R&D on time resolution studies for SciTil at SMI

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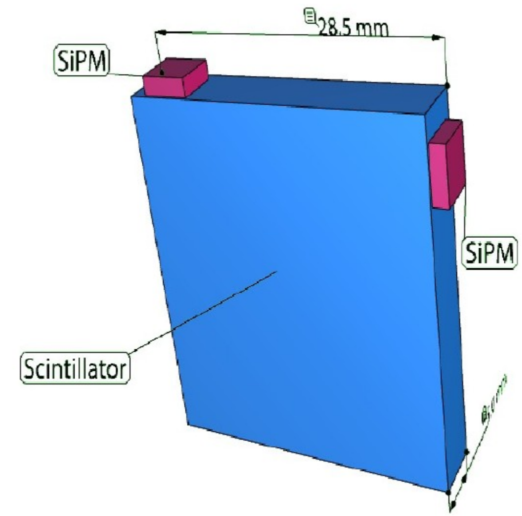
Outline

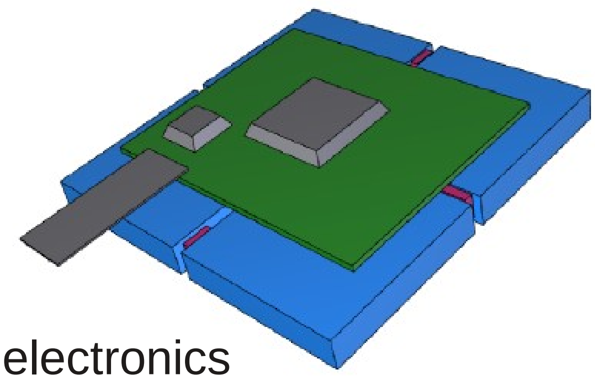
- Introduction
- R&D with digital SiPM (DPC)
- R&D with conventional (analog) SiPM
- Detector optimization procedure
- Conclusion
- Beam test at FZ Jülich
- Summary

Introduction

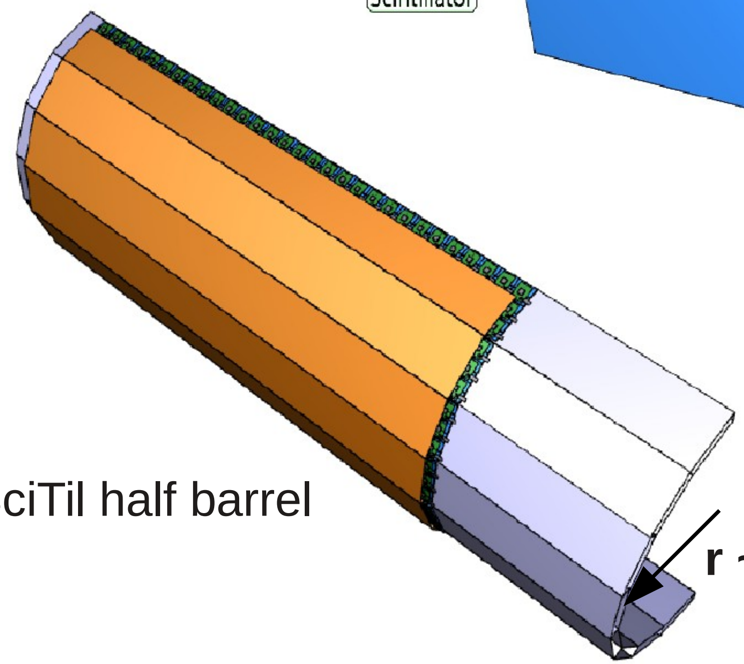
SciTil detector layout

- **Small plastic scintillator tiles (~ 30 x 30 x 5 mm³)**
- **Detect photons with directly attached Silicon Photomultipliers (SiPMs)**
- **In total about 6000 tiles and 12000 SiPMs**





4 tiles with electronics



SciTil half barrel

r ~ 50 cm

R&D to optimize sensor/scintillator geometry and configuration (incl. feasibility study)

Requirements

- **Minimum material:**
  - **2% of a radiation length**
  - **2 cm radial thickness (including readout and support)**

- **Excellent time resolution:**
  - **$\sigma_t \approx 100$ ps**

Plastic scintillators for fast timing applications

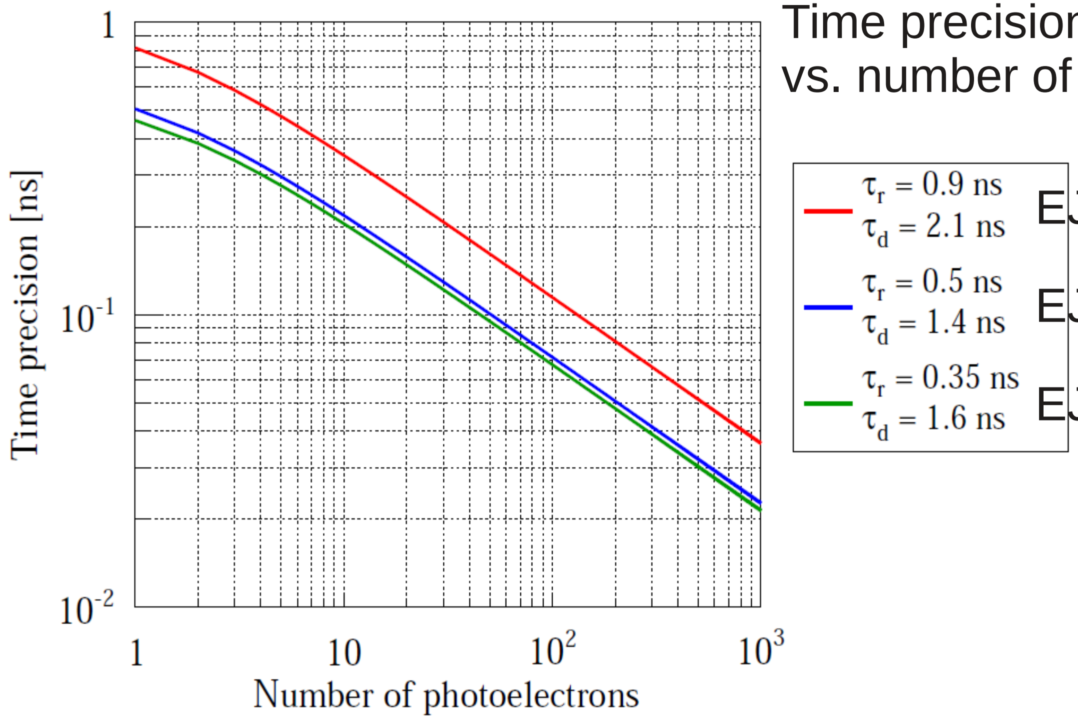
	EJ-232* **NE-111A/BC-422****	**EJ-228** **Pilot-U/BC-418**	**EJ-204** **NE-104/BC-404**	**EJ-200** **Pilot-F/BC-408**
Light yield [% Anthracene]	55	67	68	64
Light yield [photons/MeV]	8,400	10,200	10,400	10,000
Rise time [ns]	0.35	0.5	0.7	0.9
Decay time [ns]	1.6	1.4	1.8	2.1
Wavelen. of Max. Emission [nm]	370	391	408	425
Prize per piece*** (28.5 x 28.5 polished) [EUR]	80	75	65	65

** Eljen Technology, http://www.eljentechnology.com/*
*** Saint-Gobain Crystals, http://www.crystals.saint-gobain.com/*
**** Scionix Netherlands, http://www.scionix.nl/*

Scintillator time resolution

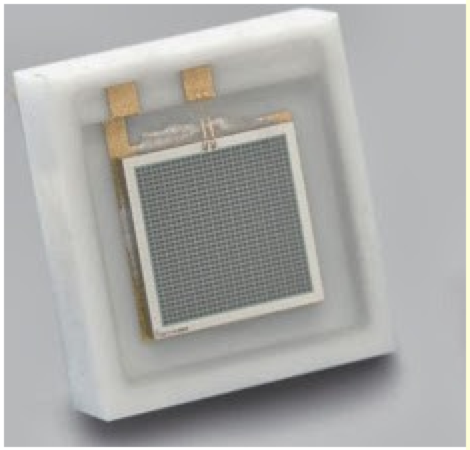
- **The time resolution of a scintillator is limited by photon statistics and photon propagation inside the scintillator**
- **Studying the statistics of the scintillation process shows that triggering on the first photon gives the best time precision**
- **This behavior changes if the photodetector response is considered (see later)**
- **The time precision improves with the detected number of photons and depends on the scintillator time constants and light yield**
- **The optimal scintillator should have shortest rise-, decay-times and highest light output and should be small to reduce the influence of photon propagation**

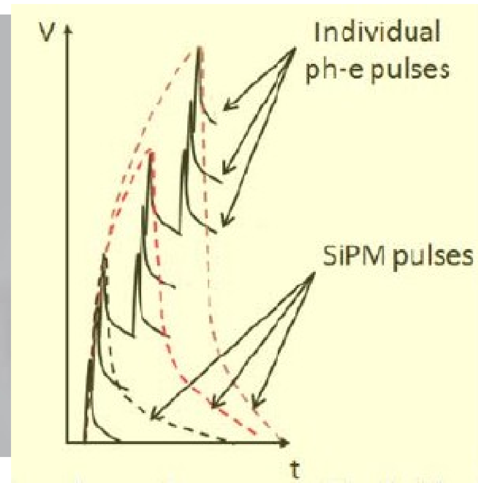
Time precision of the 1st photon vs. number of detected photons

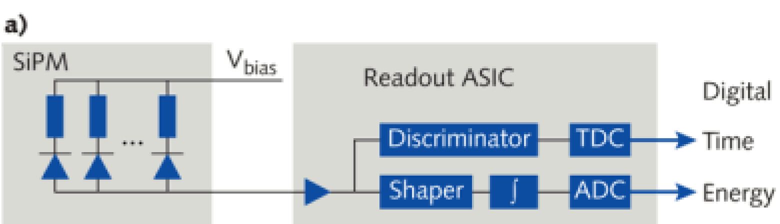


Analog and digital SiPM

Analog:

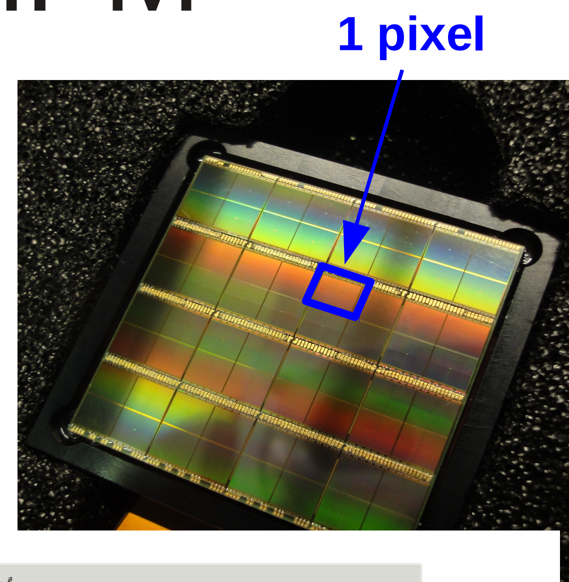


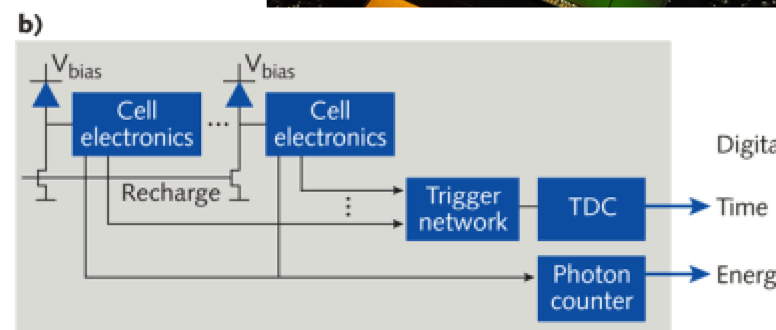




- Array of SPADs (Single Photon Avalanche Diode)
- Few 100 – few 1000 SPADs
- Signal: analog sum of individual pulses
- Pulse amplitude depend on gain/temperature
- **Hamamatsu, Ketek, AdvanSiD, SensL,...**

Digital:



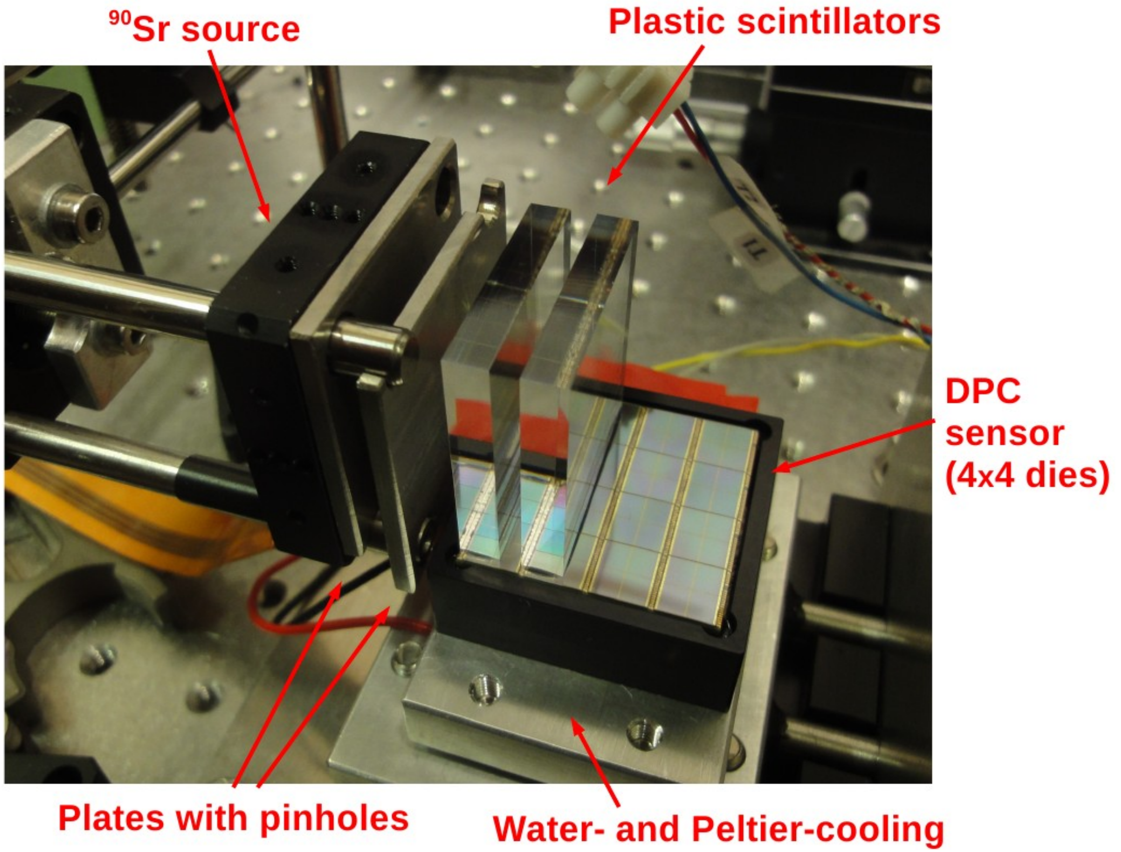


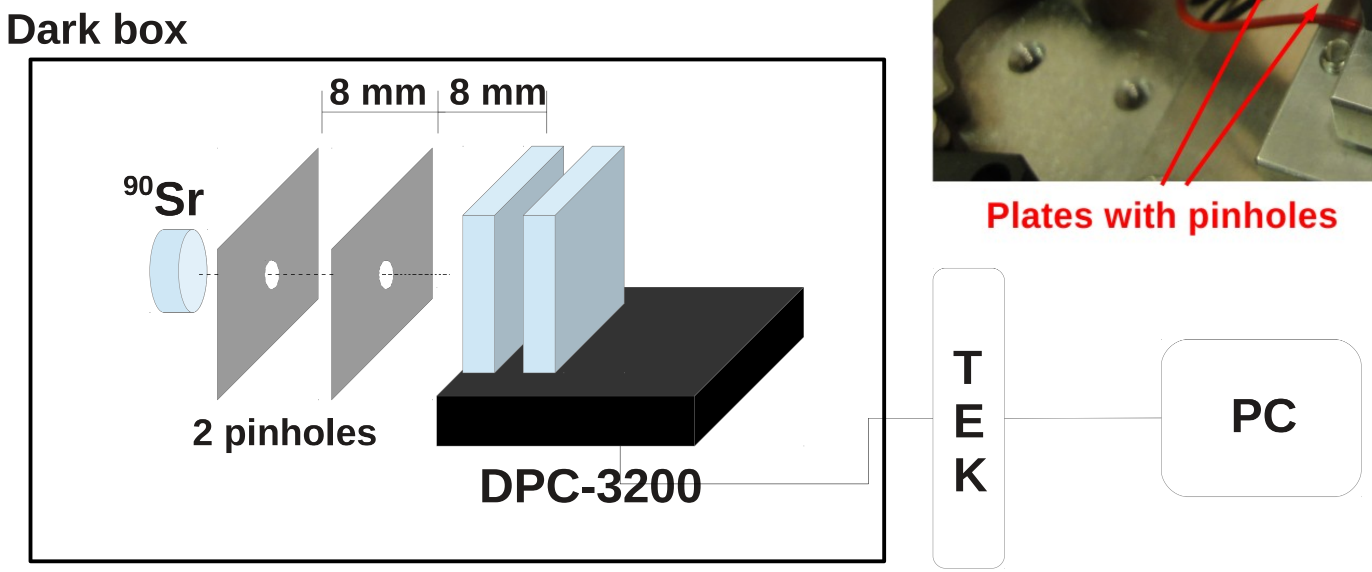
- Array of SPADs
- 3200/6400 SPADs per pixel
- Signal: digital sum of trigger bins (breakdowns) & digital time stamp from TDC
- Pulse amplitude is not relevant
- **Philips**

R&D with digital SiPM (DPC)

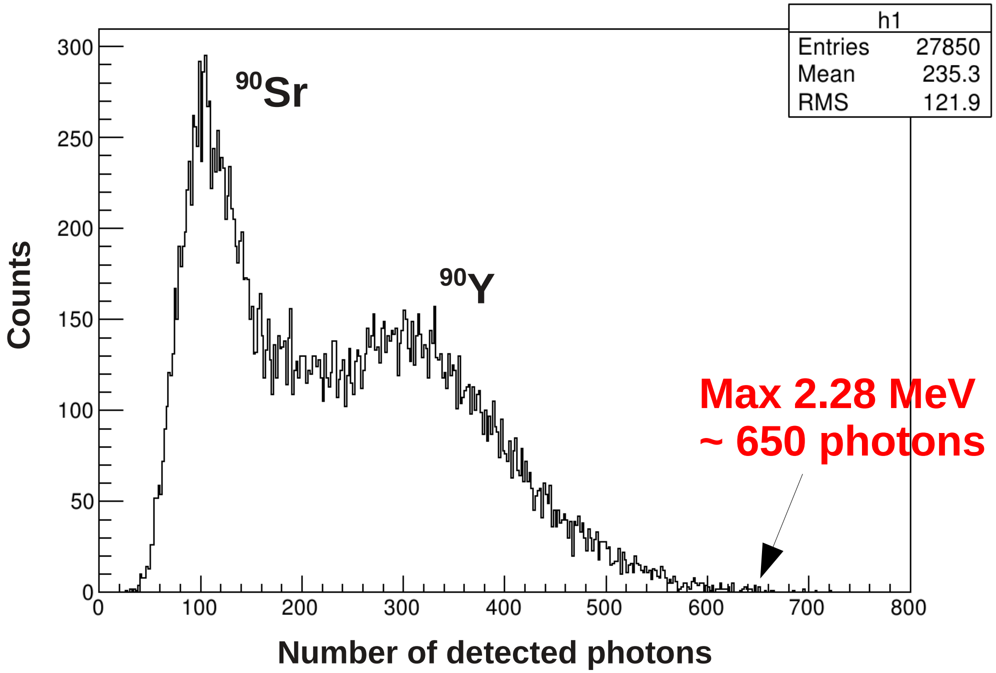
Experimental setup

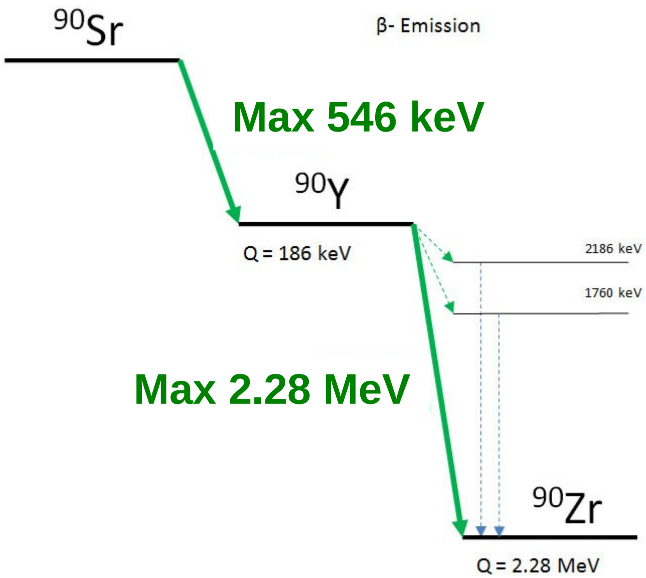
- Coincidence using two scintillator tiles
- e^- from ^{90}Sr source
- Pinholes (Al) to define beam direction
- Philips digital SiPM (Digital Photon Counter – DPC) as detector





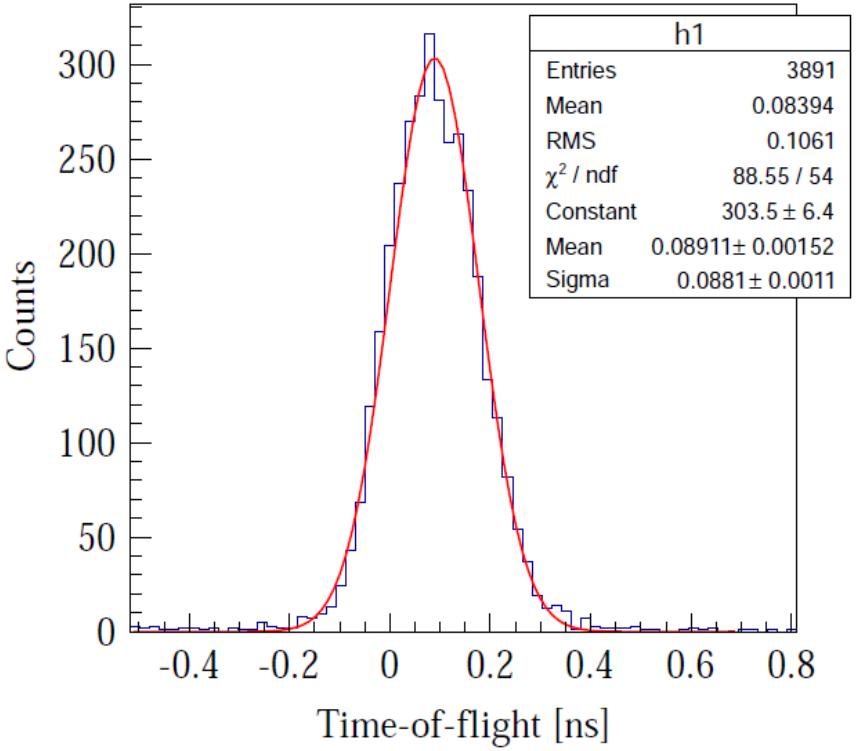
Photon spectrum





- Strontium spectrum as expected using a plastic scintillator from Eljen (EJ-228) with a size of 30 mm x 30 mm x 5 mm and the DPC
- For further measurements: cut on the spectrum (ΔE > 0.8 MeV)
- A minimum ionizing particle (MIP) in PANDA will deposit about 1 MeV in the SciTil detector

Time resolution



Since we have two identical scintillator tiles we can estimate the time resolution of a single tile by using the time-of-flight (TOF) resolution.

