Experience with Philips dSiPM

Studies on efficiency and time resolution for SciTil

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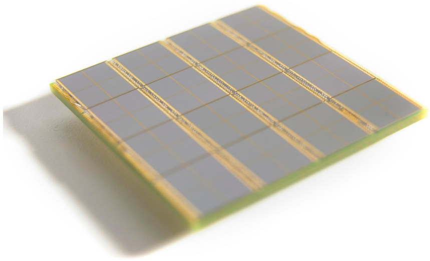
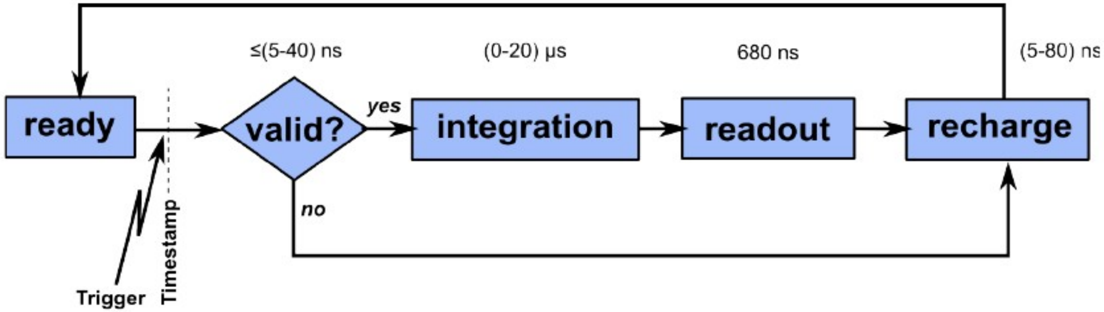
The digital SiPM

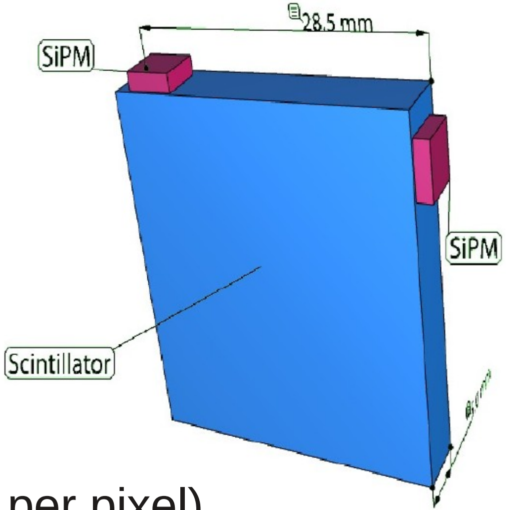


- Tile consists of 16 independent die sensors with 4 pixels each
- Two types: DPC-3200, DPC-6400 (gives the cell number per pixel)
- Possibility to enable/disable single cells
- One can create dark count maps and switch off noisy cells
- Data acquisition
  - One can set a trigger threshold (>= 1 ph.) per die and validation threshold (>= 4 ph.) per die
  - One can set a validation and integration interval
  - Time stamp per die at trigger occurrence
  - Number of photons (breakdowns) per pixel



The dSiPM for SciTil tests

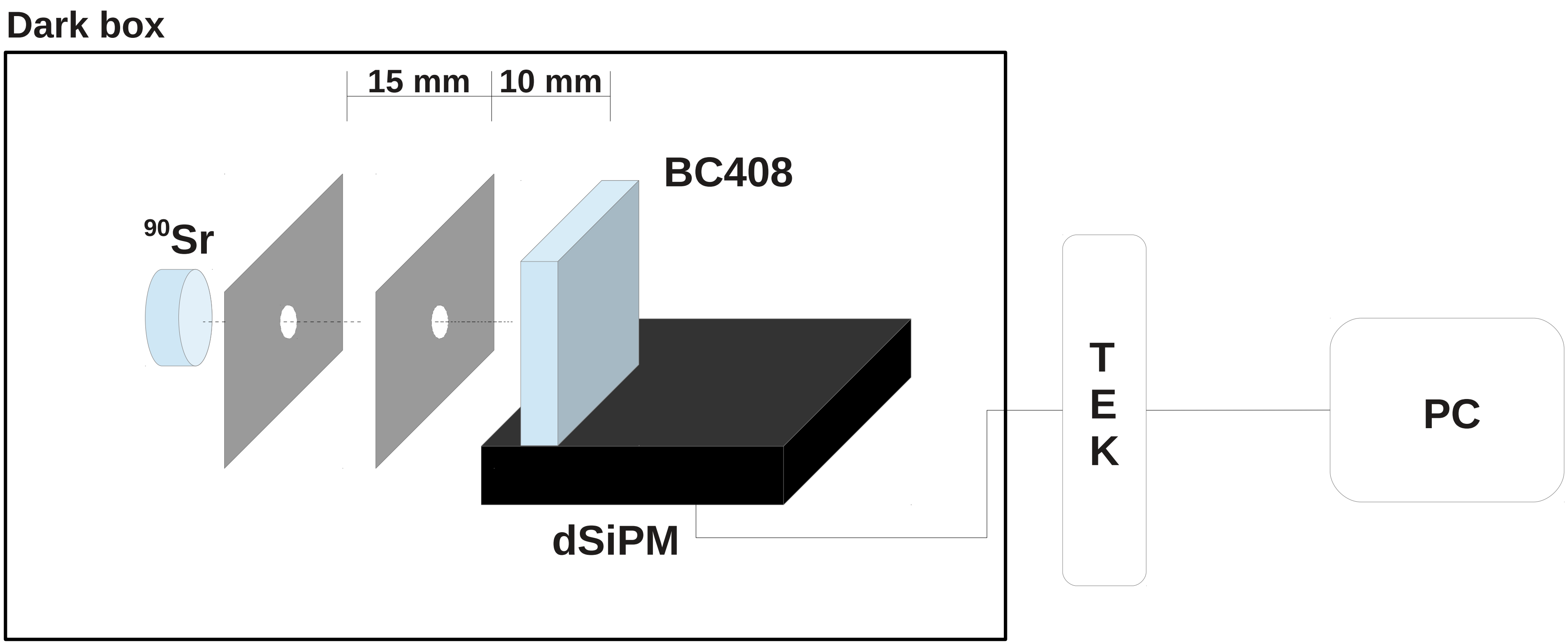
- **The dSiPM has a big sensitive area (32.6 x 32.6 mm²)**
- **One can cover the whole surface of a tile for SciTil and measure the photon distribution and time resolution as a function of the position of a pixel on the surface**
- **Without removing and repositioning the sensor several times**
- **The results can give then the ideal position of the SiPM on the tile surface**



