The ATLAS Fast Monte Carlo Production Chain Project

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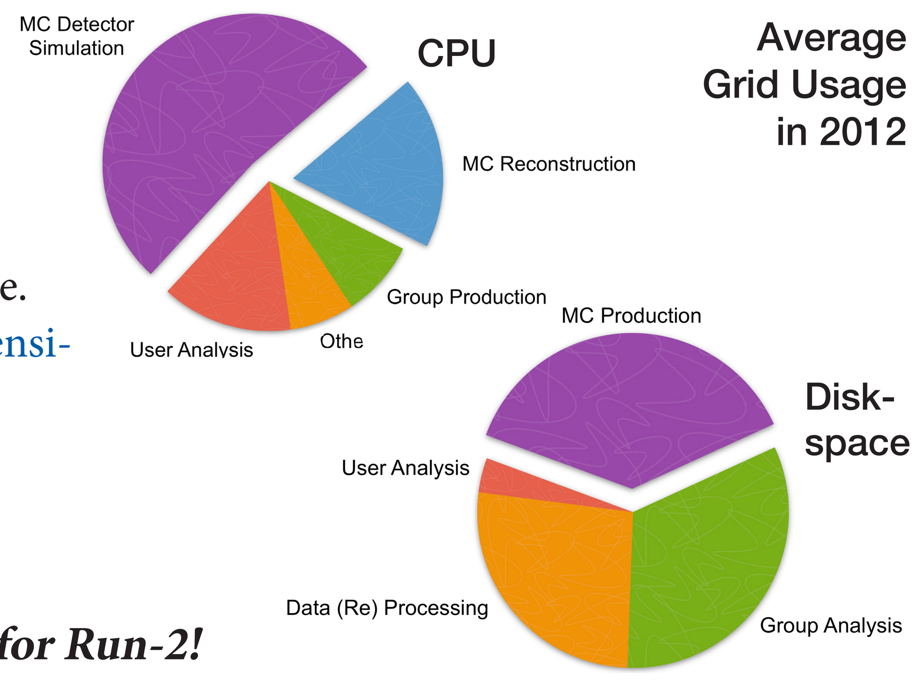
Summary: ATLAS's new integrated simulation framework (ISF) allows a flexible mixture of full and fast detector simulation techniques within the processing of one event. The therewith achieved possible speedup in detector simulation of up to a factor 100, makes subsequent digitization and reconstruction the dominant contributions to the Monte Carlo (MC) production CPU cost. In digitization due to the complexity to model the detector readout in detail and in reconstruction due to the combinatorial nature of the problem. Alternative fast approaches have been developed for these components, which are presented here. All components have been, together with the ISF, integrated into a new fast MC production chain, aiming to produce MC simulated data with acceptable agreement with fully simulated and reconstructed data at a processing time of seconds per event, compared to several minutes in full simulation.

A fast Monte Carlo chain

Why?

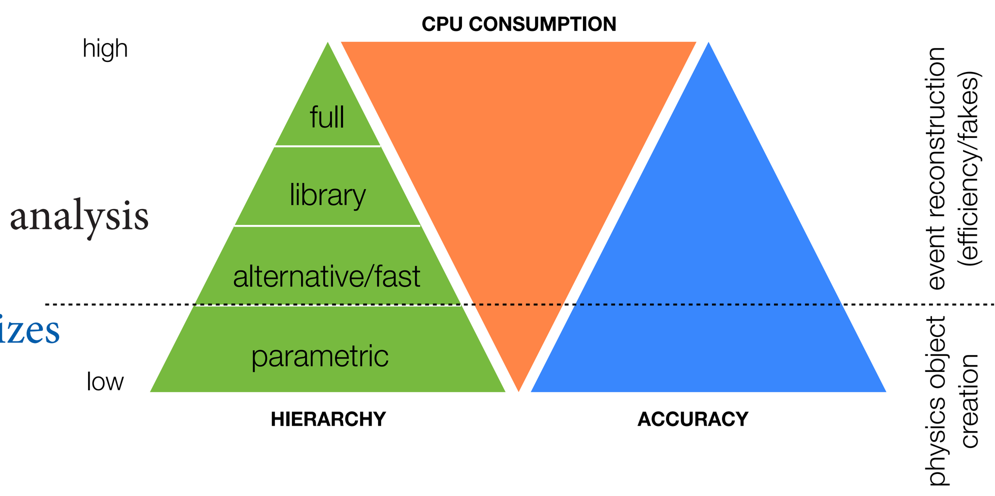
- **Grid CPU usage dominated by MC production.**
- Precise detector simulation is needed.
  ›› But highly CPU intensive!
- MC takes up large fraction of Grid disk space.
  ›› Limits available MC statistics, can limit sensitivity for physics analysis!
- Higher luminosity & pileup in LHC Run-2.
  ›› Larger MC production needed and bigger challenge for reconstruction!

