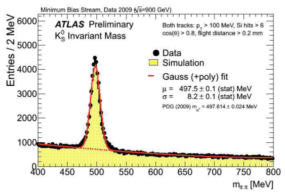
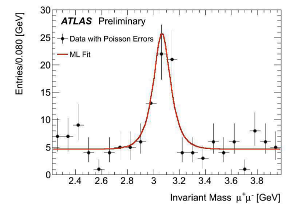


After rediscovering the physics of the fifties (K0s, L) and seventies (D*,J/Ψ)



Adele Rimoldi

University of Pavia & INFN

on behalf the ATLAS Collaboration

SIMULATION STRATEGIES FOR THE ATLAS EXPERIMENT AT LHC

Outline

- The ATLAS Detector
- Simulation
  - Flow
  - Current state
  - Core
  - In numbers
- Fast simulations with examples
- Simulation/Data
  - Matching
  - tuning
- Digitization Pileup and Overlay
- Conclusions

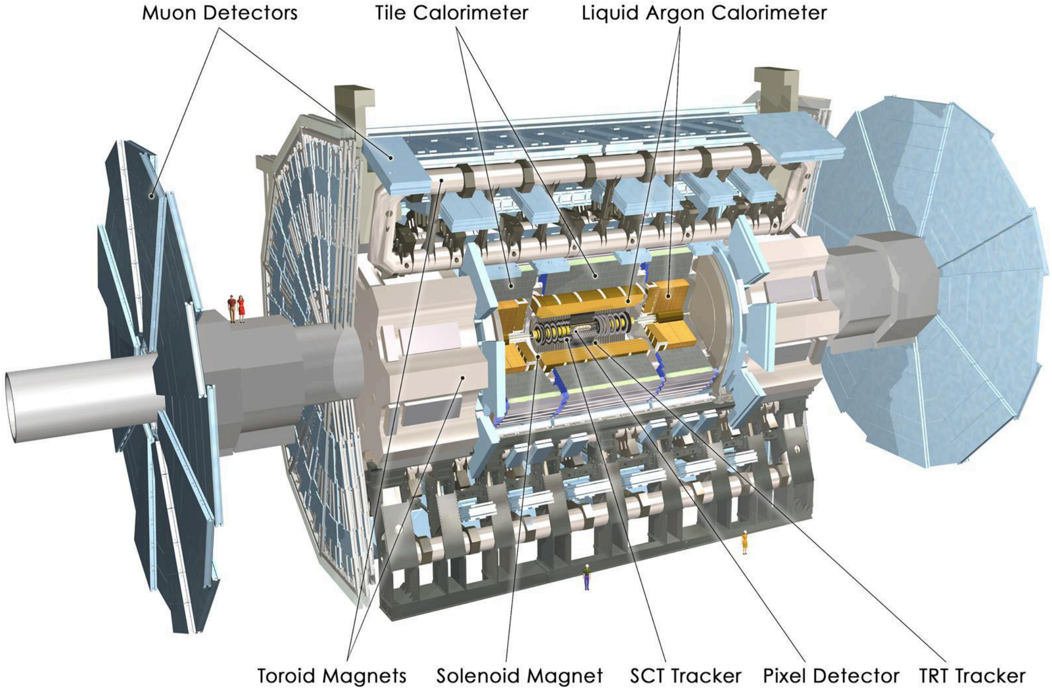
ATLAS

General purpose detector designed to cover all the expected physics channels at LHC using p-p collisions with energies up to 14 TeV and Pb-Pb collisions at 5.5 TeV/nucleon

weight ~ 7000 tons
height 25m
length 46m
~10^8channels

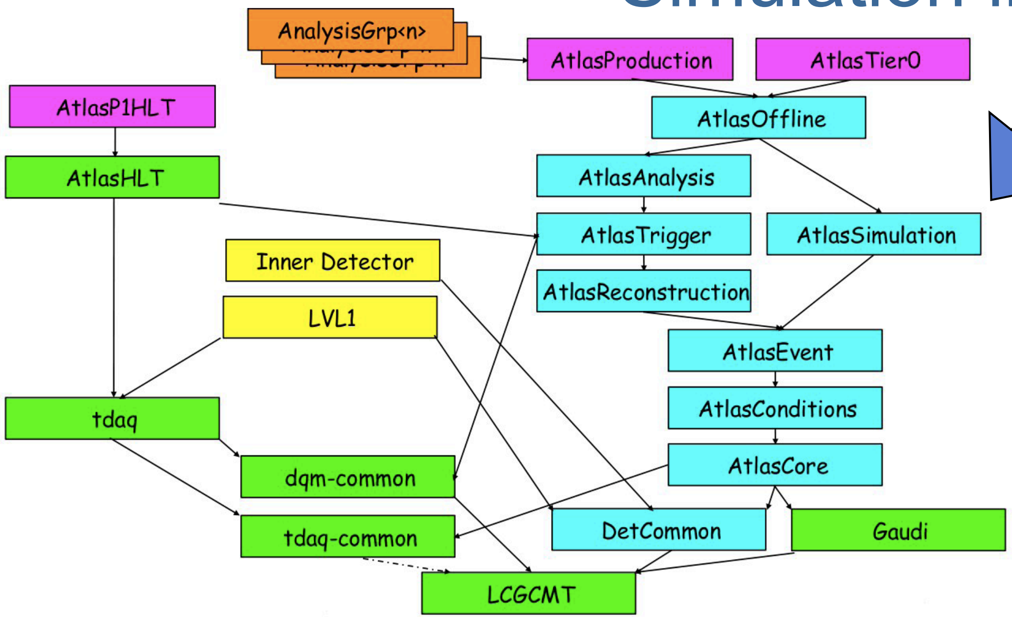
ATLAS Detector Status

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.5%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	98.0%
LAr EM Calorimeter	170 k	98.5%
Tile calorimeter	9800	97.3%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
LVL1 Calo trigger	7160	99.8%
LVL1 Muon RPC trigger	370 k	99.7%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	98.5%
RPC Barrel Muon Chambers	370 k	97.3%
TGC Endcap Muon Chambers	320 k	98.8%



