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LOI: Commissioning of a Double Frisch-grid Bragg Detector for Fission Measurements and Determination of n-induced Background at EAR1 and EAR2

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We propose a test experiment to characterise a Double-Gridded Bragg Detector (DGBD) for fission measurements, currently under development at the University of Manchester. Ultimately, the research programme would see the chamber augmented with gamma-ray and/or neutron detectors in order to address the current nuclear data requirements specified for example by the NEA nuclear data high-priority request list, such as prompt gamma-ray and neutron energy and multiplicity distributions [1]. These future studies would complement the work of the Manchester fission group with STEFF (SpecTrometer for Exotic Fission Fragments), for which there have been previous experimental campaigns at n_TOF also aimed at addressing nuclear data needs [2,3].

The chamber consists of two back-to-back axial Frisch-grid ionisation chambers sharing a common central cathode onto which a target can be mounted resulting in a $\sim 4\pi$ subtended solid angle. An incident neutron beam intercepts a thin target from which both fission fragments escape. These are then stopped in the counting gas and full digitisation of the signal traces from all electrodes allows off-line analysis to give the fragment energies, E, differential energy-loss $\mathrm{d}E/\mathrm{d}x$ within the gas, and fission fragment emission axis. Since the parent fissioning nucleus typically has low momentum in the lab frame, the measurement of both fragment energies gives the experimentalist the mass ratio of the fragments on an event-by-event basis, provided that neutron evaporation is ignored — the '$2E$' method. In this way, mass yields can be measured; the energy resolution is ~ 0.5 MeV giving an event-by-event mass resolution of a few percent.

Recent work at Manchester has investigated the measurement of nuclear charge, Z, of fission fragments using ionisation chambers based on the differential energy-loss using 'Sub-Bragg Peak Spectroscopy' [4]. This work was motivated by the fact that fission fragments of ~ 1 MeV/u do not lead to the formation of a Bragg peak, which would otherwise provide a unique identification of the nuclear charge. Data taken using the Lohengrin spectrometer (experiment 3-01-648) with a single Frisch-grid ionisation chamber with a similar geometry to the one currently under development allowed the precise functional dependence of the range and maximum energy-loss of fission fragments (both measurable quantities) on their nuclear charge and velocity, precisely known via the Lohengrin spectrometer settings, to be established. In this proposed experiment, the ratio of the measured energy to the mass as determined using the $2E$ method, E/m, would be used instead of the fragment velocity in conjunction with the results of the previous Lohengrin experiment in order to investigate the possibility of making fission fragment charge yield measurements with DGBDs. If successful, this would have certain advantages over current charge yield measurement techniques, namely that DGBDs can be built in very close geometries compared to mass-to-charge separation devices and have good radiation resistance when compared to semiconductor devices, for example.

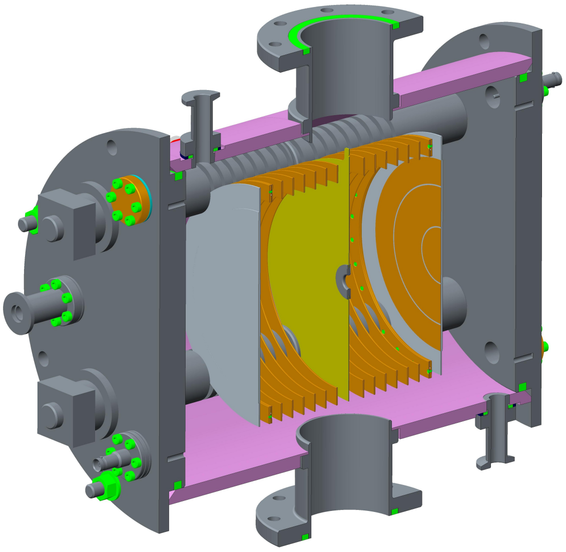

Figure 1: False colour image of the DGBD. The fissile sample (1 cm diameter, for scale) is in the centre on the cathode plane, and the the segmented anode may be seen to the right of the figure. A second, unsegmented anode is to the left. Field shaping rings maintain the uniformity of the electric field in the centre of the detector. The design can be modified to allow the neutron beam to come in either vertically or horizontally in relation to the figure shown.

