Present status and selected research activities at Ruđer Bošković Institute accelerator facility

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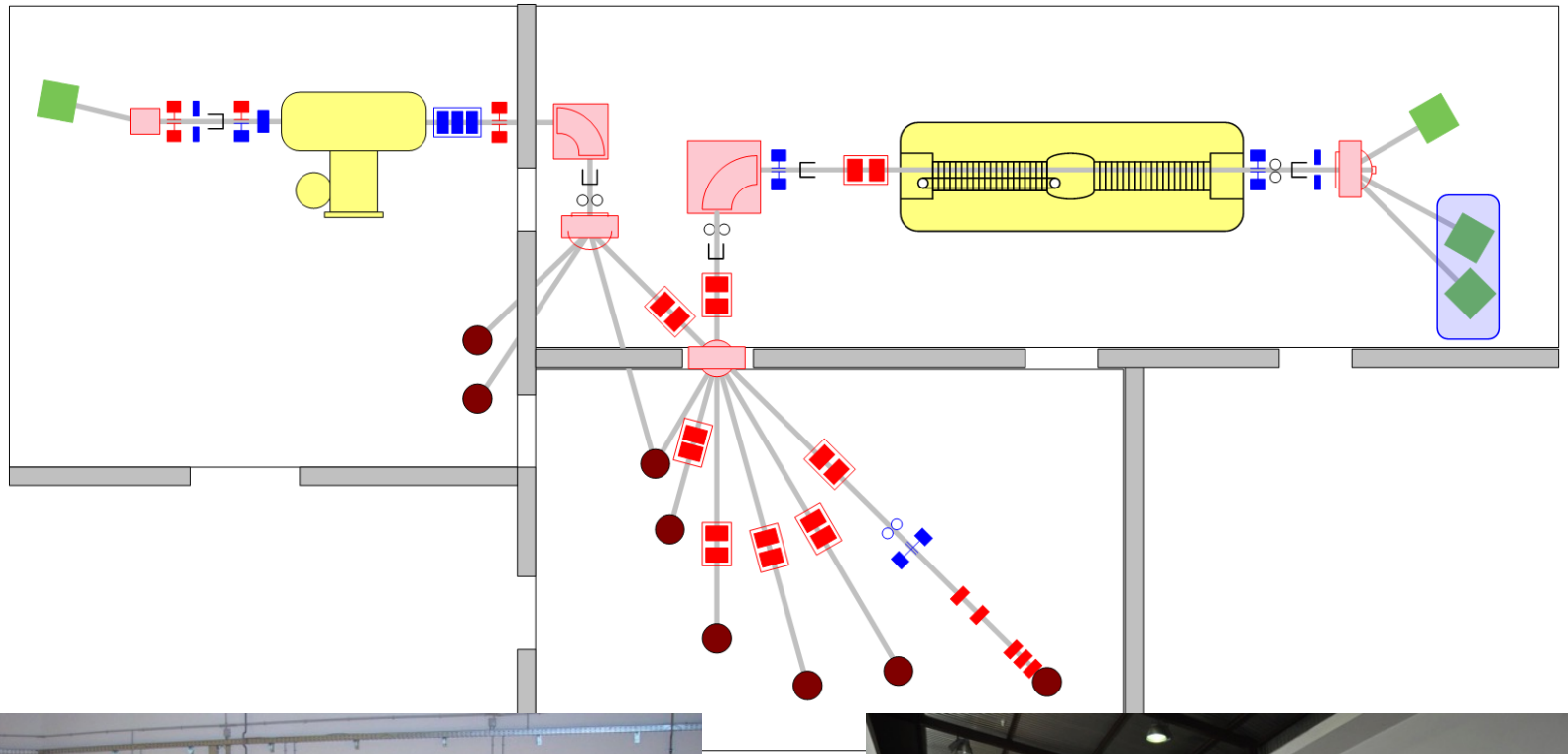
GRIT workshop, Florence, Italy

