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Positron transmission imaging of histological slices

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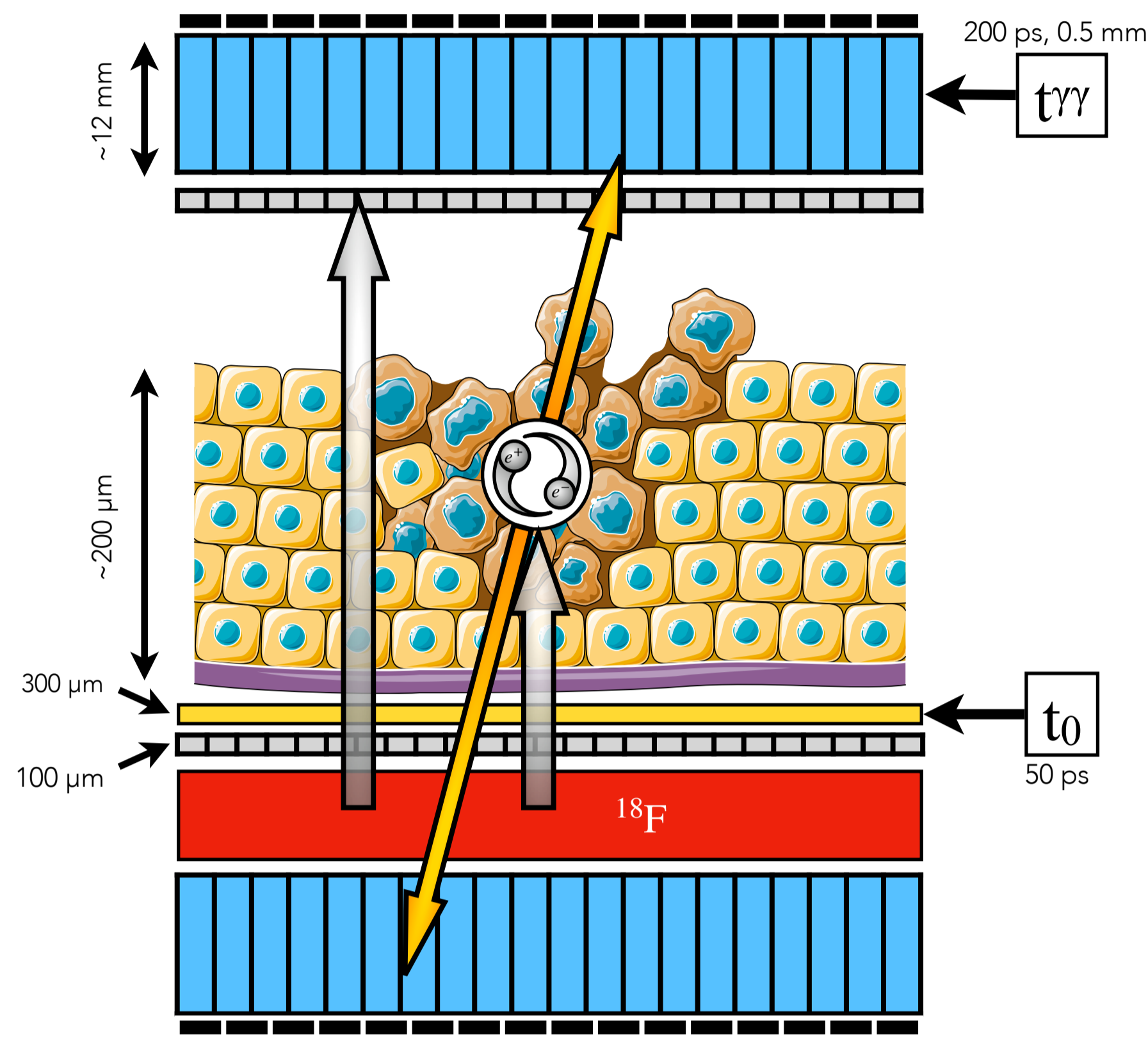
CONTEXT

