How NeutrinoGenerator works

K.Hoshina

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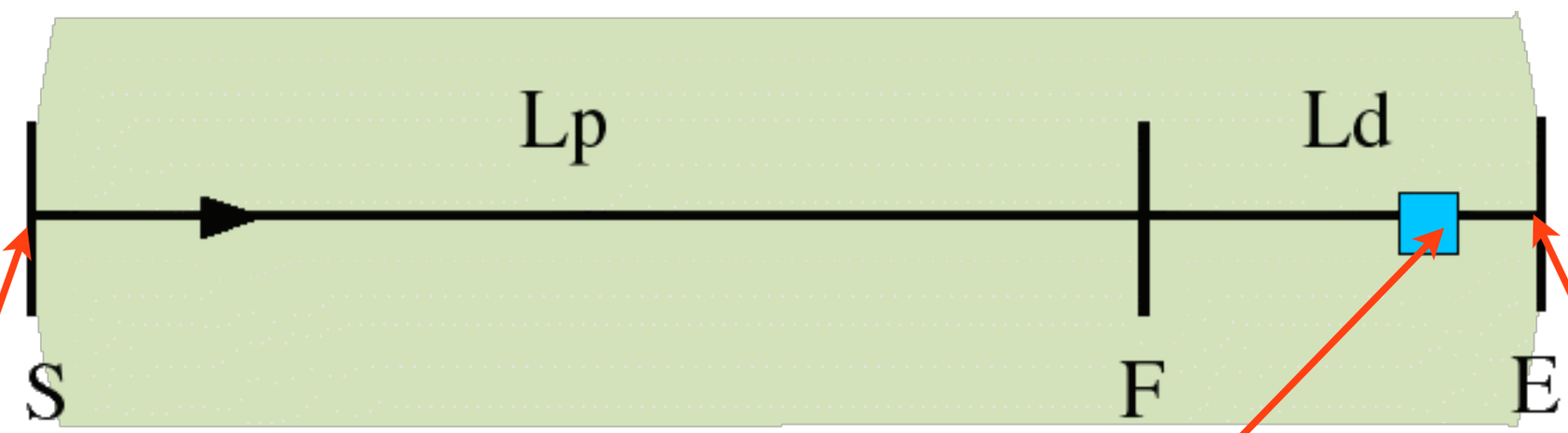
Baseline

- Neutrino-Generator(NuGen) simulates neutrino propagation inside the Earth and final weak interaction inside the Detection Volume (the word will be explained later).
- NuGen supports NuTau Regeneration
  - NuTau --- Tau --- NuTau + mu + NuMu etc.
- NuGen does NOT support oscillation
- NuGen has flexibility of several density profile models of the Earth and BedRock + ice

PropagationVolume and DetectionVolume

Propagation Volume:
- WeightedPropagation
  - CC interaction is forbidden
- NoWeight
  - all interactions

