Istituto Nazionale di Fisica Nucleare
LABORATORI NAZIONALI DI LEGNARO

UNIVERSITÀ DEGLI STUDI DI TRIESTE

Dipartimento di Fisica

ELMA Workshop on "Energy loss measurements with MAPS"

DUMBO: a 2D imaging beta detector based on ALPIDE chips for radiopharmaceutical applications

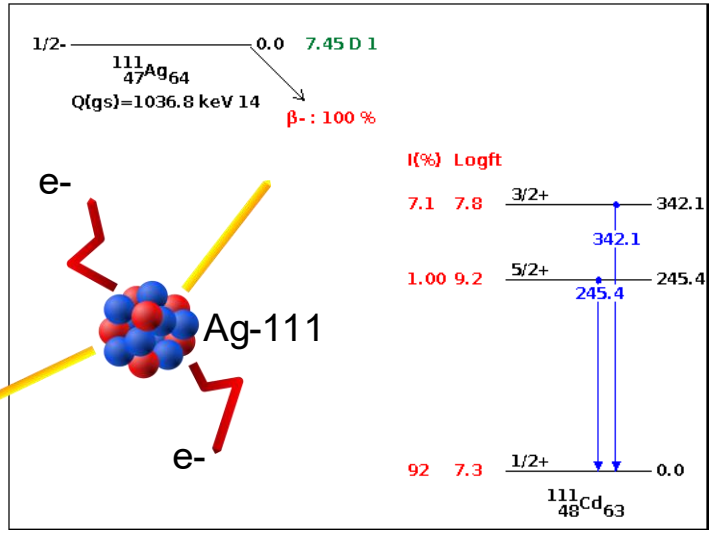
D. Serafini on behalf of the ISOLPHARM collaboration

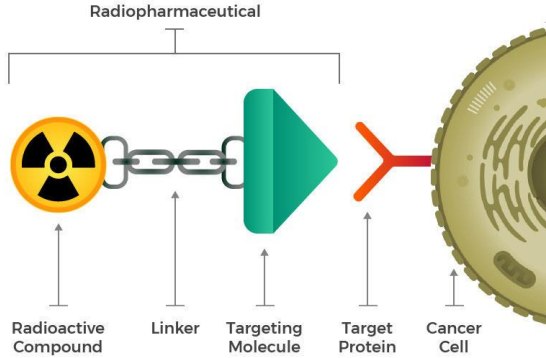
Trieste, September 10th, 2025

Outline

- Introduction to β-imaging for radiopharmaceuticals
- The new DUMBO β-imaging tool explained
- First experiments with Ag-111
- Open issues regarding DUMBO
- Conclusions

Radiopharmaceuticals



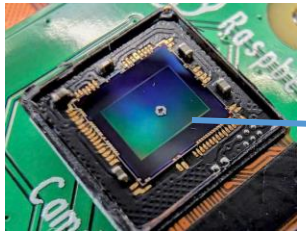


Credit: National Cancer Institute

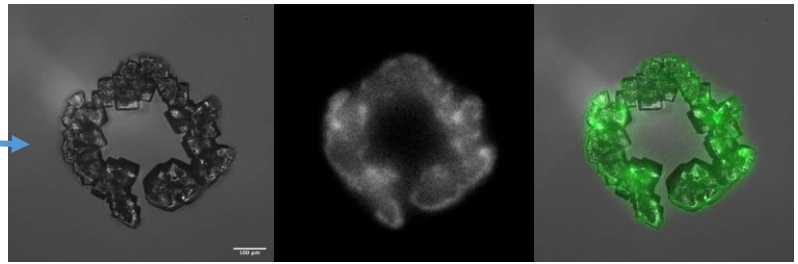
- Treating cancer is possible with Targeted Radionuclide Therapy (TRT)
- β-imaging can be used to assess the targeting ability of the radiopharmaceutical
- The ISOLPHARM project aims to develop a Ag-111 radiopharmaceutical
  - https://isolpharm.pd.infn.it/web/

