Investigations with Gaseous Electron Multipliers (GEM) for use on the ISIS spallation neutron source

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Introduction

The Gaseous Electron Multiplier (GEM) technology promises to deliver ^{3}He based neutron detectors for a wide range of applications for ISIS. When coupled to the use of CF_4 as a quench gas they could offer the potential for a 2D detector for neutrons with sub mm resolution. However, the operation of these devices at elevated CF_4 pressures has proved to be very problematic. Reducing the induction gap between the GEM and the readout plane appears to give an enhanced gain from the GEM detector which we have employed in the detectors described here.

Investigations with kapton GEMs

Standard CERN GEMs with 50μm thick copper clad kapton foil, 50μm holes patterned at 140μm hole pitch of 10mm by 10mm area have been used. The GEM foil is stretched and glued to an FR4 frame which is 1mm thick, which is also used to determine the induction gap to the readout electrode. The active gas region is formed by the addition of a drift plane placed 10mm above the GEM foil. This is housed in a pressure vessel which has been designed for a working pressure of 14bar.

Initially filled with 0.5 bar of ^{3}He and 1.0 bar CF_4 (corresponding to a neutron detection efficiency of ~4% for 1Å neutrons) the vessel was illuminated with neutrons produced from a moderated ^{241}Am:Be source. The concentration of CF_4 was then increased 0.5bar at a time and gain measurements were made in each mixture. Figure 1 shows the pulse height distribution obtained from the detector operating with 3 bars of CF_4 at a gain of ~8.

Figure 1: Pulse height distribution from ^{241}Am:Be neutron source obtained from a kapton GEM with 0.5 bar ^{3}He and 3 bars CF_4

