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Nuclear fragment energy measurements up to 400 MeV/A with BGO crystals coupled to SiPM arrays

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The measurement of proton and light nuclei fragmentation cross sections with energies up to 400 MeV/A, which is relevant for improving treatment-planning systems in hadron therapy, is the primary goal of the FOOT (*FragmentatiOn Of Target*) experiment. FOOT will use an inverse-kinematic approach profiting from the Lorentz boost to detect nuclear fragments that would otherwise stop in the target. The momentum, time of flight and energy will be measured by a spectrometer, a thin scintillator and a BGO calorimeter respectively, and will make mass identification possible. In this work we present the design of the BGO calorimeter and performance of its prototype.

The use of SiPM arrays coupled to the crystals allows a compact design for the calorimeter. We tested 2 different FBK SiPM arrays with 15 and 20 μm microcell size, respectively, coupled to 24 cm long BGO crystals in two different configurations (reflective for 15 and absorbent for 20). At the CNAO facility in Pavia, Italy, we have measured the detector response to low intensity ($\sim$ 10 KHz) proton and carbon beams with energies up to 220 MeV and 400 MeV/A, respectively. The reflective configuration on the 15 μm provides the best results: energy resolution is below 1% for carbon ions and smaller than 2% for protons down to 120 MeV; it increases to 3% for 70 MeV protons. Moreover, no saturation effect up to 4.8 GeV deposited energy is found. Non-linear response to ionizing particles is observed, which can be caused by scintillation quenching effects. The SiPM signals are sampled at 1 GHz rate to extract temporal properties of the light pulses. Observed differences in shapes of the pulses provide an additional possibility for particle identification and improved energy correction. Therefore, the 15 μm SiPMs are a good candidate for a photosensor in the BGO calorimeter of the FOOT experiment.

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