1st FCC-ee mini-workshop on Detector Requirements
17-18 June 2015
CERN

LHCb upgrade (hardware-less) trigger

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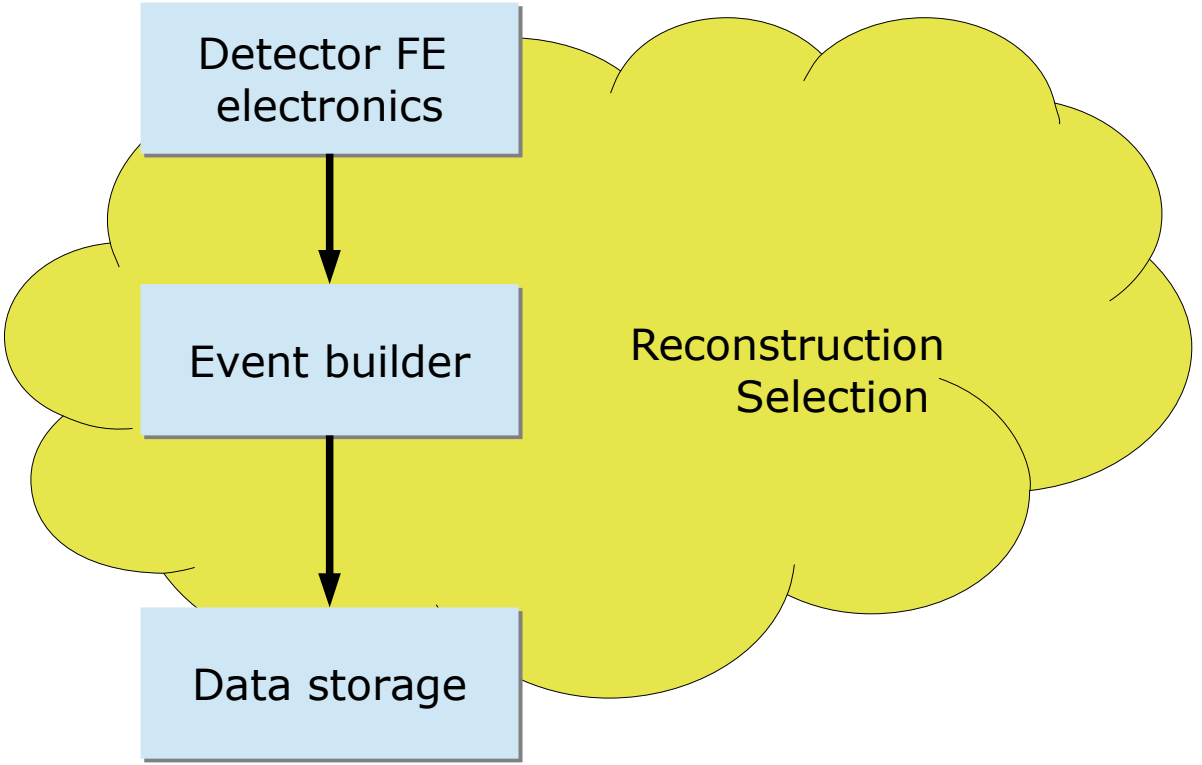
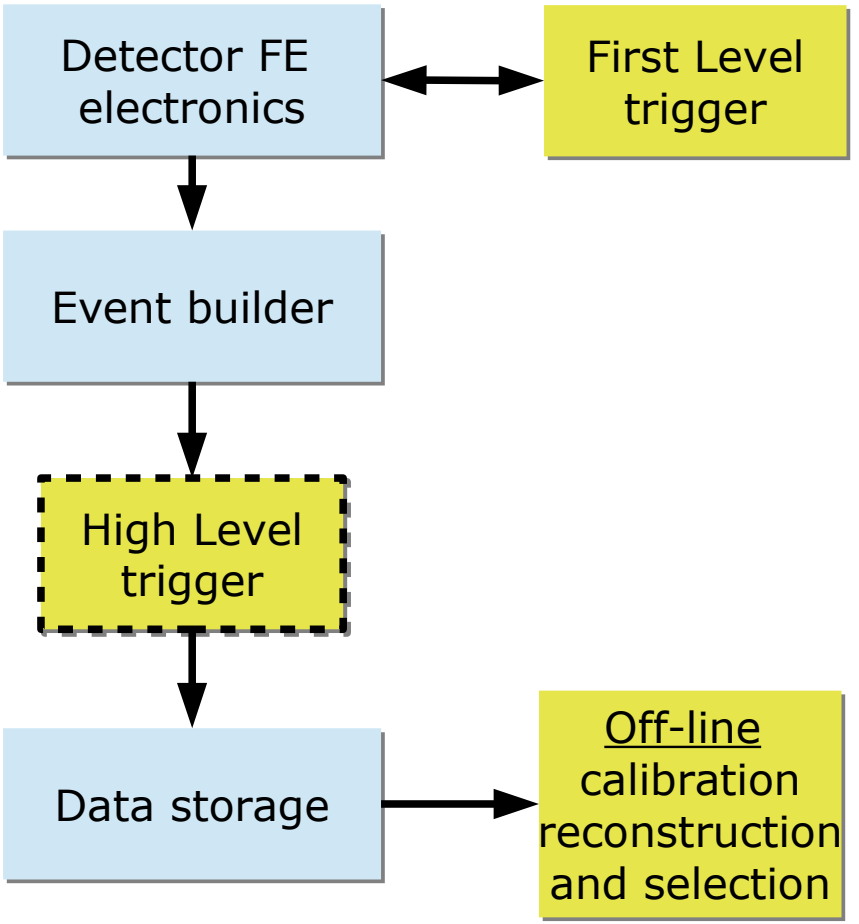
Corner stones for readout systems



