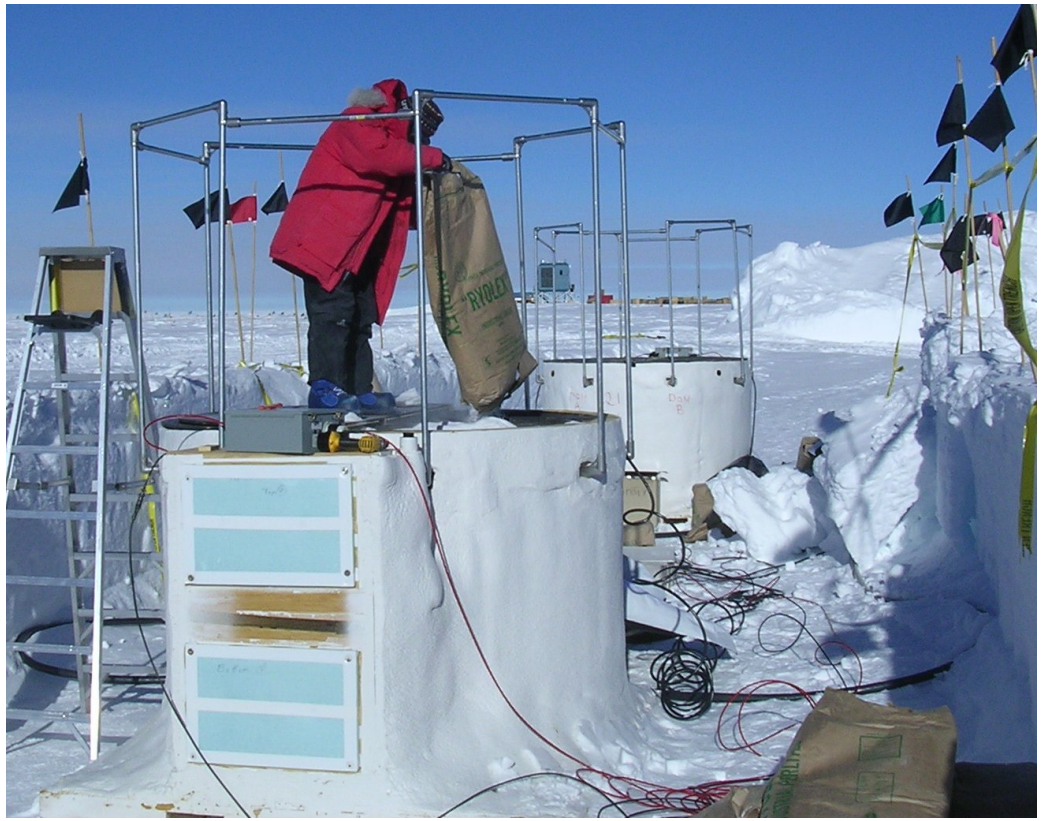

topsimulator & g4-tankreponse

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10/19/2020

IceTop

Goal:

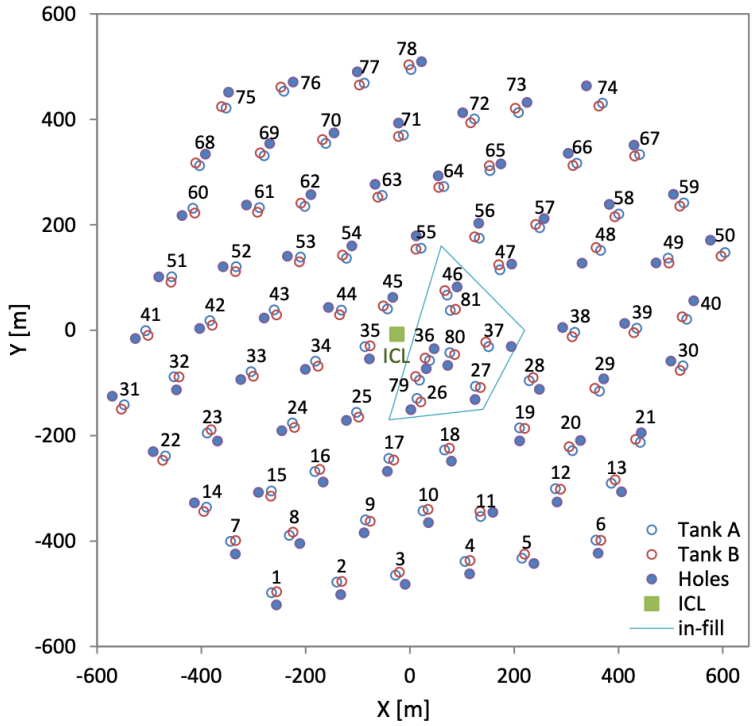
Measure electromagnetic and low energy muon components of air shower

