

Hands-On on physics

« dnaphysics »

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dnaphysics

- We are going to study the **dnaphysics** extended example which makes use of **Geant4-DNA Physics processes and models**
 - This is the « simplest » Geant4-DNA example
- This is an extended example and it is located in `$G4INSTALL/examples/extended/electromagnetic/dna`

dnaphysics

- This example teaches to Geant4 users how to **use the Geant4-DNA physics processes and models** in a liquid water volume
 - All particle interactions are simulated on a **step-by-step basis**
 - Produces a **ROOT ntuple** to analyze & visualize track structures
 - The PhysicsList class uses the **default Physics constructor** called **G4EmDNAPhysics** so you do not need to code the physics yourself
 - You can easily switch from one constructor to another
- It also explains how to easily change the density of the target material (liquid water) : « **variable density material** » feature of Geant4
 - Possibility to investigate density change effects
 - eg. **1.06 g/cm³** average density of cell nucleus (cf. PARTRAC)

dnaphysics

- Copy the `dnaphysics` extended example to your local directory, create your build directory and compile `dnaphysics`

```
cd
cp -R $G4EXAMPLES/examples/extended/medical/dna/dnaphysics .
mkdir build-dnaphysics
cd build-dnaphysics
cmake ../dnaphysics
make
```

make -jN if you have N cores

- Run `dnaphysics` (`dnaphysics.in` is read by default)

```
./dnaphysics
```

- 100 electrons of 1 keV are shot
- Auger electron production is activated
- No visualization by default
- Results are saved in `dna_t*.root` files

- Results can be analyzed using **ROOT**

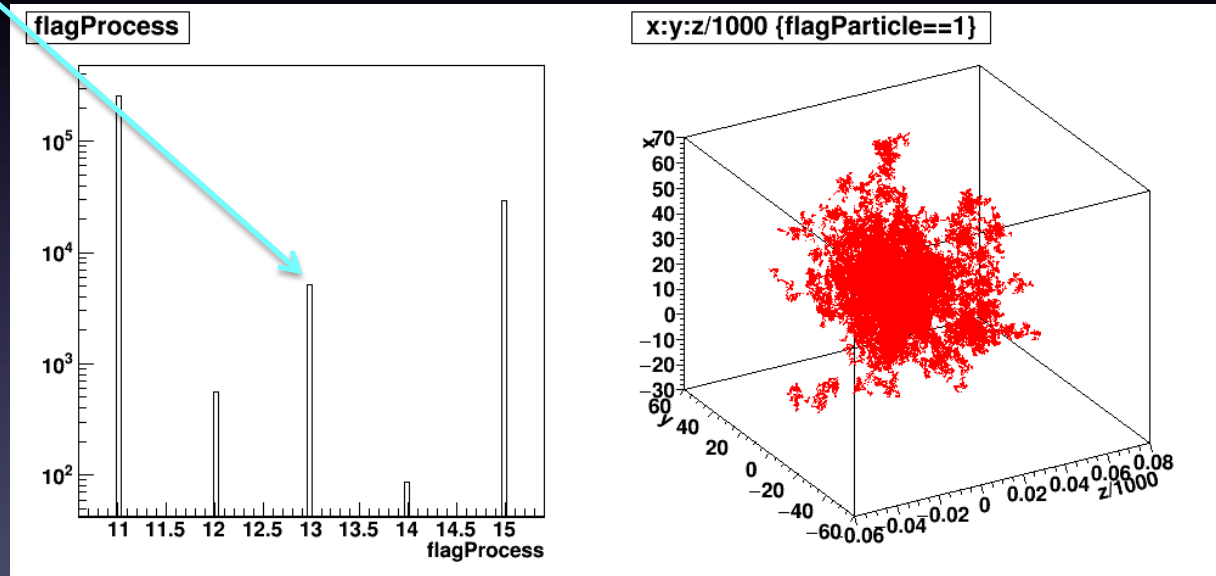
```
root plot.C
```

Output of dnaphysics

Numbering of processes from `SteppingAction` class

e-_G4DNAElastic	11
e-_G4DNAExcitation	12
e-_G4DNAIonisation	13
e-_G4DNAAttachment	14
e-_G4DNAVibExcitation	15
proton_G4DNAExcitation	17
proton_G4DNAIonisation	18
proton_G4DNAChargeDec.	19
hydrogen_G4DNAExcitation	20
hydrogen_G4DNAIonisation	21
hydrogen_G4DNAChargeInc.	22
alpha_G4DNAExcitation	23
alpha_G4DNAIonisation	24
alpha_G4DNAChargeDec.	25
alpha+_G4DNAExcitation	26
alpha+_G4DNAIonisation	27
alpha+_G4DNAChargeDec.	28
alpha+_G4DNAChargeInc.	29
helium_G4DNAExcitation	30
helium_G4DNAIonisation	31
helium_G4DNAChargeInc.	32

Eg. 100 electrons of 1 keV



Do it yourself ...

