ATLAS Trigger/DAQ Upgrades

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CERN

About myself

Working on ATLAS Trigger/DAQ since 2006

- CERN Fellow and Staff
- Now as Research Associate at University of Oregon

Areas

- HLT Algorithm Integration
- Trigger Core Software
  - Deployment of quasi real-time conditions updates in the HLT
- Trigger Operations/Run Coordinator
- Trigger Coordinator
- Phase-II Event Filter Upgrade Co-coordinator

This talk

- Highlight some areas relevant to real-time analysis

ATLAS High-Level-Trigger

Typical HLT Algorithms

- Fast reconstruction
  - Trigger-specific or special configurations of offline algorithms
  - Guided by L1 RoIs
- Precision reconstruction
  - Offline (or very close to) algorithms
  - Full detector data available

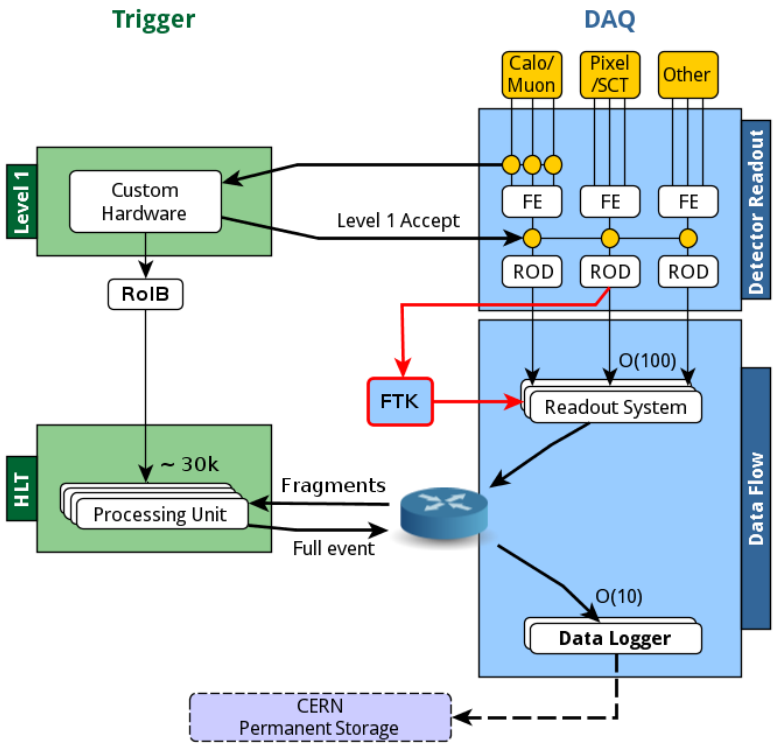
Resources

- Output rate ~1 kHz (full events)
- Processing time ~300 ms

Partial Event Building

- Partial events with data from a subset of the detectors
- Special case: Trigger-Level Analysis
  - Only write the objects created by the HLT (e.g. jets)
  - Allows much higher output rates thanks to smaller event sizes

