Development of a Laser Test Stand for SiPMs for CMS HGCAL

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HELMHOLTZ

Outline

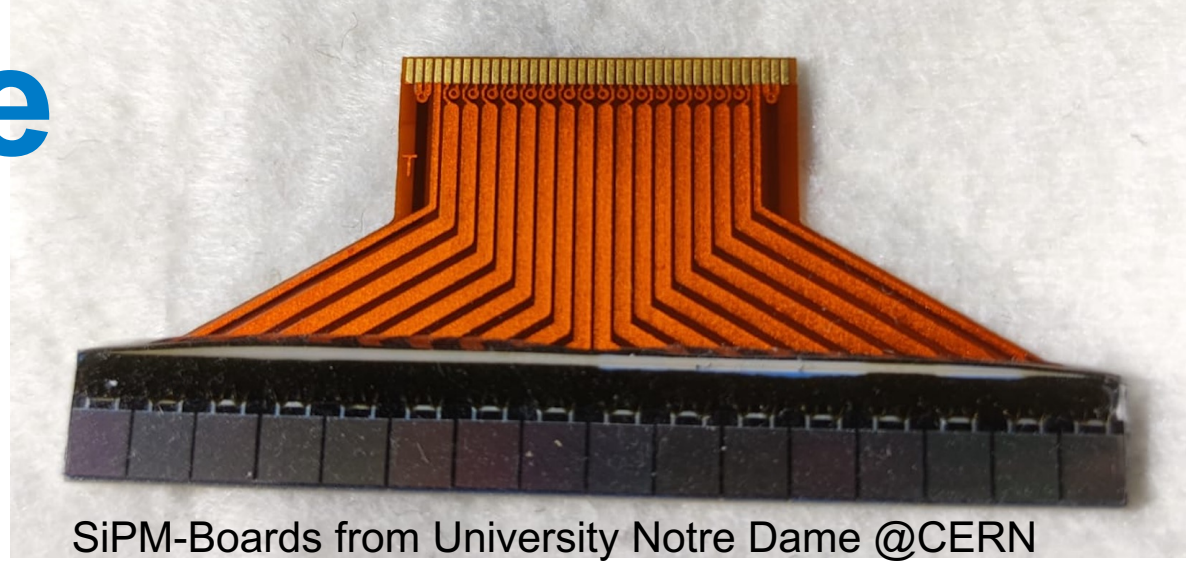
- **Motivation**
  - Quality Assurance
  - SiPM-Saturation
- **Laser Test Stand**
  - Schematic
  - Realisation
  - Measurement Box
- **Summary and Outlook**

Motivation

1) Quality Assurance for HGCAL SiPMs

2) Saturation Analysis at high illumination for HGCAL SiPMs

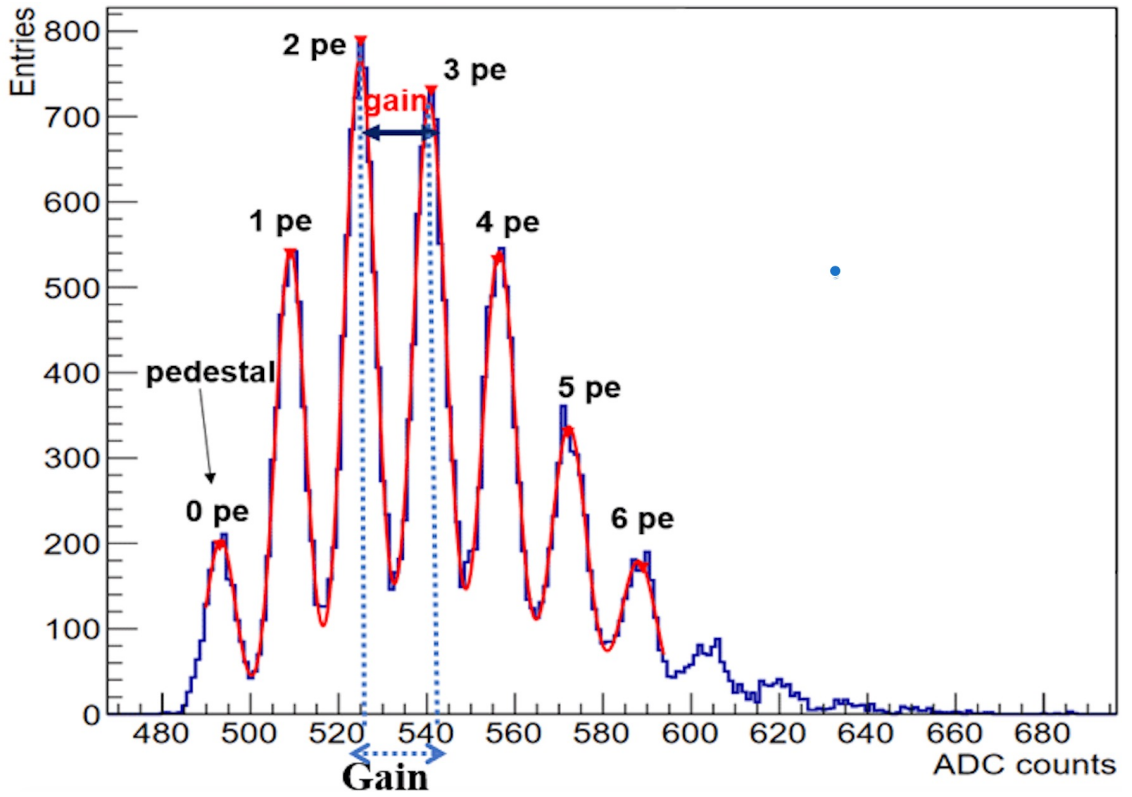
Quality Assurance for HGCAL SiPMs



SiPM-Boards from University Notre Dame @CERN

- **Uniformity** in produced charges from Hamamatsu
- Characteristic **SiPM parameters**:
  - Gain
  - Overvoltage
  - Dark Count Rate
  - **Saturation?**
- Reuse CERN SiPM-Boards holding 16 SiPMs:
  → Previously used for current-based QA of HGCAL und BTL SiPM

- **<u>Quantities:</u>**
  - 1.0 - 1.5 % of HGCAL SiPMs
    → 2000-3000 SiPMs (80 - 100 SiPM-Boards)
  - Measure 2 Boards simultaneously

