i3SIMulation

IceCube Bootcamp 2012

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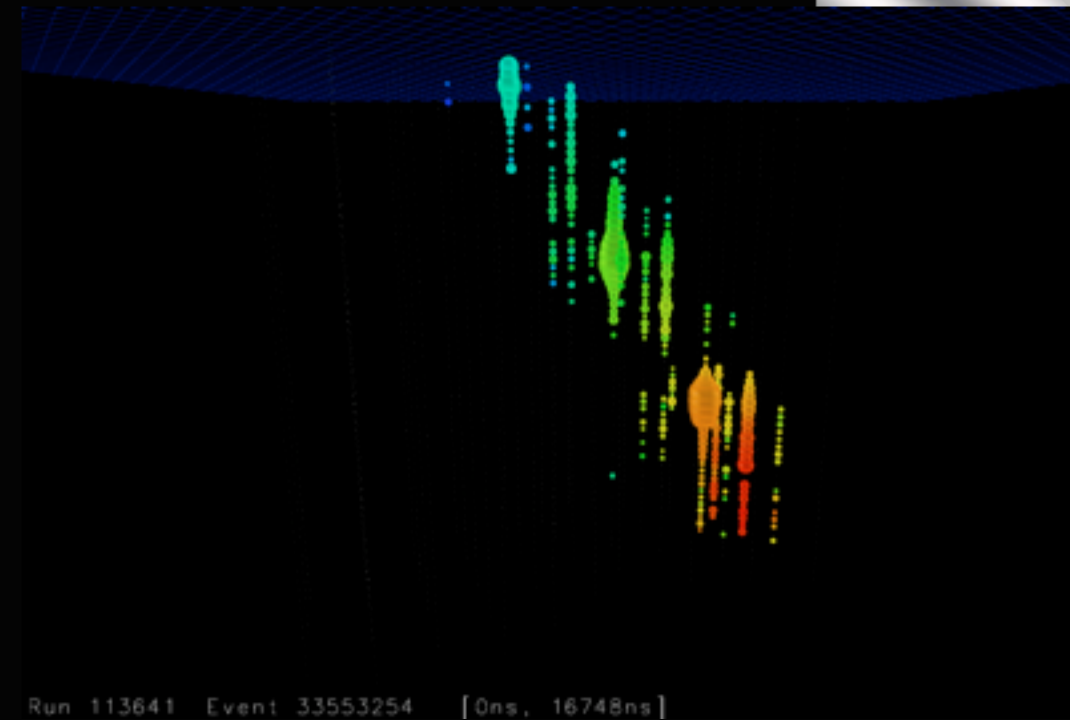
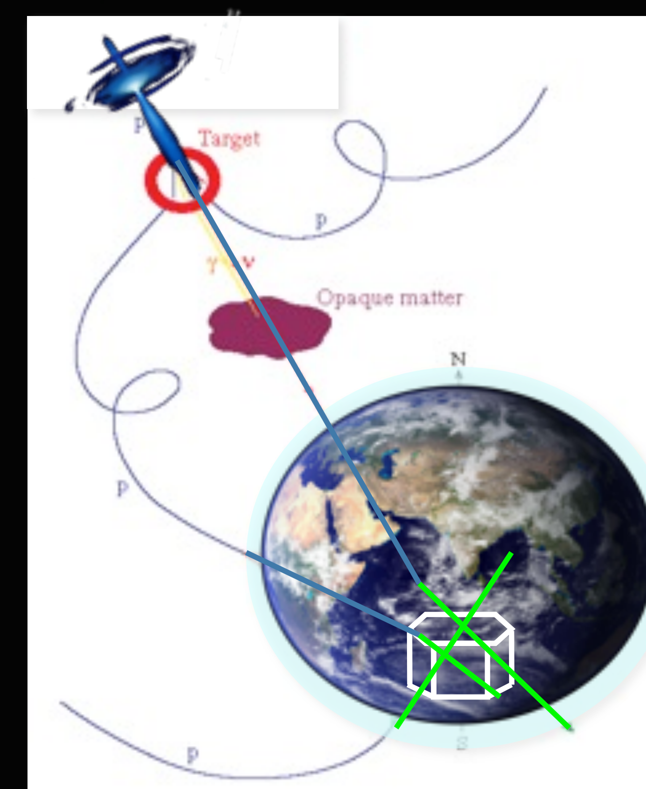
motivation

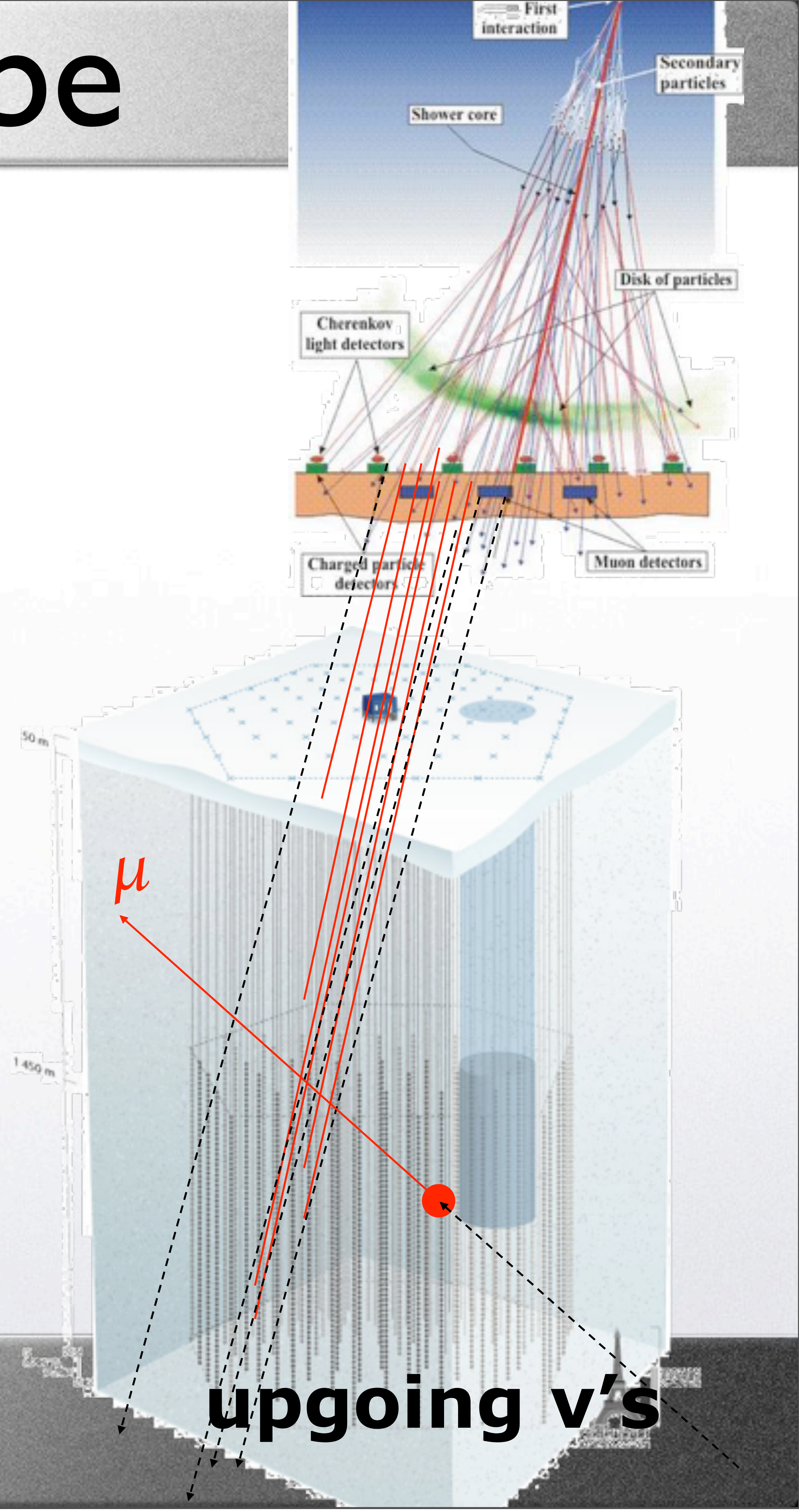


1. need to understand our detector
2. test reconstruction algorithms
3. understand the backgrounds in our analyses
1. atmospheric muons
2. atmospheric neutrinos

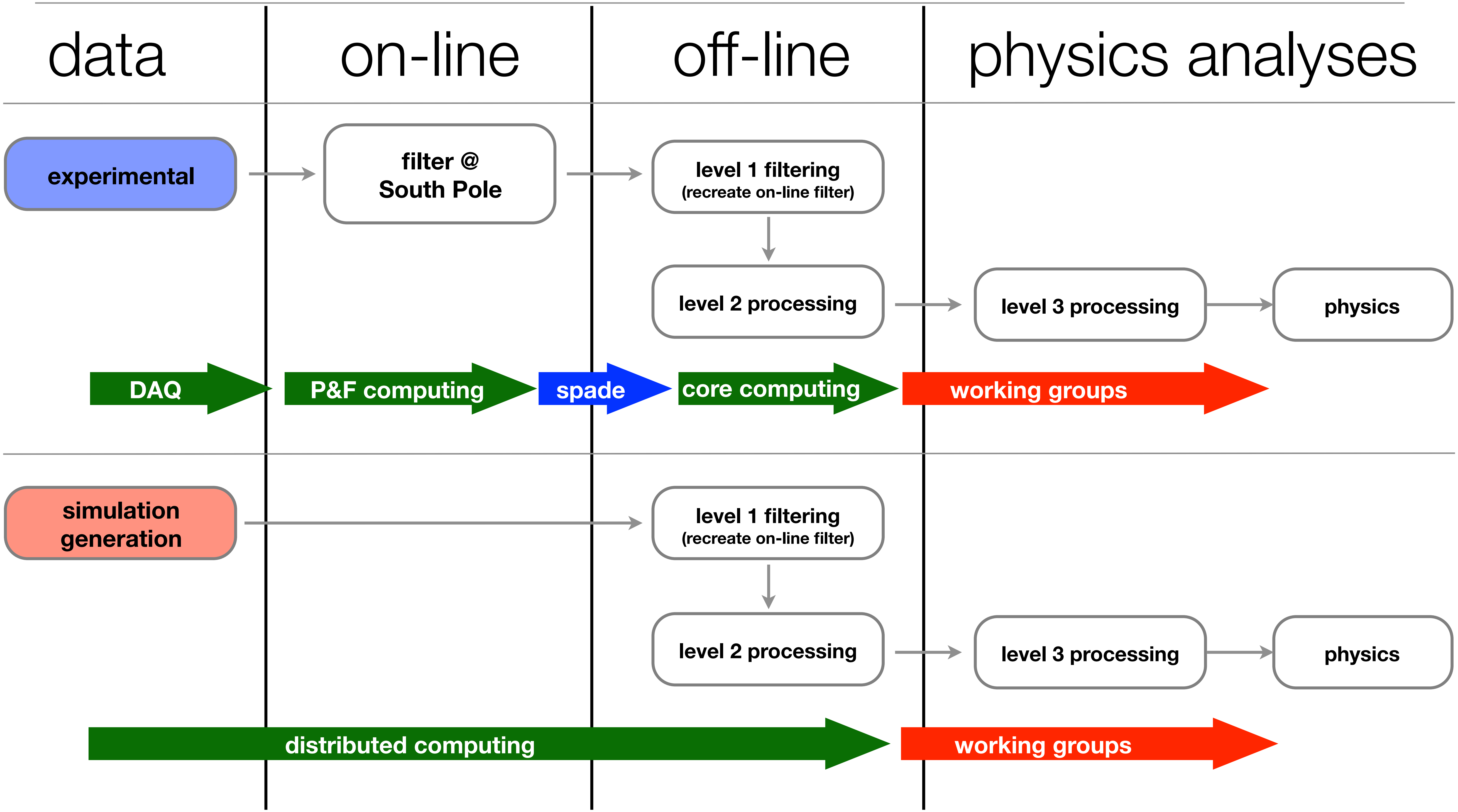


events in icecube

- Air shower detection @ surface
- Penetrating muon detection in deep ice
- Events dominated by cosmic ray muons : 10^6 μ for every ν that interacts in IceCube
- Upgoing ν's (atmospheric)



flow of experimental and simulation data



Simulation

tree<I3Particle>

(direction, position, energy, type)

OM, vector<I3MCHit>

(photoelectrons)

OM, vector<PMTWaveform>

(pe PMT response waveforms)

OM, vector<DOMLaunch>

(digitized PMT response waveforms)

