Ion microbeam facility at RBI as a tool for detector characterization

N. Skukan, **M. Jakšić**, I. Bogdanović-Radović, T. Tadić, S. Fazinić, Z. Siketić, I. Zamboni, I. Božičević Mihalić, **I. Sudić**, D. Španja, Ž. Periša, A. Kovačević

(**Veljko Grilj**)

Ruđer Bošković Institute, Bijenička c. 54, 10000 Zagreb, Croatia

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654168.

Outline

- 1. Facility
- 2. Statistics in brief
- 3. Ion Beam Induced Charge
- 4. Some AIDA runs

WP12 -Detector Characterization Facilities

WP12.1. – RBI Accelerator Facility

- **8 TA projects** have been already **approved**
- **7 TA access** have been **completed** by 30th March 2017 (on schedule –completed)

- Users from **6 countries supported**

RBI	User Projects		Total users	TA units
	Submissions	Selected		
M1-M22	8	8	**17 (11 supported)**	**280**
M1-M48	16		24	640

WP12 .1 : RBI Accelerator Facility

RBI	User-projects		Total no. of users benefitting from the TA	Units of access (RBI=beam operation hour)
	Eligible submissions	Selected		
Period 1 (M1-M18)	5	5	11 (8 received financial support)	200
Foreseen for project (M1-M48)	16		24 (with the financial support)	640

RBI	User-projects		Total no. of users benefitting from the TA	Units of access (RBI=beam operation hour)
	Eligible submissions	Selected		
Mid-term (foreseen*) (M1-M24)	8	8	19 (12 with the financial support)	320
Foreseen for project (M1-M48)	16		24 (with the financial support)	640

* i.e. assuming that recently approved project AIDA-2020-RBI-2017-1 will be implemented in April.

WP12 .1 : RBI Accelerator Facility

Periodic Report	Researcher			Employing organisation/Home institution			TA project acronym	Activity Domain (Discipline)
	Name	Gender	Nationality	Name	Legal status	Country		
2015								
P1	Jerzy Pietraszko	Male	Poland	GSI Helmholtzzentrum für Schwerionenforschung (	RES	Germany	AIDA-2020-RBI-2015-1	Physics
P1	Michal Pomorski	Male	Poland	CEA - Commissariat à l'énergie atomique et aux én	RES	France	AIDA-2020-RBI-2015-2	Physics
P1	Jacques de Sanoit	Male	France	CEA-Commissariat à l'Energie Atomique et aux éne	RES	France	AIDA-2020-RBI-2015-2	Physics, Chemistry,
P1	Michael Kokkoris	Male	Greece	National Technical University of Athens	UNI	Greece	AIDA-2020-RBI-2015-3	Physics
P1	Srdjan Petrović	Male	Serbia	Vinča Institute of Nuclear Sciences	RES	Serbia	AIDA-2020-RBI-2015-3	Physics
P1	Iain Haughton	Male	UK	The University of Manchester	UNI	UK	AIDA-2020-RBI-2015-4	Physics
P1	Steven Murphy	Male	UK	The University of Manchester	UNI	UK	AIDA-2020-RBI-2015-4	Physics
2016								
P1	Claudio Verona	Male	Italy	University of Rome "Tor Vergata"	UNI	Italy	AIDA-2020-RBI-2016-1	Physics
P1	Gianluca Verona Rinati	Male	Italy	University of Rome "Tor Vergata"	UNI	Italy	AIDA-2020-RBI-2016-1	Physics
P1	Giulio Magrin	Male	Austria	EBG MedAustron	RES	Austria	AIDA-2020-RBI-2016-1	Physics
P1	Mandy Bandorf	Female	Austria	EBG MedAustron	RES	Austria	AIDA-2020-RBI-2016-1	Physics
P1	Giulio Magrin	Male	Italy	EBG MedAustron	Profit or not profit Pr	Austria	AIDA-2020-RBI-2016-2	Physics
P1	Alberto Fazzi	Male	Italy	Politecnico di Milano	UNI		AIDA-2020-RBI-2016-2	Physics
P1	Sofia Colombi	Female	Italy	Politecnico di Milano	UNI		AIDA-2020-RBI-2016-2	Physics
P1	Michael Kokkoris	Male	Greece	National Technical University of Athens	UNI		AIDA-2020-RBI-2016-3	Physics
P1	Konstantinos Preketes-Sig	Male	Greece	National Technical University of Athens	UNI		AIDA-2020-RBI-2016-3	Physics
P1	Srdjan Petrović	Male	Serbia	Vinča Institute of Nuclear Sciences	RES		AIDA-2020-RBI-2016-3	Physics

WP12 .1 : RBI Accelerator Facility

- **PUBLICATIONS**

  - **4 Oral contributions to conferences :**

    Jerzy Pietraszko at al., “**Radiation damage in scCVD diamond material measured with relativistic Au ions for future CBM/HADES experiments at FAIR**“ **4th ADAMAS Workshop at GSI** , December 4, 2015, GSI Helmholtzzentrum für Schwerionenforschung,, Germany

  - Jerzy Pietraszko at al., **DPG Spring Meeting, Darmstadt**, 14 - 18 March 2016 “**Systematic study of radiation hardness of single crystal CVD diamond material investigated with an Au beam and IBIC method.”**

  - Veljko Grilj at al., **15. ICNMTA 2016**, 31. Jul-5. Aug 2016 “**Radiation hardness study on multi-strip diamond sensor** ”, invited

  - Alex Oh "**3D diamond detectors for particle tracking and dosimetry**", invited talk, **European Materials Research Society Symposium Materials for electronics and optoelectronic applications**, Warsaw, Poland, 19-22 September 2016.

