

Geant 4

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Short Course*

Simulation Techniques Using Geant4

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<http://www.ge.infn.it/geant4/events/nss2008/geant4course.html>

This course exploits training material developed by several Geant4
Collaboration members: thanks to all of them!

Materials

How to describe the materials in the
experimental set-up

Basic concepts

- Geant4 lets you define
 - Isotopes
 - Elements
 - Materials
 - Compounds
 - Mixtures
- How to define them
- How to define vacuum

Definition of Materials

- Different kinds of materials can be defined:
 - isotopes - G4Isotope
 - elements - G4Element
 - molecules - G4Material
 - compounds and mixtures - G4Material
- Attributes associated to materials:
 - density (mandatory)
 - temperature
 - pressure
 - state (liquid, gas, etc.)

Isotopes, Elements and Materials

- **G4Isotope** and **G4Element** describe the properties of *nuclei* and *atoms*:
 - Atomic number, number of nucleons, mass of a mole, shell energies, etc...
 - Cross-sections per atoms, etc...
 - **Elements** are possibly **built out of isotopes**
- **G4Material** describes the *macroscopic* properties of generic matter:
 - temperature, pressure, state, density
 - radiation length, absorption length, etc...
 - **Materials** are **built out of elements**

Elements

- The simplest way to define an element is:

```
G4Element(const G4String& name,          //its name const
           G4String& symbol,             //its symbol
           G4double Z,                   //atomic number
           G4double A);                 //mass of mole
```

- *For instance:*

```
G4Element* oxygen =
    new G4Element("Oxygen", symbol="O", z=8., a=16*g/mole);
```

- Isotopes can be **assembled into elements**

```
G4Isotope (const G4String& name,
           G4int      z,      // number of atoms
           G4int      n,      // number of nucleons
           G4double  a );    // mass of mole
```

- ...building elements as follows:

```
G4Element (const G4String& name,
           const G4String& symbol, // element symbol
           G4int      nIsotope ); // # of isotopes

G4Element::AddIsotope(G4Isotope* isotope, //isotope
                     G4double abundance); //relative abundance
```

Elements

- Elements can also be defined using a [Geant4 internal database](#):

```
#include "G4NistManager.hh"  
[...]  
G4NistManager* manager = G4NistManager::Instance();  
// define elements  
G4Element* carbon = manager->FindOrBuildElement("C");
```

- To print information on a constituent element:

```
std::cout << carbon << std::endl;
```

Material: single element

- **Single-element** materials can be quickly defined:

```
G4double density = 1.390*g/cm3;  
G4double a = 39.95*g/mole;  
G4Material* liquidAr =  
  new G4Material("liquidArgon",z=18.,a,density);
```

- Materials composed by **many elements** (molecules or compounds) must be defined through their **constituent elements**
- Tip: use **low-density** material rather than vacuum

Material: molecule

- A **molecule** is made out of several elements

```
a = 1.01*g/mole;
G4Element* elementH =
    new G4Element("Hydrogen", symbol="H", z=1., a);
a = 16.00*g/mole;
G4Element* elementO =
    new G4Element("Oxygen", symbol="O", z=8., a);
density = 1.*g/cm3;
G4Material* H2O =
    new G4Material("Water", density, nComponents=2);
H2O->AddElement(elementH, nAtoms=2);
H2O->AddElement(elementO, nAtoms=1);
```

define molecule
define elements

Material: compound

- **A Compound** is made out of several elements:
 - composition by **fraction of mass**

define elements
define compound

```
a = 14.01*g/mole;  
G4Element* elementN =  
    new G4Element(name="Nitrogen", symbol="N", z= 7., a);  
a = 16.*g/mole;  
G4Element* elementO =  
    new G4Element(name="Oxygen", symbol="O", z= 8., a);  
density = 1.29*mg/cm3;  
  
G4Material* air =  
    new G4Material(name="Air", density, ncomponents=2);  
air->AddElement(elementN, 70.*perCent);  
air->AddElement(elementO, 30.*perCent); number of  
                                         components
```

Material: mixture

- Composition of **compound materials**

```
G4Element* elC = ...; // define "carbon" element
G4Material* SiO2 = ...; // define "quartz" material
G4Material* H2O = ...; // define "water" material

density = 0.200*g/cm3;
G4Material* aerogel =
    new G4Material("Aerogel", density, nComponents=3);
aerogel->AddMaterial(SiO2, fractionMass=62.5*perCent);
aerogel->AddMaterial(H2O, fractionMass=37.4*perCent);
aerogel->AddElement(elC, fractionMass= 0.1*perCent);
```

- Mixtures could also be defined using their **elemental mass composition**

Material: NIST database

- Materials can also be defined using the [internal Geant4 database](#), based on NIST reference data

```
#include "G4NistManager.hh"
G4NistManager* manager = G4NistManager::Instance();
// define pure NIST materials
G4Material* Cu = manager->FindOrBuildMaterial("G4_Cu");
// define NIST materials
G4Material* H2O = manager->FindOrBuildMaterial("G4_WATER");
```

- The list of [available material names](#) can be accessed at [run-time](#):

```
Idle> /material/nist/listMaterials all
```

or [in the code implementation](#)

```
G4NistManager::Instance()->ListMaterials("all");
```

Example: define a gas

- It is necessary to specify temperature and pressure
 - dE/dx computation is affected
- For density $<10 \text{ mg/cm}^3$ the material is automatically considered a gas

```
G4double density = 27.*mg/cm3;  
G4double temperature = 325.*kelvin;  
G4double pressure = 50.*atmosphere;
```

```
G4Material* CO2 =  
    new G4Material("CarbonicGas", density, nComponents=2  
                  kStateGas, temperature, pressure);  
CO2->AddElement(C,nAtoms = 1);  
CO2->AddElement(O,nAtoms = 2);
```

Example: define "vacuum"

- **Absolute vacuum** is not compatible with Geant4
Cannot define materials with density = 0
- It is rendered as a gas at **very low density**
 - transparent to particles being tracked

```
G4double atomicNumber = 1.;
G4double massOfMole = 1.008*g/mole;
G4double density = 1.e-25*g/cm3;
G4double temperature = 2.73*kelvin;
G4double pressure = 3.e-18*pascal;
G4Material* vacuum =
    new G4Material("interGalactic", atomicNumber,
                  massOfMole, density, kStateGas,
                  temperature, pressure);
```

Print material information

- To print **information** on a given user-defined G4Material:

```
std::cout << Air << std::endl;
```

or at **run-time** via the UI command

```
Idle> /material/g4/printMaterial materialName
```

- To print the **full list** of user-defined materials:

```
std::cout << *(G4Material::GetMaterialTable())  
            << std::endl;
```