The experiment performs according to design specifications and the understanding of the detector response and MC tools is extremely good and beyond expectations for this early phase

Simulation in ATLAS



Simulation is a component of the ATLAS Software Project and uses the GEANT4 simulation toolkit

The Simulation software is being used for large scale productions on the LHC Computing Grid

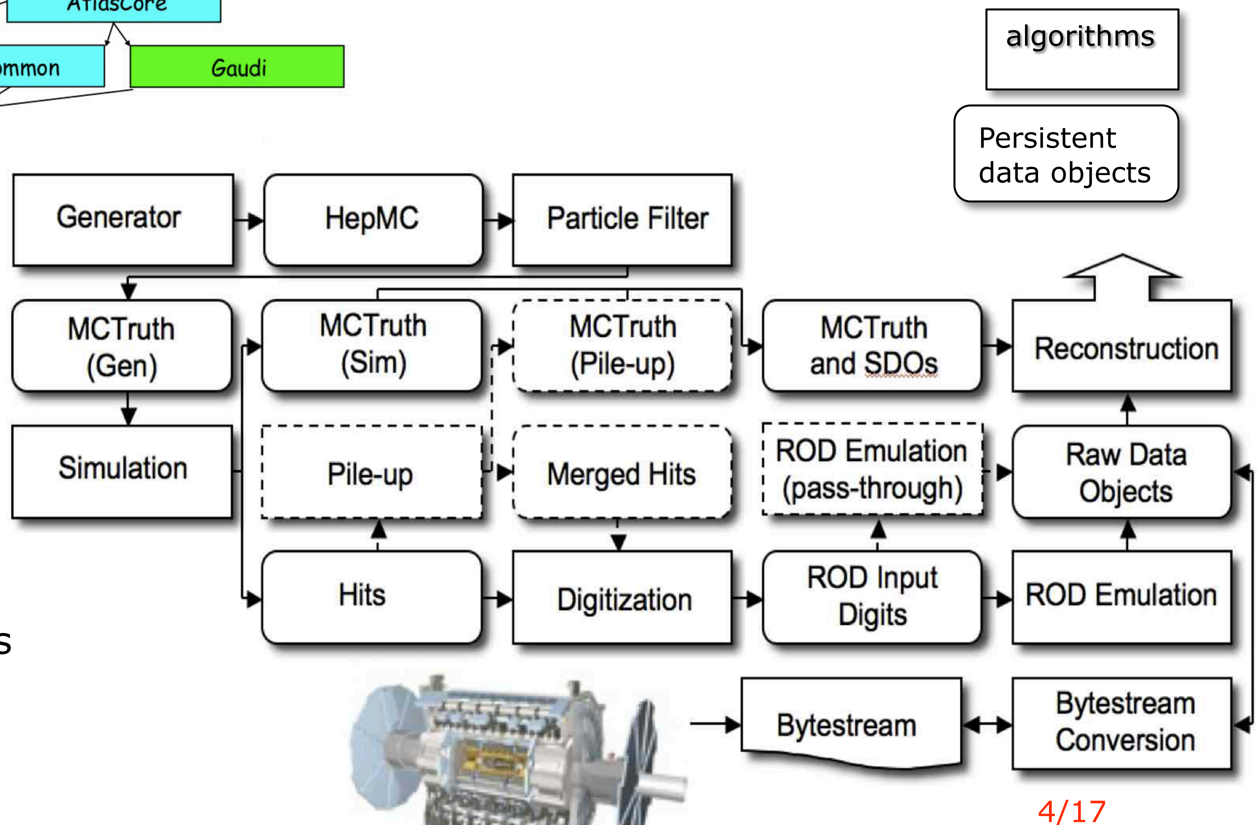
main steps

event generation

physics and detector response

digitization of physics quantities

output



ATLAS Simulation in the current state

- Event generation with ~40 generators available, tested and used
  - Each event contains particles from a single interaction with vertex at (0,0,0), beam properties being applied at a later stage before being passed through GEANT4
- Physical construction parameters and conditions data are contained in databases to allow an identical description for sim/digi/reco and connected @runtime
  - Test stand layouts
  - Installation configurations (as alternate layouts in the commissioning phase)
  - Data-taking set-up
  - Full detector + forward detectors
  - Misalignments, material distorsions, extra-materials allowed and described
- Fast simulations are set to optimize the necessary limited computing resources needed to model the complexity of both detector and physics
  - Fast calorimetry
  - Fast tracking
- Full simulation, in production these days, now uses GEANT4.9.2.p2.a4

  (Fixes to the main versions provided by GEANT4 team (p) and ATLAS team (a))
  - Atlas Software release 15.6.12.5/ Geometry release ATLAS_GEO-16-00-00/Conditions data OFLCOND-SRD-BS7T-02

ATLAS Core Simulation

- Detector geometry built in GEANT4 format
- Event flow is monitored in the general framework (ATHENA)
- Physics models chosen and parameters optimized
  - Wide range of physics lists, range cuts,..
- Python interface used for configuration
- Several GEANT4 classes are wrapped in a specific *simulation-framework* to allow selection and configuration with precompiled libraries
- detector description with PYTHON dictionaries and simulation-framework catalogues available to the user before building the application
- ATLAS and GEANT4 are closely connected communities through development and validation since many Years

