

# Advancing *otsdaq* for Optimized Data Acquisition

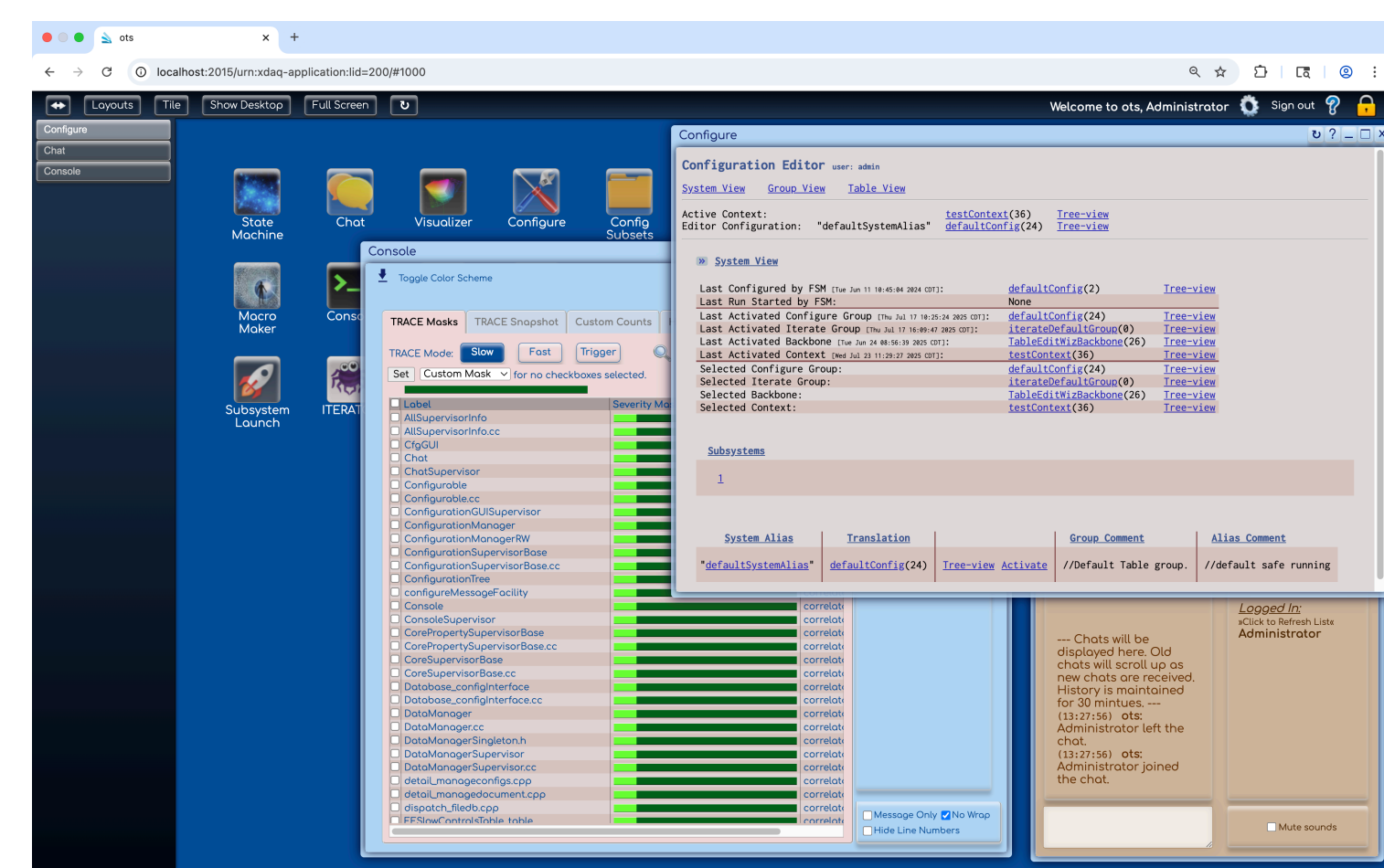
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High-energy physics (HEP) experiments demand data acquisition (DAQ) systems capable of orchestrating complex detector operations, high data throughput, and responsive, real-time feedback. Traditional systems often have steep learning curves, making onboarding difficult for new users. The Off-The-Shelf Data Acquisition (*otsdaq*) framework was developed to address these issues by providing a modular and flexible interface that is easier to operate while remaining customizable enough for experimental setups. As the upcoming Mu2e experiment prepares for deployment, improving stability, usability, and performance has become increasingly critical. Our work enhances *otsdaq* with features that streamline visualization, correct data metrics, improve debugging workflows, and stabilize the user interface.

