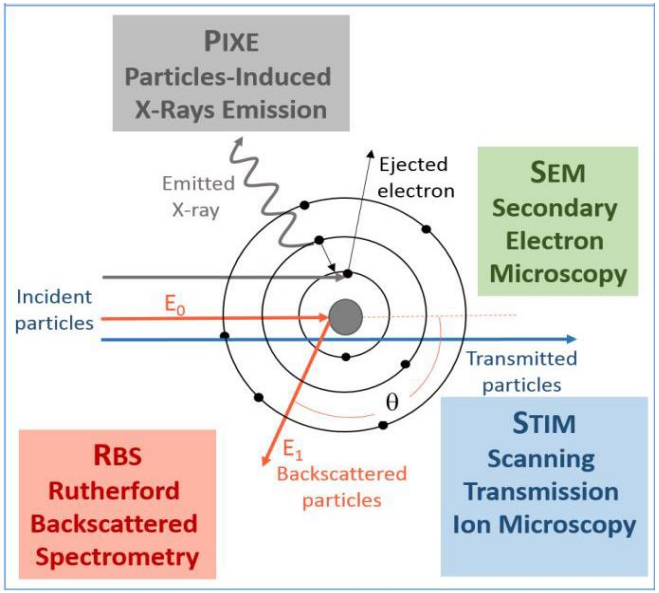
Ion beam analysis applied to life science

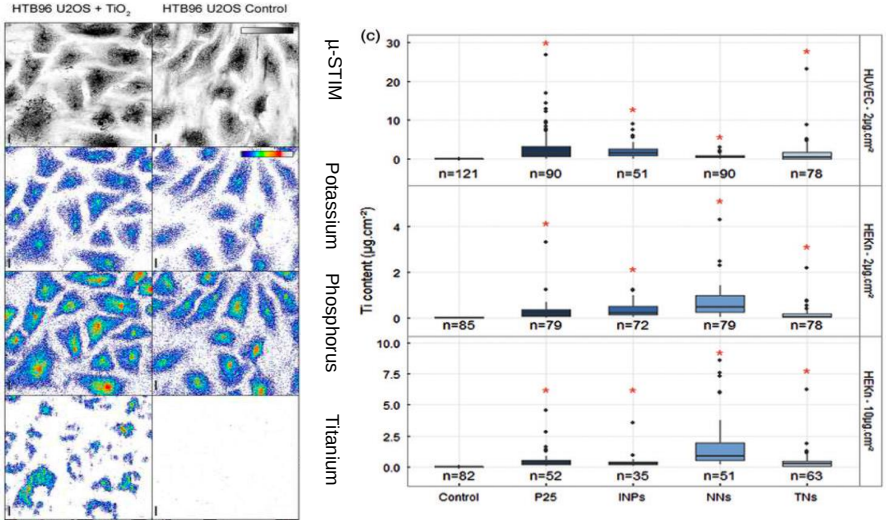
Philippe Barberet

Centre d'Etudes Nucléaires de Bordeaux-Gradignan (CENBG)

CNRS / Université de Bordeaux

IBA on biological samples





Quantification of inorganic elements in organic matrix

⇒ µg/g sensitivity

⇒ p or α beams of a few MeV (AIFIRA)

⇒ developments for analysis at higher energy (Arronax)

Microbeam (AIFIRA):

⇒ Elemental mapping

⇒ Quantification at the cellular scale

⇒ Cell by cell analysis / distribution

Why IN2P3 ?

