3D microbeam characterization of large-area silicon carbide detectors

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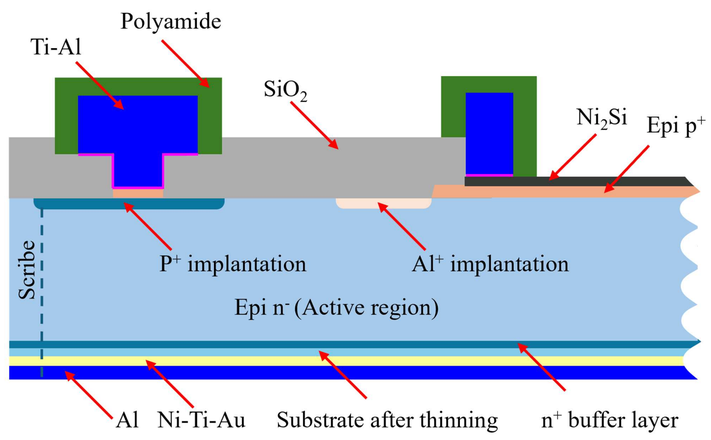
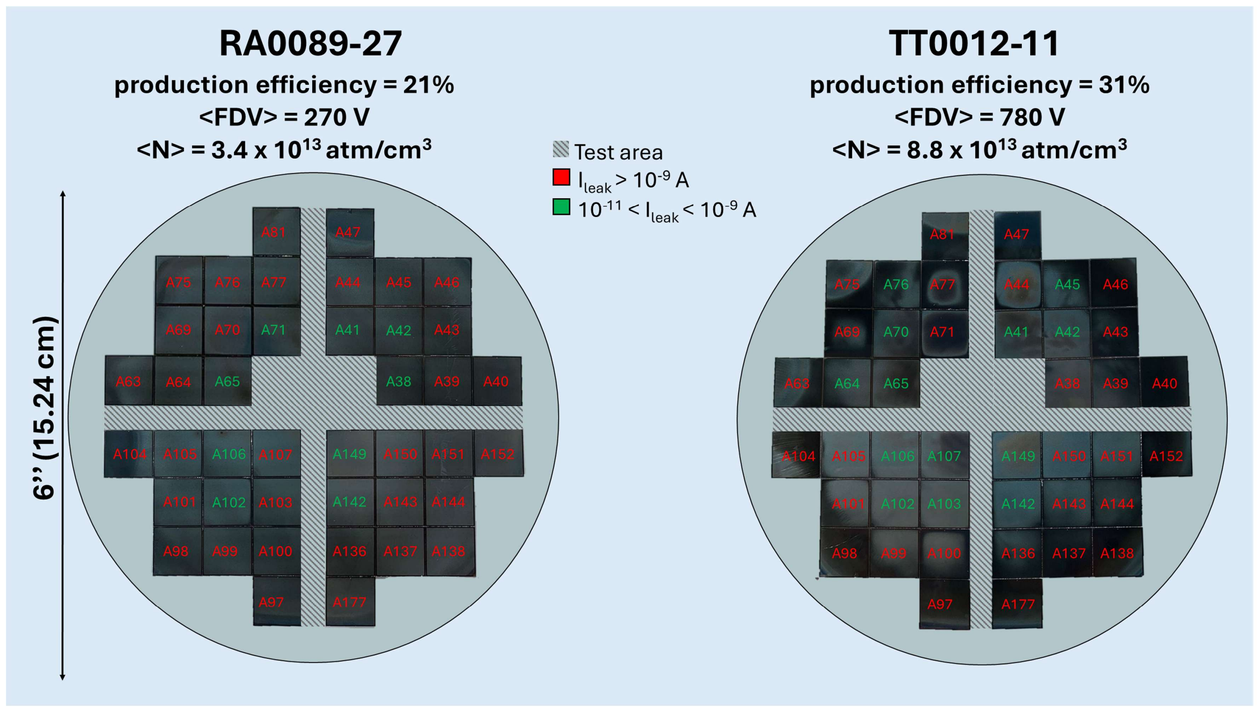
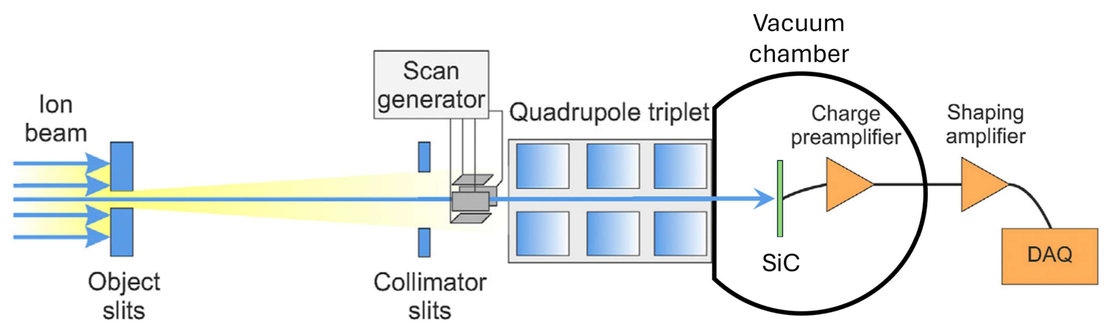
Large area SiC detectors - design

