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J-PET

Investigation of the DOI capable configuration in dealing with the parallax error in the Total-Body J-PET tomograph: A simulation study

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on behalf of J-PET collaboration

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2022.05.31, Elba, Italy

Positron Emission Tomography (PET)

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Current clinically available tomographs provide a limited detection area.
Extension of axial field of view (AFOV) as a solution to improve sensitivity and imaging performance of PET scanners.

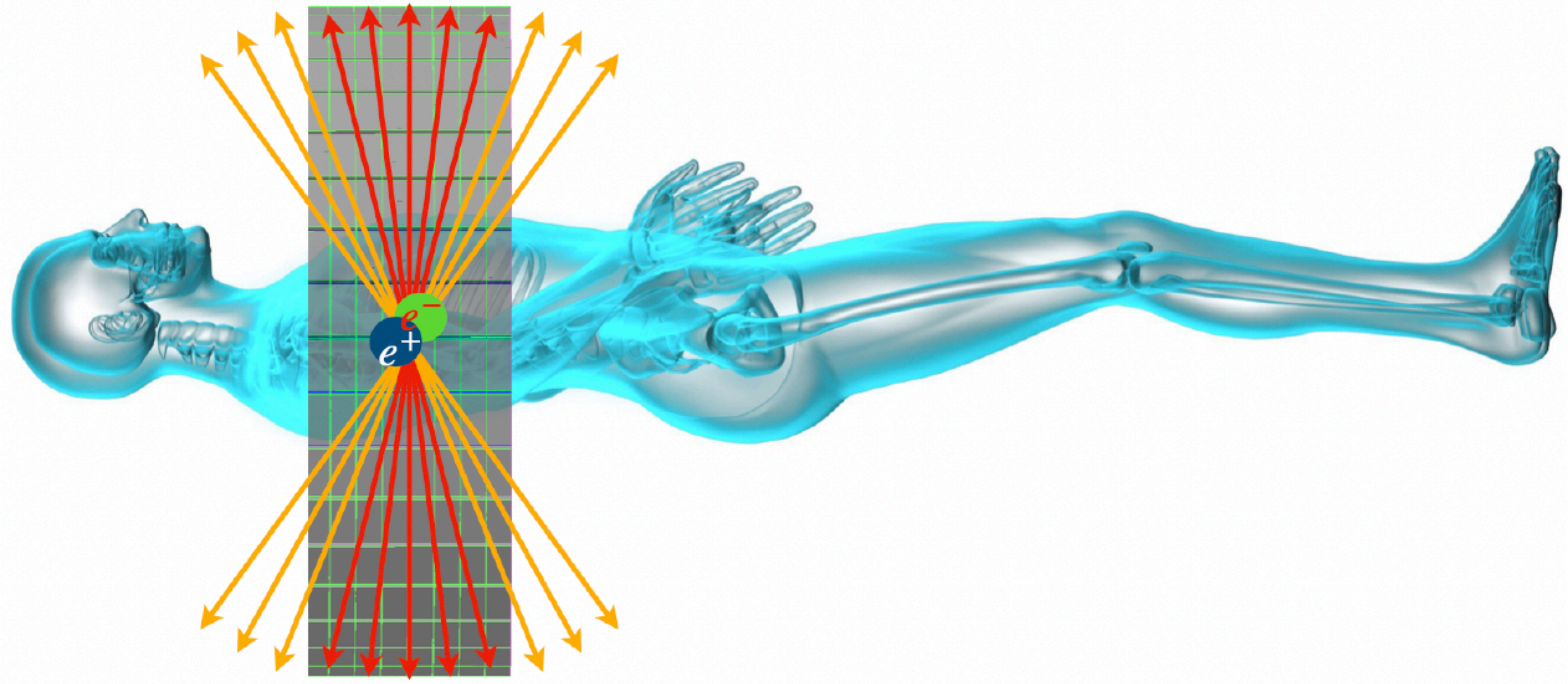

Fig. 1: Schematic visualization of a patient inside PET scanner which is detecting only a fraction of the emitter gamma photons (red) , while rest escapes without detection

Total-Body PET scanners

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Extended AFOV provides:

- Larger detection area
- Higher sensitivity
- Higher detection probability
- Shorter imaging time
- Improved lesion detectability

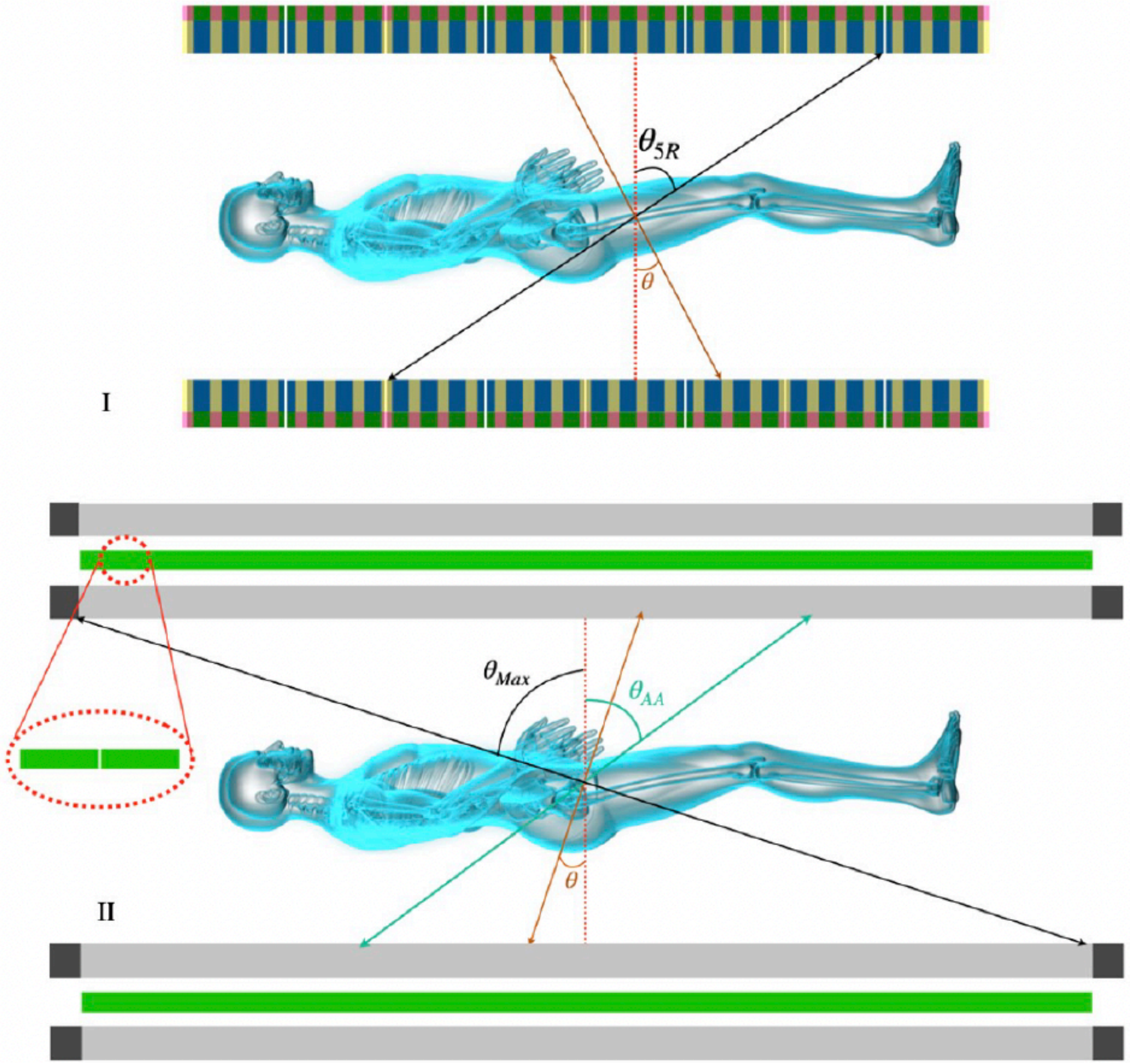

Fig. 2: (I) Schematic visualization of the Total-Body PET scanners based on the current technology and (II) geometrical configuration of the Total-Body PET scanners based on the J-PET technology.

Reference: Meysam Dadgar, et al., Comparative studies of the sensitivity of sparse and full geometries of Total Body PET scanners build from crystals and plastic scintillators, preprint of manuscript for EJNMMI Physics.

