Silicon Photomultiplier tests in LN, LAr

Janicskó József

June 10, 2008

What is a SiPM?

History

ELSEVIER

Nuclear Physics B (Proc. Suppl.) 61B (1998) 347–352

NUCLEAR PHYSICS B
PROCEEDINGS
SUPPLEMENTS

Limited Geiger-mode silicon photodiode with very high gain

G.Bondarenko[a], B.Dolgoshein[a], V.Golovin[b], A.Ilyin[a], R.Klanner[c], E.Popova[a]

[a]Moscow Engineering and Physics Institute (MEPHI), Russia

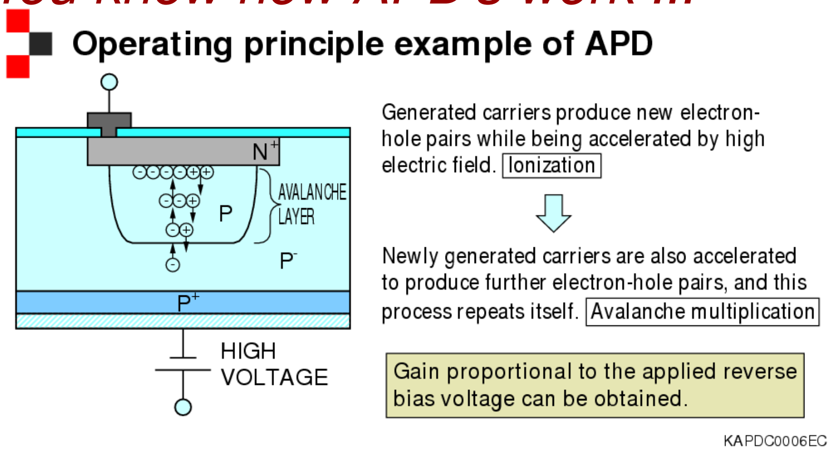
[b]Centre of Perspective Technology and Apparatus (CPTA), Moscow, Russia

[c]DESY, Hamburg, Germany

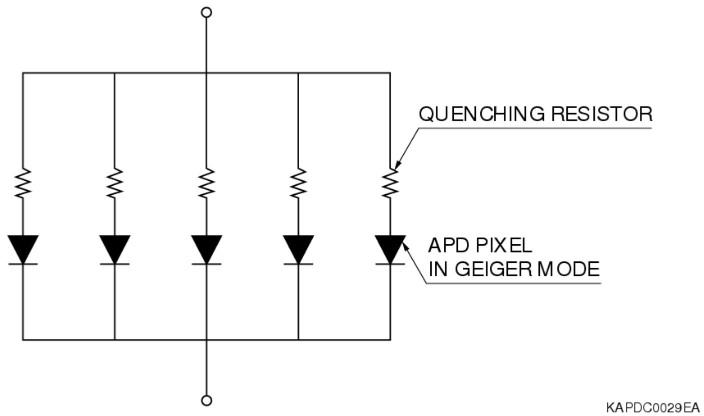
The novel type of the Silicon Photodiode – Limited Geiger-mode Photodiode (LGP) has been produced and studied. The device consists of many $\approx 10^4$ mm^{-2} independent cells $\approx$10 mkm size around n^+ -"pins" located between p-substrate and thin SiC layer. Very high gain more than 10^4 for 0.67 mkm wave length light source and up to $6 \cdot 10^5$ for single electron have been achieved. The LGP photon detection efficiency at the level of one percent has been measured.

What is a SiPM?

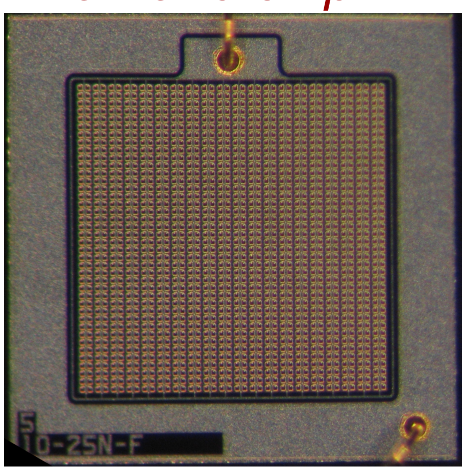
You know how APD's work ...



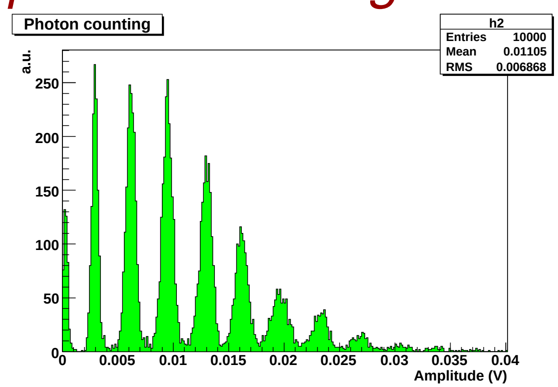
Make an array of Geiger-mode APD's



... on one chip



binary device, 1,2,3... APD cells fire at the same time, and you do photon counting



Motivation

Everybody is doing it: MAGIC, T2K, ILS.
And we have MPI HLL in Munchen.

It is known to be:

- UV sensitive
- High QE (>50%)
- Supposed to work in LN
- No high voltage required
- Small (0.1 g), should be OK for radiopurity
- Price

Typical values	PMT	SiPM
HV	1000 V	30 - 70 V
Dark rate	kHz	100 kHz - MHz
Gain	10^6	10^6
QE	20 - 30 %	20 - 60 %
Dyn. range	?	Nb. of pixels
Linearity	Linear	Nonlinear
Weight	kg	100 mg
Surface	cm^2	mm^2
B field	sensitive	insensitive

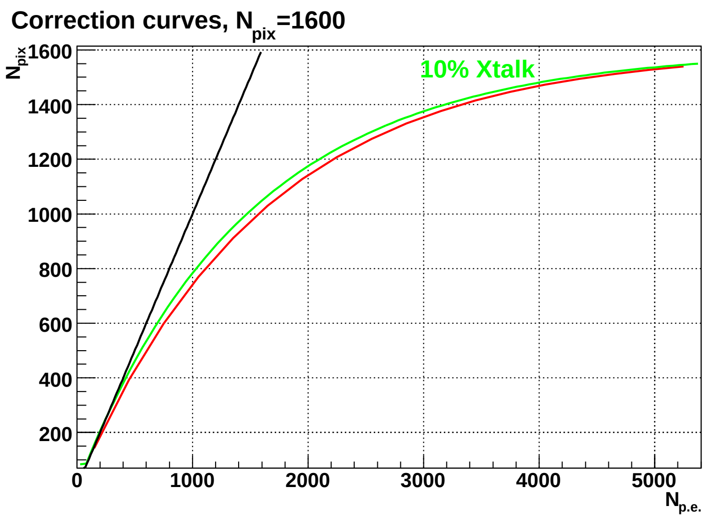
$\Longrightarrow$ ideal candidate for detecting scintillation light in LAr

