



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



Outline

01 Introduction

02 Telescope family in 2019/2020

03 News & Upgrades

→ Mixed Mode results at DESY TB

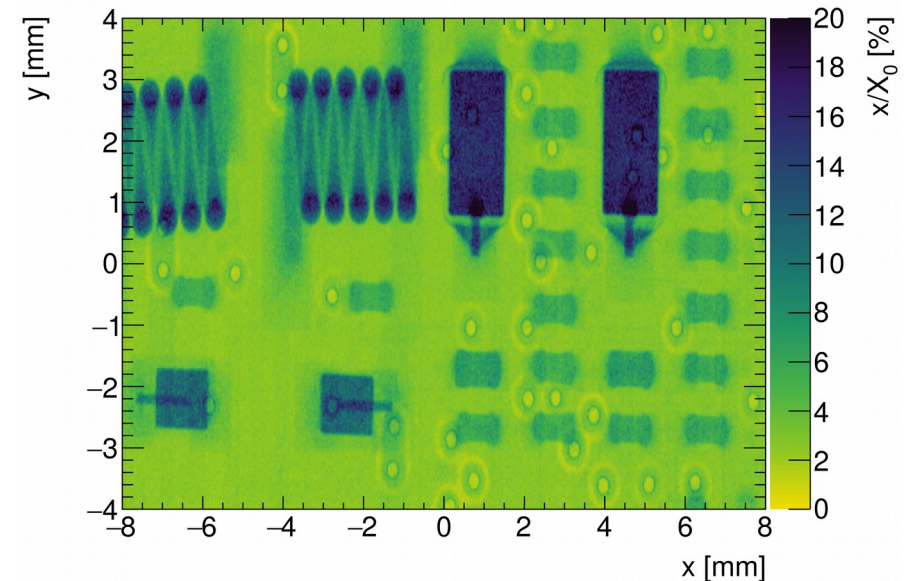
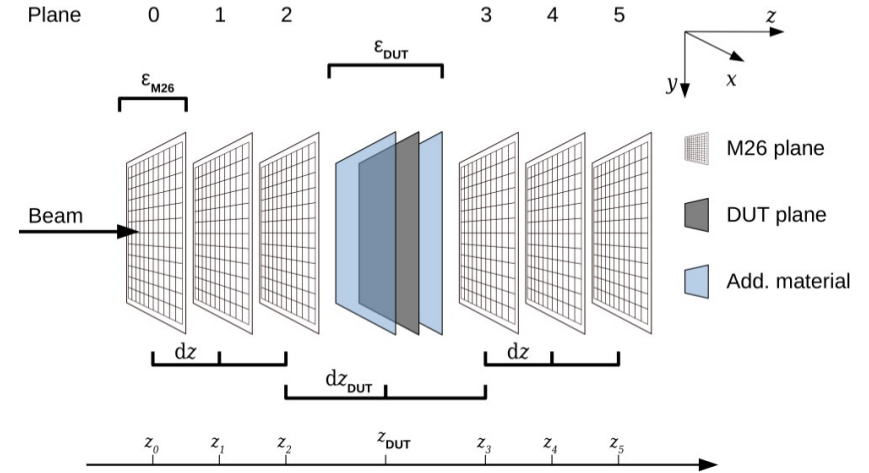
04 Summary & Outlook

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 ($> 1.8 \mu\text{m}$) or angular resolution ($> 0.03 \text{ mrad}$) @ 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

