# Characterization of semiconductor detectors using IBIC imaging method

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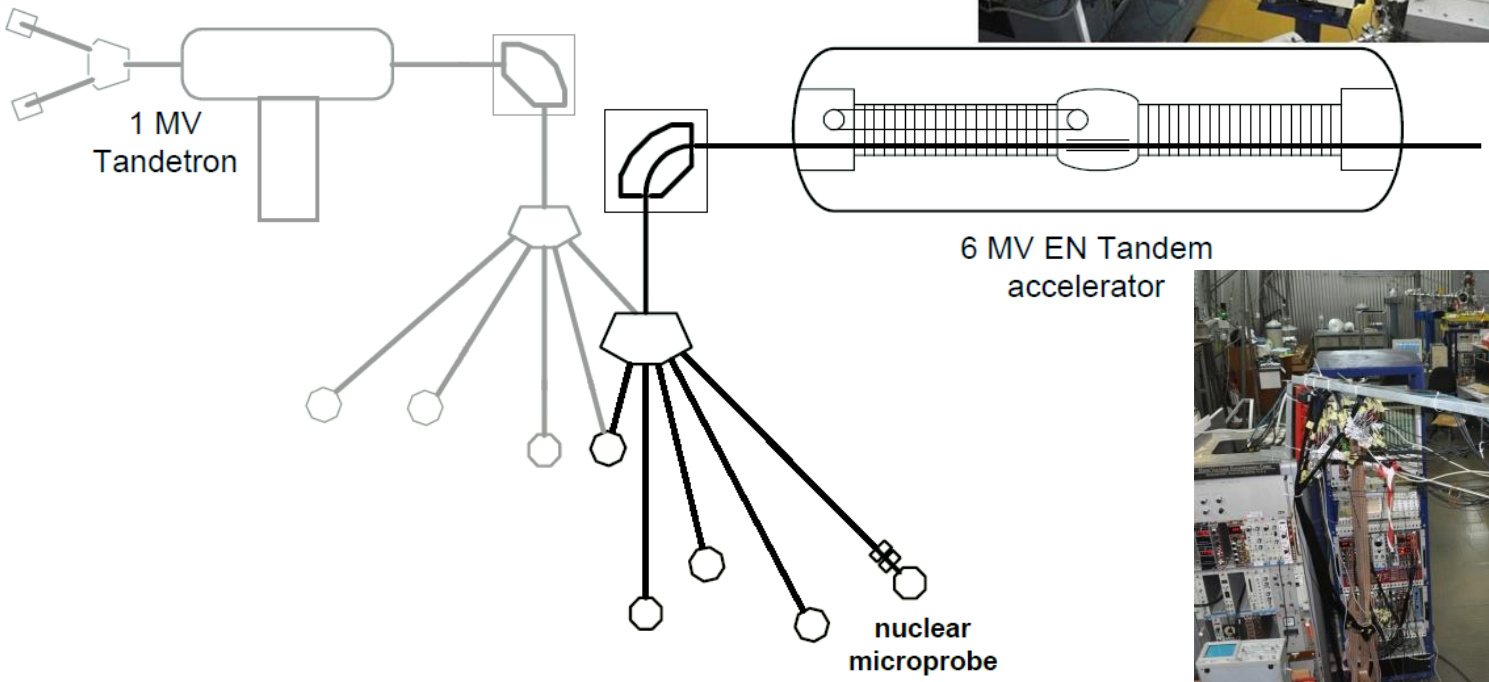
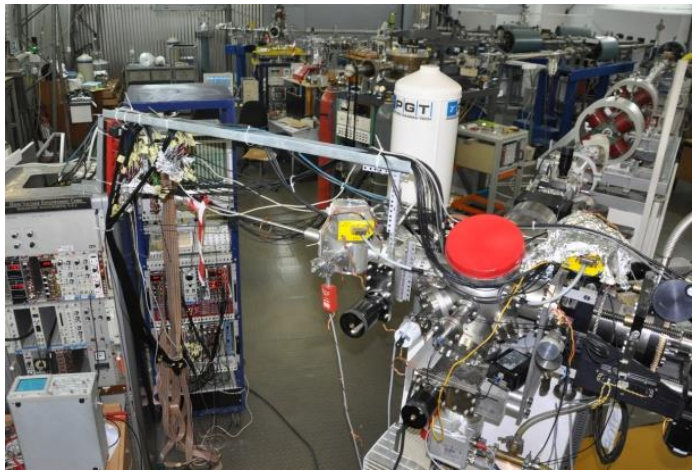
33rd RD50 Workshop – CERN
November 27, 2018

