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Thorium
232.038



Séminaire de Radiothérapie Interne Vectorisée

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Projet BePAT :

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

15/03/2022



IV Nantes
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 ☺



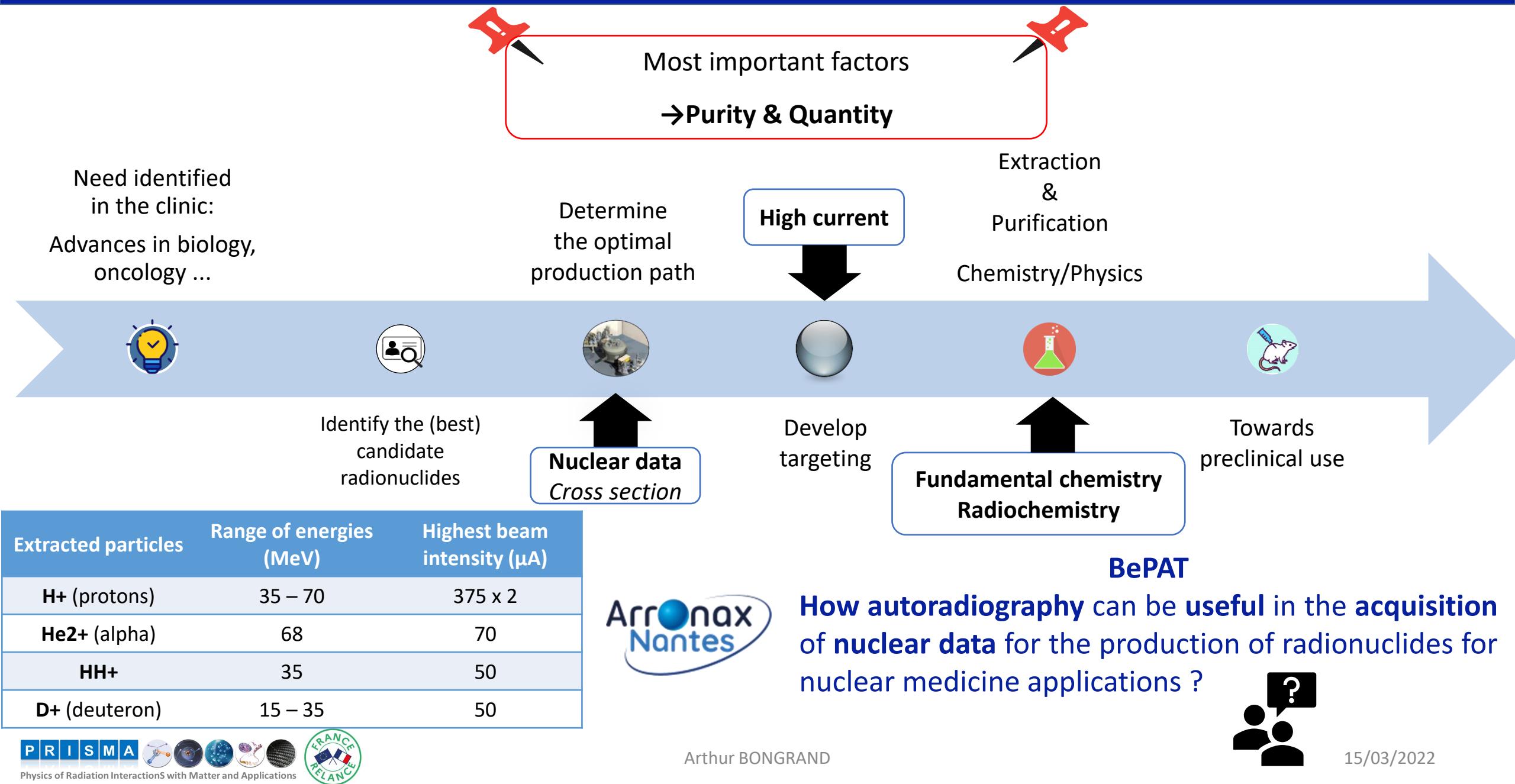
IRMa → Interaction Rayonnement Matière – Radiation-Matter Interaction

- ✓ 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*

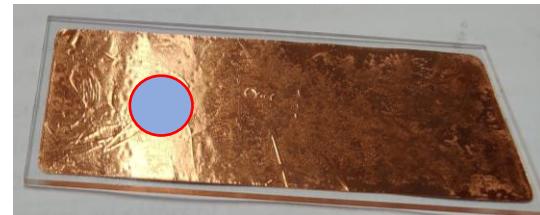
Radionuclide production scheme and RaMI's expertise



- **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

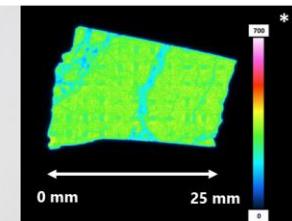
- **Applications**

- Pre-clinical (oncology + drug discovery)

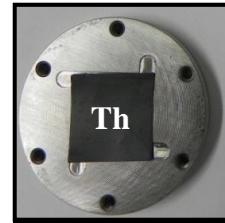
Visualization of molecules or fragments of molecules

labeled with radioactive elements

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



Lefevre *et al.*, under review NIMA

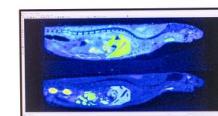


Metal foil

- **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)**



BeaQuant

- **Specificities of the BeaQuant**

- Real-time direct counting

- ✓ Quantification

- ✓ Tracking

Technology	Direct gaseous counter
Performance	<ul style="list-style-type: none"> • Spatial: Alpha 20 μm – Beta 20 μm – High energy β or β^+ 50 μm • Linearity over 5 orders of magnitude • Sensitivity: 0.0005 cpm/mm² (\approx mBq)
Markers	All radioisotopes

