MTT activities in Aachen

Oliver Pooth

RWTH Aachen 3B
Achim Stahl (Günter Flügge)
in collaboration with
Aachen 3A, Thomas Hebbeker

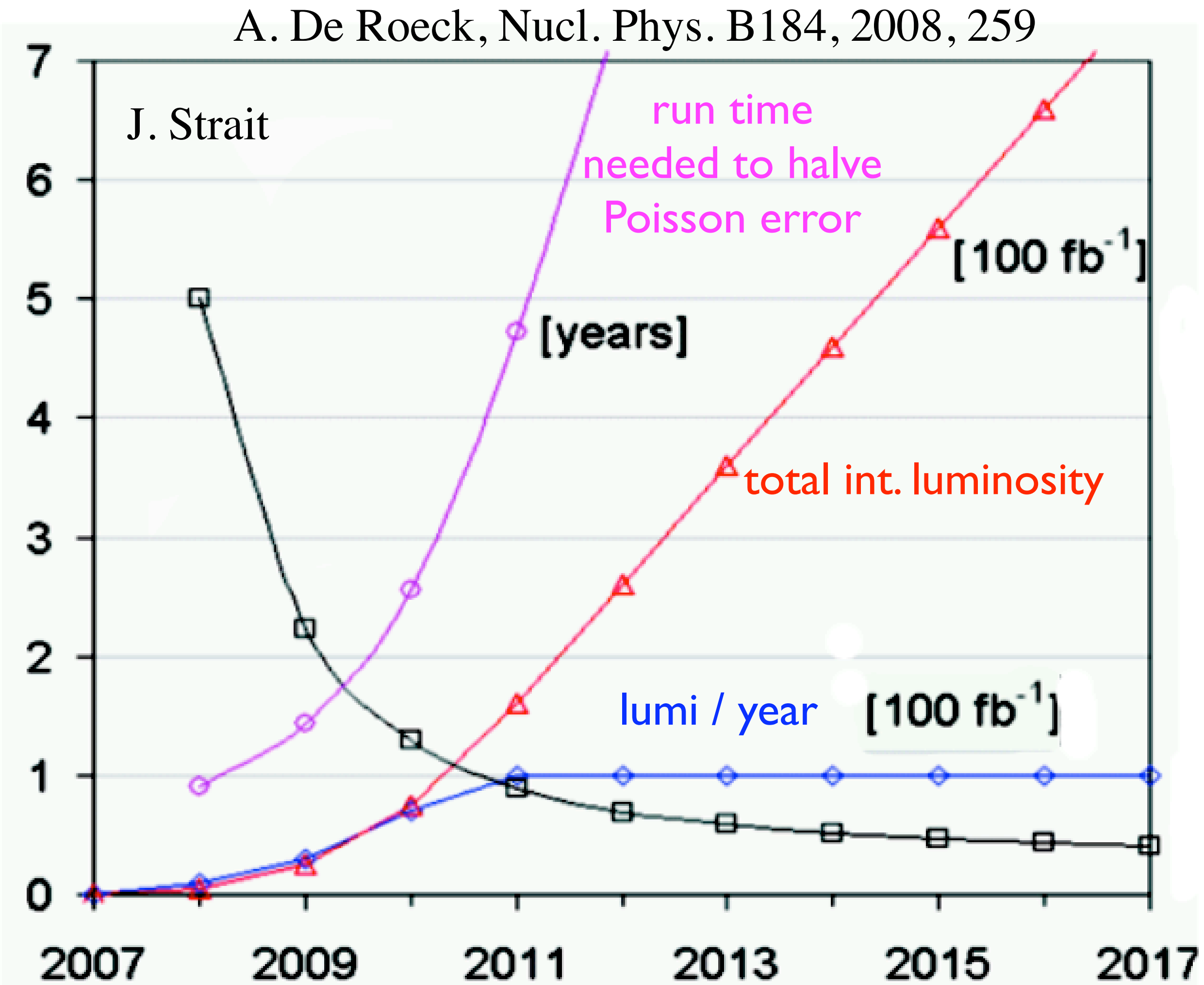
Main activities of our institute:
Tracker Commissioning & DQM
Top Quarks and Tau Leptons

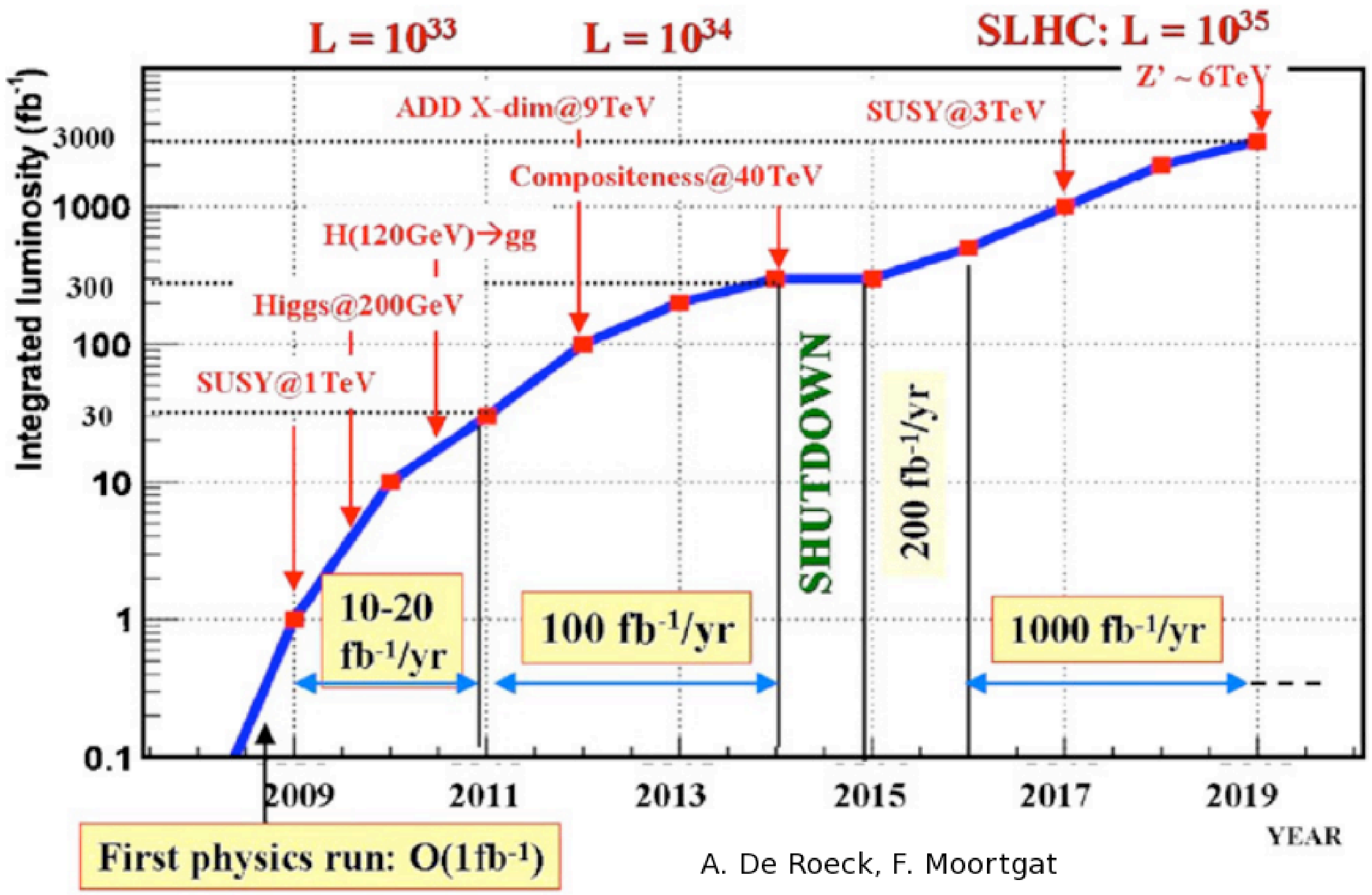
MTT in Aachen

- simulation of possible prototype modules
- characterization of SiPMs / front end electronics
- preparation of new lab envirmonment

group: 2 seniors (10%), 1 PhD student, 2 students

SPONSORED BY THE
Federal Ministry of Education and Research





SLHC: 1000 fb^{-1}/year

⇒ NP, extended limits

Improvement of relative precision is marginal after several years of LHC running

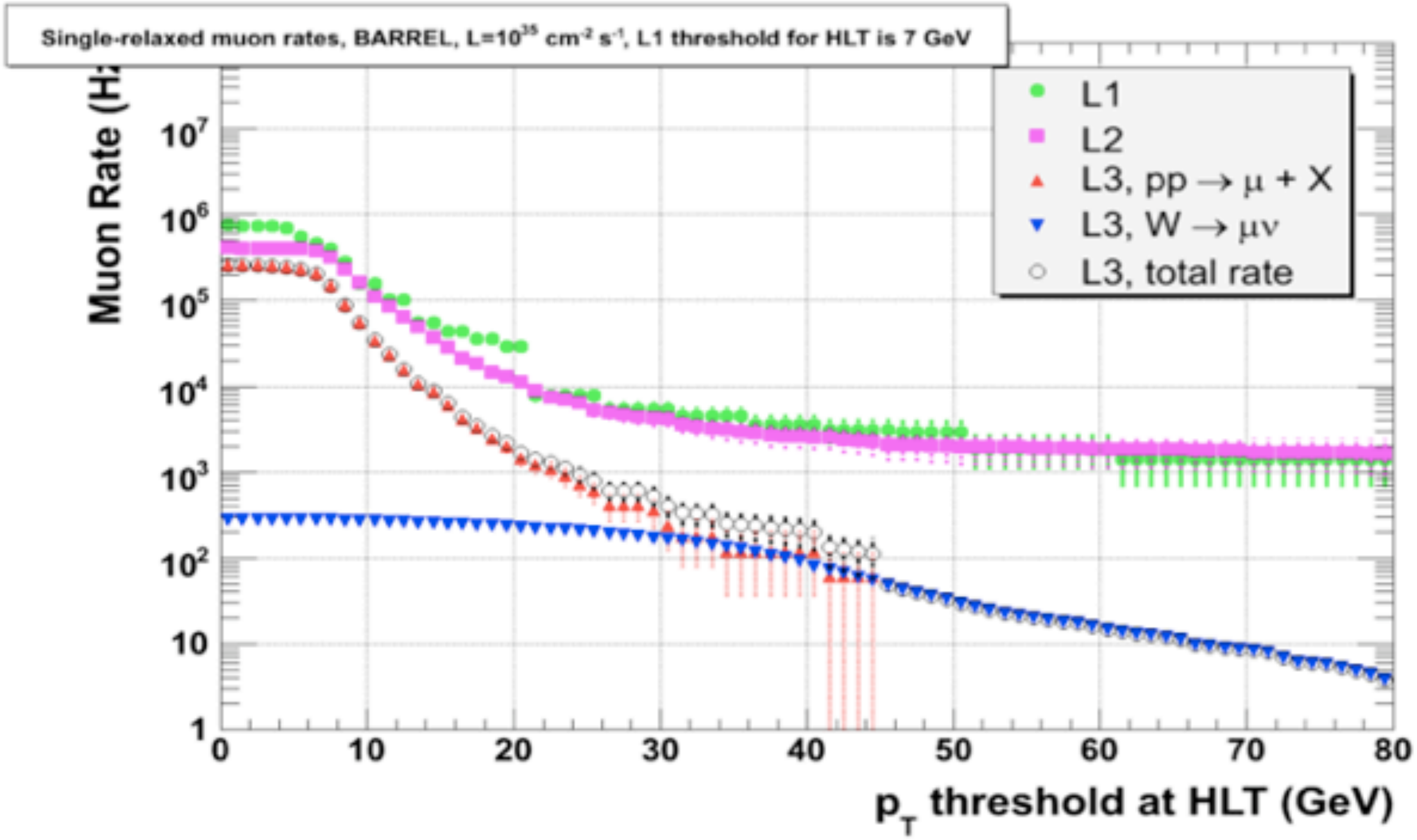
⇒ increase luminosity ⇒ SLHC

various scenarios

E_{beam}, f_{BX}, N_p/bunch

under discussion

MTT motivation

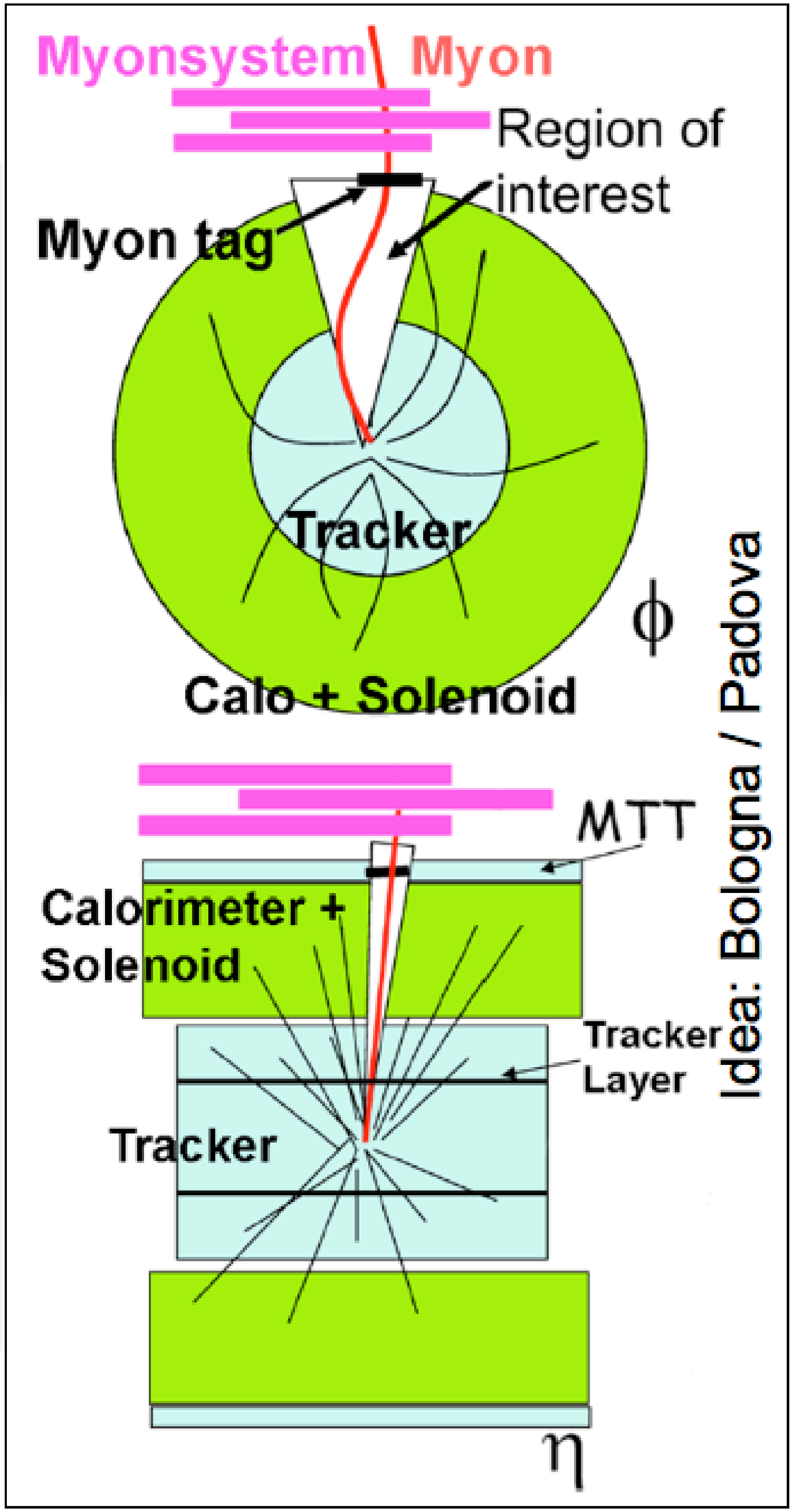


Triggering on muons at 10^{35} $cm^{-2}s^{-1}$ possible?
Keeping the original L1 trigger rate of muon system (Level-1 with muon p_t > 14 GeV (to limit the rate))

