Progress and Plans in Radioactive Decay

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Outline

- Progress since last year
  - splitting of biased/unbiased RDM, correlated gamma emission, databases, new extended example
- Projects underway
  - validation of gamma correlation, beta-delayed particle emission to continuum, consistent treatment of floating levels
- What's next
  - better atomic de-excitation model
  - matrix method for time-evolution of Bateman equations
  - example for correlated gammas

Progress Since Last Year

Improvements in Radioactive Decay

- IT no longer instantiates G4PhotonEvaporation
  - now done only once in G4RadioactiveDecay, significantly reducing memory churn
- All handling of nuclear polarization moved into G4PhotonEvaporation
  - removes need for static cache of G4NuclearPolarization
- Accommodated change in G4VDecayChannel which prohibits branching ratios greater than 1
  - G4RadioactiveDecay::LoadDecayTable() now divides by 100
- Reproducibility OK only when correlated gamma not used

Separating Biased and Unbiased Radioactive Decay

- Two new radioactive decay models
  - G4RadioactiveDecayBase (all variance reduction code stripped out)
  - G4Radioactivation (derived from G4RadioactiveDecayBase, only VR code kept)
  - Original class G4RadioactiveDecay kept
- Interface changes
  - Refactored code contains changes that would break user code
    - must wait until major release to replace G4RadioactiveDecay
  - two user commands will become obsolete
    - fBeta
    - analogueMC

Correlated Gamma Emission

- Angular distribution of emitted gamma will depend on previous emissions
  - nuclear polarization must be transferred from nuclide to its daughter
  - code committed and verified → part of 10.4 release
- Angular momentum data for each nuclide added to PhotonEvaporation database
  - also multi-polarity information for mixed transitions
- Code is part of G4PhotonEvaporation and called from G4RadioactiveDecay by G4ITDecay class
  - may turn on/off
  - uses G4PhotonEvaporation::EmitFragment() method

Databases

- Latest set
  - RadioactiveDecay5.1.1
  - PhotonEvaporation4.3.3/5.0.2
  - ENSDFSTATE2.2

- Correlated Gammas
  - multipolarity and mixing ratio columns added to DB

- Beta-delayed neutron and proton decay data also added to DB
  - for $^{16,\ 17}$N and ^{17}O and ^{16}C

New Extended Example: Activation

- Developed by Michel Maire
- Surveys energy deposition and particle flux from a hadronic cascade
  - FTFP_BERT_HP hadronic physics
  - IonPhysics
  - GammaNuclear
  - basic EM physics
- plots evolution of nuclear species as a function of time
  - samples time uniformly over user-specified interval
- calculates activity
- macros for ^{209}Bi and ^{60}Co decay
- does not use biased code

Projects Underway

Improvement and Validation of Correlated Gammas

- Reports of factor of 10 – 100 slow-down when used
  - Jason Detwiler to work on this
- A few benchmarks are available:
  - ^{60}Co, ^{133}Ba and ^{208}Th are particularly good due to relative simplicity of angular distribution and existence of lots of data
  - Ian and jason to work on this
- Need to work on reproducibility

Beta-delayed Particle Emission

- Neutron and proton emission after beta decay now a working part of Geant4
  - β decay to discrete level
  - level decays by neutron or proton emission

- Decay to continuum not yet done
  - model required to decide what level β decay reaches – probably easy – just sample from a level density parameterization
  - particle emission from continuum → use precompound model?

Floating Levels

- Floating levels (X, Y, Z, U, V, W, A, B, C, D, E)
  - discrete levels in nucleus whose energy is unknown or poorly determined
  - a chain of well-defined decays may be built on an X-level, leaving absolute scale undetermined
  - currently dealing with these as unique states
    - ^{234}Pa[73.92+X], for example, is a different ion than ^{234}Pa[73.92]

- Decide how to handle
  - floating → floating, non-floating → non-floating OK
  - what about floating → non-floating and non-floating → floating?

What’s Next

What's Next?

- Continue work on biasing
  - fix negative values bug in accumulated decay time spectra
  - use scoring instead
  - use generic biasing methods
- Resolve some floating levels
  - enough data to resolve several of them
  - Martin Venhart to work on this (but haven't heard from him)
- Implement reduced number of DB files
  - version already available for photon evaporation
  - do the same for RDM
  - binary DBs (Andrea, Makoto)

What's Next?

- More detailed atomic de-excitation code
  - Kibedi code a good possibility
  - any conflict with low energy EM?

- General code improvement
  - tests show Geant4 as a whole is CPU-bound
  - true for RDM?

- Decay Data Evaluation Project
  - international effort to analyze existing radioactive decay data and recommend best for most used nuclei
  - some Geant4 data already corrected using this (^{55}Fe)
  - will continue case-by-case corrections using DDEP

What's Next?

- Two more extended examples
  - demonstrate recently added decays (beta-delayed particle emission, etc.)
  - H*10 dose

- Only MIXMAX random number generator is free from artifacts (Alex)
  - all others have one problem or another
  - more testing?

- Implementation of double beta decay to continuum

Other Tasks

- Attach scorer to process for biasing (Makoto Asai)
- Check correctness of generic biasing in both at-rest and in-flight modes (Marc Verderi)
- Allow assignment of G4Region to G4RadioactiveDecay
  - just like currently done with G4LogicalVolume?
- Check lower limit on lifetime
  - can we accommodate 10^{-14} s as needed for ^{9}B decays?