

Simulation of Nucleon Decays

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Nucleon decay in GENIE

- There is a nucleon decay generator in GENIE:
 - gevgen_ndcy - A GENIE-based nucleon decay event generation application.
 - The primary decay is simulated using a phase-space-decay generator. For bound nucleons, the nuclear environment is simulated as in neutrino scattering. The nucleon is assigned a Fermi momentum and removal energy and it is off the mass shell. The propagation of decay products is simulated using an intranuclear cascade Monte Carlo.

- **11 modes supported**

ID	Decay channel	Current limit ($\times 10^{34}$ yrs)
0	$p \rightarrow e^+ \pi^0$	1.3
1	$p \rightarrow \mu^+ \pi^0$	1.1
2	$p \rightarrow e^+ \eta^0$	0.42
3	$p \rightarrow \mu^+ \eta^0$	0.13
4	$p \rightarrow e^+ \rho^0$	0.07
5	$p \rightarrow \mu^+ \rho^0$	0.02
6	$p \rightarrow e^+ \omega^0$	0.03
7	$p \rightarrow \mu^+ \omega^0$	0.08
8	$n \rightarrow e^+ \pi^-$	0.2
9	$n \rightarrow \mu^+ \pi^-$	0.1
10	$p \rightarrow \bar{\nu} K^+$	0.4

Existing LArSoft Module

- **larsim/EventGenerator/NDKGen_module.cc**
 - Written by Eric Church
 - Takes the output from gevgen_ndcy (text output, not genie event record), converts truth information to MCTruth, randomly distributes decay position inside the TPC active volume.
 - Original position distribution was Gaussian, which was recently changed to uniform distribution.
- **It has been widely used by people working on MicroBooNE and DUNE to do proton decay studies.**
- **It is difficult to include it in the standard production because it requires running standalone GENIE application.**
- **One solution is to convert the GENIE nucleon decay application to a larsoft module (just like GENIEHelper for neutrino simulation).**

New Module

- **I converted the GENIE nucleon decay application to a larsoft module.**
 - The GENIE application is `${GENIE}/src/support/ndcy/EvGen/gNucleonDecayEvGen.cxx`
 - The larsoft module is `larsim/EventGenerator/GENIE/NucleonDecay_module.cc`
 - One fcl parameter to specify the decay mode - “DecayMode”.
 - Only simulate nucleon decay in Ar nucleus.
 - Call functions in GENIE to do simulation.
 - Convert GENIE record to MCTruth.
 - Distribute decay position randomly inside TPC active volume.
 - Output file can be passed to the next standard g4 simulation.
- **I got a lot of help from Robert Hatcher**
 - List of GENIE libraries in `CMakeLists.txt`
 - It is important to start GENIE Messenger even if you never need it.

FHiCL File

- **Example fcl file prodndk.fcl to do nucleon decay simulation in the DUNE 1x2x6 geometry.**
- **Can be modified to do simulation in MicroBooNE by changing the service.**
- **Everything is committed. Feel free to try it. Let me know if there are problems.**