⇒ increase p_t threshold

or
extend trigger concept

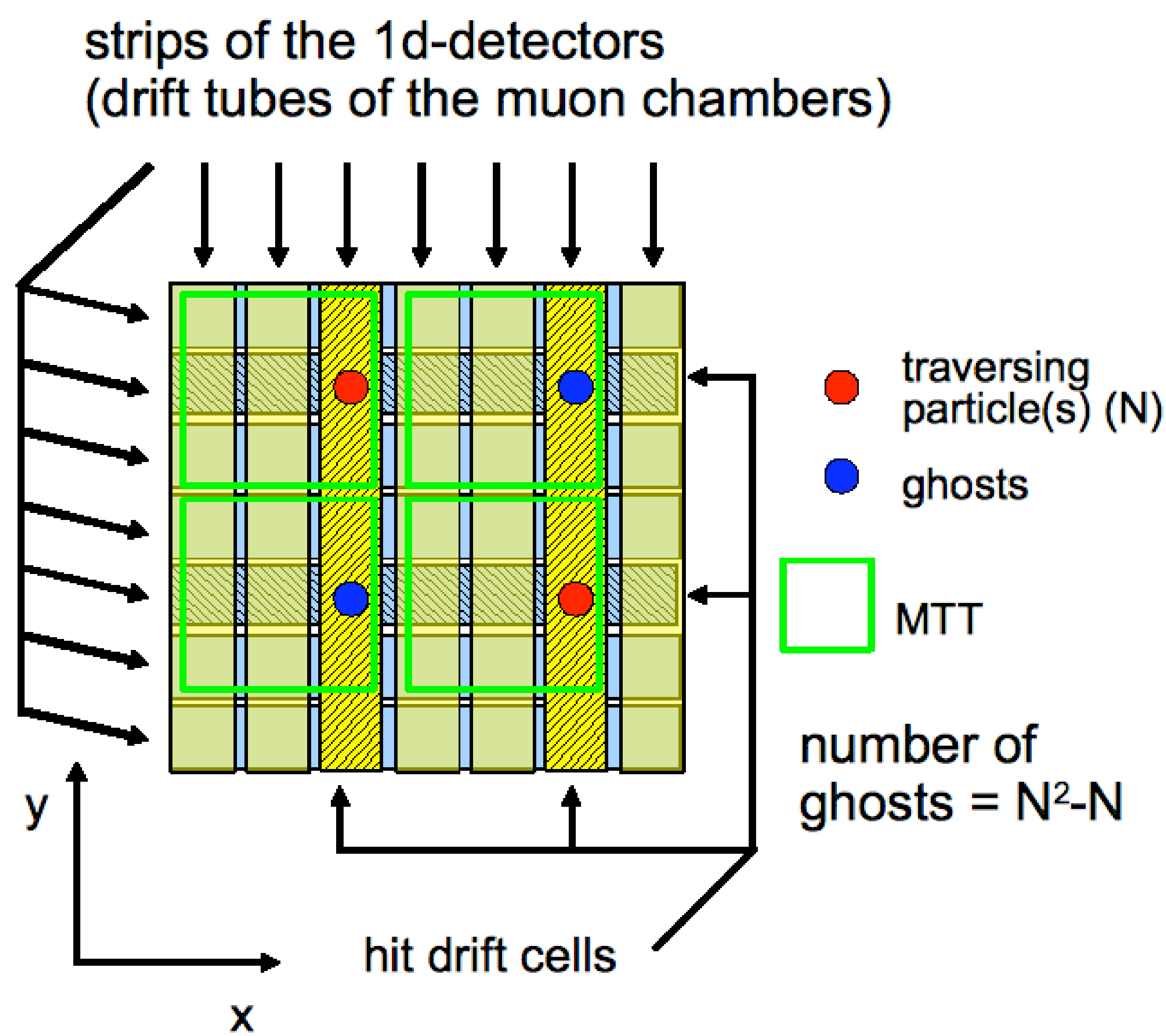
⇒ **MTT** (fast 2D trigger behind HCAL outer)



Improve muon momentum resolution of L1 trigger

- tracker → excellent p_t measurement
- muon system → muon ID

resolve muon ambiguities →



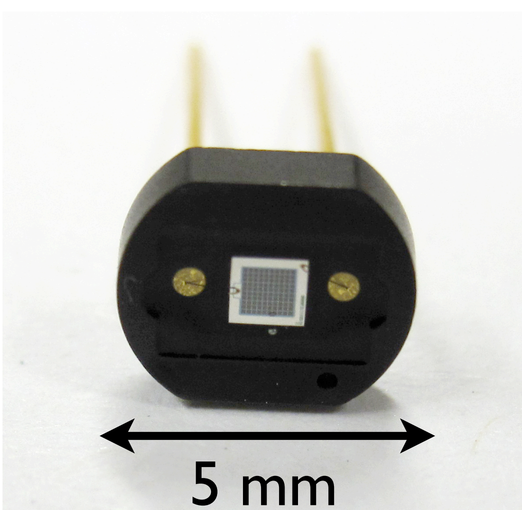
optimal granularity?
→ start with 25 x 25 x 1 cm^3
alternative 10 x 10 x 1 cm^3

Constraints → det. module

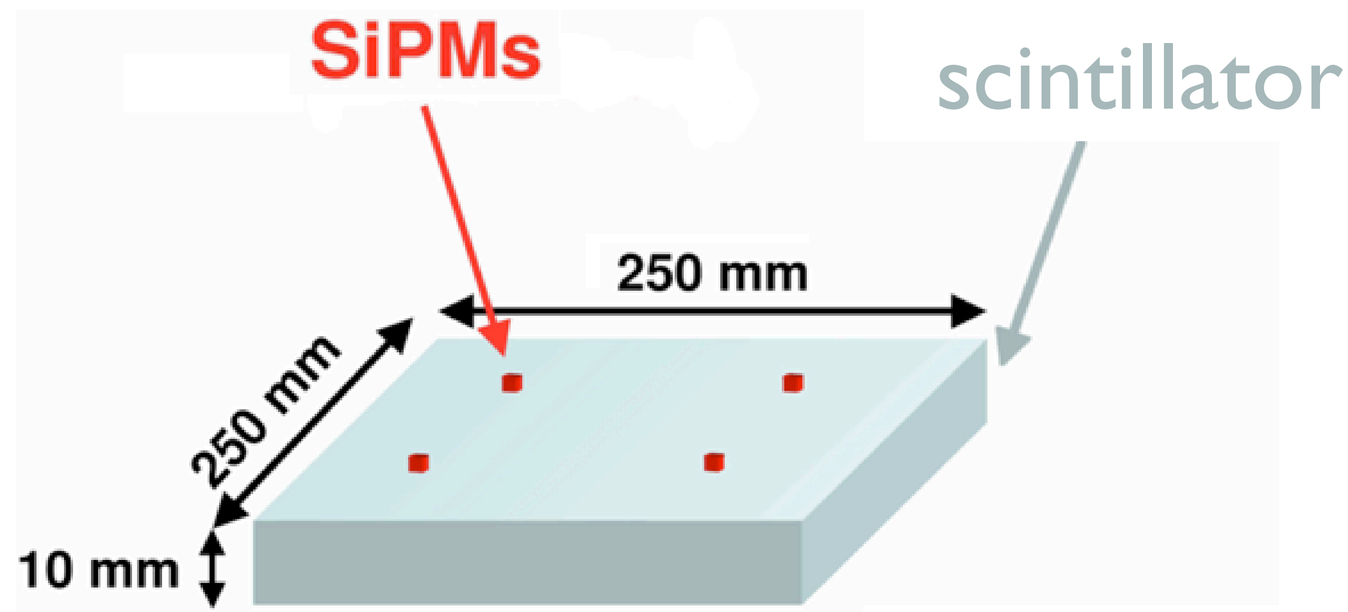
- Area:
  approx. 300 m^2 ⇒ affordable
- Space:
  thin: ≲ 10 mm
- Timing:
  fast: ≲ 10 ns (BX identifiction)

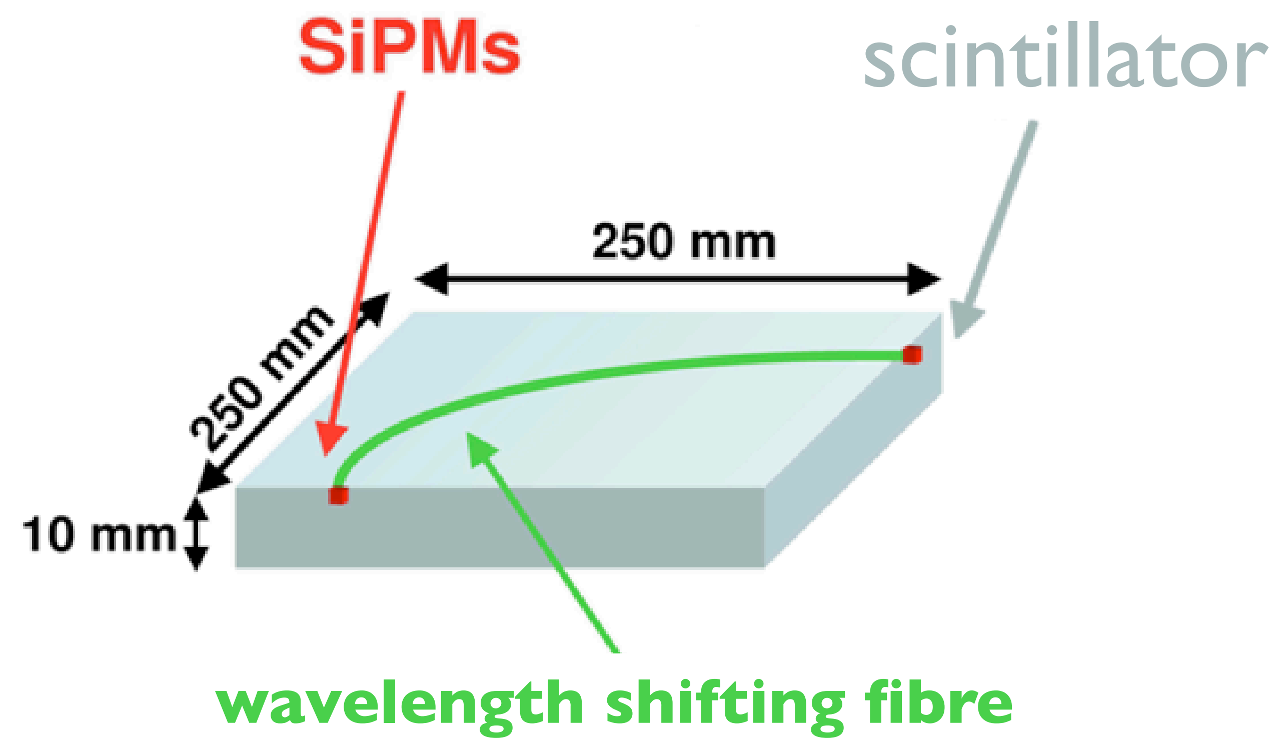
⇒ **Plastic scintillators**

read out by silicon PMs



Array of APDs
in
Geiger mode





How to connect?
Two scenarios under investigation →

Simulation of detector prototypes

Model various (sizeable) prototypes with GEANT4.

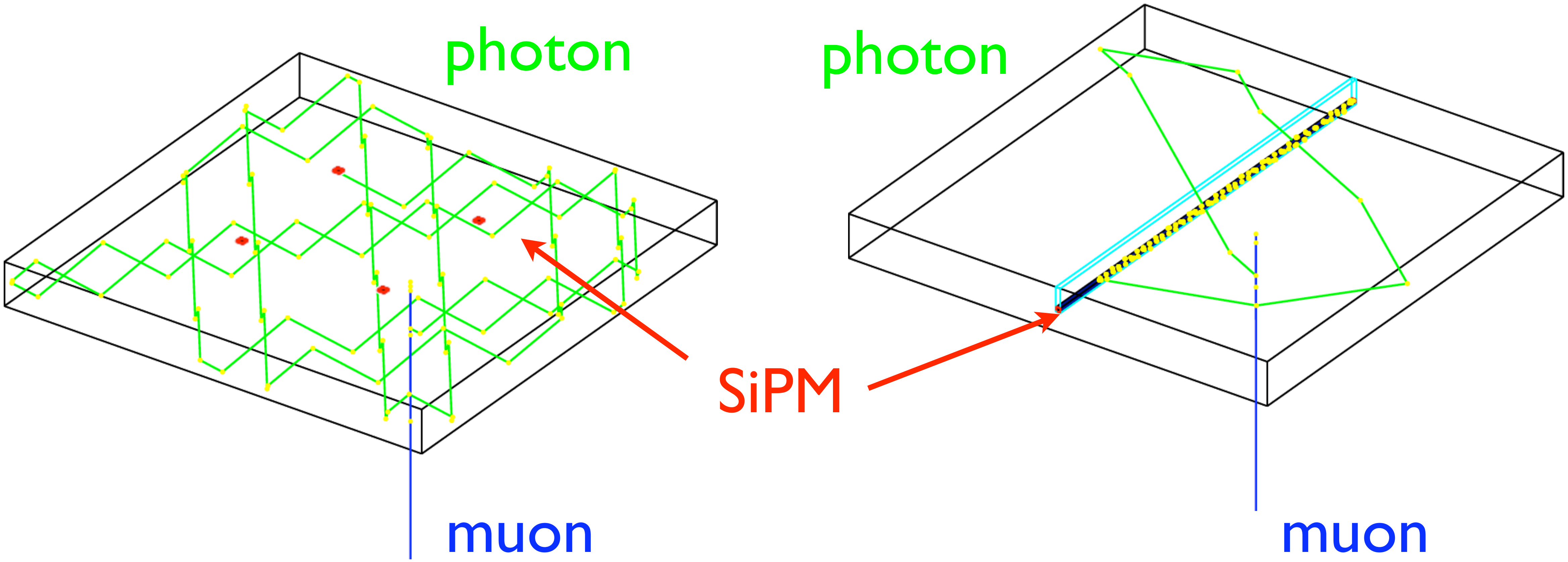
- scintillator: 100 x 100 x 10 mm^3 (BC 404, *Bicron (Saint Gobain)*)
- (optional) wavelength shifting fibre (BCF 92, *Bicron (Saint Gobain)*)
  all properties according to data sheets

