



Geant4 Usage and Feedback from Fermilab Intensity Frontier Experiments

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(based on input from Mu2e and g-2)

Geant4 Technical Forum

March 26th, 2013

Mu2e



- Mu2e is an experiment looking for neutrino-less muon-to-electron conversion in the Coulomb field of a nucleus (^{27}Al target) currently under design at Fermilab
- Given that the experiment is looking for a very rare process, both signal and background related simulations are very important
- Mu2e has been using Geant4 v9.4.p02 and has almost completed the transition to v9.6.p01
 - QGSP_BERT_HP is the main physics list used
 - Scientific Linux (SL) 5 is the predominant platform, SL6 is also used
 - Fermilab Scientific Computing Division written **art** framework is used to control the event loop; Geant4 is used through a custom art module

Mu2e - physics list comparisons

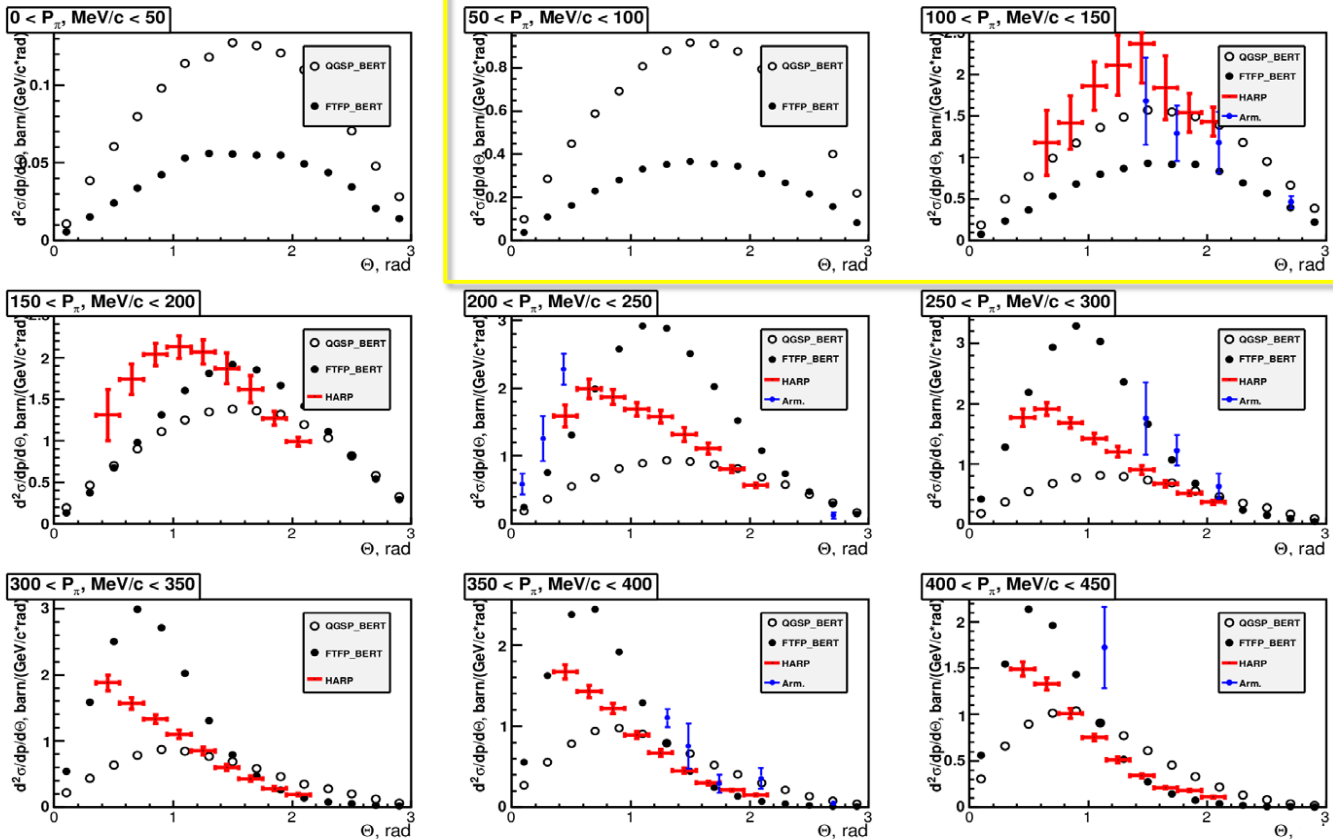


- Stopped muons production:
 - 8GeV (kinetic energy) protons strike a (thick) tungsten target
 - (predominantly) backscattered negative pions are collected using magnetic field
 - pions decay into muons
 - muons transported through a solenoid/collimators hit an aluminum target
- Only small subset of pions produce stopped muons: backscattered pions with $60 < p < 140$ MeV/c
 - the QGSP_BERT physics list was chosen based on comparisons with experimental data in this specific kinematic region

Geant4 comparison with experiments in kinematic regions important to Mu2e



G4.9.6.p01, QGSP_BERT vs FTFP_BERT



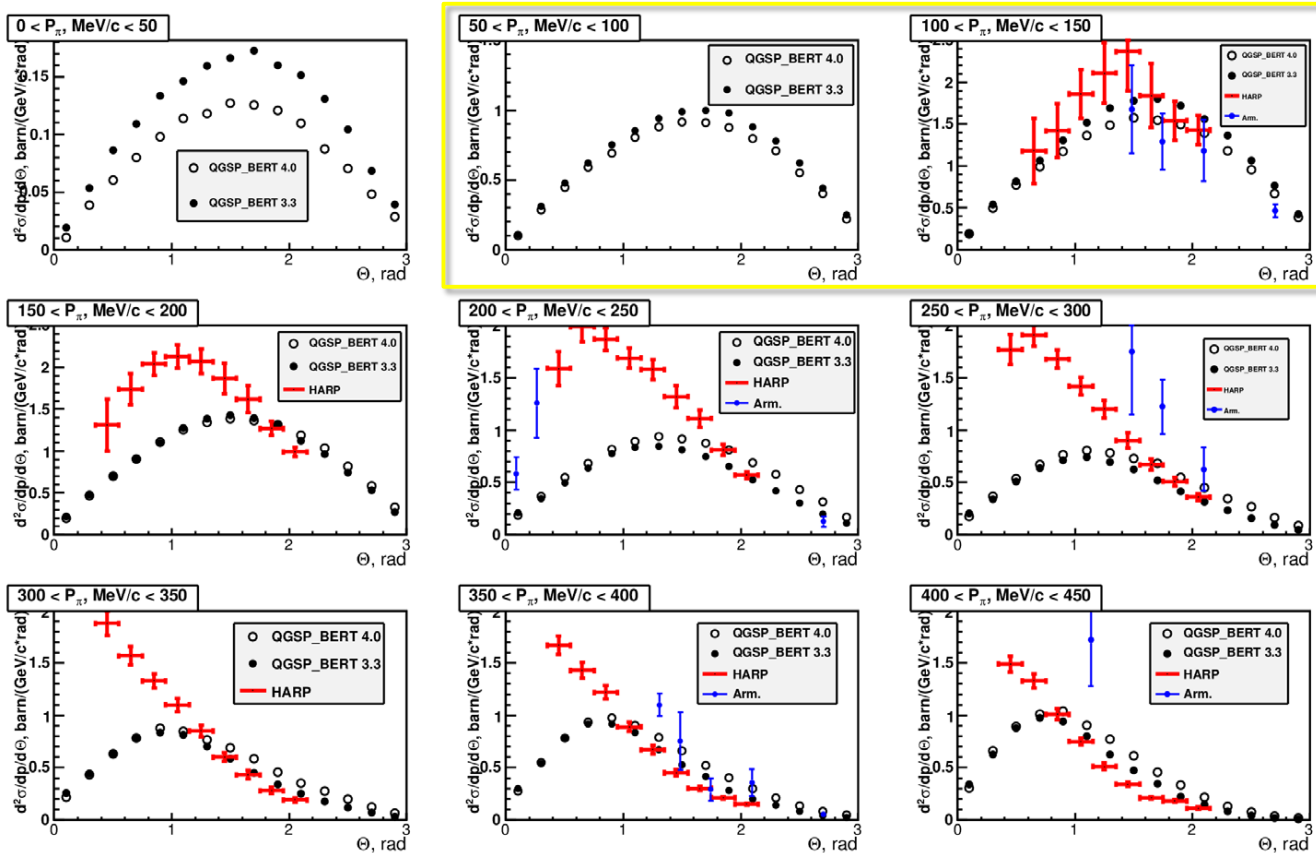
$d^2\sigma/dp d\theta, p+\text{target} \rightarrow \pi^- + X$

