Status of the EUDET-type beam telescope infrastructure

Jan Dreyling-Escheiler for the DESY team

BTTB7, CERN, 15th January 2019
Outline

01 Introduction

02 Telescope family in 2019/2020

03 News & Upgrades
   → Mixed Mode results at DESY TB

04 Summary & Outlook
EUDET-type beam telescopes
High precision reference tracker

In a nutshell

- Mimosa26 based 6-plane beam 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 and tomo

- **User infrastructure**: Trigger and DAQ user interfaces and track reconstruction software

@BTTB Friday 12:15
session talk
User infrastructure
Providing the whole package: Device Integration – data acquisition – track reconstruction

EUDET-type hardware
- 6x Mimosa sensors & DAQ
- Mechanics
- Trigger System

EUDAQ
- Top-Level DAQ software
  - Central run control & monitoring
  - Synchronisation & acquisition

EUTelescope
- Track reconstruction framework
  - Masking, Clustering, Alignment, ...
  - Track finding, fitting & results

In the last decade a workhorse for various test beams...

telescopes.desy.de  eudaq.github.io  eutelescope.github.io
EUDET-type telescopes family
7 copies around the world at 5 different beam test beam facilities

Supported by AIDA2020 (WP15, WP5, WP10)

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

AIDA @ SPS, H6B
AZALEA @ PS, T10
ACONITE @ SPS, H6A

Mainly self-managed

CALADIUM @ SLAC in Stanford, USA

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

TB contact:
Daniel Elsner
Telescope contact:
David-Leon Pohl

General Contact:
Carsten Hast
EUDET-type telescopes family
7 copies around the world at 5 different beam test beam facilities

Supported by AIDA2020 (WP15, WP5, WP10)

TB contact:
Ralf Diener, Norbert Meyners, Marcel Stanitzki

Telescope contact:
Hendrik Jansen, Jan Dreyling-Eschweiler

SPS/PS contact:
Henric Wilkens

Telescope contact:
André Rummler

Mainly self-managed

LCLS shutdown in 2019
(and maybe no TB anymore...)

General Contact:
Carsten Hast

TB contact:
Daniel Elsner

Telescope contact:
David-Leon Pohl

LHC Shutdown!
From now until 2020

AIDA @ SPS, H6B
AZALEA @ PS, T10
ACONITE @ SPS, H6A

DATURA @ TB21
DURANTA @ TB22

CALADIUM @ SLAC in Stanford, USA

ANEMONE @ BONN / ELSA
In 2019/20: 3 telescopes at 3 beam lines at DESY

Azalea from CERN, PS is installed in TB24 at DESY

(full) schedule at http://testbeam.desy.de
News & upgrades of the infrastructure
Requests from BTTB6-forum: Higher time resolution & User support

1) Integration of new AIDA TLU
   @BTTB Thursday 12:30 session talk
2) Exploring MMC3 board as new Mimosa DAQ (Univ. Bonn)
3) Exploring new sensor candidates
   @BTTB Thursday 19:00 discussion in the Forum

- Cl for version 1
- Optimizing version 2 for telescope usage with new TLU and new data-taking modes
  @BTTB Thursday 14:00 hands-on

- Updated GBL Processor
- Updated user examples
  - Only telescope
  - Passive DUT (SUT)
    @BTTB Tuesday 14:00 hands-on
  - DUT
    @BTTB Tuesday 16:30 hands-on

New trigger and data taking options are ready to use, for example the “Mixed Mode”...
“EUDET/standard mode”: One trigger = one RO from all devices

- Event-based synchronisation for robust data-taking
- Unique event definition: **EUDAQ1 event**
- But trigger rate is limited by the slowest device!
Towards higher rates
... and more timing information

“EUDET/standard mode”:

- Event-based synchronisation for robust data-taking
- Trigger rate is limited by the slowest device

Telescope records all tracks, but only one trigger/time information per event
Towards higher rates

... and more timing information

Strategy for new mode

Allow multiple triggers within 1 telescope event
Towards higher rates
... and more timing information

Strategy for new mode

Allow **multiple** triggers within 1 telescope event

→ **ignore** busy from slow devices → **AIDA TLU**

→ synchronise by **trigger ID** → **EUDAQ2 data collector**
New data flow and event building

Ignoring busy and synchronisation by trigger number ("Mixed mode")

"Mixed mode" a multiple trigger, not waiting for the slow devices

- **AIDA TLU**: ignore busy of MimosaDAQ
- **EUDAQ2 Data Collector**: Trigger ID-based synchronisation
- Event re-definition for analysis
  - e.g. **EUDAQ1-like event** by data duplication of Mimosa
Results for “Mixed mode”

Getting more timestamped tracks

Results & updated limits

- Trigger rate now limited by
  - busy time for clocking out trigger ID
    - here, $8.8 \, \mu s = 115 \, kHz$ (factor $\sim 30$)

- 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

<table>
<thead>
<tr>
<th>Mixed mode</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUDAQ 2 Sync. by Trigger ID</td>
<td>EUDAQ 1 Evt. ID</td>
</tr>
<tr>
<td>Trigg. ID</td>
<td>TLU</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

