A fast muon track tag for the CMS Level 1 trigger @ SLHC

Jörg Rennefeld

RWTH Aachen 3B
Achim Stahl, Oliver Pooth, Günter Flügge
in collaboration with
RWTH Aachen 3A
Thomas Hebbeker, Jens Frangenheim,
Paul Papacz, Markus Merschmeyer

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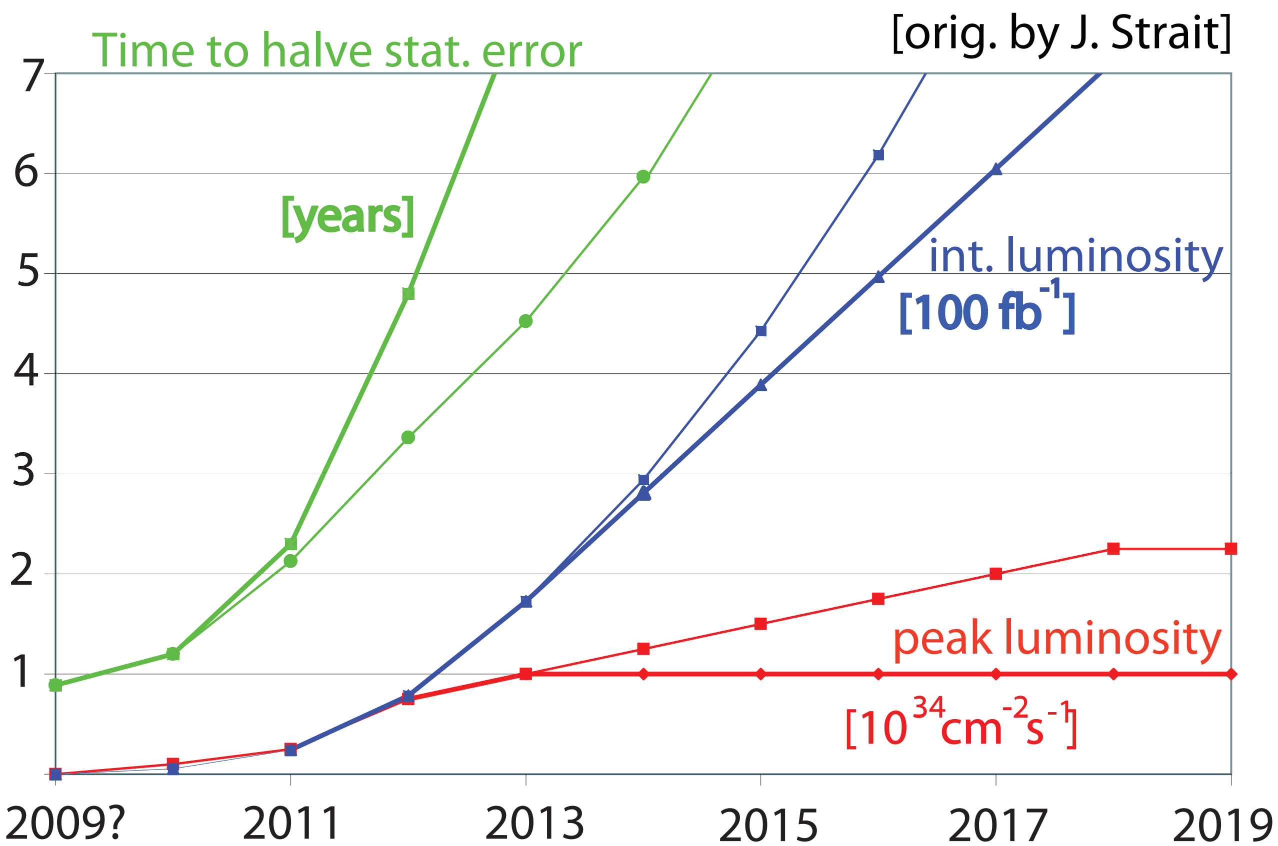
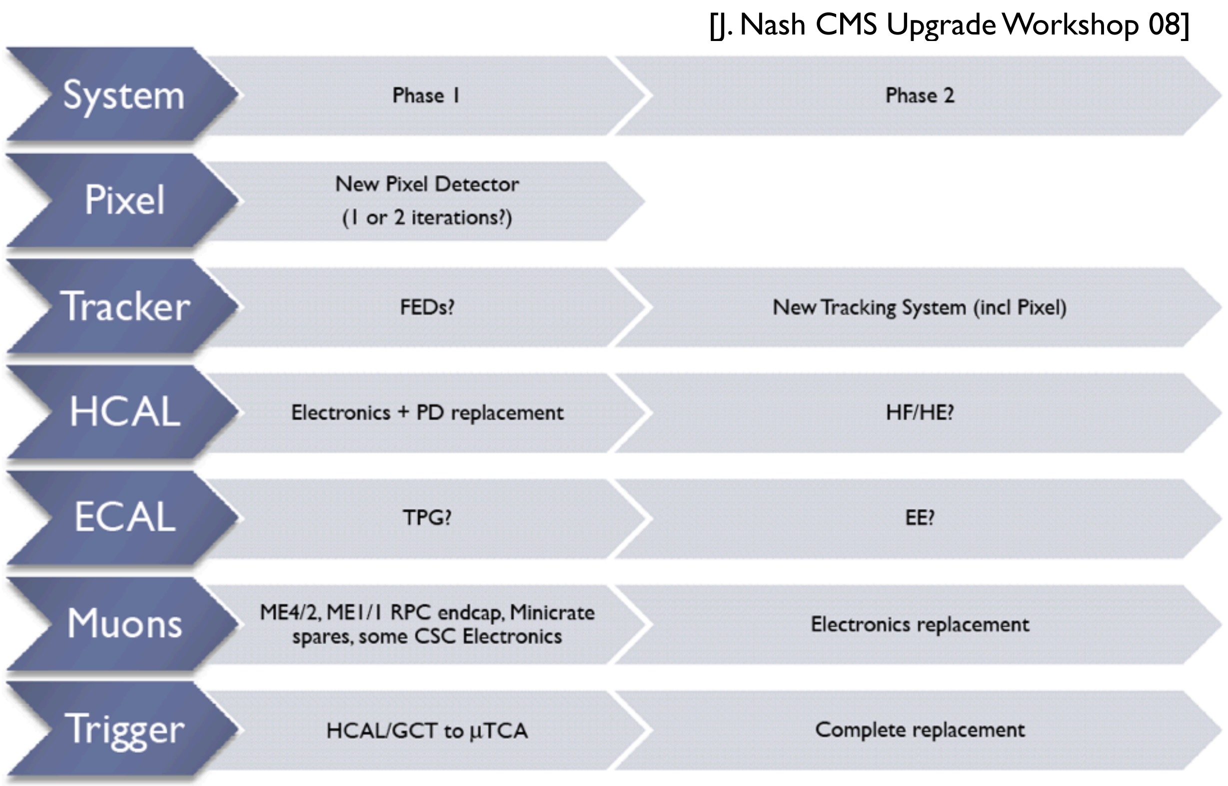
Overview

- Motivation LHC Upgrade
- Motivation MTT
- Activities in Aachen 3. Inst.
  - Scintillator Simulation
  - Studies on SiPM properties

Motivation LHC upgrade



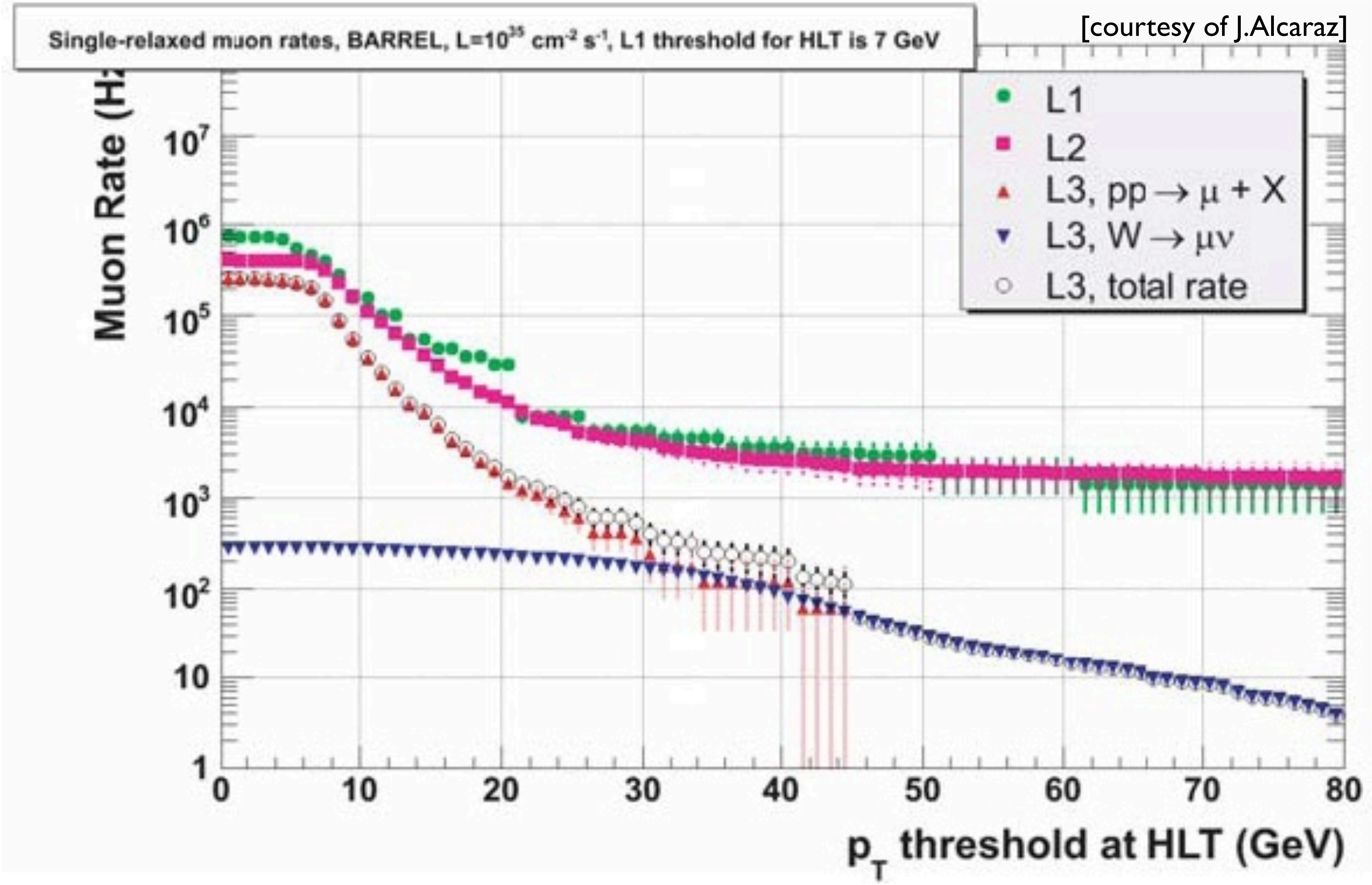


SLHC: continuous upgrades of machine and detectors in different phases

Main Goal: get more statistics → increase luminosity (~10^{35} cm^{-2}s^{-1}peak)

also: replace and improve of end of life components

MTT Motivation



SLHC: keep L1 trigger rate O(10 kHz) for single muons

→ There may not be enough rejection power using the current trigger to handle the higher luminosity conditions at SLHC

→ Adding tracking information at L1 gives the ability to adjust transverse momentum (p_t) thresholds

Muon Track fast Tag (MTT)

Idea: fast 2D Detector just beyond the Calorimeters and Solenoid.

