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Novel High-Resolution Neutron Detectors for the NMX Instrument at ESS

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ESS instruments like the macromolecular crystallography instrument NMX require an excellent neutron detection efficiency, high-rate capabilities, time resolution, and an unprecedented spatial resolution in the order of a few hundred micrometers over a wide angular range of the incoming neutrons. For these instruments solid converters in combination with Micro Pattern Gas Detectors (MPGDs) are a promising option. A GEM detector with Gadolinium converter was tested on a thermal neutron beam at the IFE research reactor in Norway. The uTPC analysis, proven to improve the spatial resolution in the case of 10B converters, is here extended to Gadolinium based detectors. For the first time, a Gadolinium-GEM was successfully operated to detect neutrons with an estimated efficiency larger than 10 % at a wavelength of 2 Å and a position resolution better than 500 µm.

Despite the very large neutron capture cross section of 155 Gd and 157 Gd, the material is not a popular converter due to the nature and the energy of the secondary particles. In fact, after the neutron capture, Gadolinium releases prompt gammas with an energy of up to 6 MeV and conversion electrons with energies ranging from 20 keV to 200 keV, considerably smaller compared to the energy of the secondaries from 3He, 6Li, and 10B converters. For this reason, and being a high Z material, Gadolinium based detectors are more sensitive to gamma background, when only the signal amplitude is used for the signal discrimination. Further, the range of the conversion electrons of at least 1 cm seems to be in contrast with the spatial resolution requirements.

Graph 1 shows a typical track that is created by the conversion electrons in the drift volume of the detector. The conversion electrons from the neutron capture ionize a macroscopic portion of the active volume, and an offline analysis takes care of the reconstruction of the neutron interaction point from the three dimensional topology of the event. With the help of an algorithm based on Principal Component Analysis (PCA), the position of the impinging neutron can be reconstructed. Graph2 shows the obtained position resolution.

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