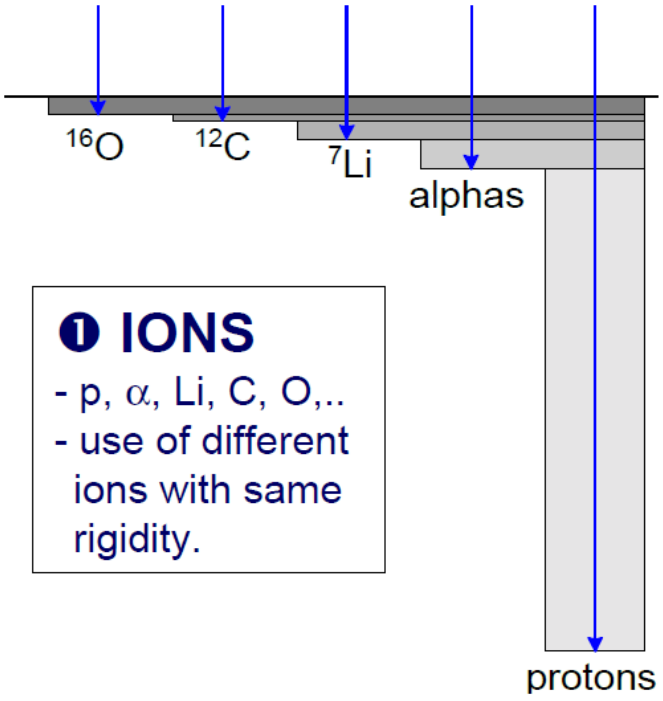

# Laboratory for ion beam interactions
# Ruđer Bošković Institute, Croatia

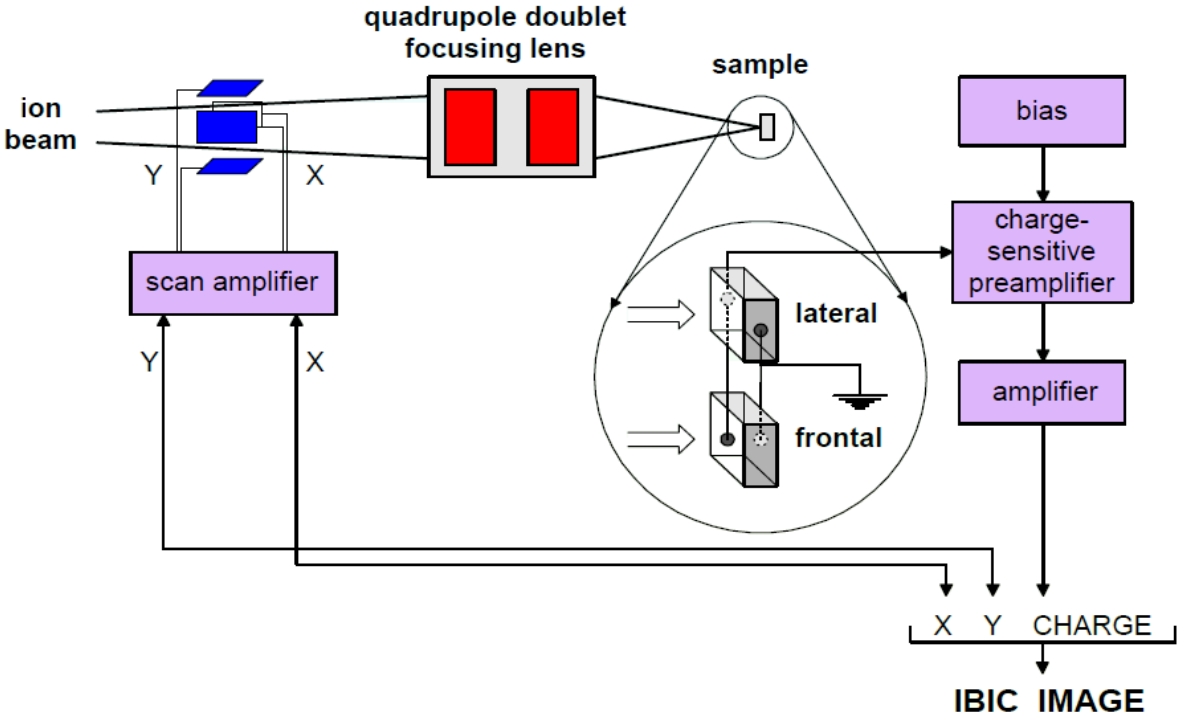


https://www.irb.hr/Laboratory-for-ion-beam-interactions

# Ion Beam Induce Current
# Ideal radiation source for detector testing




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

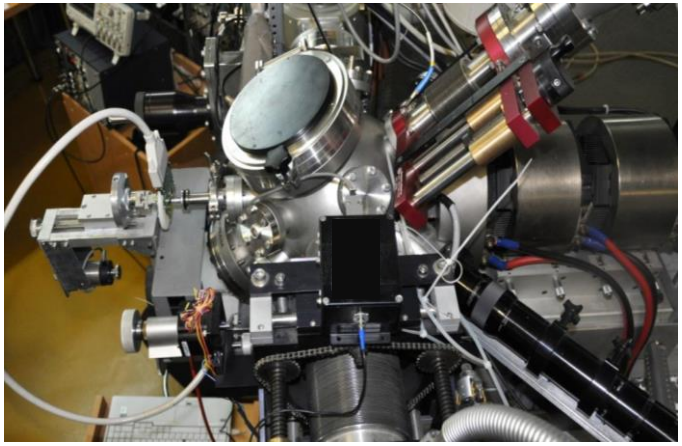
## ❷ RANGE
- 2 to 200 μm
- advantage over OBIC and EBIC
- large range - insensitive to surface
- depth profiling

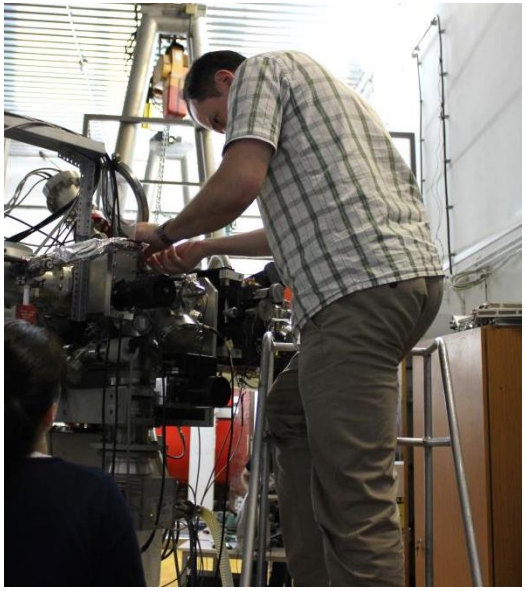
## ❸ ION RATE
- beam current is reduced by decrease in object and collimator slits

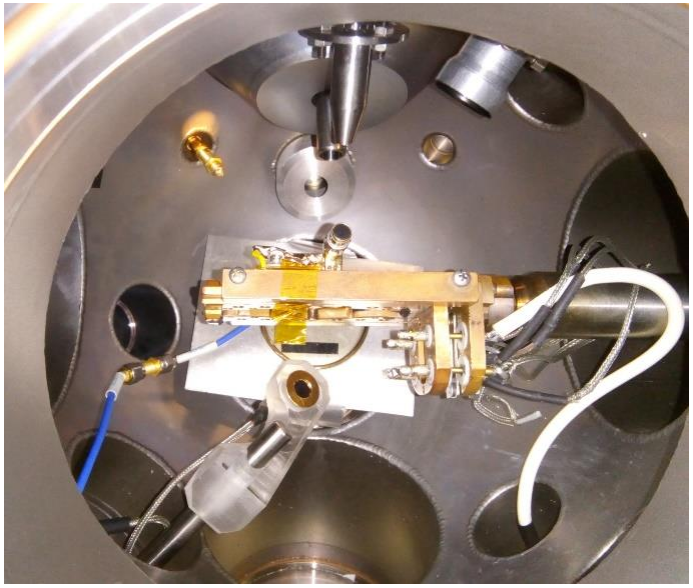
## ❹ ION POSITION
- determined by scanning coils
- scanning pattern - arbitrary area, line, point

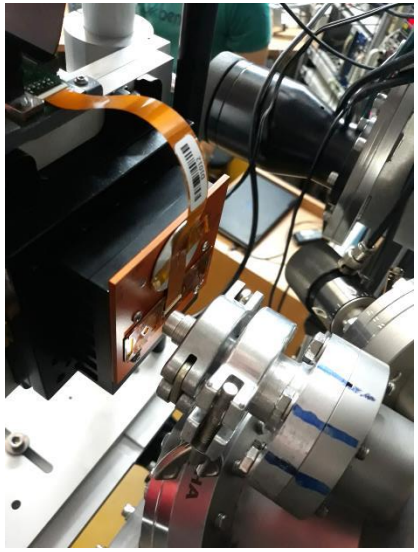
https://www.irb.hr/Laboratory-for-ion-beam-interactions