Correction curves

Nonlinearity is easy to correct.
Because more than one photon can hit the same pixel ...

$$N_{fired} = N_{pix}(1 - e^{-N_{pe}/N_{pix}})(1 + p\, e^{-N_{pe}/N_{pix}})$$

N_{pix} number of pixels
p cross talk probability
$N_{pe} = N_{photons} \times Q.E.$



Producers

Is not an experimental device any more. One can buy them at:

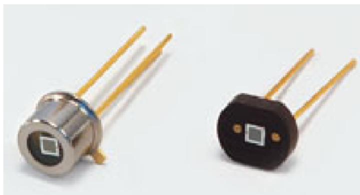
- SensL (U.S.A.)
- Photonics S.A. (CH)
- Hamamatsu (since 2007)

Still, expect new developments in the near future:

- improved UV sensitivity
- increased active surface (6mm x 6mm already available), 1 cm^2 device under development
- I expect the prices to drop as well

Hamamatsu MPPC

MPPC



The MPPC (Multi-Pixel Photon Counter) is a new type of photon counting device made up of multiple APD (avalanche photodiode) pixels operated in Geiger mode.

The MPPC is essentially an opto-semiconductor device with excellent photon counting capability and which also possesses great advantages such as low voltage operation and insensitivity to magnetic fields.

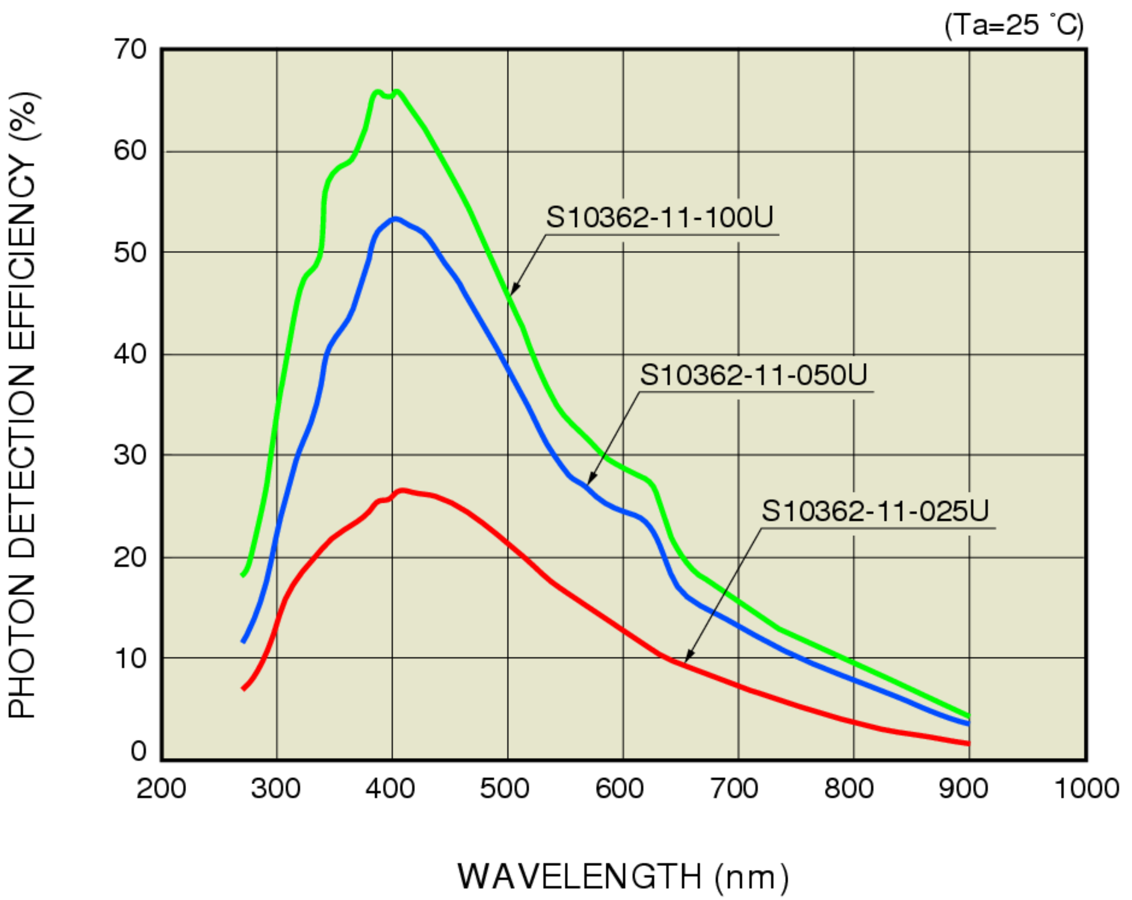
How to use filters | Undo last action | Reset table to default | Printable version

Part Number			Package	Effective active area mm	Number of Pixels	Pixel size m	Min λ nm	Max λ nm	Peak λ nm	Photo Detection Efficiency λ=λp %	Dark count kcps
S10362-11-100U			metal	1 x 1	100	100 x 100	270	900	400	65	400
S10362-11-100C			ceramic	1 x 1	100	100 x 100	270	900	400	65	400
S10362-11-050U			metal	1 x 1	400	50 x 50	270	900	400	50	270
S10362-11-050C			ceramic	1 x 1	400	50 x 50	270	900	400	50	270
S10362-11-025U			metal	1 x 1	1600	25 x 25	270	900	400	25	100
S10362-11-025C			ceramic	1 x 1	1600	25 x 25	270	900	400	25	100

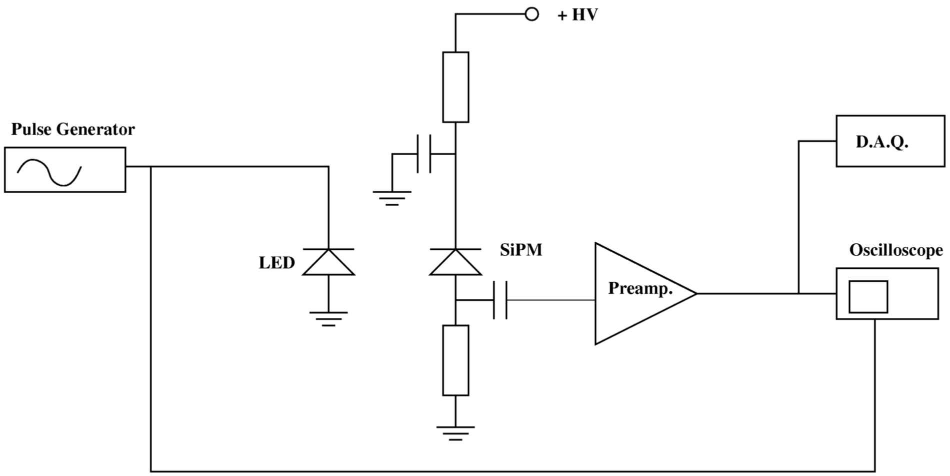
Part Number | Package | Effective active area | Number of Pixels | Pixel size | Min λ | Max λ | Peak λ | Photo Detection Efficiency λ=λp | Dark count