β-imaging systems

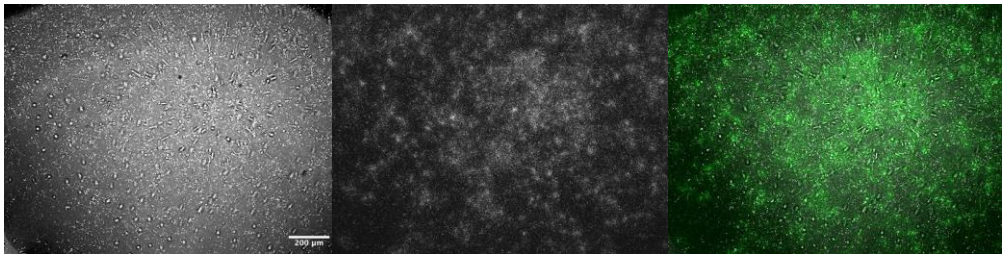
- Radiographic films
- Phosphor screens
- CMOS sensors
  - 3,280 × 2,464 square pixels, each 1.12 μm in size, and a total active area of 3.79 × 2.69 mm.



N. Belcari, EMIM25



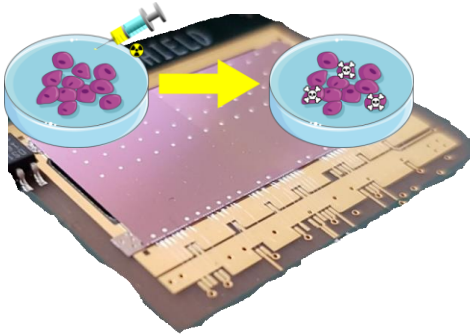
- Test with ^{18}F-FDG

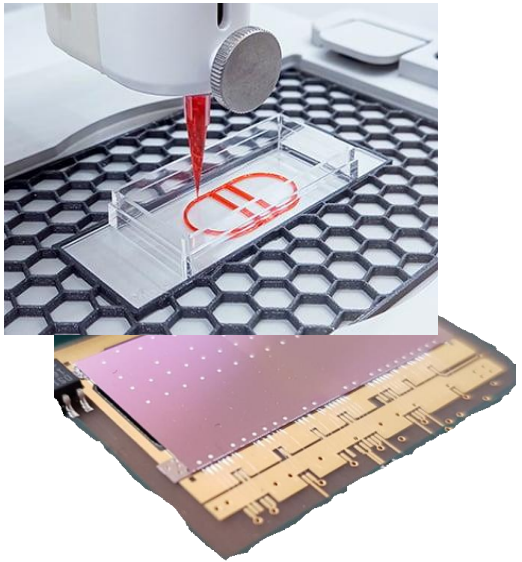


- Test with cells taking up ^{18}F-FDG

DUMBO

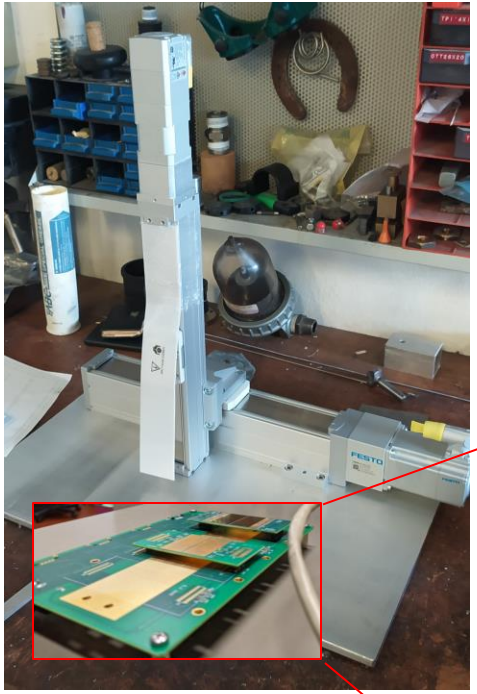
Detector
Using
Maps for
Beta-rays
Observation



