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Data acquisition for the ILC

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Introduction

A DAQ system needs to pass data to and from the detector to some off-detector system

DAQ systems need to cater for the following needs in high energy particle physics:

- Cope with high bandwidth data
- May have to pick out (trigger on) interesting or spectacular events
- Collect data with 100% (!) efficiency
- Work for a long time without (!) fault
- Integrate a system of many different components
- Cope with upgrades of accelerators and detectors or other very different running conditions.

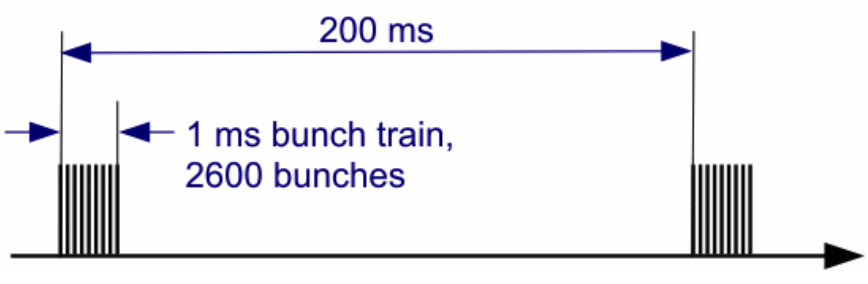
Other issues within HEP

- HEP has been a driving force for technology − the collection and transfer of data of such high volume and rate was not common at the advent of collider physics.
- Each accelerator / experiment / detector had a bespoke system to cater for its needs.
- With industry advances and more common high-speed data transfer, have the opportunity to use commercial off-the-shelf equipment to reduce costs, development time and risk.

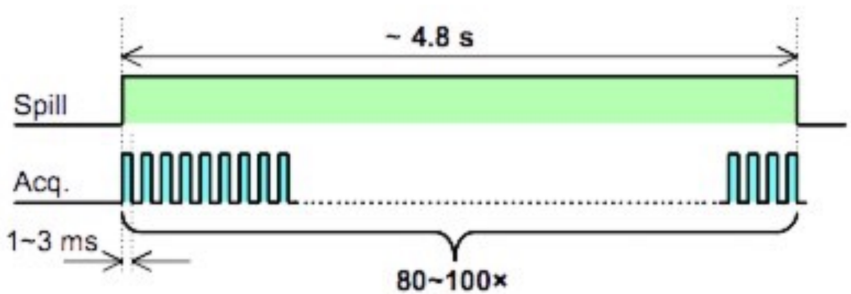
DAQ considerations for the ILC

The ILC's much lower rate and no-trigger operation compared to the LHC make it seem simple(r). However, there are a number of challenges:

- Highly granular detectors leads to an unprecedented number of channels
  - Robust control and monitoring is essential
  - Significant data compression at detector electronics level
  - Power consumption needs to be low
- The beam structure is very different to recent colliders with a 1 ms train ~300 ns-spaced bunches, all 5 times per second.
- This is all very different when running beam tests.



ILC mode



Test-beam mode

Original CALICE DAQ architecture

During the development of first CALICE (EUDET) technical prototypes, UK groups were developing the DAQ system*:

- Basic R&D into data acquisition systems for itself and for calorimeters at the ILC.
- Developed a conceptual design of a DAQ system for calorimetry at the ILC (even though far off).
- Develop a system using industrial standards and advances: flexible, high-speed serial links, scalable, using commercial off-the-shelf components.
- Deliver DAQ system for prototype calorimeters.
- DAQ system could be applicable for final system of other detector systems.

Serves as a good example of an overall DAQ system design and much of the design is still in use today.

It addresses the boundary between on- and off-detector and detector-specific and generic.

It is also an integrated hardware and software solution.

*M. Wing et al., "A proposed DAQ system for a calorimeter at the International Linear Collider", LC note, LC-DET-2006-008.
M.J. Goodrick et al., "Development of a modular and scalable data acquisition system for calorimeters at a linear collider", JINST **6** (2011) P10011.