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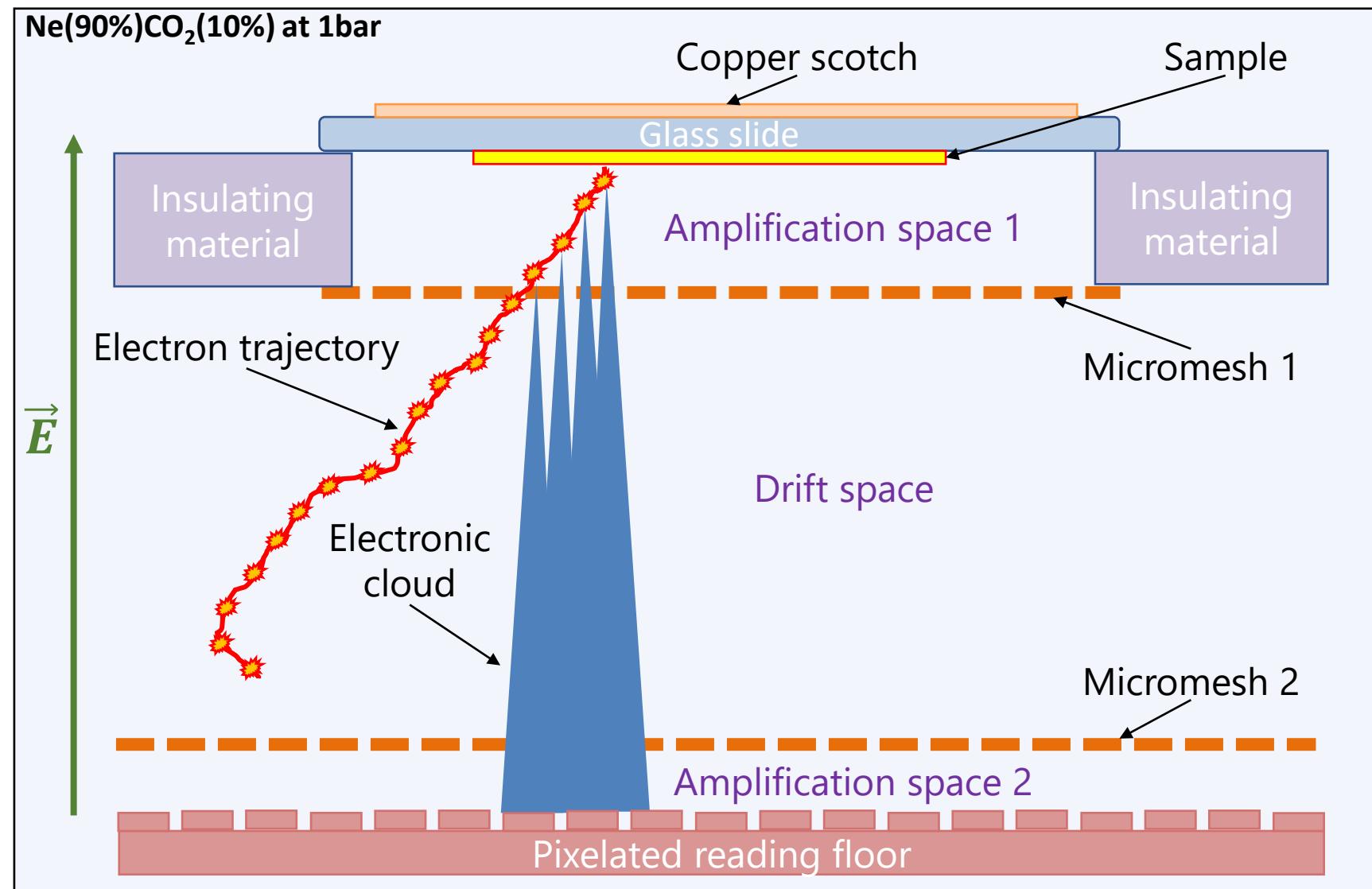


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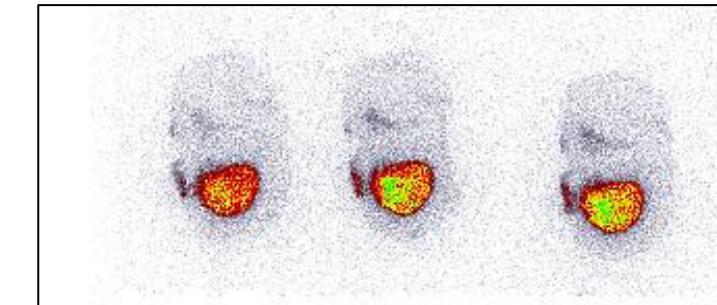
BeaQuant autoradiograph schematic diagram for β^+ , β^- , Auger...

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Sectional view

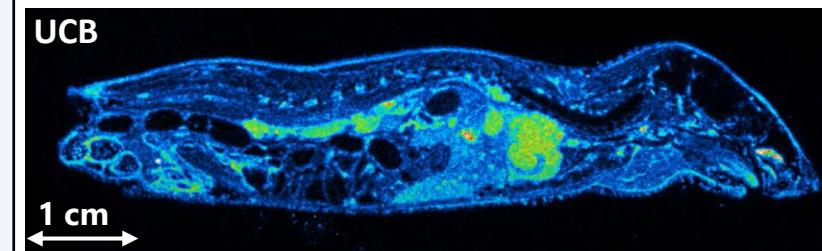


Laboratoire Imagerie et Cerveau, Unité Inserm
930 Université François-Rabelais de Tours