..that's why a faster chain is necessary for Run-2!



How?

- **Resource usage dominated by accurate detector simulation, digitization & reconstruction.**
- Sacrifice some level of accuracy for speed by:
  - Use fast simulation approaches,
  - only fully simulate when needed,
  - use parametric digitization,
  - skip track reconstruction!
- And, go from event generator output to analysis input (ROOT files) in one go:
  ›› No intermediate output files (minimizes file I/O overhead and disk space)!



Event Generation → ***Fast* Detector Simulation** → ***Fast* Digitization** → ***Fast* Reconstruction** → **Analysis Input**

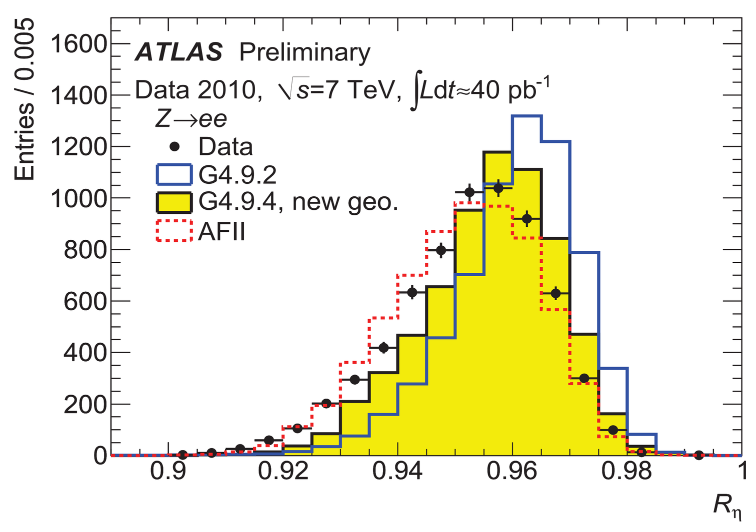
Fast Detector Simulation

- **Standard ATLAS simulator: Geant4.**
  ›› Stable, precise & fully validated simulation for Run-2.
- But, very high CPU consumption (up to 15 minutes/event).
  - Mostly in electromagnetic (EM) calorimeter.
  - Every microscopic particle interaction within detector material simulated.
  - Simulation of ~30M volumes.

Faster approaches:

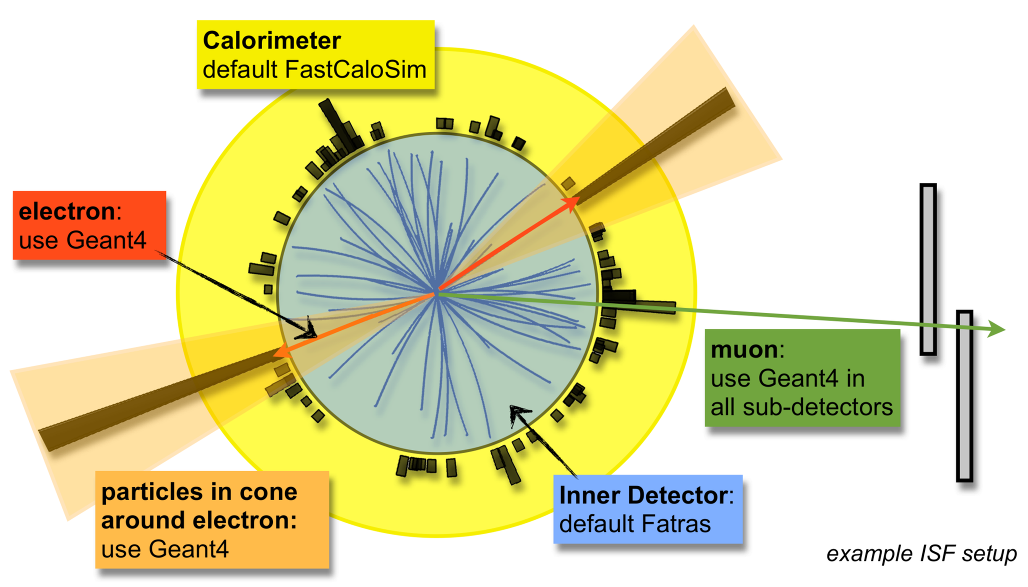
Frozen Showers: replace low-energetic particles in particle showers with pre-simulated Geant4 EM showers based on particle characteristics!

