AIDA-2020-SLIDE-2019-025

AIDA-2020

Advanced European Infrastructures for Detectors at Accelerators

Presentation

Status of the EUDET-type beam telescope infrastructure

The AIDA-2020 Collaboration

15 January 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 **15: Upgrade of beam and irradiation test infrastructure**.

The electronic version of this AIDA-2020 Publication is available via the AIDA-2020 web site <http://aida2020.web.cern.ch> or on the CERN Document Server at the following URL: <http://cds.cern.ch/search?p=AIDA-2020-SLIDE-2019-025>

Status of the EUDET-type beam telescope infrastructure

Jan Dreyling-Eschweiler for the DESY team

BTTB7, CERN, 15th January 2019

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

AIDA 2020

DESY TEST BEAM.

DESY.

Outline

EUDET-type beam telescopes

High precision reference tracker

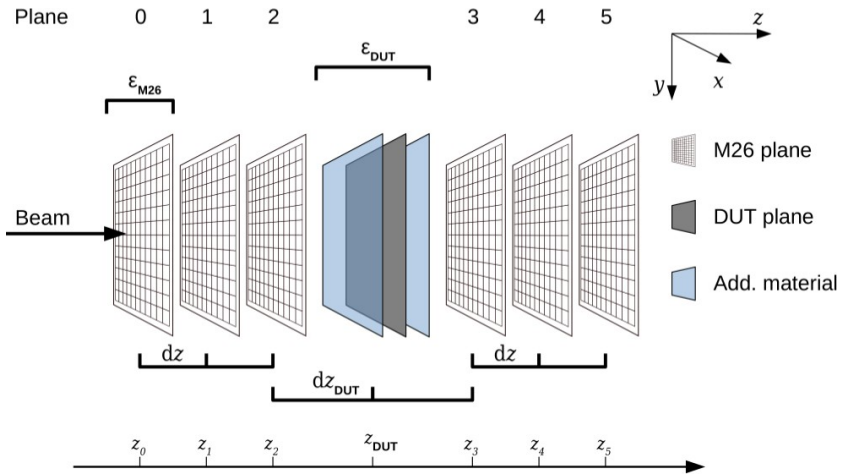
In a nutshell

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

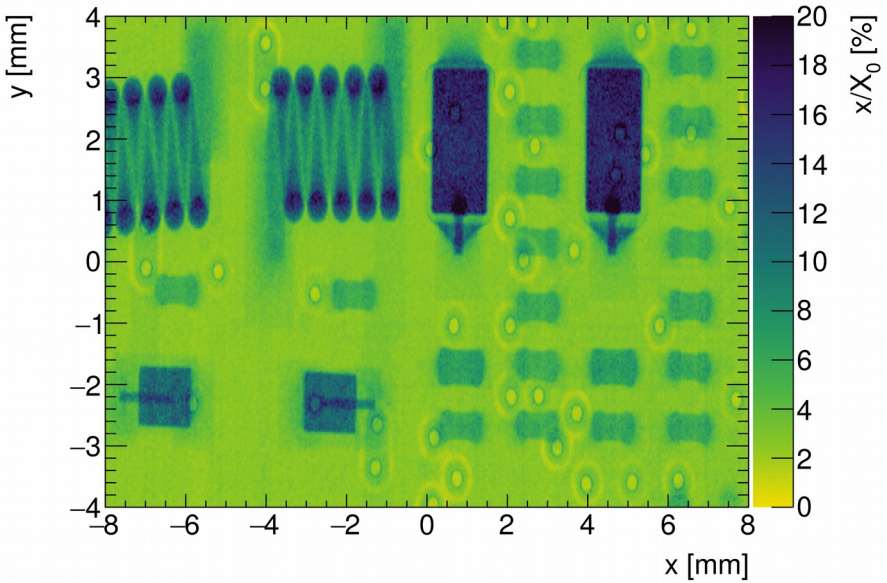
- Pointing resolution (> 1.8 µm) or
  angular resolution (> 0.03 mrad) @ 1-6 GeV/c
  → **Material Budget (X0) imaging and tomo**

@BTTB Friday 12:15 session talk

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



H. Jansen et al https://doi.org/10.1140/epjti/s40485-016-0033-2



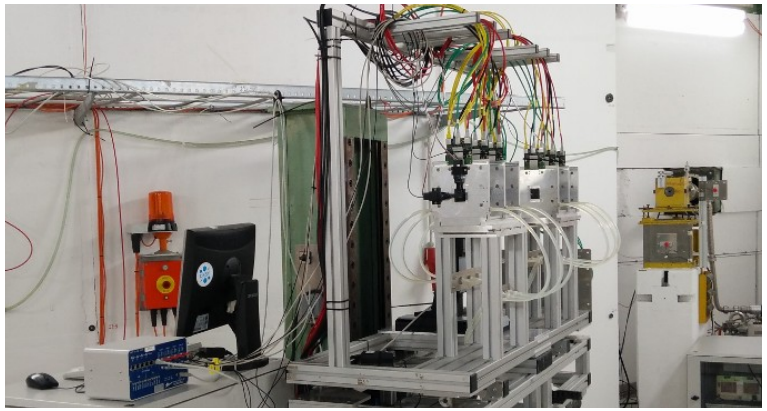
Electronic Board for ATLAS ITk strip upgrade (J.-H. Arling, C. David, M. Queitsch-Maitland)

