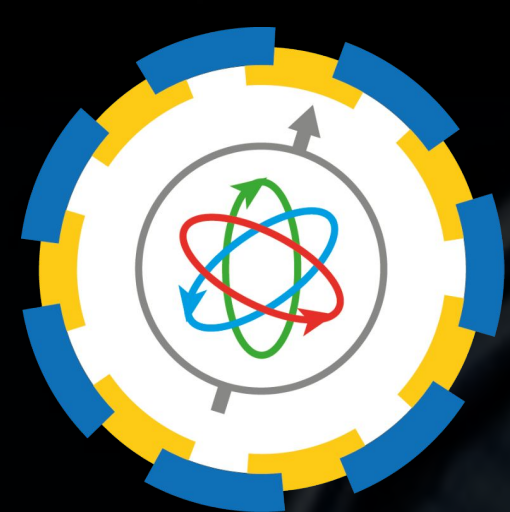




J-PET

Evaluation of the Performance of a Plastic Scintillator Based Brain PET Insert



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Abstract

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Positron Emission Tomography (PET) is an important imaging technique in modern medicine that can detect changes in tissue function before structural changes appear. The Jagiellonian Positron Emission Tomography (J-PET) collaboration is developing a novel PET technology based on plastic scintillators which can lower costs and make PET imaging more widely available [1]. The J-PET system is designed as a total-body scanner with a long axial field of view (over 250 cm). This allows for faster scans, lower radiation doses, and the ability to image the entire body at once [2]. In addition, a brain PET insert based on plastic scintillators is being developed to improve brain imaging when used together with the full system.

To evaluate the performance of the scanner, Monte Carlo simulations were performed using the GATE platform [3]. The simulations were carried out according to standard NEMA protocols, including sensitivity, scatter fraction, and spatial resolution [4]. The results of the plastic scintillator-based brain PET insert will be presented, offering a comprehensive evaluation of its feasibility and performance for clinical and research applications.

Brain PET Geometry

No of adjacent rings	1
Inner radius [mm]	144.3
Outer radius [mm]	184.9
No of modules per ring	12
No of scintillator layers per modules	2
No of scintillators per layer	16
Scintillator (axial) length [mm]	330
Scintillator cross section [mm]	18 × 4
No of WLS layers per module	1
No of WLS per layer	75
WLS dimensions [mm]	4 × 75 × 4
Gap between rings [mm]	-
Axial FOV [mm]	330

