The Fast Simulation Chain in the ATLAS experiment

Martina Javurkova

University of Massachusetts-Amherst

On behalf of the ATLAS collaboration

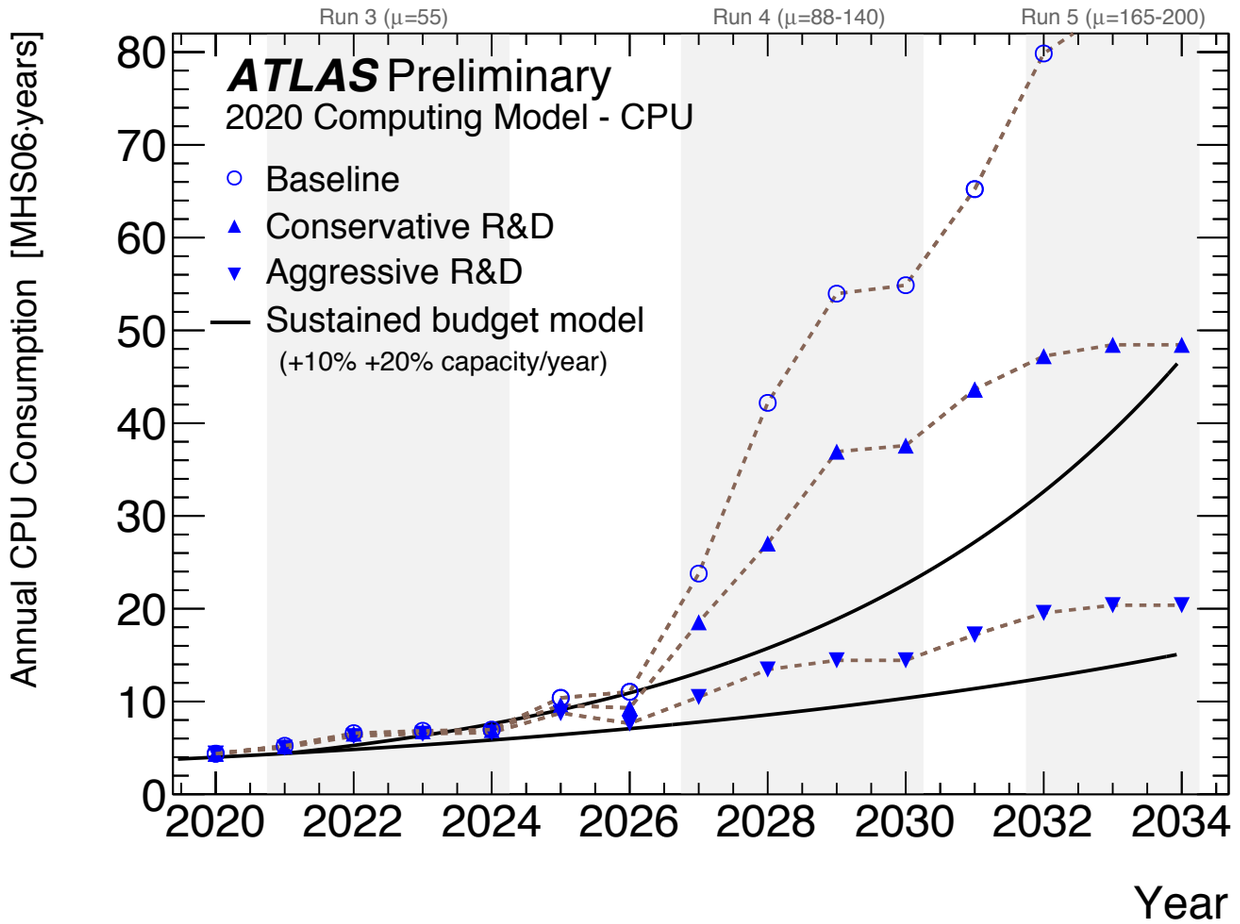
vCHEP'21 conference

17 - 21 May 2021

Computing challenges

- *Requirements for large-scale MC production will increase significantly in the upcoming years*
- *More computing resources will be needed than the WLCG infrastructure provides nowadays*

- Simulation of the ATLAS detector is the biggest CPU resource consumer: very fast simulation is critical but not sufficient
- Digitisation* and event reconstruction time become comparable to the simulation time
- Fast Chain aims to address this problem by designing and developing fast alternatives to the algorithms used in the standard MC production chain



Projected CPU requirements of ATLAS between 2020 and 2034

* Simulation of detector electronics, read-out and addition of parallel soft collision events

Fast Chain overview

- ***Fast Chain*** *combines fast and full simulation tools in a single workflow to meet computing and modelling accuracy requirements*

Various tools for events of interest (hard-scatter) and additional pp collisions (pile-up)

- Hard-scatter (HS) Simulation
  - Fast Tracking Simulation
  - Integration to A Common Tracking Software
- Pile-up (PU) Simulation
  - RDO-overlay: overlay of the detector output for the sum of all in- and out-of time background events
- Digitisation
  - Fast Silicon Digitisation
- Reconstruction
  - Fast Track Reconstruction
  - Track-overlay