User infrastructure

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

EUDET-type hardware ⟷ **EUDAQ** → **EUTelescope**

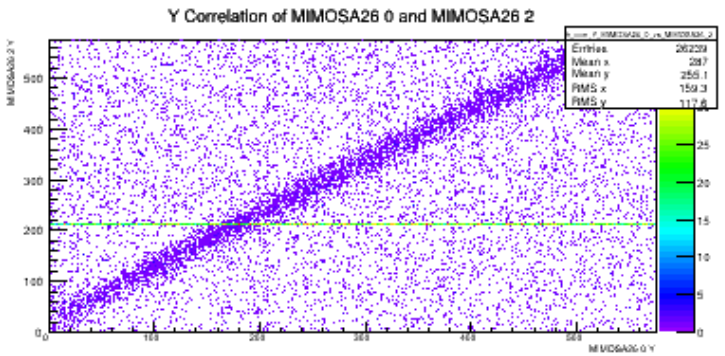
- 6x Mimosa sensors & DAQ
- Mechanics
- Trigger System



telescopes.desy.de

Top-Level DAQ software

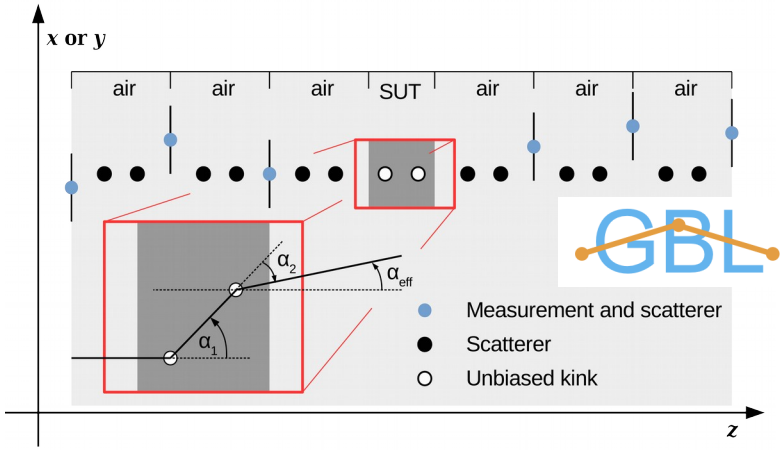
- Central run control & monitoring
- Synchronisation & acquisition



eudaq.github.io

Track reconstruction framework

- Masking, Clustering, Alignment, ...
- Track finding, fiiting & results



eutelescope.github.io

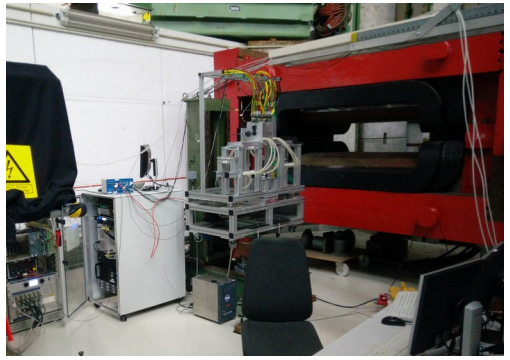
In the last decade a workhorse for various test beams...

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



DATURA @ TB21

DURANTA @ *TB22*

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

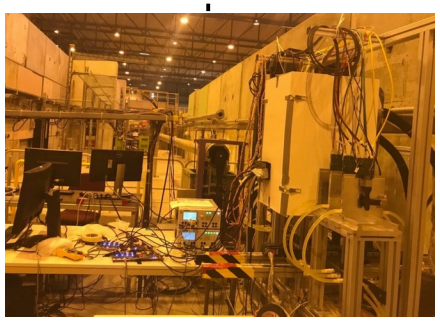
AIDA @ SPS, H6B

AZALEA @ PS, T10

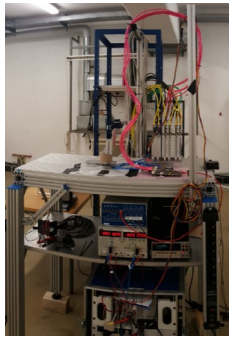
Mainly self-managed

CALADIUM @ SLAC in Stanford, USA

General Contact:
Carsten Hast



ACONITE @ SPS, H6A



ANEMONE @ BONN / ELSA

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

EUDET-type telescopes family

7 copies around the world at 5 different beam test beam facilities

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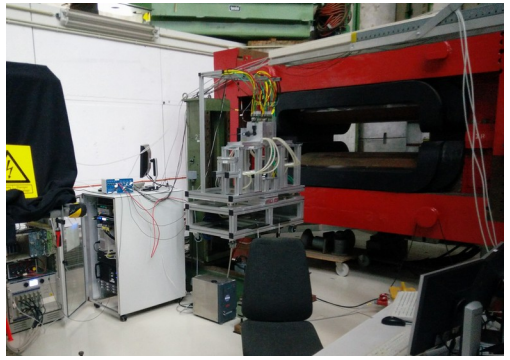


DATURA @ TB21

DURANTA *@ TB22*

Mainly self-managed

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

CALADIUM @ SLAC in Stanford, USA

Carleton UNIVERSITY

SLAC NATIONAL ACCELERATOR LABORATORY

General Contact:
Carsten Hast

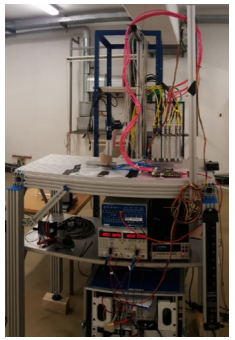
SPS/PS contact:
Henric Wilkens
Telescope contact:
André Rummler