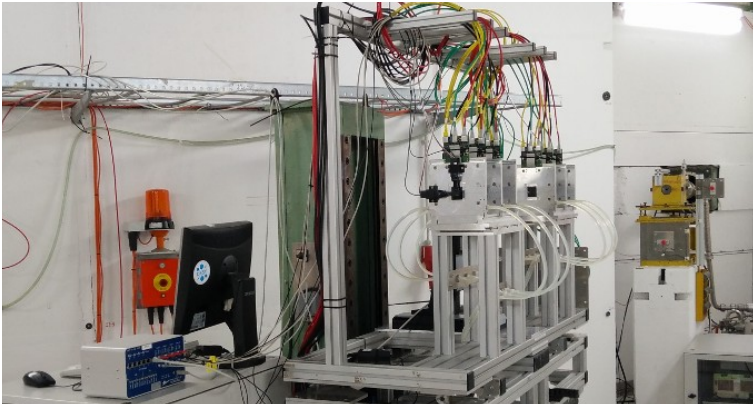


User infrastructure

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

EUDET-type hardware

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

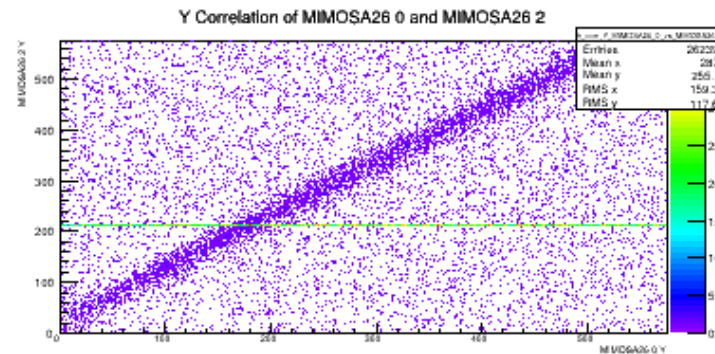


telescopes.desy.de

EUDAQ

Top-Level DAQ software

- Central run control & monitoring
- Synchronisation & acquisition

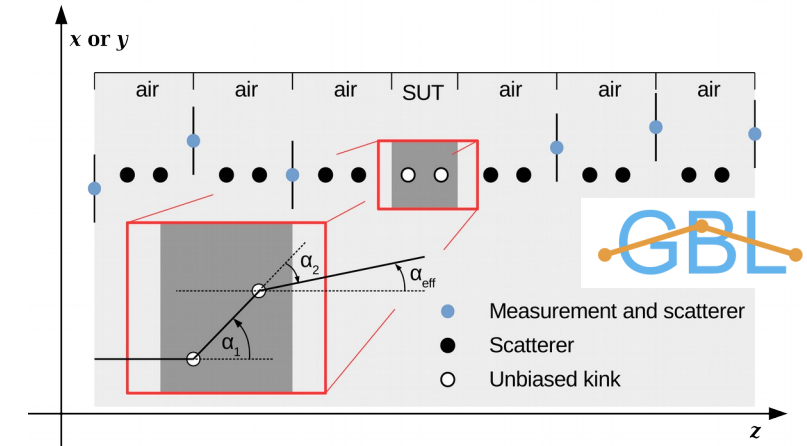


eudaq.github.io

EUTelescope

Track reconstruction framework

- Masking, Clustering, Alignment, ...
- Track finding, fitting & 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)

Mainly self-managed

TB contact:

Ralf Diener, Norbert Meyners, Marcel Stanitzki

Telescope contact:

Hendrik Jansen, Jan Dreyling-Eschweiler



DATURA @ TB21



DURANTA @ TB22



CALADIUM @ SLAC in Stanford, USA



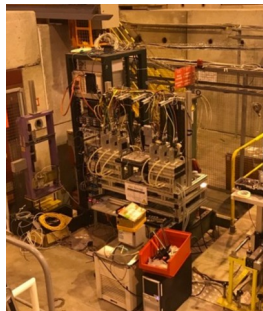
General Contact:
Carsten Hast

SPS/PS contact:

Henric Wilkens

Telescope contact:

André Rummler



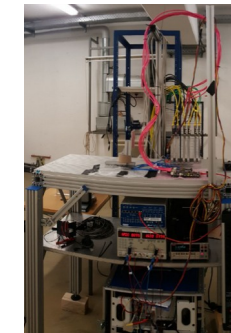
AIDA @ SPS, H6B



AZALEA @ PS, T10



ACONITE @ SPS, H6A



ANEMONE @ BONN / ELSA

TB contact:

Daniel Elsner

Telescope contact:

David-Leon Pohl



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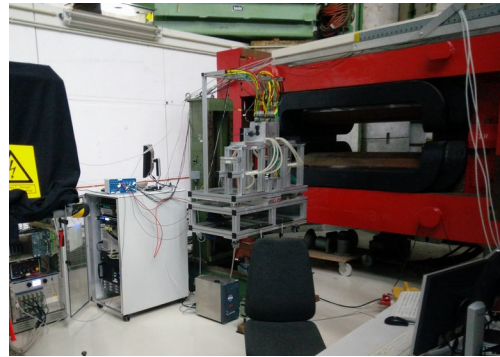
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DATURA @ TB21



DURANTA @ TB22

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

CALADIUM @ SLAC in Stanford, USA



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Carsten Hast

SPS/PS contact:

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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

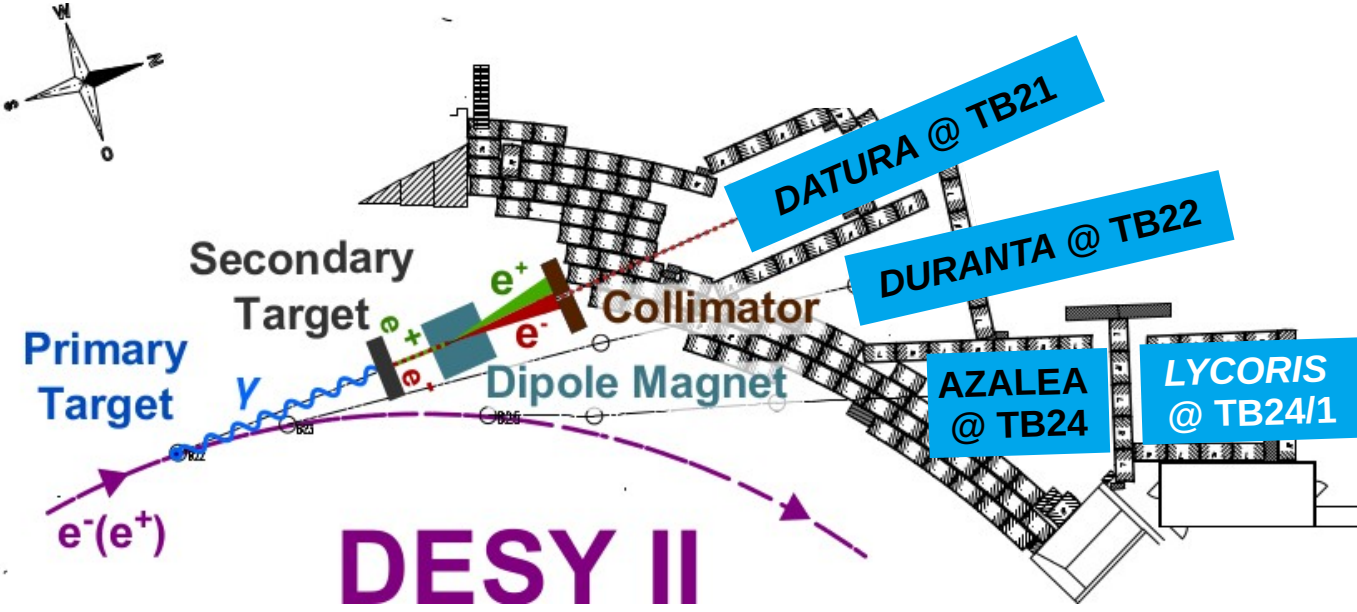
Telescope contact:

