# The Feedback System for the LHC Luminous Region within the ATLAS High Level Trigger

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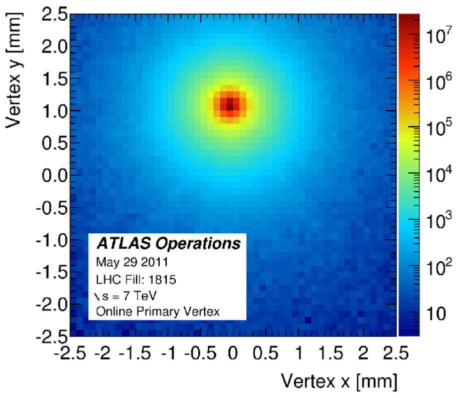
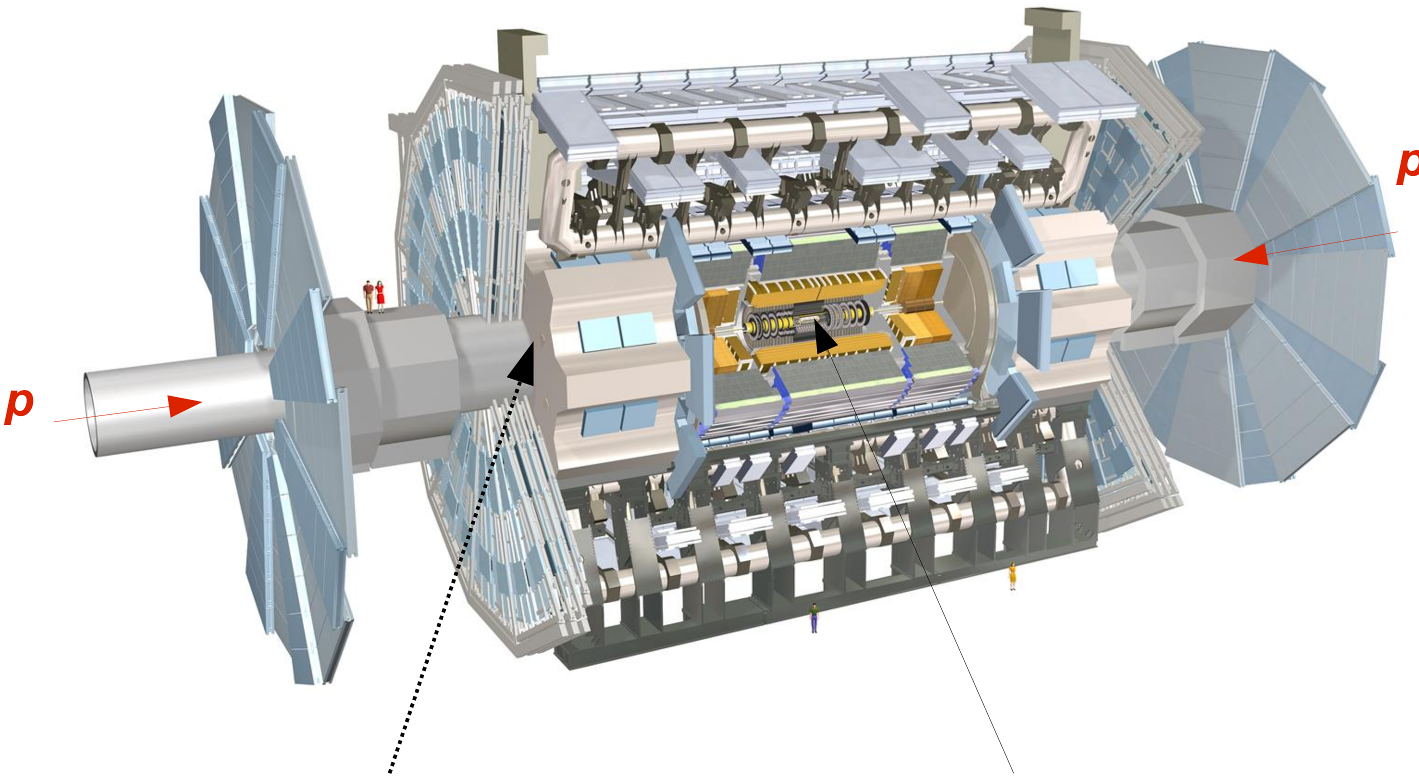
SLAC



# ATLAS as "Beam Instrumentation"




*Beam Position Monitor*
~ 21.5 m from the IP
2 channels (analog)

