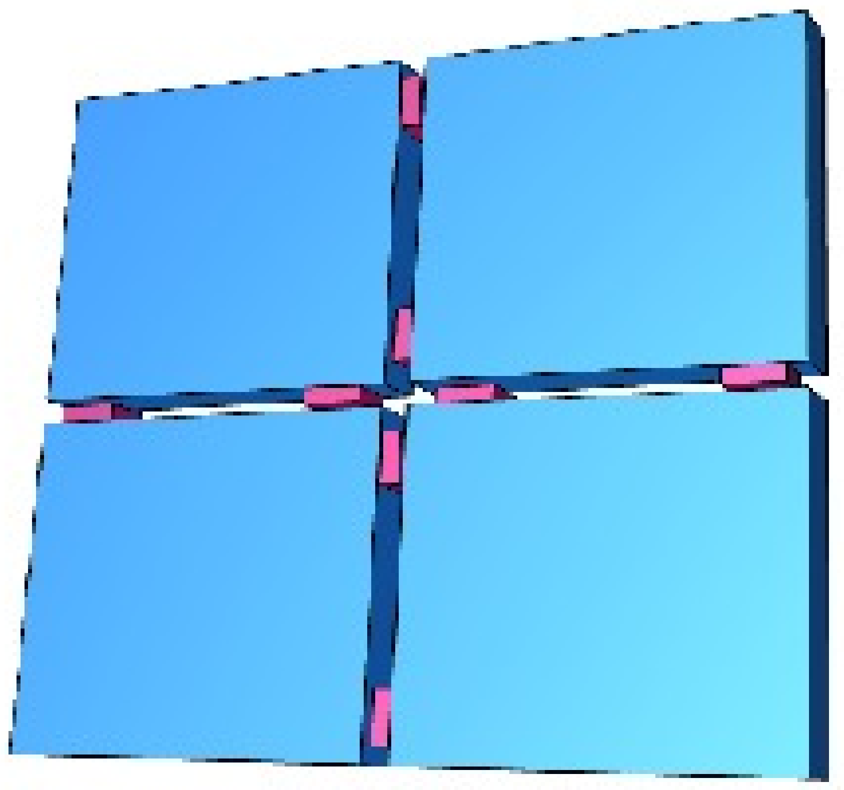
Characterization of a timing detector prototype for the $\bar{P}$ANDA experiment

Current Status of the thesis

September 12, 2013

Content

Motivation for this work is to study the feasibility of a timing detector with a time resolution better than 100ps.
It is to be used for event timing, conversion detection and charged particle ID.



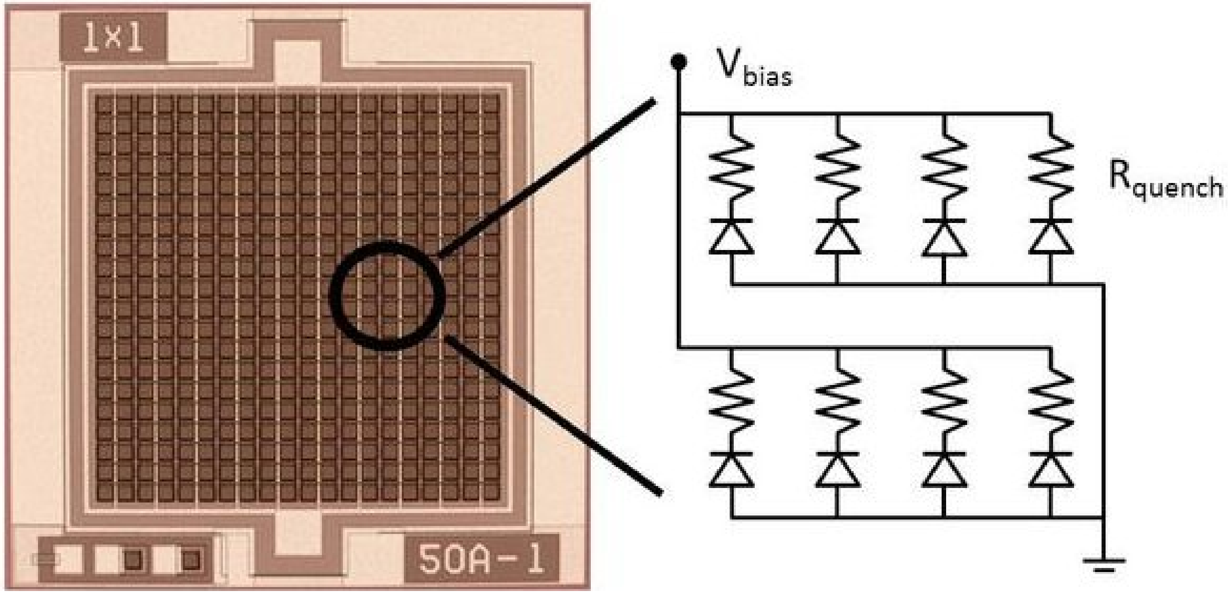
The core is based on a plastic scintillator with SiPM readout[a]

[a] SiPM workshop 6-7 Oct2001, GSI

Structure of a SiPM

A Silicon PhotoMultiplier is comprised of many parallel conected geiger mode Avalancha Photodiodes.

It is compact and insensitive to magnetic fields, operating at low voltage and providing good (intrinsic) time resolution.



Construction of the detector[a]

[a] www.ketek.net/products/sipm-technology/

Structure of a SiPM

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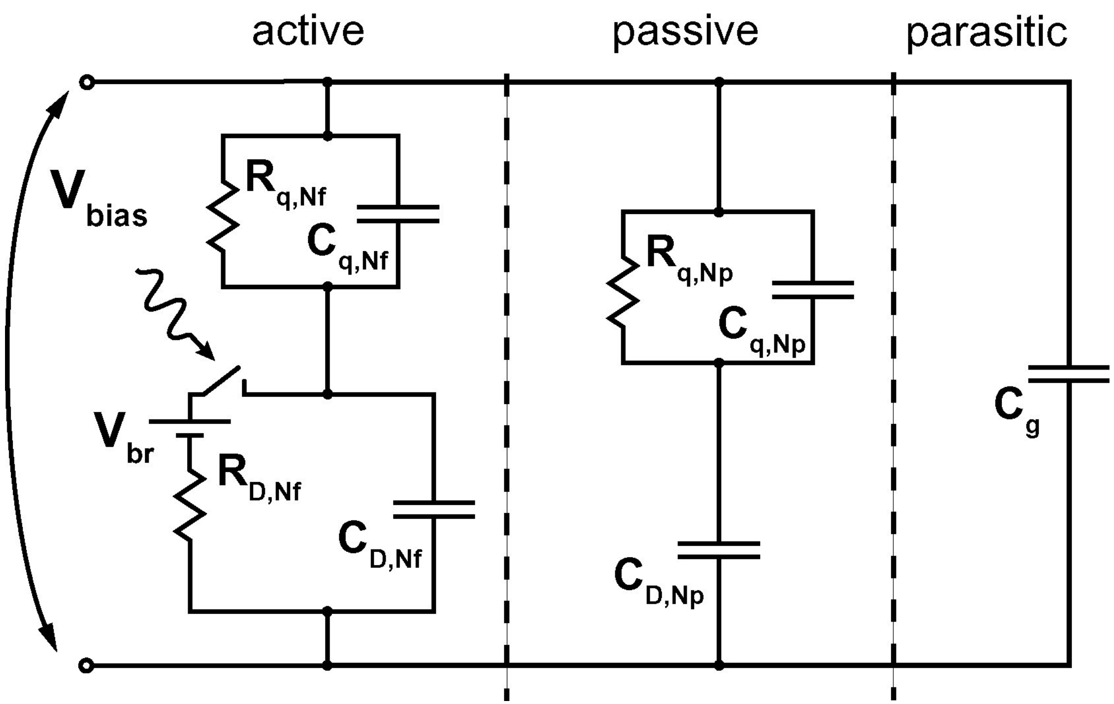


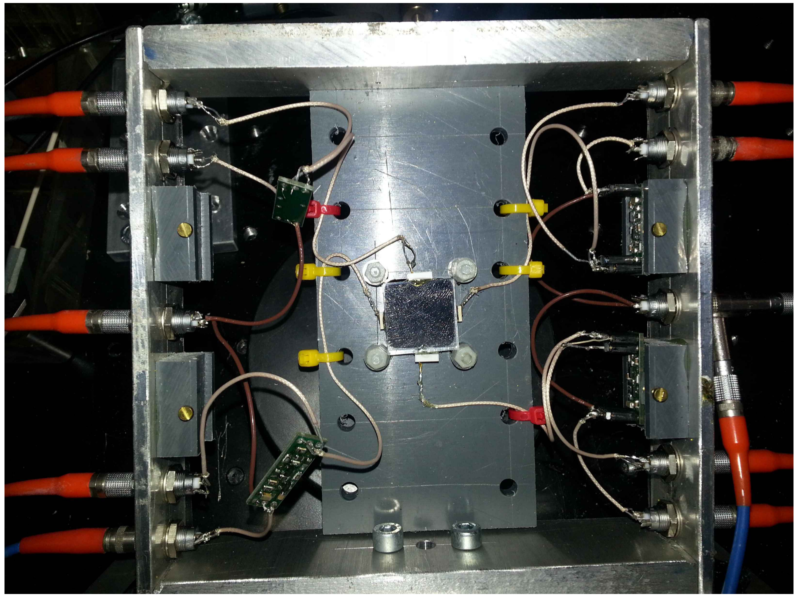
The equivalent circuitry[a]

[a] Simulation of SiPM Signals, Seifert et al., IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 56, NO. 6, DECEMBER 2009

Content

A compact prototyp manufactured by Carsten provided the basis.

A darkbox provides the measurement envirement.

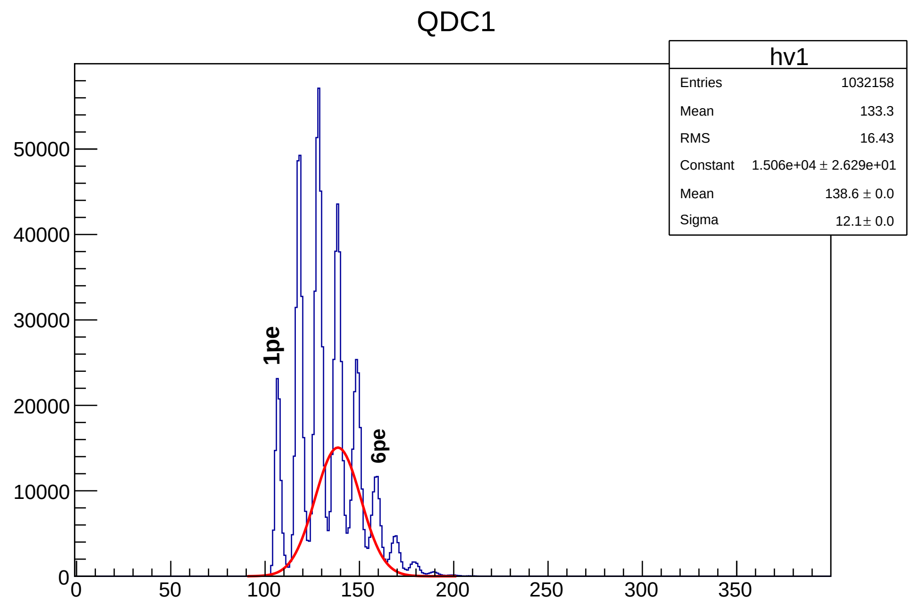


The detectors are stick to the scintillator either via glue or with screw.