Photon Detection Efficiency

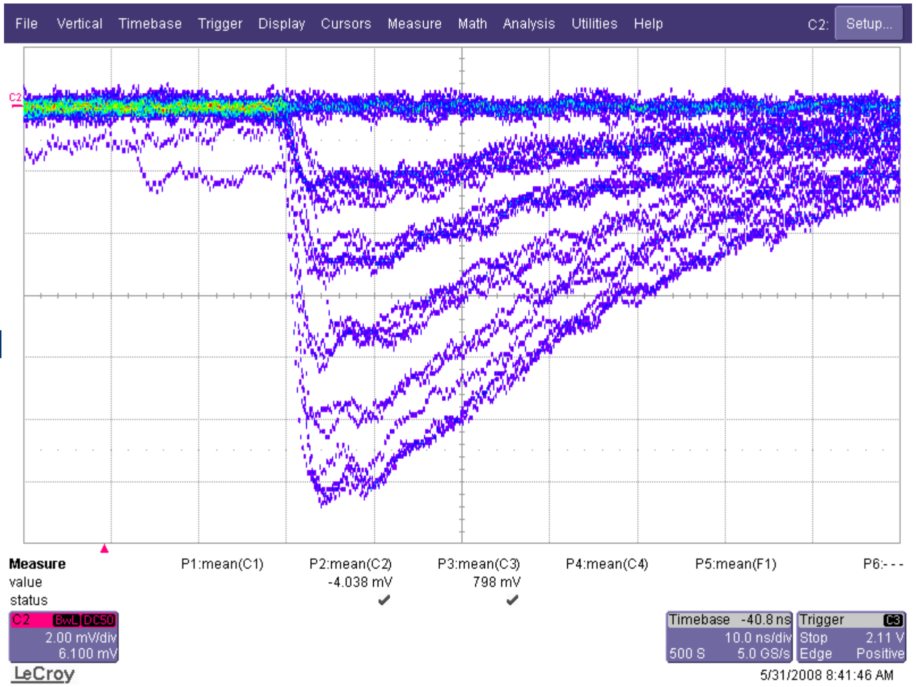
- APD QE peak 70% is a typical value
- Fill factor is 78.5 , 61.5, 30.8 for the 100, 400, 1600 pixel MPPC's



Setup



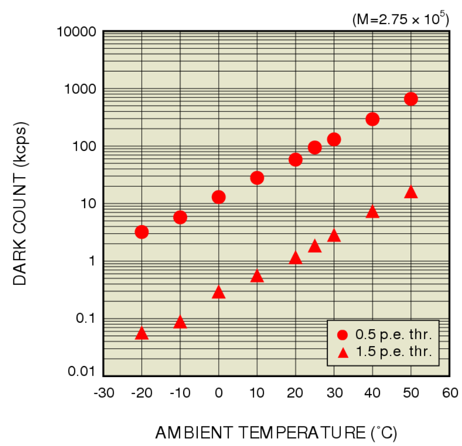
- Bias circuit and amplifier built on one PCB
- Preamp. works in LN
- works with a coax. cable between the SiPM and the PCB
- in the final setup SiPM in LN, preamp. at RT

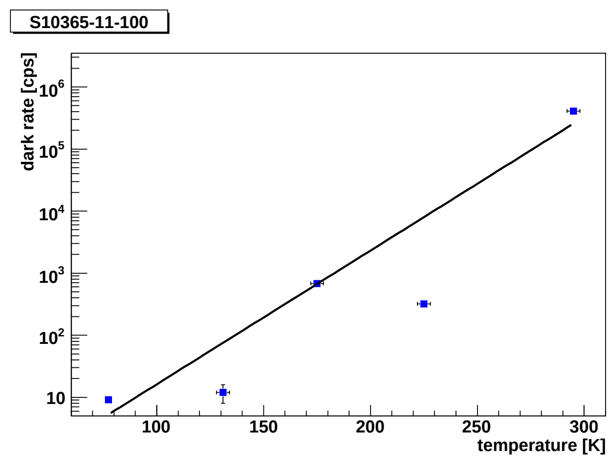


SiPM properties at LN temperature

Dark rate v. temperature

The main reason for cooling down a Si device is the thermal noise. We don't have cryostat, I just wait until the temperature stabilyzes in the dewar. A Pt-100 is attached to the SiPM





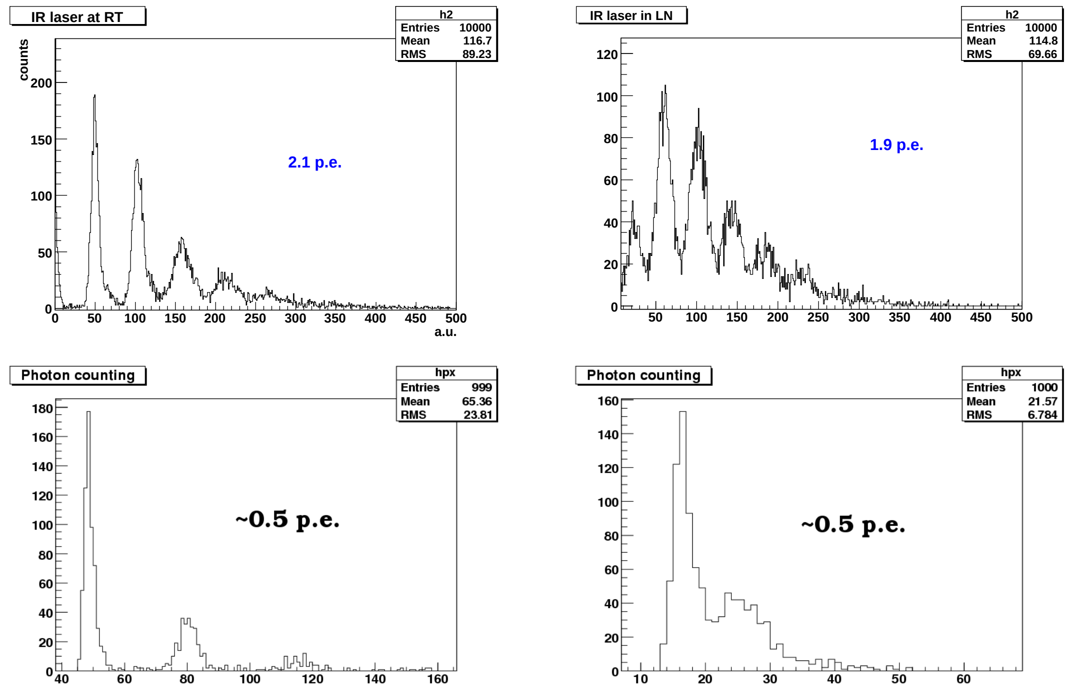
Effect of ambient light is not exluded, during overnight measurement the rate droped below 1Hz. $\Longrightarrow$ Up to 6 orders of magnitude reduction in dark rate.