Readout system with trigger



Custom electronics

Farm of CPUs running in real time

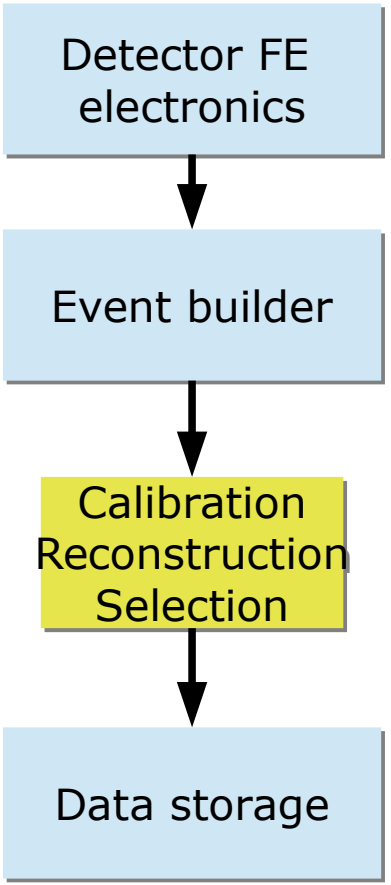
GRID

Pro and Cons

- Pro
  - Reduce the bandwidth a soon as possible
  - Minimize the size of the event builder
  - Calibrations and final reconstruction are ran off-line and can be repeated several times

- Cons
  - Complex integration of the first level trigger with the FE electronics
  - Bias and inefficiencies introduced by the first level trigger
  - Coherence between *on-line* and *off-line* reconstruction
  - Require large computer resource on the GRID

Readout system trigger-less "*b* and *c* -factory": full reconstruction and selection in real time



