Example : Activation

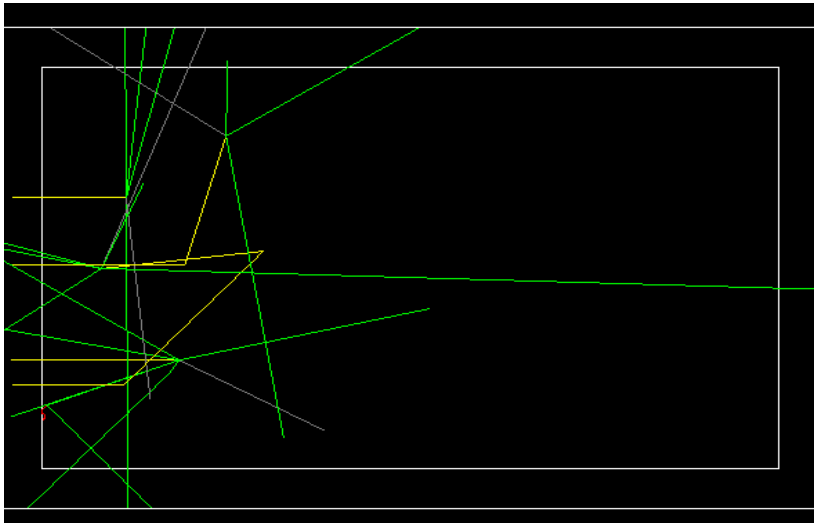
Michel Maire (Lapp – G4AI)

beam + target → A + … ---> B ---> C --->

- Evolution of populations : $N_a(t)$, $N_b(t)$, $N_c(t)$ … as a function of time
- Activities of emerging particles

purpose

Provide an example as simple and generic as possible, to illustrate this family of applications

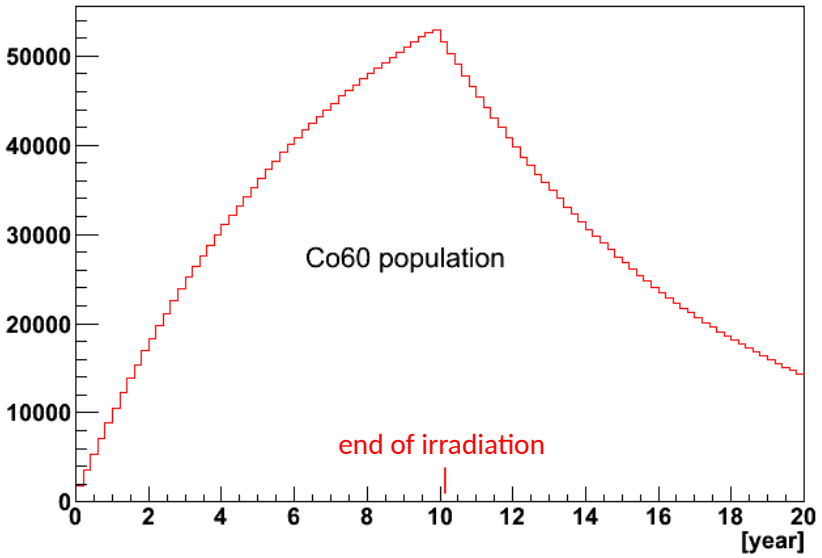


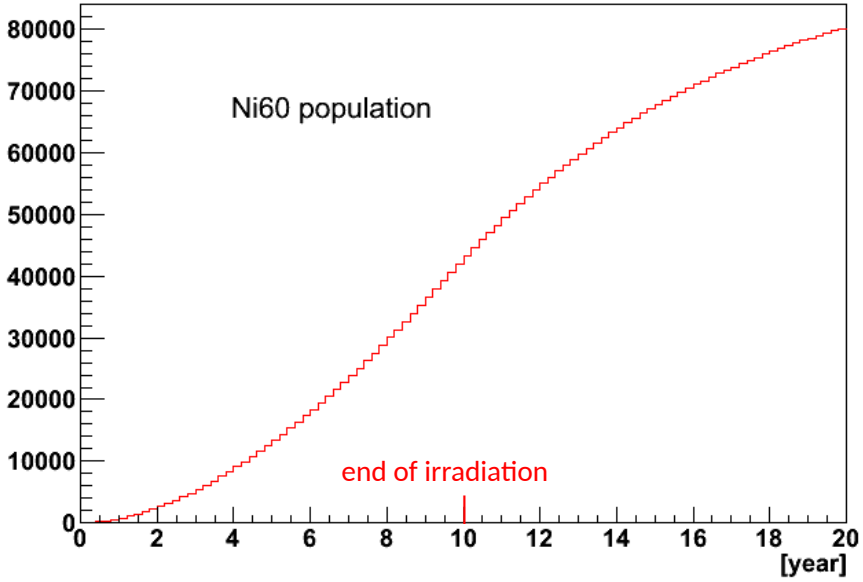
Results of an example :

