Status of EUDAQ1 and EUDAQ2

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02 April 2019

The AIDA-2020 Advanced European Infrastructures for Detectors at Accelerators project has received funding from the European Union’s Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168.

This work is part of AIDA-2020 Work Package 5: Data acquisition system for beam tests.
Status of EUDAQ1 and EUDAQ2

Jan Dreyling-Eschweiler (DESY) for the telescope and test beam team

AIDA-2020 Fourth Annual Meeting
WP5: Data acquisition system for beam tests
Oxford, 2\textsuperscript{nd} April 2019
Contents

01 Origin & Framework

02 Data taking modes
  • Application example: EUDET-type telescopes
  • EUDAQ 1 → centralized
  • EUDAQ 2 → decentralized

03 Summary & Outlook
Starting in 2006 with EUDET-type telescopes
Building up an infrastructure for EUropean DETector research & development

Initial EUDET packages for beam telescopes DAQ

- Pixel Sensor (CNRS/IPHC Strasbourg) from Mimotel to *Mimosa26*
- Sensor DAQ (DESY, CNRS/IPHC) from EUDEB (VME64x) to *NI DAQ*
- Synchronization (Univ. of Bristol) trigger logic units: *EUDET TLU*

- **Common DAQ software** (DESY) *EUDAQ version 1*

**DUT = Device under test**

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**Strategy for Common DAQ**

- Lightweight, top-level DAQ software with interfaces for specific device integration
- Synchronization using a simple trigger-busy communication protocol

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Talk in WP15, 04.04., 10:50
EUDAQ software framework

An easy-to-use, top-level test beam DAQ

Data in from DUT DAQ:

- Producer
- Examples: TLU, Mimosa, FEI4, ...

Data out for monitoring or reconstruction:

- Converter
- Examples: LCIO, ROOT, ...

Finite State Machine of Run Control:

- Connect → Initialize
- Initialized → Configure (or Re-initialize)
- Configured → Start Run (or Re-configure)
- Started → Stop Run
- Stopped → Start next Run / Initilise / Configure / Reset
Telescope DAQ system
Trigger system & Mimosa DAQ

- 2x2 trigger devices
- EUDET TLU
- 6x Mimosa26 planes
- FPGA Xilinx Virtex 5 for NI COTS system
- EUDET-type hardware

Diagram showing the interaction between particle trigger, busy, and various frames in the MIMOSA and DUT sections.
“EUDET mode”: One trigger = one read-out from all devices

- Event-based synchronisation for robust data-taking
- Unique event definition: EUDAQ1 event
- But trigger rate is limited by the slowest device!
User evolution and examples

Many various and different applications

EUDAQ1 paper in editing phase:
Architecture and applications: ALICE ITS, ATLAS Itk, Belle II Vertex, CALICE, CLIC devel., CMS IT-PH1, CMS OT-PH2, CMS HGCAL, MIB, Mu3e devel., SiLab devel, outreach, ...

EUDAQ – A data acquisition software framework for common beam telescopes

Infrastructure evolution: 7 copies around the world
Same beam telescope at different beam lines

Prototype Demonstrator

1st telescope EUDET-type (Mimosa26/NI) → “AIDA” telescope now at SPS

2nd telescope “ANEMONE” for Bonn

3rd telescope “DATURA” at DESY

4th telescope “ACONITE” for ATLAS now at SPS

5th telescope “CALADIUM” now at SLAC

6th telescope “DURANTA” at DESY

7th telescope “AZALEA” at DESY

“BTTB1” “BTTB2” BTTB3 BTTB4 BTTB5 BTTB6 BTTB7 BTTB8 ...

EUDAQ v1

Development for version 2

EUDAQ v2
Why a second version?

1) Higher trigger rates

1) Strategy for new mode

Allow multiple triggers within 1 telescope event

→ ignore busy from slow devices
Why a second version?