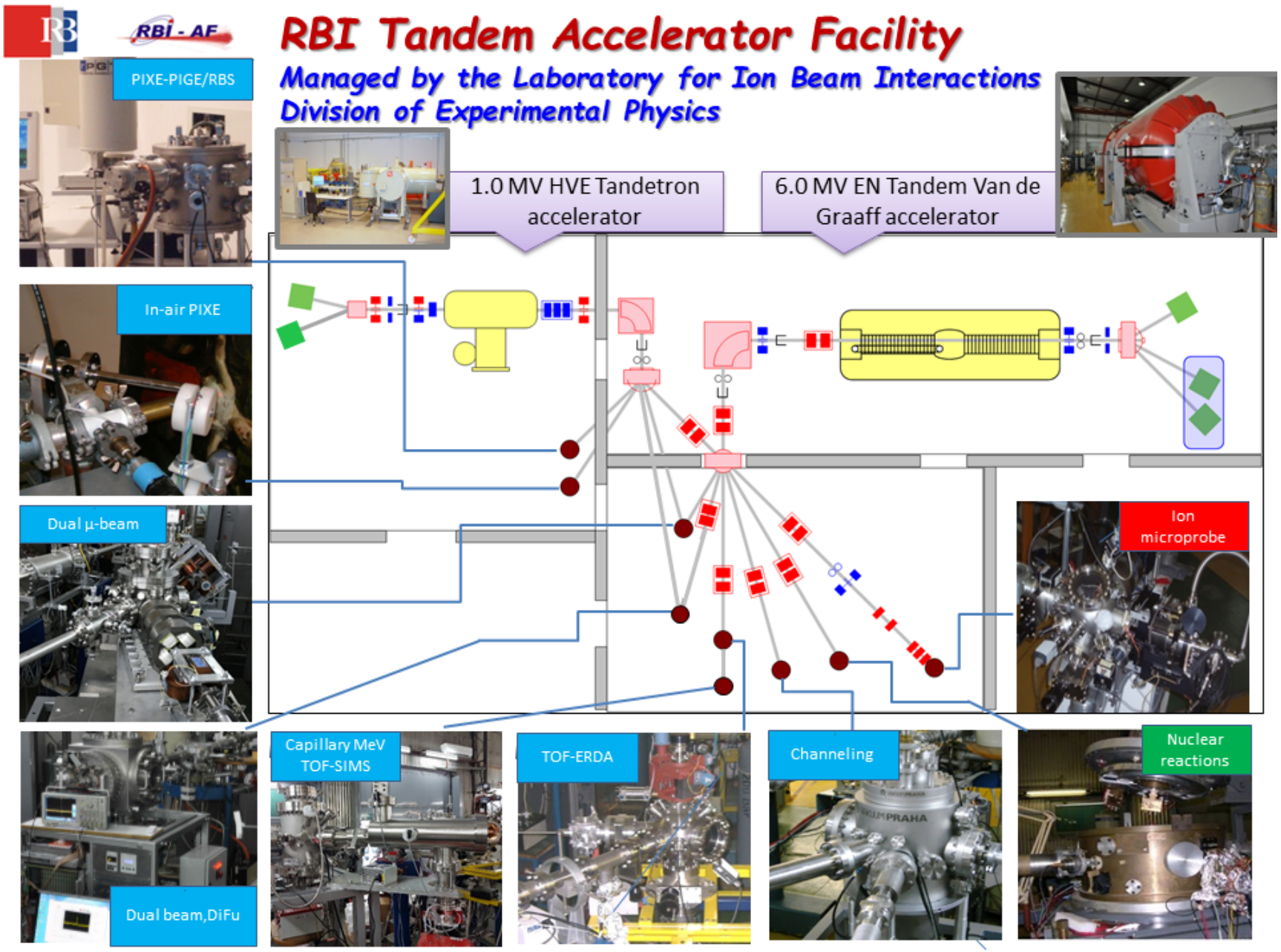
RBI accelerator complex



1 MV HVE Tandetron accelerator

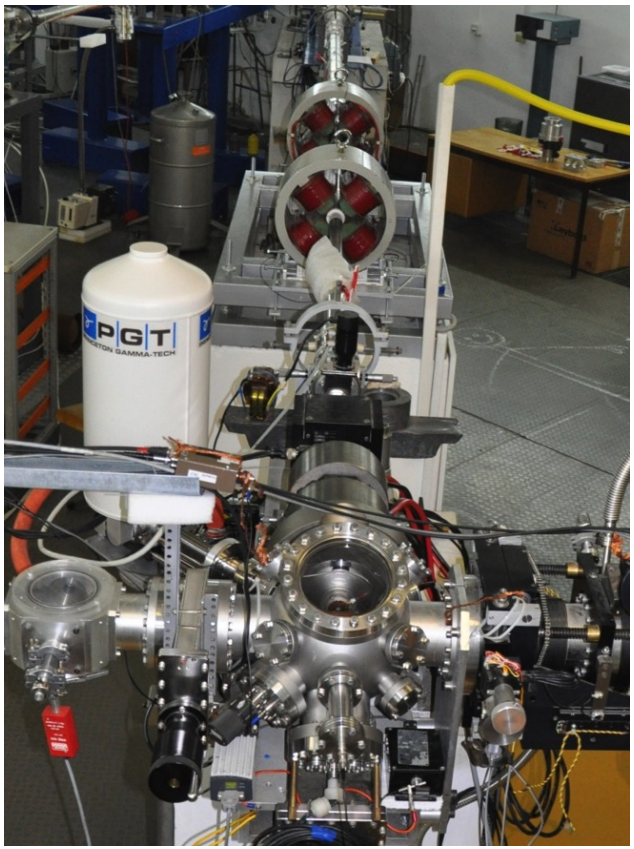
6 MV EN Tandem Van de Graaff accelerator