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J-PET technology

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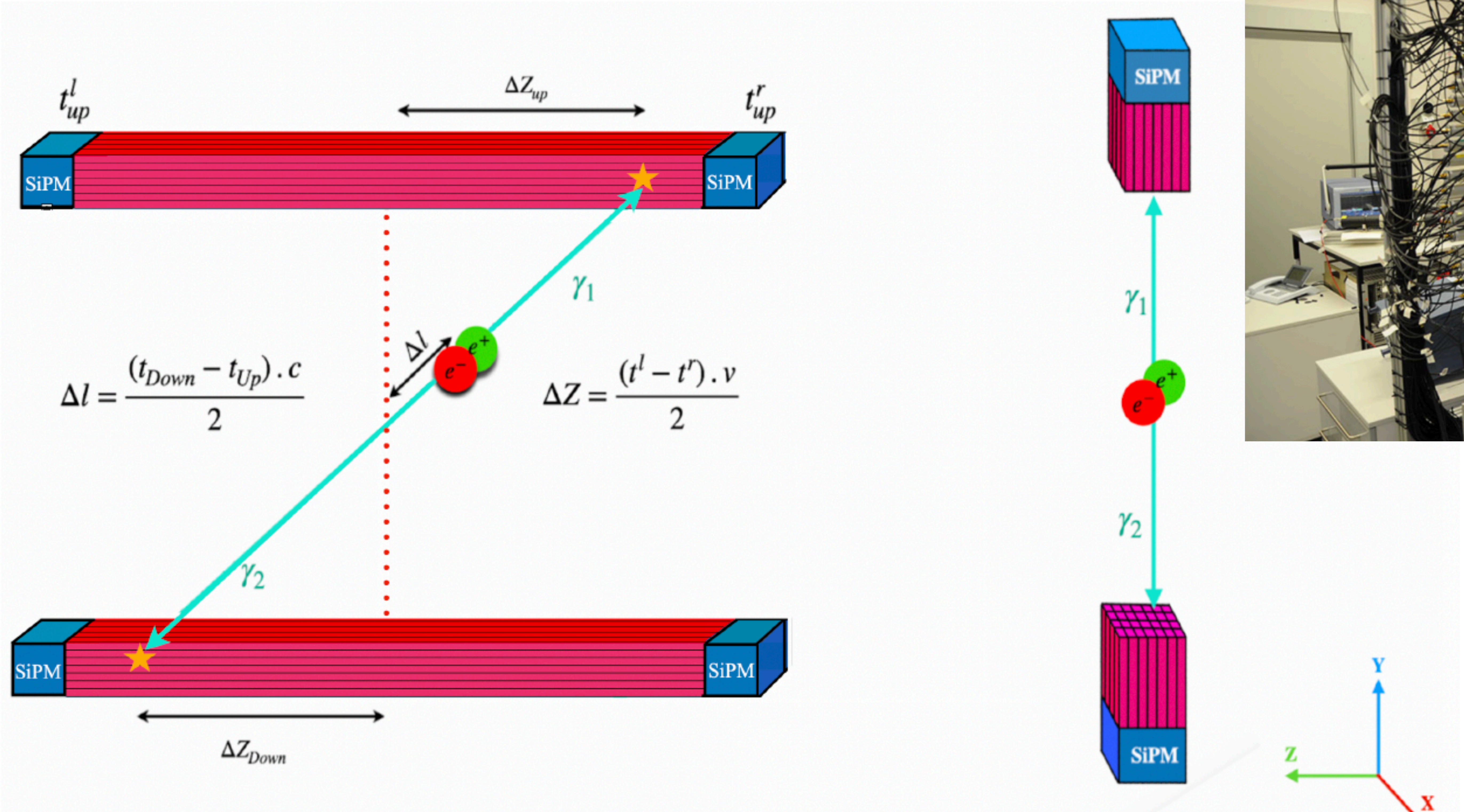
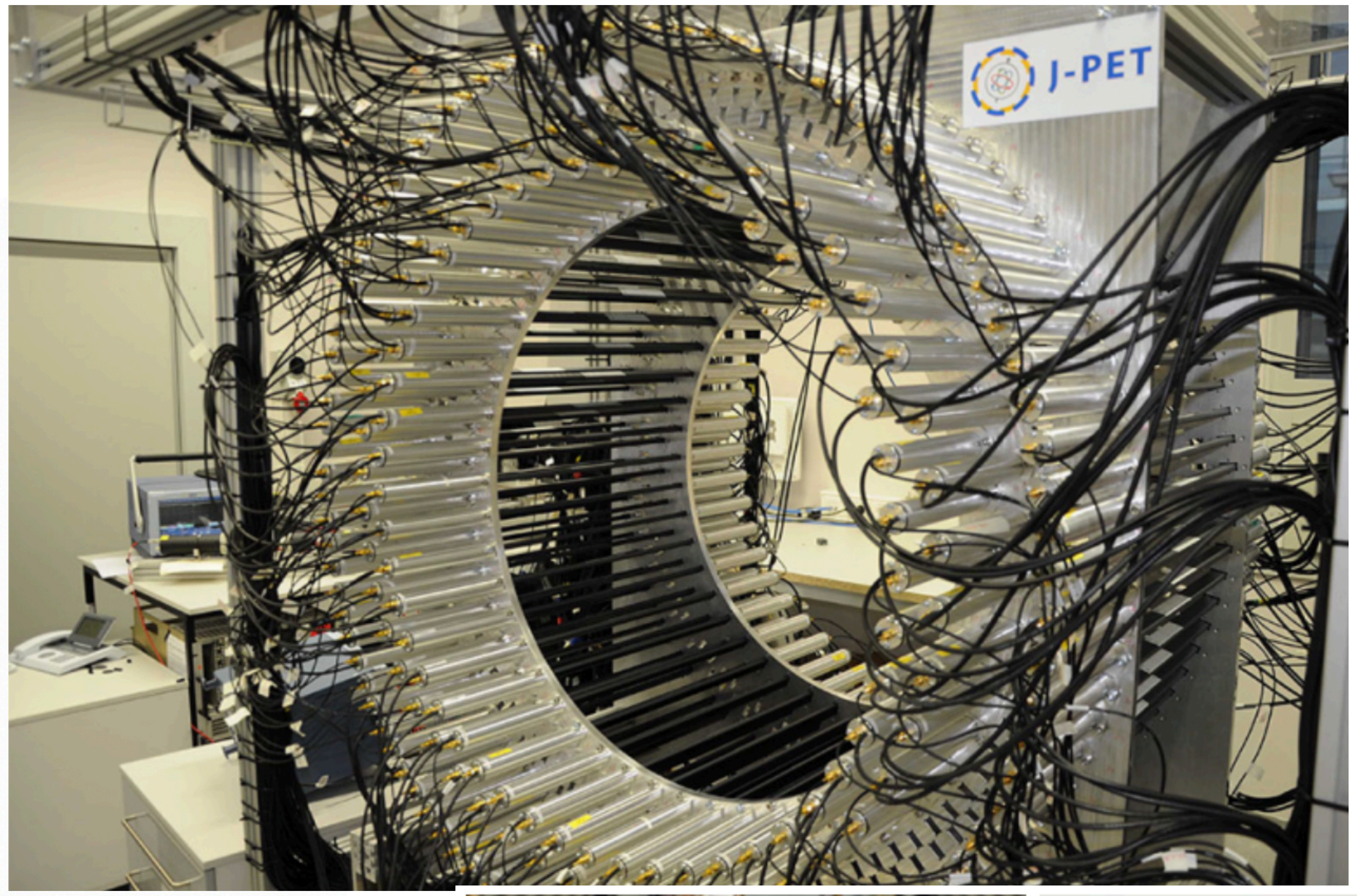
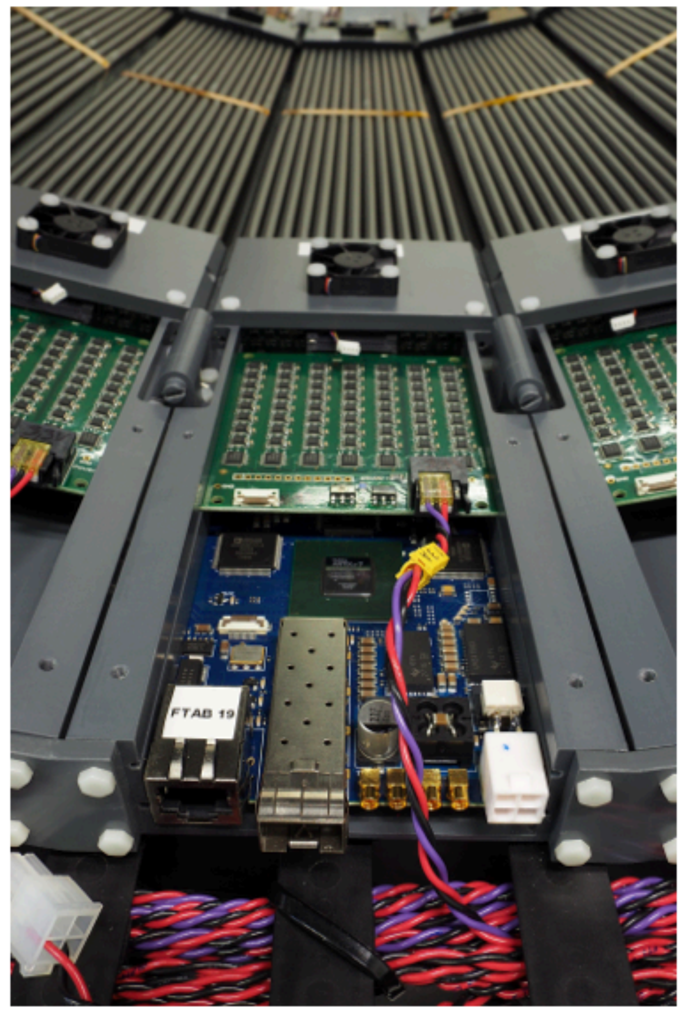
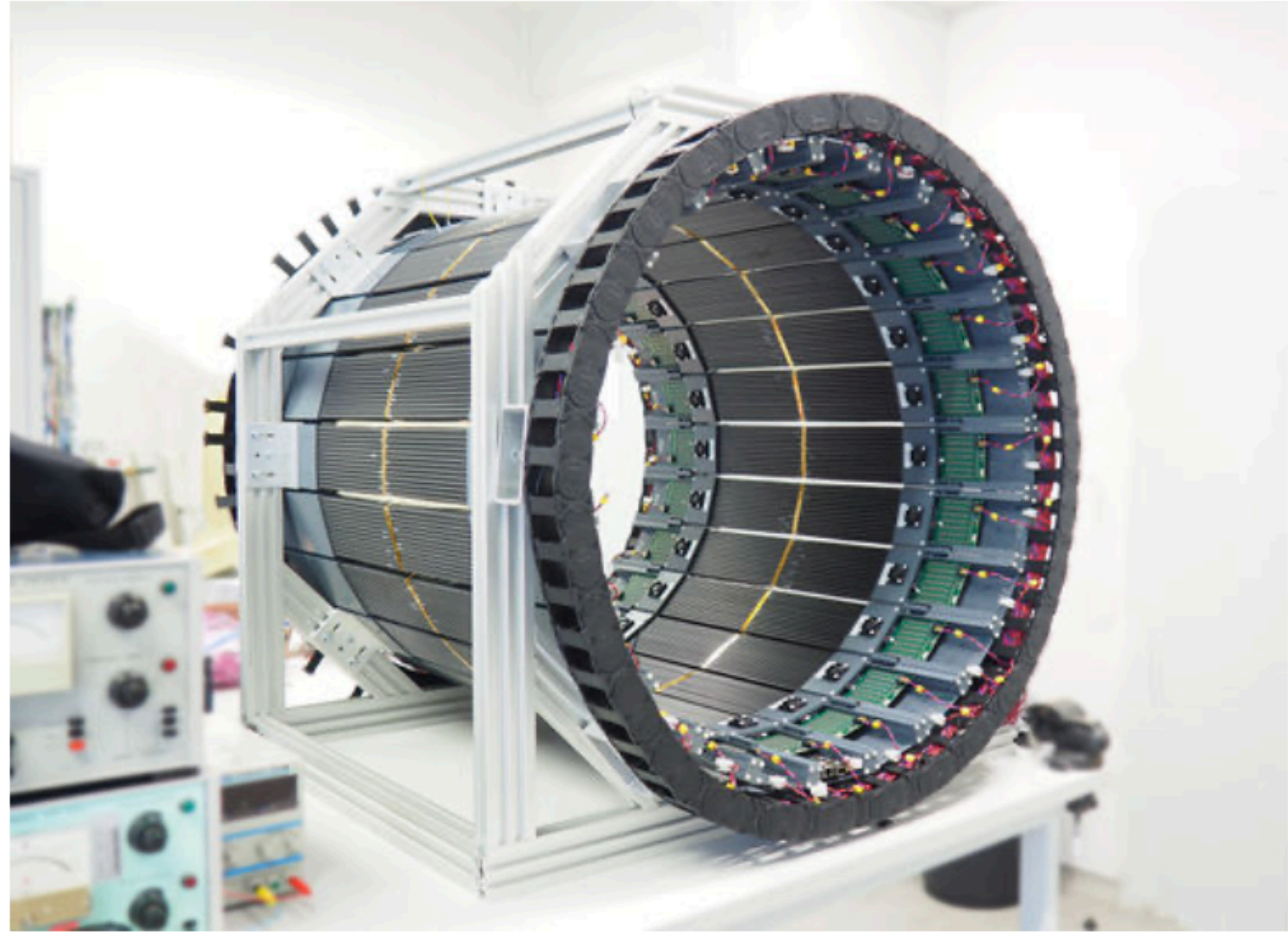


Fig. 3: Schematic visualization of the J-PET vs traditional scanners







Reference: Meysam Dadgar, et al., Investigation of novel preclinical Total Body PET designed with J-PET technology: A simulation study, preprint of manuscript for IEEE TNS.

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Total-Body J-PET scanners

- Scintillator material – plastic (EJ230, Eljen Technology)
- Axial arrangement
- Silicon photomultiplier (SiPM) readout at both ends

Cost-efficient long field of view PET system

- 200 cm AFOV
- 79 cm diameter
- 2 layers × 24 modules × 16 scintillators

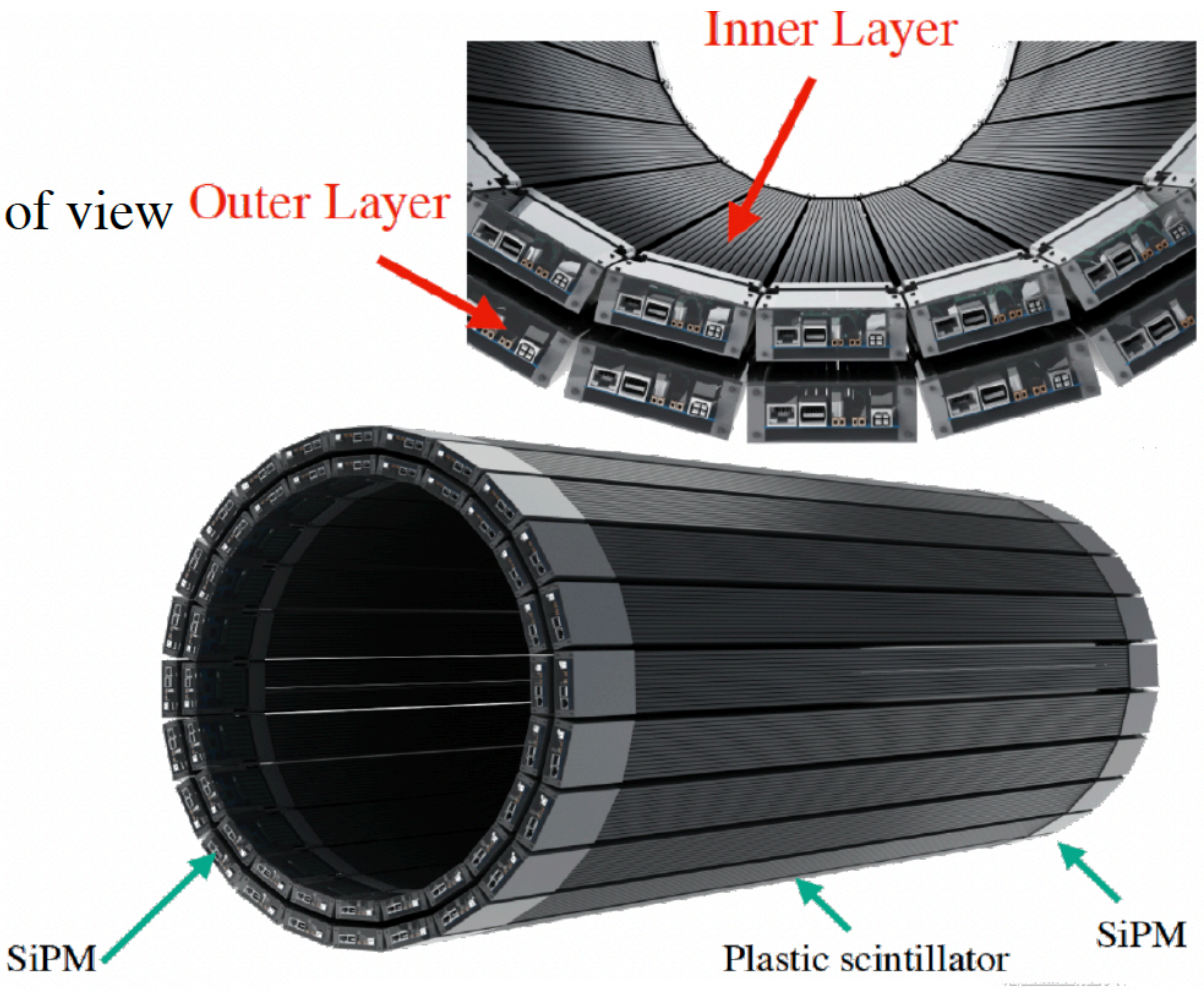

Fig. 4: 3D rendered images of Total-Body J-PET

J-PET Collaboration, Jagiellonian University, Krakow, Poland

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http://koza.if.uj.edu.pl/pet

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Parallax error:

Unknown depth-of-interaction of the photons within the scintillators causes a shift in the hit position. Such displacement propagates then to the line of response and as a consequence, causes incorrect annihilation position reconstruction

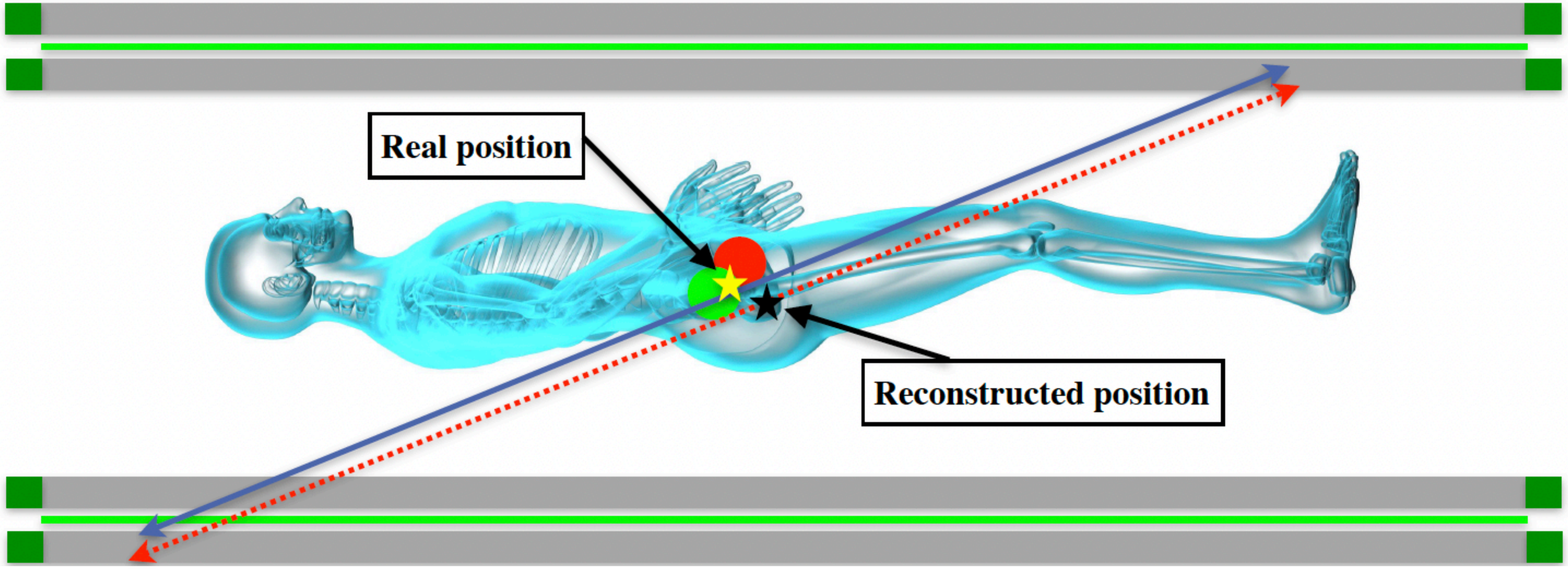

Fig. 5: Uknown depth of interaction of the oblique LORs which will give an incorrect annihilation photons and decreases quality of imaging

