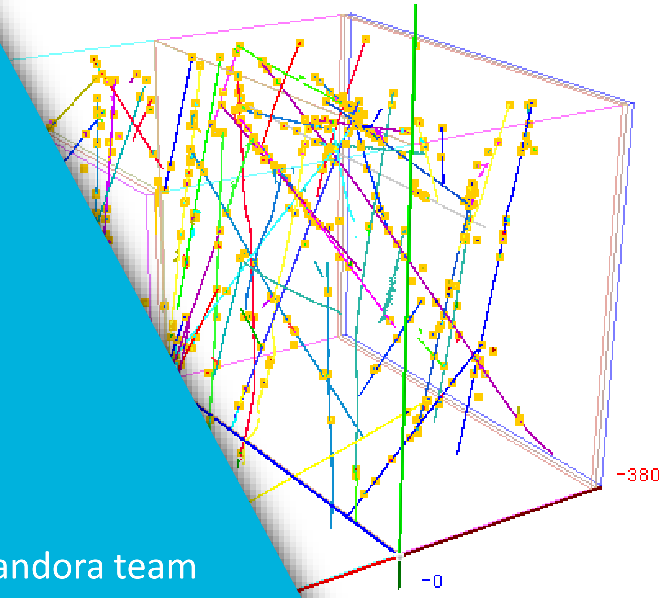
Running the reconstruction

(Exercise)



Maria Brigida Brunetti, Andy Chappell and Steve Dennis for the Pandora team

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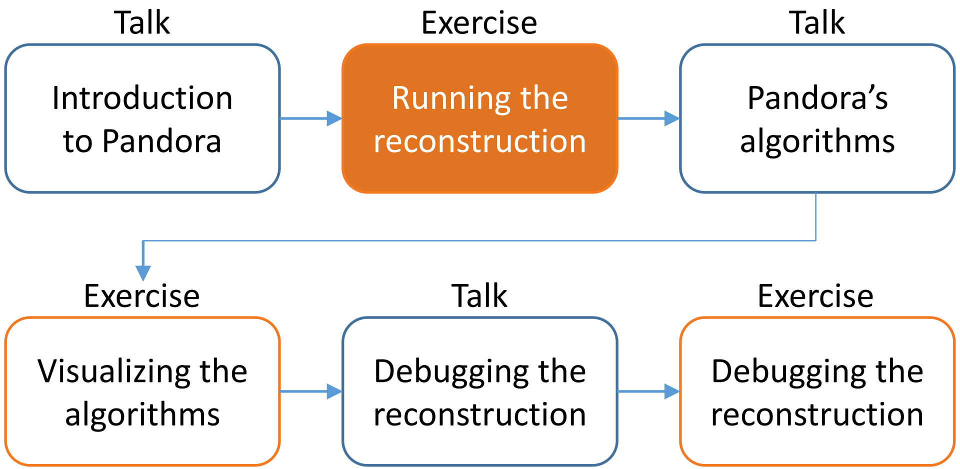
8th UK LArTPC Software and Analysis Workshop

Reconstruction session



Talk: Introduction to Pandora

Exercise: Running the reconstruction

Talk: Pandora's algorithms

Exercise: Visualizing the algorithms

Talk: Debugging the reconstruction

Exercise: Debugging the reconstruction

Credit: These slides are based on previous LArSoft workshop slides by Andrew Smith

Key references: Pandora ProtoDUNE paper
Pandora MicroBooNE paper

Goals

- This session is scheduled for 1 hour
- Main goal 1 - Find and get to grips with the SBND reconstruction FHiCL files
  - Find the standard_reco1reco2_sbnd.fcl configuration file
  - Look at the different reconstruction steps that we will run
  - Understand what each of them do
- Main goal 2 - Run the reconstruction
  - Run the reconstruction on the files we simulated yesterday
  - This includes running Pandora
  - Dump out the new output products to confirm we produced what we wanted

Before we get started…

- Later today we'll be running the event display
- Follow the steps from yesterday to get everything set up. To check, make sure MRB_TOP points to where you expect. Let us know if you have any issues here

```
$ echo $MRB_TOP # This should print the path to your development area
```

Main Goal 1

Understanding the SBND reconstruction FHiCL files

SBND reconstruction FHiCL file

- Open standard_reco1reco2_sbnd.fcl, we’ll use this to run the reconstruction

```
$ less $MRB_SOURCE/sbndcode/sbndcode/JobConfigurations/standard/standard_reco1reco2_sbnd.fcl
$ less $MRB_SOURCE/sbndcode/sbndcode/JobConfigurations/base/reco_sbnd.fcl
```

includes

First time using less? Use the ↑ / ↓ arrow keys to navigate the file, and press q to quit

File looks empty? Make sure you setup your working area again, otherwise $MRB_SOURCE won’t point to anywhere!