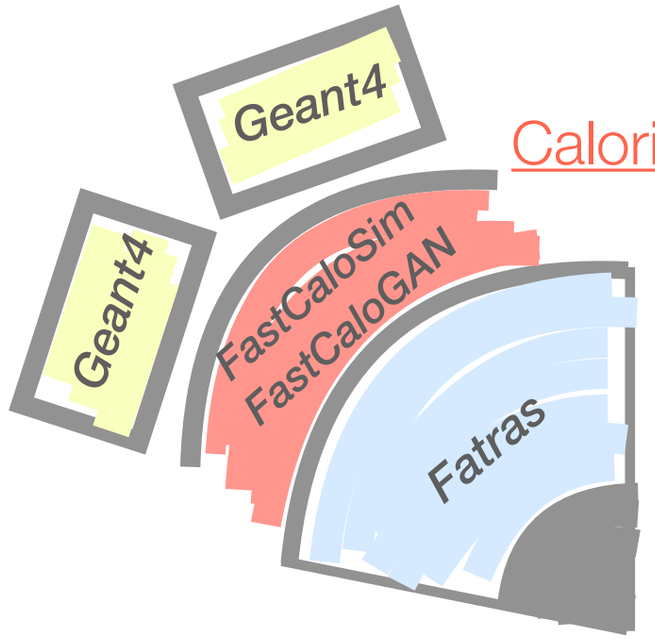
: Validation : Integration : Development

Hard-scatter simulation

- *Traditional way to model particles traversing the ATLAS detector is a very accurate simulation provided by the **Geant4** framework*
- *Efforts focused on reducing CPU time spent on **simulations***

Simulation configuration to be used

- 200 times faster than full Geant4
  - Fatras in the Inner Detector (ID)
    - Fast simulation of charged particle propagation using the *simplified geometry* and *simplified interaction models*
  - FastCaloSim+FastCaloGAN in Calorimeters
  - Geant4 in the Muon Spectrometer (MS)



