

**Th**  
Thorium  
232.038



# Séminaire de Radiothérapie Interne Vectorisée

# Arthur BONGRAND

Samuel DUVAL, Arnaud GUERTIN & Julie CHAMPION

# Projet BePAT :

# **BeaQuant, un autoradiographe numérique au service de la production de radionucléides pour des applications en médecine nucléaire**

15/03/2022



**IV** Nantes  
**U** Université



UNIVERSITÉ  
DE MONTPELLIER





# Physics of Radiations InteractionS with Matter and Applications

RaMI

IRMa

HB

**RaMI** → Radionucléides Médicaux Innovants – Innovative Medical Radionuclides

- ✓ Health
- ✓ Nuclear medicine
- ✓ Radionuclides

*Cross section measurement*  
*Isotope productions*  
*Masse separation and laser ionisation: SMILES* ☺



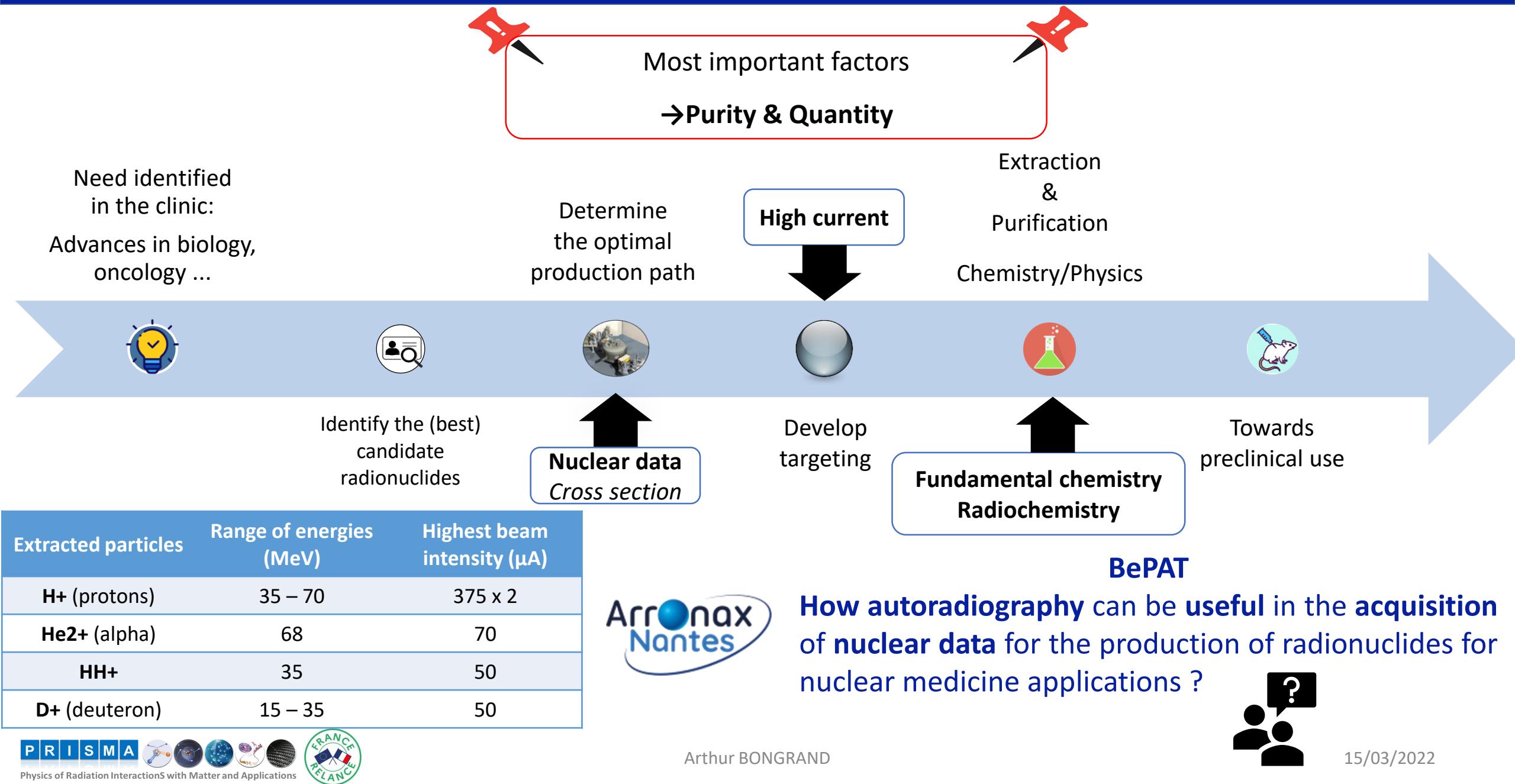
**IRMa** → Interaction Rayonnement Matière – Radiation-Matter Interaction

- ✓ Ion Beam Analysis, materials → *IBA platform: visible, X, γ*
- ✓ Non Destructive Testing → *Nuclear data X, γ: PIXE/PIGE - High Resolution X-Ray Tomography System*
- ✓ Detector development and characterization → *profilers, diamond detectors, dosimeters...*

**HB** → HadronBiologie – HadronBiology

- ✓ Health, Radiobiology, Dosimetry, Flash Hadrontherapy → *In-situ dose monitoring & Irradiation platform: proton and α beams*

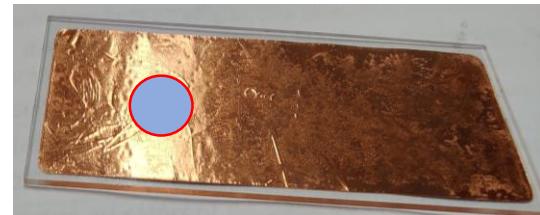
# Radionuclide production scheme and RaMI's expertise



- **Autoradiography**

- An **emission imaging technique** carried out from a radioactive source placed in contact with an emulsion, a photographic film or an adapted detector

- Area of interest located at the surface ( $\approx 10 \mu\text{m}$  deep)



Glass slide

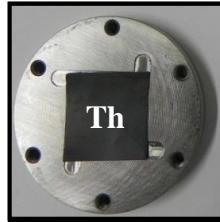
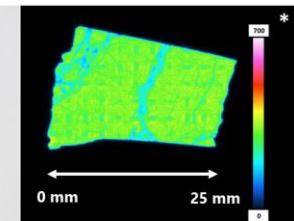
- **Applications**

- Pre-clinical (oncology + drug discovery)

*Visualization of molecules or fragments of molecules*

*labeled with radioactive elements*

- Geology (study of uraniferous rocks, environmental pollution...)