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

^{18}F Spatial resolution: 50 μm

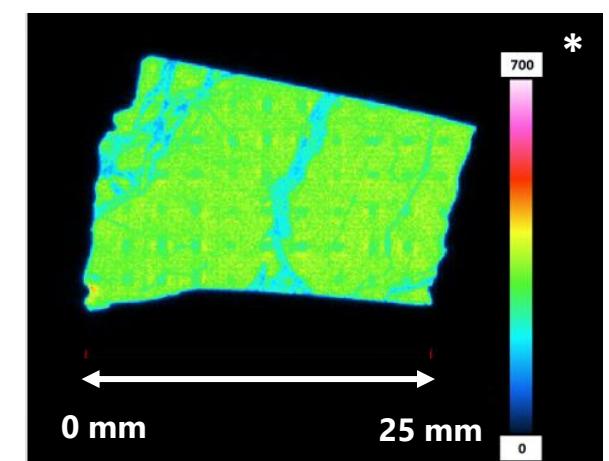
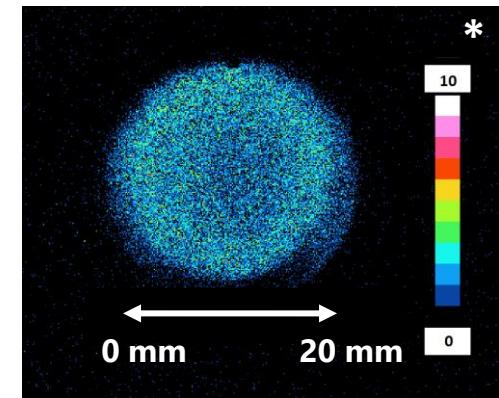
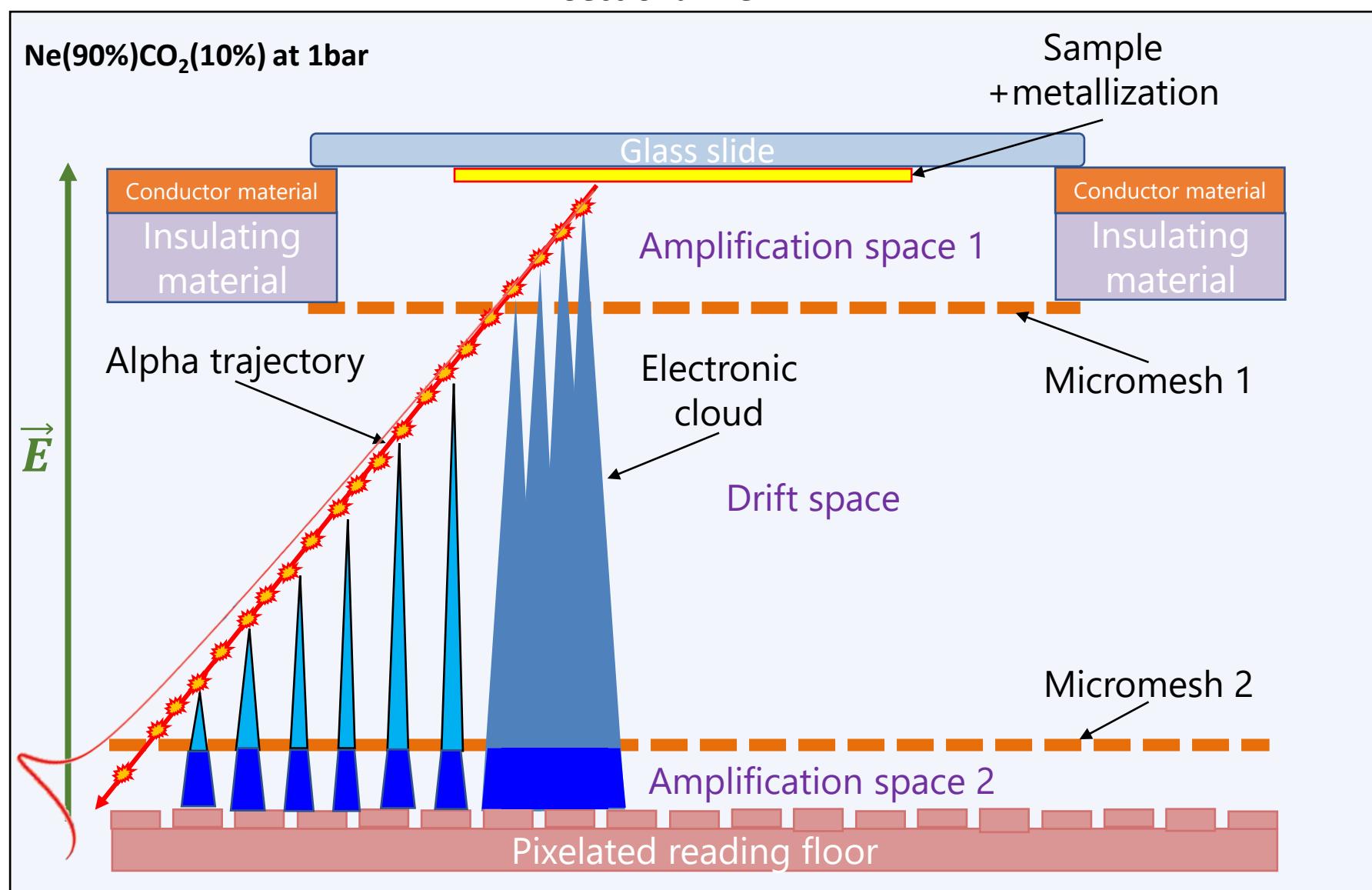


1 cm

^{125}I QWBA
Spatial resolution: 50 μm

BeaQuant autoradiograph schematic diagram for α

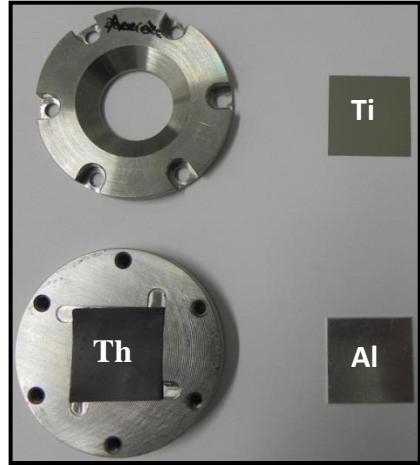
Sectional view



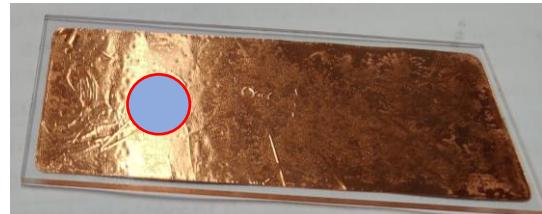
* Lefèuvre et al., under review NIMA

Some rules for the preparation of the BePAT samples

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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 γ and X

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

} Specific calculations required !

