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Latest development of α emitter imaging and quantification on a large Field Of View

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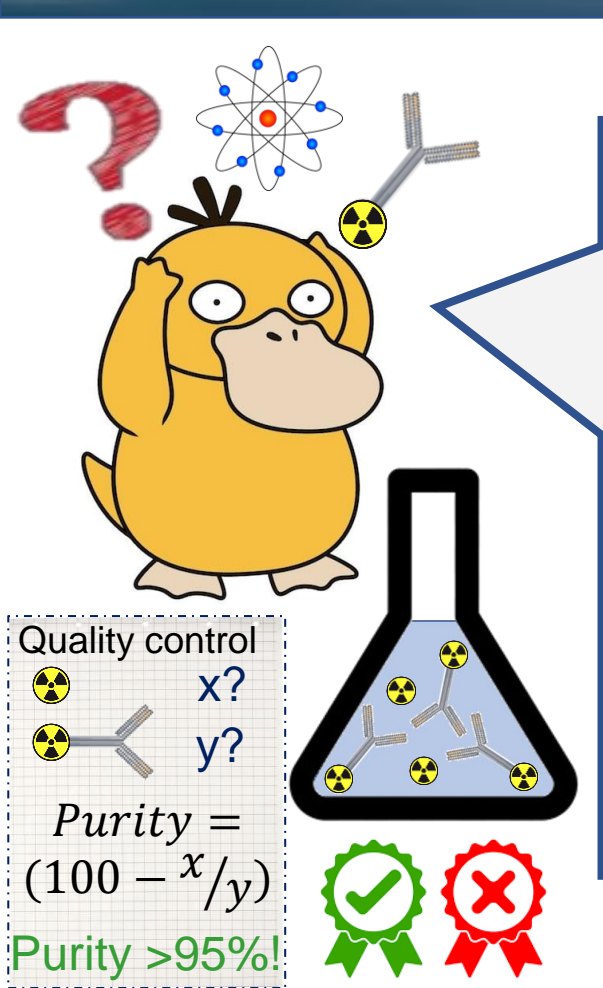
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Latest development of α emitter imaging and quantification on a large Field Of View



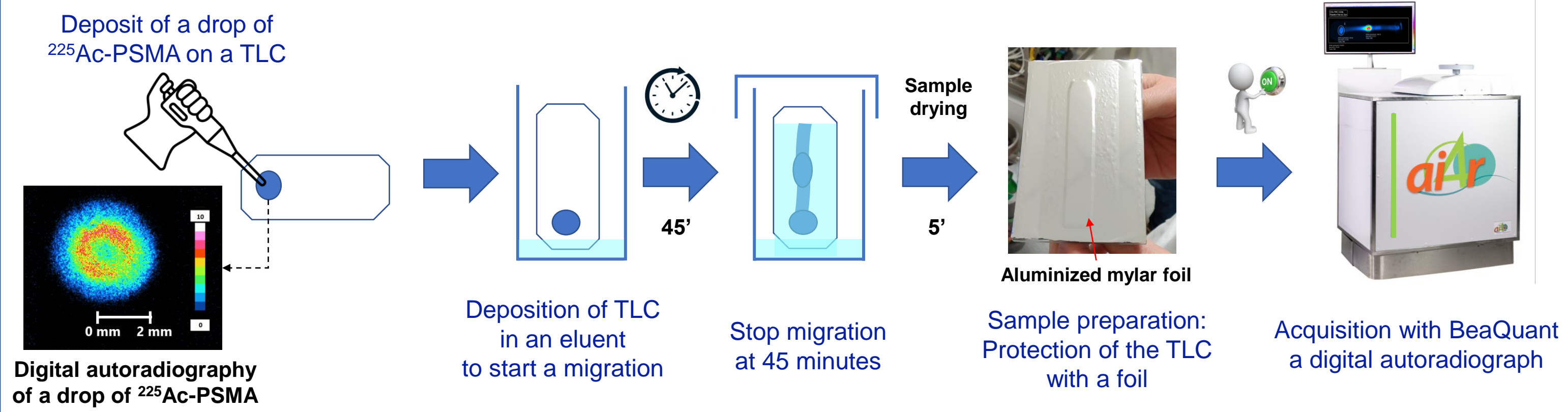
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Currently, the **characterization** of the **nature** and **spatial distribution** of **radionuclides** in a sample is **time consuming** and **fastidious**. Indeed, it necessarily requires the use of two distinct analytical techniques and detectors of different nature. Moreover, the spatial resolutions of the two methods are often detector dependent, which makes it difficult to integrate and interpret these two measurements together.