David-Leon Pohl



In 2019/20: 3 telescopes at 3 beam lines at DESY

Azalea from CERN, PS is installed in TB24 at DESY



@BTTB Wednesday 9:00
Facility talk

@BTTB Wednesday 11:10
LYCORIS talk

@BTTB Wednesday 9:20
photon tagging talk

(full) schedule at <http://testbeam.desy.de>

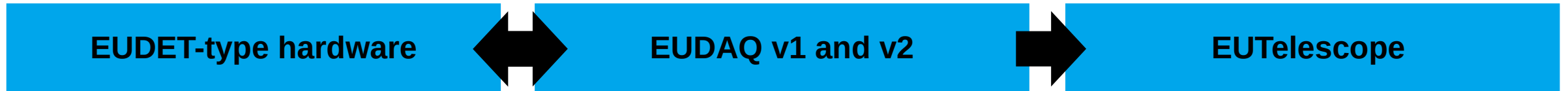
DESY TEST BEAM
Rail Diener, Norbert Meyners, Marcel Stanitzki - DESY Test Beam Coordinators

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

Week	TB21		TB22		TB24/1		TB24			
	status	status	status	status	status	status	status			
7-Jan-19									ANNOUNCED	
14-Jan-19	Shutdown									
21-Jan-19	Shutdown									
28-Jan-19	Shutdown									
4-Feb-19	Shutdown									
11-Feb-19	Startup		Startup		Startup		Startup			
18-Feb-19	CMS-Pixel-Phase2	X	STRIDENAS				LYCORIS	X		
25-Feb-19	CLIC PIXEL	X	TELEALPID	X			dSPM			
4-Mar-19	ELAD	X								
11-Mar-19	ATLAS-X0	X					CALICE AHCAL			
18-Mar-19	CMS-Pixel-Phase2	X	ATLAS-ITk-Pixel	X			CALICE AHCAL			
25-Mar-19	CMS-Pixel-Phase2	X	ATLAS-HGTD	X			ATLAS-BCM			
1-Apr-19	ACDC	X	ATLAS-HGTD	X			Belle-II	X		
8-Apr-19	TBMST	X	ATLAS-ITk-TJCMOS	X			Belle-II	X		
15-Apr-19	CMS-Pixel-Phase2	X	ATLAS-ITk-TJCMOS	X			Belle-II	X		
22-Apr-19	Setup Time				Setup time					
29-Apr-19	ATLAS-ITk-Strips	X	Mu3e	X	LYCORIS+TPC					
6-May-19	CMS Outer Tracker	X	Mu3e	X			TOTEM	X		
13-May-19	CMS Outer Tracker	X	ATLAS-HGTD	X						
20-May-19	CMS-Pixel-Phase2	X					CMS-BCM1F	X		
27-May-19	CMS-Pixel-Phase2	X					NICA-MPD			
3-Jun-19			Setup Time		Setup Time					
10-Jun-19	CLIC PIXEL	X	ATLAS-ITk-Strips	X	TZK					
17-Jun-19	TBMST	X	ATLAS-ITk-Strips	X	TZK					
24-Jun-19	CMS-Pixel-Phase2	X	AFP-TOF	X	CALICE-SIW-ECAL					
1-Jul-19	CMS-Pixel-Phase2	X	Mu3e	X	CALICE-SIW-ECAL					
8-Jul-19	GammaMeV	X	ATLAS-ITk-Pixel	X			CALICE AHCAL			
15-Jul-19	CLIC PIXEL	X	ATLAS-ITk-Pixel	X			CALICE AHCAL			
22-Jul-19	X-Ray-Crystal-Rad	X	ATLAS-ITk-Pixel	X						
29-Jul-19			Setup Time		Setup Time					
5-Aug-19	TBMST	X	SummerStudents	X						
12-Aug-19	BL4S	X	SummerStudents	X			BL4S	X		
19-Aug-19	TBMST	X	ATLAS-HGTD	X			CBM-TRD			
26-Aug-19	ELAD	X	SHIP-SplitCAL				CBM-TRD			
2-Sep-19	CMS-Pixel-Phase2		Setup Time							
9-Sep-19	CMS-Pixel-Phase2	X	ATLAS-ITk-Strips	X			CEPC-STFC	X		
16-Sep-19	AFP-TOF	X	Mu3e	X			CEPC-STFC	X		
23-Sep-19	CLIC PIXEL	X	ATLAS-ITk-Pixel	X			TOTEM	X		
30-Sep-19	X-Ray-Crystal-Rad	X	ATLAS-ITk-Pixel	X			ATLAS-BCM			
7-Oct-19							HEP for Teachers			
14-Oct-19	BL4S	X	SHIP-SBT				BL4S	X	DRAFT	
21-Oct-19	BL4S	X	SHIP-ScFI				BL4S	X	DRAFT	

