Cooled SiPM matrixes module

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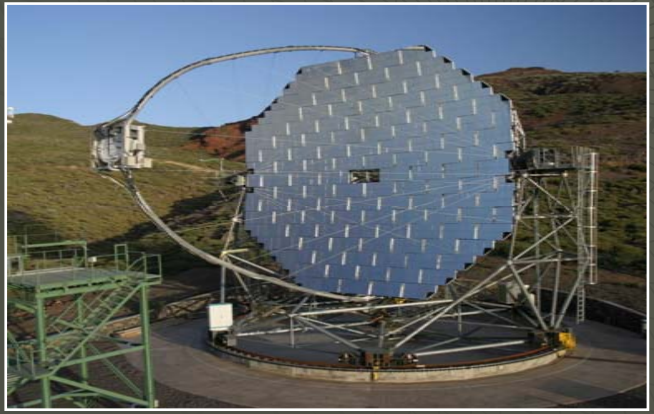
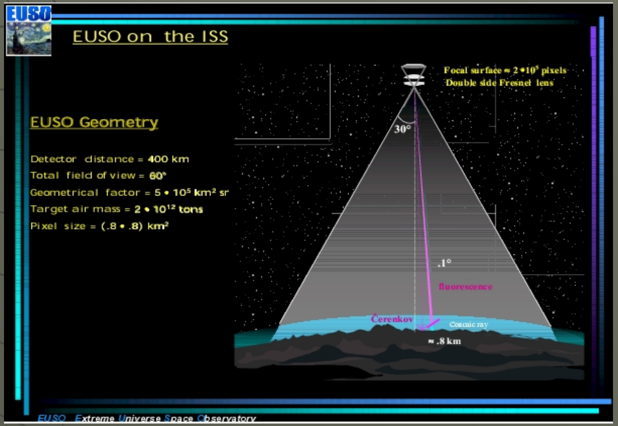
On behalf
of MEPhY-MPI for Physics-PULSAR collaboration

MAGIC and EUSO requirements to photosensors:

- High sensitivity to the near UV light (300-400nm)
- Size not less then 5x5 mm2
- Single photon counting capability and single photon resolution
- Minimum value of optical crosstalk between the SiPM pixels, ENF~1
- Fast signal, timing resolution <2.5ns
- Ability of high density packing of photosensors with minimum gap between them
- Acceptable intrinsic dark rate





Such requirements necessitate to find complex solution – to develop not single SiPM but whole detecting assembly for specific experiment, some kind of

basic module

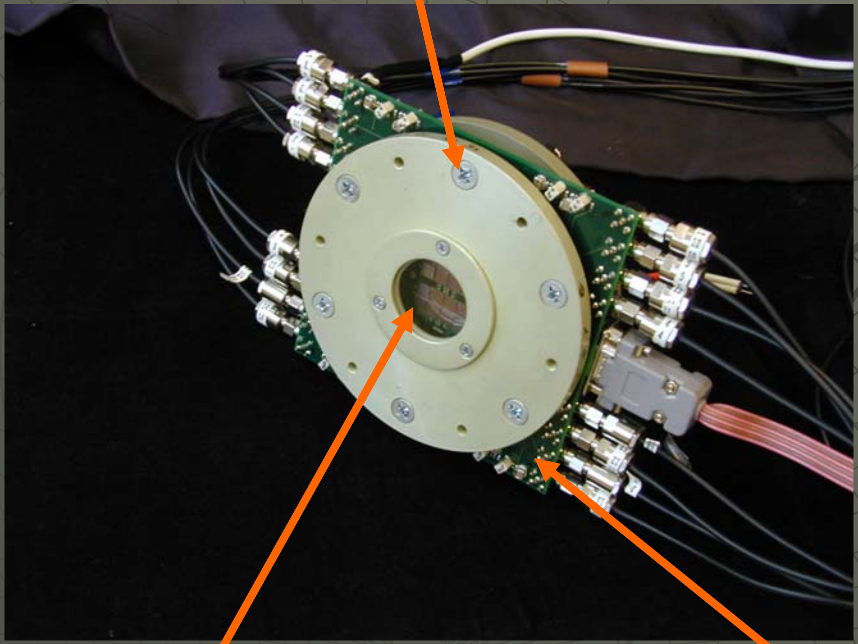
This module should consists of SiPM matrixes, monolithic or assembled from single elements, analogue electronics,

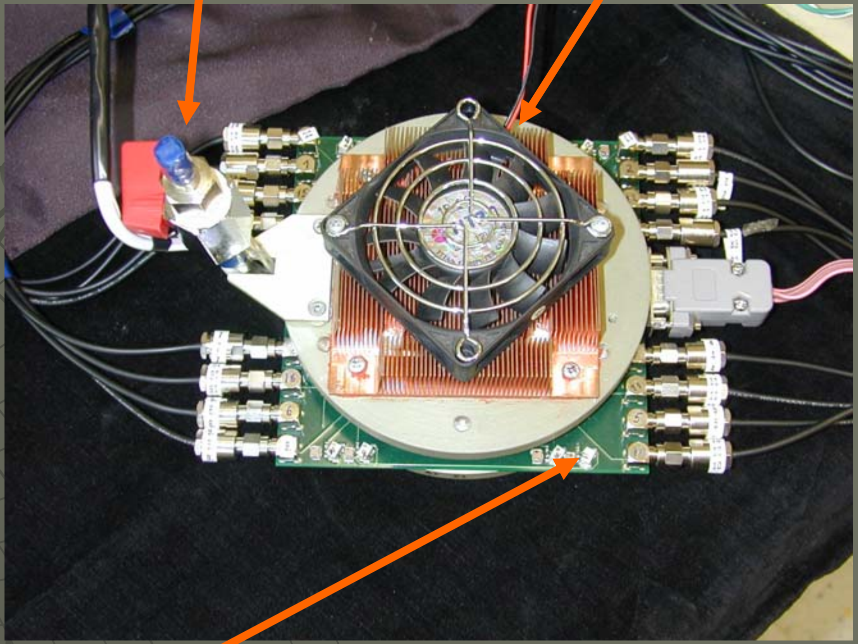
cooling/temperature stabilization system and light concentrators for low light losses

Cooled SiPM matrixes module (first prototype)

