High Pressure Gain Characterisation of the µRWELL for Thermal Neutron Detectors

*Raheema Hafeji**, Davide Raspino, Erik M. Schooneveld, Nigel J. Rhodes
ISIS Neutron and Muon Source, STFC Rutherford Appleton Laboratory, Harwell Campus, Oxfordshire OX11 0QX, United Kingdom
*Past affiliation
raheema.hafeji@gmail.com

The µRWELL was characterised with an AmBe neutron source, using a gas mixture of helium-3 (1 bar) as the neutron conversion medium and up to 6 bar of CF_4 as a stopping gas.
It can successfully operate with adequate gain and no sparks seen at these high pressures.
This gas mixture can provide sub-millimetre position resolution, with a 2D charge readout from strips.

µRWELL layout

- The µRWELL is a spark-protected structure with Diamond-Like Coating (DLC) separating amplification stage from readout electrodes [1].
- Kapton foil (50 µm) cladded on one side with copper (5 µm).
- 50 x 50 mm^2 active region and DLC resistivity 80 MΩ/□.
- Conical holes with lower diameter 50 µm, upper diameter 70 µm and pitch 140 µm.

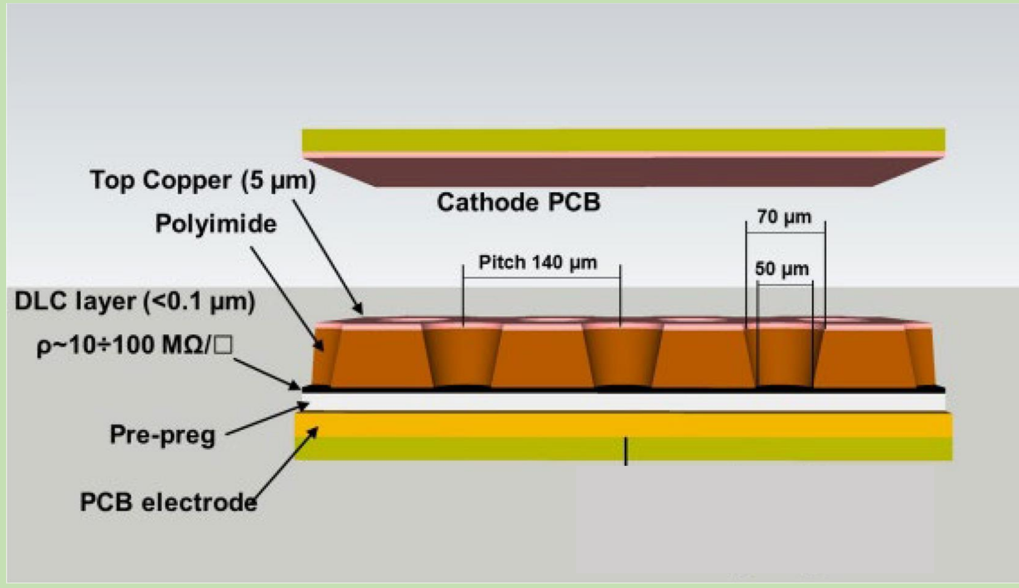

Figure 1. Layout of the µRWELL [2].

Stopping gases in helium-3 neutron detectors

- When helium-3 is used as a conversion medium, neutrons undergo the following reaction:

$$^{1}n + {}^{3}He \rightarrow {}^{1}H + {}^{3}H + 764\ keV$$

- The proton and triton are emitted at 180° to each other, and their range is the intrinsic limit on the position resolution of the detector.
- Stopping gases reduce the range of the proton and triton pair, thus improving the position resolution.
- Adding over 4 bar of CF_4 to the gas mixture can provide sub-millimetre position resolution.