Original CALICE DAQ architecture

Detector Unit: ASICs

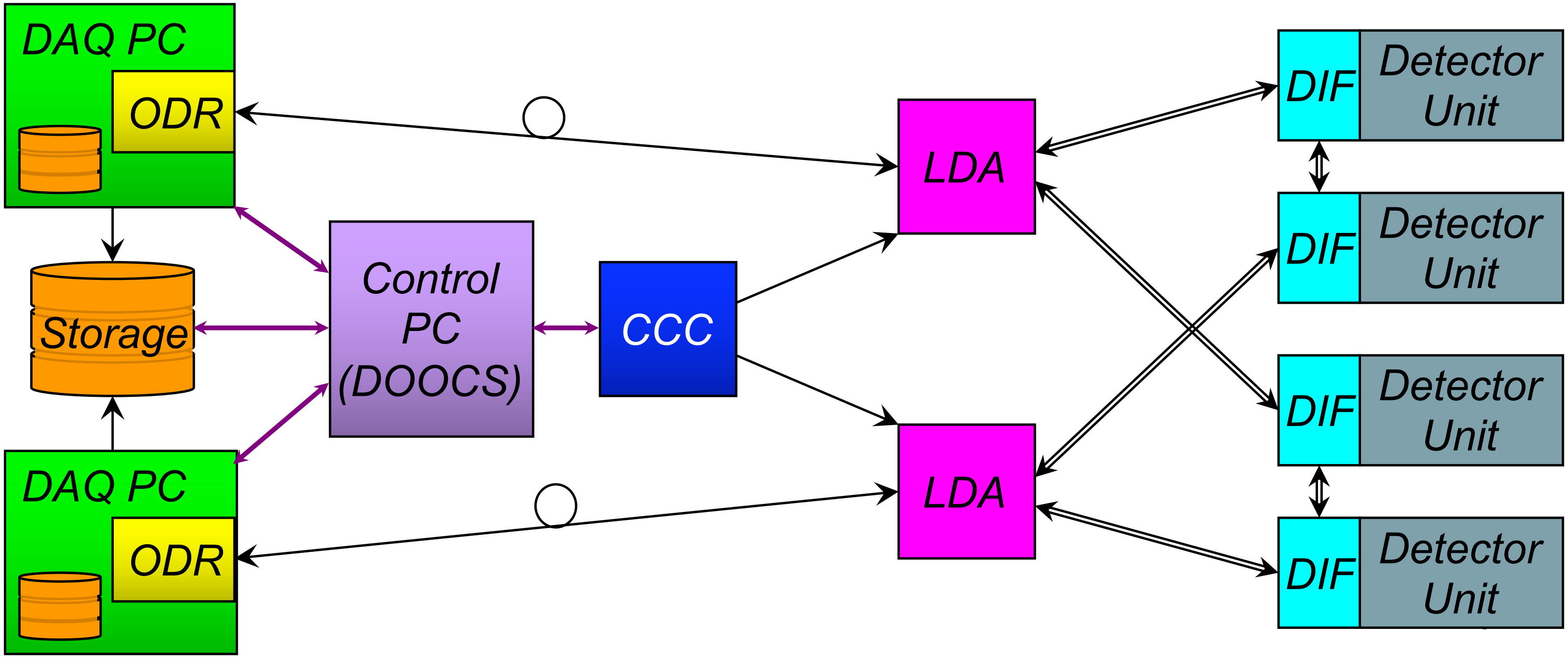
DIF: Detector InterFace connects generic DAQ and services

LDA: Link/Data Aggregator fansout/in DIFs and drives links to ODR

ODR: Off-Detector Receiver is PC interface

CCC: Clock and Control Card fansout to ODRs (or LDAs)

Control PC: Using DOOCS (software)



Ongoing common DAQ work, AIDA-2020

Principles, motivation, boundary conditions

- As part of the AIDA-2020 programme, we aim to provide a common DAQ system.
- We are not designing a prototype DAQ system for a Linear Collider detector.
- We cannot develop a fully integrated hardware / software solution from scratch.
- Priority is to ease running of detectors in a beam test (a service).
- Should allow more physics and technical understanding to be extracted. Understand performance of detector and / or validation of reconstruction algorithms for individual and multiple detectors.
- Clear links with other parts of the collaboration on software, calorimetry and, indeed, all detectors under development.
- In principle (ideally) we should be as inclusive as possible, developing solutions which are useable by all and providing common frameworks and tools.
- The developments could be used by other (non-LC) detectors too.
- As a by-product, learning about a future Linear Collider DAQ and some of its challenges.
- Will discuss here the common solutions being worked on.