Reconstruction

I3Particle

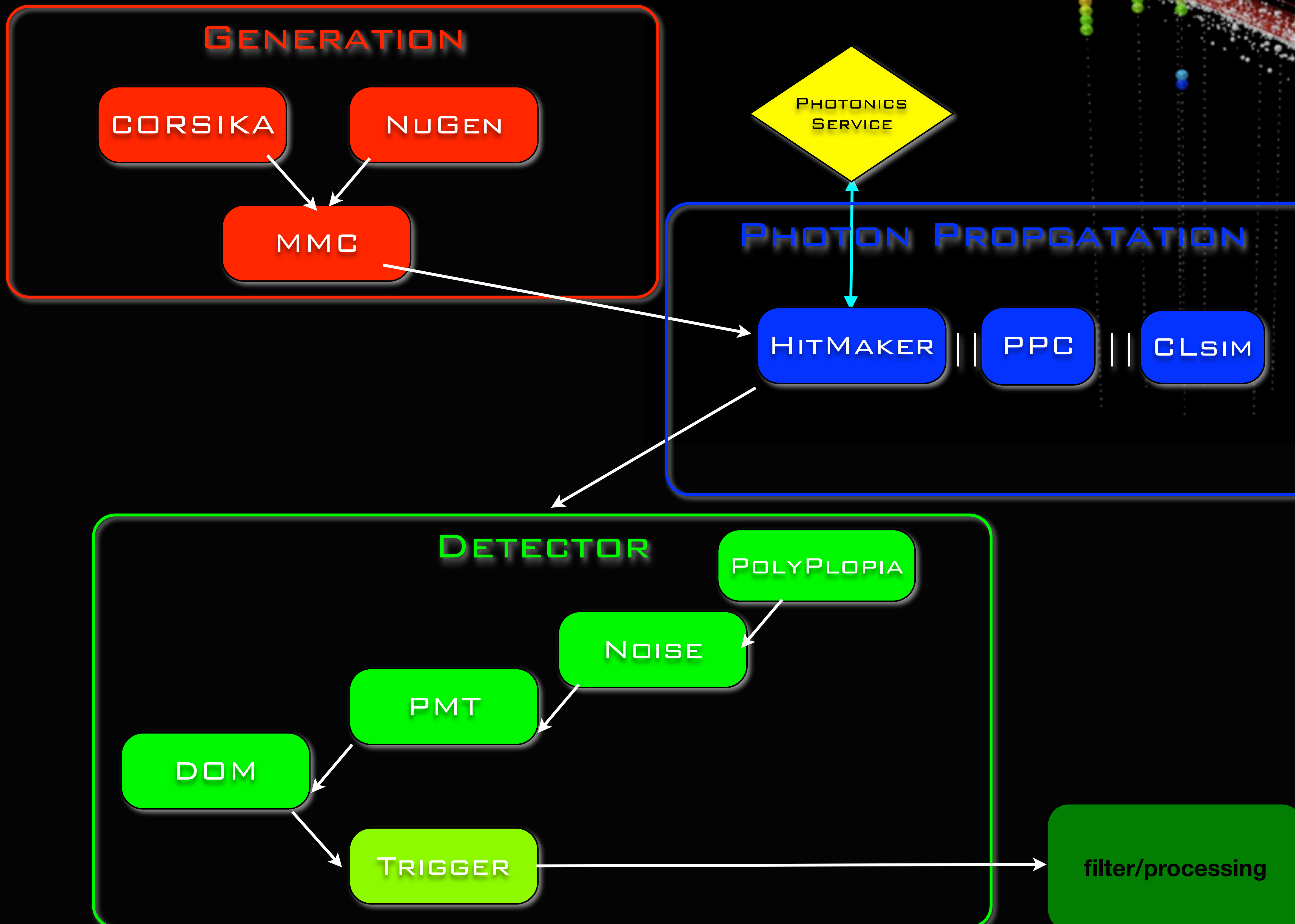
OM, vector<I3RecoPulse>

(pe pulses)

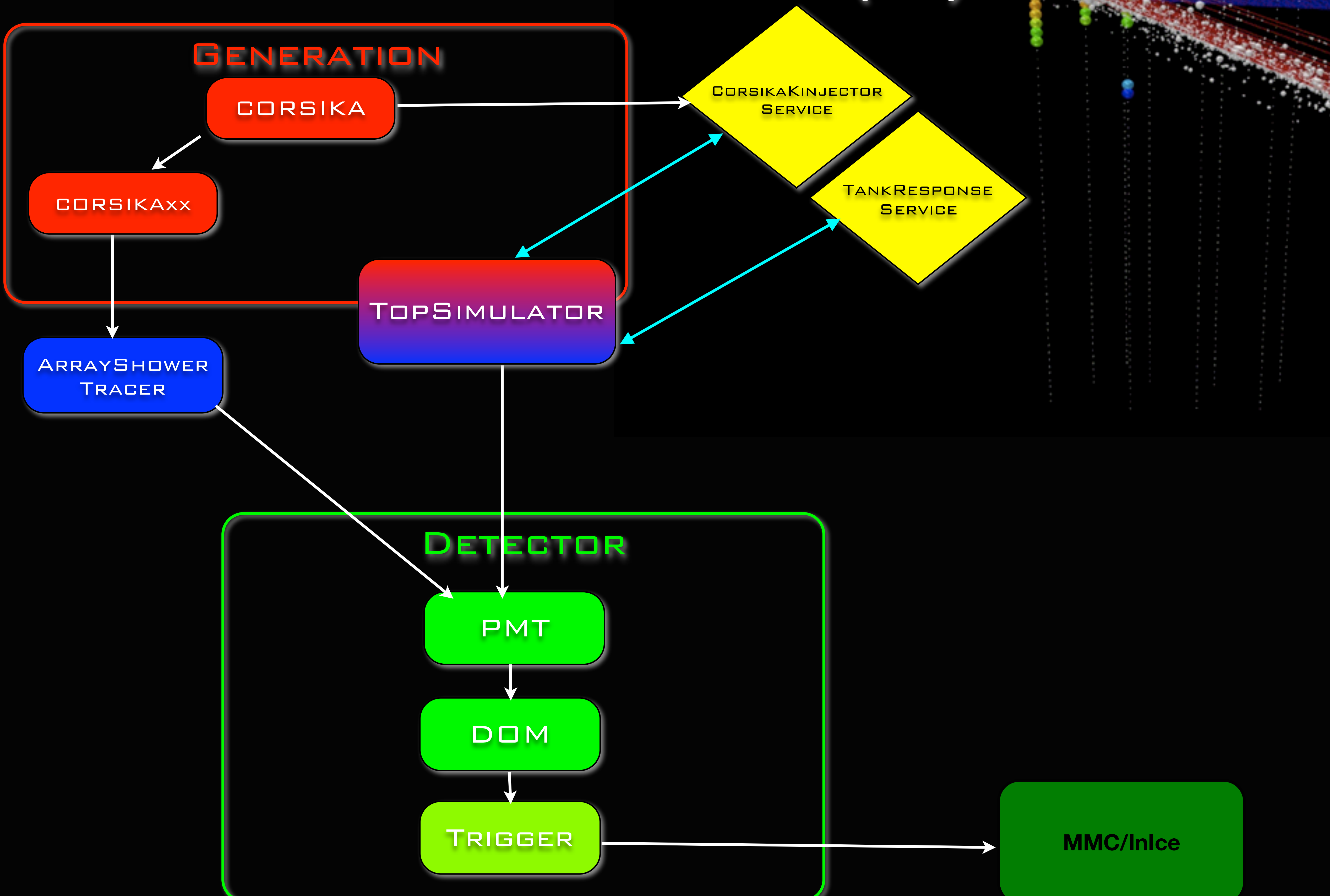
OM, vector<DOMLaunch>

(digitized PMT response waveforms)

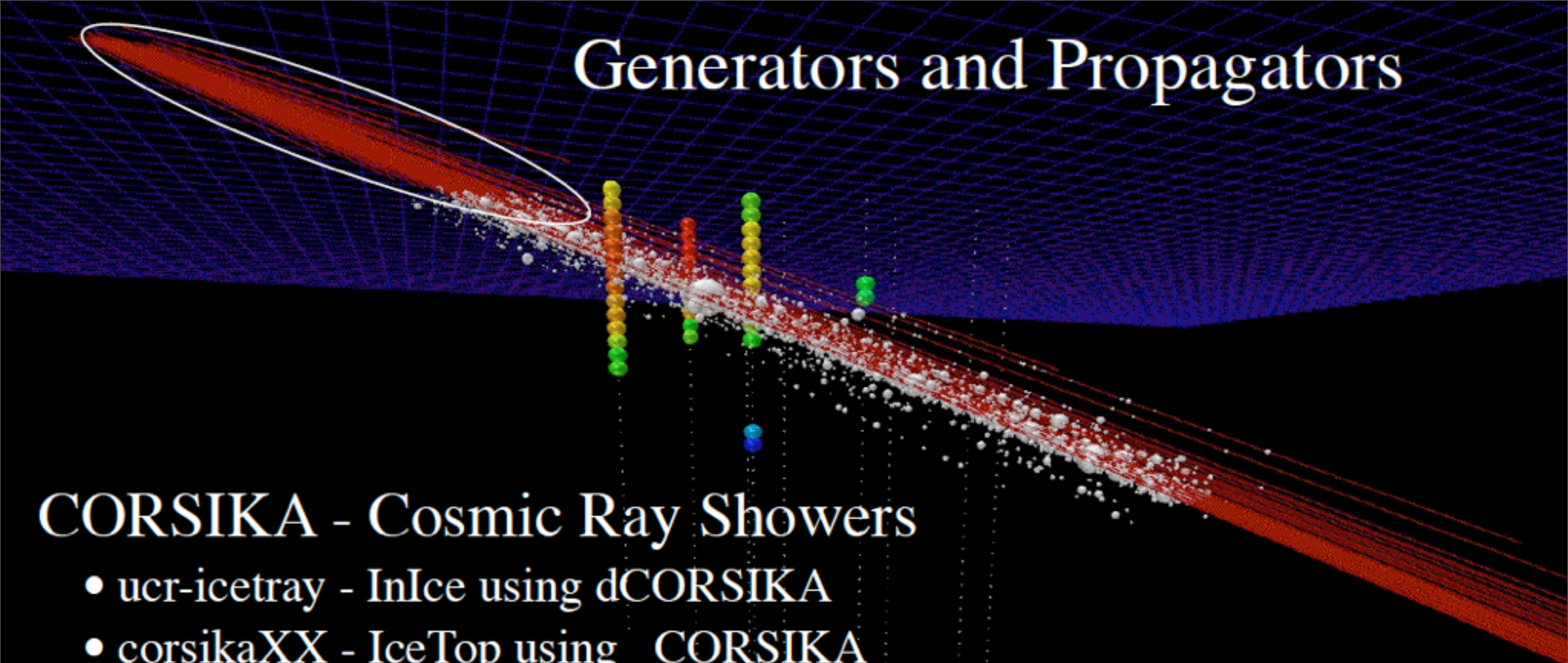
simulaton chain



simulaton chain (IT)



