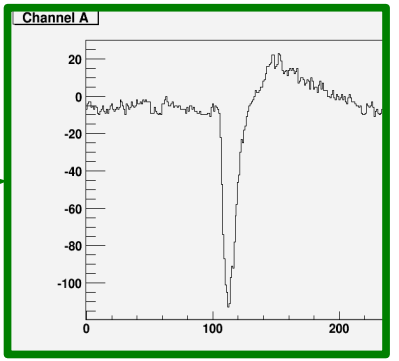
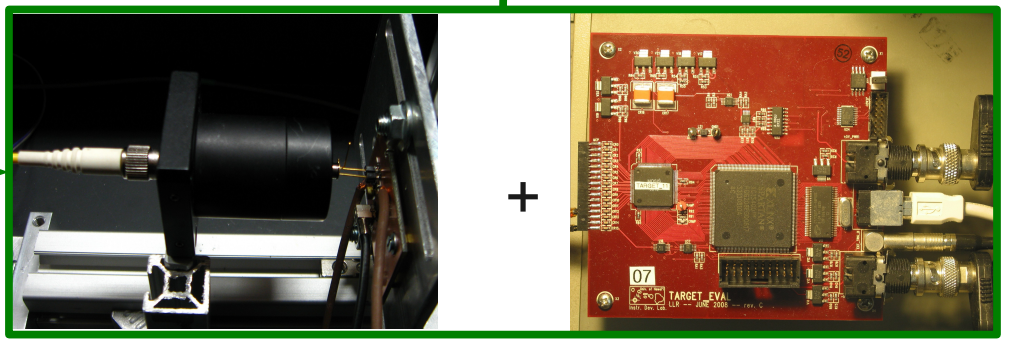
TARGET Waveform sampler for SiPM

- Using **TARGET** for single photon detection and precise timing:
  - Test fast preamplifier (µPC2710TB) with different inductors (0.047 µH, 1 µH & 22µH)
  - Compare different Hamamatsu SiPM's:
    - 3x3 mm; *100 µm* pitch; model S10931-100P(X); Serial **# 19**; V_{op} = 69.82 V
    - 1x1 mm; *25 µm* pitch; model S10362-11-025C; Serial **# 34**; V_{op} = 71.67 V
    - 1x1 mm; *100 µm* pitch; model S10362-11-100U; Serial **# 147**; V_{op} = 70.52 V
  - Compare different operating Voltages
  - Compare different light intensities (Filters → 6.25%; 12.5%; 50%)

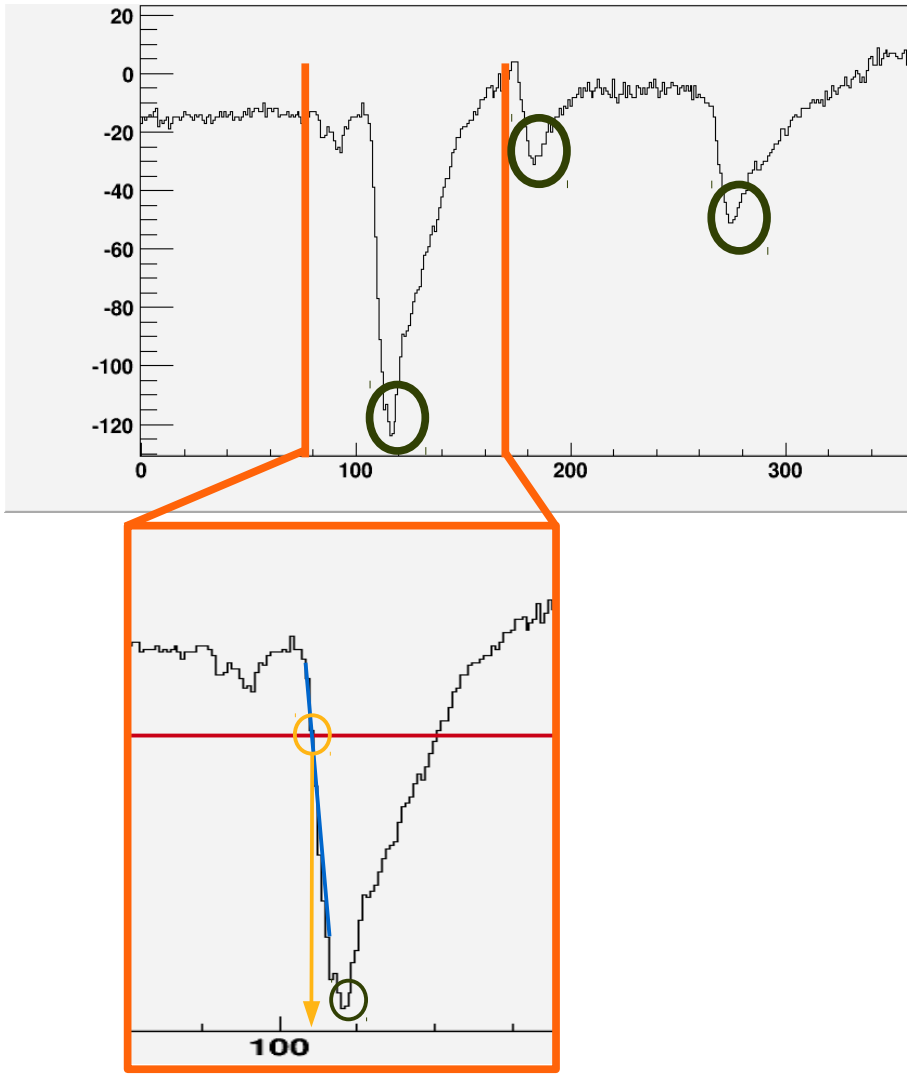
Setup:

- Laser, filters, diffuser → small # of photons hit SiPM
- *Attenuator + Ortec fast amplifier for the 3x3 mm SiPM*





Basic Waveform Analysis



1) Baseline compensation

2) Look for peaks, I use ROOT TSpectrum

3) Only select peaks in a certain time window

4) @ this moment I only allow 1 peak for further analysis

5) Use a simplified CFD for time determination:

   a) Get peak height

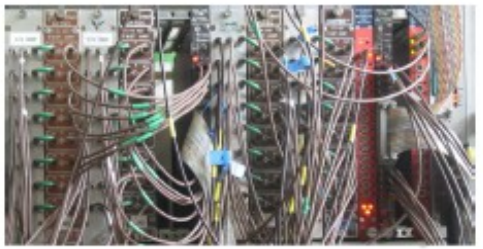
   b) 30% of peak height = threshold

   c) Lin fit around crossing of threshold determines the time of detection

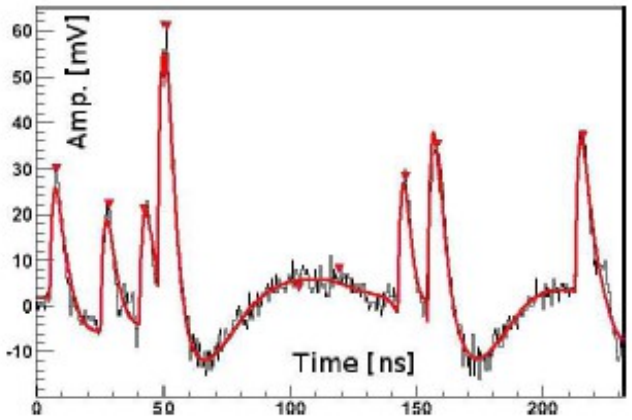
6) Histogram peak heights and time

TARGET Waveform Analysis of SiPM signals

- Digital sampling of electronic signal:
  - Switched Capacitor Array (SCA) stores total signal
  - Charge on each capacitor is measured → sampled waveform
  - Rebuild waveform for testing (slow readout)
  - Analyse waveform on FPGA (fast readout)
- Very POWERFULL tool because:
  - Incorporate waveform analysis algorithms on FPGA for deconvolution of piled-up signals (~~classic electronics~~)
  - QDC and TDC all in 1 device!
  - High density of channels, cheap (VLSI), fast (up to 20 GSa/s), FPGA → flexible, low power



