Institut Ruđer Bošković

DRD3

Study of advanced detectors for future accelerator facilities with ion beam microscopy

Georgios Provatas, Milko Jakšić, Donny Cosic, Karla Ivanković Nizić, Zdravko Siketić

The RBI-AF: Laboratory For Ion Beam Interactions

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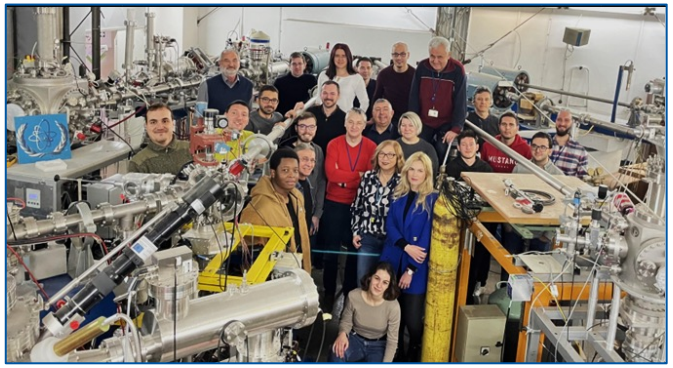

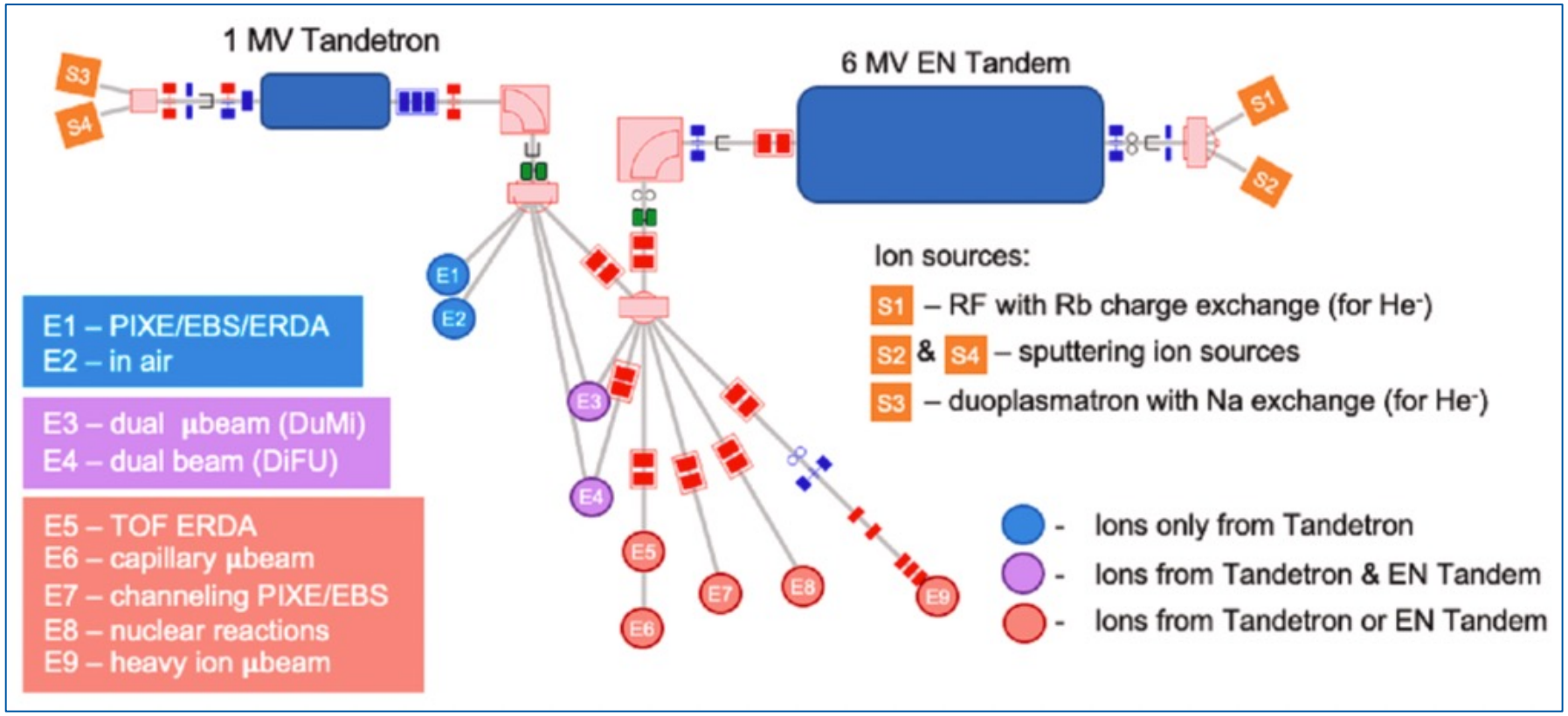

CERIC
Central European Research Infrastructure Consortium

ReMade @ ARI

EURO-LABS
EUROPEAN LABORATORIES FOR ACCELERATOR BASED SCIENCES

The RBI-AF: Laboratory For Ion Beam Interactions

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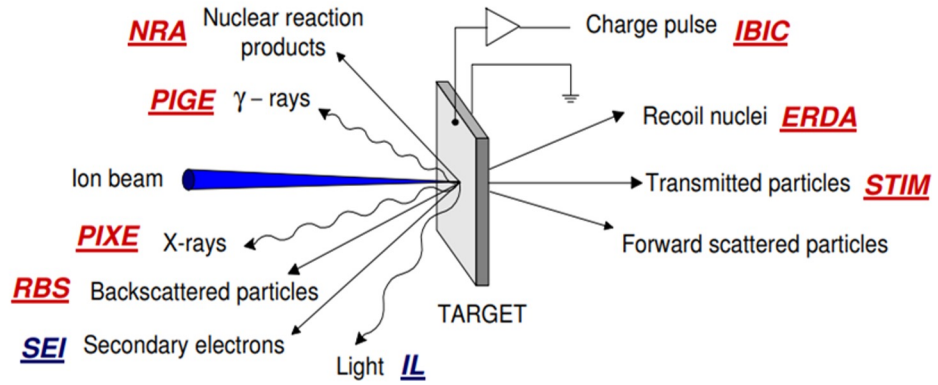
Ion Beam Analysis