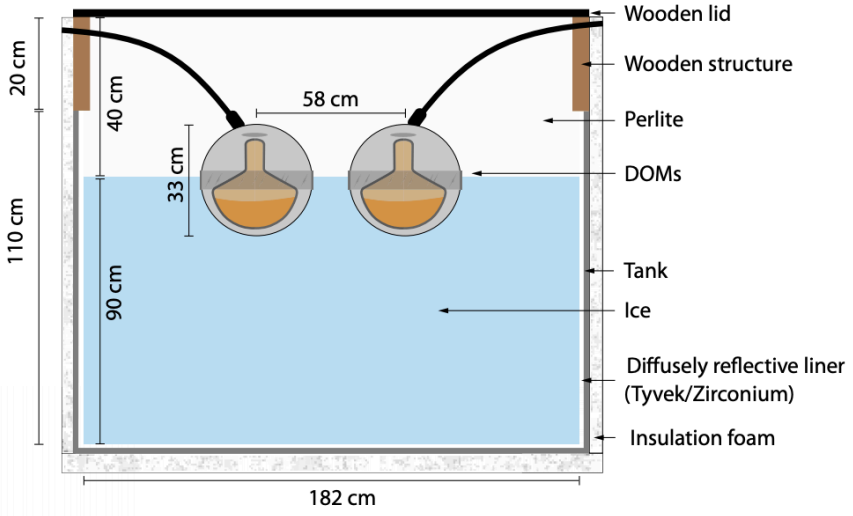
Surface Air Shower Array

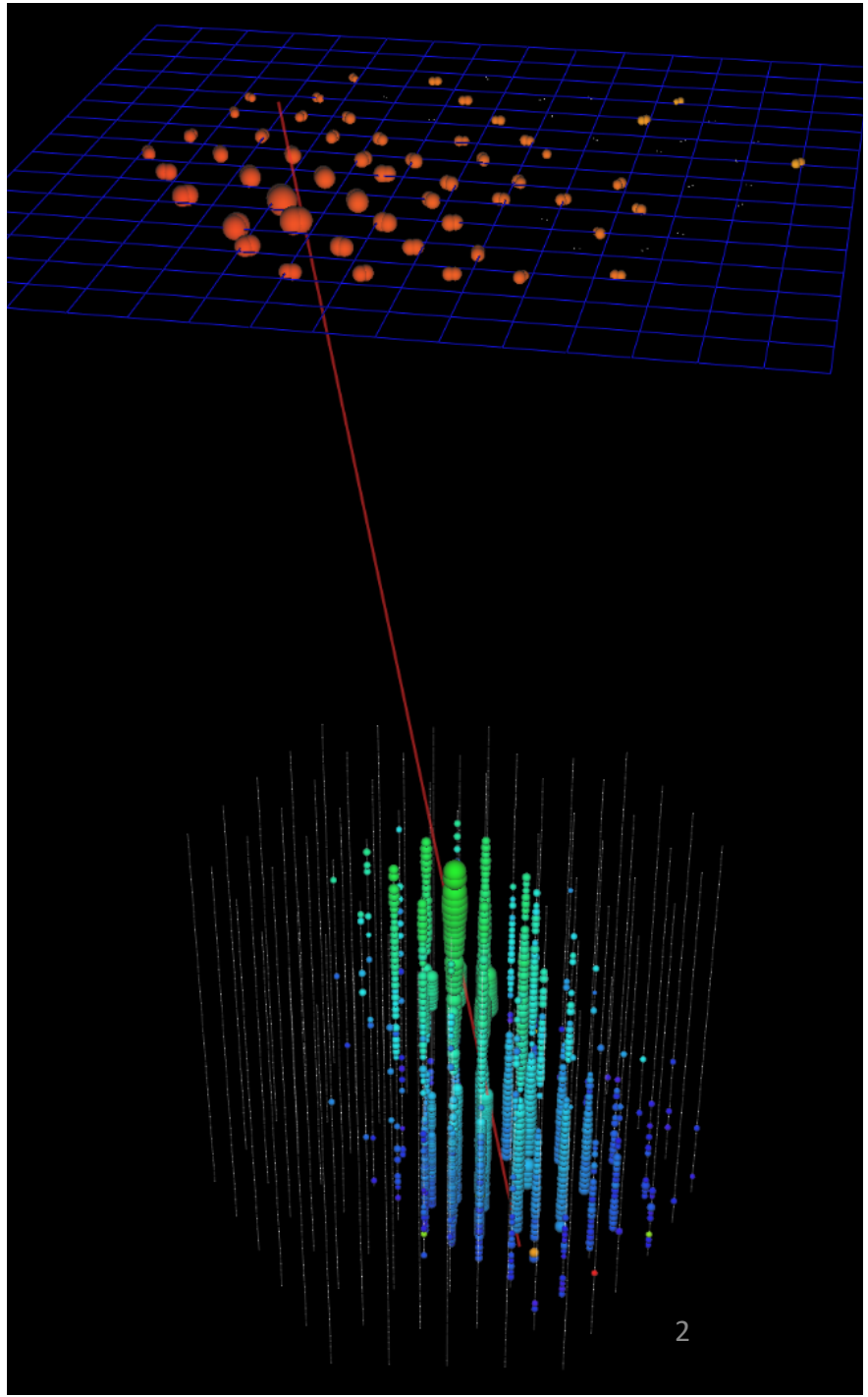
- ~1 km^2 instrumented area
- 81 stations with 2 tanks each
- 125m spacing between stations
- 2 DOMs per tank→ 324 total DOMs

Future Enhancements Array

- Scintillator detectors (expanded existing simulation modules shown here)
- Radio antenna array (new sim. modules)
- IceAct telescopes (new sim. modules)