*ATLAS Inner Detector*
~ 0.05 m from the IP
> 80 million channels

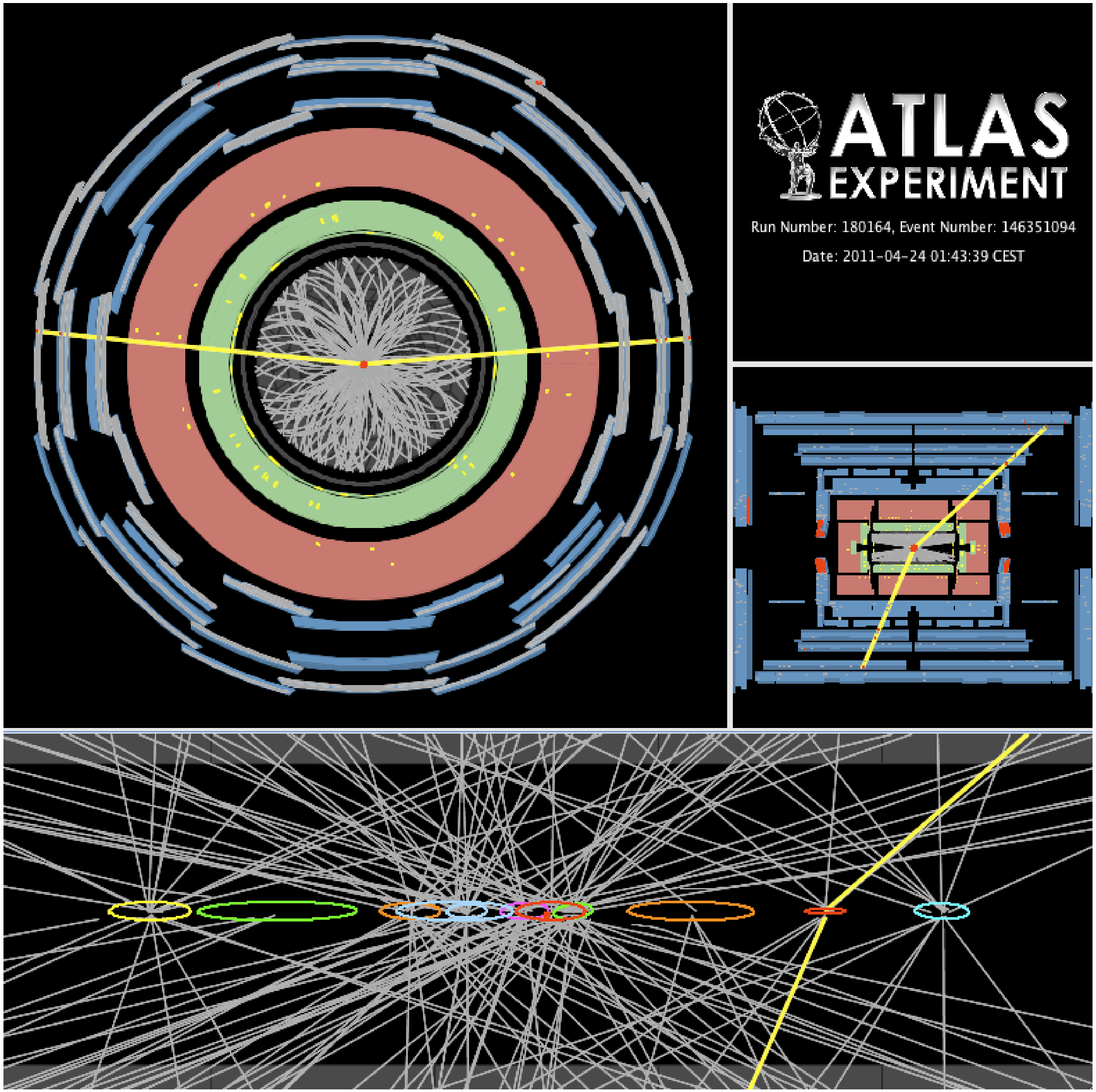
- The LHC is an extremely well instrumented machine
- It is amazing how much we know about its beams and how well we know it
- Nevertheless, close to the interaction region the experimental detectors are not only best positioned but overwhelmingly well equipped to characterize it

- Their sophisticated High Level Trigger systems allow to do that in real time

# Overview

- The ATLAS High Level Trigger (HLT) provides a unique platform for measuring LHC luminous region parameters
- Doing this in the online environment is particularly challenging in several ways:
  - Tightly constrained CPU and bandwidth budget of the trigger system
  - Massively parallel execution of algorithms that need special infrastructure to be aggregated and fanned out again
  - You get to see every event only once
    - No iterations on conditions, resolution etc: everything is 'at the edge of time'
- On the positive side, it offers unique advantages, too:
  - Unparalleled statistics, taking advantage of the many rejected events
    - Practically the only place with enough rate to see per-bunch time-evolutions
  - Very short latency to give quasi real-time feedback (minute scale)
- In addition, the Trigger itself needs to know very precisely - and adjust to - the position, size and orientation of the luminous region (*e.g. b*-tagging)
- This measurement is part of a bigger feedback loop around the HLT

