FONDAZIONE
BRUNO KESSLER

Silicon 3D & SiPM

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Fondazione Bruno Kessler

2 Research Centers with a common strategy

- Center for Information Technology
- Center for Materials & Microsystems

- 118 researchers
- 68 collaborators
- 56 technologists
- 8 secretaries
- 62 PhD students
- 12 visiting professors

CMM: Micro Technologies Lab

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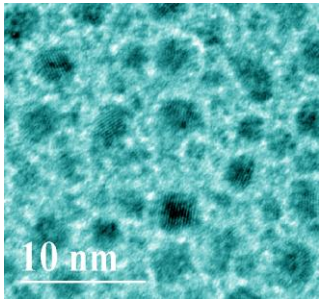
MTLab a reliable and a technological updated facility for:

- R&D
- primary-stage product development
- product manufacturing activities

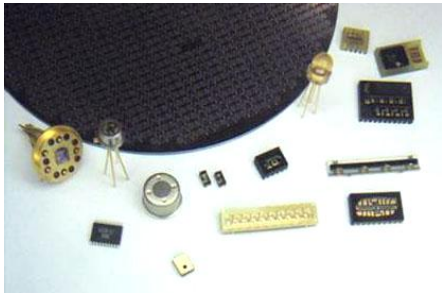
in the area of MEMS, micro and nano technologies.



MicroFabrication Lab

- ✓ Clean Romm class 10-100 (500m^2) , 1000
  increase the clean area dedicated to MEMS process
- ✓ 4” wafers (Si, Quartz, Glass)

Staff: 7 researchers & 9 technicians



MF Lab technology

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DOPING
Ion Implanter (As , B and BF_2 , P) Solid source doping (B and P)

FURNACES for oxidation (wet and dry) and diffusion

LPCVD Silicon oxide (TEOS and LTO), Poly-silicon and Silicon Nitride

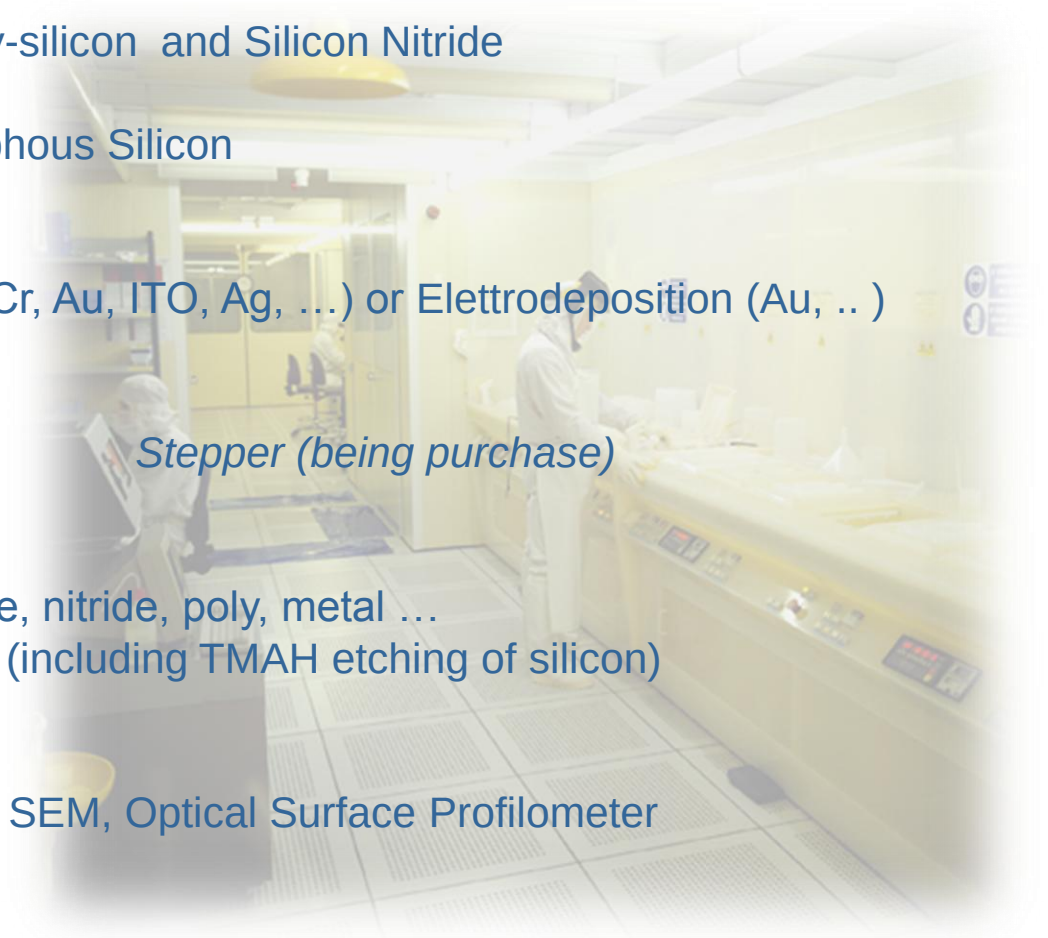
PECVD Silicon oxide, Silicon Nitride, Amorphous Silicon

METALLIZATION
Sputtering (Al1%Si, Ti, TiN) or Evaporator (Cr, Au, ITO, Ag, …) or Elettrodeposition (Au, ..)

LITHOGRAPHIC EQUIPMENT
Two Mask aligner and two track system and *Stepper (being purchase)*

ETCHING
Tegal systems for dry etching of silicon oxide, nitride, poly, metal …
Deep RIE of silicon and oxide , Wet etching (including TMAH etching of silicon)

ON-LINE INSPECTION
Ellipsometer, Interferometer, 4-point probe, SEM, Optical Surface Profilometer



Silicon detectors activities

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Aim: development and production of radiation detectors.

We have been working in this field since 1994 and now this activity is going on in partership between Memsrad group and Mtlab

Our expertise covers the main aspects of the development:

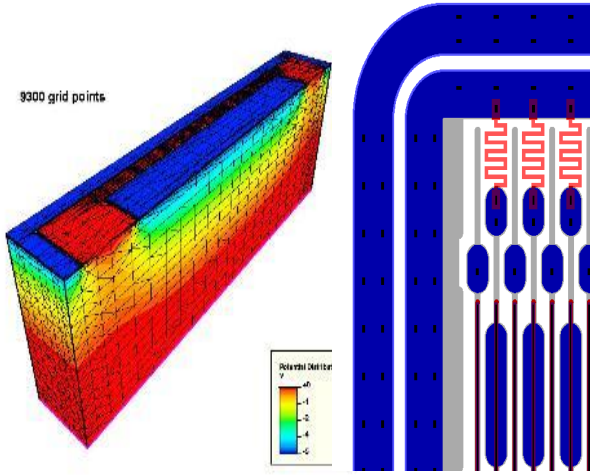
TCAD simulation
CAD design

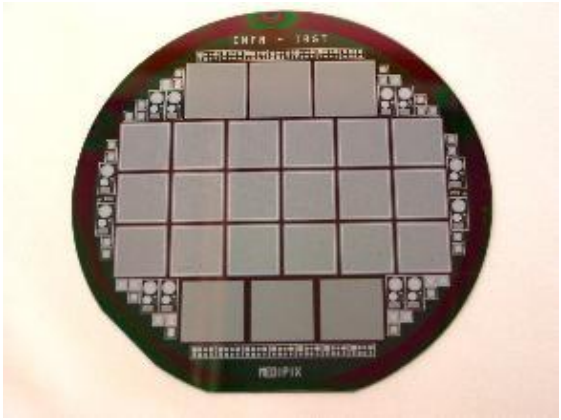
→

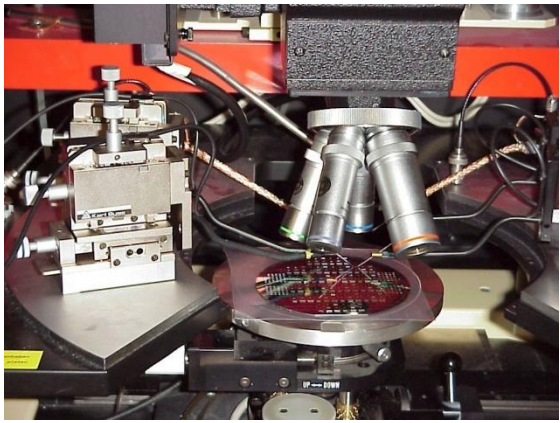
Fabrication

→

Device testing







Silicon Detectors activities

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"Standard" technology

From the specifications given by the customer
we design, produce, and (electrical) test the detector.

Examples:

- single/double-sided strip detectors
- p-on-n/n-on-n pixel detector

R&D activities

Development in cooperation with the partners

- 3D detectors
- silicon photomultipliers

Standard tech.: strip detectors

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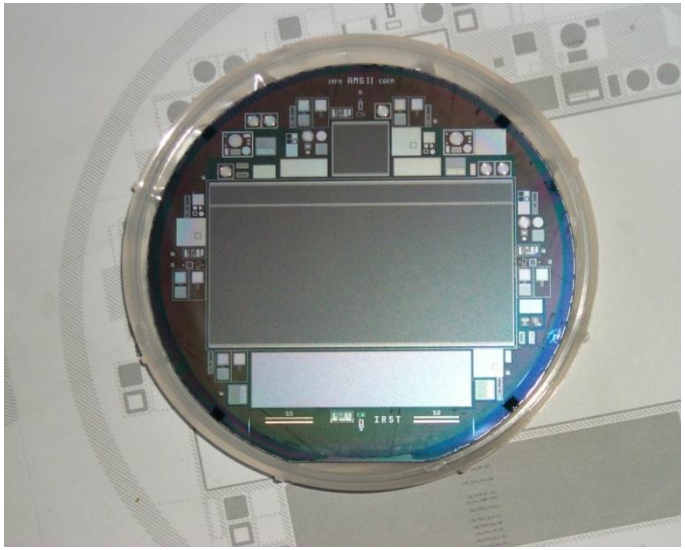
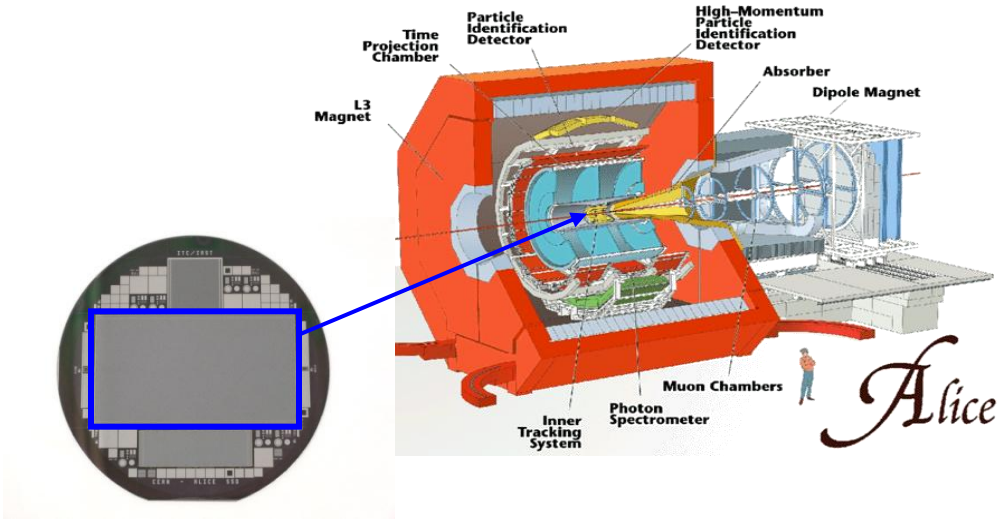
AMS experiment (@ISS)



ALICE experiment (@CERN)



Detector characteristics:

- Area: 7.2x4.2cm2
- double-sided with orthogonal strips
- DC coupled
- spec: defective strips < 0.5% per side

700 in spec detectors were fabricated (2002-2004).

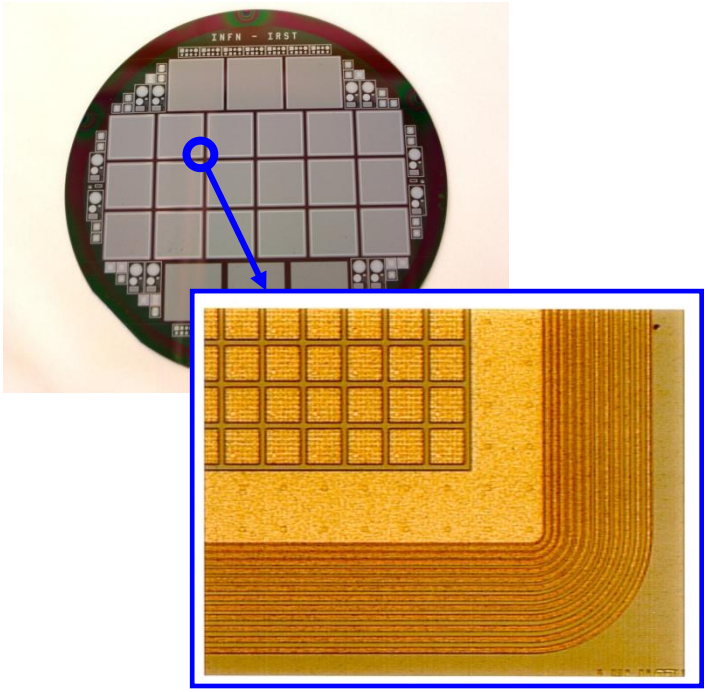
Detector characteristics:

- Area:7.5x4.2cm2
- double-sided with strips slightly tilted
- AC coupled
- spec: defective strips <3% per detector

600 in spec detectors were fabricated (2003-2005).

Standard tech.: pixel detectors

Medipix 1&2

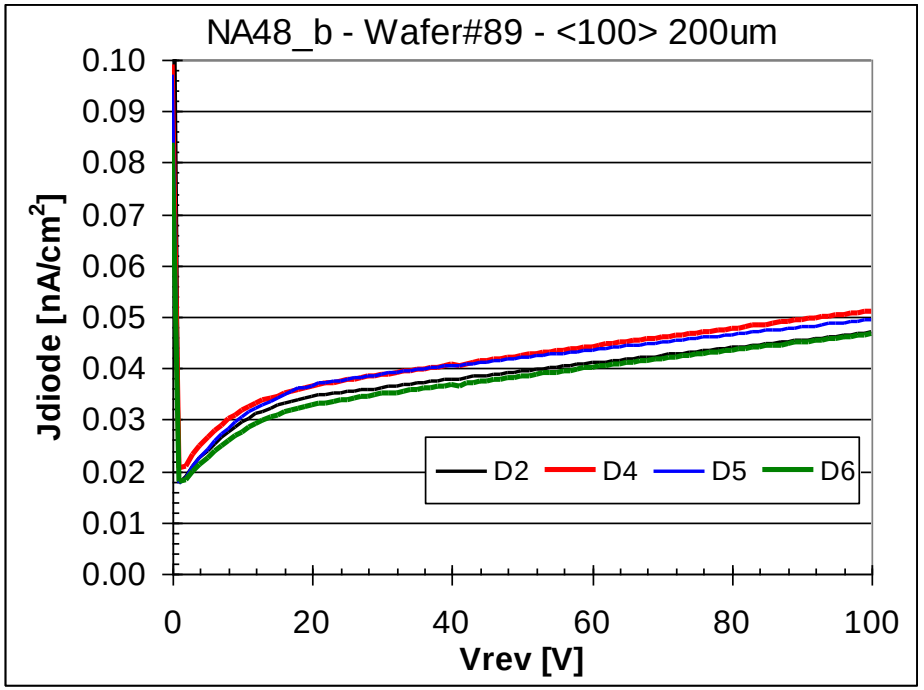


Multiguard termination structure

- Medipix1: pixel size 170x170mm2
- Medipix2: pixel size 55x55mm2
- QUAD

Substrate thick.: up to 1.5mm

ALICE



Gettering tecnique to control leakage

- ALICE SPD layout, pixel size 50x400mm2
- NA62 CERN collaboration

Substrate thickness: 200μm

Silicon Detectors activities

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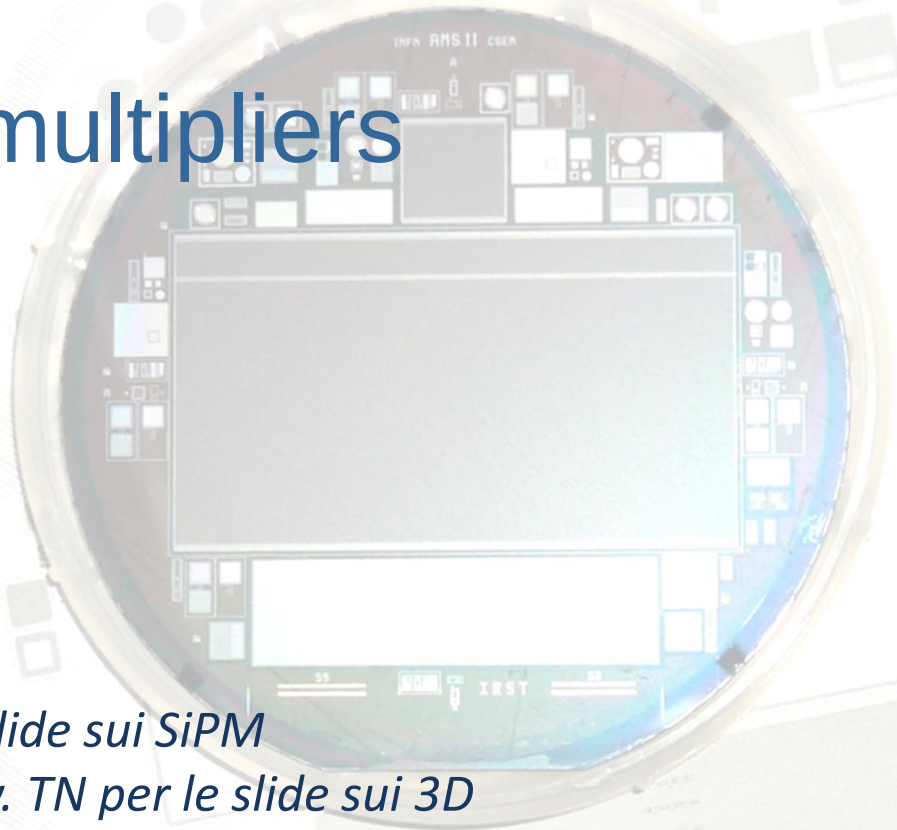
R&D activities

- silicon photomultipliers
- 3D detectors



Ringrazio

Dr. Claudio Piemonte FBK per le slide sui SiPM
Prof. Gian-Franco dalla Betta Univ. TN per le slide sui 3D

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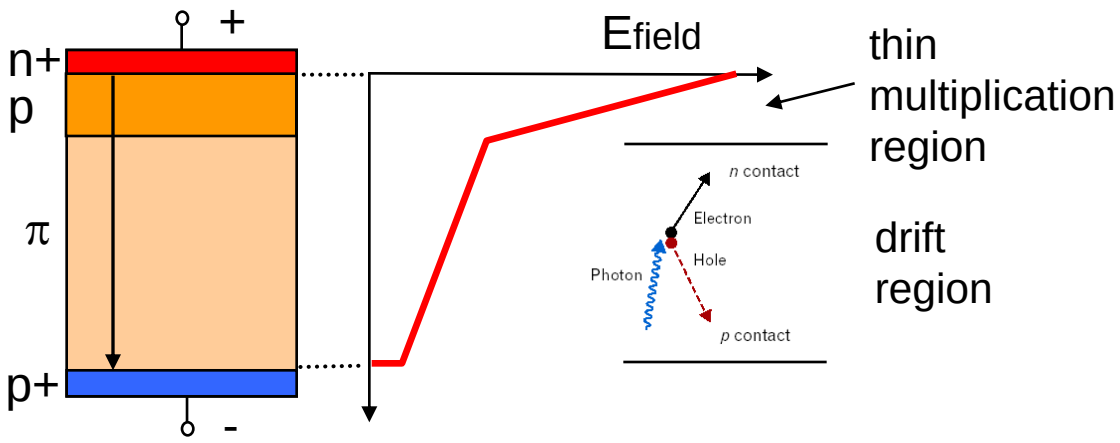
SiPM

Silicon photo multiplier

Realistic structure for an APD



All the electrons photo-generated in the drift region are multiplied (on average) by the same factor!

- $V < V_{APD}$
  => photodiode — 1 collected pair/generated pair
- $V_{APD} < V < V_{BD}$
  => APD — <M> collected pairs/generated pair
- $V > V_{BD}$
  => Geiger-mode APD — in principle inf. collected pairs/generated pair

SINGLE PHOTON DETECTOR!

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Geiger-mode APD

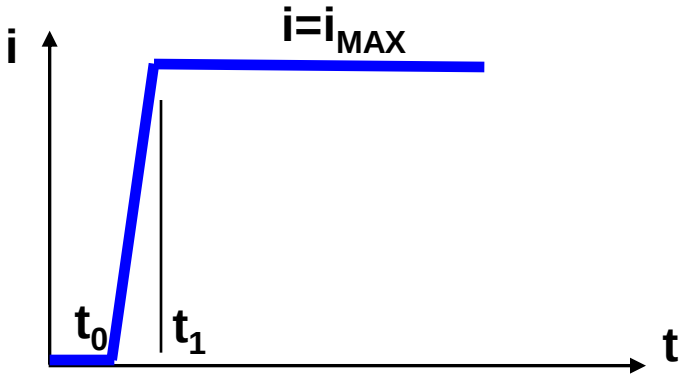
t = 0 ……..**let's bias the diode at V>V_{BD}**

t < t_0 ……..**i=0** (if no free carriers in the high field region)

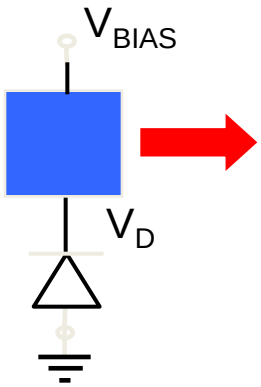
t = t_0 .....photo**carrier initiates the avalanche**

t_0 < t < t_1….**avalanche spreading**

t > t_1 ……..**self-sustaining current** (limited by series resistances)

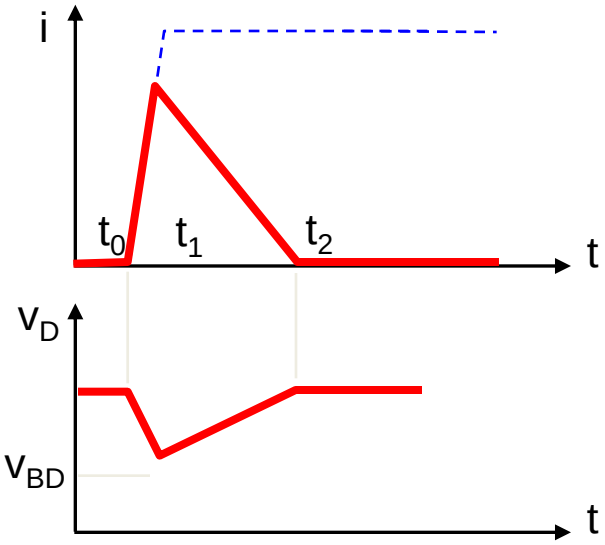


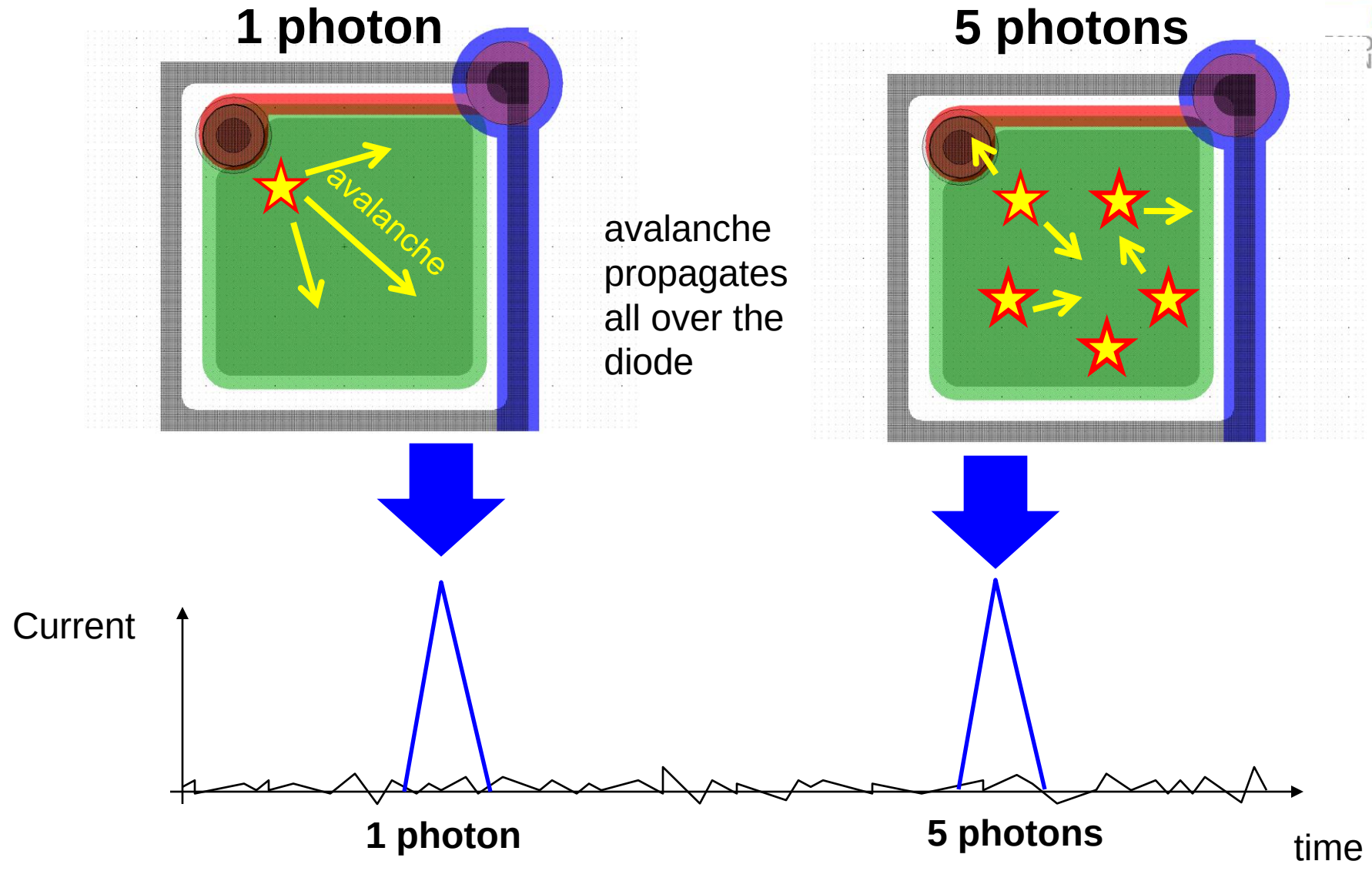
To detect another photon a quenching mechanism is needed!