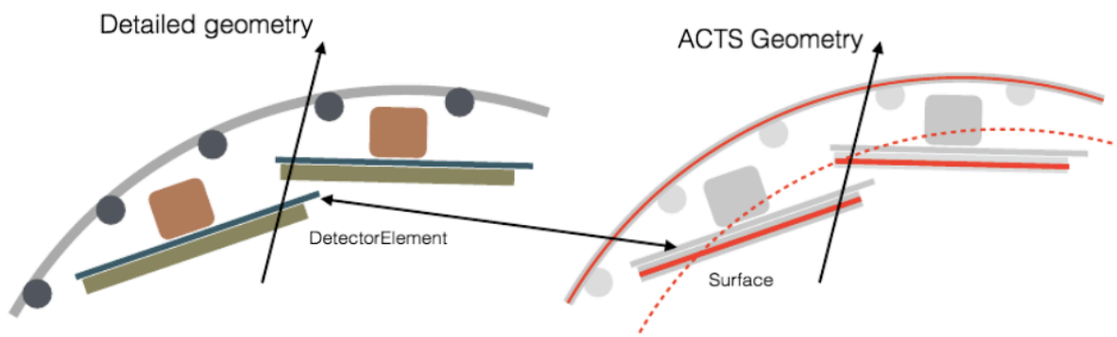
Hard-scatter simulation: Fatras

- *Fast Tracking Simulation around for several years (Fatras)*

Systematic validation of the performance for different physics processes

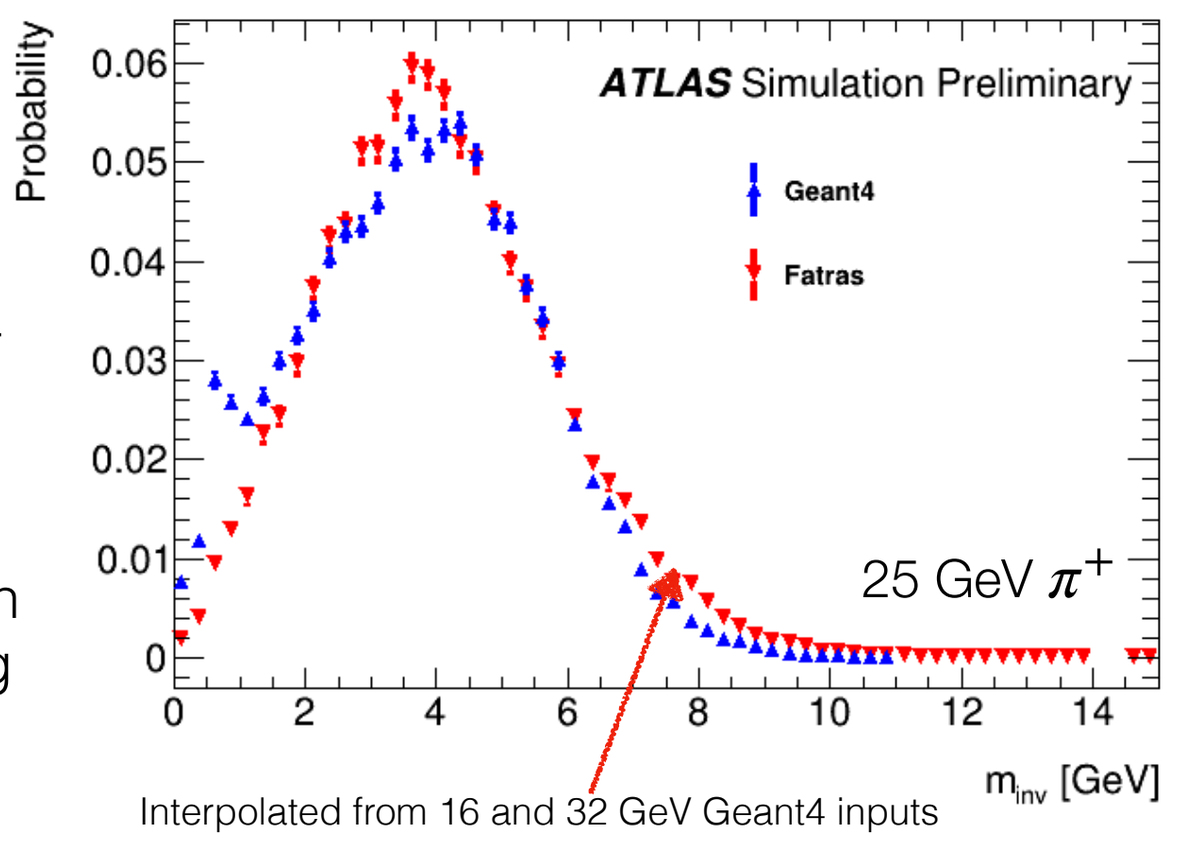
Integration into A Common Tracking Software (ACTS)

- Thread-safe fast simulation of the ID



New parametrisation method for nuclear interaction

- Based on histograms obtained from Geant4 simulations for different initial conditions
- Histograms form a decision tree, starting with the *interaction probability* after a certain distance and followed by the corresponding *multiplicity*

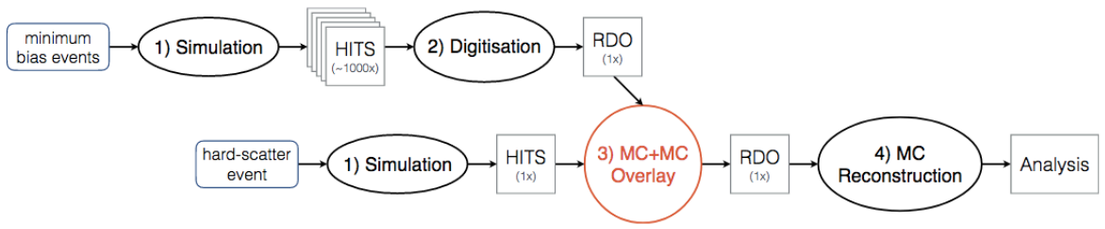


Pile-up Simulation

- *Fast and accurate description of **additional pp collisions** by overlaying MC events*

RDO-overlay [Ref]

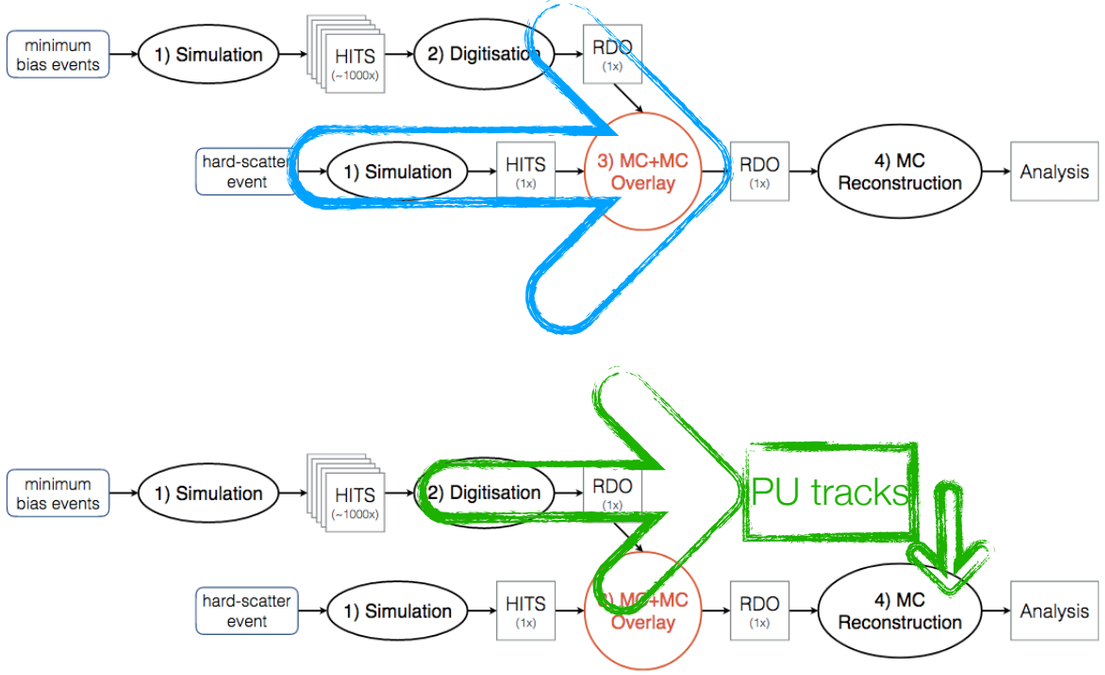
- Pre-sampling: produce large PU sample from simulated minimum bias events during a separate digitisation step
- Overlay: digitise simulated HS event and combine them with an event from these PU dataset