# Primary Vertices



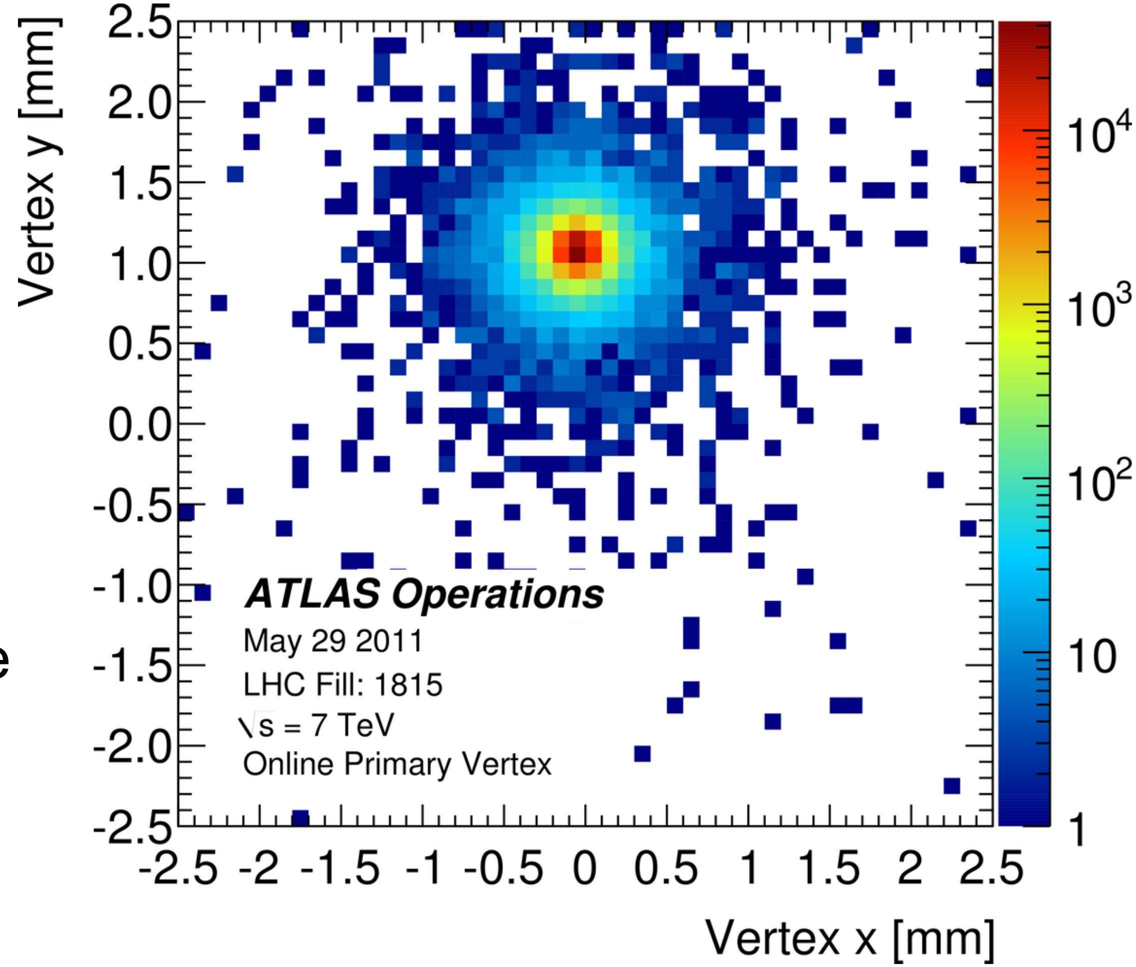

- At present luminosities, just above $10^{33}$ $cm^{-2}$ $s^{-1}$, there are on average 6 interactions per bunch crossing
  - Called "pile-up"
- In principle these allow us to make several measurements on each event
- However, they are computationally very **expensive to reconstruct and resolve in real time**

# ATLAS High Level Trigger

- Runs after the Level 1 hardware trigger
- Massively parallel, farm of 1000+ nodes
- Two stages: Level 2 (L2) + Event Filter
- Current rates: 50 kHz L1 → 4.5 kHz L2 → 400 Hz Event Filter (logging to disk)
- L2 does partial reconstruction
  - First trigger with access to Si-tracker data
- Chose L2 Trigger to host **beam spot algorithm**
  - Highest available statistics, low latency
  - But: challenge to do full scan of silicon tracker detectors for data transfer and pattern recognition, track reconstruction
  - At the edge of available bandwidth + CPU
- Currently 10 racks of 30 nodes with 8 cores each (2400 processes)
- From the spatial distribution of primary vertices we extract through fits the **position, size, and orientation of the luminous region**
  - Parameters are the centroid $x$,$y$,$z$; widths $\sigma_x$,$\sigma_y$,$\sigma_z$; and title angles $\theta_{xz}$,$\theta_{yz}$

