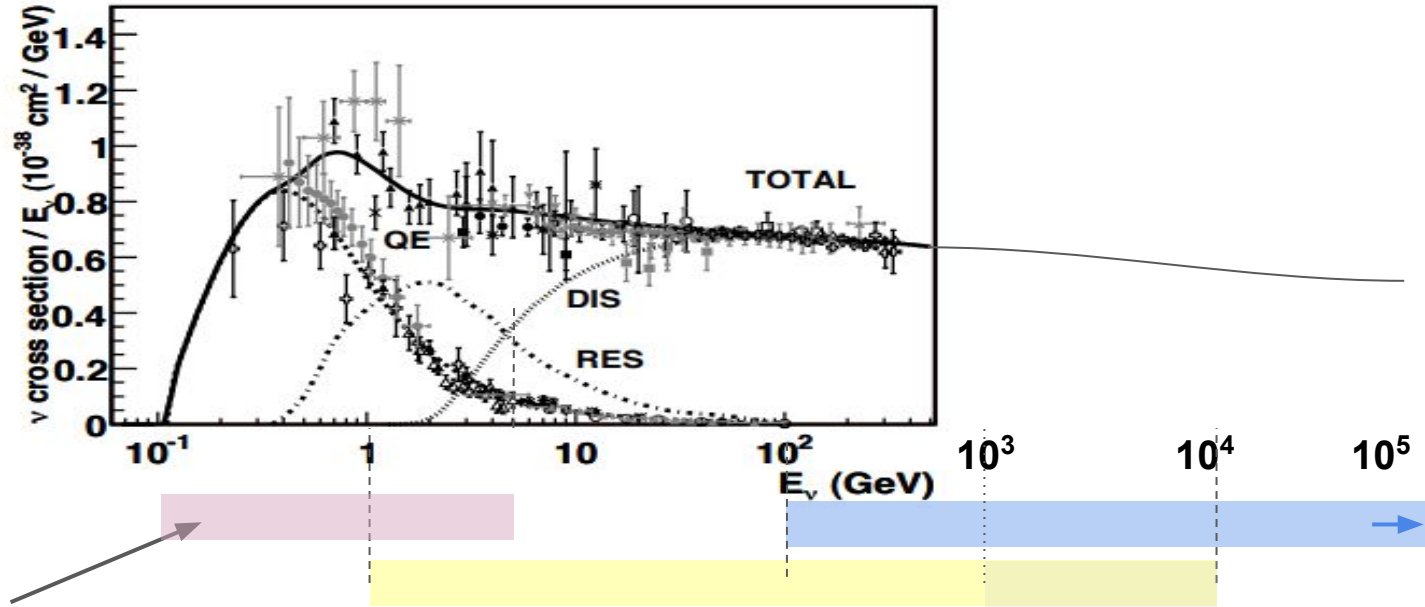


Use of GENIE in IceCube low-en simulation

Maria Liubarska, Michael Larson

April 22, 2024
Oscillation phone call

Neutrino generators in IceCube



ELOWEN (0.1-5 GeV)