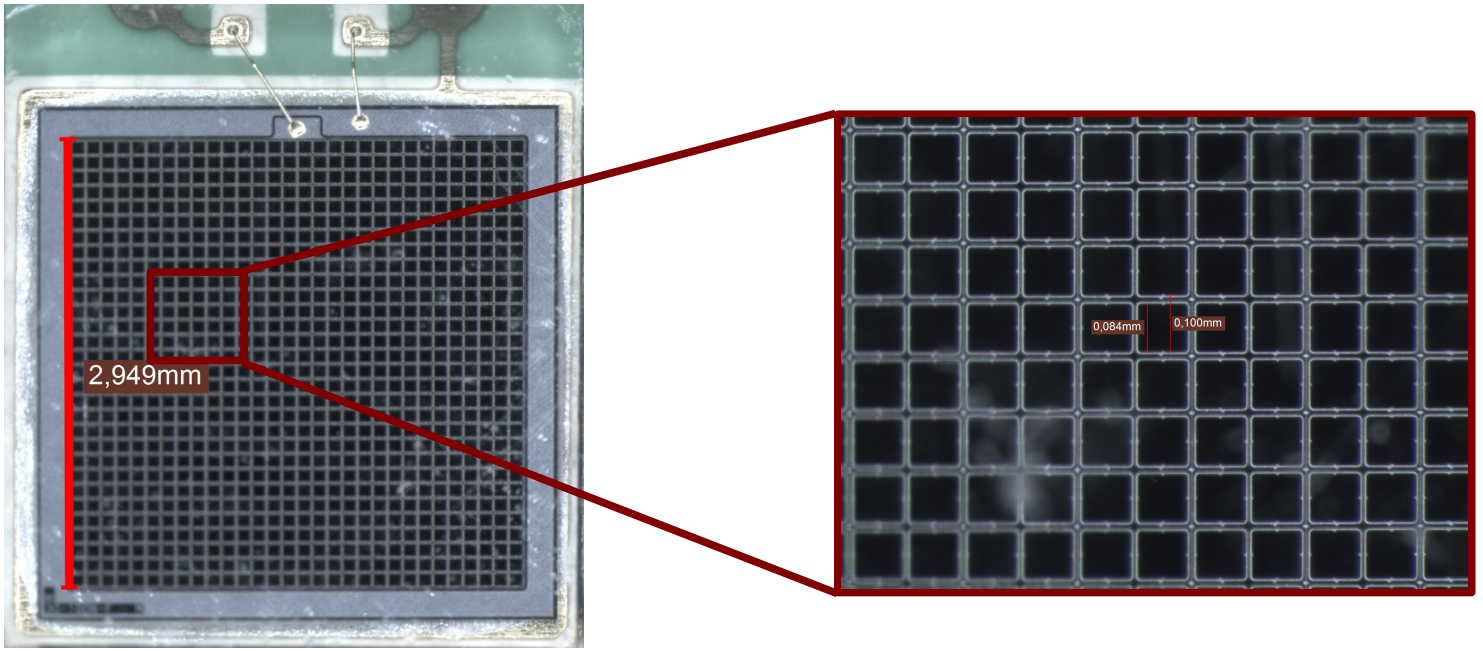
V.S.



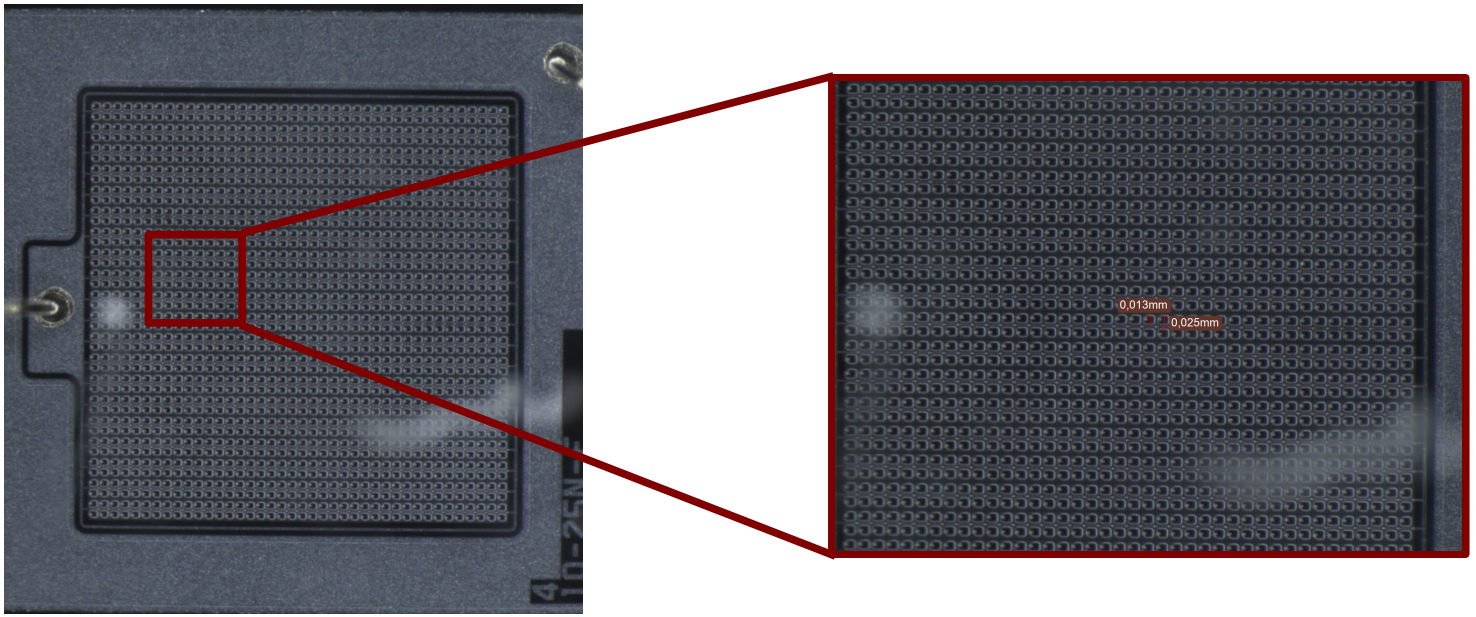
Fitfunction is based on a preamplifier & differentiator combination

$$V = \frac{Q_{in}}{C_f} \cdot \frac{1}{\tau_f - \tau_d} \cdot \left[\exp\left(-\frac{t}{\tau_d}\right) - \frac{\tau_d}{\tau_f} \exp\left(-\frac{t}{\tau_f}\right) \right]$$