Total-Body J-PET with mini-bar configuration

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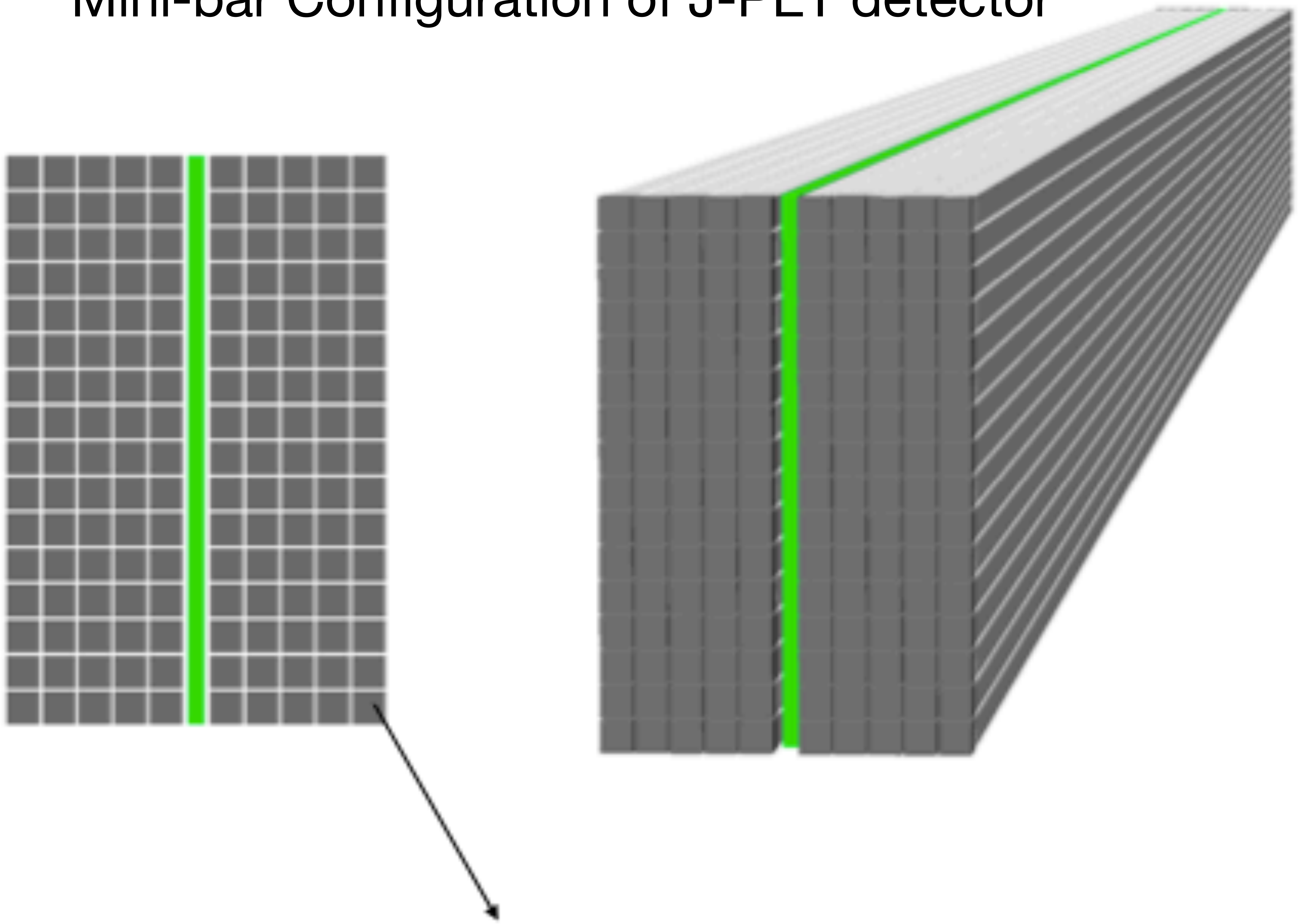
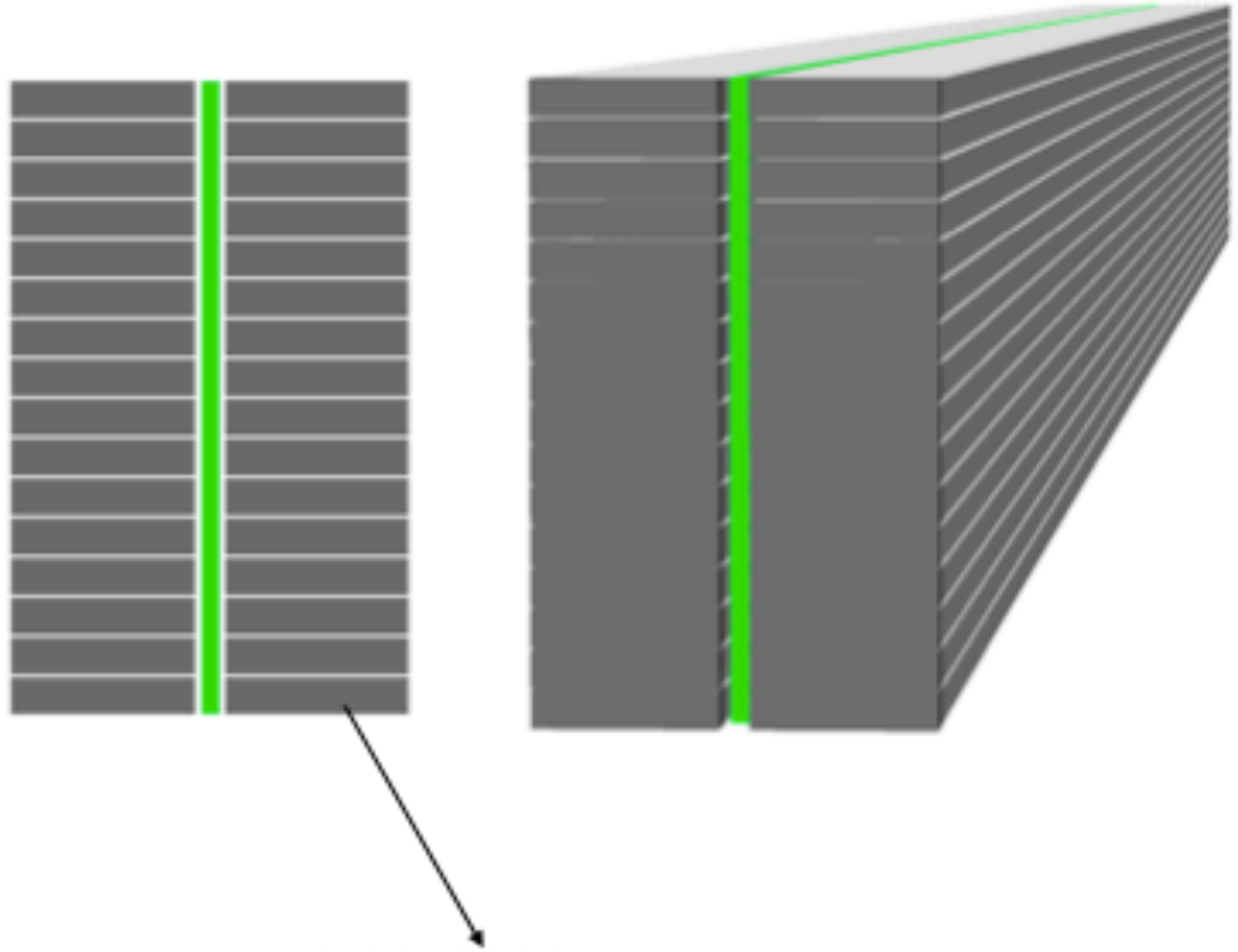
Mini-bar Configuration of J-PET detector



6x6x2000 mm
0.5 mm Gap between bars

Standard Configuration of J-PET detector



6x30x2000 mm

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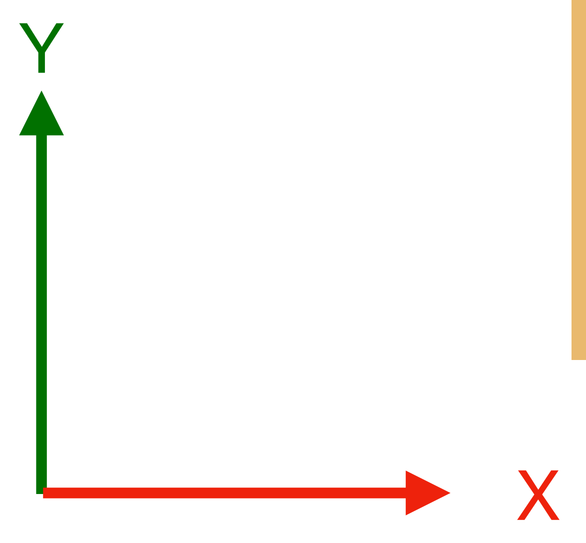
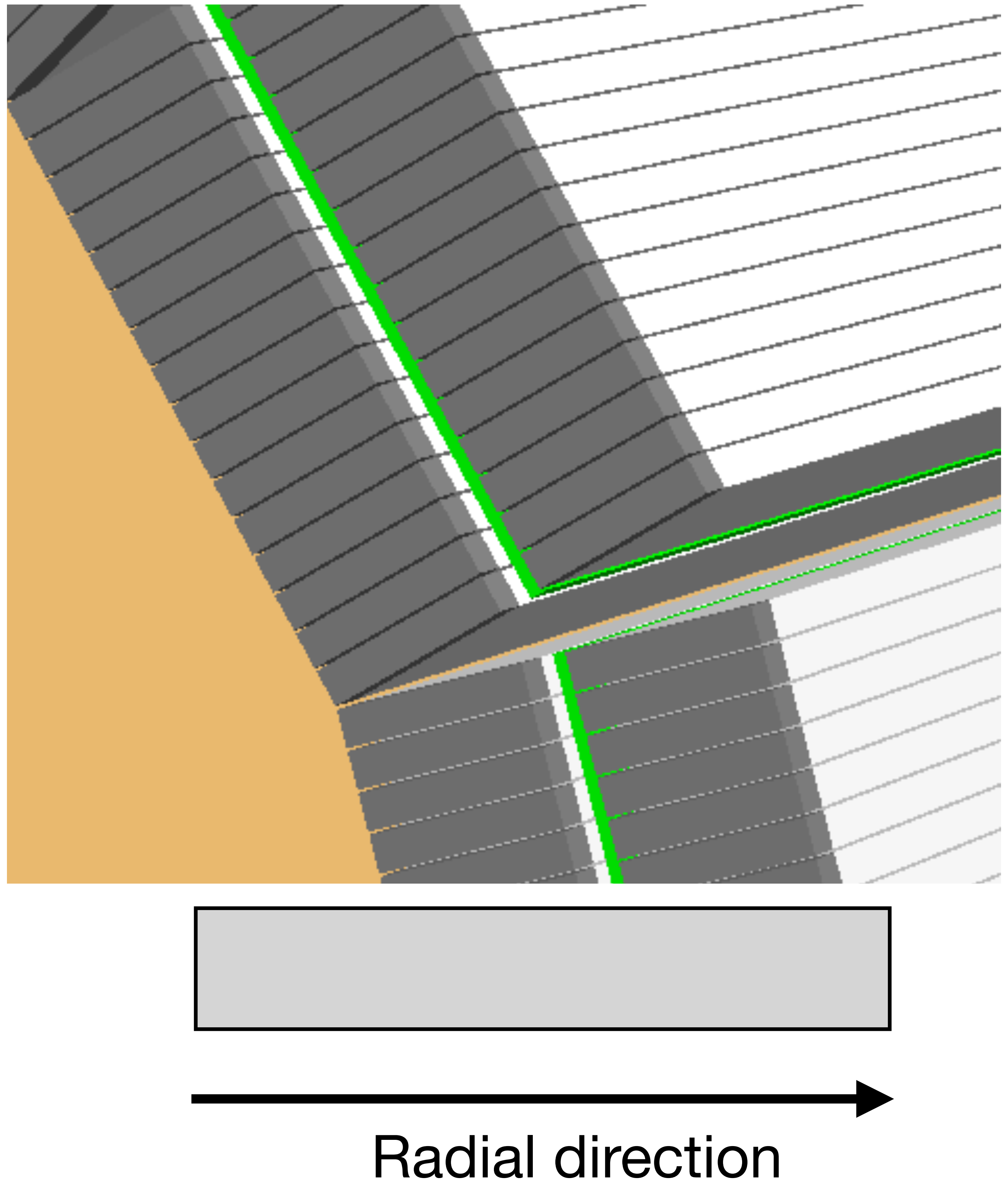
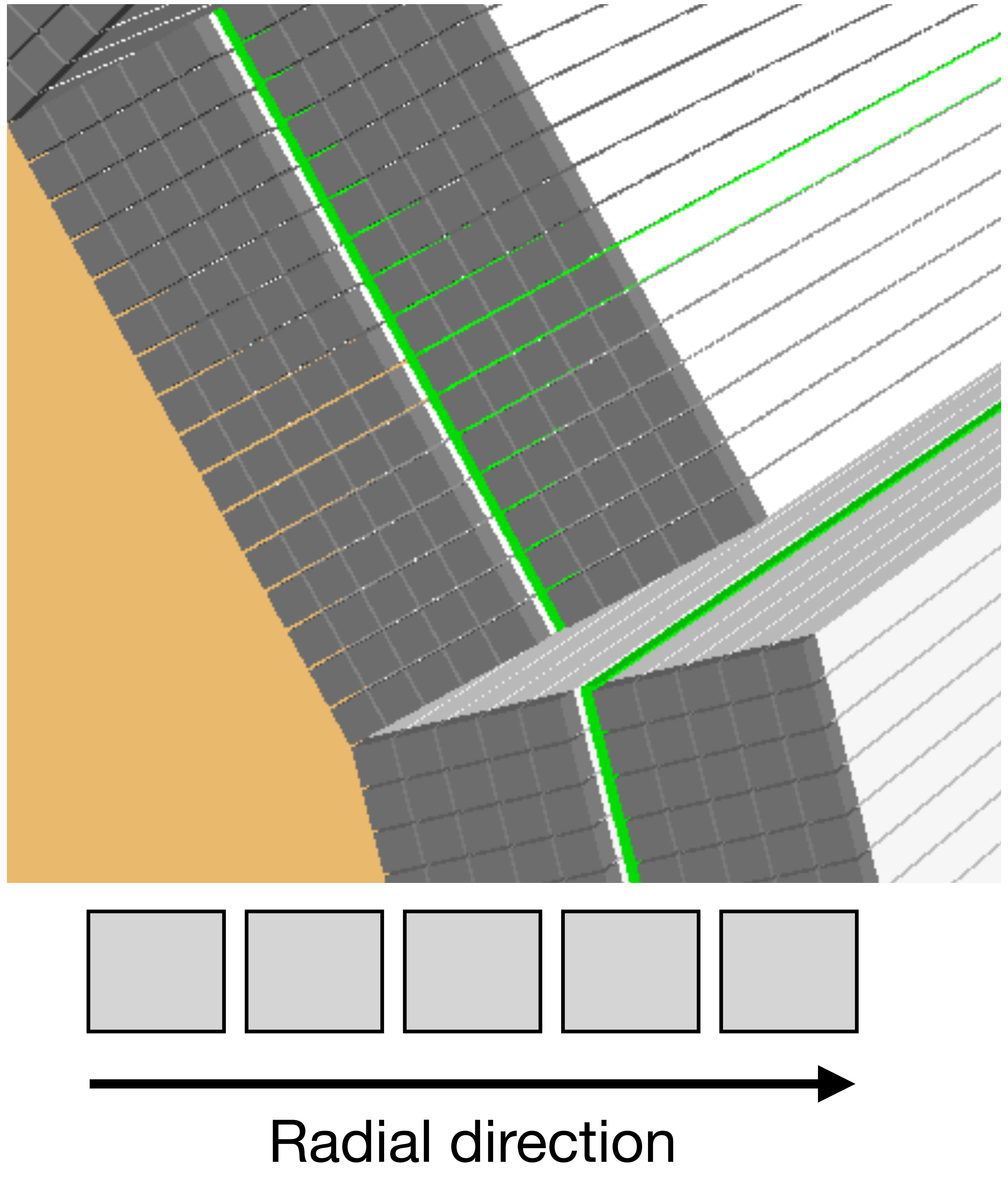
Mini-bar Configuration of J-PET detector





