FONDAZIONE
BRUNO KESSLER

Micro-Nano Characterization and Fabrication Facility @ CMM

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Fondazione Bruno Kessler

Centre for Materials and Microsystems

FBK capability

- Simulation & Desing
  - Silvaco , L-Edit, …
- Fabrication Process at 6-inch
  - 500m^2 of class 10-100 detectors technology
  - 200m^2 of class 100-1000 MEMS technology
- Micro-Nano Analytical Lab
  - SIMS, SNMS, ..
- Electrical Testing
  - Manual and automatic
- Integration Lab
- Custom CMOS design
  - external services

http://mtlab.fbk.eu/

FBK technology capabilities

Two separate clean room

- 500m^2 of class 10-100 micro Technologies
- 200m^2 of class 100-1000 equipped for MEMS technology

The lab now is upgraded to 6 inch wafers

MEMS Fabrication Area main equipment

LITHOGRAPHIC EQUIPMENT

Mask aligner

Dry film

ETCHING

Tegal systems for dry etching

Wet etching (including TMAH etching of silicon and lift-off)

OWEN

for diffusion and annealing

METALLIZATION

Evaporator and Elettrodeposition (Gold)

WAFER BONDING

MicroFabrication Area main equipment

LITHOGRAPHIC EQUIPMENT
Mask aligner (front to back-side alignement)
Stepper

ETCHING
Deep RIE (AMS 2000)
3 Tegal systems for dry etching
Wet etching (including TMAH etching of silicon)

DOPING Ion Implanter & gas ($POCl_3$ and BBr_3)

2 FURNACES for oxidation and diffusion

LPCVD TEOS, Poly-silicon and Si_3N_4
PECVD Deposition SiO_2, Si_3N_4, Amorphous Silicon

METALLIZATION
Sputtering (Al, Al1%Si, Ti, TiN)

Testing Area

Main Equipment

- ✓ manual parametric testing
- ✓ automatic parametric/functional testing
- ✓ optical testing

Microsystems Integration Area

Main Equipment

- ✓ Micro-assembly station
- ✓ bonding
- ✓ micromilling/drilling
- ✓ screen printing (thick film deposition)

Micro-Nano Analytical Laboratory

http://minalab.fbk.eu

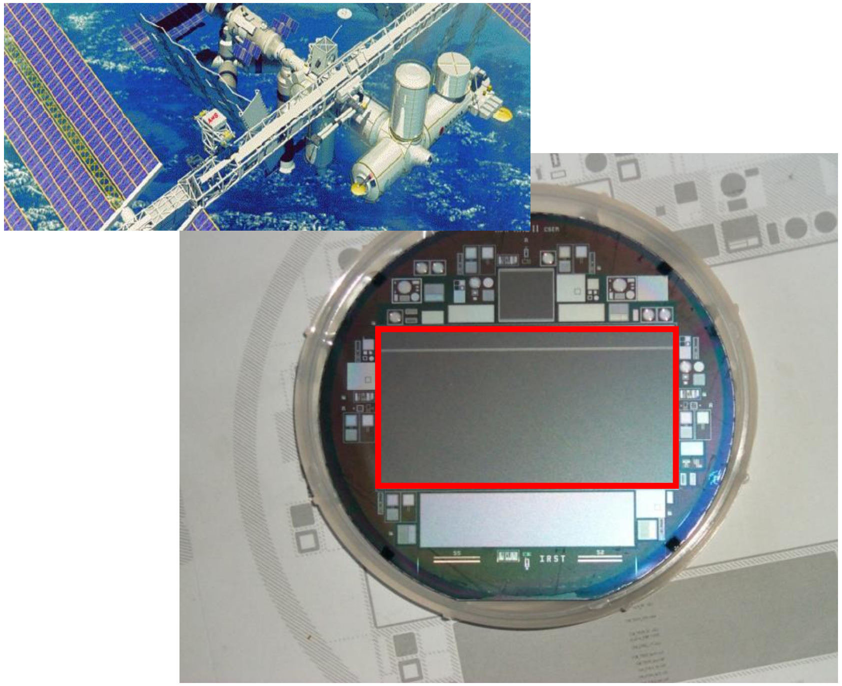
Develop and apply innovative **surface science analytical methodologies** to fully characterize both inorganic and organic materials at **micro and nano scale**

SIMS	**Dynamic Secondary Ion Mass Spectrometry**	**SC-ULTRA**	**CAMECA**
ToF-SIMS	**Time of Flight Secondary Ion Mass Spectrometry**	**TOF-SIMS IV**	**Iontof**
XPS	**X-Ray Photoelectron Spectroscopy**	**ESCA 200**	**SCIENTA**
SEM/EDX/EBSD	**Scanning Electron Microscopy**	**JSM-7401F**	**Jeol**
AFM	**Atomic Force Microscopy**	**Solver Uni (P47)**	**Nt-mdt**
AFM	**Atomic Force Microscopy**	**Solver P47H**	**Nt-mdt**
TXRF	**Total Reflection X-Ray Fluorescence**	**TXRF 8010W**	**Atomika**
Profilometer	**Mechanical profilometer**	**P-6**	**KLA-Tencor**
AES	**Auger electron spectroscopy**	**Model 590**	**PHI**
AES	**Auger electron spectroscopy**	**Model 4200**	**PHI**
XRD	**X-ray diffraction**	**APD 2000**	**Italstructures**
	CSM Micro Scratch Tester		**CSM Instruments**
PTR-MS	**Proton Transfer Mass Spectrometry**		**Kore technology**
XRD/XRF	**X-Ray diffraction-fluroscence- reflettometry**	**Prototype**	**TNX**
XPS	**X-Ray Photoelectron Spectroscopy**	**Axis-Ultra**	**Kratos**

SILICON TECHNOLOGY

Strip Detectors: past examples

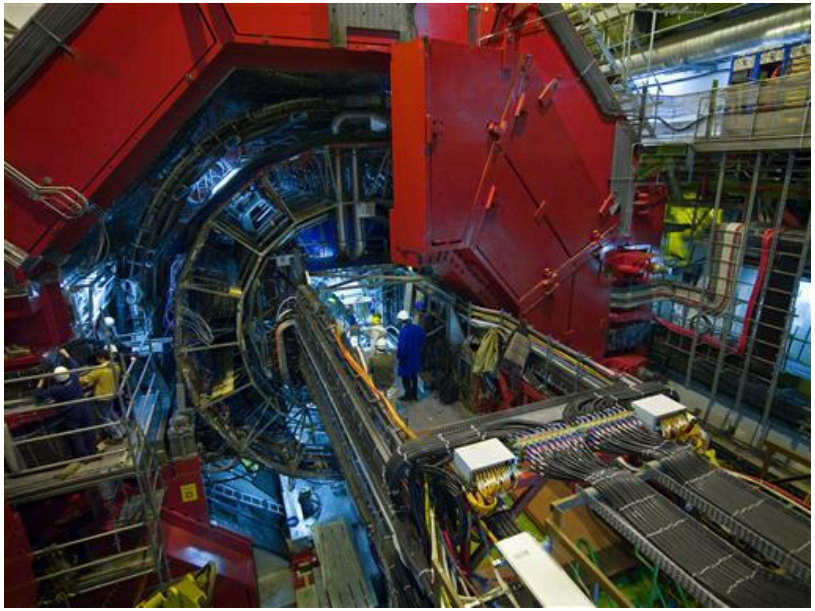
AMS experiment (@ISS)



Silicon microstrip detectors:

700 large-area double-sided in spec detectors fabricated in 2002-2004.

