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Alignment data streams for the ATLAS Inner Detector

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Outline

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- The ATLAS Trigger System
- The ATLAS Computing Model
- ID Alignment Stream
  - Trigger Chains
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- PEB and Trigger Chain Tests
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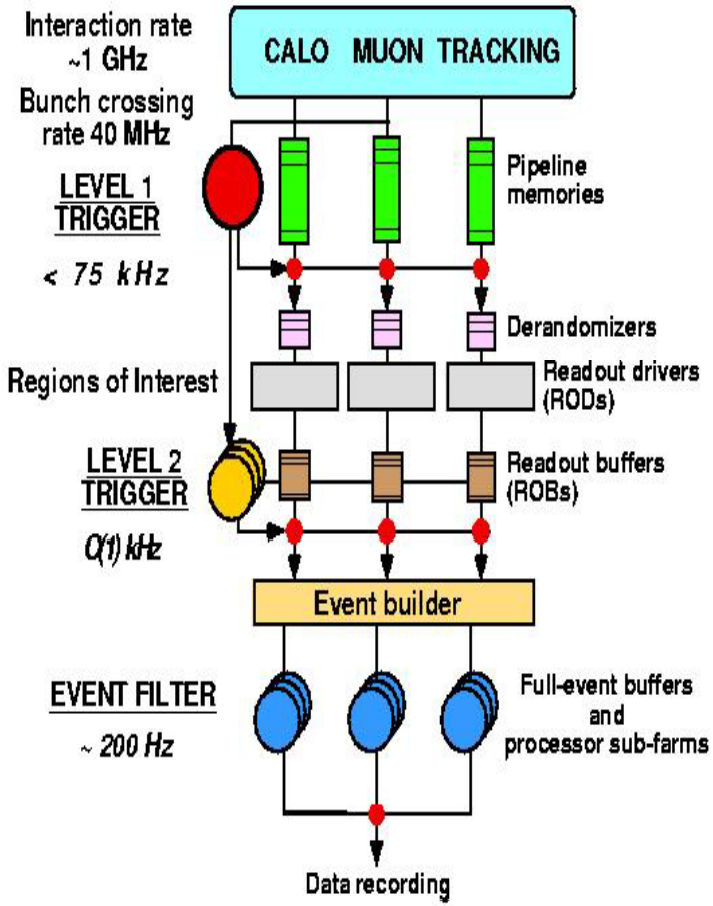
- Summary and Future Plans

LHC and ATLAS Inner Detector

- Large Hadron Collider (LHC) is being built at CERN
  - Proton beams will collide with a centre of mass energy of 14 TeV
  - Proton bunches cross at 40MHz and luminosity up to 10^{34} $cm^{-2}s^{-1}$.
- A Toroidal LHC ApparatuS (ATLAS) is one of the LHC detectors
  - It will record pp interactions.
- The ATLAS Inner Detector (ID) tracks charged particles from the Interaction Point (IP) to the electromagnetic (EM) calorimeters
  - It consists of three sub-detectors:
    - Pixels - 1744 modules to align with a resolution of 10 μm (rφ) and 115 μm (rz)
    - SemiConductor Tracker (SCT) – 4088 modules to align with a resolution of 17 μm (rφ) and 580 μm (rz)
    - Transition Radiation Tracker (TRT) – 992 modules to be align with a resolution of 130 μm (rφ).
  - Challenging alignment of ~40,000 degrees of freedom (DoF)
    - Initial knowledge of module positions larger than intrinsic resolution
    - Determine positions with track based alignment procedure.
  - Will allow particle identification and momentum measurement.

The ATLAS Trigger System

- Designed as a three-level system
  - Level-1 trigger (LVL1) - hardware based and responsible for the first event selection
    - Use of information from calorimeters and the muon system
    - Identify Regions-of-Interest (RoI).
    - Reducing the event rate to less than 75 kHz.
  - Level-2 trigger (LVL2) - software based
    - Can access information in RoIs from all ATLAS sub-detectors
    - Event rate O(1) kHz.
  - Event Filter (EF) – software based
    - Runs after event building
    - Complete information available
    - Final event rate of ~200 Hz (1.5 MB per event)
    - Recording rate: 300 MB/s.



