Data acquisition system for beam tests (WP5)

Matthew Wing (UCL) on behalf of

WP5 groups: University of Bristol, DESY Hamburg, Institute of Physics AS CR Prague, University of Sussex, UCL

Essentially showing talk will be giving at AIDA-2020 mid-term review tomorrow.

LC-UK meeting, QMUL — 19 April 2017

Outline

- Overall concept of work-package
- Outline of tasks — original goals and progress
  - Task 5.1 Scientific coordination
  - Task 5.2 Interface, synchronisation and control of multiple-detector systems
  - Task 5.3 Development of central DAQ software and run control system
  - Task 5.4 Development of data quality and slow control monitoring
  - Task 5.5 Event model for combined DAQ
- UK contribution
- Project management — deliverables
- Summary

Overall concept of workpackage

This workpackage will provide a common data acquisition (DAQ) system for use by Linear Collider detectors in beam tests to characterise their properties.

- Priority is to ease running of two or more detectors together in a common beam test.
- Should allow more physics and technical understanding (of the detectors) to be extracted. Understand performance of detector and/or validation of reconstruction algorithms for individual and multiple detectors. E.g.
  - Calorimeter with external tracking for position resolution, uniformity, particle flow, …
  - TPC and external silicon tracker for TPC momentum resolution
  - Calorimeter with tail catcher to assess shower containment / leakage
- Clear and strong links with other parts of the programme on software, calorimetry, test beam facilities (including tracking and beam telescopes).
- In principle useable by any (also non-Linear Collider) detector; hardware designs, firmware and software will be freely available.
- A common DAQ system will provide standard interfaces to allow any Linear Collider detector to be read out using the system to be developed here.
- Provide run control, data sanity and quality checks.
- Convert data to common format for ease of analysis.
- As a by-product, learning about a future Linear Collider DAQ.

What WP5 DAQ broadly encompasses

Assume that a given detector has its own DAQ system with electronics. WP5 will provide framework and tools to allow multi-detector beam tests.

- Need hardware (trigger logic unit) to control and synchronise systems.
  - Assume that all events will be kept, so no trigger in the sense of data reduction, but need to trigger the detector to record data an event.
  - Detectors have very different triggering and need to synchronise to ensure that they associate data to the same event.
- Need software to control the (TLU) hardware, interface to the dedicated DAQ systems and read-out and merge the data into a coherent record.
- The data needs to be stored in a way for ease of use in analysis; common format.
- A run control is needed to deal with the possible states of the detectors and control whether e.g. data is taken, stopped, etc.
- Provide software to check the data quality of a given detector and combination of detectors; crucial to ensure success of beam test.

Task 5.1 Scientific coordination — goals

Along similar lines to other workpackages:

- Coordinate and schedule the execution of the workpackages tasks.
- Monitor the work progress (milestone and deliverable reports, follow-up on the workpackages budget and the use of resources).
- Reporting to the project management.
- Organise workpackages meetings and disseminate information.
- Carried out by workpackages coordinators and task leaders.
- Foster and coordinate links with other workpackages.
- Task responsibles: **UCL, Bristol**. Task leaders: **D. Cussans, M. Wing**.

Task 5.1 progress

Major points of progress:

- Assigned task leaders to each of the four tasks.
- Have face-to-face meetings (with some people remote) to assess progress. Eight since the start of the project. Open to all.
- Have ~ monthly expert meetings on progress.
- Communication with other WPs, particularly WP14, calorimeters and WP15, upgrade of test beams (including tracking and beam telescopes).
- Consultation with detector community in delivering “Definition of detector interface standards”, D5.1 and MS25.
- Set up a wiki page for collecting and sharing information within group and with detector groups: http://flcwiki.desy.de/AIDA2020WP5

Task 5.2 Interface, synchronisation and control of mulitple-detector systems — goals

Principal task for definitions, specifications and hardware, all to be able to run multiple different detectors together.

- Specification of interfaces for the common DAQ: trigger logic unit (TLU); clock and control card (CCC); and potentially other DAQ systems.
- Harmonise timing and synchronisation signals ⇒ correlation of different detectors.
- Compatibility between TLU and CCC and development of their firmware.
- Extend TLU for extra functionality, e.g. ability to synchronise using time-stamps as well as (or instead of) trigger numbers. Hardware, firmware and software changes.
- Provide TLUs for combined beam tests as well as laboratory set-ups.
- Set up different beam tests, integration to common DAQ and expert support.
- First aspect of task is definition of interface standards and technical document detailing these so any detector can use synchronisation system.
- Completion of beam tests with multiple detectors.
- Task responsibles: **Bristol**, UCL. Task leader: **D. Cussans.**

Task 5.2 first deliverable and milestone

Deliverable Number [14]	Deliverable Title	Lead beneficiary	Type [15]	Dissemination level [16]	Due Date (in months) [17]
D5.1	Interface definition	30 - UCL	Report	Public	15

- D5.1 Definition of interface standards for the common DAQ system which will describe how the detector DAQ system connects to the common DAQ. (Task 5.2)

Number	Definition	Beneficiary	Month	Verification
MS25	Definition of detector interface standards with common DAQ (Definition of interface standards for the common DAQ system which will describe how the detector DAQ system connects to the common DAQ, Task 5.2)	UCL	15	Report to StCom

The deliverable and milestone were completed and are available.

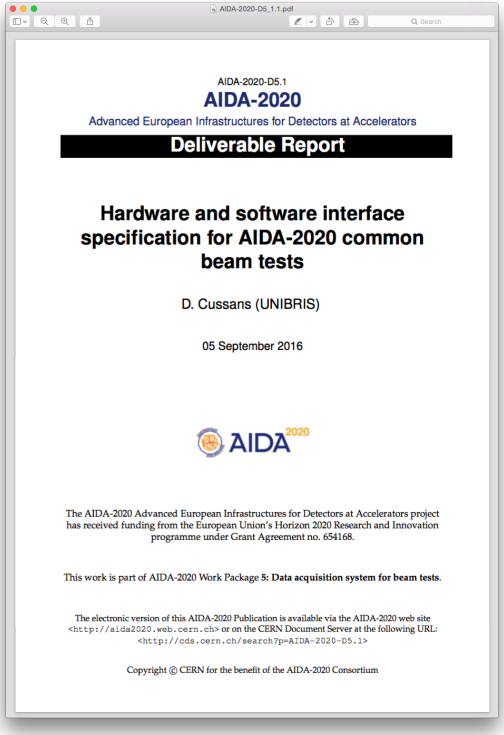
Note also the documents referred to in the deliverable report.

