

# MuonNuclear Physics in larsim

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# Introduction

- MuonNuclear Physics is disabled by default in larsim.
- Information printed to stdout is misleading.
- Justification given in comments seems incorrect.
- MuonNuclear is vital for cosmogenic studies in all experiments.

# Relevant code

LArG4/ConfigurablePhysicsList.icc, lines 78-89:

```
if (!PhysicsName.compare("SynchrotronAndGN"))
{
    mf::LogWarning("ConfigurablePhysics") <<"ConfigurablePhysicsList : "
                << PhysicsName
                << ": Turning on MuNuclear, Gam\
maNuclear, Synchrotron.";
    G4String on("on");
    // We want MuonNuclear off, since we're gonna activate it
    // within a Wrapped Process. This would double count these evts.
    // EC, 23-May-2011!
    //(G4EmExtraPhysics*)g4v->MuonNuclear(on);
    ((G4EmExtraPhysics*)g4v)->GammaNuclear(on);
    ((G4EmExtraPhysics*)g4v)->Synch(on);
}
```

Misleading print statement

LArG4/PhysicsList.cxx, line 108

```
G4bool genSecondaries(false);
```

... lines 117-119

```
if (!PhysicsName.compare("SynchrotronAndGN") && lgp->K0Bias()){
    genSecondaries = true;
}
```

... lines 126-132

```
if (genSecondaries){
    G4int nSecondaries(lgp->K0Bias());
    G4int fXSBIAS(lgp->MNXSBIAS());
    G4int xSBIAS(lgp->MNXSBIAS());
    mf::LogInfo("PhysicsList: ") << "Turning on WrappedMuNuclear for "
                << particle->GetParticleName()
                << "s with " << nSecondaries
}
```

No double-counting if "K0Bias" is off

# Suggested change

- Turn on MuonNuclear when “K0Bias” is off. We cannot comment on “K0Bias”: its goals, requirements and effects.

LArG4/ConfigurablePhysicsList.icc, lines 80-93:

```
mf::LogWarning("ConfigurablePhysics") <<"ConfigurablePhysicsList : "  
                                     << PhysicsName  
                                     << ": Turning on GammaNuclear, \  
Synchrotron.";  
    G4String on("on");  
    // We want MuonNuclear off, since we're gonna activate it  
    // within a Wrapped Process. This would double count these evts.  
    // EC, 23-May-2011!  
    if (!lgp->K0Bias())  
    {  
        mf::LogWarning("ConfigurablePhysics") << "ConfigurablePhysicsLis\  
t : "  
                                     << PhysicsName  
                                     << ": Turning on MuNuclear\  
.";  
        ((G4EmExtraPhysics*)g4v)->MuonNuclear(on);  
    }
```

- MuonNuclear on unless conflict with wrapped version.
- Misleading print statement corrected.