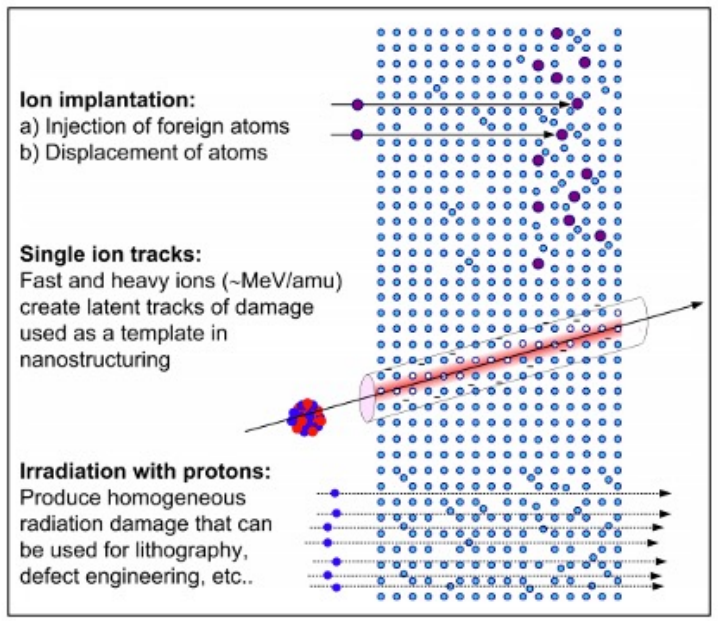


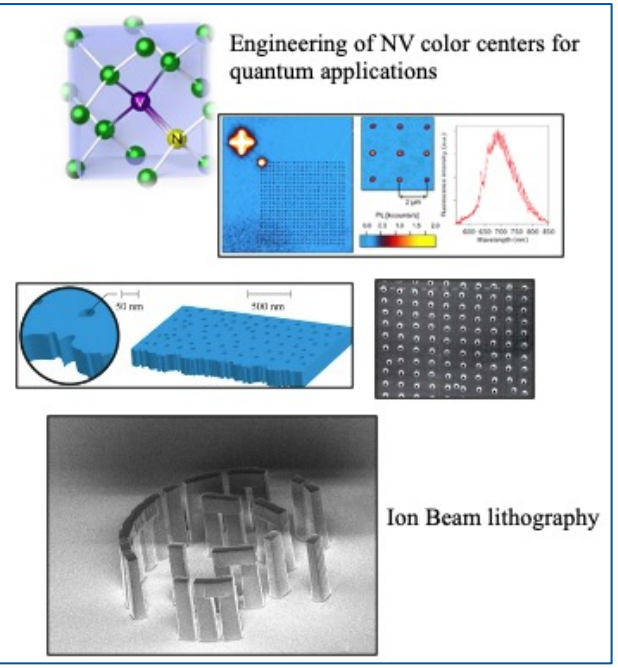
Concentrations and/or depth profiles:
Elements - x-rays (PIXE)
- backscattered particles (RBS)
- recoiled ions (ERDA)

Isotopes - gamma-rays (PIGE)
- nuclear reactions (NRA)

Density variations – transmitted ions (STIM)
Charge transport – ion beam induced current (IBIC)
Chemical bonds – light (IL), x-rays (high –resolution)
Crystal structure – channeling RBS, STIM, PIXE
Morphology – secondary electrons (SEI)

Ion Beam Materials Modification





Ion Beam Induced Charge (IBIC) microscopy

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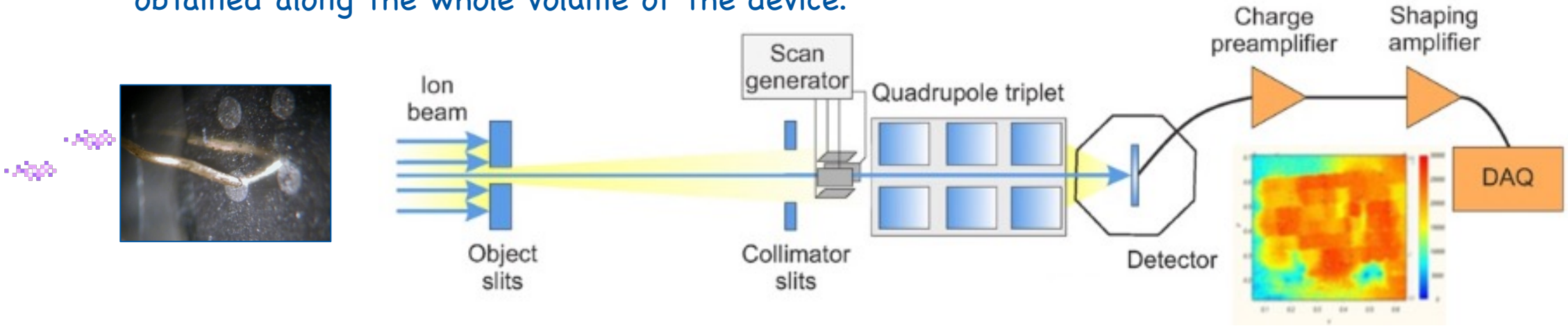
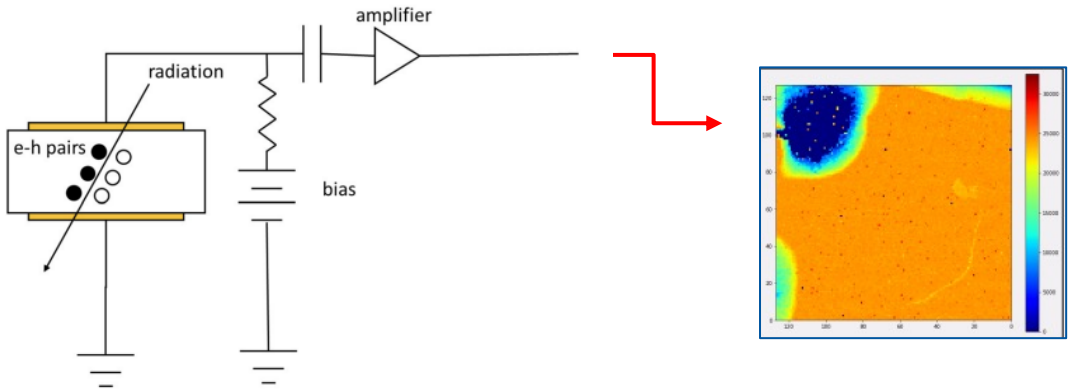
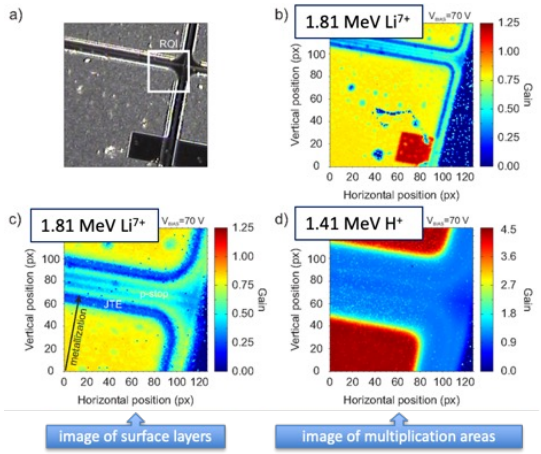
In Ion Beam Induced Charge (IBIC) microscopy, the charge collection properties of semiconductor devices are studied. With IBIC the detectors response, i.e. the CCE, is obtained along the whole volume of the device.

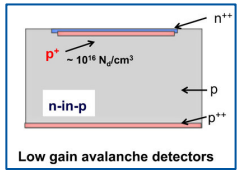


The charge transport properties of particle detectors are probed with IBIC, using ion beams of ~1 kHz rate.