Deliverable is the technical document:

http://cds.cern.ch/record/2213430/files/AIDA-2020-D5_1.1.pdf

Milestone document explains the process:

http://cds.cern.ch/record/2207953/files/AIDA-2020-MS25.pdf



AIDA-2020-D5.1

AIDA-2020

Advanced European Infrastructures for Detectors at Accelerators

Deliverable Report

Hardware and software interface specification for AIDA-2020 common beam tests

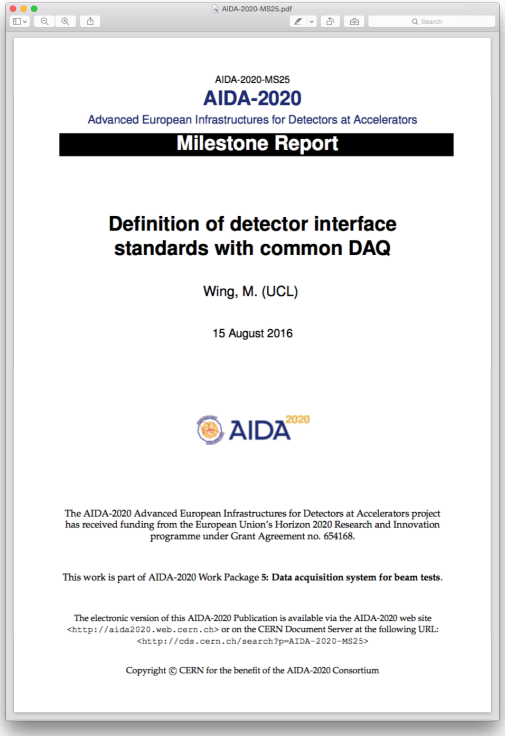
D. Cussans (UNIBRIS)

05 September 2016

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**.

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-D5.1>



AIDA-2020-MS25

AIDA-2020

Advanced European Infrastructures for Detectors at Accelerators

Milestone Report

Definition of detector interface standards with common DAQ

Wing, M. (UCL)

15 August 2016

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.

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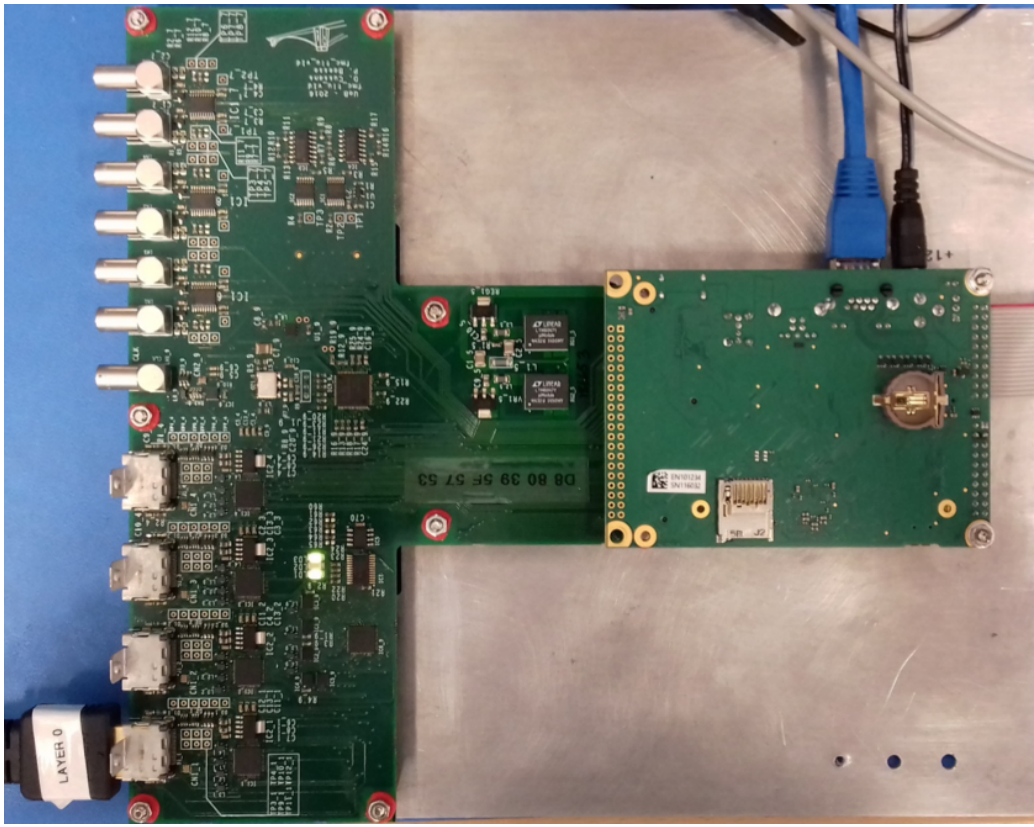
Task 5.2 TLU development

- New hardware based on successful previous TLUs from AIDA and EUDET
- More trigger inputs (4 → 6)
- Increased number of DUT (3 → 4)
- Multiple clock generation options
- miniHDMI → HDMI connectors
- Fast threshold discriminators for trigger detection
- Firmware ported to Xilinx7 devices
- Launching production in April