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**

- 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**

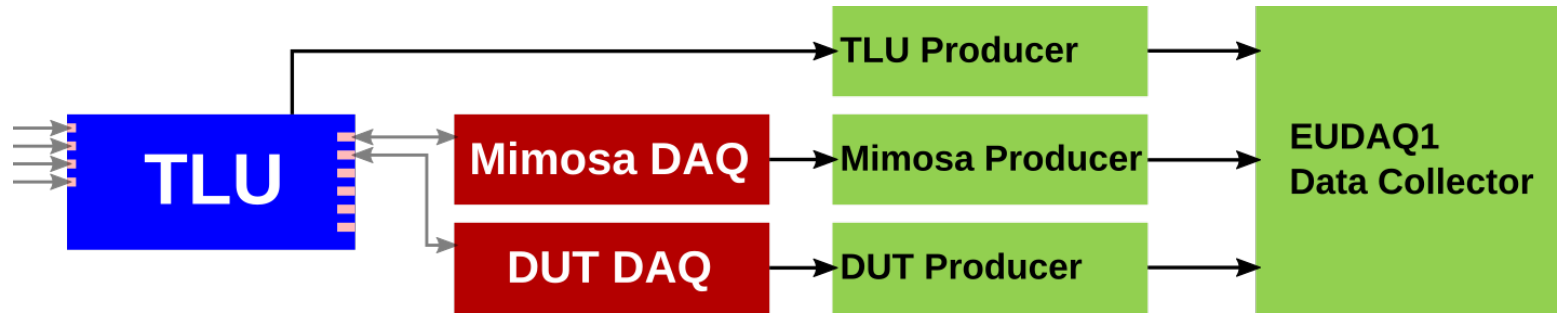
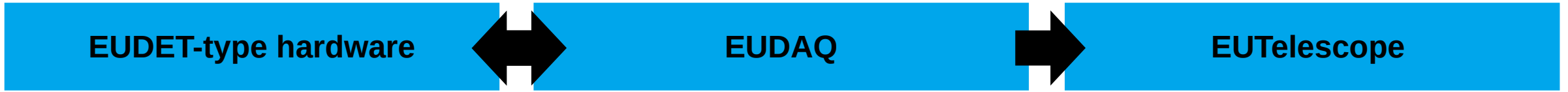
- DUT

