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Description:

In a multi-layered boron detector, neutron absorption efficiency, neutron detection efficiency, homogeneity and suitability of the converter layers as gas detector components, are the most important characteristics of the layers in future detectors for neutron scattering application. By optimising the shape of the converter layers, there is the potential for improving neutron detector efficiency.

To examine this relationship in detail, TUM has modelled a variety of different macro structured boron-lined converters using the GEANT 4 simulation package. The object is to develop structures with enhanced neutron absorption efficiency whilst still allowing the neutron (n,α) reaction products to ionise the gas in the detector.

To evaluate these macro structures experimentally a general purpose small size test detector shown in Figure 1 has been designed and constructed. This detector allows the performance of different Boron-10 converters to be determined in a gaseous detector. The device has an active area of 10 cm x 10 cm and consists of a gas tight aluminium vessel with a thin entrance window. It contains a stack of up to 5 Multiwire Proportional Chambers (MWPC). Further details are given in D21.12, “Small size test detector.”

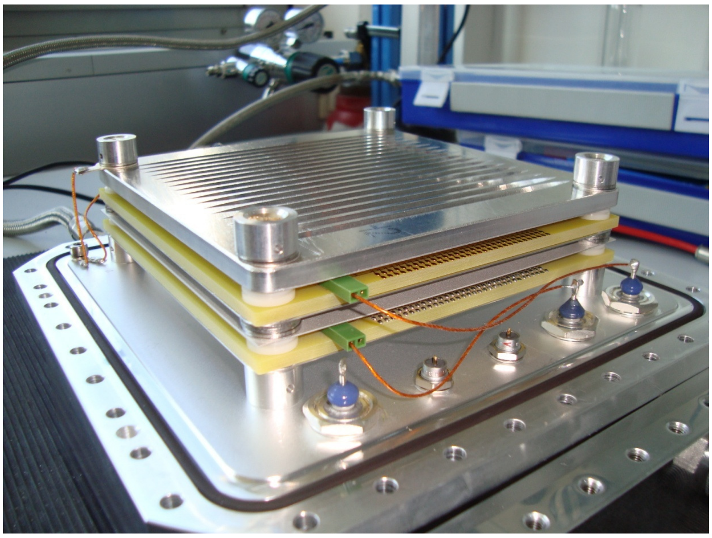

Figure 1: A set of two MWPCs with corrugated cathode plates mounted inside the test detector

A number of the macro structures have been produced and evaluated in the test detector using the collimated λ = 4.7 Å neutron beam of TREFF at FRM II. The most efficient option developed to date has been named the “Grooved Converter” concept shown in Figure 2. The development of the grooved converter is described in detail by I. Stefanescu et al., in NIM A727 (2013) and I.Stefanescu et al., in JINST 8 (2013).

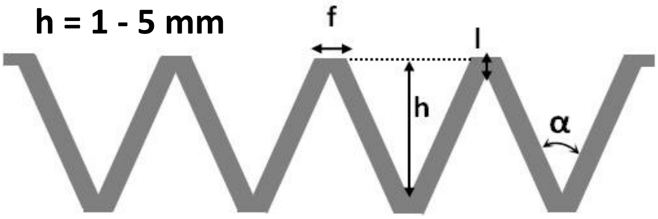

Figure 2: Schematic cross section of the "Grooved Converters"

Figure 3 shows the measured detection efficiency as a function of the depth of the grooves varying from 1.1 mm to 5 mm in comparison with GEANT4 simulation calculations assuming two different models to describe the coating inside the grooves. Measurement and simulation show good agreement and indicate a saturation of the detection efficiency with increasing groove depth. For neutrons with a wavelength of 4.7 Å this design has been shown to increase neutron detector efficiency by a factor of 1.3, compared to a flat cathode.

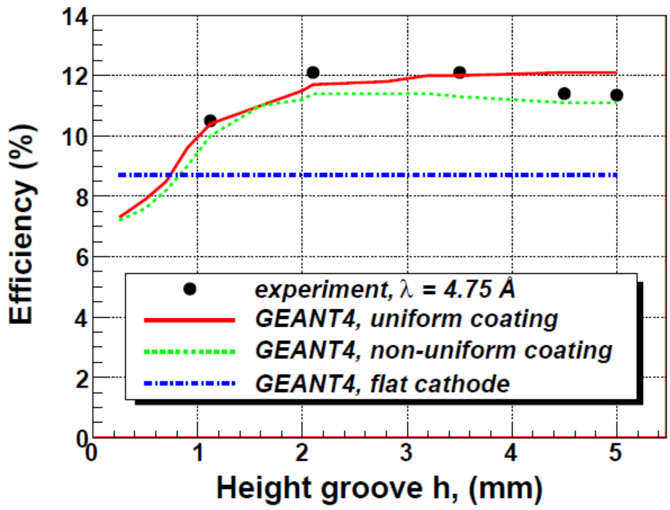

Figure 3: Neutron detection efficiency as a function of groove depth for a single corrugated converter layer coated with enriched B_4C in the MWPC detector.