GENIE

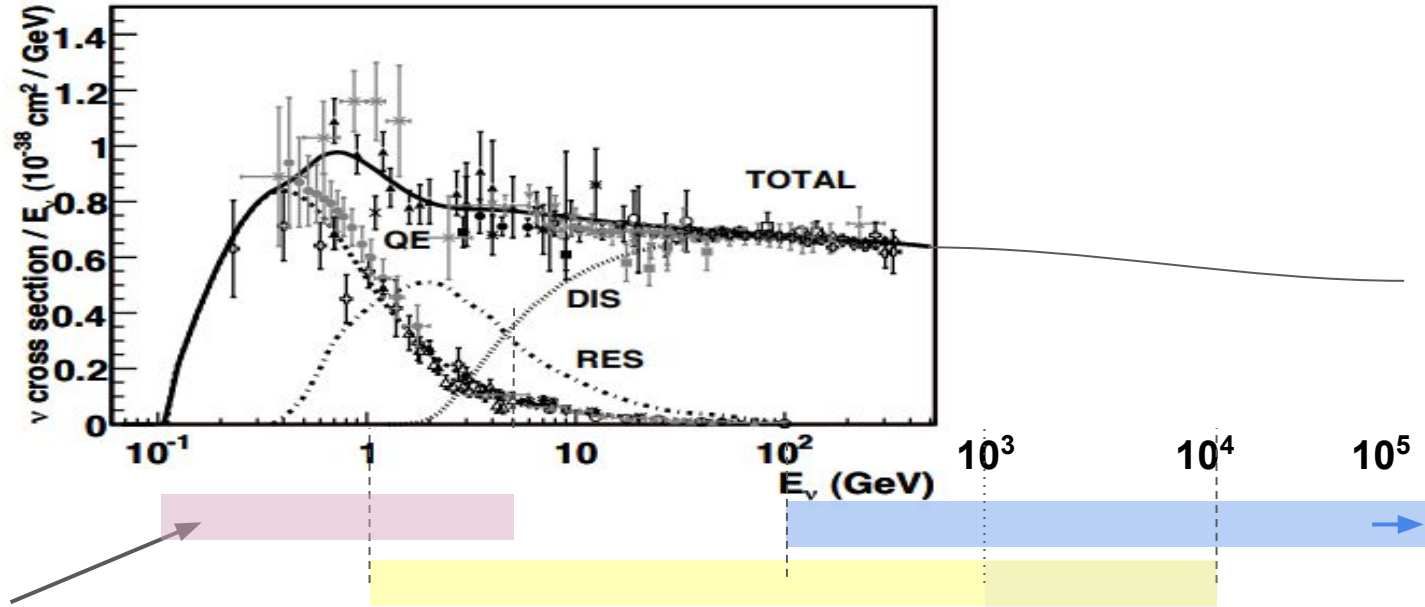
Low-Energy (DeepCore)

GENIE

Everyone else (IceCube)

NuGen, LeptonInjector

Neutrino generators in IceCube



ELOWEN (0.1-5 GeV)

GENIE

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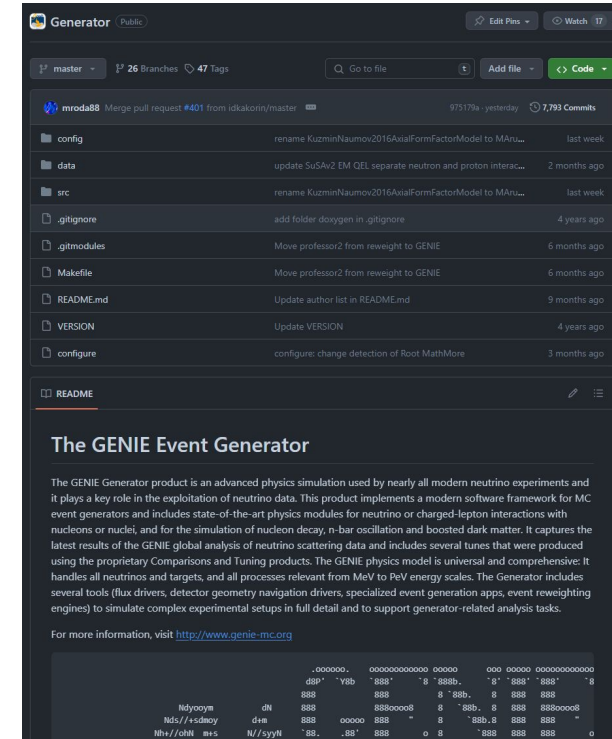
NuGen, LeptonInjector

Why are we different?

- At the time of oscNext development the only “recent” & available model covering 100 MeV - 1 TeV range is offered by GENIE
 - RES and QE events need to be modelled differently
 - For DIS at E below ~ 100 GeV low Q^2 contribution becomes important - not present in most common nu DIS xsec model (e.g. CSMS)

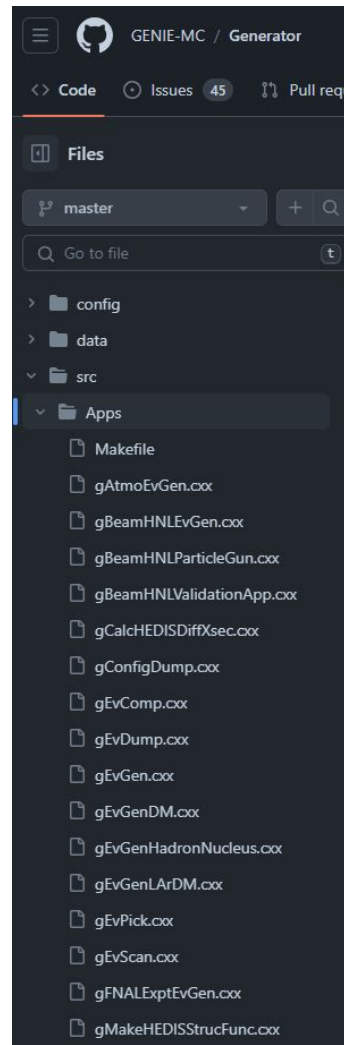
What is GENIE

- Framework for neutrino generation and event weighting
- Offers its own combined model of different neutrino interactions, which allows for ~realistic modeling of ν with $E < 100$ GeV
- Main products:
 - **Generator** - cross section calc, event generation
 - **Reweight** - systematic variations