Generators and Propagators



CORSIKA - Cosmic Ray Showers

- ucr-icetray - InIce using dCORSIKA
- corsikaXX - IceTop using CORSIKA

Neutrinos - neutrino-generator, GENIE

Test Generators

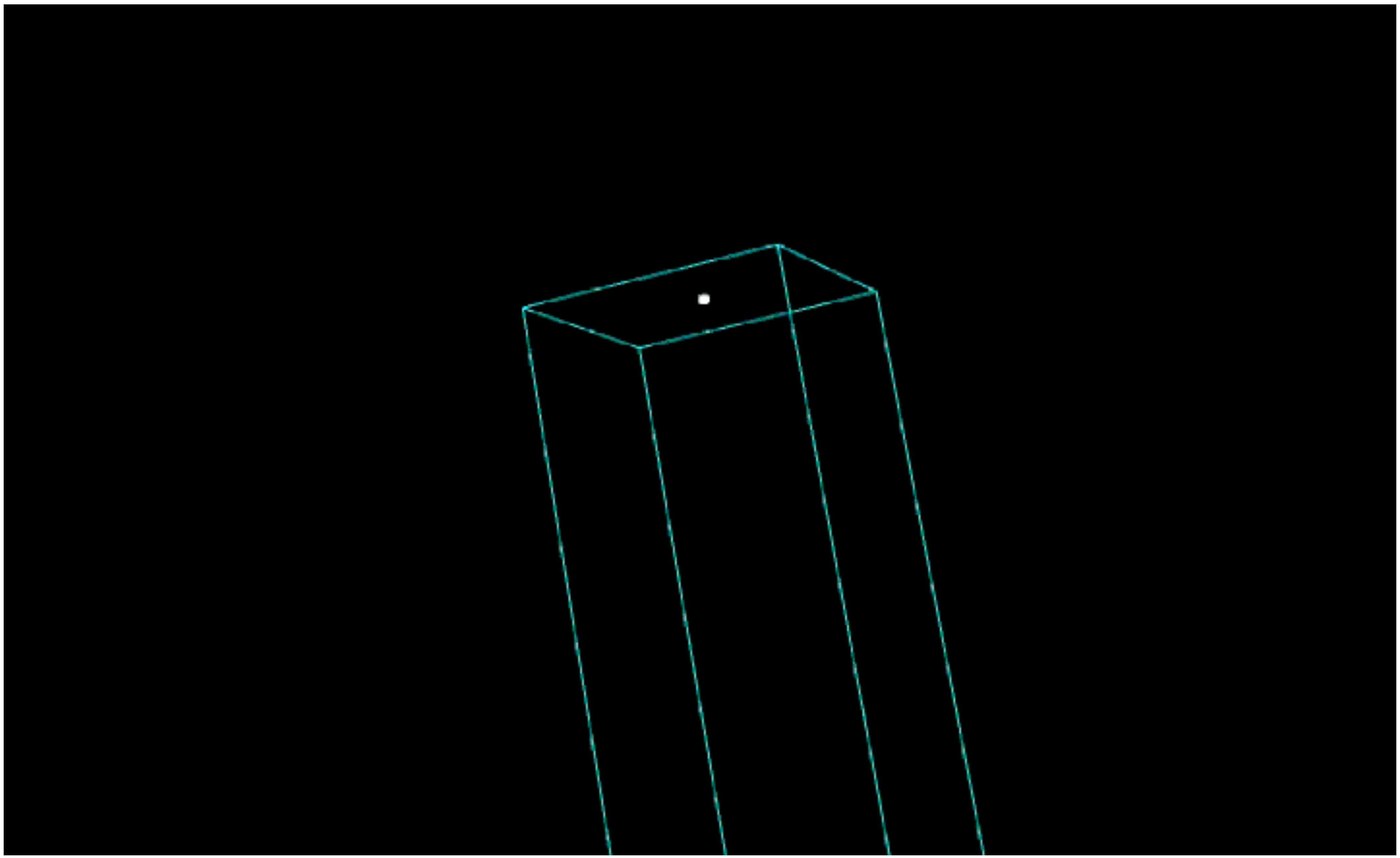
- simple-injector - injects **any** type of particle

Propagators

- MMC/mmc-icetray
- JULIeT/juliet-interface
- PROPOSAL (C++ implemetation of MMC)

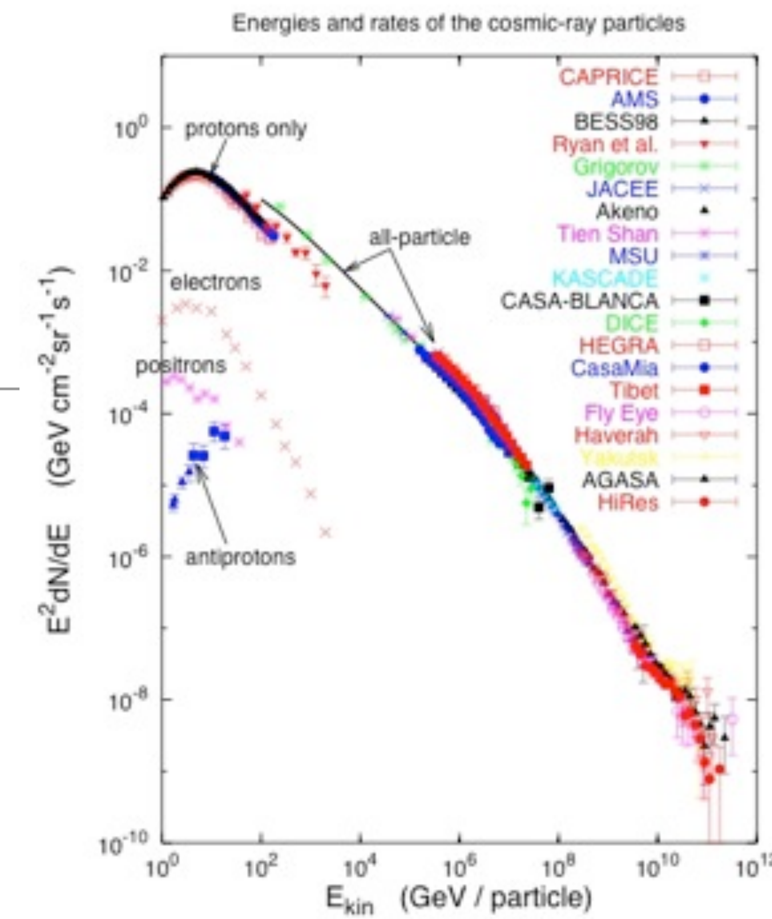
generators : CORSIKA

(**CO**smic **R**ay **SI**mulations for **KA**scade)



generators : CORSIKA

(**CO**smic **R**ay **SI**mulations for **KA**scade)



- FORTRAN code developed for KASCADE
  - dCorsika: IceCube-specific modifications
  - ucr-icetray: IceTray reader for dCorsika f2k
  - corsikaXX: IceTray reader for CORSIKA files
- poly-gonato model (fails > 10-100 PeV & @ horizon)

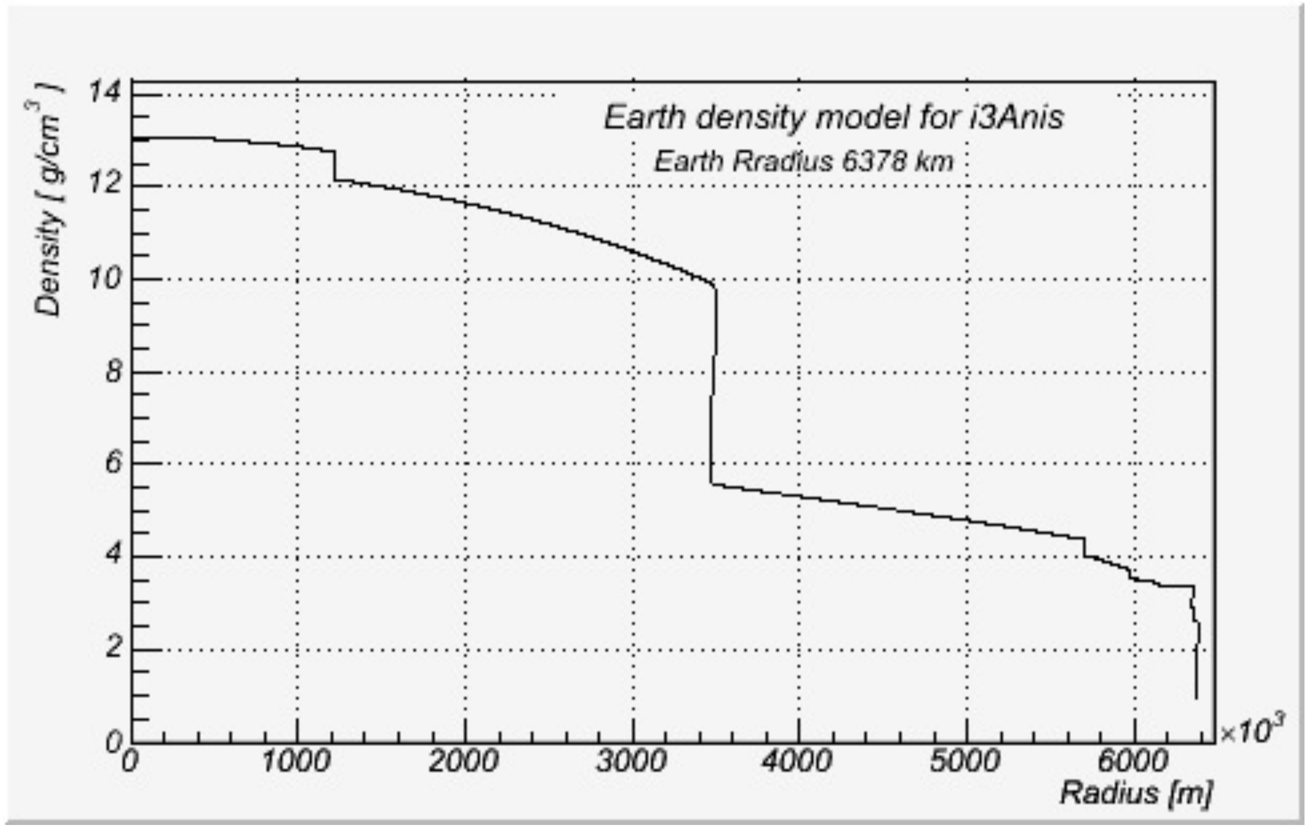
➡ weighted events : artificially flat spectrum

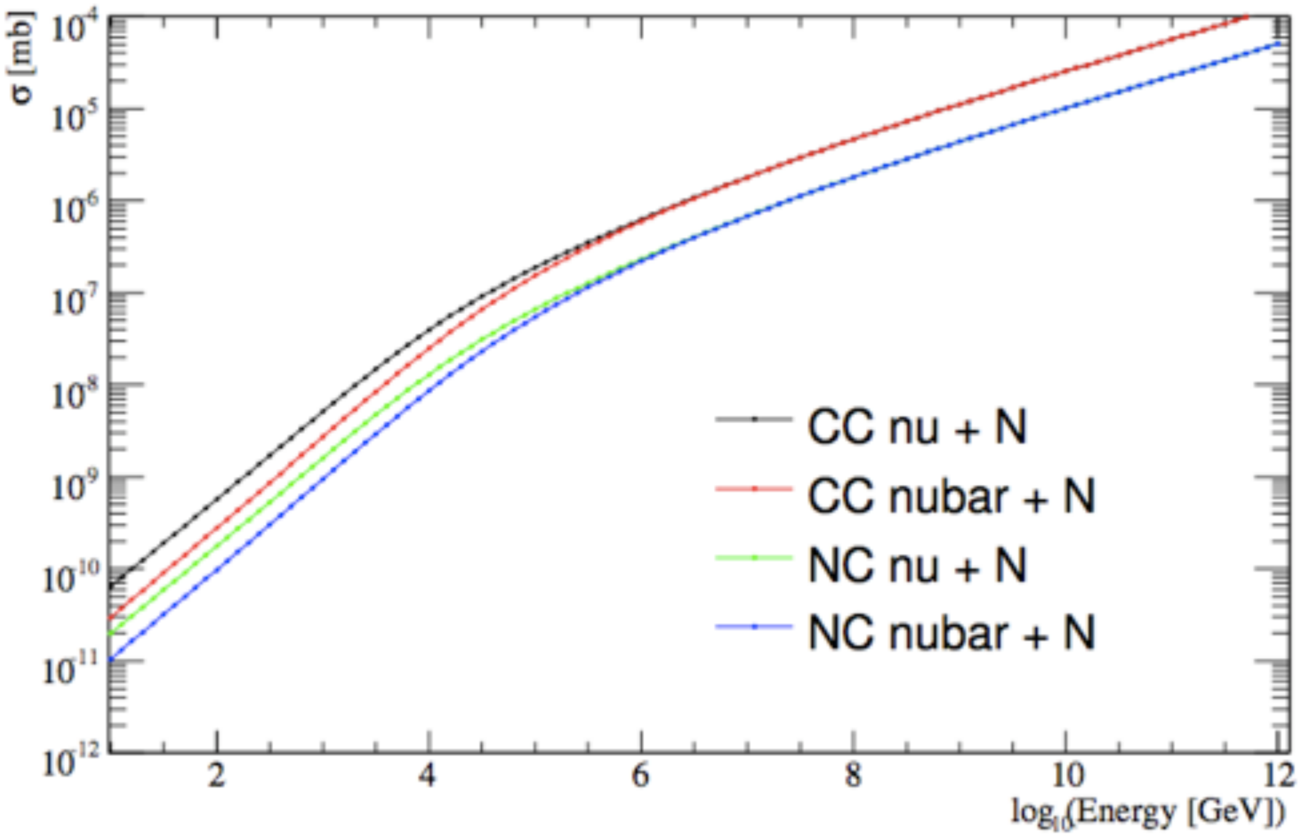
➡ better livetime efficiency @ 10 TeV but poor efficiency @ TeV