Relative efficiency

RT LN

850nm IR laser

400nm Blue LED

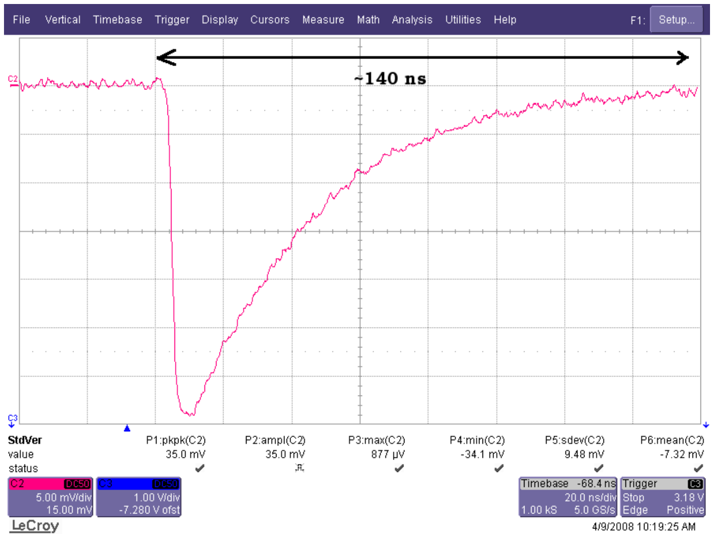


No visible efficiency drop at LN temperature (compared to RT)

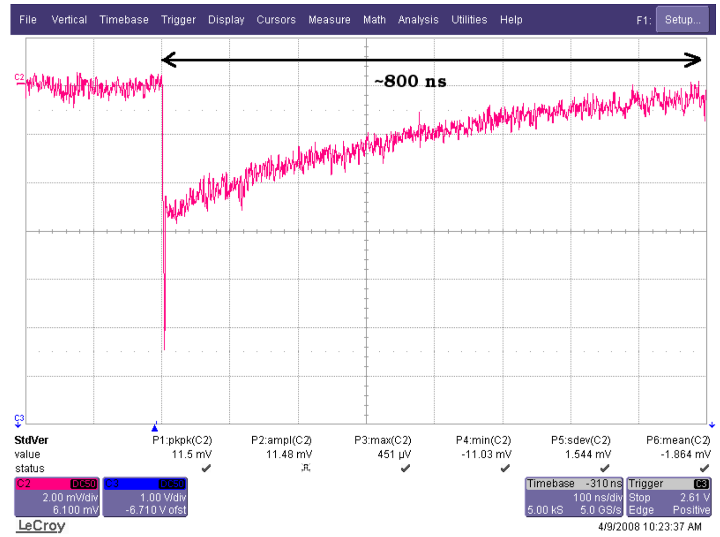
Looks like we can have low dark rate and high QE in the same time

Pulse shape in LN

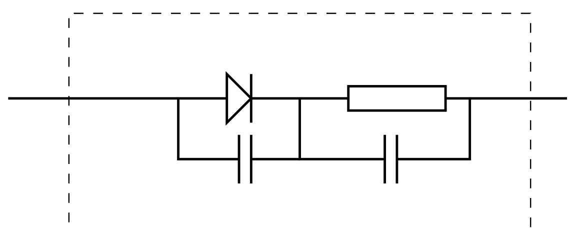
RT



LN

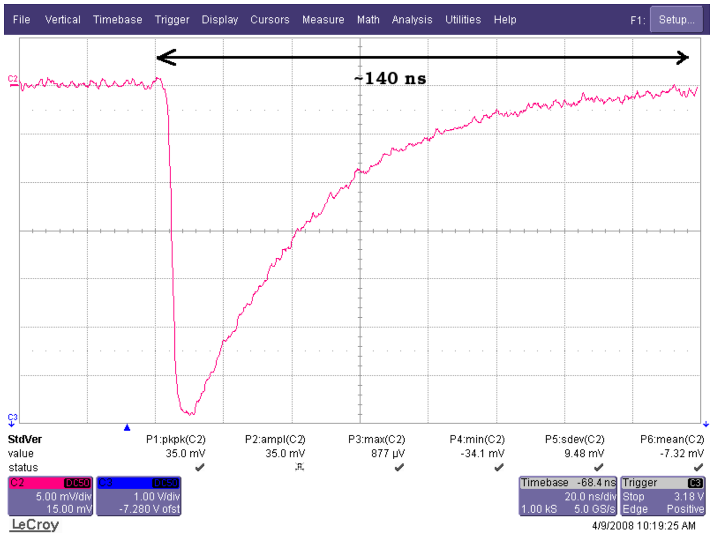


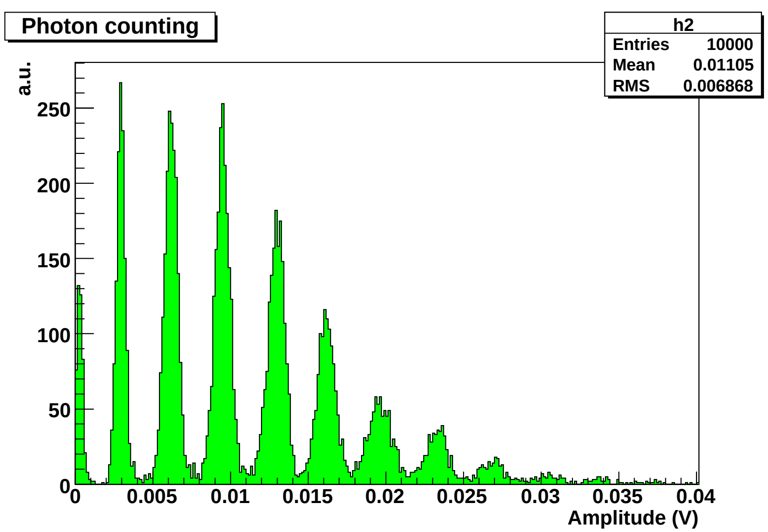
Can be explained by structure of the SiPM. The polysilicon resistor is temperature dependent.