How other experiments use GENIE

- Write a C++ application which uses GENIE library
- Requires dependencies on number of libraries
 - ROOT, pythia, LHAPDF, ...
- Experiments (at least some) have their GENIE programs maintained within GENIE Generator/Apps



How we use GENIE in IceCube

- GENIE is a standalone neutrino generator, but we don't use it this way
- We use IceTray for MC processing



genie-icetray

(oscNext,
DRAGON,
GRECO,
ELOWEN,
bsm?)

genie-reader

(Upgrade,
new filters,
future projects)

genie-icetray

- Technically a GENIE application (C++), but incorporated within IceTray module so the output can be passed to e.g. I3Writer
 - **Not supported anymore. Genie-icetray is no longer part of icetray!**
- Generates both nu and nubar in a single file
- Changed the way GENIE counts events
 - Number of events is number of thrown events, not number of successful interactions
- Had to be compiled with GENIE as dependency
 - This ties your metaproject to a specific GENIE version
 - Latest supported version is R-2.12.8
- Geometry is simulated within GENIE

<https://github.com/icecube/icetray/tree/main/genie-reader>
<https://docs.icecube.aq/icetray/main/projects/genie-reader/index.html>

genie-reader

- Partially a wrapper project running a generic GENIE generator app (gevgen)
 - No patches or new dependencies for icetray beyond uproot
- Reads events from GENIE's output root file into icetray using uproot
- Sampling event geometry inside the project (python) using fixed-size cylinder
- Able to use output files from any GENIE version without recompiling
- **NOTE: Only produces either nu or nubar for each file.**
 - Weighting is slightly different from genie-icetray!

Event weighting differences

https://docs.icecube.aq/icetray/main/projects/genie-reader/event_weighting.html

- genie-icetray:

```
frac = 0.7 if is_nu else 0.3
```

```
nevents = len(files)*frame["I3MCWeightDict"]["nevents"] * frac
```

- genie-reader

```
for file in files:
```

```
    nevents += sframe['I3GenieInfo'].n_flux_events
```

- genie-reader weighting supported by [simweights](#)!

Charm bug

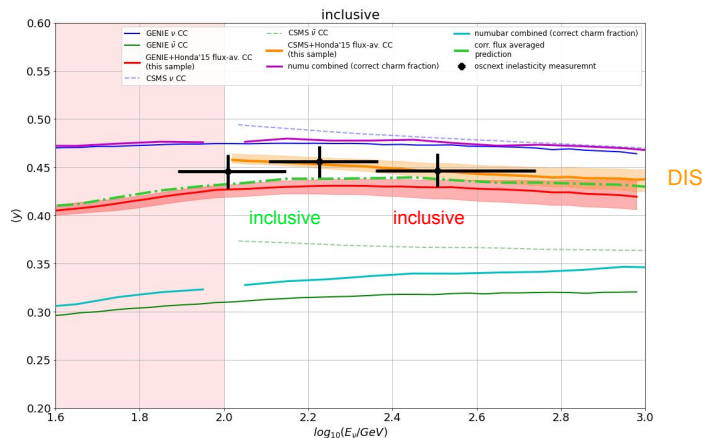
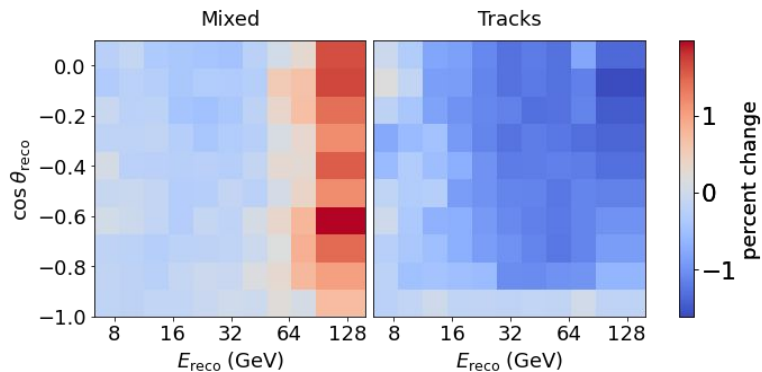
Impact on VS numu disappearance:

https://docs.google.com/presentation/d/1dlpgPSUxYREKclUagTyEEuYtDLBv2i6QK_KVDc_PVBM/edit?usp=sharing