Positron lifetime imaging

- Traditional 2γ positron emission tomography (PET) reconstructs the topological biodistribution of an injected radio-labeled molecule
- Biological information extracted from the specificity of the tracer to a biological function
- Information on the annihilation tissue encoded in the positron lifetime
- Ortho-positronium (O-Ps) state's lifetime sensitive to physical and chemical state of the annihilation medium (PALS)
- O-Ps lifetime not used in clinical PET yet

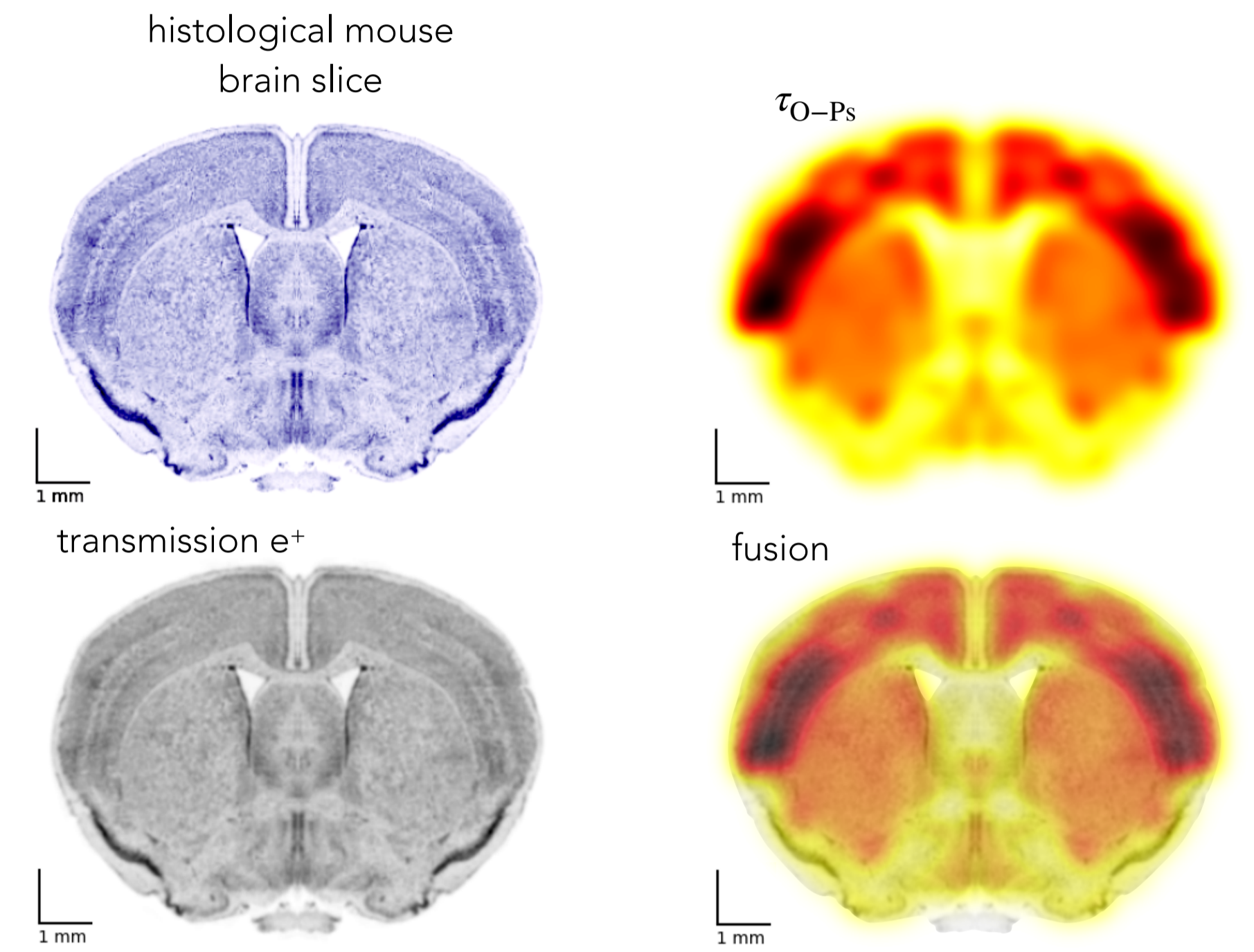
3D in-vivo positron lifetime imaging

- Measuring a lifetime requires a trigger of positron time of emission : (β^+, γ) emitters $\Rightarrow 3\gamma$ coincidences (J-PET, uExplorer, Xemis, ...)
- Requires high sensitivity, excellent coincidence time resolution tomographs
- New upcoming technology
- Challenges :
 - Information restricted to the biodistribution
 - High statistics per voxel required to untangle the different lifetimes
 - Still poor understanding on the biological causes of τ_{O-PS} changes (correlation to pathologies, lesions, chemical imbalance, ...)