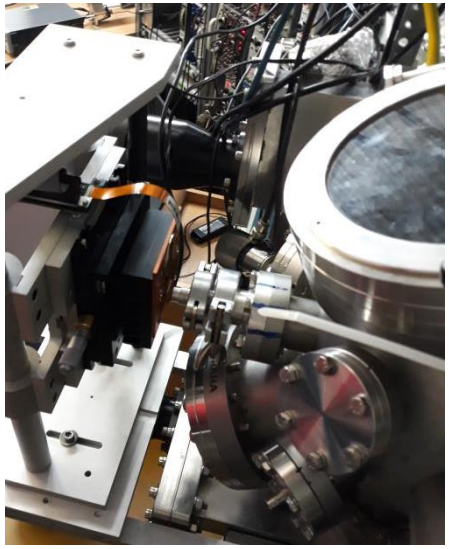
# IBIC Measurements











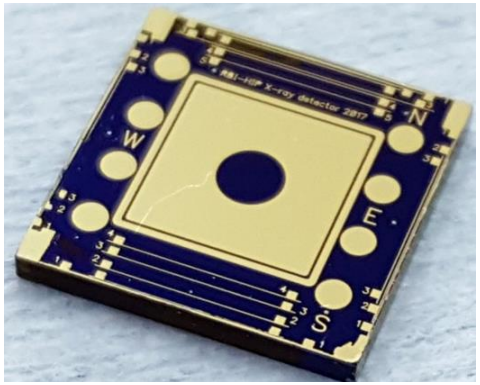
# IBIC Measurements

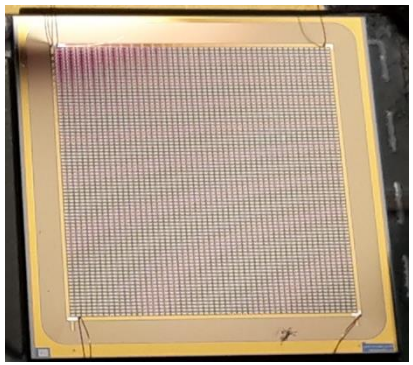
Prime Minister of Croatia, Andrej Plenković during a his visit at the Accelerator Lab

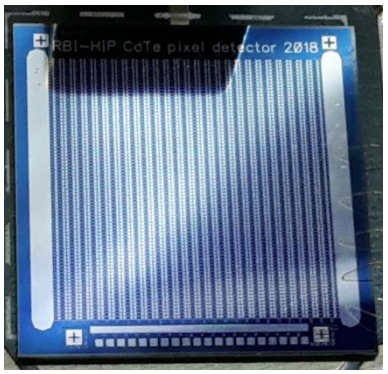
*Visiting scientists Ms. Jennifer Ott from HIP, Dr. Matti Kalliokoski from RBI PaRaDeSEC - project, and Rrof. Milko Jakšić from RBI.*

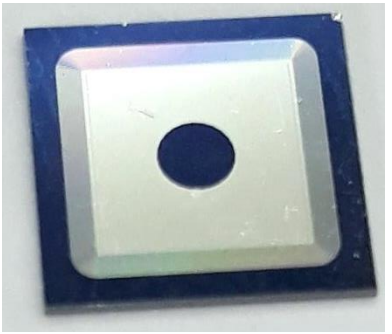
# Semiconductor detectors

- So far we have irradiated various  CdTe and Si devices with 2 MeV protons
- With either positive or negative voltage applied to the anode/cathode



