Four-Stage Diamond Spectrometer for Low-Energy Proton Identification

J. Melbinger[1,2], C. Weiss[1,2] and E. Griesmayer[1,2]
[1]TU Wien, Wien, Austria | [2]CIVIDEC Instrumentation GmbH, Wien, Austria

Abstract | Thin planar single-crystal chemical vapour deposition (sCVD) diamond sensors enabled the development of a multi-stage spectrometer capable of measuring low-energy protons in the range of 3 MeV to 20 MeV. In this study, a CIVIDEC B14 Diamond Telescope Detector [1] was utilised to analyse a proton beam generated by neutron interactions with a polyethylene converter. This shows the background suppression capabilities of the spectrometer. The experimental data was compared with Geant4 simulations for a proton beam with a Gaussian energy distribution of (13.7 ± 0.5) MeV. The comparison shows an excellent agreement between the measurement and simulation, allowing for a detailed study of the proton interaction with sCVD diamond. The capabilities and limitations of the proton spectrometer will be evaluated and presented in this paper.

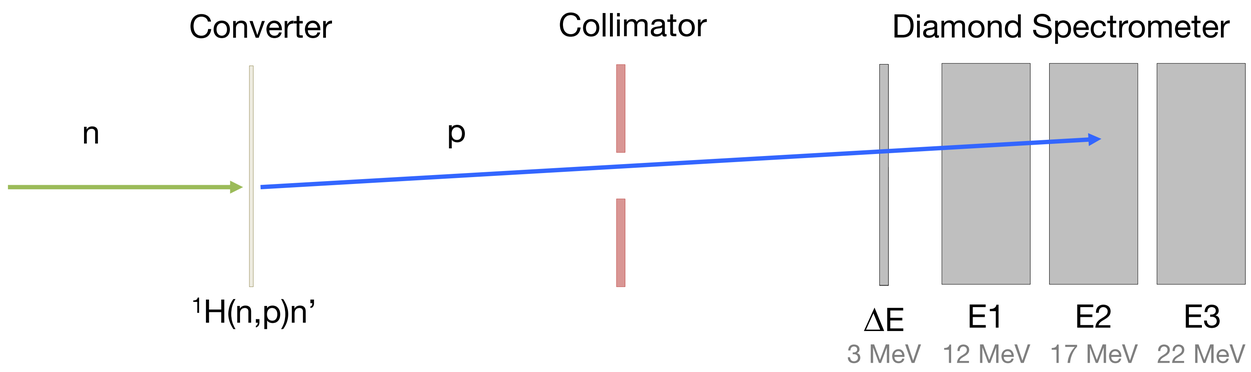

Figure 1: Measurement principle of the Four-stage Diamond Spectrometer and the maximum stopped proton energy per sensor. [2]

Measurement principle | A proton traverses the first and second sensors and is stopped in the third sensor. These interactions in multiple sensors can be extracted from a background by coincidence measurements.

Depending on the the coincidence condition, different proton energies can be extracted from 3 MeV up to 22 MeV.

Measurement

The proton beam was created by the interaction of neutrons with a polyethylene converter. The neutrons were used as background, showing the suppression of uncharged particle interactions.

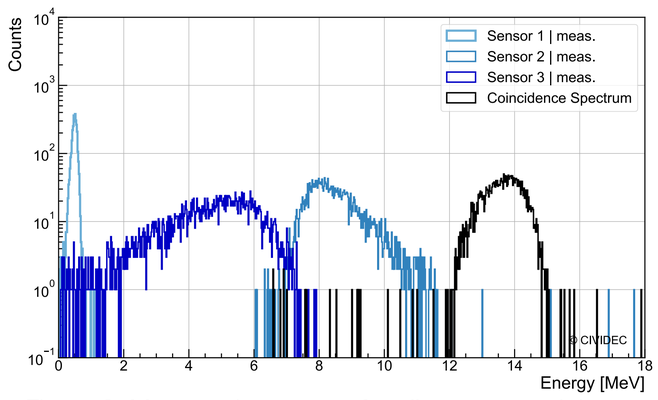

Figure 2: Measured spectrum for all sensors and the reconstructed proton spectrum.

