



The ATLAS Detector Digitization Project for 2009 data taking

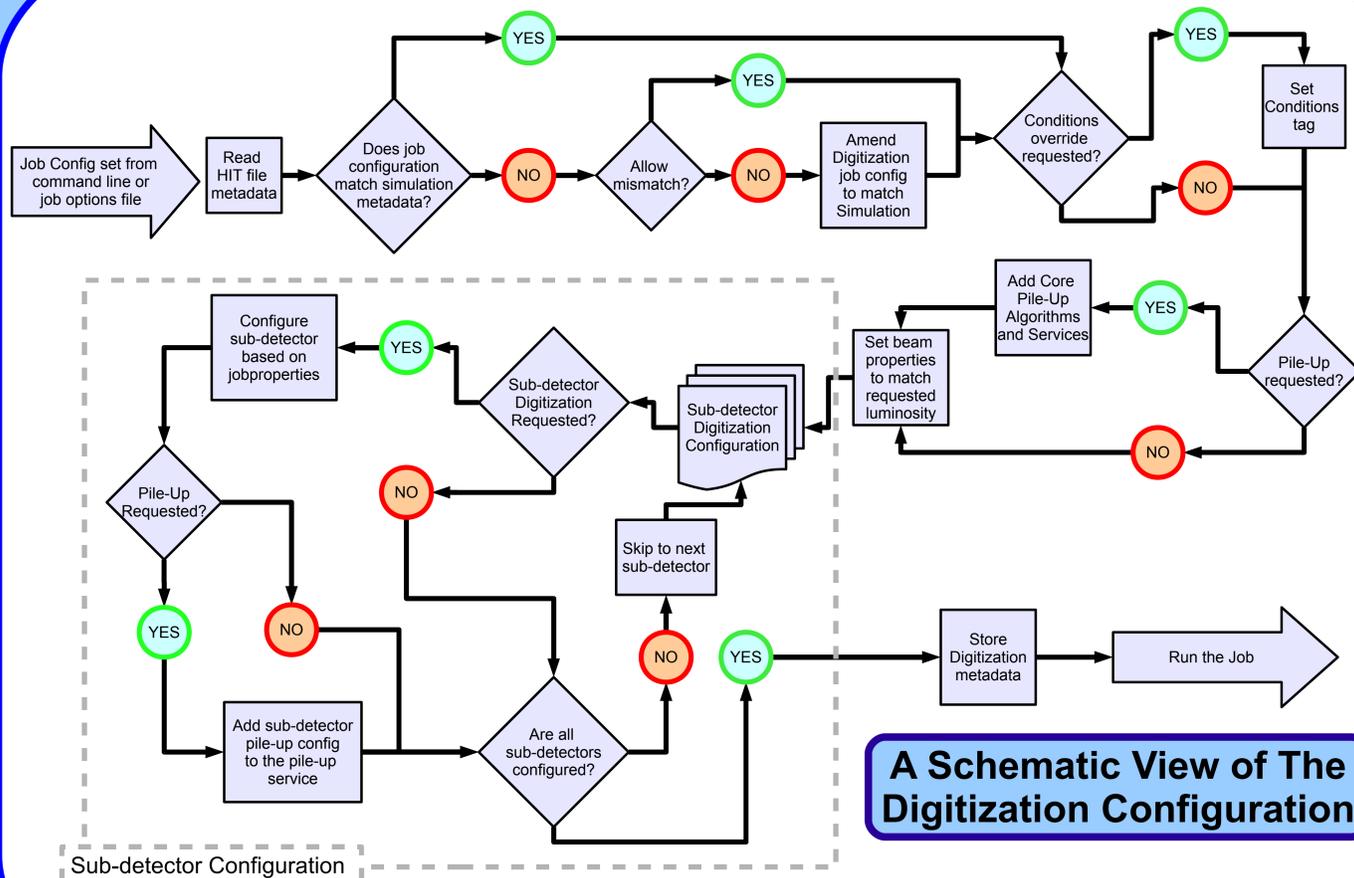


What do we mean by Digitization in ATLAS?

In ATLAS, digitization refers to the process of converting GEANT 4 simulated hits in active volumes of the detector to Raw Data Objects (RDOs), which act as an input to the reconstruction. This includes propagating charge to readout electrodes, front end electronics simulation and conversion of these responses into RDOs. Level 1 trigger simulation can also be performed during the digitization step. As part of the digitization process it is also possible to simulate the electronics response to a number of GEANT 4 simulated subevents as a single digitized event. This process is called "pile-up". The real ATLAS detector writes out data in various byte stream formats. When byte stream is read into a reconstruction job it is converted into the appropriate transient RDO representation. The transient RDO representations can be persisted (saved to file) in POOL format. An advantage of this is that the "digitization output of the Monte Carlo", the "Truth Digitization", which is not available in the byte stream format, can also be persisted. Some digitization algorithms simulate this step, others produce RDOs directly. In all cases algorithms exist to convert RDOs into byte stream format and vice-versa. The formats are similar, the main difference is that the separate transient and persistent representations of the RDOs allow more efficient storage.

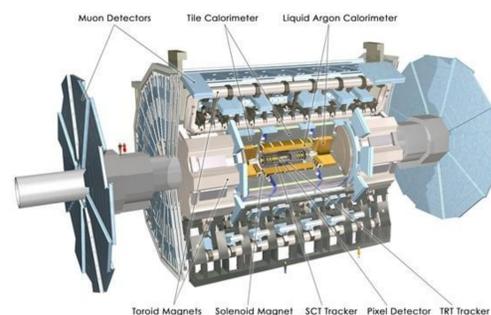
Core Digitization Framework

- Entirely PYTHON based.
- Highly configurable.
- Ensures sensible default values and resolves any conflicting settings.
- Inputs: Hit Objects (produced by the ATLAS GEANT 4 simulation)
- Outputs: Raw Data Objects (can be written out to a POOL file if required)
- Can be run stand-alone or as part of simulation or reconstruction jobs.