Ion beam accelerators

Nuclear instrumentation

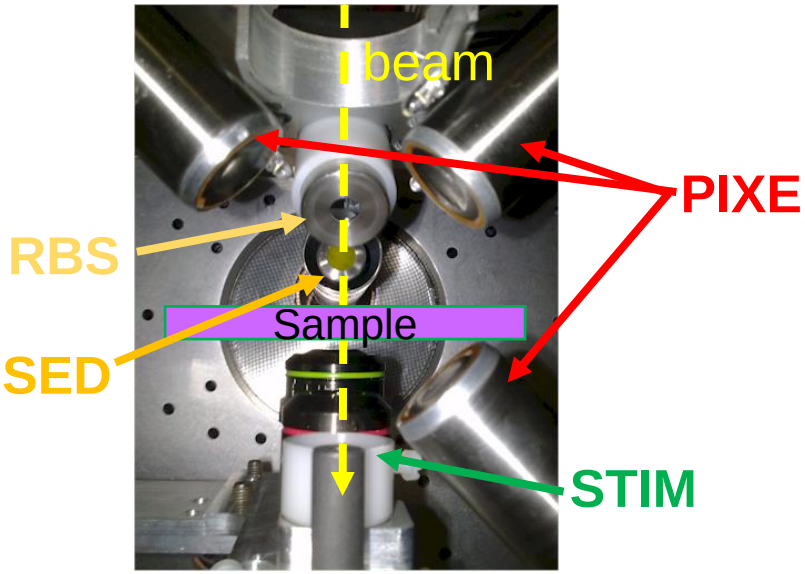
Data acquisition and analysis

Facilities

AIFIRA (Bordeaux) : p, d, α 1 to 3 MeV

- Ion microbeam opened to the community
- Elemental mapping at the µm scale



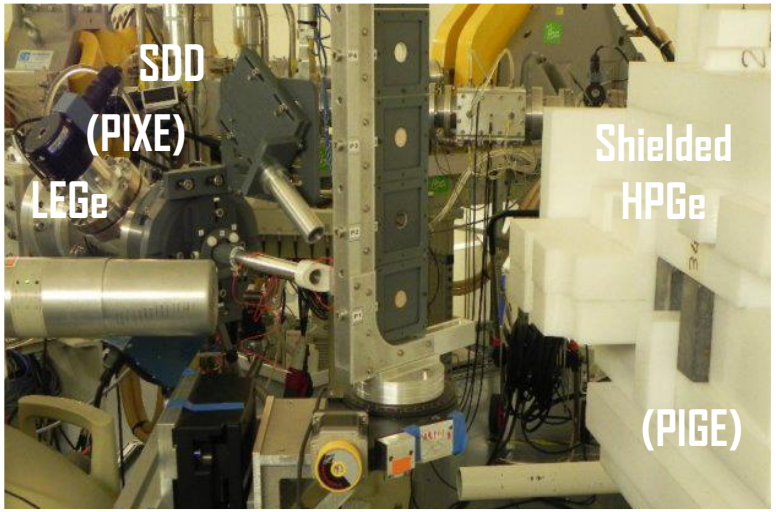


BEAM: H^+
1- 3 MeV
Ø ≈ 0.3 - 1µm
I ≈ 200 pA

Facilities

Arronax (Nantes) : p,d,α up to **70 MeV**

- High energy beamline
- In air analysis
- Higher analysis depth

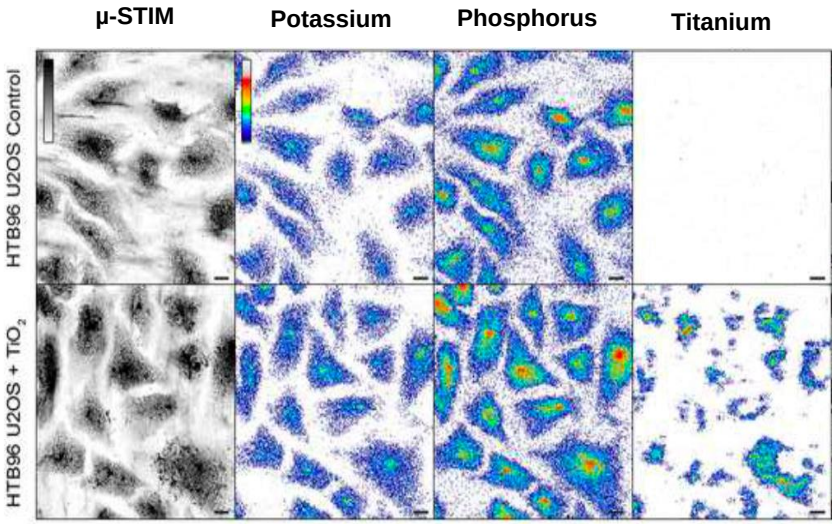


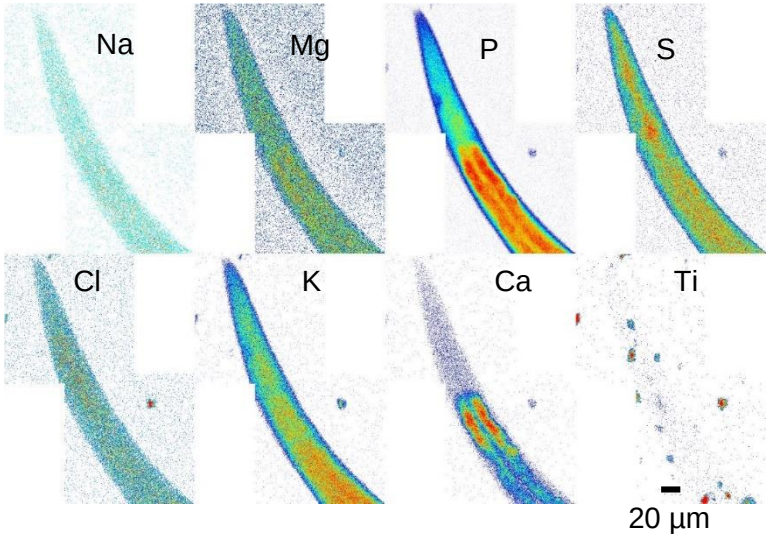
(No microbeam @ high energy)