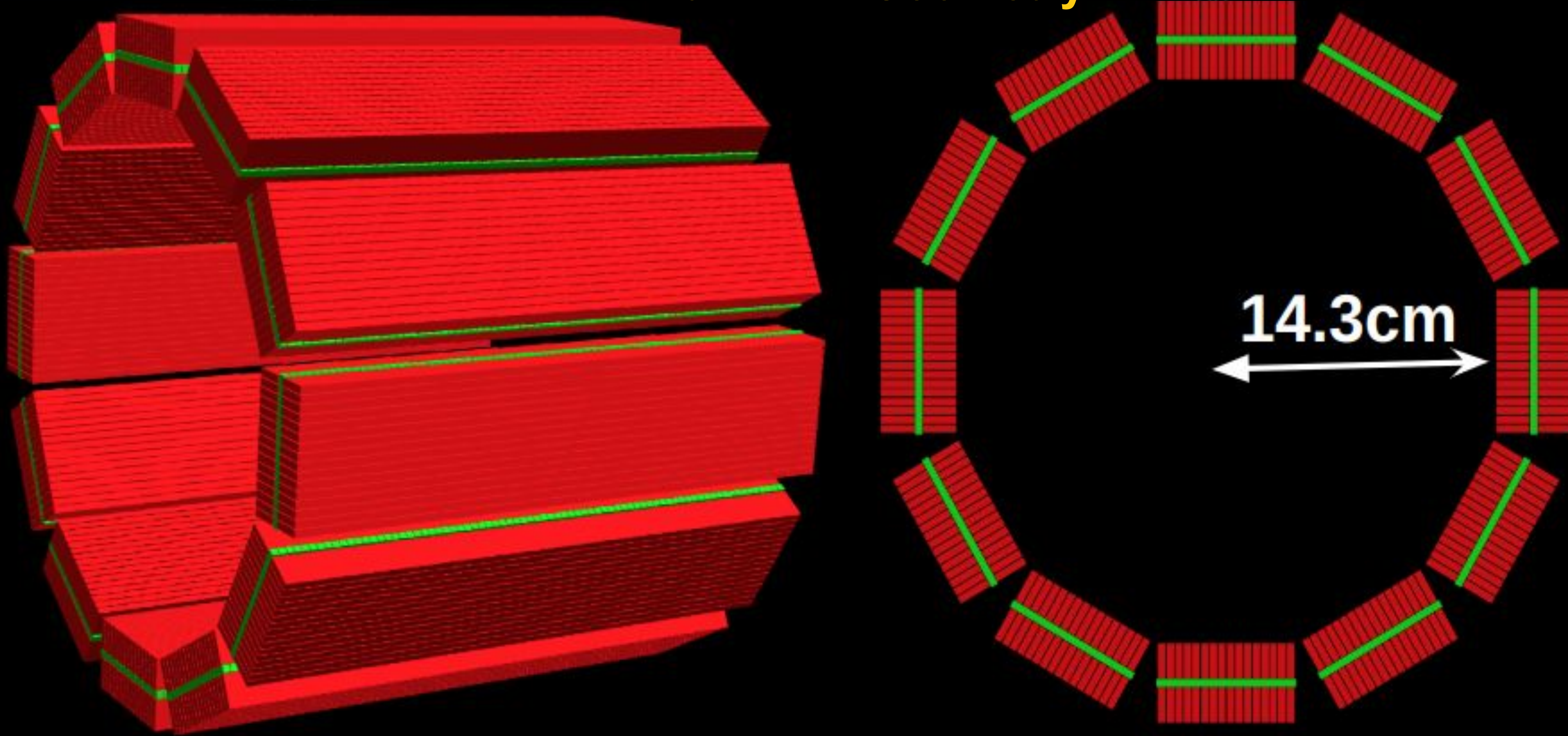
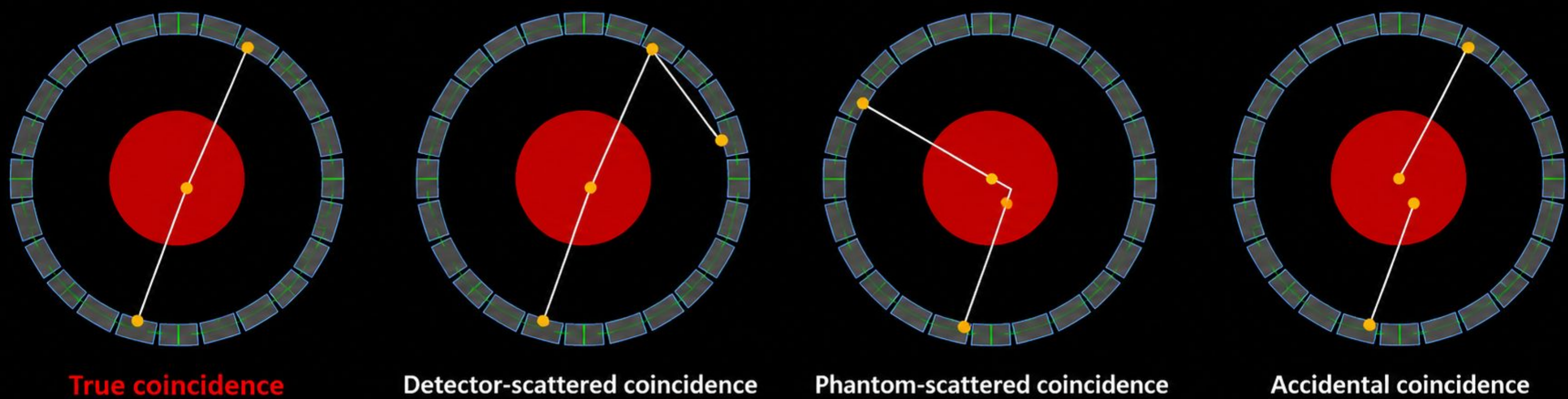