Task 5.3 Development of central DAQ software and run control systems — goals

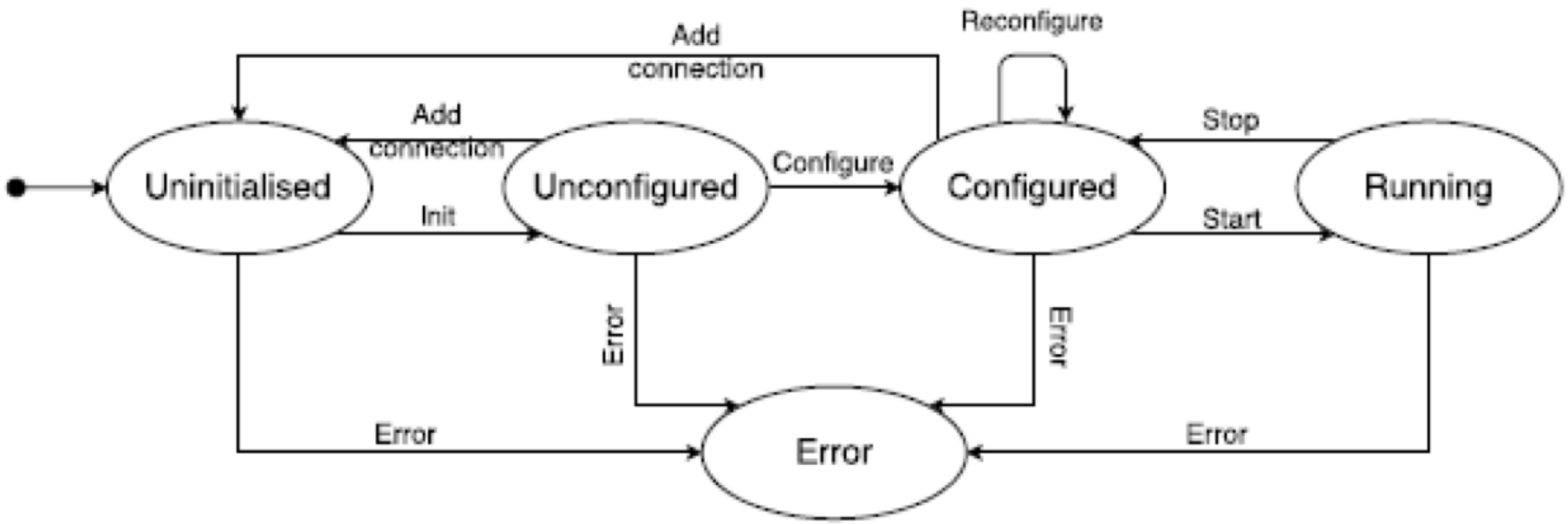
- Combining data from different detectors using common EUDAQ software. Interface to detector-specific DAQ systems. EUDAQ suited to the common DAQ task:
  - Successfully used for beam telescope and the multitude of detectors it has been run with.
  - Undergoing development (e.g. scalability) and supported.
  - Need to have a software suited to our needs for linear collider detectors.
- Development of central run control.
- Development of online checks of data sanity, e.g. trigger or event rate and event size.
- Provide computing hardware for common DAQ.
- Tests of common DAQ system with single components.
- Use of common DAQ for combined beam tests with continued development and maintenance.
- Task responsibles; **DESY, UCL**, Bristol, Prague, Sussex. Task leader: **M. Wing.**

Task 5.3 EUDAQ

- EUDAQ1 was originally developed as a DAQ system for EUDET telescopes
- Used extensively in beam tests with the EUDET telescopes and TLU
- For our purposes, we need an upgraded DAQ software, EUDAQ2:
  - Needs a scalable, rather than single, data collector.
  - Needs a flexible, rather than fixed, finite state machine.
  - Needs to cater for more general use.
- Also provide other improvements and updates, e.g. monitoring.

Task 5.3 EUDAQ RunControl

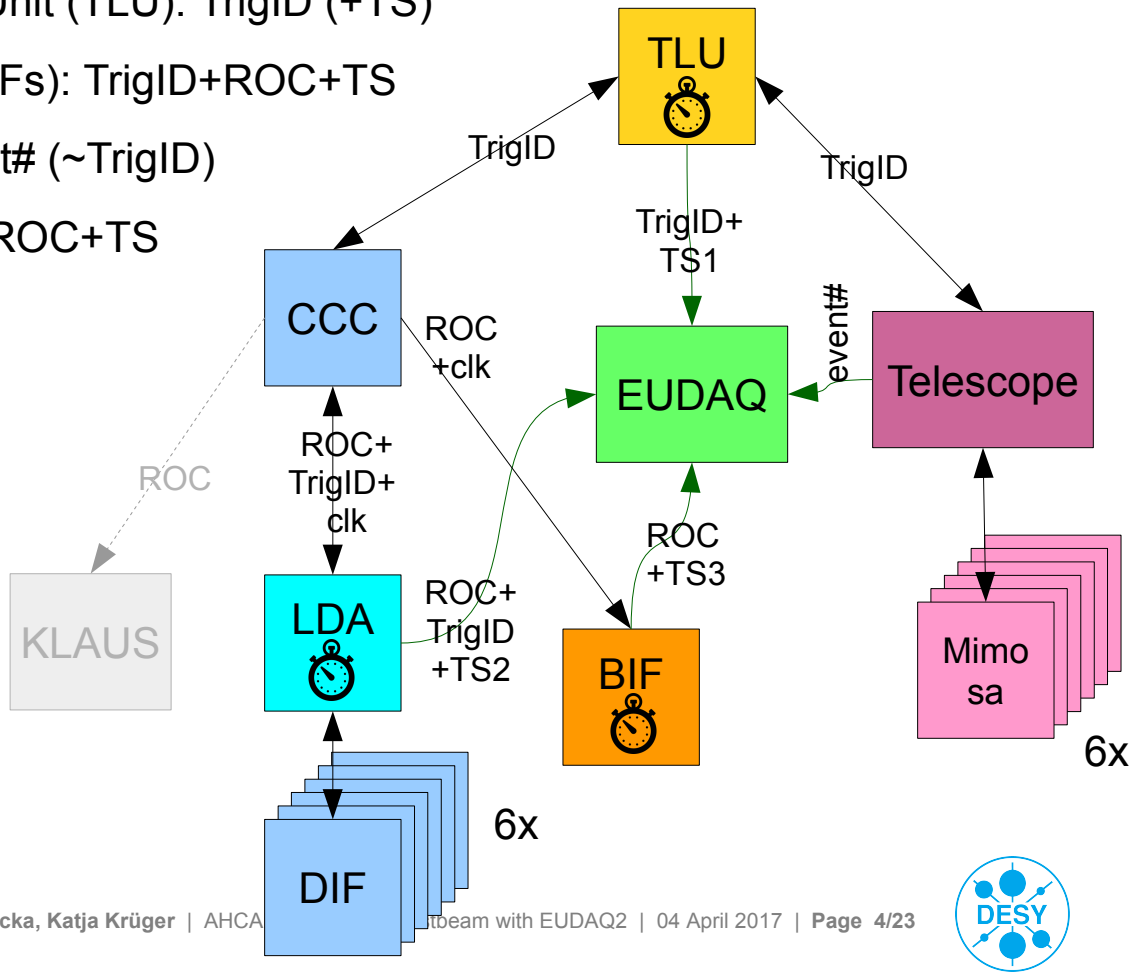
- RunControl maintains a database about the address of clients and sends commands to them. Standard EUDAQ RunControl fulfils most user cases.
- New in EUDAQ2:
  - Qt GUI is decoupled from RunControl and EUDET telescope
  - User can re-use GUI with their own RunControl without touch GUI code.
  - Provide flexibility to have RunControl that can integrate other DAQ systems.
  - …
- Essentially finished and tested.



