Overview on sensors design and prototyping at STMicroelectronics

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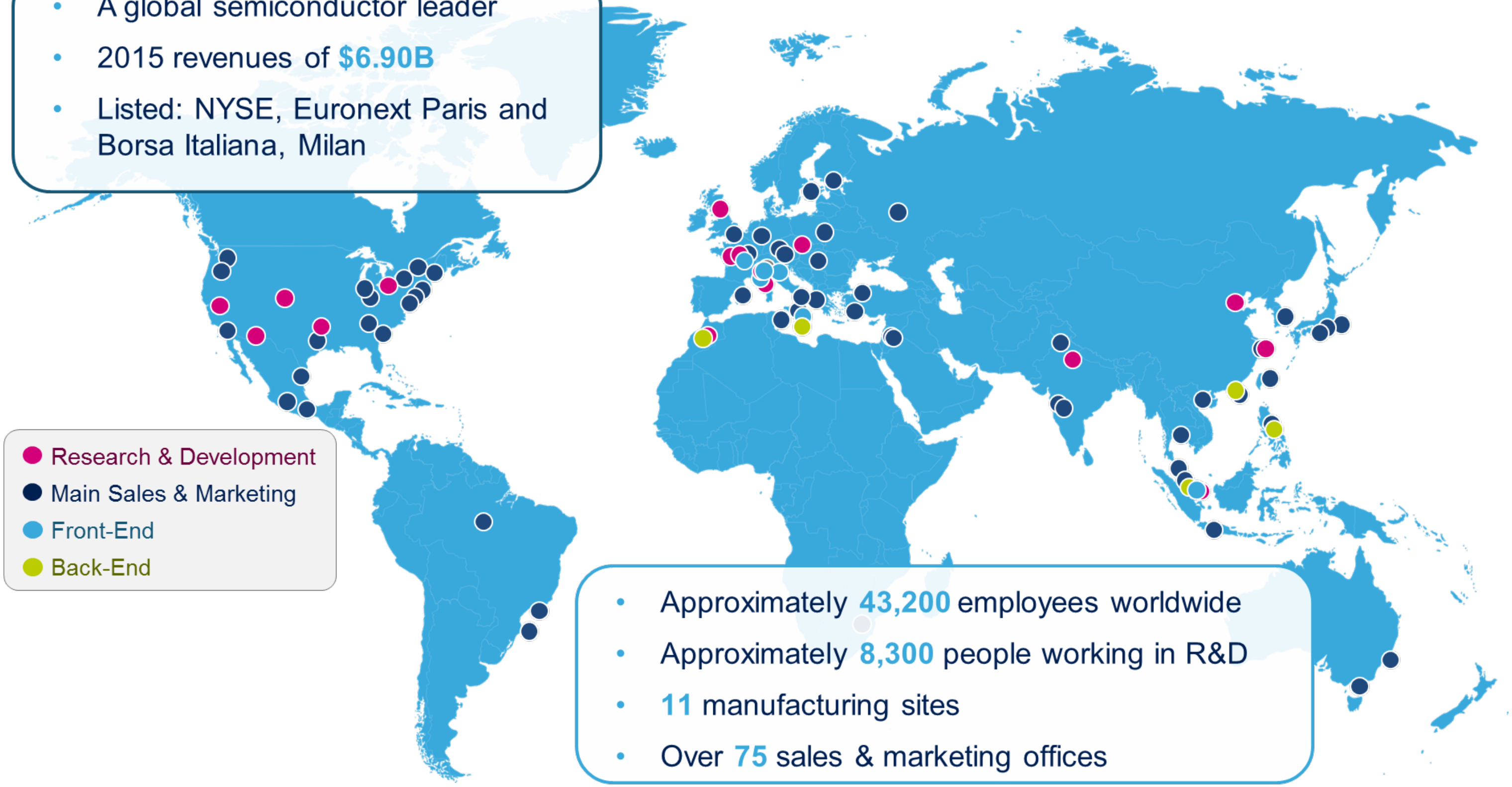
Outline

- Company presentation
- New technologies development for sensors
- Overview on STM sensors developed
- Recent developments on our Monolithic Silicon Telescope technology

Company presentation

Who We Are

- A global semiconductor leader
- 2015 revenues of **$6.90B**
- Listed: NYSE, Euronext Paris and Borsa Italiana, Milan



- Approximately **43,200** employees worldwide
- Approximately **8,300** people working in R&D
- **11** manufacturing sites
- Over **75** sales & marketing offices

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As of December 31, 2015

Flexible and independent Manufacturing

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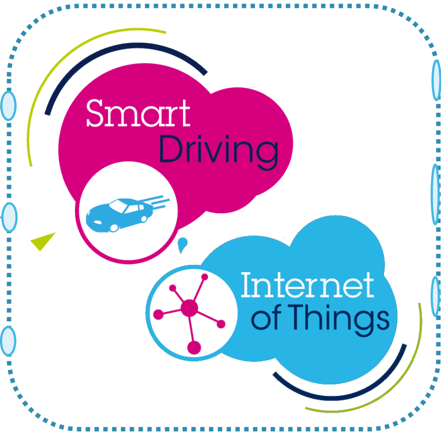
Product Family Focus

The leading provider of products and solutions for Smart Driving and the Internet of Things

- Dedicated Automotive ICs
- Discrete & Power Transistors
- Analog, Industrial & Power Conversion ICs



- MEMS & Specialized Imaging Sensors
- Digital ASICs
- General Purpose & Secure MCUs EEPROM

Portfolio delivering complementarity for target end markets, and synergies in R&D and manufacturing

Knowledge sharing

Collaborative Patenting activity: about 20% of the total number

- Marie Curie Projects:

THE PICOSEC MC-NET PROJECT

Pico-second Silicon Photomultiplier Electronics & Crystal research

ARDENT

Advanced Radiation Dosimetry European Network Training

Shared Laboratories

IMM Istituto per la Microelettronica e Microsistemi

ST-Polito

CATANIA RICERCHE

SUPERLAB

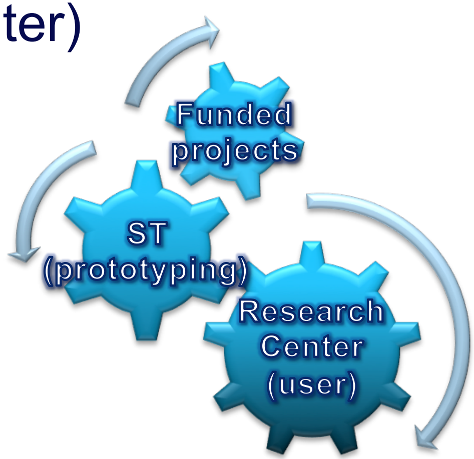
Arces

- Tutoring activity: > 100 degree theses /year (Catania plant)
- Scientific Publications