Can we perform a fast and accurate quality control of radiopharmaceuticals with a single system?

Quality control protocol with Digital Autoradiography!

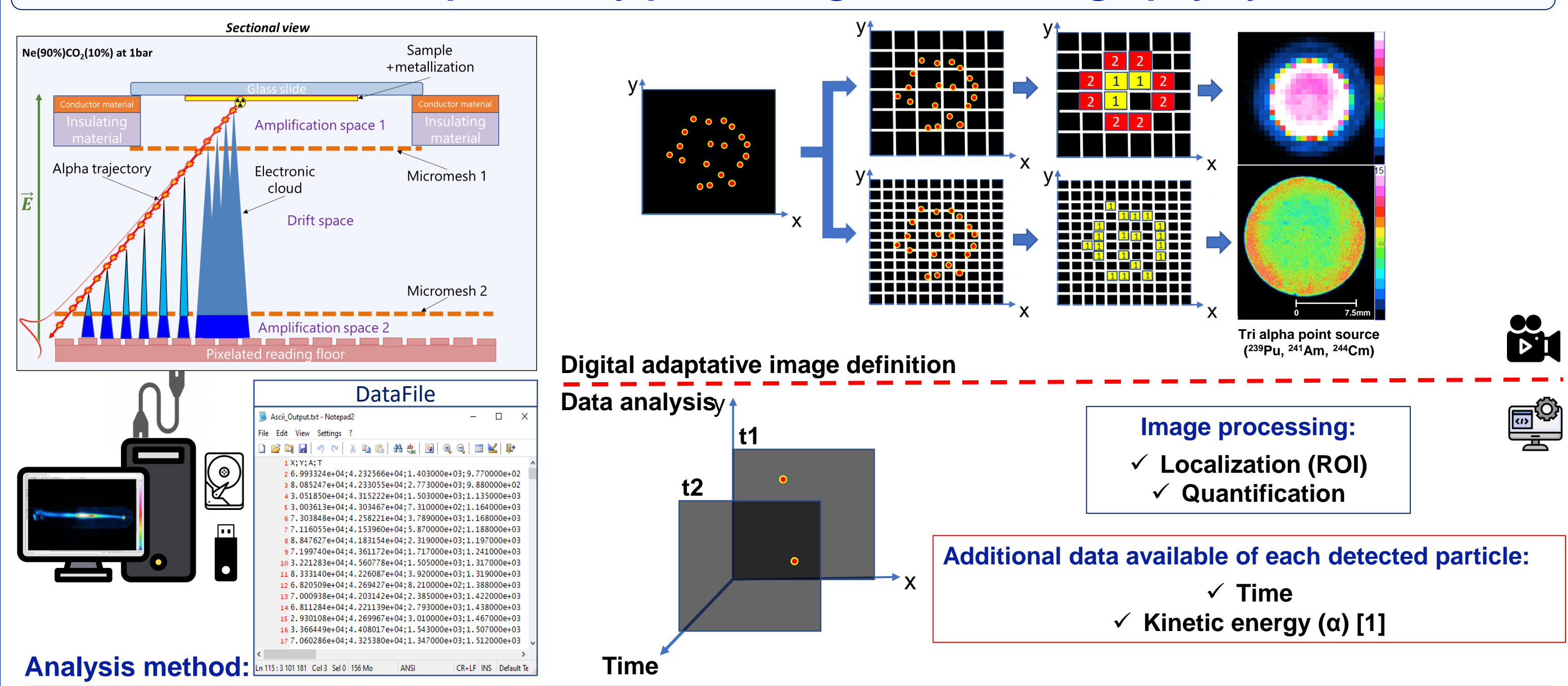


Digital Autoradiography...

