Contribution ID: **39** Type: **not specified**

Toward a new generation of detectors for TOF-PET with heterostructured scintillators

Saturday, June 4, 2022 11:45 AM (15 minutes)

Lutetium-based scintillators (LSO, LYSO, LGSO) are commonly used for TOF-PET, representing the better compromise between stopping power, light yield, energy and time resolution. However, the limit in the improvement of time performances of these materials has been reached, and new technologies to break the current boundaries are being investigated. Heterostructured scintillators are gaining ground as a possible solution to the conflict between high sensitivity and fast timing (coincidence time resolution below 100ps) of TOF-PET detectors. They rely on the combination of two materials with complementary properties (e.g. high stopping power and ultra-fast scintillation kinetics) and the mechanism of energy sharing by the recoil photoelectron. For the energy sharing to be effective, the geometry of heterostructures must be chosen carefully, taking into account conflicting factors (i.e. overall sensitivity, percentage of shared events, amount of energy deposited in the fast material). We performed such an optimization study for heterostructures made up of alternating layers with Monte Carlo simulations (Geant4 toolkit), using as heavy material BGO and as fast material EJ232 plastic scintillator. Afterward, the timing performances of two different configurations were assessed experimentally and compared to those of bulk BGO and layered BGO (stack of BGO plates having the same thickness as those used in real heterostructures). Collimated depth-of-interaction (DOI) measurements were also performed, allowing us to conclude that the main limiting factor of heterostructures is represented by light transport and DOI contribution. Carrying on previous development of our group, preliminary tests on the inclusion of these heterostructured pixels in a full matrix, which allow for a DOI correction based on a light sharing method, are already ongoing. In this way, it will be possible to push even further the timing capability of this new emerging generation of TOF-PET detectors.

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Session Classification: Technologies for ≤100ps TOFPET resolution: Scintillators

Track Classification: Technologies: Scintillators