New technologies development for sensors

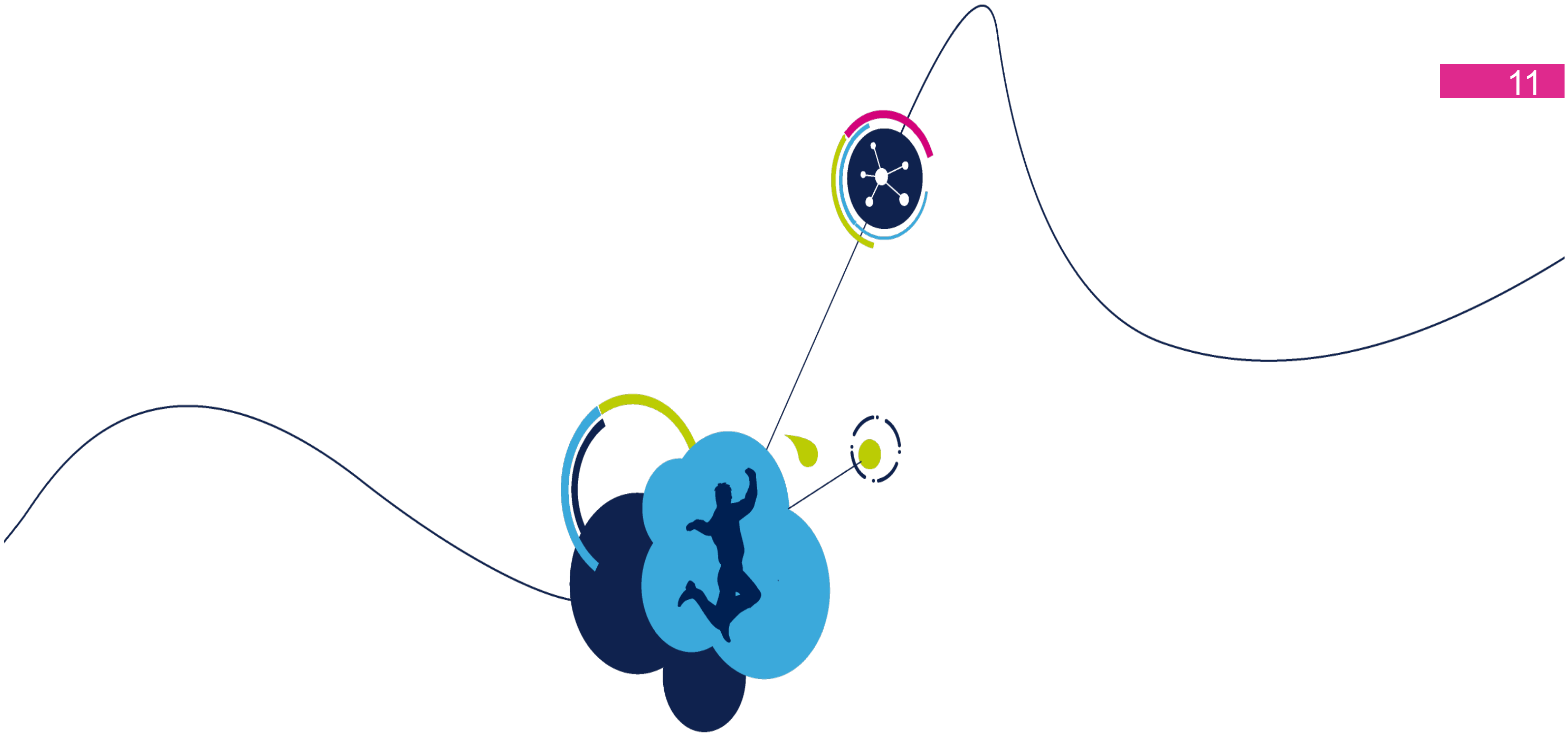
New technology development process

- Sensor target request (Research Center)
- Feasibility study
- Design of the sensor layout
- New front-end process flow
- Electrical test on wafer
- Assembly (find package solutions)
- Application test (Research Center)



Technological critical issues

- ✓ Compatibility with equipment used for standard technologies
- ✓ Very low substrate doping level → Enhanced sensitivity to charges and impurities
- ✓ Large sensors often need redundant process steps to guarantee zero defects



Overview on STM sensors developed

Particle detectors

HEP

1. Pad detectors
2. Macrostrip detectors
3. Microstrip detectors

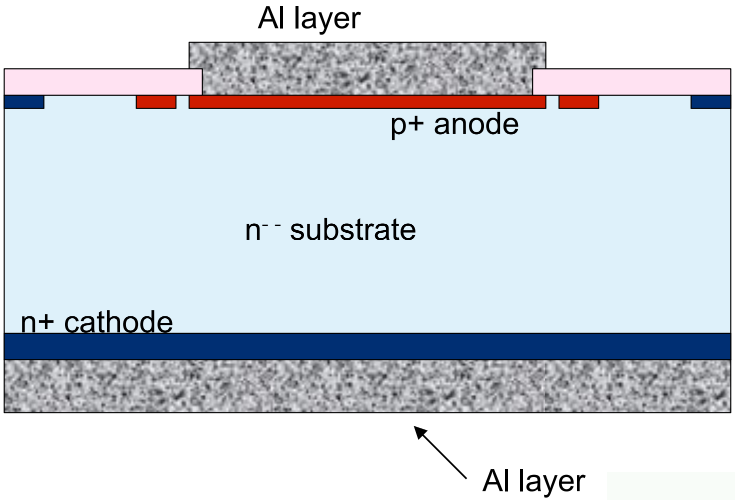
Heavy ions

4. Energy detectors
5. ΔE/E telescopes (MST)
6. Position MST detectors

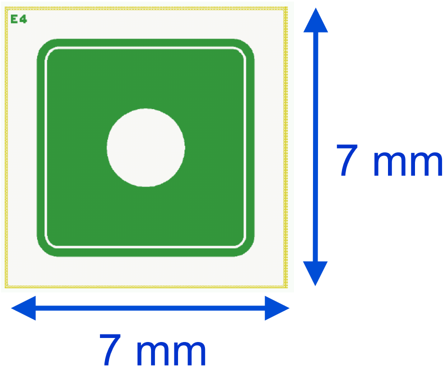
Medical appl. & radioprotection

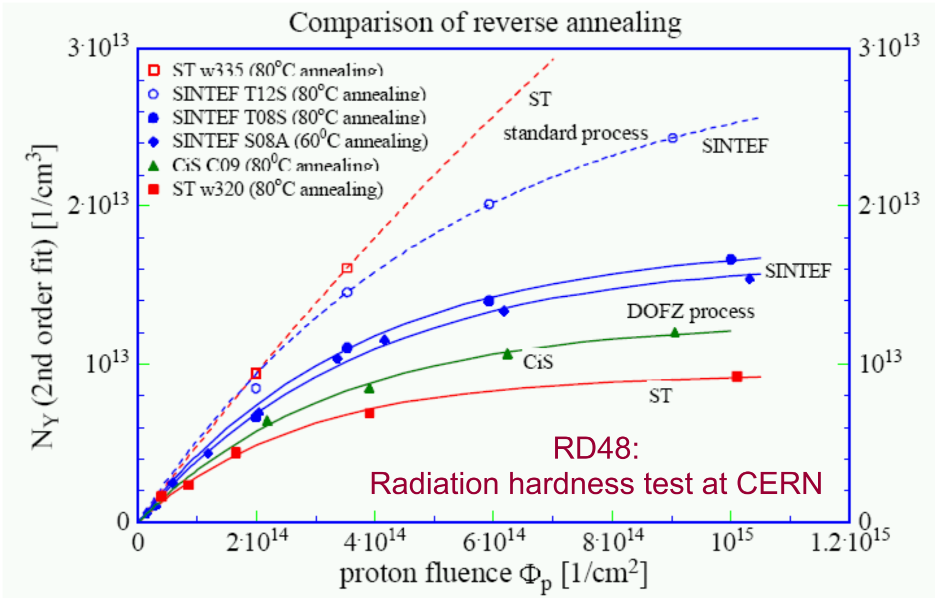
7. Neutron spectrometers
8. Microdosimeters

Pad detectors



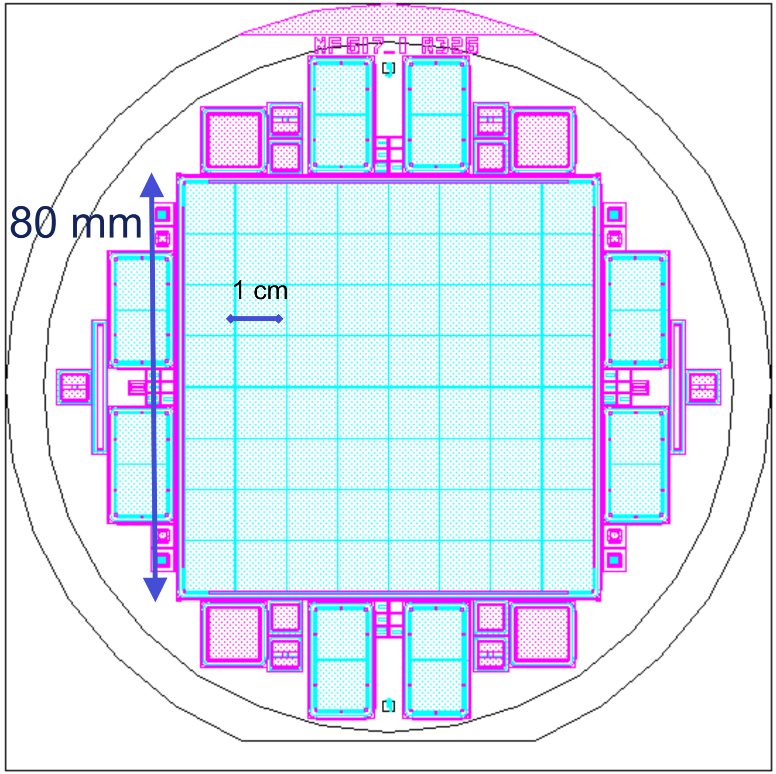
- ♦PiN diode structure
- ♦DC coupling
- ♦Active area = 5 mm ´ 5 mm
- ♦Thickness = 500 μm
- ♦Bias = 100 ÷ 200 Volt





