NCal position sensors characterization

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Introduction

This note provides the characterization of the NCal position sensors planned to be used on Advanced Virgo+ for O4. The goal is to monitor the position of the NCals with a precision of a few tenths of a millimeter. The datasheet of the position sensors can be found at https://www.piher.net/pdf/PS2P-LINIntroduction.pdf and the study reported here uses a PS2P-LIN-CE-M002-1-A0-L0000-ELS120-05.

1 Experimental set-up

Figure 1 shows the layout of the experiment. One part of the position sensor is fixed on a 2D positioning platform which is controlled in the x (horizontal) and y (vertical) directions. The second part of the sensor is attached to a vertical support and the gap between the two parts in the z direction is only measured via rulers. Figure 2 gives the cartesian frame as defined for our study. The sensor is supplied with 5 V and the output voltage of the sensor is read through a digital Keithley multimeter and the precision of the measurement with the position sensor is of the order of 5 mV for typical output values ranging from 1 to 4 V.

Figure 1: Layout of the position sensor characterization.

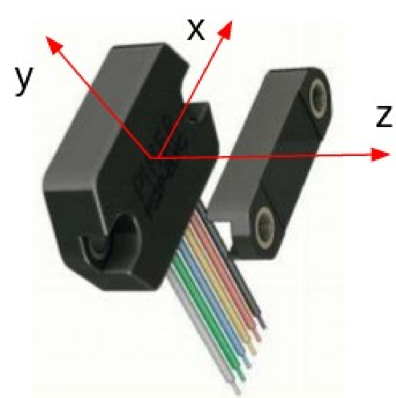

Figure 2: Cartesian frame used in the study.

2 Measurements

2.1 Sweep of the voltage supply

The nominal voltage supply for the sensor is +5 V. The specifications mention that the output voltage should be linear with the supply voltage. We perform a set of measurement spanning +4.5 V to +5.4 V and record the output voltage for the nominal position of the sensor (x=0, y=0, z = 3 mm). Figure 3 shows that the dependency is indeed linear which means that a reasonable uncertainty of ±0.1 V for a supply voltage of 5 V gives 2% uncertainty on the output voltage.

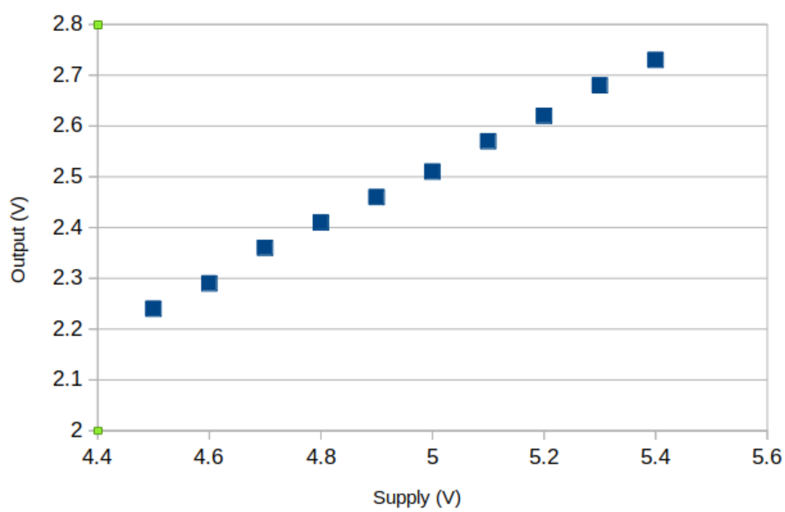

Figure 3: Voltage (V) as a function of the supply voltage. The behaviour is linear between 4.5 and 5.4 V as stated in the datasheet.

2.2 Linearity along the x-axis

The datasheet mentions a nominal air gap of z = 3 mm between the two parts of the sensor and a centering of the concentric magnet (y = 0 mm) for an optimal functioning. The horizontal displacement of the position sensor is linear between -6 and 6 mm as shown in Figure 4 which corresponds to the specifications of the product. It is reasonable to think that those position sensors will mainly be used for precision positioning which should range between -4 and +4 mm. We also checked in Figure 5 that there are no discretized steps for small values (0.1 mm) of displacement along the x-axis. We even checked further with steps of 10 µm in Figure 6.
We performed measurements to check the linearity of the position sensor along the x-axis (-4, -2, 0, 2, 4 mm) for different positions on the y-axis (-4, -2, -1, 0, 1, 2, 4 mm) and z-axis (1, 3,

