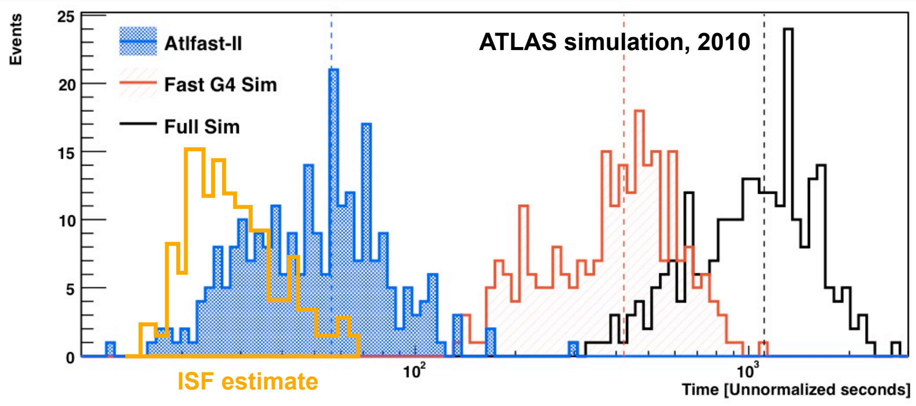
CHEP 2012 Poster Session, 21-25 May 2012, New York (USA)

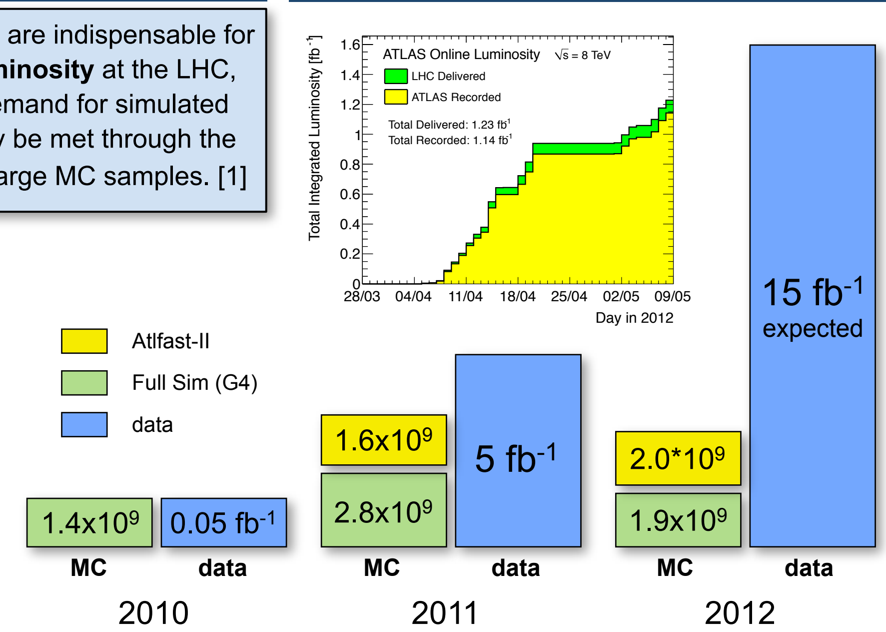
Fast simulation for ATLAS: Atlfast-II and ISF

Simulation Requirements for the ATLAS Detector

Monte Carlo simulations of physics events, including detailed detector simulation, are indispensable for every analysis of high energy physics experiments. **Increasing the recorded luminosity** at the LHC, and hence the amount of ATLAS data to be analyzed, leads to a steadily rising demand for simulated MC statistics. These MC requirements for more refined physics analyses can only be met through the implementation of **fast simulation strategies** which enable faster production of large MC samples. [1]



MC samples vs. data



Timing Issues

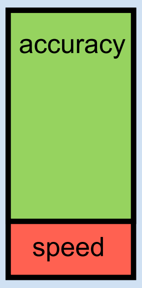
For many physics analyses, like the W mass precision measurement, **large MC samples** are required to study systematics and background processes. The full Geant4 simulation [2] can become too time-consuming for this purpose.

