Event Generation in LArSoft

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Introduction

- The purpose of this talk is to teach you how to generate single particles, neutrinos and cosmic rays with LArSoft.
- The majority of this talk is intended for those that have never used larsoft before.
- Supplementary material can be found at:
  - http://www.nevis.columbia.edu/twiki/bin/view/LArSoft/WebHome
  - http://www.genie-mc.org
    - http://hepunx.rl.ac.uk/~candreop/generators/GENIE/manuals/GENIE_UserManual_20091012.pdf
  - http://nucear.llnl.gov/simlation/cry.pdf
  - MicroBooNE docDB #80v2 "GENIE and Nuance for ArgoNeuT tech note"

Event generation in GENIE

- Event generators provide neutrino interaction products (post-FSI) as they leave the nucleus. On an event-by-event basis, GENIE takes only three inputs: neutrino 4-momentum, flavor, and interaction medium.
  - GENIE knows about detector geometry and can simulate neutrino interactions on all parts of the detector.
- GENIE takes this information and simulates the primary (neutrino-nucleus/nucleon) interaction. The products of this interaction are then propagated through the nucleus. The output file provides information about the pre- and post-FSI products and the neutrino itself. This information can then be passed on to Geant4, etc to be propagated through the detector medium.
- It is worth noting (especially for xsec enthusiasts) that GENIE can also simulate (non-neutrino) hadron-nucleon/nucleus and electron-nucleon/nucleus interactions.

Generating a neutrino event with GENIE

```
ana -x argoneut.xml -x prodgeniesim.xml -n 2 -i /dev/null/000/000/000 -o myoutputfile.root
```

Detector

Job control file

# of events to generate

Input file

Output file name

Executable

The more user-specific job control comes from the xml files rather than the command line

Neutrino generator job control file (genie.xml)

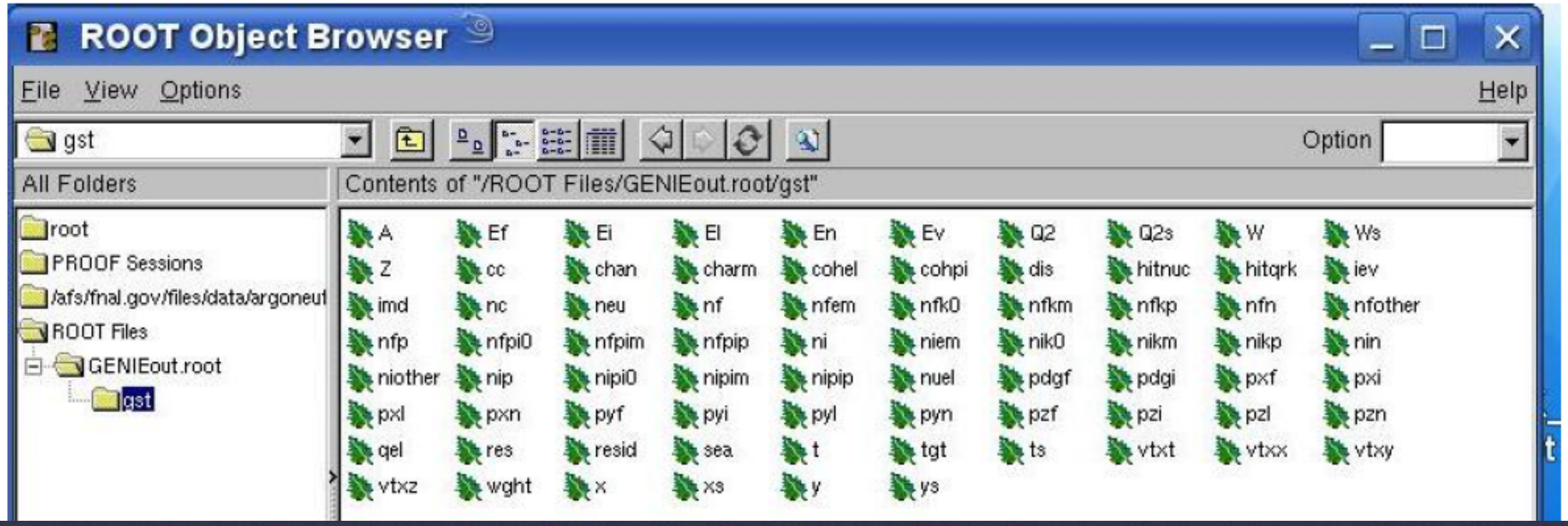
- POT per spill generated
- events per spill generated
- name/location of detector
- name of file containing fluxes
- radius of cylinder used for histogram flux mode
- location of beam center in xyz used for histogram flux mode
- direction of beam used for histogram flux mode