➡ energy-targeted generation of (H,He,CNO,Mg,Fe) with $E^{-1(2)}$

generators : neutrino-generator

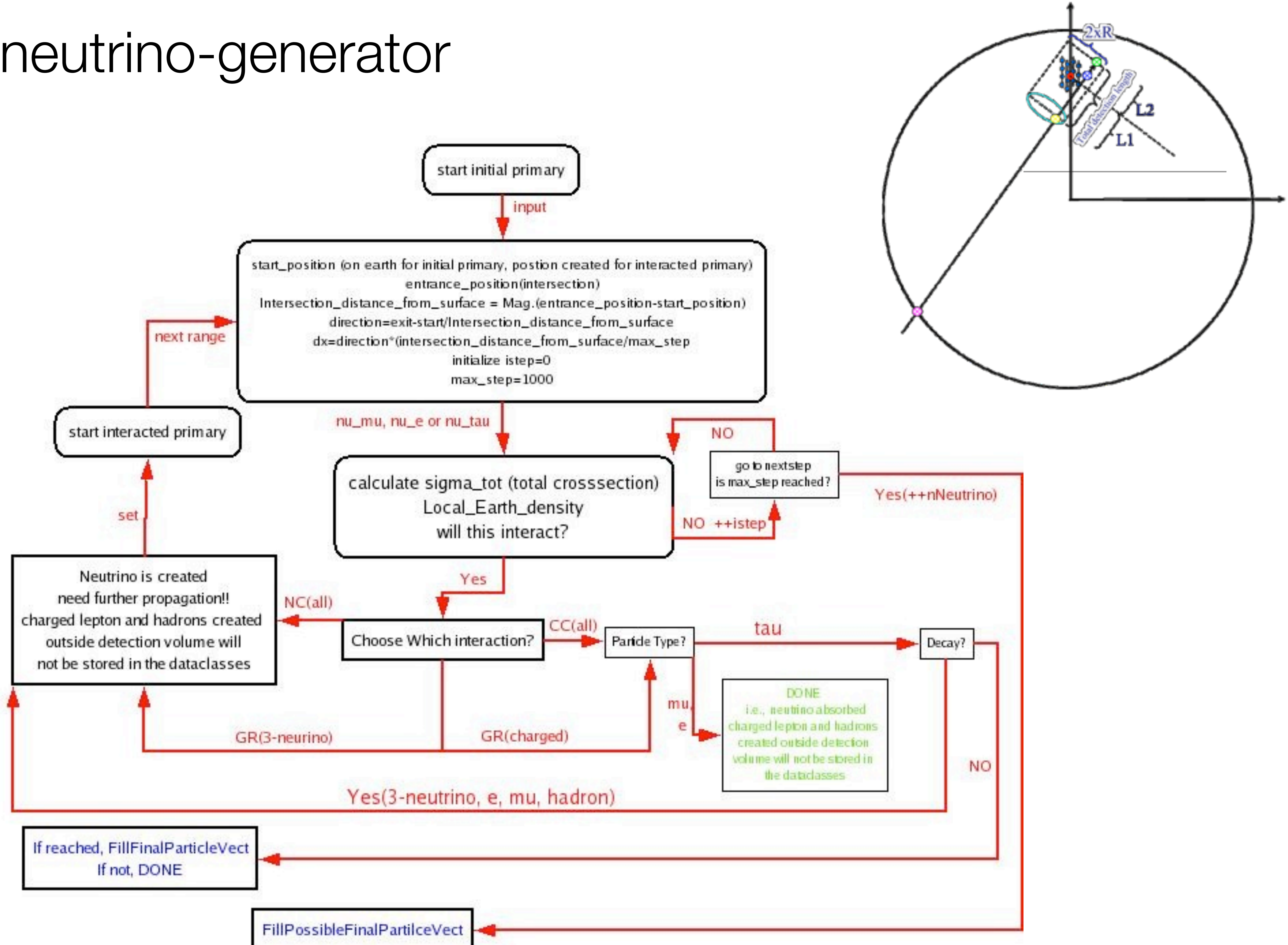
- produce a $E^{-\gamma}$ ν_μ, ν_e, ν_τ with
  - PRELIM Earth's density model



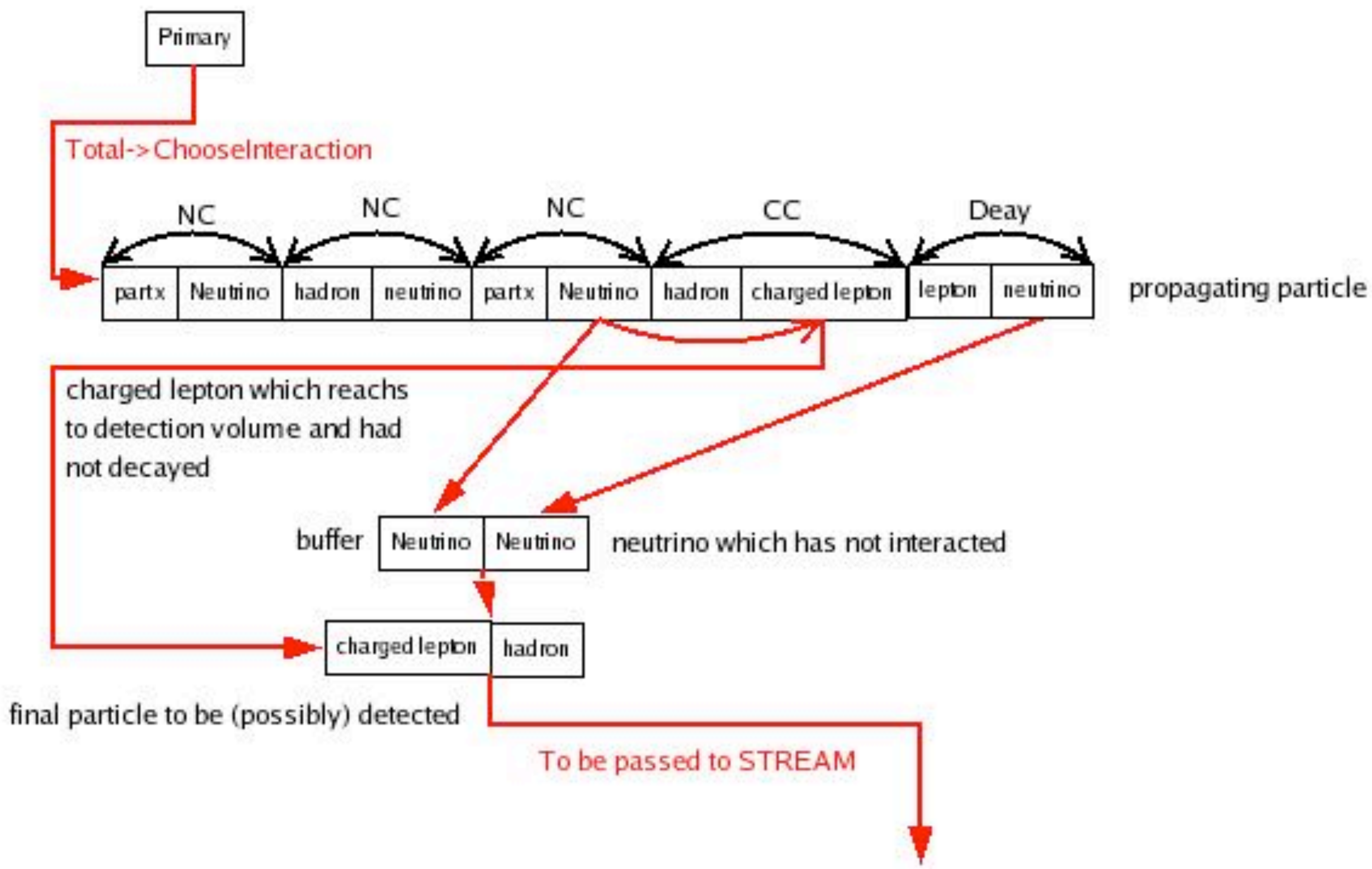


- CTEQ5 parton distribution functions
- prop & interaction of neutrinos into a weight : flexible spectral weight