**@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”)



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!**



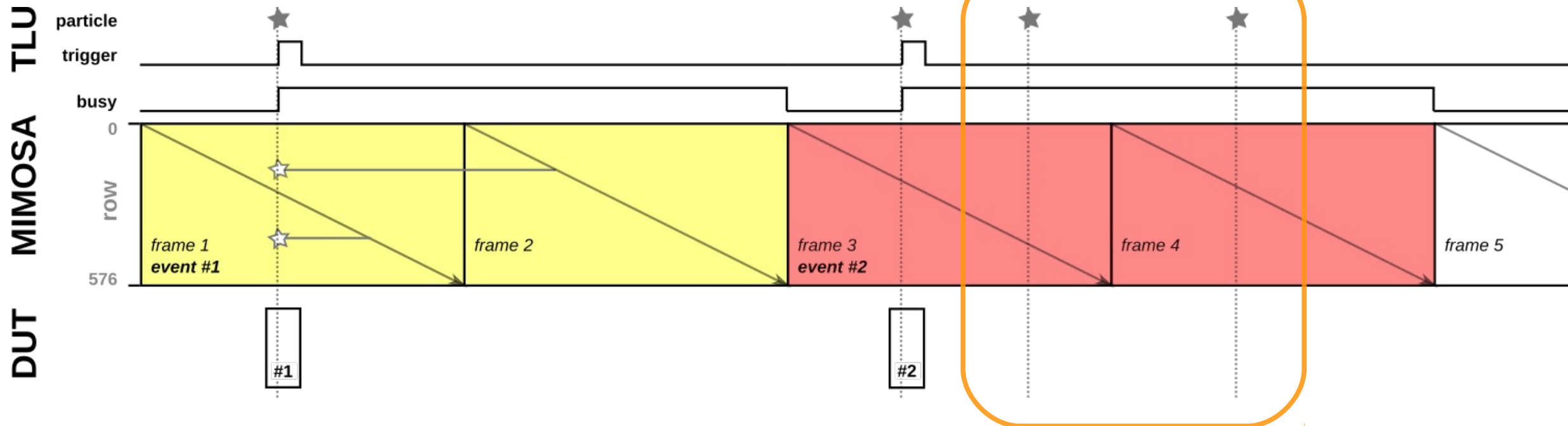
Towards higher rates

... 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

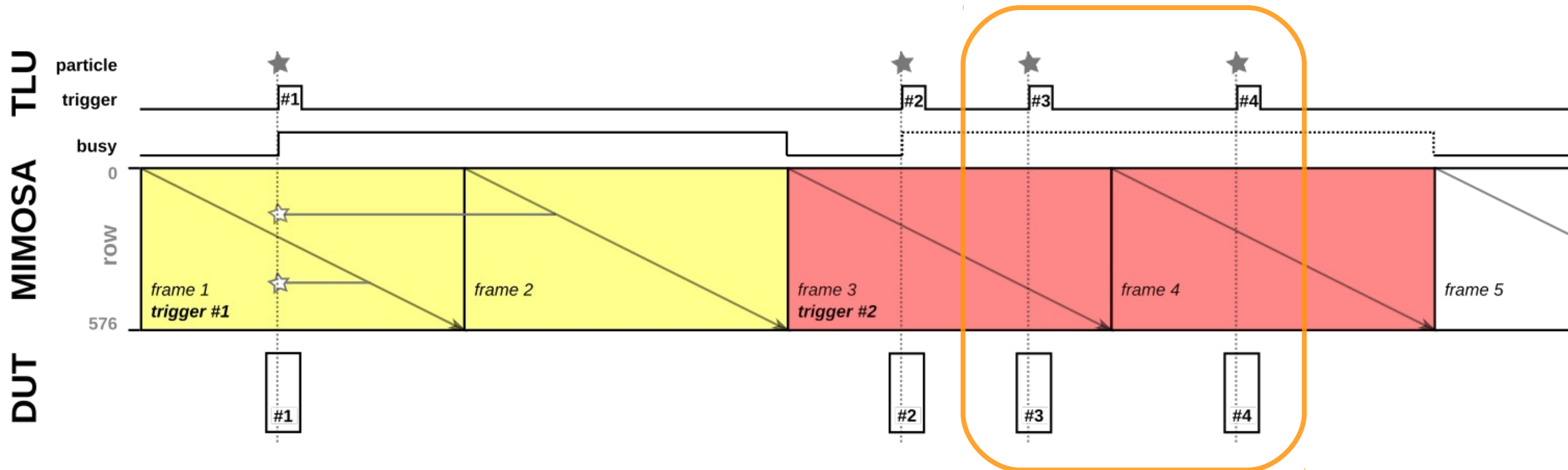


Towards higher rates

... and more timing information

Strategy for new mode

Allow **multiple** triggers within 1 telescope event



Towards higher rates

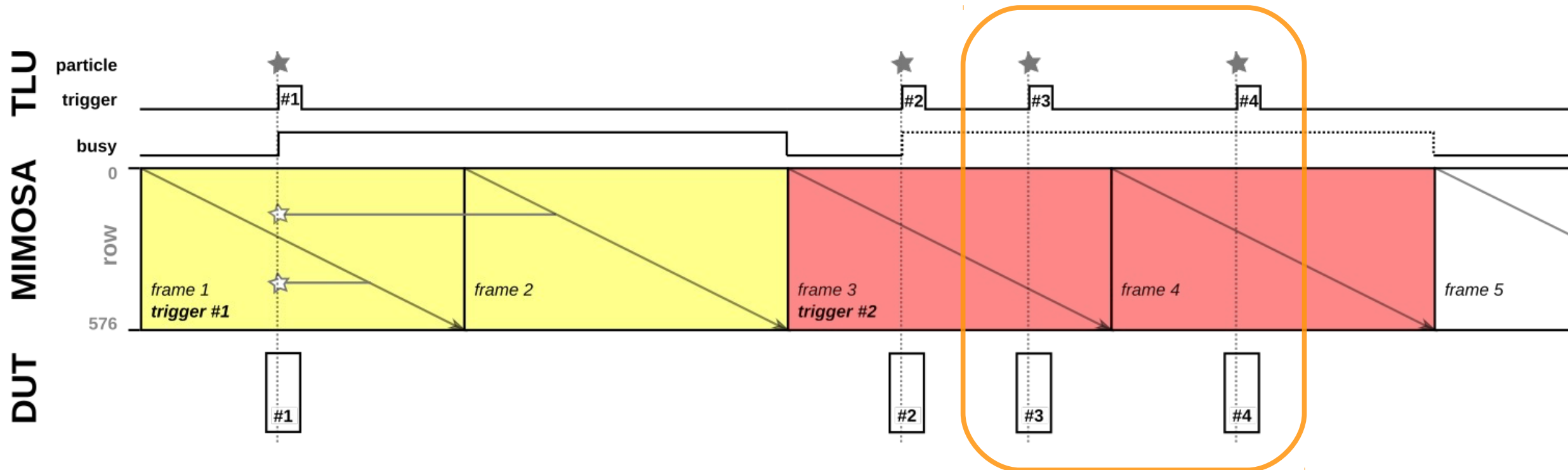
... and more timing information

Strategy for new mode

Allow **multiple** triggers within 1 telescope event

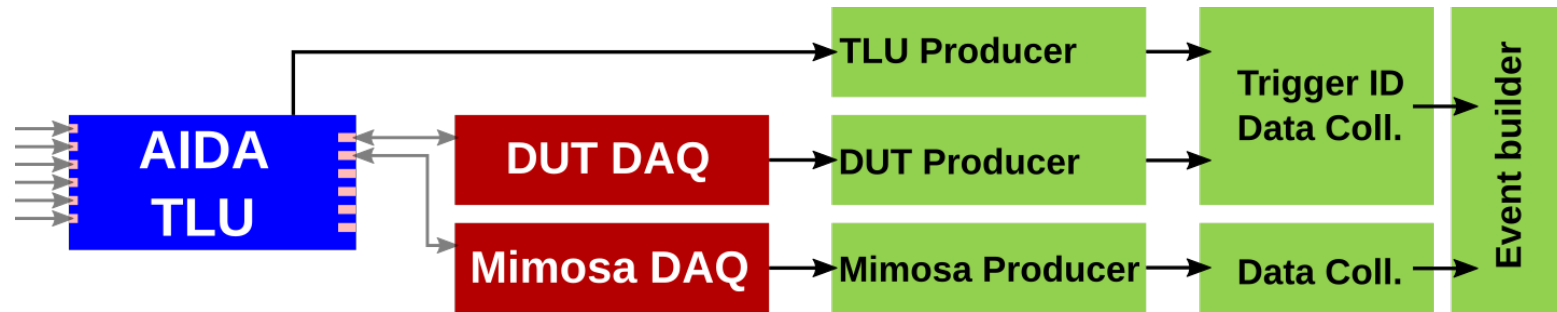
→ **ignore** busy from slow devices → **AIDA TLU**

→ synchronise by **trigger ID** → **EUDAQ2 data collector**



New data flow and event building

Ignoring busy and synchronisation by trigger number (“Mixed mode”)



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
..

