ISOLPHARM
SPES exotic beams for medicine

UNIVERSITÀ DI SIENA 1240

Dipartimento di Fisica e Astronomia Galileo Galilei

INFN
Istituto Nazionale di Fisica Nucleare

ADMIRAL

ISOLPHARM
SPES exotic beams for medicine

Laboratori Nazionali di Legnaro – INFN

Development of a β imaging detector tailored to Ag-111 for the ISOLPHARM project

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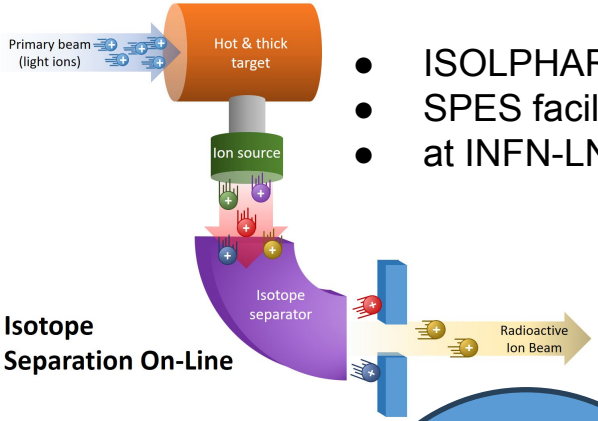
February 28th, 2024

Targeted Radionuclide Therapy



Isotope Separation On-Line

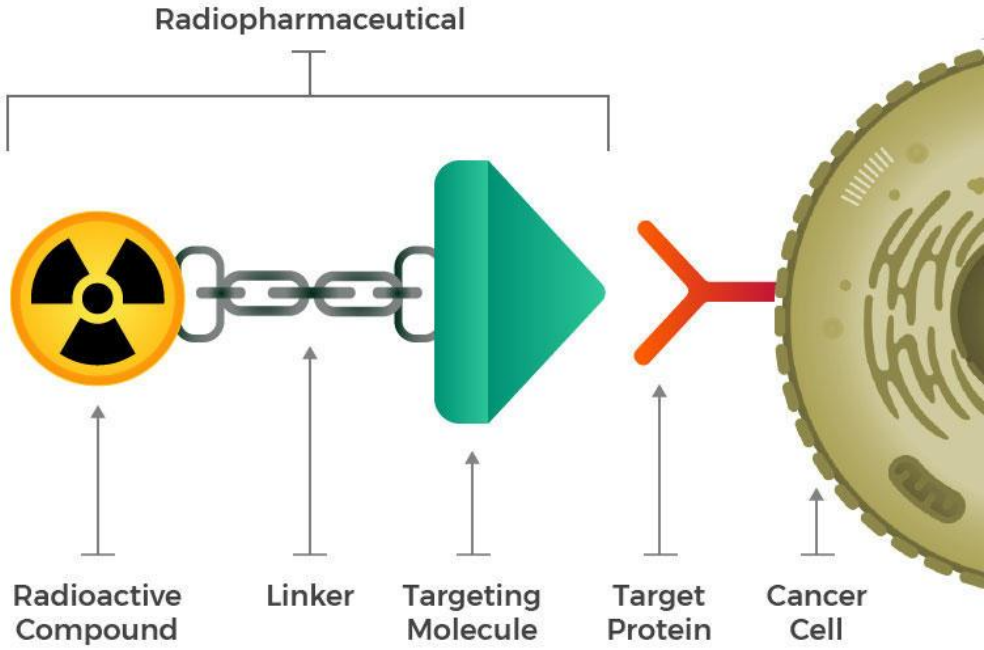
- ISOLPHARM project
- SPES facility
- at INFN-LNL