- Find the trigger_paths: […].
  - Q: which producers are we going to run?
  - A: Ultimately, it’s the ones in the reco1 and reco2_no_opt0finder paths:

```
reco1: [
   rns,
   ophitpmt,
   ophitarapuca,
   opflashtpc0,
   opflashtpc1,
   caldata,
   gaushit,
   fasthit ]
```

```
reco2_no_opt0finder: [
   rns, pandora,
   pandoraTrack,
   pandoraShower,
   pandoraShowerSBN
   pandoraCalo, pandoraPid,
   crthit, crttrack,
   crthitt0, crttrackt0,
   fmatch,
   caloskimCalorimetry ]
```

- In the last session, we were introduced to pandora, but there are many other steps in the reconstruction chain too!
- Next is a single-slide overview of these steps - not nearly enough to do them justice - but today we will mainly be focusing on pandora

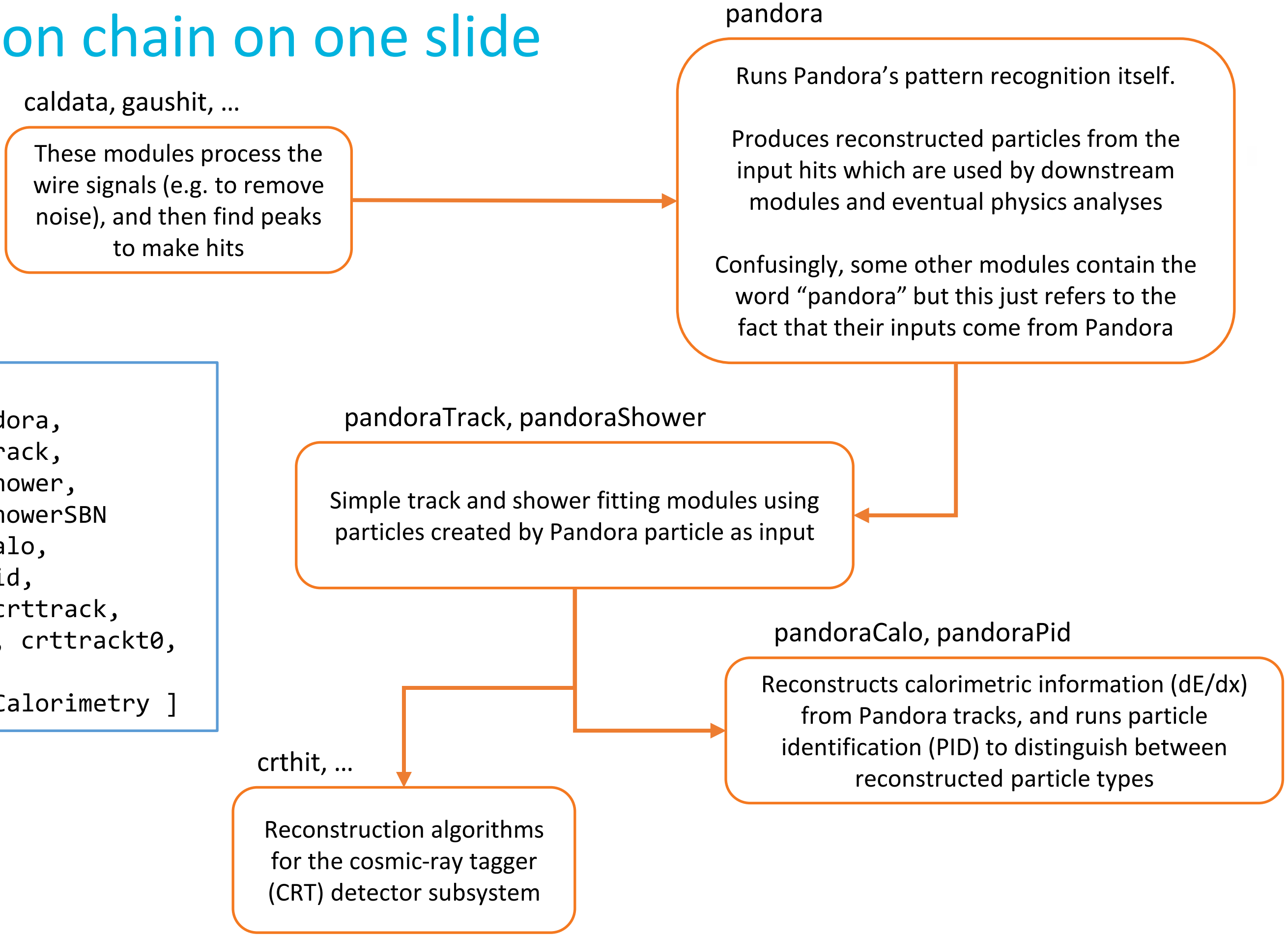
SBND reconstruction chain on one slide

rns

“Random number saver” saves the state of art’s random number generator

```
reco1: [
   rns,
   ophitpmt,
   ophitarapuca,
   opflashtpc0,
   opflashtpc1,
   caldata,
   gaushit,
   fasthit ]
```

```
reco2: [
   rns, pandora,
   pandoraTrack,
   pandoraShower,
   pandoraShowerSBN
   pandoraCalo,
   pandoraPid,
   crthit, crttrack,
   crthitt0, crttrackt0,
   fmatch,
   caloskimCalorimetry ]
```



caldata, gaushit, …

These modules process the wire signals (e.g. to remove noise), and then find peaks to make hits

pandora

Runs Pandora’s pattern recognition itself.