Constraints for the Detector:

- Has to cover large area (~300 m^2)
- Not much space at designated location (~10 mm)
- Has to be fast (< 10 ns signal rise time)

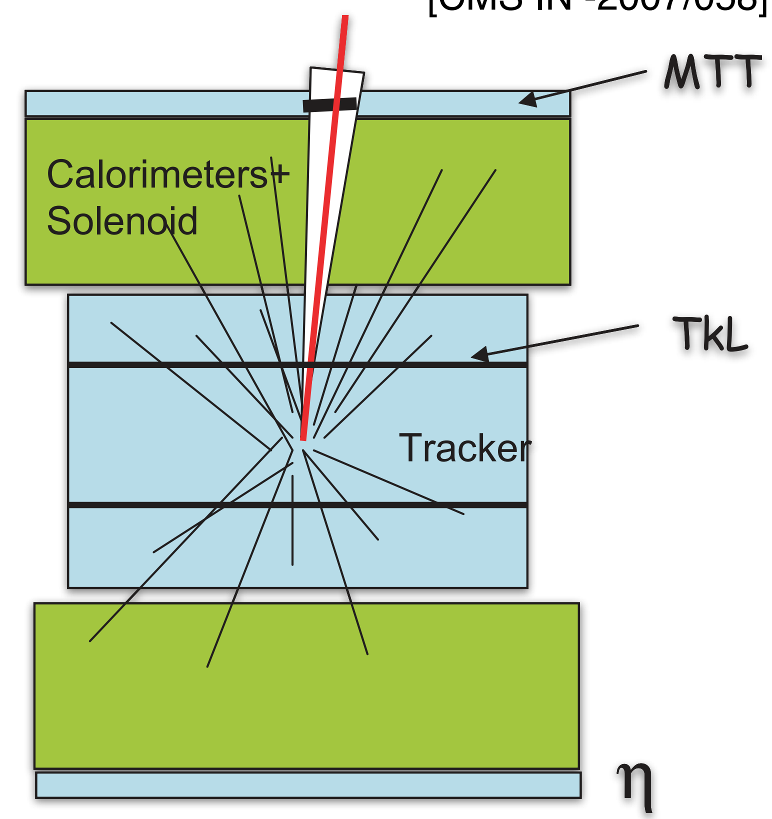
⇩

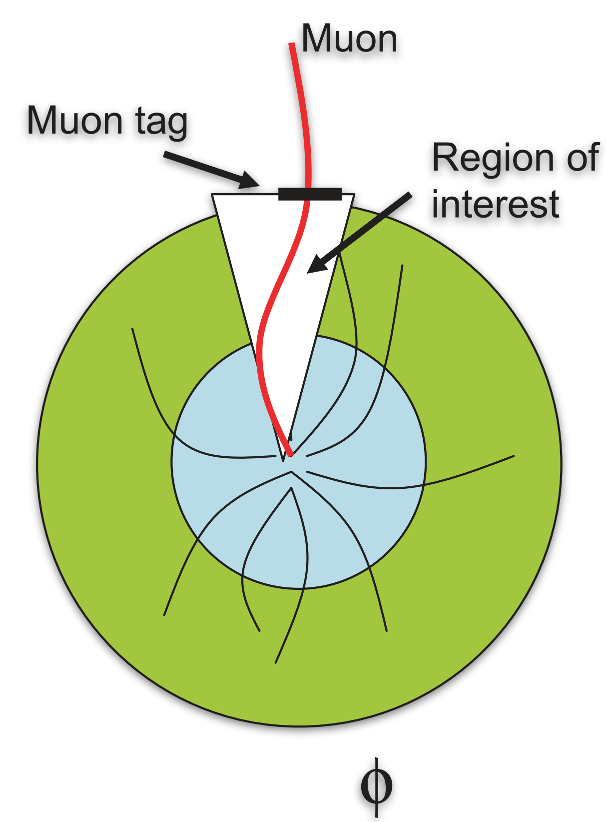
The detector comprises plastic scintillator tiles read out by silicon photomultipliers

⇩

A hit in the detector defines a Region of interest in the tracker and allows for fast partial readout (static mapping)

[CMS IN -2007/058]





Muon Track fast Tag (MTT)

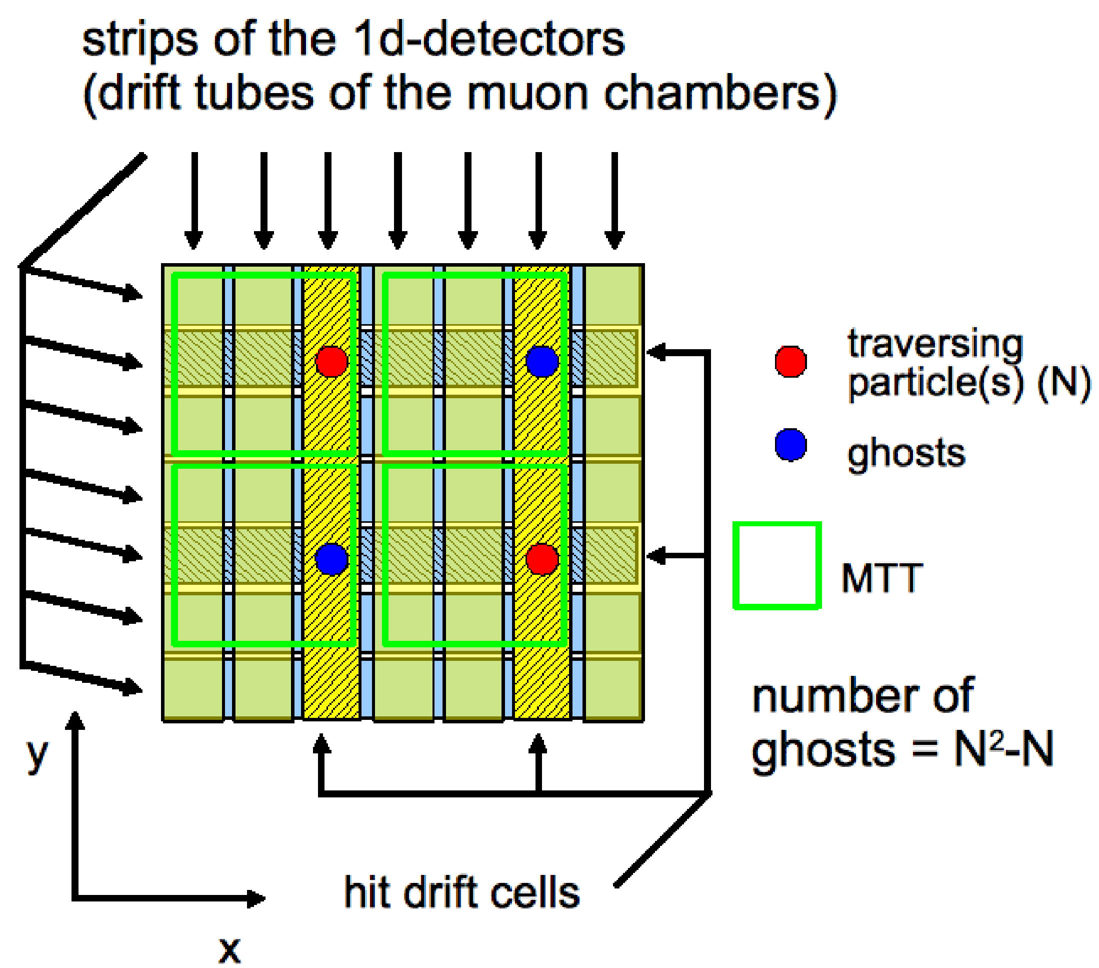
Tracker will most probably provide own L1 p_t trigger information

Designs under discussion: long Barrel vs. Hybrid

→ Tracker generates own track trigger

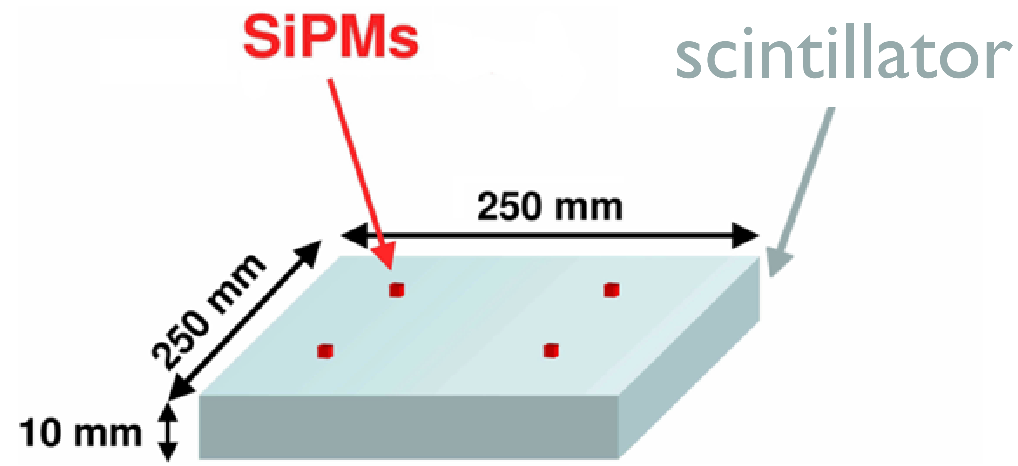
MTT still a good idea:

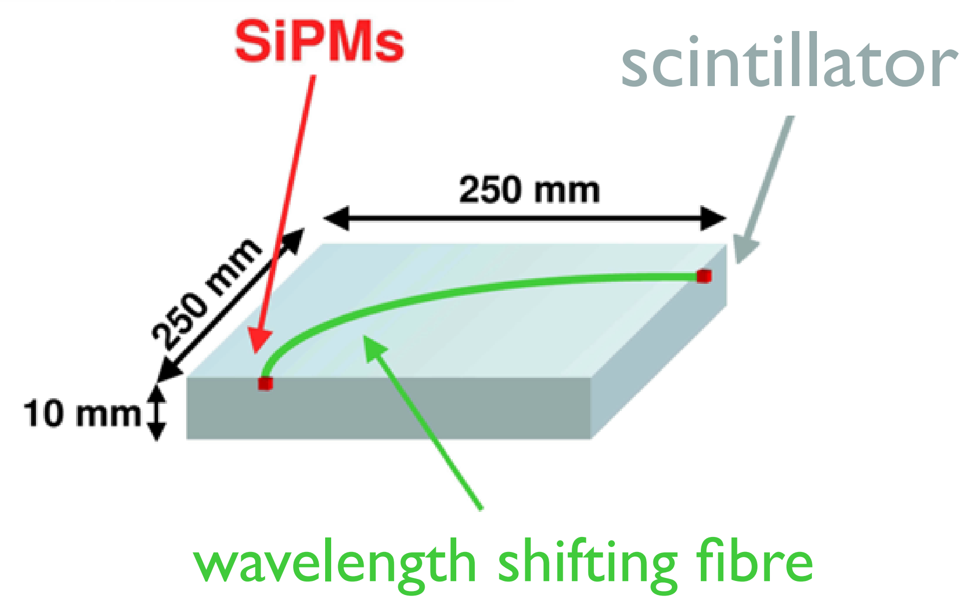
- ➡ tracker cannot identify muons
- ➡ can resolve muon ambiguities at high rates (ghost/fake suppression)
- ➡ trigger can be combined with tracker track trigger

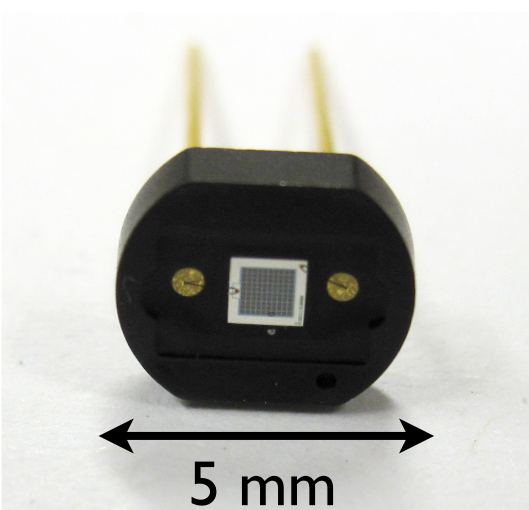


Experimental work in Aachen

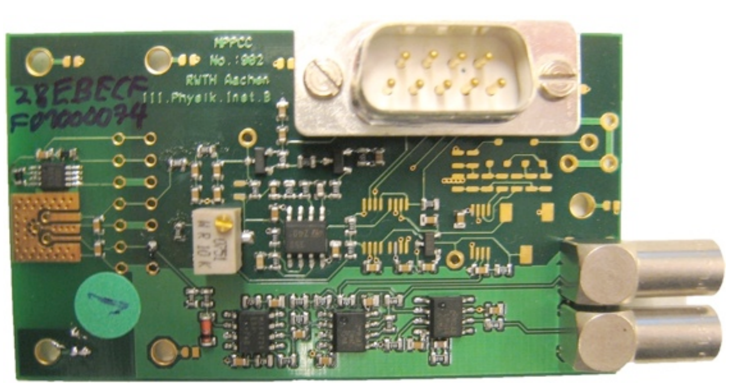
- Simulation of scintillator tiles
- Development of frontend (FE) electronics
- Studies on SiPM properties
- Planning and building detector prototypes







SiPM: Array of geiger-mode APDs



SiPM prototype FE

Simulation of detector prototypes

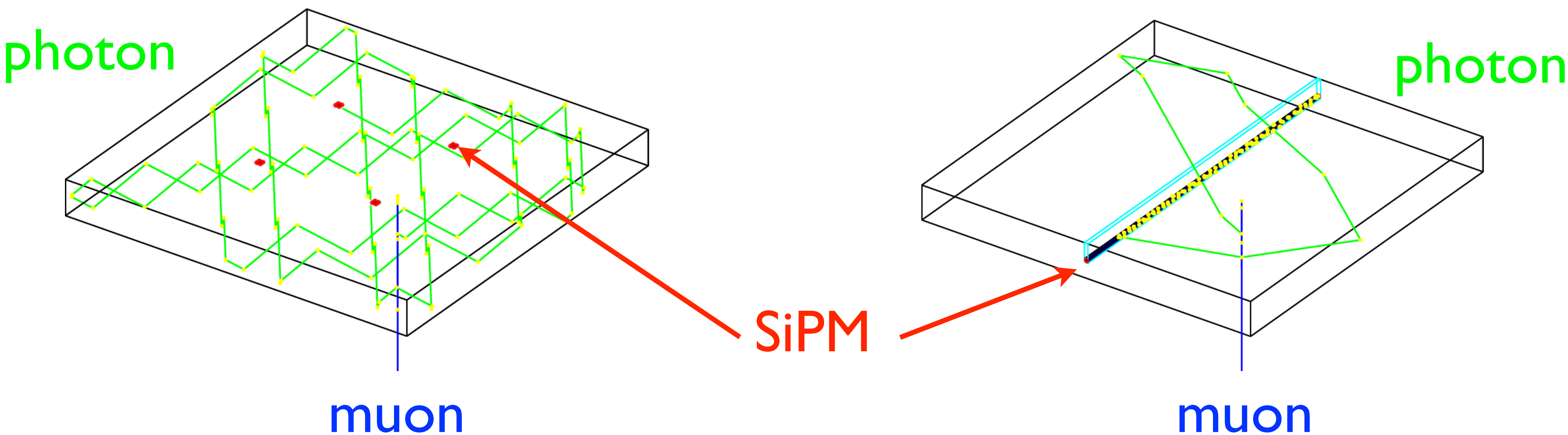
Model various (sizeable) prototypes with GEANT4.

- scintillator: 100 x 100 x 10 mm^3 (BC 404, *Bicron (Saint Gobain)*)
- (optional) wavelength shifting fibre (BCF 92, *Bicron (Saint Gobain)*)
  all properties according to data sheets

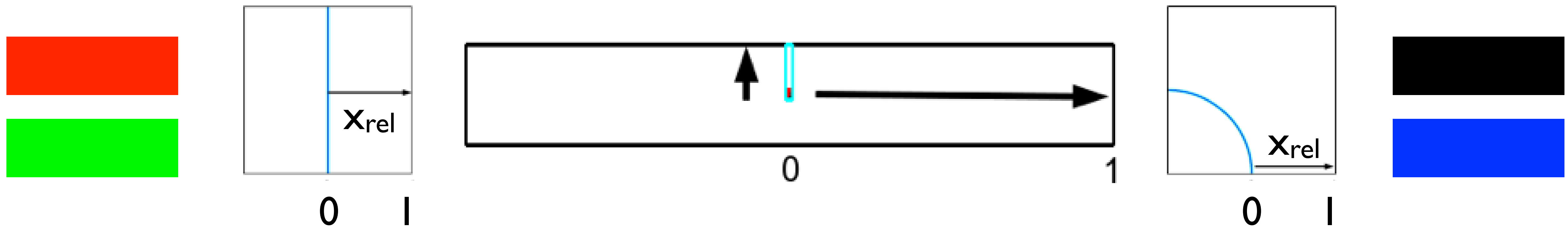
- SiPMs with realistic detection efficiencies (*Hamamatsu data sheets*)
- muon gun → 1 GeV muons homogeneously distributed across surface