Ag-111

Half-life
- 7 days

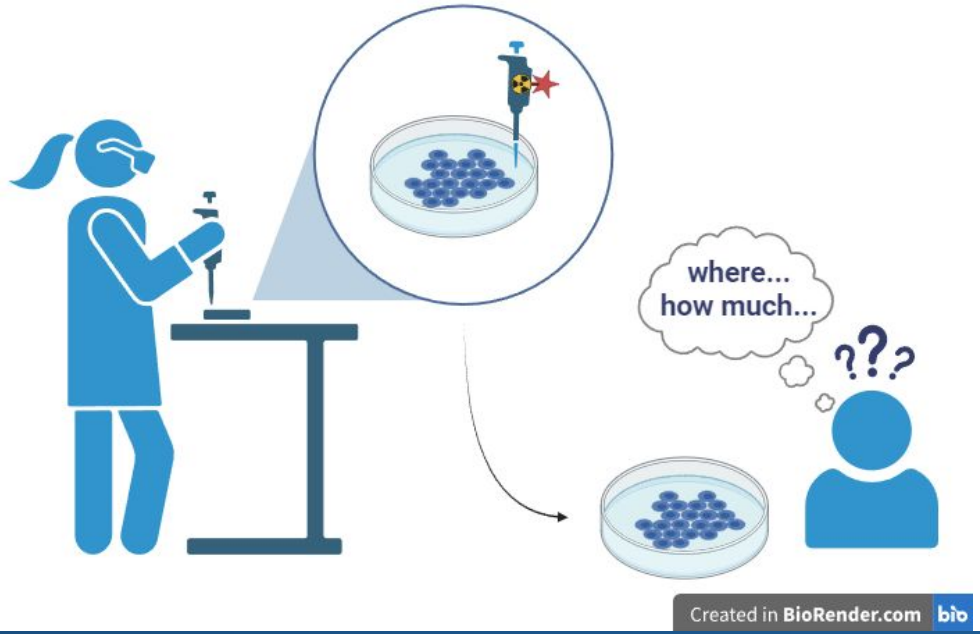
γ emission
- 342 keV (7%)
- 245 keV (1%)

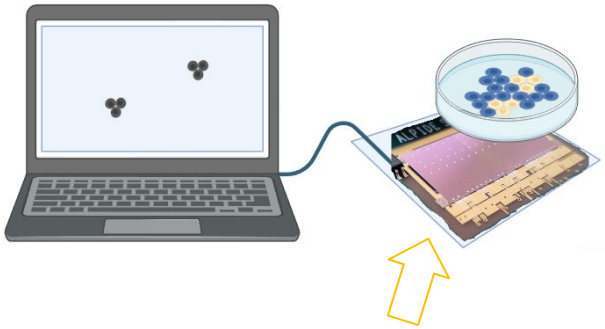
β emission
- mean 360 keV (92%)



Credit: National Cancer Institute

Preclinical Experiments



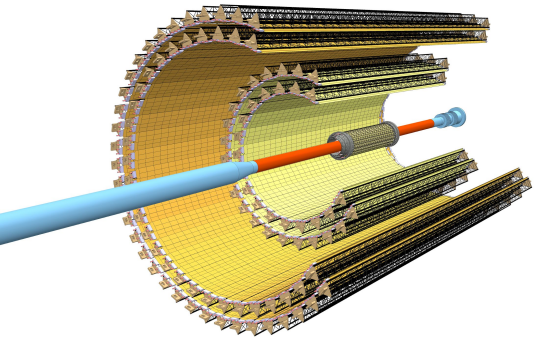


β imaging detector

Requirements for uptake experiments:

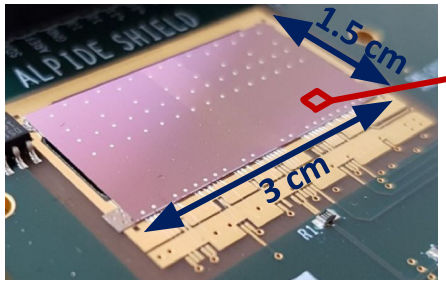
- 0.1 – 1 mm spatial resolution
- Activity quantification