neutrino-generator



neutrino-generator

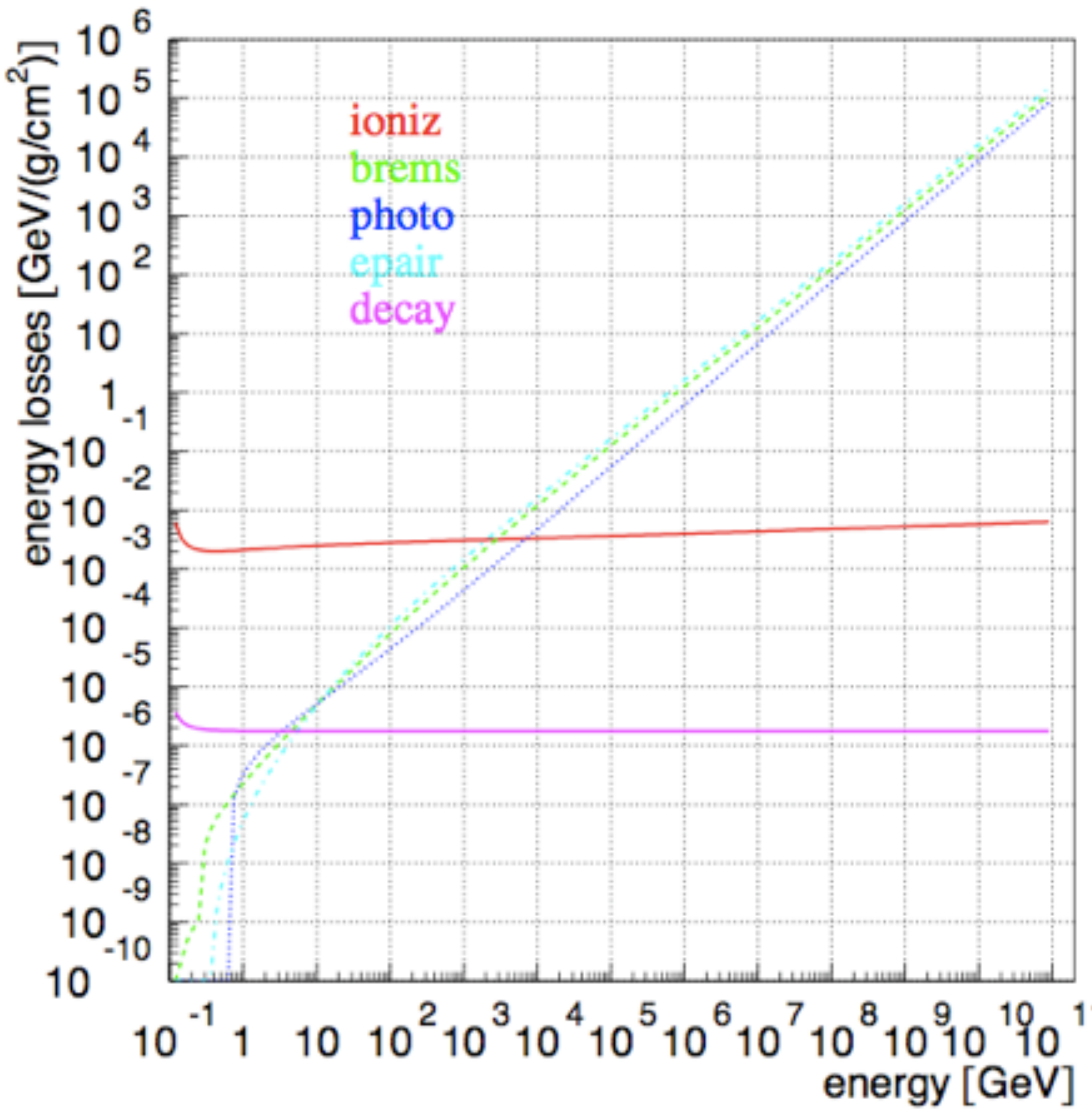


propagator : MMC, Juliet, PROPOSAL

propagates μ, e, τ & monopoles

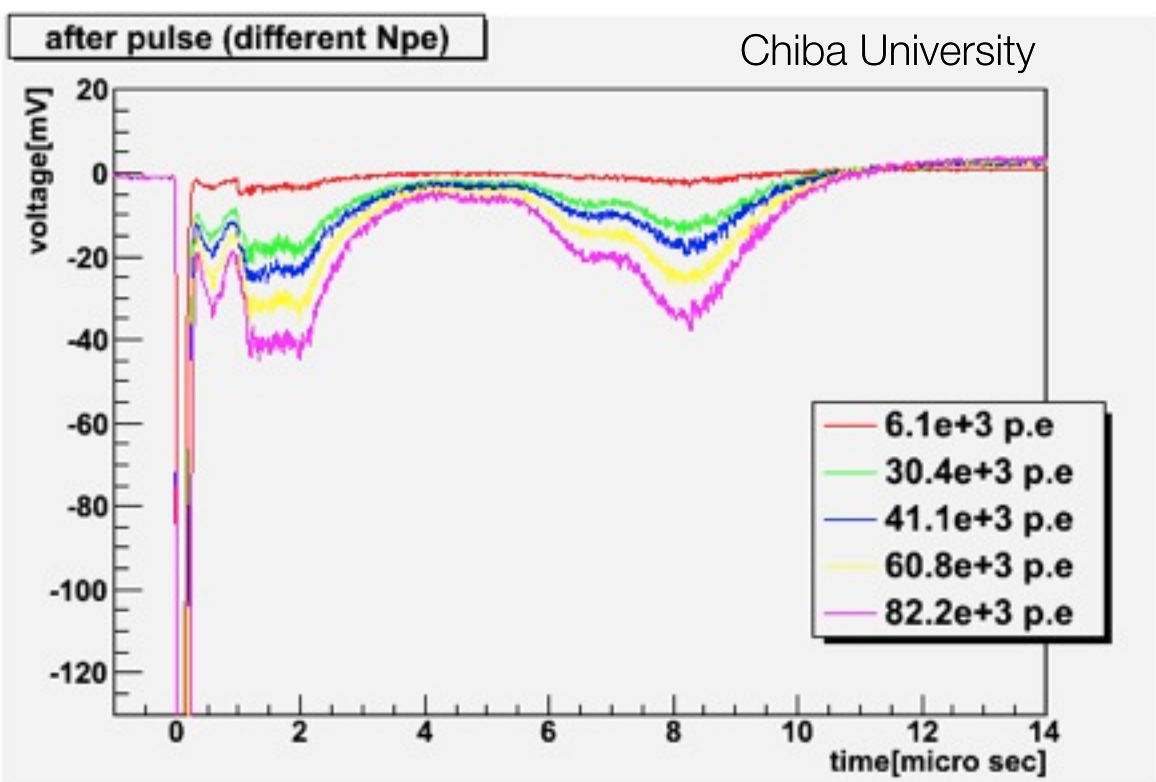
calculates continuous and stochastic energy losses

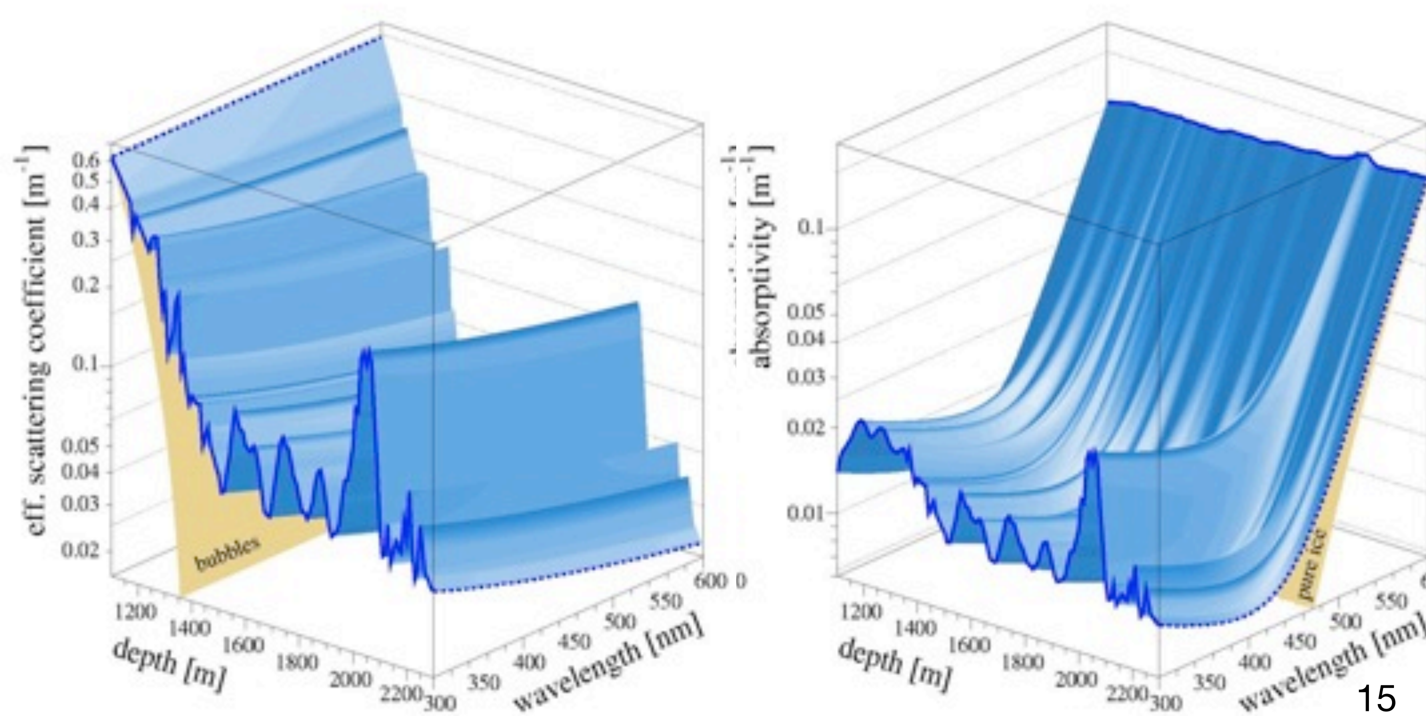
$$\frac{dE}{dx} = a(E) + b(E) \cdot E$$



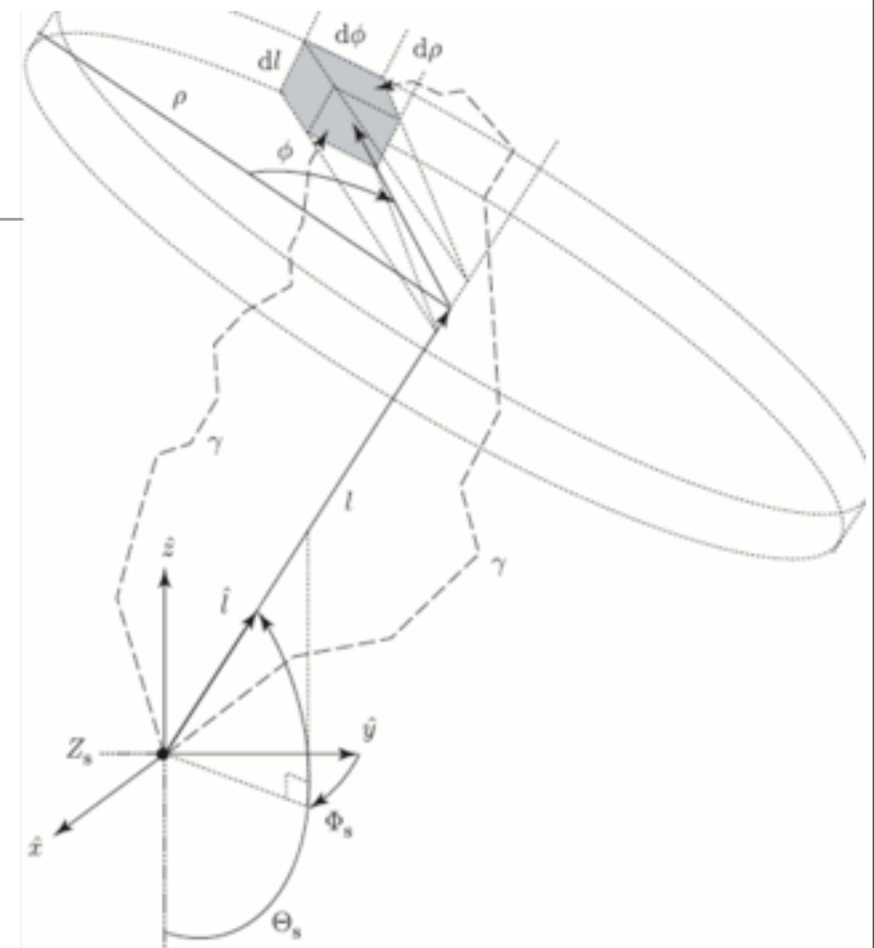
HitMaker

- μ energy lost + cascades ➙ photons ➙ p.e.
  - photon propagation : ice properties + PMT response + DOM glass/gel
  - pre-generated lookup table : amplitude ad time distribution