- **Challenge**

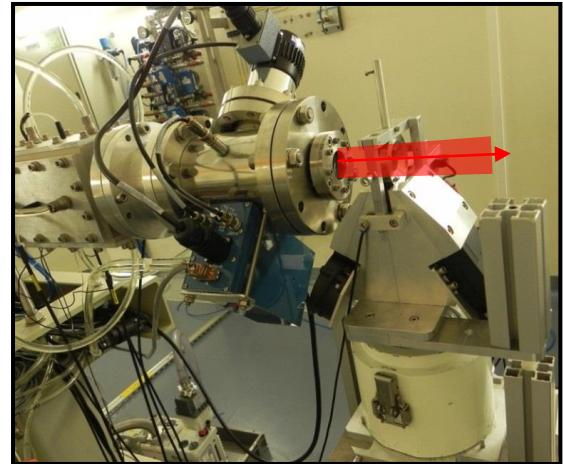
- Short-lived isotope !



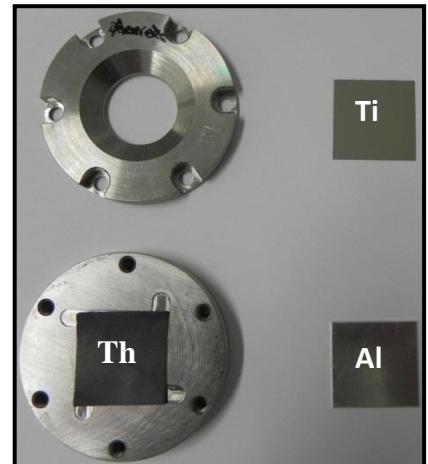


Protons

« Stacked foil » experiment

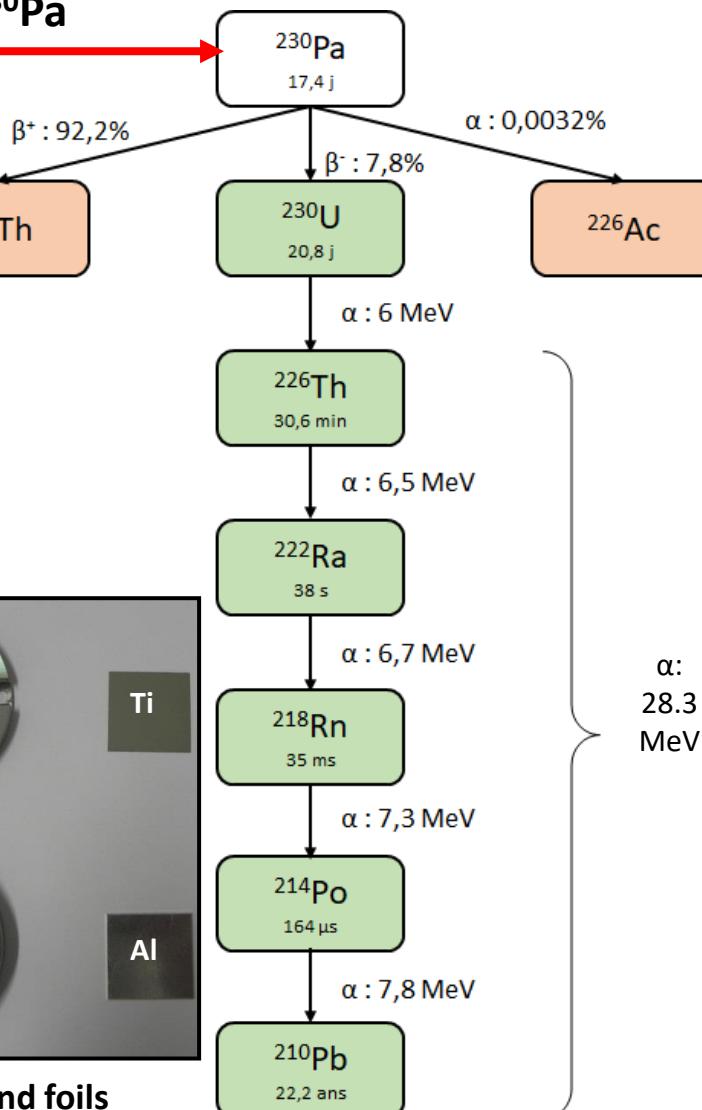


Irradiation station and beam line



Capsule and foils

Goal : ^{230}Pa



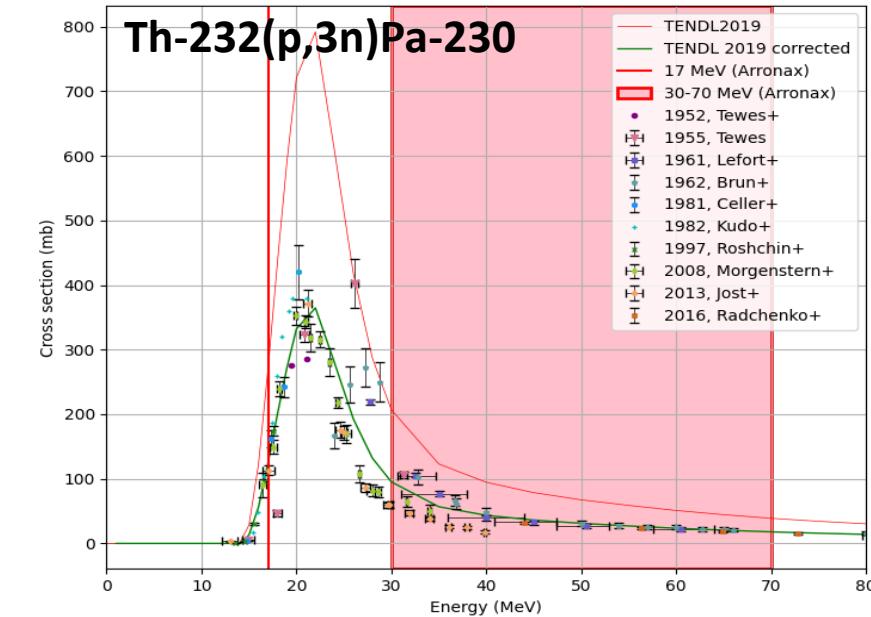
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• α therapy benefit

