# Task 4.2: Micro-beam upgrade at RBI accelerator facility

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Georgios Provatas

# Task 4.2: Micro-beam upgrade at RBI accelerator facility

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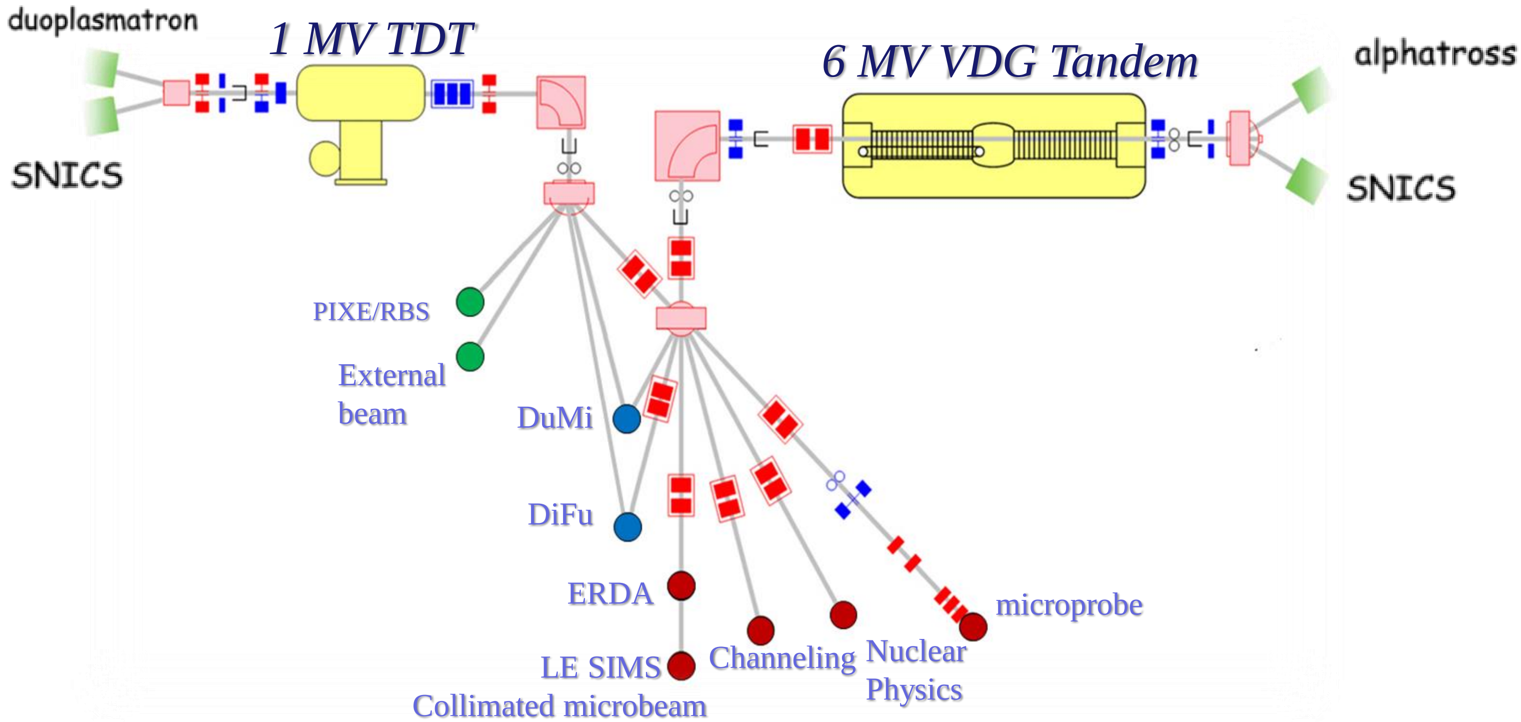
- Upgrade the two existing ion micro-beam end stations
  - Upgrade of microprobes with precise target positioning systems
  - Sample cooling option for the old microprobe

# Task 4.2: Micro-beam upgrade at RBI accelerator facility

The RBI accelerator facility infrastructure




The RBI-AF consists of two electrostatic accelerators with four ion sources and nine end stations

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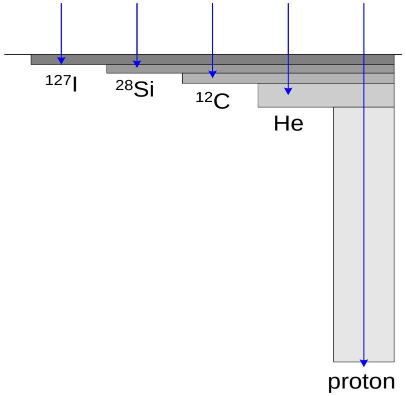
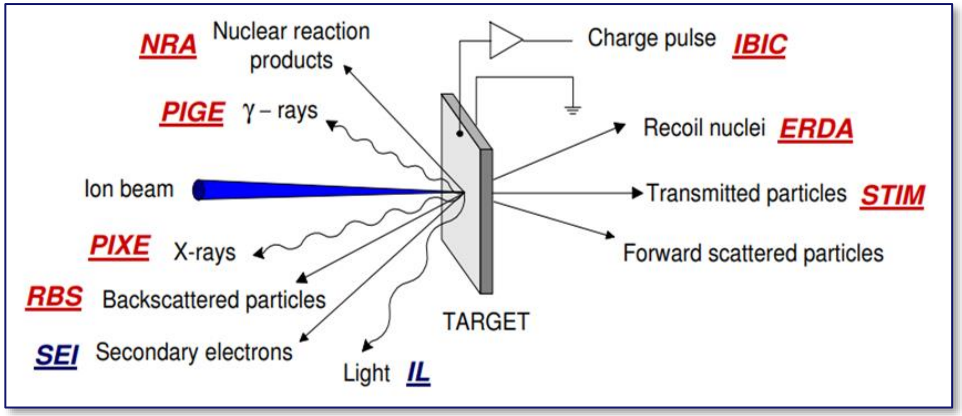
Various ions can be accelerated using one of the four available ion sources. For example, **protons** ban be accelerated to energies between about **100 keV** to **10 MeV**. In silicon 1 MeV protons have range of 16.3 µm and 10 MeV protons 709 µm




| Silicon | I 127 | Si 28 | C 12 | He 4 | H 1 |
|---|---|---|---|---|---|
| Range(µm) E=1 MeV | 0.37 | 1.13 | 1.6 | 3.5 | 16.3 |
| Range (µm) E=10 MeV | 3.7 | 4.8 | 9.5 | 69.7 | 709 |