ATLAS Simulation in numbers

Language	Files	Comments	lines
C++	930	24,000	120,000
FORTRAN	270	15,000	42,000
C/C++Header	1,100	13,000	34,000
Python	430	16,000	27,000
HTML	62	130	15,000
Bourne Shell	390	1,000	7,300
C shell	380	210	3,800
XML	52	1,200	3,400
Sum	3,600	70,000	250,000

project	C/C++ code	C/C++ headers	Python code	Total code
Core	390,000	43,000	240,000	860,000
Event	200,000	110,000	16,000	350,000
Conditions	280,000	90,000	21,000	620,000
Detector	38,000	6100	8400	140,000
Sum	910000	250,000	280000	2,000,000

Total memory to build the ATLAS detector in memory (MB)	Subsystem	Materials	Solids	Logical Volumes	Physical Volumes	Total Volumes
	Beampipe	43	195	152	514	514
	BCM	40	131	91	453	453
22	Inner detector	243	12,501	18,440	56,838	1,824,614
44	Calorimetry	73	52,366	35,864	182,262	1,557,459
32	Muon System	22	33,594	9,467	76,945	1,424,768
98	ATLAS Total	327	98,459	63,769	316,043	4,806,839

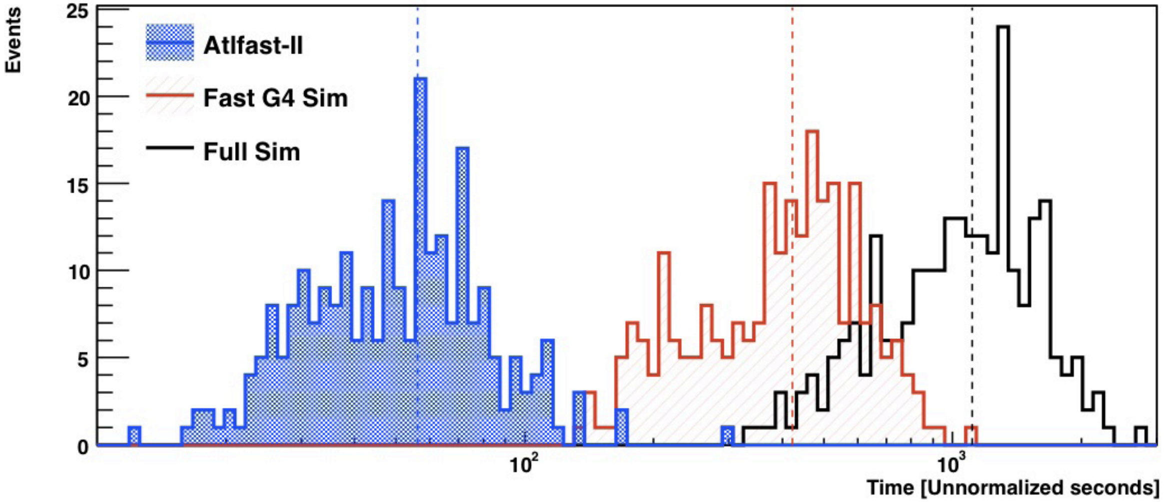
ATLAS Fast simulations

For some studies more statistics or faster turn-around are needed

CPU time consumption reduction by adopting fast simulations in critical productions

- ATLFAST-I
  - developed for physics parameter space scans — MC Truth
  - objects smeared by detector resolution
- ATLFAST-II
  - uses parameterised particle showers (FastCaloSim) and simplified detector description tracking (FATRAS)
- FAST G4
  - Standard full simulation uses pre-simulated shower libraries (energy 1 GeV->10 MeV) and single hit energy depositions at lower energy