LArSoft invokes the GENIE program to generate neutrinos

Neutrino generator physics control file $GENIE/config/UserPhysicsOptions.xml

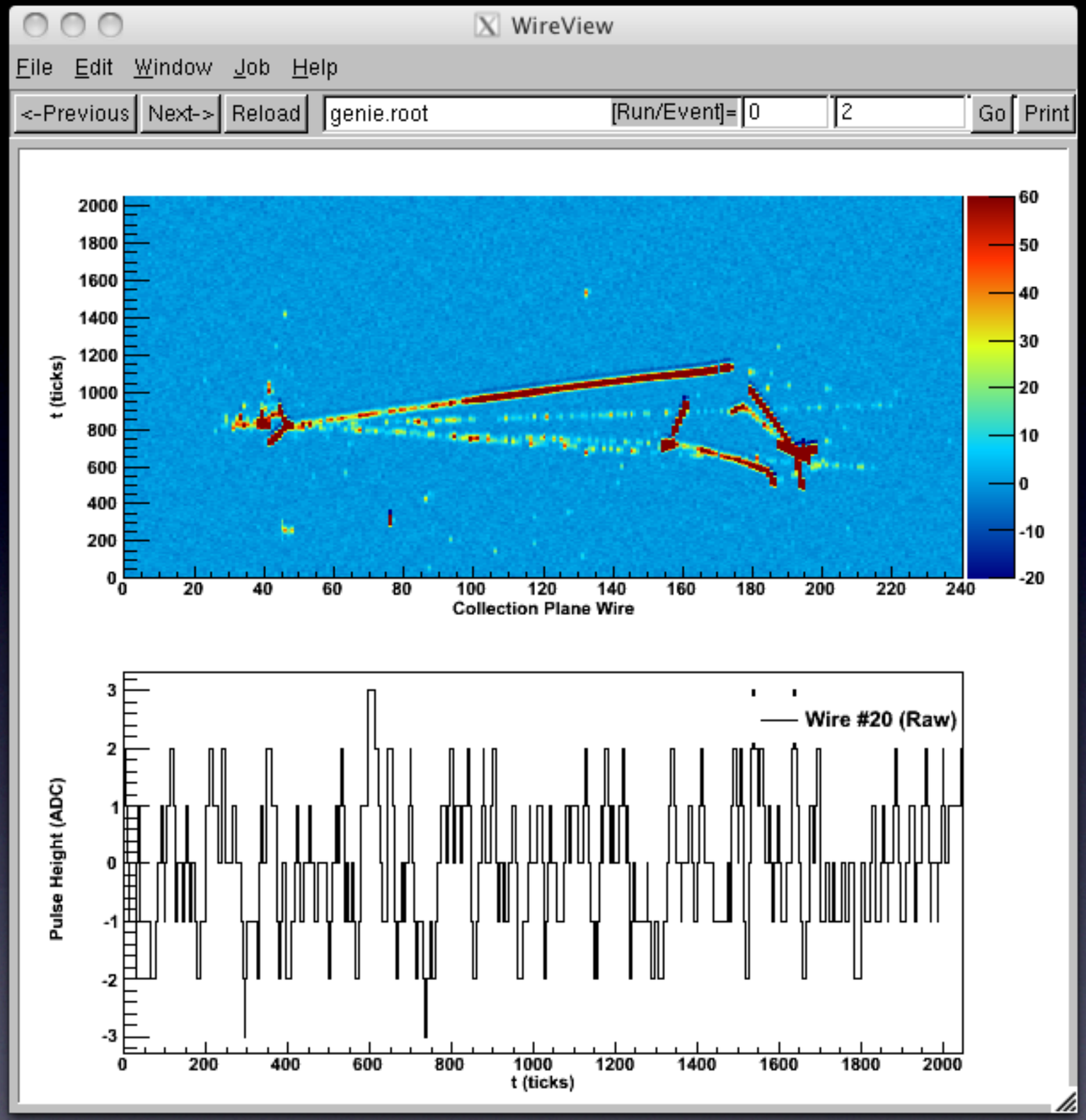
- This file allows the user to control various physics variables used by GENIE.
  - For those familiar with nuance, this is the GENIE-equivalent of nuance-defaults.cards.
- The file allows you to specify things as diverse as MA, the Cabbibo and Weinberg angles, the Fermi Gas Model parameters, the Bodek-Yank DIS structure function model parameters, and many, many more. The list of parameters is quite extensive.
- There are also generation-specific environmental variables one can specify. For example, one can specify the type of interaction to simulate (e.g. CCQE, CCpi+, etc.).

GENIE output



By default, the event generator output gets passed to Geant4 for propagation through the detector medium and then to electron drift, etc.

Note: To produce GENIE output only remove everything after the "evgen::GENIEGen" line in the job control file.



