Studies on efficiency and time resolution for SciTil using Philips dSiPM

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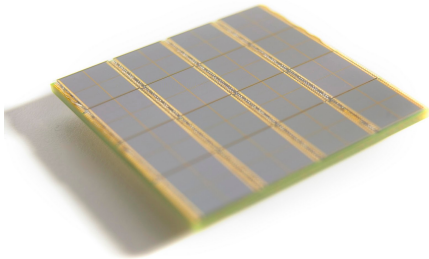
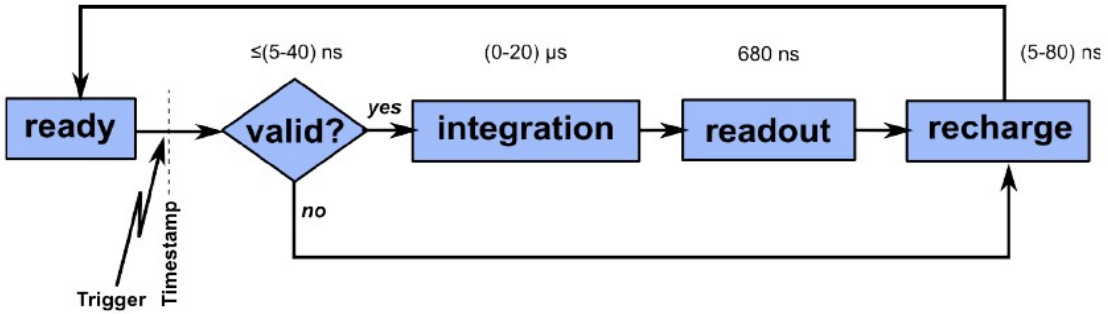
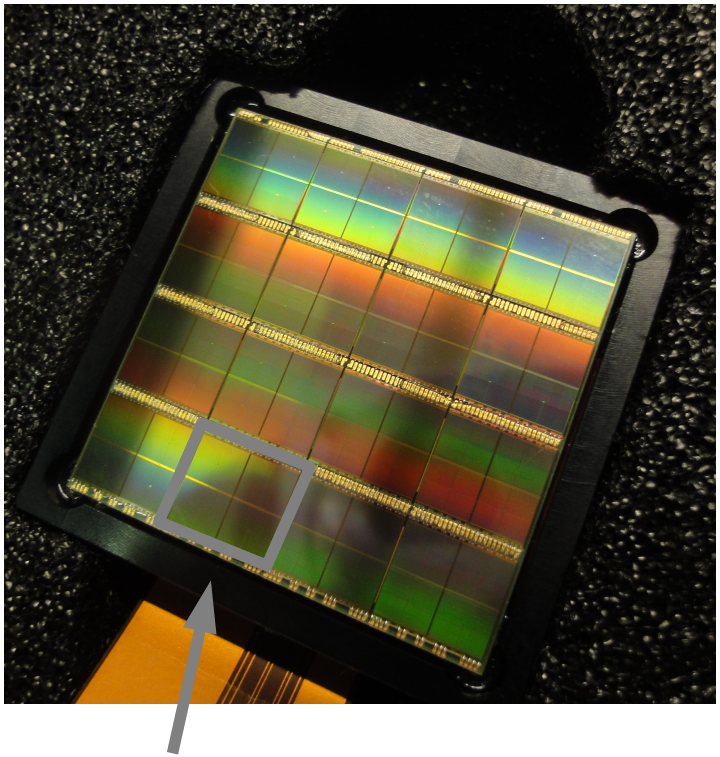
The digital SiPM



