Tests of IRST SiPMs

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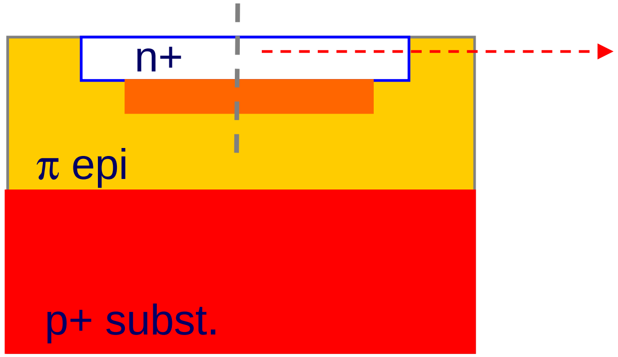
Outline

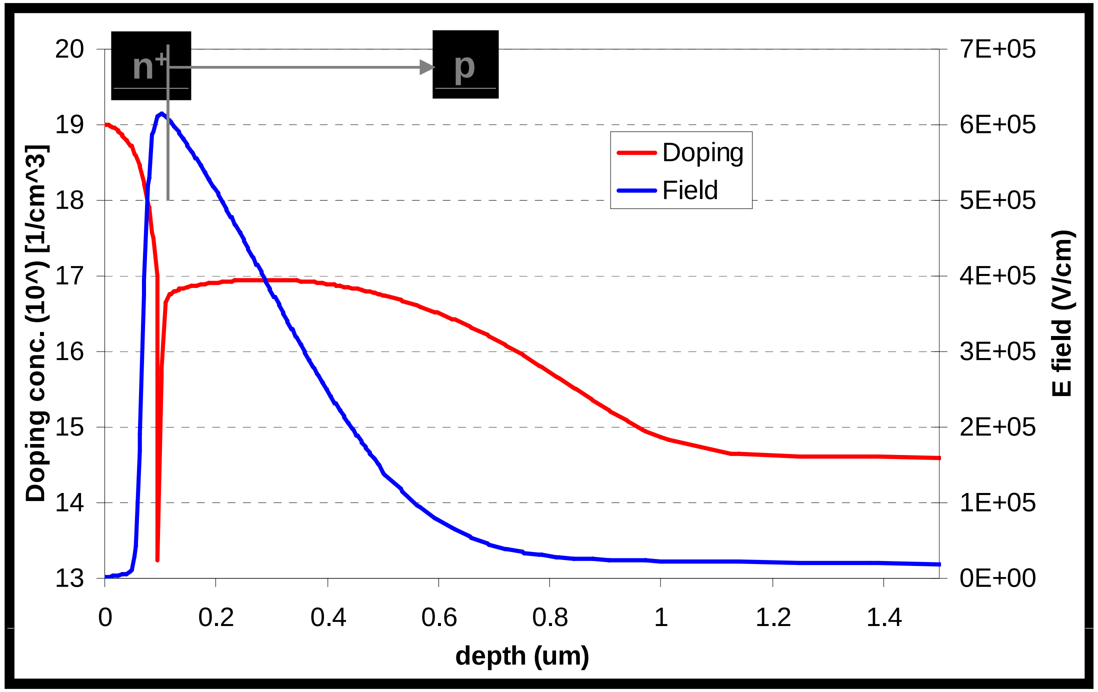
1. IRST SiPMs : baseline characteristics
2. first application at FNAL test beam
3. subsequent evolution
4. New devices for T956

IRST technology

*C. Piemonte "A new Silicon Photomultiplier structure for blue light detection" NIMA 568 (2006)

Shallow-Junction SiPM





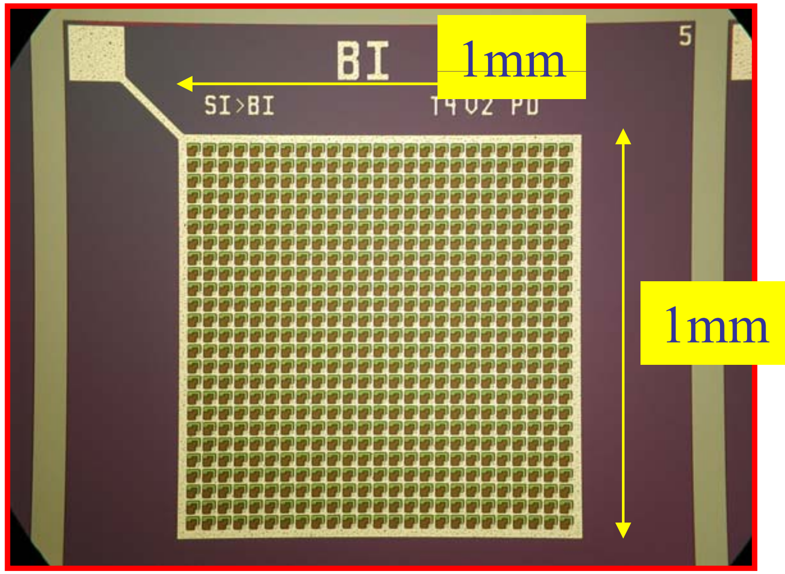
Distinguishing characteristics:

1) **Very shallow junction**
2) **ARC optimized for short wavelenghts (~400nm)**
3) **polysilicon quenching resistors**