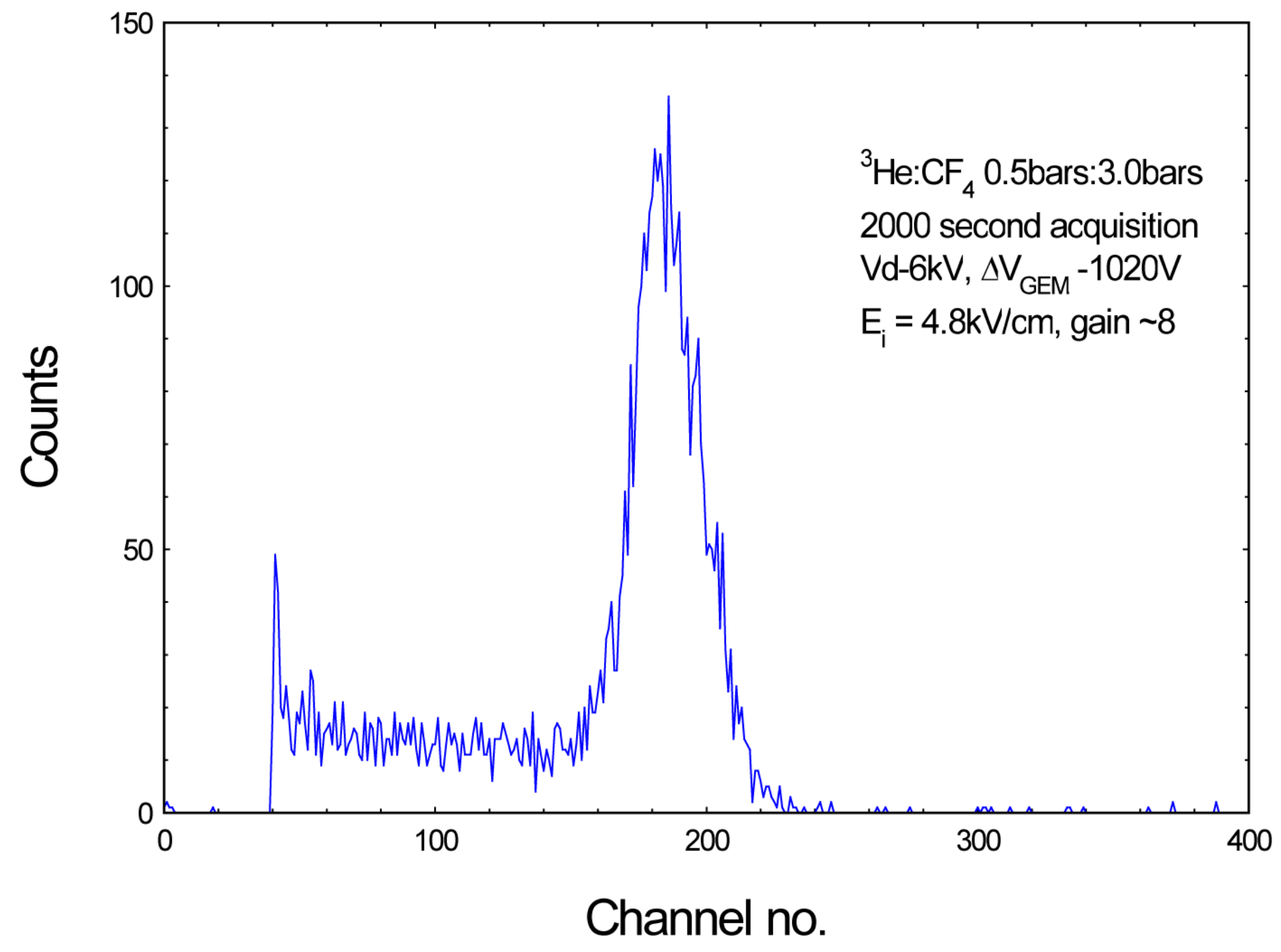