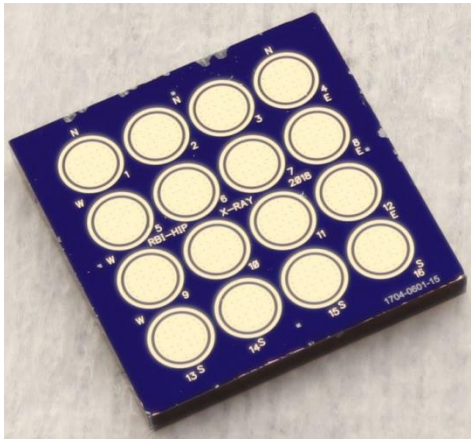


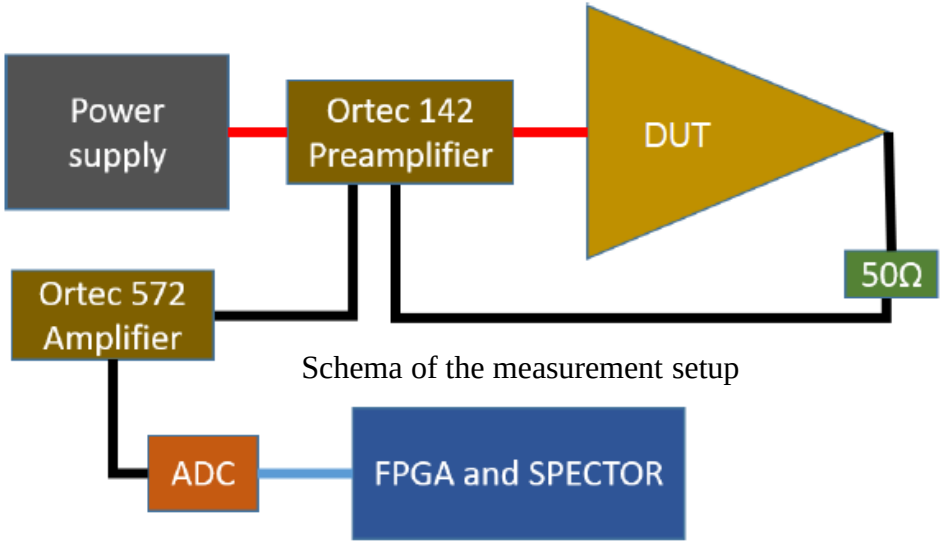


Si

CdTe

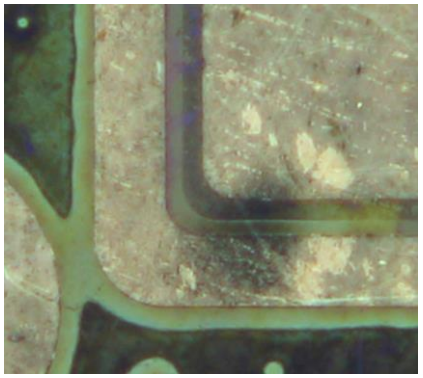


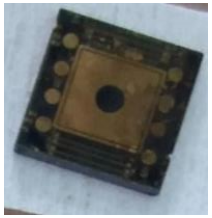


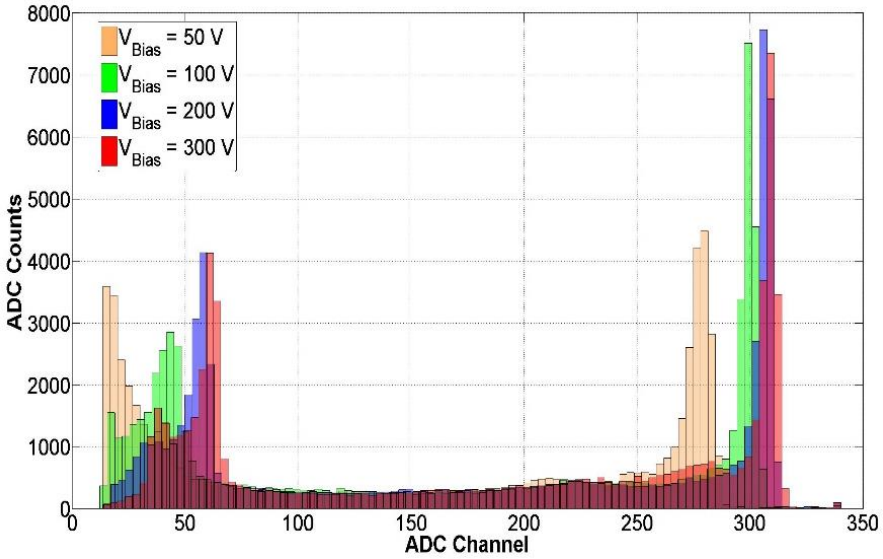

Schema of the measurement setup

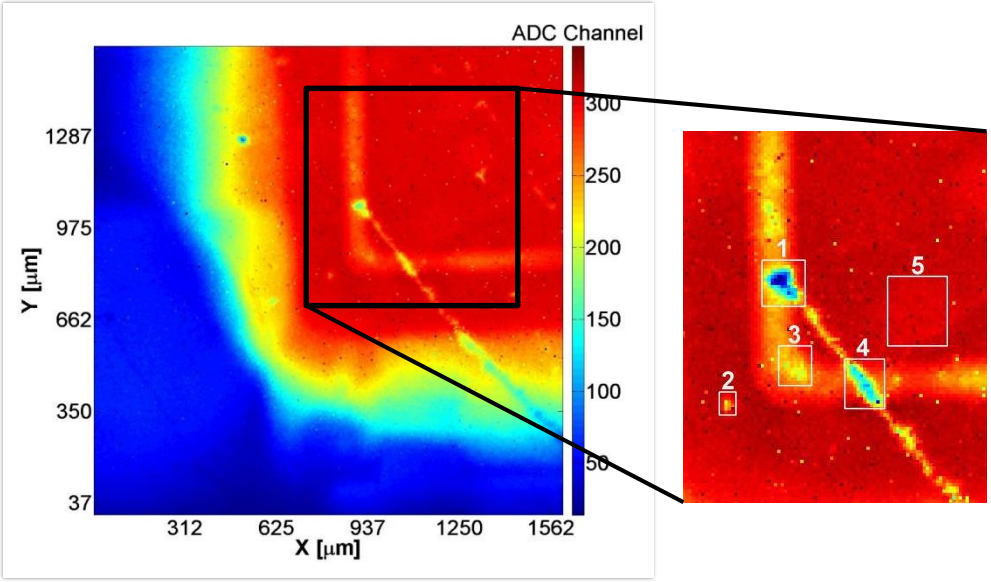
# CdTe IBIC measurements

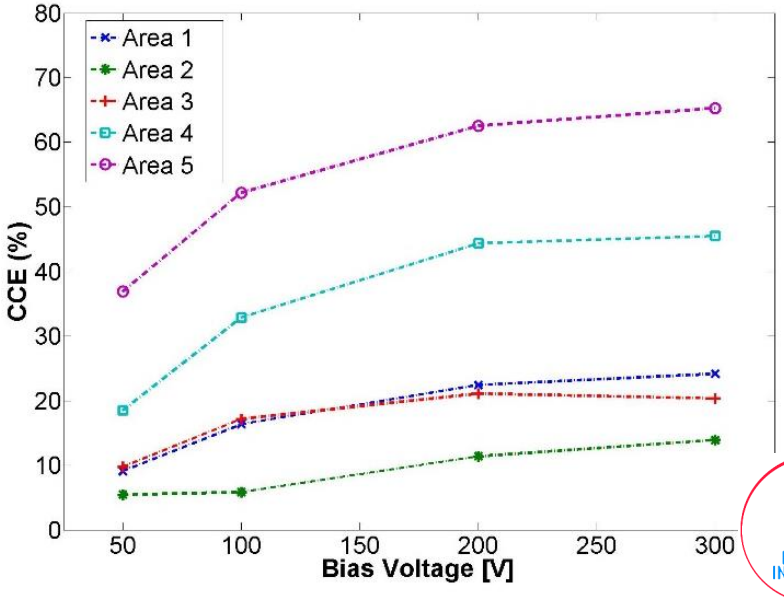
CdTe with AlN





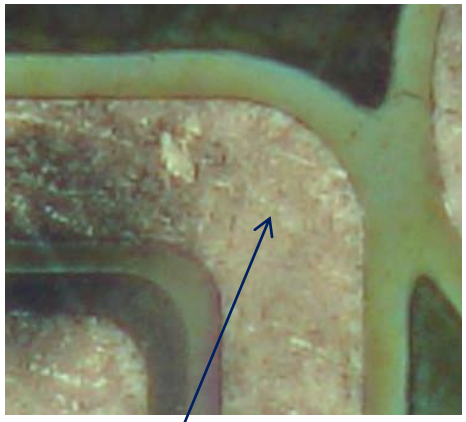


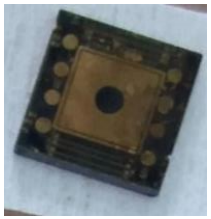



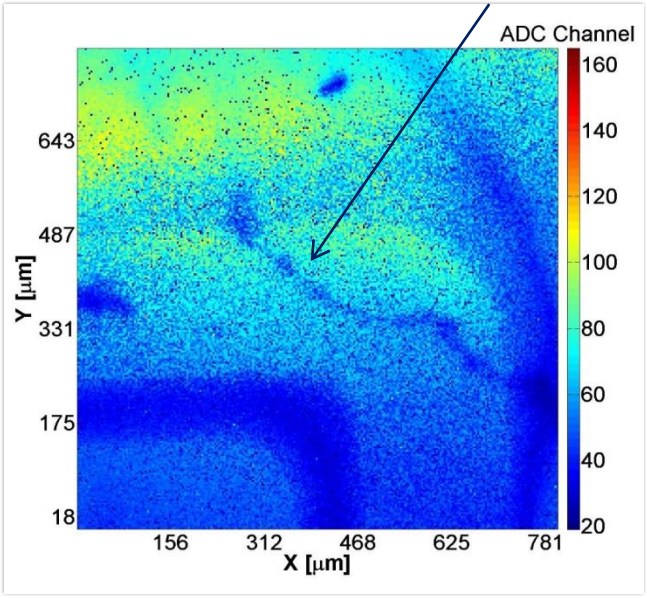
# CdTe IBIC measurements

CdTe with AlN

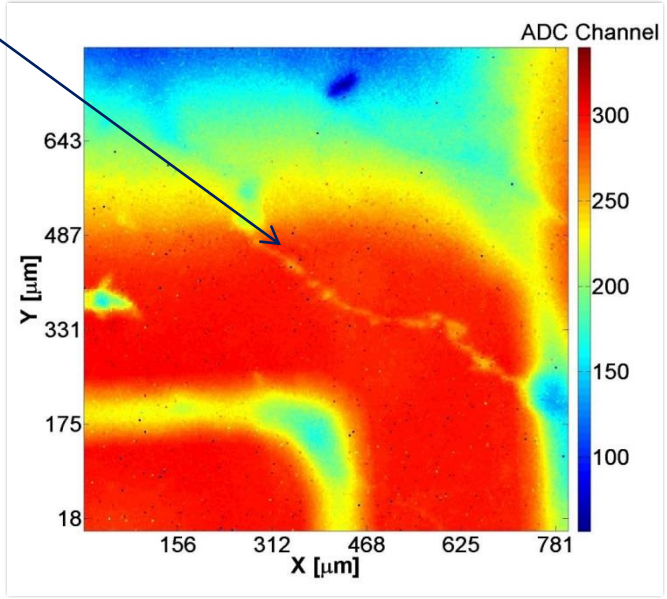




Features



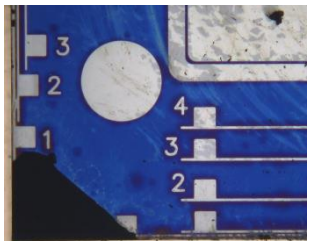

$V_{bias}$ = +100 V

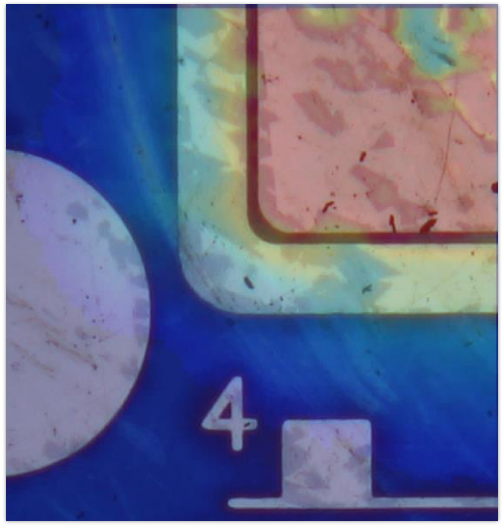


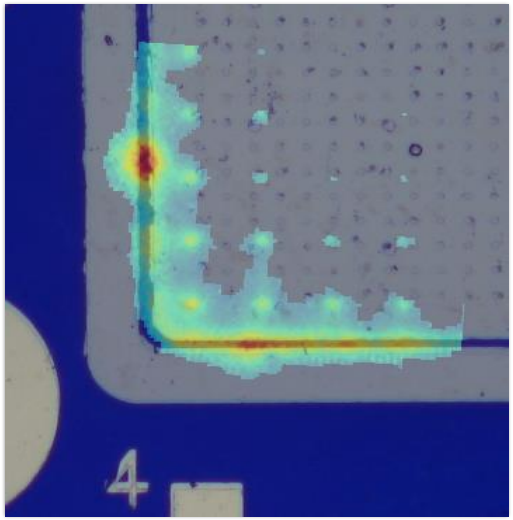

Reverse $V_{bias}$ = -100 V

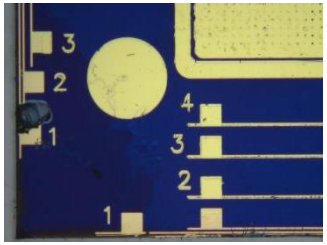
# CdTe IBIC measurements

## CdTe with $Al_2O_3$



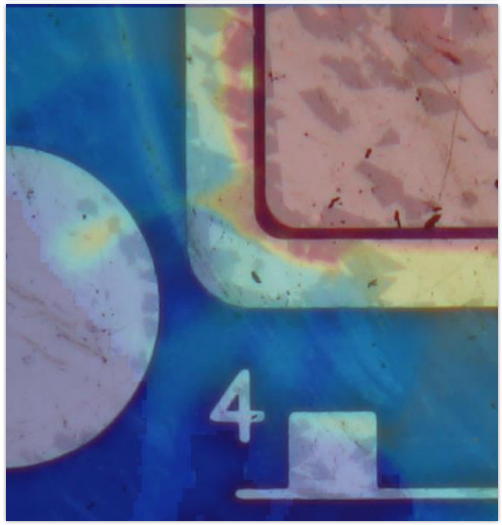