Settings for the measurements:

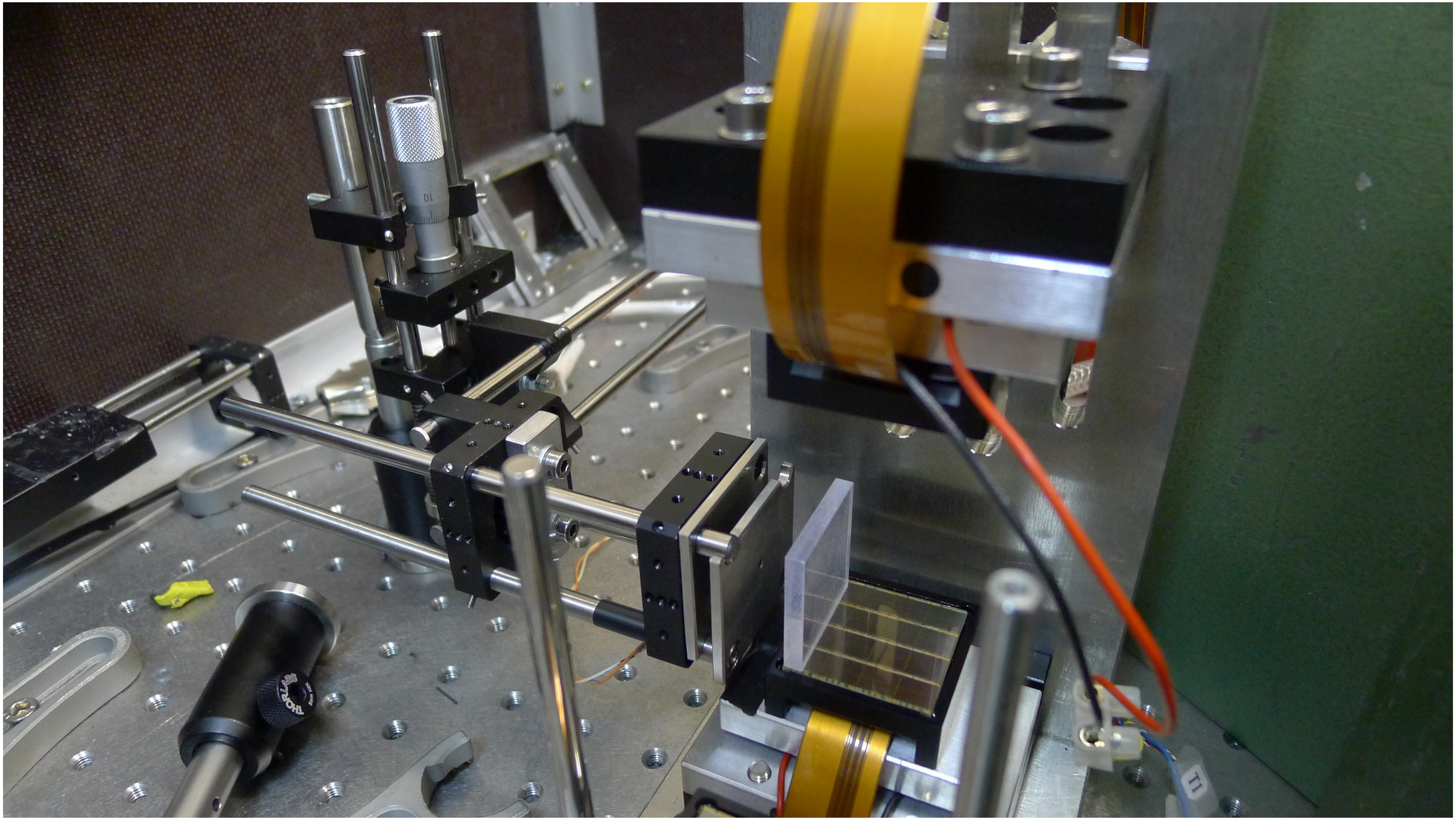
- DPC-6400
- Trigger threshold: 1 photon
- Val. threshold: 4 photons
- Val. interval: 10 ns
- Integration interval: 45 ns
- 200k frames per measurement: ~ 60 s (10-15k val. events per pixel)

Experimental setup



BC408 30 x 30 x 5 mm^3 and 20 x 20 x 5 mm^3 (no wrapping)
Philips dSiPM + PDPC-TEK unit + PC
Strontium-90 source
2 Pinholes with 2 mm diameter
Source and pinholes moveable with step motor and µm-stage
Water- and Peltier-cooling

