# Update on nuclear de-excitation

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# Outline

- New datasets in Geant4 11.3
- Continuum and discrete transitions for gamma/IC
- Definition of “stable” isomers
- Plans for 11.4

# New datasets in Geant4 11.3

- For release 11.3 3 datasets are updated
  - G4ENSDFSTATE3.0 – list of possible isomers
  - PhotonEvaporation6.1 – nuclear level parameters
  - RadioactiveDecay6.1.2 – data on radioactive decay
  - The data in 3 datasets are much more coherent than it was before
- G4PhotonEvaporation class
  - Uses nuclear level parameters
  - Is called by G4VRadioactiveDecay class
  - Is called by G4Evaporation

# Continuum and discrete transitions for gamma/IC

- Inside G4PhotonEvaporation we consider now several cases for gamma/IC transitions
  - From continuum to discrete level
  - From continuum to continuum
  - From discrete to discrete
  - The choice of the type of transition is based on initial state of the fragment
    - It is needed to use tolerance for nuclear width
    - Initial fragment state is defined by previous models (cascade, pre-compound)

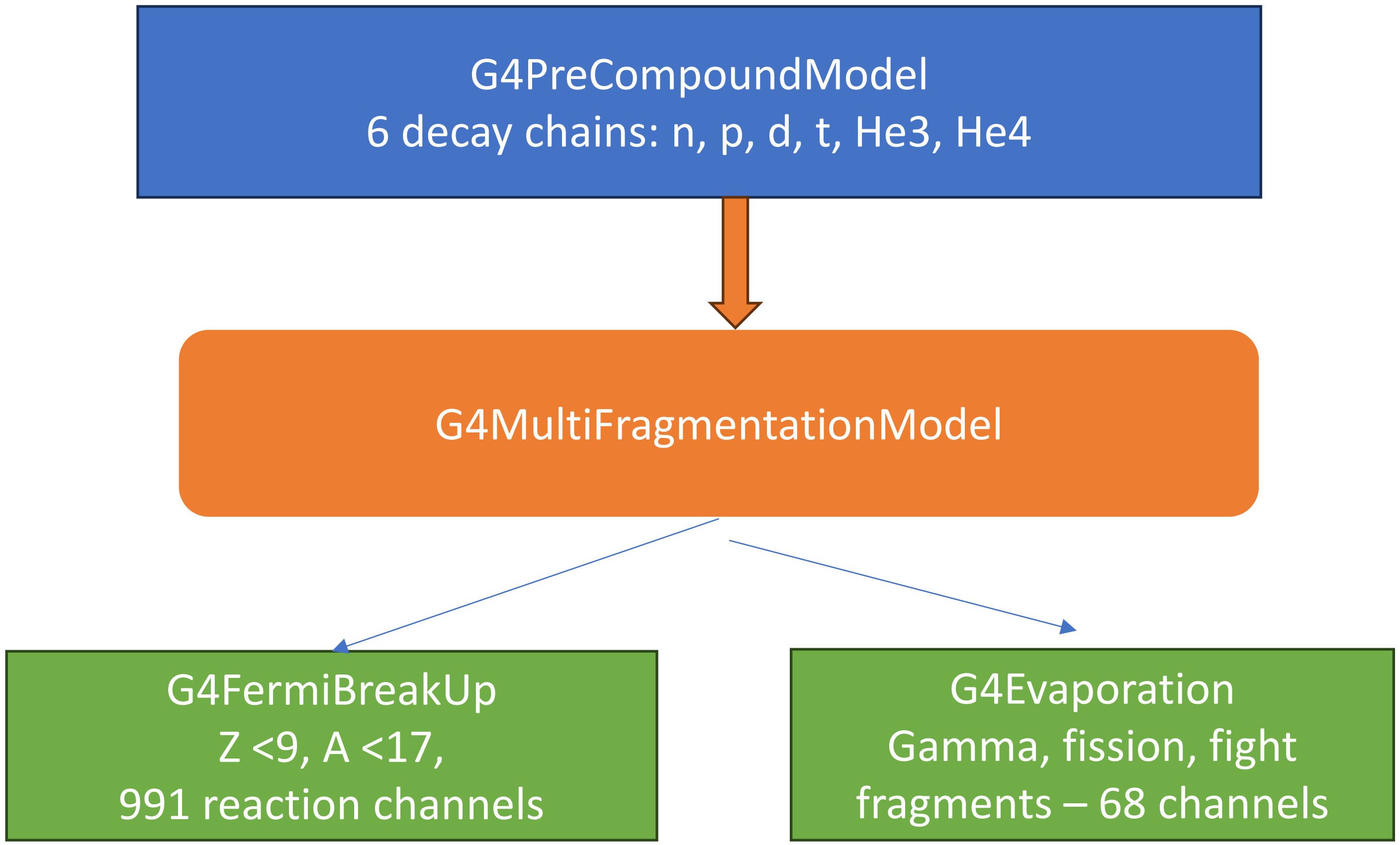
# Definition of “stable” isomers

- “Stable” isomer should have lifetime above threshold value
  - Curren default 1 ns
- To fix problem 2384 inside G4PhotonEvaporation this limit in increased
  - For today it is 10 ns
  - There are many levels in G4LEVELGAMMADATA with lifetime ~1 ns but with zero
- If a fragment become “stable” the de-excitation chain is stopped and a new G4Ion is released for tracking
  - If an ion is not in the G4IonTable a new G4Ion is created without usage of G4ENSDFSTATE, no radioactive decay or gamma transition for this ion will be known
- With 2384 and some other reports it become clear that G4ENSDFSTATE3.0 include many levels with zero lifetime
  - Corresponding data on radioactive decay is usually absent

# Plans for 11.4 (V.Ivanchenko, N.Chalyi, …)

- For datasets
  - Level gamma data and Radioactive decay data may stay unchanged
    - Specific problems of these datasets may be addressed separately
  - G4ENSDFSTATE3.0 requires some corrections
    - Only states, which are long-lived, or which have radioactive decay data can be considered
- For pre-compound/de-excitation
  - Reorganize order and schema of models
  - Change algorithms of sampling