- 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

(- study surface properties: roughness, reflectivity)

direct readout | **readout via wavelength shifting fibres**



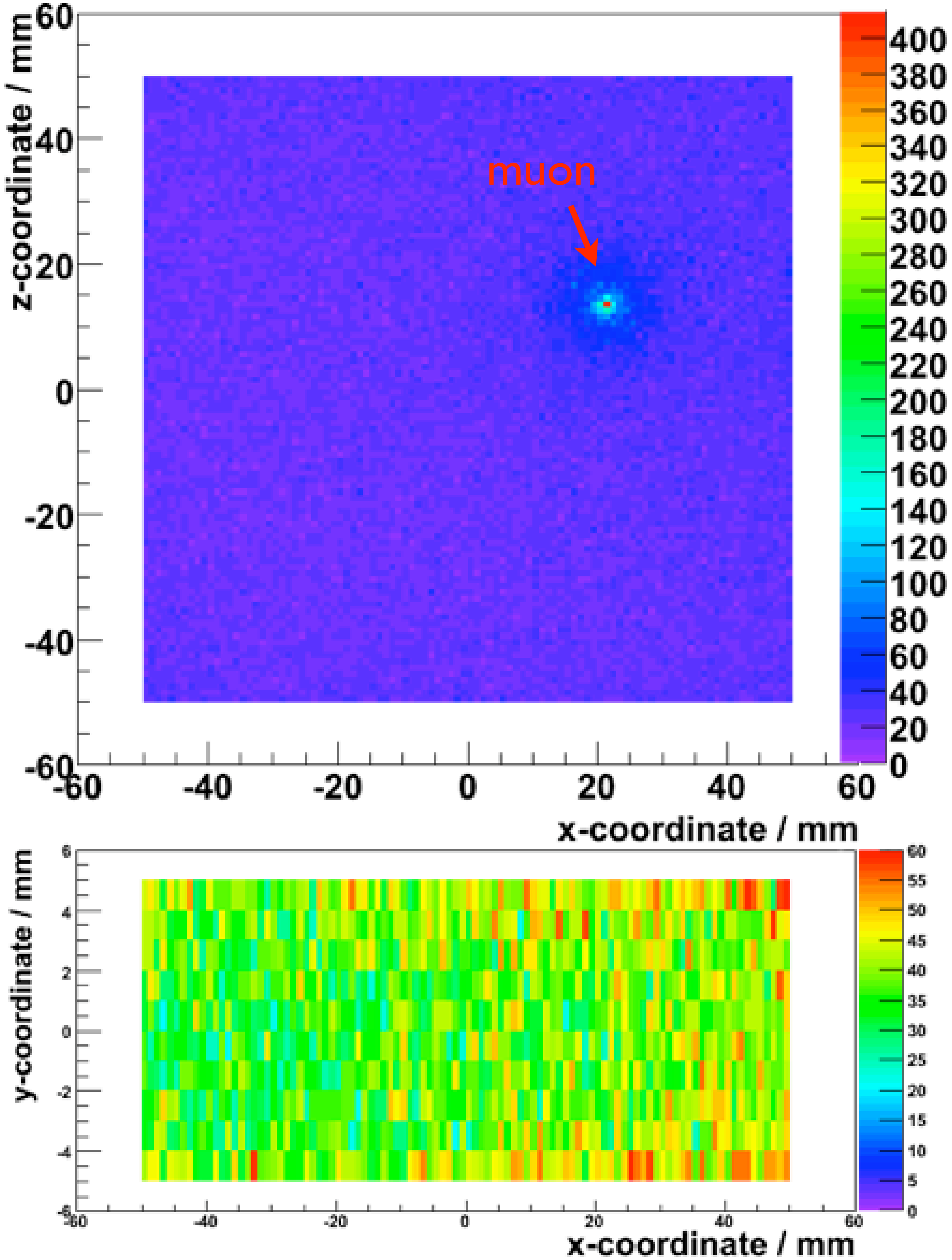
Pro:
simple detector module

Con:
low light yield
more SiPMs needed

Pro:
good light collection via fibre

Con:
detector module more complex

Direct readout



- SiPM in direct contact to scintillator surface

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

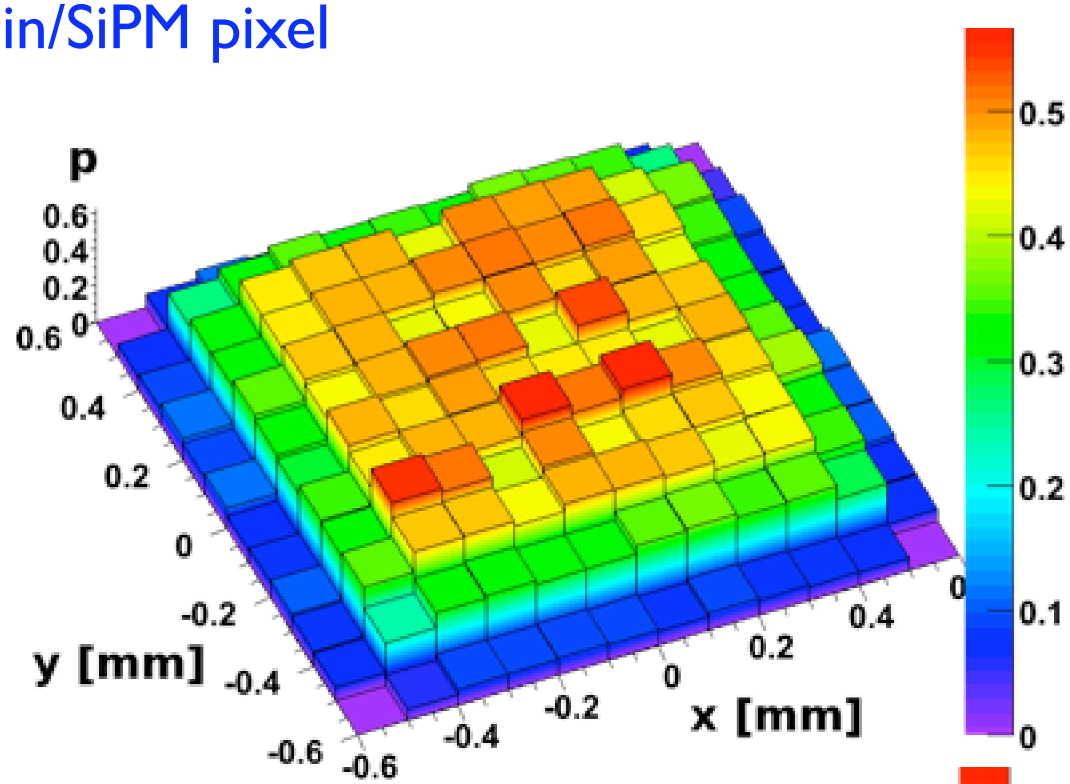
⇒ Photon density at the surface:

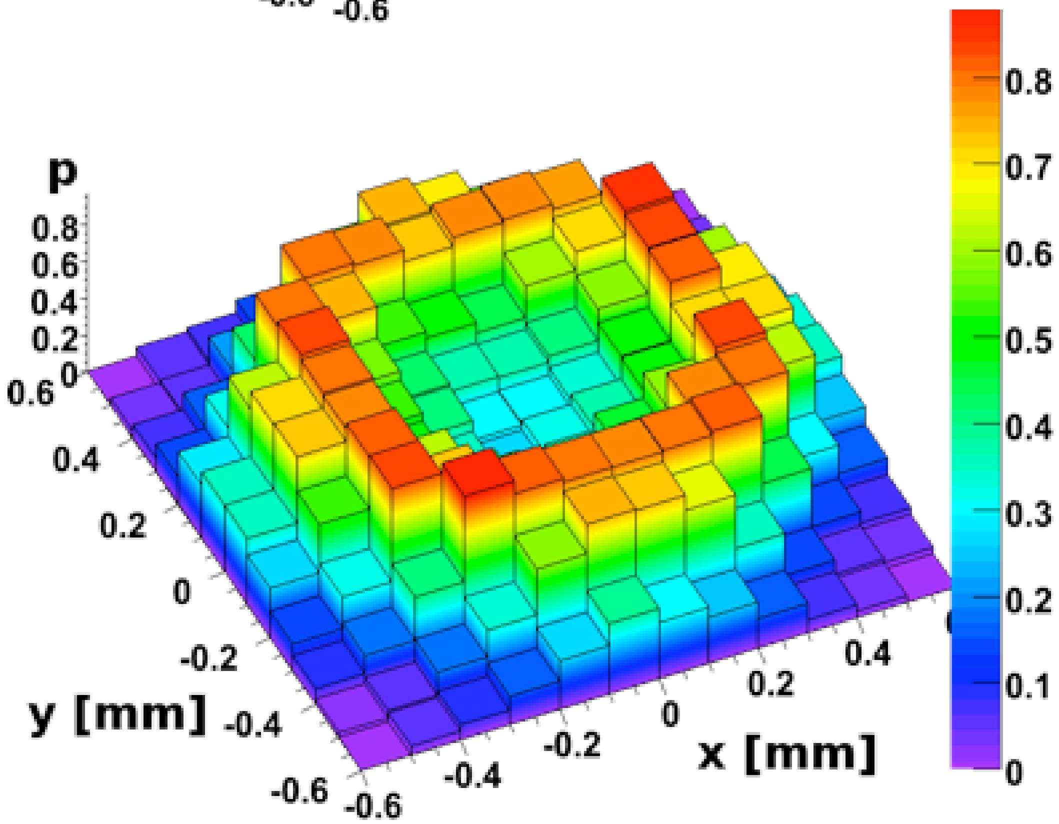
  - approx. homogeneous
  - 20-30 γ/mm^2
    → *ideal world*

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

WLS fibre readout

1 bin/SiPM pixel

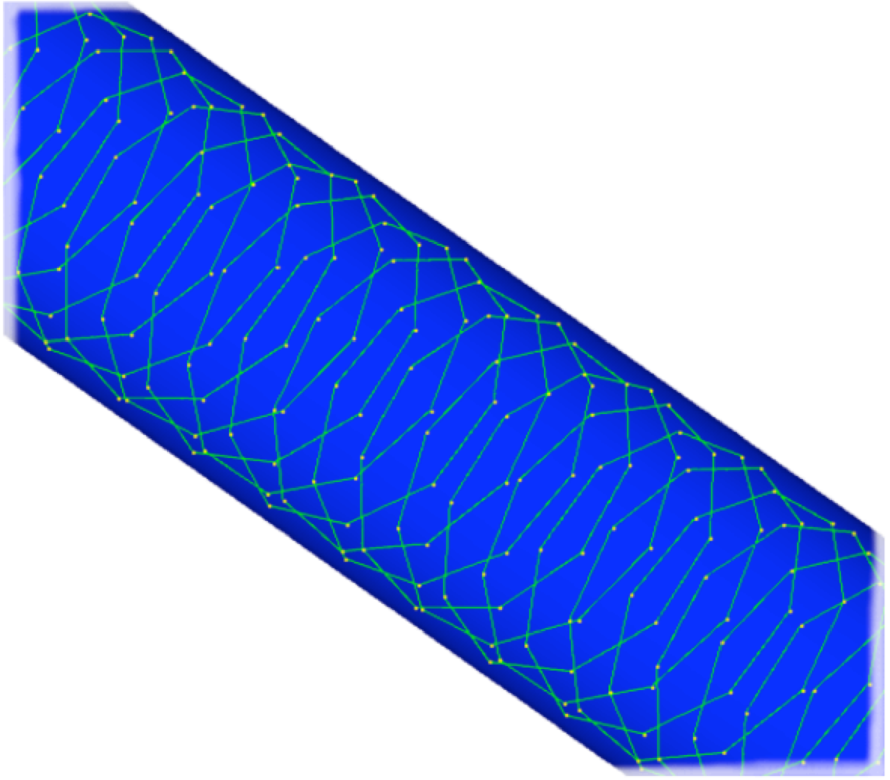




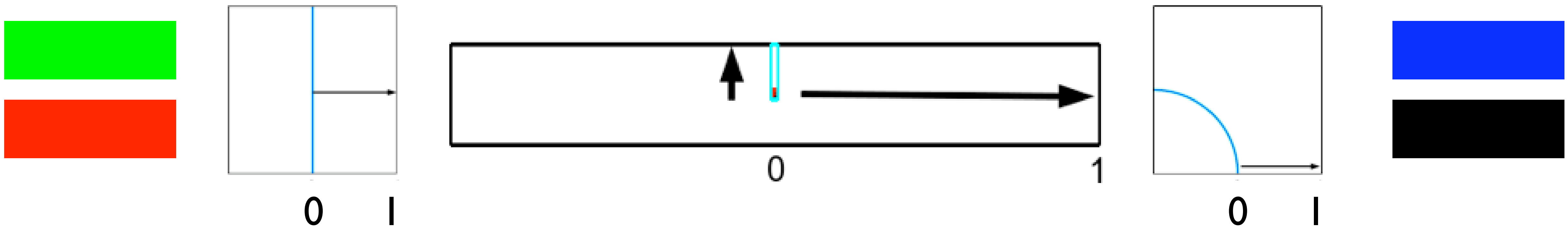
- SiPM coupled to WLS fibre

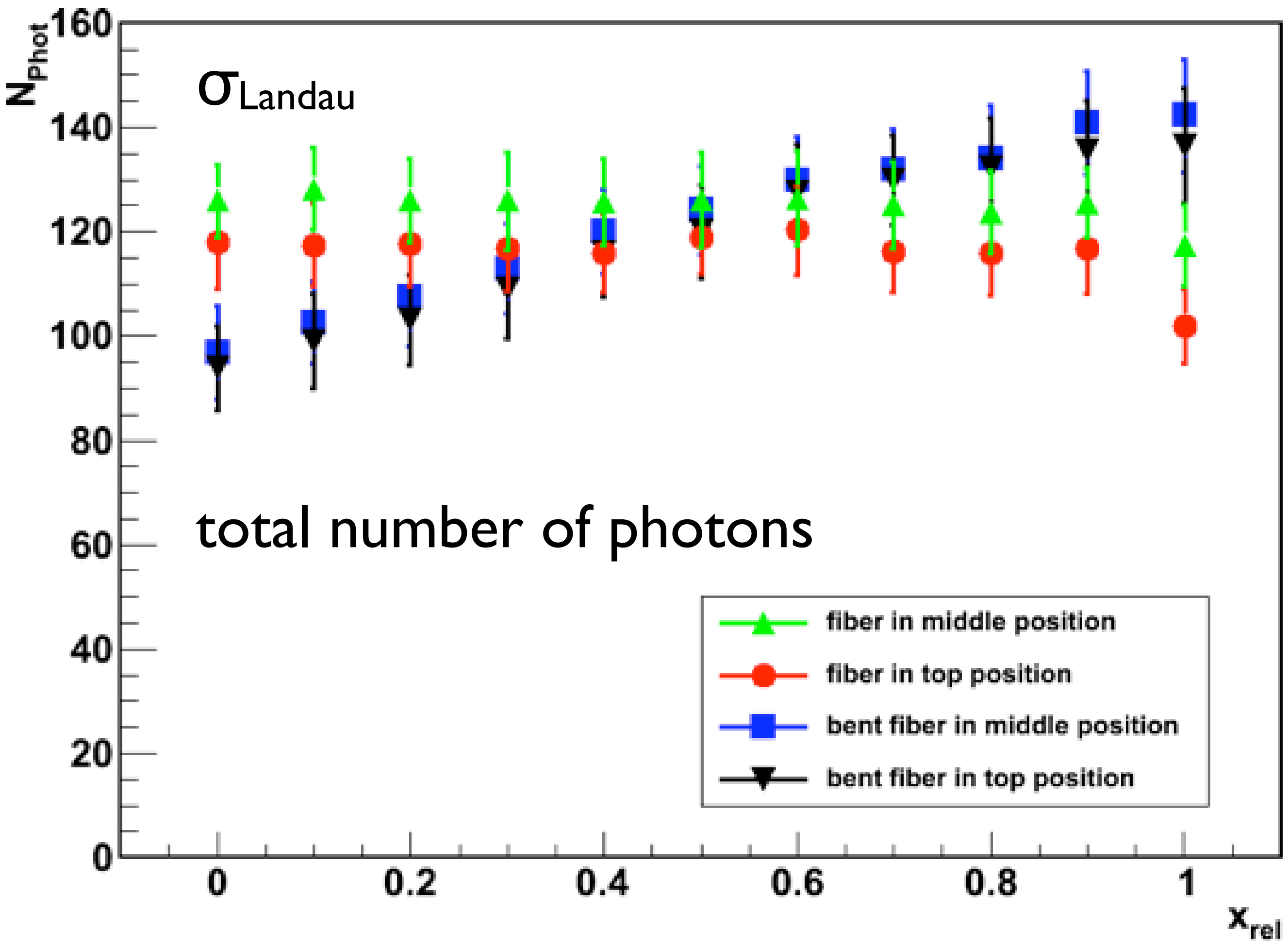
rectangular fibre → homog. distribution
circular fibre → preferably at the fibre edges