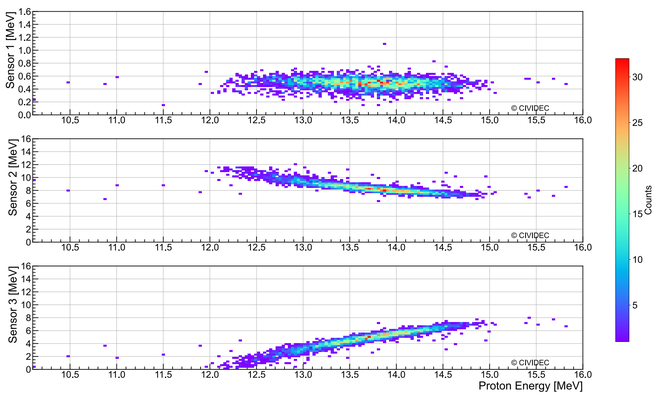

Figure 3: Measured energy deposition as function of the total deposited energy in the telescope.

Application

The four-stage Diamond Spectrometer is designed to measure low-energy protons while suppressing background interactions from heavy, light (e-) and neutral particles (neutrons).

The presented data is from a measurement campaign in Frascati. The coincidence condition is:

Event = (ΔE ∧ E1 ∧ E2) ∧¬ E3

In the presented measurement, 3124 proton interactions were extracted from a total of 11.6 million counts, as shown in Figure 1.

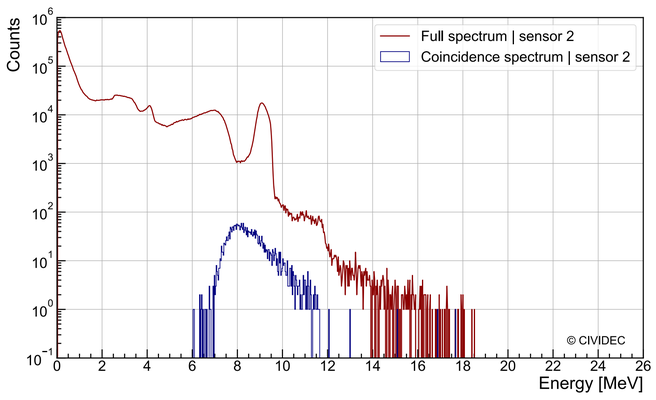

Figure 4: Comparison of the spectrum with background (red) and the proton coincidence spectrum (blue).

Geant4 simulation

The Geant4 simulation with a pencil proton beam of (13.7 ± 0.5) MeV energy shows excellent agreement with the measurement results.

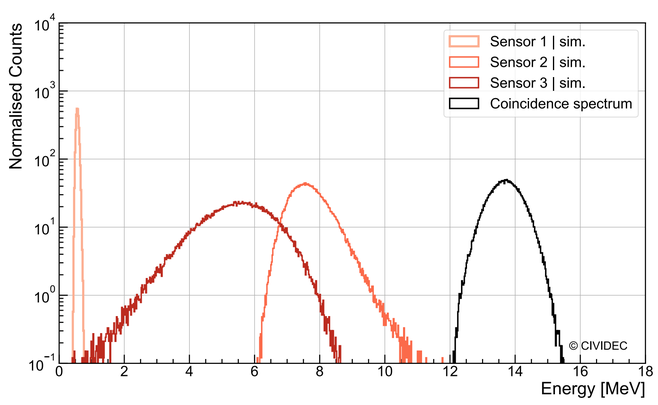

Figure 5: Simulated spectrum for all sensors and the reconstructed proton spectrum.

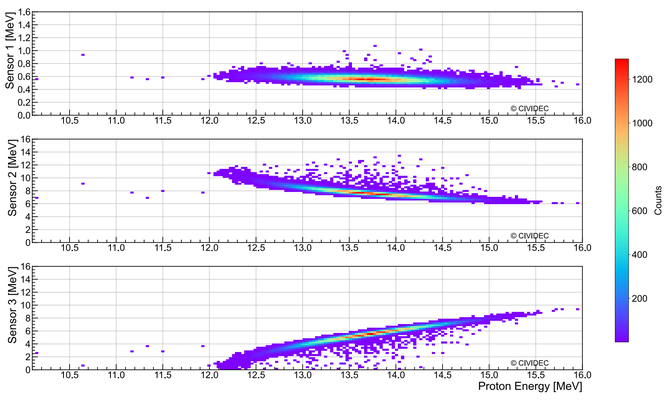

Figure 6: Simulated energy deposition as function of the total deposited energy in the telescope.

References |

[1] C. Weiss and E. Griesmayer, Fusion Eng. Des. 203, (2024) 114453. https://doi.org/10.1016/j.fusengdes.2024.114453

[2] CIVIDEC Instrumentation GmbH, B14 DIAMOND TELESCOPE DETECTOR, https://cividec.at/detectors-B14.html