Development started at the beginning of 2005

Baseline geometry

SiPM structure:
- 25x25 cells
- microcell size: 40x40mm^2

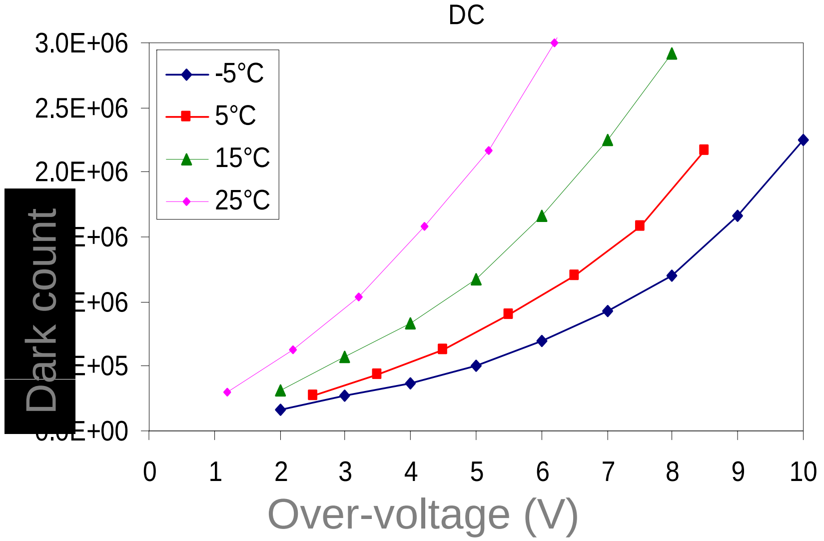


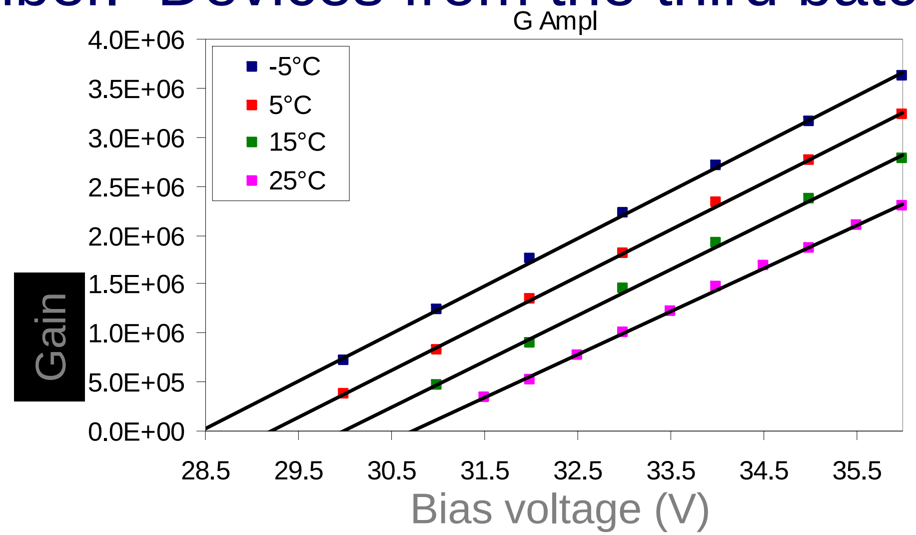
Geometry of baseline model
NOT optimized formaximum PDE
(fill factor ~20%) .

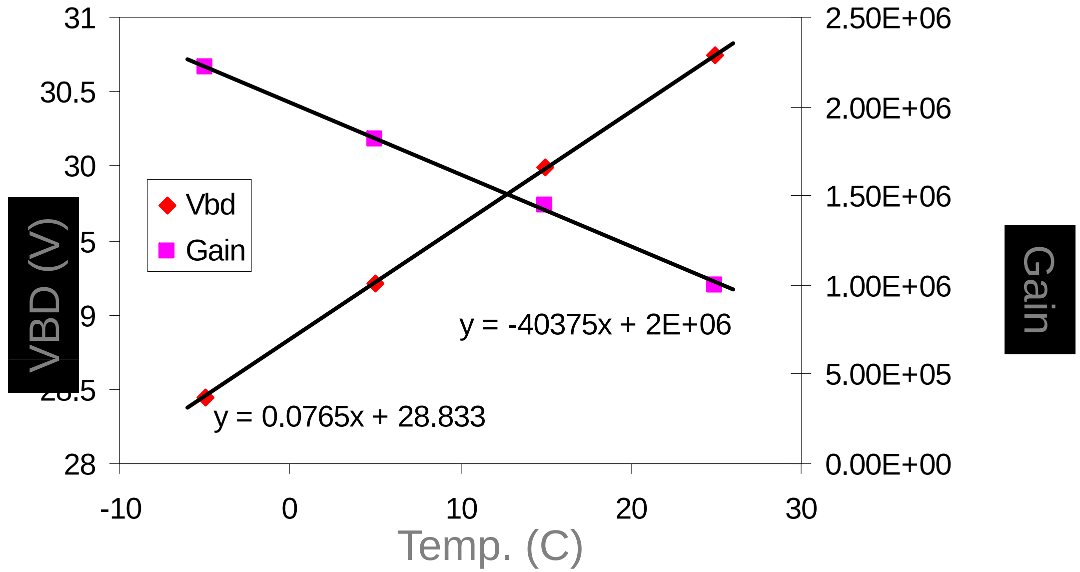
Development has continued over last two years: several succeeding production runs to to develop geometries for different applications and to optmize operational characteristics

Gain & Dark count

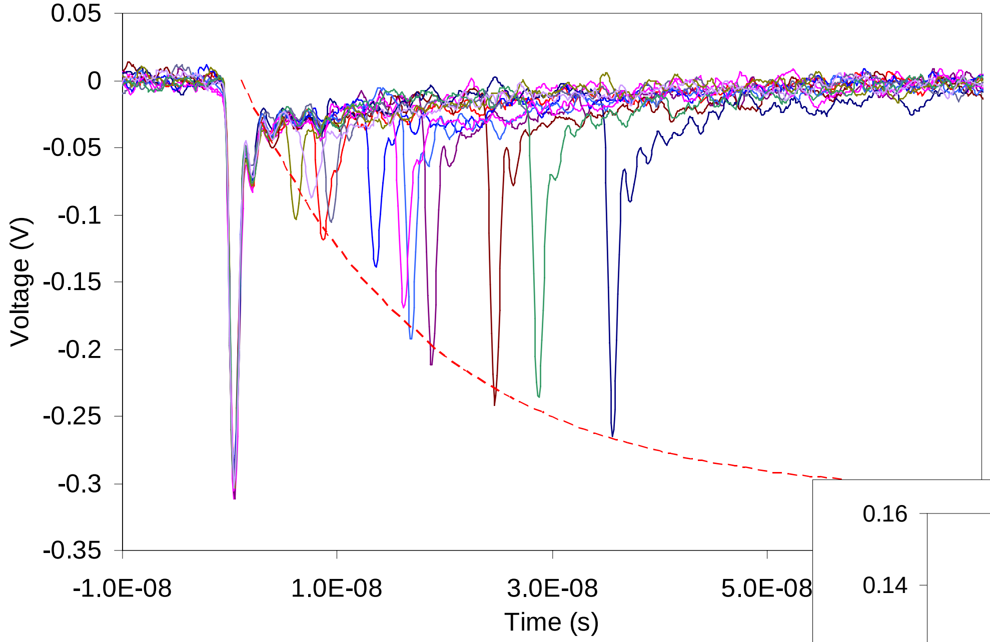
Performed in the climatic chamber. Devices from the third batch







After-pulsing



Events with after-pulse measured on a single micropixel.

The amplitude of the after-pulse increases as the cell recovers to its opertional condition

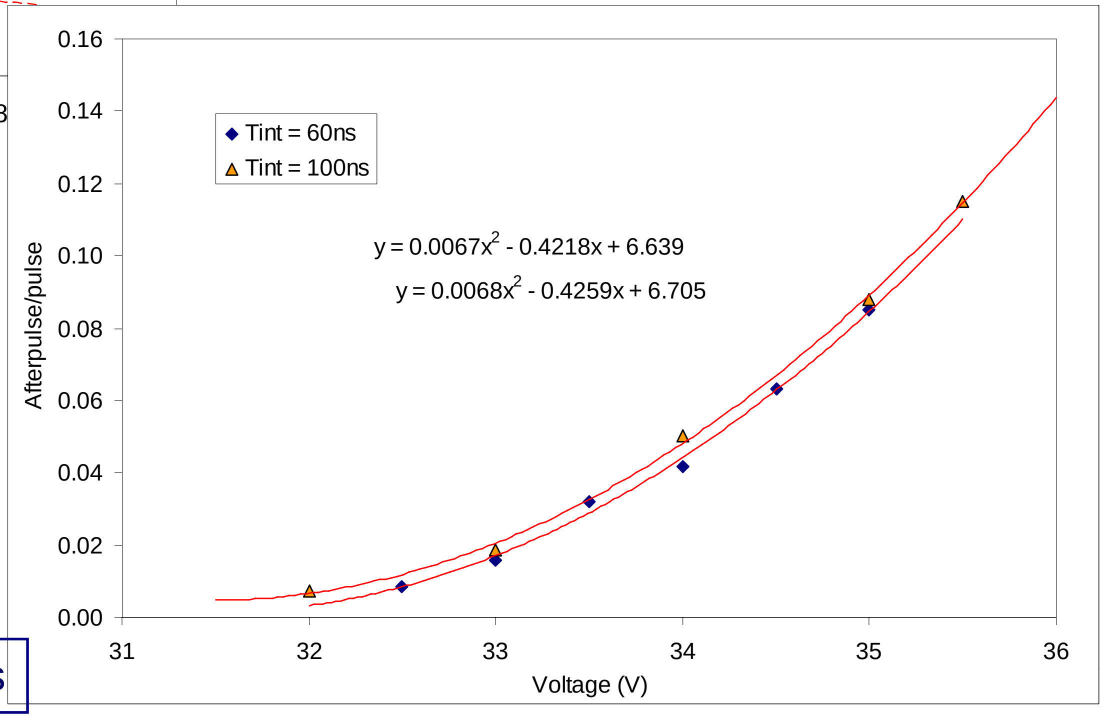
After-pulse probability *vs* bias

It increases following a parabolic law:

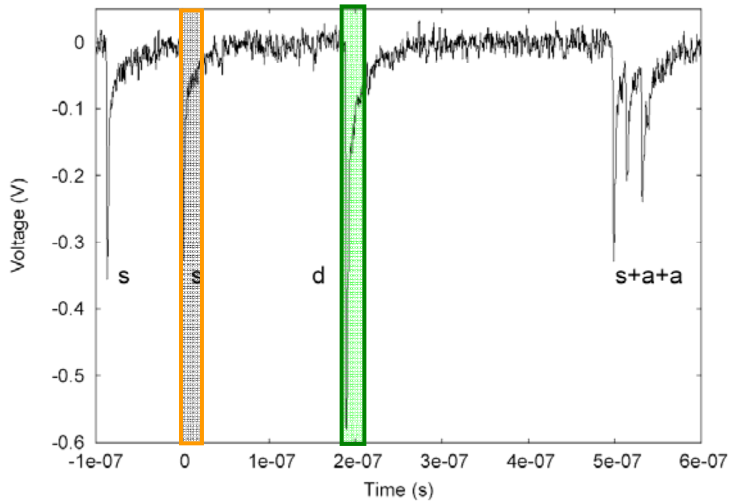
$$P_a = P_c \cdot P_{01}$$

linear with Vbias

linear with Vbias

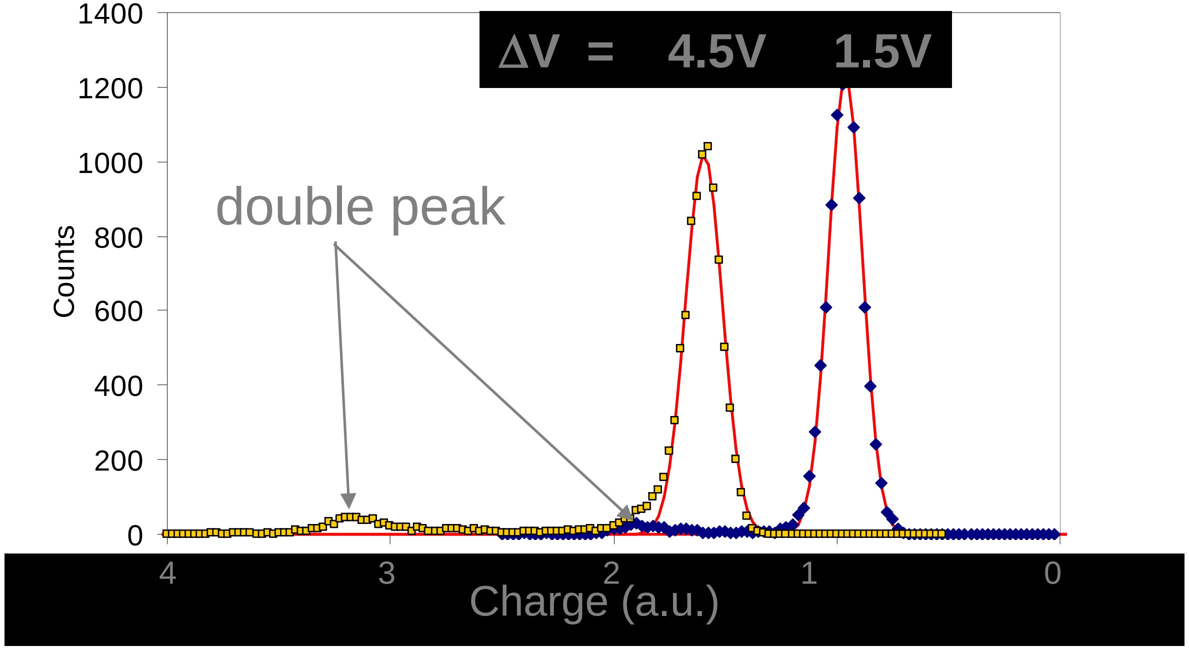


Optical cross-talk



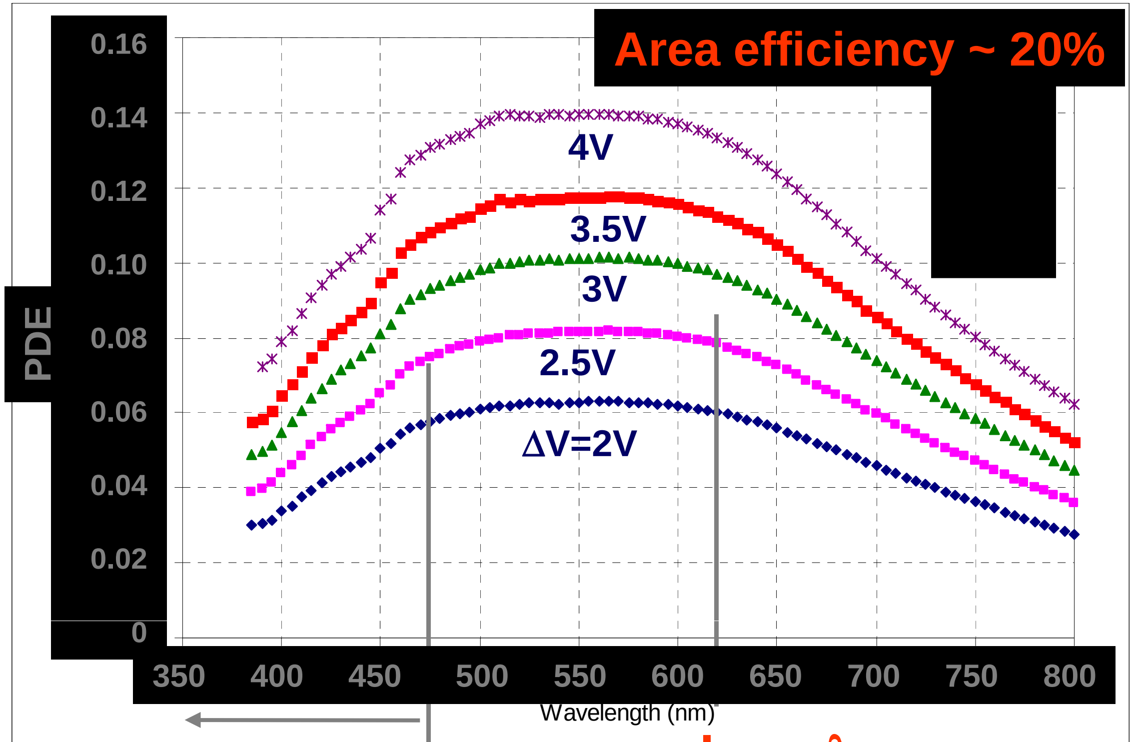
Short integration time
⇒ only single/double/….pulses are counted

Number of events with optical cross-talk increases with voltage



Cross-talk below 5% at 4V over-voltage.