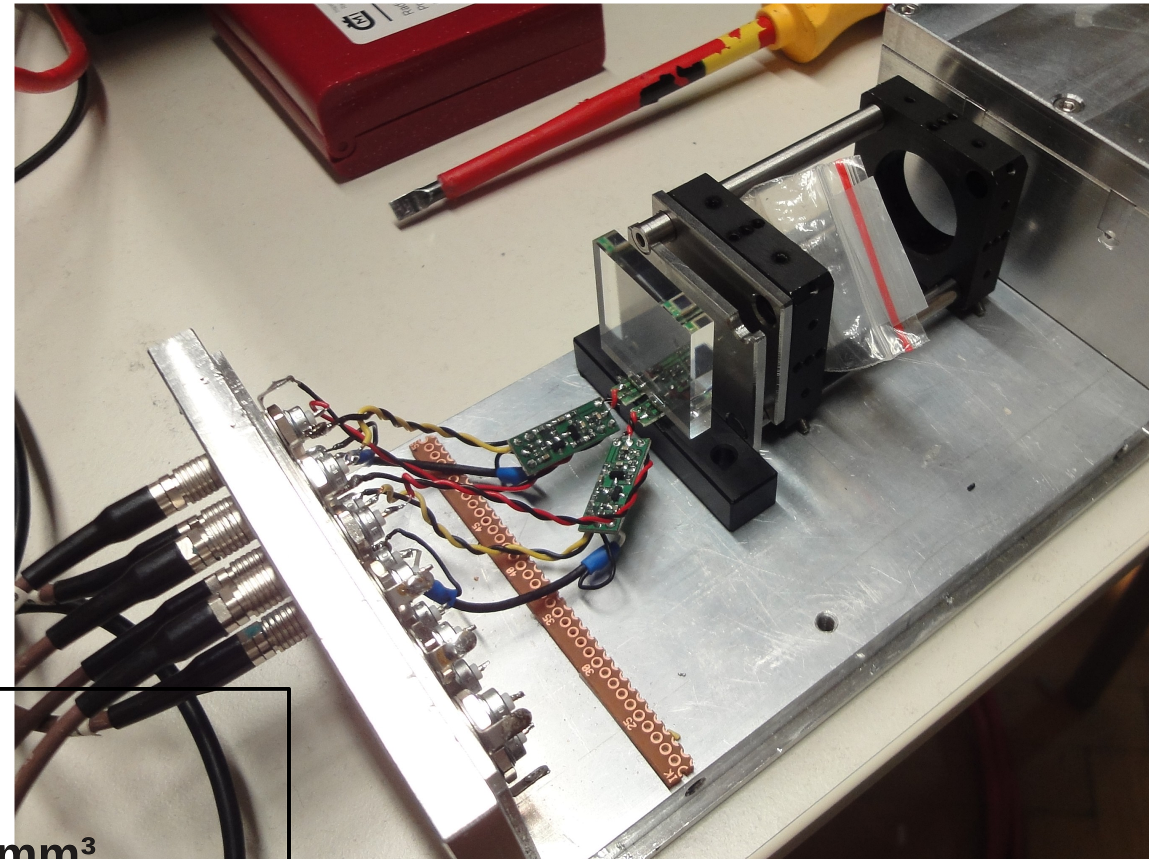
$$\sigma_{tile} \sim \sigma_{TOF}/\sqrt{2} \sim 62 \text{ ps}$$

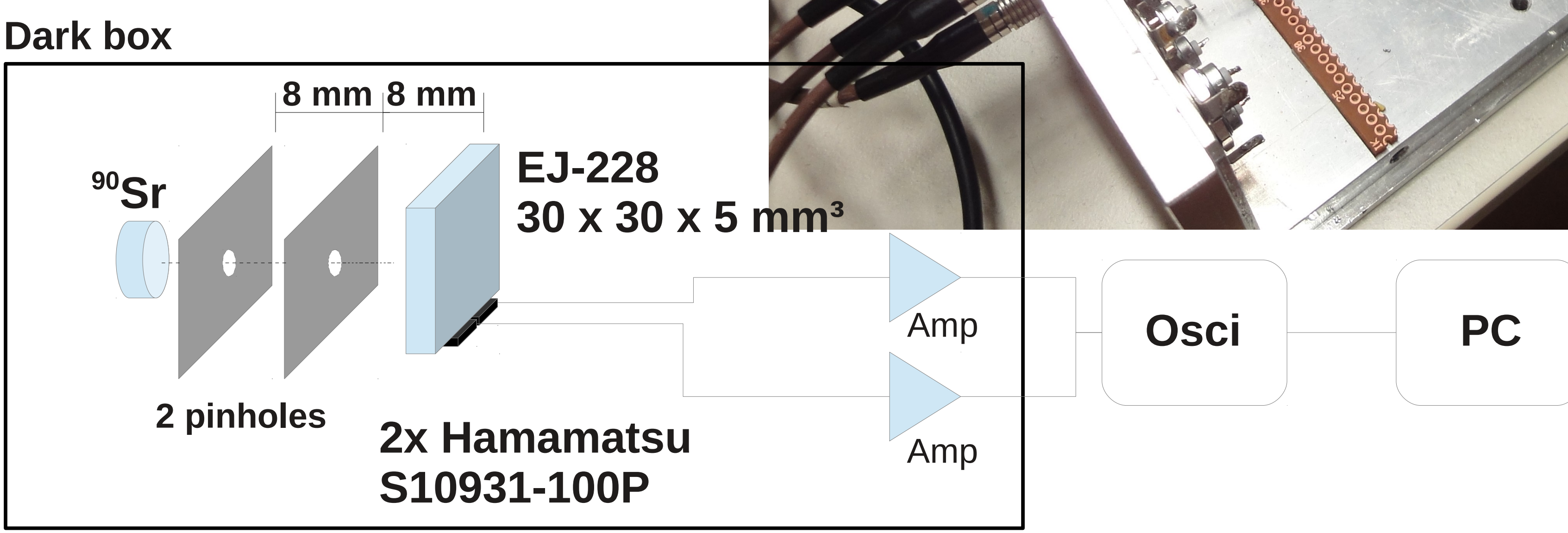
Time resolution with DPC about 60 ps.

R&D with conventional SiPM

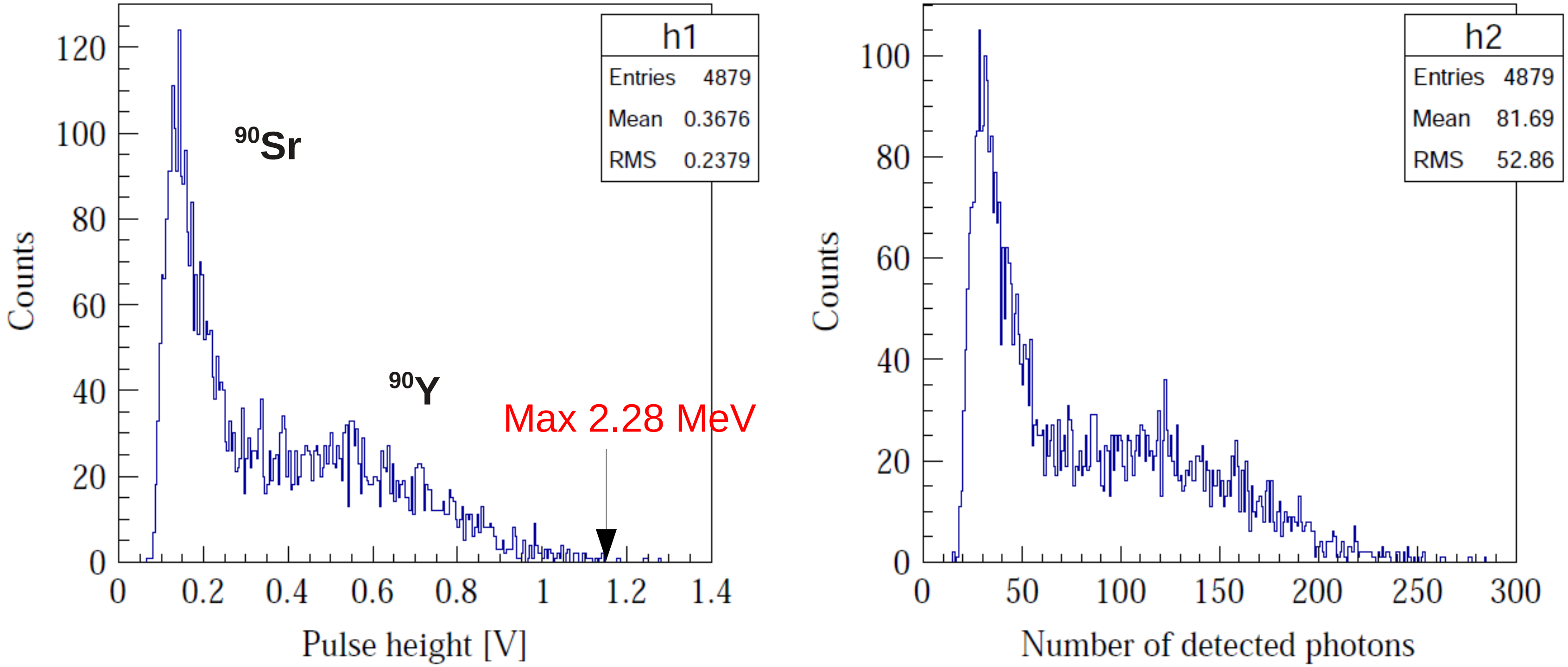
Experimental setup

- **Now only one scintillator tile**
- **e$^-$ from ^{90}Sr source**
- **Pinholes (Al) to define beam direction**
- **Hamamatsu 100P as detector**



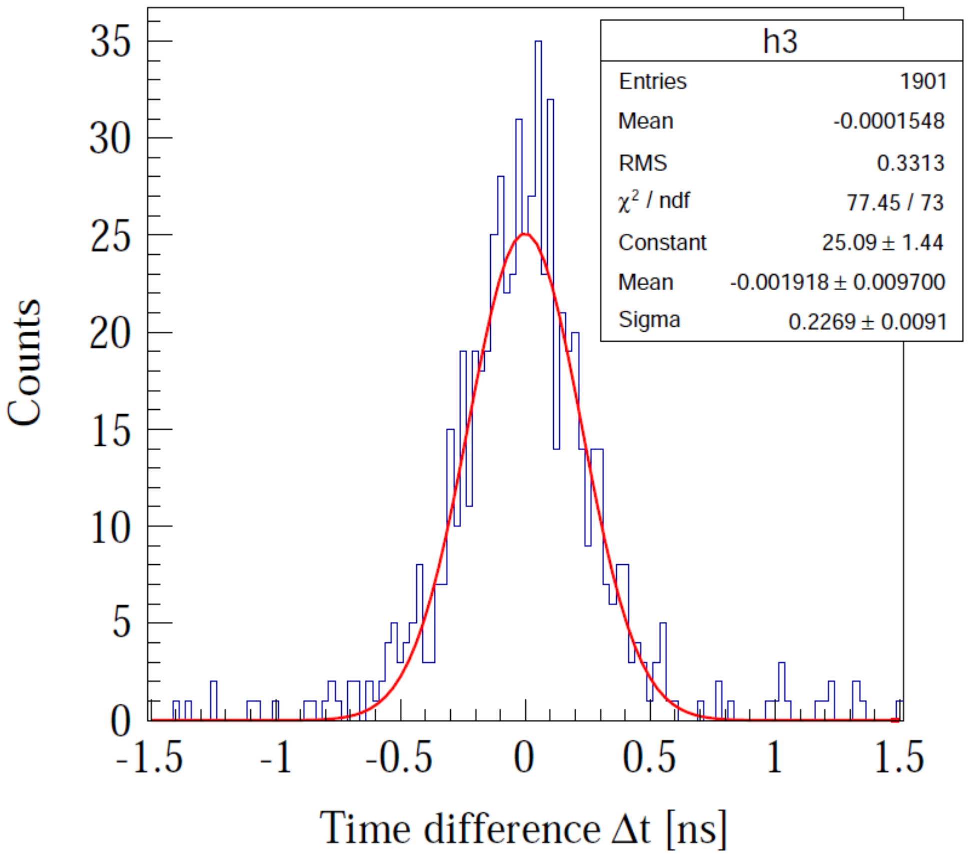


Pulse height spectrum



- **^{90}Sr spectrum as expected using a plastic scintillator from Eljen (EJ-228) with a size of 30 mm x 30 mm x 5 mm and SiPM from Hamamatsu**
- **Factor 3 less photons compared to DPC due to smaller sensitive area**
- **For further measurements: cut on the spectrum (ΔE > 0.8 MeV)**

Time resolution



- **Data taking with oscilloscope**
- **Offline waveform analysis**
- **Software threshold: best results at 6% of the amplitude (CFD)**
- **Energy cut: ΔE > 0.8 MeV (MIP) (Amplitude > 0.2 V)**

- **Estimation of the time resolution of single tile readout with two SiPM from time difference:**

$$\sigma_{tile} \sim \sigma_{diff}/2 \sim 113 \text{ ps}$$

Time resolution with conventional SiPM about 110 ps.
Potential for improvement (SiPM type, operating conditions, …)

Detector Optimization

Degrees of freedom

- Optical coupling
- Photodetector
- Position of photodetector
- Number of detectors
- Electronics threshold
- Scintillator material
- Scintillator geometry
- Scintillator wrapping

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Optical coupling

- **Photodetector is usually attached to the scintillator using optical grease or cement**
- **We used BC-630 silicone optical grease with n_{gr} = 1.465**
- **Scintillator: n_{scint} = 1.58**
- **SiPM glass window: n_{scint} = 1.55**
- **Using optical grease, the critical angle for total internal reflection changes from**

$$\Theta_c = \arcsin\left(\frac{n_{\text{air}}}{n_{\text{scint}}}\right) = 39.3^\circ$$

- **to**

$$\Theta_c = \arcsin\left(\frac{n_{\text{grease}}}{n_{\text{scint}}}\right) = 68.0^\circ$$

Measurements showed that a factor 1.4 more photons can be detected using grease !

Degrees of freedom

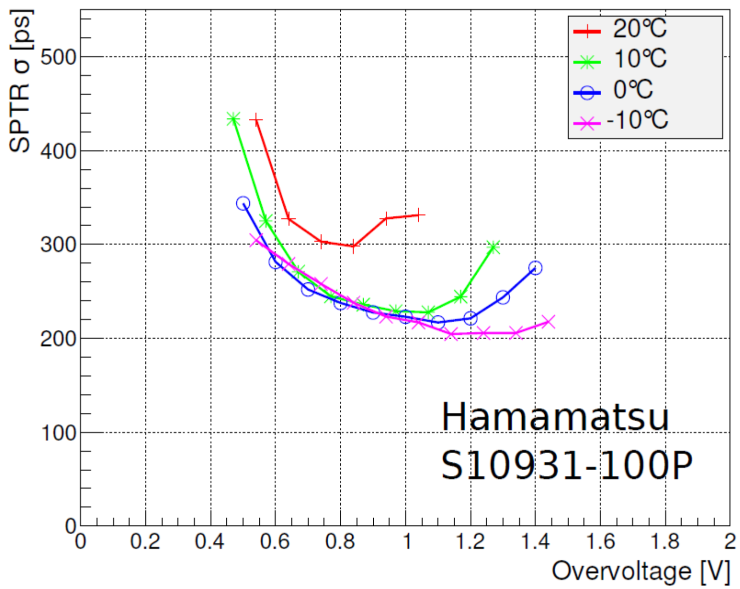
- Optical coupling
- Photodetector
- Position of photodetector
- Number of detectors
- Electronics threshold
- Scintillator material
- Scintillator geometry
- Scintillator wrapping

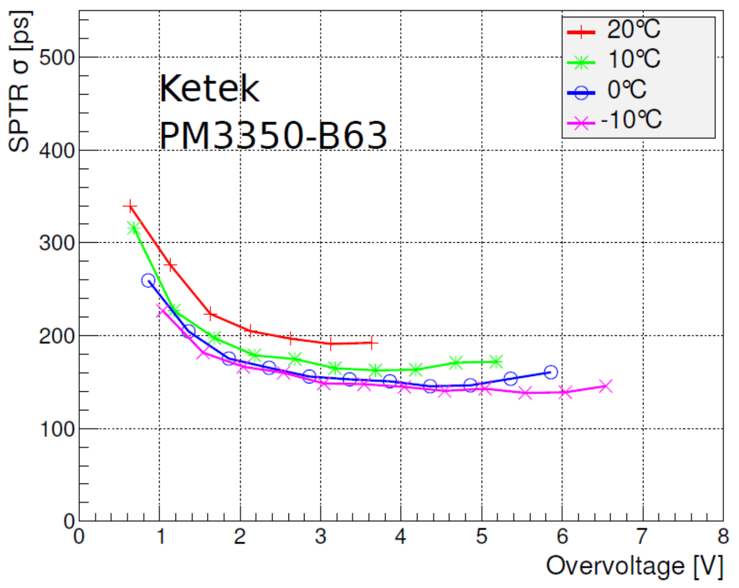
Photodetector - SiPM

- **SiPM time resolution studies with picosecond pulsed laser (400 nm)**
- **2 options: Hamamatsu or Ketek (3x3 mm²)**
- **AdvanSiD: worse timing, low PDE**
- **SensL: also lower PDE**
- **Ketek with optical trenches showed best results**

Time resolution follows 1/sqrt(Nb of photons)
We expect ~ 60 photons per SiPM:
- Hamamatsu 100P → σ ~ 40 ps
- Ketek PM3350 → σ ~ 25 ps

Single Photon Time Resolution



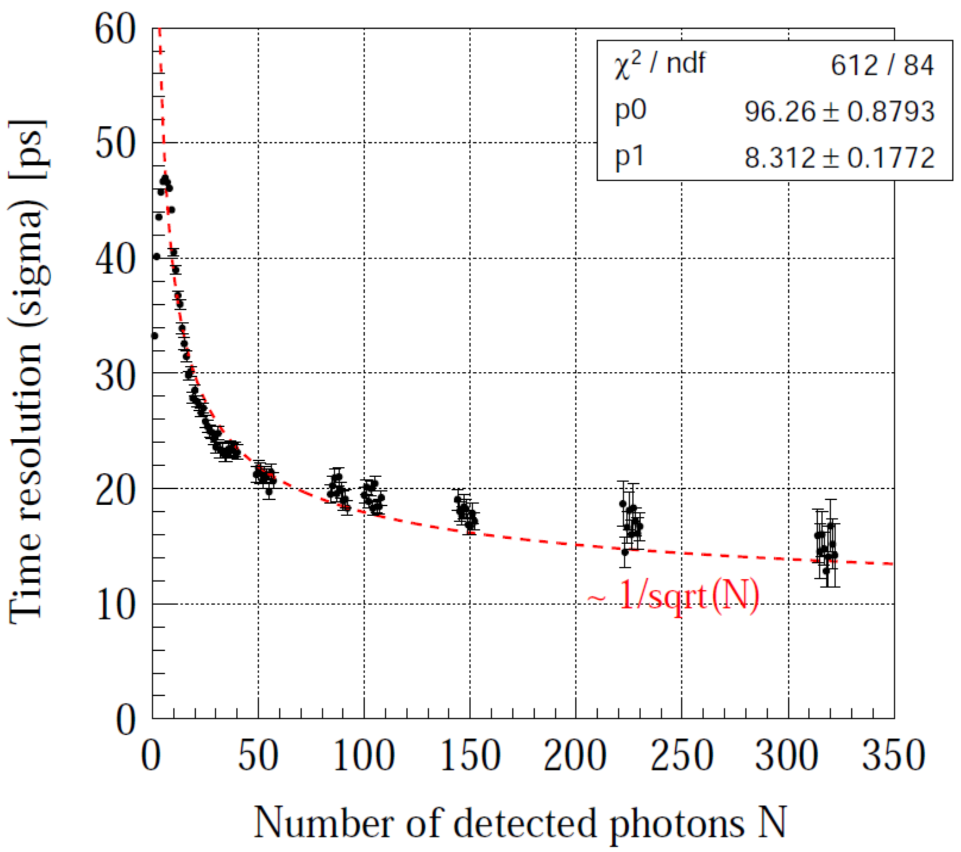


"Time resolution below 100 ps for the SciTil detector of PANDA employing SiPM"
S.E. Brunner, L. Gruber, J. Marton, H. Orth, K. Suzuki.