  - **1 paper publication**

    M. Erich et al, EBS/C proton spectra from a virgin diamond crystal, **NIMB 381 (2016)96-102**.

  - **3 papers in preparation**

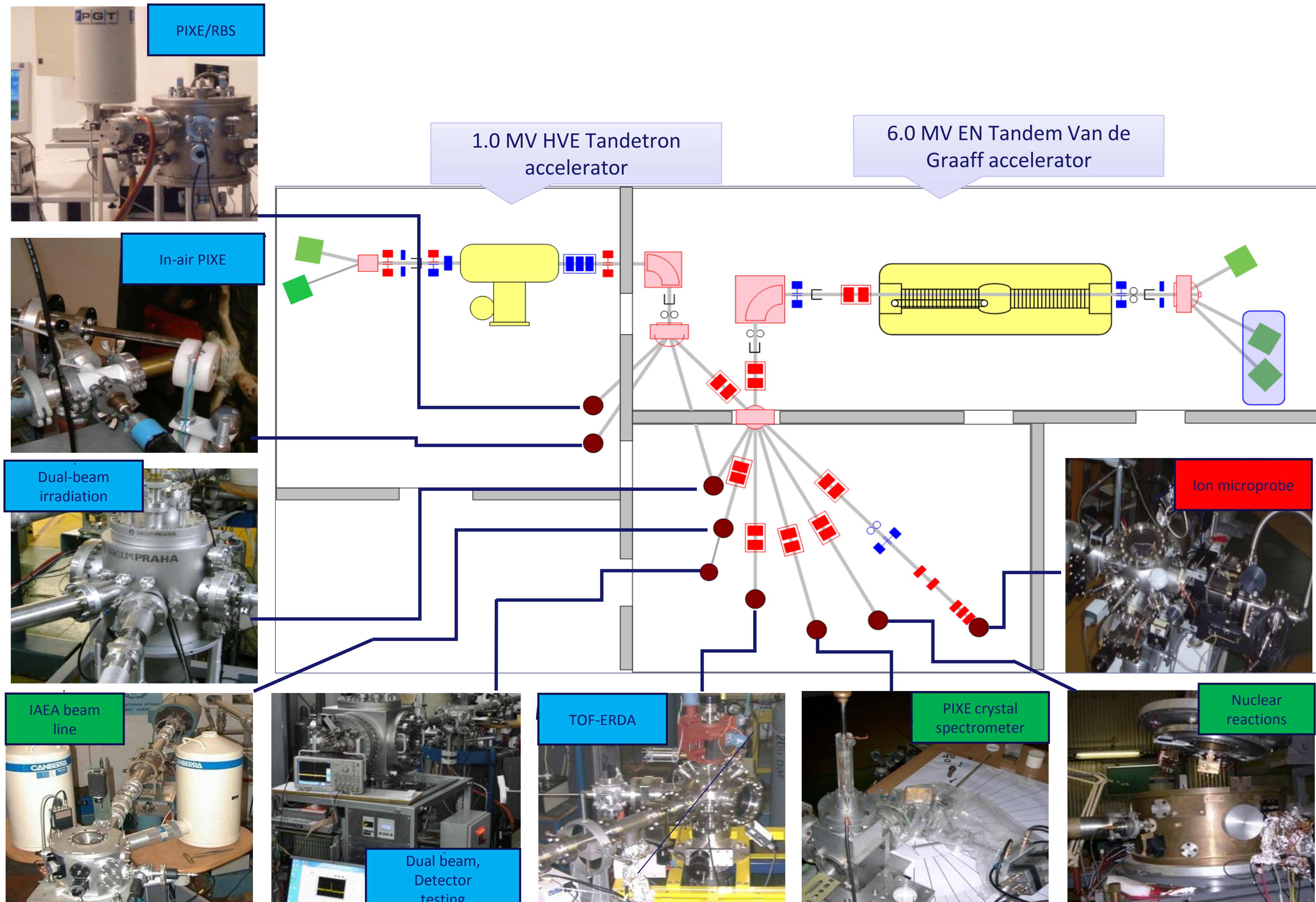
  - **+ several posters**

Laboratory for ion beam interactions

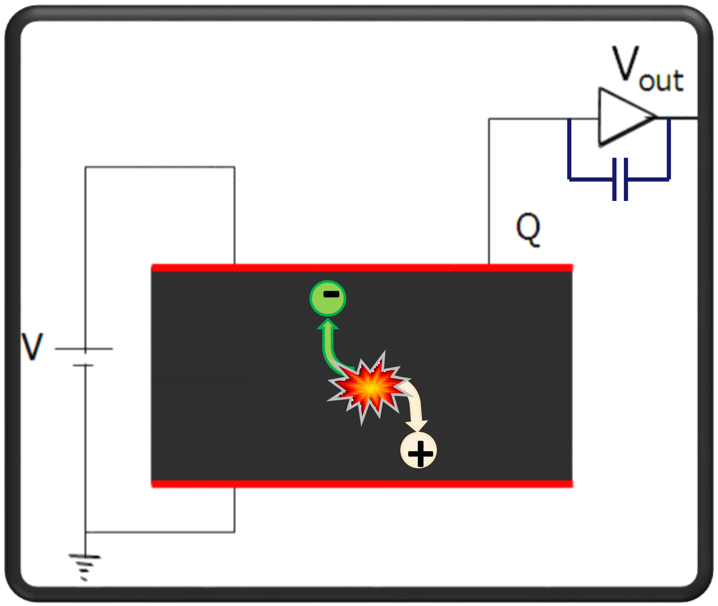
Accelerator facility

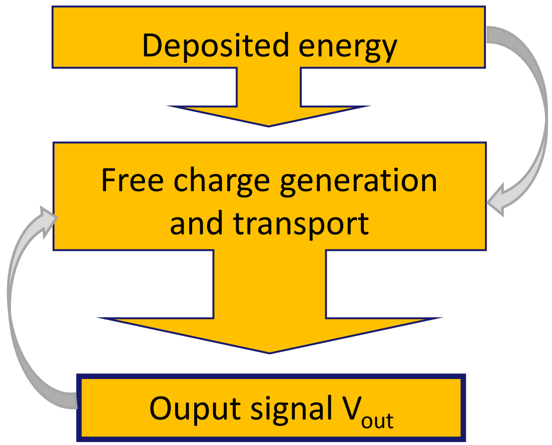
1.0 MV HVE Tandetron accelerator

6.0 MV EN Tandem Van de Graaff accelerator


PIXE/RBS
In-air PIXE
Dual-beam irradiation
1.0 MV HVE Tandetron accelerator
6.0 MV EN Tandem Van de Graaff accelerator
Ion microprobe
IAEA beam line
Dual beam, Detector testing
TOF-ERDA
PIXE crystal spectrometer
Nuclear reactions

Ion Beam Induced Charge





Gunn's Theorem:

$$i_i = -q\vec{v}\,\frac{\partial \vec{E}(\vec{r}(t))}{\partial V_i}\bigg|_{V_j=const.}$$

V_{out} = F (deposited energy, free carrier transport)

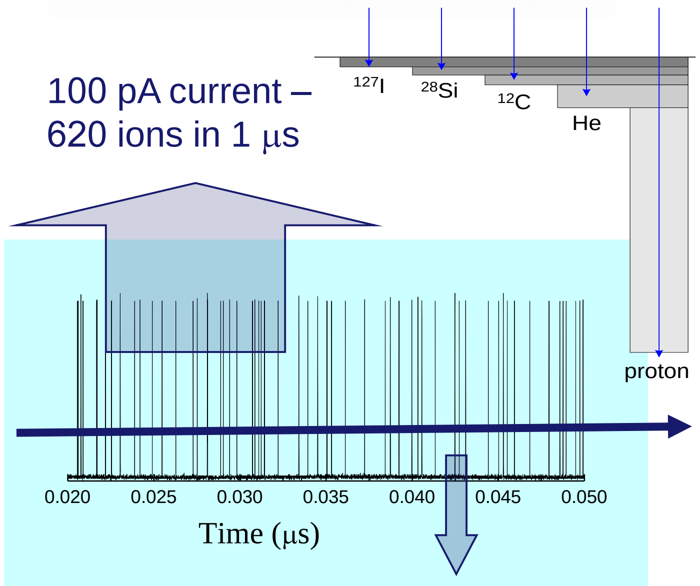
What is needed for IBIC?