Photodetection efficiency

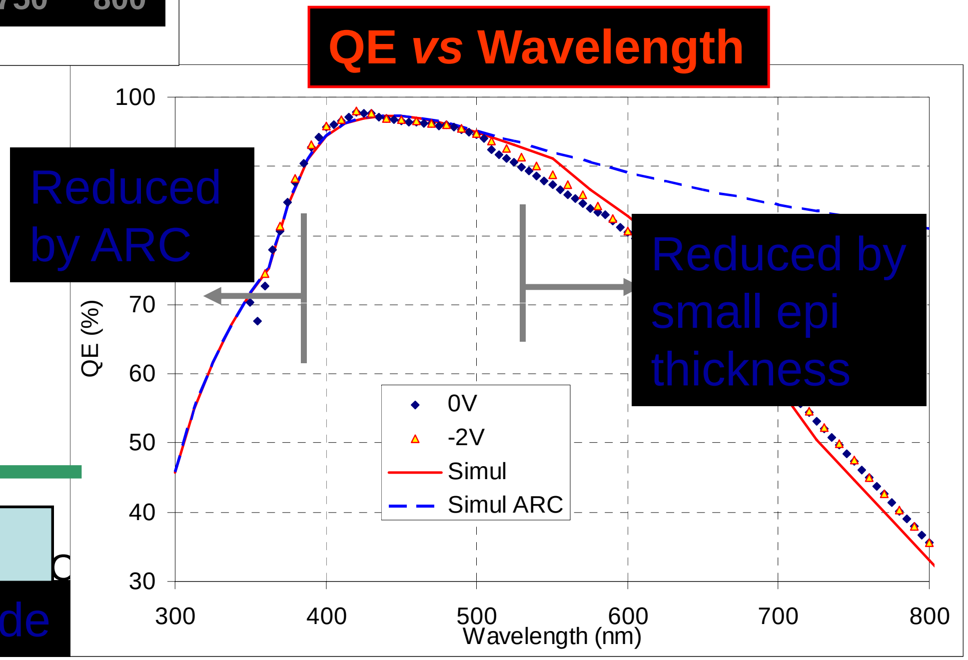


PDE=QE*Pt*Ae

QE=quantum eff.
P_t=avalanche prob.
A_e=area eff.