- **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**

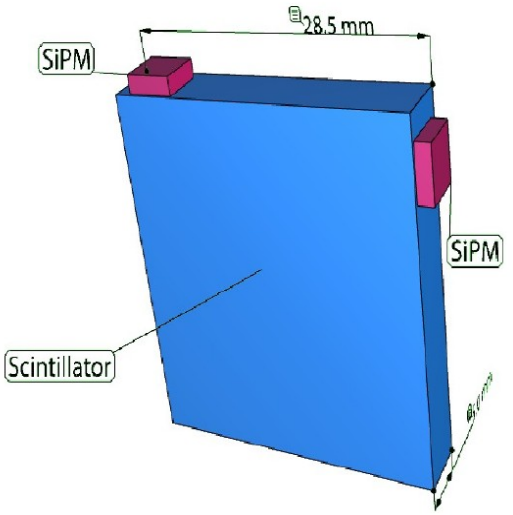




One die consists of 4 pixels
The whole tile has 16 dies

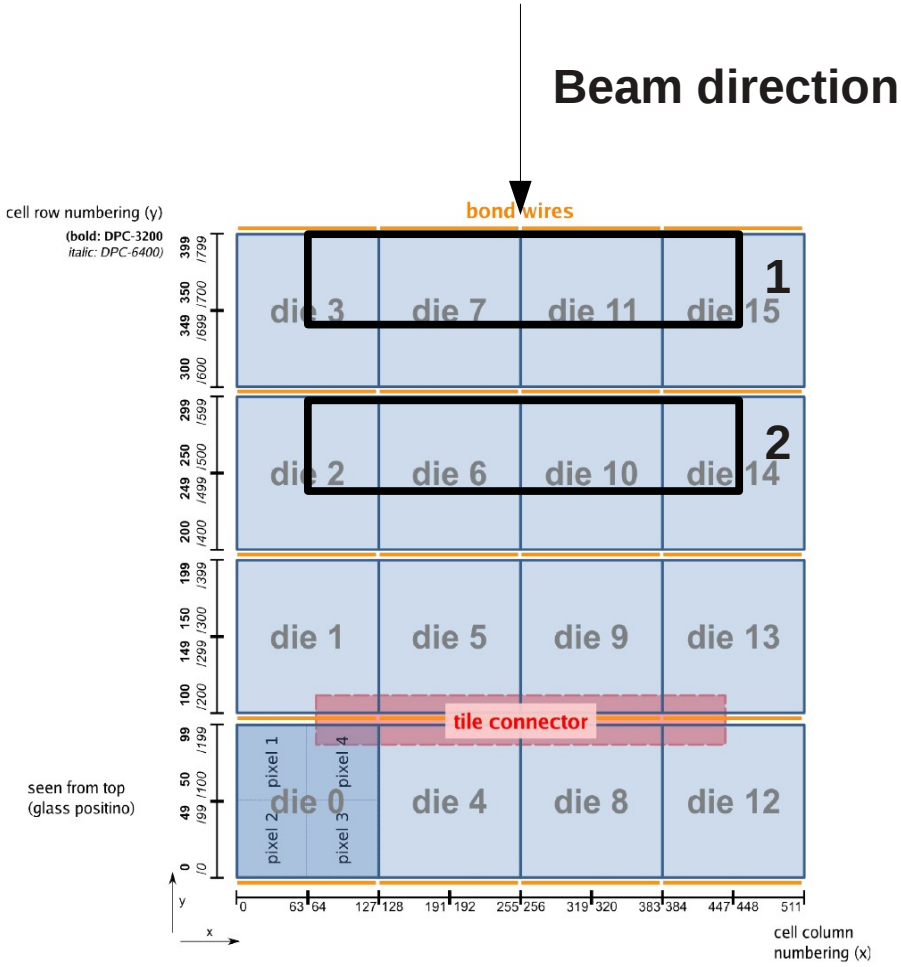
Photon number

- **Minimum Ionizing Particle (MIP): ΔE = 1MeV = 10^4 photons generated**
- **Assuming that 70% hit the rim: 7000 photons**
- **Detection area of dSiPM: 1 die = 2 pixels = 25 mm²**
- **Assuming 50% PDE for DPC-3200, 30% for DPC-6400**
- **DPC-3200:**
  - **30 x 30 x 5 mm³ → ~ 150 photons per die**
  - **25 x 25 x 5 mm³ → ~ 180 photons per die**
  - **20 x 20 x 5 mm³ → ~ 220 photons per die**
- **DPC-6400**
  - **30 x 30 x 5 mm³ → ~ 90 photons per die**
  - **25 x 25 x 5 mm³ → ~ 105 photons per die**
  - **20 x 20 x 5 mm³ → ~ 130 photons per die**