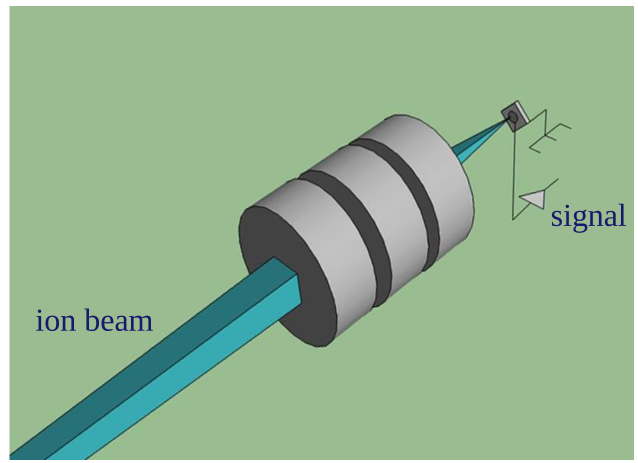
❸ IONS
- p, α, Li, C, O,..

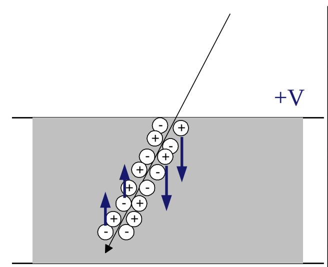
❹ RANGE
- 1 to 1000 μm

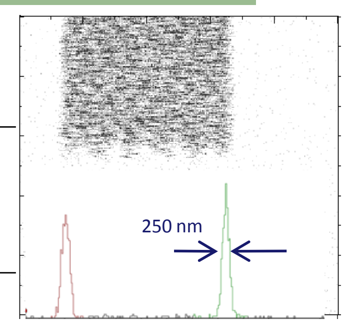
❷ POSITION
- Focusing and scanning

100 pA current –
620 ions in 1 μs





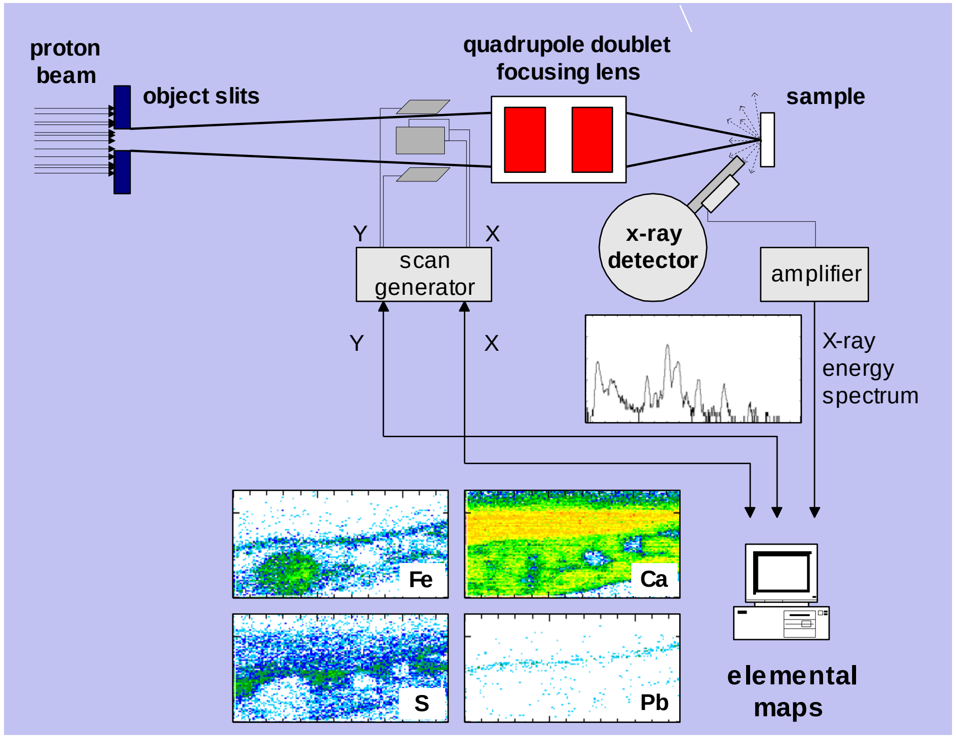


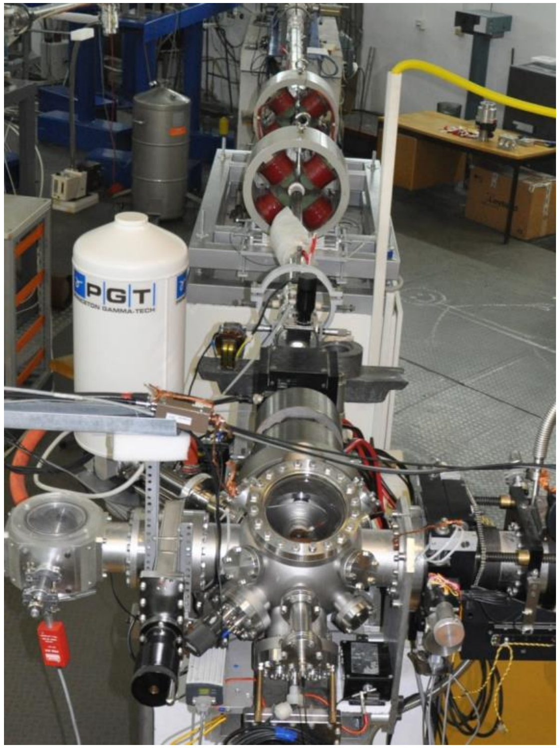


❶ RATE
- 0 - 10^6 p/s

0.1 fA current –
620 ions/second

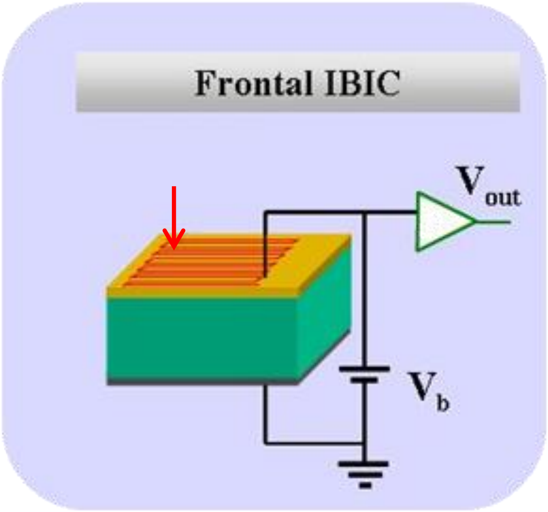
Nuclear microprobe

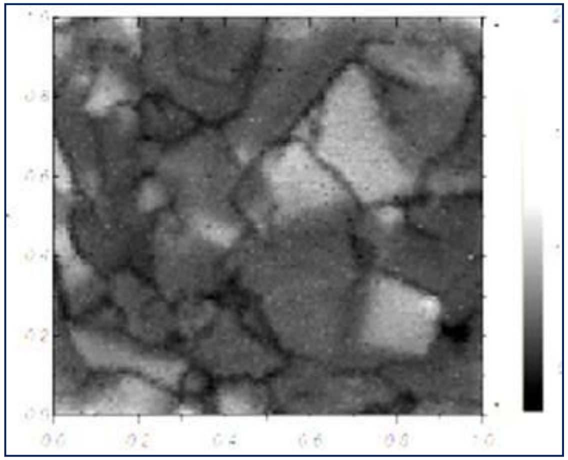




IBIC imaging

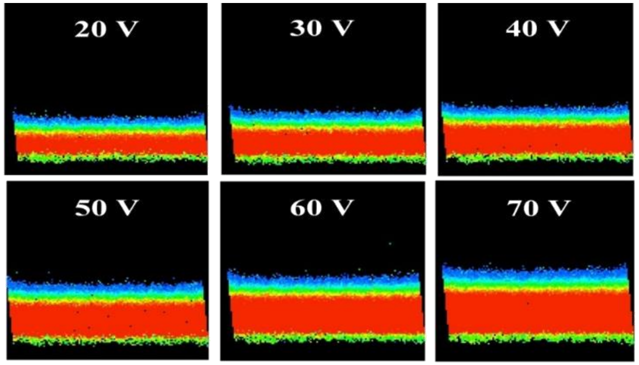