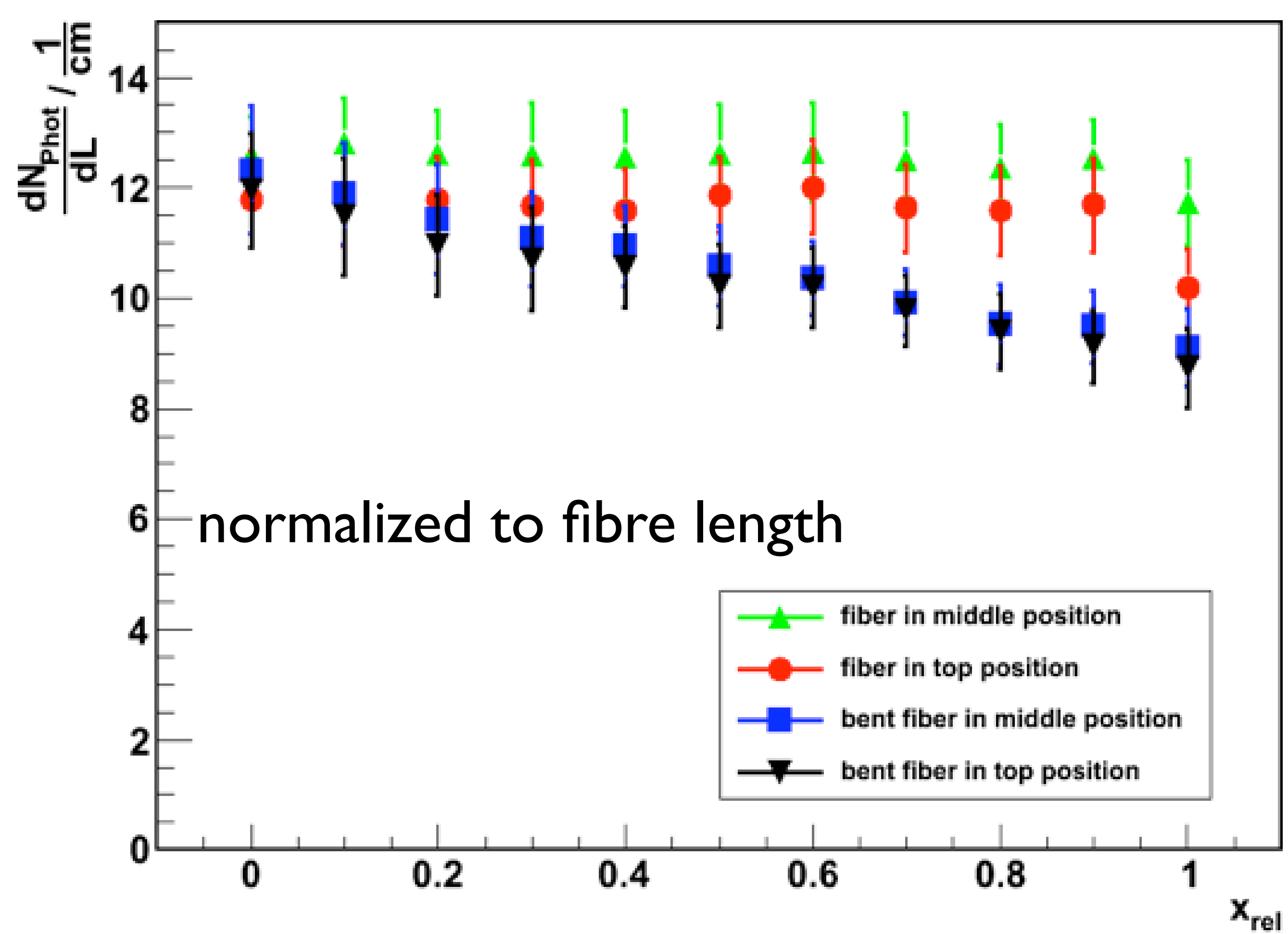
Expect smearing out with real fibres ... needs to be checked



bent vs. straight fibre

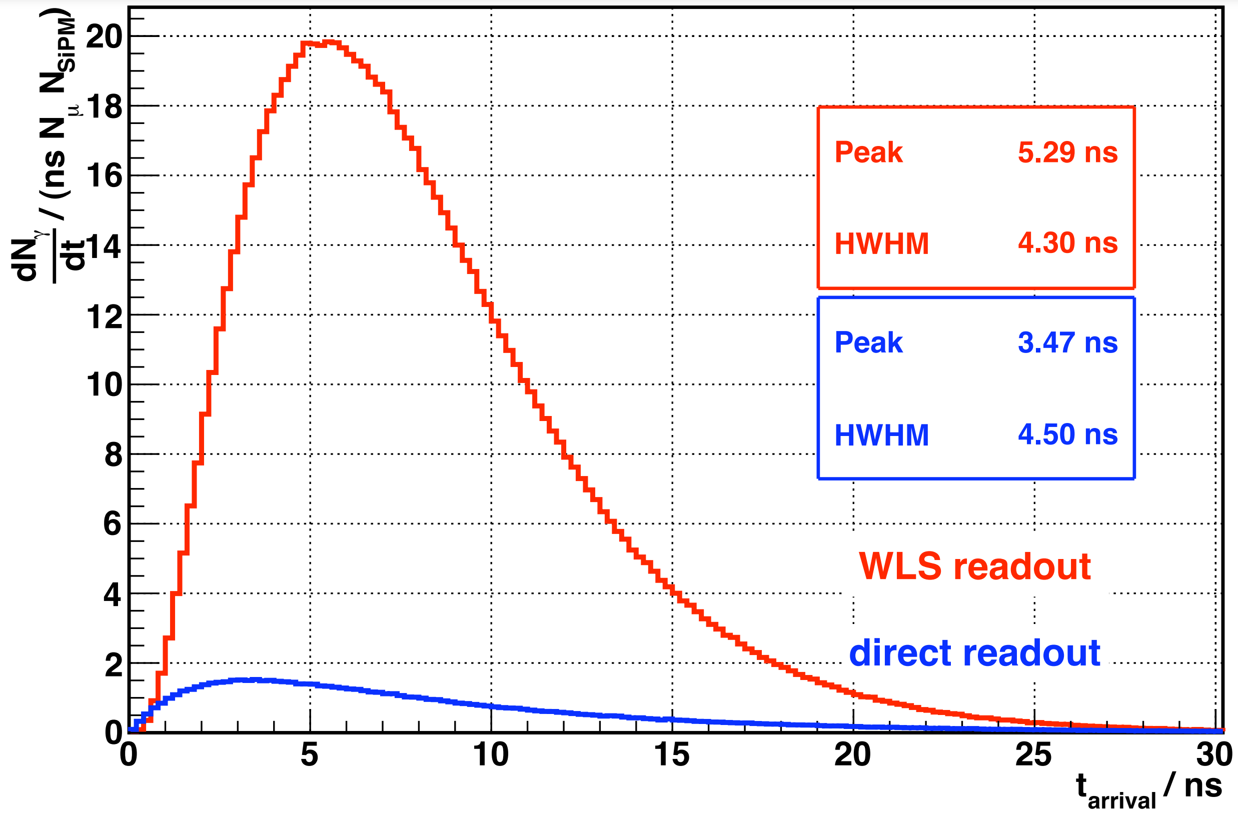


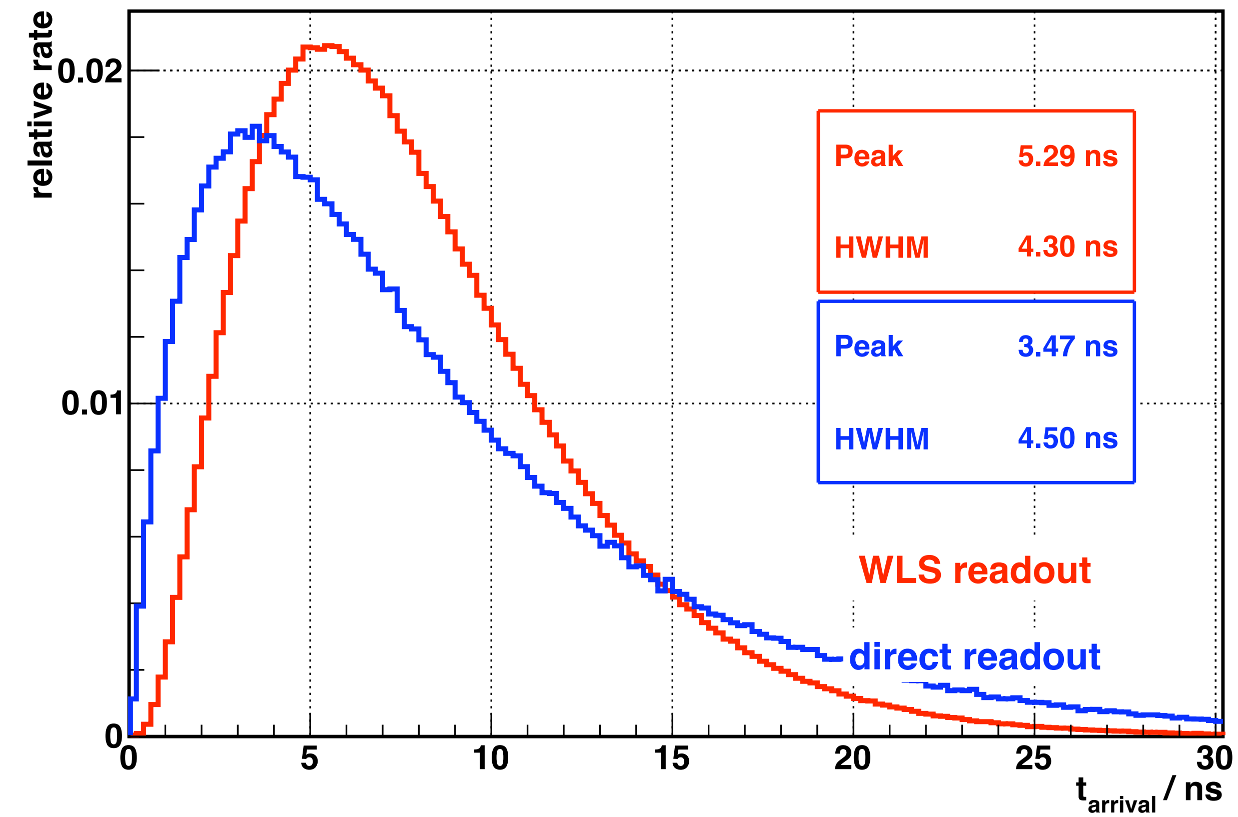




⇒ Photon collection marginally better with bent fibre.

Photon arrival time





remember:
SLHC bunch crossing distance: 50 ns

Prototype:
100 x 100 x 10 mm^2

⇒

- photons arrive at SiPM in ≤ 20 ns
- direct r/o 1.5x faster

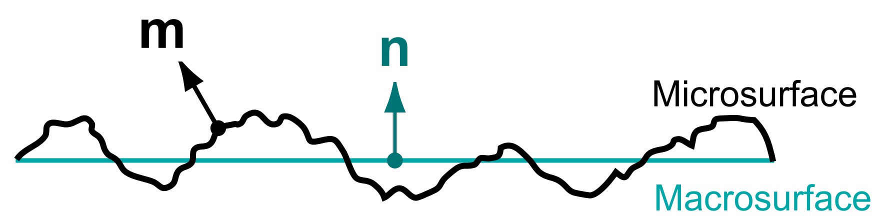
→ no timing problems?!

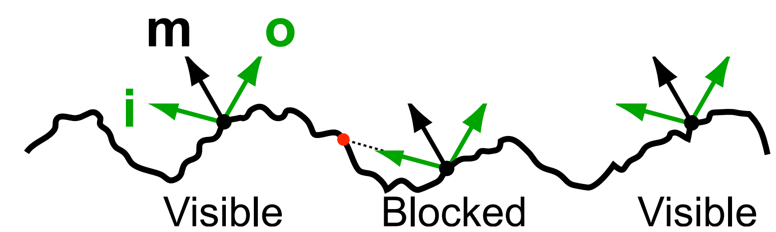
needs to be the checked for 250 x 250 x 10 mm^2

