PROCEEDINGS OF SCIENCE

EUDAQ and EUTelescope – Software Frameworks for Testbeam Data Acquisition and Analysis

Hanno Perrey[*†]
DESY
E-mail: hanno.perrey@desy.de

A high resolution ($\sigma \approx 2\,\mu$m) beam telescope based on monolithic active pixel sensors was developed within the EUDET collaboration. It has become the primary in-beam tool for many groups including several CERN based experiments, largely due to its precise spatial resolution, reliable operation and DAQ integration capabilities. For the telescope to deliver this excellent performance, two software packages play a central role: EUDAQ, a multi-platform data acquisition system that allows easy integration of the device-under-test, and EUTelescope, a group of processors running in ILCSoft's Marlin framework that allows the spatial reconstruction of particle tracks and the final data analysis.

In parallel to their successful operation in test beams for many years, both software packages are under constant development: from the integration of new device types and use-cases, to improvements to usability and flexibility, and the support of new features such as the high-rate capabilities of the next-generation pixel beam telescope developed within the new European detector infrastructure project AIDA.

In this contribution, we present the features of the current releases of both EUDAQ and EUTelescope and discuss the plans for development toward an easy-to-use software stack with the capability for high particle and data rates.

Technology and Instrumentation in Particle Physics 2014,
2-6 June, 2014
Amsterdam, the Netherlands

[*]Speaker.
[†]on behalf of the AIDA collaboration.

PoS(TIPP2014)353

1. Introduction

Beam tests of future tracking devices are crucial to determine their characteristics under realistic operating conditions. By determining the track of a charged particle in a test beam to high precision using a beam telescope, one can perform detailed studies of newly developed detectors.

Originally built at DESY within the EUDET JRA1 project for detector R&D toward the International Linear Colider (ILC), the EUDET beam telescope [1] was designed as an easy-to-use system with well-defined interfaces allowing test beam studies on a short time scale.

Since the first EUDET telescope has been used in beam tests in 2007, it has become the primary beam tool for many groups, largely due to its precise pointing resolution of $\sim 2\,\mu$m, reliable operation and DAQ integration capabilities.

For the telescope to deliver this excellent performance, two software packages play a central role:

- EUDAQ [2], a multi-platform data acquisition (DAQ) system that allows easy integration of the device-under-test, and
- EUTelescope [3], a library that provides tools for the spatial reconstruction of particle tracks and the final data analysis.

2. From EUDET to AIDA

Based on the EUDET telescope shown in figure 1, a next generation telescope is developed within the European AIDA project to better fulfill the evolving requirements of the user community. It will provide more than two orders of magnitude higher trigger rates of up to 1 MHz, precise time-stamping in the sub-nanosecond range, and large-area sensor planes of $4 \times 4\,\text{cm}^2$. This is made possible by a new trigger logic unit (TLU) with both faster discriminators and a simplified, shared-clock interface to the connected devices and by replacing one of the two telescope arms consisting of a triplet of MIMOSA26 sensors with three MIMOSA28 quad-planes.

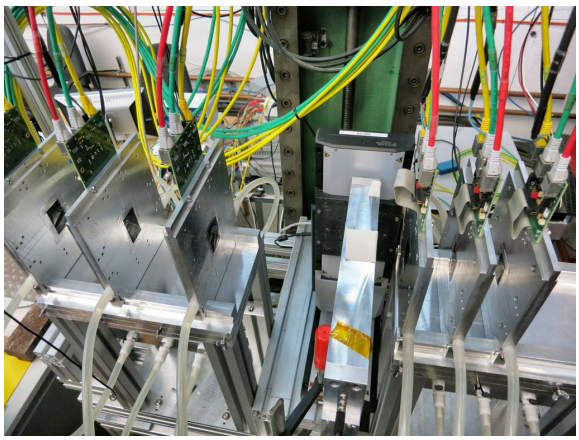

Figure 1: The EUDET/AIDA telescope consisting of two arms each equipped with three MIMOSA26 planes, and in-between a device of the CLICpix collaboration as device-under-test. Courtesy D. Dannheim.