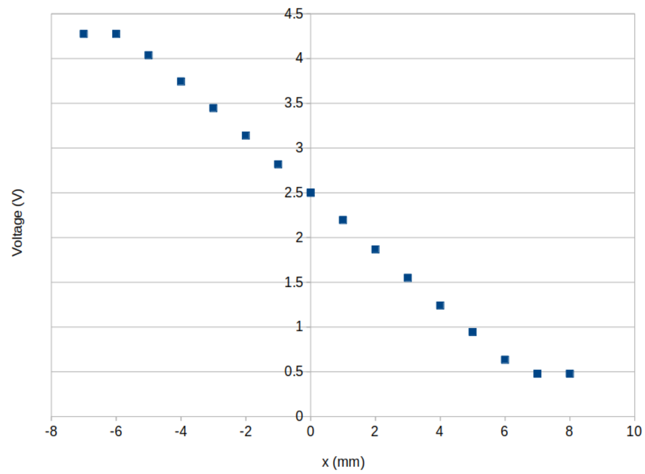

Figure 4: Voltage (V) as a function of the horizontal position x (mm). The behaviour is linear between -6 and 6 mm as stated in the datasheet and then a saturation appears for values below and above.

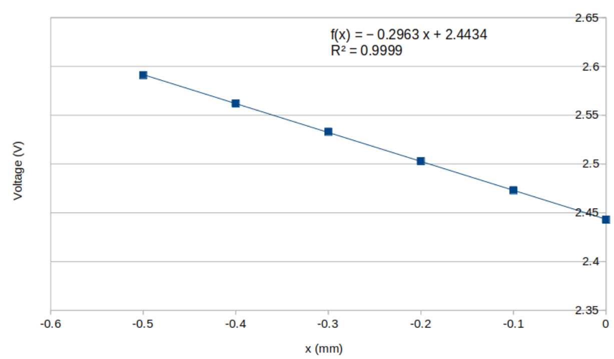

Figure 5: Voltage (V) as a function of the horizontal position x (mm). The behaviour is linear between -0.5 and 0 mm using steps of 0.1 mm.

4, 5.5, 6.5, 8 mm). Figures 7, 8, 9, 10, 11, 12 show the data points and the linear fit for the different y and z positions. The behaviour of the sensor is linear for all the cases we considered but the coupling factor (slope in V/mm) ranges from 0.298 to 0.385 and the offset (V) at x = 0 mm varies from 2.470 to 2.596.

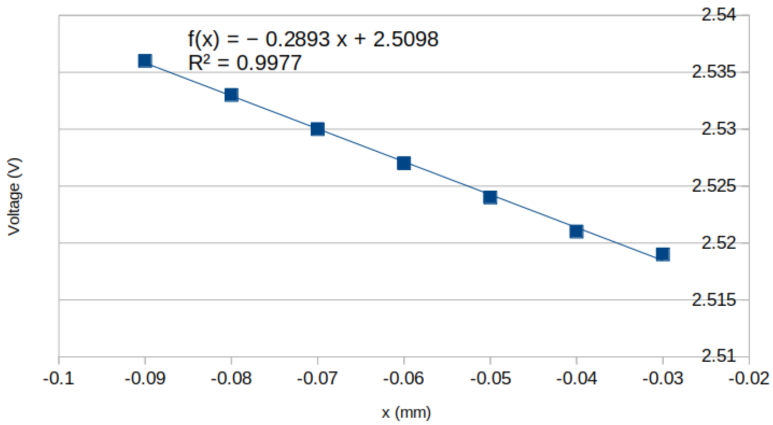

Figure 6: Voltage (V) as a function of the horizontal position x (mm). The behaviour is linear between -0.09 and -0.03 mm using steps of 0.01 mm.