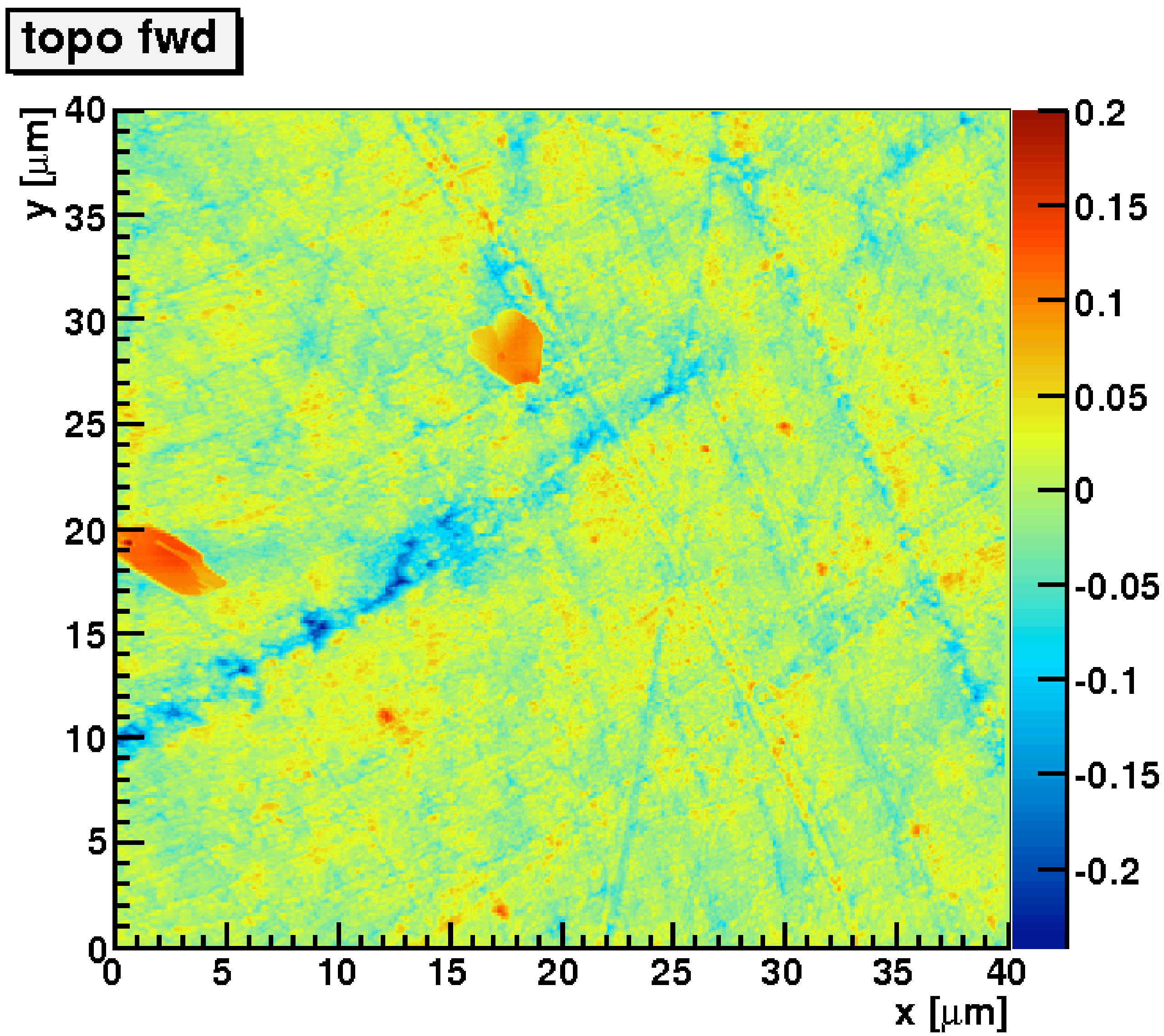
NB:
diffuse reflector 98% reflectivity

Scintillator surface under an AFM

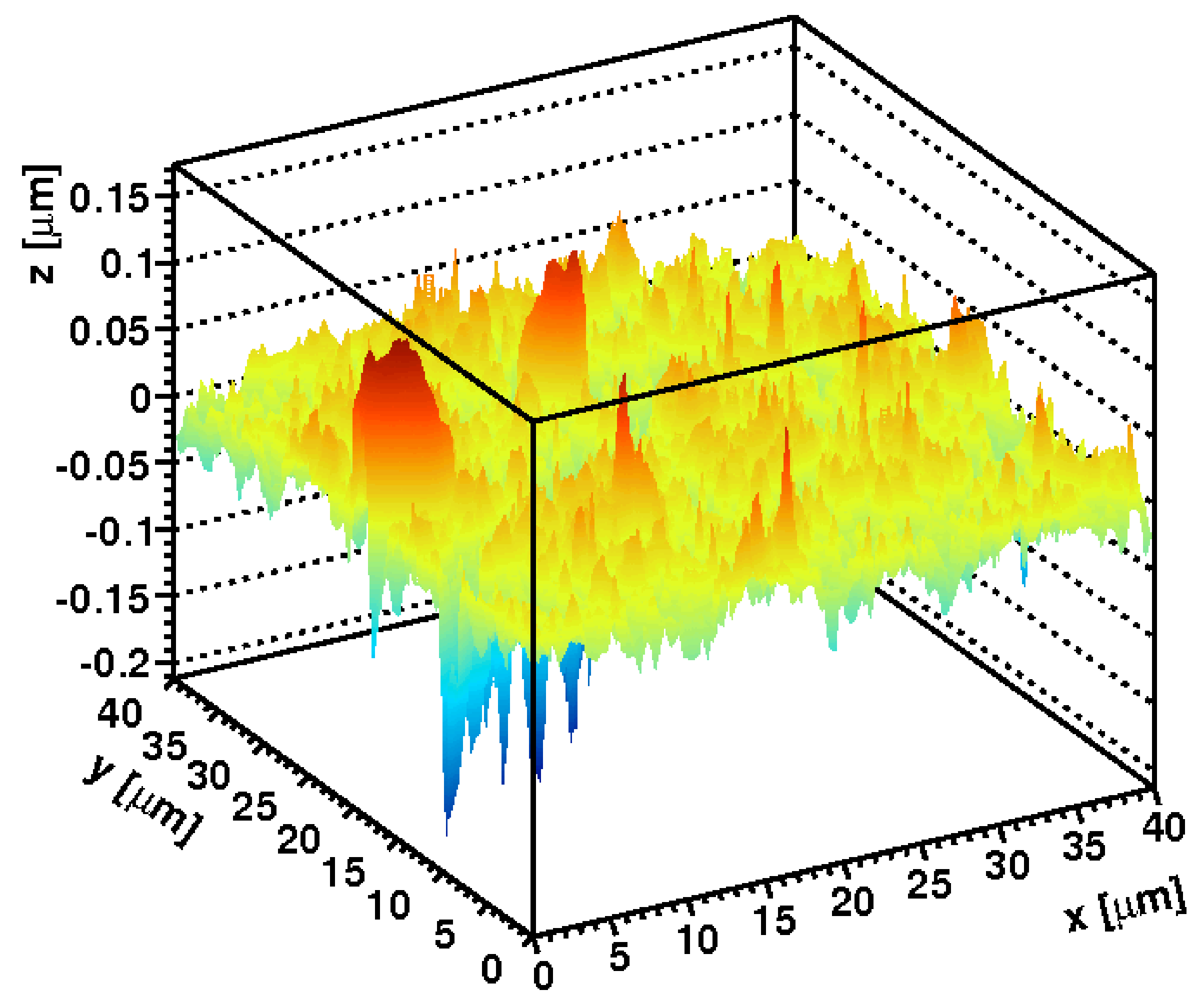
improve surface modelling







M. Liebmann, Physics Inst. IIA, RWTH Aachen



⇒ many small structures, one larger scratch, some speckles → input for simulation

Experimental work

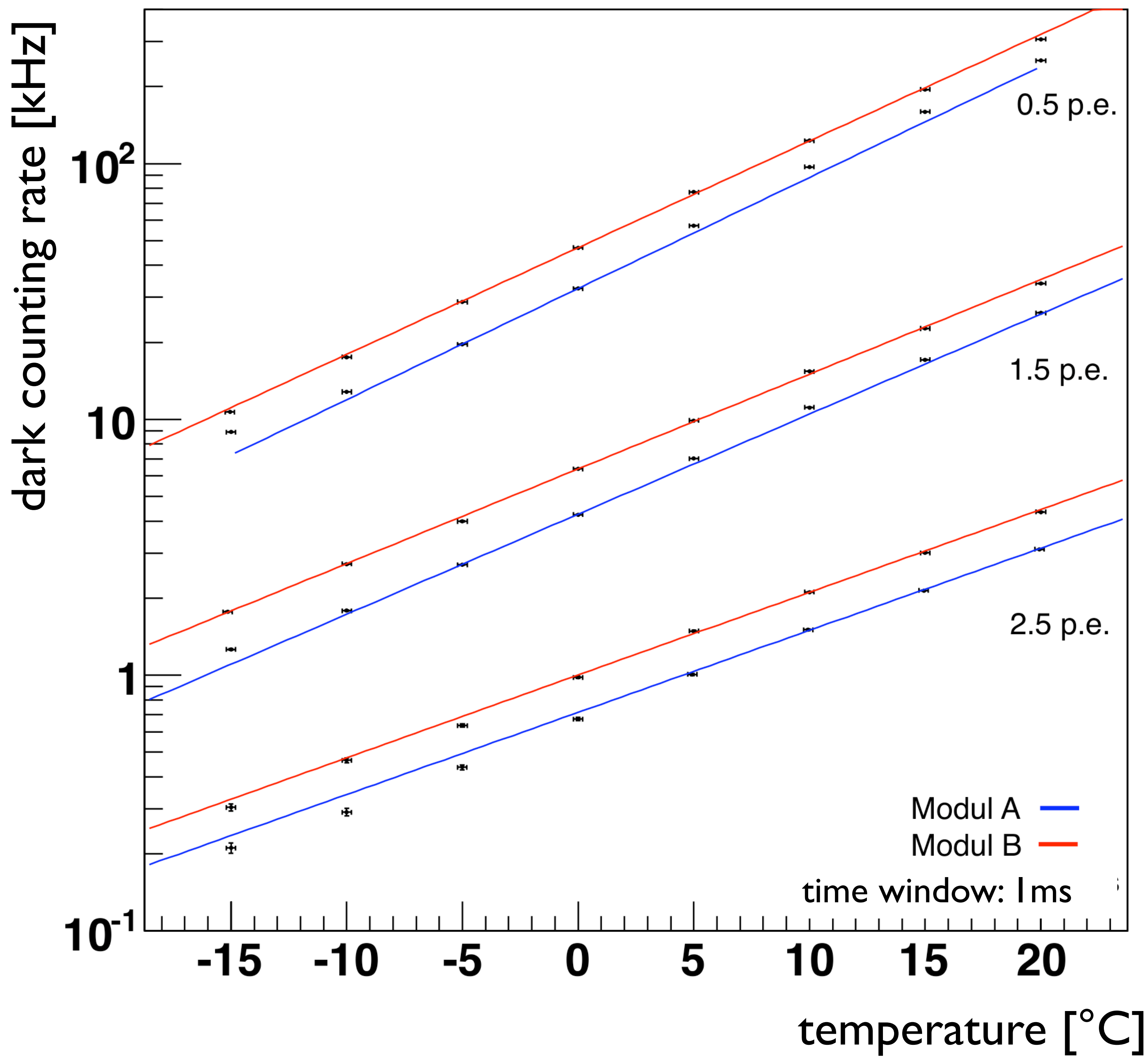
- Characterization of SiPMs
- Development of FE electronics

First measurements

- Dark counting rate vs. temperature (-15°C .. 20°C) → see next slide
  complements measurement from Hamamatsu

Hamamatsu SiPM evaluation kit:
SiPM, HV, amplifier, comparator,
USB connector

dark counting rate vs. temperature



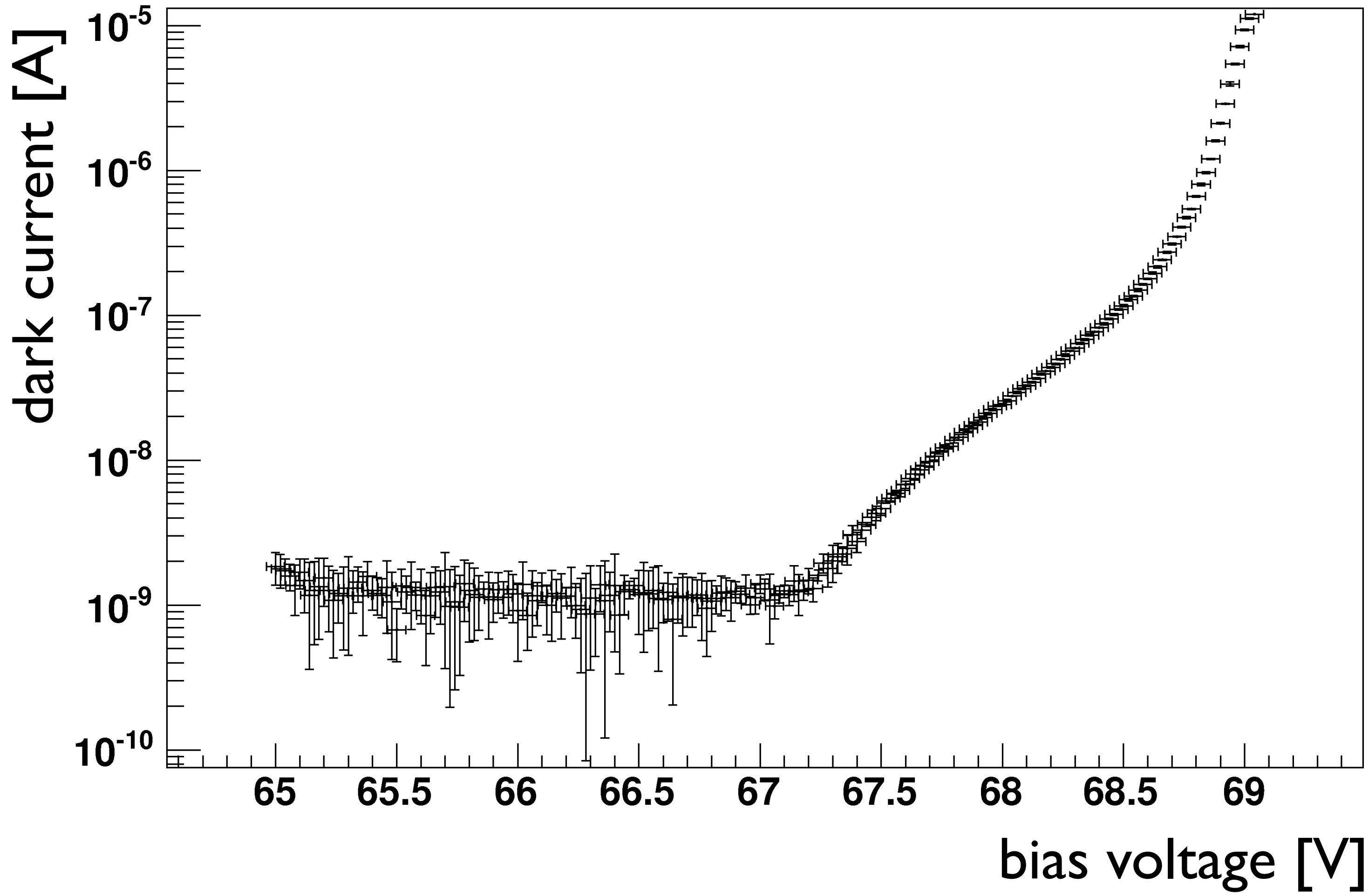
threshold: 0.5 p.e.

threshold: 1.5 p.e.

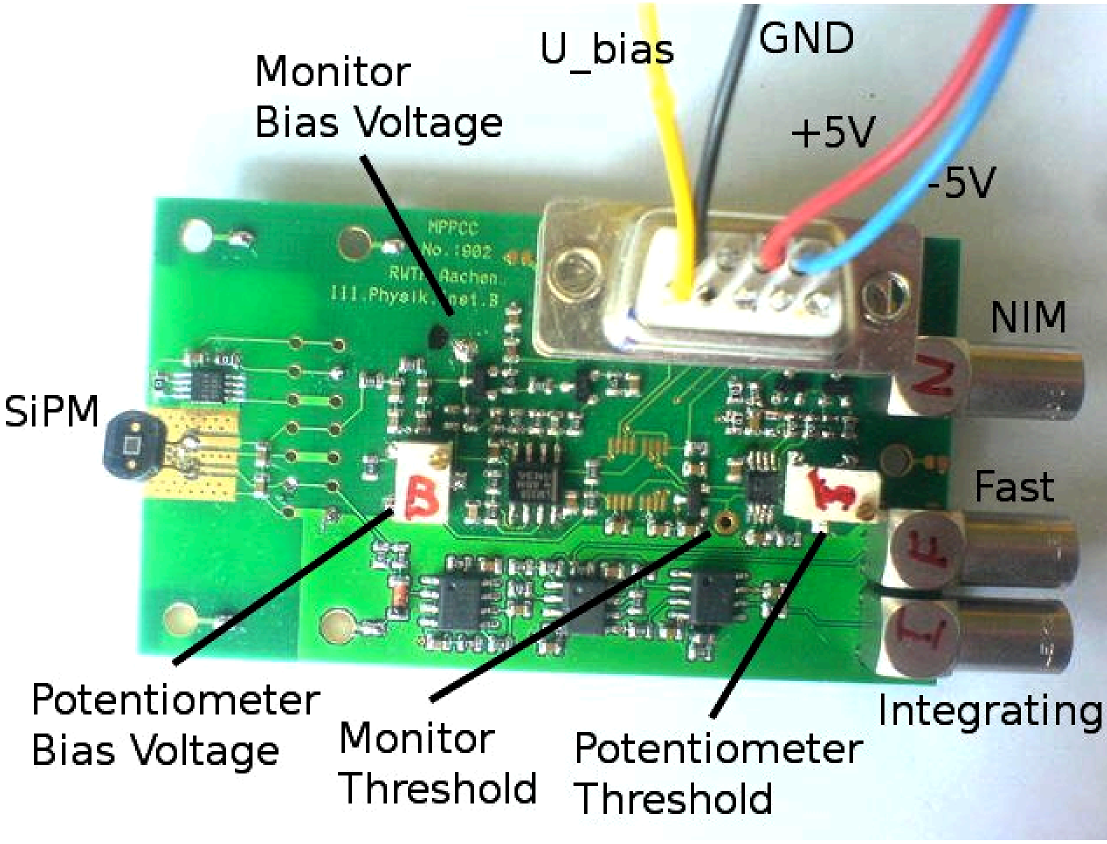
threshold: 2.5 p.e.