- Fast Chain integration: run simulation and digitisation in a single Athena job

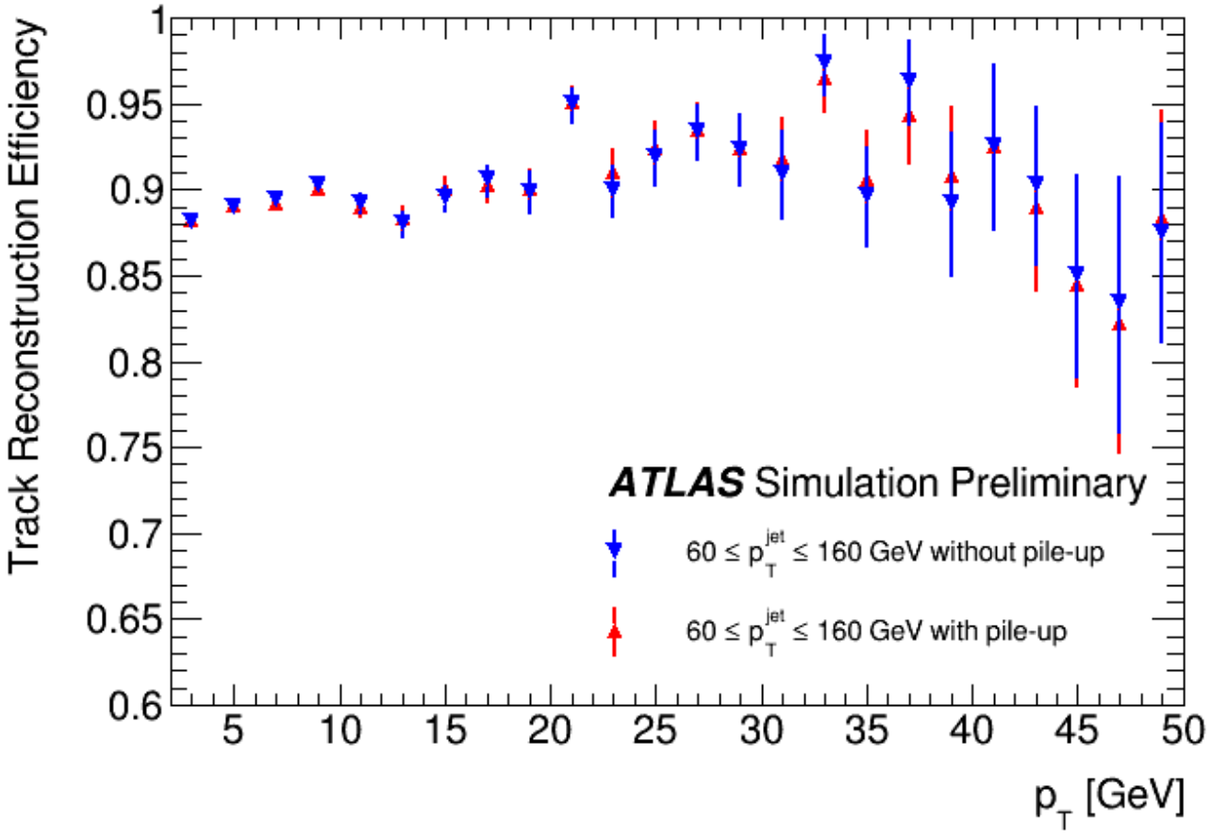
Track-overlay

- Pre-sampling: reconstruct PU tracks in a separate job
- Overlay: combine independently reconstructed HS tracks with the PU track collections
- Validation: study track reconstruction efficiency in samples reconstructed w/ and w/o PU → If comparable, HS track reconstruction not affected by surrounding PU