short λ:
low PDE because avalanche triggered by holes

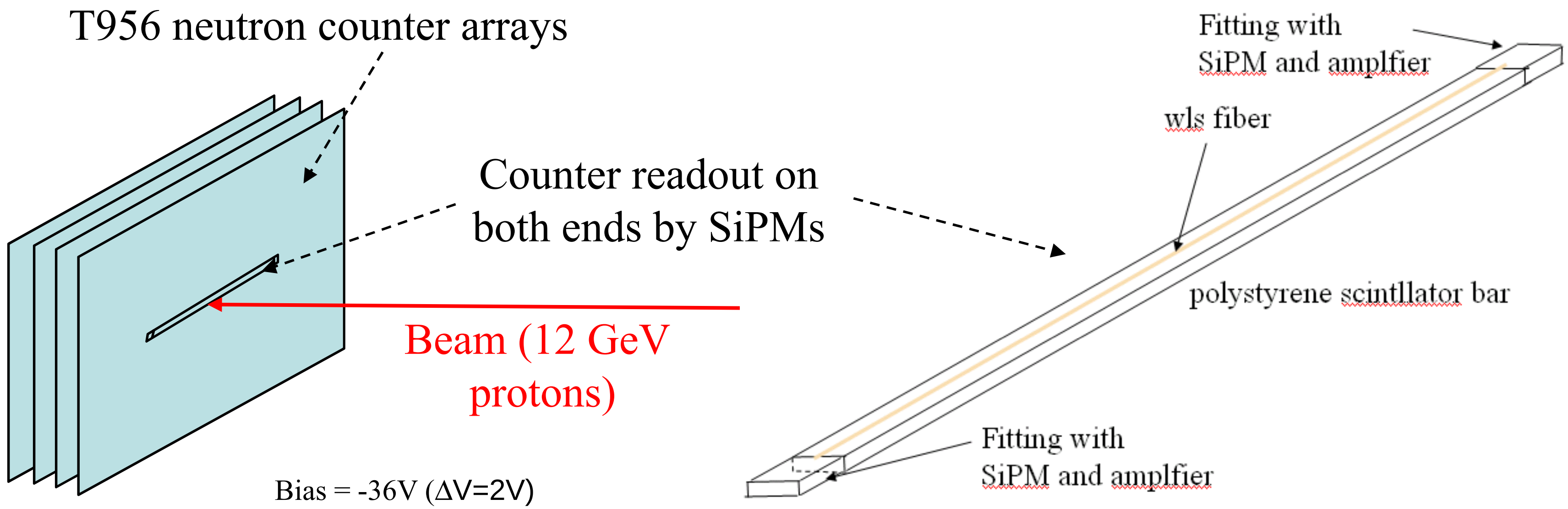
long λ:
low PDE because low QE

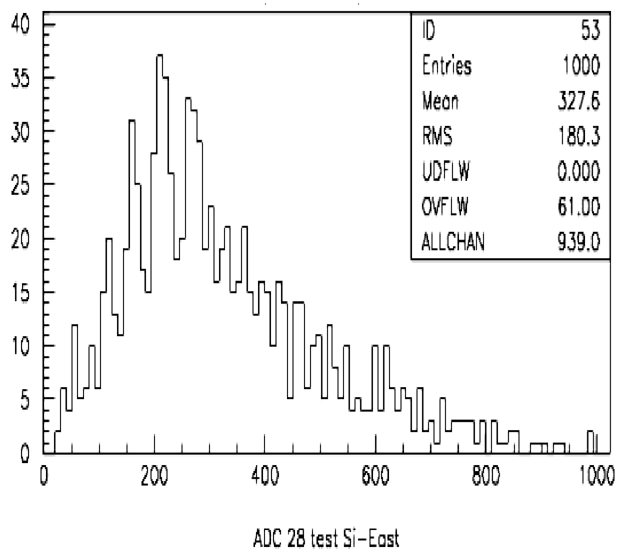


Measured on a diode

Application at FNAL T956

Preliminary study of Scint. Strip viewed by IRST SiPM at the FNAL test beam





Data with 120 Gev proton - beam

$$N_{p.e.} \approx 6.5\, p.e.$$

$$\varepsilon = 99\%$$

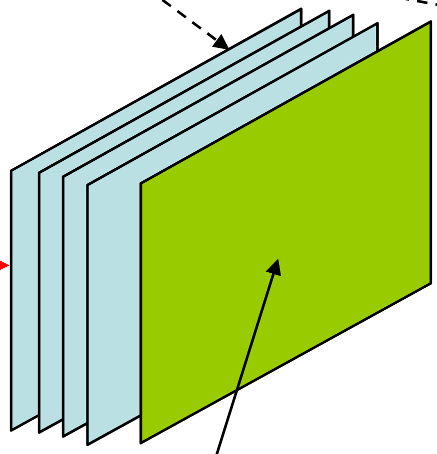
$$N_{d.c.} \approx 1.5 MHz$$

$$G \approx 1.6 \times 10^6$$

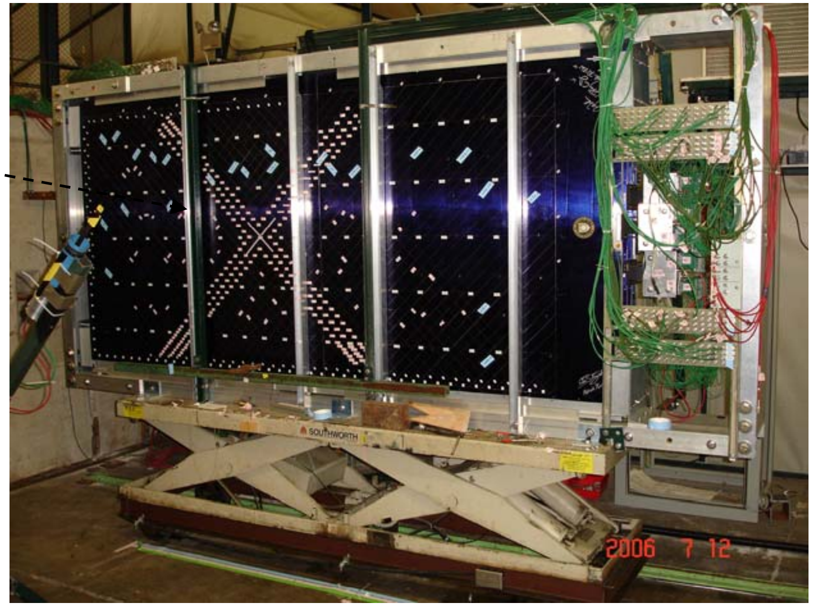
Future work

T956 neutron counter arrays:
64 scint strips each
(read out by wls fiber
and MAPMTs)

Beam (p,π,e)

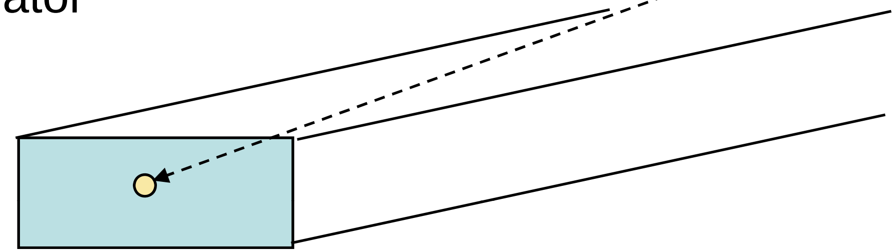


Add one plane
of scint strips read
out by Wls fiber and
SiPMs



Whole assembly mounted on
movable (x,y) support

Scintillator strips : 4cm x 1cm x (1 – 2 m), read out by wls fiber. Groove for fiber extruded with scintillator



Perspective

Development started at the beginning of 2005.

September 2005

First batch * Establish functionality and base-line parameters

Trento/INFN funds development of SiPM devices, mainly for PET application

May 2006

Second batch

* Verify reproducibility of the first batch
* First attempt to reduce optical cross-talk

Second Batch tested at FNAL (T956). FACTOR collaboration (Ts/Ud/Me) apllies for INFN funding to develop: for calorimetry/muons

October 2006

Third batch * First attempt to reduce dark count rate

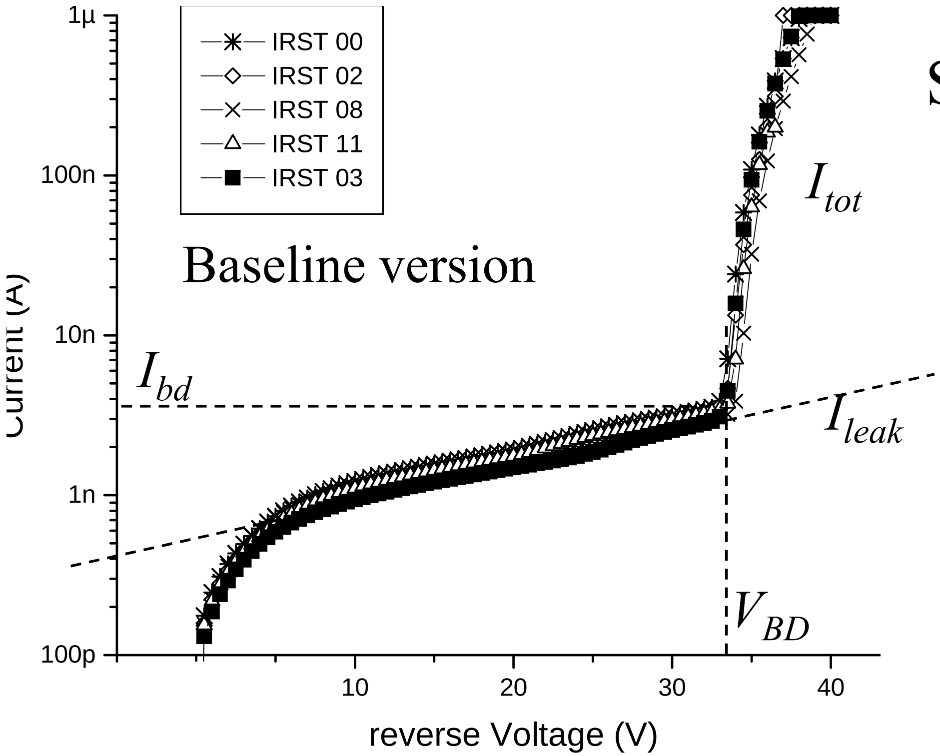
FACTOR funded

May 2007

Fourth batch

* optimize fill factor
* new geometries for different applications (including T956)
* continue the study on dark count reduction

Static measurements-1



Rapid check functionality & uniformity

Sensitive to principal characteristics

dark current $I_{dc} = I_{tot} - I_{leak}$

is prop. to gain G and dark count (DC)

$$I_{dc} \propto G.(DC)$$

and since $G \propto V, \quad DC \propto V$

$$I_{dc} \propto V^2$$

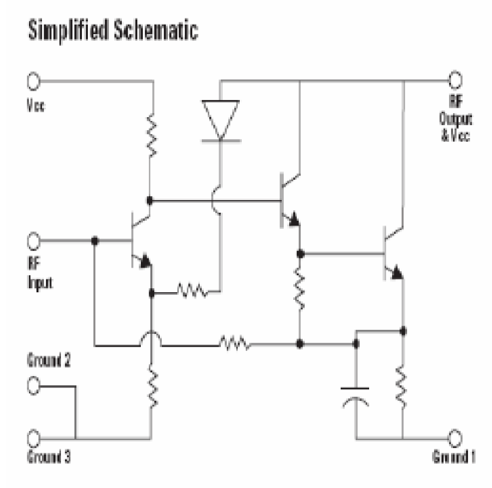
SiPM	Vbd (V)	Ibd (nA)
IRST-00	32,5	3,6
IRST-02	33,0	3,6
IRST-03	33,0	3,1
IRST-08	33,5	3,2
IRST-11	33,5	3,8

