

Physics Issues Addressed in 9.5p01

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The logo for Geant 4, featuring the text "Geant 4" in a stylized, brown, serif font with a slight shadow effect, set against a light green rectangular background.

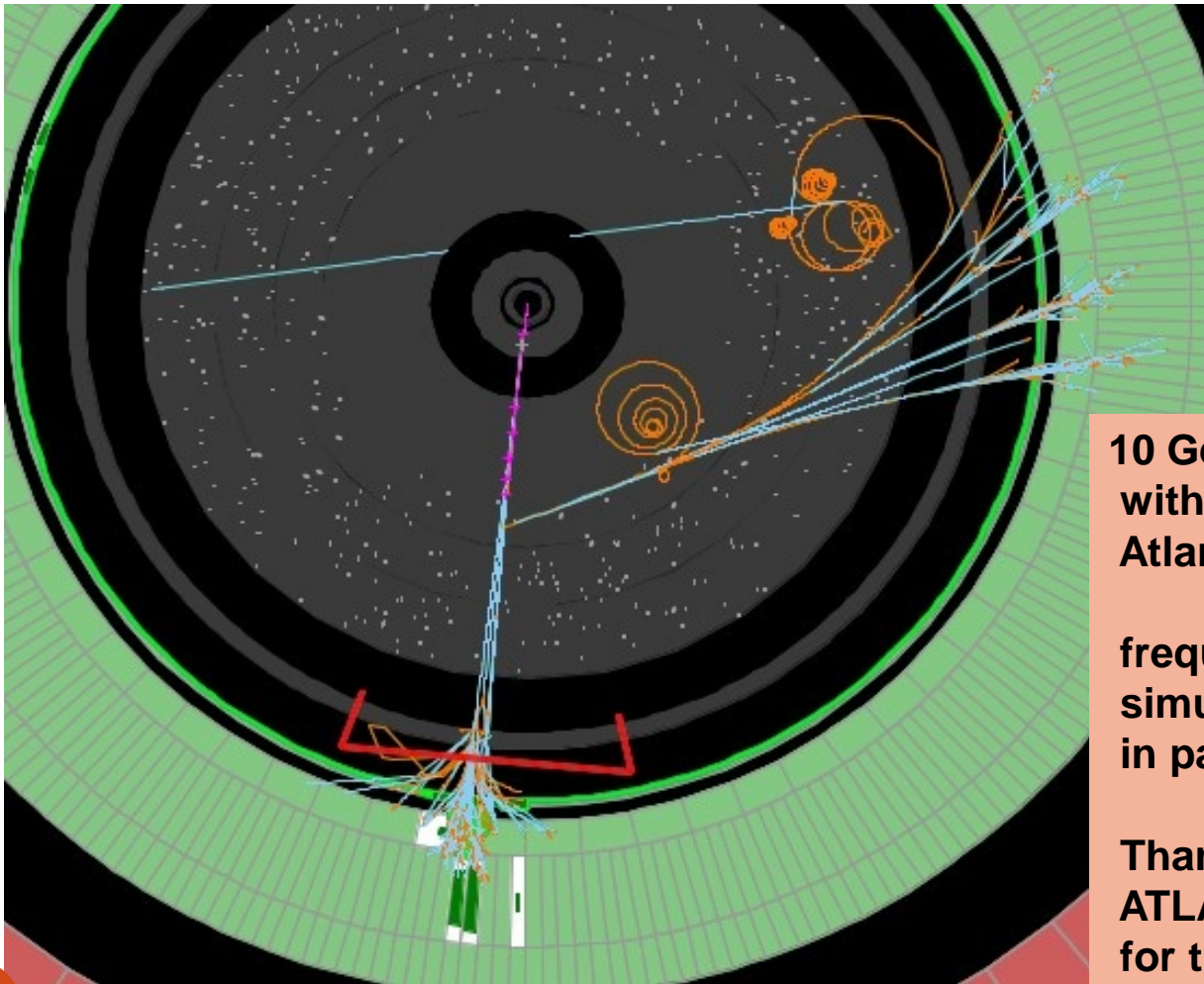
Outline

- Problems and fixes for multiple scattering models
- Problem and fix of fluctuation model for low-energy muons
- Catastrophic energy non-conservation in anti_proton annihilation at rest
- Memory growing at run time for HP Physics Lists