SiPM Optical pictures

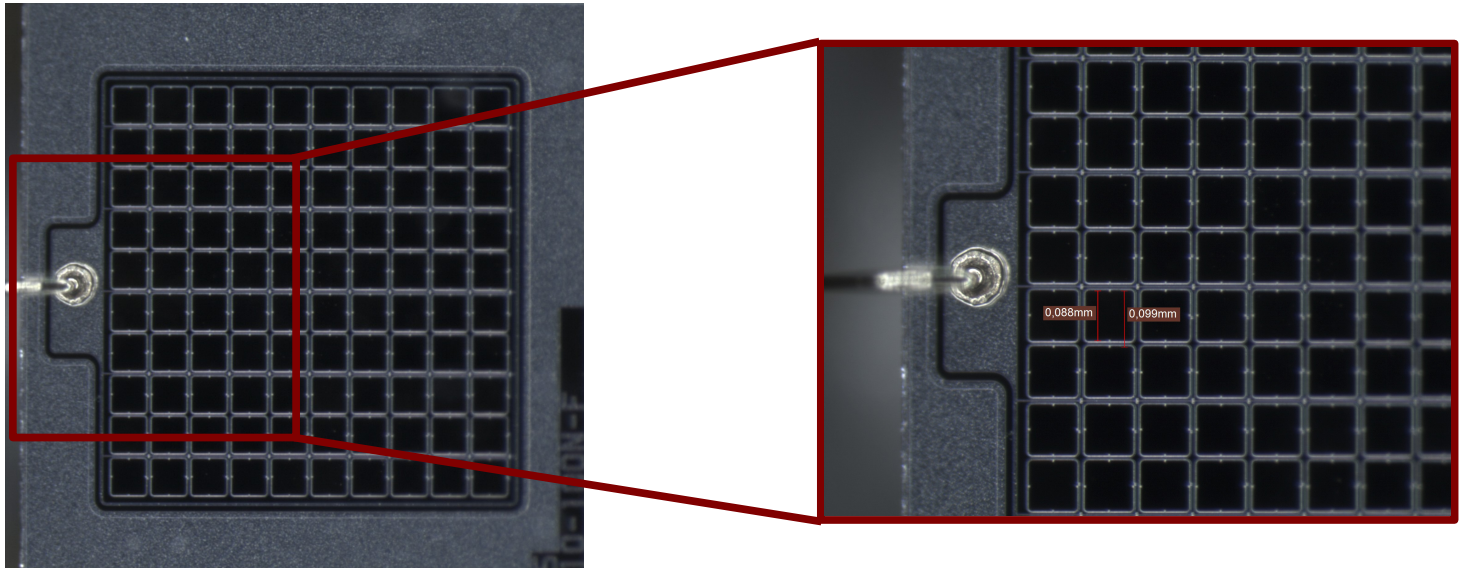


Hamamatsu 3x3 mm^2:
- 100 micron pitch
- ~ 84 micron cell size



Hamamatsu 1x1 mm^2:
- 25 micron pitch
- ~ 13 micron cell size

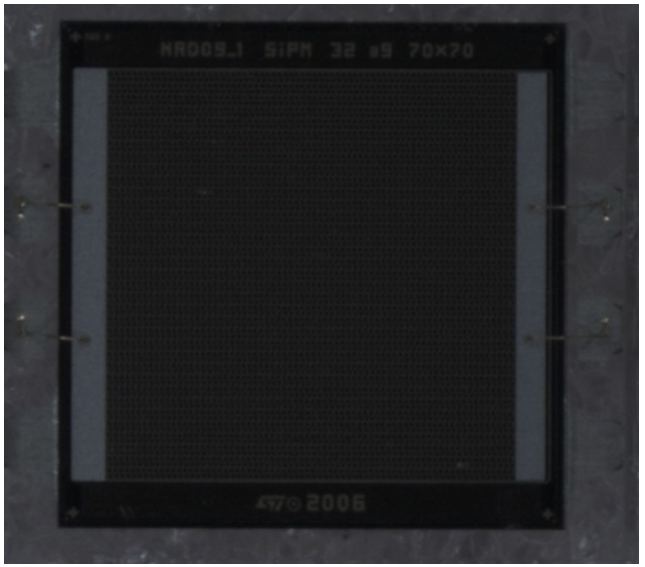
Optical pictures

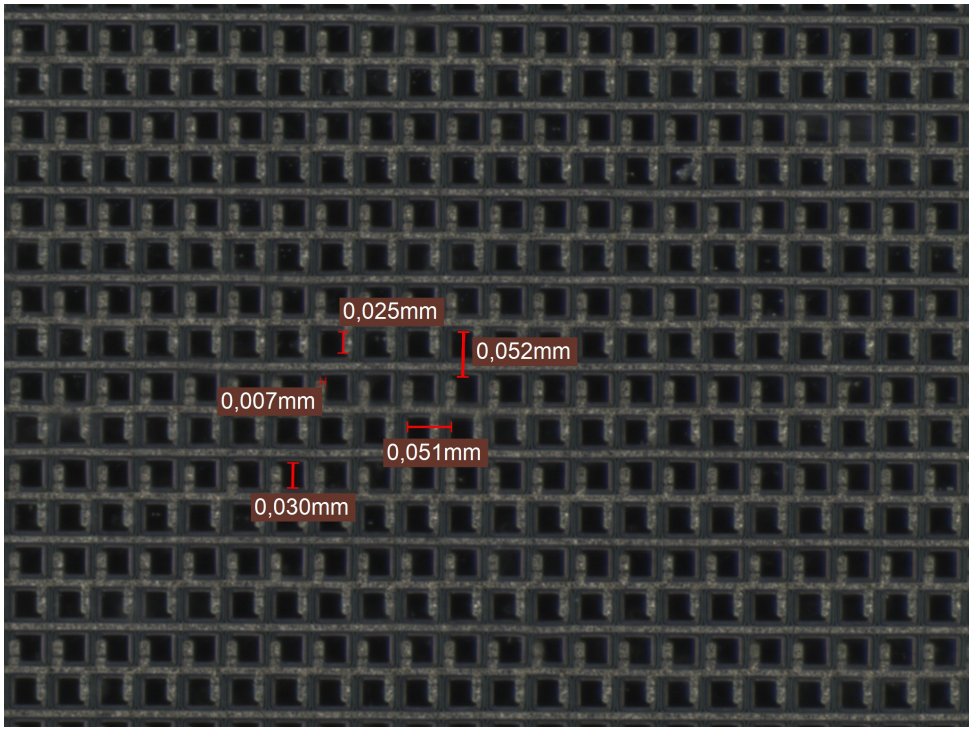


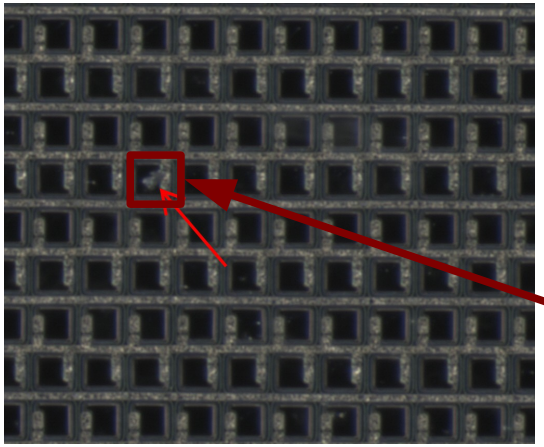
Hamamatsu 1x1 mm^2:

- 100 micron pitch
- ~ 88 micron cell size

STM SiPM PROTOTYPES: Mod A



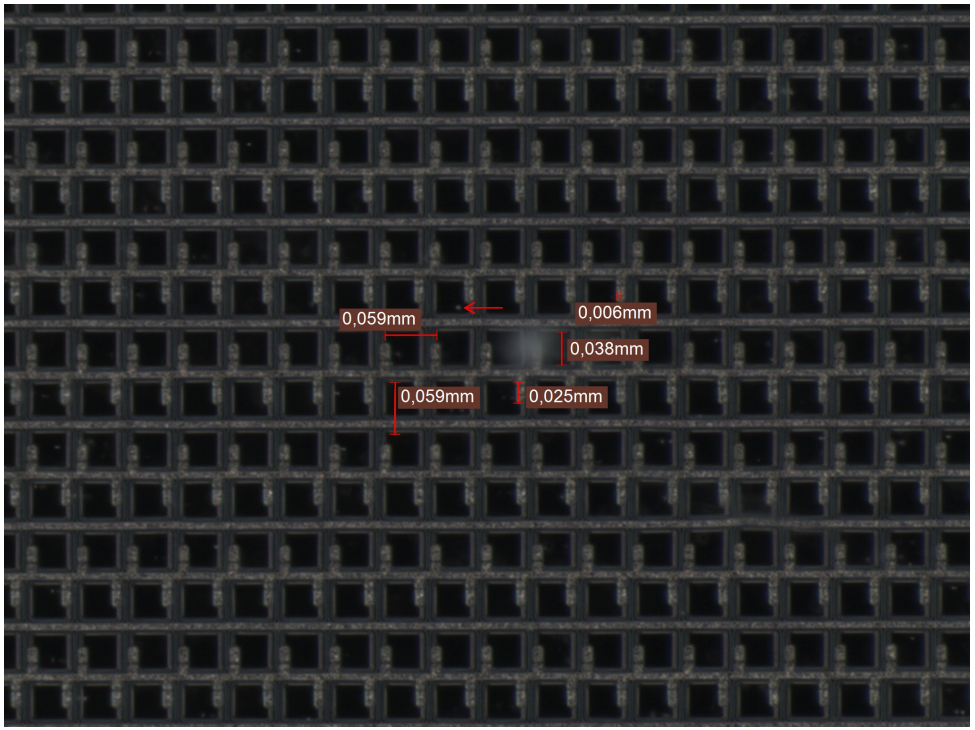


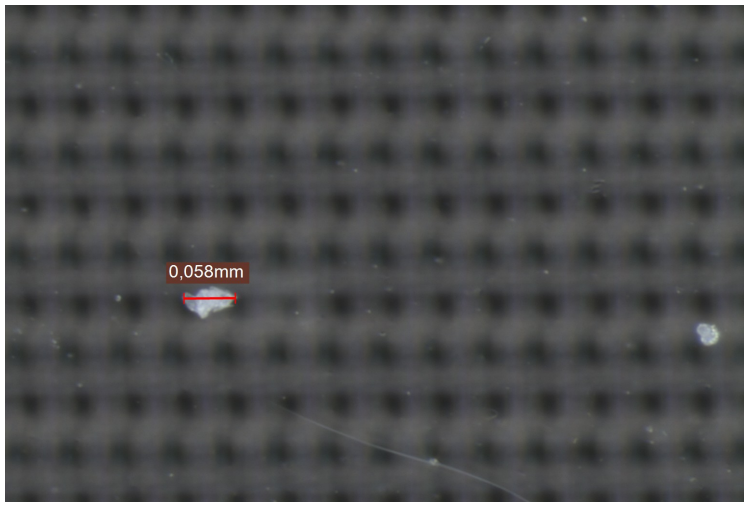


- Die Size: 4.37mmx4.37mm
- Array Size: 3.5mmx3.5mm
- # of cells: 70x70
- Pitch 50 micron
- Fill factor: 36% (~30% from pic)

- Some dirt on top, handling after production, cleaning → removal

New STM SiPM PROTOTYPES: Mod C

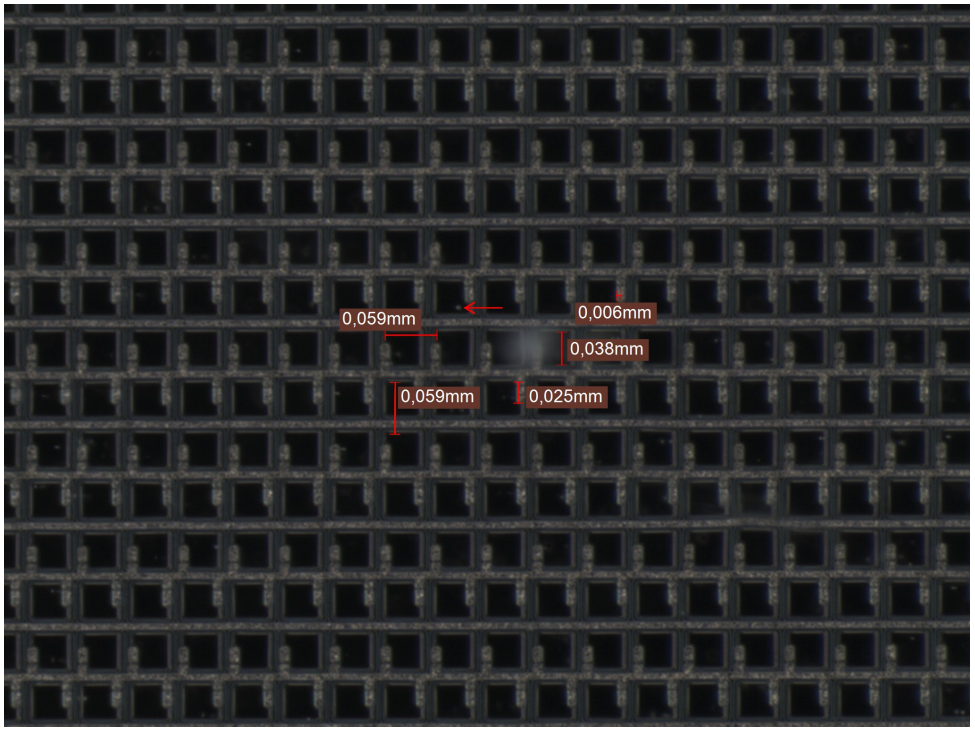


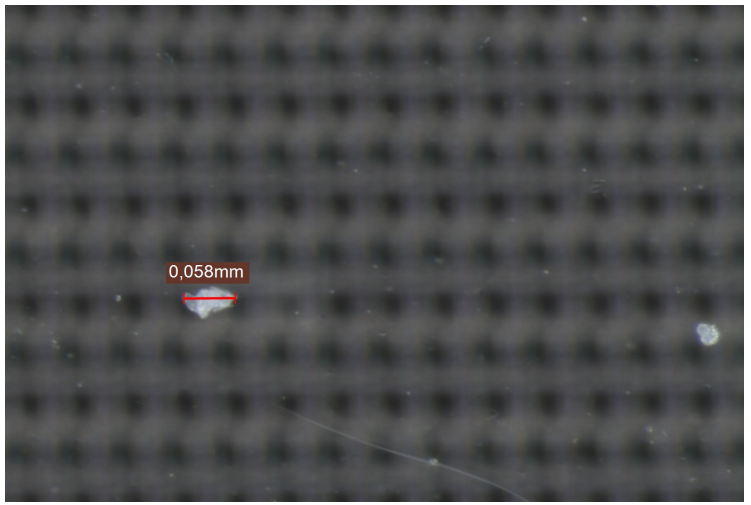


- Die Size: 4.37mmx4.37mm
- Array Size: 3.5mmx3.5mm
- # of cells: 60x60
- Pitch 58 micron
- Fill factor: 45% (~37% from pic)

- Some dirt on top, handling after production, cleaning → removal

New STM SiPM PROTOTYPES: Mod C





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SiPM Characteristics measured

Single SiPM:

- Gain vs (V_{op} ; T)
- Linearity (laser & rad. sources)
- Timing resolution (V_{op} ; T ; threshold)

