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Measurement of neutron yields in the Xe+CsI reaction by the Highly Granular time-of-flight Neutron Detector prototype in the BM@N experiment

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One of the goals of the BM@N experiment is to study the equation of state (EoS) of dense nuclear matter in heavy-ion collisions with energies up to 4.65A GeV. The EoS includes a symmetry energy term that characterises the isospin asymmetry of nuclear matter, which is important for studying the properties of astrophysical objects such as neutron stars. The neutron to proton ratio and the neutron-proton differential directed flow in Au-Au collisions were found sensitive to the contribution of symmetry energy to the EoS[1]. Measuring the energy distributions of neutrons produced in projectile fragmentation allows estimation of the temperature of the emitting source [2]. While the proton yields are measured by the BM@N magnetic spectrometer the neutron yields in heavy ion collisions will be measured by the Highly Granular time-of-flight Neutron Detector (HGND) which is currently under development [3].
The HGND has multilayer longitudinal structure with alternating absorber and highly granular scintillator detectors (11×11) layers. Each of the 4×4×2.5 cm^3 scintillator detectors with individual light readout by SiPM (MPPC) provides a time resolution of about 150 ps. The HGND will provide the capability to measure neutrons with kinetic energies of 0.3–4 GeV by time-of-flight with high detection efficiency.
To validate the concept of the full-scale HGND the compact HGND prototype was designed and built [4]. The prototype has a longitudinal segmentation into 15 alternating layers of absorber and scintillator with a transverse segmentation of scintillator layers as a matrix of 3×3 scintillation cells with a size of 4×4×2.5 cm^3. The first scintillator layer is used as a veto for charged particles. The total length of the detector is about 2.5 nuclear interaction lengths, which allows efficient neutron detection. The light readout from each scintillator detector is realised by individual Hamamatsu S13360-6050PE MPPCs. The time and amplitude of the signal are read by the TQDC modules.
The HGND prototype was first tested in the BM@N experiment in collisions of 3.8A GeV Xe with a CsI target. The detector was placed in 0 degrees position during the measurements to test and calibrate by measuring spectator neutrons and neutrons from electromagnetic dissociation (EMD). The neutron kinetic energy spectrum reconstructed by time-of-flight is compared with the Geant4 simulations in the full geometry of BM@N setup using the DCM-QGSM-SMM and UrQMD-AMC models as heavy-ion collision generators and using the RELDIS model as EMD events generator. The neutron yields in the HGND prototype acceptance were obtained by correcting for model-estimated efficiencies for central and semi-central collisions and for EMD.

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