Sample	Full G4 Sim	Fast G4 Sim	Atlfast-II	Atlfast-IIF
Minimum Bias	551.	246.	31.2	2.13
$t\bar{t}$	1990	757.	101.	7.41
Jets	2640	832.	93.6	7.68
Photon and jets	2850	639.	71.4	5.67
$W^{\pm} \to e^{\pm}\nu_e$	1150	447.	57.0	4.09
$W^{\pm} \to \mu^{\pm}\nu_\mu$	1030	438.	55.1	4.13

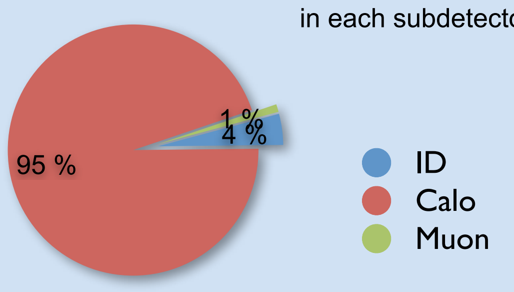
kSI2K seconds per event

Full and Fast G4 Simulation

The total CPU time spent for the simulation of a typical $t\bar{t}$ event (see table above) differs by a factor ~3 between the **Full Simulation** with G4 and the **Fast G4 Simulation**, which uses pre-calculated "**frozen shower**" libraries for the electro-magnetic particles in the forward calorimeter.

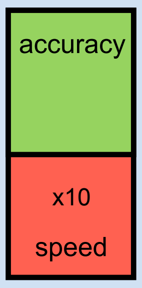


Geant4 provides the **most accurate** simulation, which is essential for several but not all parts of physics analyses. The pie chart below shows the typical fraction of full simulation CPU time spent in each subdetector.

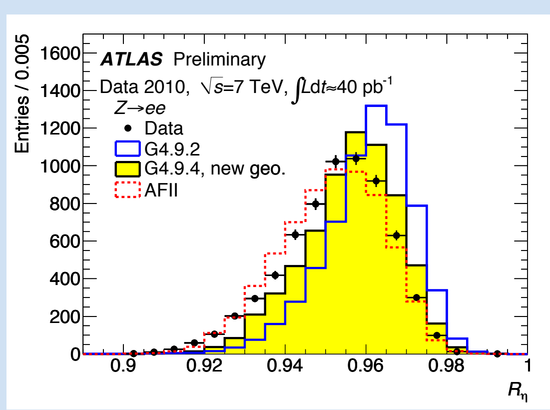


Atlfast-II and FastCaloSim

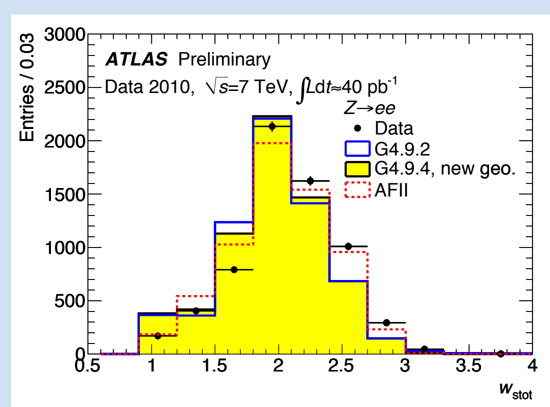
The simulation time can be reduced by more than an order of magnitude by using the **Atlfast-II** fast simulation, which uses **FastCaloSim** in the calorimeter. The energy of single particle showers is deposited directly using **parameterizations** of the longitudinal and lateral energy profile. It is intrinsically less accurate, but **can be tuned** against data.



This fast simulation approach has been **used since 2011** for the production of large MC samples needed for new physics searches as well as precision measurements. It has been **validated** against the Geant4 based full simulation for electrons, jets and missing ET. Validation plots of the calorimeter shower shapes of high E_t electrons are below.



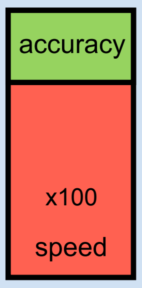
Energy ratio R_η in a $\Delta\eta$*$\Delta\varphi$ = 3x7 cells cluster with respect to a 7x7 cells cluster size in the bulk EM calorimeter layer 2.