RBI-AF main applications are materials analysis and materials modification



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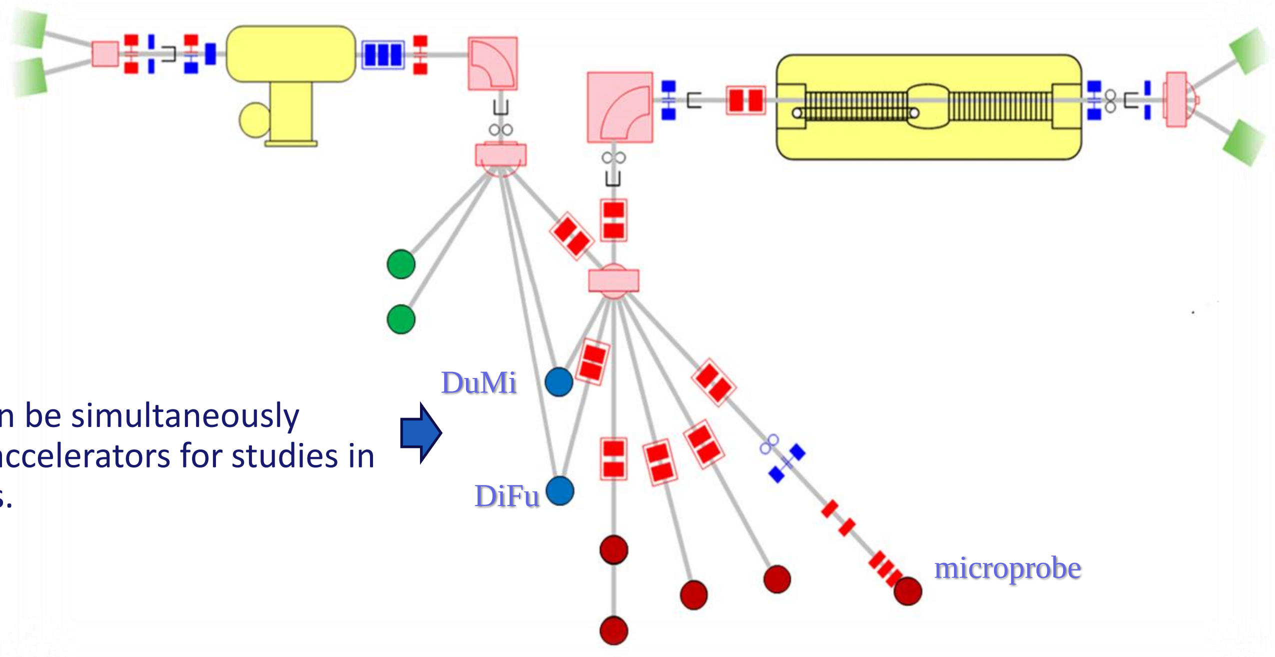


Two end-stations can be simultaneously reached from both accelerators for studies in mixed environments.

The RBI-AF is regularly used for detector characterization by means of the IBIC technique and detectors/materials hardness studies and fabrication by means of precise irradiations

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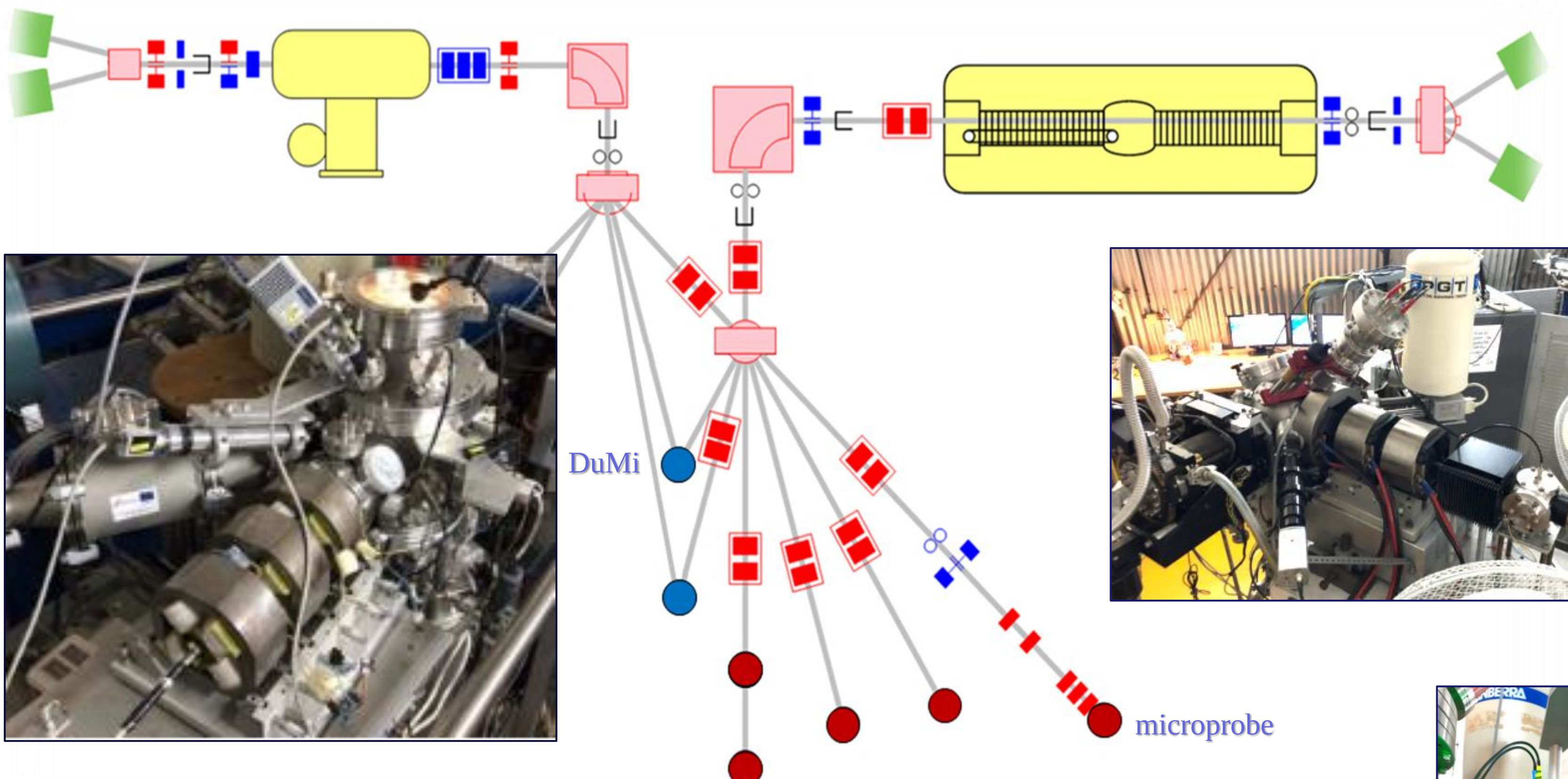


Detector characterization and precise irradiations are carried out by ion beam scanning microscopy. The lab has two microprobe end stations, providing microbeams (vacuum/ambient) with resolutions ranging from 120 nm to several um.