LHC Shutdown !
From now until 2020

AIDA @ SPS, H6B

AZALEA @ PS, T10

ACONITE @ SPS, H6A



ANEMONE @ BONN / ELSA

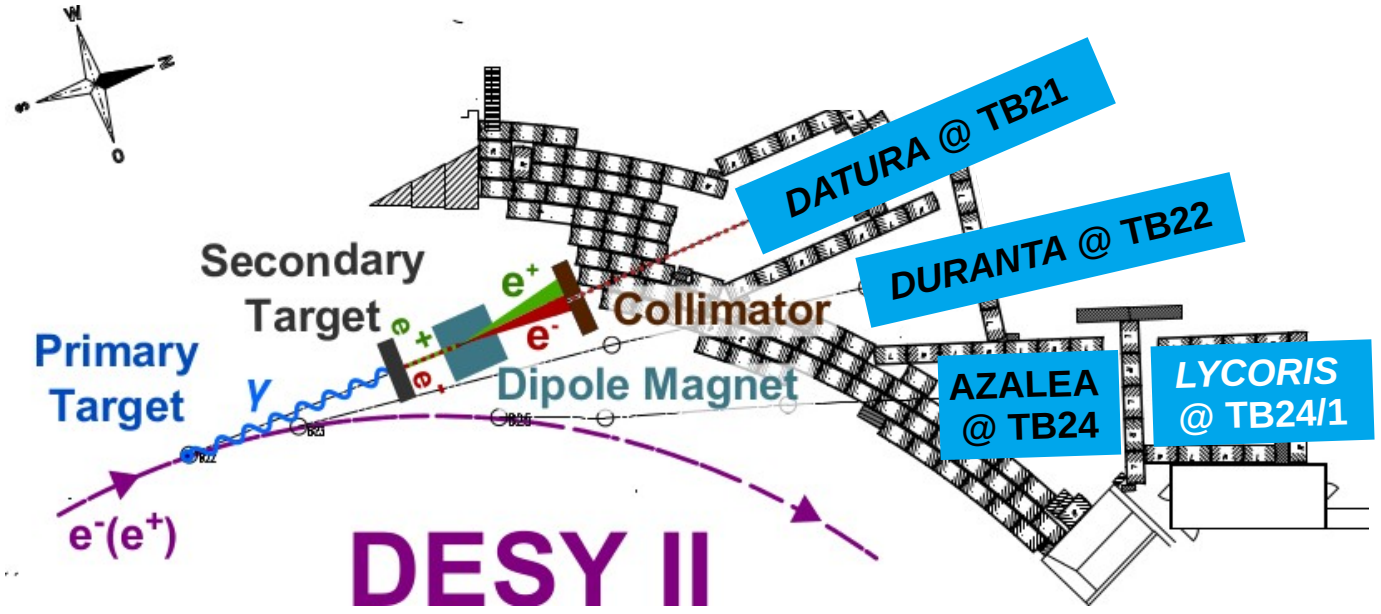
TB contact:
Daniel Elsner
Telescope contact:
David-Leon Pohl

ELSA

SILAB Silizium Labor Bonn

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

DESY TEST BEAM.

DESY Test Beam Schedule 2019 - Version 3 11/01/2018 DRAFT

Ralf Diener, Norbert Meyners, Marcel Stanitzki - DESY Test Beam Coordinators

	Week		TB21		TB22		TB24/1		TB24		
				DATURA		DURANTA	PCMAG	Telescope on PCMAG		AZALEA	
7-Jan-19	2		Shutdown								
14-Jan-19	3										
21-Jan-19	4										
28-Jan-19	5		Startup		Startup		Startup		Startup		
4-Feb-19	6		CMS-Pixel-Phase2	X	STRIDENAS				LYCORIS	X	ANNOUNCED
11-Feb-19	7		CMS-Pixel-Phase2	X					dSiPM		
18-Feb-19	8		CLIC PIXEL	X	TELEALPID	X					
25-Feb-19	9		ELAD	X							
4-Mar-19	10		ATLAS-X0	X					CALICE AHCAL		
11-Mar-19	11		CMS-Pixel-Phase2	X	ATLAS-ITk-Pixel	X			CALICE AHCAL		
18-Mar-19	12		CMS-Pixel-Phase2	X	ATLAS-HGTD	X					
25-Mar-19	13		ACDC		ATLAS-HGTD	X			ATLAS-BCM		
1-Apr-19	14		TBMST	X	ATLAS-ITk-TJCMOS	X			Belle-II	X	
8-Apr-19	15		CMS-Pixel-Phase2	X	ATLAS-ITk-TJCMOS	X			Belle-II	X	
15-Apr-19	16		CMS-Pixel-Phase2	X					Belle-II	X	
22-Apr-19	17		Setup Time				Setup time				
29-Apr-19	18		ATLAS-ITk-Strips	X	Mu3e	X	LYCORIS+TPC				
6-May-19	19		CMS Outer Tracker	X	Mu3e	X			TOTEM	X	
13-May-19	20		CMS Outer Tracker	X	ATLAS-HGTD	X					
20-May-19	21		CMS-Pixel-Phase2	X					CMS-BCM1F	X	
27-May-19	22		CMS-Pixel-Phase2	X					NICA-MPD		
3-Jun-19	23				Setup Time		Setup Time				
10-Jun-19	24		CLIC PIXEL	X	ATLAS-ITk-Strips	X	T2K				
17-Jun-19	25		TBMST	X	ATLAS-ITk-Strips	X	T2K				
24-Jun-19	26		CMS-Pixel-Phase2	X	AFP-TOF	X	CALICE-SiW-ECAL				
1-Jul-19	27		CMS-Pixel-Phase2	X	Mu3e	X	CALICE-SiW-ECAL				
8-Jul-19	28		GammaMeV	X	ATLAS-ITk-Pixel	X			CALICE AHCAL		
15-Jul-19	29		CLIC PIXEL	X	ATLAS-ITk-Pixel	X			CALICE AHCAL		
22-Jul-19	30		X-Ray-Crystal-Rad	X	ATLAS-ITk-Pixel	X					
29-Jul-19	31		Summer Shutdown								
5-Aug-19	32		TBMST	X	SummerStudents	X					DRAFT
12-Aug-19	33		BL4S	X	SummerStudents	X			BL4S	X	
19-Aug-19	34		TBMST	X	ATLAS-HGTD	X			CBM-TRD		
26-Aug-19	35		ELAD	X	SHiP-SplitCAL				CBM-TRD		
2-Sep-19	36		CMS-Pixel-Phase2		Setup Time						
9-Sep-19	37		CMS-Pixel-Phase2	X	ATLAS-ITk-Strips	X			CEPC-STFC	X	
16-Sep-19	38		AFP-TOF	X	Mu3e	X			CEPC-STFC	X	
23-Sep-19	39		CLIC PIXEL	X	ATLAS-ITk-Pixel	X			TOTEM	X	
30-Sep-19	40		X-Ray-Crystal-Rad	X	ATLAS-ITk-Pixel	X			ATLAS-BCM		
7-Oct-19	41								HEP for Teachers		
14-Oct-19	42		BL4S	X	SHiP-SBT				BL4S	X	
21-Oct-19	43		BL4S	X	SHiP-SciFi				BL4S	X	