A view of a neutrino interaction in ArgoNeuT's collection plane with wire view using the EventDisplay package

Generating a single particle

```
ana -x argoneut.xml -x singlesim.xml -n 2 -i /dev/null/000/000/000 -o myoutputfile.root
```

Detector

Job control file

# of events to generate

Input file

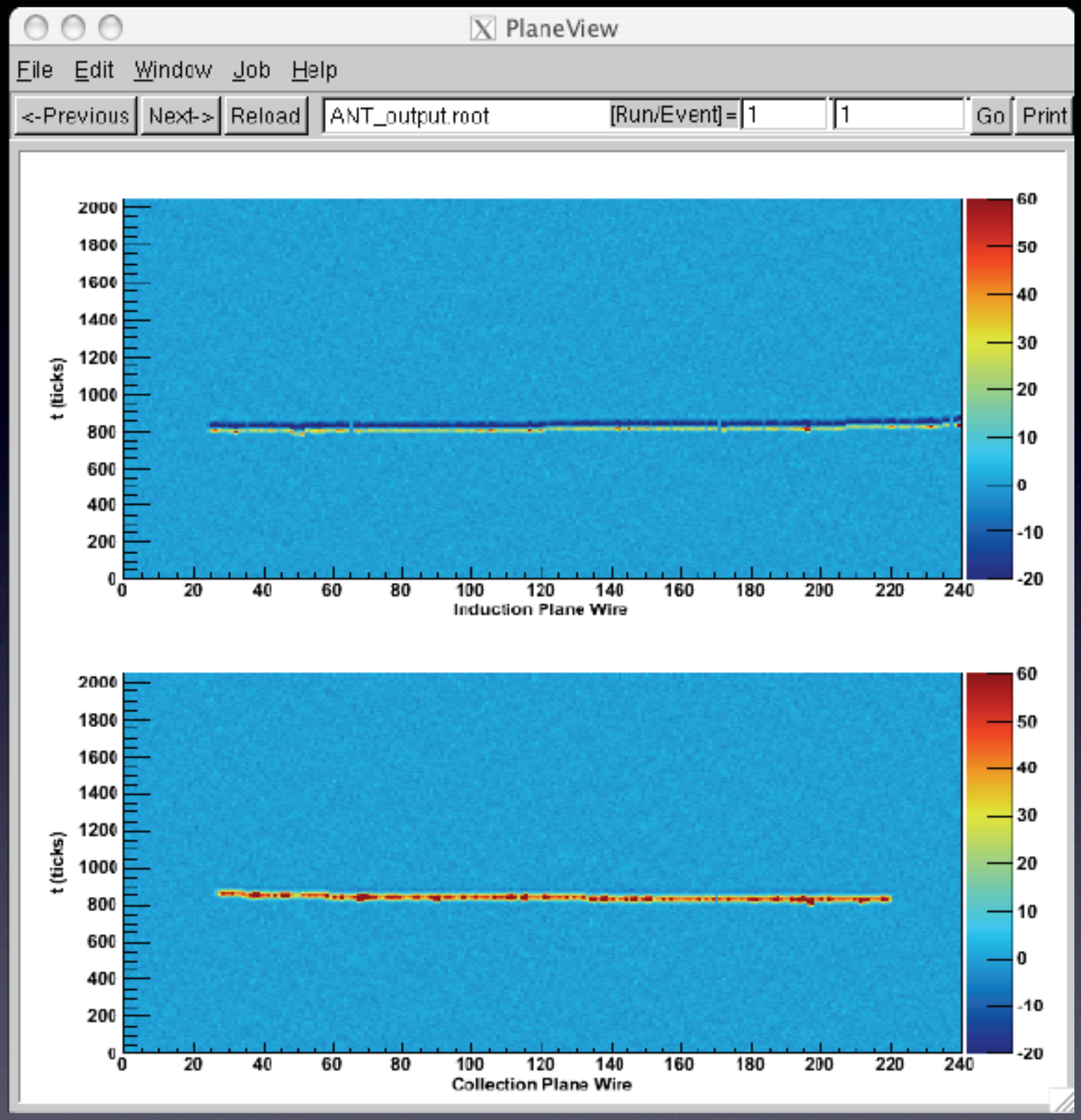
Output file name

Executable

The more user-specific job control comes from the xml files rather than the command line

Single particle generator job control file

- Particle ID
- Mean momentum, XYZ initial position, and angle (in XZ and YZ) of particle
- Random variation to momentum, position, and angle of particle
- Distribution of momentum, position, and angle spread, if any (Gaussian or uniform)



A view of a muon in ArgoNeuT's induction and collection planes using the EventDisplay package

Generating a cosmic ray

```
ana -x argoneut.xml -x prodcosmicsim.xml -n 2 -i /dev/null/000/000/000 -o myoutputfile.root
```