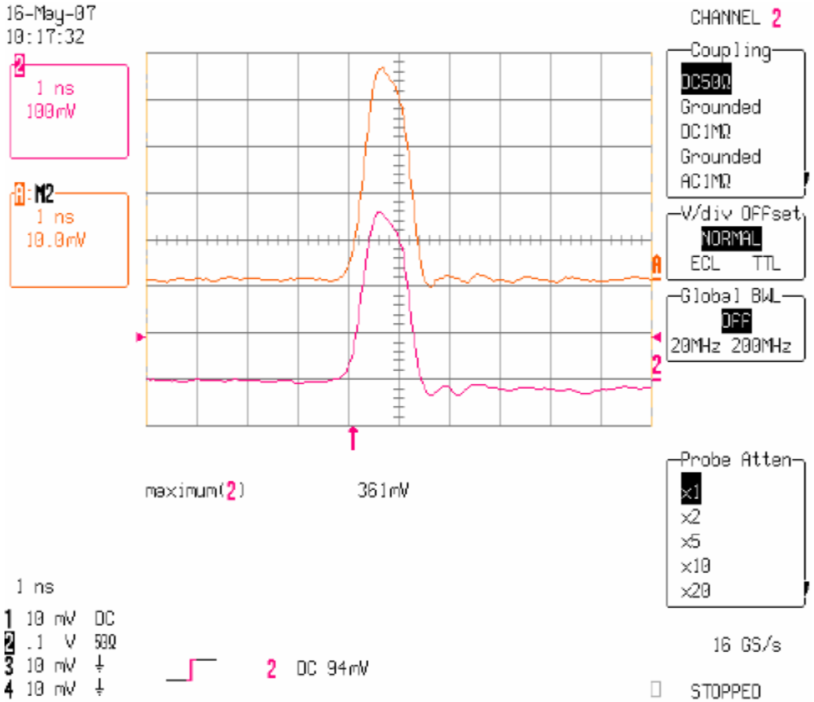
IRST 1mm^2
second batch

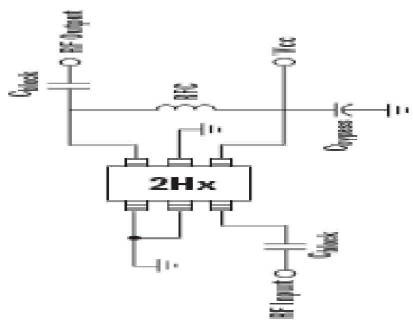
IRST devices generally very uniform

dynamic measurements-1

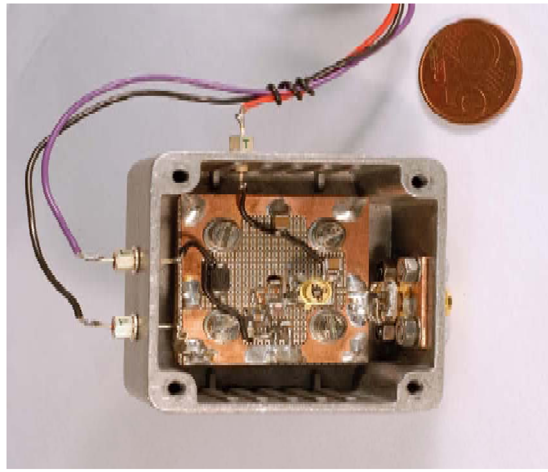
Amplifier used for fast characterization of SiPMs:
Agilent ABA-52563 3.5 GHz RFIC Amplifier
(economic, compact, internally 50-Ω matched, gain ~ 20 dB)
Dimensions 1.8 x 1.8 mm2



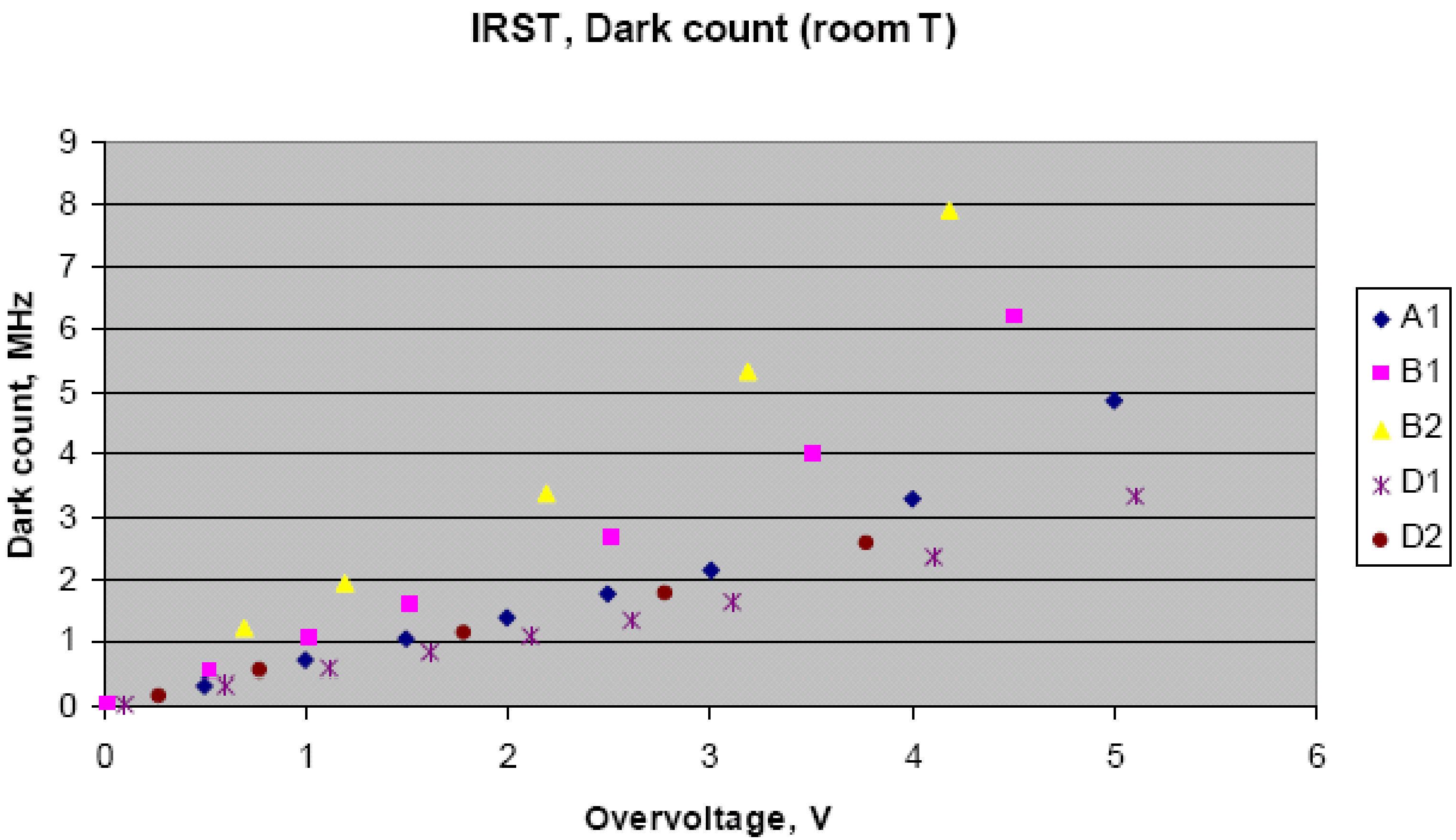




Orange trace: input from pulse generator, FWHM = 0.9 ns, tr = tf = 300 ps
Red trace: amplifier’s output