→ an accurate up-to-date emission imaging technique !

- ✓ Allows to study and locate in 2 dimensions the radioactivity emanating from a surface sample at scales until **10 micrometer**.
- ✓ Well suited for pre-clinical TAT as it allows **understanding** and **quantifying** **biodistributions** in tissues at **high spatial resolution** and **low activity**.
- ✓ Digital autoradiography → Ability to analyze and reanalyze endlessly the digital data acquired!
- ✓ Variety of applications: Radio-TLC, Geological Studies, Radio Toxicology...

BeaQuant: a particle by particle digital autoradiography system



The Spatio Temporal Spectroscopic Autoradiography Analysis (STSA)

Dr. Harry Bateman

$$\frac{dN_1(t)}{dt} = -\lambda_1 N_1(t)$$

$$\frac{dN_2(t)}{dt} = -\lambda_2 N_2(t) + \lambda_1 N_1(t)$$

$$\frac{dN_k(t)}{dt} = \lambda_{k-1} N_{k-1}(t) - \lambda_k N_k(t)$$

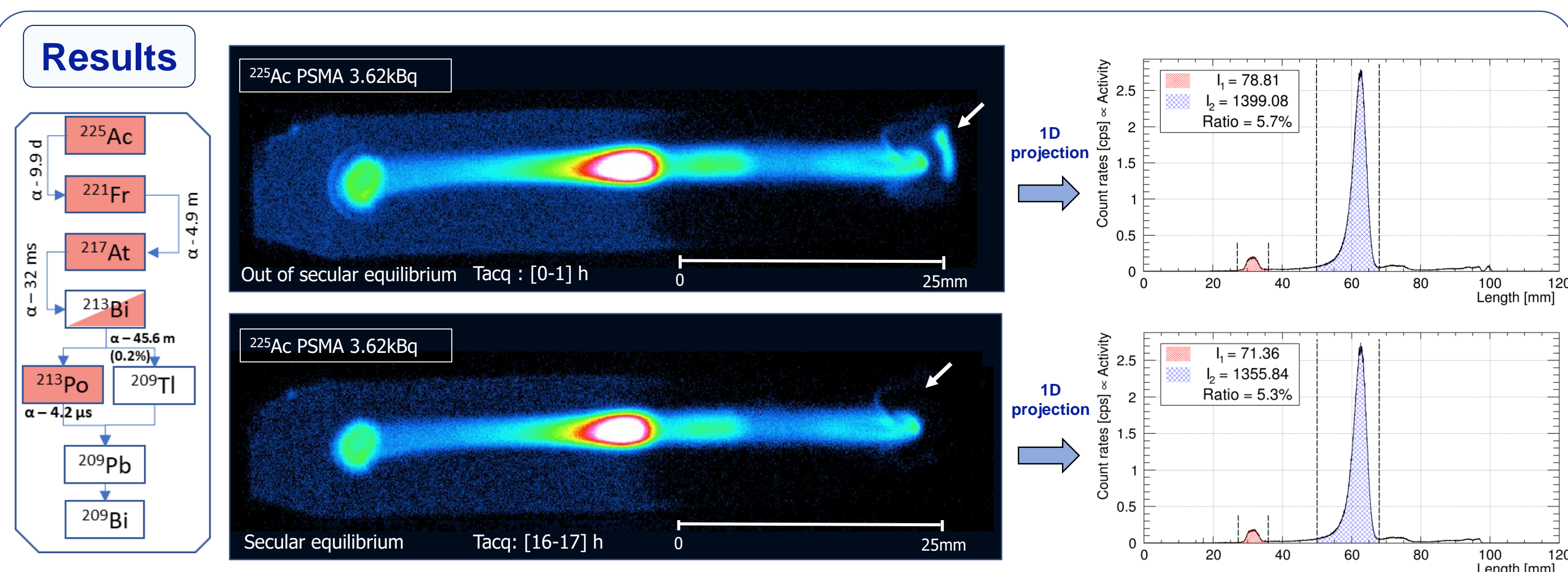
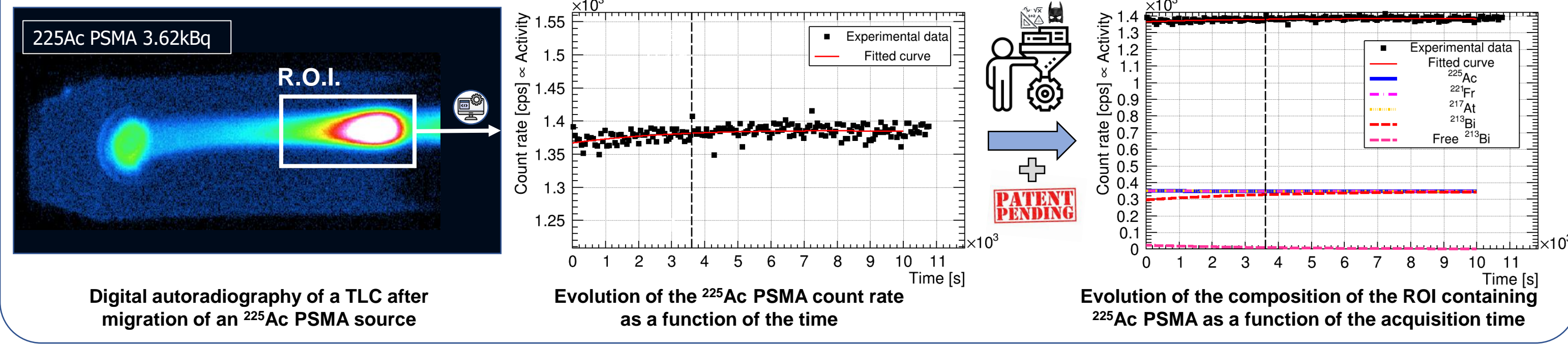
$$N_n(t) = N_1(0) \times \left(\prod_{i=1}^{n-1} \lambda_i \right) \times \sum_{j=1}^n \prod_{i=j, i \neq 1}^n (\lambda_i - \lambda_j) e^{-\lambda_i t}$$