Silicon carbide (SiC) detectors are considered a state-of-the-art technology for particle detection. The most relevant feature of SiC devices is the **high radiation hardness** due to their wide energy bandgap (3.23 eV) and the strength of their chemical bonds (displacement energy ≈ 25 eV for 4H-SiC). Large area SiC detectors were recently produced within the SiCILIA project [1]. They are single-pad SiC detectors having an **area of 15.4 × 15.4 mm²**, a total thickness of 110 μm (**100 μm epitaxy** and 10 μm inert substrate) and an edge structure ≈ 400 μm wide that runs along the perimeter of the sensor. Because of their radiation hardness and good energy resolution, such SiC detectors have been chosen as the ΔE stage of new telescopes for the particle identification in the context of the **NUMEN** project [2], which requires the detection of heavy ions at very forward angles up to very high rates (≈ 10 kHz). Design and characterizations of such telescopes is ongoing within the **PARIDE** project [3].

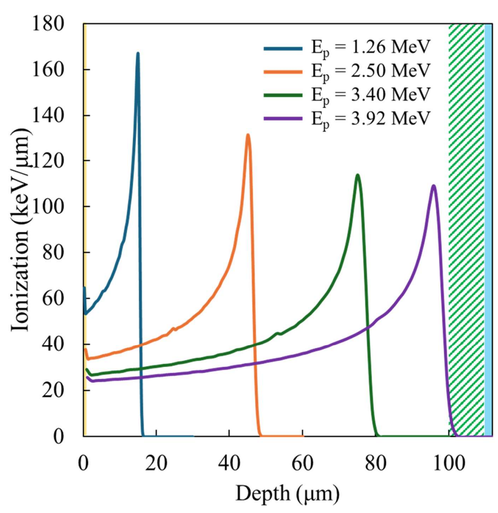


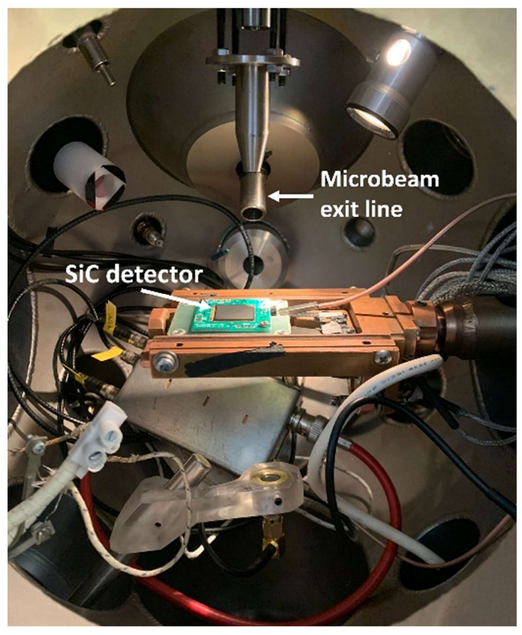


Proton MicroBeam Irradiation



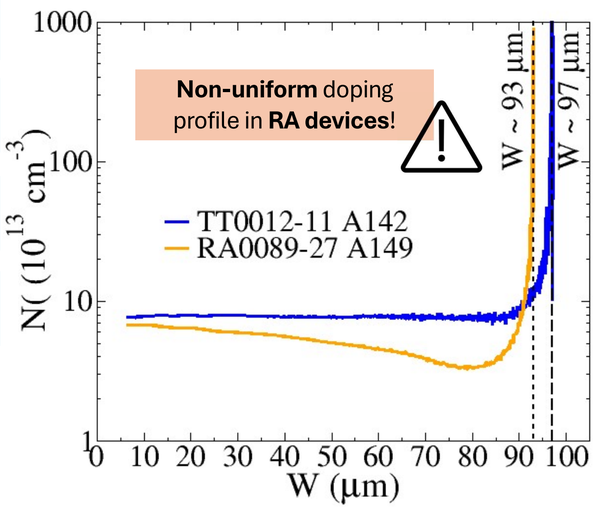
3D scanning
10 µm scanning pitch (x and y directions)
4 proton energies (z direction)





First tests[4]

- I-V and C-V
  - Full depletion voltage (FDV)
  - Doping profile (N)
- α-source
  - Energy resolution
  - Dead layer thickness

