Presentation

Higher rates for common beam telescopes

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Higher rates for common beam telescopes

New synchronisation modes and decentralized data-taking for the EUDET-based infrastructrue

Jan Dreyling-Eschweiler
for the beam telescope development team
IEEE NSS-MIC 2018 Sydney

Outline

R&D in particle physics
Future experiments meet new challenges and need test facilities

Now

Upgrade in 2026
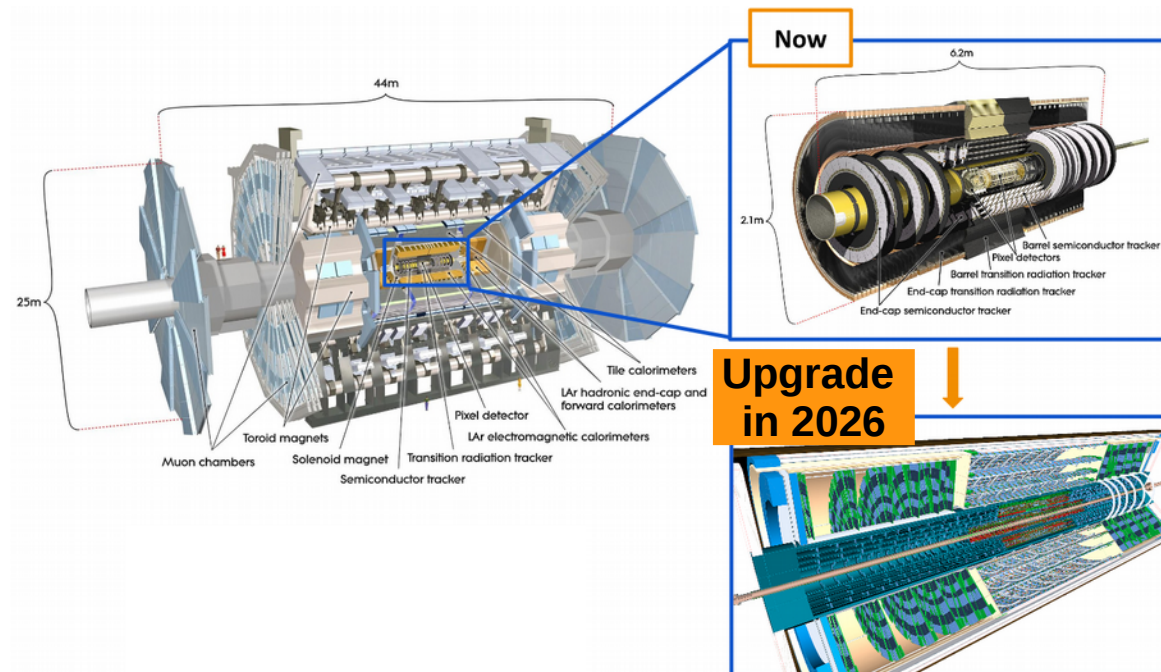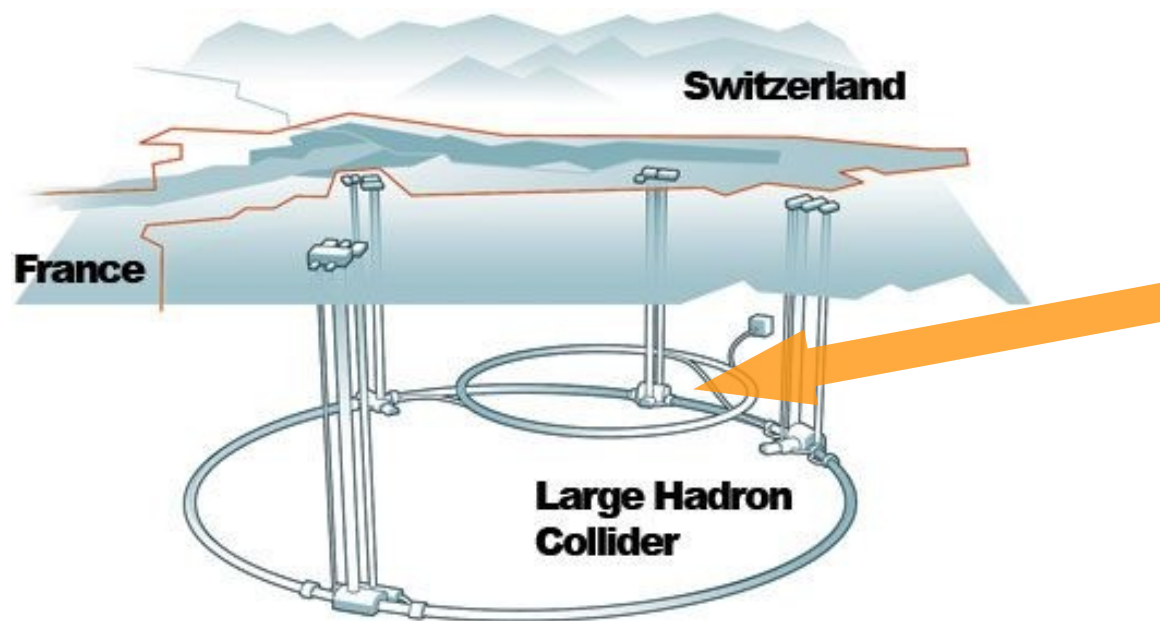
E.g. ATLAS ITk endcap upgrade for the high-luminosity LHC

- Challenge for tracking detectors: higher **particle flux** (rate per area)

- In total ~12 years of R&D in laboratories and at **test beams**

A. Blue et. al., Testbeam Evaluation of Silicon Strip Modules for the ATLAS Phase-II Strip Tracker Upgrade
2017, HSTD11 NIM A proceedings