@BTTB Wednesday 9:00
Facility talk

@BTTB Wednesday 9:20
photon tagging talk

@BTTB Wednesday 11:10
LYCORIS talk

News & upgrades of the infrastructure

Requests from BTTB6-forum: Higher time resolution & User support

EUDET-type hardware ⟷ **EUDAQ v1 and v2** → **EUTelescope**

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 canditates

   @BTTB Thursday 19:00 discussion in the Forum

- CI 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

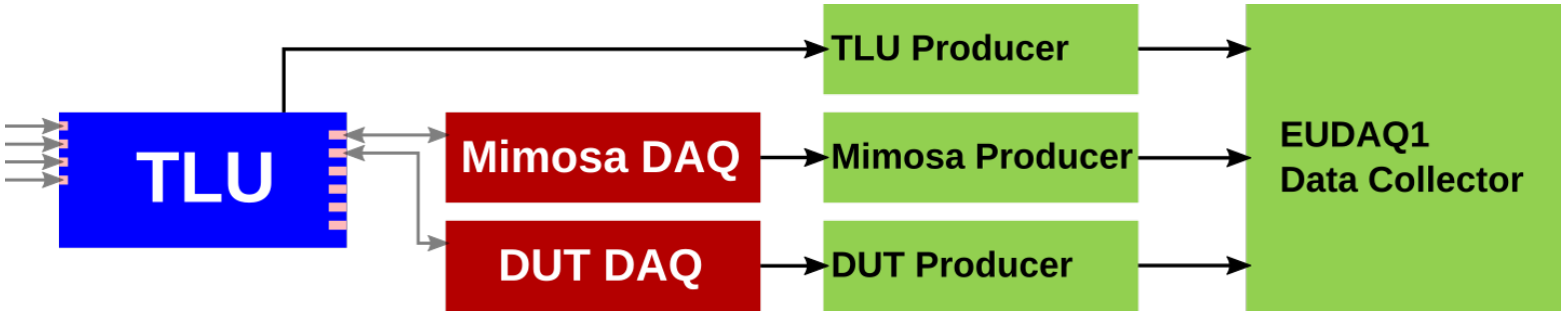
    @BTTB Tuesday 16:30 hands-on

New trigger and data taking options are ready to use, for example the **“Mixed Mode”**...

DAQ system: data flow and event building

Central data collection and synchronisation by event number (“EUDET/standard mode”)

EUDET-type hardware ⟷ **EUDAQ** → **EUTelescope**



EUDAQ Data Collector

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
..	..	..	..

