E.Popova

EUDET CALO meeting, DESY, December 8-9, 2005

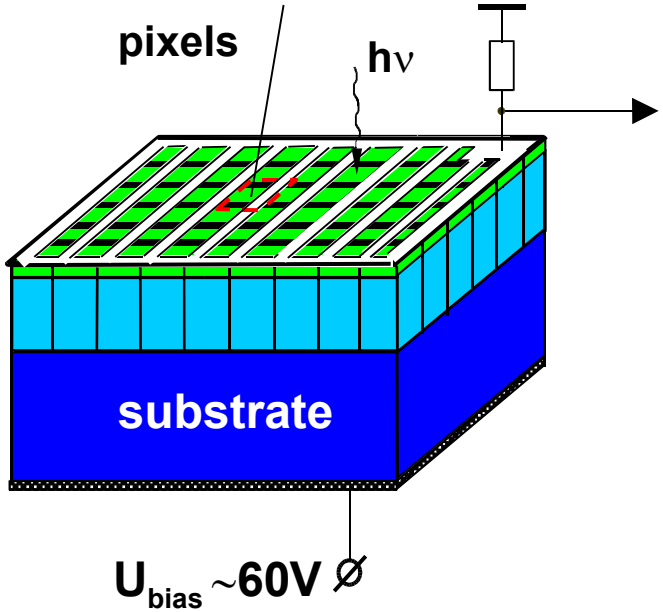
Future SiPM's developments

MEPhI&PULSAR

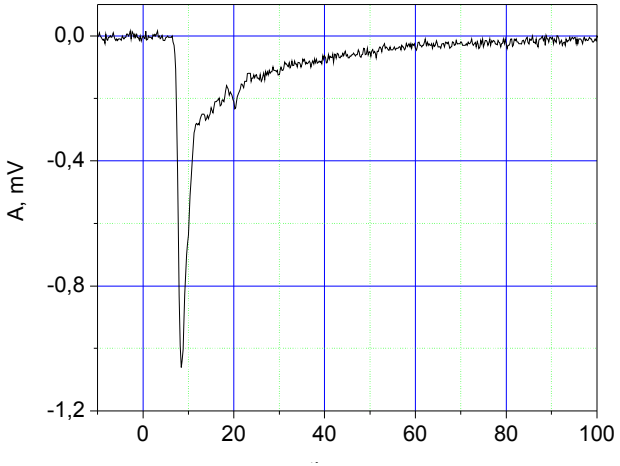
In framework of CALICE
collaboration and ISTC project 3090

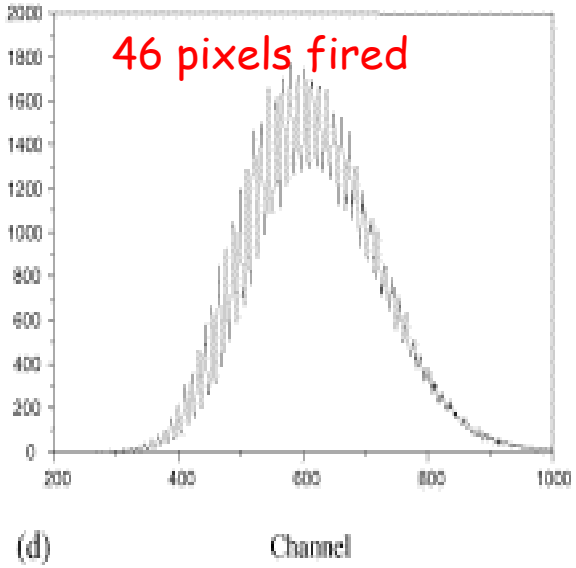
Silicon photomultiplier (SiPM)

Multy pixel device with common readout



One pixel signal



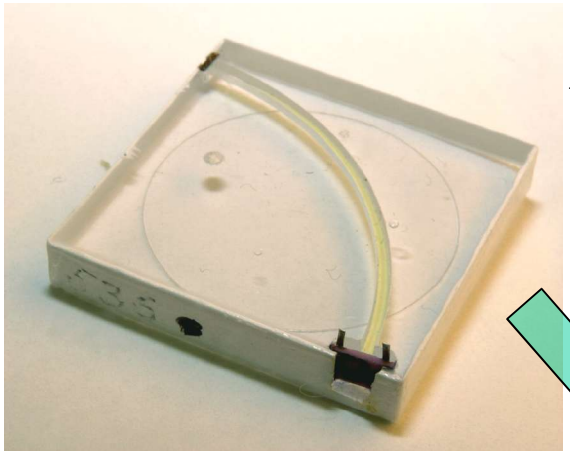


SiPM main features:

Each pixel operates in self-quenching geiger mode
Number of pixels: 1156
Recovery time/pixel $R_{pixel}*C_{pixel}$~100÷500 ns

One pixel – digital signal (0 or 1)
SiPM at whole – analogue device

SiPMs in Tile HCAL prototype

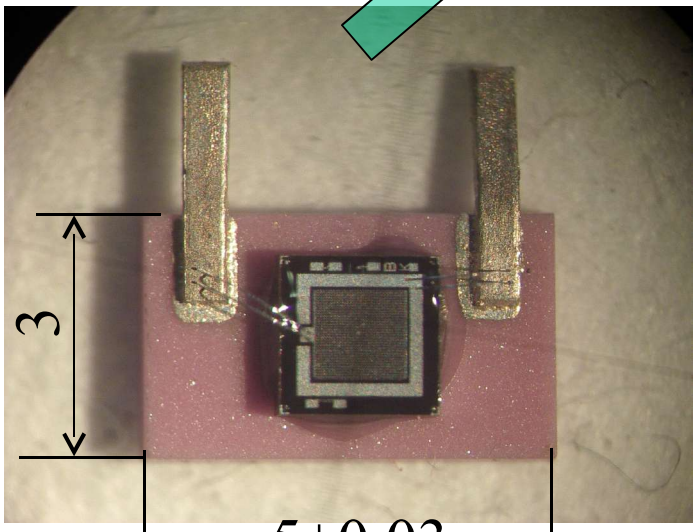


Tile with milled groove for WLS and precise hole for SiPM installation

SiPMs

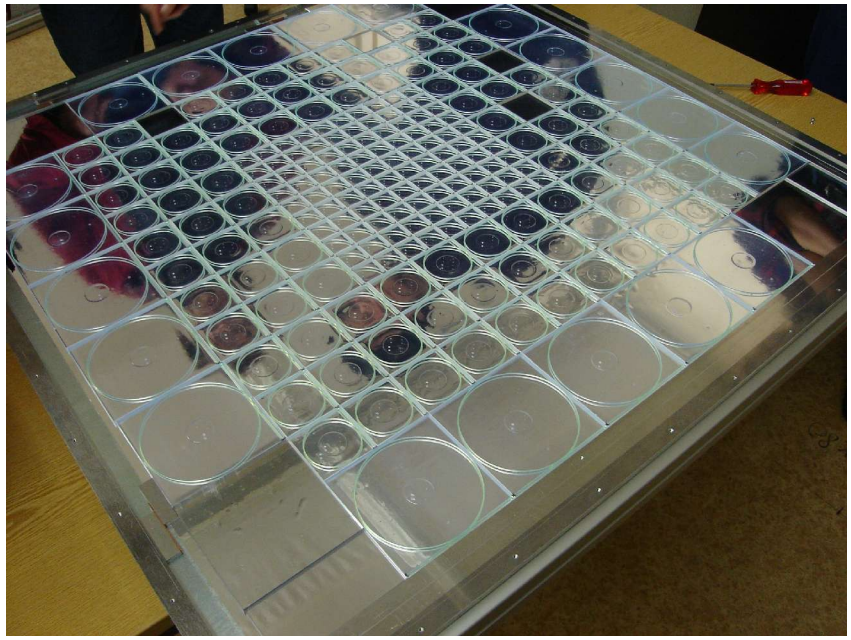
1156 pixels

1x1 mm^2



Precise ceramic plate

The first HCAL prototype cassette



40 Cassettes will be required

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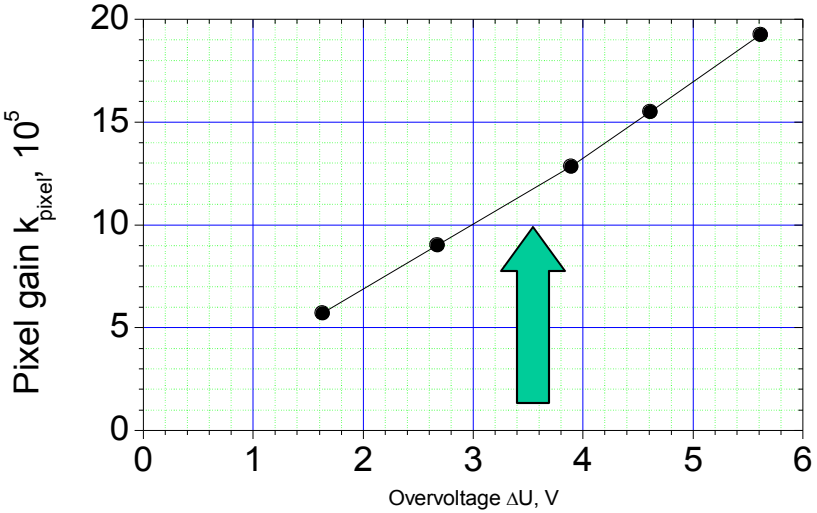
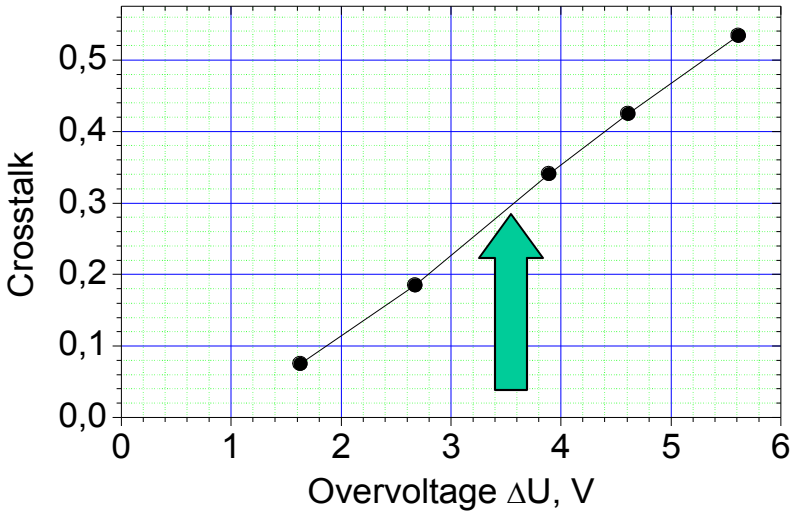
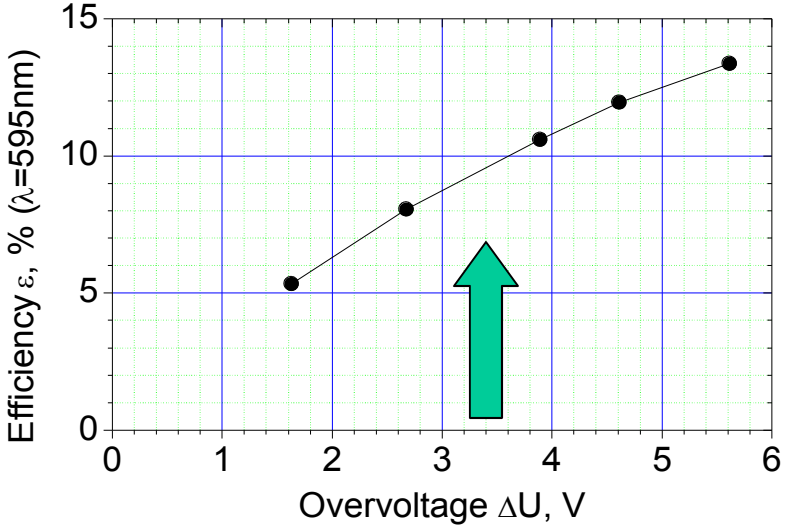
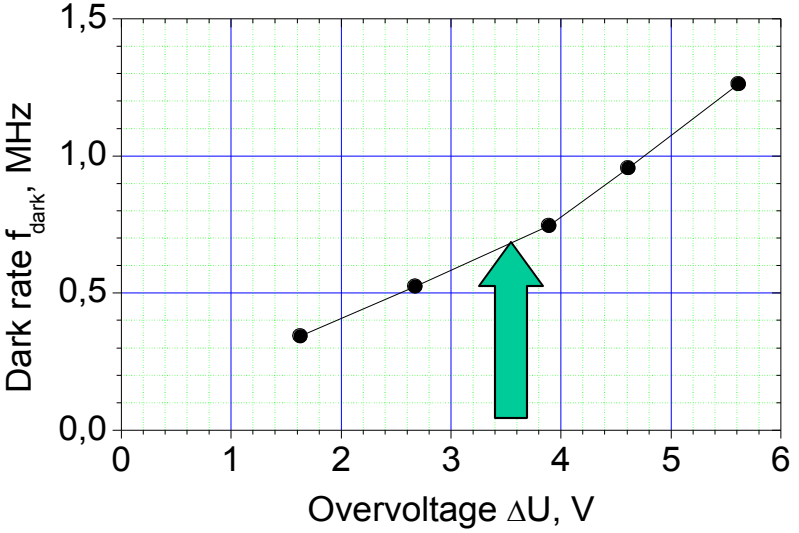
Typical HCAL prototype SiPM parameters









