Quantum entanglement of positron annihilation gamma – fundamental research applied to Positron Emission Tomography (PET) imaging

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The University of York nuclear group led recent paradigm-shifting advances in our understanding of the quantum entanglement (QE) of the 2-gamma final state following positron annihilation, including establishing benefits in next-generation QE-PET imaging and revealing QE is extremely robust to interactions with the environment.

This talk will present first results from our next stage programme to establish and quantify QE in the 3-gamma final state following positronium annihilation. Such systems are among the few in nature predicted to exhibit genuine tripartite QE. However, this has never been tested or confirmed. There are therefore rich possibilities for both fundamental science and applications, e.g. the emerging modality of 3-gamma PET, which offers event-by-event source reconstruction and the potential for clinically relevant environmental sensitivities.

Preliminary analysis of a new dataset will be presented, obtained with a large acceptance array comprising 2048 LYSO and 1024 GAAG detector crystals - assembled through a new collaboration between the universities of York and Tokyo. Measurements were obtained using clinically relevant F-18 positron sources, in a range of annihilating media, prepared by collaborators at King's College London. Early results from analysis of these new data will be presented, including new methods to isolate 3-gamma and 2-gamma yields in PET crystals, comparison of yields with a new Geant4 simulation, and some first studies of the dependence of the 3-gamma/2-gamma ratio on the annihilating media employed in the experiment. An outlook for the next stages of the programme, including the key QE measurements, will also be presented.