Needs of common DAQ

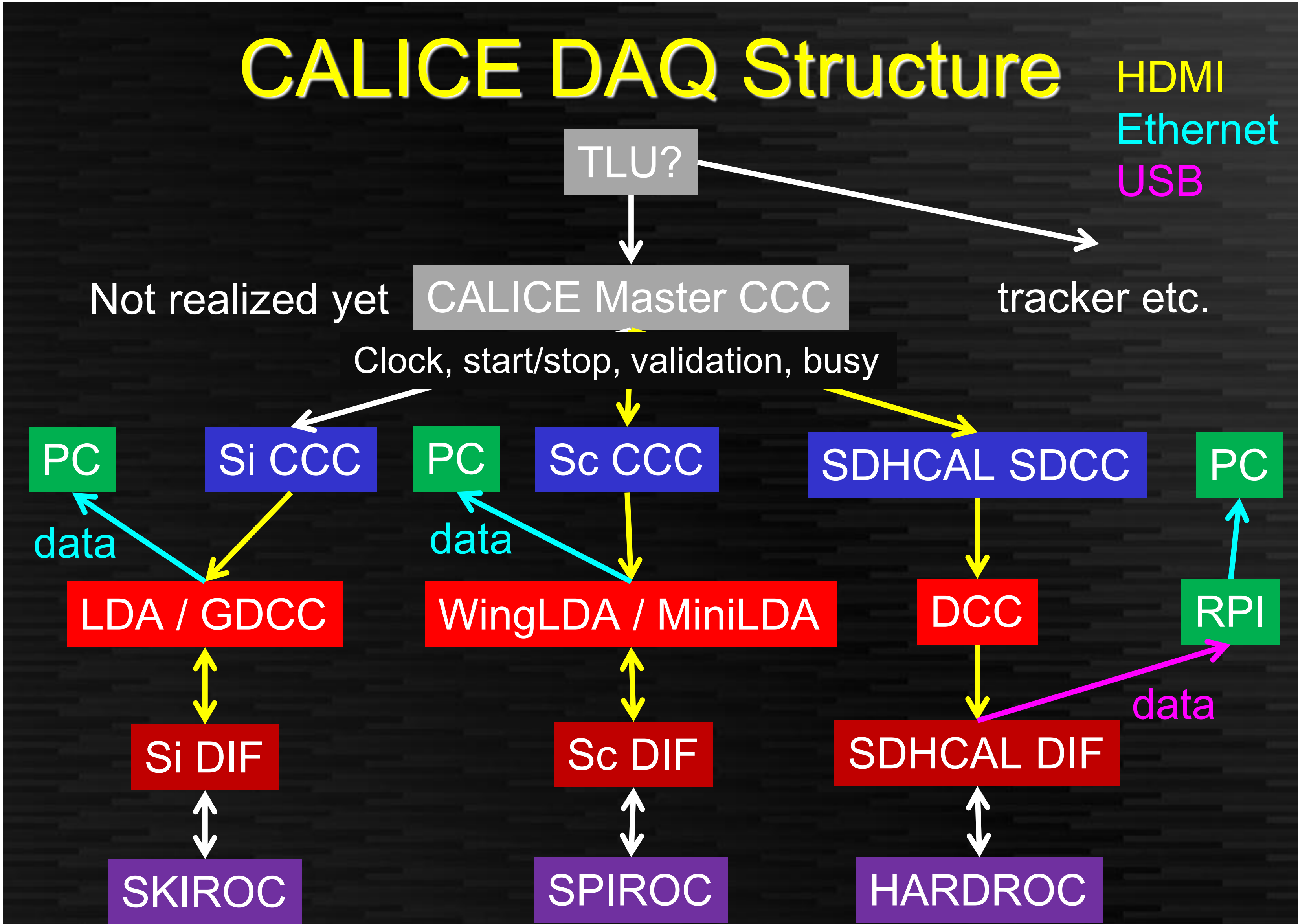
Beam tests envisaged:

- More than one calorimeter, e.g. an electromagnetic and a hadronic calorimeter − large number of physics, technical and integration issues to be addressed.
- TPC and silicon reference tracker − momentum resolution of TPC.
- Calorimeter plus tracking − position resolution of calorimeter, uniformity, particle flow.
- Forward beam-pipe calorimeter (FCAL) plus tracking − position resolution of FCAL.