1) Higher trigger rates

1) Strategy for new mode

Allow multiple triggers within 1 telescope event

→ ignore busy from slow devices → no event-based sync.

→ synchronisation by common clock or trigger ID
Why a second version?
1) Higher trigger rates and 2) Common test beam DAQ

1) Strategy for new mode
Allow multiple triggers within 1 telescope event
→ ignore busy from slow devices → no event-based sync.
→ synchronisation by common clock or trigger ID

2) Motivation for WP5 AIDA2020
Common DAQ software framework – not only tracker devices, also for calorimeter...
→ EUDAQ1 suitable candidate
Telescope Upgrade: AIDA TLU ...
New options meet reliable techniques

AIDA TLU: new options and faster

- New options: **Individual busy** & common clock option
- Backward-compatible (clock out **Trigger ID**) 
- New FPGA Xilinx Artix: **1 MHz** maximum trigger rate
- 6x inputs for coincidence logic & 4x interfaces for DUT communication (HDMI)

“**Trigger-data-handshake**”

- Trigger-busy communication
- Plus: device clocks out 15bit unique trigger ID on trigger line
Telescope Upgrade: … and EUDAQ2

Independent data flow and event building

“Mixed mode”: multiple trigger, not waiting for the slow devices

- Trigger ID-based synchronisation
  → New data collector options in EUDAQ version 2
- Event re-definition for analysis
  → e.g. EUDAQ1-like event by data duplication of Mimosa (duplicated track rejection after analysis)
Telescope Upgrade: Results for “Mixed mode”

Getting more timestamped tracks

E.g. 2 GeV/c test run at DESY II TB using the telescope and a fast reference plane FEI4

Results & updated limits

- Trigger rate now limited by
  - busy time for clocking out trigger ID
    - here, 8.8 μs = 115 kHz
      (factor ~30)

- Timestamped tracks (with FEI4)
  - all tracks with high time resolution
    - factor 5.5 at 2 GeV/c
    - factor 2.6 at 3 GeV/c
    - factor 1.1 at 5 GeV/c
  - potential factor 6.9 at 2 GeV/c
    - losing tracks due to 2-frame read-out
**EUDAQ version 1 and version 2**

**Data taking**

**EUDAQ 1 – robust**

- **Centralized Data Taking** with EUDET TLU
  - One Data Collector
  - Online synchronisation by event number (unique event definition)

**EUDAQ 2 – more flexible**

- **Decentralized Data Taking** with AIDA TLU
  - Multiple Data Collector (and connections)
  - Online or **offline** synchronisation by event number, **Trigger ID** or **timestamps**

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### Data-taking modes of EUDAQ and EUDET TLU

<table>
<thead>
<tr>
<th>Modes</th>
<th>Trigger comm.</th>
<th>Sync. by</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUDET</td>
<td>Global</td>
<td>Event ID</td>
</tr>
<tr>
<td></td>
<td>Trigger-Busy</td>
<td></td>
</tr>
</tbody>
</table>

### Available data-taking modes of EUDAQ2 and AIDA TLU

<table>
<thead>
<tr>
<th>Modes</th>
<th>Trigger comm.</th>
<th>Sync. by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard/ EUDET</td>
<td>Global Trigger-Busy</td>
<td>Event ID/ Trigger ID</td>
</tr>
<tr>
<td>mixed</td>
<td>Individual Trigger-Busy</td>
<td>Trigger ID</td>
</tr>
<tr>
<td>Timestamp/ AIDA</td>
<td>Common Clock Timestamps</td>
<td></td>
</tr>
</tbody>
</table>
### Realizations