Bateman equation (general explicit formula)

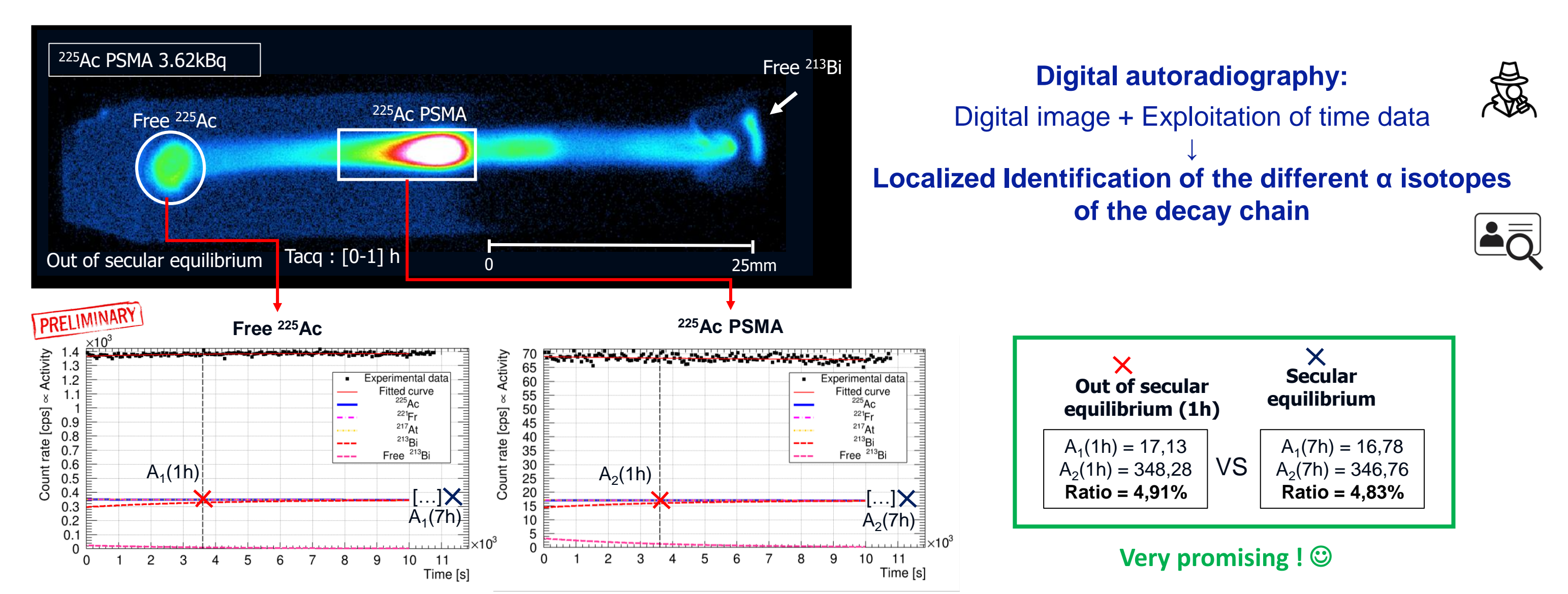
In **nuclear decay physics**, a radioactive equilibrium exists when a radioactive nuclide decays at the same rate as it is produced.