DetectionVolume:
2km~ 15km
make force interaction



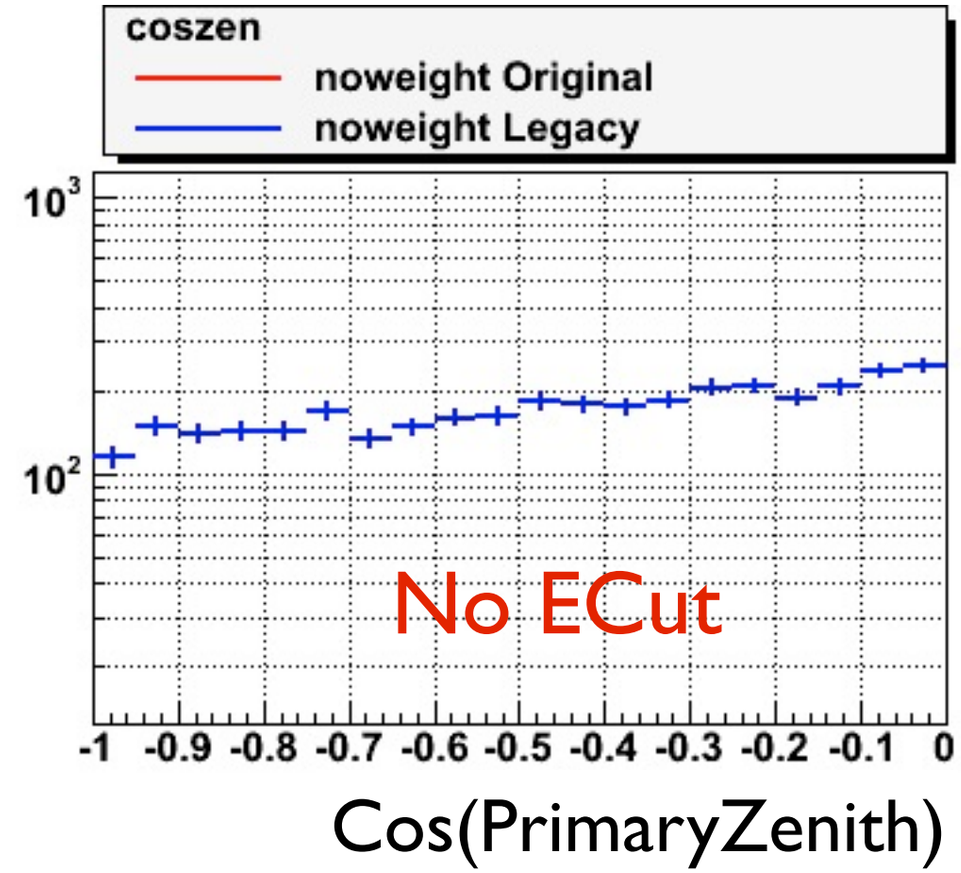
IceCube

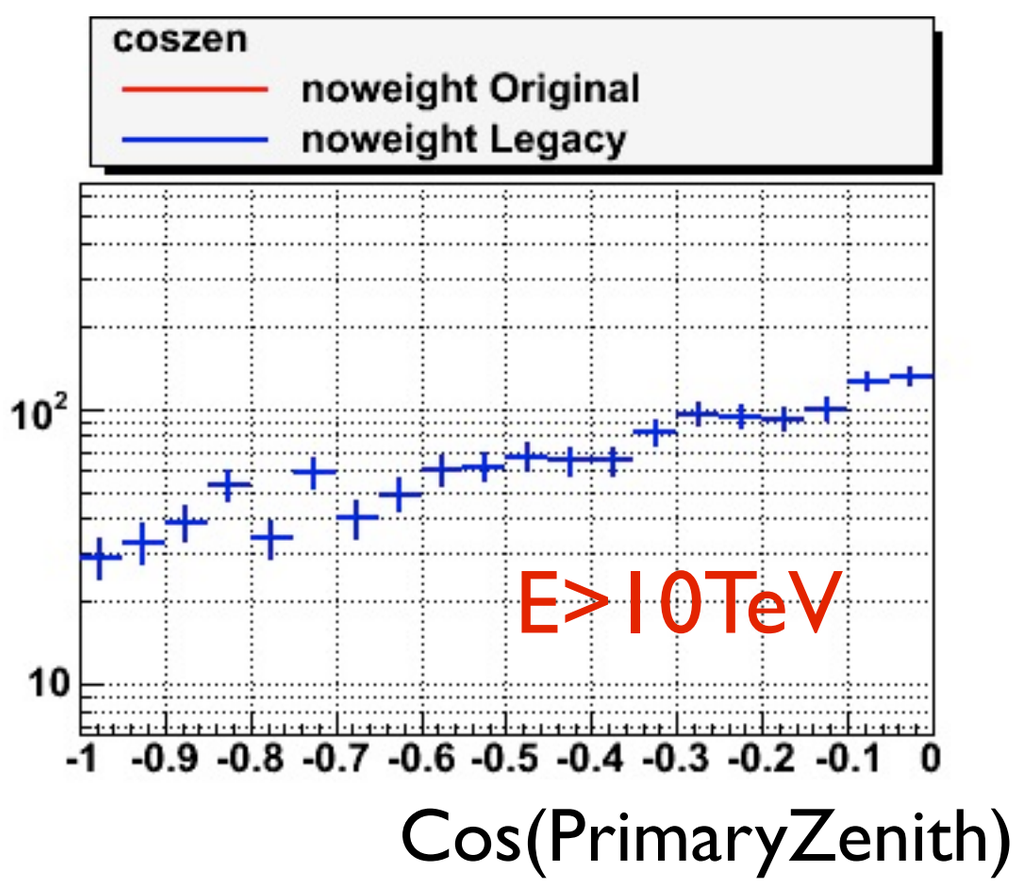
Entrance Point to the Earth

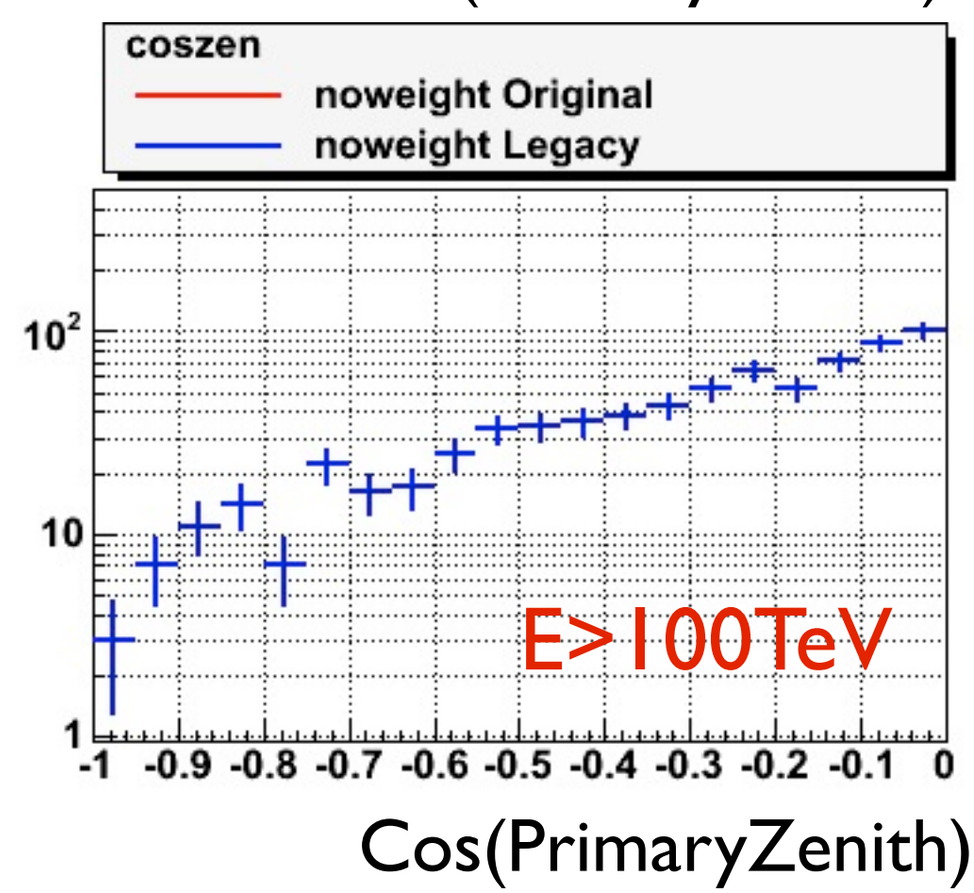
Exit Point from the Earth

Example: NoWeight propagation mode

- E^{-1}, 10^1~10^8 GeV, 10000events
- No Detector Sim