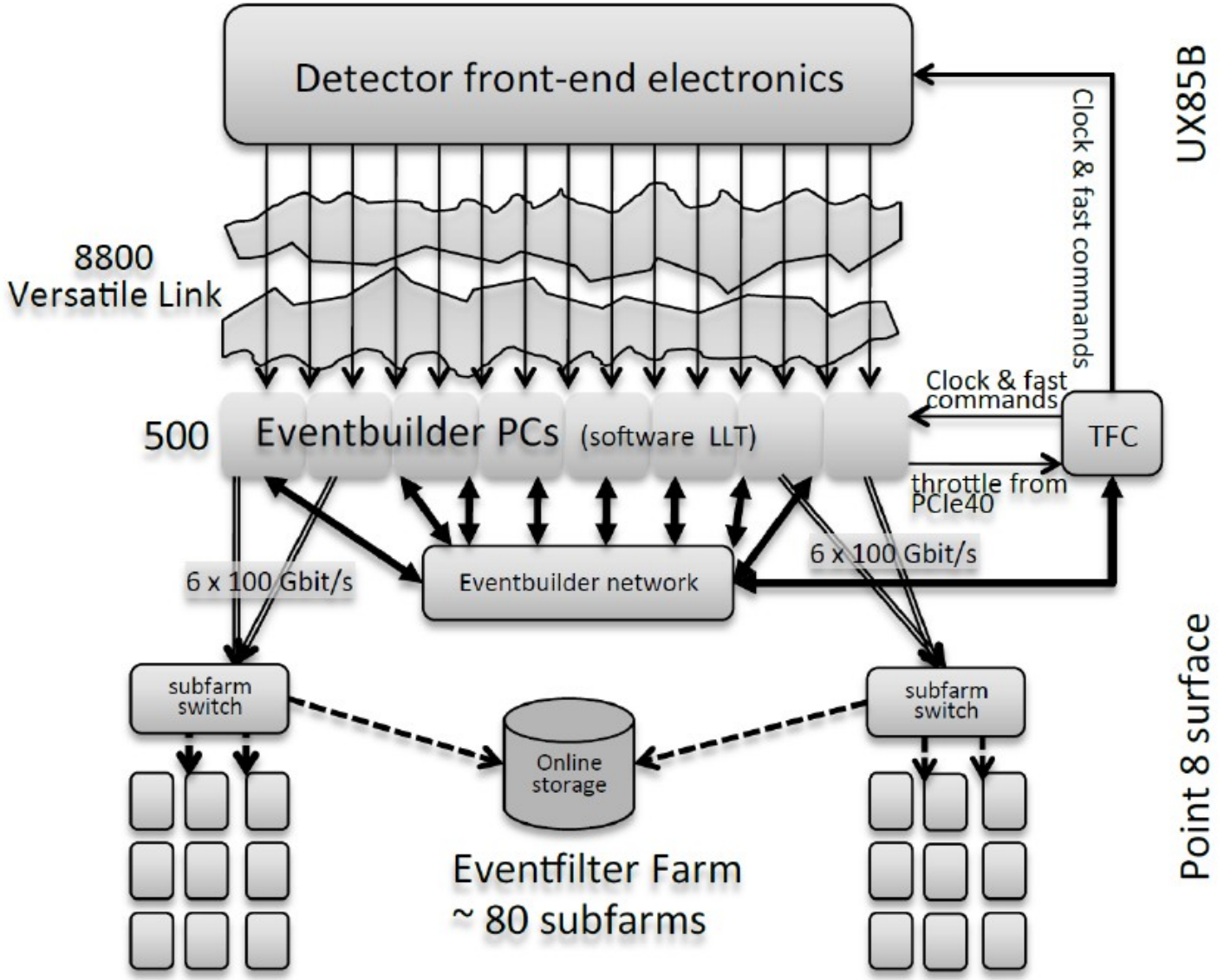
Farm of CPUs running in real time

Pro and Cons

- Pro
  - **Maximize the efficiencies to collect many particles** (D, D_s, B, B_s, Λ_b...) **with very different production rates and kinematic phase spaces**.
  - Data are ready to be analysed as soon as they are collected
  - Only one reconstruction and selection process
  - Storage might be reduced (no RAW keep only micro-DST)
  - GRID resource might be reduced

- Cons
  - Large bandwidth requires between the FE and the event builder
  - Large scale event builder
  - Large scale event filter farm
  - Calibration has to be determined in real time
  - Reconstruction is only run once

LHCb readout system for the upgrade



Front-end electronics

- One of the most difficult part
  - Custom electronic which is specific to each detector
  - Running in a harsh environment
    (space, radiation, power dissipation, cooling, ...)
  - Many channels distributed over either small or large volume
  - Zero suppression and data compression

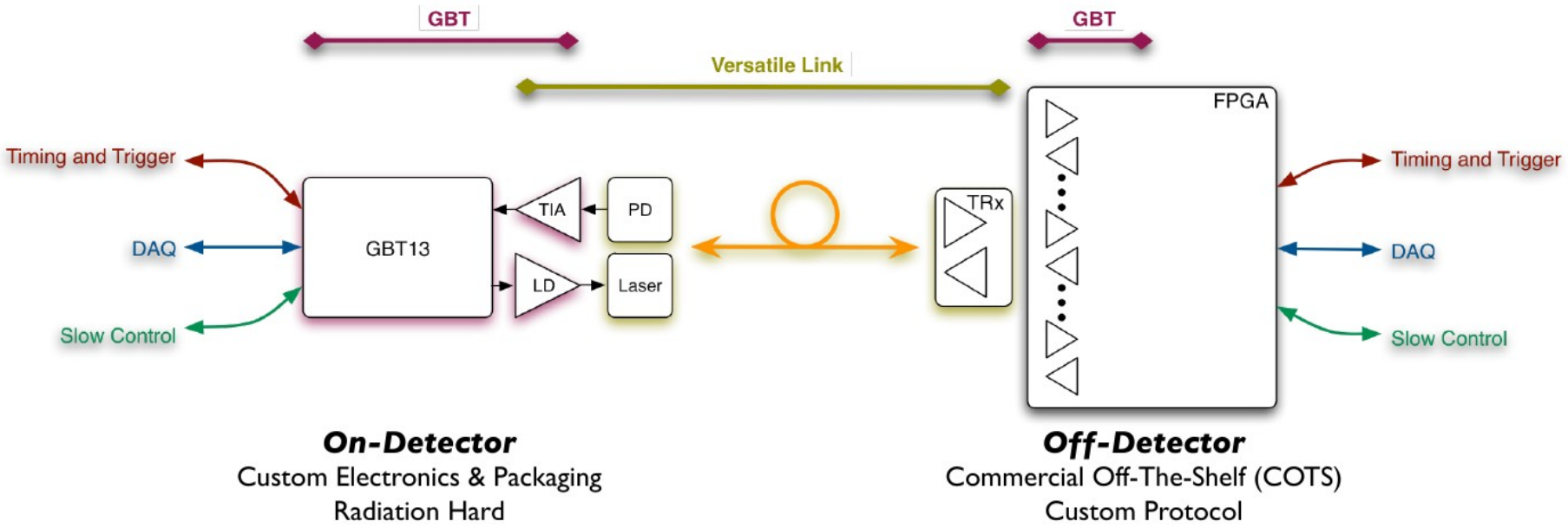
- Challenge
  - Would it be possible to concentrate data as much as possible and to push them on very large bandwidth links using a well established network protocol (100 Gb Ethernet, 400 Gb ....) ?

Serial high speed optical links

- ~9000 data links in LHCb upgrade
- Very nice:
  - Large bandwidth, cable with small diameter and light weight material
  - No electromagnetic coupling between FE and the event builder
- But expensive
  - Cost increases with the bandwidth and the distance
  - Cost decreases when links are merged into ribbon: 12 / 24 / 48 fibres
- Emitter
  - No commercial rad-hard emitter
    CERN developed the GBT chip and the Versatil link (4.5 Gb/s)
  - Current bandwidth for commercial off-the shelf component, 10 -25 Gb/s on a single fibre, 100 Gb/s by aggregating several fibres, ...)

