Lepton Injector/Weighter

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significant work from C.Weaver, B. Smithers, and A. Schneider
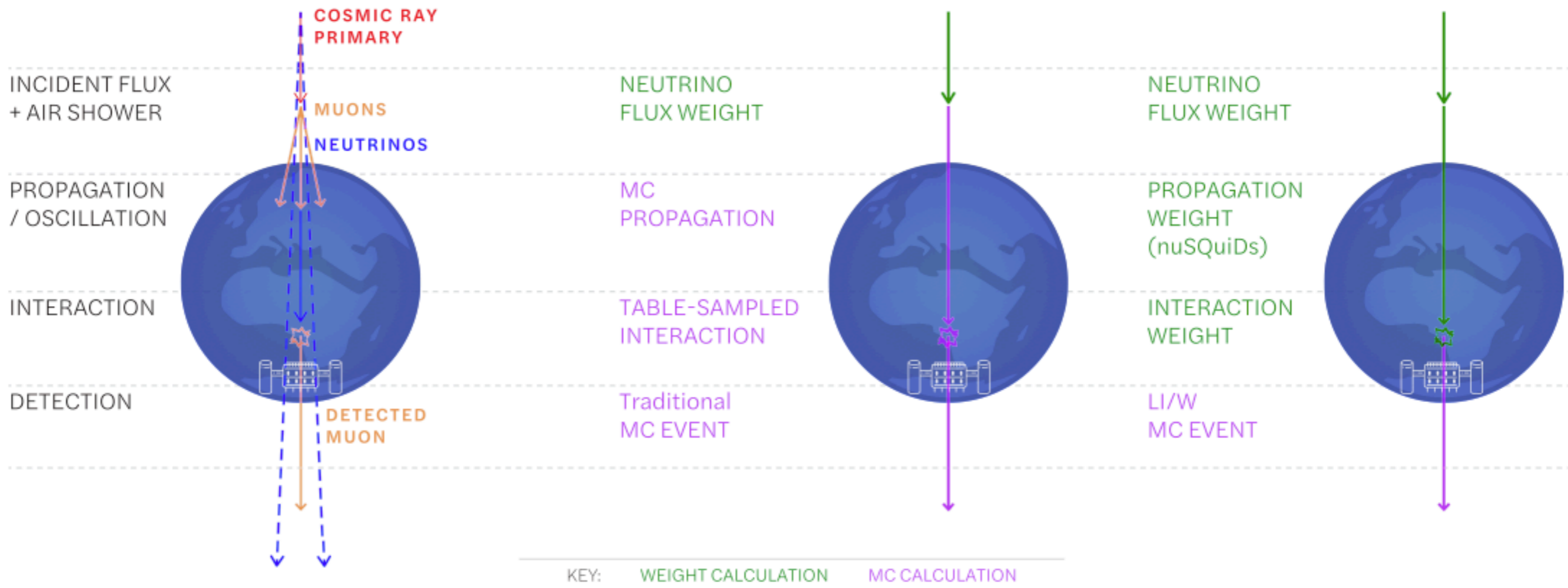
What is the objective?

