The histograms are implemented into the FPGA's Block RAM. Their size ranges from 256 to 4096 bins (an 8-bit or a 12-bit histogram, respectively), depending on the required histogram resolution. For instance, the width parameter is measured with a 0.2 ns resolution; the expected maximum pulse width is less than 20 ns. This yields the maximum range of 100 bins, making an 8-bit histogram sufficiently large. The same reasoning is applied to the amplitude measurement. In this case the maximum range is defined by the 8-bit resolution of the ADC. The area measurement, however, yields higher values and can therefore have a more refined binning (12-bit). Finally, a single 12-bit 2D histogram is included, with 6 bits for every axis. It is used as an online scatter plot for comparing one measured parameter to another. An example for it is a comparison of the width against the area, which can help the user determine the cuts that need to be applied to the measurement.

1.8 Performance results

The device has been tested in the lab using a pulse generator as well as several radioactive sources. The results show that: 1) the amplitude, area and width measurement are linear across all input ranges, 2) the highest rate of the PSA algorithm is $\sim 5 \times 10^6$ pulses per second and 3) the lowest SNR where the algorithm still functions is $\sim$5.

Trigger rate A pulse generator was used to verify the highest achievable rate at which the PSA still analyses every incoming pulse. The final state machine implemented in the pulse analysis module prevents the triggering block from issuing a trigger due to an incoming pulse if the previous analysis is still in ongoing. Given that all the pulses were of the same length, the analysis duration was always the same. When the time between the incoming pulses was shorter than the time of the analysis, the pulses were not analysed. Figure 1.12 shows the sharp decline in the percentage of the analysed pulses when reaching the rate of 5 MHz. Therefore the overall analysis duration for a 10 ns pulse is approximately 200 ns.

Linearity A pulse generator was used to verify the linearity of the measurements across all input ranges. The pulse width and the amplitude were varied and measured both with the oscilloscope and the PSA to estimate the systematic error of the PSA measurements with respect to those taken by the oscilloscope. The results are shown in figures 1.13a and 1.13b. The measured amplitude error e_{ampl} is within ± 3 % of the real value throughout the amplitude range. The width error e_{width}, however, increases significantly in the lower width range. This stems from the low bandwidth limit of the PSA, which affects the pulse shape via a slow rising and falling time, effectively smearing the pulse along the time axis. Therefore the PSA cannot measure rectangular pulses shorter than 2 ns.

Stability The input pulse signal was superimposed with the white noise generated by a noise generator with a variable gain. The mixed signal yielded pulses with an SNR ranging from 5 (very noisy) to 100 (noise negligible). The PSA then performed the pulse parametrisation at different SNRs without changing the pulse shape. The results of the measurement errors for amplitude, width and area are shown in figures 1.14a, 1.14b and 1.14c. The amplitude is highly overestimated at a low SNR (high noise). This is because

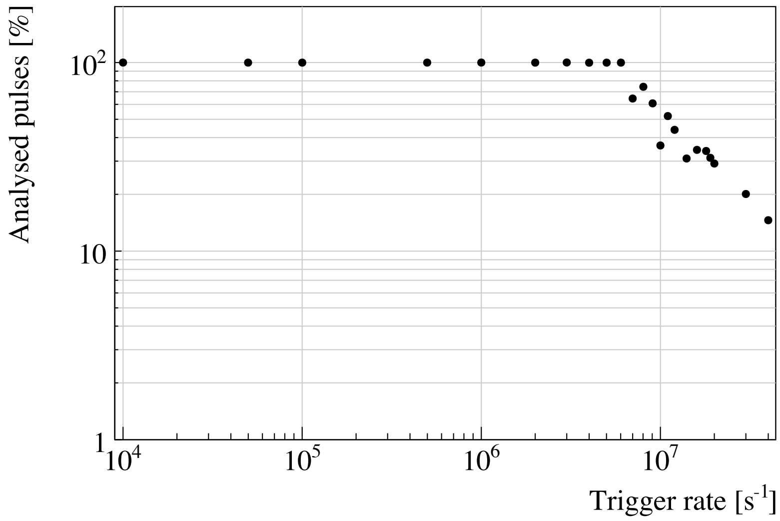

Figure 1.12: This figure shows the capability of the device to analyse all arriving pulses for a range of input frequencies. The highest achievable rate with zero lost pulses is 5×10^6 s^{-1}.

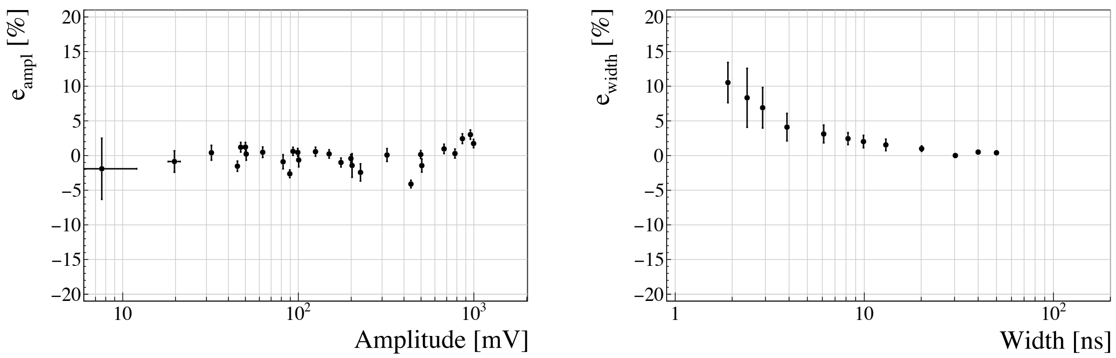

Figure 1.13: These figures show the measurement errors for amplitude (left) and width (right) across the measurement range.

the algorithm takes the peak of the signal as the maximum amplitude and these peaks are higher with a higher noise. Therefore the e_{ampl} is always positive and increasing with increasing noise. The width measurement, on the other hand, is stable even for the low SNR. The e_{width} does not exceed ± 5 %. Finally, the mean of the area measurement error e_{area} is always 0, but the spread of the error increases with noise. This means that the increased noise only affects the resolution of the measured area spectrum, not its position.