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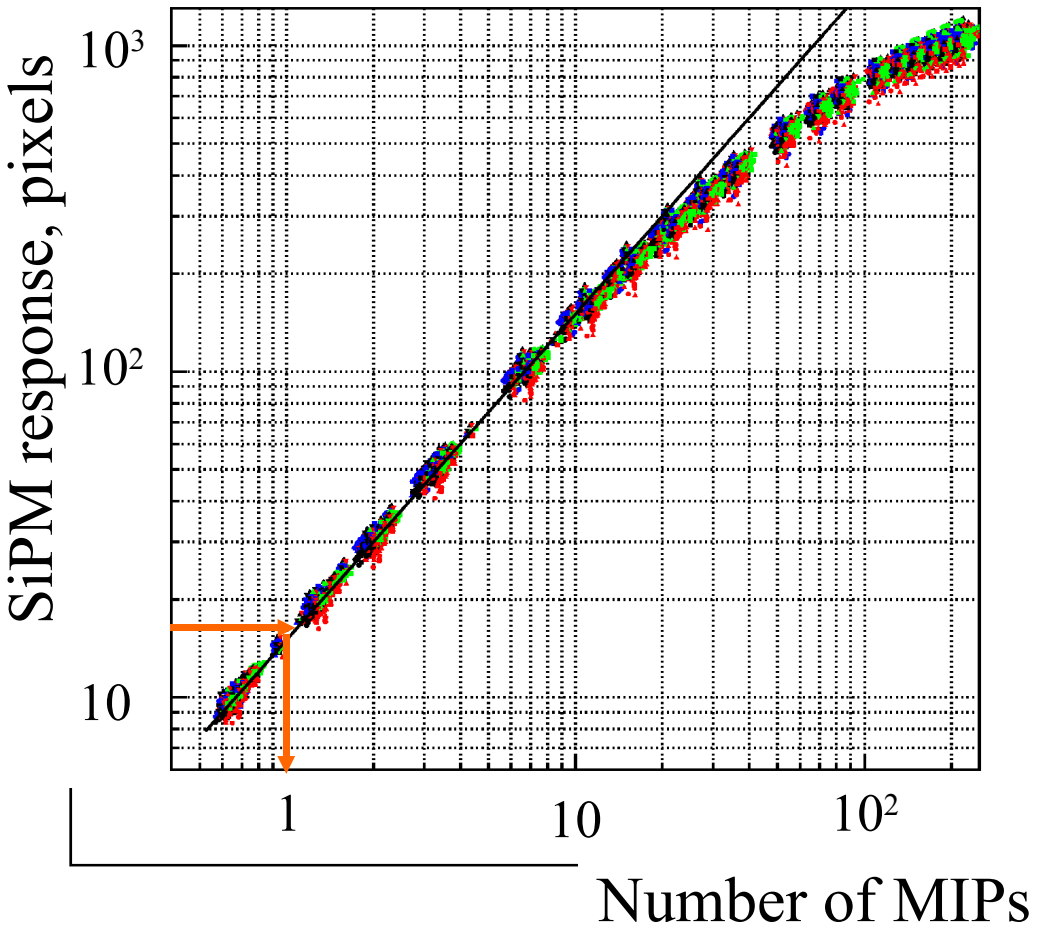
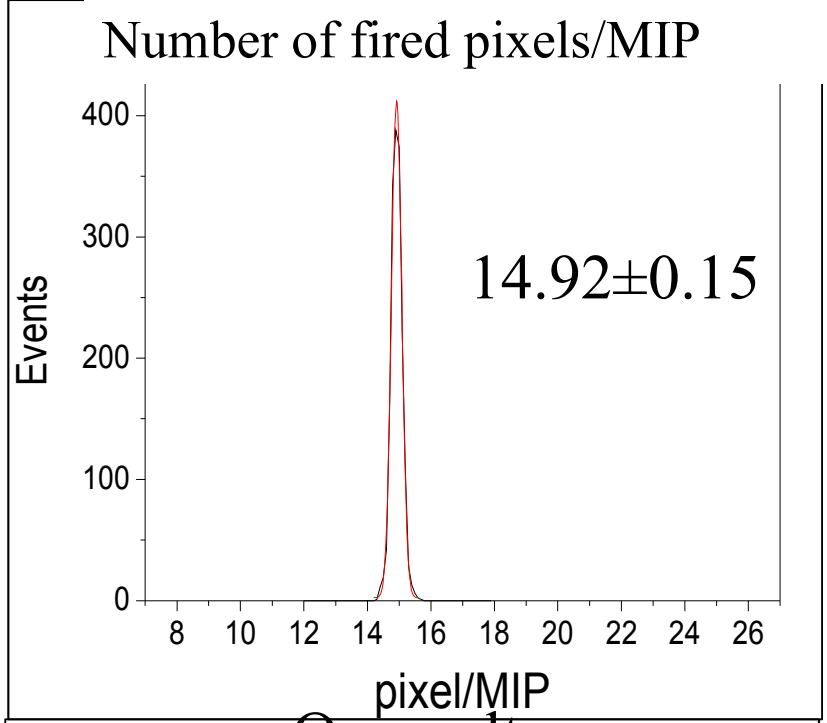
ITEP test procedure

