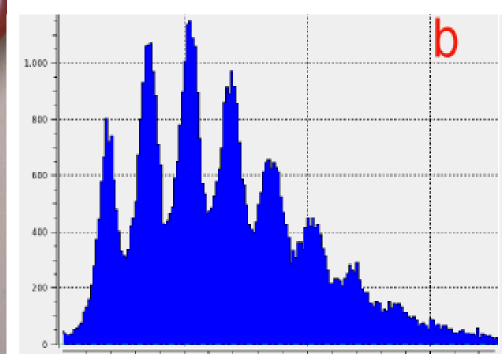
- Pixel-by-pixel fill-factor measurements – Device uniformity, comparison of different devices, dependence on operating parameters

Practicum SiPM-box

Simple & "economic" way to get started with SiPM characterization. Ready to use box for practicum classes or bachelor students.

- First box in use in the Uni.HH lab.
- Second prototype used Bonn
- Third under discussion with KIT

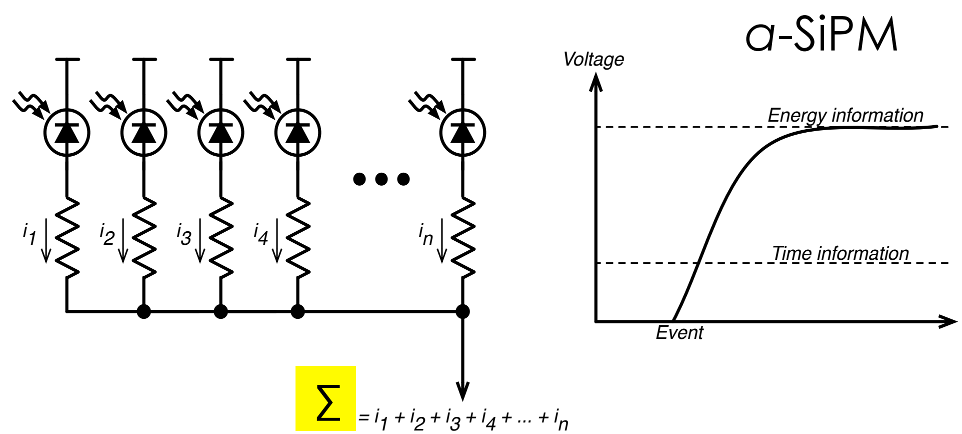




Digital vs analog SiPMs

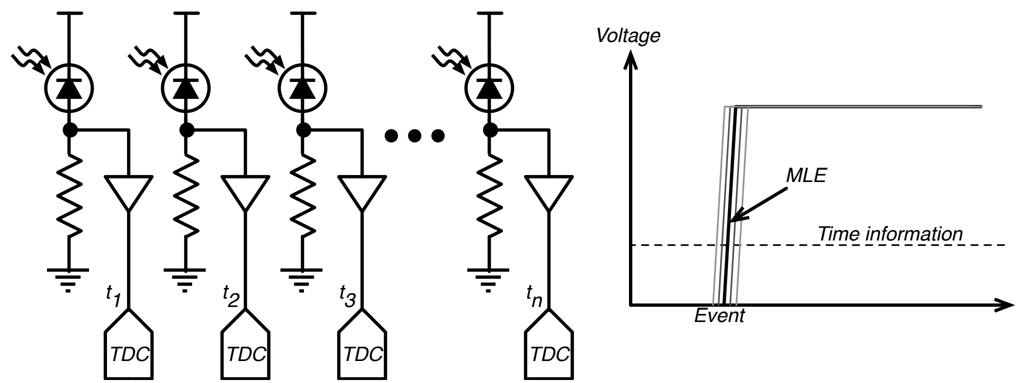
The *a*-SiPM

- low rise time;
- high capacitance;
- reasonable fill factor (FF);
- mature technology;
- commercially available
- time over threshold discr.
- require dedicated ASIC



The *d*-SiPM

- very low rise time;
- individual SPAD readout
  → single photon counting
  → optimum timing
- high functionality
- ambitious/risky
- novel technology