Task 5.3 AHCAL+telescope beam test with EUDAQ2 — the challenge

- 3 Synchronizations: **TriggerID** or **Readout cycle(ROC)** or **TimesStamps(TS)**
- EUDET Trigger Logic Unit (TLU): TrigID (+TS)
- AHCAL (CCC+LDA+DIFs): TrigID+ROC+TS
- Beam Telescope: Event# (~TrigID)
- 2017: Mini-TLU (BIF): ROC+TS
- 2017: Klaus: ROC

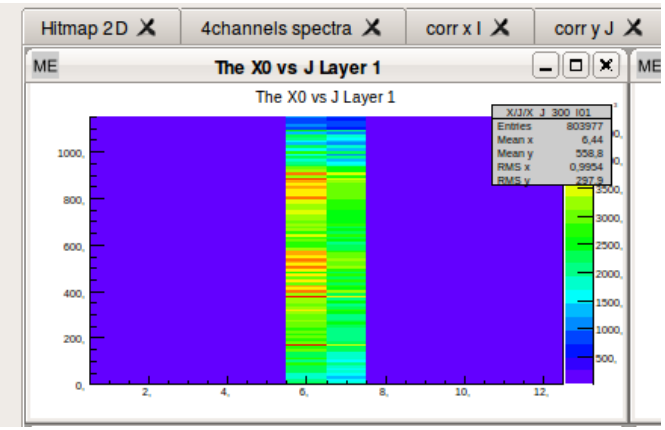
- Many new components
- New event building needed with custom data collector
- Data format compatible with EUDAQ1 → use DQM4HEP



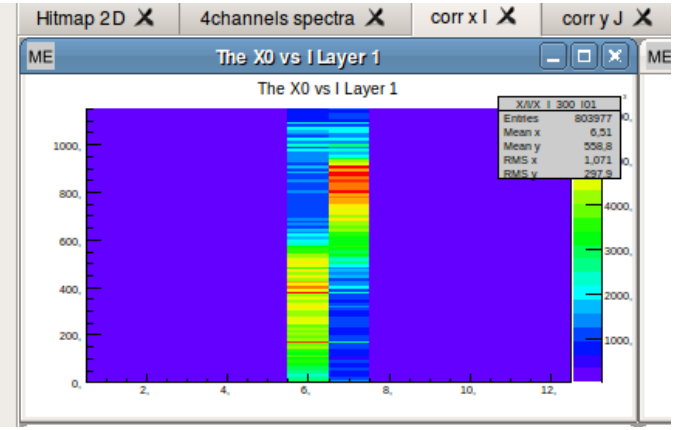
Task 5.3 AHCAL+telescope beam test with EUDAQ2 — the results

- Multiple data collectors in EUDAQ allowed testing of several configurations at the same time.
- DQM4HEP monitoring of spatial correlations of telescope hits vs, AHCAL hits.

Uncorrelated



Correlated



- Obtained sustained event rates of ~ 500 Hz, with correlations remaining stable.

Task 5.3 EUDAQ2 — what next ?

- EUDAQ2 has been successfully tested with a calorimeter for the first time.
- Multiple detectors have been run in a test beam using EUDAQ2 and with DQM.
  - ➡ Have fulfilled the overarching goal of this WP with a particular set-up.
- EUDAQ2 code is frozen and ready to be released.
  - ➡ Documentation is ongoing and needs to be completed before release.
- Can then test in another system / set-up.
  - ➡ Combined CMS HGCAL and CALICE AHCAL beam test to use EUDAQ and DQM4HEP.

Task 5.4 Development of data quality and slow control monitoring — goals

- Development of near-online checks of data quality: for individual detectors and coincidences between different detectors.
- Interface to slow control systems of different detectors providing a common and synchronised slow control monitor of various conditions.
- Continued development and maintenance of system.
- Task responsibles: **Prague, DESY, Sussex**, UCL. Task leader: **F. Salvatore**.

Task 5.4 DQM4HEP

Using DQM4HEP, developed for SDHCAL beam tests by R. Eté (IPNL, Lyon) and A. Pingault (UGent): `https://github.com/DQM4HEP`

Generic data structures compatible with any input data type.

Interfacing with EUDAQ.

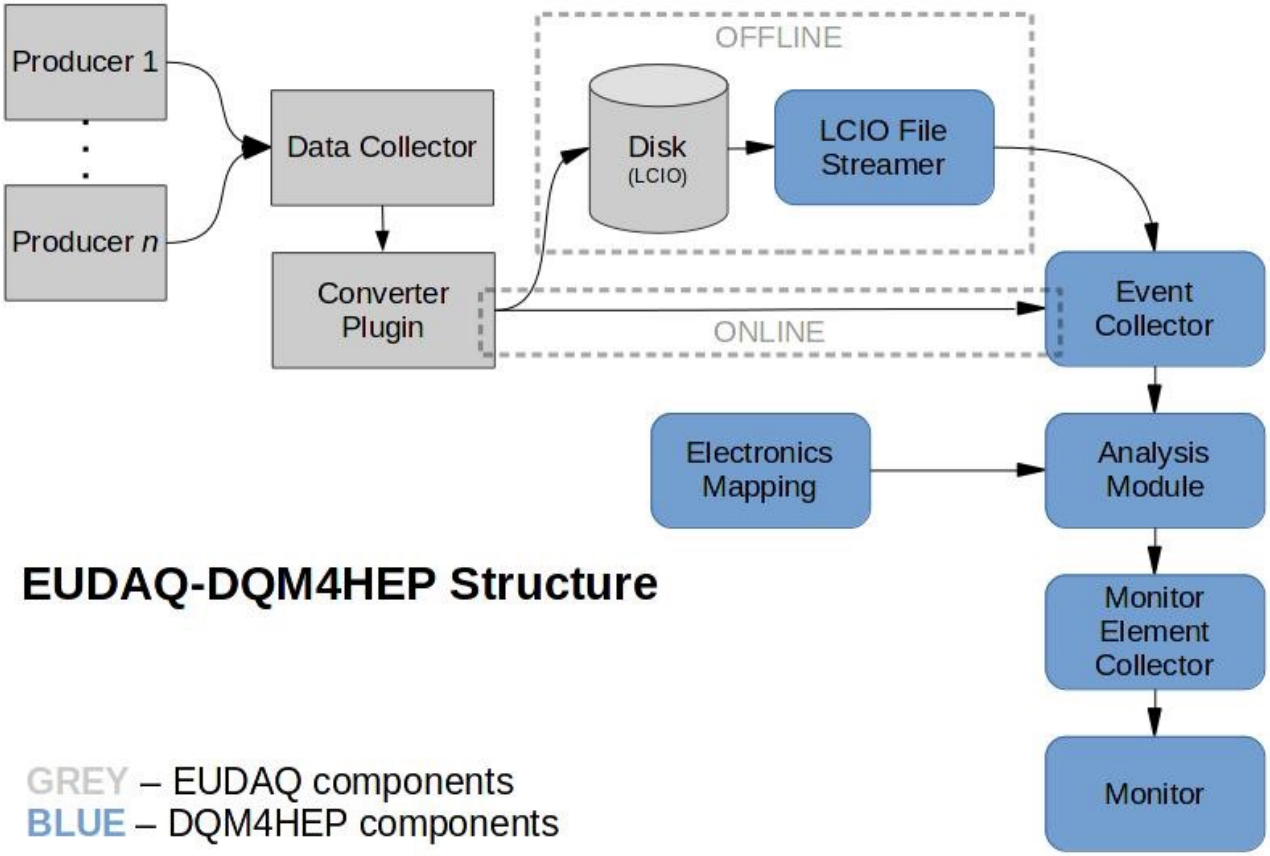
System set up at DESY and used in AHCAL beam tests.