ttbar events



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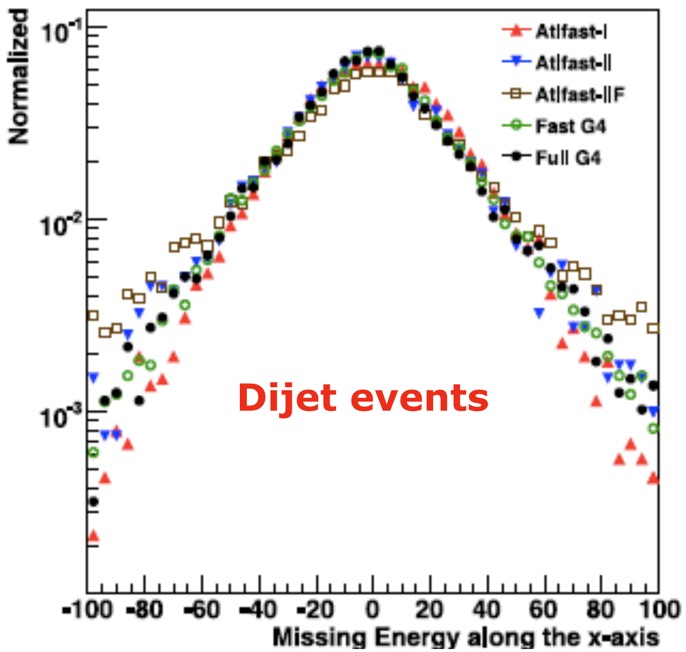
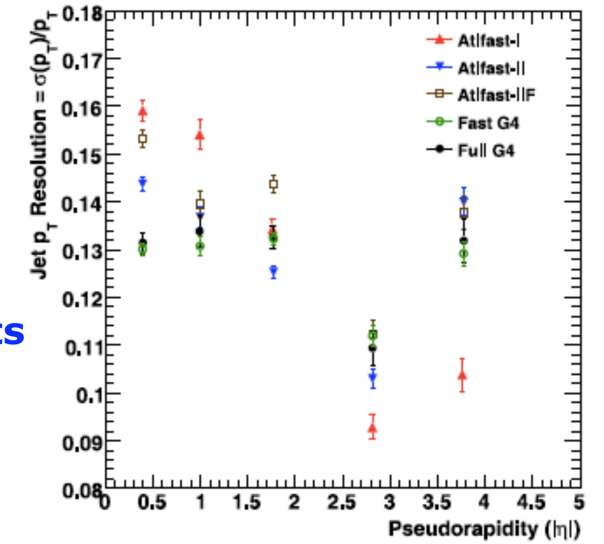
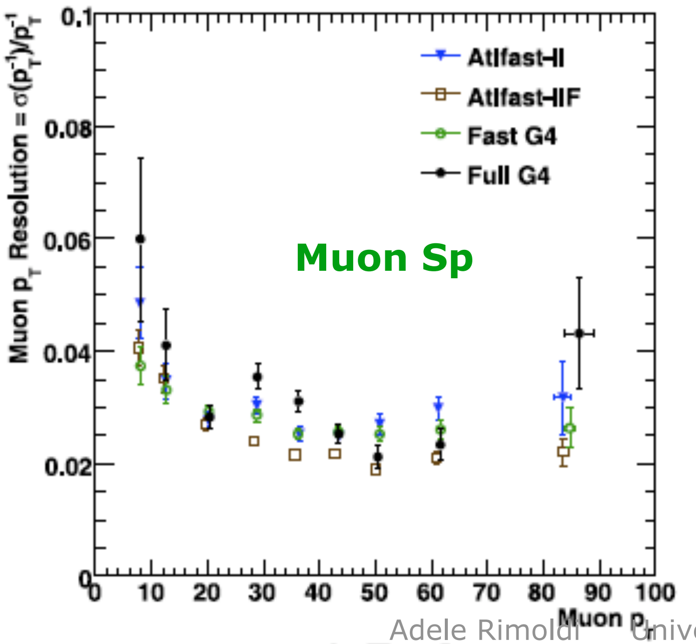
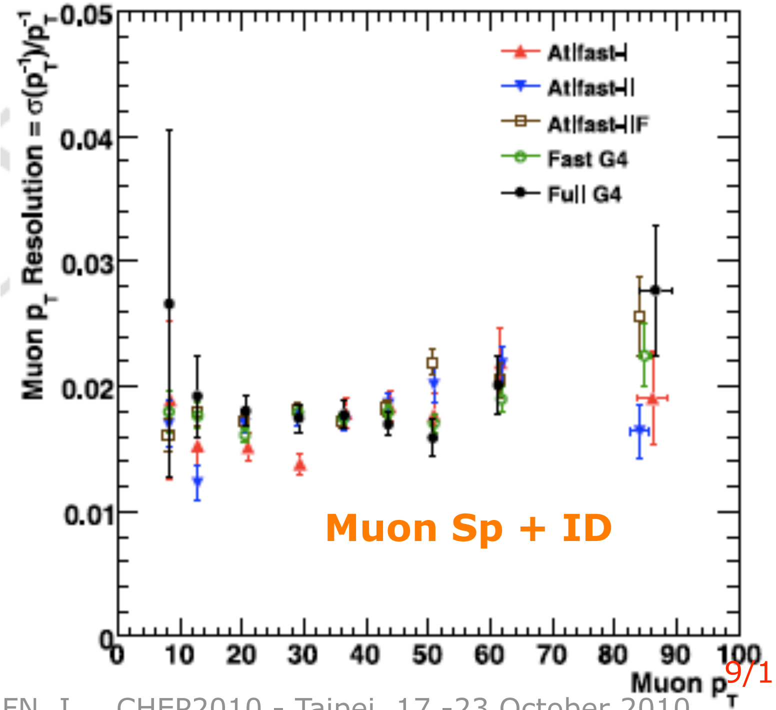
Atlas Fast Simulations vs.fullSim



