Simulation of correlated gamma emission

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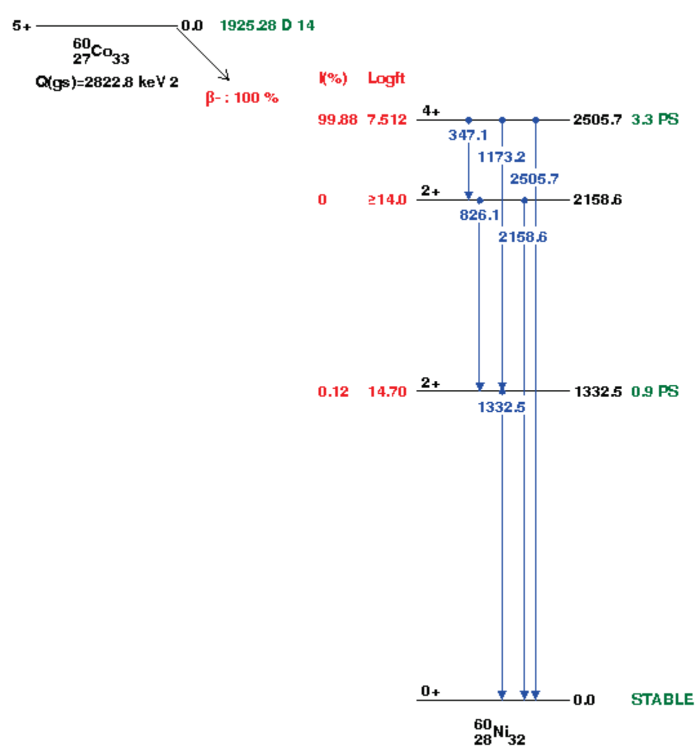
Introduction

- During several years a group from University of Washington (Jason Detwiler et al.) was in contact with me and Dennis
- They develop possibility to simulate correlated gamma emission using Geant4
- The detailed talk was presented at CERN mini-workshop on radioactive decay: http://indico.cern.ch/event/372884/timetable/#20150304
- After the workshop we start process of integration of their work
- Few slides fom their presentation will be shown below

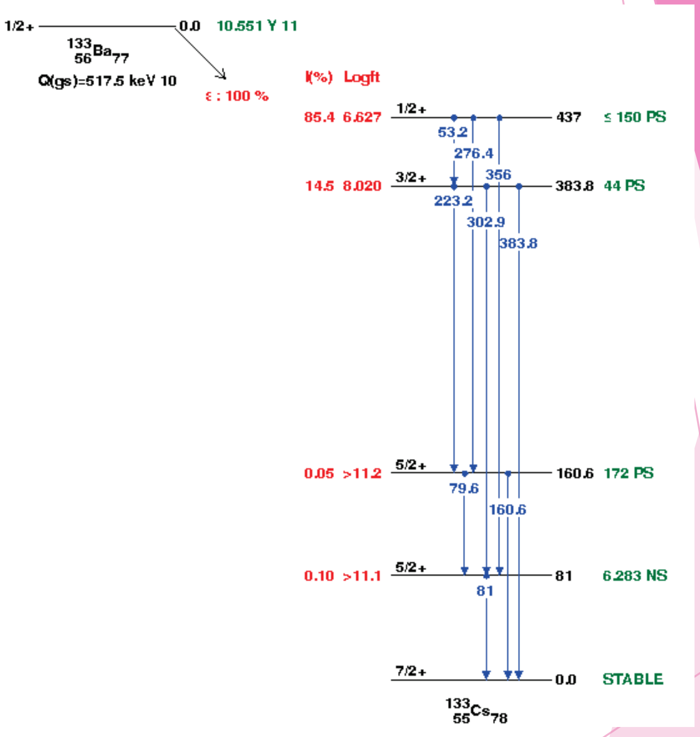
Motivation: ^{60}Co Decay

- An important source of background in my experiment (MAJORANA neutrinoless double beta decay search)
- Background rate depends on both gammas hitting one detector: angle between the gammas matter
- Well-known angular dependence, used for thermometry ("nuclear orientation thermometry")



Motivation: ^{133}Ba

- A common calibration source for radiation detectors
- Jason experiment: spectral fit useful for determining dead layers, active volume
- Gamma summing depends on angular correlations in the cascade



IT Multipole Expansion

- Nucleus decays from level with $J = J_1$, parity π, to state with $J = J_2$, parity π', via emission of a gamma with angular momentum L:

- Nomenclature:

$$J_1^{\pi} \rightarrow J_2^{\pi'} + L$$

	L = 1	L = 2	L = 3	L = 4	L = ...
π□= π	E1	M2	E3	M4	...
π□= π	M1	E2	M3	E4	...

IT Multipole Expansion

- For a particular value of M_1, consider the transition:

$$|J_1^{\pi}, M_1\rangle \to |J_2^{\pi'}, M_2\rangle + |L, M\rangle$$

- In this transition, the amplitude for photon emission in direction ***k*** is

- To include all M_1, sum over the density matrix for the nuclear polarization states and square to get the probability for emission in direction ***k***

$$\text{Amplitude}(\mathbf{k}) = \sum_{M_2,L,M} A_{J_1,M_1,\pi,J_2,M_2,\pi',L,M}\, T_{J_1,J_2,L}\, D_{L,M}(\mathbf{k})$$

Clebsch-Gordannery

Nuclear Data

Spherical Harmonics

Sampling Gamma Emission

- Relevant equations are given explicitly in Alder and Winther, Electromagnetic Excitation, Appendix G (1975).

- Required nuclear data is the dominant *L*, and for some transitions, the next most-important *L* (*L'*) and the relative strength between it and the dominant *L* (δ). Available from the same ENSDF files from which PhotoEvaporation is derived, Laurent has made a test version in the past that included these.

Sampling Gamma Emission

Typical calculation for an excited nucleus with $J=J_1$ that is going to de-excite to levels with $J = J_2, J_3, \ldots$ down to the ground state:

1. Start unpolarized: the "statistical tensor" representing the entangled nuclear state is trivial (rank 1 and equal to 1).
2. Sample ***k*** based on J_1^{π}, $J_2^{\pi\square}$, and L (and sometimes also L' and δ).
3. Update the statistical tensor based on the sampled value of ***k***: the statistical tensor now represents a non-trivial entanglement of M_2 states.
4. Repeat from step 2 for $J_2 \rightarrow J_3$, $J_3 \rightarrow J_4$, etc. until you reach the ground state.

Geant4 implementation

- 4 classes were provided by Jason are already integraded :
  - hadronic/util:
    - G4NuclearPolarization - keep polarization tensor
  - hadronic/model/util:
    - G4Clebsh – extended class
    - G4LegandrePolinomial
    - G4PolynomialPDF
    - G4Fragment – is updated – instead of vector of polarisation is keeping now a pointer to G4NuclearPolarization
- What is left to do:
  - We need to get one extra utility class to handle polarization tensor and to add a way optionally enable enable sampling of gamma emission using these classes
  - New G4PromptPhotonEvaporation model should be capable to include these
  - New evaporation data from Laurent