ATLAS Geant4 Simulation Update

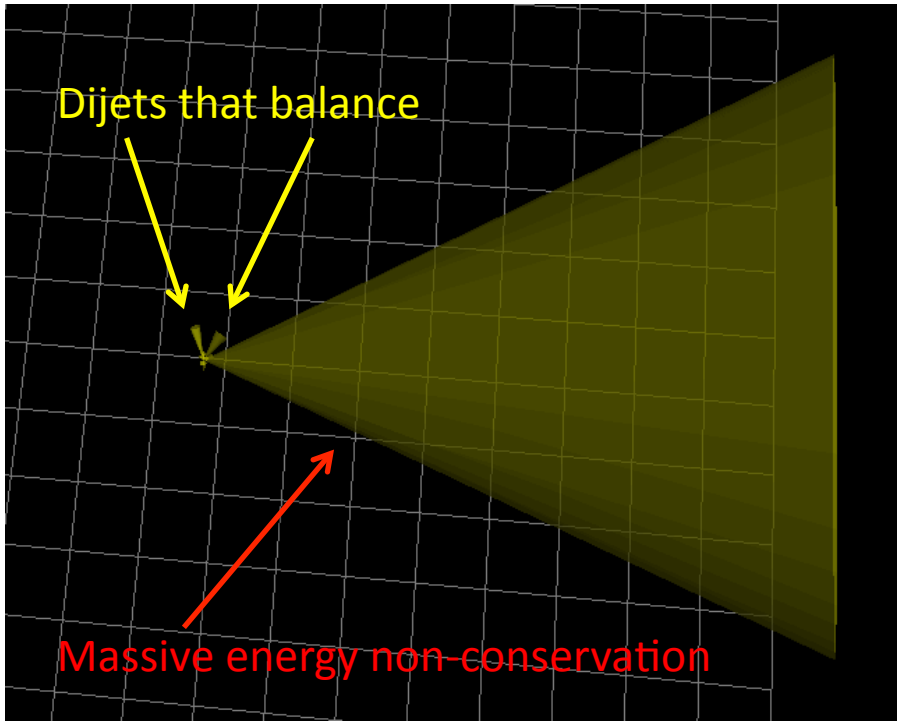
Zach Marshall (CERN)
For the ATLAS Sim Team
G4 Tech Forum, 27 March 2012

General Status

- Currently launching MC12 production campaign
  - ~3500M events will be produced (2000M G4 only, 1500M G4-hybrid)
  - G4 9.4 p3 in production, from G4 9.4 p1 in MC11
- Understood the desire to develop only FTFP_BERT
  - ATLAS is validating the move from QGSP_BERT in MC12
- Developing for MC13, expect freezing around ~Dec.
  - Anticipating using G4 9.5, possibly with G4 internal CLHEP version (if ATLAS doesn't move to 2.X in time)
- Major infrastructure revisions underway
  - Integrated Simulation Framework to combine Geant4 simulation with "fast" simulation flavors in the same event
  - Will feed back to G4 developers any interesting issues that arise during development and benchmarking (G4 developers on the review team)
  - Hoping to take advantage of the parallel geometry developments and some other parallelism developments that have come up in G4 – but memory is still not an issue for us, so large-scale parallelism is not yet necessary.
- Still, the finalization of MC12 took us quite a while…

