

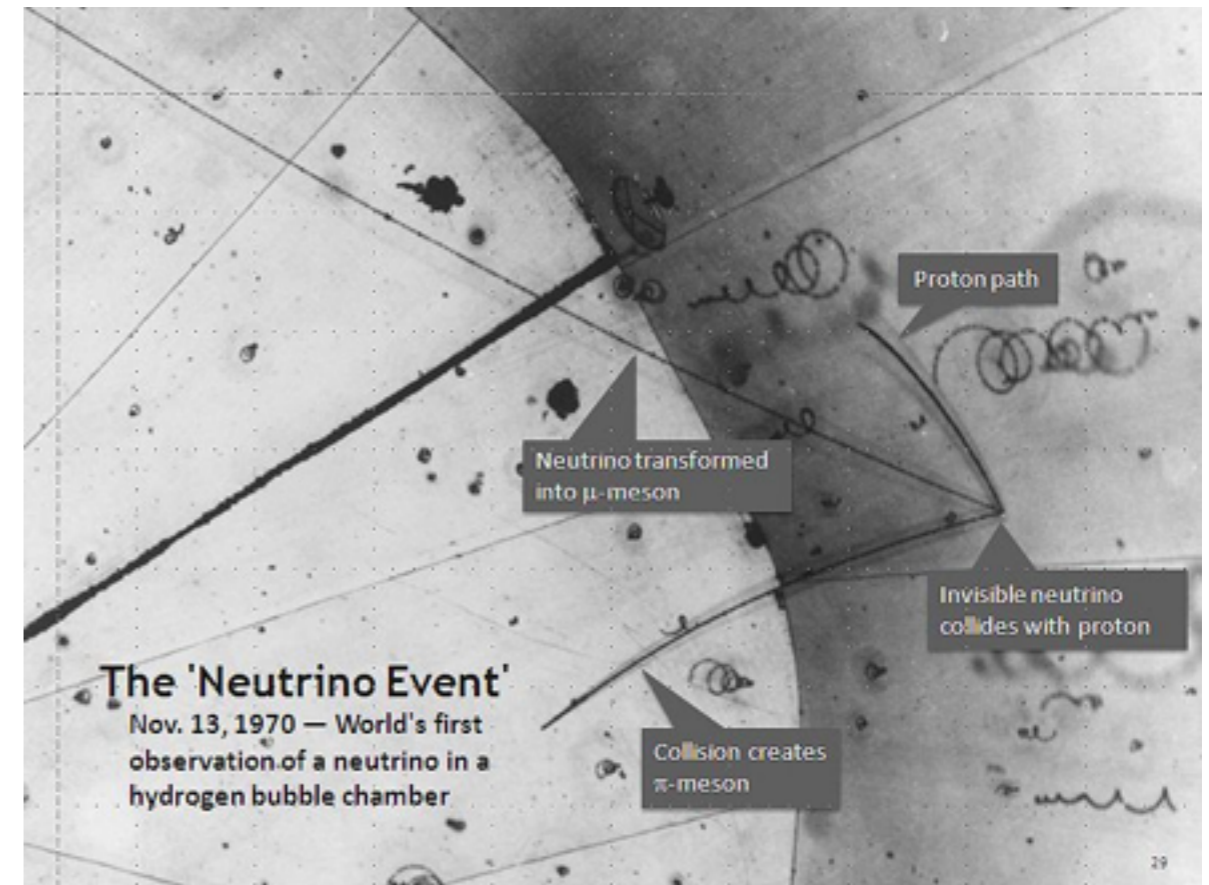


Young DUNE One Day Software Tutorial

Aaron Higuera

DUNE FD Event Display

Why we need an event display?