Two solutions:

- **large resistance:** **passive quenching**
- **analog circuit:** **active quenching**



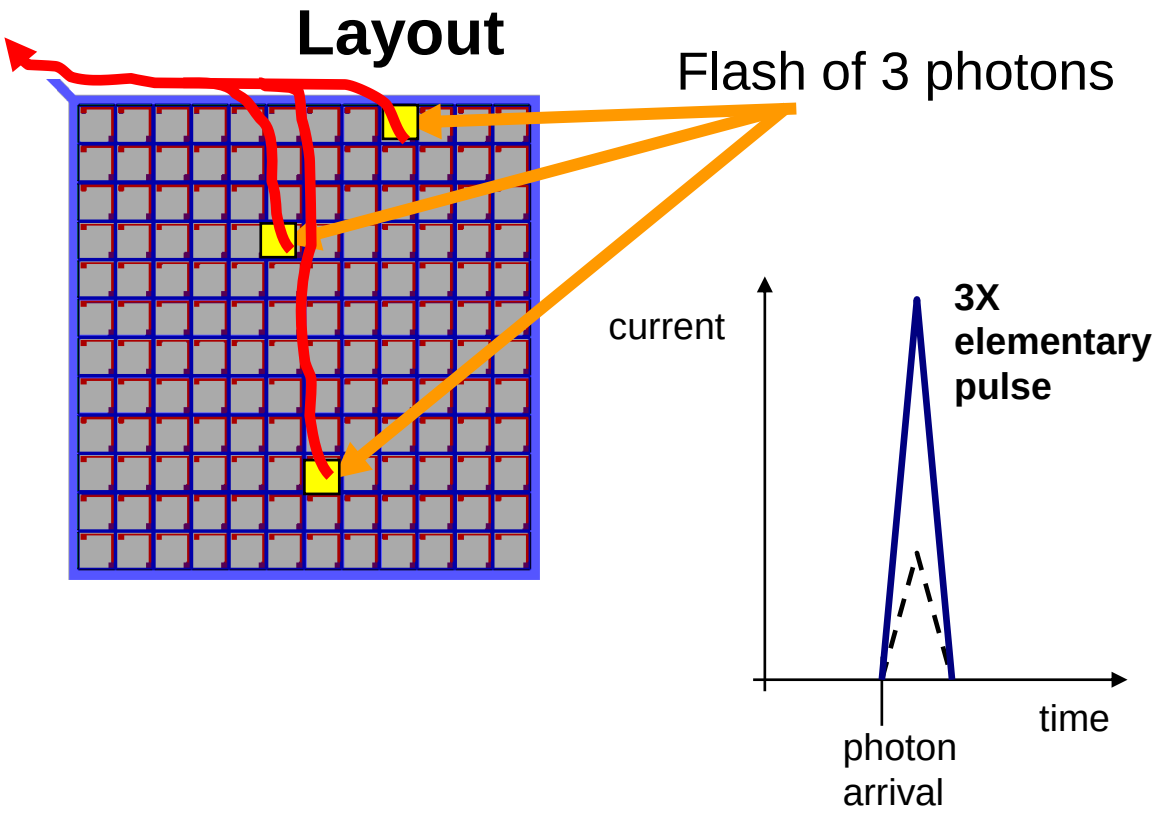


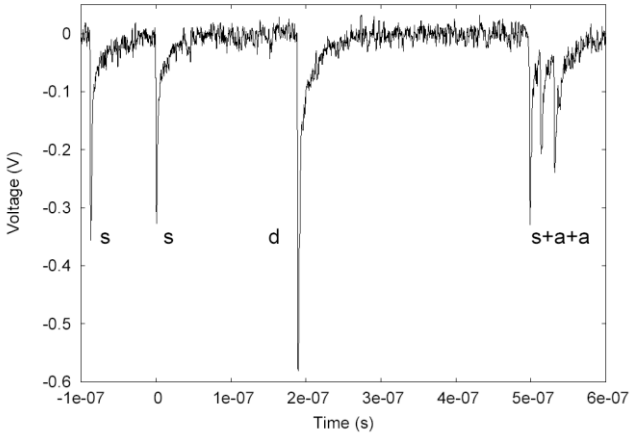
With GM-APDs you cannot count the number of photons

SiPM

How to count photons? parallel of mini-GM-APDs

first proposed by Golovin and Sadygov in the '90s





Proprieties:
- Single photon sensitivity
- Response proportional to number of photons (up to few hundred)
- Extremely good timing resolution (tens of ps)

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Features of a SiPM

Most important features of a SiPM are:

- **capability to detect extremely low photon fluxes** giving a proportional information;
- **extremely fast response** (determined by avalanche discharge): in the order of few hundreds of ps.

Other features are:

- Low bias voltage (<100V)
- Low power consumption
- Insensitive to magnetic fields
- Compact and rugged

→ **extremely interesting alternative to PMTs**

Problematics (apart from technological):

- temperature dependence of dark count and gain
- low radiation resistance (generation and trapping centers)

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Labs developing SiPMs

Pioneering work in the 90's by russian institutes

- JINR, Dubna
- Obninsk/CPTA, Moscow
- Mephi/PULSAR, Moscow

→ Metal-Resistive-Semiconductor polysilicon resistor

Recently, more institutes/companies involved in SiPM production:

- Hamamatsu, Japan
- SensL, Ireland
- IRST, Italy
- MPI, Germany
- Zecotek, Canada

→ Front-side illumination **devices available**

→ Back-side illumination; device ready by end 2007

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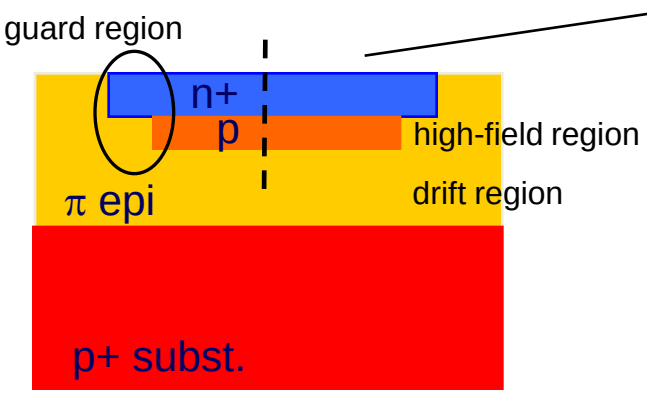
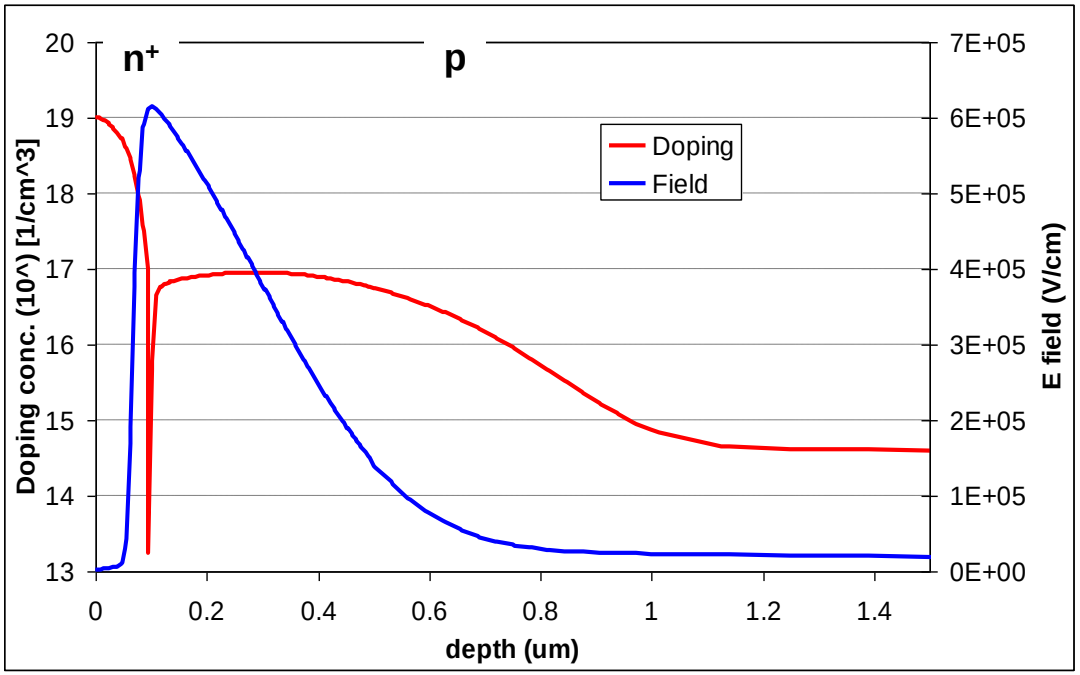
IRST technology

Shallow-Junction SiPM





High field region ⟷ Drift region

1) Substrate: p-type epitaxial
2) Very thin n+ layer
3) Quenching resistance made of doped polysilicon
4) Anti-reflective coating optimized for λ~420nm

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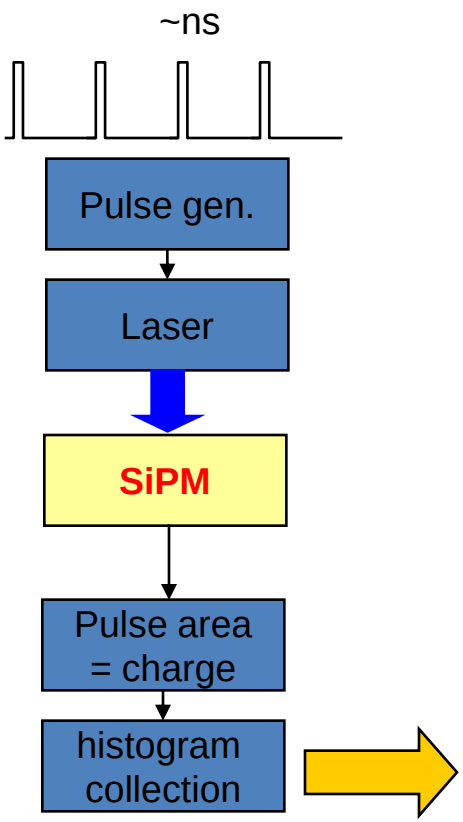
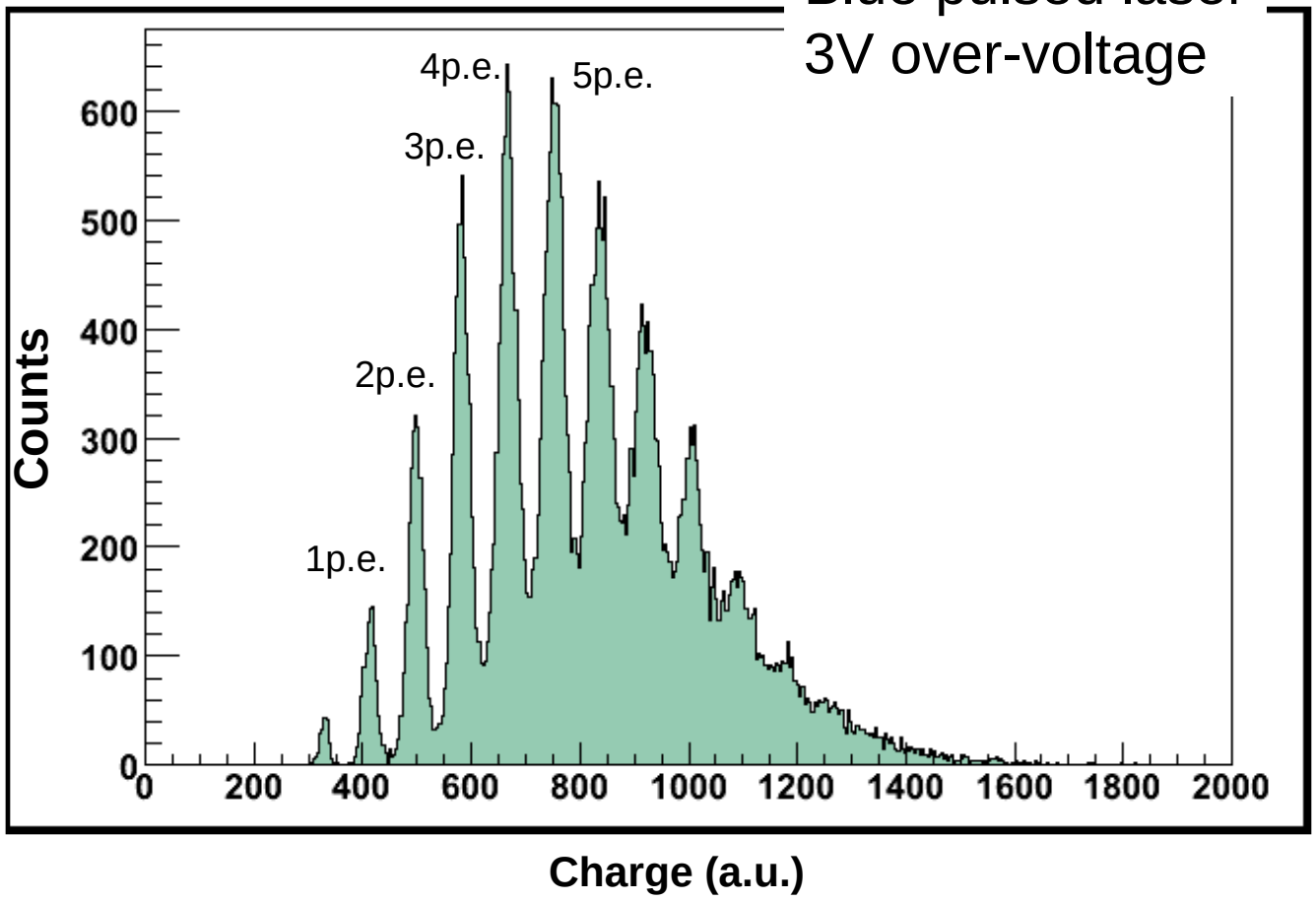
Single-cell charge resolution



Blue pulsed laser
3V over-voltage



It is possible to count the number of photons in a light pulse

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Important parameters in a SiPM

- **Gain** → Number of electrons per photon detected

- **Noise**: primary dark count; → pulses triggered by non-photogenerated carriers
  secondary: after-pulse;
  optical cross-talk;

- **Photodetection efficiency** → Number of counts over Number of impinging photons

- **Dynamic range** → Linearity of the response

- **Time resolution** → Precision in the determination of the photon arrival time

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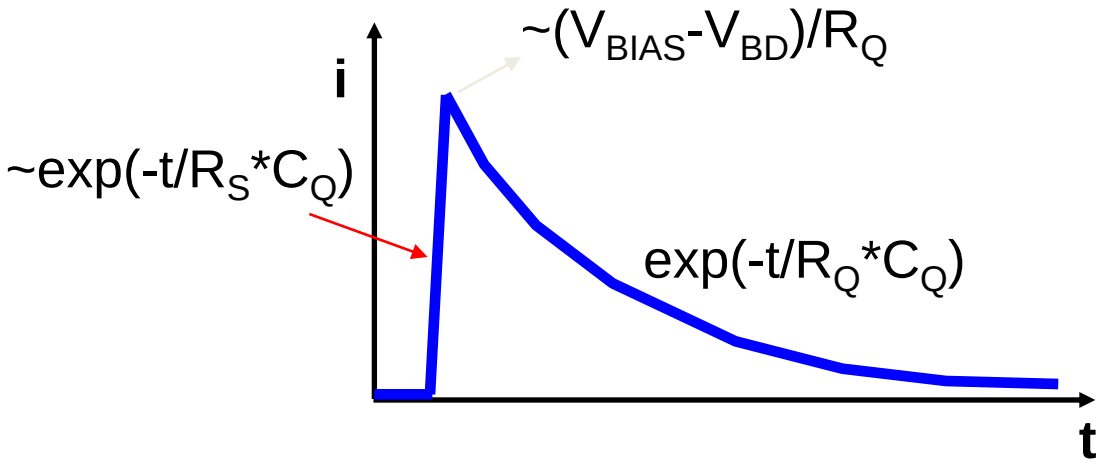
Gain in a GM-APD

Gain = number of electrons per photon absorbed



charge collected per event is the area of the exponential decay which is determined by circuital elements and bias.

$$\textbf{Gain} = I_{MAX}\frac{*\tau_Q}{q} = \frac{(V_{BIAS}-V_{BD})}{R_Q}\frac{*\tau_Q}{q} = \frac{(V_{BIAS}-V_{BD})*C_D}{q}$$

NOISE

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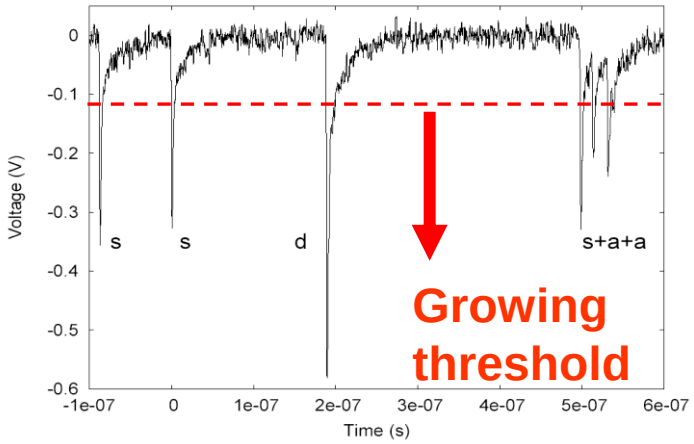
Primary DARK COUNT

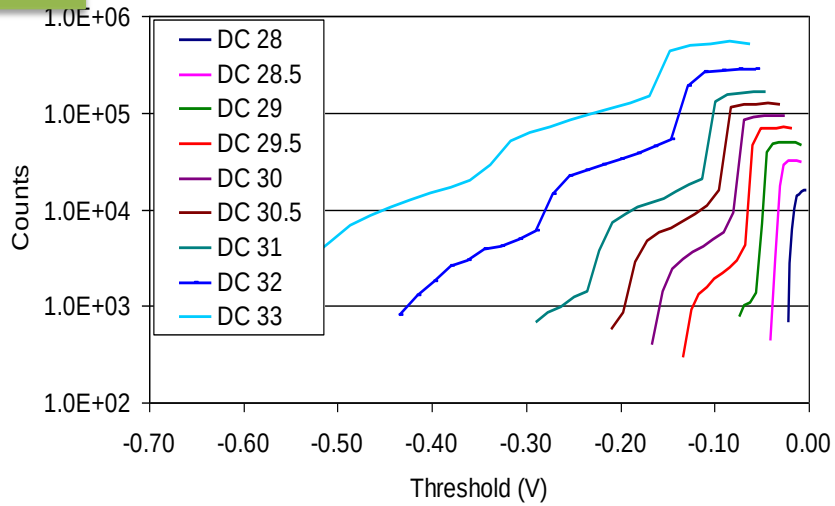
False current pulses triggered by non photogenerated carriers

Main source of carriers: **thermal generation in the depleted region.**

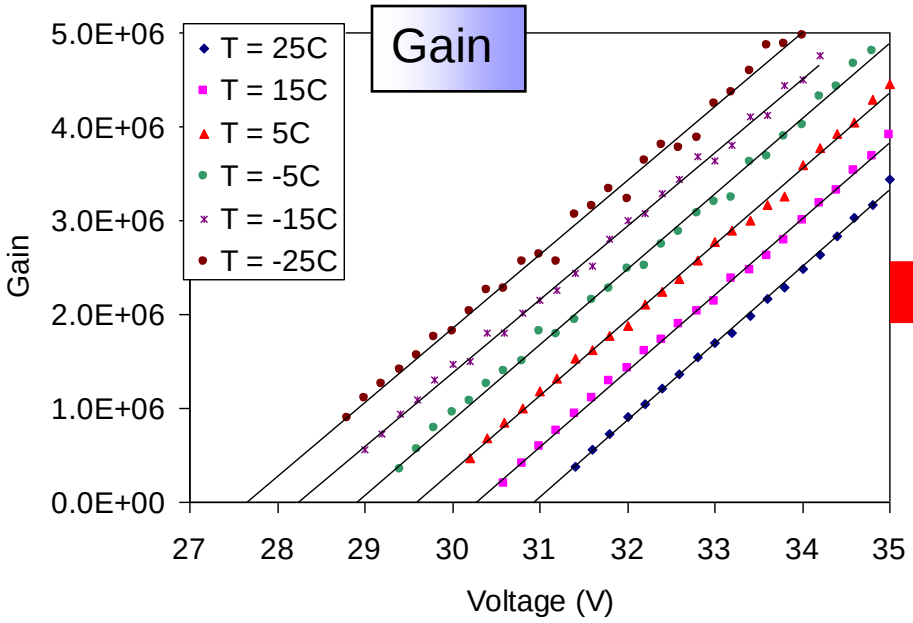
Critical points: **quality of epi silicon**; **gettering techniques.**

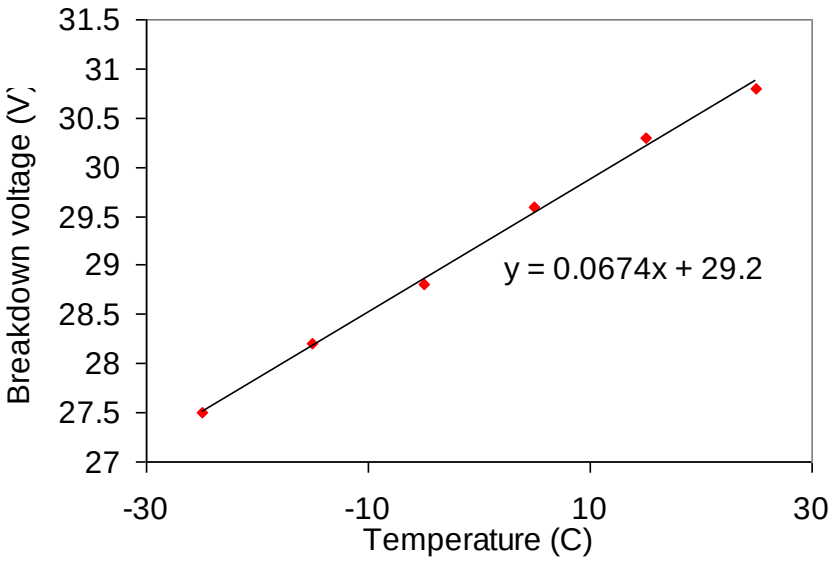
Dark count rate as
a function of the threshold
and the temperature

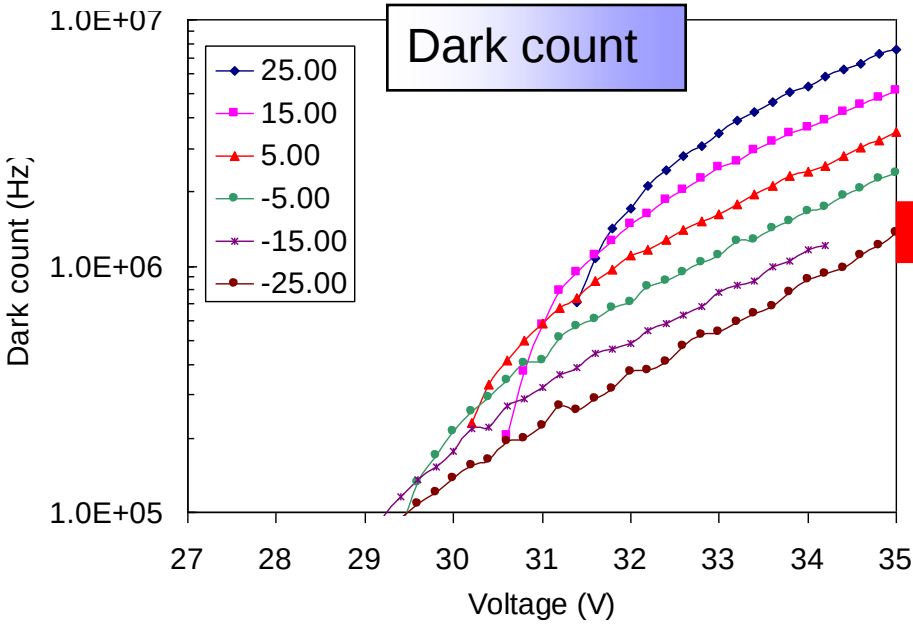


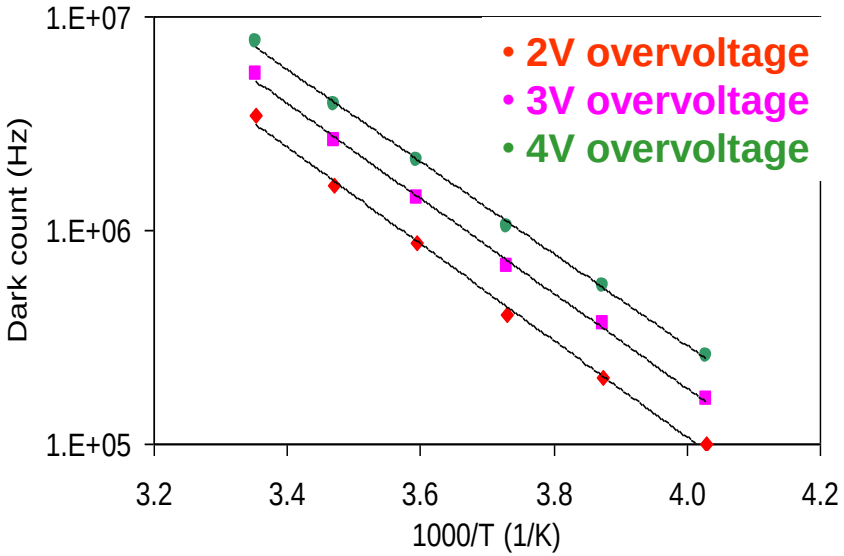


Temperature dependence

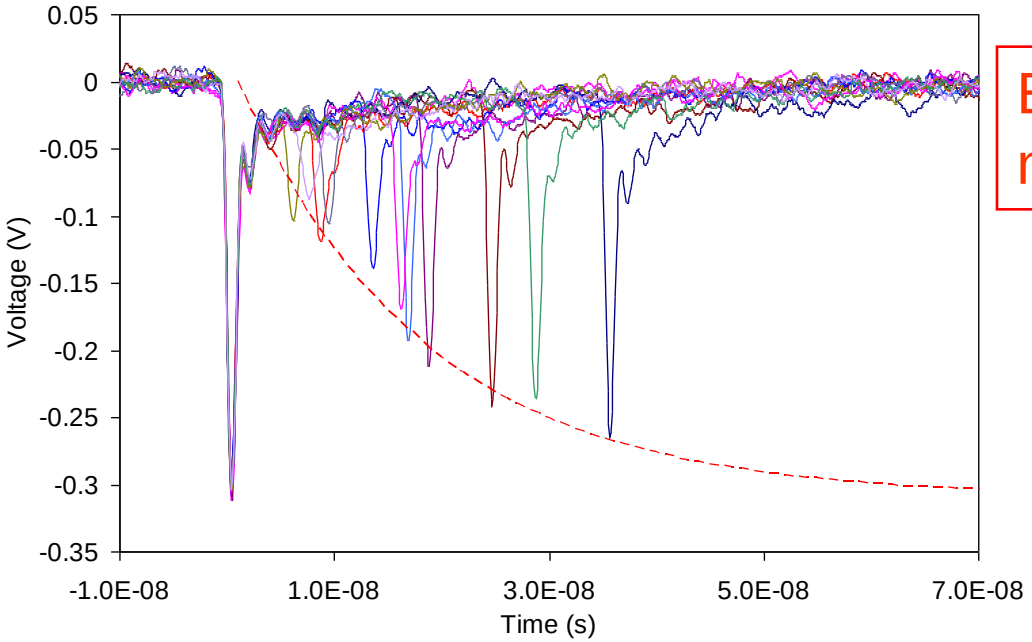








Afterpulse



Events with after-pulse measured on a single micropixel.