ALICE experiment (@LHC)

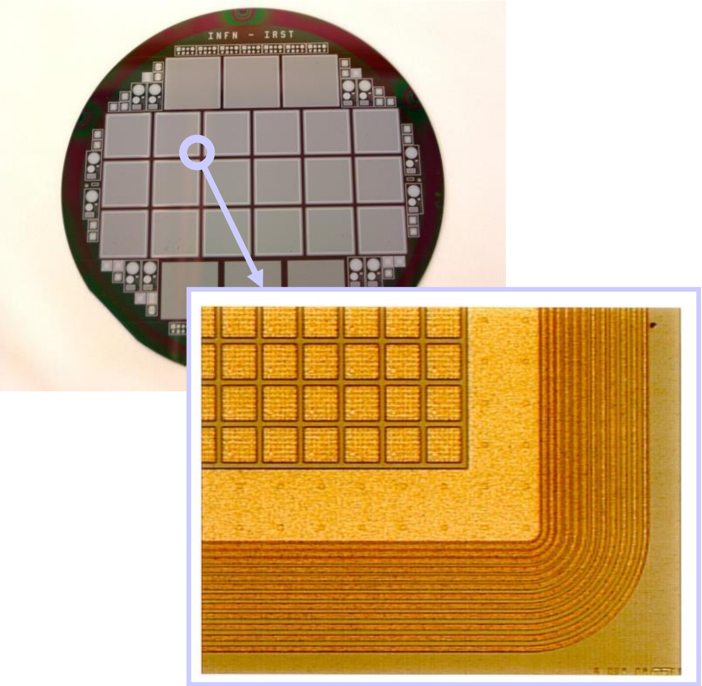


Silicon microstrip detectors:

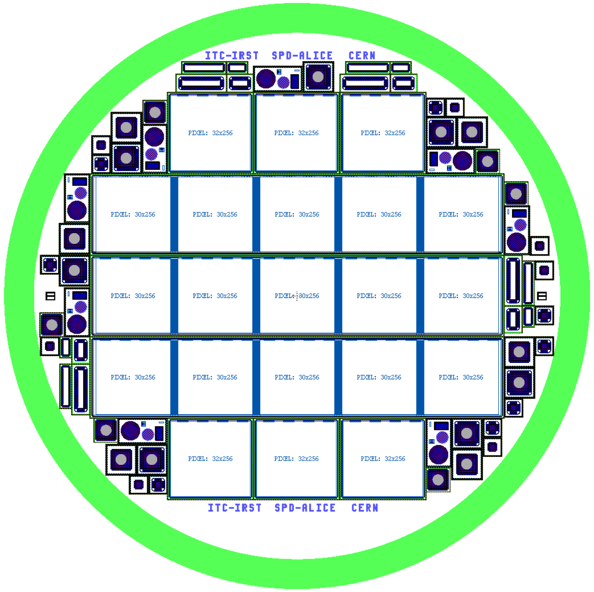
600 large-area double-sided in spec detectors fabricated in 2003-2005.

Pixel detectors: examples

Medipix 1&2



NA48/ALICE experiment



- Medipix1: pixel size 170x170um^2
- Medipix2: pixel size 55x55um^2

- ALICE SPD layout
- pixel size 50x400um^2

Substrate thick.: up to 1.5mm

at 4 inch !!!

Substrate thickness: 200um

Leakage current ~100pA/cm2 for 300um substrates

“Standard” detector technology

Double/Single side detectors

Substrates: Floating Zone but also Epi, Quarz, SOI, … from 200μm to 1.5mm thick @4 inch

Microstrip

- Coupling: DC or AC ($SiO_2 + Si_3N_4$)
- Bias: Polysilicon resistor or punch-through
- n-side isolation: p-stop or p-spray

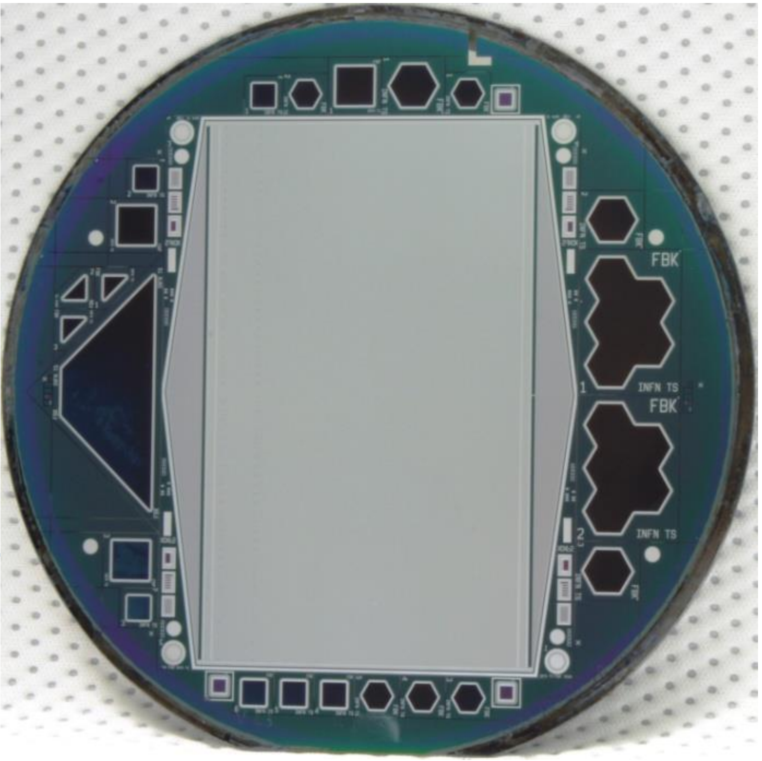
Pixel

- p-on-n , n-on-n or n-on-p tech.
- n-side isolation: p-stop or p-spray

Silicon Drift Detectors

3 running public project:

- INFN/INAF
  development of very large
  linear SDD for astrophysics experiment



6 inch wafer

- ESA - PoliMi (2010-2012)
  development of gamma ray spectrometer
  based on SDD coupled to LaBR scintillator

- EU INSERT – PoliMi (2012-2015)
  development of a SPCT system integrated with MR

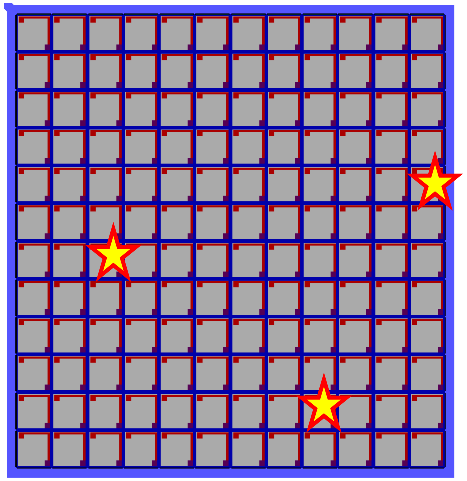
Low-level light sensors

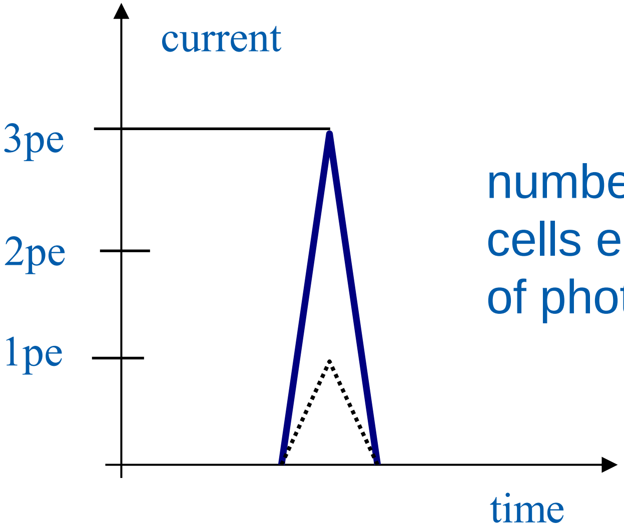
Avalanche Geiger-mode photodiodes

Each photon triggers a discharge which is shortly quenched

SiPM
array of tiny SPADs connected in parallel to give proportional information

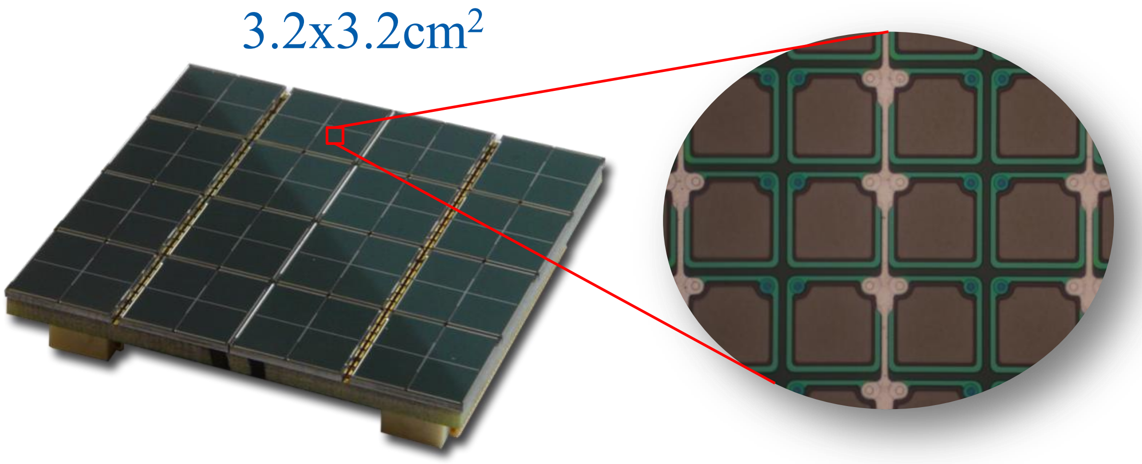
- Gain ~10^6
- Timing ~ 100ps /1ph.e.
- Bias voltage <100V
- Sensitivity ~1 ph. e.
- QE ~ medium





number of activated cells equal to number of photons (PDE=1)