Photon tracking with tables

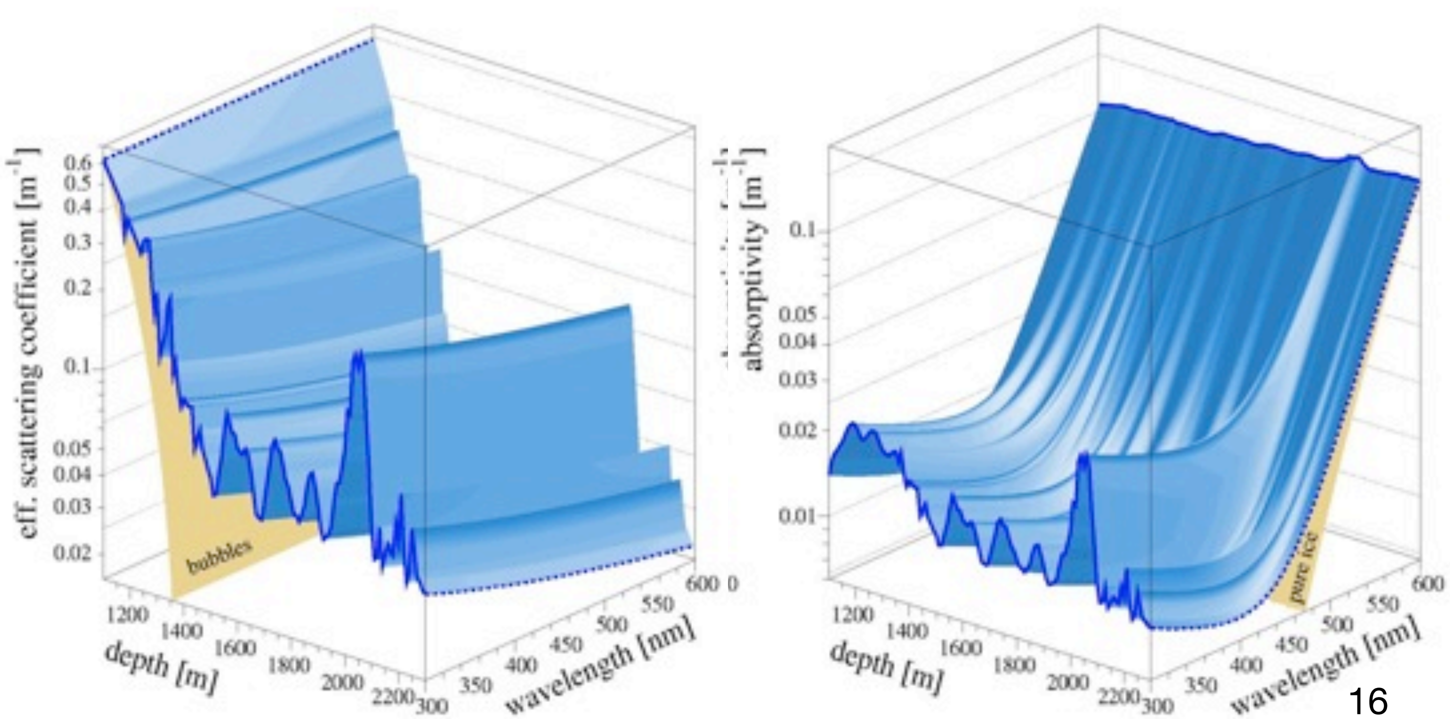


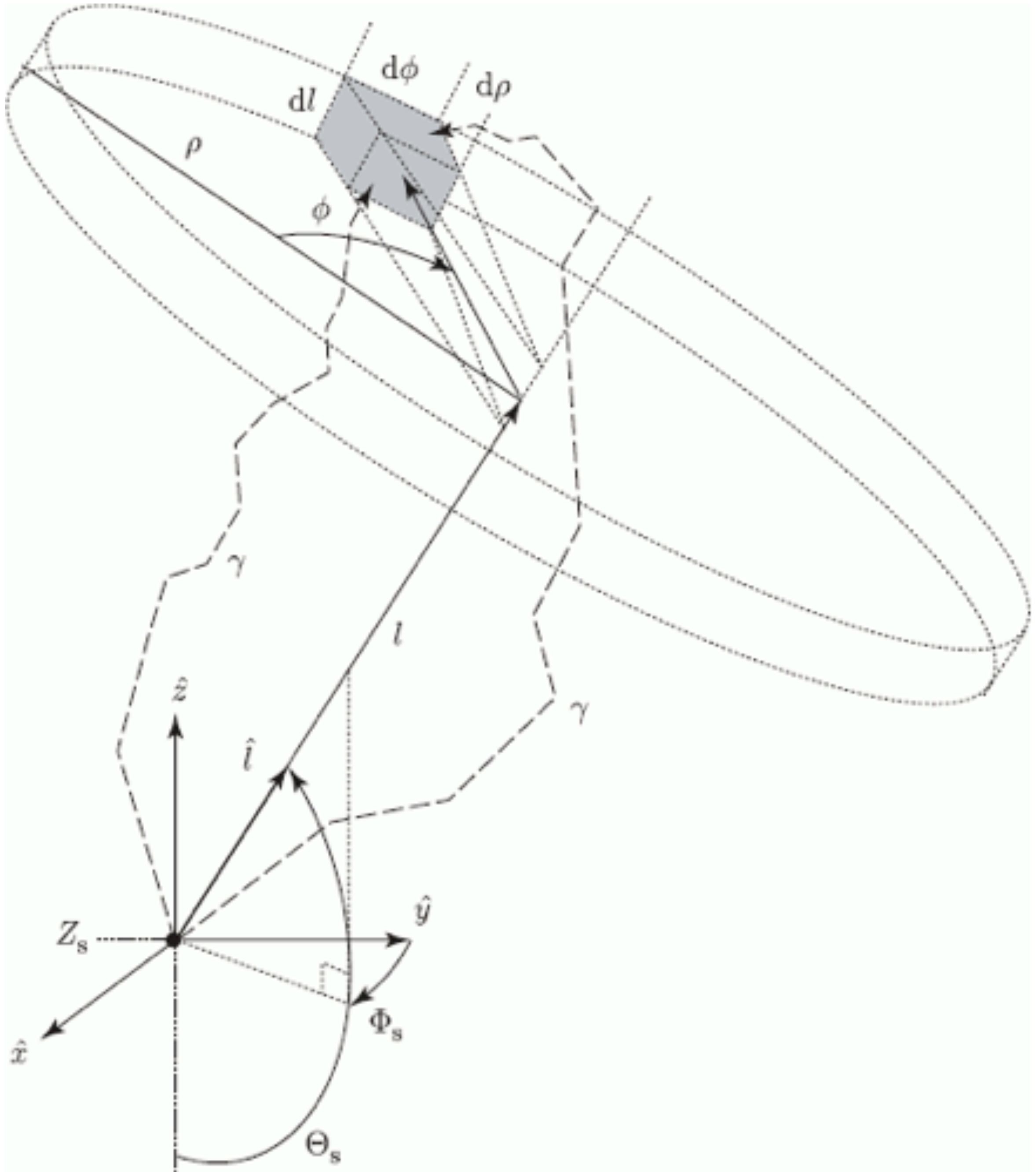
First, run photonics to fill space with photons, tabulate the result

Create such tables for nominal light sources: cascade and uniform half-muon

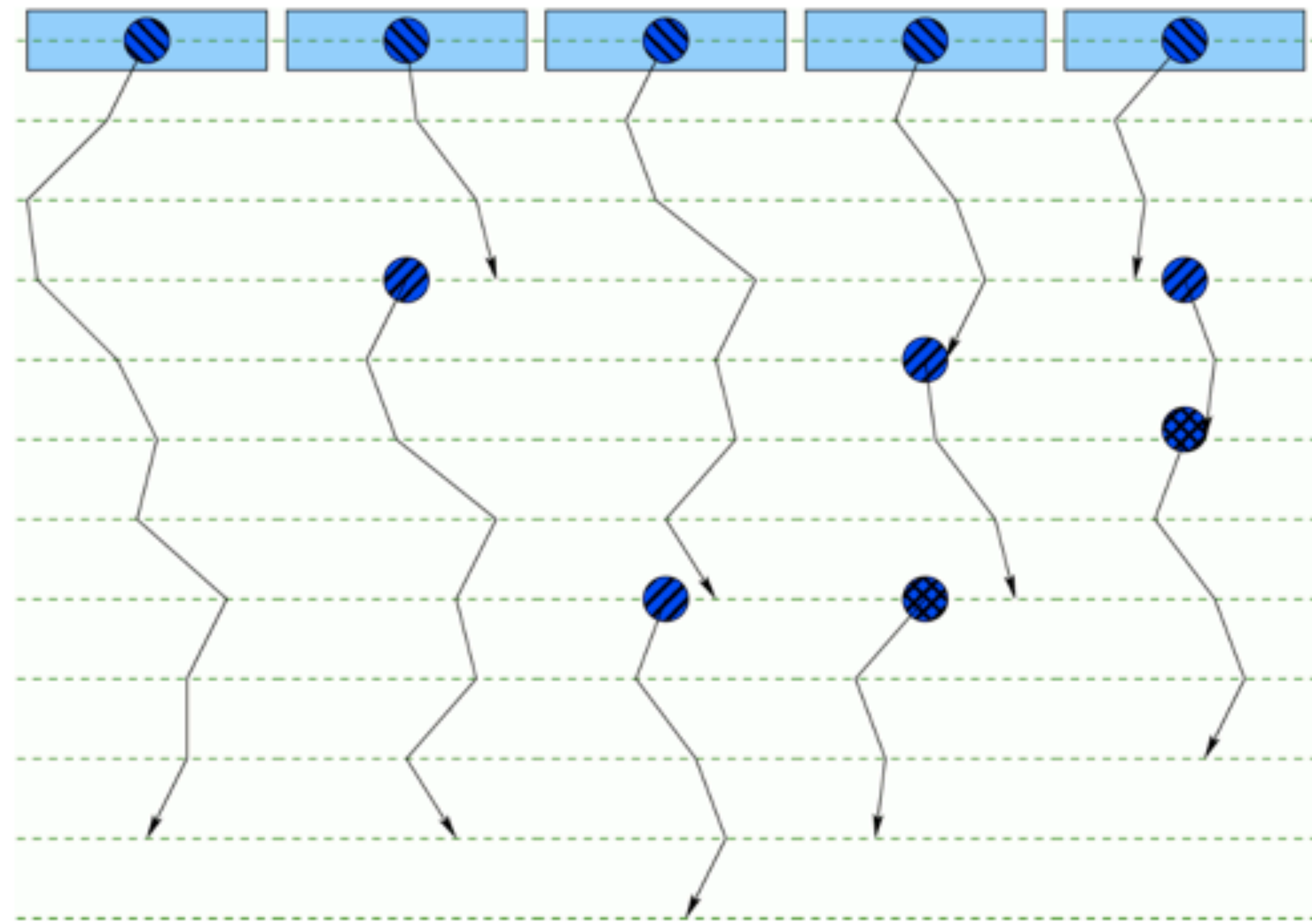
Simulate photon propagation by looking up photon density in tabulated distributions

Table generation is slow
Simulation suffers from a wide range of binning artifacts
Simulation is also slow! (most time is spent loading the tables)
Tables are large ~7GB





PPC simulation on GPU



Direct photon tracking with PPC

diplopia

(from gr. διπλόος, "double", and ὄψ, ὀπός, "vision")

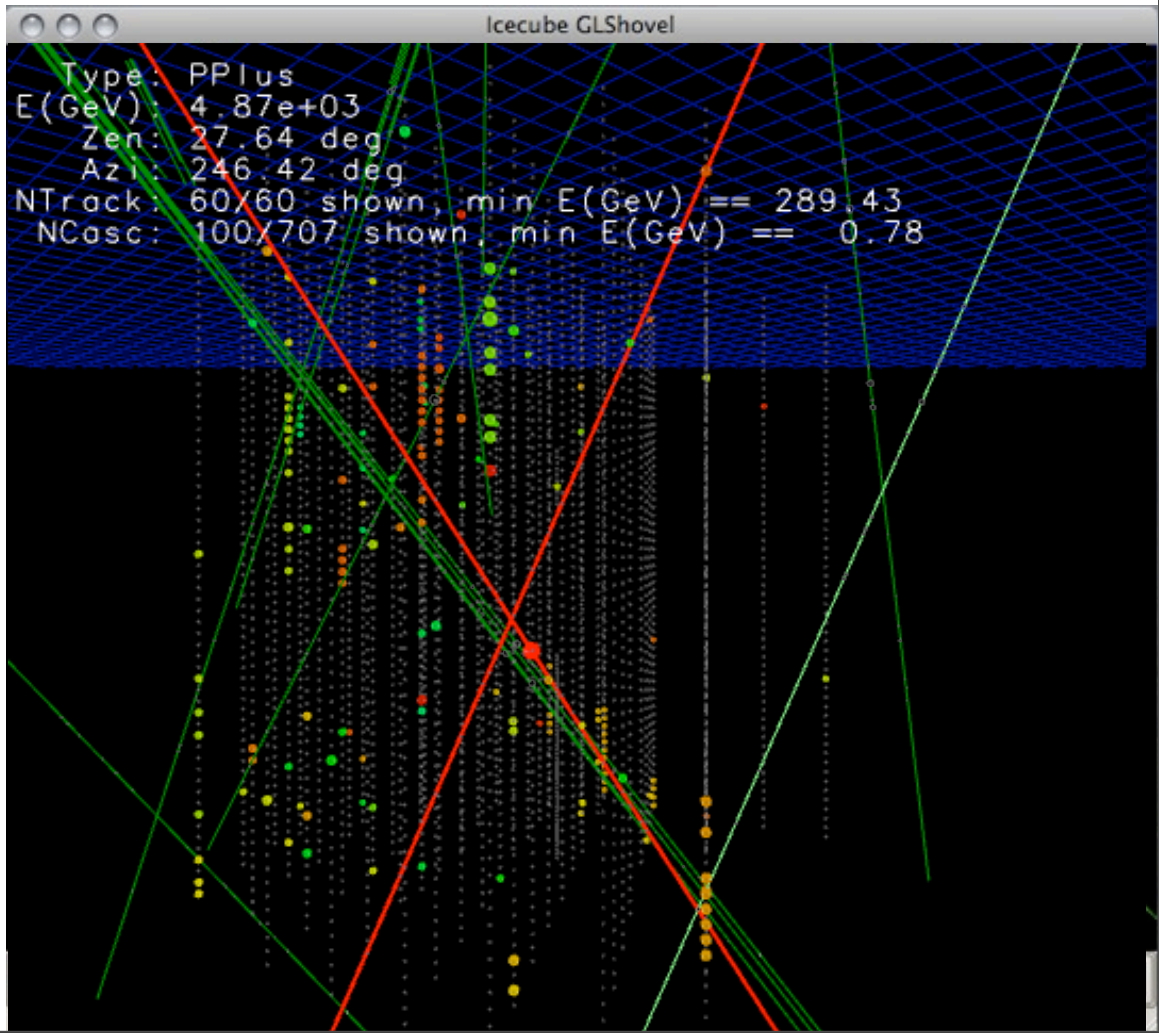
coincident atmospheric shower events in IceCube