Photodetector - DPC

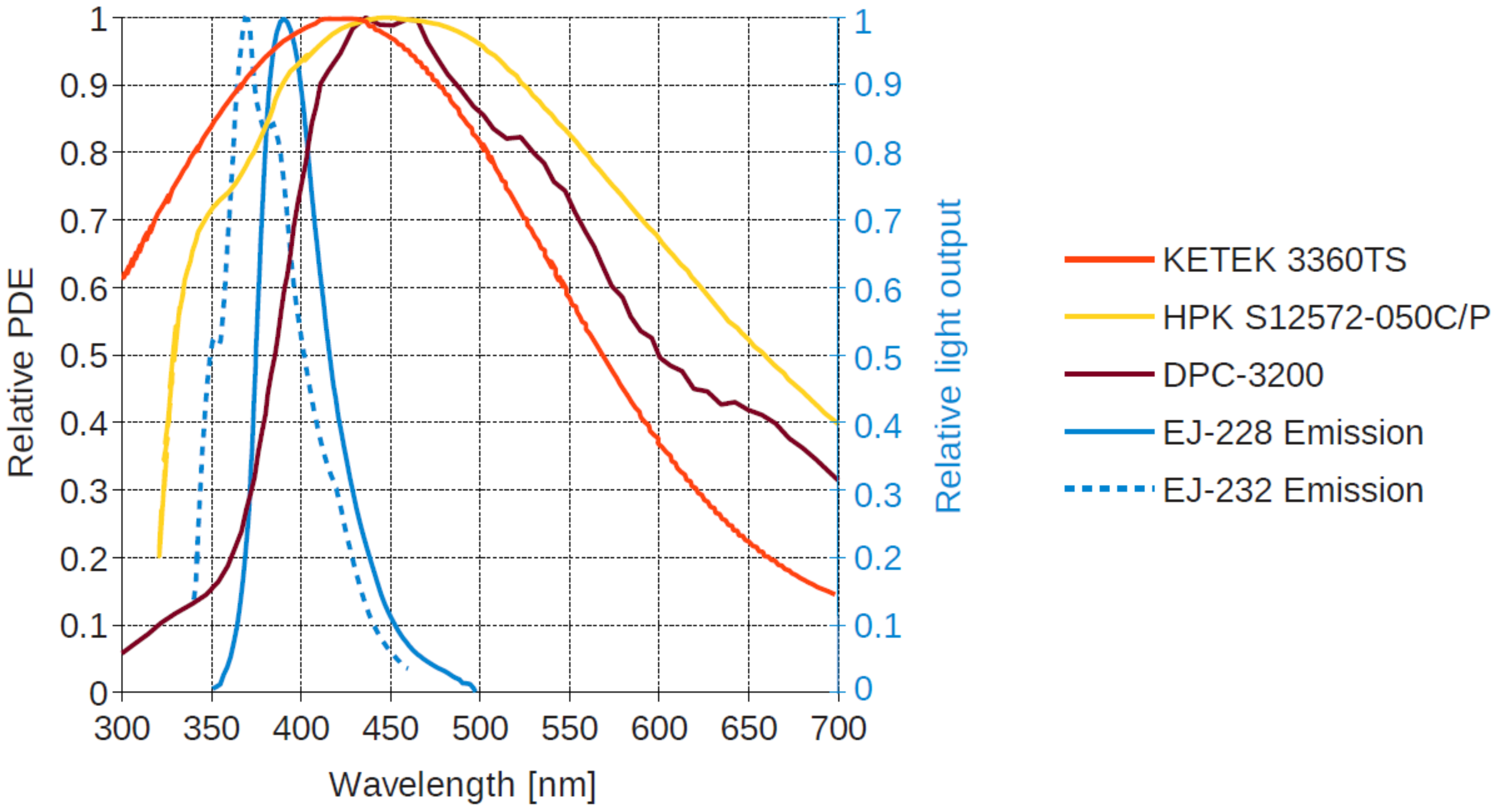
- **DPC time resolution studies with femtosecond pulsed laser (400 nm)**

Time resolution follows 1/sqrt(N)
We expect ~ 160 photons per die:
→ σ ~ 18 ps



Photodetector

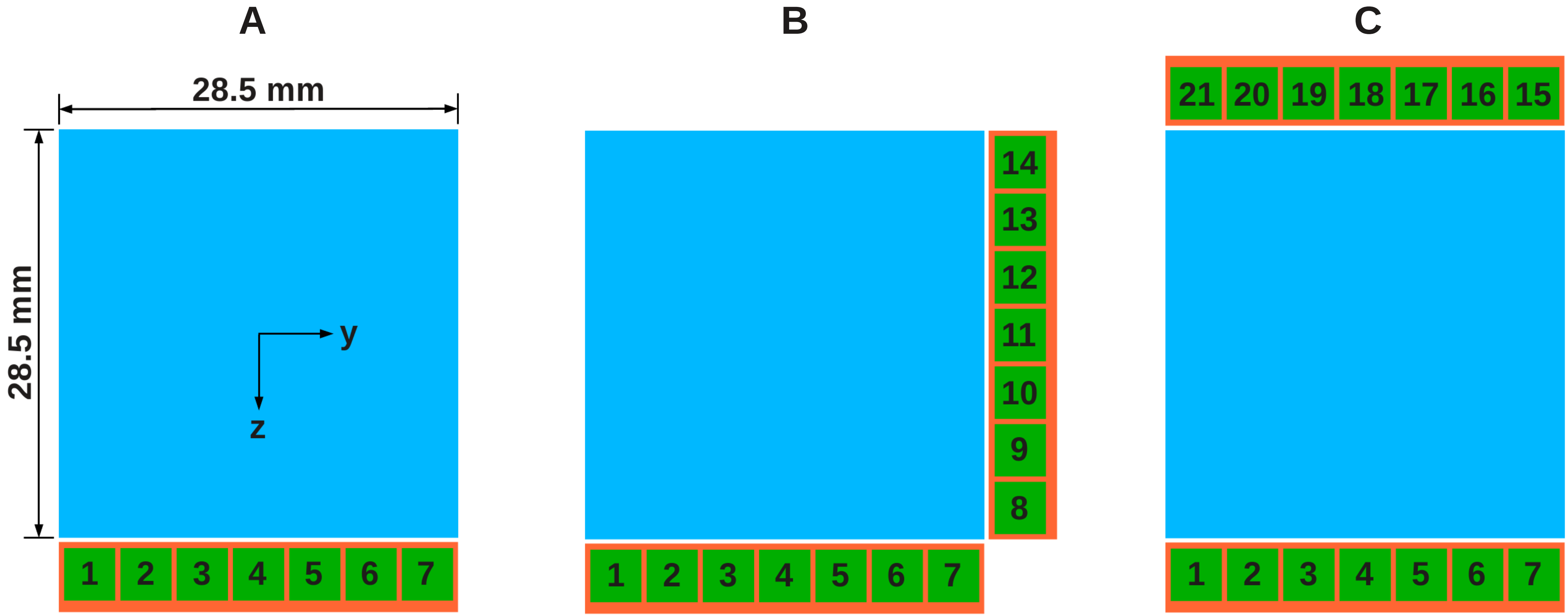
- **Photon detection efficiency should match the emission spectrum of the scintillator**



The Ketek SiPM seems to fit best.

Photodetector position

Using two detectors, there are several possible combination how to place the sensors on the scintillator tile.

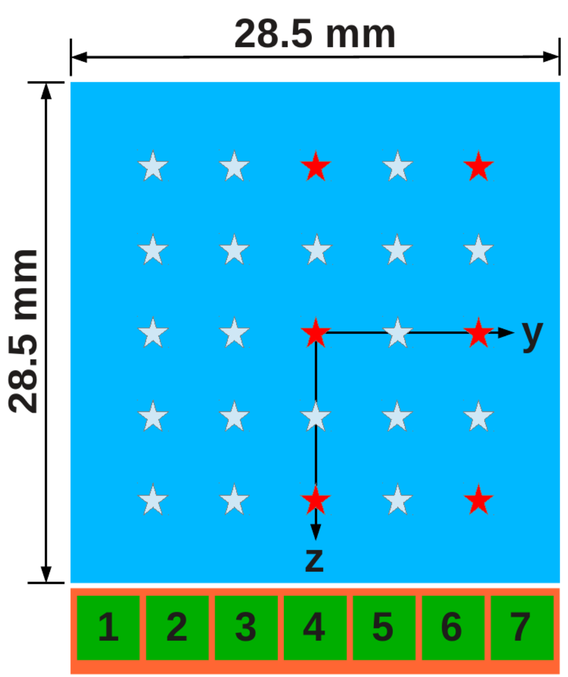


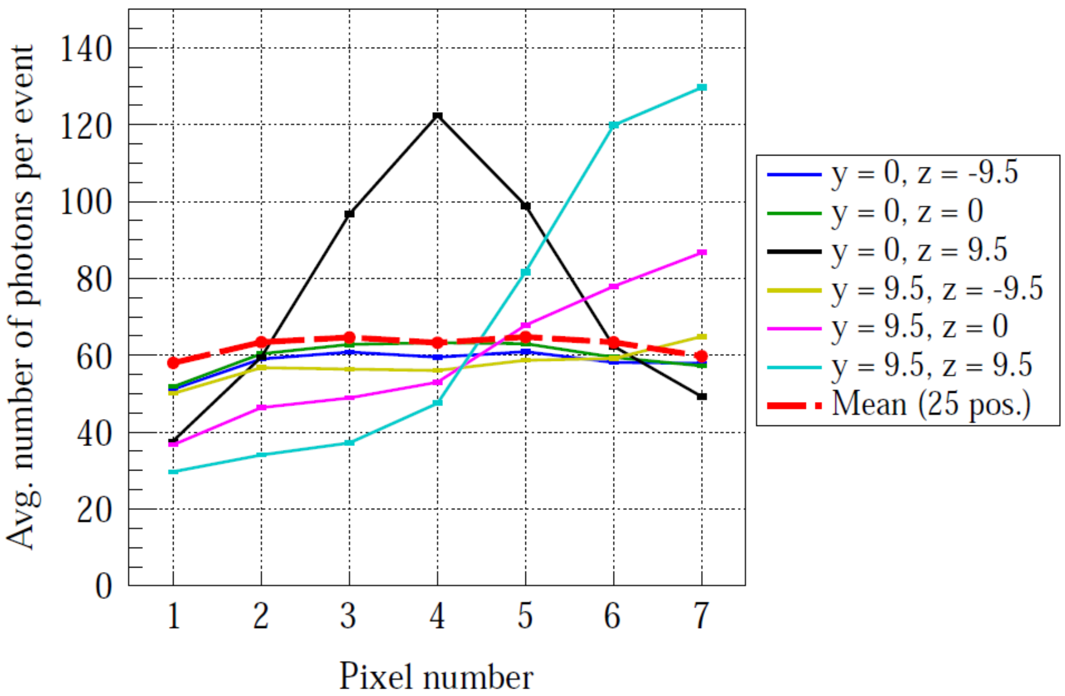
Which one is the best for best time resolution?

Photodetector position

Idea:

- **Measure photon number and time resolution in dependency of the detector position**
- **Use the DPC: large sensitive area, which can be adjusted in size by software**
  → no need to change the hardware (detector)
- **Switch off pixels that are not needed**
- **Change beam position and calculate average photon number & time resolution**

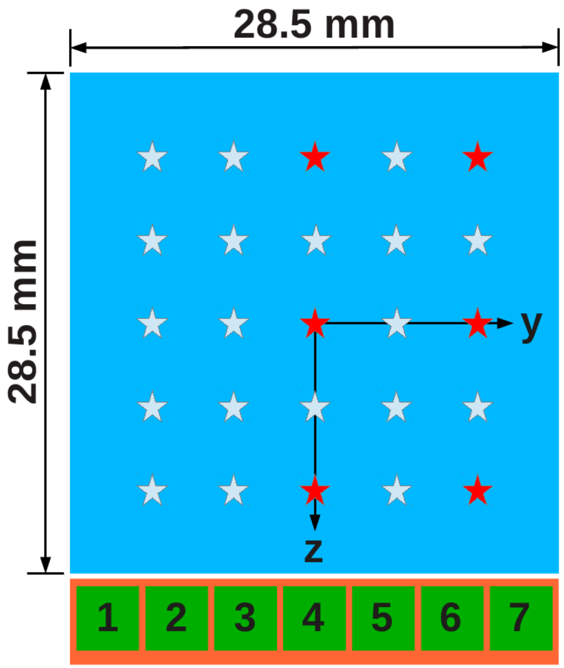


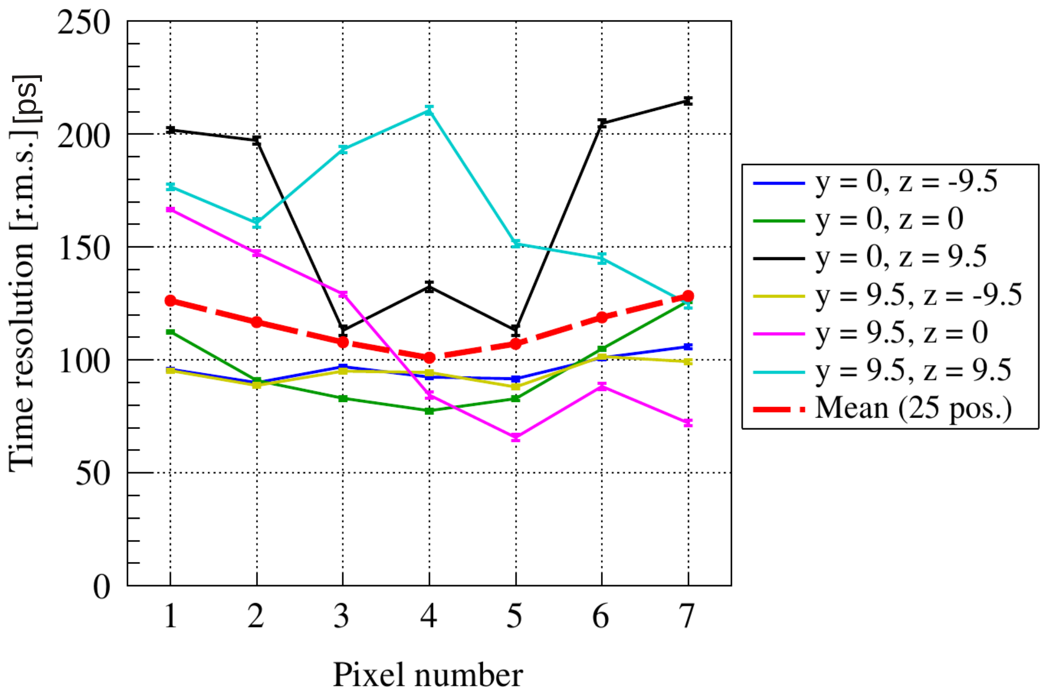


Strong position dependency !
On average, the photons are equally distributed on the scintillator rim !

Photodetector position

Time resolution:



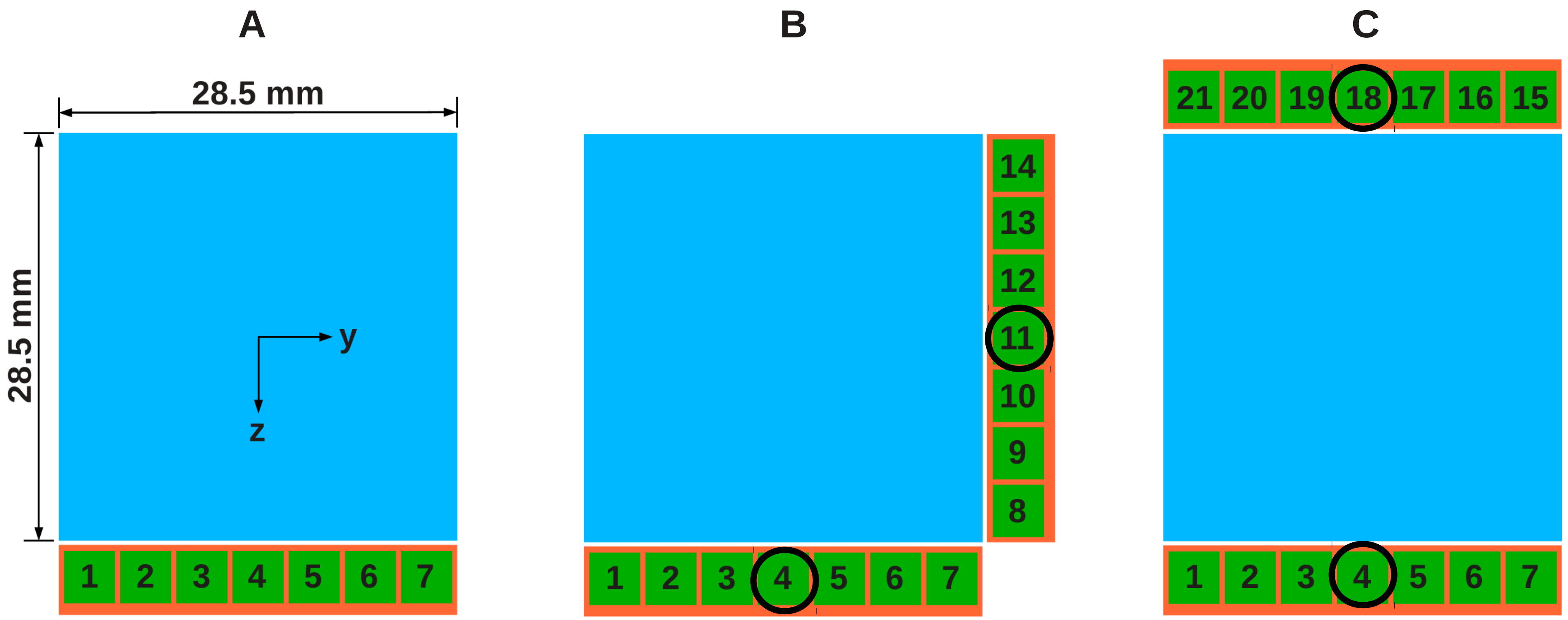


Strong position dependency !
Central position of the sensor is favored !

"Time resolution below 100 ps for the SciTil detector of PANDA employing SiPM"
S.E. Brunner, L. Gruber, J. Marton, H. Orth, K. Suzuki.

Photodetector position

Using two detectors, there are several possible combination how to place the sensors on the scintillator tile.



Best time resolution:
Case B: position 4 & 11
Case C: position 4 & 18

Degrees of freedom

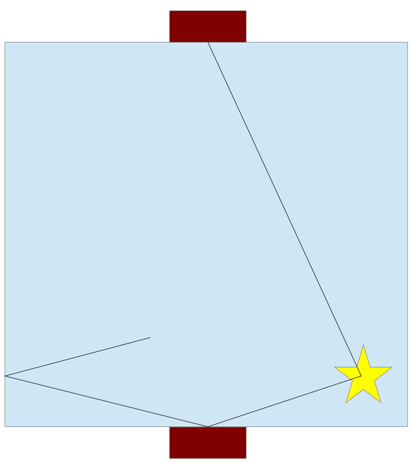
- Optical coupling
- Photodetector
- Position of photodetector
- Number of detectors
- Electronics threshold
- Scintillator material
- Scintillator geometry
- Scintillator wrapping

Number of detectors

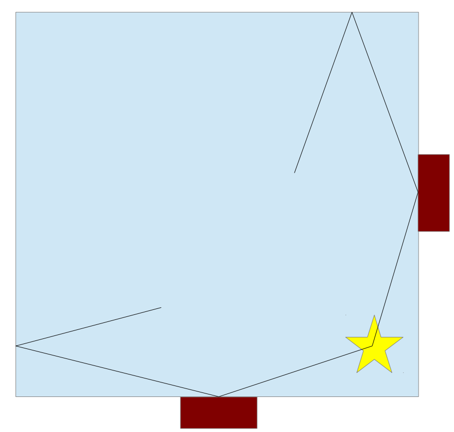
- **100 ps can be expected when using two SiPMs**
- **Increasing the number of detectors N_{det}:**
  - → **increases number of detected photons: prop. N_{det}**
  - → **improves time resolution by $1/\sqrt{N_{det}}$**
  - → **increases total amount of channels**
  - → **decreases the impact of photon propagation**

With the DPC one could anyway cover larger surfaces and 100 ps are easy to reach !

Favored positioning:



For any position of interaction, direct photons can be seen by at least one detector.



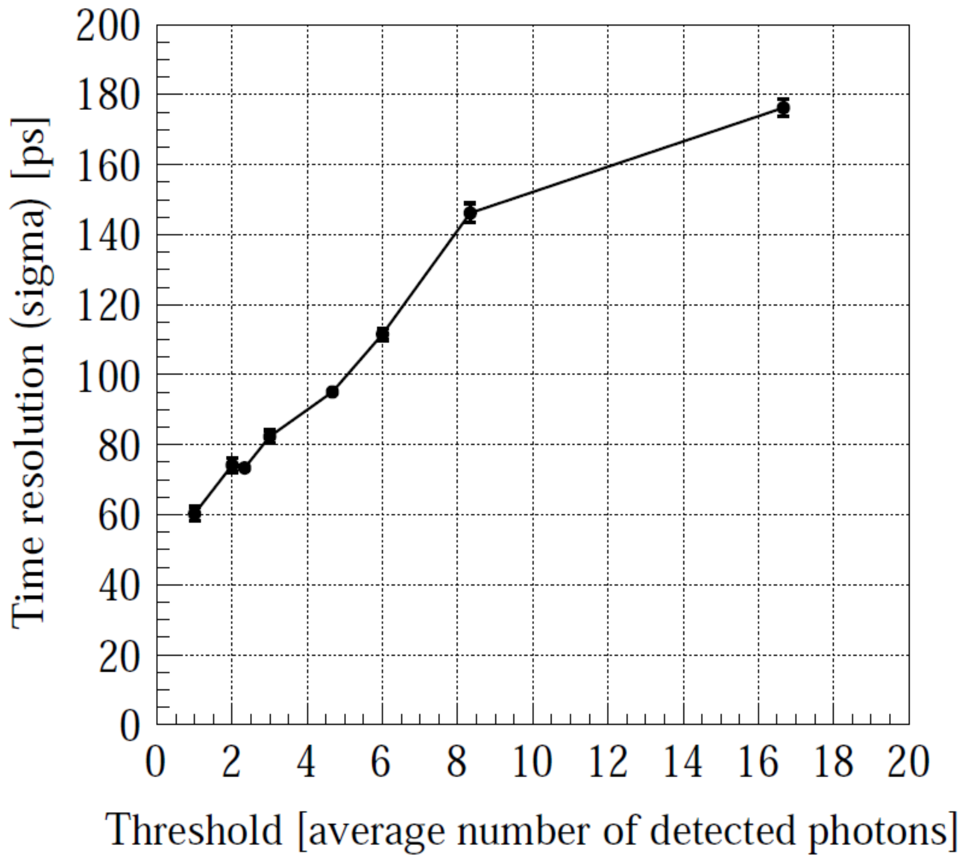
For some position of interaction, there might be no direct photons seen.