Silicon photomultiplier



SiPM
array of tiny SPADs
connected in parallel to give
proportional information

http://srs.fbk.eu/

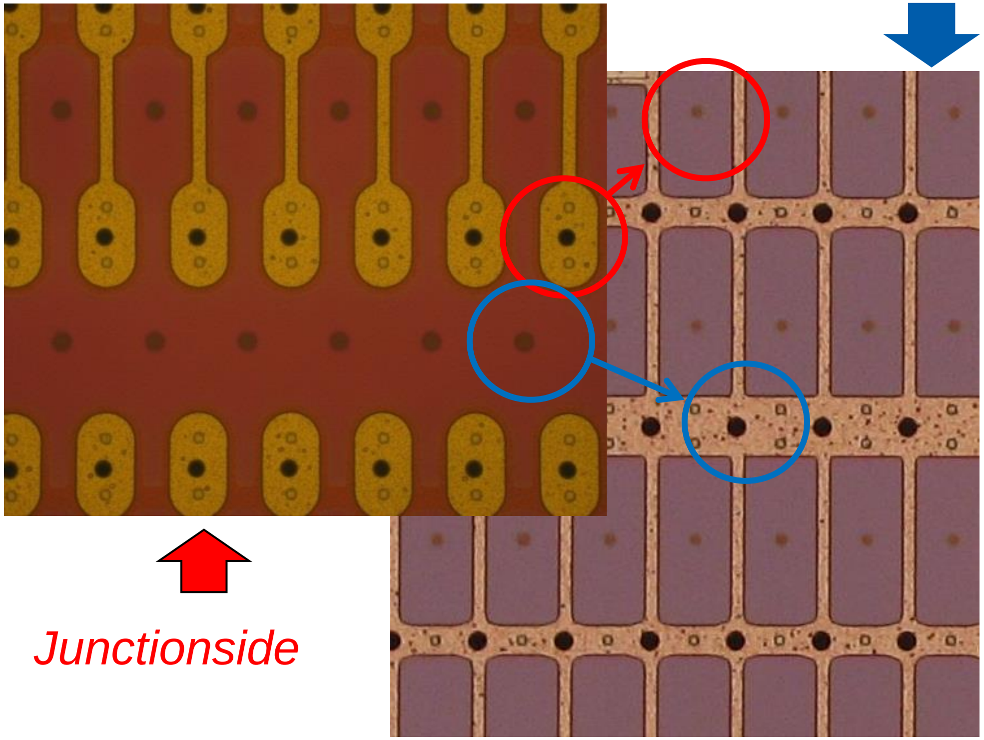
Giovedi , 13 marzo alle 10:00
Sensors for calorimetry photo-detectors and silicon sensors
Alberto Gola (FBK)

Industrial Poster Exibition

AdvanSiD
Advanced Silicon Detectors

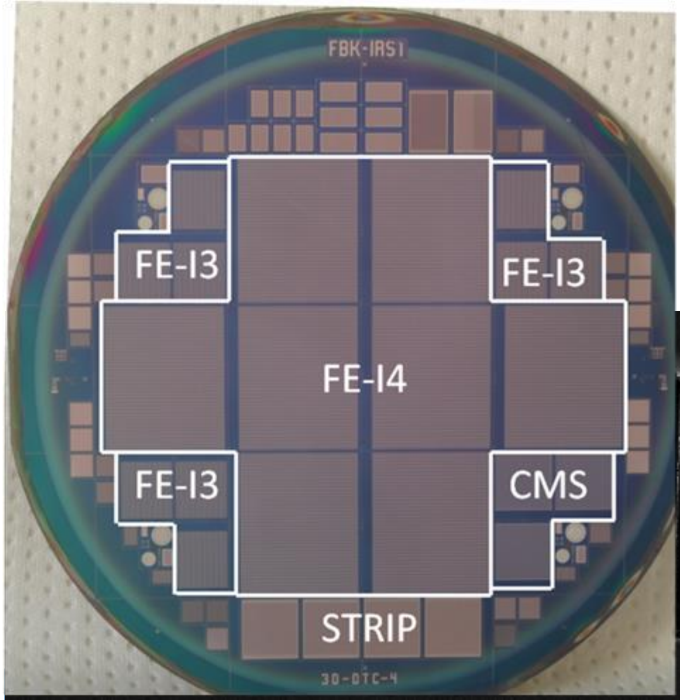
FBK Si-3D for IBL ATLAS

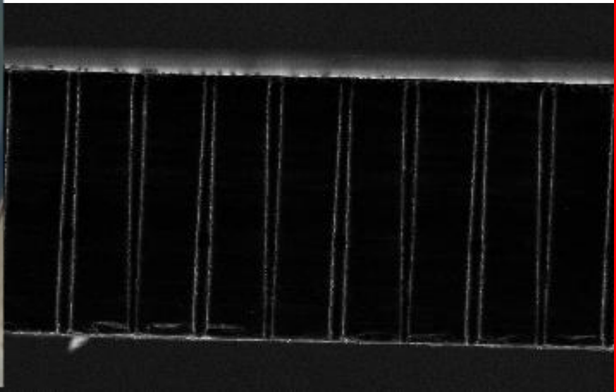
- Double side technology
- Columns are passing and empty
- No support wafers
- Surface isolation with p_spray on both side
- 200micron slim edge