Experimental setup

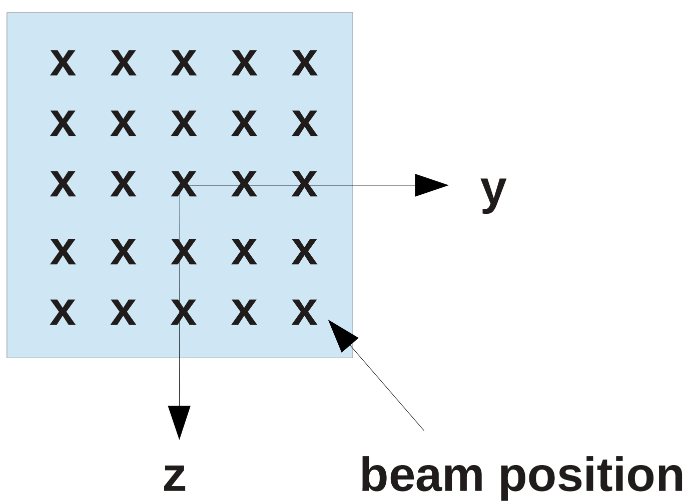


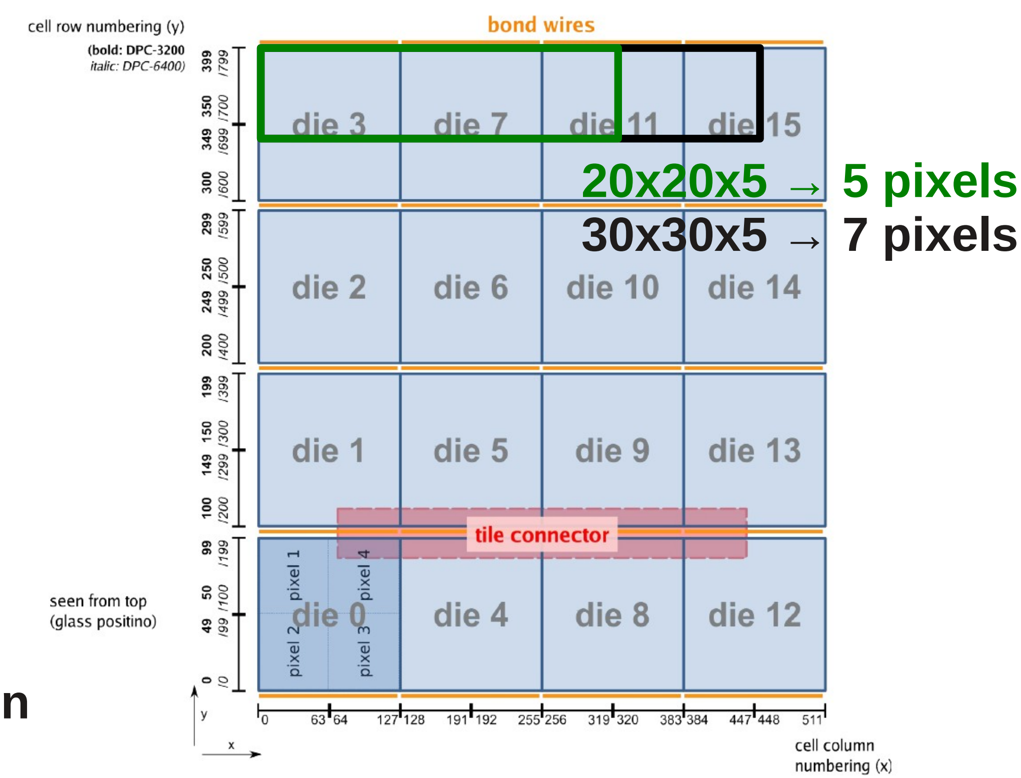
Measurement procedure

Idea: Scan the scintillator in 2 dimensions and measure the efficiency (# of detected photons) and time resolution as a function of the position of the beam (e-) for different positions of the photo sensor. Then evaluate the best position of the sensor on the scintillator surface.

Compare different geometries (30x30x5 and 20x20x5) of the scintillator

Measure with and without grease, wrapping, …

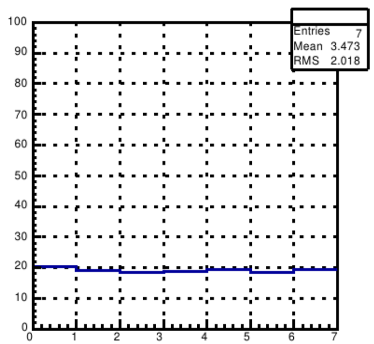


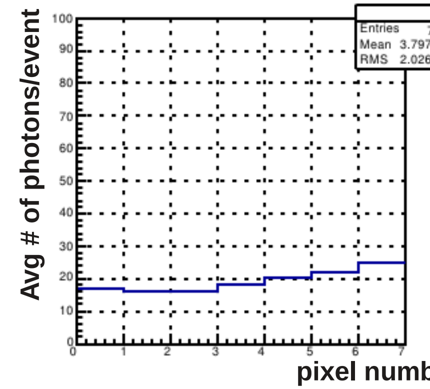


Photon distribution

30 x 30 x 5 mm³ without grease

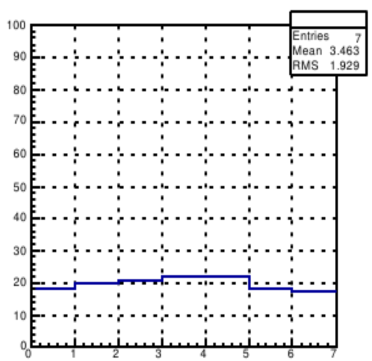
y = 0, z = -12

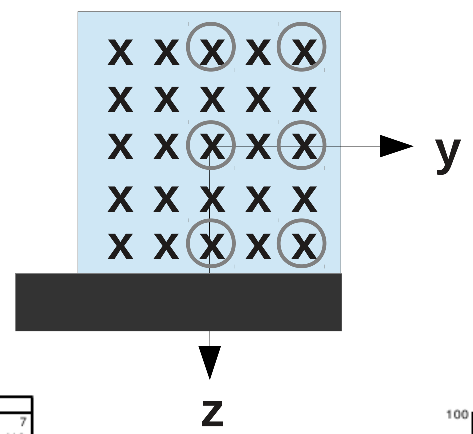


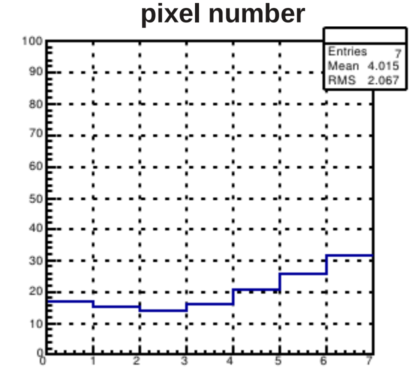


y = 12, z = -12

Strong position dependency !