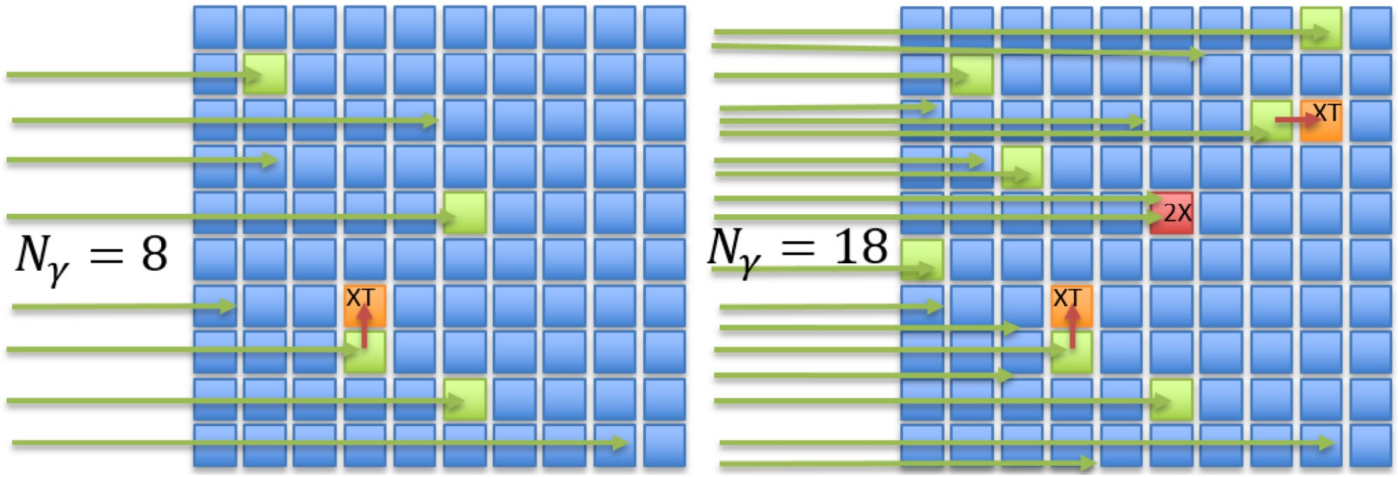


SiPM-Saturation

- Saturation effects due to pixel recovery
- High illumination non-linear SiPM response

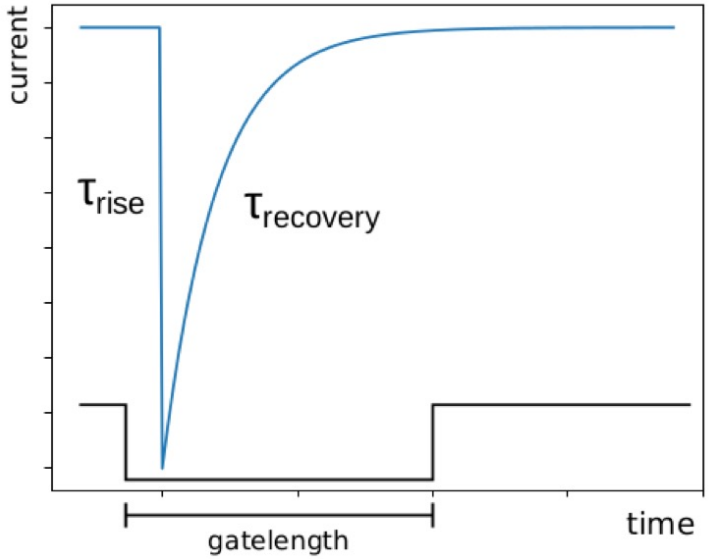
- Simplest model: $f_{Saturation} = N_{Pixel}\left(1 - exp\left(-\frac{\epsilon_{PDE} \cdot N_\gamma}{N_{Pixel}}\right)\right)$

- Require 1 million photons for a SiPM with 40000 pixel
- Uniformity in charges (device to device)