FastCaloSim: parametrize calorimeter response from full simulation and tune to data for EM shower shapes!



Fatras: fast simulation for tracking system, simplified detector geometry and interaction processes!

ISF: new ATLAS simulation framework – main feature:
use different simulation techniques within same event, i.e. depending on region or particle type.
›› Just simulate in detail what is really needed for physics:



Possible speedup in simulation when using ISF:

ISF simulation setup	Speedup	Accuracy
Full Geant4	1	best possible
Geant4 with FastCaloSim	~25	approximated calorimeter
Fatras with FastCaloSim	~750	all subdetectors approximated
Fatras with FastCaloSim simulate only particles in cones around photons	~3000	all subdetectors approximated event simulated only partially

$gg \to H \to \gamma\gamma$ no pileup

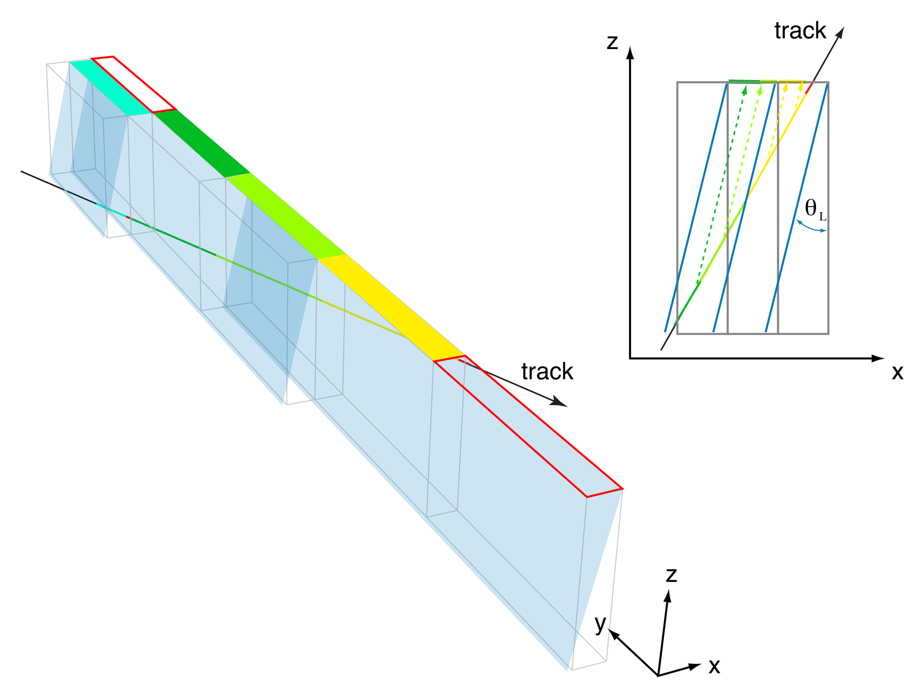
Fast Digitization

- **Digitization: from simulated hits to detector readout.**
  ›› Needs to be sub-detector specific and handle treatment of pileup correctly.
- ~50% CPU consumption from emulating Inner Detector.
- Linear dependence on pileup.

Faster approaches:

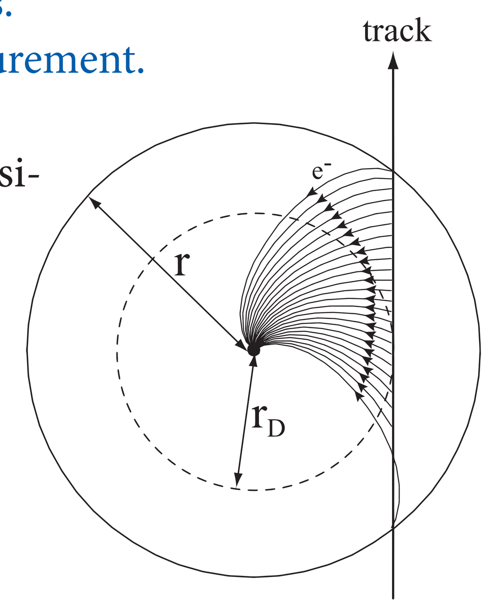
Silicon detector:

- Charge deposition estimated for each readout channel.
  ›› Simulated track length projected on readout surface.
- Correct for Lorentz angle drift ($\vec{E}\times\vec{B}$).
- Smear charge deposit to account for multiple scattering of drifting charge carriers.