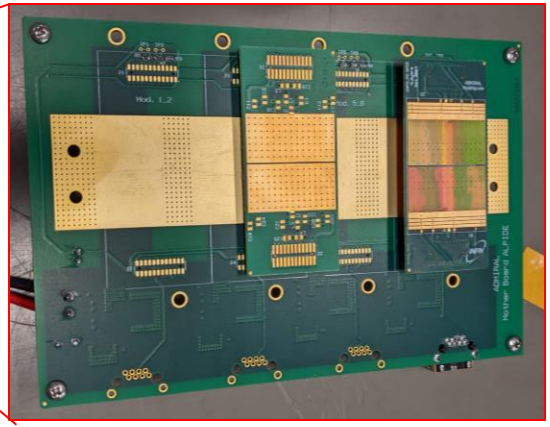


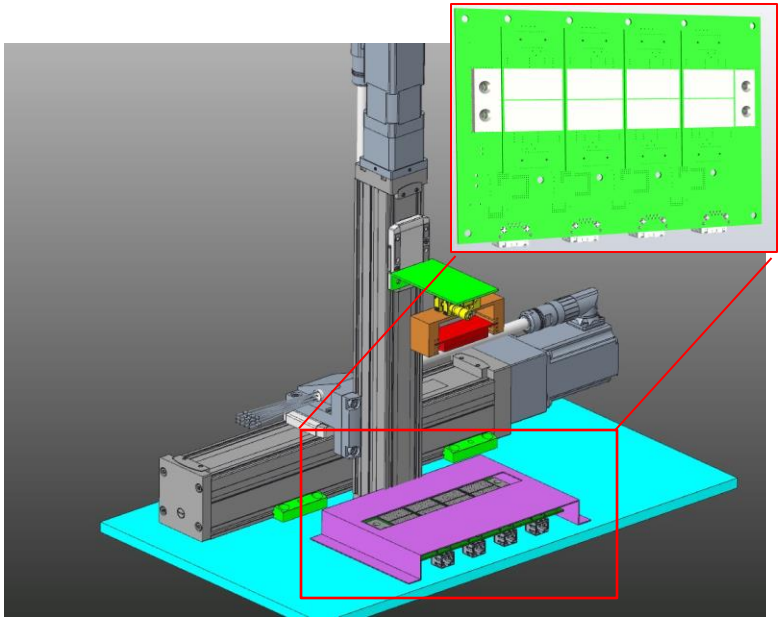
- Features of DUMBO
  - Sample **isolated** from the detector
  - Spatial resolution of about 1 mm at 500 um distance
  - Large sensitive area (**15 × 30 mm²**)
  - Scanner function using **stepper motors** to increase FoV
  - Easy to use
- Applications
  - Cell clusters imaging in-vitro for uptake
  - Imaging of **2.5D scaffolds**

