Special Topics in Nuclear Physics 0342797

Course web

http://nuclear.bau.edu.jo/ju/ju-special-topics/

or

http://nuclear.dababneh.com/ju/ju-special-topics/

Grading

Mid-term Exam	40%
Projects and HWs	20%
Final Exam	40%

- Homeworks and small projects are due after one week unless otherwise announced.
- Remarks or questions marked in red without being announced as homeworks should be also seriously considered!
- Some tasks can (or should) be sent by email.

Main Project

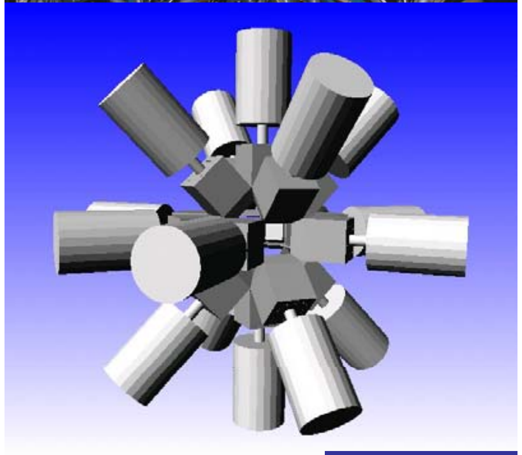
- Please do your own **thorough research** on relevant topics you may find appropriate.
- Provide your **suggestion** next week.
- **Final decision** on the subject of your project should be taken before the end of February.
- Due date for **written version** is Tuesday, May 3rd.
- **Presentation** date will be decided later.

Topic I

Monte Carlo Techniques in Radiation Detection and Measurement

Why MC … ?

- Design a setup.
- Optimize a setup.
  - Geometry, materials, orientation, fields, electronics, acquisition, analysis …



- Save money and time.
- Calibrate a setup … !
- Solve chronic issues.
- More through examples …

Geant4

- A toolkit.
- CERN.
- High-energy physics … !
- Low-energy ▶ nuclear, accelerator, astro, medical, environmental …
- C++.
- Unix flavors, Linux, Cygwin on Windows.

Simulate what … ?

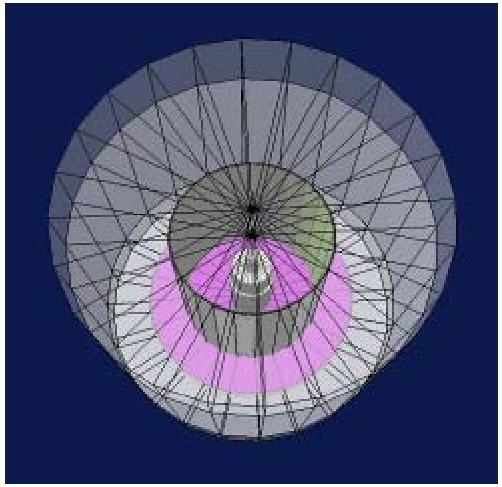
- Geometry of the system (Modeling).
- Materials.
- Fundamental particles of interest.
- Primary events.
- Physics processes governing particle interactions with materials and fields.
- Storage of events and tracks.
- Visualization of the detector and particle trajectories.
- Analysis of simulation data at different levels of detail and refinement.

How ?

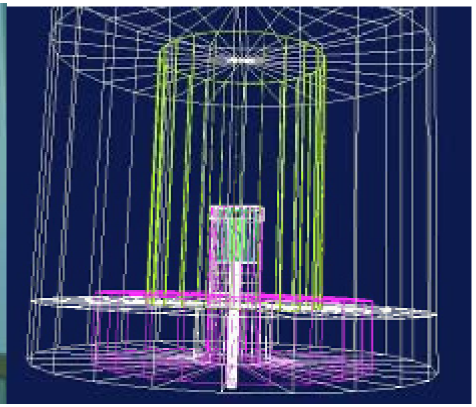
- Define physics, geometry, materials, particles …… etc…
- Random number generator.
- Fast processors ▶ large number of “events”.
- Event ▶ primary ▶ interaction ▶ secondaries ▶ interaction ▶ ▶ ▶ detector ▶ response …
- Simulation vs. calculation …

A gamma spectrometer

Modeling an ORTEC GMX Detector.



