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Evaluation of a Multiwire Proportional Counter for the SURF Reflectometer at ISIS.

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Abstract

The performance of a ^{3}He filled multiwire proportional counter with delay line readout has been evaluated for the detection of neutrons at the ISIS pulsed neutron source. Detector characteristics have been determined and are discussed in relation to the detector requirements of SURF, a new reflectometer at ISIS.

Introduction

ISIS is the world's most powerful source of pulsed neutrons, [1]. It provide scientists and engineers with a facility to determine the structure and dynamics of materials on the atomic/molecular scale. ISIS operates a variety of instruments, each of which exploits a particular area of neutron scattering research, [2]. A recent addition to the ISIS instrumentation suite is SURF, a second generation neutron reflectometer, designed to investigate problems in surface chemistry, [3]. One of the requirements for SURF is a two dimensional position sensitive neutron detector, ideally spanning 200 mm x 200 mm, with 1 mm x 1 mm pixel resolution. Other important criteria for this detector include a high neutron detector efficiency in the range of 2 - 10 Å, a low sensitivity to gamma radiation and a low intrinsic detector background while maintaining a high pulse pair resolution in the region of 1μs. This report describes the detector characteristics of a multiwire proportional counter in terms of these criteria and assesses the potential of this detector to meet the requirements of the SURF reflectometer.

Equipment

The multiwire proportional counter, MWPC, used for this evaluation was fabricated at the European Molecular Biology Laboratory, Grenoble, [4], [5]. The active detector area was 200 mm x 200 mm with a plane of anode wires centred between two orthogonal planes of cathode wires. Each set of cathode wires was connected to a delay line readout. Signals from each end of each delay line were pre-amplified and passed to fast amplifier low level discriminators. Time differences were measured for each set of cathodes with time to pulse height converters and these outputs were digitised with analogue to digital converters, ADCs, to give an XY position encoded output. The gas pressure in the detector was 2 bars of CH_4 and 1.72 bars of ^{3}He. The operating voltage was 5.741 kV.

To interface to a standard ISIS instrument crate and Data Aquisition Electronics, DAE, the XY encoded output of the multiwire detector was converted to a single binary output using a multiplexer card developed by the ISIS electronics group. In this manner 14 bit detector inputs were fed into the DAE using 4 multiplexed DIM 2 Data Input Modules giving 16 K detector positions. For current purposes the data was then condensed onto a 4 K matrix using software mapping.

Detector Efficiency

The pressure of ^{3}He in the detector was 1.72 bars. Calculation gives a neutron detector efficiency of 30 % at 1 Å. A higher gas pressure requires a higher operational voltage. For this particular detector, which had been designed for X-ray work, a higher operational HT was not possible without the risk of HT breakdown. For a purpose built detector it should be possible to increase the ^{3}He pressure. Five bars of ^{3}He gives a calculated neutron detection efficiency at 1 Å of 63 %.

A comparison of the neutron detector efficiency of this detector with a fibre coupled ZnS/^{6}Li scintillator detector has been made. The scintillator detector had an active area of 80 mm x 80 mm with 5 mm x 5 mm pixel resolution. The detector consisted of a 0.4 mm sheet of ZnS/^{6}Li scintillator containing 3.2% ^{6}Li as the neutron absorber. The scintillator is viewed by an array of fibre optics arranged in an XY code. A time of flight spectrum was recorded on the TEST BEAM at ISIS from a CaF_2 crystal using the MWPC. Without changing the crystal geometry the gas detector was replaced by the scintillator detector and a new data set obtained. Time of flight spectra for the (h00) reflections are shown in Figures 1 and 2.

Intensities of the six principle reflections from each spectrum were measured and normalised to counts per μAhr. The maximum theoretical neutron detection efficiencies of the MWPC and the ZnS/^{6}Li scintillator detector were calculated from the concentrations and neutron absorption cross sections of ^{3}He and ^{6}Li. These values are recorded in Table 1 as a function of neutron wavelength. The observed efficiency of the MWPC was derived from the relative intensities of the reflections and the theoretical efficiency of the ZnS/^{6}Li detector. Data from these measurements and calculations is shown in Table 1. There is good agreement between the theoretical and observed neutron detector efficiency of the MWPC indicating that the detector is operating near its maximum neutron detection efficiency.

Gamma Sensitivity

The sensitivity of the detector to gamma radiation was measured at 1 MeV using a ^{60}Co source placed 10 cm from the active detector area. Gamma sensitivity expressed as a ratio of photons detected to photons incident on the detector was 7 x 10^{-4}.

Intrinsic Detector Background

Intrinsic detector backgrounds were recorded as 10 counts per second over the whole detector.

