Neutron Simulation with WCSim

Noah Grethen, 7/10/23

Simulation Setup

Using the Geant4 and ROOT based WCSim (water Cherenkov simulation) program.

GitHub repository page link: https://github.com/indigo40123/WCSim_USJapan

Detector information

- Detector Geometry: cylindrical water Cherenkov detector, 3.0 m diameter, 2.0 m height
- With and without Gd (*0.1 wt%*)
- Photo coverage ~36% and ~89%
- 3-inch PMT

How to add Gd to the detector in WCSim_USJapan github code

"Doped Water" can be a material defined in "WCSimConstructMaterials.cc" with whatever Gd concentration. Furthermore, one can add in "WCSimDetectorMessenger.cc" a command for the final ~.mac file to easily turn on/off Gd doping.

In particular, one can make the "Doped Water" material creation a function that takes in a Gd percentage value as so to the right:

(code bit already in "WCSimConstructCylinder.cc" where WCAddGd is defined/turned false/true in "WCSimDetectorConfigs.cc")

```
//Decide if adding Gd
water = "Water";
if (WCAddGd)
{water = "Doped Water";}
```

```
/WCSim/DopingConcentration 0.1
/WCSim/DopedWater true
```

(defining in "WCSimDetectorMessenger.cc" commands for the .mac file)

(Added into the final ~.mac file that is run, easy to turn on/off and change Gd percentage)

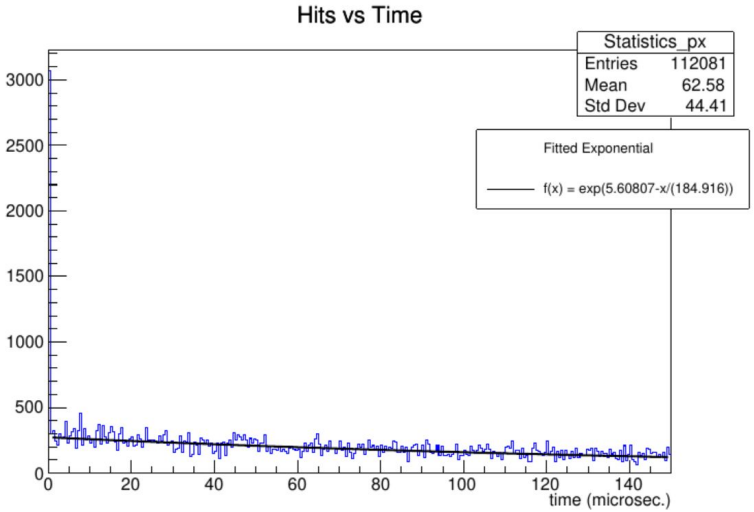
```
if(command == DopedWater) {
        G4cout << "Setting Gadolinium doping of water: " << newValue << G4endl;
        WCSimDetector->SetDopedWater(DopedWater->GetNewBoolValue(newValue));
}

if(command == DopingConcentration) {
        G4cout << "Setting Gadolinium doping concentration: " << newValue << " percent" << G4endl;
        WCSimDetector->AddDopedWater(DopingConcentration->GetNewDoubleValue(newValue));
}
```

Also added neutron capture physics for Gd and H (using so called “FTFP_BERT_HP” physics list)

Using “NoTrigger” mode along with “40%” (effectively ~36% pc), 10,000 neutrons generated uniformly, isotropically inside detector

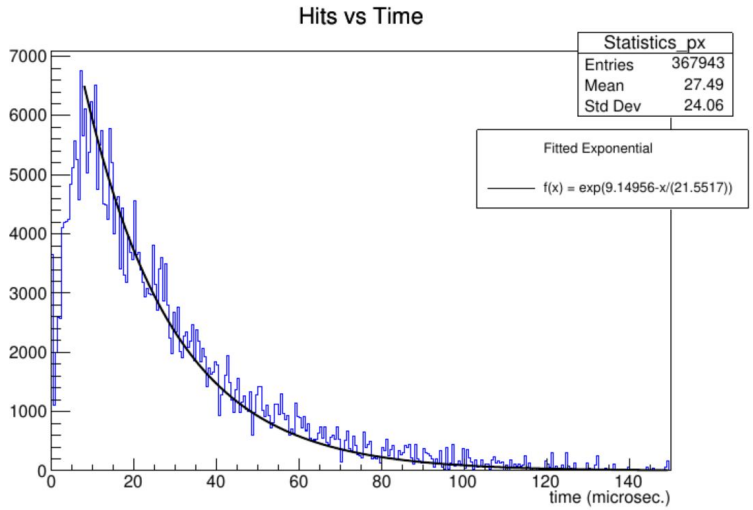
5 MeV neutrons without Gd

- Percentage of generated neutron events with any PMT hits is 76.96%



5 MeV neutrons with 0.1 Gd

- Percentage of generated neutron events with any PMT hits is 86.64%

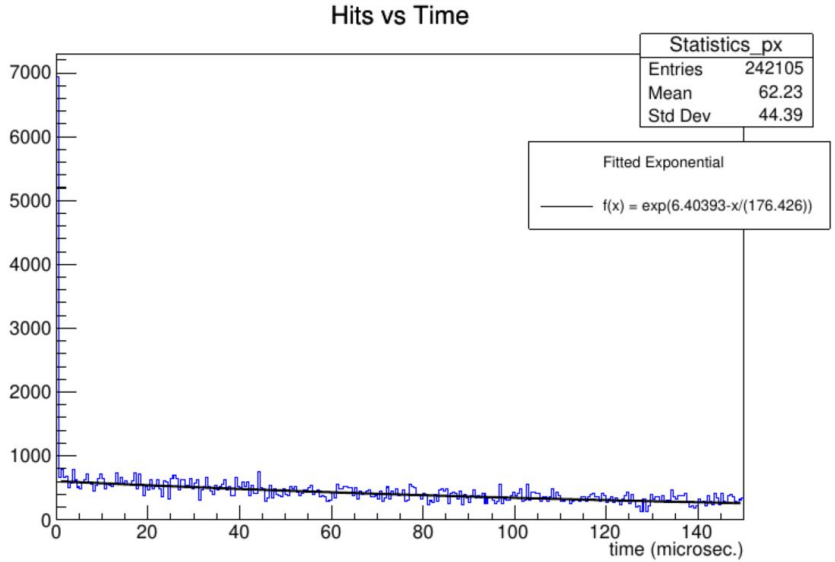


*Fitted capture time constants mostly as expected (~30 micro-sec for 0.1% Gd and ~200 micro-sec for pure water). Sorry statistics are low, will fix in future