Lefevre *et al.*, under review NIMA

**BeaQuant**

- **Samples**

- "Thin" (<1 cm thick)  $\approx$  size of a small sugar square

- Can be electroplated on a glass slide, a "sugar" or a **metal foil (new)**

- **Specificities of the BeaQuant**

- Real-time direct counting

- ✓ Quantification

- ✓ Tracking

Technology	Direct gaseous counter
Performance	<ul style="list-style-type: none"> <li>• Spatial: <b>Alpha 20 <math>\mu\text{m}</math> – Beta 20 <math>\mu\text{m}</math></b> – <b>High energy <math>\beta</math> or <math>\beta^+</math> 50 <math>\mu\text{m}</math></b></li> <li>• Linearity over 5 orders of magnitude</li> <li>• Sensitivity: <b>0.0005 cpm/mm<sup>2</sup> (<math>\approx \text{mBq}</math>)</b></li> </ul>
Markers	All radioisotopes

Arthur BONGRAND

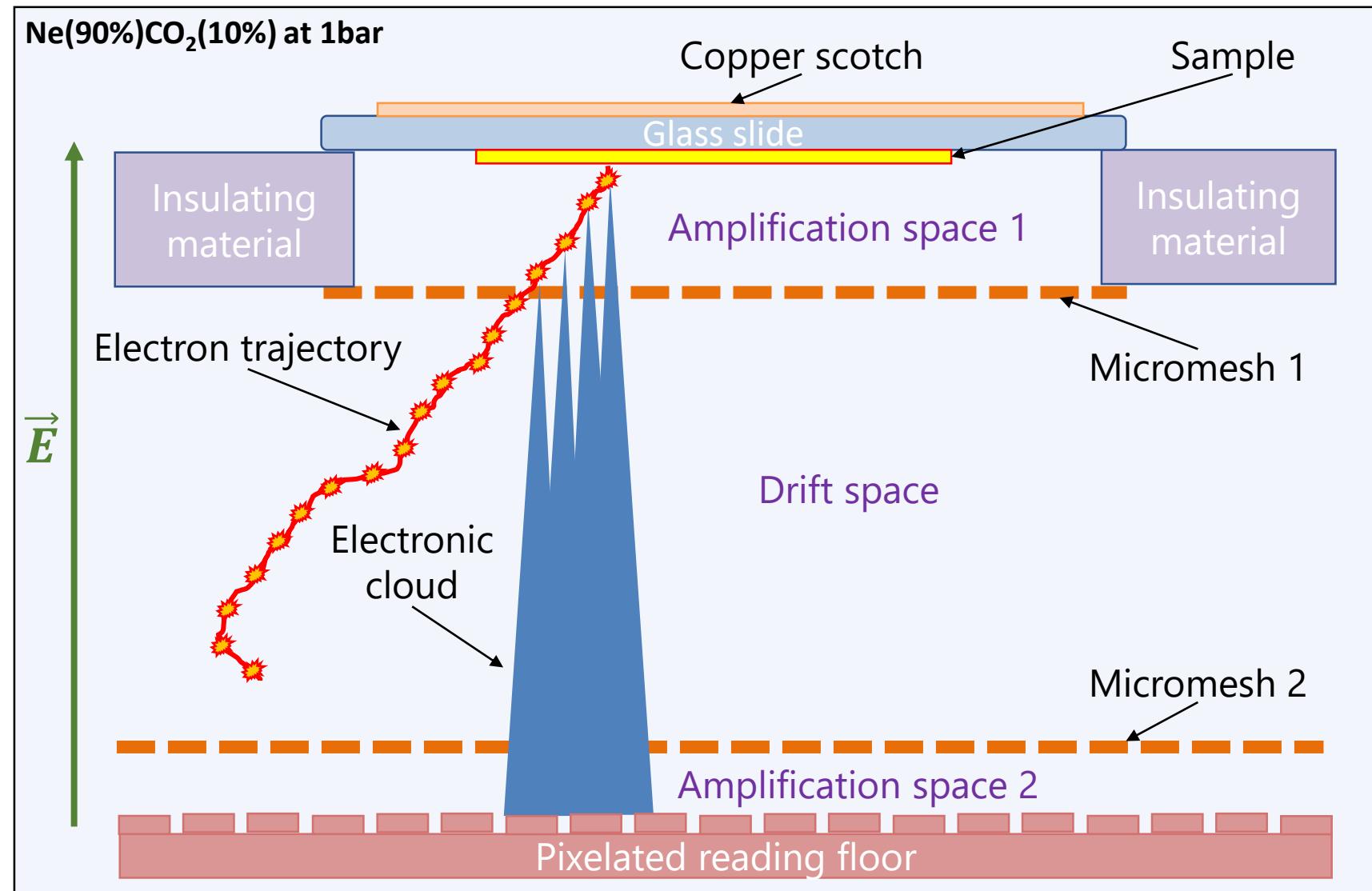


15/03/2022

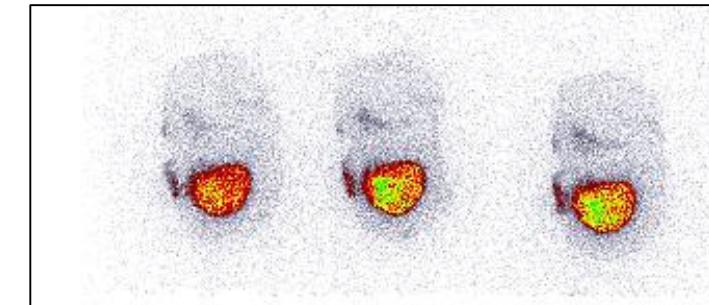
# BeaQuant autoradiograph schematic diagram for $\beta^+$ , $\beta^-$ , Auger...