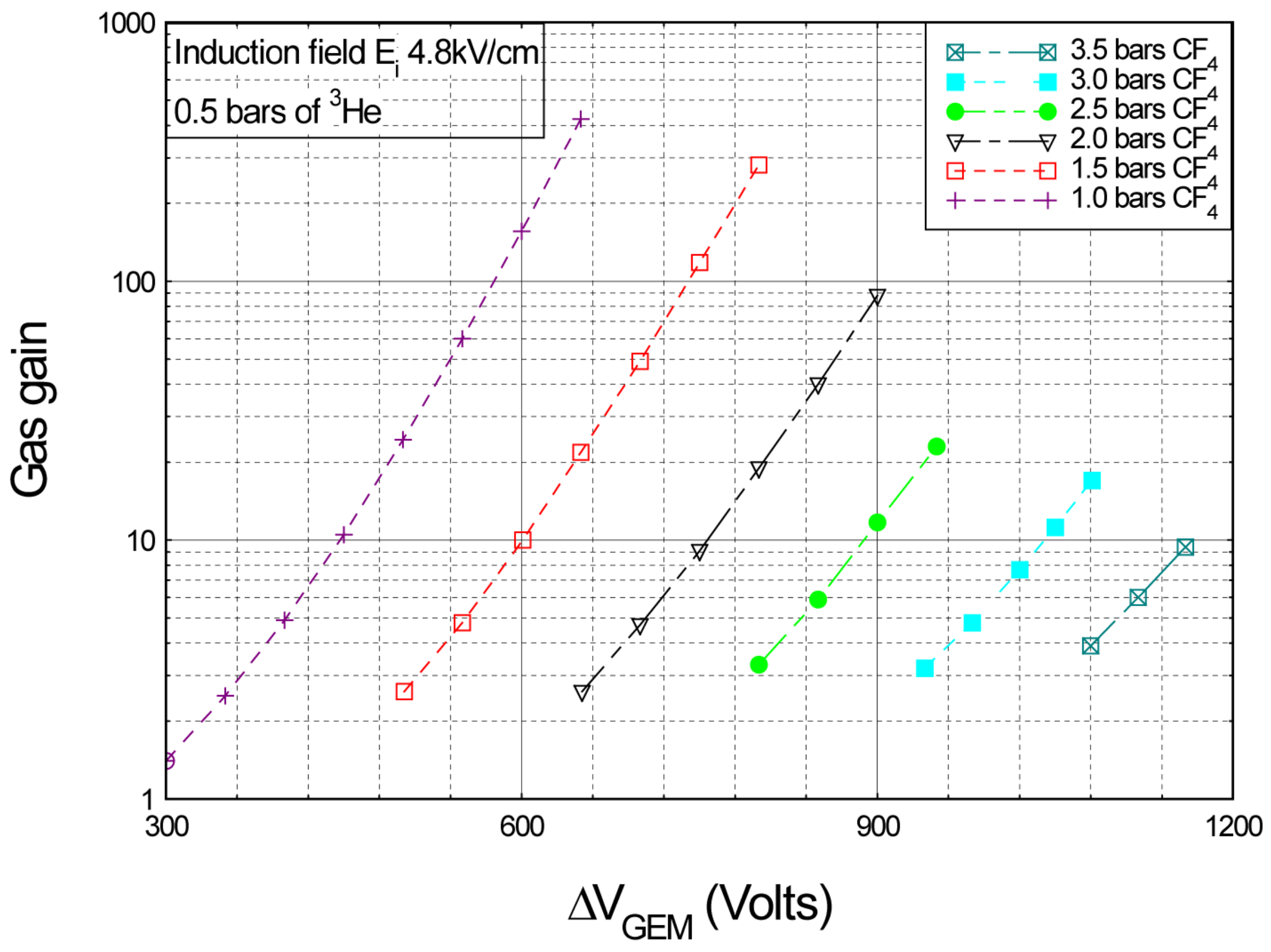


