SiPM Development at MPI Munich

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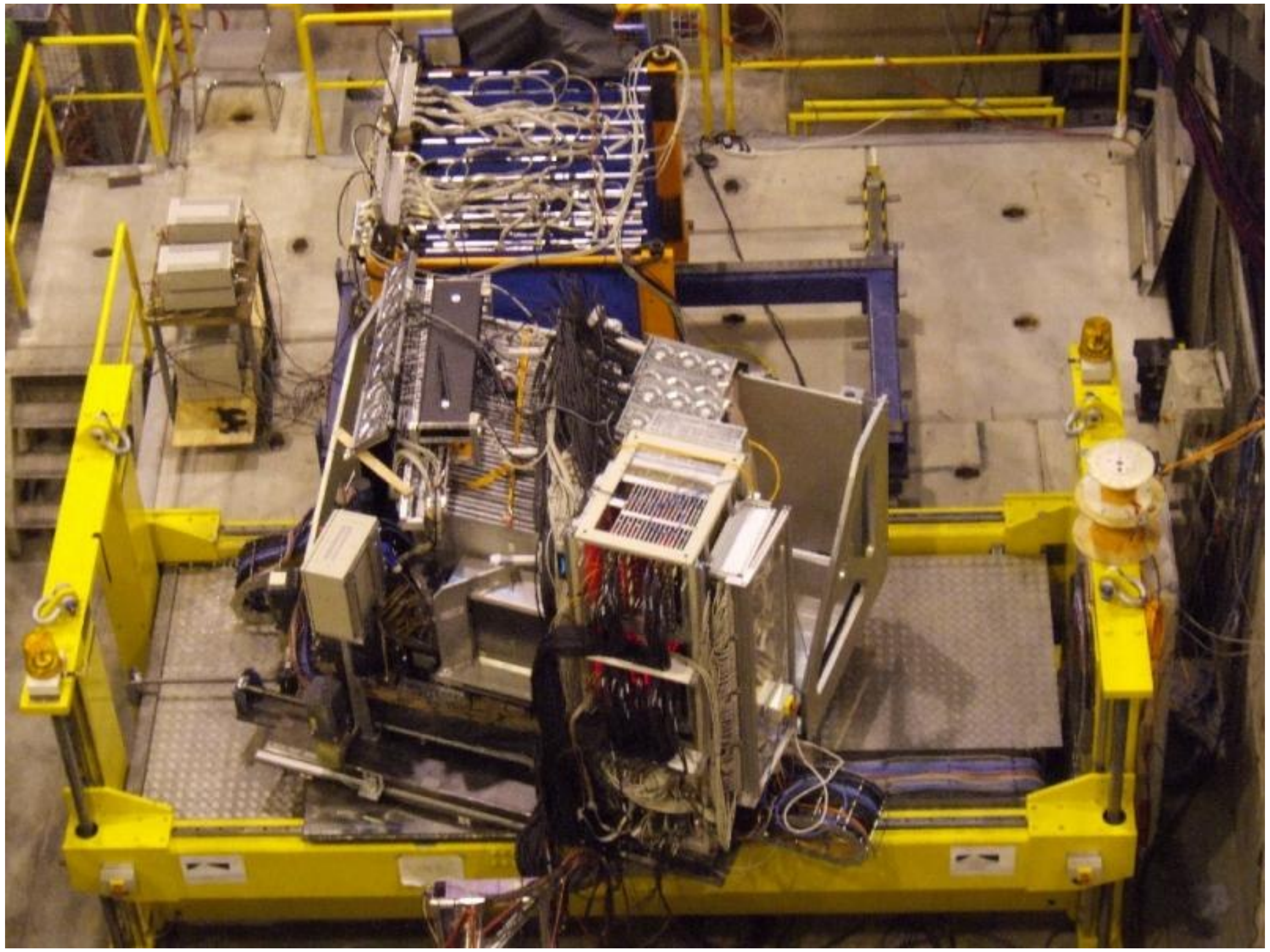
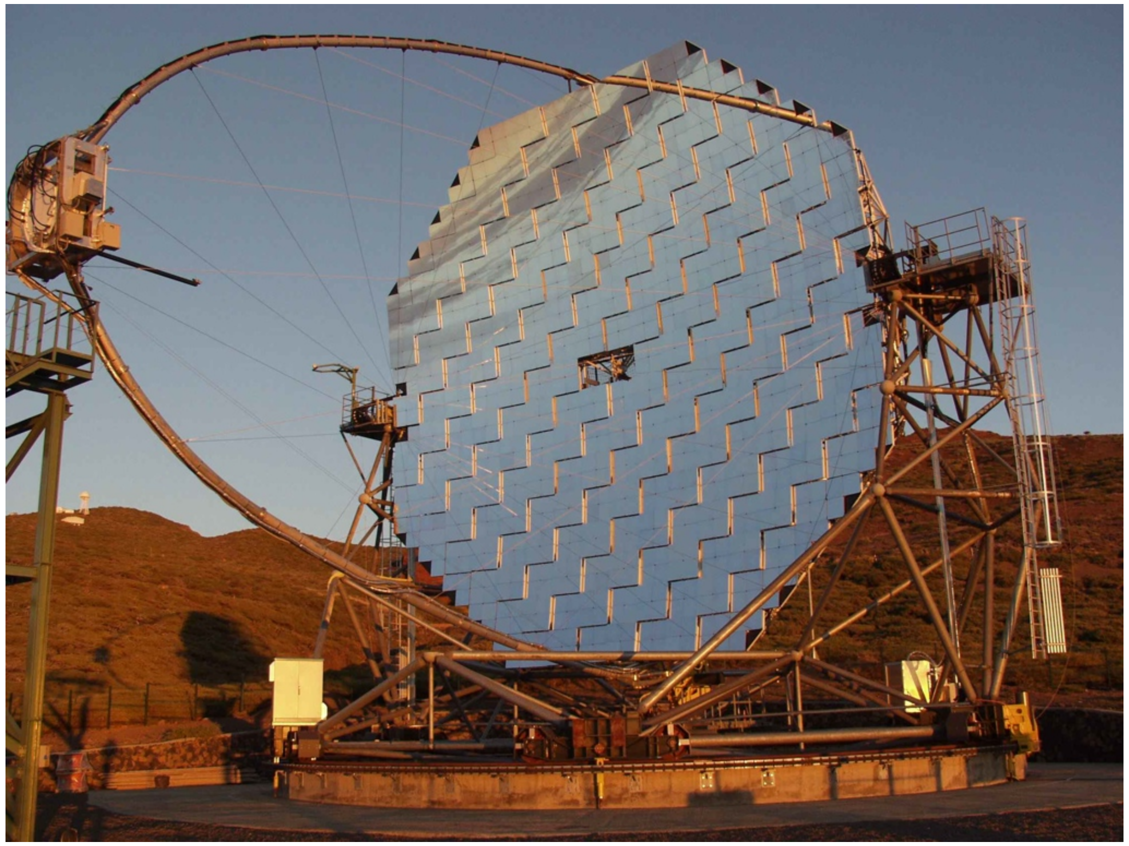
- CALICE AHCAL Main Meeting, DESY, June/July 2008 -

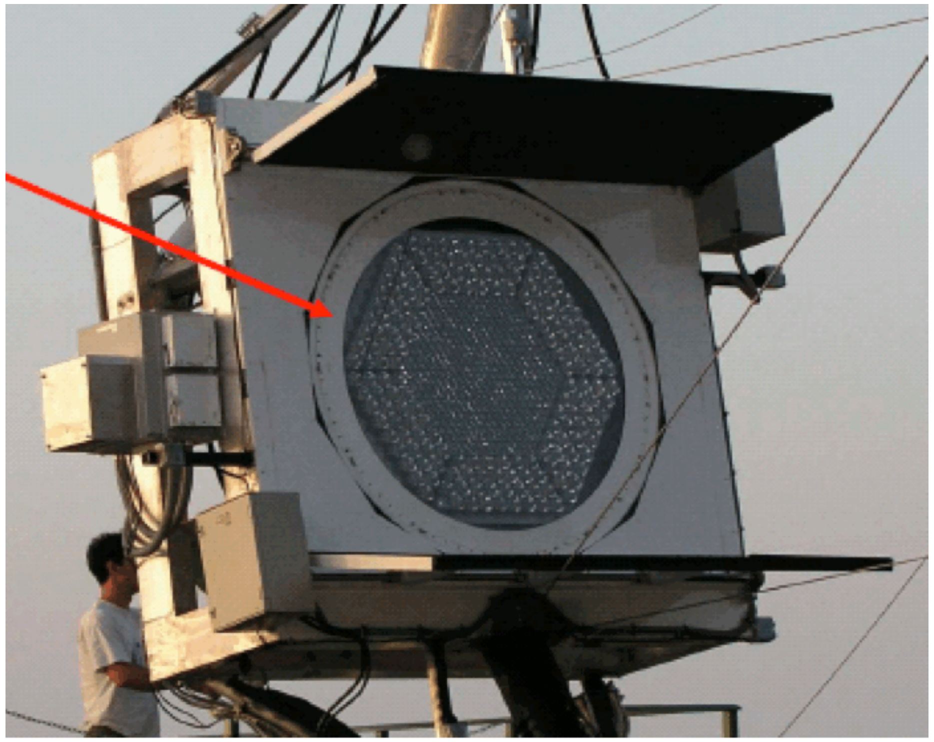
Outline:

- SiPM Characterization
- Scintillator Tiles & SiPMs
- A New Type of SiPM

MPI Interests: Synergy of Fields

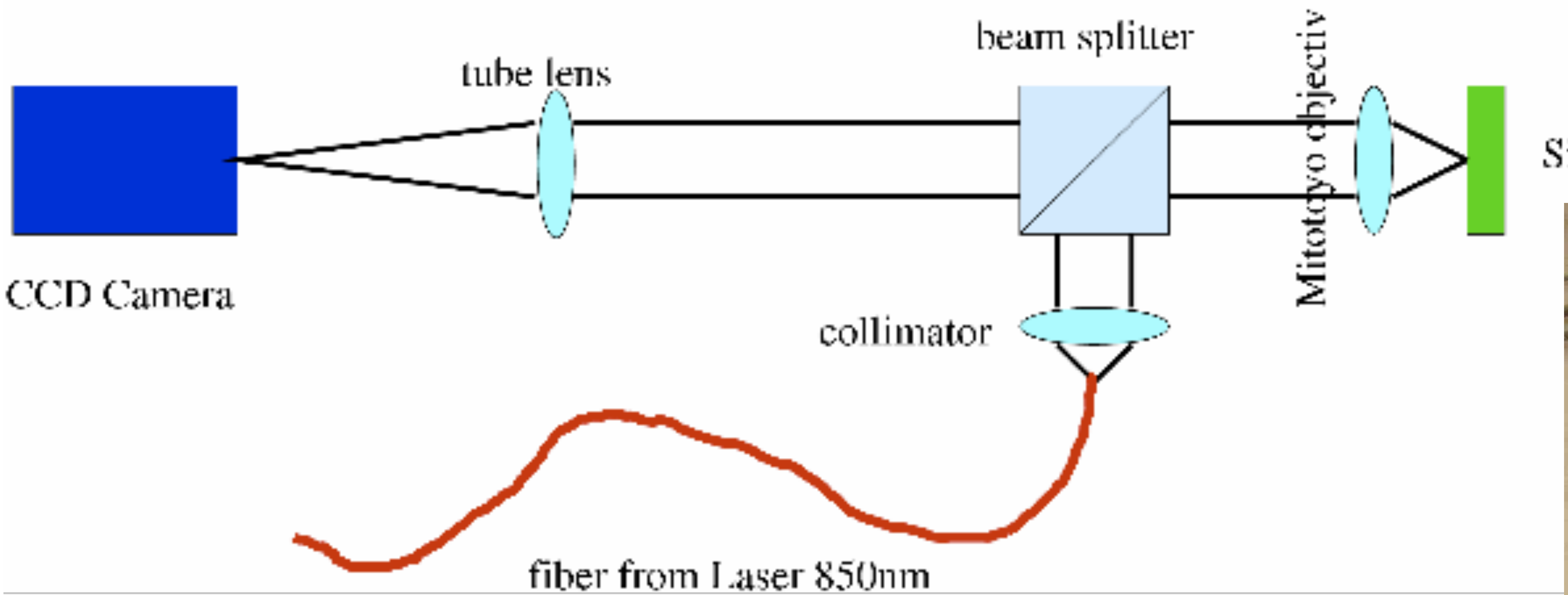




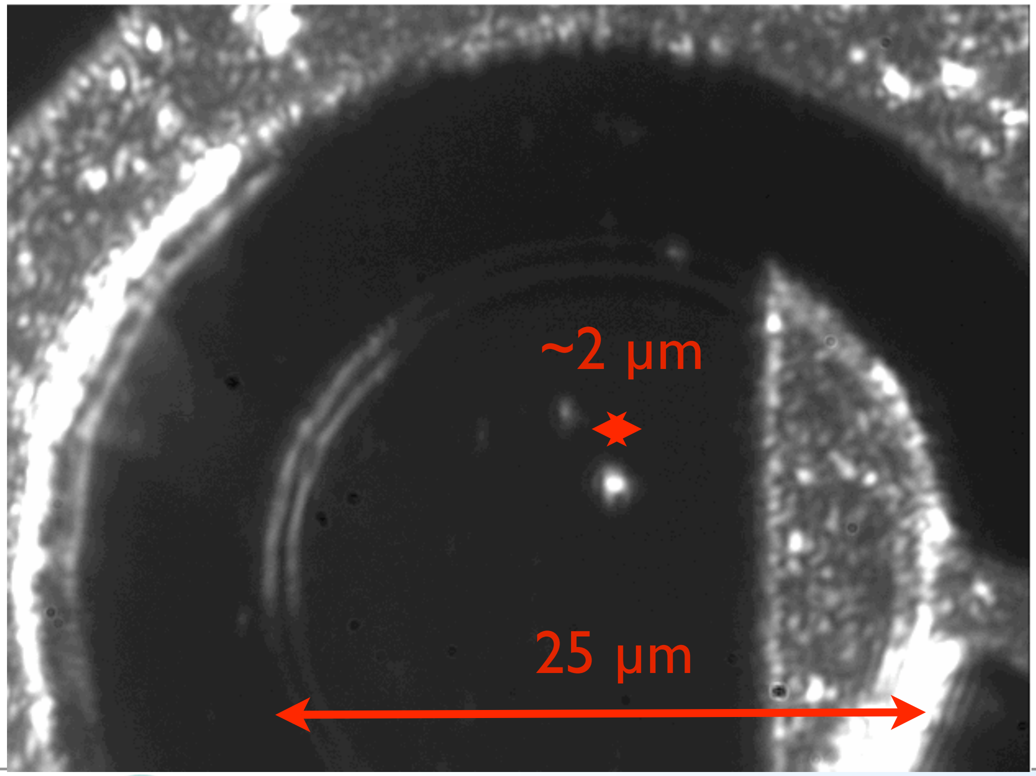


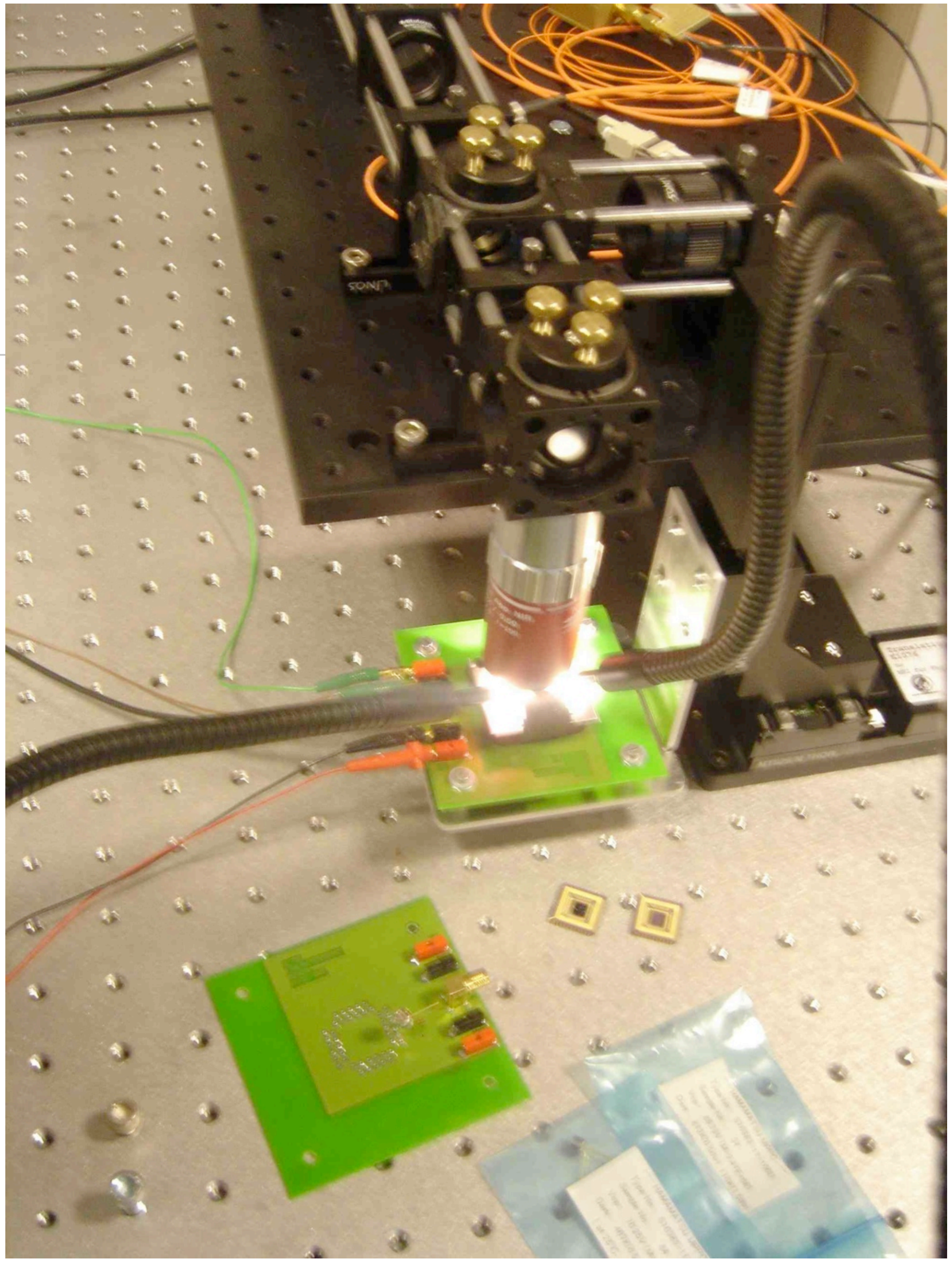
- Highly granular calorimetry for future collider experiments: Readout of scintillator tiles
- The "next big thing" in Gamma-ray astroparticle physics: CTA (Cherenkov Telescope Array), ~20 Telescopes, needs alternative to PMTs for cherenkov light detection

