SiPM technology at FBK

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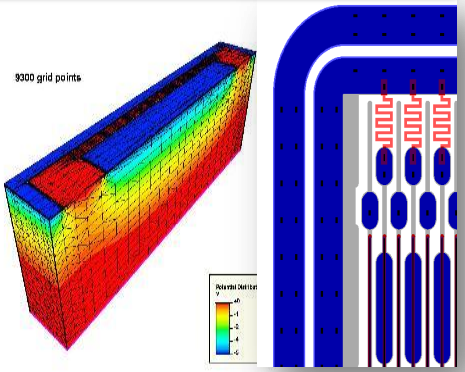
Outline

- **FBK fabrication capabilities**
- **FBK SiPM technology**
- **Results achieved during the years**
  - **2006**
  - **2007**
  - **2008**

FBK

Capabilities in silicon technology

TCAD simulation
CAD design



Fabrication

- 500m^2 lab for silicon device processing.
- no process steps out.
- all autom. equipment.
- 4'' wafers.

Device testing

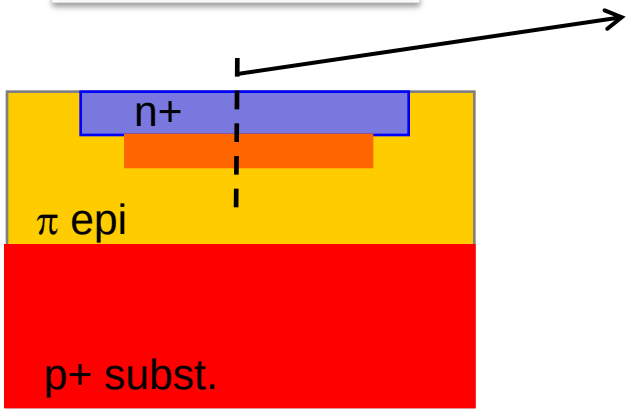
- 3 automatic probers
- 2 manual probers
- optical bench
- basic lab for functional tests

15-year experience in silicon radiation detectors

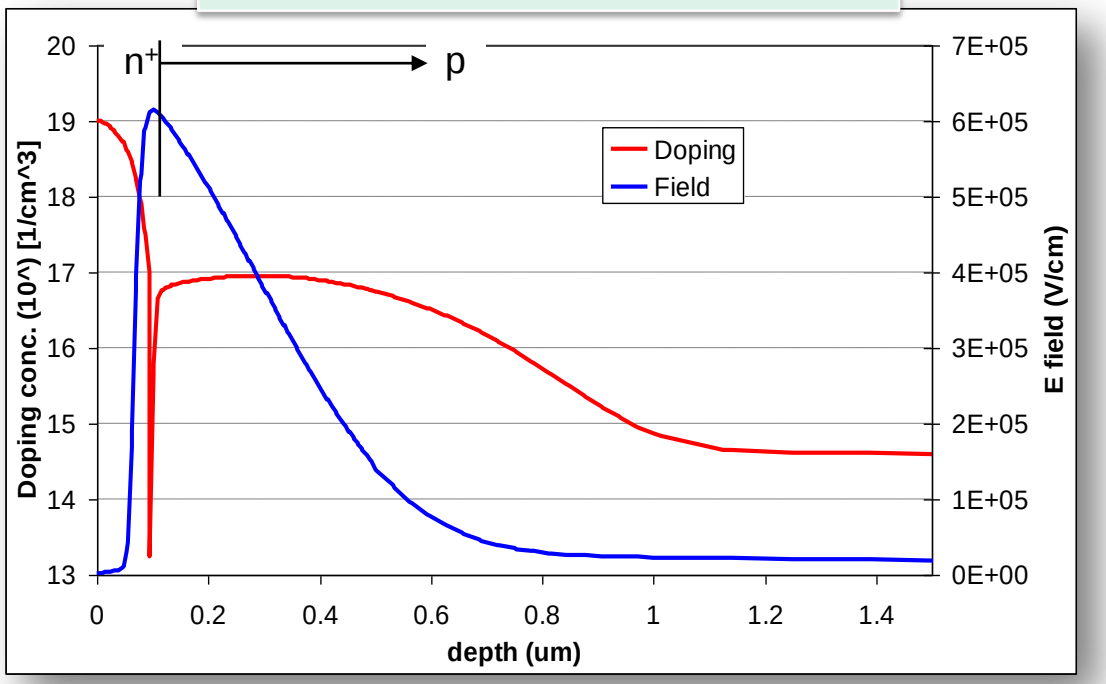
SiPM Technology

Developed in 2005

Cross section



Shallow-Junction SiPM



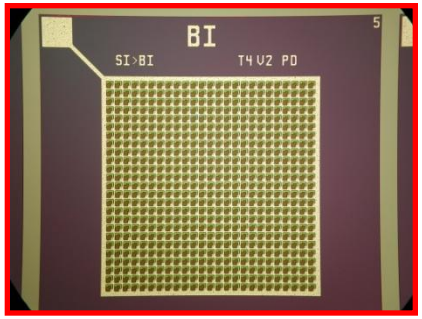
Standard approach but with two peculiarities:

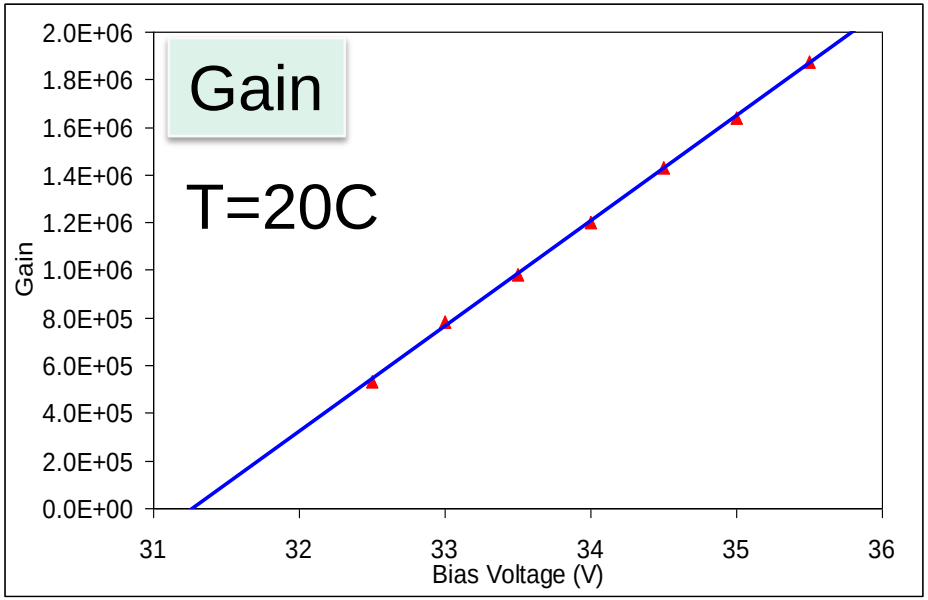
1) Very shallow junction
2) ARC optimized for short wavelenghts

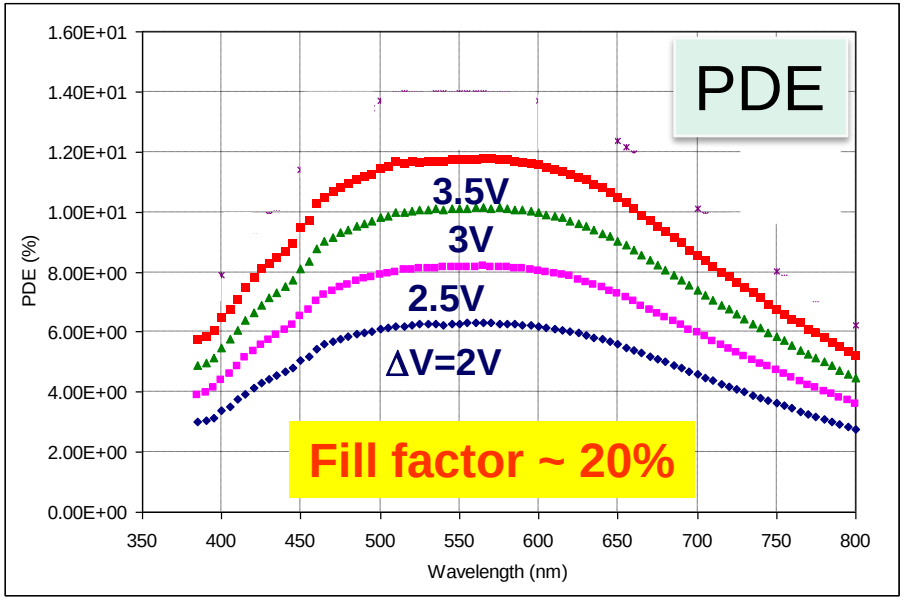
⇨ To enhance QE at short wavel.