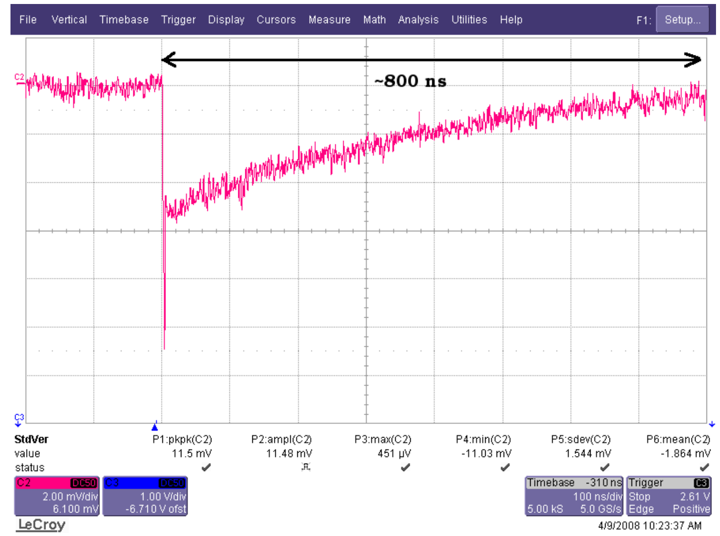
Photon counting

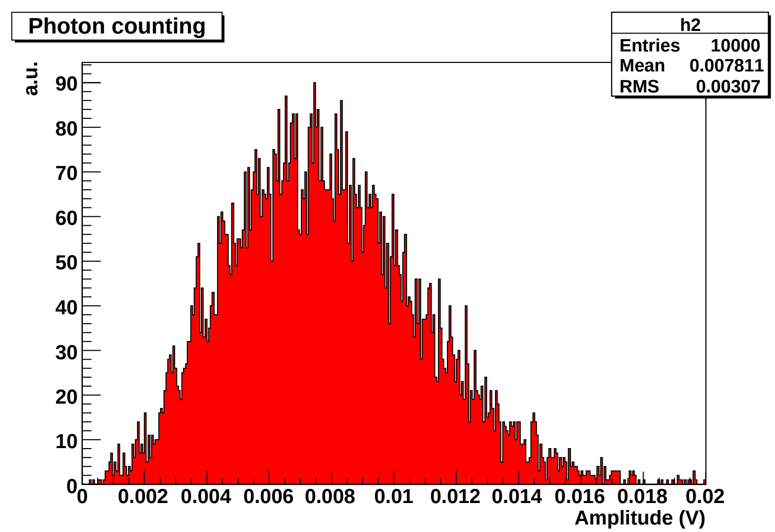
RT





LN

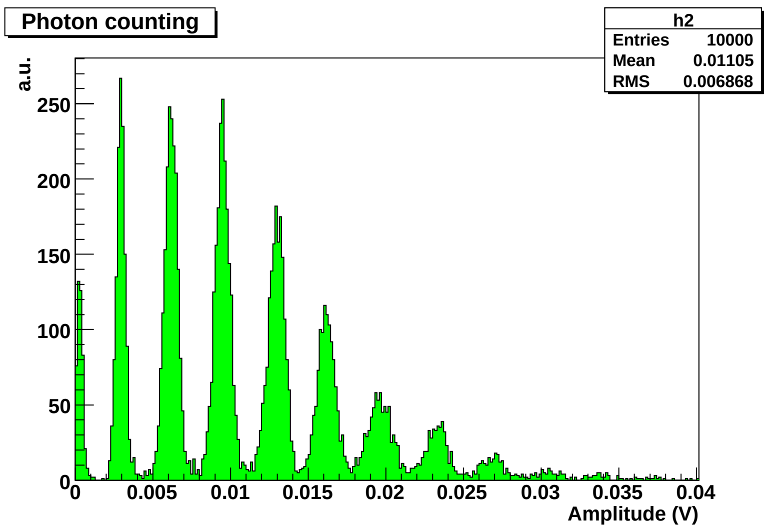




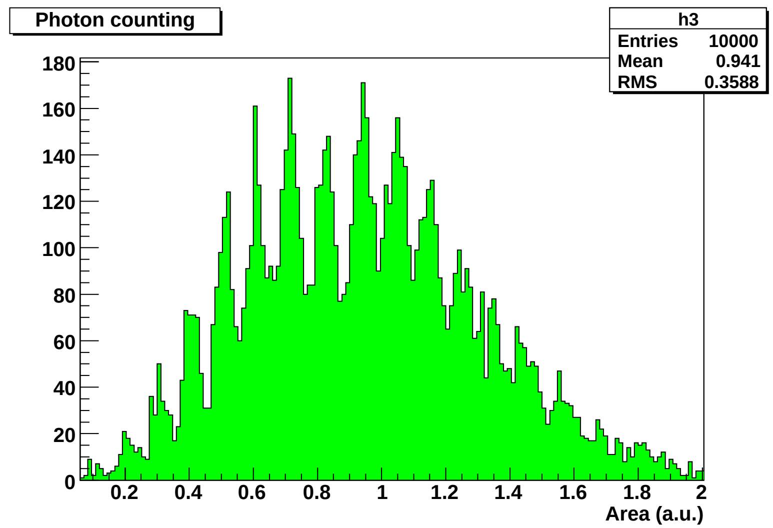
Photon counting

- The peak amplitude cannot be measured accurately
- By integrating the area under the pulse (offline analysis) I could restore the resolution