TRICERA τO-PS

- **TRIPLE COINCIDENCE EVENTS** from β^+ **RA**diotopes to image **TO-PS**
- 2γ τ_{O-PS} Imaging : usual β^+ isotope (^{18}F)
 - Emission time from plastic scintillator
 - Annihilation γ detected by LYSO:Ce crystal matrix + SiPM
- Measurement **INDEPENDANT** from radiotracer biodistribution
 - Uniform high activity source
 - Remove biodistribution dependency
 - Allows for pixelized tissue-related τ_{O-PS} studies
- **e+ transmission** imaging
 - Pixelized detection layers upstream and downstream of tissue sample
 - Measure positron attenuation in tissue
 - High resolution reference anatomical imaging for τ_{O-PS} image comparison
 - Possible technologies :
 - CMOS \Rightarrow focus on this technology in this poster
 - MWPC
 - MicroMegas
 - Fibrous hodoscope
- Both imaging modalities acquired **simultaneously**
 - Limit tissue slice ageing
 - No need to image registration
- **TRICERA τO-PS** will allow us to bridge the gap between PALS measurements of large biological samples and 3D in-vivo measurements in 3γ PET scans
- **High resolution, high activity, τ_{O-PS} imaging** of tissue slices will improve our knowledge of τ_{O-PS} variation for various tissues and pathologies and of the underlying biological reason for such change



Illustrations of the planned imaging modalities

Image reconstruction

Simulations

- Simulations performed with Gate 9.1
- ^{18}F source
- CMOS : 100 μm thick Si layer, 50 μm pixelization
- Trigger : 300 μm thick scintillating PMMA
- Si Derenzo phantom : 200 μm thick, inserts ranging from 600 to 100 μm

Tissue layer position reconstruction

- Assume straight line from CMOS-pixel to CMOS-pixel
- Error from true tissue layer crossing : ~ 0.15 mm

Attenuation factor evaluation

- Comparison between pixel i in the tissue-image I_i and water-only image $I_{0,i}$:

$$\mu_i = -\frac{1}{\langle \Delta z \rangle} \ln \left(\frac{I_i}{I_{0,i}} \right)$$
 with $\langle \Delta z \rangle \sim 250$ μm the average path in the tissue layer

In this poster, we will focus on the novel concept of positron transmission imaging