Knock-down (assembled/disassembled) vacuum chamber

pumping cooler

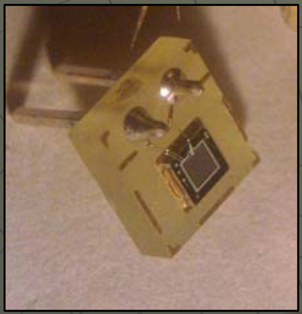


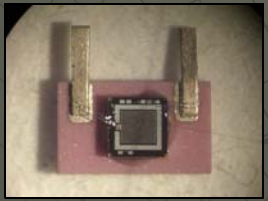


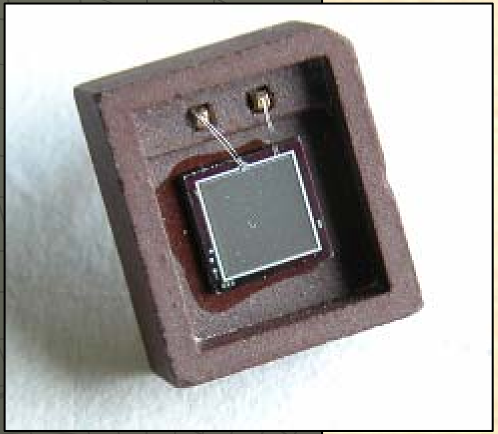
16 SiPMs 5x5 mm^2 electronics

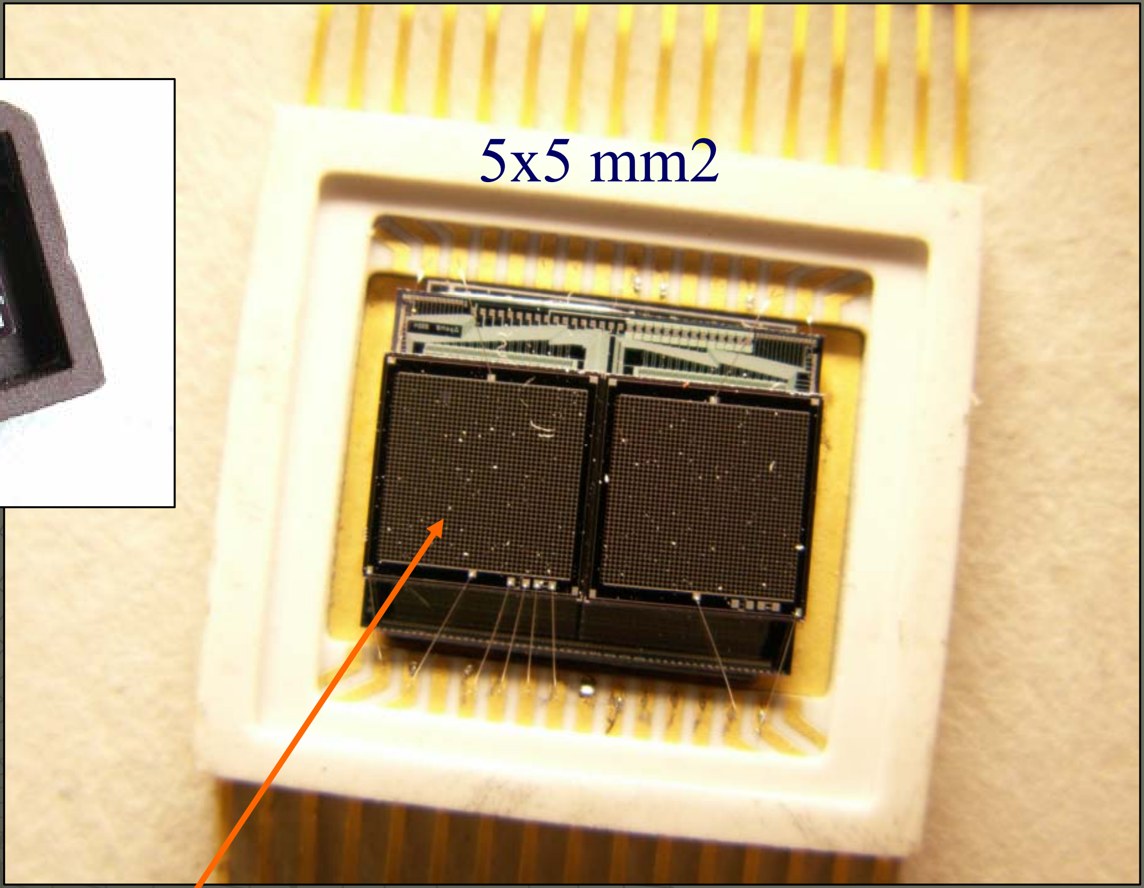
- Double stage Peltier element inside
- Temperature sensors for cool and warm levels