IV curves / new front end

Two new possibilities in our lab.



Precision measurement (pA meter) of IV curves (here T = 0°C)

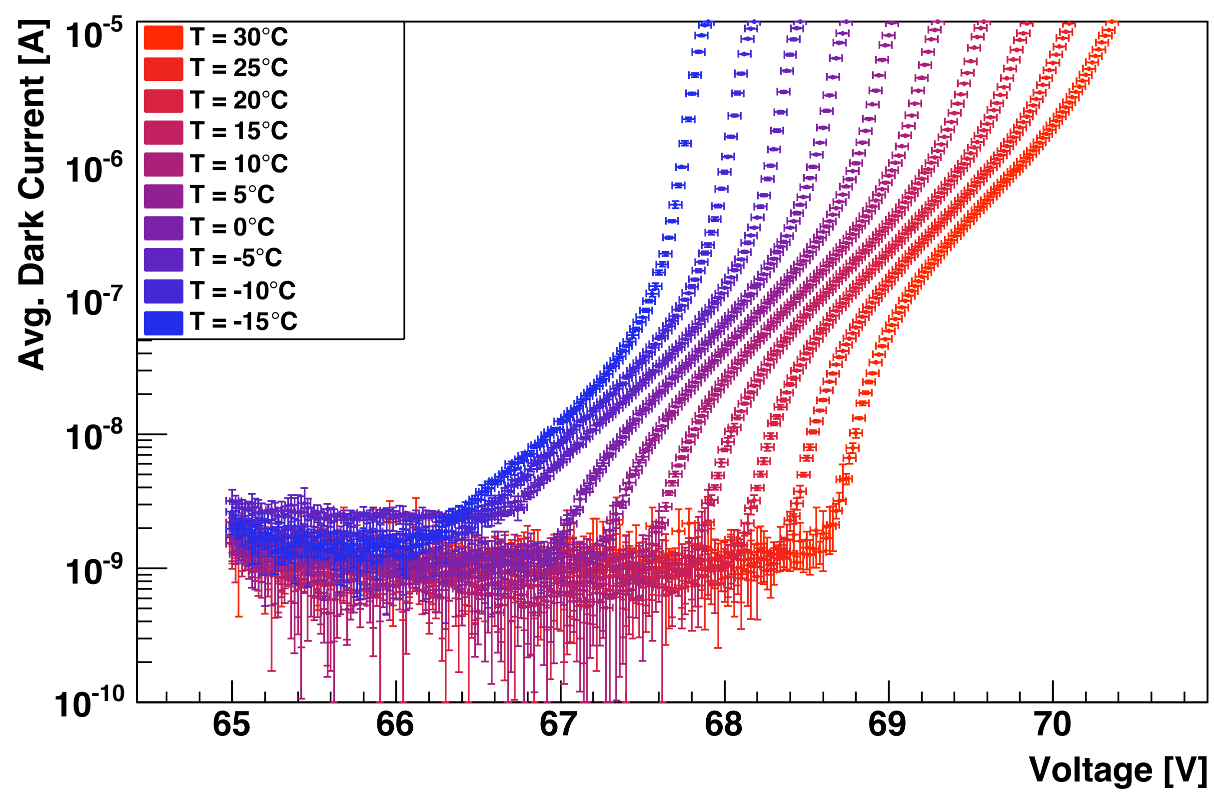


new front end prototype

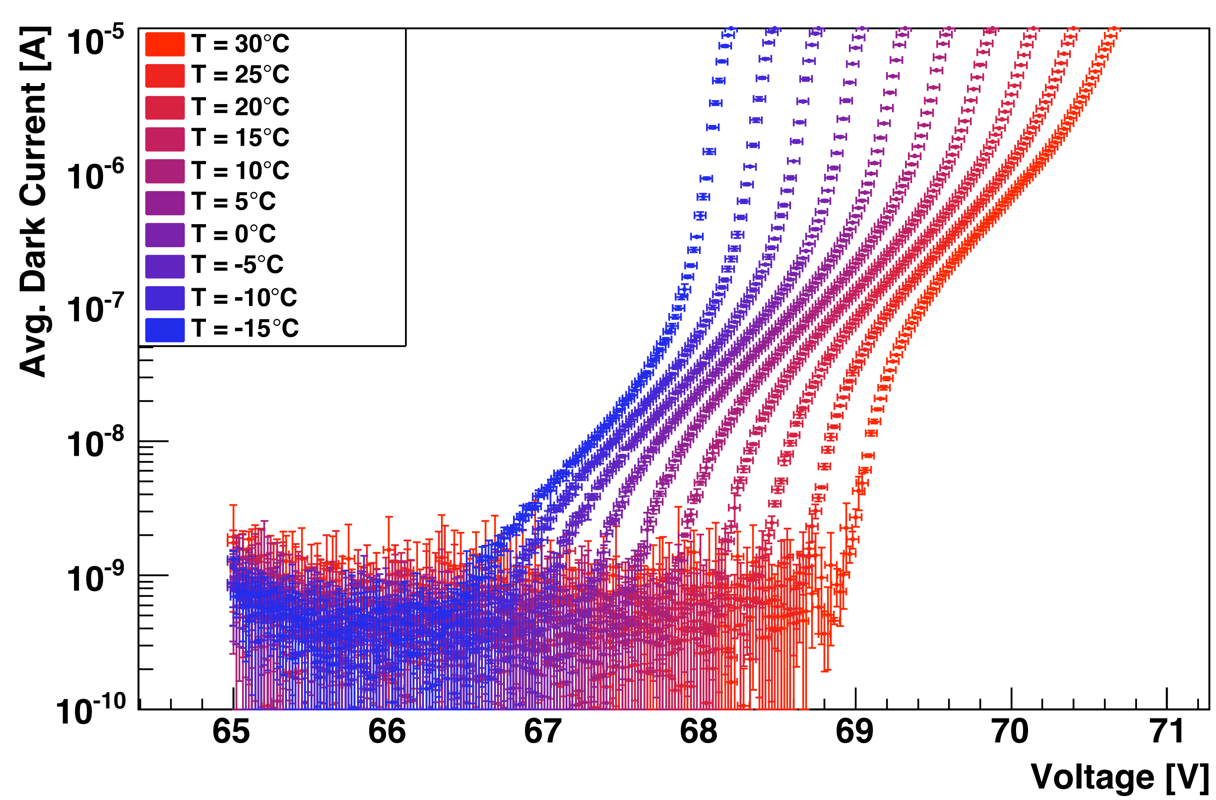
IV curves ⇔ temperature

2 Hamamatsu sensors
100 pixel (100 x 100 μm²)

sensor 1

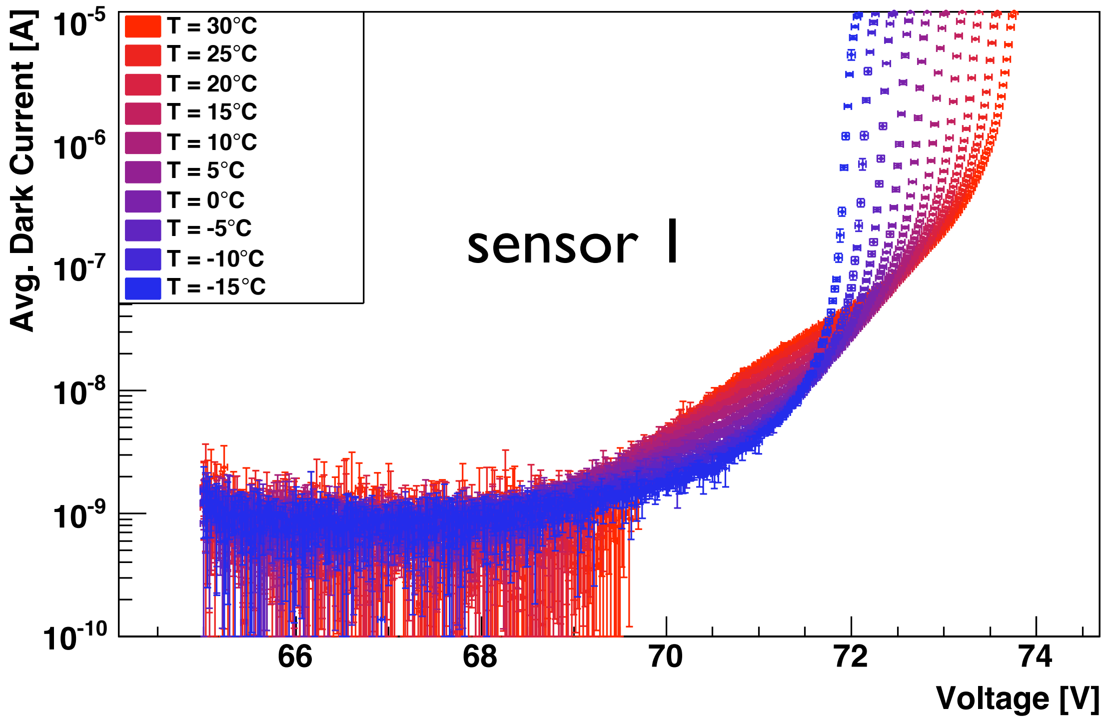


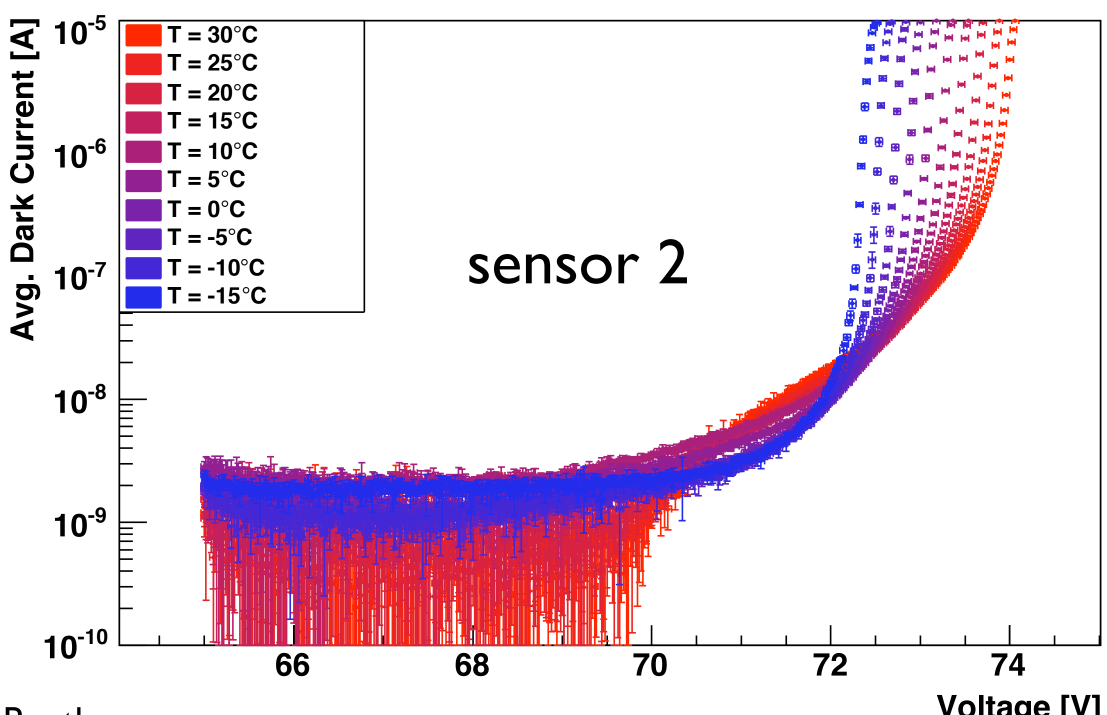
sensor 2



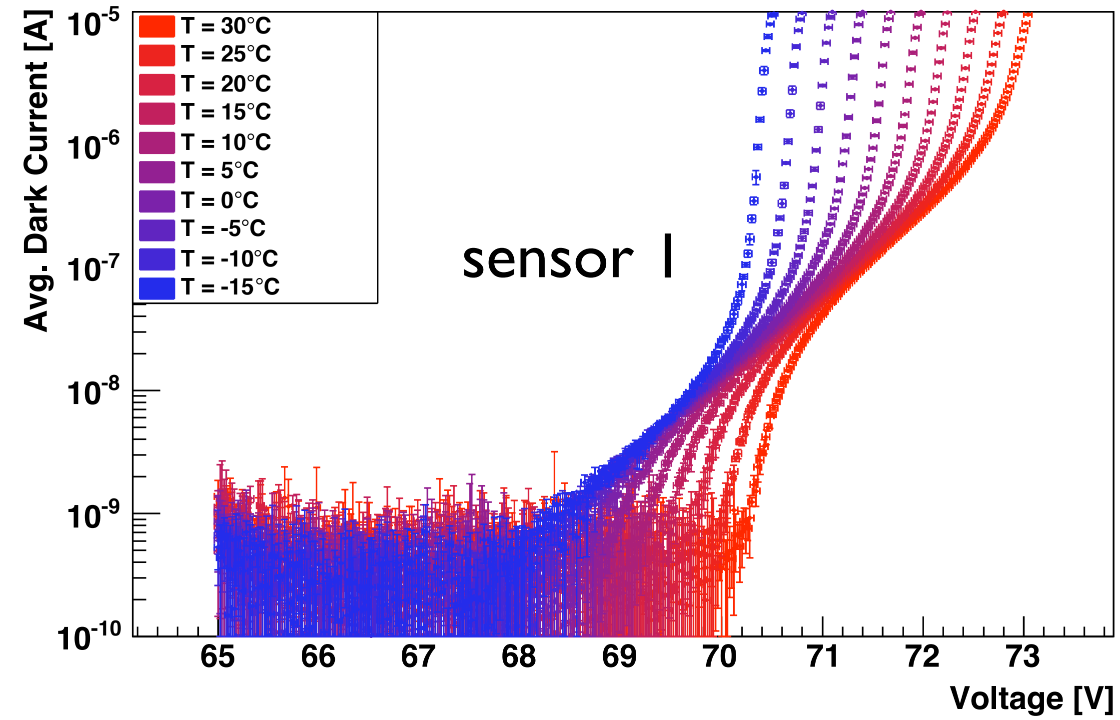
IV curves ⇔ temperature

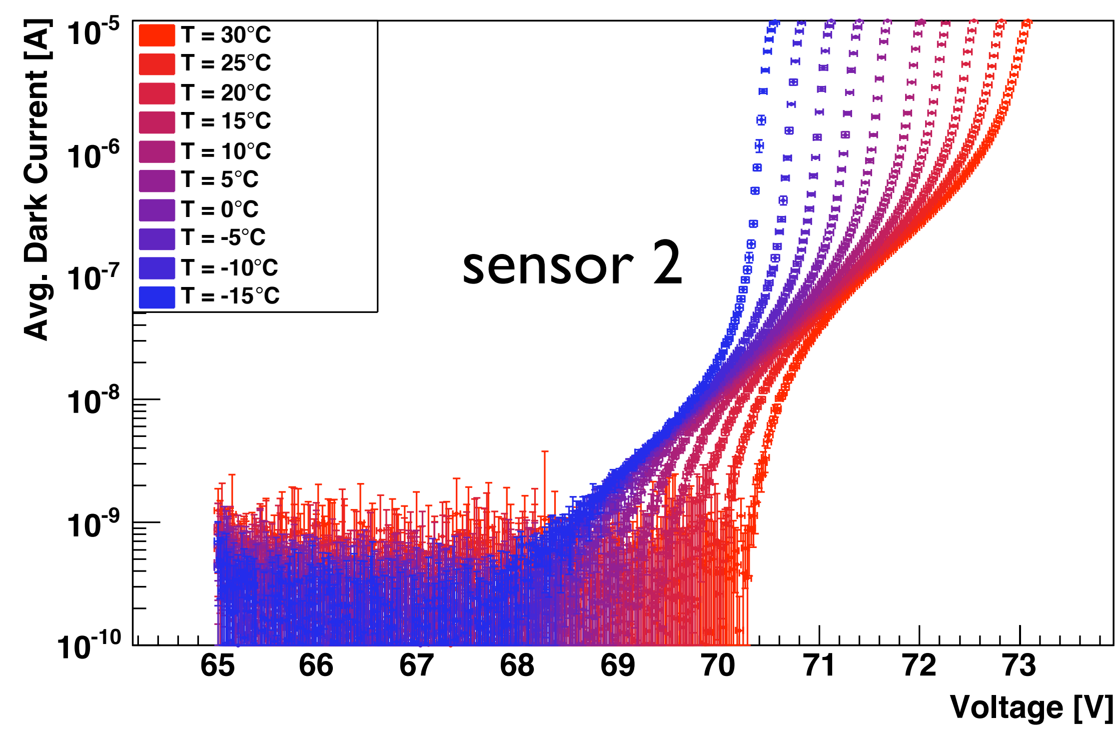
2 Hamamatsu sensors
1600 pixel (25 x 25 μm²)





2 Hamamatsu sensors
400 pixel (40 x 40 μm²)





Info on sensor package

Systematic comparison underway ...

What next?

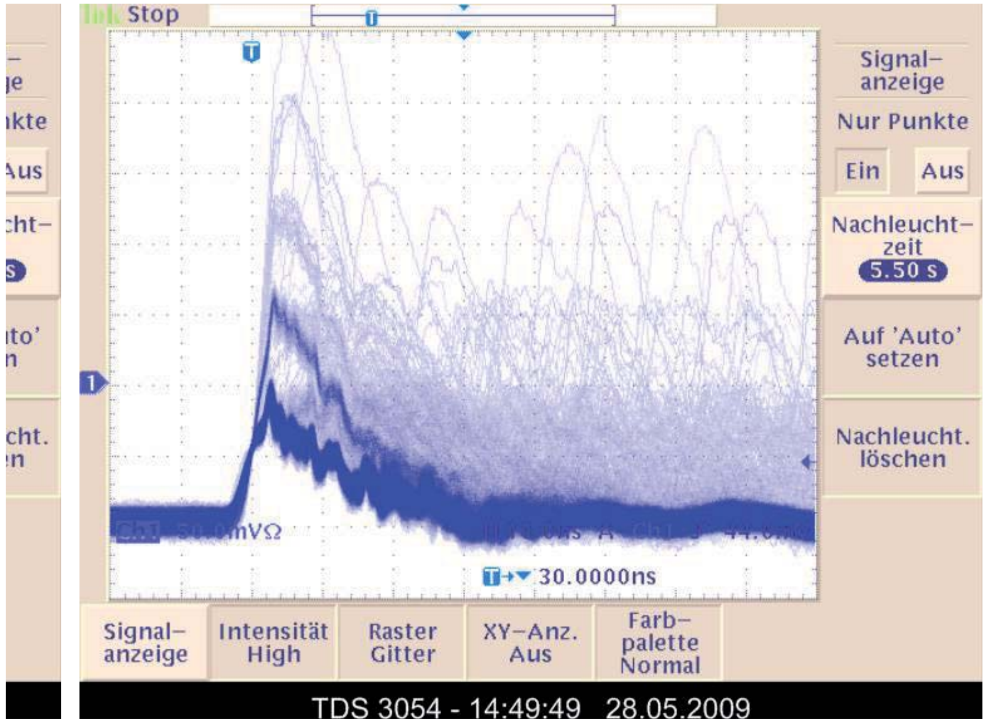
Tasks:
- Improve simulation: fibre (geometry, position),
  SiPM more accurately (pixels → fill factors, area 3x3mm^2)
- Segmentation (25x25 cm)
- coupling SiPM - scintillator (direct vs. wls fibre)
- temperature dependency of gain (→ stabilizing the gain)
- controlled process variable? dark current, single-photon events (kHz), ...