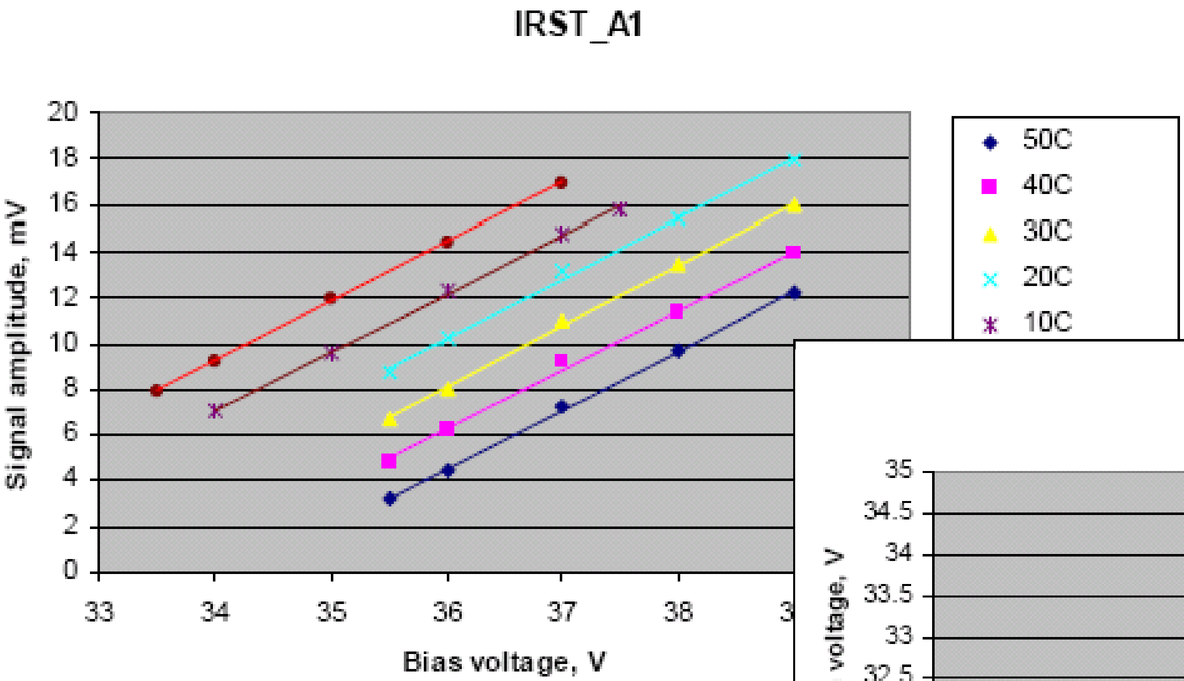


dynamic measurements-5

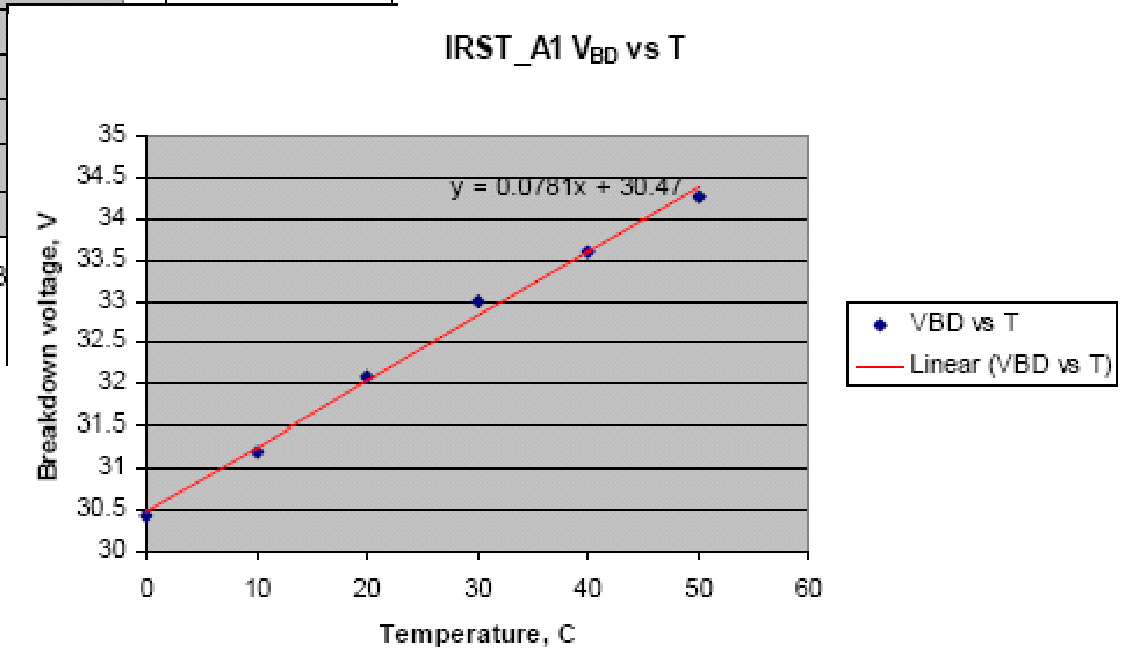


type "A", D.C.(ΔV=2V) ≈ 1.5 MHz
type "B", D.C.(ΔV=2V) ≈ 2- 3 MHz
type "D", D.C.(ΔV=2V) ≈ 1 MHz

dynamic measurements-6



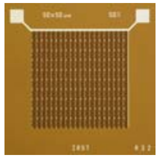
Temperature Dependences - 1



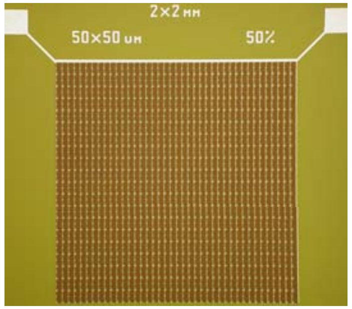
Measurements performed in a climatic chamber (with humidity control)
The amplifier was located outside the chamber, connection via a special 18 GHz ft
50 Ω cable