Figure 2 shows a plot of the gain curves obtained for each gas mixture. The operating point with 4 bars of CF_4 was not attainable before the onset of a terminal discharge.
Our results indicate that kapton GEMs could be operated with sufficient gain (~10) at the necessary CF_4 pressure (~2.5 bars) to localise the proton from the ^{3}He (n,α) t reaction to 1mm.

Figure 2: Gain curves obtained from a kapton GEM in various ^{3}He:CF_4 gas mixtures



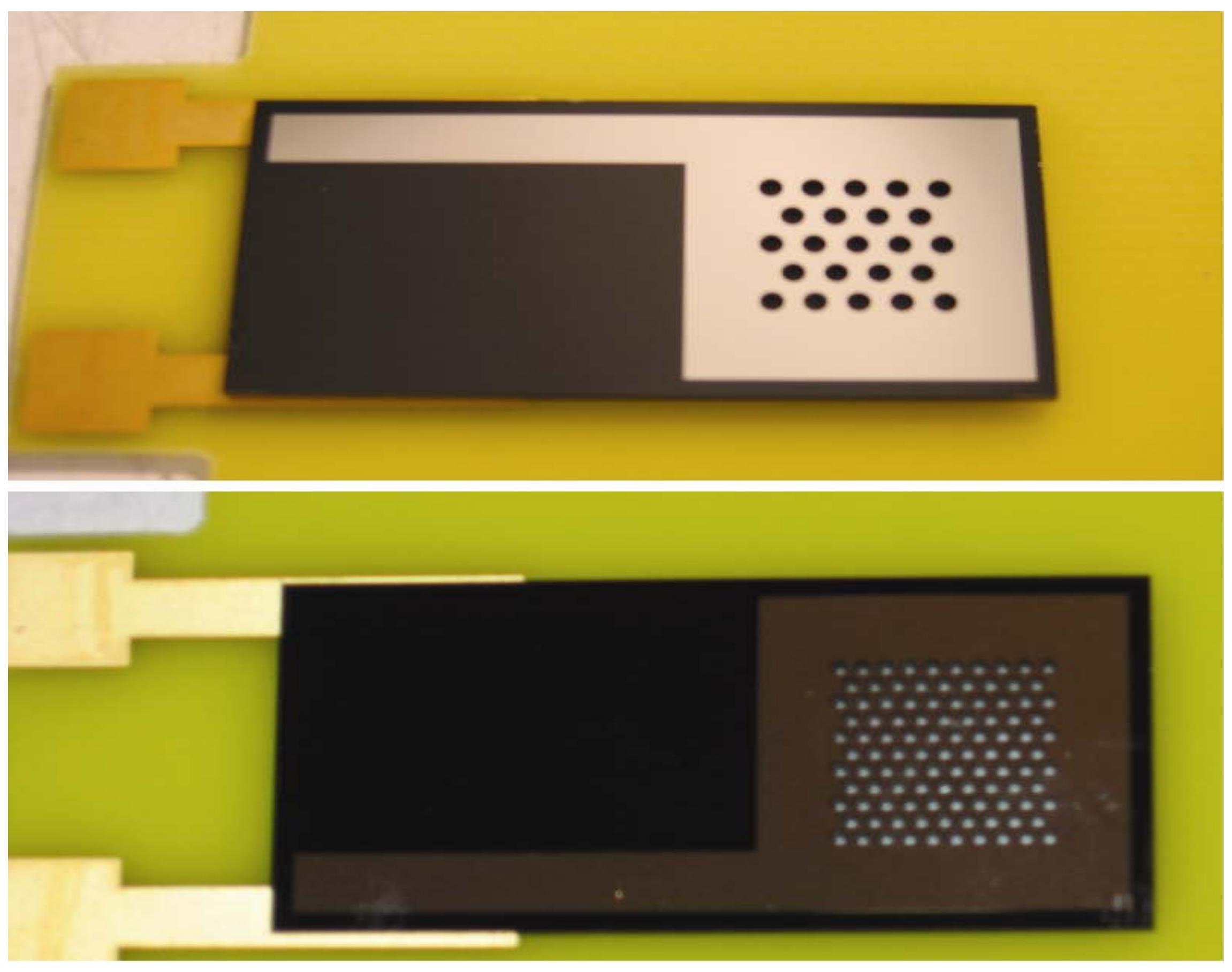
These results have been obtained from GEMs with an area of 10mm by 10mm, which for most of the envisaged applications is too small. Therefore, larger GEMs of 100 by 100mm were obtained which are currently being assembled with the intention of repeating the measurements made on the small GEMs.