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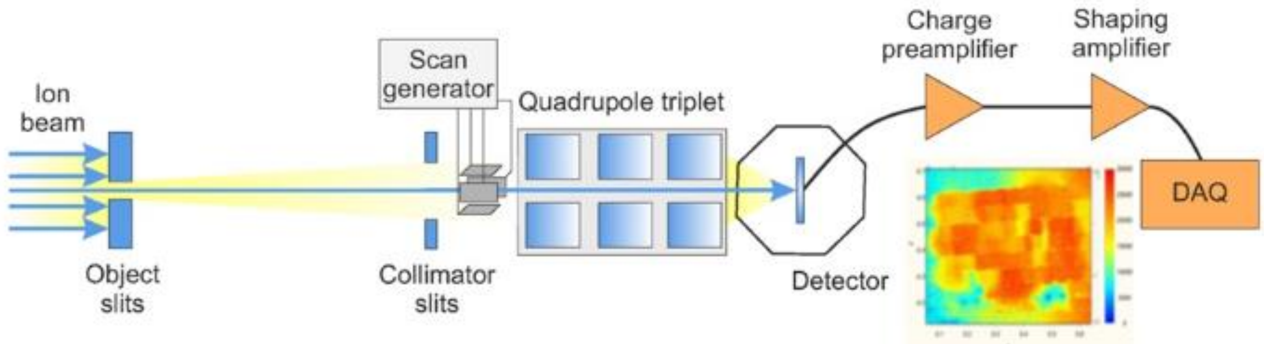
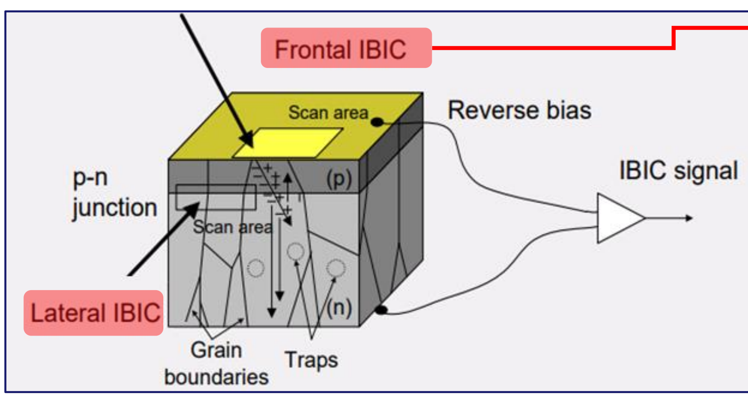
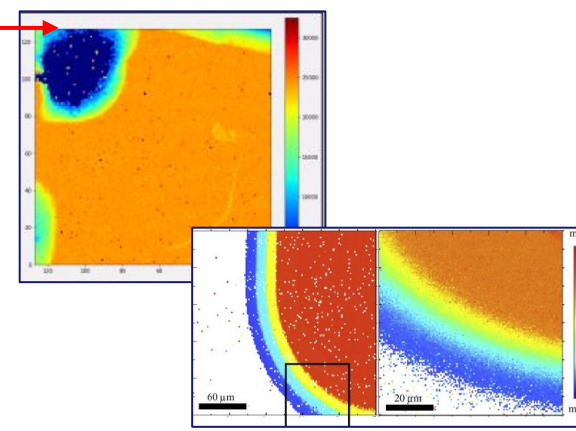
In Ion Beam Induced Charge microscopy, the charge collection properties of semiconductor devices are studied. With IBIC the detectors response, i.e. the CCE, is obtained along the whole volume of the device.




CCE mapping

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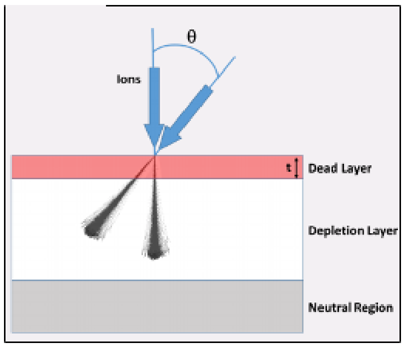
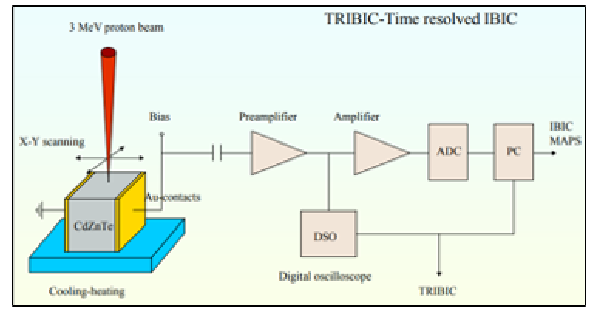
Other properties of detectors (dead/depletion layer, charge carriers kinetics … ) can be studied with variations of the IBIC microscopy.