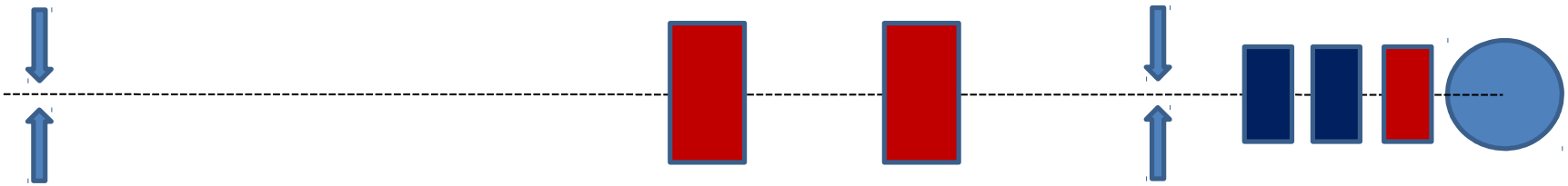
RBI accelerator complex: 9 beam lines



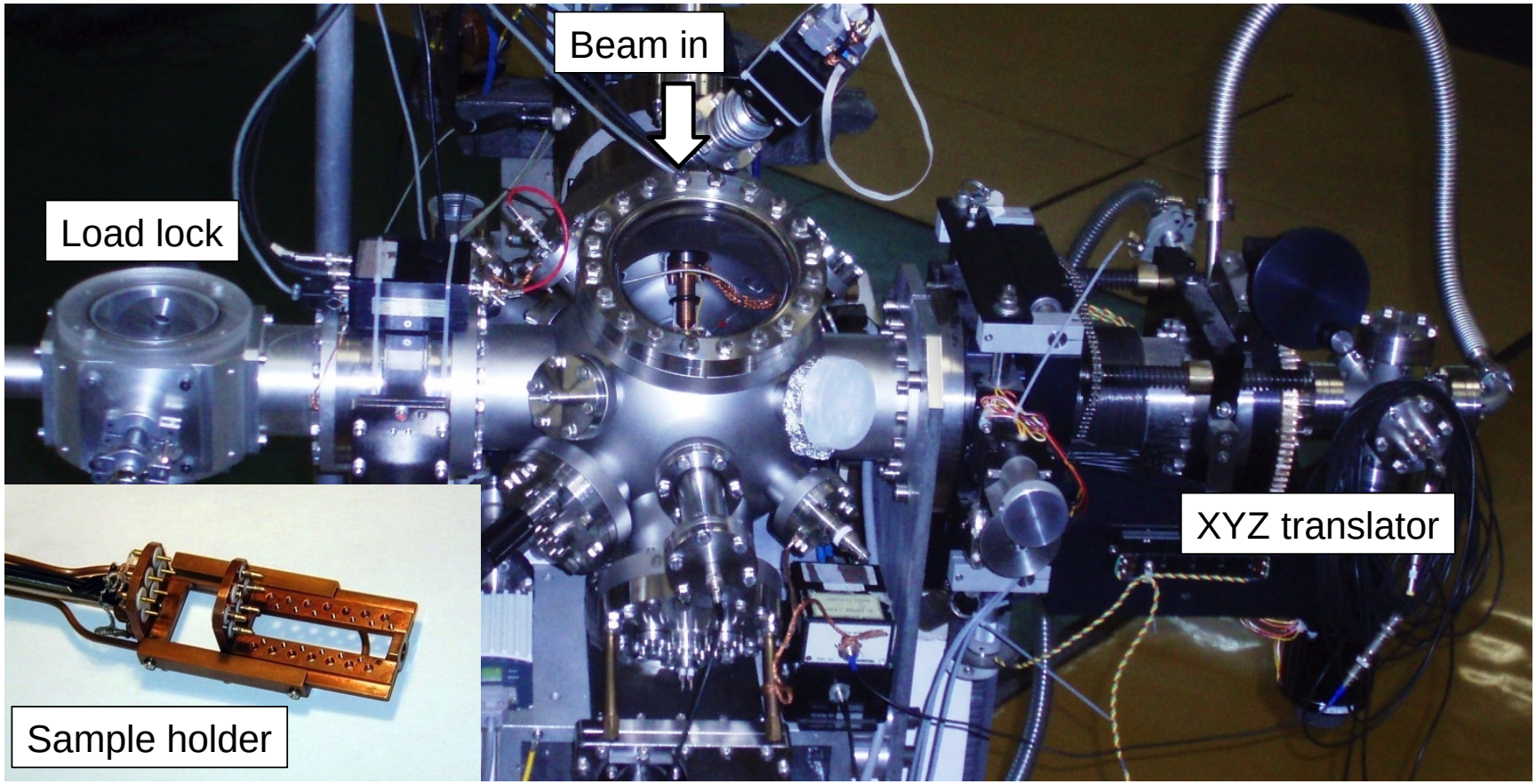
Nuclear microprobe

- a system of quadrupole lenses (doublet, triplet or quintuplet) - focus an ion beam to the μm size
- available beams: protons (0.4 to 8 MeV), most of other heavier ions (up to ME/q^2 ratio of 15 MeV)
- typical currents: 1 - 1000 pA, for the low current techniques (STIM and IBIC) reduced to fA range
