G4beamline Spin Tracking

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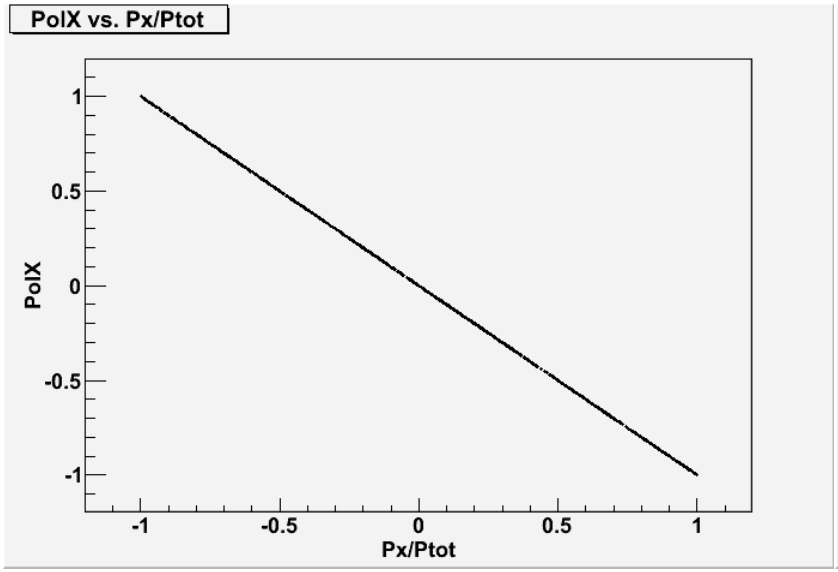
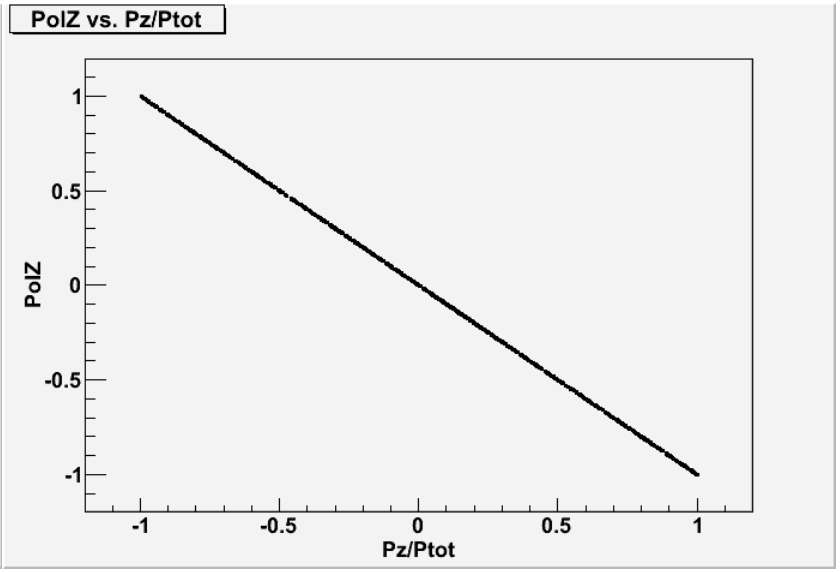
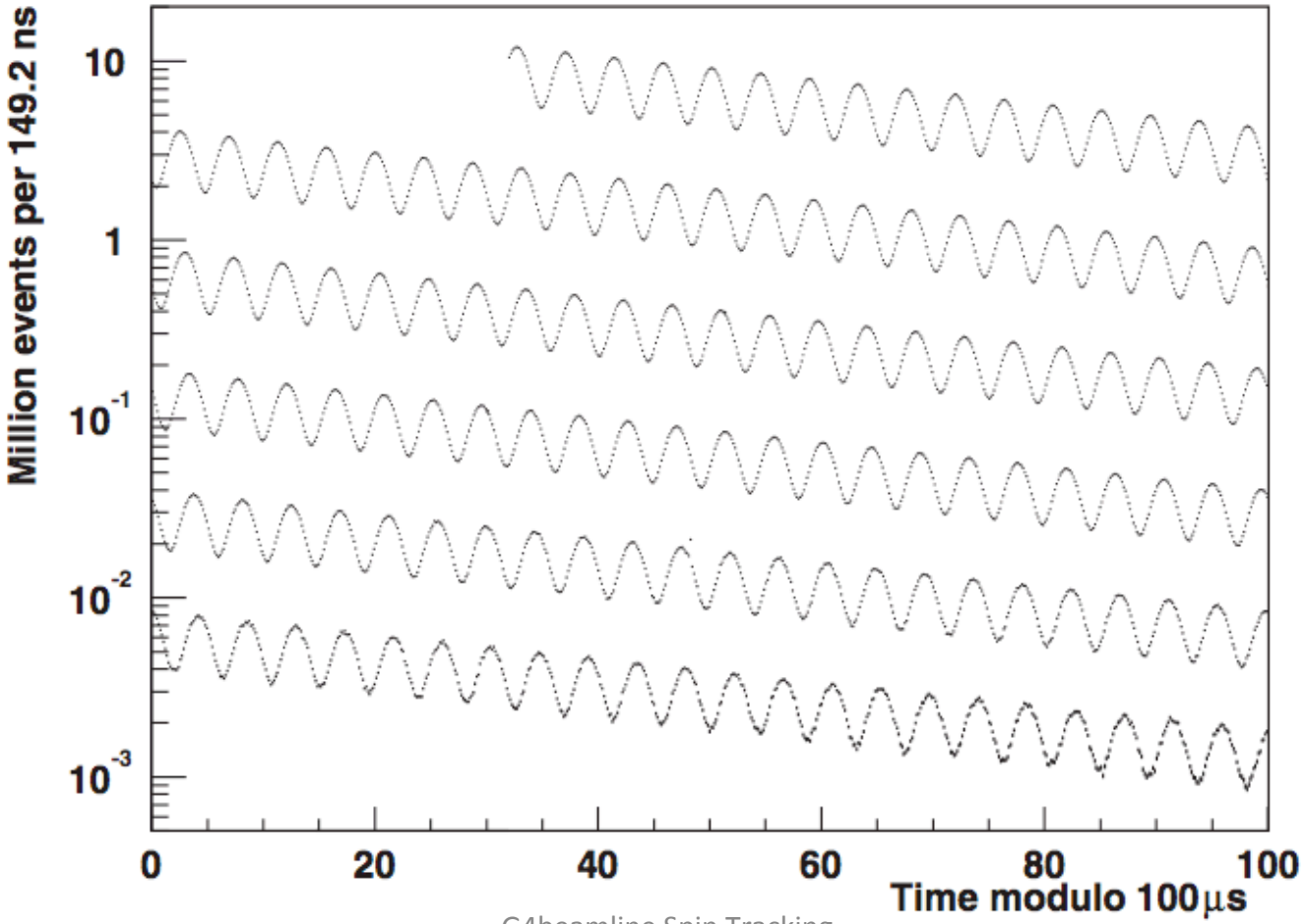
- In G4beamline 2.12, the tracking of muon and electron spins is introduced:
  - decay of pions into polarized muons
  - tracking of muon and electron polarization
  - decay of polarized muons into unpolarized electrons and neutrinos (including the 1.4% radiative decay).
- **Test 1 – pion decay with spin**
- In its rest frame, pi+ decay to a polarized mu+ is correct (pi- also correct):

