The GENIE event library generator interface

New Directions in Neutrino-Nucleus Scattering

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Introduction ᴜᴄᴸ

- ▶ Aim to give experimenters easy access to interactions from multiple generators, respecting full flux, geometry, and det sim
  - ▶ Trivially overlay properly forwards-folded generator predictions on cross-section measurements
  - ▶ Evaluate bias of oscillation analysis when confronted with fake data from an alternate generator

- ▶ **Workshop on common neutrino event generator tools**[1]
  "Experimenters generally do not have the resources to simulate events in all generators."
- ▶ GENIE has sophisticated flux driver and ROOT geometry interface
- ▶ Standard tool for many experiments: LAr expts, NOvA, T2K ND...
- ▶ From technical POV, ideal to have alternate physics available via GENIE config – no other changes to experiment software required
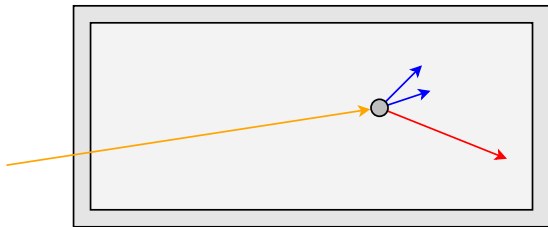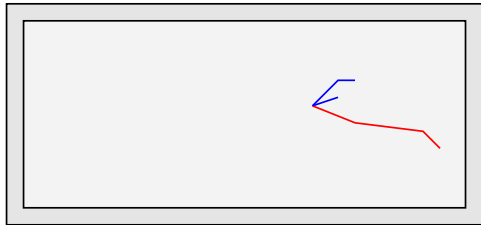
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[1]arXiv:2008.06566
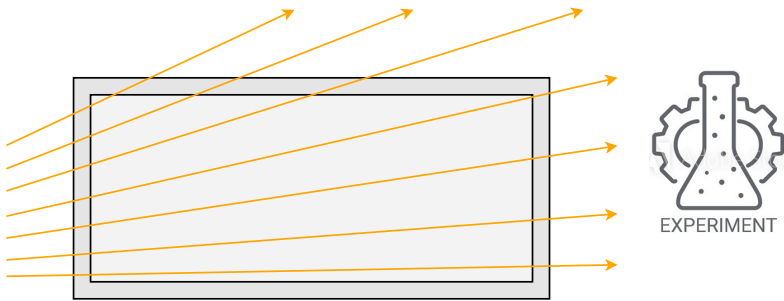
1 Experiment provides geometry description and flux ($\sim$ set of rays)
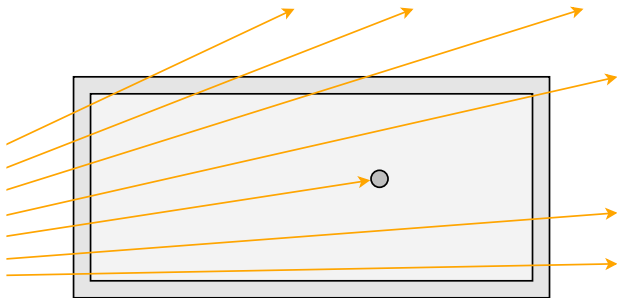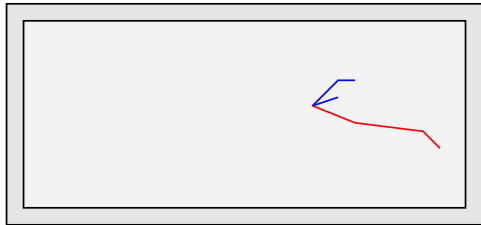
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GENIE sampling

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2 GENIE picks a target based on integrated matter density along ray and total interaction cross-sections

3 GENIE interaction physics produces final state 4-vectors

4 Experiment-specific software propagates particles (GEANT) and simulates detector response

1. Experiment provides geometry description and flux ($\sim$ set of rays)
2. GENIE picks a target based on integrated matter density along ray and total interaction cross-sections
3. GENIE interaction physics produces final state 4-vectors
4. Experiment-specific software propagates particles (GEANT) and simulates detector response

▶ **2** is technically very valuable but is "just" maths. All the detailed interaction physics is in **3**