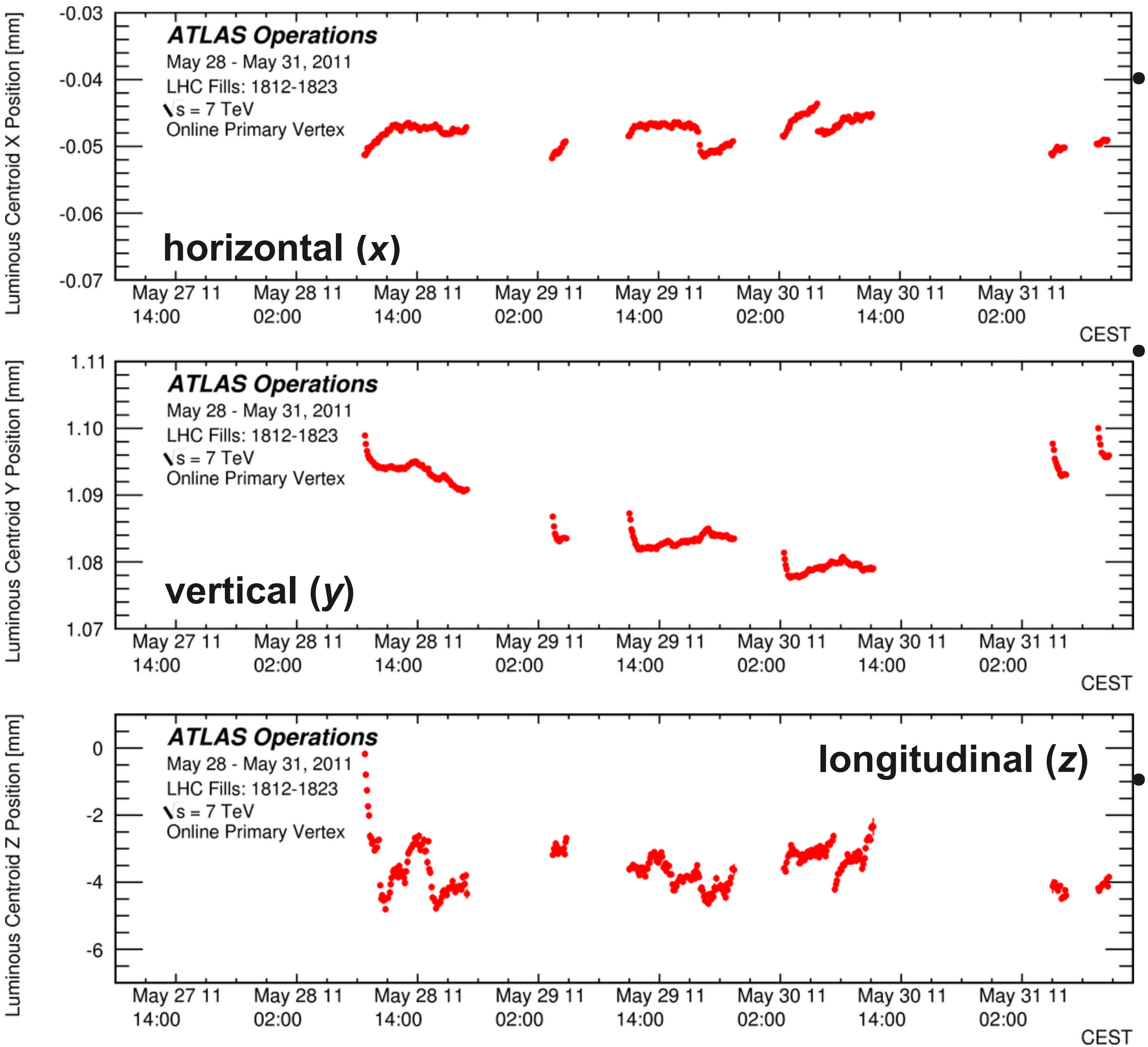
# Primary Vertex Distributions

- Projections of the three-dimensional distribution of reconstructed primary vertices are histogrammed and published once per minute
- They are aggregated ("gathered") across the farm and re-published
- The large amount of available statistics gives rise to very precise determinations of all parameters
- In addition, the vertex count can serve as a measure of luminosity (although this gets increasingly difficult with pile-up)