#### Options and Status

<table>
<thead>
<tr>
<th>#</th>
<th>Mode</th>
<th>Sync.</th>
<th>TLU</th>
<th>EUDAQ</th>
<th>Streams</th>
<th>DataCollector</th>
<th>Event building</th>
<th>Realizations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EUDET</td>
<td>global busy</td>
<td>EUDET</td>
<td>1</td>
<td>1</td>
<td>DataCollector</td>
<td>Online by DC</td>
<td>EUDAQ1</td>
</tr>
<tr>
<td>2</td>
<td>EUDET</td>
<td>global busy</td>
<td>both</td>
<td>2</td>
<td>1</td>
<td>EventnumberSyncDataCollector</td>
<td>Online by DC</td>
<td>ATLAS ITK</td>
</tr>
<tr>
<td>3</td>
<td>EUDET</td>
<td>global busy</td>
<td>both</td>
<td>2</td>
<td>&gt;1</td>
<td>DirectSaveDataCollector</td>
<td>Offline by EventnumberSyncEventBuilder</td>
<td>TORCH and telescope upgrade crew</td>
</tr>
<tr>
<td>4</td>
<td>mixed</td>
<td>Trigger ID</td>
<td>AIDA</td>
<td>2</td>
<td>1</td>
<td>TriggernumberSyncDataCollector (based on Ex0TgCollector)</td>
<td>Online by DC</td>
<td>Telescope upgrade crew</td>
</tr>
<tr>
<td>5</td>
<td>mixed</td>
<td>Trigger ID</td>
<td>AIDA</td>
<td>2</td>
<td>&gt;1</td>
<td>DirectSaveDataCollector</td>
<td>Offline by TriggernumberSyncEventBuilder</td>
<td>Telescope upgrade crew</td>
</tr>
<tr>
<td>6</td>
<td>AIDA</td>
<td>timestamp</td>
<td>AIDA</td>
<td>2</td>
<td>1</td>
<td>TimestampSyncDataCollector</td>
<td>Online by DC</td>
<td>CALICE, BIF and CaliceTelDataCollector</td>
</tr>
<tr>
<td>7</td>
<td>AIDA</td>
<td>timestamp</td>
<td>AIDA</td>
<td>2</td>
<td>&gt;1</td>
<td>DirectSaveDataCollector</td>
<td>Offline by TimestampSyncEventBuilder</td>
<td>CLIC</td>
</tr>
</tbody>
</table>
EUDAQ version 1 and version 2

Overview

EUDAQ 1 – robust

- **Centralized Data Taking** with EUDET TLU
  - One Data Collector
  - Online synchronisation by event number (unique event definition)

- **Versions**
  - Latest release v1.9.1, Dec. 2018
  - Development Branch: v1.x-dev

- **Code**
  - One library
  - One thread
  - Component-based Structure (only change/update for users)

EUDAQ 2 – more flexible

- **Decentralized Data Taking** with AIDA TLU
  - Multiple Data Collector (and connections)
  - Online or **offline** synchronisation by event number, Trigger ID or timestamps

- **Versions**
  - Latest release v2.2.0, Jan. 2019
  - Development branch: **master**

- **Code improvements**
  - Core Library, Converter Library, …
  - Producer abstraction (modules) and multi-threading
  - User-based file/folder structure
EUDAQ version 1 and version 2

Overview

EUDAQ 1 – robust

- **Centralized Data Taking** with EUDET TLU
  - One Data Collector
  - Online synchronisation by event number (unique event definition)

- **Versions**
  - Latest release v1.9.1, Dec. 2018
  - Development Branch: v1.x-dev

- **Code**
  - One library
  - One thread
  - Component-based Structure

EUDAQ2 paper in draft phase:
Architecture and applications: EUDET-type beam telescope upgrade, ATLAS ITk strips, KPiX strip telescope (LYCORIS), CALICE AHCAL

only change/update for users
04 Summary & Outlook

Summary

- EUDAQ is under constant user-driven upgrade for beam tests
- EUDAQ2 and AIDA TLU can run in EUDET mode plus two new data taking modes
- User’s code have not to be rewritten
  - Producer
  - Converter
  - (in EUDAQ2 maybe: Collector/Merger)