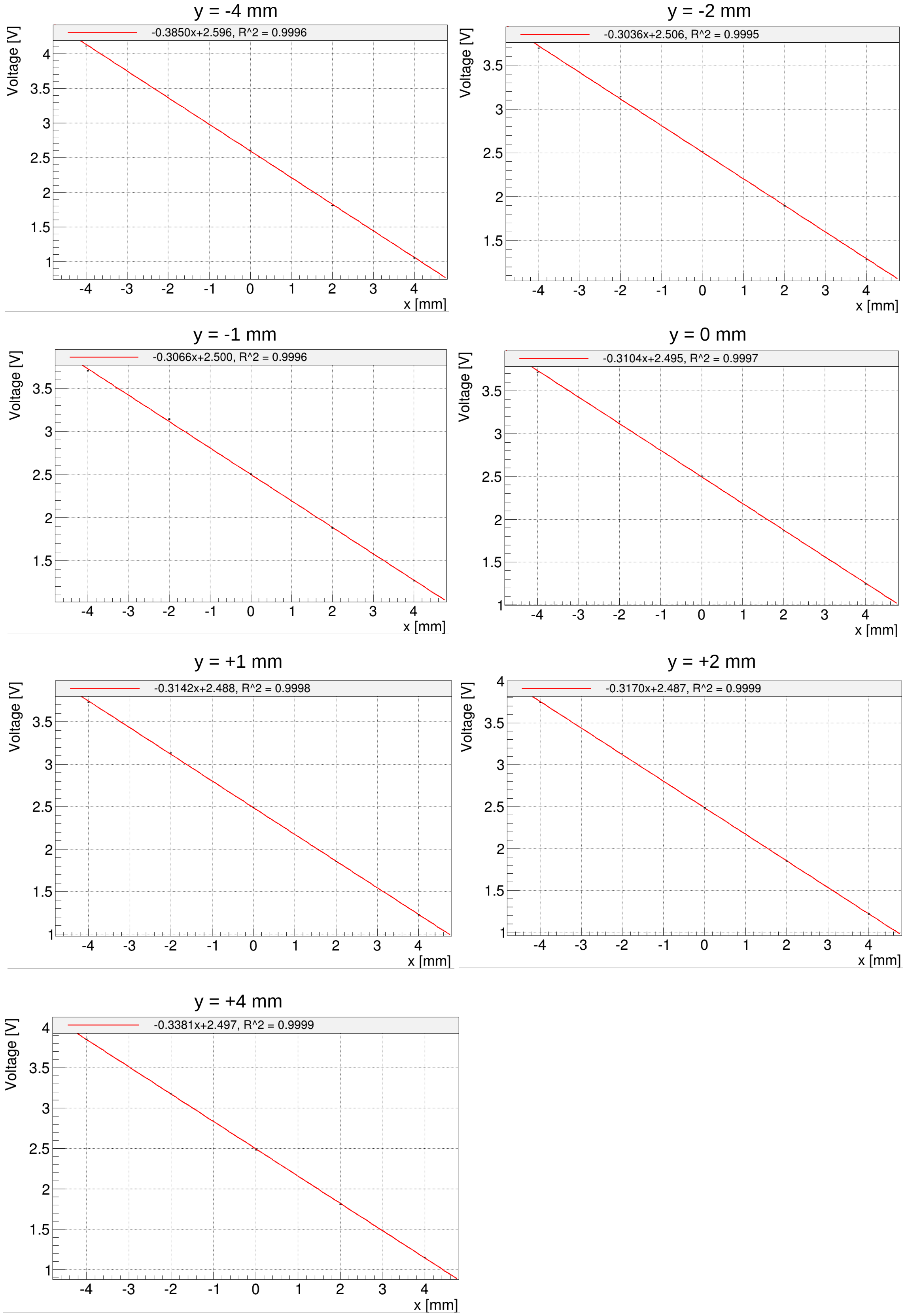

Figure 7: Linear fit of the voltage output (V) as a function of the horizontal position x (mm) for different vertical position y (mm). Gap z = 1 mm.