ATLAS problems in EM physics 9.4p03

- **Muon scattering:**
 - Reconstructed mass in $Z \rightarrow \mu^+ \mu^-$ is slightly shifted
 - Responsible is **G4WentzelVIModel**
 - **G4UrbanMscModel90** model was used for several years for muons and hadrons, so the prompt fix was to use Urban90 for ATLAS production
- **Artificial scattering back of e^+ / e^- in G4UrbanMscModel93**
 - **The problem was reported by NOvA experiment in the fall of 2011**
 - It was difficult to reproduce in a simple setup
 - A protection was included in all Urban models in last days before the releases 9.4p03 and 9.5
 - **This was not enough!**
 - **ATLAS reported the issue March, 12**
 - Some deviations in several quantities found by ATLAS Heavy Ion team (Andy Haas et al.)
 - First for 9.4p01 but later for 9.4p03 as well

BIG problem in electron multiple scattering identified by ATLAS



10 GeV pT electron tracks within $1 < \eta < 2$ viewed in Atlantis.

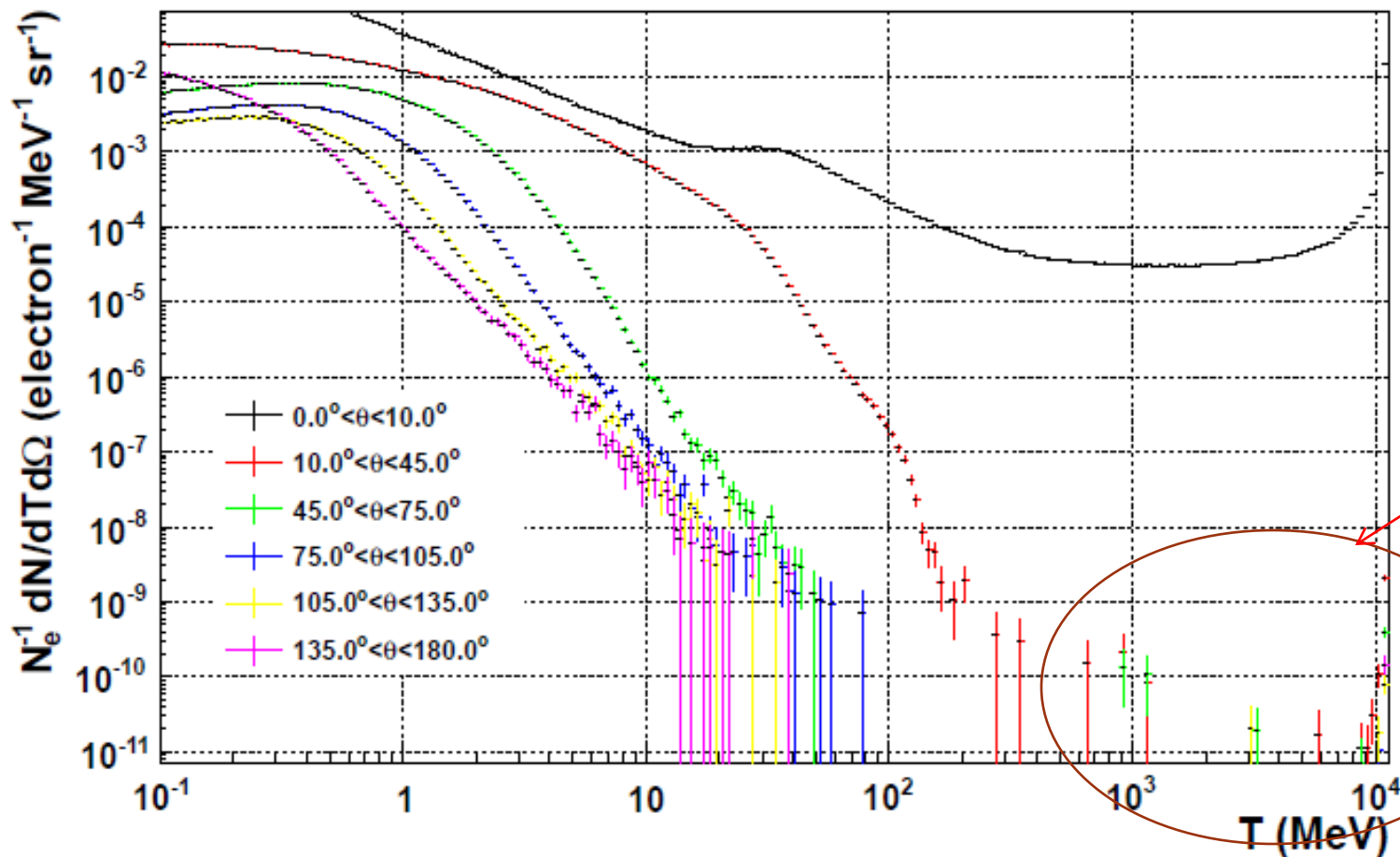
frequency depends on simulation conditions, in particular, geometry