The used QDC has 4096 channels with an input range from $0 \div 400$pC.

For the gain determination it is used $\frac{400pC}{4096ch}$.

A calibration of the QDC with known pixel to pixel resolution is possible.



Spectrum of a Ketek PM3375 with INR_Preamp at **23.1V** with $L_{int} = 4.6$.

The used QDC has 4096 channels with an input range from $0 \div 400$pC.

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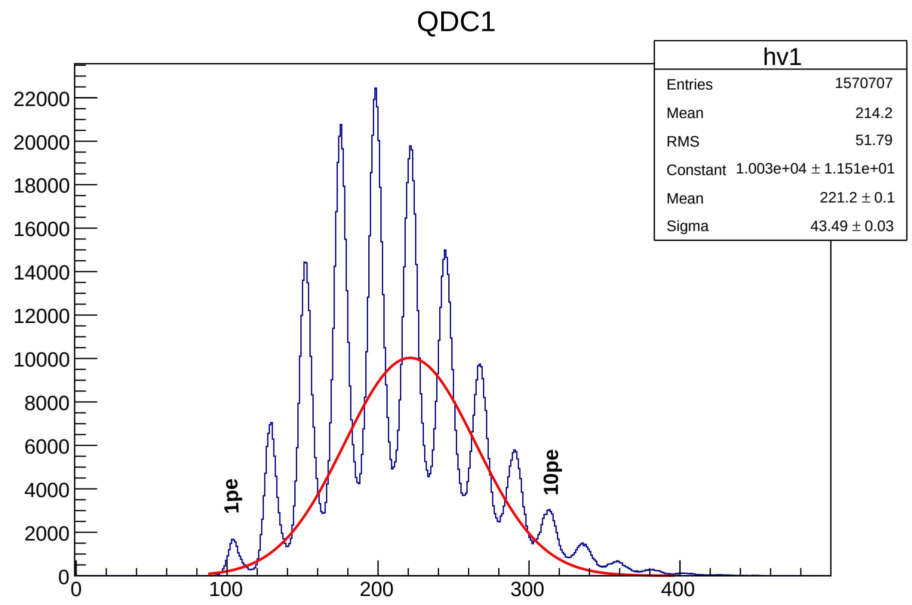

Spectrum of a Ketek PM3375 with INR_Preamp at **23.6V** with $L_{int} = 4.6$.

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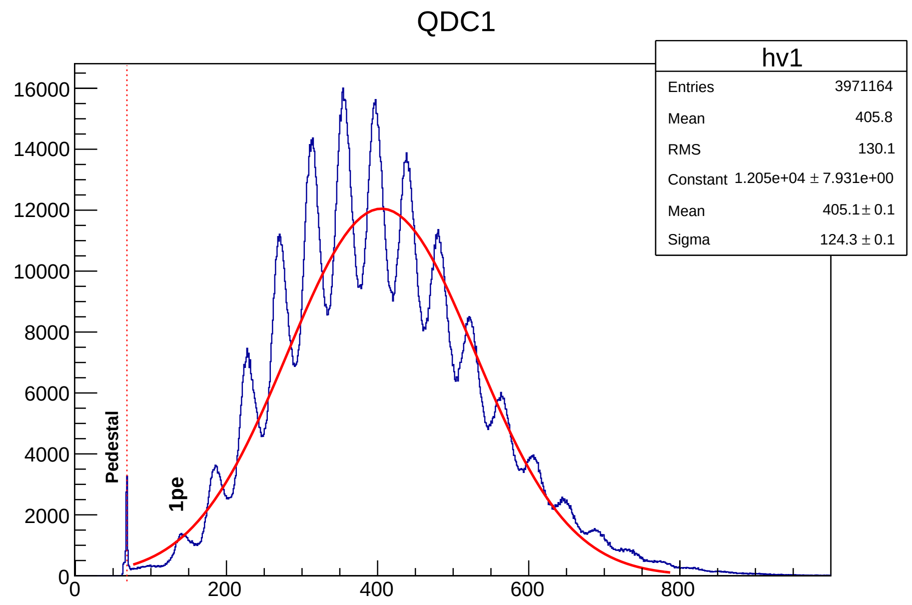
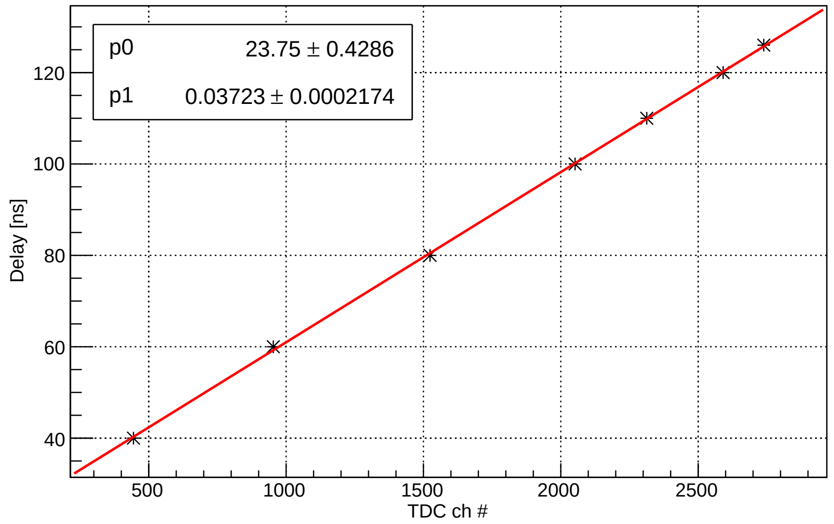


Spectrum of a Ketek PM3375 with INR_Preamp at **24.5V** with $L_{int} = 4.6$. Pedestal at ch 68.

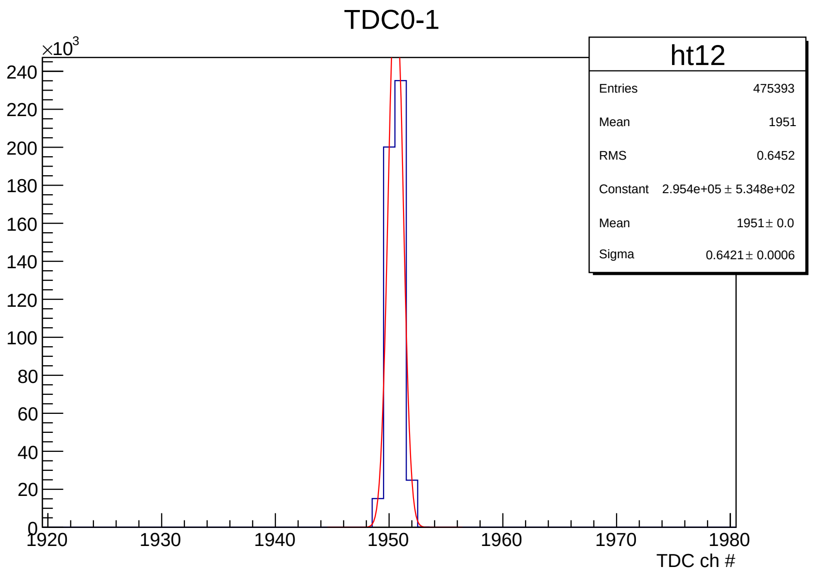
The used TDC has 4096 channels with a full scale range from $140 - 1200$ns.

It is set on to $35\frac{ps}{bin} \implies 143ns$.

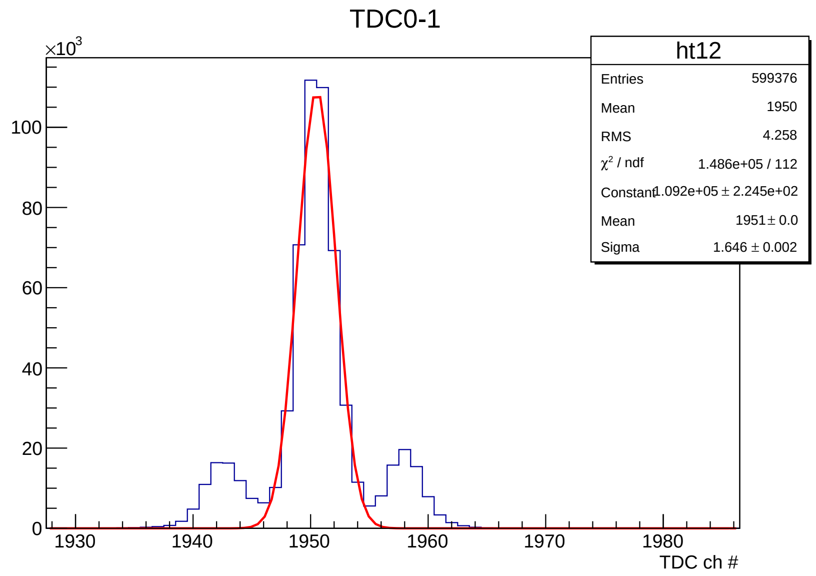
A calibration of the TDC with delays delivers $37\frac{ps}{bin}$.



Calibration of the TDC with delays.



