Production of Excited Isomers

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**Measurement and calculation of characteristic prompt
gamma ray spectra emitted during proton irradiation
J C Polf et al.,** Phys. Med. Biol. **54 (2009) N519–N527**

- Geant4 9.1
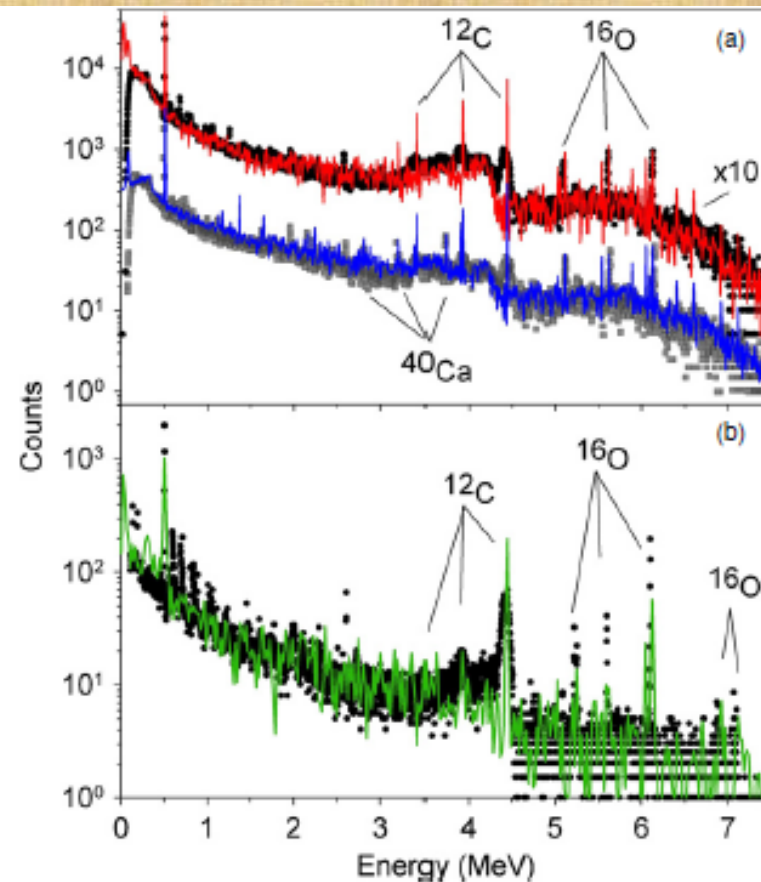- Nice agreement for Oxygen lines
- Not so nice for Carbon lines

Figure 4. (a) Comparison of measurements to Monte Carlo calculations of total gamma-ray spectra from Lucite (black circles) and bone equivalent plastic (gray squares) to Monte Carlo calculated total spectra from Lucite (red line) and bone equivalent plastic (blue line). Measured and calculated total spectra from Lucite are multiplied by a factor of 10 for display purposes. (b) Comparison of measured (black circles) and Monte Carlo calculated (green line) Compton suppressed spectra from Lucite.