“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

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
..

Results & updated limits

- Trigger rate now limited by
 - busy time for clocking out trigger ID
 - here, $8.8 \mu\text{s} = \mathbf{115 \text{ kHz}}$
(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 (continuous 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

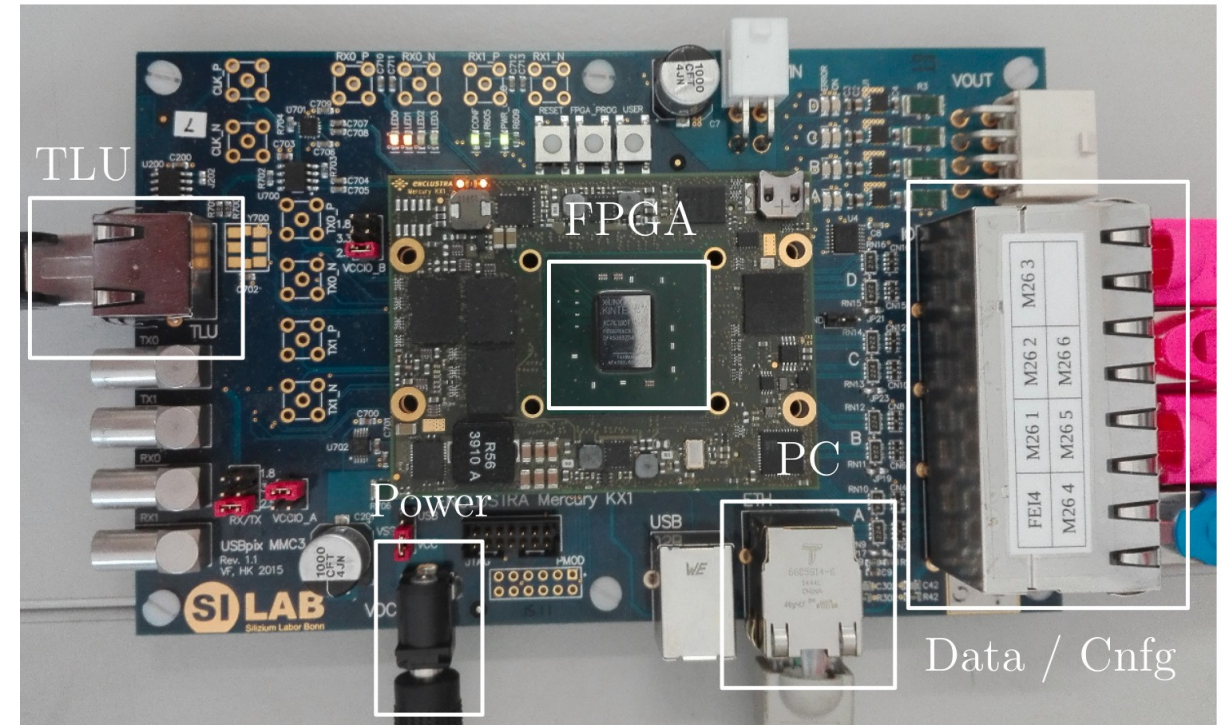
Jan Dreyling-Eschweiler
High-energy department, ATLAS group
Mail: jan.dreyling-eschweiler@desy.de
Phone: 0049 (0)40 8998 2794