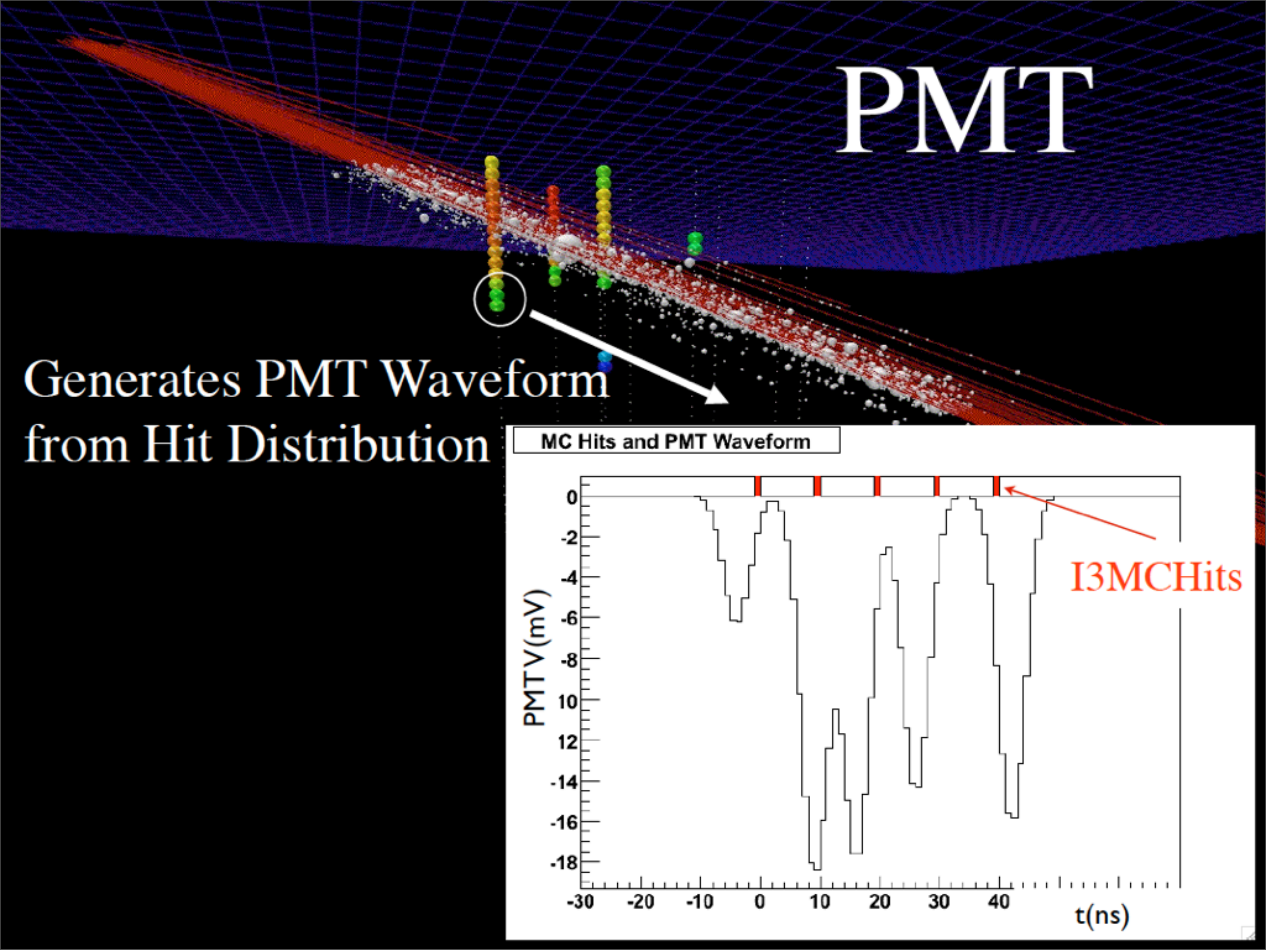
- I3Polyplopia:
  - Forces *n* coincidences in a time window *\Delta t*
  - calculates weight based on Poisson probability of events within time interval.

$$f(k;\lambda t) = \frac{e^{-\lambda t}(\lambda t)^k}{k!}$$

- I3PolyplopiaExp:
  - merges events with different multiplicities based on exp. distribution of time between events

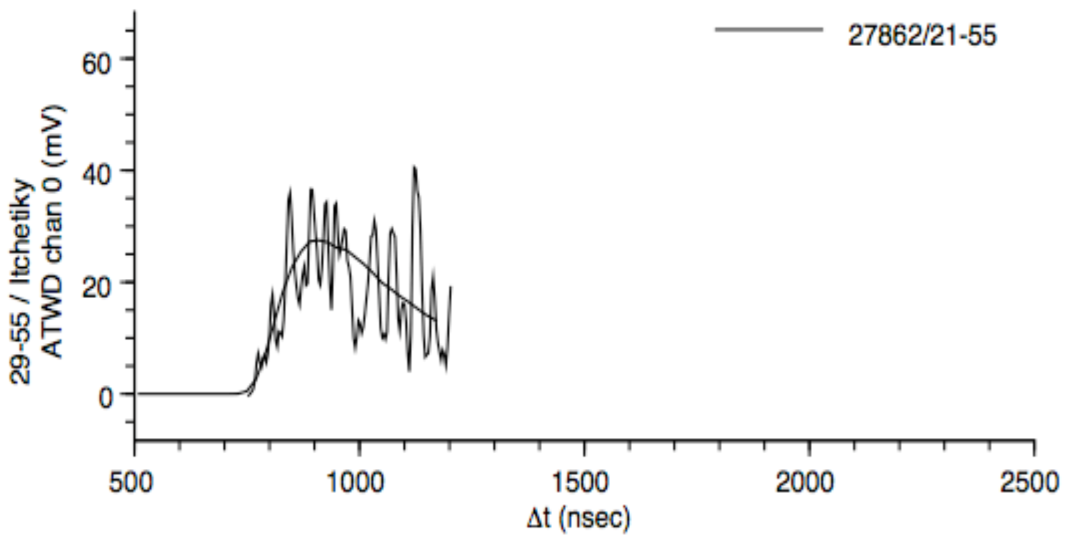
$$p(t) = \frac{1}{\tau}\exp(-t/\tau), \tau = \Delta t R$$

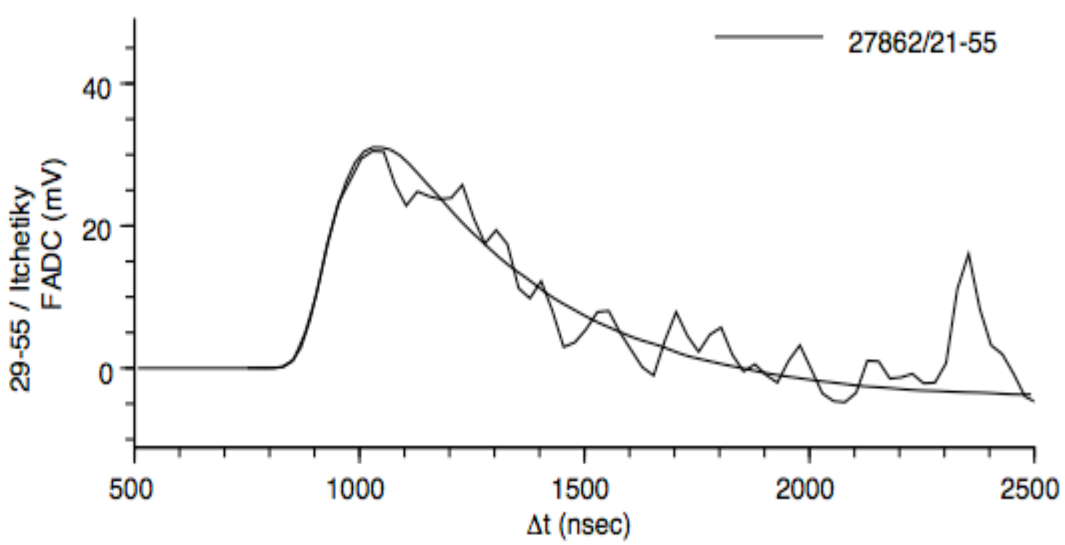


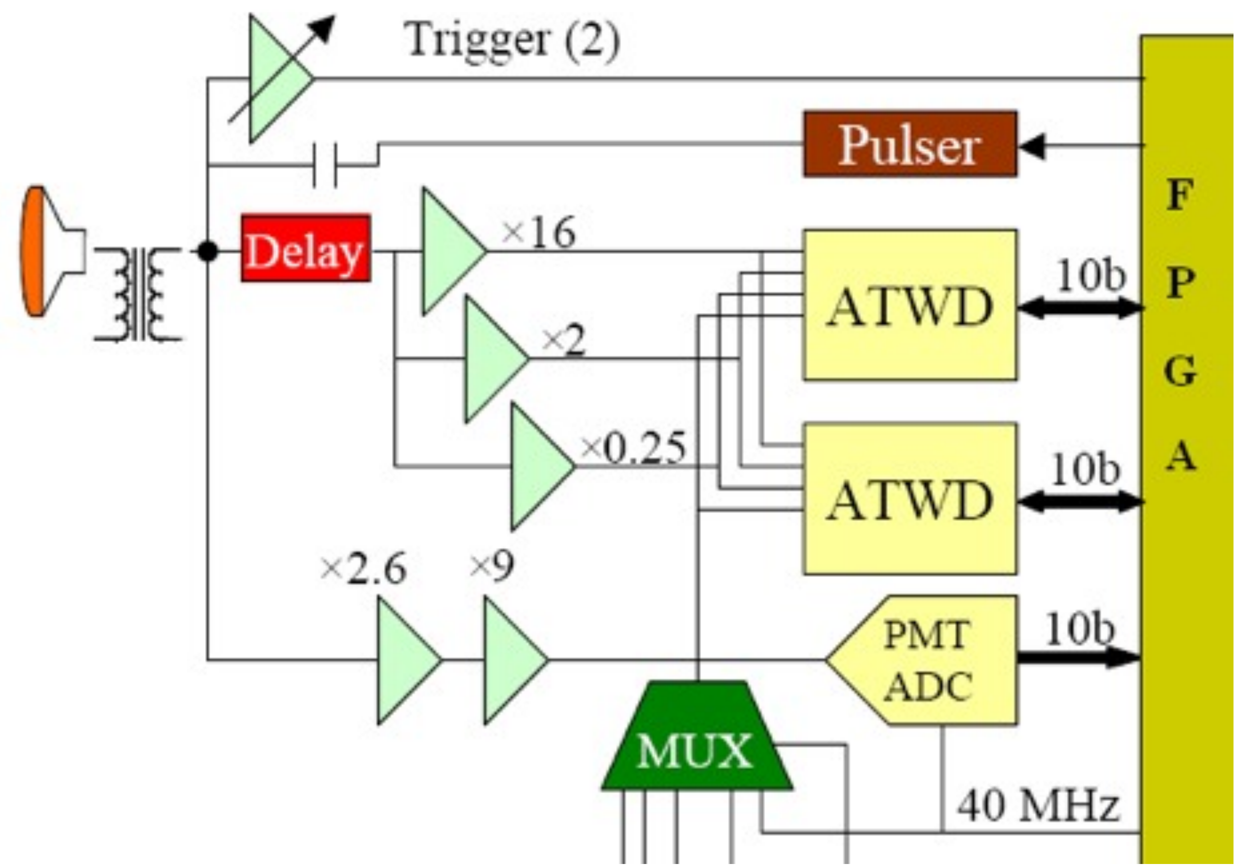

PMT
Generates PMT Waveform from Hit Distribution
MC Hits and PMT Waveform
PMT V(mV)
t(ns)
I3MCHits
0
-2
-4
-6
-8
10
12
-14
-16
-18
-30
-20
-10
0
10
20
30
40

DOM mother board simulation

- core of detector simulation
    - digitization & timing @ MB

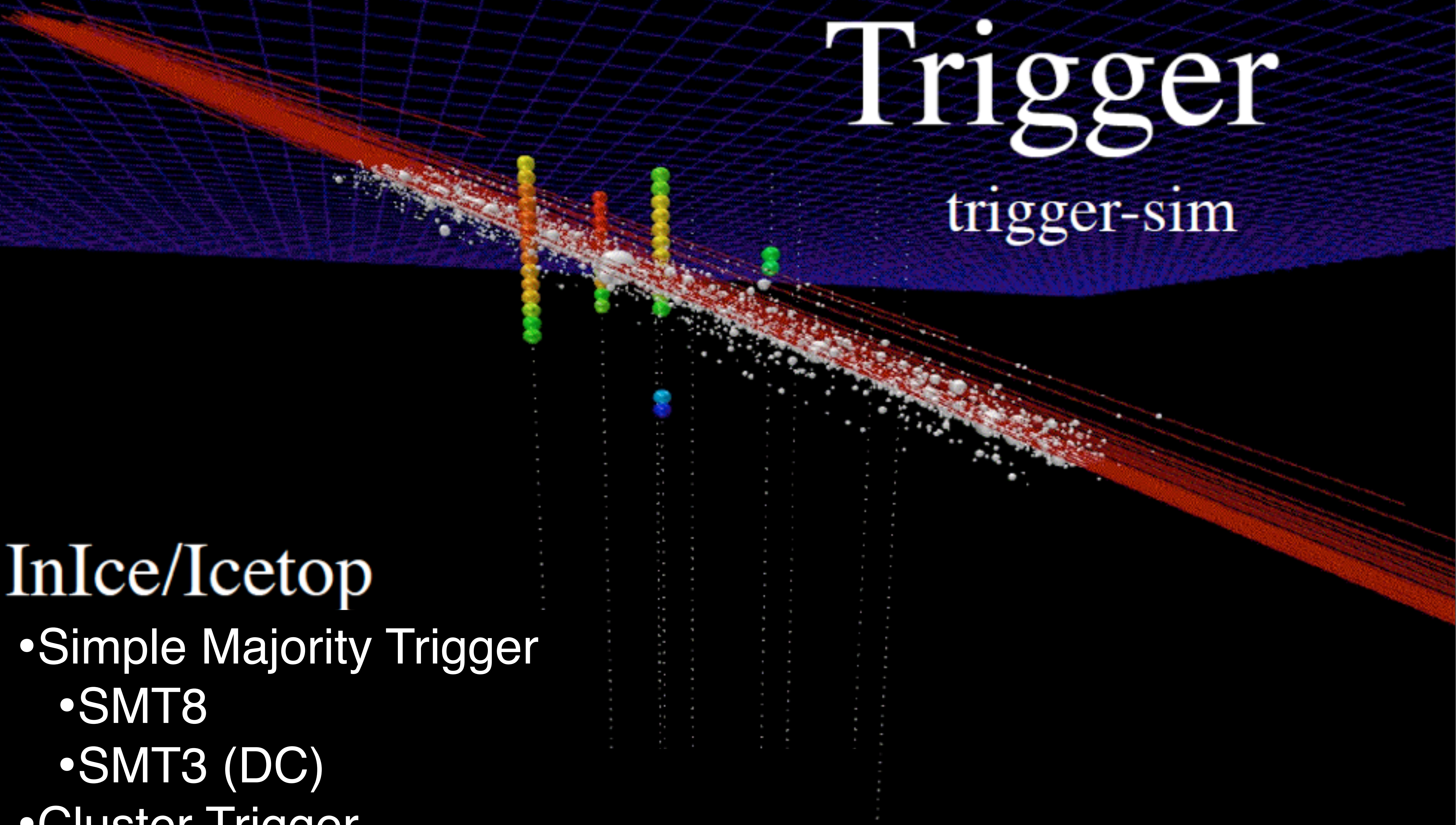






Trigger

trigger-sim



InIce/Icetop

- Simple Majority Trigger
  - SMT8
  - SMT3 (DC)
- Cluster Trigger
- Volume Trigger
- SlowMP

