

Muon background simulations for proton decay

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Introduction

- MuonNuclear Physics is disabled by default in larsim.
- Information printed to stdout is misleading and justification given in comments seems incorrect.
- MuonNuclear is vital for cosmogenic studies in all experiments.
- Results presented to larsoft coordination group, who have agreed to fix.
- Running with own patch to enable MuonNuclear until fixed version of larsoft appears.

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

Patch to enable MuonNuclear

- 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.

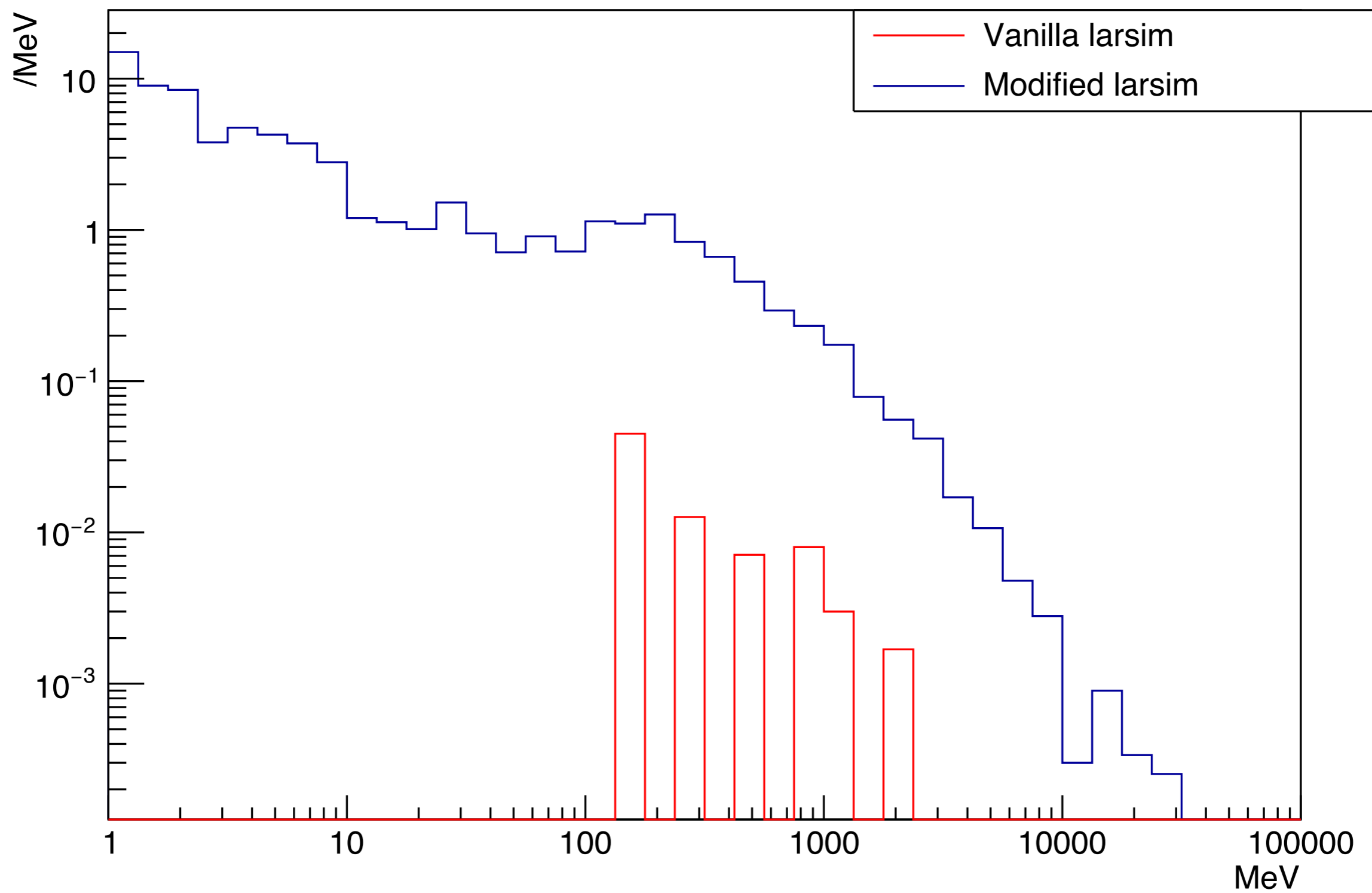
Effect on CPU time and disk usage.