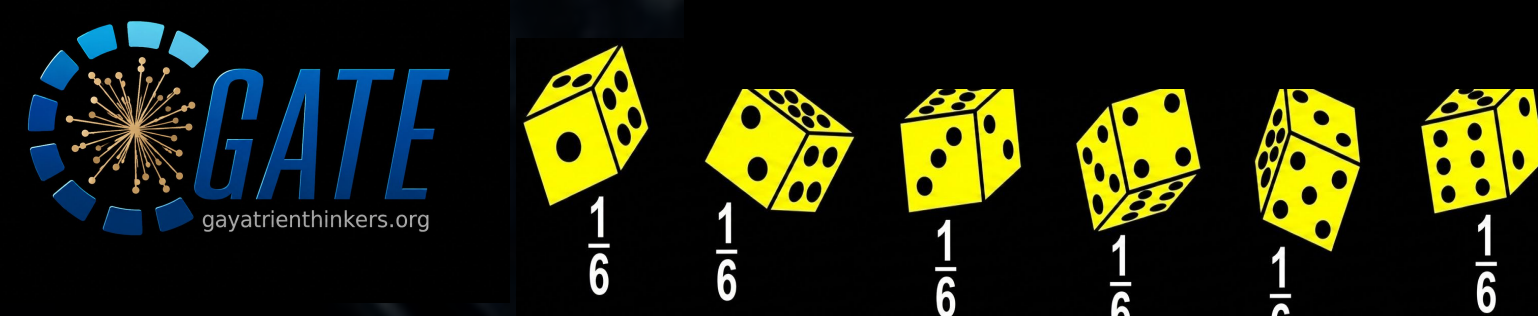