ATLAS Run-2



Real-time conditions updates in the HLT

Deployed mechanism to update conditions in the HLT during the run

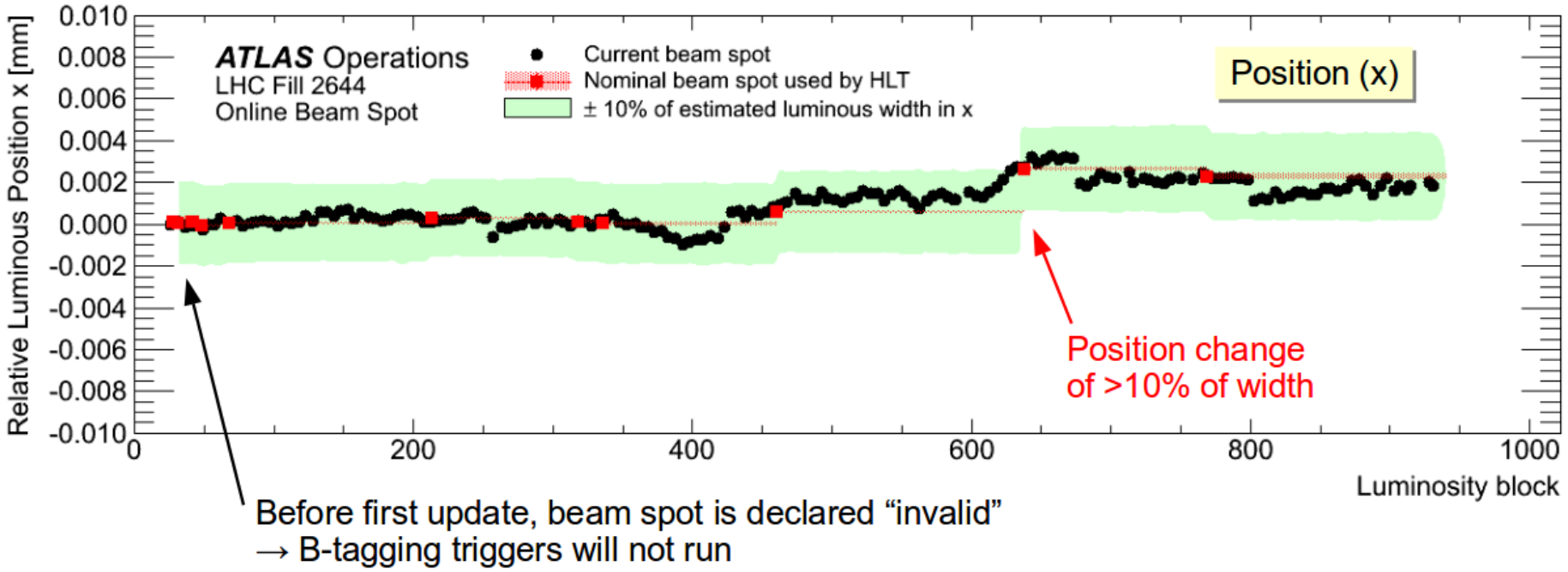
- Beamspot
  - Required for b-tagging
- Luminosity / Pileup
  - LAr energy reconstruction
  - Pile-up dependent selection algorithms (e.g. electrons, taus)
- Can be extended to other conditions if needed

Update mechanism

- Want to keep update frequency at a reasonable level
  - Measure quantity X
  - If X changes by more than N% write new value into conditions DB
  - Notify the HLT to reload conditions
- By construction this introduces a lag of ~2 minutes
  - Not a problem for the use-cases so far

Example: Beamspot Update

- Beam Spot Update Criteria
  - Positions move by ±10% of the width; or
  - Widths change by ±10% from nominal (both with 2σ significance); or
  - Uncertainties improve by more than 50%
  - First valid beam spot
- Example: Position (x-horizontal)