Investigations with S8900 GEMs

Encouraging though these results are, we see evidence for the GEMs 'charging up' over time (~20% gain rise over a period of 24 hours, under continuous neutron illumination), which would need to be addressed before incorporating detectors based on GEMs into any of the ISIS instruments. We postulate that the gain increase of the GEM device is due to charge collecting on the (very small) kapton 'ridge' that is present at every GEM hole. We propose the use of S8900 electron conducting glass as a solution to this charging, and attempted to make a GEM type structure on an S8900 substrate. The first devices were made by IMT in Switzerland using our standard 1mm thick glass. This is both rigid and manageable. The holes were put into the glass by using a laser drilling technique.

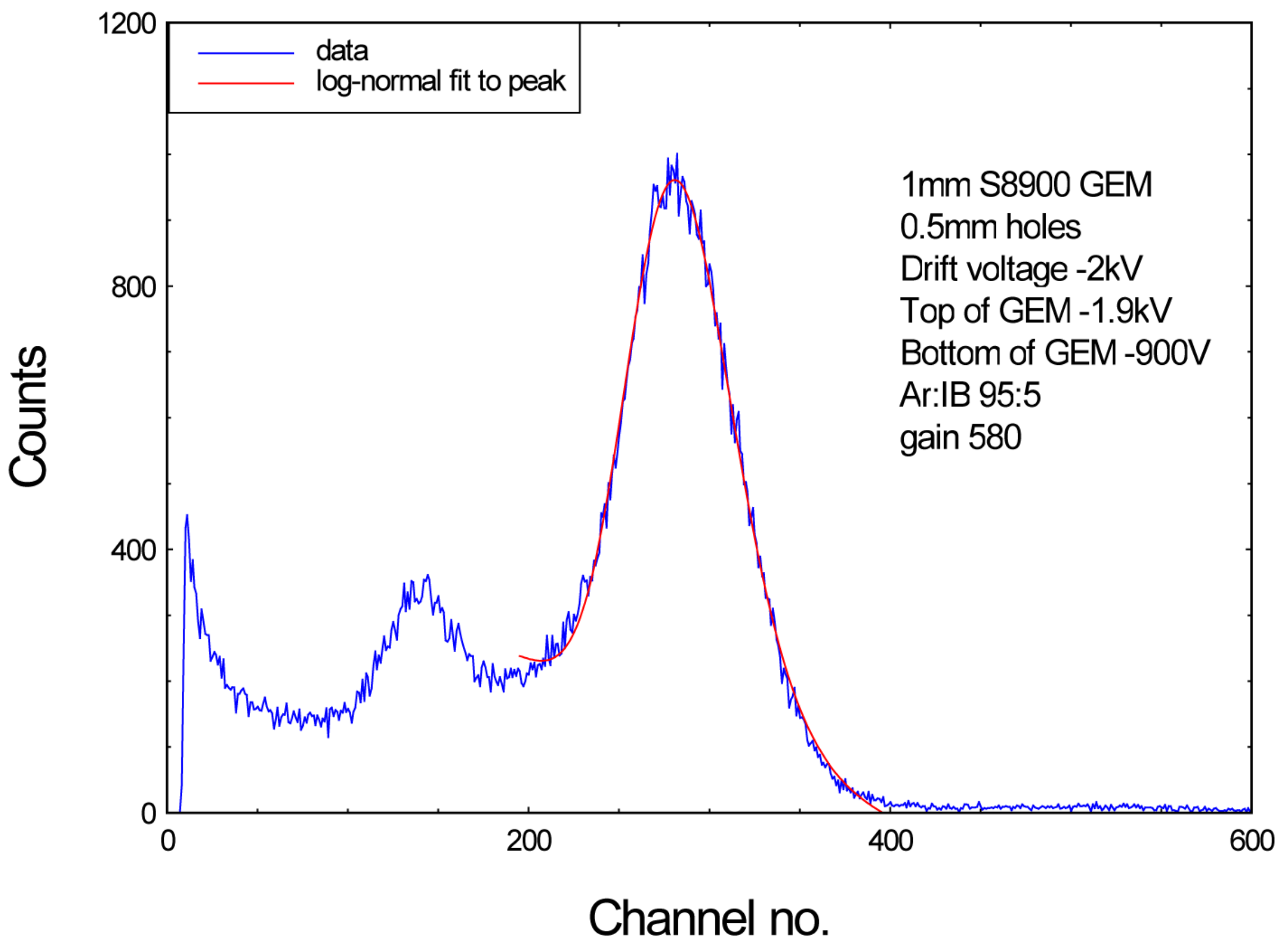
In the first batch of S8900 GEMs, two different geometries were investigated, one with 1mm diameter holes and one with 0.5mm diameter holes through the glass, both in a hexagonal array with an active area of 10 by 10mm. A chromium layer was then lithographically added to both sides of the glass, leaving 100μm of clearance around both hole sizes. The glass GEMs were mounted on carrier boards, see figure 3, enabling them to be easily incorporated into one of our current flowing gas vessels.