Lateral view



Top view

Material definition

```
G4double a;
G4double z;
G4double density;
G4String name, symbol;
G4int ncomponents;
G4double fractionmass;
a = 14.007*g/mole;
G4Element* elN = new G4Element(name="Nitrogen", symbol=" N" , z=7., a);
a = 15.999*g/mole;
G4Element *elO = 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(elO, fractionmass=30.0*perCent);
Air->AddElement(elN, fractionmass=70.0*perCent);
```

Volumes

```
G4double startFi = 0.0*deg;
G4double endFi = 360.0*deg;
G4double PbCapInR2 = 28.7/2*cm;
G4double PbCapHalfh2 = 41.3/2.*cm;
G4double AlCuthick =0.2*cm;
G4double CuCapOutR = PbCapInR2;
G4double CuCapInR = PbCapInR2-AlCuthick;
G4double CuCapHalfh = PbCapHalfh2;
G4Tubs *CuCap_tube = new
    G4Tubs("CuCap_tube",CuCapInR,CuCapOutR,CuCapHalfh,startFi,endFi);
G4LogicalVolume *CuCap_log = new
    G4LogicalVolume(CuCap_tube,Cu,"CuCap_log",0,0,0);
G4double Pos_x = 0.0*cm;
G4double Pos_y = 0.0*cm;
G4double Pos_z = 6.95*cm;
G4VPhysicalVolume *CuCap_phys = new
    G4PVPlacement(0,G4ThreeVector(Pos_x,Pos_y,Pos_z),CuCap_log,"CuCa
    p", World_log,false,0);
```

Daughter

Mother

Physics … !

```
#include "G4ComptonScattering.hh"
#include "G4GammaConversion.hh"
#include "G4PhotoElectricEffect.hh"
void XriPhysicsList::ConstructEM()
{
  theParticleIterator->reset();
  while( (*theParticleIterator)() ){
    G4ParticleDefinition* particle = theParticleIterator->value();
    G4ProcessManager* pmanager = particle->GetProcessManager();
    G4String particleName = particle->GetParticleName();
    if (particleName == "gamma") {
      pmanager->AddDiscreteProcess(new G4PhotoElectricEffect());
      pmanager->AddDiscreteProcess(new G4ComptonScattering());
      pmanager->AddDiscreteProcess(new G4GammaConversion());
```