Angle resolved IBIC




Study of dead layer
Probing different depths
without change of beam

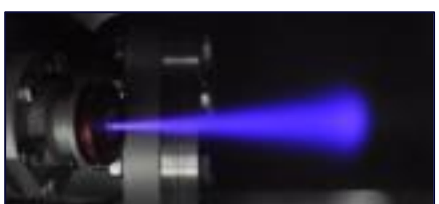
Time resolved IBIC

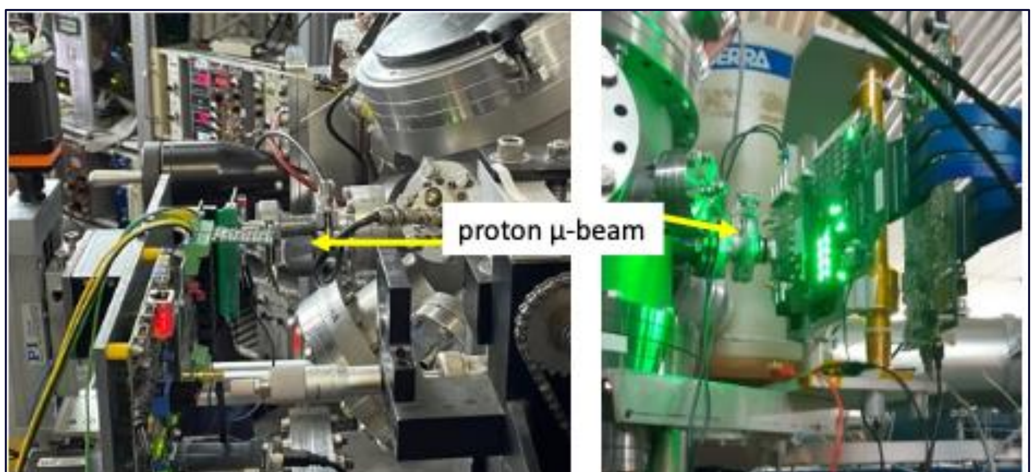



Transient current or charge pulses studies

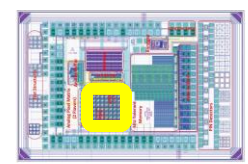
If the device is too big,

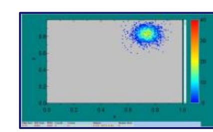
*We can extract the beam in atmosphere*

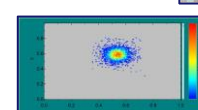





Study of pixel detectors

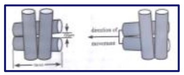


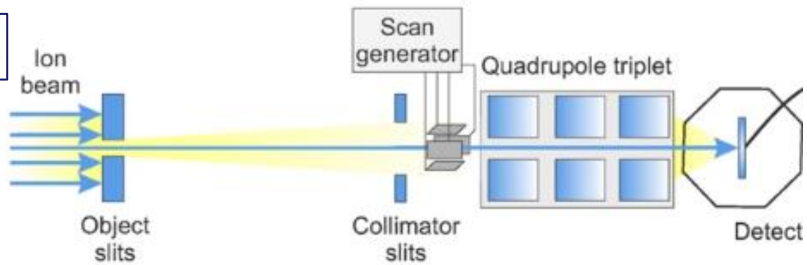




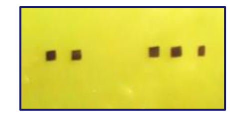
# Task 4.2: Micro-beam upgrade at RBI accelerator facility

*Applications requiring precise irradiation control, i.e. radiation hardness studies, materials modification, creation of color centers etc, are carried out in a microprobe setup.*

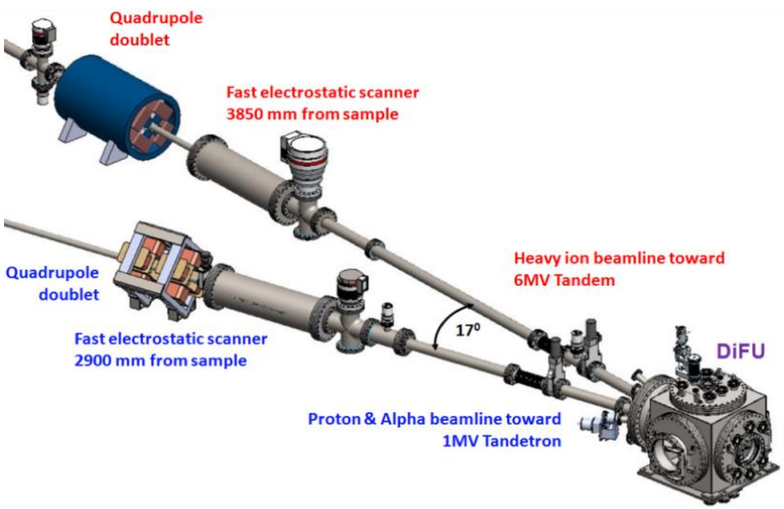





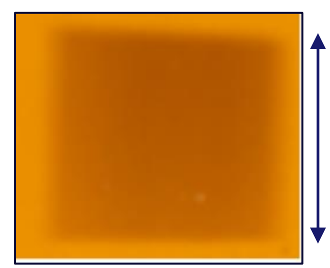

*Precise current control within fA-nA range.*

*A um beam spot is scanned over areas up to 1x1 mm$^2$*

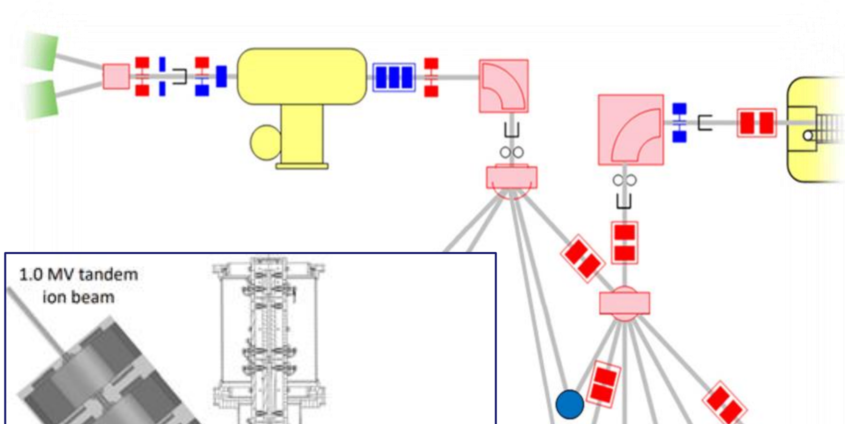



*For irradiations of larger areas, the DiFu end-station is employed. There the beam is scanned by electrostatic scanners positioned 3-4 m from the sample.*

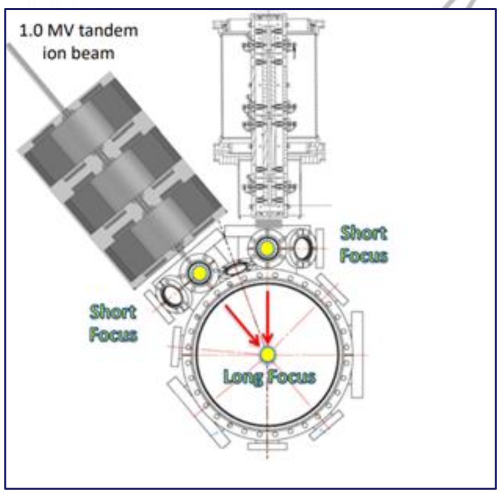


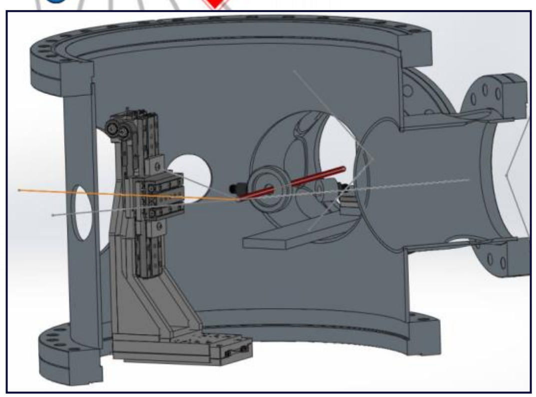
*3 x 3 cm$^2$*

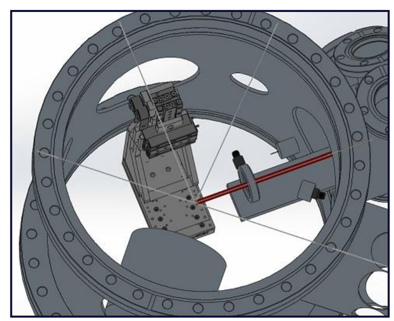
# Task 4.2: Micro-beam upgrade at RBI accelerator facility

