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The Role of Particle Physics in Revolutionising Imaging Technologies: From Quantum Entanglement to Clinical Applications

Positron emission tomography (PET) has become an indispensable tool in clinical medicine over the past three decades, enabling high-resolution imaging with spatial resolution of 1–3 mm and temporal resolution on the order of seconds. However, a significant portion of signal information is currently discarded due to photon scattering. Harnessing this lost data—for instance, by exploiting the quantum entanglement of annihilation photons [1]—could substantially improve scan sensitivity. For example, measuring the scattering angle of one photon could inform the reconstruction of its entangled counterpart. Yet, current PET technology faces limitations, including an energy resolution of only 8–10% for 511 keV photons, which must be improved without compromising timing resolution. Additionally, recent studies suggest that positronium half-life measurements may correlate with hypoxic cells [2], but existing detectors lack the sensitivity for low-energy photons and triple-gamma annihilations. These challenges underscore the urgent need for advancements in particle physics technologies with impact in medical applications. Integrating next-generation PET imaging into the European Strategy for Particle Physics would amplify its scientific, societal, and industrial impact, further demonstrating the field's broader relevance.

[1] Watts et al (2021) Photon quantum entanglement in the MeV regime and its application in PET imaging. Nature Communications: 12:2646, https://doi.org/10.1038/s41467-021-22907-5.

[2] Moskal et al (2024) Positronium image of the human brain in vivo. Science Advances 10(37): eadp2840, https://doi.org/10.1126/sciadv.adp2840.

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