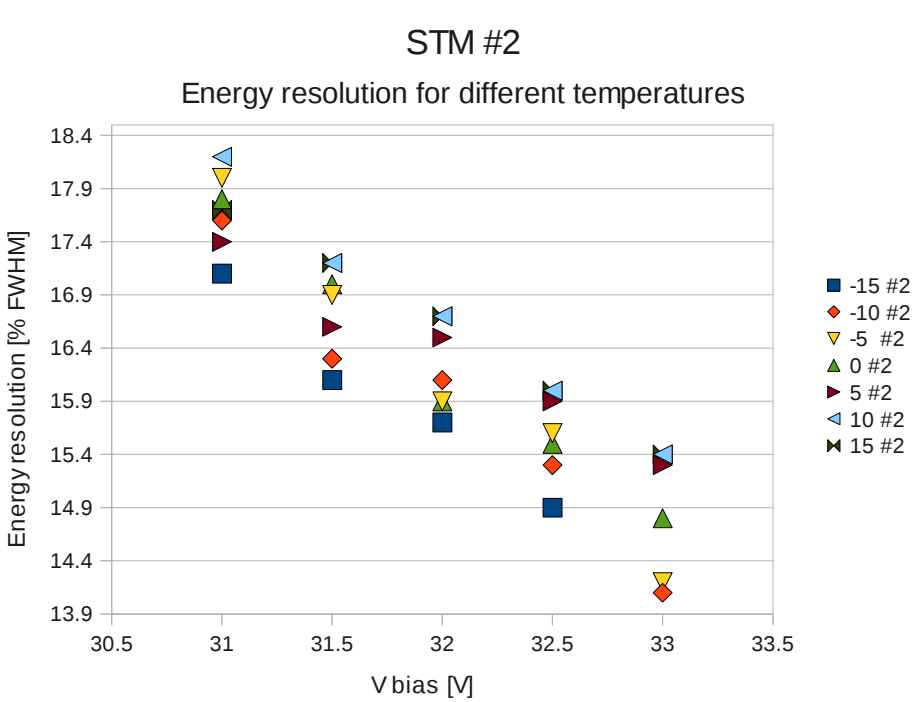
2 SiPM PET:

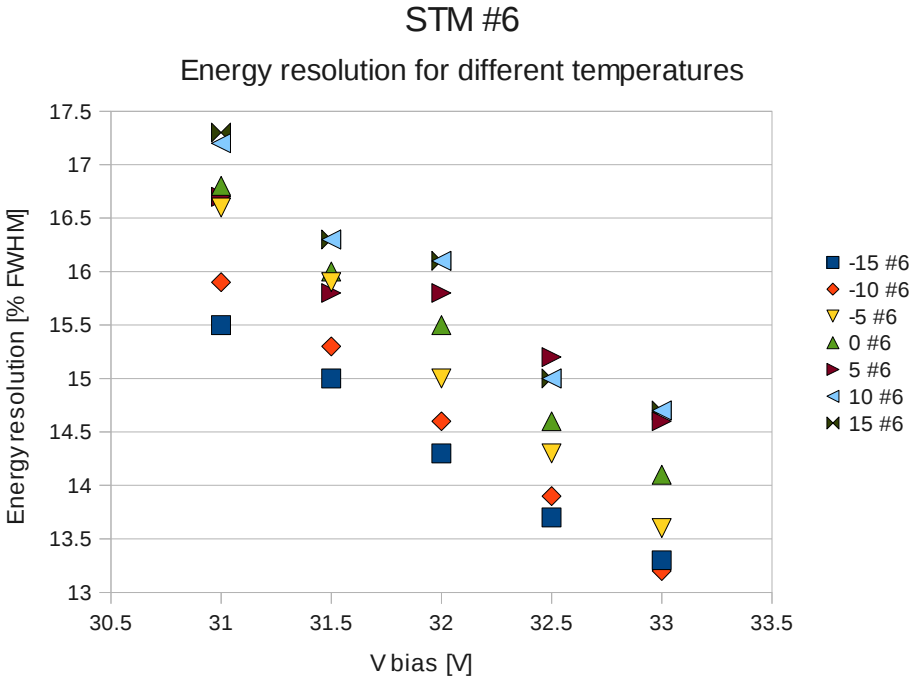
- Energy resolution vs (V_{op} ; T)
- Back to back Timing resolution vs (V_{op} ; T ; threshold)

SiPM: Single and PET Setups

- Gain & Intrinsic Timing:
  - Laser set to single Photon level (neutral density filters)
  - Single SiPM from STM (# 3)
- PET Setup:
  - 2 SiPMs with Saint-Gobain LYSO
  - OR trigger
- Freezer:
  - Temperature control
  - Range: -15°C → 20°C

Energy resolution: #2 & #6



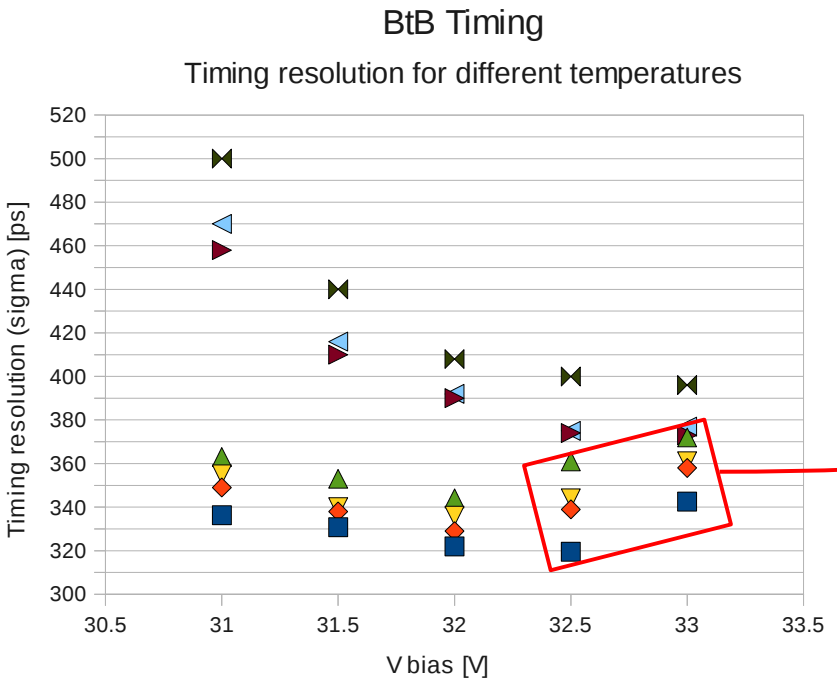


· Only minor improvement by lowering the temperature (related to improvement of gain by lowering temperature?)