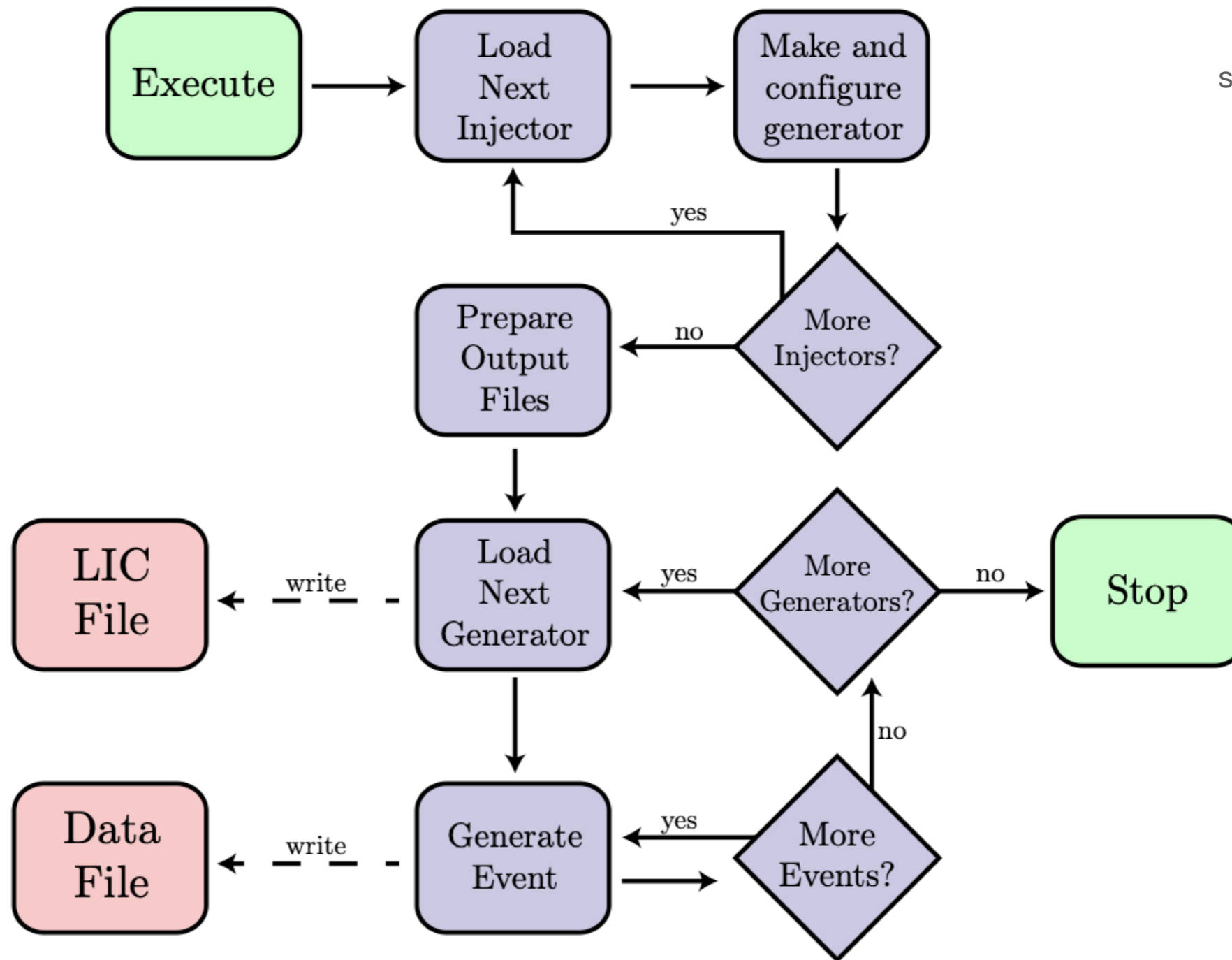Speed, accuracy, and <u>flexibility</u>

# LeptonInjector BirdEyeView

- Multiple "Injector" are allow within a single run.
- Output of each injector into a Lepton Injector Configuration (LIC) file