Photodetectors









3x3 mm2

1x1 mm2

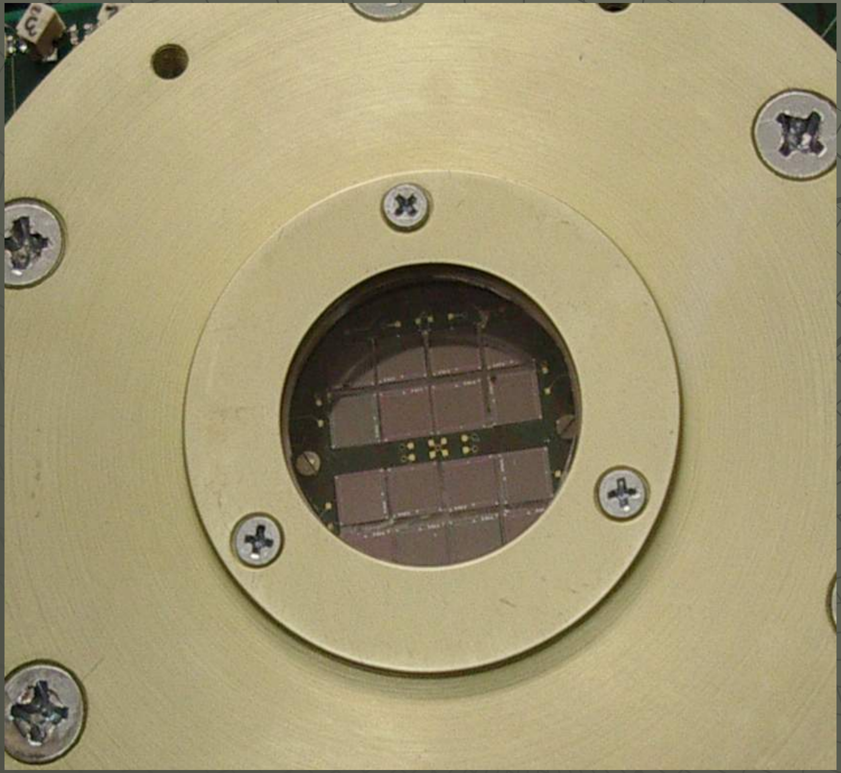
TESLA type

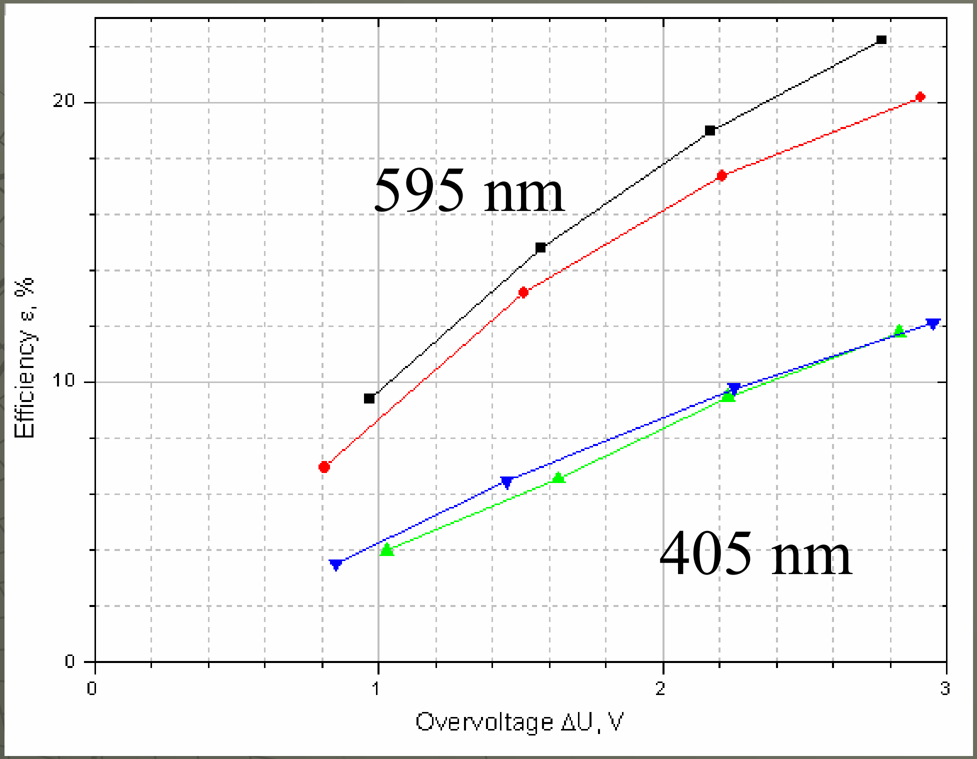
(CALICE)

SiPM size for MAGIC/EUSO application should be not less then 5x5 mm^2

16 SiPMs 5x5 mm² have been selected and glued into the module

Measurements after installation of SiPMs and quartz input window show that PDE doesn't change