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

@ DESY II TB
Summary & Outlook
EUDET-type beam telescope infrastructure

- EUDET-type beam telescopes provide high spatial resolution and proper user infrastructure
- Result using new TLU and EUDAQ v2 in “Mixed mode”
  - Individual instead of global busy
  - Trigger ID for synchronisation
  - 5.5x more timestamped tracks at DESY TB at 2 GeV/c
- Ultimate upgrade for timestamped Mimosa tracks: MMC3 (continuous Mimosa read-out) and AIDA mode (synchronisation by common clock)

<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</td>
<td>Timestamps</td>
</tr>
</tbody>
</table>
Thank you

Upgrade Team

- TLU: Paolo Baesso, David Cussans (Univ. of Bristol)
- EUDAQ: Yi Liu, Thomas Daubney (DESY)
- EUTeleoscope: Xiaocong Ai, Edo Rossi, Cyril Becot (DESY)
- MMC3: Yannick Dieter, David-Leon Pohl (Univ. of Bonn)
- Further support: Jan-Hendrik Arling, Hendrik Jansen (DESY), Andre Rummler, Maarten Van Dijk (CERN), Marcel Stanitzki, Ingrid Gregor (DESY), and many more

Contact

**DESY.** Deutsches Elektronen-Synchrotron

High-energy department, ATLAS group

Mail: jan.dreyling-eschweiler@desy.de

Phone: 0049 (0)40 8998 2794
Outlook: Continuous read-out and common clock

New Mimosa DAQ

MMC3 board as new Mimosa DAQ

- Custom FPGA board developed by Univ. of Bonn
- **Continuous** Mimosa read-out
- Synchronization by **timestamp** by **common clock** provided by the TLU (“AIDA mode”) and event building with EUDAQ2
Limits of “EUDET/standard mode”

- Trigger rate is limited due to Mimosa DAQ busy to max. 8.6 kHz (EUDET TLU to max. 3.6 kHz)
- Recorded particle tracks per event
  - **One track with high time resolution** (incl. time reference plane, e.g. FEI4, 25 ns)
  - Other tracks within Mimosa read-out

To make the best usage of the beam!
Telescope DAQ system

Trigger system & Mimosa DAQ

- EUDET-type beam telescope infrastructure
- Jan Dreyling-Eschweiler, 15 Jan 2019

- 6x Mimosa26 planes
- FPGA Xilinx Virtex 5 for NI COTS system

- 2x2 trigger devices
- EUDET TLU
- 2x2 trigger devices

Diagram showing particle trigger, busy signals, and frames with events.
**Telescope DAQ system**

**Trigger system & Mimosa DAQ**

---

**Trigger system**
- 4x “Scintillator & PMT” devices
- **EUDET Trigger Logic Unit (TLU)**
  - Programmable logic on FPGA handles 4x inputs for coincidence logic & 6x interfaces for DUT communication
  - Trigger-busy communication: **Global busy** vetos the next trigger

**Mimosa DAQ**
- Sensor architecture: rolling shutter & continuous data read-out
- FPGA handles trigger-in, raise busy and select corresponding frames
  - Busy signal: 1-2 frames (115.2 to 230.4 μs)
  - Particle hit is in frame $n$ or $n+1$
  - Telescope event: 6x **two** sub-sequent frames

---

*D. Cussans D, Description of the JRA1 Trigger Logic Unit (TLU), v0.2c. EUDET-MEMO-2009-04*
**New 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
## New modes

### Overview

<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/User</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>EventIDSync DataCollector</td>
<td>Online by DC</td>
<td>ATLAS ITK and EUDET telescope</td>
</tr>
<tr>
<td>3</td>
<td>EUDET</td>
<td>global busy</td>
<td>both</td>
<td>2</td>
<td>&gt;1</td>
<td>DirectSave DataCollector</td>
<td>Offline by euClimMerger StandardEvtID</td>
<td>TORCH and EUDET telescope</td>
</tr>
<tr>
<td>4</td>
<td>mixed</td>
<td>Trigger ID</td>
<td>AIDA</td>
<td>2</td>
<td>1</td>
<td>TriggerIDSync DataCollector</td>
<td>Online by DC</td>
<td>EUDAQ1</td>
</tr>
<tr>
<td>5</td>
<td>mixed</td>
<td>Trigger ID</td>
<td>AIDA</td>
<td>2</td>
<td>&gt;1</td>
<td>DirectSave DataCollector</td>
<td>Offline by euClimMerger StandardTrigID</td>
<td>EUDAQ1</td>
</tr>
<tr>
<td>6</td>
<td>AIDA</td>
<td>timestamp</td>
<td>AIDA</td>
<td>2</td>
<td>1</td>
<td>TimestampSync DataCollector</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>DirectSave DataCollector</td>
<td>Offline by TimestampSync EventBuilder</td>
<td>na</td>
</tr>
</tbody>
</table>