Degrees of freedom

- Optical coupling
- Photodetector
- Position of photodetector
- Number of detectors
- Electronics threshold
- Scintillator material
- Scintillator geometry
- Scintillator wrapping

Electronics threshold: DPC

- **Studying photostatistics we saw that the best time precision can be achieved when triggering on the first photon**
- **Using the DPC, this statement holds**



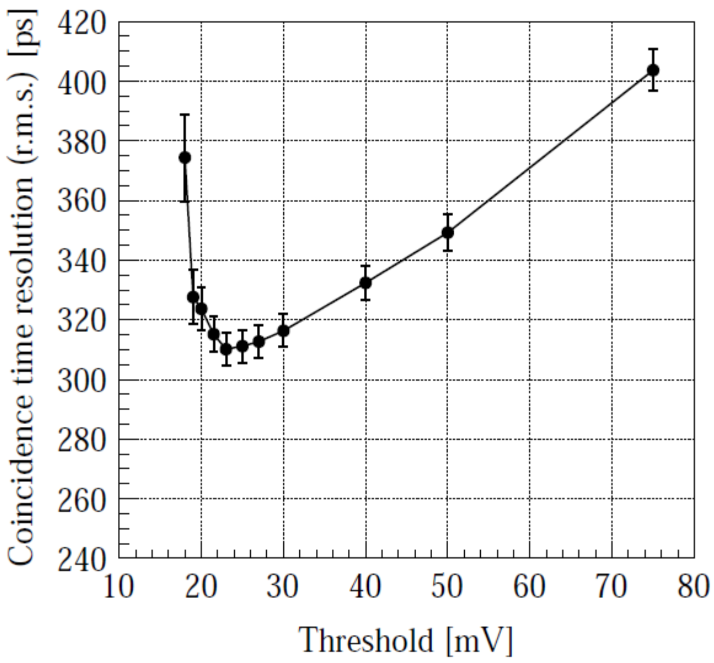
Time resolution of a scintillator tile read-out with the Philips DPC.

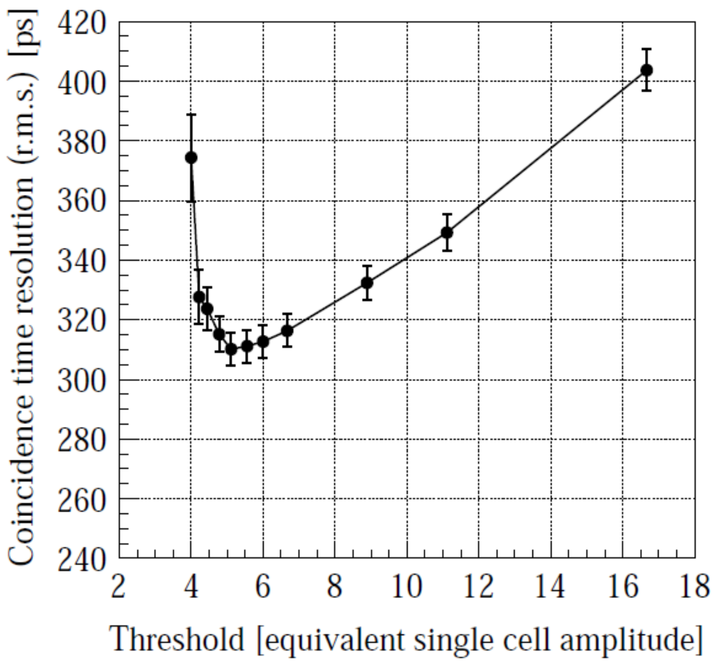
The trigger threshold should be set to the first detected photon !

Electronics threshold: SiPM

- **Using however analog SiPMs, this behavior is changed due to electronics noise and the SPTR of the SiPM.**

Time resolution of a scintillator tile read-out with the Hamamatsu SiPMs.





The trigger threshold should not be set to the first detected photon !

Electronics threshold: SiPM

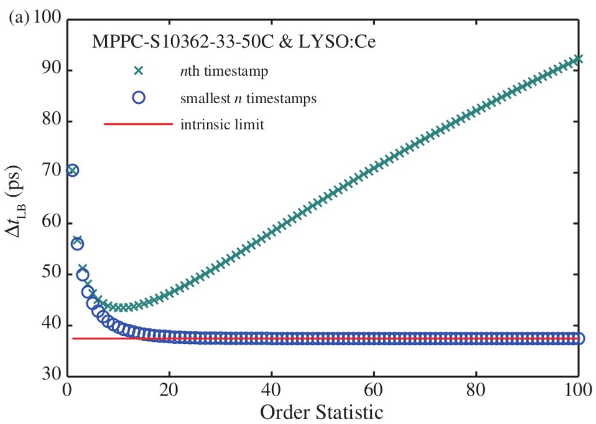
- **A similar behavior has been also reported by others**

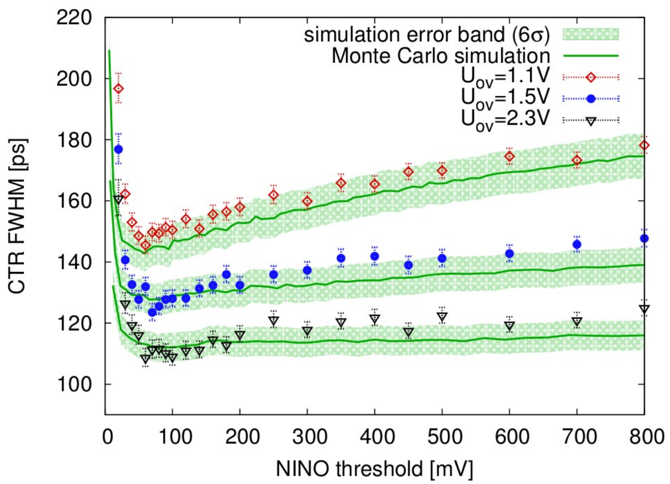
S. Gundacker et al., Time of ight positron emission tomography towards 100ps resolution with L(Y)SO: an experimental and theoretical analysis, J. Instrum. 8 (2013) P07014.

S. Seifert, H. van Dam, D. Schaart, The lower bound on the timing resolution of scintillation detectors, Phys. Med. Biol. 57 (2012) 1797-1814.

S. Seifert et al., A Comprehensive Model to Predict the Timing Resolution of SiPM-Based Scintillation Detectors : Theory and Experimental Validation, IEEE Trans. on Nucl. Sci., Vol. 59, pp. 190-204, 2012.

Effects of scintillation light collection on the time resolution of a time-of-flight detector for annihilation quanta
S. Ziegler at al. (1990)





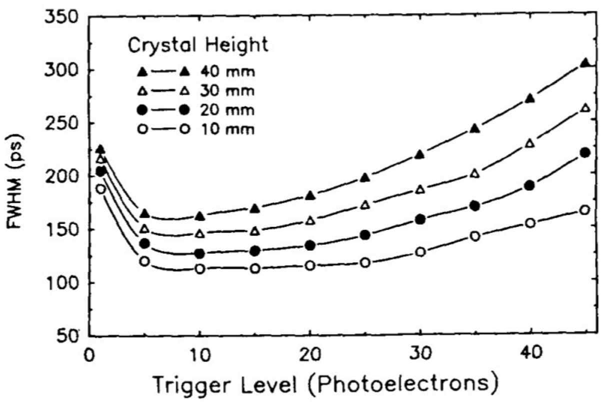


Fig. 2. Calculated width of trigger time distribution for cylindrical BaF_2 crystals with radius 15 mm, energy threshold 480 keV.

Degrees of freedom

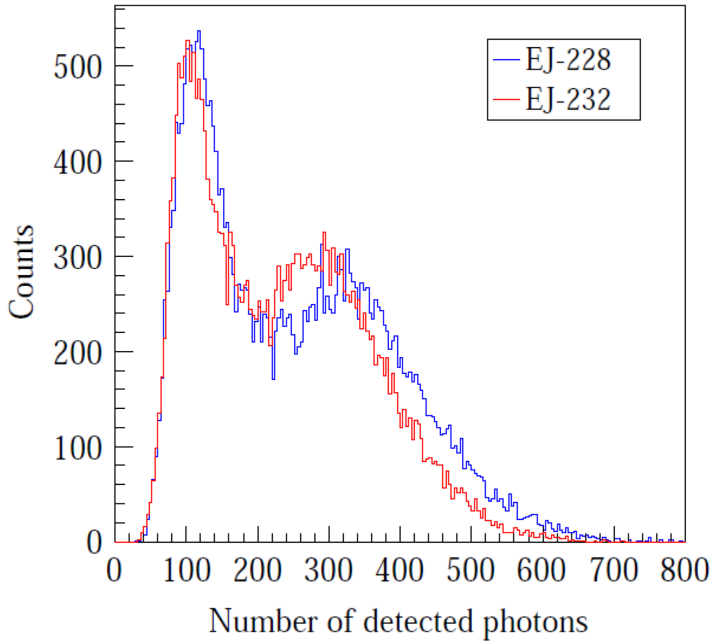
- Optical coupling
- Photodetector
- Position of photodetector
- Number of detectors
- Electronics threshold
- Scintillator material
- Scintillator geometry
- Scintillator wrapping

Scintillator material

Scintillator**	Time resolution*(sigma) [ps]
EJ-232	59.4 ± 1.7
EJ-228	60.5 ± 1.7
EJ-204	66.5 ± 1.5
EJ-200	81.0 ± 1.5

*** measured with DPC**
**** dimensions: 28.5 x 28.5 x 5 mm³**

As expected, fastest scintillators show best results!
EJ-232 and EJ-228 nearly identical.
EJ-232 slightly faster but lower light yield !



Degrees of freedom

- Optical coupling
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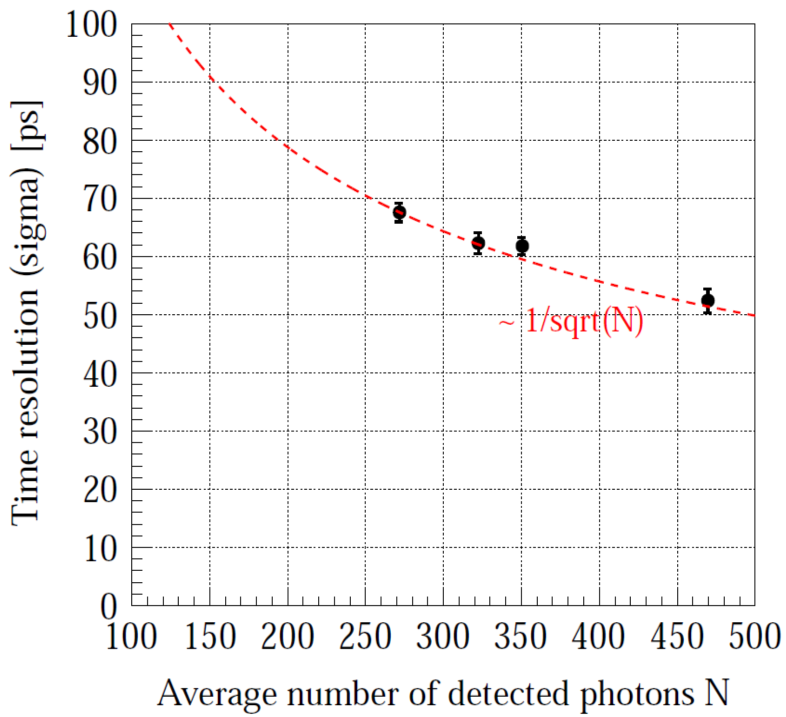
Scintillator geometry

Dimensions [mm^3]	Avg. nb. of detected photons	Time resolution*(sigma) [ps]
$40 \times 40 \times 5$	271.8	67.6 ± 1.6
$30 \times 30 \times 5$	322.4	62.3 ± 1.8
$28.5 \times 28.5 \times 5$	350.6	61.8 ± 1.5
$20 \times 20 \times 5$	469.7	52.4 ± 2.0

*** measured with DPC**



Scintillator geometry

- **5 mm thickness seems to be optimum in terms of radial space, timing, efficiency, other barrel detectors**
- **Decreasing the size:**
  - → **increases ratio between detection area (A_D) and scintillator surface (A_s)**
  - → **increases number of detected photons (N_{ph}) prop. A_D/A_s**
  - → **improves time resolution**
  - → **increases the total number of channels in SciTil**
  - → **reduces the impact of photon propagation**

- **Increasing the size:**
  - → **decreases number of detected photons**
  - → **worsens time resolution**
  - → **decreases amount of channels**
  - → **degrades spatial resolution**

28.5 x 28.5 x 5 mm^3 seems optimal.
Tradeoff between time resolution, spatial resolution and number of channels.

Degrees of freedom

- Optical coupling
- Photodetector
- Position of photodetector
- Number of detectors
- Electronics threshold
- Scintillator material
- Scintillator geometry
- Scintillator wrapping
  - No wrapping considered up to now (100 ps reached with DPC)
  - Test first without wrapping
  - However, still to be done (reflective, absorptive wrapping)

Conclusion

- **Optical coupling:**
  - Optical grease or something equivalent has to be used

- **Photodetector:**
  - Intrinsic time resolution and PDE are important
  - It is crucial to detect as many photons as possible
  - Technology against crosstalk, afterpulse should be considered
  - Ketek PM33 with optical trench and Philips DPC show best performance

- **Photodetector position:**
  - Detector should be positioned in the center of the rim
  - The 2nd detector should be placed on the opposing rim to reduce the influence of photon propagation

- **Number of detectors:**
  - Minimum two detectors (3 x 3 mm^2) are needed to achieve 100 ps
  - Using the Philips DPC, larger surfaces can be covered (100 ps easy)

Conclusion

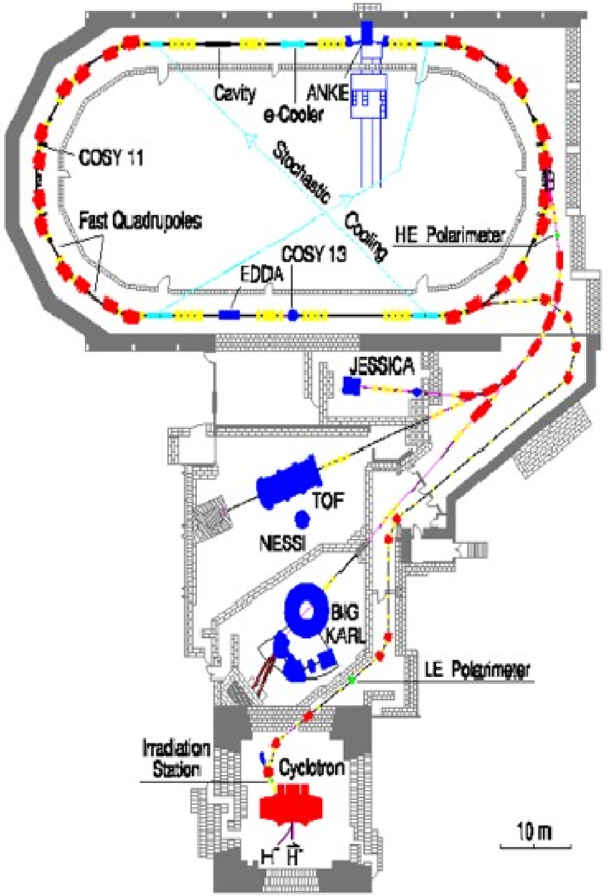
- **Electronics threshold:**
  - Best solution: 2 thresholds (1 for event validation, 1 for time stamp generation)
  - SiPM: threshold has to be optimized, 1st photon does not give the best result
  - DPC: threshold should be set to the 1st detected photon

- **Scintillator material:**
  - Short rise and decay time, high light yield
  - EJ-232 (BC-422) and EJ-228 (BC-418) show best (almost identical) results
  - EJ-228 might be favored due to lower cost and emission spectrum

- **Scintillator size:**
  - ~ 30 x 30 x 5 mm^3 seems optimal (space constraints, timing, spatial resolution)
  - one may increase the size and use more detectors per tile and use pulse height information for position resolution

- **Scintillator wrapping:**
  - Not yet considered
  - Reflective wrapping might be advantageous to increase the number of photons

Test beam at COSY (FZ Jülich)



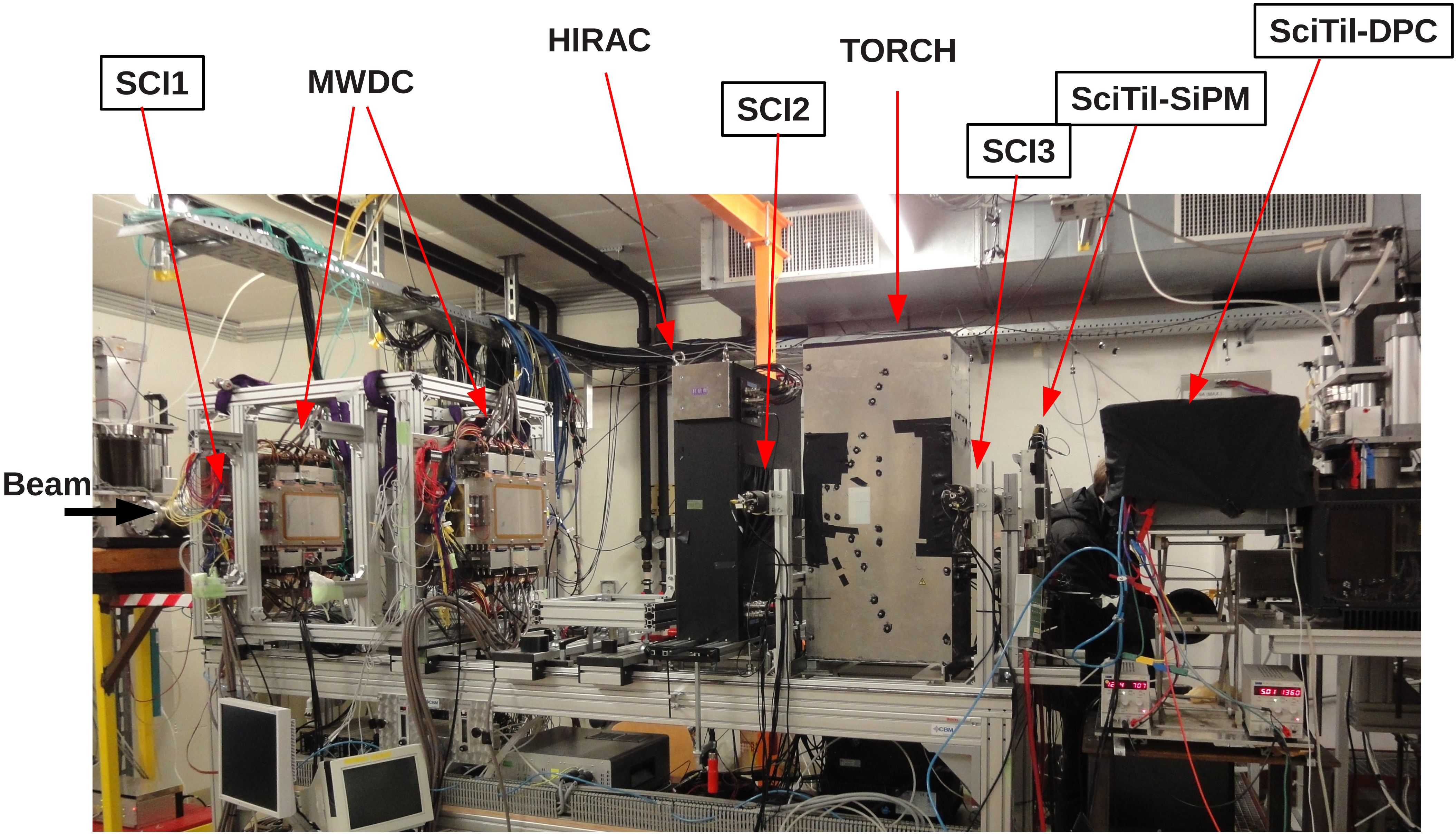
Facts:

- **FZ-Jülich, COSY-JESSICA external beam line**
- **Week no. 5 and 6, 2014 (Jan 27 to Feb 9, 2014)**
- **During week: beam during night (9 p.m. - 8 a.m.)**
- **On weekends: 24 hours**
- **Beam: 2.7 GeV/c and 1.5 GeV/c protons**
- **Intensity: ~ 10^4 – 10^5 Hz**
- **Defocused beam: ~ 5 cm x 5 cm**

Activities:

- **EtaPrime Experiment (GSI):**
  - **Cherenkov counters (mini-HIRAC, HIRAC, TORCH)**
  - **Multi-wire drift chambers (MWDC)**
  - **Time-projection chambers (TPC)**
  - **Plastic scintillators (SCIs)**
- **3 SciTil prototypes:**
  - **SMI prototype: SciTil + SiPM**
  - **SMI + Philips prototype: SciTil + DPC (Digital Photon Counter)**
  - **Erlangen prototype: SciRod + SiPM**