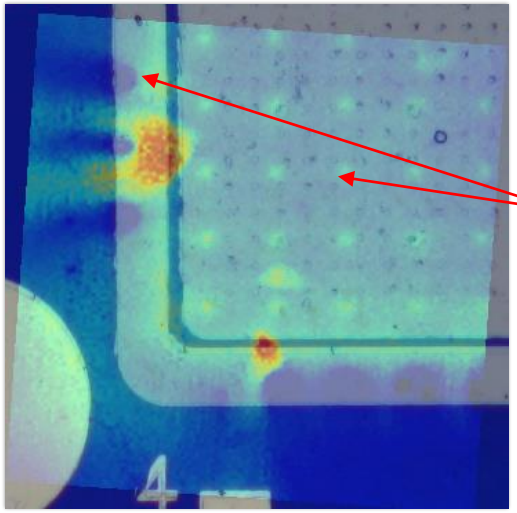




$V_{bias}$ = +50 V

Reverse $V_{bias}$ = -10 V



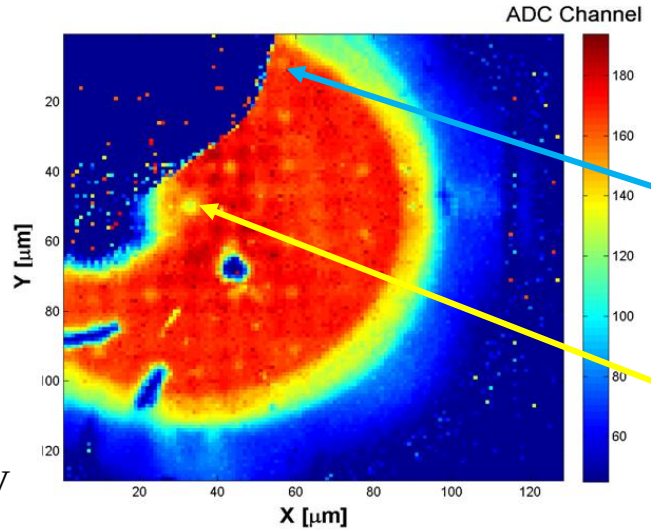




Schottky contacts

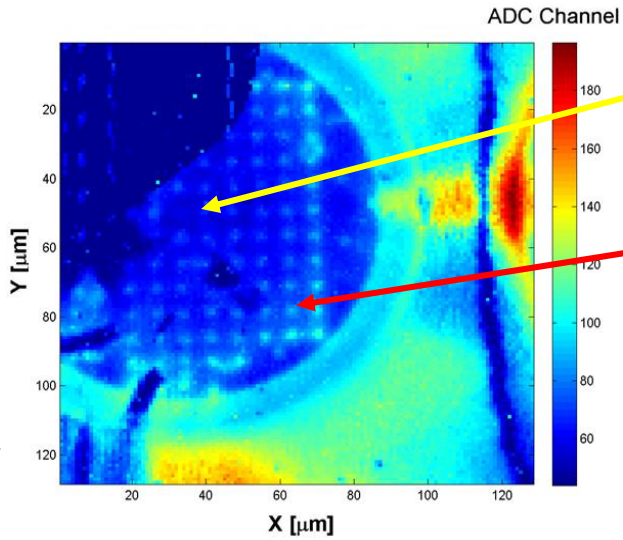
$V_{bias}$ = +500 V

Reverse $V_{bias}$ = -50 V

# CdTe IBIC measurements

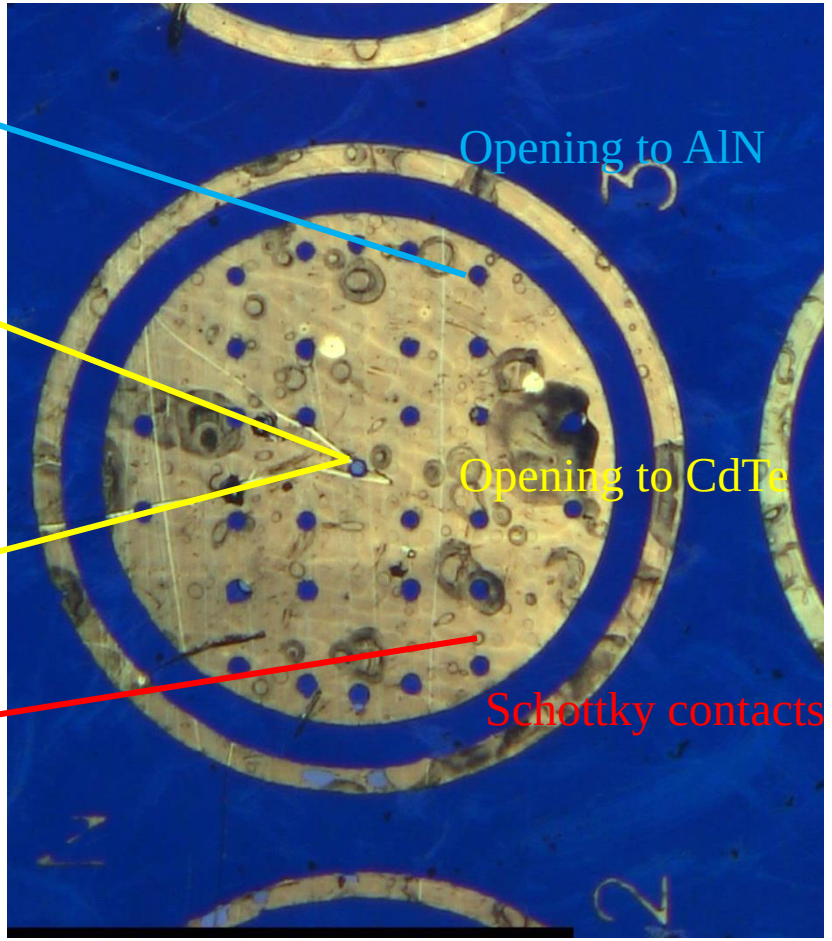



$V_{bias}$ = +50 V



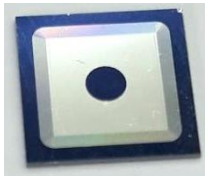

Reverse $V_{bias}$ = -50 V

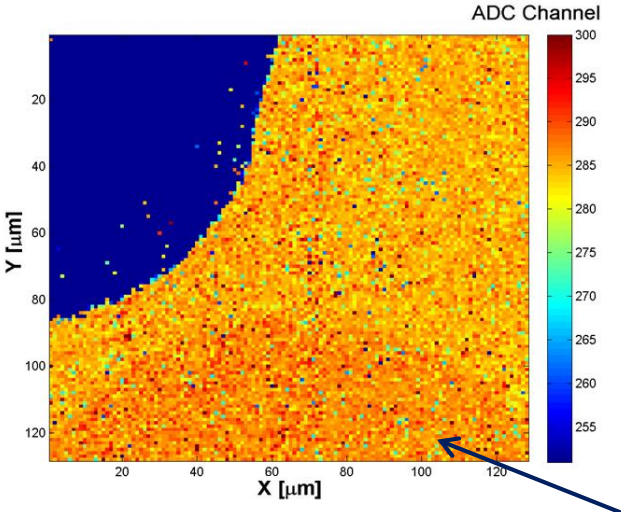
CdTe with AlN



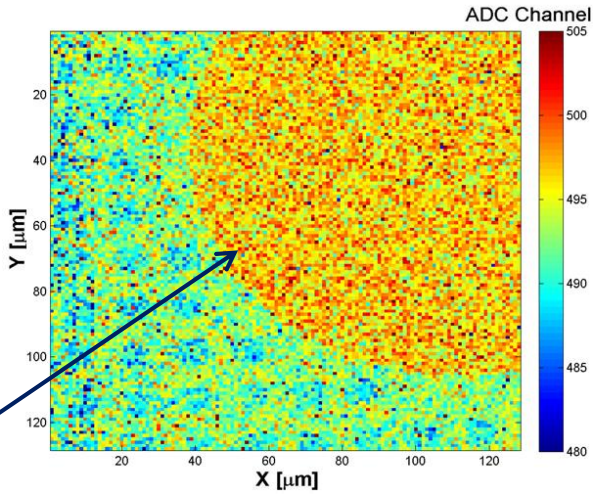
# Si IBIC measurements

Si nFz





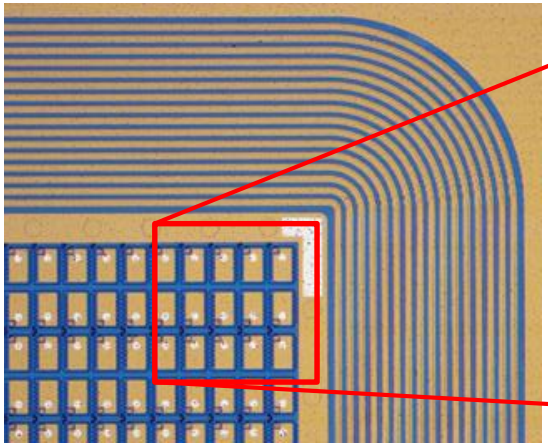

$V_{bias}$=+100V



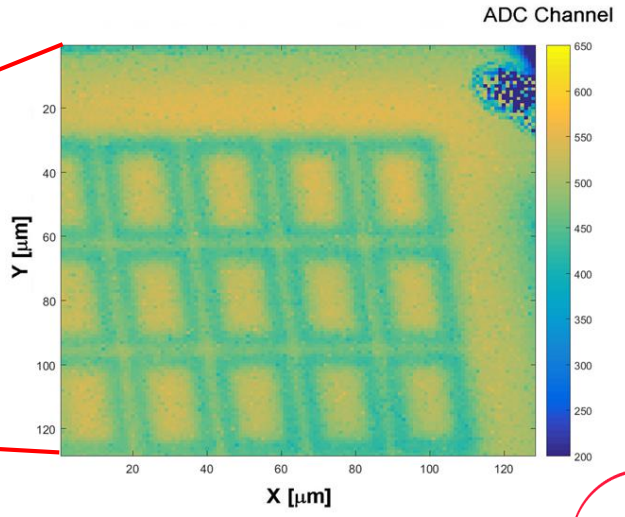

Si pFz

$V_{bias}$=-50V

Optical opening



n$^+$-in-p AC-coupled
pixel detector on p-type MCz Si

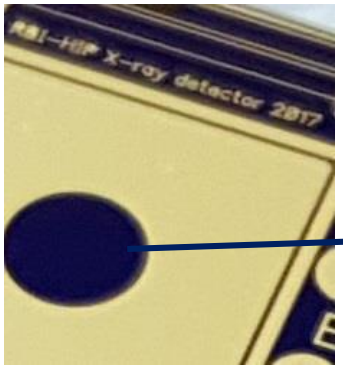


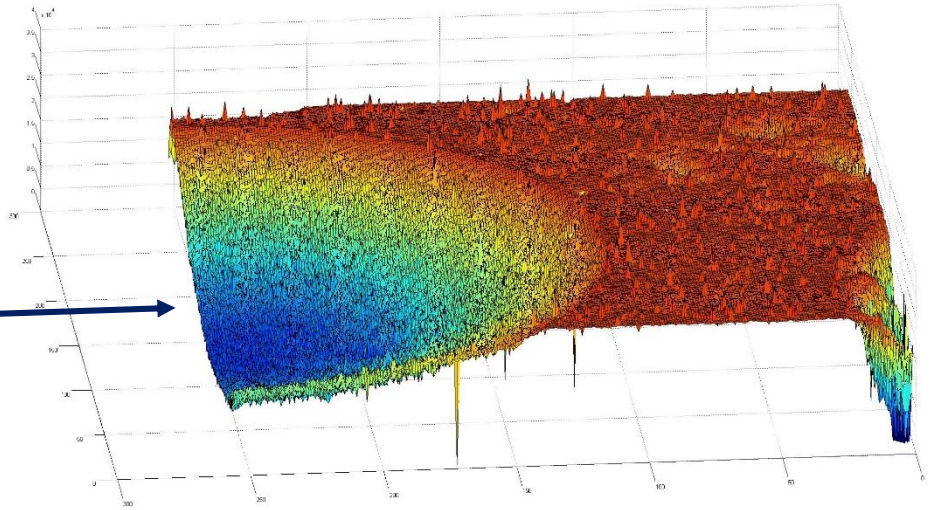

$V_{bias}$=-100V