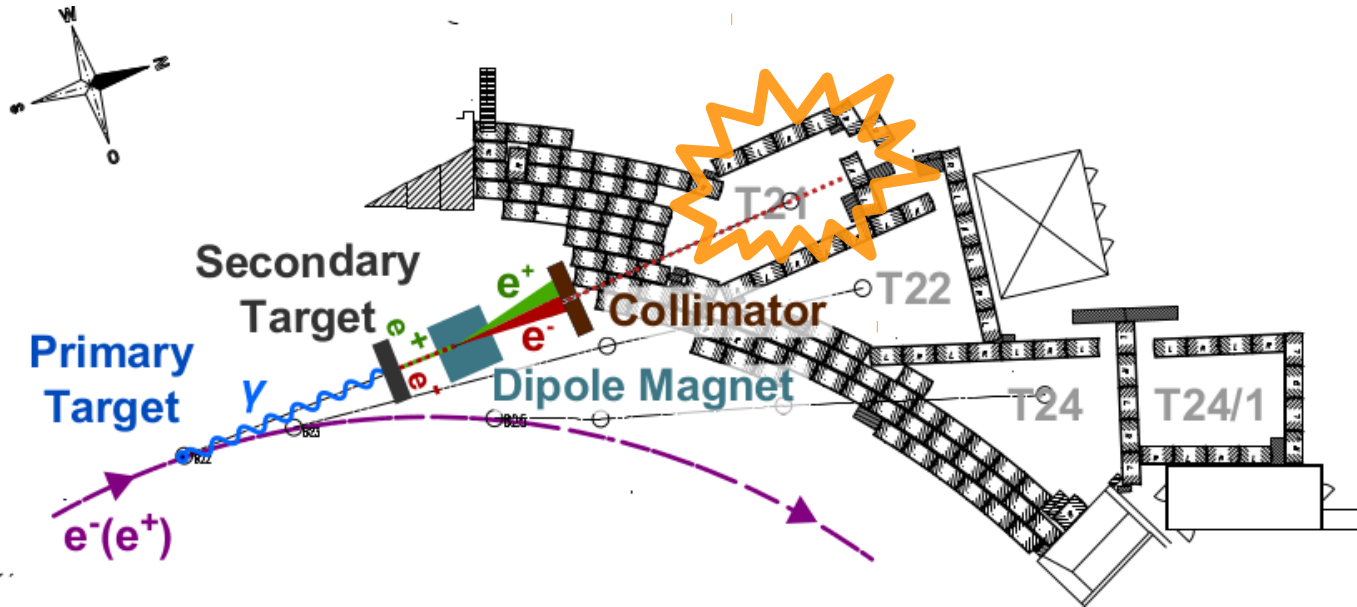# Particle source: test beams

Test beams provide a well-known particle source

E.g. DESY II Test Beam Facility with 3 beamlines

- Parasitic usage of pre-accelerator **DESY II**

- Continuous-like **electron** (positron) source

- Selectable momentum between **1-6 GeV/c**

R. Diener et al., The DESY II Test Beam Facility
2018, preprint for NIM, arXiv:1807.09328
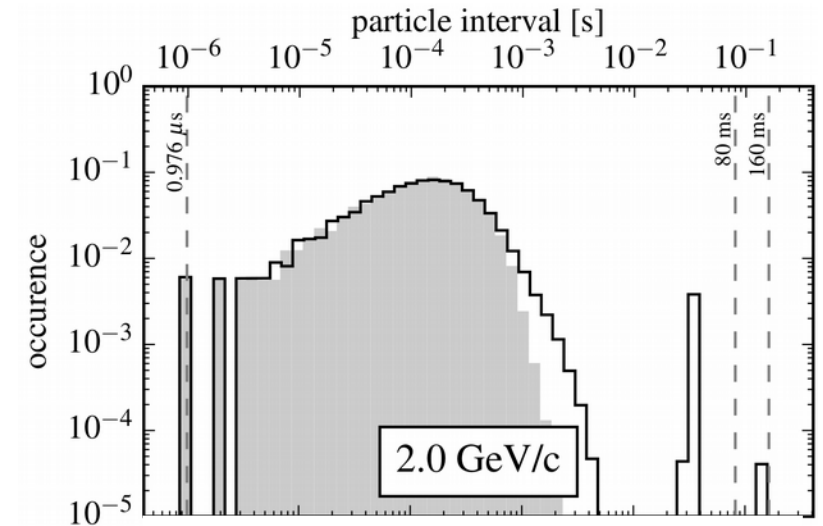
Timing analysis of DESY II TB

- Minimum particle interval 0.976 μs
  (= synchrotron frequency)

- Average particle flux (@ 2 GeV/c):
  1-10 kHz/cm^2 electrons

Particle detector: beam telescope
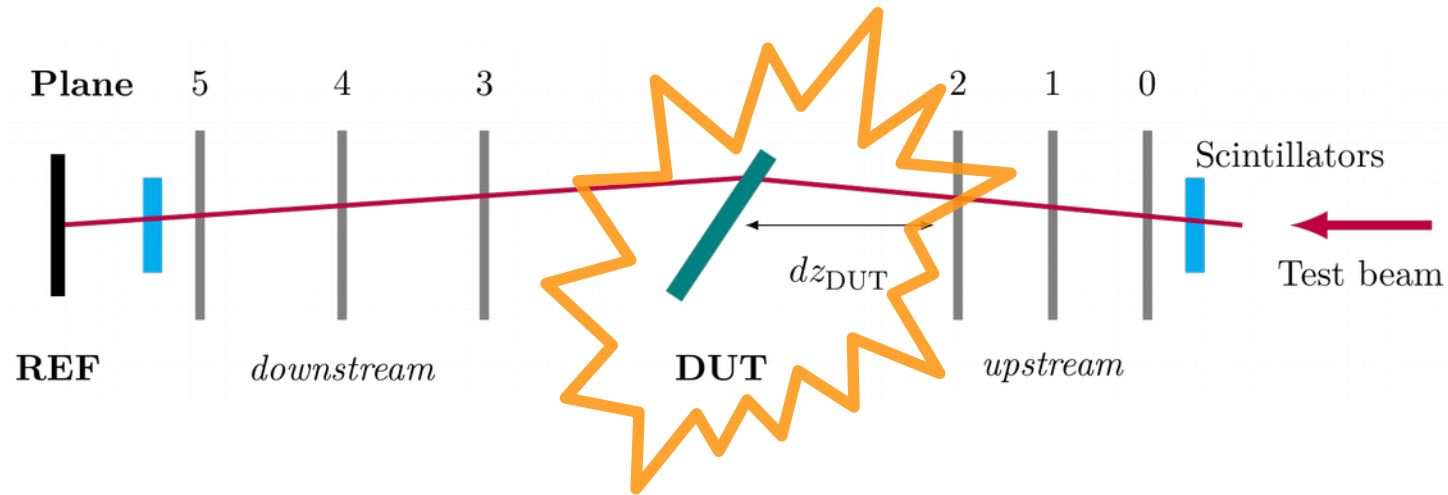
Telescope systems provide a spatial & temporal track reference