Produces reconstructed particles from the input hits which are used by downstream modules and eventual physics analyses

Confusingly, some other modules contain the word “pandora” but this just refers to the fact that their inputs come from Pandora

pandoraTrack, pandoraShower

Simple track and shower fitting modules using particles created by Pandora particle as input

pandoraCalo, pandoraPid

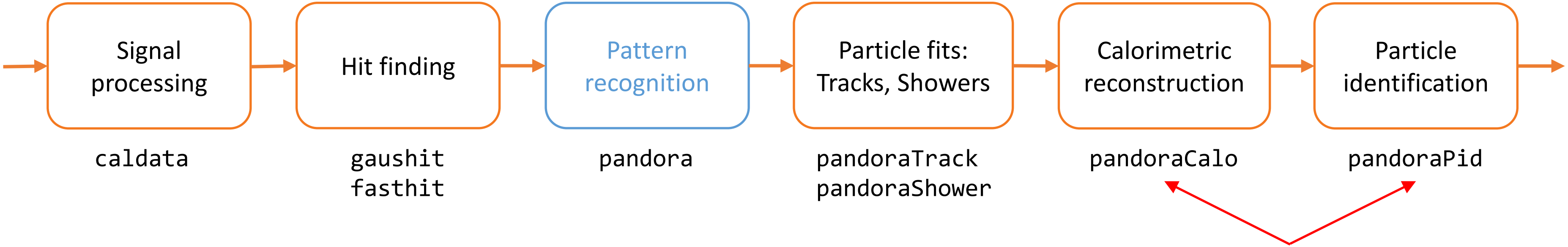
Reconstructs calorimetric information (dE/dx) from Pandora tracks, and runs particle identification (PID) to distinguish between reconstructed particle types

crthit, …

Reconstruction algorithms for the cosmic-ray tagger (CRT) detector subsystem

A note on other experiments

- Remember here we are looking at the configuration for **SBND**
- Each experiment has its own unique needs, so expect to see some differences in the reconstruction chain if you work on MicroBooNE, ProtoDUNE, DUNE, etc.
- As far as Pandora is concerned, we can generalise the reconstruction chain to the following steps:



Signal processing → Hit finding → Pattern recognition → Particle fits: Tracks, Showers → Calorimetric reconstruction → Particle identification

caldata

gaushit
fasthit

pandora

pandoraTrack
pandoraShower

pandoraCalo

pandoraPid

- Next, let's see how pandora is configured for SBND

Historically, modules using Pandora outputs frequently have Pandora in the name.