(a) fan in/out ⟶TDC(LC)



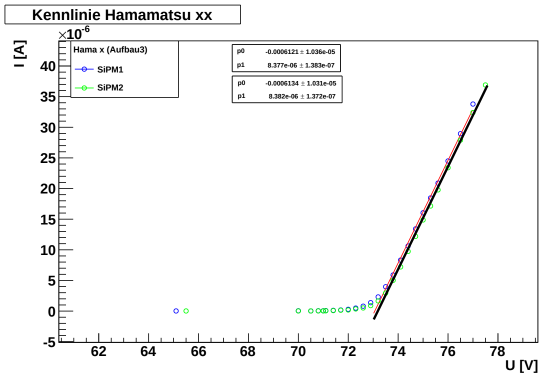
(b) SiPM⟶FTA820⟶CFD⟶TDC(LC)

Time jitter with the determined TDC resolution

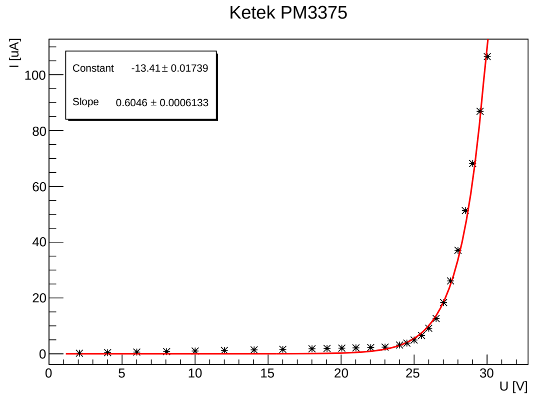
Time jitter	TDC0 [ps]	TDC1 [ps]	TDC2 [ps]	TDC3 [ps]
LC	15	22	21	21
FTA820+CFD+LC	61	55	61	53

Content

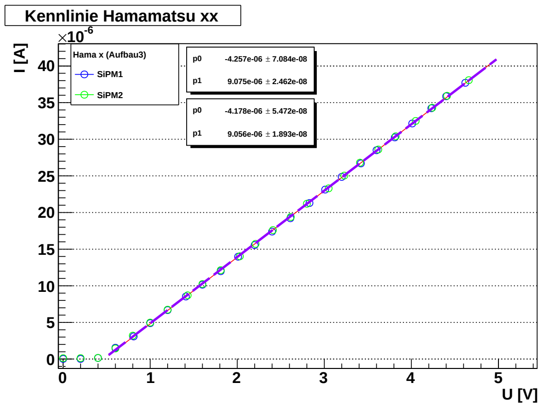
Current-Voltage Characteristics



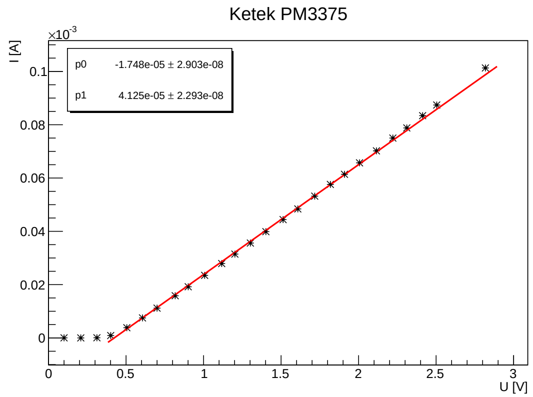
(c) Hamamtsu S10931



(d) Ketek PM3375



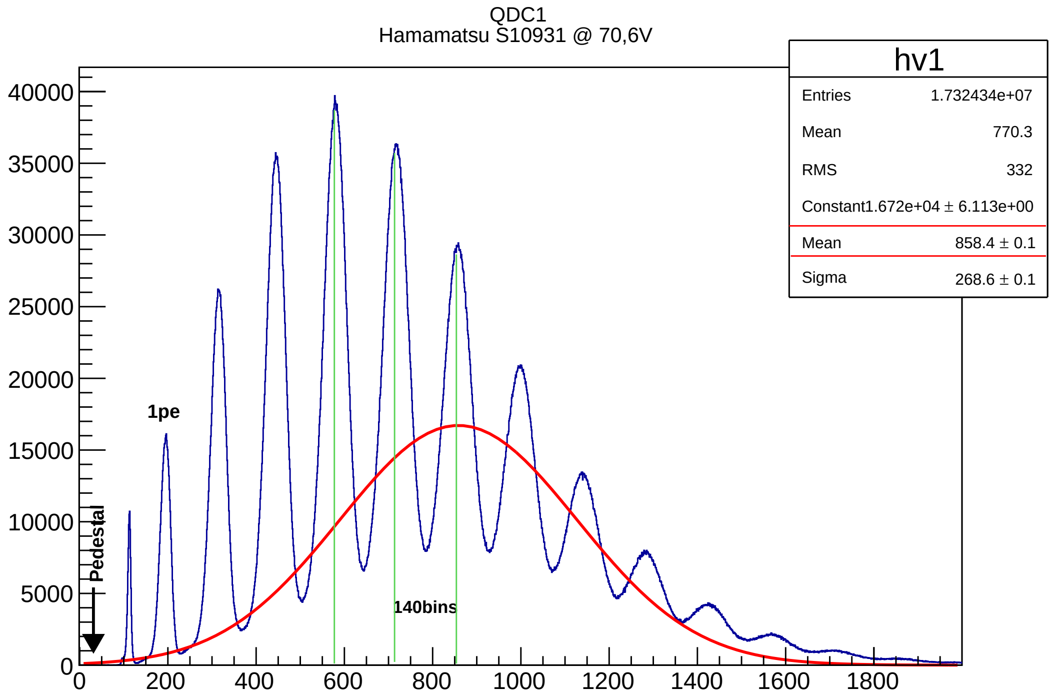
(e) Hamamatsu S10931



(f) Ketek PM3375

Reverse and forward bias characteristics of the Hamamatsu and Ketek SiPM.
The breakdown voltage can be estimated by the reverse I-V-characteristic.

Gain Determination

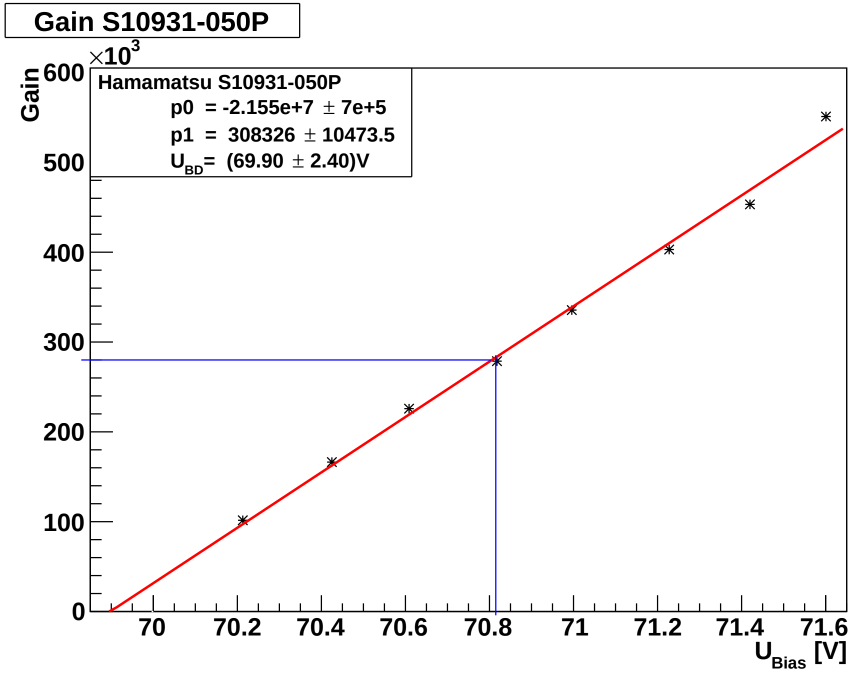


Spectrum of a Hamamatsu S10931-50P at 70.6V with Amp_604 ($20-60x$ amplification) at $L_{int}=5.0$.
The gain depends on the operating voltage (and amplification).

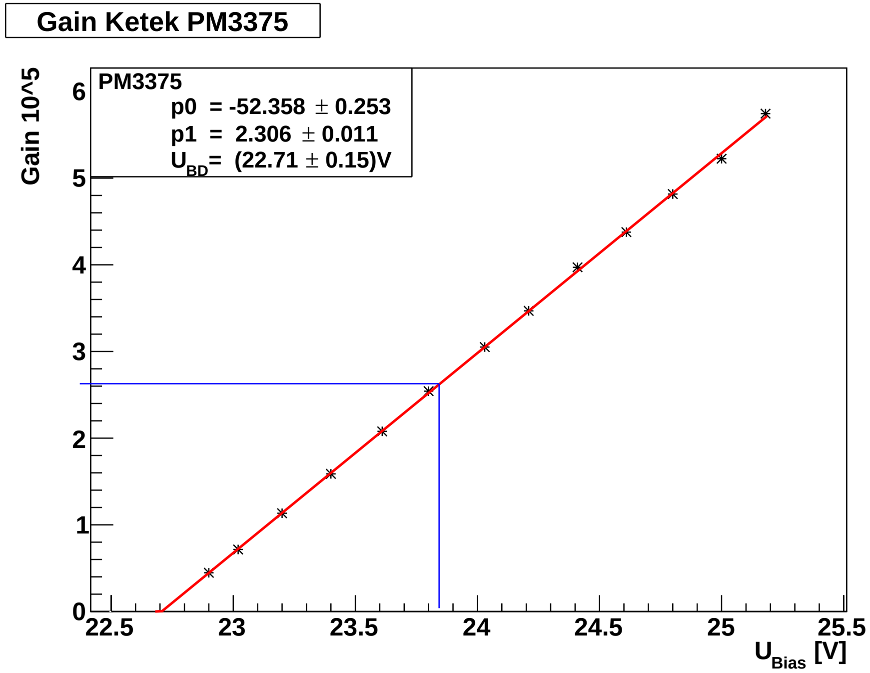
$G=\frac{\Delta Q \cdot \Delta QDC}{e \cdot Amp}$

ΔQ : Peakdistance; $\Delta QDC=\frac{400pC}{4096ch}$; e : Electronvolt; Amp : Amplification

Gain Determination



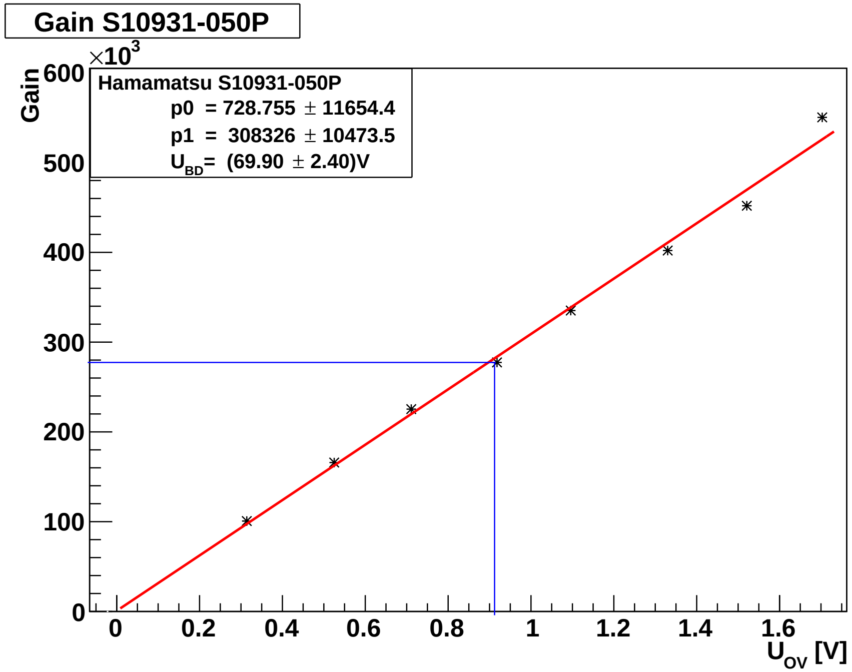
(a) Hamamatsu S10931 $U_{BD} = (69.9 \pm 2.4)V$