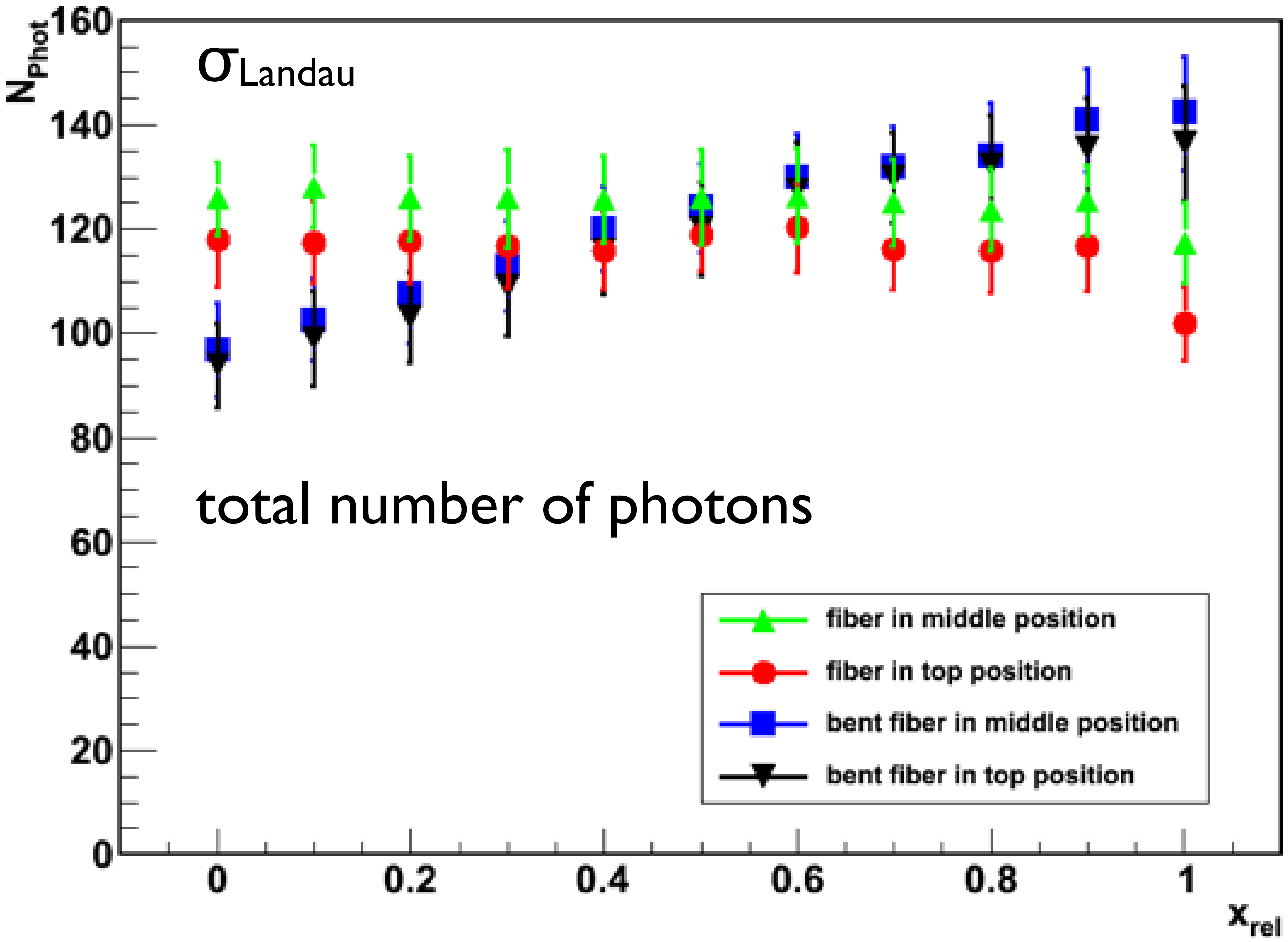
⇒ O(10000) photons per muon, each tracked individually

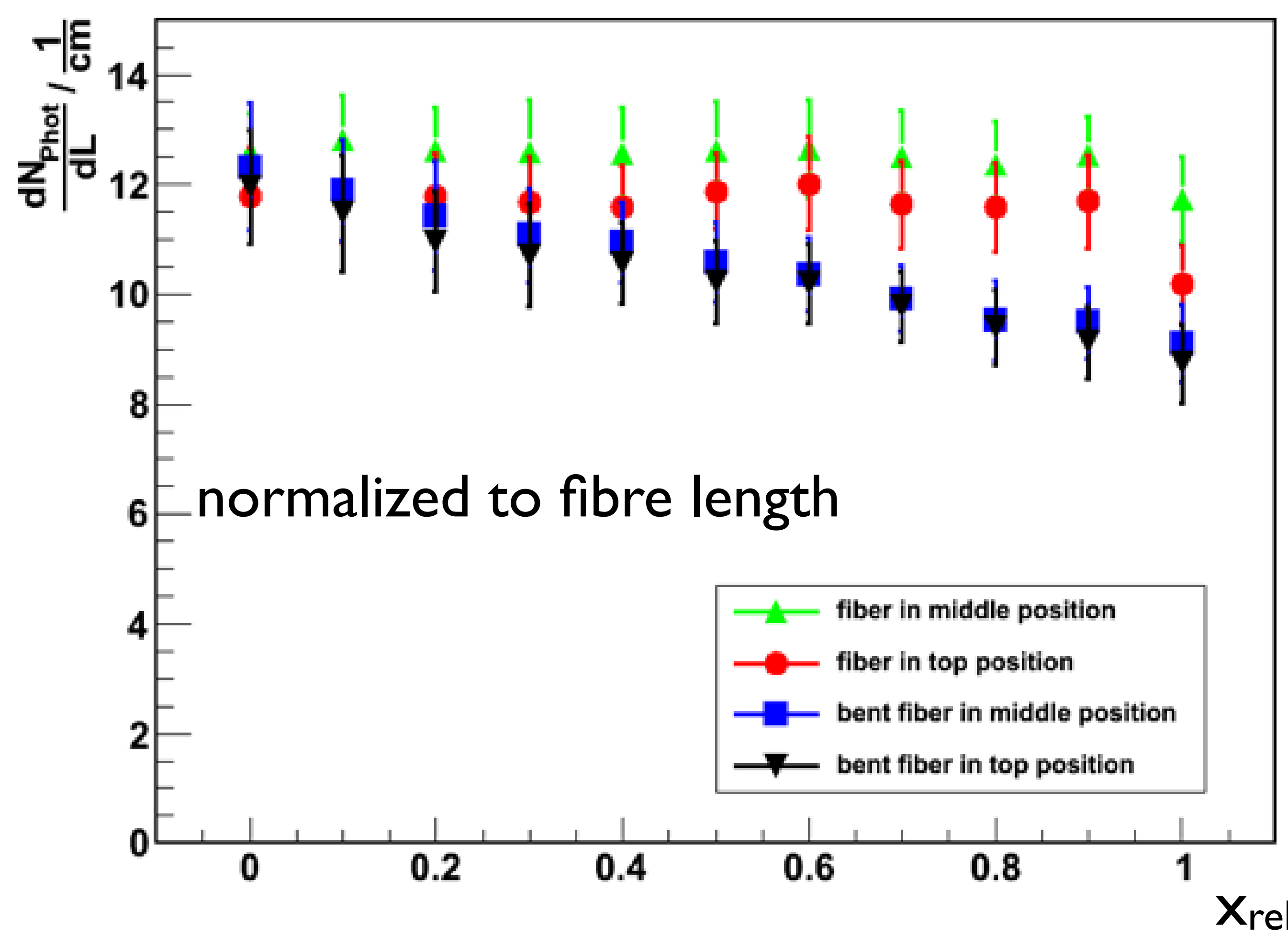
direct readout | **readout via wavelength shifting fibre**