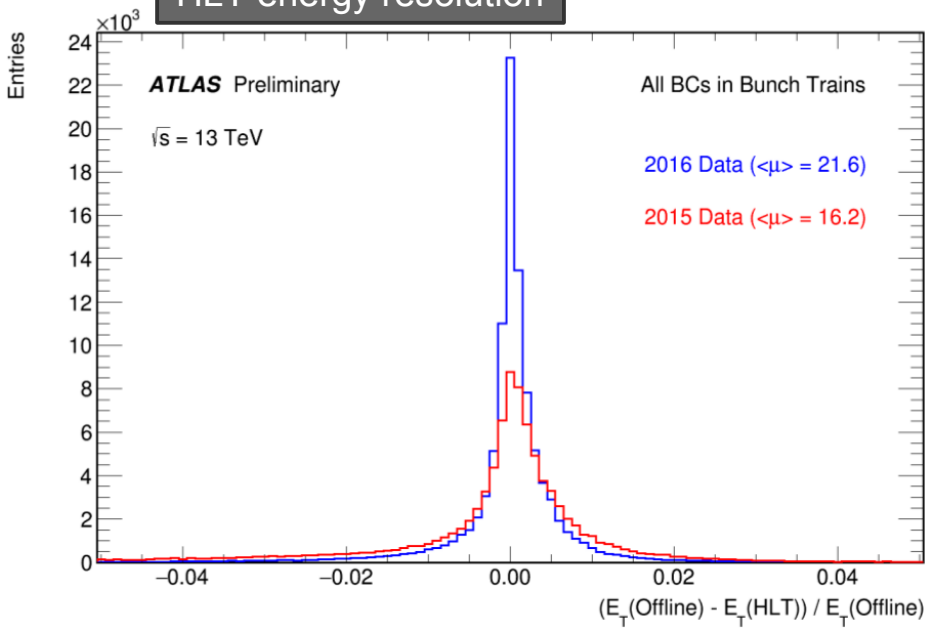


Example: LAr pedestal correction

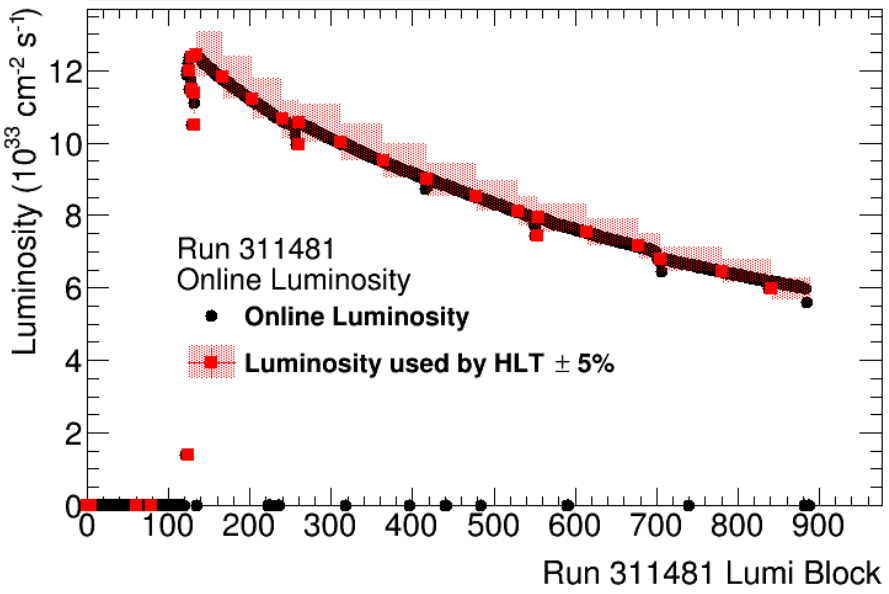
Bunch-crossing-dependent energy correction

- In 2016 introduced bunch-crossing dependent pedestal correction
  - Requires per-bunch luminosity measurement distributed to HLT nodes
  - Luminosity is updated at the HLT if changed by >5%
- Clear improvement in energy resolution, i.e. for bunches at front of the train