Standard Configuration of J-PET detector



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Mini-bar configuration in small animal Total-Body J-PET

Mini-bar configuration in small animal Total-Body J-PET

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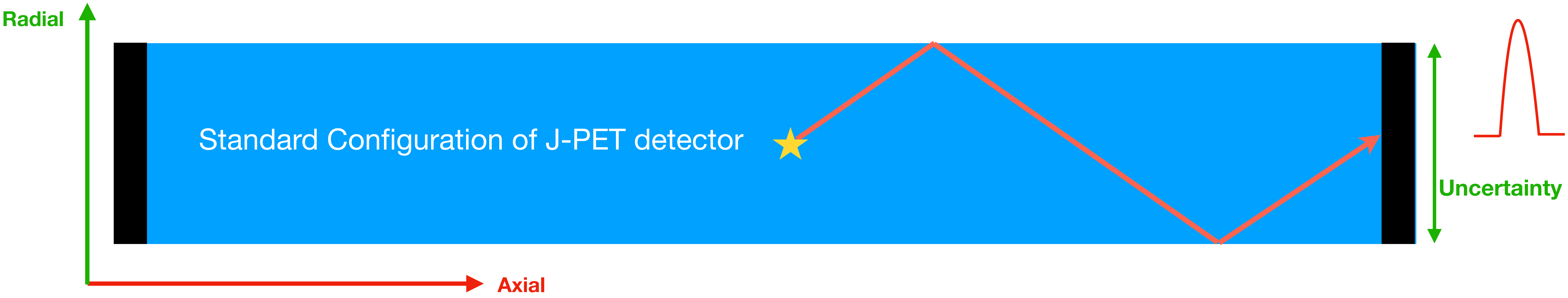
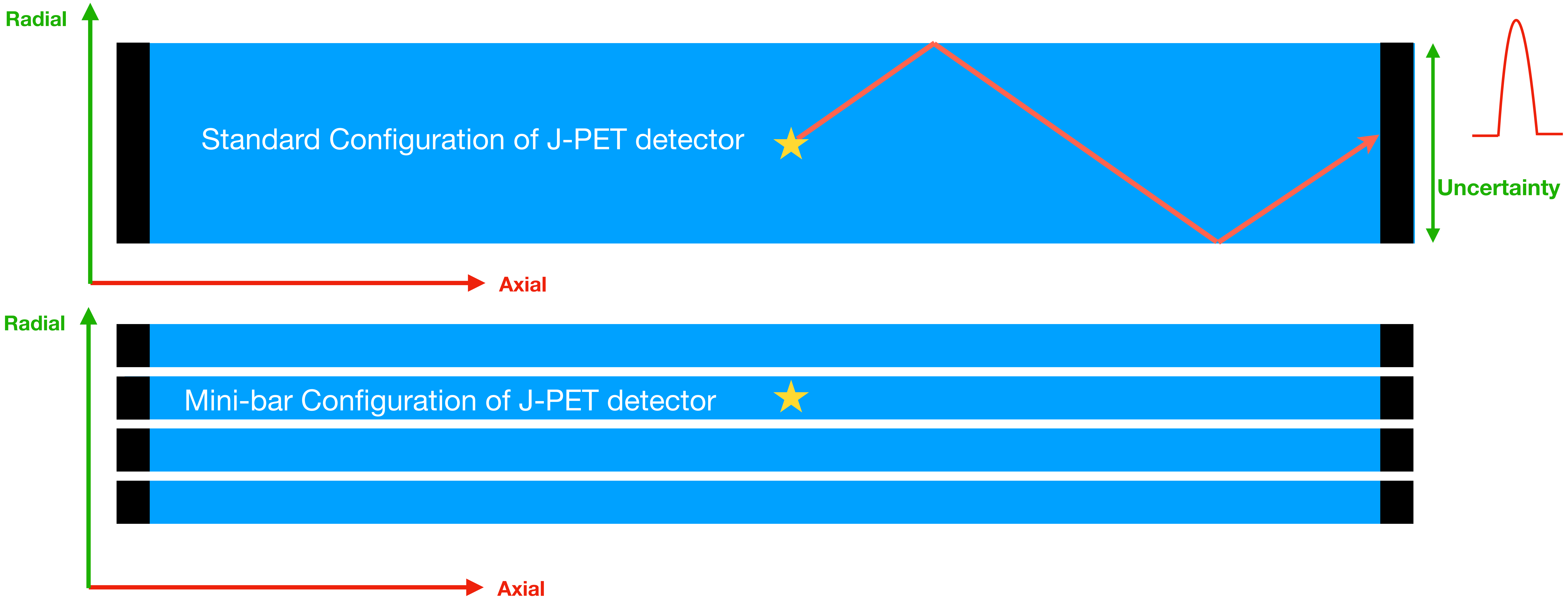
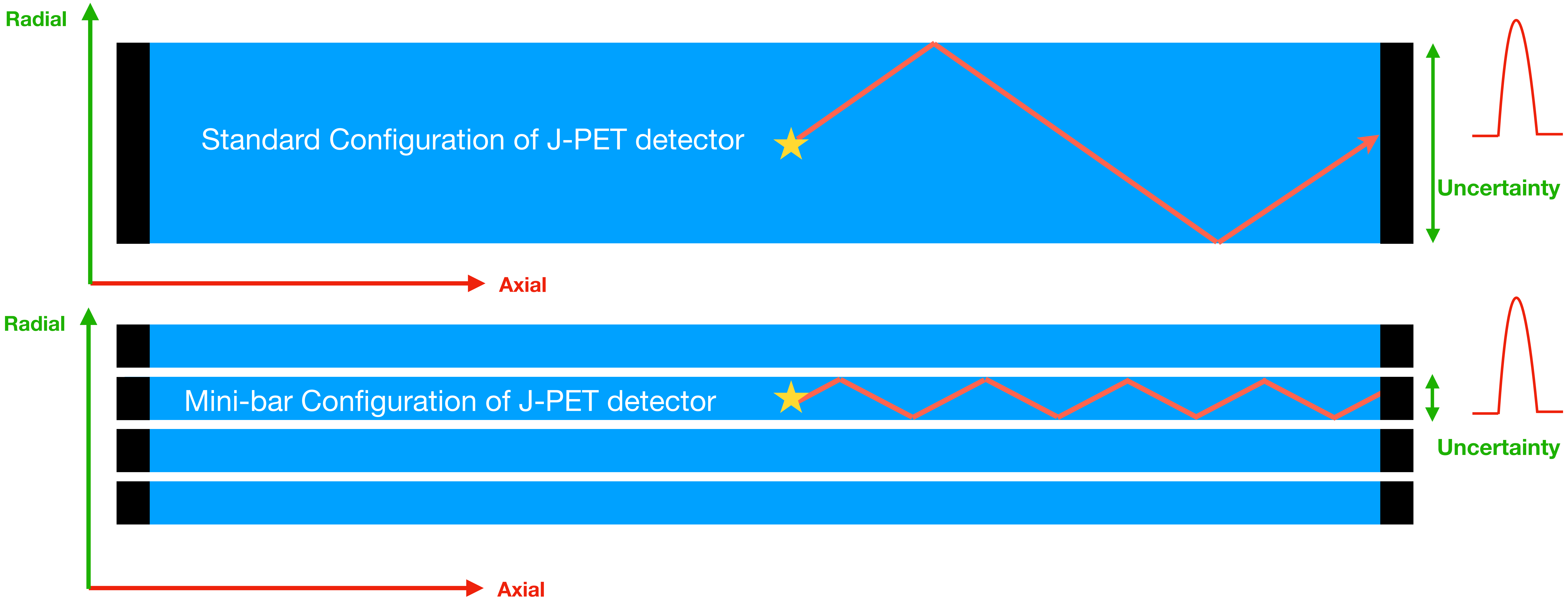


Mini-bar configuration in small animal Total-Body J-PET



Mini-bar configuration in small animal Total-Body J-PET



Total-Body J-PET with mini-bar configuration

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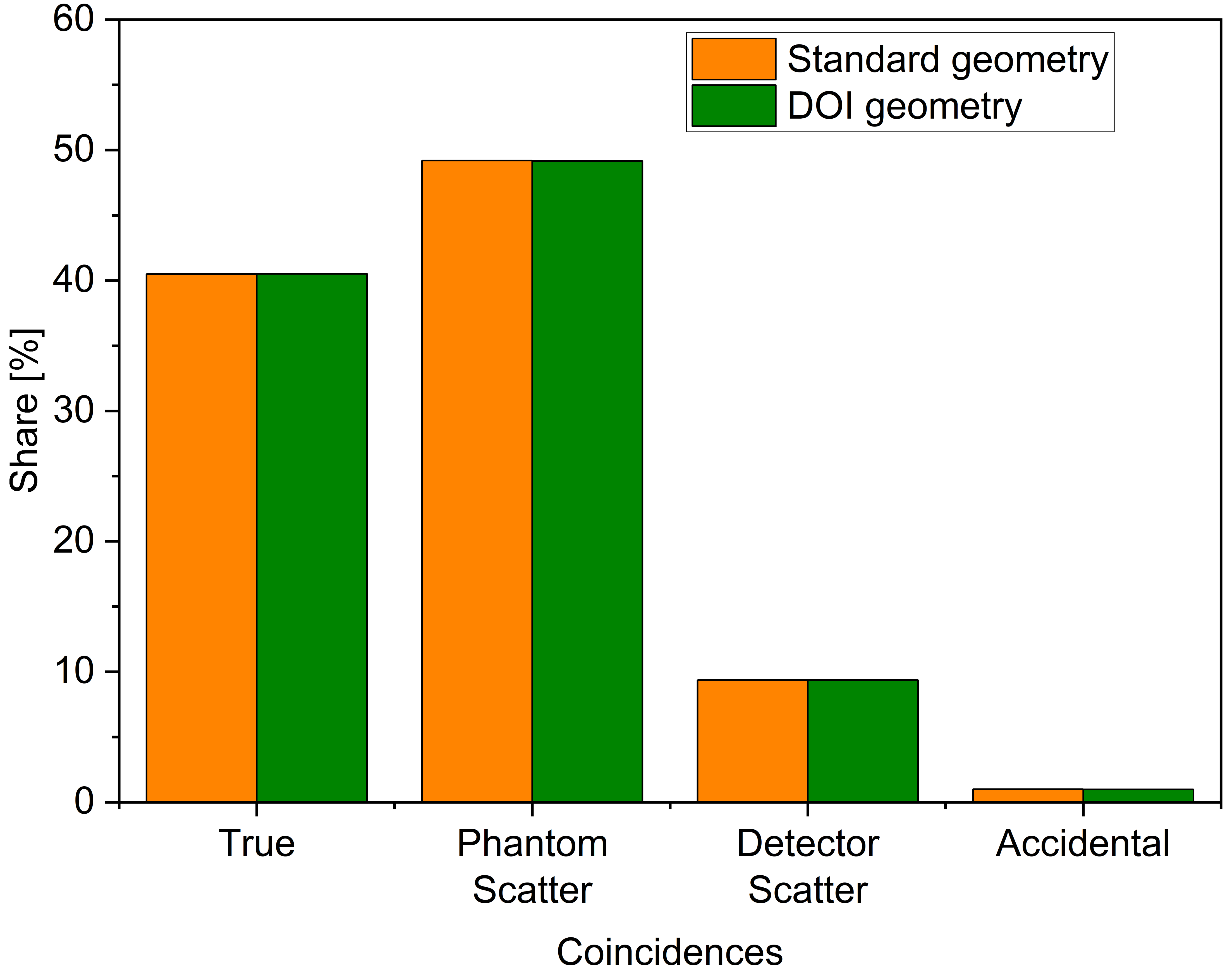
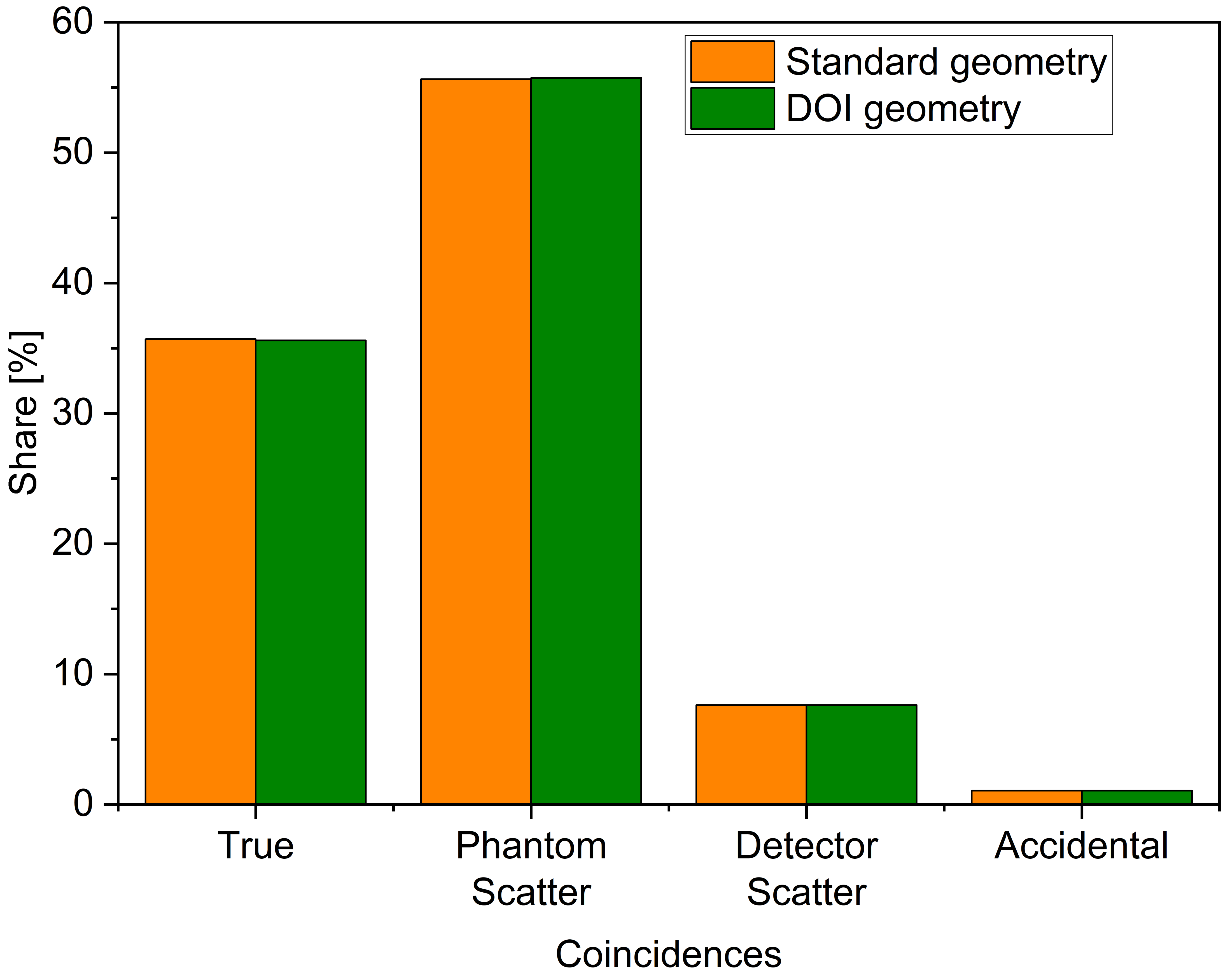
70 cm length of the phantoms and source