bent vs. straight fibre



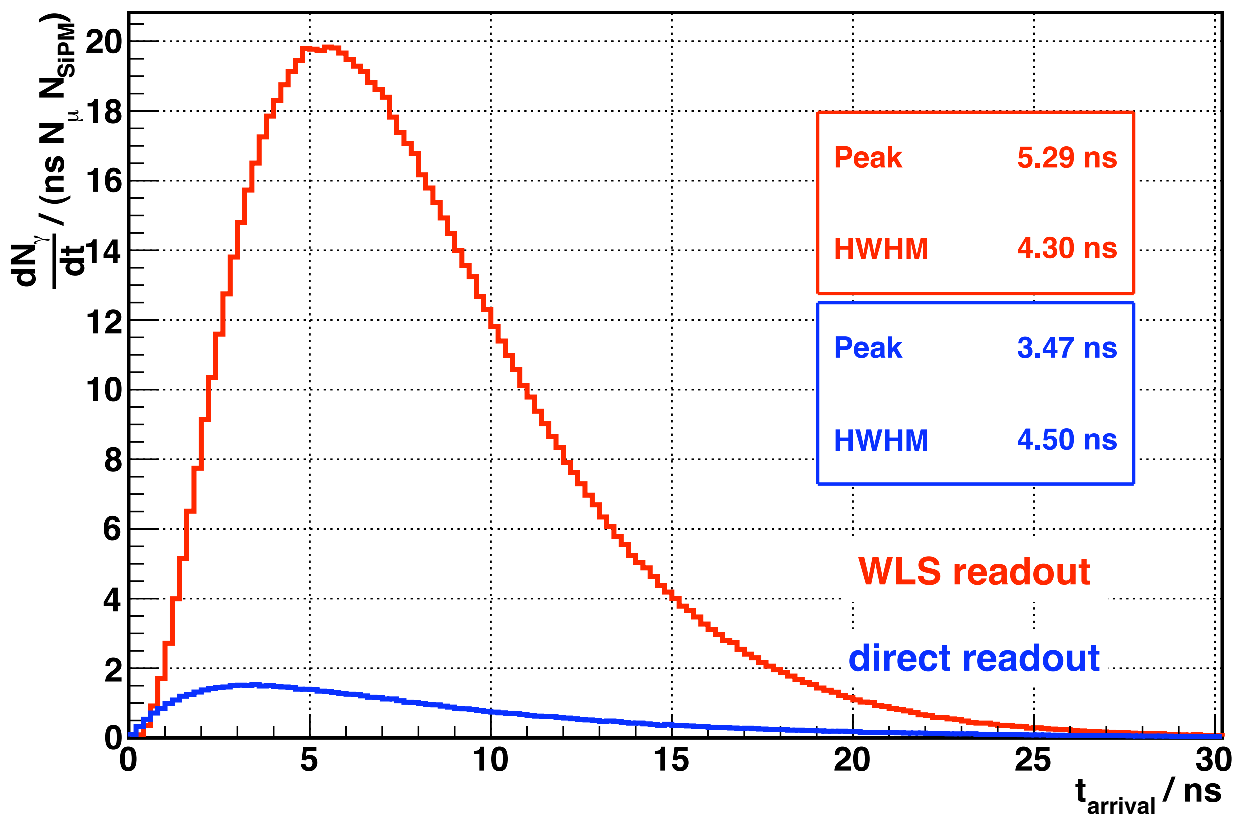


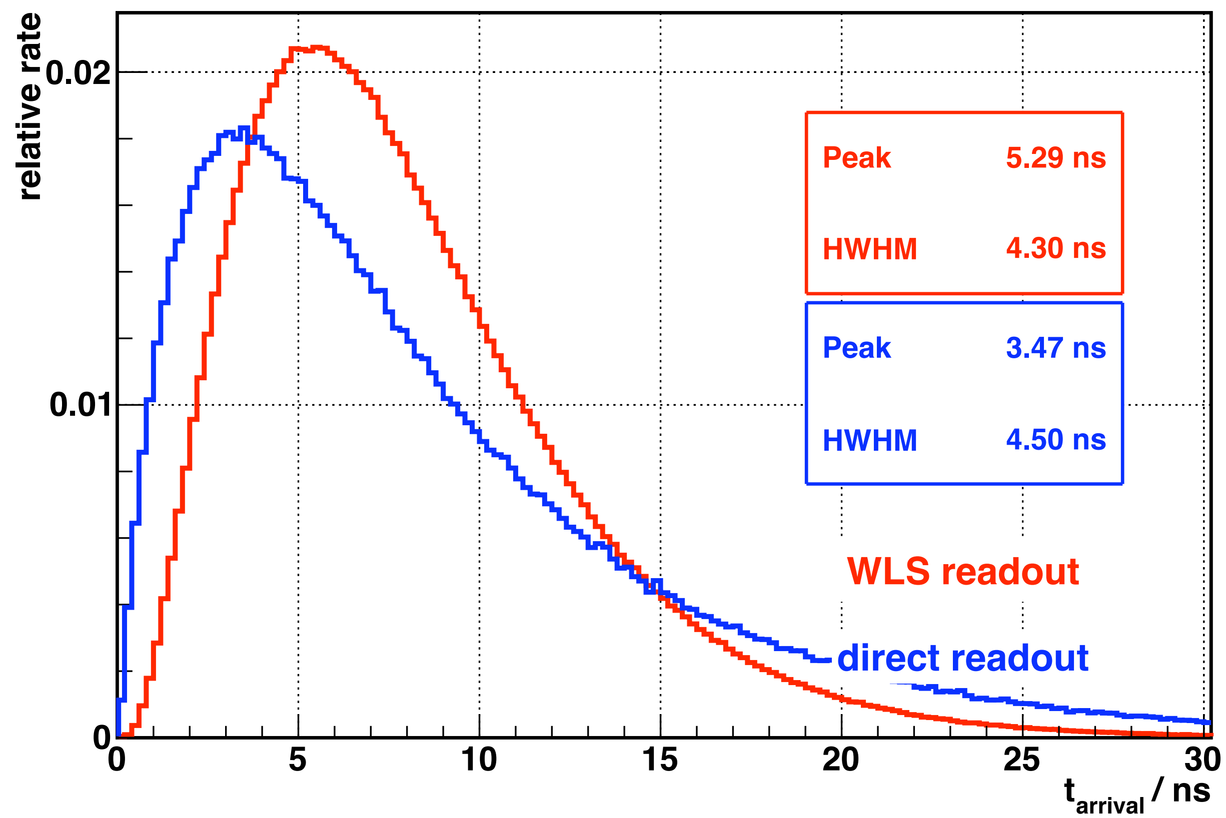


⇒ Photon collection marginally better with bent fibre.

But: additional mechanical effort for groove and bending the fibre may not be justified

Photon arrival time





Prototype:
100 x 100 x 10 mm^2

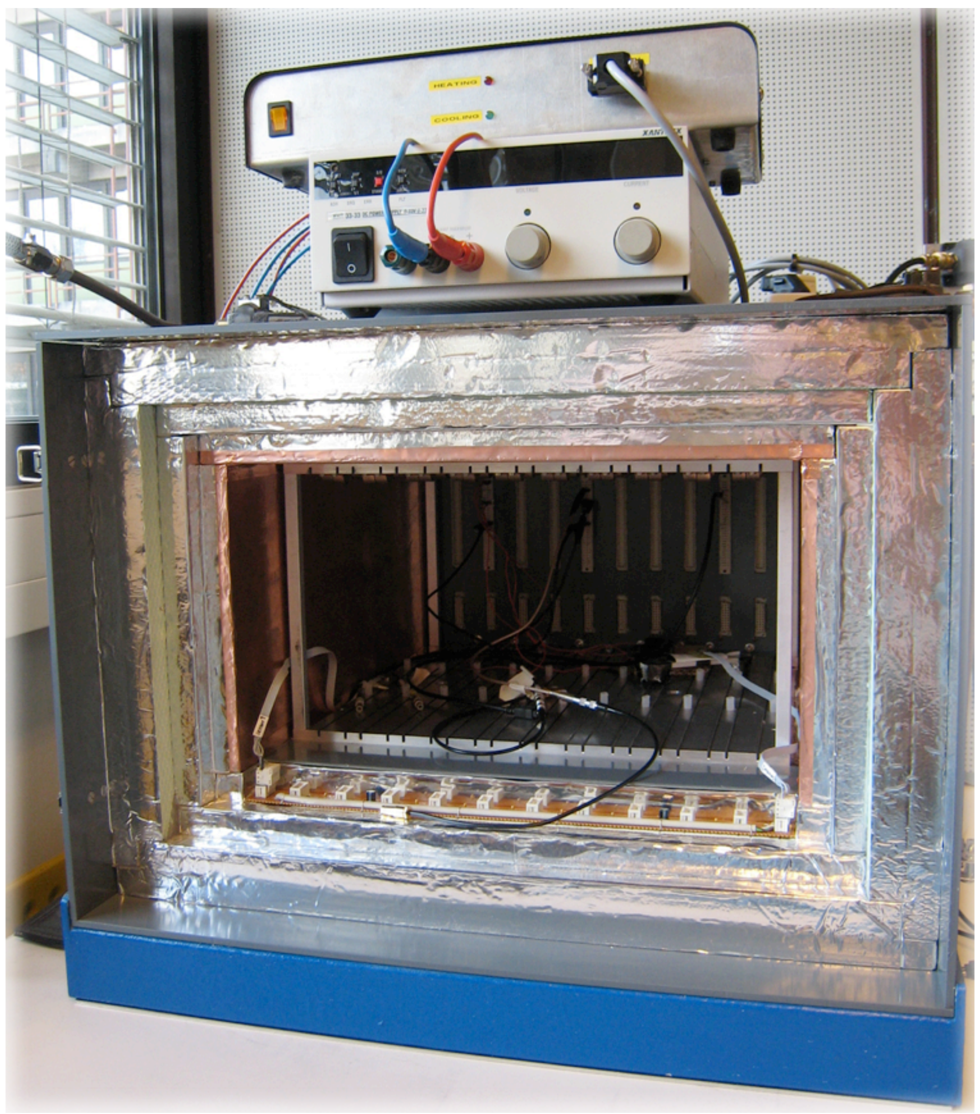
most photons arrive at SiPM in ~20 ns
→ no timing problems?!

needs to be the checked for
250 x 250 x 10 mm^2

NB:
diffuse reflector 98% reflectivity

Studies on SiPM properties

SiPM Signals vary strongly with op. temp and bias voltage
→ dependencies need to be studied and understood

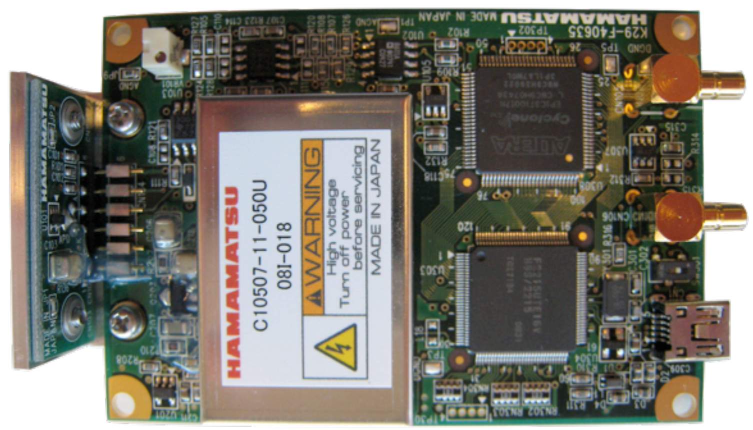


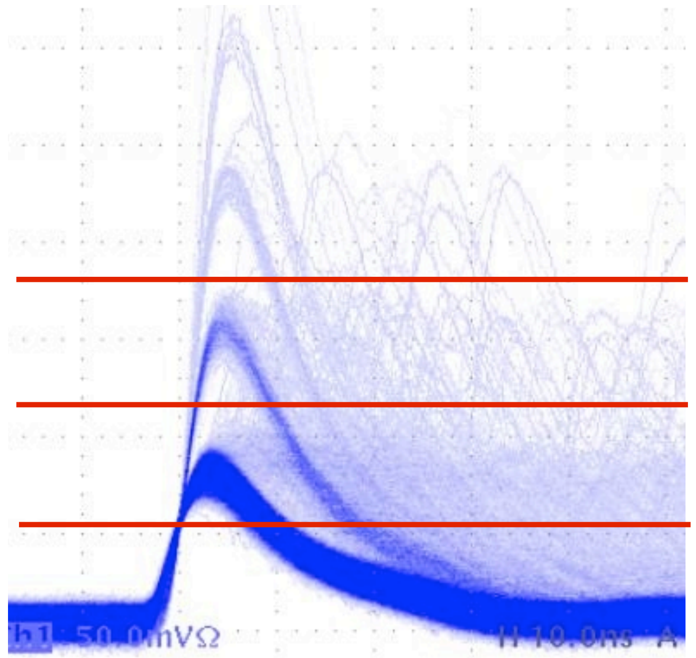
former Si strip sensor testbox allows for temp measurements in controlled env.