DUMBO mechanics

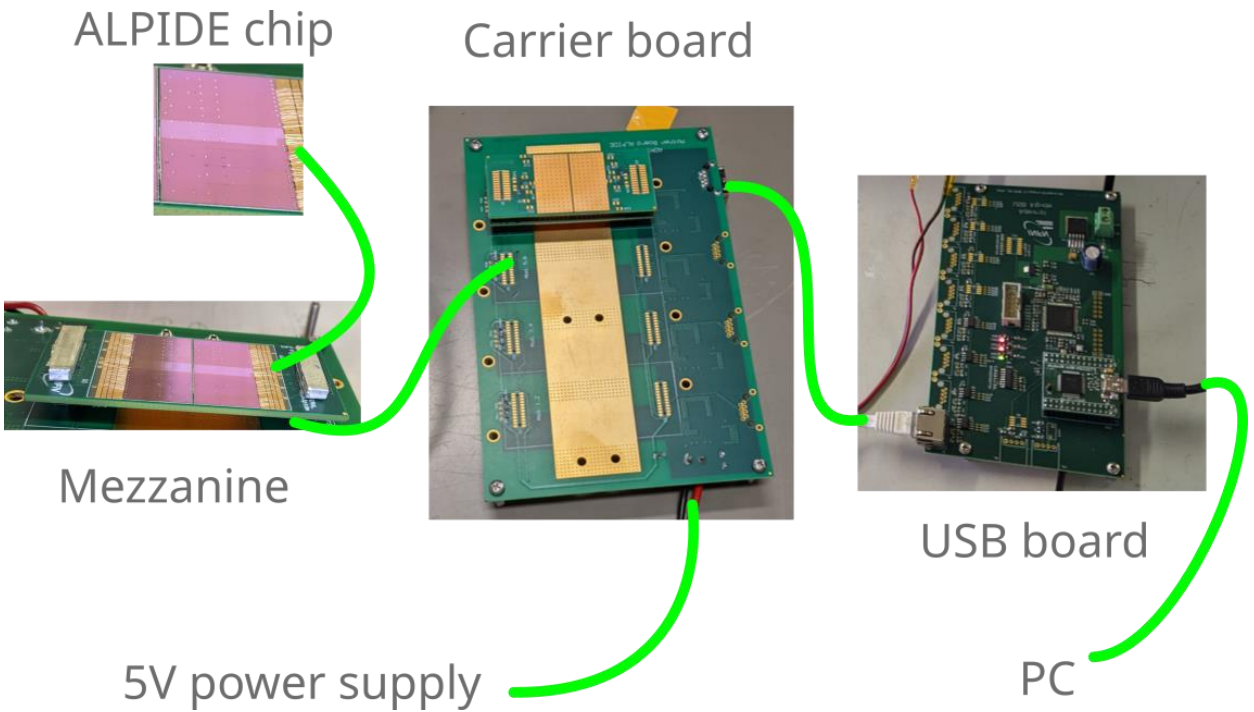


- 8 ALPIDE chips are the sensitive elements
  - 4 × 2 configuration
- Mechanics system to place the sample
  - x-y movement

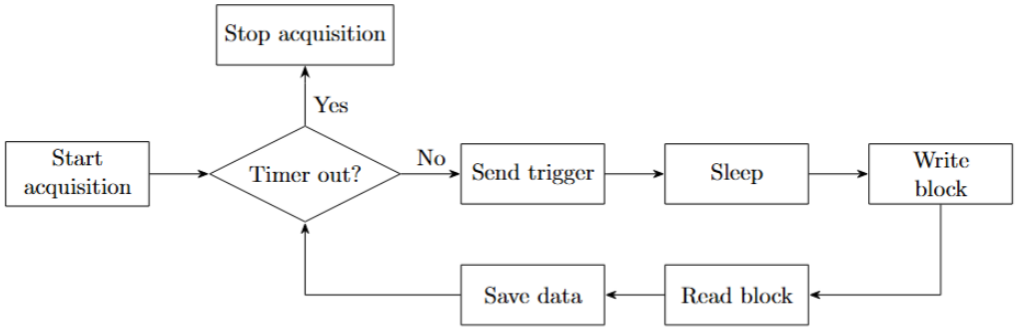




DUMBO electronics scheme



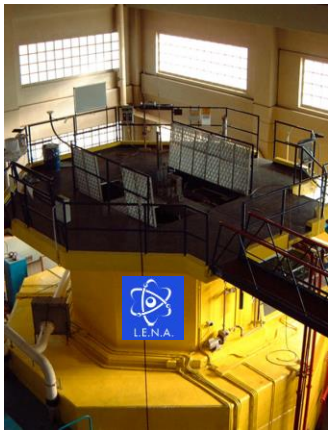
DUMBO DAQ



- **DCTRL** ports are used retrieve the data
- **PySerial** module sends the messages
- String of many data query (200) is sent to the chip
- Readout is performed in a cycle until buffer is empty

Address	Value	Description
0x0001	0x020A	continue readout at 20 MHz, no clustering
0x0004	0x0000	disable busy monitoring
0x0005	50000	strobe duration ($\simeq 1.25$ ms)
0x0006	5000	strobe gap ($\simeq 125$ µs)
0x0010	0x0060	disable Manchester encoding
0x0602	0x0093	set reset voltage of the charge collecting node
0x060E	53	ITHR pixel charge threshold (about 0.5 nA)

Experiment in July 2025



DUMBO tests at LENA:

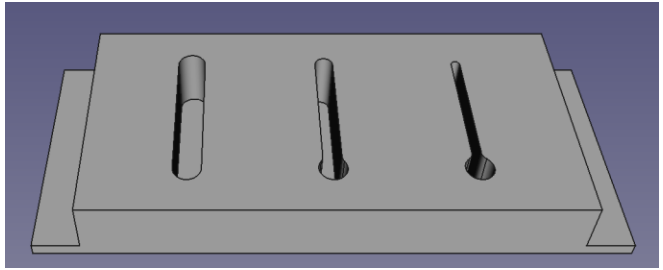
- Characterize the whole device
  - ALPIDE chip
  - Movement system