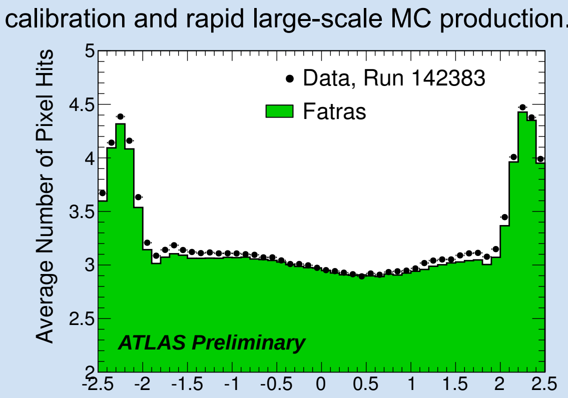


Shower width W_{stot} determined in a window corresponding to the cluster size in the high granularity strip layer 1.

Atlfast-IIF and Fatras

Another factor of ~10 in CPU time can be gained in **Atlfast-IIF** using the Fast ATLAS Tracking Simulation (**Fatras**) for the Inner Detector and Muon System. Fatras uses simplified **physics parameterizations** and the simpler **reconstruction geometry** instead of the full geometry [3]. Fatras **can be tuned** against data and is useful for validation studies, fast material calibration and rapid large-scale MC production.

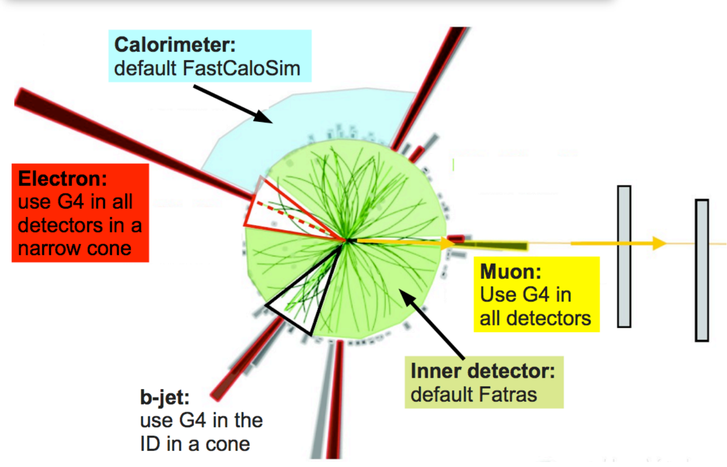




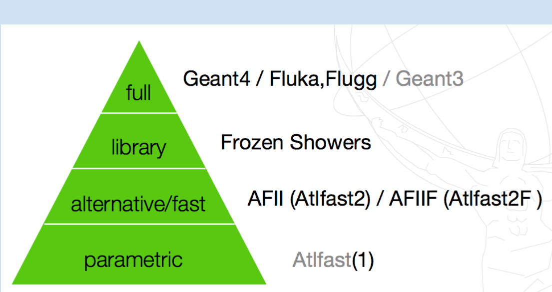
Pixel hits in η with Fatras and 900 GeV collision data.

The Integrated Simulation Framework (ISF)

Many studies require large MC samples, but are interested in high precision simulation only for certain particles and regions. These current and future physics demands can only be supported by an **Integrated Simulation Framework** that flexibly combines different simulation strategies.