- No interaction weight is applied (pure number of survived events)
- Use it for NuTau simulation (for regeneration)

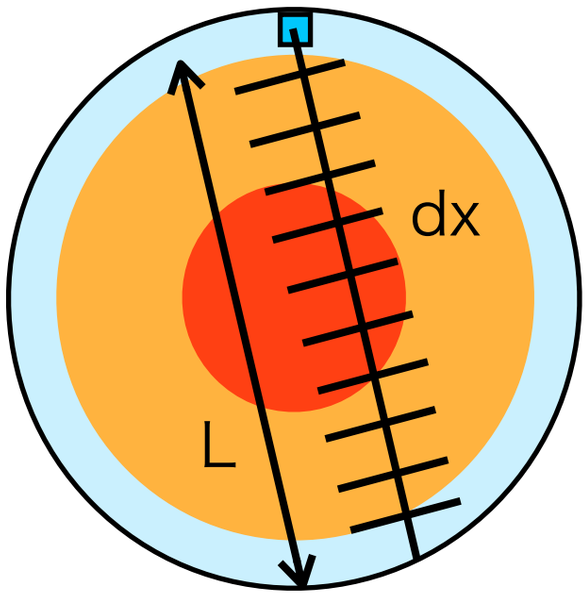






Weighting Propagation Mode

$$
\begin{aligned}
P_{surv} &= exp(-L/\lambda) \\
&= exp(-L\sigma_{tot}N_A) \\
&\simeq exp(-L\sigma_{tot}/M_p) \\
&= \prod_{i=1}^{N} exp(-dx_i\sigma_{tot}(x_i)/M_p)
\end{aligned}
$$