Figure 3: S8900 GEMs mounted on carrier boards; the top photo shows the GEM with the 1mm diameter holes and the bottom photo shows the GEM with 0.5mm diameter holes



The initial measurements were made with the 0.5mm hole structure in a 95:5 mixture of argon and isobutane as this minimised the voltage required across the GEM. Figure 4 shows a typical ^{55}Fe X-ray spectrum at a gas gain of 580 with the drift field at 100Vcm^{-1} and the induction field at 9kVcm^{-1}. As the drift field is increased to 1kVcm^{-1}, the gain reduced by 25% and the FWHM energy resolution of the peak in the spectrum increased by 30%.

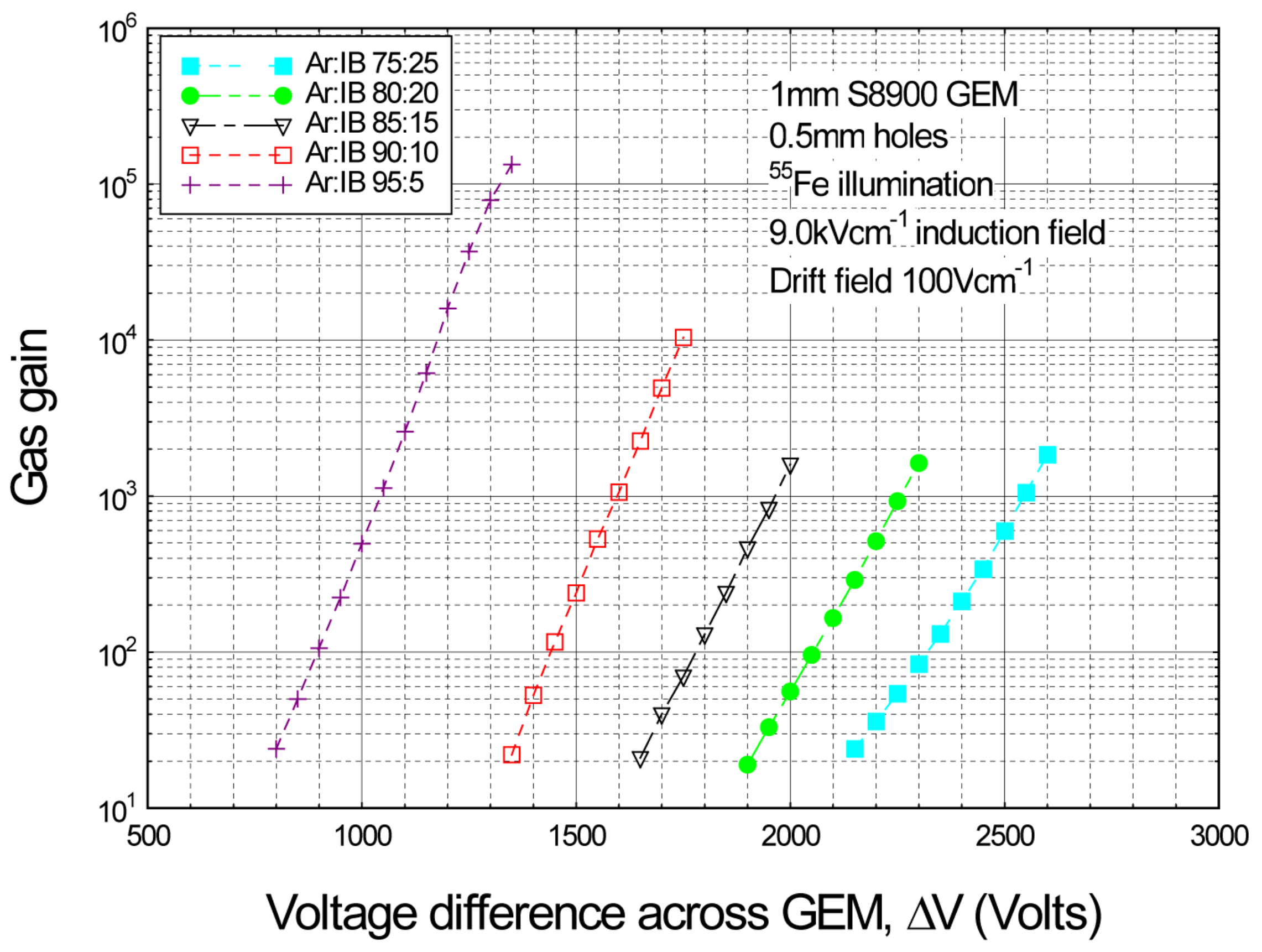
Figure 4: ^{55}Fe X-ray spectrum obtained from S8900 GEM with 0.5mm holes



The gas gain was measured as the voltage across the GEM was steadily increased, and also as a function of induction field. A series of measurements were then made as the concentration of quench gas was increased, which is summarised in figure 5, for an induction field of 9kVcm^{-1} and a drift field of 100Vcm^{-1}.