Distributions for tested SiPMs

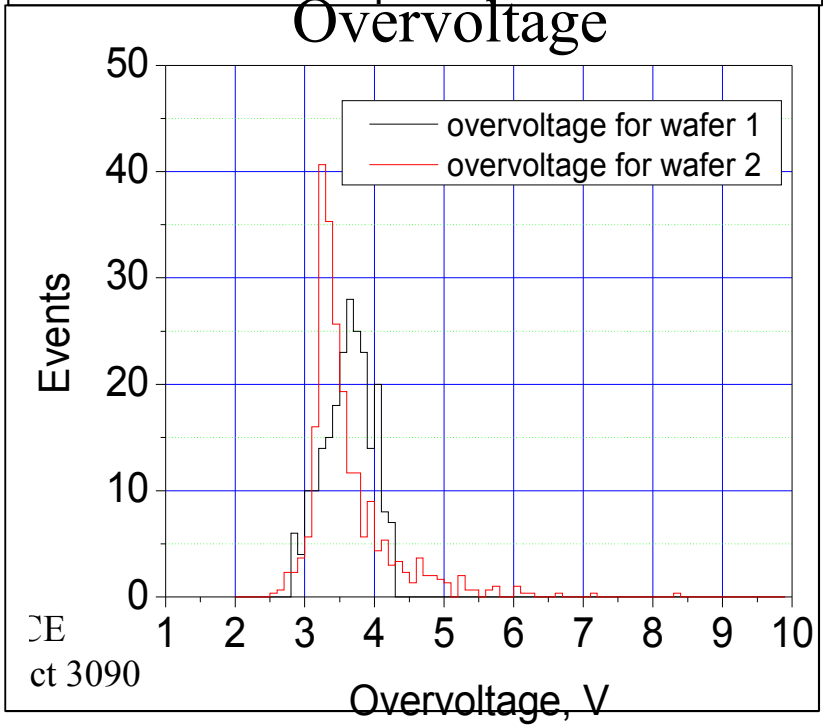
SiPMs response function



Number of fired pixels/MIP



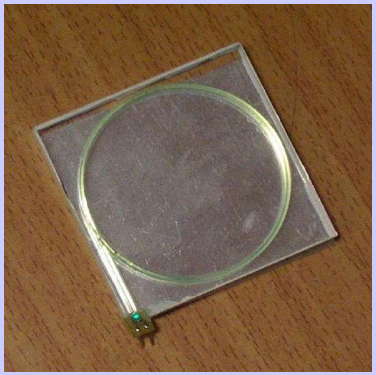
Overvoltage



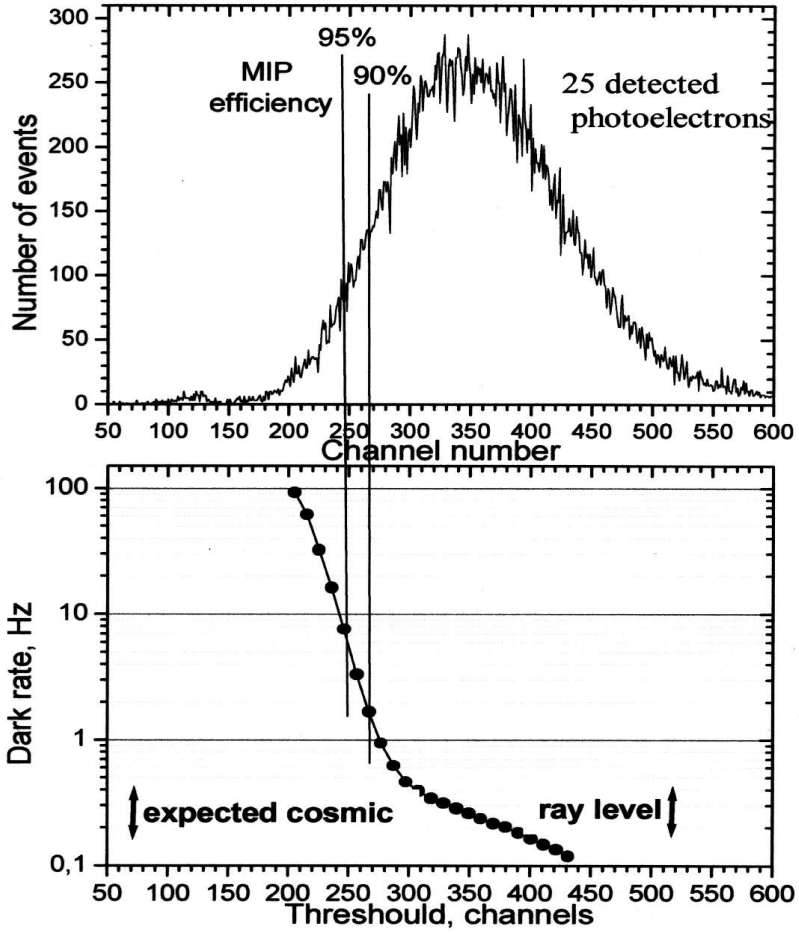
MIP particles registration

MINICAL system 25 fired pixels/MIP

Source tests

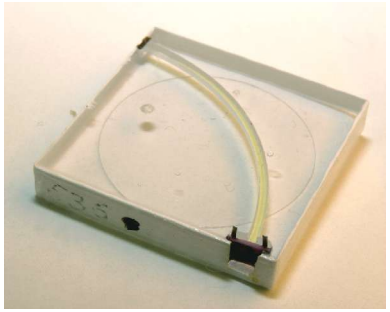


5x5x0.5cm^3 tile



For prototype SiPM-tile assembly

We have 15 pixels/MIP

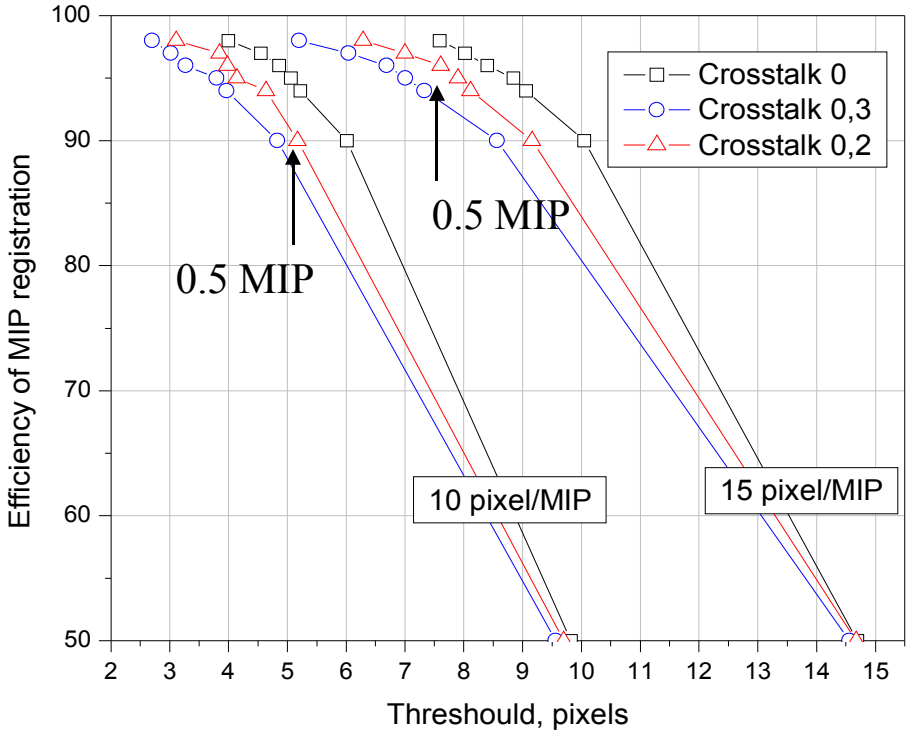


3x3x0.5cm^3 tile

Key's questions:

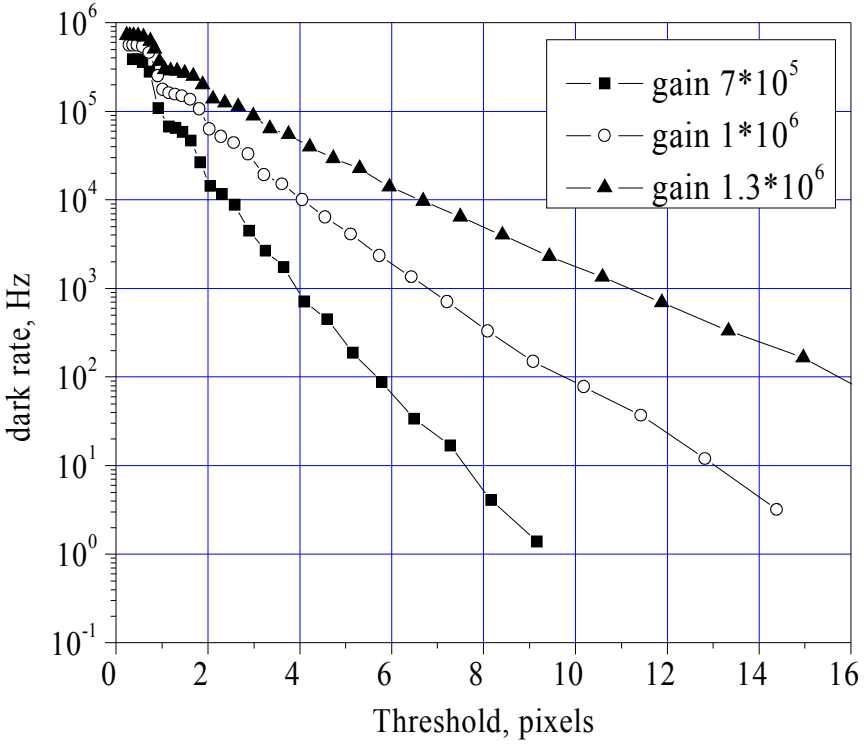
- Efficiency of MIP registration
- Noise registration probability

Efficiency of MIP registration for different MIP signals and interpixel crosstalk (MC)



Crosstalk violates the pixels independence and leads to non-Poissonian behaviour of the fired pixels distribution

The dark rate of the SiPM for different gains in dependence on the level of the threshold



Crosstalk increases the manypixel firing probability

We need to suppress crosstalk

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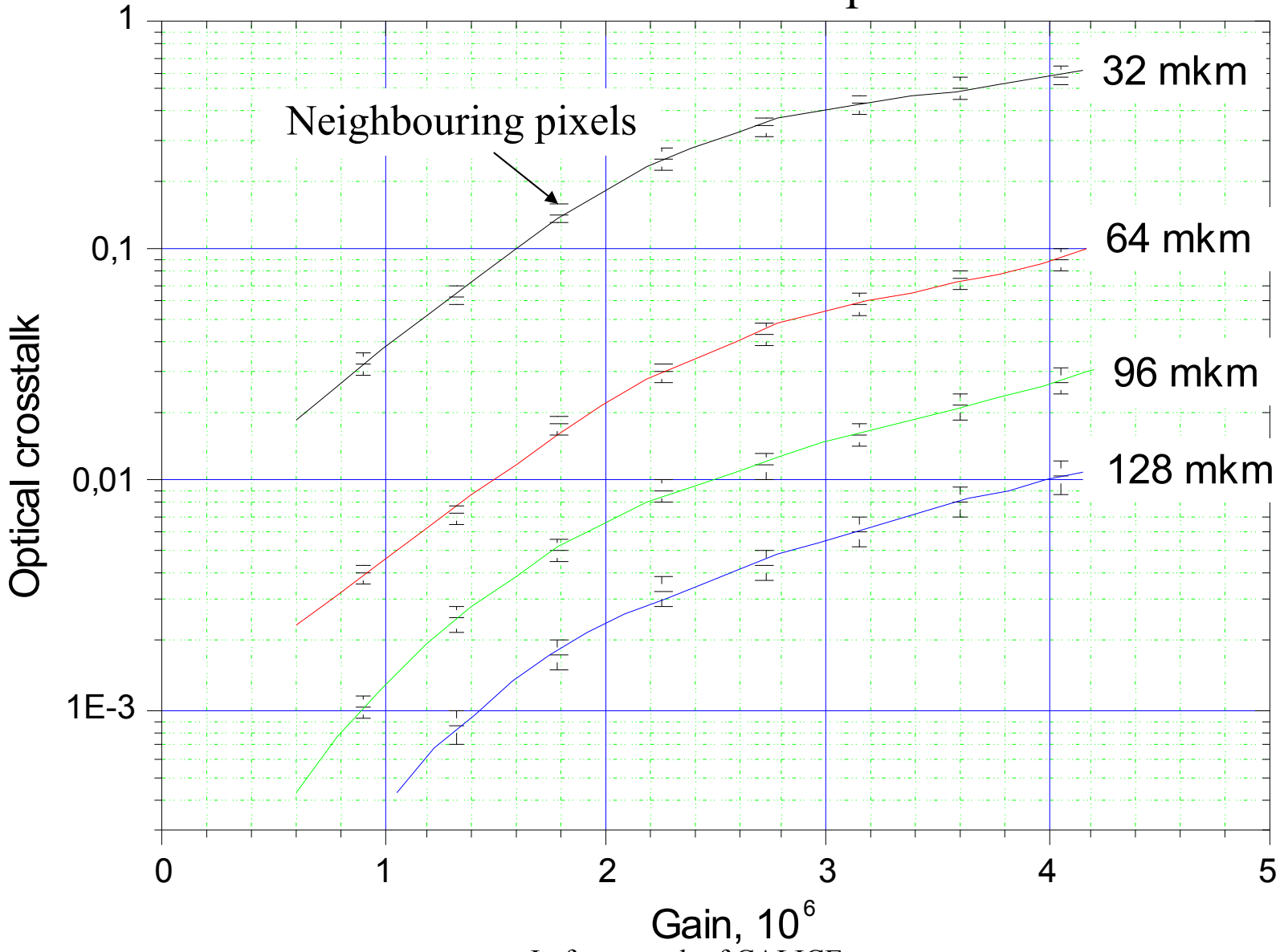
Dependence of interpixel crosstalk on gain for different distance between pixels



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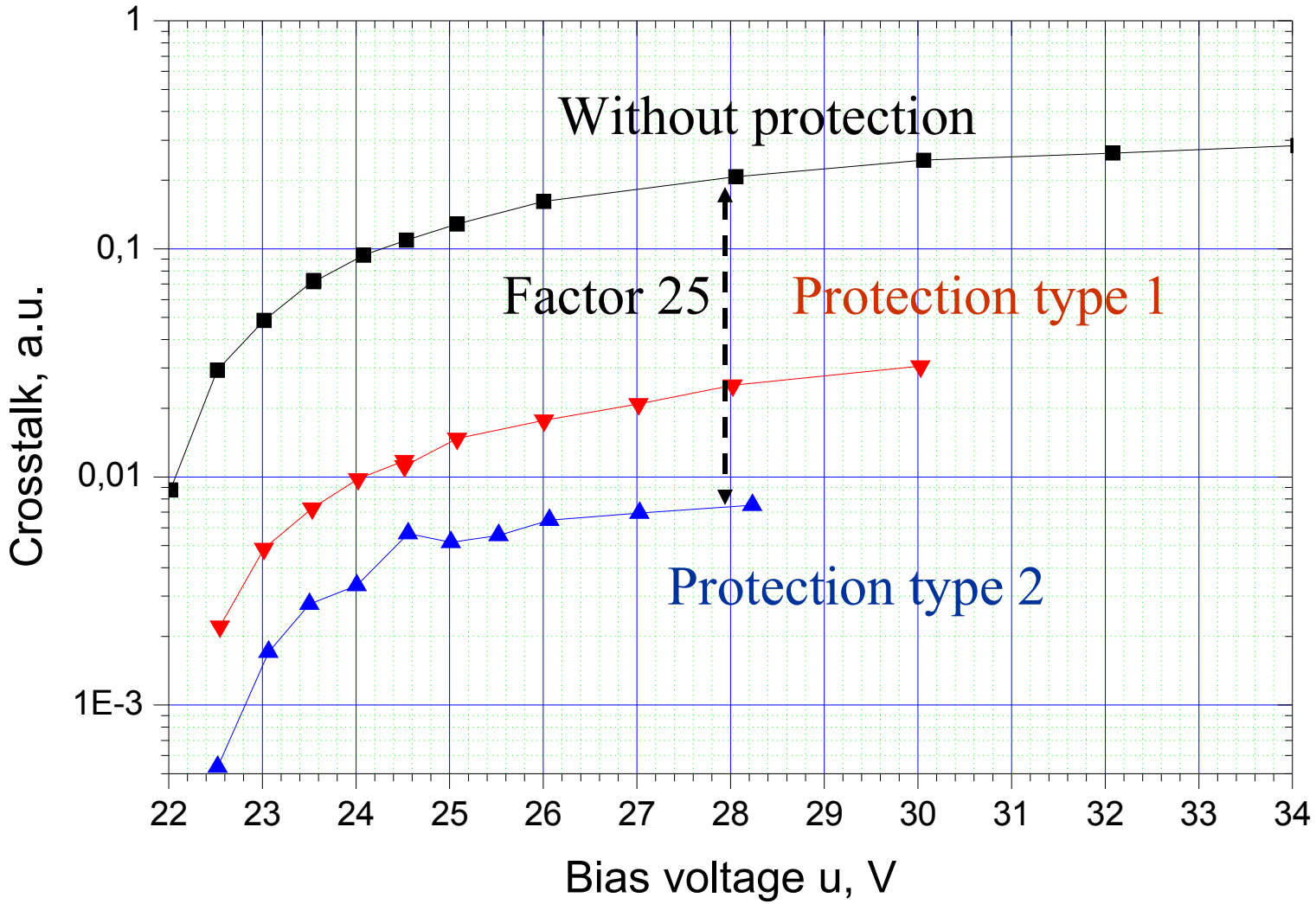
Crosstalk protection