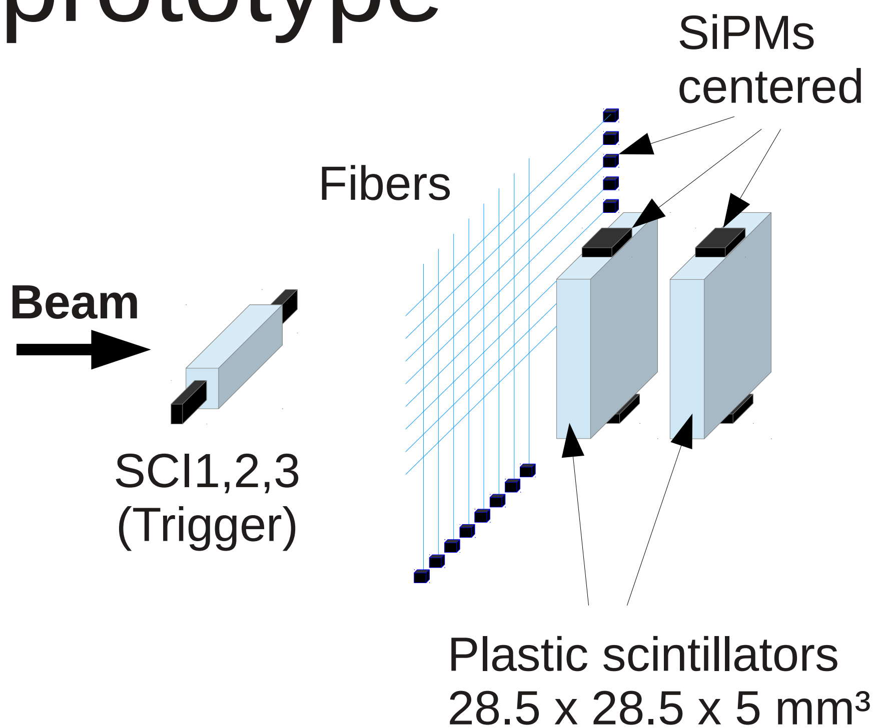
The beam line at JESSICA



The SciTil-SiPM prototype

Setup:

- **Scintillating fiber grid for position resolution in x and y: 8 + 8 fibers, 4 mm pitch**
- **Fibers are readout with 1 x 1 mm² SiPMs**
- **2 SciTil layers: plastic scintillators readout with two 3 x 3 mm² SiPMs each**
- **No cooling: room temperature ~ 15 °C**



SiPMs tested (most promising):

HPK MPPC S12572-33-050P (low afterpulse)
HPK MPPC S12572-33-025C (low afterpulse)
Ketek PM3350TS (low crosstalk)
Ketek PM3360TS (low crosstalk)

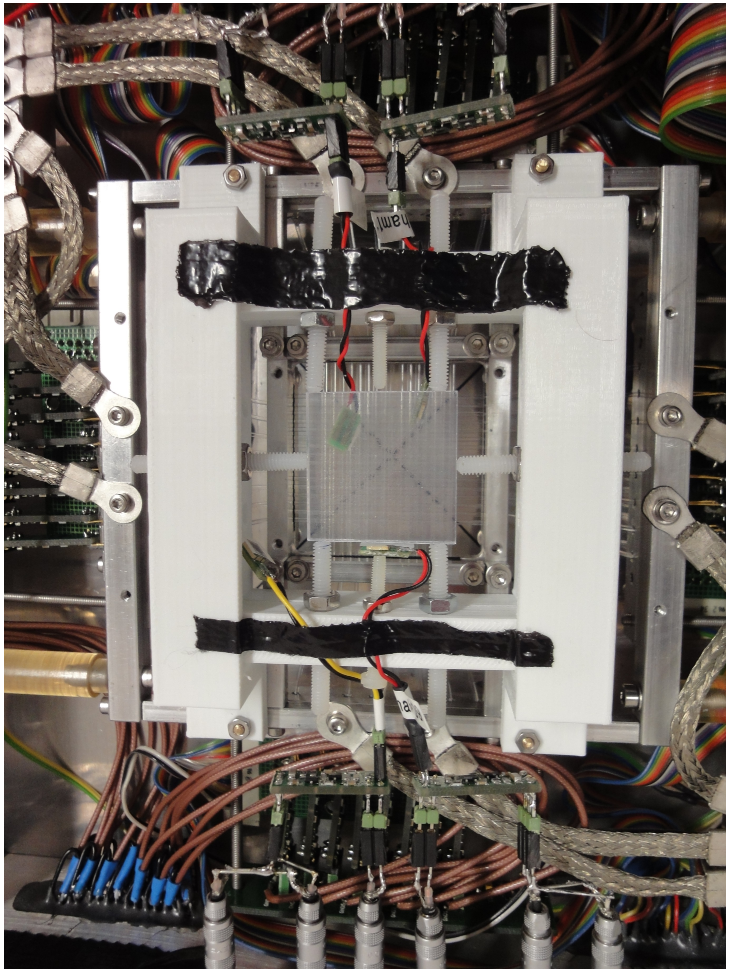
Scintillators tested (most promising):

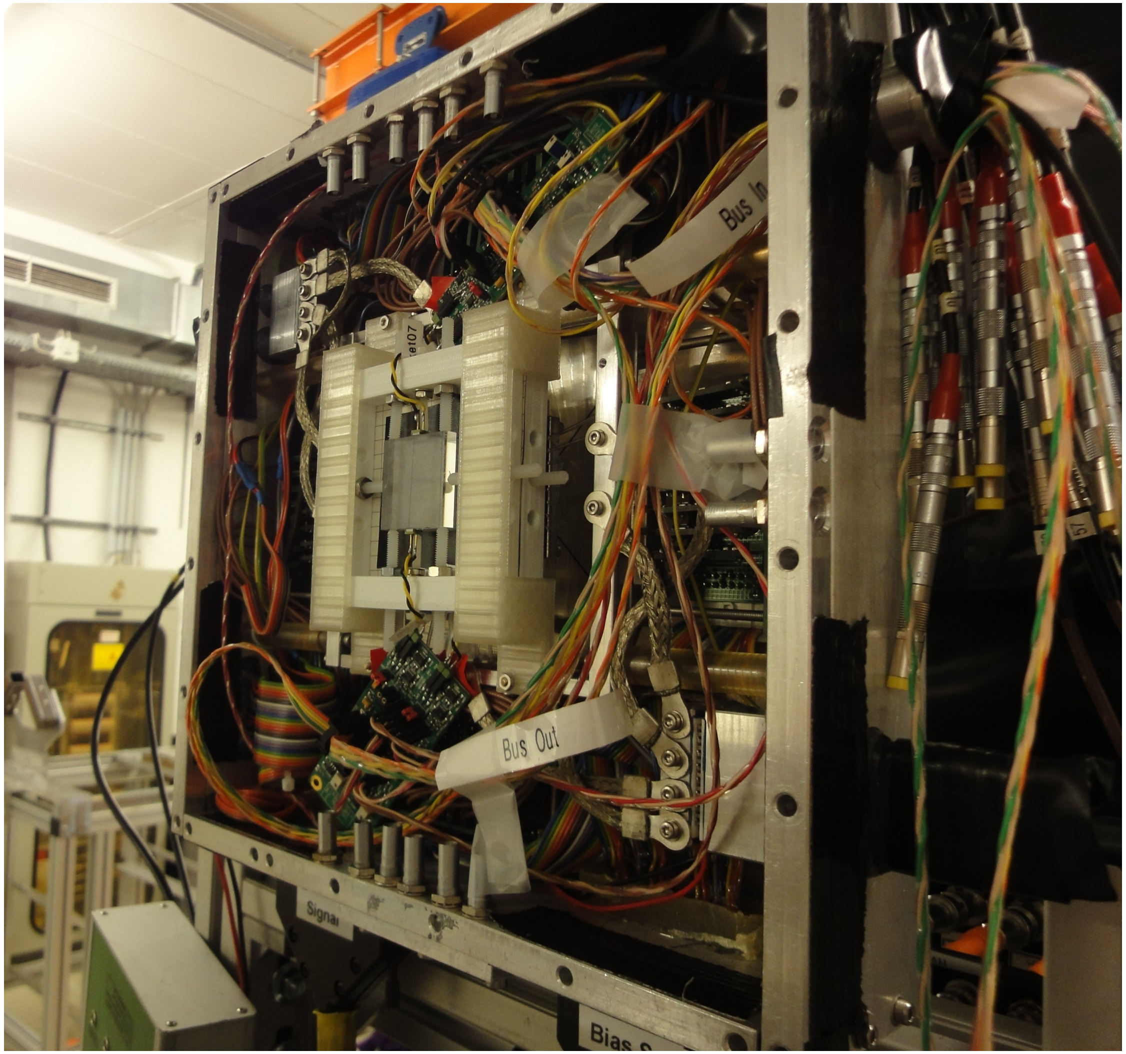
	EJ-228 Pilot-U/BC-418	**EJ-232 NE-111A/BC-422**
Light yield [photons/MeV]	10,200	8,400
Rise time [ns]	0.5	0.35
Decay time [ns]	1.4	1.6
Wavelen. of Max. Emission [nm]	391	370

Goal:

Time resolution of SciTil prototype: σ < 100 ps

The SciTil-SiPM prototype



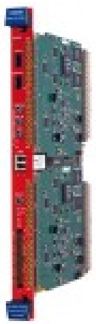


Readout electronics

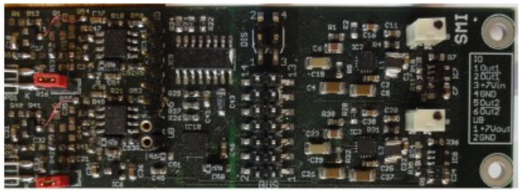
Data acquisition:

- **SiPM signals are amplified using Photonique preamplifier AMP-0604**
- **The signals are then readout:**

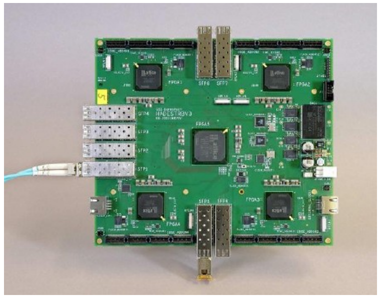
1.) CAEN V1742 waveform digitizer: → **analyzed**
- **full waveform**
- **32 Channels**
- **sampling rate: 5 Gs/s**
- **trigger: coincidence SCI1, 2 and 3 (EtaPrime)**



2.) SMI "IFES" boards: → **analysis ongoing**
- **test boards with fully differential readout**
- **analog and digital signals → V1742**
- **2 channels per board**
- **trigger: coincidence SCI1, 2 and 3 (EtaPrime)**



3.) PADIWA boards + TRBv3 board: → **analysis ongoing**
- **time information: leading-, trailing edge**
- **time-over-threshold**
- **trigger: MCP (from Erlangen group)**



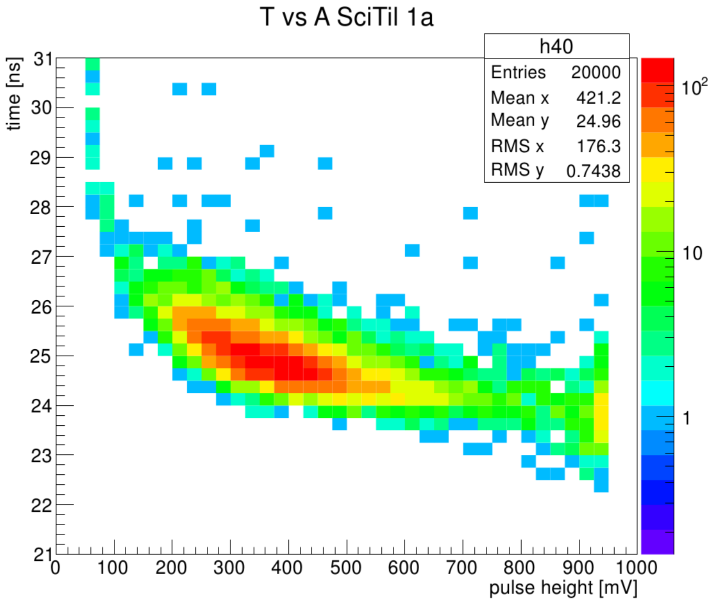
In total 5 TB of data in 2 weeks.

Number of photons

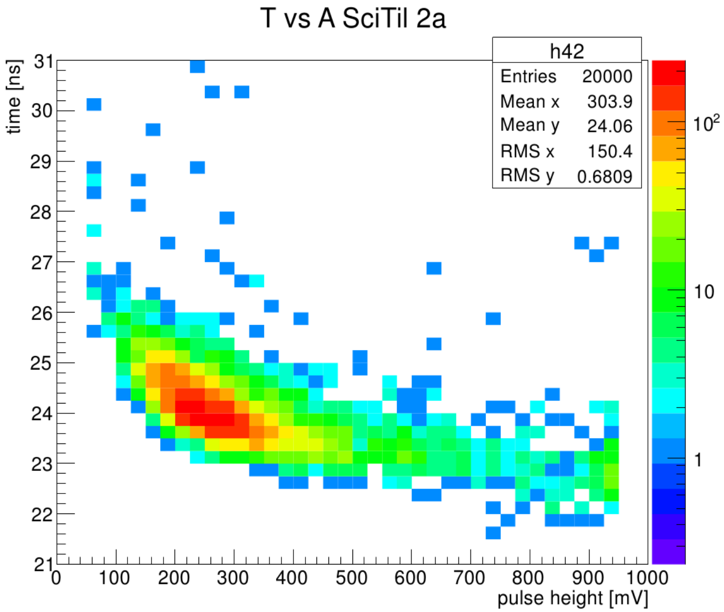
Waveform analysis (V1742):

- **Signal amplitude → number of photons**
- **Threshold crossing time: leading edge (LE) discriminator**
- **Threshold: - 50 mV ~ 10 photons**

HPK S12572-050P with EJ-228



Ketek PM3350 with EJ-232

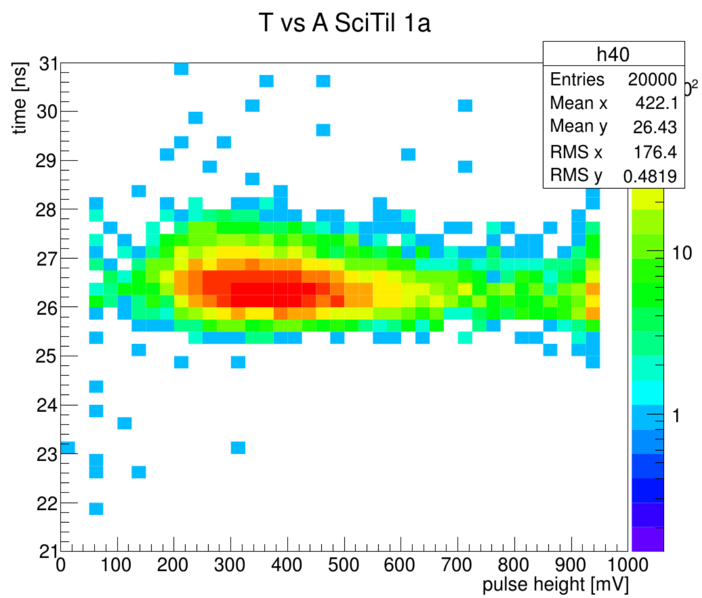


Approx. 65 – 70 photons per event per SiPM.
<u>There is strong time walk → One has to correct !</u>

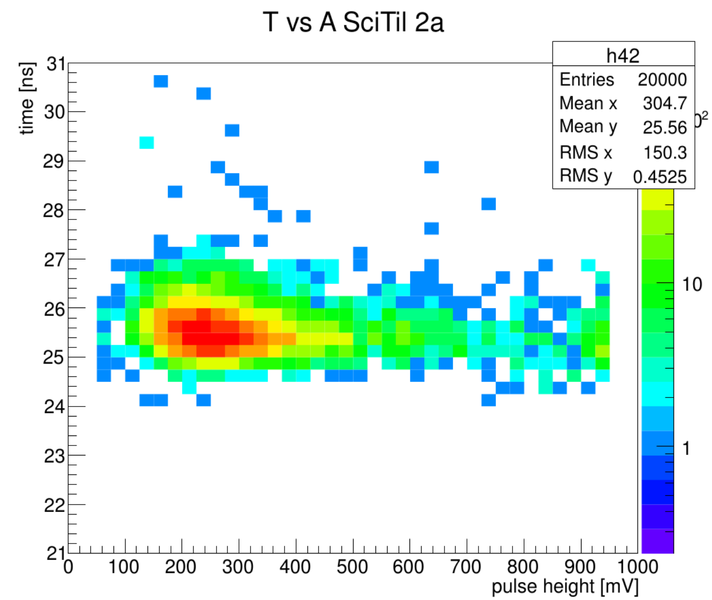
Time walk correction

- **We tried to correct for time walk:**
  1.) using pulse height information
  2.) using a constant fraction discriminator (CFD)
- **Both options are working and give comparable results**
- **CFD settings for this run: threshold = - 50 mV, delay = 2 ns, attenuation = 1/5**

HPK S12572-050P with EJ-228

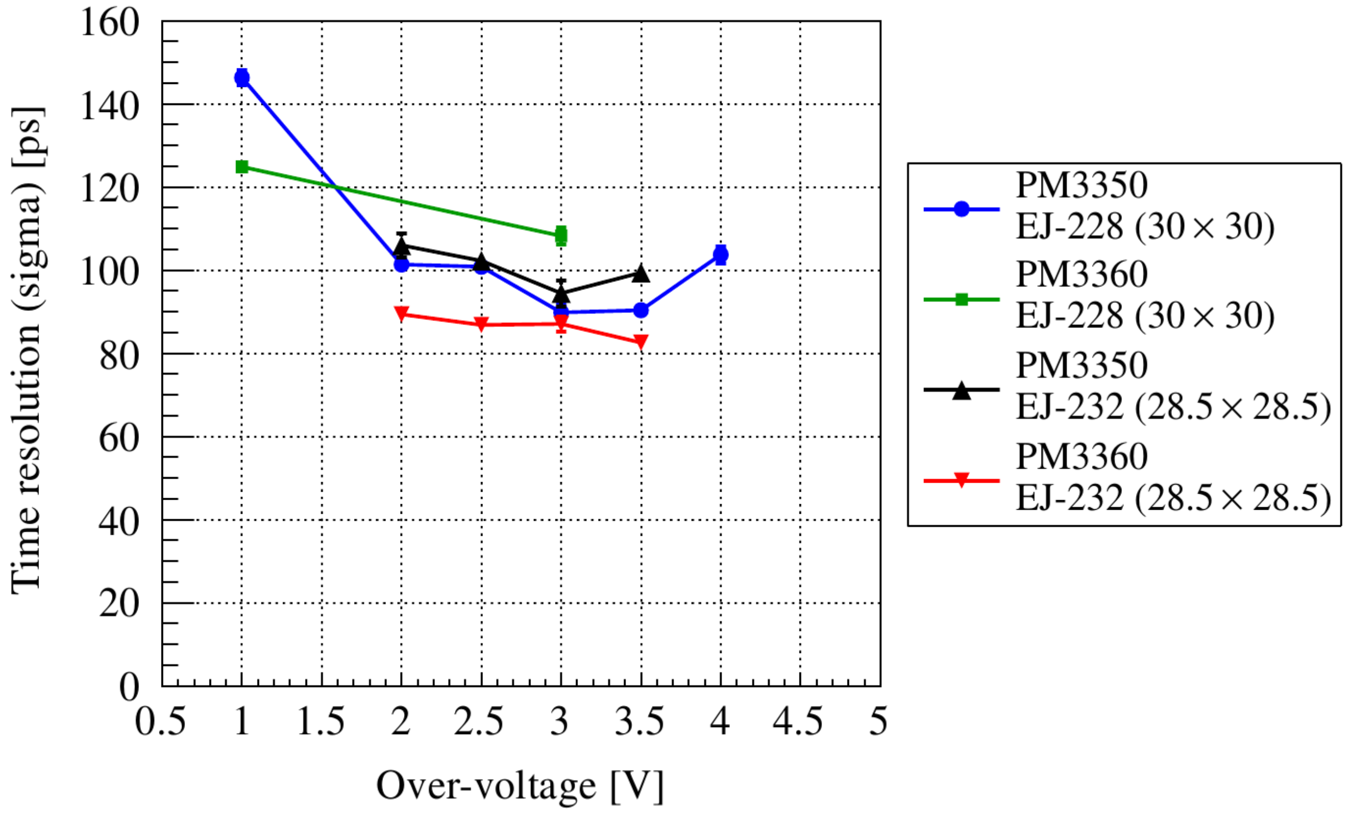


Ketek PM3350 with EJ-232



No time walk.

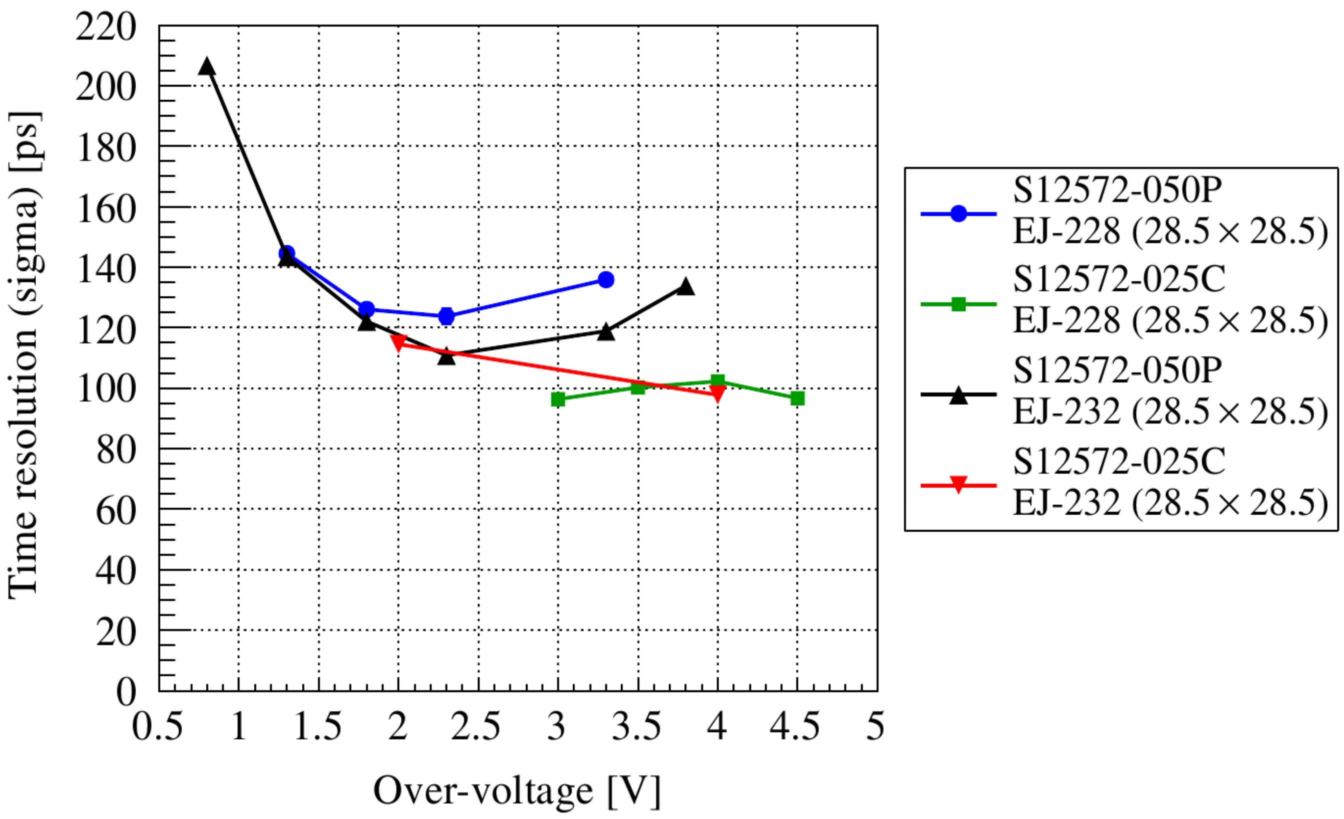
Ketek time resolution



Time resolution dependent on SiPM type, scintillator and over-voltage.