HLT energy resolution



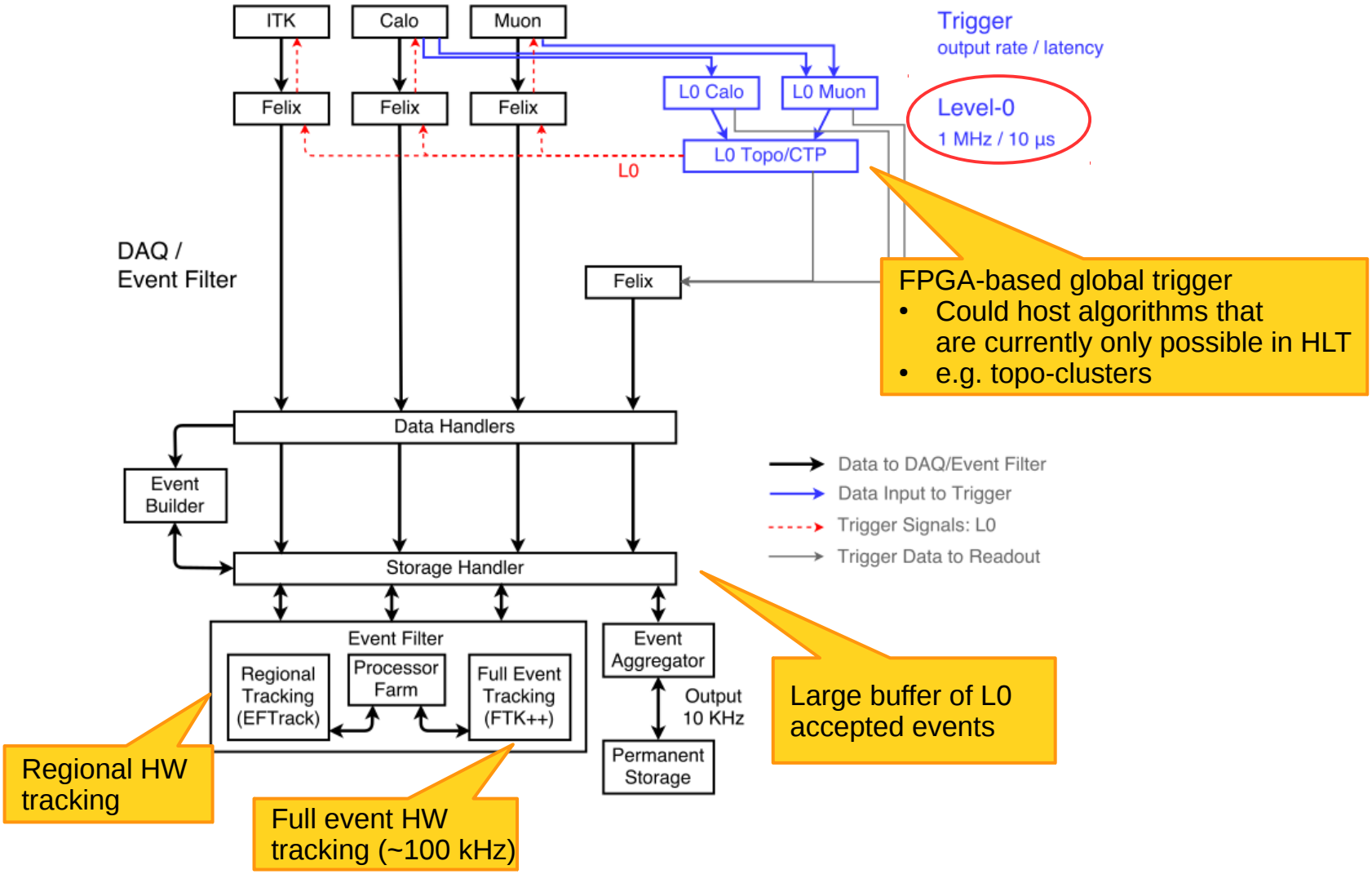
Online lumi update



ATLAS TDAQ in Phase-II

Completely new Trigger/DAQ system in Phase-II

- Now is the time to think about new features required



Timing-based HW jet trigger

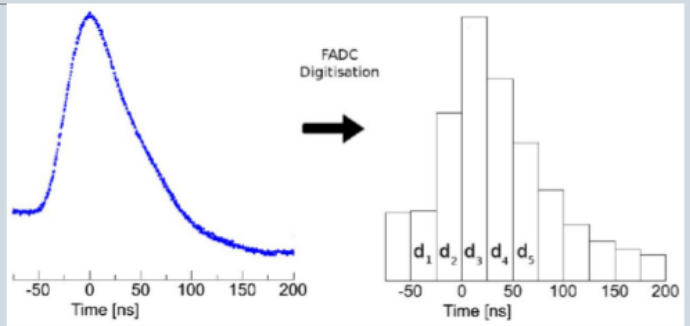
LLPs could be triggered efficiently based on L1 jet timing