Injection Flowchart

1. Neutrino energy sampled from a power-law distribution.
2. For DIS interactions Bjorken-x and inelasticity (y) are sampled from the two dimensional distribution using Metropolis-Hastings. In the case of neutrino-lepton scattering the relevant y-distribution is sampled.
3. Injection mode: volume or ranged (more on this later)
4. Compute final state kinematic momenta.
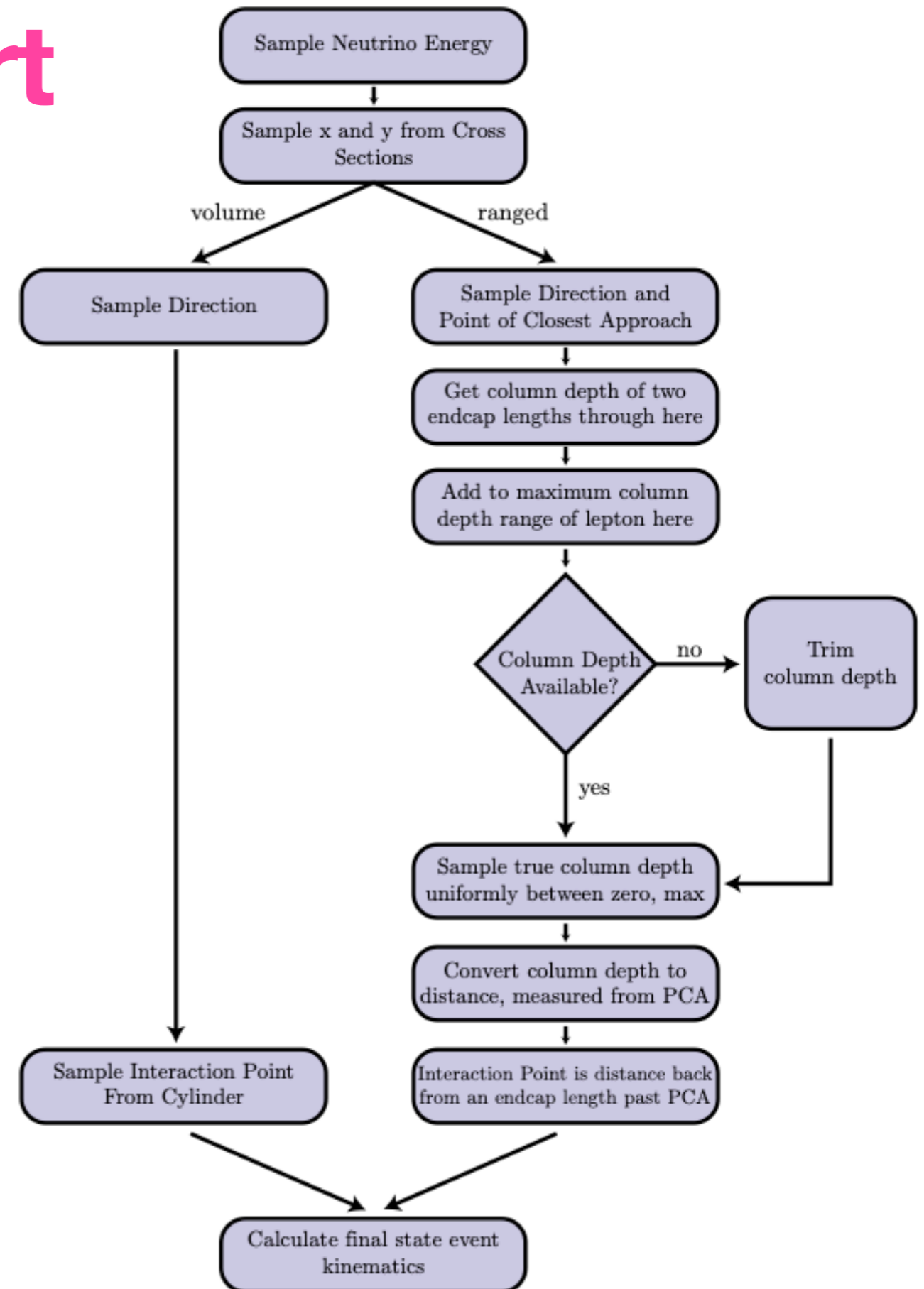
Range Injection Mode
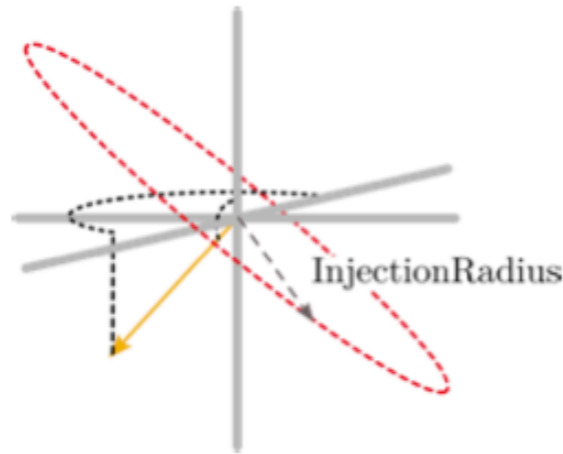
(a) A direction (orange) is chosen and a perpendicular disc of radius `InjectionRadius` (red) is constructed.
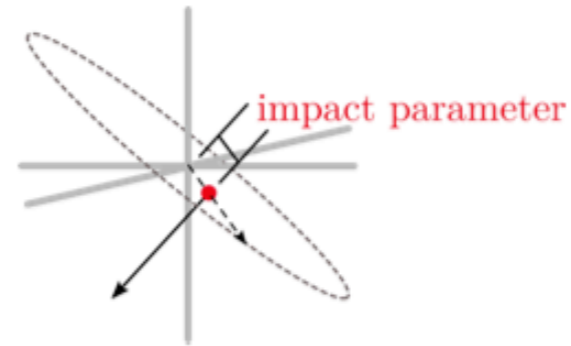
(b) A point of closest approach is randomly sampled on that `InjectionRadius` disk.
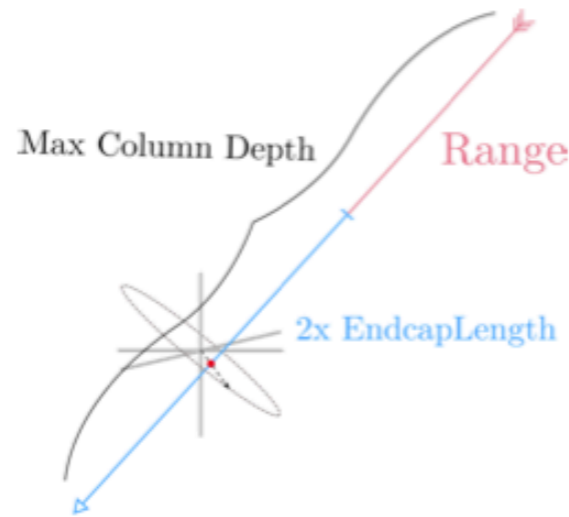
(c) Preliminary column-depth calculation of the lepton range (red) plus two `EndcapLengths` (blue)
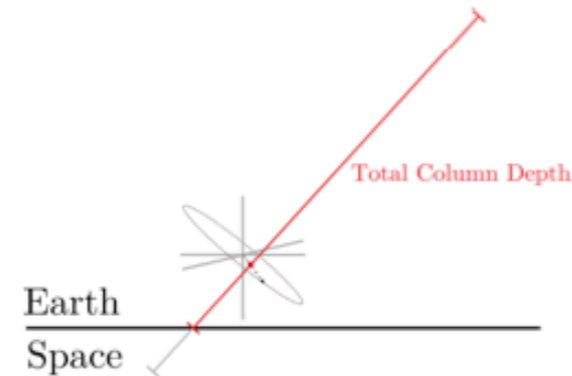
(d) If the actual column depth available is less than the column depth computed in part (c), reduce it appropriately.
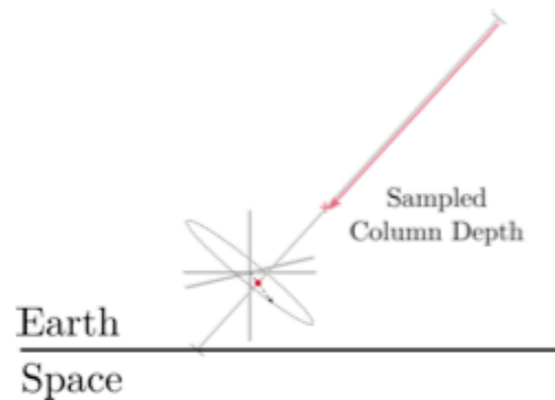
(e) Sample uniformly from the total column depth available for insertion depth.