State of the art and perspectives

Exposure to exogenous compounds, metals and nanoparticles (NPs)

- Currently ⇒ Mainly toxicology studies
  - # µ-analysis of exposed cells or organisms at different doses
  - # Impact on cellular homeostasis
  - # Groups at CENBG and AIFIRA external users



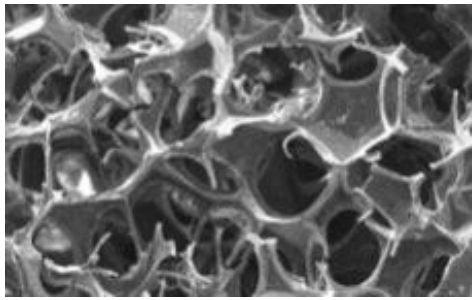


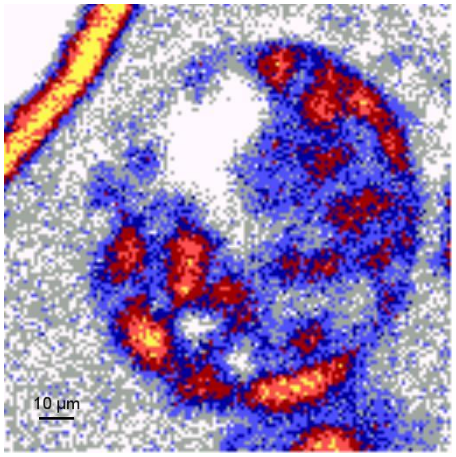
- Future ⇒ Internalization for treatment (radiosensitization or radio-isotopes)
  - # Metals, NPs or radio-isotopes designed to be internalized in cells
  - # Gold-carbenes or Au-NPs (LPC Clermont)
  - # New isotopes (INCIA Bordeaux)

State of the art and perspectives

- Currently ⇒ Development of bioactive materials used as bone substitutes (LPC Clermont)
  - # Materials behaviour at the interface with living tissues
  - # Release of trace elements in tissues
  - # 4 patents







- Future ⇒
  - Development of bioactive glasses doped with antibacterial trace elements (Cu, Zn, Ag)
  - Development of hybrids bioactive glasses/polymer macroporous scaffolds doped with trace elements to induce bone formation

Key aspects

- Ion beam analysis and imaging

  Our techniques remain limited:

  # Acquisition time
  # Data reduction and analysis
  # Specific sample preparation protocoles
  # External user support mainly provided by research groups

  We need to develop or improve:

  # Correlative imaging
  # Standardization: sample preparation & data processing
  # Higher throughput: Acquisition and automatisation
  # Enhanced data processing : Towards IA / ML technologies ?
  # Meta analysis

- IBA @ higher energies
  - In air analysis
  - Higher analysis depth ⇒ Tissues, organs ….

Presentation built from the contribution of :

Chemical physics of biomaterials and nanostructures, LPC Clermont

E. Jallot, J. Lao

Biology and Biophysics of cell damage, LPC Clermont

P. Vernet, G. Montarou

Prisma team @ Subatech

V. Métivier, F. Haddad, C. Koumeir, A. Guertin

iRiBio group @ CENBG

H. Seznec, P. Barberet, G. Devès, L. Plawinski









Publication list

- **Biomaterials**

E. Jallot et al.. Applied Materials and Interfaces, 2(6) : 1737-1742 (2010).

J. Lacroix et al.. Journal of Physical Chemistry C, 117(44): 23066-23071 (2013).

J. Lao et al. Surface and Interface Analysis, 46 (10-11): 702-706 (2014).

J. Lao et al. Journal of Materials Chemistry B, 4 (14): 2486-2497 (2016).

J. Lao et al. Journal of Materials Science, 52(15): 9129-9139 (2017).

- **TiO2 NPs exposure & IBA protocoles**

M. Simon *et al. Nanotoxicology 2011*, 5(2), pp. 125–139..

M. Simon et al. Nanotoxicology 2017 (11) 134-145

Q. Le Trequesser *et al. Journal of Chemical Biology*, (2015) 8(4), pp. 159–167

G. Devès et al. NIM B, 348, 62-67 (2014)

Q. Le Trequesser et al. Anal Chem. 2014 Aug 5;86(15):7311-9

G. Muggiolu et al, *J. Vis. Exp.* (132), e55041, (2018)

- **High energy PIXE @ Arronax**

A. Subercaze et al. NIMB 417 pp. 41-45 (2018)

A. Subercaze et al. NIMB 406 pp. 104-107 (2017)