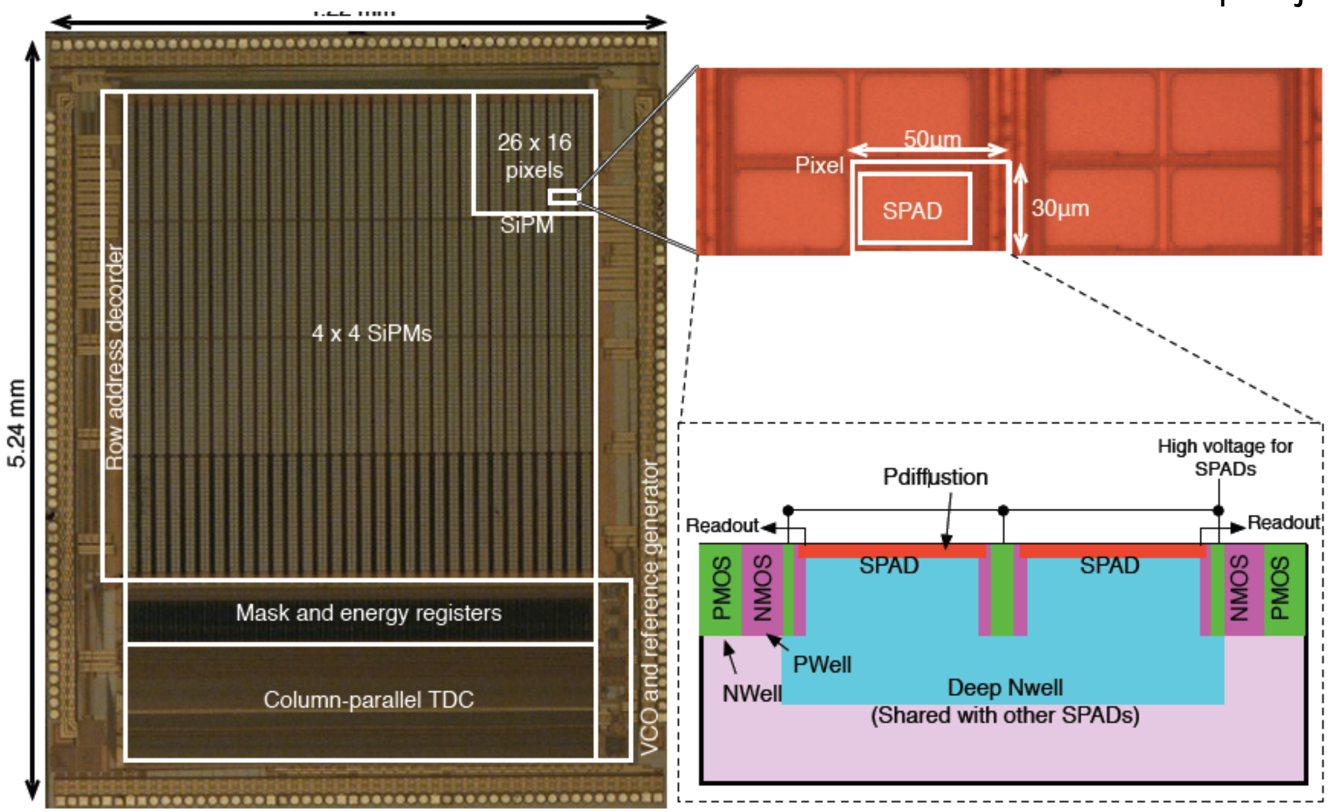


E. Charbon - TU Delft

dSiPM Activities at DESY & UniHH

Gain experience with dSiPM Application in medical imaging

custom-made prototype chip with 16 test geometries produced for the EndoTOFPET-US project