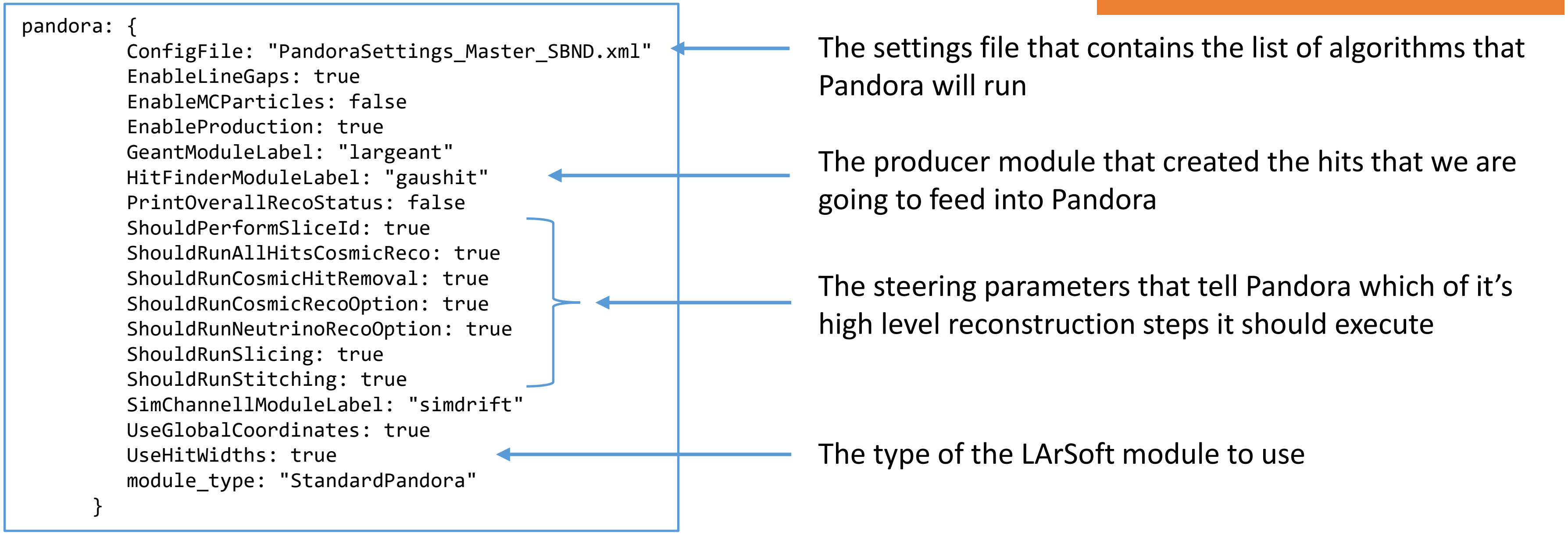
Most of these modules aren't actually part of Pandora and aren't maintained by the Pandora development team.

Pandora’s configuration

- fhicl-dump follows all #includes to get the bottom-line configuration. We can pipe (|) its output to less and search for a producer to learn more. Search for pandora by typing:

```
$ fhicl-dump standard_reco1reco2_sbnd.fcl | less -p "pandora:"
```

less’s -p option allows us to jump straight to the part of the file we are interested in



```
pandora: {
         ConfigFile: "PandoraSettings_Master_SBND.xml"
         EnableLineGaps: true
         EnableMCParticles: false
         EnableProduction: true
         GeantModuleLabel: "largeant"
         HitFinderModuleLabel: "gaushit"
         PrintOverallRecoStatus: false
         ShouldPerformSliceId: true
         ShouldRunAllHitsCosmicReco: true
         ShouldRunCosmicHitRemoval: true
         ShouldRunCosmicRecoOption: true
         ShouldRunNeutrinoRecoOption: true
         ShouldRunSlicing: true
         ShouldRunStitching: true
         SimChannelModuleLabel: "simdrift"
         UseGlobalCoordinates: true
         UseHitWidths: true
         module_type: "StandardPandora"
      }
```