E.g. EUDET-type beam telescopes

- Based on **Mimosa26** (Monolithic Active Pixel Sensor)
  AMS 350 nm technology, 18.4 μm pitch, 2x1 cm^2 area, only 50 μm thick

- High-precision reference tracker: **σ > 1.8 μm** (< LHC tracking sensors)

- Extendible system for **Device Under Tests (DUT)**

Jansen, H. et al. EPJ Techn Instrum (2016) 3: 7.
https://doi.org/10.1140/epjti/s40485-016-0033-2
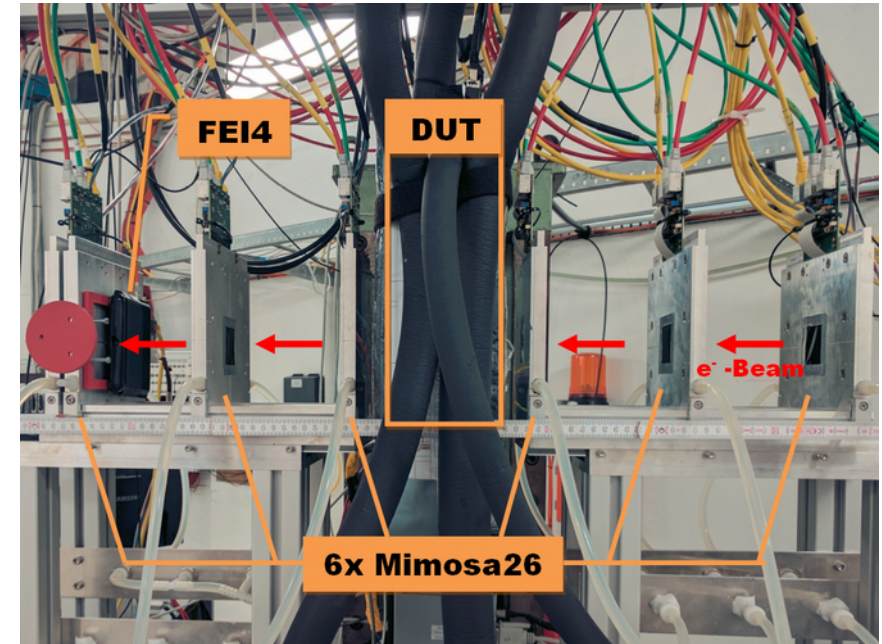
E.g. ATLAS ITk test beam setup

- Testing strip sensors

- Including a time-reference plane (FEI4)

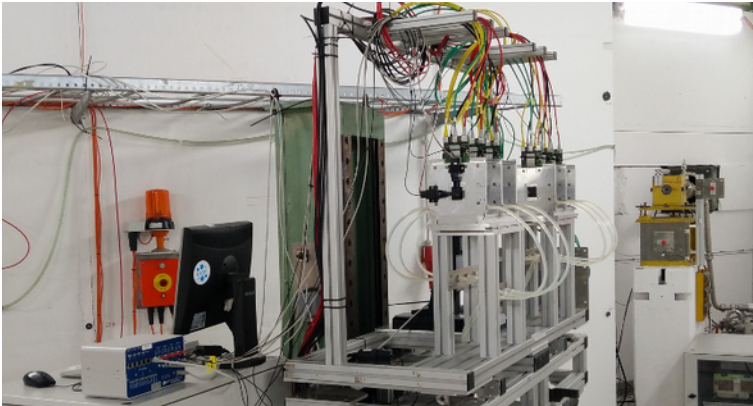# User infrastructure: EUDET-type telescopes

Providing the whole package: Device Integration – data acquisition – track reconstruction

EUDET-type hardware	**EUDAQ**	**EUTelescope**

- 6x Mimosa sensors & DAQ
- Mechanics
- Trigger System

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

Track reconstruction framework
- Masking, Clustering, Alignment, ...
- Track finding & results
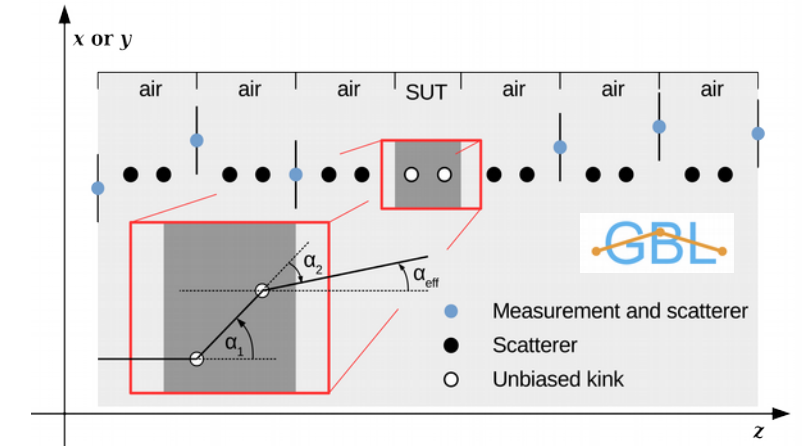
telescopes.desy.de

eudaq.github.io

eutelescope.github.io

→ **Same** system is available at test facilities (CERN PS&SPS, DESY, SLAC, ELSA) providing **different** beams
→ One decade of **usage** (incl. contributions at this conference) **& continuous development**