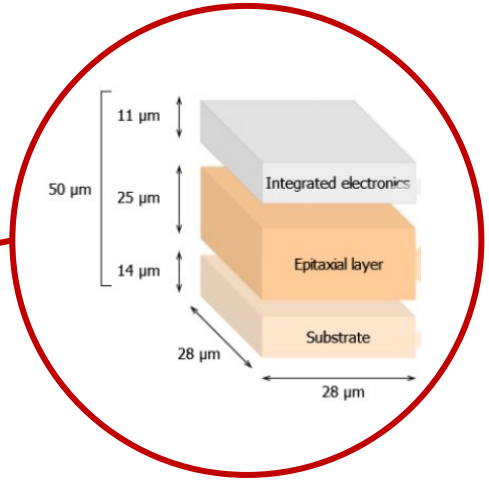
Description of the Device



- It will consist of 4 or 8 **ALPIDE chips** arranged in a flat geometry
- ALPIDE is a monolithic active pixel sensor (**MAPS**) originally developed for the Inner Tracking System of the **ALICE** experiment at CERN

- 1.5cm × 3cm × 50µm
- 1024 x 512 sensitive pixels
- 28µm × 28µm × 50µm

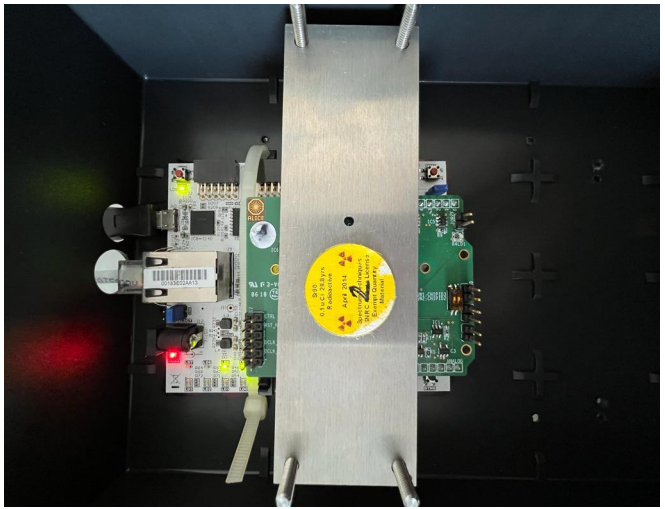




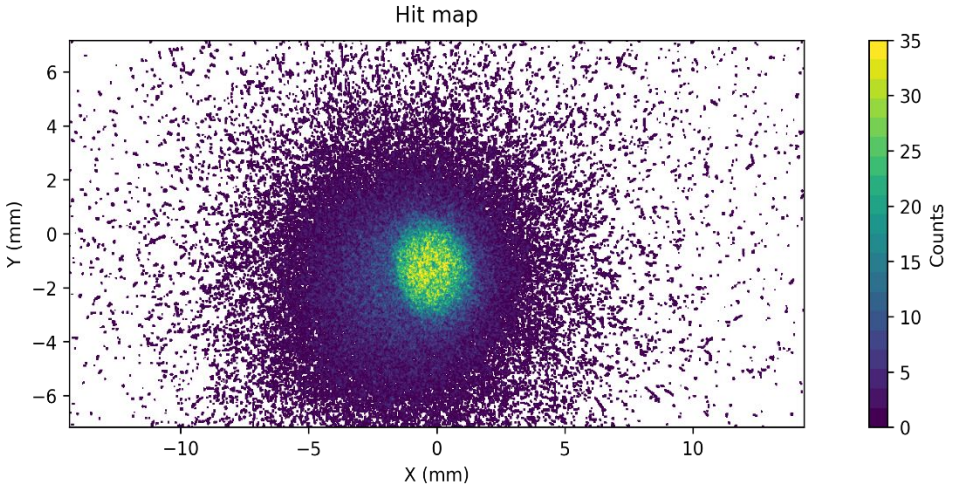
- Highly-Doped N-Wells: charge is collected
- Epitaxial Layer: where ionizing particles generate electron-hole pairs
- Substrate Layer: support to the detector

Data Acquisition Test

Sr-90 β emission
- 196 keV (100%)