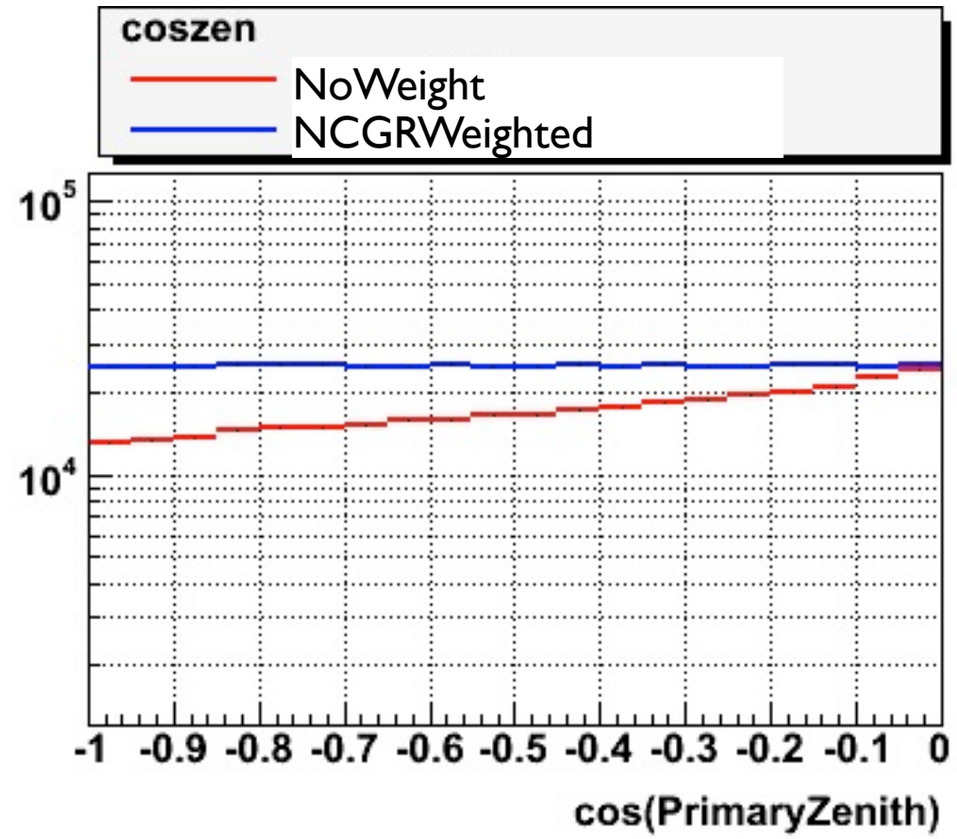


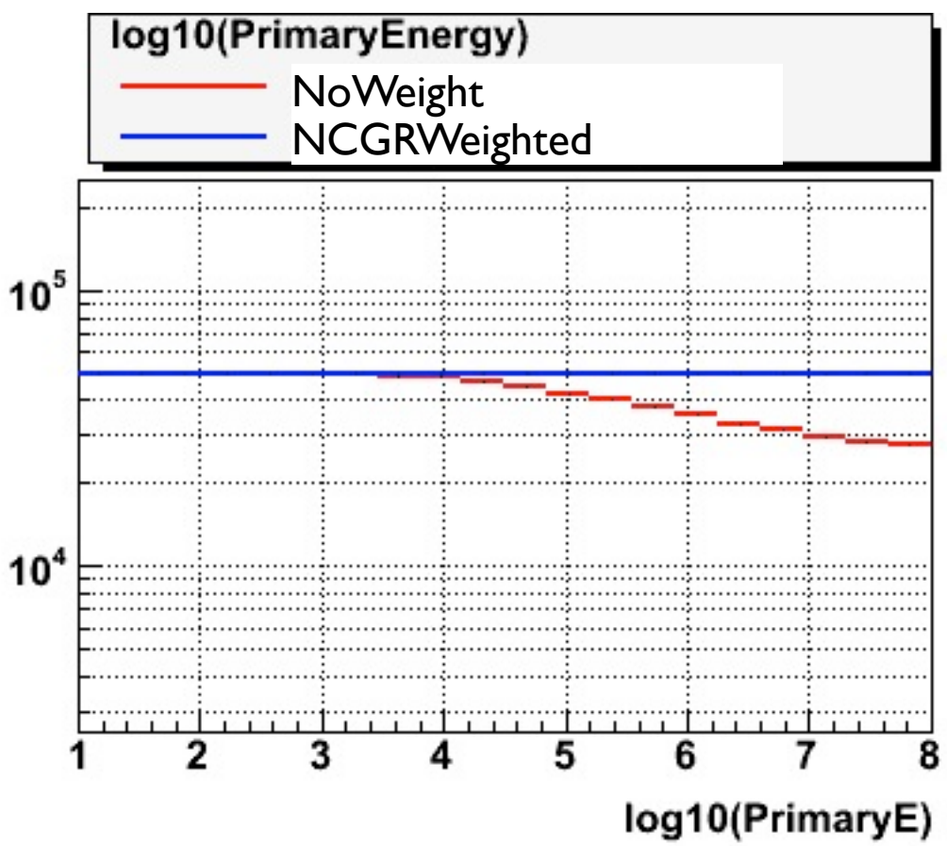
$$L = \Sigma dx \rho(r)$$

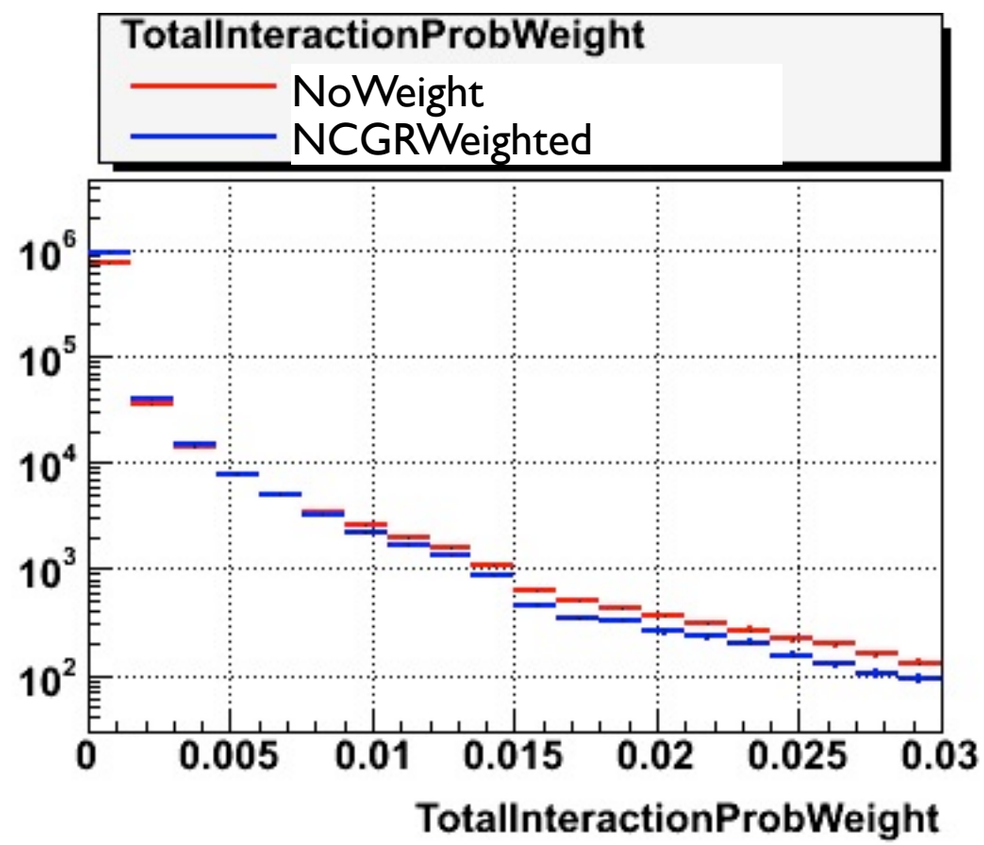
- Initialize propagation weight as 1.0
- Check Psurv at step i with total cross section and compare it with a random number[0,1]
- If interaction happens, allow only NC/GR interaction and calculate weight correction factor
- Multiply weight correction factor to propagation weight