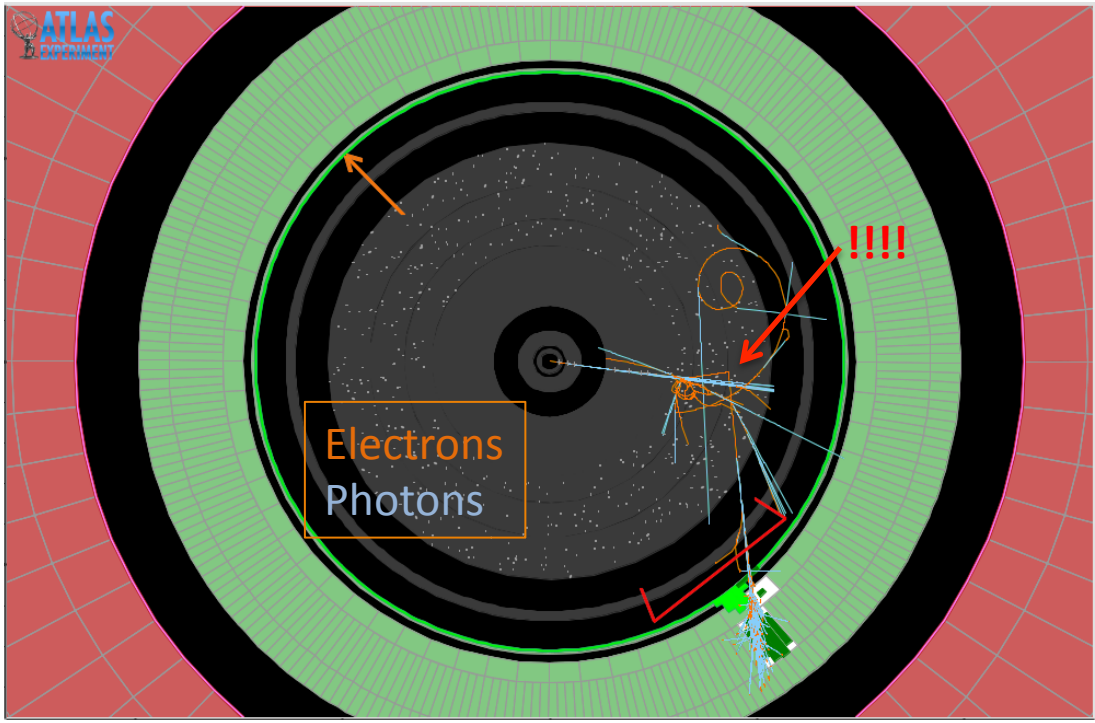
Energy Non-Conservation

- Discovered in a simple QCD event an anti-proton annihilating, producing ~1 TeV of secondaries
- Since then, found 18 other cases in MC11 (1500M events)
- Traced down to a bug in CHIPS when anti-protons annihilate on carbon, nitrogen, or oxygen
- This rate is almost below threshold for us (though it is unfortunate)
  - Bugs happen, we get it, and this is not one we expected G4 to find
- Our concern is the CHIPS code status
  - Are there enough developers and maintainers? People who understand the code?
  - If there aren't, do we need to find alternative models?
  - Seen more frequent low-energy (GeV) violations – are we protected?