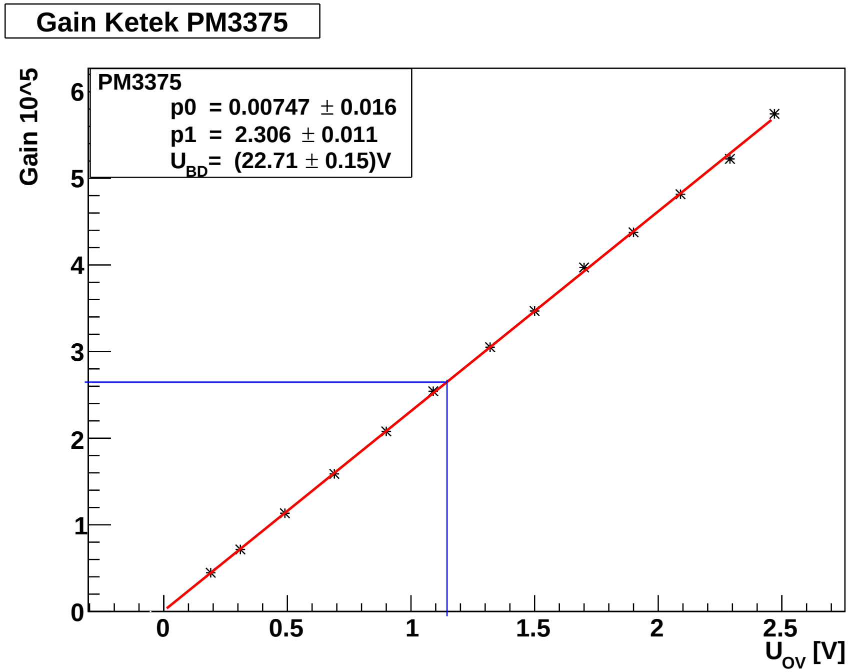
(b) PM3375 $U_{BD} = (22.7 \pm 0.2)V$

The breakdown voltage can be determined more accurately over the gain than over the I-V-characteristics.

Gain Determination



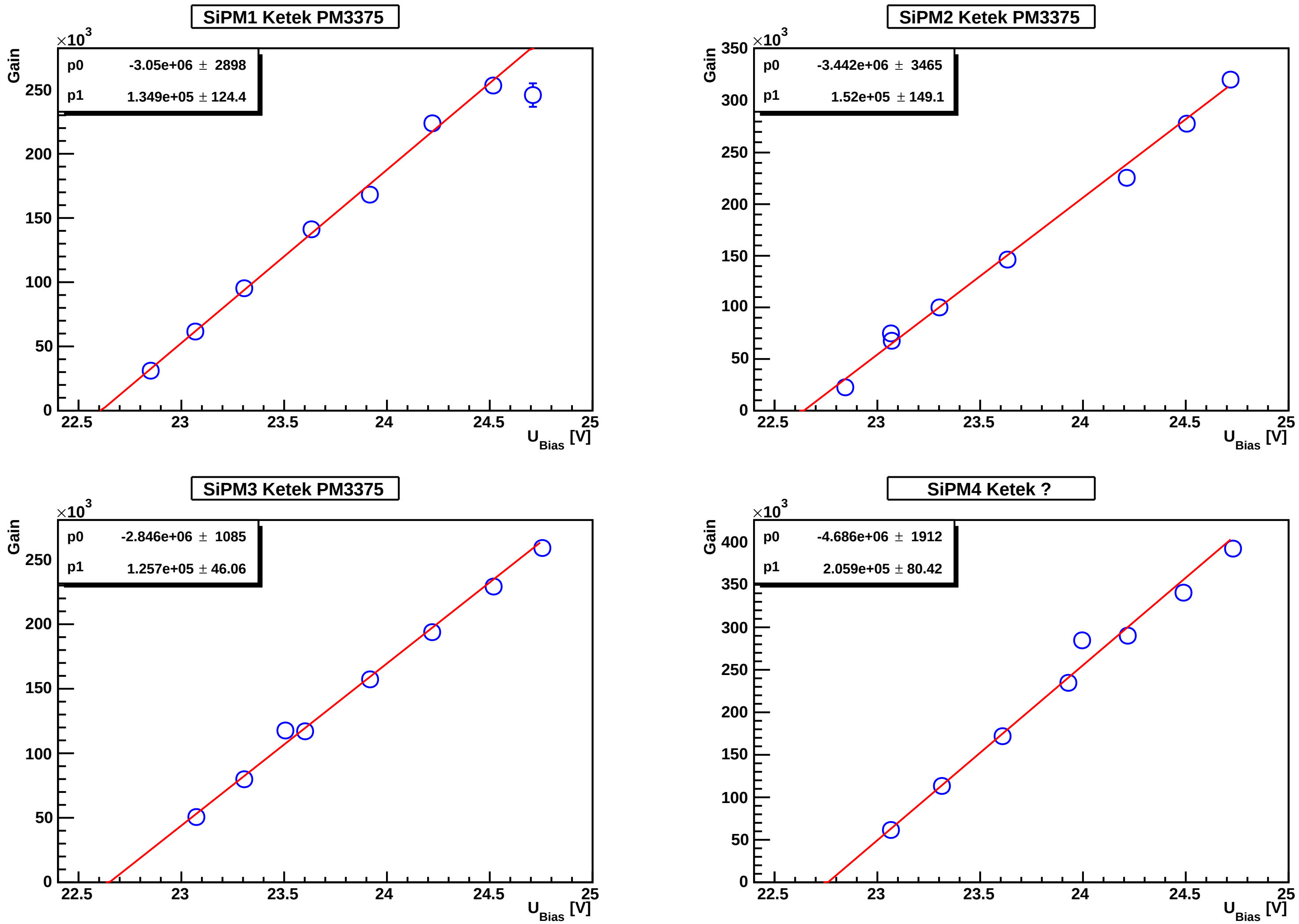
(a) Hamamatsu S10931 gain @ 1% U_{OV}



(b) PM3375 gain @ 5% U_{OV}

The manufacturer gives a gain of 7.5×10^5 for Hamamatsu and 2×10^6 for Ketek (@ 20%U_{OV}).

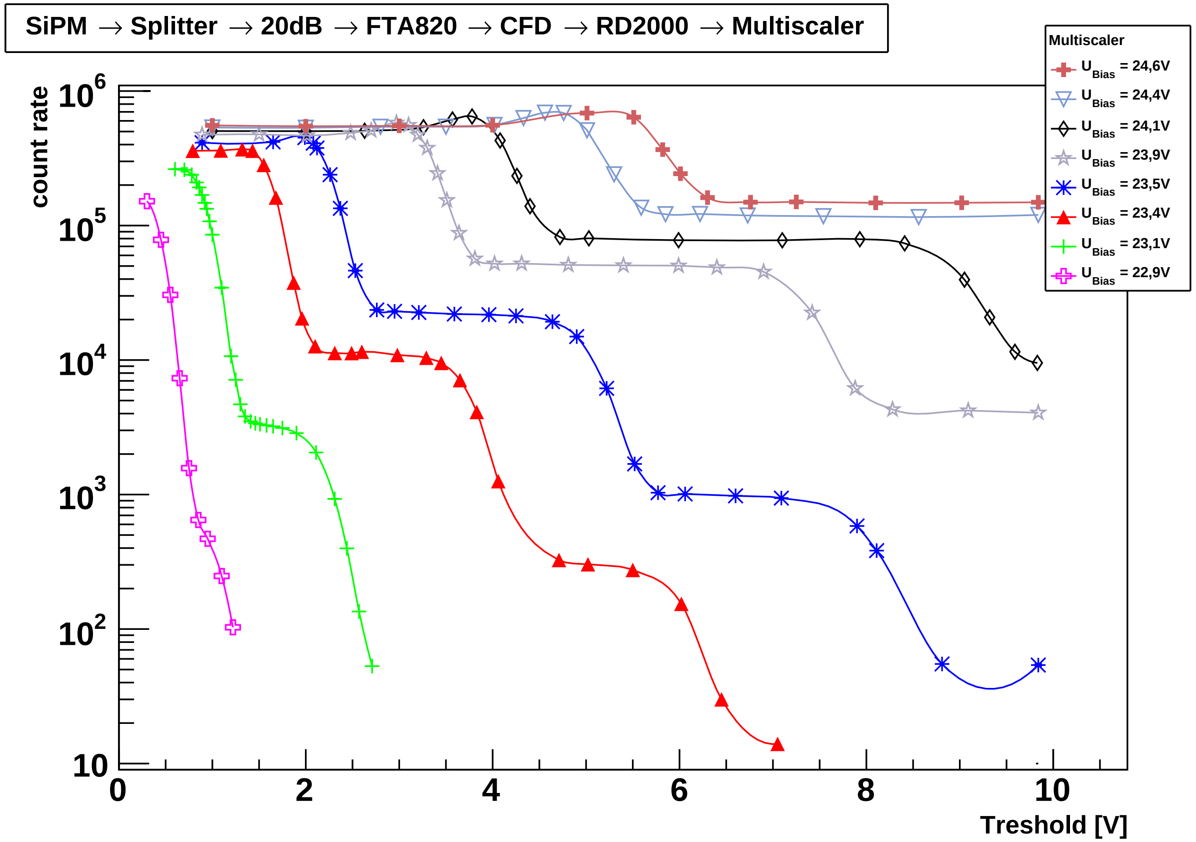
Gain Determination



The gain and breakdowm uniformity of the Ketek SiPM is particularly good.