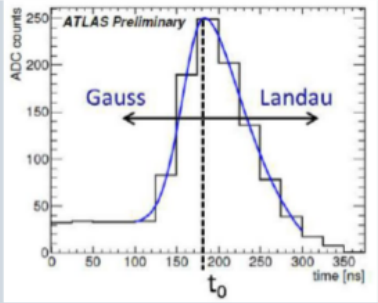
- Currently trying to develop an HLT based jet trigger
- If successful this could potential be done in hardware at Phase-II

Ben Allen (UO)

Determining L1 Jet Timing

- L1Calo digitizes calorimeter pulses with 25ns spacing
  - ~7000 0.1x0.1 trigger towers, EM and Had layers
- Determine the timing of an individual tower by fitting the peak and two adjacent slices with a parabola
- Find all TTs that make up the 0.4x0.4 L1 jet RoI, use average timing of towers
- Use only hadronic towers for timing info
  - Better timing than EM layer
- Require TT > 5 GeV
  - Timing resolution decreases dramatically at lower energy





Asychronous HLT processing

Need for large disk buffer between L0 accept and HLT currently under study

- Decouples HLT from hardware trigger system
- Allows for HLT processing between LHC fills
- Could introduce a calbration step before HLT processing
  - Would replace current conditions update mechanism
- Cost-benefit calculation is needed
  - 5 TB/s throughput and 18 PB storage per hour of buffering would be needed
  - Could equally well invest this in more HLT CPU

Possible use-cases for calibration loop

- Inner detector alignment during data-taking
  - Currently any ID movement is absorbed by our beamspot measurement
- We are very interested in other use case and new ideas!

