The ATLAS Fast Track Simulation Project

fatras

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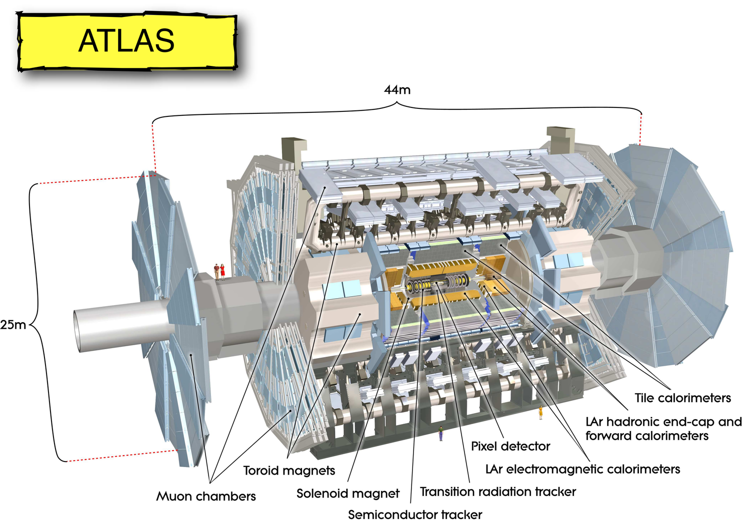
on behalf of the ATLAS collaboration

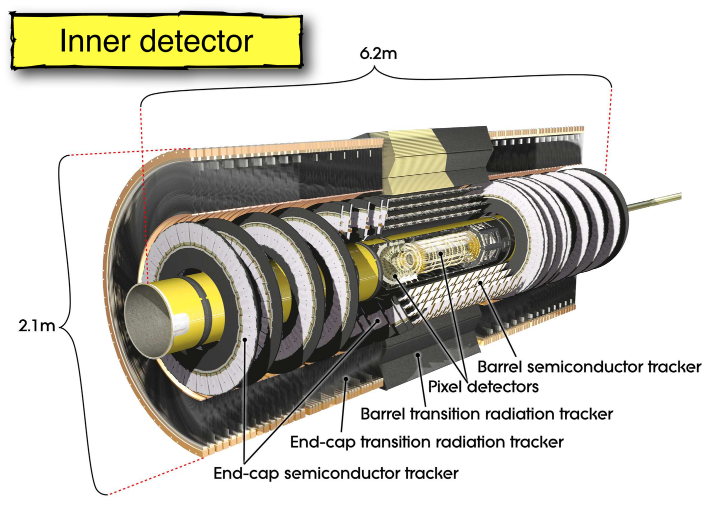
The ATLAS Experiment

About one hundred meters below the surface of the French countryside close to CERN, the Large Hadron Collider (LHC) is delivering streams of protons to four particle detectors since its startup in 2008.



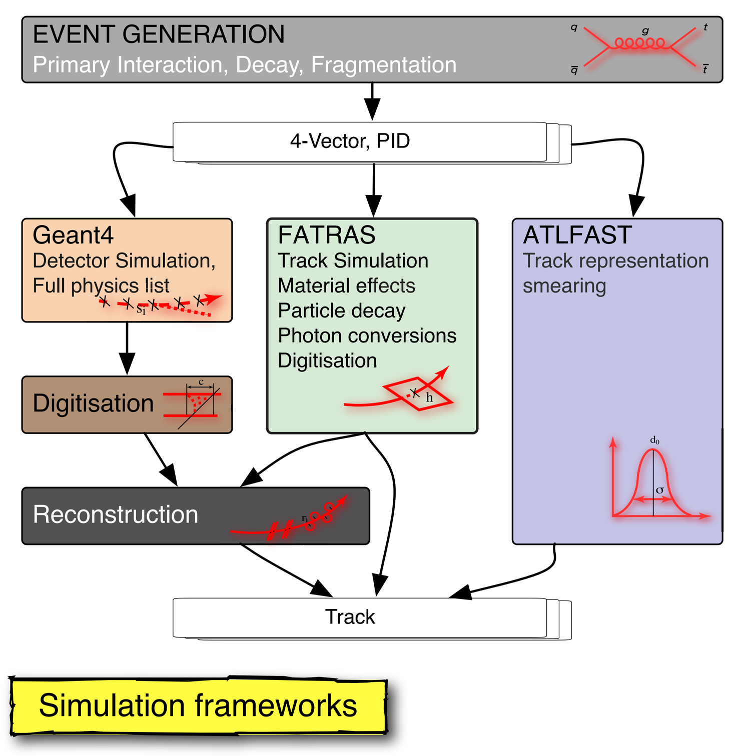
ATLAS is a "multi-purpose" detector with a primary focus on the search for new physics, such as Supersymmetry or the Higgs Boson. The apparatus can be divided into three main parts: inner detector, calorimeters and the muon system. The former and the latter are tracking systems, responsible for precisely measuring the momenta of charged particles. The calorimeters are used for determining the energies of traversing particles.