Dark Count Rate

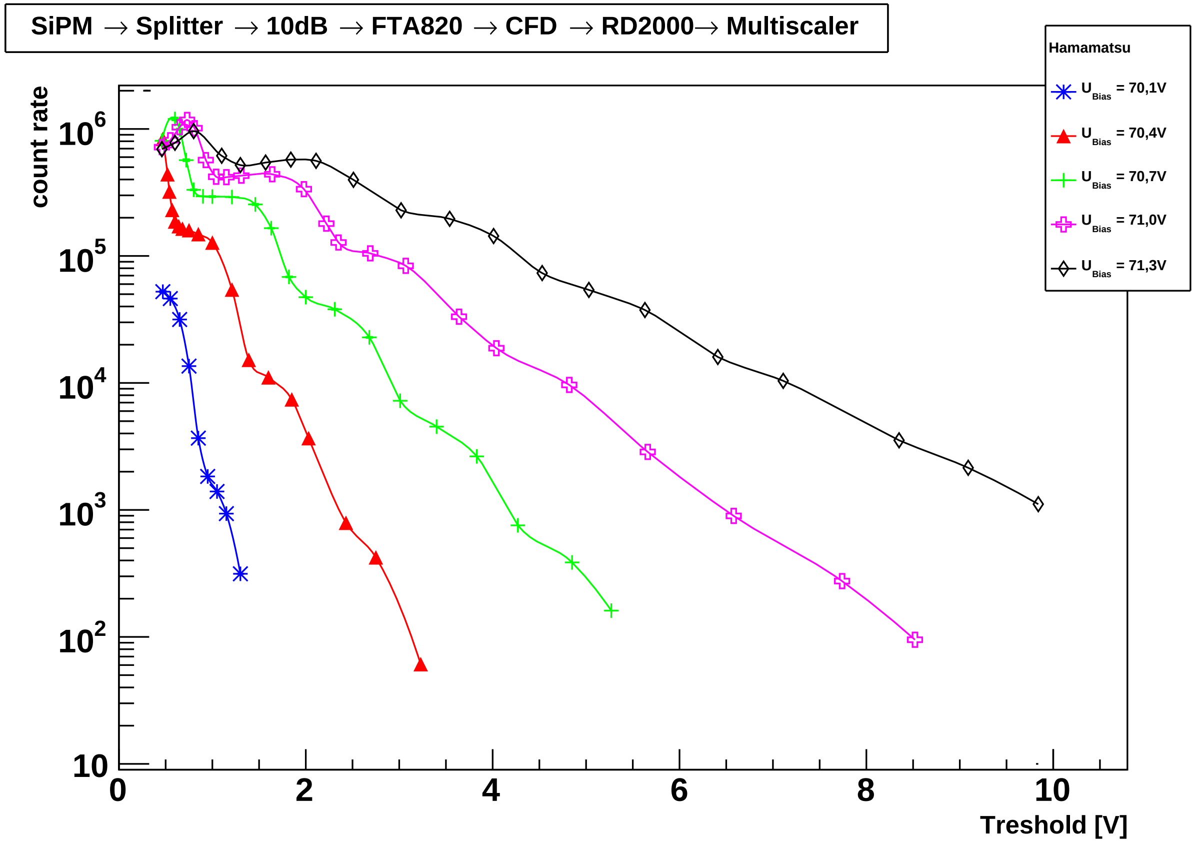
Thermally generated carriers can trigger an avalanche, leading to a signal output.



Dark Count Rate of a Ketek SiPM at different supply voltages.

Dark Count Rate

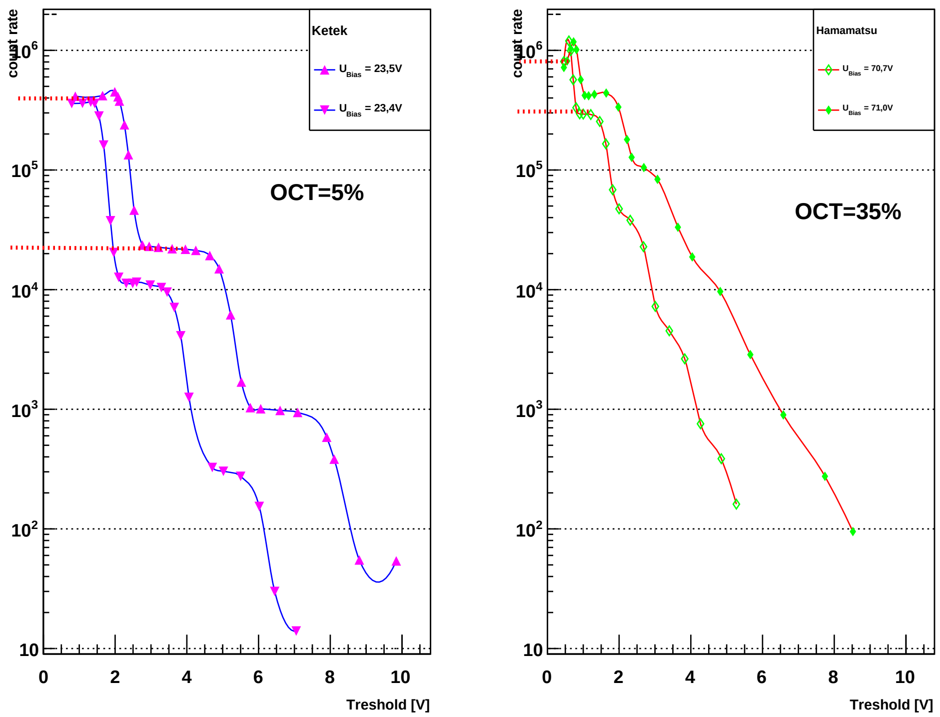
Thermally generated carriers can trigger an avalanche, leading to a signal output.



Dark Count Rate of a Hamamatsu SiPM at different supply voltages.

Dark Count Rate

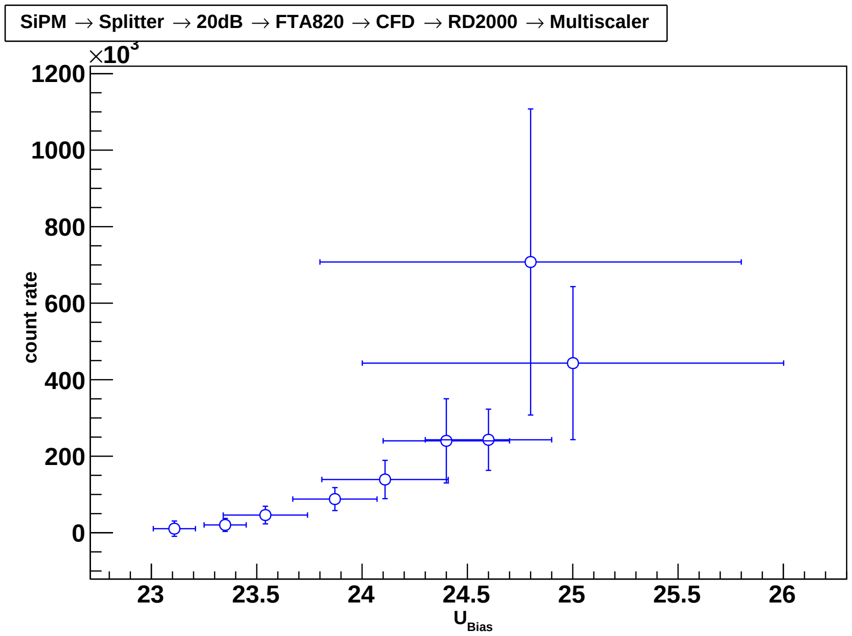
Thermally generated carriers can trigger an avalanche, leading to a signal output.



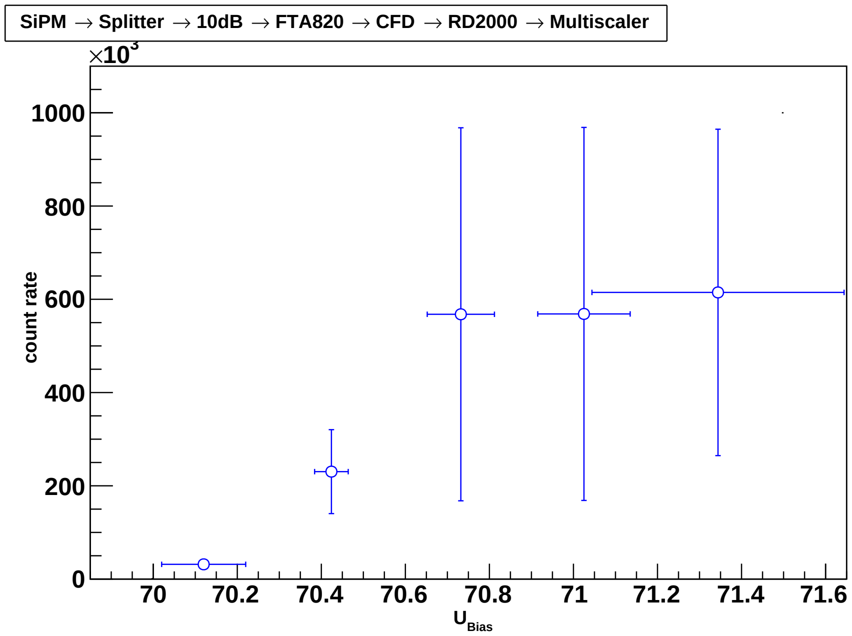
DCR of Hamamatsu and Ketek SiPM with different supply voltages.
Ketek PM3375 has a lower Optical Cross Talk probability compared with a Hamamatsu device ("Trench Technology").

Dark Count Rate

Thermally generated carriers can trigger an avalanche, leading to a signal output.



(a) Ketek

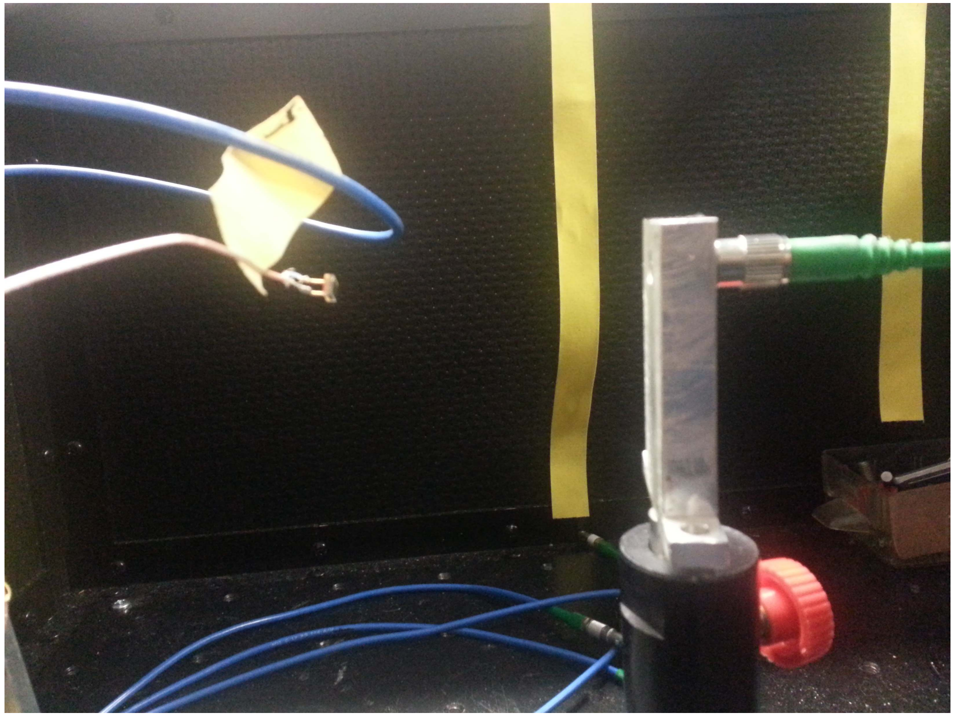


(b) Hamamatsu

DCR increases with increasing bias.