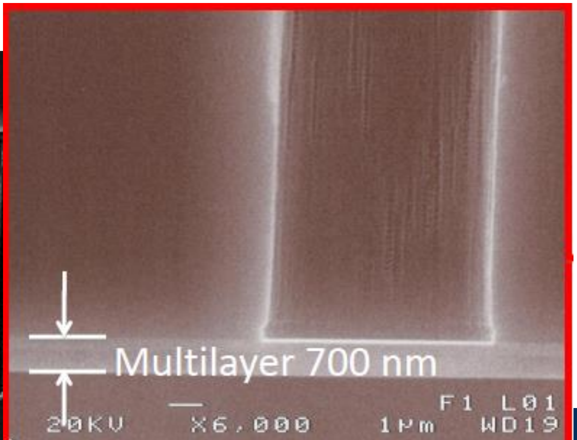


Ohmic Side

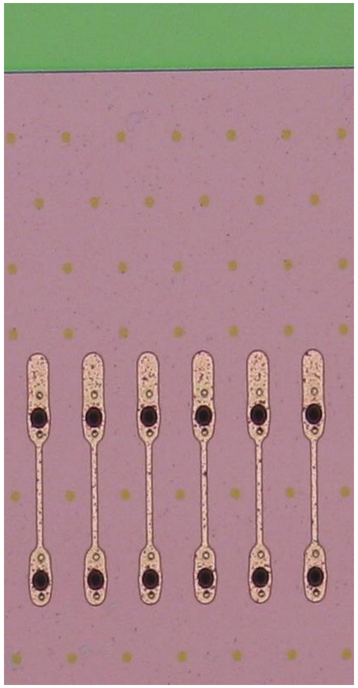
Junctionside



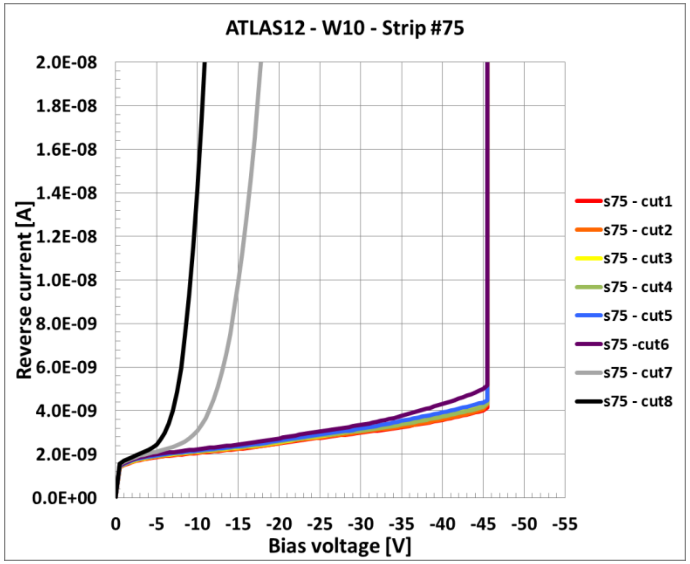


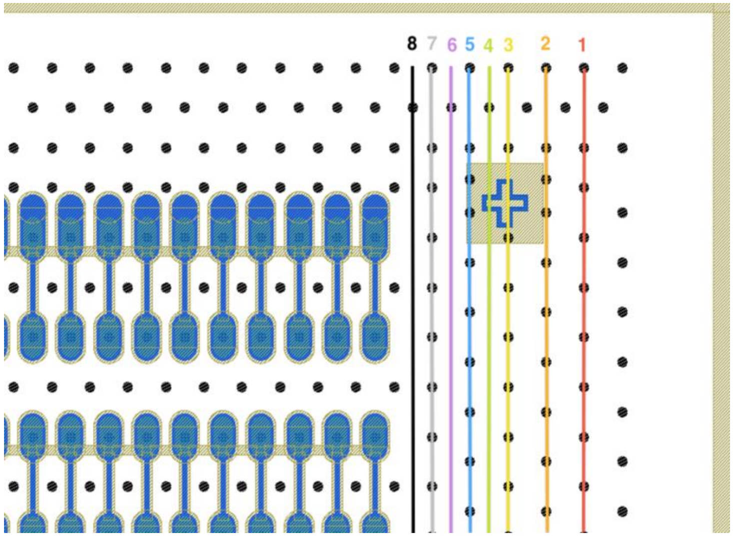


Si-3D and edgless



- FBK Si-3D tecnology is double side so incompatible with support wafers but the active area can be terminated by a multiple columns fence = **slim edge**
- We have use this approach on real pixel detectors «ATLAS like»
- The lateral dead layer is about 100micron



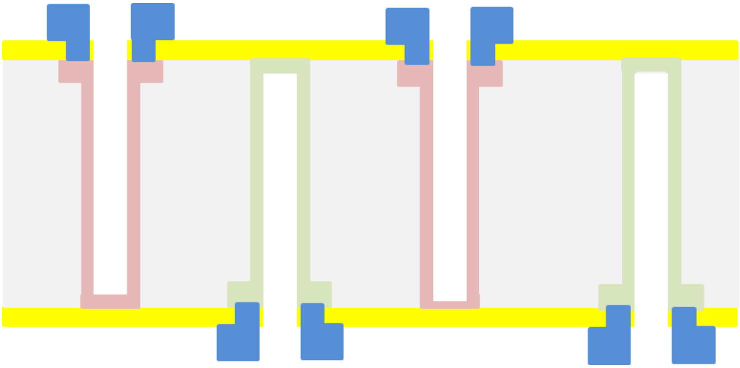


M. Povoli et al, JINST doi:10.1088/1748-0221/7/01/C01015

Si 3D detectors @ FBK

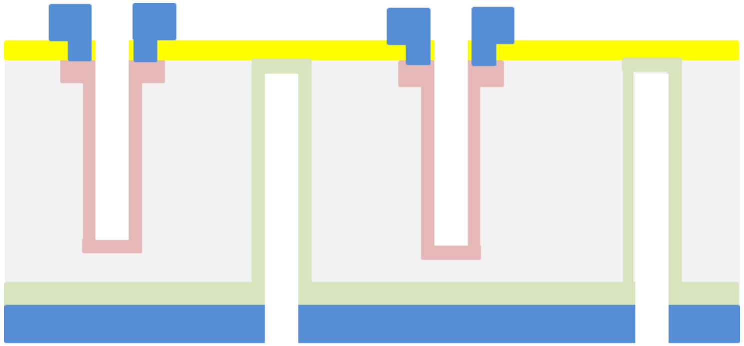
Full 3D detectors

Final version used for the production of detectors for ATLAS IBL holes etched all through the wafer



New version 3D detectors

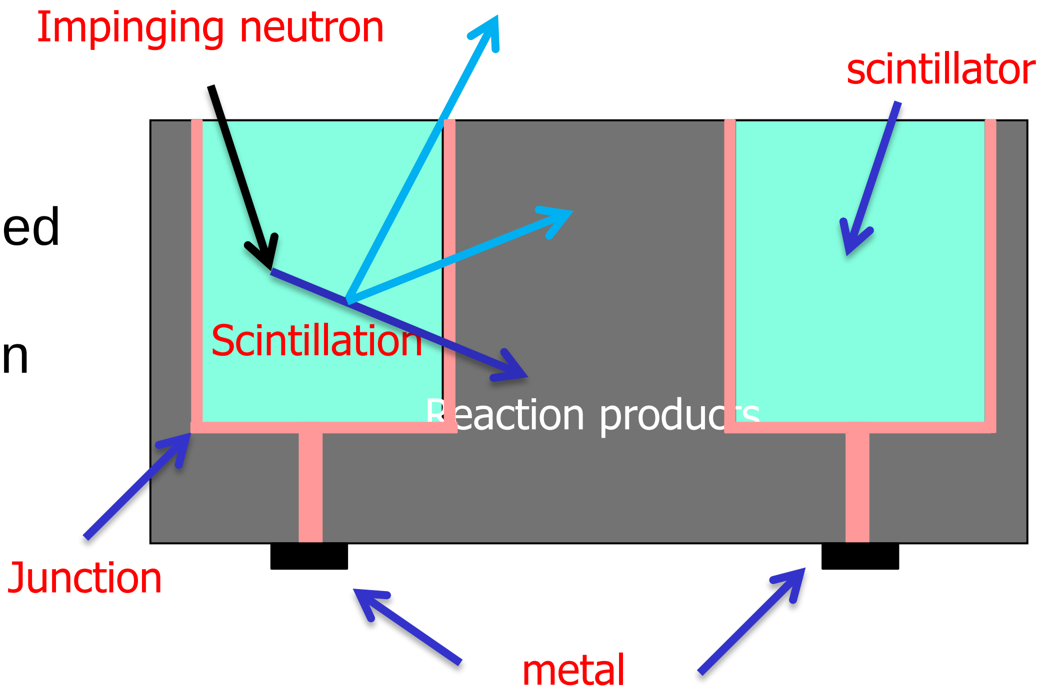
Full 3D with ohmic columns passing through & junction columns depth, less than wafer thickness

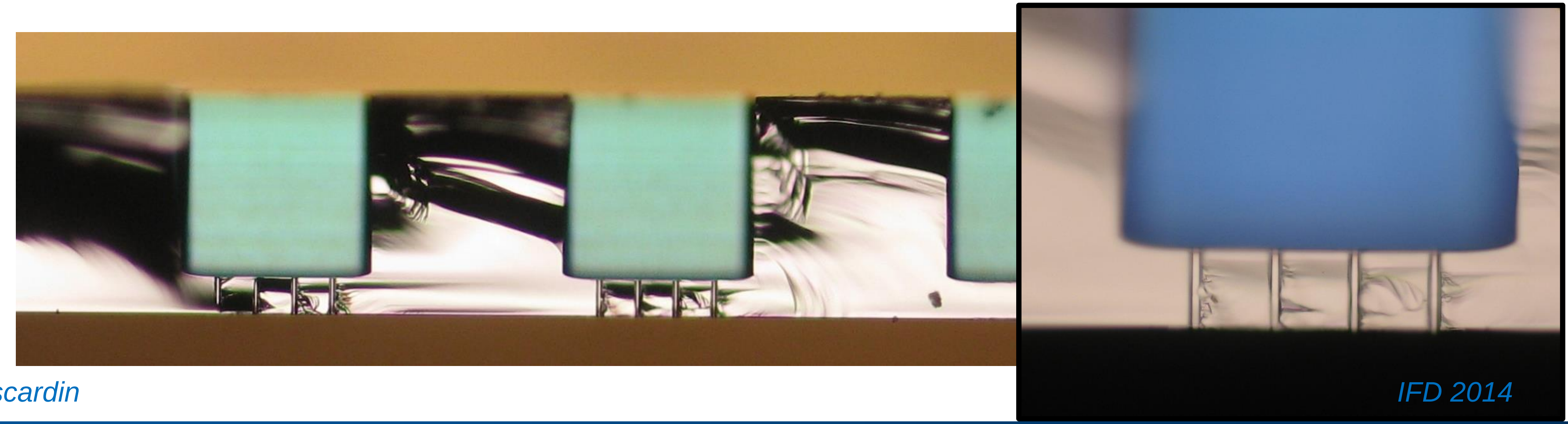


To obtained thin 3D detectors on Si-Si or SOI wafers

New hybrid 3D detectors for neutrons

- Hybrid detectors obtained by pouring polysiloxane scintillators into the 3D silicon detector cavities