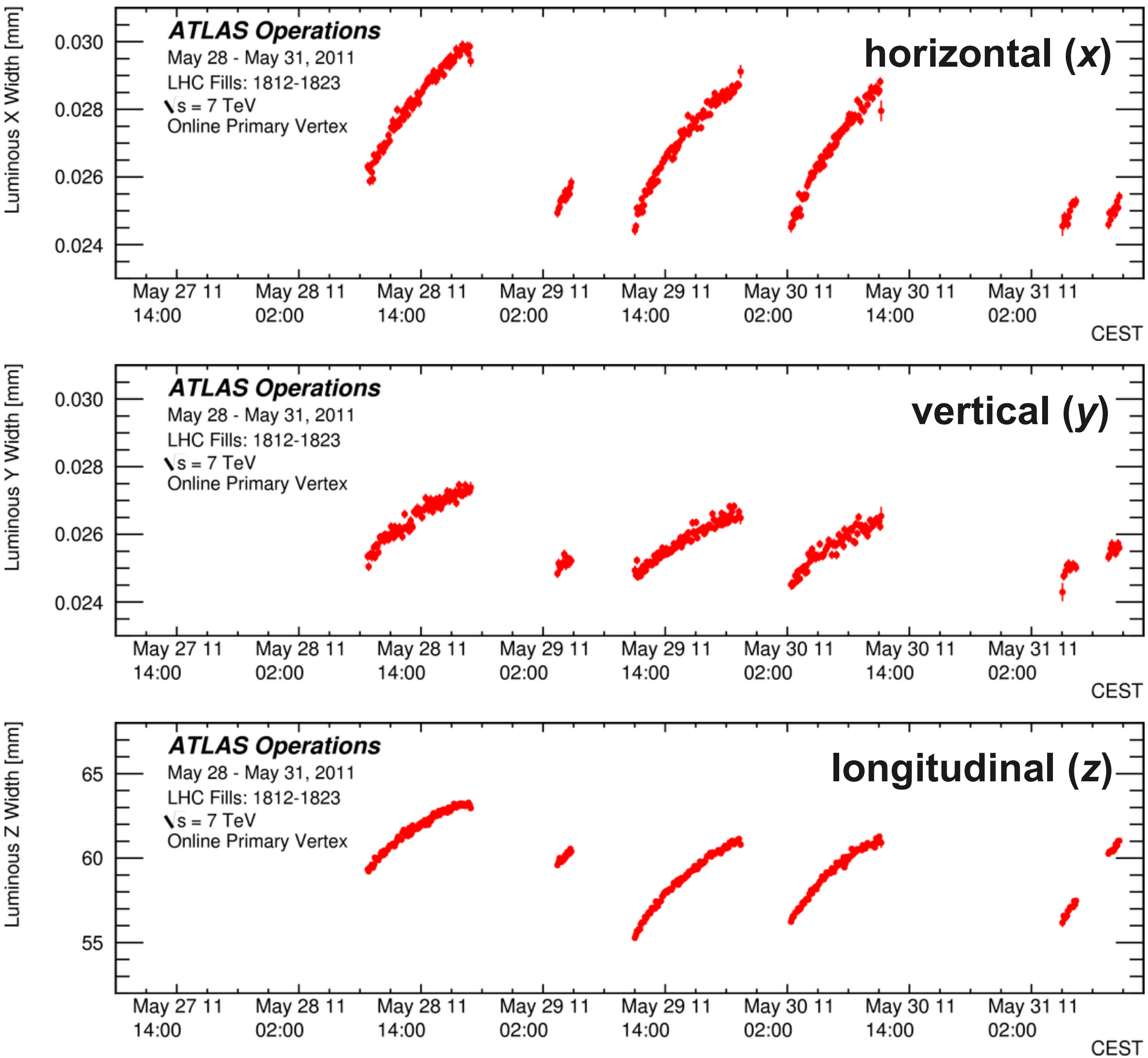

- Transverse distribution of 100,000 vertices reconstructed by the HLT
- One minute of data taking!

# Time-Variation of Beam Position




- Three-dimensional **centroid position** is measured over the course of several LHC fills
- Significant variations of the transverse position (from orbit corrections and drifts) are visible **within a fill and from fill to fill**
- Similar significant longitudinal time variations are related to RF-phase changes

# Time-Evolution of Luminous Size




- Effect of transverse **emittance blow-up** during each fill is clearly visible
  - Approximately 15% horizontal, 10% vertical luminous width increase over a 10 hour fill
- Longitudinal emittance growth behaves similarly
- Fill-to-fill variations are comparatively small, but not negligible