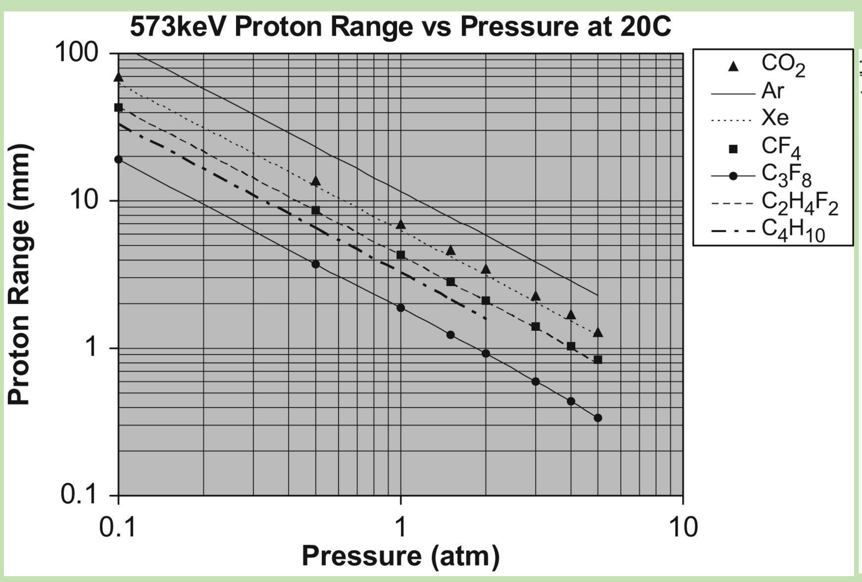

Figure 2. Ranges of protons calculated from SRIM simulations in various stopping gases at increasing pressures [3].

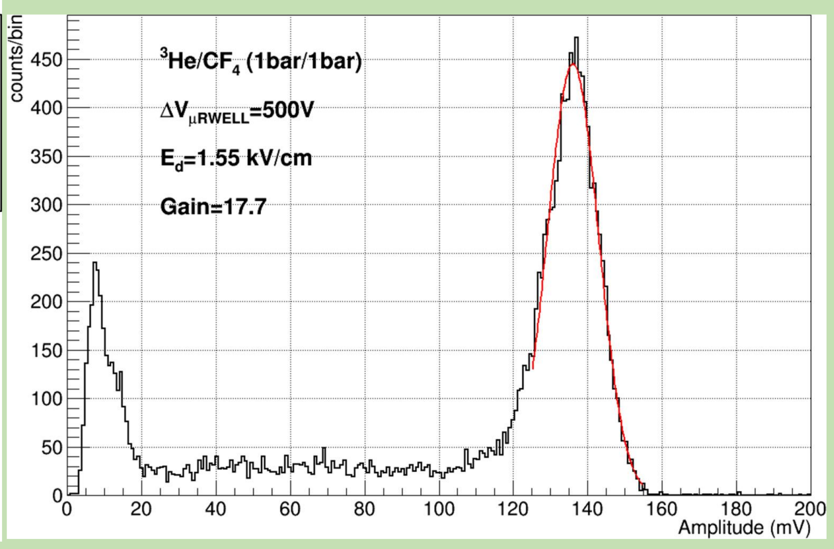

Figure 3. Pulse height spectrum from a neutron interaction within helium-3.

Assembly

- During cleanroom assembly, UV and white light were used to locate dirt particles from the surface, to prevent sparks during operation.
- These were dislodged with a paintbrush and vacuumed with a fine nozzle.
- The assembled sealed pressure vessel was baked at 60° for ~72 hours to remove water content.

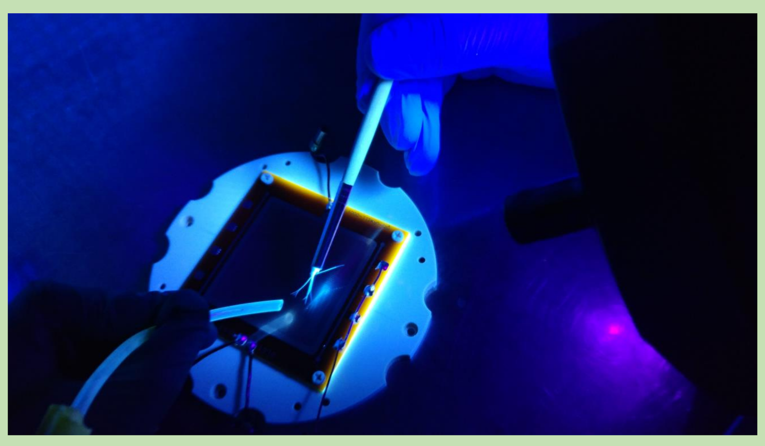

Figure 4. Removing dust particles located with a UV light.

Setup

- Neutrons were from a moderated AmBe source of 37 GBq.
- Negative bias was applied to the top of the µRWELL.
- The two long lateral bars on the µRWELL were connected to HV ground, with DLC pads remaining disconnected.
- Waveforms were recorded with a 12-bit PicoScope 4824 digitiser, operating at 20 MHz and 80MS/s.