The ATLAS Computing Model

- Tier-0 streaming baseline model includes four types of streams:
  - Physics stream with data for physics analysis
  - Express stream containing a subset of events (~ 5% of the full data).
  - Debug stream with events without a trigger decision
  - Calibration stream.
- Current goal to reconstruct express and calibration streams within 8 hours and physics stream reconstruction in 24 hours.
- Calibration stream requirements
  - Minimum amount of information per event to allow calibrations at high rate
  - Produce calibrations of sufficient quality to allow a useful first-pass processing of the main stream with minimum latency.

ID Alignment Stream

- Main purpose to collect tracks of the appropriate type to do alignment on a fill-by-fill basis in 24 hours (reached at routine way of taking data).
- Output rate should not exceed a few MB/second.
- Main ID Alignment requirements to achieve the declared precision
  - 1 M tracks
    - For a 6 hour fill this means a rate of 50 Hz of useful tracks.
  - 100 tracks per TRT straw
  - Track requirements
    - Tracks from the Interaction Point (IP)
    - Tracks passing two modules from the same pixel or SCT layer (overlap hits)
    - Tracks from secondary decays vertices (allow mass constraints)
    - Tracks with "kinks" are bad. Pions/kaons decaying in flight to muons and electrons should be avoided.

ID Alignment Stream

- In order to satisfy all requirements we need a model where we write custom byte stream files with raw data of the tracks suitable for alignment.
  - Unlike physics events, calibration events for sub-detectors do not require the full event information
    - Identifying just the tracks suitable for alignment (alignment Trigger chains).
    - Reading and writing out only the ROBs that contain hits on tracks of interest - Partial Event Buiding (PEB)
      - The writing done after LVL2 keeping the EF bandwith the same for physics events.
- Reducing the event size, a higher LVL2 accept rate can be reached, keeping the total event builder (EB) bandwidth efficiently used.
  - Necessary to achieve ID sub-detectors resolution

Alignment Trigger Chains

- Need isolated tracks that pass through the ID
  - Hadrons is the obvious choice
- LVL1 trigger
  - Hadronic signatures with energy thresholds at 6 GeV or 9 GeV (HA6 and HA9i)
- LVL2 trigger
  - Isolated tracks with momentum thresholds at 9 GeV or 16 GeV inside the η-φ region defined by LVL1 hadronic signatures
- Two items prepared
  - Trk9i_calib (prescale 40) => LVL1 item HA6 & LVL2 item trk9i
  - Trk16i_calib (prescale 1) => LVL1 item HA9i & LVL2 item trk16i
    - Prescale optimized for 10^{31} luminosity.
- The trigger algorithm is the same as used for physics triggers and therefore no extra execution time is used.

Partial Event Building

- PEB is a new feature to handle assembly and logging of calibration events implemented by the Trigger and Data Acquisition (TDAQ) system
  - Events for calibration are selected by High-level Trigger algorithms
  - Which create a list of ROBs or sub-detector identifiers based on RoI information.
  - The list is passed to the SubFarm Input (SFI)
    - Pulls the requested data fragments from the ROBs
    - Assembles the calibration event
  - Only applied if the event does not fulfill any LVL2 physics criteria.

Testing PEB on Cosmic Data

- PEB modified for testing during cosmic data taking since they trigger on tracks coming from the IP.
  - Use Trigger Chains developed for cosmic data and add PEB on those (CosmicsAllTeSiTrack*, CosmicsAllTeIDScan*)
  - Modified to loop over the tracks and get η-φ range from the tracks rather than RoIs
  - Chains that do tracking only at the TRT are not good for testing since TRT does not provide η measurement
  - Generate new cosmic menu that contains these new chains and run with this menu on cosmic data
  - **Generated raw data only with information from the ID and for the η-φ range that is defined by the PEB algorithm.**

Results from Cosmic Data

- Three raw data files compared
  - Full raw data (BS)
  - Without PEB (w/o PEB): using only the two cosmic trigger chains
  - With PEB (w/ PEB): apply PEB to the previous in the region around the tracks.
- Checked run number 90943 (only 175 files), which contains pixel, SCT and TRT hits.
- Using Athena (ATLAS framework) 14.4.0 and InDetAlignExample package.
- 25 *atlasidali* queues and data stored in castor.