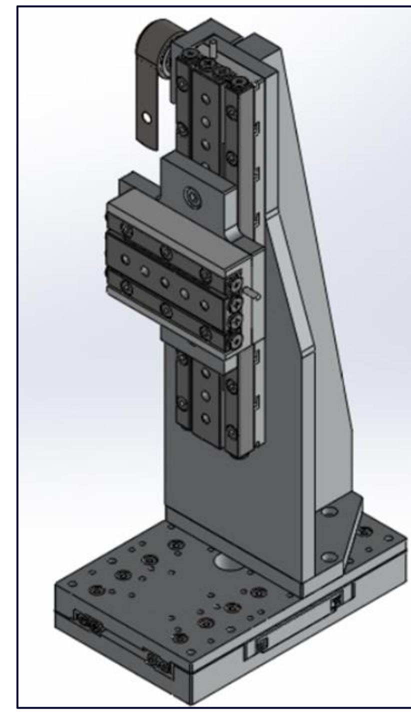


*A SmarAct Linear Piezo 3D setup with closed-loop positioning resolution of 1 nm with tens of nm positioning repeatability even over longer travel ranges was selected.*



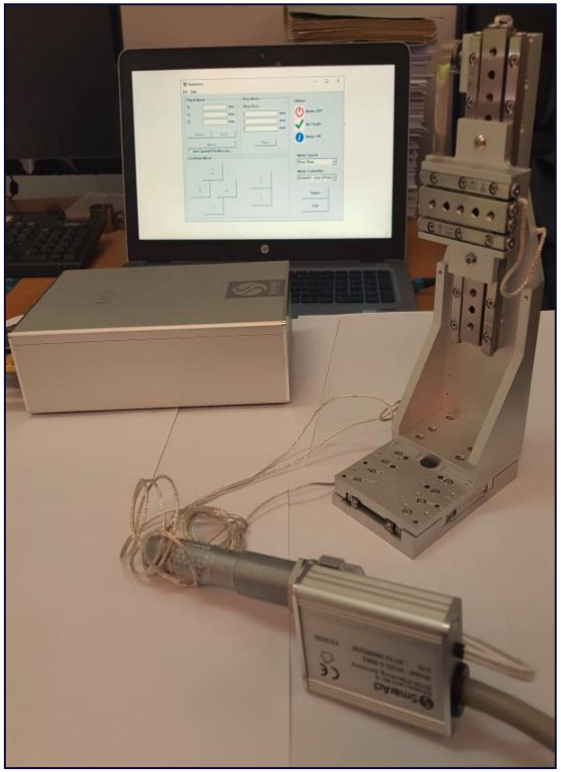



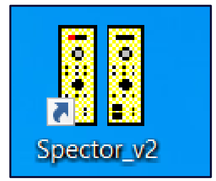




*New precise and motorized sample positioning stage for in-vacuum work at the new ion micro-beam station was designed for the DuMi vacuum chamber*

# Task 4.2: Micro-beam upgrade at RBI accelerator facility





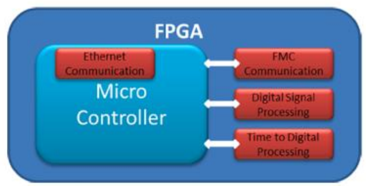
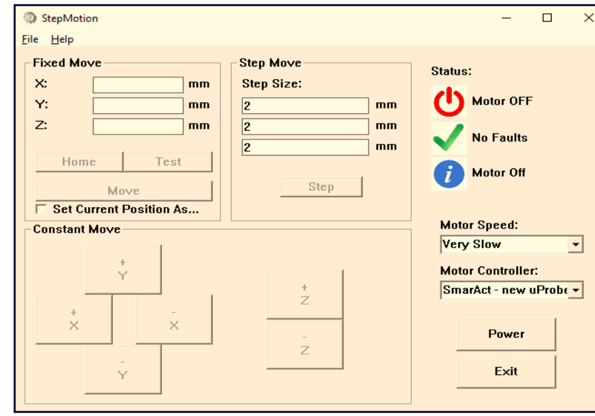



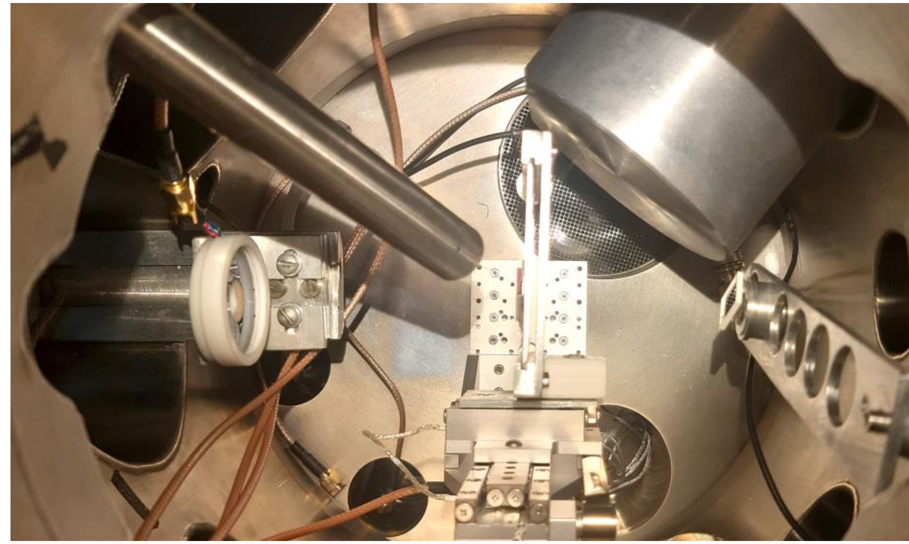

Fig. 1. FPGA Design.



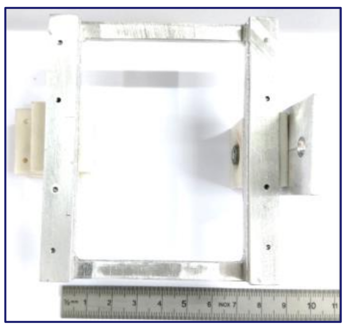

*The related software for movement of the sample on the piezo-stage has been developed and integrated with the in-house software for data acquisition SPECTOR into the unique integrated software for data acquisition and control*