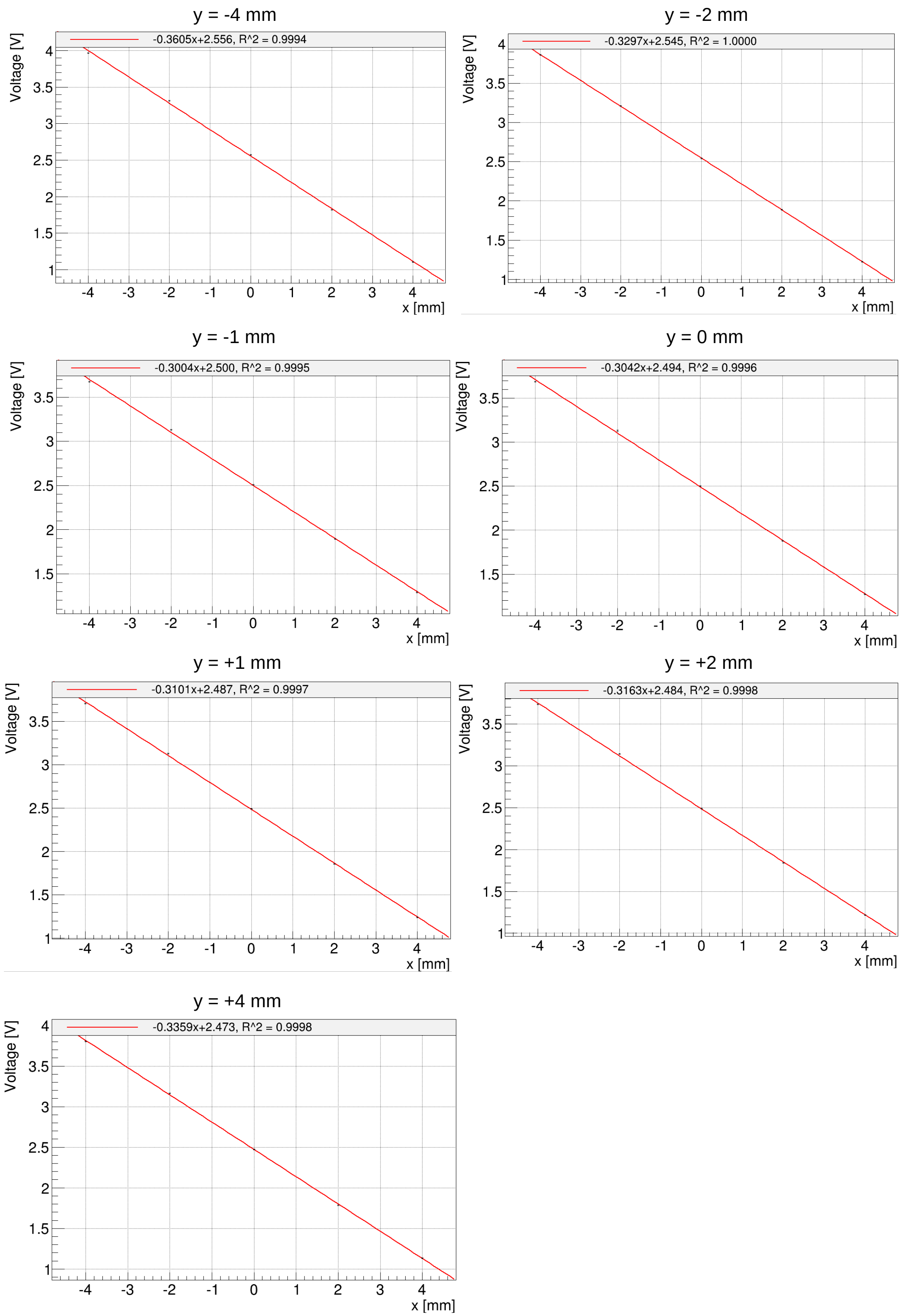

Figure 8: Linear fit of the voltage output (V) as a function of the horizontal position x (mm) for different vertical position y (mm). Gap $z = 3$ mm.