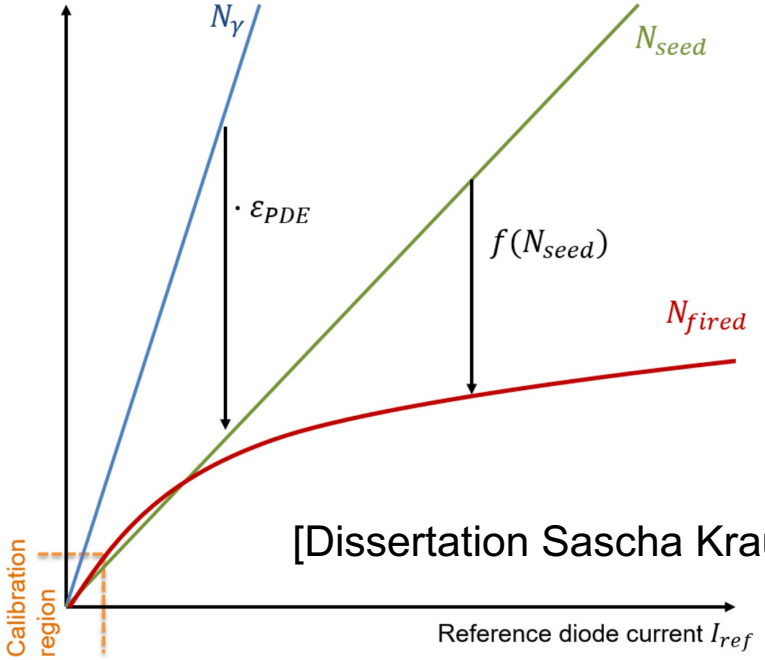


Green: Single Hit

Red: Saturation Hit

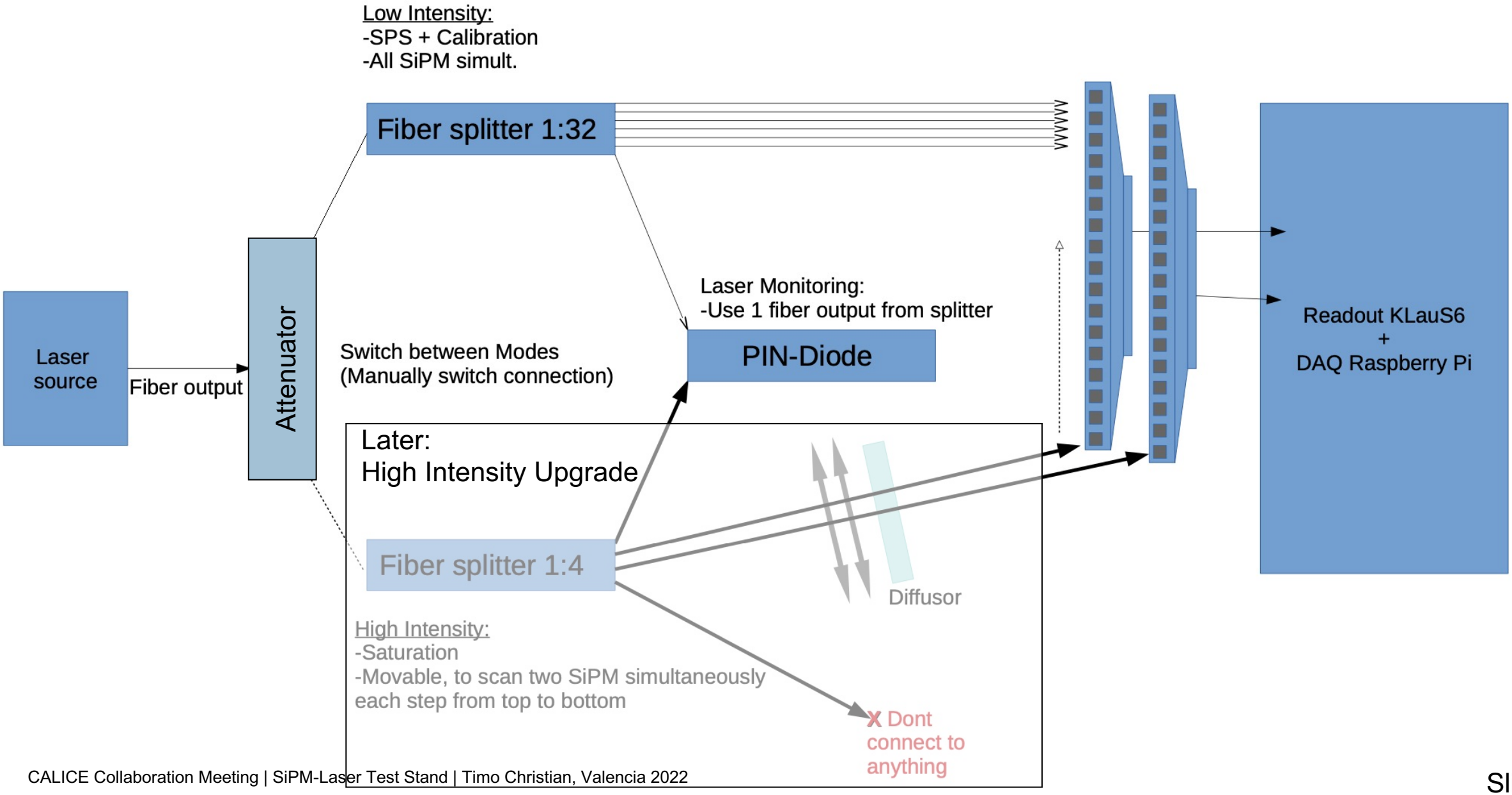


Simplified SiPM photon detection

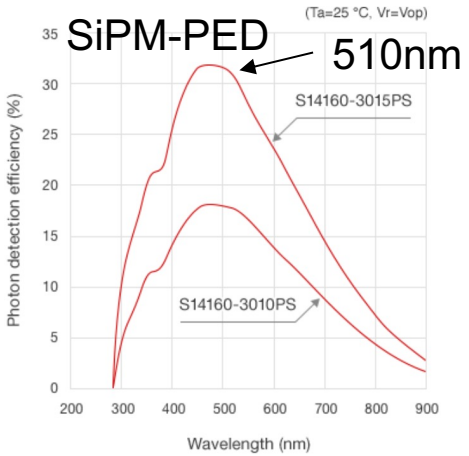


[Dissertation Sascha Krause]

Laser Test Stand-Schematic



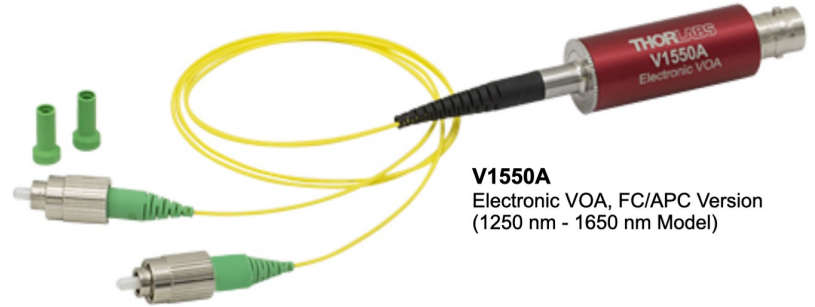
Realisation



Laser source: Pulsed Picosecond Laser
- 510 nm photon wavelength
- 0.2 mW average power at 40 MHz
- Corresponds to 12 million photons per pulse

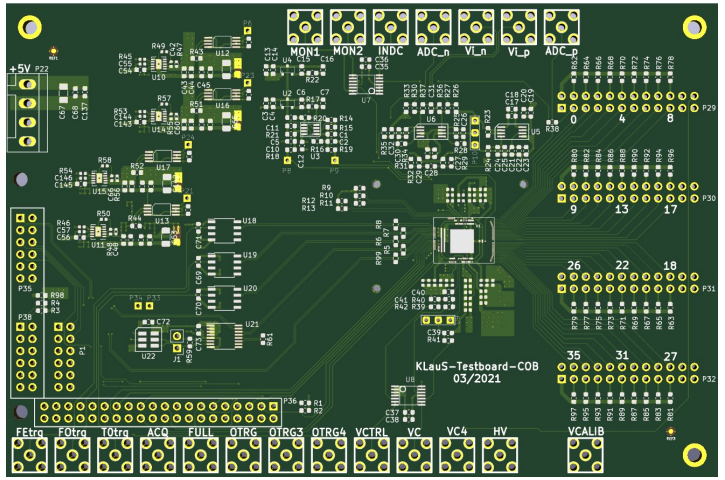
Electronic variable optical attenuator + fixed attenuators:
reduce 12 million photons to Single Photons Spectra (SPS) (~10 Photons)
- Three fixed attenuators á 15 dB
- One variable attenuator 0-30 dB

→ Up to 75 dB controlled attenutation
(+fix attenuation from splitters and connectors)



V1550A
Electronic VOA, FC/APC Version
(1250 nm - 1650 nm Model)

KLauS6-Board (**K**anaele fuer **L**adungs**au**slese von **S**iPM) + Raspberry Pi**:**
- 36-channel ASIC
- High precision charge measurement with integrated ADC/TDC
- Charge: Dynamic range up to 450pC (4 gain configurations: High-Gain down to Ultra-Low-Gain)
- Timing: Dynamic range 3.2ms with 200ps bin sized timestamps utilizing a 40MHz reference clock
- Low power consumption: 3.6mW/chn full operation