Test Setup for Detailed Studies at MPI



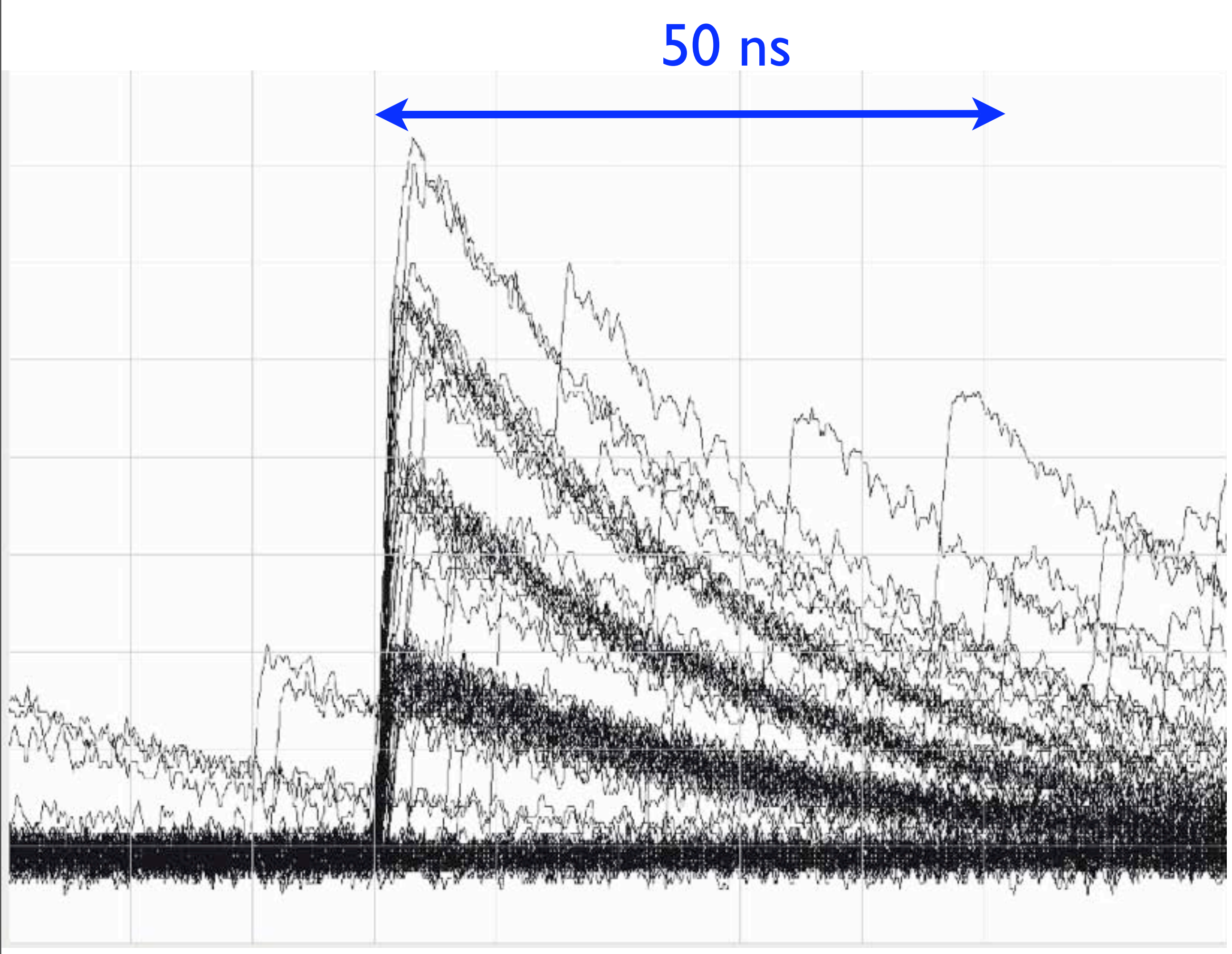
- Laser focused on SiPM

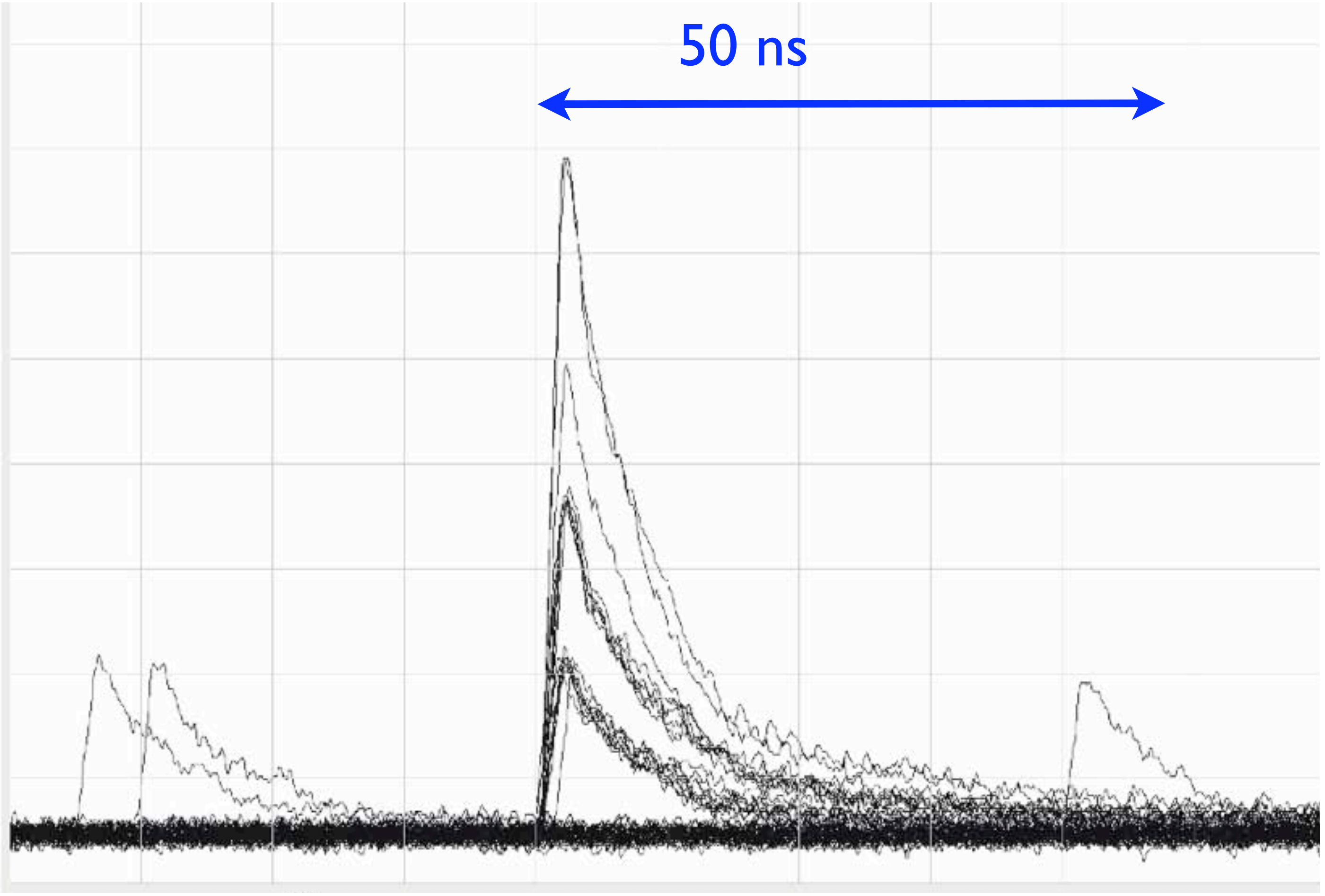




SiPM: Detailed Study

- Data Acquisition with a fast Oscilloscope (4 GHz on 4 channels)
  - Recording of individual pulses possible