# Task 4.2: Micro-beam upgrade at RBI accelerator facility

*The components for the motorized stage were installed in the DuMi chamber.*

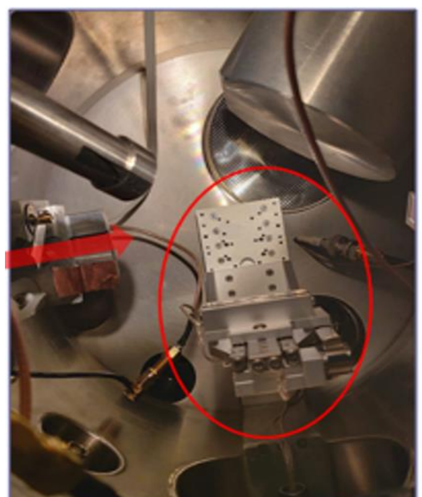


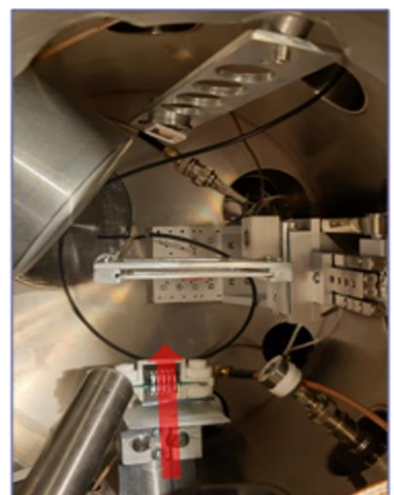
*A sample holder is attached on the piezo-stage inside the vacuum chamber*



*The working range is extended to 100 x 100 x 50 mm.*

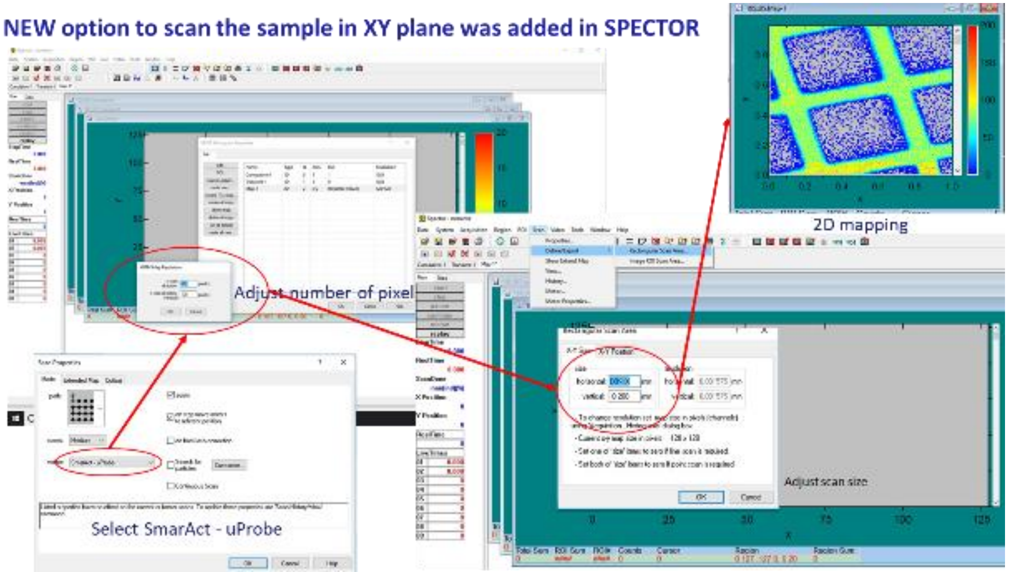
*The samples can be positioned at 90 deg and 60 deg with respect to the beam.*





# Task 4.2: Micro-beam upgrade at RBI accelerator facility

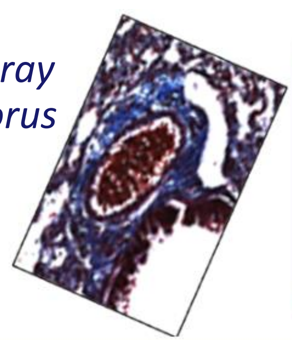
**NEW option to scan the sample in XY plane was added in SPECTOR**

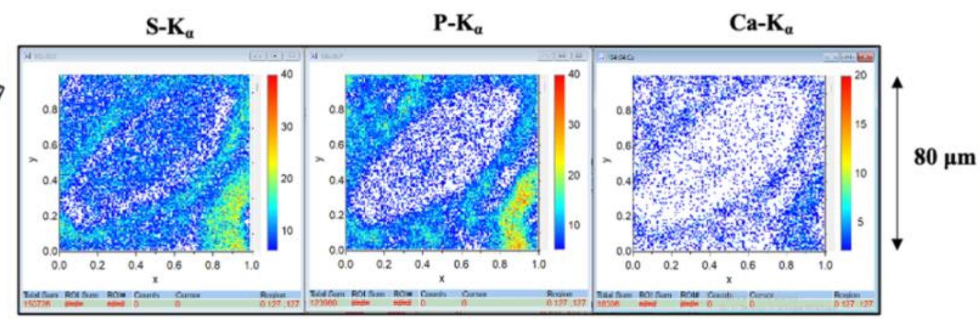



*New option to scan the sample in XY plane was added in SPECTOR.*

*Extended 2D mapping capabilities, two dimensional mapping of IBIC charge collection efficiency on samples in vacuum has been extended from areas of few mm² to few cm² in controlled way.*

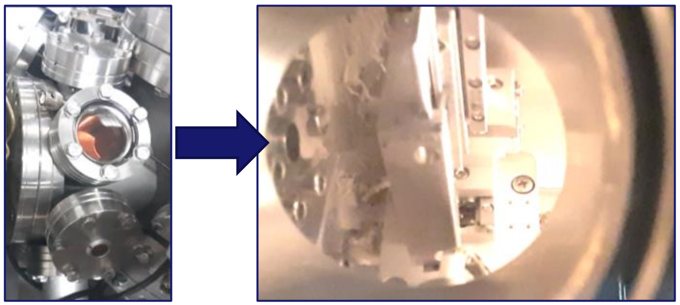
*Two dimensional maps of PIXE x-ray intensity maps (Sulphur, phosphorus and calcium) from thin samples containing organic materials.*