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

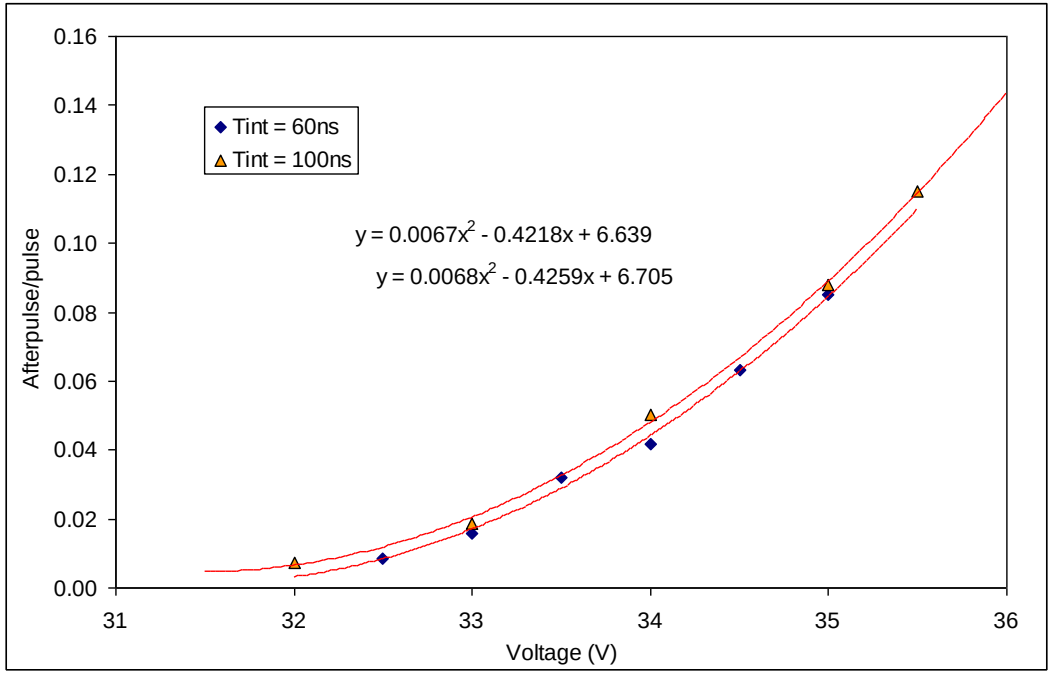
After-pulse probability *vs* bias

It increases following a parabolic law:

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

linear with Vbias

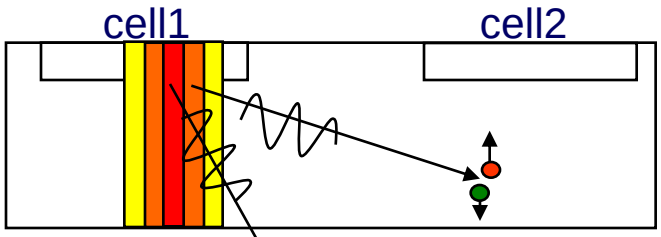
linear with Vbias



Optical cross-talk

During an avalanche discharge, photons are emitted mainly because of spontaneous direct carrier relaxation in the conduct. band.

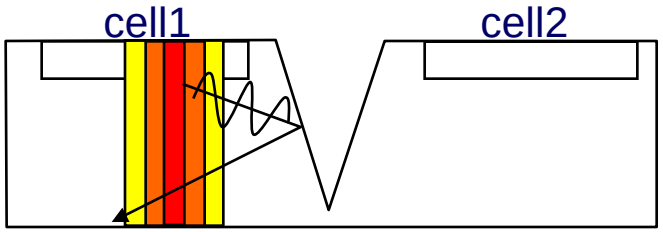
$3x10^{-5}$ photons with energy higher than 1.14eV emitted per carrier crossing the junction. [from A. Lacaita et al., IEEE TED, vol. 40, n. 3, 1993]



Those photons can trigger the avalanche in an adjacent cell: optical cross-talk.

Depends on: - distance between the high-field regions
- gain

<u>Solution</u>:
trenches in silicon filled with opaque material



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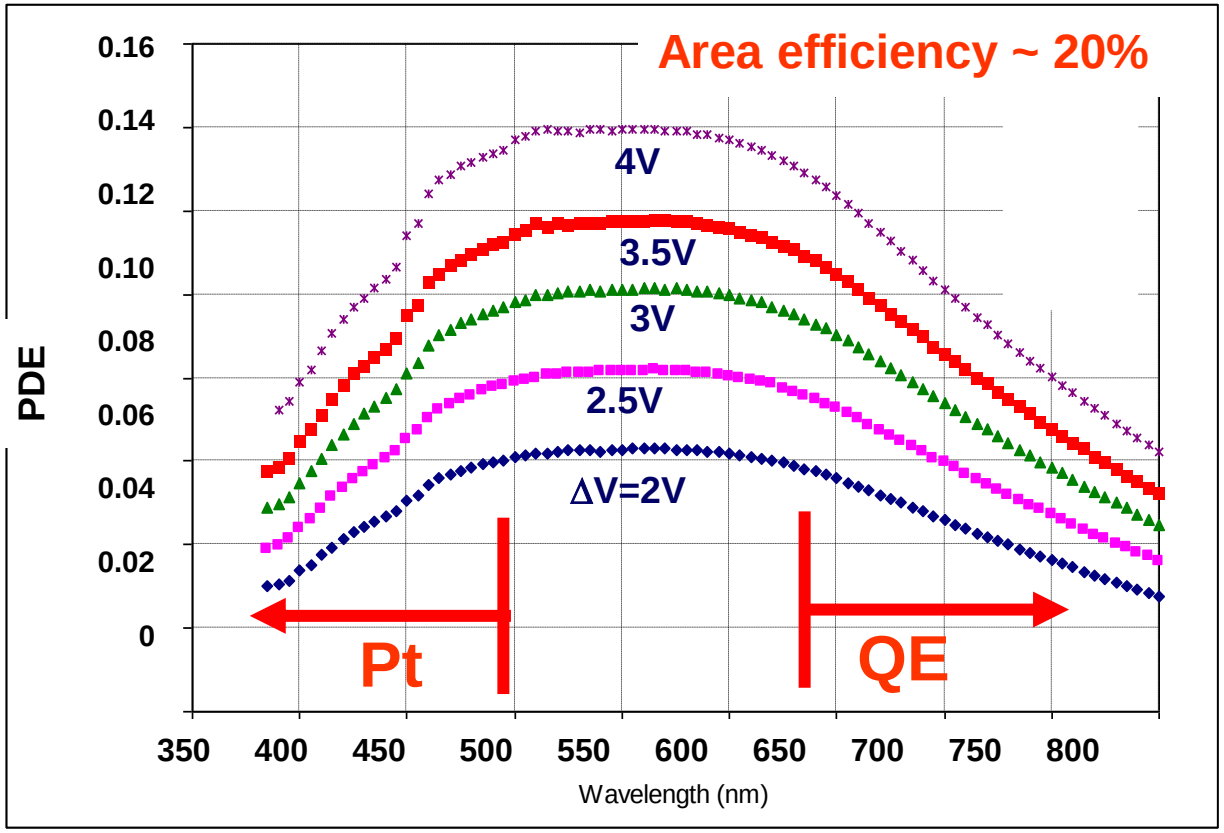
PDE - result



Why this shape?

$PDE = QE(\lambda) * Pt(\lambda) * Ae$

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

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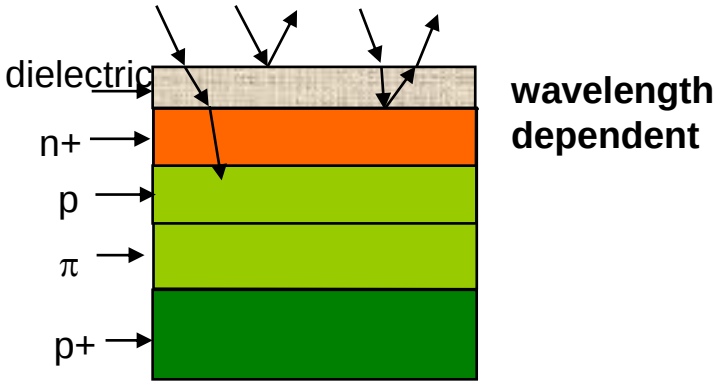
Photodetection efficiency (1)

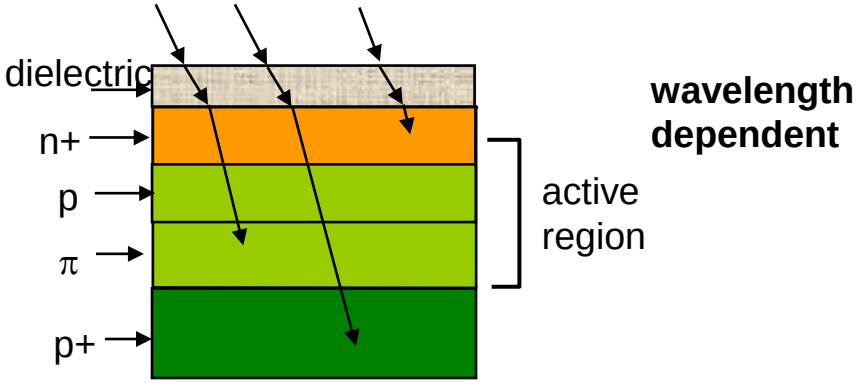
$$\mathbf{PDE} = N_{pulses} / N_{photons} = \mathbf{QE \times P_{01} \times Ae}$$

1. QE Quantum efficiency is the probability for a photon to generate a carrier that reaches the high-field region.

a. Transmission efficiency



b. Internal quantum efficiency



Optimization:
- Anti-reflective coating
- shallow junctions for short λ
  thick depletion layer for long λ

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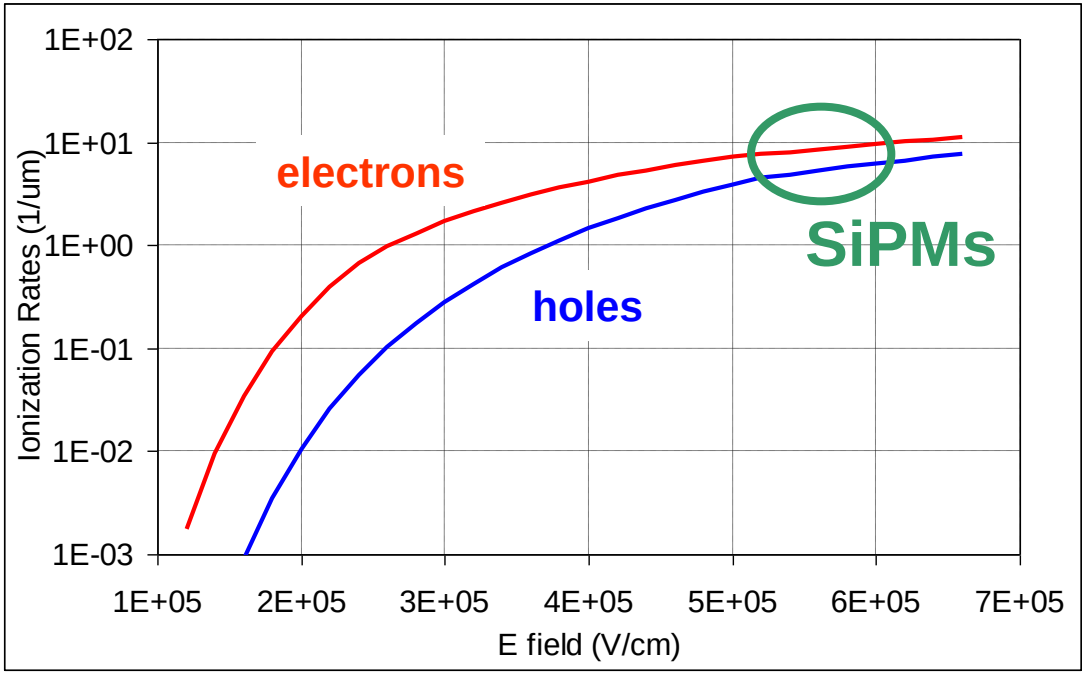
PDE (2)

2. P_{01}. triggering probability

probability for a carrier traversing the high-field to trigger the avalanche.



Ionization rates in Silicon

1. Electrons higher ionization rate. Difference decreases for higher fields, e.g. at 6e5V/cm α_n/α_p~2.

2. Ioniz. rates increase with field

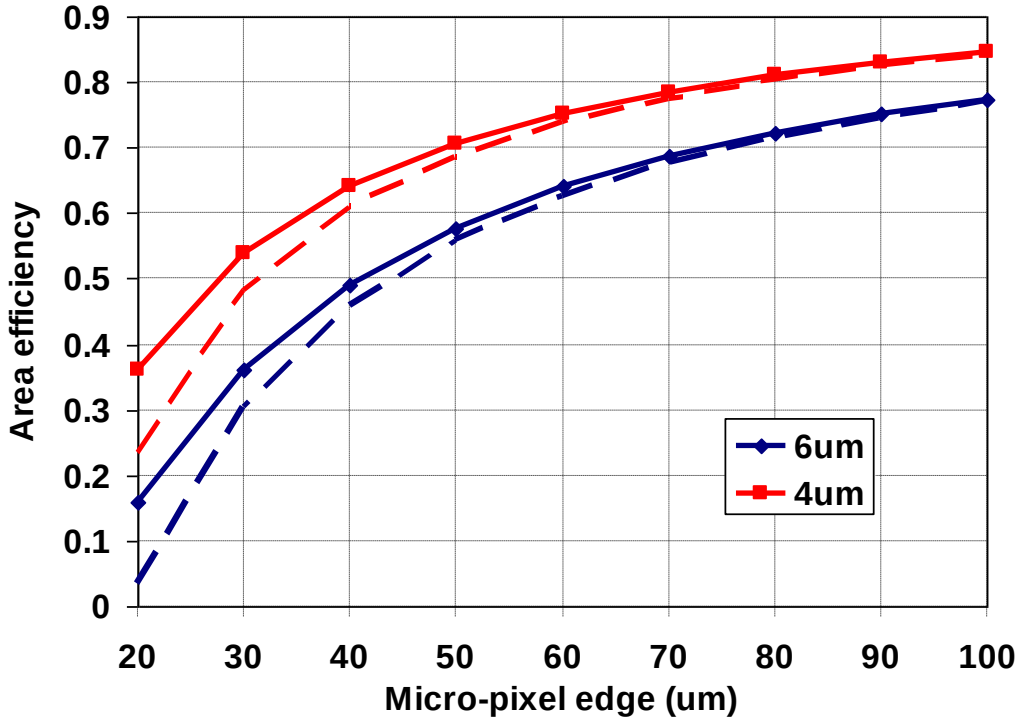
P_{01} maximization:

1. **high overvoltage**
2. **photo-generation in the p-side of the junction**
   (electrons travel through the high-field region)

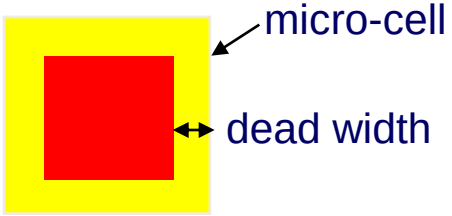
PDE (3)

3. Ae. Area efficiency

"standard" SiPMs suffer from low Ae due to the structures present around each micro-cell (guard ring, trench)



Maximum Ae for a width of the dead region of 4 and 6μm (in a front-side illuminated SiPM)



These values can be lower if the polysilicon resistor overlaps the high field region (dashed lines: 50μm^2 overlap).

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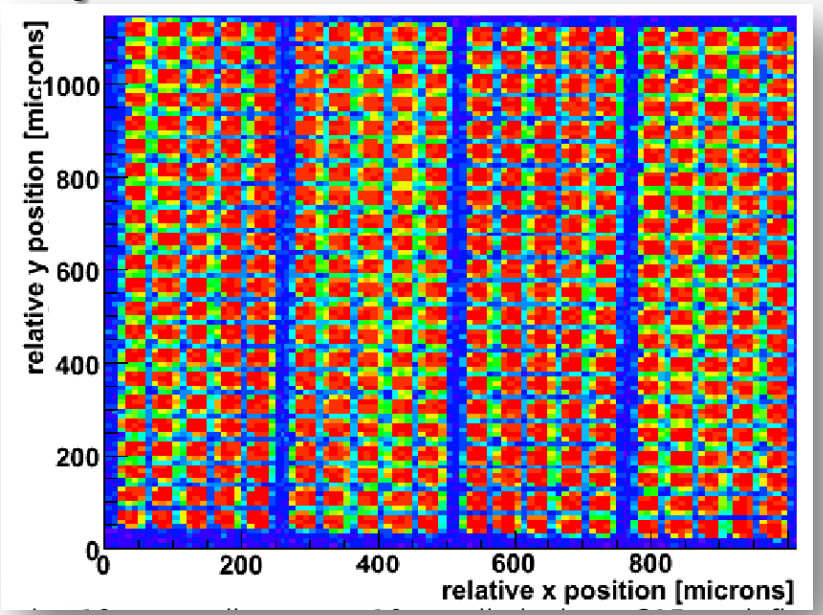
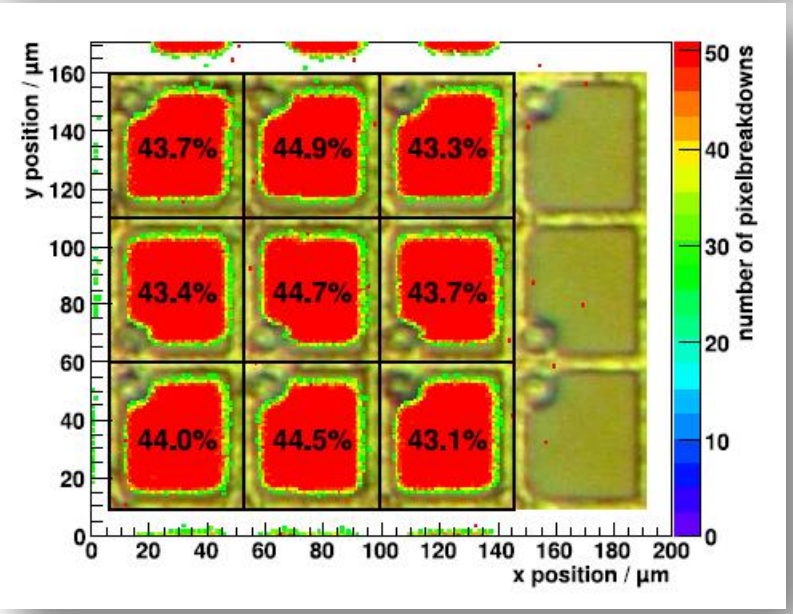
Cell functionality and fill factor

Illumination with a LED.
Spot diameter of ~5 μm.

Coarse step to verify functionality of cells



Fine step to estimate the fill factor



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

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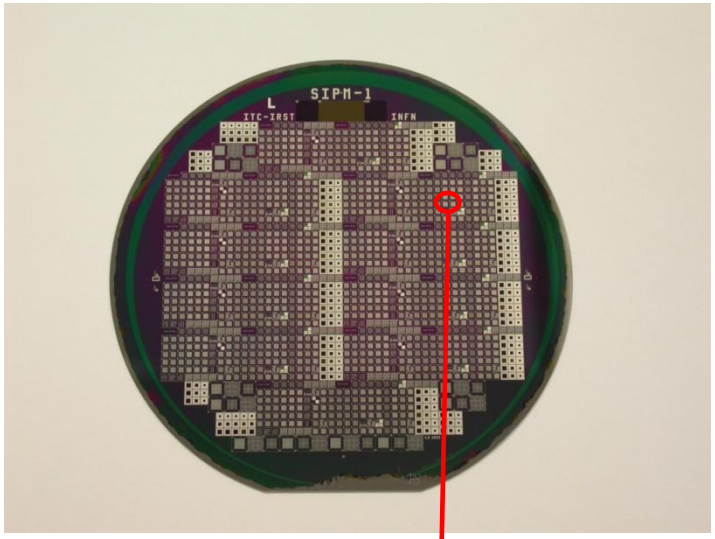
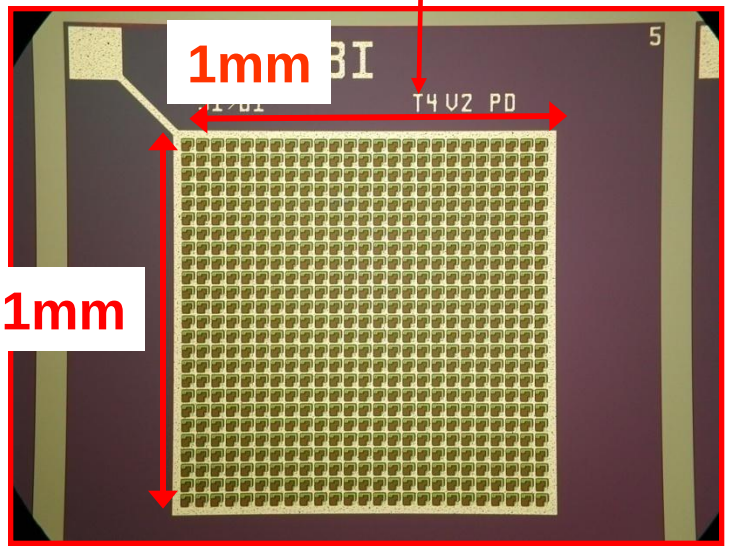
FBK Device geometry: 2005





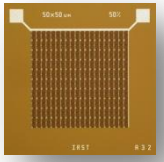
The wafer layout includes many structures:

- SiPMs;
- GM-APDs;
- "large-area" diodes;
- several test structures

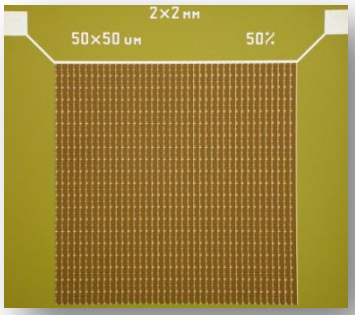
Basic structure:
- 25x25 cells
- microcell size: 40x40μm²

Fill factor ~ 30%

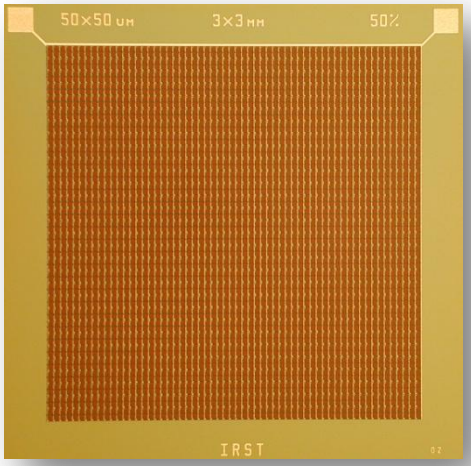
FBK Device geometry 2007



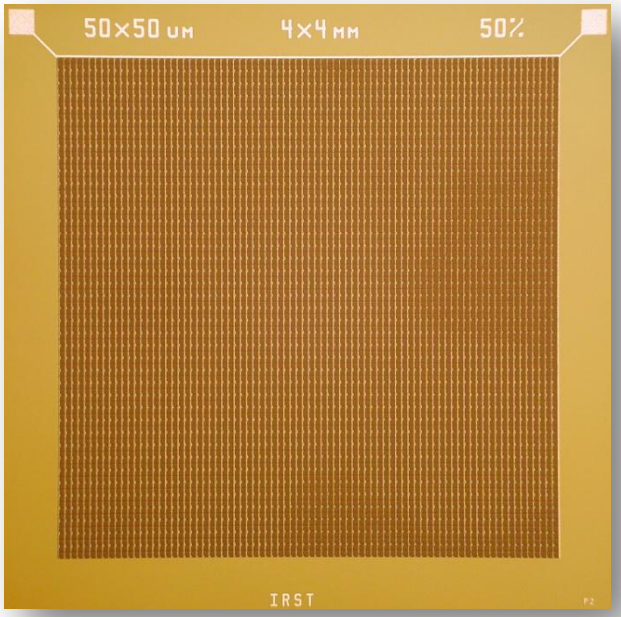
1x1mm^2



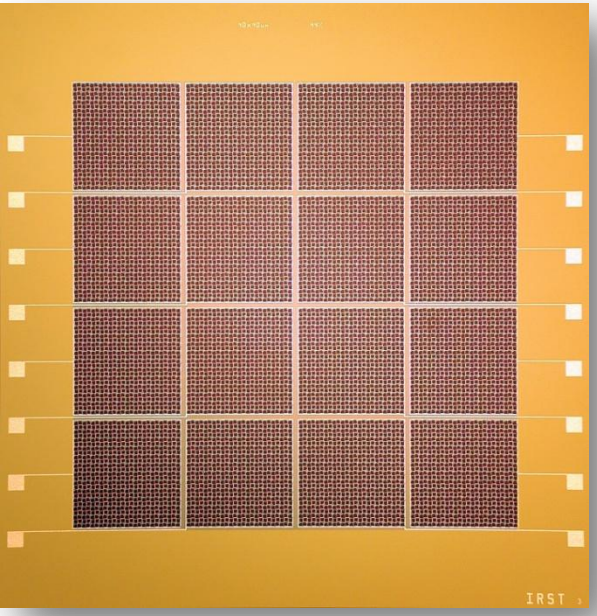
2x2mm^2



3x3mm^2 (3600 cells)