ttbar events



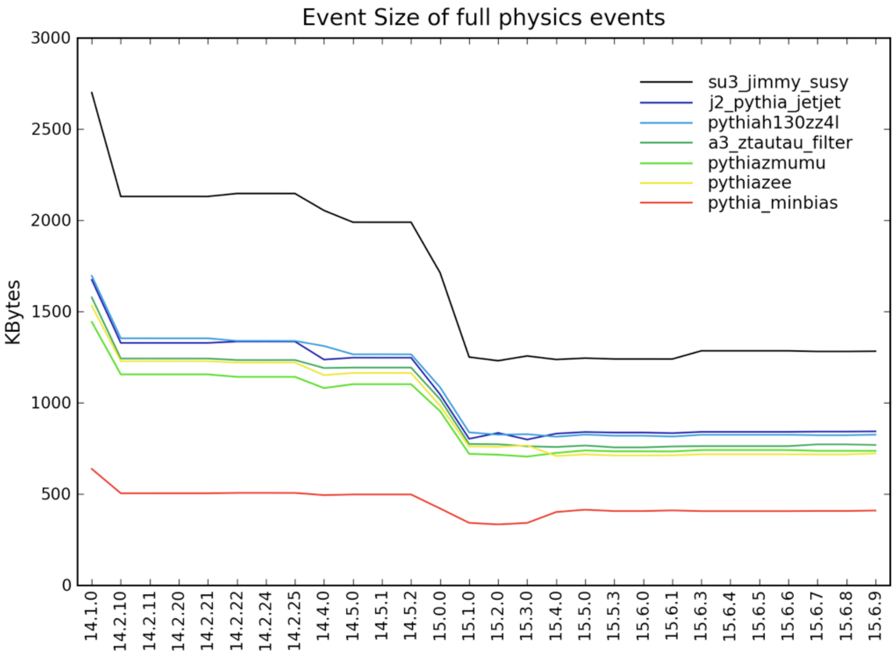




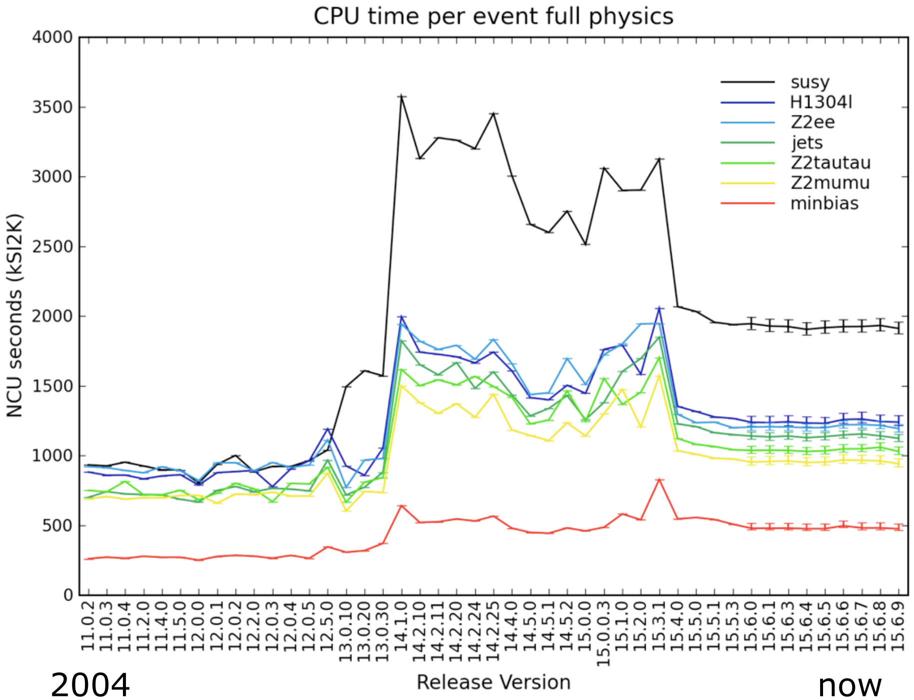
Simulation as an evolving Project

Optimize use of disk space and CPU time vs. time since the inception (~2001)