“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!**

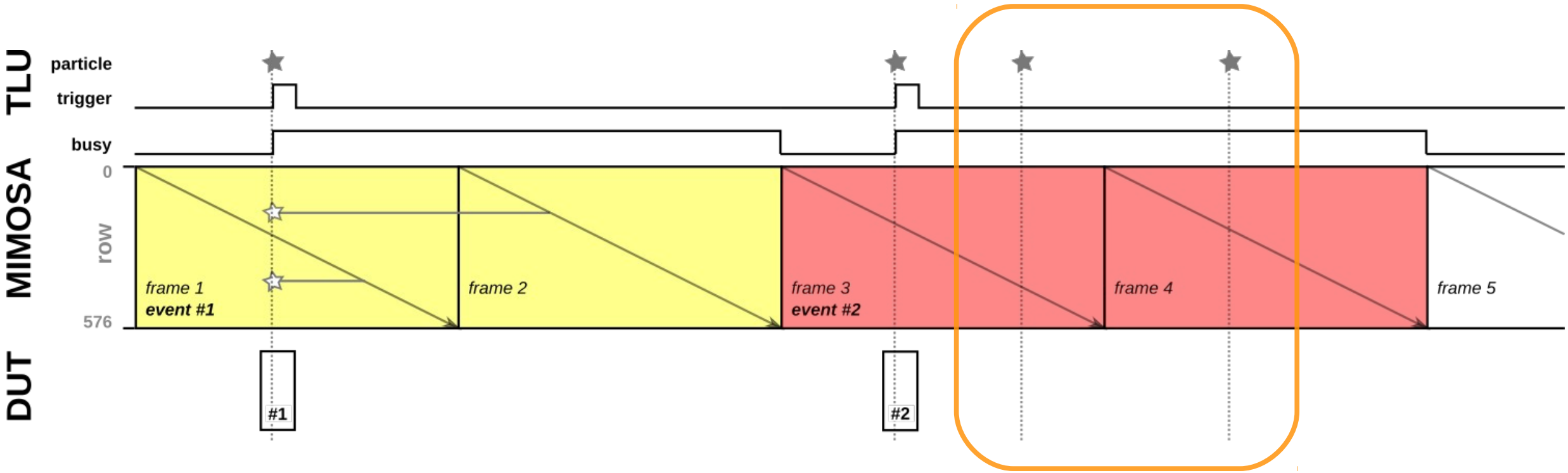
Towards higher rates

… 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

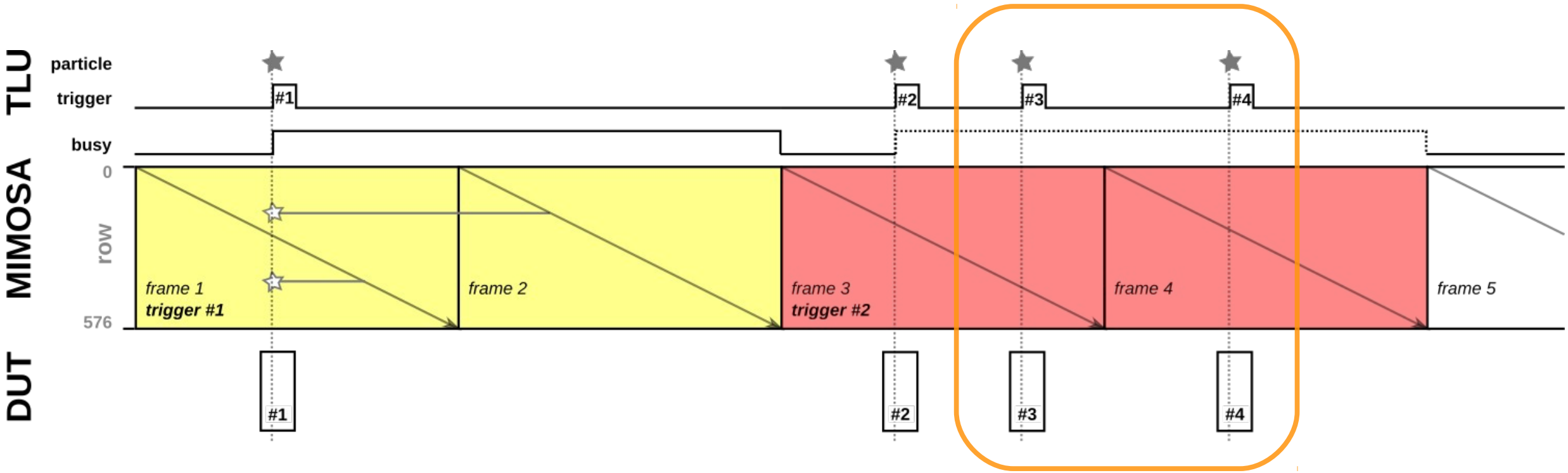


Towards higher rates

… and more timing information

Strategy for new mode

Allow **multiple** triggers within 1 telescope event



Towards higher rates

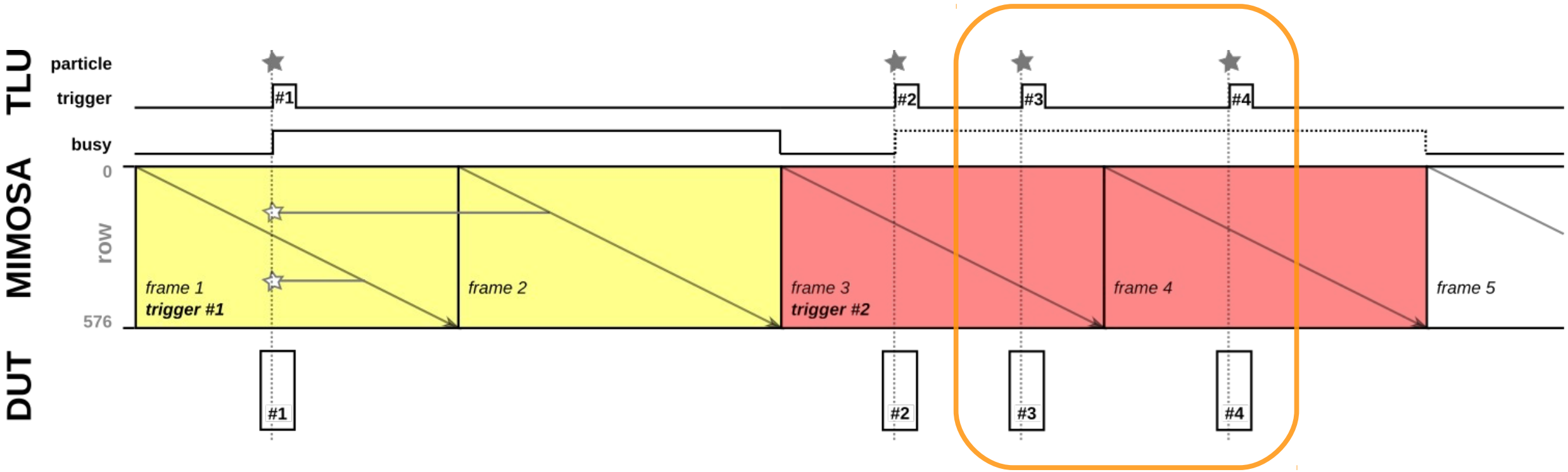
… and more timing information

Strategy for new mode

Allow **multiple** triggers within 1 telescope event

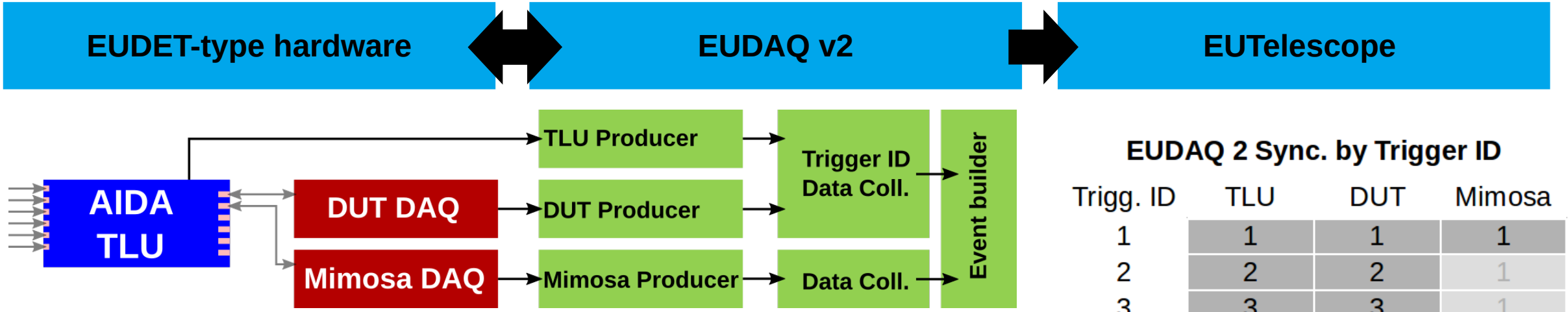
→ **ignore** busy from slow devices → ***AIDA TLU***

→ 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

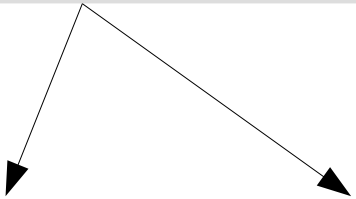
EUDAQ 2 Sync. by Trigger ID

Trigg. ID	TLU	DUT	Mimosa
1	1	1	1
2	2	2	1
3	3	3	1
4	4	4	4
5	5	5	4
6	6	6	6
7	7	7	6
8	8	8	6
9	9	9	9
10	10	10	9
11	11	11	9
12	12	12	9
..	..	..	..

