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NuMI Hadron Monitor – Calibration Stand

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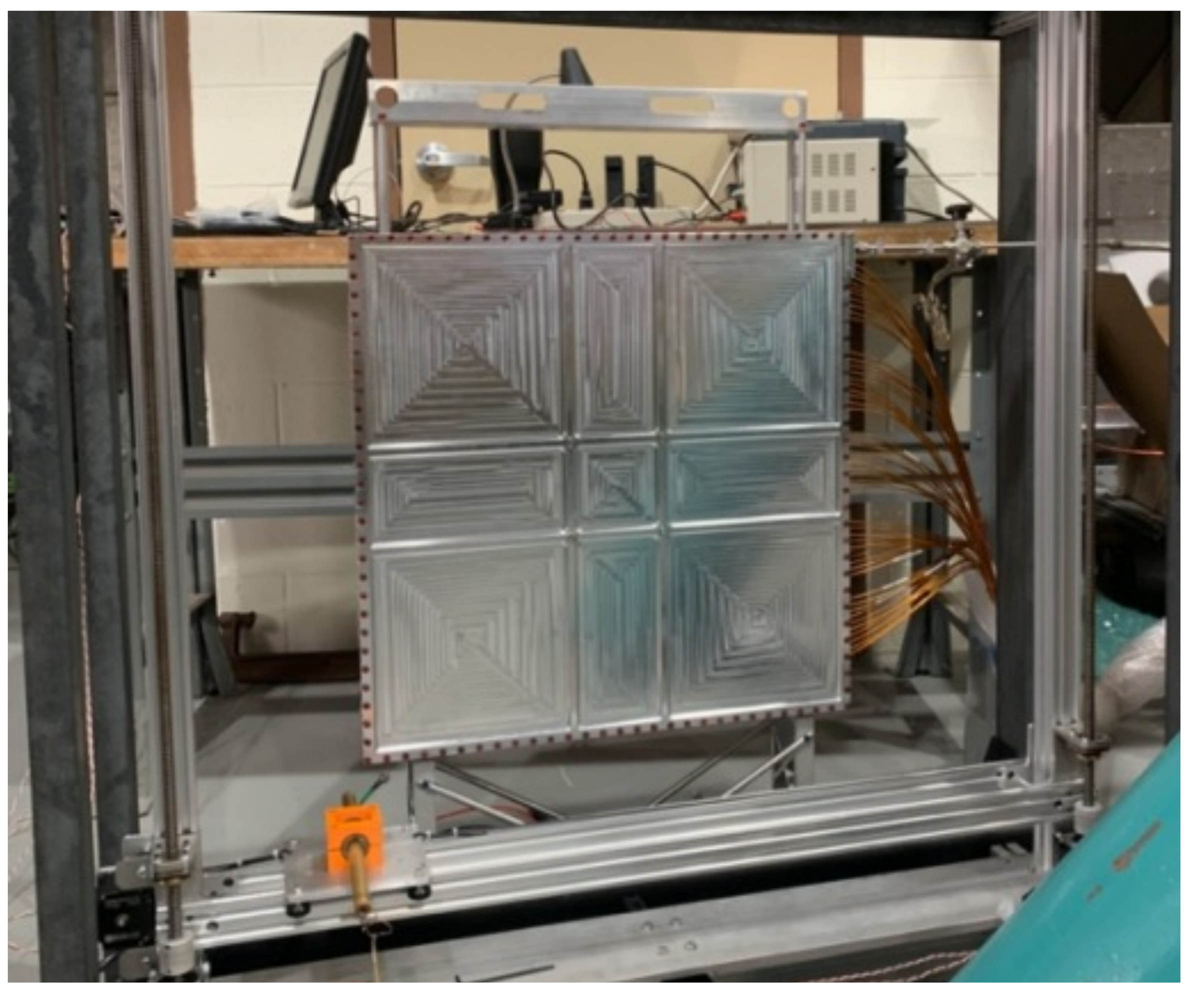
Background

The Hadron monitor consists of a 5x5 grid of square chambers that contain pure helium. Each chamber acts as a pixel in a very low-resolution 5x5 sensor, where the sensor can display the areas with the highest concentration of charged particles. Using the information from the monitor, the stand attached to the Hadron monitor will position the target to area with highest concentration of particles.

Goal

The current issue with the system is that the IR sensors display inaccurate measurements. The goal is to calibrate the sensors on the stand to display accurate readings within ±3mm.