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

• $^{230}\text{U}/^{226}\text{Th}$ from ^{230}Pa

*considering Arronax's characteristics
17 and 30-70 MeV Proton beam*



Moulin, 2021

Chemical separations of Pa-230 and U-230

after production

→ Contaminant :

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

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

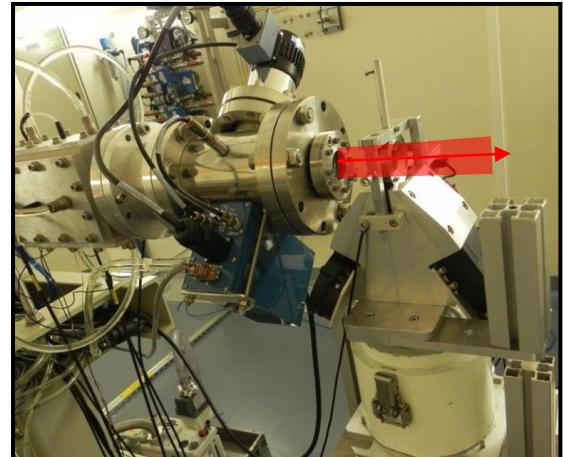
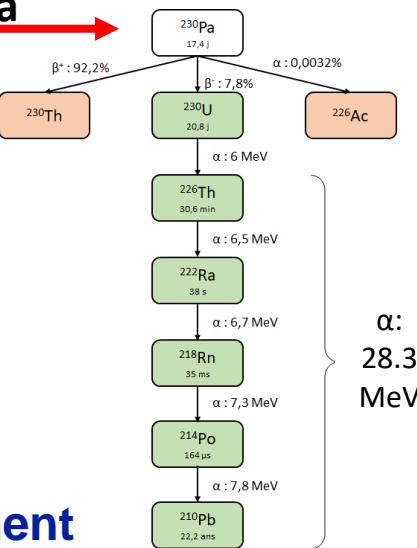


Protons

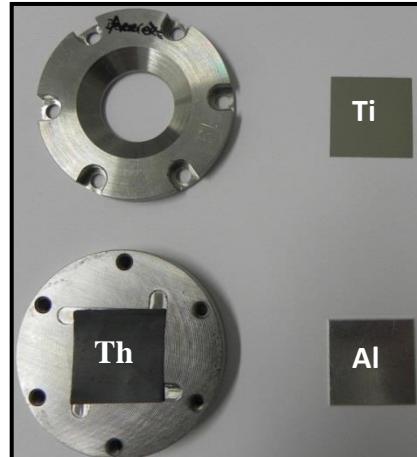
Th-232

« Stacked-foil » experiment

Goal : ^{230}Pa

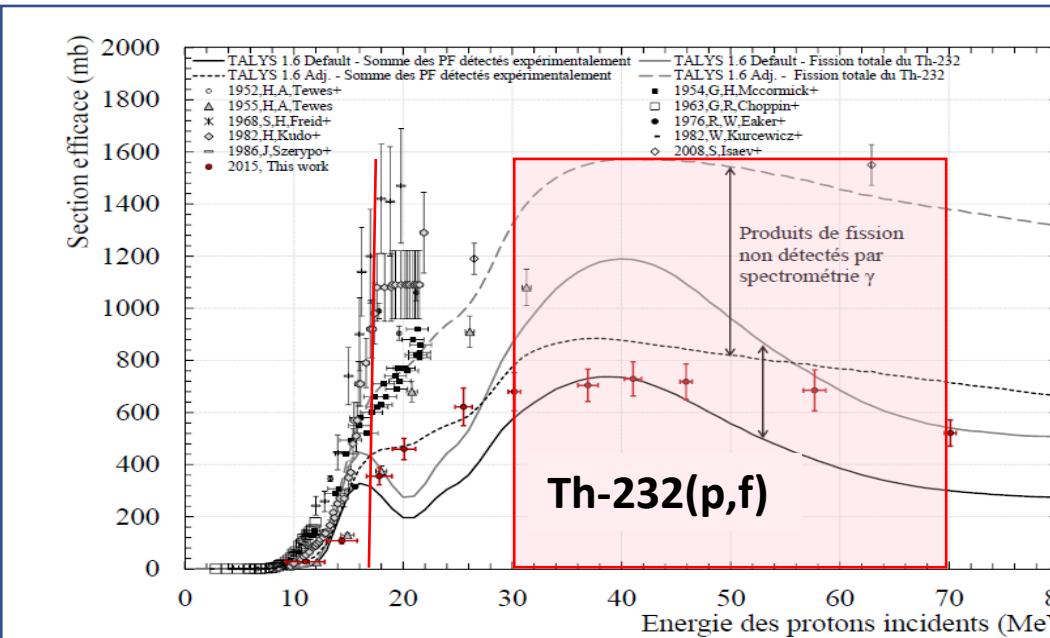


Irradiation station and beam line



Capsule and foils

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Arronax 17, 30-70 MeV

- Contaminant

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

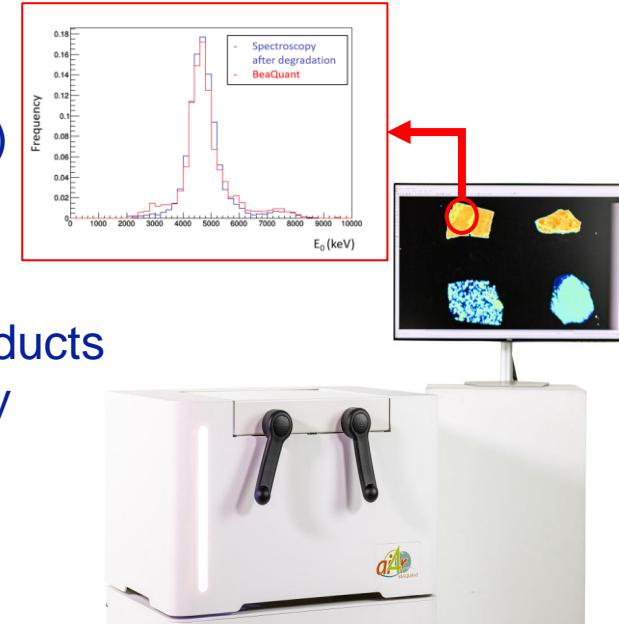
^{231}Pa ($t_{1/2} : 104 \text{ ans}$, $\alpha \approx 5\text{MeV}$)