→ The **concentration of daughter nuclei** in the radioactive equilibrium can be modeled at any time using the **Bateman equation** provided that the characteristics of the decay chain and if the initial concentrations are known.

→ For our application, as these initial concentrations are **unknown**, we have developed a method to calculate these concentrations from the **evolution of the measured count rate**.



→ Usually the quality controls are made from a 1D projection where we can distinguish the **free 225Ac** which remains on the deposit spot from the **labelled 225Ac** which migrates. To limit interpretation errors, the analysis must be performed at **secular equilibrium (~7h)**.



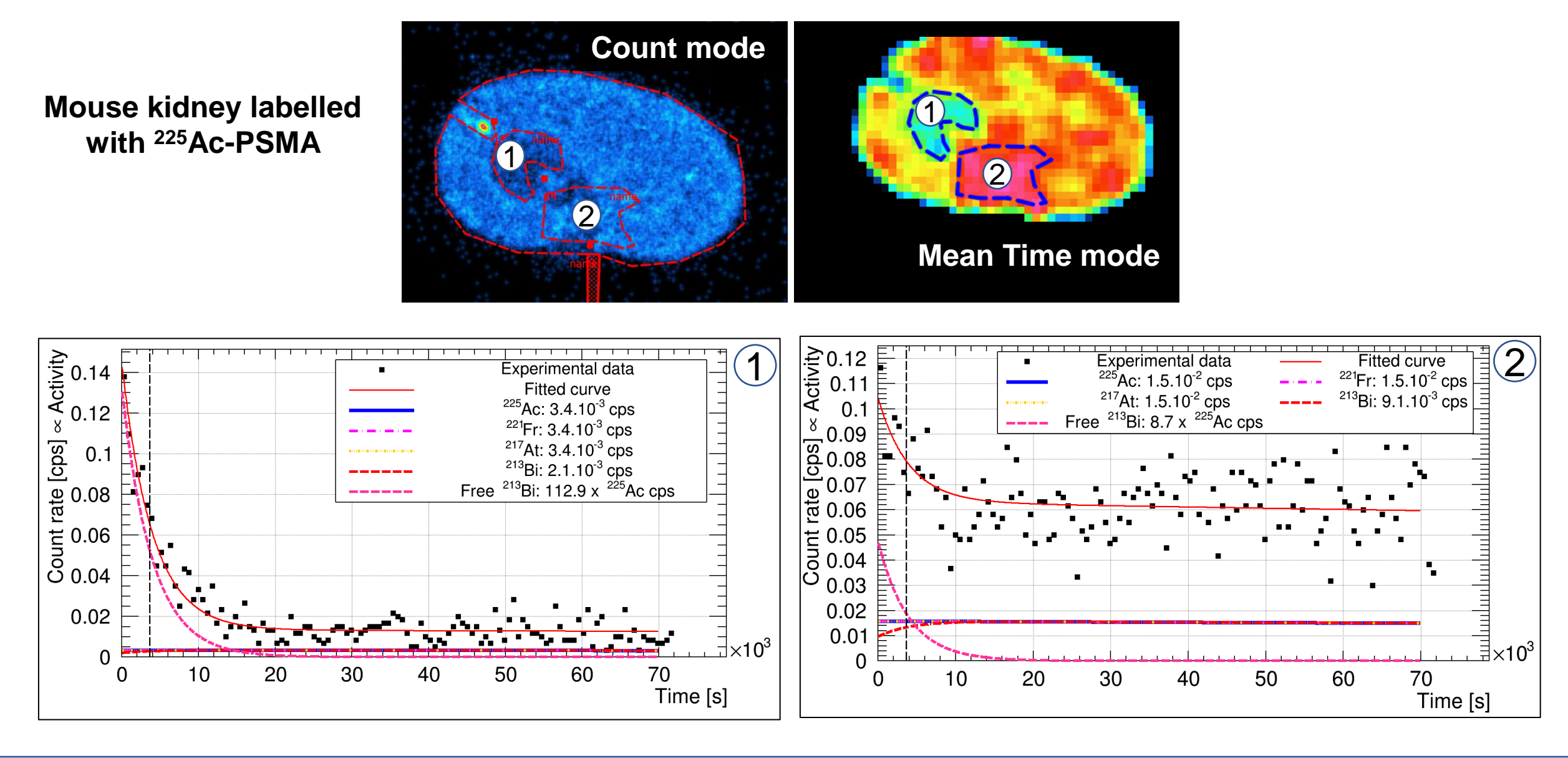
→ The **STSA** reduces the time needed for a quality control after elution to **only one hour** allowing both isotope localization and identification. Thus, the **purity** is deduced from the ratio of **free to labeled 225Ac**.

Discussion

Digital autoradiography combined with a **temporal spectroscopy** method allows the **quick and accurate identification** of different radioisotopes and to observe their localization.

The increased **robustness** of this method comes from its **low dependence** on the operator's choices compared to 1D method.