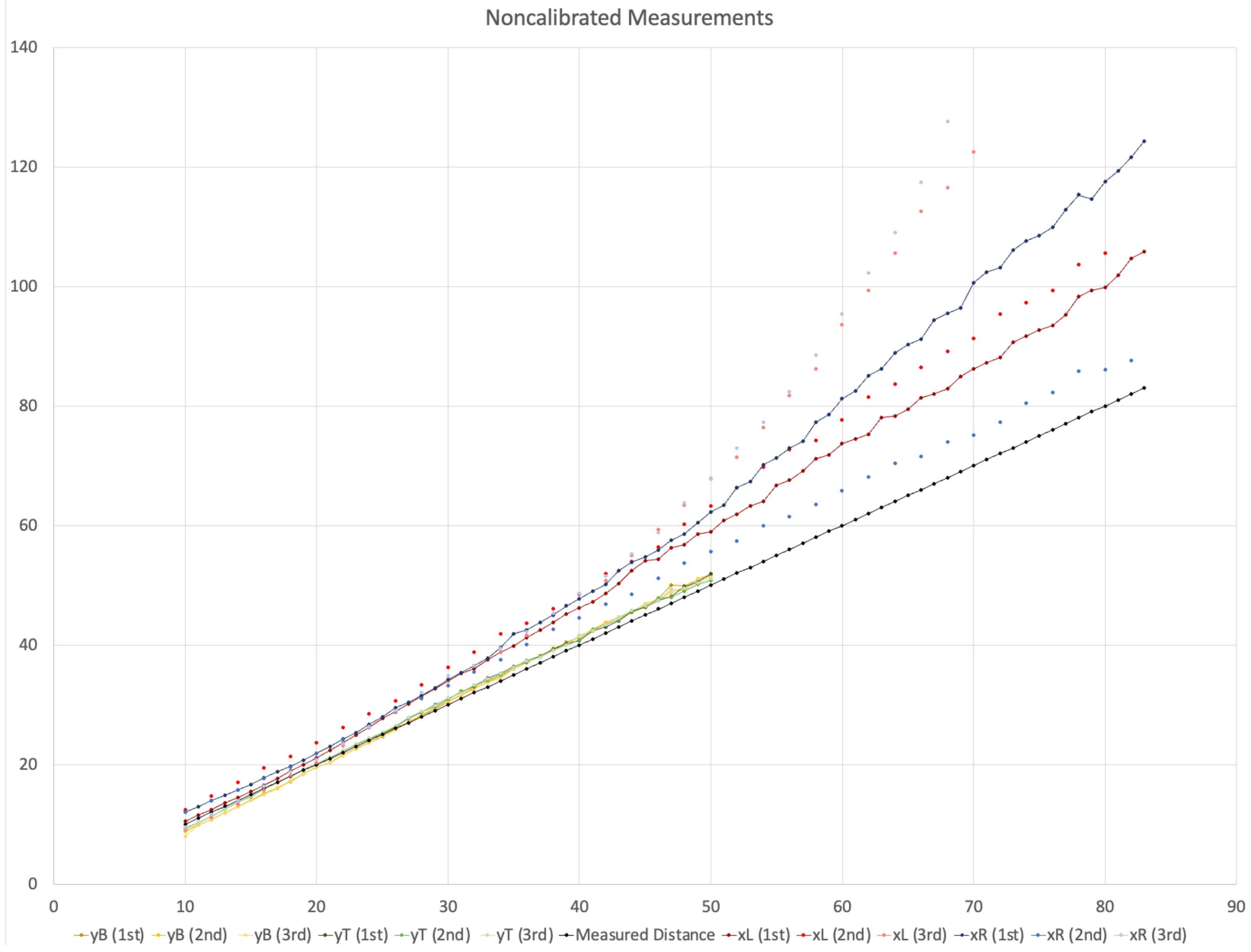
Methods and Procedure

To calibrate the sensors I need to:

- Collect and plot the raw data on a graph
- Analyze the data and find any discrepancies
- Apply a fitting curve to the graphs
- Use the formula of the fitting curve to output calibrated readings

Data was collected from four sensors: Left/Right (xL & xR) and Top/Bottom (yT & yB). It is necessary to pair two sensors for the X and Y directions, as measurements become more unstable the further you are from the sensors. It is worth noting that the manufacturer rates the sensor's readings from 10-80 cm rather than 0-80 cm, so sensors must positioned 10 cm backwards to take this into account.

Measurements were taken three times to check if outputs from the sensors are consistent and reproduceable. We notice that sensors yT and yB are quite stable and consistent with the graphs just being slightly offset. The same cannot be said however to sensors xL and xR. The graphs show the data growing exponentially and is inconsistent in terms of reproducibility.