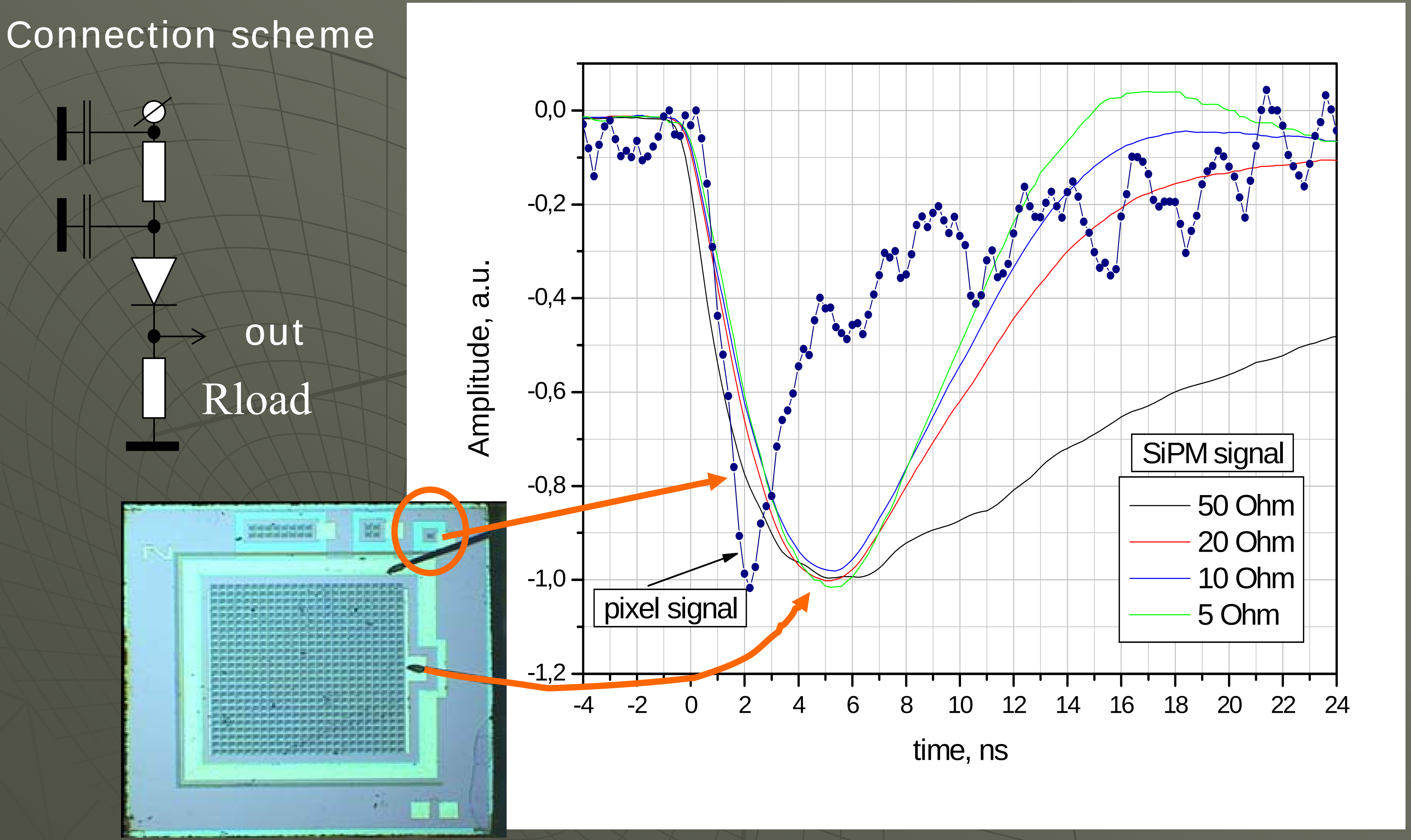




$$PDE_{SiPMalone}/ PDE_{SiPMin\_module} = 1.0 +- 0.07$$

5x5 mm2 SiPM signal for different Rload

Connection scheme

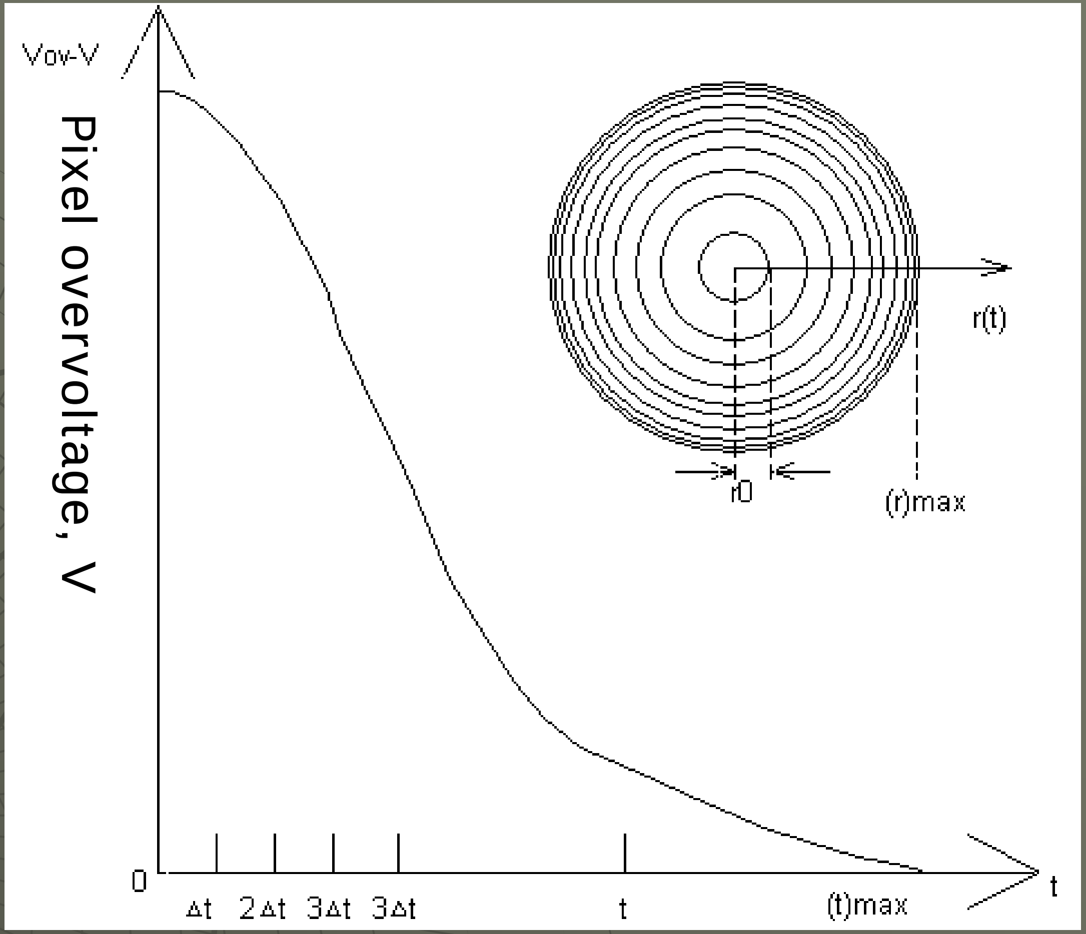


Low input resistivity electronics is needed for fast sipm signal readout

Simulation of FE electronics with SiPM

Spice model of SiPM. Single pixel

- Geiger discharge starts in tiny spot inside pixel (elementary disk) with radius r0, r0 =Kr*Vov
- $I_0(t)=K_i*\Delta V(t)$,where K_i- disk conductivity
- Discharge goes from disk to first elementary ring, second… with velocity $v(t)=K_v* \Delta V(t)$, where $K_v=3\mu m/(V*nc)$
- Overvoltage goes to 0 due to discharge current (Cpixel)

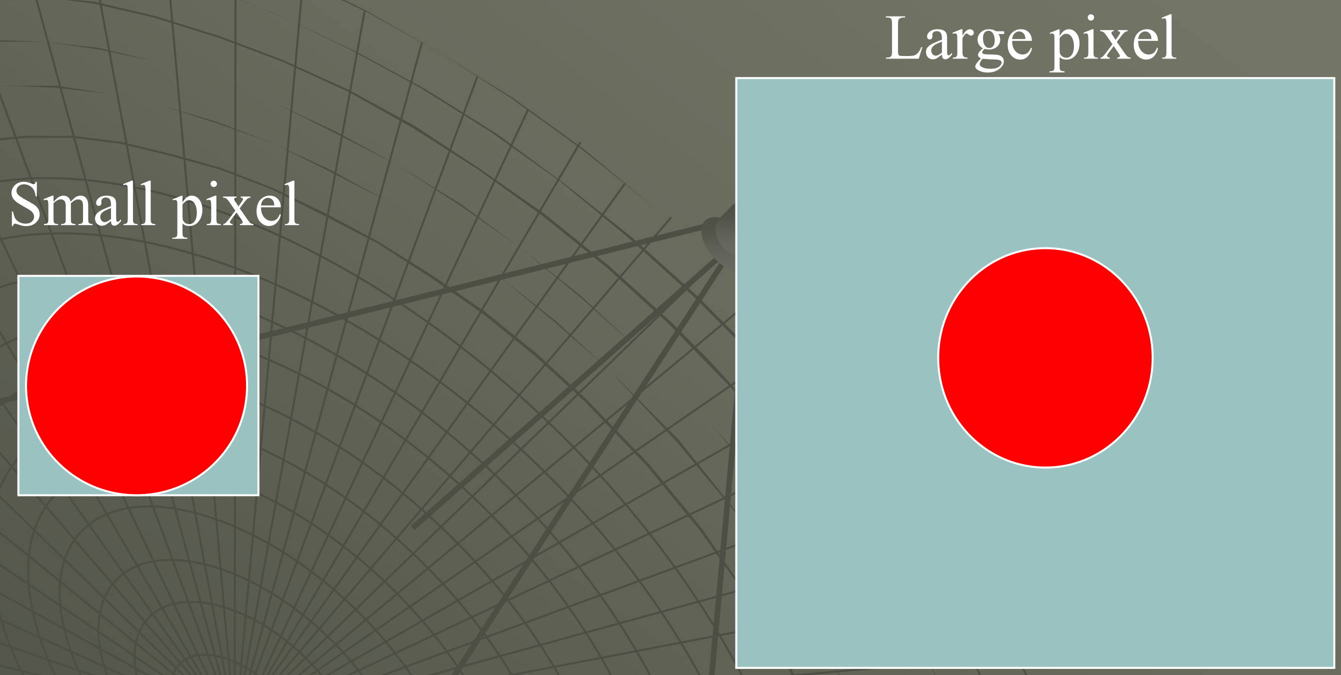


K_i, Kr, Kv - are experimental parameters

$\Delta V(t)$- overvoltage , Vov- max overvoltage

Spice model of SiPM. Single pixel

- Max discharge area exists for fixed overvoltage (in case of large pixels)



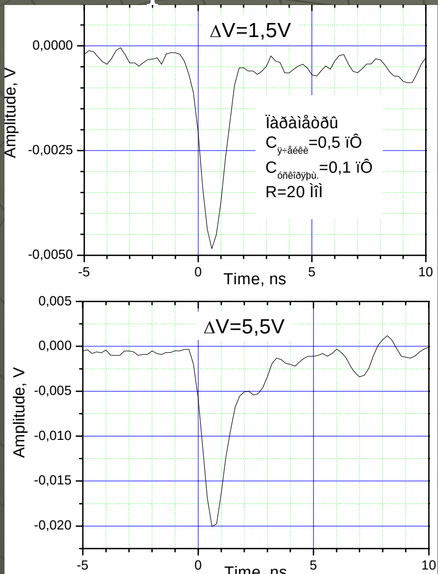
$$I(t) = Ki\Delta V(t)\{1 + \frac{K_v}{K_r}\int_{\Delta t}^{t}[\frac{Vov - V(\tau)}{Vov}]d\tau\}^2 = C_\Sigma \frac{dV(t)}{dt}$$