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Recent concerns in HyperNews hadronic physics #1192
# and private discussion with authors
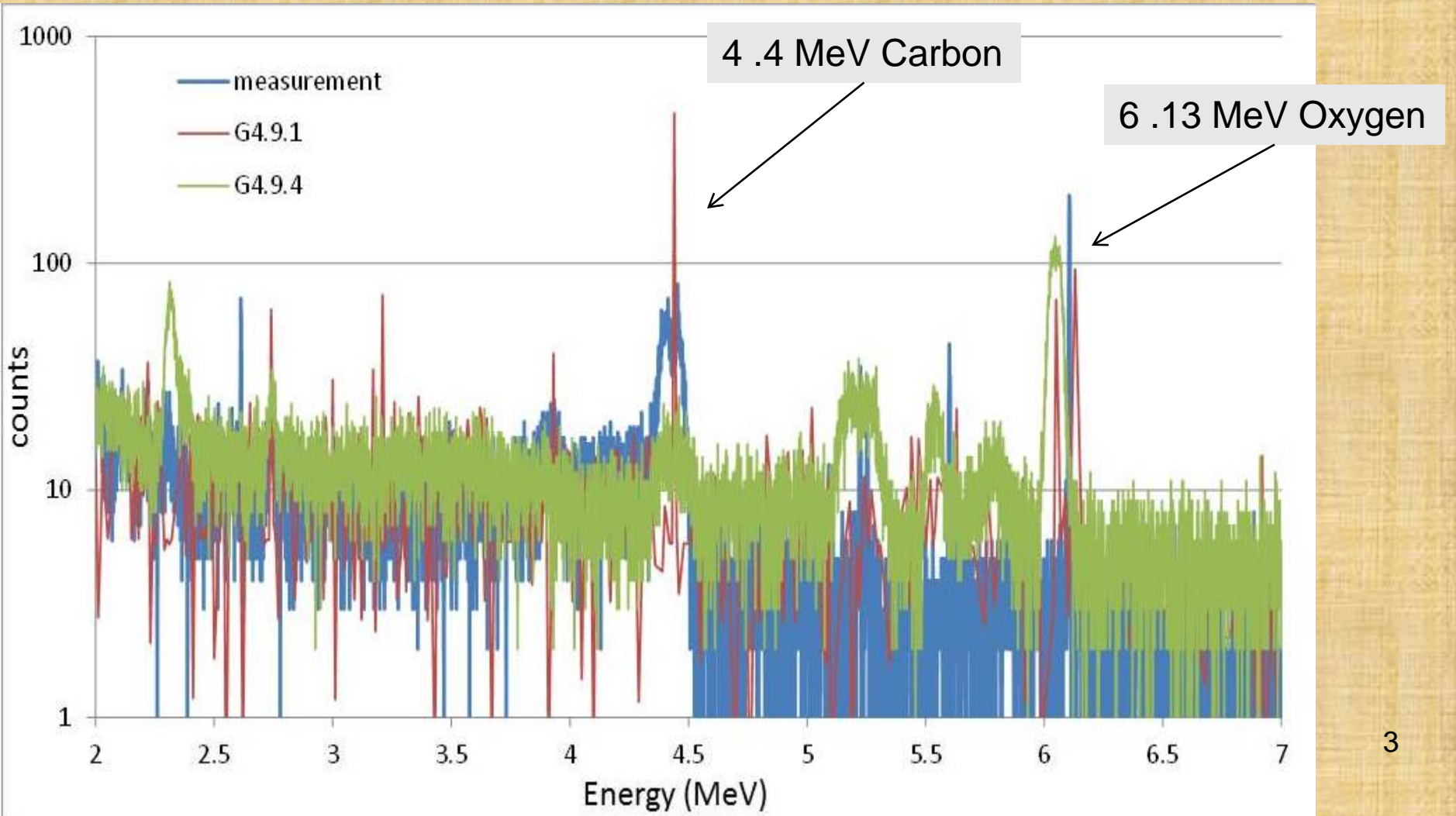
The problem

- Correct relativistic 4-momentum balance have been introduced in gamma evaporation
  - This improving shape of some lines introducing Doppler broading
  - At the same time few well known narrow lines (Oxygen, Calcium) are unnecessary broadened
- The reason: in the current gamma de-excitation we force excited nucleus to decay down to the ground state inside de-excitation module
  - Lorentz transformation to the Lab Frame is applied
- The correct physics: for long lived excited states
  - create excited ion
 - let it be tracked
  - apply radioactive decay

Proposal

- Resolve the problem in two steps
- First in the existing code check life time of a level and if it is long sample decay with gamma of fixed energy, 4-momentum balance will be slightly broken
  - No CPU penalty, no extra memory churn
  - Activated via environment variable G4AddTimeLimitToPhotonEvaporation
- Second step – make correct implementation with a possibility to create excited ion after de-excitation
  - Will require more time and a small change of logic of the G4ExcitationHandler
  - All Physics Lists should include Radioactive decay
    - G4RadioactiveDecay code should be optimized
  - CPU penalty and extra memory churn are not excluded
  - Likely an option should be added allowing to choose simplified or detailed simulation method