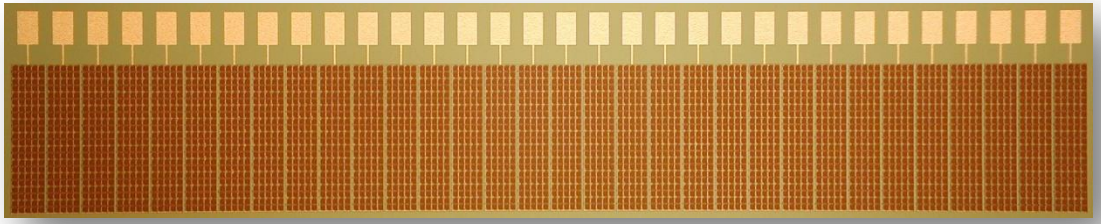


4x4mm^2 (6400 cells)



Matrices:
4x4 elements
of 1x1mm^2 SiPMs

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



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APPLICAZIONI

High energy physics

- ✓low light level detection
- ✓scintillation light readout

astrophysics / "space" experiments

- ✓Cherenkovand Fluorescenselight detection
- ✓Liquid Xenon detector

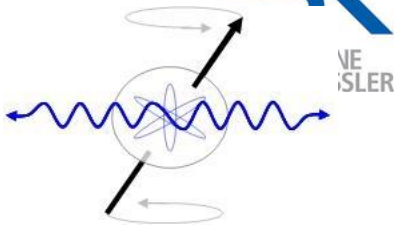
medical applications

- ✓time resolution

EU FP7 PET/MR Project: HYPERImage

www.hybrid-pet-mr.eu

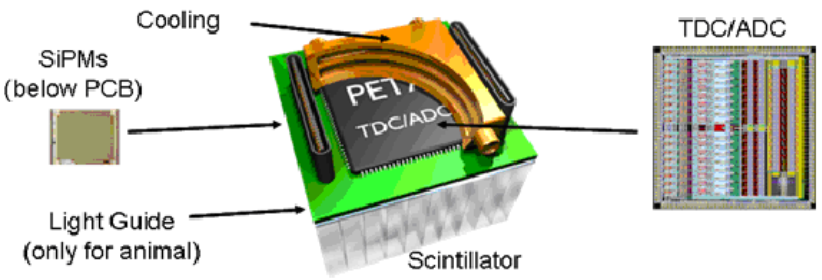
HYPERimage project

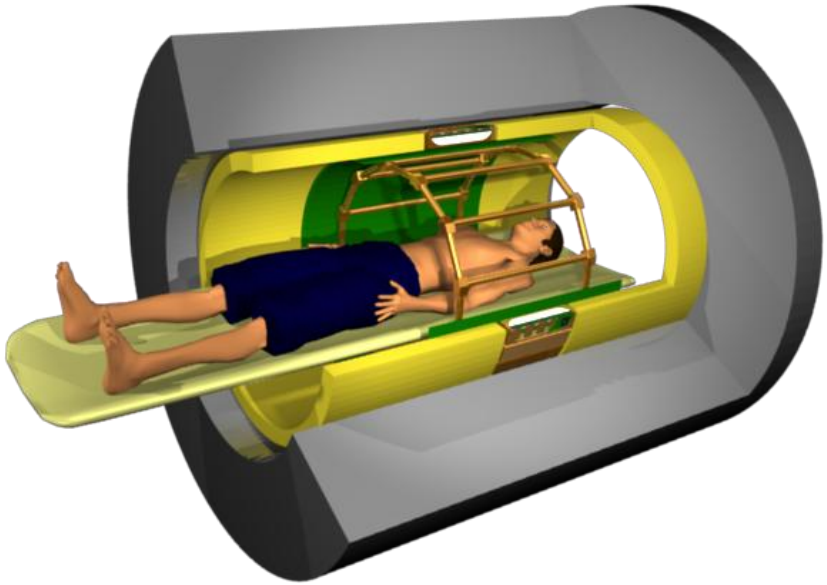


Development of **hybrid TOF-PET/MR** test system with dramatically improved effective sensitivity

First clinical whole body PET/MR investigations of breast cancer

TOF-PET building blocks





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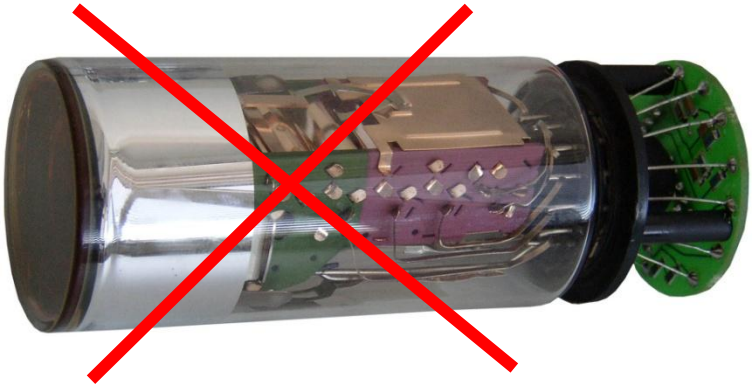
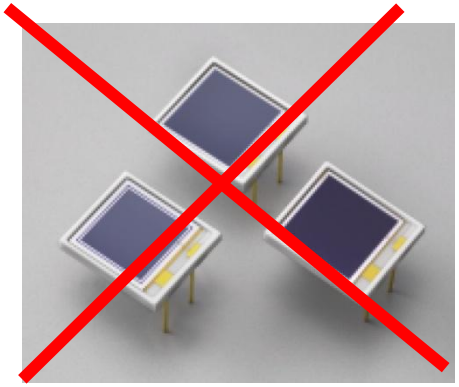
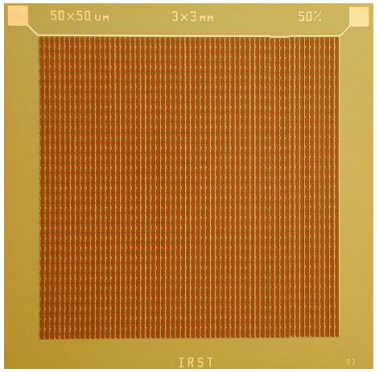
Different Sensor Technologies



PMT



APD

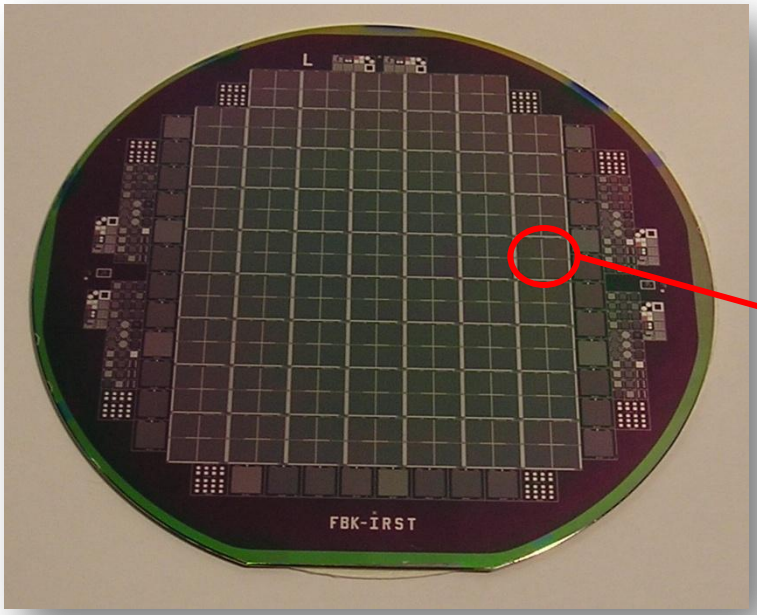


SiPM

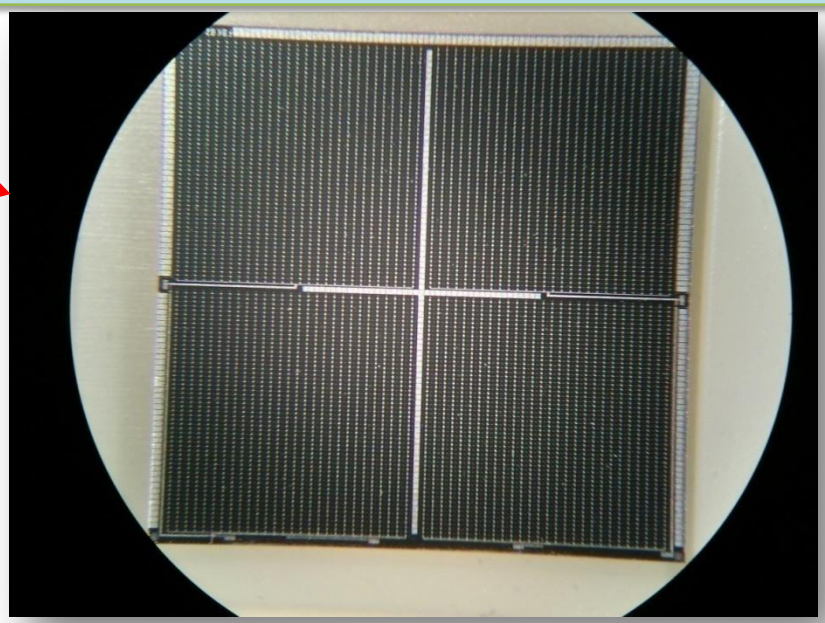
Type	PMT	APD	SiPM
MR compliant	no	yes	yes
ToF compliant	yes	no	yes

2008/09 – large area devices & first productions

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

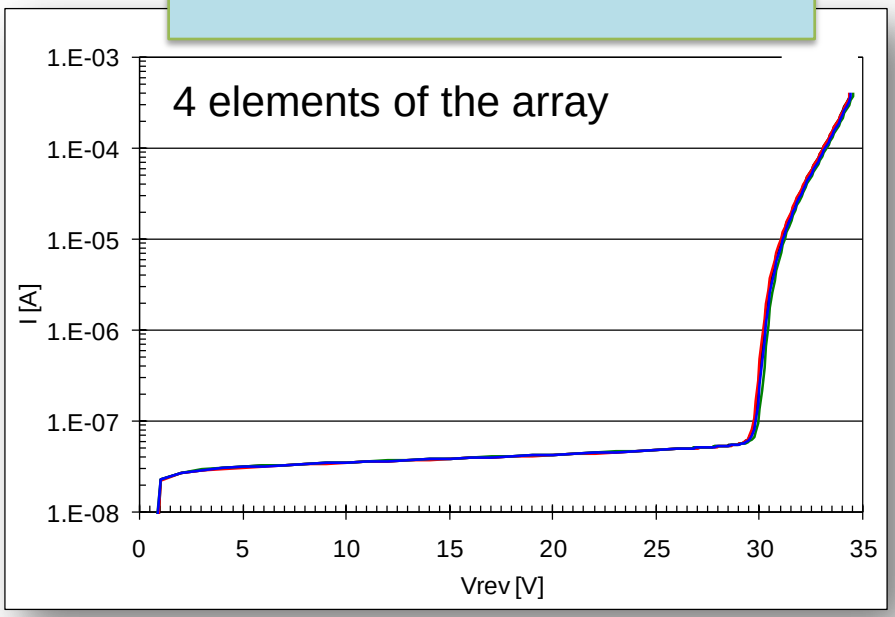


2x2 array of ~4x4mm^2 SiPMs

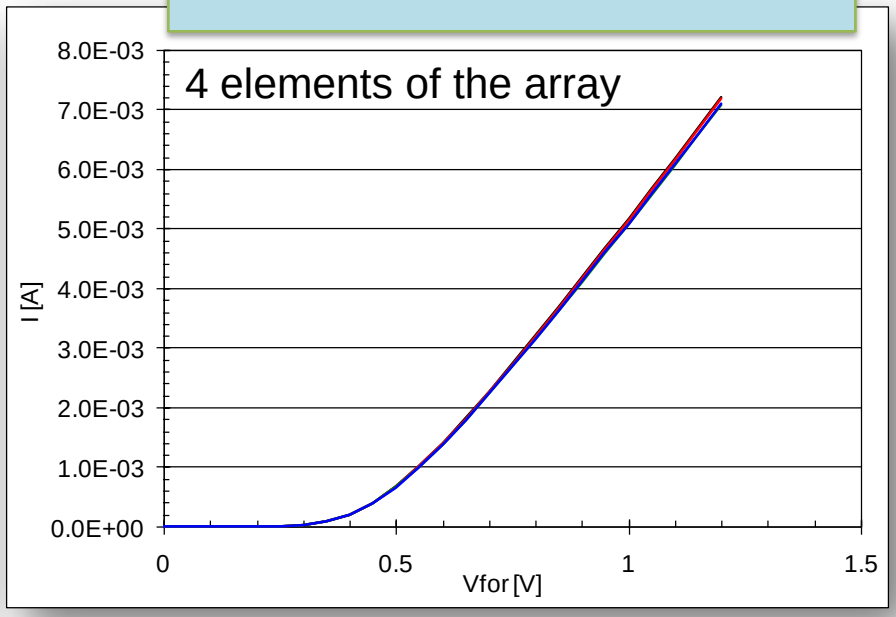


HI SiPM - testing procedure

Reverse charact.



Forward charact.



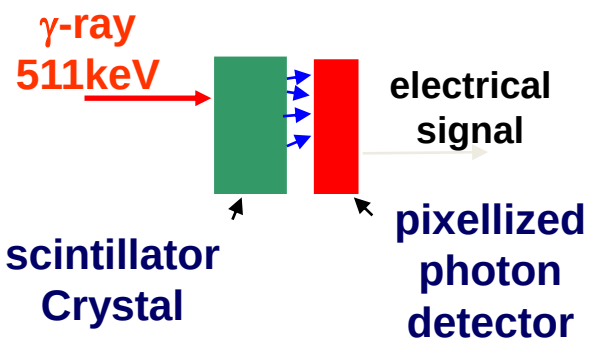
Info we get

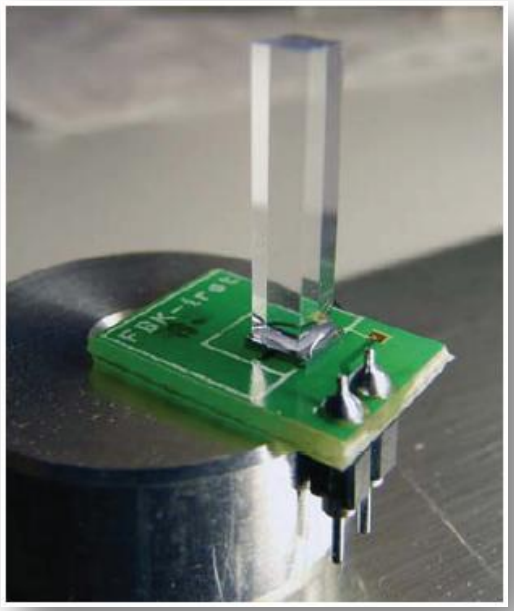
- Functionality of the device
- Breakdown voltage
- Dark count estimate

- Functionality of the device
- Resistor value estimate

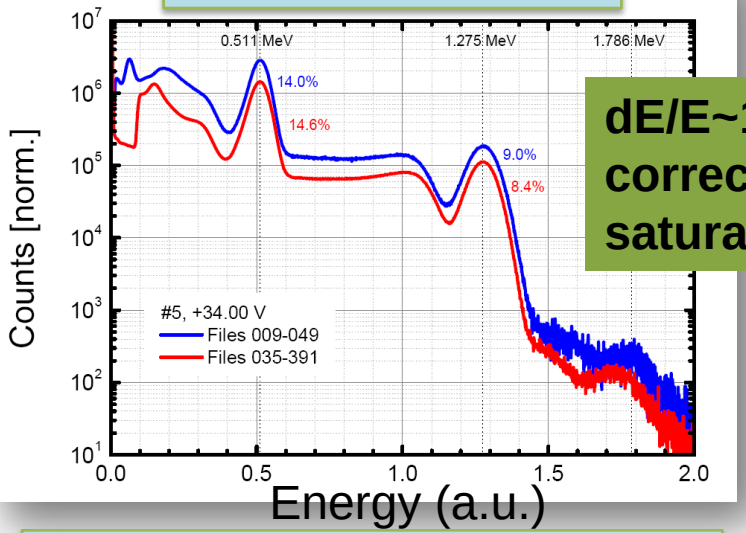
4x4mm² SiPM - 50x50mm² cell

PET application:
SiPM + LYSO



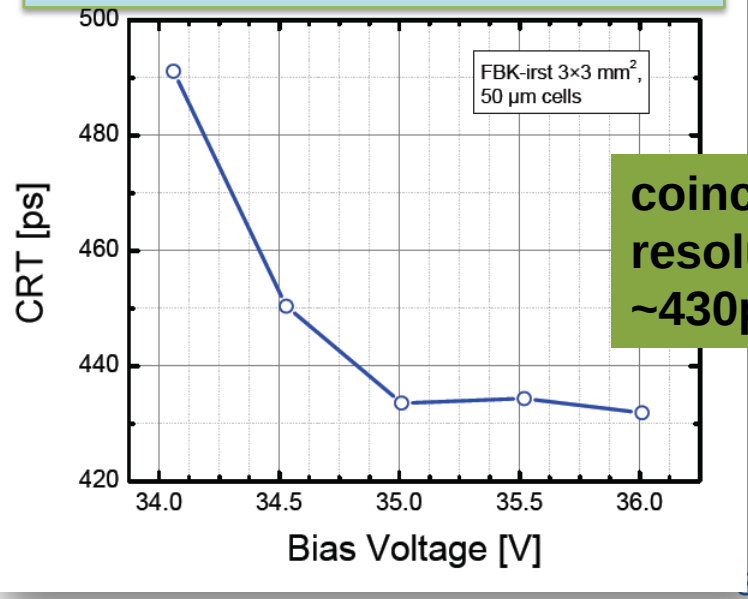


Energy resolution



dE/E~14% corrected for saturation

Coincidence time resolution



coincidence resolution ~430ps

Measurements by Philips Aachen

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Silicon 3D

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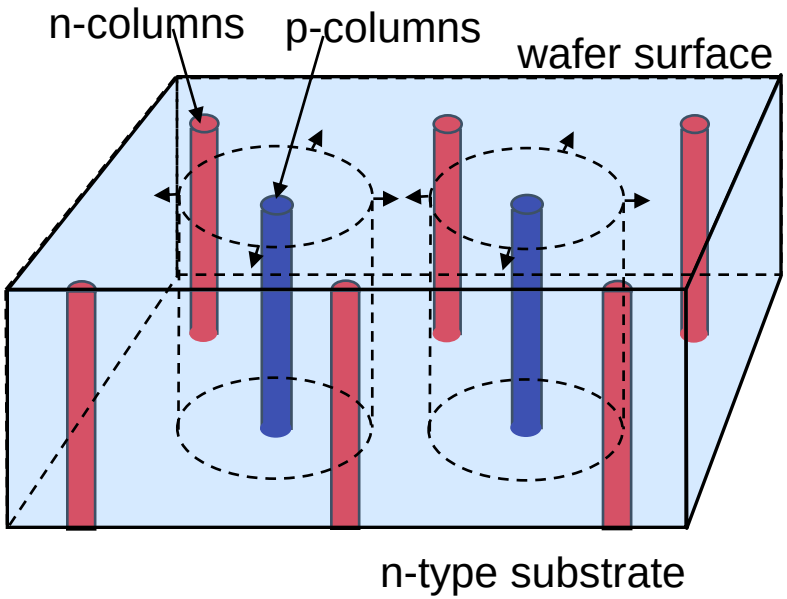
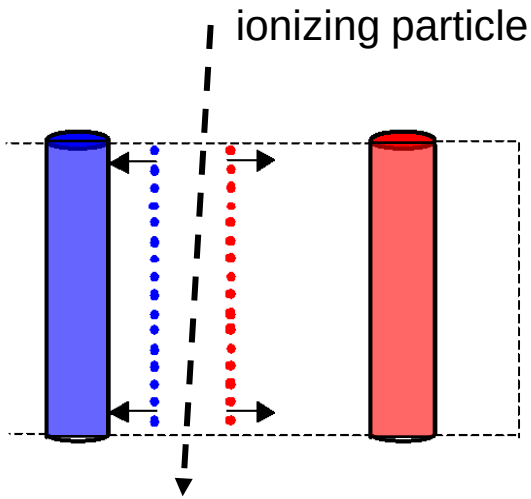
3D detectors - concept

[Parker et al. NIMA395 (1997)]





carriers collected at the same time

Distance between *n* and p electrodes can be made very short

➡ **extremely radiation hard detector**

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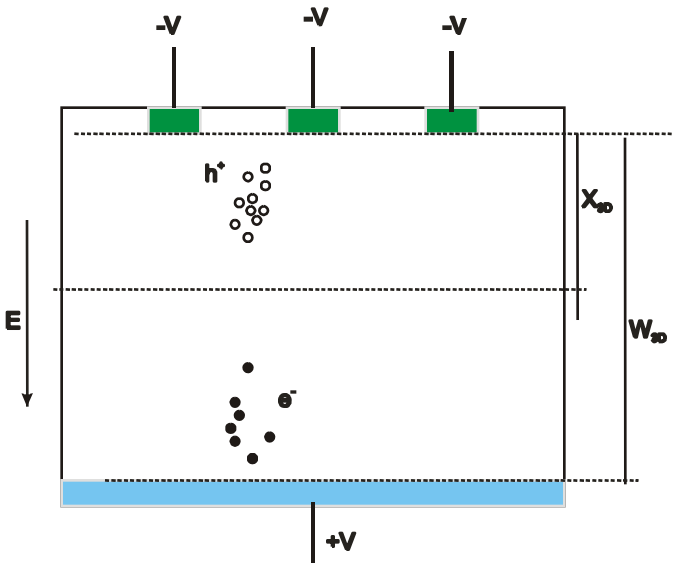
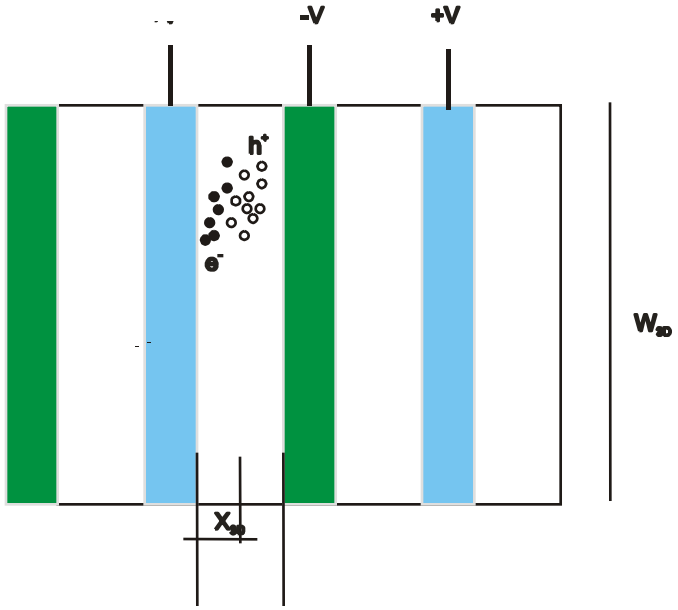
3D vs planar





3D features:

1) same collected charge as a standard planar with the same thickness;
2) lower full depletion voltage (few Volts);
3) very short collection time;

but

1) columns are partially dead regions
2) Low-field regions exist in between electrodes of same type
3) electrode capacitance is higher (noise issues at low t_p)

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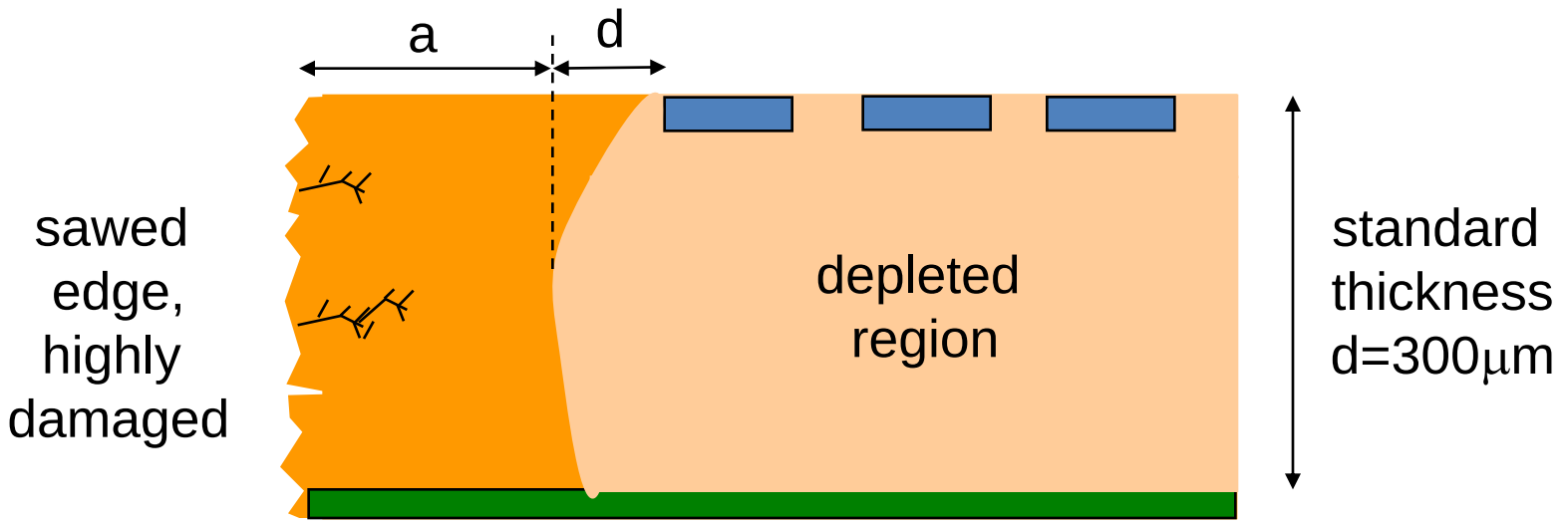
Other applications of 3d technology : active edge

Problem:

In standard detectors a dead border region must be present:

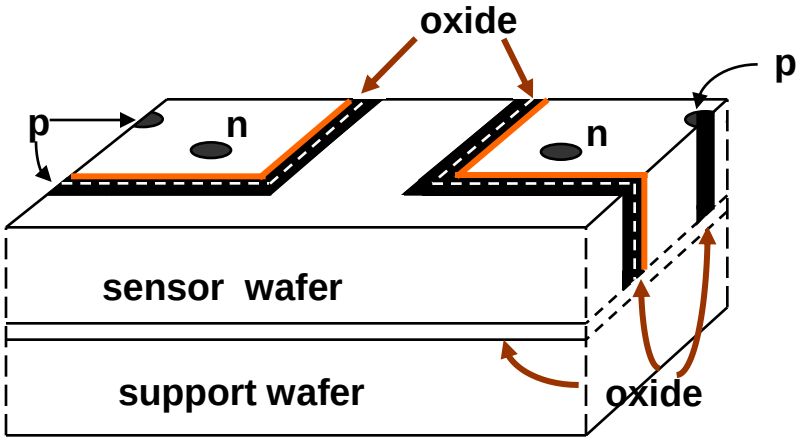


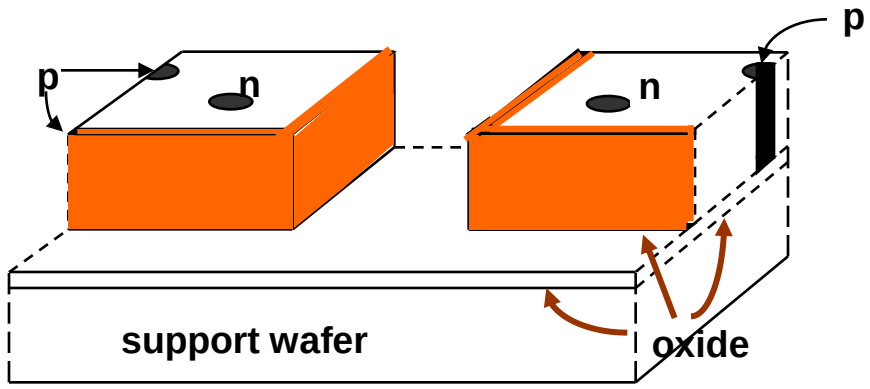
in a good design the cracks must be far from the depletion region, at least a=100-200um => **total dead region a+d=500um**

Active edge

How can we limit dead region ?