· Energy resolution improves with increase of V

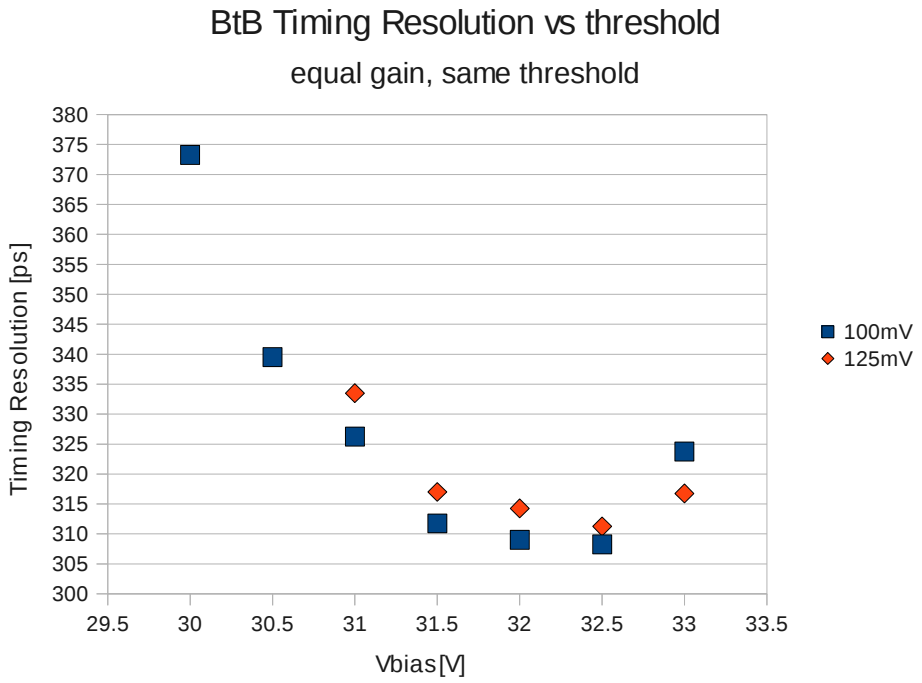
· STM #6 has a higher gain than #2

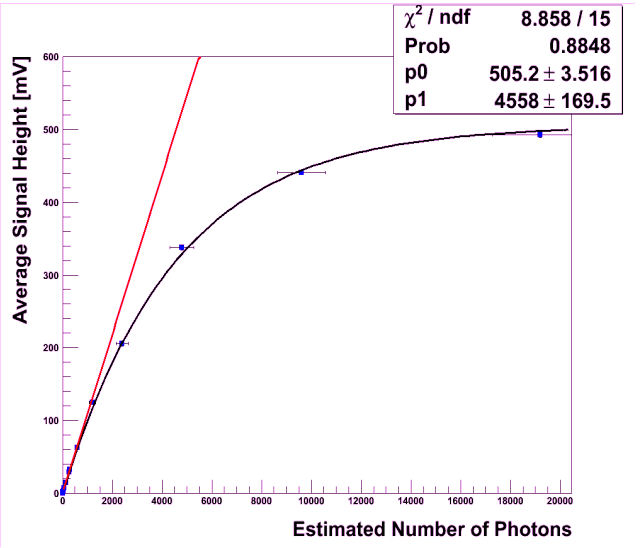
BtB timing resolution: #2 & #6



· Threshold ~ 150mV
· At higher V_{bias} noise triggers too much and degrades time res.

• Threshold ~ 300mV





Linearity

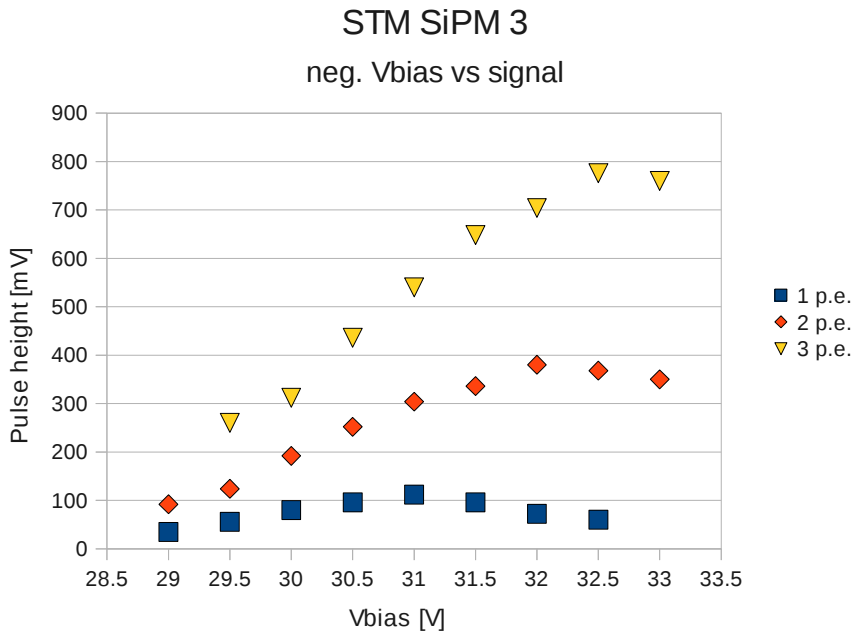
- Setup:
  - Laser pulses (635nm)
  - # of photons controlled with neutral density filters (going from 1 photon to ~ 20000 photons / pulse)
  - Uniform light distribution over surface

Fitfunction → y = p0*(1-exp(x/p1))