LeptonWeighter BirdEyeView
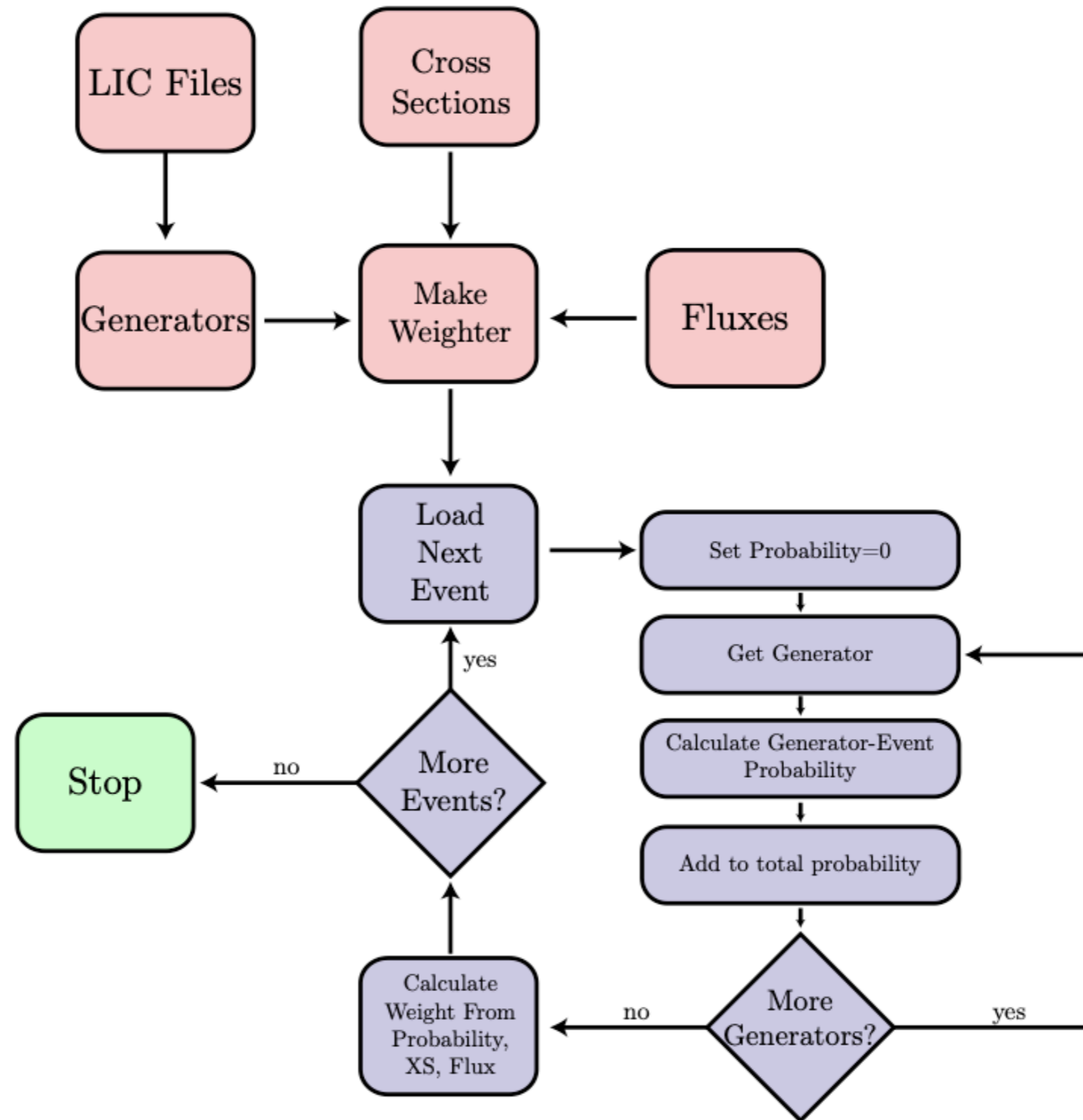
Status of the Project