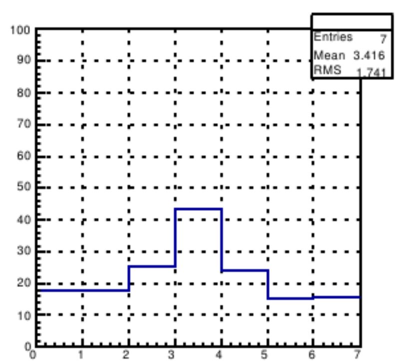


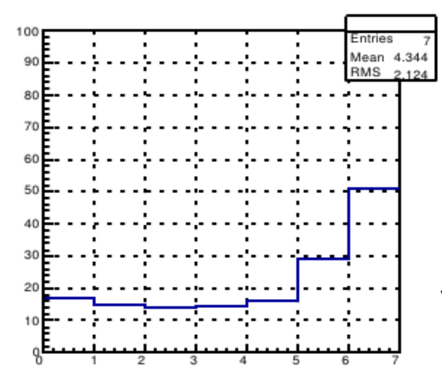


y = 0, z = 0

y = 12, z = 0

y = 0, z = 12





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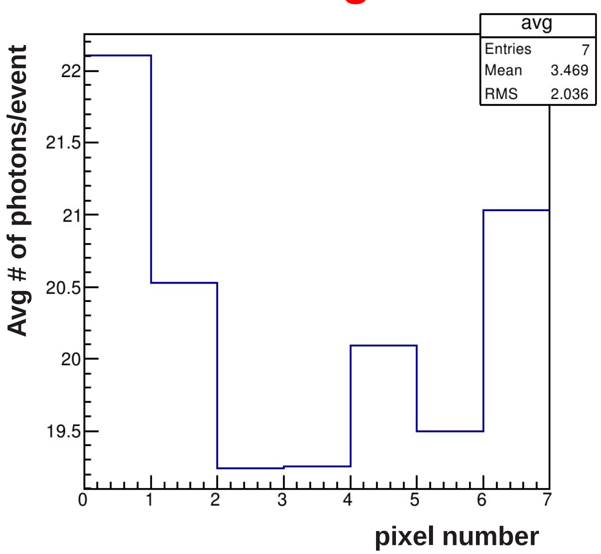
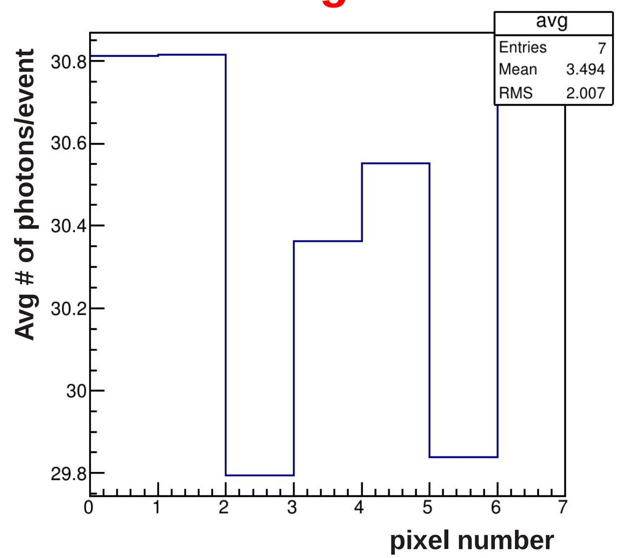
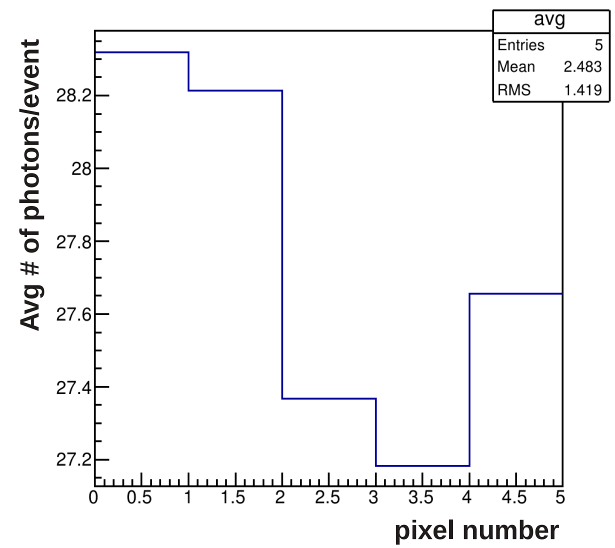


30 x 30 x 5 mm³ with grease



20 x 20 x 5 mm³ without grease



- **Plots show the average values of 25 different measurements (positions of the beam on scintillator)**
- **No favored position of the sensor can be determined (maybe edge slightly better)**
- **Photons more or less distributed equally**
- **Using grease helps to increase number of photons collected (factor 1.5)**
- **More photons collected with 20 x 20 x 5 mm³**