- the beam spot size depends on: ion species, energy and current
  - as low as 250 nm
- **ideal radiation source for detector testing**
  - plenty of sample characterization techniques: PIXE, ERDA, RBS, NRA, PIGE, coincidence scattering, IL, MeV-SIMS, SEI, STIM and IBIC

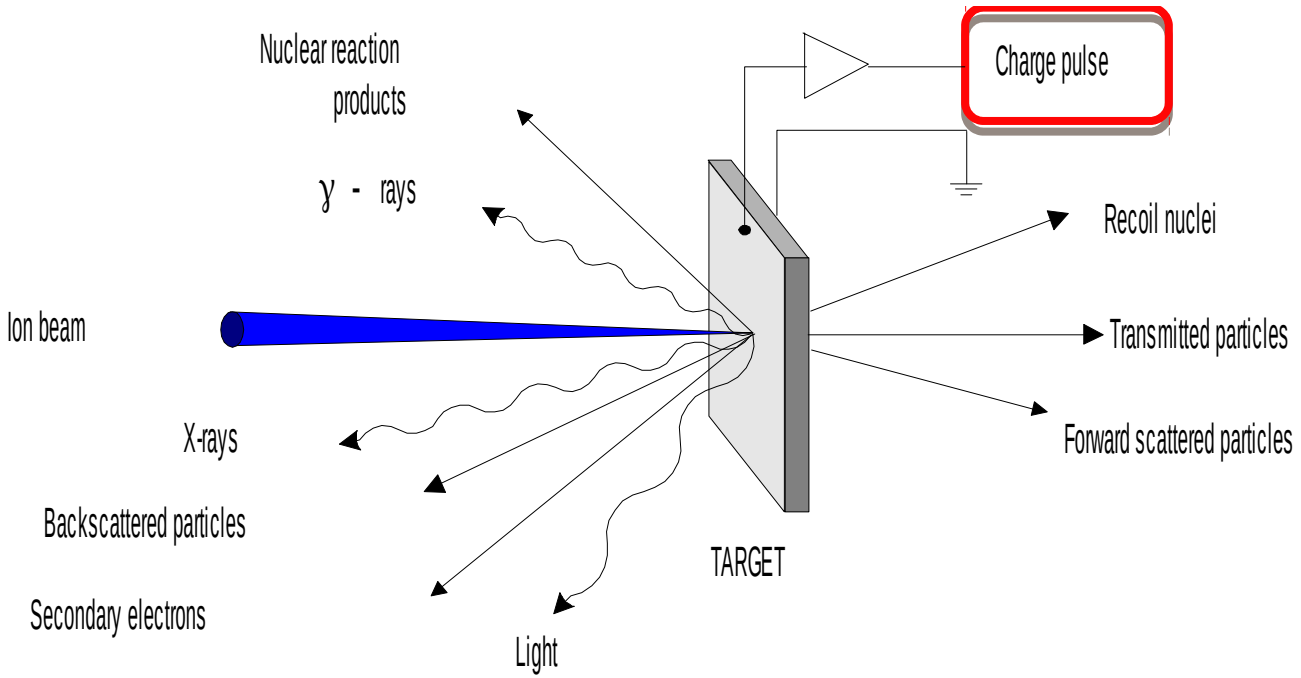




Nuclear microprobe



Ion beam analysis and nuclear microprobe



ANALYSIS (elements, isotopes) with **MeV ION BEAMS** - (nA, pA)

