SIREN

An Open Source Neutrino Injection Toolkit

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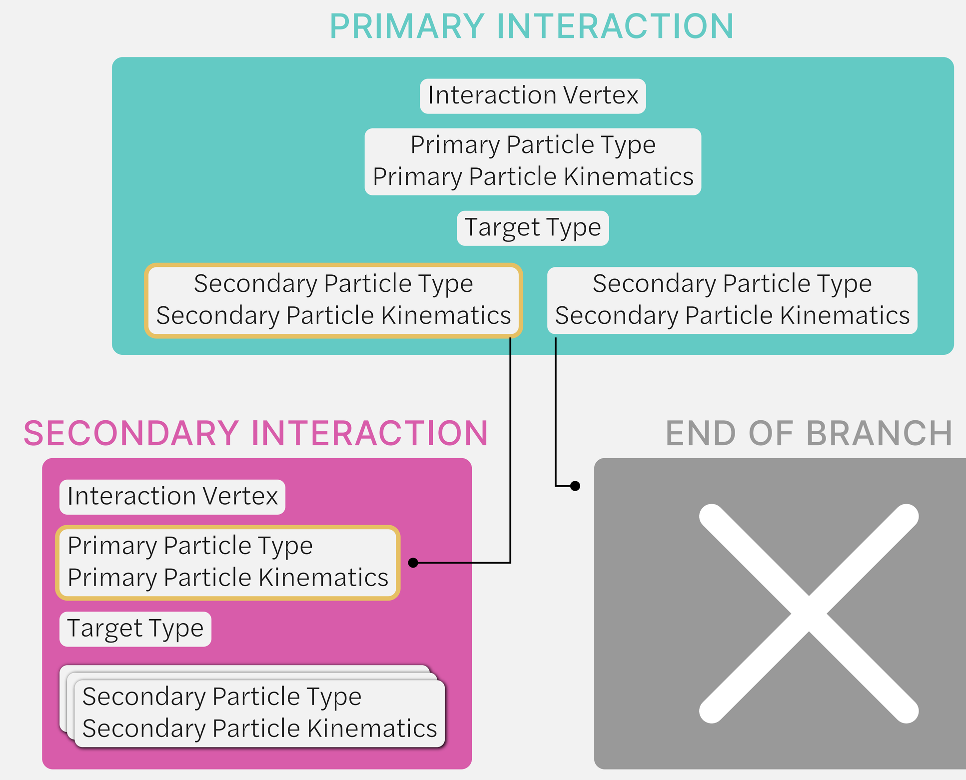
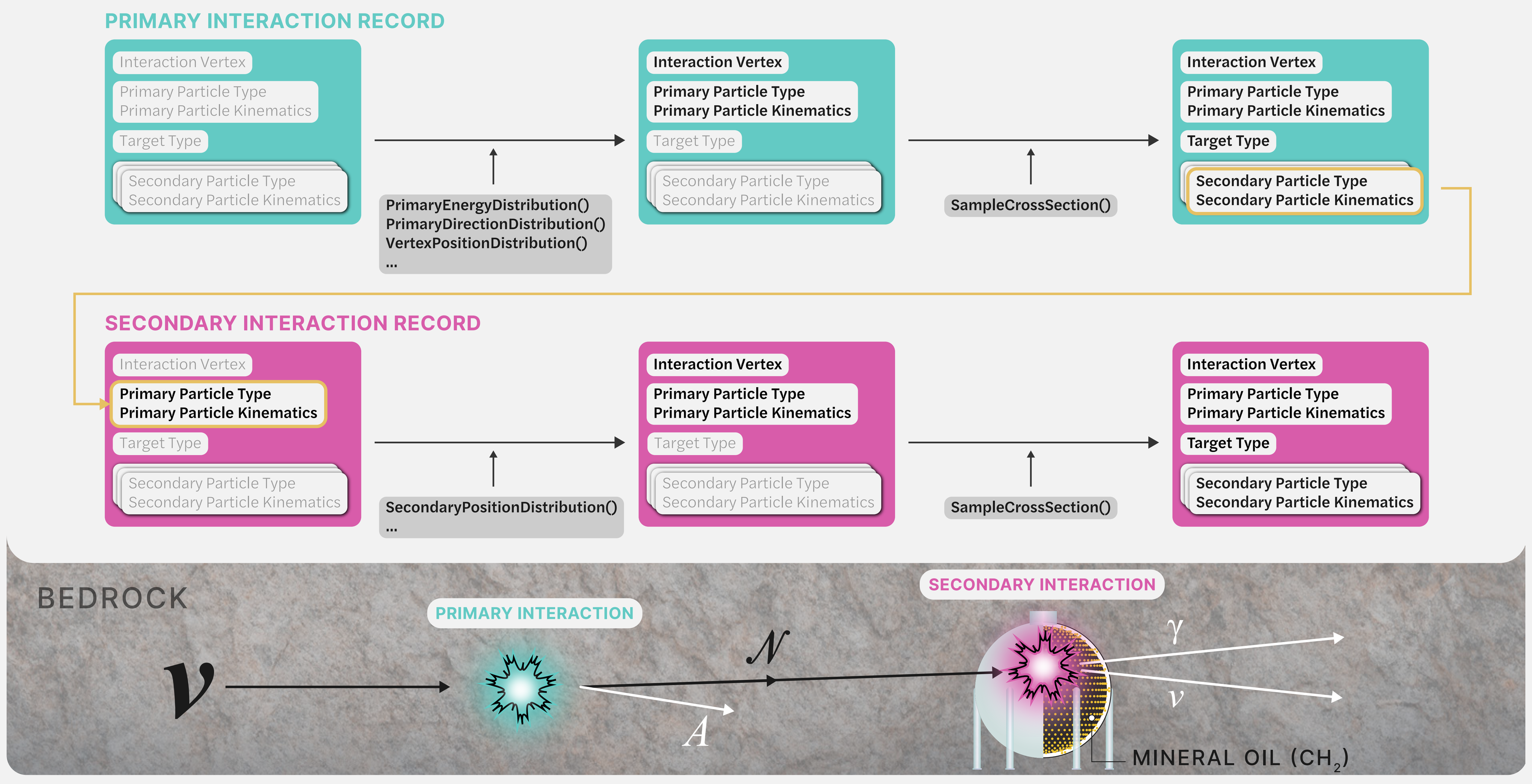
Overview