RT

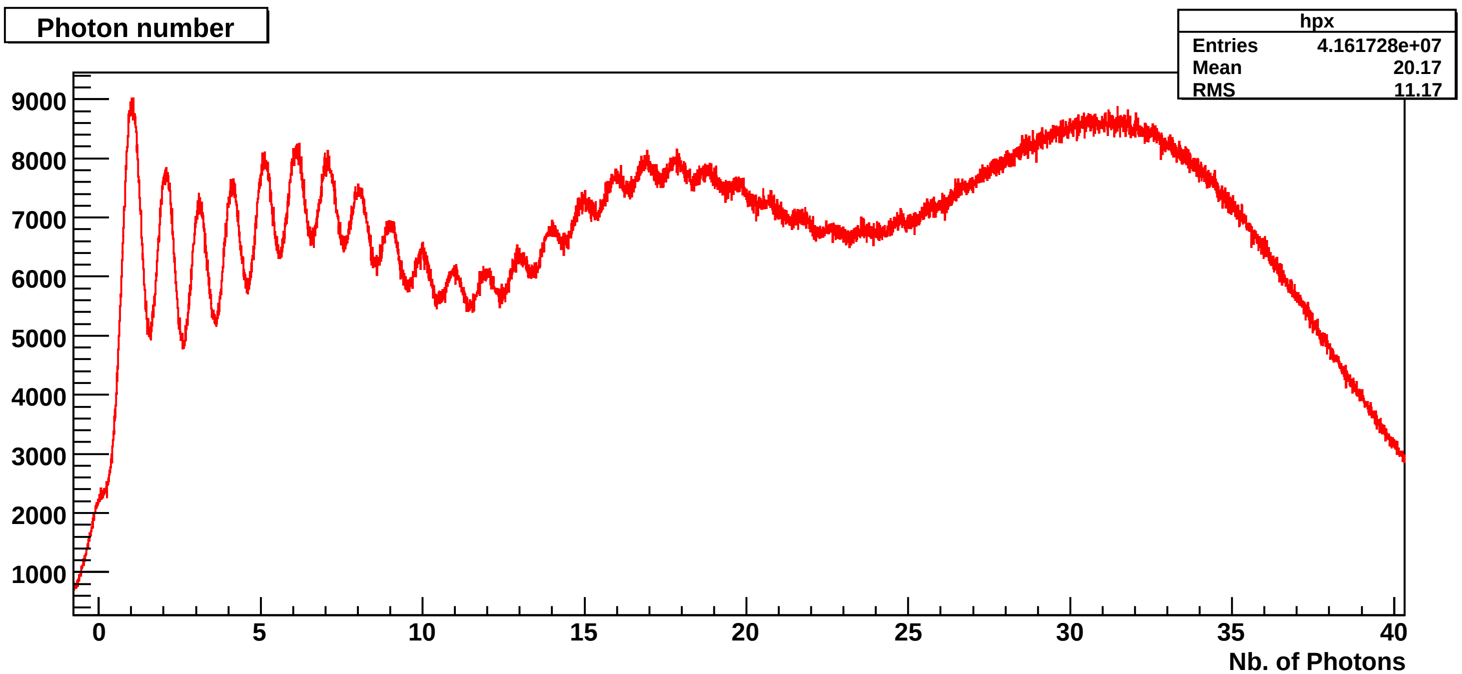


LN



DAQ and SiPM

- PIXIE4 DAQ (75 MHz, 14 bit) can record the pulse-shape without any "*charge amplifier*"
- The resolution is not so good as with the oscilloscope, but I still can distuinghish 20 photon peaks.



MCA spectrum recorded with the DAQ. The light intensity (LED) was increased in more (4) steps.

Si PM robustness

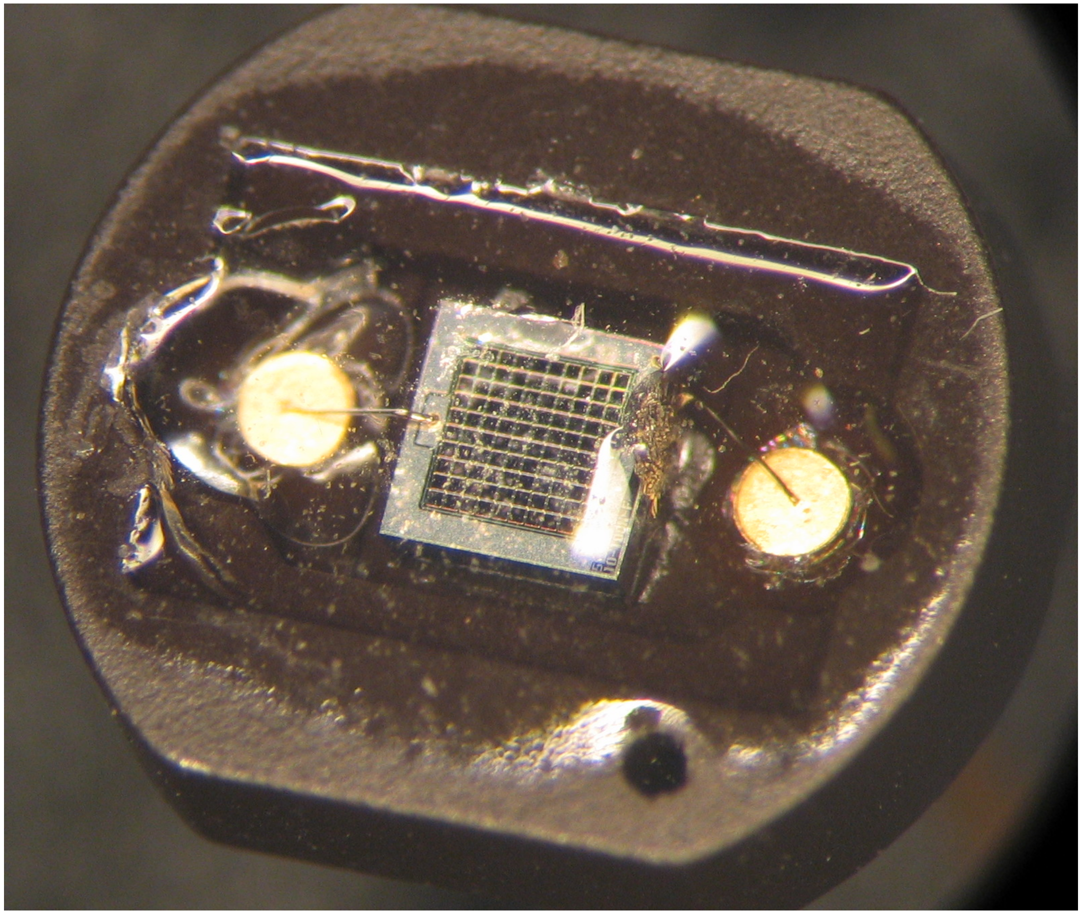
Compared to PMT's and other silicon devices the Hamamatsu MPPC is rather robust
Survives:

- exposure to daylight while operating
- higher operating voltage (by 10 V, higher not tested)
- reverse bias connected in the forward direction
- soldering many times
- many cooling cycles in LN, depends on packaging

Sensitive to mechanical stress only

Damage caused by LN

Si PM is held in place by epoxi resin, which doesn’t like LN temperatures.



One with 100 pixels is gone ... Still, survieved many ($\sim$ 100) cooling cycles

Light detection in LAr
(preliminary)

Direct light detection

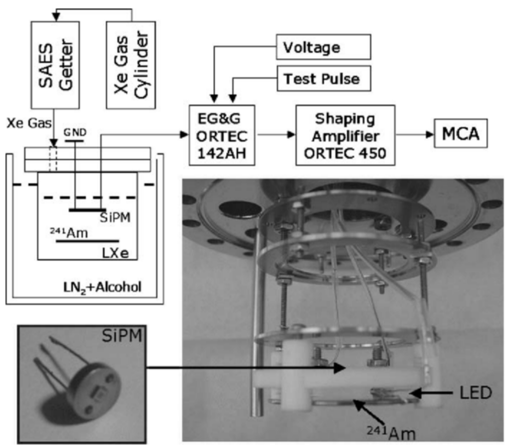
Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Nuclear Instruments and Methods in Physics Research A 556 (2006) 215–218
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Detection of liquid xenon scintillation light with a silicon photomultiplier

E. Aprile[a], P. Cushman[b], K. Ni[a], P. Shagin[b,*]

[a]Physics Department and Columbia Astrophysics Laboratory, Columbia University, New York, NY 10027, USA
[b]School of Physics and Astronomy, University of Minnesota, Minneapolis, MN 55455, USA

Received 3 February 2005; received in revised form 22 July 2005; accepted 30 September 2005
Available online 21 November 2005