Same as last slide page but with “100%” pc (effectively ~89%)

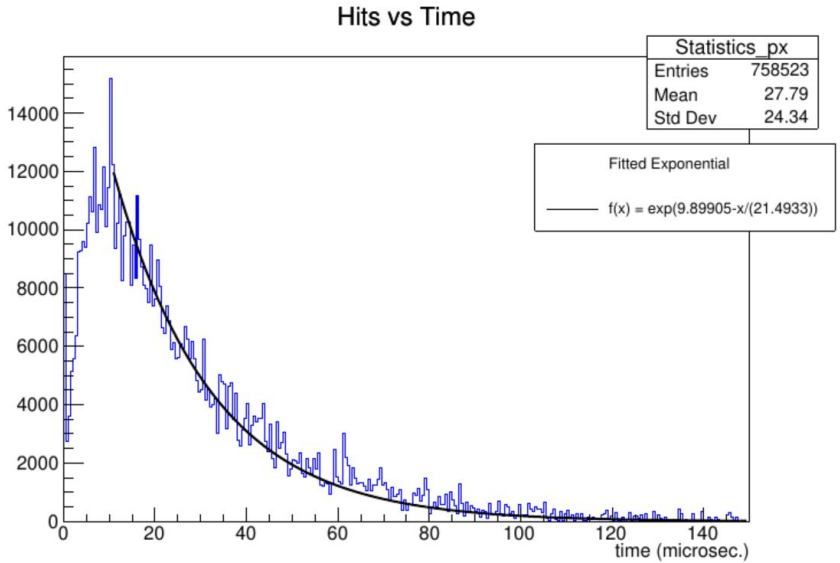
5 MeV neutrons without Gd

- Percentage of generated neutron events with any PMT hits is 76.32%



5 MeV neutrons with 0.1 Gd

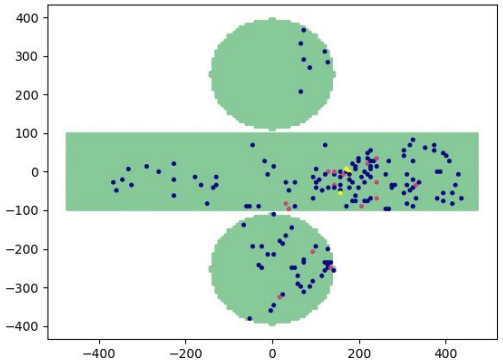
- Percentage of generated neutron events with any PMT hits is 85.6%

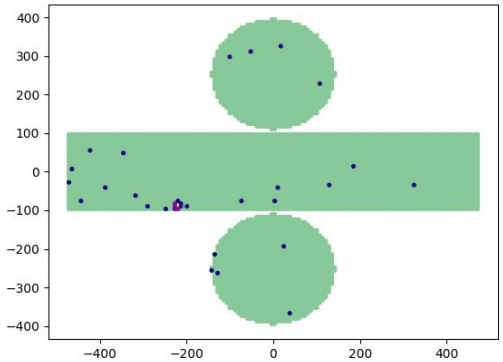


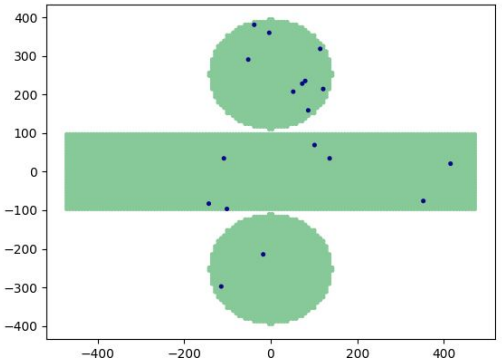
(mostly the same as 40% pc for both but with more PMT hit entries)

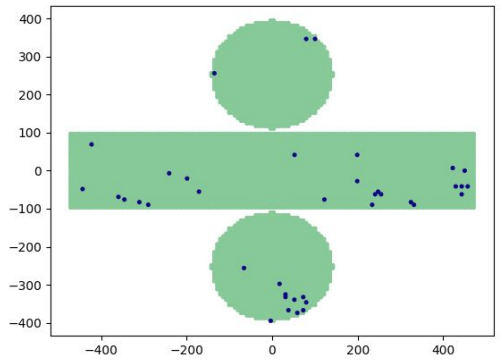
5 MeV neutron normal detector geometry hit plots (“100%” pc = ~89% effective pc)
(I just took the first two plots with PMT hits from each)

With 0.1 Gd









Without Gd

Hit plots for 5 MeV electrons and gammas with same setup, effectively 89% pc (generated isotropically and uniformly inside the normal detector geometry)

Electron **Gamma**

Notes

- Picked first two events with PMT hits with 0.1 Gd
- PMT hit timing is much shorter for both electrons and gammas (mean of ~0.3 microseconds with Gd)
- Percent of generated events with PMT hits using no Gd: Electron = 99.17%, Gamma= 81.08%