First measurements conducted with ALPIDE:
- Dedicated **firmware** mounted on the detector
- Preliminary **data acquisition** with ^{90}**Sr** source

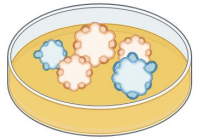


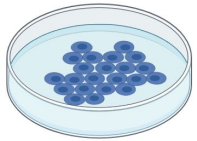
Geant4 Simulation

Cell geometry:

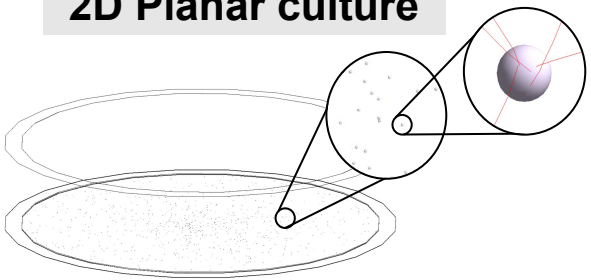
- Aqueous spherical cells (10 μm radius)
- Inside the cell volume, ^{111}Ag undergoes β decay

Source geometry:

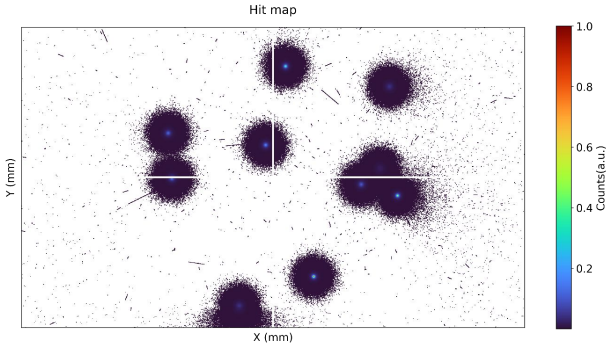




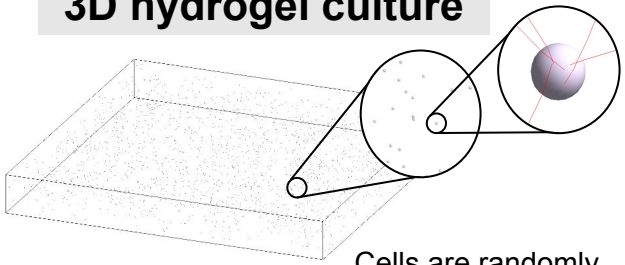
2D Planar culture



10 cells dispersed in hydrogel matrix



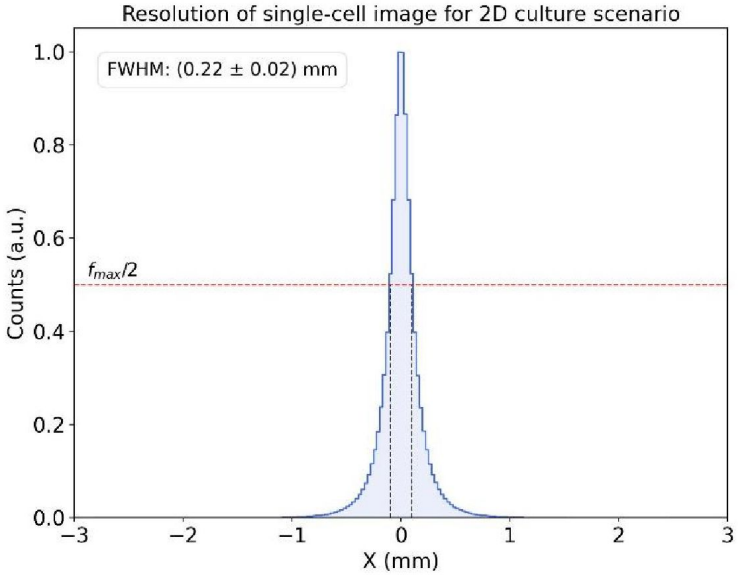
3D hydrogel culture



Cells are randomly dispersed in hydrogel matrix.