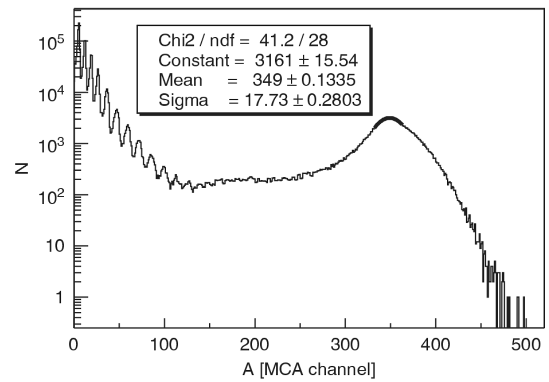
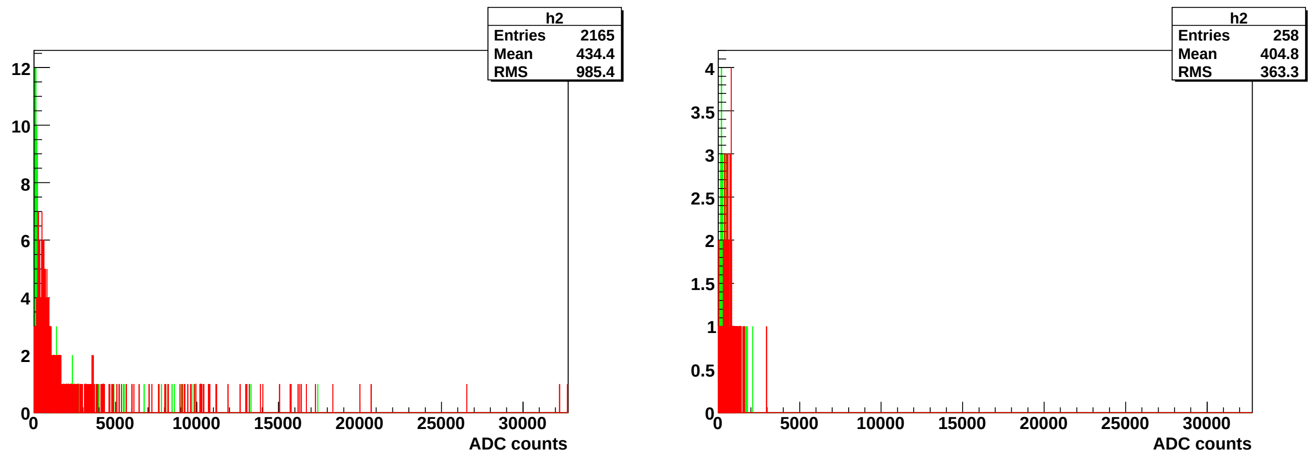


Fig. 5. Amplitude distribution for ^{241}Am α particle scintillations. Fit—Gaussian function.

178 nm, -95^{o}C

Direct light detection

2 SiPM's in LAr at 5 cm distance from a Th228 source. Dark counts removed by coincidence trigger. Overnight measurement (about 14 h)



LAr + Th source left, right LN with no source

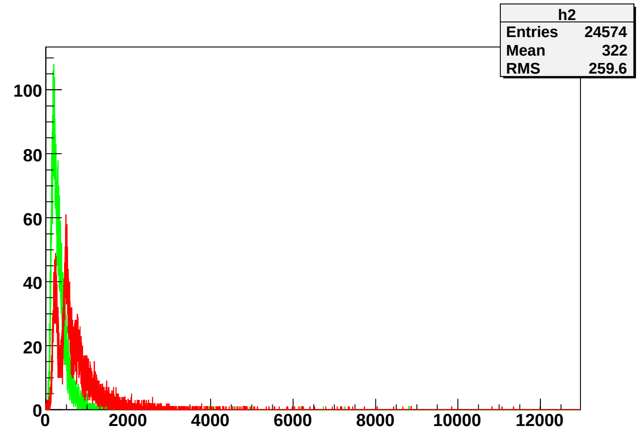
compared to LN

- LN + Th source 2-3 fold increase
- LAr, no source 2 fold increase
- LAr + Th source $\sim$10 fold increase in the countrate with coincidence trigger

VM2000 foil + WLS

Preliminary:

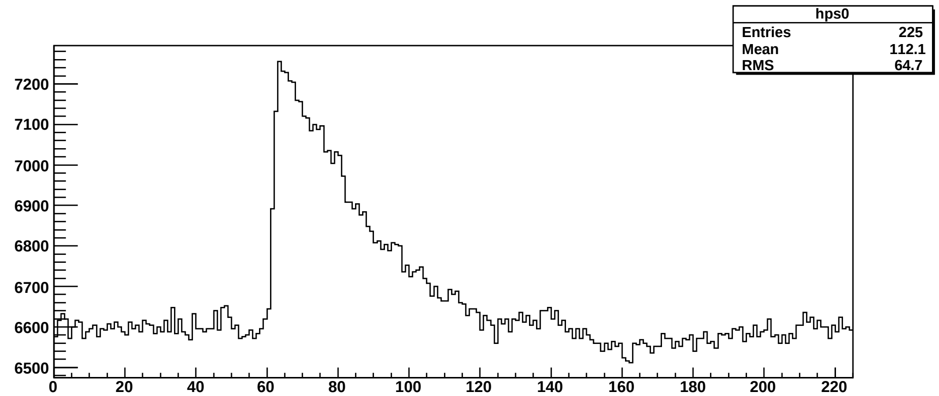
I recieved from Heidelberg VM2000 foil coated with TPB and 1 uncoated + 4 m WLS fiber (far from optimal geometry)

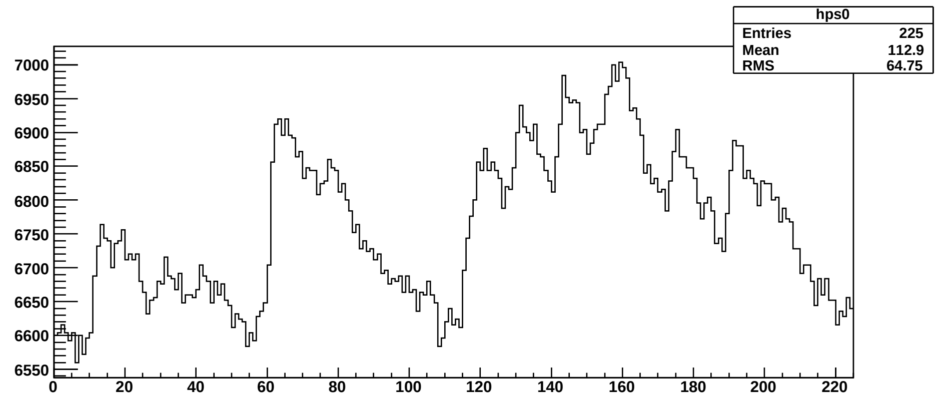


The countrate is 10$\times$ as without WLS + VM2000 (coincidence trigger)

Pulseshape analysis

- Pulse shapes recorded with the DAQ reveals the time structure of the pulses
- Offline analysis gives a better resolution than the DAQ energy filter
- Combined with a peakfinding algorithm we may measure the energy of multiple pulses