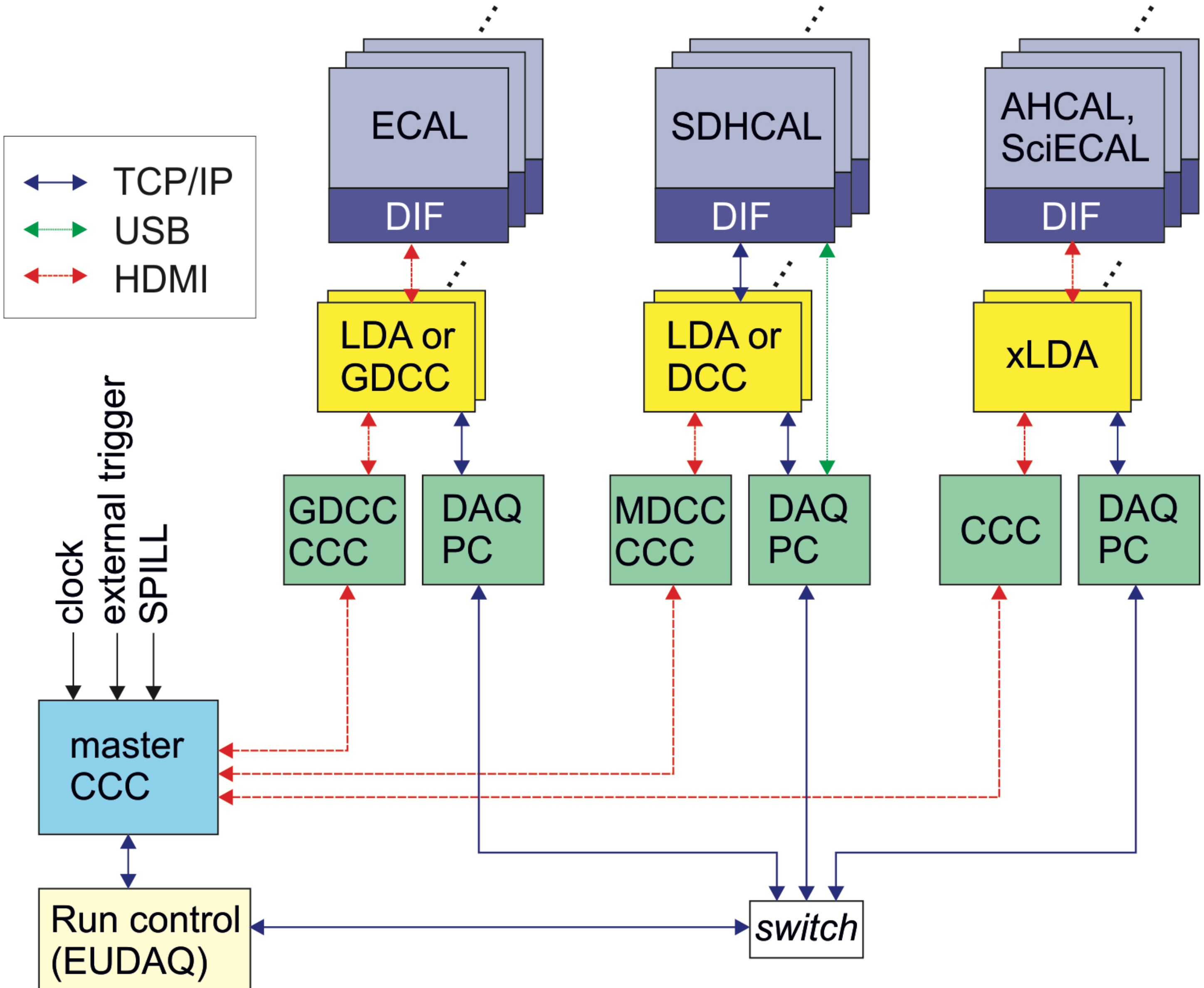
Priority is to ease running of detectors in a beam test (a service) to allow more physics and technical understanding to be extracted.

CALICE structure

Individual DAQ hardware (and software) for each calorimeter based on UK design.



CALICE DAQ structure



T. Suehara and K. Krüger, AIDA-CALICE DAQ interface, AIDA-2020-NOTE-2016-006

TPC DAQ

TPC uses modified ALTRO system from ALICE TPC (Lund)