Conclusions

- ISOLPHARM project aims to develop Ag-111 based radiopharmaceuticals
- A β detector exploiting ALPIDE chip is being developed for in-vitro experiments
- The detector was simulated using Geant4 toolkit
- The expected spatial resolution for 2D cell culture scenario is 0.2 mm



References

- B. Abelev et al and (The ALICE Collaboration) 2014 J. Phys. G: Nucl. Part. Phys. 41 087002, https://www.doi.org/10.1088/0954-3899/41/8/087002
- M. Suljic, Study of Monolithic Active Pixel Sensors for the Upgrade of the ALICE Inner Tracking System, https://cds.cern.ch/record/2303618
- V. Pavanello, Performance study of a novel 2D imaging beta detector for medical applications, M. Sc. Thesis, https://hdl.handle.net/20.500.12608/51901

Vittoria Pavanello in her M.Sc. Thesis assessed the **β detector's performance** in in-vitro environment through Monte Carlo simulations, using **Geant4** software.

UNIVERSITÀ DEGLI STUDI DI PADOVA

Dipartimento di Fisica e Astronomia "Galileo Galilei"

Master Degree in Physics

Final Dissertation

Performance study of a novel 2D imaging beta detector for medical applications

Thesis supervisor
Prof. Marcello Lunardon
Thesis co-supervisor
Dr. Piero Giubilato
Dr. Davide Serafini