User infrastructure: EUDET-type telescopes

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EUDET-type hardware

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- Mechanics
- **Trigger System**

EUDAQ

Top-Level DAQ software
- Central run control & monitoring
- **Synchronisation & Acquisition**
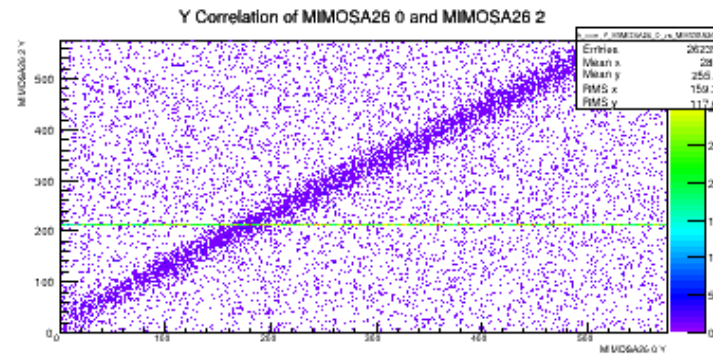
EUTelescope

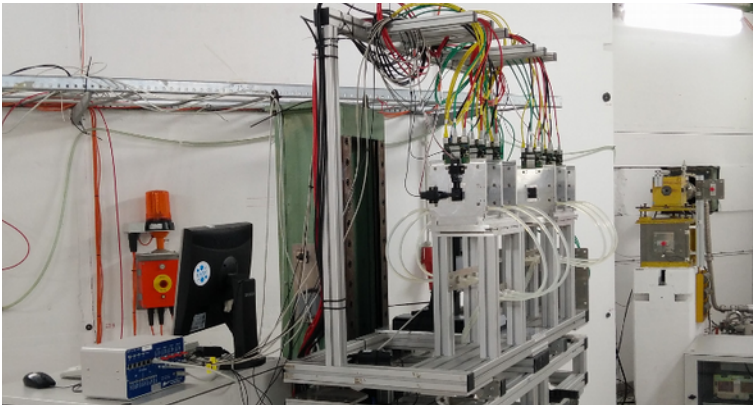Track reconstruction framework
- Clustering, Alignment, Fitting, ...
- Track finding & Results
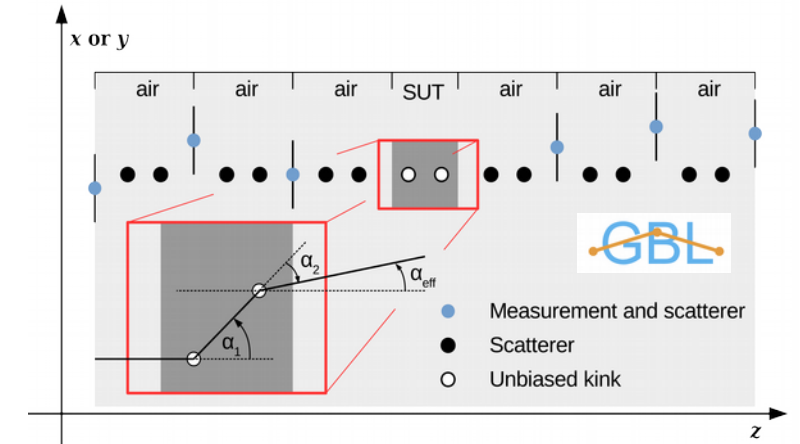
telescopes.desy.de

eudaq.github.io

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Telescope DAQ system

Trigger system & Mimosa DAQ

2x2 trigger devices

EUDET TLU

6x Mimosa26 planes

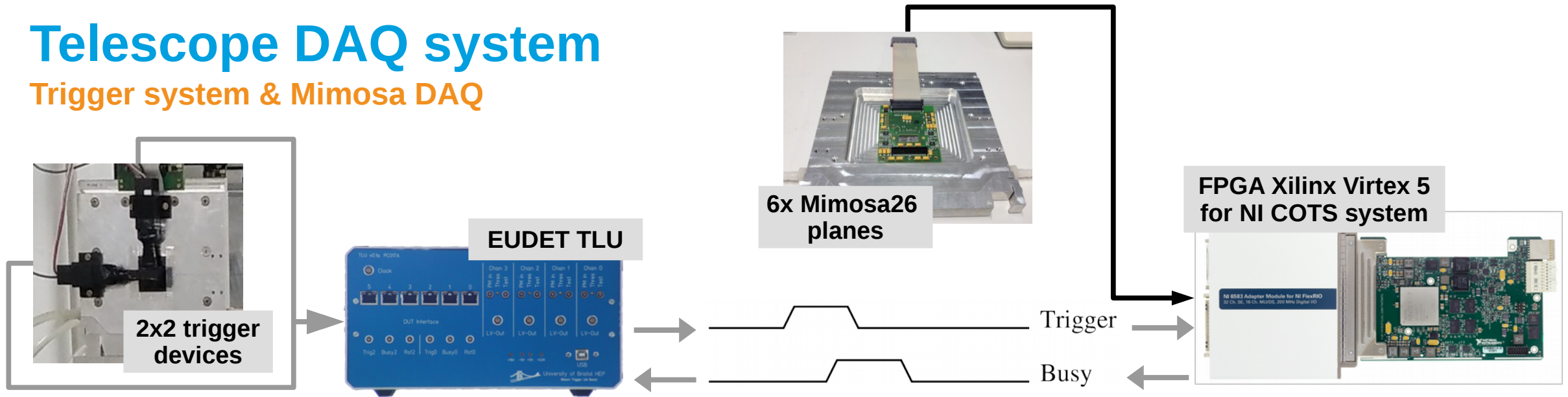**FPGA Xilinx Virtex 5 for NI COTS system**