## The *otsdaq* Software

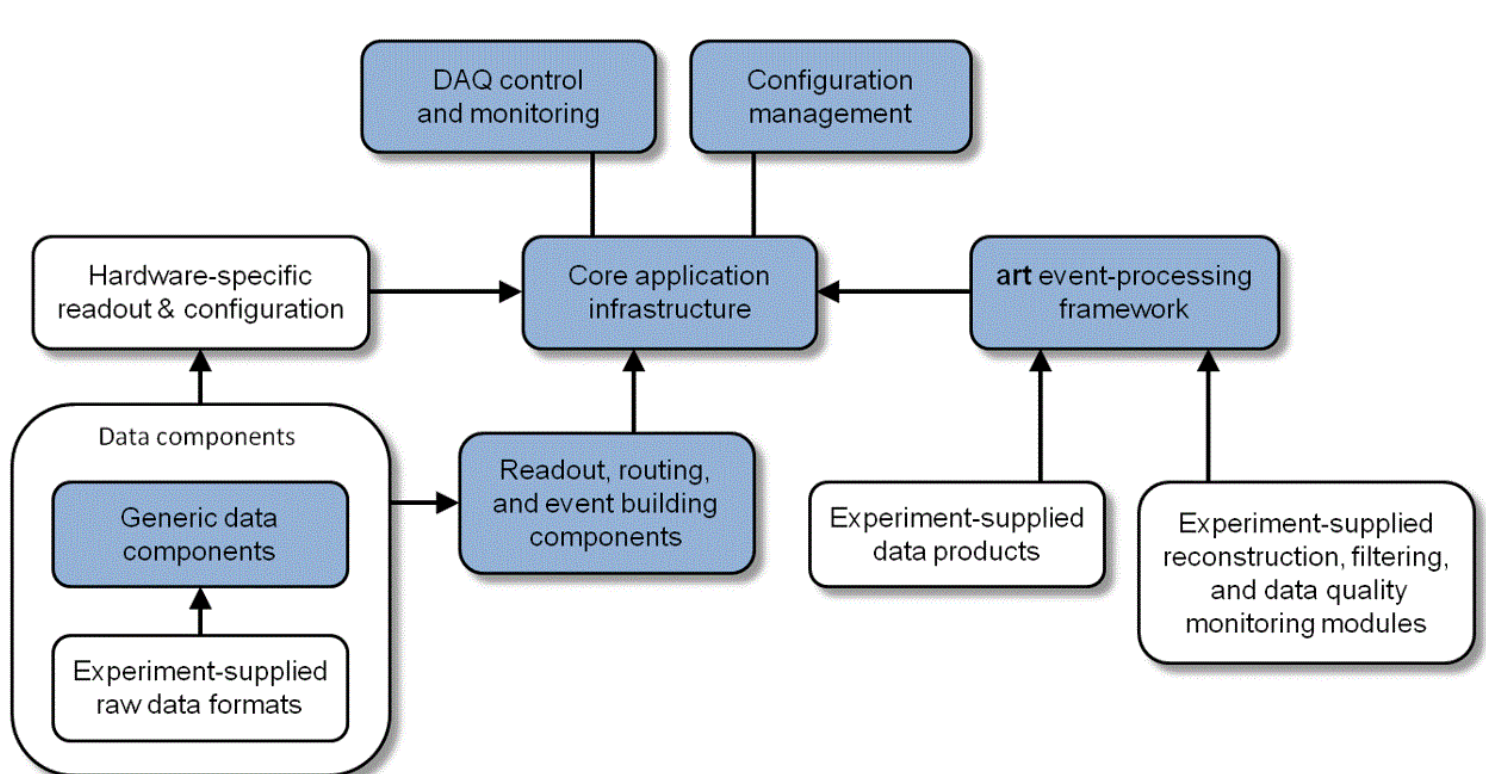
The *otsdaq* software is a web-based DAQ framework that exposes hardware control, configuration management, run operations, and monitoring through a simple and intuitive browser interface. The software is organized as a desktop in a browser, and each tool acts as its own application. Each app can be customized to a specific need, or a new application can easily be developed to meet experimental or operational requirements. Our project focused on targeting high-priority bugs and software gaps to enhance various features of *otsdaq*.



The *otsdaq* user interface with multiple open applications, including the configuration viewer, console app, and chat app

## Contributions

We implemented a dynamic bitmap visualization feature that converts large configuration matrices into intuitive images, making quality checks faster and more accurate. DTC throughput metrics were reworked to use delta-based calculations, yielding accurate, real-time rates essential for data optimization. Functionality for Source navigation to remote GitHub source files was added and implemented. Enhanced export features for macro execution history were created. User interface stability was improved by implementing custom JavaScript hooks to replace problematic native functionality.