5

## Sectional view

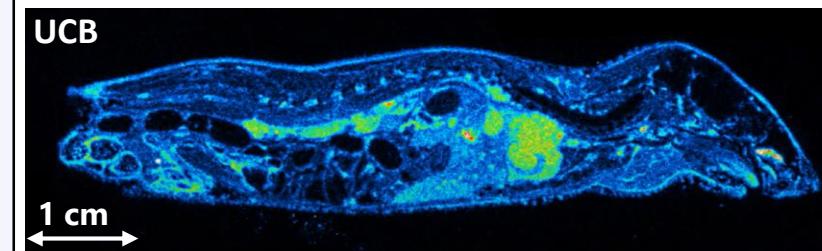


Laboratoire Imagerie et Cerveau, Unité Inserm  
930 Université François-Rabelais de Tours



In vivo rat brain labelled with LBT999 -  $^{18}\text{F}$

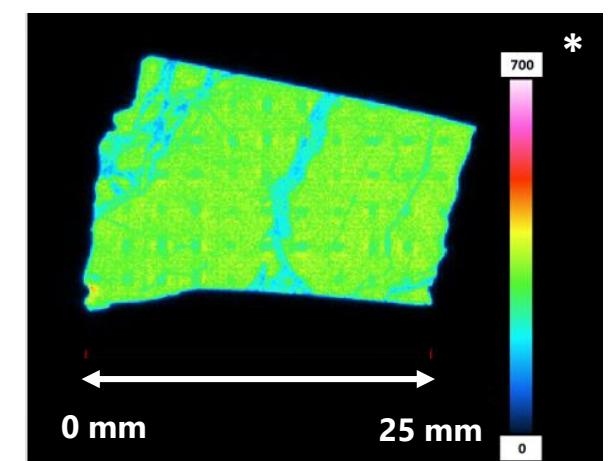
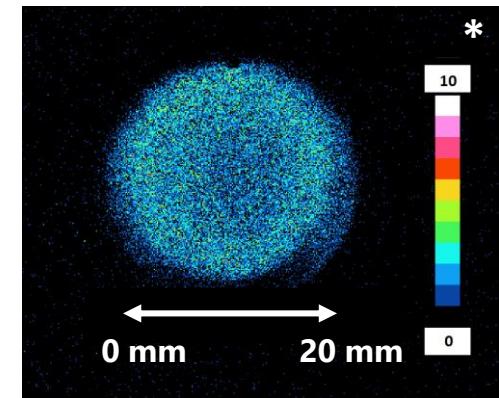
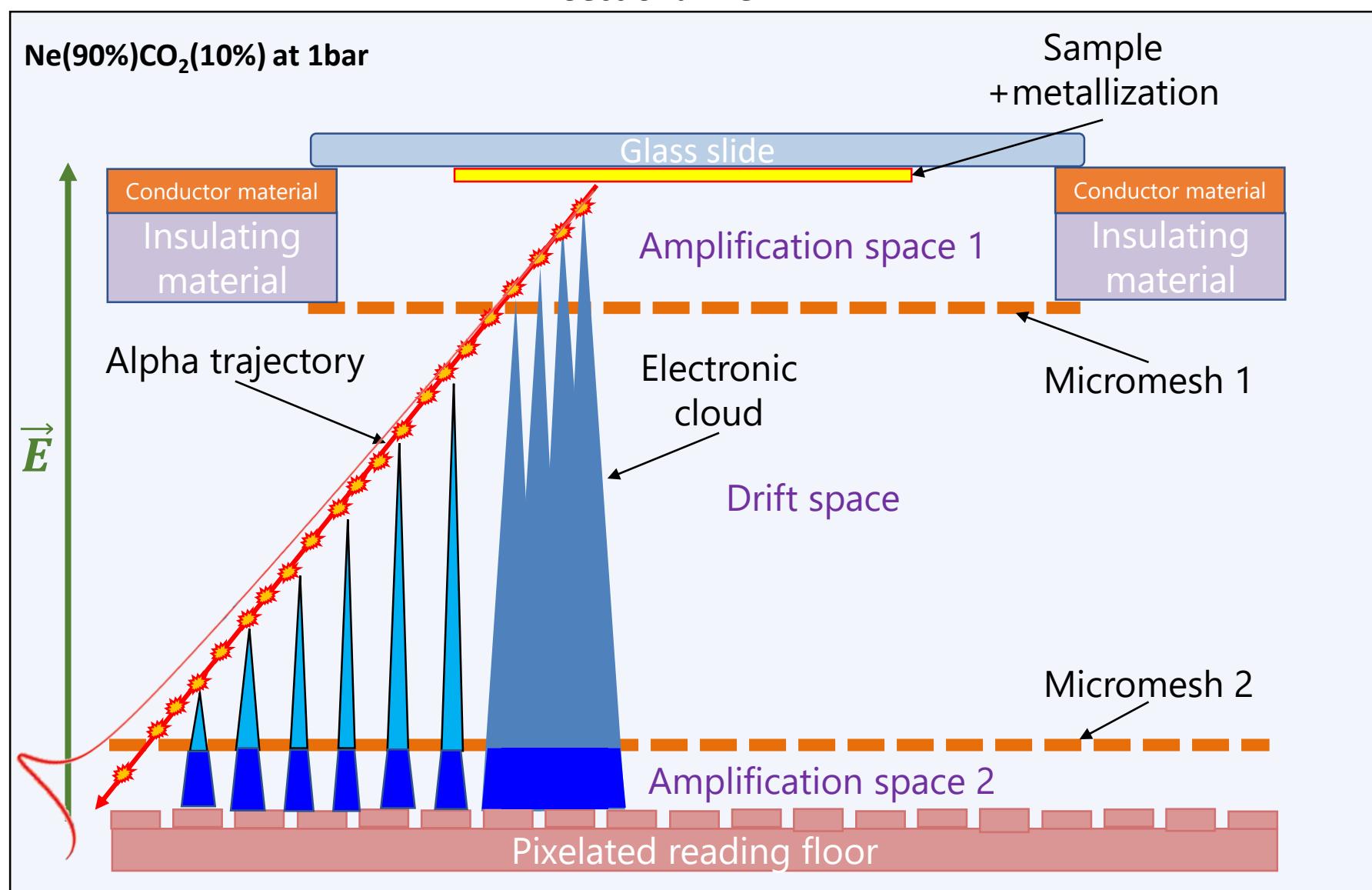
$^{18}\text{F}$  Spatial resolution: 50  $\mu\text{m}$