From the results, we can observe the **contribution** of a radioisotope called "**free 213Bi**". Clearly visible on the migration front, **free 213Bi** corresponds to **213Bi** which is not radiolabeled and whose **parent, 217At**, has **not decayed locally**. The most probable hypothesis is that the **free 213Bi** comes from the **mother solution**. This free **213Bi** has also been observed in biological samples. Studies are underway to understand its biological impact.



Conclusions

Digital Autoradiography with spectroscopic method:

- ✓ **Promising** in the **acquisition of nuclear data** for the production of radiopharmaceuticals for nuclear medicine applications like **quality control of radiopharmaceuticals** !
- ✓ A **precise tool** to understand the **temporal behavior** of a chain of labeled isotopes.
- ✓ Precise image & quantification from mBq to kBq.

Perspectives

More experiments !

- Perform simultaneous **comparisons** with **standard quality control methods**.
- Perform **multiple quality controls** of the same batch **simultaneously** using the **BeaQuant's large Field Of View**.
- Explore the method for other radiopharmaceuticals [2].

At 211 7.2h	Tb 149 4.1h
$\epsilon = 5,867...$ $\rho = 687$	$\epsilon = 3,97...$ $\rho = 352; 165...$



References
 [1] H. Lefeuve *et al.*, « Spectroscopic autoradiography of alpha particles using a parallel ionization multiplier gaseous detector », Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, vol. 1035, p. 166807, 2022.
 [2] R. Eychenne *et al.*, « Overview of the Most Promising Radionuclides for Targeted Alpha Therapy: The "Hopeful Eight" », Pharmaceuticals, vol. 13, n°6, Art. no 6, 2021.

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