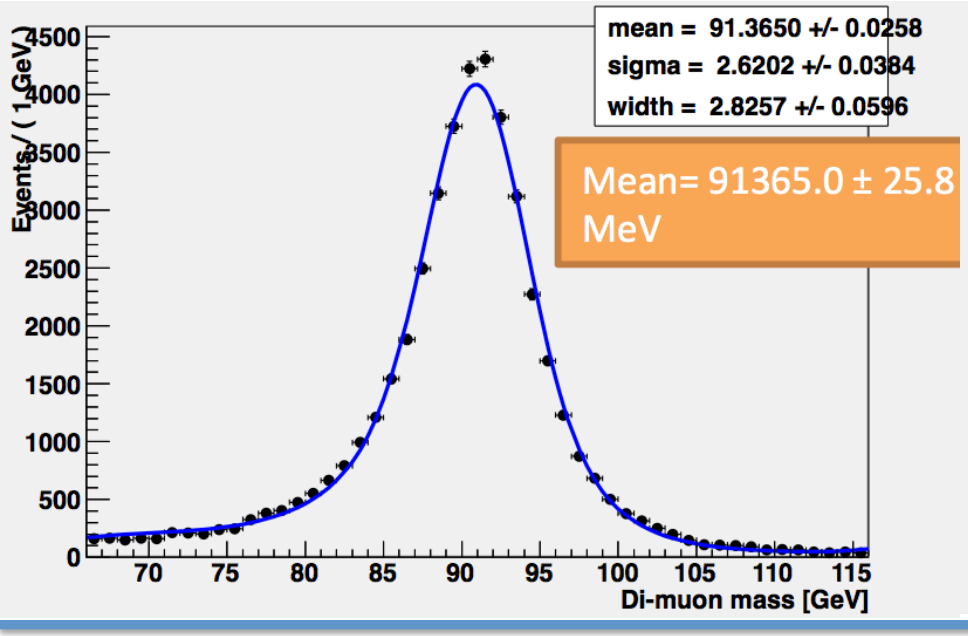
Electron Multiple Scattering

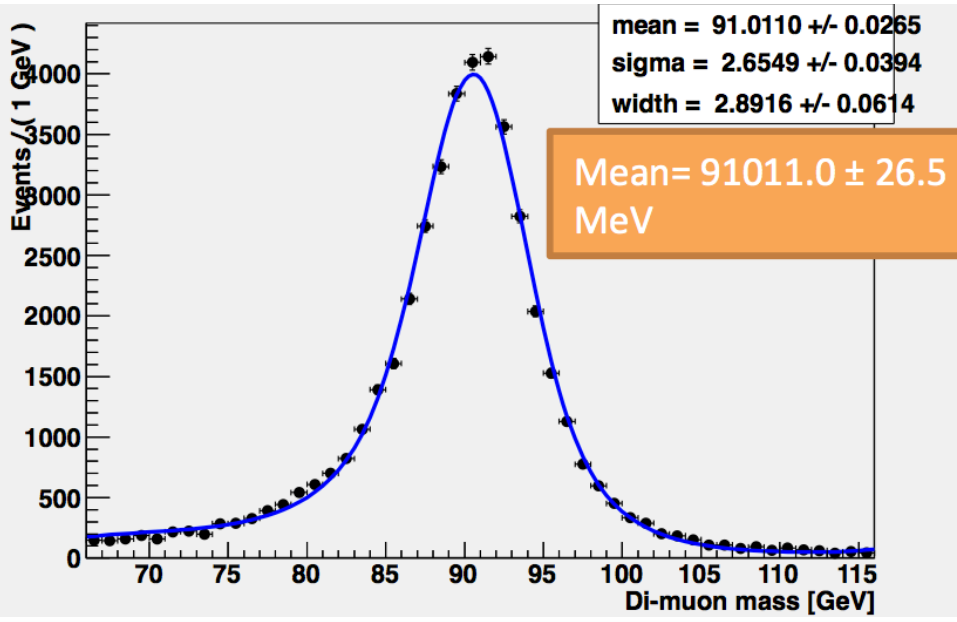
- Some rather shocking cases of large-angle multiple scattering with moderate-energy electrons (10 GeV-ish)
- Much more common in certain non-standard detector layouts
  - Still studying the rate for standard conditions
  - With these modified conditions, as many as 20-30% of events contain these
- Still, observed with standard conditions at a low rate
- Traced to an issue in tail sampling in Urban Msc 92
  - Fixed quickly by Vladimir
- Not reported in G4 9.2, and seems consistent with the 1-2% efficiency change seen moving to G4 9.4 (we think)
  - Perhaps points to a need for more complex test setups?
  - Our detectors test a lot of edge effects…



Muon Multiple Scattering

- 350 MeV shift in Z-mass scale discovered between last production and now
- Traced down to the difference between Wentzel + coulomb scattering (left) and Urban scattering (right) models (bug in Wentzel)
- Moved back to Urban for MC12 production to ensure proper scale
- Generally we expect "set physics lists" to not change; this was an exception
- We must be more careful about release notes, but I hope the G4 experts will also take care to point out any potential issues as we change releases
  - Particularly important when underlying models change!!!