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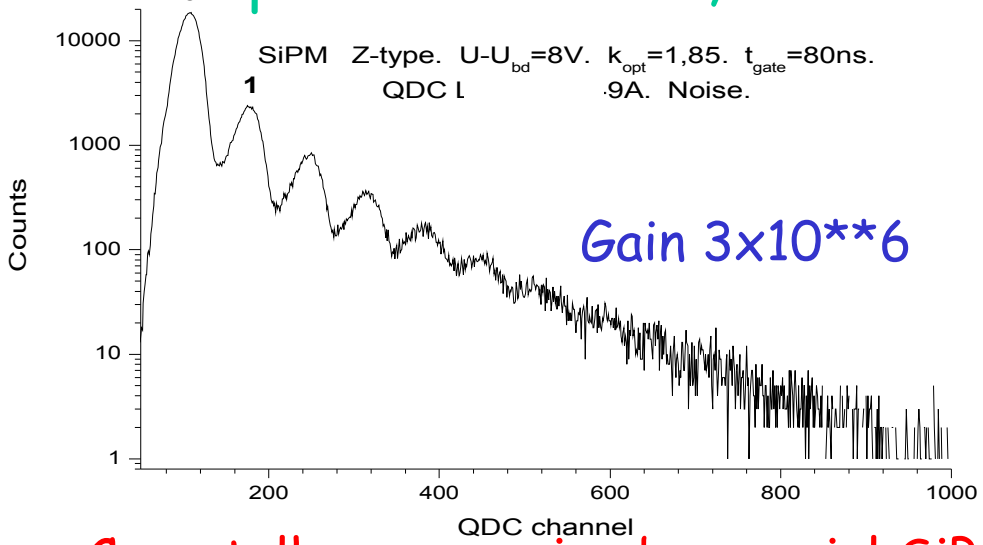
Optical crosstalk,SiPM 1x1 mm2,dark noise



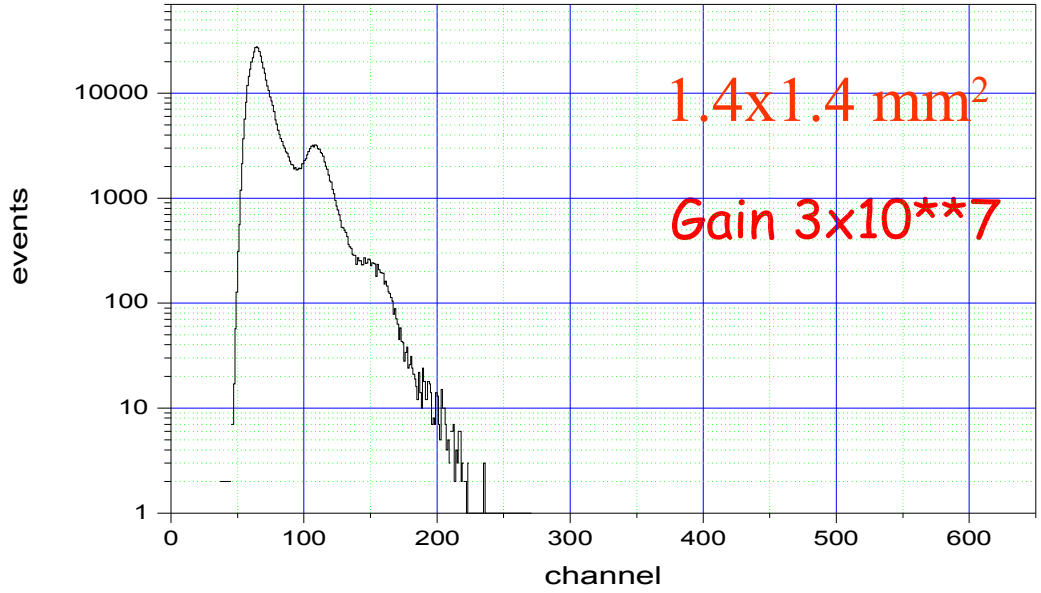
Gain 3x10**6

Crosstalk==>non-Poissonian distribution:

pixel fired/phe=1.7

ENF=1.6

Crosstalk suppression by special SiPM topology: PRELIMINARY!



Poisson distribution:

pixel fired/phe= 0.98+-0.03

ENF= 0.97+-0.05

B.Dolgoshein,'Large area SiPM's...'

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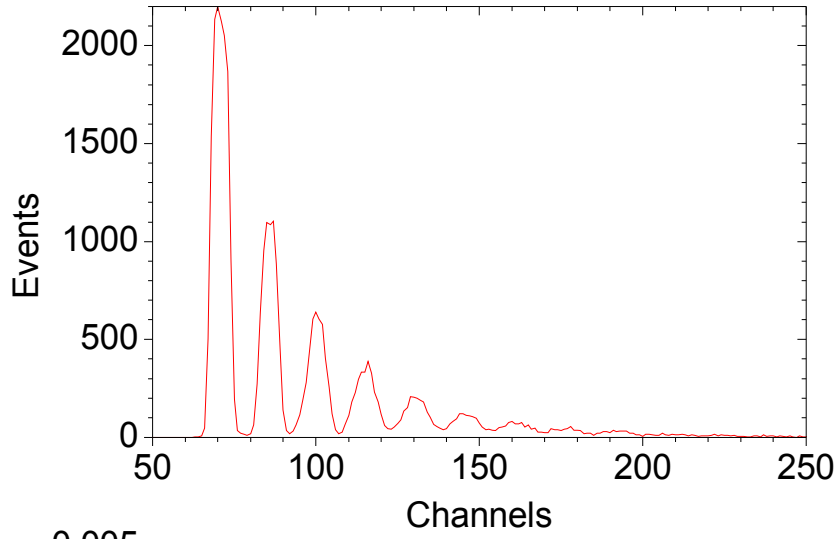
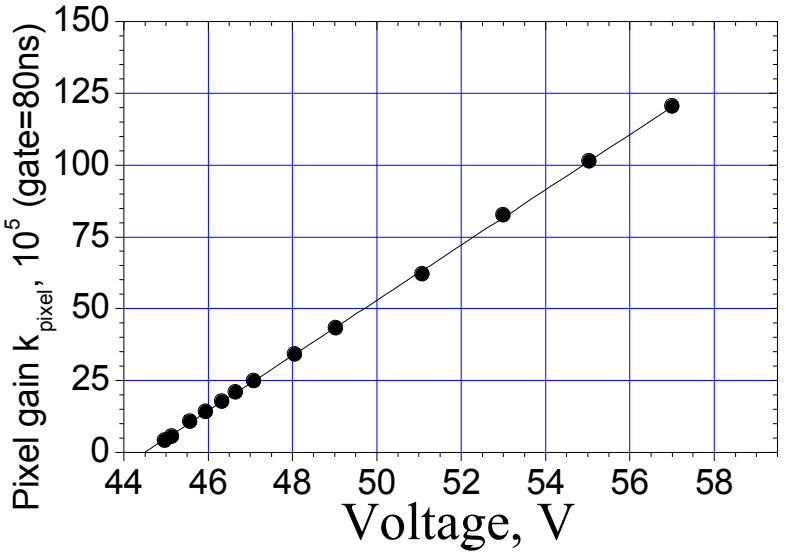
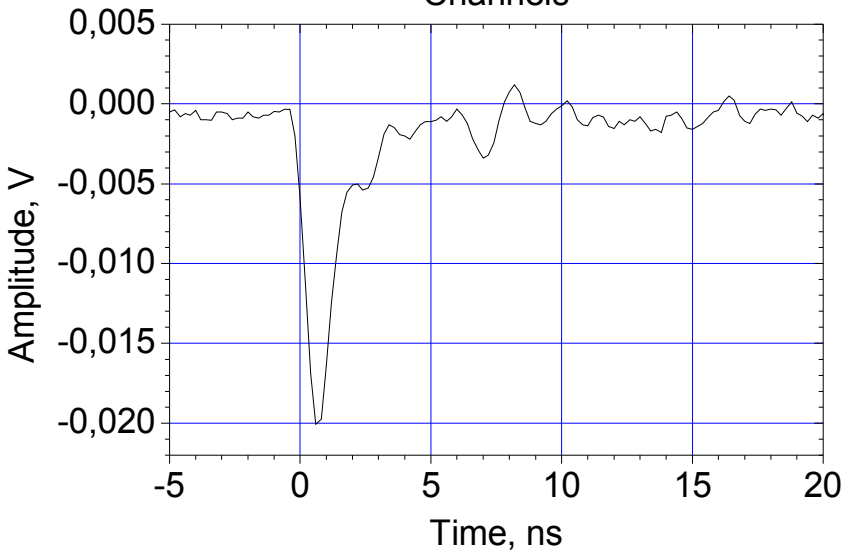
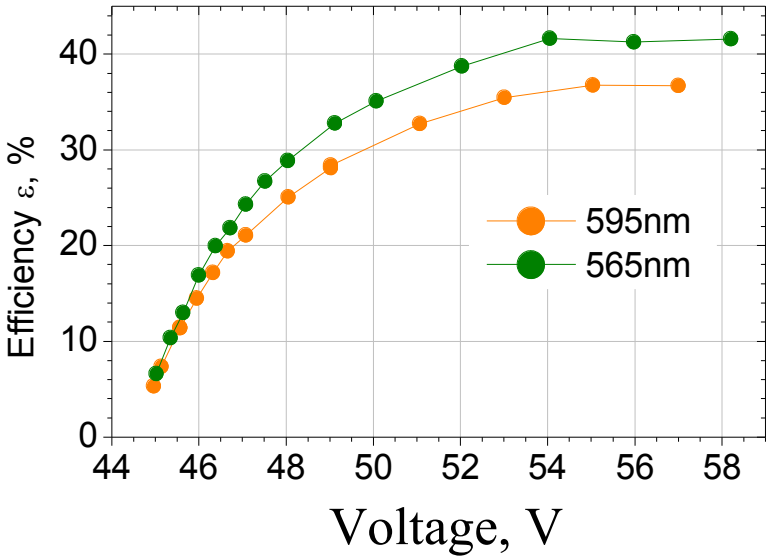
1.4x1.4mm^2 SiPM characteristics
110 pixels T=-60C