Further work at Manchester has focussed on the development of a novel method for measuring the orientation of the fission fragment emission axis in DGBDs [5]. The method makes no assumptions about the differential energy-loss in the counting gas unlike other methods found in the literature; this is advantageous when determining angular distributions of fission fragments over all possible mass splits for example, where systematic uncertainties related to the range of the fragments would otherwise obscure the results. When combined with an array of ancillary detectors, the previously mentioned fragment emission angle technique would yield correlated neutron, gamma-ray and fission fragment emission angles allowing a more complete reconstruction of the fissioning system allowing not only useful nuclear data to be extracted, but also fundamental fission information.

Tests carried out at Manchester have used a ^{252}Cf spontaneous fission source of relatively poor quality resulting in excessive energy-loss and straggling. The difficulty in applying the aforementioned techniques for the extraction of mass and charge yields using such a source is that one needs a very pure and thin source and backing material to do so due to the detrimental effects of fission fragment energy-loss and straggling. The inherent difficulties in preparing sources with the desired properties means that we are asking for beam-time in order to characterise the detector with a target of ^{235}U which would be supplied by The University of Manchester, in order to commission the chamber for use at neutron facilities where in the future more exotic targets may be studied. For example, taking advantage of the high detection efficiency of the device, it is foreseeable that μg quantities of exotic fissionable target material extracted from ISOLDE targets could be measured using the chamber at n_TOF[1]. A test experiment has recently been performed at the ILL high-flux reactor with thermal neutrons on a thin ^{235}U target. The analysis of these data are now in progress to determine the inherent resolution of the device. However, the proposed use of the DGBD with fast neutrons brings with it the difficulty of dealing with neutron-induced background resulting from interactions between neutrons and the detector material (including the counting gas). The main reactions that contribute to this background, (n, p), (n, α) and neutron scattering, while normally below the electronic trigger

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[1] Subject to limitations on count rate due to alpha activity

threshold for fission, create ionization events that degrade the fission-fragment resolution. Furthermore, the so-called ‘gamma flash’ at n_TOF is known to saturate the output of detectors placed close to the neutron beam. It has been shown that it is possible to mitigate the effects of the flash by momentarily switching off the preamps and we propose to attempt a similar approach [6]. A comparison between the data from ILL and n_TOF will determine the effect of neutron-induced background, and the gamma flash, on the detector resolution. A further cosideration is the coice of fill gas. Low-mass molecules produce larger ionization background through neutron scattering so there is an advantage to using gases with large molecular mass. We propose to use CF_4 which has proven charactaristics in this type of detector and a higher mass than isobutane. There may be an advantage to using Xe as a fill gas but this is more expensive and will require a preliminary investigation before an n_TOF experiment to determine whether the gain and charge collection times are suitable in the DGBD.

Using the DGBD at the EAR2 station the neutrons will be incident on a 1 cm^2 target area of 0.1 mg ^{235}U, with an active depth of 5 nm. In such a situation the fission reaction rate will be approximately 21 fissions per proton pulse. Combined with the intrinsic fragment-efficiency of 80% this results in a detection rate of approximately 17 fission detected per pulse over a time interval of 10ms. The expected rate at EAR1 is approximately an order of magnitude lower than this, $\sim$ 1.7 fissions per pulse. In this LOI we ask for discretionary time to test the chamber at both experimental stations in parasitic mode, if possible, so that the chamber doesn’t interfere with the main experiment. We ask for 1×10^{18} protons at EAR2 and 2×10^{17} protons at EAR1 to measure a modest sample of fission events and to access the background contributions.

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