200 cm length of the phantoms and source



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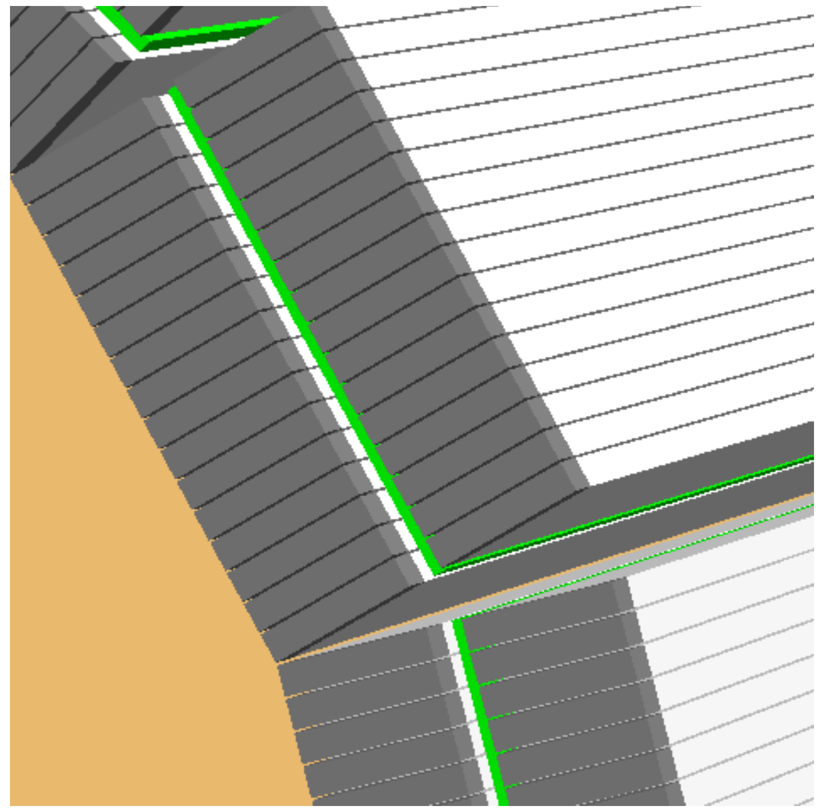
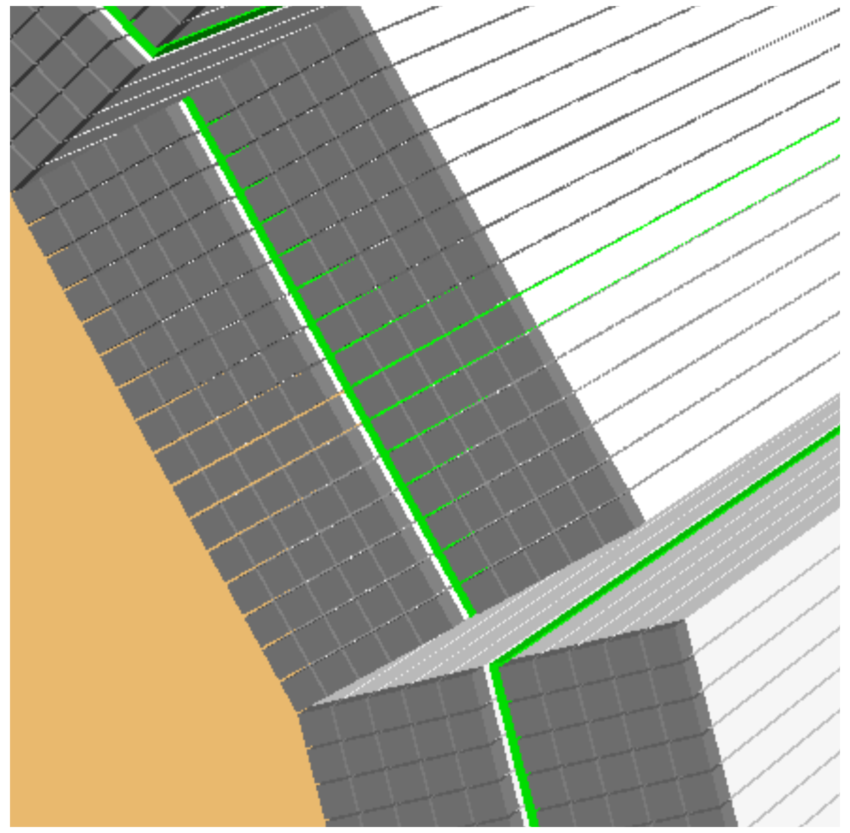
Total-Body J-PET with mini-bar configuration



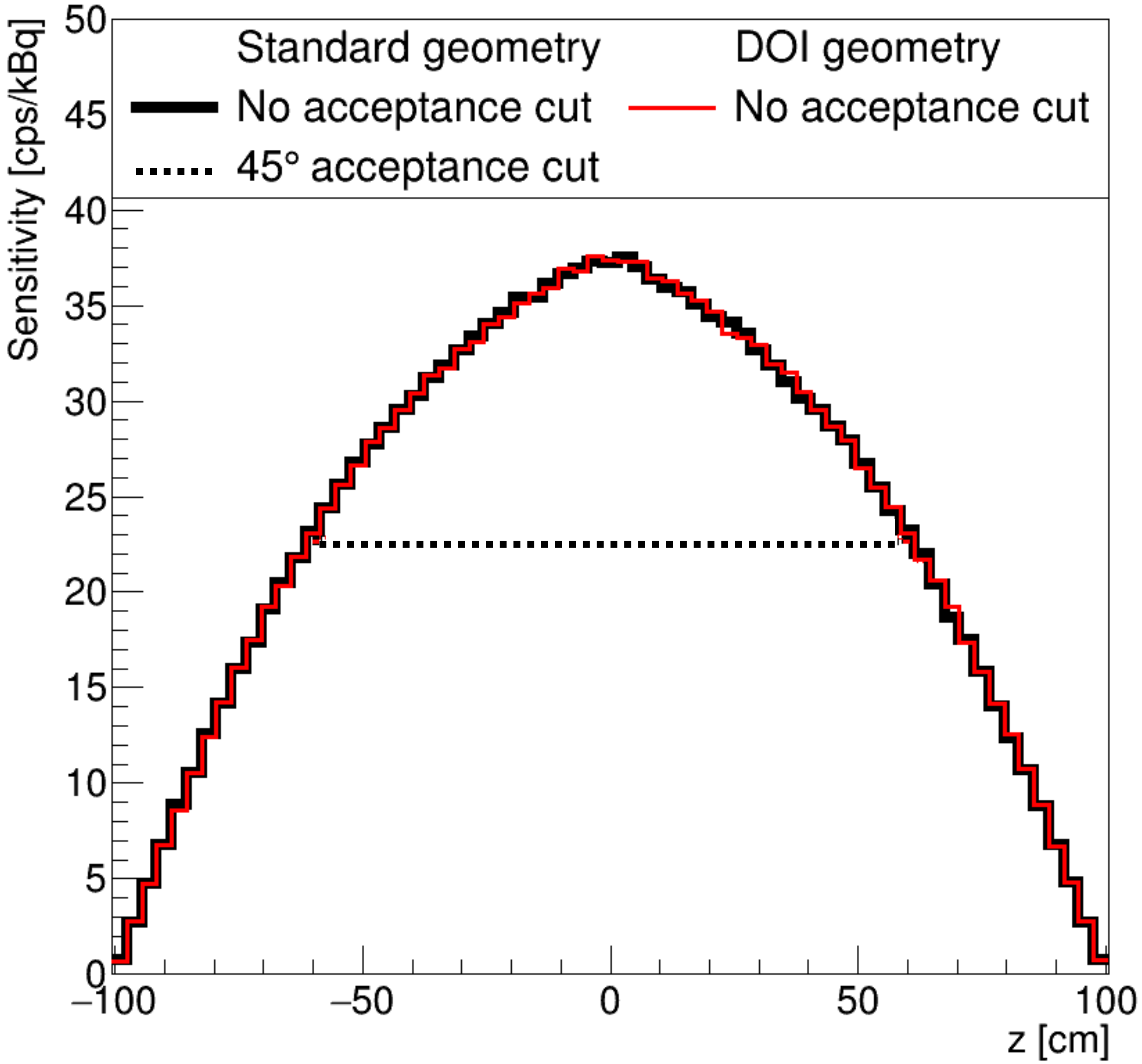
Standard Geometry

Radial direction



DOI Geometry

Radial direction



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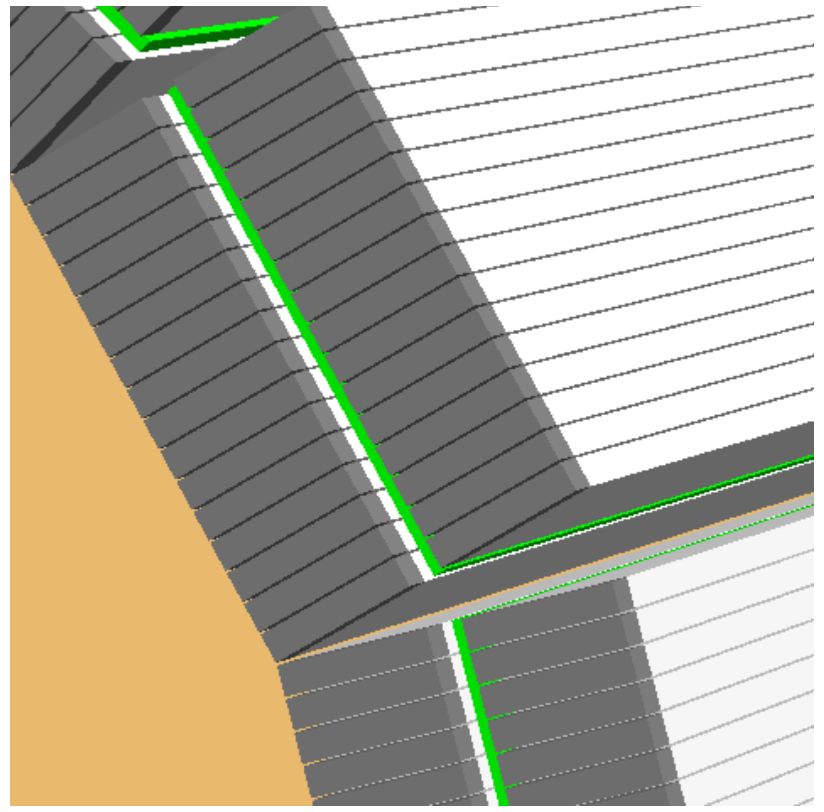
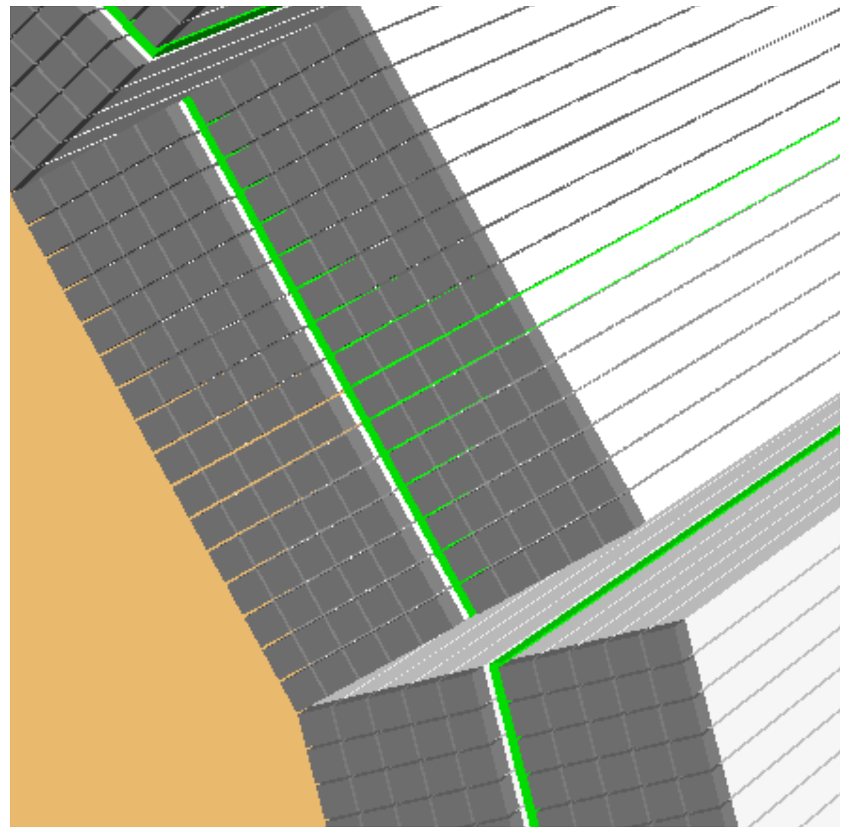


