A System for Monitoring and Tracking the LHC Beam Spot within the ATLAS High Level Trigger

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Abstract

The **position, size and orientation of the luminous region of the beam spot produced by the LHC** in the ATLAS interaction region are computed online using the ATLAS High Level Trigger (HLT) system. The high rate of triggered events is exploited to make precise measurements of the parameters in near real-time, as they change significantly even during a single data-taking run. We present the challenges for online determination and monitoring of the beam spot in ATLAS and a feedback system to publish the values for use in the HLT. Results using this system during ATLAS operations in the course of the 2011 LHC run at $\sqrt{s} = 7$ TeV and the 2012 run at $\sqrt{s} = 8$ TeV are shown. A specially designed algorithm, which uses tracks registered in the silicon detectors to reconstruct event vertices, is executed on the HLT **processor farm of several thousand CPU cores**. Monitoring histograms from all the cores are sampled and aggregated across the farm every 60 seconds. The reconstructed beam values are corrected for detector resolution effects, **measured in situ** from the separation of vertices whose tracks have been split into two collections. Furthermore, measurements for individual bunch crossings have allowed for studies of single-bunch distributions as well as the behavior of bunch trains, calibrated to the beam average. Run control invokes a comparison of the nominal and measured beam spot values, and when threshold conditions are satisfied the **farm configuration is updated**. To achieve sharp time boundaries across the event stream, which is triggered at rates of several kHz, a special datagram is injected into the event path via the Central Trigger Processor that signals the pending update to the trigger nodes. Thousands of clients then fetch the same set of values from the **conditions database** in a fraction of a second via an efficient, nearly-simultaneous access made possible through a dedicated **CORAL Server and Proxy** tree.

Event Vertex Distributions

Online Selection

- The Level 2 Trigger vertexing and beam spot measurements are initiated by signals from a Level 1 multi-jet trigger.
- Data collection and pattern recognition on the entire Inner Detector must be done within only a few tens of milliseconds.
- A fast vertex fitter reconstructs primary vertices with ≥ 4 tracks of $p_T > 1$ GeV and $|\eta| < 2.5$.

Online Monitoring

- Distribution of vertices is characterized very precisely due to the high rate of events.
- The time evolution of the position, widths and tilts is recorded in approximately 2-minute intervals.
- Upon significant changes, new values are pushed to the conditions database for use by the trigger farm.

Elements Overview

HLT

- High Level Trigger
- Second (software) stage of two-level trigger system
- Farm of currently 1600 HLT nodes with 17000 cores in total
- No cross-processor communication
- Requests data fragments from CTP and detector Read-Out Systems (ROS), e.g. Pixel, Silicon

Oracle

- Back-end technology powering a conditions database
- Makes use of a COOL abstraction layer

CORAL Server

- Translates between CORAL and Oracle commands

Proxy Tree

- Efficient database querying and caching between the HLT and the conditions database
- Each non-leaf node caches requests and propagates new ones up

Pixel and SCT ROS

- Silicon Tracker Read-Out Systems
- Provide subdetector data reception
- Handle buffering and distribution

Conditions Database

Beam spot parameters

CORAL Server Proxy

- Provides scalable solution for 10000s of clients
- Uses technology-independent protocol optimized for multiplexing and caching
- Multiplexes many client connection into single server connection
- Caches requests in memory to reduce repeated requests
- Supports hierarchical multi-level proxy trees

Beamspot Tools

- Fetch and aggregate monitoring histograms
- Fit projections of vertex and split-vertex distributions
- Calculate summary beamspot values, estimate and correct for resolution effects
- Publish new values

LHC Configuration Page

17-May-2012 11:00:13	Fill #: 2635	Energy: 4000 GeV	I(B1): 1.69e+14	I(B2): 1.59e+14
Accelerator Mode:	PROTON PHYSICS	Beam Mode:	STABLE BEAMS	
Active Filling Scheme:	50ns_1380b_1331_0_1320_144bpl12nj	Active Hypercycle:	4TeV_10Aps_0.6m	
Beta*	ATLAS: 0.60 m	ALICE: 3.00 m	CMS: 0.60 m	LHCb: 3.00 m
Crossing Angle (urad)	-145(V)	-90(V)	145(H)	0(H)
Spectrometer Angle (urad)		no_value(V)		236.99(H)
Beam Separation (mm)	-1(H)	0(H)	-23(V)	13(V)
Expected Collisions per turn	1331	0	1331	1320
BPTX: deltaT of IP (B1-B2)	ATLAS: 0.03 ns	ALICE: 0.04 ns	CMS: 0.01 ns	LHCb: 0.06 ns
Luminous size (x,y) in um	18.9,19.1	-999.0,-999.0	21.1,19.8	44.7,45.1
Luminous size (z) in mm	48.2	-999.0	49.1	54.2
Lumi Centroid (x,y) in um	-309.2,686.1	-999.0,-999.0	190.5,-504.4	624.7,89.3
Lumi Centroid (z) in mm	-0.9	-999.0	-7.2	15.6
Luminous Tilt in urads	-36.29,-65.61	-999.00,-999.00	103.09,91.06	-88.17,-2.74