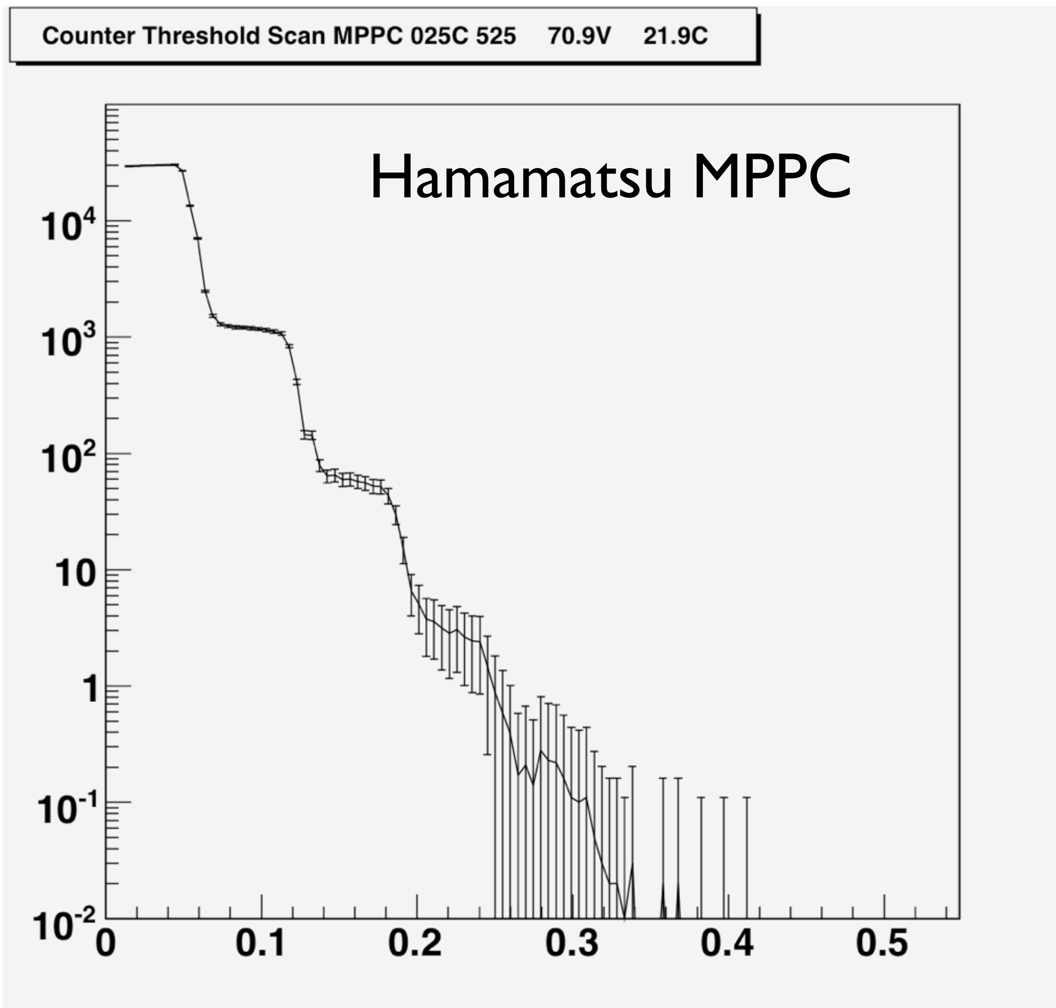


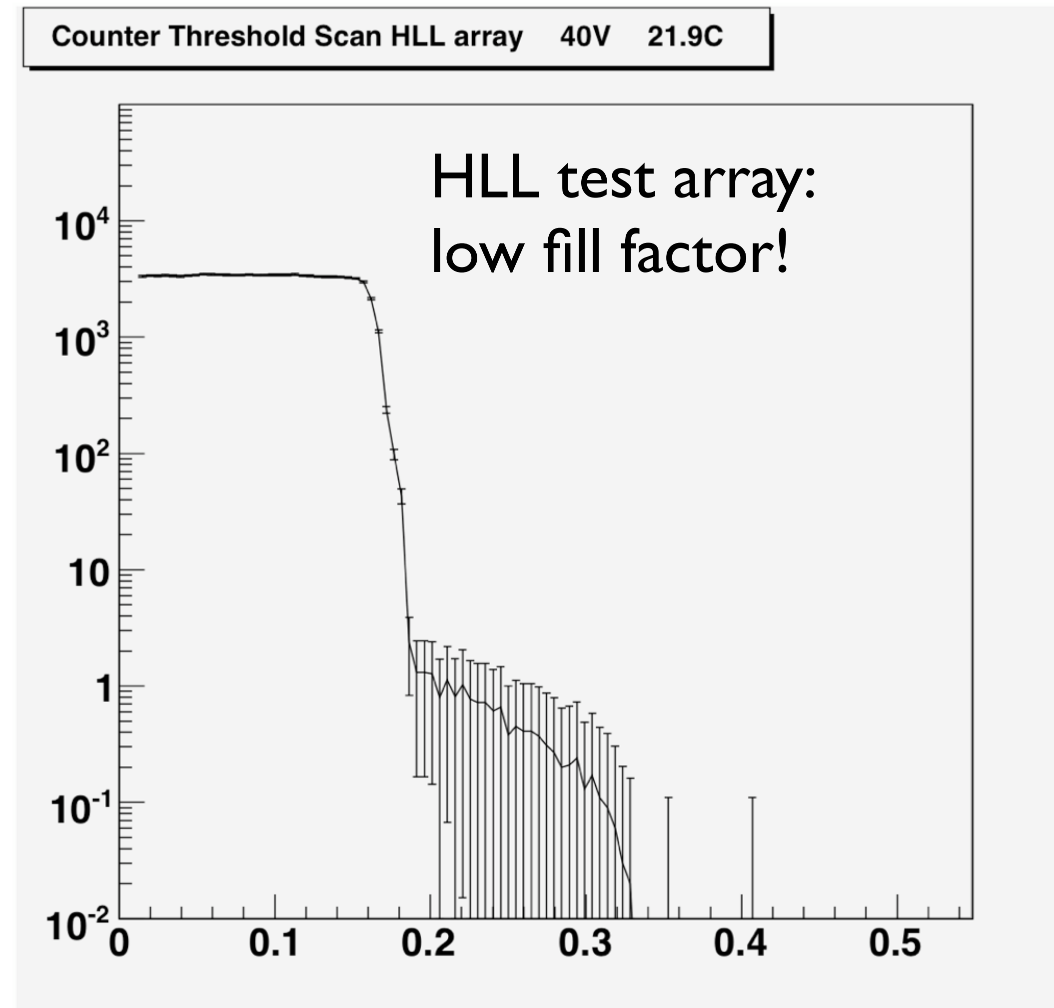
100 events each, superimposed by matching rising edge

Hamamatsu 100 UI: 100 pixels, 100 μm

MPI HLL Test array: 500 pixel, 25 μm

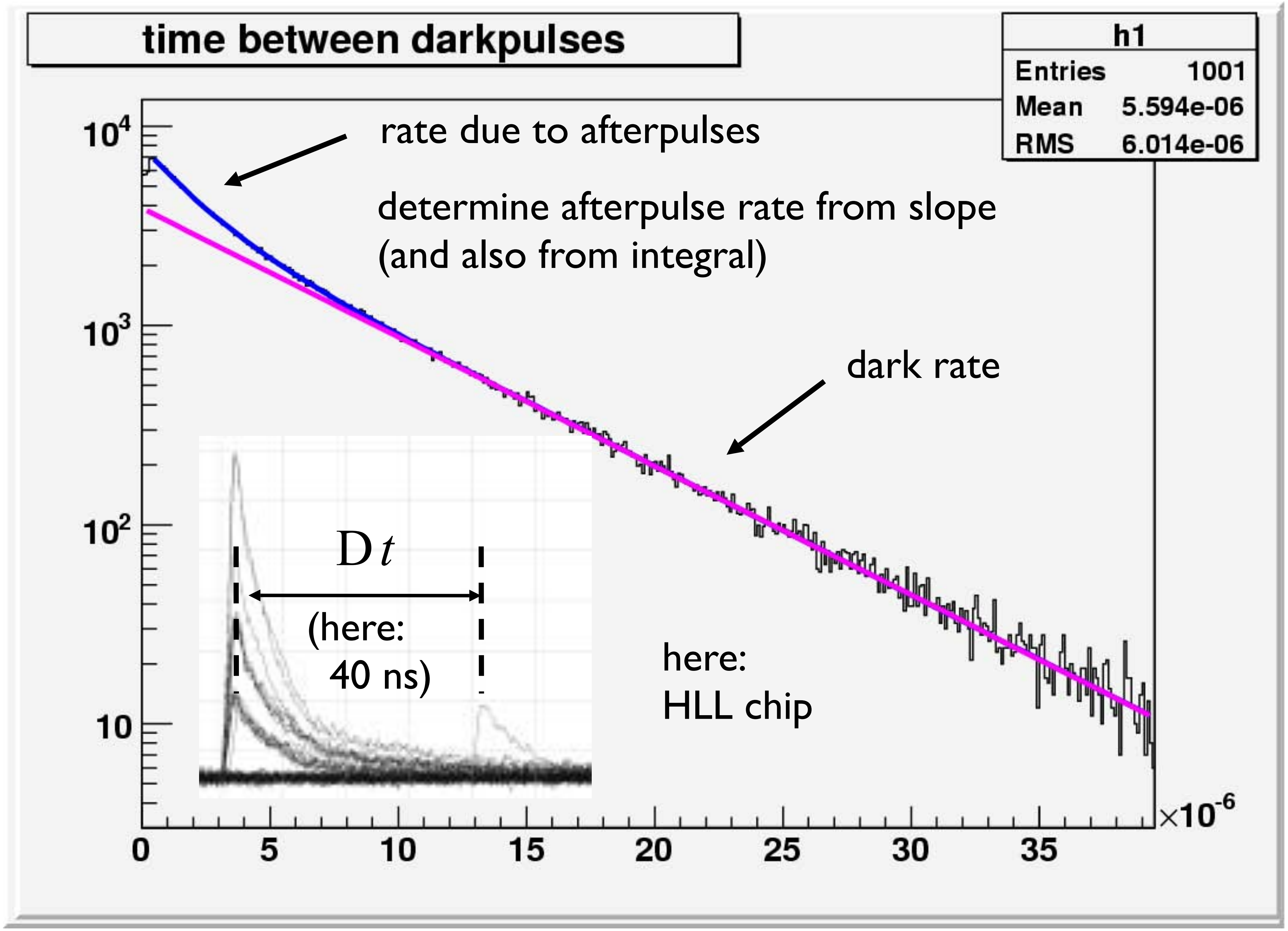
Understanding Dark Rate and Cross Talk





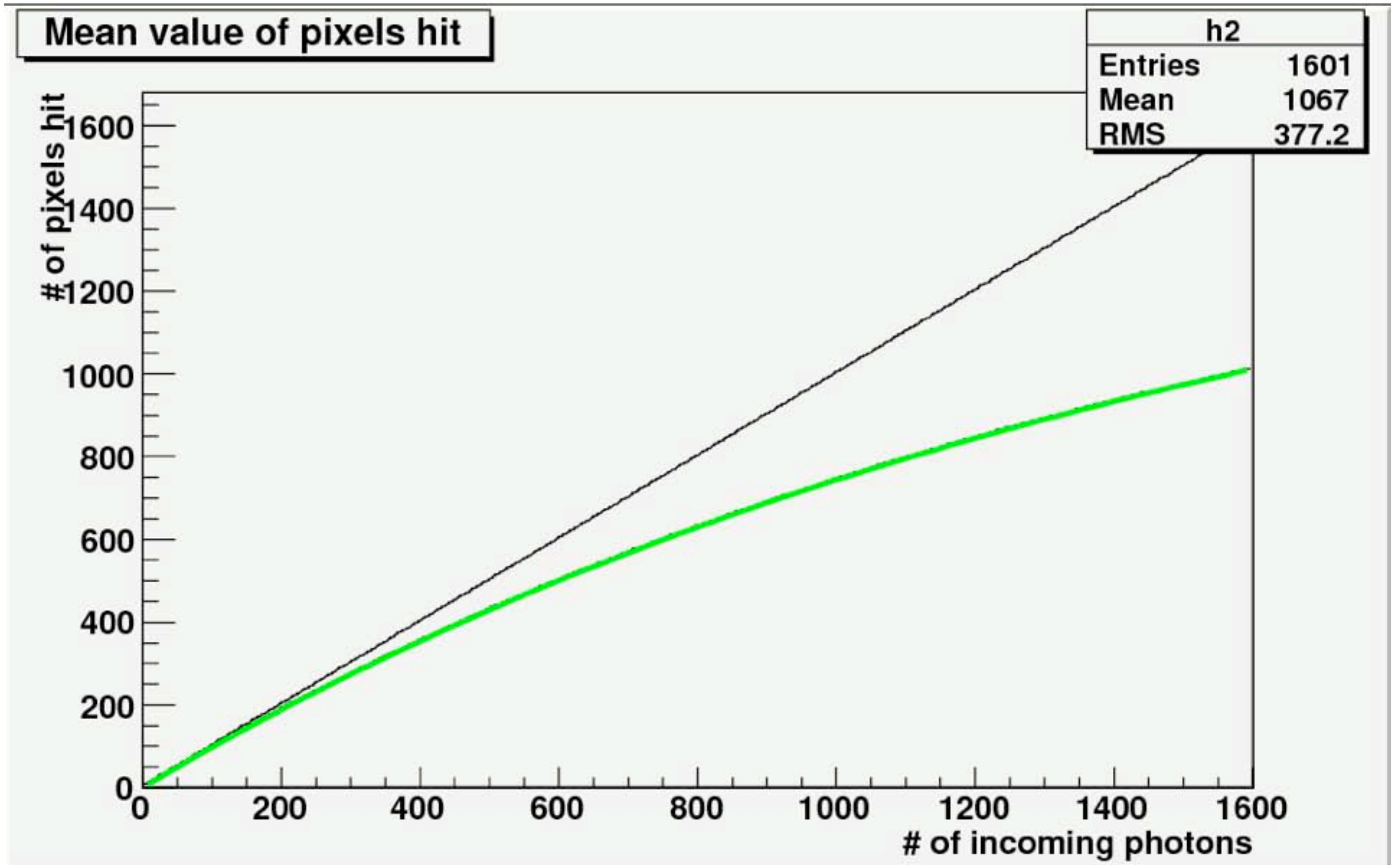
- Threshold scan without laser source: Selects one, two, three.. pixel events
- Hamamatsu MPPC ~4% cross talk
- HLL test array ~1.2×10^{-4} , but very low fill factor, so this is expected
- ▸ Consistent results are achieved with laser measurements