Trigger

Busy

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

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

Mimosa DAQ

- Sensor architecture: rolling shutter & continous 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**
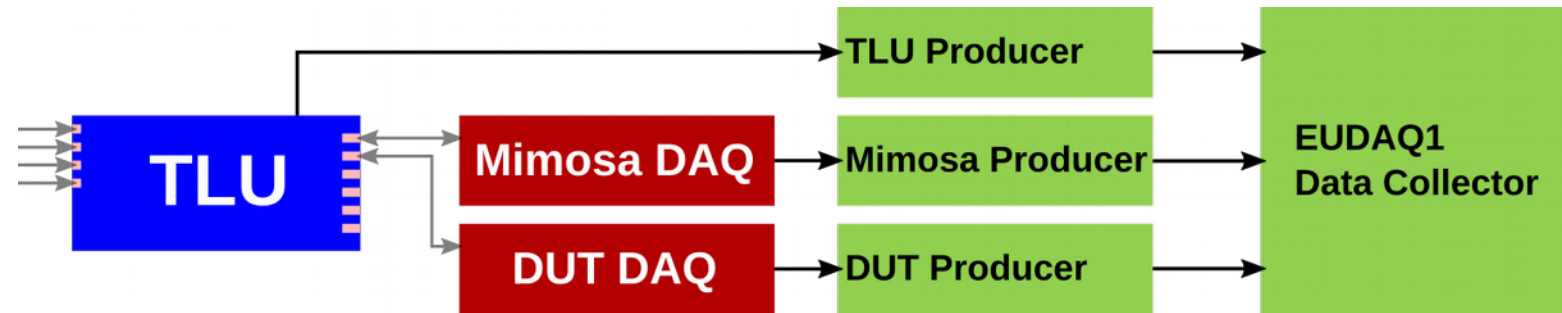
Telescope DAQ system
Trigger system & Mimosa DAQ
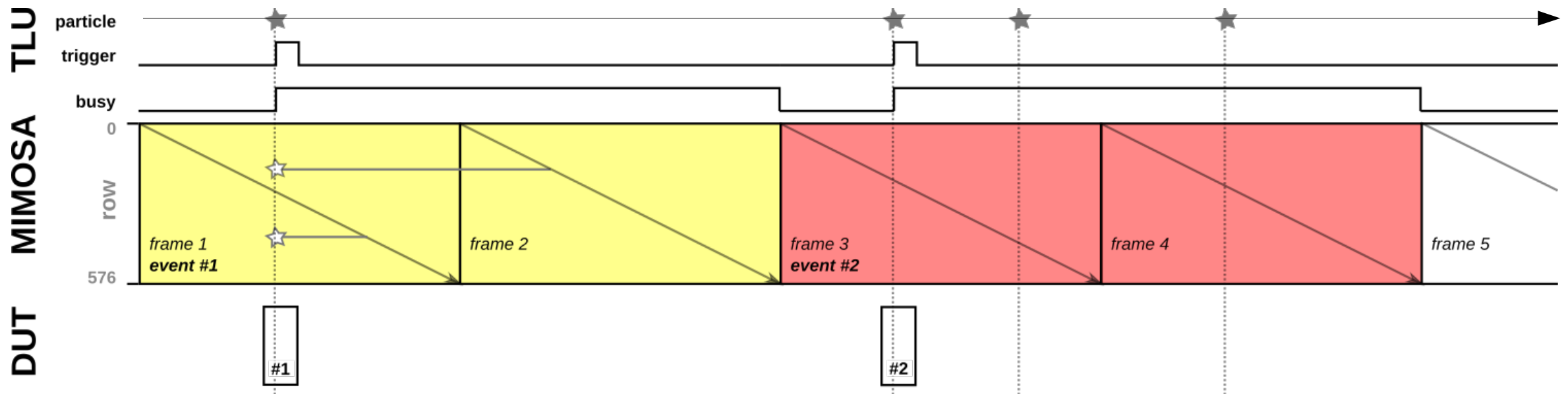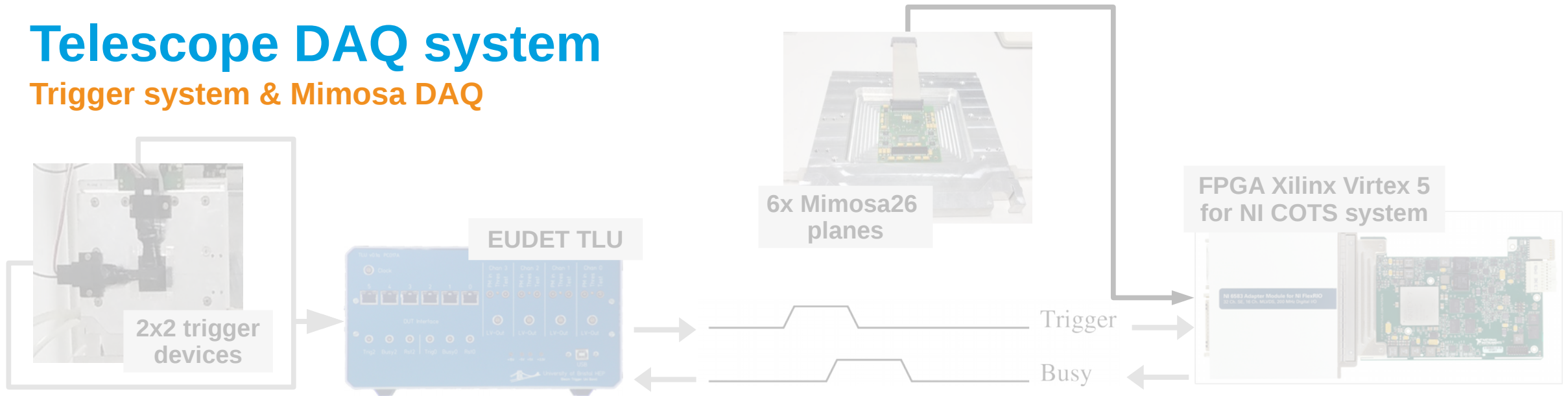
DAQ system: Data Flow and Event Building