Preliminary tests

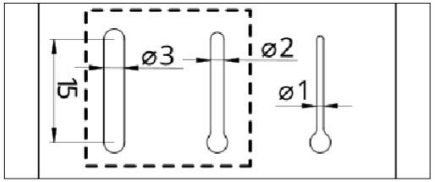
- Study of diffusion of **Ag-111** ions
  - In **GelMA** scaffolds prepared at the radiolab of Pavia in collaboration with the BIOtech of Trento

- Evaluation of the spatial resolution
  - In plastic phantoms

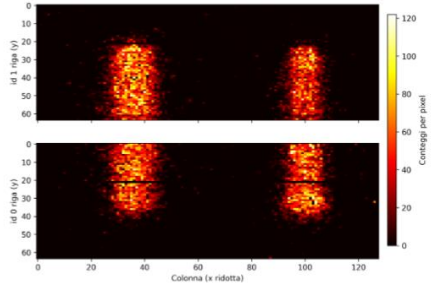
Test with POM phantoms



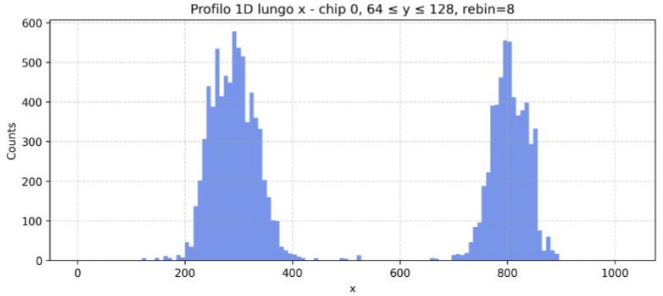
Polyoxymethylene (POM) phantoms



(a) Technical drawing of the phantom, distance values in millimeters. The dashed line indicates the phantom in the FOV of the imaging device.



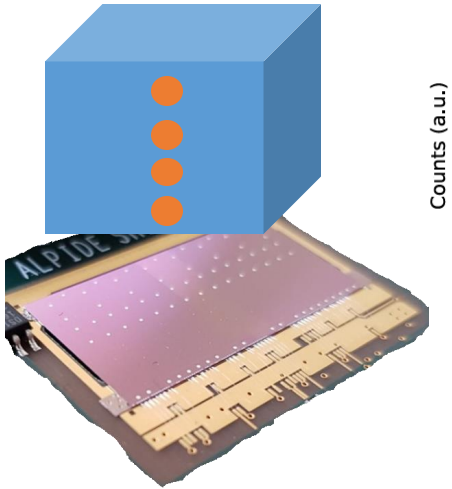
(b) Hitmap of the phantom. Binning 8×8 is used.