Goals:
Compact PCB with
- pre amplifier
- regulated power supply
- discriminator (digitization?) → expect problems.

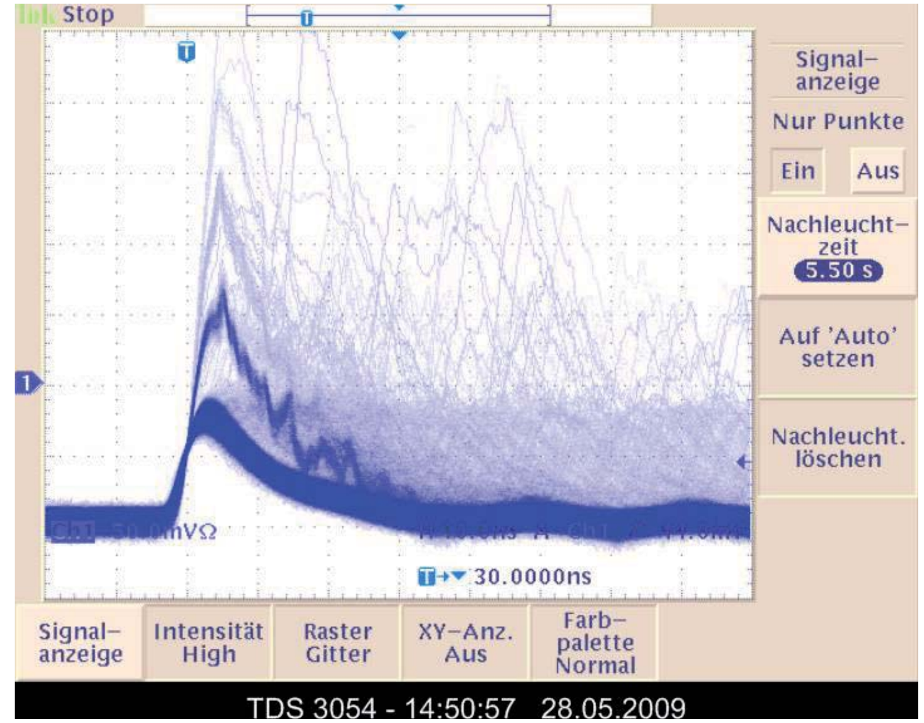
Digitization on PCB? → pulse height, pulse length
instead of „just" a comparator (1bit ADC) → 5 or 6 bit ADC → e.g. 43, 44 pe signal

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

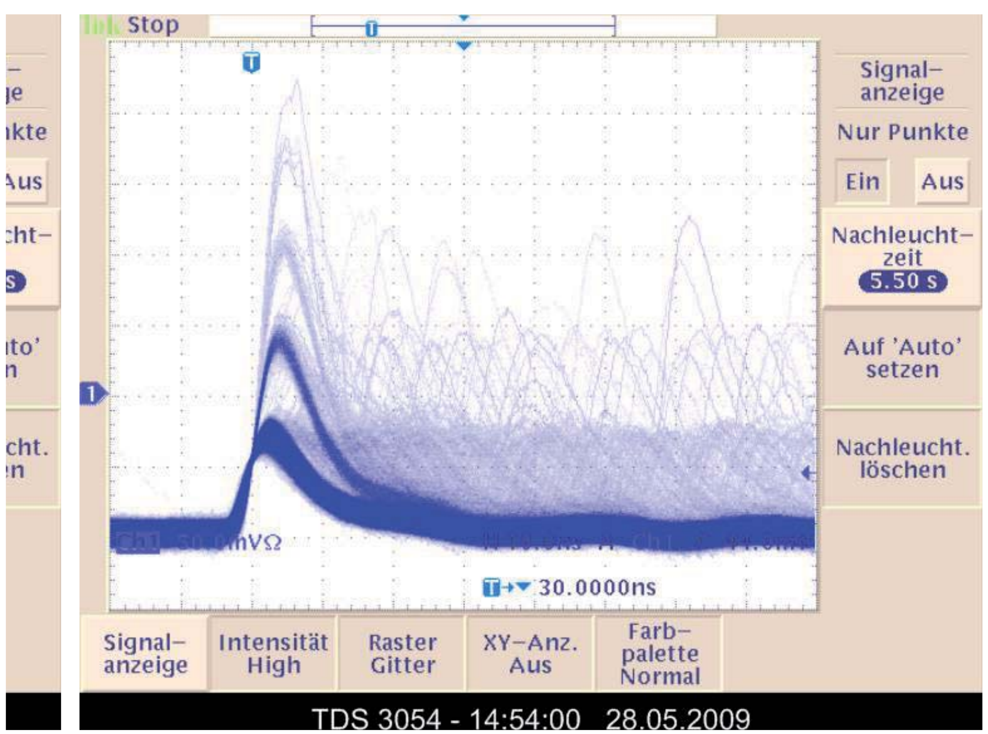
Problem with digital components



analog out with comparator level at 0.5 p.e.



analog out with comparator level at 1.5 p.e.



analog out w/o comparator

Shown:

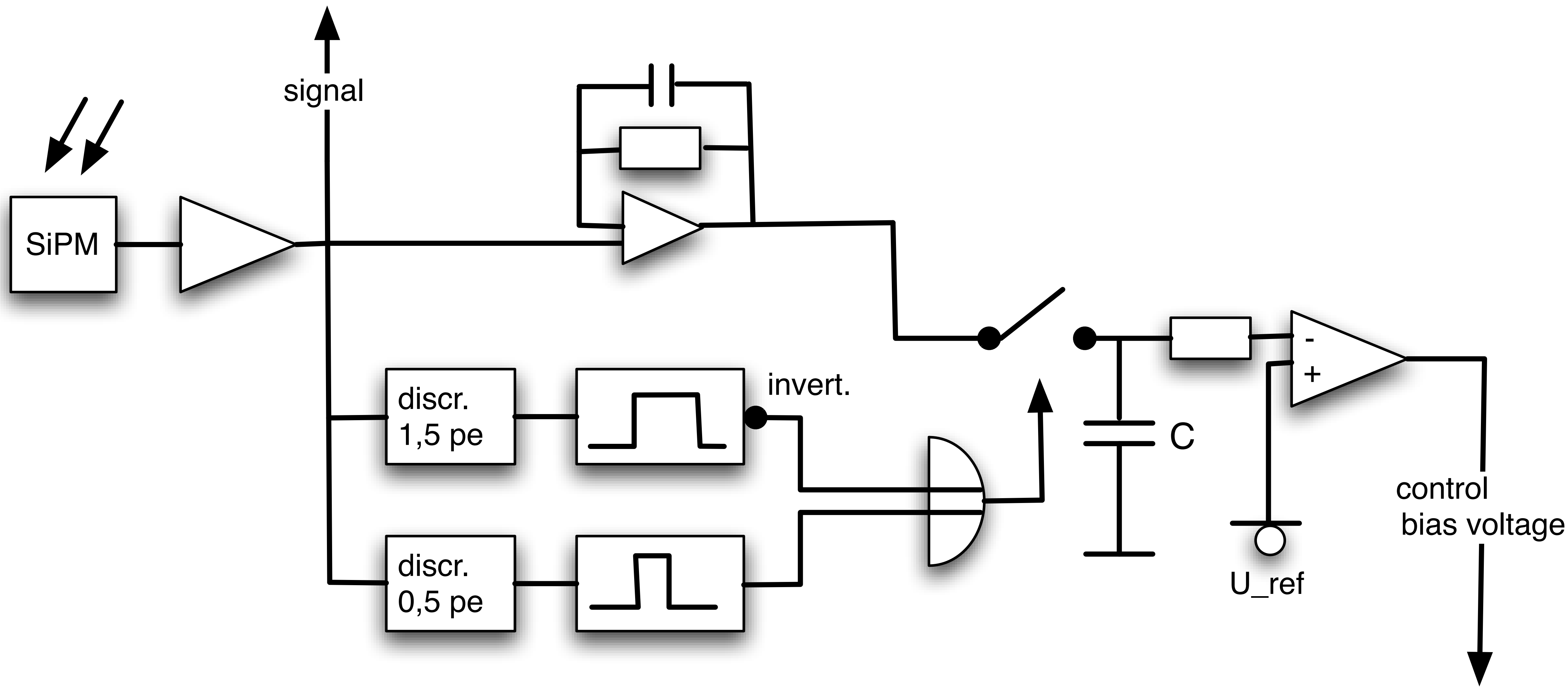
analog pulse height vs. time

→

signals distorted for pulses corresponding to

heights > active comparator threshold level

Controlled process variable



Lower discriminator opens switch in case of 1 pe signal

→ part of the shaped signal on C, if the gain raises C is charged, if the gain drops C is discharged

An inverting preamp compares to reference voltage and creates control prosses signal for the bias voltage.