Outlook

- EUDAQ 1&2 publications ongoing
- Continuous improvements
  - Repo. & code maintenance (CI, issue tracker, ...)
  - User-friendly implementations (Rate indicators, automatic scan options, ...)
  - Tackle the LogChannel limit (~10 producers)
  - Tackle the SendEvent-rate limit (~50 kHz)
    → Strategy for data-driven detectors
- Ideas for Version 3
  - Modern TCP/IP library
  - Modern OnlineMonitor (DQM4HEP...)
  - ....
Thank you

Teams for common beam telescopes

- TLU: Paolo Baesso, David Cussans (Univ. of Bristol)
- EUDAQ1/2: Andre Rummler (CERN), Yi Liu, Lennart Huth, Thomas Daubney (DESY), and many user
- EUTelescope: Edo Rossi, Jan-Hendrik Arling, Cyril Becot, Xiaocong Ai (DESY)
- MMC3: Yannick Dieter, David-Leon Pohl (Univ. of Bonn)
- Further support: Simon Spannagel, Maarten Van Dijk (CERN), Hendrik Jansen, Mengqing Wu, Marcel Stanitzki, Ingrid Gregor (DESY), WP5, WP15, and many more

Contact

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www.desy.de
Backup
03 Locations: Data Collectors and Telescope modules

Code locations and module (name) examples

**Data Collectors (today)**

<table>
<thead>
<tr>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>DirectSaveDataCollector.cc</td>
</tr>
<tr>
<td>EventnumberSyncDataCollector.cc</td>
</tr>
<tr>
<td>StdRunControl.cc</td>
</tr>
<tr>
<td>SyncByEventnumberPS.cc</td>
</tr>
<tr>
<td>SyncByTimestampPS.cc</td>
</tr>
<tr>
<td>TimestampSyncDataCollector.cc</td>
</tr>
</tbody>
</table>

**Example modules**

<table>
<thead>
<tr>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex0Monitor.cc</td>
</tr>
<tr>
<td>Ex0Producer.cc</td>
</tr>
<tr>
<td>Ex0RawEvent2StdEventConverter.cc</td>
</tr>
<tr>
<td>Ex0RunControl.cc</td>
</tr>
<tr>
<td>Ex0TgDataCollector.cc</td>
</tr>
<tr>
<td>Ex0TsDataCollector.cc</td>
</tr>
<tr>
<td>Ex0HiBDataCollector.cc</td>
</tr>
</tbody>
</table>

**EUDET-type telescopes** including Mimosa26/LV-DAQ, FEI4/USBPix, EUDET/AIDA TLU

<table>
<thead>
<tr>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>FmctluProducer.cc</td>
</tr>
<tr>
<td>MiniTluProducer.cc</td>
</tr>
<tr>
<td>HiProducer.cc</td>
</tr>
<tr>
<td>HiRawEvent2LCEventConverter.cc</td>
</tr>
<tr>
<td>HiRawEvent2StdEventConverter.cc</td>
</tr>
<tr>
<td>TluProducer.cc</td>
</tr>
<tr>
<td>TluRawEvent2LCEventConverter.cc</td>
</tr>
<tr>
<td>TluRawEvent2StdEventConverter.cc</td>
</tr>
<tr>
<td>UsbpixI4BRawEvent2LCEventConverter.cc</td>
</tr>
<tr>
<td>UsbpixI4BRawEvent2StdEventConverter.cc</td>
</tr>
<tr>
<td>UsbpixrefRawEvent2LCEventConverter.cc</td>
</tr>
<tr>
<td>UsbpixrefRawEvent2StdEventConverter.cc</td>
</tr>
</tbody>
</table>
Starting