Detector

Job control file

# of events to generate

Input file

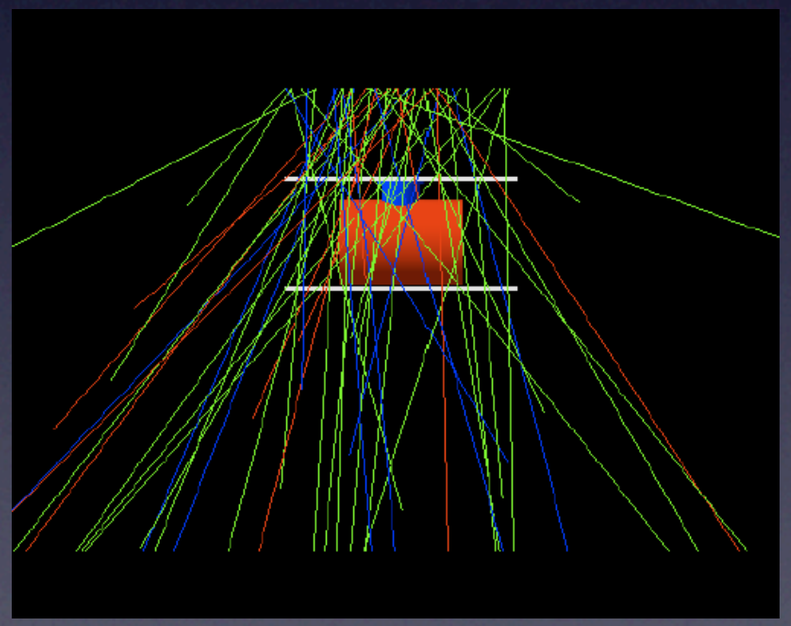
Output file name

Executable

The more user-specific job control comes from the xml files rather than the command line

Cosmic ray generator job control file

- kinetic energy threshold, below which particles will not be tracked
- length of time to integrate over
- length of time before spill to begin integration
- latitude of detector
- size of area to produce cosmic rays in



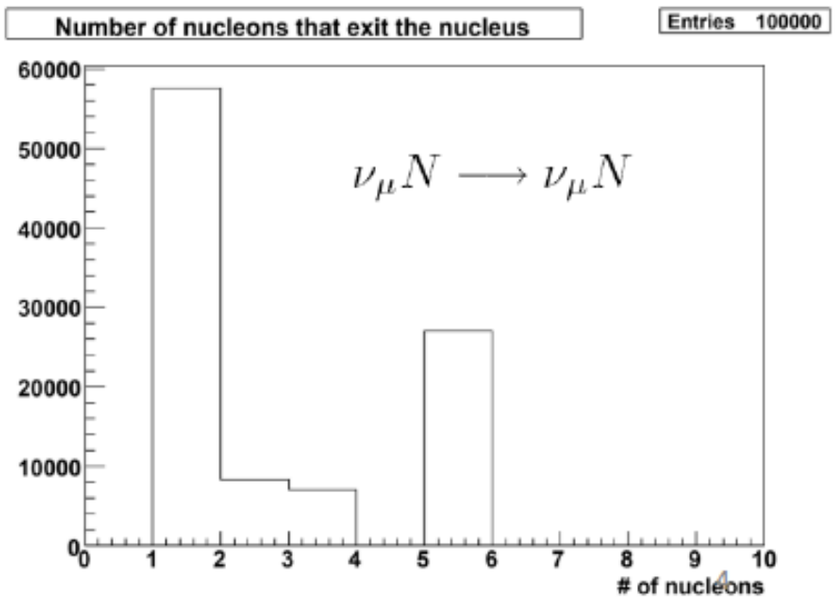
LArSoft invokes the CRY program to generate cosmics

A few words about GENIE

- GENIE is a ROOT-based (C++) Monte Carlo neutrino generator.
- GENIE is extremely well supported and documented. Please see the GENIE website for more info: (http://www.genie-mc.org/).
- To learn about GENIE's xsec model, transition region model, final state interaction model(s), and more, please see the GENIE manual available from the website above.

GENIE to-dos

- There is some (Ar-specific and low-energy-specific) work that needs to be done on GENIE in collaboration with the GENIE developers.
  - An example: photon production processes (HHH, radiative delta decays, de-excitation photons for Ar).
- The GENIE developers are currently working on a more realistic nuclear cascade model to simulate FSI.

An example of strangeness in simulating FSI in GENIE

- elastic (1)
- inelastic (1)
- charge exchange (1)
- nucleon absorption followed by np emission (2)
- nucleon absorption followed by pp emission (2)
- nucleon absorption followed by npp emission (3)
- nucleon absorption followed by nnp emission (3)
- nucleon absorption followed by 2n3p emission (5)
- pion production: n pi+ (2)
- pion production: n pi+ pi0 (3)