# Pre-compound/de-excitation interface in 11.3

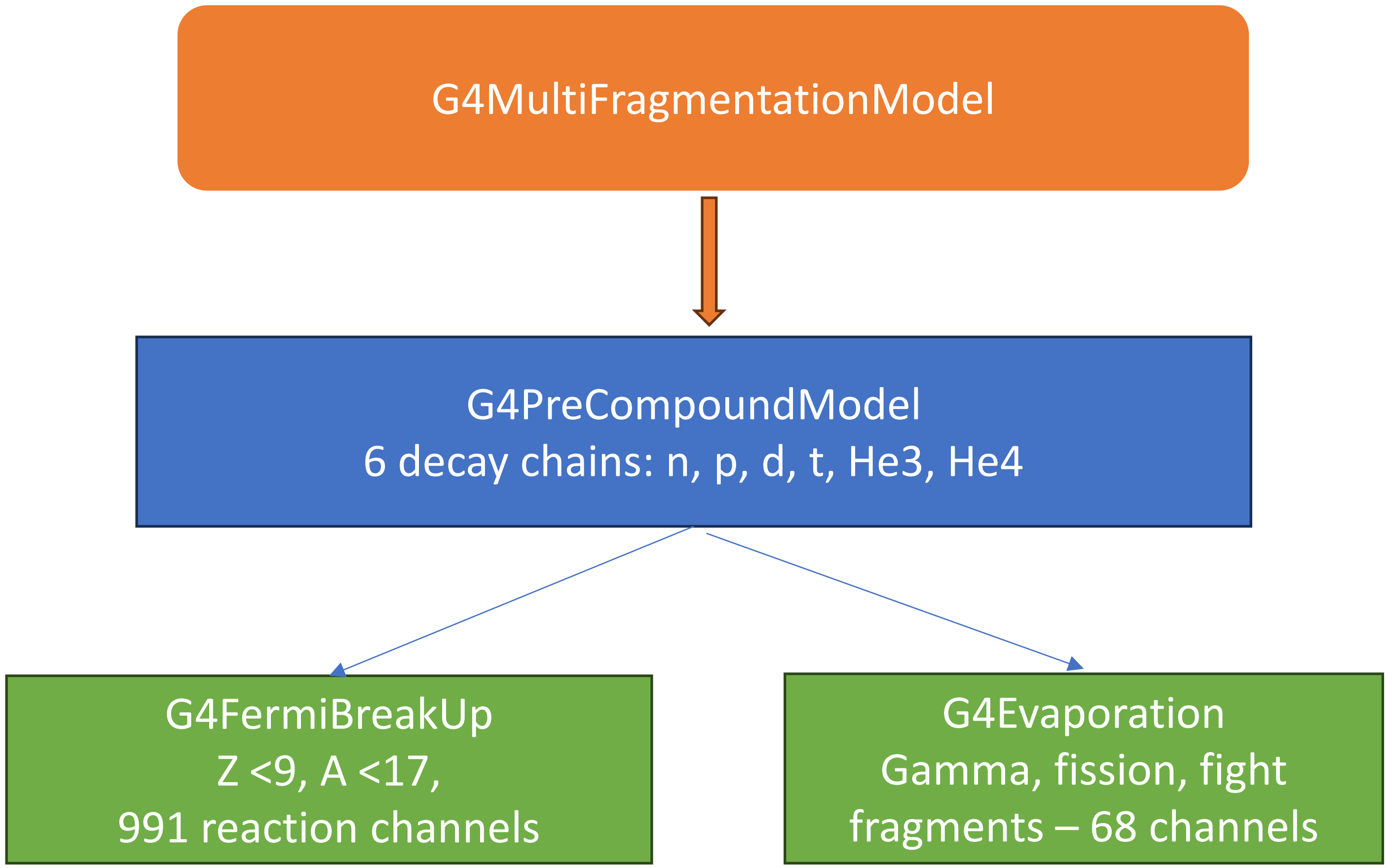



- Pre-compound model sample emission of n, p, light ions if
  - 0.1 MeV < Eex/A < 30 MeV
  - Only 1 emission
- Multifragmentation model sample secondaries if
  - Eex/A > 200 GeV
- FermiBreakUp is active for light fragments and
  - Eex < 20 MeV
- Evaporation is responsible for the rest

# Proposed solution for 11.4

- Create an alternative pre-compound model
  - A switch introduce into existing G4PreCompound model
    - In the new model, first the check on excitation will be done and overexcited fragments will be processed by multi-fragmentation
    - Option to enable/disable a new model will be added
  - Added extra parameters to handle a new model
  - Always possible to roll back and perform cross-comparison
- Expected problems
  - Degradation of some validation plots
  - Hadronic showers may be affected
  - The multi-fragmentation model may introduce 4-momentum disbalance
- We want to start asap to have enough time for validation

# Pre-compound/de-excitation interface in 11.4




- Multifragmentation model sample secondaries if
  - Eex/A > 20 MeV (to be tuned)
- Pre-compound model sample emission of n, p, light ions if
  - 0.1 MeV < Eex/A < 20 MeV
  - Condition of equilibrium
  - Condition on Z > 8; A >16
- FermiBreakUp is active for light fragments without upper limit on excitation
  - Expected 2 alternative models
  - One from MPTU university