Bi-directional versatil link

https://espace.cern.ch/project-versatile-link/public



IN LHCb, the DAQ and the ECS (timing + fast command + slow control) flows are separated since it simplifies the architecture and ease the maintenance.

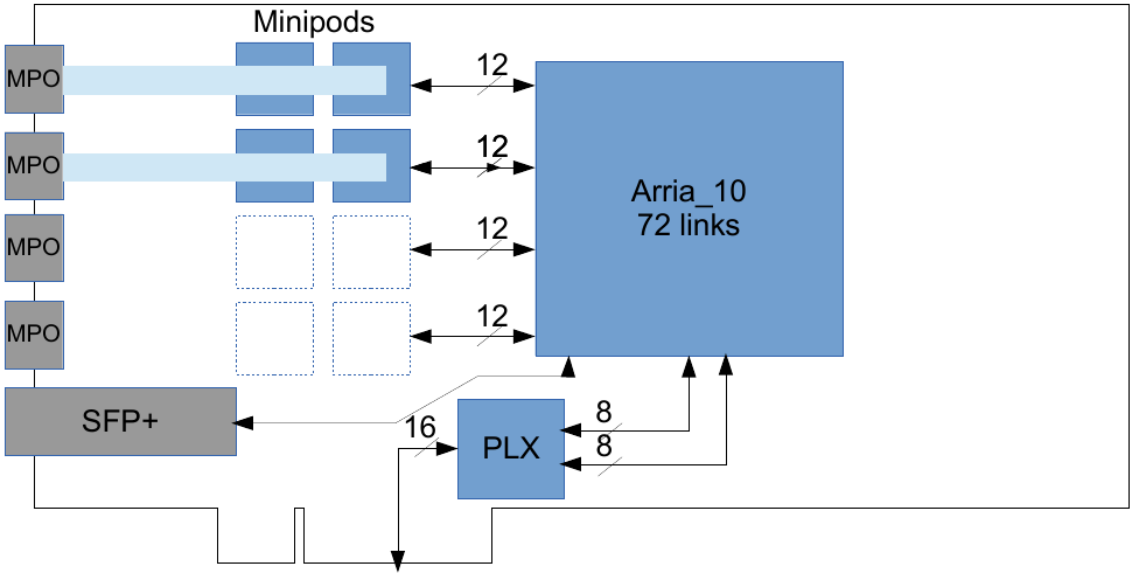
Interface the FE to the event builder

- PCI Express board.
  Complex interface based on custom electronics:

Up to 48 optical inputs
Serial signal up to 10 Gb/s

Up to 48 optical output
Serial signal up to 10 Gb/s

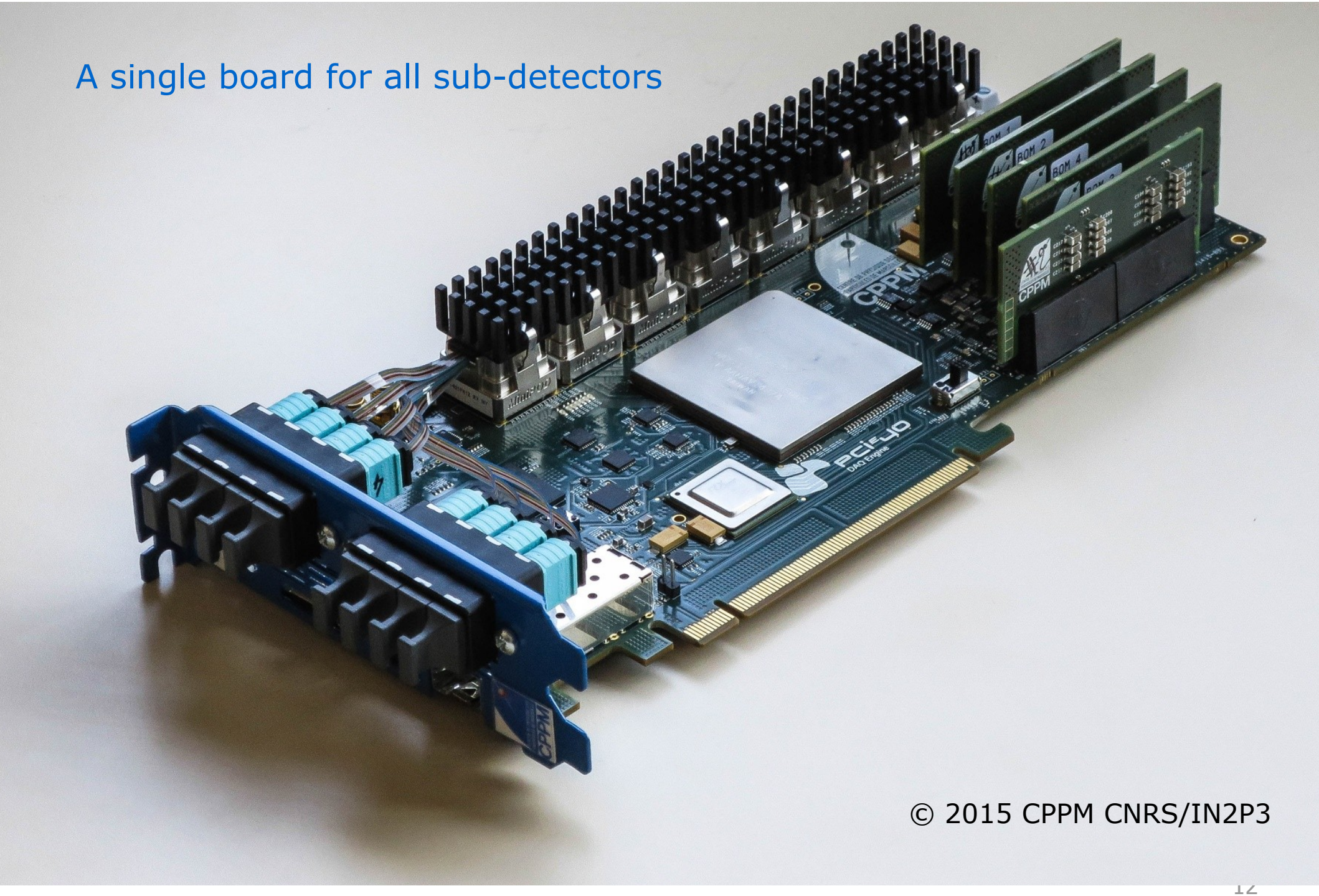
Bidirectional serial
links for the TFC



PCIe output GEN3×16 (~100 Gb/s)

- The readout board is connected to the FE electronics via 24 optical links running the GBT protocol (24×4.5 ≈ 100 Gb/s)

A single board for all sub-detectors



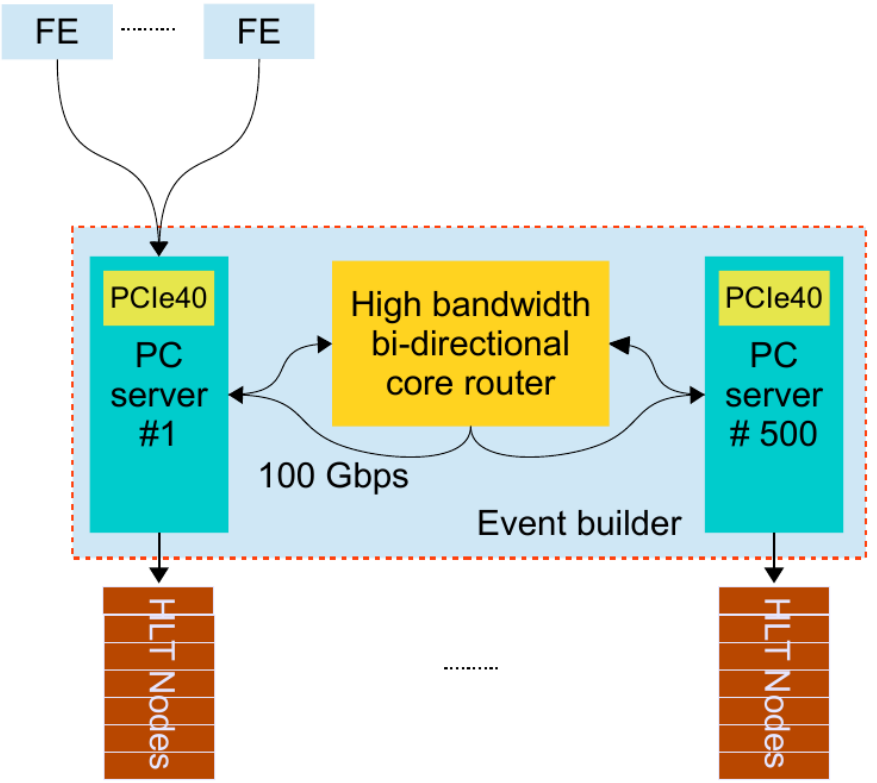
Firmwares development

- The readout board relies on the last generation of FPGA from the Altera company (Arria10):
  - 1.15 million of logic cells
  - 72 High speed links
  - ...
- Developing the firmware for such complex component is an issue:
  - Experience electronics engineers
  - In most of the case the firmware depends on the sub-detector.
  - Select generic approach as far as possible
  - Set-up a teams of developers
  - Use framework and well defined interface to isolate the user code form the hardware specificities

The event builder (IT domain)

- 32 Tbits/s
- The challenge has been to find a cost effective solution:
  - Use component / technology widely use in Data Centre
  - Reduce the distance between readout boards, PC servers and switches