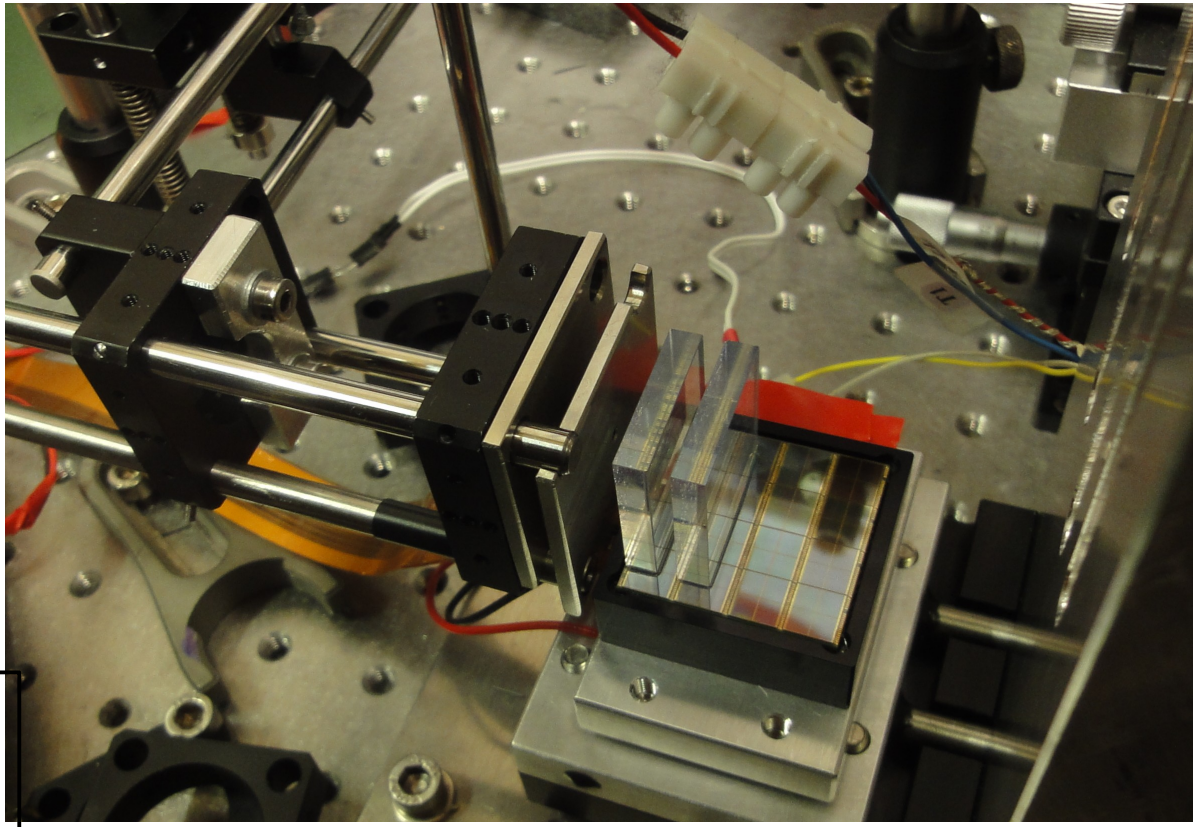


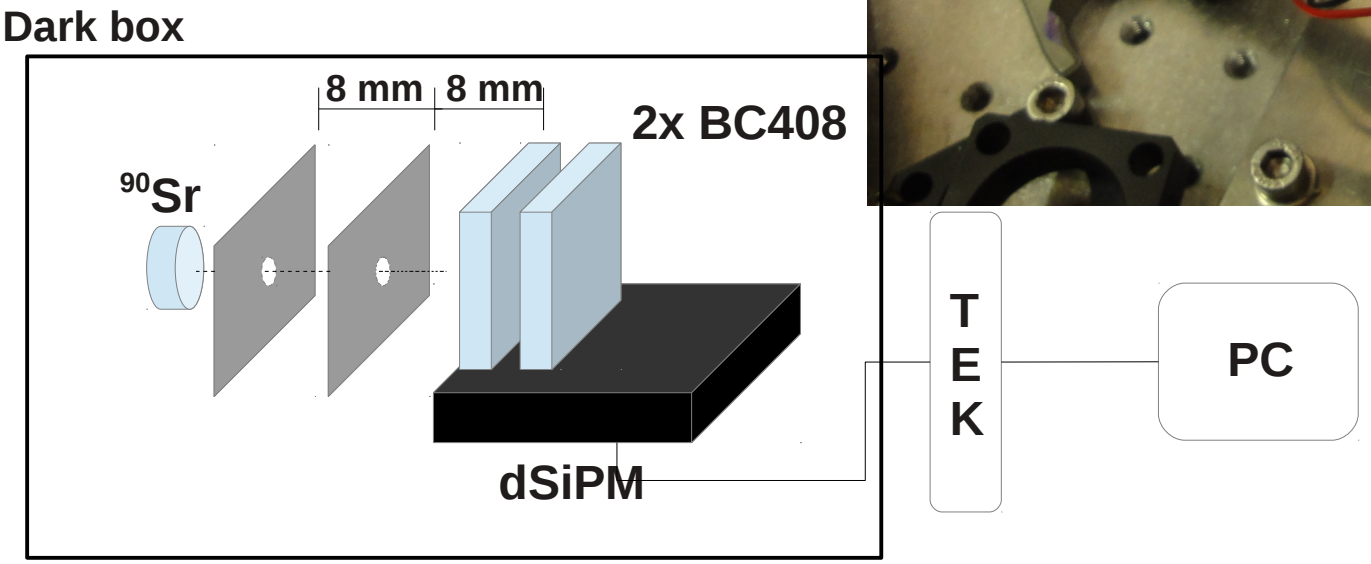
New Setup

- **Try to select only events from ^{90}Y decay**
- **Put two scintillators on a single tile**
- **Coincidence between 4 dies (die6, die10, die7 and die11)**
- **e$^-$ from ^{90}Sr decay should be stopped in first scintillator and do not reach second scintillator**