1.8.1 Comparison between the charge- and current-sensitive spectroscopy

The calibration was done using a ^{148}Gd^{239}Pu^{241}Am^{244}Cm source which emits α particles with four different energies. The PSA in combination with the current amplifier was compared against the 8-bit spectroscopic application in combination with the charge amplifier and a commercial 14-bit spectroscopic readout.

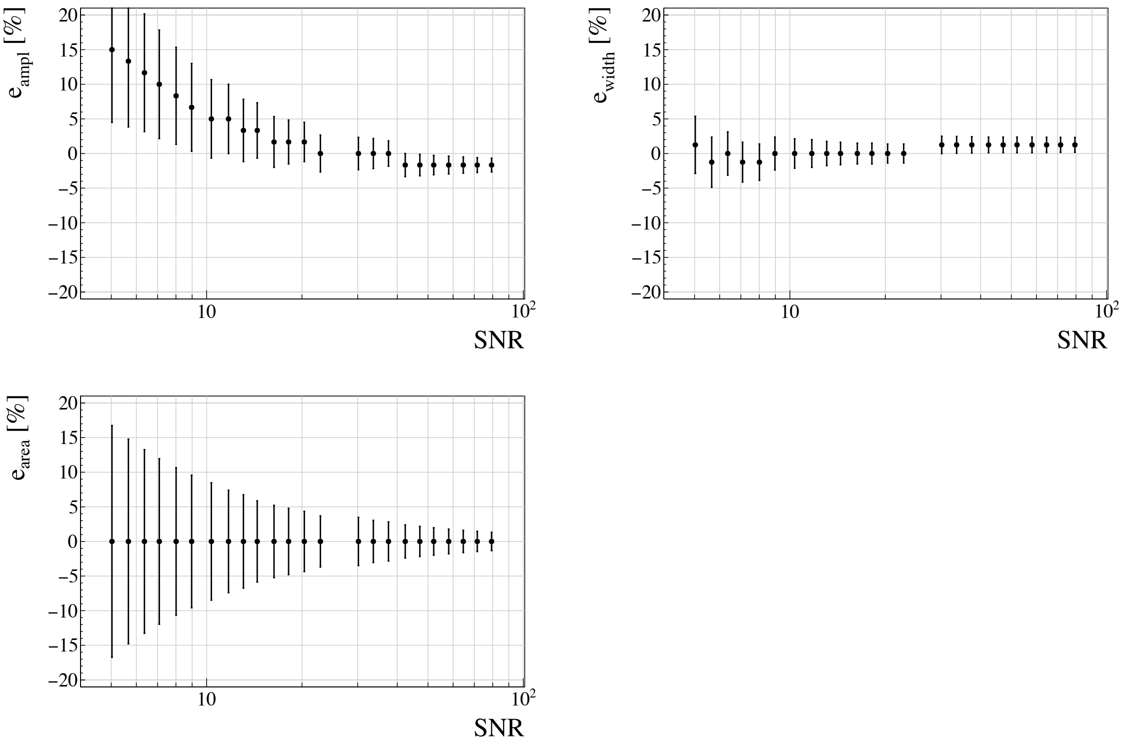

Figure 1.14: These figures show the measurements errors for amplitude (top left), width (top right) and area (bottom left) with respect to the signal-to-noise ratio.

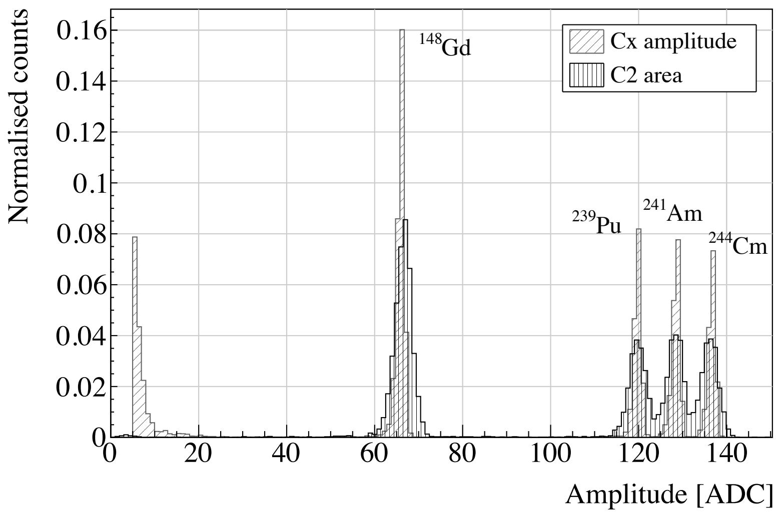

Figure 1.15: Spectrum of a ^{148}Gd^{239}Pu^{241}Am^{244}Cm source using a Cx and a C2 amplifier.

The ^{241}Am peak measured by the Cx amplifier has an RMS of 0.8 ADC, which corresponds to a 32 keV energy resolution. For comparison, the C2 amplifier measures this peak with an RMS of 1.9 ADC, which corresponds to a 75 keV energy resolution. Therefore the energy spectrum measured by the current amplifier has a lower energy resolution.