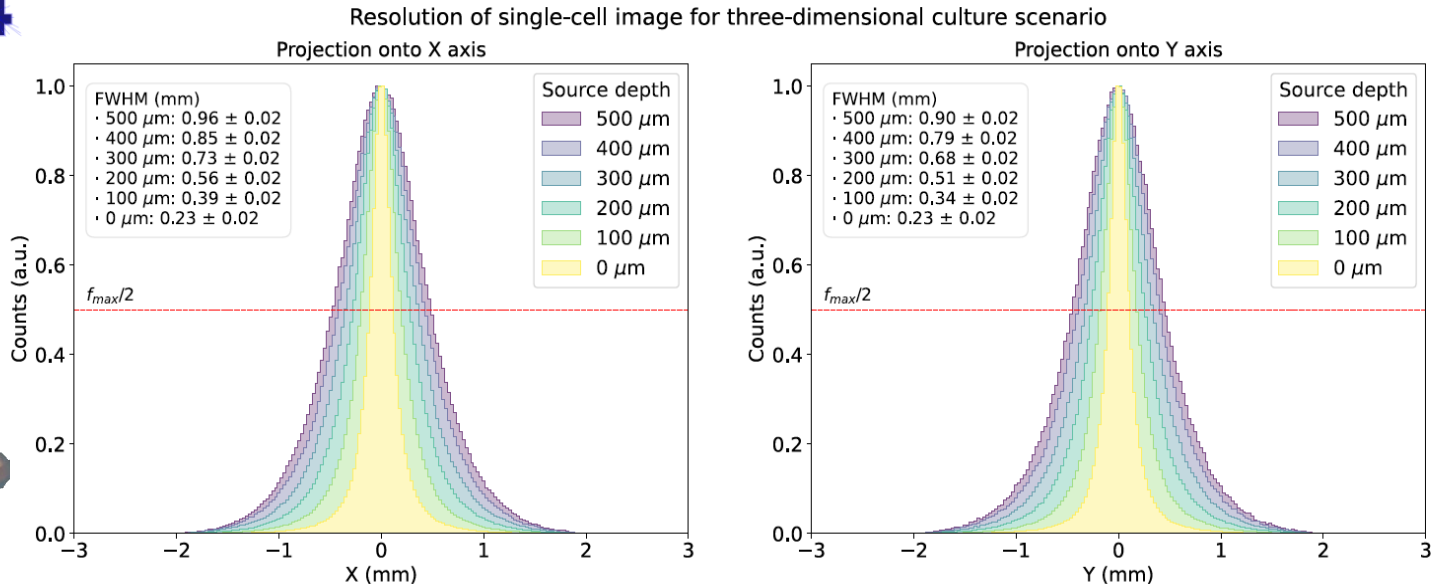


(c) Profile along the x-axis

Figure 5: Plastic phantom acquisition with Ag-111 solution.

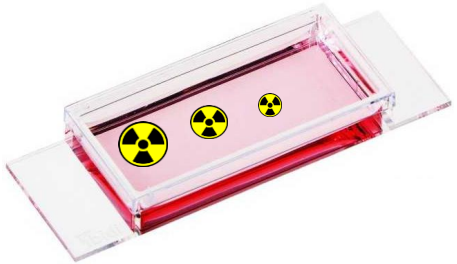
Sample-detector distance

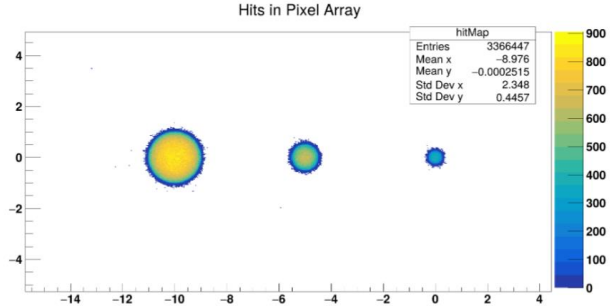




V. Pavanello, 2023

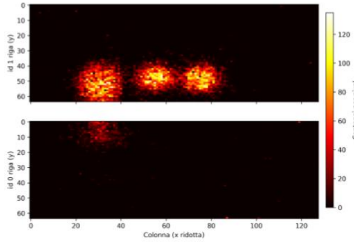
Test with GelMA phantoms





(a) Geant4 simulation of the 0.5 mm, 1 mm and 2 mm diameter wells with Ag-111 in GelMA.

(b) Picture of the GelMA phantom. The three Ag-111 spots inside the yellow square are imaged.



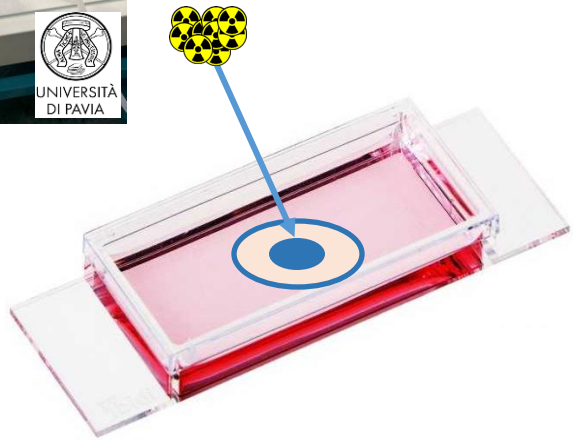
(c) Hitmap of the GelMA phantom.