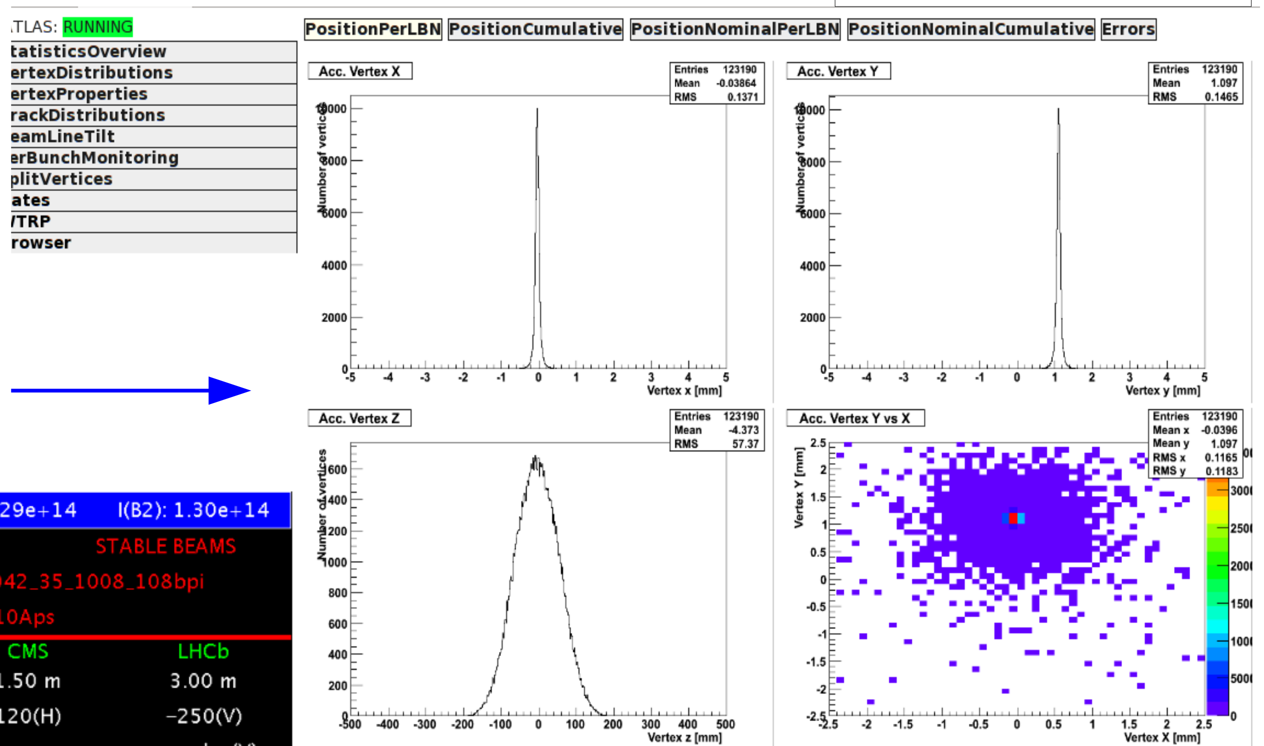
# LHC Feedback

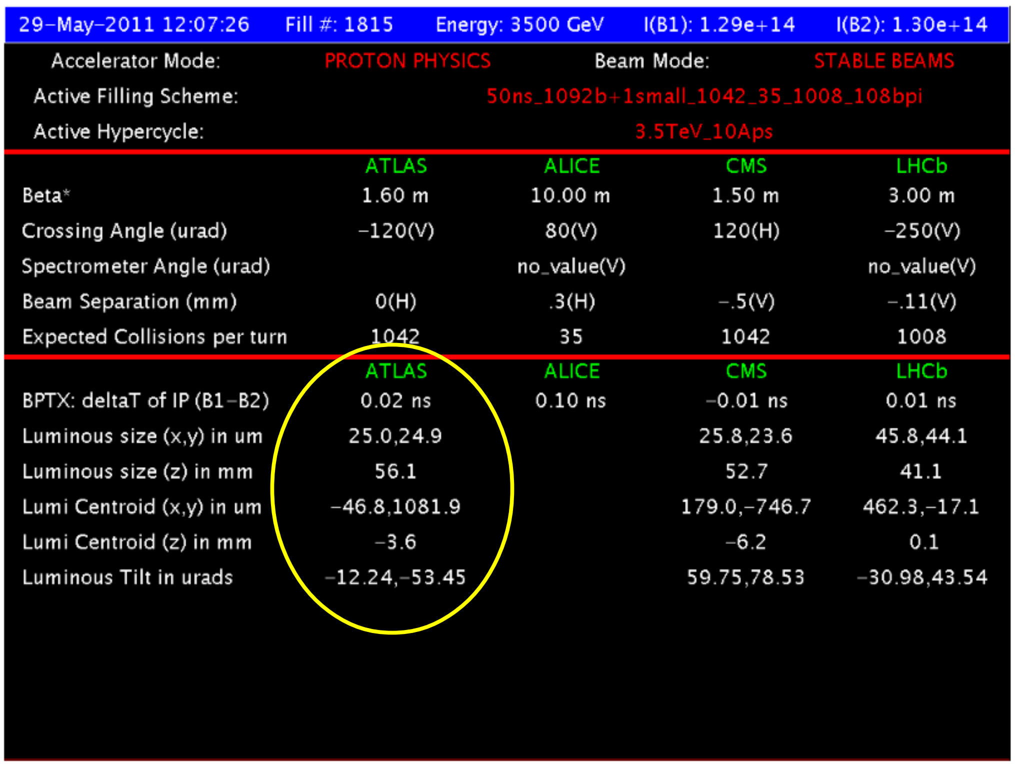
**ATLAS *Operations***

Live histograms are published once a minute

Available in the control room as well as over the web

Give details of the track/vertex distributions and parameters



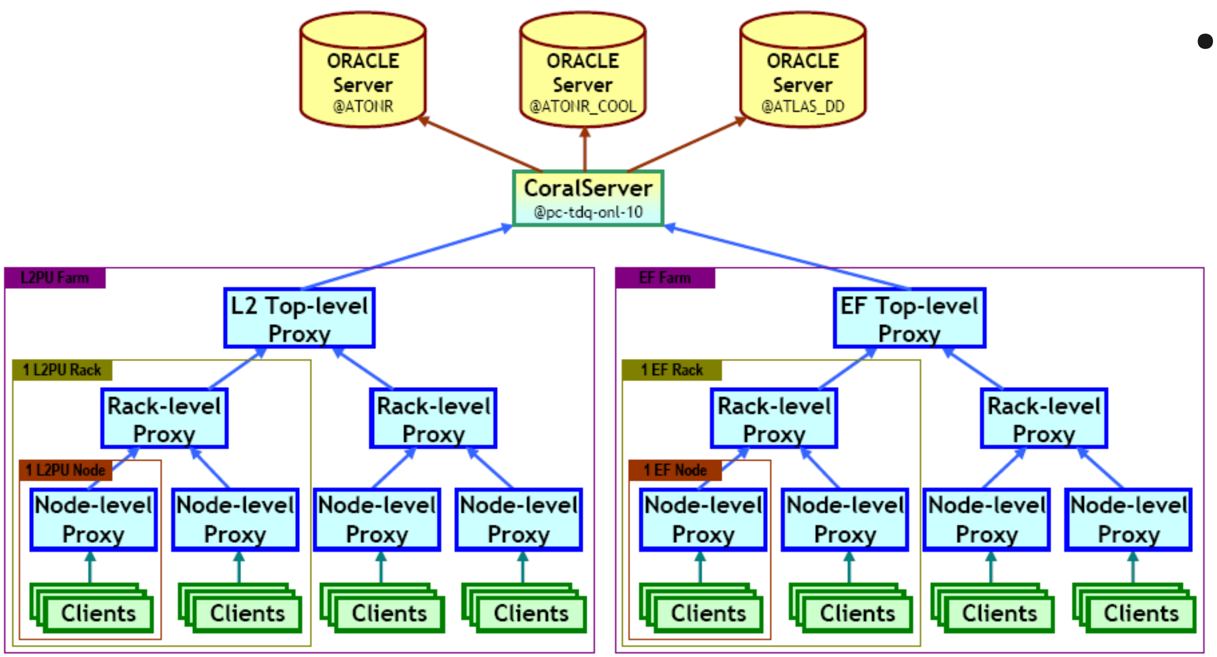
| 29-May-2011 12:07:26 | Fill #: 1815 | Energy: 3500 GeV | I(B1): 1.29e+14 | I(B2): 1.30e+14 |
|---|---|---|---|---|
| Accelerator Mode: | PROTON PHYSICS | Beam Mode: | STABLE BEAMS | |
| Active Filling Scheme: | 50ns_1092b+1small_1042_35_1008_108bpi | | | |
| Active Hypercycle: | 3.5TeV_10Aps | | | |
| | ATLAS | ALICE | CMS | LHCb |
| Beta* | 1.60 m | 10.00 m | 1.50 m | 3.00 m |
| Crossing Angle (urad) | -120(V) | 80(V) | 120(H) | -250(V) |
| Spectrometer Angle (urad) | | no_value(V) | | no_value(V) |
| Beam Separation (mm) | 0(H) | .3(H) | -.5(V) | -.11(V) |
| Expected Collisions per turn | 1042 | 35 | 1042 | 1008 |
| | ATLAS | ALICE | CMS | LHCb |
| BPTX: deltaT of IP (B1-B2) | 0.02 ns | 0.10 ns | -0.01 ns | 0.01 ns |
| Luminous size (x,y) in um | 25.0,24.9 | | 25.8,23.6 | 45.8,44.1 |
| Luminous size (z) in mm | 56.1 | | 52.7 | 41.1 |
| Lumi Centroid (x,y) in um | -46.8,1081.9 | | 179.0,-746.7 | 462.3,-17.1 |
| Lumi Centroid (z) in mm | -3.6 | | -6.2 | 0.1 |
| Luminous Tilt in urads | -12.24,-53.45 | | 59.75,78.53 | -30.98,43.54 |

