Running the reconstruction

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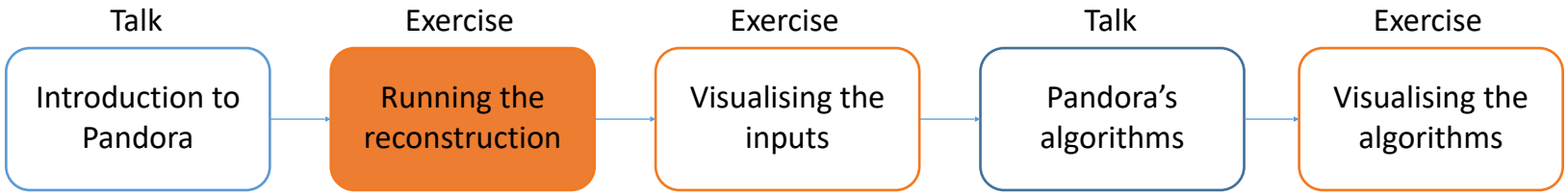
Reconstruction session



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

Key references:
Pandora ProtoDUNE paper
Pandora MicroBooNE paper

Goals

- Main goal 1 - Find and get to grips with the DUNEFD horizontal drift reconstruction FHiCL files
  - Find the standard_reco_dune10kt configuration files
  - 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
- Firstly, we need to setup the container (dunegpvm-only), environment and the software

dunegpvm example

```
$ ssh machine #e.g. ssh dunegpvm10
$ source /nashome/d/dbrailsf/setupVNC.sh
$ /cvmfs/oasis.opensciencegrid.org/mis/apptainer/current/bin/apptainer shell --shell=/bin/
bash --env PS1=\"(CONTAINER) [\H@\w]$ \" -B /cvmfs,/exp,/nashome,/pnfs/dune,/opt,/run/
user,/etc/hostname,/etc/hosts,/etc/krb5.conf --ipc --pid /cvmfs/
singularity.opensciencegrid.org/fermilab/fnal-dev-sl7:latest
$ source /cvmfs/dune.opensciencegrid.org/products/dune/setup_dune.sh
$ setup dunesw v09_90_01d00 -q e26:prof
$ source /nashome/d/dbrailsf/setupVNC.sh
```

Before we get started…

- Later today we'll be running the event display
- Firstly, we need to setup the container (dunegpvm-only), environment and the software

cca example

```
$ ssh machine #e.g. ssh cca
$ source /sps/lbno/dbrailsford/annecy2024/setupVNC.sh
$ source /cvmfs/dune.opensciencegrid.org/products/dune/setup_dune.sh
$ setup dunesw v09_90_01d00 -q e26:prof
```

There are a lot of commands provided in the slide decks for convenience. Typically they will only include dunegpvm paths. If working on a cca server you will need to modify the paths yourself.

Main Goal 1

Understanding the DUNE reconstruction FHiCL files

DUNE reconstruction FHiCL file

- Open standard_reco2_dune10kt_1x2x6.fcl, we'll use this to run the reconstruction

```
$ less $DUNESW_DIR/fcl/standard_reco2_dune10kt_1x2x6.fcl
$ less $DUNESW_DIR/fcl/standard_reco2_dune10kt.fcl
$ less $DUNESW_DIR/fcl/standard_reco_dune10kt.fcl
$ less $DUNESW_DIR/fcl/workflow_reco_dune10kt.fcl
```