Thanks to Andy Haas and ATLAS Heavy Ion group for the image and identifying the issue

Report on scattering in Liquid Hydrogen by *Eric Fuchey*

$e H \rightarrow e^- X$, $E_e = 11.0$ GeV, 15 cm LH2+ 2 x 150 μ m Al

<http://bit.ly/g4hydr2011>



Problem is rare

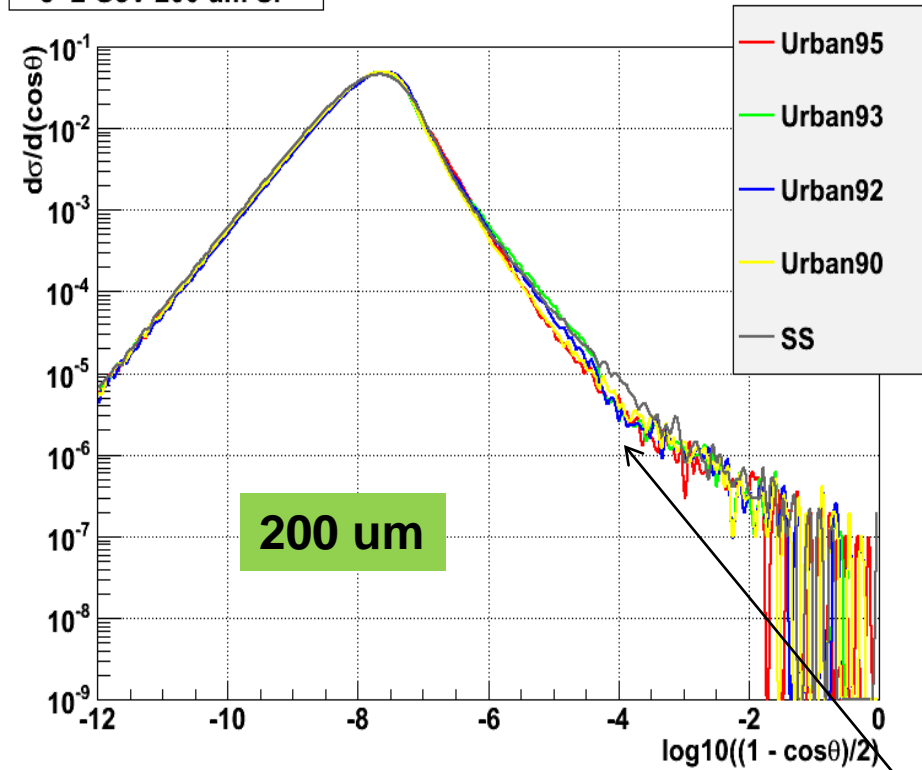


Problem description

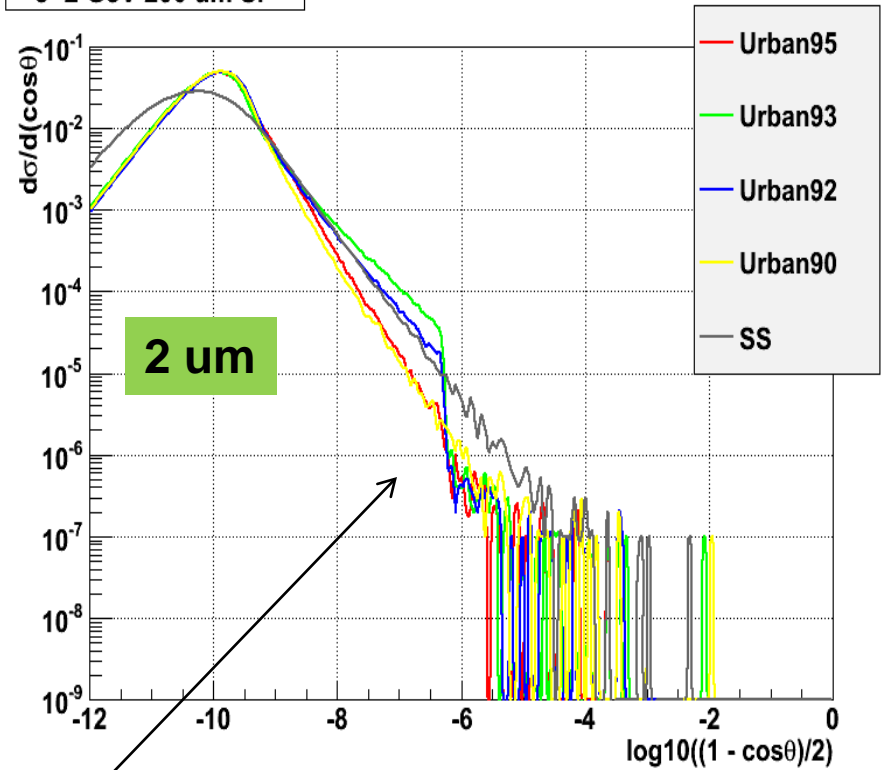
- The problem is in G4UrbanMscModel93
 - Some evidences of the problem were reported by two user groups in the fall of 2011
 - Very dependent on step size and difficult to reproduce
 - Likely happens at specific step sizes in a gas
 - Very big effect in NOvA geometry
 - About 12% for single e- for $1 < \eta < 2$ for ATLAS if alignment corrections are applied
 - The first protection has been included into 9.4p03 and 9.5 in last days before the release, thanks to NOvA report
 - ATLAS reported that in 9.4p03 there are less bad events than in 9.4p01
- A dedicated protection have been introduced inside all Urban models for 9.5p01
 - Patched version of G4UrbanMscModel93 was given to ATLAS

Effect of the fix in thin Si target

e- 2 GeV 200 um Si



e- 2 GeV 200 um Si



Extra protection reducing the tail

Looking back: why update multiple scattering?

- Number of validations versus data show not ideal agreement
 - Electron scattering benchmark (13-20 MeV e⁻ in different foils)
 - Backscattering data
 - Various calorimeter tests
 - Fano cavity theorem check
- To provide **backward compatibility** for any **change** of the parameters or algorithm of scattering we create a new version of the model and keep old versions of the model unchanged
 - G4UrbanMscModel90 – for muons/hadrons since G4 9.0
 - G4UrbanMscModel92 – for e⁺⁻ since G4 9.2
 - G4UrbanMscModel93 – for e⁺⁻ since G4 9.3
 - G4UrbanMscModel95 – for e⁺⁻ since G4 9.5