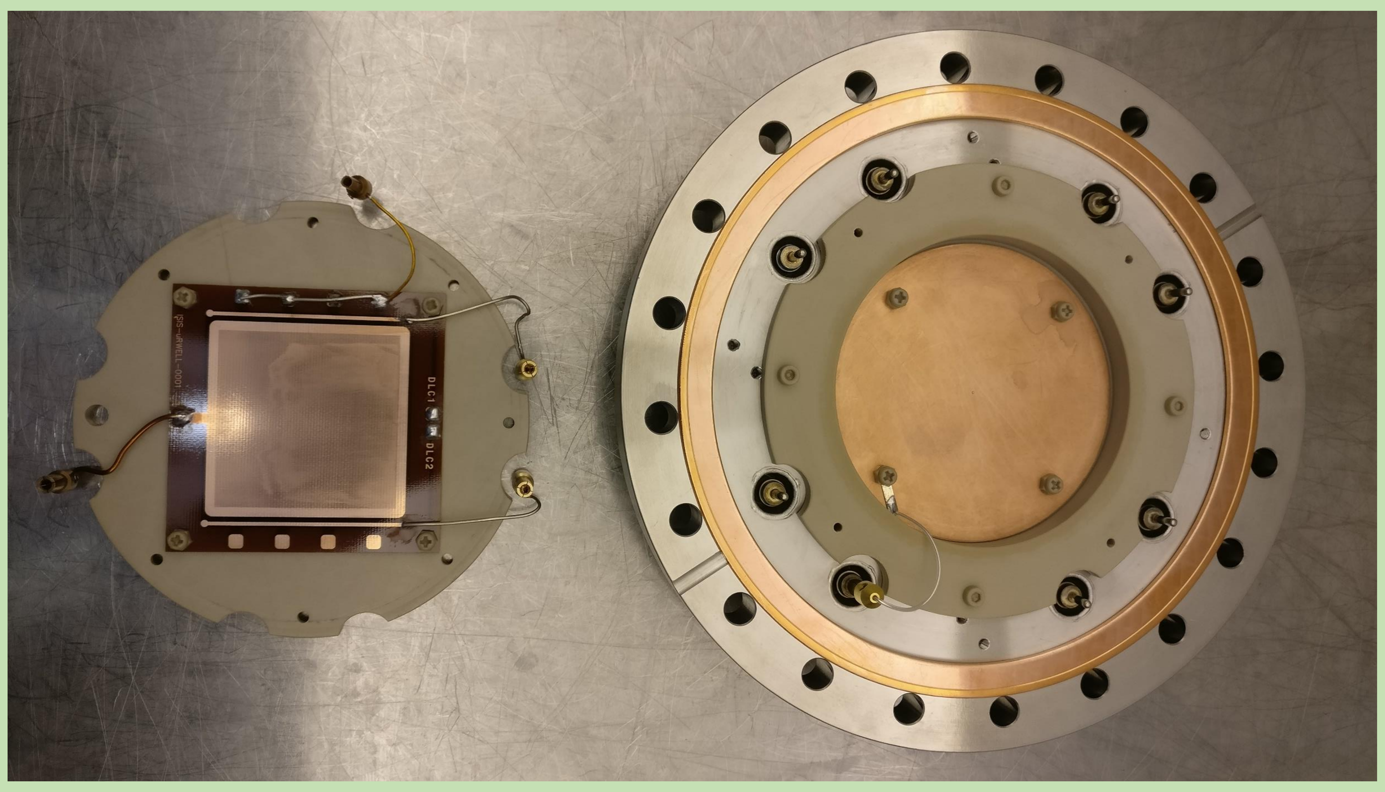

Figure 5. The µRWELL shown alongside the copper plate used as a drift electrode, before the pressure vessel was closed.

Gain Characterisation

- A gain of ~25 was measured with a gas mixture of up to 6 bar CF_4 and 1 bar helium-3.
- Although a higher gain was achievable, a gain of 25 is adequate for helium-3 based neutron detectors where the primary charge is very high.
- No sparks were seen during operation.