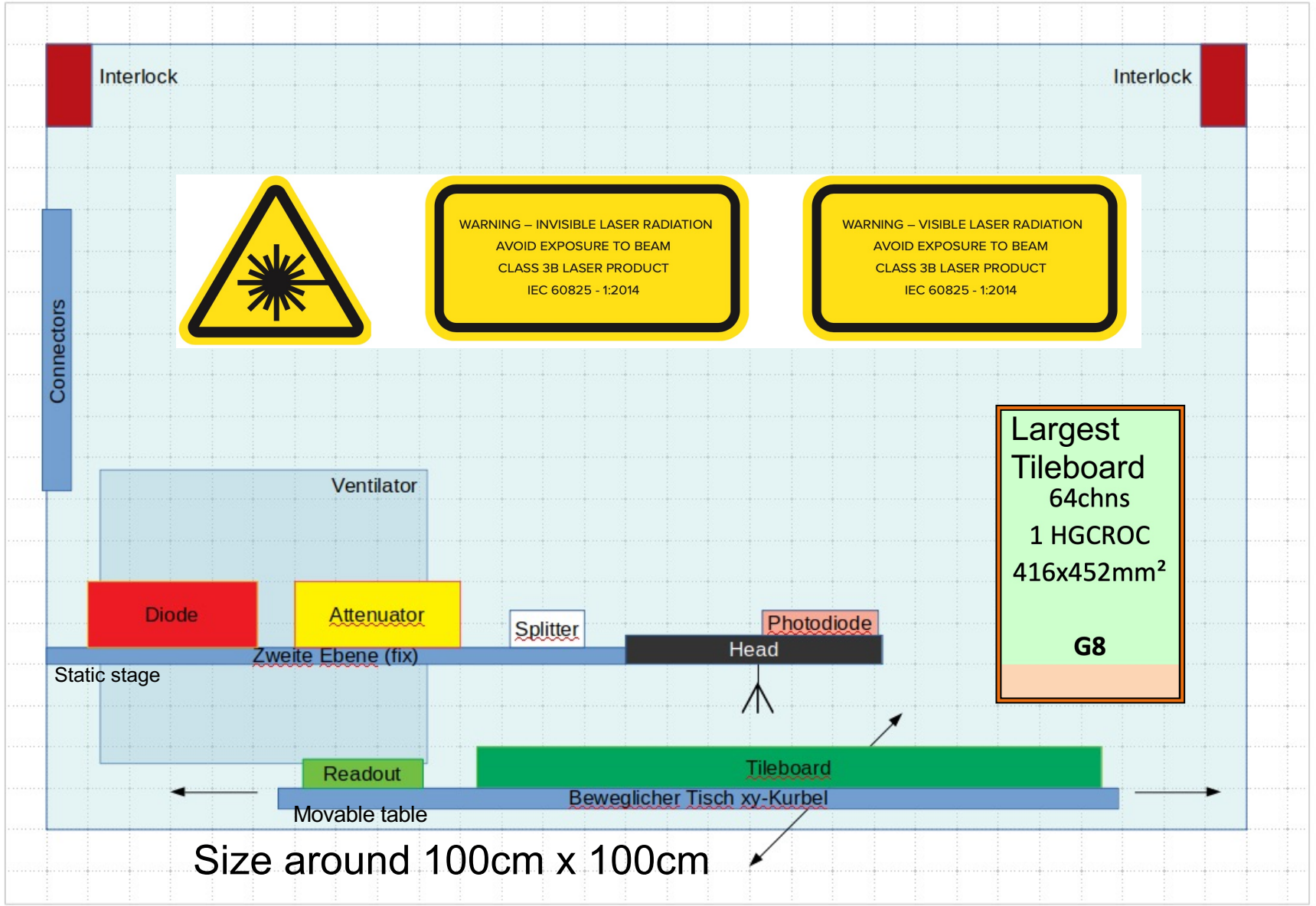
Measurement Box

Interlock Darkbox:
- 3B-Class Laser demands safety measures

Therefore:
- Create **large** scale interlock box to **be able to advance** from my **KLauS-Setup** to **HGCAL-Tileboard** setup in the further future
- **Saturation** evaluation with possible **HGCROC** non-linearities
- Consider complex geometries
- One fiber output, move tileboard in xy-plane to reach every channel

- **Reminder:** KLauS+SiPM-Board much smaller and easy geometry

Received recommendation:
- Completely separate darkbox and laser diode to guarantee clean measurements



Summary and Outlook

Motivation:

- HGCAL SiPM quality control in large quantities
- Understand SiPM behavior for large signals

Status:

- Design process of a secure darkbox
- Assemble fiber system
- Testing and understanding KLauS-Sensorboard

Outlook:

- First tests of multiple SiPMs
- Installation of the laser + control
- First full SiPM-Board evaluation with laser

Kontakt

Deutsches Elektronen-
Synchrotron DESY

Timo Christian
FTX, DTA

www.desy.de

Timo.christian@desy.de

Backup

SiPM-Saturation II

PROTOTYPE No. S16713-01(ES1), -02(ES1), -03(ES1)

Three different SiPM sizes:

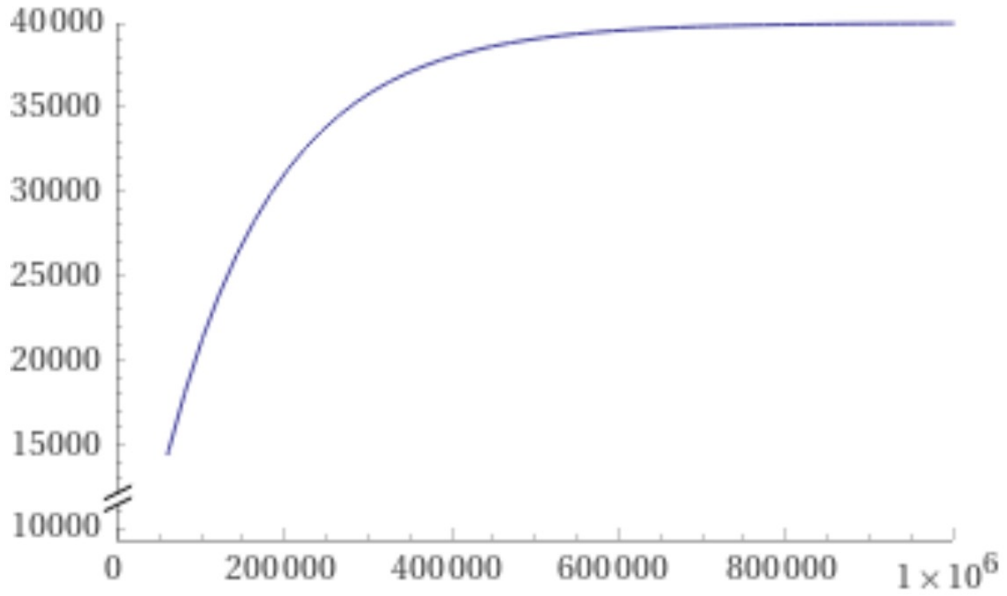
9000 pixel on 1.4x1.4 mm2

17000 pixel on 2.0x2.0 mm2

40000 pixel on 3.0x3.0 mm2

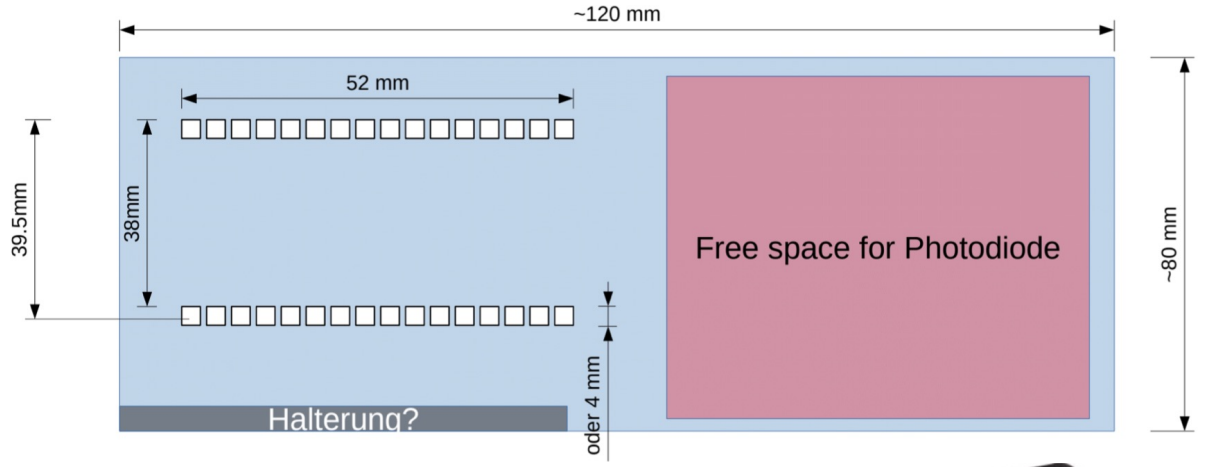
Simplest Exponential Model:

$$f_{Saturation} = N_{Pixel}\left(1 - exp\left(-\frac{\epsilon_{PDE} \cdot N_{\gamma}}{N_{Pixel}}\right)\right)$$



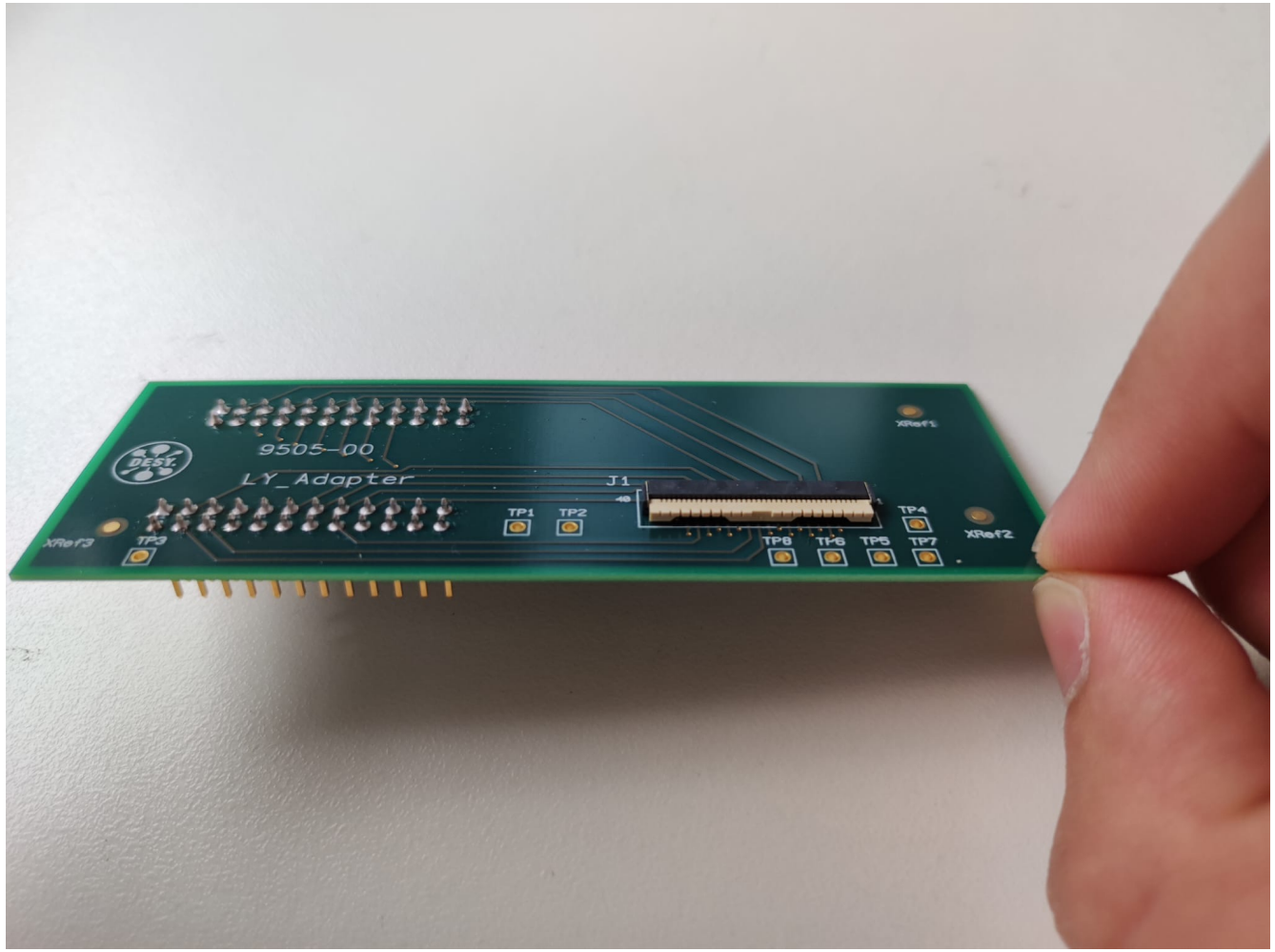
Fiber Head for Quality Assurance

- Splitter 1x32, off spectrum (1200-1600nm)
- Plastic head holding fibers
- No movement required
- Laser monitoring with a Si detector element