The settings file that contains the list of algorithms that Pandora will run

The producer module that created the hits that we are going to feed into Pandora

The steering parameters that tell Pandora which of it’s high level reconstruction steps it should execute

The type of the LArSoft module to use

Main Goal 2

Running the reconstruction

Running the reconstruction

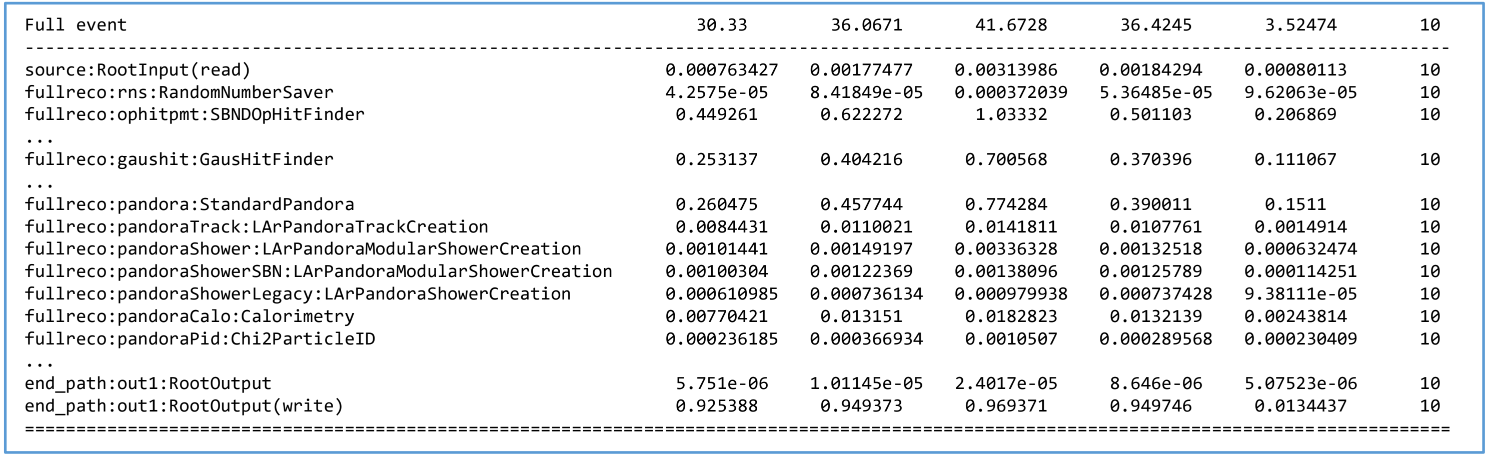
- We are now poised to run the reconstruction! Make a directory to work in, and run it:

This step can take some time, so please be patient!

The -n -1 option means run over all events in the input file

```
$ mkdir -p $MRB_TOP/reco/work
$ cd $MRB_TOP/reco/work
$ lar -c standard_reco1reco2_sbnd.fcl -n -1 -s /path/to/my/detsim/file.root -o reco_events.root
```

Can also run on pre-made gen+g4+detsim files in `/home/share/october2023/simulation/output_detsim_numu_like.root`