- Cut lines not sawed but etched with DRIE & doped





- Process is more complicated

  Need of support wafer → wafer bonding

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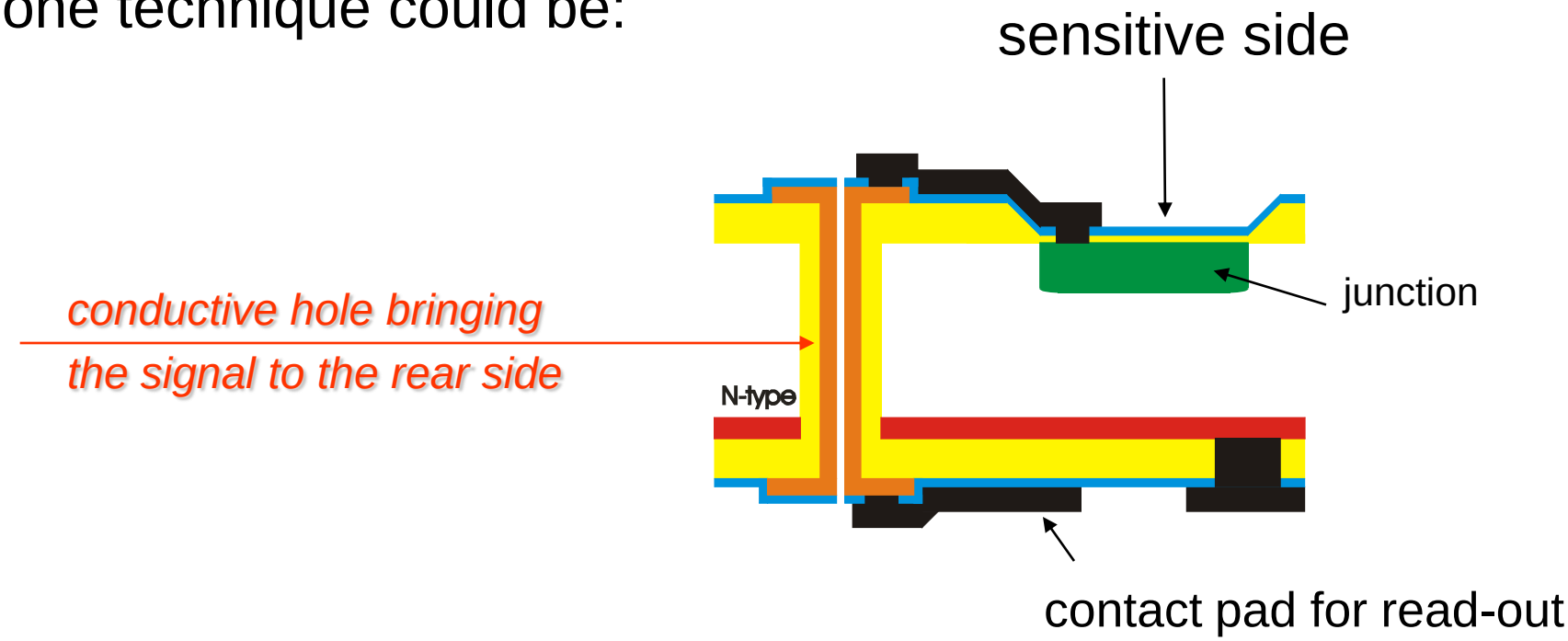
Other applications of 3d technology: through-wafer interconnects

In light sensors the sensitive side must be clear from obstacles, as can be a read-out chip.

=> one technique could be:



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Labs involved in 3D technology

- Stanford (USA)

Inventors, state-of-the-art technology (Full 3D with active edge)
But no capability of real production → partnership with SINTEF since 2006

- FBK-IRST, VTT (Finland), CNM (Spain), BNL (USA)

Alternative structures with a simplified approach (single type column), moving then to double type column, prototype level

- ICEMOS (Ireland) in coop. with University of Glasgow (GB)

Full 3D, with different approach (CMOS based), first results quite disappointing

Since 2006, CERN ATLAS 3D Sensor Collaboration: joint effort to 3D detector optimization in view of SLHC

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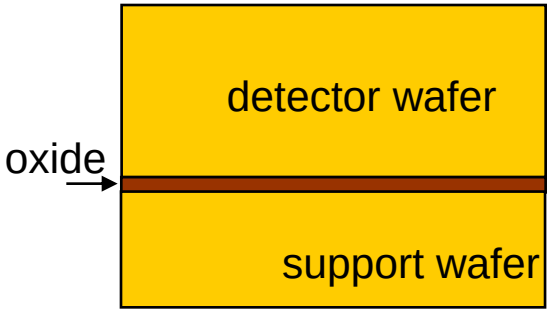
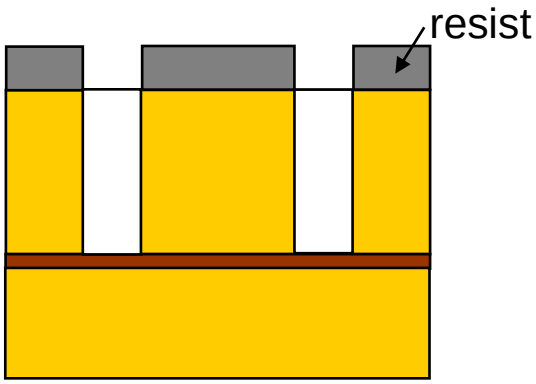
Stanford detectors: technology

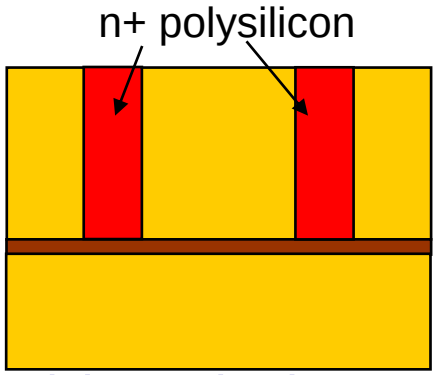
Kenney et al. IEEE TNS, vol. 46, n. 4 (1999)



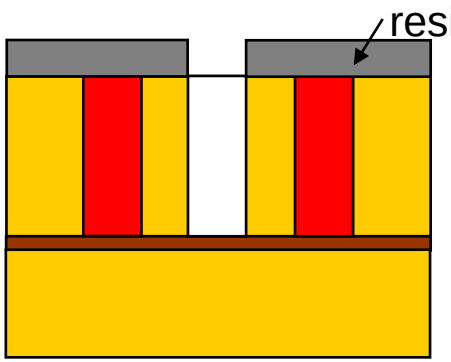
1) wafer bonding



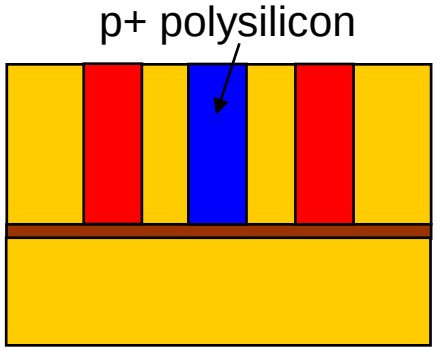
2) n+ hole definition and etching



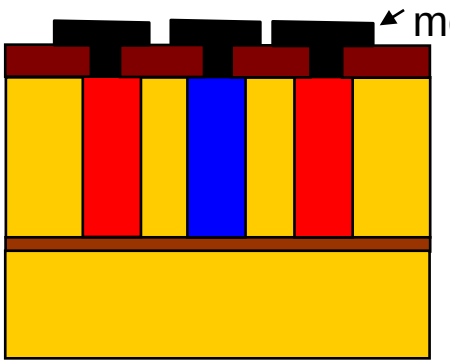
3) hole doping and filling



4) p+ hole definition and etching



5) hole doping and filling



6) Metal deposition and definition

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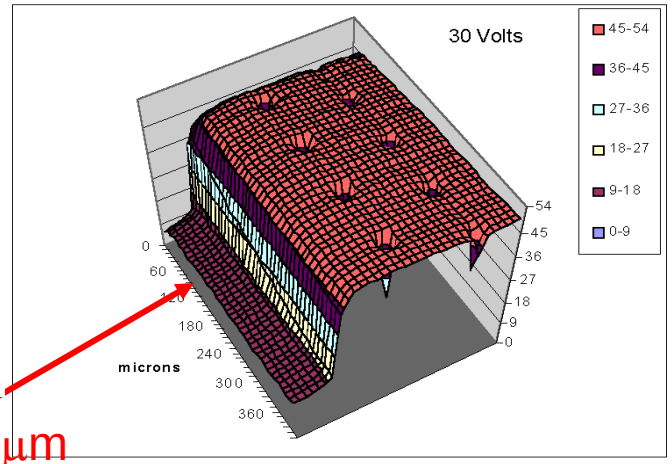
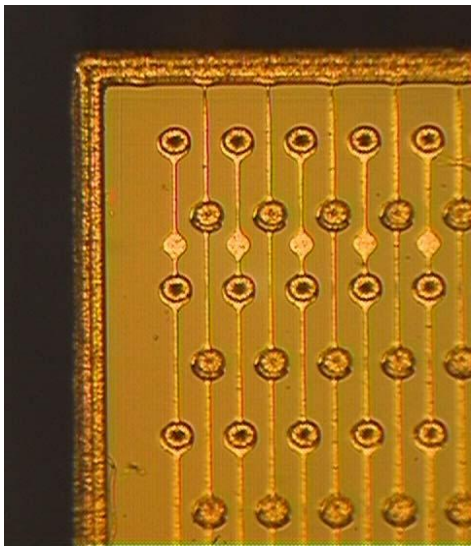
Stanford detectors: Detector inefficiencies

X-ray microbeam

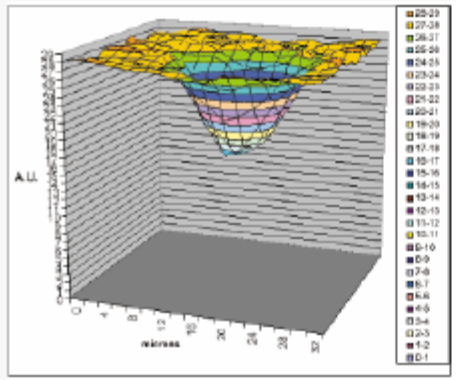
Scanning the beam over the detector surface and measuring the signal charge it is possible to evidence the inefficient regions



10-90% < 5µm

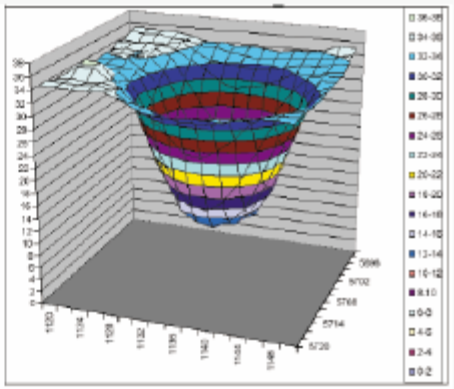


Electrode response using 12KeV X-ray beam (ALS), beam size ~ 2µm



N – Electrode

Signal Reduction 43%



P – Electrode

Signal Reduction 66%

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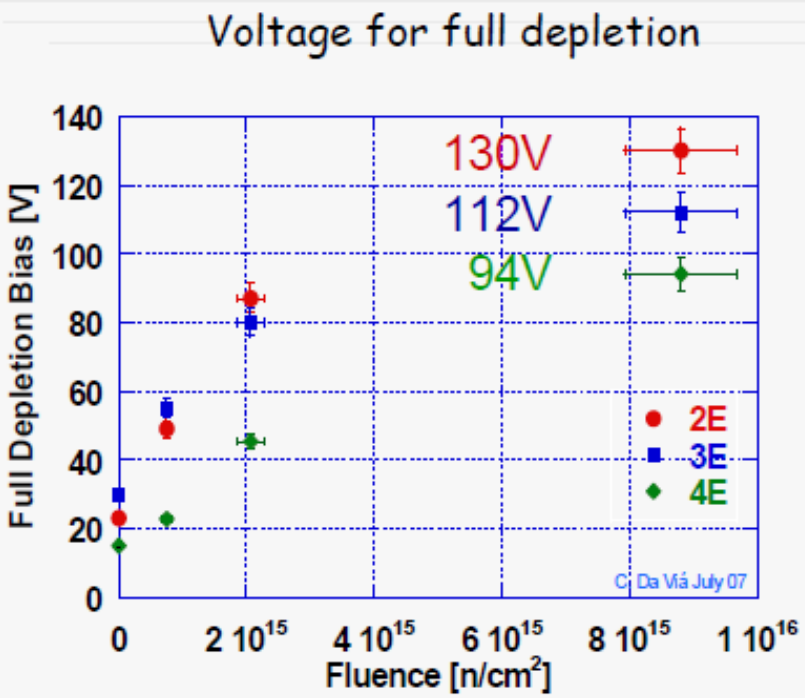
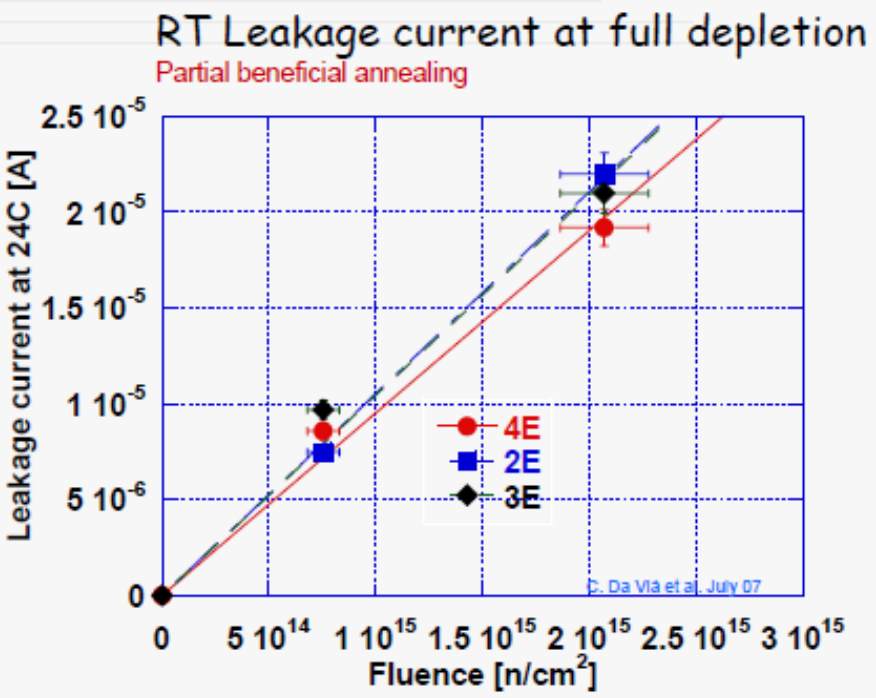
Stanford detectors: Radiation hardness





4E	Fluence [n/cm^2]	I_{FD} at 24°C[A]	Alpha [A/cm]	V_{FD} [V]	Max ampl. [mV]
Non Irrad.	0	--	--	15	124
samp1	7.55e+14	8.58e-06	6.3e-17	22	124
samp2	2.07e+15	19.2e-06	5.1e-17	45	120
samp3	8.81e+15	80.0e-06	4.3e-17	94	82

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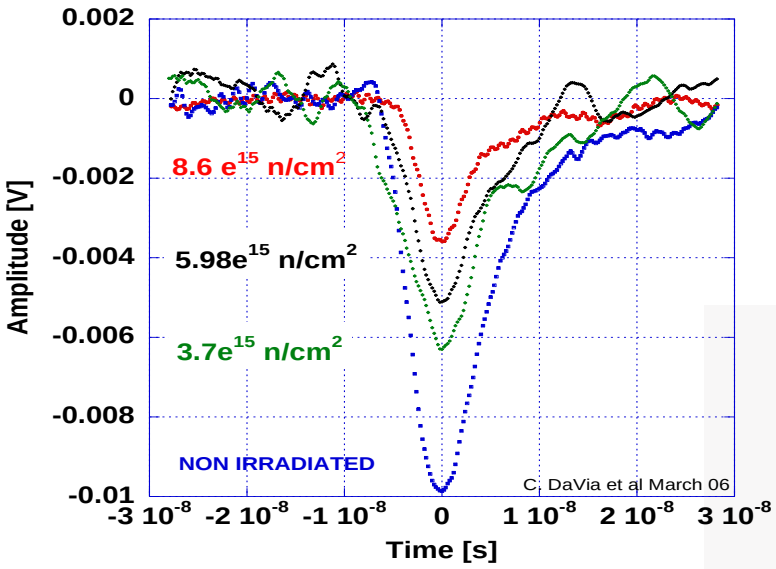
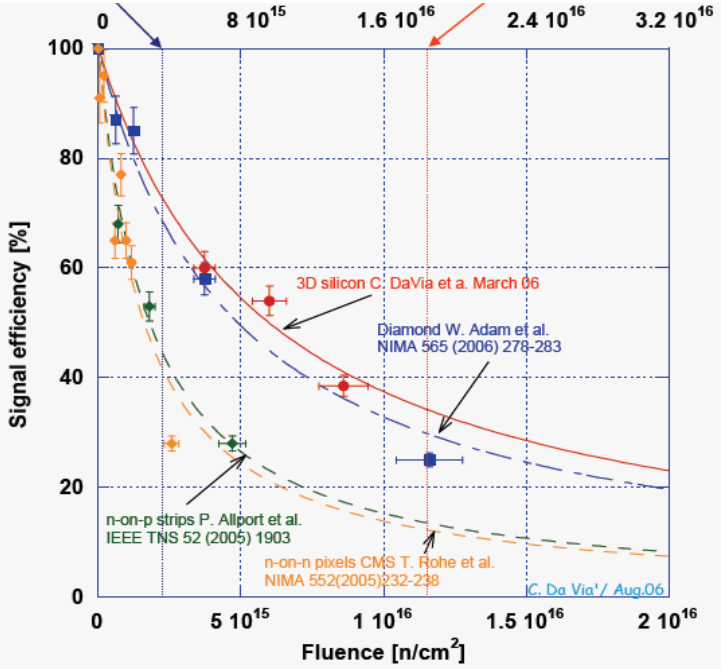
Stanford detectors: Charge collection efficiency



Increasing the irradiation level the signal decreases because of charge trapping

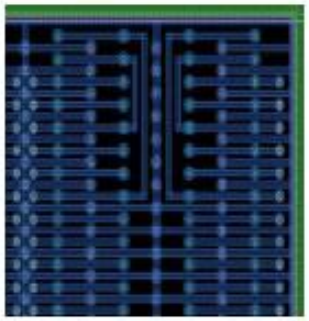


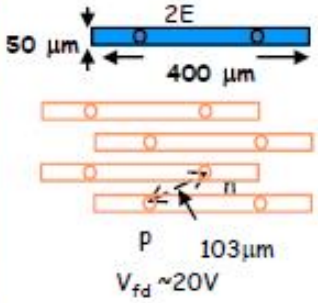
Charge collection efficiency.

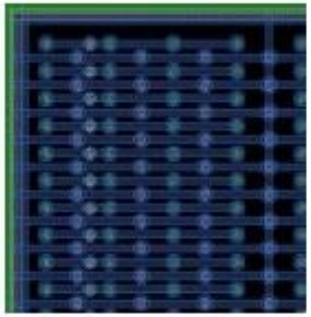
3D (red line) behave much better than standard planar (orange and green) and comparable with diamond detectors

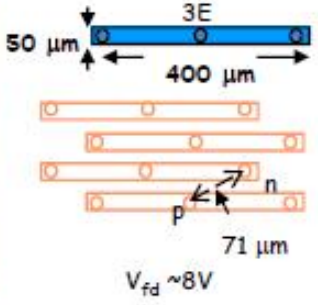
ATLAS 3D pixels

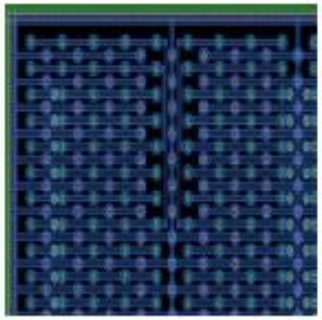
Design and fabrication by:
J. Hasi, Manchester
C. Kenney, MBC at CIS-Stanford

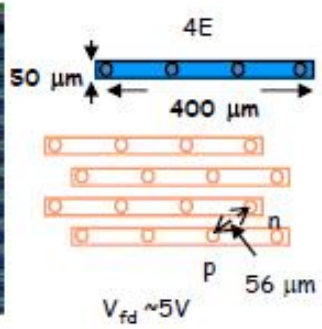




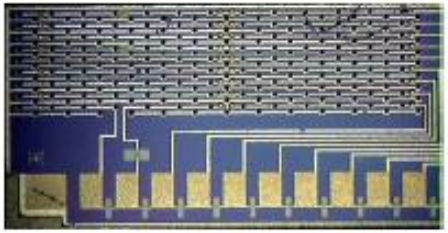




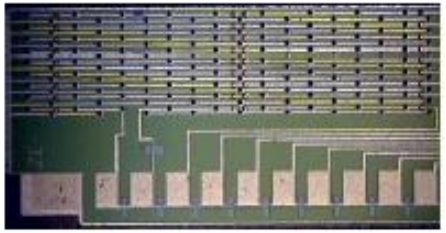




Thickness <210 µm>
p-type substrate 12kΩcm



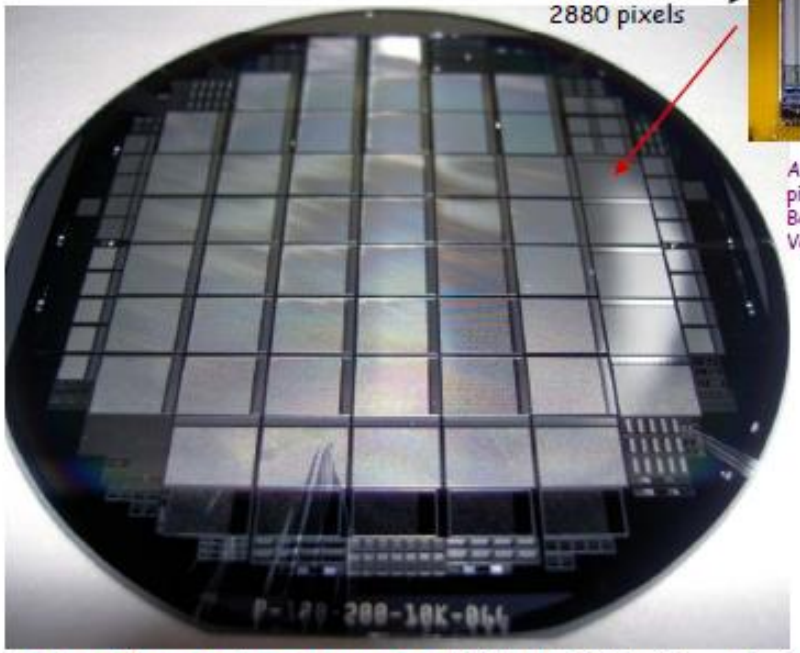
Baby-2E



Baby-3E

ATLAS pixel chip
7.2 x 8 mm²
2880 pixels

Atlas chip picture from Bekerle Vertex03

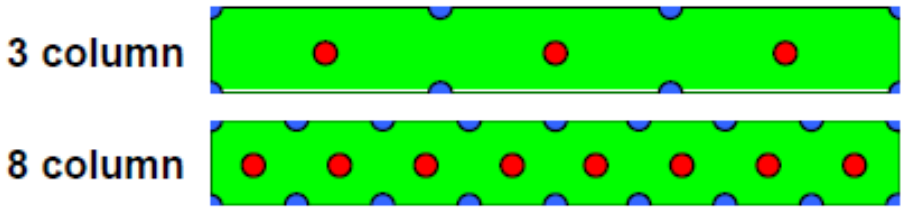


10 wafers being competed. Yield~80% (1 wafer)