Geometrical factor 50%

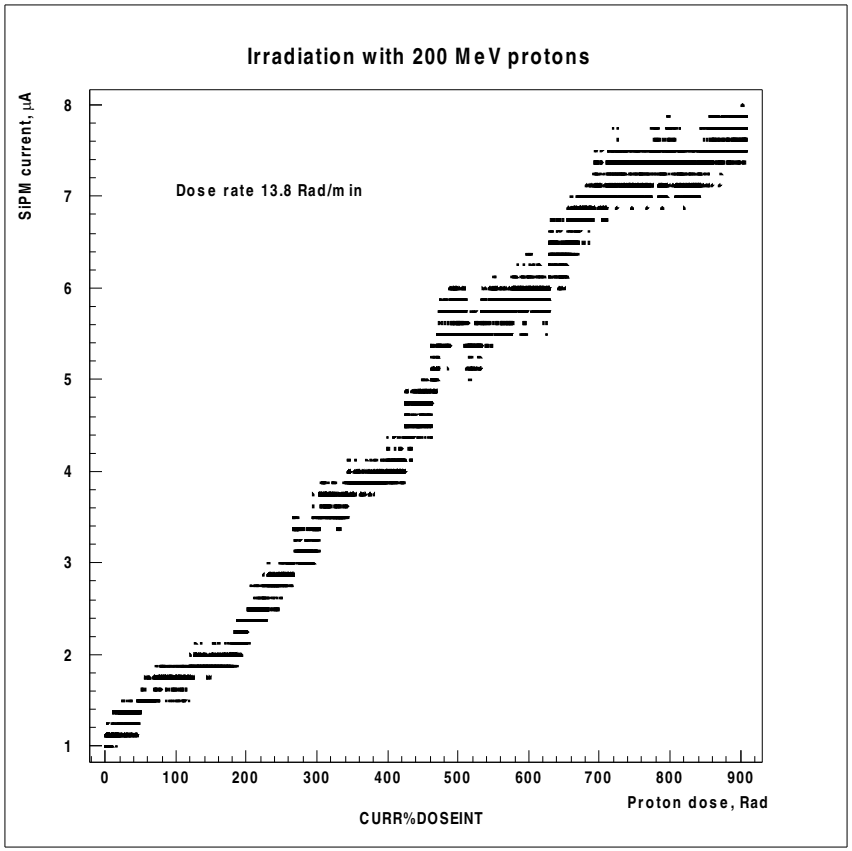
Efficiency of light registration 40%

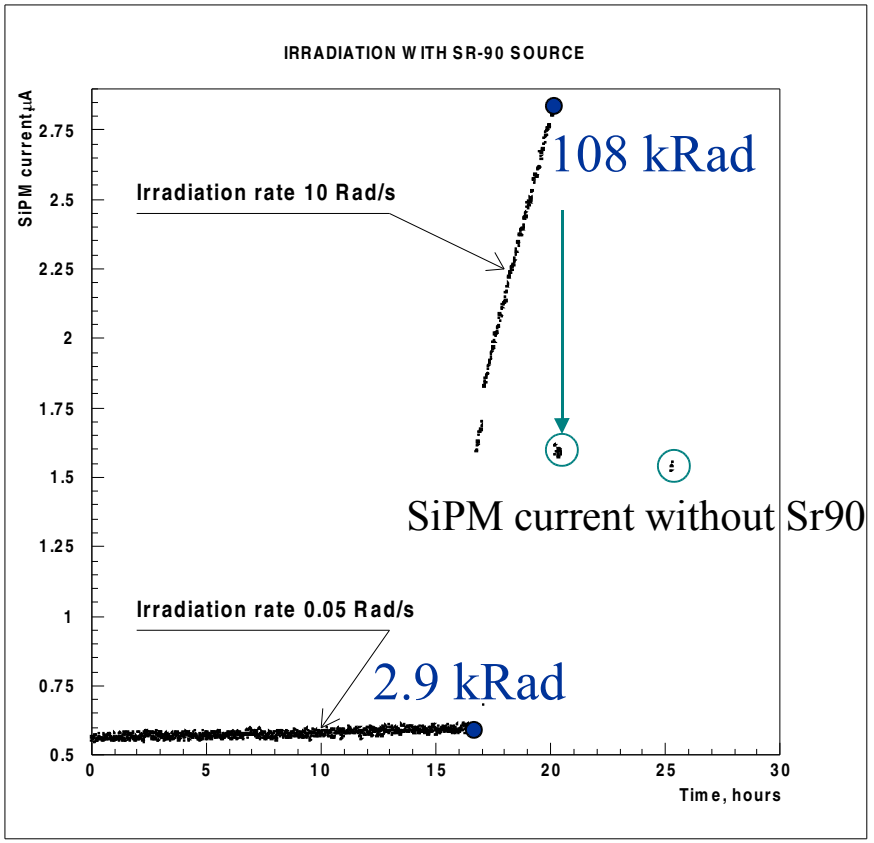
SiPM radiational hardness

preliminary results

Under investigation at ITEP now:

protons electrons neutrons gammas





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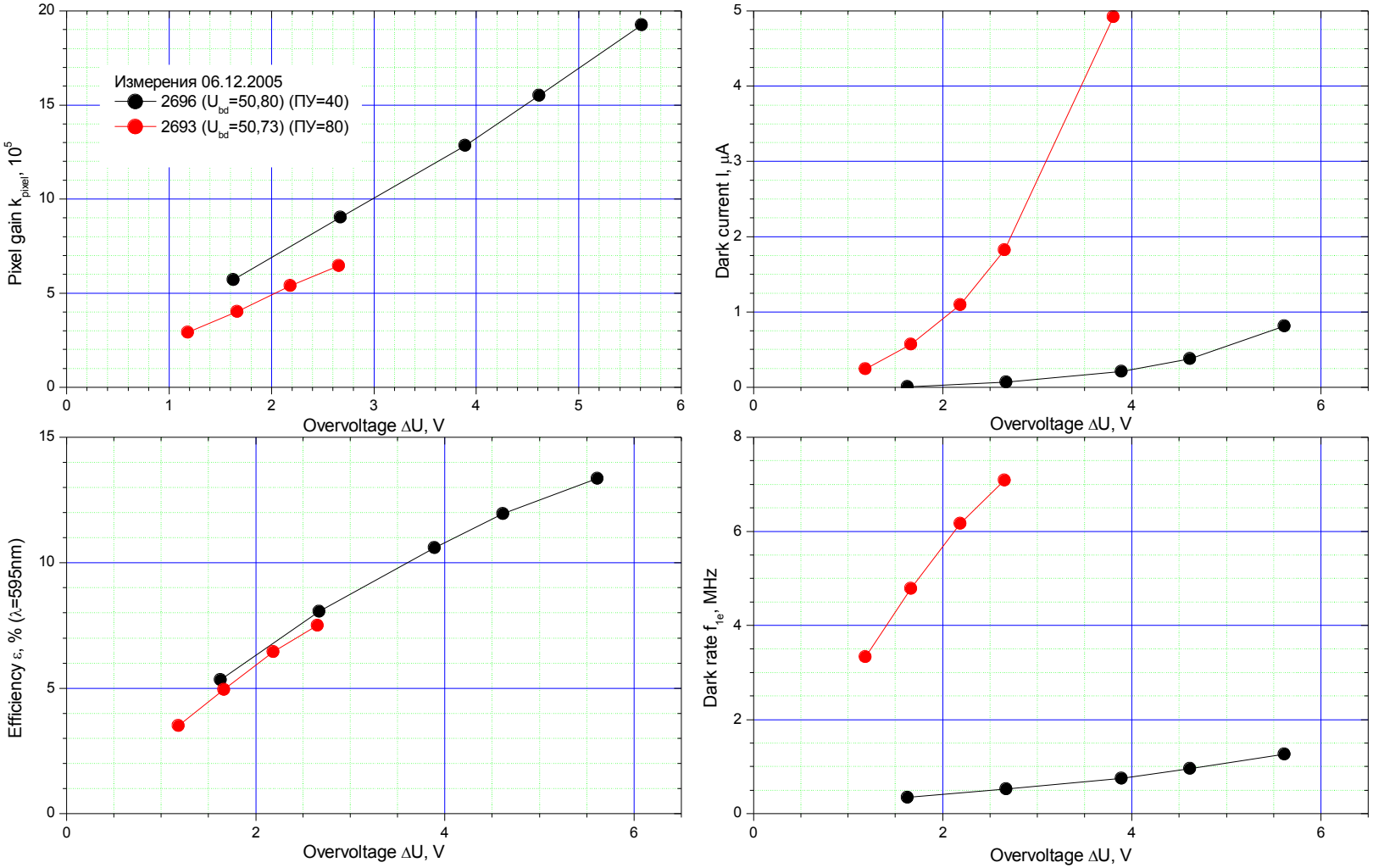
SiPM's characteristics **without irradiation** and **after 900 rad proton 200 MeV**



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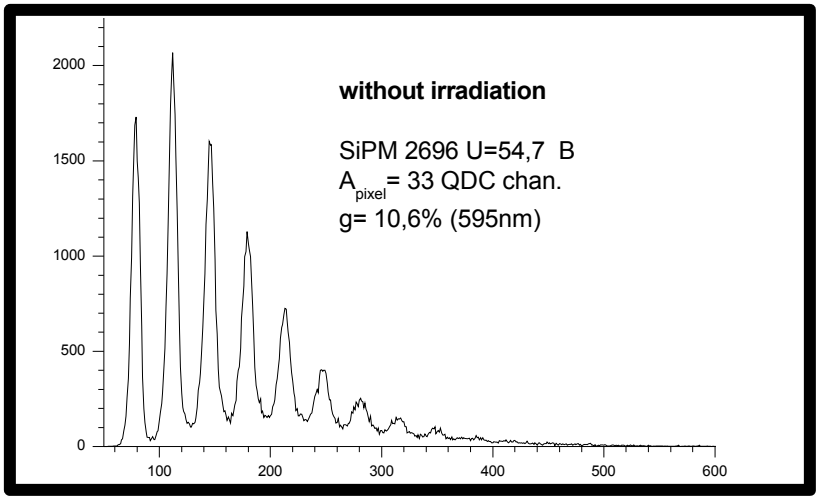
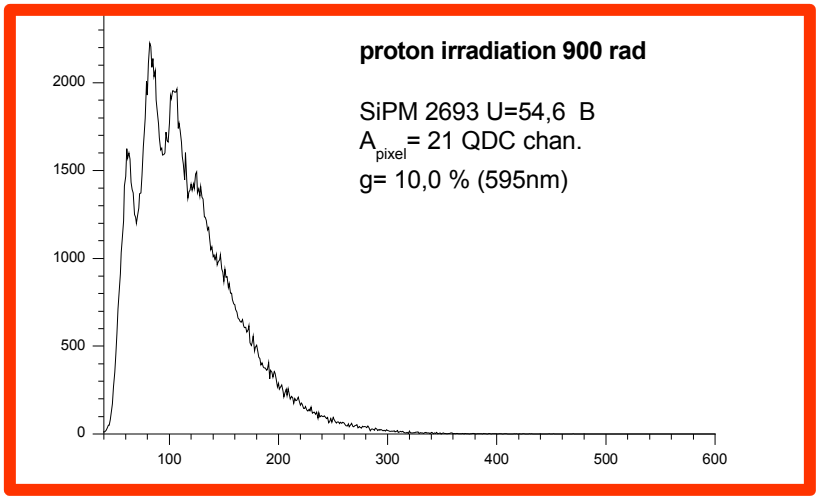
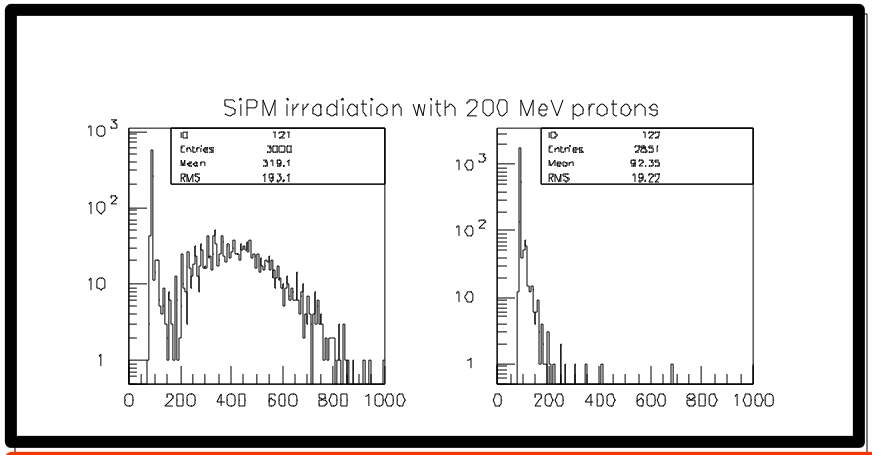
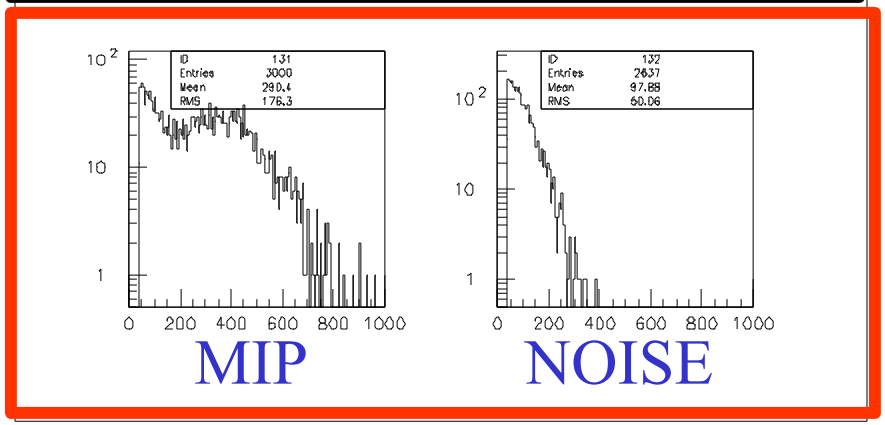
SiPM single pixel spectra and MIP registration **without irradiation** and **after 900 rad proton 200 MeV**