Fast DSO and FADC for pulse digitisation

pA sourcemeter for very precise current and voltage characteristics

Hamamatsu eval. Kit



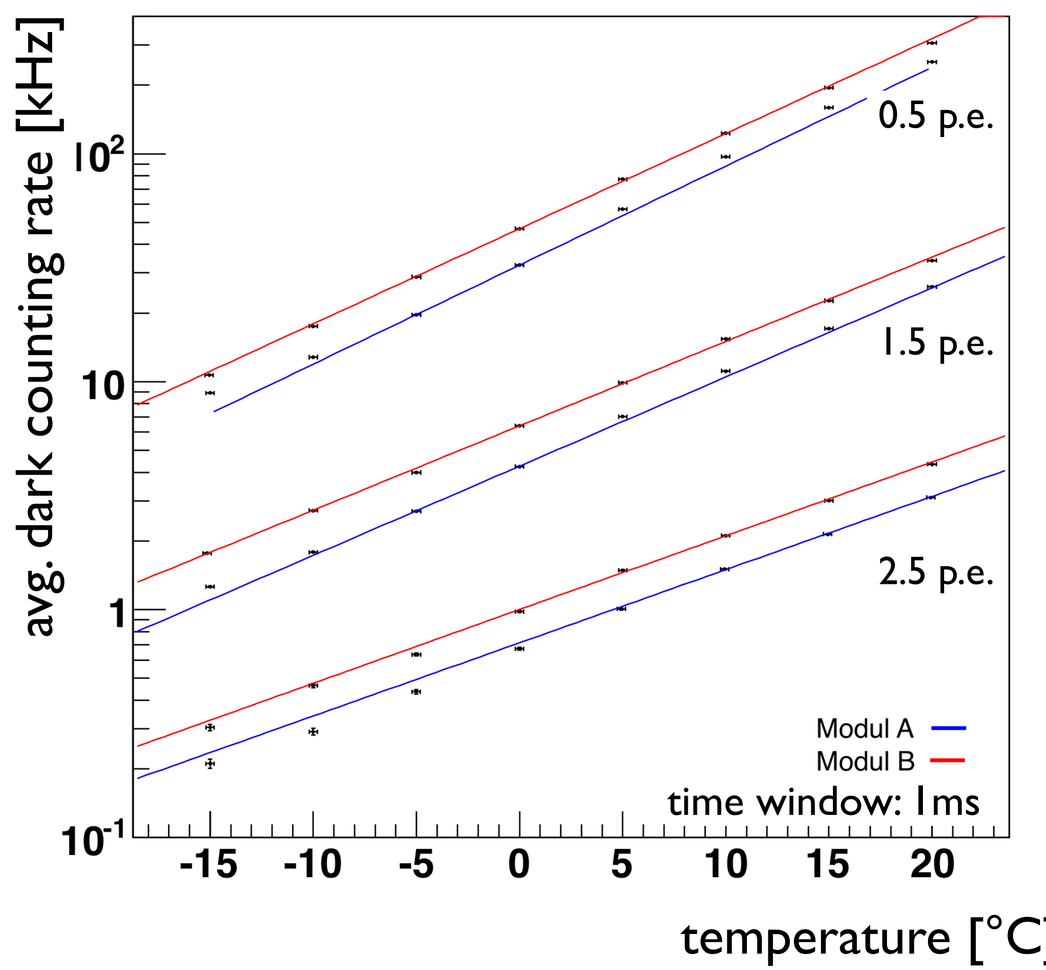


lessons learned from Ham. eval. Kit:

- temp. stabilisation of analog output possible
- compact printed circuit board (PCB) with preamp, voltage regulation and ADC possible
- BUT: Be careful with interferences between the analog and digital parts of the PCB!

⇩

Input for the Development of our own SiPM frontend



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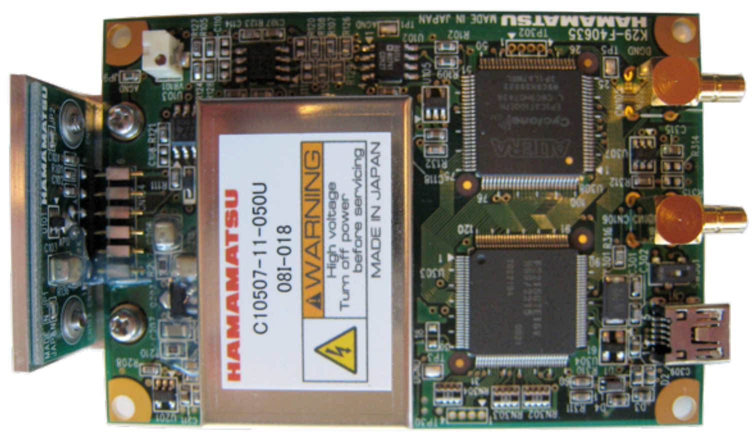

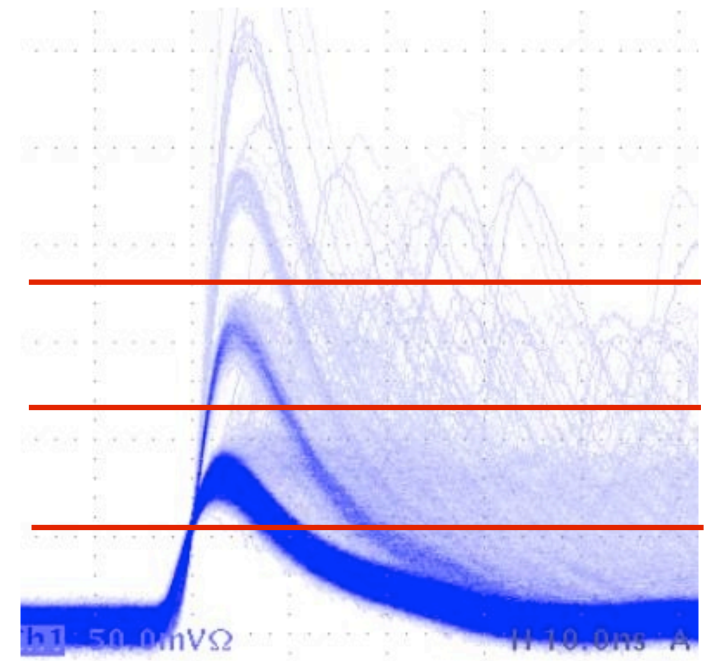

2.5 p.e.

1.5 p.e.

0.5 p.e.

photon aquivalent (p.e.) discriminator threshold

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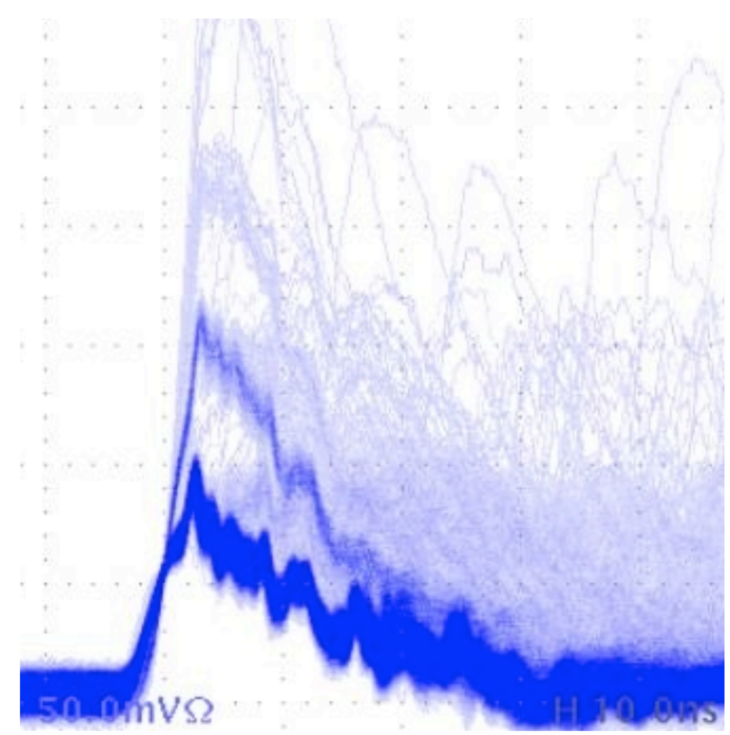
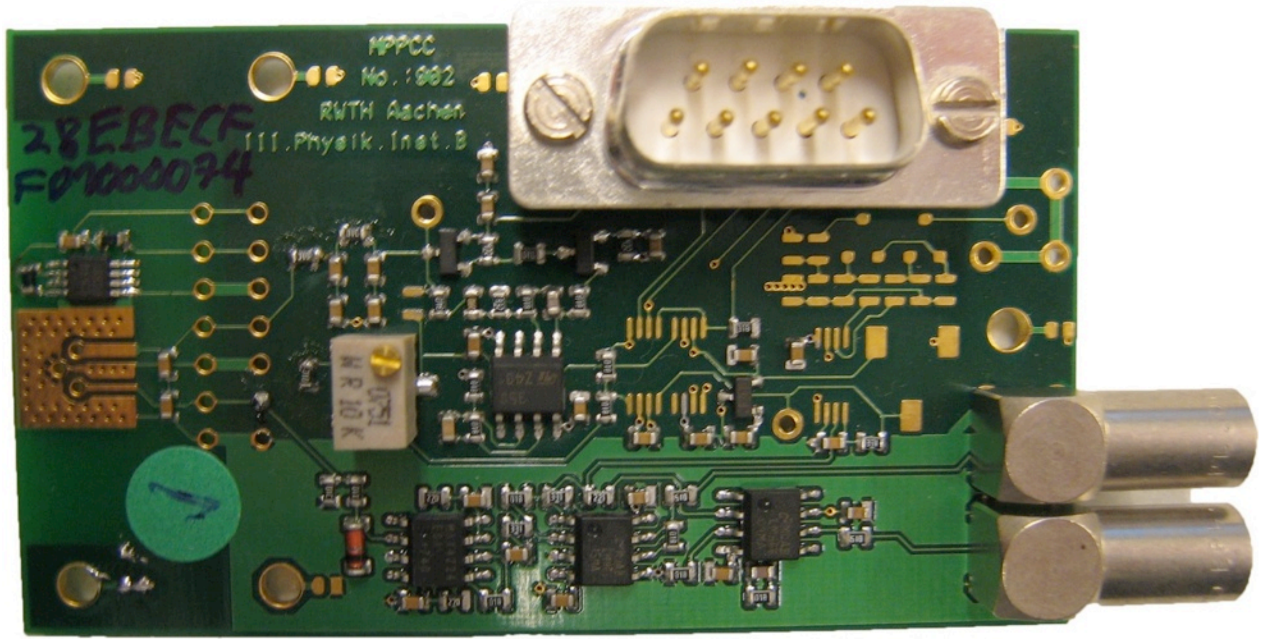


AC 3B SiPM frontend

Development of own SiPM frontend started



Current Prototype includes:

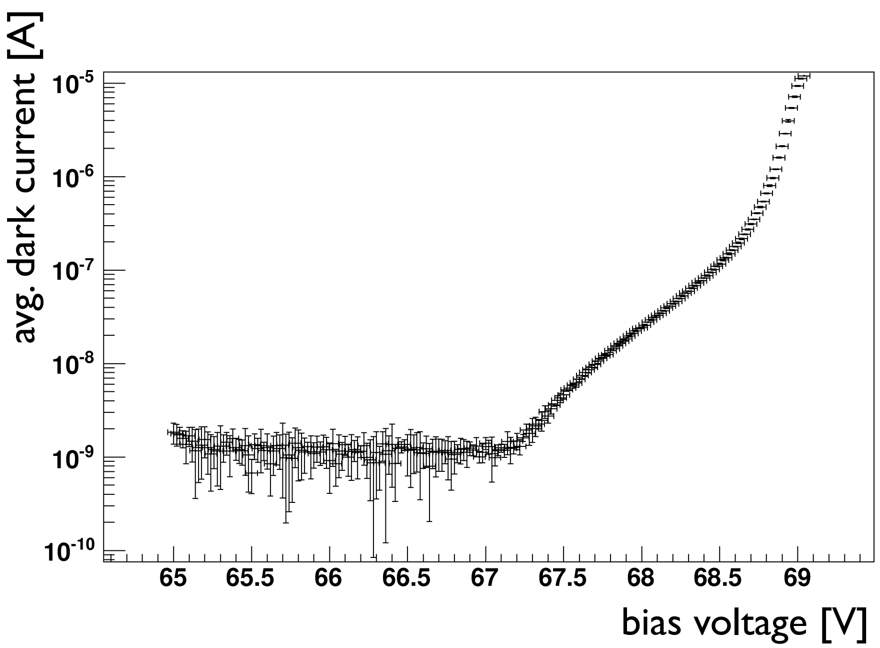
- pre amplifier
- voltage regulator
- temp sensor
- fast and slow analog outputs

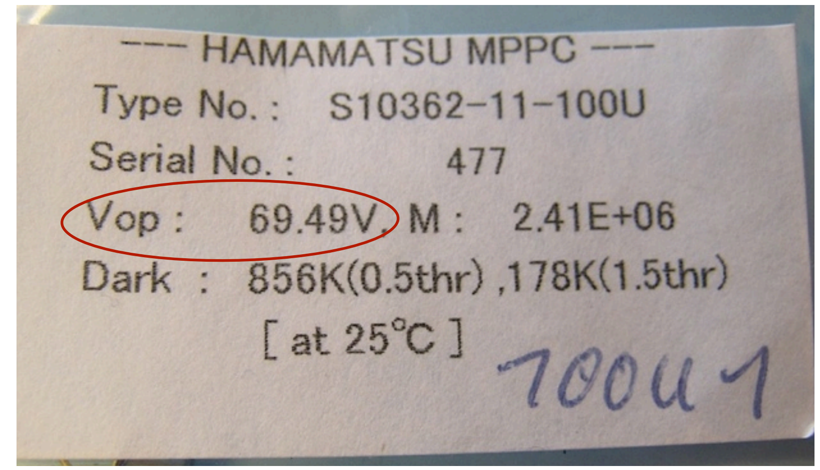
Currently working on solution to counteract gain fluctuation caused by temperature changes.

→ use dark current as a criterion

Idea: measurement of precise current - voltage characteristics for each sensor before use. Predetermine optimal operation voltage (V_{op}) for a set of temperatures.

I / V curves

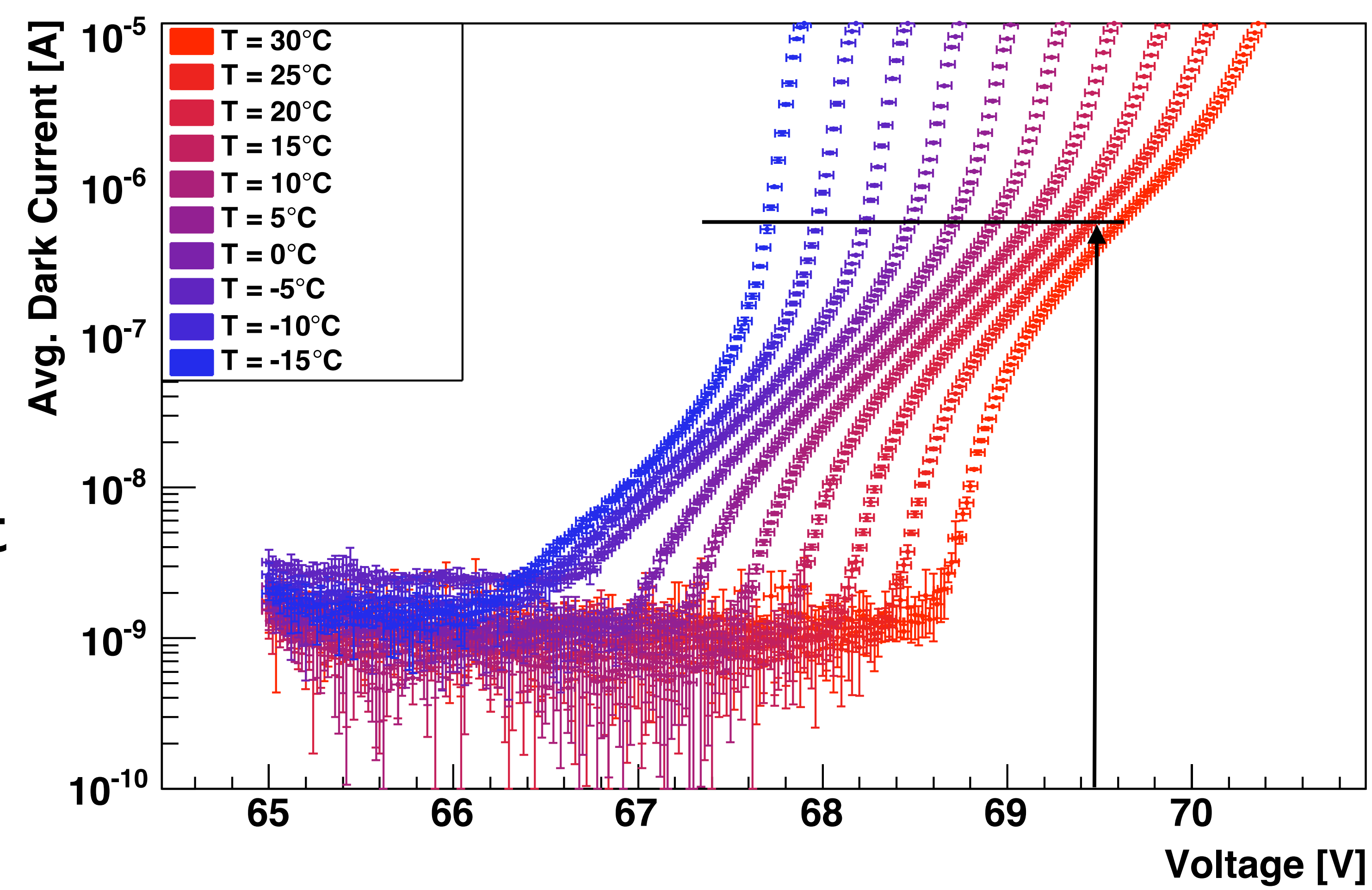




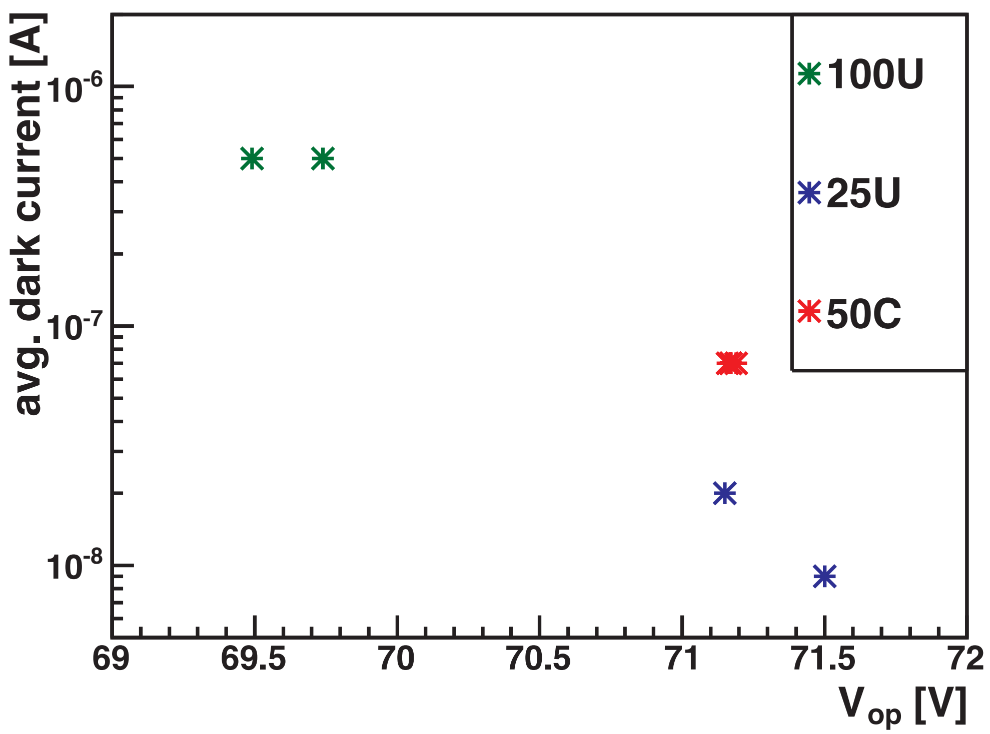
Hamamatsu suggests optimal V_{op} for their shipped sensors (at 25 °C)

Idea: use measured dark current for that operating condition and correct V_{op} for temperature fluctuation