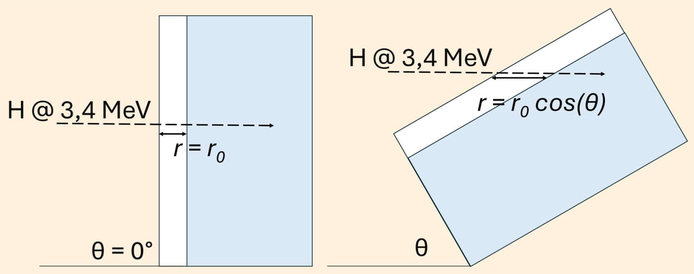


energy resolution (FWHM) = **0.5%**

Measurement of the depletion depth - BACK side irradiation

At different angles θ, the energy loss in the dead layer is expected to be compatible with:

$$\Delta E = \int_0^{r_0 cos\theta} \frac{dE}{dx} dx'$$



Step 1: Validation of the Ziegler [5] energy loss tables

- Protons @ 6 MeV in transmission
- E_{resid} measured by Si detector downstream the SiC
- Total measured thickness: 110 ± 1 µm
- θ = 0°, 10°, 20°, 30°, 40°, 50°

Step 2: Measurement of the depletion depth

- Protons @ 3.4 MeV
- E_{resid} measured by the SiC (@ FDV)
- θ = 0°, 20°, 30°, 40°, 50°

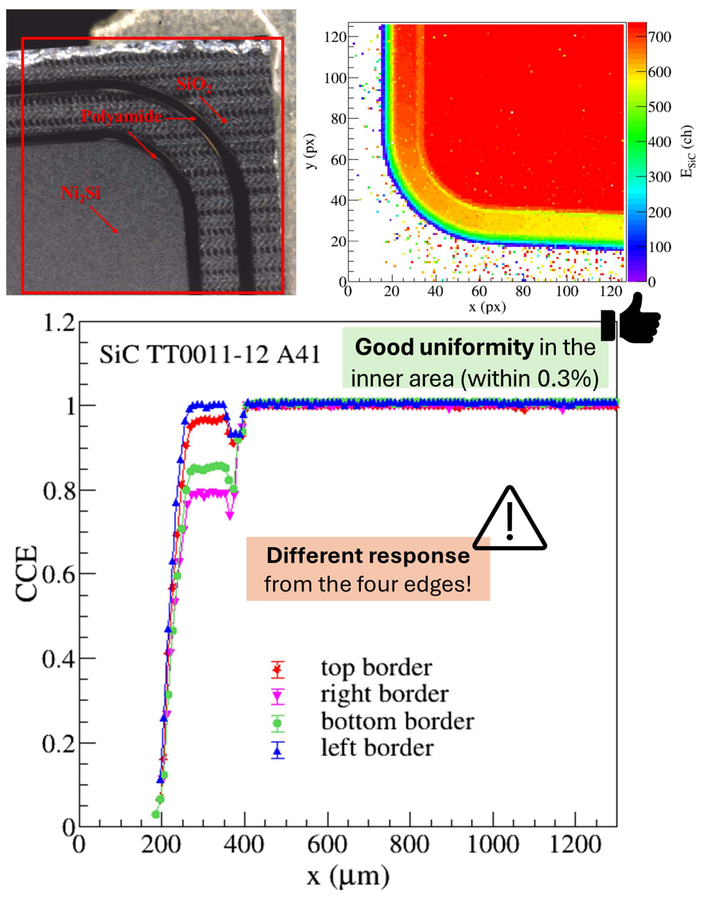
From Step 1: Ziegler tables for SiC need to be scaled by a factor **k = 0.964 ± 0.001** to reproduce total detector thickness

Wafer	Sensor	FDV (V)	Dead Layer (µm)	**Depletion depth (µm)**
TT00012-11	A41	800	10.7 ± 0.3	**99.8 ± 0.1**
TT00012-11	A45	800	11.3 ± 0.1	**98.7 ± 0.1**
RA0089-27	A106	320	15.6 ± 0.1	**94.5 ± 0.1**
RA0089-27	A102	240	15.8 ± 0.2	**94.1 ± 0.2**

Depletion depth in **RA devices** is significantly **smaller than the nominal** 100 µm **epitaxy**!

Measurement of the CCE - FRONT side irradiation

Scanning of the edge and the inner areas



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[1] S. Tudisco *et al.*, Sensors 18 (7) (2018)
[2] F. Cappuzzello *et al.*, Eur. Phys. J. A 54 (5) (2018) 72
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[5] J.F. Ziegler *et al.*, Treatise on Heavy-Ion Science: Volume 6, Springer US, Boston, MA, 1985