A Schematic View of The Digitization Configuration

Sub-detector Digitization Packages



Digitization algorithms exist for all ATLAS sub-detectors shown in the plot above and also for the Beam Conditions Monitor (situated next to the beampipe) and LUCID (situated at $\pm 17m$ from the interaction point). Algorithms for other Forward Detectors will be added as required. Work is on-going to further optimize all algorithms particularly in the case of digitizing high luminosity pileup events.

Event Pile-up

Problem

A triggered bunch-crossing in ATLAS will contain many inelastic, non-diffractive proton-proton interactions in addition to the hard scattering which triggers the detector readout. The effects of beam gas and beam halo interactions, as well as detector response to long-lived particles, are also important. Long signal integration times mean that most sub-detector responses are affected by interactions from neighbouring bunch crossings as well. However, it would take too long to simulate each event in such detail at the GEANT 4 stage.

Solution 1: Pile-Up

One solution is to simulate the hard-scattering interactions, minimum bias interactions, beam halo events, beam gas events and cavern background events separately. In the digitization stage the GEANT 4 hits are overlaid to simulate the required number of bunch-crossings at the required luminosity and bunch spacing. The resulting collection of GEANT 4 hits is then passed to the digitization algorithms.

More about Pile-Up

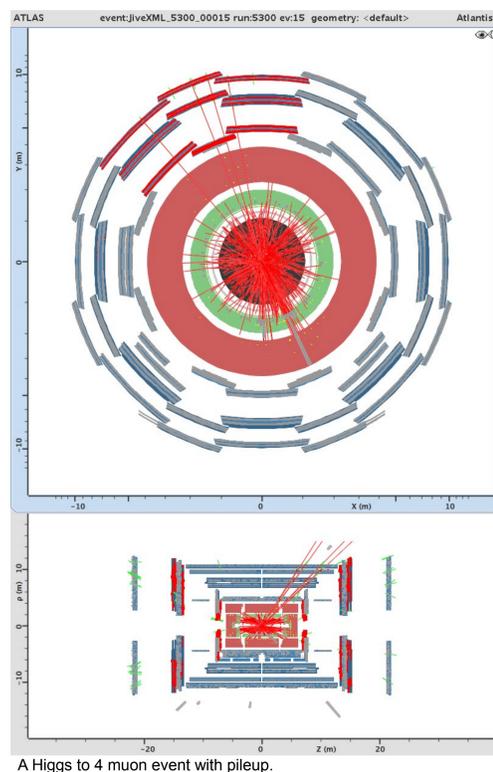
- **Minimum bias** events are generated using PYTHIA. The mean number of minimum-bias interactions per bunch crossing is 23 at the design luminosity of $10^{34} \text{ cm}^{-2}\text{s}^{-1}$ with 25 ns bunch spacing. In the simulation, it depends linearly on luminosity and bunch spacing. The number of minimum-bias interactions per bunch crossing is Poisson-distributed. Thus, some bunch crossings may have many more than the average number of interactions.
- **Cavern background** events are generated using a GEANT 3/GCALOR based program which generates particle fluxes in an envelope around the muon spectrometer.
- **Beam gas** includes the residual Hydrogen, Oxygen, and Carbon gases in the ATLAS beam pipe. Events are generated using Hijing.
- **Beam halo** is the background resulting from interactions between the beam and upstream accelerator elements. The flux from upstream (in the tunnel and collimators) is provided by the LHC Machine Division.

Solution 2: Data Overlay

Minimum bias, cavern background, beam halo, and beam gas backgrounds can be obtained from the same "zero bias" trigger used to understand detector electronic noise. Simulated hard-scattering interactions are then digitized without simulating detector noise. The resulting RDOs are then overlaid on top of real data events which passed "zero bias" triggers. In this way the detector noise and background interactions will match those seen in the real experiment by construction.

More about Data Overlay

The zero bias trigger data needed for this type of event overlay can be selected at random from the filled-bunch crossings. The sub-detectors should be read out with as little zero-suppression as is possible and with the Higher Level Trigger in "pass-through" mode. In principle one needs as many zero bias events as Monte Carlo generated events, but in practice zero bias events can be reused with independent Monte Carlo sets. During data taking, zero bias events will be sampled at all times, because detector and cavern conditions are likely to vary with time. It is proposed to use a high-pt trigger input which is linear with luminosity to seed a zero-bias trigger bit. This trigger bit would be pushed into a pipeline of exactly 1 orbit, such that the zero-bias trigger fires in exactly the same bunch crossing, but 1 orbit later. Appropriately pre-scaled to the output rate needed for simulations ($O(1-2) \text{ Hz}$), this would mean that the rate follows the luminosity and that the bunch structure is guaranteed to be right.



Detector Defect Simulation

- Dead and noisy channels can be added by non-default detector conditions database tags.
- Some sub-detectors simulate dead and noisy channels during the reconstruction step instead.
- Random noise and cross-talk may be switched on and off in the Inner Detector, Calorimeters and Muon Spectrometer separately.
- Detector misalignments are fixed in the GEANT 4 simulation step by the Geometry tags used.
- Distortions of modules are also simulated in some sub-detectors.

Performance