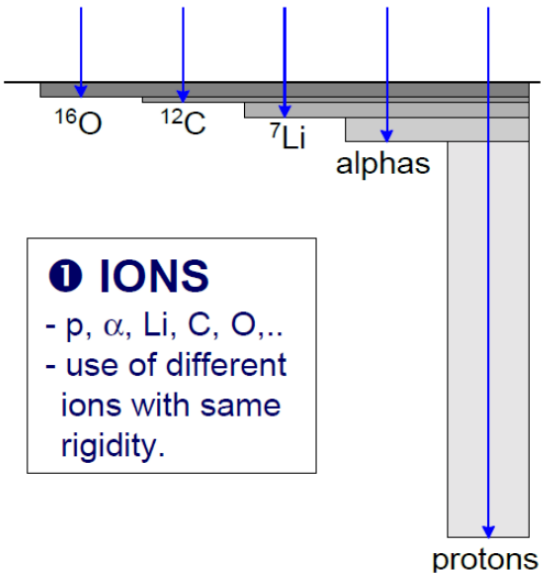
- <u>elements</u> - x-rays (**PIXE**)
  - backscattering (**RBS**)
  - recoil (**ERDA**)
- <u>isotopes</u> - nuclear reactions
  - γ - rays (**PIGE**)
  - particles (**NRA**)

CHARACTERISATION (density, charge transport, crystal structure, morphology,…) with **MeV SINGLE IONS** - (fA)

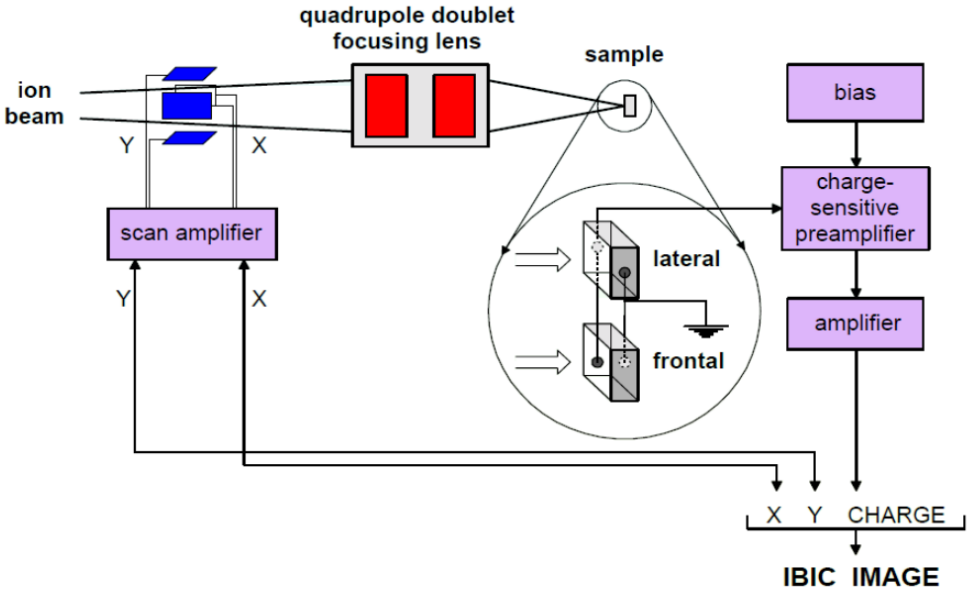
- density - transmitted ions (**STIM**)
- charge transport - charge pulse **(IBIC**)
- crystal structure - **channelling**
- morphology - secondary electrons (**SEI**)

Ion Beam Induced Charge IBIC

- measuring the electronic response of a particle-charged excitation
- IBIC signal: correlating ion position (microprobe) with signal height (depends on electric field, mobility and lifetime of charge carriers) gives images of charge collection properties
- enables mapping of parameters such as charge collection efficiency, electric field configuration, charge carrier lifetime, mobility, diffusion length...



❶ IONS
- p, α, Li, C, O,..
- use of different ions with same rigidity.