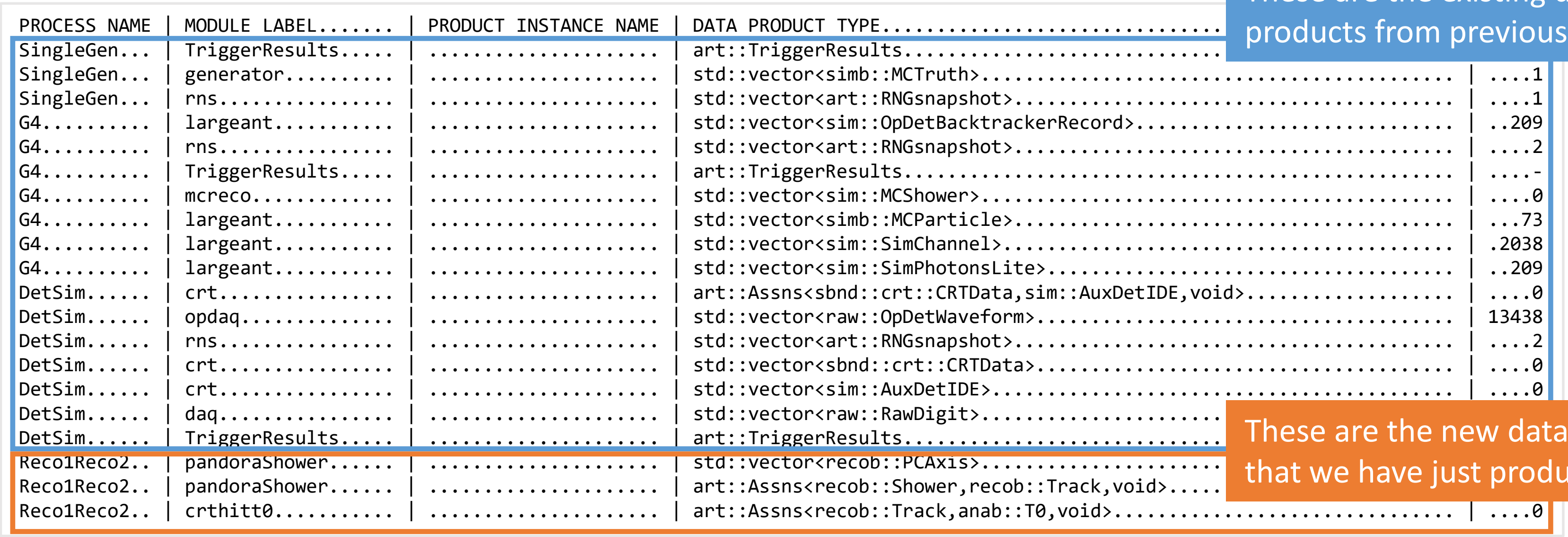
```
Full event                                            30.33      36.0671     41.6728     36.4245     3.52474       10
-----------------------------------------------------------------------------------------------------------------------
source:RootInput(read)                             0.000763427  0.00177477  0.00313986  0.00184294  0.00080113     10
fullreco:rns:RandomNumberSaver                     4.2575e-05   8.41849e-05 0.000372039 5.36485e-05 9.62063e-05    10
fullreco:ophitpmt:SBNDOpHitFinder                   0.449261     0.622272    1.03332     0.501103    0.206869      10
...
fullreco:gaushit:GausHitFinder                      0.253137     0.404216    0.700568    0.370396    0.111067      10
...
fullreco:pandora:StandardPandora                    0.260475     0.457744    0.774284    0.390011    0.1511        10
fullreco:pandoraTrack:LArPandoraTrackCreation       0.0084431    0.0110021   0.0141811   0.0107761   0.0014914     10
fullreco:pandoraShower:LArPandoraModularShowerCreation 0.00101441 0.00149197 0.00336328  0.00132518  0.000632474   10
fullreco:pandoraShowerSBN:LArPandoraModularShowerCreation 0.00100304 0.00122369 0.00138096 0.00125789 0.000114251  10
fullreco:pandoraShowerLegacy:LArPandoraShowerCreation 0.000610985 0.000736134 0.000979938 0.000737428 9.38111e-05 10
fullreco:pandoraCalo:Calorimetry                   0.00770421   0.013151    0.0182823   0.0132139   0.00243814     10
fullreco:pandoraPid:Chi2ParticleID                 0.000236185  0.000366934 0.0010507   0.000289568 0.000230409    10
...
end_path:out1:RootOutput                            5.751e-06   1.01145e-05 2.4017e-05   8.646e-06  5.07523e-06    10
end_path:out1:RootOutput(write)                     0.925388     0.949373    0.969371    0.949746    0.0134437     10
=======================================================================================================================
```

We can check to see that everything we expected has been executed, and see how long each took

So… what’s new?