Summary

Real-time analysis will be challenging also in Phase-II

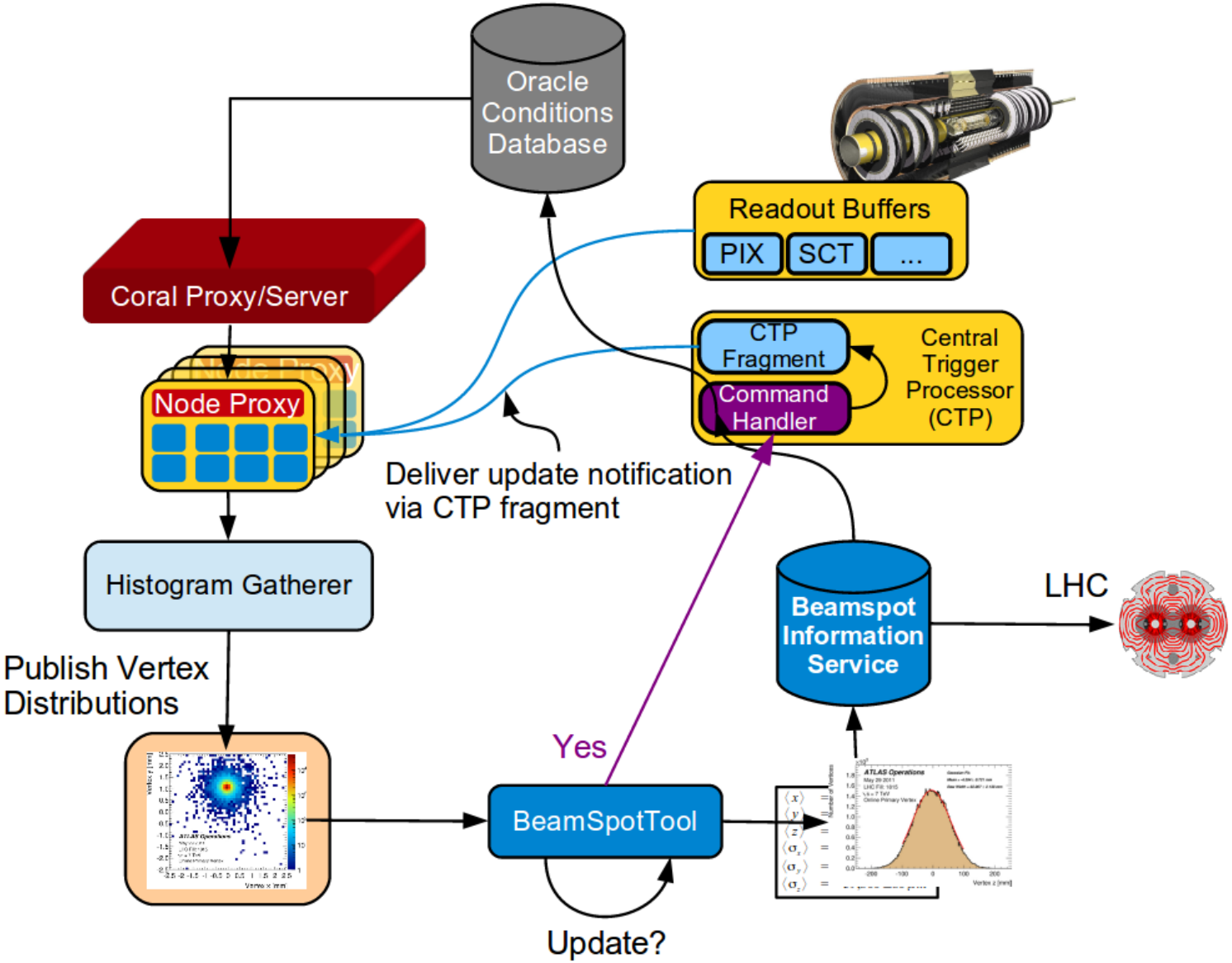
- ATLAS will not be able to follow LHCb/ALICE model of full offline reconstruction online
  - Event size x trigger rate too large
  - Full event reconstruction too slow
- But technology evolution will allow new features
  - Powerful FPGAs in hardware trigger
  - Hardware-based track reconstruction
  - Possibility to move HLT algorithms closer to offline calibrations

Input from the real-time analysis community is essential

- Next milestone is the ATLAS TDAQ Phase-II TDR (end of this year)

Backup

Beamspot Update Mechanism



The upgraded LHC experiments (LS2 and LS3)

- ALICE
  - Continuous readout at TPC limit (~50 kHz)
  - Merge of online and offline computing farm
- LHCb
  - No HW trigger → 40(30) MHz to HLT
- ATLAS/CMS
  - Increase HW trigger output rate to ~ 1 MHz
  - Replacement of the majority of FE electronics
  - New inner trackers incl. HW-based track triggers
  - Details of TDAQ systems still very much under discussion

		# Trigger Levels HW	SW	Accept rate		Event size	Event building	Permanent Storage
ALICE (Pb-Pb)	Run-3	0	1	50 kHz		60 MB	†0.5 TB/s	†90 GB/s
LHCb	Run-3	0	1	30 MHz	20 kHz	0.1 MB	4 TB/s	2 GB/s
ATLAS	Run-4	1 (or 2)‡	1	0.4(1) MHz	10 kHz	5 MB	2(5) TB/s	50 GB/s
CMS	Run-4	1	1	0.75 MHz	7.5 kHz	5 MB	4 TB/s	40 GB/s

† Alice: event compression (factor~6) and only storing reconstructed objects
‡ Atlas: One or two-level HW trigger under discussion