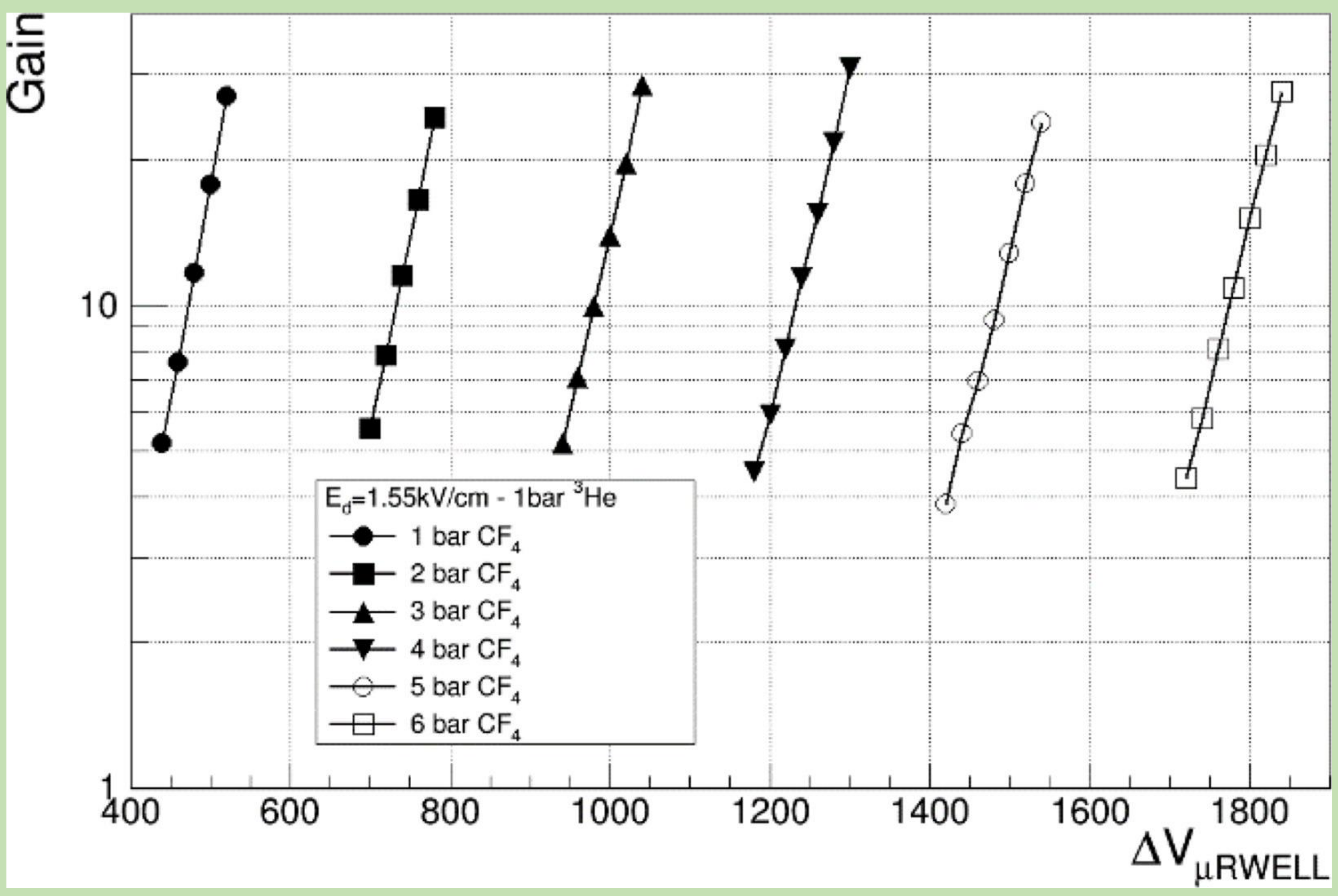

Figure 6. Gain curves from 1 bar to 6 bar of CF_4, shown with the corresponding voltage applied across the µRWELL.

Application

The µRWELL operated in a helium-3/CF_4 gas mixture can have applications with neutron scattering instruments where sub-millimetre position resolution, high efficiency (>50% at 1 Å) and high-rate capabilities (>1MHz global rate) are required.

[1] Bencivenni G., *et al.* JINST, 10 (2015), p. P02008
[2] Bencivenni G., *et al.* JINST, 14 (2019), p. P05014
[3] Doumas A., Smith G.C. Nucl. Instrum. Methods A, 675 (2012), pp. 8-14