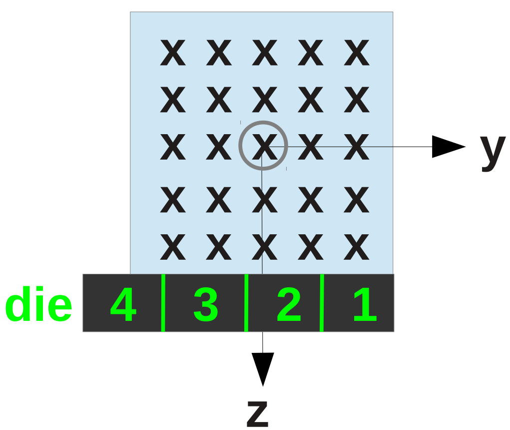
Time resolution

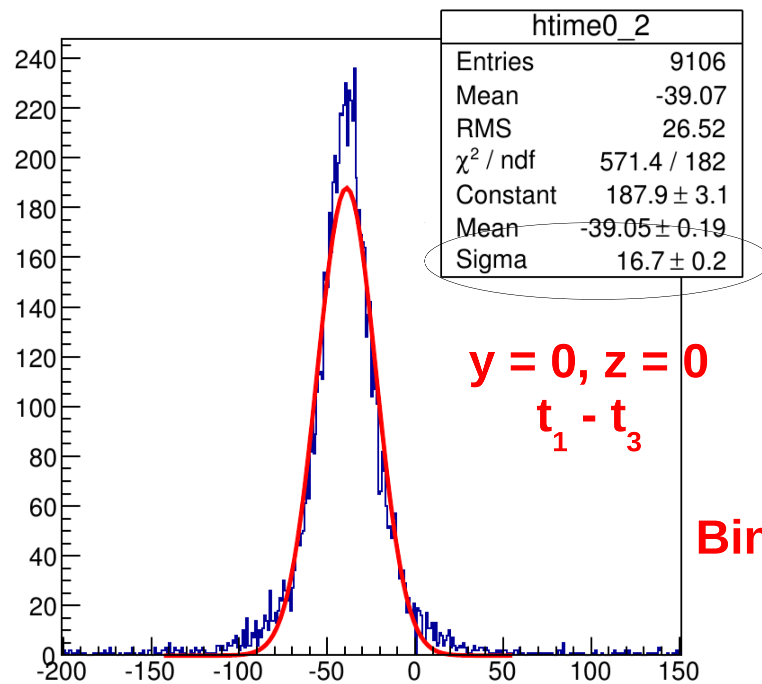
The dSiPM gives a time stamp per die at the moment of trigger occurrence (arrival of the 1st photon). One can use this time stamps to calculate arrival time difference between dies.

30 x 30 x 5 mm³ (4 dies) → 6 equations to calculate σ_i (i = 1,2,3,4)

20 x 20 x 5 mm³ (3 dies) → 3 equations to calculate σ_i (i = 1,2,3)

Perform a fitting to solve the equations and evaluate time resolution of a channel/die.





30 x 30 x 5 mm³ with grease

σ_{13} = 326 ps

Binning of TDC: 10 ns/512

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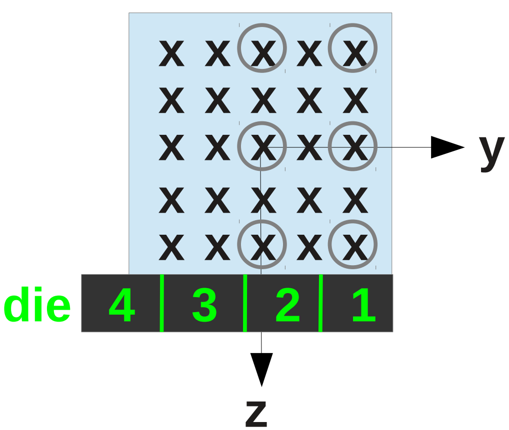
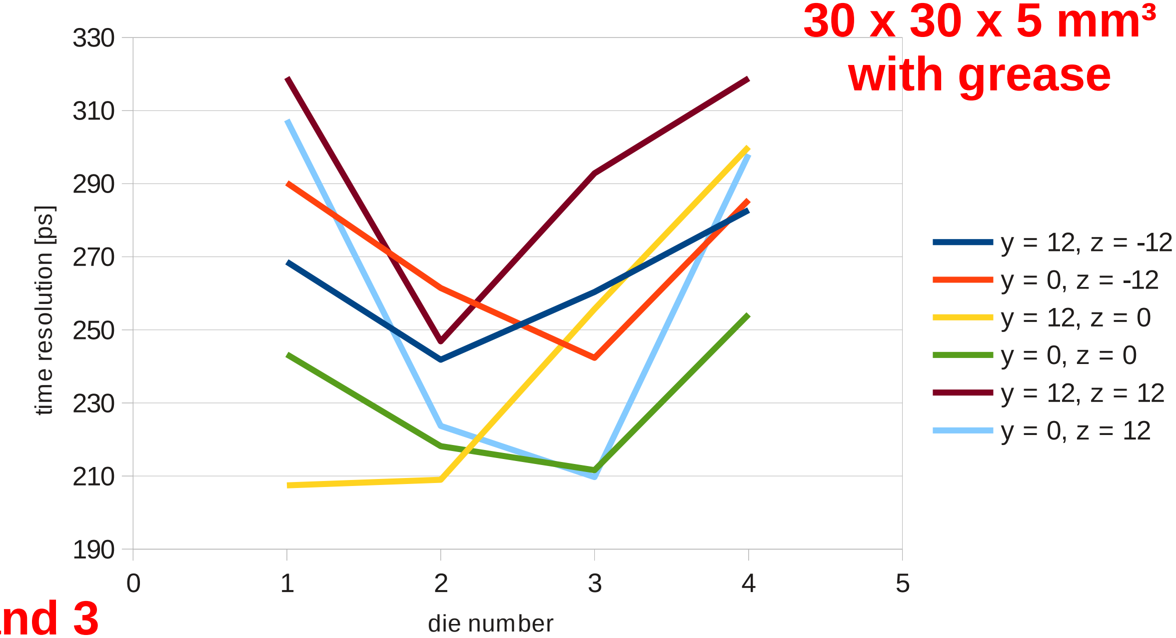
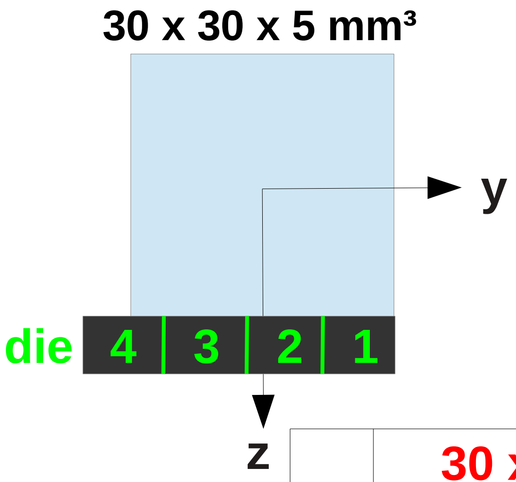
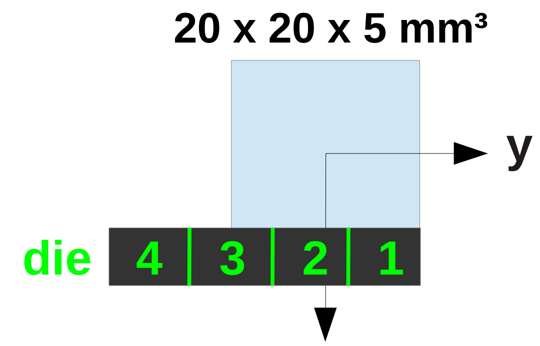