Fig. 2: Schematic view of the front view of a brain PET scanner, consisting of 12 modules.



Sensitivity

Sensitivity is expressed as the rate in counts per second that true coincidence events are detected for a given source strength.



GATE version	9.3
System Type	Brian PET
Energy window	> 200 keV
Time window	4 ns
Source type	Gamma back to back line source at the center
Source length	254 cm
Activity	1 MBq
Simulation time	10.000 s

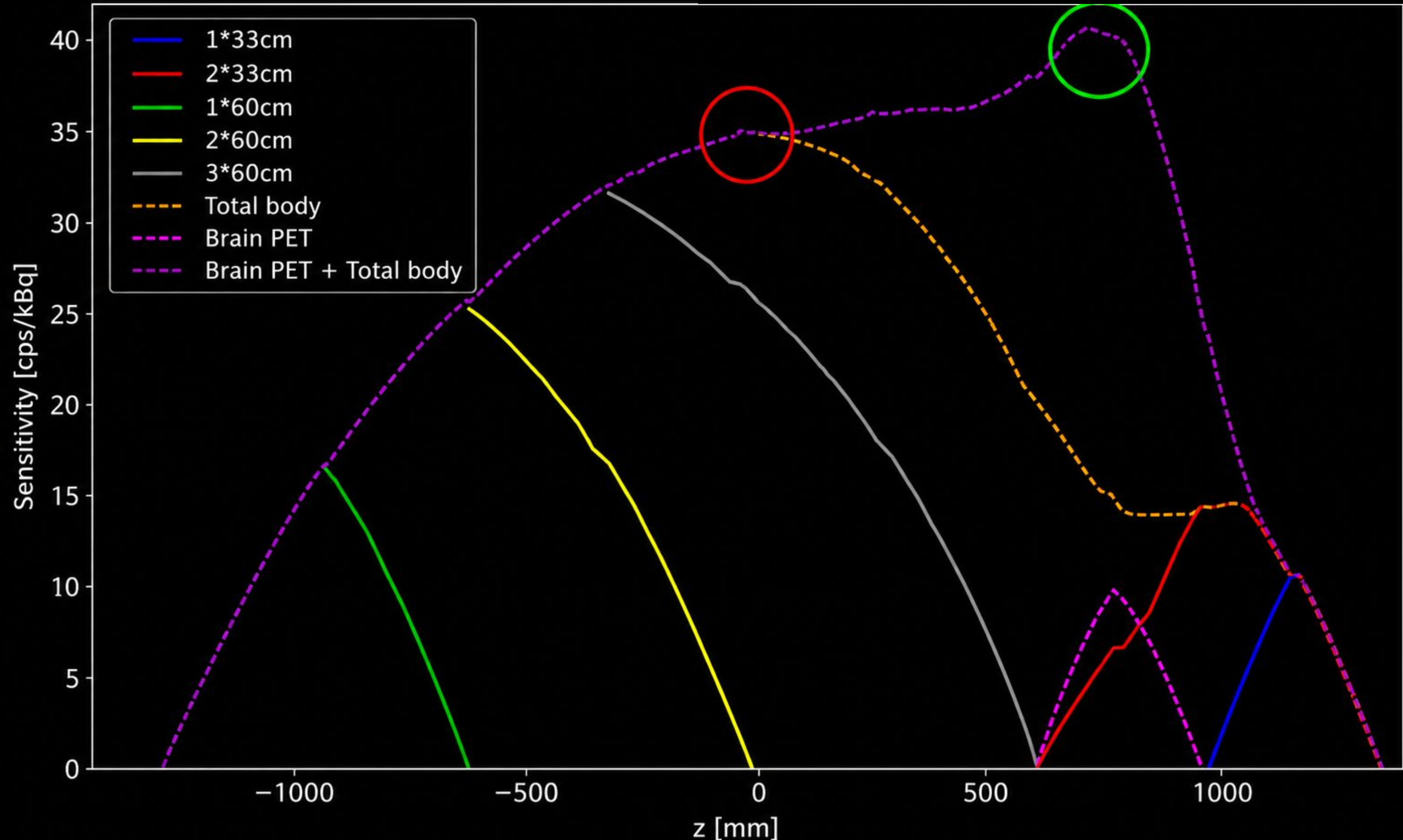


Fig. 1: Preliminary results of the axial sensitivity profile for the brain PET insert integrated into the total-body J-PET system, shown for individual rings and the full system. The X-axis represents the axial (Z) coordinate of the annihilation position, while the Y-axis shows the count rate in counts per second per kBq of source activity.

Simulation details

Phantom	Radius: 10cm
	Phantom length: 70 cm
	Source Type: Gamma back to back
Source	Activity: 1 MBq
	Source length: 70 cm
	Time window: 4ns
Digitizer	Energy window > 200 Kev
	Simulation time: 500 s

Scatter fraction

Scatter fraction is expressed as a ratio between the scattered coincidences and the sum of scattered and true coincidences.