Test30: 4-momentum balance g4 9.5p07
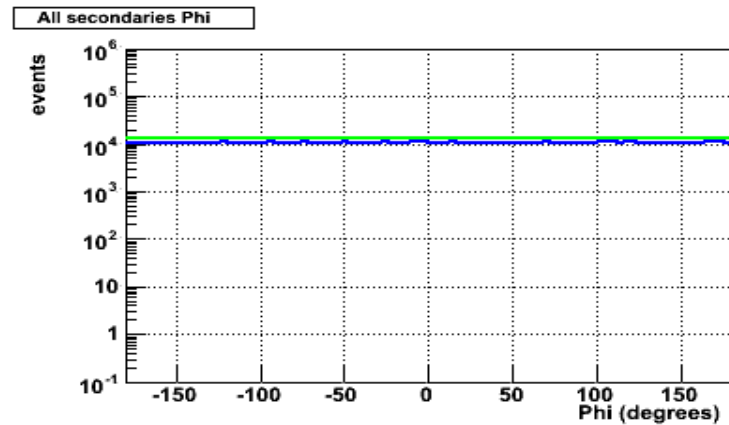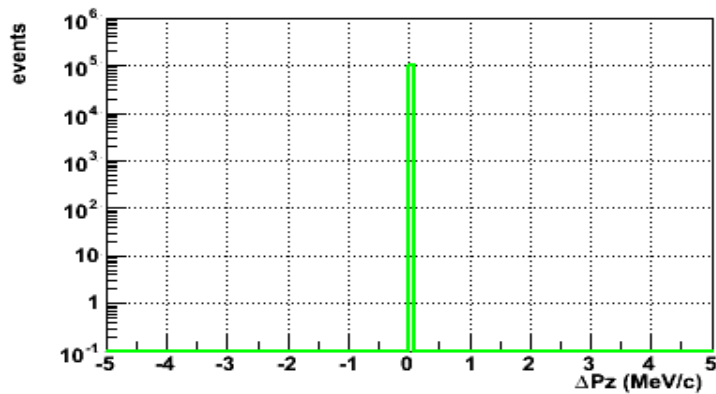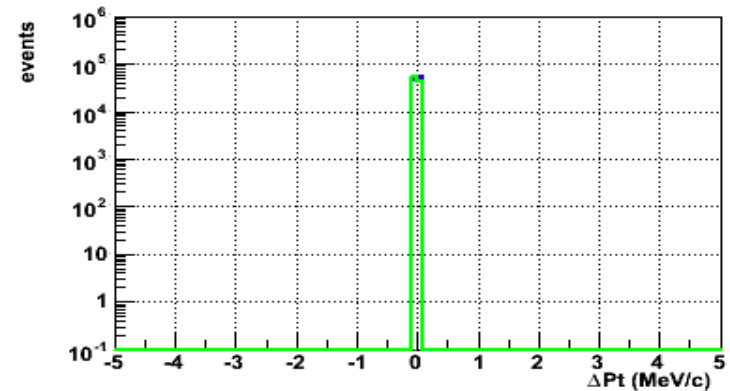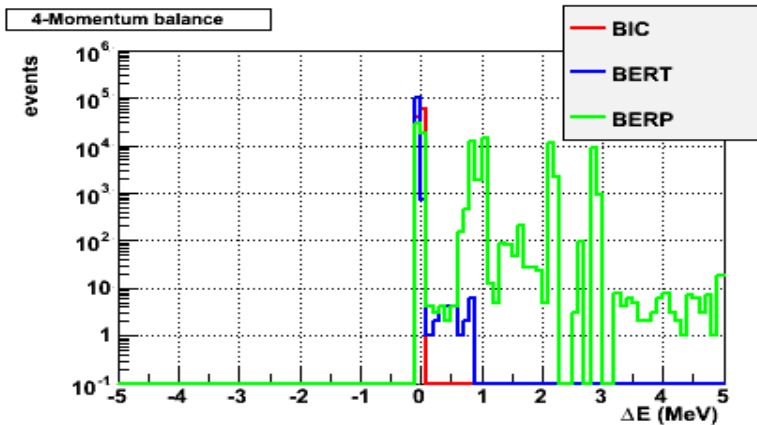
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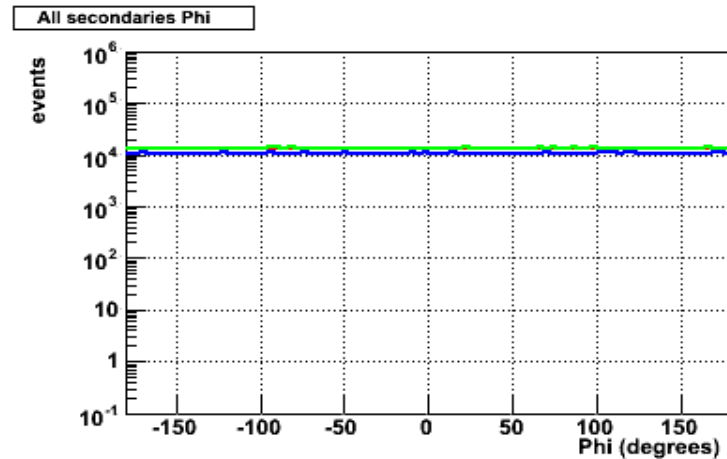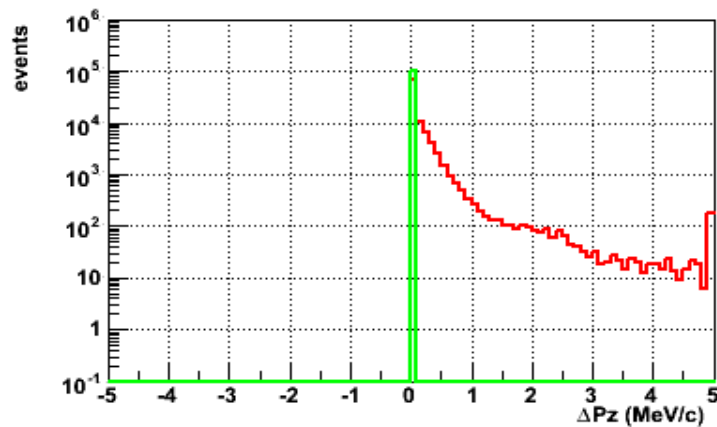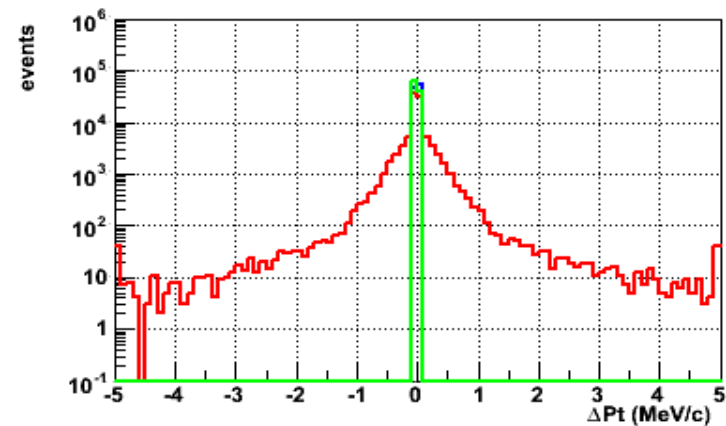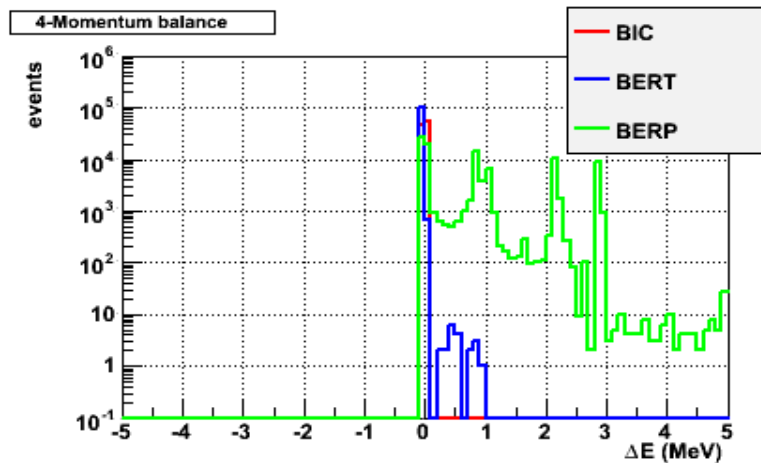
Summary

- Production of excited isotopes can be implemented
  - G4ExitationHandler, G4Evaporation, G4PhotonEvaporation should be modified
- Optimal time – beginning of the next year
- Critical requirement: G4RadioactiveDecay should be part of all Physics lists
  - Review of the code is necessary, so no effect on CPU performance and memory footprint