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

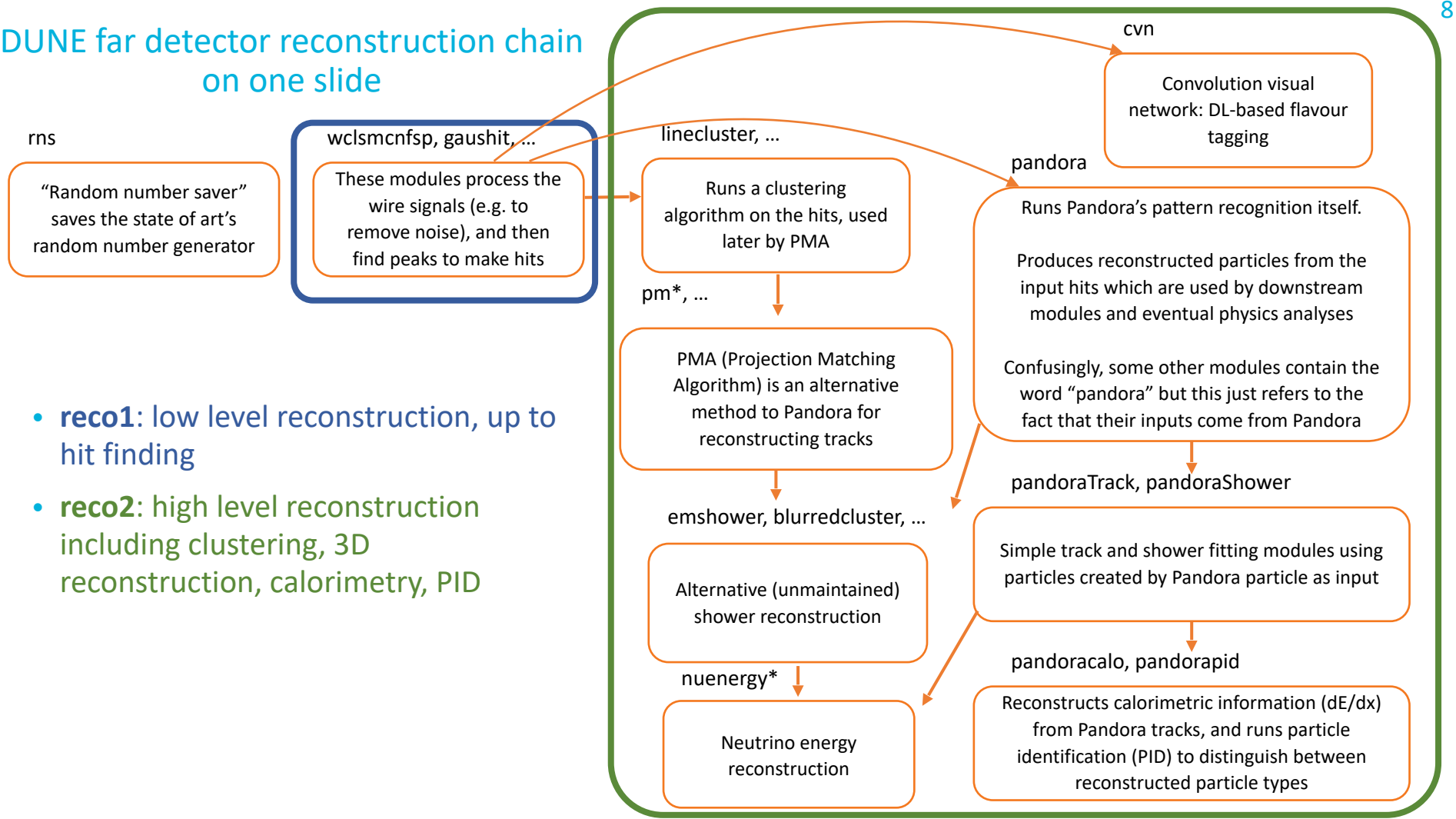
- Find the physics.reco path in standard_reco2_dune10kt.fcl
  - Q: which producers are we going to run?
  - A: It's the ones in the dunefd_horizdrift_workflow_reco2 path
    - The sequence contents are found higher up in the fcl file

```
dunefd_horizdrift_workflow_reco2: [
   …
   @sequence::dunefd_horizdrift_pandora,
   … ]
```

```
dunefd_horizdrift_pandora: [
   pandora,
   pandoraTrack,
   pandoraShower,
   pandoracalo,
   pandorapid ]
```

- Next is a single-slide overview of all the reco steps - not nearly enough to do them justice - but today we will mainly be focusing on pandora

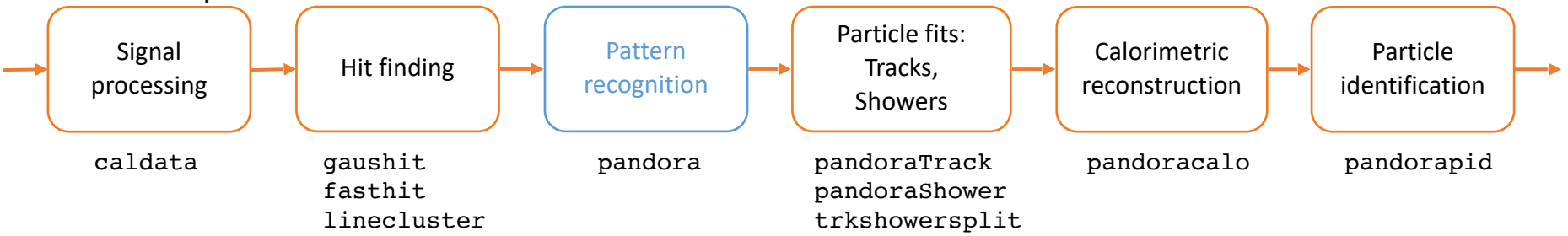
DUNE far detector reconstruction chain on one slide



