THE FAST SIMULATION CHAIN IN THE ATLAS EXPERIMENT

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Abstract

The ATLAS experiment relies heavily on simulated data, requiring the production of billions of simulated proton-proton collisions every run period. As such, the simulation of collisions (events) is the single biggest CPU resource consumer. ATLAS's finite computing resources are at odds with the expected conditions during the High Luminosity LHC era, where the increase in proton-proton centre-of-mass energy and instantaneous luminosity will result in higher particle multiplicities and roughly five-fold additional interactions per bunch-crossing with respect to LHC Run-2. Therefore, significant effort within the collaboration is being focused on increasing the rate at which Monte Carlo events can be produced by designing and developing fast alternatives to the algorithms used in the standard Monte Carlo production chain.

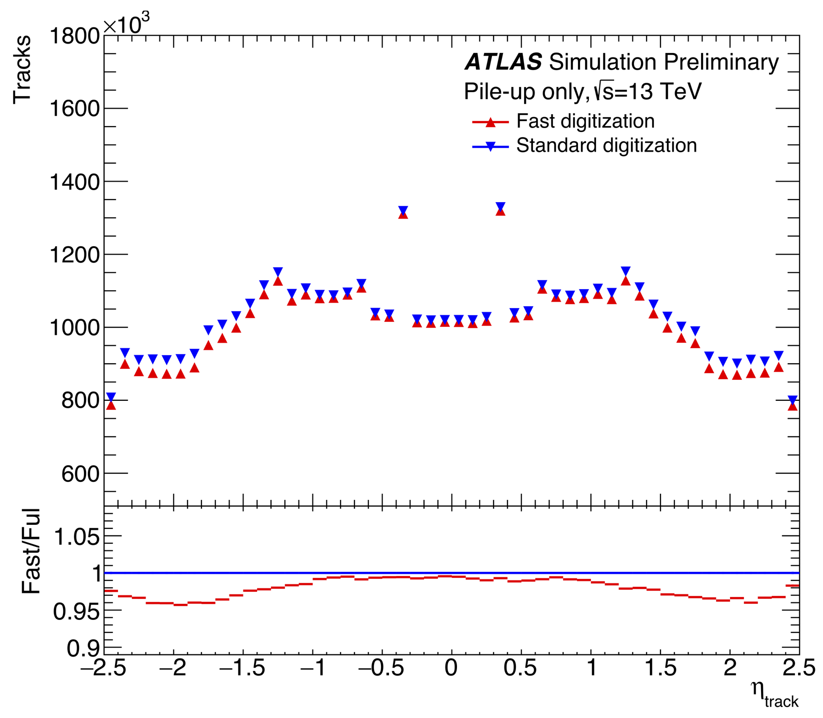
Fast Digitization

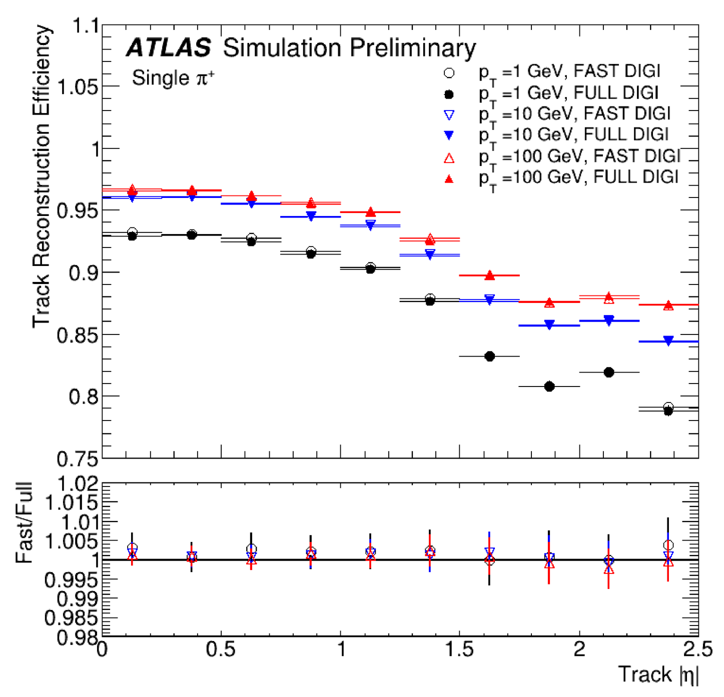
The **Fast Digitization** of the Inner detector is a parametric simulation of the conversion of the energy deposited in each sensor of the Pixel and Strip detectors into digital signals. The Digitization approach steps:

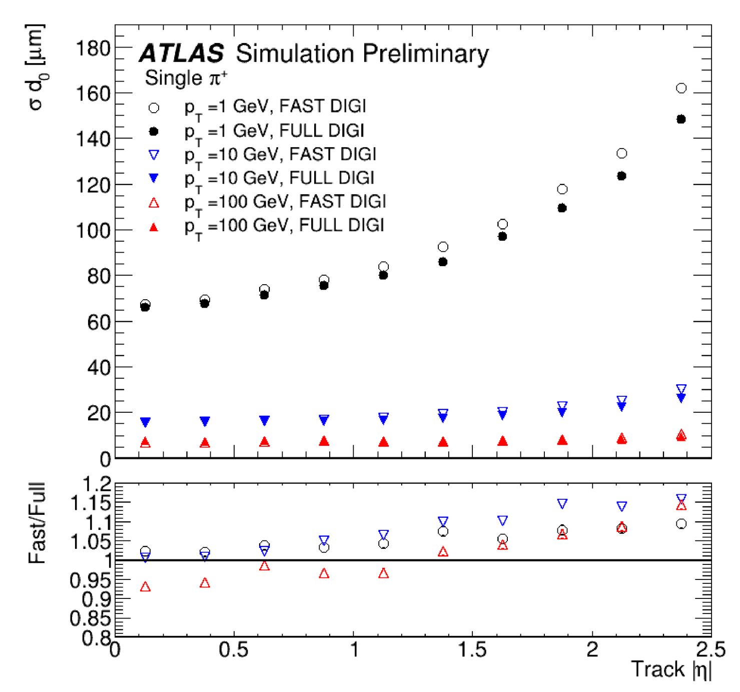
- Estimate the energy deposition per channel.
- Project the simulated track length onto read-out surface for each read-out channel.
- Form clusters from track information.

Fast Digitization: Performance

- The reconstructed tracks in pile-up events simulations (fast/full Digi) are in good agreement with differences of the order of maximum 5% in the largest part of the distributions.[3]
- The Fast Digitization efficiency is in sub-% agreement with the Full Digitization.[2]
- The Fast Digitization yields up to about 10-15% worse resolution in the forward region ($|\eta| > 1.5$).[2]





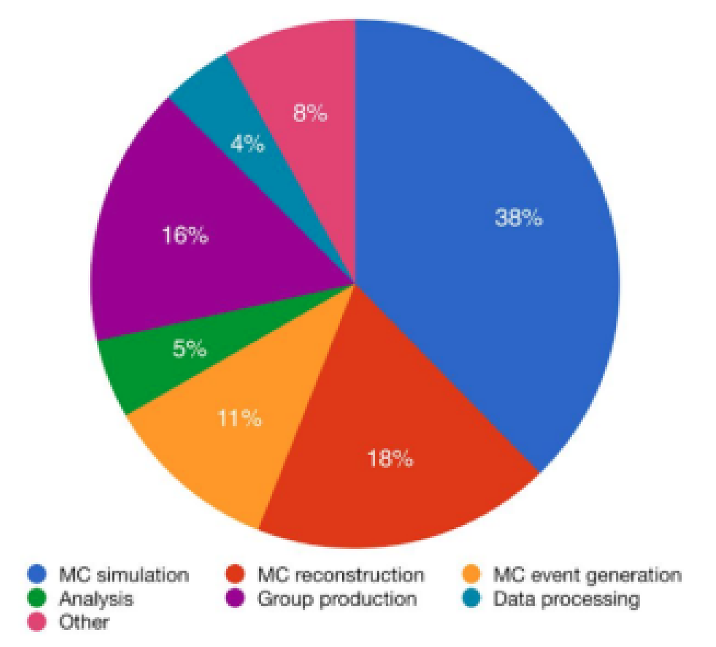


Fast Chain project

The high luminosity phase of the LHC will have a severe impact on the CPU time required in the simulation of the ATLAS detector, due to the large-scale MC production. Therefore, efforts are focused on the **Fast chain** project, which aims to combine fast and full simulation tools in a single transform to reduce CPU time and to meet computing and modeling requirements.