- 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.

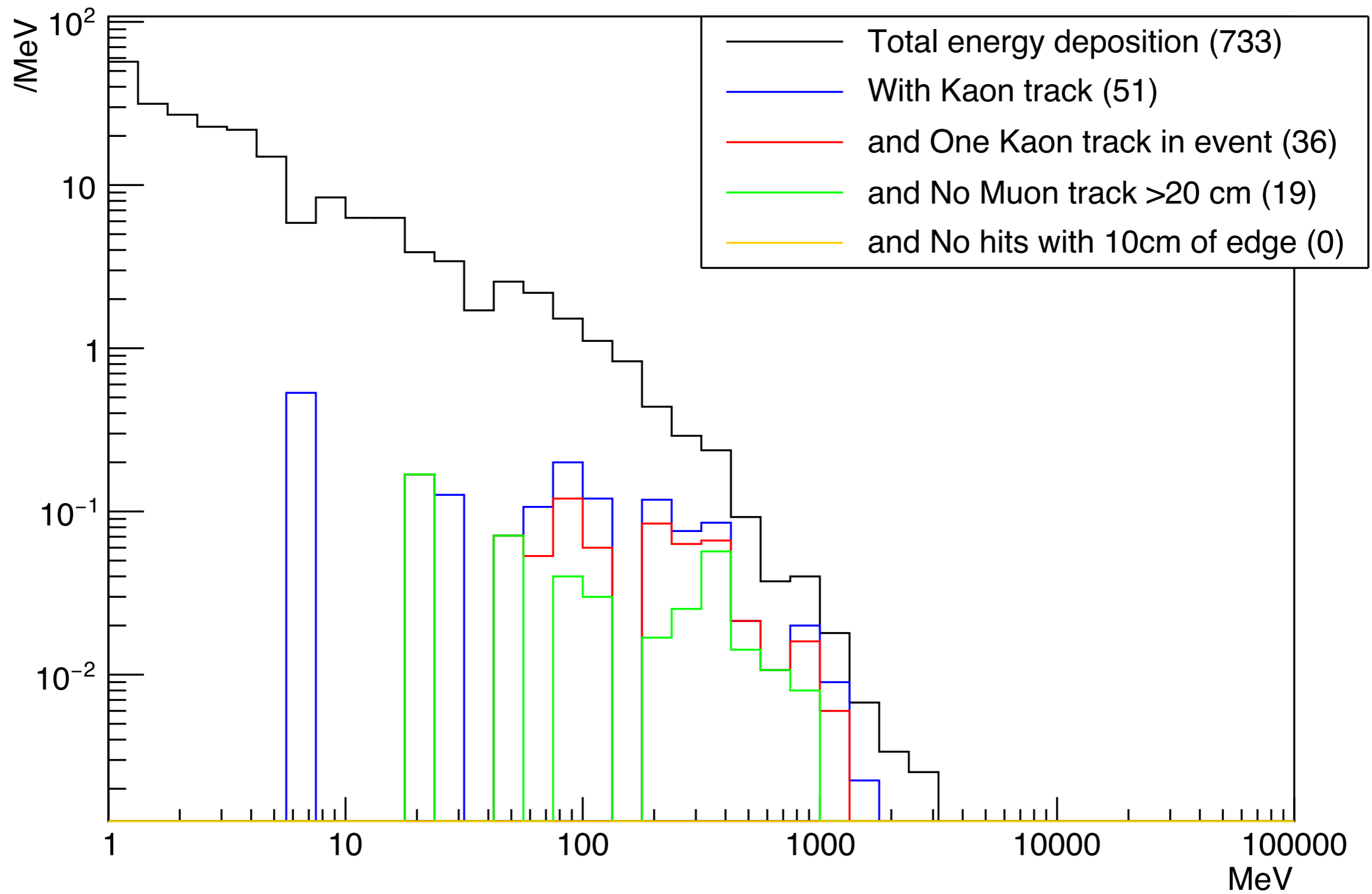
Proton decay background study

- Without MuonNuclear physics, 10^6 cosmogenic muons produces $\sim 10 K^\pm$. With MuonNuclear physics this increases to $\sim 1000 K^\pm$.
- Initial simulation run with 10^6 muons and no filtering.
- Partially complete simulation run with 10^8 muons with empty events and events containing $> 1m$ muon tracks filtered out.
- Current reconstruction not useful as it breaks down in the presence of Muon Bremstrahlung.