- Paper draft under Software-working group review. Several iterations now.

- Two versions: stand-alone on Github and i3 on SVN.

- At generation level all relevant kinematical distributions are known to be the same as NuGen.

- At final analysis-level muon track distributions has been shown to agree with NuGen simulations. Similar checks for cascade have been less conclusive and are not complete.

- Version available in analysis-dev CVMFS for testing.

Room for improvement

- Beyond Standard Model signatures are been added on development branches. E.g., neutral-heavy leptons.

- Currently weighting Range+Volume mode simulations of the same flavor is not trivial.

- More cross section splines tables have not yet been made available.

- More user input is great!

Thanks! Gracias!

Please read the paper and provide comments if you have any!

https://wiki.icecube.wisc.edu/index.php/LeptonInjector_Paper

LeptonInjector and LeptonWeighter: A neutrino event generator and weighter for neutrino observatories

(IceCube Collaboration)

(Dated: October 19, 2020)

We present a high-energy neutrino event generator, called Lepton Injector, alongside an event weighter, called Lepton Weighter; both designed for large-volume Cherenkov neutrino telescopes such as IceCube. The neutrino event generator allows for quick and flexible simulation of neutrino events within and around the detector volume, and implements the leading standard model neutrino interaction processes relevant for neutrino observatories: neutrino-nucleon deep-inelastic scattering and neutrino-electron annihilation. In this paper, we discuss the event generation algorithm, the weighting algorithm, and the main functions of the publicly available code while providing examples.

Bonus Slides

What is in the LIC file?

- LIC file contains:
  - Which Injection Mode was used (Volume, Range, …)
  - Properties of the Injection Mode (min. energy, max. energy, power-law spectra, *etc*).
  - Generation deep Inelastic neutrino-nucleon scattering cross section (stored as a photospline spline)
- LIC files are serialized into binary file formats.
- LIC files can be deserialized by LeptonWeighter.
- LIC files can be concatenated (cat lic_little_simulation > lic_big_simulation) in order to facilitate multiple Monte Carlo weighting.

LeptonWeighter EventProperties

MC Events

properties

totalEnergy	energy of the interacting neutrino. [GeV]
Zenith	initial zenith of the lepton. [rad]
Azimuth	initial azimuth of the lepton. [rad]
finalStateX	Bjorken x of the interaction. [dimensionless]
finalStateY	Bjorken y of the interaction. [dimensionless]
finalType1	Code of first final state particle. [dimensionless]
finalType2	Code of second final state particle. [dimensionless]
initalType	Code of parent particle. [dimensionless]

Ranged/Volume Quantities

impactParameter	sampled distance from PCA to origin [cm]
totalColumnDepth	column depth where there interaction was forced. $[\mathrm{g\,cm}^{-2}]$
z	distance above the xy-plane [cm]
radius	distance from the z-axis [cm]

LeptonInjectorWeight Event flux-less weight. $[\mathrm{GeV\,cm}^2\,\mathrm{sr}]$