Candidate
Vittoria Pavanello

Academic Year 2022/2023

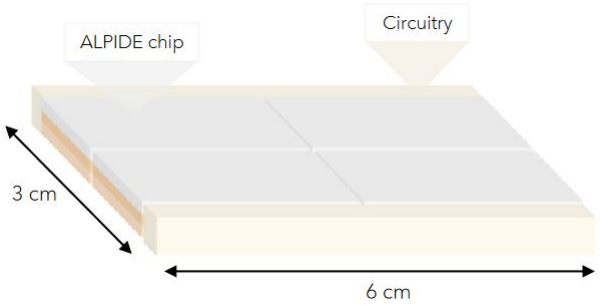
The ISOLPHARM collaboration

Thank you

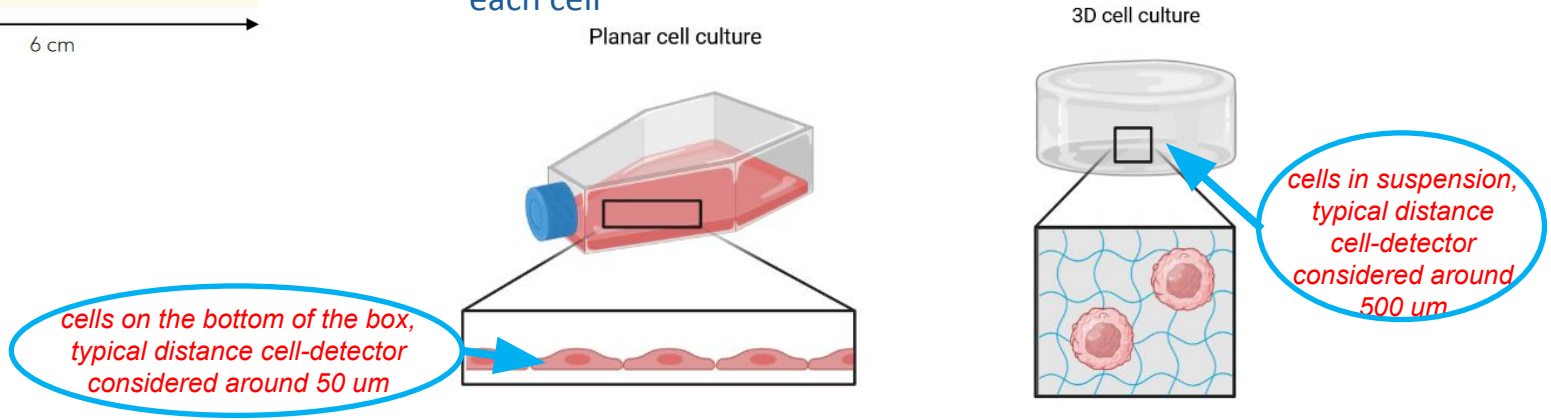
BACK-UP SLIDES

Advancements made in 2023

1. The detector in its final design (2x2 configuration)

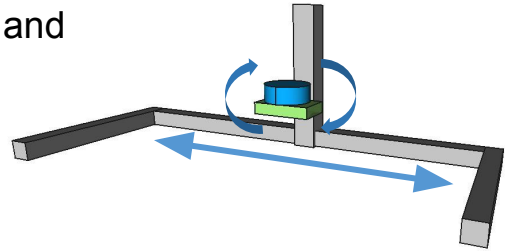


2. Biological sources represented by both traditional **cell cultures** and **hydrogel-based cultures.** ^{111}Ag deposited in each cell



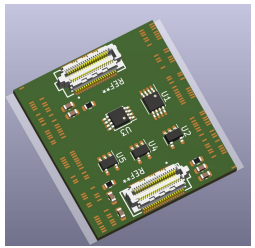
Electronics and Mechanics

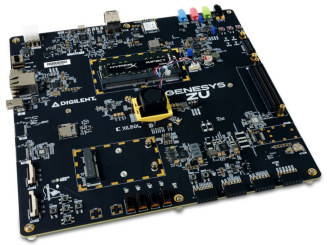
- **Sealed box** only exposes the sensitive part of the chips, the power supply and data I/O connectors
- Option to set up **upside down** the sensitive part
- Movements along vertical and horizontal axes → **scanner** mode
- The movement will be **automated**, with micrometric adjustments



Vertical mounting:

• PCB + chips → support and interfacing second board → commercial FPGA board





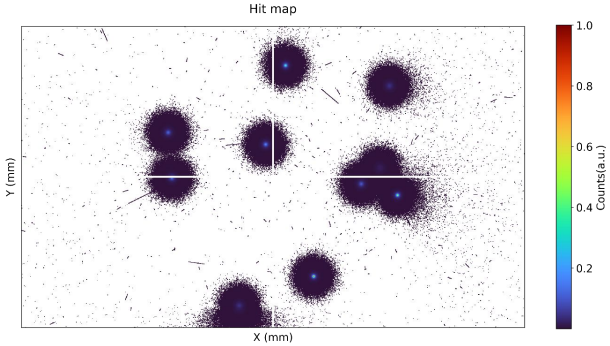
Geant4 simulation

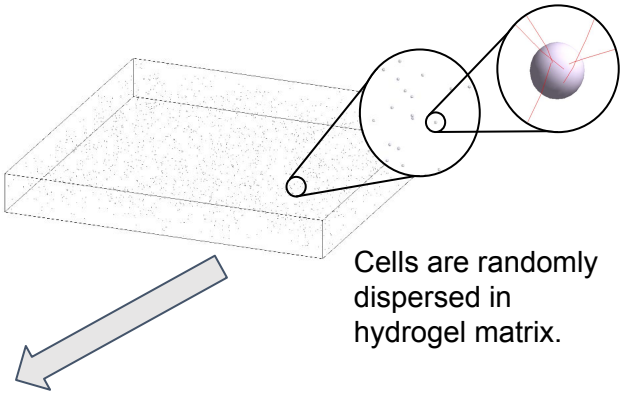
Cell geometry:

- Aqueous spherical cells (10 μm radius)
- Inside the cell volume, ^{111}Ag undergoes β decay

Source geometry:

- 2D planar cell culture
- 3D hydrogel scaffold





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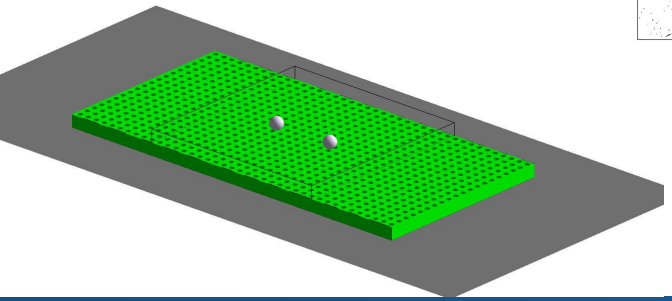