neutron (25 meV) + Co59 → Co60 + γ ---> Ni60* ---> Ni60

beam irradiation : 10 year

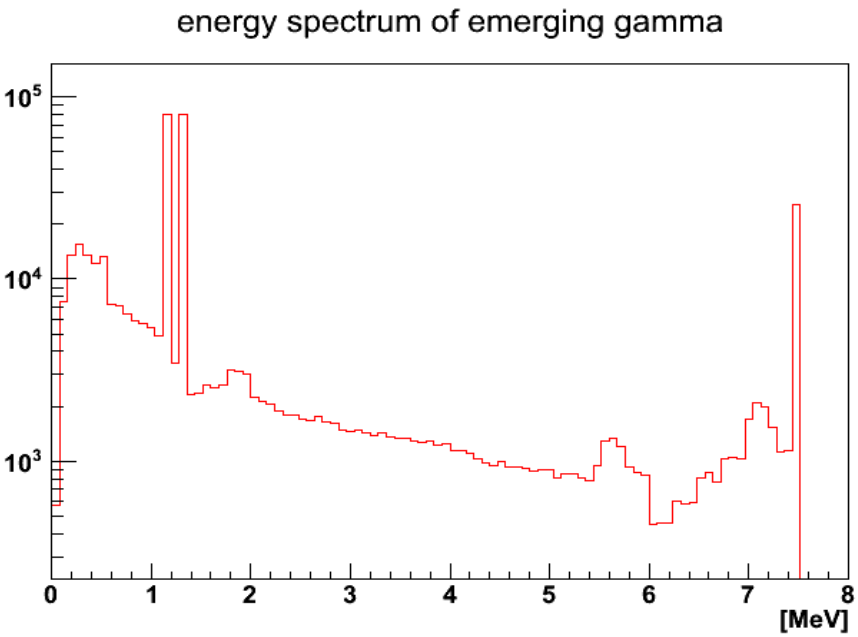
Co60 mean life : 7.6 year

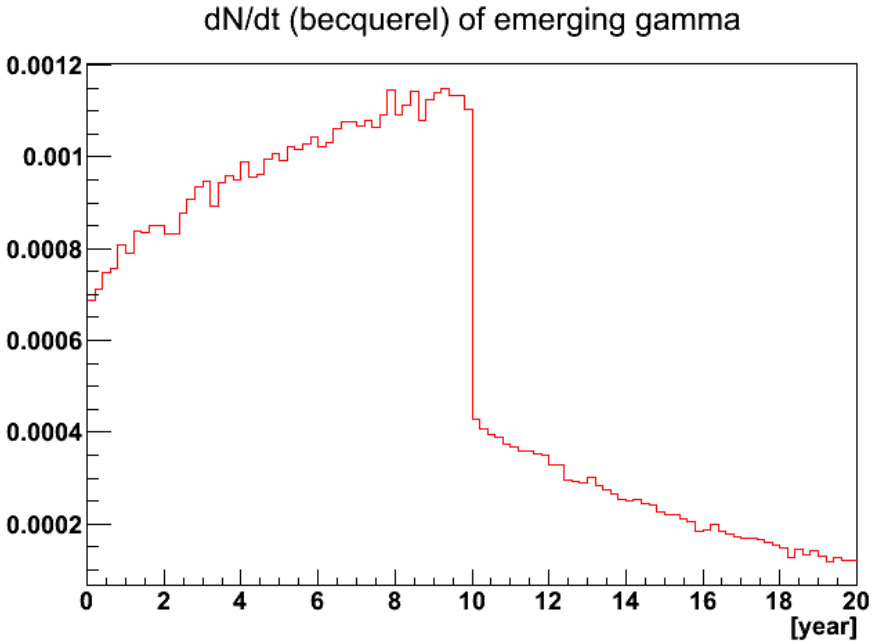




Results of an example (2)

n + Co59 → Co60 + γ ---> Ni60* ---> Ni60





Emerging gamma

```
/testhadr/det/setMat G4_Co                    |
/testhadr/det/setThickness 1 cm       |  ← target
/testhadr/det/setSizeYZ 1 cm                  |
#
/run/initialize
/process/list
#
/gun/particle neutron                         |
/gun/energy 25 meV                            |
/testhadr/gun/beamSize 8 mm                   |  ← beam
/testhadr/gun/beamTime 10 year  <-------------|----------------------
#
/analysis/setFileName Co60
/analysis/h1/set 4  100  0  8   MeV     #gamma     |
/analysis/h1/set 14 100  0 20  year     #gamma     |
/analysis/h1/set 24 100  0 20  year     #Co60      |  ← plots
/analysis/h1/set 25 100  0 20  year     #Ni60      |
/analysis/h1/set 26 100  0 20  year     #Co59      |
#
/run/printProgress 10000
/run/beamOn 100000
```