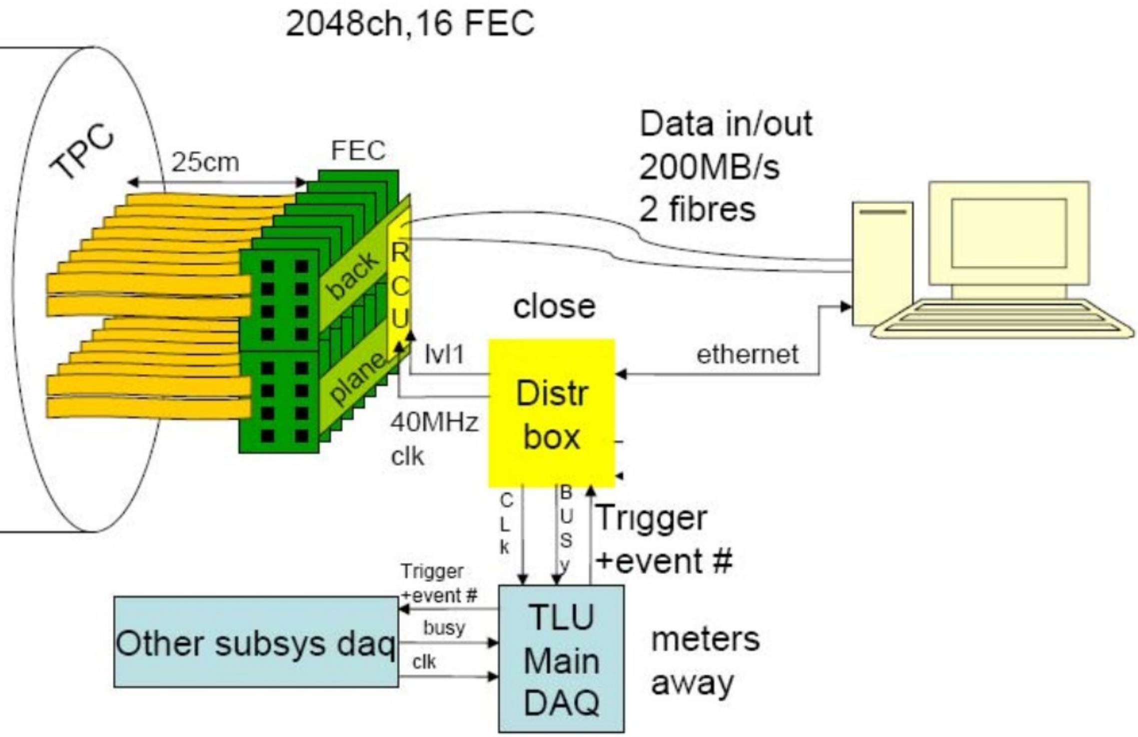
Trigger:

- External trigger
- Using NIM electronics
- TLU (never used)

Data transferred from chips via an optical link to PC

Sampling frequency is 5 / 10 / 20 / 40 MHz.

LCTPC has 10k channels



Integration with EUDAQ and TLU needed

Opportunity to re-work DAQ given need to integrate with Si tracker, based on Kpix

D. Tsionou

AIDA-2020: interface, synchronisation and control of multiple-detector systems

- Distribution of timing and synchronisation signals is key to any central DAQ system to allow data from different detectors to be correlated.
- Synchronisation of different detectors with very different integration times, e.g. vertex detector and calorimeter. Signals need to correspond to same events !
- Interfaces specified for trigger logic unit (TLU) used for EUDET/AIDA beam telescope and clock and control card (CCC) used by CALICE.
  - TLU distributes trigger signal and number and data is read out belonging to this trigger. Does not work for auto-triggered systems.
  - CCC distributes a clock and START and STOP and data readout during that acquisition cycle. Need to agree on a clock frequency; need to define an “event”.
- Compatibility between TLU and CCC is crucial. TLU undergoing development for this.
- The basic interface, synchronisation and control definitions have been documented.*
- Provide TLUs for combined beam tests and laboratory set-ups, integrate to common DAQ and provide expert support.

* D. Cussans, “Hardware and software interface specification for AIDA-2020 common beam tests”, AIDA-2020-D5.1, http://cds.cern.ch/record/2213430 and references therein.

AIDA-2020: Central DAQ and run control

Independent standalone (detector) DAQs.

EUDAQ as central, high-level DAQ

- Lightweight modular and portable framework.
- Originally developed for (EUDET) pixel telescope and used in many beam tests.