Also used in AHCAL with EUDET telescope and correlation plots made.

To extend to SiECAL.

DQM4HEP can also be used for slow control monitoring.

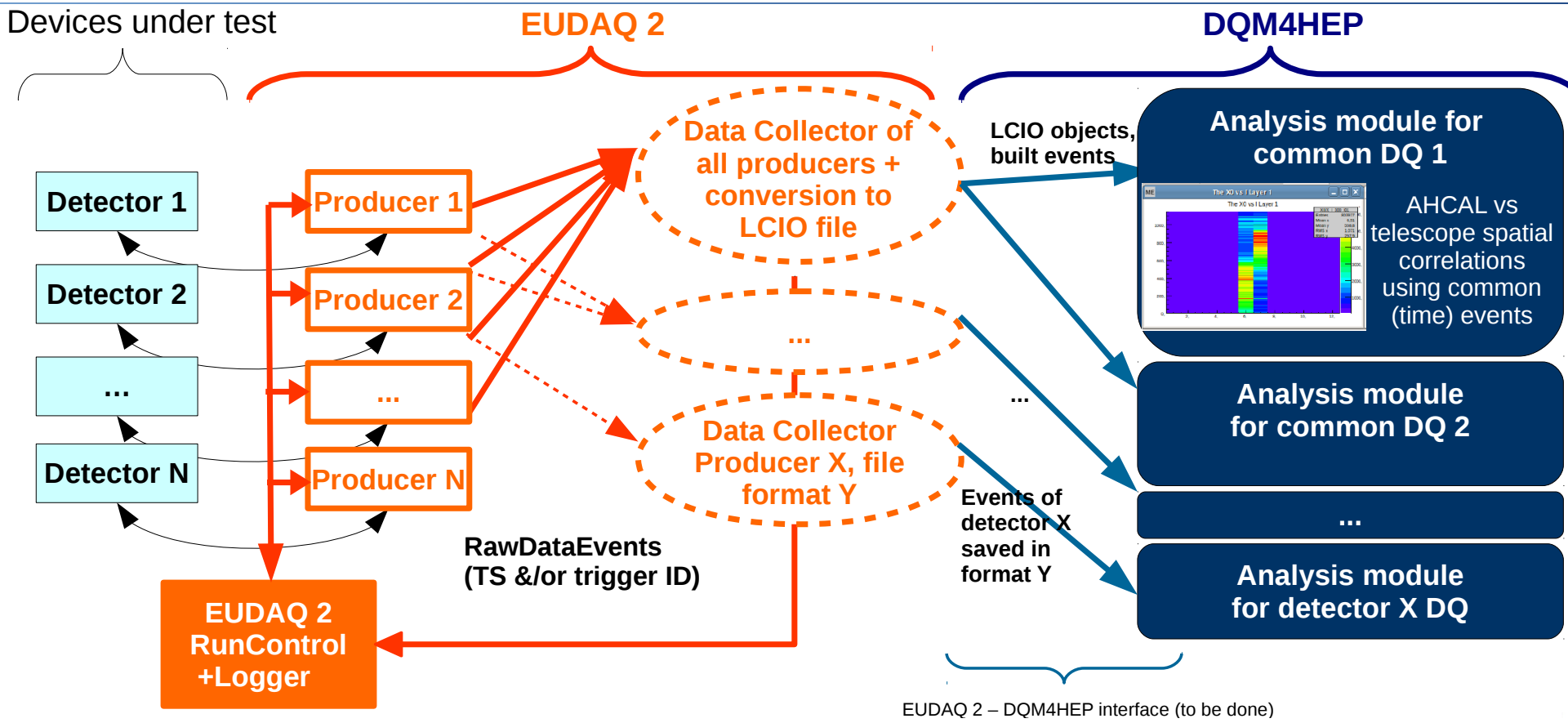
Also held a hands-on session on DQM4HEP.



Task 5.5 Event model for combined DAQ — goals

- Define concept of an event for online data, i.e. combine data from different detectors with different integration times.
- Match event model (LCIO) to online as well as offline data.
- Develop uniform and consistent model for data structure.
- Also needed for data sanity and quality checks, in Task 5.3, related to multiple-detector information.
- Task responsibles: **DESY**, UCL. Task leader: **A. Irles.**

Task 5.5 progress



Task 5.5 progress

- **Write your own producer** and send data using appropiate Timestamp &/or Trigger ID
  - Use **RawDataEvent**, filling the blocks with **total freedom.**
  - **Set the Trigger ID or timestamp** understandable by others (and DataCollector)
- In case that your **combined setup** differs from tested ones... write a modified **DataCollector**.
- Online conversion is not mandatory but if it is done → **LCIO format is recommended** for monitoring..
  - Possibility 1: **use "generic" RawEvent2LCEventConverter**
  - Possibility 2: write a new one.
- **Monitoring using DQM4HEP is recommended and supported.**

MS 47 (end of month)
Online event data model available.

Documentation and communication effort !

http://flcwiki.desy.de/AIDA2020WP5_Task5.5

- EUDAQ2 raw data is basic data structure
- Conversion to LCIO format is proposed, if needed
- Monitoring performed using DQM4HEP
- Document being written detailing the technical aspects and recommendations

UK contribution

- The UK is a strong contributor to the AIDA-2020 DAQ WP5:
  - Have 3 of 5 institutes, Bristol, Sussex and UCL.
  - Have both coordinators, D. Cussans and M. Wing.
- Bristol:
  - P. Baesso, D. Cussans (TLU, general)
- Sussex:
  - C. Chavez, T. Coates, F. Salvatore (DQM)
- UCL:
  - S. Amjad, S. Kilani, M. Wing (TLU, software, general)
- DAQ is an area of Linear Colliders where the UK have a genuine lead; EU funding crucial to this.