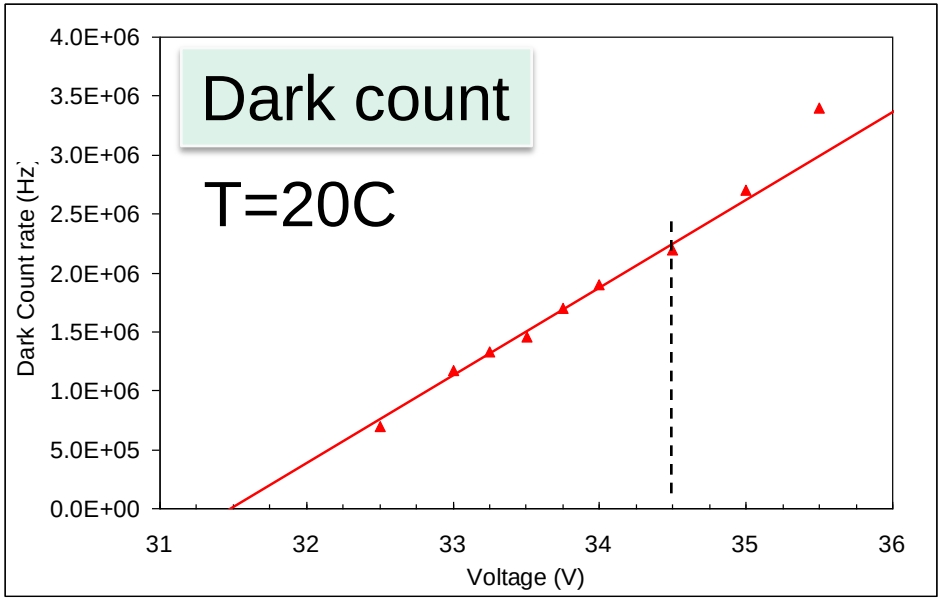
NSS 2006 – San Diego

Only 1 geometry: 1x1mm^2 with
40x40μm^2 cell
max fill factor 30%





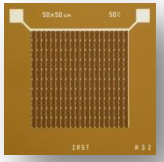




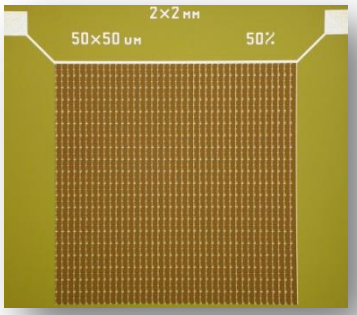
C. Piemonte

C. Piemonte et al. IEEE TNS, February 2007

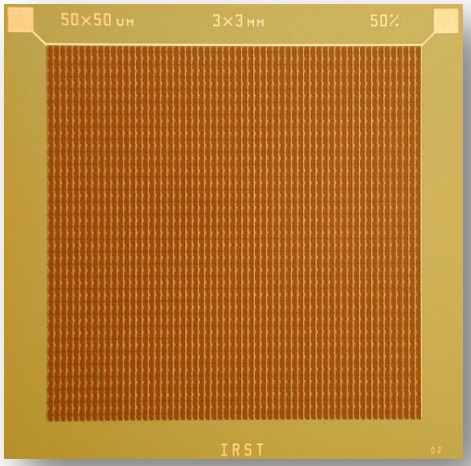
NSS 2007 - Hawaii



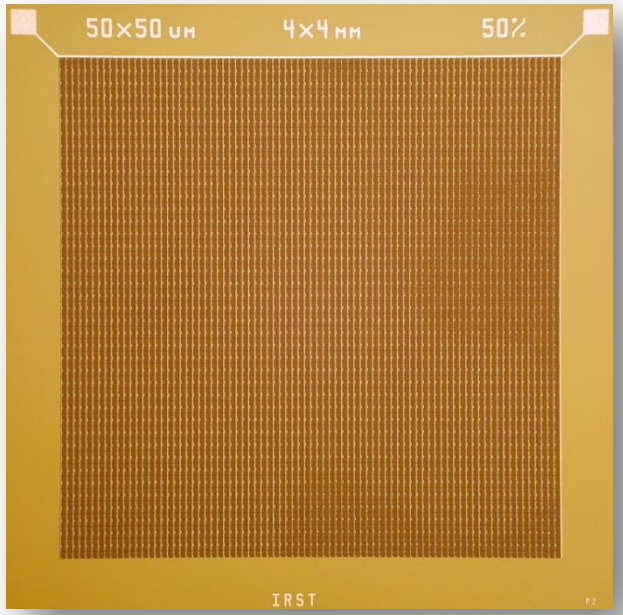
1x1mm^2



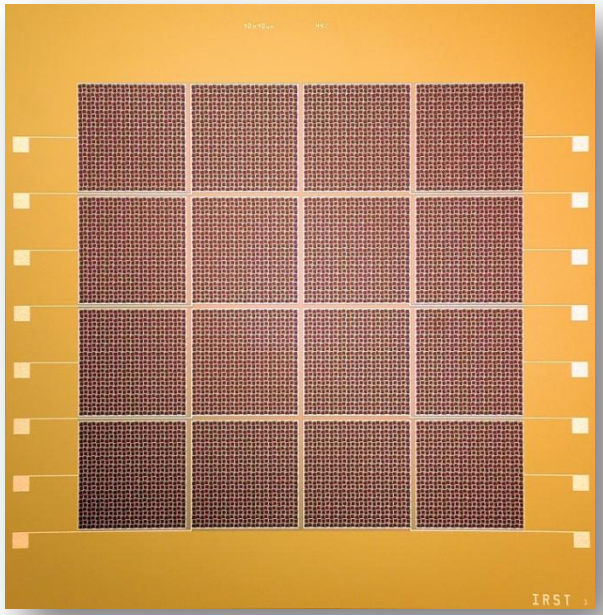
2x2mm^2



3x3mm^2 (3600 cells)

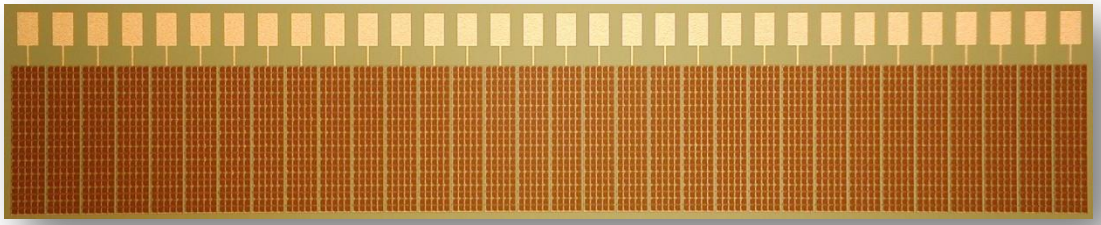


4x4mm^2 (6400 cells)