Sample	Events	# Tracks	# Align Tracks	CPU time per job (min)
Full raw data (BS)	130945	30877	29734	~30
2 chains w/o PEB	59546	26244	23370	~17
2 chains w/ PEB	59126	21515	20765	~12

Results from Cosmic Data

Efficiencies

Sample	Track eff. wrt BS	Align Trk eff. wrt BS	CPU time per job wrt BS
2 chains w/o PEB	85%	85%	44% faster
2 chains w/ PEB	70%	70%	60% faster

ID calibration stream (w/ PEB)

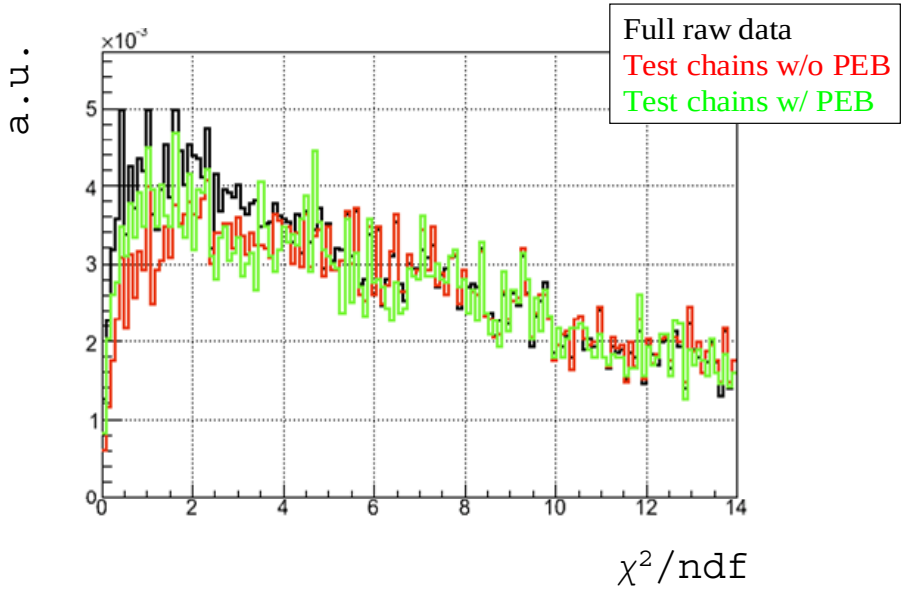
- **Has 70% of all good cosmic tracks used in alignment and it is 60% faster to process and can be run online.**
- **The size of the files w/ PEB is substantially smaller (~13% of BS)**
  - This can allow an easy data replication, if it is necessary at some point
  - First data file has: BS: 2147 MB, w/o PEB: 302 MB, w/ PEB: 277 MB.

Results from Cosmic Data

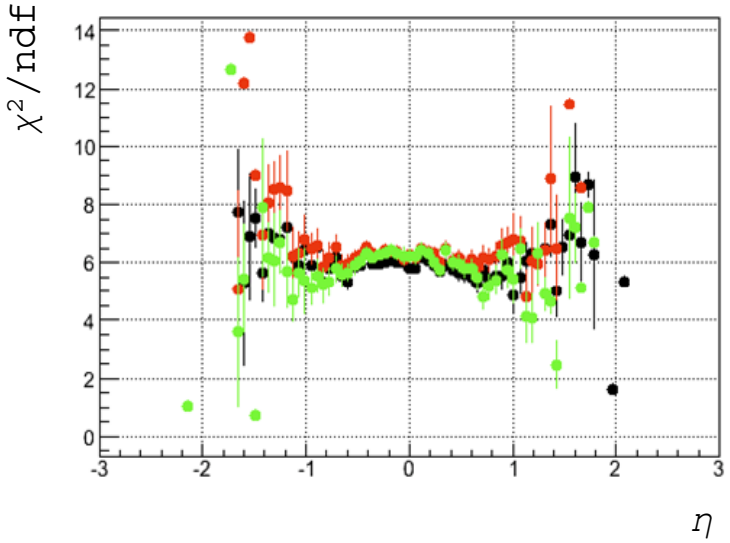
The track fit quality was found to be comparable

- Little fluctuations at large η.

Reconstructed Track χ^2/ndf



Reconstructed Track χ^2/ndf vs. η



Summary

- ID Alignment stream is of the upmost importance to get alignment constants in collision data taking.
- ID Alignment calibration items implemented and tested.
- PEB data readable
  - Smaller
    - size files
    - CPU time per job
- Future plans:
  - Include more interesting tracks for alignment keeping the rate under control.
    - Implement trigger in regions of overlapping modules
    - Introduce 2Trk9_calib item: events with 2 isolated tracks.
  - Exercise PEB for collision data.