$^{125}\text{I}$  QWBA  
Spatial resolution: 50  $\mu\text{m}$

# BeaQuant autoradiograph schematic diagram for $\alpha$

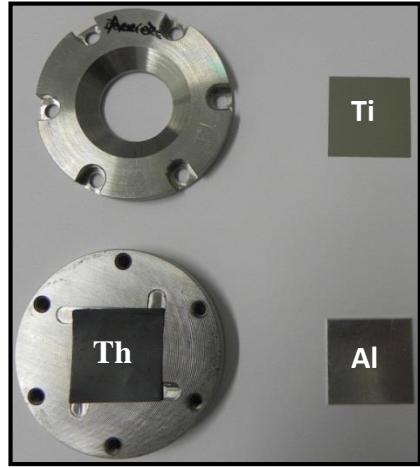
## Sectional view



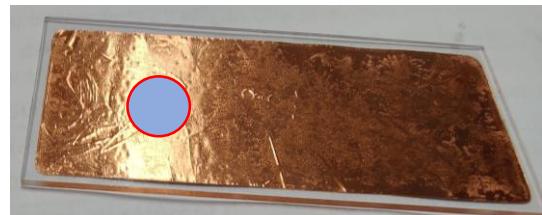
\* Lefèuvre et al., under review NIMA

# Some rules for the preparation of the BePAT samples

7



Capsule and metal foils



Metal foil can be electrodeposited  
after digestion and chemical  
separation

- **Samples**

- Metal foil

- Metal foil electrodeposited  
after digestion and chemical separation (in the future)

- **Sample activity**

- Insensitive to  $\gamma$  and X

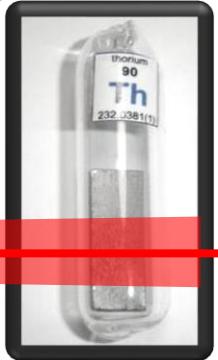
- $A(\alpha) + A(\beta+) + A(\beta-) < 20 \text{ kBq}$

} Specific calculations required !

- **Challenge**

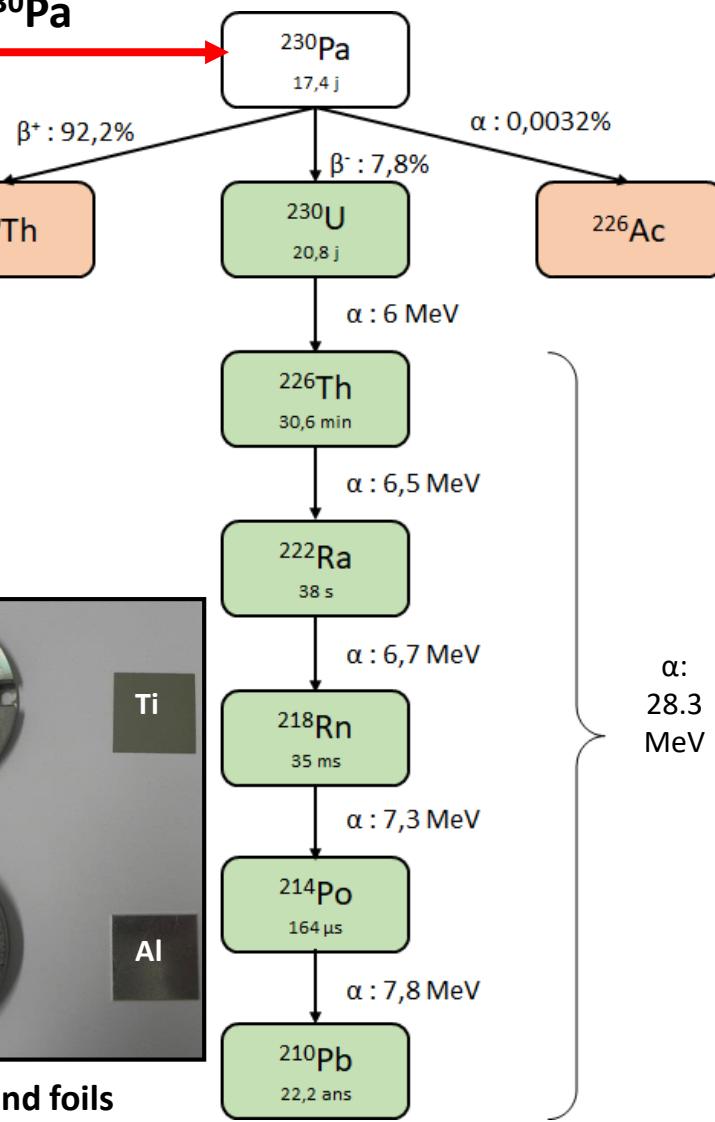
- Short-lived isotope !