Single pixel resolution deterioration

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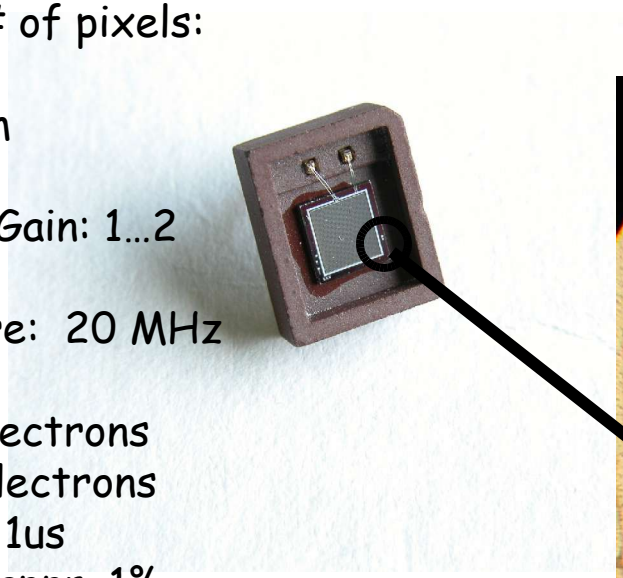
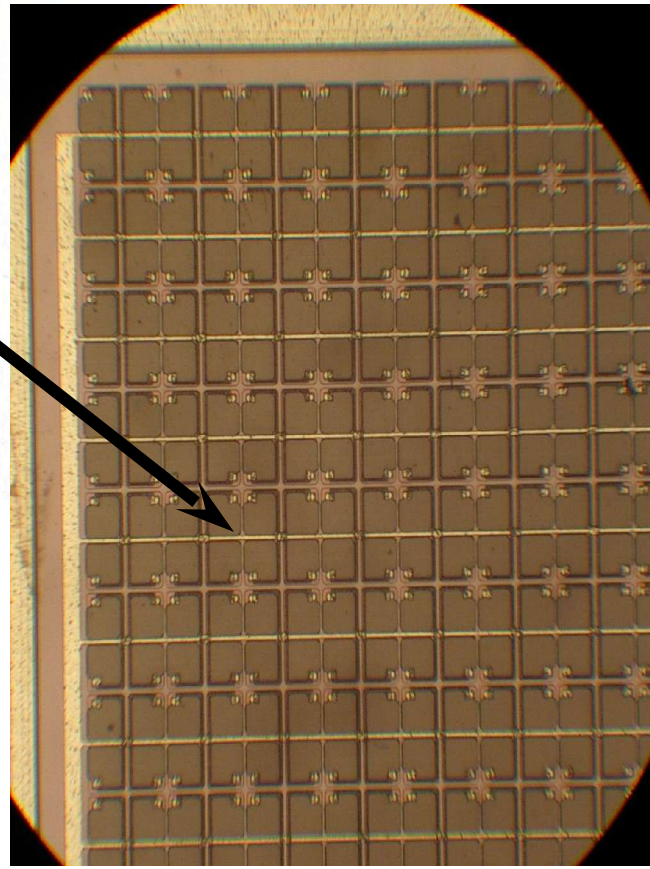
Noise events probability increasing

New proposal for HCAL based on large SiPM

3x3mm SiPM parameters

- Sensitive area : 3x3 mm2 # of pixels: 5625
- Depletion region: appr. 1 μm
- Pixel size: 30 μmx30 μm
- Working voltage: 20…25 V Gain: 1…2 x10**6
- Dark rate.room temperature: 20 MHz
- SiPM noise(FWHM):
  room temperature 5-8 electrons
  -50 C 0.4 electrons
- Single pixel recovery time: 1us
  After pulsing probability: appr. 1%
- Optical crosstalk: appr. 30 - 50 %
  ENF: appr. 1.5-2.0(overvoltage dependent)





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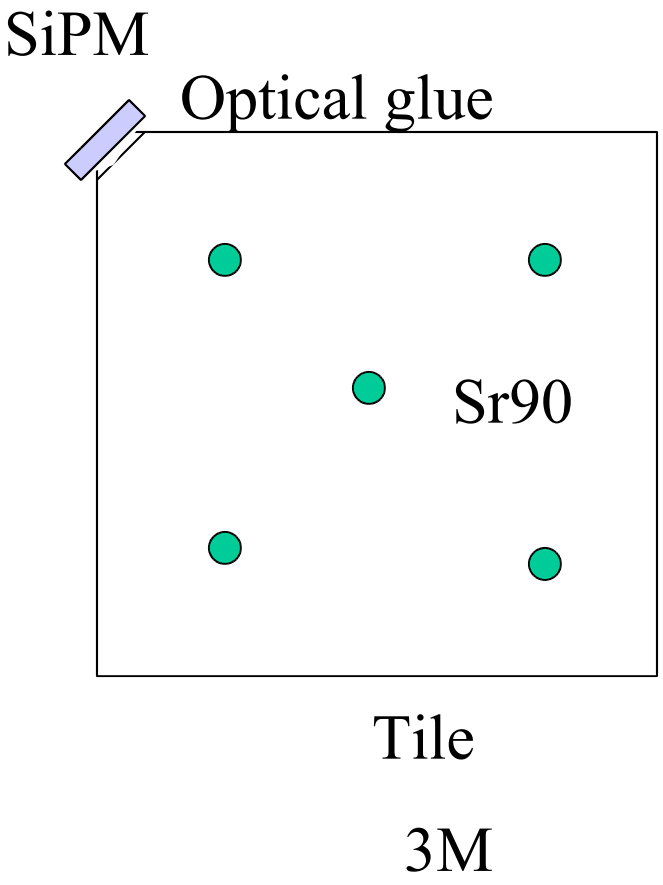
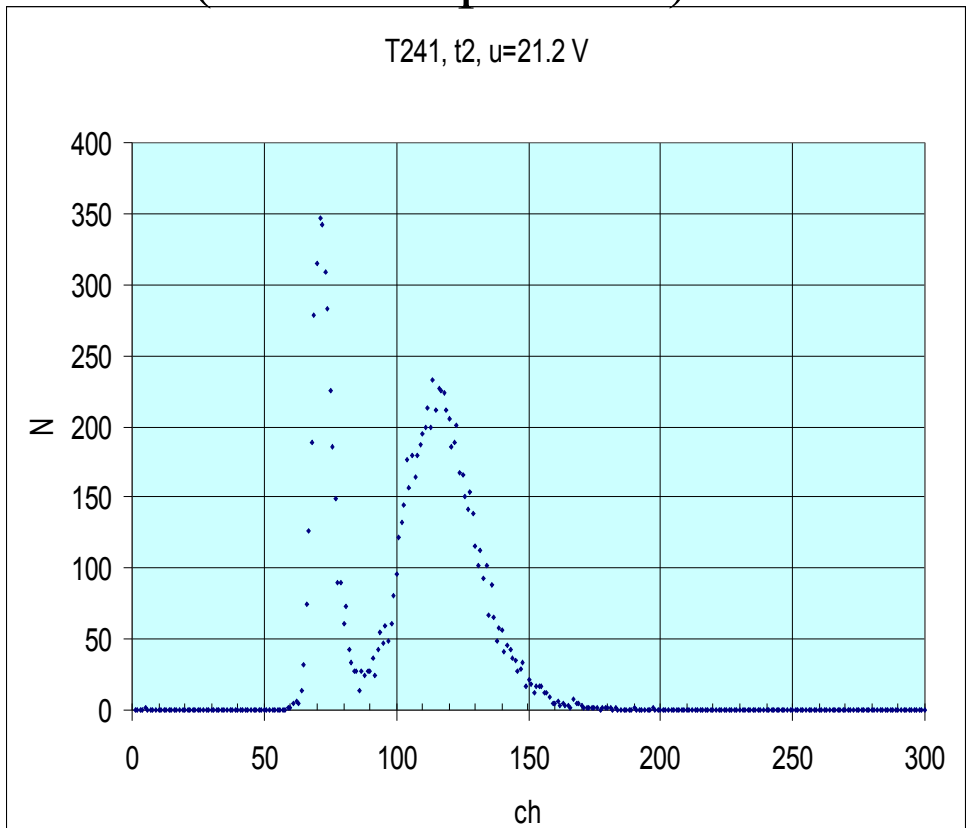
MIP signal for 3x3mm² SiPM

Plastic scintillator 30x30x5 mm³ without WLS fiber and 3x3 mm²
SiPM assembly was tested at MEPhI (room temperature) with Sr90

SiPM- tile assembly





Efficiency of light registration appr18%

Appr. 30 fired pixels/MIP

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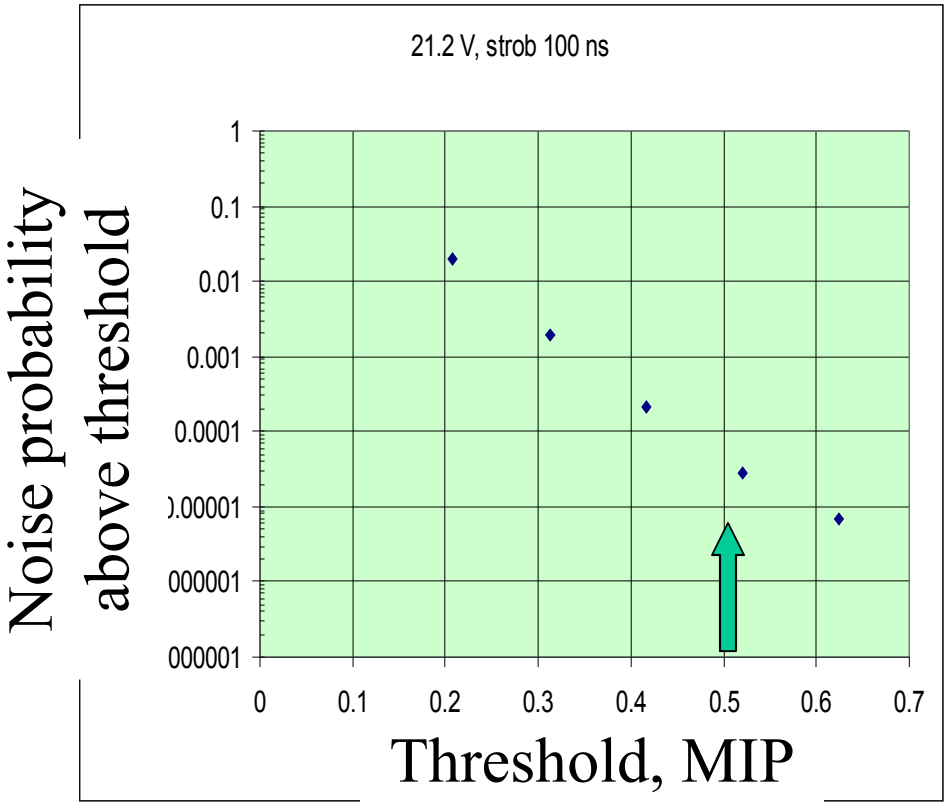
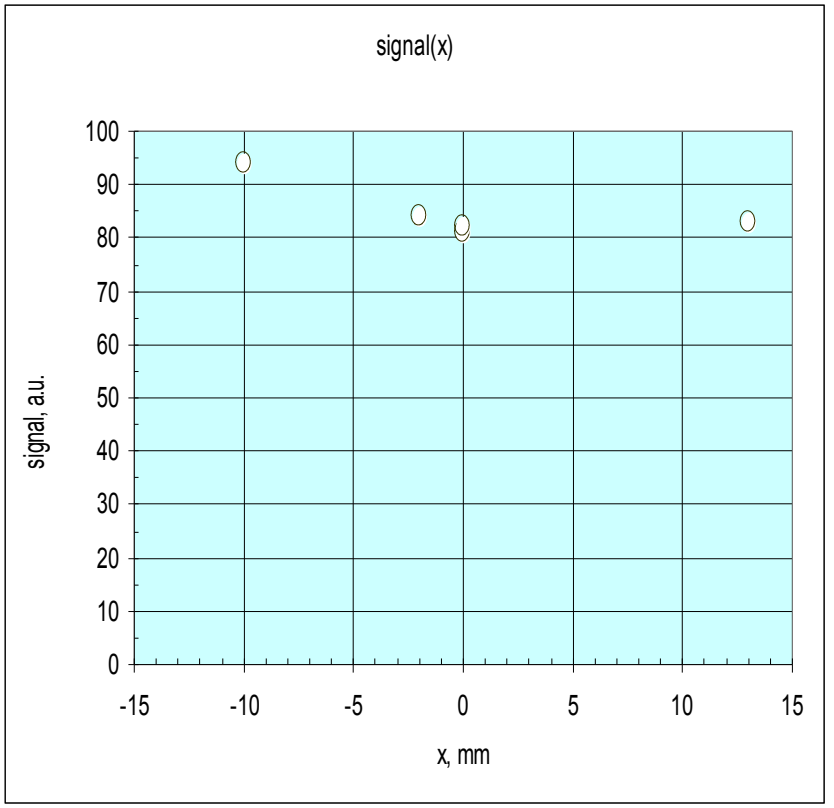
Noise probability & Light Collection Uniformity for 3x3 mm² SiPM-tile assembly