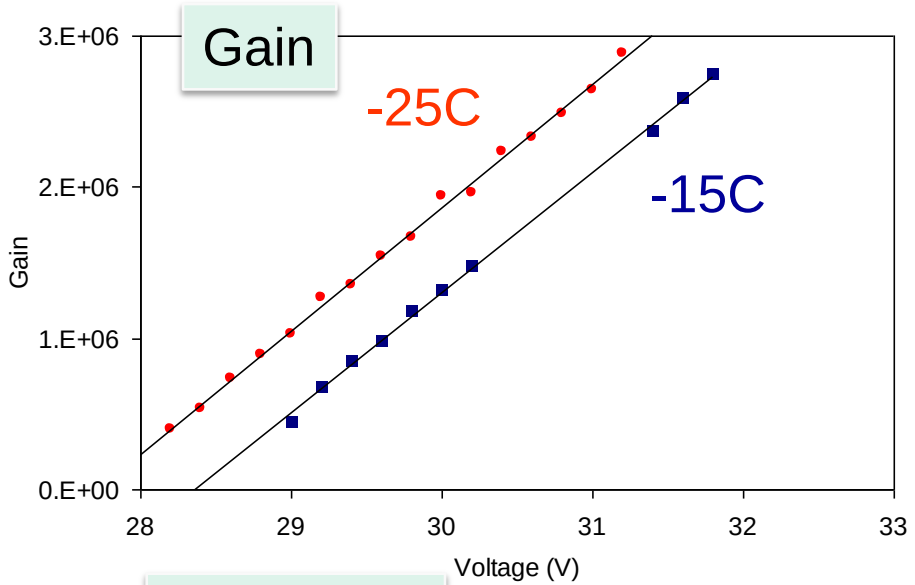
Matrices:
4x4 elements
of 1x1mm^2 SiPMs

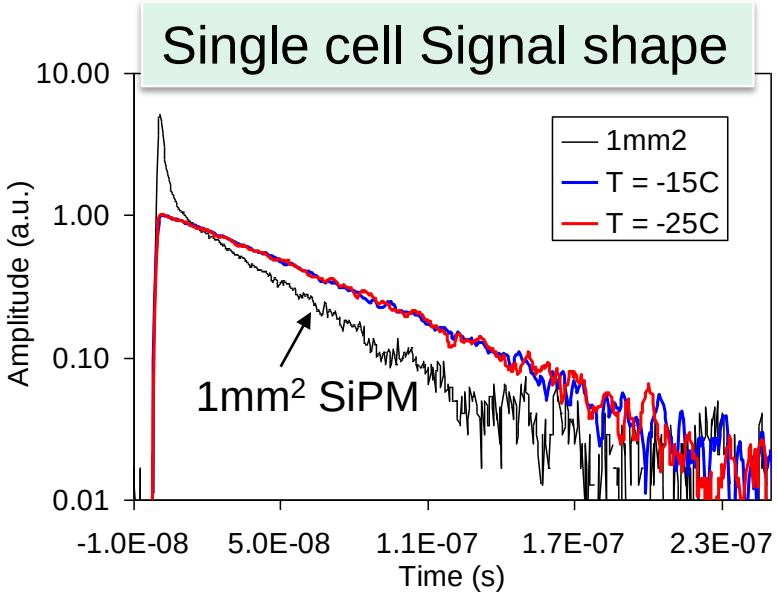
Linear arrays:
8,16,32 elements of
1x0.25mm^2 SiPMs

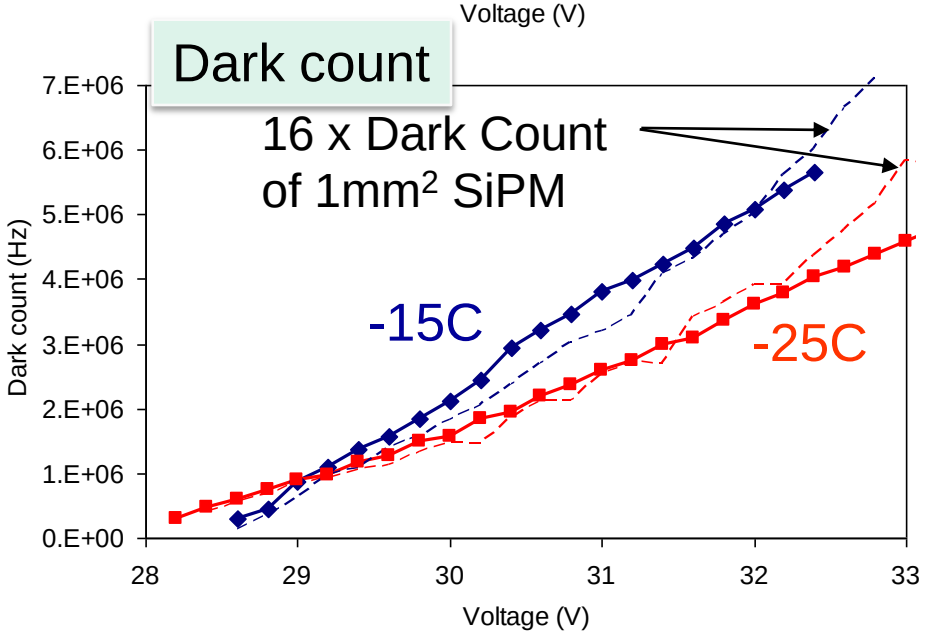


4x4mm² SiPM - 50x50mm² cell

4x4mm²

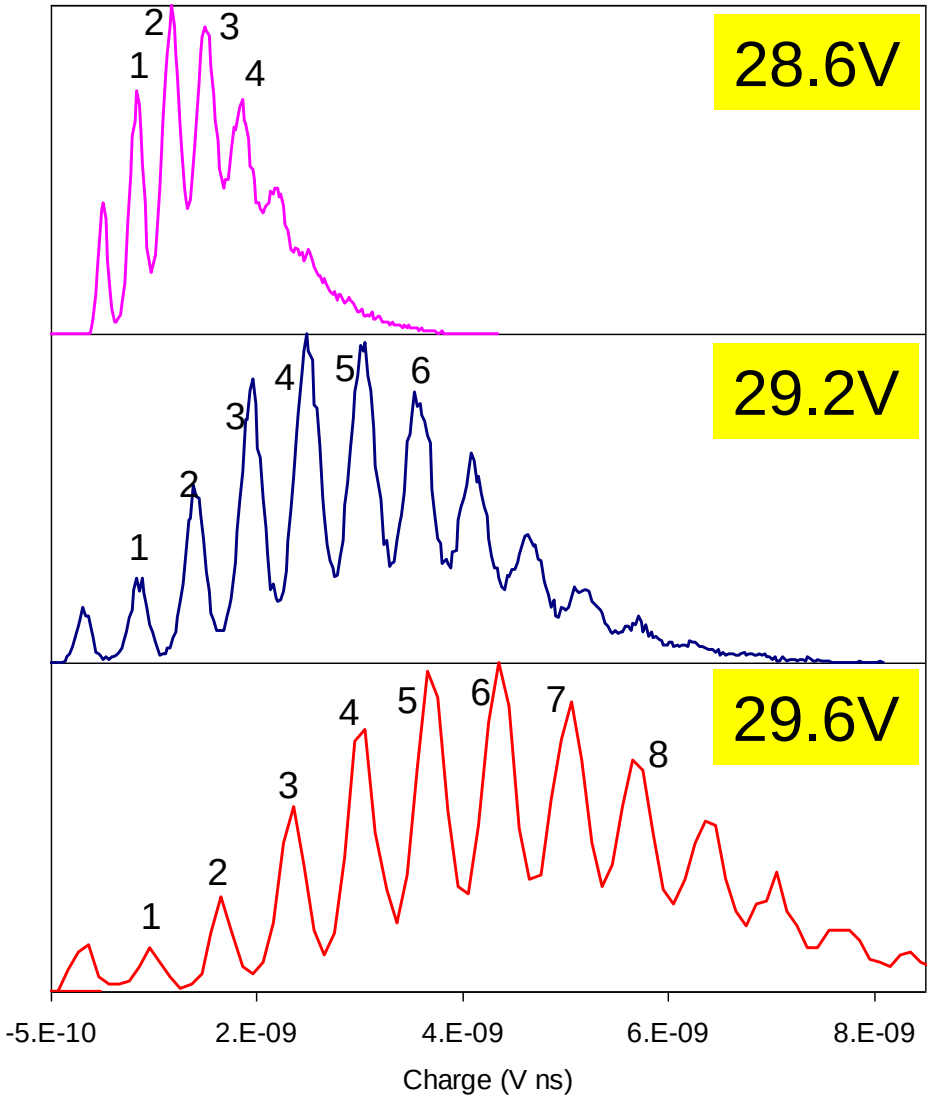






4x4mm² SiPM - 50x50mm² cell

T=-25C Vbd=27.6V

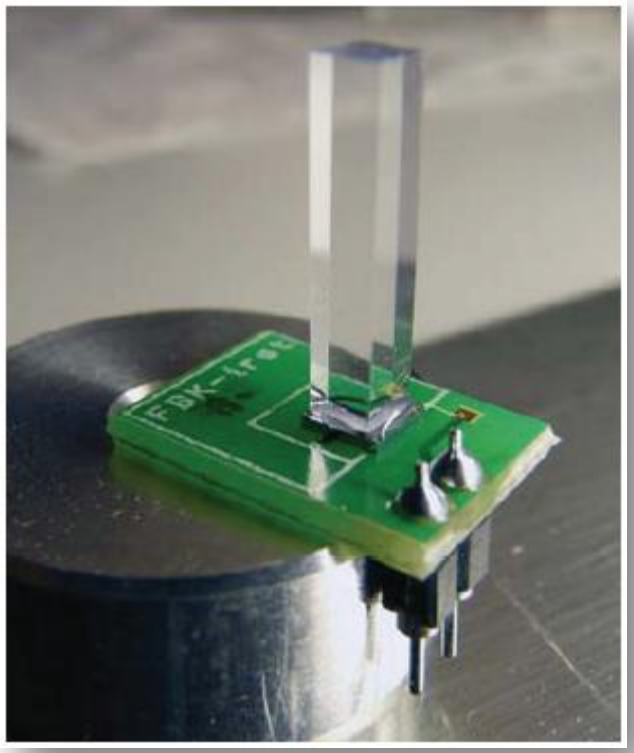


Charge spectra under illumination with short low-intensity light pulses

- Excellent cell response uniformity over the entire device (6400 cells)
- Width of peaks dominated by electronic noise

