Technological Aspect of the Trigger-Less Readout Architecture for the LHCb Upgrade at CERN

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on behalf of the LHCb Collaboration
• Introduction to LHCb and current performance

• Motivations for an upgrade of the LHCb detector
  o Current limitations

• Detector Upgrade

• Readout Architecture Upgrade
  o FE Trigger-less electronics
  o DAQ technologies
  o Firmware architecture

• Outlook on plans and future running conditions
Current LHCb detector

- Vertexing
- Particle ID
- Calorimeters
- Muon
- Tracking
- First-level HW trigger

Current LHCb detector
Upgrading LHCb

The amount of data and the physics yield from data recorded by the current LHCb experiment is limited by its detector, readout technologies and hardware trigger.

While LHC accelerator will keep steadily increasing ...

- **energy / beam** \(3.5 \rightarrow 4 \rightarrow 6.5\ \text{TeV} \rightarrow \ldots\)
- **luminosity** \(\text{peak } 8 \times 10^{33} \rightarrow 2 \times 10^{34}\ \text{cm}^{-2}\text{s}^{-1} \rightarrow \ldots\)

... LHCb will stay limited in terms of

- **data bandwidth**: limited to 1.1 MHz / 40 MHz max
- **physics yields** for hadronic channels at the hardware trigger
- **detectors degradation** at higher luminosities
Upgrade Strategy

Remove first-level hardware trigger!

→ accept all LHC bunch crossing: trigger-less Front-End electronics

Current

Upgrade

1MHz event rate

40MHz event rate

~1Tb/s

~40 Tb/s

 Courtesy K. Wyllie
Compress (zero-suppress) data already at the FE

- reduce # of links from ~80000 to ~12500 (~20 MCHF to ~3.1 MCHF)
- data driven readout (asynchronous) + variable latencies!

Efficiently usage of link bandwidth for data

- pack data on data link continuously with elastic buffer
- extensive use of CERN GBT (robust FEC or WideBus mode)
  ✓ evaluate choices based on complexity vs robustness

NO TRIGGER to FE!
→ Only commands, clock and slow control
Efficient Data Packing Mechanism

Average event size

Link bandwidth

Average event size = link bandwidth

Buffer depth

Header is the unique identifier for each event in frame

✓ Compulsory (tag for each LHC crossing)
✓ Programmable in its content (must contain length of frame and BXID)
✓ Used by readout board to decode and separate frames
Upgraded LHCb Detector

- **New Vertex Detector**
- **Particle ID**
  - Replace HPDs + electronics
- **Calorimeters**
  - Reduce PMT gain + new electronics
- **Muon new electronics**
- **New Tracking stations**
Same ATCA board used in different flavors:
same generic hardware, different firmware

Replicate for as much as needed (scalable)
Back-End: New LHCb readout board

Classical approach: ~0.5 Tb/s data aggregator board with 10 GbE to FARM

24 inputs @ 4.8 Gb GBT format
12 outputs/inputs @ 10Gb ethernet

96 inputs @ 4.8 Gb → processing in FPGA → 48 x 10G ethernet ports
ATCA40

Under test

AMC40 slots

CIPMC

COM Express module

Clock switch FPGA

Crossbar

RTM connectors

Fabric connector

Power supply connector
→ TELL40 = ATCA40 + 4xAMC40
+ specific TELL40 firmware in AMC40

Now ready and being tested!
AMC40 test setup (MiniDAQ)

The MiniDAQ is the first step to the LHCb DAQ upgrade in order to check:

- Hardware functionalities
- Firmware developments
- Software developments
LHCb data taking plan

- **2014**: LHC LSI
- **2015**: Technical reviews & technology choices (ongoing now!)
- **2016**: LHC Run II
- **2017**: Tendering & Serial production
- **2018**: Quality control & acceptance tests
- **2019**: Installation & commissioning upgrade (18 months to plan!)
- **2020**: LHC Run III
- **2021**:  
- **2022**: LHC LSIII

For high-lumi LHC $L_{peak} > 5 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$
Conclusion

An upgrade plan of the LHCb experiment has been laid out

- Aim at collecting 10x more data and 20x more hadronic events

LHCb upgrade is technologically challenging and time wise tight

- Trigger-less, ~40 Tb/s network, minimize number of components
- Optimize costs and manpower: be smarter ...
- R&D, specs, evaluation, validation are ongoing.

CERN endorsed the LHCb Upgrade by fully approving it!

We have exciting times ahead in 2014 and beyond!