Signal/Noise Ratio

The time of flight spectrum from the MWPC in Figure 1 exhibits a peak to background ratio of 800/1. This ratio is probably dominated by background neutron radiation incident on the detector. It is comparable with similar experiments performed with this crystal on the Single Crystal Diffractometer, SXD, at ISIS using scintillator detectors before rigorous attention was applied to detector shielding. However, the underlying signal/noise ratio will be dominated by the relatively high sensitivity of the detector to gamma radiation and high intrinsic detector background.

Detector Resolution

The detector was placed in the main beam with a 1 mm wide sintered B_4C slit inserted immediately in front of the detector. The results from this run are shown in Figure 3. The full width half height of the integrated peak is in the region of 1 mm indicating that detector resolution is comparable to the desired requirement.

Pulse Pair Resolution

The integration decay time constant of the preamplifiers is fast, ~1 µs. The pulse pair resolution of the detector is limited by the timing and digitisation electronics. For this particular electronic set up the pulse pair resolution of the detector was estimated at 10µs.

Conclusions

Neutron detector efficiency of the MWPC at present is 30 % at 1 Å. It will be possible to improve this value in a MWPC built specifically for SURF. Detector position resolution is adequate. At present the pulse pair resolution of the detector is significantly less than that required. This can be greatly improved if the time to pulse height converters and ADCs are replaced by time to digital converters, TDCs, [5]. Under these conditions a ppr in the region of 1 µs is anticipated. However, by only using a small fraction of the available charge, the ability to discriminate against gamma radiation and intrinsic detector background is poor. Some development of the detector electronics is needed to determine whether it is possible to reduce the gamma sensitivity and intrinsic detector background of the detector while maintaining a high pulse pair resolution.

Acknowledgements

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(h00) lambda (Å)	MWPC (cts/μAhr)	ZnS/^{6}Li (cts/μAhr)	ZnS/^{6}Li theot. eff.	MWPC theot. eff.	MWPC obs. eff.
(4 0 0) 1.8	1219	673	0.28	0.46	0.54
(6 0 0) 1.2	578	331	0.20	0.34	0.35
(8 0 0) 0.9	676	435	0.15	0.26	0.23
(10 0 0) 0.7	101	49	0.12	0.21	0.25
(12 0 0) 0.6	190	144	0.10	0.19	0.14
(14 0 0) 0.4	40	32	0.07	0.13	0.09

Table 1. Calculated and observed efficiency of the MWPC detector as a function of neutron wavelength. The observed MWPC efficiency has been derived from the theoretical efficiency of the ZnS/^{6}Li detector and the ratio of the integrated intensities of the reflections at the different wavelengths.