Matrix Pixel sensors

Application:
satellite calorimetry



Main characteristics:

- ♦64 PIN diodes array
- ♦DC-coupling
- ♦Pixel pitch = 1 cm
- ♦Thickness = 500 μm

Electrical performances:

Operative bias < 100 Volts

Pixel leakage current density (typical): 3 nA/cm^2

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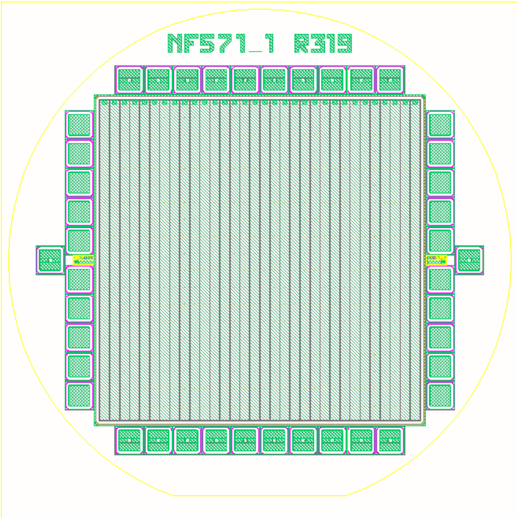
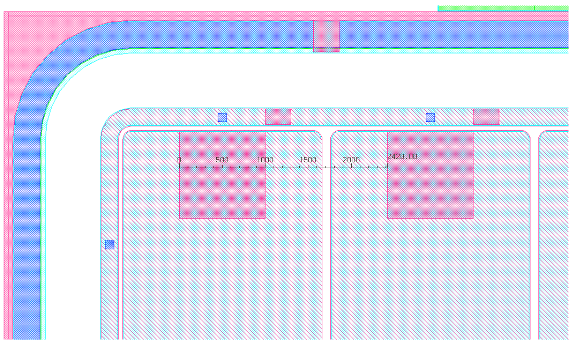
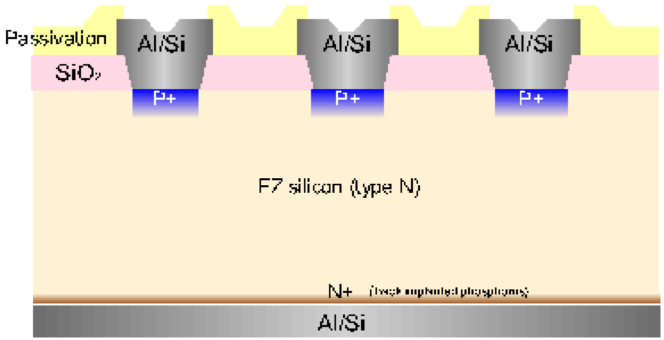
Macrostrip detectors



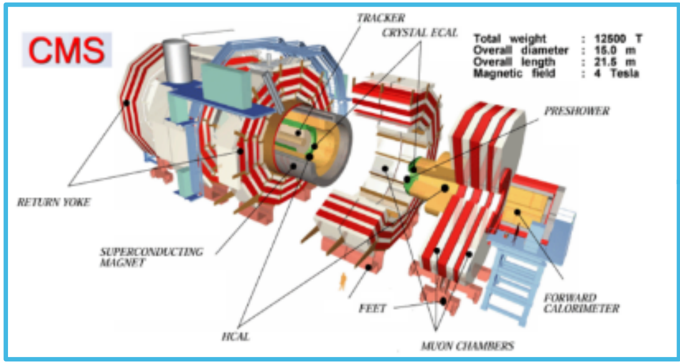
- ♦32 strips (PiN diodes)
- ♦DC coupling
- ♦Active area = 8 cm ´ 8 cm
- ♦Thickness = 380 µm
- ♦Bias = 60 ÷ 130 Volts

Satellite experiments: Wizard - Pamela



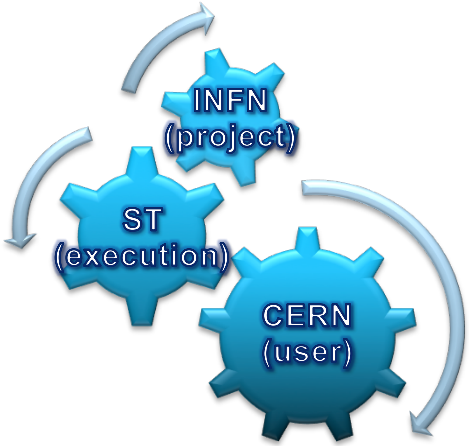


Microstrip detectors

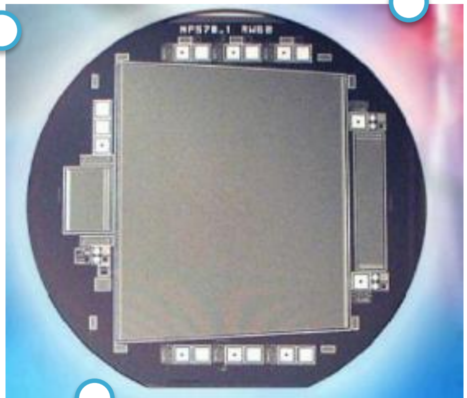


CMS experiment at CERN

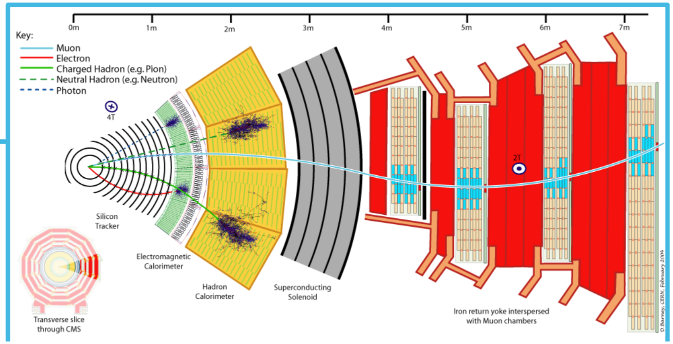
Technology transfer



GLAST experiment for studying cosmic gamma ray - bursts



Cross- section of the CMS tracker



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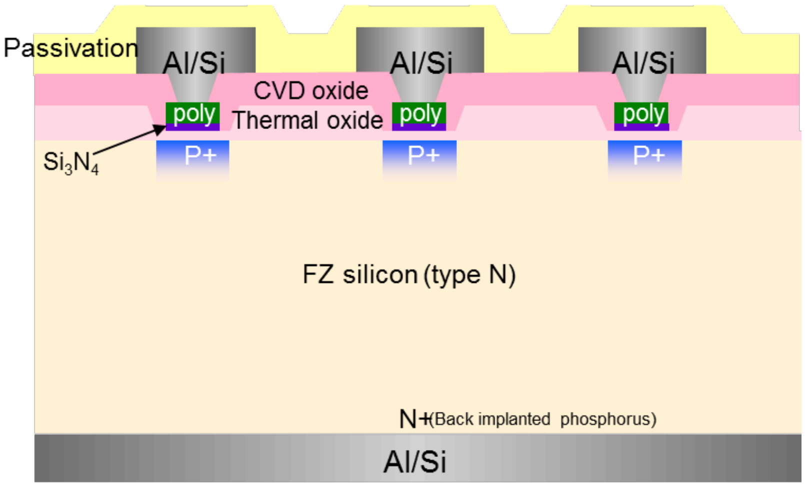
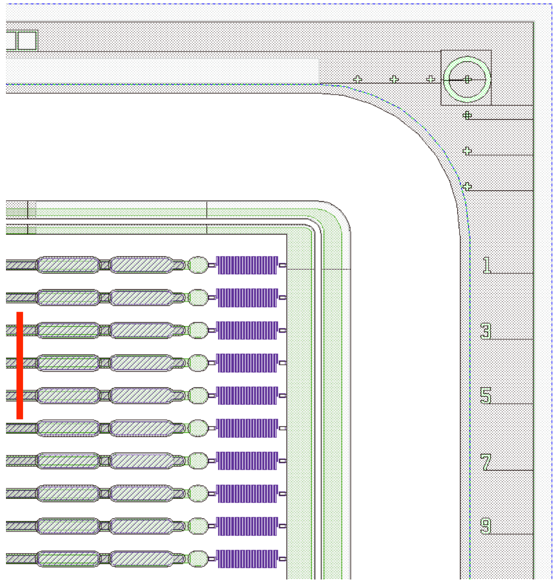
Microstrip detectors: main features