Metadata + hits for each subdetector constitute the output file of simulation

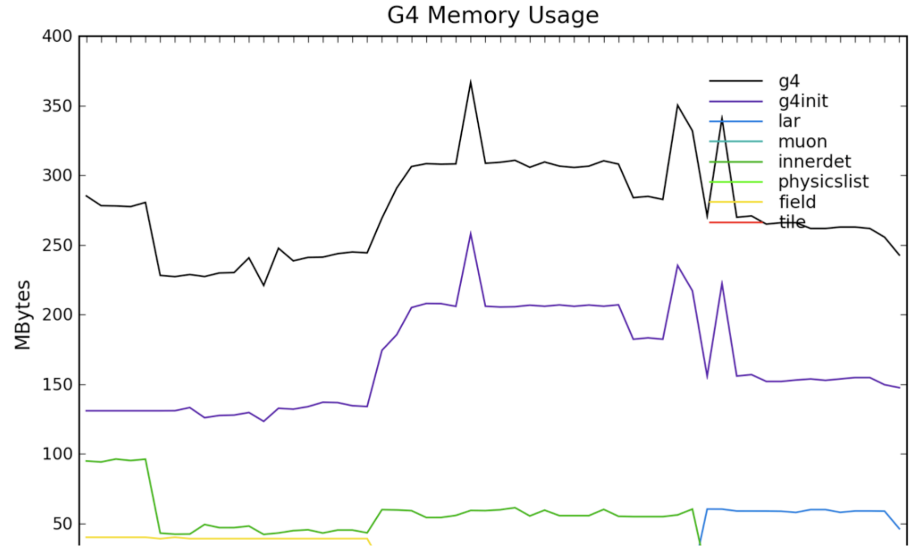


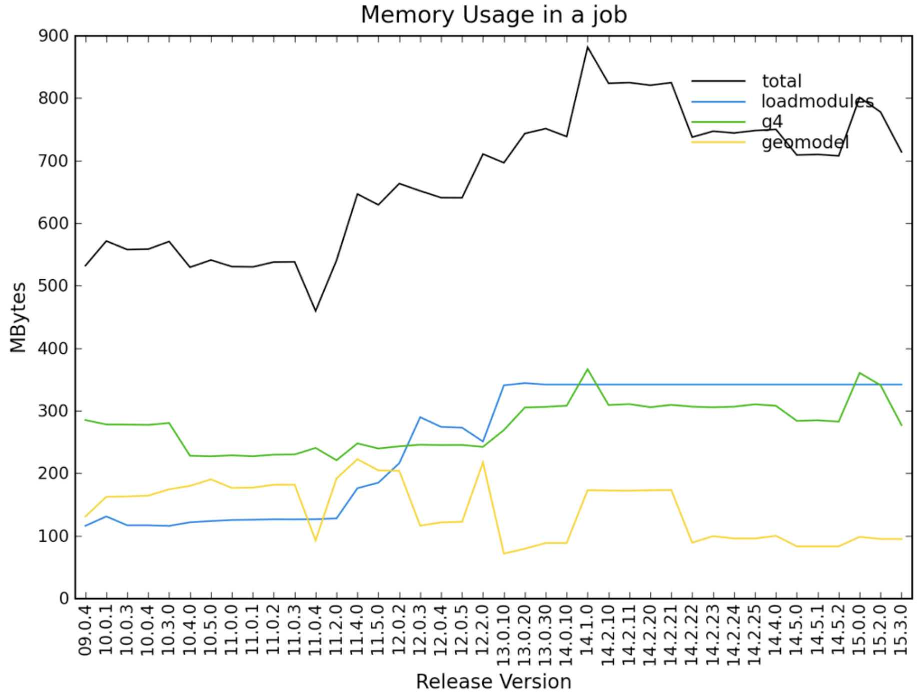
2007 now

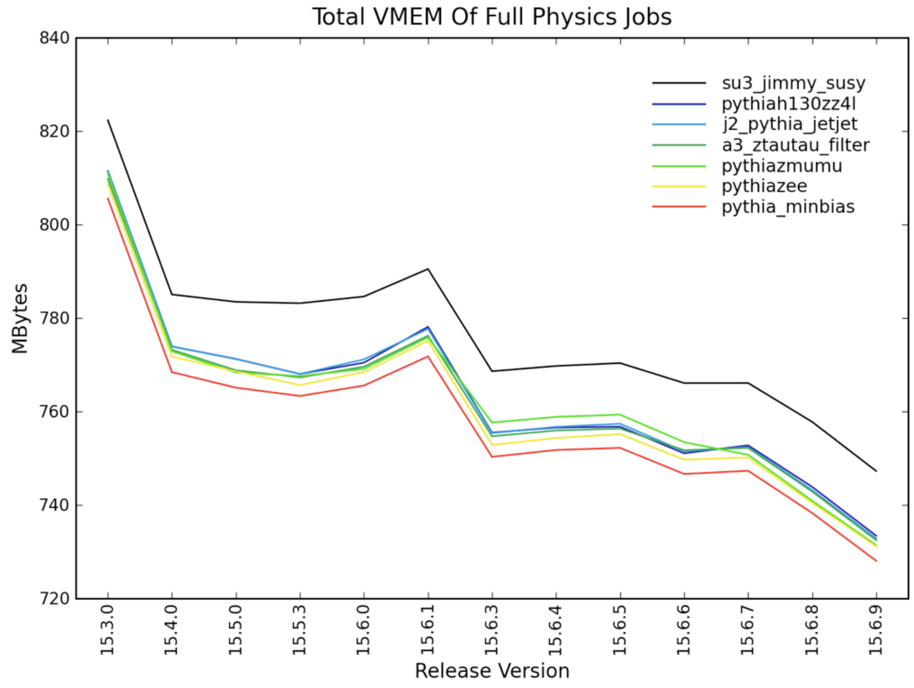


2004 now

Simulation Validation





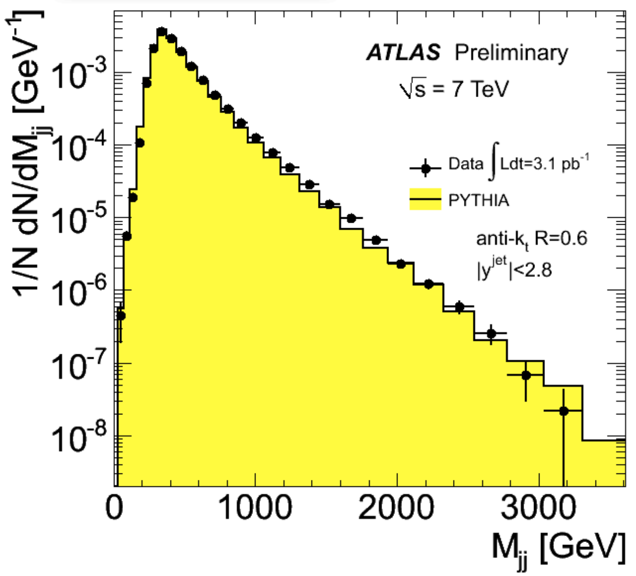


Simulation / Data matching

Comparison Dat-MC at 7 Tev through
 2 examples

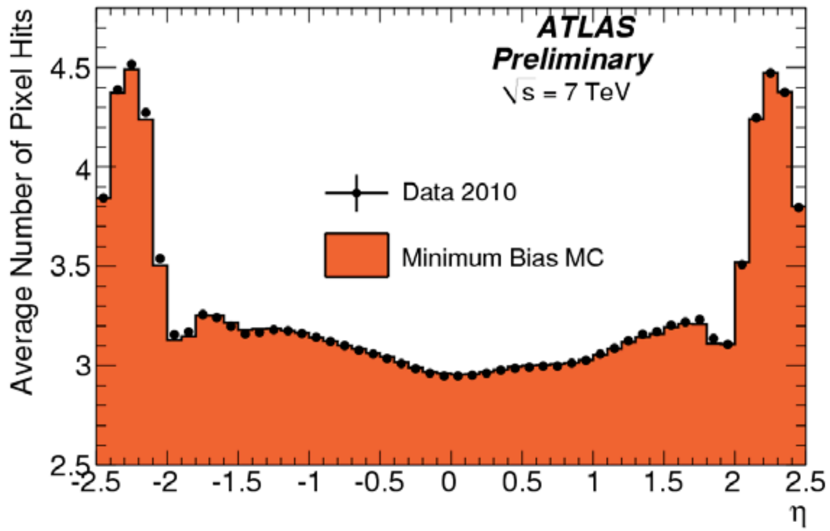
Jets reconstruction

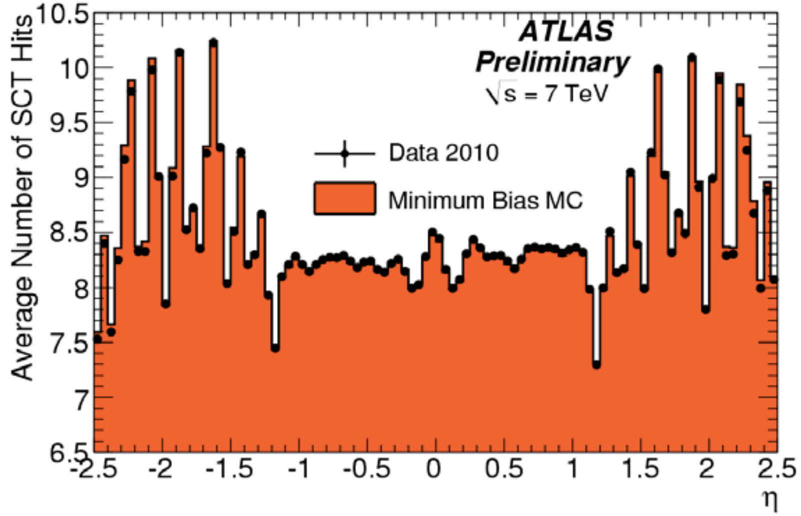
Dijet invariant mass distribution for jets with leading jet p_T(jet)>160 GeV and second jet >30 GeV, lumi~1pb^{-1}, |y|<2.8