We present SIREN [1] (Sampling and Injection for Rare EveNts), a neutrino simulation toolkit for rare neutrino interactions extended significantly from LeptonInjector [2]. The unique features of SIREN include:

- **Extensible interaction service:** Support for arbitrary interaction trees of scattering $(2 \to n)$ and decay $(1 \to n)$ processes
- **Extensible detector service:** Support for complicated detector geometries based on 3D volumes with arbitrary atomic compositions and density profiles
- **Computational efficiency:** Fast methods for injection and (re-)weighting make SIREN suitable for large simulation campaigns

Interaction Tree



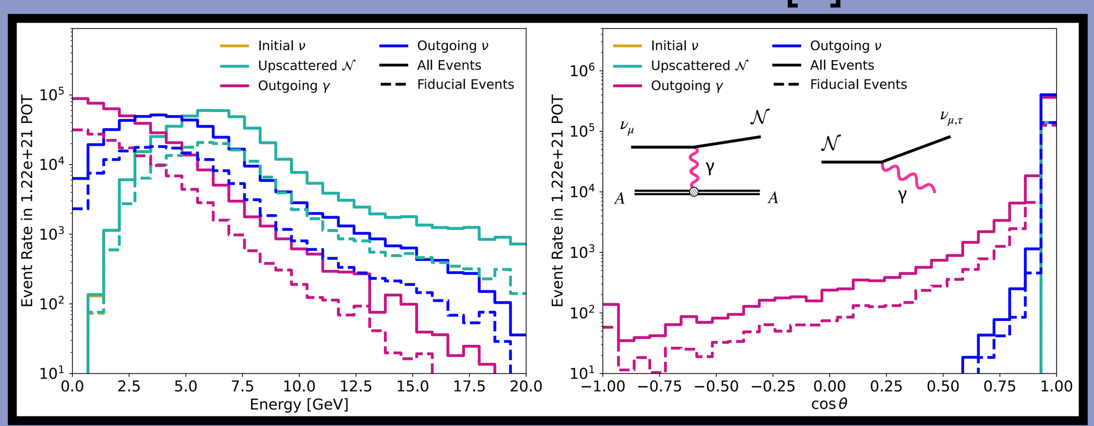


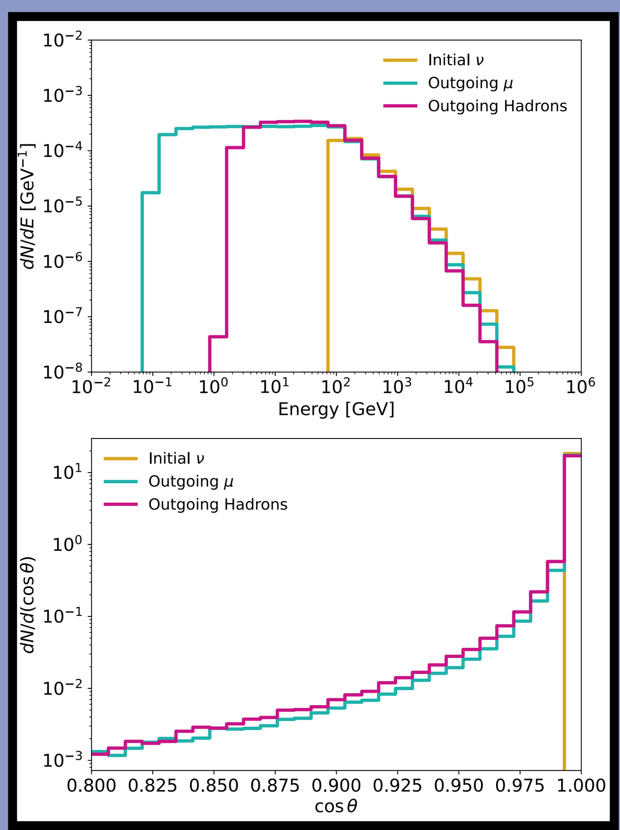
Extensible Interaction Service

Cross section and decay models are defined by specifying:

1. The possible initial and final states