Afterpulses



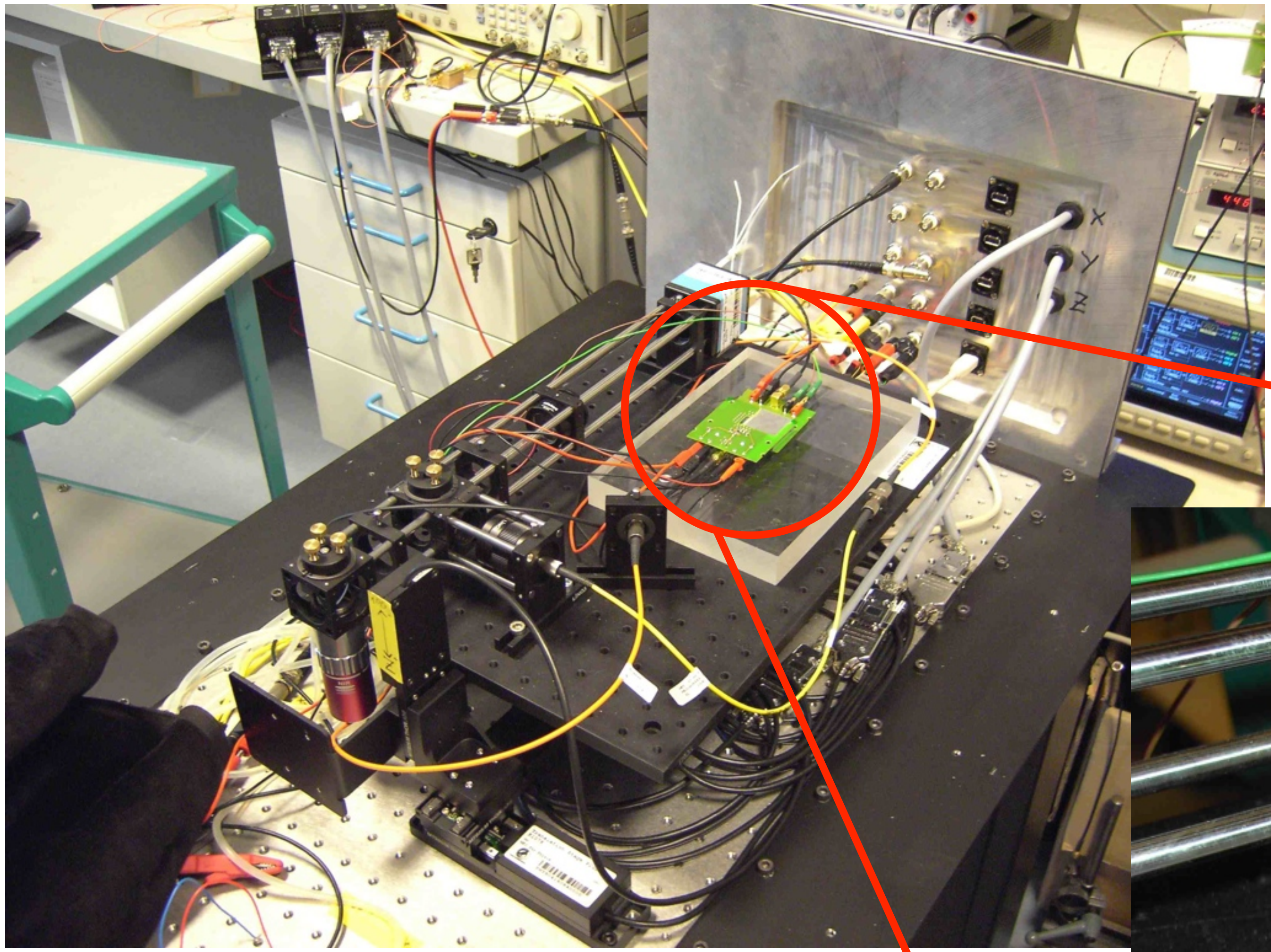
- Study of afterpulses via secondary peak identification, just beginning...

Saturation

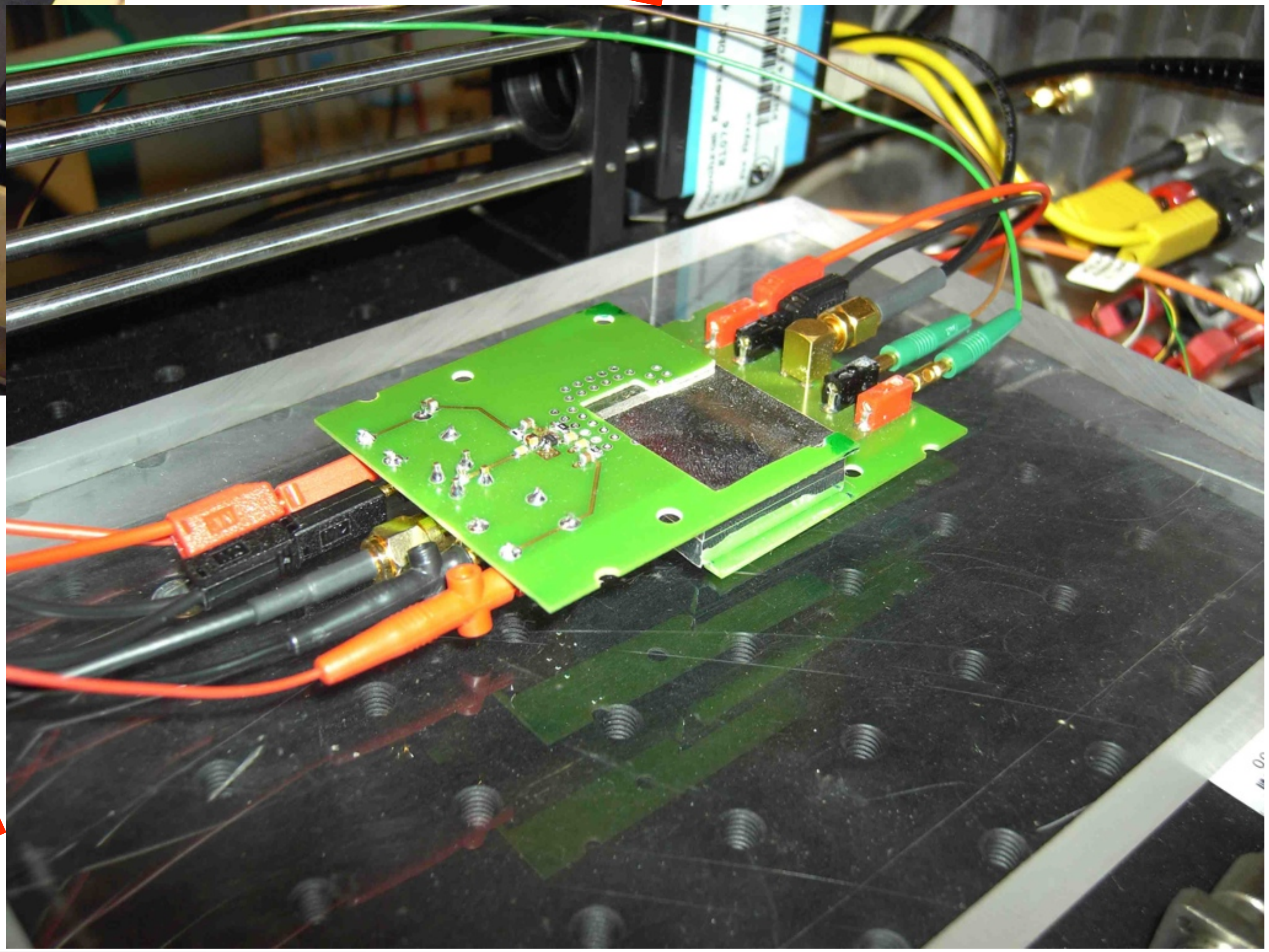


- Simulation of SiPM saturation and precise calculations
  - ideal situation: no afterpulses, no cross talk
  - further studies planned