The inner detector consists of three subsystems: closest to the LHC beam line are the pixel detectors with very high granularity for determining the origin of the hard scattering process and the position of secondary vertices from longer-lived unstable particles. The Semiconductor Tracker (SCT) and the Transition Radiation Tracker (TRT) provide additional precision hits for reconstructing tracks of charged particles.



Simulation

In high energy physics, the modeling of the detector response with Monte Carlo methods is an integral component of many studies. Tracking devices like the ATLAS pixel detectors and the SCT are extremely complex instruments that have to be commissioned and fully understood, also with respect to the results of previously conducted simulation efforts. In addition to that, physics analyses often require extensive datasets of simulated physics data for the estimation of systematic effects. The production of those simulated data to the very detail is usually a very CPU-intensive task.



The ATLAS collaboration has developed full and fast detector simulation techniques to achieve this goal within the computing limits of the collaboration. At the current stage of data-taking, it is necessary to reprocess the Monte Carlo event samples continuously, while integrating adaptations to the simulation modules in order to improve the agreement with the data taken from the detector itself.

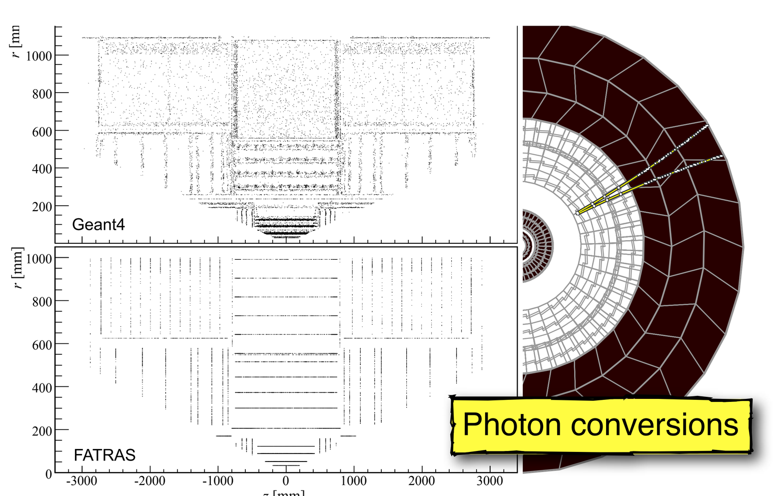
FATRAS is a fast track simulation engine of the ATLAS inner detector and muon system. It produces a full Monte Carlo simulation based on the software modules and the geometry used by the standard ATLAS track reconstruction algorithms. It can be combined with a fast parametrised-response simulation of the calorimeter. This approach shows a high level of agreement with the full simulation (based on Geant4), while reducing the amount of computing time by two orders of magnitude.