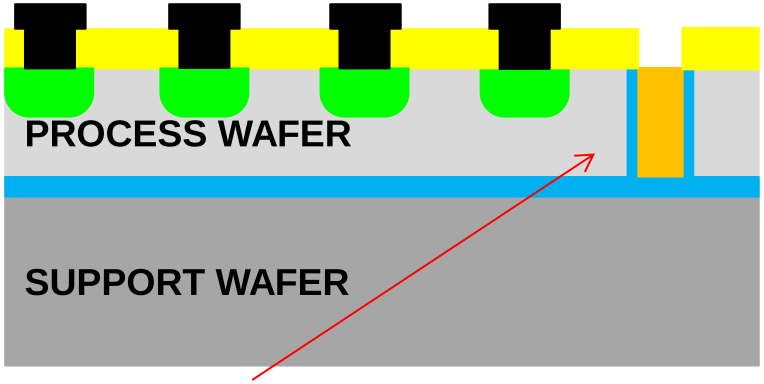
FBK edgless technology

Support wafers

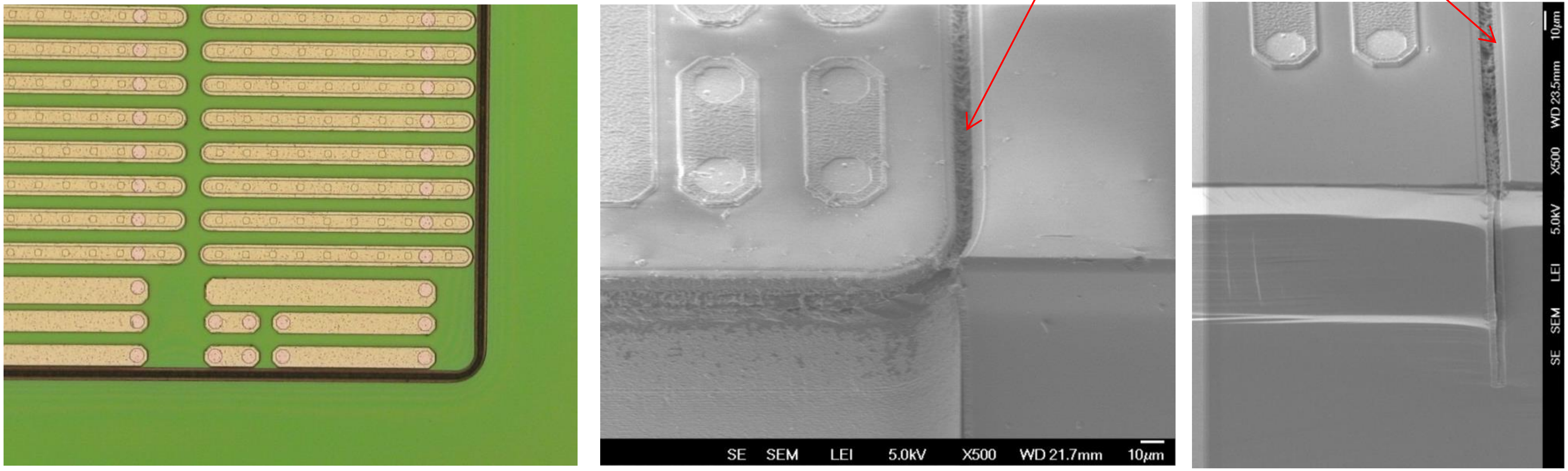
SOI wafers, epi, … Si-Si

DRIE etched trench and doping

- Trench definition and etching (DRIE)
- Doping using gas source technology
- Trench filling with polysilicon

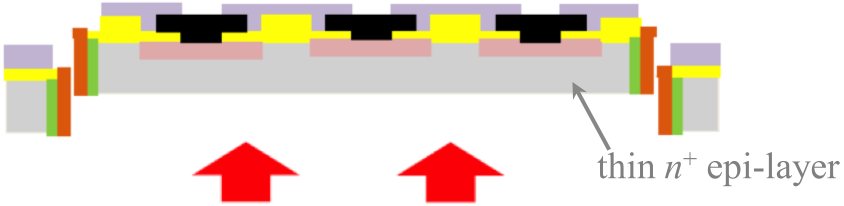


Trench filled with polisilicon



Thin & Edgeless Sensor

Substrate thinning

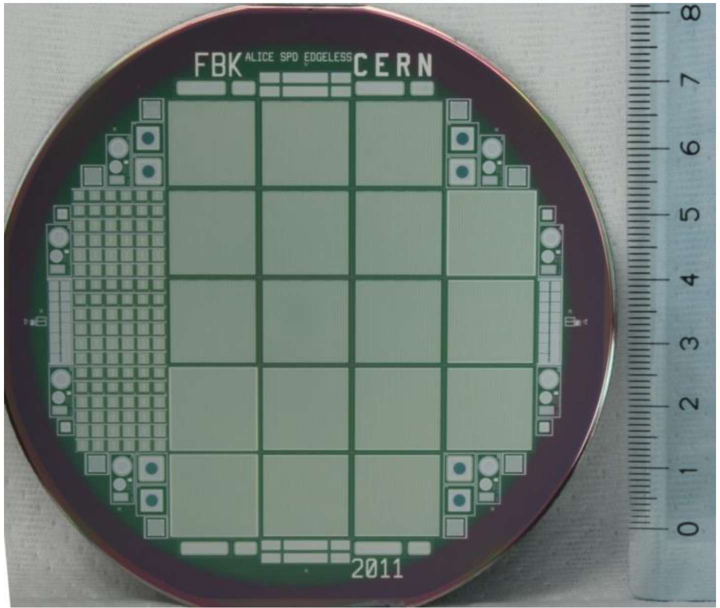


Device separation along the trenches

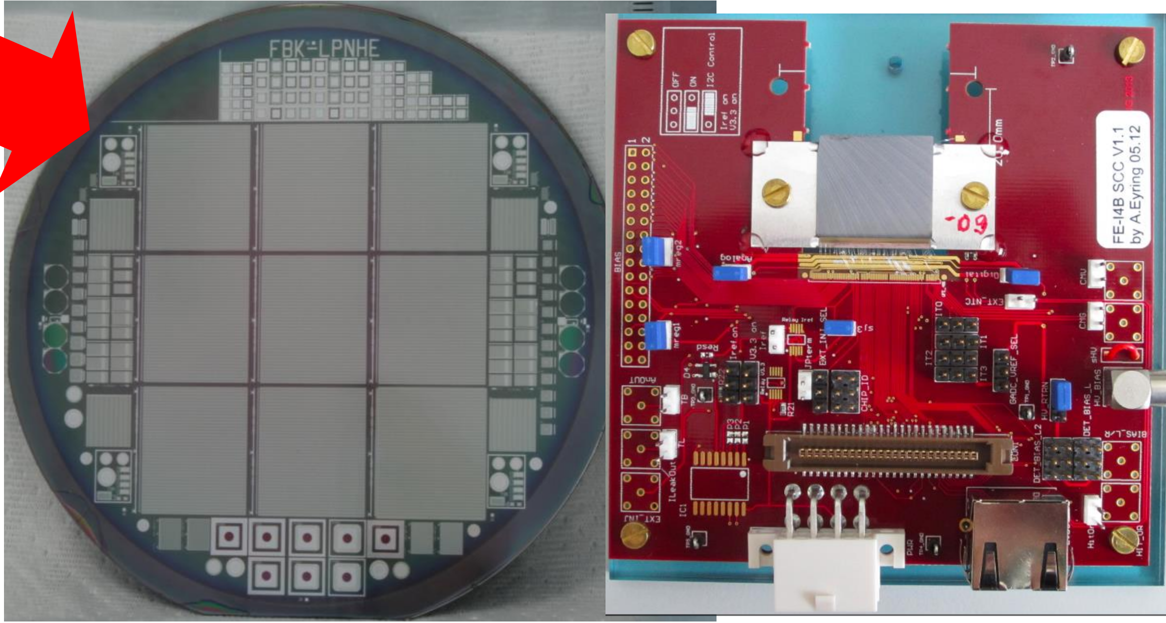
- A thin layer of heavily doped substrate is left, acting as an ohmic backside contact.
- If required for the bias contact, the device can finally be metallized on backside.
- Wafer thinning at VTT and IZM