- In a nutshell

→ Large number of fission products
not detected by γ spectroscopy

→ Need for α 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)



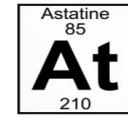
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Aluminum Pieces	Holmium Pieces	Ruthenium Pieces
Antimony Pieces	Indium Pieces	Samarium Pieces
Arsenic Pieces	Iridium Pieces	Scandium Pieces
Barium Pieces	Iron Pieces	Selenium Pieces
Beryllium Pieces	Lanthanum Pieces	Silicon Pieces
Bismuth Pieces	Lead 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

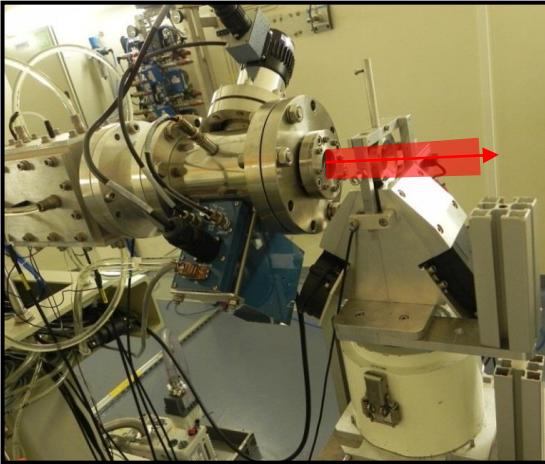
Production of α elements from ^{210}Bi !
metallic ^{211}At , ^{211}Po !



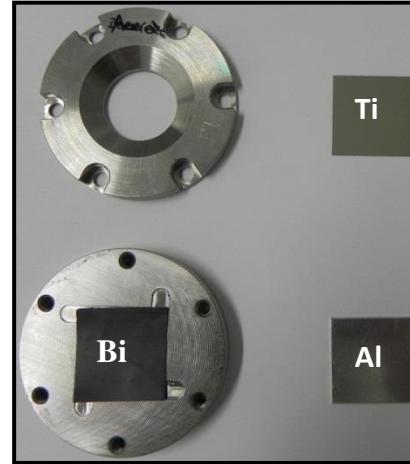
- α -emitter (5.9 MeV and 7.45 MeV)
- Can be produced "easily" @Arronax