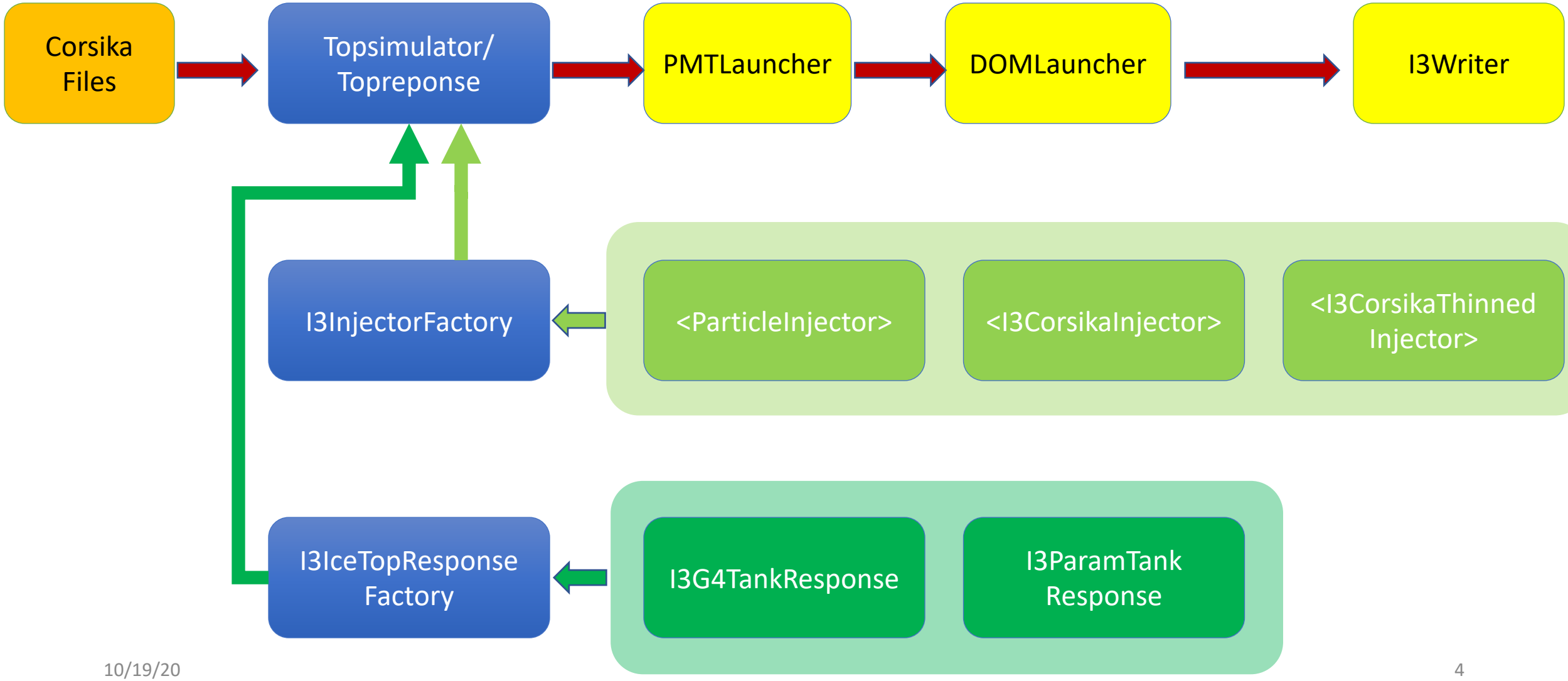
IceTop simulation

- Dedicated IceTop corsika file reader for thinned and unthinned shower
- Several particle injectors
- Geant4 and parametrized detector response service

IceTop simulation challenges

- Different snow coverage of tanks for each year (GCD) - 2012 is our current default data set
- Multiple CR primary data sets (H, He, O and Fe)
- Different hadronic interaction model
  - e.g. Sibyl2.1 for 3 year paper
  - EposLHC and QGSJetII-04 data sets for systematic
  - New current default model Sibyl2.3c
- Large energy range (primary energies between TeV – EeV)
  - Unthinned and thin corsika is needed
- Memory usage can be very large for some showers (> 12GB per shower in rare cases)

Topsimulator Chain



Topsimulator

- ResponseServiceName (g4 or param)
- InjectorServiceName (Particle, Corsika or CorsikaThinned)
- PrimaryName (I3Primary)
- IceTopHitSeriesName (I3MCHitSeries)
- IceTopPESeriesName (I3MCPESeries)
- IceTopCherenkovHitSeriesName (I3RecoPulseSeries)
- InIceMCTreeName (I3MCTree)
- IceTopMCTreeName (I3MCTree)
- IceTopTestPulsesName
- HitBinWidth (ns)
- MuonEnergyCutOff (Muon cut energy for inice. Default 273.0GeV)
- WriteEventHeader
- Tanks (Select only specify tanks)
- CompressPEs (Compress stored particle information)

ParticleInjector

- RandomServiceName
- NumParticles (number of injected particles per event)
- NumEvents (number of events)
- TankKeys (specify used tanks)
- AllTanks (bool to use alle tanks)
- ParticleType (Injected particle type)
- EnergyRange (Primary energy range)
- SpectralIndex (Spectral index for energy range)
- RadiusRange (Radius around tank)
- StartHeight (Starting height above detector)
- ZenithRange (Primary zenith range)
- ZenithPower (Primary zenith power law)
- AzimuthRange (Primary azimuth range)