Strong position dependency !
Better time resolution for dies 2 and 3

Time resolution



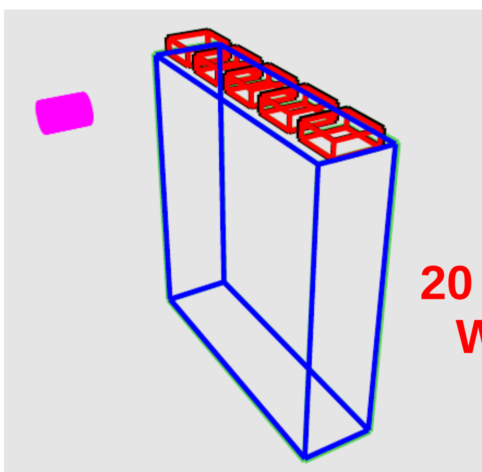


	30 x 30 x 5 mm³ without grease	30 x 30 x 5 mm³ with grease	20 x 20 x 5 mm³ without grease
σ_1	348 ps	275 ps	267 ps
σ_2	295 ps	234 ps	234 ps
σ_3	303 ps	234 ps	332 ps
σ_4	326 ps	271 ps	

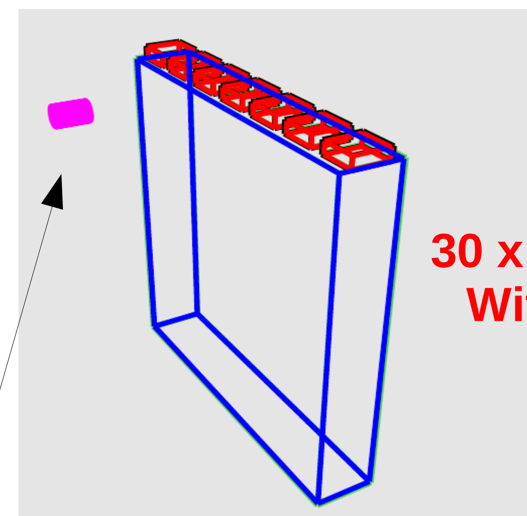
- **Average time resolution of 25 different measurements (positions of the beam on scintillator)**
- **Values are not very good (?)**
- **Better time resolution for central dies**
- **Using grease helps to improve the timing**
- **Better time resolution with 20 x 20 x 5 mm³**

Simulation

- **Simulations with SLitrani (LIght TRansmission in ANIsotropic media) to compare with measurement**
- **Monte Carlo based on ROOT to simulate light propagation**



