Hands-On on physics

dnaphysics

Sébastien Incerti

1st Geant4-DNA tutorial

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dnaphysics

- We are going to try the dnaphysics example which make use of Geant4-DNA Physics processes
- 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
  - Produces a ROOT ntuple to visualize track structures
  - The PhysicsList uses the default Physics constructor called G4EmDNAPhysics which contains the recommended Geant4-DNA physics, so you do not need to code the physics yourself

- 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/cm^3 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 /mnt/g4tuto/geant4-10.01-install/share/Geant4-10.1.0/examples/extended/medical/dna/dnaphysics .
mkdir build-dnaphysics
cd build-dnaphysics
cmake ../dnaphysics
make
```

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

```
./dnaphysics
```

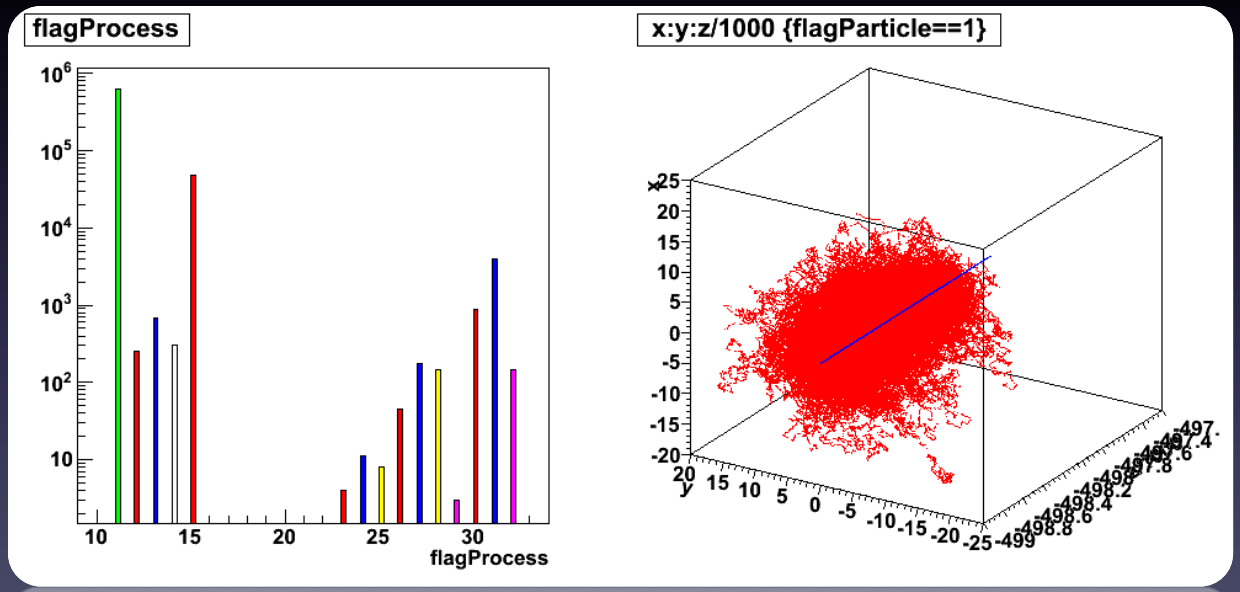
  - 100 electrons of 1 keV are shot
  - No visualization by default
  - Results are saved in dna.root file

- Results can be analyzed using ROOT

```
root plot.C
```

Output of dnaphysics

Eg. one 100 keV He^+



Do it yourself …

- Try yourself in dnaphysics.in (do **`geany dnaphysics.in &`**)
  - Set number of incident electron to 1
  - Activate visualization
  - Zoom display by 10000 (add **`/vis/viewer/zoom 10000`**) in vis.mac
  - run again
  - Try to shoot one proton, then one hydrogen, then one helium with 10 keV incident energy
- Look at the following classes
  - PhysicsList
    - Usage of G4EmDNAPhysics constructor
  - SteppingAction
    - Recording of particles & processes
    - Positions of pre-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"

//....oooOOoOOooo.....oooOOoOOooo.....oooOOoOOooo.....oooOOoOOooo.....

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

//....oooOOoOOooo.....oooOOoOOooo.....oooOOoOOooo.....oooOOoOOooo.....

PhysicsList::~PhysicsList()
{}
```

What is included in the G4EmDNAPhysics builder ?

```
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");
}
```

Proton and He^{2+} nuclei can gain electrons and become H, He^{+}, He^{0}

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

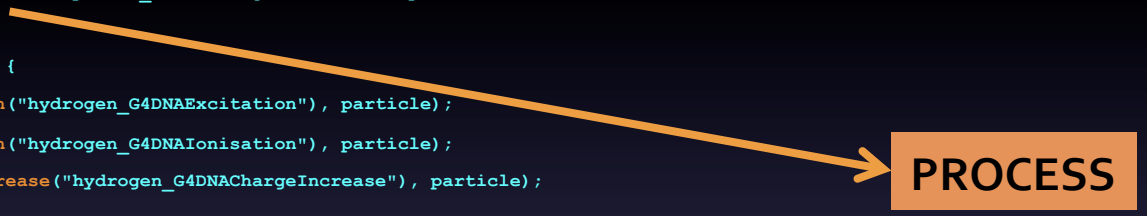
```
} else if ( particleName == "proton" ) {
    ph->RegisterProcess(new G4DNAExcitation("proton_G4DNAExcitation"), particle);
    ph->RegisterProcess(new G4DNAIonisation("proton_G4DNAIonisation"), particle);
    ph->RegisterProcess(new G4DNAChargeDecrease("proton_G4DNAChargeDecrease"), particle);

  } 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);
  }
```



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 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
- Flag of particle

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

- Flag of process

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

- 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;
```