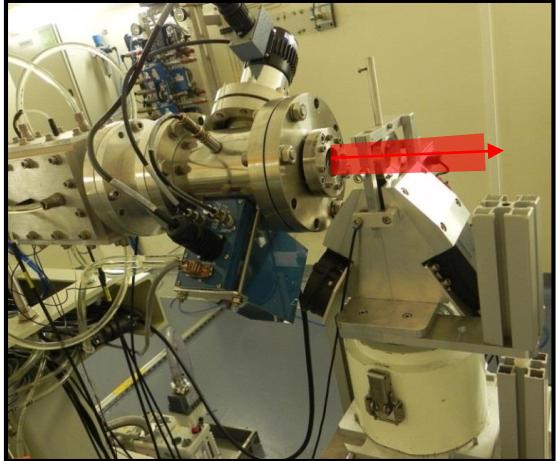
# Protons

## Goal : $^{230}\text{Pa}$

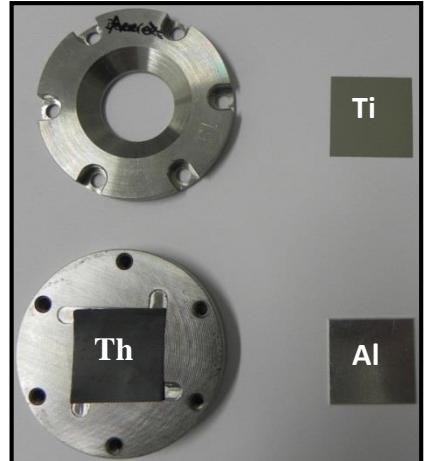


Arthur BONGRAND

## « Stacked foil » experiment



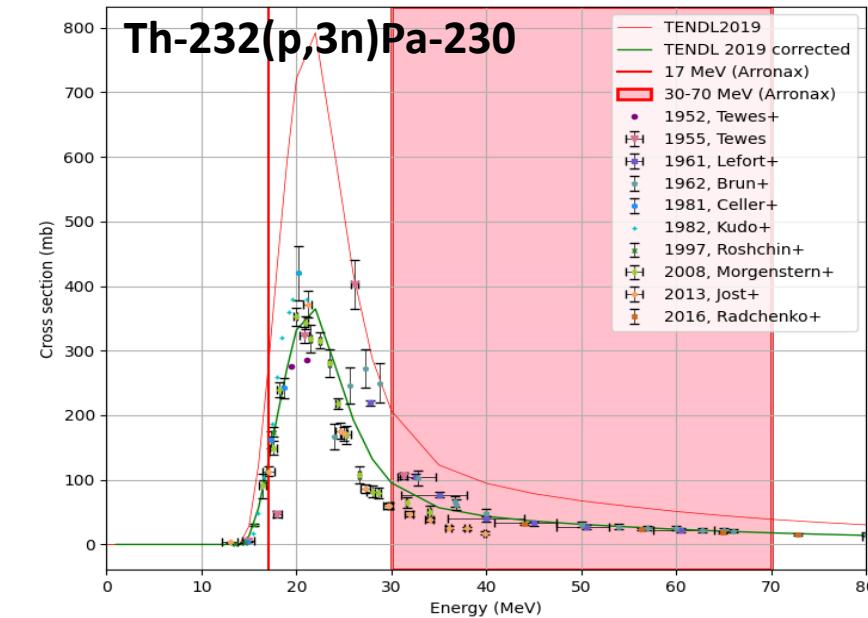
## Irradiation station and beam line



## Capsule and foils

- **α therapy benefit**
  - Short range in human tissues :  $\approx 100\mu\text{m}$  ( $\approx$  cell diameter)
  - High Linear Energy Transfer (LET) : 60-200 keV/ $\mu\text{m}$
  - Great DNA damages  $\rightarrow$  no cell repair

- $^{230}\text{U}/^{226}\text{Th}$  from  $^{230}\text{Pa}$   
considering Arronax's characteristics  
17 and 30-70 MeV Proton beam



# Chemical separations of Pa-230 and U-230

## after production

## → Contaminant :

$^{231}\text{Pa}$  ( $t_{1/2} : 104$  ans,  $\alpha \approx 5\text{MeV}$ )

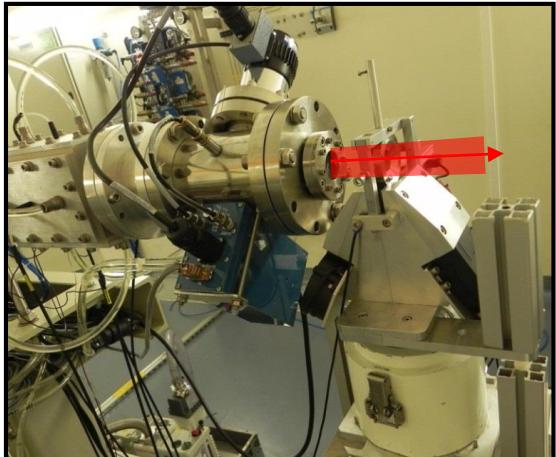
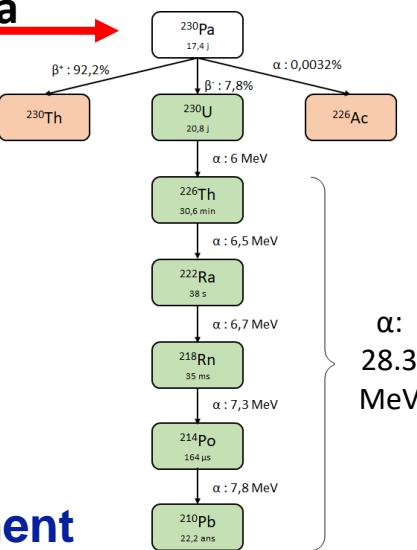


Protons

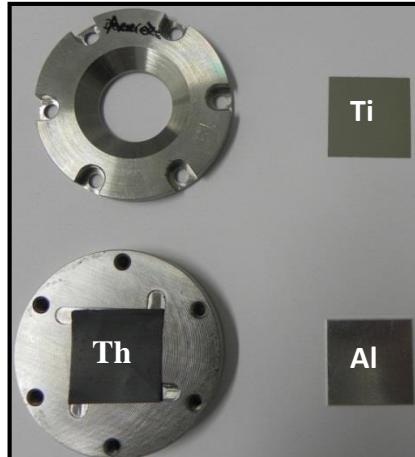
Th-232

« Stacked-foil » experiment

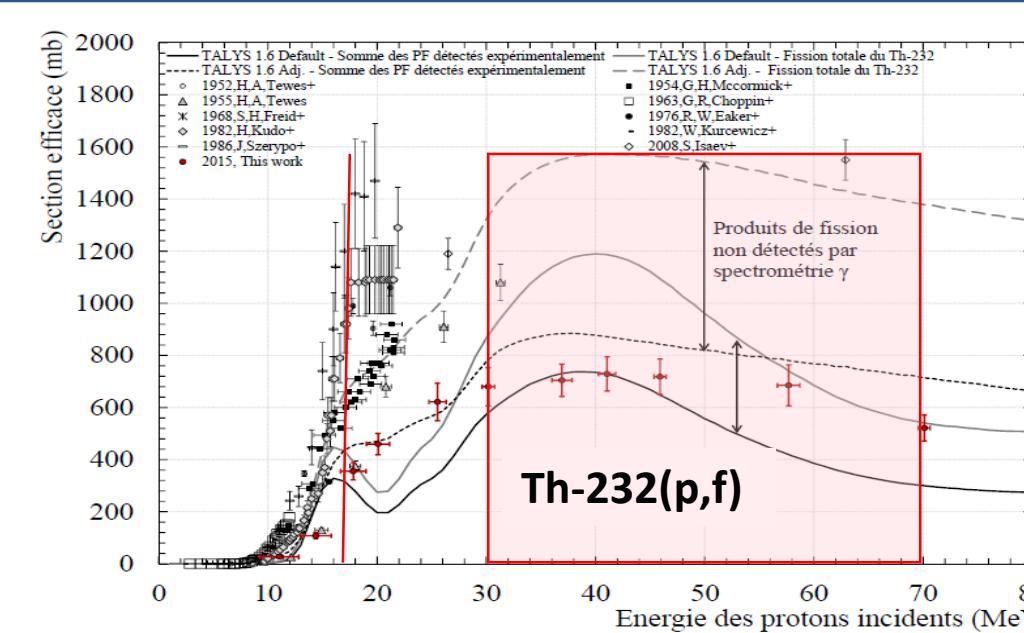
Goal :  $^{230}\text{Pa}$



Irradiation station and beam line



Capsule and foils



Arronax 17, 30-70 MeV

Duchemin, 2015  
tel-01220522

- Contaminant

$^{233}\text{Pa}$  ( $t_{1/2} : 27\text{j}$ ,  $\beta^-$ )