*For more details see:*
*Jennifer Ott, "Processing of pixel detectors …" on Wednesday @ 10:10*

# 3D CCE

Spatially resolved Charge Collection Efficiency of a CdTe X-ray detector



The signal is excited by 2 MeV proton beam

# Laboratory for ion beams - activities

**Material science applications**

- Charge transport in semiconductors
- Development and application of depth profiling techniques (TOF-ERDA), NRA
- Ion microprobe modification of materials (ion tracks, damage structuring, implantation, charge collection properties - IBIC)
- Chemical and molecular imaging (MeV- SIMS, HR-PIXE)
- Detector characterization and testing (AIDA2020)
- Ion Beam Irradiation of materials
- Ion Beam Analysis for Nuclear Fusion Research (EUROFUSION)

**Other applications**

- Cultural heritage μPIXE analysis
- Technological projects (cement, glass, solar cells)
- Analytical services and irradiation services

**Transnational Access policies**

- CERIC-ERIC
- AIDA 2020
- RADIATE Project (from 2019)

# Thank you for your attention!


https://www.irb.hr/Laboratory-for-ion-beam-interactions

# Backup slides

# Nuclear microprobe

- Two accelerators, 6.0 MV Tandem Van de Graaff and 1.0 MV Tandetron
- Protons (0.4 to 8 MeV), ions up to $ME/q^2$ ratio of 15 MeV
- Beam spot size can be as low as 250 nm, in normal use ~few μm
- Scanning area from 1.5 mm down to tens of μm

# Ion sources of tandem accelerators

- Tandetron up to 1.0 MV
- Duoplasmatron –> He (new)
- Sputtering –> p, heavy ions

Voltages from 0.1 to 1.0 MV

Ions / max. currents (μA)

| | |
|---|---|
| H | ≈ μ A |
| $^{16}O$ | 0.5-1.0 |

# Ion sources of tandem accelerators

EN tandem up to 6.0 MV
- Alphatross NEC
- Sputtering – NEC multicatode

Voltages 0.4 to 6.0 MV

<u>Sputtering source</u>
Ions / source currents (μA)