… as simple and generic as possible …

beam irradiation

Physics via PhysicsConstructors

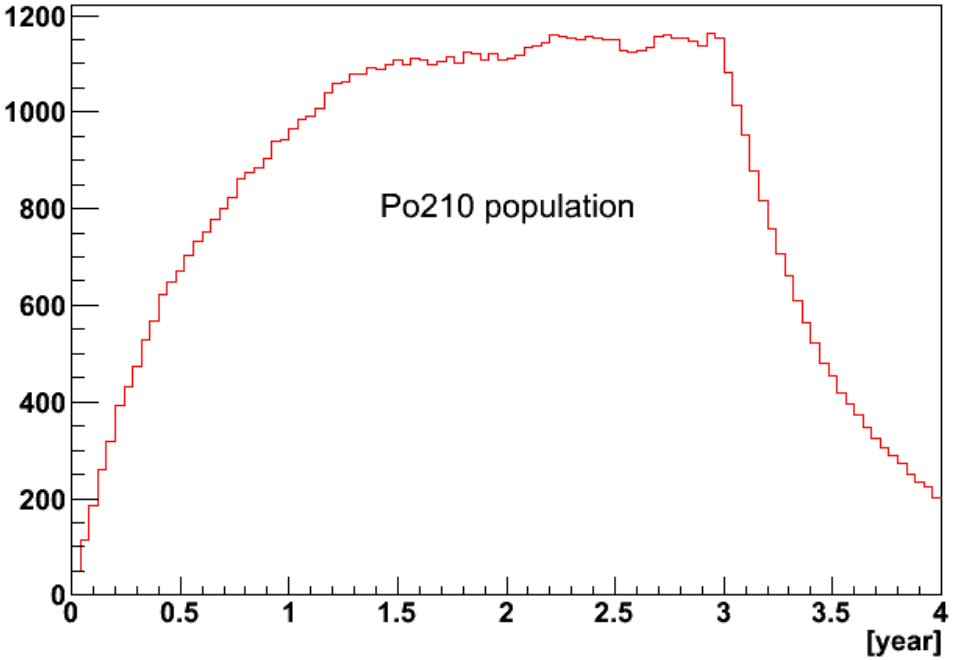
Physics constructors

- Hadron elastic
  - neutron thermal scattering in option
- Hadron inelastic
- Ion elastic
- Ion inelastic
- Gamma-nuclear physics
- Electromagnetic (minimal, fast)
- Radioactive decay

Another example :

neutron (25 meV) + Bi209 → Bi210 + γ ---> Po210 ---> Pb206

Population of Po210 ?



Bi210 mean life : 7 days
Po210 mean life : 200 days

beam irradiation : 3 years

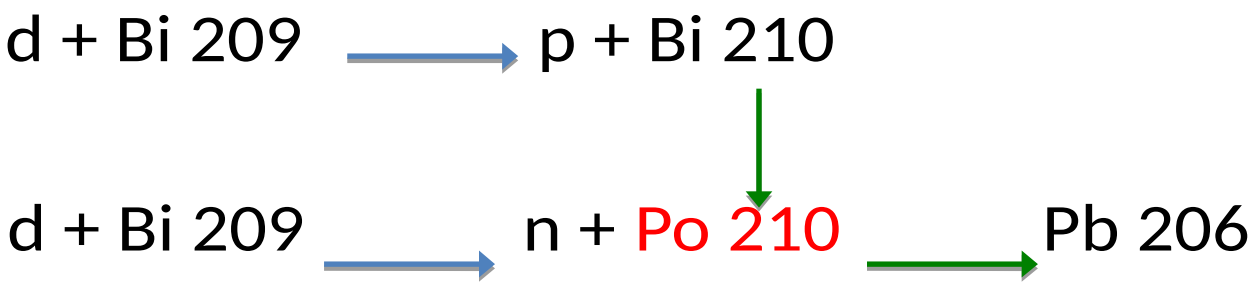
We observe the date of equilibrium : ~1.5 years

Histograming : few details

- A 1D histogram is assigned to each metastable isomer to plot its population as function of time

- Type and number of isomers created in a run cannot be predicted in advance.
  - the assignation isomer <---> histo_ID is done 'on fly'
  - in multithread mode, to avoid conflict, a lock mechanism is necessary (thanks to Ivana)

A last example : production of Polonium



Population of Po 210 ?

first step : d + Bi 209 → p + Bi 210 σ1 ~130 mb

→ n + Po 210 σ2 ~36 mb

– Q1 > 0 Q2 > 0 Coulomb barrier ~ 10 MeV

---> deuteron Ekin = 12 MeV

Binary light ion

one channel missing : σ1 = 0 ; σ2 = 41 mb

INCL

both channels (among others), but wrong ratio : σ1 = 121 mb ; σ2 = 270 mb

INCL is slow

ParticleHP + G4TENDL

both channels (among others), but wrong ratio : σ1 = 26 mb ; σ2 = 134 mb

ParticleHP is slow; results are suspicious

Conclusion Geant4 seems unable to simulate properly the reaction d + Bi 209

- Question
  - All hadronic packages generate only ground states. How to activate metastable isomers ?
- Comment
  - This example can be useful to test biasing methods both for nuclear channels and radioactive decays