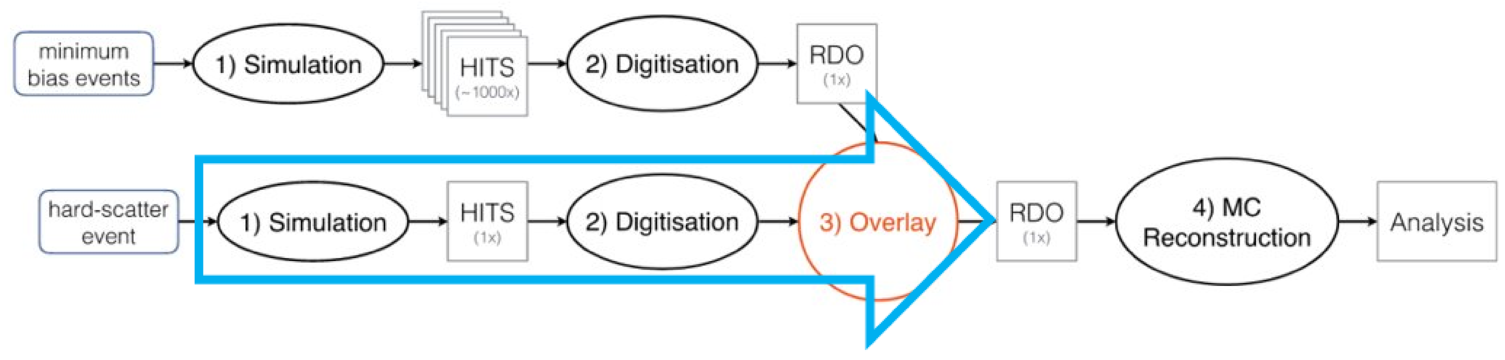
Fast Chain components:

- FATRAS
- Fast ID Digitization
- Track-Overlay



Relative CPU grid usage by the ATLAS experiment in 2018. The simulation is the biggest CPU Consumer during the Run 2 data taking.[1]

Fast Chain Workflow



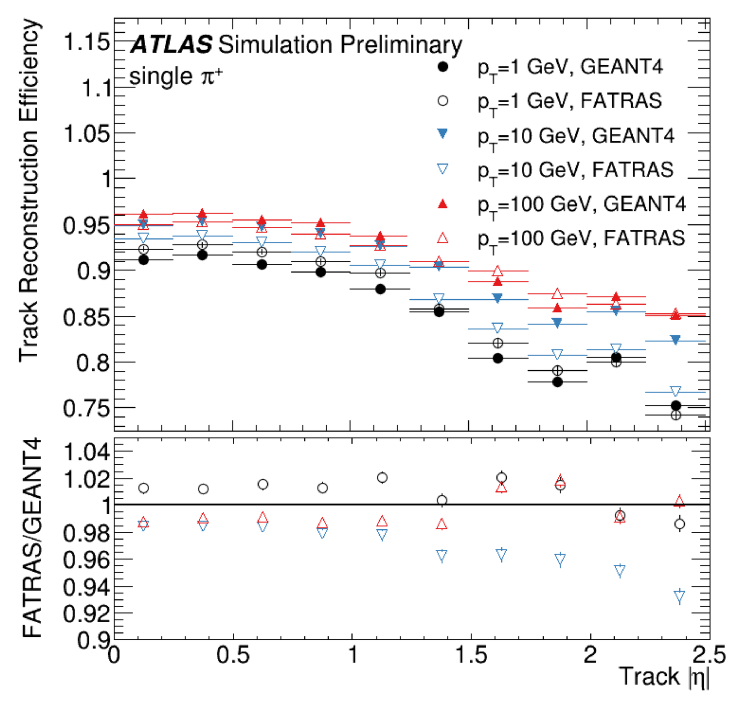
Fast Chain: run simulation and Digitization in a single job