# Start Run Control
euRun

# Start Logger
euLog -r tcp://<rc_ip>

# Start TLU Producer
euCliProducer -n FmctluProducer -t fmctlu
  -r tcp://<rc_ip>

# Start Telescope Producer
euCliProducer -n NiProducer -t niproducer
  -r tcp://<rc_ip>

# Start two DataCollectors
euCliCollector -n DirectSaveDataCollector
  -t tlu_dc -r tcp://<rc_ip>
euCliCollector -n DirectSaveDataCollector
  -t ni_dc -r tcp://<rc_ip>

EUDAQ Config file

[Producer.fmctlu]
# Telescope at HDMI1
DUTMask = 0x1
# HDMI1 is reading out Trigger ID
DUTMaskMode = 0xFC
# EUDET or mixed mode to ignore busy at HDMI1
# DUTIgnoreBusy = 0x1 # yes (mixed)
DUTIgnoreBusy = 0x0 # no (full EUDET)
...
# Data collector – producer connection
EUDAQ_DC = tlu_dc

[Producer.niproducer]
...
# Data collector – producer connection
EUDAQ_DC = ni_dc

[DataCollector.ni_dc]
EUDAQ_FW = native
EUDAQ_FW_PATTERN = PATH/run$6R_ni_{$12D$X

[DataCollector.tlu_dc]
EUDAQ_FW = native
Beam Telescopes

High-precision reference tracker

EUDET-type telescopes in a nutshell

- Mimosa26 based 6 plane telescope
  → **Device Under Test (DUT) in between** (or behind)
  → Response studies, efficiency, Lorentz angle, etc.

- Pointing resolution (> 1.8 μm) or angular resolution (> 0.03 mrad) @ 1-6 GeV/c
  → **Material Budget (X0) imaging**

References

- **Portal & Manual & Description:** telescopes.desy.de
- **Performance & Reference Paper:** H. Jansen et al to https://doi.org/10.1140/epjti/s40485-016-0033-2
Common Beam Telescopes
A common tool used by many different users from various experiments

Today & User interfaces

- A workhorse for various (HEP) test beams: 7 copies at 5 different test beam facilities
- 3 pillars of EUDET-type telescope package: from data to results

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**EUDET-type hardware**

- **Defined Interfaces**
  - DUT integration e.g. in μm-precise stages
  - TLU communication
- **Starting point:** beam-telescopes.github.io

**EUDAQ DAQ software**

- **Defined Interfaces**
  - Producer for DUT-DAQ communication
  - Converter for data proc.
- **Starting point:** eudaq.github.io

**EUTelescope Track Reconstruction SW**

- **Interfaces**
  - To EUDAQ 1 events
  - DUT implementation
- **Starting point:** eutelescope.github.io

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*Talk in WP15, 25.04., 14:35*
EUDETAQ - EUDAQ 1 & 2 | Jan Dreyling-Eschweiler | 2nd April 2019

EUDET-type telescopes family today

Documentation & Development

- AIDA @ SPS, H6B
  - SPS/PS contact: Henric Wilkens
  - Telescope contact: André Rummler
  - Talk by Maarten (this morning)

- AZALEA @ PS, T10
  - Contact: Carsten Hast

- ACONITE @ SPS, H6A
  - Talk by Alexander (this morning)

- ANEMONE @ BONN / ELSA
  - Telescope contact: David-Leon Pohl

- CALADIUM @ SLAC in Stanford, USA

- DATURA @ TB21

- DURANTA @ TB22

- ACONITE @ SPS, H6A

SPS/PS contact: Henric Wilkens
Telescope contact: André Rummler

- TB contact: Ralf Diener, Norbert Meyners, Marcel Stanitzki
Telescope contact: Hendrik Jansen, Jan Dreyling-Eschweiler

- Talk by Mengqing (Thursday)
- Talk by Mengqing/Uwe
- Talk by Ralf (yesterday)
- Talk by Dennis (yesterday)
- Talk by Maarten (this morning)
- Talk by Alexander (this morning)
- Talk by Daniel Elsner
Telescope contact: David-Leon Pohl