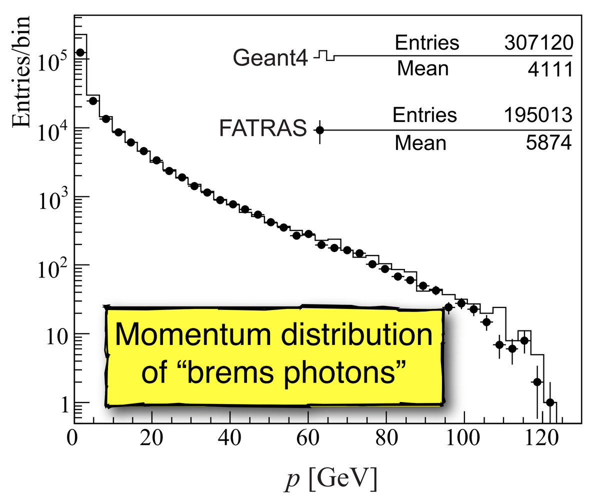
FATRAS was designed to provide a fast feedback cycle for tuning the MC simulation to real data, including the material distribution inside the detector, the integration of misalignment and current conditions, as well as calibration at the detector hit level.

Features of FATRAS

The software takes care of modeling the most dominant effects of the traversed detector material on the particle, such as:

- multiple scattering/ionization loss
- bremsstrahlung
- hadronic interactions
- photon conversions





Also particle decays are simulated for all unstable particle types and their decay products are iteratively processed by the same algorithms.

Design specifics of the detectors (e.g. their granularity and readout methods) are also accounted for such as for example the cluster creation in the pixel detectors from neighbouring detector elements being hit.

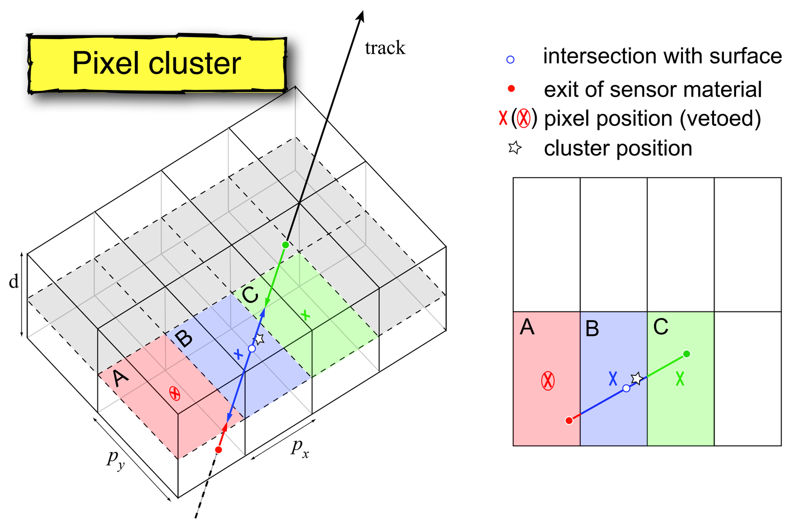
Timing

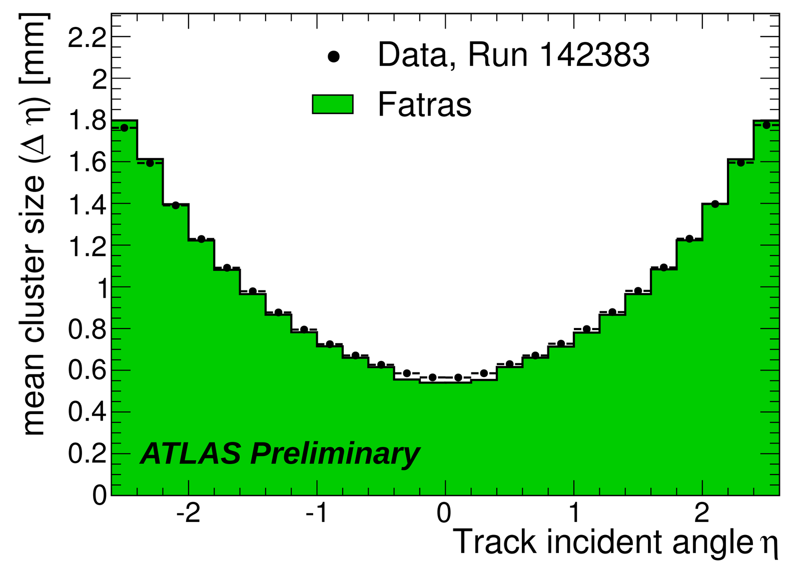
Comparison of the simulation time per event in kSI2K seconds for different simulation frameworks used by the ATLAS collaboration show a significant speed gain when using FATRAS combined with a fast calorimeter simulation (ATLFAST-IIF) w.r.t. to the Geant4 full simulation or standard fast simulation.