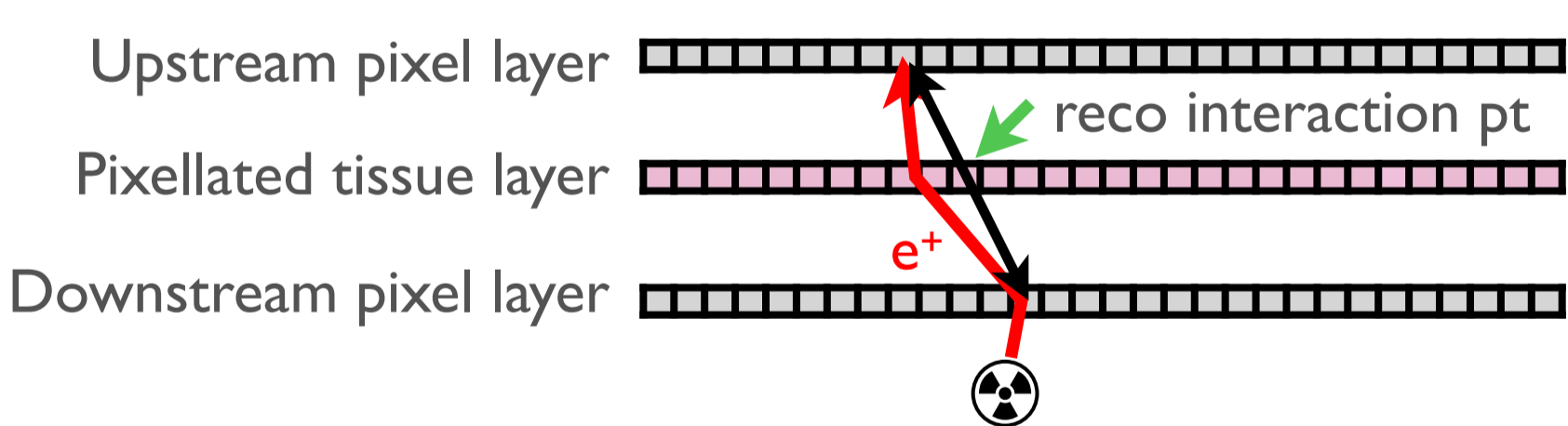
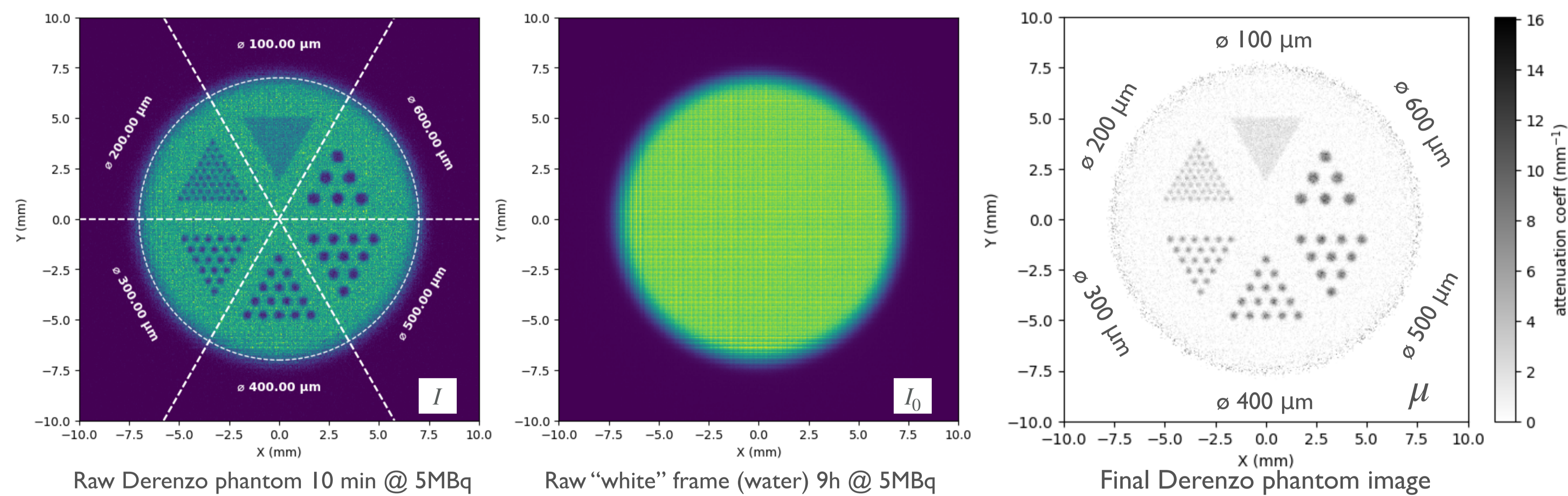