$$dV_{BD}/dT \approx 78\ mV/C$$

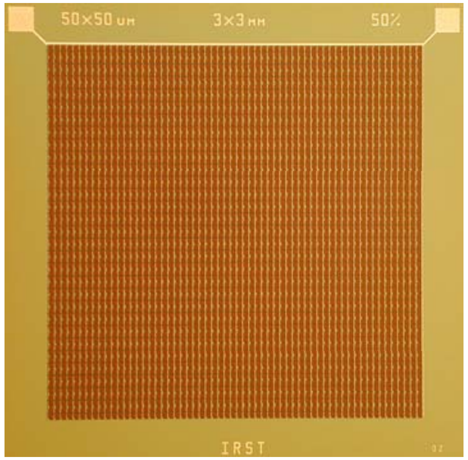
last batch



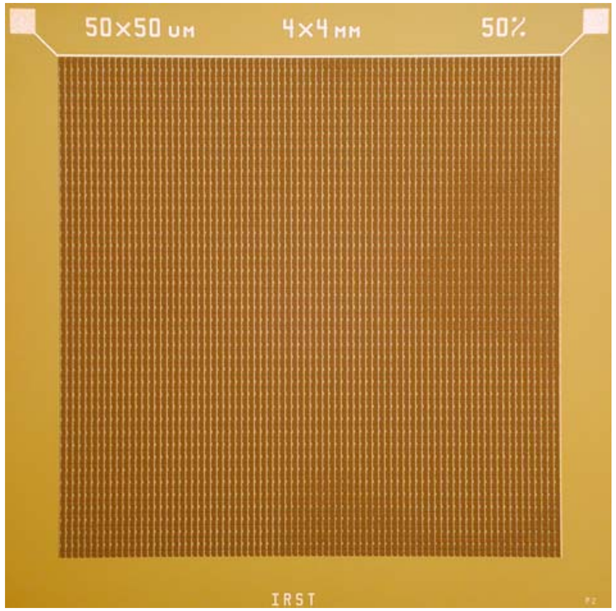
1x1mm



2x2mm



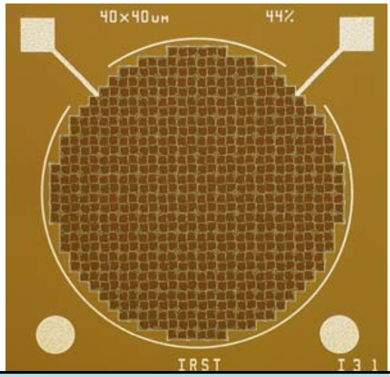
3x3mm (3600 cells)



4x4mm (6400 cells)

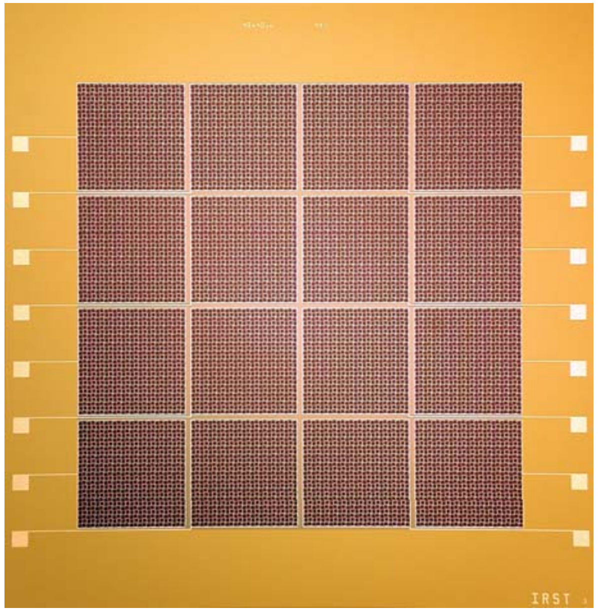
increased fill factor:

40x40mm => 44%
50x50mm => 50%
100x100mm => 76%;



Circular
(1.2 mm –
diameter)

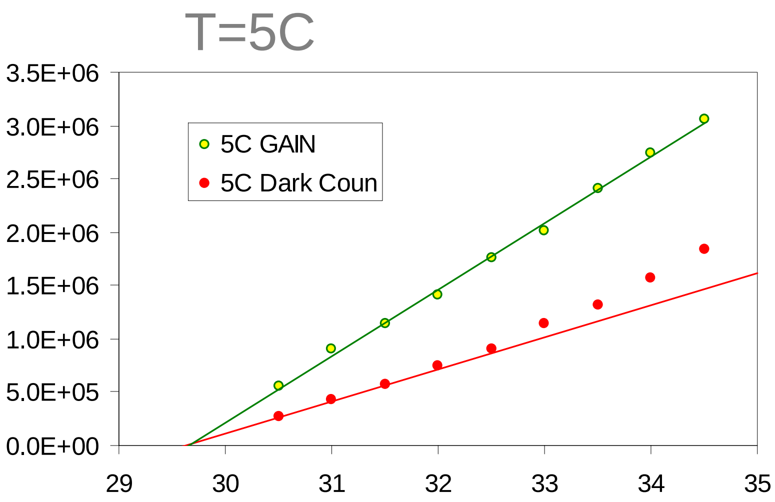
Array

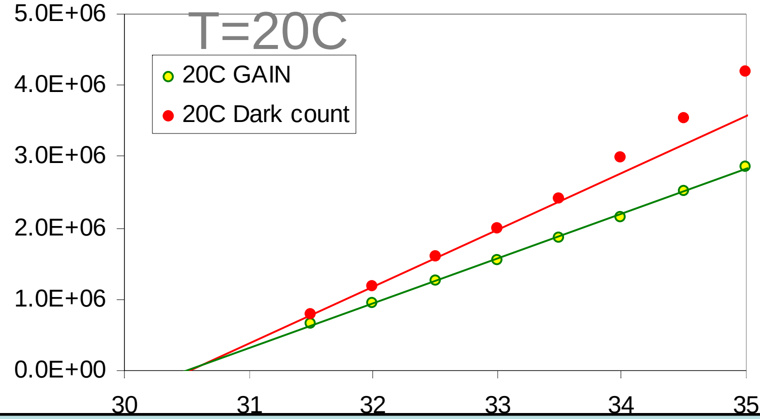


First signal and noise characteristics of the last devices

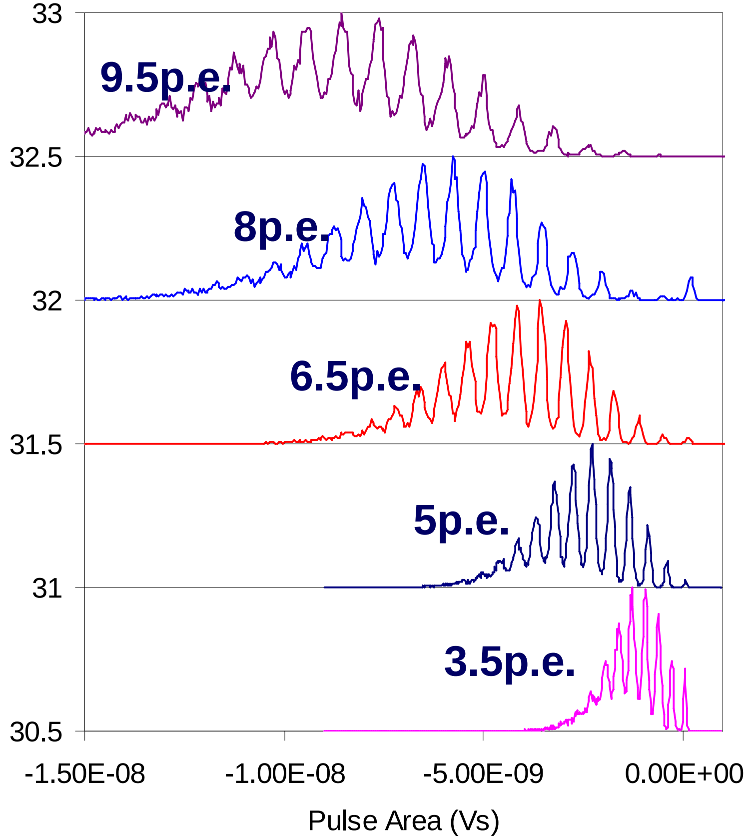
Noise and charge resolution

1x1mm^2 SiPM with 40x40μm^2 cells





Charge spectra at different Voltages with the same light Intensity (pulsed)



resolution limited by electronic noise

T956 devices packaged with and without protective resin for test