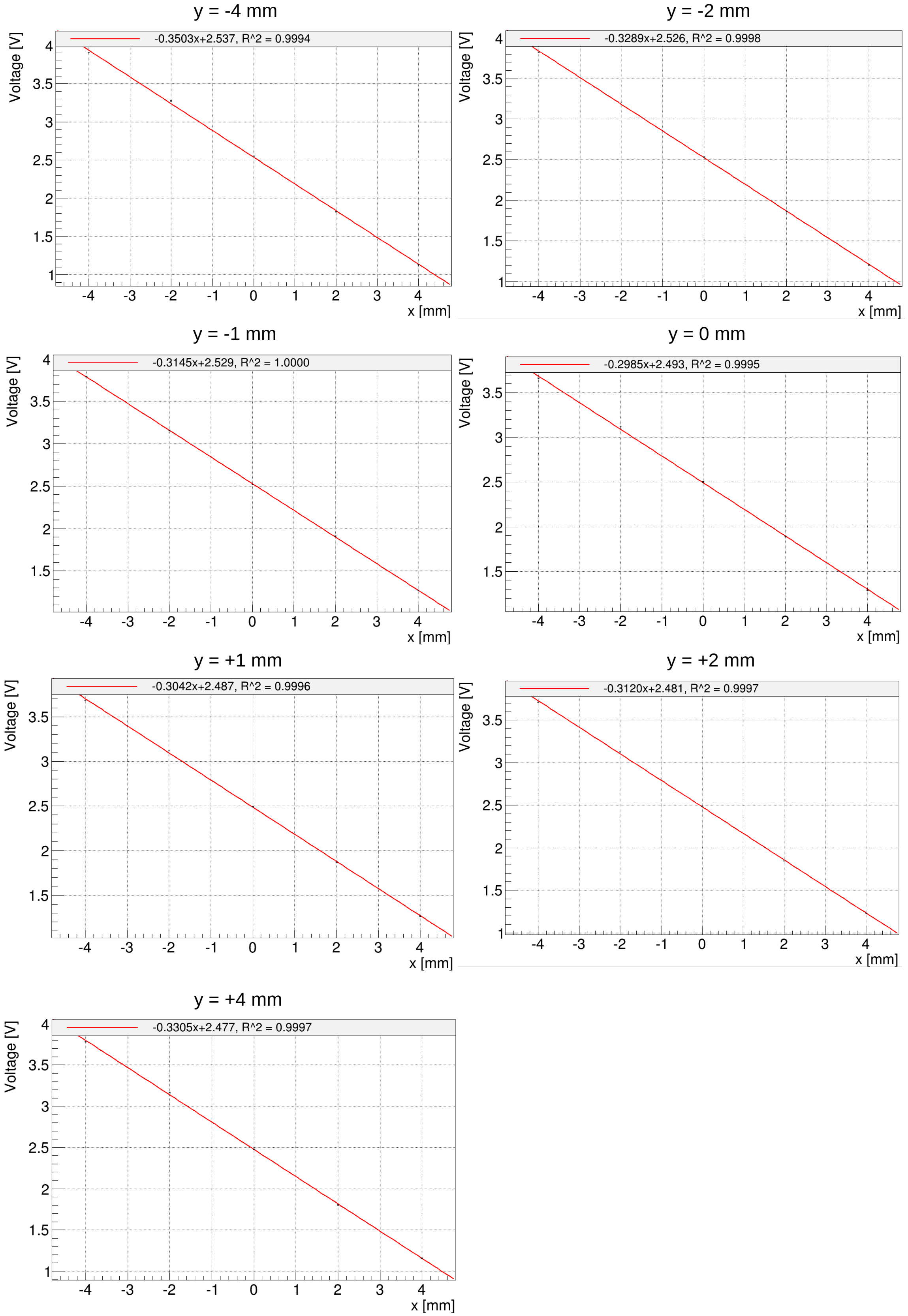

Figure 9: Linear fit of the voltage output (V) as a function of the horizontal position x (mm) for different vertical position y (mm). Gap $z = 4$ mm.

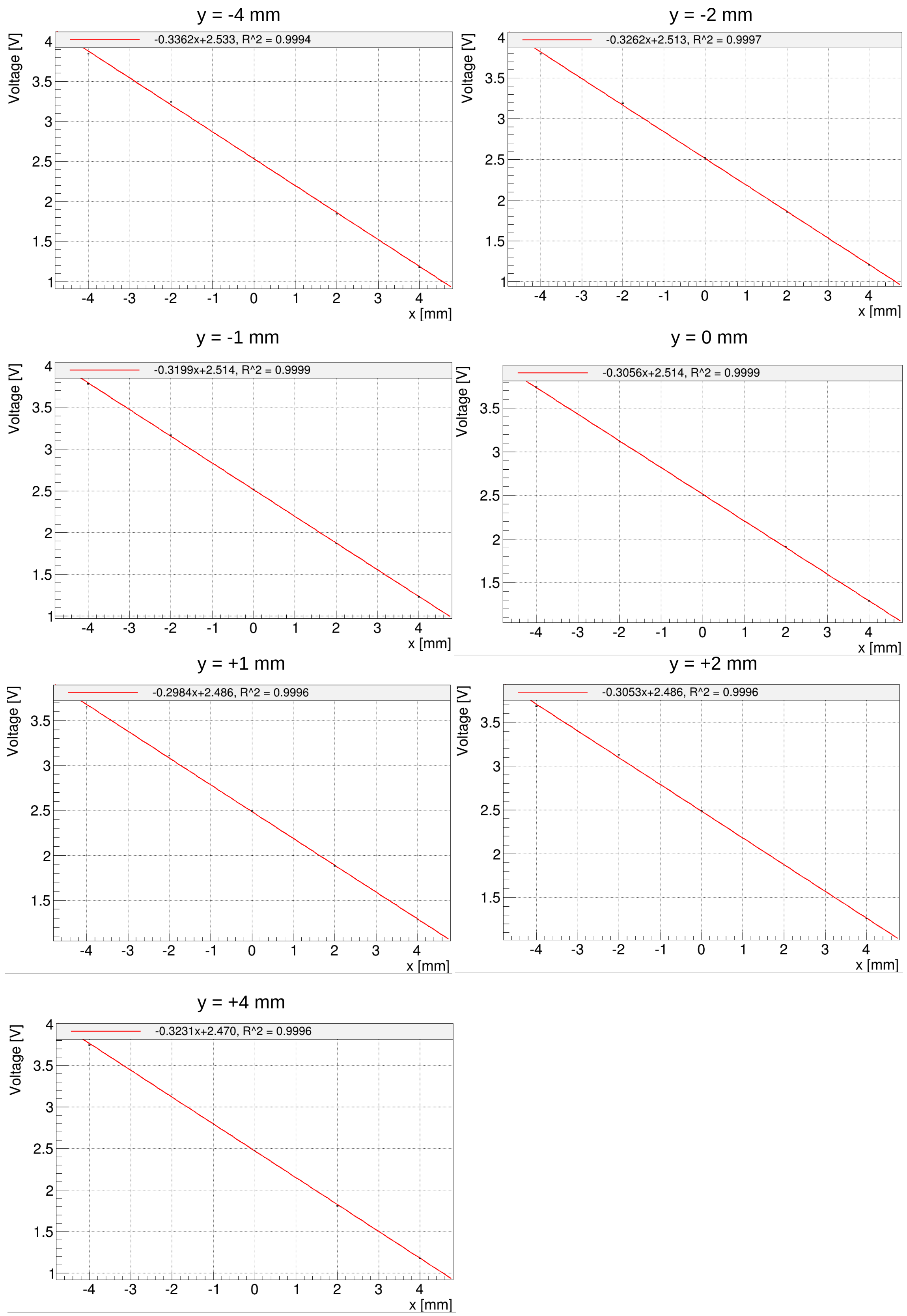

Figure 10: Linear fit of the voltage output (V) as a function of the horizontal position x (mm) for different vertical position y (mm). Gap z = 5.5 mm.