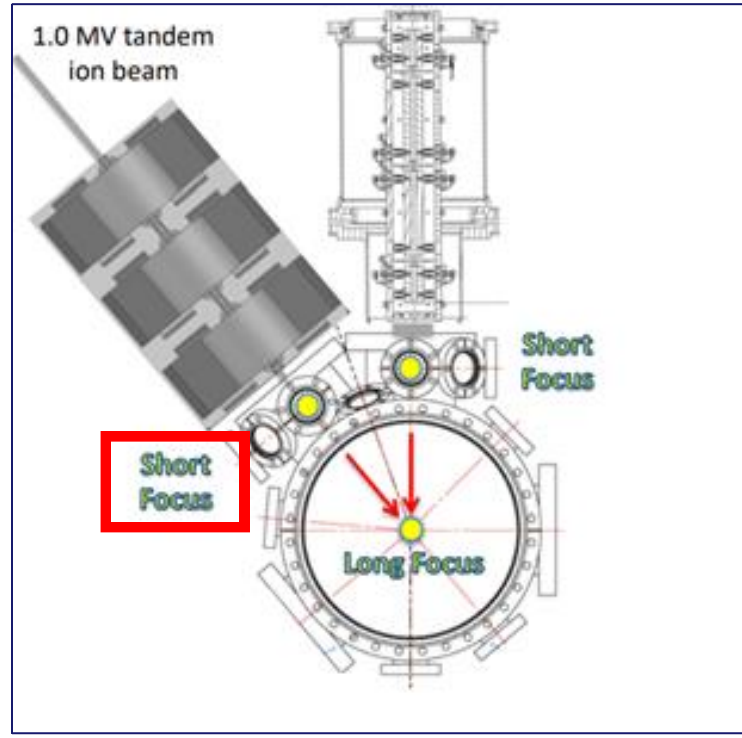


# Task 4.2: Micro-beam upgrade at RBI accelerator facility

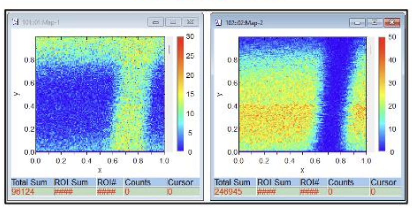
*DuMi offers the possibility of a working distance at 7 cm (**short focus**) with 150 and -35 demagnification values in x and y correspondingly.*

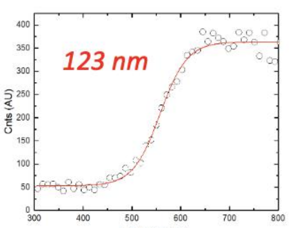


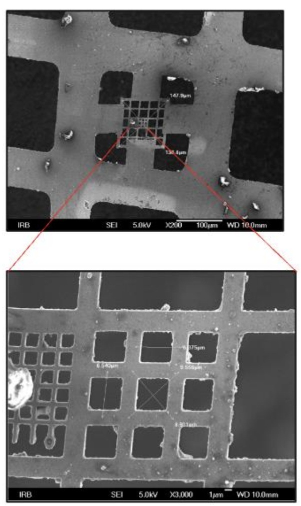
*Another SmarAct motorized piezo stage with 10x10x10 mm working range has been procured, installed and tested.*

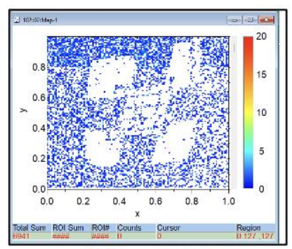



*On-axis STIM*

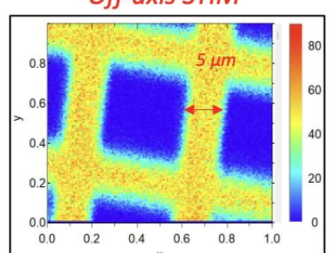






*Off-axis STIM*



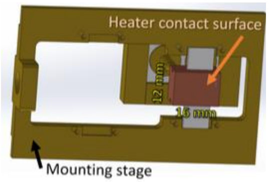

*With accurate positioning of a micromachined Ni grid in short focused we obtained the best ever RBI beam resolution*
***123 nm***

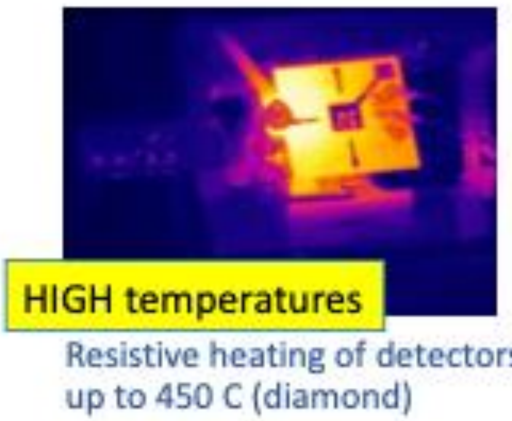


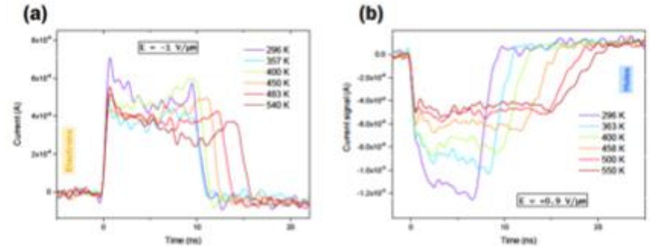
G. Provatas (RBI)

# Task 4.2: Micro-beam upgrade at RBI accelerator facility

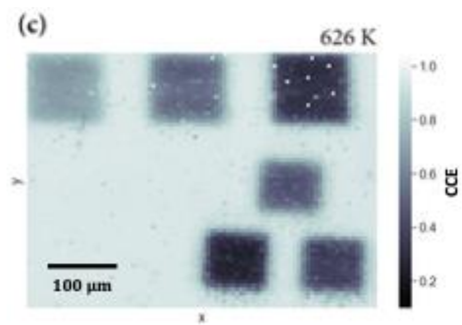
*Within RBI projects is the **study of detectors in extreme conditions**, i.e. radiation hard environments, high and low temperatures.*

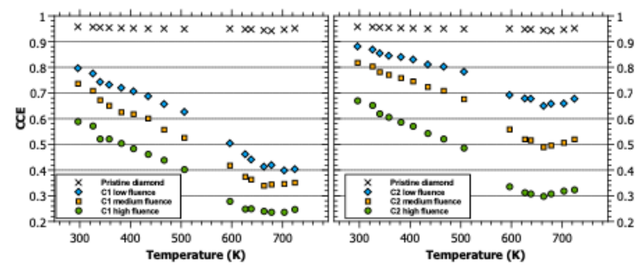



*Kinetics of charge carriers was studied in elevated temperatures by means of TRIBIC technique.*



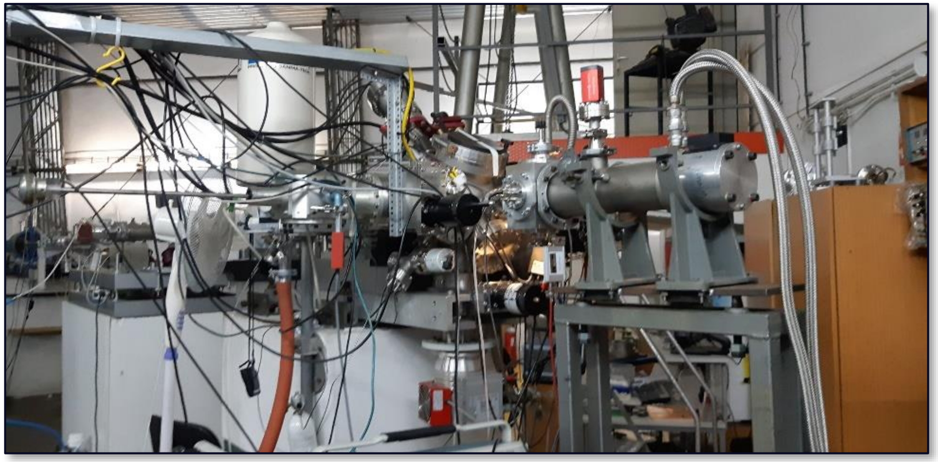




*Previously, studies of diamond response after high dose irradiations and at high temperatures by means of resistive heating was carried out.*