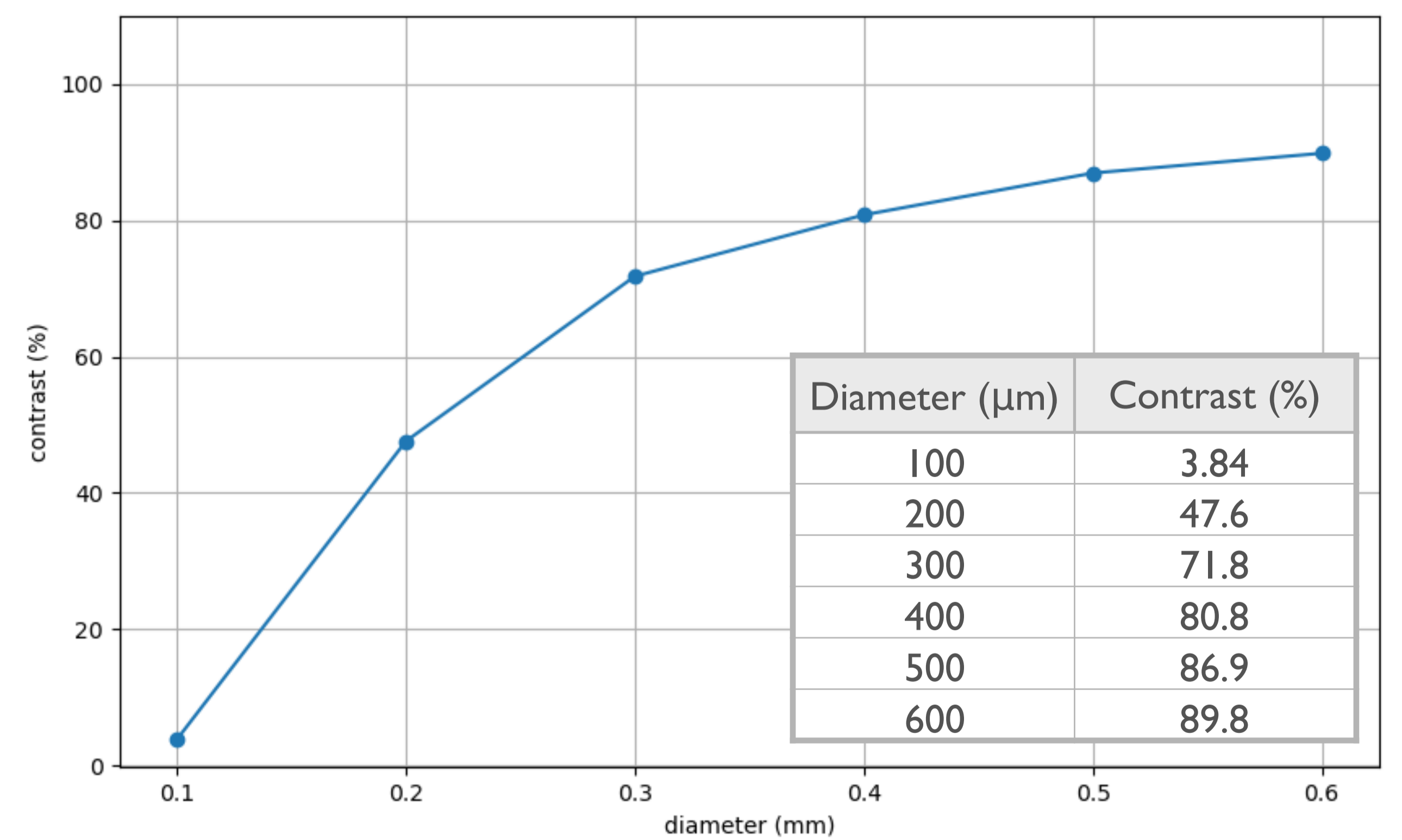
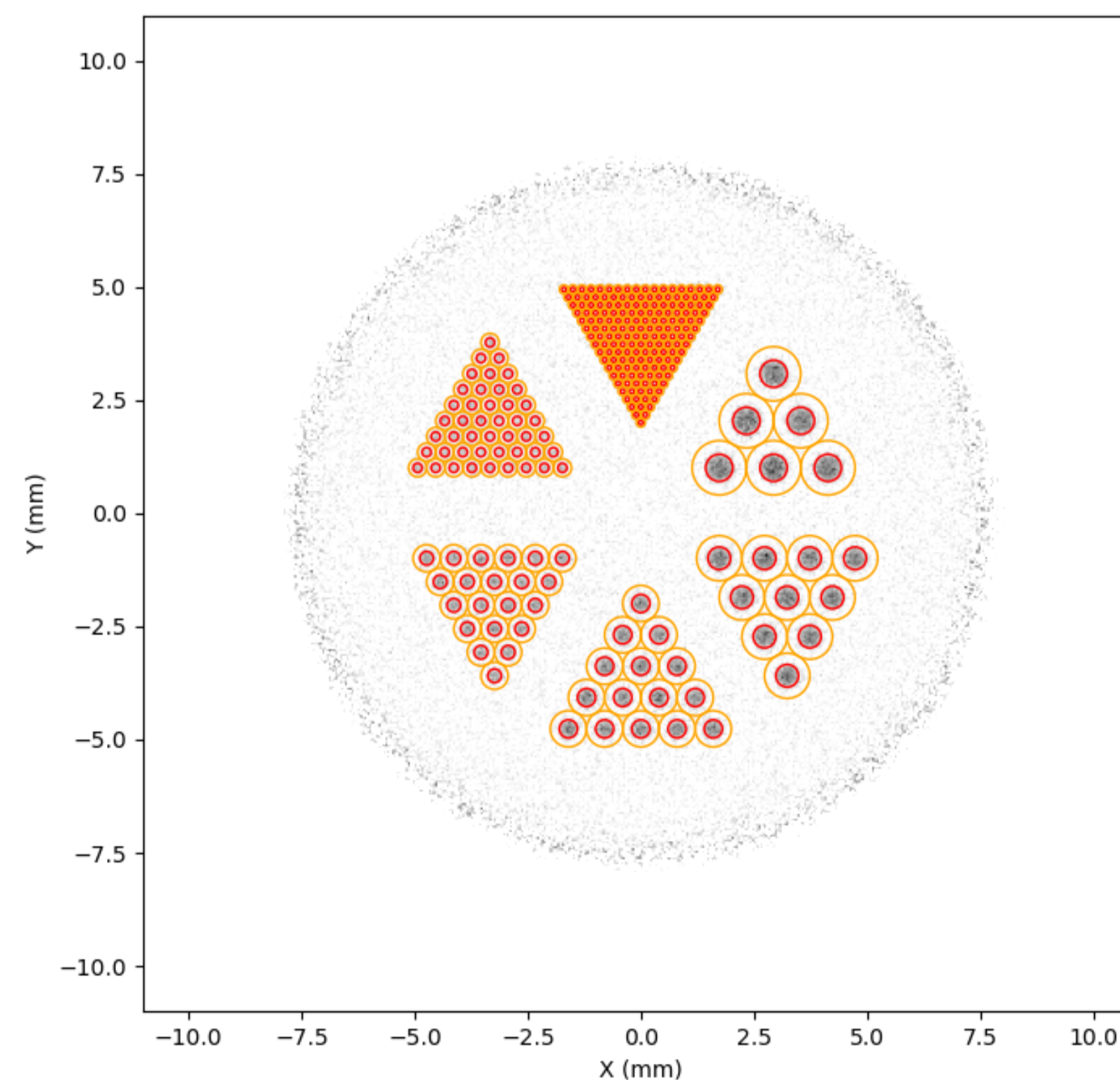