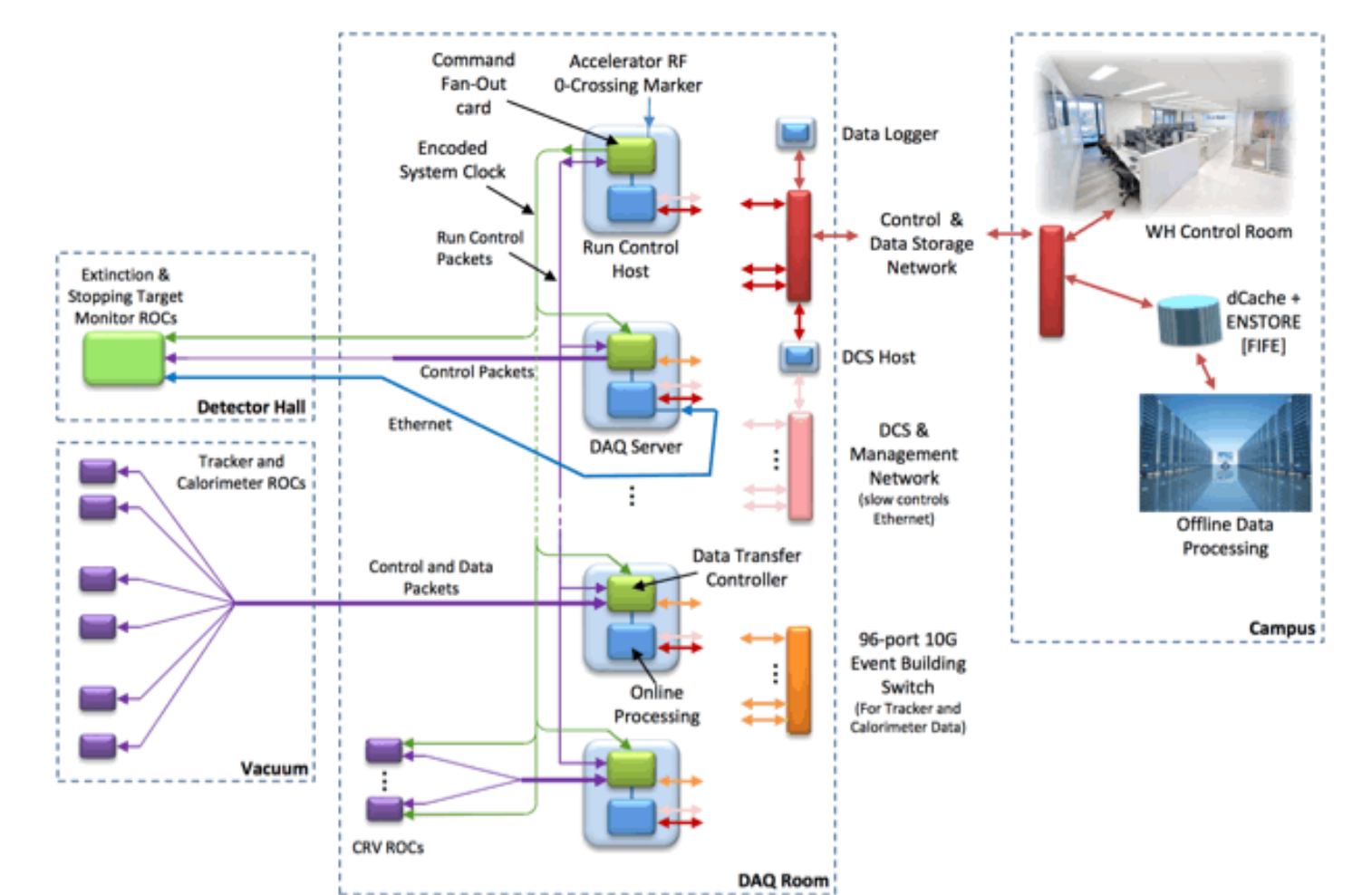
High-level software overview of the *otsdaq* system for the Mu2e experiment (Mu2e Collaboration)