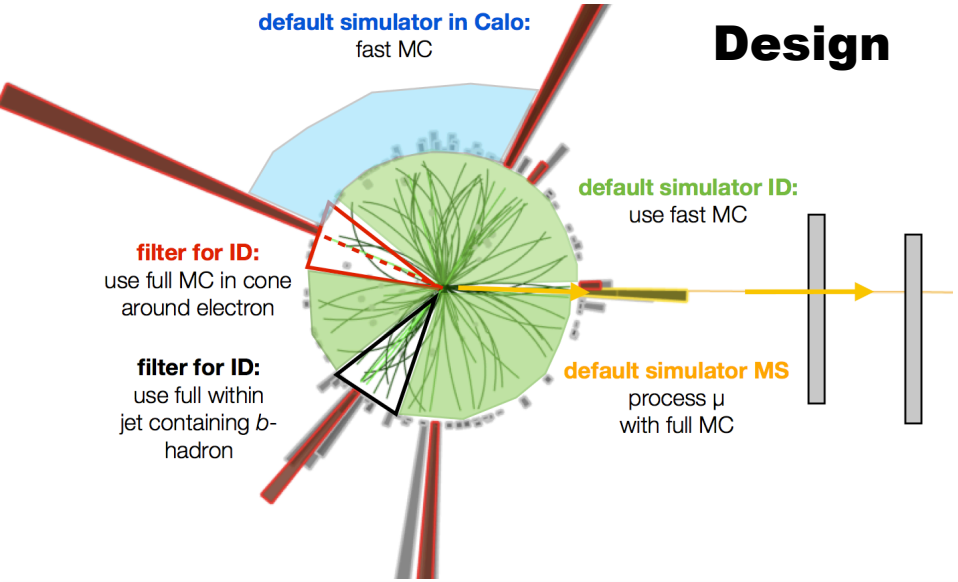


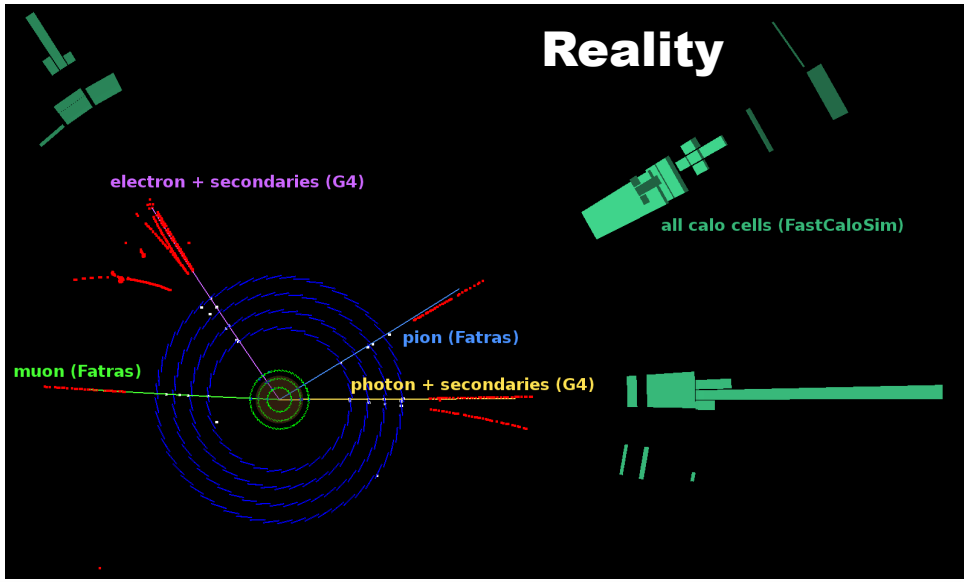
Computing Performance

- We haven't been particularly focused on computing performance in the last year or so
  - Developing fast simulations is necessary anyway and has had priority
- Still, several areas where improvements could be made
  - Random number generators identified by our guys
  - G4 Computing Task Force
    - https://twiki.cern.ch/twiki/bin/view/Geant4/G4CPT
    - Is this now defunct? No activity in some time…
  - "Opportunities" listed by Philippe Canal
    - https://indico.fnal.gov/getFile.py/access?contribId=17&sessionId=3&resId=0&materialId=slides&confId=4986
    - Many in initialization, some large-scale changes, but some simple changes
- Probably it is about time for another careful review of the ATLAS simulation performance
  - Reaching 20M events per day is not out of the question and would be beneficial to us; but we are coming to the point where disk and reconstruction (pile-up) issues dominate
  - Should come with our new development, the "ISF"…

Future: Integrated Simulation Framework

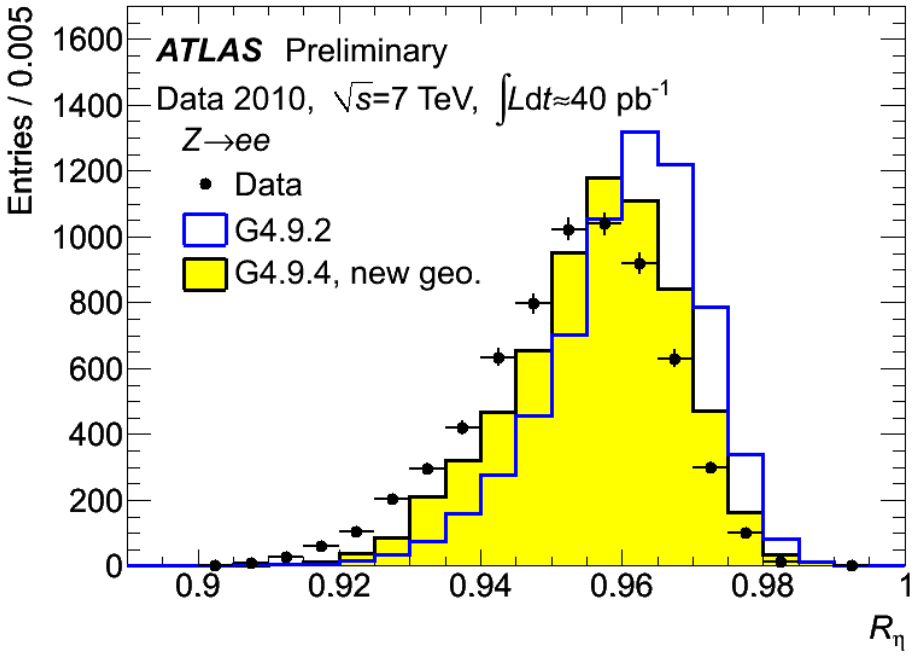
- Merging of our various flavors of fast simulation
  - Shower libraries (e+,e-,g) in the calorimeter
  - Fast parameterization of calorimeter energy deposition (FastCaloSim)
  - Fast tracking in a simplified geometry (FATRAS)
- One event handler and stack to divvy up particles amongst the flavors
  - Hand particles to G4 as individual *G4Events* – may be modified after testing
- Now functional, but not benchmarked / battle-tested
  - Expected roll-out as a part of MC13, testing this year