To fully exploit the new hardware capabilities, both the DAQ framework and the analysis framework have to be extended to be able to deal with a significant increase in data rates, to support time stamping and multiple triggers per device readout, and to allow for a more challenging (offline) alignment of sensor planes composed of several individual devices.

An ongoing effort is made to incorporate these features and which are foreseen to be released as versions EUDAQ 2.0 and EUTelescope 1.0 later this year.

3. EUDAQ 2.0 – A Flexible High-Rate Capable DAQ Framework

EUDAQ is a generic DAQ framework that has been successfully used in testbeams with the EUDET-family of beam telescopes since 2007. It allows the easy (but optional) integration of the device-under-test and its DAQ into the telescope data stream and gives the user a central interface to control and monitor the operation of the full system. EUDAQ features a very modular design in which individual components communicate via TCP/IP and can run on different networked machines.

The central authority is called *RunControl*. It provides the user with a choice of either a graphical or console-based interface with status information on the current operation and allows to configure, start or stop the data taking. The actual device-hardware interaction with the telescope or the device-under-test is performed by independent *Producers*. Well-documented examples are provided to make the integration as easy and straightforward as possible. All Producers send their raw or already-decoded data to a *DataCollector* which stores it to disk.

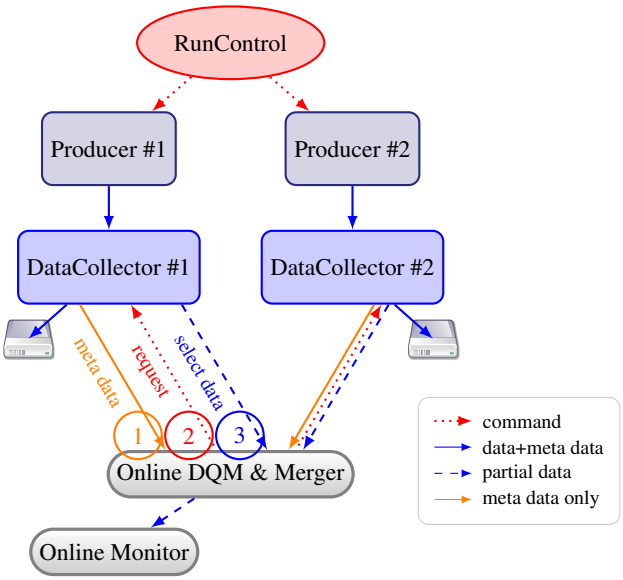

Figure 2: A schematic overview of the components of EUDAQ and the foreseen data flow for version 2.0. Shown is the communication between components when writing data from multiple data sources (devices/Producers) to local data sinks (DataCollectors) and monitoring the system online based on a partial sub-set of the stored data merged by a central data quality monitoring process (Online DQM & Merger).

EUDAQ will also be the DAQ framework of choice for the AIDA telescope. A new extended data format will allow for storage of additional meta data such as time stamps and multiple triggers per device readout to make use of the capabilities of the newly developed AIDA TLU.

In order to cope with the high data rates expected from the increased trigger rates and the large-area sensor planes, EUDAQ 2.0 will allow to run multiple DataCollectors simultaneously as illustrated in figure 2. Each DataCollector can be assigned to a single Producer and can run locally on the same physical machine as the Producer itself. This makes the setup more flexible and avoids bandwidth bottlenecks such as slow network connections.

The additional meta data available will make more thorough consistency checks and online verification possible: as devices obtain their clock directly from the TLU, synchronization loss and missed triggers can be reliably detected online. For this purpose, the meta data only will be collected from each DataCollector and verified by a central data quality monitoring process. Additionally, the data can be (partially) merged online by requesting packets containing specific trigger ranges – this allows to generate e.g. correlation plots online or even run the data analysis on a sub-set of the data while the recording is ongoing.