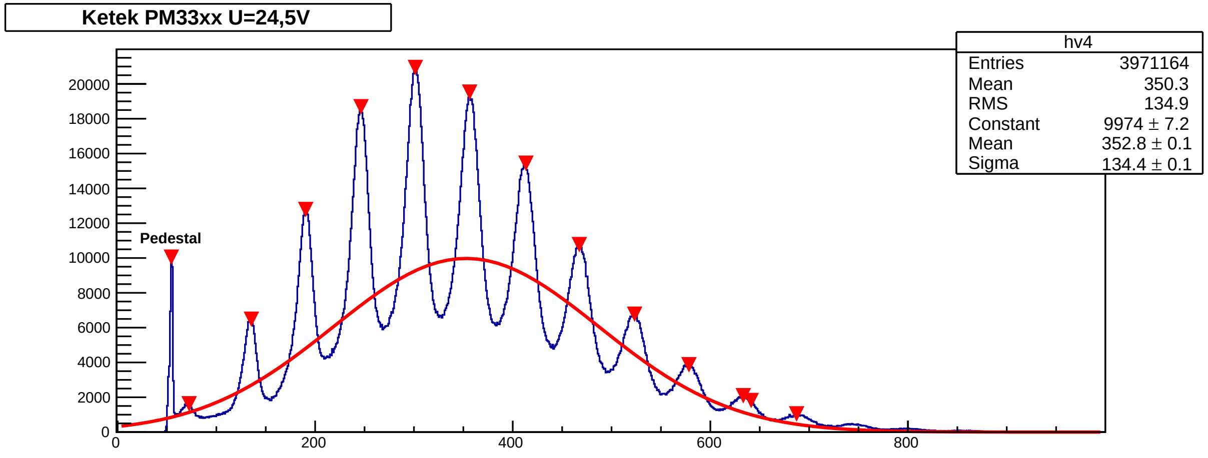
Content

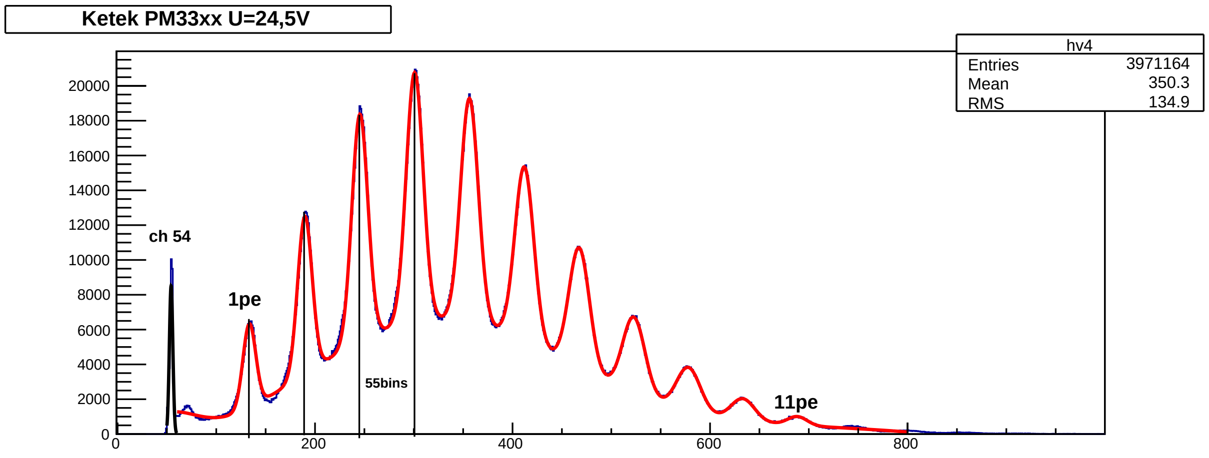
Photonnumber vs Laserintensity



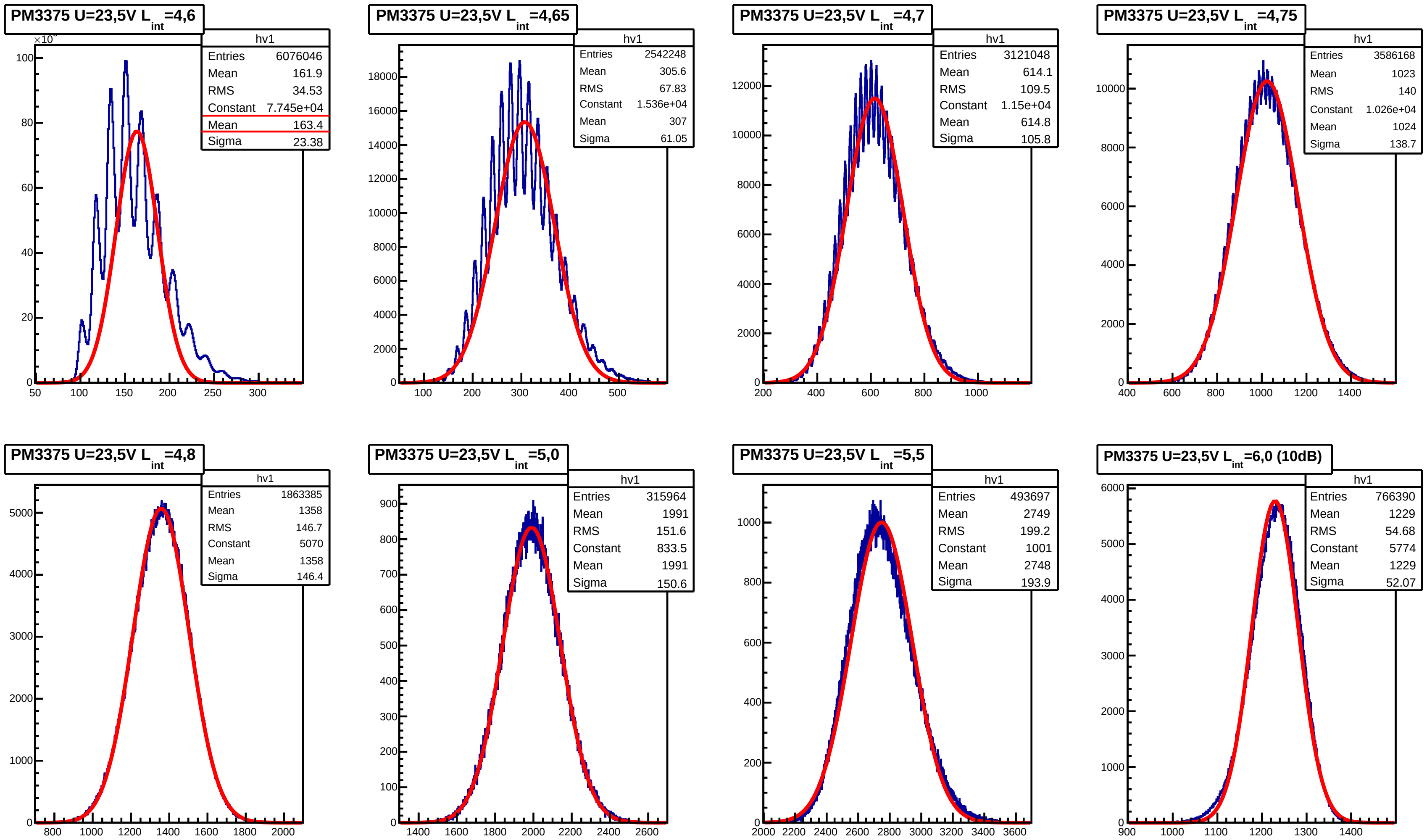
Attempt to find out the seen Photonnumber at a given laserintensity.
A Ketek is illuminated directly with laser at different intensities.

Photonnumber vs Laserintensity



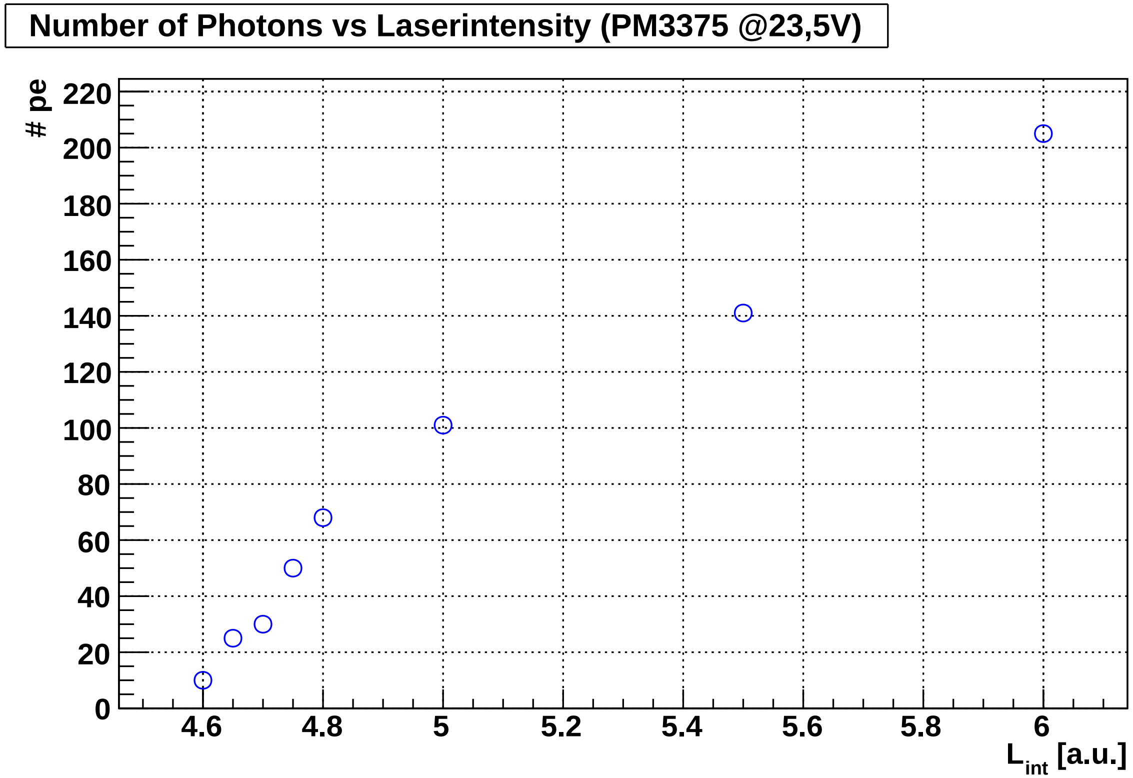


At low light intensities one can count the seen photons. An average number can be defined with the mean value of the fitted Gaussian function: $\overline{N}_{seen} \approx (\mu - pedestal) \div pixeldistance$.