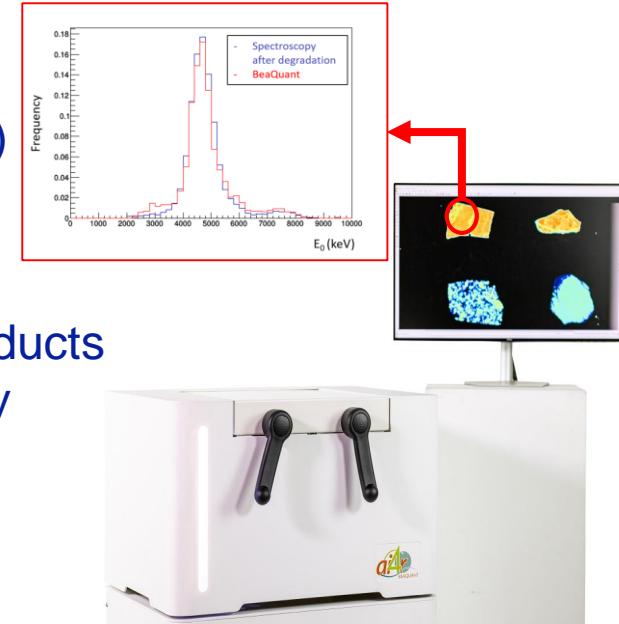
$^{231}\text{Pa}$  ( $t_{1/2} : 104 \text{ ans}$ ,  $\alpha \approx 5\text{MeV}$ )

- In a nutshell

→ Large number of fission products  
not detected by  $\gamma$  spectroscopy

→ Need for  $\alpha$  spectrometry !

→ BePAT ! ←





# Problem of purchasing metal foil for $Z>83$ !



03/2022

Z>83 : there remains the "grey" market: the stock of other laboratories...



The law is hard, but it's the law (Dura lex, sed lex)



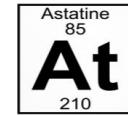
Arthur BONGRAND

 AMERICAN ELEMENTS  
THE ADVANCED MATERIALS MANUFACTURER®

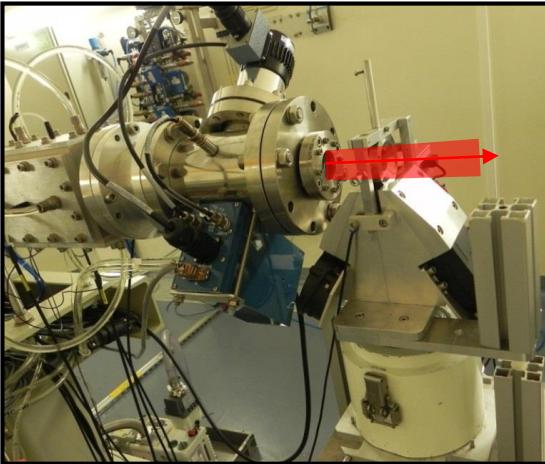
Aluminum Pieces	Holmium Pieces	Ruthenium Pieces
Antimony Pieces	Indium Pieces	Samarium Pieces
Arsenic Pieces	Iridium Pieces	Scandium Pieces
Barium Pieces	Iron Pieces	Selenium Pieces
Beryllium Pieces	Lanthanum Pieces	Silicon Pieces
Bismuth Pieces	Lead Pieces	Silver Pieces
Boron Pieces	Lithium Pieces	Strontium Pieces
Cadmium Pieces	Lutetium Pieces	Tantalum Pieces
Calcium Pieces	Magnesium Pieces	Tellurium Pieces
Carbon Pieces	Manganese Pieces	Terbium Pieces
Cerium Pieces	Molybdenum Pieces	Thallium Pieces X
Chromium Pieces	Neodymium Pieces	Thulium Pieces
Cobalt Pieces	Nickel Pieces	Tin Pieces
Copper Pieces	Niobium Pieces	Titanium Pieces
Dysprosium Pieces	Osmium Pieces	Tungsten Pieces X
Erbium Pieces	Palladium Pieces	Vanadium Pieces
Europium Pieces	Platinum Pieces	Ytterbium Pieces
Gadolinium Pieces	Potassium Pieces	Yttrium Pieces
Germanium Pieces	Praseodymium Pieces	Zinc Pieces
Gold Pieces	Rhenium Pieces	Zirconium Pieces
Hafnium Pieces	Rhodium Pieces	

## Aim of BePAT: to work on the development of spectrometry with metal foil

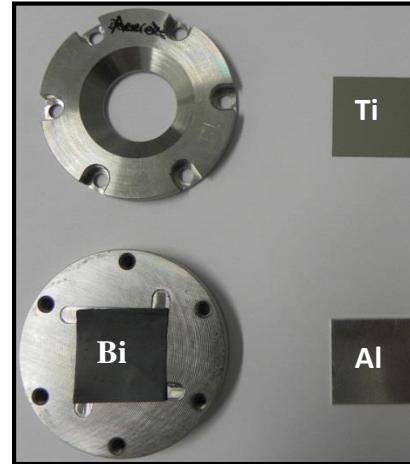
Production of  $\alpha$  elements from  $^{210}\text{Bi}$  !  
metallic  $^{211}\text{At}$ ,  $^{211}\text{Po}$  !



- $\alpha$ -emitter (5.9 MeV and 7.45 MeV)
  - Can be produced "easily" @Arronax
    - Well-known element but
- Ideal to optimize  $\alpha$  spectroscopy method

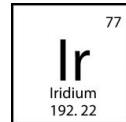


Irradiation station and beam line



Capsule and foils

Study of a theranostic pair:  
( $^{187}\text{Ir}$  ,  $^{189}\text{Ir}$ )