*Response/annealing after irradiation was study up to 700 °C by employing IBIC.*

# Task 4.2: Micro-beam upgrade at RBI accelerator facility

*In Task 4.2 **sample cooling** was considered only for the old microprobe. Two different sample cooling options have been tested.*

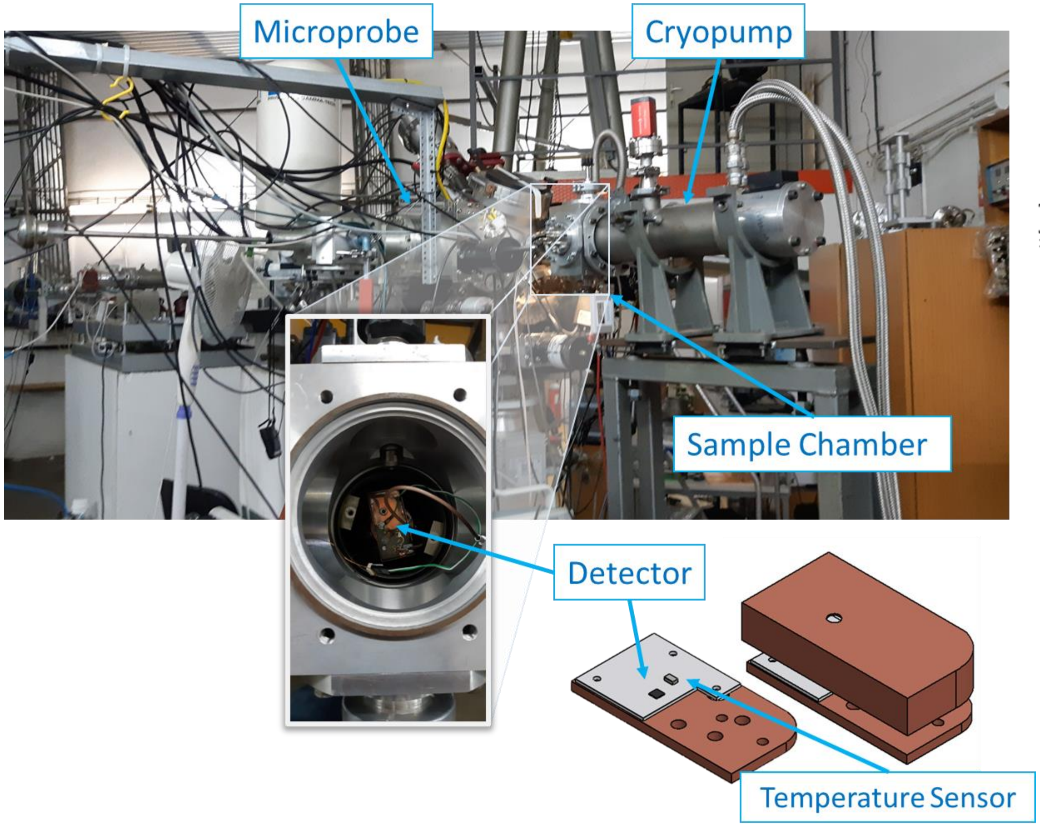


*Option A: Cooling to cryogenic temperatures with the use of a modified cryo-pump and resistive heating.*

*Option B: Passive LN2 cooling.*

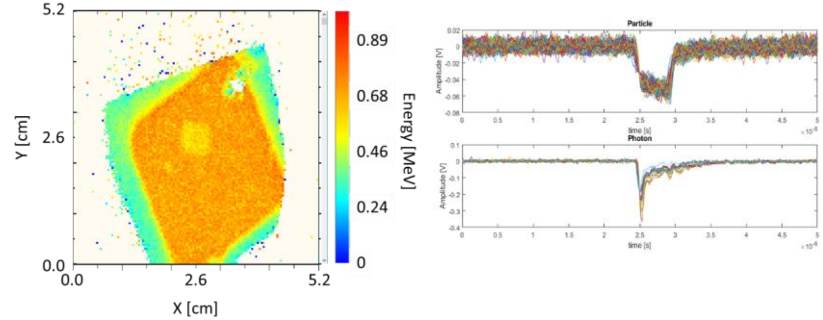
*IBIC study of detectors down to -4 $^{o}$C*

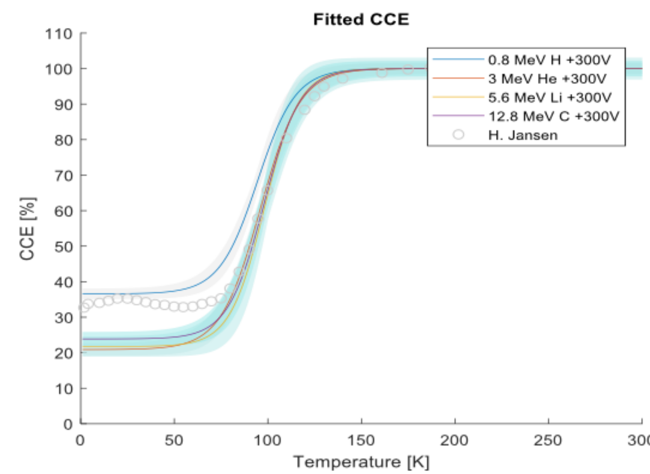
# Task 4.2: Micro-beam upgrade at RBI accelerator facility




*A 300 um thick diamond detector, planned to be used as a beam-loss monitor in DEMO Oriented Neutron Source (DONES) at cryogenic temperatures was studied with the developed system.*

*IBIC and TRIBIC characterization of diamond down to 38 K*




*CCE drop significantly below 100 K due to exciton formation*

# Task 4.2: Micro-beam upgrade at RBI accelerator facility

***Summary:***

- ✓ ***Two precise motorized positioning*** *systems for long and short focus positions at the* ***DuMi*** *setup have been designed, related components procured assembled and tested.*
- ✓ *The existing home made data acquisition and control system* ***SPECTOR*** *has been* ***upgraded*** *to enable the control of the new piezoelectric motorized stage.*
- ✓ *Upgrade of the old microprobe with possibilities for sample cooling. Cryogenic and passive LN2 cooling have been installed and tested. Detectors can now be tested down to 38 K.*

*Milestone M23 has been achieved*

***Future activities within Task 4.2:***

- *Installation of precise target positioning system at the old microprobe*
- *Improvements of old microprobe cooling system for studies below 38 K.*

# Thank you!

On behalf of RBI group:

Iva Božičević Mihalić, Donny D. Cosic, Stjepko Fazinić, Milko Jakšić, Milan Vićentijević, Andro Kovačić