❷ RANGE
- 2 to 200 μm
- advantage over OBIC and EBIC
- large range - insensitive to surface
- depth profiling

❸ ION RATE
- beam current is reduced by decrease in object and collimator slits

❹ ION POSITION
- determined by scanning coils
- scanning pattern - arbitrary area, line, point

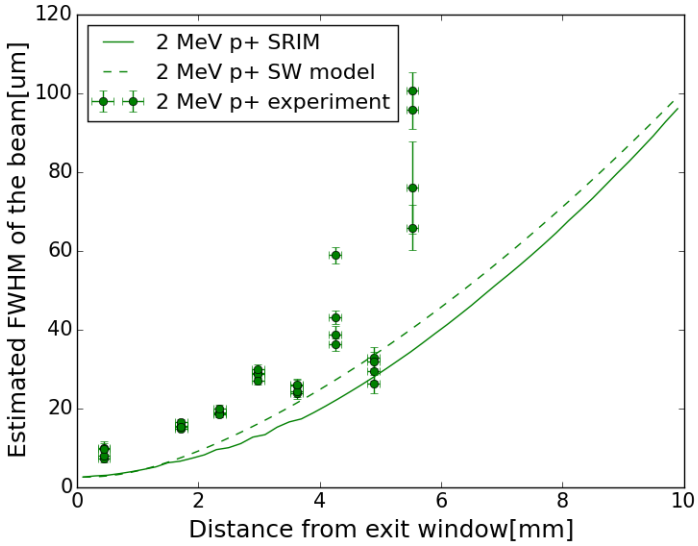
In-air IBIC experiment

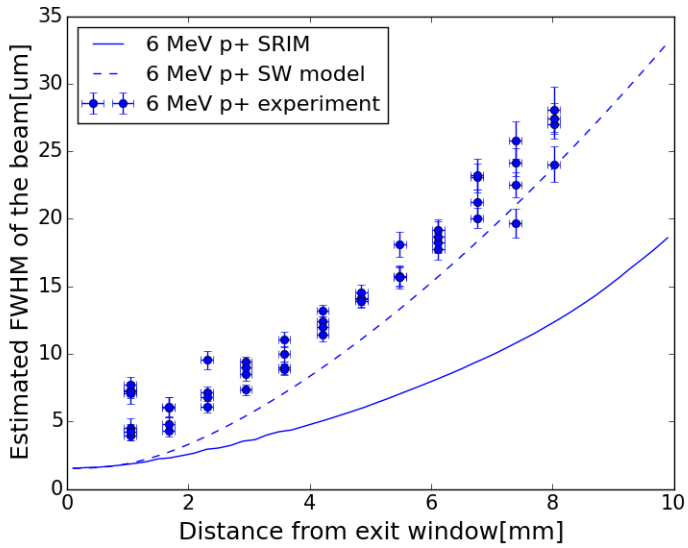
- Large detector structures (above 8 cm) can not be tested in small vacuum chamber
- Alternative: in-air microbeam!
- But - beam spot degradation

Energy / air path	100 nm Si_3N_4	6 µm diamond
3 MeV / 0.5 mm	1.02	9.0
3 MeV / 2.0 mm	4.39	30.6
6 MeV / 0.5 mm	0.50	4.3
6 MeV / 2.0 mm	2.06	14.8
9 MeV / 0.5mm	0.34	2.9
9 MeV / 2.0 mm	1.40	9.9

Degradation of beam spot (in micrometers) for SiN and diamond exit foil

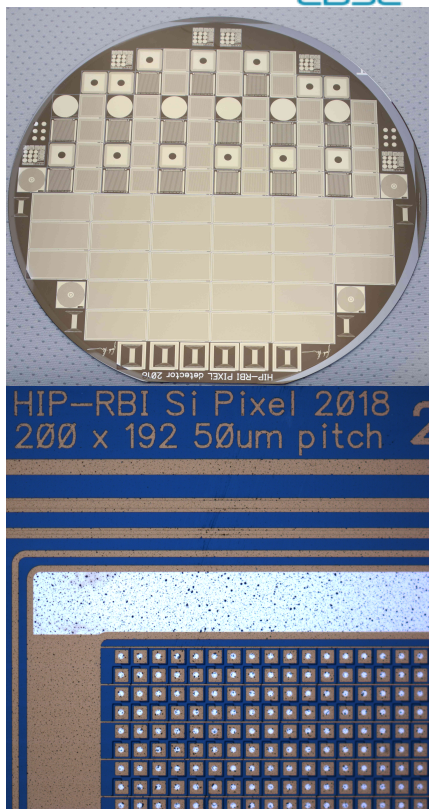
- SOLUTION:
  - SiN exit foil
  - up to 2 mm working distance
  - proton energy > 6 MeV !!