SiPMs + Scintillator

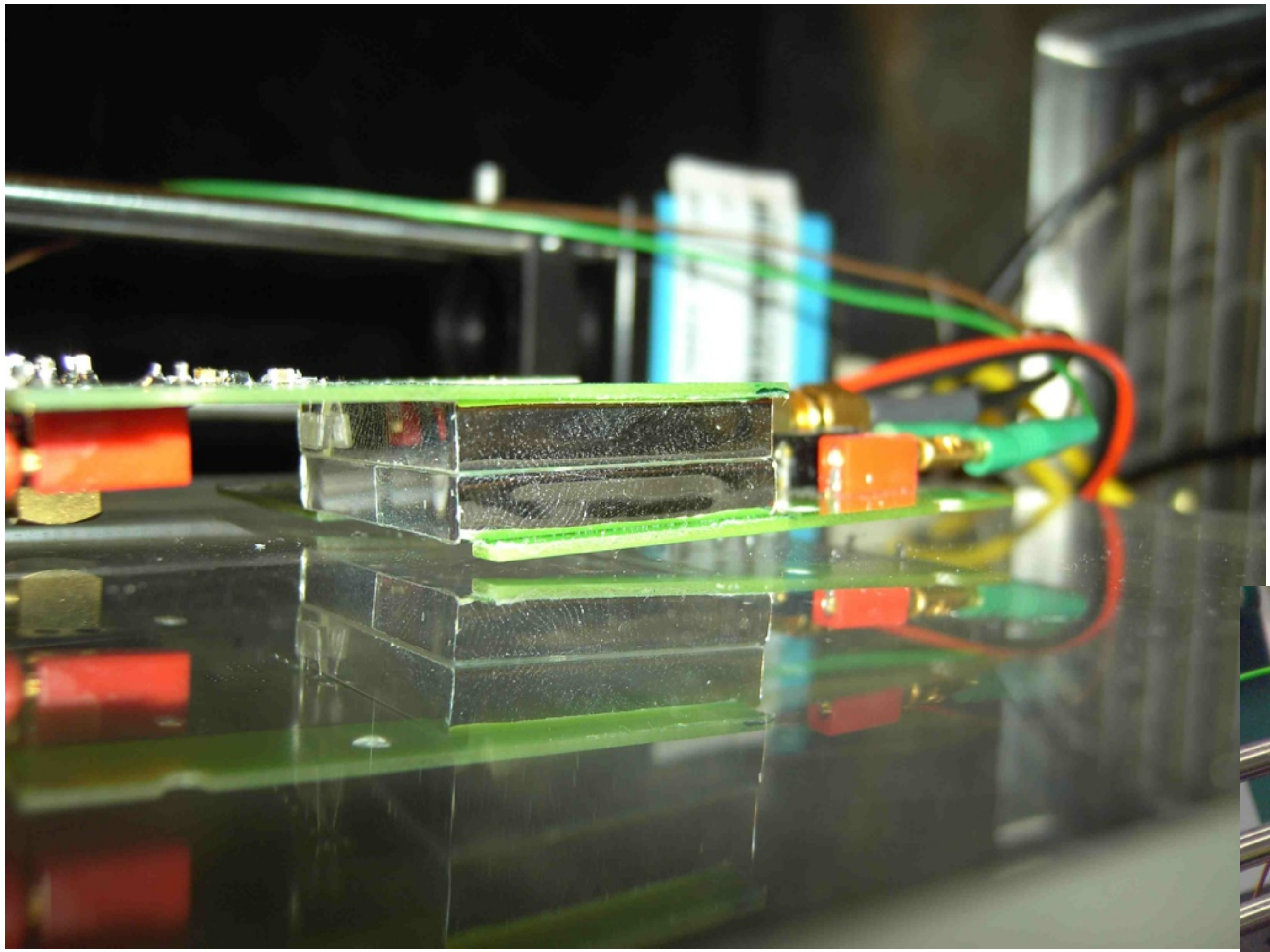


- Test setup in a light-tight box
- readout of two SiPMs separately or in coincidence

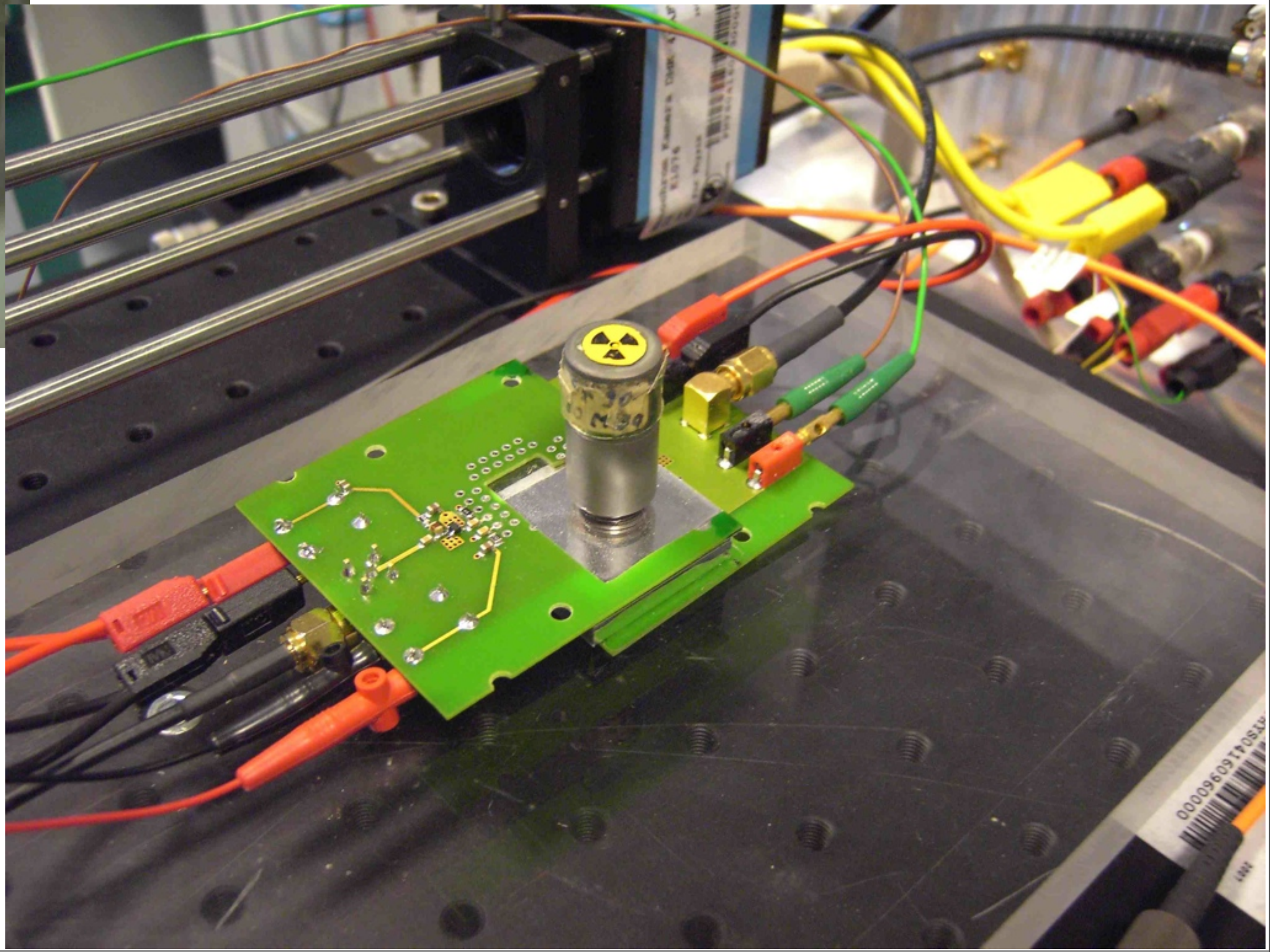


Scintillators from Erika

SiPM + Scintillator



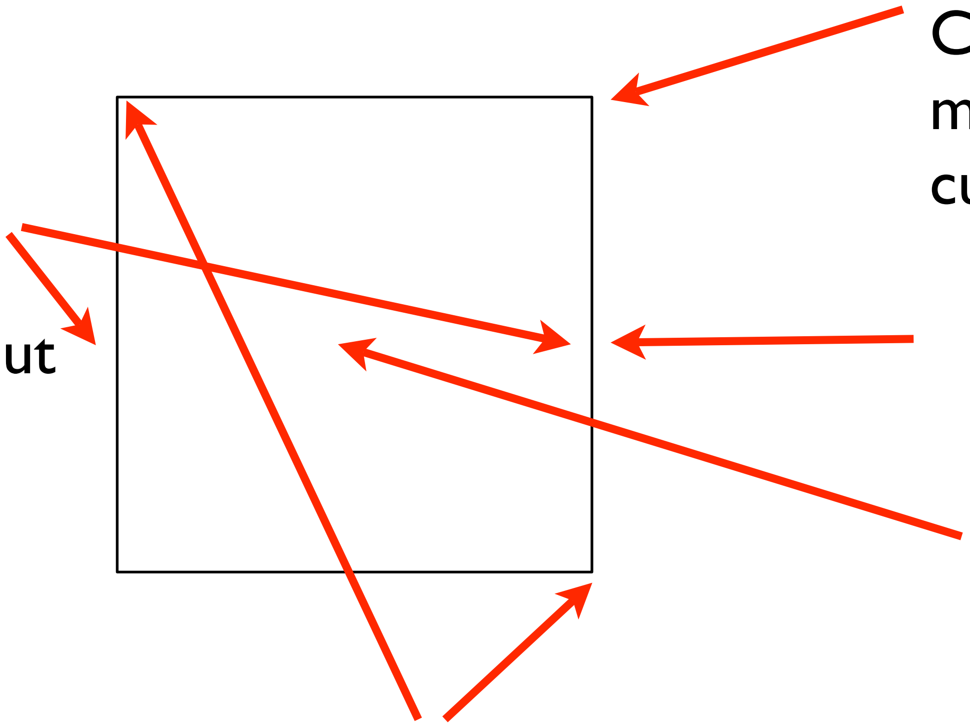
- 2 Scintillators back to back:
  - Cosmic coincidence rate ~0.1 Hz
  - Rate with source (^{90}Sr, 2.2 MeV EP):4.3 kHz, 100 Hz with 1 mm collimation



- Coming up:
  - Uniformity tests in the lab with ^{90}Sr source, maybe with cosmics
  - Test beam at DESY (longer time scale)

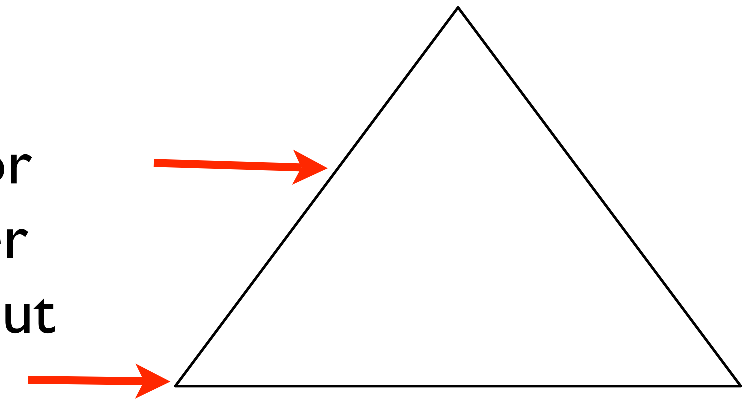
Plans for Scintillator Studies

- Study the coupling of SiPM and scintillator
  - Mounting (air gap, glue, grease,...)
  - SiPM surface (glass, soft resin, ...)
  - Shape of tile and positioning of SiPM