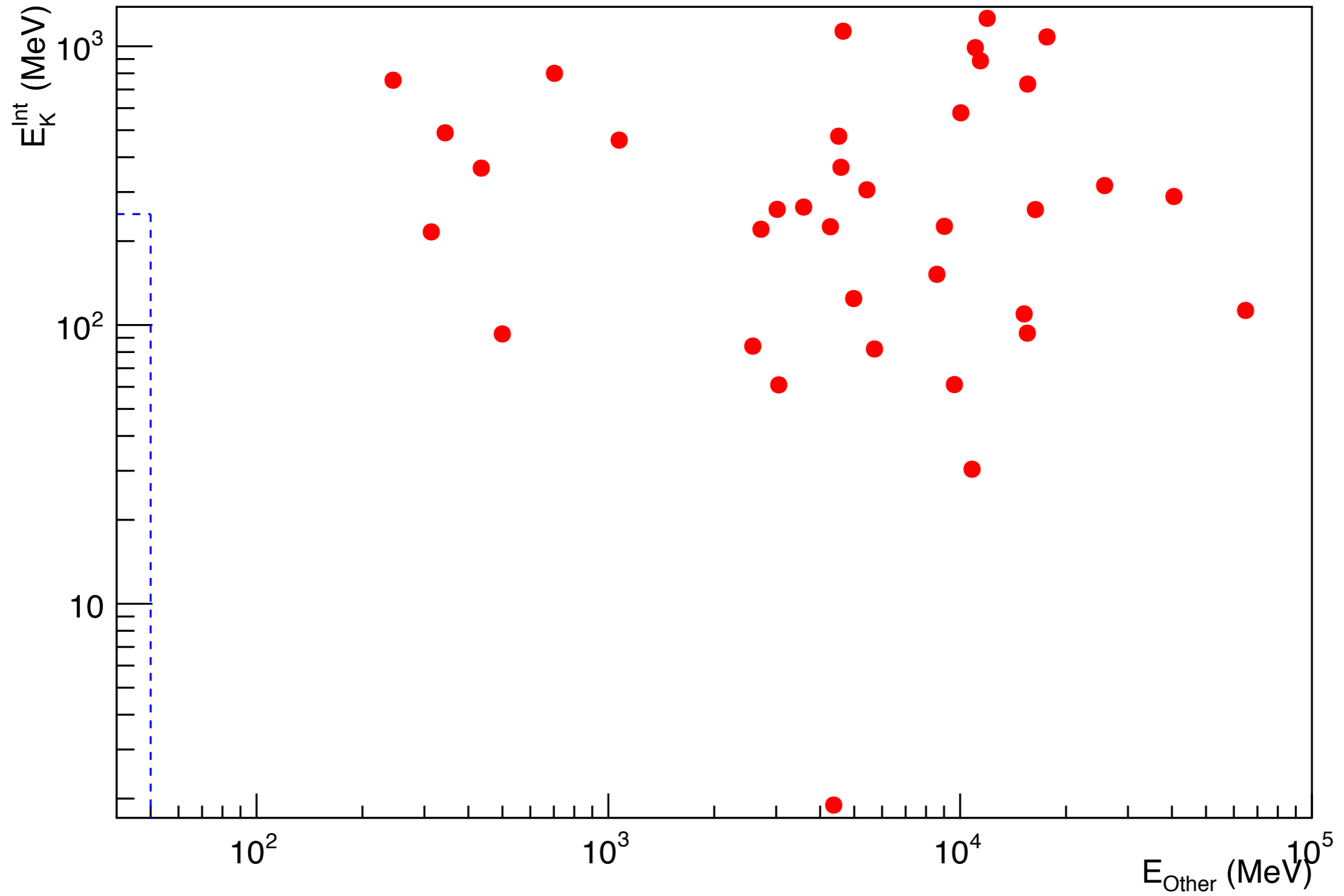
Charged Kaon Spectrum 10^6 unfiltered



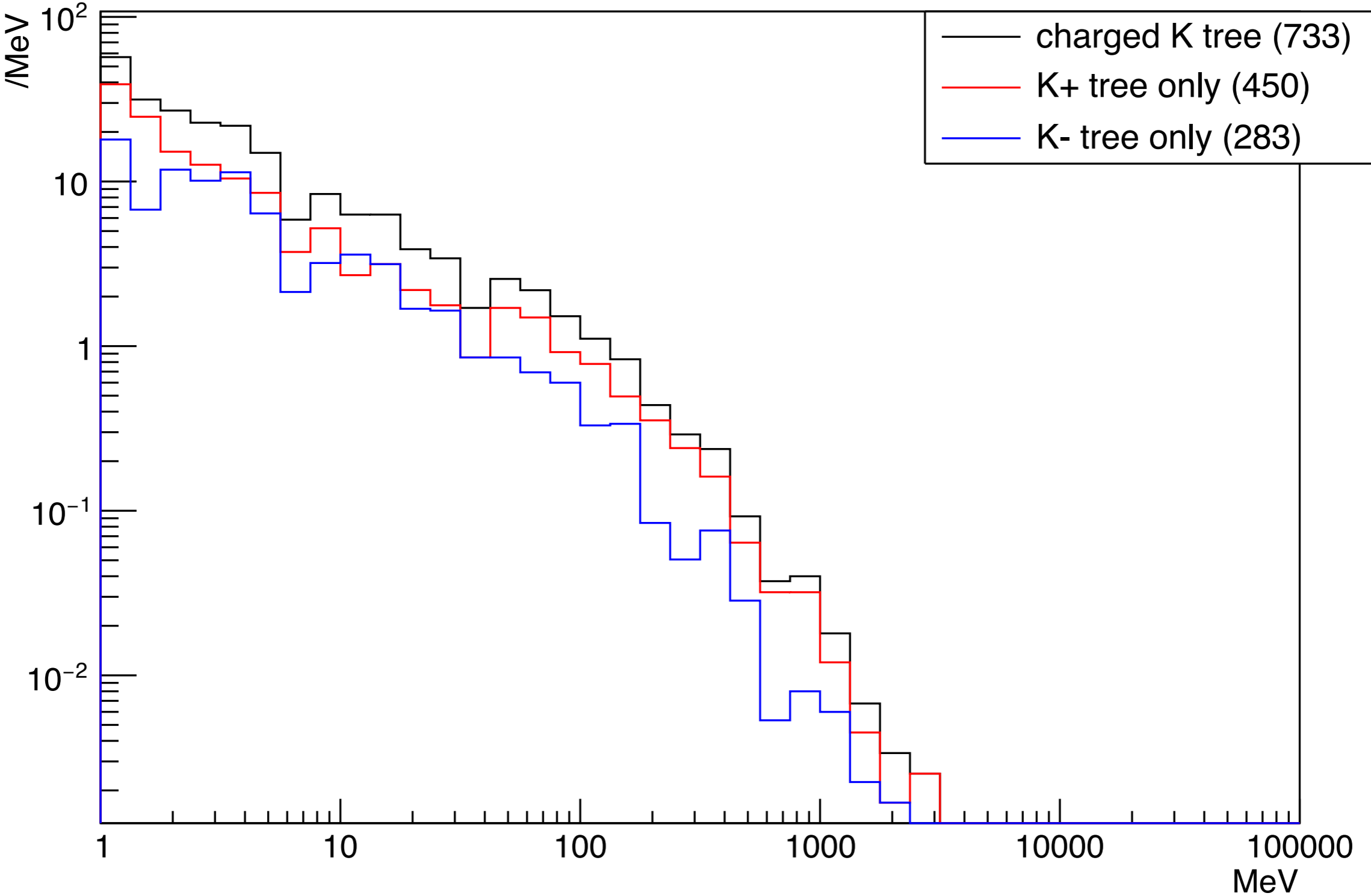
Charged Kaon Spectrum, 1.5×10^7 filtered muons



Kaon Singles Event Selection



Charged Kaon Spectrum, 1.5×10^7 filtered muons



Conclusions

- MuonNuclear physics is disabled in larsoft and has a big impact on simulations of high energy muons. It increases K^\pm production by a factor of ~ 100 .
- Running own patch to larsim until fixed release produced. Run of 10^8 muons in progress.
- More needed on analysis module and cuts to apply to realistically model detector.
- Reconstruction group looking into Bremsstrahlung issue.