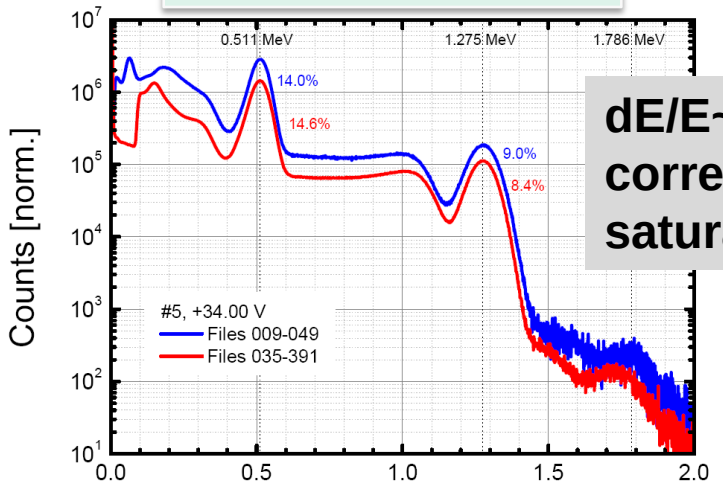
4x4mm² SiPM - 50x50mm² cell

PET application:
SiPM + LYSO



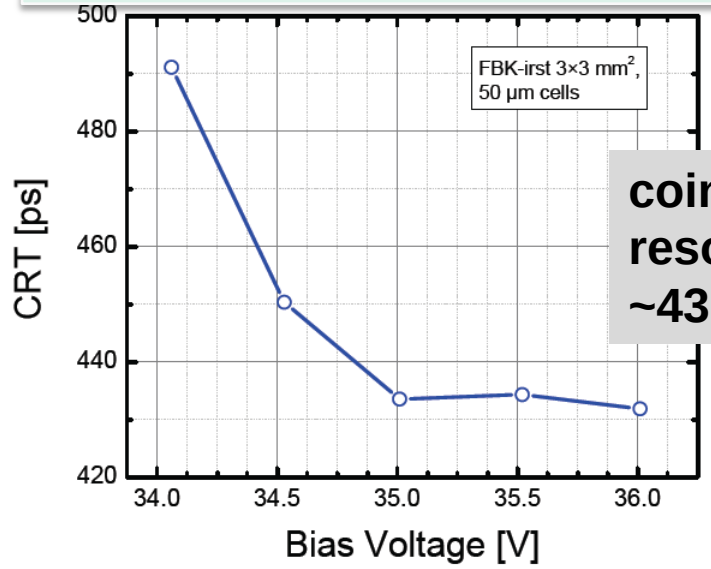
Measurements by Philips Aachen

Energy resolution



dE/E~14% corrected for saturation

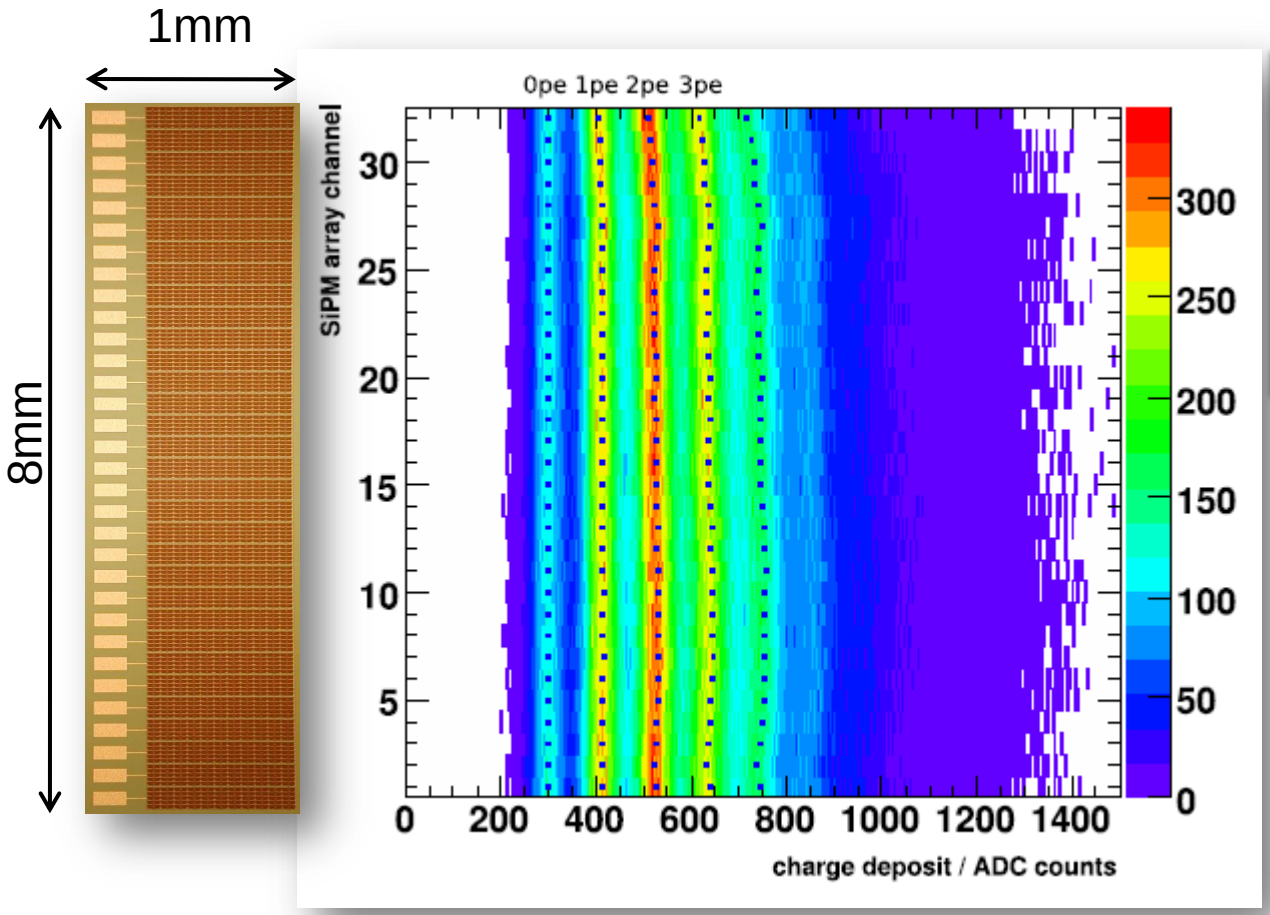
Coincidence time resolution



coincidence resolution ~430ps

Response uniformity

SiPM array for fiber tracking application



Charge deposited versus SiPM array channel under illumination with a pulsed LED.

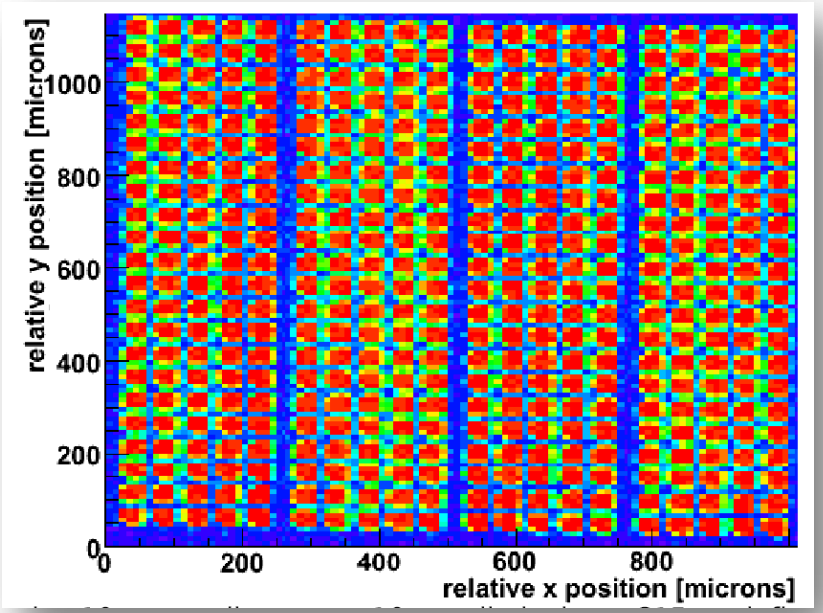
Gain variation of 2%

R. Greim, H. Gast, T. Kirn, J. Olzem, G. Roper Yearwood, S. Schael, N. Zimmermann, G. Ambrosi;c, R. Battiston; C. Piemonte
presented at Siena conference 2008