Image evaluation

- ROIs centered on each phantom inserts
- signal ROI (red) : $r_{\text{pix-ROI center}} < r_{\text{insert}}$
- background ROI (orange) :
 $r_{\text{insert}} < r_{\text{pix-ROI center}} < 2 \times r_{\text{insert}}$
- contrast : $\frac{\langle \mu_i \rangle_{\text{signalROI}}}{\langle \mu_i \rangle_{\text{backgroundROI}}}$
- Good contrast ($\geq 50\%$) down to 200 μm



Summary

Conclusions

- A **novel imaging** technique : **positron transmission imaging** will serve as a high resolution anatomical reference image
- A first study with a dense material provides a limit on spatial resolution for high contrast images
- Preliminary studies show a < 200 μm spatial resolution using two CMOS.
- Resolution limited by tissue layer diffusion : ~ 0.15 mm

Perspectives

- Other possible technologies, each with their advantages :
 - **MWPC** (upstream) \Rightarrow provides (X,Y) and **e+ directionality**
 - **MicroMegas** (downstream) \Rightarrow provides high resolution (X,Y)
 - **Scintillating fibers hodoscope** \Rightarrow provides (X,Y) and **trigger time**
- **Iterative reconstruction** \Rightarrow account for e+ scattering, improving spatial resolution
- Sensitivity studies : **contrast and resolution achievable with biological tissues?**