Standard Geometry

Radial direction



DOI Geometry

Radial direction

Method	70 cm source		200 cm source	
	Standard geometry	DOI geometry	Standard geometry	DOI geometry
SSRB	36.711 ± 0.034 [%]	36.622 ± 0.034 [%]	35.896 ± 0.027 [%]	35.841 ± 0.027 [%]
True MC (Ph. Scat. + Det. Scat.)	59.117 ± 0.053 [%]	59.010 ± 0.053 [%]	63.930 ± 0.062 [%]	64.026 ± 0.062 [%]
True MC (Ph. Scat)	54.855 ± 0.056 [%]	54.832 ± 0.056 [%]	60.917 ± 0.066 [%]	61.021 ± 0.066 [%]

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Total-Body J-PET with mini-bar configuration

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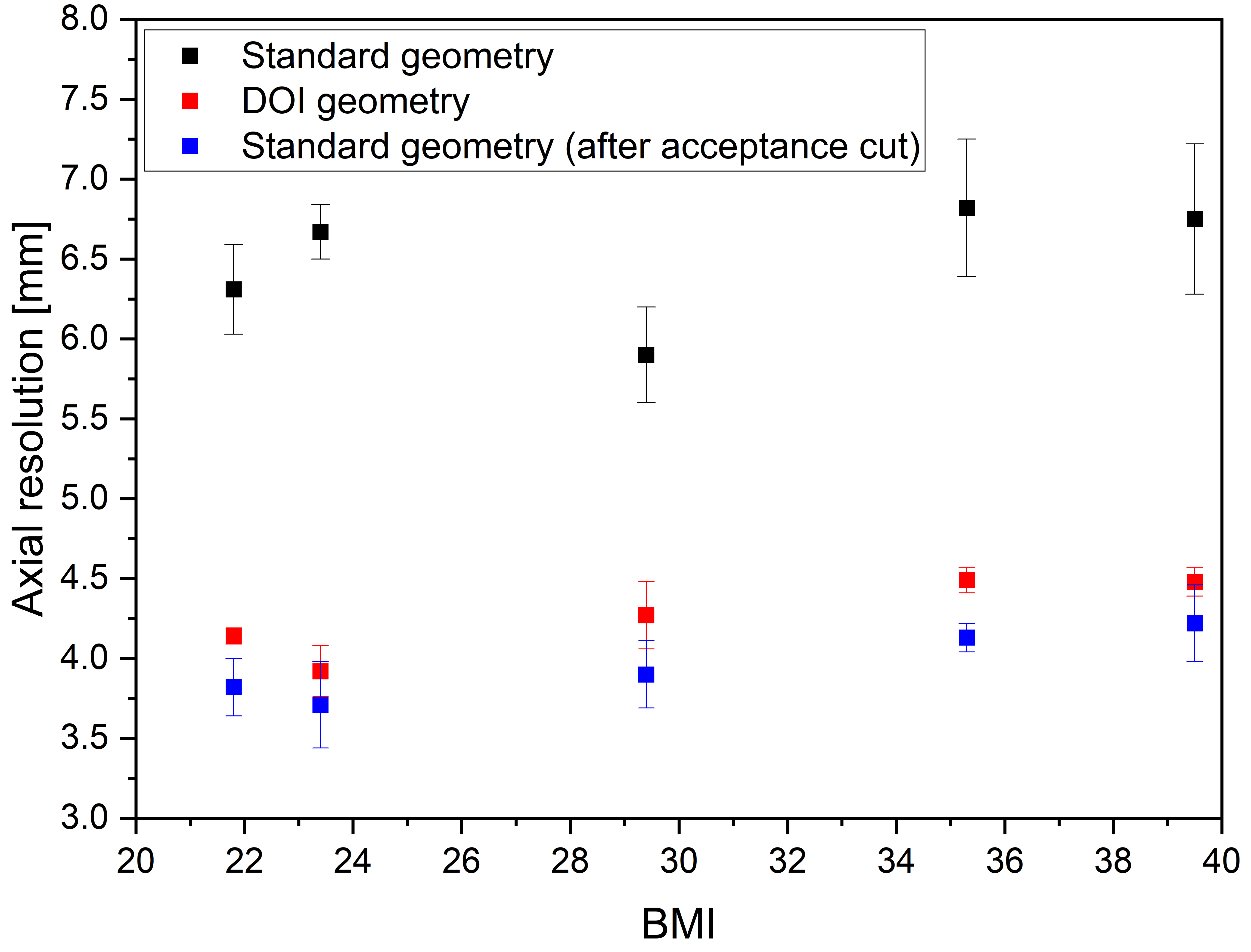

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Applying of acceptance angle cut

Acceptance angle is a maximum azimuthal angle for which the line of responses are still taken into image reconstruction

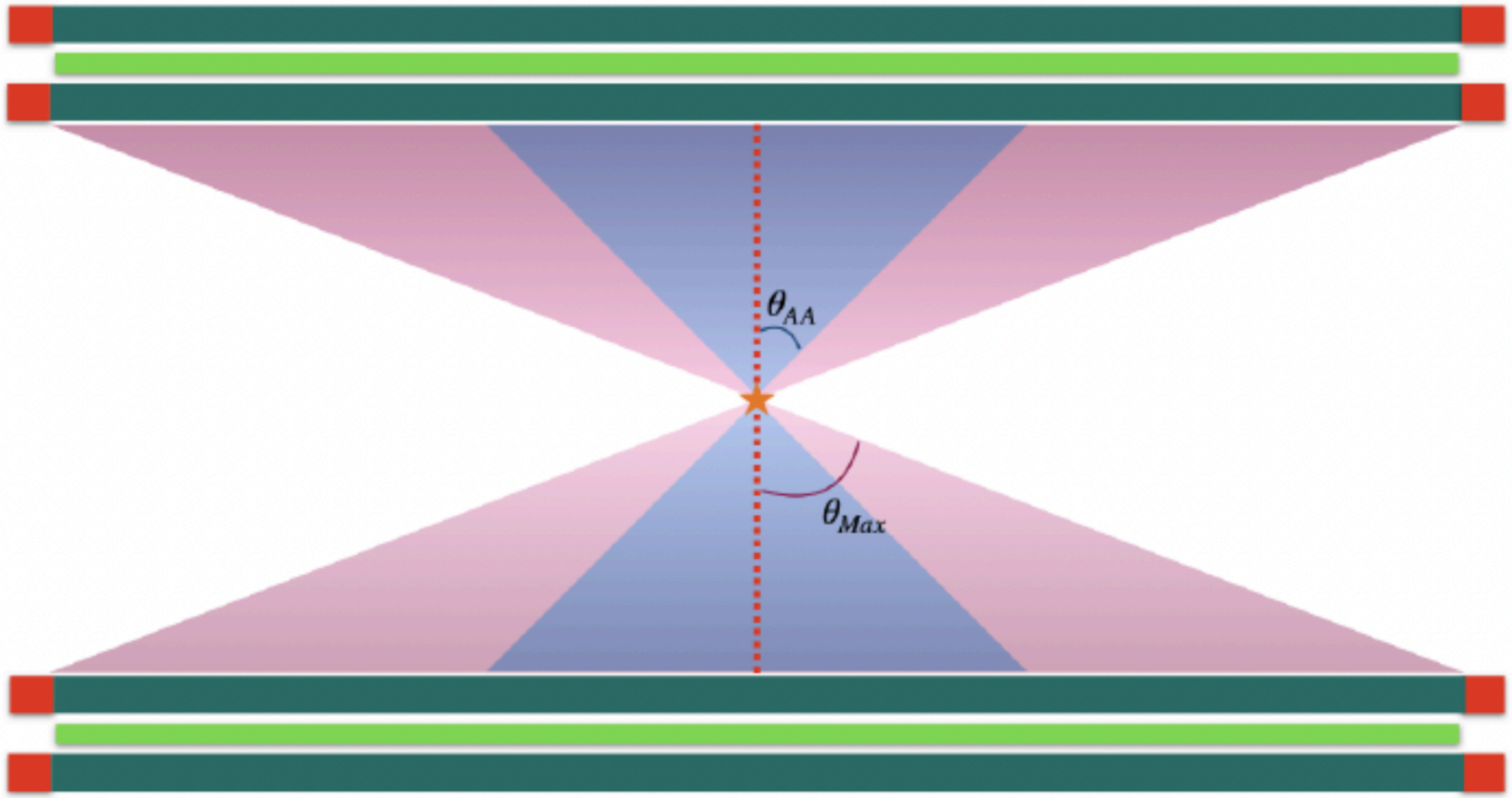

Fig 6: the red area represent the angle of all possible LOR as θ_{max} and blue area shows only those coincidences which has smaller or equal to the acceptance angle (θ_{AA})

Fig. 8: The

Reference: M. Dadgar, S. Parzych and F. Tayefi, "A Simulation Study to Estimate Optimum LOR Angular Acceptance for the Image Reconstruction with the Total Body J-PET," in MIUAOxford, UK, 2021, pp. 189–200.

Sensitivity Vs. Acceptance angle cut

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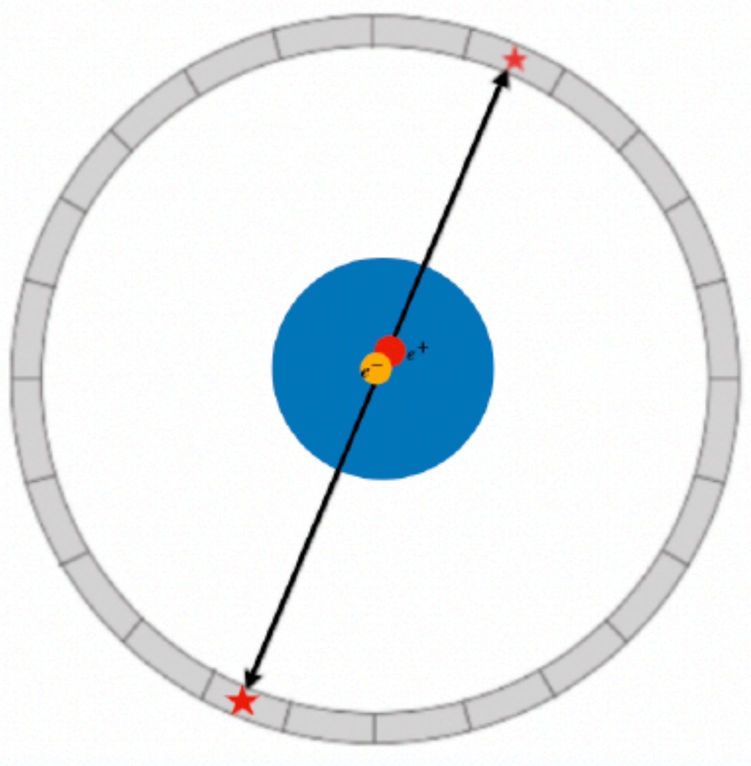
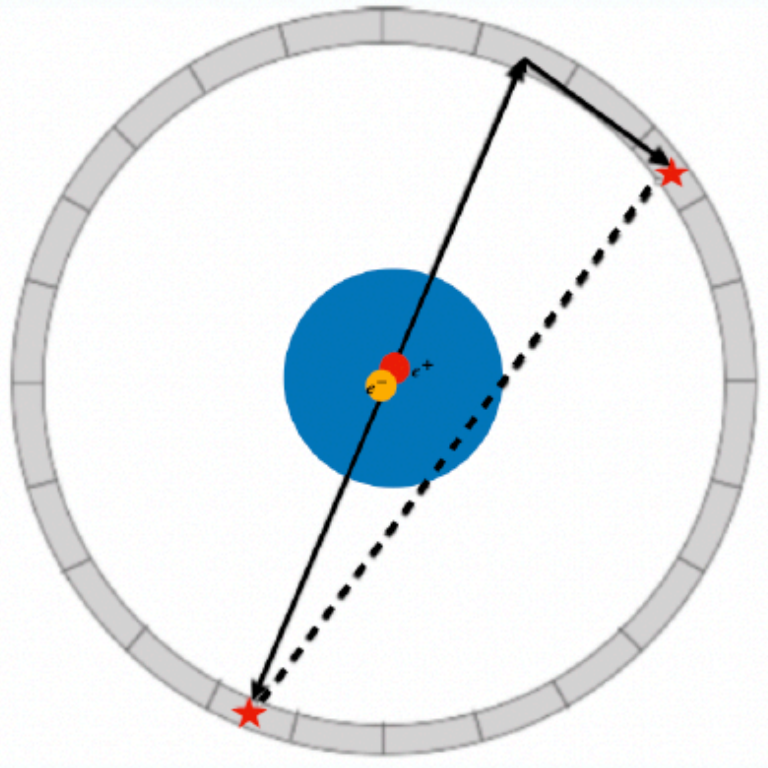
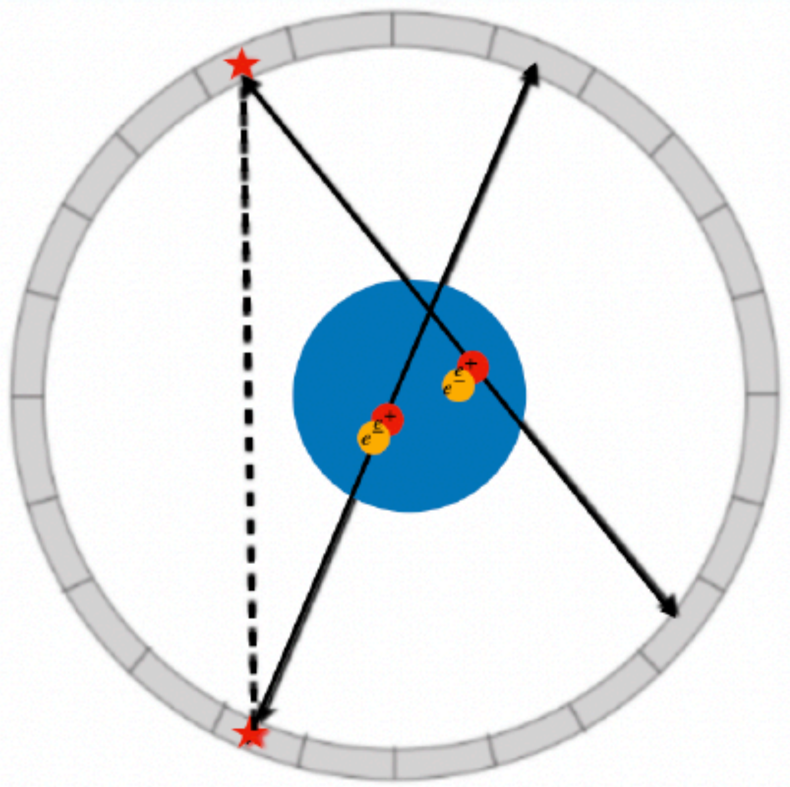


