Fermilab

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Geant4 Usage and Feedback from Fermilab Intensity Frontier Experiments (based on the input from Mu2e, Muon g-2)

Krzysztof Genser

38th Geant4 Technical Forum

January 14th, 2015

Mu2e

- Experiment, being designed at Fermilab, to look for neutrino-less muon-to-electron conversion in the Coulomb field of a nucleus (^{27}Al target); Muons are produced using 8GeV (kinetic energy) protons striking a (thick) tungsten target; the signal are monoenergetic conversion electrons with a momentum of about 105 MeV/*c*
- Signal and background related simulations are very important given the expected experiment event sensitivity of about 3×10^{-17}; Almost all time is spent in simulating, overlaying and studying background events
- Using a locally patched and enhanced Geant4 v9.6.p03
  - Patches, mainly backported from v10:
    - G4Cons correction PenelopeOscilatorManager correction; newer PhotonEvaporation and RadiativeDecay datasets; minimally corrected radioactive decay/nucl decay; added labeling of tracks originating from stopped muons;
  - Main physics list used: ShieldingM equivalent
  - Operating system: Fermi Linux (SLF) 5 and 6
  - Compiler: gcc 4.9.1
  - Event processing framework: Fermilab's art
    - controls event loop
    - Geant4 used through a custom art module using the granular G4RunManager API functions introduced in v9.6

Mu2e and antiprotons

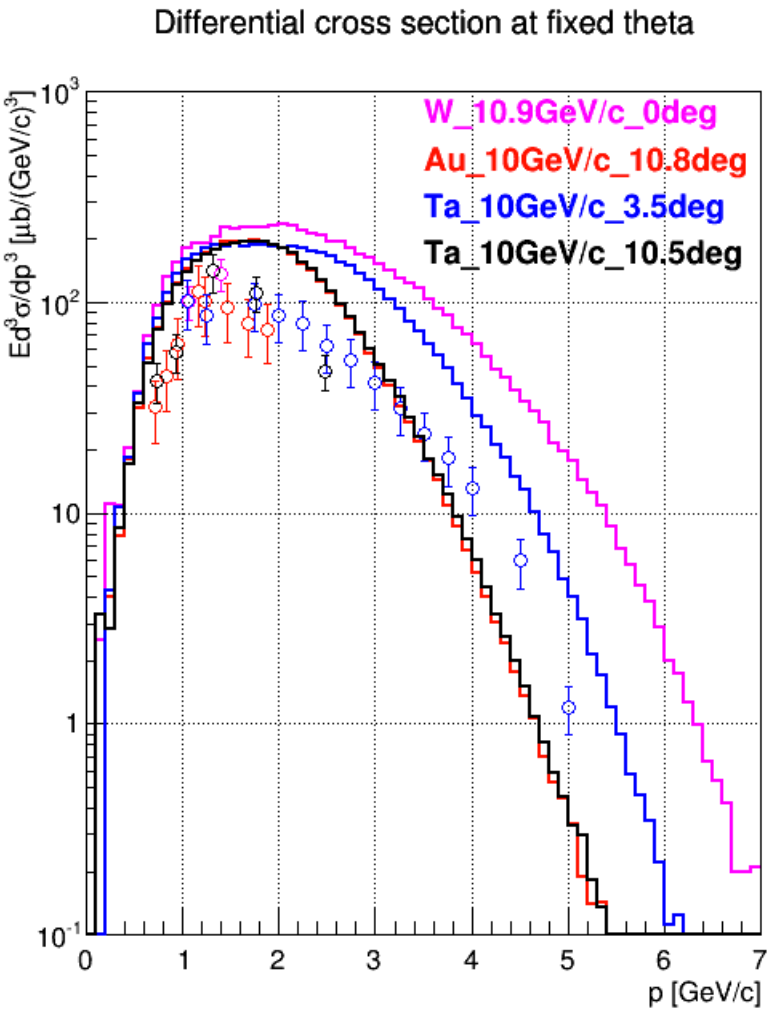
- One of the larger background sources are antiprotons which can enter the fiducial area, annihilate and produce electrons with the momentum in the signal window
- Plot on next page right shows comparison of proton beam induced antiproton production from various experiments with Geant4 simulations
- Simulation was performed using FTFP physics list
- The Geant4/data ratio of differential cross section is about **~1.3~3**
- Given the impact and importance of the antiproton background **the request would be to improve the agreement of the simulation with the data**

Mu2e and antiprotons

- Proton beam induced antiproton production; Geant4 9.6.p03 (FTFP) simulation compared to data from various experiments

  (Data compiled by S. Striganov; Geant4 simulation by Z. You)

  - Amann et al - 0 degree, 1 and 1.4 GeV/c, tungsten, 10 GeV/c
  - Sibirtsev et al – 3.5 degree, 1.25 – 5 GeV/c, tantalum,10 GeV/c
  - Barabash et al - 10.8 degree, 0.72-1.85 GeV/c, gold, 10 GeV/c
  - Averichev et al – 61 and 90 degree, 0.5 GeV/c, lead, 8.9 GeV/c
  - Boyarinov et al – 97 and 119 degree, 0.6-1.207 GeV/c, tantalum, 10 GeV/c
  - Kiselev et al - 10.5 and 59 degree, 0.58-2.5 GeV/c, tantalum, 10 GeV/c



Muon g-2

- Experiment under construction at Fermilab to measure the muon anomalous magnetic moment at the 0.14 ppm level
- Using Geant4 to simulate the muon storage ring and detectors with the focus on tracking multiple muons, their decay and spin properties; Using Fermilab's art event processing framework
  - Geant4 v9.6.p03 patched; gcc4.9.1; SLF5 and SLF6; FTFP_BERT physics list (info provided by A. Lyon)
- Tried to use parallel worlds approach to cope with the complexity of the detector (implementation by N. Froemming)
- Encountered a problem: spin information in post steps in the first event is not defined when using parallel worlds while tracking with spin
  - **Geant4 Bugzilla report 1696**
  - the problem was reproduced with Geant4 v10.0.p03
- The request is to address the problem in a timely manner

Treatment of spin

- Given that spin effects are becoming more and more important to many experiments, consider an effort of making spin treatment an integral, although turned on optionally, part of the Geant4 toolkit where effects like radiative muon decays with spin and tracking with spin could be enabled e.g. by choosing a physics list with an appropriate suffix (as it is the case for electromagnetic options today) or in a similar way to make sure all the required underlying options are set properly and to allow for a routine testing.