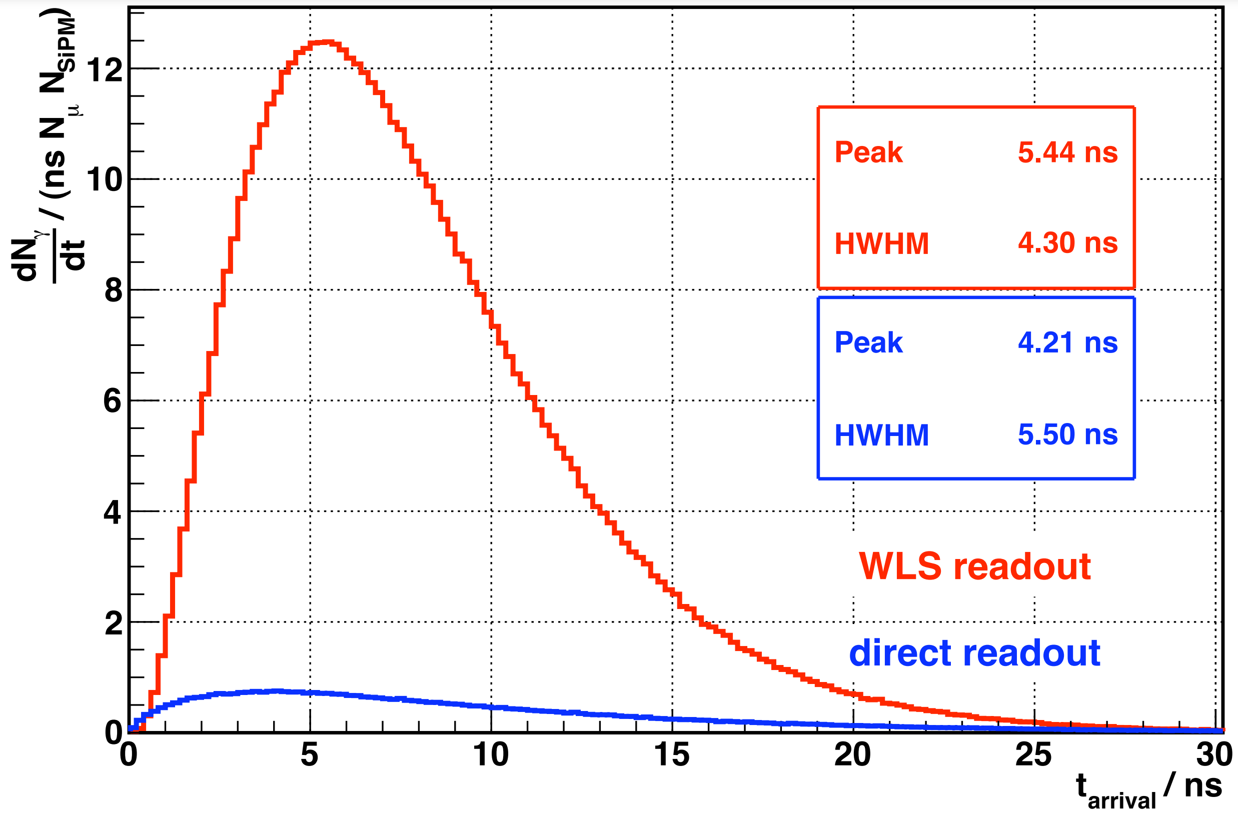
Lab installations in preparation

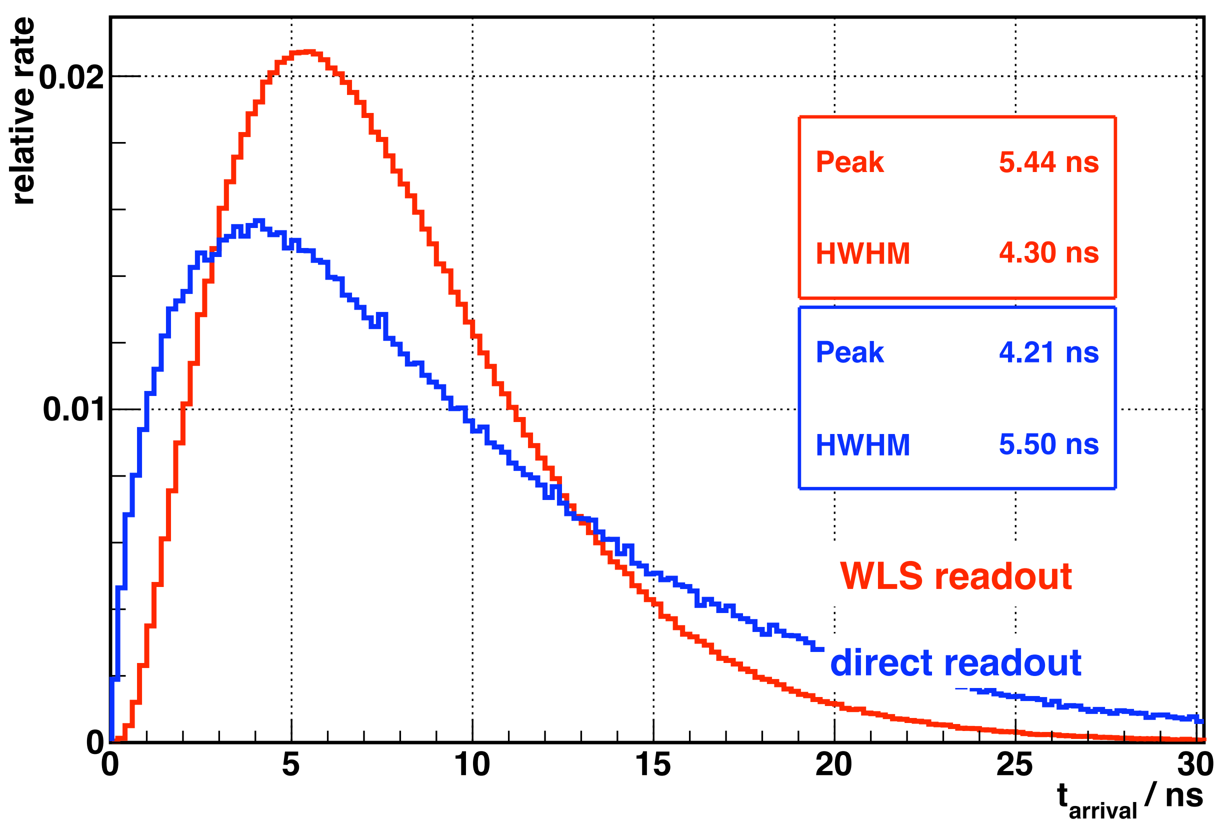
Pulsed UV Laser
266 nm
pulsewidth ≤ 1 ns
→ high statistics
→ adjustable impact position
→ known number of photons
→ timing studies coming soon

Scintillator setup:
→ individual, flexible setups
→ cosmic trigger

Backup

Photon arrival time, w/o reflector





remember:
SLHC bunch crossing distance: 50 ns

Prototype:
100 x 100 x 10 mm^2

⇒

- photons arrive at SiPM in ≤ 20 ns
- direct r/o 1.3x faster

→ no timing problems?!

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

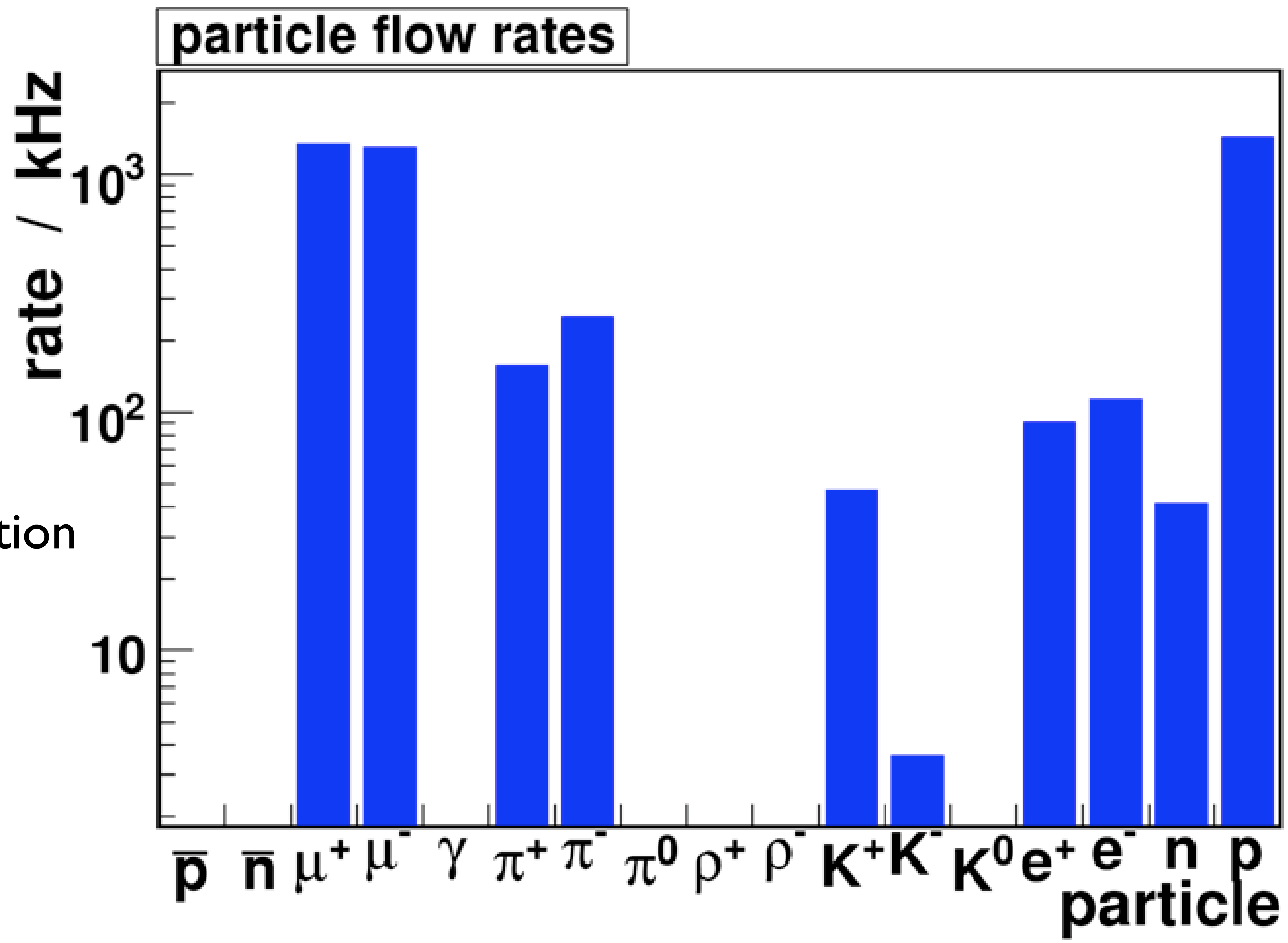
NB:
perfectly polished scintillator
w/o diffuse reflector

Particles in MTT

Simulation scenario:
400 collisions / bx
20 MHz bx rate
⇒ 8 GHz pp collision rate

Strategy:
- use existing min. bias MC samples
- lower threshold in GEANT to 10 MeV
- „measure“ particle rate at 1st RPC station

⇒ ???



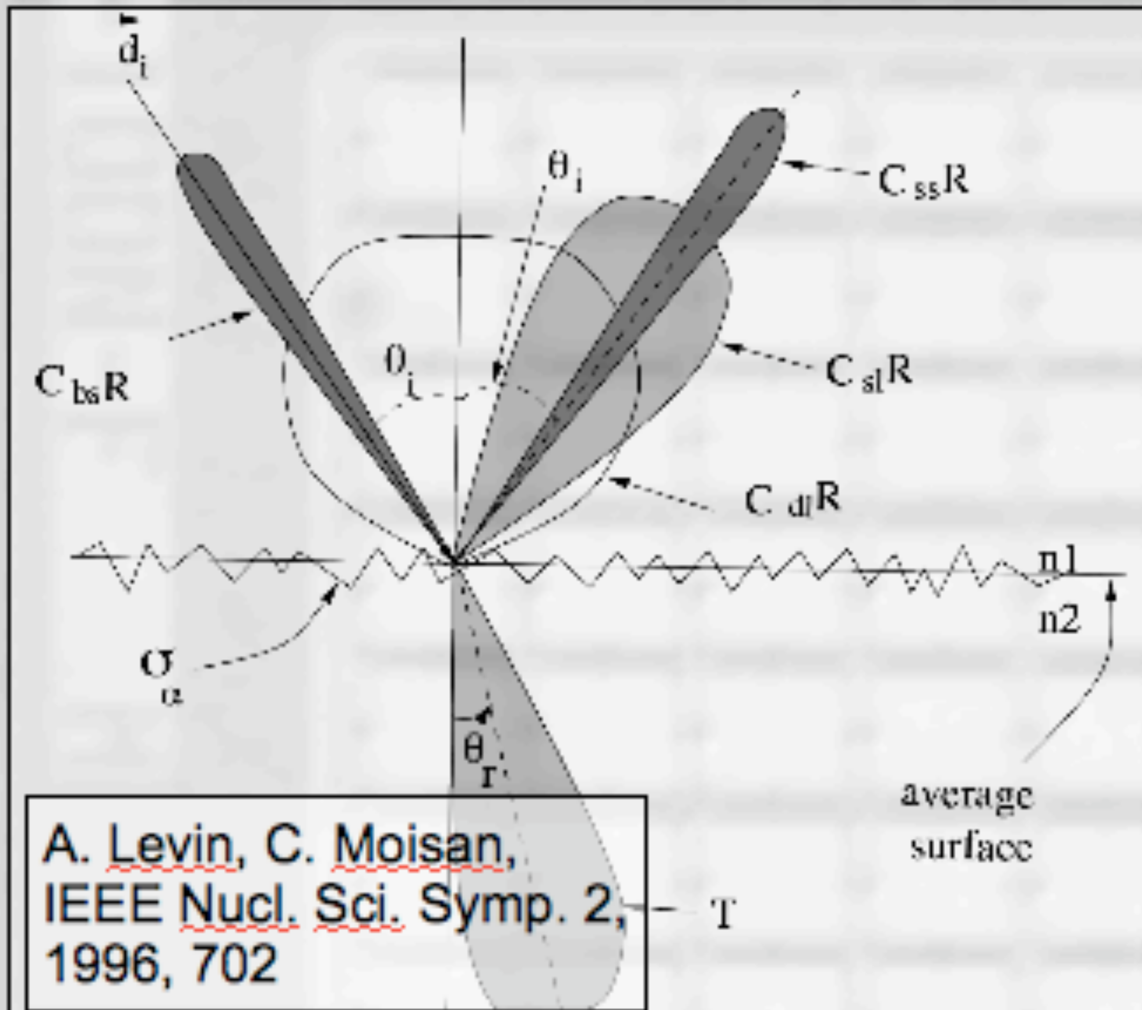
Open questions:
- Origin of particles?
- Effects of low energy particles?

→ Activity stopped (manpower, requires probably substantial CMSSW tuning)

First data will tell us the quality of prediction ...

Surface modelling

Surface Modelling in GEANT4



A. Levin, C. Moisan, IEEE Nucl. Sci. Symp. 2, 1996, 702

$$
\begin{aligned}
J_U(\theta_i,\theta_r,\phi_r) \approx\ & R(\theta'_r,n_1,n_2)[C_{sl}\, g(\alpha_r;0,\sigma_\alpha) \\
+\ & C_{ss}\delta(\theta_i-\theta_r)\delta(\phi_r) + C_{bs}\delta(\theta_i+\theta_r)\delta(\phi_r) \\
+\ & C_{dl}\cos(\theta_r)] \\
+\ & T(\theta'_i,n_1,n_2)\, g(\alpha_t;0,\sigma_\alpha),
\end{aligned}
$$

- UNIFIED Model (Knoll et al.)
- (empirical) model parameters
  - n_1, n_2 (refractive indices)
  - C_{ss}, C_{sl}, C_{bs}, C_{dl} ($\Sigma C_{xy} = 1$)
  - σ_α: gaussian standard dev.
  - refl. coeff. RC (ext. diff. refl.)
- parameter constraints

C_{xy} : height distrib., wavelength

- $\sigma_h/\lambda<0.025 \rightarrow C_{ss}$ or $C_{sl}=1$, $\sigma_\alpha=0$
- $\sigma_h/\lambda>1.5 \rightarrow C_{ss}=0$, $C_{sl}=1$

σ_α : analysis of facet slopes