20 x 20 x 5 mm³
With 5 APDs

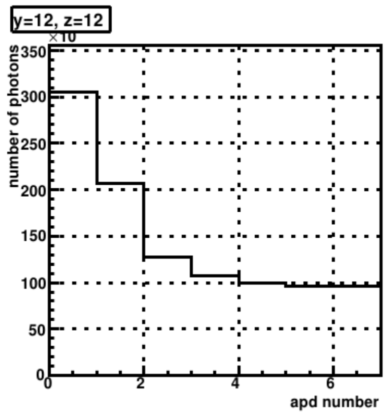


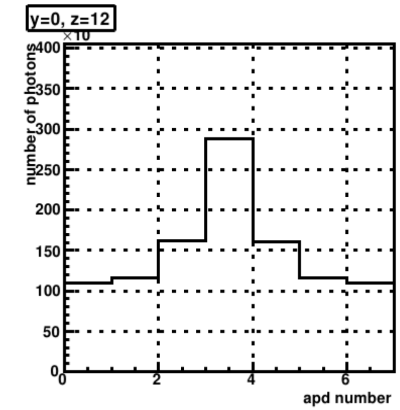
30 x 30 x 5 mm³
With 7 APDs

1000 e- per shot
25 positions as done in measurement

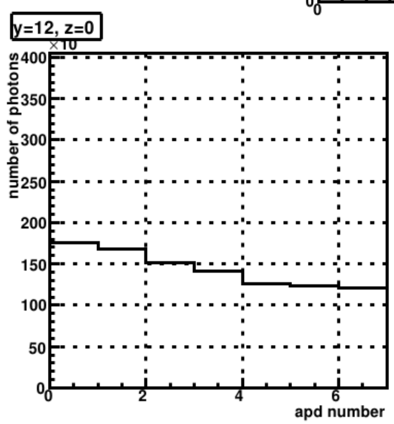
Simulation: photon distribution

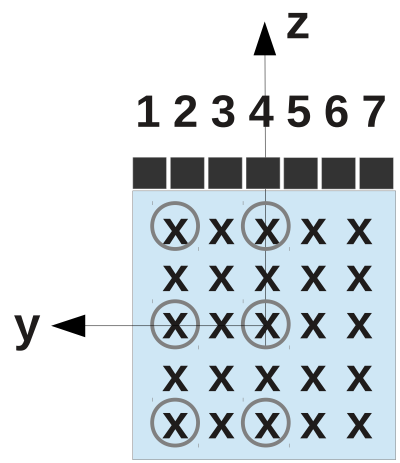
30 x 30 x 5 mm³

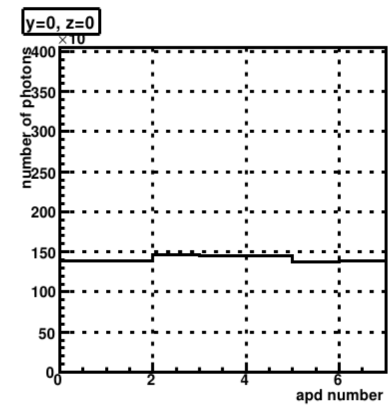


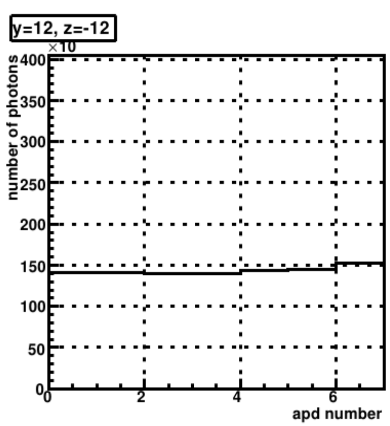


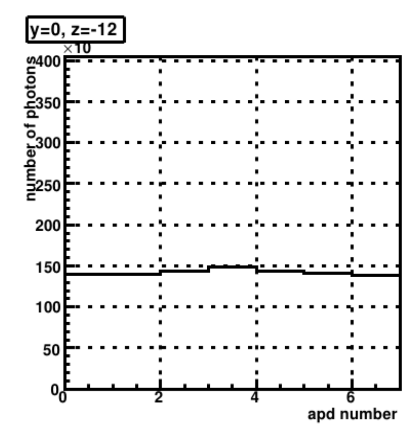
Strong position dependency !