Conduct simulations with a **collimator** to assess possible **spatial resolution improvements** for radioactive sources at millimetric distance from the detector

Geant4 validation

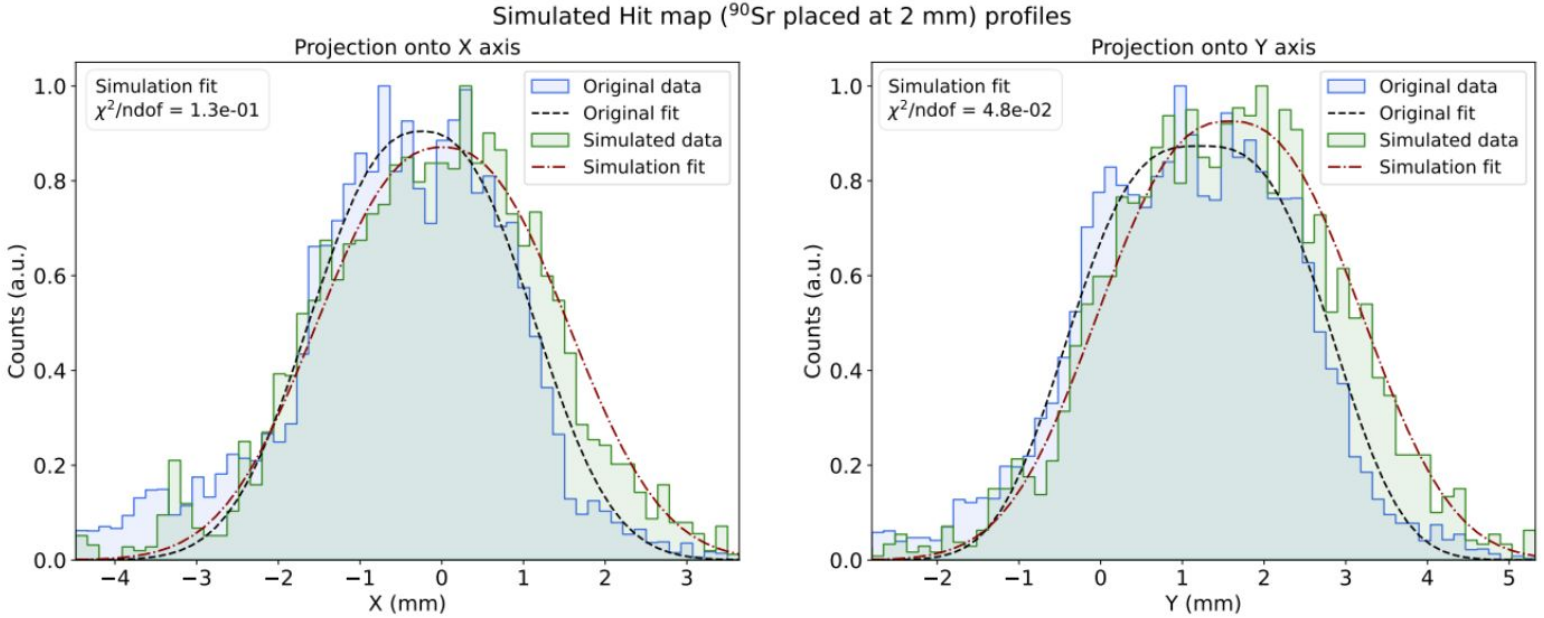

Figure 4.19: Comparison between the profiles of the original and simulated ^{90}Sr images. The developed GEANT4 simulation replicates the setup of tests performed with the ALPIDE detector using a ^{90}Sr source. The source is positioned 2 mm away from the detector surface. The profiles are fitted using a super-Gaussian distribution (generalized Gaussian function).