Even with these fundamental changes to the data-handling concept of EUDAQ, a lot of effort has been invested to make the modifications backward-compatible in order to preserve existing device integrations by the users.

4. EUTelescope 1.0 – A Powerful Toolset for Track Reconstruction

EUTelescope is a generic set of processors that run in ILCSoft's Marlin framework providing tools for clustering, alignment, track reconstruction, and data analysis. Originally developed for the EUDET telescope, it has since been used in other setups such as the CMS Pixel telescope [4].

Especially when analyzing data recorded at low-energy beams such as the DESY-II or ELSA testbeam facilities, it is important to take into account effects of multiple scattering. Therefore, the upcoming 1.0 release of EUTelescope will provide tracking based on General Broken Lines (GBL) [5] which treats scattering more accurately in all materials present. GBL also offers alignment capabilities using a direct interface to Millepede-II.

Furthermore, a new geometric clustering algorithm allowing for generic pixel shapes and combinations has been developed together with a simplified geometry core based on ROOT::TGeo.

These changes significantly simplify the analysis flow, easily allow for an iterative alignment strategy, and improve the usability and run-time speed. EUTelescope 1.0 will therefore be better suited for immediate offline-analysis directly after online merging in EUDAQ, providing a powerful semi-online monitoring facility.

5. Continuous Operation Needs Active Development

Since the successful usage of the first EUDET telescope for testbeam studies in 2007, four additional copies have been produced and are being operated in various beams around the world. This results in a constantly growing user base with evolving needs. These have been the focus particularly of recent releases of EUDAQ and EUTelescope, by constantly extending the available

documentation and examples, by providing support through online forums and workshops, and by making the installation easy and straightforward.

The quickly progressing development over the past years has been made possible by the open development model followed for both software frameworks which encourages external contributions. With open source code managed through *git* and hosted on GitHub, new functionality has been integrated in close collaboration with developers from many different institutes. Using automated nightly builds based on the CMake/CTest toolset, problems can be identified and fixed early in the development cycle. Furthermore, data-driven regression tests are used to constantly verify the output of the frameworks against a set of known good references. This ensures the stability and continued validity of the results.

6. Summary

EUDAQ and EUTelescope are central software components of the EUDET beam telescopes and a key factor in their success. They offer the user a ready-to-use framework for DAQ integration and testbeam data analysis and are constantly being evolved to meet the user's needs. For the next-generation AIDA telescope, both EUDAQ and EUTelescopes are being extended to be able to cope with higher data rates, to provide an extended data format and to handle more challenging offline synchronization and alignment tasks.

These features will be part of upcoming releases of EUDAQ 2.0 and EUTelescope 1.0 foreseen for late 2014.

7. Acknowledgments

The research leading to these results has received funding from the European Commission under the FP7 Research Infrastructures project AIDA, grant agreement no. 262025. The support is gratefully acknowledged. *Disclaimer*: The information herein only reflects the views of its authors and not those of the European Commission and no warranty expressed or implied is made with regard to such information or its use.

References

[1] *EUDET/AIDA Pixel Beam Telescopes References and Documentation*. URL: `http://beam-telescopes.desy.de`.

[2] *EUDAQ Documentation and Source Code*. URL: `http://eudaq.github.io`.

[3] *EUTelescope Documentation and Source Code*. URL: `http://eutelescope.desy.de`.

[4] Simon Spannagel. "A High-Rate Beam Test for the CMS Pixel Detector Phase I Upgrade". Diploma thesis. Karlsruher Institut für Technologie (KIT), 2012.

[5] Claus Kleinwort. "General Broken Lines as advanced track fitting method". In: *Nucl.Instrum.Meth.* A673 (2012), pp. 107–110. DOI: `10.1016/j.nima.2012.01.024`. arXiv: `1201.4320 [physics.ins-det]`.