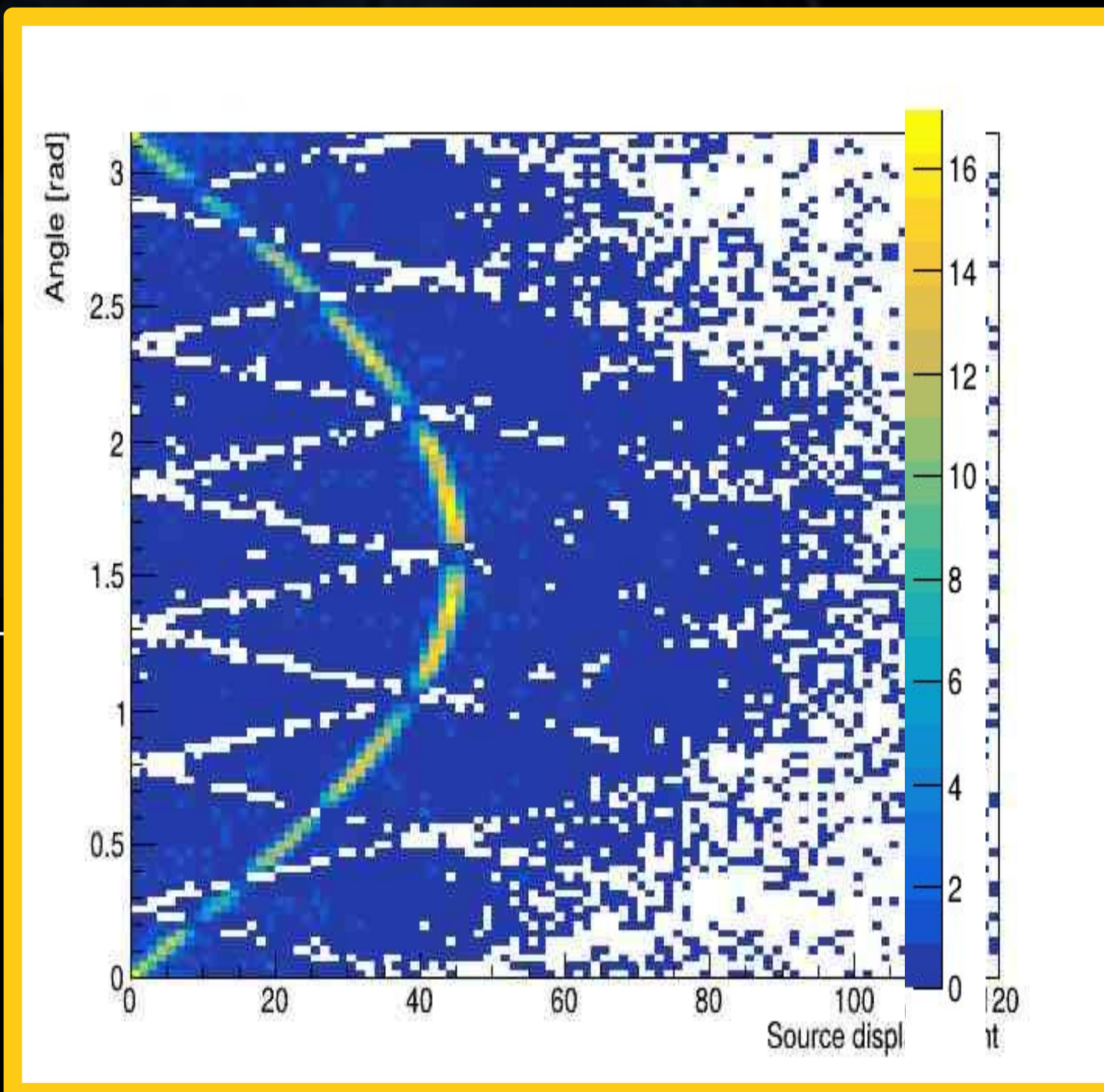


Fig. 3: Simulations result for the Brain J-PET scanner with the WLS layer; with the 70 cm long source and 1 MBq total activity. Sinogram for a whole scanner.