Geant4 simulation from S. Busatto thesis, UNIPD, 2025

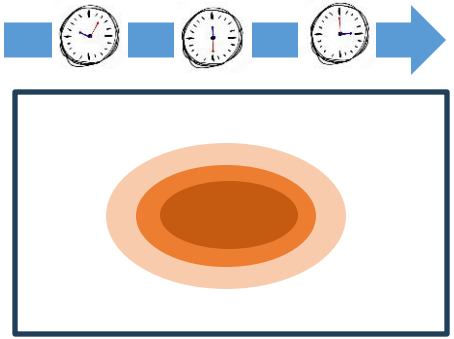
Future experiments

Experiments on Ag-111 diffusion:

- Estimate diffusion of Ag-111 in 2D cell cultures
- Estimate diffusion of Ag-111 in GelMA



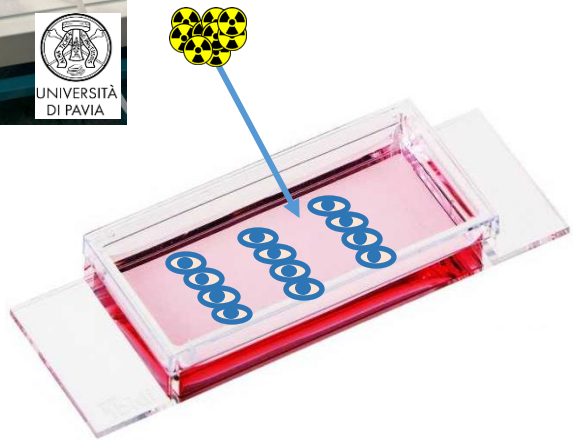
DUMBO imaging



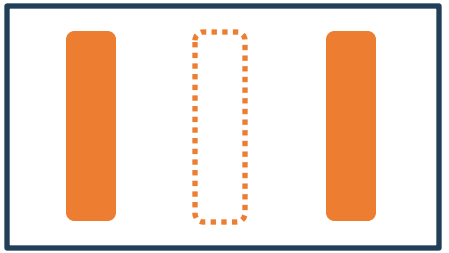
Future experiments

Experiments with cells:

- Estimate uptake of different cell lines in the same culture
  - Uptake of Ag-111 ions
  - Uptake of Ag-111 radiopharmaceutical