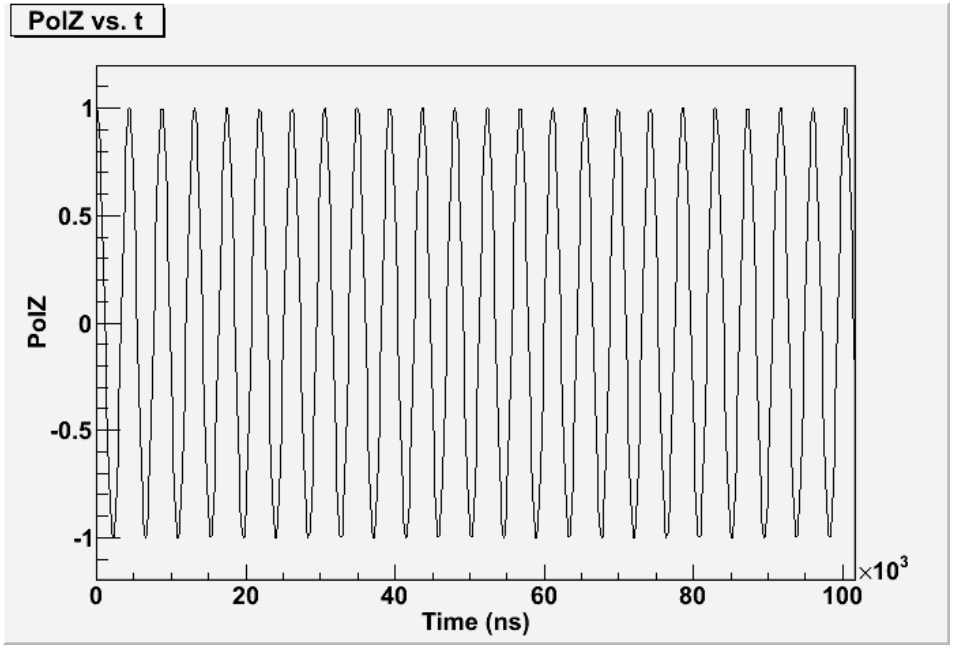




- **Test 2 – Muon Spin Precession in the BNL g-2 Storage Ring**
- This experiment measured the anomalous magnetic moment of the muon by storing muons in a ring and watching the orientations of their decays. Their ring has a highly uniform B field of 1.4513 Tesla, which stores muons with the "magic momentum" of 3.094 GeV/c; this momentum is "magic" because this choice makes the spin precession due to their electrostatic quadrupoles vanish. 149.2 ns is the period around the ring.