Effective intrepad distance & gain supression **LGADs**



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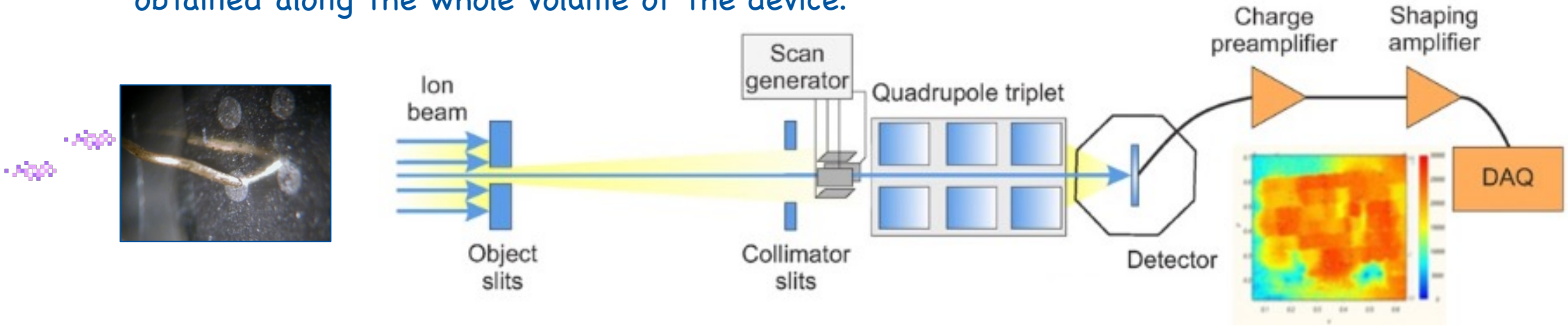
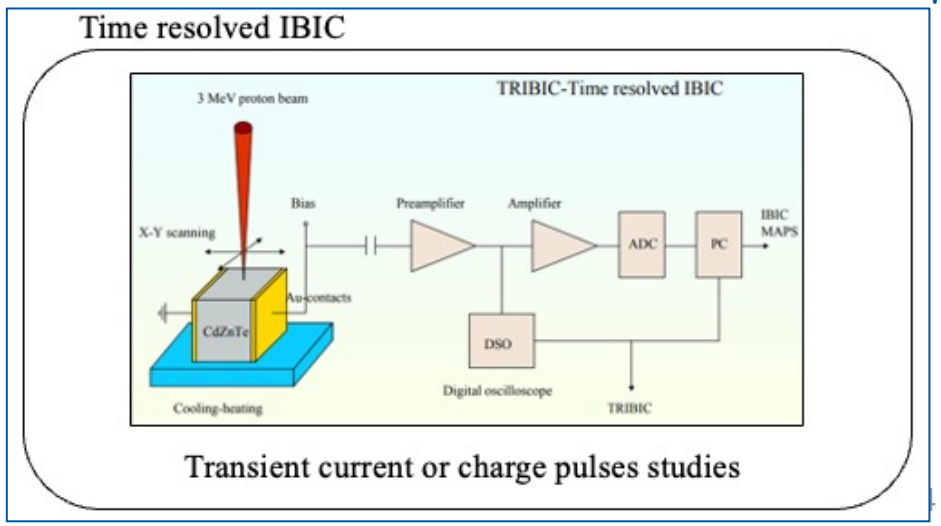
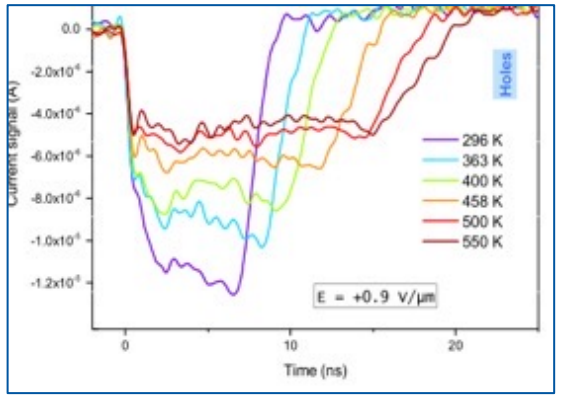
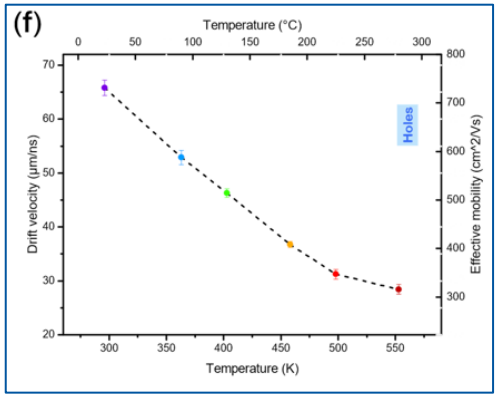


With Ion-beam Transient Current Technique (ion-TCT) the charge currier kinetics can be studied along with IBIC



Ion beam - TCT





Ion Beam Induced Charge (IBIC) microscopy

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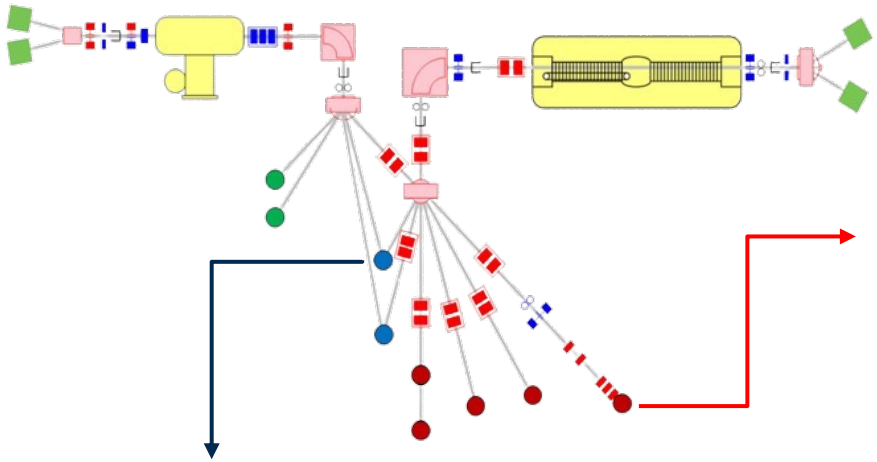
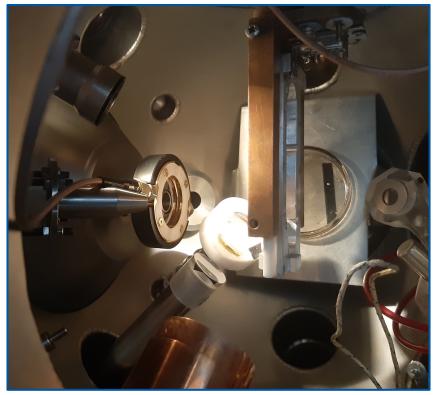


Dual Microprobe

The RBI microprobe



- Beam spots down to 120 nm
- Precise irradiations from low (few Hz) to high current (nA) modes.
- Scanning and imaging possibilities of areas up to several mm.
- In-house DAQ Software SPECTOR.
- Target positioning using nm precise piezo-stages.
- Alignment of samples for angular resolved studies/channeling.
- Available temperatures from 40K up to 700 °C
- Probing and damaging using two simultaneous microbeams