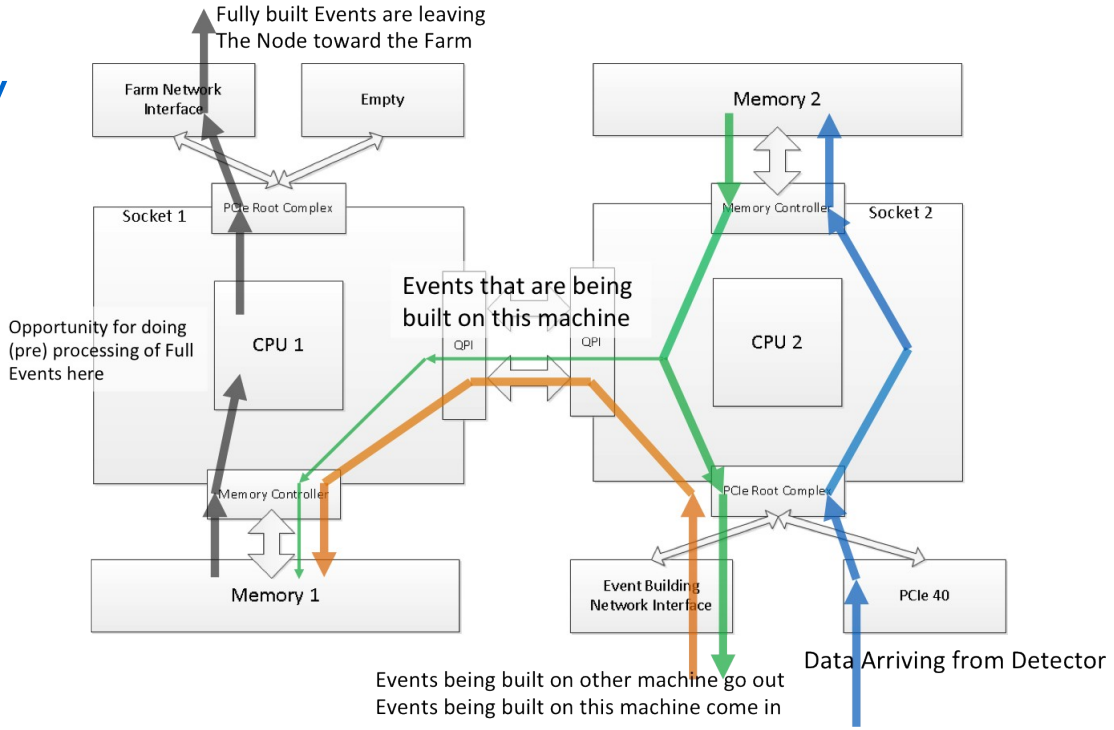
- 500 PC-servers connected to one switch through high bandwidth bi-directional links at 100 Gbps (Ethernet, infiniband, ...)



Event builder PC-server data flow

- 4 DMA transfers running in parallel and continuously

  Total flow of 400 Gb/s

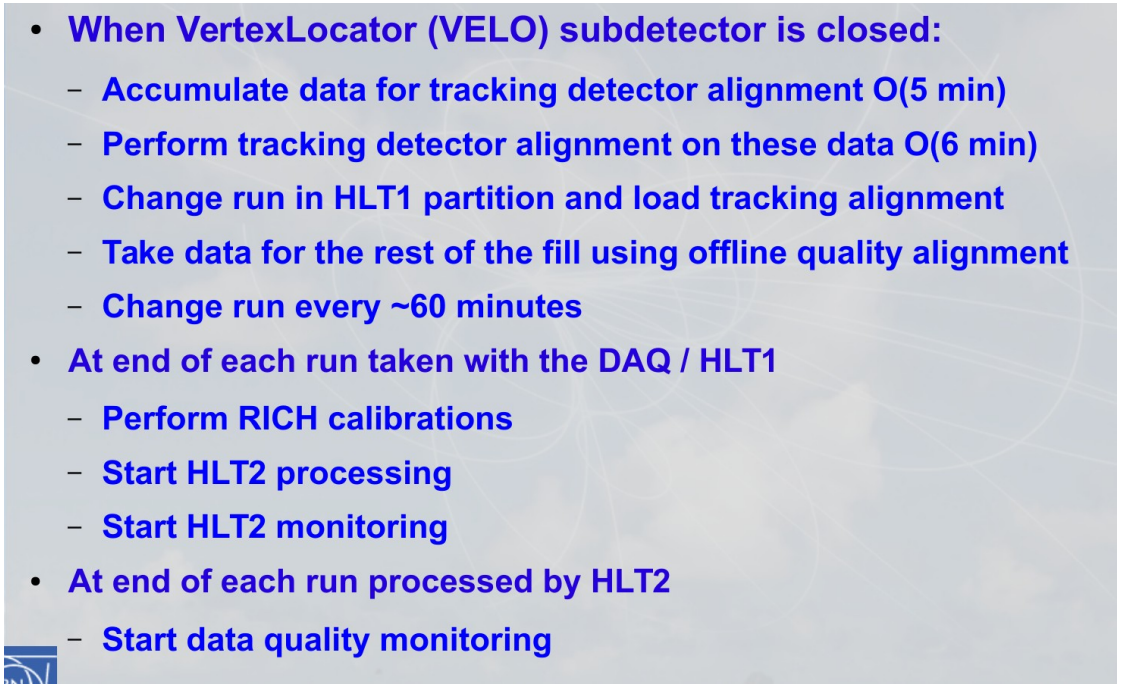


- Difficult to experience a large scale system in the lab (High Performance Computing sites)
- Scalability of the event builder is under study.

Calibration in real time

- Difficult to achieve day 1 since you have to understand your detector.