- Try yourself to modify `dnaphysics.in` (do `geany dnaphysics.in &`)
 - Set number of incident electrons to `1`
 - Activate visualization in `dnaphysics.in`
 - Edit `vis.mac`
 - Replace 'OGL' by 'OGLIXm' at line `/vis/open...`
 - Zoom display by 1000 (add `/vis/viewer/zoom 1000`) in `vis.mac`
 - run again
 - Try to shoot one `proton`, then one `hydrogen`, then one `helium` with 10 keV incident energy
- Then, look at the following classes
 - `PhysicsList`
 - Usage of `G4EmDNAPhysics` constructor
 - `SteppingAction`
 - Recording of particles & processes
 - Positions of pre/post-step points
 - Energy deposit for each step, step length, energy loss
 - `DetectorConstruction`
 - Change of value of water density
 - `RunAction`
 - Handling of ntuples (creation, filling up, saving)
- Try do change density value of water by one order of magnitude and shoot one 1 keV electron; what happens ?

PhysicsList header

```
#include "G4VModularPhysicsList.hh"
#include "globals.hh »

class G4VPhysicsConstructor;

class PhysicsList: public G4VModularPhysicsList
{
public:
    PhysicsList();
    virtual ~PhysicsList();
};
```

PhysicsList implementation

```
#include "PhysicsList.hh"
#include "G4SystemOfUnits.hh"
#include "G4EmDNAPhysics.hh"

//.....ooo00000ooo.....ooo00000ooo.....ooo00000ooo.....ooo00000ooo.....

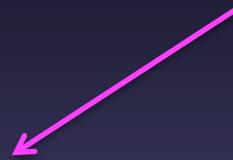
PhysicsList::PhysicsList()
: G4VModularPhysicsList()
{
  SetDefaultCutValue(1.0*micrometer);
  SetVerboseLevel(1);
  RegisterPhysics(new G4EmDNAPhysics());
  G4ProductionCutsTable::GetProductionCutsTable()->SetEnergyRange(100*eV, 1*GeV);
}

//.....ooo00000ooo.....ooo00000ooo.....ooo00000ooo.....ooo00000ooo.....

PhysicsList::~PhysicsList()
{}


```

G4EmDNAPhysics constructor



What is included in the G4EmDNAPhysics constructor?

```
void G4EmDNAPhysics::ConstructParticle()  
{  
  // bosons  
  G4Gamma::Gamma();  
  
  // leptons  
  G4Electron::Electron();  
  G4Positron::Positron();  
  
  // baryons  
  G4Proton::Proton();  
  G4GenericIon::GenericIonDefinition();  
  G4DNAGenericIonsManager * genericIonsManager;  
  genericIonsManager=G4DNAGenericIonsManager::Instance();  
  genericIonsManager->GetIon("alpha++");  
  genericIonsManager->GetIon("alpha+");  
  genericIonsManager->GetIon("helium");  
  genericIonsManager->GetIon("hydrogen");  
}
```

Source located in
\$G4INSTALL/source/physics_lists/constructors/electromagnetic

Proton and He²⁺ nuclei can
gain electrons and
become H, He⁺, He⁰

G4EmDNAPhysics: Physics processes & models for electrons

```
void G4EmDNAPhysics::ConstructProcess ()
{
  G4PhysicsListHelper* ph = G4PhysicsListHelper::GetPhysicsListHelper();
  theParticleIterator->reset();
  while( (*theParticleIterator)() )
  {
    G4ParticleDefinition* particle = theParticleIterator->value();
    G4String particleName = particle->GetParticleName();

    if (particleName == "e-") {
      // *** Elastic scattering (two alternative models available) ***
      G4DNAElastic* theDNAElasticProcess = new G4DNAElastic("e-_G4DNAElastic");
      theDNAElasticProcess->SetModel(new G4DNAChampionElasticModel());

      // or alternative model
      //theDNAElasticProcess->SetModel(new G4DNAScreenedRutherfordElasticModel());
      ph->RegisterProcess(theDNAElasticProcess, particle);

      // *** Excitation ***
      ph->RegisterProcess(new G4DNAExcitation("e-_G4DNAExcitation"), particle);
      // *** Ionisation ***
      ph->RegisterProcess(new G4DNAIonisation("e-_G4DNAIonisation"), particle);
      // *** Vibrational excitation ***
      ph->RegisterProcess(new G4DNAVibExcitation("e-_G4DNAVibExcitation"), particle);
      // *** Attachment ***
      ph->RegisterProcess(new G4DNAAttachment("e-_G4DNAAttachment"), particle);
    }
  }
}
```