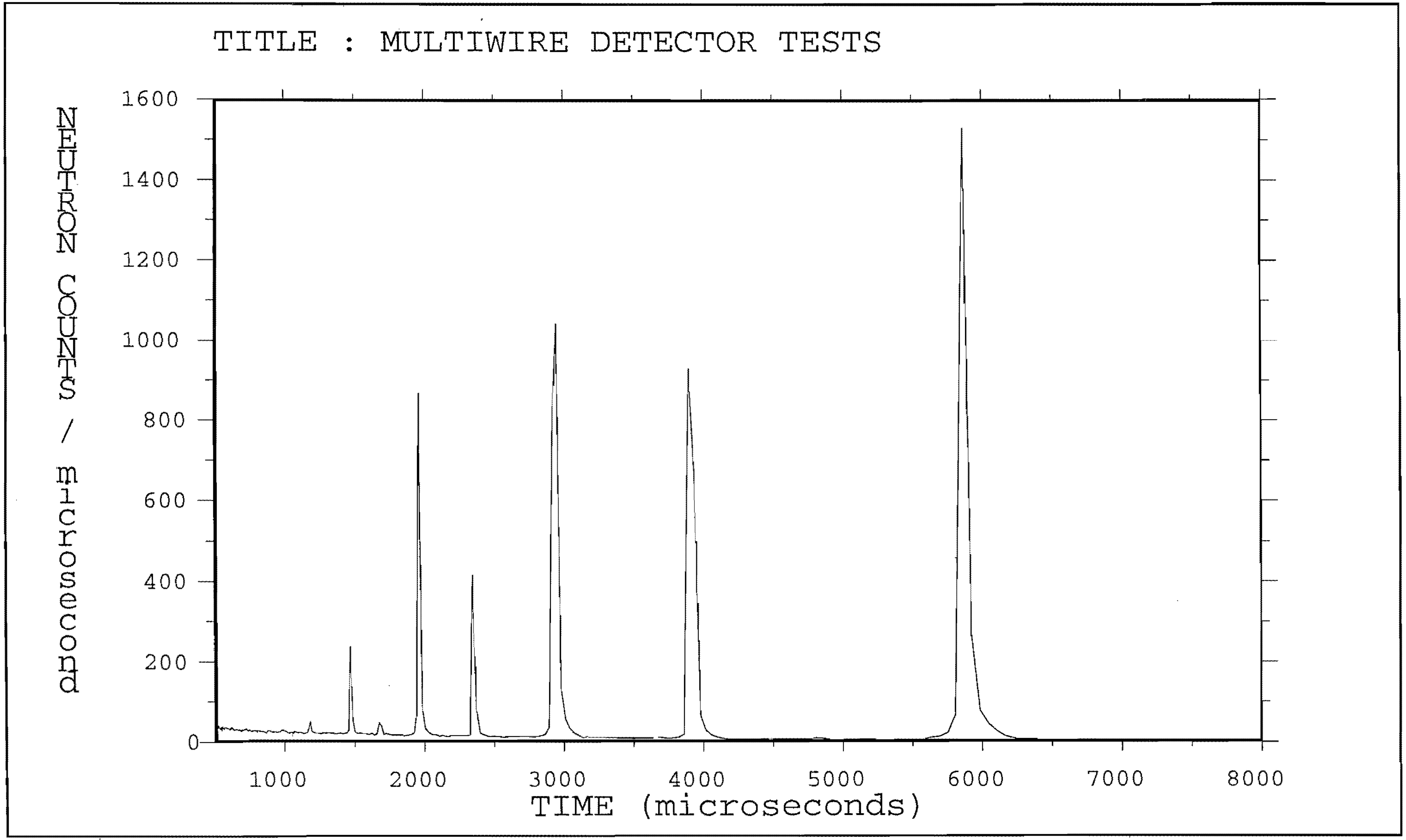

Figure 1. Time of flight spectrum of the (h00) reflections from a calcium fluoride crystal recorded using the MWPC.