The luminous region parameters are extracted through fits also once a minute

Corrections are performed and values are sent over to the LHC

# Beam Spot Parameter Redistribution

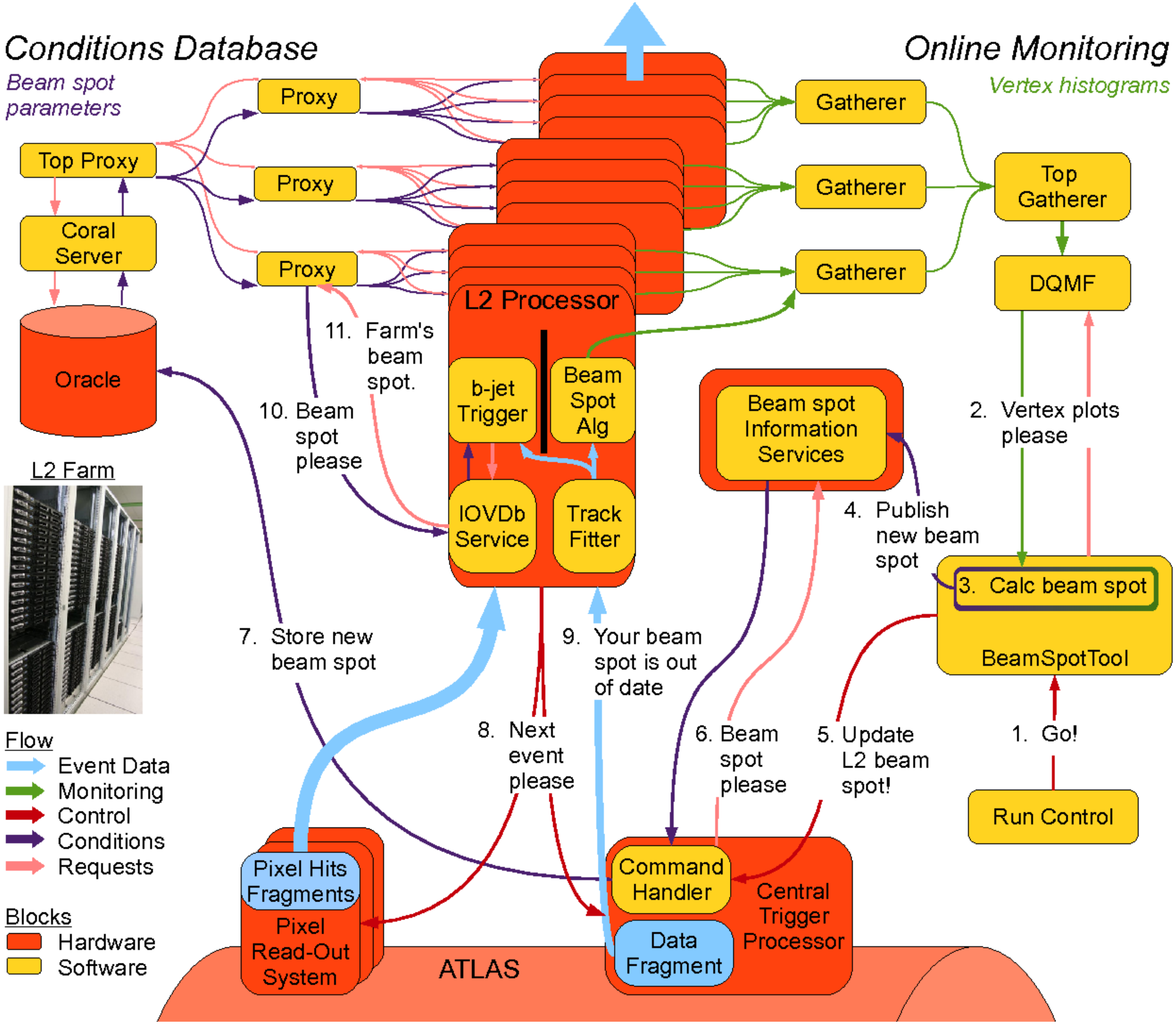
- Time variations make it necessary to update parameters used by the HLT **during running** (including a bootstrap at the beginning of a fill)
- Critical for algorithms sensitive to primary vertex such as *b*-tagging
- The first challenge is how to transmit the parameters back to the many thousands of HLT processes (on a sharp time boundary)
- ATLAS has a proxy-technology for database configurations that makes it possible to do such updates extremely fast also within a run