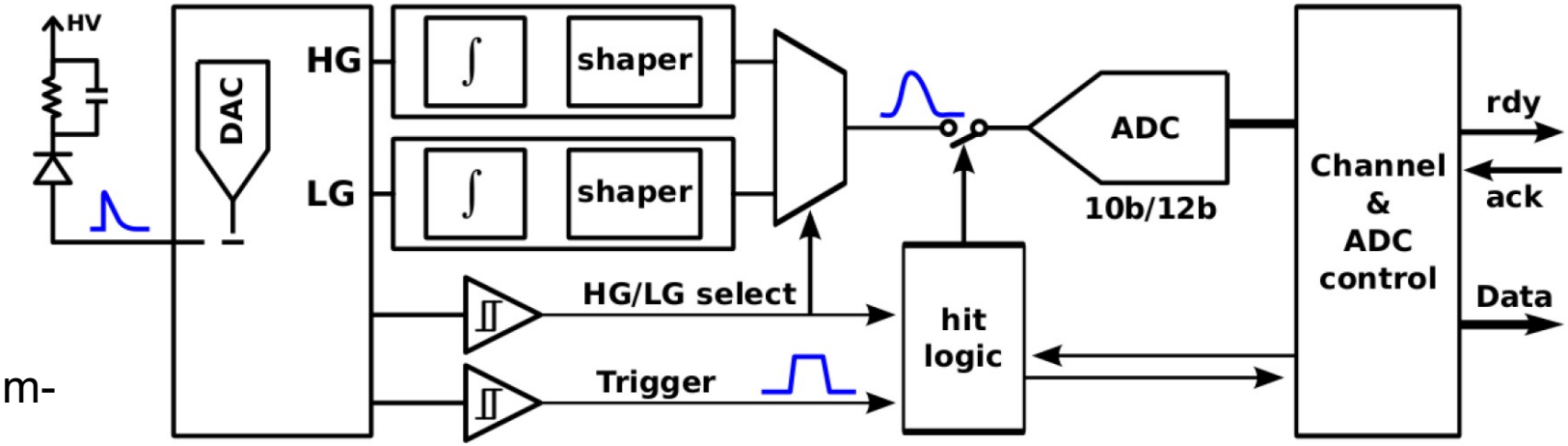
Item #	Wavelength	Detector	Bandwidth	Max Peak Power	Rise Time	Fall Time
DET02AFC	400 - 1100 nm	Si	1 GHz	18 mW	1 ns (Max)	1 ns (Max)
DET025AFC	400 - 1100 nm	Si	2 GHz	18 mW	150 ps (Typ.)	150 ps (Typ.)

Adapter and Fiber Head



KLauS6

Introduction by Erik and Konrad



Kanäle für die **L**adungs**au**slese von **S**ilizium-Photomultipliern:

- 36-channel ASIC
- Auto/External triggered
- High precision charge measurement with integrated ADC/TDC
- Charge: Dynamic range up to 450pC (4 gain configurations: High-Gain down to Ultra-Low-Gain)
- Timing: Dynamic range 3.2ms with 200ps bin sized timestamps utilizing a 40MHz reference clock
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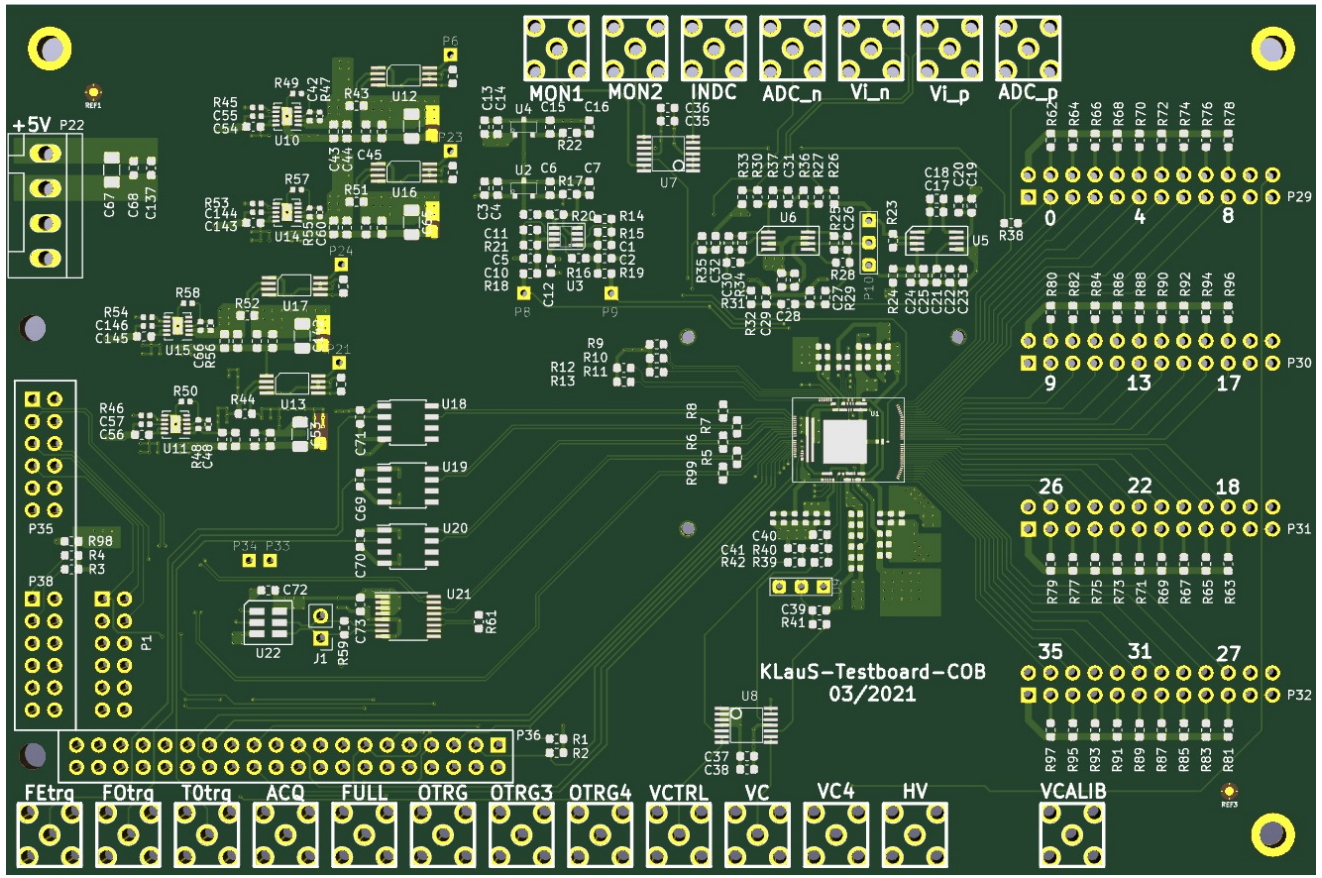
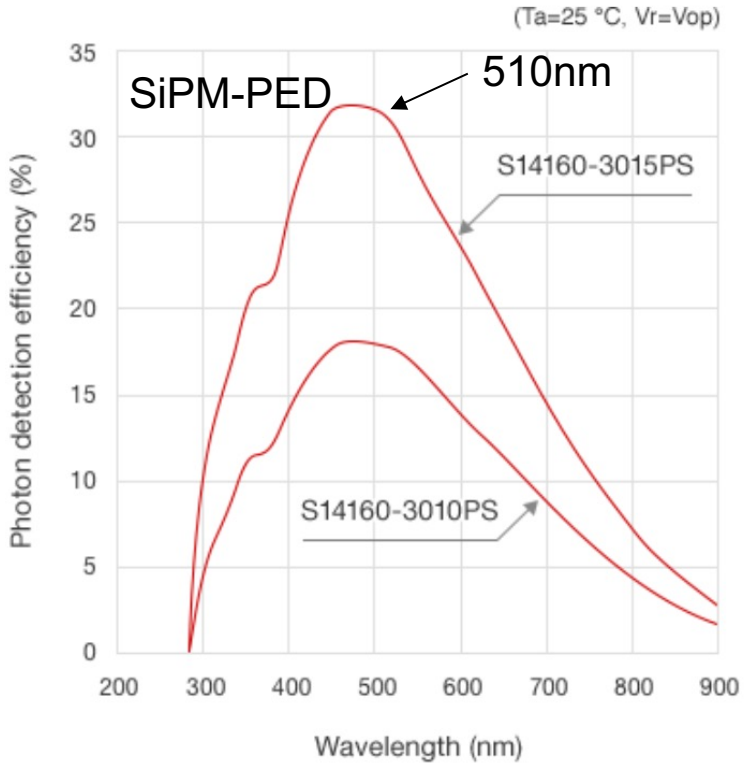
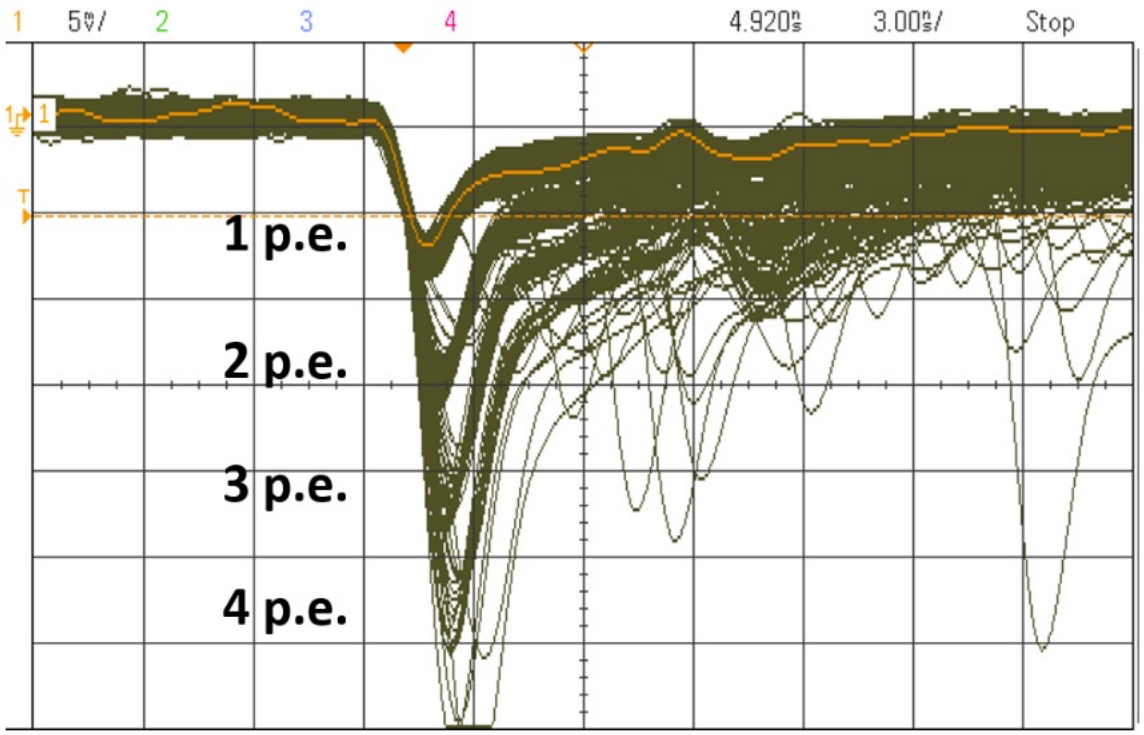