Configurations:



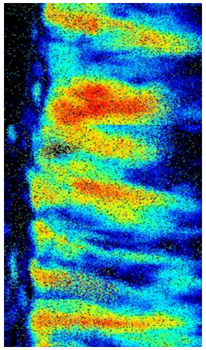


IBIC imaging

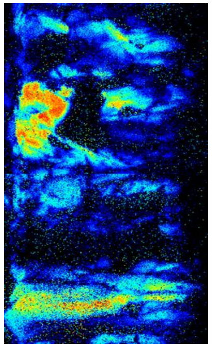
Configurations:

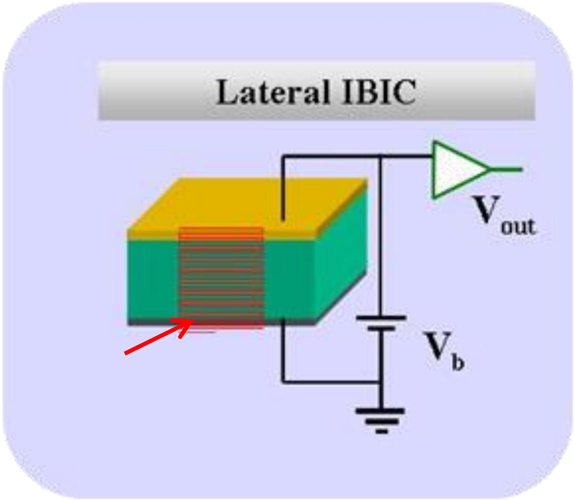


2 MeV p^+



2 MeV He^+



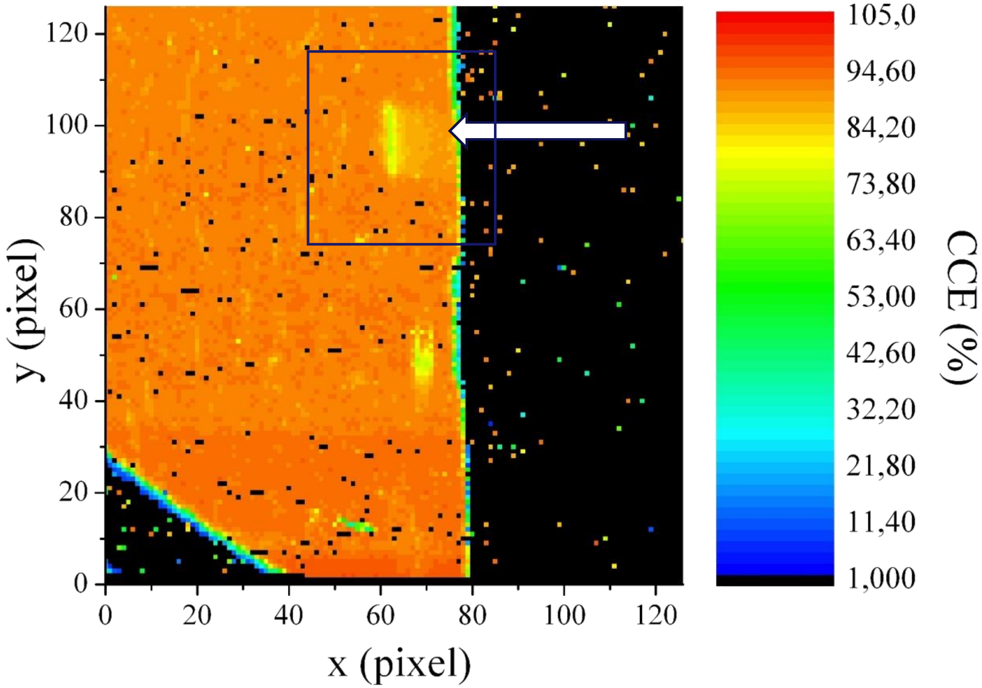


Examples – defects mapping

http://www.unito.it/

Lateral damage creation

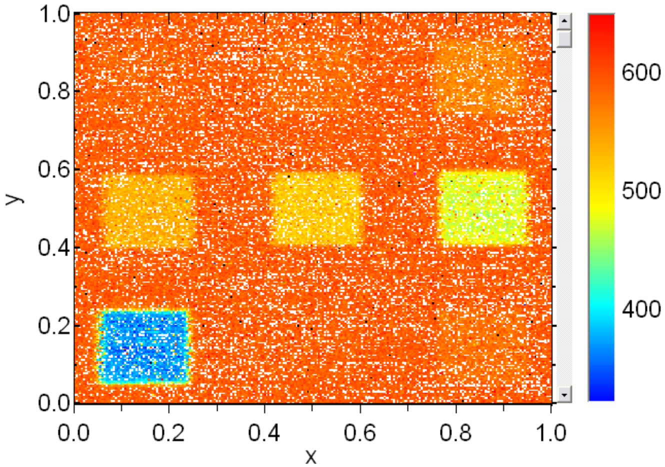
- frontal IBIC defect mapping
- Bragg peak clearly visible



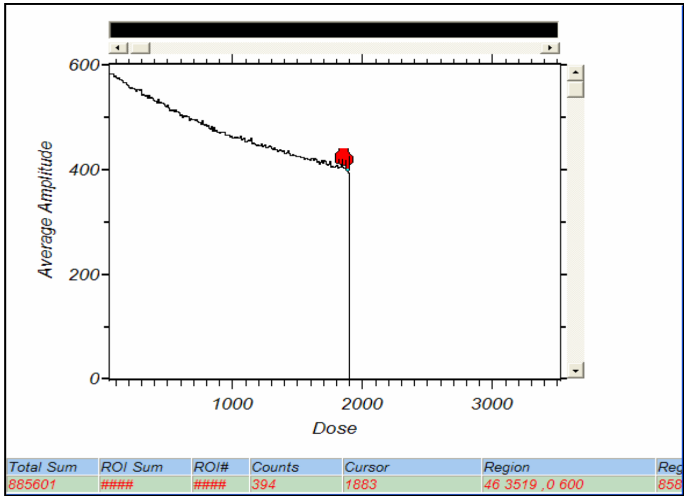
Examples – radiation hardness tests

An ion microprobe allows for:

- selective damage introduction



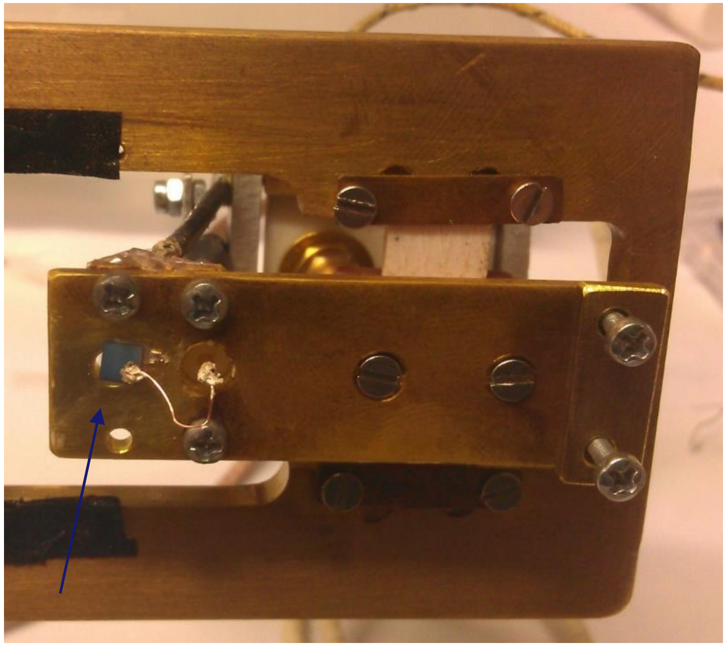
- on-line monitoring of CCE degradation and total fluence



Charge transient spectroscopy (QTS) setup

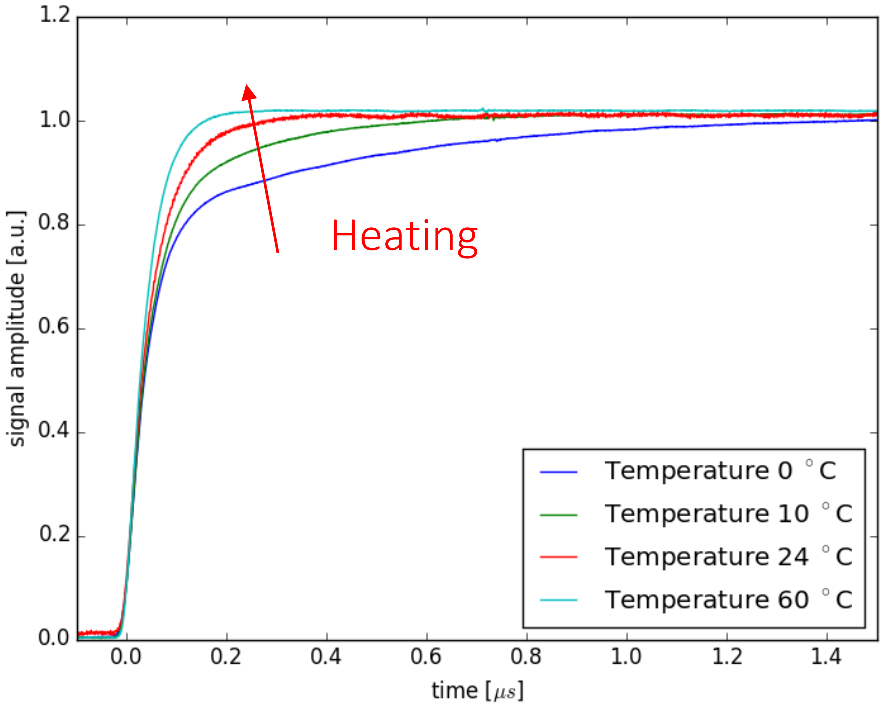
(similar to DLTS)

- CoolFET preamplifier +WaveMaster 8500A oscilloscope
- Target temperatures: -100°C to +700°C
- Achieved: -40°C to 600°C
- Stability ± 0.5°C



NDT sample mounted on QTS setup

QTS trace analysis- NDT HPHT sample

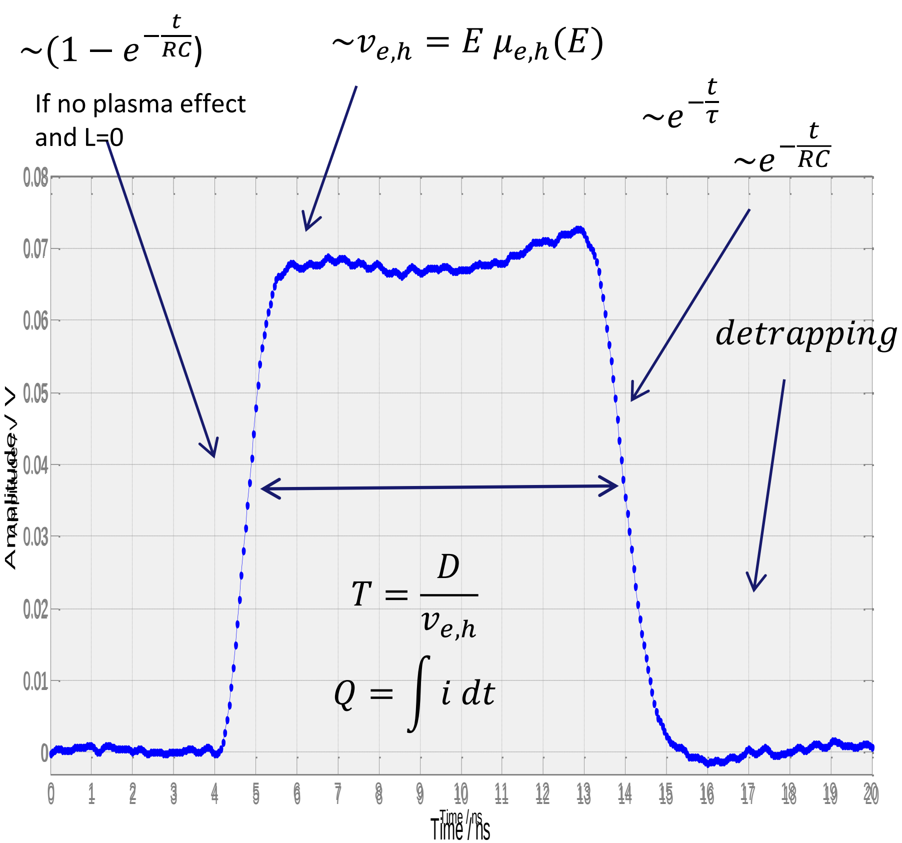


$$A = A_0(1 - e^{-e_1 t})$$

$$e_1 \sim \sigma\, N_D e^{-\frac{\Delta E}{kT}}$$

- Traps in whole sample:
  - ΔE = 0.53 eV ±0.1 eV
  - $\sigma\, N_D$ is lower
  - Boron? Arsenic?
- Traps close to the edge:
  - ΔE = 0.43 eV ± 0.04eV
  - $\sigma\, N_D$ is higher
  - Boron? Arsenic?