Experimental setup



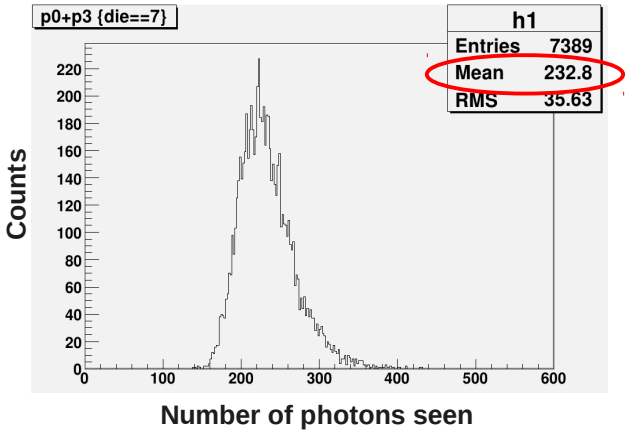


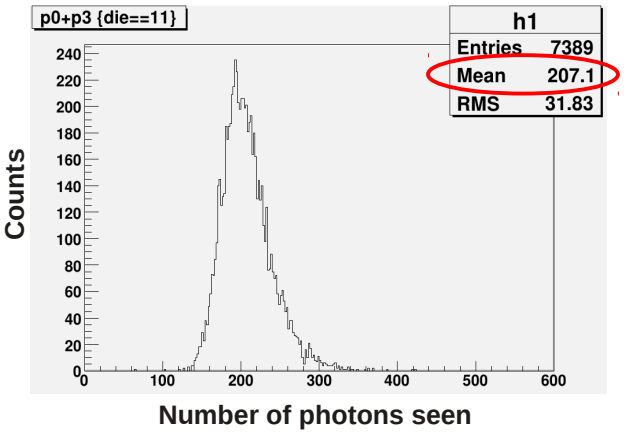
Photon number

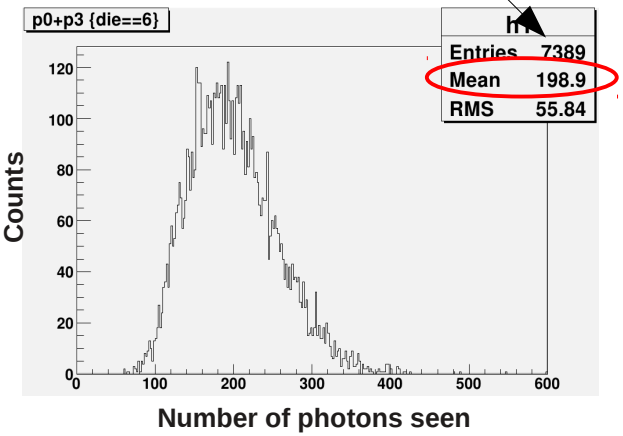
DPC-3200

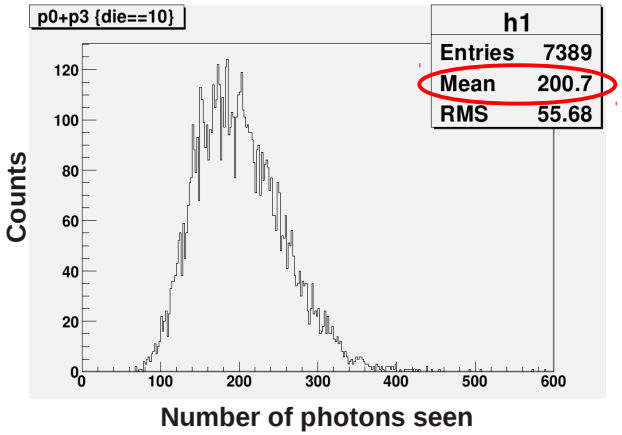
2x BC-408 25 x 25 x 5 mm³ with grease

Event rate ~ 5 Hz





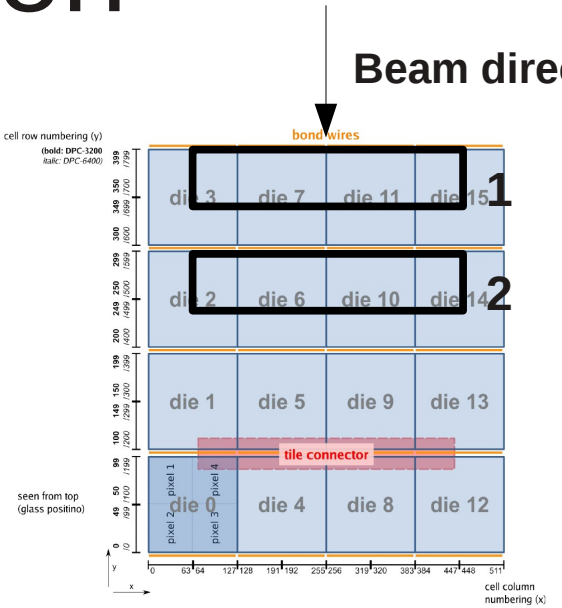




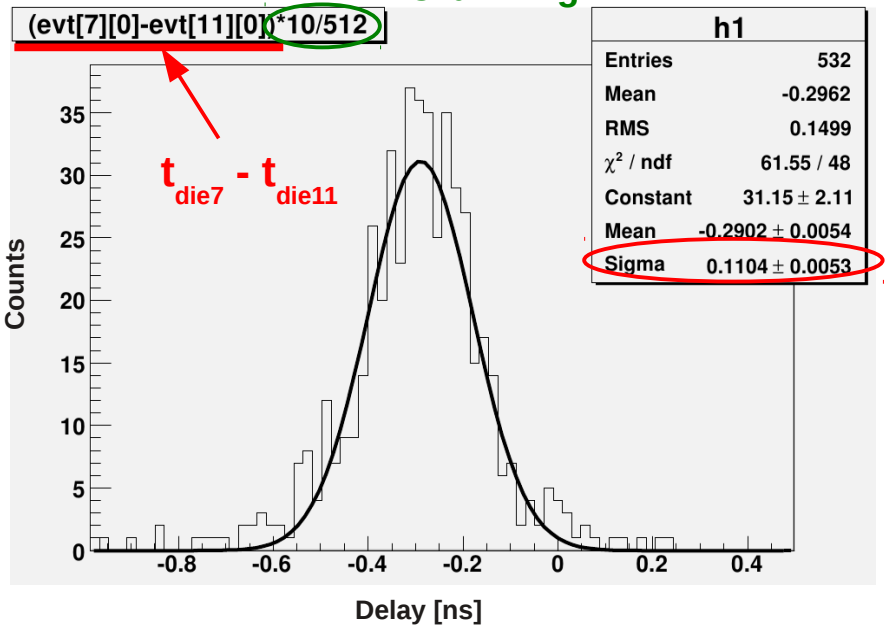
- **Measurement time now set to 5000k frames (~ 1600 s) because of lower event rate (4 dies in coincidence)**
- **Validation threshold set to 8 photons to reduce dark counts (we anyway expect now enough photons)**
- **First peak from ^{90}Sr disappears**
- **Expected: ~ 200 photons**
- **We see the right number of photons!!!**

Time resolution

- **Look at coincidence timing**
- **Same setup as before (4 dies in coincidence) to select “good” events**
- **Start with die7 and die11**
- **Take 200k frames to test**



TDC binning

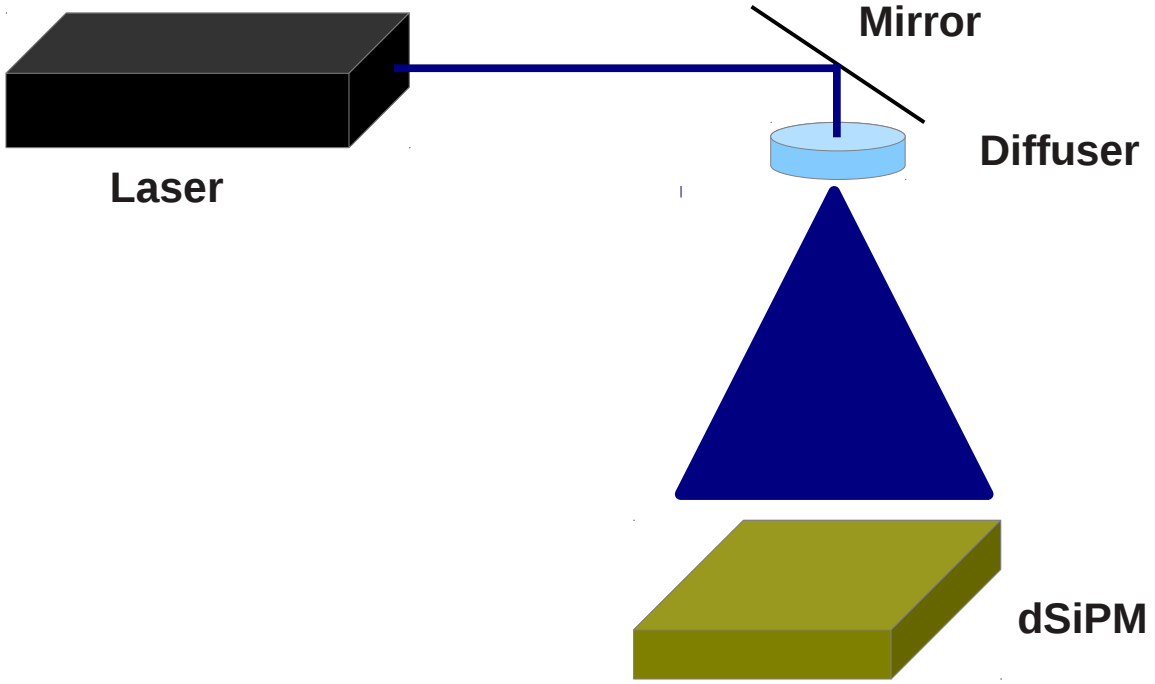


- **Low statistics (only 200k frames)**
- **Delay spectrum not centered around 0 ns**
- **Skew between dies (see TEK User Manual p. 24) → one should correct**
- **Timing: σ ~ 110 ps**
- **Assuming two identical dies:**

$$\sigma_{die7} \sim \sigma_{die11} \sim 78 \text{ ps}$$

Skew correction

- **Skew correction needed to use also absolute time, not only relative**
- **Perform skew correction using pulsed laser (~ 30 ps pulse width, repetition rate 1 kHz)**
- **Measure delay between dies and correct for offset**

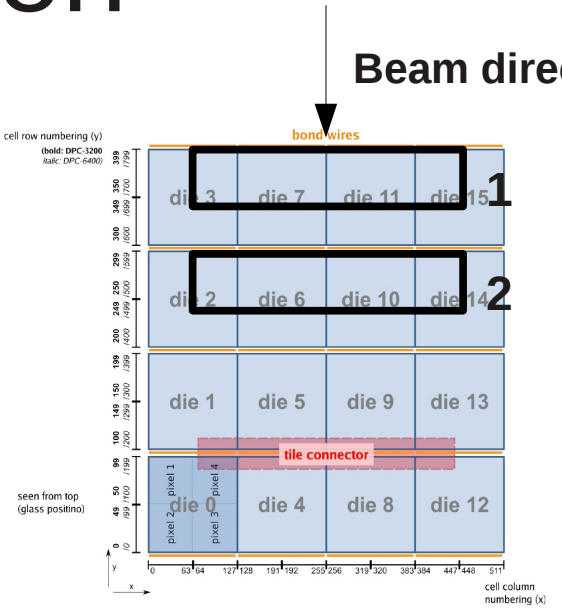


Die number	Skew correction [TDC bins]
0	+14
1	+15
2	+42
3	+39
4	+7
5	+9
6	+15
7	+15
8	+10
9	+19
10	+4
11	+0
12	+16
13	+16
14	+20
15	+16

