

# Michel electrons Identification using NuGraph for ICEBERG

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# NuGraph – Graph Neural Network

- **Objective of the study:** Analyze ICEBERG Michel Electrons using NuGraph.
- NuGraph is a general-purpose particle reconstruction Graph Neural Network to be used for LArTPC detectors (<https://larsoft.org/nugraph-gnn>, developed by *A. Aurisano (UCincinnati)*, *G. Cerati (FNAL)*, *V. Hewes (UCincinnati)*, *J. Kowalkowski (FNAL)* )
- NuGraph aims to classify each detector hit according to particle type.
- Use five semantic categories:
  - **MIP: Minimum ionising particles (muons, pions etc)**
  - **HIP: Highly ionising particles (protons, nucleons etc)**
  - **EM showers**
  - **Michel electrons**
  - **Diffuse activity (Compton scatters, neutrons etc)**

V Hewes, [NuGraph2 - A graph network for particle reconstruction](#)

# ICEBERG MC files

- For training NuGraph: generated 200k cosmic events MC using the fcl configuration (cosmic + refactored) : [prodsingle\\_iceberg\\_cosmics\\_nozs\\_refactored.fcl](#)
- Those files are already stored in SamWeb :  

```
hrazafin_detsim_iceberg_cosmics_nozs_refactored
```
- However, after converting the files, we saw some issues where information needed by NuGRAPH were not present in the MC input files.
- Needed to specify that the Electromagnetic Shower Daughters information should be kept and not discarded :
  - [services.LArG4Parameters.KeepEMShowerDaughters: true](#)
  - [services.ParticleListAction.keepEMShowerDaughters: true](#)
- Recently tested inputs with a few hundreds of events and they could be used as inputs to NuGRAPH after the fix. Currently re-generating all the MC with the EM Showers Daughters saved.

# NuGraph Inputs Conversion

## MC Files

Generate MC Files

Run Wire Deconvolution and Hit Finding using  
`legacy_reco_iceberg_wirecell.fcl`

Convert the Root File outputs into the HDF5  
format used as input for NuGRAPH using  
`hd5maker_iceberg.fcl`

## Data Files

Run LArSoft over the ICEBERG HDF5 Data files to  
access the RawDigit data Product

Run Wire Deconvolution and Hit Finding using  
`legacy_reco_iceberg_wirecell.fcl`

Convert the Root File outputs into the HDF5 format used  
as input for NuGRAPH using `hd5maker_iceberg.fcl`

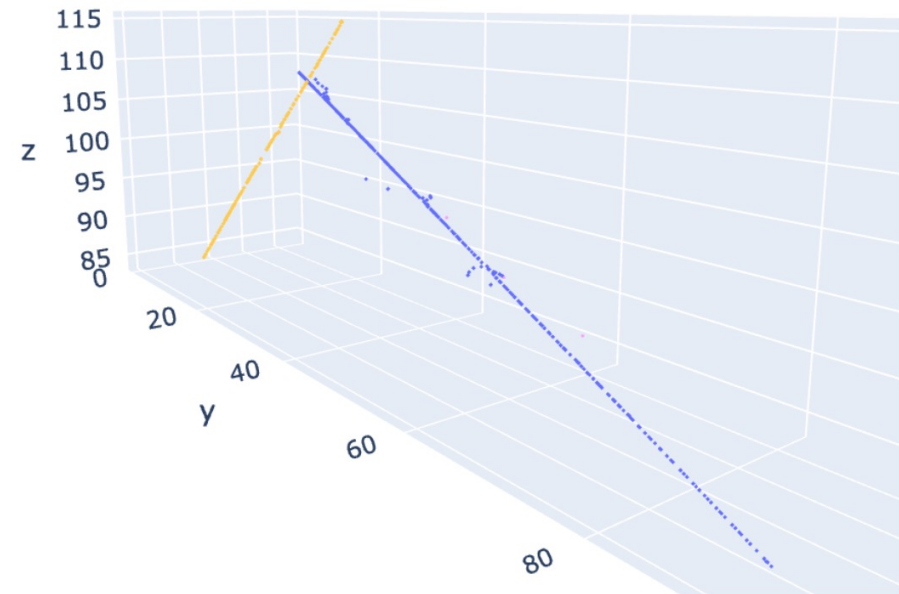
# Analyzing test inputs with NuGraph

- Generated 500 events with the EM Shower Daughter Information saved – Processed the files to generate the HDF5 input files.
- Process the test files with NuGraph.