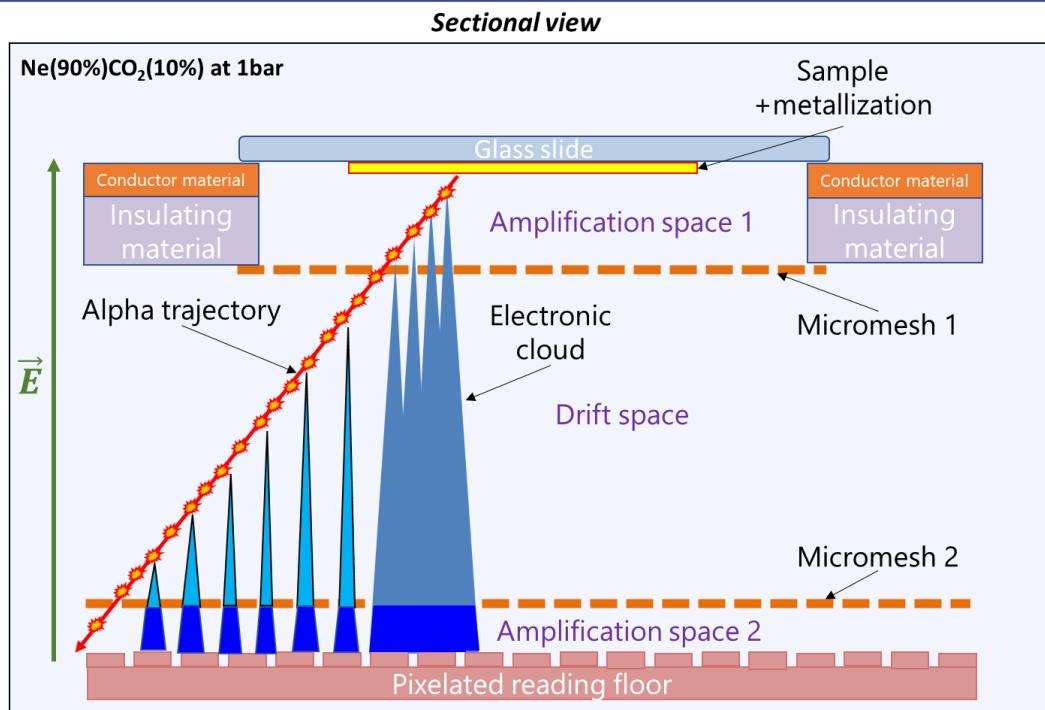
- "Strike" Auger \*  
Targets DNA or important structural units 1-100nm  
cell nucleus and other organelles 1-10 $\mu\text{m}$
- $\beta^+$ /Auger pair produced **at the same time with a natural rhenium metal foil &  $\alpha$  beam**
- Good chemical characteristics but many contaminants 188-190Ir
- Exploratory work
- Gamma spectroscopy methods can be used !
- Ø  $\alpha$  produced



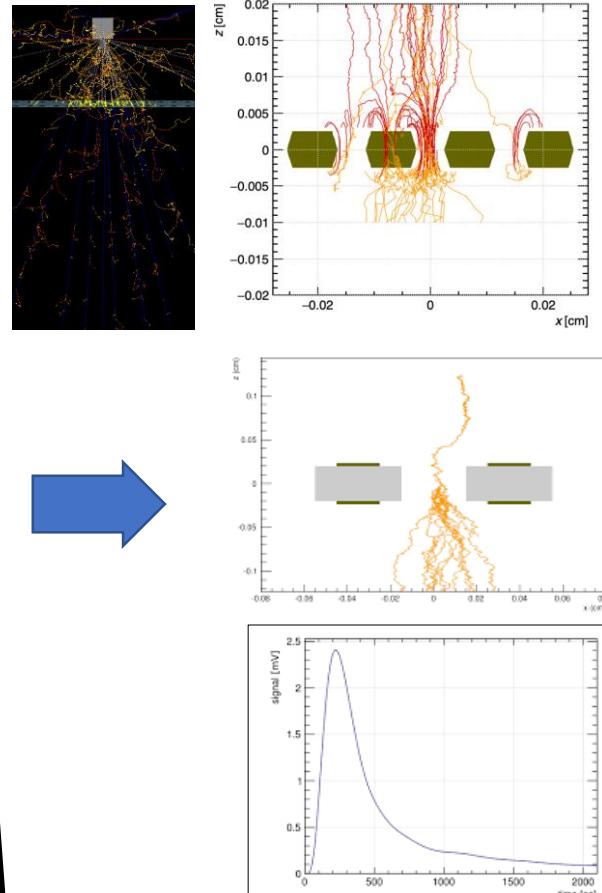
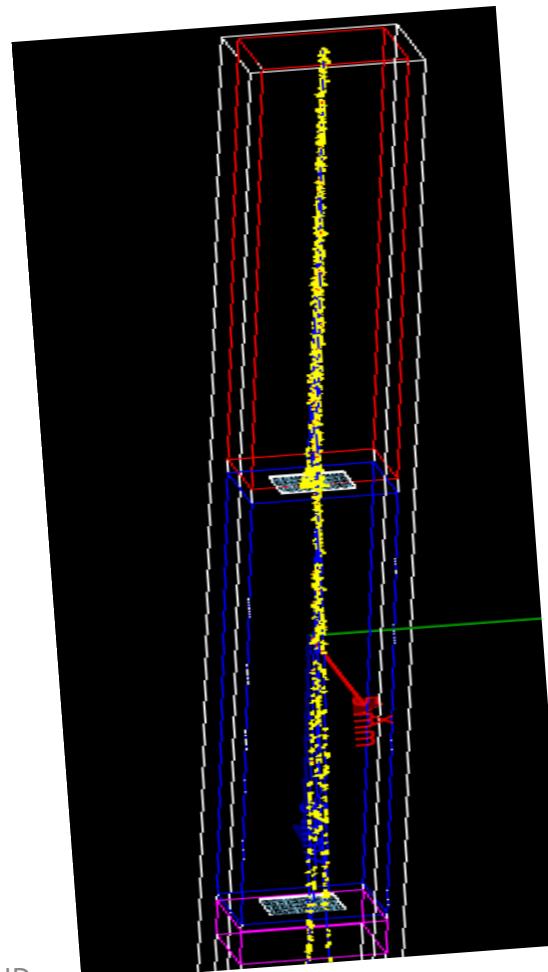
**Goal : Search for the energy deposit in the gas to get the initial kinetic energy of the  $\alpha$  particle**

## Simulation Monte-Carlo:

- Understanding the signals induced by the  $\alpha$
- Characterization of the detector
- Simulation of a localized  $\alpha$ -spectroscopy using Garfield++ (CERN) in Geant4