Study of Diamond detectors at cryogenic temperatures

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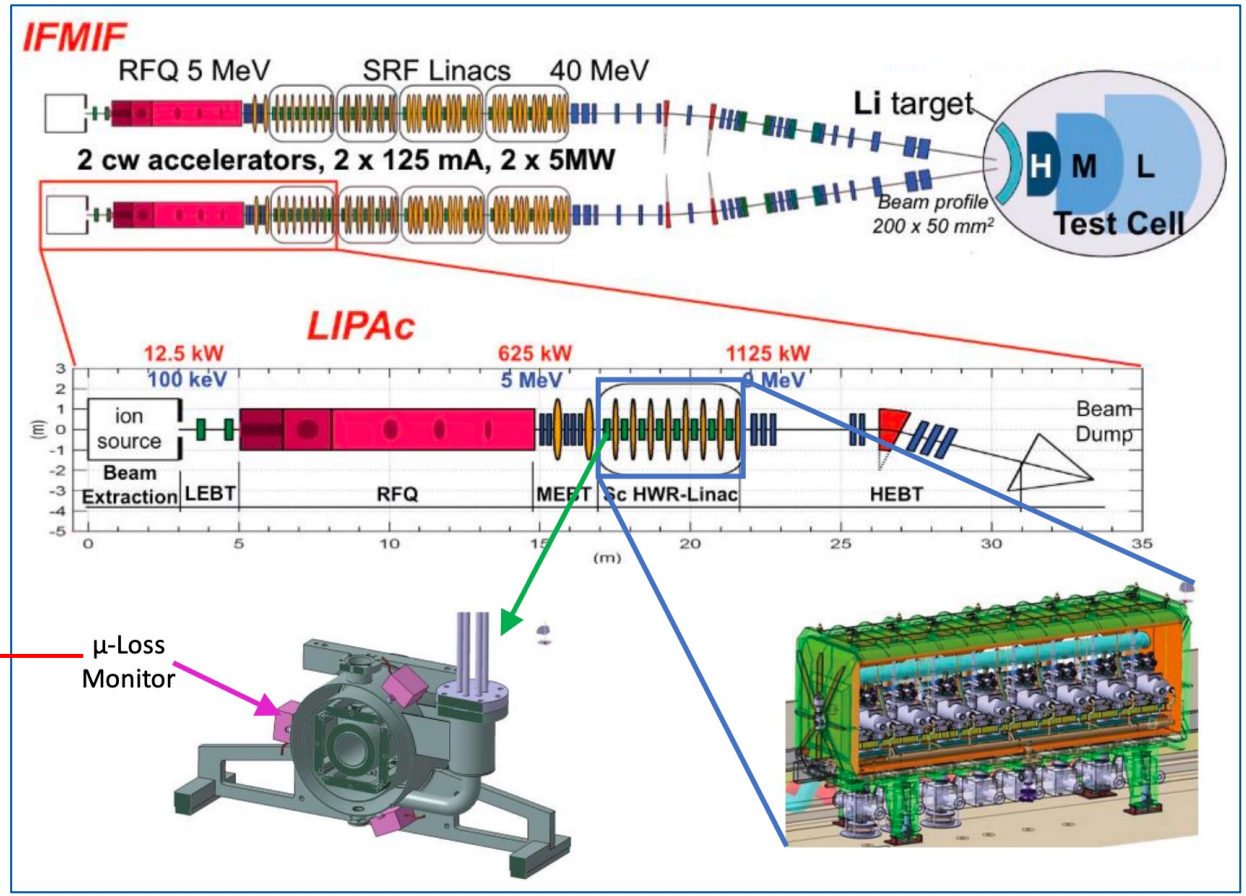
To study effects generated by fusion on materials in the immediate surrounding of the reactor core in ITER, a dedicated International Fusion Material Irradiation Facility – DEMO Oriented Neutron Source (IFMIF-DONES) is being constructed to produce similar neutron fluence of 10^{18} n/sm^2.

IFMIF DONES GRANADA



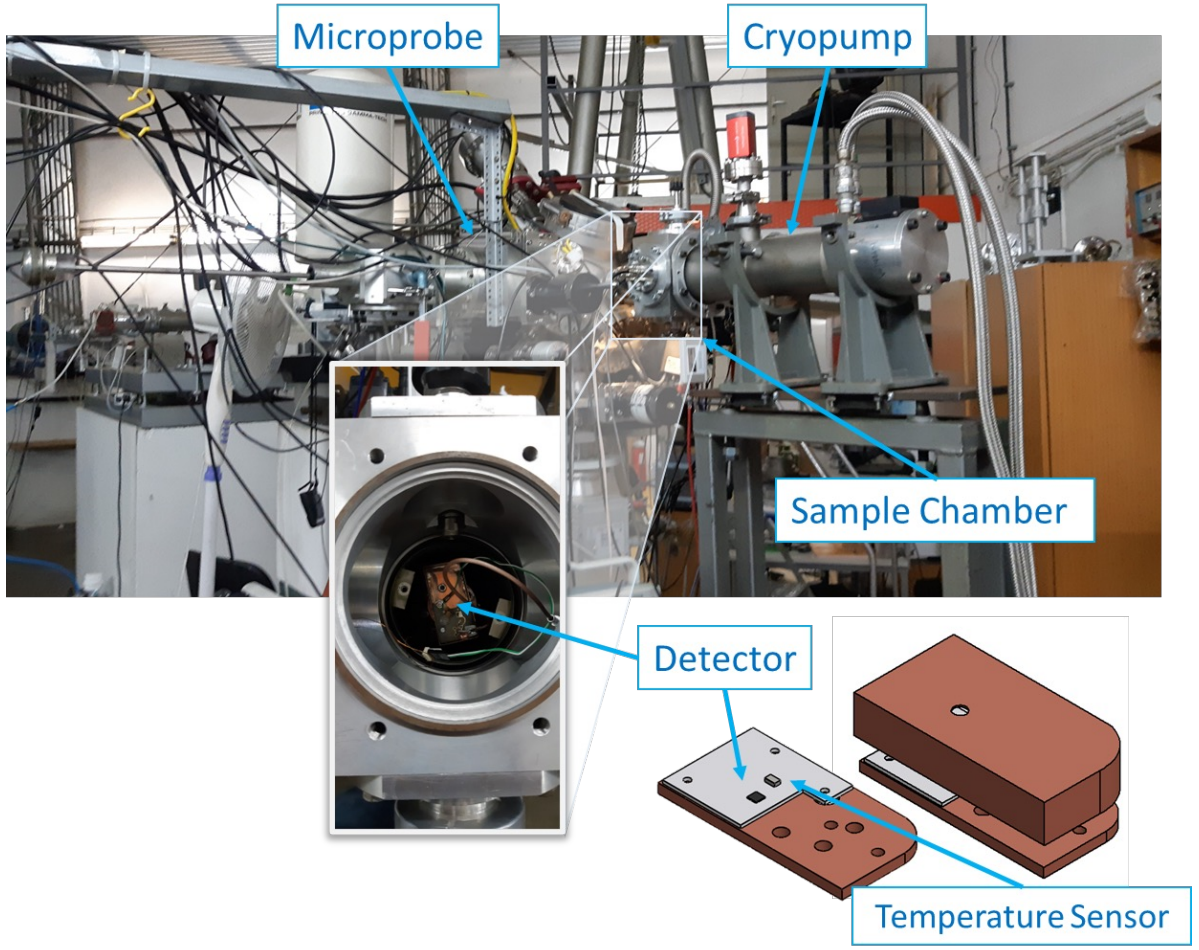
- High radiation tolerance
- Stability at cryogenic temperatures
- Fast response time
- High sensitivity to neutrons and lower sensitivity to γ-rays