- Well-known element
but

Ideal to optimize α spectroscopy method

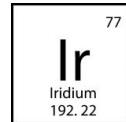


Irradiation station and beam line



Capsule and foils

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



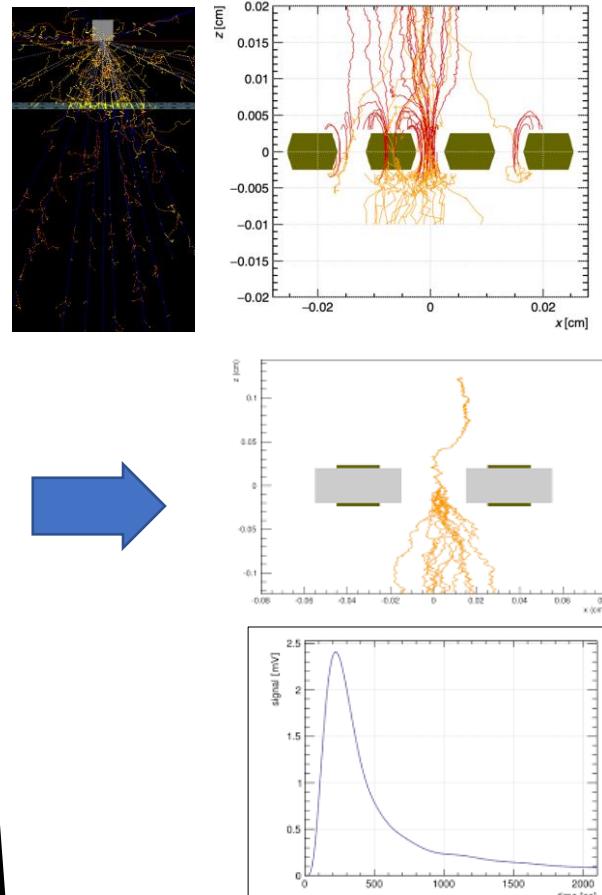
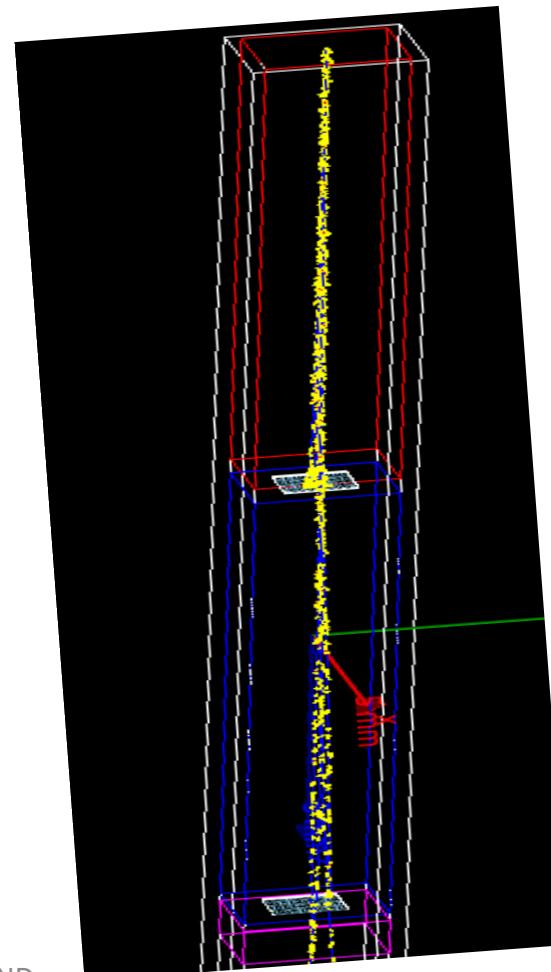
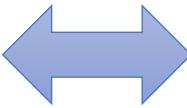
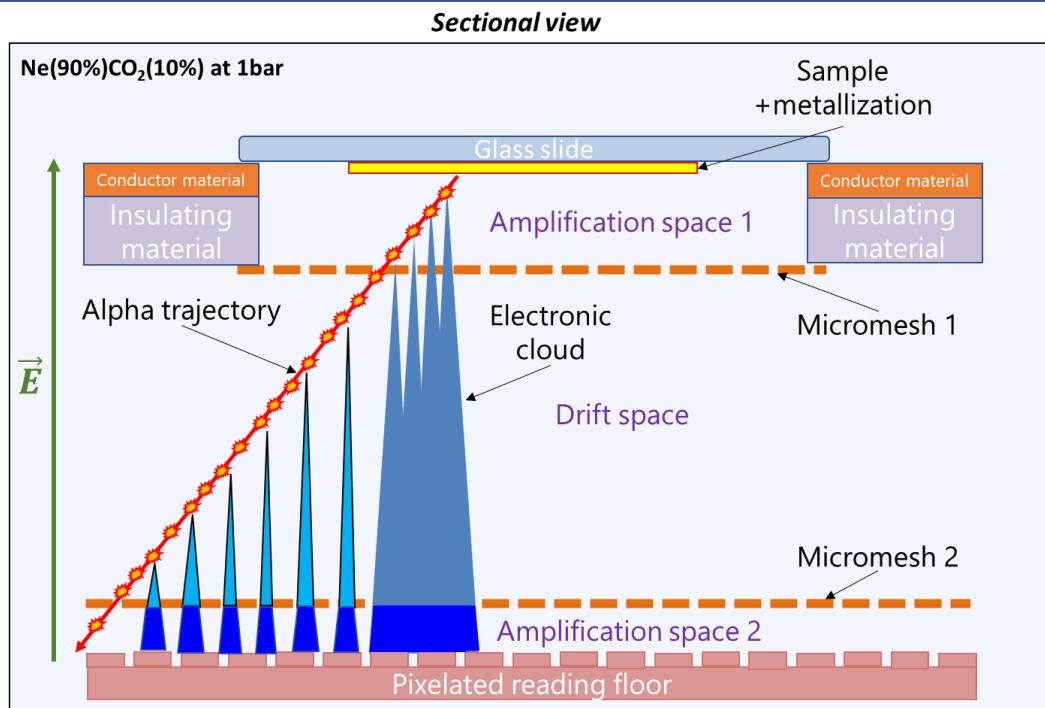
- "Strike" Auger *
Targets DNA or important structural units 1-100nm
cell nucleus and other organelles 1-10 μm
- β^+ /Auger pair produced **at the same time with a natural rhenium metal foil & α beam**
- Good chemical characteristics but many
contaminants 188-190Ir
- Exploratory work
- Gamma spectroscopy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



Goal : Search for the energy deposit in the gas to get the initial kinetic energy of the α particle

Simulation Monte-Carlo:

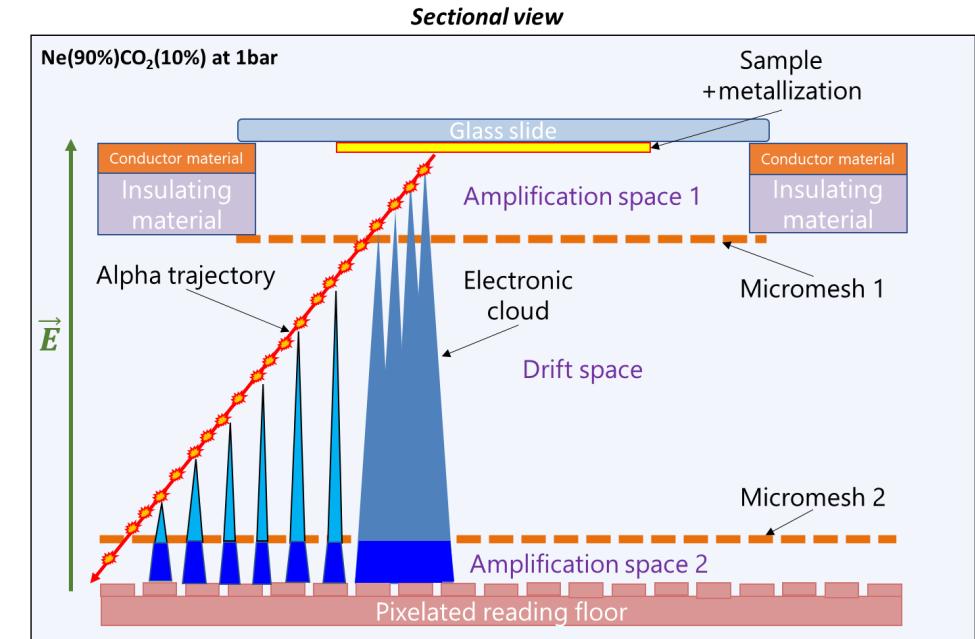
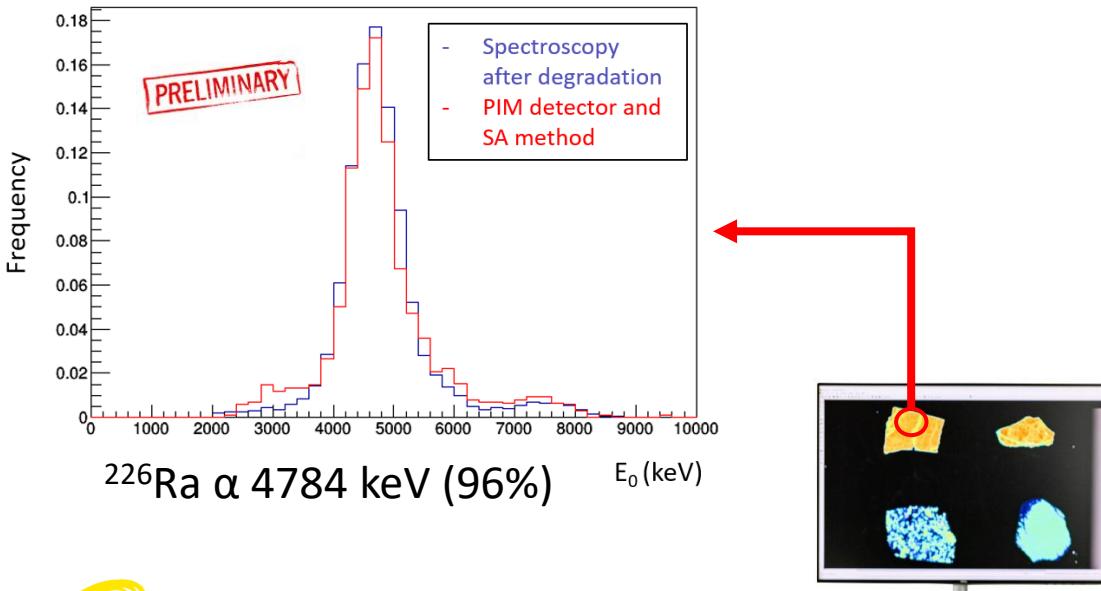
- Understanding the signals induced by the α
- Characterization of the detector
- Simulation of a localized α -spectroscopy using Garfield++ (CERN) in Geant4



