Simulation of physics in the presence of pile-up at the ATLAS experiment

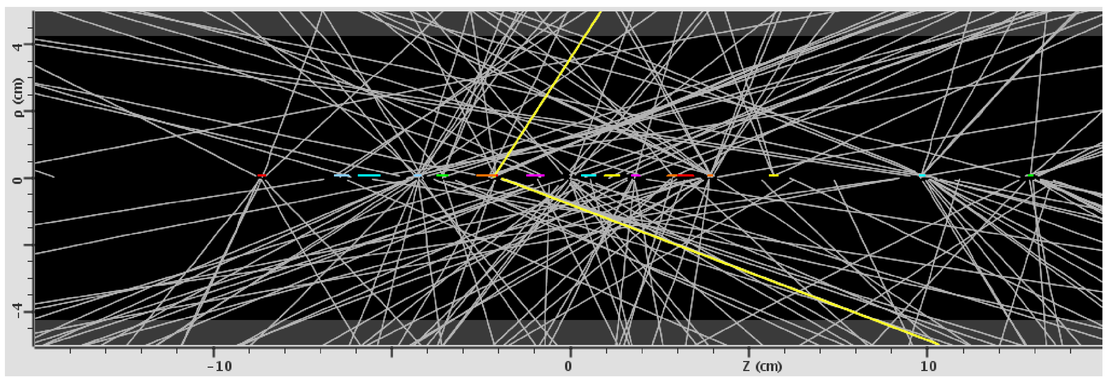
Andrew Haas, for the ATLAS Collaboration

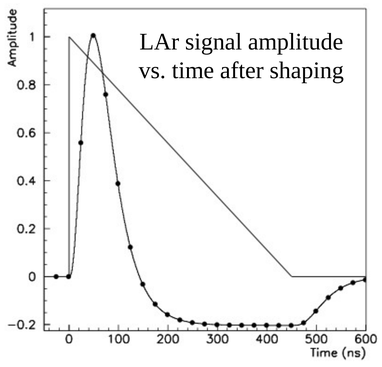
NEW YORK UNIVERSITY

CHEP 2012
21-25 May 2012
New York City, NY, USA

Introduction

~30 proton-proton collisions per filled LHC bunch crossing in 2012 – called "pile-up".
More pile-up expected in the future, up to 400 in some Super-LHC projections.





Detectors are sensitive to many bunch crossings in the past or future, 1000's of pp collisions for one event.

Subdetector	Simulation window [ns]	No. Bunch crossings (25 ns bunch spacing)	No. Bunch crossings (75 ns bunch spacing)
BCM	−50, +25	4	1
Pixel trackers	−50, +25	4	1
SCT	−50, +25	4	1
TRT	−50, +50	5	1
LAr calorimeter	−801, +126	38	12
Tile calorimeter	−200, +200	17	5
Muon chambers	−1000, +700	69	23

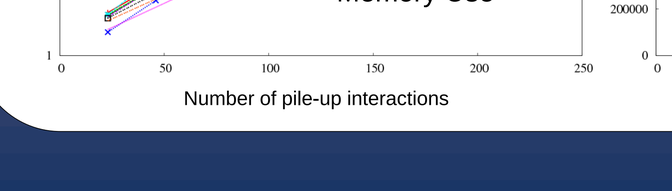
Simulated Pile-up

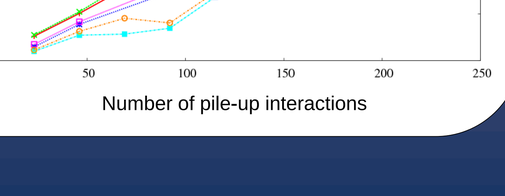
Minimum-bias pp events are generated with Pythia (6 or 8) and simulated with Geant4.
"Cavern background" also simulated using special generators and Geant4.

PileUpTools approach: To avoid having too much information in memory at once, background truth information is pre-filtered down to the bare-minimum (vertex position and truth jet 4-vectors) and digitized from one bunch-crossing at a time.
Algorithm approach: Create a cache of minimum-bias events in memory, so they can be re-used. A minimum-bias event is replaced in the cache depending on its use:

Background Type	In-time/Out-of-time	Replacement Probability
High pT Minimum Bias	Both	100%
All	In-time	100%
Low pT Minimum Bias	Out-of-time	~1% (tunable)
Cavern Background	Out-of-time	~1% (tunable)

Average number of minimum-bias events in each bunch crossing can vary in data.
There is also a non-trivial bunch structure in data.