Central data collection and synchronisation by event number ("EUDET/standard 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!**
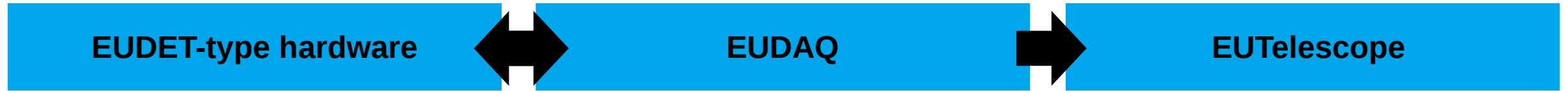
Evt. ID	TLU	DUT	Mimosa
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9
10	10	10	10
11	11	11	11
12	12	12	12
..	..	..	..

EUDAQ Data Collector

Limits and motivation for upgrades

A successful but limited strategy

Limits of "EUDET/standard mode"

- Trigger rate is limited due to Mimosa DAQ busy to max. **8.6 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

115.2 µs to 230.4 µs busy

Now: We want to make the best usage of the beam!
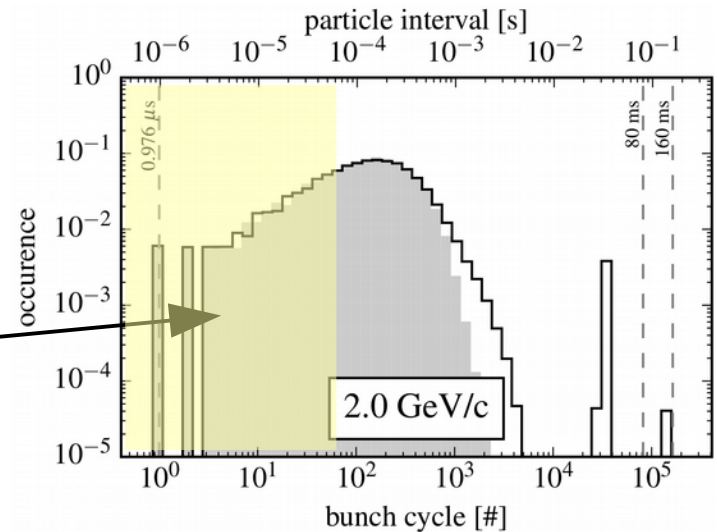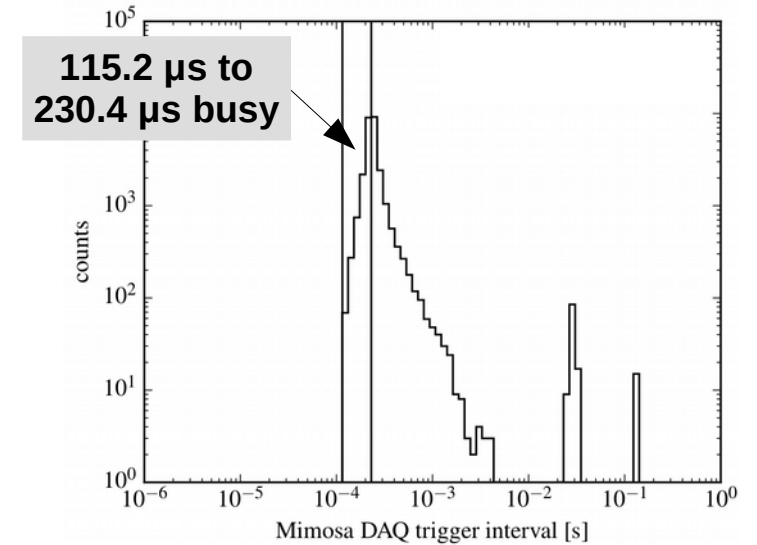
Towards higher rates