- **reco1**: low level reconstruction, up to hit finding
- **reco2**: high level reconstruction including clustering, 3D reconstruction, calorimetry, PID

A note on other experiments

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



- Next, let's see how pandora is configured for the DUNE Far Detector

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_reco2_dune10kt_1x2x6.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_DUNEFD.xml"
         EnableLineGaps: true
         EnableMCParticles: false
         EnableProduction: true
         GeantModuleLabel: "largeant"
         HitFinderModuleLabel: "hitfd"
         PrintOverallRecoStatus: false
         ShouldPerformSliceId: false
         ShouldRunAllHitsCosmicReco: false
         ShouldRunCosmicHitRemoval: false
         ShouldRunCosmicRecoOption: false
         ShouldRunNeutrinoRecoOption: true
         ShouldRunSlicing: false
         ShouldRunStitching: false
         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

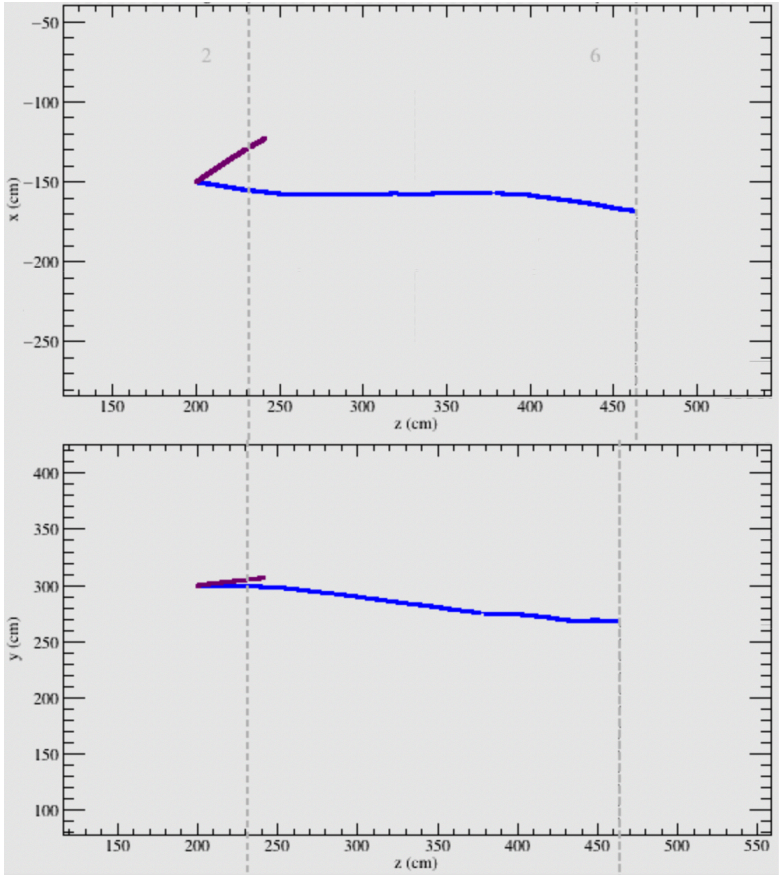
The type of the LArSoft module to use

Main Goal 2

Running the reconstruction

What's the sample?