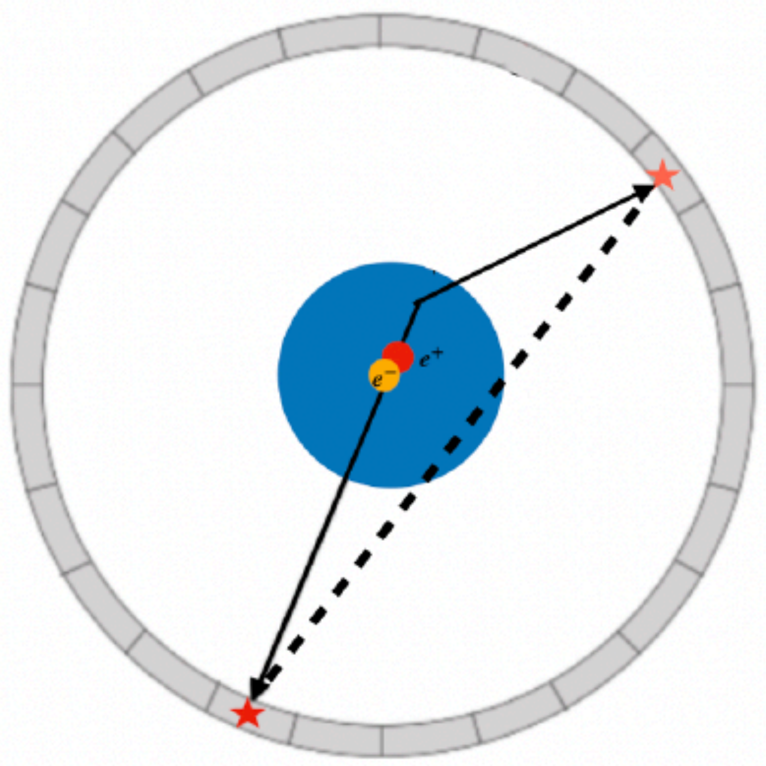
True Coincidences



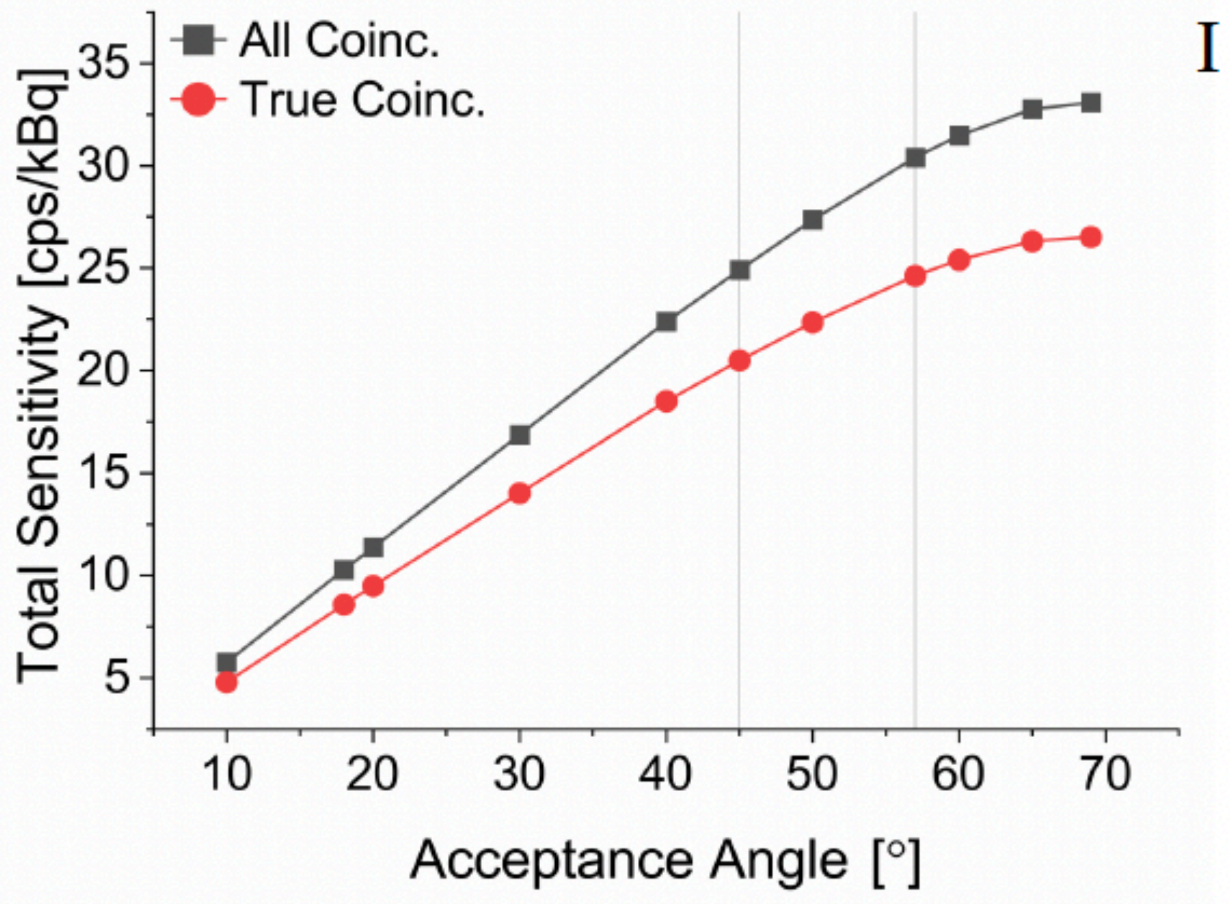
Detector scatter

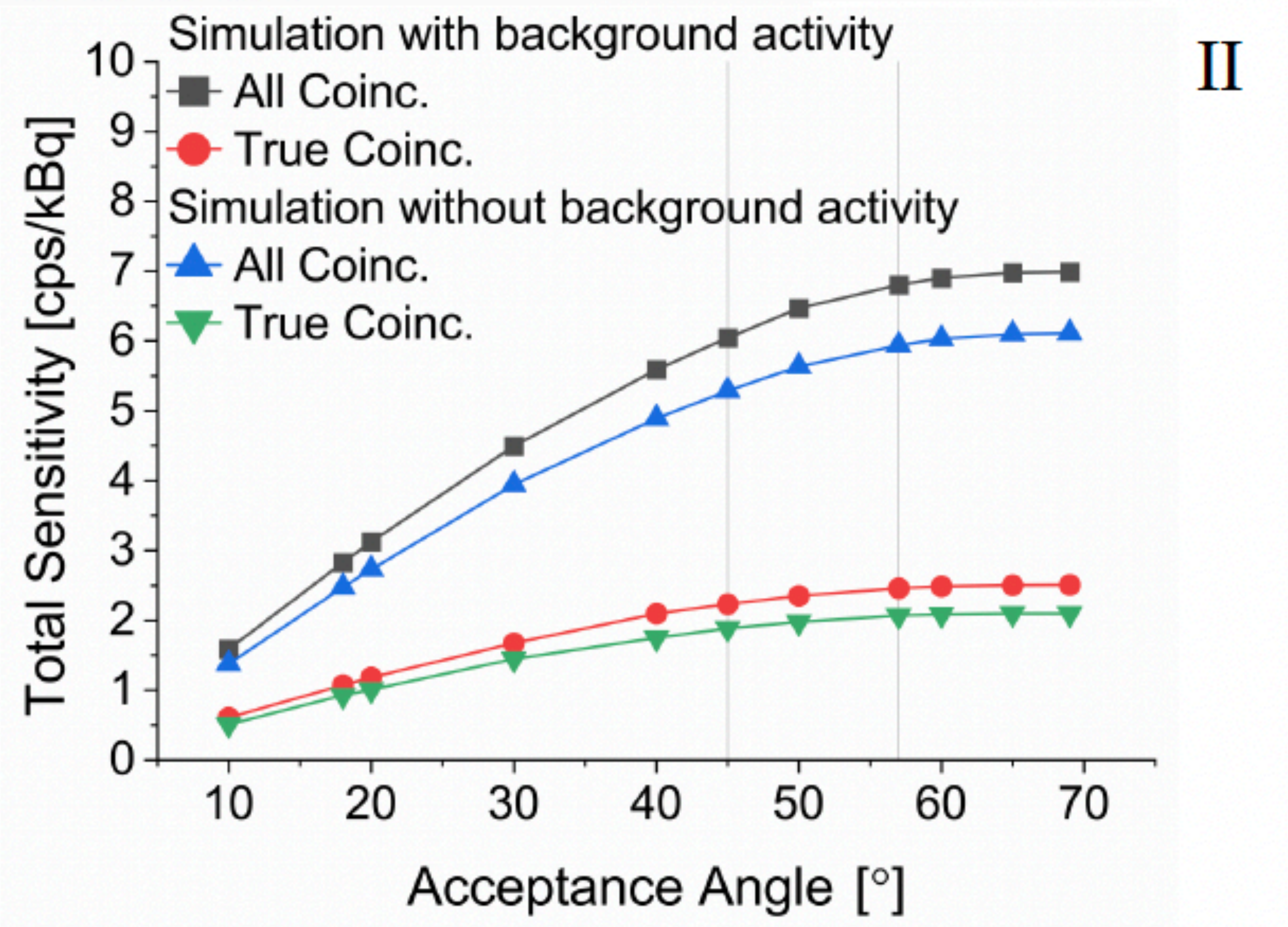


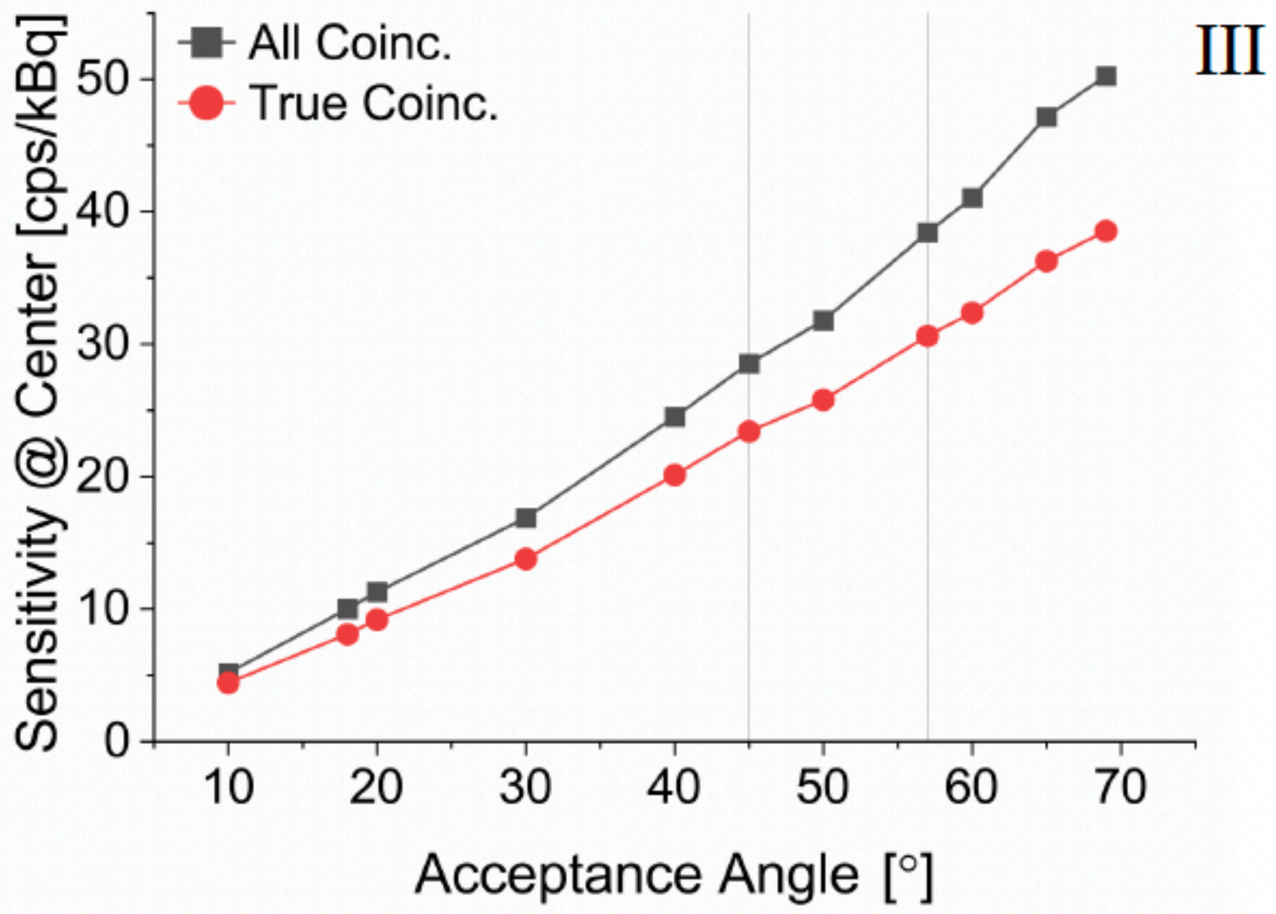
Random coincidences

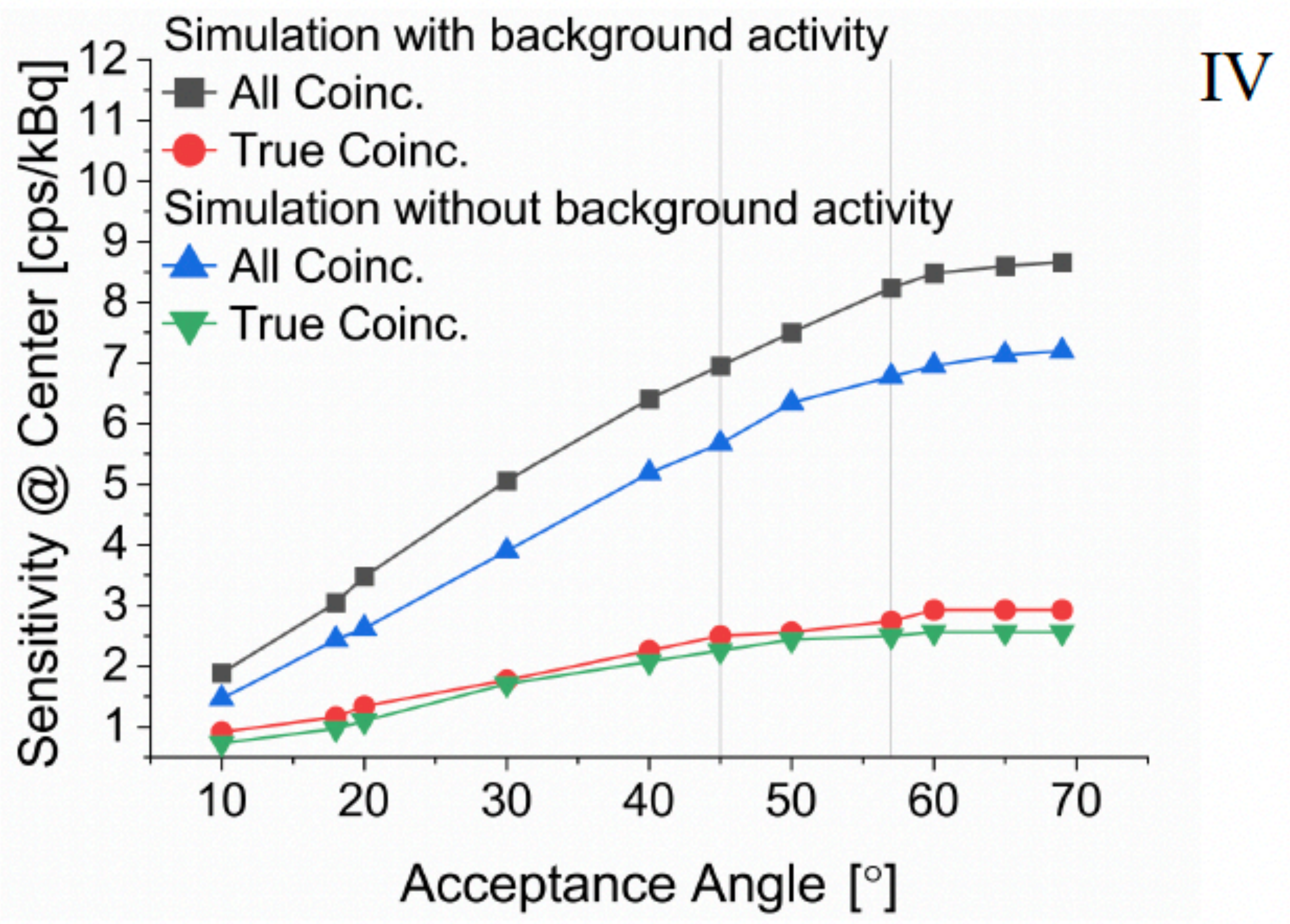


Phantom Scatter









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Spatial resolution Vs. Acceptance angle

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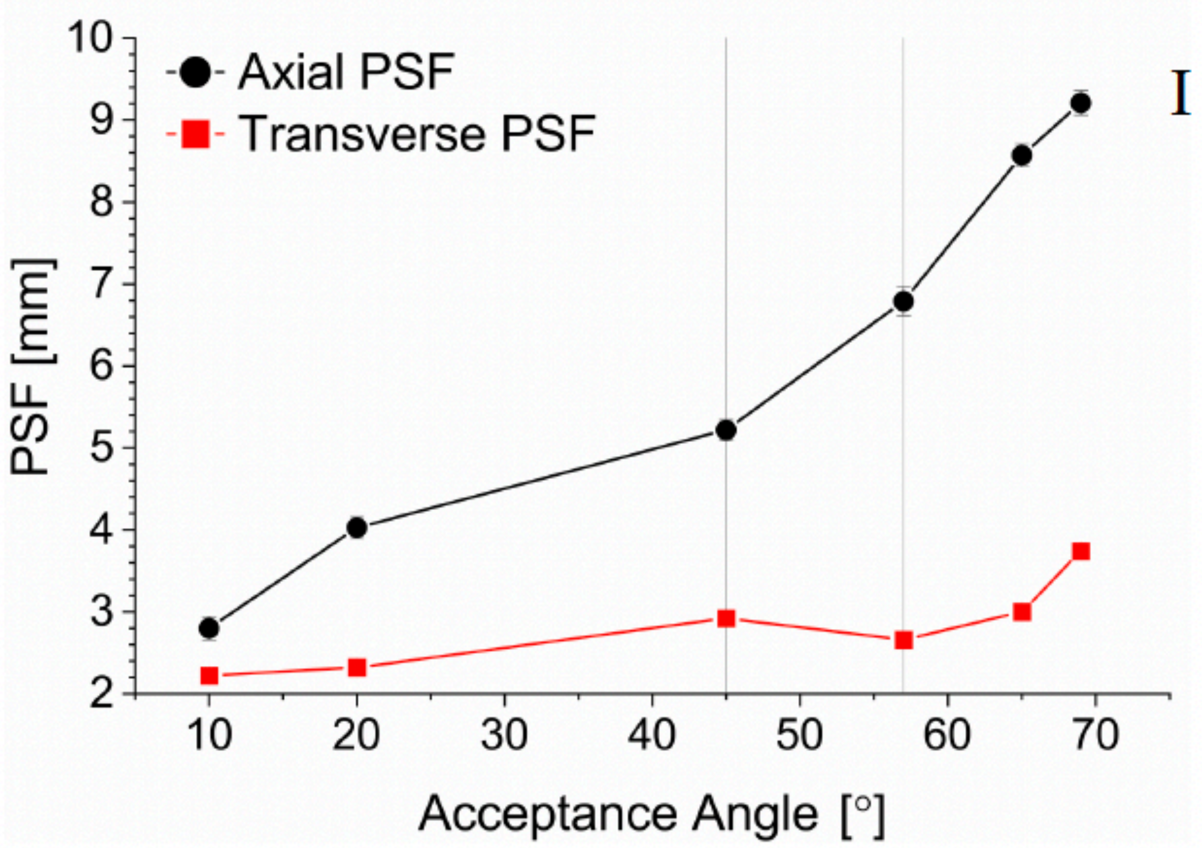
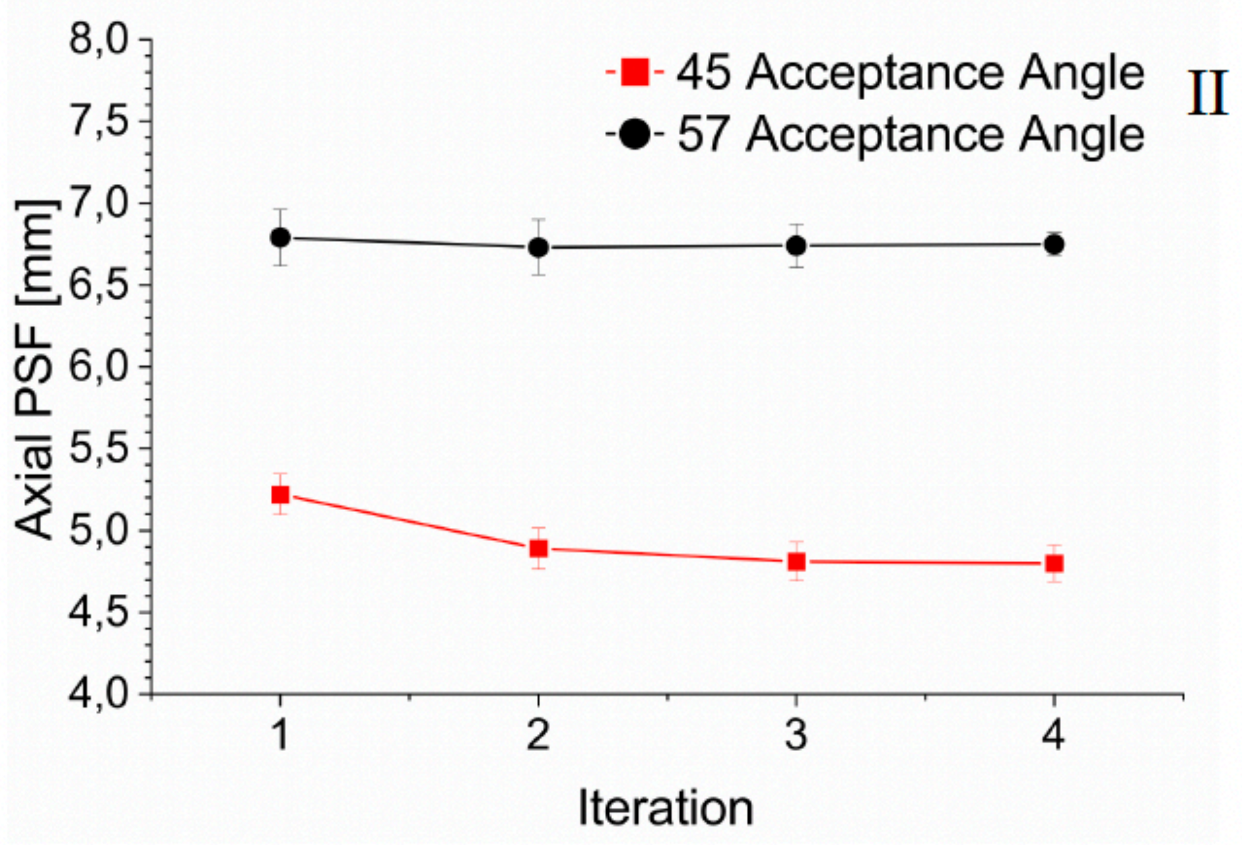
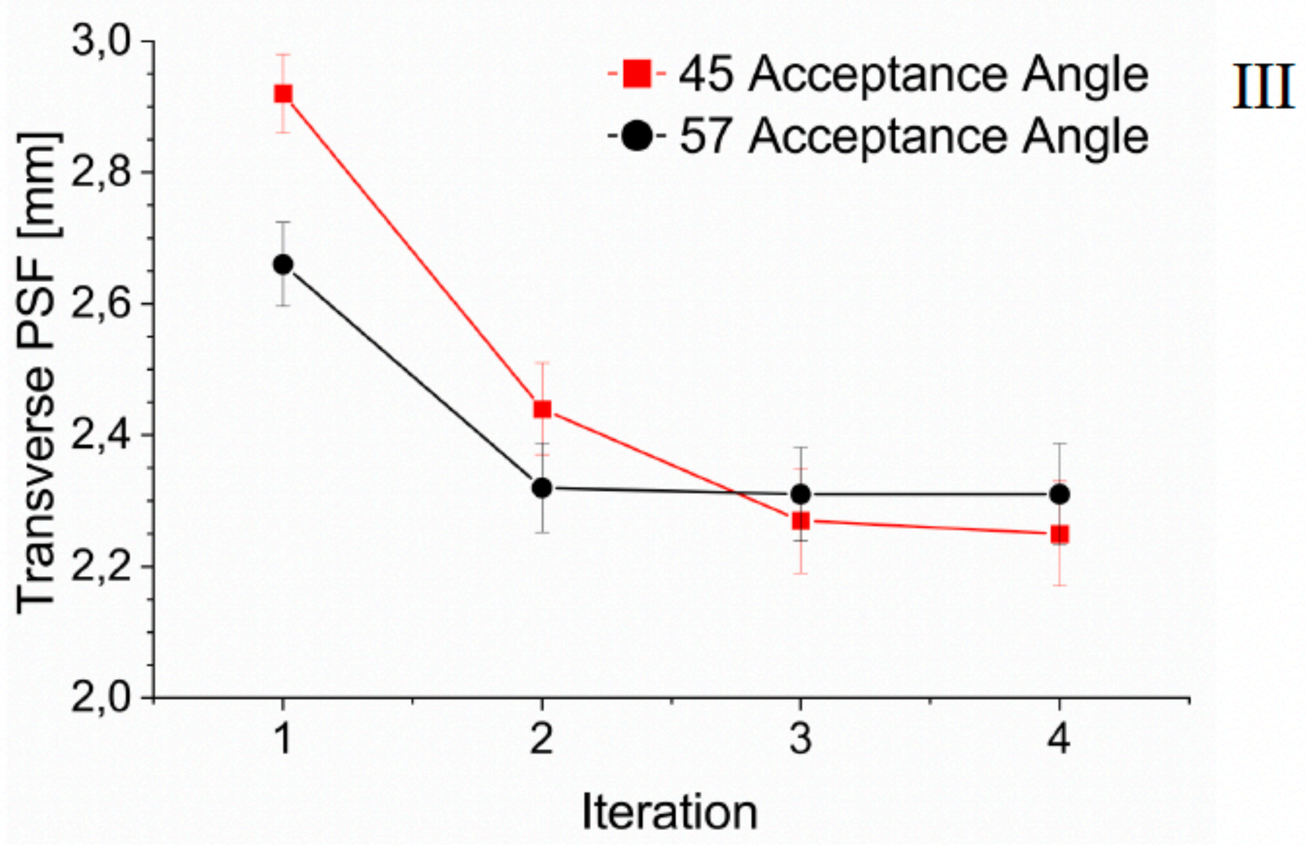
Spatial resolution

Spatial resolution is one of the most important characteristics of PET scanners, which determines the possible size of detectable lesions. One of the classic approaches to investigate the quality of spatial resolution utilizes a Point Spread Function (PSF). PSF is defined as a full width at half maximum of the either transverse or axial one-dimensional projection of the slice of reconstructed image, which contains the radioactive source.







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Conclusion

- Parallax error has an undeniable destructive influence on axial resolution in Total-Body PET scanners
- One of the approach is preselecting the coincidences by applying acceptance angle cut to remove contribution of oblique coincidences in image reconstruction.
- Acceptance angle improves axial resolution by the cost of reduction in the sensitivity.
- Minibar configuration, improves axial resolutions without any angle wise cut over the coincidences.

Reference: M. Dadgar, S. Parzych and F. Tayefi, "A Simulation Study to Estimate Optimum LOR Angular Acceptance for the Image Reconstruction with the Total Body J-PET," in MIUAOxford, UK, 2021, pp. 189–200.

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Question/ comments?