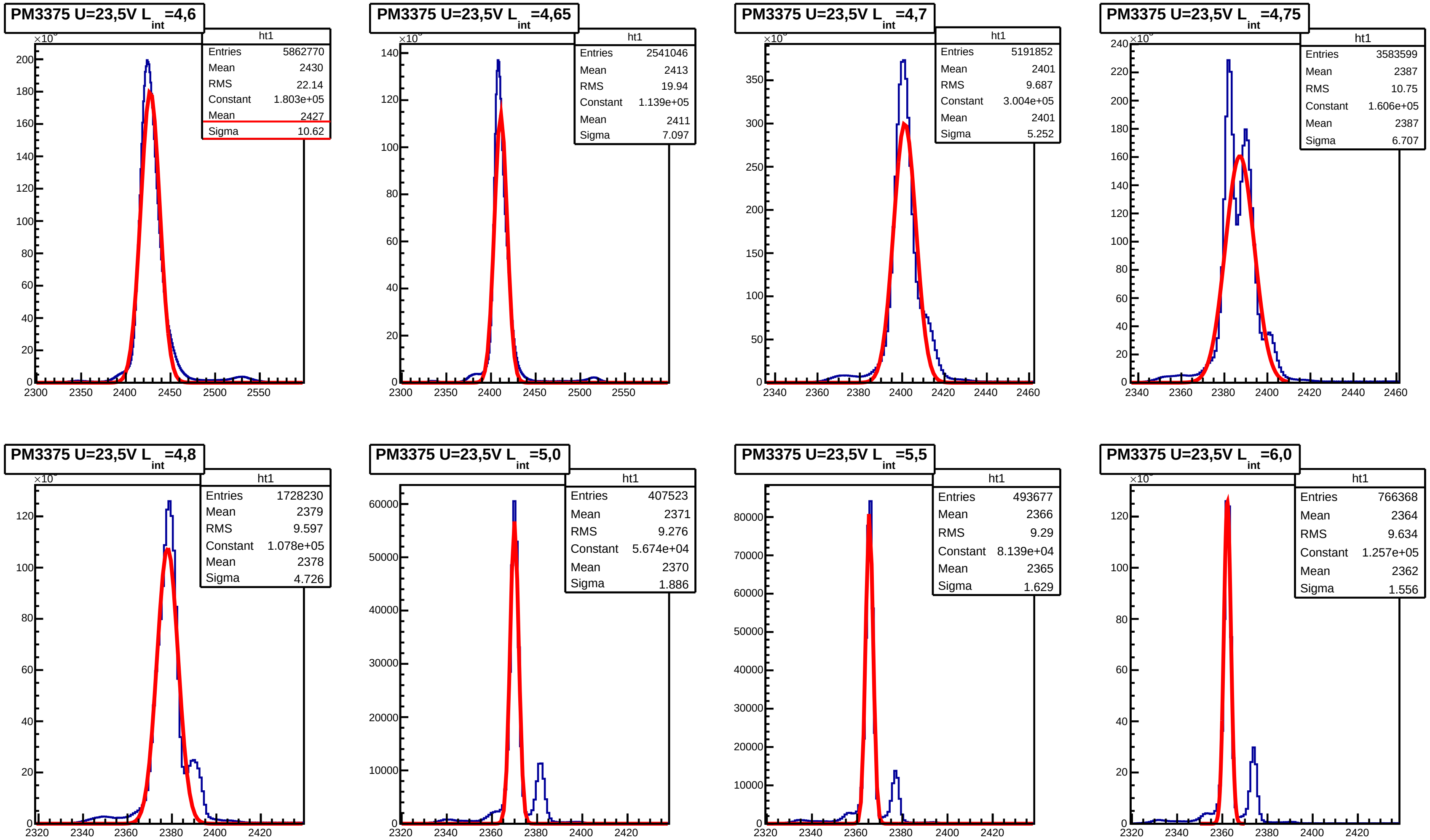


SiPM⟶INR_Amp⟶ Splitter⟶ Delay⟶ QDC

At constant detector bias the laserintensity is slight increased. More photons can be detected and so the resolution get smeared.

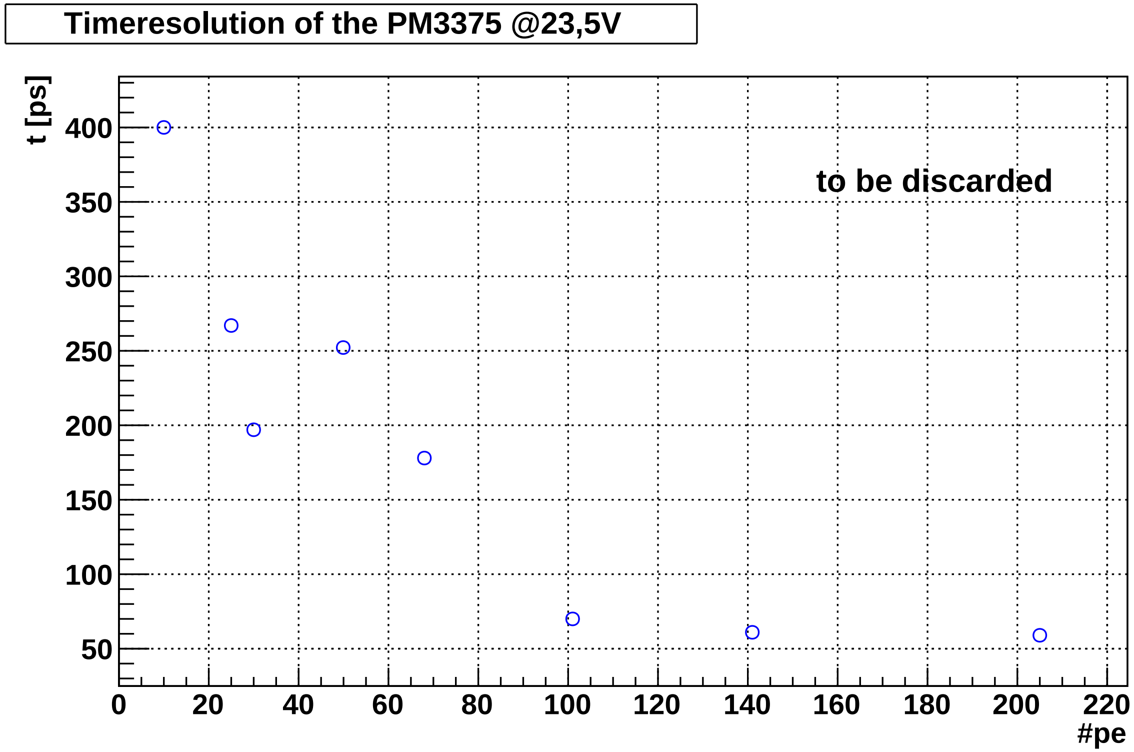


A linear trend can be determined from these assignment.



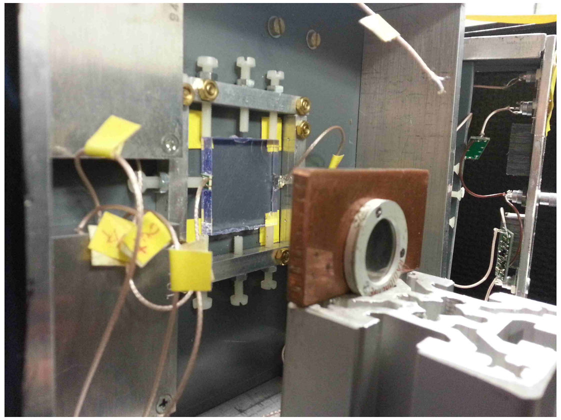
SiPM⟶INR_Amp⟶ Splitter⟶FTA820⟶CFD⟶Delay⟶ TDC

The time resolution of the detector is incresing with the seen number of photons.

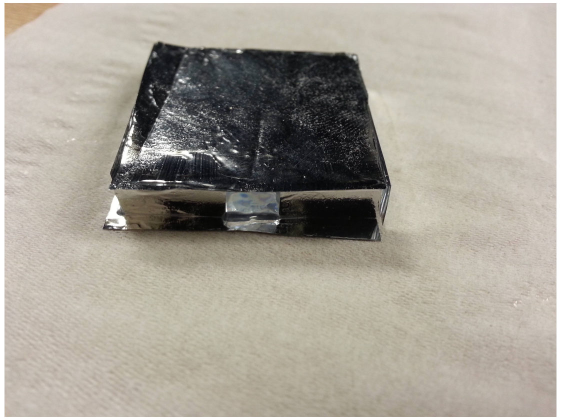


The time resolution of the detector is incresing with the seen number of photons.
But the results are falsified, because of a reversed connection between the LC and the TDC.