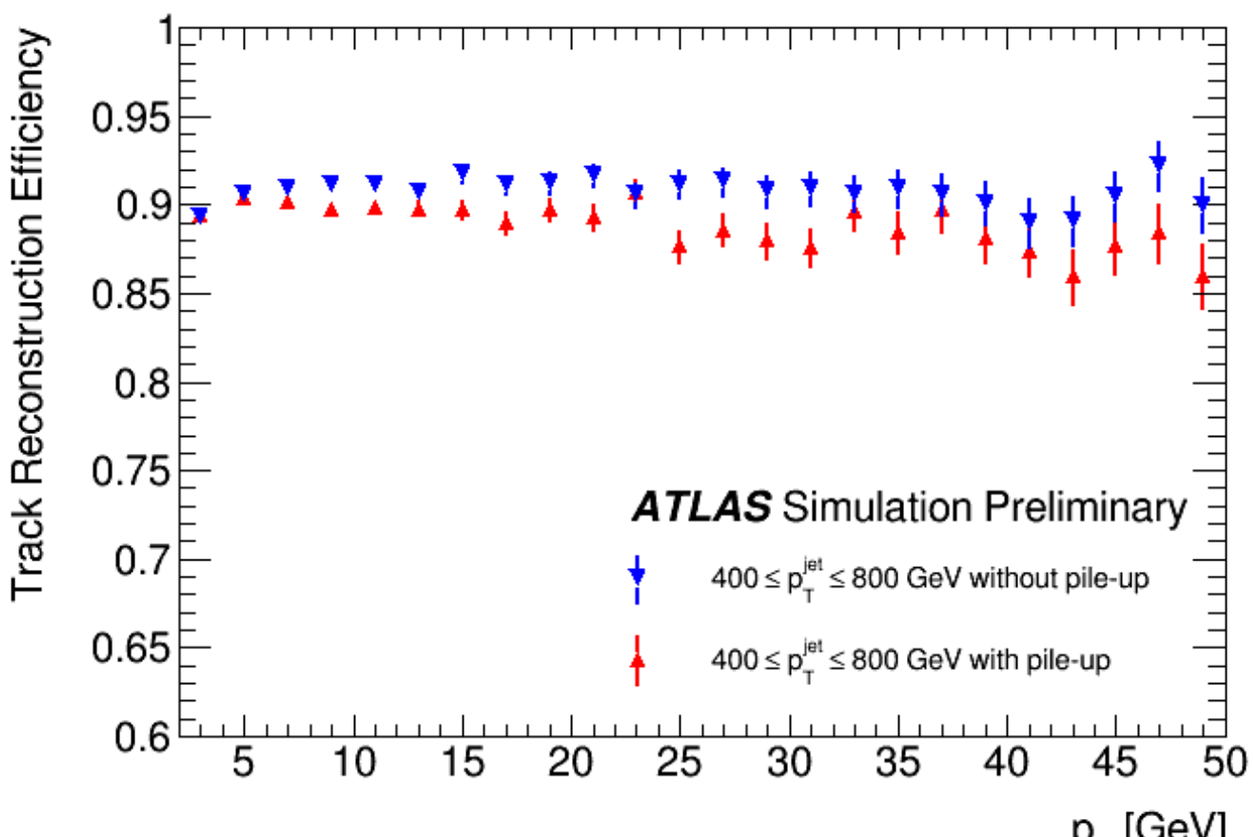


Pile-up Simulation (II)

- *Fast and accurate description of **additional pp collisions** by overlaying MC events*