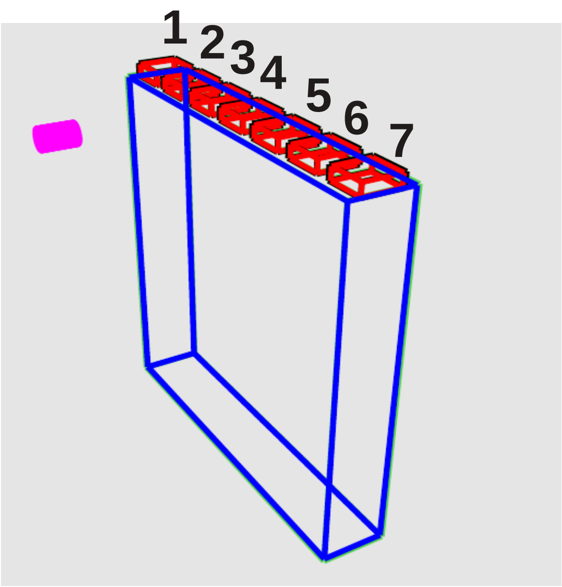




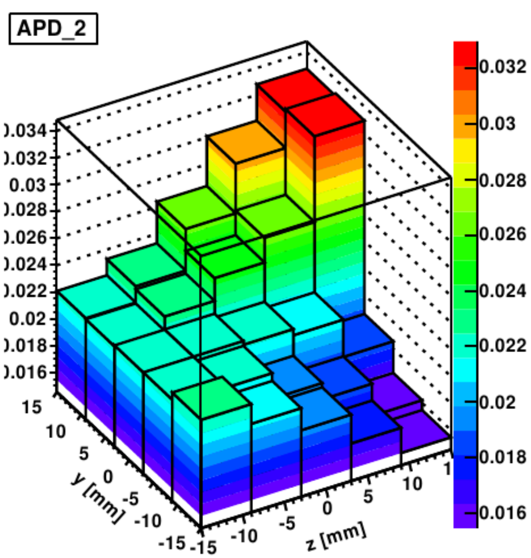


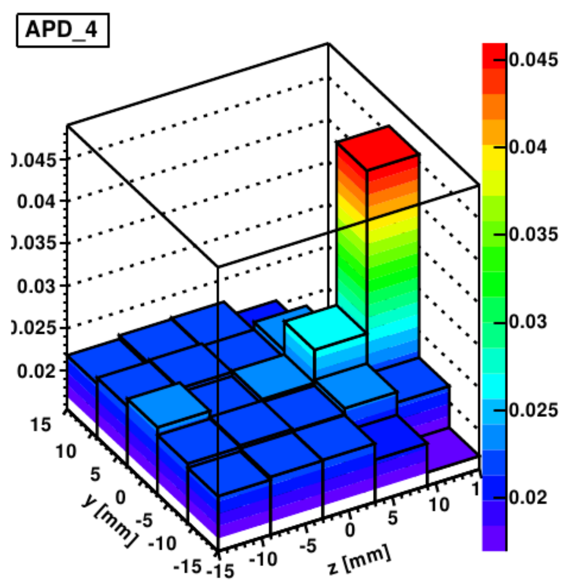
Simulation: collection efficiency

30 x 30 x 5 mm³



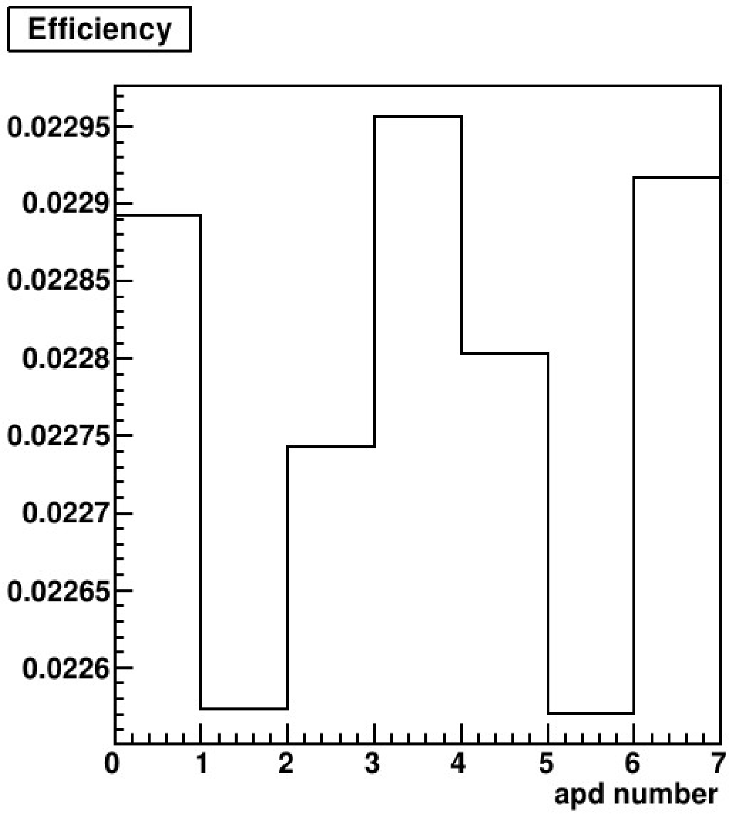
Collection efficiency: $\varepsilon_{col} = N_{seen}/N_{gen}$



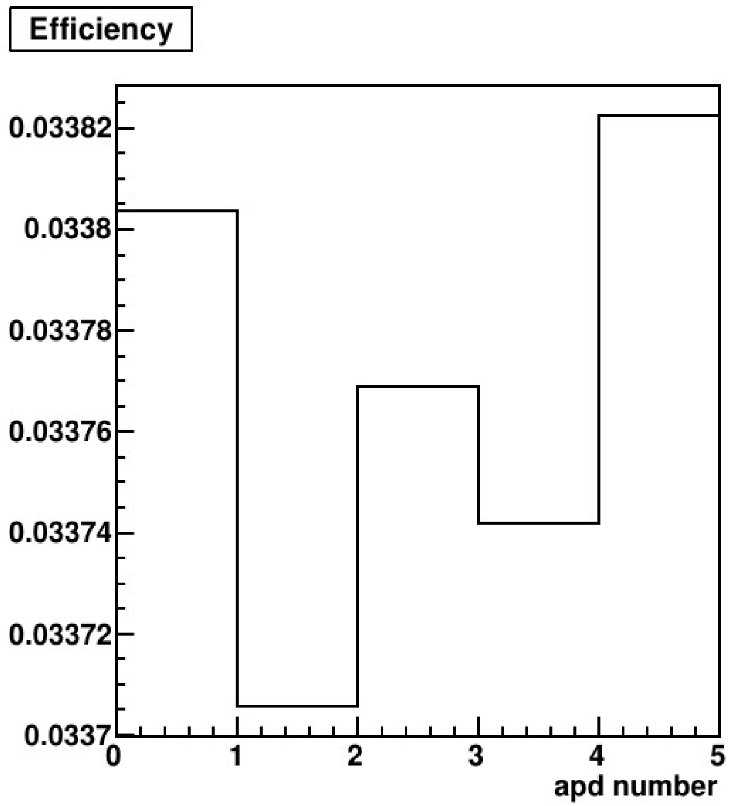


Simulation: collection efficiency

30 x 30 x 5 mm³



20 x 20 x 5 mm³



- **Plots show the average values of 25 different positions of the beam on scintillator**
- **Values are very close together, variations at per mill level**
- **Good agreement between measurement and simulation**

Summary

- The dSiPM has been used to study the photon distribution and time resolution of a scintillator tile for SciTil.
- Simulation and measurement showed that the collected photons are distributed rather equally over one tile surface.
- However, it seems that a better time resolution can be obtained by placing the sensor at the center.
- Using grease helps to improve timing and collection efficiency.
- Using the 30 x 30 x 5 mm^3 scintillator with grease, one can achieve approx. the same results (timing ~ 230 ps and collected photons ~30/event) as with the 20 x 20 x 5 mm^3 without grease.
- The best value for the time resolution from this first measurement is σ = 230 ps for a single channel (die).
- There is a good agreement between simulation and measurement.

To do

- **Study the time resolution.**
- **Measure time resolution of the dSiPM itself, using a laser.**
- **Place sensors on two neighboring sides of the tile.**
- **Study the influence of wrapping.**
- **Do more simulations, also with timing (include PDE, electronics threshold,...)**

Remarks on dSiPM

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- **Large active area ↔ bulky (large frame)**
- **“Plug and play”**
- **Quick information: # of photons, time stamp**
- **Change settings quickly**
- **Enable/disable single cells**

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- **Gets hot (10° in first 20 s if all dies enabled) → cooling needed**
- **“Black box”**
- **“Easy” things ↔ “difficult” things**
- **Manual can be improved**