Pixel discharge current

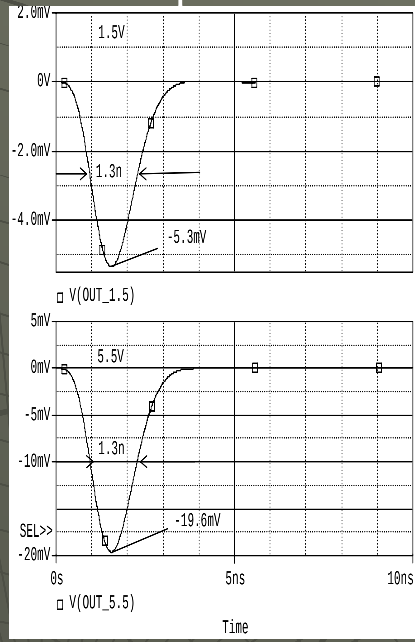
Spice model of SiPM. Single pixel

MEPhI

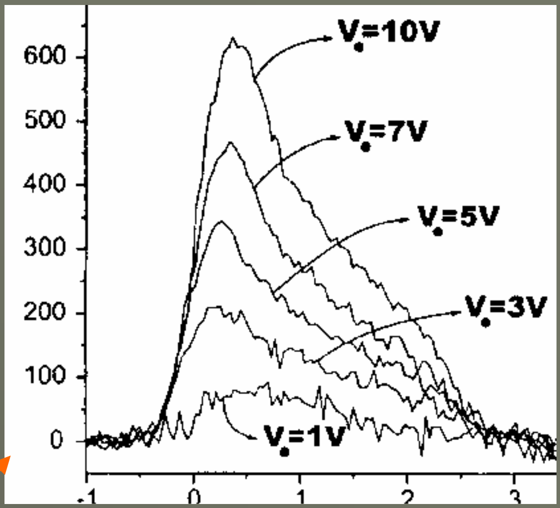
experimental

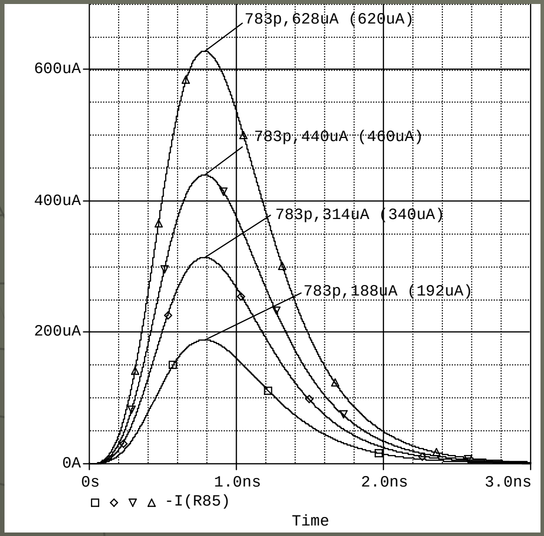


spice



experimental





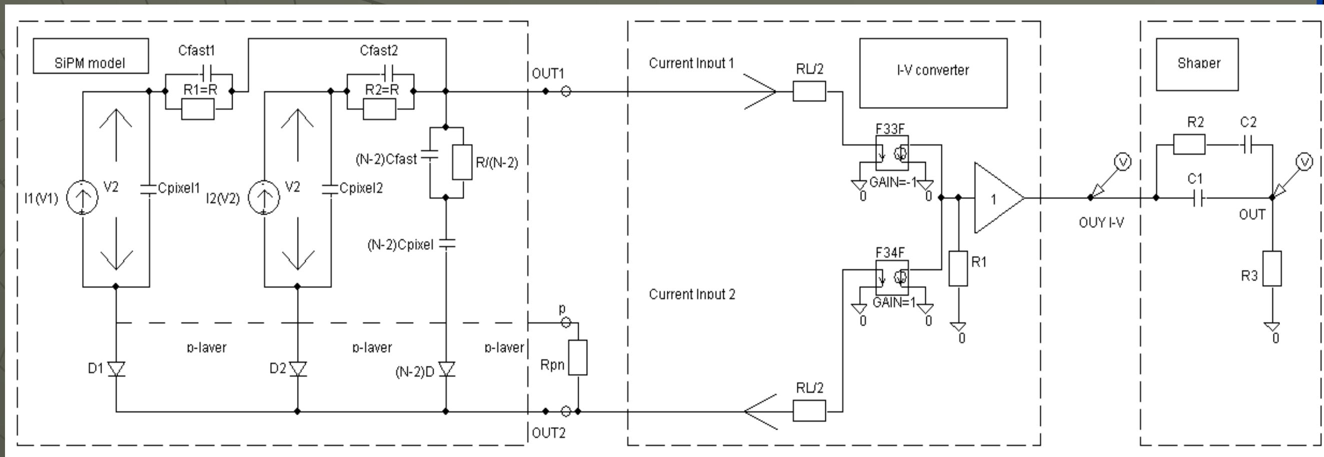
spice

The value Ki = 10^{-7} A/V and Kr =0.03μm/V have been taken from experiment at MEPhI and have been proven with another one

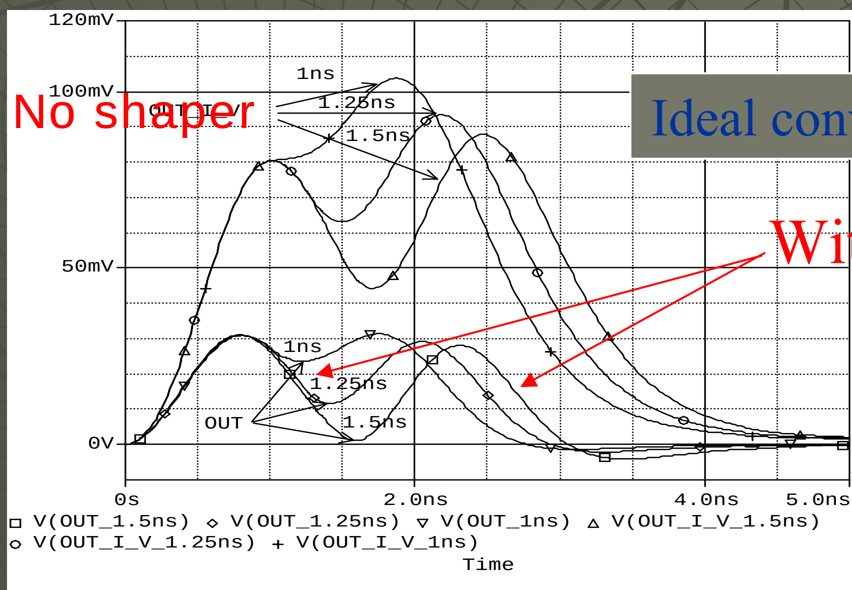
A.Rochas and others, “Single photon detector fabricated in a complementary metal-oxide-semiconductor high-voltage technology”, Review of Scientific Instruments, volume 74, Number 7, July 2003.