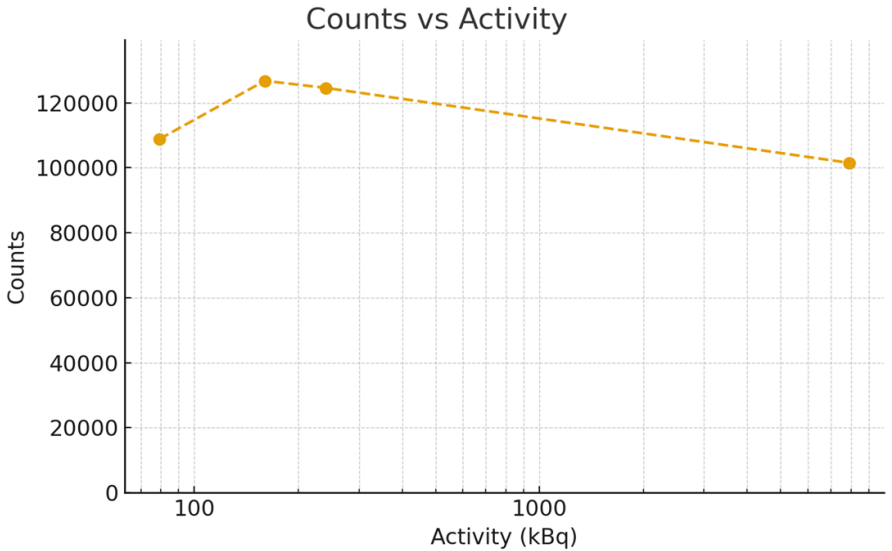


DUMBO imaging



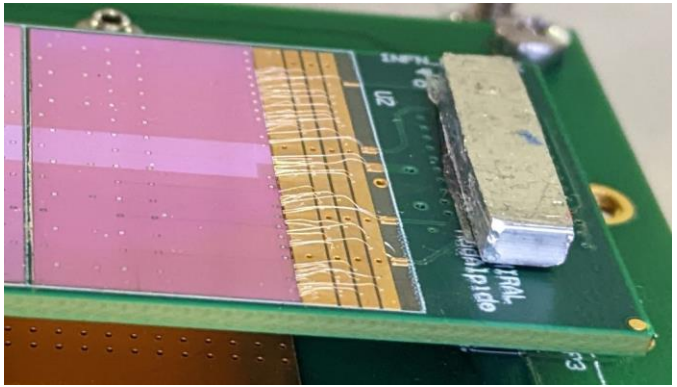
Problem with DAQ

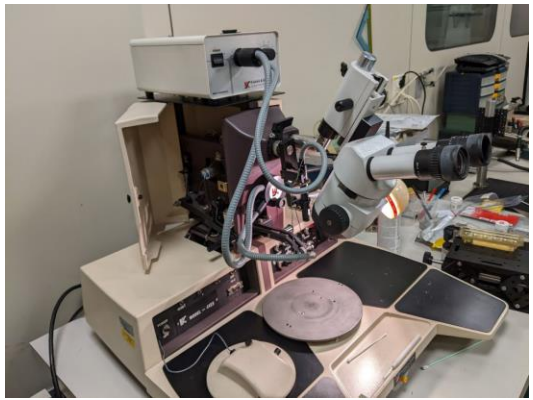
- Activity quantification is needed
- The intensity of the signal does not increase increasing the radionuclide activity
- The maximum acquisition rate is reached
- We need to lift the saturation limit



Problem with bonding

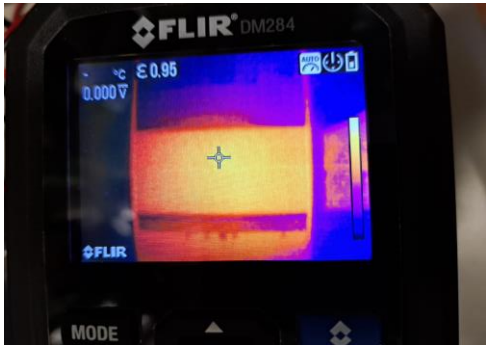
- Bonds on the surface are fragile
- Two possible solutions:
  - Covering them with resin
  - Bonding on the back

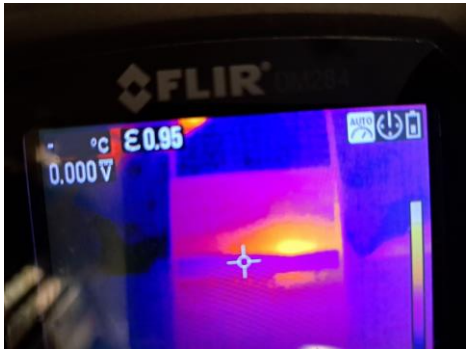




Problem with bonding

- Bonds on the surface are fragile
- Covering them with resin leads to excessive current drain
  - Maybe it is a problem of these thin (50 um) chips
- Bonding on the back would be ideal

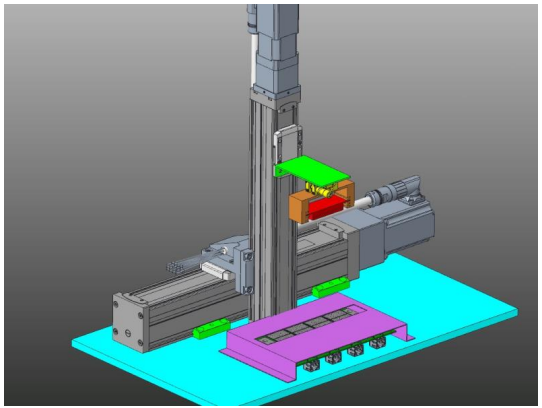




Alpide heat map as seen by a thermal camera

Conclusions

- A device for beta-emitting radionuclides was developed: DUMBO
- An experiment with Ag-111 was performed -> it works but
- The maximum acquisition rate was reached even at low activities
  - The DAQ needs to be improved
- The adopted bonding is too fragile for this application
  - A more stable bonding is desirable
- Is the overcurrent a typical problem for thin (50 μm) ALPIDE chips?



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- https://isolpharm.pd.infn.it/web/, 2025

Thanks