Edgeles pixel

- **Epi 100micron**
- Layout based on **ALICE**
- **p-on-n pixel**
- INFN Bari e Trieste

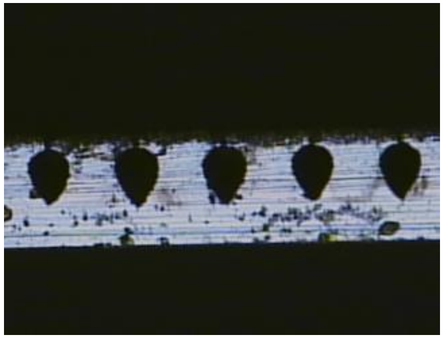


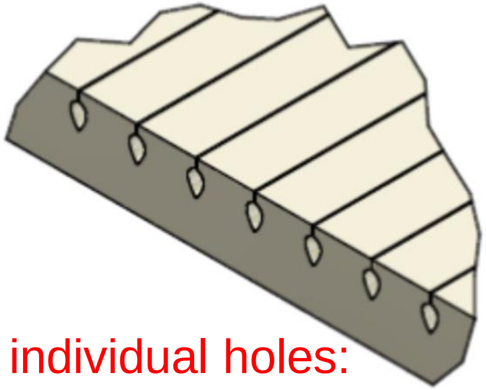
- **SOI 200um Fz**
- layout based on **ATLAS**
- **n-on-p pixel**
- *LPNHE Paris, Università di Trieste e Ginevra*



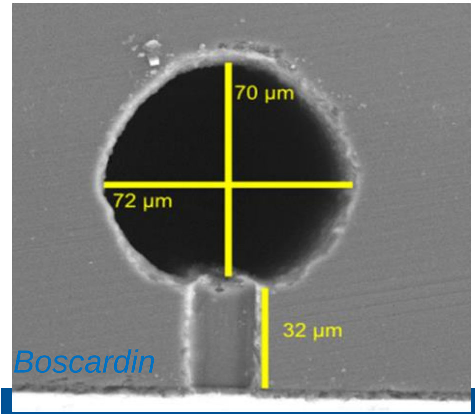
Silicon buried channels for detector cooling

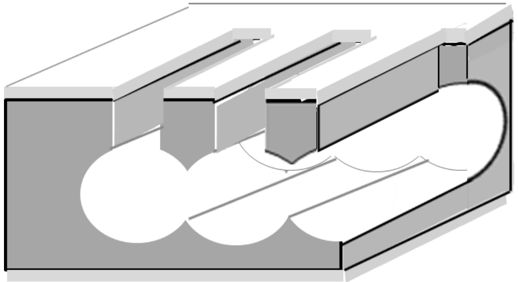
Channels made with individual holes:
The section is determined by the DRIE process, the length by the layout



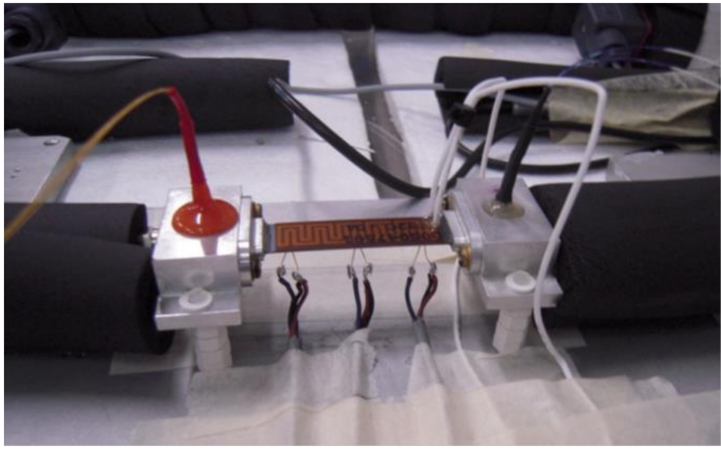


Channels realized as a sum of individual holes:
The section is determined by the process and by layout, the length by the geometry





Experimental results made in the lab TFD INFN of Pisa show a general compliance of the temperature of the sample to the specific fixed at least up to a power of about 2.5 W/cm^2.

