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Simulations using NCrystal & Geant4 for innovative solid-state neutron detectors

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Due to their lack of charge, low-energy neutrons are not detectable in typical semi-conductors often applied to radiation detection, and instead detectors use expensive or dangerous gases (e.g., 3He, BF3) in bulky, immobile devices. An INDet (Improved Neutron DETection) detector aims to fix these issues using pulse plasma etching (described in more detail in [1]) to generate a 3-D silicon diode consisting of a series of sub-structures each with an enriched boron carbide (B¬xC) coating. By making use of the 10B(n, 11B*) capture reaction, the spontaneous fission of the excited 11B nucleus into two charged decay products (α and 7Li) can be used as a signature for a neutron event by detecting either product in the silicon.

Using 3-D sensors allows for an increase in the thickness of the deposited BxC layer, and thus an increase in conversion efficiency. However, the optimal coverage of boron does not necessarily correspond to the best detection geometry, nor what is manufacturable reliably.

A simple mathematical treatment can determine the expected number of converted events for regular geometries, but Monte Carlo methods are required in order to determine the performance of the entire detector; to this end, a series of simulations were created using the NCrystal library [2], developed by the detector group at the European Spallation Source, which allows for more accurate simulation of sub-keV neutrons within Geant4. These simulations have been compared to existing work and geometries, such as pyramids on top of a planar surface [3], and improved via comparison to 'real-world'scenarios.

Simulations of trenches have shown a detection efficiency of over 30% when using a converter thickness of 1 µm. Other geometries consisting of a series of holes, squares, and pyramids have also been generated with lower efficiency, but allowing for better comparison with experimental datasets.

This presentation will discuss the capabilities and advantages of NCrystal, the setup and technique used to simulate many small sub-structures atop the main diode, and the comparison with existing physical devices

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