NoWeight vs NCGRWeighted

- E^{-1}gen, No Detector Sim
- No interaction weight is applied
  (pure surviving number of events)

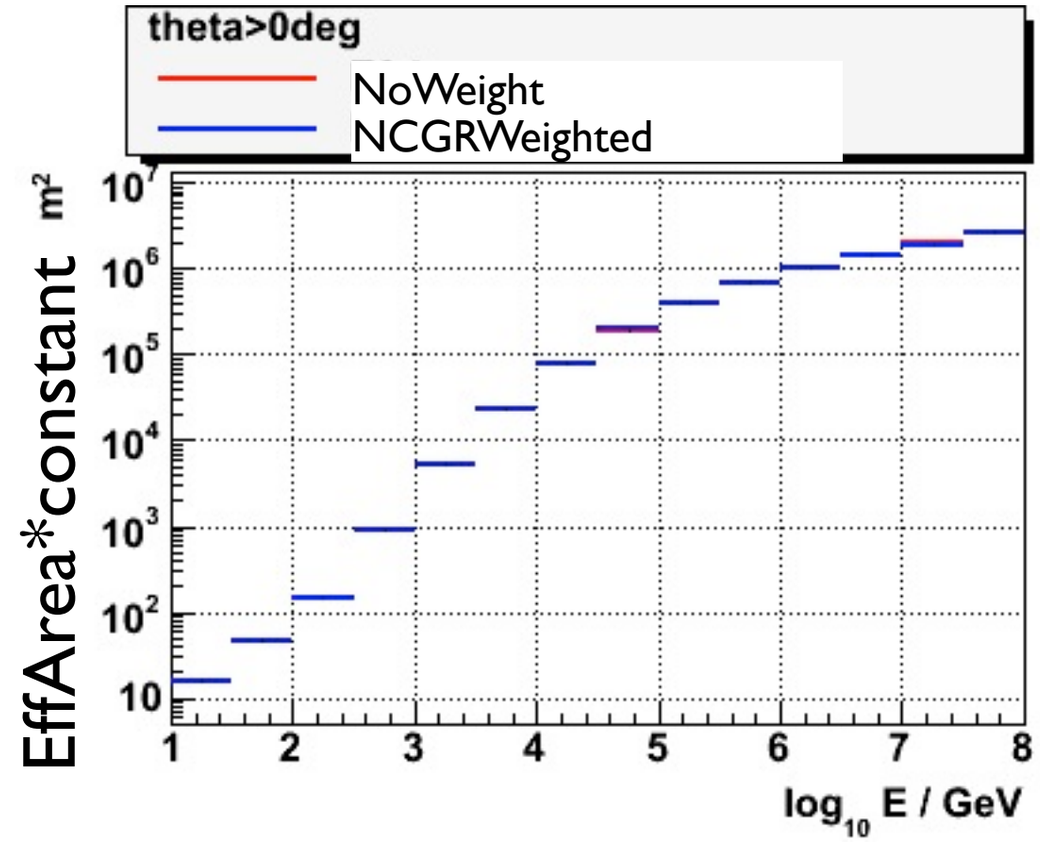


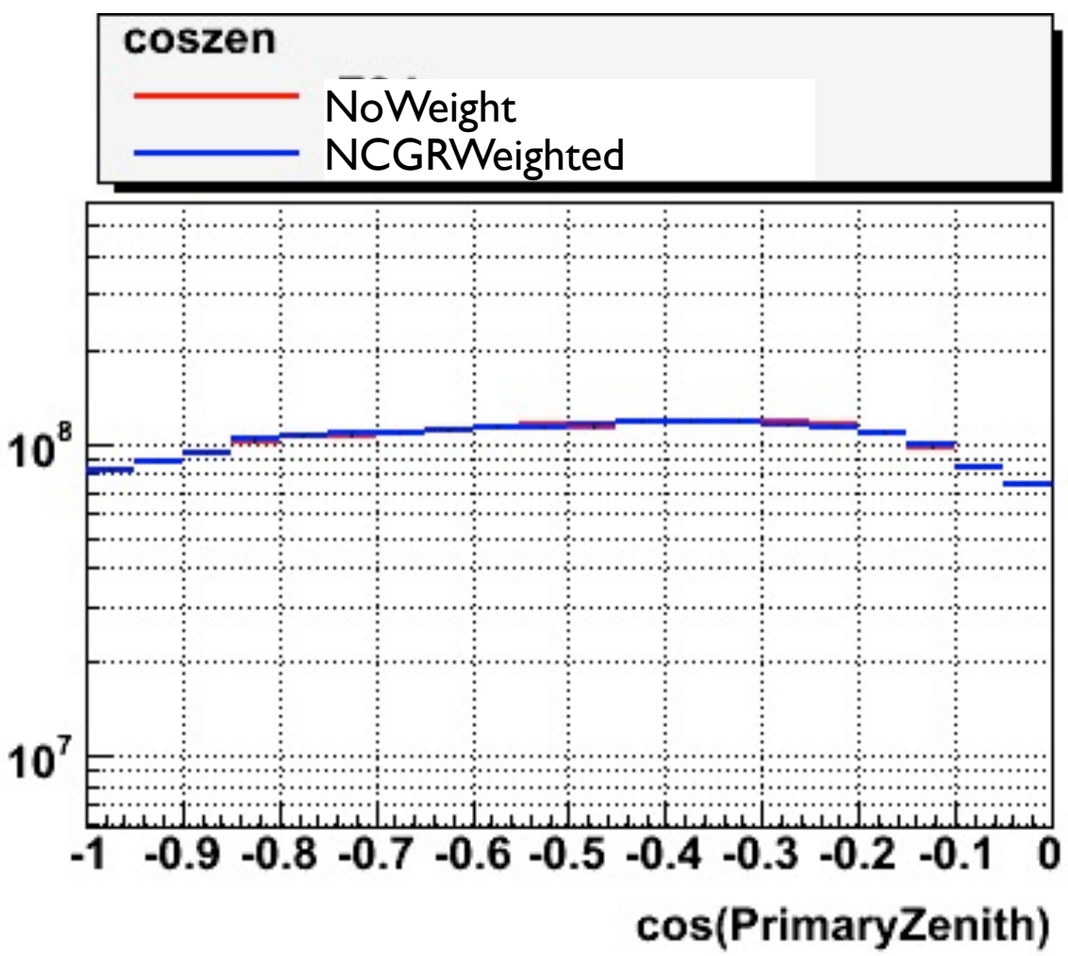


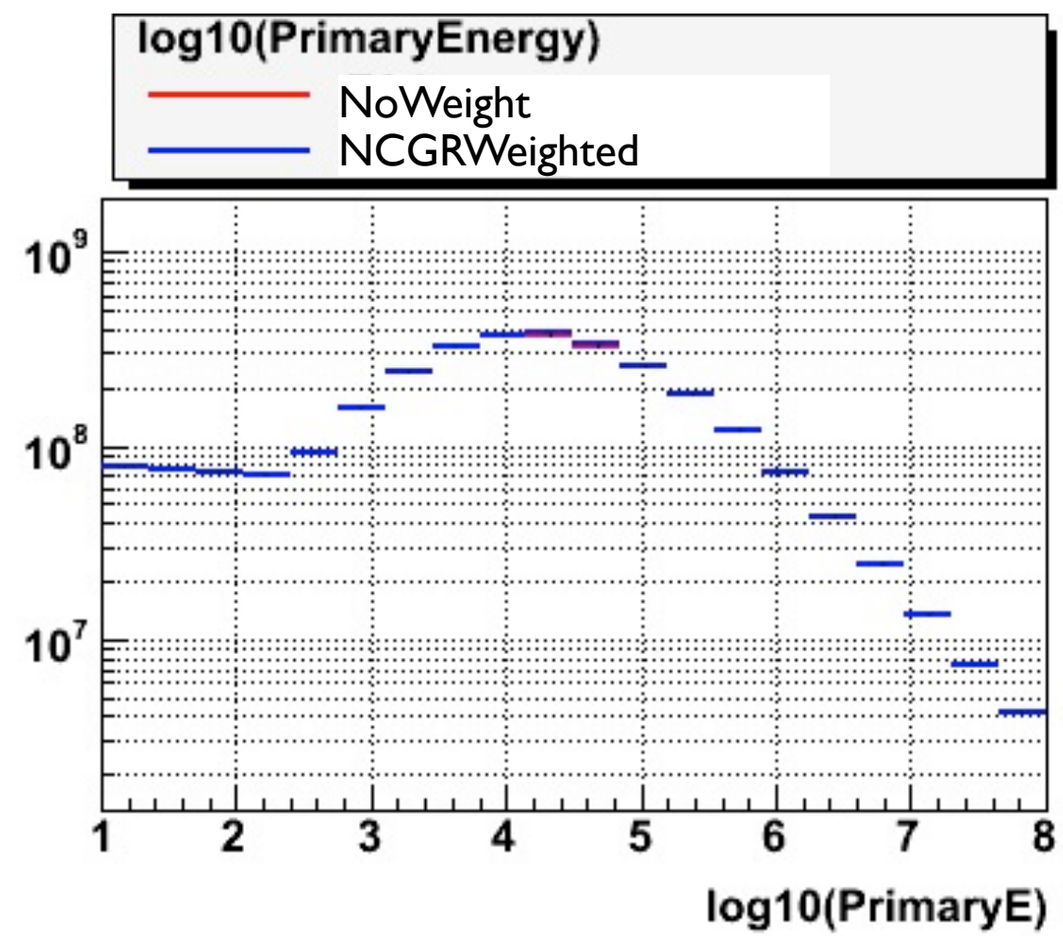


NoWeight vs NCGRWeighted