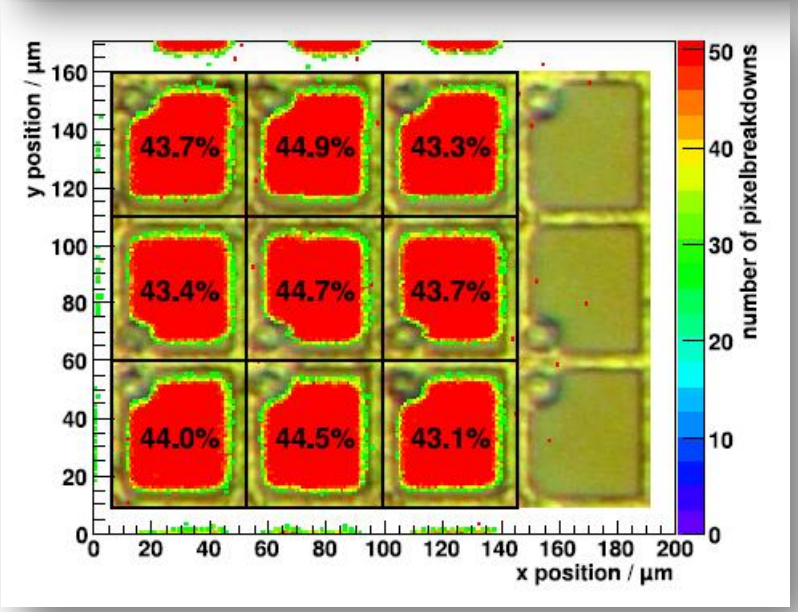
Cell functionality and fill factor

Illumination with a LED spot diameter of ~5 µm.

Coarse step to verify functionality of cells



Fine step to estimate the fill factor



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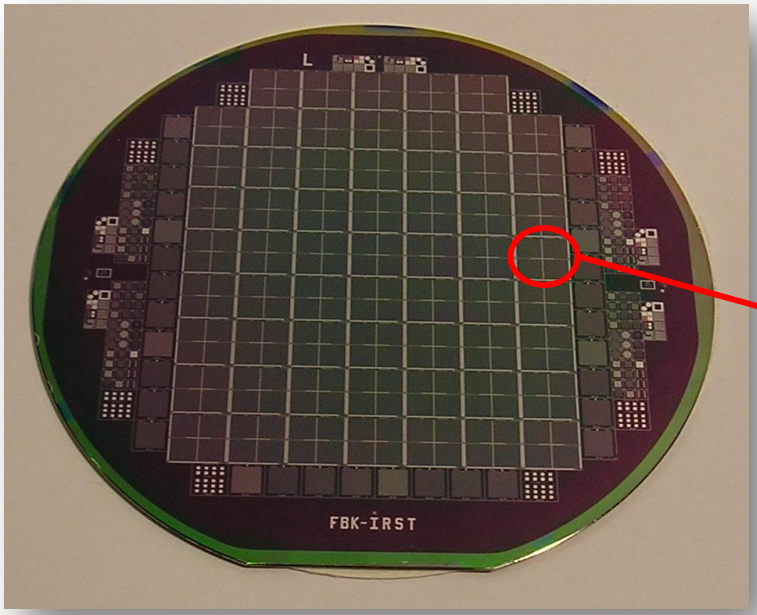
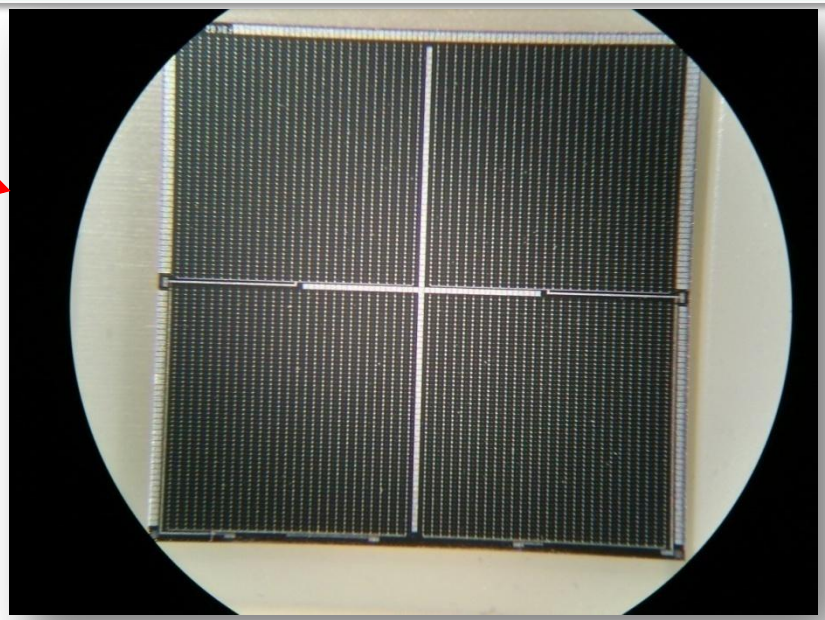
2008/09 – large area devices & first productions

HyperImage EU-funded project (www.hybrid-pet-mr.eu)

Finalized small production for first small animal PET/MR
Produced ~700 fully working arrays

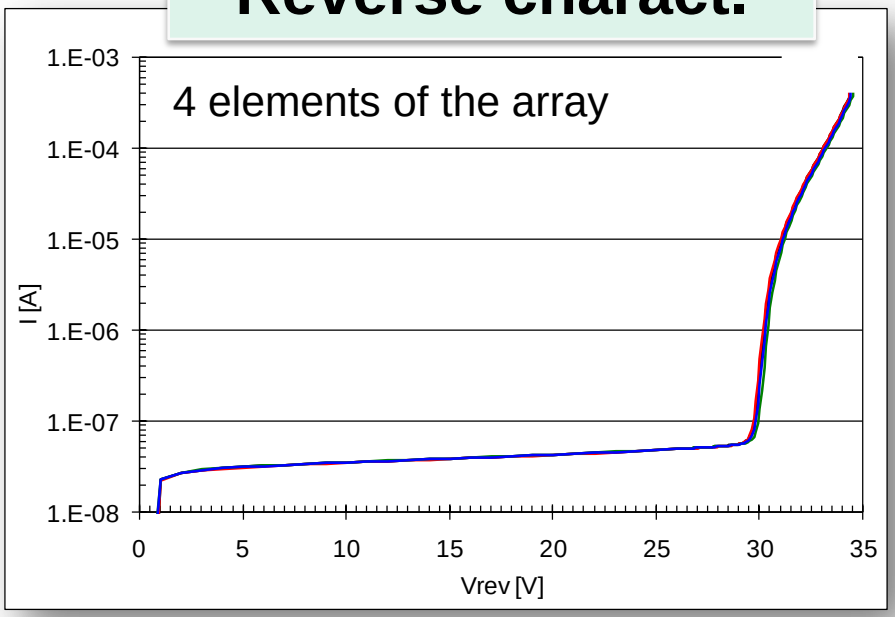


2x2 array of ~4x4mm^2 SiPMs

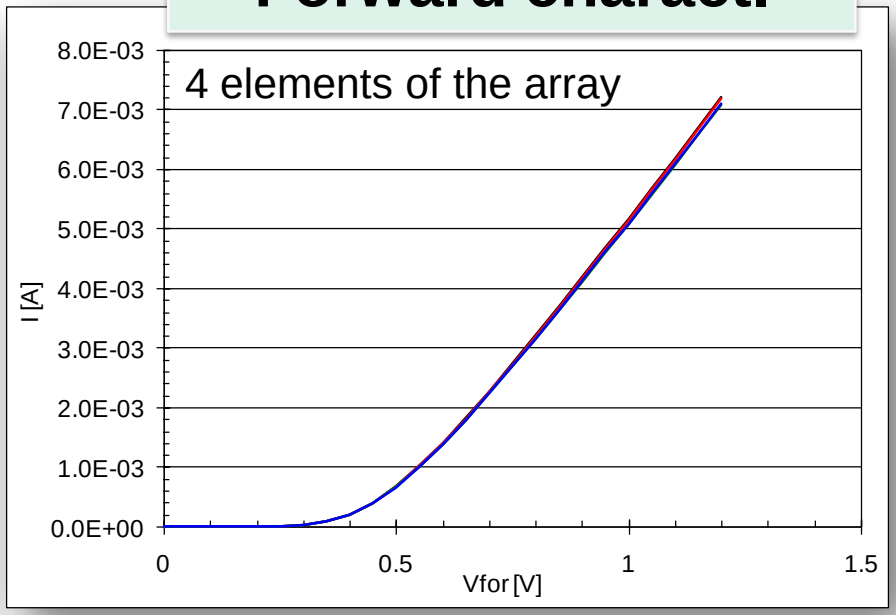


HI SiPM - testing procedure

Reverse charact.