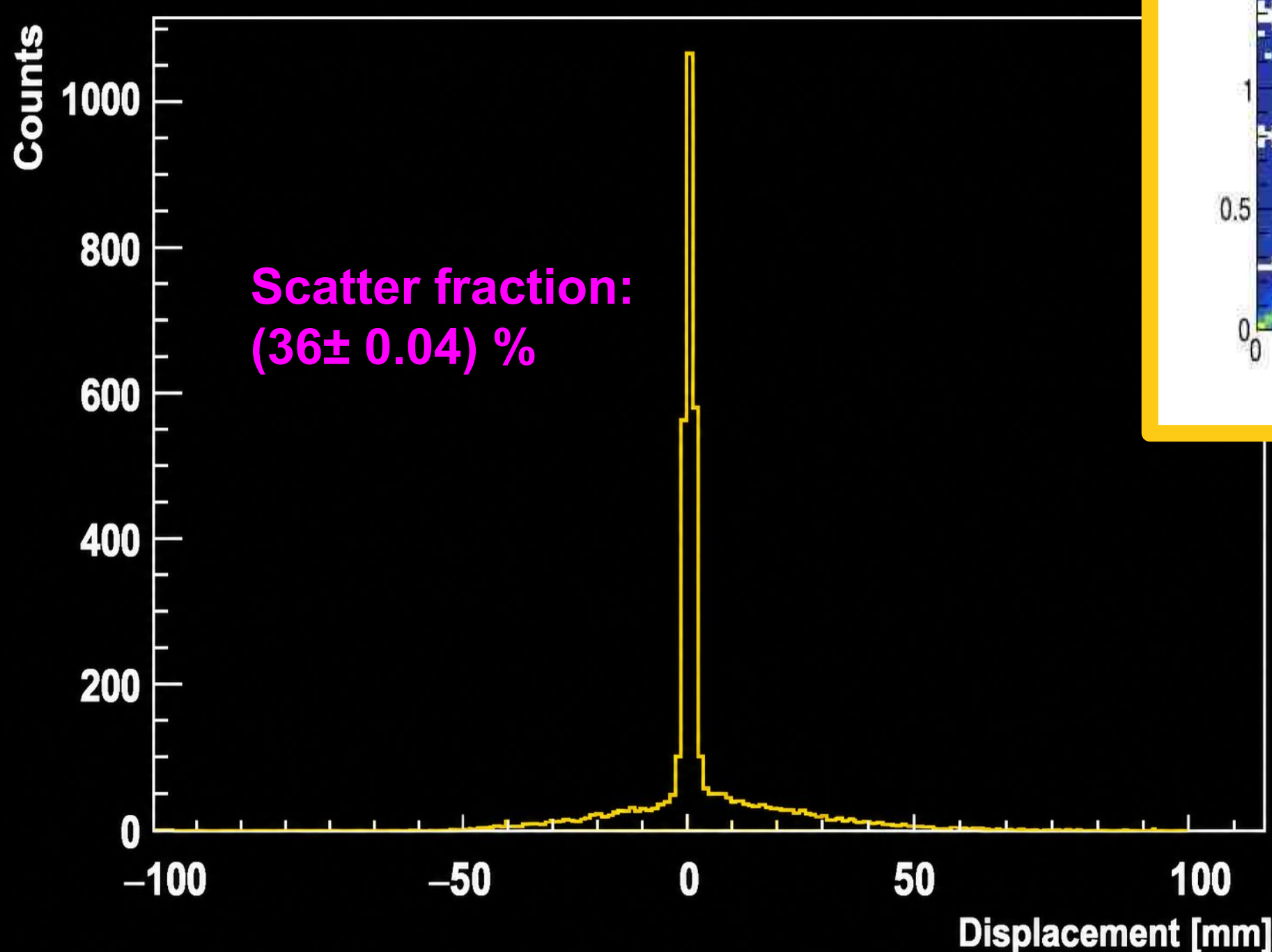


Fig. 4: Simulations result for the Brain J-PET scanner with the WLS layer; with the 70 cm long source and 1 MBq total activity. Aligned to zero and summed sinogram.

Conclusion

- The sensitivity of the total-body system increased from **35 cps/kBq** to **40 cps/kBq** after integrating the dedicated brain PET insert.
- The addition of the brain PET insert significantly improves sensitivity in the brain region

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References

- P. Moskal, E. Stępień, "Prospects and Clinical Perspectives of Total-Body PET Imaging Using Plastic Scintillators", PET Clinics; vol. 15, pp. 439- 452, 2020.
- P. Moskal, P. Kowalski, et al., "Simulating NEMA characteristics of the modular total-body J-PET scanner and economic total-body PET from plastic scintillators", Phys. Med. Biol. vol. 66, pp. 175015, 2021.
- David Sarrut, et al., "The OpenGATE ecosystem for Monte Carlo simulation in medical physics", Phys. Med. Biol. ; vol. 67, pp. 184001, 2022.
- M. Rädler, P. Moskal, "Optimising the event selection of the total-body J-PET scanner with a brain PET insert: A simulation study", Bio-Algorithms and Med-Systems; vol. 21, pp. 1-12, 2025.