Good agreement

2 pulses time resolution
Simulation of FE electronics with SiPM spice model



Current-voltage converter & RC shaper



No shaper

Ideal converter (R_L=0)

With shaper 1.5 ns

$N = 1000$, $C_{pixel} = 0.5$ pF,

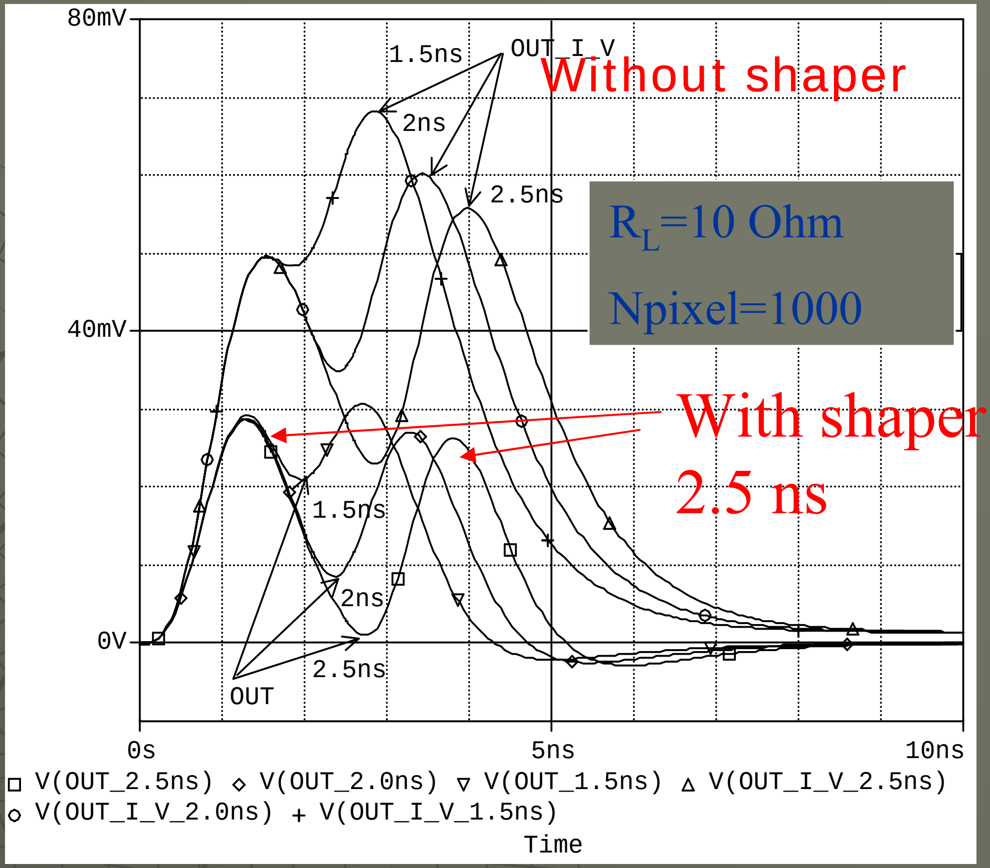
$C_{fast} = 0.1$ pF,

Vov =5.5 V, $R_L = 0$

2 pulses time resolution
Simulation of FE electronics with SiPM spice model

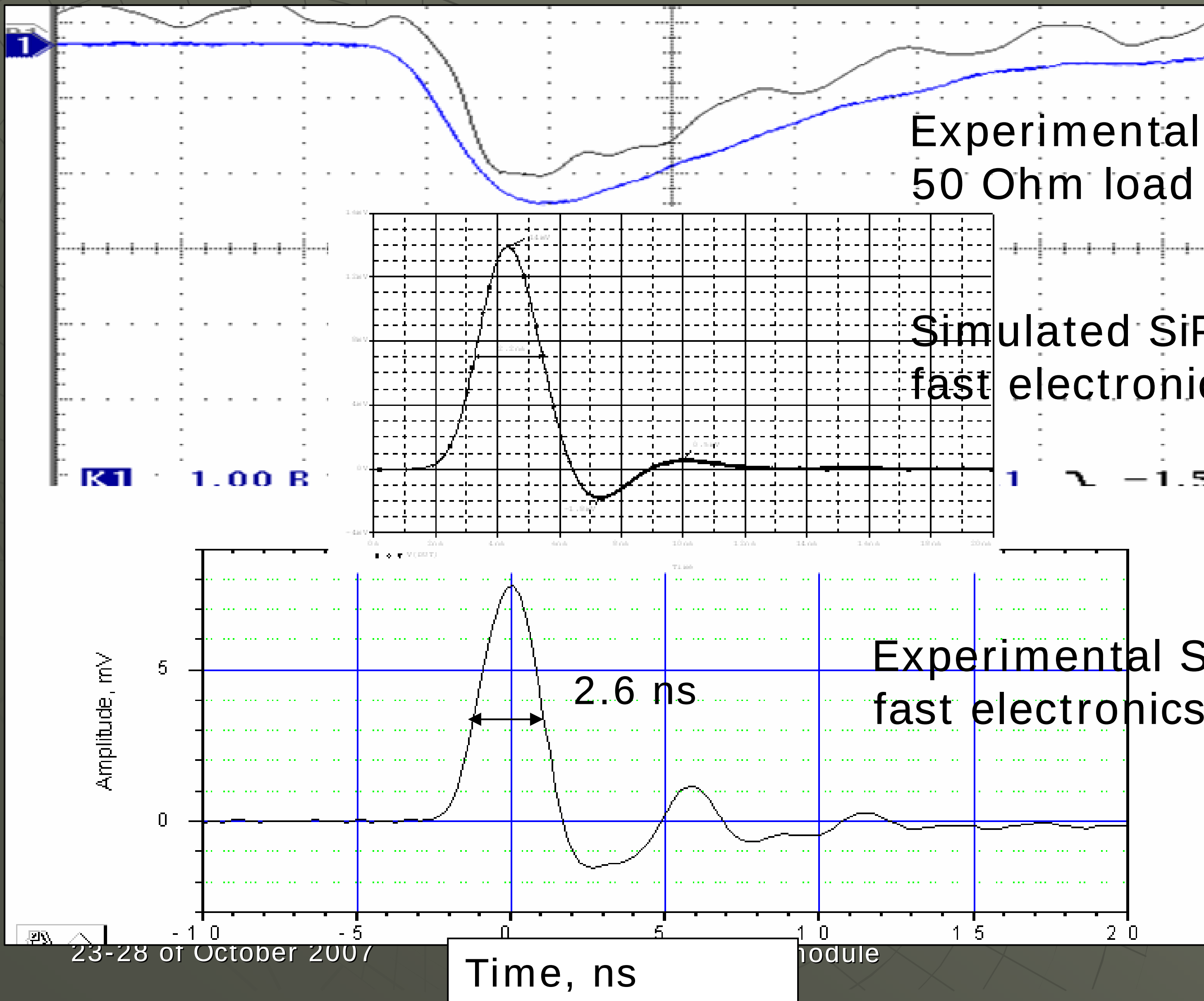
C_{pixel} = 0.5 pF, C_{fast} = 0.1 pF,

Vov =5.5 V, R_L = 10 Ом

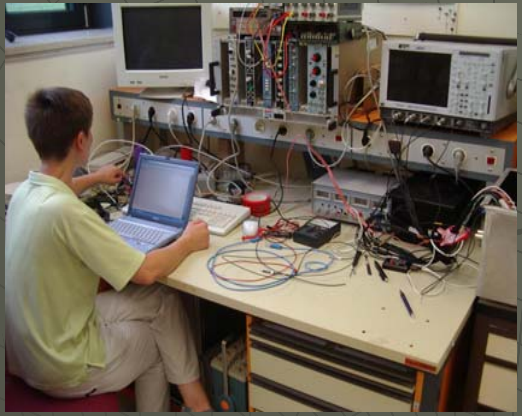


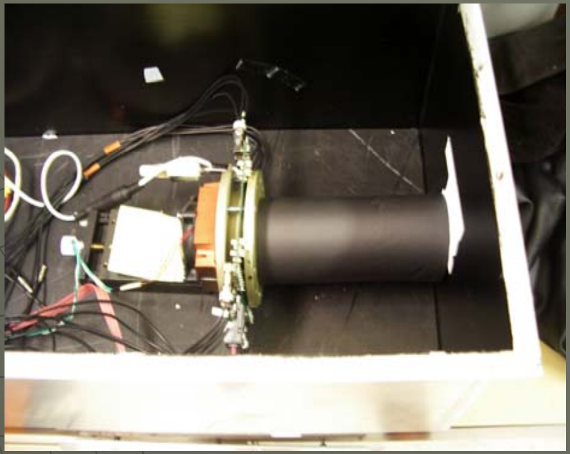
Electronics for fast SiPM readout (current amplifier or current-voltage converter) should be with minimum input impedance and minimum parasitic inductance