- ♦Hundreds of strips (PiN structure)
- ♦AC coupling (integrated capacitors)
- ♦Integrated poly resistances for biasing
- ♦Thickness = 500 µm

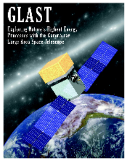




Detail of the detector edge

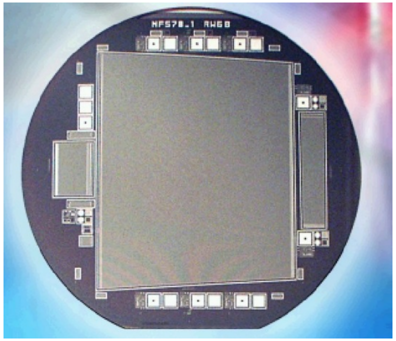
Microstrip detectors: products developed

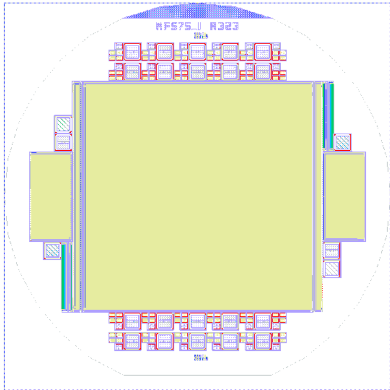
CMS
(8 products)

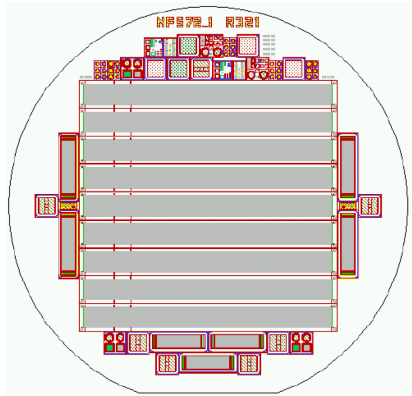


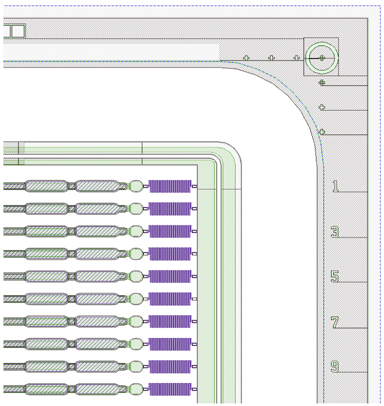
GLAST
(prototypes)

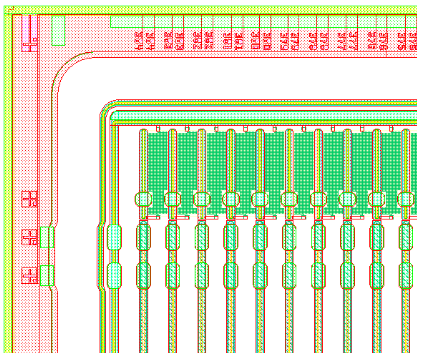
CDF-I (L00)
(prototypes)