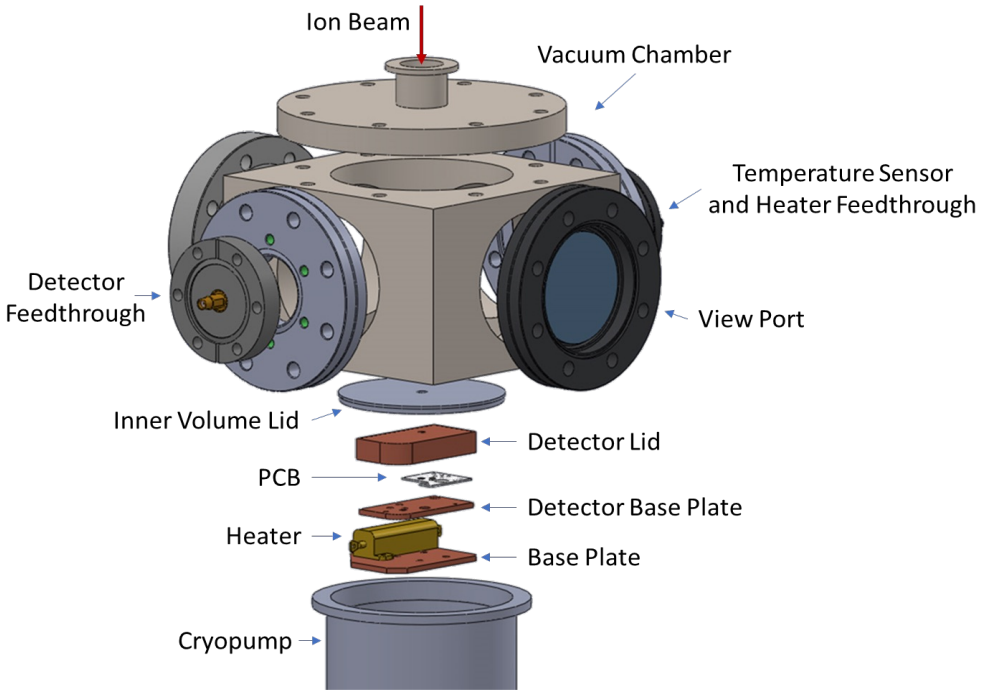
scCVD diamond detectors

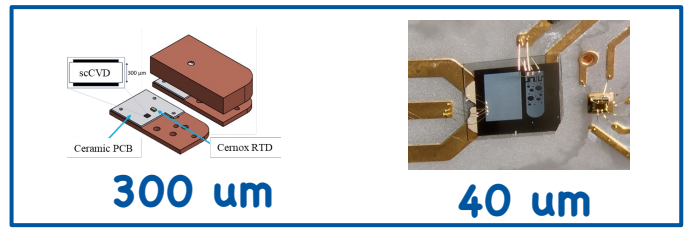
Study of Diamond detectors at cryogenic temperatures

DRD3

Two scCVD diamond crystals were obtained. The detectors were fabricated at LIBI and at CEA-LIST. A portable cryogenic setup was developed.



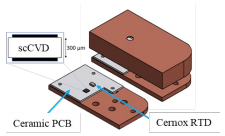




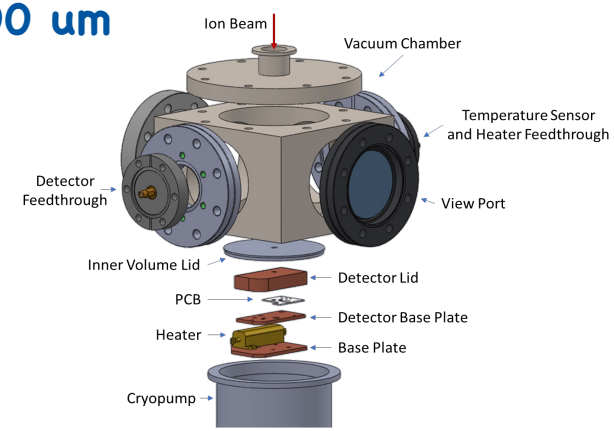
Study of Diamond detectors at cryogenic temperatures

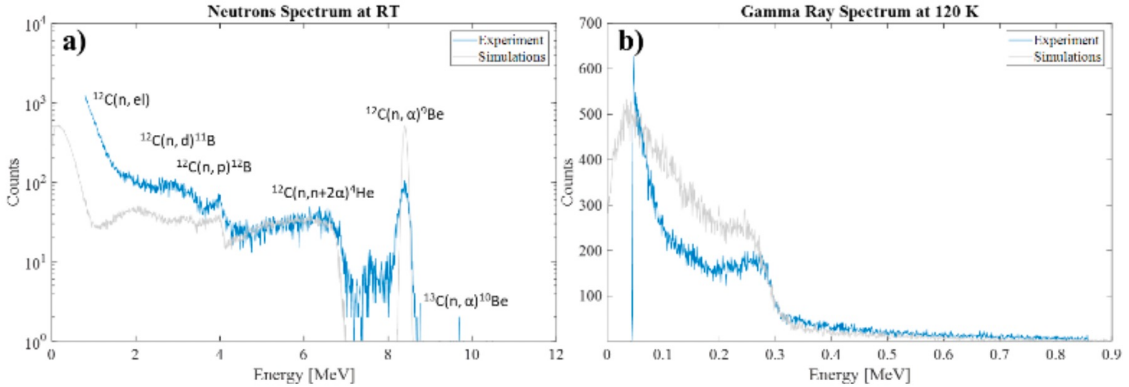
DRD3

Using the 300 um thick detector, measurements were carried out in neutron and gamma ray fields.

