Building and Programming a Multi-Detector Reconstruction of the Rutherford Experiment

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Introduction

The aim of this summer placement was to research, design and develop a modern reconstruction of the Rutherford Experiment[1] for RAL to use during outreach events. The experiment is an example of a major turning point in particle physics and demonstrates the discovery of the structure of the atom. It also displays the iterations of modern particle detectors with an array of three types of silicon-based sensors. All the data from the sensors was collected and calibrated by code written during the project and the monitoring system Prometheus along with the Grafana interface was used to display the experimental data in real time.

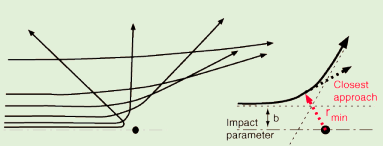


Figure 1: Rutherford Scattering experiment [2]

Detectors

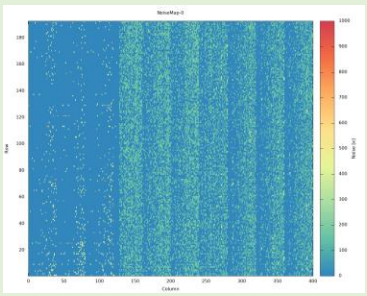
This project involved using modern detectors in the place of the fluorescent screen originally used. There were a few options available as spare parts and old test samples were used for the setup. Initially, we planned to trial each detector and choose one, however the idea of a multi-detector array was proposed.. As this was an experiment designed for outreach rather than data collection, the differences between detectors wasn't an issue as there was no need for precise data readings, just an indication of a hit/no-hit on the detectors. As such, multiple detectors could be calibrated to fit together, detecting a visual of representation of the data that can be used to show what is happening in real time. The three types of detectors used in the array were the single-chip version of the ITkPix sensor[3], the silicon photomultiplier (SiPM)[4] and a SPM Micro V2 (aka John) sensor. These are a good indicator of the different iterations of particle detectors over the past few decades and enables us to display the various detector types used in particle physics as an add-on to the outreach project.

Figure 2: Cosmic watch sensor (top) and silicon sensor (bottom)

Software

We used a combination of techniques in order to display the data collected in the experiment live on both OLED screens and using a Grafana dashboard. The cosmic watch and the (small silicon detector) are both connected to a raspberry pi and each hit from an alpha particle sends a signal to the pi where a piece of code is run creating a histogram bin for each detector and displaying it on the Grafana dashboard. The pixel detector, however, is more complex due to its readout method and has its own processing system.

Figure 3: single-chip pixel sensor from RAL, soon to be used in next ATLAS update



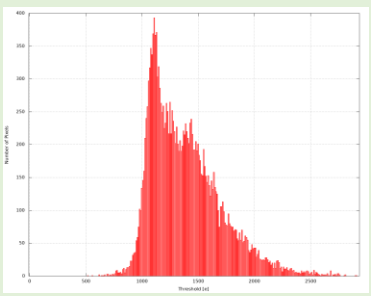


Figure 4: Background noise map from ITk sensor(above) and background threshold distribution (below)

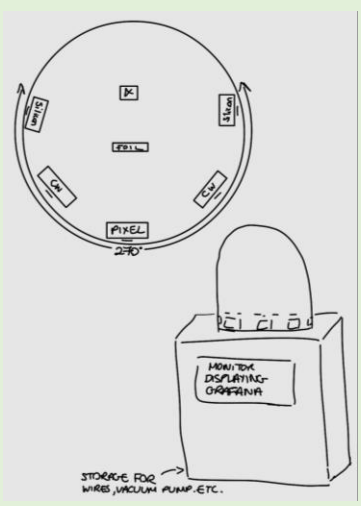


Figure 5: Experimental setup for Scattering Experiment

Project Reflections

This project has involved learning many news skills such as the use of C++ (a coding language neither students had used before), building hardware, using an open monitoring system such as Prometheus and learning how to record data from sensors such as the ITk pixel sensor.
Aside from the practical skills learnt, the placement has also given us the opportunity to experience what work in an academic/research capacity entails.

References: [1] E. Rutherford, "The Scattering of α and β Particles by Matter and the Structure of the Atom", *Philosophical Magazine*. Series 6, vol. **21**. May 1911, [2] *Rutherford Scattering*. (n.d.). Hyperphysics.phy-Astr.gsu.edu. http://hyperphysics.phy-astr.gsu.edu/hbase/Nuclear/rutsca2.html, [3] Crescioli, F., Dalla Betta, G.-F., & .et al. (2022). Test of ITk 3D sensor pre-production modules with5 ITkPixV1.1 chip. *ATL-ITK-PROC-2022-013*. [4] Axani, S.N., Frankiewicz, K. and Conrad, J.M. (2018) *CosmicWatch: The Desktop Muon Detector Instruction Manual* [Preprint]. Available at: http://www.cosmicwatch.lns.mit.edu/.

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