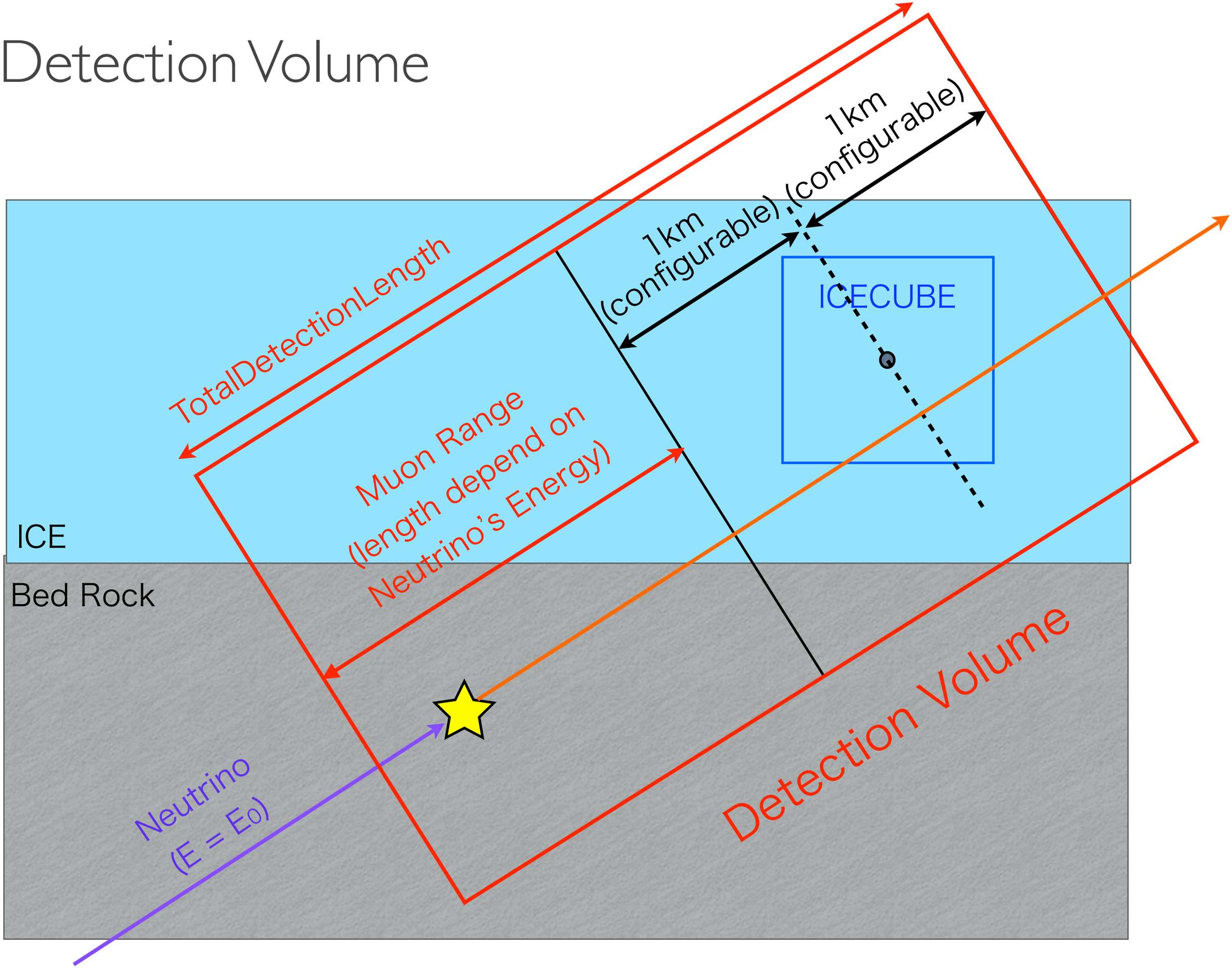
- E^{-1}gen, No Detector Sim
- E^{-2} weight and interaction weight are applied