Global Trigger
I3TimeShifter

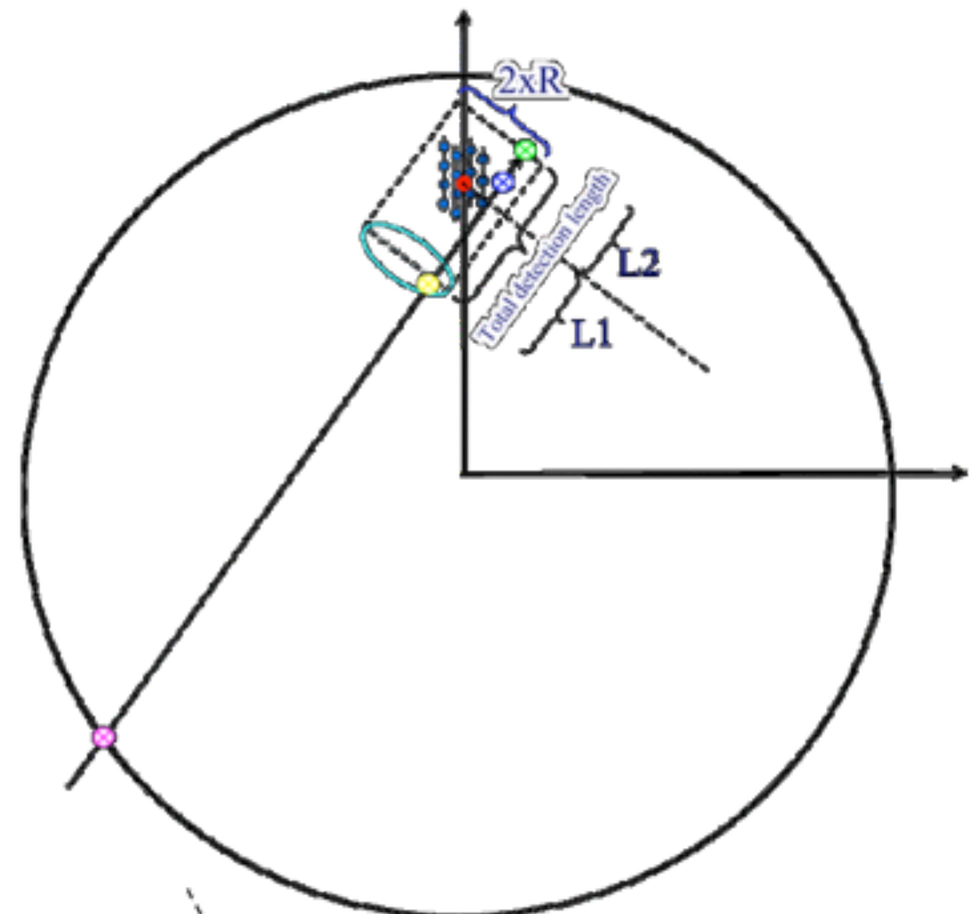
http://wiki.icecube.wisc.edu/index.php/Simulation_Time_Issues

Weights

neutrino-generator

- Calculates the propagation probability (i.e. that the neutrino will reach the detector)

- It forces an interaction within a volume around the dector and computes the probability of this interaction



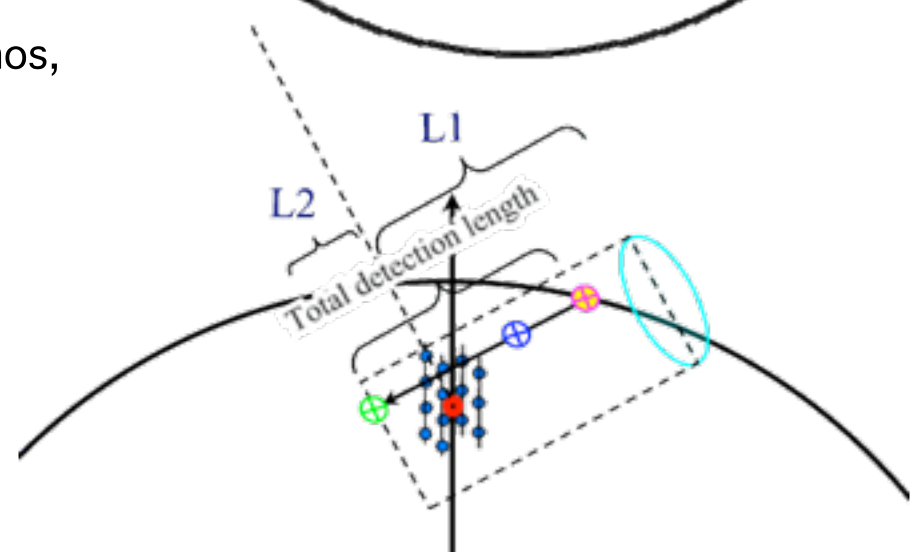
$$OneWeight = \left(\frac{P_{int}}{E^{-\gamma}}\right) \cdot \int_{E_{min}}^{E_{max}} E^{-\gamma} dE \cdot Area \cdot \Omega \cdot T [GeV \cdot cm^2 \cdot sec \cdot sr]$$

where

- P_{int} = TotalInteractionProbabilityWeight,
- $E^{-\gamma}$ is the neutrino generation energy spectrum shape,
- E_{min} and E_{max} are the minimum and maximum generation energy of neutrinos,
- Area is the generation surface,
- Ω the generation solid angle
- and T = 1sec is the timescale.

- The weight corresponding to a given theoretically motivated neutrino flux is

$$\boxed{w_i = \frac{OneWeight_i}{NEvents} \times \frac{d\Phi_\nu(E_\nu)}{dE_\nu}}$$



https://docushare.icecube.wisc.edu/dsweb/Get/Document-44937/OneWeight.pdf

CORSIKA weights

- In addition, we calculate a weight "DiplopiaWeight" which accounts for the probability of a given event to fall within the trigger window of other events.

- When combining events from different files *j* then the weight is

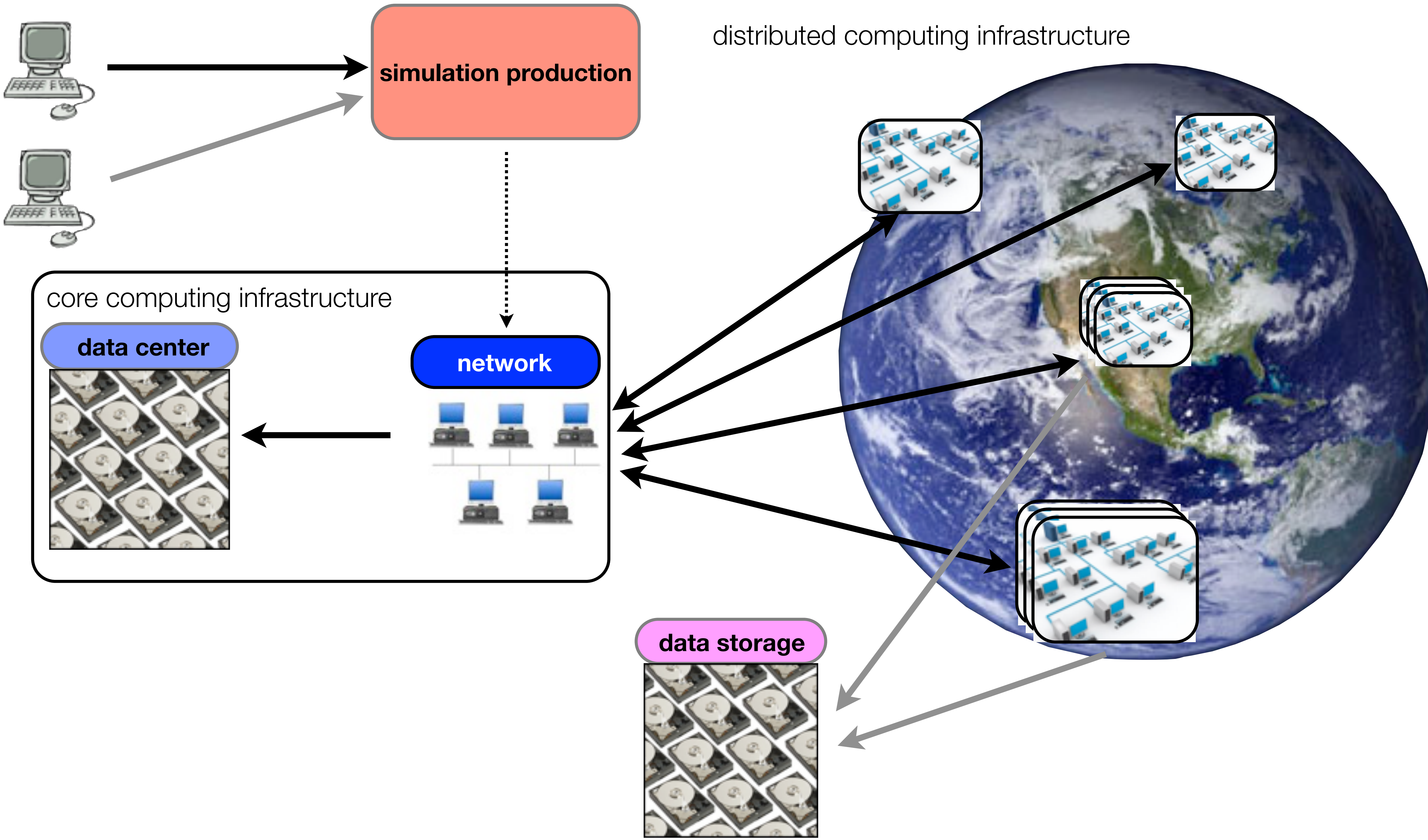
$$\boxed{w_i = \frac{W_i}{\sum_j TimeScale_j} = \frac{Weight_i \cdot DiplopiaWeight_i}{\sum_j TimeScale_j}}$$

- in general *TimeScale* might be different for different files. When using this weight we get, for each bin, the number of events per second.

CORSIKA weights Re-weighing 5-component CORSIKA

- http://wiki.icecube.wisc.edu/index.php/Weights_in_CORSIKA_Simulation_Data#5-component_CORSIKA

Simulation Production



More on simulation

1. http://wiki.icecube.wisc.edu/index.php/Simulation_Documentation_Wiki
2. http://wiki.icecube.wisc.edu/index.php/IceCuber's_Guide_to_IceSim_2.6
3. http://wiki.icecube.wisc.edu/index.php/Simulation_Production
4. http://internal.icecube.wisc.edu/simulation/datasets/dataset_category/PHYSICS
5. IRC @ irc.efnet.net: /join #icesim

On cobalt01 or cobalt02

Get IceSim:

cp /data/sim/sim-new/simulation.candidates.V03-02-04-RC.Linux-x86_64.gcc-4.4.5.tar.gz .

tar xzf simulation.candidates.V03-02-04-RC.Linux-x86_64.gcc-4.4.5.tar.gz

Replace env-she.sh:

cp /net/user/juancarlos/bootcamp/env-shell.sh simulation.candidates.V03-02-04-RC.Linux-x86_64.gcc-4.4.5/

Get scripts:

cp /net/user/juancarlos/bootcamp/*.py .