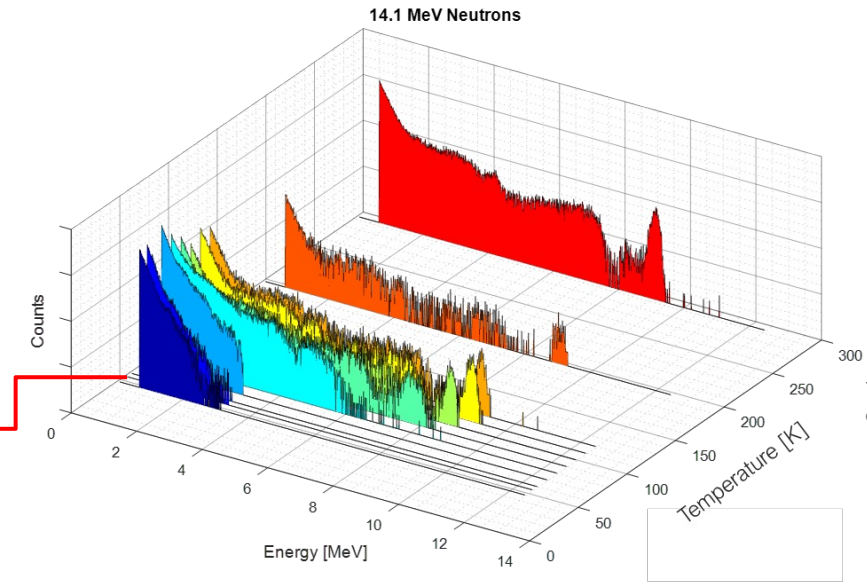


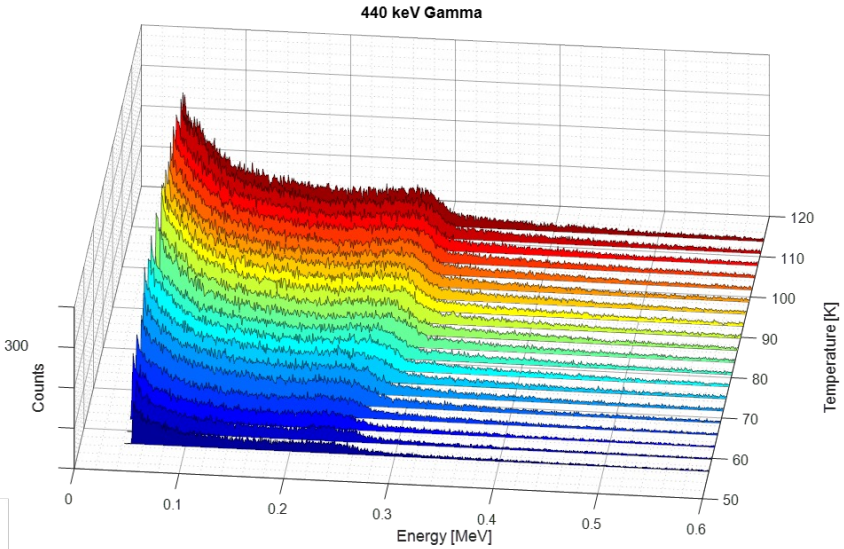
300 um





Room temperature pulse height spectra



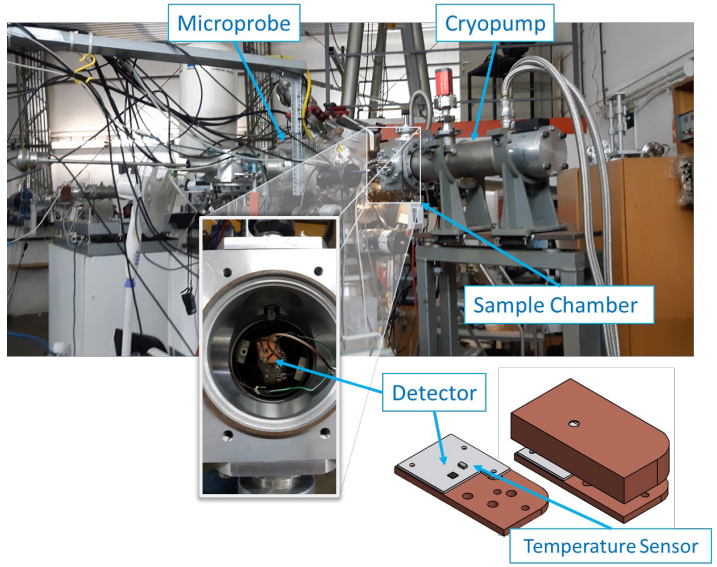


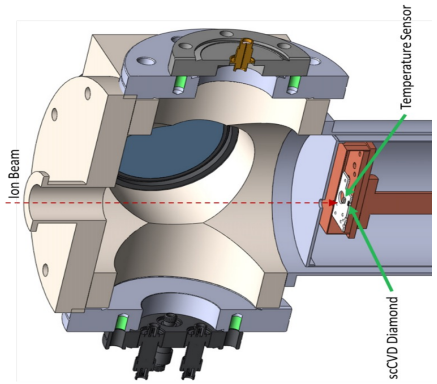
Drastic degradation of detectors signal on neutrons below 120 K !

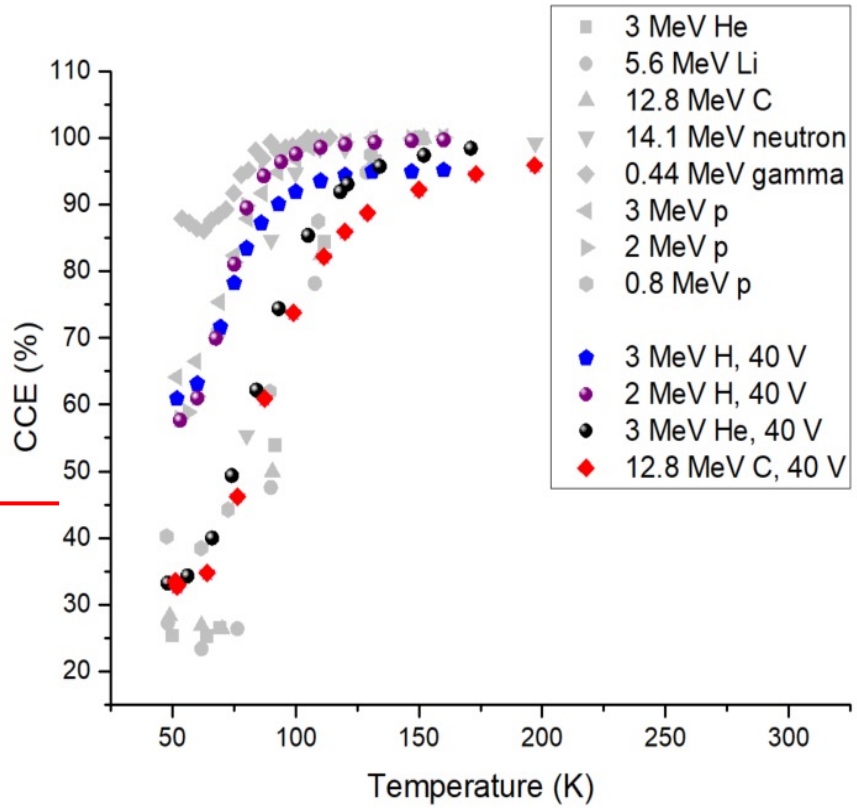
Study of Diamond detectors at cryogenic temperatures

DRD3

A systematic IBIC study was carried out at the RBI microprobe using a thick and a thin detector.

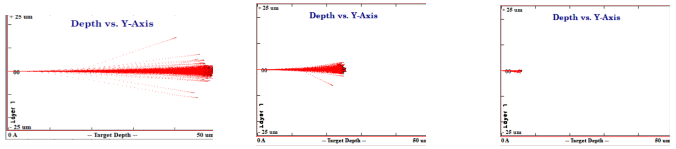


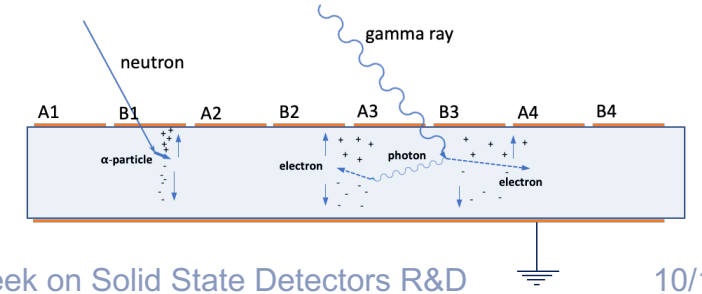




Lattice energy is not enough to break the excitons formed below 120 K. As such less charge is collected.

Signal drop depends on type of radiation. i.e. the density of the charge cloud.