Detection Volume



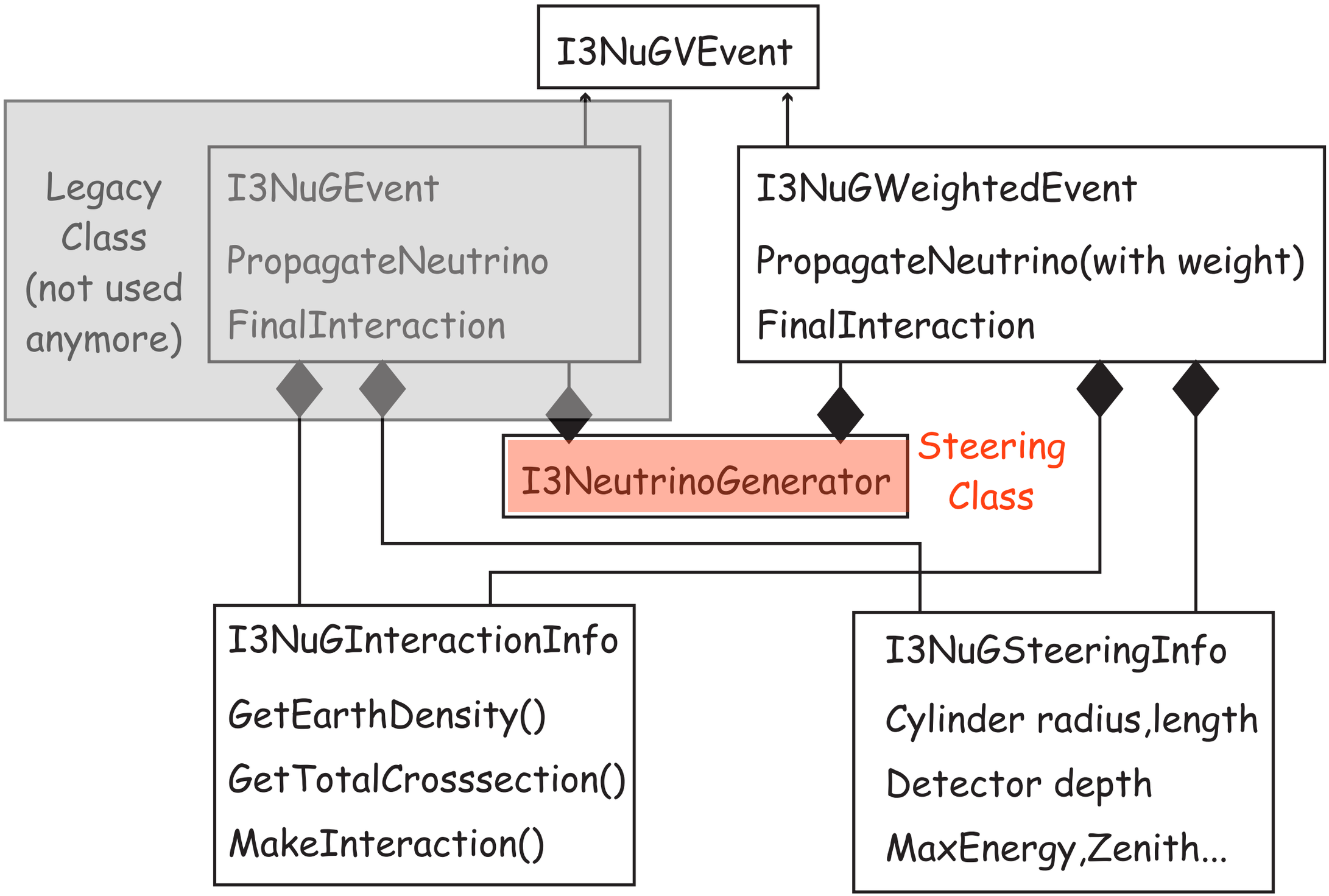
After propagation part is done...

- You may have multiple neutrinos (for NuTau sim)
  - Choose only one of them with taking into account of maximum interaction probability, and make force interaction inside the DetectionVolume
- Once the chosen neutrino (we call it InIce neutrino) makes weak interaction inside the DetectionVolume, NuGen stops simulation (and go to next event)
  - If the interaction is NC interaction, NuGen do NOT simulate probability of second weak interaction within remaining path of DetectionVolume
- Propagation and Interaction of Charged Particles are taken over by mmc

Cross sections and Interaction

- We use same cross section for Nu + p interaction and Nu + n interaction
  - Our target is "Iso scalar nucleon N = 1/2(p + n)"
  - may affect ~4% on interaction probability at low energy
- No detailed hadronic interaction is simulated
  - NuGen calculates only total energy deposit of hadronic cascade

Class Diagram



Possible Updates

- Add new I3NuGInteractionInfo class
  - We may be able to use GENIE as core sub-module for calculation of interaction probability, if GENIE is available as I3Service etc.
  - Needs some modifications around class structures of I3NuGInteractionInfo
- Stop to use isoscalar nucleus
  - Need code change and new cross section tables for both proton and neutron, but this is relatively easy change (I think).

Backup

Weighting Propagation Mode

example 1

$R_{\sigma_{CC}} = 0.5,\ R_{\sigma_{NC}} = 0.3,\ R_{\sigma_{GR}} = 0.2,\ total = 1.0$

Forbid CC :

$R'_{\sigma_{CC}} = 0,\ R'_{\sigma_{NC}} = 0.3,\ R'_{\sigma_{GR}} = 0.2,\ total = 0.5$

$R'_{\sigma_{CC}} = 0,\ R'_{\sigma_{NC}} = 0.6,\ R'_{\sigma_{GR}} = 0.4,\ total = 1.0$

weight correction factor for NC : $0.3/0.6 \simeq 0.5$

example 2

$R_{\sigma_{CC}} = 0.6,\ R_{\sigma_{NC}} = 0.3,\ R_{\sigma_{GR}} = 0.1,\ total = 1.0$

Enhance NC with ratio 1 : 2 : 1

$R'_{\sigma_{CC}} = 0.6,\ R'_{\sigma_{NC}} = 0.6,\ R'_{\sigma_{GR}} = 0.1,\ total = 1.3$

$R'_{\sigma_{CC}} = 0.46,\ R'_{\sigma_{NC}} = 0.46,\ R'_{\sigma_{GR}} = 0.077,\ total = 1.0$

weight correction factor for NC : $0.3/0.46 \simeq 0.65$