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

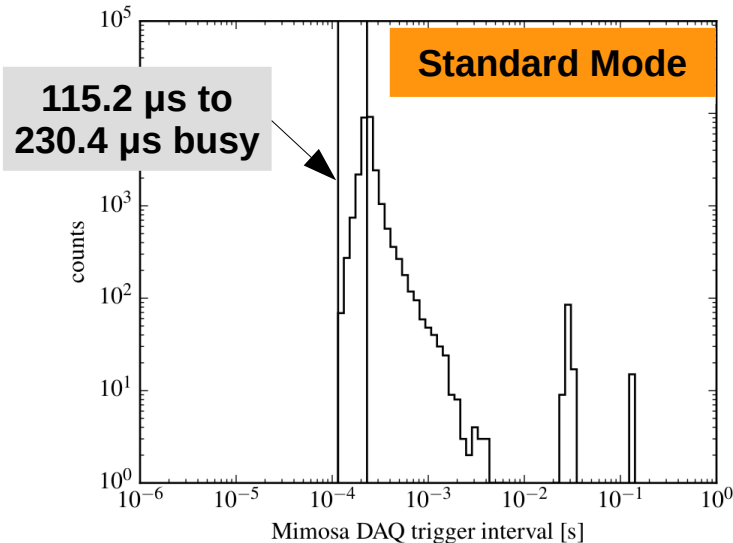


Limits @ DESY TB

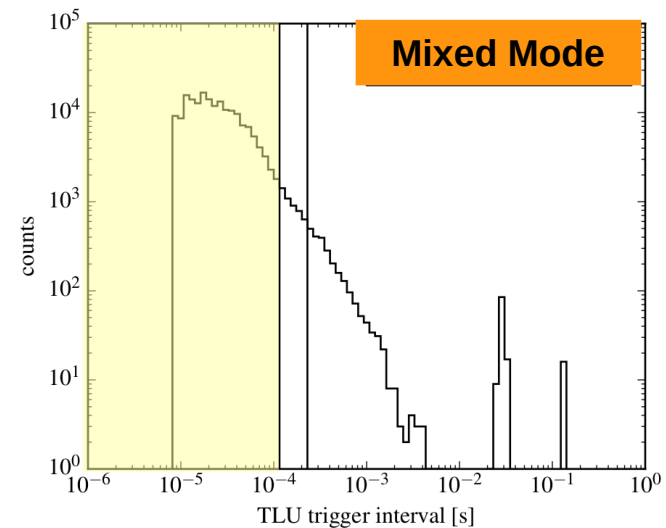
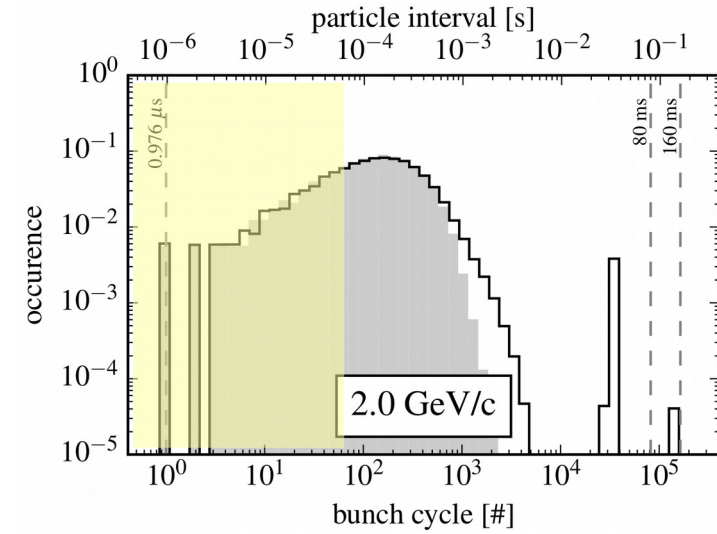
A successful but limited strategy

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

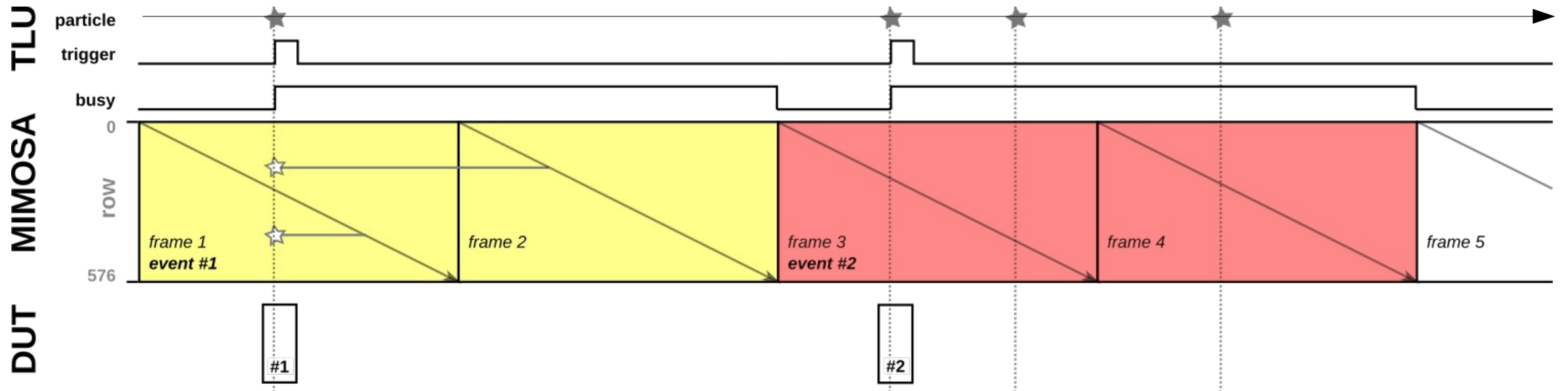
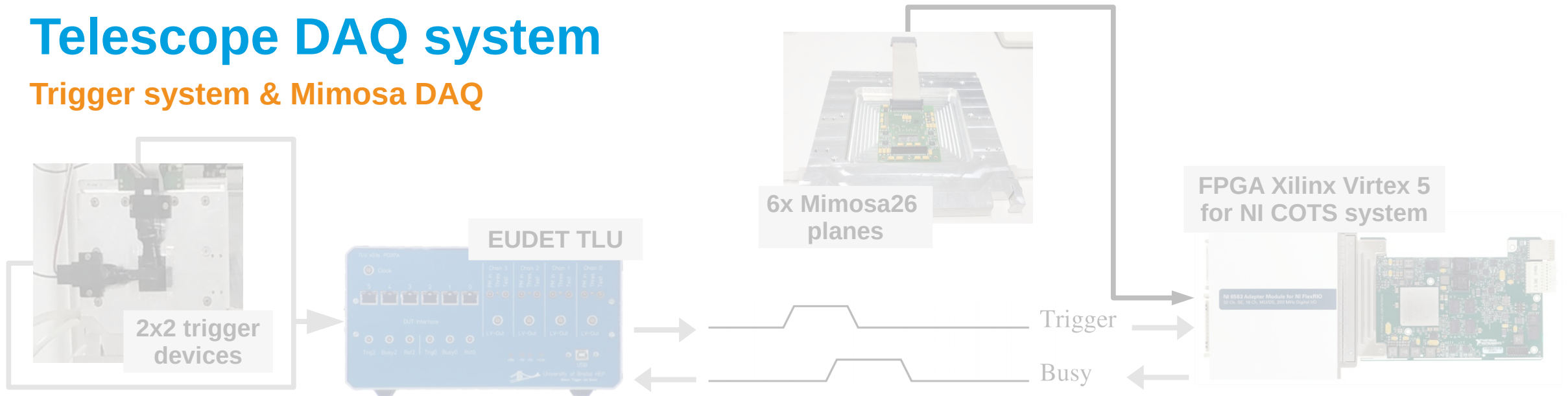