Study of Diamond detectors at cryogenic temperatures

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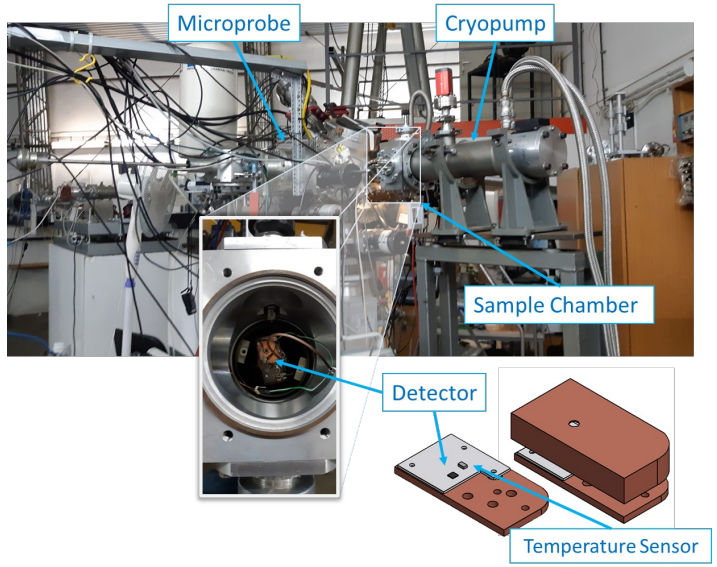
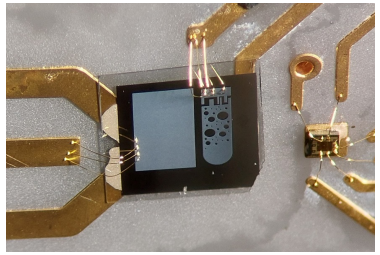
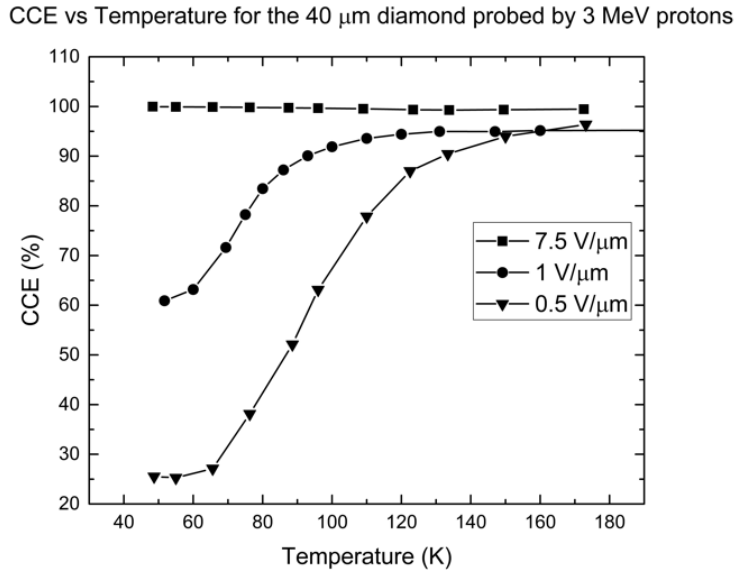




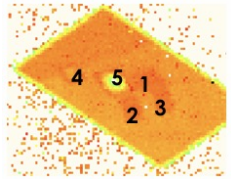
40 um

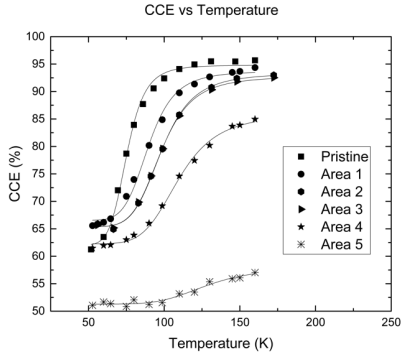
Voltages up to 10 V/um
Could be applied

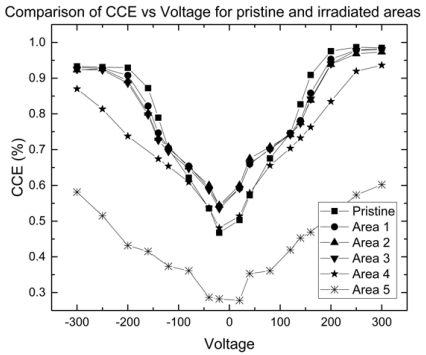
Recovery of signal

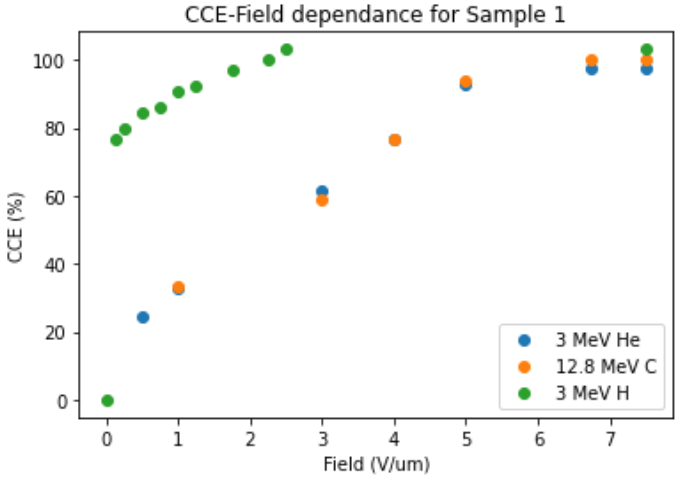


Radiation hardness study of scCVD diamond at cryogenic temperatures









Examples of IBIC detector studies at RBI within EURO-LABS and RADIATE

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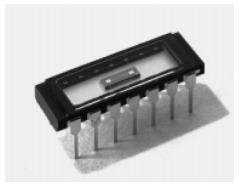
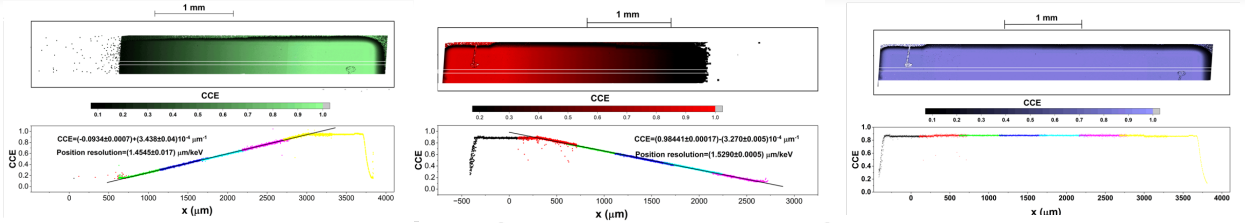
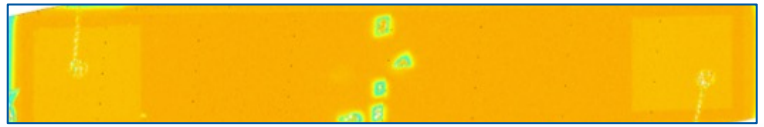
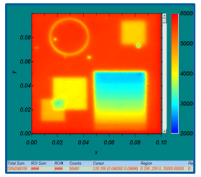
Fabrication of Si position sensitive detectors – Structuring Radiation Damage (E. Vittone – EURO-LABS)

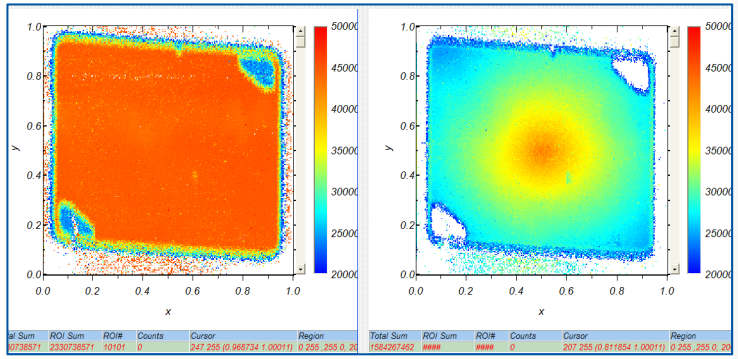




$$Q_i(x) = \int_0^R dy[\Gamma(y) \cdot Q_i(x,y)] = -q[\psi_i^+(x,0) - \psi_i^+(x,d)] \cdot \int_0^R dy[\Gamma(y)]$$
$$= -q[\psi_i^+(x,0) - \psi_i^+(x,d)] \cdot E_I$$
$$CCE_i(x) = \frac{Q(x)}{q \cdot E_I} = [\psi_i^+(x,0) - \psi_i^+(x,d)]$$