Special electronics for 5x5 mm² SiPM readout



Cooled module has been tested at MPI for Physics laboratory

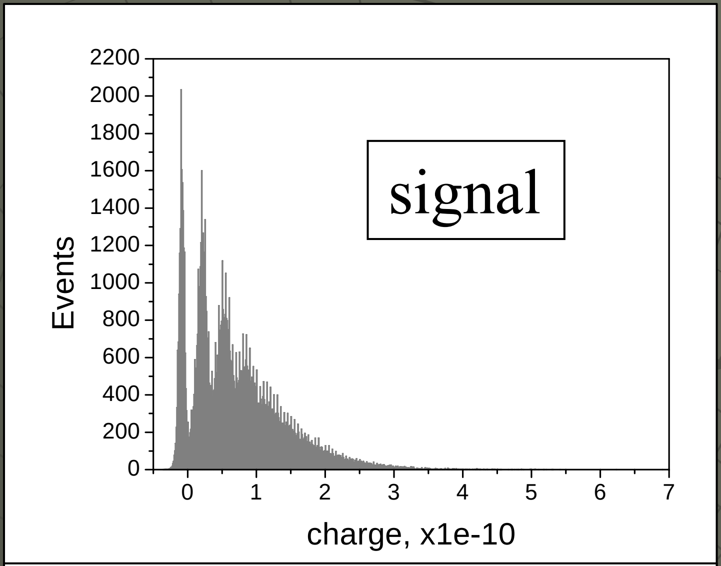


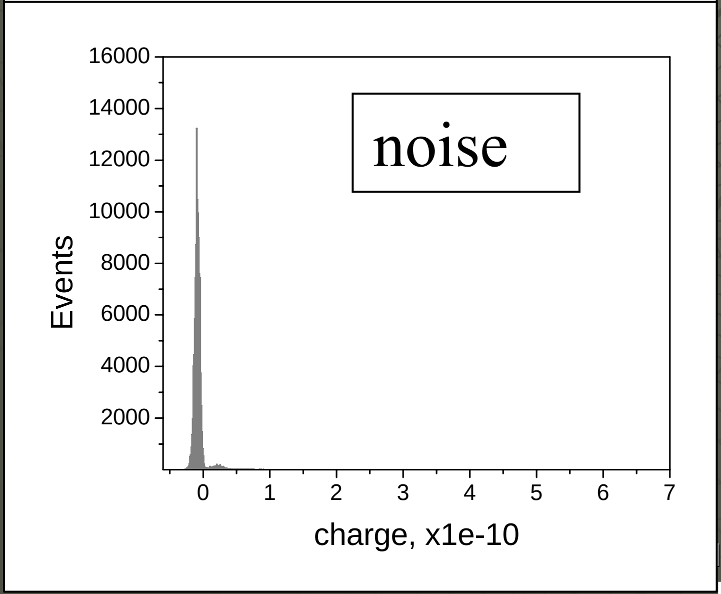


Thanks to Juergen Hose (MPI) for his help in measurements

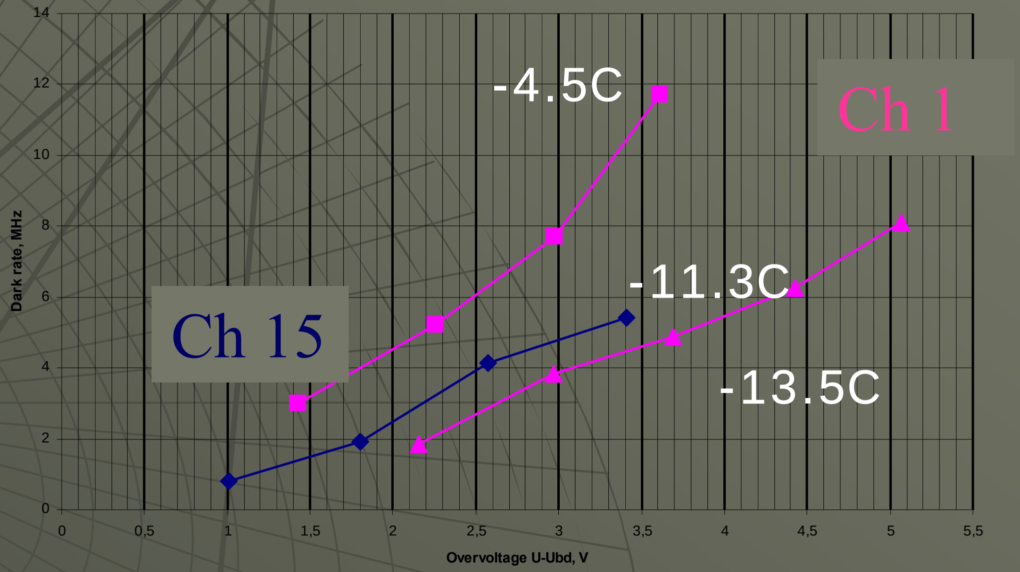
Digital scope measurements (500 Mhz) at MPI