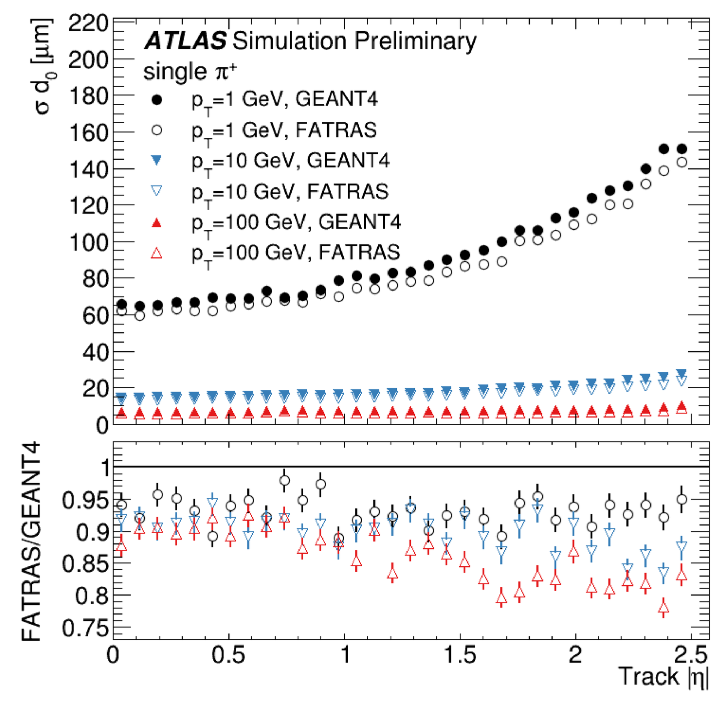
FATRAS

The **Fast ATLAS Tracking simulation** (FATRAS) produces a Monte Carlo simulation based on the simplified physics parameterization and a simplified inner tracker detector geometry instead of the standard ATLAS full geometry.

FATRAS: Performance [2]

- FATRAS leads to about 2% higher efficiency for 1 GeV particles, a net excess of material in FATRAS is unlikely to fully explain the mis-modelling.
- FATRAS yields about 5% (15%) better resolution compared to GEANT4 for 1 GeV (100 GeV) pions.

