Mapping for a Cylindrical Micro-Resistive Well Detector

Requirements Document

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2 February 2026

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1. Introduction

1.1 Purpose

The purpose of this document is to define the requirements for a data processing system designed to analyze the efficiency and spatial resolution of a cylindrical micro-resistive well detector. This document will establish the functional, performance, interface, and reliability requirements for the product. Outlining these specific requirements will relieve ambiguities in the expectations between the developers and the clients.

1.2 Scope

This project aims to provide support for physicists so their data can be more easily accessed and visualized. The proposed software will operate as an analysis tool to be used after data acquisition. Therefore, although external interfaces are described in this document, we will not interact with the hardware directly.

1.3 Definitions

The following terms, acronyms, and abbreviations will be used frequently throughout this document and future communications regarding the product.

Detector- A detector is a device used in particle physics to measure the position of charged particles.

µRWELL (Cylindrical micro-resistive well detector)- µRWELL is a type of micro-pattern gaseous detector that combines gas electron multiplication with a resistive protection layer and a segmented readout structure to measure charged particles with high precision [1]. Designing a detector that is cylindrical is the novelty here.

Tracker- In the context of this project, a tracker refers to an external planar detector. Four trackers are used to create a reference system for evaluating the efficiency of the cylindrical detector.

Readout board- A readout board is an electronic circuit board that collects signals from detector channels. The readout board hosts APV chips and interfaces between the detector strips and the data acquisition system. Each readout board can only capture a single plane of the data. So in planar detectors, typically there is one for x and y positions, respectively.

Channels/strips- Channels or strips are the readout elements on the detector surface that collect charge from ionization events. Each strip is connected to a specific APV channel. Strip signals are used to reconstruct particle hit positions.

APV chip (Analog Pipeline Voltage chip)- An APV chip samples analog signals from each channel on the readout board in time bins.

Time bin- A time bin is a discrete time sample recorded by the APV chip. Typically, 12-16 time bins are used to reconstruct the pulse shape of a beam.

ADC (Analog to Digital Converter value)- ADC represents a numerical value for the current recorded on a particular strip.

AMORE-SRS (Analysis and Monitoring Of Readout Electronics and Scalable Readout System)- AMORE-SRS is a live data acquisition framework for monitoring and organizing the data from the APV chips into a root file for analysis.

Root file- The root file stores event data such as strip information, ADC values, and metadata. The data is organized into branches that correspond to specific variables.

3D Pulse plot- A 3D pulse plot is a visualization of a single event where the x axis is time bin, the y axis is the strip number, and the z axis is the ADC value.

Resolution plot- A resolution plot is a reconstruction of the 2d hit positions represented as a heat map.

Efficiency plot- Efficiency plots compare the detectors efficiency against other performance characteristics such as amplification or drift field. Efficiency itself is defined as the ratio of the number of events with strip clusters seen in all five detectors divided by the number of events with strip clusters seen in just the four trackers [2].

1.4 References

[1] K Gnanvo, N Liyanage, B Mehl and R Oliveira, Performance of a resistive micro-well detector with capacitive-sharing strip anode readout. Nuclear Instruments and Methods (2022).

[2] M Lavinsky, J Hadley, M Hohlmann and A Zhang, Construction and Beam Test of a Low-Mass GEM Detector with Large Area. Nuclear Instruments and Methods (2025).

2. Product Overview

2.1 Product features

This proposed software program will be an analysis tool for physicists to aid their development and testing of a cylindrical micro-resistive well detector. The μRWELL analysis software will:

- Update and correct APV channel-to-strip mappings within root data files
- Filter noisy data to select the best candidates for analysis
- Reconstruct two-dimensional hit positions and automatically generate resolution plots
- Automatically calculate and generate efficiency plots
- Process multiple root data files in an automated pipeline

2.2 User interfaces

The physicist will initiate the pipeline by running our program from the command line. They will then be prompted to select the root file or a folder of root files for analysis. The user will select their file/s from a file explorer window popup. The user can then select what types of plots they would like generated from the data (e.g., pulse plots, resolution plots, efficiency plots). Through this interface, the user can also adjust various data analysis attributes including but not limited to:

- ADC thresholds for detecting good event candidates
- Methods for noise reduction
- Procedure type for handling event collisions on the same strip
- Performance characteristics to plot against efficiency

There will also be default parameters set based on the physicists recommendations so selection is not necessary and the process can be streamlined. The program will output a folder containing the desired plots in their specified file format for the physicist to easily view and access.

3. Specific requirements

3.1 External interfaces

The complete pipeline for this work begins with the μRWELL and ends with the generated data plots. Firstly, the readout boards on the μRWELL collect signals from detector channels. These signals are sampled in time bins on the APV chips. The AMORE-SRS collects this data and organizes it into a root file. Next, our proposed software would use this root file to perform various types of analysis and output desired visual representations. So although it's important to specify how our proposed software relates back to the hardware, our program will primarily interface with the user and the root file alone.

3.2 Functions

3.2.1 Channel mapping

- The system must support six APV chips with 128 channels each.
- The system must correctly maintain classification for strips by their global channel numbering and local orientation respectively.
- The system must preserve all existing branches and metadata while updating the mapping without data corruption.

3.2.2 Hit reconstruction

- The system must reconstruct 2D hit positions based on the adc values for strips in different planes on the same event.
- The system must perform Gaussian fitting on strip clusters with a 10% peak threshold for cluster definition.
- The system must compare alignment between the cylindrical detector and the external trackers.

3.2.3 Resolution plot generation

- The system must use the hit reconstruction data to generate resolution plots.
- The system must use color or depth as the third dimension for the adc values which would very clearly highlight potential dead channels.

3.2.4 Efficiency calculation and plot generation

- The system must use data from all five detectors to calculate the efficiency ratio for the cylindrical detector.
- The system must generate efficiency plots versus selected performance parameters.

3.3 Performance requirements

Our µRWELL analysis software must adhere to the following performance requirements:

- Processing a single root file should take under ten minutes.
- The program should support batch processing without halting between files.
- The memory constraints of a standard laboratory computer should not be exceeded.
- The program should not fail silently.

3.4 Reliability

To ensure our software is reliable, significant preprocessing will be performed on the data. First the system will inspect the root file structure to detect missing or corrupted branches. There will also be sanity checks on the numerical values of particular attributes to ensure they are within their expected ranges. For example, local strip numbers should always only be between 0-128. Of course, our system will log all relevant processing steps and errors during its execution.

3.5 Maintainability

For the longevity and portability of the project, the software will be modular, encapsulating the mapping, reconstruction, and plotting into separate components. The program will also be well documented through inline comments as well as a detailed readme file. Clear documentation will allow future physicists and/or developers to continue expanding the software. Additionally, all source code will be version controlled using Git.