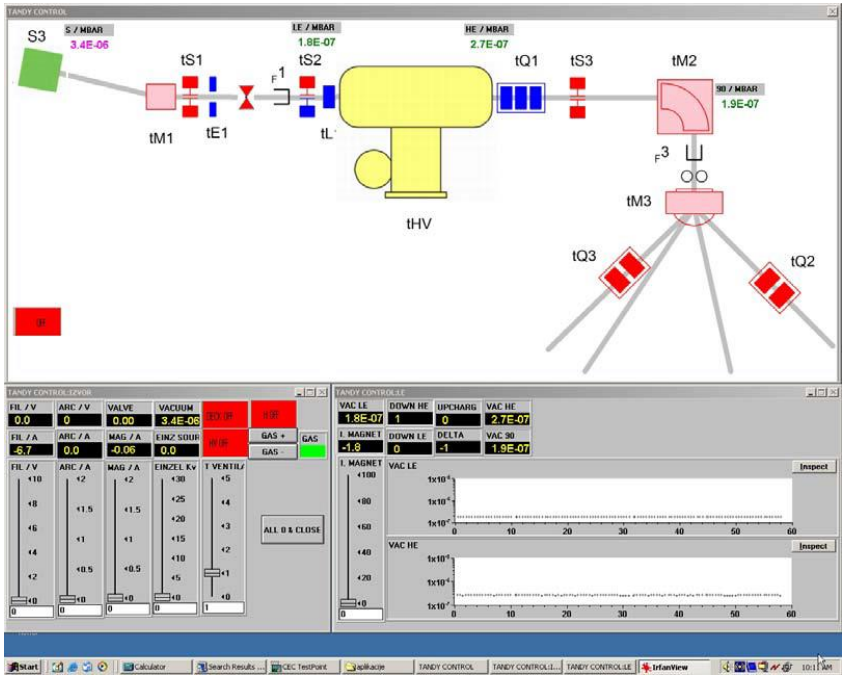
| | |
|---|---|
| H | 10 |
| D | 1 |
| $^{6}$Li | 0.5 |
| $^{7}$Li | 1.0 |
| $^{10,11}$B | 1.0 |
| C ,O | 20 |
| F, Si | 20 |
| Cl, I | 20 |

<u>Alphatross source</u>
Ions / source currents (μA)

| | |
|---|---|
| H | 1 |
| D | 0.5 |
| $^{3}$He | 0.5 |
| $^{4}$He | 1.0 |

# Computer control

ACCEL6 for EN Tandem Van de Graaff and ACCEL1 for Tandetron accelerator



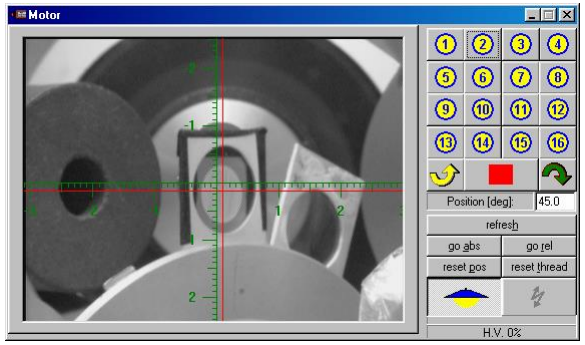

- 16 bit AD/DA modules (8 AD, 8DA) (controls for ion sources, accelerator and beam optics system)
- Controls are based on TESTPOINT

**Capabilities:**

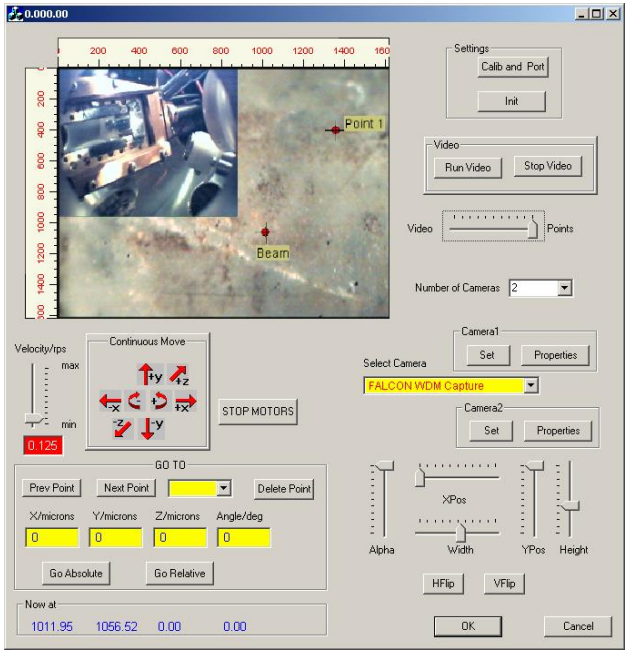
- ❖ Remote control (from remote computers)
- ❖ Reads beam optics parameters from previous experiments
- ❖ Calculates changes of parameters for change of energy and/or ion
- ❖ Security interlock system
- ❖ 16 bit AD/DA modules (8 AD, 8DA)
- ❖ (controls for ion sources, accelerator
- ❖ and beam optics system)
- ❖ 8 digital inputs, 8 digital outputs

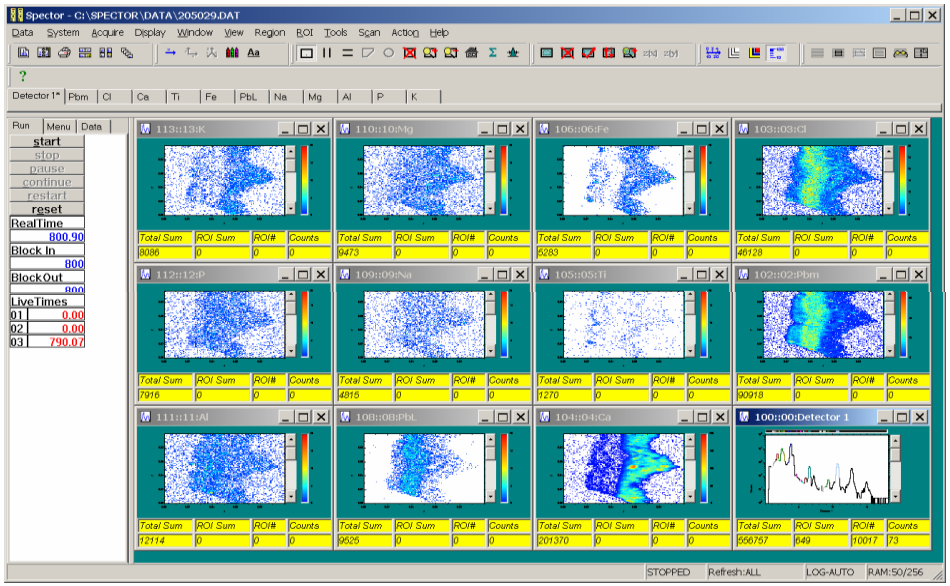
# Data acquisition

**SPECTOR** – Data acquisition with digital and analog pulse processing
target positioning / beam scanning software / remote operation




**Home made!!!**



# Laboratory for ion beams - activities

**Basic Research**

• Inner shell ionization, chemical effects on X-ray production, data base
• Elastic scattering data base (p, He beams) for ion beam analysis

**Material science applications**

• Charge transport in semiconductors
• Development and application of depth profiling techniques (TOF-ERDA), NRA
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