Area



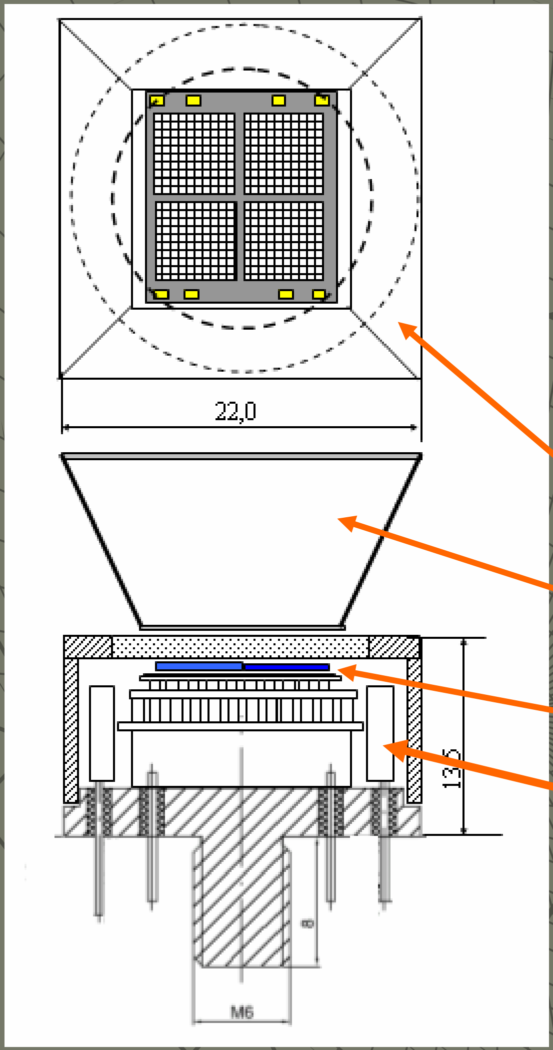


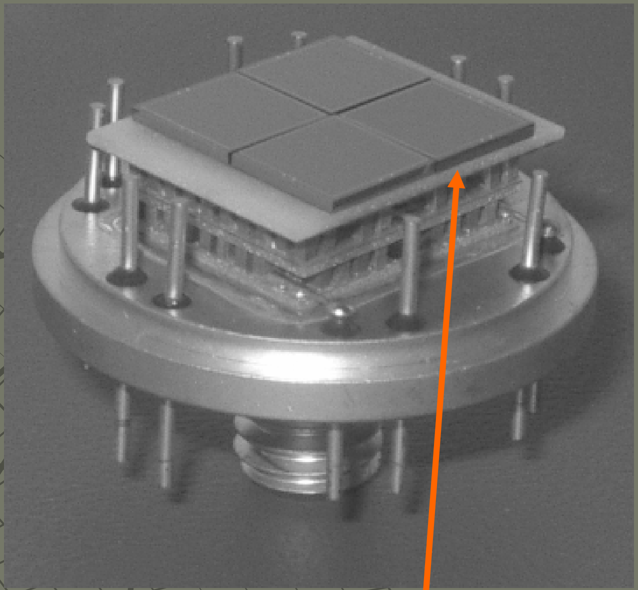
Dark rate vs overvoltage for different temperatures



New module for Magic with adapted geometrical parameters

Submodule





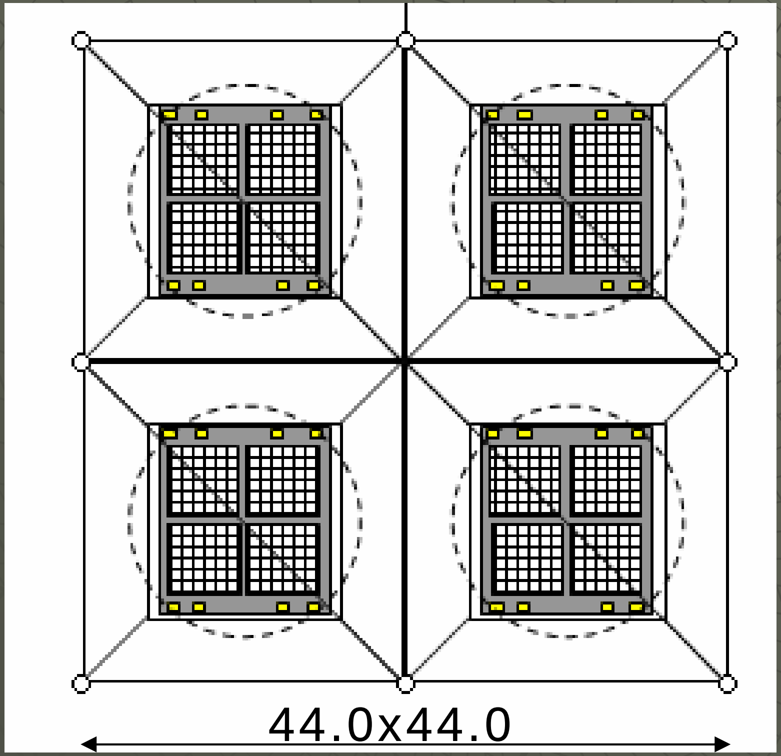
4 SiPMs
5x5 mm^2

Peltier element

- Winstone cone
- New detectors (B.Dolgoshein talk)
- Improved electronics

New module for Magic with adapted geometrical parameters

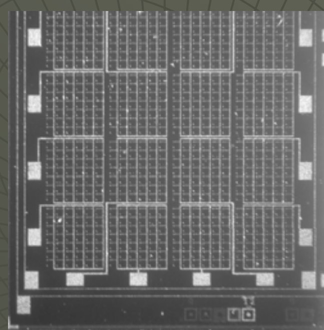
Basic module consists of 4 submodules



SiPM matrix

In future it is very attractive to use monolithic SiPM matrix not only for Astropartical application

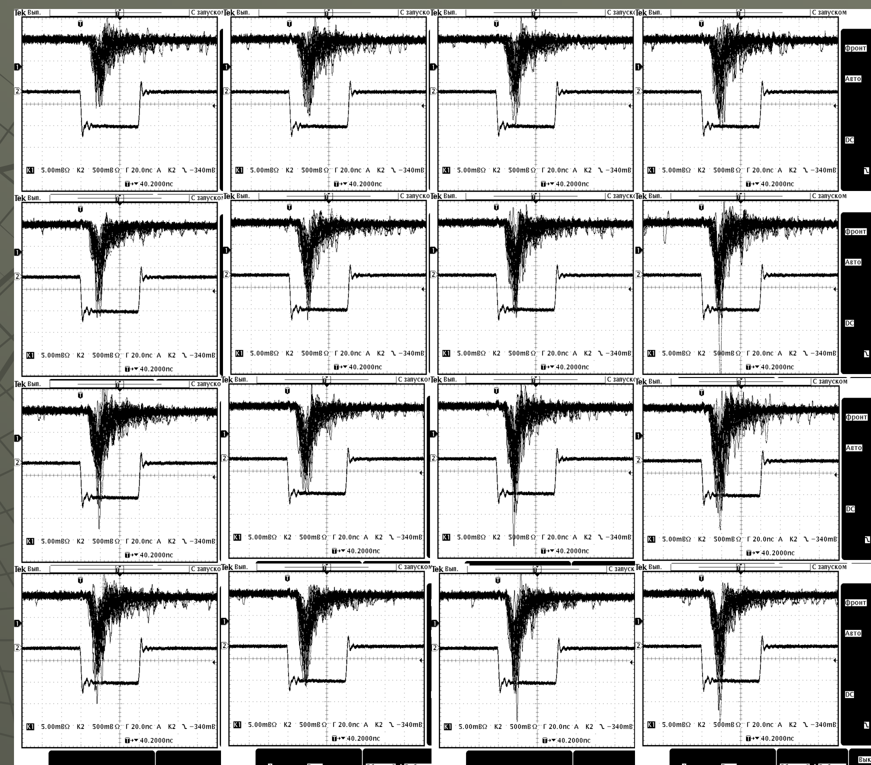
- For decreasing of light losses
- For position sensitivity
- For fast readout



16 SiPMs in matrix

SiPM $0.75x0.75mm^2$

Common bias voltage U=57.8B



Signals on scope from LED pulses

Conclusions

- First prototype of cooled module for MAGIC on the basis of double stage Peltier element with 16 SiPMs 5x5 mm^2 has been developed
- Special fast 16 channels amplifiers-shapers have been developed and integrated into the module
- Laboratory tests have been successfully passed
- New prototype of cooled module with sizes well suited for MAGIC application is under development now
- Solutions which will are found for this task can be easily adapted for many others fields of SiPM applications