Event replacement

► One approach: allow GENIE to simulate events within the experiments' framework, as usual, then later replace the 4-vectors

Original GENIE simulation
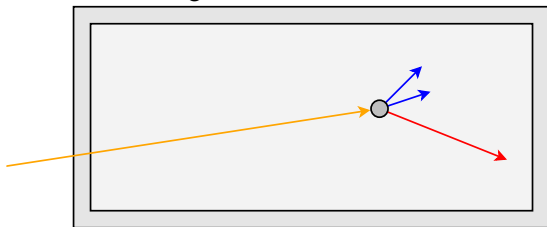
Event replacement

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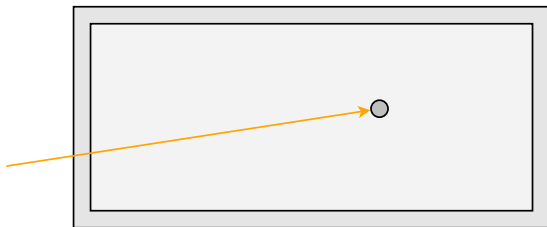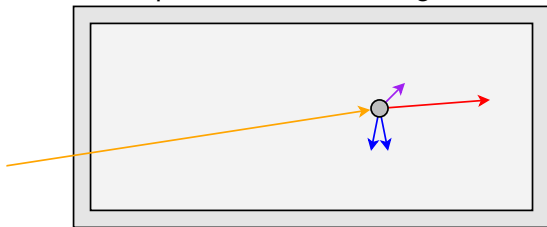
Discard GENIE 4-vectors

Event replacement

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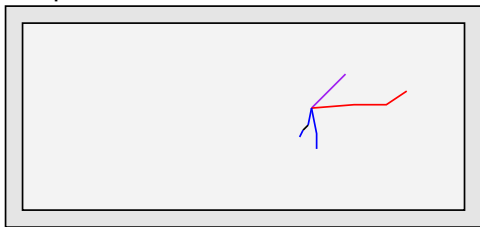
Replace with alternate generator

▶ For each GENIE event, simulate a replacement with the same neutrino energy and flavour, on the same target nucleus

Event replacement ▪UCL

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Repeat GEANT and detector simulation

▶ For each GENIE event, simulate a replacement with the same neutrino energy and flavour, on the same target nucleus

Event replacement 🏛**UCL**

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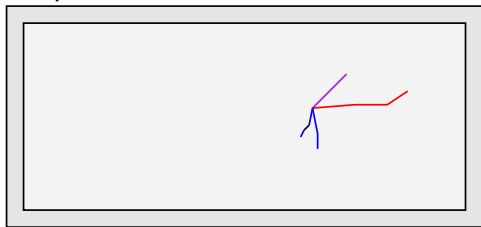
Repeat GEANT and detector simulation

▶ For each GENIE event, simulate a replacement with the same neutrino energy and flavour, on the same target nucleus
▶ Result will be sampled correctly for the detailed flux and geometry and the **GENIE** total cross-section
▶ Requires weights $\sigma_{\text{altgen}}/\sigma_{\text{genie}}$ to retrieve correct distributions

- ▶ Where do the substituted events come from?

- ▶ Ideally one would call simple functions exported by generators
- ▶ No such interface currently exists
- ▶ Would need to understand internals of each generator and implement seperately

- ▶ Pre-generate a library of events in a simple format
- ▶ Something that can be done for all generators
- ▶ Run the generator executable (the supported interface) and convert output files to event library format

