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Design of Distributed Multi-level Real-time Matching Algorithm for In-beam PET Readout System

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Heavy ion therapy is an advanced radiation treatment , and In-Beam Positron Emission Tomography (In-Beam PET, ib PET) is a non-invasive method for monitoring heavy ion tumor therapy. It provides rapid and accurate imaging of beam positioning and dose by identifying and sorting coincidence events of positron-electron annihilation in the irradiated area. This work presents a timestamp-based distributed real-time pipeline coincidence algorithm. The algorithm distributes coincidence event tasks across multiple edge modules and a central module, forming a two-level pipeline. The increased data volume from additional detectors is managed by distributing it across edge modules, enabling channel expansion with existing hardware. This algorithm ensures stable operation under high event rates, ensuring that coincidence events are accurately selected and imaging. The algorithm has been validated on the In-beam PET prototype developed independently by the Chinese Academy of Sciences. Joint testing with the detector included background irradiation and 22Na radioactive source tests. The results show an average energy resolution of 14% at 511 keV, a time resolution of 1.63 ns full width at half maximum (FWHM), and real-time event processing capability of up to 8.5 Mcps. Furthermore, in clinical beam tests at the Heavy Ion Medical Machine (HIMM) treatment terminal, the system accurately identified the Bragg peak position within 30 seconds, with a spatial resolution of 2 mm along the beam direction. The positron activity peaks in the vertical (Y) direction less than 0.5 mm error relative to the carbon ion beam position, enabling accurate localization of the carbon ion beam in the Y direction. These results demonstrate that the algorithm provides rapid, accurate, and real-time monitoring of beam distribution and dose, offering reliable dose feedback and ensuring treatment safety in heavy ion beam therapy.

Workshop topics

Front-end electronics and readout

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