Figure 4 shows the resulting pulse height spectra recorded with the anode wires of the MWPCs for converters with a groove depth of 5mm and 2.1mm respectively coated with a 2.95µm thick layer of enriched B_4C in comparison to a "standard" flat converter with a 2.45µm layer of enriched B_4C. The comparison of the three pulse-height distributions indicates that the spectra measured with the grooved cathodes contain extra counts below 1 MeV. These events arise from the reaction products with restricted line-of sight generated in the reaction of the incident neutrons with the Boron converter inside the groove, and are responsible for the enhancement of the overall efficiency with respect to the flat cathode.

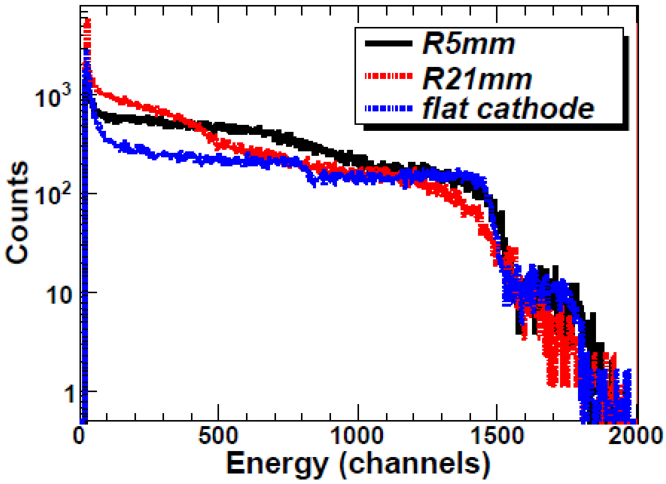

Figure 4: Anode wire pulse height spectra recorded for converters with a groove depth of 5mm and 2.1mm respectively coated with a 2.95µm thick layer of enriched B_4C in comparison to a "standard" flat converter with a 2.45µm layer of enriched B_4C.

As a single Boron-10 layer has far too low detection efficiency to be used in a neutron detector for scattering applications, a realistic design of a prototype has to consist of a multilayer structure employing 20 -30 layers of enriched Boron. To prove the gain in efficiency employing multiple converter layers up to 10 Boron-10 coated grooved converters had been mounted inside the multiple MWPC type test detector. In Figure 5, a compilation of experimental data for multiple "grooved" converter arrangements with different thickness of enriched B_4C-coatings is shown in comparison with the corresponding GEANT4 simulation calculations. In summary, simulation and measurement show good agreement.

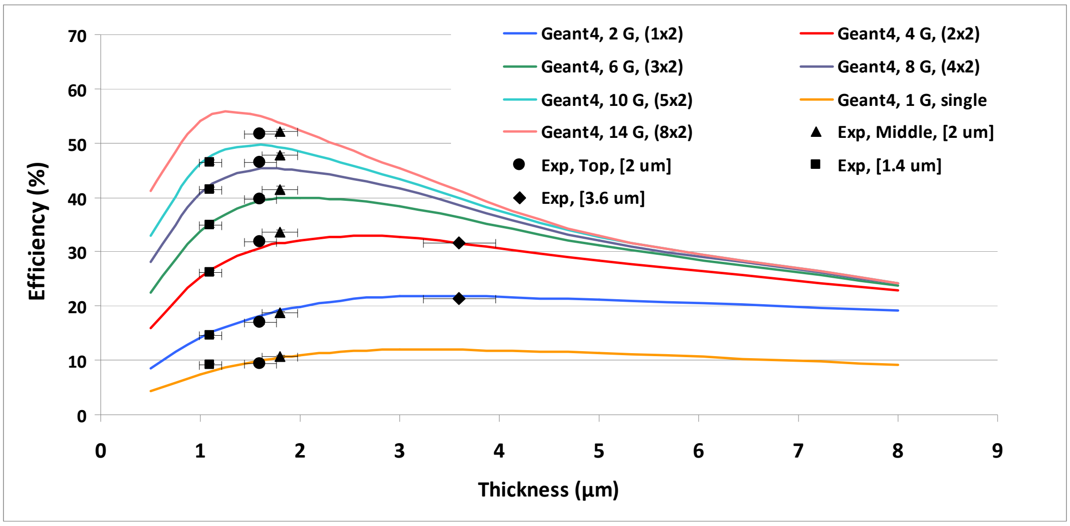

Figure 5: Comparison of the measured detection efficiency for λ =4.7A neutrons of various multiple grooved converter arrangements in the test detector with the corresponding GEANT4 simulation calculations.

The results of these studies consequently led to the design of the 40cm x 40cm active area demonstrator detector with “grooved” converter geometry coated with 1.4μm thick $^{10}B_4C$ layers. The $^{10}B_4C$ layers have been produced by magnetron sputtering technology in Linköping, Sweden.