Scintillator finger

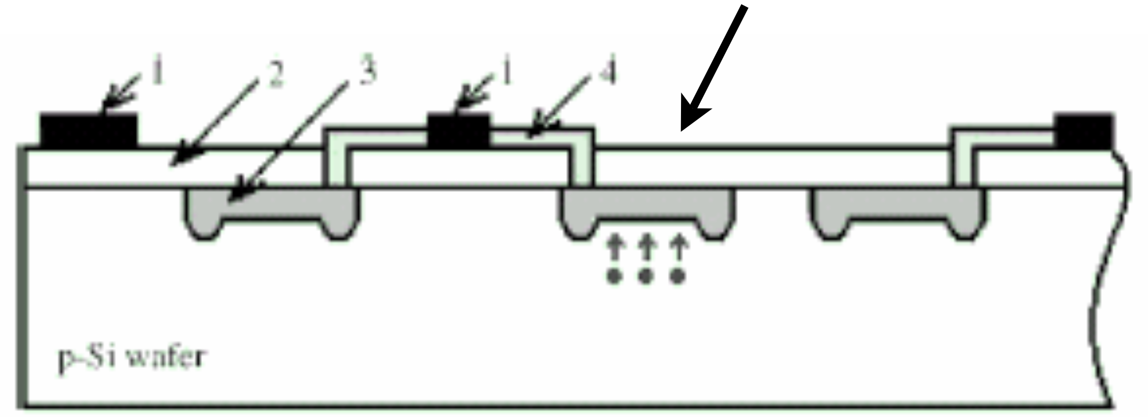
Unilateral Triangle



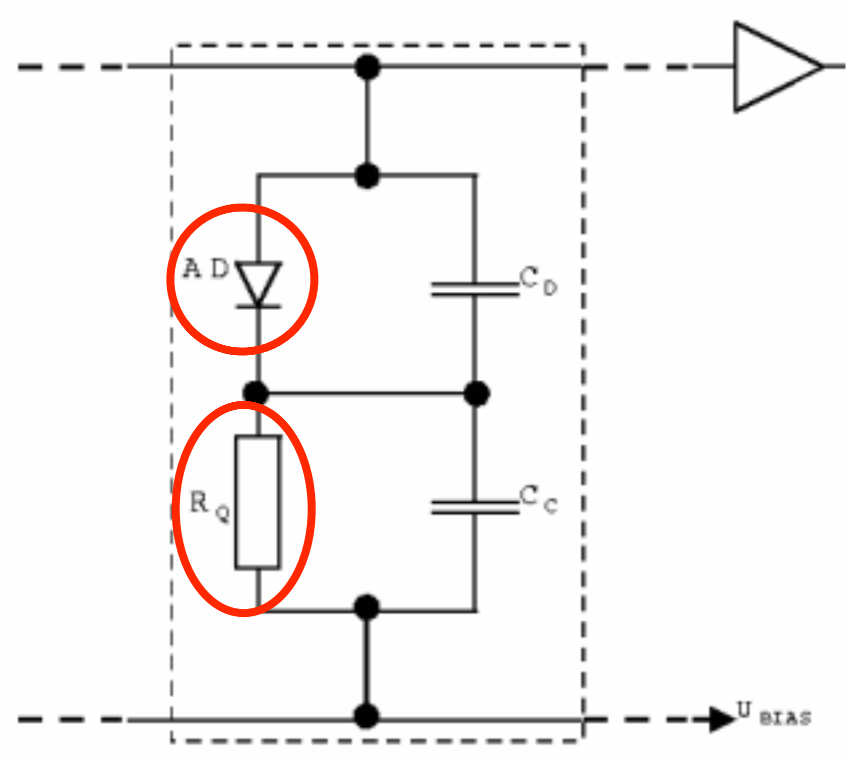
- In parallel: Simulations to find out how much uniform response matters

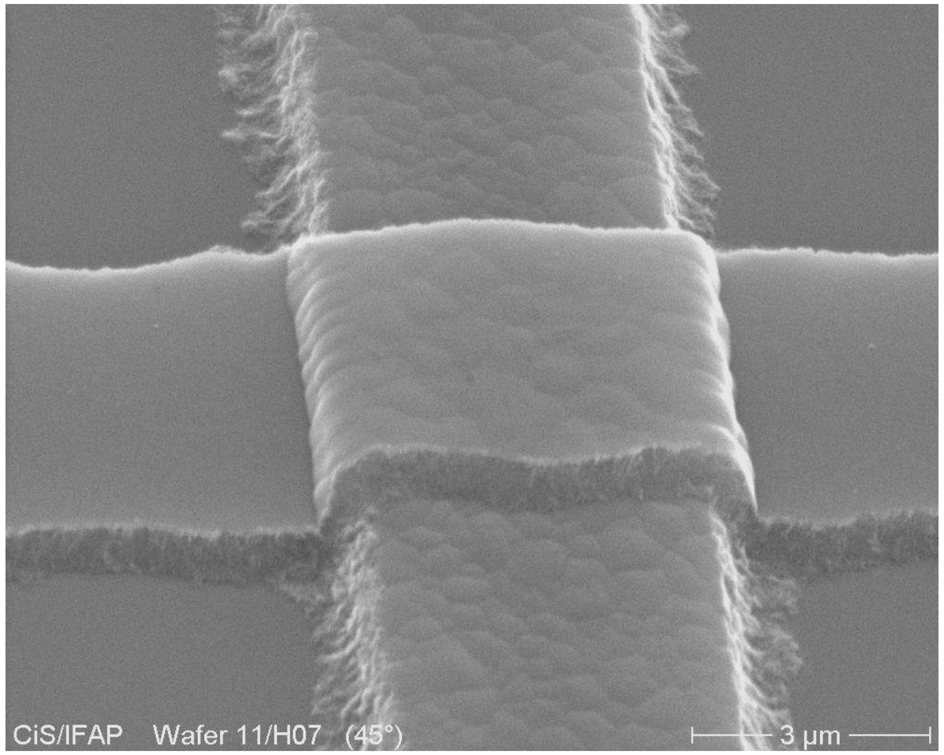
Silicon Photomultipliers: Conventional Design

- Conventional SiPM principle (Dologshein et al.):
  1. Polysilicon quench resistor
  2. highly doped insulating layer
  3. high field region
  4. Al contacts



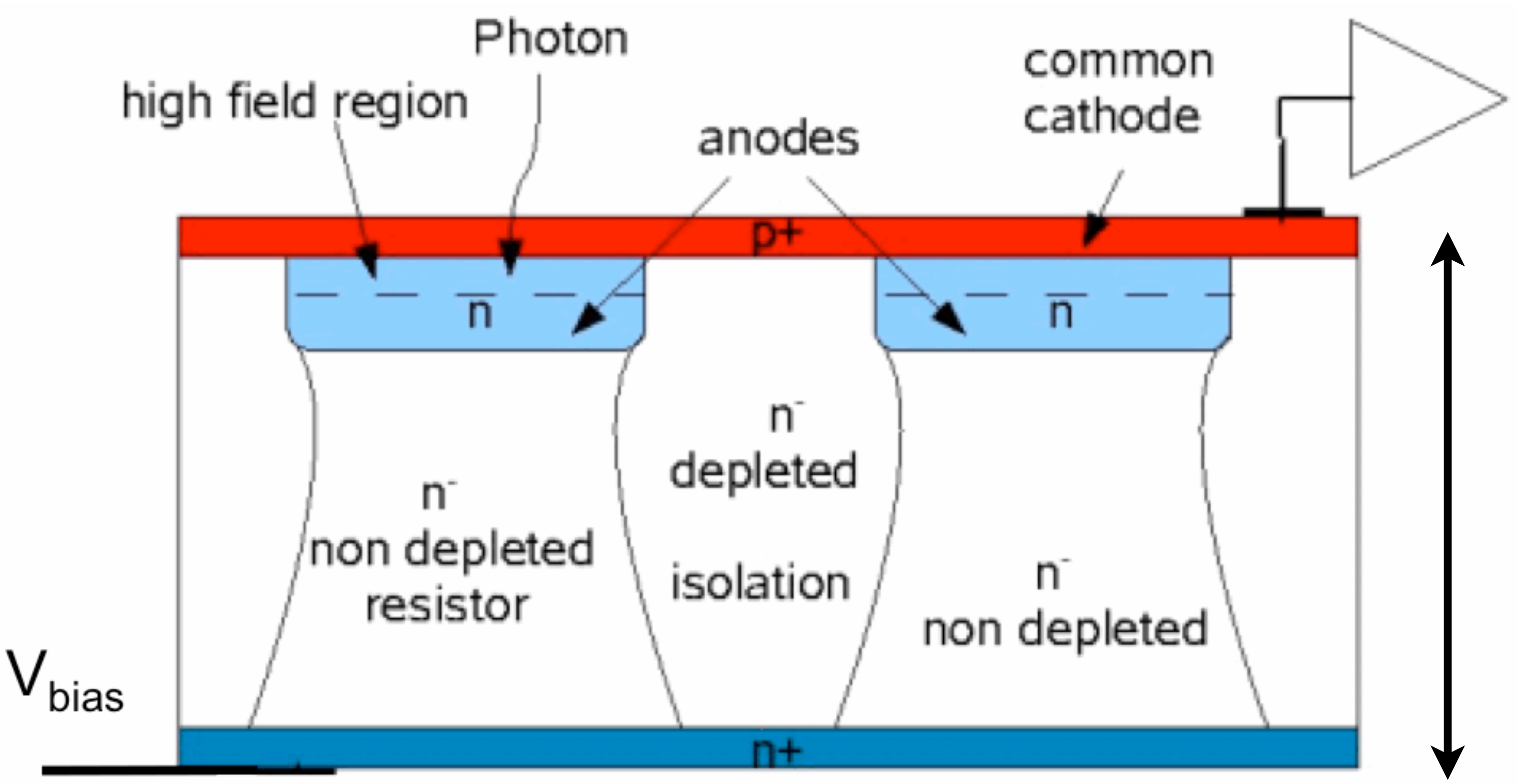
- Surface structures reduce active area and QE
- Polysilicon resistors tricky to produce:
  - very sensitive to annealing temp, deposition cond., preconditioning, layer thickness...