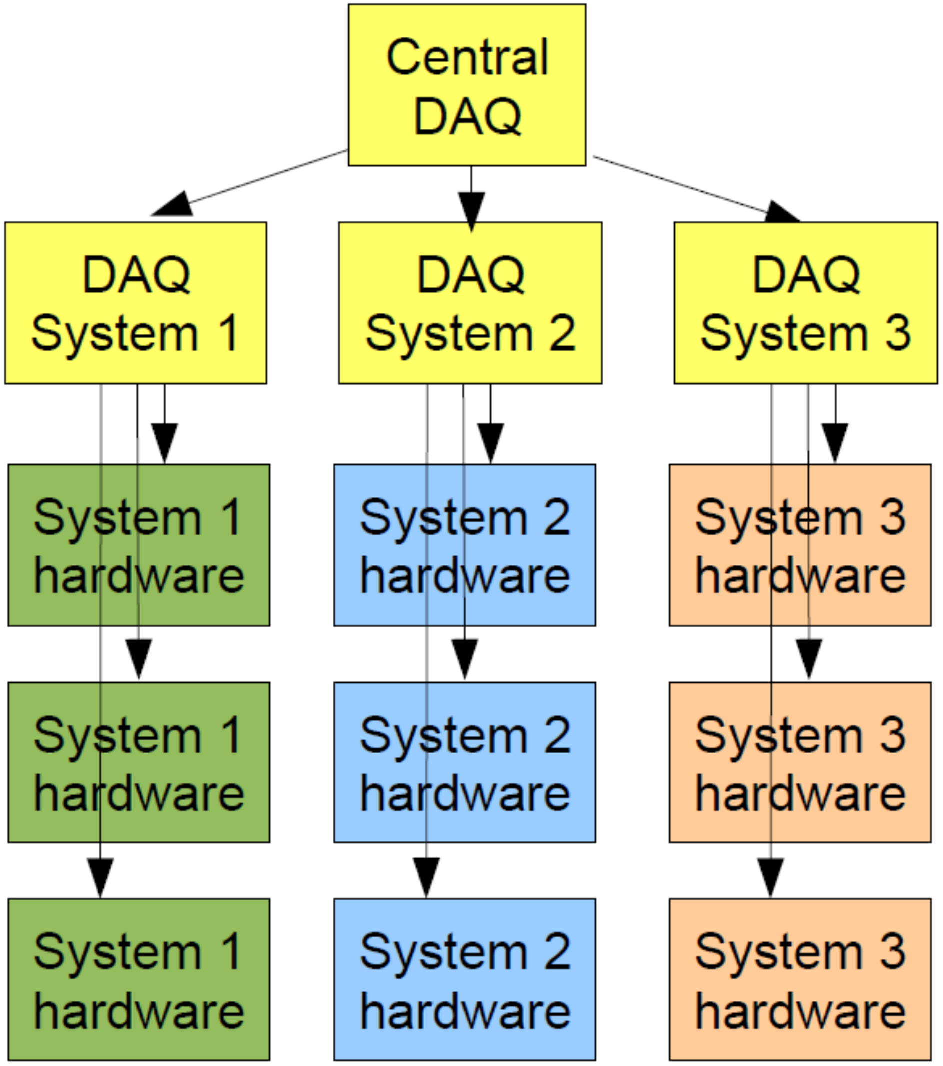
EUDAQ1 has a stable release and used for many years. Also in AHCAL beam tests.

EUDAQ2 scalable and applicable to multi-detector setups.

- A lot of recent progress; hope for a release soon.

Users have to provide routines to interface their system.

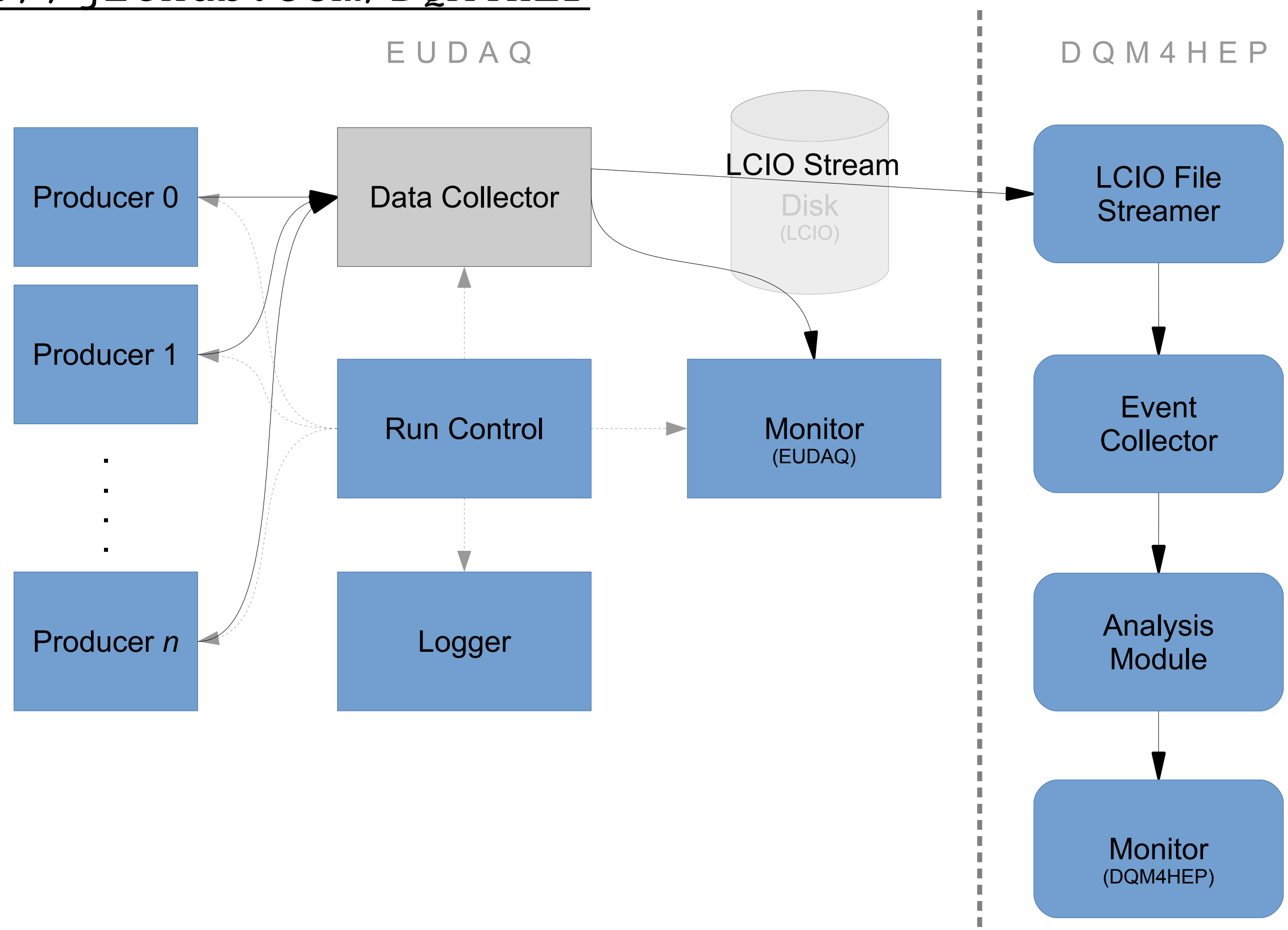
Laboratory tests AHCAL+BIF (Beam InterFace) and now do AHCAL+beam telescope in beam tests → big step in common DAQ / EUDAQ integration.