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 — **EUDAQ 2 Sync. by Trigger ID**

Standard — **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
..	..	..	..	..

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

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 (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

Contact

DESY. Deutsches Elektronen-Synchrotron

www.desy.de

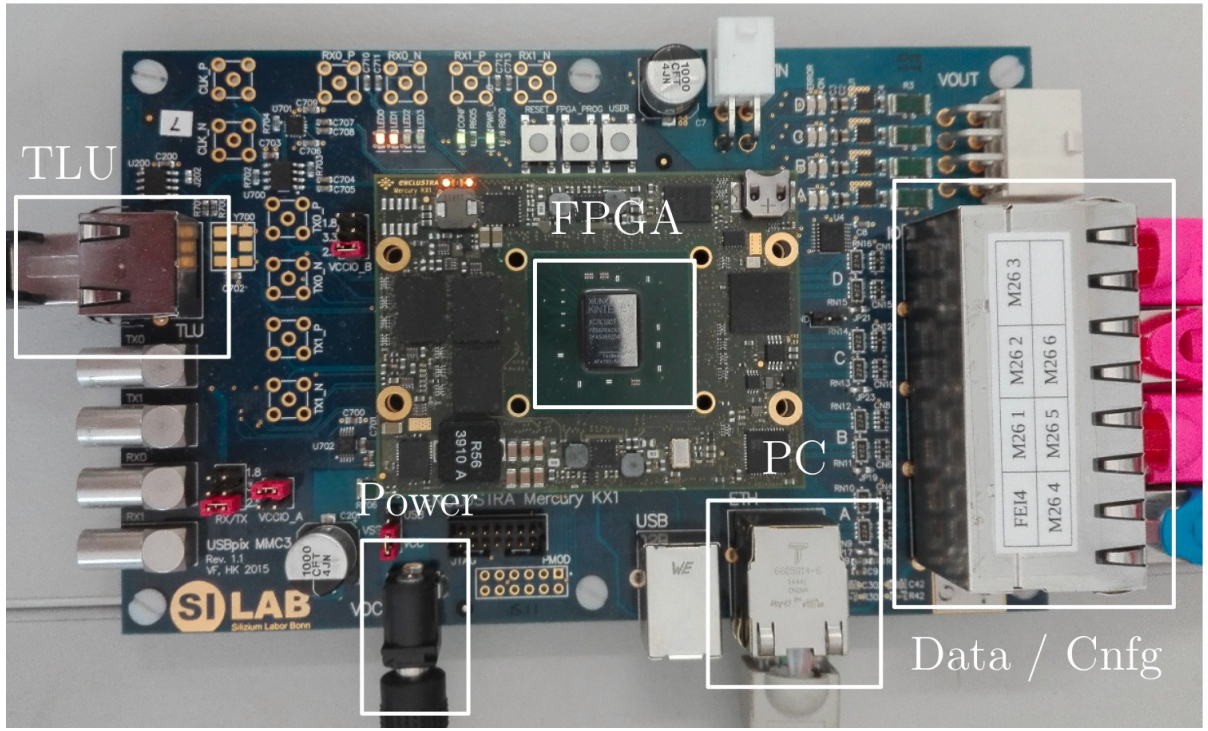
Jan Dreyling-Eschweiler
High-energy department, ATLAS group
Mail: jan.dreyling-eschweiler@desy.de
Phone: 0049 (0)40 8998 2794