… and more timing information

Strategy for new mode

Allow **multiple** triggers within 1 telescope event

→ **Ignore** busy from slow devices

Towards higher rates
… and more timing information
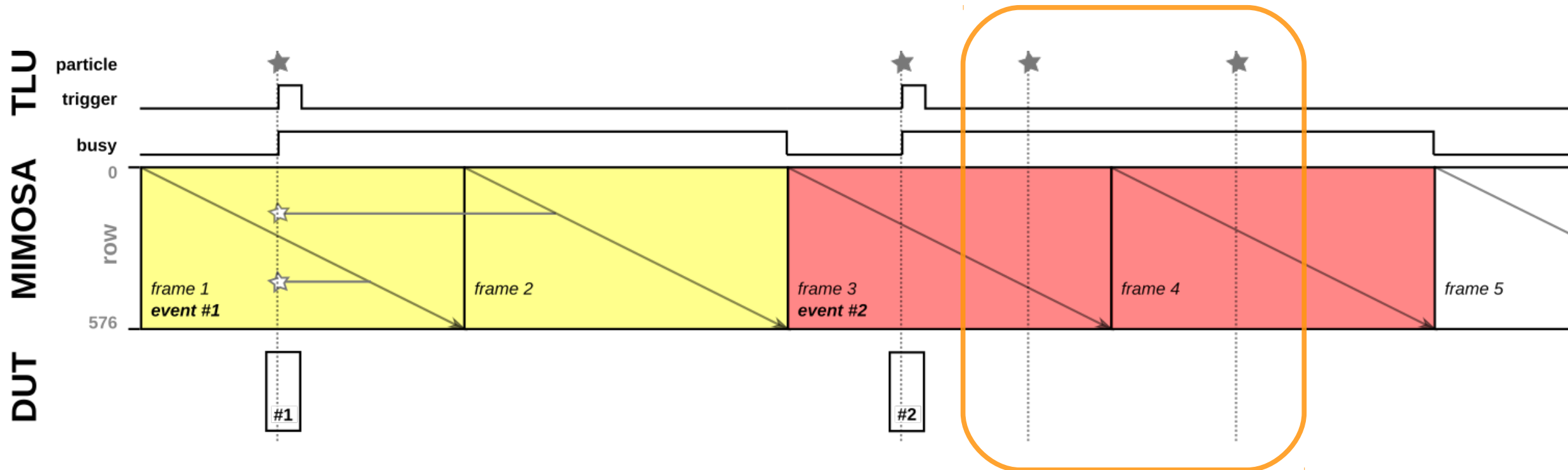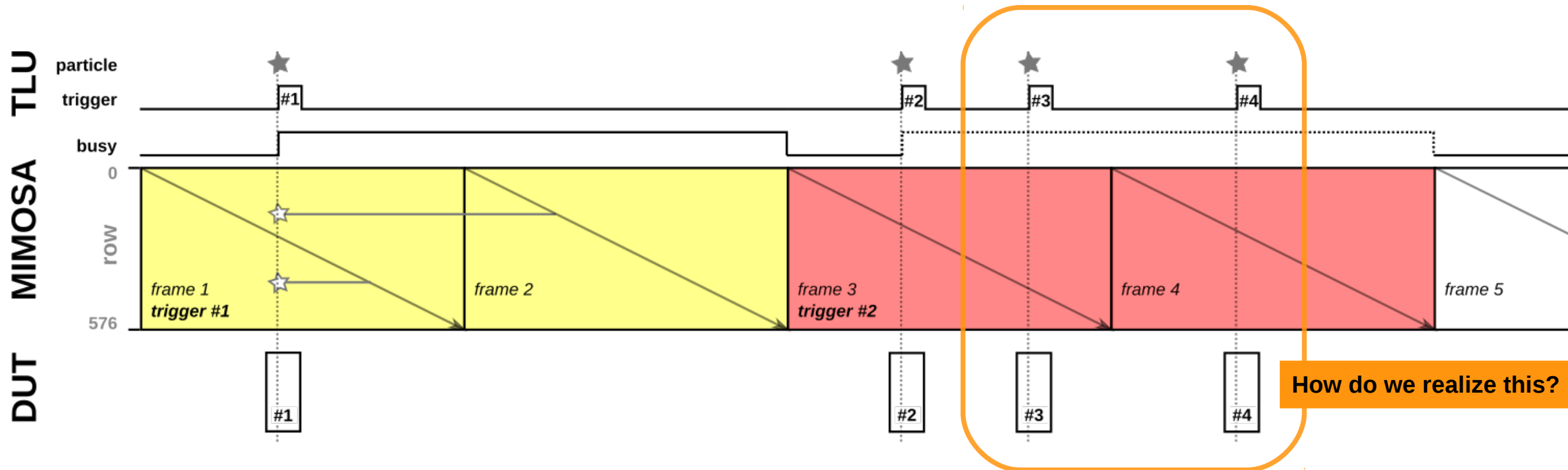
Strategy for new mode

Allow **multiple** triggers within 1 telescope event

→ **ignore** busy from slow devices

→ synchronise by **trigger ID**

How do we realize this?

New TLU

New options meet reliable techniques
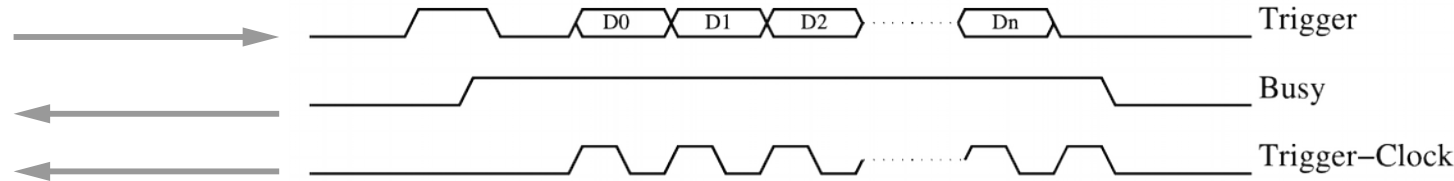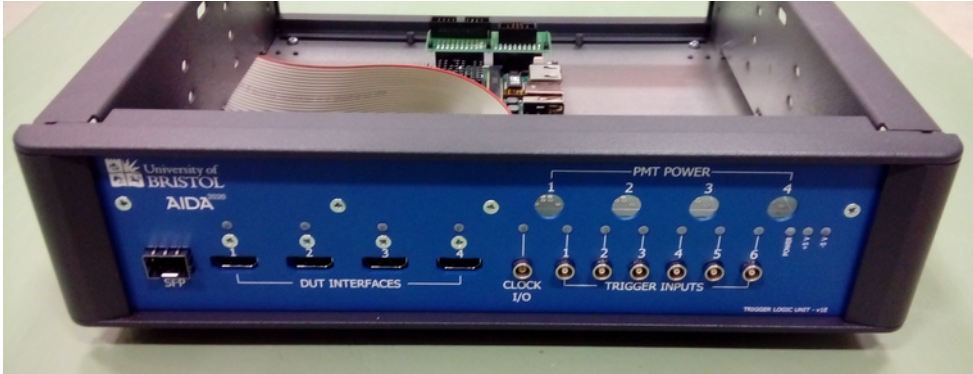
AIDA TLU: new options and faster

- 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

Independent data flow and event building

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

"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)

Results for "Mixed mode"