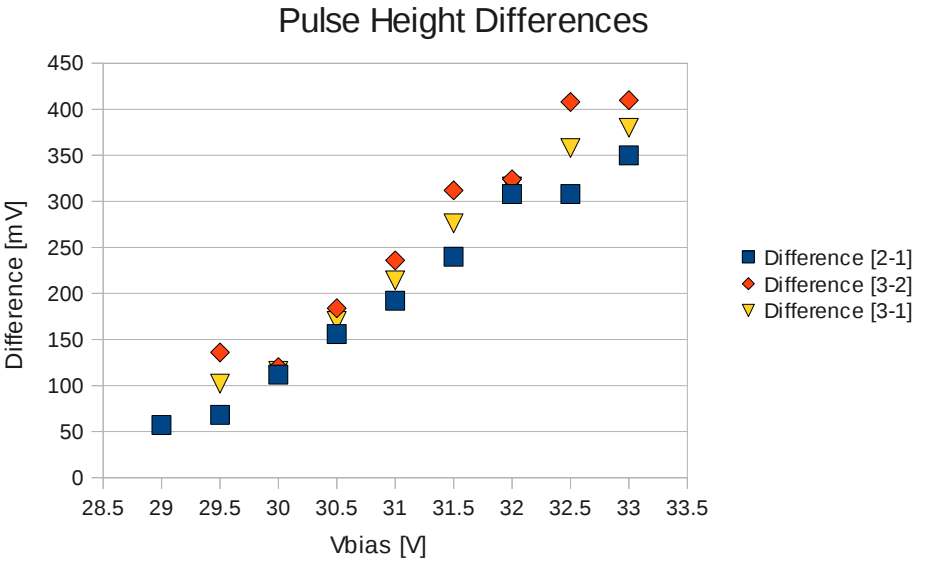
Line → y = 0.109*x - 0.118

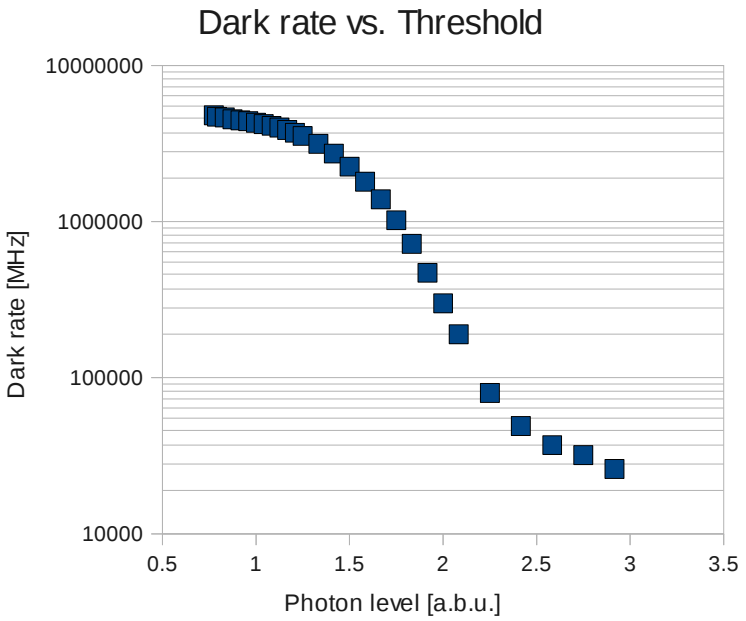
Low light intensity

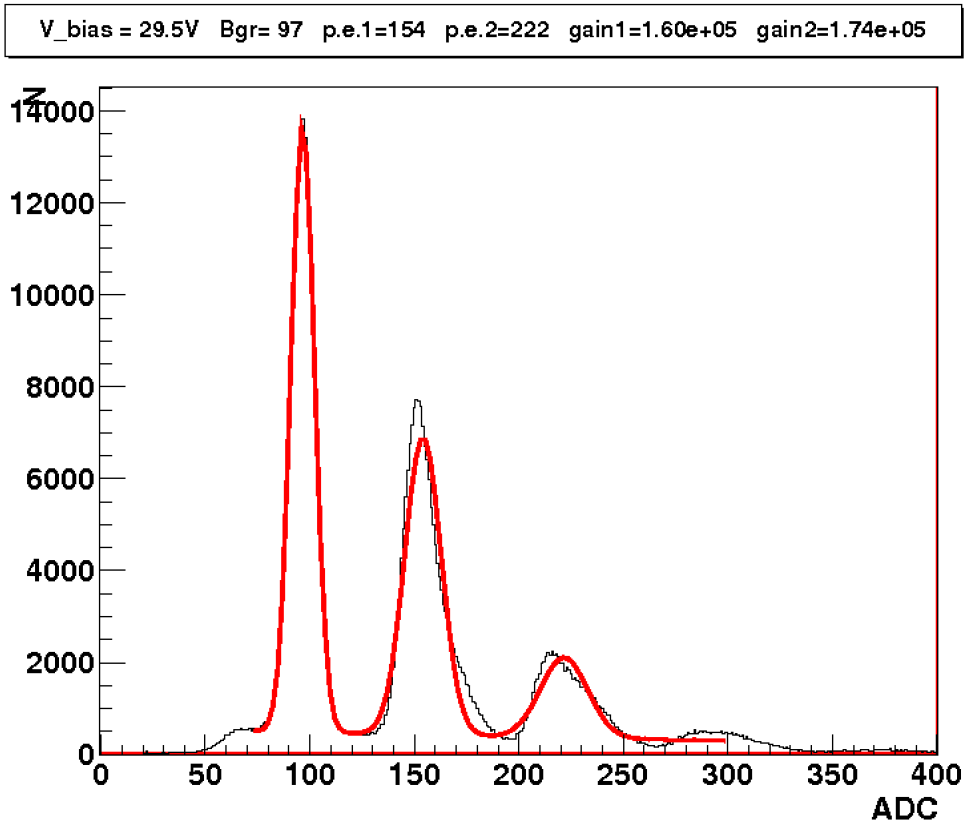
Signal saturates with increasing V_bias



Differences in signal between single, double and triple photo-electrons behaves linear



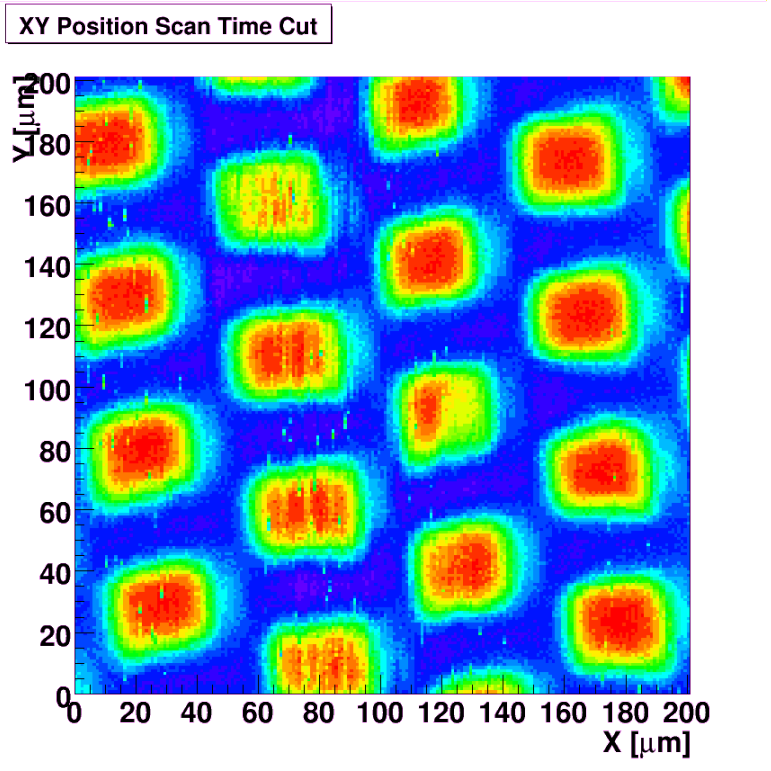


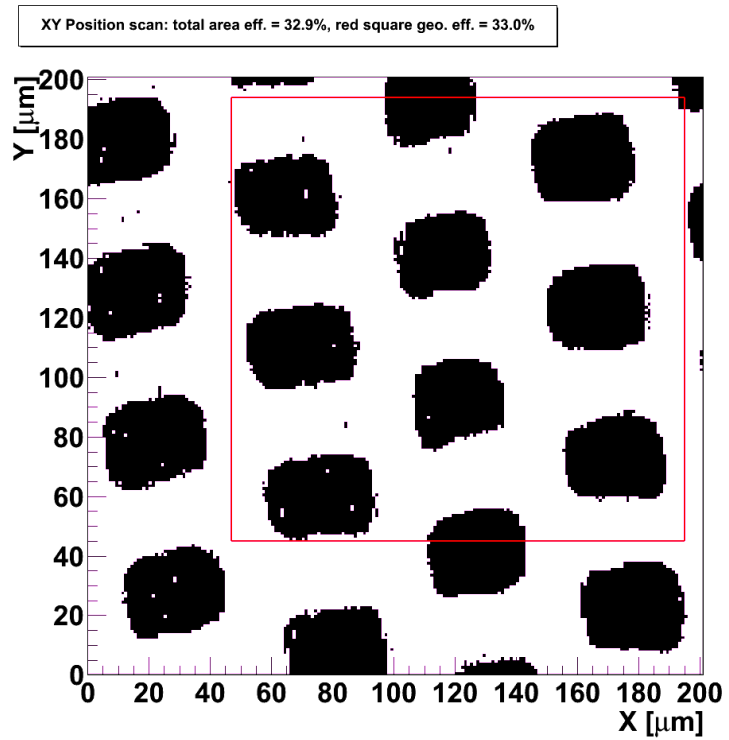


· Gain is ~ 1.67e5
  Gain = average of gain calculated from 1 p.e. and 2 p.e.

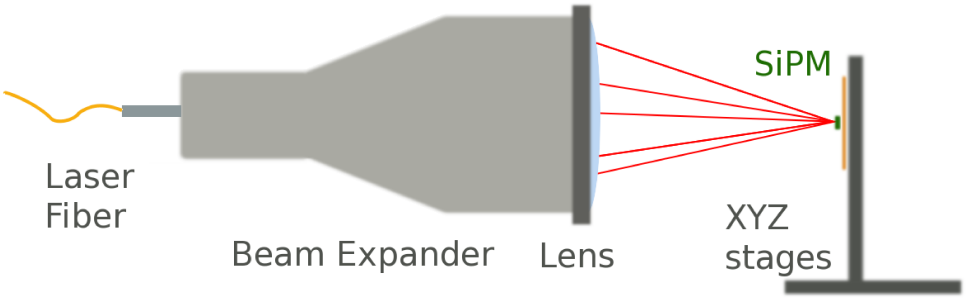
· ADC has 25fC/count

· Amplification factor is 450





Position Scans



Setup:

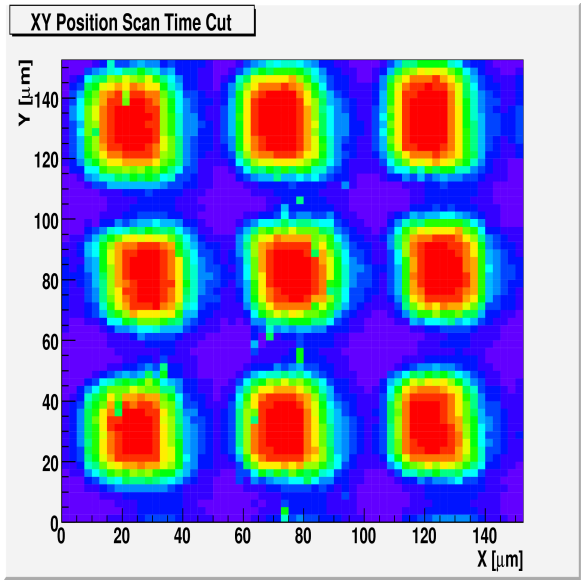
· Pulsed laser (635 nm)
· Single Photon light intensity
· Sigma laser focal point ~ 4-5 μm
· 1 μm stepsize (XYZ stages)