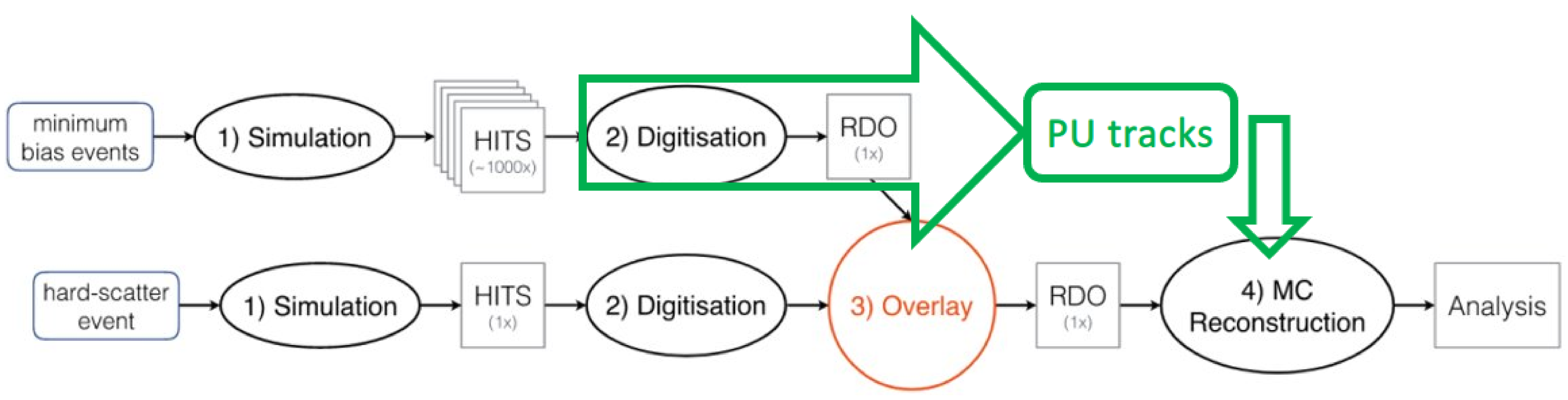




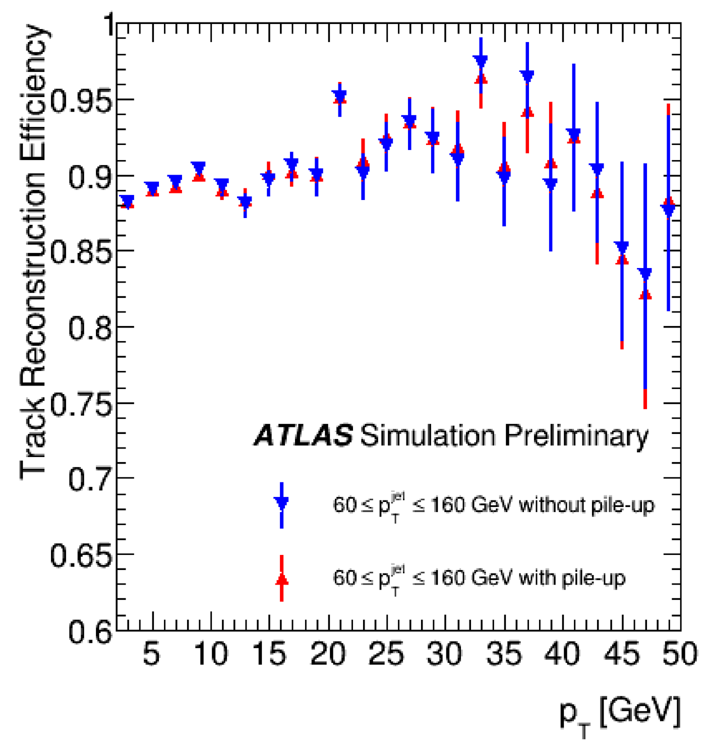
MC and Track-Overlay

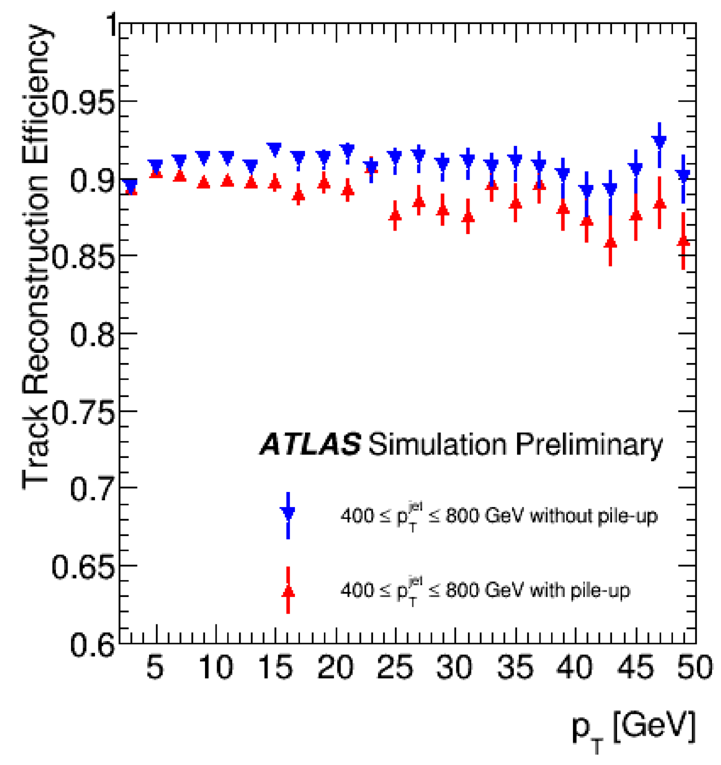
The **MC-Overlay** method aims to combine hard-scatter and pile up events in Run 3 at the detector digitization. The digitized pile up events are reused for several hard-scatter events. **Track-overlay** method is a possible faster alternative to MC-Overlay, in which pile up tracks and hard-scatter tracks would be reconstructed in a separate job, and tracks from pile-up events overlayed to several hard-scatter events.

Track-overlay Workflow



- The track overlay is feasible, when hard-scatter track reconstruction is not strongly affected by the pile-up events. This holds for events with low p_T jets (left), but not for events with high p_T jets (right).[3]





Conclusion

Fast Chain aims to provide a faster alternative to the standard MC production chain with more efficient handling of I/O and CPU resources. Its configuration incorporates various fast components and combines them with more precise ones in an easily adaptable way.

References

[1] P. Calafiura, J. Catmore, D. Costanzo, A. Di Girolamo, ATLAS HL-LHC Computing Conceptual Design Report, CERN-LHCC-2020-015 (2020)
[2] https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/SIM-2021-008/
[3] https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/SIM-2021-005/

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