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



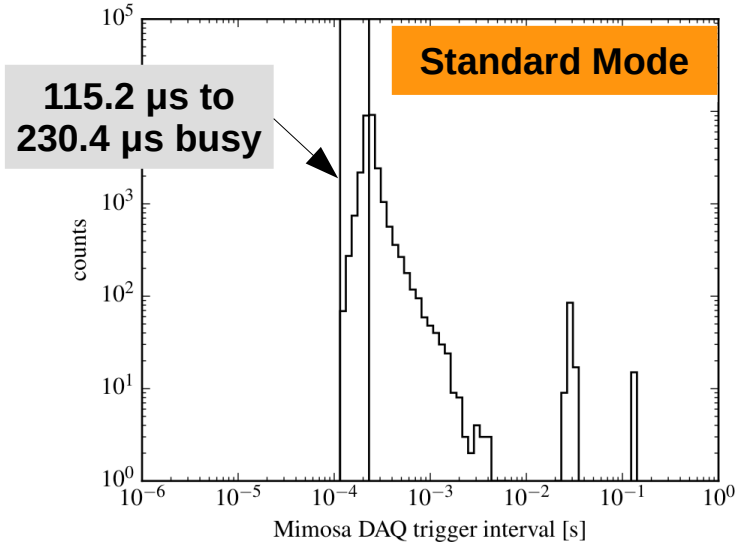
Limits @ DESY TB

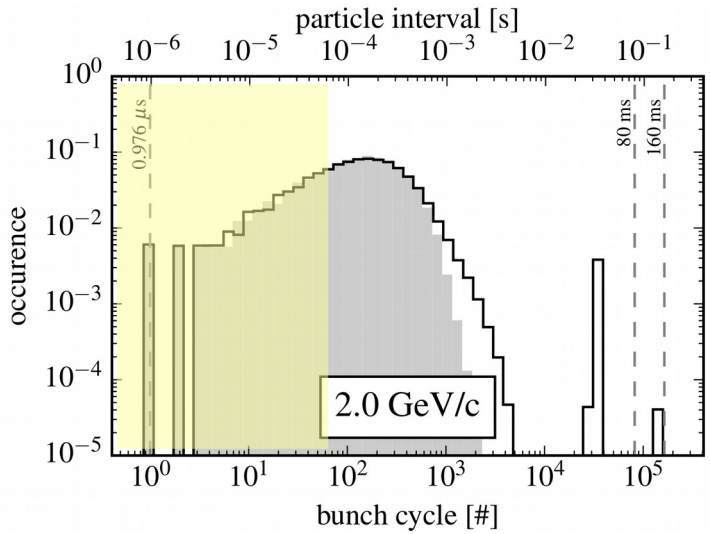
A successful but limited strategy

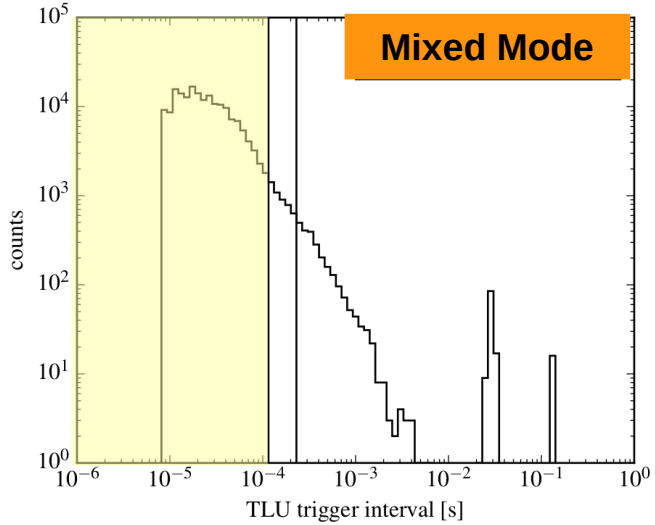
To make the best usage of the beam!