Sample	Full Sim	ATLFAST-II	ATLFAST-IIF
Minimum Bias	551	31.2	2.13
ttbar	1990	101	7.41
Jets	2640	93.6	7.68
Photon + Jets	2850	71.4	5.67
W→eν	1150	57	4.09
W→μν	1030	55.1	4.13
Heavy Ion	56000	3050	203

Comparison with Experimental Data

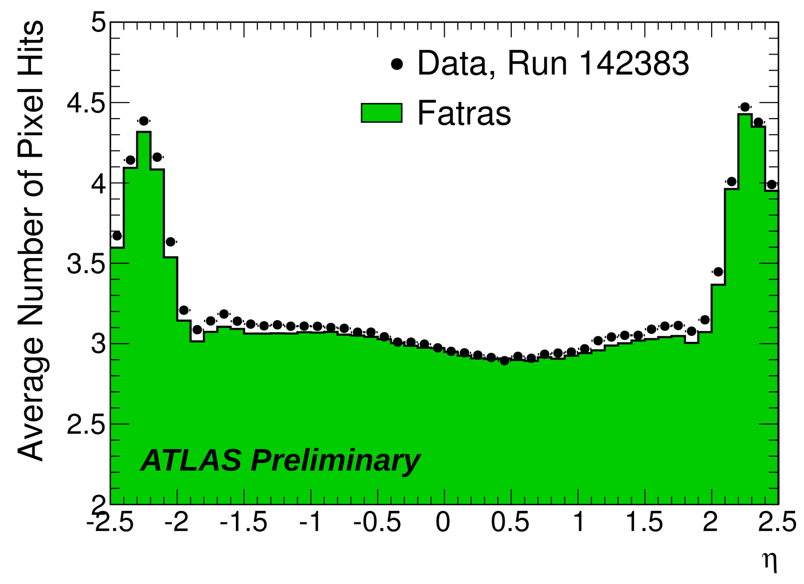
Based on data taken at a centre-of-mass energy of 900 GeV, several tracking-specific observables have been compared to output from FATRAS. The plots shown here concentrate on distributions related to the pixel detectors.