Forward charact.



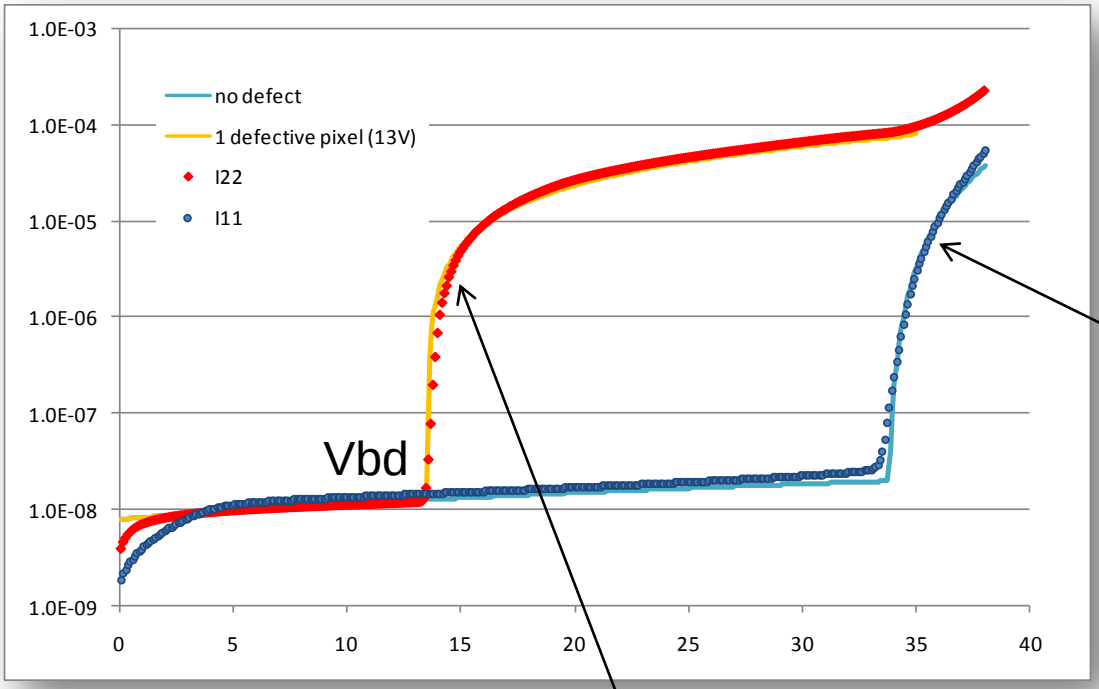
Info we get

- Functionality of the device
- Breakdown voltage
- Dark count estimate

- Functionality of the device
- Resistor value estimate

HI SiPM – faulty devices

Most common defect is premature breakdown

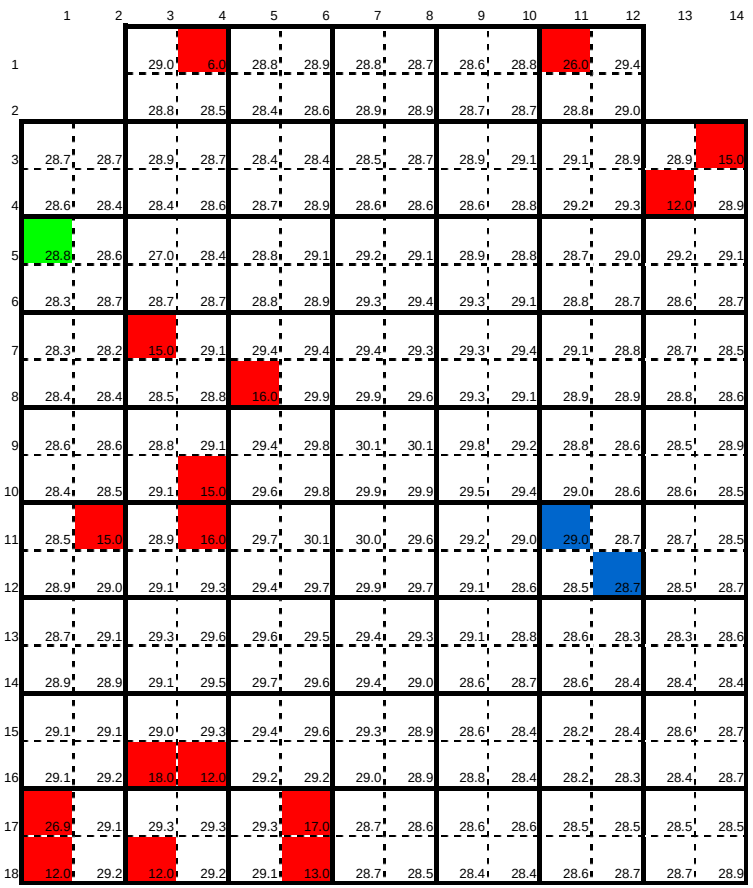


working SiPM.
The current can
be roughly modeled
as I=q*DC*G

SiPM with 1 defective cell.
The current can be modeled
as I=(V-Vbd)/Rq

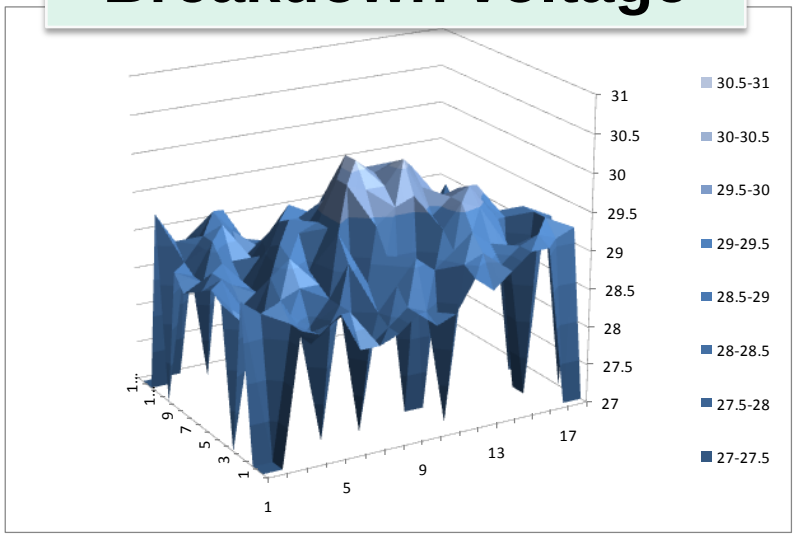
HI SiPM – summary of a wafer test (good one)