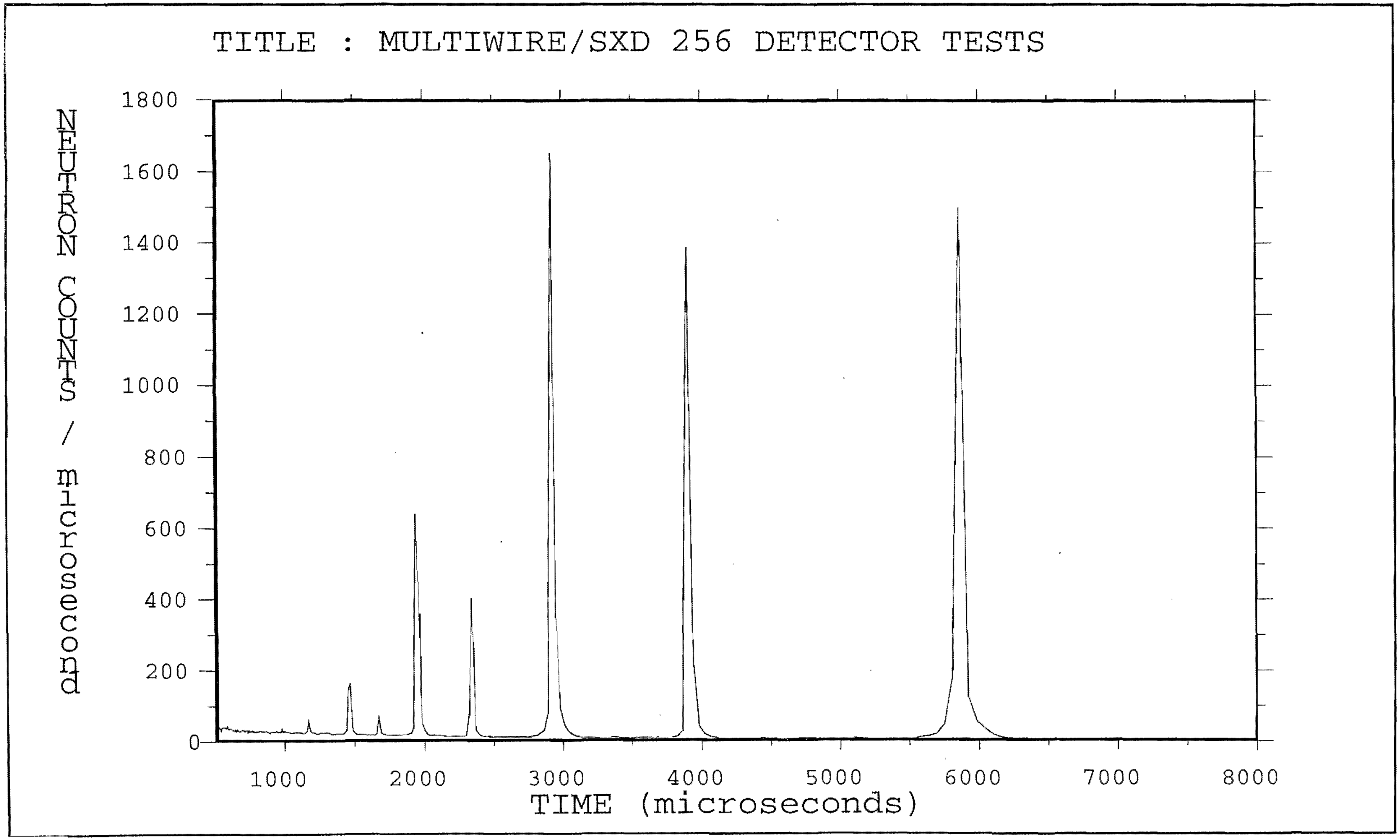

Figure 2. Time of flight spectrum of the (h00) reflections from a calcium fluoride crystal recorded using the SXD 256 $ZnS/^6Li$ scintillator detector.

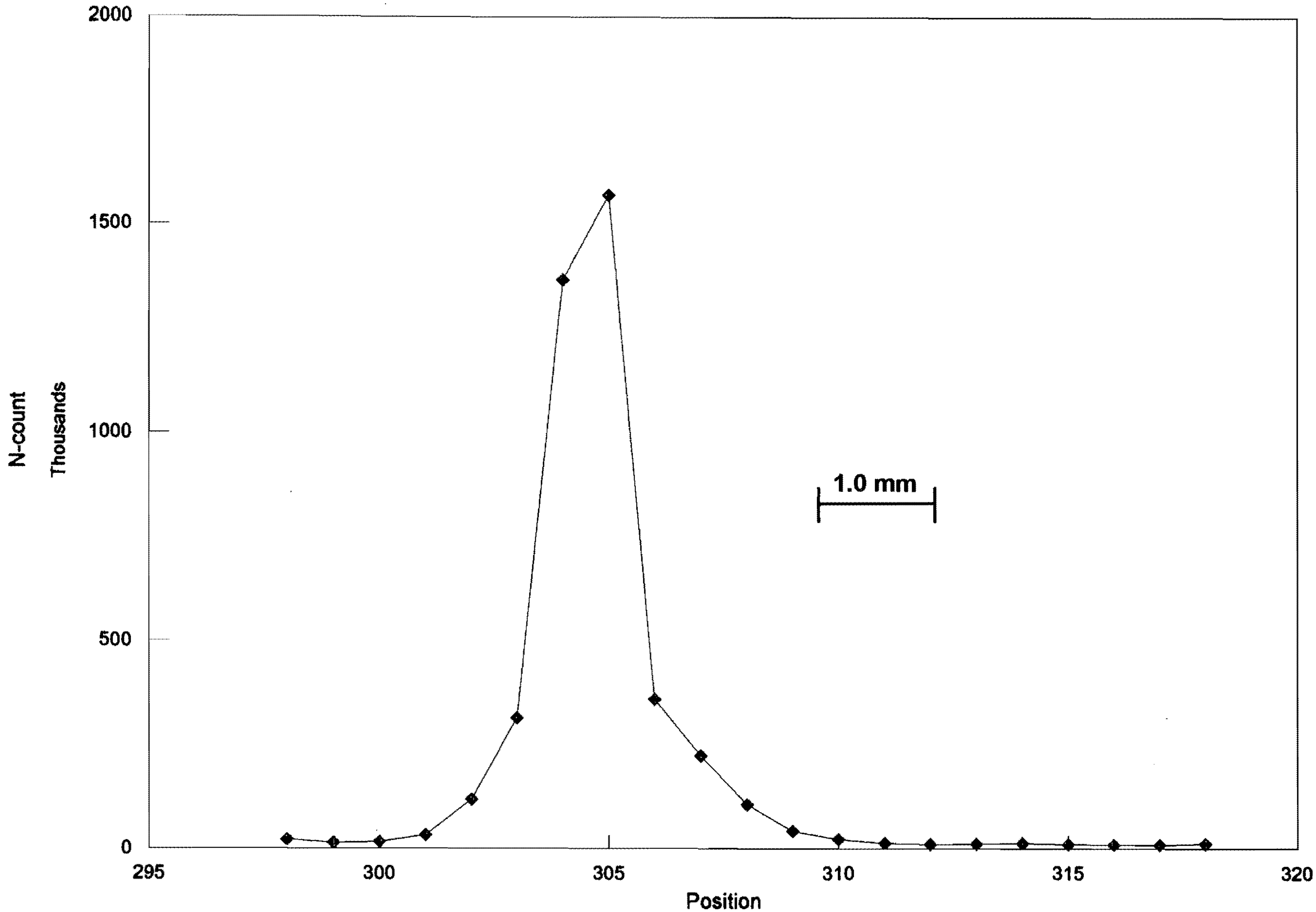

Figure 3. The response of the MWPC placed in the direct neutron beam immediately behind a 1 mm sintered B_4C slit. The full width half height of the neutron peak is 0.9 mm.