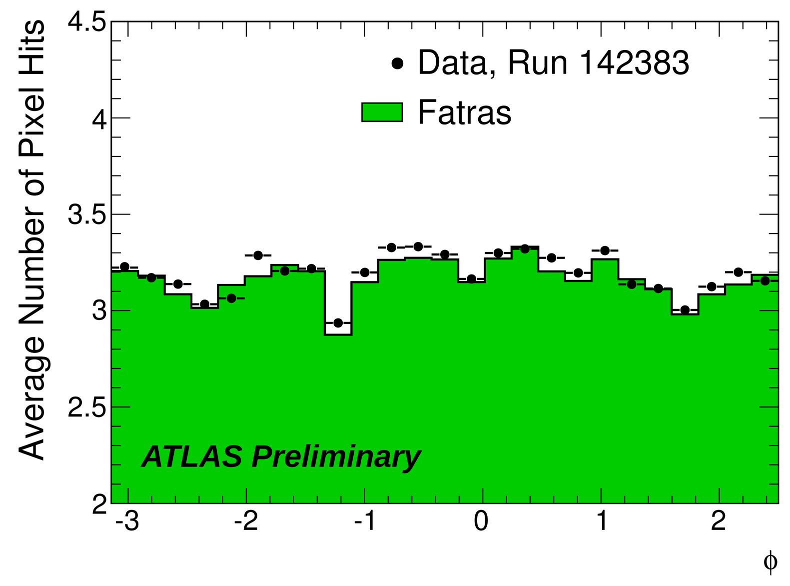


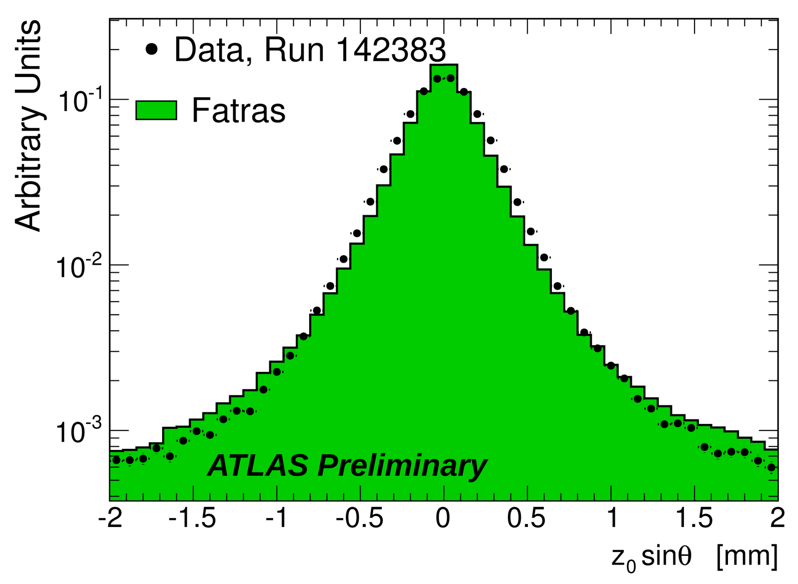


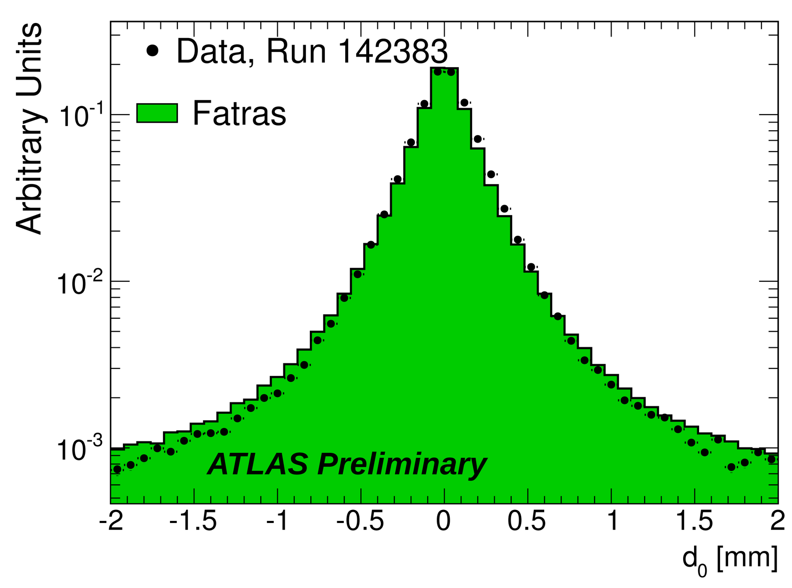
The simple geometrical approach for reproducing the proper sizes for neighbouring pixels shows an excellent agreement between data and MC.

The number of hits in the pixel detector in dependance of the pseudorapidity (η) and the azimuthal angle (ϕ) are reproduced to a large extend, the general shape fits very nicely.









The impact parameters z0 and d0 give information about the closest point of approach of a track w.r.t. to the beamline. They are relevant for vertex reconstruction. While the general shape is reproduced sufficiently well by FATRAS, small deviations exist in the tails of the distributions.

Summary

Since the development of FATRAS was started, it has proven to be a useful tool, not only for debugging the track reconstruction algorithms and the simplified reconstruction geometry of the ATLAS detector, but also as a fast simulation engine. Comparisons with real collision data show that the description of the physics processes and the material distribution are modeled in a realistic way. The speed increase with respect to a detailed detector simulation which also uses a much more complex description of the detector is significant. This implies that FATRAS is a perfect tool for investigating questions that are related to tracking and also for simulating alternative geometries. It has already been successfully used for studying different concepts of a potential replacement of the ATLAS inner detector.

References

The ATLAS Collaboration et al, 2008, JINST 3 S08003, doi: 10.1088/1748-0221/3/08/S08003.

The ATLAS Collaboration et al, *The ATLAS Simulation Infrastructure*, 2010, arXiv:1005.4568v1.

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