✓Track-overlay should be OK



✤ Extra corrections needed

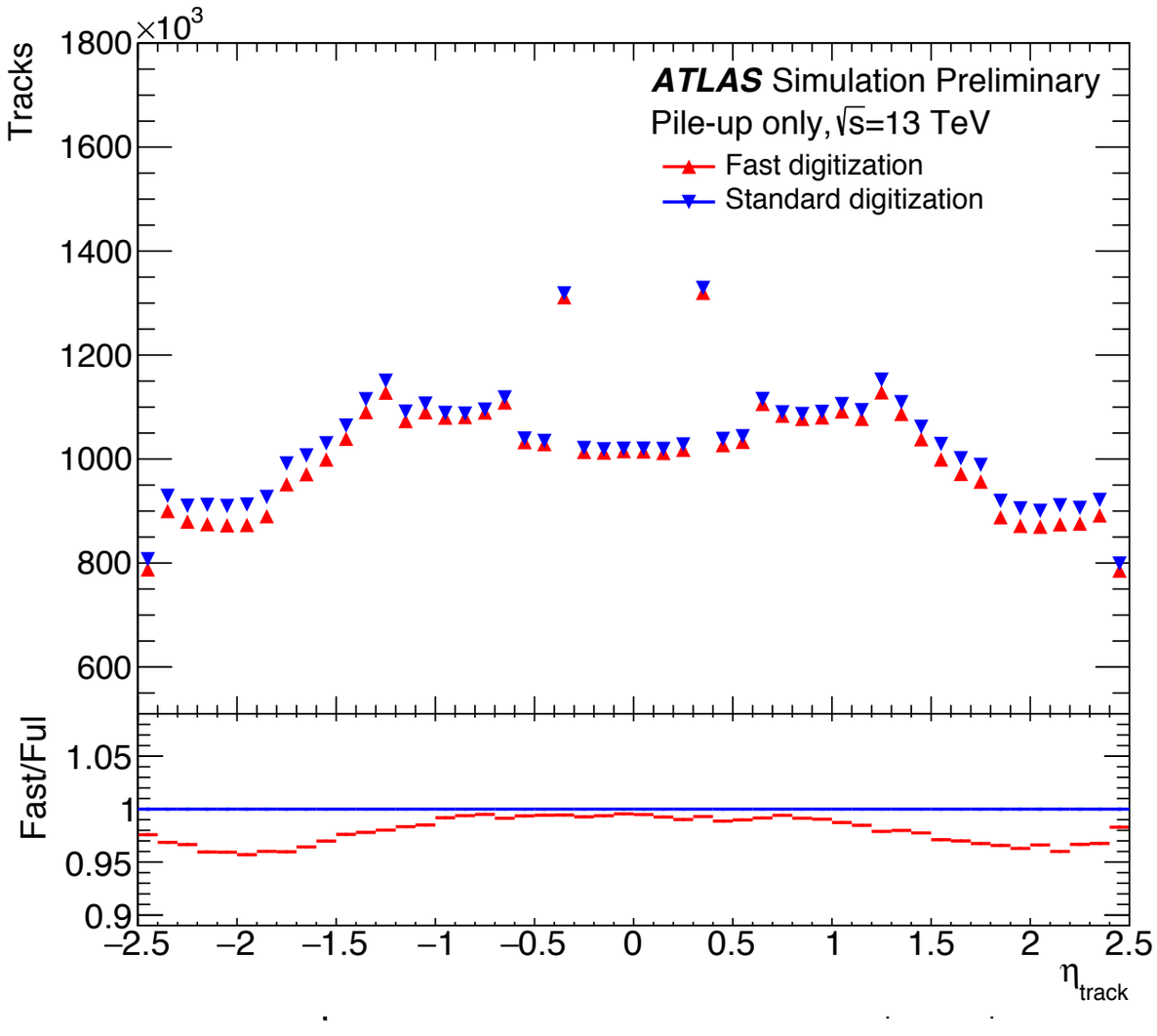
Fast digitisation of the silicon detector

- *Information about the sensitive detector energy deposits (HITS) is converted in a format of detector signals (RDO) in a process of digitisation*
- ***Fast Silicon Digitization** has been developed to speed up this step, in particular for the PU*

Parametric simulation

- Faster algorithm which parametrises the digitisation of the signal and creates clusters exploiting truth information
  - Starting from the locations of the energy deposits in each sensor of the pixel and strip detectors, the geometrical trajectory of every particle inside each module is reconstructed

Validation is ongoing



Fast reconstruction

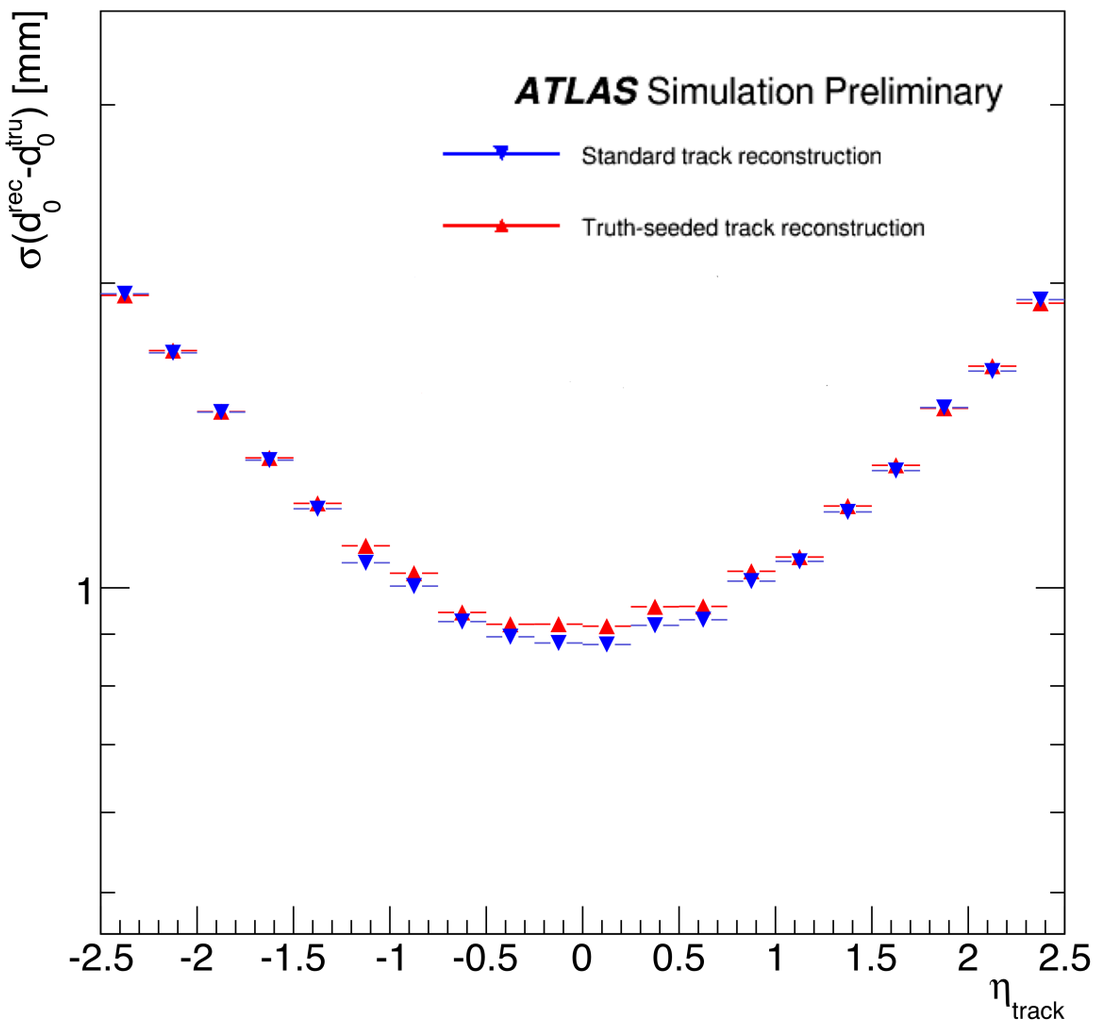
- *Reconstruction is used to find tracks and identifies physics objects (particles, jets)*
- *Most CPU consuming reconstruction algorithm is the ID track reconstruction which identifies track candidates from tracking detector hits*