Why genie-reader simulation **will** look different:

- GENIE v2 has a bug which makes most charm events to be thrown out unless they are strictly upgoing in lab frame (fixed in v3)
- Modifies inelasticity distribution at high energy side, but not total xsec
- **Does not** affect genie-reader simulation for **any** GENIE version since we sample event geometry ourselves

Charm bug correction (VS)



How to use genie-reader

- Documentation:
<https://docs.iccube.aq/icecube/main/projects/genie-reader/index.html>
- Main script to run oscNext-style simulation:
https://github.com/iccube/icecube/blob/main/genie-reader/resources/scripts/step1_genie.py

genie-reader

The goal of this project is to convert Monte-Carlo simulation from GENIE to IceCube. The project relies on GENIE generic command-line tools. Because it is a wrapper, Example step1 production scripts are provided in [resources/scripts/](#).

- [Release Notes](#)

For more information on genie-reader see:

- [Dependencies](#)
 - [uproot4](#)
 - [GENIE Generator and GENIE Reweight](#)
 - [PROPOSAL](#)
- [I3GenieReaderSegment](#)
 - [Example usage](#)
 - [Signature](#)
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 - [Number of events vs. Number of flux events](#)
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For information on GENIE see:

- [GENIE cross section splines](#)
- [GENIE on CVMFS](#)
- [GENIE installation instructions](#)

Known external issues that might affect generation:

- [Known external issues](#)

Step1_genie.py subprocess env arguments (old style)

-env-workdir ENV_WORKDIR (default: `'/cvmfs/icecube.opensciencegrid.org/users/mliubarska/py2-v3.1.1/GENIE/R-2_12_8'`)

WORKDIR enviromental variable for generation

-env-log4cpp ENV_LOG4CPP (default: `''`)

LOG4CPP enviromental variable for generation

-env-rootsys ENV_ROOTSYS (default:

`'/cvmfs/icecube.opensciencegrid.org/users/mliubarska/py2-v3.1.1/ROOT/build-6.09.02'`)

ROOTSYS enviromental variable for generation

-env-pythia ENV_PYTHIA (default: `'/cvmfs/icecube.opensciencegrid.org/py2-v3.1.1/RHEL_7_x86_64/lib'`)

PYTHIA6 enviromental variable for generation

-env-lhapdf ENV_LHAPDF (default: `'/cvmfs/icecube.opensciencegrid.org/py2-v3.1.1/RHEL_7_x86_64/lib'`)

LHAPDF enviromental variable for generation

-env-lhapath ENV_LHAPATH (default: `''`)

LHAPATH enviromental variable for generation (path to PDFs)

This was simplified by Michael in genie3 branch!

Using GENIE 3 with genie reader

1. Provide corresponding environment variables to subprocess
 - Environment where GENIE was compiled
 - No need to be in the same environment when running the script
2. Provide cross section splines for your build and tune (!!!)
 - Non version independent!
3. Use normal arguments to setup zenith, energy ranges, etc.

Simplified GENIE installation instructions available (v2020):

https://docs.icecube.aq/icetray/main/projects/genie-reader/genie_install_instructions.html

<https://www.overleaf.com/read/ypgqrtssmnxp>

genie3 branch

- Intended to simplify usage before upgrading to GENIE v3.4.2 or v3.6.0
- Configure environment variables for GENIE by passing in shell script
 - Previously needed to include every variable as command line argument
- Added “verbose” option to see GENIE’s printout for debugging
- Updates the MCTree generation with parent/daughter relationships
 - Previously got a flat MCTree with all particles under the neutrino
- Introduced an “override” folder to change underlying physics
 - Added so that we can enable additional particle decays, but may be broadly useful for testing

Questions?

Have a question about IceCube GENIE simulation?