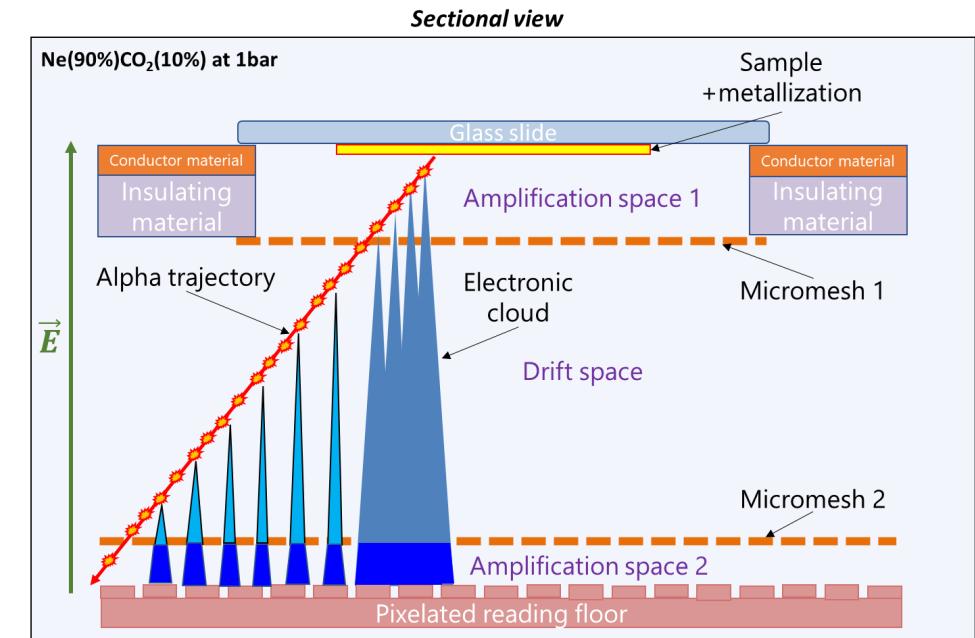
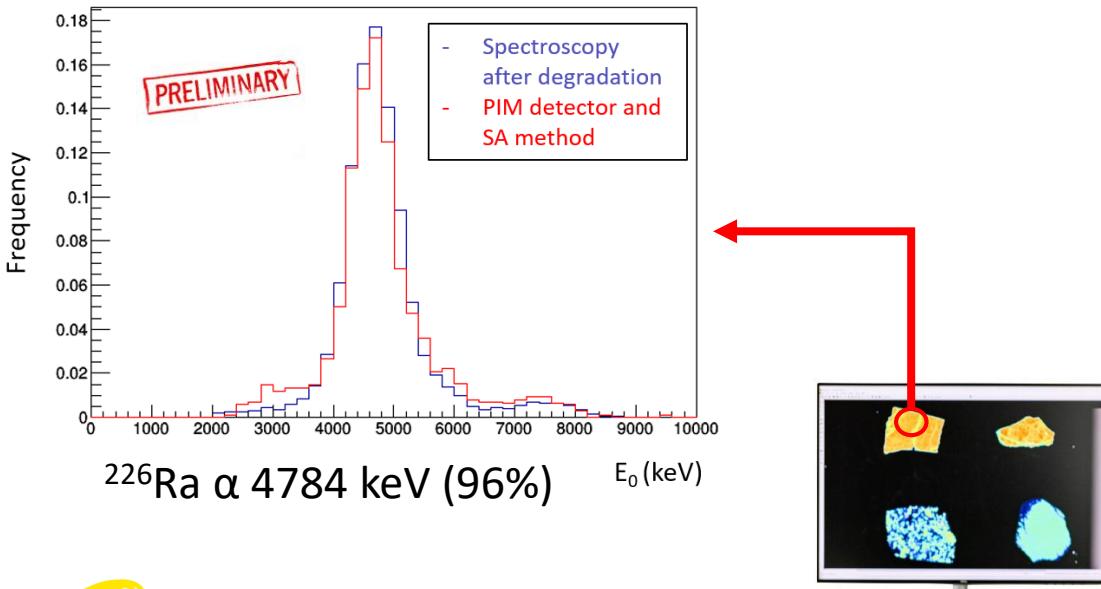
Arthur BONGRAND



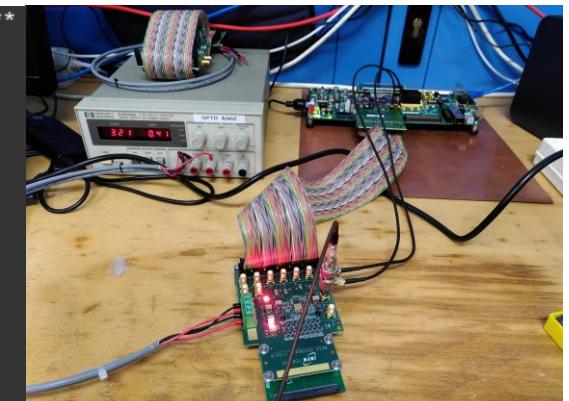
15/03/2022

# Localized $\alpha$ -spectrometry

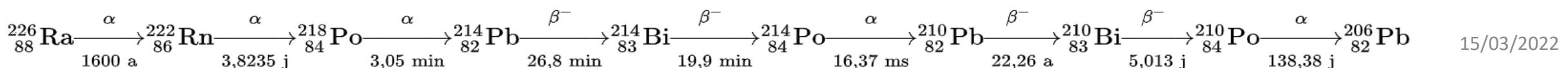
Lefevre et al., under review NIMA



```
*****
Packet number: 0
Packet size: 32
64-bit words to be read: 3
*****
***Event word***
*****
Header (chip ID) : 0
Channel : 20
Check10 : 2
Tacid : 0
Tcoarse : 33775
Ecoarse : 13
Tfine : 246
Efine : 187
Ewcoarse : -994
d_nentry : 1
```



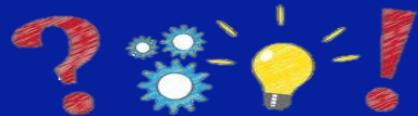
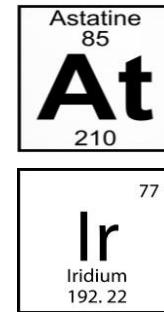
INFN Torino TIGER design group



## BePAT's goal:

Demonstrate how autoradiography can be useful in the acquisition of nuclear data for the production of radionuclides for nuclear medicine applications !

- To work on the development of spectrometry with metal foil
- Localized spectrometry
- Supported by the simulation



Thank you for your attention !  
[arthur.bongrand@subatech.in2p3.fr](mailto:arthur.bongrand@subatech.in2p3.fr)