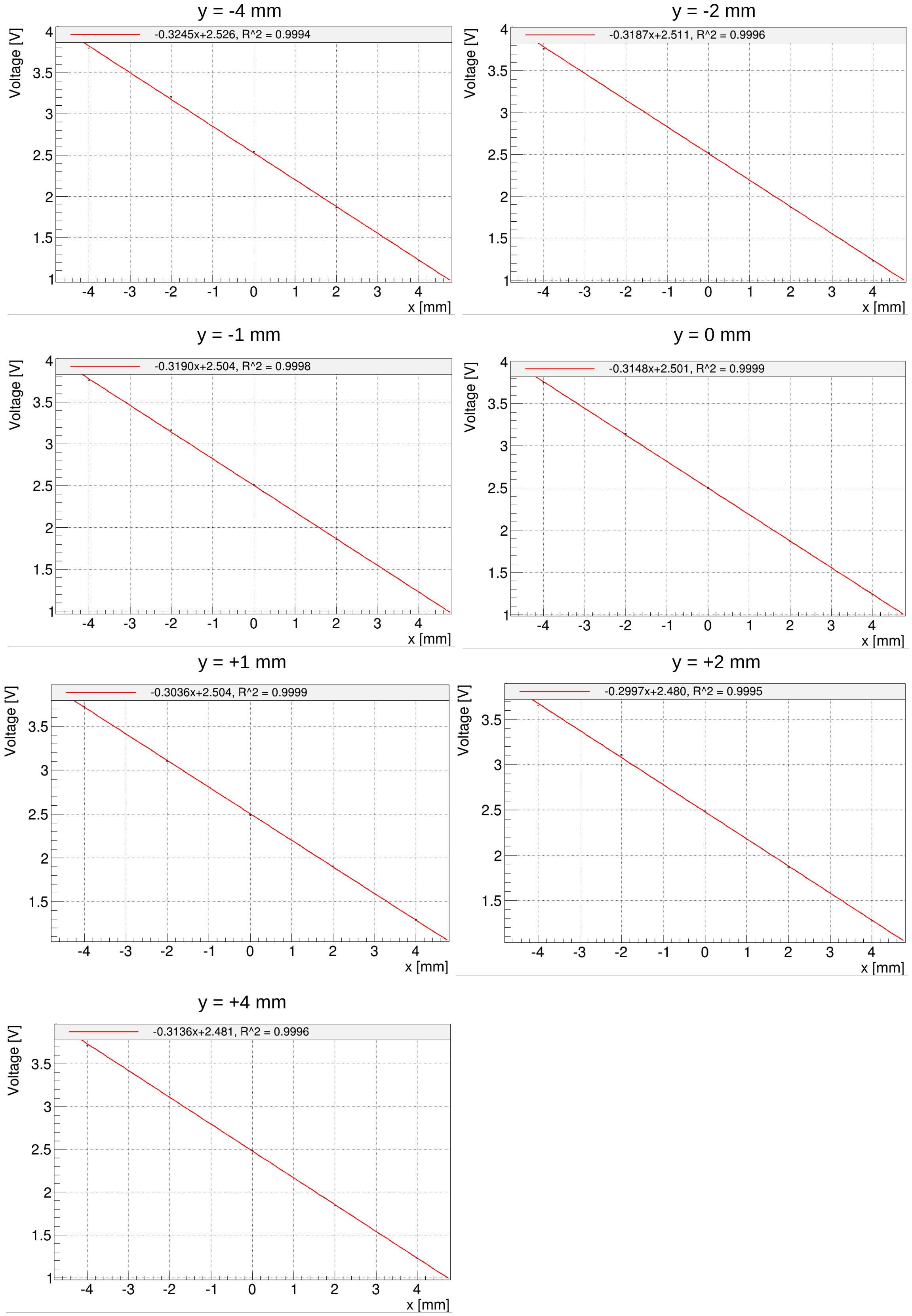

Figure 11: Linear fit of the voltage output (V) as a function of the horizontal position x (mm) for different vertical position y (mm). Gap $z = 6.5$ mm.