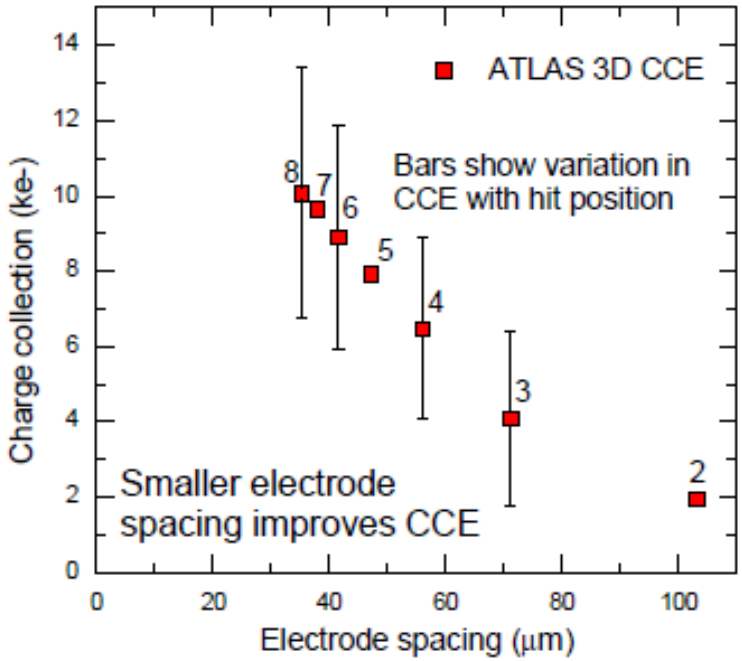
Pixel capacitance

- ATLAS pixel is 400μm * 50μm
  - Different layouts available
  - Trade-offs between V_{dep}, CCE, capacitance, column area…

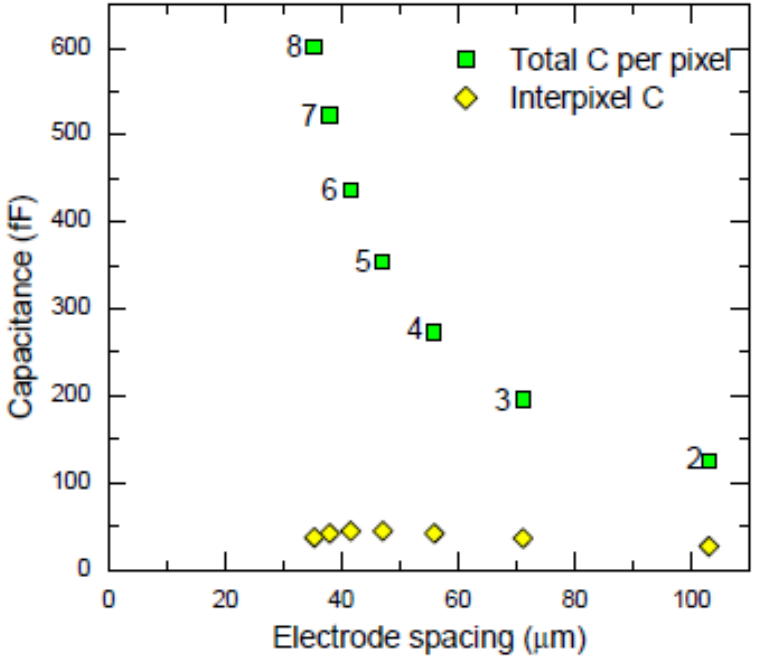
D. Pennicard et al., *Nucl. Instr. Meth.* A 592 (2008) 16



Charge collection with $10^{16} n_{eq}/cm^2$ radiation damage



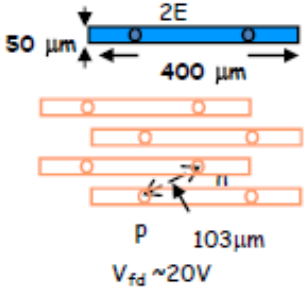
Capacitance at each pixel



Radiation hardness

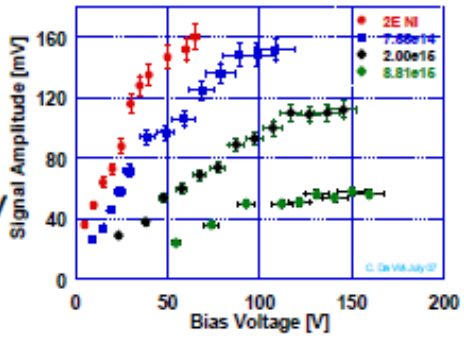
$8.81 \times 10^{15} n/cm^2$
$1.73 \times 10^{16} p/cm^2$

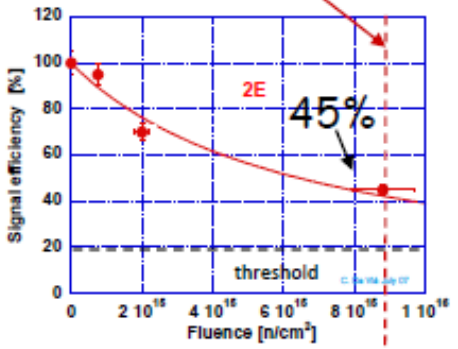
Irradiation and measurements performed in Prague
C. Da Viá, T. Slaviceck, V. Linhart, P. Bem, S. Parker,
S. Pospisil, S. Watts (process J. Hasi, C. Kenney)

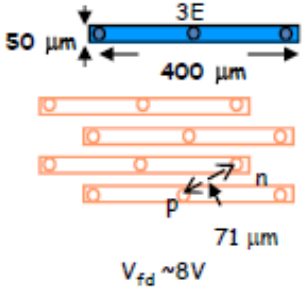


V_{fd} ~20V

2E
9000e⁻
V_b~130V

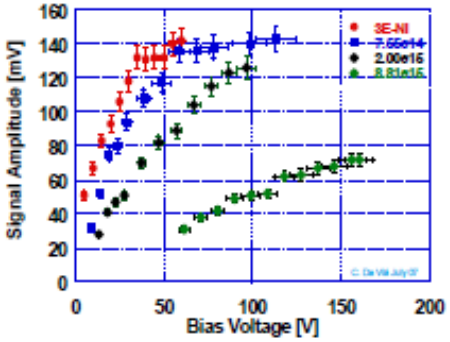


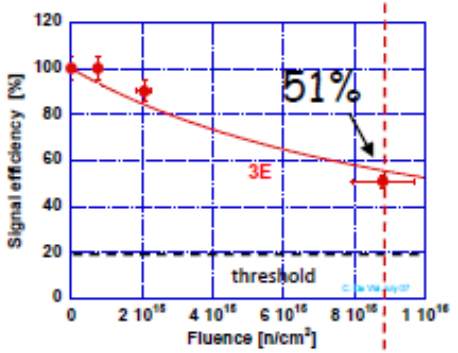


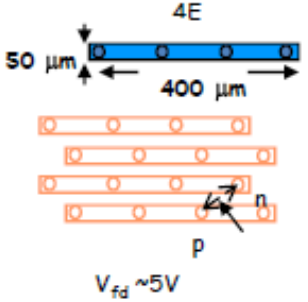


V_{fd} ~8V

3E
10200e⁻
V_b~112V

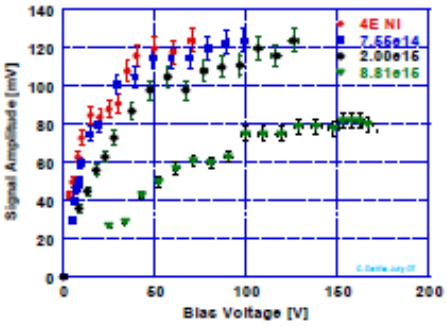


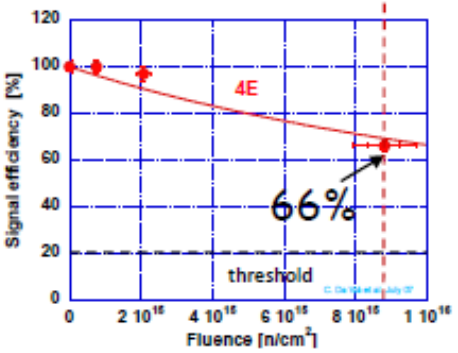




V_{fd} ~5V

4E
13200e⁻
V_b~94V



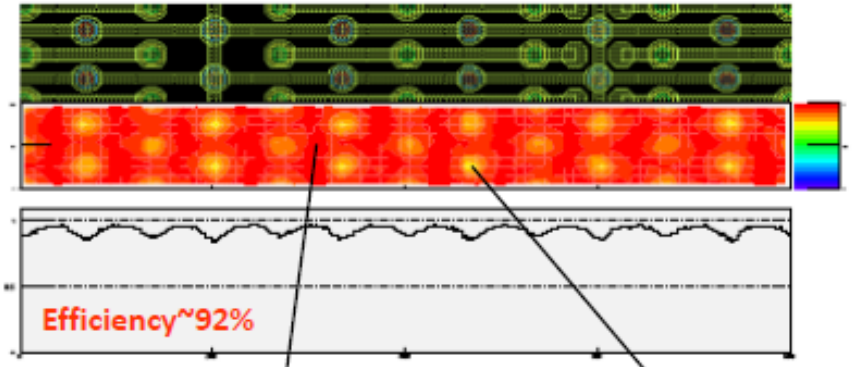


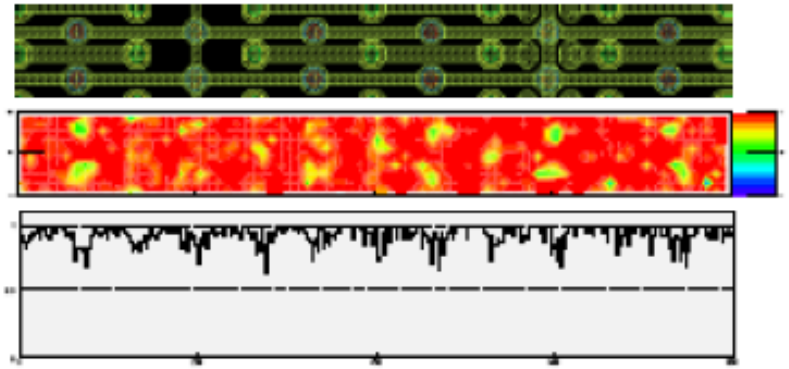
Preliminary results: test beam June 2008

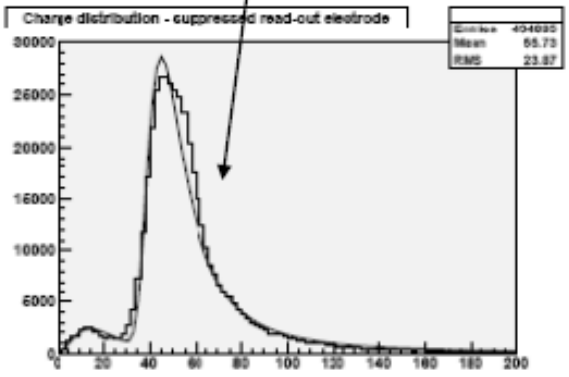
Ian McGill
Beniamino Di Girolamo
Bonn University with IZM **Bump-bonding and telescope**
E. Bolle, B. Buttler, C. Da Via, O. Dorholt, S. Fazio, H. Gjersdal, J. Hasi, A. La Rosa, C. Kenney, D. Miller, C. Young, V. Linhart, H. Pernegger, T. Slavicec, K. Sjobak, M. Tomasek, S. Watts

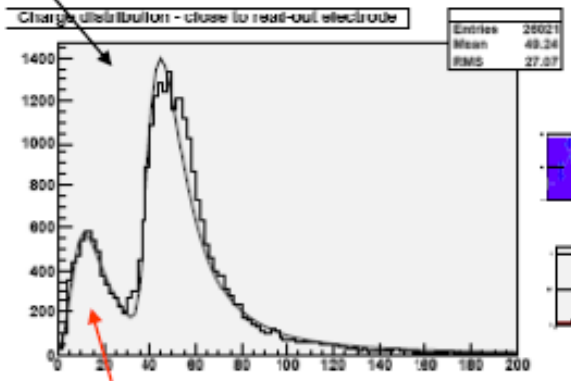
3E-40V

3E-10V

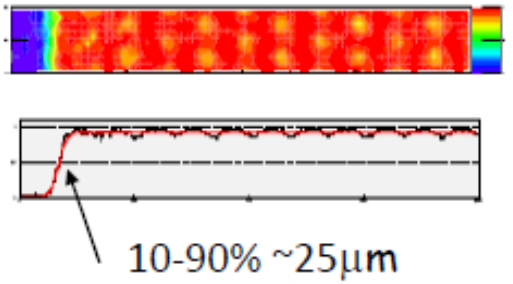








Edge response

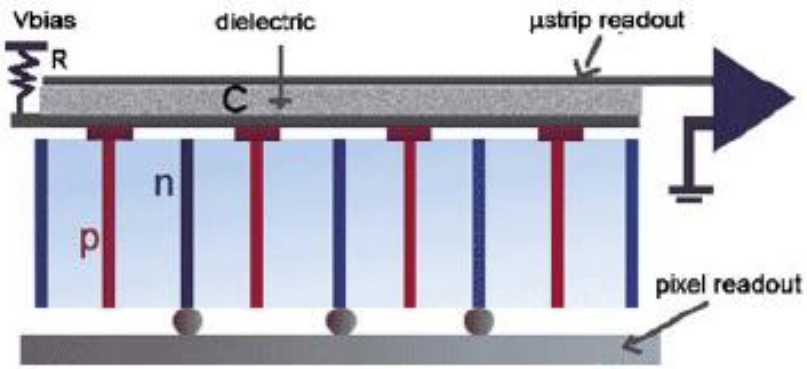


Data presented at IEEE-NSS08 by O. Rohne, Olso

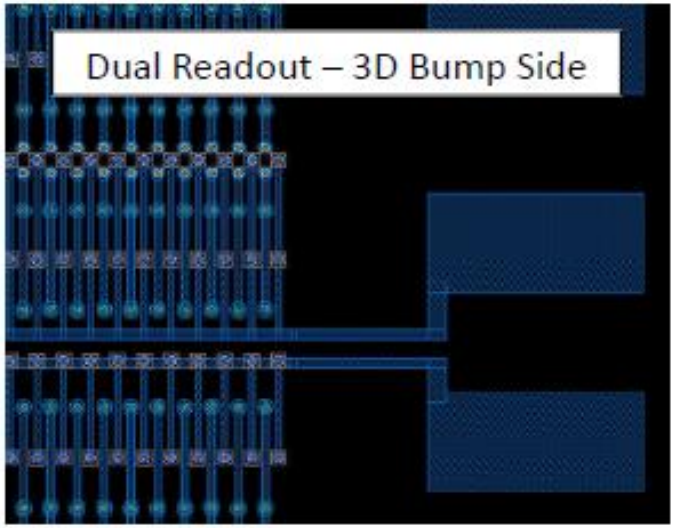
Electrode efficiency~27%

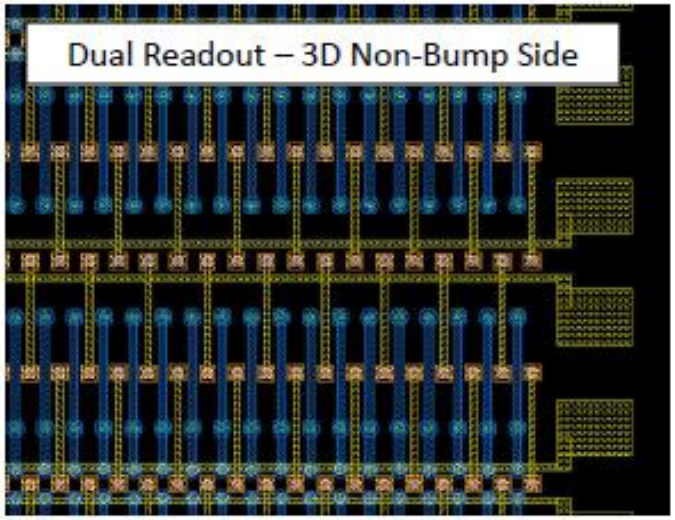
Dual read-out

From Kenney US Atlas Upgrade meeting
September 08



C. Da Via et al., "Dual readout - strip/pixel systems", NIM A594, pp. 7-12 (2008).





Devices being presently processed
Prototypes available in spring-summer09.
Might be used for trigger at AtlasFP

3d detectors @ FBK

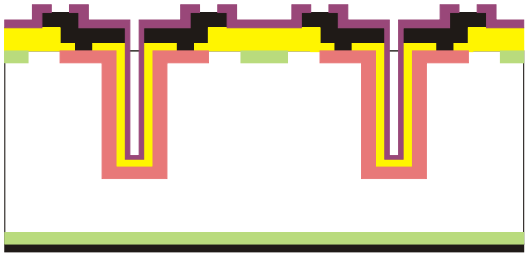
FBK is developing the technology for the production of 3D detectors in a three phases program:

SINGLE TYPE COLUMNS

Simple fabbrication process

- holes not etched all through the wafer
- Single side process

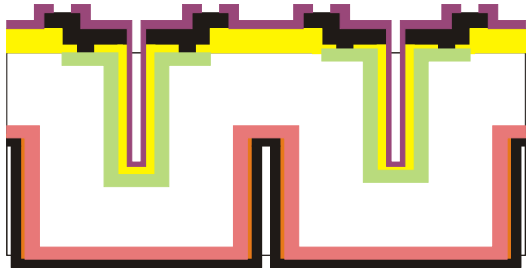
Colection mechanism not very efficient



DOUBLE TYPE COLUMNS

Performance enhancement with accettable process complication

- holes not etched all through the wafer
- Double side process
- p-on-n an n-on-p



FULL 3D

holes etched all through the wafer

Single or double side process

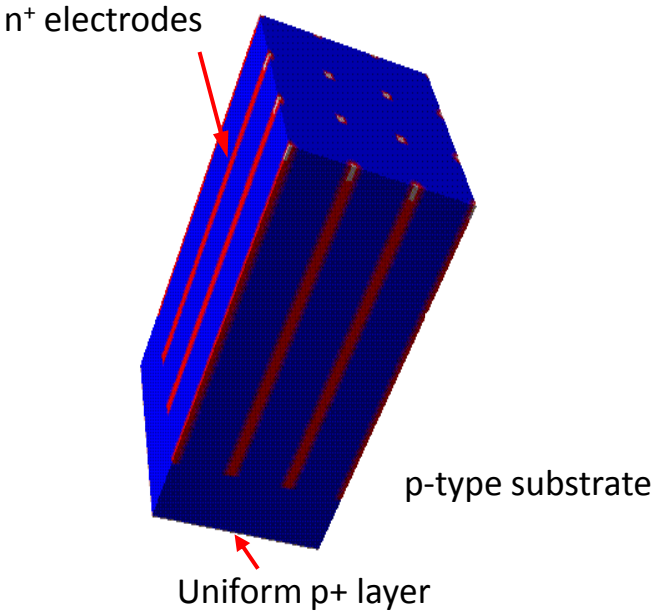
EDGELESS 3D DETECTORS

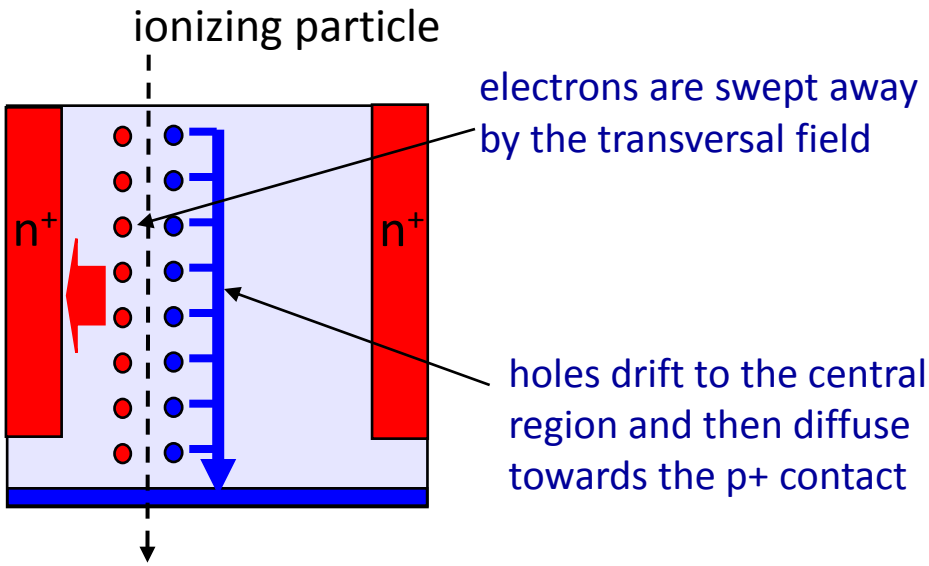
FONDAZIONE BRUNO KESSLER

Single-Type-Column 3D detectors

[C. Piemonte et al NIMA 541 (2005)]

…on the way to a fully 3D device: 3D-STC





Fabrication process is much simpler:

- column etching and doping performed only once
- holes not etched all through the wafer

…BUT

Collection mechanism is not very efficient!

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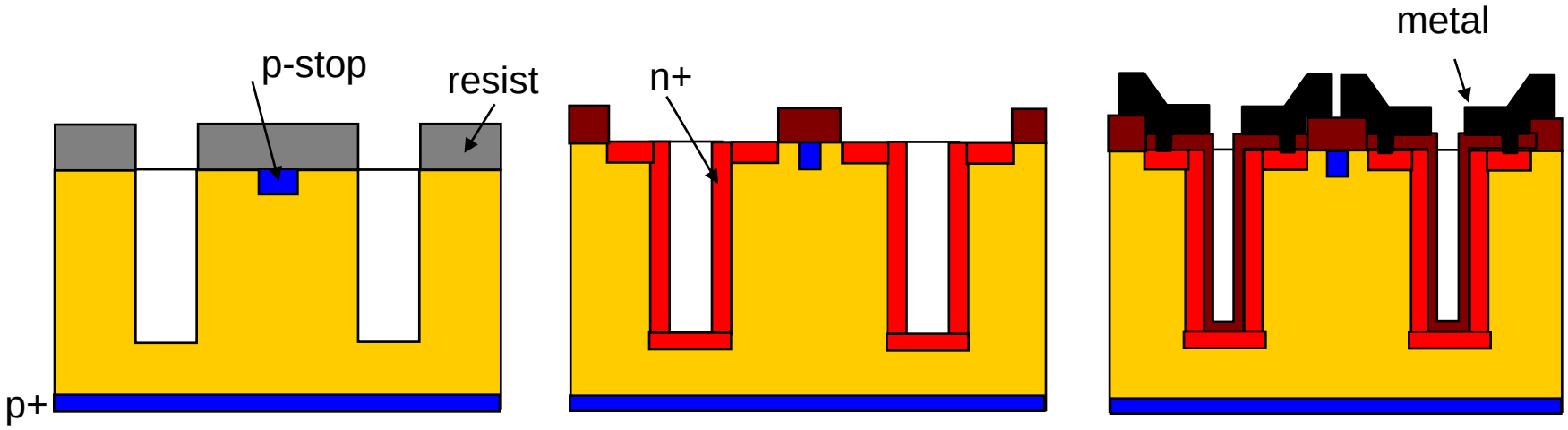
3D-STC detectors - technology



1) n+ hole definition and etching

2) hole doping

3) Metal deposition and definition

Holes:
200μm depth with a radius of ~5μm

Doping by simple P diffusion or by P-doped poly-Si deposition

Holes are **partially** filled with thermal oxide or TEOS.

Contact only at the top.

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Punti chiave per la realizzazione di un 3D

- DRIE
  - Ad ora è l'unica tecnologia utilizzabile per la realizzazione di fori profondi
  - Che tipo di mascheratura ?
  - Aspect ratio ?
- Drogaggio tramite sorgenti a stato solido
  - Non si può pensare di impiantare in un foro profondo
- Riempimento con polisilicio
  - Se da buoni risultati in termini di riduzione dell'area morta sicuramente complica decisamente il processo
    - Riempire il foro 10diametro = 5 micron di poly
    - Necessita di CMP
- Wafer bonding
  - Fondamentale per edgless
  - Il problema è staccare la fetta di supporto
- Litho in presenza di fori
  - In generale la gestione dei fori è un problema "pratico"
  - Resistenza meccanica

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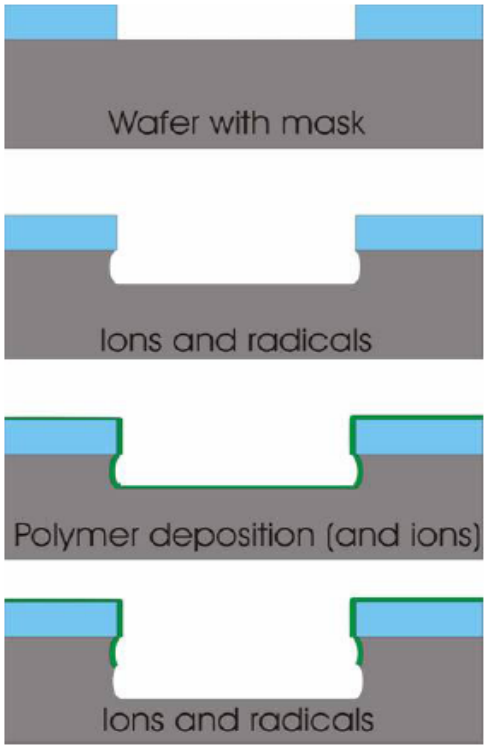
Deep Reactive Ion Etching

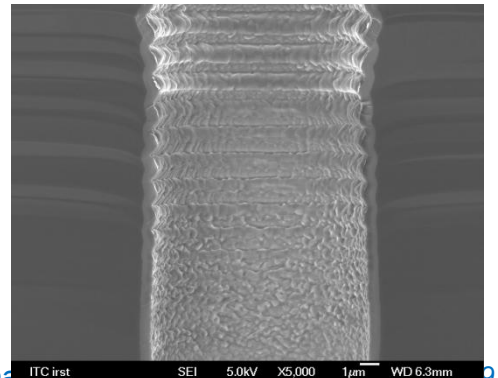
Deep reactive-ion etching (DRIE) is a highly anisotropic etch process

Aspect ratio of 20:1 or more.