- Run eventdump.fcl to see all of the new collections we just made

```
$ lar -c eventdump.fcl -s reco_events.root -n 1
```



```
PROCESS NAME | MODULE LABEL....... | PRODUCT INSTANCE NAME | DATA PRODUCT TYPE...............................
SingleGen... | TriggerResults..... | ..................... | art::TriggerResults.............................
SingleGen... | generator.......... | ..................... | std::vector<simb::MCTruth>........................................... | ....1
SingleGen... | rns................ | ..................... | std::vector<art::RNGsnapshot>........................................ | ....1
G4.......... | largeant........... | ..................... | std::vector<sim::OpDetBacktrackerRecord>............................. | ..209
G4.......... | rns................ | ..................... | std::vector<art::RNGsnapshot>........................................ | ....2
G4.......... | TriggerResults..... | ..................... | art::TriggerResults.................................................. | ....-
G4.......... | mcreco............. | ..................... | std::vector<sim::MCShower>........................................... | ....0
G4.......... | largeant........... | ..................... | std::vector<simb::MCParticle>........................................ | ...73
G4.......... | largeant........... | ..................... | std::vector<sim::SimChannel>......................................... | .2038
G4.......... | largeant........... | ..................... | std::vector<sim::SimPhotonsLite>..................................... | ..209
DetSim...... | crt................ | ..................... | art::Assns<sbnd::crt::CRTData,sim::AuxDetIDE,void>.................. | ....0
DetSim...... | opdaq.............. | ..................... | std::vector<raw::OpDetWaveform>...................................... | 13438
DetSim...... | rns................ | ..................... | std::vector<art::RNGsnapshot>........................................ | ....2
DetSim...... | crt................ | ..................... | std::vector<sbnd::crt::CRTData>...................................... | ....0
DetSim...... | crt................ | ..................... | std::vector<sim::AuxDetIDE>.......................................... | ....0
DetSim...... | daq................ | ..................... | std::vector<raw::RawDigit>......................
DetSim...... | TriggerResults..... | ..................... | art::TriggerResults.............................
Reco1Reco2.. | pandoraShower...... | ..................... | std::vector<recob::PCAxis>......................
Reco1Reco2.. | pandoraShower...... | ..................... | art::Assns<recob::Shower,recob::Track,void>....
Reco1Reco2.. | crthitt0........... | ..................... | art::Assns<recob::Track,anab::T0,void>............................... | ....0
```

These are the existing data products from previous steps

These are the new data products that we have just produced

Additional information

Configuring Pandora steps

(For reference)

- Pandora’s full reconstruction chain is designed to handle neutrino interactions in dense cosmic environments. As you will hear later, there are two main algorithm chains optimised for cosmic rays, and neutrinos respectively
- For SBND, an experiment that will have neutrinos and cosmics - we normally want to run all of the steps
- For cosmic events, we only need to run the cosmic algorithm chain. For neutrino events, we only need to run the neutrino algorithm chain. We can configure Pandora to run one, many or all of the steps in its full reconstruction chain by modifying the FHiCL steering parameters
- Make a new directory to work in for this session, and add a new FHiCL file with the following lines, then save and close the file:

```
$ mkdir -p $MRB_TOP/reco/config
$ cd $MRB_TOP/reco/config          # Put your new .fcl file here
$ vim my_reco_sbnd_basic.fcl
```

Please use your favourite text editor, here we use vim. If you accidentally opened vim and want to close it type Esc, :qa, Return ↵

```
#include "standard_reco1reco2_sbnd.fcl"

physics.producers.pandora.ShouldRunAllHitsCosmicReco: false
physics.producers.pandora.ShouldRunStitching: false
physics.producers.pandora.ShouldRunCosmicHitRemoval: false
physics.producers.pandora.ShouldRunSlicing: false
physics.producers.pandora.ShouldRunCosmicRecoOption: false
physics.producers.pandora.ShouldRunNeutrinoRecoOption: true
physics.producers.pandora.ShouldPerformSliceId: false
```

Include the standard configuration

Example:
Only run the neutrino algorithm chain

Pointing to a new configuration (For reference)

- We want to make sure that LArSoft will know where to look for our new FHiCL file, to do this we add it to the FHICL_FILE_PATH environment variable. Start by printing it to the terminal:

```
$ echo $FHICL_FILE_PATH
```

- You will see many many directories, all separated by a ':'. To add our reco/config folder to this list run the following command:

```
$ export FHICL_FILE_PATH=$MRB_TOP/reco/config:$FHICL_FILE_PATH
```

- Echo the FHICL_FILE_PATH again to check that everything worked (it should be the first in the list)
- Now run fhicl-dump again to make sure our new configuration file is set up as we want

```
$ fhicl-dump my_reco_sbnd_basic.fcl | less -p "pandora:"
```