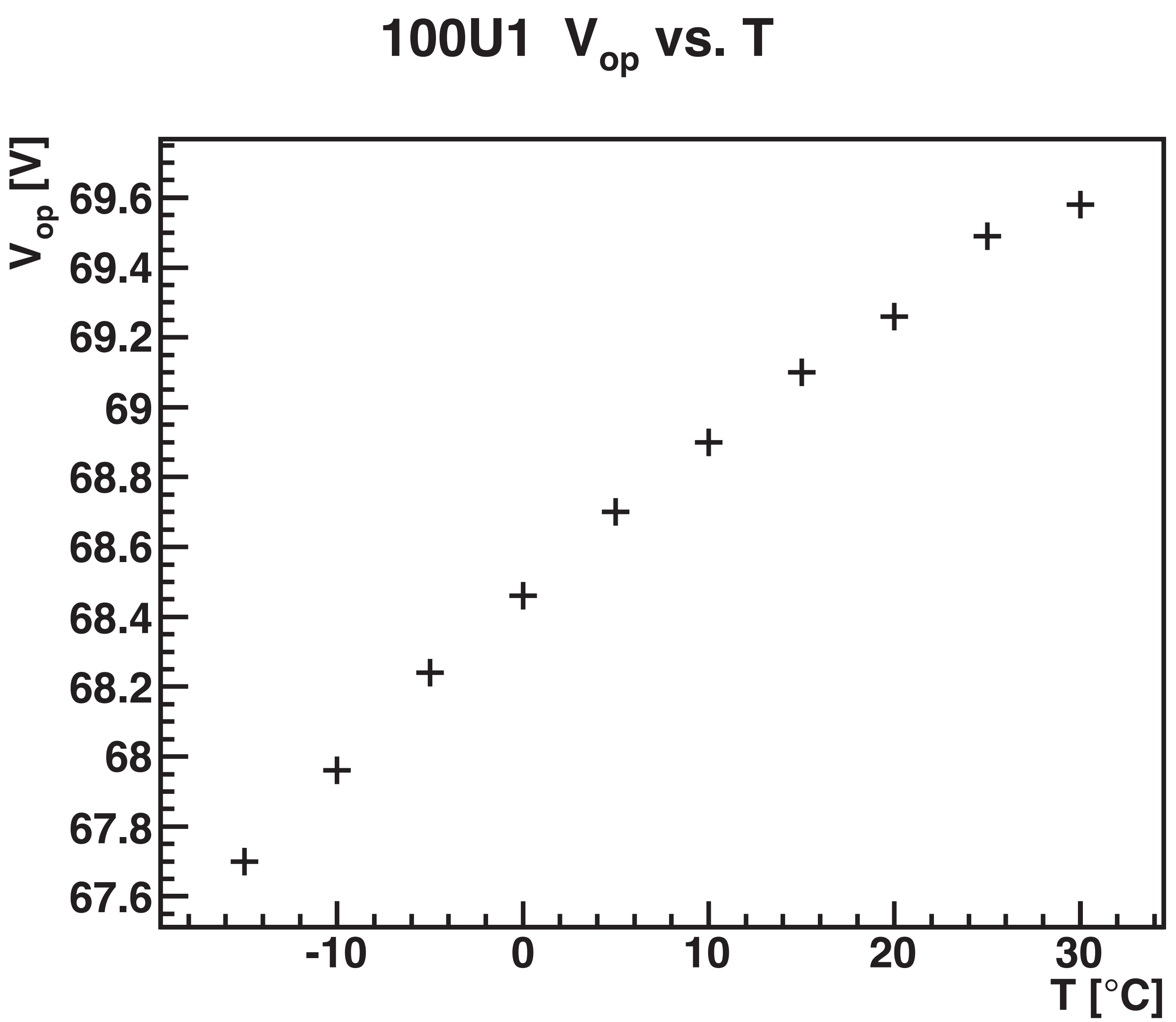
Characteristic Curves for 100U1



V_{op} vs. temperature



Dark current at sugg. V_{op} very similar for sensors with same number of pixels.



create lookup table from measurements and regulate V_{op} directly on SiPM frontend via microcontroller

Outlook

Tasks:

- Improve simulation: more realistic surface modelling, absorption in glue, ...
  model SiPM more accurately
  (pixels → fill factors, area 3x3mm^2)
- Segmentation: bigger tiles (25x25 cm)
- temperature dependency of gain (→ stabilizing the gain)
- find controlled process variable? dark current, single-photon events (kHz), ...

Goals:

Compact PCB with
- pre amplifier
- voltage regulator
- (temp) stabilised output → controlled by microcontroller?
- discriminator (digitisation?) → expect problems.

Digitisation on PCB? → pulse height, pulse length
instead of „just“ a comparator (1bit ADC) → 5 or 6 bit ADC

Detector prototype module (mechanics, ...) ⇔ comparison with simulation

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Thank you

for your attention!

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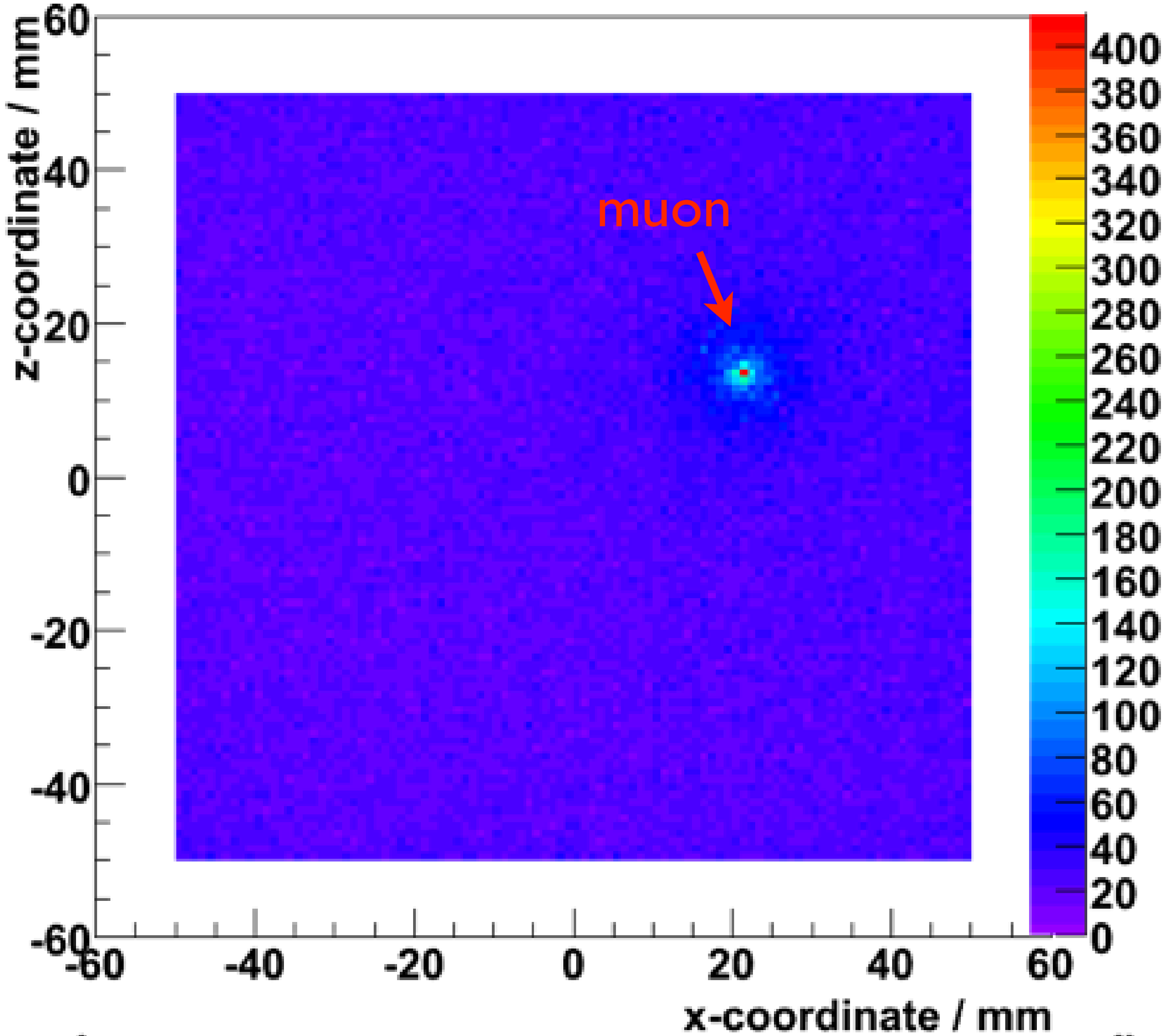
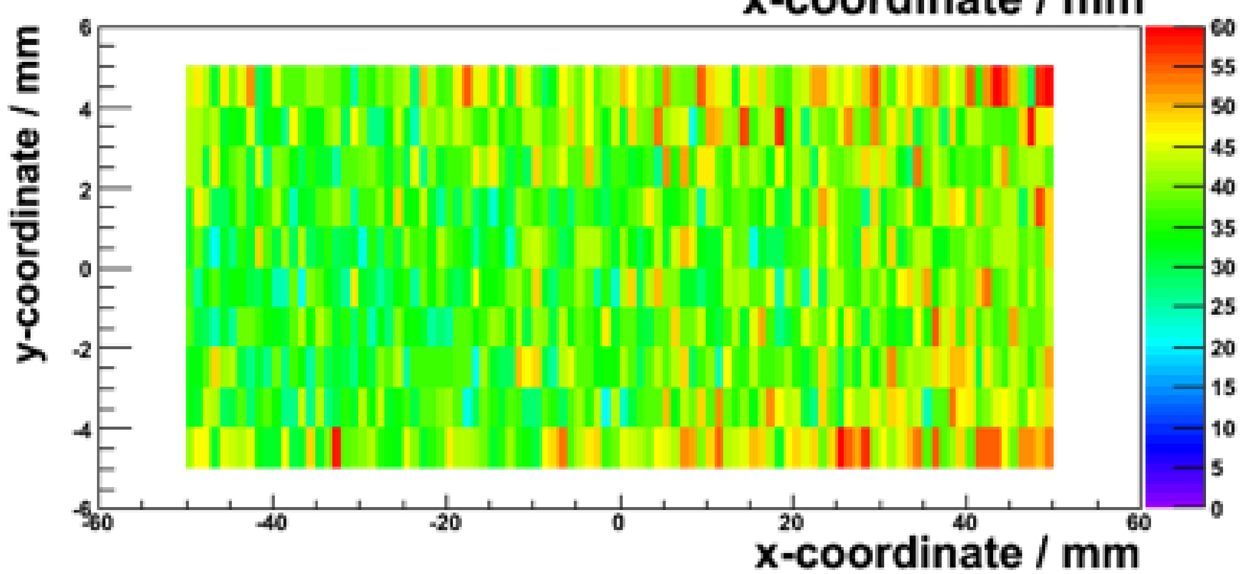
Backup: Direct readout





- SiPM in direct contact to scintillator surface

- surface: diffuse (Lambert) reflector (98%)

⇒ Photon density at the surface:

  - approx. homogeneous
  - 20-30 γ/mm^2
    → *ideal world*

but:
only a fraction of the surface is covered by SiPMs.