2. The total and differential cross section or decay width
3. A method for determining final state kinematics

SIREN includes built-in support for ν DIS [2], $\nu - e$ elastic scattering, and several heavy neutral lepton models through a custom interface to DarkNews [3]





Top: Dipole-portal HNL kinematic distributions in MINERvA, as studied in [4]

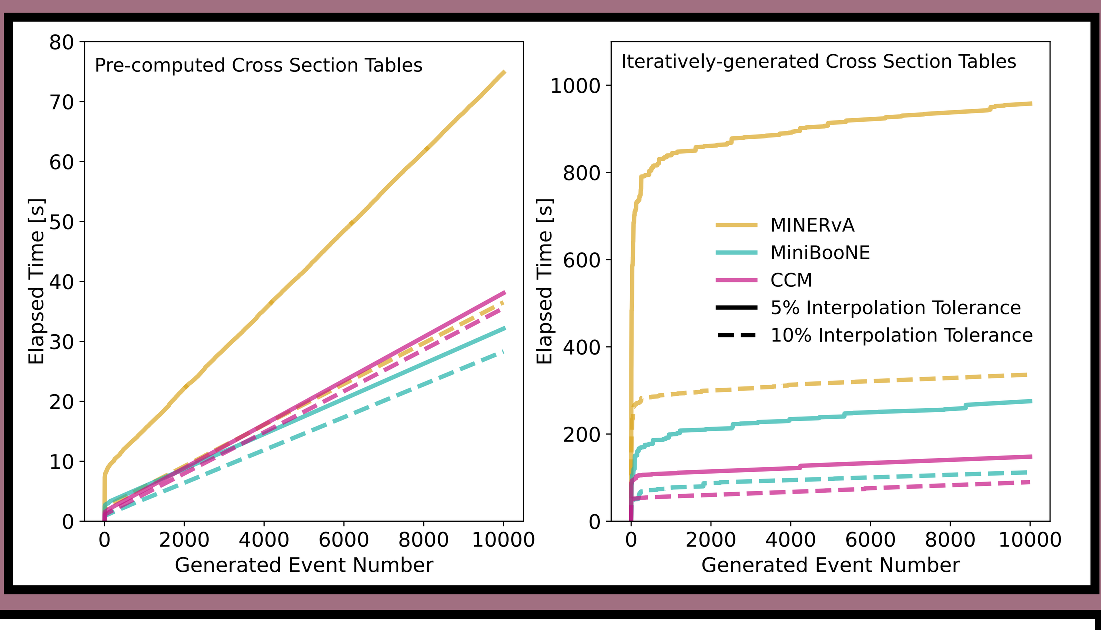
Right: ν_μ DIS kinematic distributions in ATLAS from supernova neutrinos, as studied in [5]

Computational Efficiency

SIREN can generate/re-weight $\mathcal{O}(10^3 - 10^5)$ events per second, depending on the interaction and detector models

Left: Simulation times for dipole-portal HNLs in MiniBooNE, MINERvA, and CCM via the DarkNews interface

Bottom: Elapsed time per event generation and weight calculation for the six examples in [1]