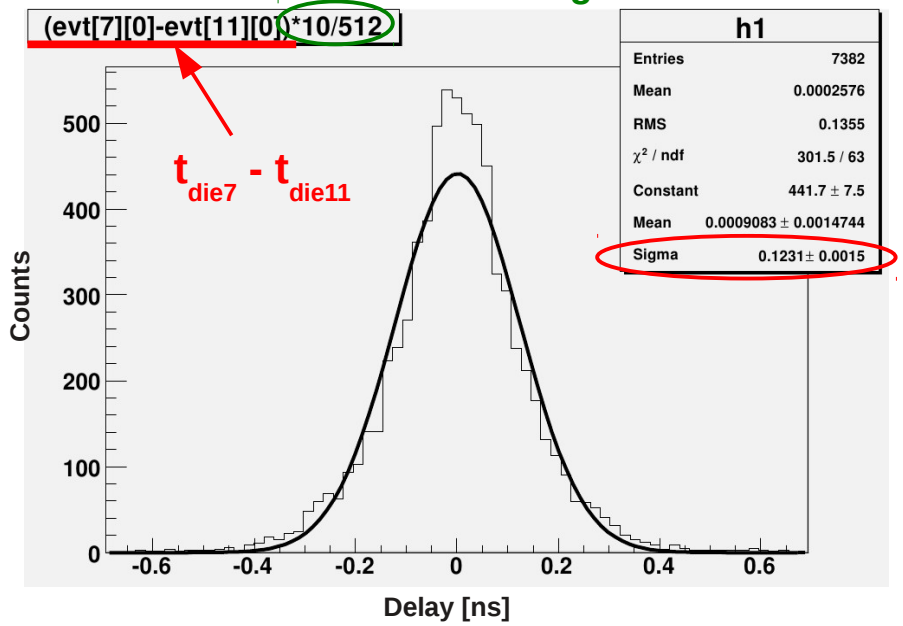
Time resolution

Skew corrected

- **Look at coincidence timing**
- **4 dies in coincidence to select “good” events**
- **5000k frames**



TDC binning



- **Now centered at 0 ns**
- **Timing: σ ~ 120 ps**
- **Assuming two identical dies:**

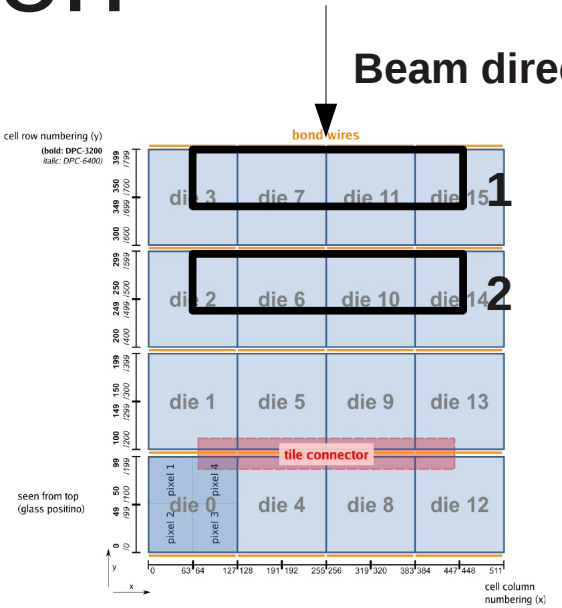
$$\sigma_{die7} \sim \sigma_{die11} \sim 85\ ps$$

- **In agreement with previous measurement from slide 13**

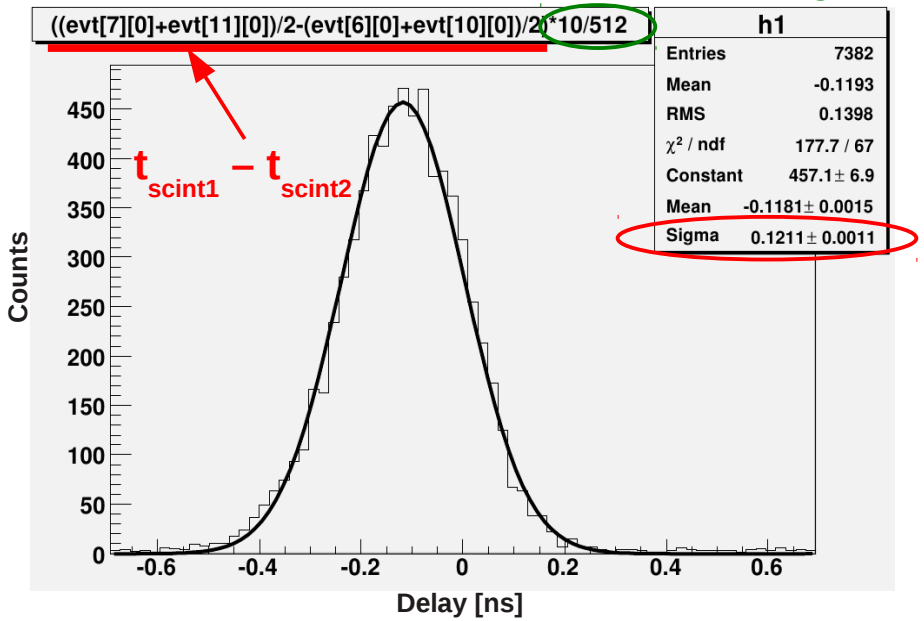
Time resolution

Skew corrected

- **Use scintillator 1 as start to evaluate TOF resolution**
- **4 dies in coincidence to select “good” events**
- **Since we have 2 dies per scintillator, we can use mean timing of these two**
- **5000k frames**



TDC binning



- **TOF resolution: σ ~ 120 ps**
- **Assuming two identical layers:**

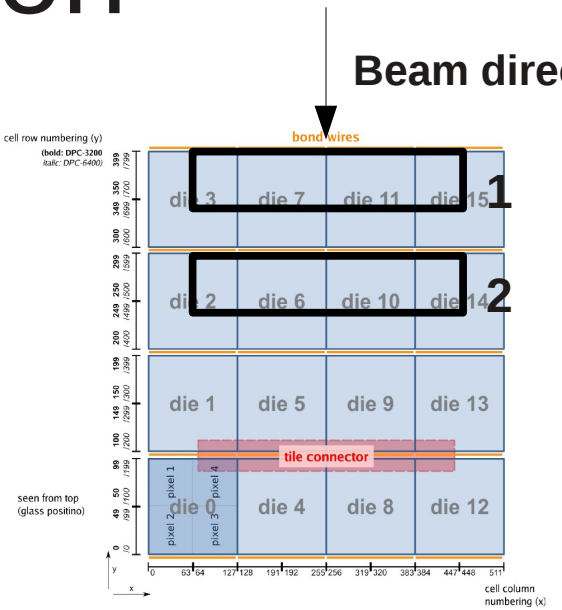
$$\sigma_{scint1} \sim \sigma_{scint2} \sim 85\ ps$$