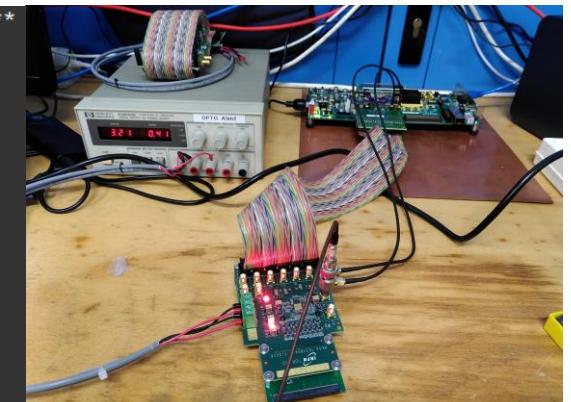
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Localized α -spectrometry

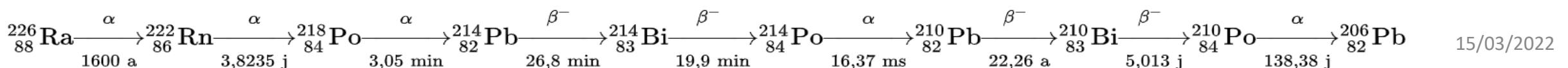
Lefevre et al., under review NIMA



```
*****
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
```



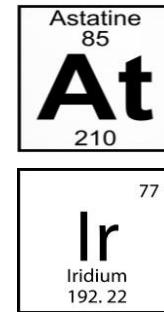
INFN Torino TIGER design group



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



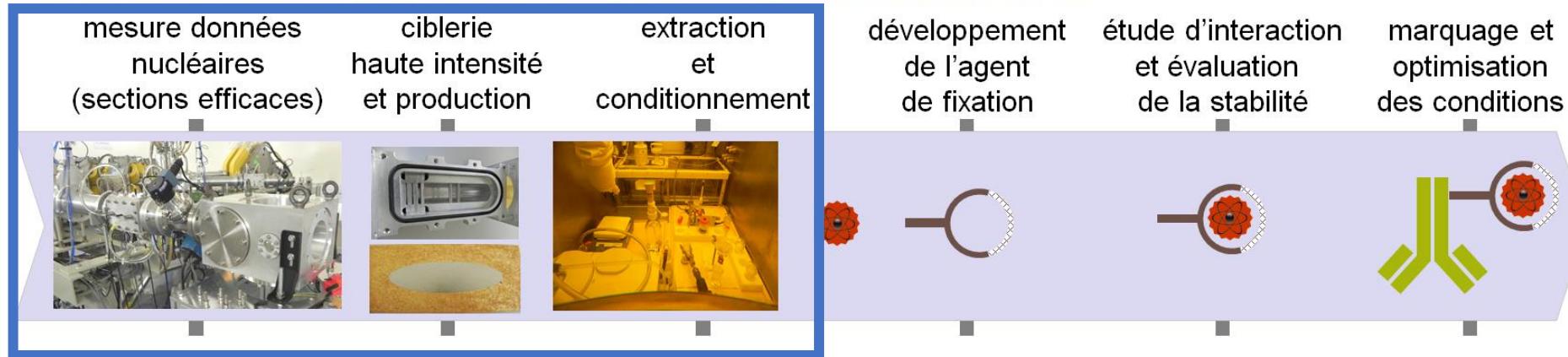
Thank you for your attention !
arthur.bongrand@subatech.in2p3.fr

Backup

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DE LA PRODUCTION AU RADIOMARQUAGE



Collaborations: à l'échelle locale : GIP Arronax, Ceisam, Ai4R; à l'échelle nationale IJC Lab, pHLAM, et à l'échelle internationale: INR.

Financements: TransForMed (Next), PRC Franco-Russe (PaTH project , 2020-2022), ANR CHESS (2022-2026), Plan de relance (2021-2023), Labex IRON2 (2020-2024).

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