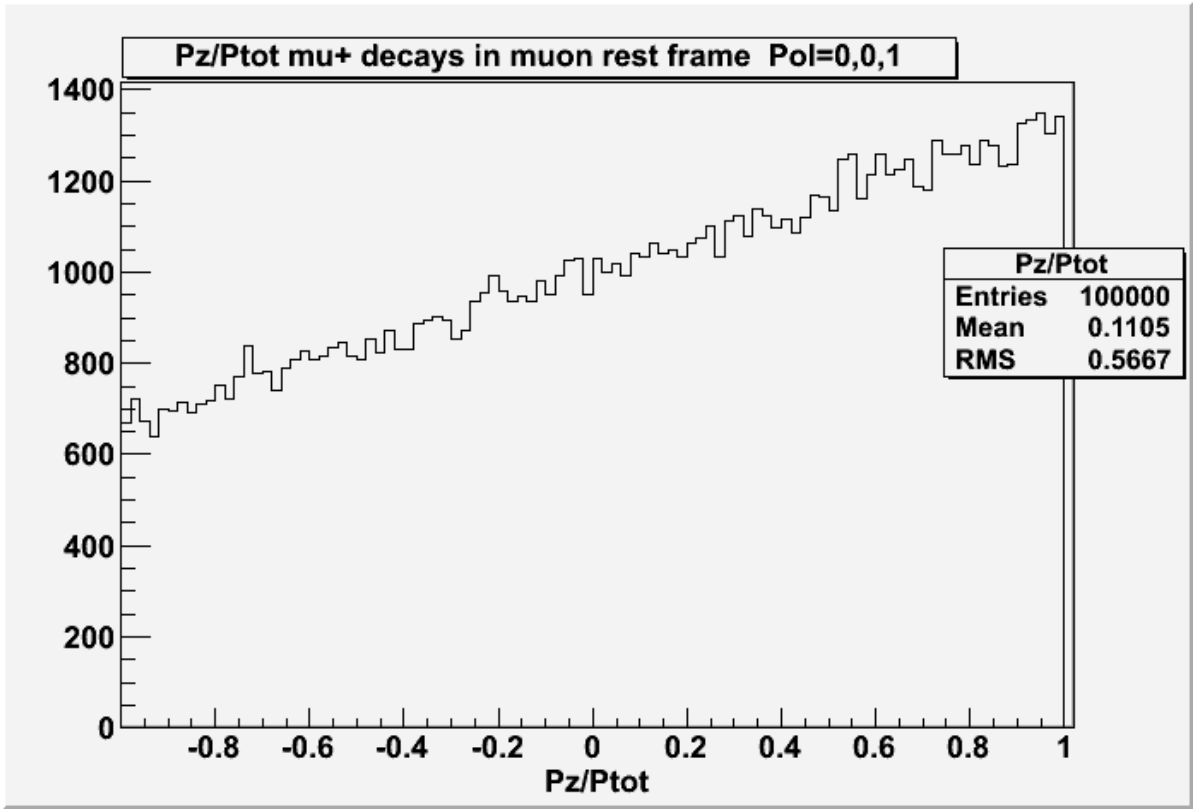


- This simulation tracks a single muon with decay disabled, in a uniform 1.4513 Tesla magnetic field, with no quadrupoles. The plot is of the z component of polarization, sampled every turn at z=0 (momentum in +z direction); the muon started with polarization=(0,0,1) at z=0.