Fast Track Reconstruction

- Truth-seeded tracking algorithm [Ref]
  - Removes time consuming pattern recognition, track seeding and ambiguity treatment
  - Uses the MC truth information to assign tracking detector hits to particle tracks

Track-overlay

- Possible replacement of Fast Track Reconstruction

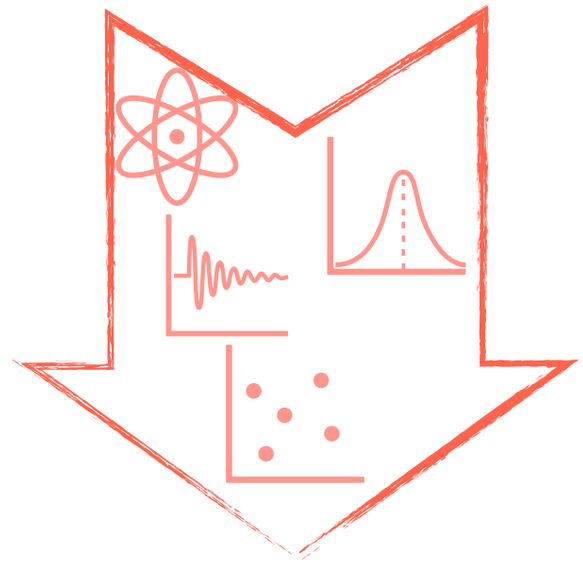


Fast MC production chain

- *Designed to be **flexible** in preparing different configurations with various combination of fast and full tools*
- ***No intermediate files** persistently stored: generate one single output from the input event generator files*

Baseline configuration for Run 3

- ATLFAST3F simulator
  - ACTS Fatras in the ID, FastCaloSim/FastCaloGAN in Calorimeters, Geant4 in the MS
- RDO-overlay (EVNT→RDO)
- Standard reconstruction algorithms



Possible configurations for Run 4 and further

- Use one or more fast tools to speed up the pre-sampling
  - Fast Silicon Digitisation
  - Fast Track Reconstruction
  - Track-overlay

Monitoring & validation

- *Tools currently used to monitor the performance of the Fast Chain and the CI with the main ATLAS software framework (Athena)*

Daily ART tests [Ref]

- Monitor current developments in the Fast Chain simulation workflow
- Various simulators are being tested with different configurations and different conditions

Mini-analysis

- Validate the entire MC production chain at the highest level by comparing the yield of some analysis-based event selection strategy using the derivation data formats
- Configuration tailored for a specific physics analysis

Conclusions

- Fast Chain aims to provide a faster alternative to the standard MC production chain with more efficient handling of I/O and CPU resources
- Several faster components have been developed
  - Fast Tracking Simulation (Fatras)
    - Very nice progress on ACTS integration
    - Validation of new parametrisation method for nuclear interaction
  - Fast Calorimeter Simulation (FastCaloSim/FastCaloGAN)
  - Fast Silicon Digitisation: ongoing validation
  - Fast Reconstruction: ongoing validation of Truth-seeded tracking algorithm and implementation of Track-overlay
- Goal is to deploy the baseline Fast Chain scenario for the MC production in 2021 and study the other scenario