Track variables

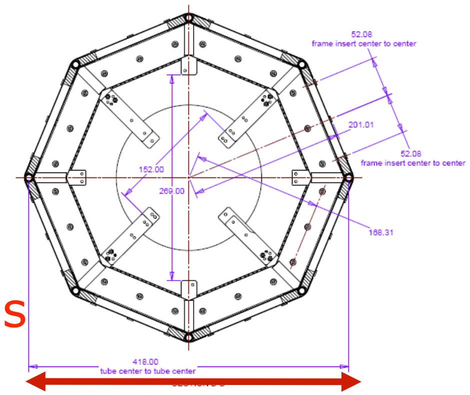
all detectors are included as well as the beam spot
Excellent agreement



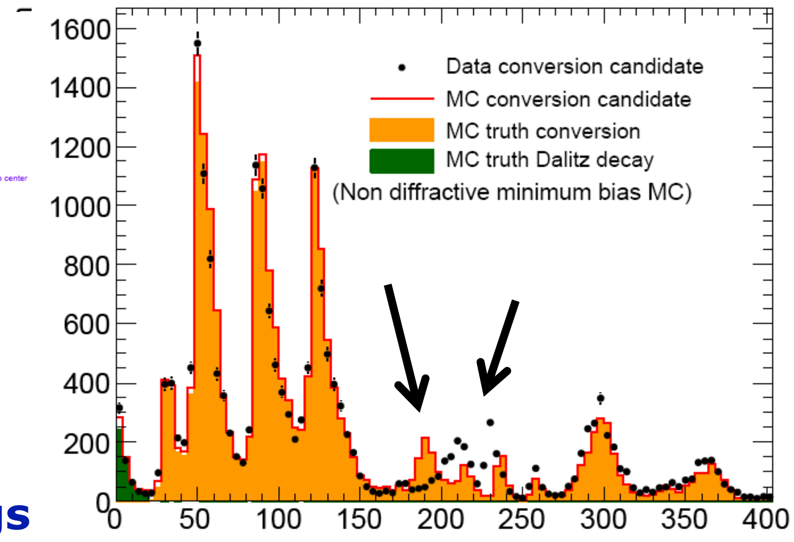


Simulation tuning to data

In geometry



Photon conversion radius
Data/MC comparison



Incorrect radius

Description updated according to drawings

And we also found a Geant4 energy non conservation..

Sample J0 (Pt < 14GeV):

Jet1: 67GeV Jet2: 55GeV

No truth particles matching the two jets

Energy not conserved in photon interaction in G4 γ+Pb → X+ π^+ π^-

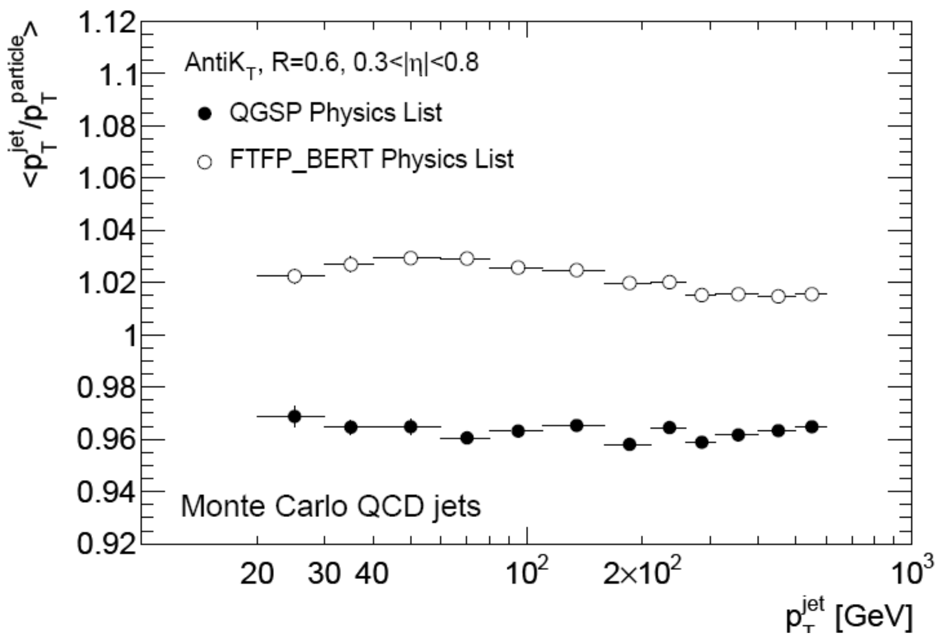
Another interesting case: π^++He → X+pp (**47TeV** each) (Minimum bias sample)