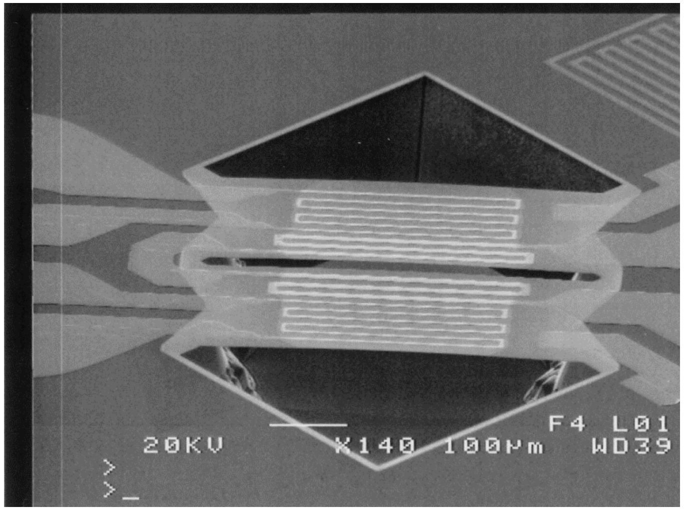


Anisotropic TMAH Etching

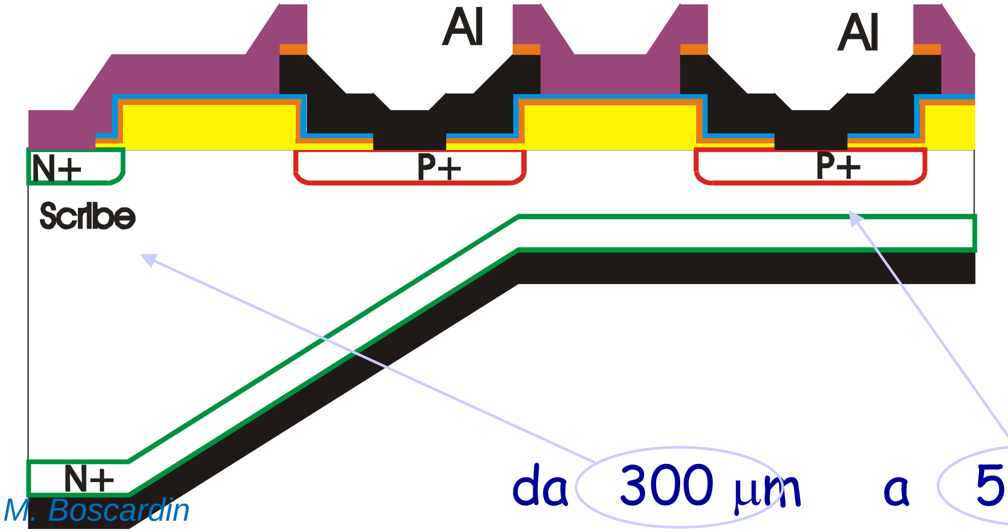
tetramethylammonium hydroxide

Application

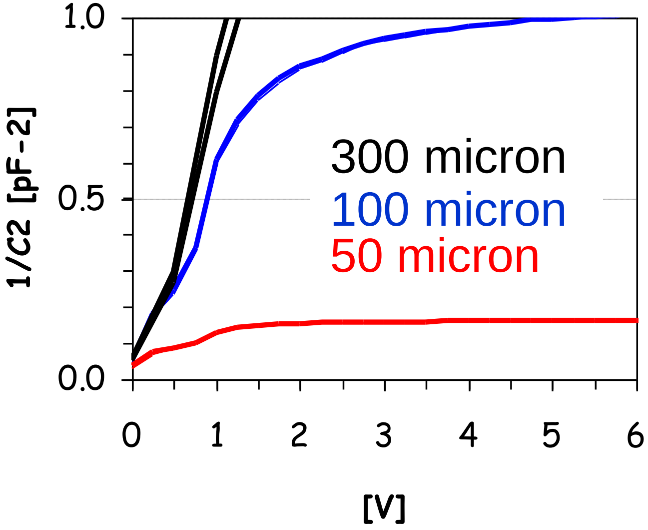
Air Flow Sensor



Thin detectors



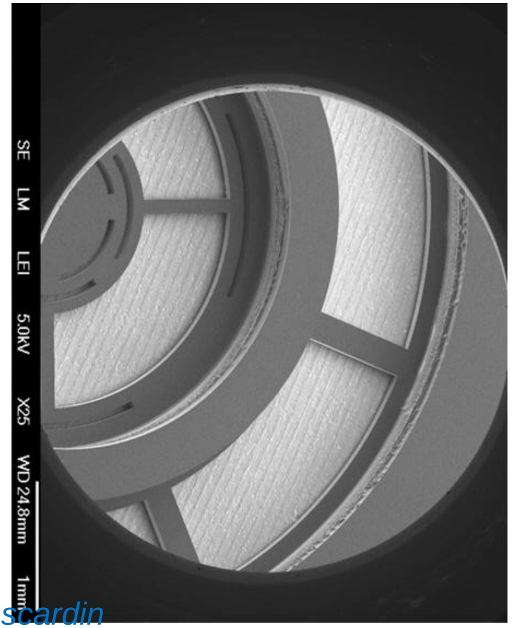
da 300 µm a 50 µm

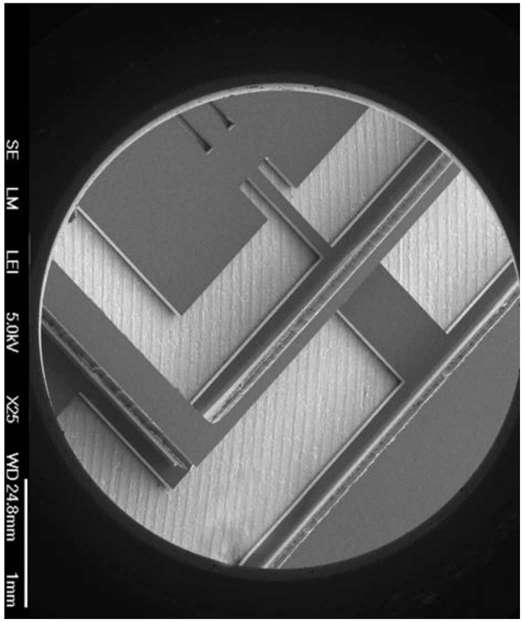


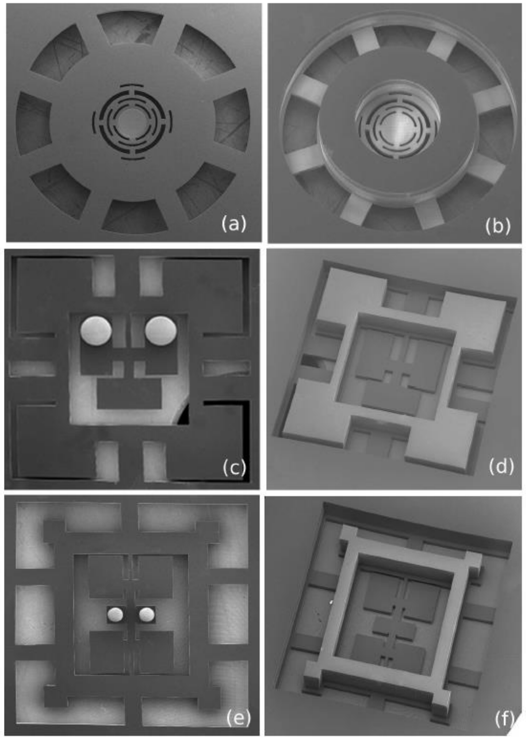
MICRORESONATORS

(high-Q MOMS resonators for quantum optics)

- Opto-mechanical micro-resonators developed to detect radiation-pressure coupling between light and a macroscopic body
- Double side SOI wafer micromachining with wafer-through features
- In partnership with INFN (Trento, Firenze), LENS, University of Firenze e Trento, CNR





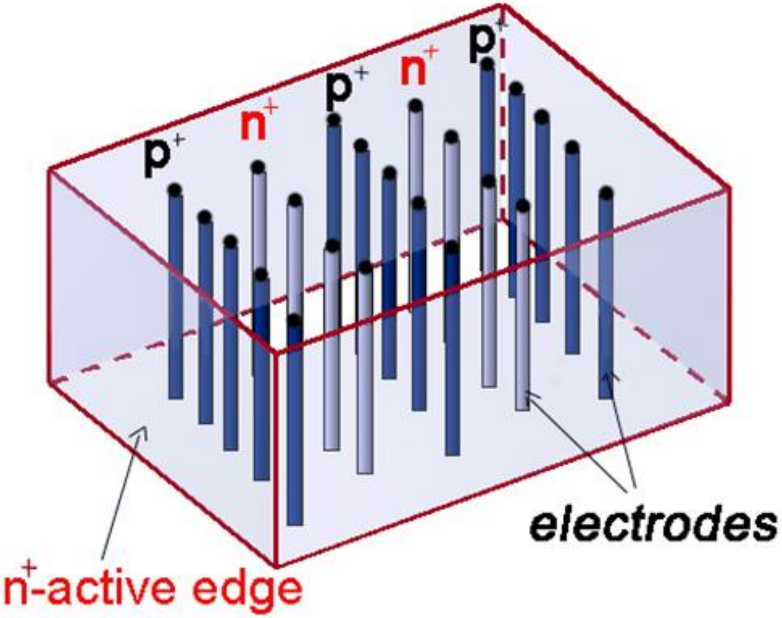


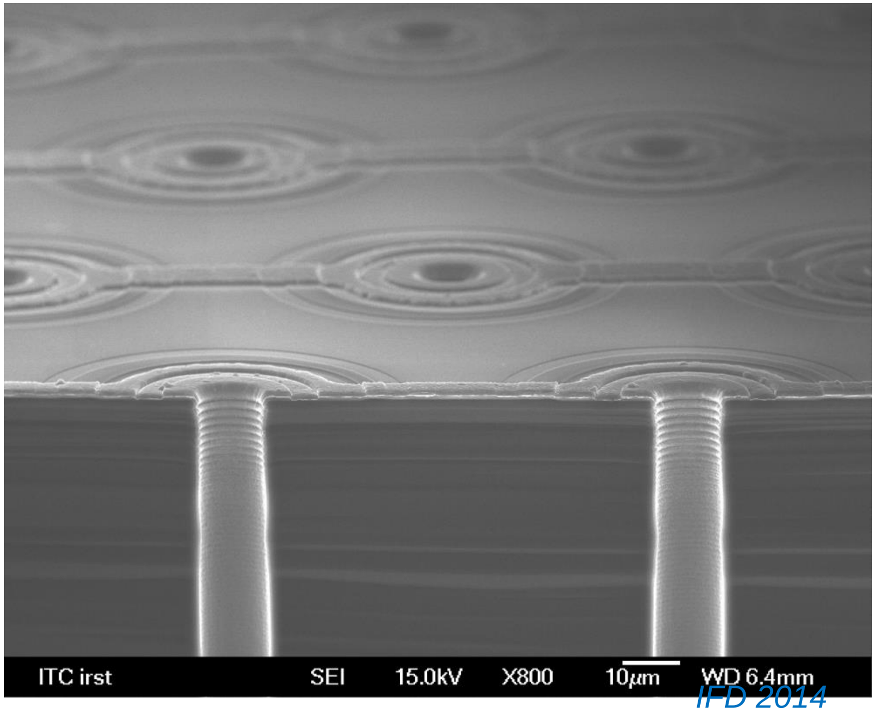
FONDAZIONE
BRUNO KESSLER

Grazie per l’attenzione

Si 3D Detectors Technology

- Ultra radiation-hard silicon particle detectors for future high-energy physics experiments
- Based on columnar electrodes (Pass through columns)