- **The two layers are of course not completely identical due to e.g. different number of photons seen (see slide 12)**

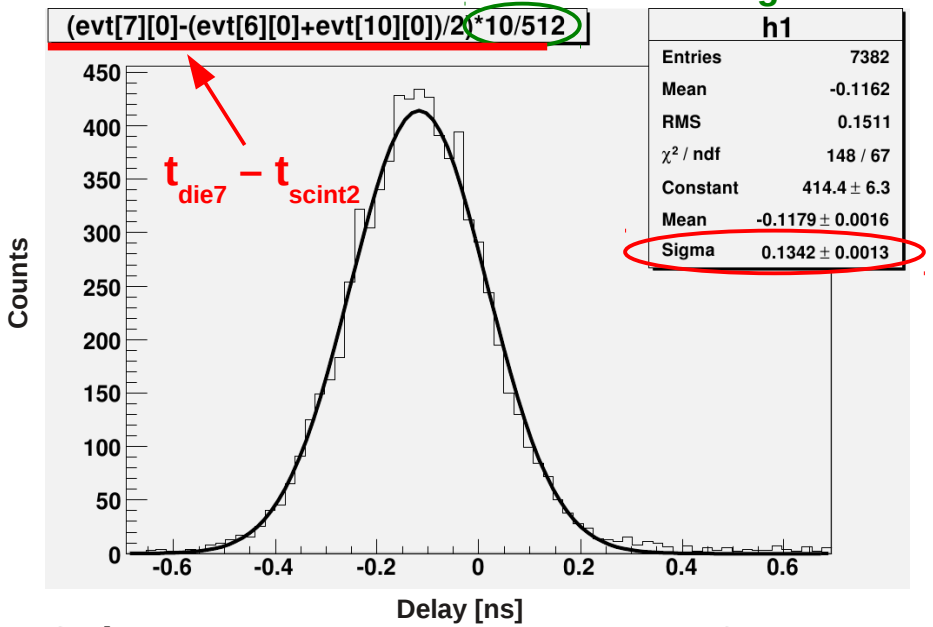
Time resolution

Skew corrected

- **Use scintillator 1 as start to evaluate TOF resolution**
- **4 dies in coincidence to select “good” events**
- **Use only die7 of Scint1 and mean timing of die6 and die10 of Scint2**
- **σ_{die7} can be determined (see slide 15) → σ_{scint2}**
- **5000k frames**



TDC binning



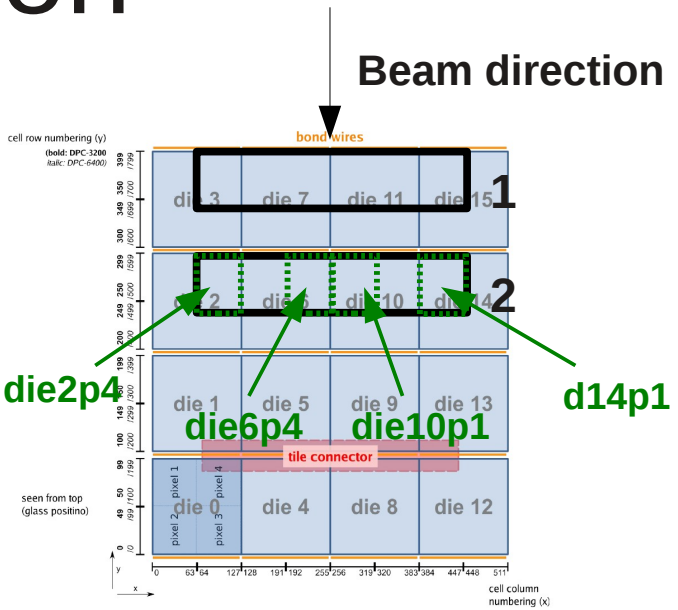
- **TOF resolution: σ ~ 135 ps**
- **Time resolution of 2nd layer (Scint2) using mean timing of two dies (6, 10):**

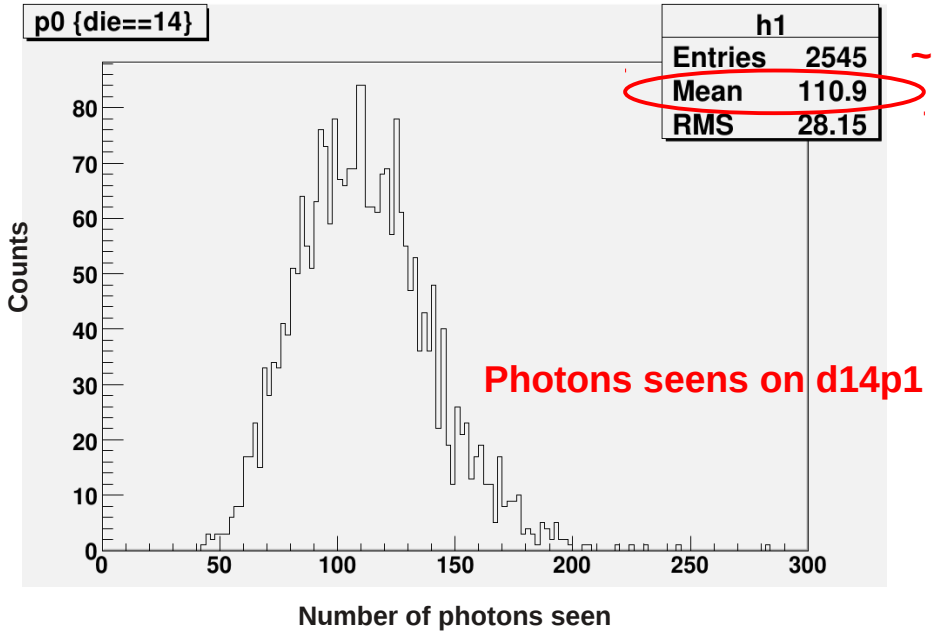
  σ_{scint2} ~ 105 ps

Time resolution

Skew corrected

- **Use scintillator 1 (die7) as start to evaluate TOF resolution**
- **Try to evaluate time resolution of a single pixel → active area is comparable to a single 3 x 3 mm² SiPM**
- **Switch on only single pixels of Scint2 (die2p4, die6p4, die10p1, die14p1)**
- **σ_{die7} can be determined (see slide 15) → σ for other pixels**
- **5000k frames**