CorsikaInjector

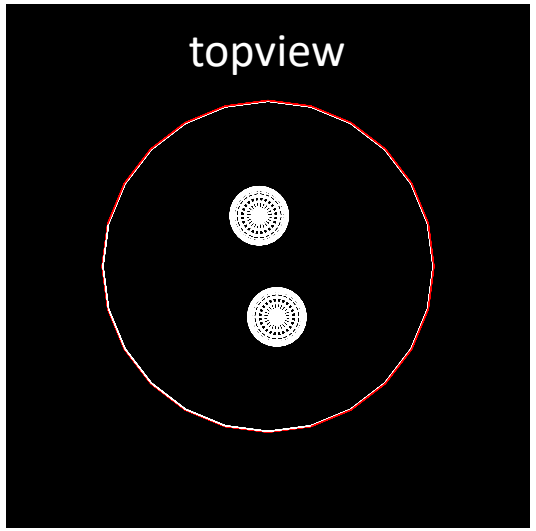
- FileNameList (Corsika filename list)
- RelocationStation (Relocate shower core to station)
- Tanks (Select only specify tanks)
- ImportanceSampling
- RelocationX (Relocate shower core in IceCube coordinates)
- RelocationY
- RelocationR (Sampling radius around X and Y)
- NumHpTMuons (After corsika simulation, number of inject Hpt muon)
- HpTMuonTotalMomentum (Hpt muon total momentum)
- HpTMuonTransverseMomentum (Hpt muon transverse momentum)
- NumSamples (Number of resampling of shower)
- UnThinRadius
- RandomServiceName
- PartDistr (Output particle distribution in root)
- IgnoreParticleTypes (Corsika particle to ignore in simulation)
- SamplingArea
- OnRegionArea
- TankSampleDistance
- RaiseObservationLevel (Fix observation level bug to use old corsika files)
- CorrectObservationLevel

CorsikaThinnedInjector

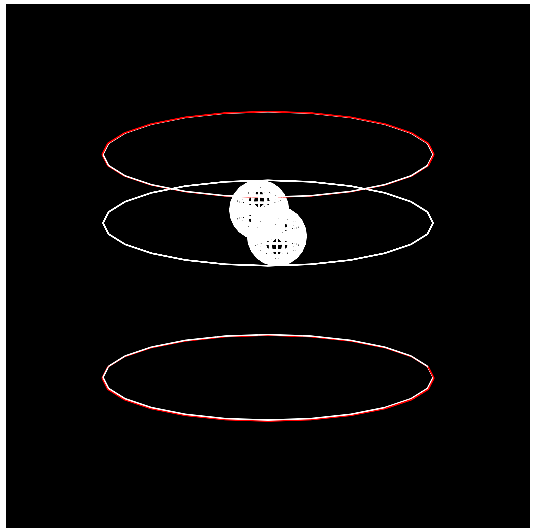
- FileNameList(Thinned Corsika filename list)
- IgnoreParticleTypes
- RaiseObservationLevel(Fix observation level bug to use old corsika files)
- CorrectObservationLevel
- RelocationX
- RelocationY
- RelocationR
- NumSamples
- RandomServiceName
- SmartUnthinning (Boolean for direct particle simulation when weight=1)