$3*10^{-5} * 8000=0,24$ events/prototype

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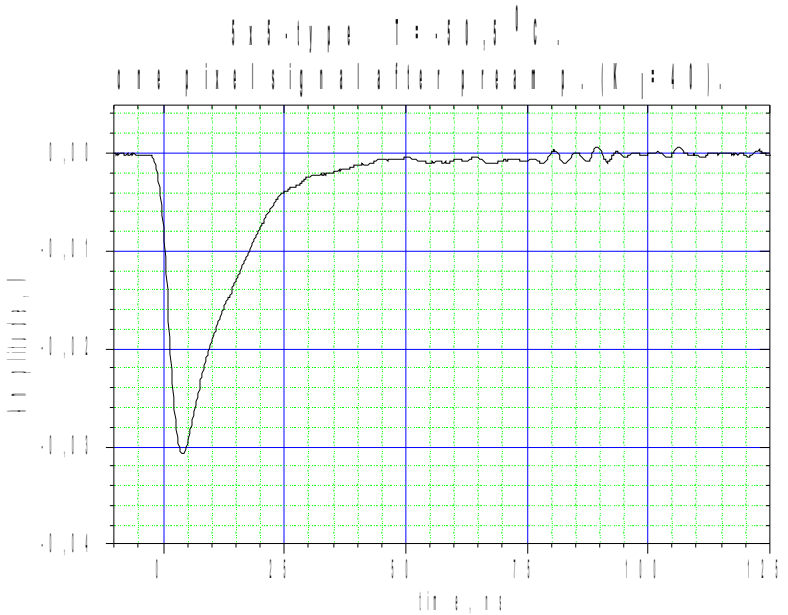
5x5 mm² SiPM

SiPM: sensitive area 5.2x4.9 mm²

Number of pixels 40x40=1600

Active pixel area 100x100 μm²

Period 130x120 μm²



Under investigation now

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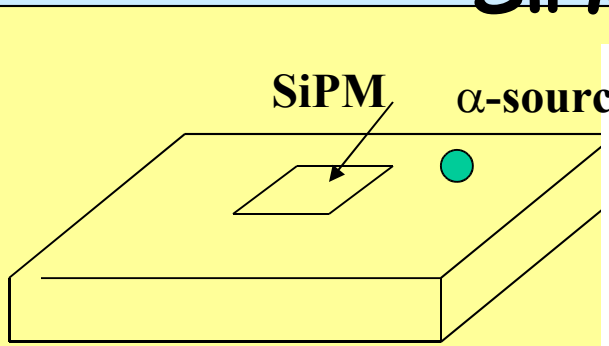
SiPM's future development



Tile 3x3 cm²

Without WLS

Without precision requirements to support plate

Without precision milling and assembling

Electronics

Without single pixel resolution

Self triggering

With internal delay

Efficiency of light registration 20%

Geometrical efficiency 25%

Dark rate 40 MHz

Period 30x30 μm

Total number of pixels 27800

MIP signal 50 pixels

Noise signal (100 ns) 4 pixel

Crosstalk suppression

Dynamic range 27800/50≈550

Fast signal ~ 5 ns

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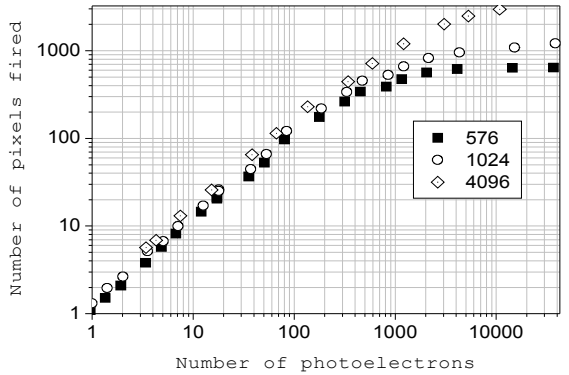
Response functions for the SiPMs with different total pixel numbers measured for 40 ps laser pulses



Monitoring and calibration with SiPM:
- Monitoring by measurement of MIP or alpha signals
No need single pixel spectra

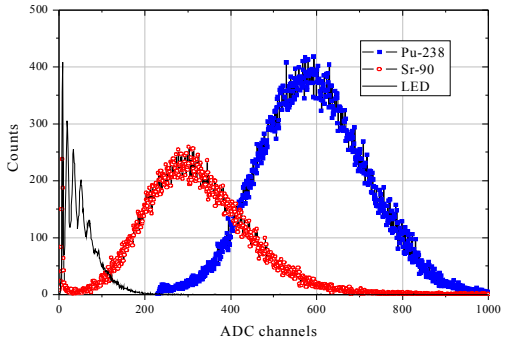


Fig3

Conclusions:

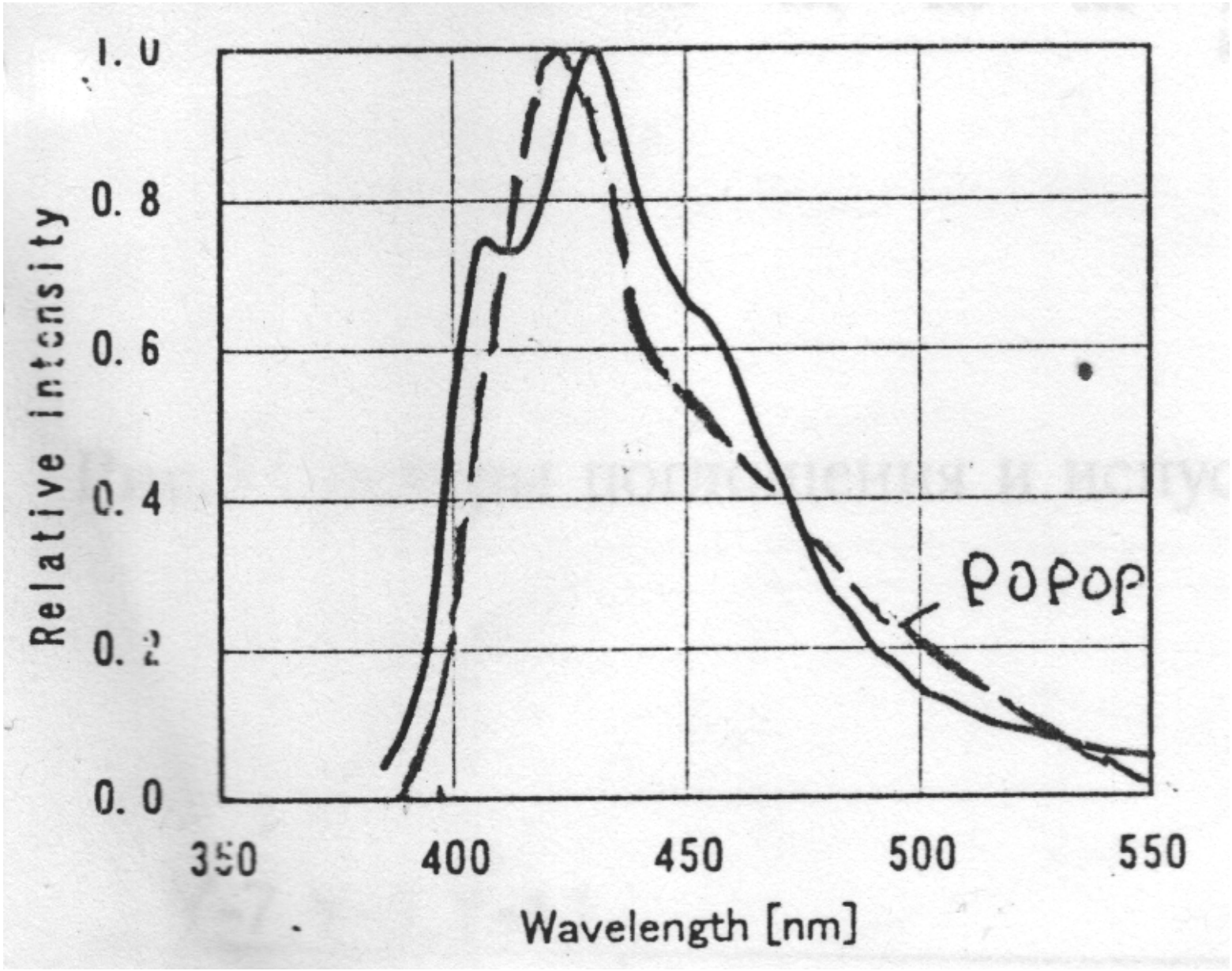
- New generation of SiPM's with suppression of:
  - optical crosstalk
  - afterpulsing
  - dark rate

  is under development now in order to obtain the SiPM's with:

  Area up to 10x10 mm2
  PDE of 40-50%
  ENF=1.0…1.05
  Subnanosecond timing

- It increases significantly the number of SiPM applications

Emission spectrum for Vladimir scintillyator (POPOP)



Light Collection Uniformity,

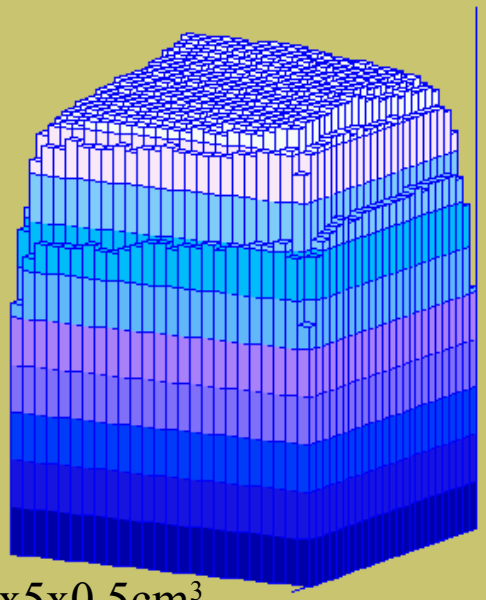
Y11 MC 1mm fiber, Vladimir Scintillator, mated sides, 3M foil on top and bottom

Reduction in light yield near tile edges is due to finite size of a β source

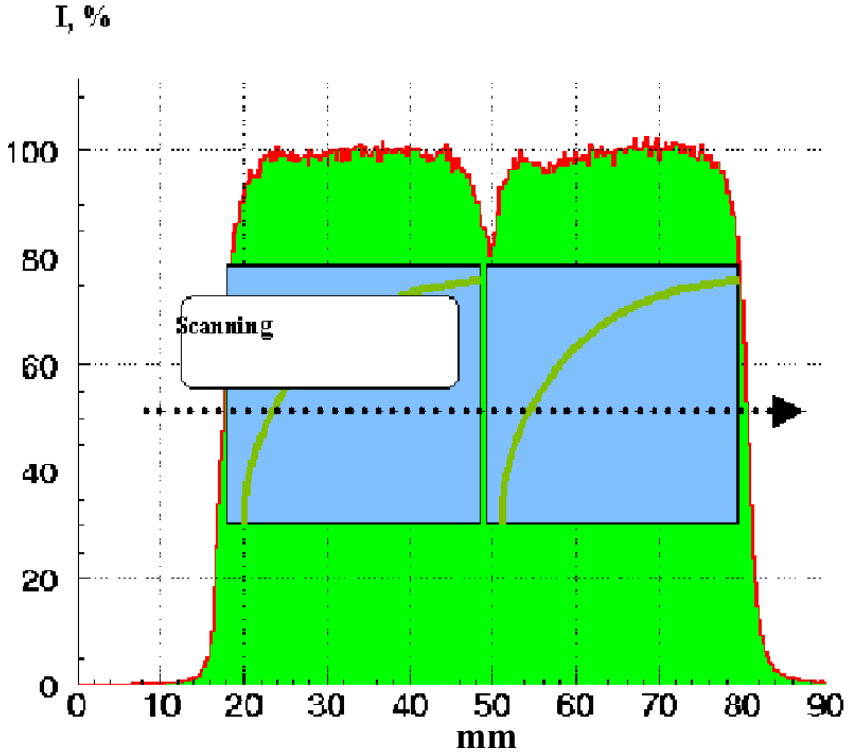
Light yield drop between tiles acceptable (Calorimeter geometry is not projective)