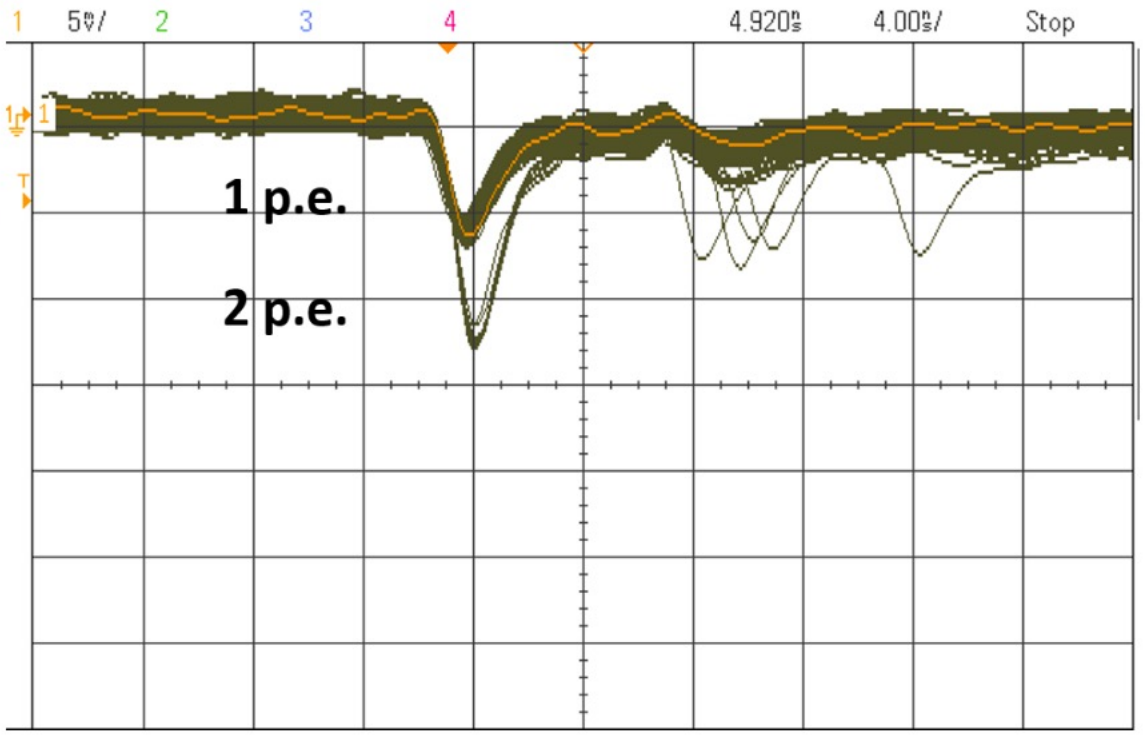
Laser

Model	Output	Wavelength	Spectral width	Pulse width	Peak power	Avg. power [1)]	Max. repetition rate
PIL051-FC	FC/APC	510 ± 15 nm	< 10 nm	< 110 ps	> 40 mW	> 0.2 mW	40 MHz



Crosstalk


1
5mV/
2
3
4
4.920ns
3.00ns/
Stop
1 p.e.
2 p.e.
3 p.e.
4 p.e.

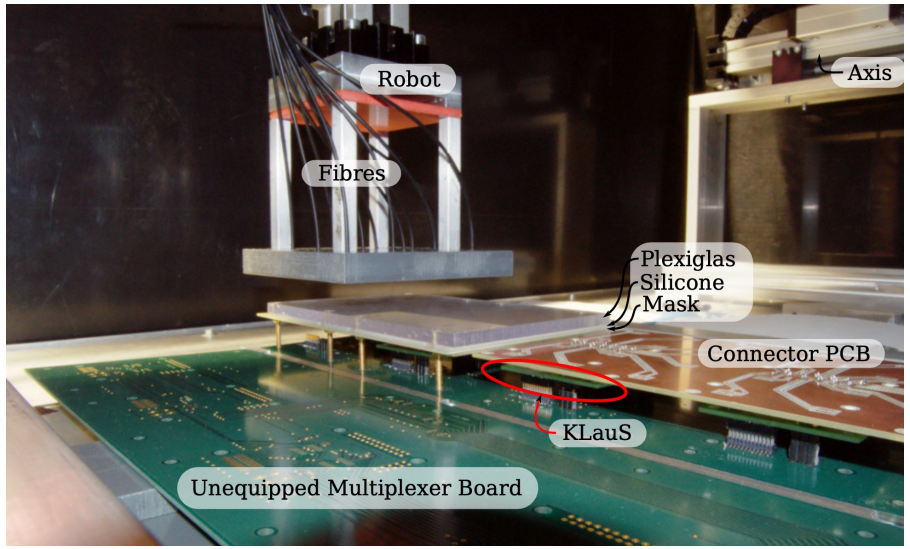

1
5mV/
2
3
4
4.920ns
4.00ns/
Stop
1 p.e.
2 p.e.

Previous Setups

Large-Tile-Tester, Heidelberg

Bachelor/Master Thesis

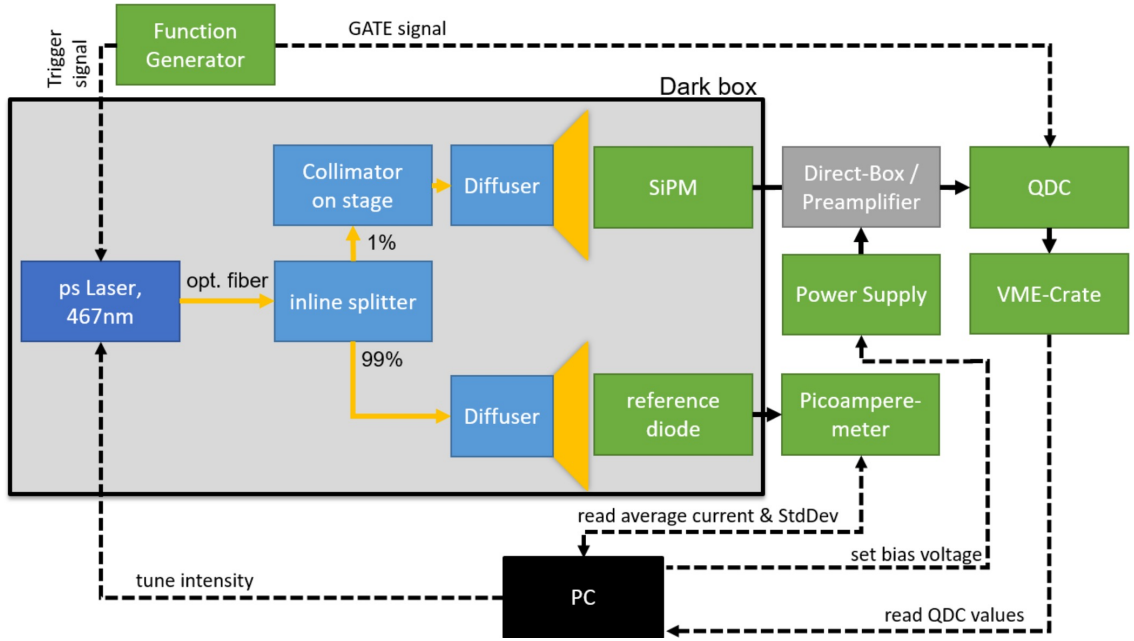
Felix Passenberg/Thorwald Klapdor-Kleingrothaus



- High quantity SiPM testing for ILD
- Automated measurements
- Fiber system on a robot head

Saturation Measurements, Mainz

Dissertation of Sascha Krause



- High intensity illumination
- Saturation region of SiPM with max 2668 Pixels
  -> ≈ 40000 Pixels for our tests