## Example of Event 3D Position truth from NuGraph

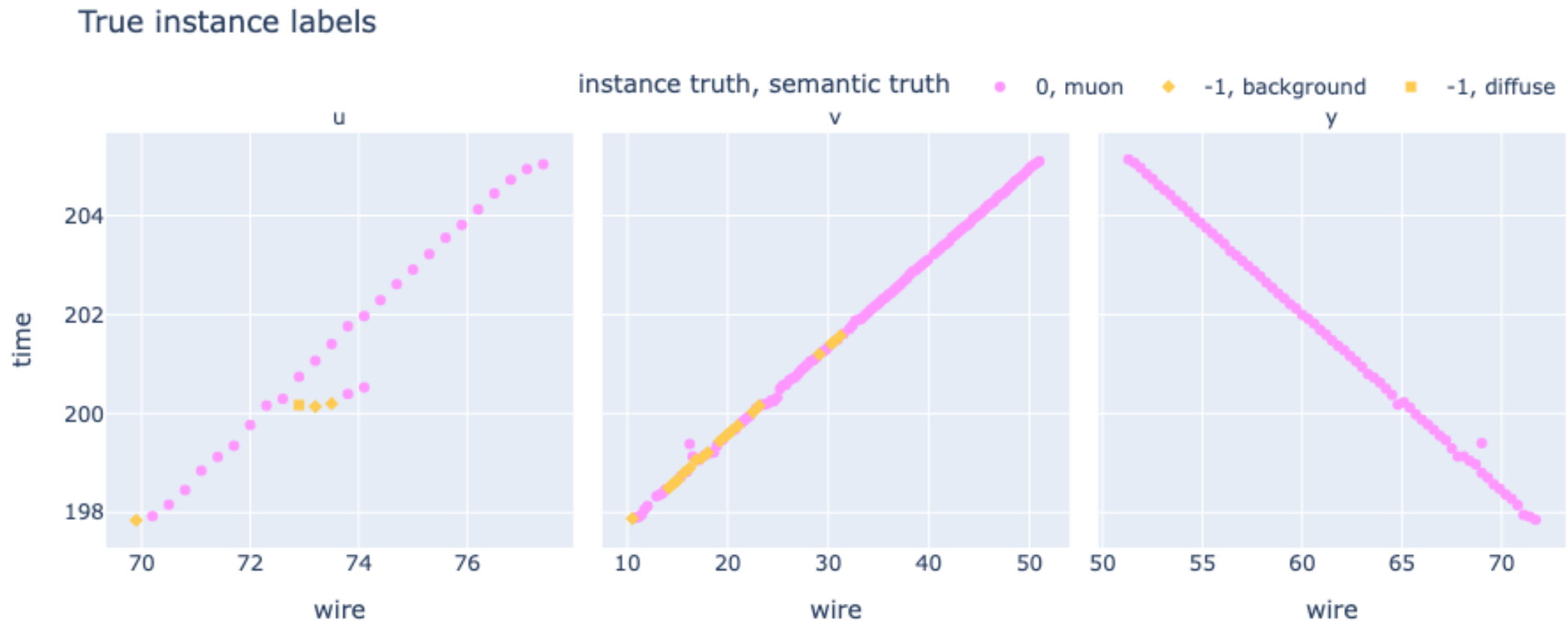
→ the 3D position truth for each hit is working as expected

True instance labels  
tic truth    • -1, background    • -1, diffuse    • 1, muon    • 0, muon