Module Option

g4-tankresponse

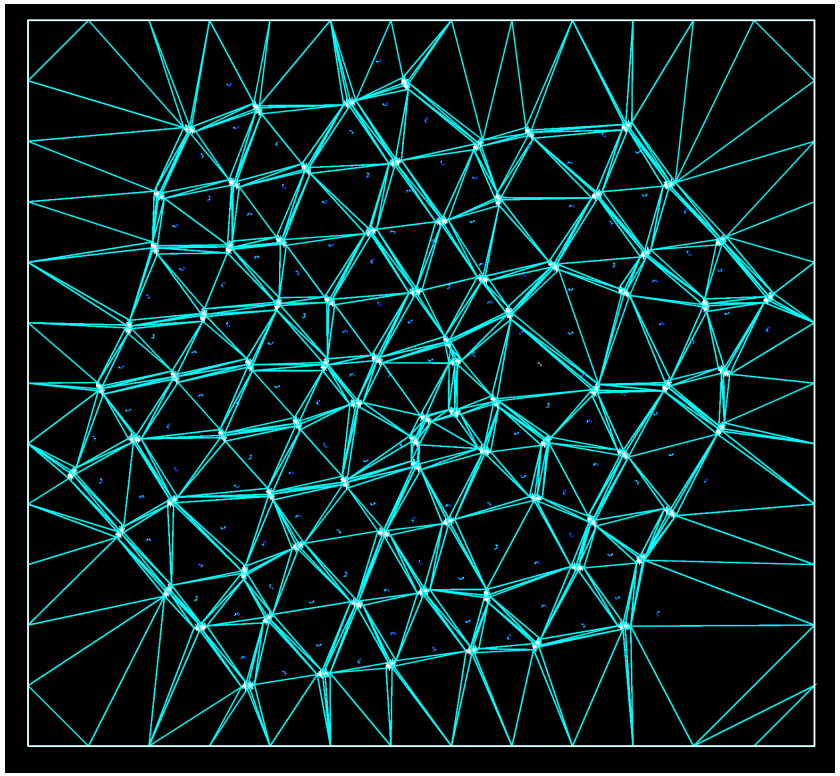


Tank

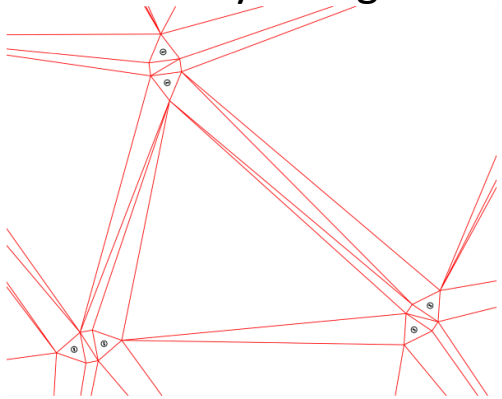


- Simulates particle interaction in the material
  - Snow
  - Tank/scintillator model
  - Ice
- Snow surface is modeled using Delaunay triangles
- **No optical photon tracking**
  - Deposited dEdx converted to Cherenkov photons and VEMs according to tank parametrization from detailed simulation and tank calibration
  - Simulated VEM converted to NPE in MCPESeries
- New scintillators use the same technique and the same module classes
  - More details in detector model included due to no snow cover to track low energy particles