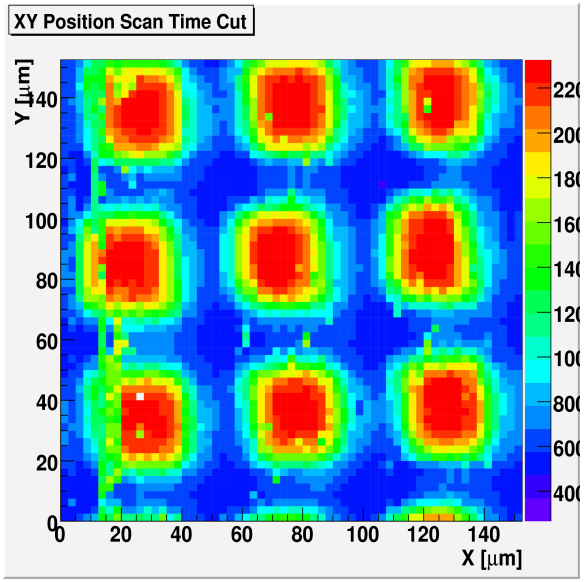
Geometrical factor:

· Color picture → Black & White:
  · Value above 50% of max value → count pixel as within active area (Black area)
  · Value below 50% max value → pixel is outside active area (White Area)

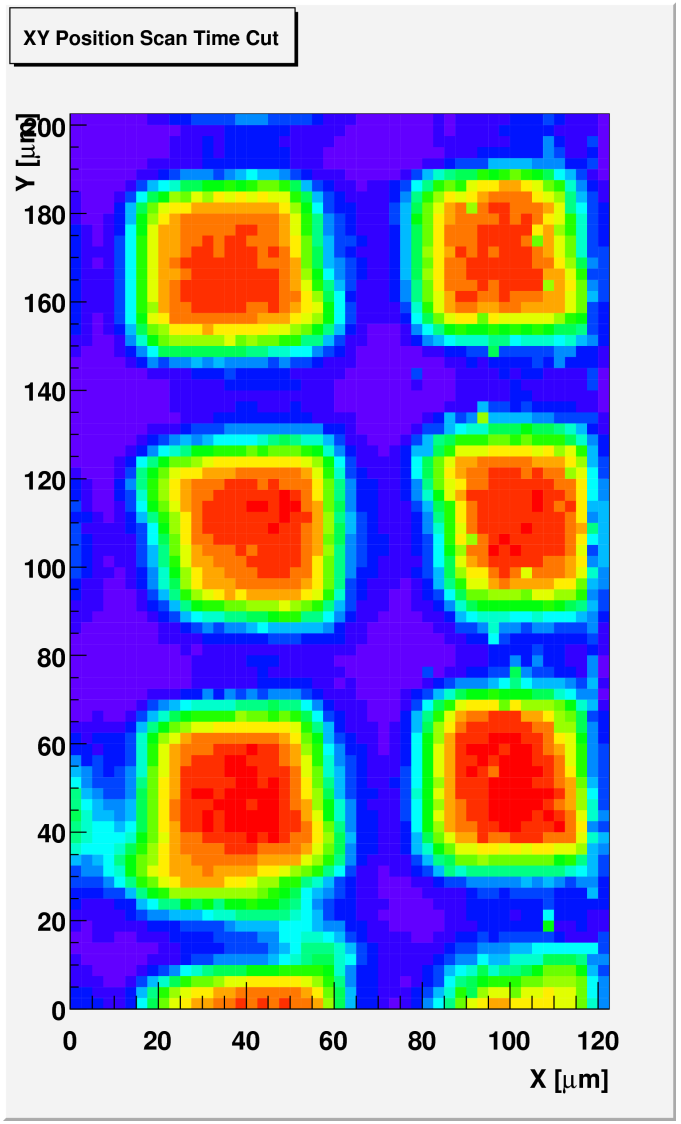
· Geometrical factor result from total scan area is ~32.9 %
· Geometrical factor result from red square area is ~33.0 %

new STMicroelectronics SiPM Model A





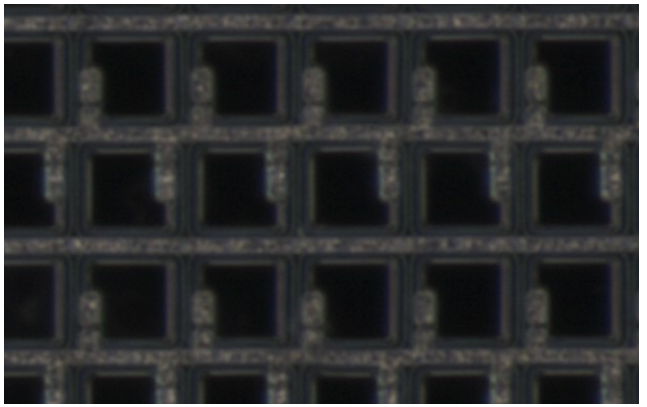
new STMicroelectronics SiPM Model C

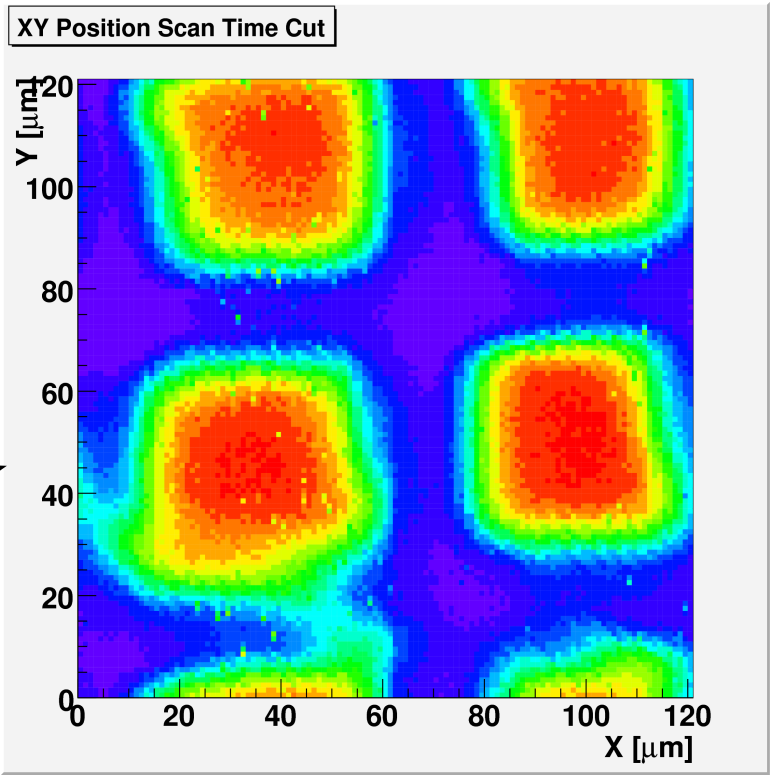


new STMicroelectronics SiPM

2D scans:

- Mod C 1micron step →
- Mod A 2x2.5 Micron step at different locations →behaviour is fairly uniform





Gain STMicroelectronics SiPM for T = 15C → -20C