Getting more timestamped tracks

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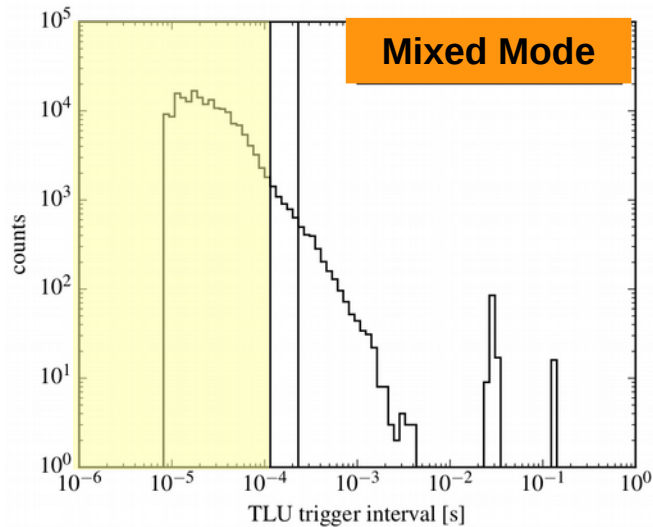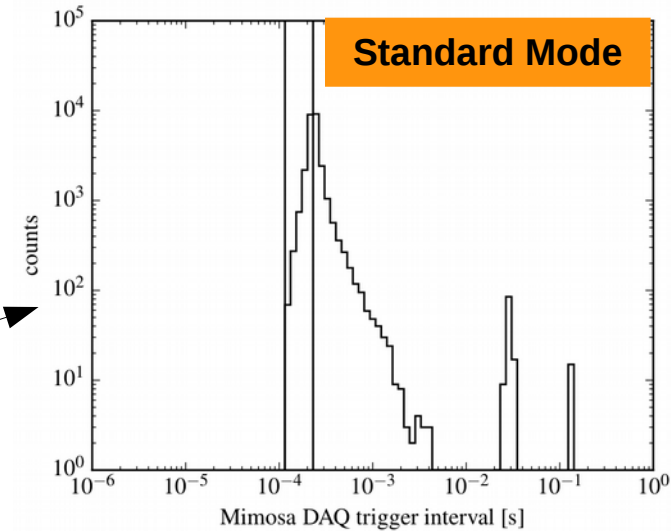and a fast reference plane FEI4

	Mixed mode			Standard
	EUDAQ 2 Sync. by Trigger ID			EUDAQ 1
Trigg. ID	TLU	DUT	Mimosa	Evt. ID
1	1	1	1	1
2	2	2	1	X
3	3	3	1	X
4	4	4	4	2
5	5	5	4	X
6	6	6	6	3
7	7	7	6	X
8	8	8	6	X
9	9	9	9	4
10	10	10	9	X
11	11	11	9	X
12	12	12	9	X
..	..	..	..	..

Standard Mode

Mixed Mode

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 @ **DESY II TB**
    → factor 1.1 at 5 GeV/c

  - potential factor 6.9 at 2 GeV/c
    → losing tracks due to
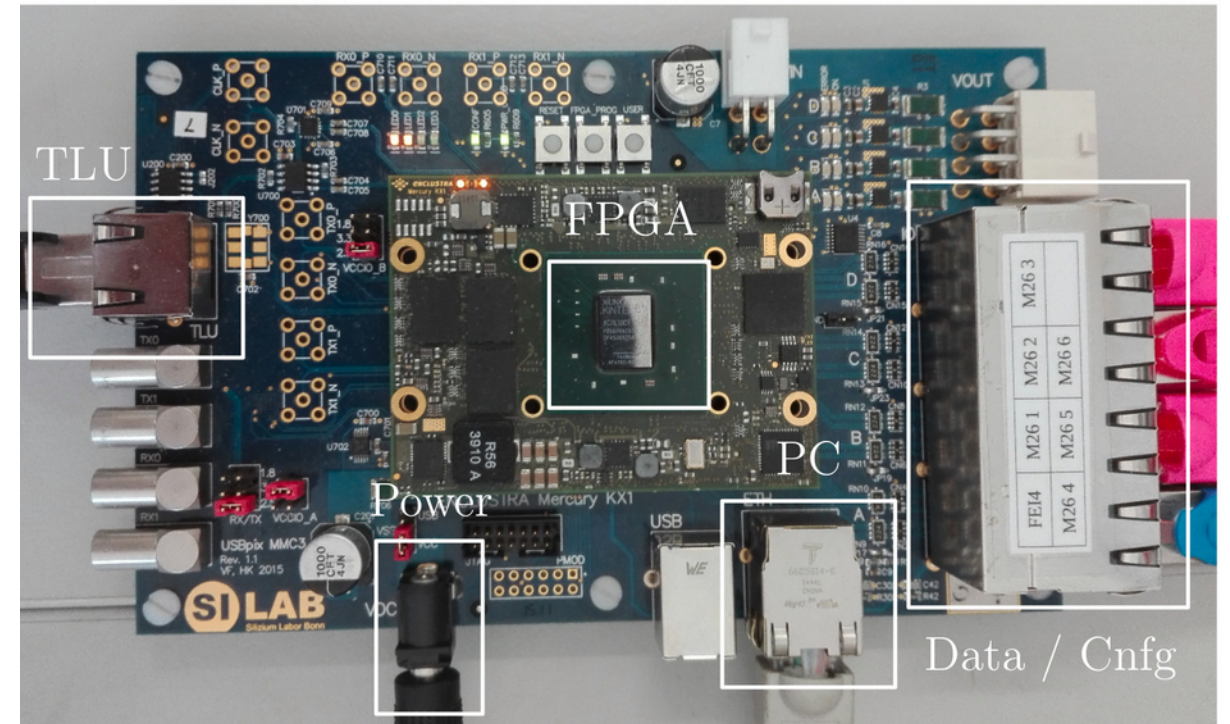   2-frame read-out

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

Summary

Higher rates for common beam telescopes

- Detector R&D needs test beam and 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 (continous Mimosa read-out) and
  AIDA mode (synchronisation by common clock)

Available data-taking modes for EUDET-type telescope and DUTs		
Modes	**Trigger comm.**	**Sync. by**
Standard/ EUDET	Global Trigger-Busy	Event ID/ Trigger ID
mixed	Individual Trigger-Busy	Trigger ID
Timestamp/ AIDA	Common Clock	Timestamps

Thank you

Upgrade Team

- TLU: Paolo Baesso, David Cussans (Univ. of Bristol)

- EUDAQ: Yi Liu, Thomas Daubney (DESY)

- EUTelescope: 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

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