Project management — deliverables

List of deliverables

Deliverable Number [14]	Deliverable Title	Lead beneficiary	Type [15]	Dissemination level [16]	Due Date (in months) [17]
D5.1	Interface definition	30 - UCL	Report	Public	15
D5.2	Trigger Logic Unit ready	31 - UNIBRIS	Demonstrator	Public	30
D5.3	Data acquisition software	30 - UCL	Report	Public	30
D5.4	Data acquisition hardware	31 - UNIBRIS	Demonstrator	Public	30
D5.5	Online event data model	9 - DESY	Report	Public	30
D5.6	Common DAQ system used in combined beam tests	30 - UCL	Report	Public	45

All v0 parts of system

- D5.1 Interface standards (M15, Jul/2016). Done.
- D5.2 TLU ready (M30, Oct/2017). Testing prototypes — on track.
- D5.3 DAQ software (M30, Oct/2017). Essentially EUDAQ and DQM4HEP — on track.
- D5.4 DAQ hardware (M30, Oct/2017). Linked to D5.2 — on track.
- D5.5 Online event data model (M30, Oct/2017). Linked to D5.3 — on track.
- **D5.6 Common DAQ system (M45, Jan/2019). Already running common beam tests with common DAQ; improved and more-widely validated system — on track.**

Enhancements — highlights

	AIDA	AIDA-2020
DAQ Software (EUDAQ)	Single data collector Fixed FSM Focused on beam telescope	Scalable data collector Flexible FSM General
Data model	Tag event with trigger number	Tag event with trigger and/or timestamp
Data quality monitoring	Dedicated to pixel detectors	Use DQM4HEP framework (general)
Hardware (TLU)	Ageing FPGA family 4 trigger inputs	Modern FPGA 6 trigger inputs Low jitter clock
Beam telescope	Trigger rate < O(10 kHz)	Trigger rate < O(1 MHz)

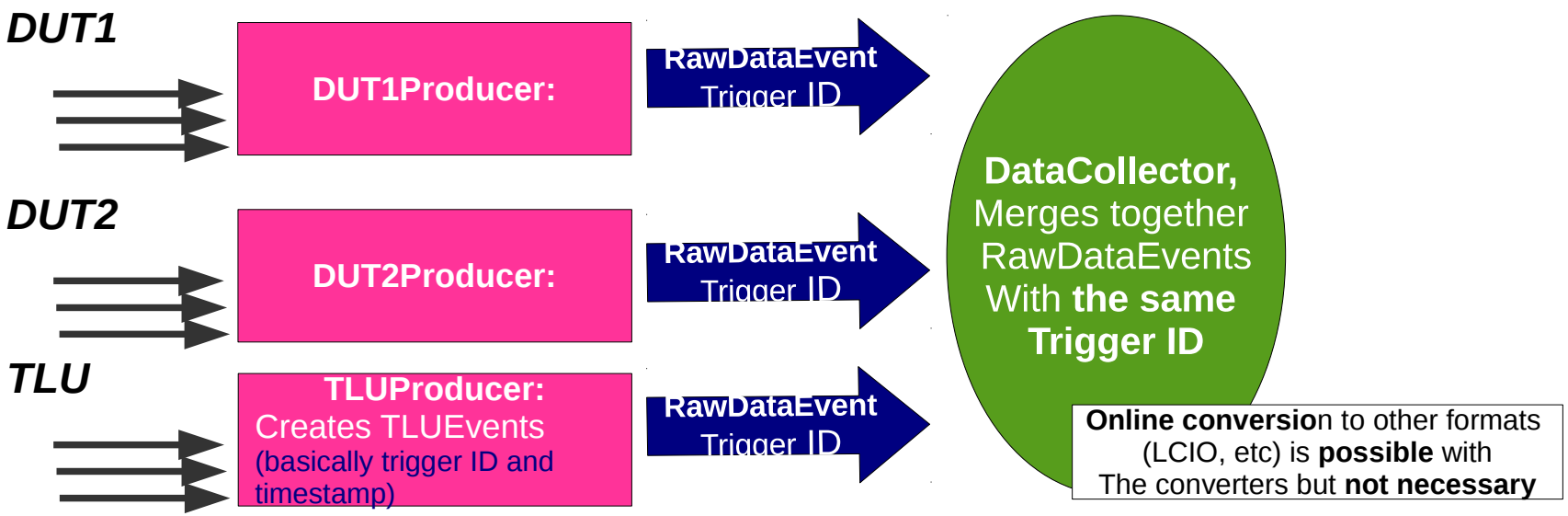
Summary

- Workpackage 5 on common DAQ tools for beam test users has made good progress.
- After community consultation, outlined clearly how to interface detectors to the common DAQ system.
- A new TLU is being developed to provide the control and timing for the beam tests.
- Software, EUDAQ2 and DQM4HEP, proving to suit the requirements.
- Already carried out beam tests with multiple (very different) detectors using the developed DAQ tools.
- Expect to enable simplicity of common beam tests for Linear Collider detectors and enhance their programme.
- Developments also proving useful for non-Linear Collider detectors.

Back-up

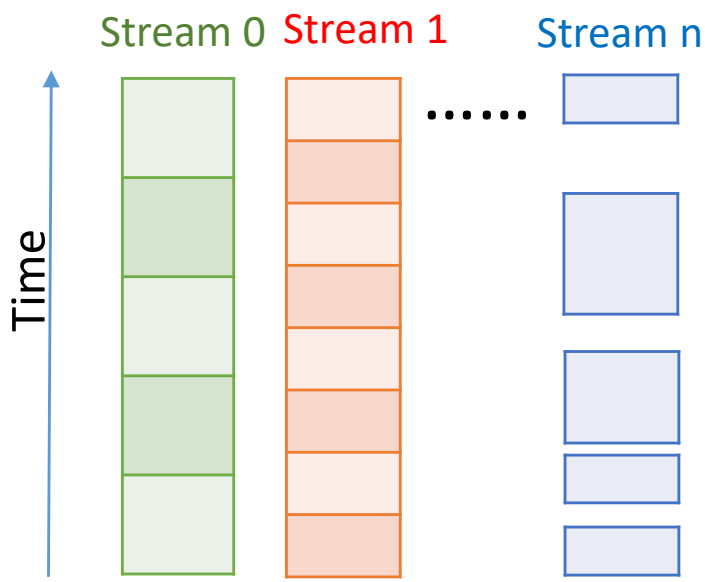
Task 5.3 EUDAQ1 event building

- **EUDAQ 1 philosophy : common readout frames in synchronization with trigger id driven by the TLU → trigger number and event number are the same !**



Task 5.3 EUDAQ Event building

Using only a trigger ID to merge multiple data sources is inefficient when integration time is different (externally triggered / self-triggered / continuous integration).