Conclusions

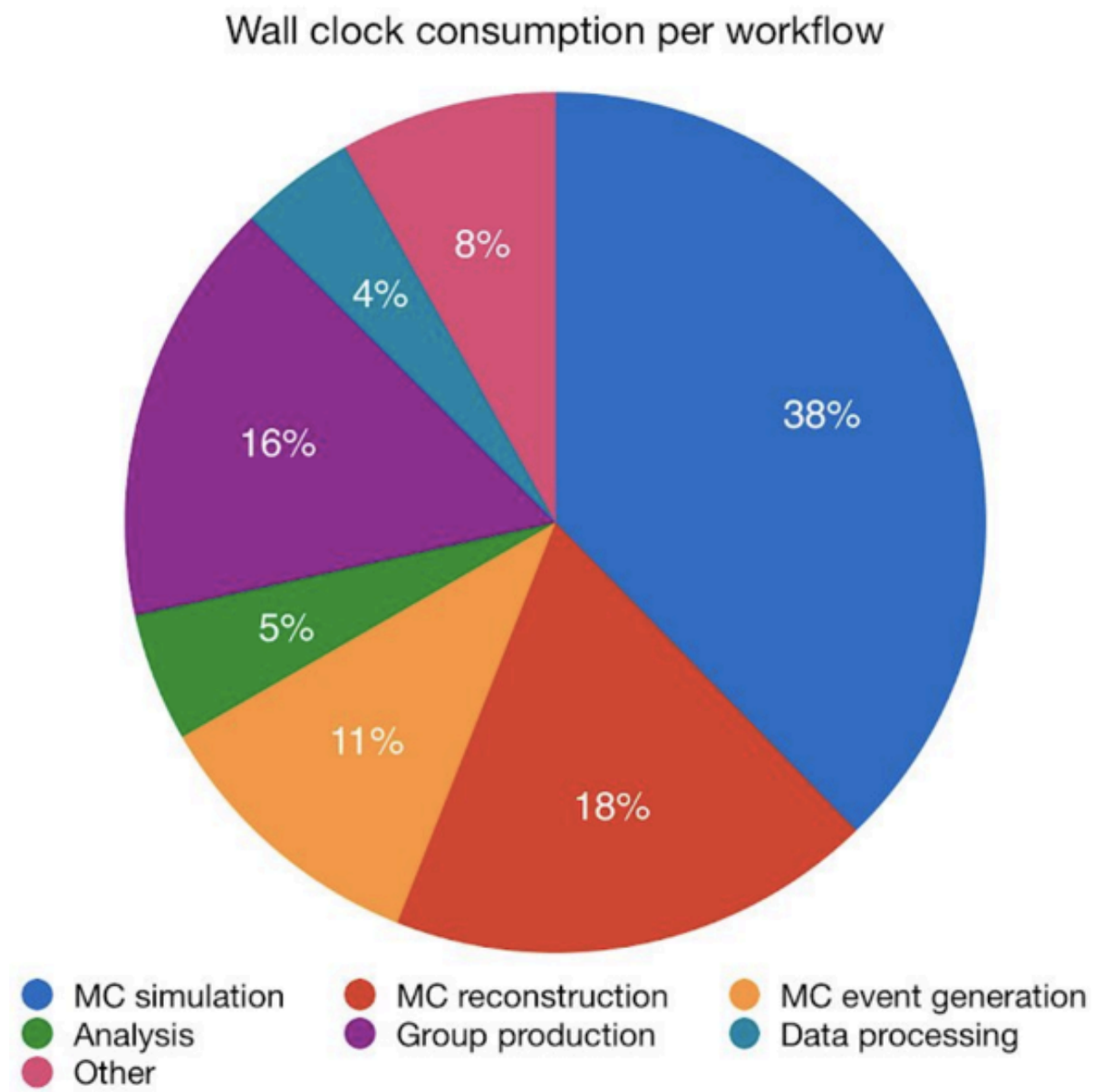
- Fast Chain aims to provide a faster alternative to the standard MC production chain with more efficient handling of I/O and CPU resources
- Several faster components have been developed
  - Fast Tracking Simulation (Fatras)
    - Very nice progress on ACTS integration
    - Validation of new parametrisation method for nuclear interaction
  - Fast Calorimeter Simulation (FastCaloSim/FastCaloGAN)
  - Fast Silicon Digitisation: ongoing validation
  - Fast Reconstruction: ongoing validation of Truth-seeded tracking algorithm and implementation of Track-overlay
- Goal is to deploy the baseline Fast Chain scenario for the MC production in 2021 and study the other scenario

Thank you for your attention!

Backup

ATLAS CPU hours

- *ATLAS CPU hours used by various activities in 2018*



Truth-seeded track reconstruction

- *Truth track creation in the ID*