Wafer map

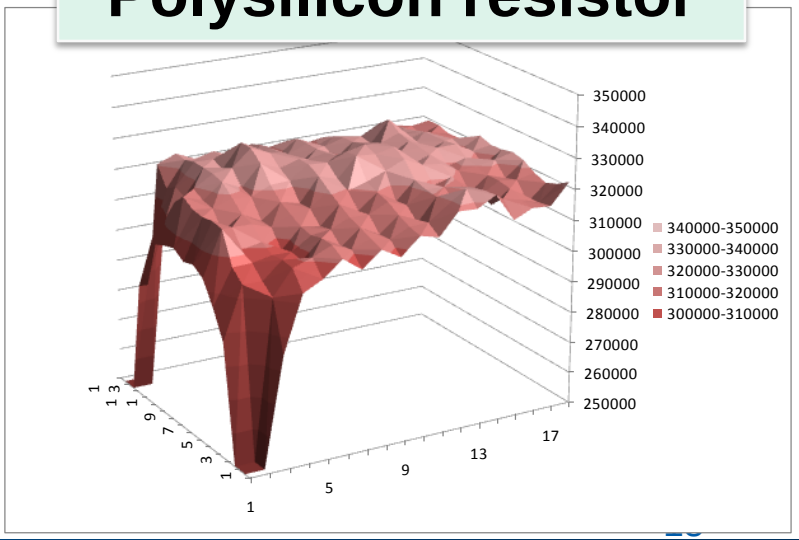


white = OK
red = premature breakdown
green/blue = problems after breakdown

Breakdown voltage

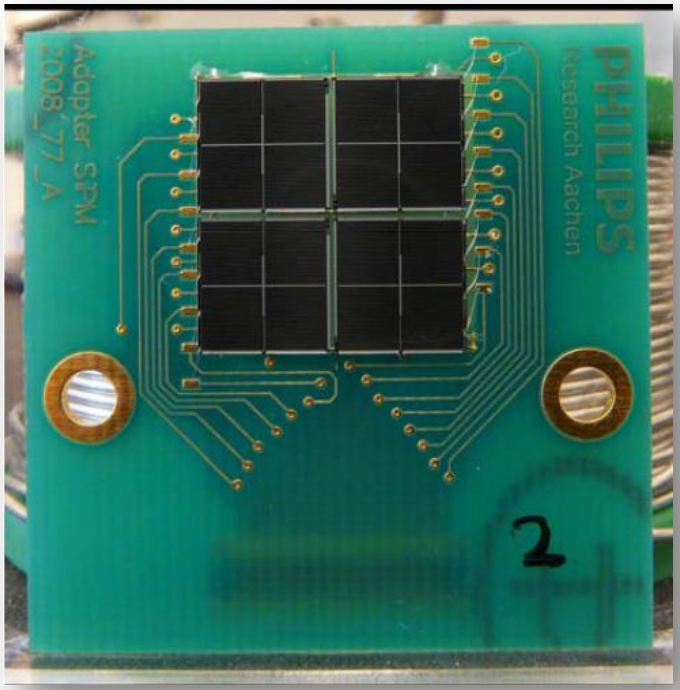


Polysilicon resistor

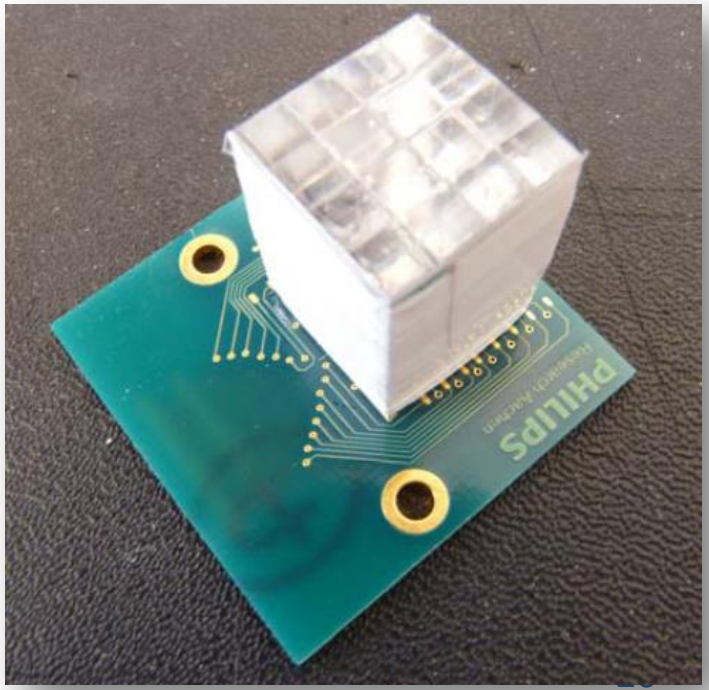


C. Piemonte

HI SiPM – first functional tests ongoing



4 arrays mounted on test PCD

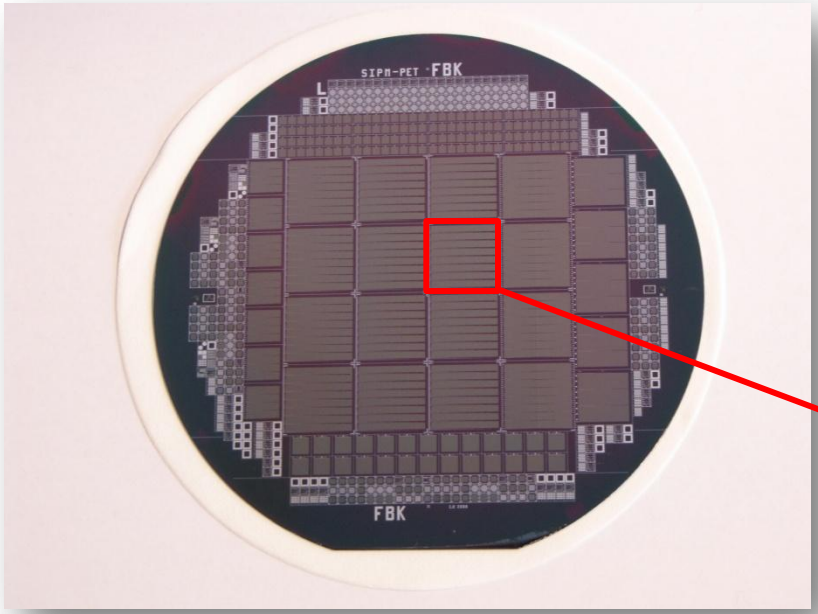


LYSO crystal mounted on the SiPMs

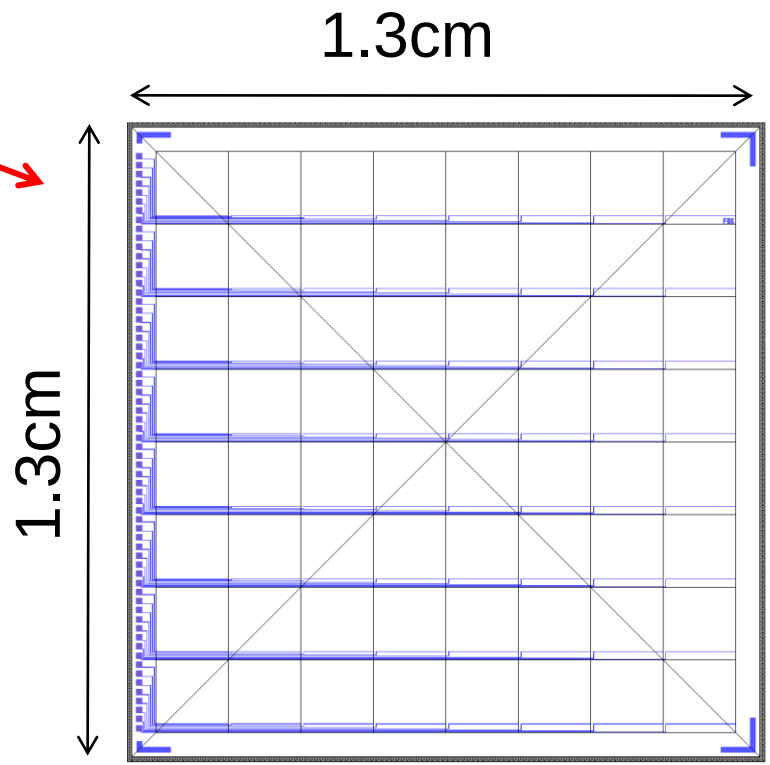
mounting @ Philips Aachen

Arrays for INFN-DaSiPM2 project

INFN Pisa
Bari
Bologna
Perugia
Trento

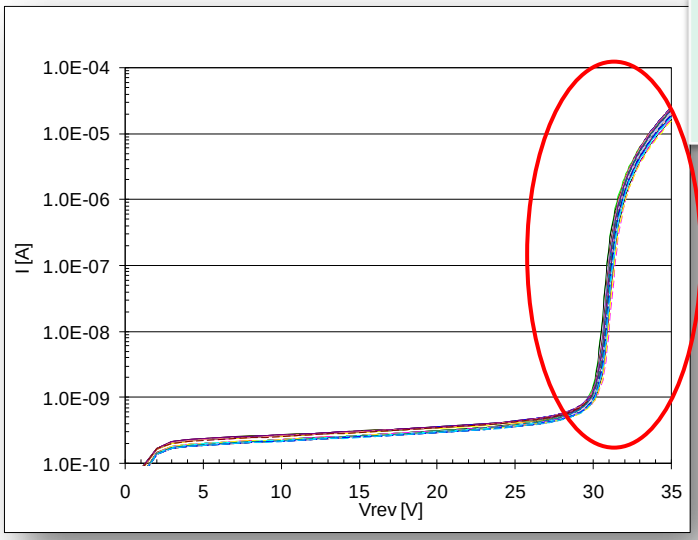


- 8x8 array
- 1.5mm element pitch
- read-out on one side

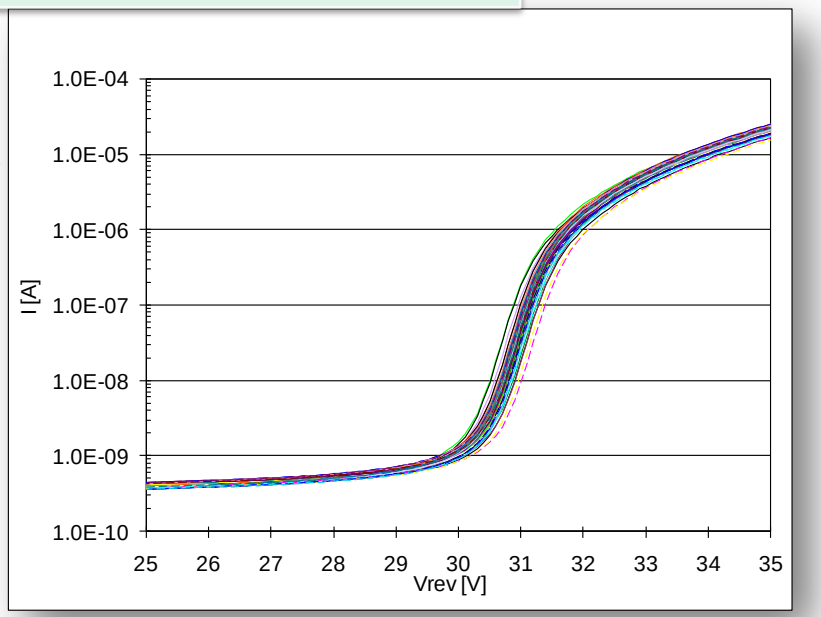