New Type of SiPM at MPI: SiMPL

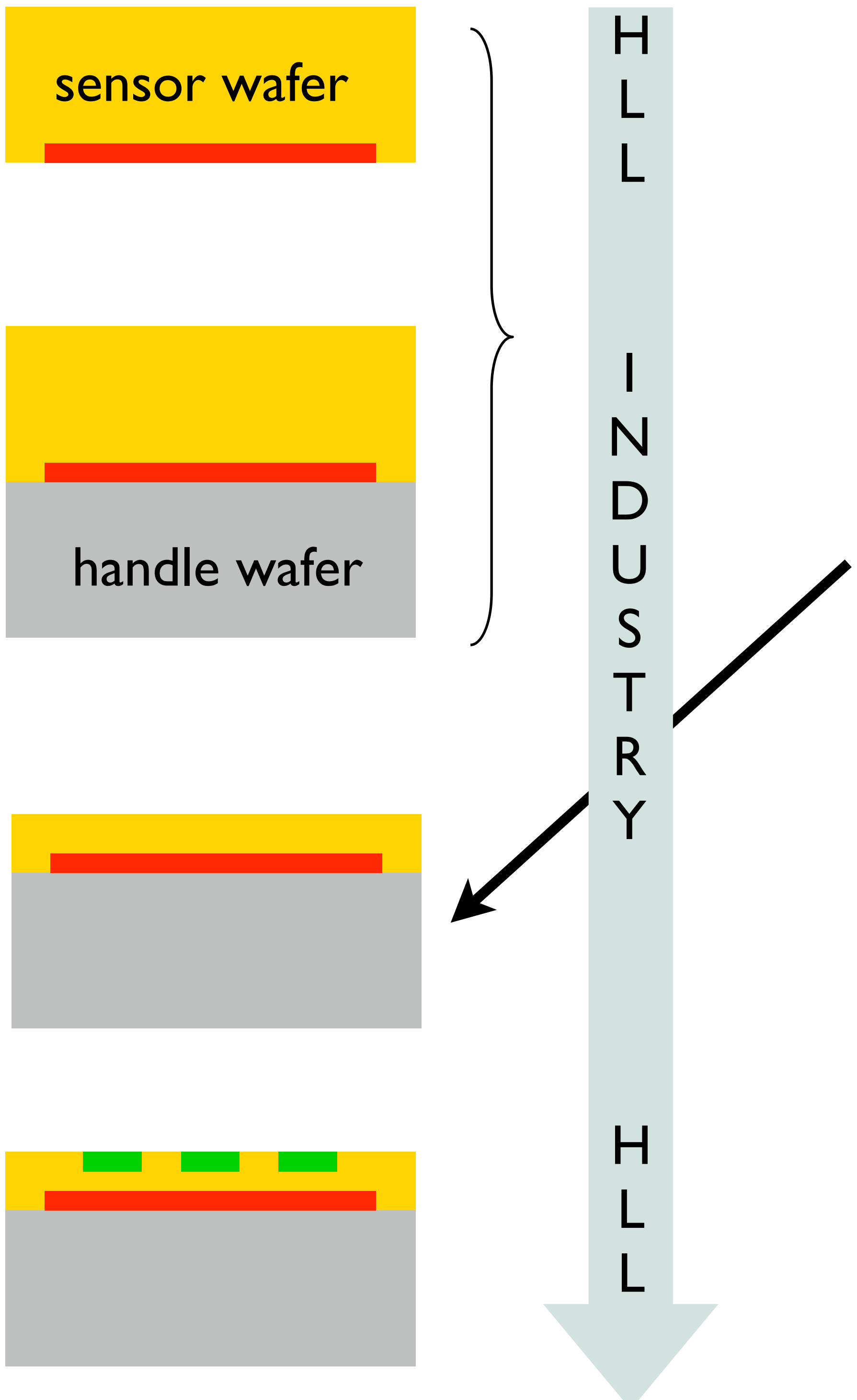
- Simplified SiPM (SiMPL):
  - Common cathode and n^+ backside: significantly reduced surface obstructions
  - Anode is an internal node within Si bulk
  - Bulk region beneath the anode acts as vertical resistor, shielded by the anode from depletion
  - Gap regions are depleted and isolate the individual resistors



thin Si (or EPI material)

The Challenge:
resistor matching via Si thickness (does not work with usual wafer thickness)

SiMPL Production



1. Implant backside on sensor wafer

2. Bond sensor wafer to handle wafer

   (the whole SOI wafer can be ordered from industry)

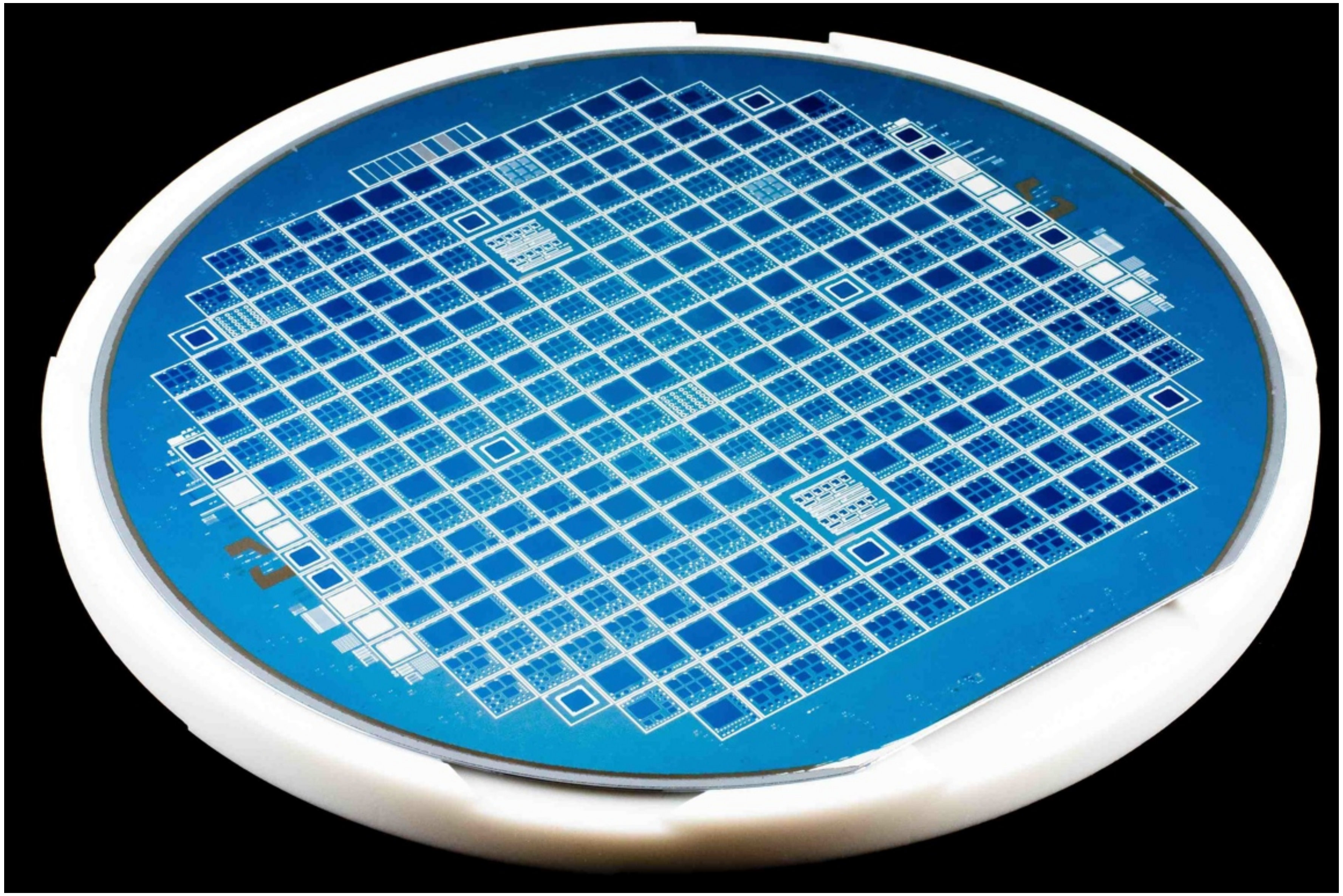
3. Thin sensor layer to desired thickness

4. Further processing of top side
   (e.g. reflectivity, ...)

Pros and Cons of SiMPL

- Advantages:
  - no need of polysilicon
  - free entrance window for light, no metal necessary within the array
  - coarse lithographic level
  - simple technology allows cheaper devices
  - inherent diffusion barrier against minorities in the bulk -> less optical cross talk?
  - hopefully better radiation hardness
- Drawbacks:
  - required depth for vertical resistors does not match wafer thickness
  - wafer bonding is necessary
  - changes of subpixel size requires other material (different resistivity)
  - vertical ‘resistor‘ is a JFET -> parabolic IV -> longer recovery times (factor 2-3)

First Test Wafer



150 mm wafer

- Only ~2.5 month production time

  (HLL R&D lab, parallel to main production)

- Wafer-level tests ongoing, resistor in the expected range

- Optimization of parameters for next round: UV sensitivity, pixel size,...
- Tests at the chip level with improved prototypes

Summary

- MPI has a strong interest in SiPM development driven by both particle and astrophysics applications
- A test stand for detailed characterization of SiPMs has been set up
- Efforts started to work on R&D for a scalable solution for hadron calorimeters (CALICE and ILD): millions of cells at reasonable costs
- Investigation of scintillator tile readout with SiPMs: coupling without WLS fiber using blue sensitive SiPMs, study of tile shapes and SiPM placement
- Very interesting new developments at MPI's HLL: potential low cost, blue sensitive SiPM, optimization for HCAL applications seems possible