Microdosimetry for ion-beam therapy at EBG MedAustron
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Detectors and methodology

- **Diamond Detector**
  - Detector prototypes
  - Zagreb microbeam: Ion-Beam Induced Charge, IBIC
  - Proton microdosimetry

- **Common solid state transversal characteristic**
“Suboptimal” definition of the sensitive volume

Prototype version 0
- The substrate is an (extended) electrode
- Definition of the cross section of the sensitive volume though the shape of the metallic contact on top of the diamond
- Built in potential
- Need of a small cross section to be capable of working with high beam intensities

To the electronics

Intrinsic diamond

p+ substrate: deep electrode

Collaboration with
U. Tor Vergata, Rome:
Reduced size of the detector

MicroDiamonds

- Nominal thicknesses of sensitive volume: from 0.25 µm to 5 µm
- Diameter of sensitive cross area: 100 µ, 2000 µm
- Overall volume of the order of 1 mm$^3$
Distorsion of the definition of the sensitive volume

Microbeam test IBIC

- Single particles (5 MeV silicon ions in the example) are scanned toward the sample
- The uncertainty in the beam position order of 1µm.
- The detector is operative and perpendicular to the beam direction. When the particle passes through the sensitive area the ionization is registered.
- The synchronization between of the signal and the scanning of the beam provide the transversal position
- The process is repeated several times
Building a clear sensitive volume

The welding material on top of the metallic contact is thick enough to stop the alpha particles which do not reach the sensitive area.
Improving the prototypes

Prototype version 1

- Aluminium oxide (Al₂O₃) is grown on the side of the metallic contact to create a region non-sensitive to radiation where to weld the wire
- The dielectric constant of the oxide is approximately twice that of the diamond
- The thickness of the oxide cannot exceed 1 or 2 µm: cracks
- A secondary peak (red in figure 2) appears

**Figure 1.**
The welding of the external wire is on the

**Figure 2.**
A second peak at low channels is visible when 6V are supplied. Am-241 alpha source. 2µm thick diamond.
Improving the prototypes

Prototype version 2

- A metal layer is deposited on the intrinsic diamond before growing the aluminium oxide and it is electrically connected to the substrate (figure). The region between the two has zero voltage and therefore the ions produced by the irradiation do not contribute to the pulse.
- No secondary peaks are visible.

A single peak.
Lithium 14.46 MeV. 2µm thick diamond
Improving the prototypes

Prototype version 3

- The purpose is to shape also the p+ substrate to the same shape of the metal contact. The electric field is created by two electrodes of the same shape.
- The intrinsic diamond extends outside the region of the

Figure.
The latest configuration. The sensitive volume is straightly defined between the superficial metal contact and the p+ substrate.
Microscopic imaging

Scanning Electron Microscope image of the diamond

Atomic force microscopy image of intrinsic diamond growth

Cr contact
CVD diamond
p-type diamond
Realization of the prototype 3.0
Tests with 10 different radiation qualities

- Electron stopping power / keV·µm⁻¹

- Energy in diamond / keV

- Lineal Energy y (KeV/µm)

- Background (noise)

- 60° tilting

- 0° tilting

- Counts

- Energy (KeV)

- 0° (0.7µ-thick sensitive volume)

- 60° (1.4µ-thick sensitive volume)
Ion Beam Induced Charge tests of carbon ions (15 MeV) in diamond detectors. The map (left) shows distortions of reading in the detector areas. The peak (ideally a thin Gaussian) enlarged and distorted.
Transversal characteristic in solid state detectors: borders

- Resolution of the system given by the unknown “beam size” (of the order of 3-4 µm)

- Extract of a pixel line: Transition in pixel response between homogeneous area and undetectable response

- Sigmoid interpolation

- with C-ion 15 MeV, the border ≤3.33 ± 0.71 µm
Transversal characteristic in solid state detectors: uniformity

- **Uniformity studies**

- Total fluctuations depend on pulse height fluctuations, the number of particles per pixel, and non-uniformity of the local response.

- Rescan the same pixels with different ion probes to see correlations of the response: very challenging because of the time dependence of IBIC test.