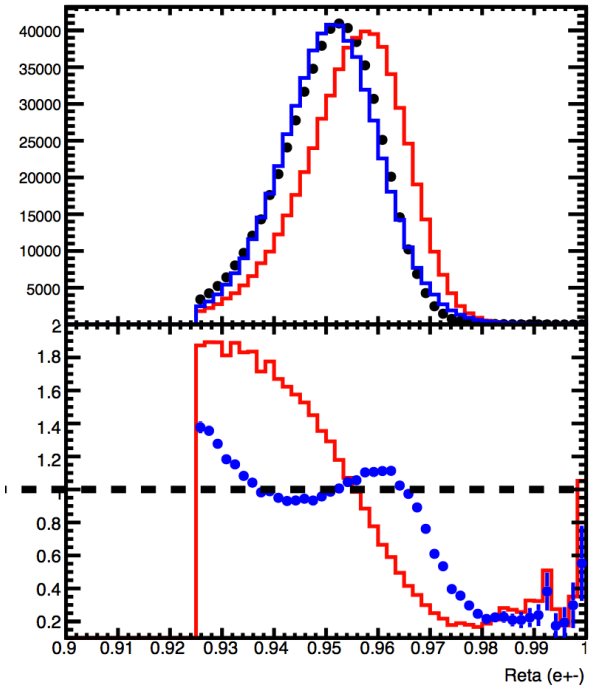




One Reason for Fast Sim: Lateral Shapes

- After some bug-fixing, the lateral shower shapes for electrons are in somewhat better agreement than they were (left)
  - Hadronic shower shapes are also still off
- Still, fast simulation allows us to tune our MC to match our data in a way G4 does not (right)
  - We would like for this problem to be understood and fixed, of course





A variable describing lateral $e^{\pm}$ shower width

Data
MC
FastCaloSim

Summary

- Generally quite happy with the G4 performance
  - Some issues reported here are really edge effects!
  - 1600M G4-only events produced for MC11 (~10^{-6} crashes per event)
- A few concerns with the kinds of things we're finding
  - MCS models changing, with bug reports not quite getting around to us
  - Rare but obvious hadronic bugs, with very difficult fixes
    - Very new, massless helium production: http://savannah.cern.ch/bugs/?92931
- With the billions of events we run, ATLAS and CMS are probably the best battle-testing G4 gets
  - Our detectors are pretty complicated, though
  - Do the simple tests that G4 runs cover a sufficient range of possibilities?
- In the coming months, most ATLAS focus will be on performance and integration of fast simulations
  - I am sure we will continue to profit from a close collaboration with G4!

Bonus Slides!

More on Energy Violation

- Reproduced by John A. and a few others standalone
- Appears to be mostly C, N, and O targets with anti-p incident
- Small energy violations are virtually impossible to catch and are more common, but 3-15 GeV of energy is not as critical to us as TeV-scale violation

'Small': GeV violations

Element (target)	Interactions (Millions)	O(GeV) Errors	Low DE (GeV)	GeV 'Endpoint'
Carbon	50	16	9.0	10.8
Nitrogen	36	20	3.5	9.8
Oxygen	39	38	3.8	10.9
Overall	125	74	3.5	10.9

'Big': TeV violations

Element (target)	Interactions (Millions)	TeV+ Errors	MaxDE (GeV)	Crashes
Carbon	50	4	8900	0
Nitrogen	36	7	7100	2
Oxygen	39	5	7000	3
Total:	125	16	8900	5