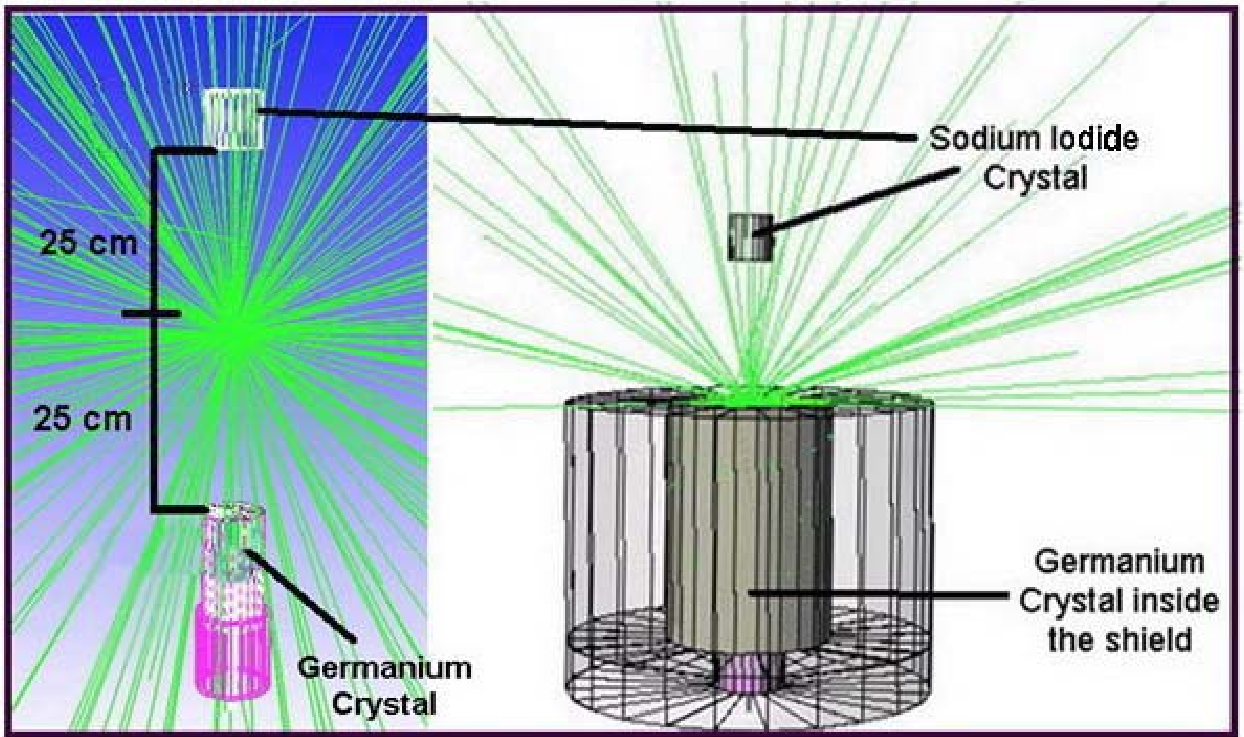
etc …

Other particles are included in a similar manner but with their individual physics processes of interest

Validation

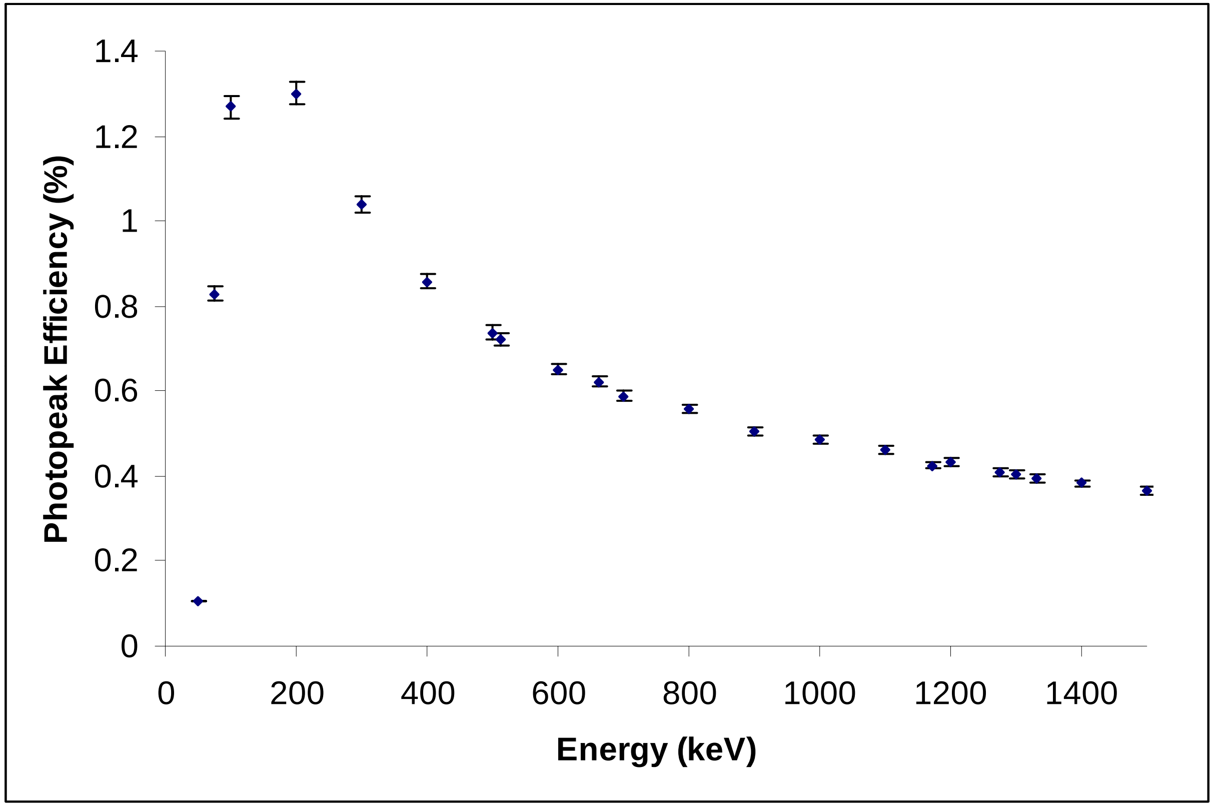
Simulation results exhibit excellent agreement when compared to real documented and experimental data for relative and absolute efficiencies.

Relative
Efficiency:
Manufacturer
50 %
Simulation
50.19 ± 1.06 %



Absolute Efficiency

- The measured and simulated absolute efficiencies at 662 keV of ^{137}Cs are (0.6232 ± 0.0050)% and (0.6212 ± 0.0079)%, respectively.
- Relative error of 0.32%.
- ^{137}Cs is summing free.
- So what about Correction Factors … ?!!!



Spectra … Experiment vs. simulation