- Evaporation is responsible for the rest including emission of light fragments

# Probability of evaporation

- Classical expression for probability of evaporation:

$$\mathrm{P}(E_i, \varepsilon)d\varepsilon = \; g_f \; \sigma_{inv}(\varepsilon)\frac{\rho_f\left(E_f\right)}{\rho_i(E_i)}\varepsilon d\varepsilon,$$

- $E_x$ – excitation energy of the fragment, Ɛ –is kinetic energy of emitted particle.
  - In 11.3 Ɛ was the sampling variable, $E_x$ was a value, which computed from energy/momentum conservation.
  - We plan to switch to $E_x$ to consider nuclear levels inside sampling algorithm directly, Ɛ will be computed variable.
    - In that case, nuclear levels will be taken in the algorithm directly

# Nuclear level width

- G4LEVELGAMMADATA include information on majority of known levels based on experiment
  - Energy, Lifetime, spin/parity, gamma transitions, IC transitions
- Not all nuclear level are known and not all parameters of levels are known
  - In our algorithms we should consider this fact
- Lifetime of many levels is zero
  - This means a prompt transition if these transitions are known
  - We need to sample width of a such level when we sample final state
  - Do out nuclear physics experts have idea how to choose this width?
- There are a fraction of levels, for which lifetime is known, so the width of these levels may be computed, and they are narrow
  - In the first order we may consider zero width in this case