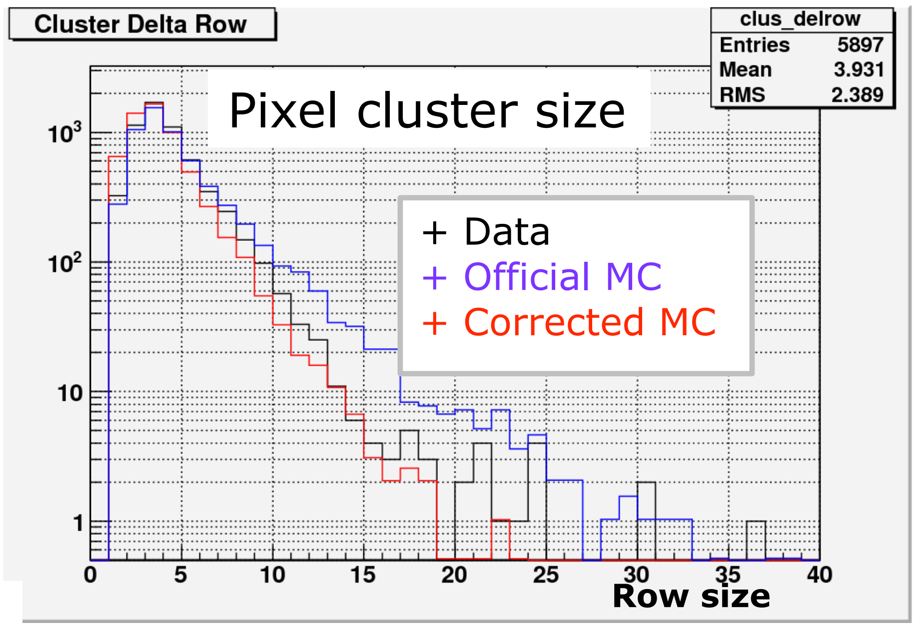
Geant4 team produced patches for these

Simulation Parameters Tuning

Comparison of jet energy response using different physics lists:

ATL-COM-PHYS-2010-404





Delta rays with E<7KeV not propagated in G4

Simulate MB events with different delta ray cuts in Silicon detectors

Digitization Pile-up and Overlay

- Subdetector response contains
  - Cross talk, Electronic noise, Channel dependent variations
  - Digitization algorithms tuned to data (test-beams, cosmics ray runs)
- Top level PYTHON digitization package to steer digitization
- Raw Data Object produced per subdetector
- Tuning ongoing at subdetector level
  - Chamber efficiency, cross talks efficiency, average readout efficiency, access to detector conditions for dead channels, …
- Beam-gas, beam-halo, cavern background (neutron haze), additional interaction off-time are all overlayed to hard scattering events (pile-up, overlay)

Simulate all processes in MC and mix together in proper ratios with realistic timing	Simulate signal process in MC and overlay a "random" data event to include all backgrounds
done	**in progress**

Overlay

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Use 0-bias triggered events from a well defined data period

Simulate events with the same conditions

Merge data and MC and produce a data-like event to reconstruct

Status:

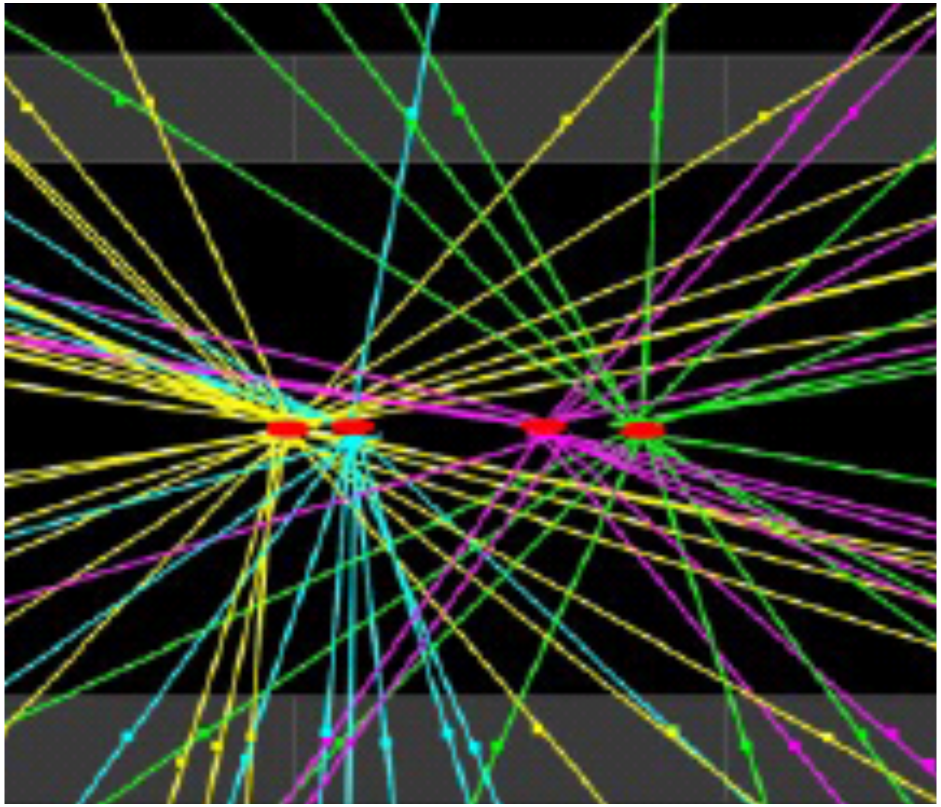
0-bias event selection almost ready (to be tested in production)

Need to avoid overlaps in AtlasG4 misaligned simulation

Use realistic conditions for muon Digitization

Example: 4 data events overlay

(to simulate a crossing with 4 collisions)



To be deployed shortly

Conclusions

Simulation is very close to data	
Production	in progress 1 Million events/day
Optimization	not over
New Geant4	under test
Pileup/overlay	ready/advanced deployment
Fast Simulations	in validation phase
Forward detectors	deployed
Documentation	ATLAS Simulation Paper arXiv:1005.4568 Submitted to Eur. Phys. J. C
Ongoing activity	development and improvements