## The Mu2e Experiment

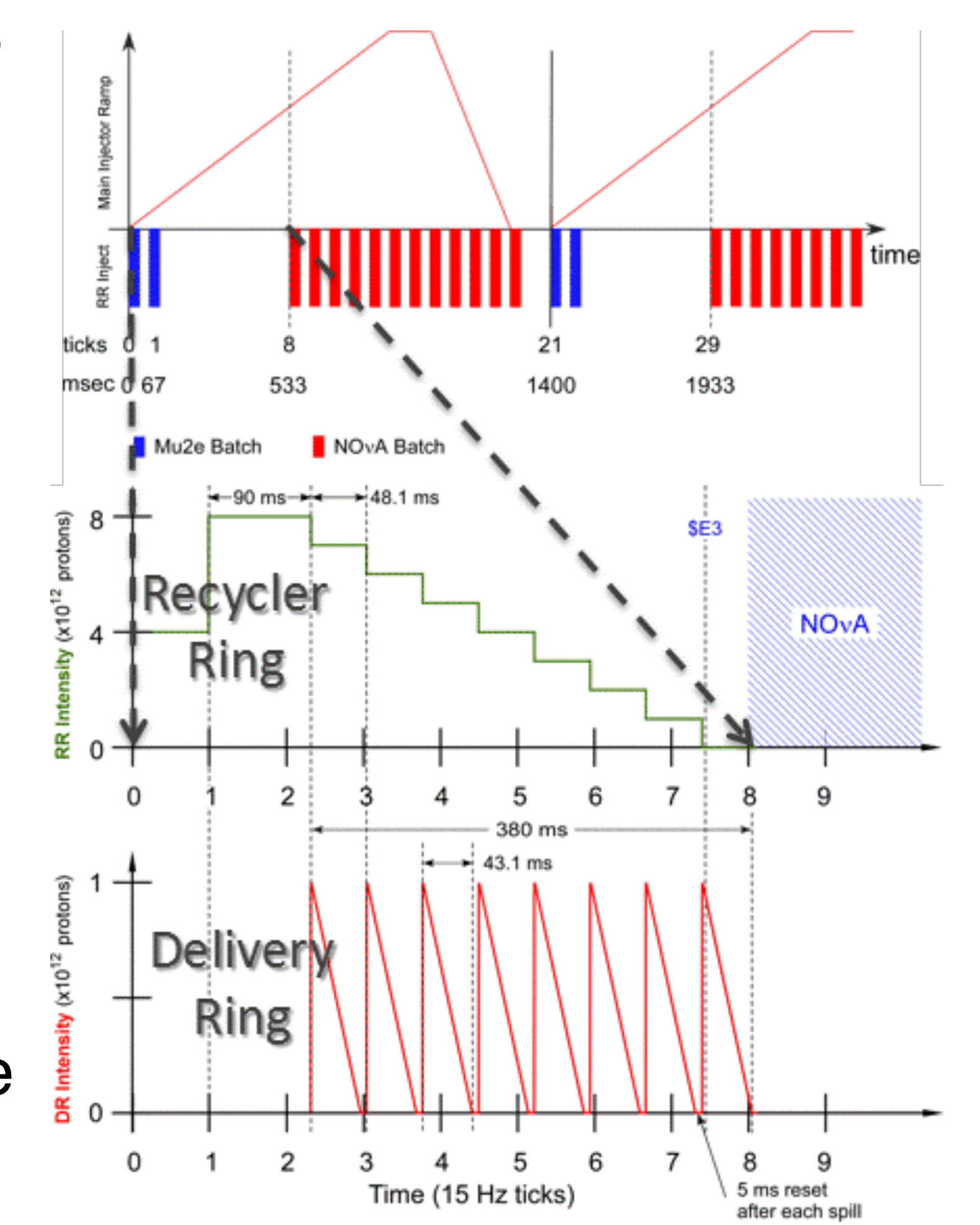
The Mu2e experiment aims to search for charged-lepton flavor violation by observing the conversion of a negative muon into an electron in the field of an aluminum nucleus. Such a process is forbidden in the Standard Model but predicted by its extensions. Mu2e will improve the sensitivity to this process by four orders of magnitude compared to previous experiments. To achieve its goals, Mu2e requires a highly reliable Trigger and Data Acquisition system (TDAQ) that synchronizes subsystems, monitors detector status, and manages high-throughput data flow from the detector hall to the Mu2e remote control room. The *otsdaq* framework serves as the primary interface for controlling and monitoring these operations.

## *otsdaq* in Mu2e

The Mu2e DAQ chain must operate within incredibly tight tolerances to match the beam delivery cycle, where proton pulses arrive dozens of times per second during spills lasting a few hundred milliseconds. Minor timing drifts can lead to missed events and misaligned data, making synchronization critical to the experiment. The *otsdaq* software provides a centralized framework to configure and control ROCs, DTCs, and online processing nodes while ensuring alignment of data with beam delivery. Improvements implemented in this project strengthen this capability by improving real-time monitoring, simplifying error detection, and reducing operator response time, better equipping *otsdaq* to handle the performance demands of Mu2e's DAQ environment.



TDAQ sequence from detector hall to Mu2e control room and campus (Mu2e Collaboration)



Mu2e beam delivery timeline (Mu2e Collaboration)

## The Future of *otsdaq*

The *otsdaq* software is not only a tool for HEP, but can be used in various applications where real-time monitoring and rapid response are critical. The lightweight architecture, fast data handling, and flexible device control allow it to be applied to manufacturing systems for process automation, industrial robots, or industrial IoT networks requiring centralized oversight.

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