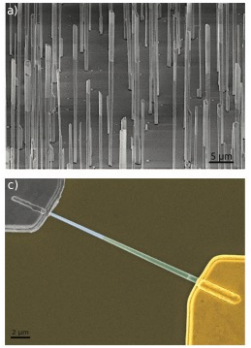


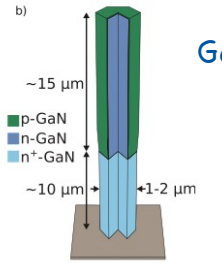
Silicon linear PSD IBIC analysis

Model and Experiment

Study of Charge Collection Efficiency properties of GaN nanowire detectors (D. Verheij – RADIATE)

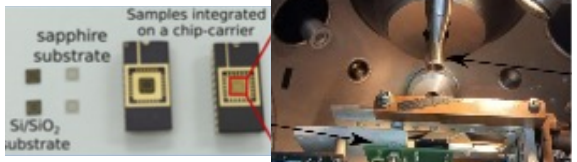
CCE characterization of GaN nanowires



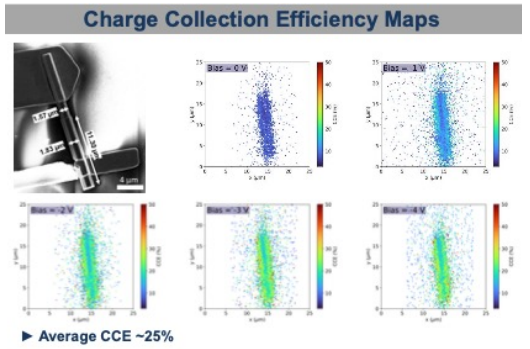


GaN microwires grown on sapphire substrate

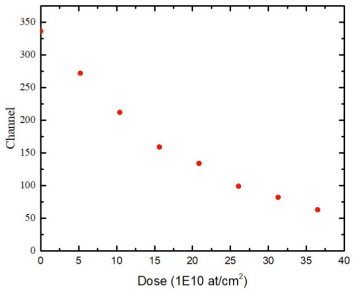
Low-noise electronics



GaN core-shell p-n junction microwires (Particle and UV light detection)



Degradation of the signal at the highest CCE pixel area



GaN signal near the core-shell. First radiation hardness studies on GaN

Moving soon to the New LIBI with upgraded 6 MV accelerator

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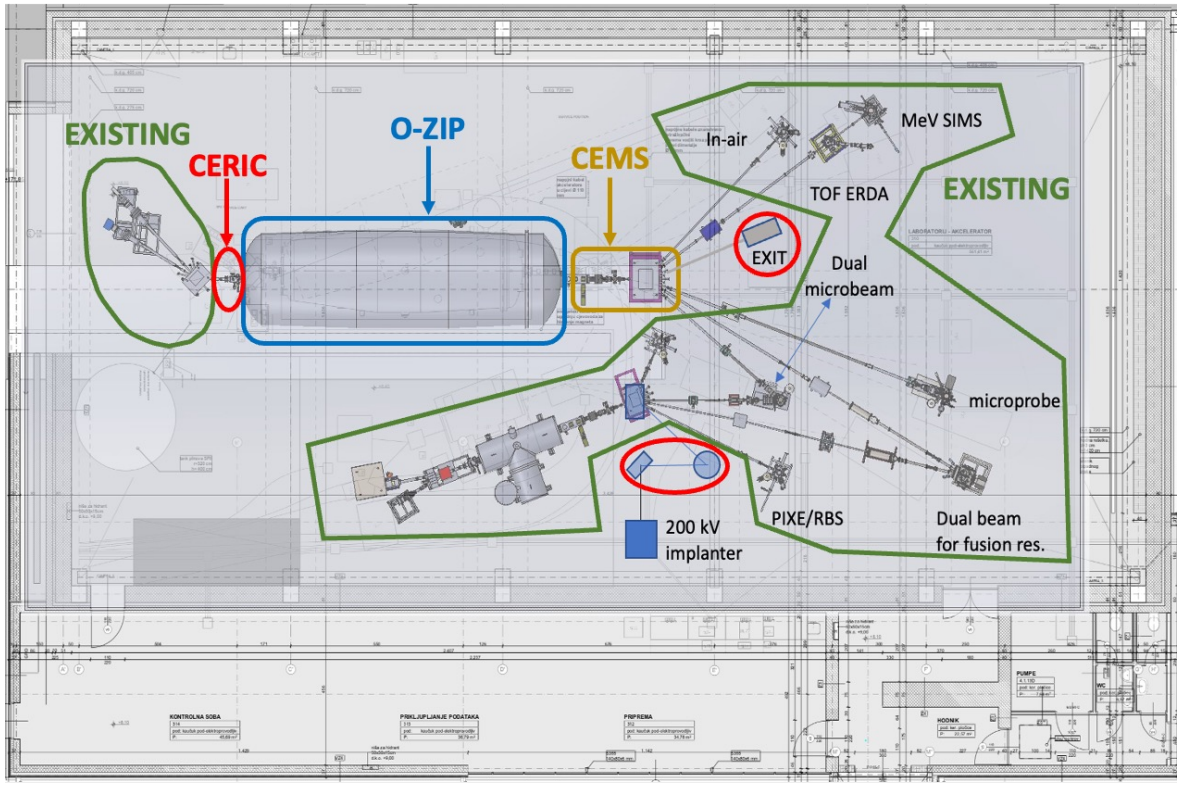
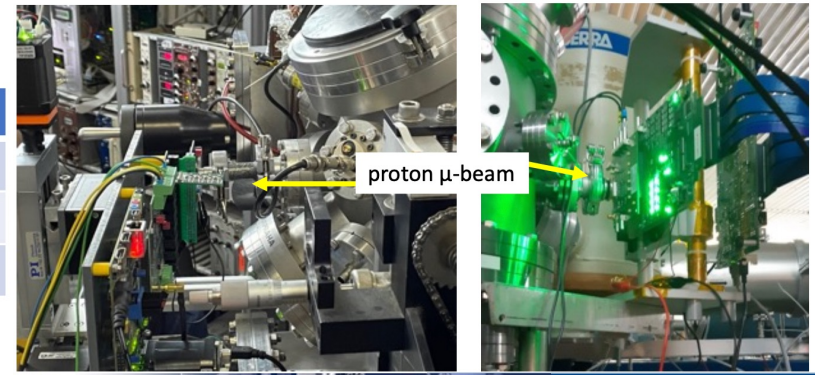


Moving to the new site starts in Spring 2025!

Increased penetration depth up to 700 um

In air beam spots of 1um will be achieved.

Energy / air path	100 nm Si_3N_4	6 µm diamond
3 MeV / 0.5 mm	1.0 µm	9.0 µm
6 MeV / 0.5 mm	0.5 µm	4.3 µm
9 MeV / 0.5mm	0.3 µm	2.9 µm



Thank You !