- In LHCb Run2, the calibration is performed by run and by fill. A complex sequence of processes have been deployed to run simultaneously the calibration and the event selection:

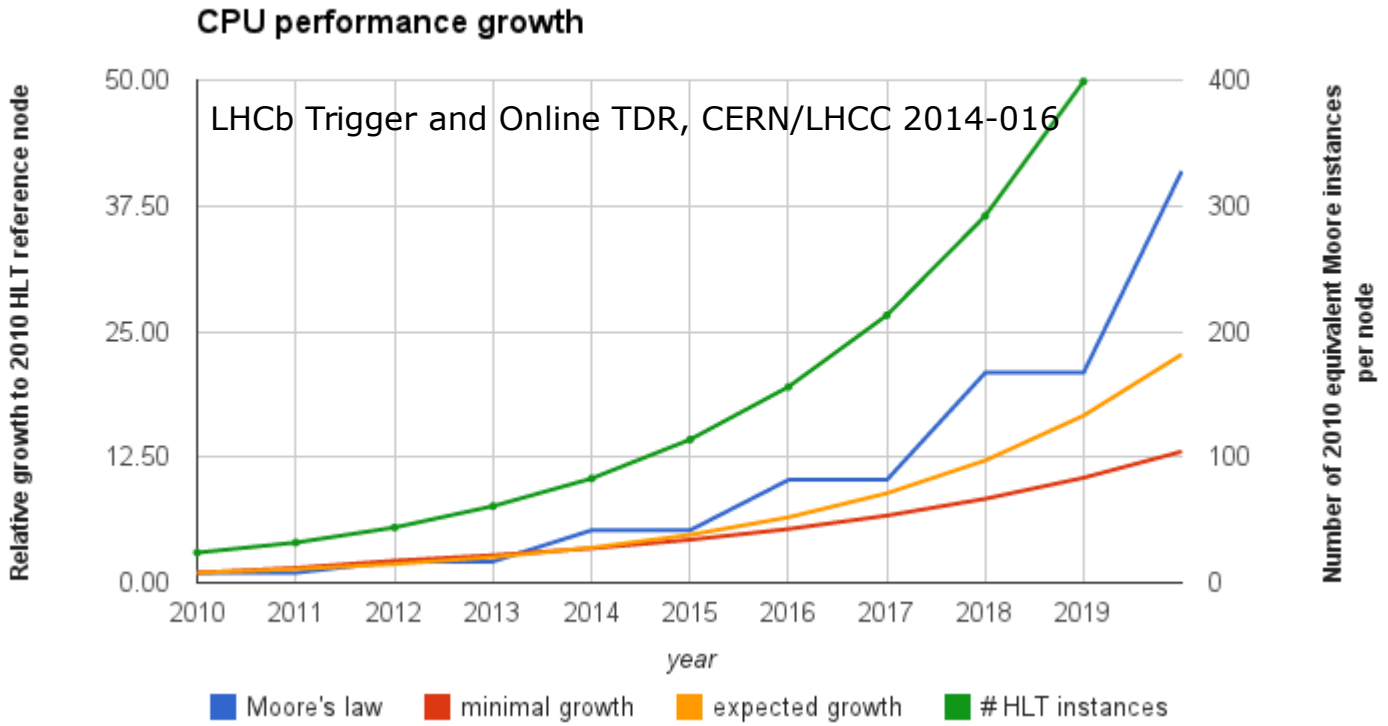


CHEP 2015 Markus Frank et al.

Reconstruction, selection in real time

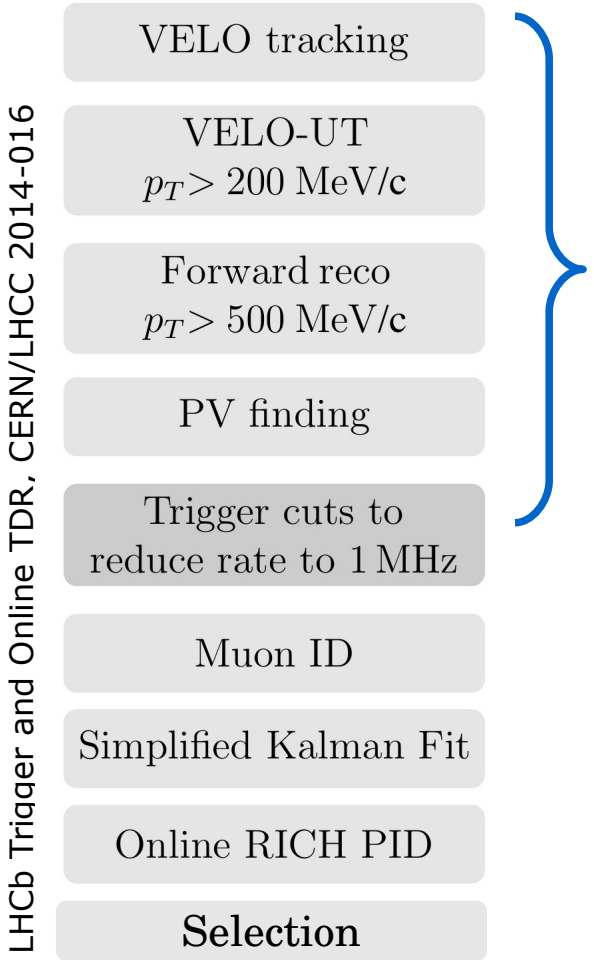
- Not an easy to extrapolate the CPU resource in 2020:

Server (2019)	1000
Tasks/ server	400
Time per collision	13 ms



Event filter algorithms for the upgrade

The design of the detector has been optimized to minimized the time of the tracking algorithm



~ 5.5 ms

13 ms

Interesting algorithm for inclusive b-selection based on BDT

Output stream

- The size of the output event has to be minimized. This is mandatory to maximize the statistics of interesting events.