In practice

▶ Sucessfully implemented that scheme within NOvA code
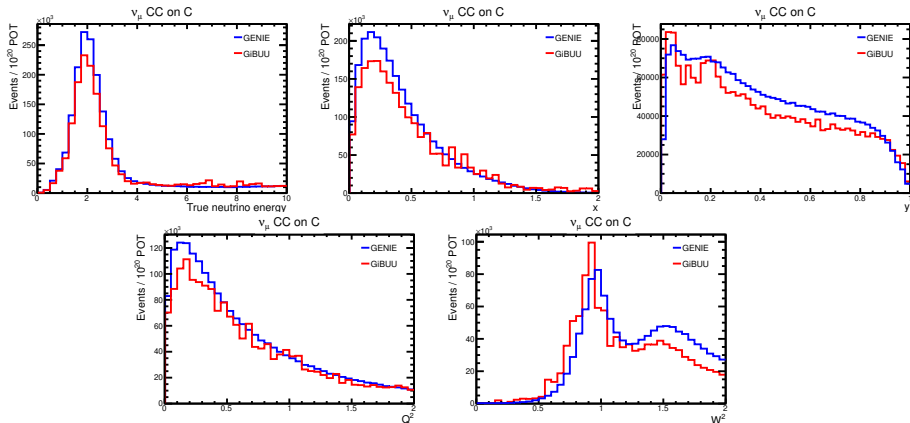
GENIE v2.12, GiBUU v2016, previous iteration of NOvA flux and geometry

- Weighted events are not ideal
- Only need to replace GENIE's total cross-section splines with alternate generator's xsec to sample correctly

- Experiment-specific code not ideal
- Can we teach GENIE to read the simple library format?

IF YOU WANT TO GO
FAST
GO ALONE.
IF YOU WANT TO GO
FAR
GO TOGETHER.
-AFRICAN PROVERB-

EvtLib

▲UCL

- ▶ Wrote new **EvtLib** tool – accepted into GENIE
- ▶ Will be released as part of GENIE v3.2.0

- ▶ Substitutes GENIE xsec splines with values read from evtlib file
- ▶ For every event sampled – pick event from library for the appropriate neutrino and nucleus having the closest E_ν

- ▶ Accessible in GENIE as a "tune" – EX00_00a_00_000

- ▶ Event kinematics filled in from simple invariant expressions
- ▶ Repeated events (expected due to birthday paradox) mitigated by randomly rotating around neutrino axis before outputting

As easy as 1, 2, 3   ♠UCL

1 Specify event library path in $GENIE/config/EvtLibPXSec.xml
and $GENIE/config/EventLibraryInterface.xml
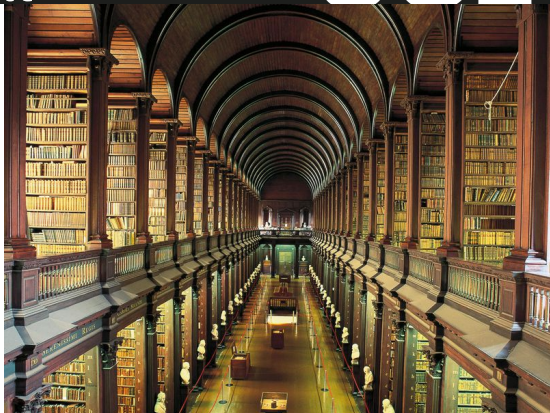
2 Extract splines (for ν_μ on ^{12}C)

```
$ gmkspl -p 14 -t 1000060120 -o evtlibxsec.xml \
  --tune EX00_00a_00_000
```

3 Generate events! (for ν_μ on ^{12}C, flat flux 1-3 GeV)

```
$ gevgen -e 1,3 -f 1 -p 14 -t 1000060120 \
  --tune EX00_00a_00_000 --cross-sections evtlibxsec.xml
```

Library format   UCL

- ▶ Library is formatted as a simple ROOT file
  - ▶ Easy to generate
  - ▶ Space efficient
- ▶ Fully documented in the GENIE manual

- ▶ Directories for each combination of neutrino flavour and target nucleus containing:
  - ▶ `TGraph` with total cross-section in this channel
  - ▶ `TTree` with pdg codes and 4-vectors for final state particles
- ▶ Library of NOvA-appropriate events is approx 100MB / 10^6 events

Future directions   ▲UCL

- ▶ Try it out for real when v3.2.0 comes out!

- ▶ Simple scripts to generators to convert native output formats to library format
    - ▶ Or even patches to add evtlib as a supported output format?

- ▶ In a future version, provide a way to attach arbitrary metadata to events, *e.g.* sufficient info to enable NEUT systematic weights

- ▶ Potentially provide a more general tool that calls out to user-supplied functions to get appropriate 4-vectors
    - ▶ EvtLib tool would become a special case of that

- ▶ [Your ideas here]