Session 1:

Run simulation $\rightarrow$ reconstruction chain and see the result
(updated on 24.01.2018)
Start this excersises when you have:

- LArSoft environment configured

What is illustrated:

- run:
  - particle gun
  - G4 particle propagation through detector
  - detector readout simulation
  - reconstruction chain
  - using provided standard configuration files

- have a look into standard FHiCL’s

- simulation and reconstruction results visualisation
Simulations / reconstruction in ProtoDUNE

- particle gun
- beam simulation
  - and/or cosmogenics
    - particle list, kinematics
    - general det.sim.
      - energy depositions, light
    - specific det.sim.
  - Corsika
    - Geant4

raw data like from real detector

reconstruction paths

Login (just a remainder of setup steps), then prepare some directories for output:

```bash
[rosulej@dune-vm-build-02 larsoft]$ source /cvmfs/dune.opensciencegrid.org/products/dune/setup_dune.sh
Setting up larsoft UPS area... /cvmfs/fermilab.opensciencegrid.org/products/larsoft/
Setting up DUNE UPS area... /cvmfs/dune.opensciencegrid.org/products/dune/
```

```bash
[rosulej@dune-vm-build-02 larsoft]$ source /cvmfs/fermilab.opensciencegrid.org/products/larsoft/setups
[rosulej@dune-vm-build-02 larsoft]$ setup mrb
Use your release number here:
```

```bash
[rosulej@dune-vm-build-02 larsoft]$ source localProducts_larsoft_v06_40_00_e14_prof/setup
MRB_PROJECT=larsoft
MRB_PROJECT_VERSION=v06_40_00
MRB_QUALS=e14:prof
MRB_TOP=/afs/cern.ch/work/r/rosulej/ larsoft
MRB_SOURCE=/afs/cern.ch/work/r/ rosulej/ larsoft/srns
MRB_BUILDDIR=/afs/cern.ch/work/r/ rosulej/ larsoft/build_slf7.x86_64
MRB_INSTALL=/afs/cern.ch/work/r/ rosulej/larsoft/localProducts_larsoft_v06_40_00_e14_prof
PRODUCTS=/afs/cern.ch/work/r/ rosulej/ larsoft/localProducts_larsoft_v06_40_00_e14_prof/:/cvmfs/fermilab. opensciencegrid.org/products/larsoft:/cvmfs/dune. opensciencegrid.org/products/dune:/cvmfs/fermilab. opensciencegrid.org/products/common/db
```

```bash
[rosulej@dune-vm-build-02 larsoft]$ mrbslp
local product directory is /afs/cern.ch/work/r/ rosulej/ larsoft/localProducts_larsoft_v06_40_00_e14_prof
---------- this block should be empty ----------
```

```bash
[rosulej@dune-vm-build-02 ~]$ cd /afs/cern.ch/work/r/ rosulej/ ← your folder, e.g. in AFS work area, or EOS in the future
[rosulej@dune-vm-build-02 rosulej]$ mkdir job ← make a directory for job configuration files
[rosulej@dune-vm-build-02 rosulej]$ mkdir data ← make a directory for LArSoft output files: sim, reco
[rosulej@dune-vm-build-02 rosulej]$ cd ~/larsoft ← run LArSoft (lar -c ...) from this location
[rosulej@dune-vm-build-02 larsoft]$ ls build_slf7.x86_64 ← build area ($MRB_BUILD), run compilation from here
localProducts_larsoft_v06_40_00_e14_prof/srcs ← development area ($MRB_SOURCE), edit code here
```
For your future work: **Upgrade to the newest LArSoft release** (please, login to a fresh terminal):

[rosulej@dune-vm-build-02 larsoft]$ source /cvmfs/dune.opensciencegrid.org/products/dune/setup_dune.sh
Setting up larsoft UPS area... /cvmfs/fermilab.opensciencegrid.org/products/larsoft/
Setting up DUNE UPS area... /cvmfs/dune.opensciencegrid.org/products/dune/

[rosulej@dune-vm-build-02 larsof]$ source /cvmfs/fermilab.opensciencegrid.org/products/larsoft/setups
[rosulej@dune-vm-build-02 larsof]$ setup mrb

*Use your NEW release number here:*

[rosulej@dune-vm-build-02 larsof]$ mrb newDev -p -v v06_41_00 -q e14:prof
[rosulej@dune-vm-build-02 larsof]$ source localProducts_larsoft_v06_41_00_e9_prof/setup

MRB_PROJECT=larsoft
MRB_PROJECT_VERSION=v06_41_00
MRB_QUALS=e14:prof
MRB_TOP=/afs/cern.ch/work/r/rosulej/larsoft
MRB_SOURCE=/afs/cern.ch/work/r/rosulej/larsoft/srcs
MRB_BUILDDIR=/afs/cern.ch/work/r/rosulej/larsoft/build_slf7.x86_64
MRB_INSTALL=/afs/cern.ch/work/r/rosulej/larsoft/localProducts_larsoft_v06_41_00_e14_prof
PRODUCTS=/afs/cern.ch/work/r/rosulej/larsoft/localProducts_larsoft_v06_41_00_e14_prof:/cvmfs/fermilab.opensciencegrid.org/products/larsoft:/cvmfs/dune.opensciencegrid.org/products/dune:/cvmfs/fermilab.opensciencegrid.org/products/larsoft:/cvmfs/fermilab.opensciencegrid.org/products/common/db