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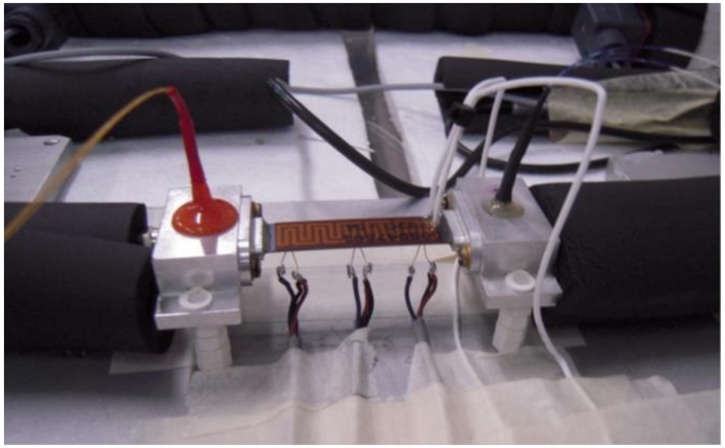
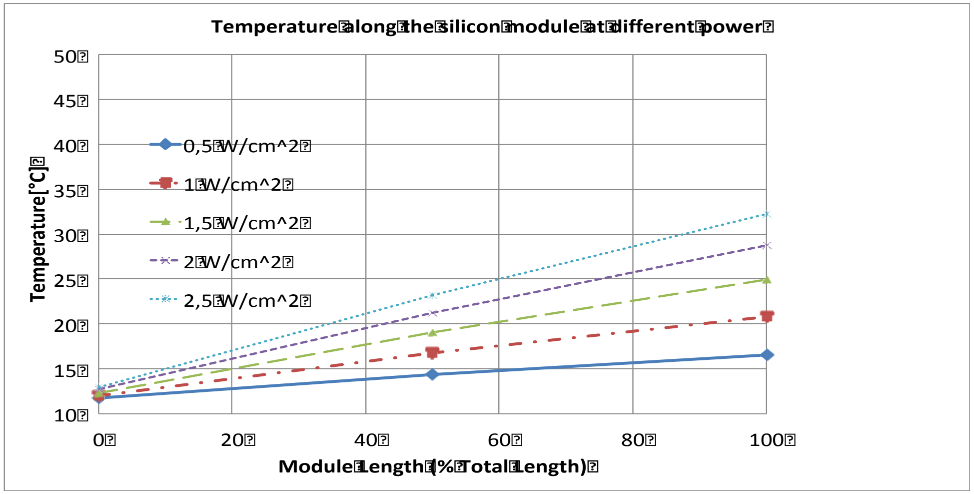
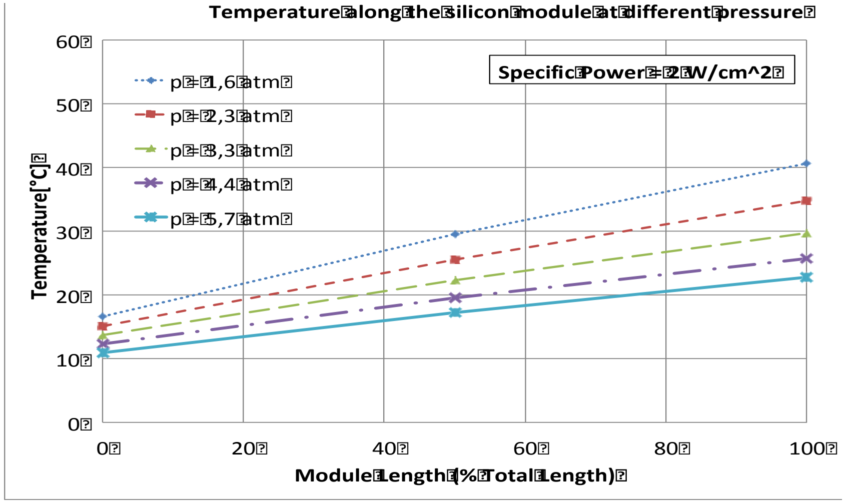
In partnership with INFN Pisa

M. Boscardin, et al., NIMA (2012), http://dx.doi.org/10.1016/j.nima.2012.10.014

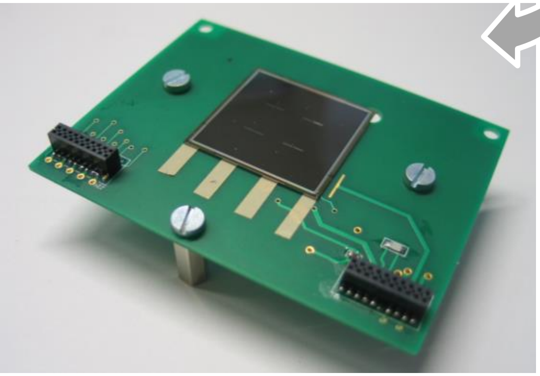






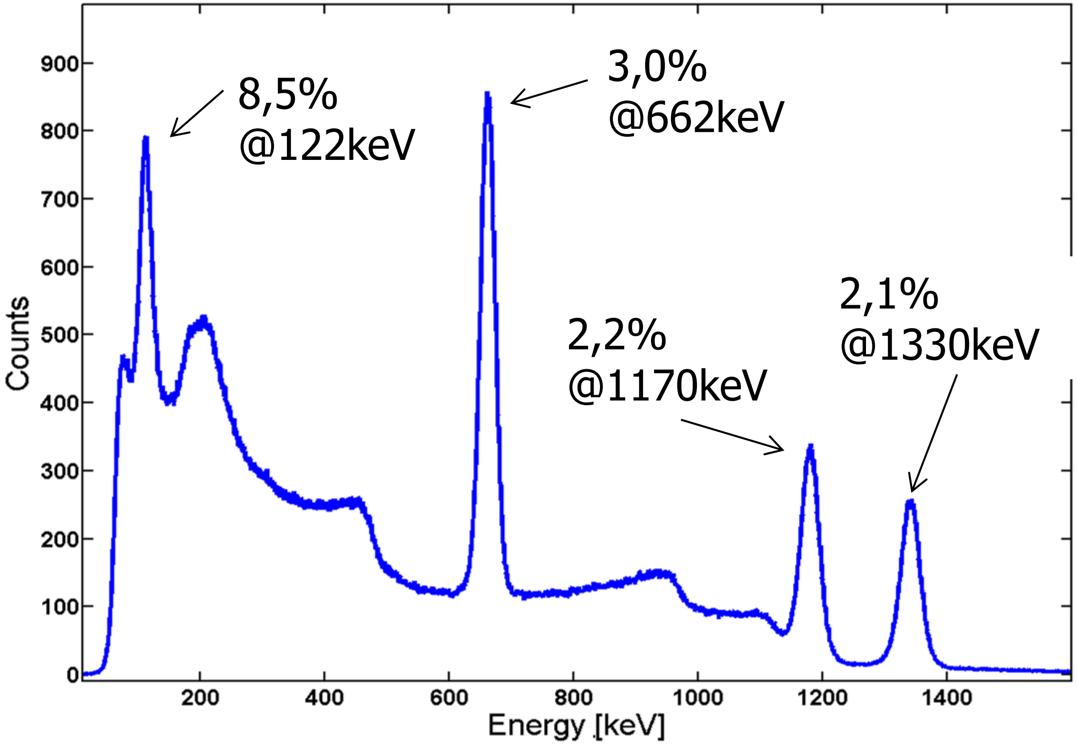
Silicon Drift Detectors

gamma spectrometer for ESA



T=: -20°C
peaking time: 6 μs

^{57}Co, ^{137}Cs, ^{60}Co spectra measured with the SDD array coupled to a 1'' LaBr$_3$ crystal



Energy resolution @662keV measured with a PMT = 3.2% (courtesy F.Quarati)

presented at IEEE NSS-MIC 2012

FBK Si-3D for IBL ATLAS

- The temporary metal shorts 336 pixels together in a strip
- The IV characteristics of 80 strips form a FE-I4 pixel sensor
- Allows to perform electrical tests on the FE-I4 pixel sensors
- before bump-bonding
- Good correlation between wafers and Module