Content

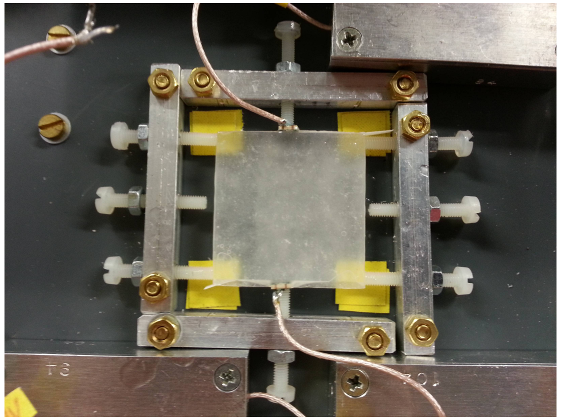


(a) w/o wrapping



(b) reflective foil

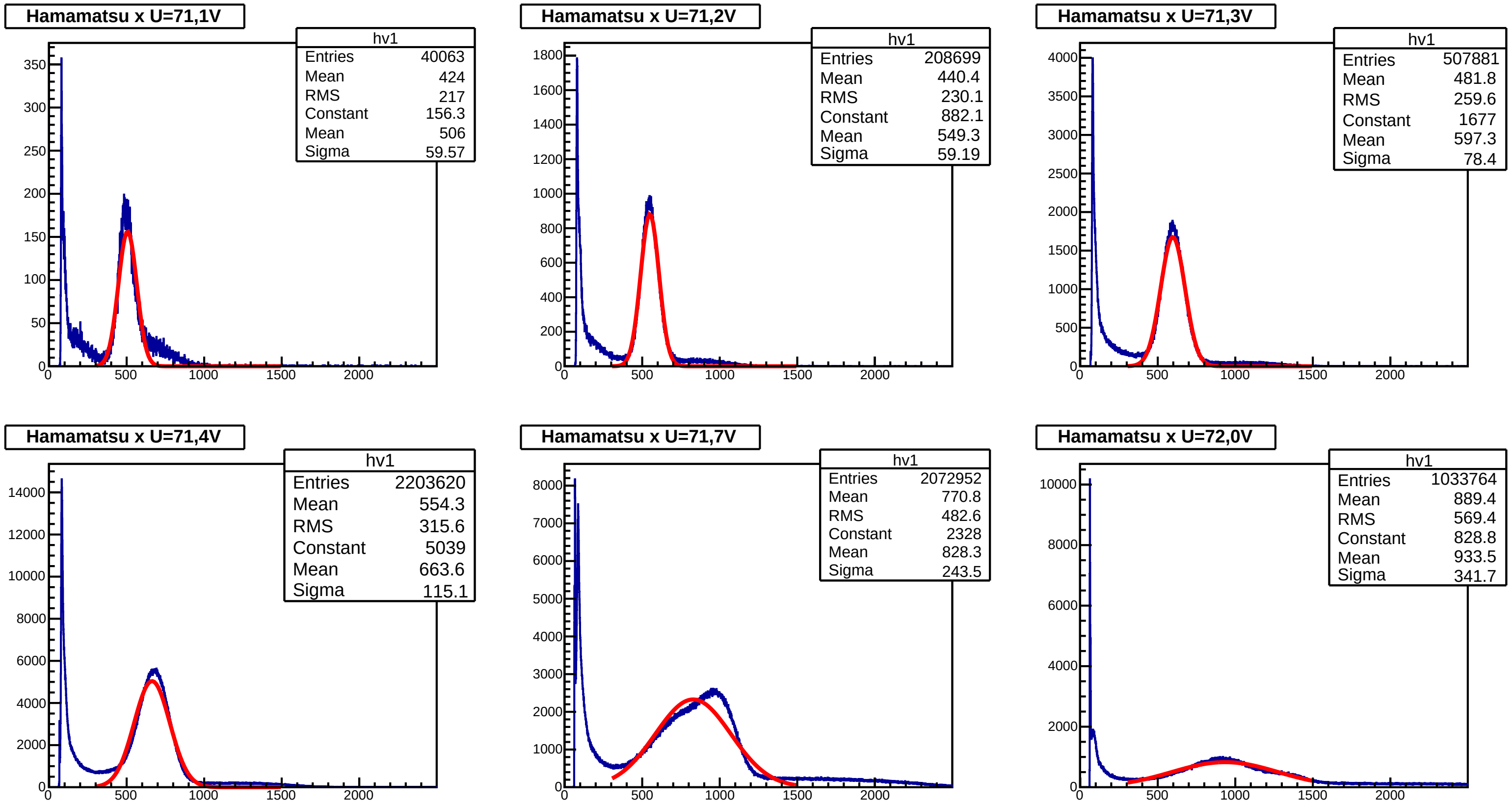
(c) black tape



(d) mylar foil

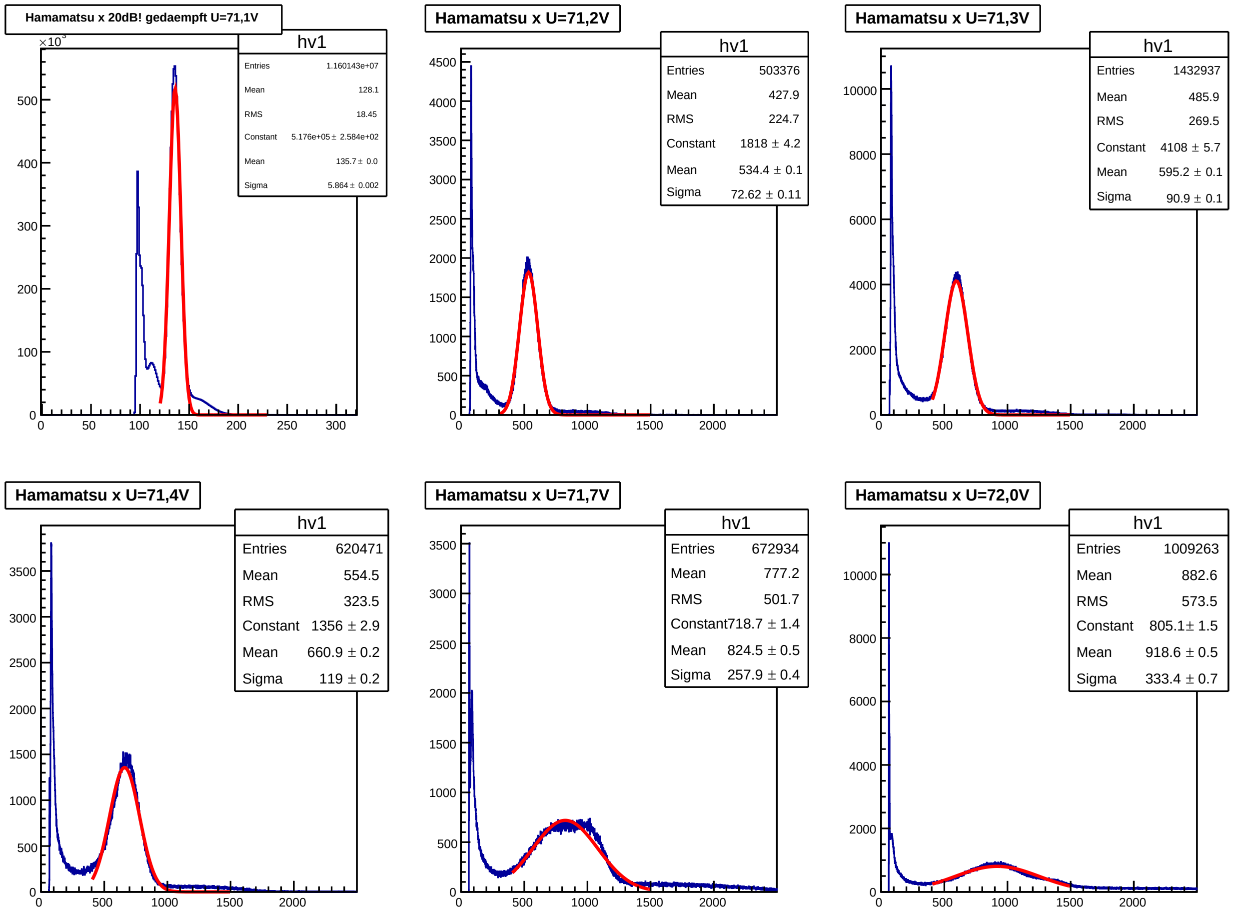
Comparative measurements with various configurations to study reflections and refraction.
The coupling between SiPM and scintillator with and without optical grease and the influence of wrapping was examined.

Comparison of Scintillators



Hamamatsu S10931 + BC408 *without wrapping*
A significant difference between the configurations could not be seen in the QDC spectra.

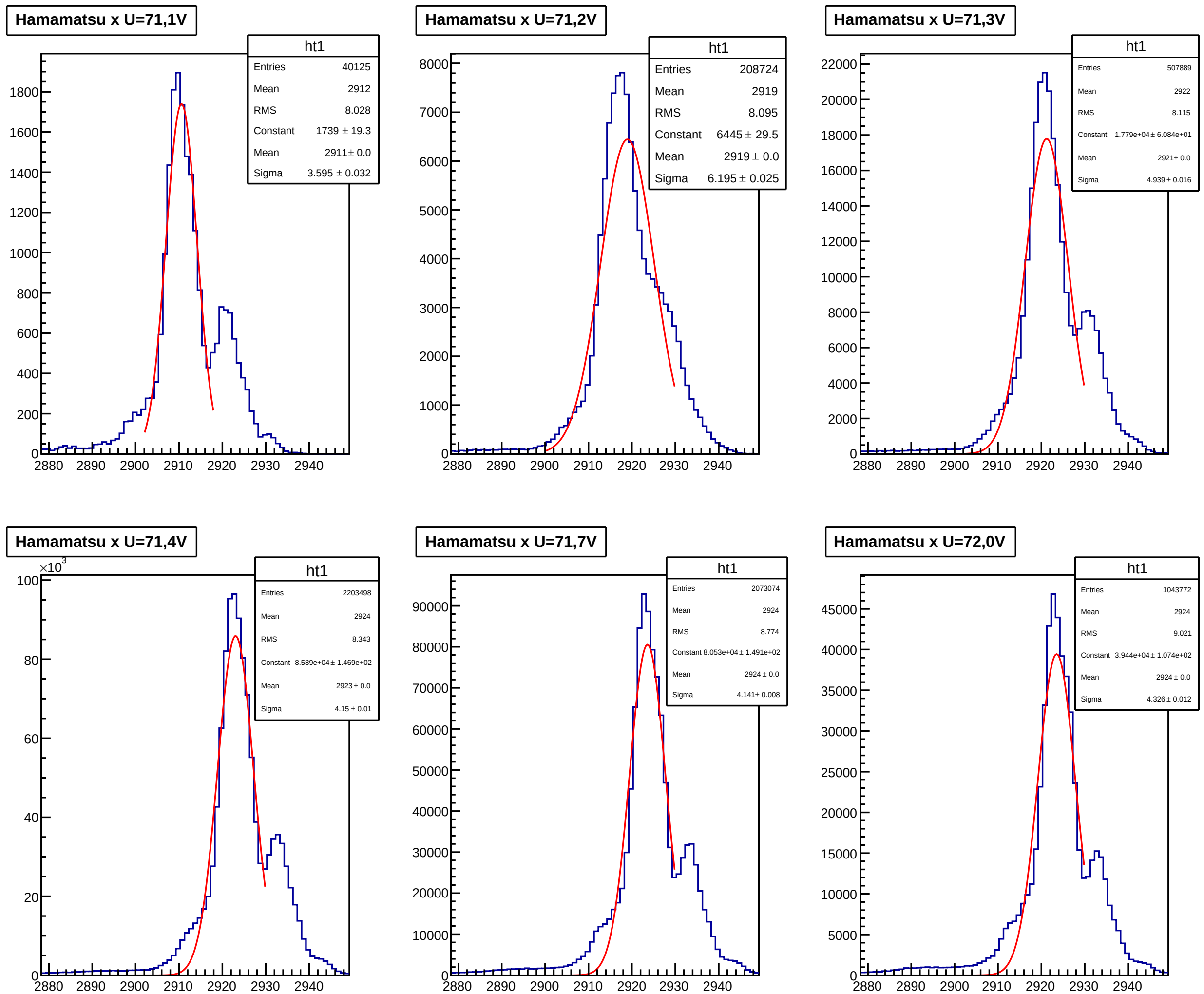
Comparison of Scintillators



Hamamatsu S10931 + EJ228 *without wrapping*

A significant difference between the configurations could not be seen in the QDC spectra.

Comparison of Scintillators



The time study was due to the satellite peak useless.

- General characteristics of the present SiPMs were measured.
  - Ketek with different Preamps.
  - Measurements with two different scintillators (BC408 & EJ228).
  - Charged particle measurement.

- Outlook
  - Measurements concerning timing will be performed again.
  - Simulation with SLitrani(C++) or Litrani (Fortran).
  - Detailed comparision of studied detectors, preamps and scintillators.
  - Measurement of temperature dependence?