comparison with
 HARP
 Phys. Rev.
 C77, 055207
 (2008)
 and
 bubble chamber
 experiment
 data
 Armutliiski et al.,
 JINR
 P1-91-191
 (1991)
 done by
 I. Logashenko

Geant4 comparison with experiments in kinematic regions important to Mu2e



QGSP_BERT 3.3/G4.9.3.p01 vs QGSP_BERT 4.0/G4.9.6.p01



comparison with
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$$d^2\sigma/dp d\theta, p+\text{target} \rightarrow \pi^- + X$$

Mu2e - physics lists



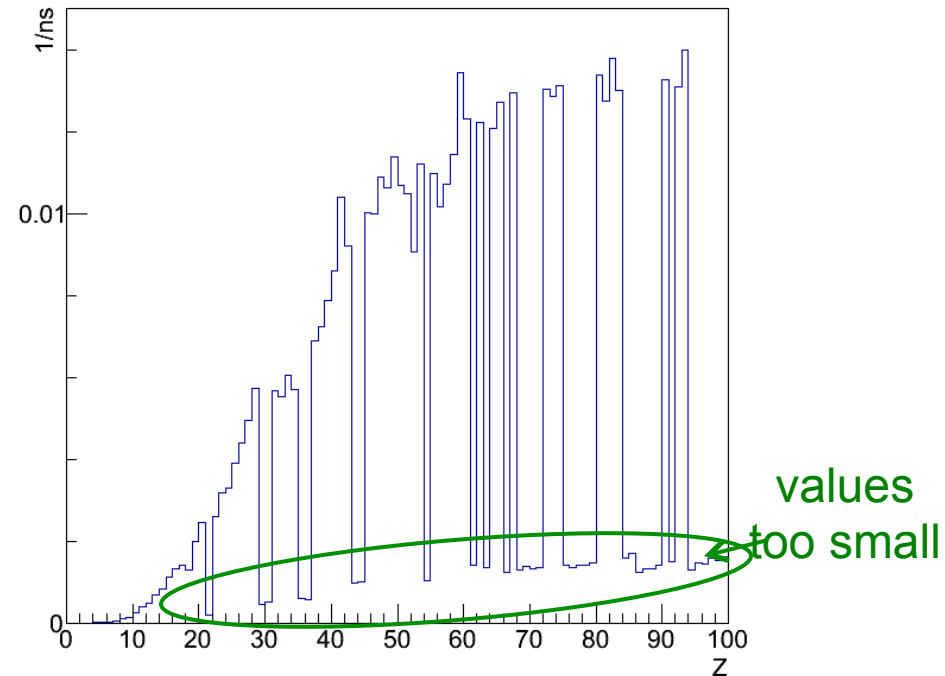
- In addition to QGSP_BERT and FTFP_BERT physics lists, comparisons with other physics list was also done (QBBC, QGSP_BIC and FTF_BIC) and the conclusion was that **none of the lists represents the data in the important to Mu2e region as well as QGSP_BERT does, therefore:**
 - Mu2e would like to request that the to be deprecated QGSP_BERT list be preserved or that another list with a similar behavior would be provided