<u>Time resolution of about 85 ps reached with PM3360TS!</u>

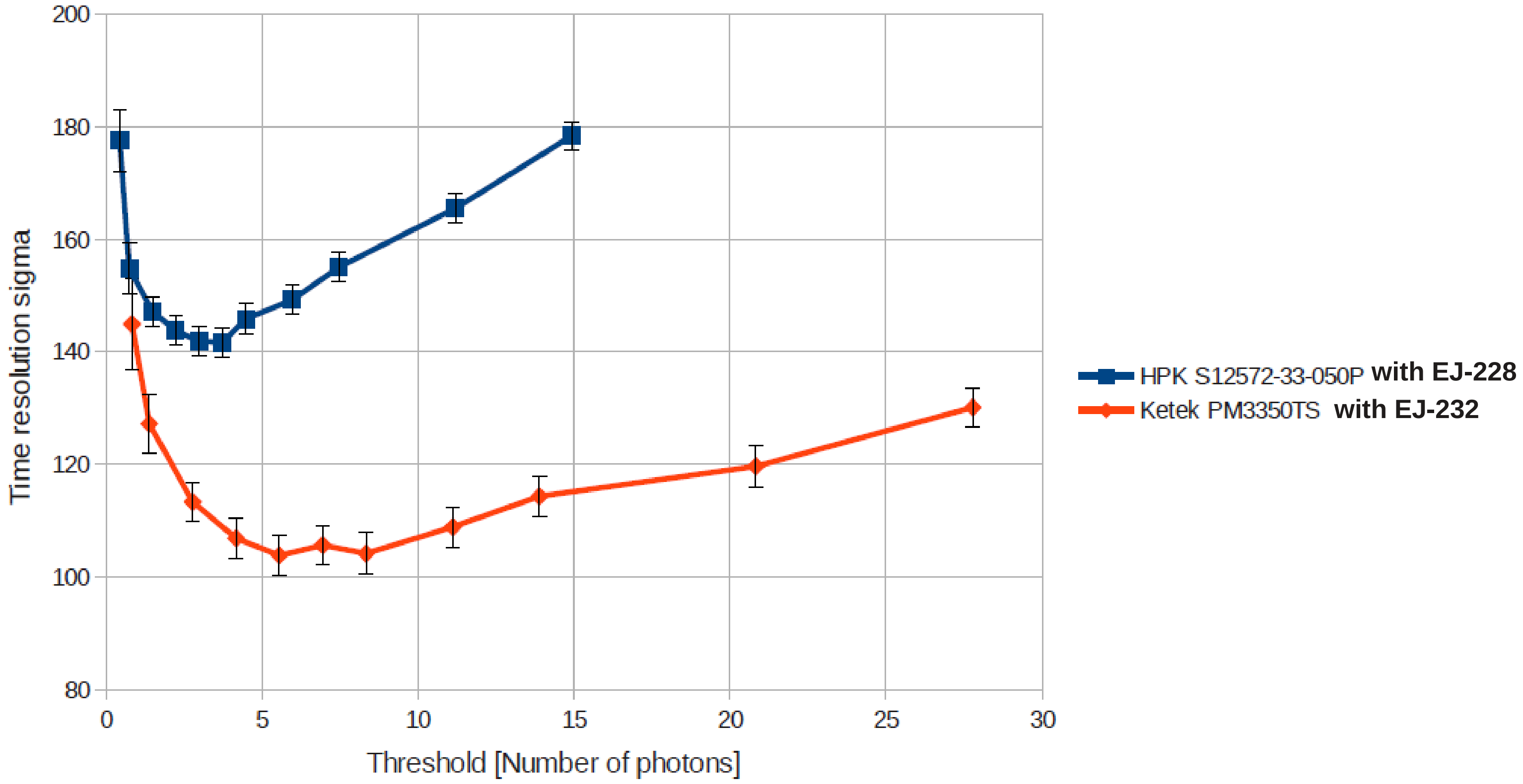
Hamamatsu time resolution



Time resolution dependent on SiPM type, scintillator and over-voltage.

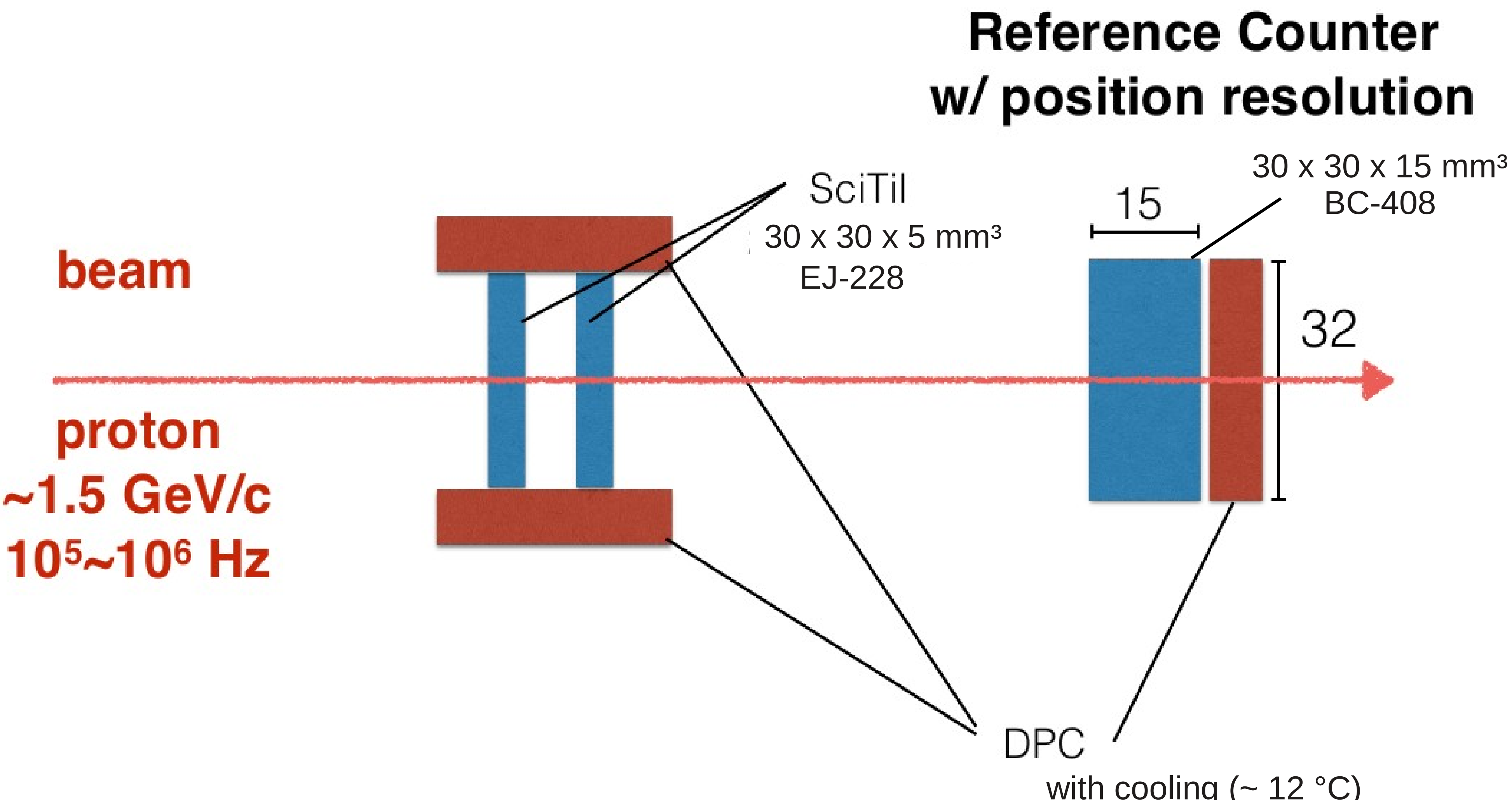
<u>Time resolution of about 95 ps reached with S12572-025C!</u>

Threshold dependence



The best result was achieved setting the threshold equivalent to ~ 4 photons (HPK) and ~ 6 photons (Ketek).

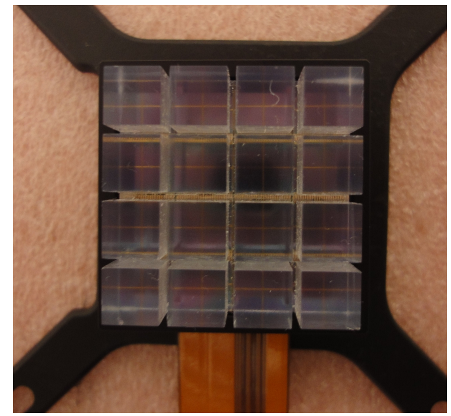
The SciTil-DPC prototype

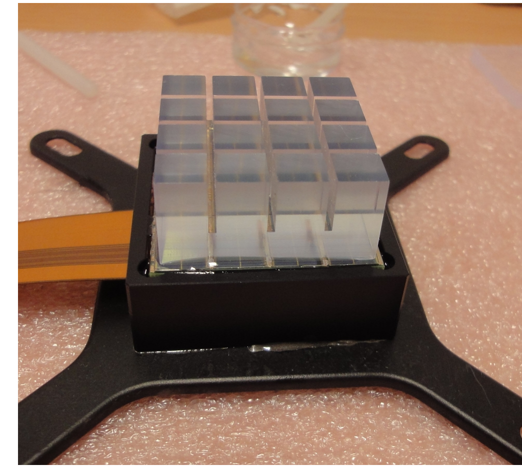


The SciTil-DPC prototype

Reference counter readout with Philips DPC:

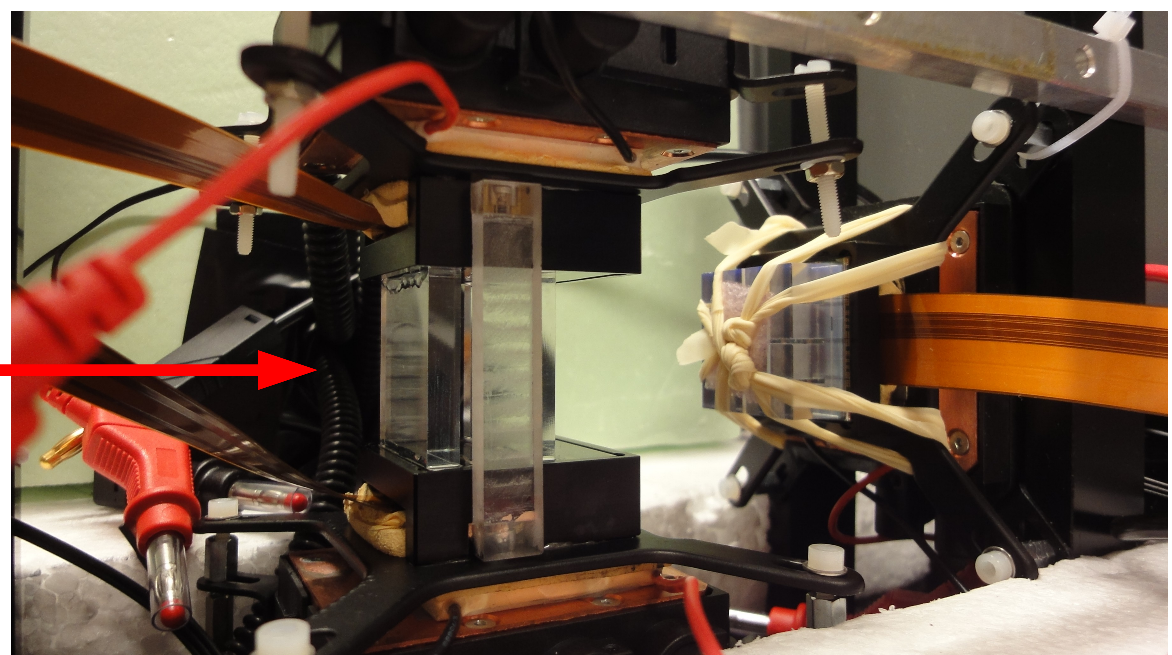
- **Thick (15 mm) scintillator to have many photons**
- **Monolithic block with slits: 1 mm wide, 10 mm deep**
- **Position information from centroid**





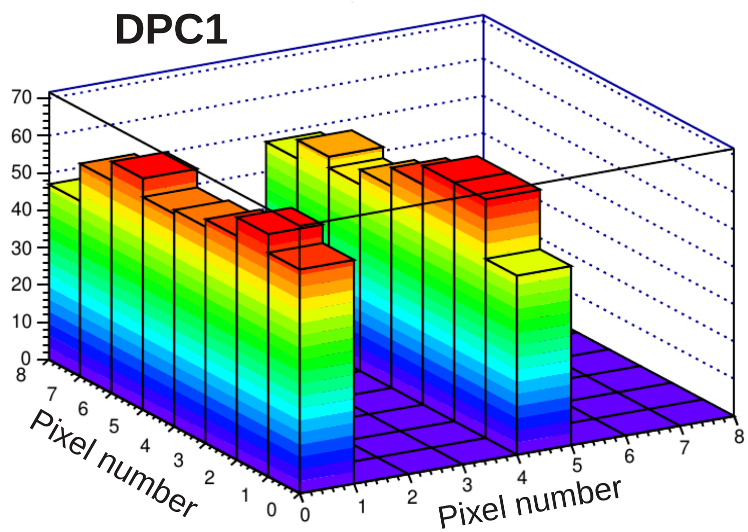
The whole setup:

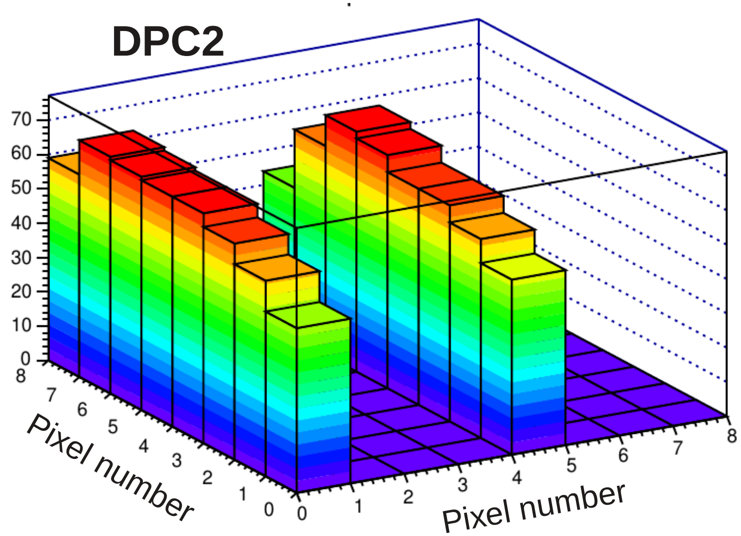
Beam

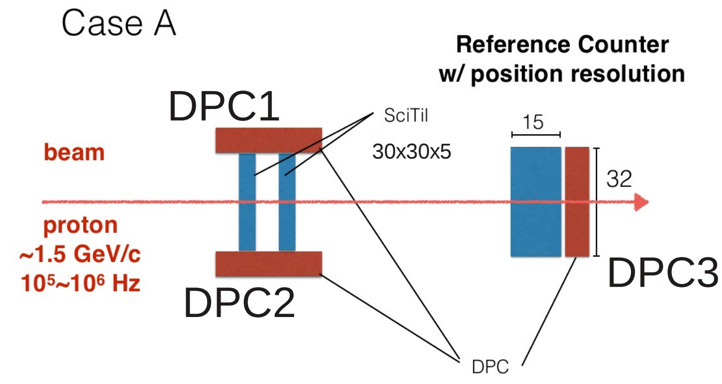


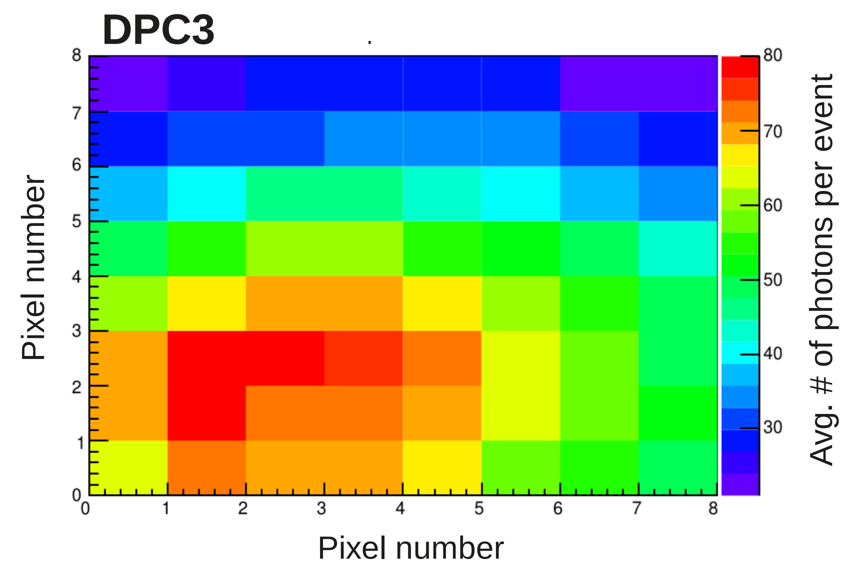
Results using DPC: photon number

Avg. # of photons per event





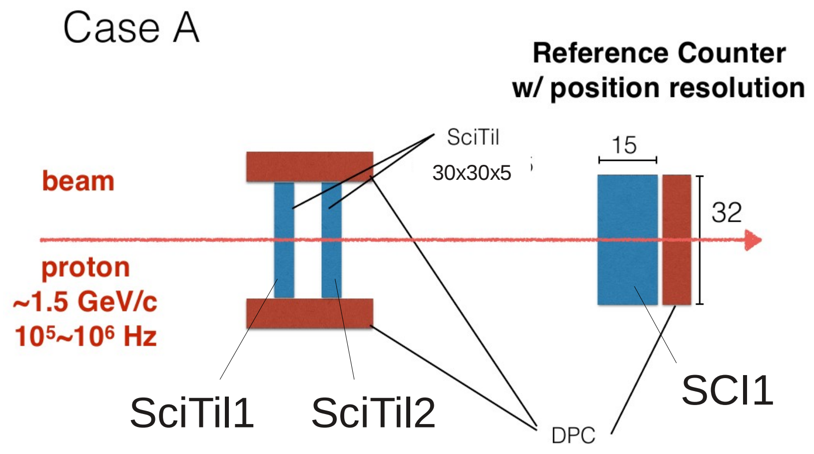




60 – 70 photons per event per DPC pixel.
Beam hitting slightly off center.