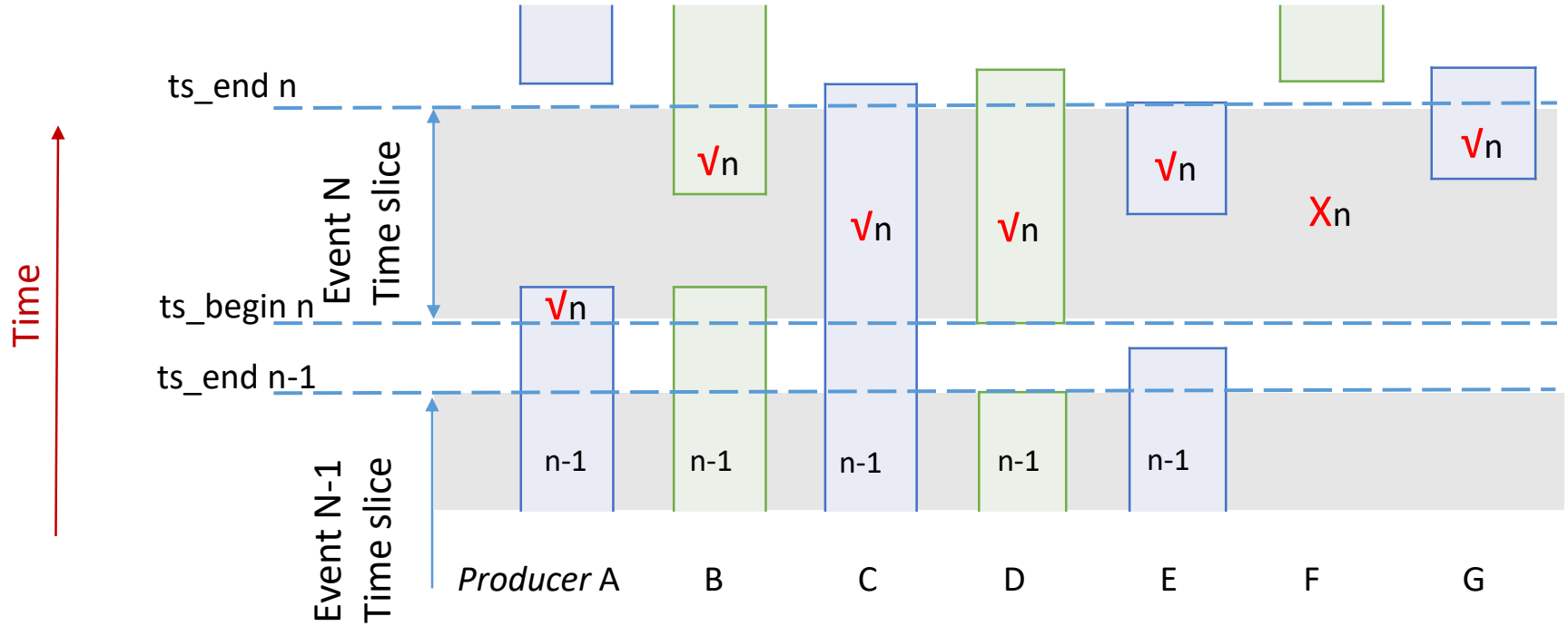
In generic case, sub events can arrives in any random time.

How to defined a physical event?
How to defined a valid trigger?
Which detector is the trigger device?

- Users can write their own event builder
- Generic DataCollectors for direct synchronisation by timestamp and trigger number cases are provided

Task 5.3 EUDAQ Event building

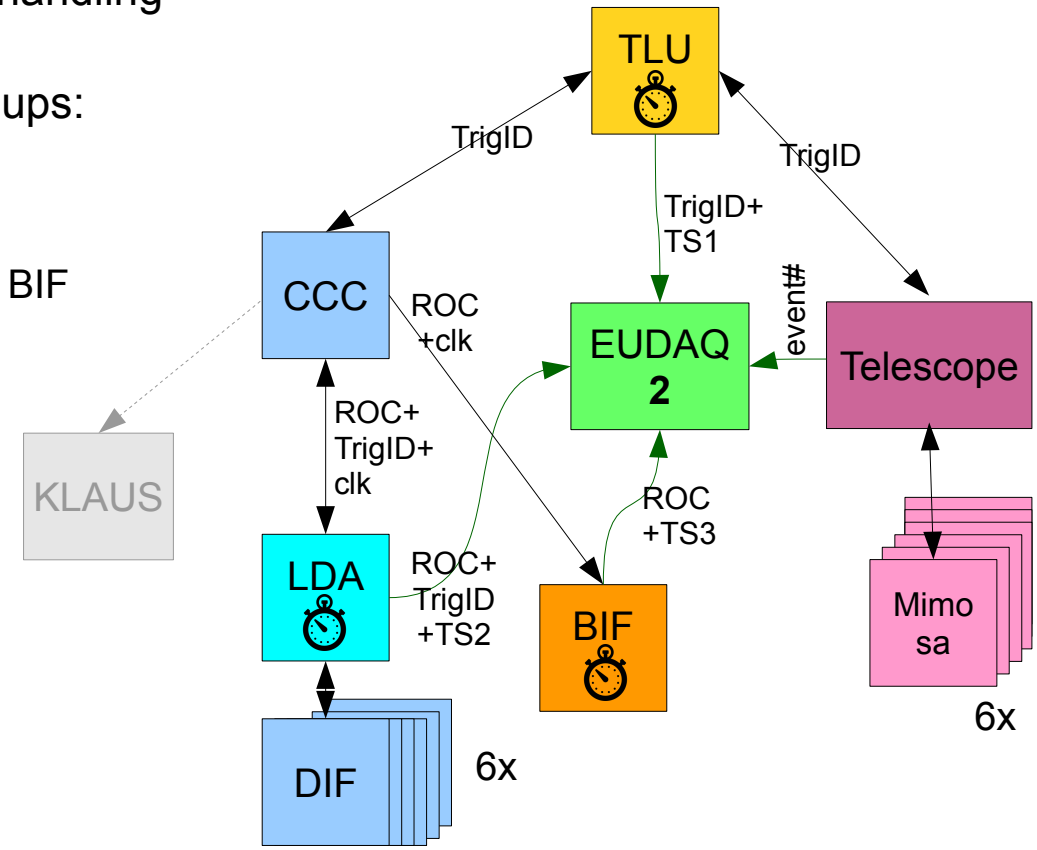
- Time length of incoming event is flexible
- Time slice of merged event is variable
- All producers are equal to each other
- Can cope with unmatched data (e.g. noise hits)