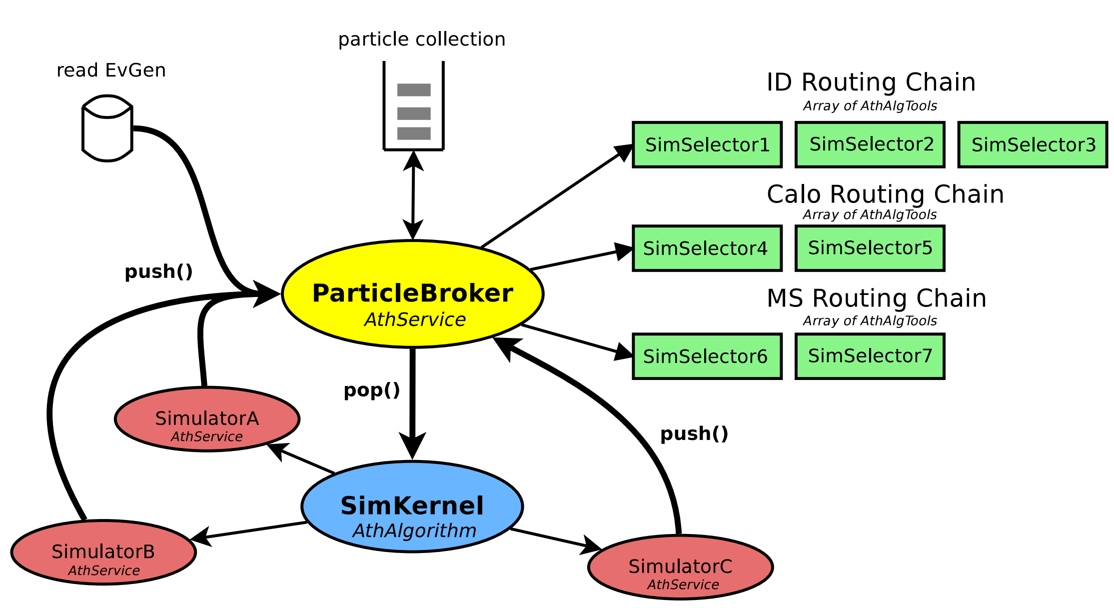


The new Integrated Simulation Framework is based on the requirement to allow to **run all simulation types in the same job**, even within the same sub-detector, for different particles.



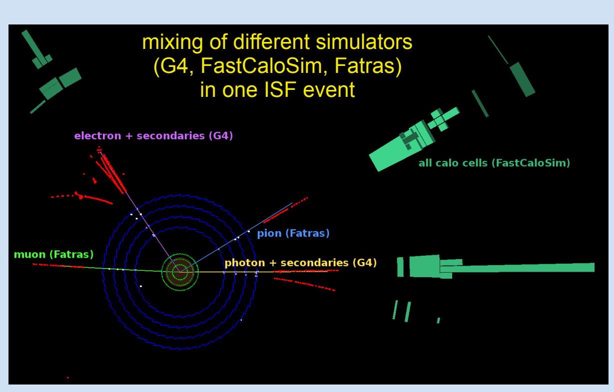
This framework is designed to be extensible to new simulation types as well as the application of **parallel computing techniques** in the future.

The ISF is fully embedded in the ATLAS framework (Gaudi-Athena). The general simulation flow is steered by the **SimKernel**, which is a single algorithm that holds **Simulator** services for the sub-detectors, a **ParticleBroker** service and the truth service. The SimKernel retrieves particles from the ParticleBroker and routes them to their associated simulation engines. All simulators fill a **common set of hit collections** which are then processed in the same digitization and reconstruction chain.



Each particle processed by the ISF is passed by the ParticleBroker through **configurable routing chains** for the current sub-detector. The particle is associated to a simulator according to the first filter rule that applies to its current properties.

Prior to the simulation launch, users can configure these **filter rules** according to their specific physics analysis requirements. They can find an **optimal balance** between precision and execution time by selecting faster simulation flavors for all parts that do not require full detail.



Visualization of an ISF event with VP1.

Conclusion

The fast simulation **Atlfast-II** with the calorimeter simulation **FastCaloSim** has been developed in order to reduce the simulation time in the ATLAS calorimeter system. It can be **tuned** against data, has been **validated** against the Geant4 based full simulation and has been **used since 2011** for large-scale MC production.

In order to meet the increasing physics demands on MC samples, the **Integrated Simulation Framework** (ISF) is being developed. It allows the flexible combination of full and fast simulation strategies in a single event to provide an **optimal balance** between precision and execution time, depending on the required accuracy.

The ISF is expected to be ready for production in 2013/2014 and **will be used for all simulations** and large-scale MC productions from **2015** onwards, when the LHC is expected to deliver a much higher integrated luminosity than today.

References

[1] The ATLAS Collaboration, *The ATLAS Simulation Infrastructure*, Eur. Phys. J. **C 70** (2010) 823–874

[2] S. Agostinelli et al., *Geant4 - A Simulation Toolkit*, Nucl. Instr. Methods Phys. Res. **A 506** (2003) 250–303

[3] Jörg Mechnich (on behalf of the ATLAS Collaboration), *FATRAS - the ATLAS Fast Track Simulation project*, J. Phys.: Conf. Ser. **331** (2011) 032046

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