K. Krüger

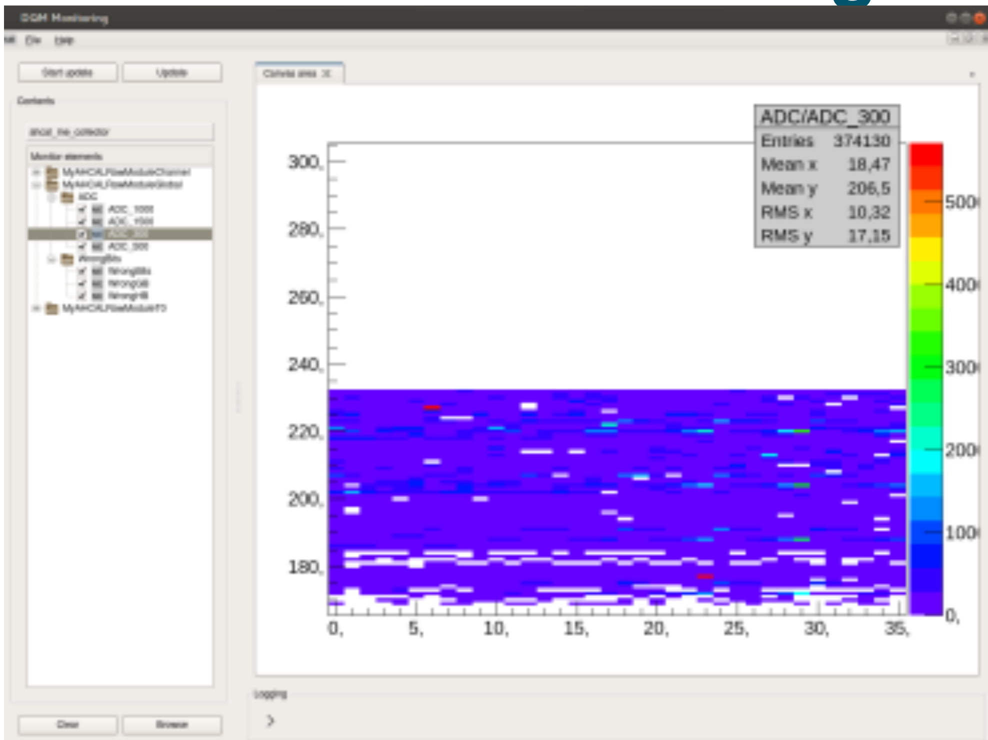
AIDA-2020: Monitoring

- Development of near-online checks of data quality: for individual detectors and coincidences between different detectors.
- 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.
- Interfaced with EUDAQ.
- System set up at DESY and used in AHCAL beam test.
- Participated in June SiECAL / SDHCAL beam test.