Task 5.3 Event building in beam test

Testbeam Setup in February 2017: putting it all together

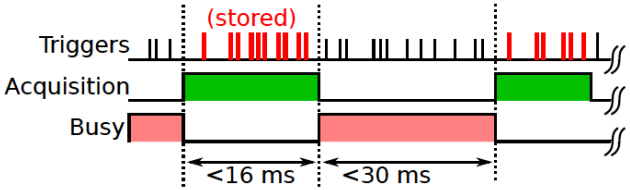
- TLU is master device handling busy signals
- independent clock groups:
  - TLU
  - telescope
  - CCC + LDA + DIFs + BIF
  - KLAUS
- new components
  - readout scheme
  - EUDAQ2
  - AHCAL producer
  - telescope producer
  - TLU producer
  - data collector

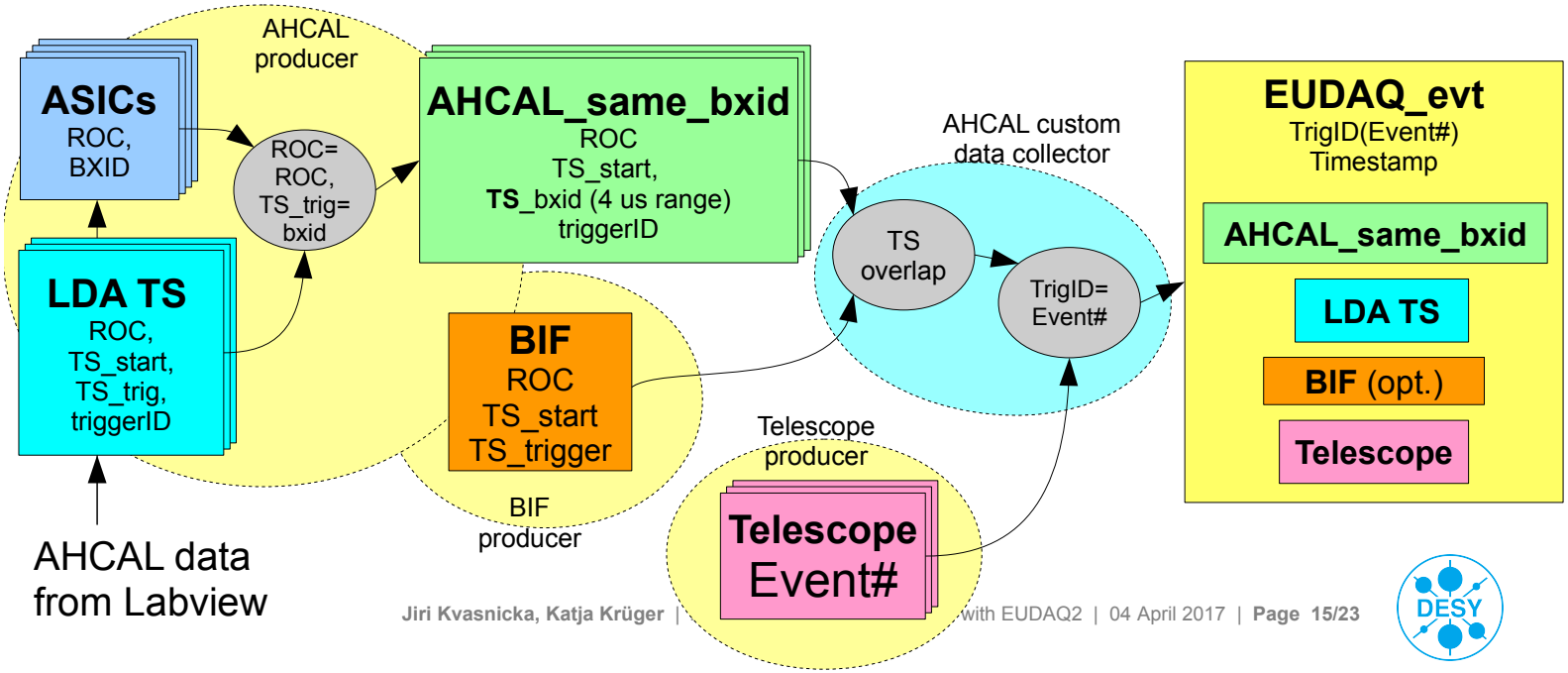


Task 5.3 Event building in beam test

EUDAQ2: New event building

- simple data collectors available in EUDAQ (triggerID sync / timestamp sync)
- here event building is more complex → need a custom data collector
- data format kept compatible with EUDAQ1 → analysis in DQM4HEP unchanged





Project management — milestones I

Number	Definition	Beneficiary	Month	Verification
MS25	Definition of detector interface standards with common DAQ (Definition of interface standards for the common DAQ system which will describe how the detector DAQ system connects to the common DAQ, Task 5.2)	UCL	15	Report to StCom
MS43	Trigger logic unit (TLU) design ready (This will include the design of the interface to the CCC as well as firmware block diagrams and implementation plan,Task 5.2)	Bristol	21	Report to StCom
MS46	EUDAQ interfaces to other DAQs available (EUDAQ interfaces to other DAQs available for integrating different software and hence different detector systems into the central common system, Task 5.3)	DESY	24	Test running results
MS47	Online event data model available (Definition of the online event data model, i.e. the concept of an event for detector systems having very different integration times, compatible with the offline software and in coordination with WP3,Task 5.5)	DESY	24	Test running results
MS62	Development of run control ready (Development of run control ready, incorporating controls for data taking, the ability to send and receive configuration data and receive status messages, Task 5.3)	UCL	27	Test running results
MS66	TLU hardware, firmware and software ready for tests beams (The hardware, along with the interface to the CCC, as well as the firmware and software will be ready for integration by detector systems, Task 5.2)	Bristol	30	Test running results
MS67	Data quality monitoring tools ready (Data quality monitoring tools ready, comparing quantities as soon as possible after data taking but as accurate as possible as offline to expected distributions, Task 5.4)	UCL	30	Test running results
MS68	Slow control system ready (Slow control system ready to monitor environmental conditions from the various detector systems, providing a synchronised picture of the conditions, Task 5.4)	Prague	30	Test running results
MS80	Common DAQ system ready for combined test beams (Tasks 5.1, 5.2, 5.3, 5.4, 5.5)	UCL	36	Test running results

Project management — milestones II

- MS25, MS43 — done.
- MS46 (M24, Apr/2017). Release of EUDAQ2 — writing ongoing.
- MS47 (M24, Apr/2017). Online event model — writing ongoing.
- MS62 (M27, Jul/2017). RunControl — ready when EUDAQ2 released, on track.
- MS66 (M30, Oct/2017). TLU ready — see D5.2, on track.
- MS67 (M30, Oct/2017). DQM4HEP — see D5.3, on track.
- MS68 (M30, Oct/2017). Slow control — can use DQM4HEP.
- MS80 (M36, Apr/2018). Common DAQ ready — beam tests already being done with common DAQ tools, on track.