Other EM problems fixed in 9.5p01

- Muon scattering:
 - report from **Ice-Cube** simulation of TeV muon track length problem inside 10 m of water: mean track length is less than water thickness
 - **Problem was in G4WentzelVIModel**
 - affecting also Z-boson reconstruction
- Urban fluctuation model problem for straggling of low-energy muons ($\sim 25\text{MeV}/c$)
 - Range was very sensitive to step limitation due to numerical problem
 - **Reported at 8th Geant4 User Workshop, Tsukuba, December, 2011**
- Urban fluctuation model for small steps in gaseous detectors
 - Bad shape of signal in 3 mm Ar gas gap if a particle does only 1 step
 - Internal limitation of the Urban model
- Shift of low-energy ion ranges for very low cuts ($\sim 1\text{ }\mu\text{m}$)
 - Fixed ion ionisation computation

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Hadronic physics



ATLAS report

- ATLAS reported an event with about 8 TeV of excess energy in outgoing particles
 - QGSP_BERT with G4 9.4 patch 01
 - Process: Anti-proton annihilation at Rest
- Example of secondaries from anti-proton capture are:
 - 63 GeV deuteron
 - 84 GeV proton
 - 310 GeV neutron
 - 734 GeV neutron
- Cryptic message precedes it
 - *G4QH::Decln2:*Boost* 4M=(502.543,217.45,155.206;-3164.85),e-p=-3733.99
 - *!*G4QE::FSI: 939.565+939.565=1879.13>-145544

Reproducing it

- Geant4 CERN group study the issue (J. Apostolakis, A. Dotti, A. Ribon, V. Ivanchenko)
- Created new, simple Unit test (Alberto Ribon)
 - Ran 10s million interactions with H, and a few million each with Si, Al, Cu, Fe, W, Pb
 - found no 'big' E violation (or crashes)
 - Ran C, N, O >30M interactions
 - both 'big' E violations (and crashes!)

TeV violations statistics

| Element (target) | Interactions (Millions) | TeV Errors | MaxDE (TeV) | Crashes |
|------------------|-------------------------|------------|-------------|---------|
| Carbon | 50 | 4 | 8.9 | 0 |
| Nitrogen | 36 | 7 | 7.1 | 2 |
| Oxygen | 39 | 5 | 7.0 | 3 |
| Total: | 125 | 16 | 8.9 | 5 |

'Small': GeV violations statistics

| Element (target) | Interactions (Millions) | O(GeV) Errors | Low DE (GeV) | High DE (GeV) |
|------------------|-------------------------|---------------|--------------|---------------|
| 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 |

Workaround

- Created a check in `G4QCaptureAtRest.cc`
 - tests the products of an interaction
 - re-spins (redoes interaction) if violation over limit
 - Chose $\Delta E_{\text{limit}}=2.0$ GeV.
- NOTE: Every time a big violation occurred an error message is reported
- Recently the check code was improved
 - There is a probability of sampling “quasi-free” annihilation on a single nucleon – this case is taken into account
 - Due to that the protection provided in the 9.5p01 is less verbose (too large printout was seen in Helium media)
 - Internal limit on number of attempts (100) is added – if it is exceeded the Geant4 FatalException is thrown
- Regular checks on big energy violations will be included in all models for 9.6

Fixes for memory management problems in Geant4 hadronics

- FNAL and other users reported that at run-time Geant4 memory significantly increased when HP Physics List is used
 - Memory was released at the end of run, so no problem was reported by Valgrind
 - The problem was observed only when HP models were used
 - It was in generic elastic process and not in HP model itself
 - The fix provides proper deletion of allocated memory for recoil in elastic scattering
- Proper deletion of the pre-compound/de-excitation module at the end of a run was introduced

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Summary

- Some problems were identified in Geant4 EM and hadronic physics
- 9.5p01 includes necessary fixes
- We plan to back-port the most important fixes to 9.4p04
- We are working on improving our validation suites to extend test coverage