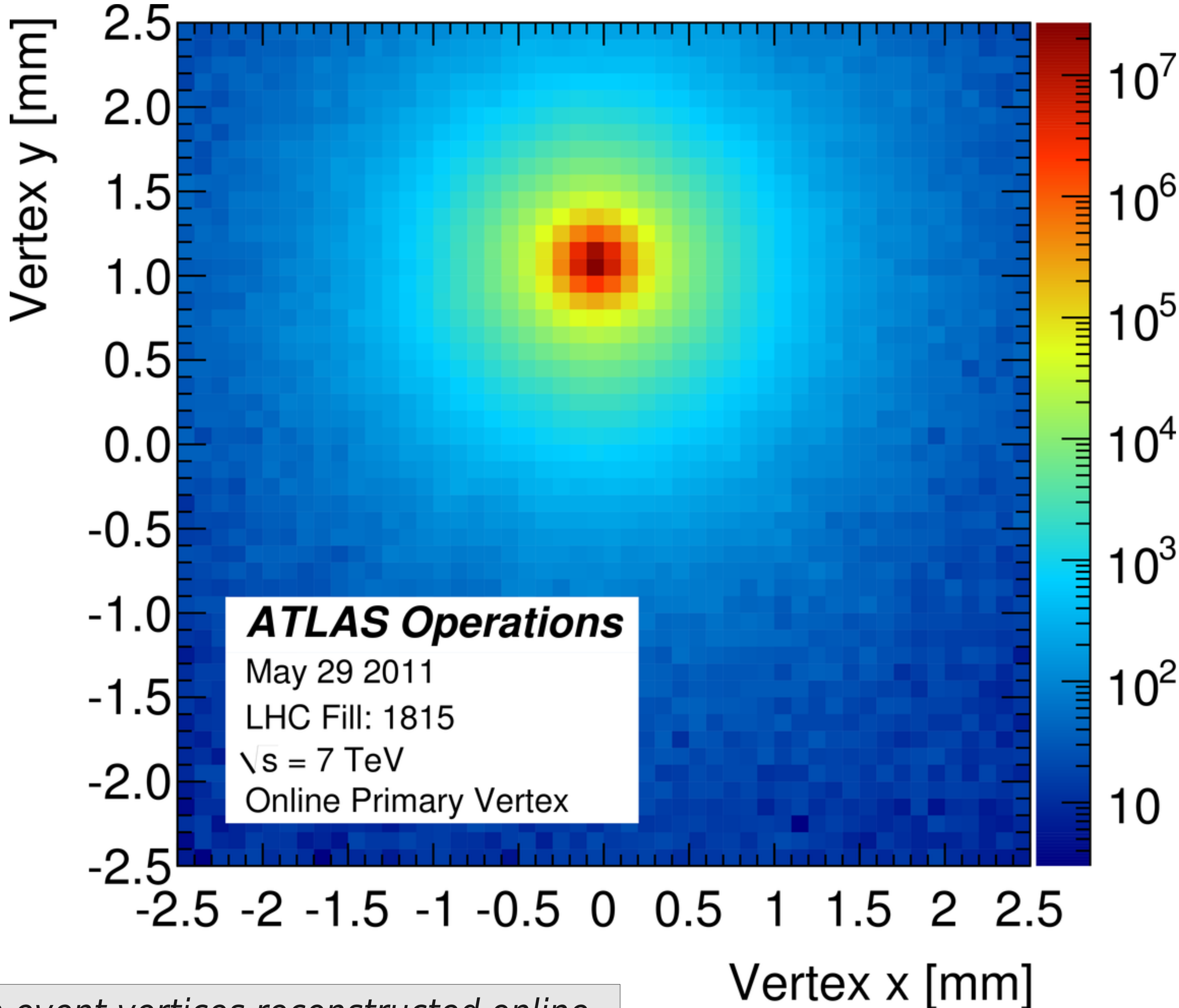



- CORAL Server & Proxy
  - Dedicated database technology developed for ATLAS HLT as example
  - Proxy hierarchy allows simultaneous access of 1000s of clients
  - *Multiplexes* and *caches* queries and responses

(Collaboration with CERN IT + U.Mainz)

# High Level Trigger Feedback Loop






*70 million event vertices reconstructed online by the ATLAS High Level Trigger*