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

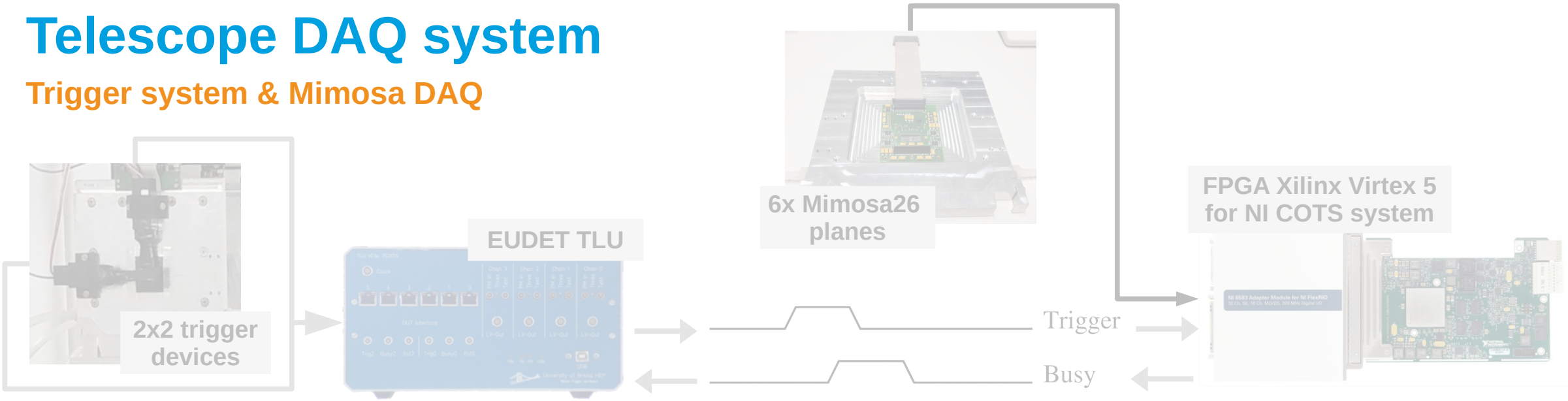


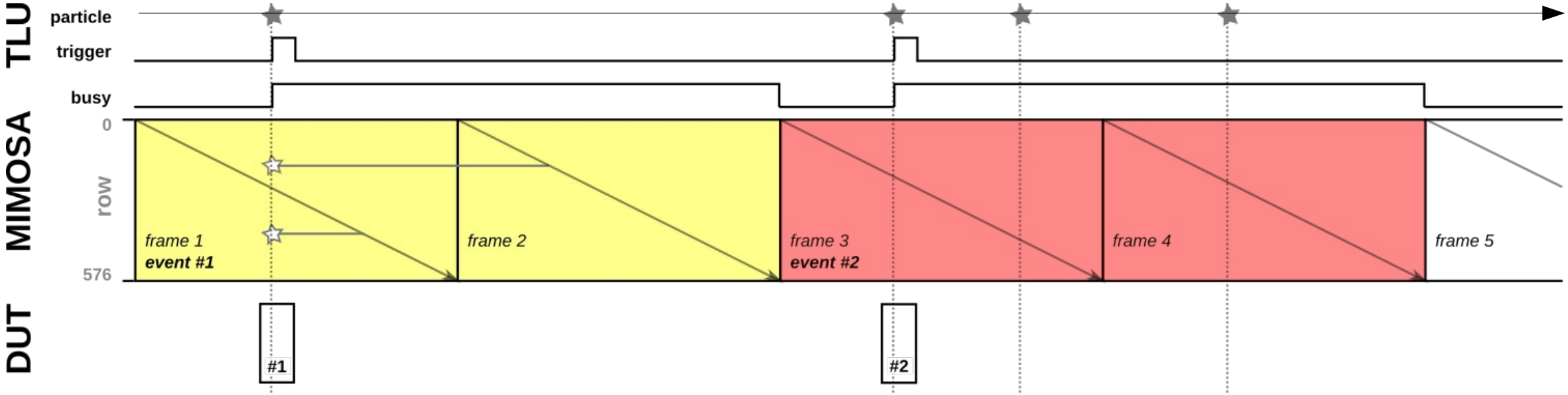




Telescope DAQ system

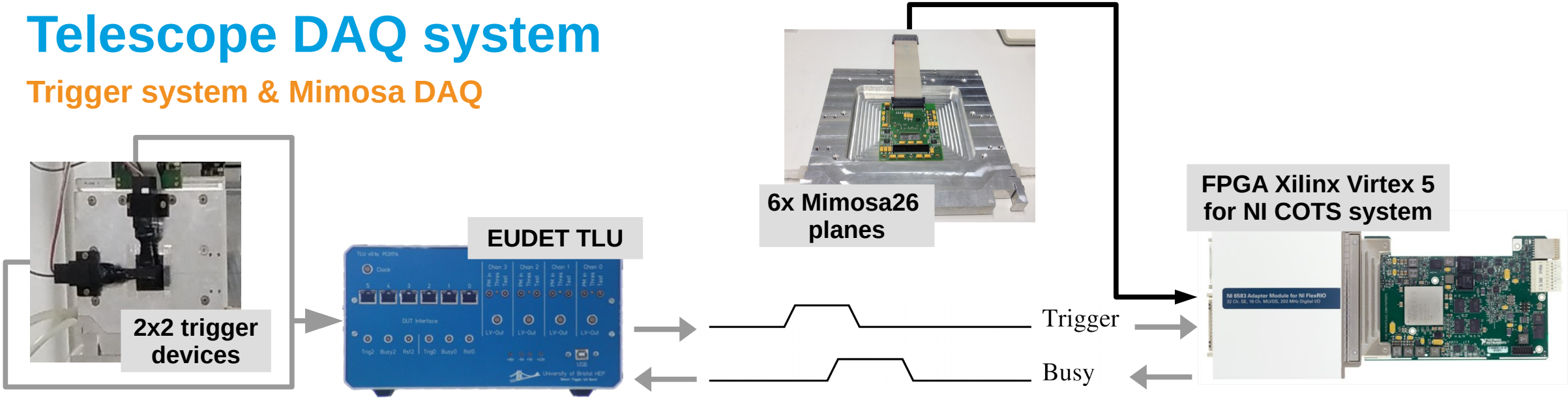
Trigger system & Mimosa DAQ





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

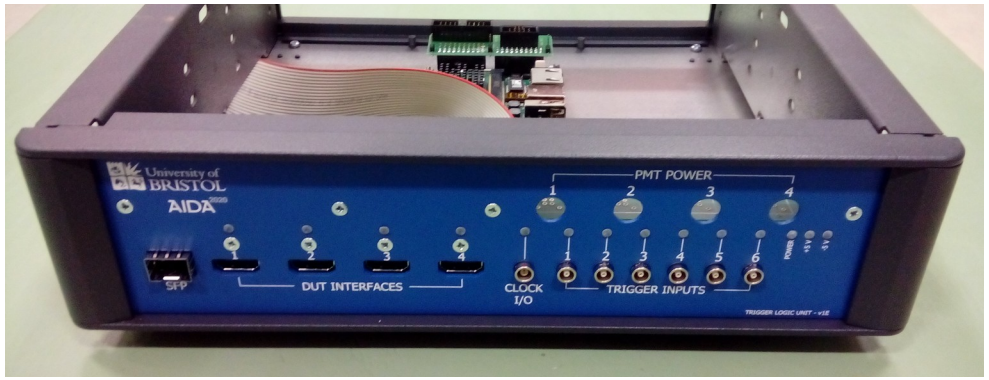
D. Cussans D, Description of the JRA1 Trigger Logic Unit (TLU), v0.2c. EUDET-MEMO-2009-04

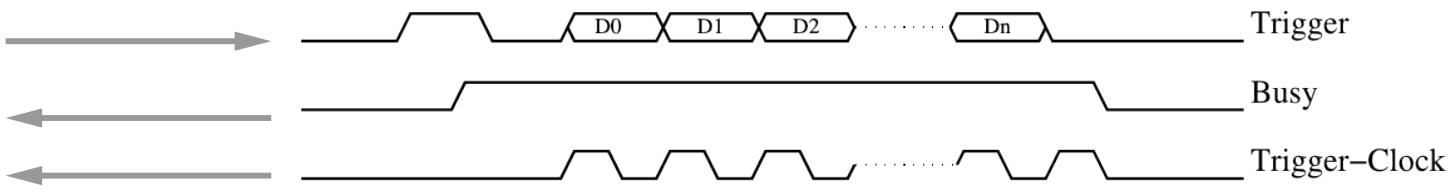
Mimosa DAQ

- 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**

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

#	Mode	Sync.	TLU	EUDAQ	Streams	DataCollector	Event building	Realizations/User
1	EUDET	global busy	EUDET	1	1	DataCollector	Online by DC	EUDAQ1
2	EUDET	global busy	both	2	1	**EventIDSync DataCollector**	Online by DC	ATLAS ITK and EUDET telescope
3	EUDET	global busy	both	2	>1	**DirectSave DataCollector**	Offline by **euCliMerger StandardEvtID**	TORCH and EUDET telescope
4	mixed	Trigger ID	AIDA	2	1	**TriggerIDSync DataCollector**	Online by DC	EUDET telescope
5	mixed	Trigger ID	AIDA	2	>1	**DirectSave DataCollector**	Offline by **euCliMerger StandardTrigID**	EUDET telescope
6	AIDA	timestamp	AIDA	2	1	**TimestampSync DataCollector**	Online by DC	CALICE, BIF and CaliceTelDataCollector
7	AIDA	timestamp	AIDA	2	>1	**DirectSave DataCollector**	Offline by ***TimestampSync EventBuilder***	na