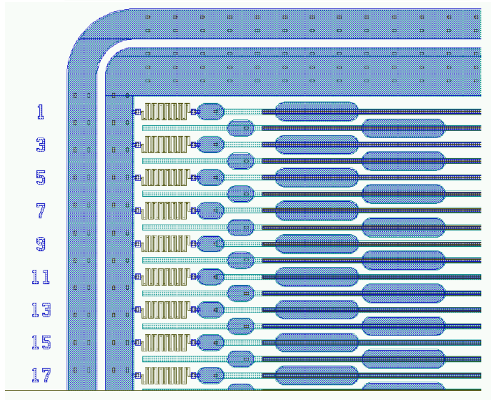




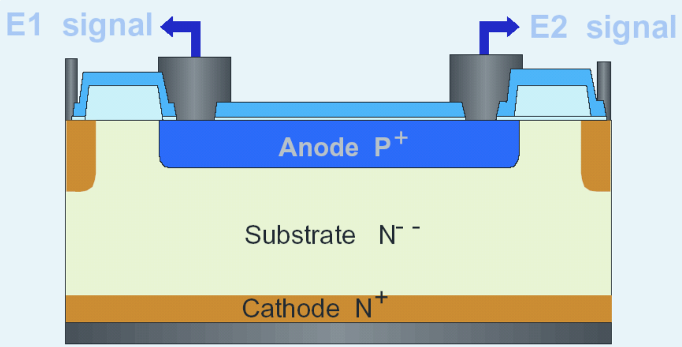




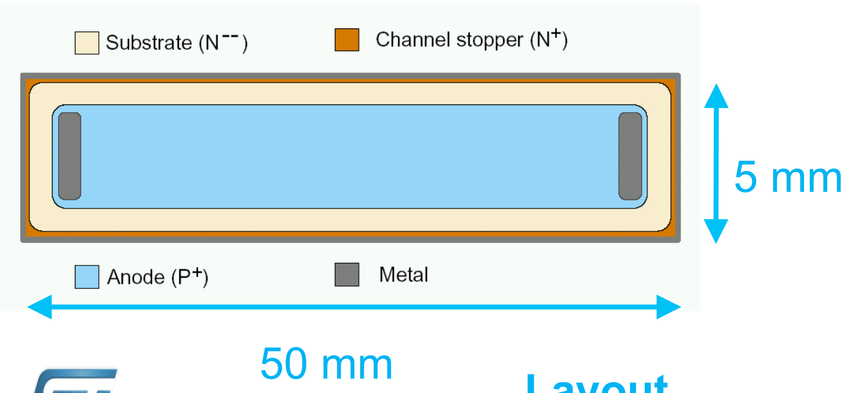




Energy detector



Vertical cross section

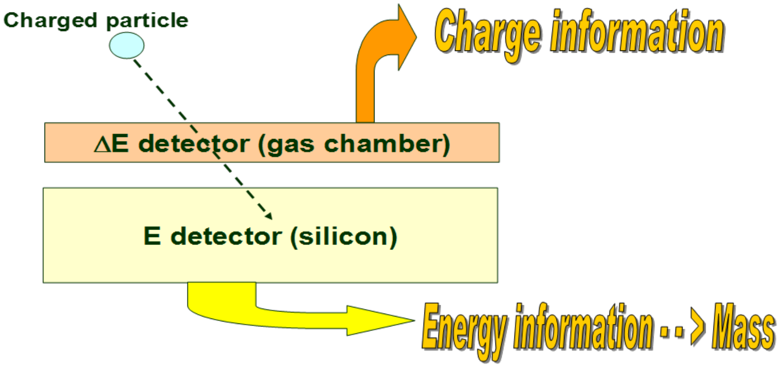


Layout

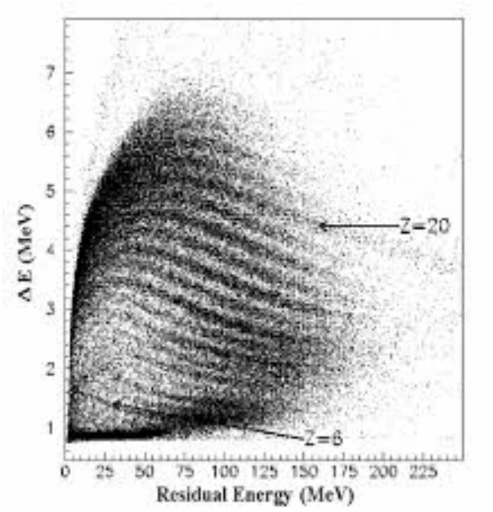
Heavy ions detection

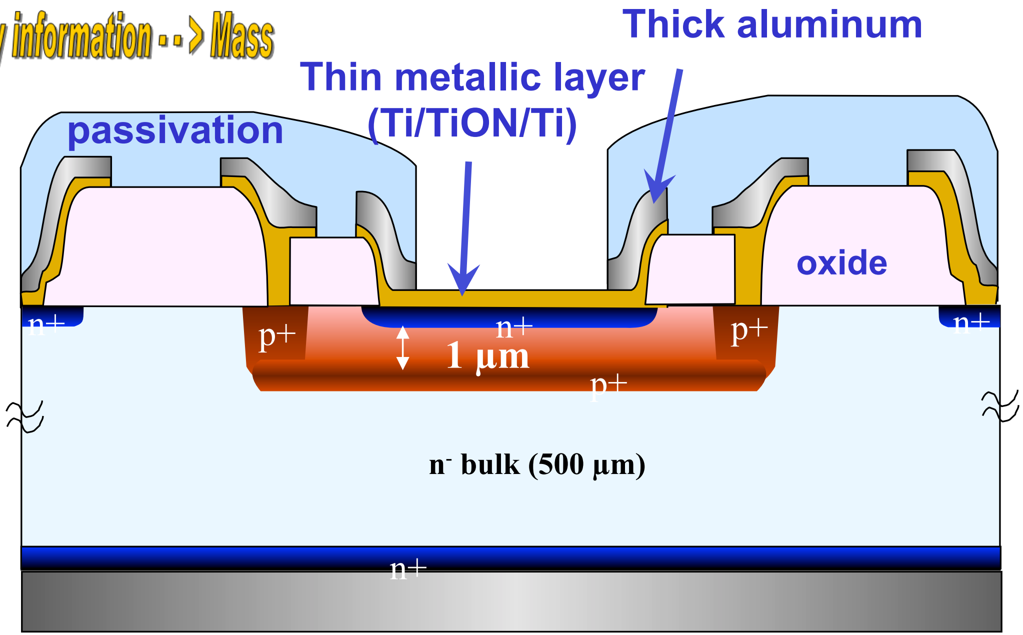
- ♦PiN diode with resistive partition on the anode
- ♦Partition resistance: 1.2 kΩ
- ♦DC coupling
- ♦Active area = 5 mm × 50 mm
- ♦Thickness = 500 μm
- ♦Bias = 100 ÷ 200 Volts

Monolithic Silicon Telescopes



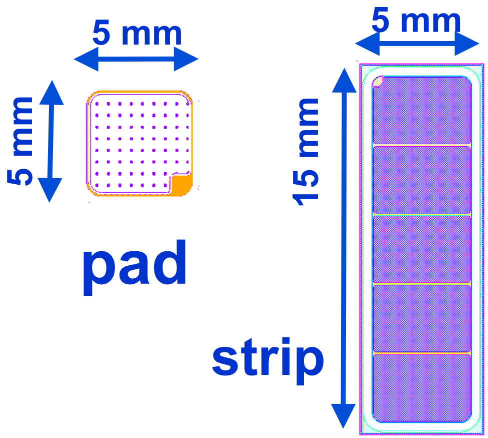
ΔE-stage thickness: ~ 1 μm
E-stage thickness: 500 μm