- A few particle gun events have been simulated for you
  - Generation -> G4 tracking -> Detector response and signal processing -> reco1
- The sample is a set of 'vertex-like' particle gun events
  - A muon and proton fired from a common point
  - Sample mimics the signature of a neutrino vertex
  - Avoid the simulation complexities of neutrino generation interrupting with learning about the reconstruction



Reco1 file path

```
$ /exp/dune/data/users/dbrailsf/workshops/annecy2024/prod_mu_proton_dune10kt_1x2x6_gen_g4_detsim_reco1.root
$ /sps/lbno/dbrailsford/annecy2024/prod_mu_proton_dune10kt_1x2x6_gen_g4_detsim_reco1.root
```

Running the reconstruction

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

```
$ mkdir -p /exp/dune/data/users/$USER/reco/work
$ cd /exp/dune/data/users/$USER/reco/work
$ lar -c standard_reco2_dune10kt_1x2x6.fcl -n -1 -s /path/to/reco1.root -o
reco2_1mu1p.root
```

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

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

```
================================================================================================================================================
TimeTracker printout (sec)                                    Min           Avg           Max           Median          RMS           nEvts
================================================================================================================================================
Full event                                                    14.4235       16.7021       22.9312       15.3978       3.17841       5
------------------------------------------------------------------------------------------------------------------------------------------------
source:RootInput(read)                                        0.000452972   0.000635409   0.000780154   0.000701023   0.000128122   5
reco:linecluster:LineCluster                                  0.0167877     0.0195162     0.0252377     0.0173858     0.00333468    5
reco:trajcluster:TrajCluster                                  0.0550071     0.0701446     0.0917665     0.0652082     0.0124367     5
reco:pandora:StandardPandora                                  0.748147      1.25079       2.75524       0.862925      0.760793      5
reco:pandoraTrack:LArPandoraTrackCreation                     0.00308148    0.00406956    0.00777318    0.00316728    0.00185255    5
reco:pandoraShower:LArPandoraModularShowerCreation            0.0162824     0.0203825     0.0253648     0.0192886     0.00303779    5
reco:pandoracalo:Calorimetry                                  0.00431279    0.00504067    0.00715086    0.00455915    0.00106172    5
reco:pandorapid:Chi2ParticleID                                9.6464e-05    0.000435184   0.00172821    0.000110911   0.000646606   5
reco:trkshowersplit:TrackShowerHits                           0.00274607    0.00313384    0.0042873     0.00287603    0.000582228   5
reco:pmtrack:PMAlgTrackMaker                                  0.54331       1.18013       2.20622       1.2577        0.603529      5
reco:pmtrackcalo:Calorimetry                                  0.000723637   0.00180062    0.00485471    0.00117207    0.00155474    5
…
```

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 reco2_1mu1p.root -n 1
```

```
G4..... | largeant..... | ..... |
art::Assns<simb::MCTruth,simb::MCParticle,sim::GeneratedParticleInfo> | ...13
G4..... | largeant..... | LArG4DetectorServicevolTPCPlaneUOuter. |
std::vector<sim::SimEnergyDeposit>..... | ....0
G4..... | largeant..... | LArG4DetectorServicevolTPCActiveOuter. |
std::vector<sim::SimEnergyDeposit>..... | ....0
detsim..... | opdigi..... | ..... |
std::vector<sim::OpDetDivRec>..... | ..907
detsim..... | tpcrawdecoder..... | simpleSC..... |
std::vector<sim::SimChannel>..... | 30720
detsim..... | tpcrawdecoder..... | wiener..... |
std::vector<recob::Wire>..... | 30720
Reco1..... | spsolve..... | ..... |
art::Assns<recob::Hit,recob::SpacePoint,void>..... | .3546
```

These are the existing data products from previous steps

```
Reco2..... | pmtracktc..... | ..... |
art::Assns<recob::PFParticle,recob::Cluster,void>..... | ....0
Reco2..... | pmtrajfit..... | kink..... |
art::Assns<recob::Track,recob::Vertex,void>..... | ....0
Reco2..... | pandoraShower..... | ..... |
art::Assns<recob::Shower,recob::PCAxis,void>..... | ....2
Reco2..... | pandoraShower..... | ..... |
art::Assns<recob::Shower,recob::SpacePoint,void>..... | .1658
```

These are the new data products that we have just produced

Got spare time?

Try starting the next tutorial – running the event display

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 DUNE-FD - we normally want to run the cosmic and neutrino reconstruction completely independently
- 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 /exp/dune/data/users/$USER/reco/config
$ cd /exp/dune/data/users/$USER/reco/config # Put your new .fcl file here
$ vim my_reco.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_reco2_dune10kt_1x2x6.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
```

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=/exp/dune/data/users/$USER/reco/config:$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.fcl | less -p "pandora:"
```