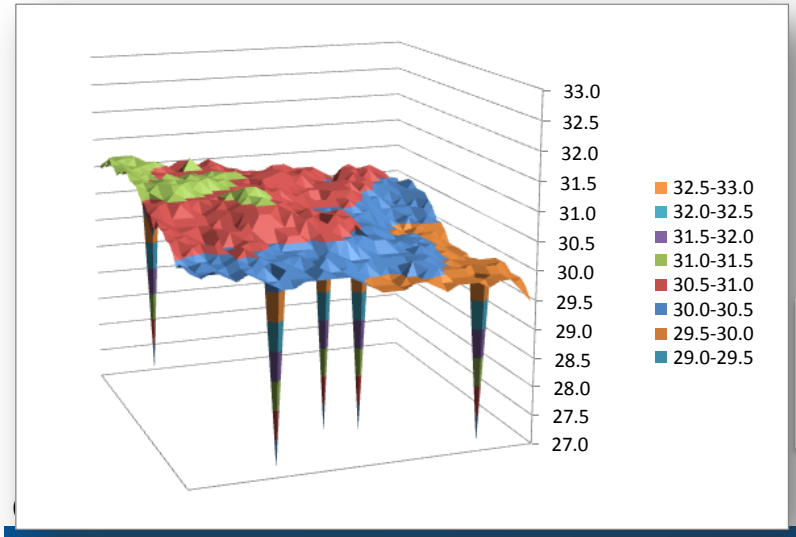
So far, our largest area monolithic array!!

DaSiPM2 Arrays, IV



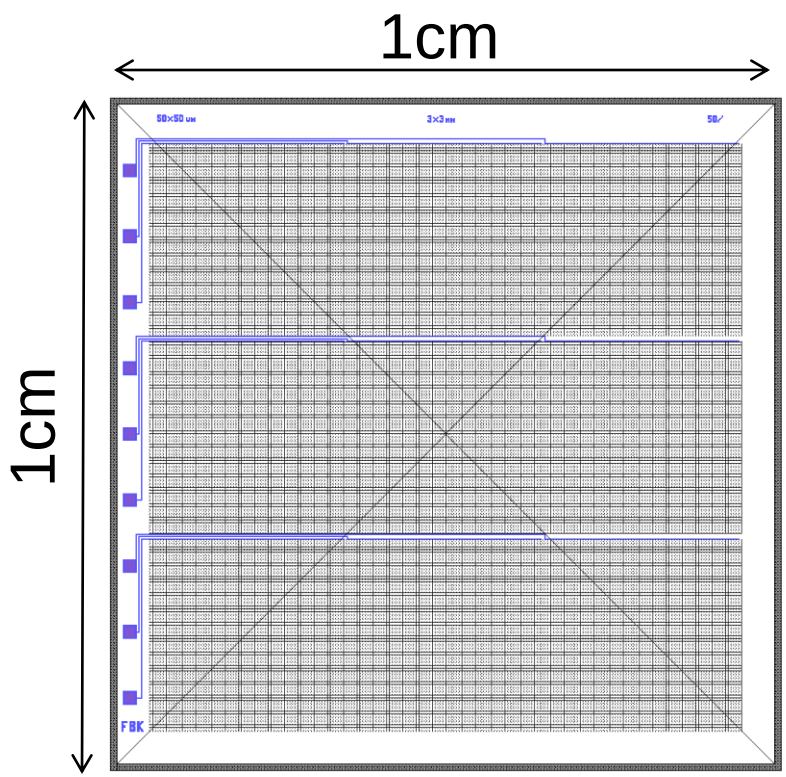
IV plot of the 64 elements of the array

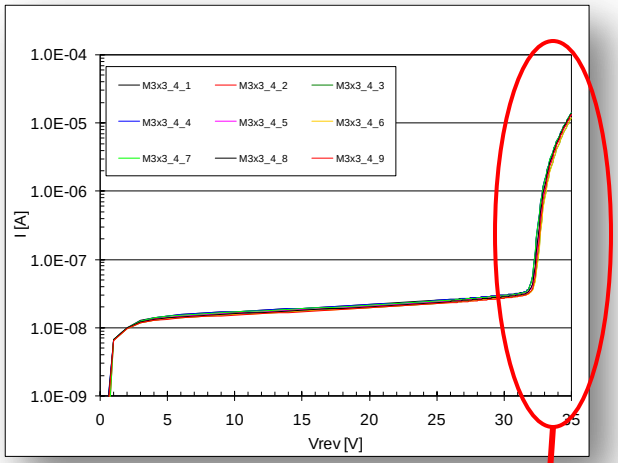


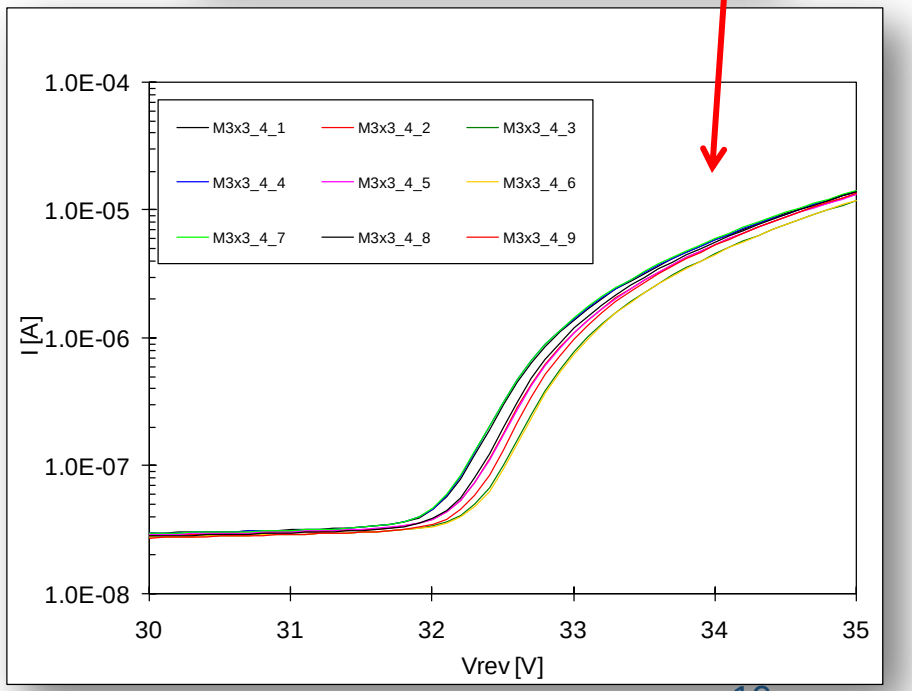


Breakdown voltage over the entire wafer surface

3x3 array of 3x3mm² SiPMS







Conclusion

- **Collaborations both in nuclear medicine and HEP**
- **We are moving towards large area monolithic arrays.**
  - Long tedious work to understand origin of defects and improve yield
  - Working to improve BD uniformity

- **R&D:**
  - on array/SiPM interconnectivity;
  - new SiPM technology.