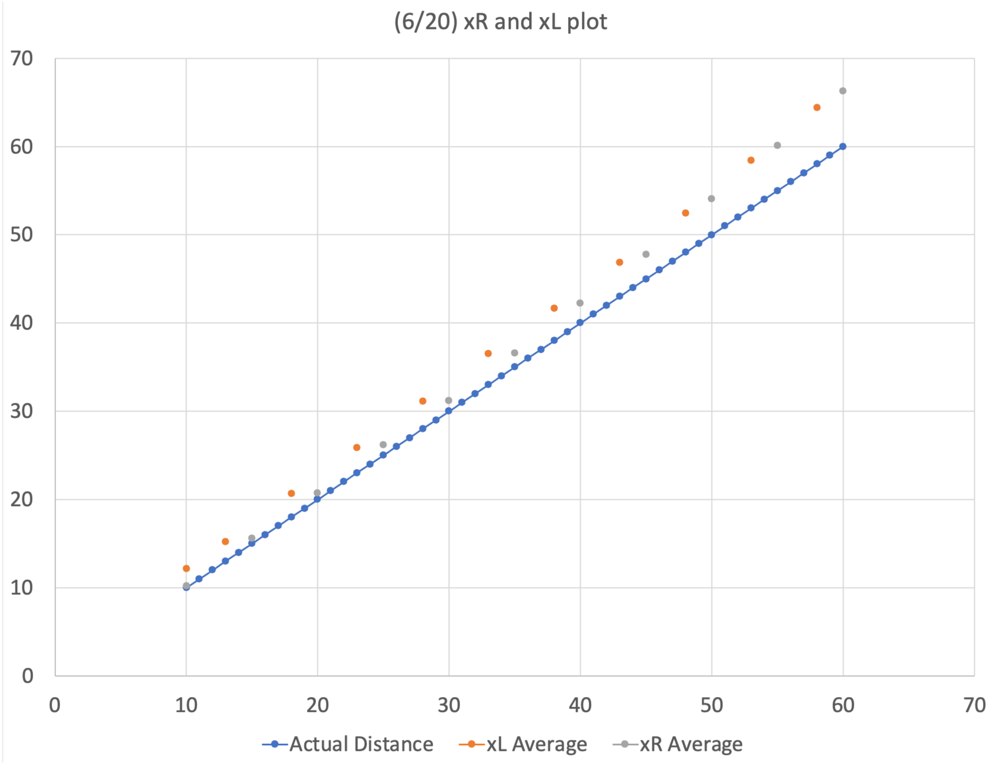
However, after reviewing the setup used to measure the sensor's output, we noticed that the metal plate used to reflect off the infrared light might've been unstable and shaky when recording data. This could be due to factors such as the plate being long and relatively thin, which could've resulted in small vibrations that went unnoticed.

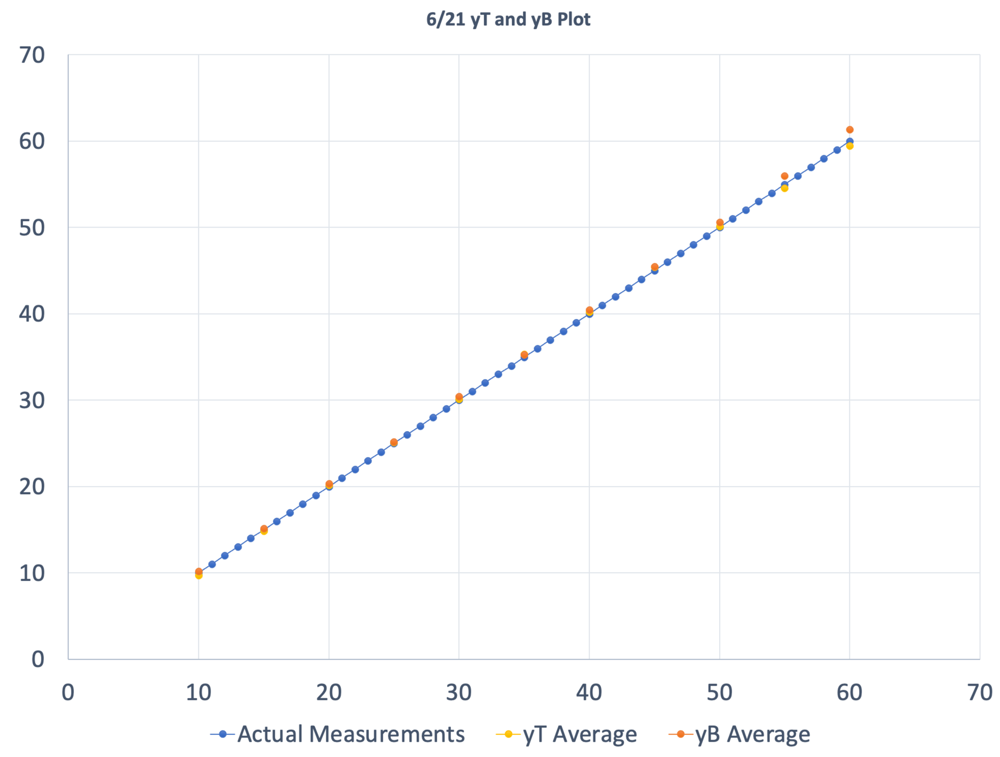
After modifying the system to stabilize any potential vibrations, we retook the measurements and resulted in more consistent, reproduceable data.

Once the new data was collected, we then took the data, inverted it, and then applied a fitting curve. The horizontal sensors needed a second degree polynomial fitting while vertical sensors only needed a linear fitting. Inverting the axes of the graphs simplified the calculations as they would circumvent the need for the quadratic formula as the graph output would spit out the calibrated measurements since we wouldn't need to find x.

Results

All of the sensors have been calibrated to a range 10-50cm, which provides 40cm of accurate, calibrated ouputs. Sensors yT and yB output incredibly accurate readings, while xL and xR are quite accurate in the the range of 10-25cm, but they need better calibration beyond those ranges as they can be off by 0.5-2 cm from the actual distance.





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