Largest fill factor: 57%

TU Delft

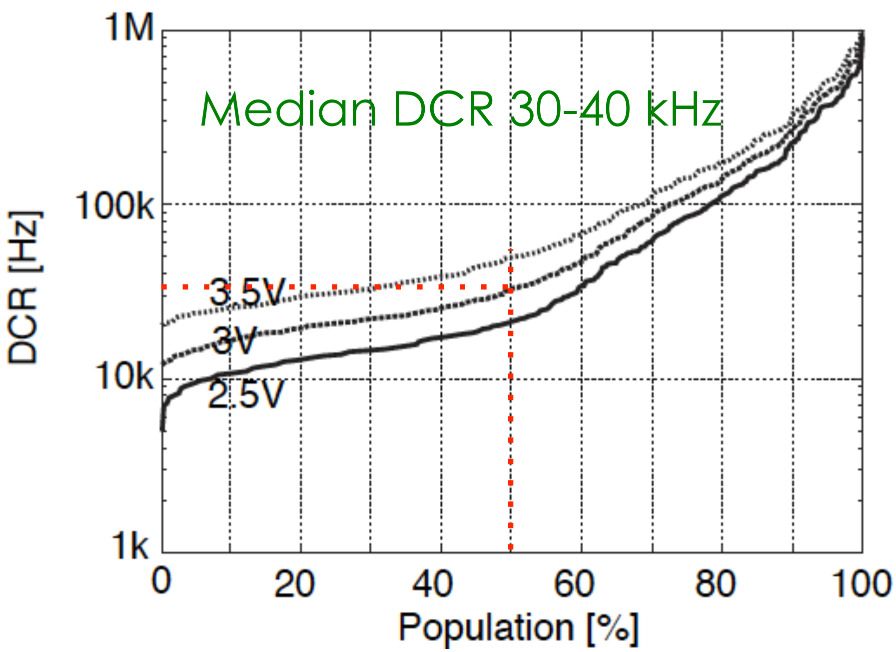
[See S. Mandai and E. Charbon, IEEE 2012]

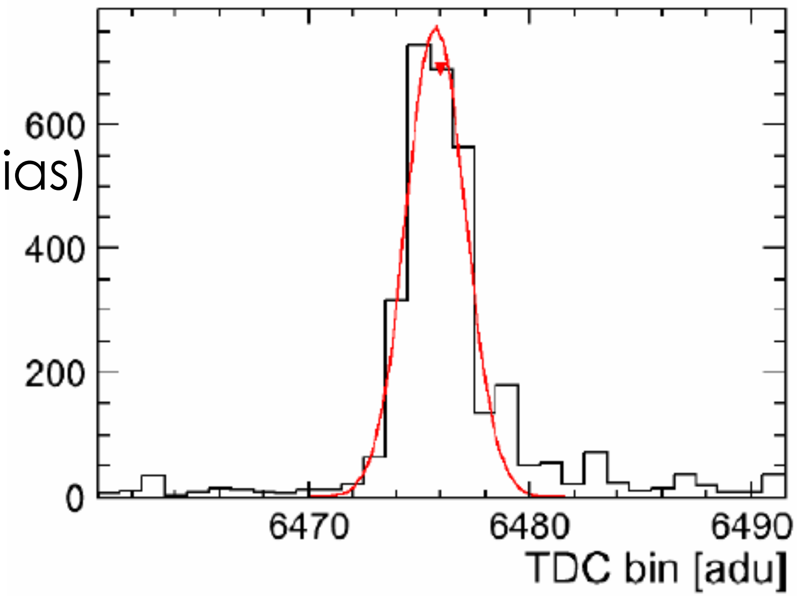
Energy measurement: 416 pixels / SiPM with single bit count

Time measurement: 48 TDC / SiPM with < 50ps time bin

dSiPM Activities at DESY & Uni.HH

SPAD array characterization:
- PDE = 12.5% (for FF = 57%)
- DCR = ~10 MHz (@25°C, 2.7V excess bias)
- DCR can be reduced by masking noisy pixels





Single pixel time resolution:
Measured 144.0 ± 13.0 ps (FWHM)
Subtracting laser jitter (35ps) and clock and PLL jitter 115.0 ± 13.0 ps

Conclusion & Outlook

Thanks to the Alliance VSL it was possible to:

- Boost the application of SiPM in high energy physics experiments
- Share knowledge, experience and tools for SiPM operation
- SiPM dedicated ASIC chips (for high precision charge or time measurements) KLauS2.0 samples available on request; STiC2.0 available after evaluation.
- Sophisticated simulations tools to model the SiPM response ➔ available
- Characterization test benches for SiPMs and SiPMs + active media ➔ usable on request
- A simple practicum SiPM-box ➔ available
- Support existing projects employing SiPMs as photo-detector and starting new ones

A very valuable experience to connected the community ➔ to be continued …