The INSIDE project: in-beam PET scanner system features and characterization

V. Ferrero, on behalf of the INSIDE Collaboration

The INSIDE collaboration has recently completed the construction of an in-beam PET detector, now under commissioning at the CNAO (Centro Nazionale di Adroterapia Oncologica) synchrotron facility in Pavia. In-beam PET is one of the options for real-time monitoring of the Bragg peak depth in hadron-therapy sessions, crucial to treatment quality assessments.

The system characterization with proton and carbon beam is ongoing and first measurements showed very promising results for real-time range verification in hadrontherapy.

The detector features two planar heads of 10x25 cm² area, mounted on a mobile support and placed at a 25 cm distance from the isocenter. Each head is made of 2x5 modules based on 16x16 matrices of segmented Lutetium Fine Silicate (LFS) scintillating crystals coupled to Hamamatsu Multi-Pixel Photon Counters (MPPCs). Custom designed front-end (FE) is based on the 64-channels TOFPET ASIC. The FE boards are configured and read out locally by Xilinx SP605 FPGA boards (Tx), which decode the TOFPET data streams and apply energy thresholds before transmission to the Data AcQuisition system (DAQ), implemented on a server with a real-time high performance software, using a custom UDP-based Gigabit Ethernet protocol. Specifically, the data is transmitted via a 24-port switch to two separate Ethernet NIC’s hosted by the DAQ server (32 cores HT, 128 GB ram).

A dedicated LabView software controls the complete system, including power supplies and chiller, and provides calibration, configuration and on-line monitoring of operational parameters. A dedicated and optimized multi-threading C/C++ software, based on BOOST libraries, applies on-line data sorting and writes time-tagged coincidence data. A custom Graphical User Interface (GUI) C/C++ software based on ROOT/BOOST libraries helps perform advanced and complex system calibrations and monitors the in-beam PET performances, recording the Line-Of-Response (LOR) files in list mode during data acquisition, and allowing reconstruction of PET images from separated in-spill (1s) and inter-spill (4s) data sets.

Dedicated simulations were implemented in FLUKA accounting for the detector geometry and performances and the beam delivery informations and compared to acquired data. Different delivering configurations on PMMA phantoms were investigated, with successful data acquisition in both in-spill and inter-spill modality, with a Coincidence Time Resolution (CTR), measured without a fine time calibration, of about 380 ps σ. Monoenergetic proton beams at different energies and real treatment plans were delivered. The reconstructed activity profiles along the beam axis show an agreement between the data and simulation distal fall-off position (corresponding to the Bragg Peak depth) within 1 mm for both the mono-energetic and the real treatment plan deliveries.

The system will be further characterized to evaluate its overall uncertainty and to obtain a reliable compliance index between experimental and simulated images in order to start testing with patients at CNAO.