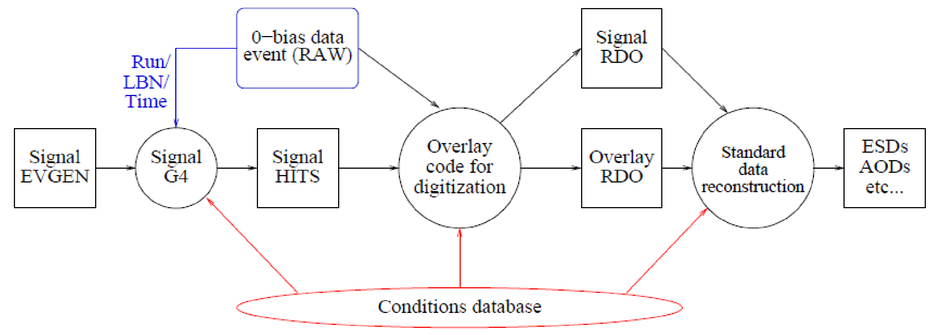




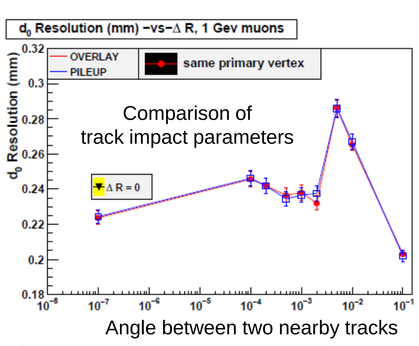
Need to simulate ~200 pp collisions per filled bunch crossing for upgrade studies.
Memory is conserved, to stay below effective 32-bit limit of ~3 GB.
CPU time was dominated by random number generators, recently optimized.

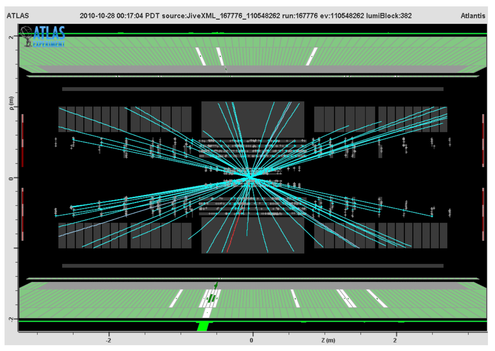
Overlay on real data

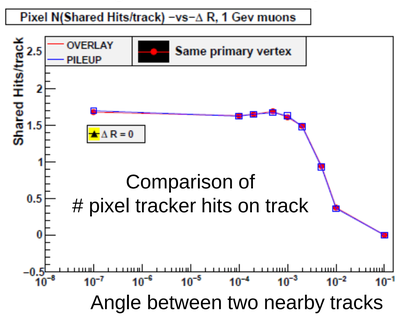
Uses a single data event, recorded with a special zero-bias trigger, to model all pile-up.
Trigger event from hard-scatter process is simulated using Geant4 and overlaid.
Simulated event must use data geometry, alignments, magnetic field, and beam-spot corresponding to the selected zero-bias data event.
Automatically includes cavern background, detector noise, full bunch structure, non-uniform bunch luminosity, and detector conditions (dead channels, etc.)

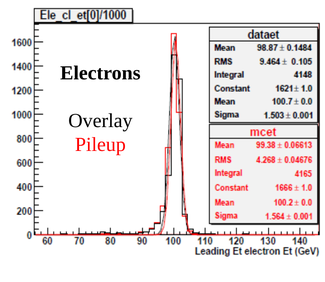


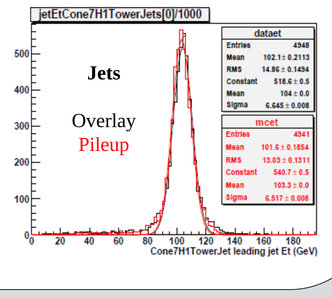
Zero-bias trigger fires one proton revolution after a (pre-scaled) high-pt trigger.
Events are selected offline into datasets of 50k events, with proper luminosity profile.











Performance

Data from calibration samples are compared to simulation, for various amounts of pile-up.

Data is also compared to simulation as a function of position in the bunch structure, to test the modeling of in-time vs. out-of-time pile-up.

Overall good agreement of simulated pile-up and data, up to ~20 pp / crossing.