Conclusion

SiPM's:

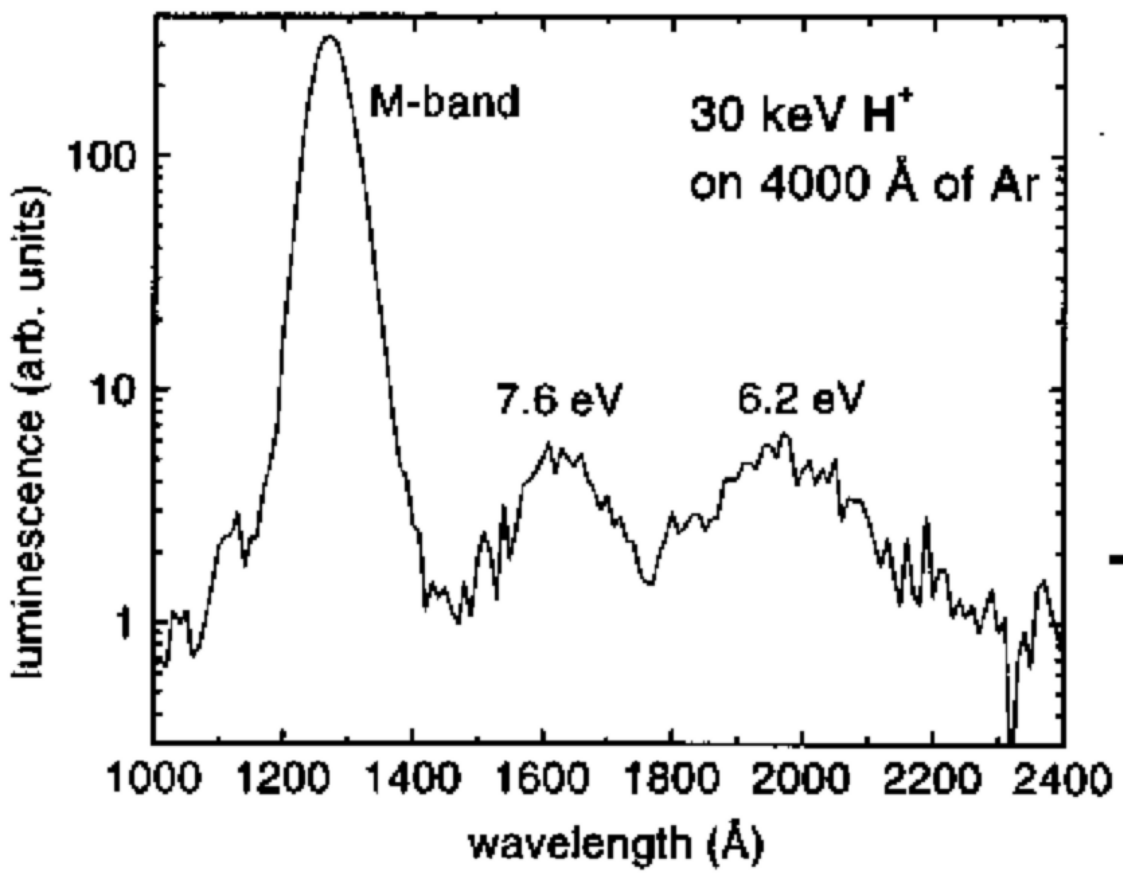
- they are easy to use
- excellent resolution
- they do work in LN
- I could see some light in LAr

A more serious test-setup is under construction:

- 10 more SiPM ordered from Hamamatsu,
- wavelengthshifting fiber ordered from Saint-Gobain,
- TPB + VM2000 we already have
- mechanical parts + electronics ordered in the workshop

Goal is to have an active volume of 20l of LAr

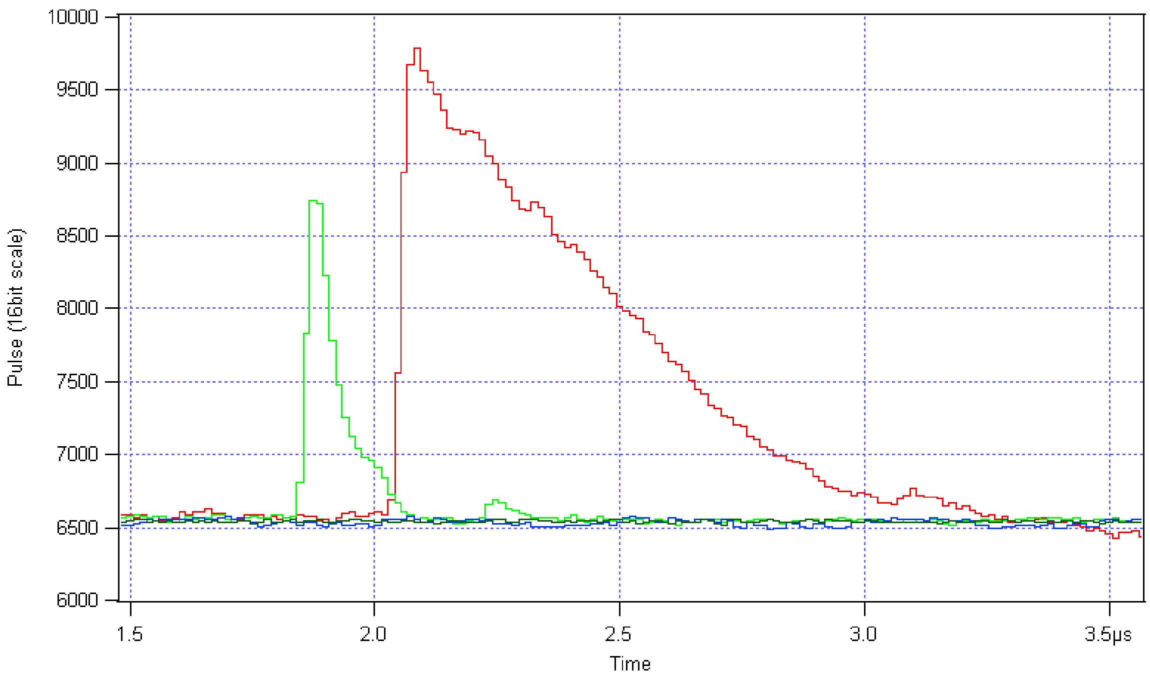
Backup slides



n(LN) = 1.2, n(LAr)= 1.24, n(H2O)=1.33

DAQ and SiPM

- PIXIE4 DAQ (75 MHz, 14 bit) can record the pulse-shape without any "*charge amplifier*"
- Cooling the SiPM gives longer pulse, better for the DAQ



Typical pulse shapes for the 1600 and 100 pixel Si PM. Recorded with the DAQ.

VM2000 + Th228

Off-line energy measurement and expected Th spectrum (Geant4)