*Update source codes in repositories you are developing (remember to call „kinit username@FNAL.GOV“):*

[rosulej@dune-vm-build-02 larsof]$ cd $MRB_SOURCE
[rosulej@dune-vm-build-02 srcs]$ cd dunetpc
[rosulej@dune-vm-build-02 srcs]$ git checkout develop
[rosulej@dune-vm-build-02 srcs]$ git pull

...and rebuild:

[rosulej@dune-vm-build-02 srcs]$ cd $MRB_BUILDDIR
[rosulej@dune-vm-build-02 build_slf7.x86_64]$ mrb z
[rosulej@dune-vm-build-02 build_slf7.x86_64]$ mrbsetenv

local product directory is /afs/cern.ch/work/r/rosulej/larsoft/localProducts_larsoft_v06_41_00_e14_prof

--------- this block should be empty ---------

---------------------------------------------------------

[rosulej@dune-vm-build-02 build_slf7.x86_64]$ mrb i --j4
Run particle gun:

```
lar -c srcs/dunetpc/fcl/protodune/gen/gen_protoDune_pion_2GeV_mono.fcl -n 10 -o pi_gen.root
```

location of DUNE standard configuration files
you may skip entire path using .fcl files committed to the repository
(but it is good to know where they come from)
this will work as well:

```
lar -c gen_protoDune_pion_2GeV_mono.fcl -n 10 -o pi_gen.root
```

number of events to produce (do not skip it, default is huge!)

```
lar -c gen_protoDune_pion_2GeV_mono.fcl -n 10 -o pi_gen.root
```

output file with events, place it in your data directory

What was generated:

- $\pi^+$ at 2GeV/c, monoenergetic
- in ProtoDUNE single-phase geometry
- in the position just in front of beam window, pointing towards it
Run G4 propagation of particles:

```
lar -c srcs/dunetpc/fcl/protodune/g4/protoDUNE_g4.fcl pi_gen.root -o pi_g4.root
```

G4 (as each sim/reco step has its own directory for configuration files)

```
lar -c protoDUNE_g4.fcl pi_gen.root -o pi_g4.root
```

use output file from previous step as input to the next step

```
lar -c protoDUNE_g4.fcl pi_gen.root -o pi_g4.root
```

and put the path/filename for output

**What was simulated:**

- $\pi^+$ with the initial momentum 2GeV/c, all interactions of it and secondary particles
- in ProtoDUNE single-phase geometry
- full MC truth information is saved to the output file
- energy deposits in LAr were recorded as well
Run detector simulation:

```
lar -c srcs/dunetpc/fcl/protodune/detsim/protoDUNE_detsim.fcl  pi_g4.root  -o pi_detsim.root
```


here is the place of detector simulation job files

```
lar -c protoDUNE_detsim.fcl  pi_g4.root  -o pi_detsim.root
```

use G4 simulation as input to the detector simulation

```
lar -c protoDUNE_detsim.fcl  pi_g4.root  -o pi_detsim.root
```

and put the path/filename for output

What was simulated:

- scintillation light and ionization electrons from energy deposits in LAr
- recombination of ionization electrons
- attenuation of electrons number due to LAr impurities at given drift distance
- longitudinal and transverse diffusion of electrons at given drift distance

ProtoDUNE single-phase readout:

- E-field response for induction and collection planes
- electronics response
- noise
- ADC waveforms on readout channels
Run reconstruction:

```
lar -c srcs/dunetpc/fcl/protodune/reco/protoDUNE_reco.fcl  pi_detsim.root  -o pi_reco.root
```

several reconstruction chains

```
lar -c protoDUNE_reco.fcl  pi_detsim.root  -o pi_reco.root
```

use detector simulation as input to the reconstruction

```
lar -c protoDUNE_reco.fcl  pi_detsim.root  -o pi_reco.root
```

and put the path/filename for output

**What was reconstructed (with a success or not):**

- deconvoluted ADC waveforms (recob::Wire’s)
- hits on wire waveforms (recob::Hit)
- 2D clusters (recob::Cluster)
- 3D tracks (recob::Track)
- 3D vertices (recob::Vertex)
- Full event description (all above bounded in particle hierarchy, recob::PFParticle)
FHiCL job configuration file (here protoDUNE_reco.fcl):

```
#include "services_dune.fcl"

process_name: Reco

services: {...}

source: {...}

physics:

producers:

{
    rns: { module_type: RandomNumberSaver }
    caldata: @local::producer_adcprep
    ...
    ...
    pmtrack: @local::dunefd_pmalgtrackmaker
}

reco: [ rns, ophit, opflash, ... ]

stream1: [ out1 ]

trigger_paths: [reco]

end_paths: [stream1]

}

outputs:

{ out1: {...} }
```

At the end of file: configuration of module parameters:

physics.producers.pmtrack.HitModuleLabel: "linecluster"
physics.producers.pandora.HitFinderModuleLabel: "linecluster"

Event display:
lar -c srcs/dunetpc/dune/Utilities/evd_protoDUNE.fcl pi_reco.root

or simply:
lar -c evd_protoDUNE.fcl pi_reco.root

All event display features illustrated in YoungDUNE tutorial: https://indico.fnal.gov/getFile.py/access?contribId=5&resId=0&materialId=slides&confId=12889
Lunch