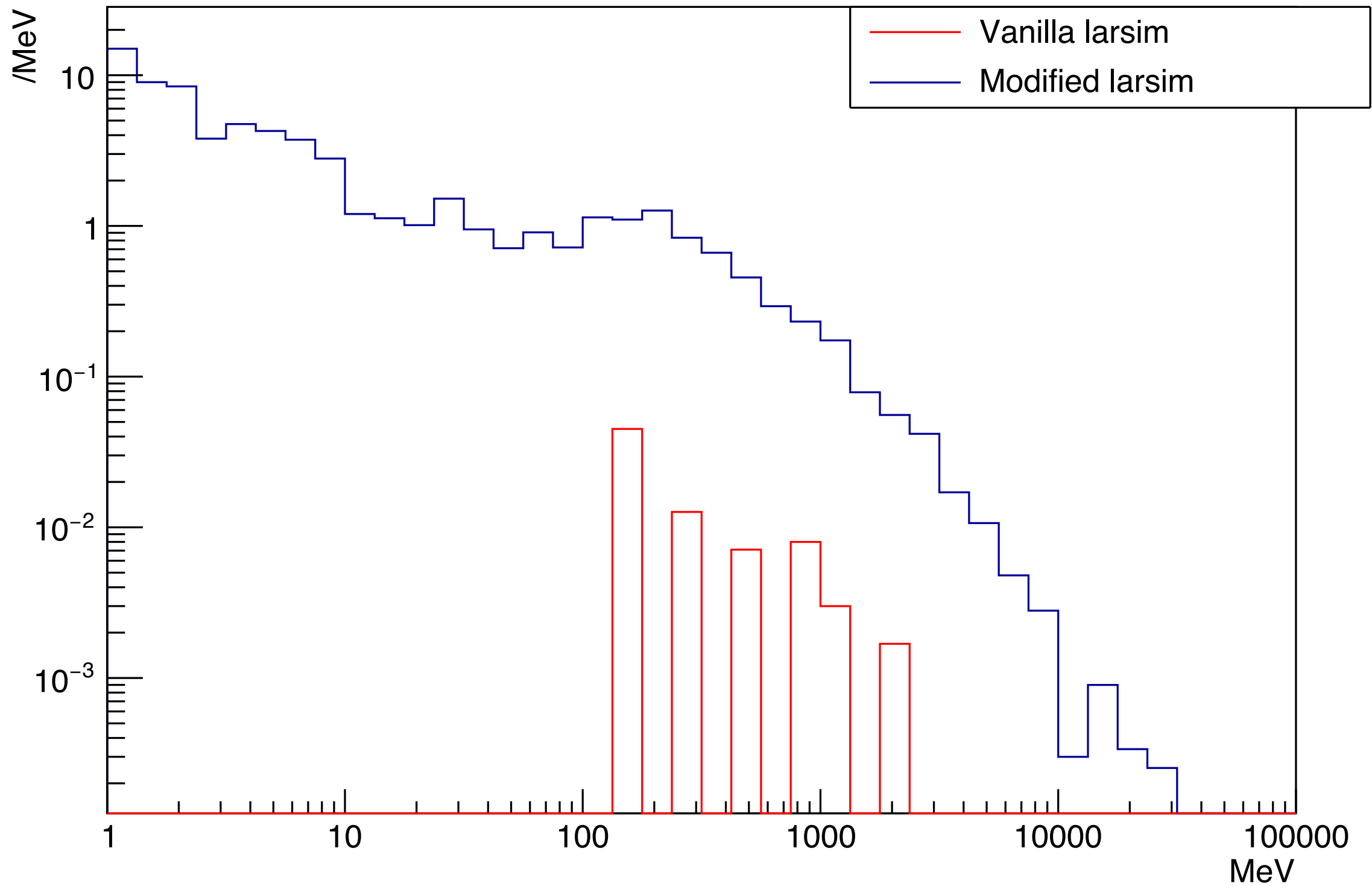
# Effect on CPU time and disk usage.

- 2 simultaneous runs on the same SL6 PC, each with 10000 cosmogenic muons from MUSUN module.
- LArG4 mean time per event went from 0.700 s to 0.779 s.
- Average event size on disk went from 1.3 MB to 1.5 MB.
- The extra information stored is information we need for cosmogenic studies and is unlikely to affect simulations without high energy muons.

# Example: Proton decay background study

- Charged kaons are a key background for proton decay study.
- Without MuonNuclear physics,  $10^6$  cosmogenic muons produces  $\sim 10$   $K^\pm$ . With MuonNuclear physics this increases to  $\sim 1000$   $K^\pm$ .
- It seems highly likely that any large LAr experiment is going to want to study cosmogenic muon induced background and/or background from dirt induced by high-energy muons from neutrinos. They won't expect MuonNuclear to be off by default.

# Charged Kaon Spectrum



# Other concerns

- Other background studies may require G4NeutronHP. Is this available? Can't find any mention of G4NeutronHP in LArG4 source.
- Is there any way in fhicl/ups to switch to geant4.10.x and to one of the geant4 standard physics lists such as "Shielding"?
- If no to both, this will be a problem.



# Conclusions

- MuonNuclear physics has a big impact on simulations of high energy muons. For example it increases  $K^\pm$  production by a factor of  $\sim 100$ . It should really be on unless “K0Bias” (and therefore wrapped MuonNuclear) is on.
- Effect on simulations not involving high energy muons may be small (this was not checked), but there is no harm in simulating this process even for low energy muons. If the effect is small, there will be no penalty in CPU time or disk usage. Even evaluation of background from dirt should be done with MuonNuclear otherwise many hadrons may not appear in the simulated sample.