Simulation case	Generation time per event [s]	Weight calculation time per event [s]
ν_μ DIS in IceCube	$7.37^{+1.24}_{-1.31} \times 10^{-5}$	$12.83^{+1.45}_{-3.36} \times 10^{-5}$
ν_μ DIS in DUNE	$5.63^{+0.98}_{-0.76} \times 10^{-5}$	$8.63^{+1.41}_{-1.93} \times 10^{-5}$
ν_μ DIS in ATLAS	$3.74^{+0.14}_{-0.10} \times 10^{-5}$	$6.58^{+0.21}_{-0.29} \times 10^{-5}$
Dipole-portal HNLs in MiniBooNE	$2.97^{+0.04}_{-0.07} \times 10^{-3}$	$2.07^{+0.03}_{-0.25} \times 10^{-3}$
Dipole-portal HNLs in MINERvA	$4.72^{+5.93}_{-1.12} \times 10^{-3}$	$4.00^{+1.91}_{-0.42} \times 10^{-3}$
Dipole-portal HNLs in CCM	$3.83^{+0.05}_{-0.07} \times 10^{-3}$	$4.25^{+0.08}_{-0.13} \times 10^{-3}$

Get started today!

pip install siren

Extensible Detector Service

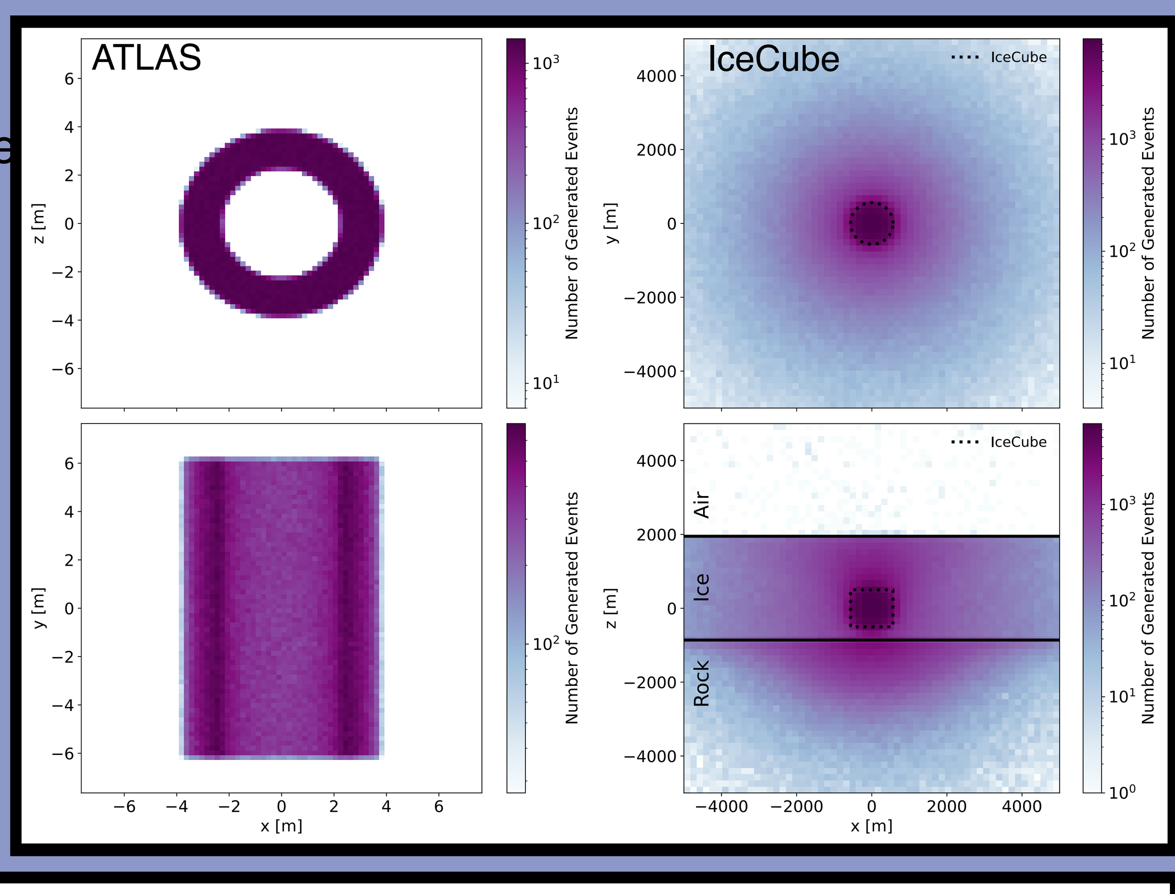
A detector model is defined through a plain text file specifying:

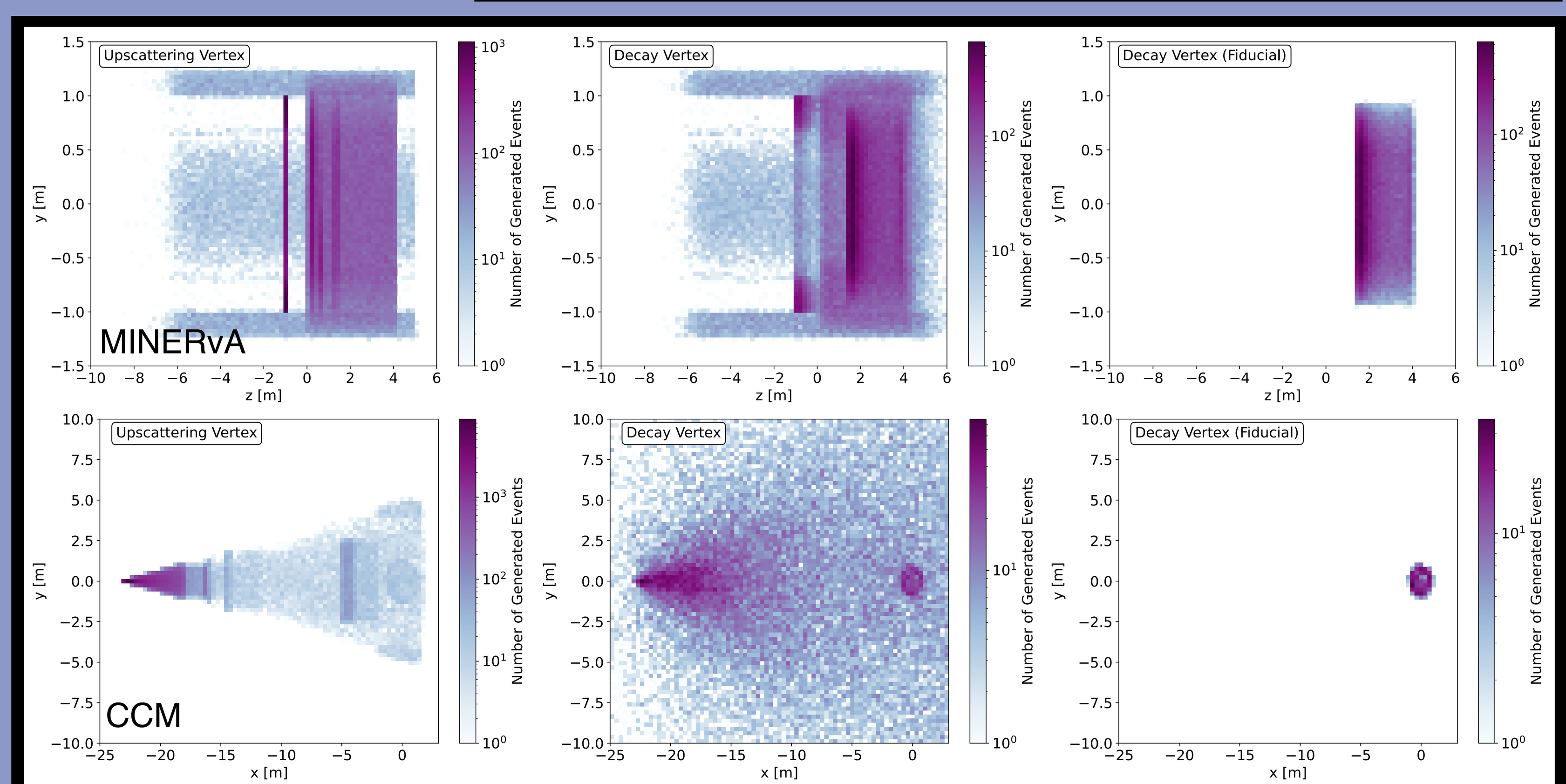
1. A set of three-dimensional objects
2. The atomic composition and density profile of each object
3. A special 3D object representing the fiducial volume (optional)

SIREN includes built-in detector models for IceCube, DUNE, ATLAS, HyperK, MiniBooNE, MINERvA, and CCM

Left: ν_μ DIS spatial distributions in IceCube and the ATLAS hadronic calorimeter, using ranged and volume injection, respectively

Bottom: Dipole-portal HNL production and decay spatial distributions in MINERvA and CCM





References

[1] A. Schneider, N. Kamp, A. Wen arXiv:2406.01745

[2] IceCube Collab. arXiv:2012.10449

[3] A. Abdullahi+ arXiv:2207.04137

[4] N. Kamp, M. Hostert, A. Schneider+ arXiv:2206.07100

[5] A. Wen+ arXiv:2309.09771

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