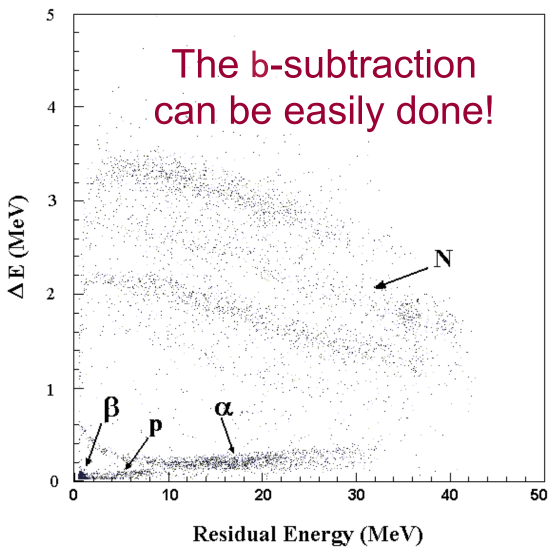


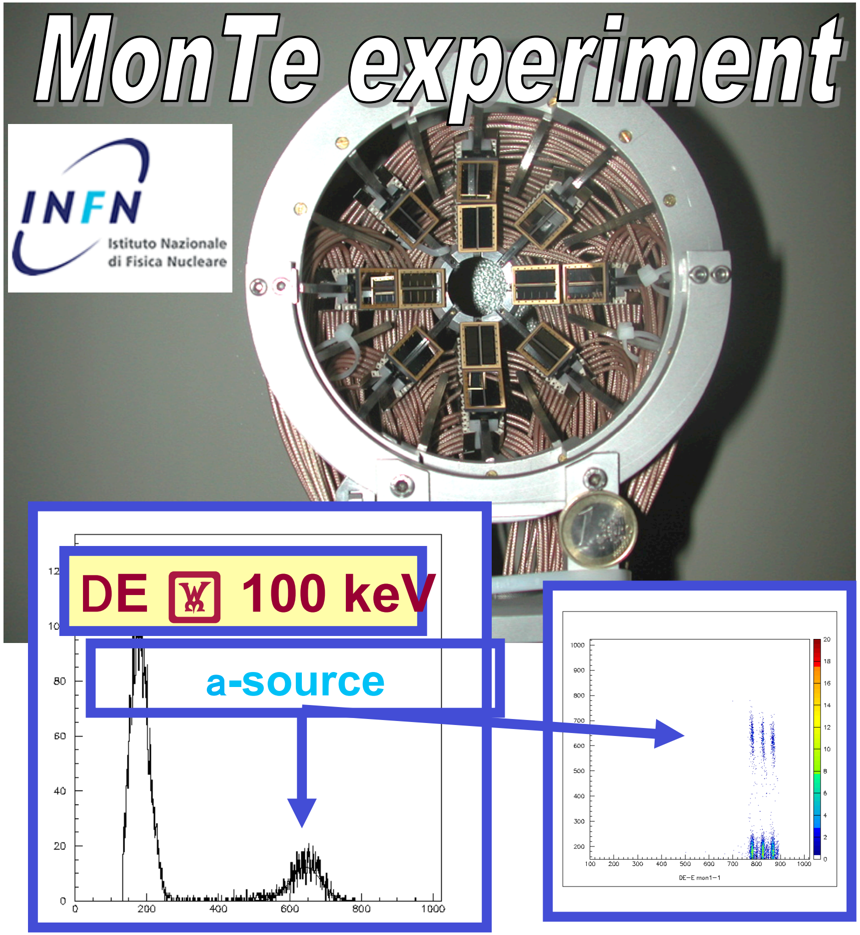


ST patent

MST detectors for nuclear physics

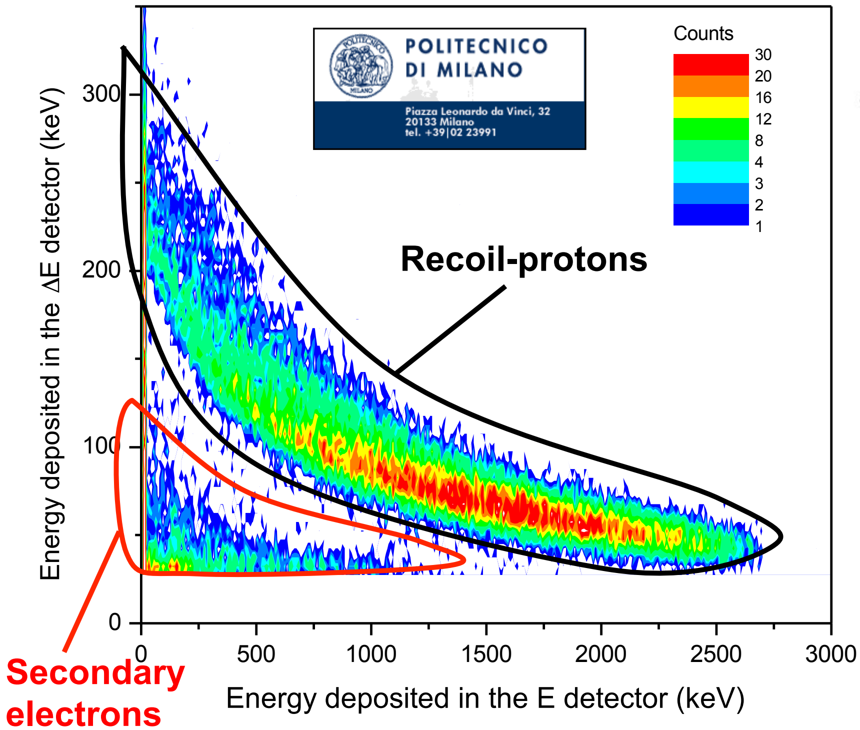




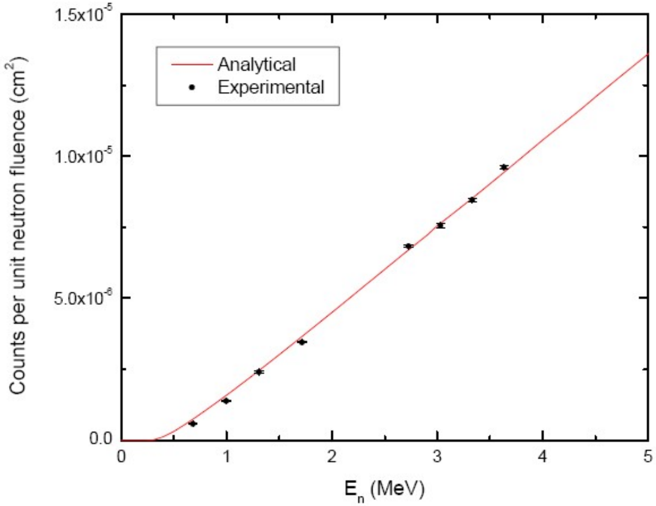


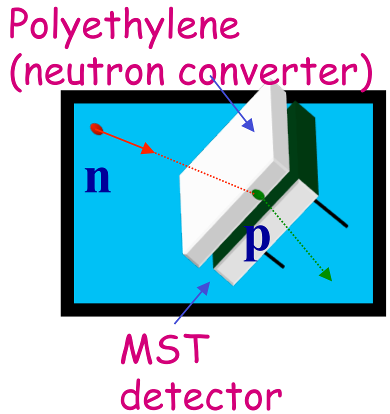
➢F. Amorini *et al*., Nucl. Phys. A **550** (2005) 248-257

Radioprotection application: neutron spectrometry



Detection efficiency





A. Fazzi et al. - **Improvement of the low energy limit of a silicon-based neutron spectrometer**, *NSS-MIC (2005)*

S. Agosteo et al. - **Neutron spectrometry with a monolithic silicon telescope**, *Radiation Protection Dosimetry (2007)*

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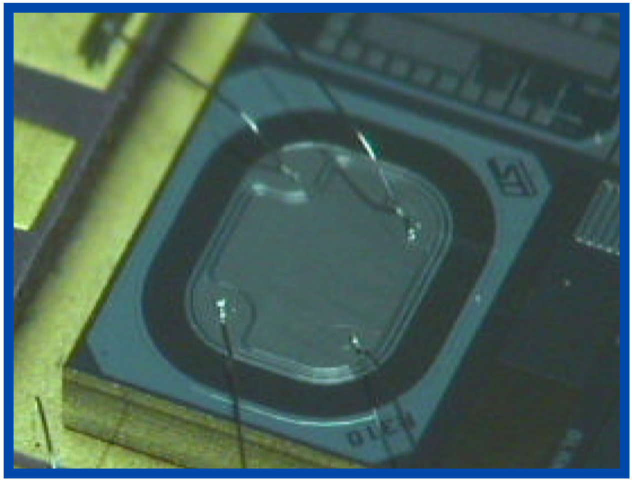
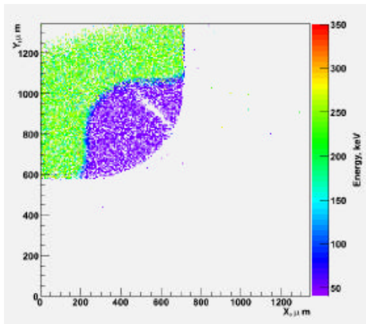
MST detector test

ANSTO Ion Microprobe

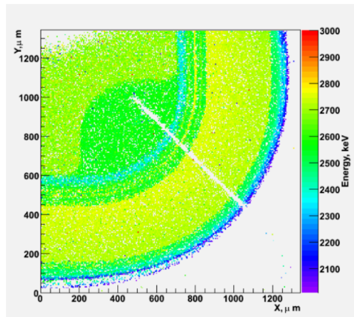
- Tandem VdG accelerator
- 3 MeV He^{+} ions
- 5 μm spot size
- 1400x1400 μm^2 scan area
- Charge collected by sample, Q, measured in coincidence with beam position in list mode (Q, x, y)
- Cornelius et.al, 2003



DE channel



E channel



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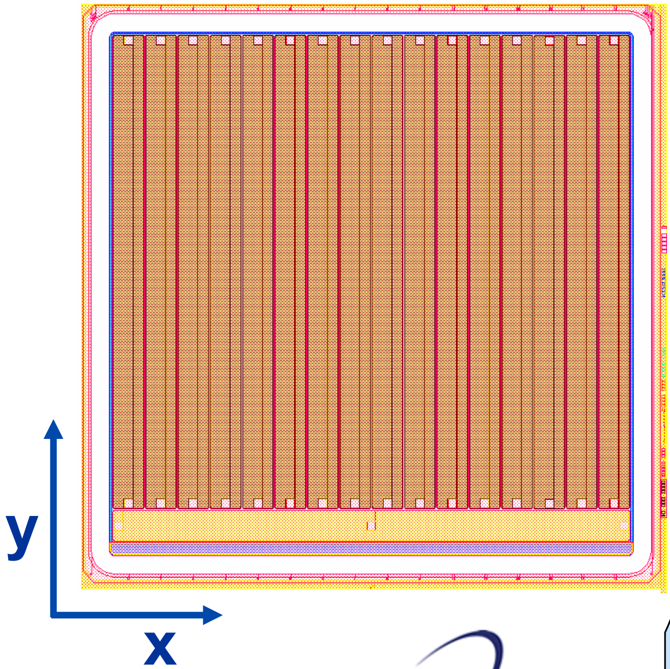
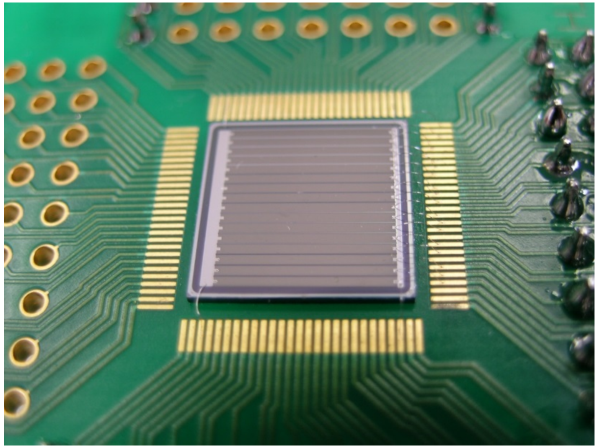
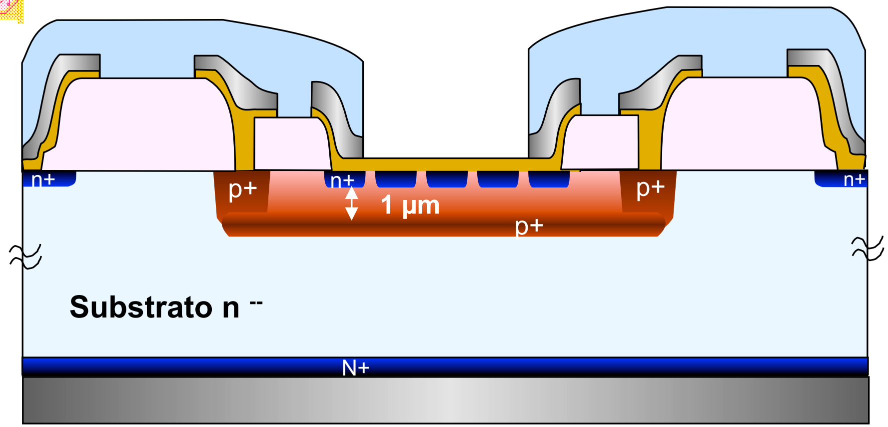
Position MST detector