Time resolved IBIC (AKA mapped TCT)



TCT gives different information about physical parameters of the sample depending on the beam and energy chosen

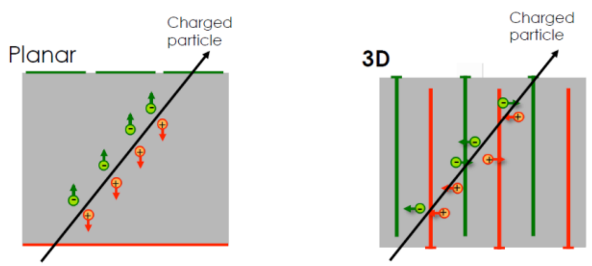
Coupled with beam scanning, possible to characterize the sample spatially

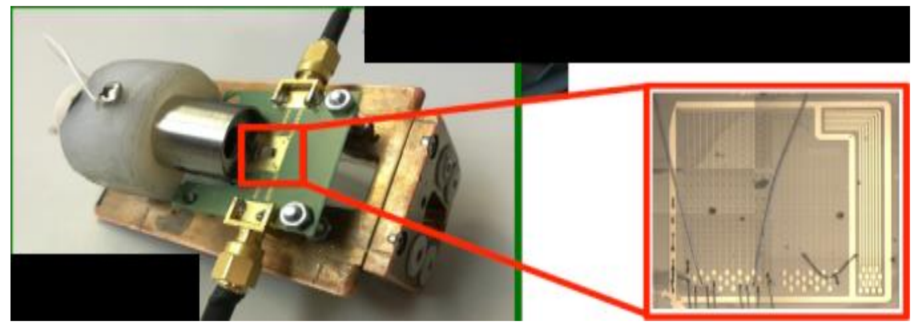
scCVD diamond
Ideal case

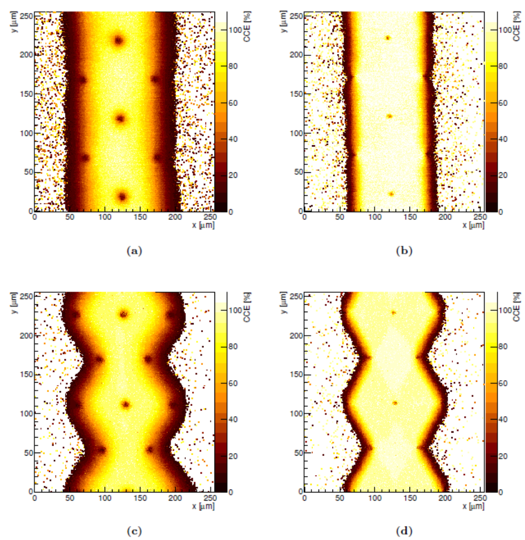
AIDA-2020-RBI-2015-4

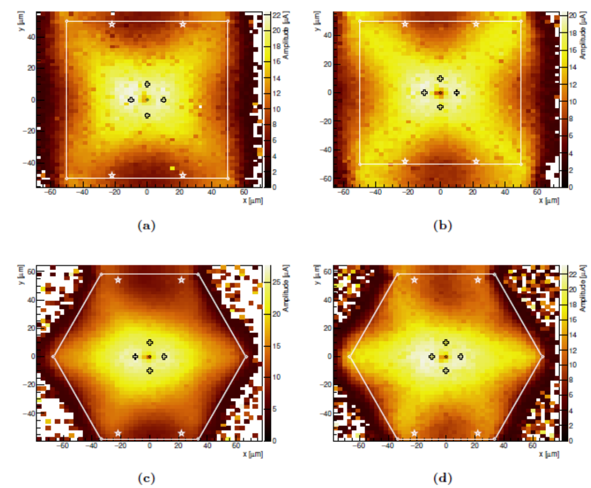
3D diamond, Alexander Oh, University of Manchester, **UK**

MANCHESTER 1824
The University of Manchester







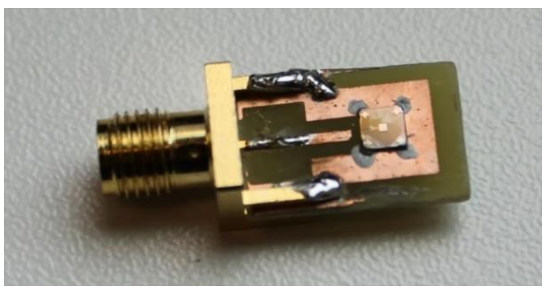
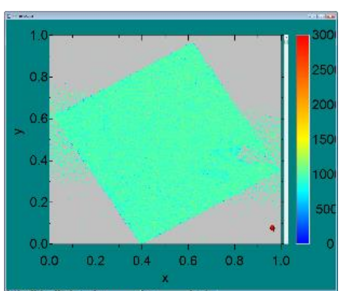


CCE maps for different biases and geometries

TRIBIC (TCT) amplitude maps

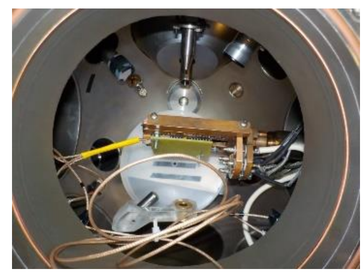
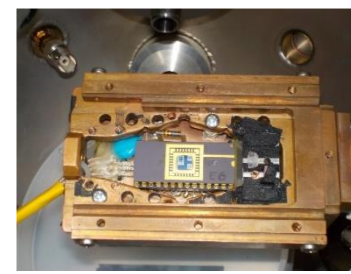
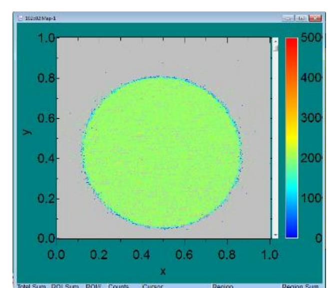
➢ AIDA-2020-RBI-2016-1

IBIC characterization of single crystal diamond based Shottky diodes for microdosimetry application, Claudio Verona, ‘Tor Vergata’ University, **Italy**

➢ AIDA-2020-RBI-2016-2

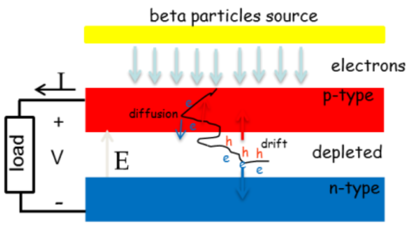
Microbeam tests of silicon telescope for clynical dosimetry, G. Magrin, Austron, **Austria**