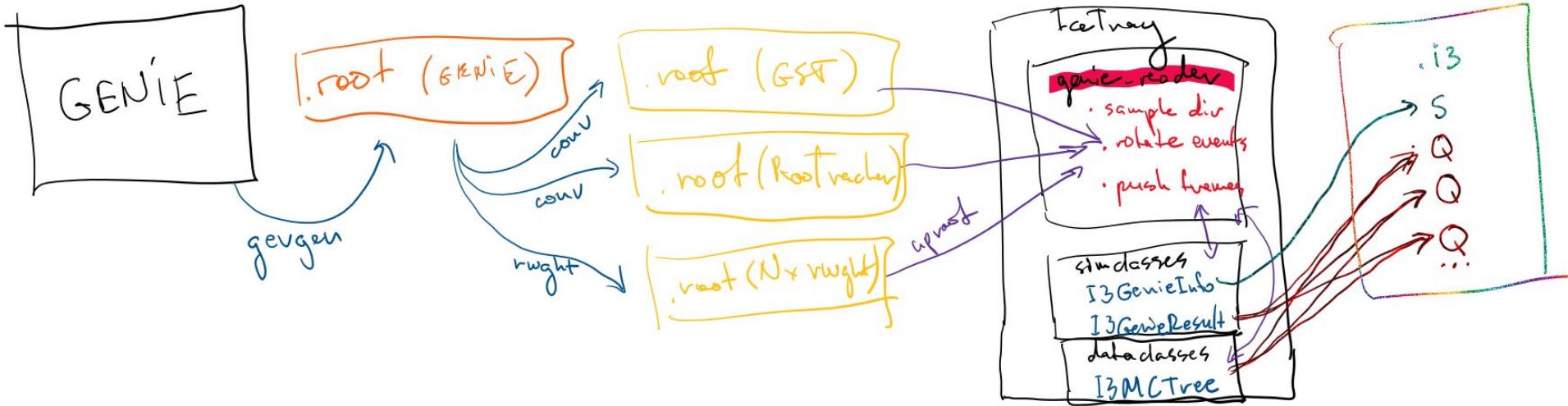
- Please post your questions to #le-osc channel on slack

Backup

History - how we got here

- LE sim used to run older versions via genie-icetray
 - The most recent used version is **GENIE 2.12.8** (our current default, used in oscNext)
 - Hard to maintain, icetray project tied to GENIE version
 - Was annoying to build project not with CVMFS GENIE - had to tweak cmake files to make it work
- Software group decided to stop maintaining GENIE installation and genie-icetray after py2-3.1.1 (spring 2020)
 - It is Osc WG responsibility to maintain GENIE and it's dependencies
- After consultation with Osc and Software WGs decided to move to a wrapper project to run GENIE outside of icetray
 - Similar to corsika-reader
 - No dependence on GENIE or ROOT, can work with any GENIE version, GENIE can be compiled in different environment then icetray
 - Genie simulation from gevgen can be used has to be altered and weights have to be updated to produce realistic neutrino simulation
- Latest stable GENIE release: **3.4.0**

genie-reader : current setup & use



- `genie-reader` can work with any GENIE version (at least after 2.12.8)
 - The `icetray` module is only reading standard GENIE output files
 - It is up to user to run GENIE and make sure right corresponding files are fed in (!)

Present issues

- Sampling issue (workaround in upgrade and main, [#3354](#))
- We are using GENIE above recommended energy
 - Not much we can do
- Modelling - known discrepancies in nubar between Bodek&Yang and other models (see recent Alfonso et al. paper, DIS syst report)
 - We can introduce systematics to account for the range of predictions from available models
 - Wait for new updated B&Y... Newly retuned in 2020, so maybe fixed in GENIE 3?

Common questions & past issues

- **Check out the documentation!**

- compiled documentation included in the current icetray docs reference:
<https://docs.iccube.aq/icetray/main/projects/genie-reader/index.html>

- **genie-reader lives in icetray main branch**

- Also exists in icetray_upgarde
- If you want to contribute please submit a PR to main (or open an issue if you want other people to look at the problem)

- **Weighting & number of events per file in genie-reader sim was different from genie-icetray until PR [#3400](#)**

- **Scripts in resources dir are **example scripts****

genie-reader

The goal of this project is to convert Monte-Carlo simulation from GENIE to IceTray format without interfering with GENIE classes. Two IceTray modules and segment which combines them are available.

The project relies on GENIE generic command-line tools. Because it is only possible to use them with a single-point geometry, interaction positions and primary neutrino directions are sampled in the cylindric volume, aligned with the new neutrino direction.

Example step1 production scripts are provided in [resources/scripts/](#). These scripts are based on [oscNext_step1 scripts](#) and should produce equivalent output.

- [Release Notes](#)

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