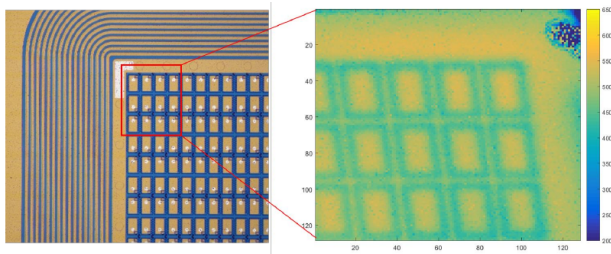




PaRaDeSEC and CDSE

- **Particle and Radiation Detectors, Sensors and Electronics in Croatia**
- Horizon 2020 ERA Chair Project
- Project manager: Neven Soić
- Project coordinator: Jaakko Härkönen
- duration: 1.7.2015 - 30.6.2020
  - final conference June 2020 in Zagreb
- established Center for Detectors, Sensors and Electronics
  - development and testing of detectors (emphasis on Si) and electronics
- examples:
  - radiation hardness test with the ^{60}Co gamma irradiation for new Pixel detector (for CERN)
  - test for nuclear and particle physics experiments: double sided Si, pixel CERN
- http://lnr.irb.hr/PaRaDeSEC/
- http://cems.irb.hr/en/



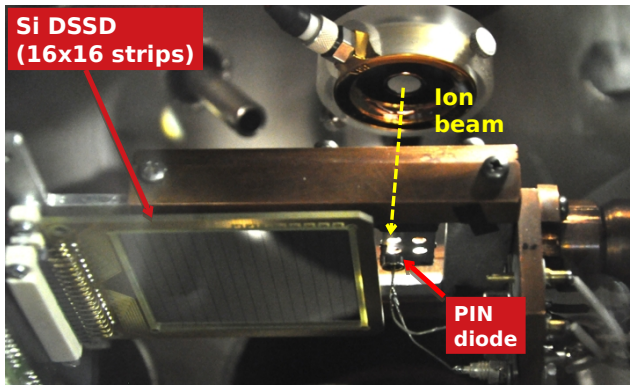


Examples: DSSSD Si detector

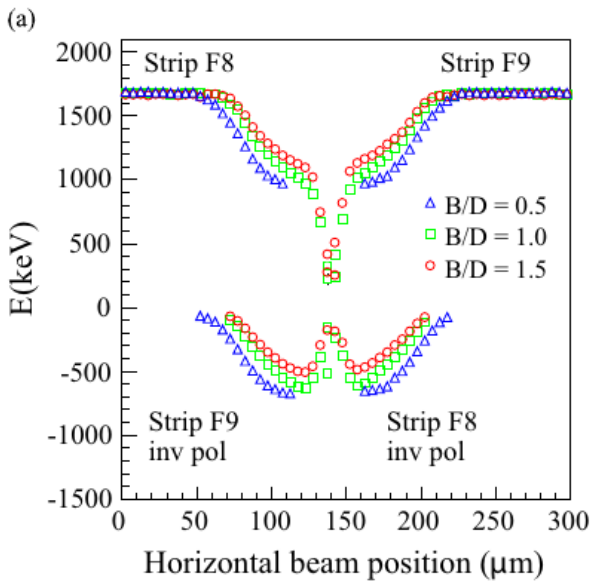
- IBIC - a technique of choice for detector tests:
  - Si pixel detectors (CERN)
  - Diamond detectors for HADES (GSI)
  - 3D diamond detectors (CERN)

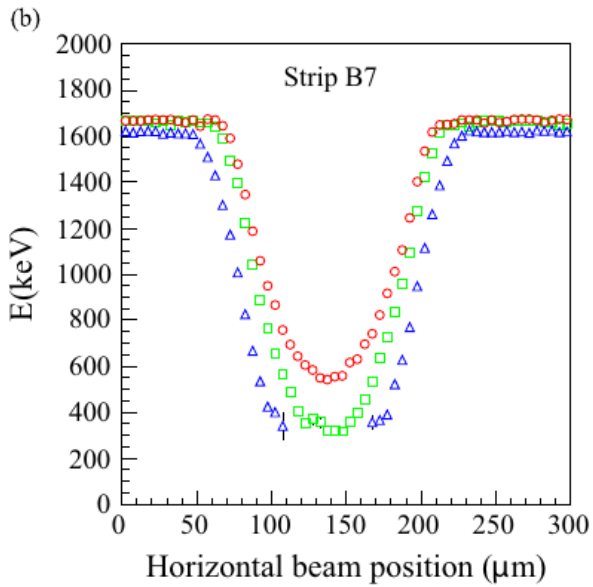
Example: DSSSD

- Study of the inter-strip gap effects using proton micro-beams
- The effective width of the inter-strip region (related to the efficiency for full energy detection) varies with both detected energy and bias voltage
- Investigation of reverse polarity pulses