AIDA-2020-RBI-2015-2

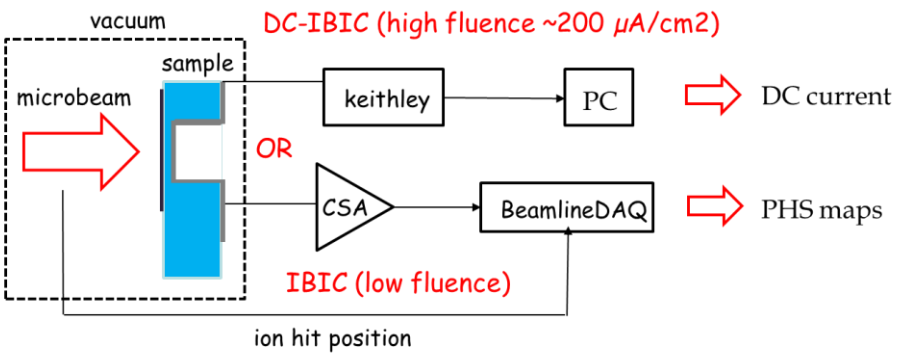
Diamond Membranes for Radioisotope Batteries BATDiαm, Michal Pomorski, CEA, LIST, **France**

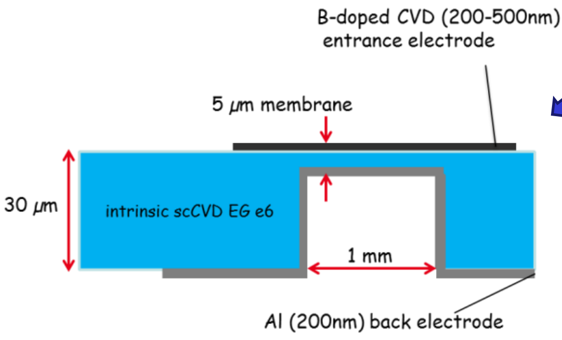
Generation of power by coupling a beta source to a semiconductor junction device

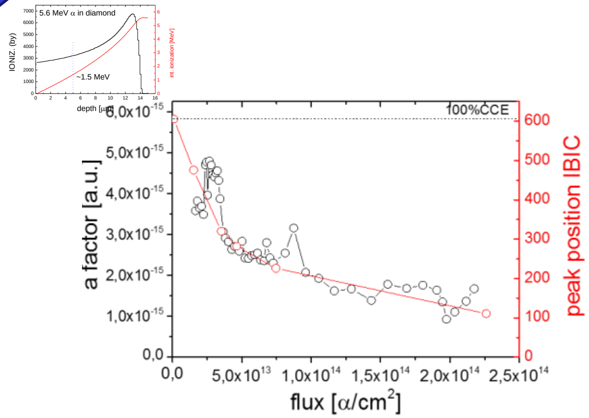


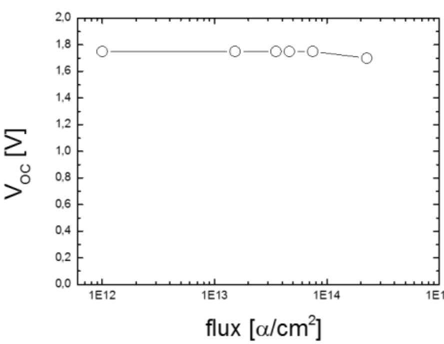
α instead of β

particles







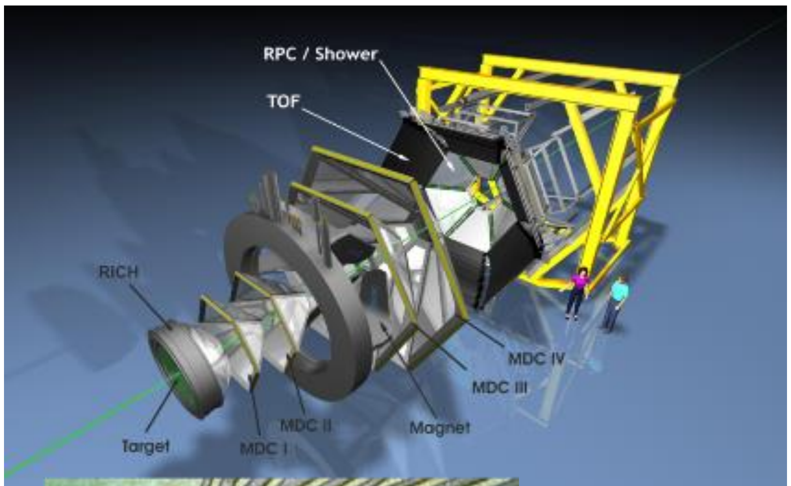


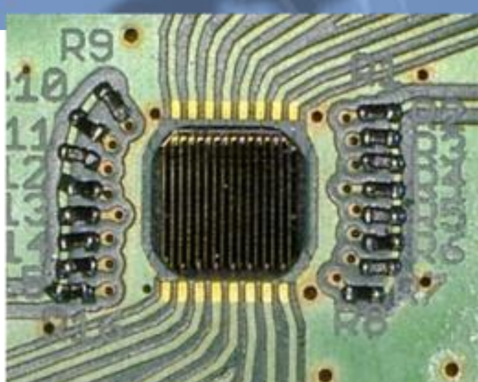
AIDA 2020

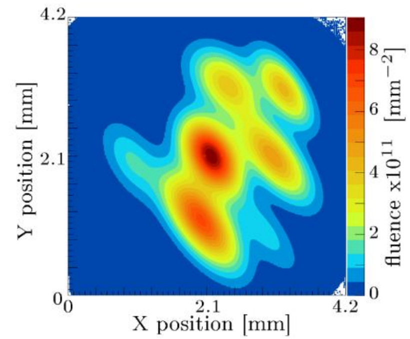
AIDA runs

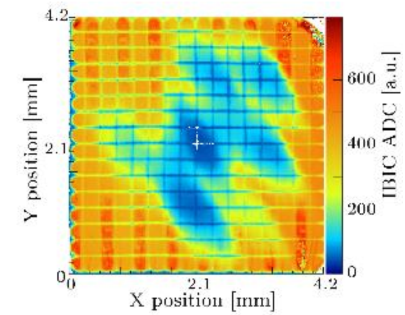
- **AIDA-2020-RBI-2015-1**

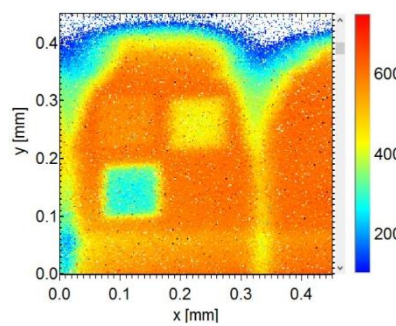
Systematic study of radiation damage in scCVD diamond material irradiated with relativistic Au beams, Jerzy Pietraszko, GSI Darmstadt, HADES, **Germany**

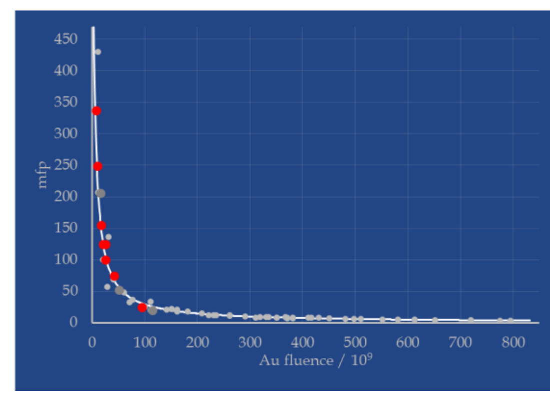












Number of traps:

Au / $p_{4.5MeV}$ / p_{24GeV} = 1 / 30 / 2430

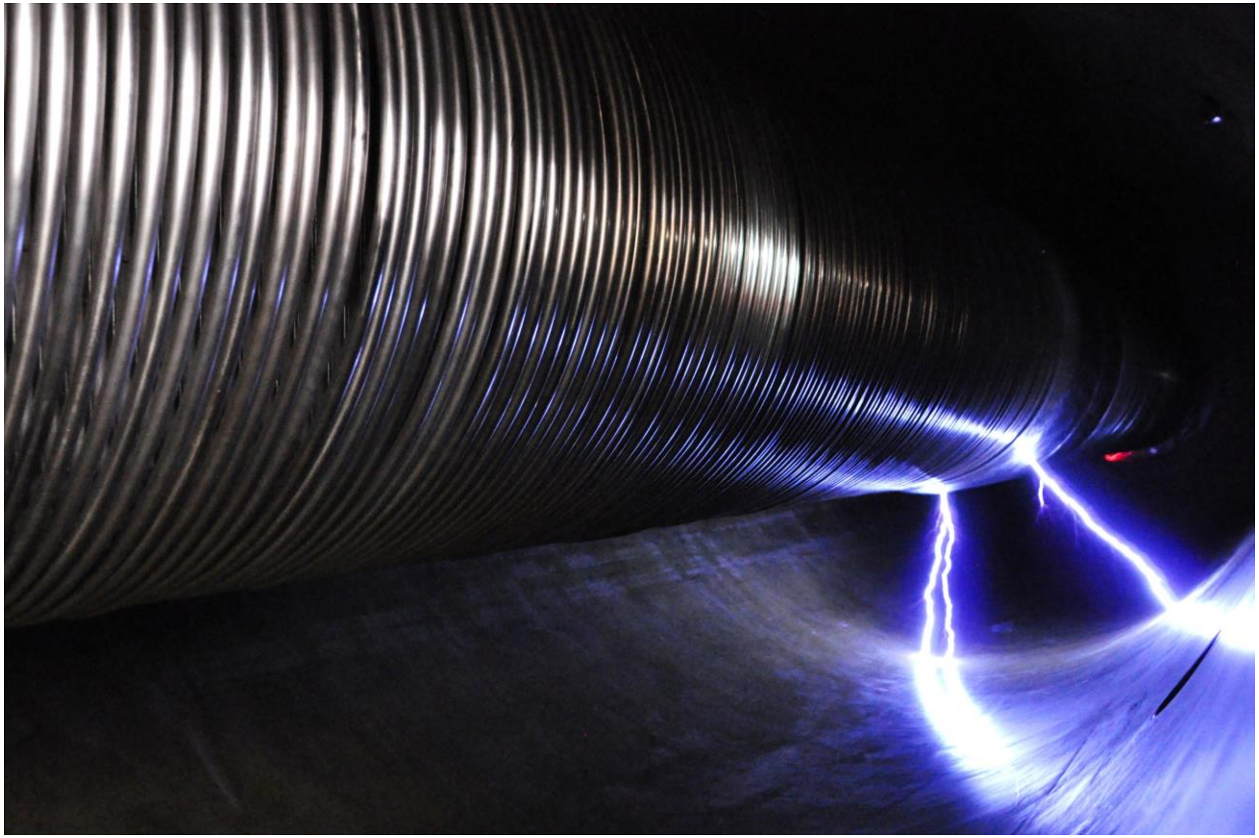
$p_{4.5MeV}$ / p_{24GeV} = 81

Correlating fluences from different sources and detector degradation scCVD diamond strip detector

To conclude:

- RBI accelerator facility hosts microbeam line used for IBIC and semiconductor modification among other uses
- Ion Beam Induced Charge/Current is efficient method for mapping basic properties of semiconductor and insulator detector materials
- Several different setups of IBIC exist: Lateral, Frontal, TRIBIC (TCT), Temperature dependent…
- So far 7 (+1 in the following month) different characterizations carried out through AIDA transnational access program

Thank you for attention!



WP12 .1 : RBI Accelerator Facility

- **TA completed:**
  - **AIDA-2020-RBI-2015-1**
    Systematic study of radiation damage in scCVD diamond material irradiated with relativistic Au beams, Jerzy Pietraszko, GSI Darmstadt, HADES, **Germany**.
  - **AIDA-2020-RBI-2015-2**
    Diamond Membranes for Radioisotope Batteries BATDiαm, Michal Pomorski, CEA, LIST, **France**
  - **AIDA-2020-RBI-2015-3**
    Investigation of channeling depth profiles of high energy carbon and silicon ions implanted in diamond and SiC crystals for detector characterization, Michael Kokkoris, National Technical University of Athens, **Greece**
  - **AIDA-2020-RBI-2015-4**
    3D diamond, Alexander Oh, University of Manchester, **UK**
  - **AIDA-2020-RBI-2016-1**
    IBIC characterization of single crystal diamond based Shottky diodes for microdosimetry application, Claudio Verona, 'Tor Vergata' University, **Italy**
  - **AIDA-2020-RBI-2016-2**
    Microbeam tests of silicon telescope for clynical dosimetry, G. Magrin, Austron, **Austria**
  - **AIDA-2020-RBI-2016-3**
    Investigation of channeling depth profiles of high energy carbon and silicon ions implanted in SiC /Si crystals for detector characterization, University of Athens, **Greece**

WP12 .1 : RBI Accelerator Facility

- **The last TA proposal submitted and approved in March 2017:**

  - **AIDA-2020-RBI-2017-1**
    Diamond Membrane Microdosimeter, Michal Pomorski, CEA, LIST, **France**

    expected two users; one or both supported by the project

    Realization expected before the end of April (although there is high possiblity to delay the experiment due to some problems in the sample preparation as reported recently by the PI).

AIDA 2020

AIDA 2020 Advanced European Infrastructures for Detectors at Accelerators

Home | Project | Activities | Transnational Access | Events | Results | AIDA | Contact

Transnational Access

AIDA-2020 Transnational Access supports small teams to carry out experiments and tests at one of the 10 European facilities listed below:

Type of facility	Access provider	Infrastructure	Country	Facility Coordinator Contact
Beam test	CERN	PS&SPS	International Organisation	Henric Wilkens
	DESY	DESY-II	Germany	Marcel Stanitzki
Irradiation test	CERN	IRRAD	International Organisation	Michael Moll
	CERN	GIF++	International Organisation	Michael Moll
	JSI	TRIGA Reactor	Slovenia	Vladimir Cindro
	KIT	KAZ	Germany	Alexander Dierlamm
	UCLouvain	CRC	Belgium	Eduardo Cortina Gil
	UoB	MC40 Cyclotron	UK	David Parker
Detector characterisation	RBI	RBI-AF	Croatia	Stjepko Fazinić
	ITAINNOVA	EMClab	Spain	Fernando Arteche

Ion beam analysis