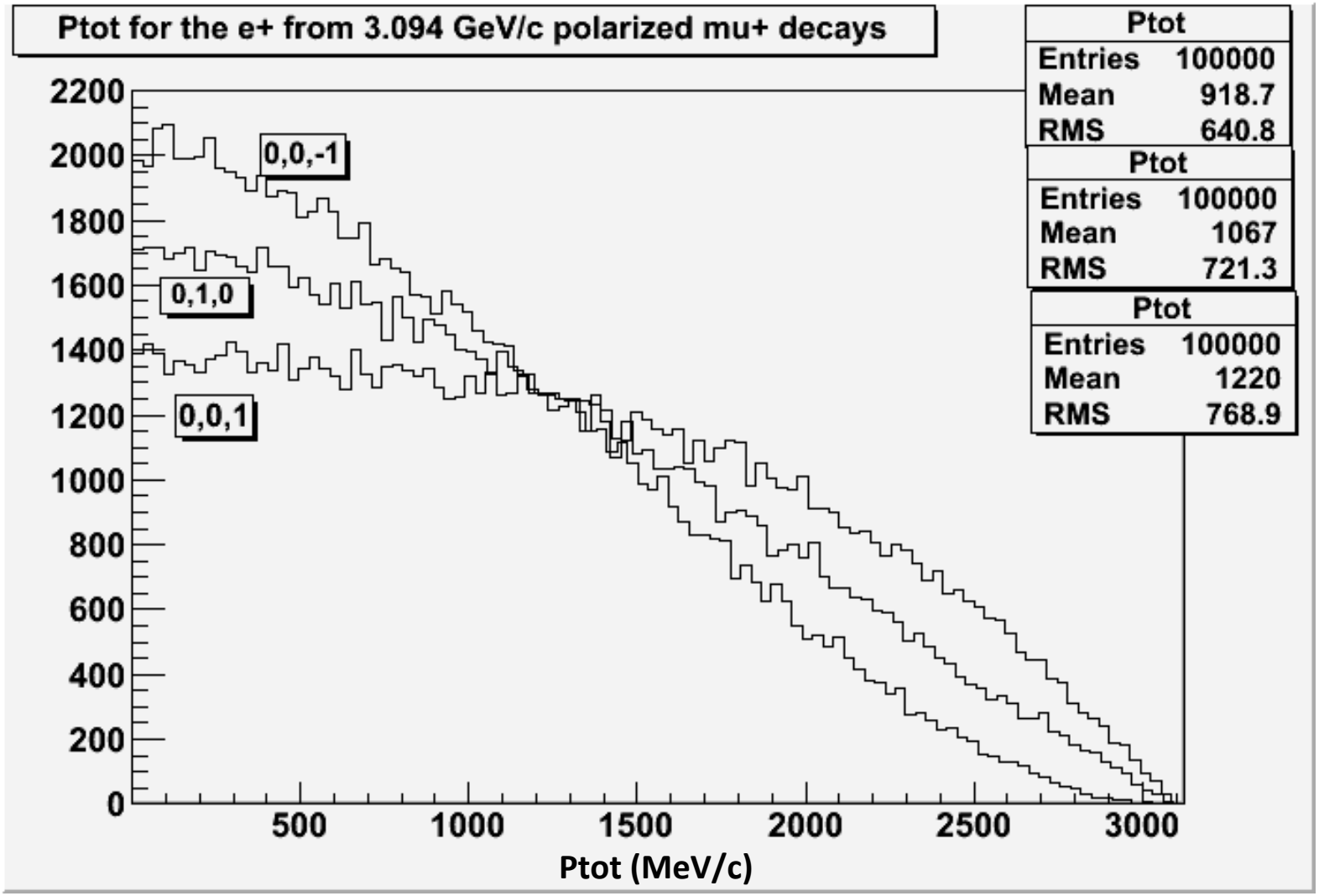


- The BNL plot has 114.3 peaks in 500 μs, for a period of **4.374 μs**. The G4beamline plot has 45.7 peaks in 200 μs for a period of **4.376 μs**. These are equal to the accuracy of the analysis method.

- **Test 3 – Polarized Muon Decay**
- The Geant4 implementation of polarized muon decay is designed to give the correct distribution of the electron or positron, but only approximate neutrino distributions.
- The decay products are all unpolarized.
- In the muon rest frame, for muons with Polarization=(0,0,1), the distribution of Pz/Ptot is correct:



- The distribution of the positron's P_{tot} for 3.094 GeV/c polarized muon decays is also correct, for three polarization states:



Omission

- The interaction of a particle's magnetic moment with a B-field gradient is **not** yet working.

- For the Fermilab g-2 experiment this is not a problem because the large muon momentum makes this effect be very small.
- Moreover:
  - In the beamline:
    - Quadrupole gradients are approximately perpendicular to the muon's longitudinal polarization
    - Longitudinal gradients in magnet fringe fields are small and always cancel in pairs
  - In the storage ring, the field gradient is negligible

Summary

- The current code should be adequate to simulate:
  - Pion decay into polarized muons
  - Transport of polarized muons to the storage ring
  - Injection of polarized muons into the storage ring
  - Tracking of polarized muons around the storage ring
  - Polarized muon decay with the correct electron distributions
  - All polarized-muon tracking includes the spin precession

- G4beamline 2.12 should be released in about two weeks.

- Pion production from thick targets is still not modeled very accurately in Geant4; we intend to use MARS for the pion production.