Results using DPC: time resolution

- **SciTil1: EJ-228 readout with Philips DPC**
- **SciTil2: EJ-228 readout with Philips DPC**
- **SCI1: BC-408 readout with Philips DPC**

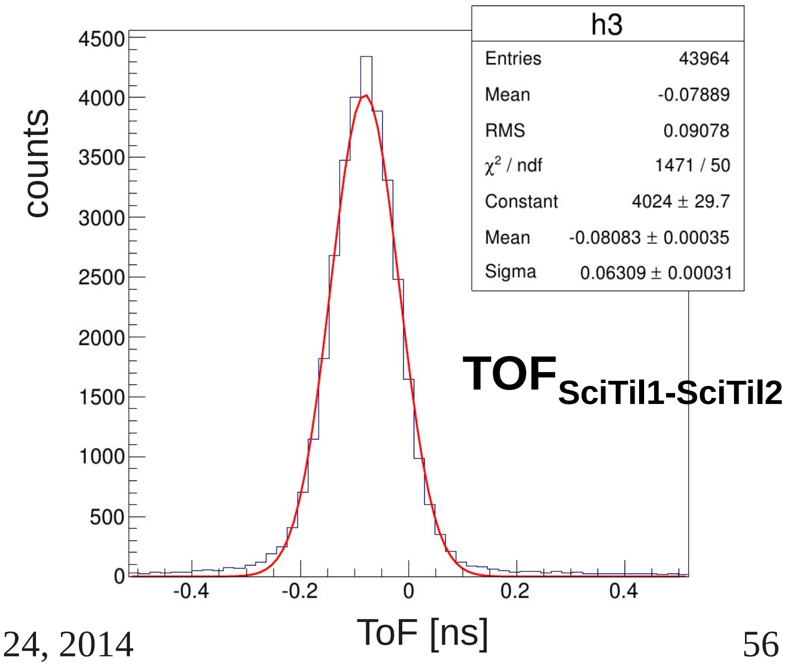


Calculate σ_i from TOF resolutions:

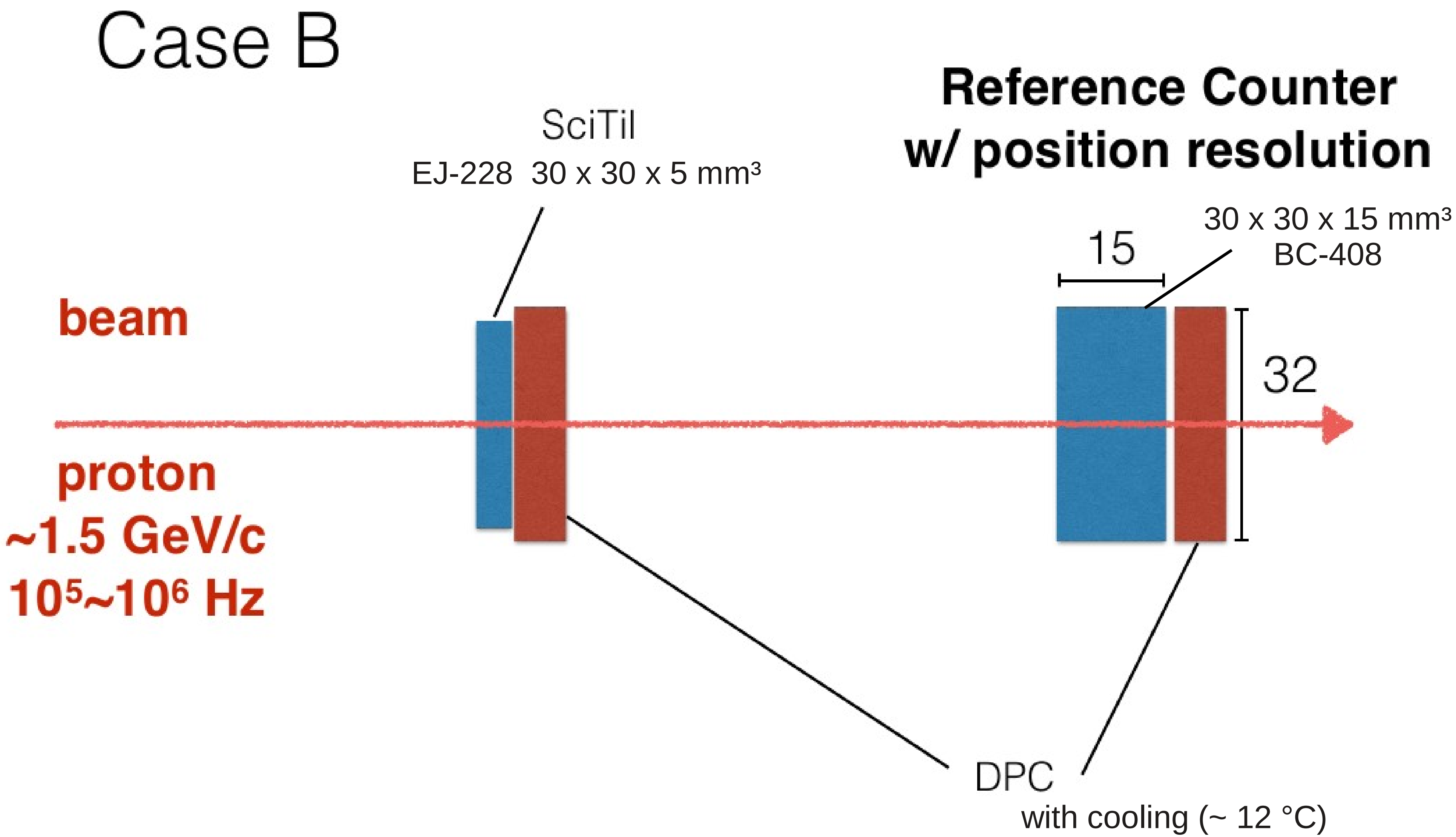
$\sigma_{SciTil1}$ = 46.9 ± 0.6 ps

$\sigma_{SciTil2}$ = 42.2 ± 0.7 ps

σ_{SCI1} = 57.0 ± 0.5 ps

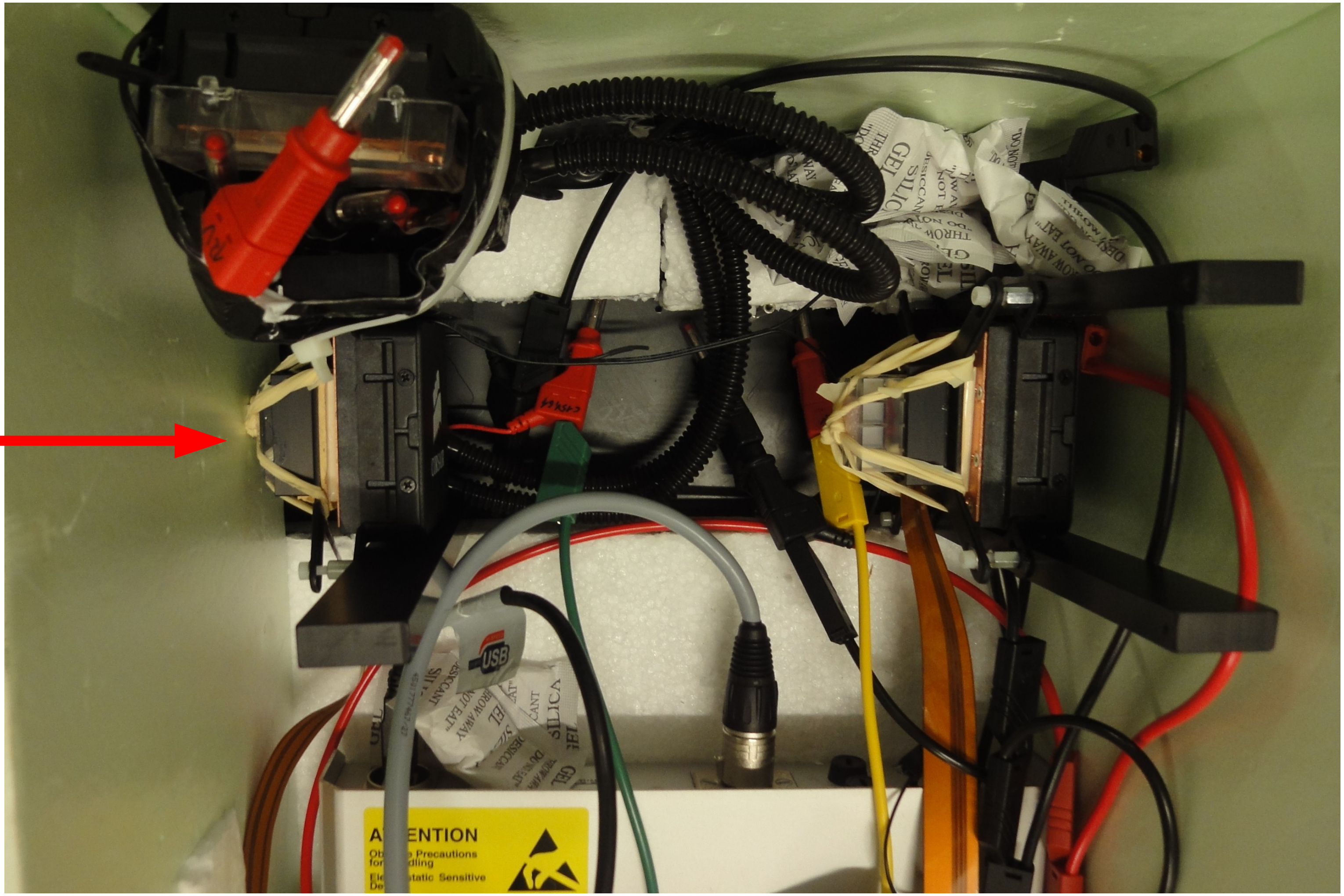


The SciTil-DPC prototype

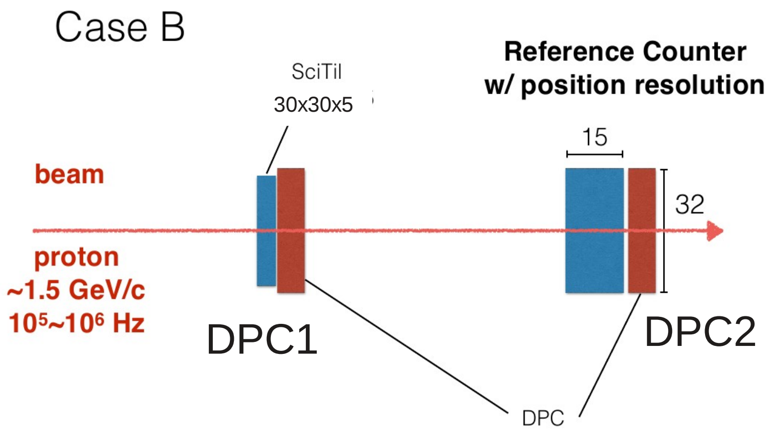


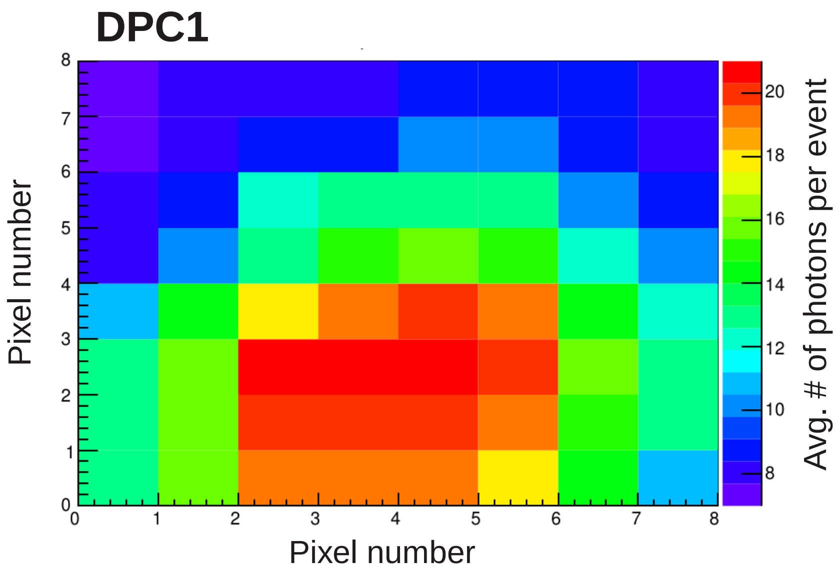
The SciTil-DPC prototype (Case B)

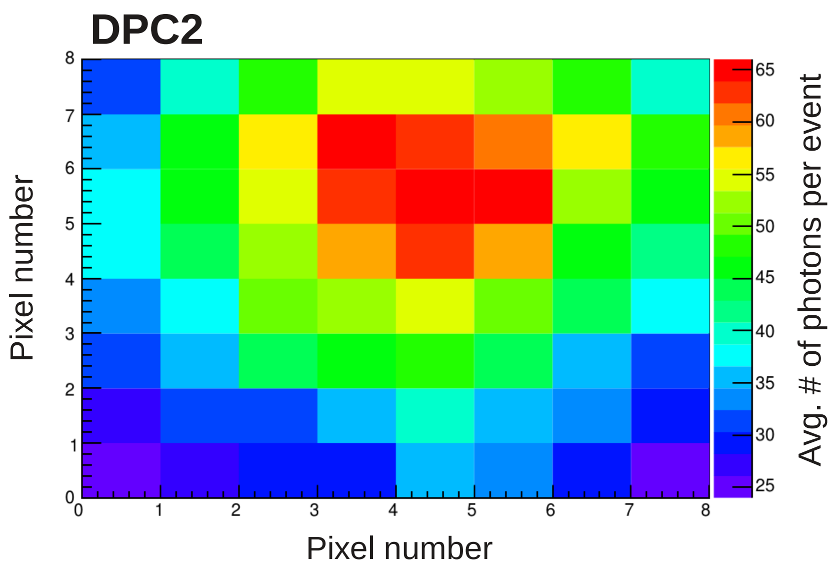
Beam



Results from case B: photon number

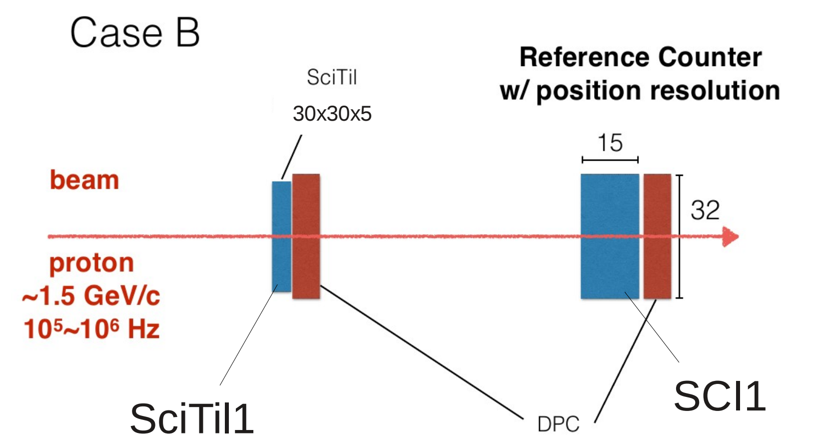






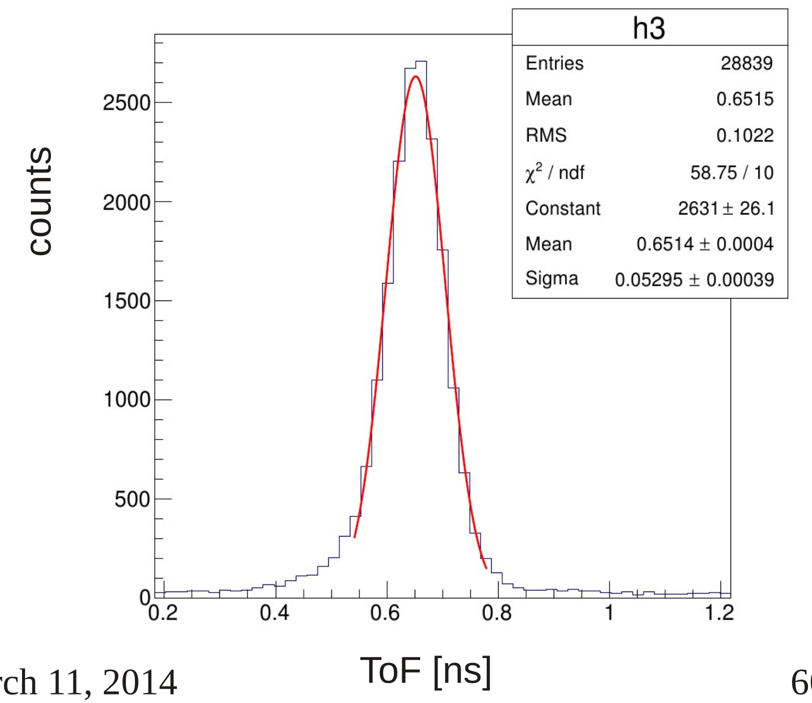
DPC2 sees 3 times more photons since scintillator is 3 times thicker.
Slightly misaligned.

Results from case B: time resolution



- **SciTil1: EJ-228 readout with Philips DPC**
- **SCI1: BC-408 readout with Philips DPC**

TOF resolution:
σ_{TOF} = 52.9 ± 0.4 ps



Summary

- **Measurements at a test beam facility using proton beams have shown, that a time resolution below 100 ps is feasible with the proposed detector layout, also in a “real” particle beam.**

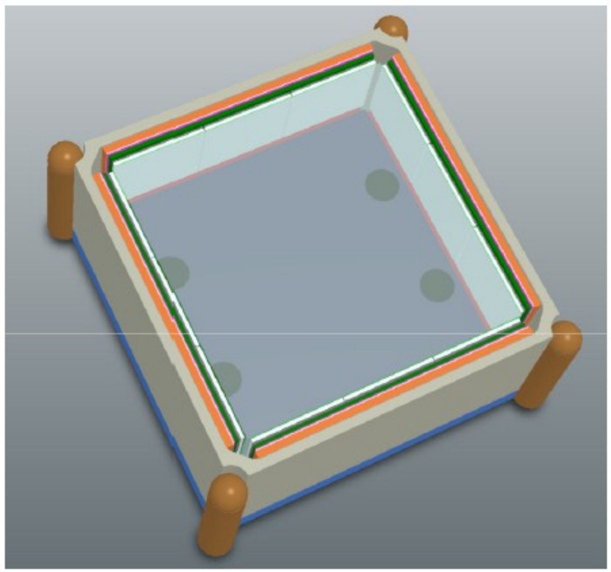
- **Time walk correction (CFD, pulse height correction,...) is a crucial point to reach the required timing.**

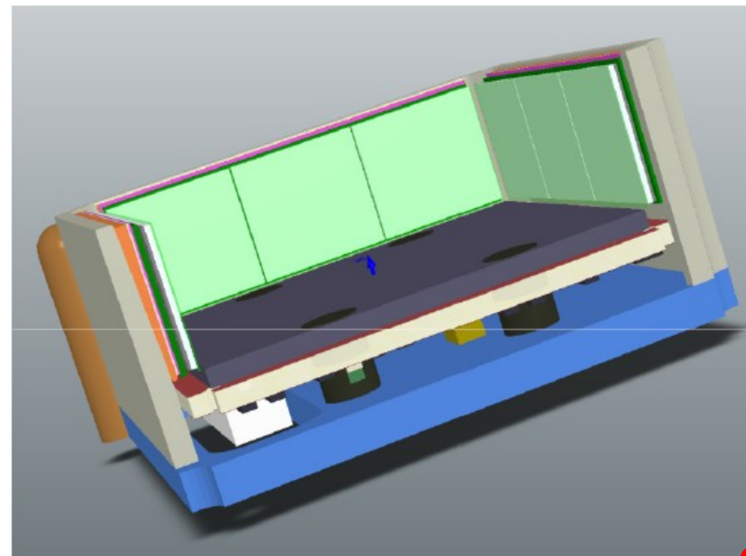
- **Ketek SiPMs show better results than Hamamatsu sensors. A time resolution of $\sigma \sim 85$ ps could be achieved with Ketek PM3360TS. With Hamamatsu S12572-33-025C sensors, $\sigma \sim 95$ ps was achieved.**

- **With a time resolution of $\sigma \sim 45$ ps, the Philips DPC shows even superior timing, however with a much larger sensitive area. A new DPC layout is needed to use this detector for SciTil.**

DPC layout for SciTil

Building Block: Tile (1/2)





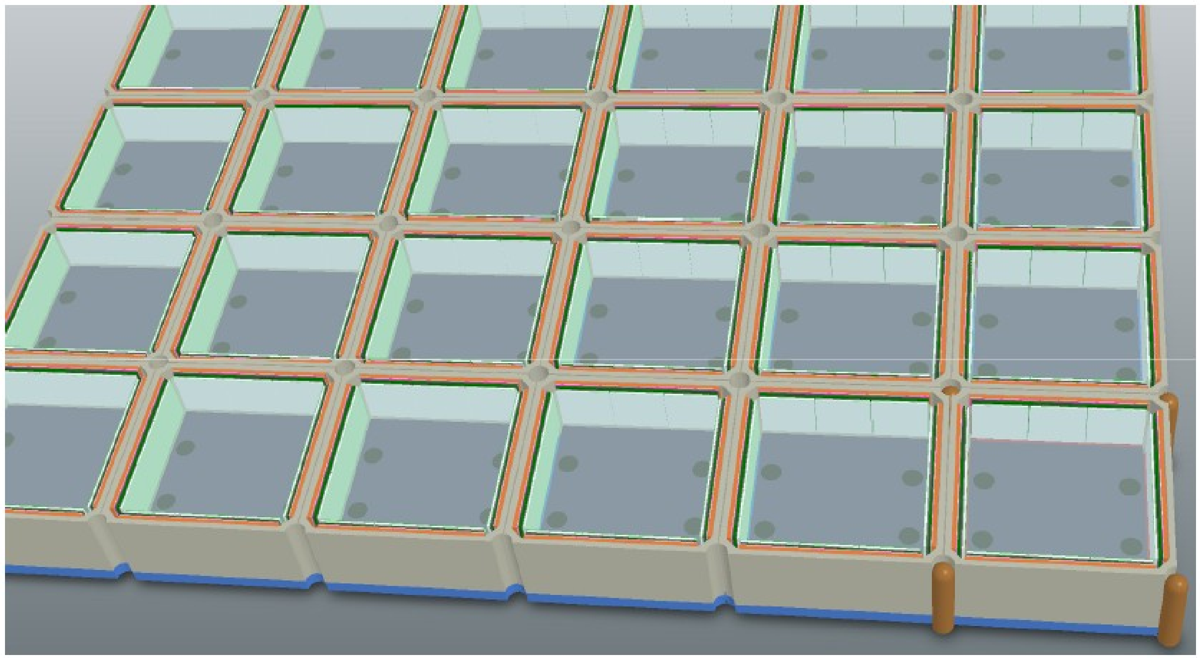
Confidential

- Tile housing: 29.8 x 29.8 x 17 mm³
  - Incl. 1 mm plate and 2 mm bottom cap
- Scintillator: 24.4 x 24.4 x 7.4 mm³, area FF 66%

6 2014-01-24 PDPC Aachen Confidential

DPC layout for SciTil

PANDA 'Super Module' Matrix



Confidential

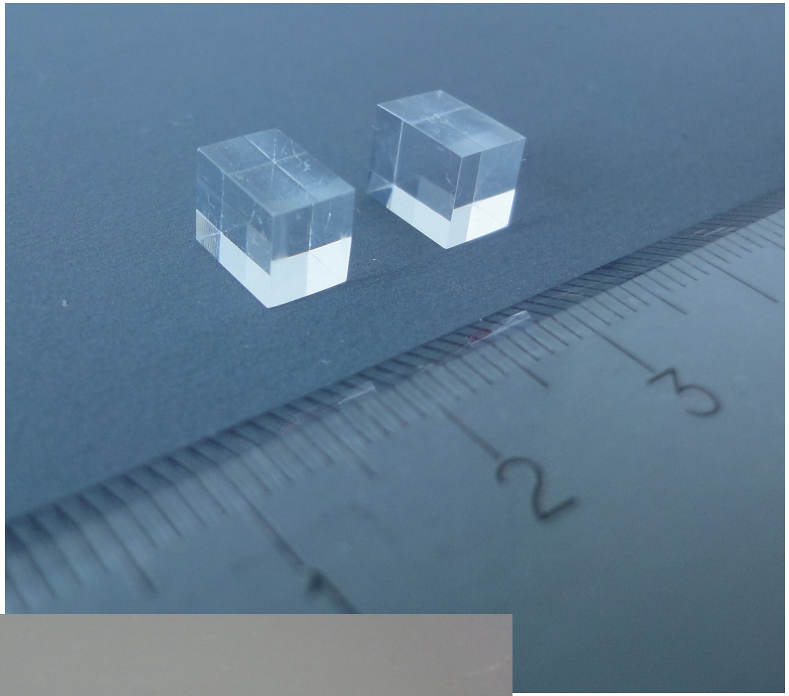
- 180 x 1800 mm^2 = 3240 cm^2, 6 x 60 tiles
- Tile → Module (tbd) → NN (tbd) → Super module

8 2014-01-24 PDPC Aachen Confidential

Thank you !