Mu2e - muon capture rate



- It has been observed (Y.Oksuzian, J.Miller, et al) that Geant4 uses incorrect (too small) muon capture rate for certain isotopes, namely those not in the internal lookup table; problem report 1457 was submitted
 - Mu2e would like to request the problem to be addressed in the next release (a local patch is being used right now)

Muon Capture Rate G4.9.6.p01



muon capture rate (weighted average over mass number) for a given atomic number as calculated by Geant4 (histogram by KLG)

Mu2e - a suggestion



- It has been noted (A. Gaponenko) that it is possible to create materials with the same name but different properties
 - It would seem natural to disallow (abort?) such configurations as they can lead to potential problems

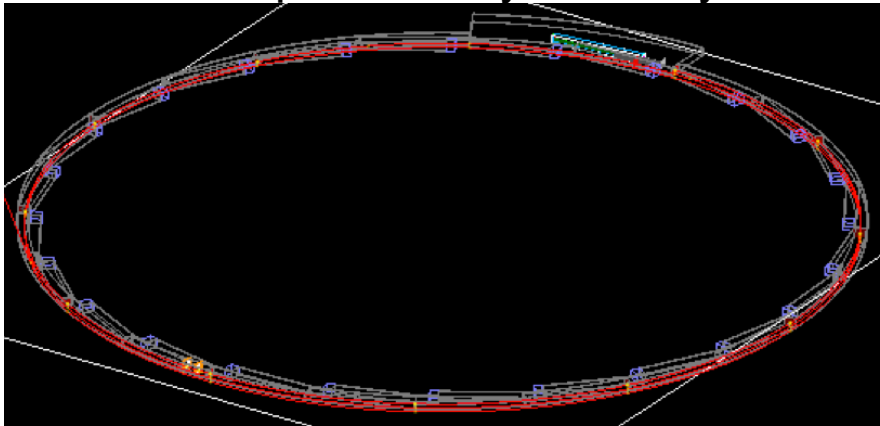
g-2



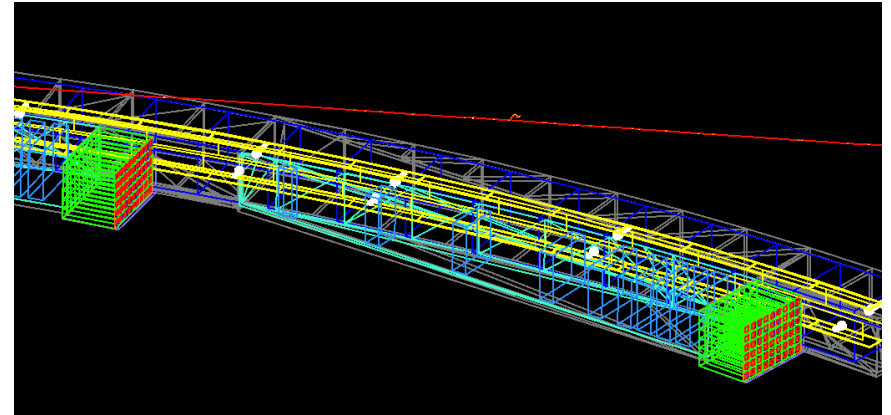
0.14 ppm measurement of the muon anomalous magnetic moment

- Implemented a detailed Geant4 simulation of the muon storage ring and detectors
- Wrote a generic software layer that integrates Geant4 with the common Fermilab art framework
- Uses Geant4 v9.5p01 (will upgrade to v9.6.p01 next month)
- Created a hand-written physics list, intend to investigate others (e.g. QGSP_BERT based) with the focus on tracking multiple muons, their decay and spin properties

Information provided by Adam Lyon



The g-2 ring



Calorimeters in the ring



Thank You