TRT detector:

- Create TRT detector response from simulated hits.
  ›› Evaluate closest approach radius.
  ›› Determine uncertainty of measurement.
- Create smeared hit position.
- Additional parametrization of transition radiation (for particle identification).



References:

FastCaloSim: ATL-PHYS-PUB-2010-013
FATRAS: ATL-SOFT-PUB-2008-001
ISF: "ATLAS Detector Simulation in the Integrated Simulation Framework applied to the W Boson Mass Measurement" Ritsch, E., PhD Thesis
Truth based Reconstruction: CERN-THESIS-2013-194

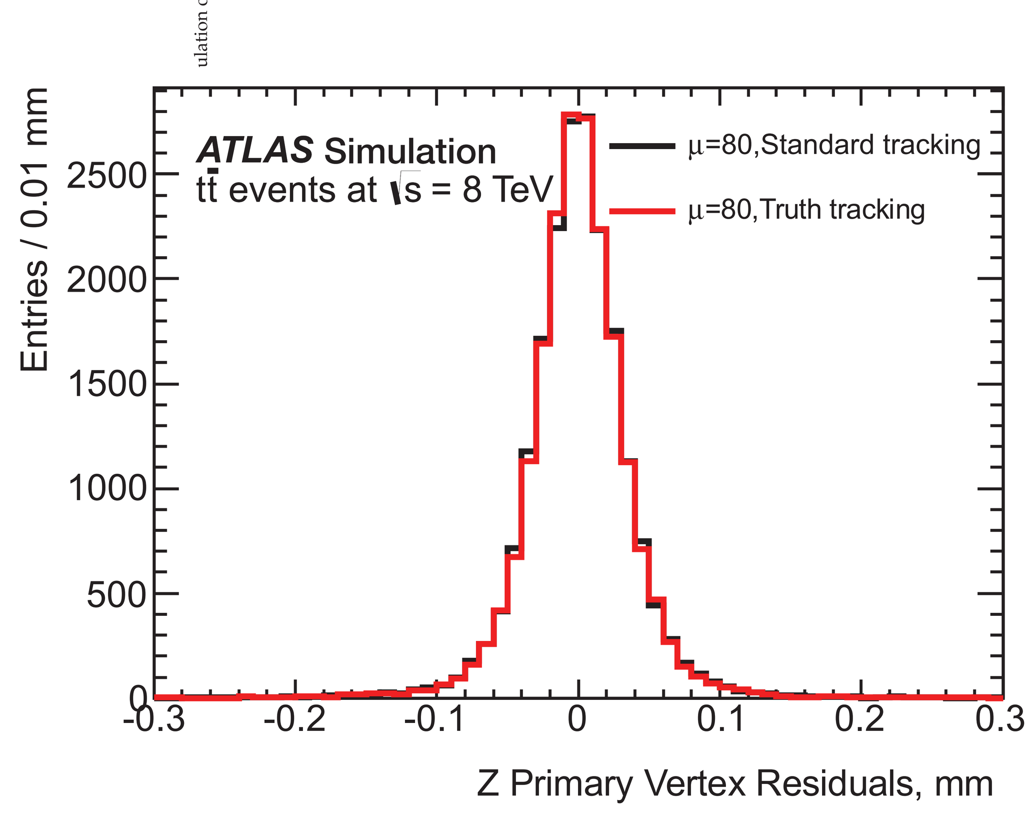
Fast Reconstruction

- **Reconstruction: find particles trajectories from digitized hits.**
- Significant CPU usage even in full MC chain.
  ›› Naturally combinatorial problem, explodes with high pileup!
  ›› Main consumer Inner Detector reconstruction.

Faster approaches:

- Need to preserve effects of reconstruction for signal event.
- Combinatorics only getting worse for high pileup.

›› Just skip most time consuming steps for pileup:
- Pattern recognition.
- Track seeding.
- Ambiguity treatment.



›› How? Reconstructed track from MC truth directly!
- Manipulate these tracks to mimic default reconstruction effects and selections.
- Still run default reconstruction on signal event.
- Result: good agreement with standard reconstruction & significant speedup!