Spare

The SciTil-DPC prototype (Case C)

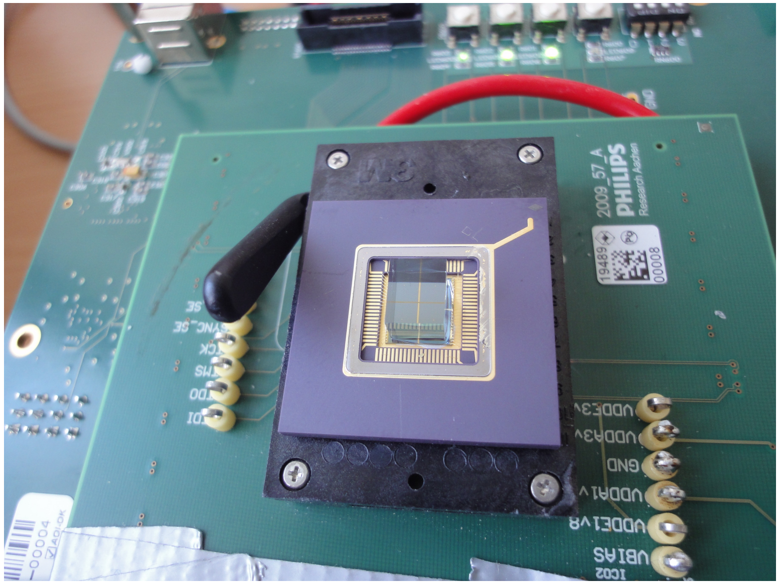


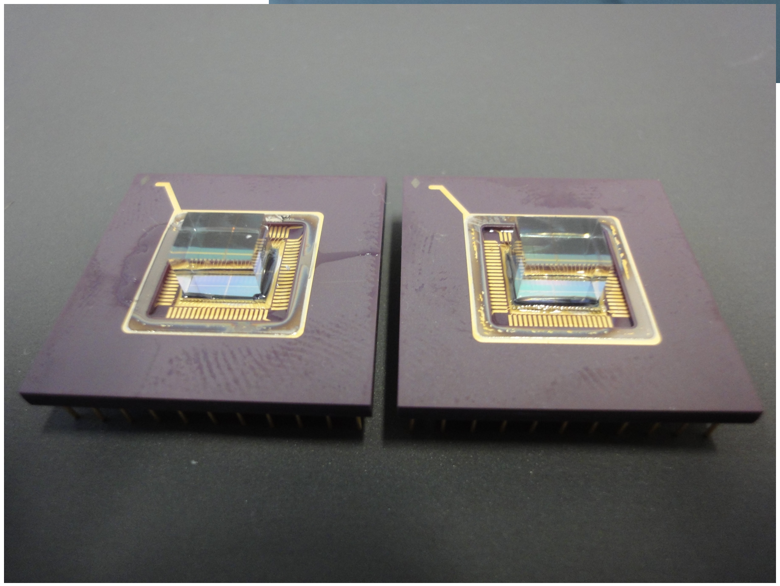
Testing of single-die DPC prototype:

- **Approx. 8 mm x 7 mm sensitive area**
- **Use only single die to avoid jitter between dies**
- **No additional time jitter from FPGA**
- **Small and fast scintillator: EJ-232 ~ 7 x 6 x 5 mm^3**
- **Two modules in coincidence**

TOF resolution: σ_{TOF} ~ 40 ps

Assuming two identical detectors: $\sigma_1 = \sigma_2 \sim 30$ ps





Radiation hardness

At the moment, we cannot give numbers on the radiation hardness of the SiPM sensors from these measurements. More quantitative details after analyzing the drift chamber data.

Beam condition at JESSICA:

- **2.7 GeV/c and 1.5 GeV/c protons**
- **Intensity: ~ 10^5 – 10^6 Hz**
- **Defocused beam: ~ 5 cm x 5 cm**

However, we realized a drastic increase of SiPM dark count rates after 1-2 days of operation in beam (factor 3-4, quick measurement with oscilloscope). The gain of the SiPMs didn't change.

Afterwards, the dark count rates seem to stay constant.

This observation needs further investigation. It is necessary to have a dedicated measurement on the radiation hardness of the SiPMs sensors used for SciTil.

Very rough estimation: 1% of 10^6 for 20 hours → 7 x 10^8 particles

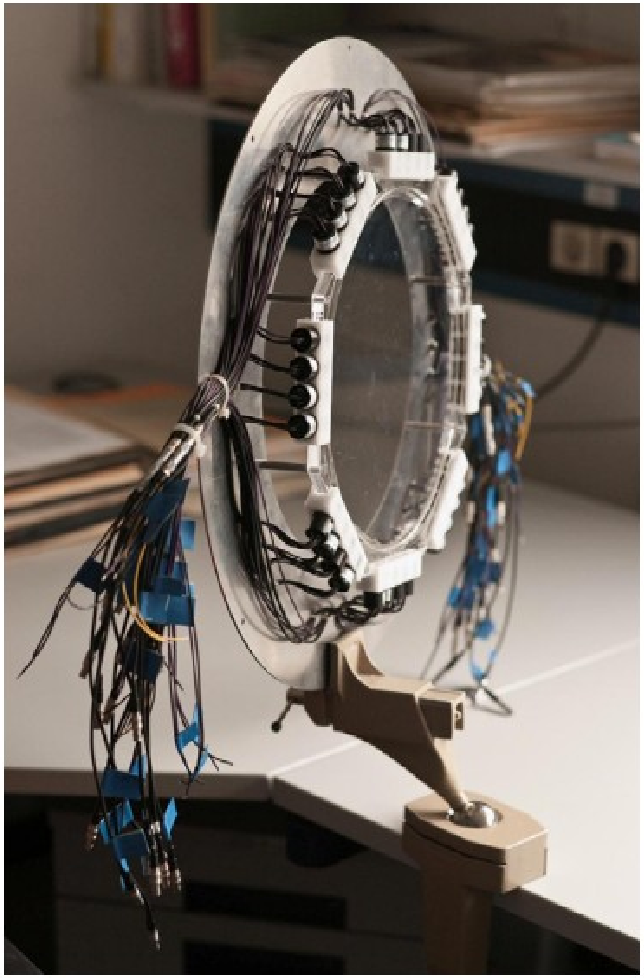
Revisiting SciTil Concept

Is the current design really optimum?

28.5 x 28.5 x 5 mm^3 tile with two SiPMs

RISING timing detector

- R. Hoischen et al. (RISING experiment) NIMA 654 (2011) 354.
- Octagonal shaped scintillator (ø=20cm) with 32 PMTs to achieve 10 ps time resolution
- Precise calibration and position determination
- (but for heavy ion!!)



MEG experiment ToF Tile

- More recent development with similar concept from MEG experiment
- arXiv:1402.1404v1
- 60x30x6 mm^3 BC422 plus 6 3x3 mm^2 aSiPM
- 42 ps (sigma) time resolution

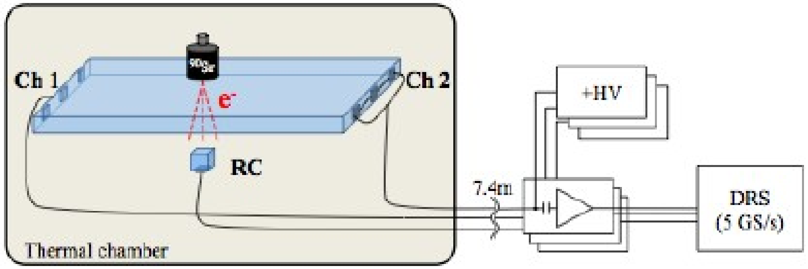
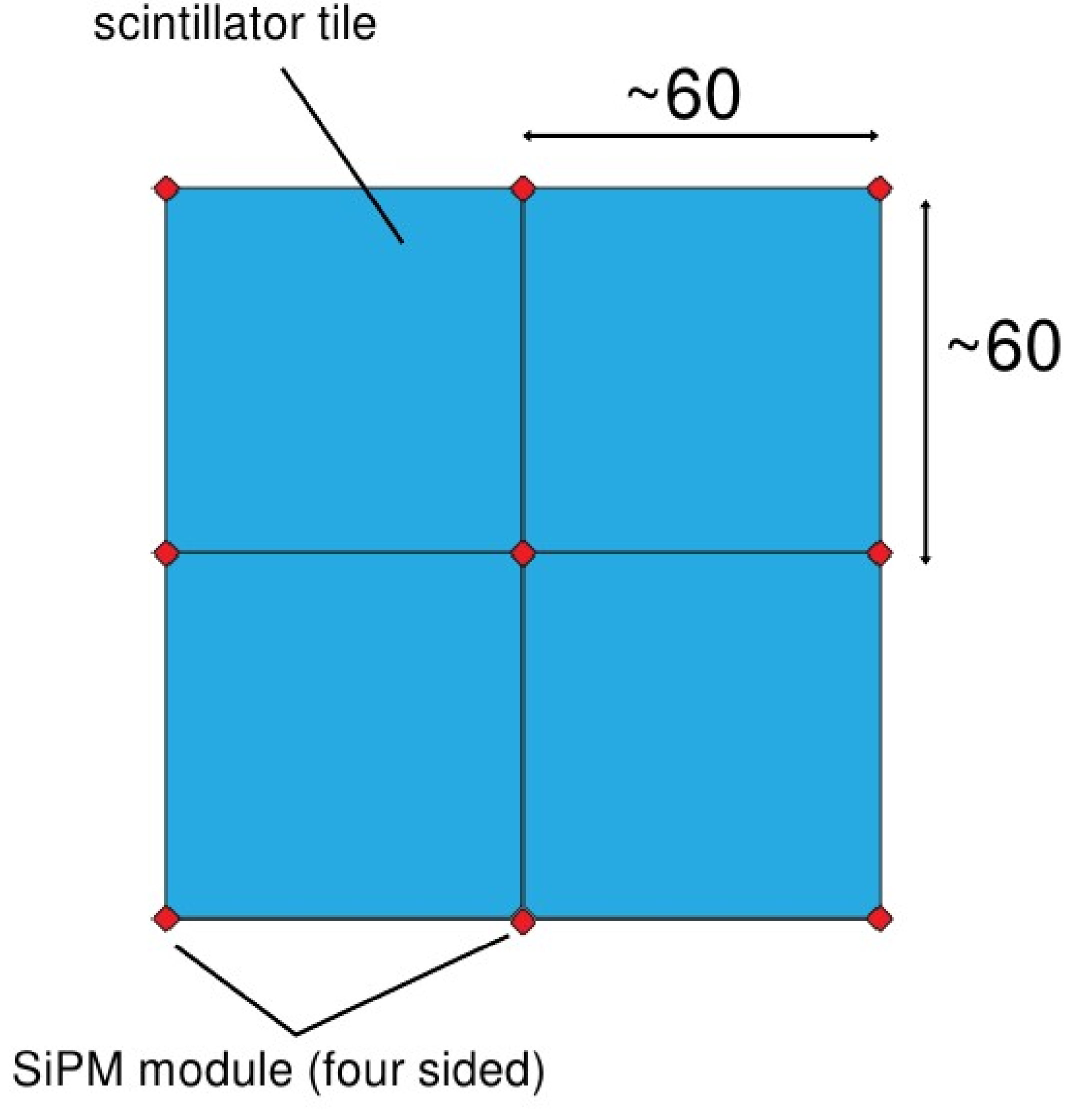


Fig. 1. Setup of the tests of counter time resolution. RC denotes the reference counter. See in the text for details.

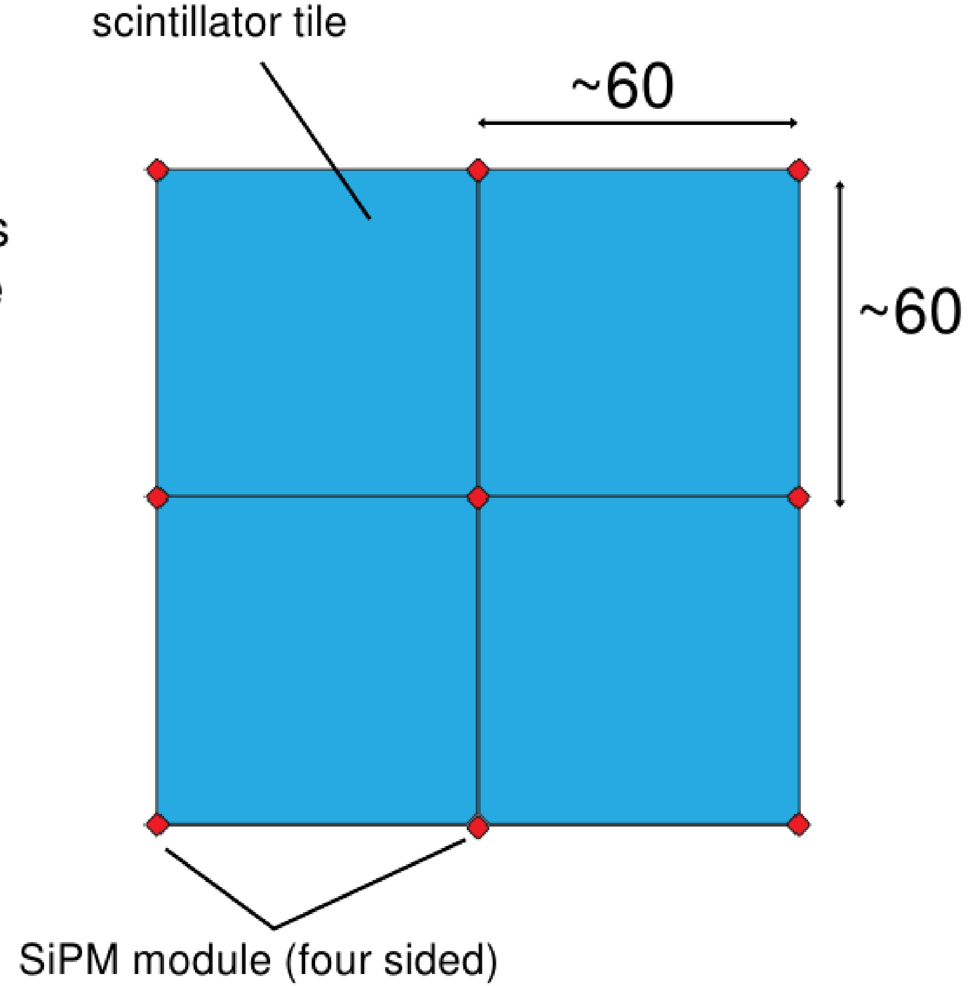
New Design Concept

- four sensors per tile
- symmetric configuration
- use charge distribution information to reconstruct the position on tile and apply a correction



Expected Advantage

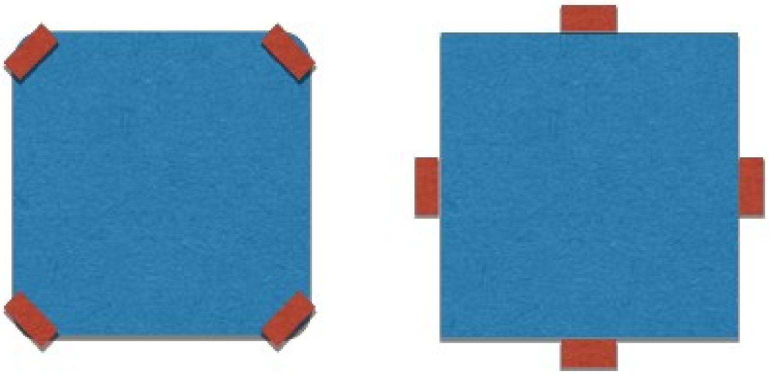
- Either the number of channels decreases with the same time resolution, or
- the number of channels stays the same, but with better time resolution
- minimize insensitive area



Questions

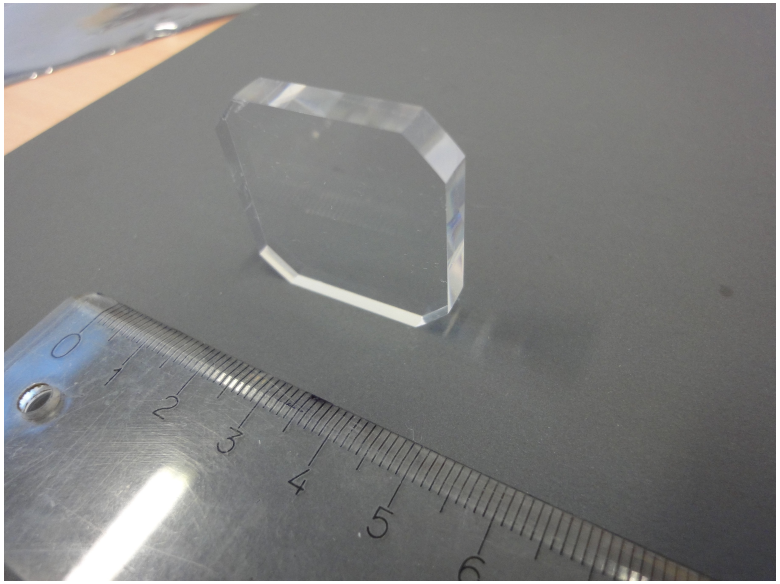
- 4 SiPMs per tile instead of 2, or even more?
- 4 centers or 4 corners?
- Position resolution skew at the corner?

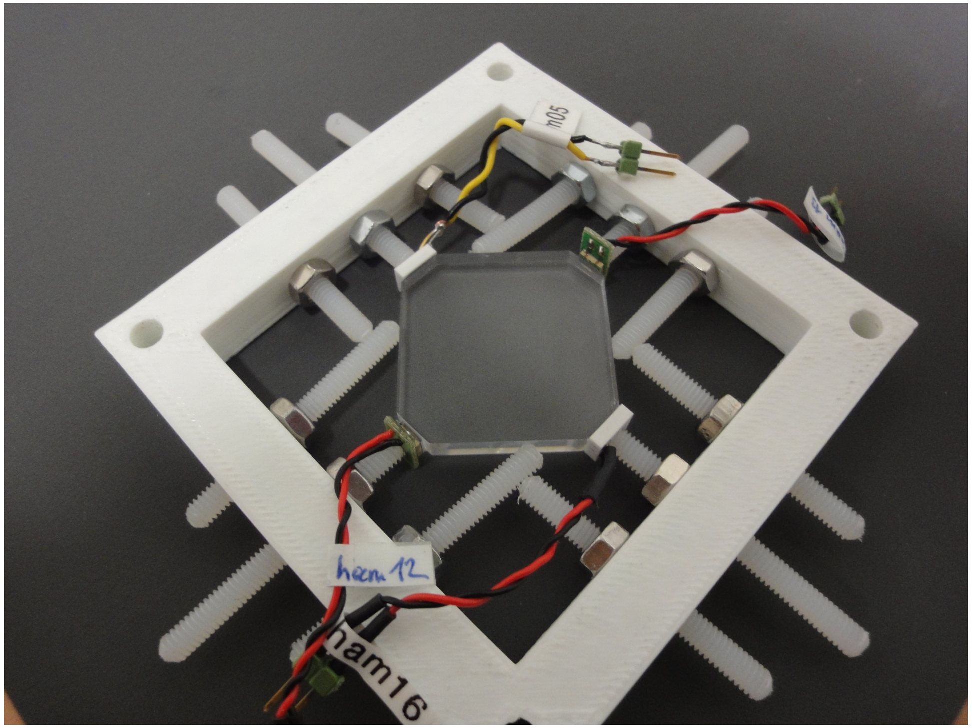
→ **SIMULATION!**



New SciTil prototype

- We prepared a scintillator (EJ-228, 28.5 x 28.5 x 5 mm³) with edges cut
- Tested during last night of test beam
- 4 Hamamatsu SiPMs (S12572-050C and -050P)
- Idea is to use the information from the charge distribution to reconstruct the position and apply a correction

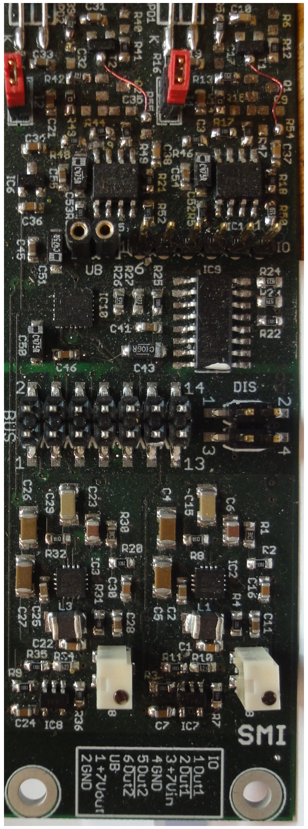




Data are not yet analyzed.

IFES board

- **preamplifier board developed at SMI**
- 2 channels with full differential readout (signal from cathode and anode are used) → robust against noise
- Only one bias supply: 5 V
- Including an time over threshold discriminator
- **Bias and threshold settings of the two SiPM are controlled remotely via an Arduino Leonardo board**
- The boards can be daisy chained up two 256 channels
- Gain: 16 - 100 (by changing two resistors) → affects the rise time



- Amplifier and discriminator stage could be replaced by NINO → reduction in size
- Bias and threshold control could be done by IFES
  - → more channels on single board
  - → less power consumption
  - → full remote control

Option for PANDA SciTil?