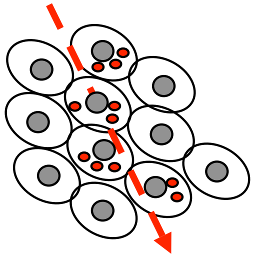






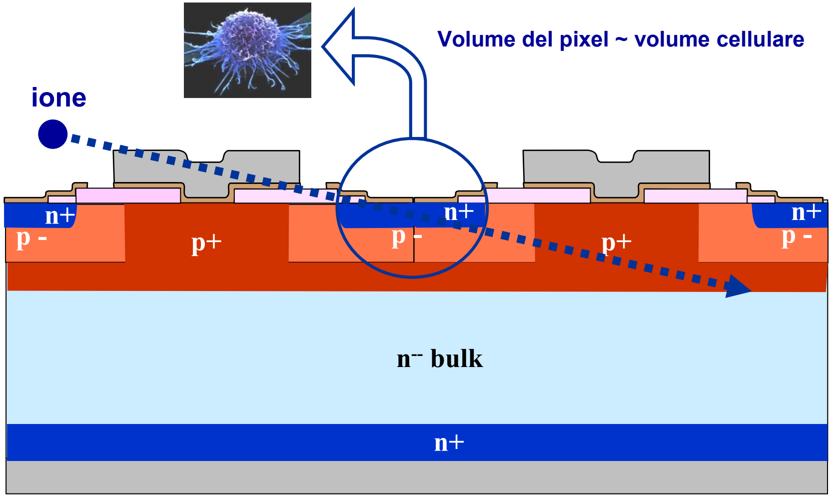
MST microdosimeter

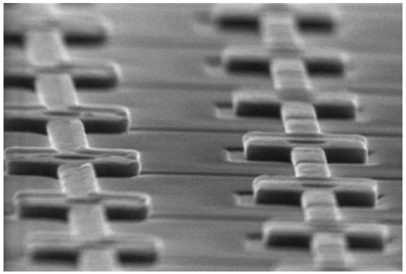
Ionizing particle

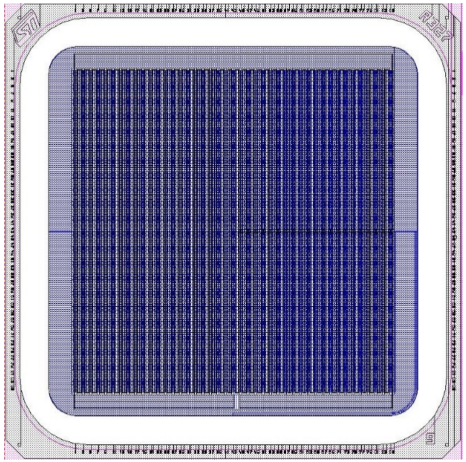


Localized ionization

MICRODOSIMETRY



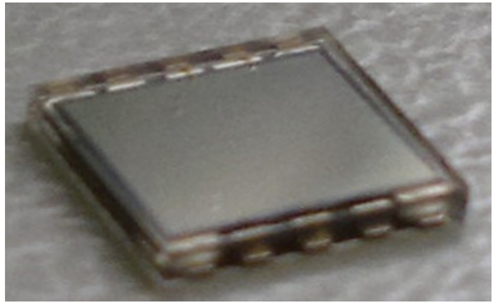


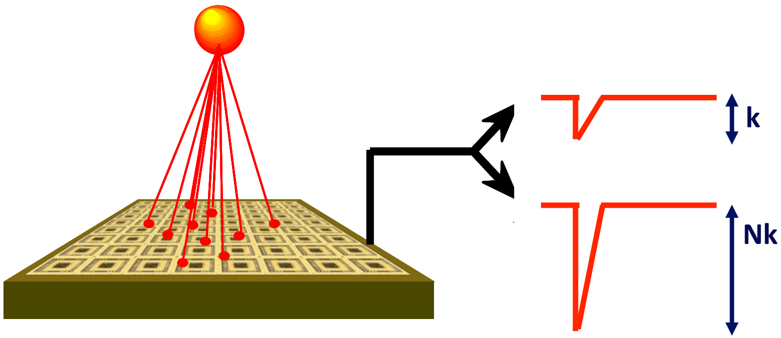


Low pixel density → to avoid multiple track detection from adjacent pixels

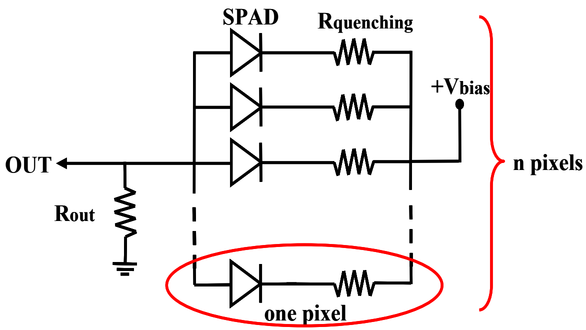
Silicon PhotoMultiplier (SiPM)

- Array of several micro-cells, connected in parallel
- Each cell is a Single Photon Avalanche Diode (SPAD)
- The device is biased above its breakdown voltage
- Each cell is sensitive to one photon (digital response)
- The whole array is an analogue device





N activated pixels



SiPM equivalent circuit

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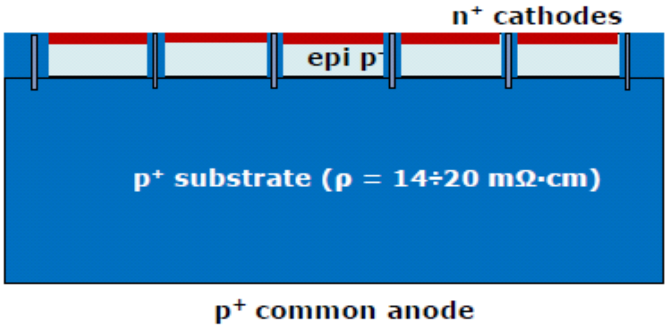
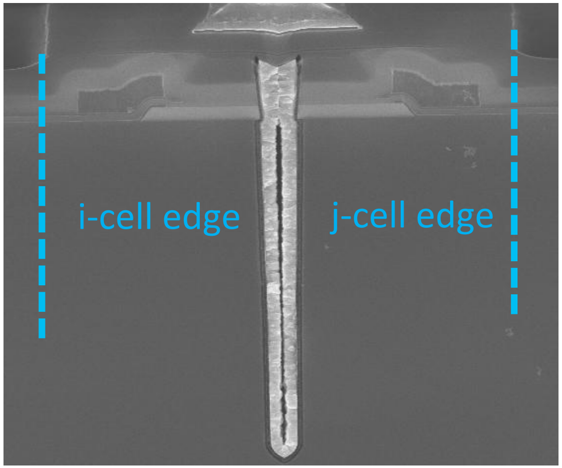
SiPM key technological features

- Two similar technologies: n/p and p/n
- Poly integrated quenching resistors
- Integrated optical mirrors (W-filled trenches)
- Integrated anti-reflection coating
- Thin (500 Å) ultrapure junction

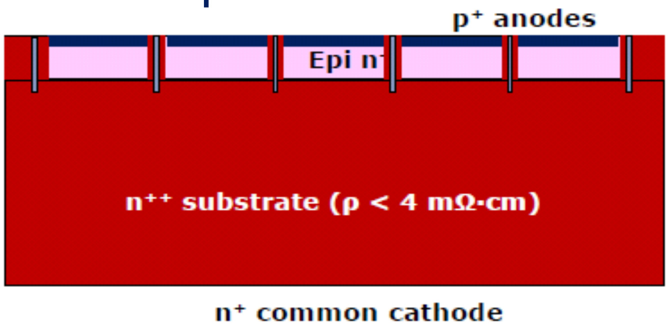
n/p structure





SEM cross section

p/n structure



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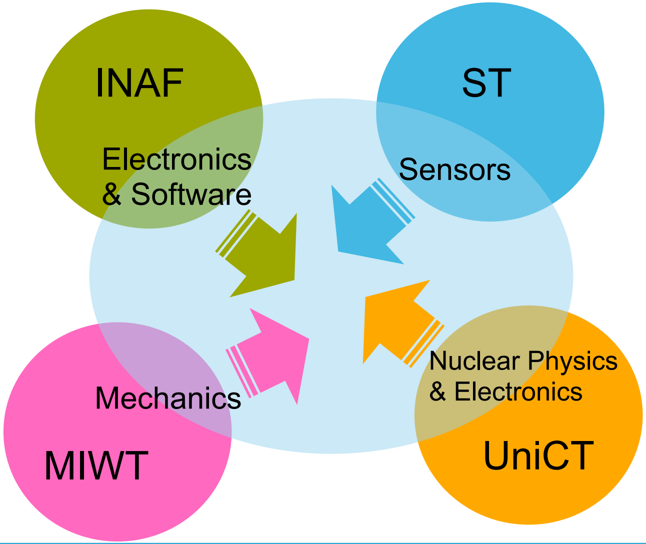
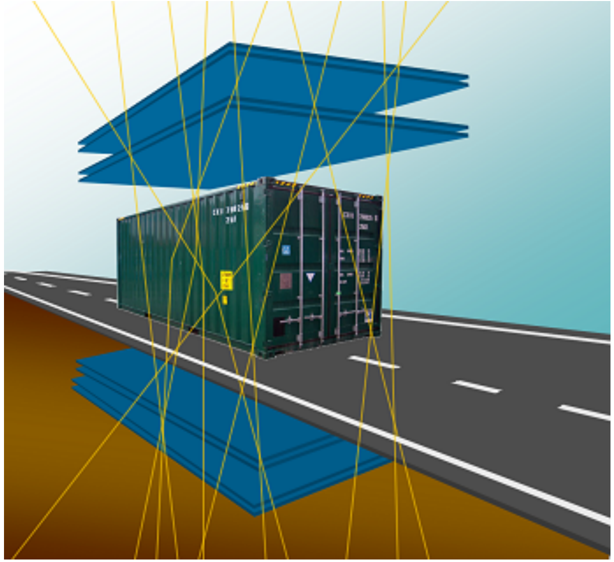
The Muon Portal project





A large muon tracker (8 planes, 6 m long and 3 m wide) large enough for the inspection of standard containers.
Results of simulations demonstrate the possibility of reaching detection times of few minutes.
Each plan is made of hundreds of scintillator bars, with SiPMs at their end.