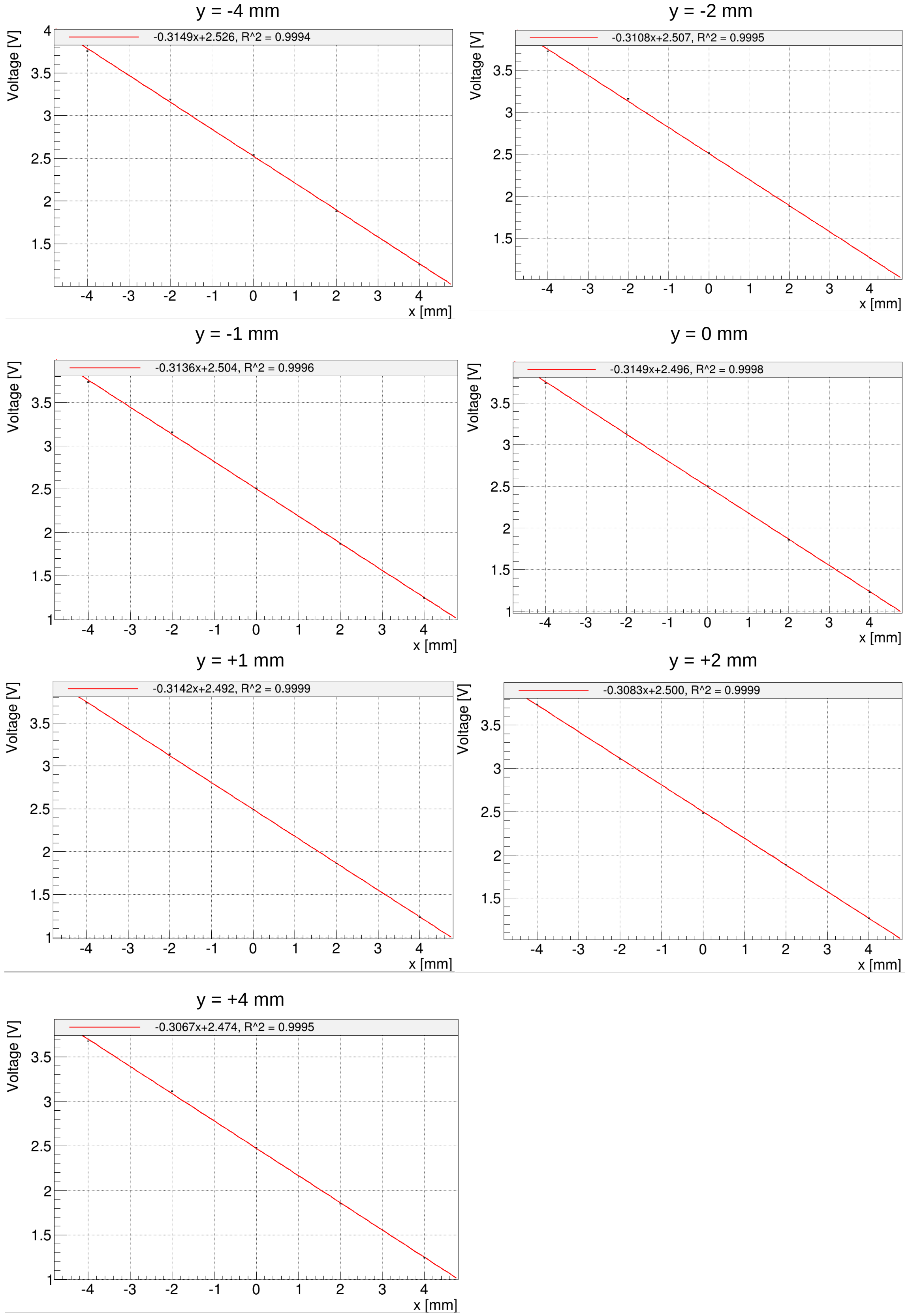

Figure 12: Linear fit of the voltage output (V) as a function of the horizontal position x (mm) for different vertical position y (mm). Gap z = 8 mm.

2.3 Coupling factor and offset stability

Figure 13 shows the coupling factors and offsets for the set of measurements performed in section 2.2. It allows us to assess the tolerance along the y-axis and z-axis in terms of positioning. Most of the variations seen in the different plots comes from the change in the y position and the change on the coupling factor (V/mm) is more significant for small values of the gap. For instance at z = 1 mm, a -4 mm offset on the y axis will give a higher coupling factor by $\sim$ 20% and the value at x = 0 mm will be higher by $\sim$ 4%. For a gap z = 4 mm (close to the nominal value) the maximum variation of the coupling factor for an offset of -4 mm on the y axis is $\sim$ 15% and the value at x = 0 mm changes by $\sim$ 2%.

3 Conclusion

The position sensor we characterized meets the requirements we need to monitor the position of the NCals for O4. In practice, the gap z should not vary significantly once the NCals are suspended and operating. We verified that the sensor works in its linear regime for a large range of values from 1mm to 8 mm and the nominal value for the gap will be chosen close to 3 or 4 mm. This value for the gap will ensure to stay within the range previously measured if the NCal support moves.

