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Studying the influence of the edge effects on the energy resolution of the novel GRAiNITA calorimeter

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This abstract describes the results of the Geant4 simulation done by participants in the Group of Taras Shevchenko National University of Kyiv in LHCb collaboration in close coworking with researchers at Université Paris-Saclay, CNRS/IN2P3, IJCLab, France.

The calorimeters play an essential role in high-energy physics detector setups. One of the widely used nowadays calorimeter techniques is the so-called Shashlyck calorimeter, which contains successive layers of absorber material, with high density and atomic number, and layers of scintillator material. Scintillation light is proportional to the deposited energy, it is gathered by WLS fibres and carried to the photomultiplier. The conventional Shashlik detectors provide a resolution of about R˜$10\%/\sqrt{E}$

The novel calorimeter type GRAiNTIA was proposed as an advanced version of Shashlik calorimeters. The key difference of this is that the absorber and scintillator are combined in one volume in scintillation grand and high-density liquid as an absorber. The expected energy resolution of such a detector type is about R˜$2\%/\sqrt{E}$

To evaluate the energy resolution of the detector, the detector prototype, of dimensions 168x168x400 mm was simulated with the Geant4 toolkit. The prototype was simulated as a single volume with a single material of radioactive properties that match the mixture of $ZnWO_4$ grains and heavy liquid. The detection energy loss caused by the escape of secondary particles from the detector was calculated from the simulation.

The result of the simulations for 25 GeV gamma quants shows, that for most of the volume (the inner volume which is more than 14 mm off from the detector edge), the expanded energy has a fixed value and its uncertainty stays below 1% of the induced particle energy.

Further studies show that in case the primary hit was close to the detector edge, the escaped energy is correlated with the deposited one. Thus the escaped energy could be predicted, as a consequence, the uncertainty of the escaped energy can be decreased to the value below 1%.

Studies of sources of energy escape indicate that there is always uncertainty due to exit-facet escape, and this part dominates if the primary hit is in the inner part of the detector. Close to the edge of the detector, mean uncertainty in energy escape is due to side-facet escape.

For studies of the effects of shower development on the exit-escape energy, the pre-shower (energy deposited in first 64 mm in detector volume along primary particle movement) was calculated. The result of the simulation for 25 GeV gamma shows that most of the events with exit-escape energy larger than 250 MeV got less than 20 MeV in the pre-shower.

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