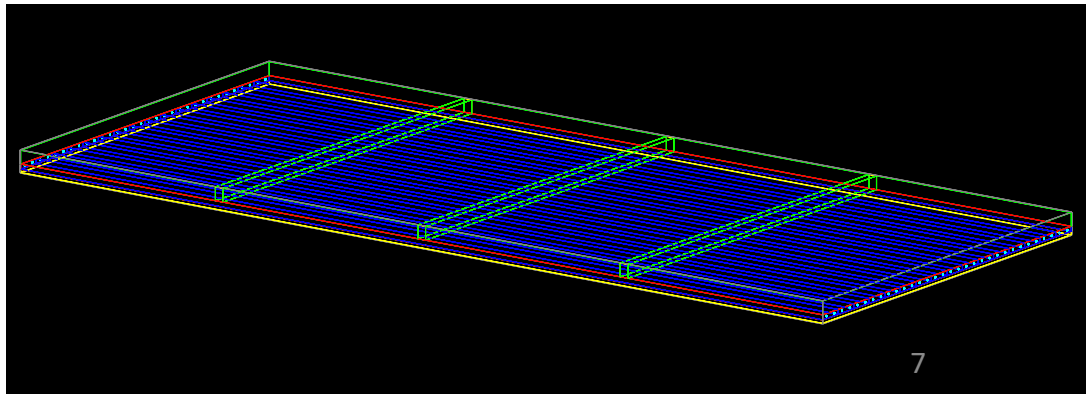
Snow coverage in simulation



Delaunay triangles



Scintillator



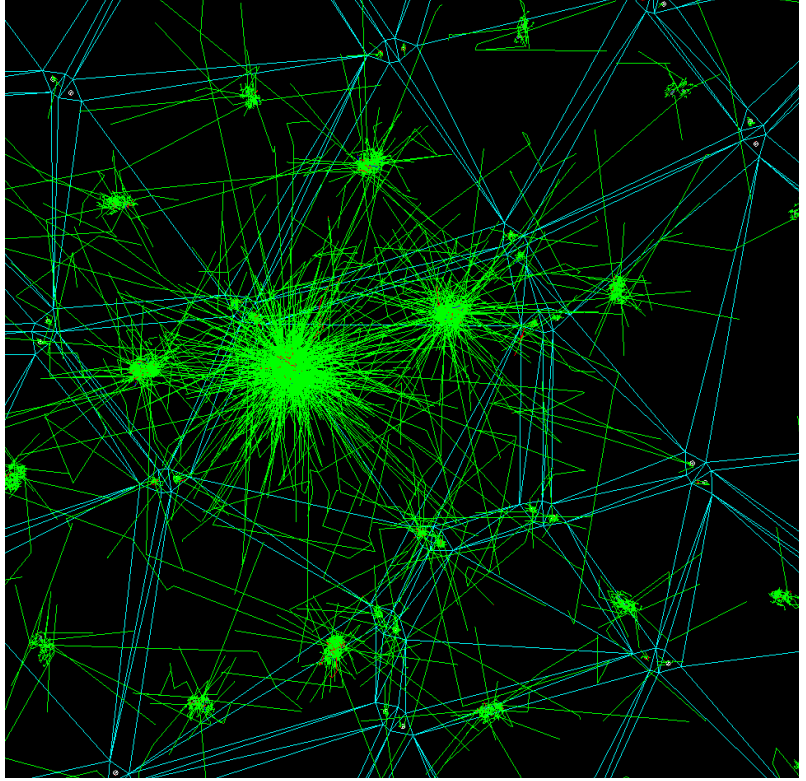
g4-tankresponse

- **All particles are simulated** and tracked in corsika to observation level and

- **All particles are read-in** by the topsimulator-I3CorsikaReader sequentially and the detector-response is directly simulated

  - Mostly low energy electron, gammas and muons

- Only particle close to the tanks and scintillators are tracked in geant4 to speed up simulation and save resources