The displacement along the y-axis is the most critical parameter of the three dimensions but the effect on the sensor response is also reasonable for the precision we need. With a gap z = 3 or 4 mm, an offset of 2 mm along y changes the coupling factor by $<$ 10 %. This means that we are likely to reach a precision of a few tenths of a millimeter on the NCal position using those sensors. Combining multiple sensors in the three dimensions it will be possible to further improve the precision and have a better knowledge of the NCal position.

Eventually the uncertainty on the supply voltage could be reduced using an ADC readout of the input voltage on site but this uncertainty does not limit the precision of the measurements.

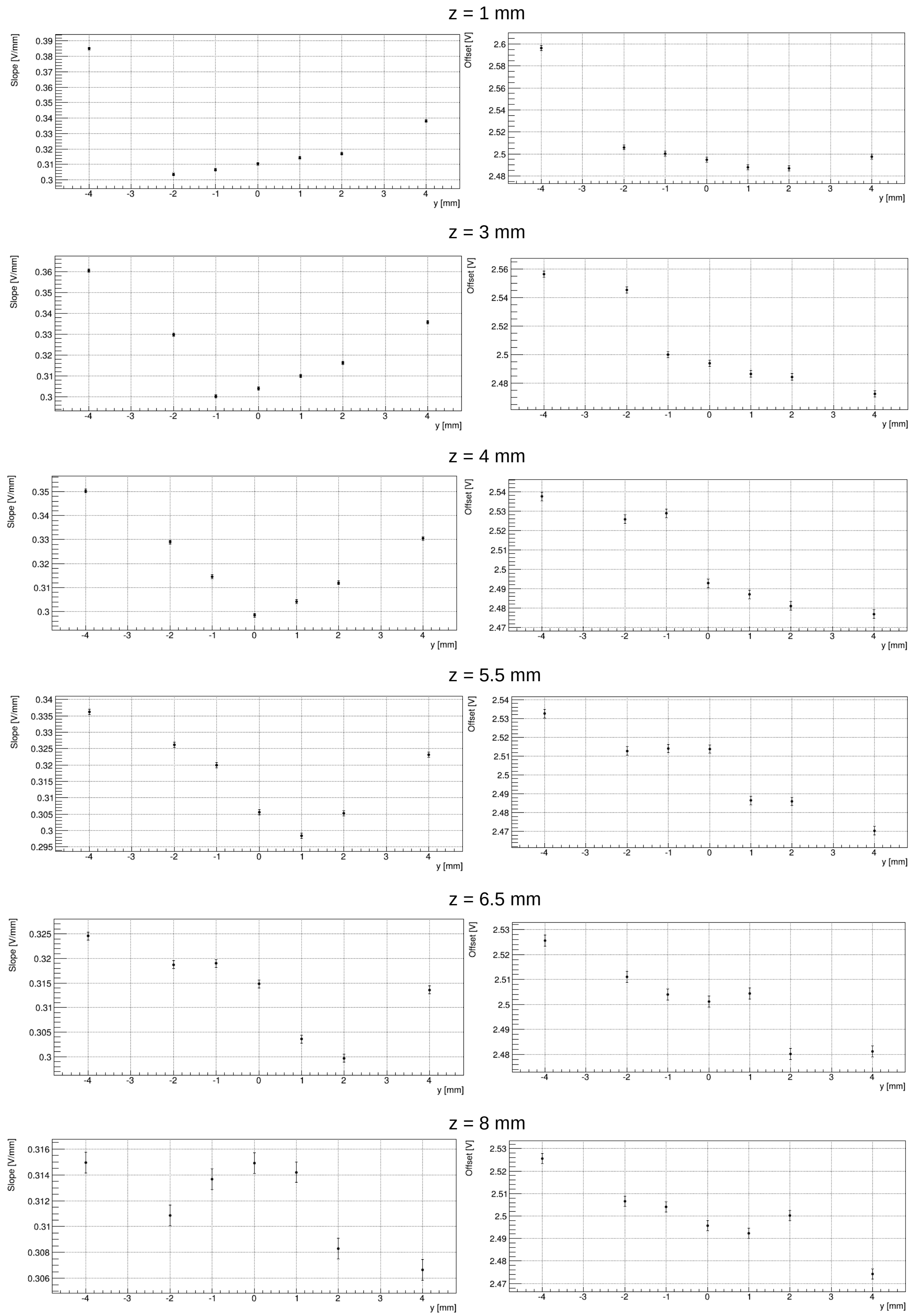

Figure 13: Slope (V/mm) and offset (V) of the linear fit as a function of the vertical position y (mm) and for different values of gap z (mm).