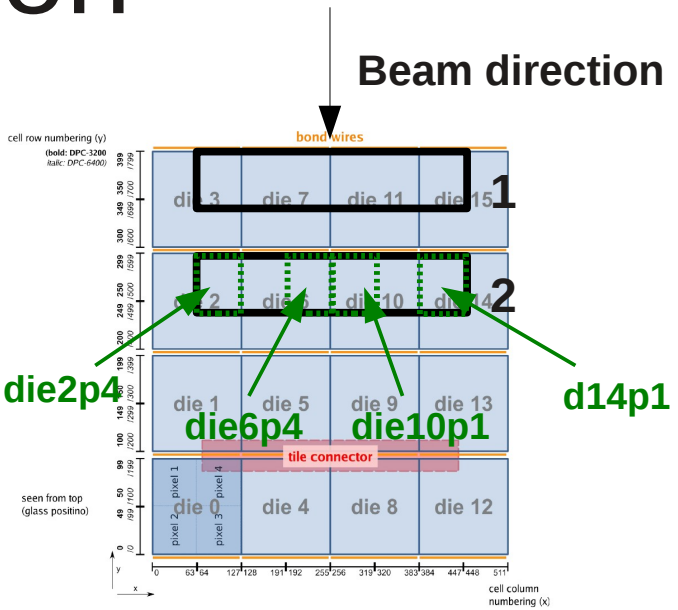
~ 100 photons per pixel

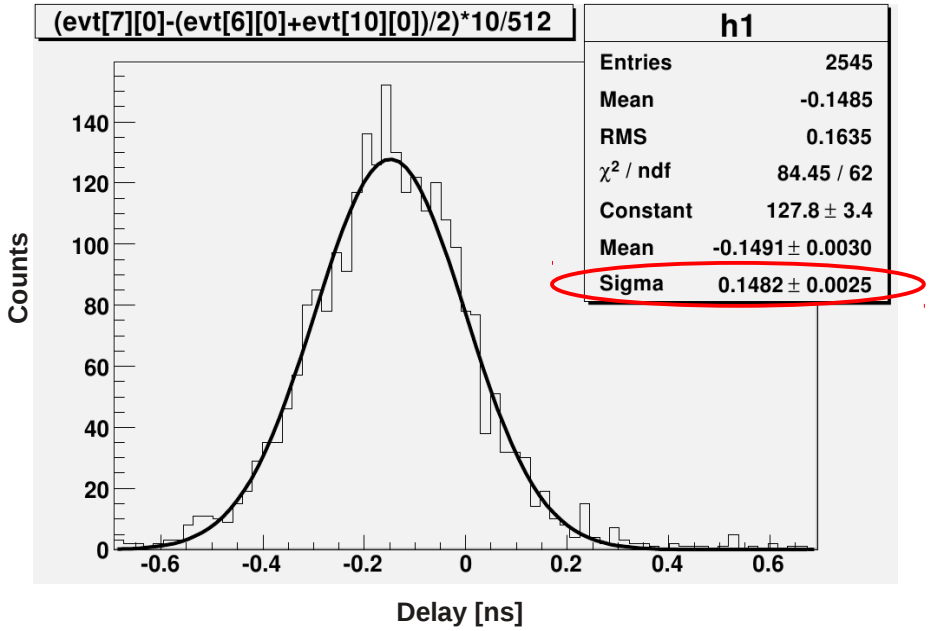
Pixel	Time resolution (σ)
die14p1	165 ps
die10p1	155 ps
die6p4	150 ps
die2p4	170 ps

Time resolution

Skew corrected

- **Use scintillator 1 (die7) as start to evaluate TOF resolution**
- **Take mean timing of two pixels (e.g. die6p4 and die10p1) → active area is comparable to two 3 x 3 mm² SiPMs**
- **5000k frames**



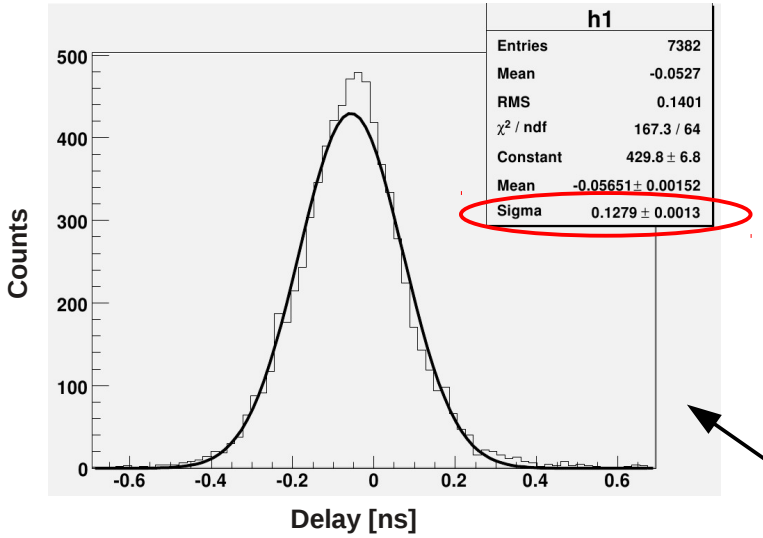


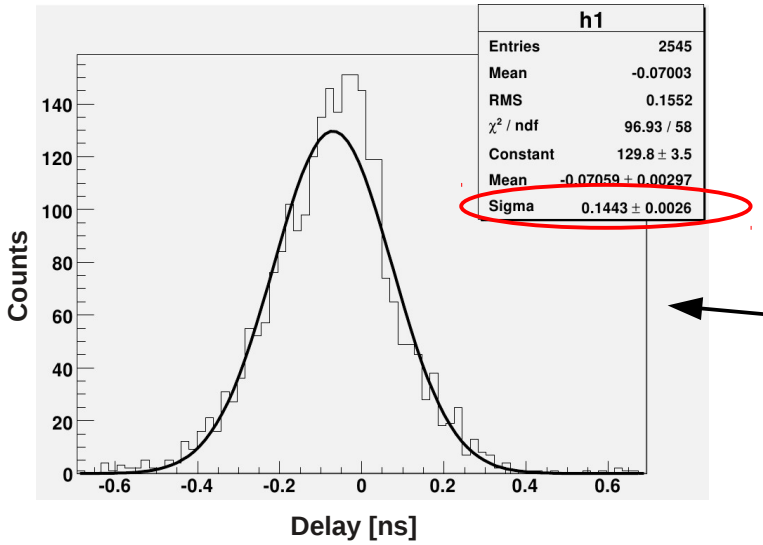
- **TOF resolution: σ ~ 150 ps**
- **Time resolution of 2nd layer (Scint2) using mean timing of two pixels:**

$$\sigma_{scint2} \sim 120 \text{ ps}$$

Time resolution

Skew corrected





- **Use scintillator 1 (die7) as start to evaluate TOF resolution**
- **Take not the mean timing of two dies/pixels but the first time stamp of the two**
- **5000k frames**