Cross-talk between tiles ~2% - acceptable

Light collection efficiency



5x5x0,5cm^3

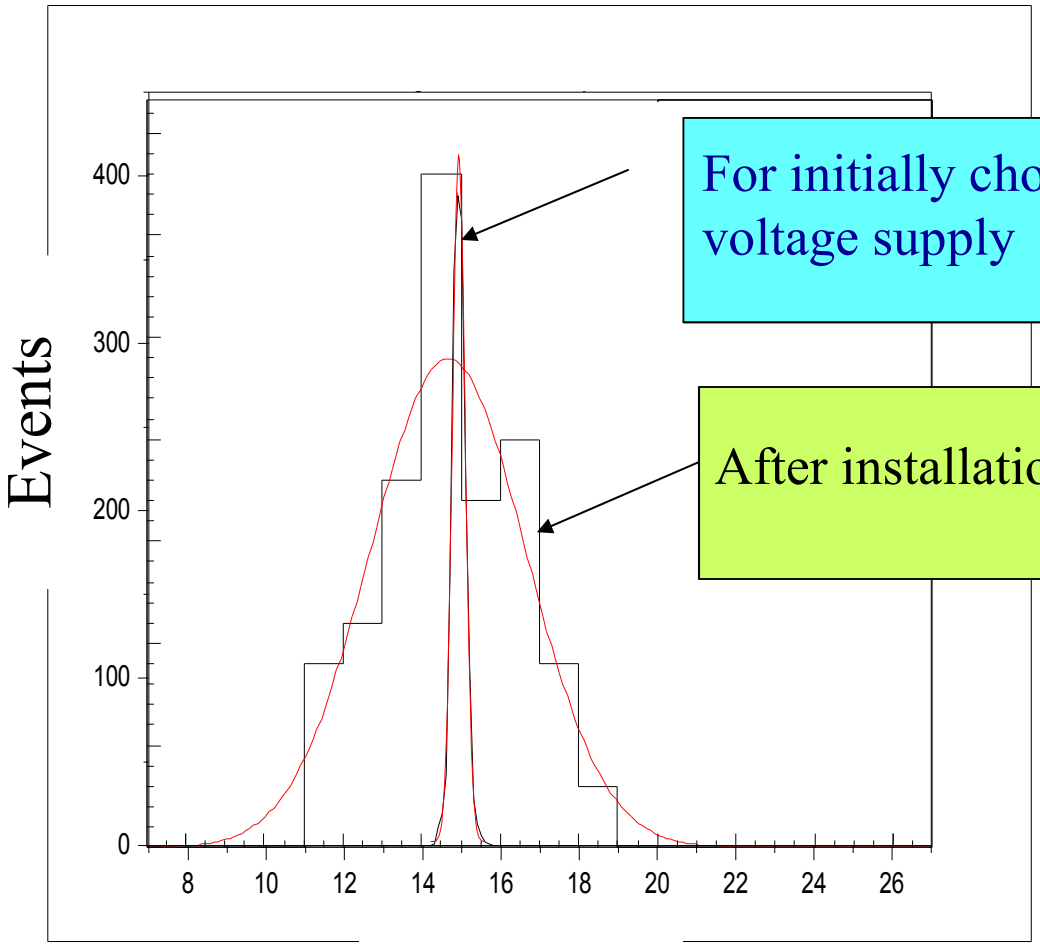


Sufficient uniformity for a hadron calorimeter even for large tiles

Acceptable cross-talk between tiles of ~2% per side

Sufficient light yield of 17, 28, 21 pixels/mip for 12x12, 6x6, and 3x3 cm^2 tiles (quarter of a circle fiber in case of 3x3 cm^2 tile)

Pixel/MIP distribution for SiPMs-tile-WLS assembly



For initially chosen voltage supply

Mean = 14.92

Sigma = 0.15

After installation in tile

Mean = 14.68

Sigma = 1.98

Matching well with MINICAL result

For SIPM working point

Gain ~10^6

Efficiency of light registration ~10%

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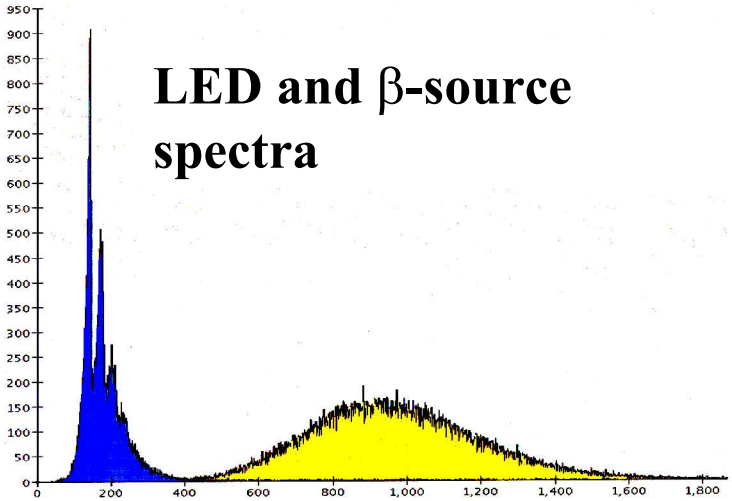
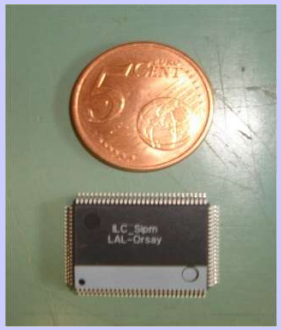
Calibration of the SiPM

For SiPM saturation correction we need to know the value

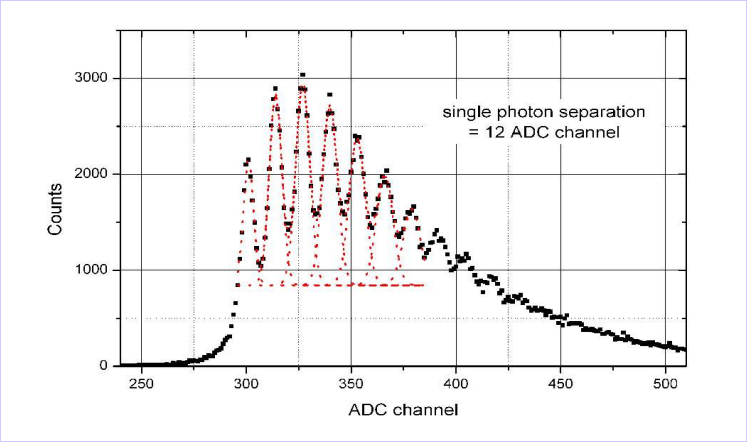
Number_of_fired_pixels/MIP





LAL 18 ch. SiPM FE chip

CALICE DAQ board for 8 planes (UK groups)



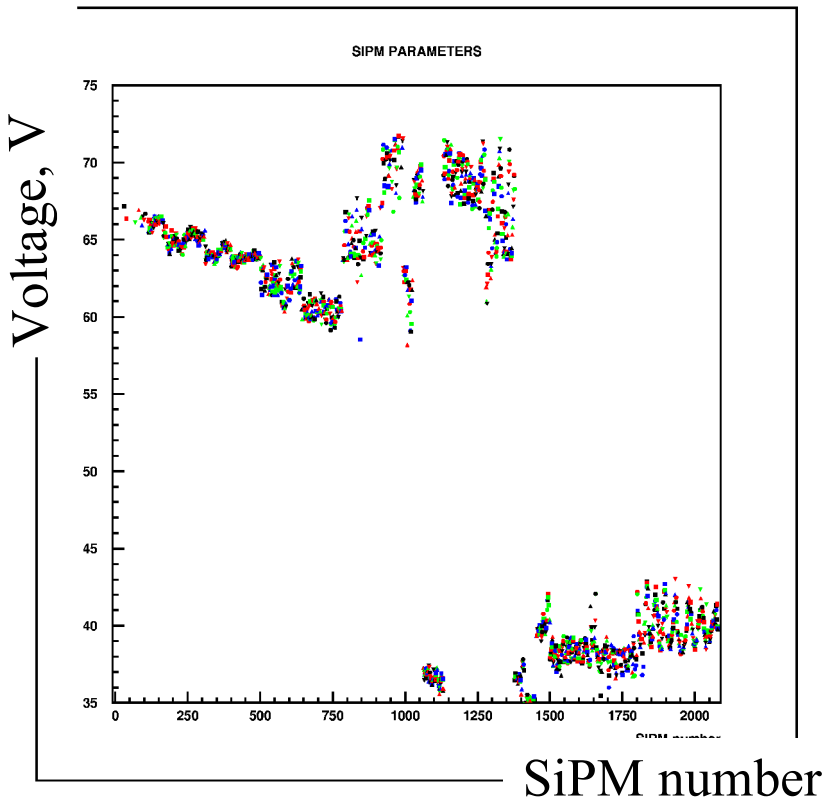
Temperature and bias voltage dependence:

delta T(V)	Gain	Signal=Gain x PDE x Crosstalk
-1 C	+2.2%	+4.5%
+0.1V	+4.3%	+7%

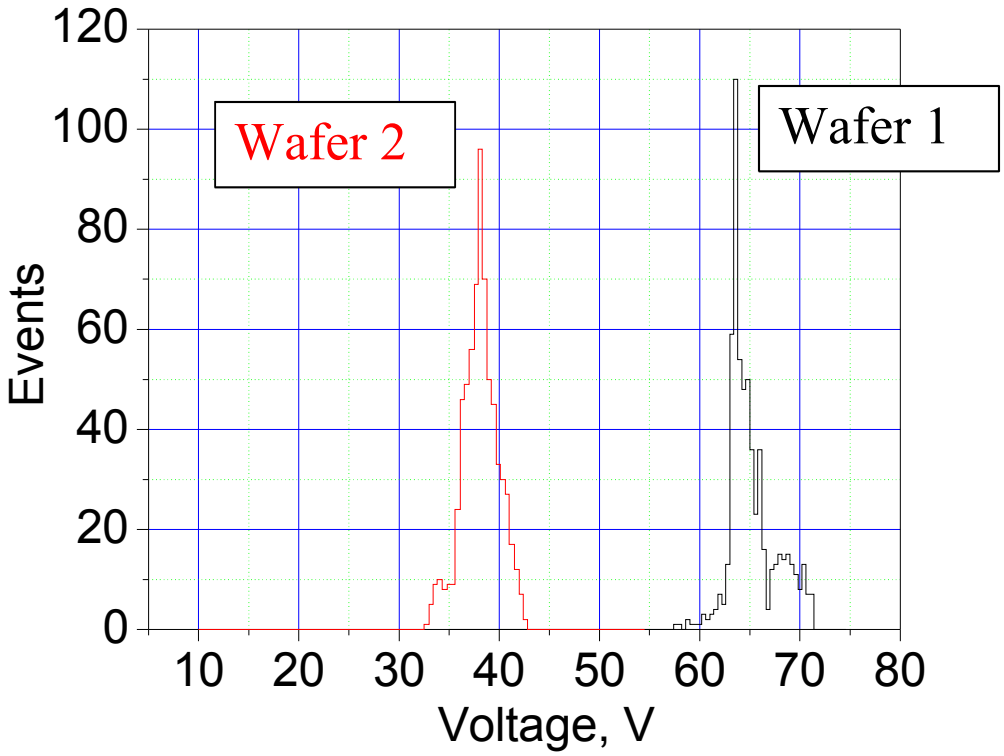
Up to now several thousand SiPMs have been tested already

Operational voltage

For all SiPMs tested



Distributions for 2 wafers



mework of CALICE
collaboration and ISTC project 3090

SiPMs parameters