We have two models for electron elastic scattering in liquid water

PROCESS

MODEL

G4EmDNAPhysics: Physics processes & models for other Geant4- DNA particles

```
} else if ( particleName == "proton" ) {  
    ph->RegisterProcess(new G4DNAExcitation("proton_G4DNAExcitation"), particle);  
    ph->RegisterProcess(new G4DNAIonisation("proton_G4DNAIonisation"), particle);  
    ph->RegisterProcess(new G4DNAChargeDecrease("proton_G4DNAChargeDecrease"), particle);  
  
} else if ( particleName == "hydrogen" ) {  
    ph->RegisterProcess(new G4DNAExcitation("hydrogen_G4DNAExcitation"), particle);  
    ph->RegisterProcess(new G4DNAIonisation("hydrogen_G4DNAIonisation"), particle);  
    ph->RegisterProcess(new G4DNAChargeIncrease("hydrogen_G4DNAChargeIncrease"), particle);  
  
} else if ( particleName == "alpha" ) {  
    ph->RegisterProcess(new G4DNAExcitation("alpha_G4DNAExcitation"), particle);  
    ph->RegisterProcess(new G4DNAIonisation("alpha_G4DNAIonisation"), particle);  
    ph->RegisterProcess(new G4DNAChargeDecrease("alpha_G4DNAChargeDecrease"), particle);  
  
} else if ( particleName == "alpha+" ) {  
    ph->RegisterProcess(new G4DNAExcitation("alpha+_G4DNAExcitation"), particle);  
    ph->RegisterProcess(new G4DNAIonisation("alpha+_G4DNAIonisation"), particle);  
    ph->RegisterProcess(new G4DNAChargeDecrease("alpha+_G4DNAChargeDecrease"), particle);  
    ph->RegisterProcess(new G4DNAChargeIncrease("alpha+_G4DNAChargeIncrease"), particle);  
  
} else if ( particleName == "helium" ) {  
    ph->RegisterProcess(new G4DNAExcitation("helium_G4DNAExcitation"), particle);  
    ph->RegisterProcess(new G4DNAIonisation("helium_G4DNAIonisation"), particle);  
    ph->RegisterProcess(new G4DNAChargeIncrease("helium_G4DNAChargeIncrease"), particle);  
}  
}
```



PROCESS

More on Geant4-DNA Physics

- Some DNA models « kill » the particle below a certain energy threshold because the models are not validated or defined below this threshold
 - In this case, tracking is stopped and the kinetic energy is locally deposited
 - Electrons below 7.4 eV (by `G4DNAChampionElasticModel`) or below 9 eV (by `G4DNAScreenedRutherfordElasticModel`)
 - Protons & H below 100 eV by `G4DNARuddIonisationModel`
 - He^{2+} , He^+ and He^0 below 1 keV by `G4DNARuddIonisationModel`
- See other hints from the Geant4-DNA web page
 - <http://geant4-dna.org>, in section Physics - FAQ
 - How to access total cross sections
 - How to « kill » particles below a certain energy threshold
 - ...

SteppingAction

- Show you how to record useful information

- You can flag a particle

```
if (step->GetTrack()->GetDynamicParticle()->GetDefinition()->GetParticleName() == "e-") flagParticle = 1;
```

- You can flag a process

```
if (step->GetPostStepPoint()->GetProcessDefinedStep()->GetProcessName()=="hydrogen_G4DNAExcitation")  
    flagProcess =20;
```

- You can extract step information

```
x=step->GetPreStepPoint()->GetPosition().x()/nanometer;  
y=step->GetPreStepPoint()->GetPosition().y()/nanometer;  
z=step->GetPreStepPoint()->GetPosition().z()/nanometer;  
xp=step->GetPostStepPoint()->GetPosition().x()/nanometer;  
...step->GetTotalEnergyDeposit()/eV  
...std::sqrt((x-xp)*(x-xp)+(y-yp)*(y-yp)+(z-zp)*(z-zp))/nm  
...(step->GetPreStepPoint()->GetKineticEnergy() - step->GetPostStepPoint()->GetKineticEnergy())/eV )
```

DetectorConstruction

- Definition of water material

```
// Water is defined from NIST material database  
G4NistManager * man = G4NistManager::Instance();  
G4Material * H2O = man->FindOrBuildMaterial("G4_WATER");
```

- Change of density value

```
// If one wishes to test other density value for water material, one should use instead:  
// G4Material * H2O = man->BuildMaterialWithNewDensity("G4_WATER_MODIFIED", "G4_WATER", 1.1*g/cm3);  
// Note: any string for "G4_WATER_MODIFIED" parameter is accepted  
// and "G4_WATER" parameter should not be changed  
// Both materials are created and can be selected from dnaphysics.in
```

- Display density

```
G4cout << "-> Density of water material (g/cm3)=" << waterMaterial->GetDensity()/(g/cm/cm/cm) << G4endl;
```