- **Using two dies (die6 and die10):**
  - **TOF resolution: σ ~ 125 ps**
  - **Time resolution of 2nd layer (Scint2):**

    σ_{scint2} **~ 95 ps**

- **Using two pixels (die6p4 and die10p1):**
  - **TOF resolution: σ ~ 145 ps**
  - **Time resolution of 2nd layer (Scint2):**

    σ_{scint2} **~ 115 ps**

First results with EJ-228 scintillator

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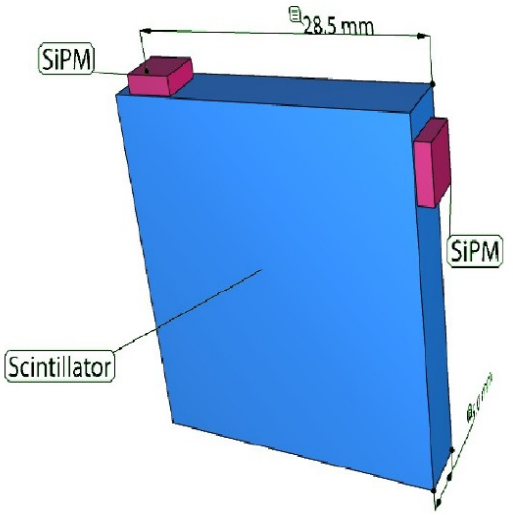
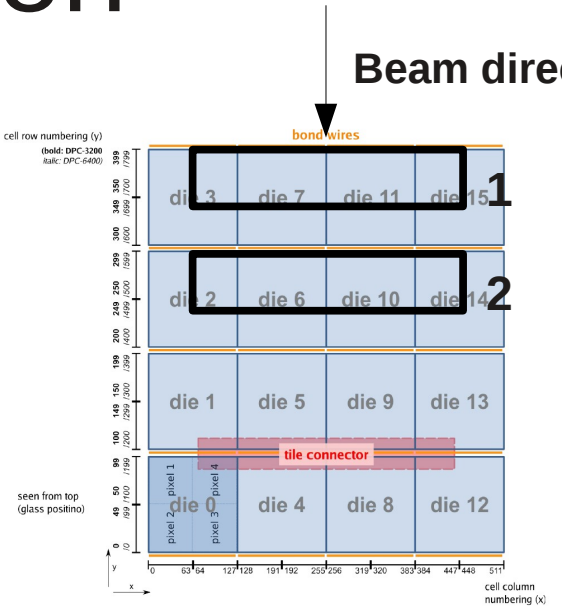
Photon number

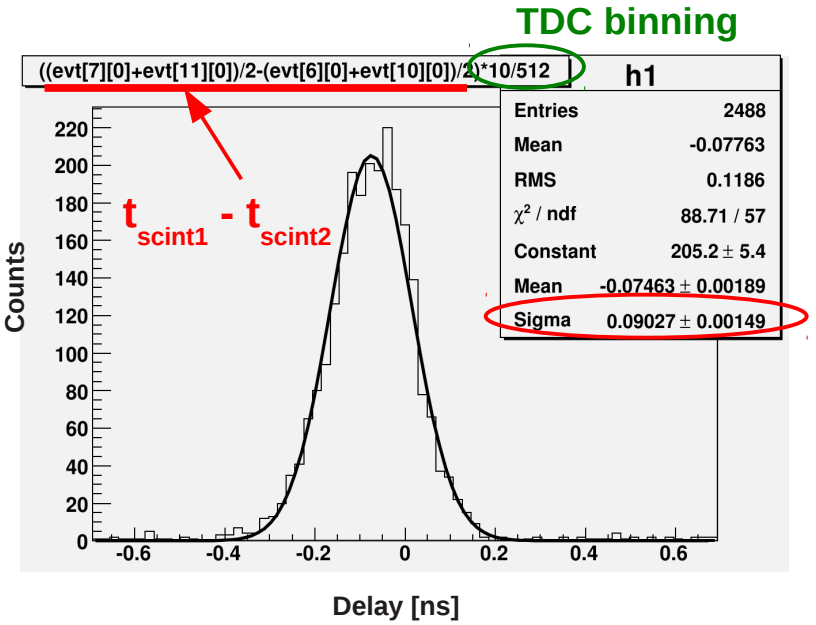
- **Minimum Ionizing Particle (MIP): ΔE = 1MeV = 10^4 photons generated**
- **Assuming that 70% hit the rim: 7000 photons**
- **Detection area of dSiPM: 1 die = 2 pixels = 25 mm²**
- **Assuming 50% PDE for DPC-3200**
- **DPC-3200:**
  - **30 x 30 x 5 mm³ → ~ 150 photons per die**
  - **25 x 25 x 5 mm³ → ~ 180 photons per die**
  - **20 x 20 x 5 mm³ → ~ 220 photons per die**



Time resolution

- **Look at coincidence timing**
- **Same setup as before (4 dies in coincidence)**
- **Take 6000k frames**
- **Use mean timing of 2 dies per scintillator**





- **Timing: σ ~ 90 ps**
- **Assuming two identical layers (ok since we have ~ the same # of photons):**

$$\sigma_{scint1} \sim \sigma_{scint2} \sim 60 \text{ ps}$$

Comparison with BC-408

- **Used same setup for both scintillators**
- **Only size of the two scintillators is different**
- **EJ-228: less photons because larger (30 x 30 x 5 mm^3)**
  - **~ 150 photons per die → ~ 75 per pixel (~ size of 3 x 3 mm^2 SiPM)**

- **BC-408: factor ~ 1.4 more photons (25 x 25 x 5 mm^3)**
- **BUT:**
  - **EJ-228: time resolution of one scintillator read out with 2 dies: σ ~ 60 ps**
  - **BC-408: time resolution of one scintillator read out with 2 dies: σ ~ 85 ps**

- **EJ-228: Better timing although larger and less photons, EJ-228 is faster**
- **Rise Time EJ-228: τ_R = 500 ps**
- **Rise Time BC-408: τ_R = 900 ps**