UNDER CONSTRUCTION AT LNS

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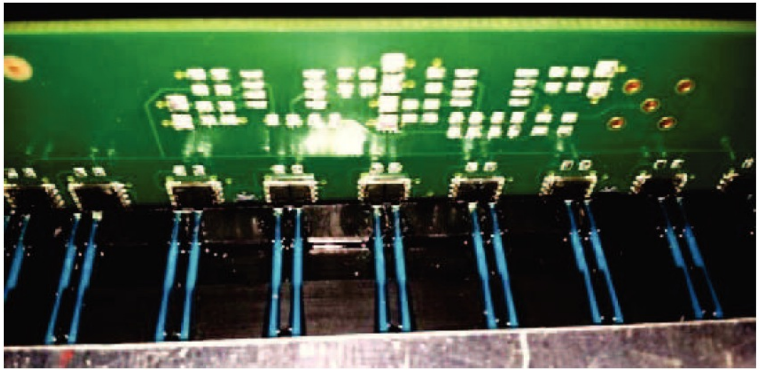
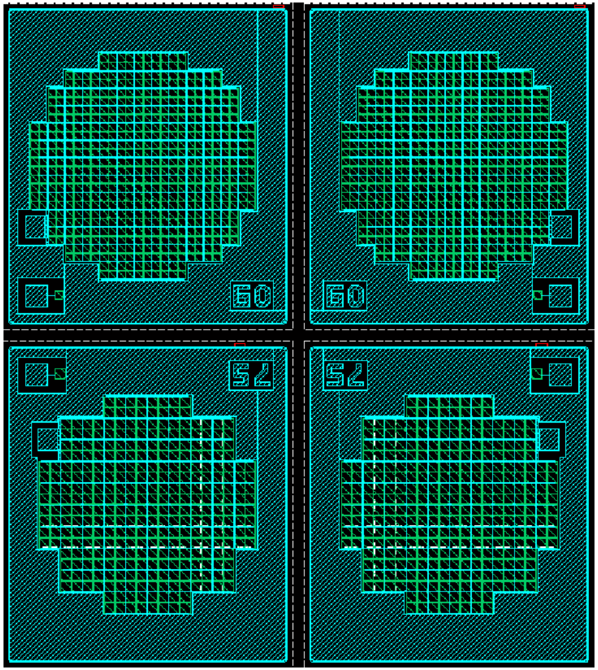
SiPM for muons detection

When a muon crosses the scintillator, it emits a light burst.



The green photons travel on optical fibers to the detection system, where are detected by SiPMs.

SiPM layout for the Muon Portal



SiPM technology: n/p

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Recent developments on our Monolithic Silicon Telescope technology

Recent MST technology upgrade

Microdosimeter

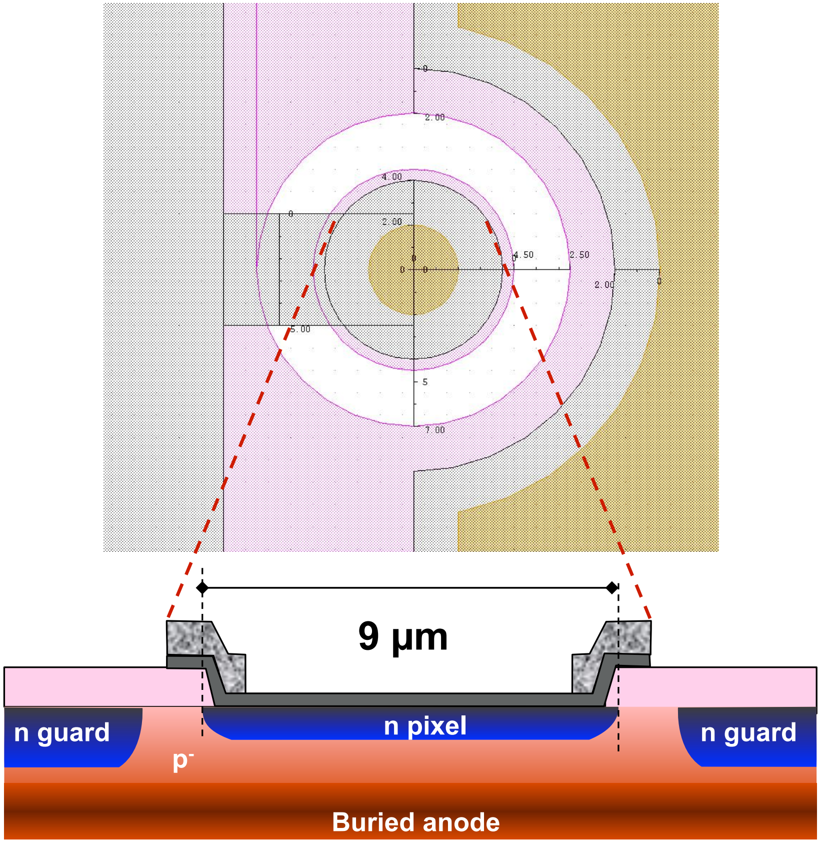
- Reduce the ΔE pixel diameter to 1÷2 μm
- Reduce the metallic barrier thickness on the sensitive area
- Reduce the buried layer resistivity

Fab

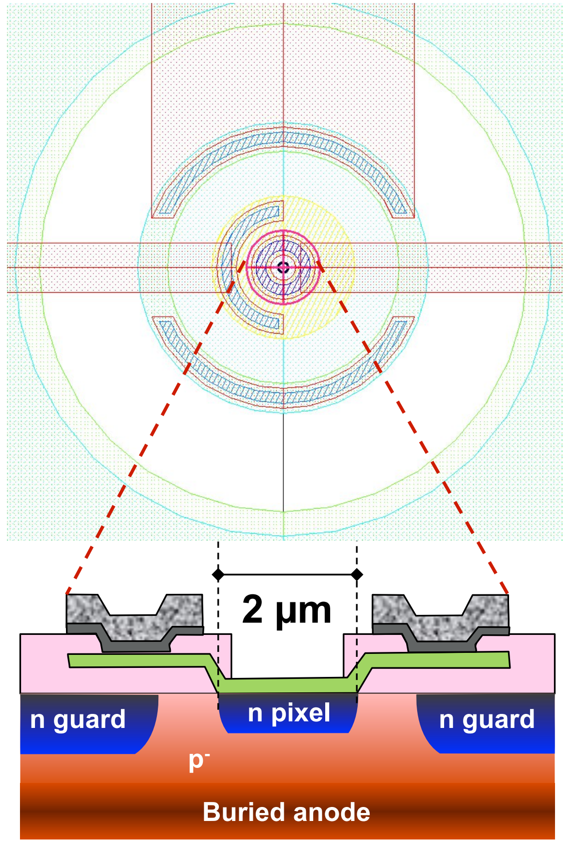
- Compatibility with 8” wafer fab
- Avoid “not-standard” process steps

Integration of the SiPM cathode module process into the MST technology

Pixel structure comparison



OLD MST



NEW MST

Conclusion

- ✓ Develop a new technology is a challenging activity that needs a synergy between Research Centers and Industry.

- ✓ Each development has increased our know-how on the specific technological critical issues of radiation sensors.

- ✓ Even if this business has never been crucial for ST, some technological hints learnt while developing sensors have become useful also for other technologies.

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Thank you!