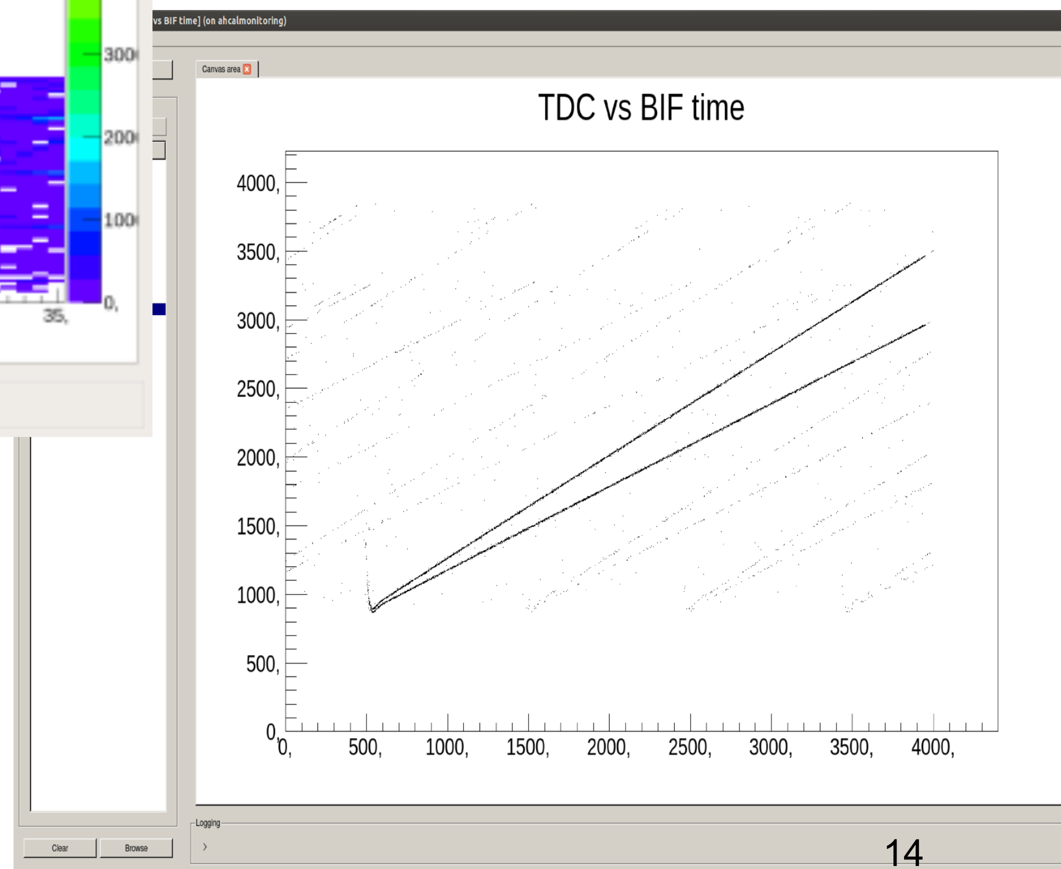


T. Coates (Sussex)

AIDA-2020: Monitoring



Online time correlation of two detectors: AHCAL+BIF



Real **progress** made on **common** system.

AIDA-2020: Event model

- To define an event model for online data, from different detectors with very different signals and properties.
- Based on LCIO framework.
- Also needed for data sanity and quality checks related to multiple-detector information.
- Lots of information gathering on current systems and their data (format).
- First proposal for EUDAQ raw data format.
- Information and proposals collected at:

`http://flcwiki.desy.de/AIDA2020WP5_Task55_EventModelforCombinedDAQ`

Summary and outlook

A DAQ system for the ILC presents different challenges to the super-high-rate machines like the LHC.

Some more generic R&D would be interesting:

- Overall system architecture
- Technology choices and survey of commercial solutions
- On- / near-detector processing

Current focus is on providing common aspects to ease integration of multiple detectors in beam tests with progress in:

- Definition of interfaces and method of synchronisation
- Use of EUDAQ as the basic software
- Generic monitoring framework
- But, still much to do and many combinations of detectors to test. Expect significant progress over the next year or two

Not able to provide a fully hardware- and software-integrated common DAQ system with detector specific parts and generic components.

Ideally by the end of AIDA-2020, will have delivered on several aspects of the common system and can then move onto a more generic and fuller common DAQ system.