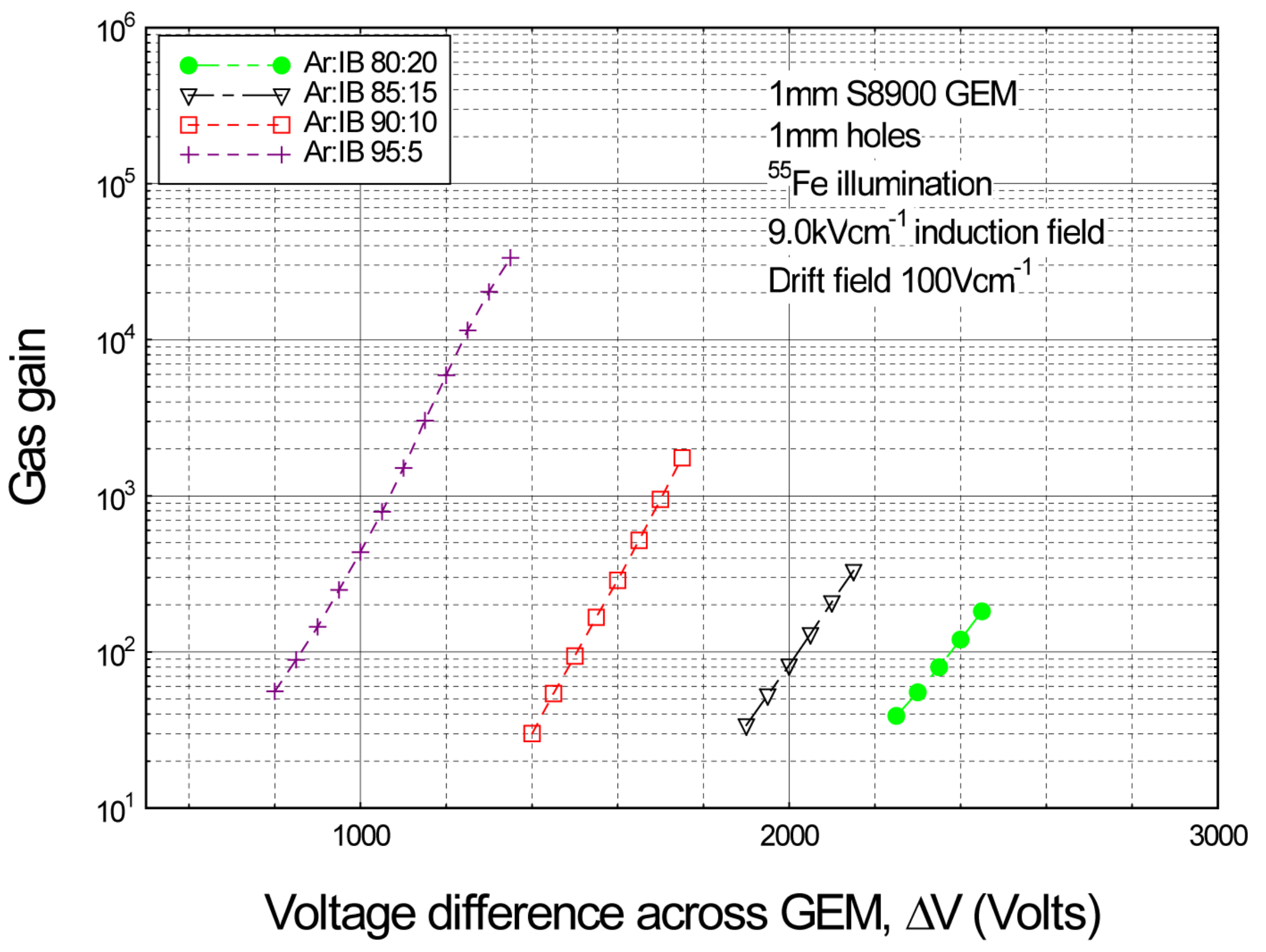
Investigations with S8900 GEMs (cont)

Figure 5: Gain curves in various Ar:Isobutane gas mixtures from S8900 GEM with 0.5mm holes



A similar series of measurements were made with the 1mm hole GEMs, which are summarised in figure 6, again for an induction field of 9kVcm^{-1} and a drift field of 100Vcm^{-1}. It is noticeable from figures 5 and 6 that the maximum gain obtainable in each gas mixture reduces as the quench gas concentration is increased. As expected the GEM with the 0.5mm hole produces a higher gas gain at a lower voltage across the GEM electrodes. A maximum gas gain of 10^5 was achieved from the 0.5mm hole GEM in a 95:5 gas mixture. Some evidence of an initial charging under illumination has been observed, (a fall in gain of 5% in the first 15mins) but the GEM then stabilises and tracks atmospheric conditions.

Figure 6: Gain curves in various Ar:Isobutane gas mixtures from S8900 GEM with 1.0mm holes



Discussion and future work

Clearly, we are still in the early stages of demonstrating the potential of the GEM detector for applications in ISIS instruments. Whilst we have shown that it is feasible to operate kapton GEMs with sufficient CF_4 to obtain a desired position resolution of 1mm, we need to ensure that this is scalable for larger GEMs.

An application of such a large area, 2D GEM detector, would be as a high count rate, high position resolution neutron detector for the reflectometry instruments OffSPEC, PolREF and INTER on the second target station of the ISIS spallation neutron source. Such a device would have a very large impact on the science output of their respective programmes, and could also be exploited worldwide at other neutron scattering institutions.

Further studies with the S8900 GEMs are required to fully characterise the stability issues before such a device could be mounted in a pressure vessel in a ^{3}He:CF_4 atmosphere in order to evaluate its suitability as a thermal neutron detector.

The authors would like to acknowledge financial support from the Centre for Instrumentation at the Science and Technology Facilities Council

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