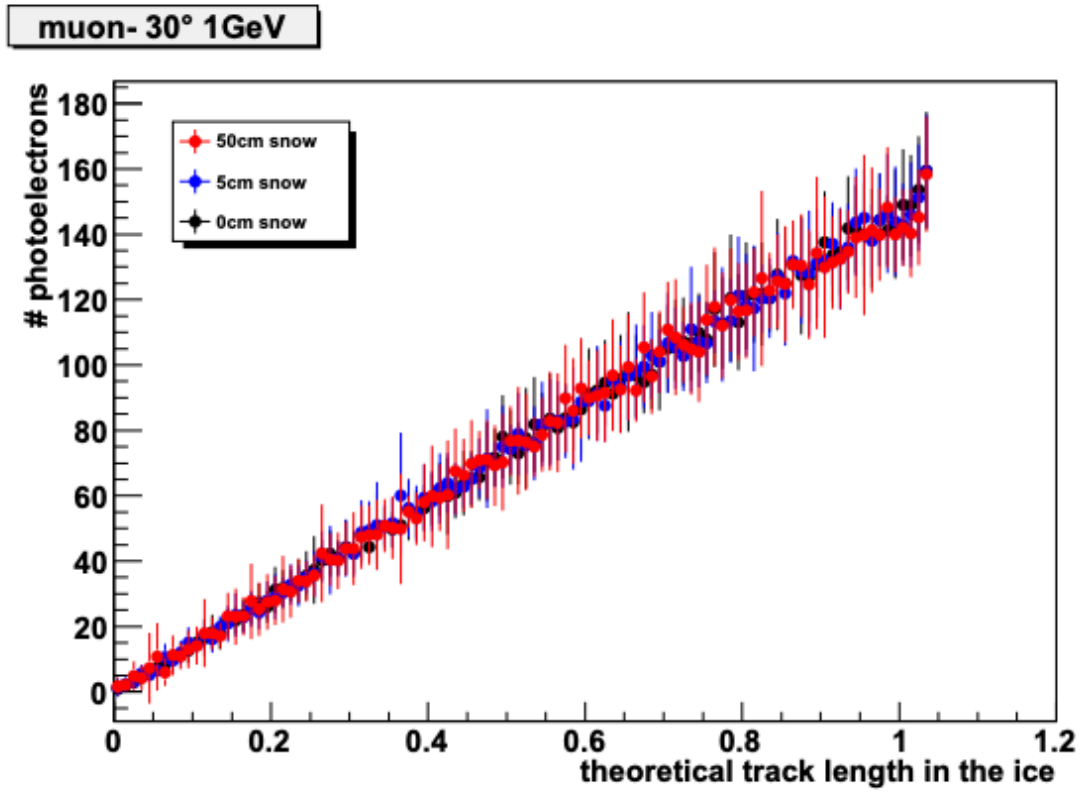


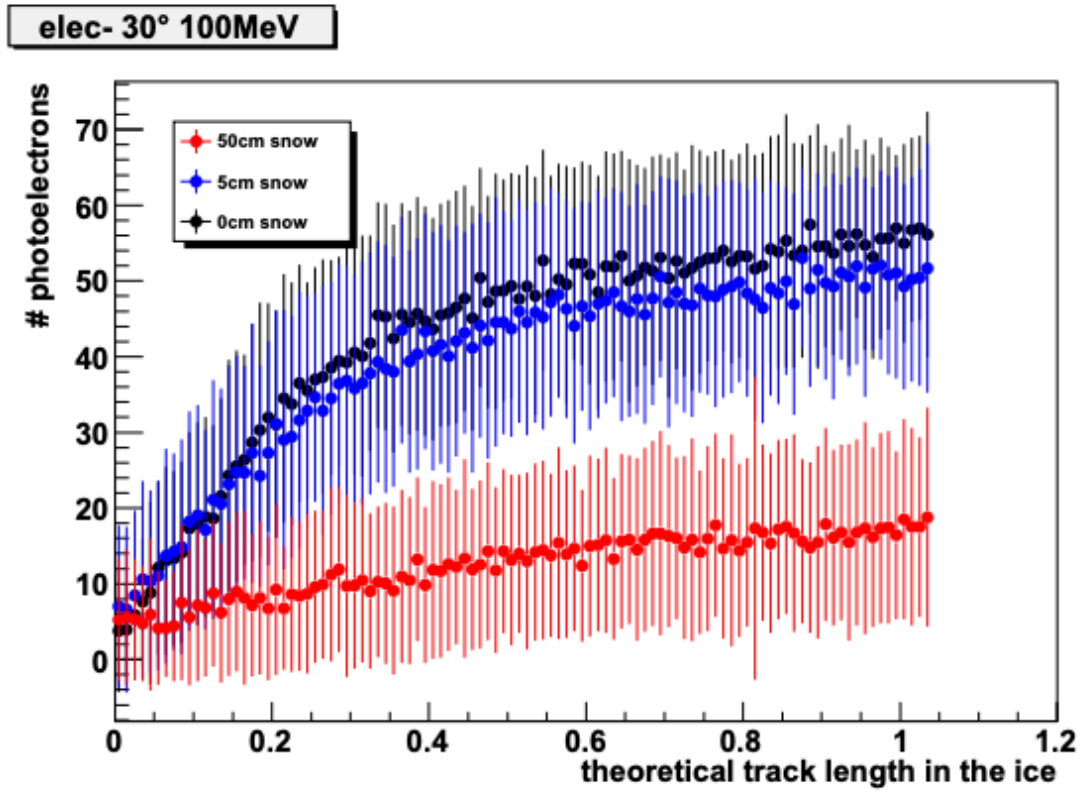
Module Option

- TimeConstantZirco (Time decay constant 26.5 ns)
- TimeConstantTyvek (Time decay constant 42.0 ns)
- RandomServiceName
- SafetyMargin (Only track particles which trajectories will not missing the tank inside the margin. Default margin 25 cm)
- ChargeScale (Charge scaling factor. default 1.02)
- CherenkovMethod (use cherenkov or dEdx parametrization to calculate seen NPEs)
- TankSamplingRadius (only particle in this radius are consider for simulation. default 25m)

g4-tankresponse

- Snow simulation is very important as even small changes have large effects on the low energy electromagnetic component





Summary

- Cosmic ray simulation of IceTop is easy in current setup but very computing (CPU) intensive
- Geant4 detector response is already parametrized for the most part and gives good data/MC agreement (disclaimer… in most cases)
- Snow coverage simulation of paramount importance

ToDos

- Dynamic stack Corsika IceTop simulation (progress hopefully this week)
- General speedup if possible (e.g. include snow coverage parametrization)
- Merge R&D surface array trunk with combo for future release