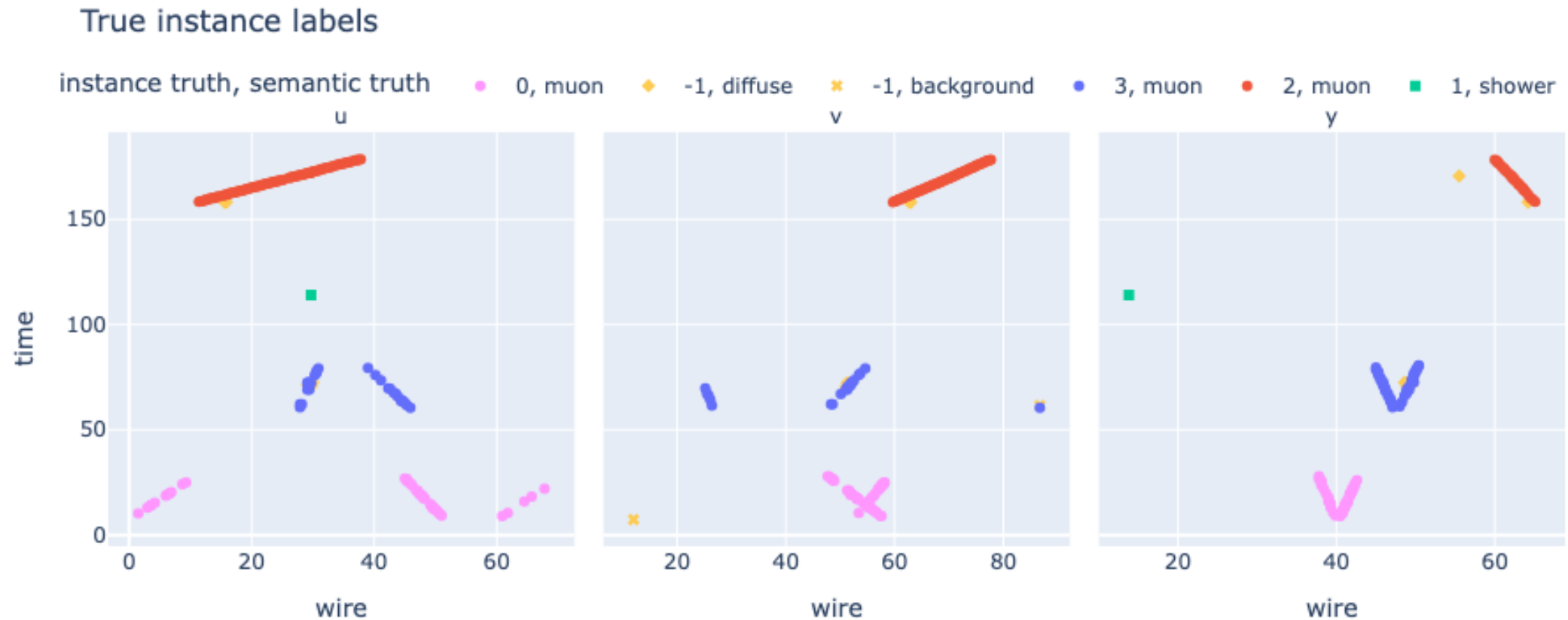
# Analyzing test inputs with NuGraph

- Example of Events from NuGraph:



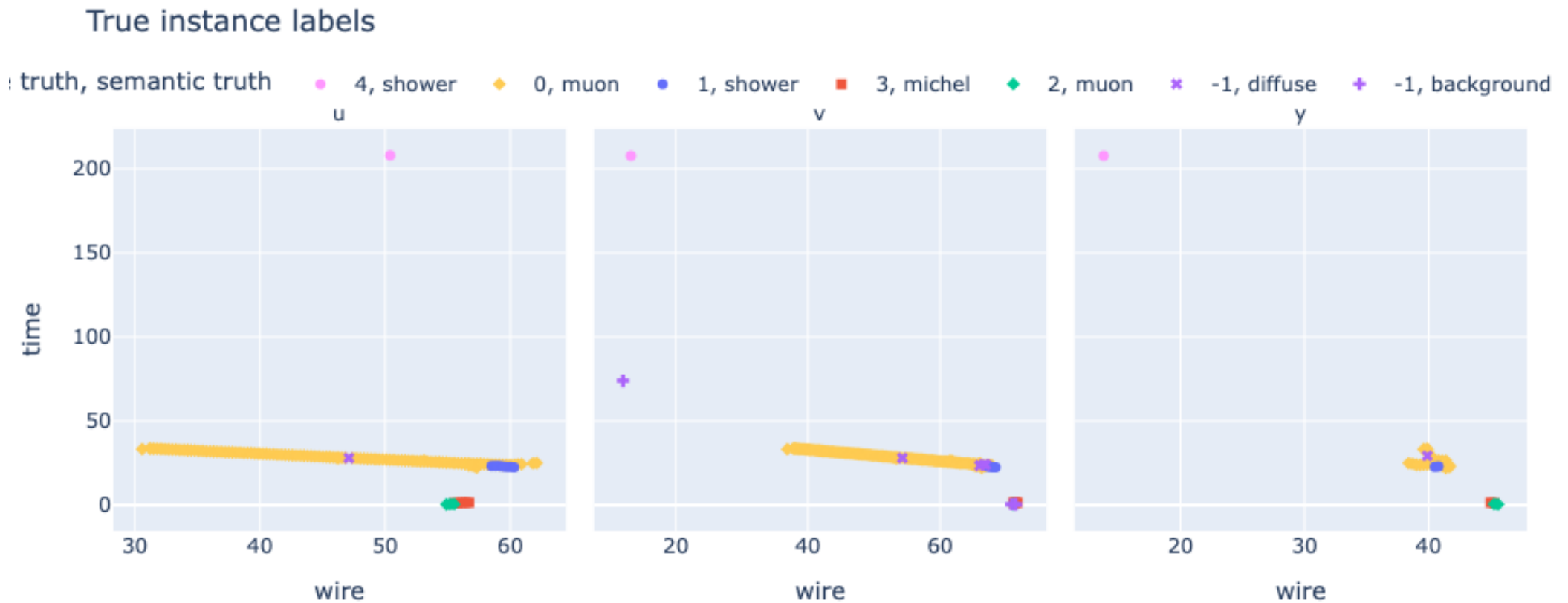
# Analyzing test inputs with NuGraph

- Example of Events from NuGraph:



# Analyzing test inputs with NuGraph

- Example of Events from NuGraph:





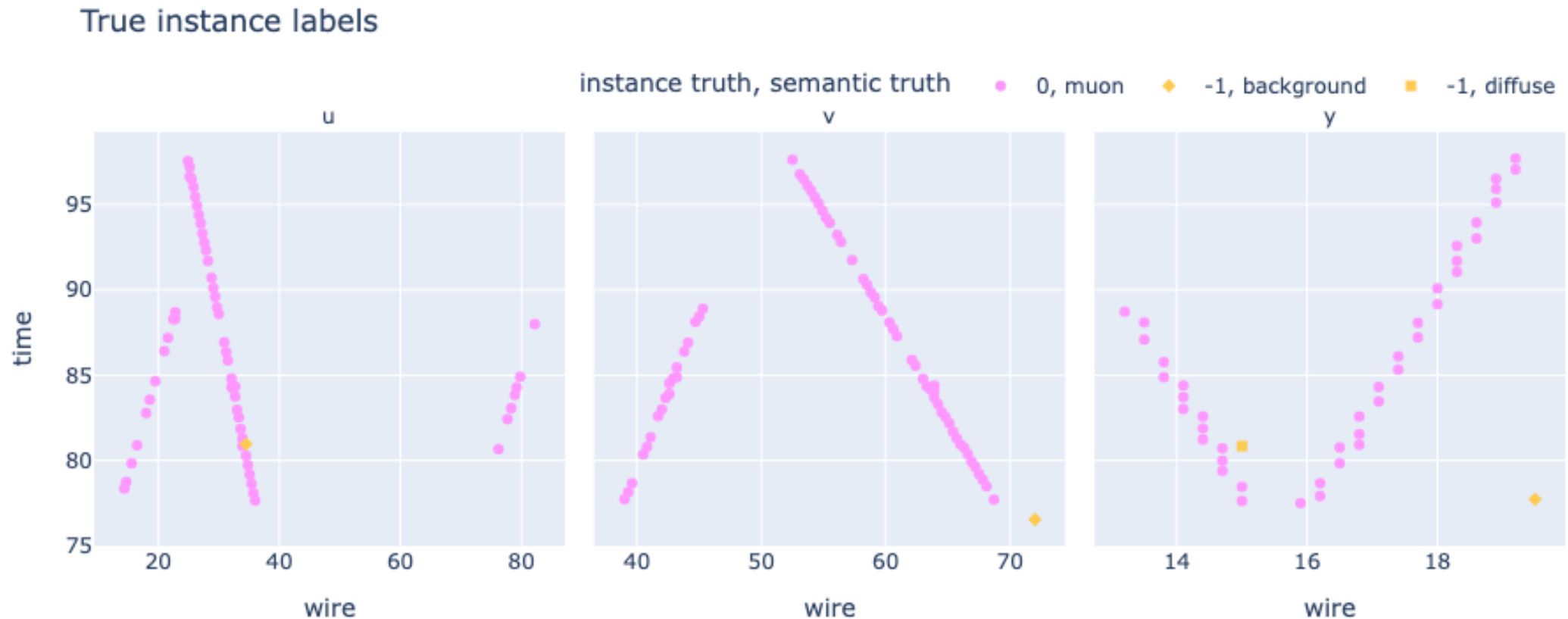
# Analyzing test inputs with NuGraph

- Example of Events from NuGraph:



# Analyzing test inputs with NuGraph

- Example of Events from NuGraph:



# Next steps of the analysis

- Now that the end-to-end workflow is working well, we plan to re-generate all the MC events at full scale.
- Needs about 100k signal events for training with NuGraph.
- Tom's comments: "Most randomly-sampled events at ICEBERG don't even have a cosmic ray let alone a stopping muon. So they still need filtering out to generate signal MC. As ICEBERG sees around 1/70<sup>th</sup> as much Lar per wire as ProtoDUNE-SP, in principle we need 70x as much MC, unless we filter out all events that don't have Michels in them."
- So still needs to work on the filtering.
- Question : should I use the [nozs](#) version of the fcl file or would the [prodsingle\\_iceberg\\_cosmics\\_refactored.fcl](#) be OK?