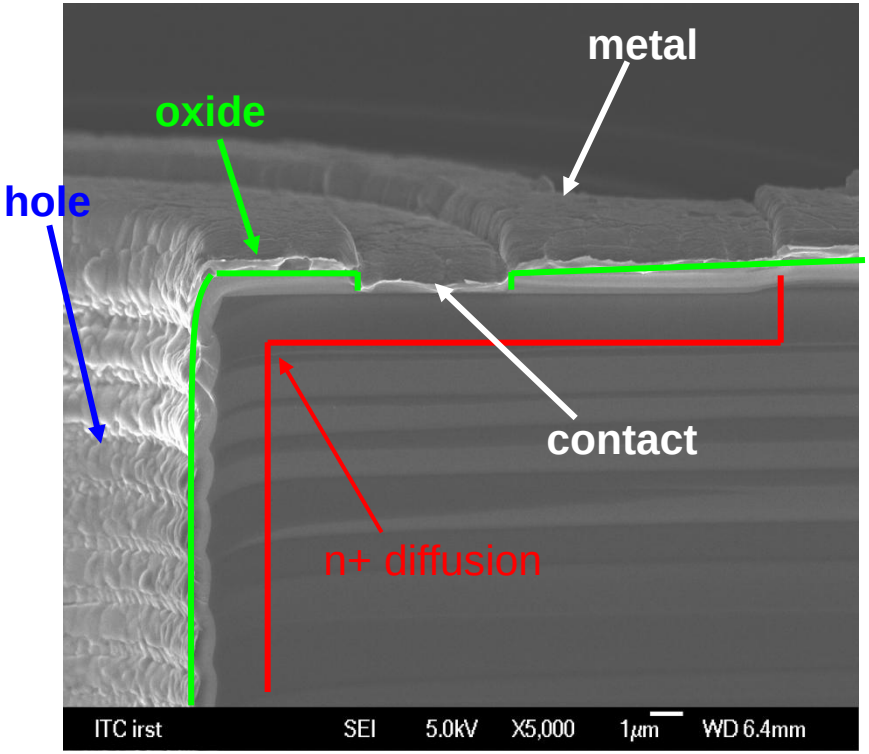
The Bosch process alternates repeatedly between two modes to achieve nearly vertical structures.

1. A standard, nearly isotropic plasma etch
2. Deposition of a chemically inert passivation layer

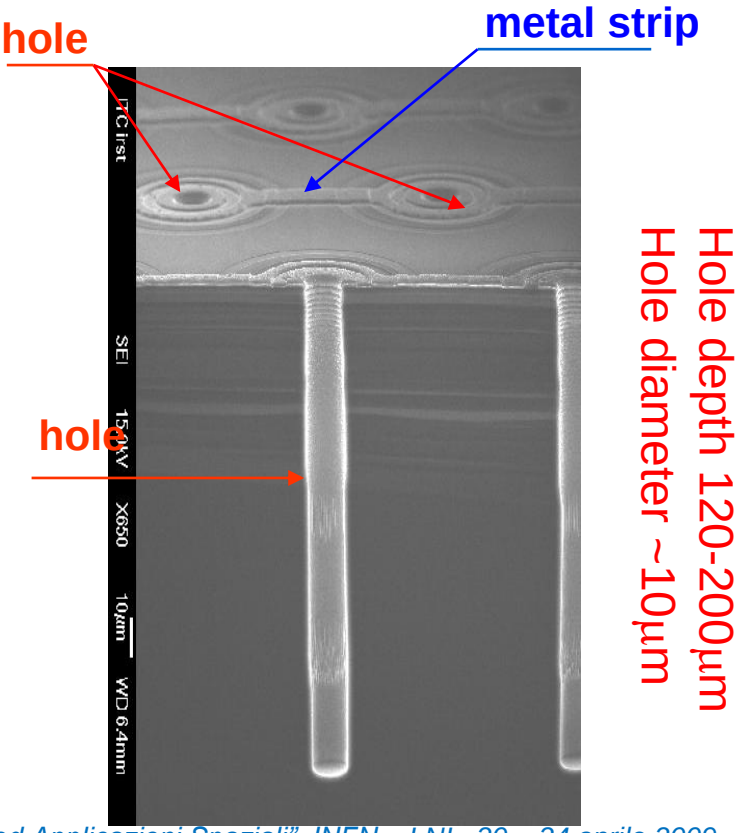




3D-STC detectors - FBK technology



- Hole etching with Deep-RIE technology
- Wide superficial n+ diffusion in which the contact is located
- Passivation of holes with oxide



- Si High Resistivity, p-type, <100>
- Surface isolation: p-stop *or* p-spray
- Holes are "empty"

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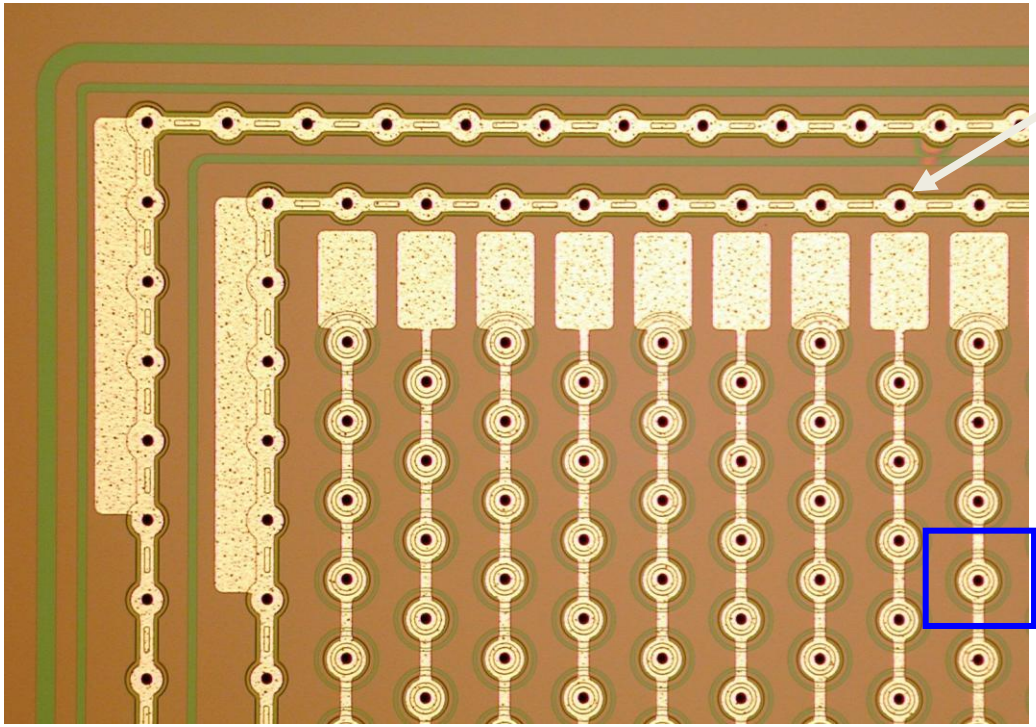
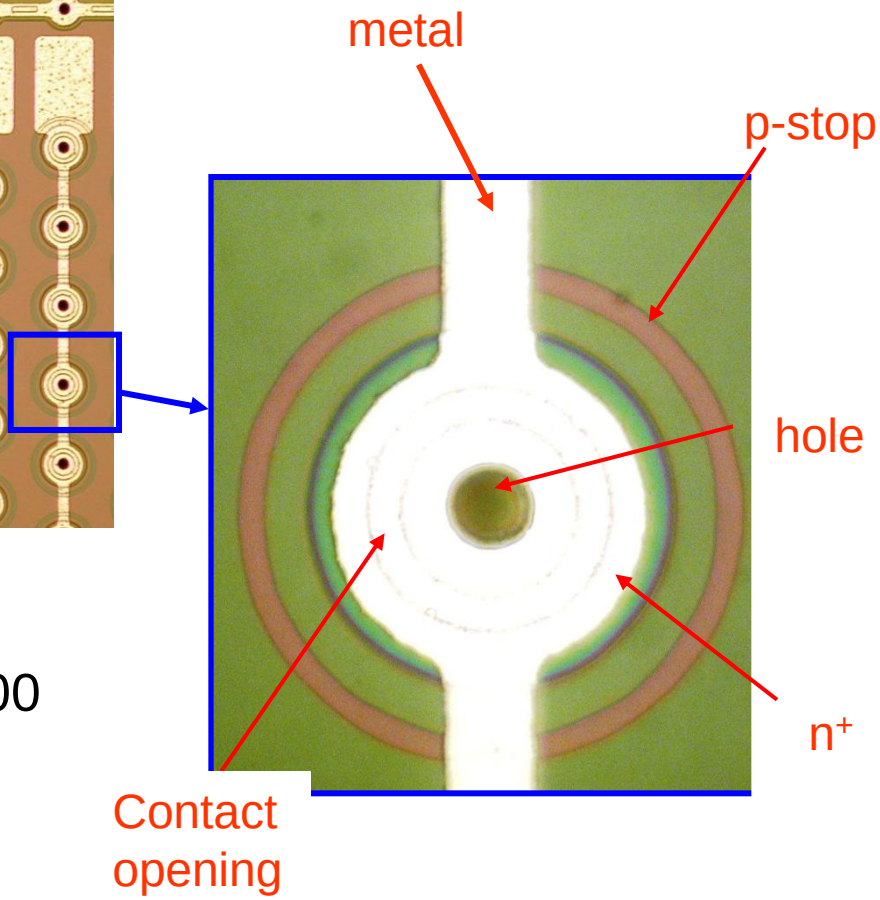
3D-STC detectors - Strip detectors





Different strip-detector layouts:

- Number of columns from 12000 to 15000
- Inter-columns pitch 80-100 μm
- Holes Ø 6 or 10 μm

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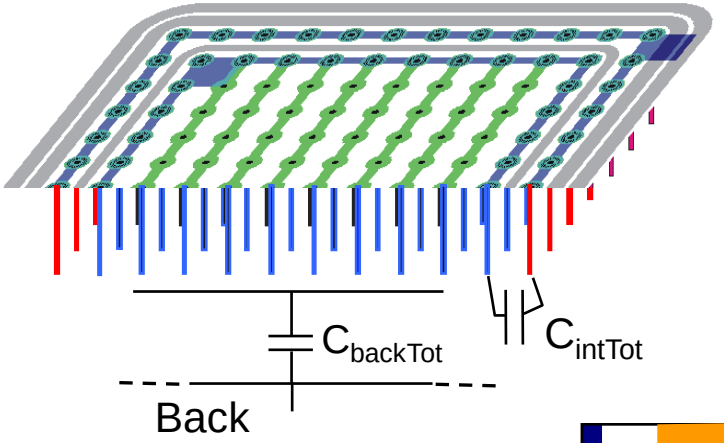
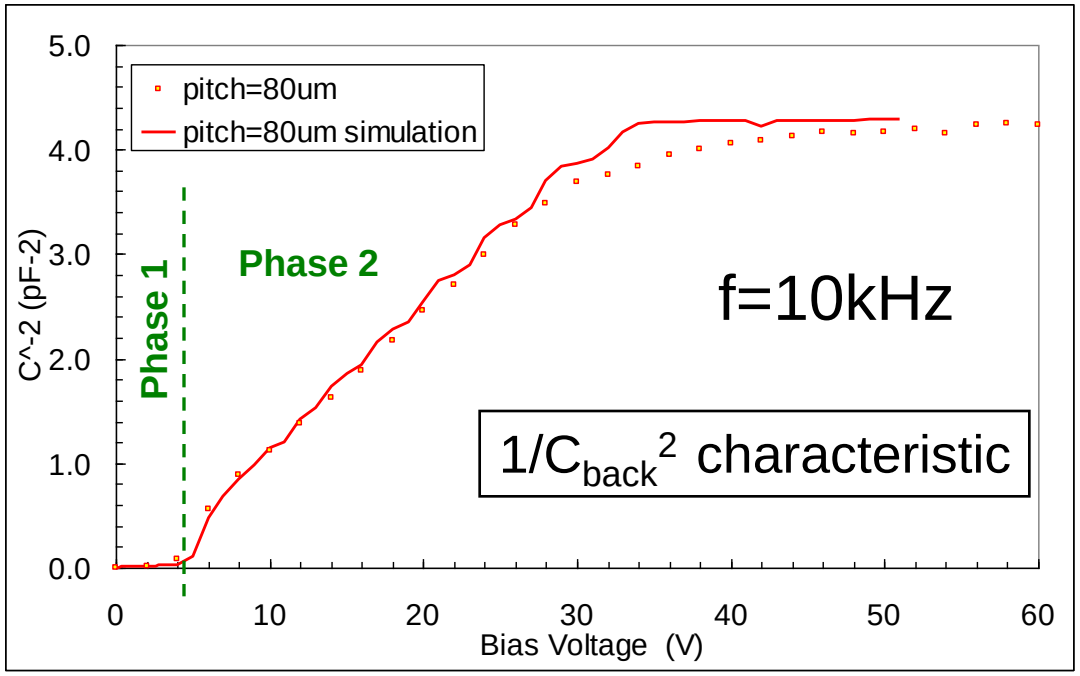
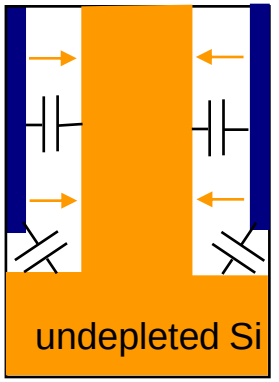
Full depletion evaluation from 3D diode capacitance





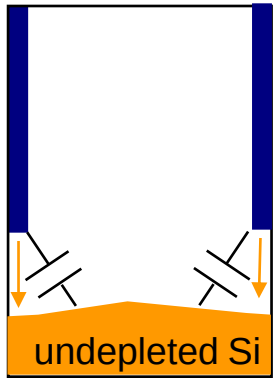
Phase 1

- high C_{back}
- ~ zero C_{int}



Phase 2

- max C_{int}
- slowly dec. C_{back}



From $1/C^2$ curves one can determine:

- **full depletion between columns** (in this case ~5V for 80μm col. pitch)
- **full depletion of the bottom region** (~35V for column depth of 150μm)

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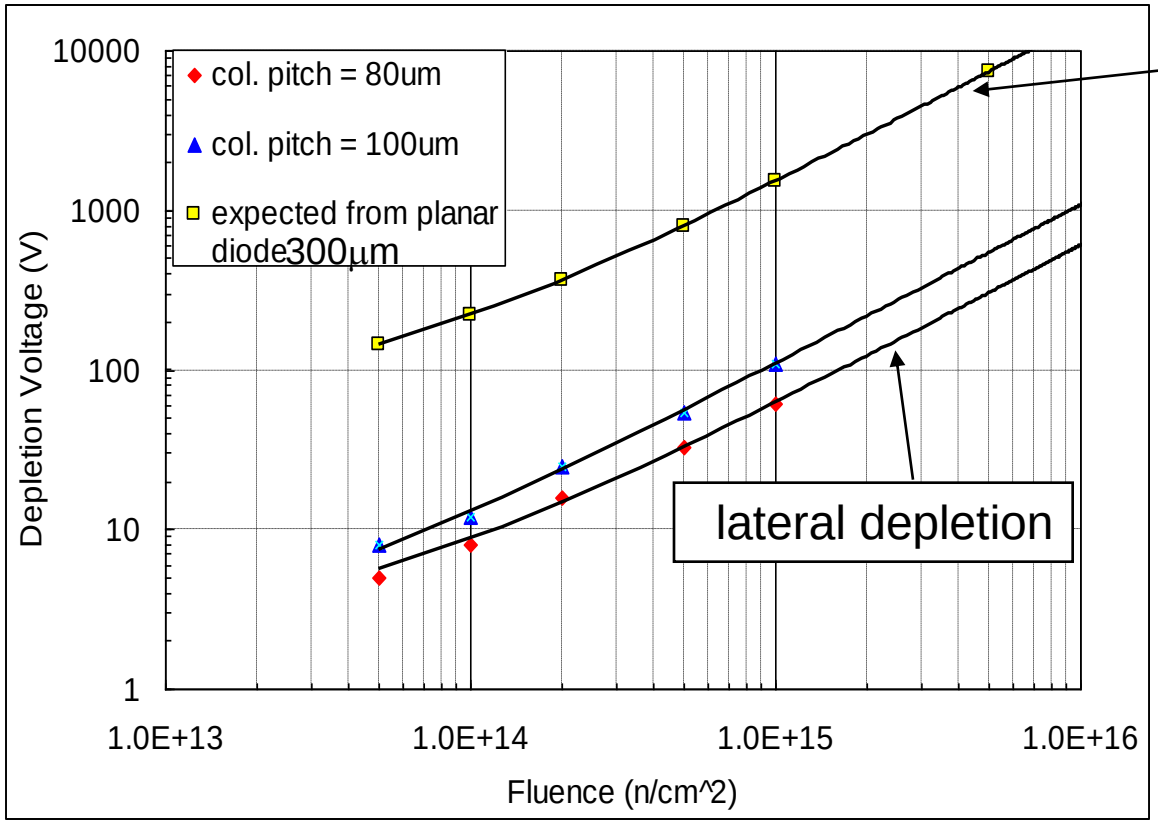
Depletion voltage after irradiation

(JSI Ljubljana)

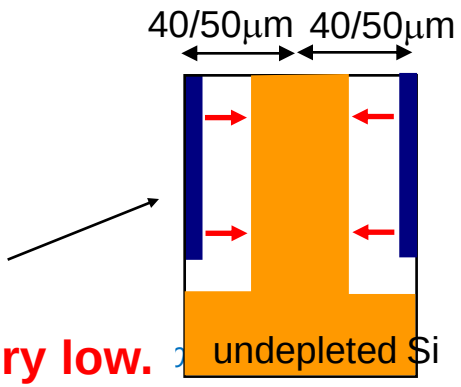


$$\Delta N_{eff} = \beta * \Phi \quad (*)$$
$$\beta = 0.021 cm^{-1}$$

see V. Cindro's talk at 8th RD50 workshop: http://rd50.web.cern.ch/rd50/

Simulating the full lateral depletion voltage with N_{sub} estimated from equation (*) we obtain values comparable with those reported on the plot.

- 3D diodes and planar diodes (FZ, 500μm)
- Neutron irradiation at TRIGA reactor (6 fluences)
- Annealing 15 days at RT



Each column depletes half col. pitch
➡ the lateral depletion voltage is very low.

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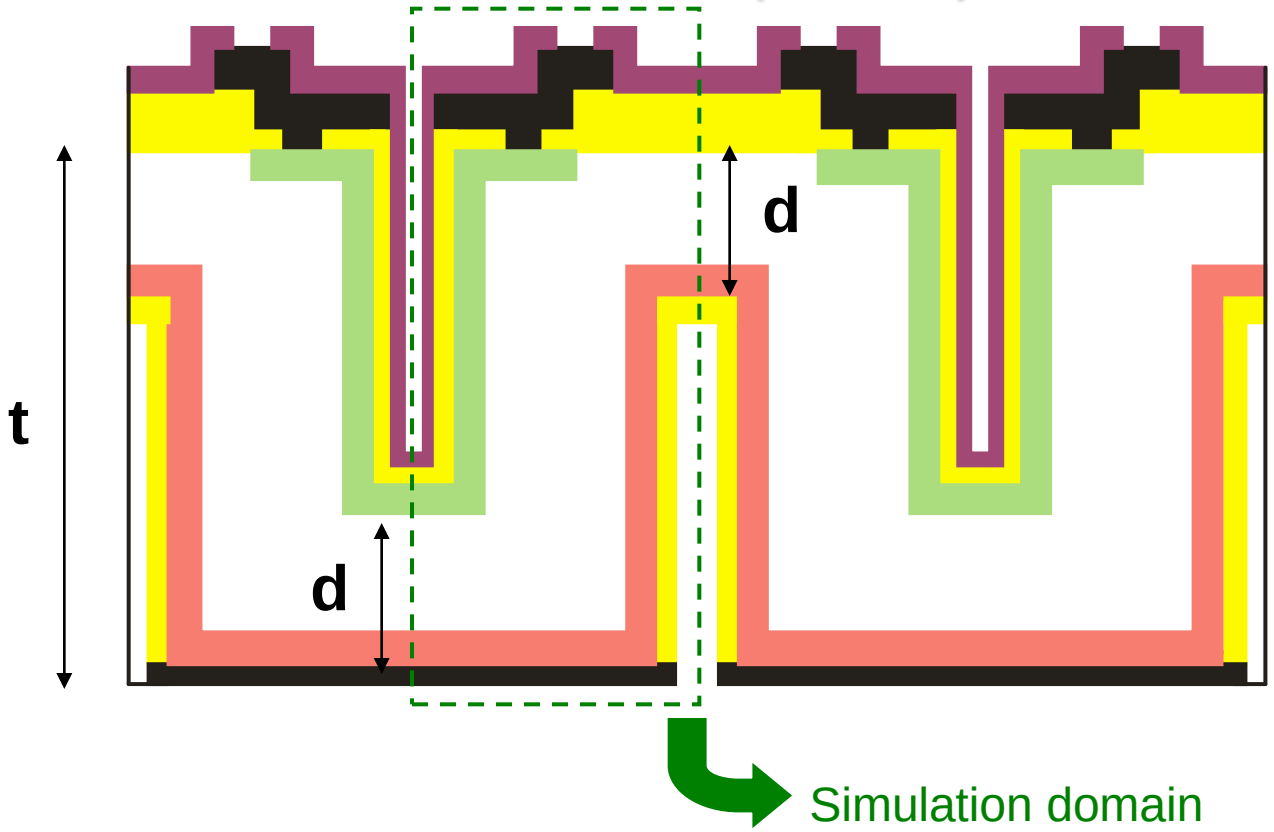
3D Double-side Double-Type Column (DDTC) detectors



Front side as in STC

Back side:
+ litho and DRIE

- Detector concept able to ease the fabrication process
- Expected to have performance comparable to standard 3D detectors (if **d** is much smaller than **t**)

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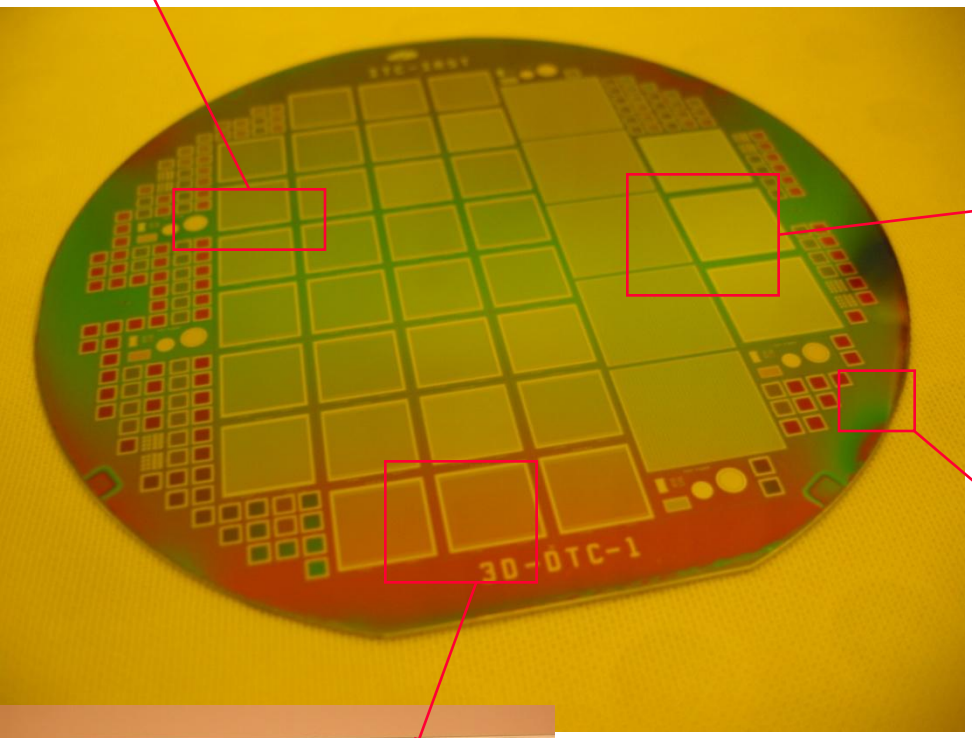
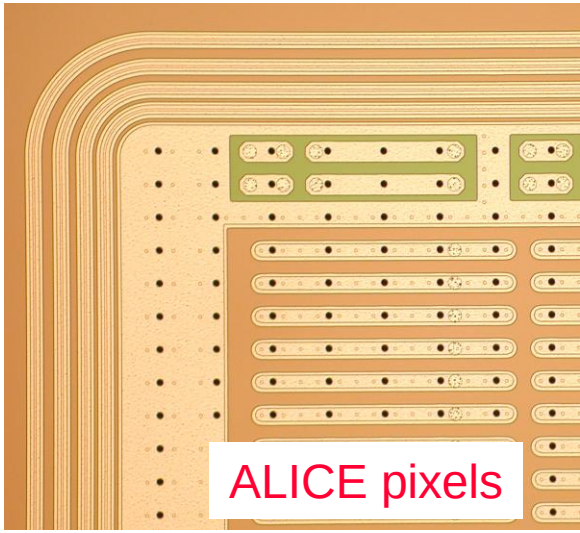
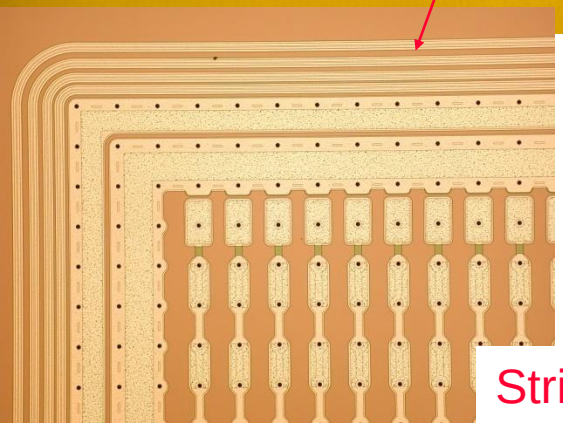
3D-DTC-1: some pictures