998 μm





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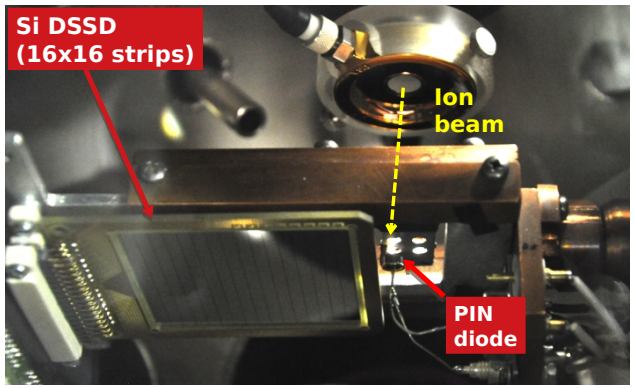
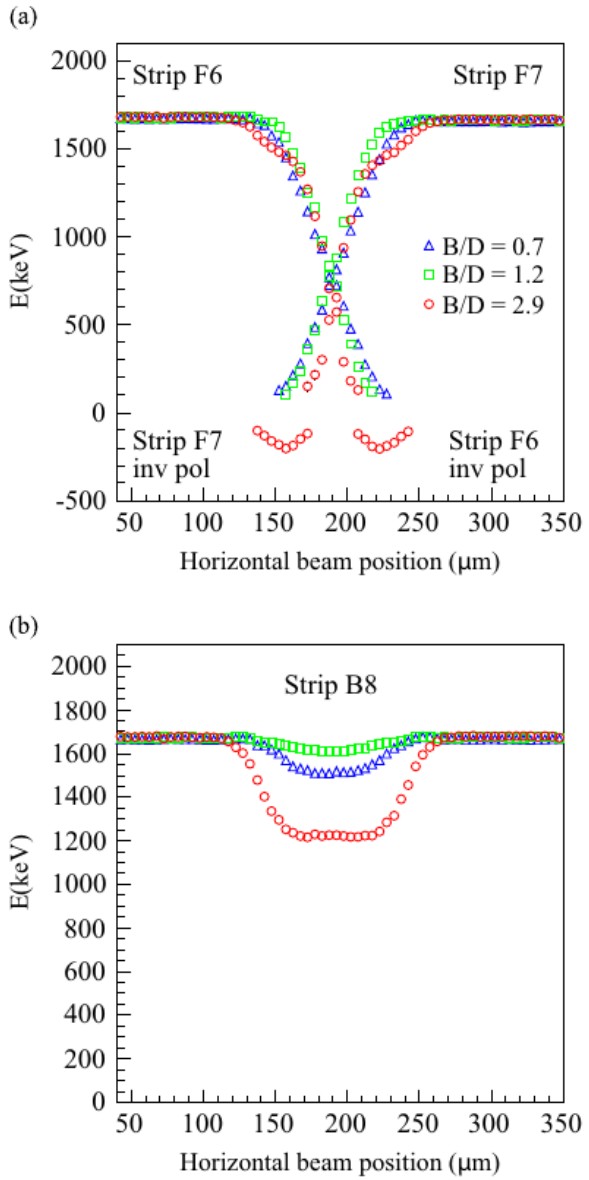


75 μm



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Summary

- RBI accelerator facility hosts microbeam line used for IBIC
- IBIC (Lateral, Frontal and TRIBIC) is efficient method for mapping basic properties of semiconductor and insulator detector materials
  - powerful techniques for radiation hardness studies
  - only small regions are irradiated without a need to damage the whole device
- Other ion beam characterisation and irradiation techniques can be used as well
- New RBI dual microbeam irradiation facility - simultaneous performance of irradiation and probing
- Future plans: 2020 starting of O-ZIP, 72 million Euro project that includes new 5 MV accelerator

Transnational Access funding

- CERIC-ERIC
- **RADIATE (from 2019)**
  https://www.ionbeamcenters.eu/radiate/

CERIC
Central European Research Infrastructure Consortium

RADIATE

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Thank you!

Iva Božičević, Stjepko Fazinić, Milko Jakšić, Aneliya Karadzhinova-Ferrer, Georgios Provatas, Suzana Szilner, ...

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