To make the best usage of the beam!



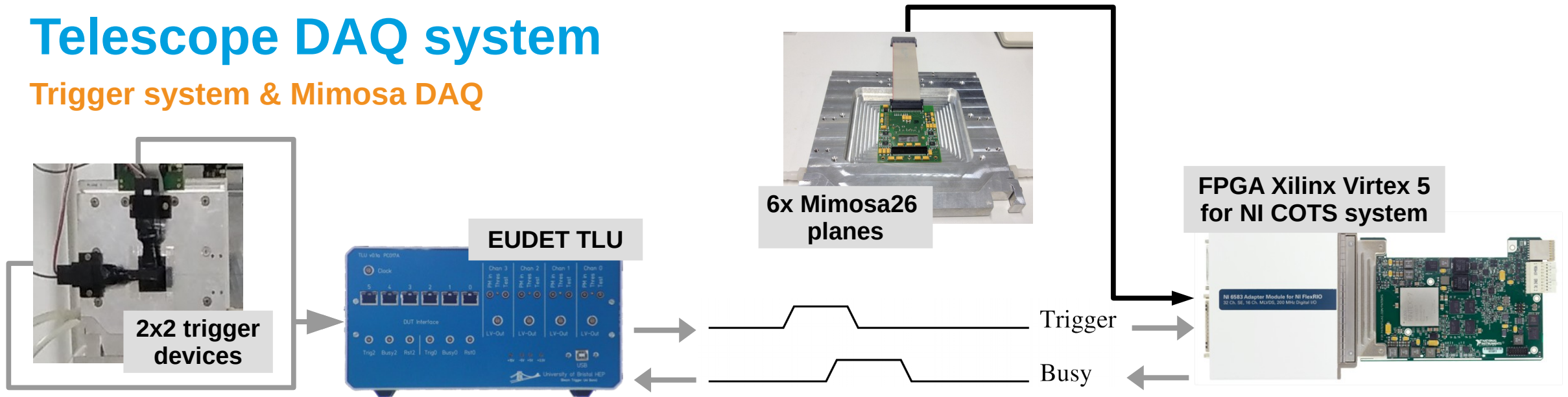
Telescope DAQ system

Trigger system & Mimosa DAQ



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

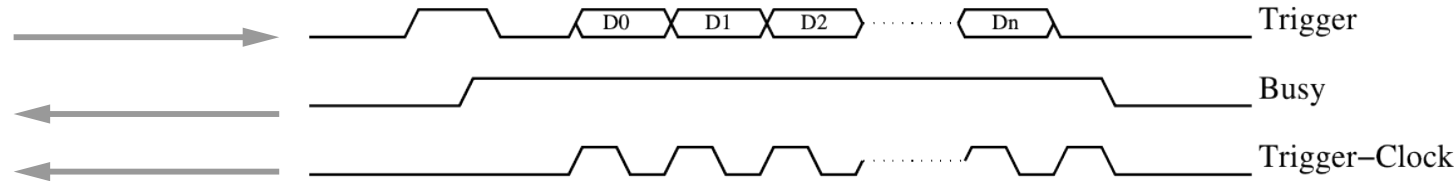
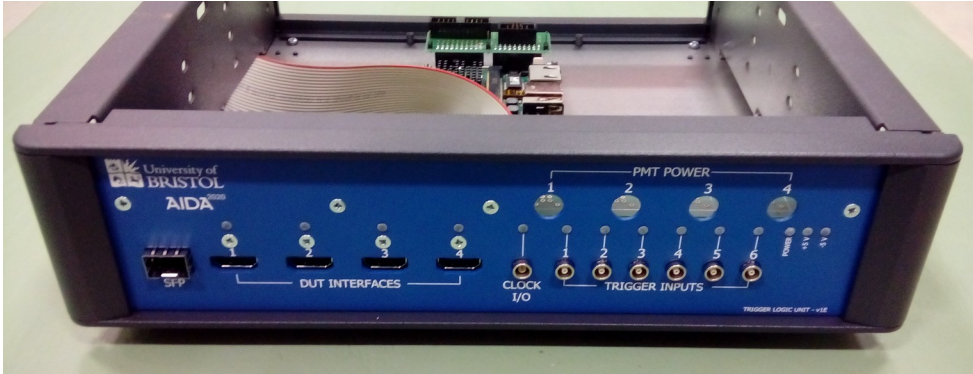
D. Cussans D, Description of the JRA1 Trigger Logic Unit (TLU), v0.2c. EUDET-MEMO-2009-04

Mimosa DAQ

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

New TLU

New options meet reliable techniques



“Trigger-data-handshake”

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-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