Planar TS

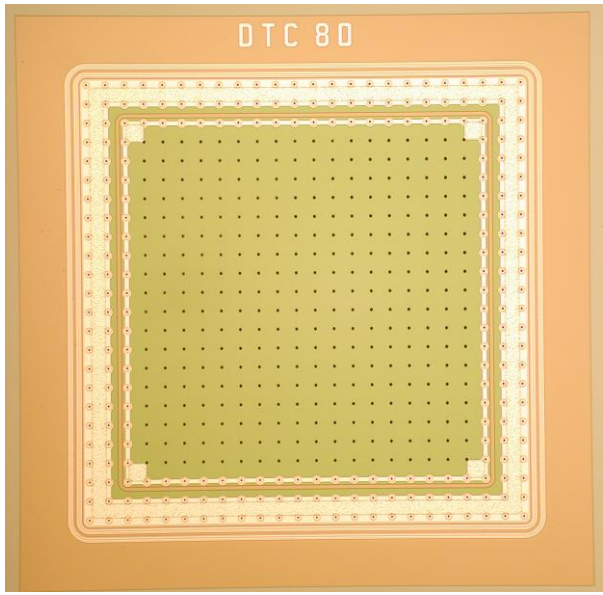




ALICE pixels



Strip detectors



3D diodes:
16x16 or 20x20
column array

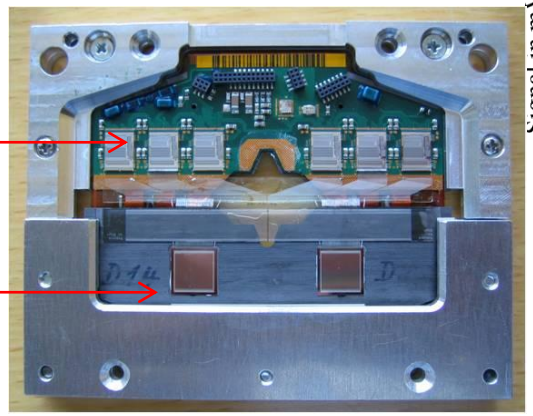
Position resolved CCE with ATLAS SCT readout

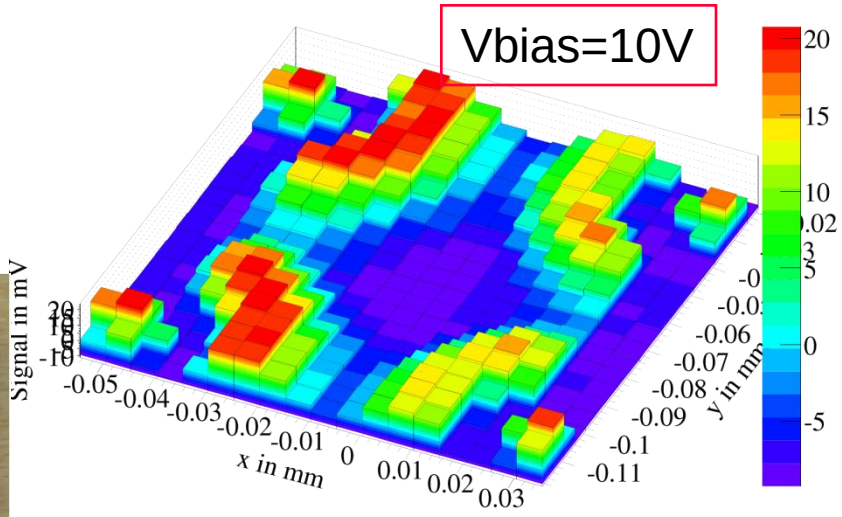
(Univ. Freiburg)

DEVICES: long strip detectors

ABCD3T binary chip
20ns shaping time

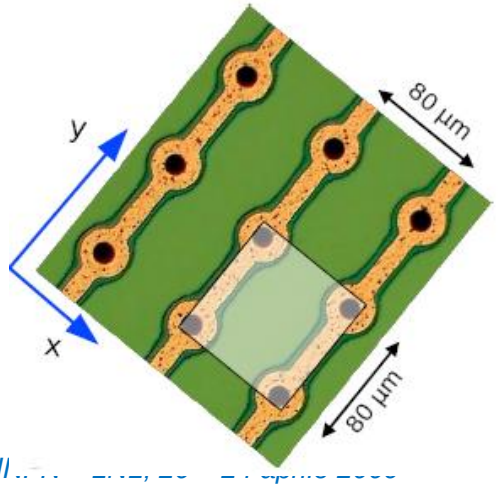
Detectors





SETUP:

- 982 nm IR laser – light spot diameter 4-5 μm
- Pulse width ~ 1-2ns, synchronized with DAQ
- ATLAS SCT binary readout, shaping time 20 ns



DTC vs STC

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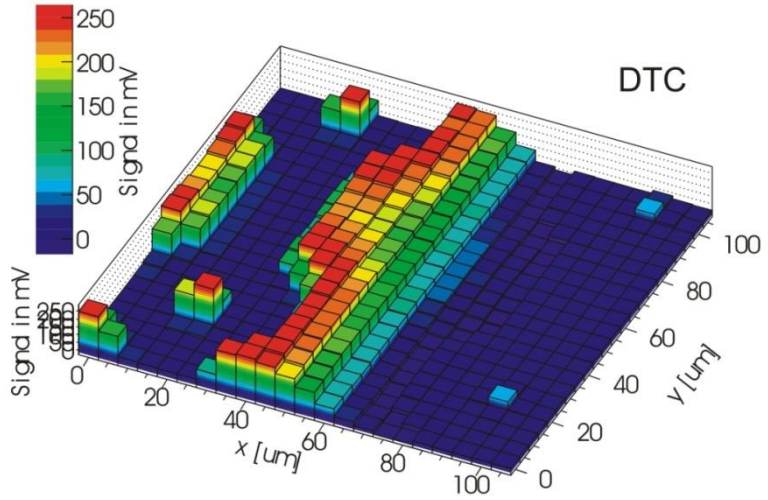
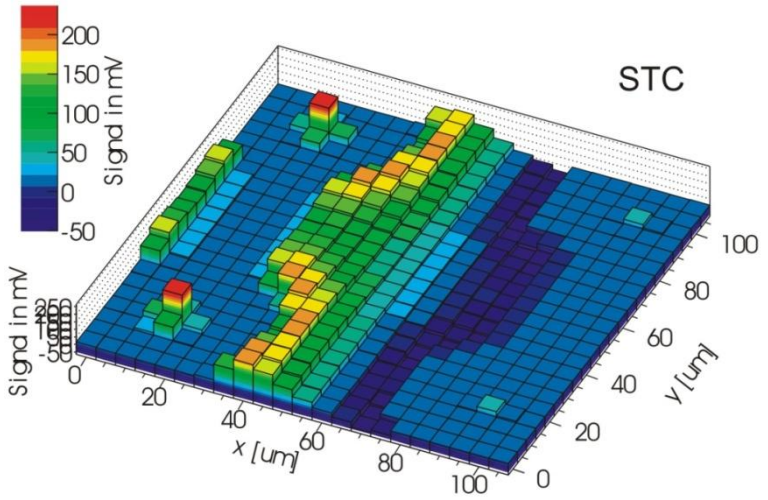
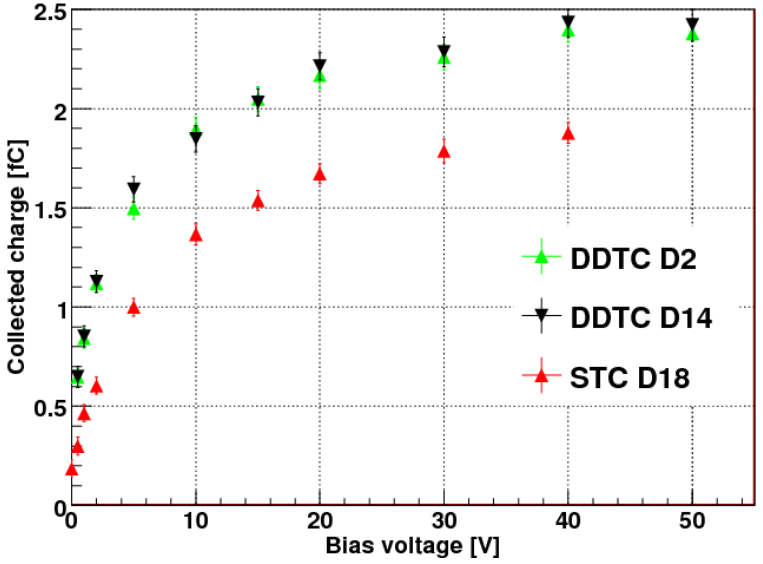
Signal induced on left strip at 10V





Setup:

- Sr ^{90} beta source, MIP like charge deposition within the active area
- Events triggered by two scintillators in coincidence



	Max	Negative
DDTC	250mV	-5mV
STC	180mV	-50mV

In agreement with laser measurements:
DDTC collects more charge than STC

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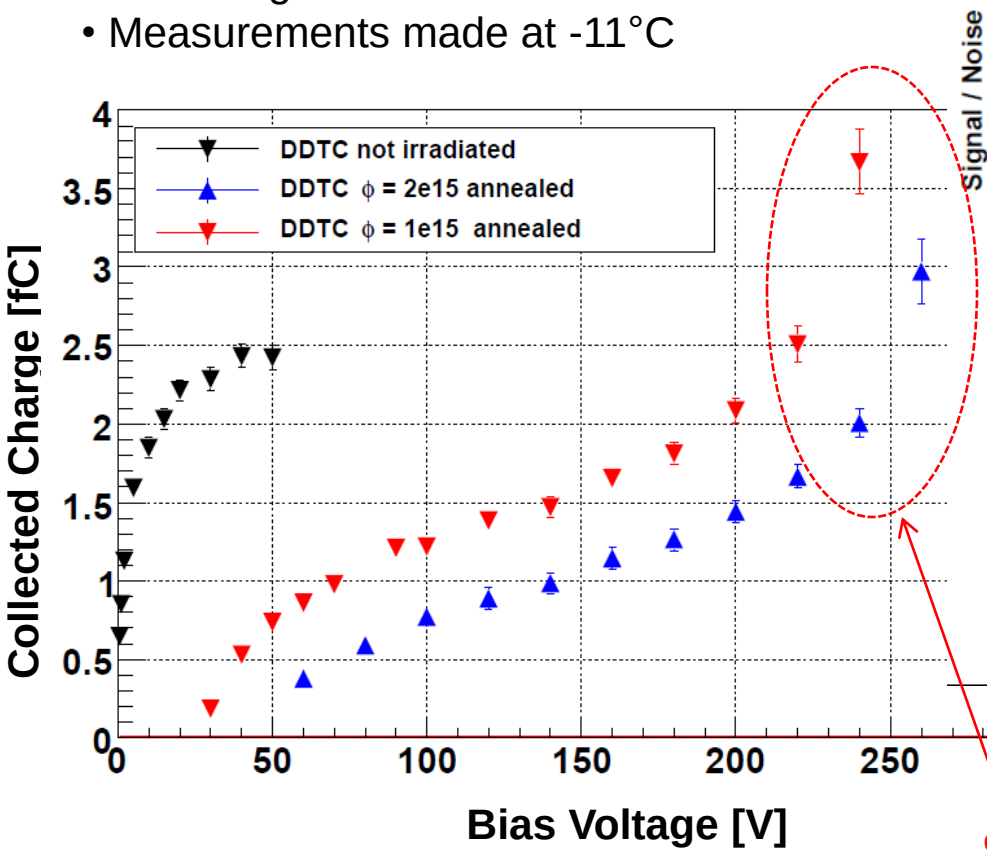
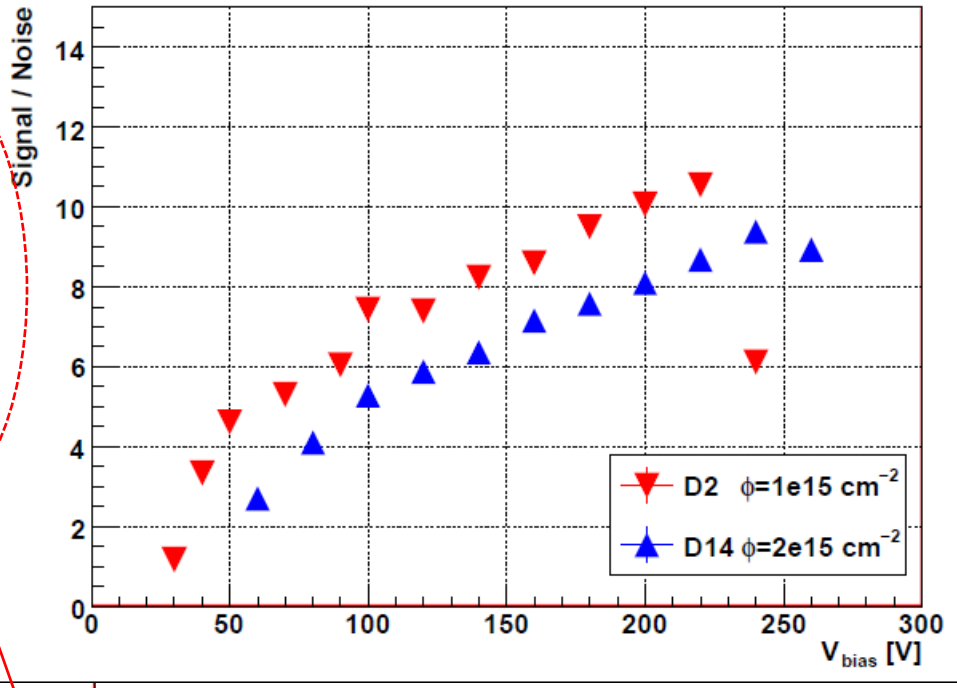
Beta source tests after irradiation

^{90}Sr β source setup

- Strip detectors read-out with ABCD3T binary chip, 20ns shaping time
- After irradiation with 24 MeV protons up to a fluence of 2×10^{15} cm^{-2}
- Annealing at 60°C for 80 minutes
- Measurements made at -11°C





Charge multiplication effect at high voltages

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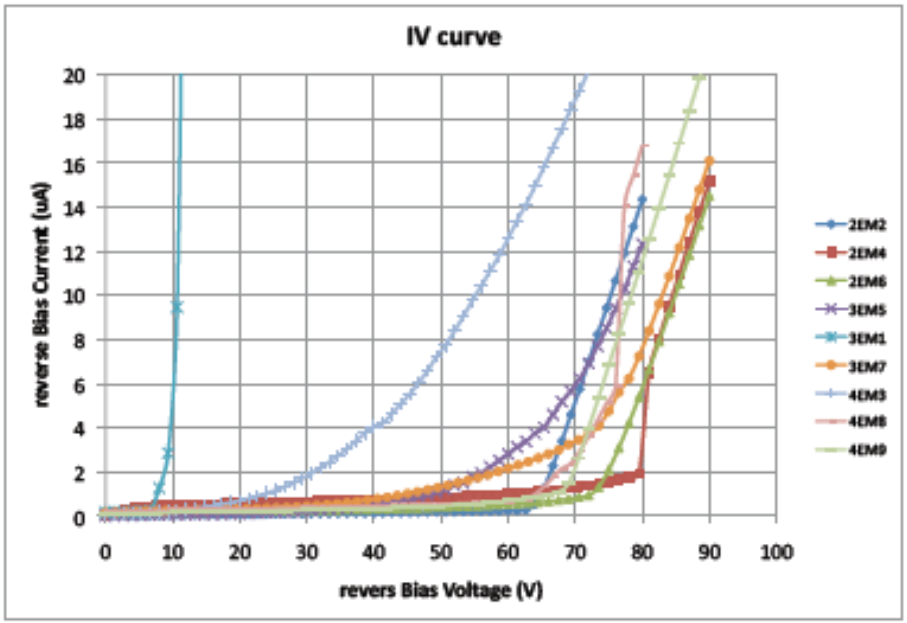
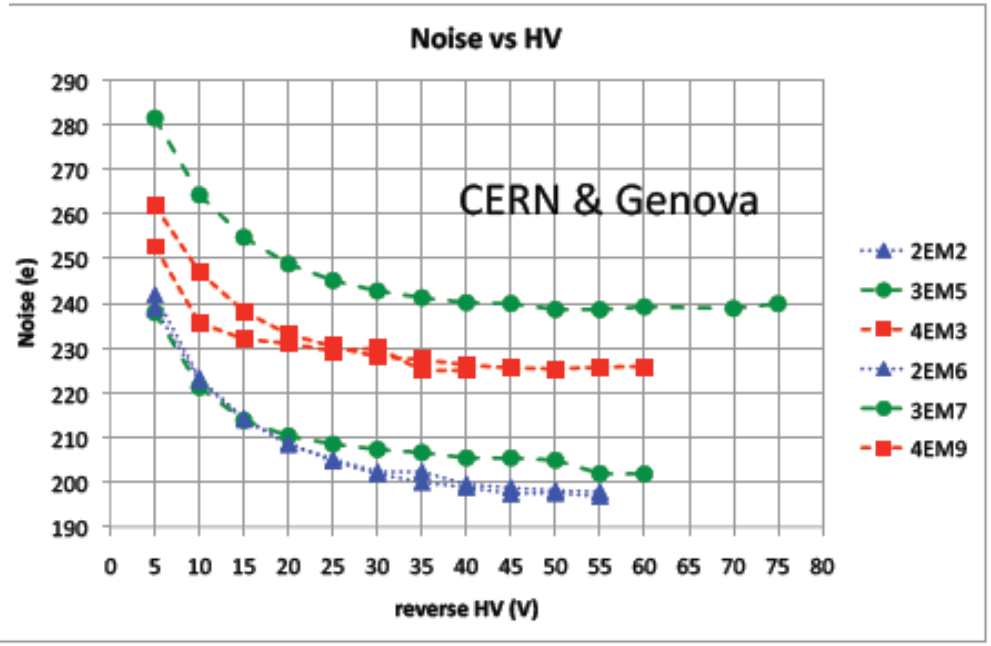
Initial results with ATLAS pixels

ATLAS pixel detectors with different column configurations assembled with FE-I3 ATLAS ROC (bump bonding at SELEX SI)

Leakage current



Noise scan



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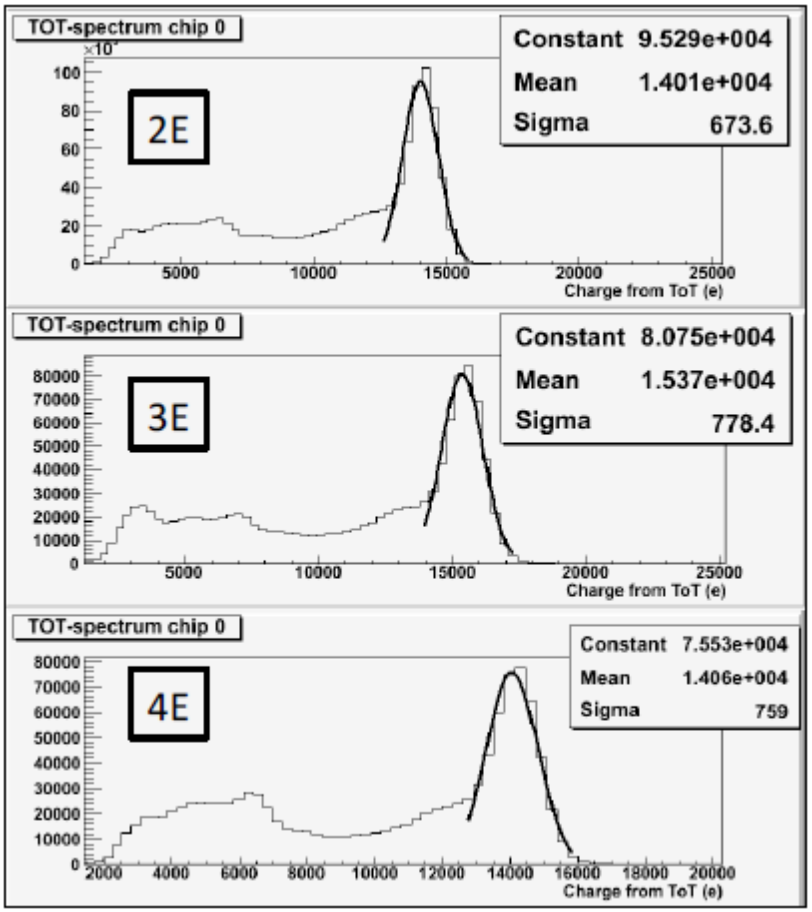
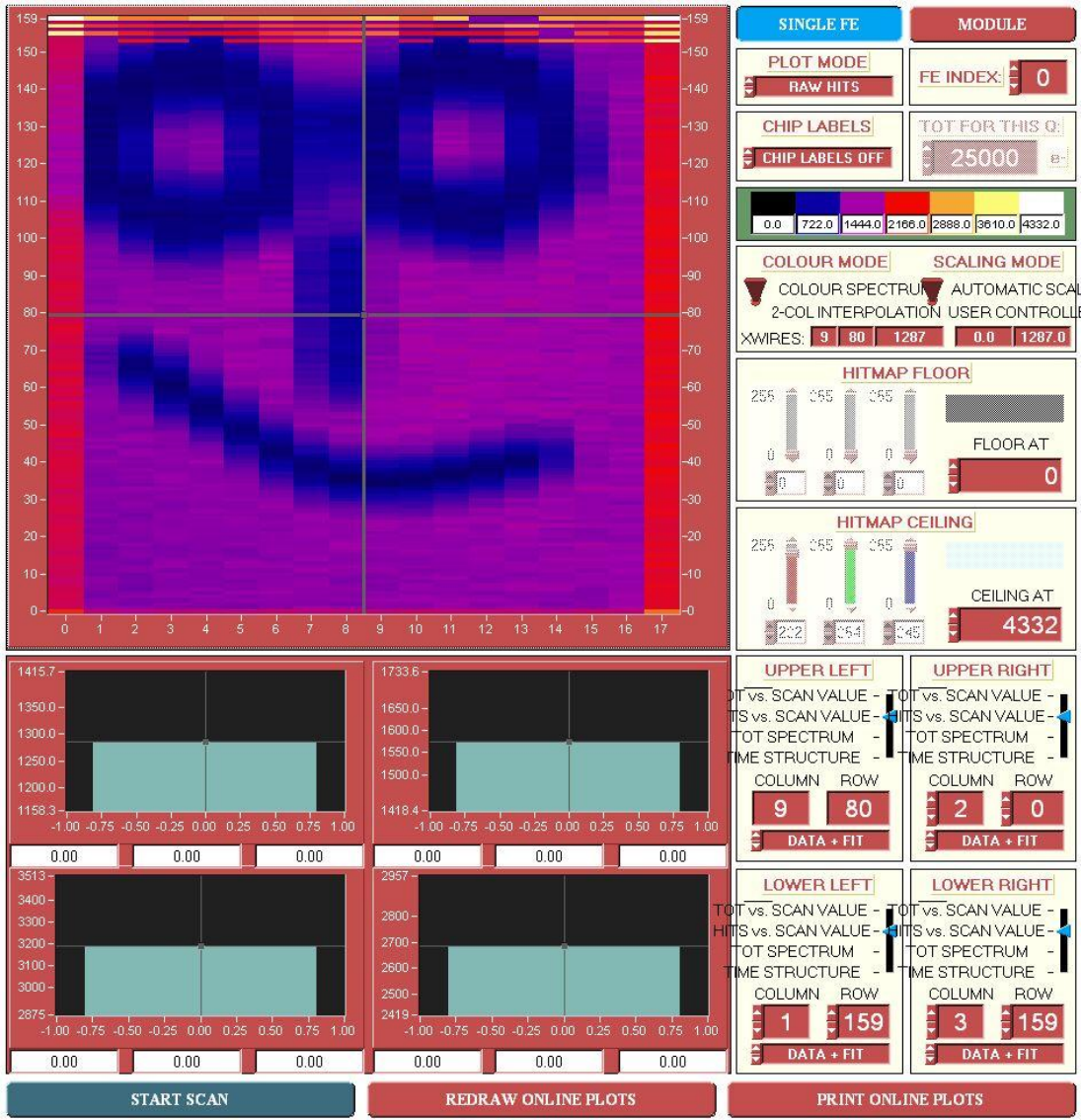
^{241}Am source preliminary tests





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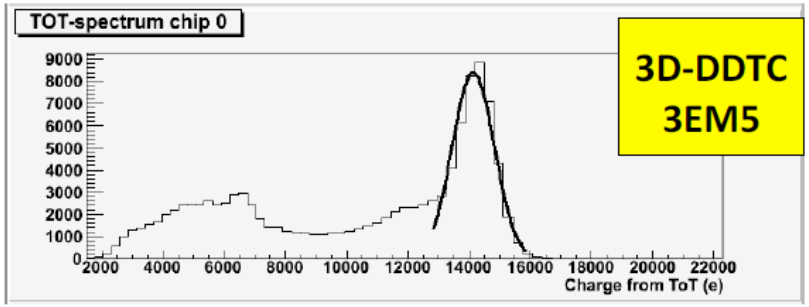
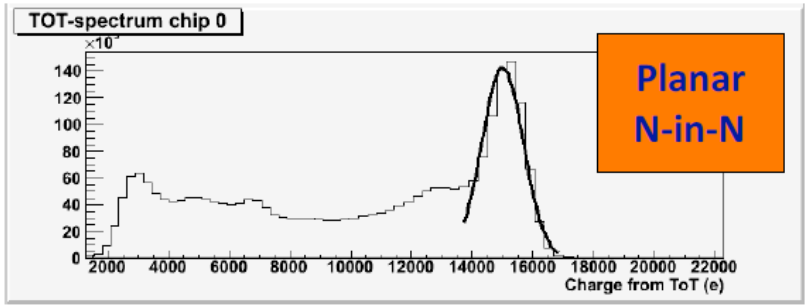
Source test (Am-241)

Preliminary measurement with Am-241 source in comparison with **ATLAS N-in-N Planar sensor single-module**

Spectrum as a sum over all pixel without any clustering





Detector	Peak (10^4 e)	Sigma (e)
3D-2EM2	1.411	695.3
3D-2EM6	1.401	673.6
3D-3EM5	1.414	686.2
3D-3EM7	1.537	778.4
3D-4EM3	1.406	759.0
3D-4EM8	1.383	775.2
3D-4EM9	1.415	760.0
Planar (N-in-N)	1.501	688.4

See the expected 60keV peak

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Attività in corso

Appena terminato un secondo lotto 3D-DDTC2: n-on-p, 200-μm, doppie colonne non passanti (160μm giunzione 180μm ohmiche)

In fabbricazione

3D-DDTC3: n-on-p, 250-μm thick substrate, full 3D detectors (passing-through) columns.

Per maggiori informazioni

http://tredi.fbk.eu/