  The Grail is to keep only micro-DST containing reconstruct object.

LHCb Run 2:

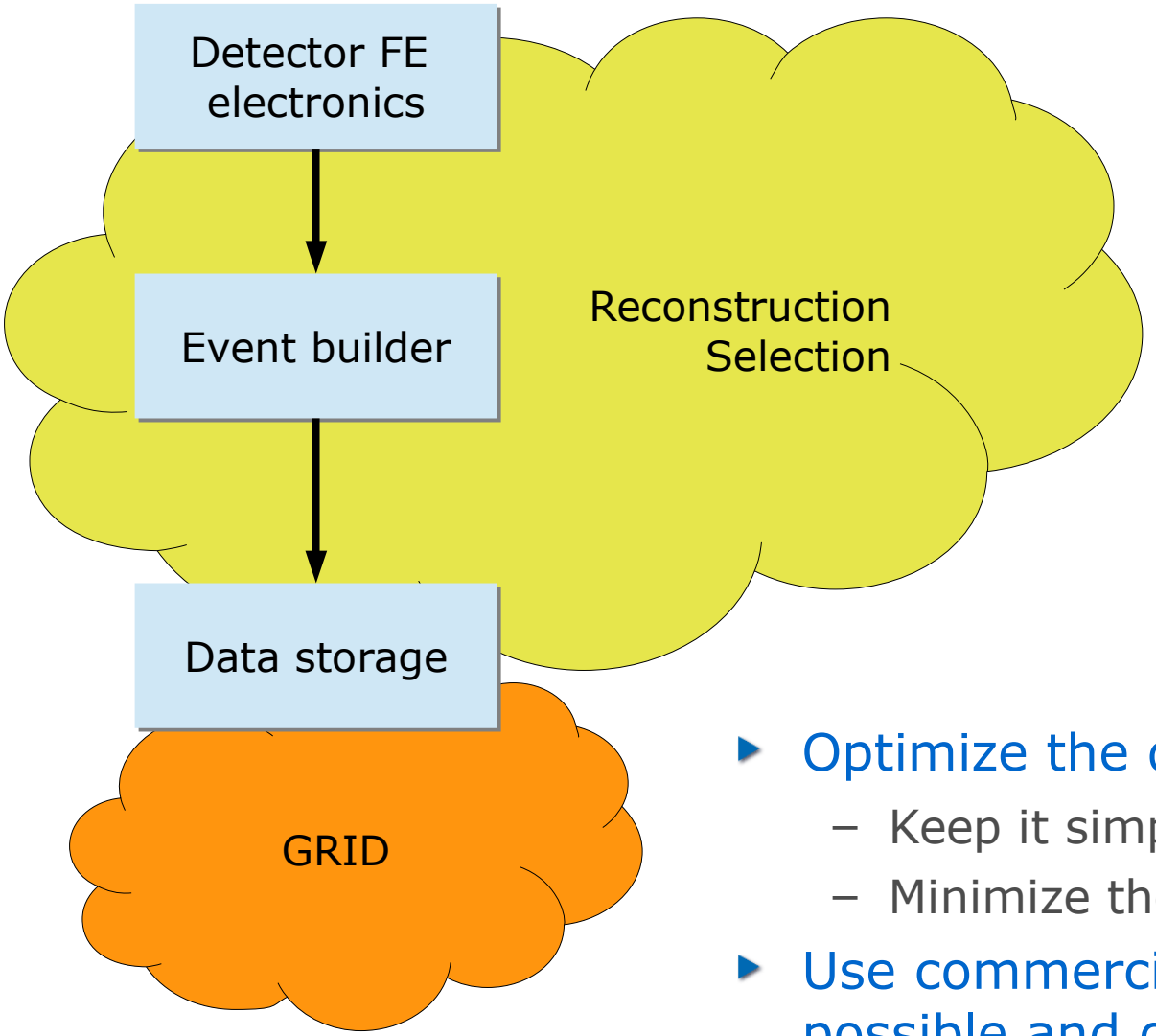
A fraction of the full stream will be parked and reconstructed during the next Long Shut down (2019-2020)

- How do you distribute the physics among the different stream ?

Software

- Nowadays, software require high level expertise:
  - The framework has to take benefit of multi-core CPU
  - Deal with multi-threading, vectorization, ...
  - Convergence off-line / on-line
  - Run on several CPU architectures (X86, GPU, XEON PHI, ARM, ...)
- Code optimisation is mandatory to reduce the CPU resources.

Conclusions: data processing



- Optimize the data processing globally:
  - Keep it simple, efficient and flexible
  - Minimize the cost and human resources
- Use commercial components as far as possible and deal with human aspect related to skill, contribution, ...