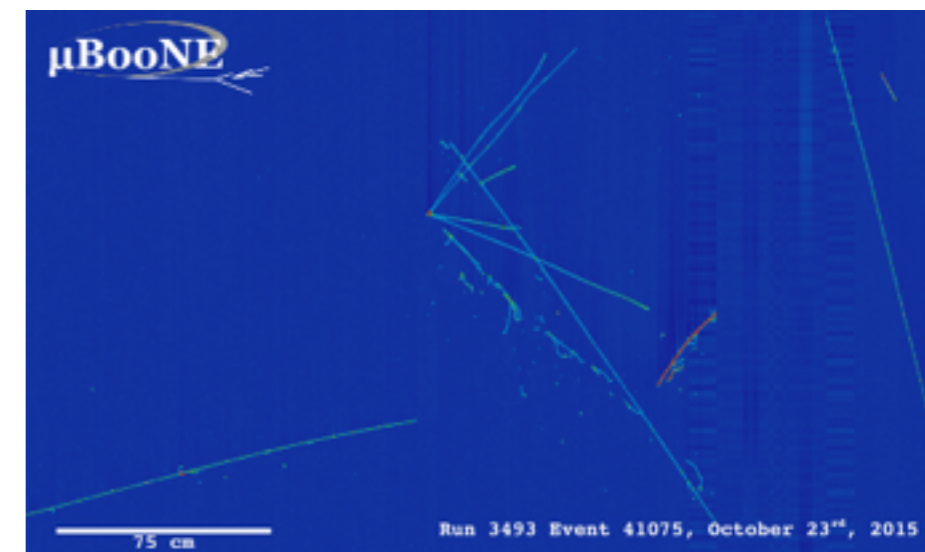
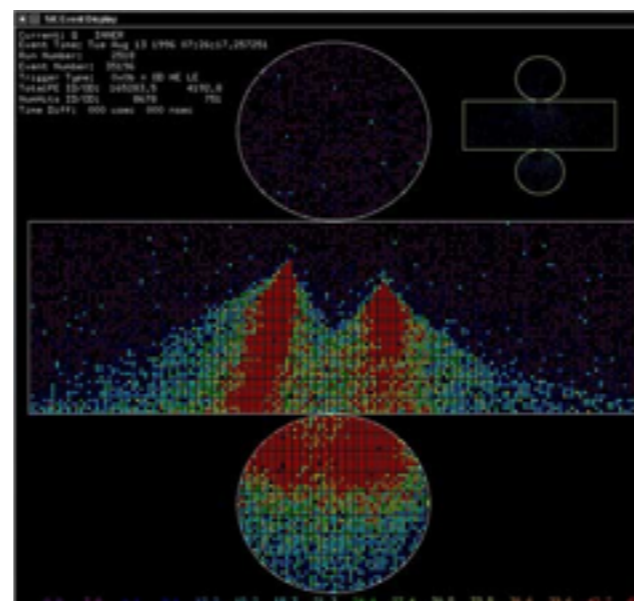
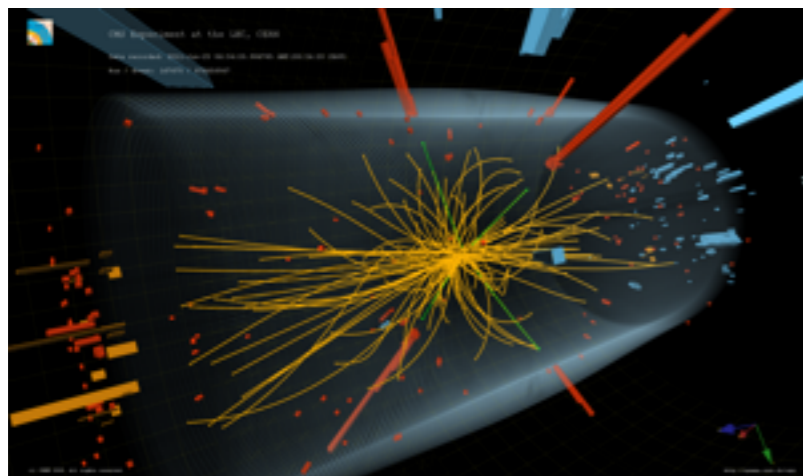
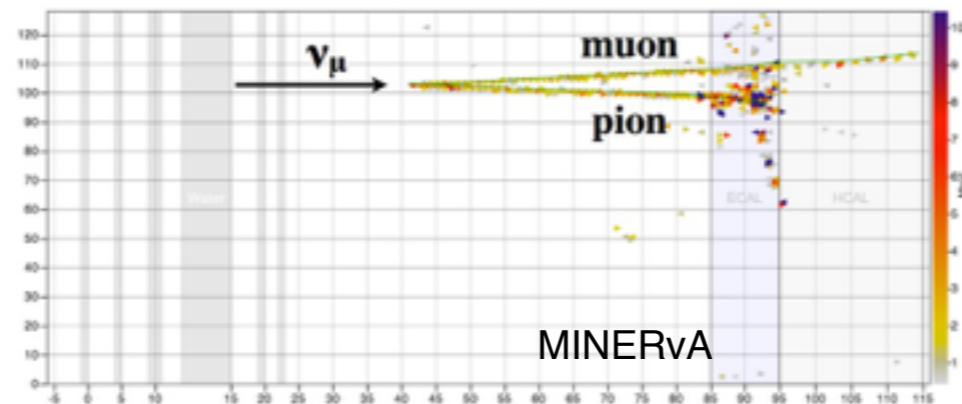
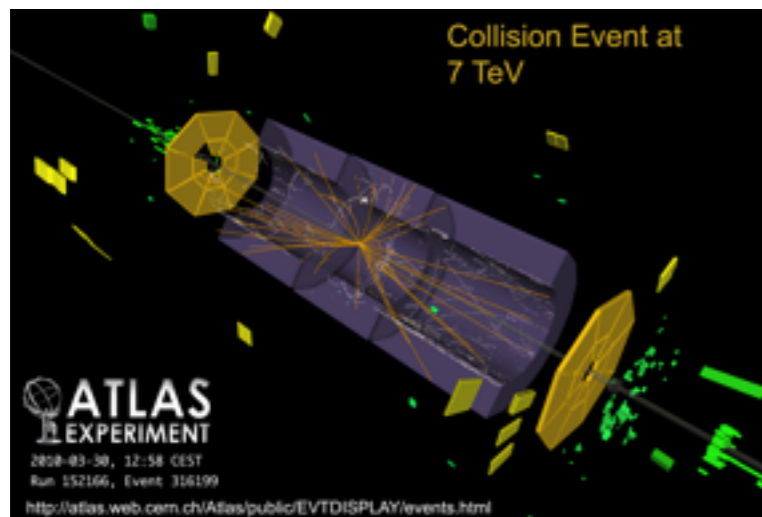
We want to "see" neutrinos!!

DUNE FD Event Display

Why we need an event display?

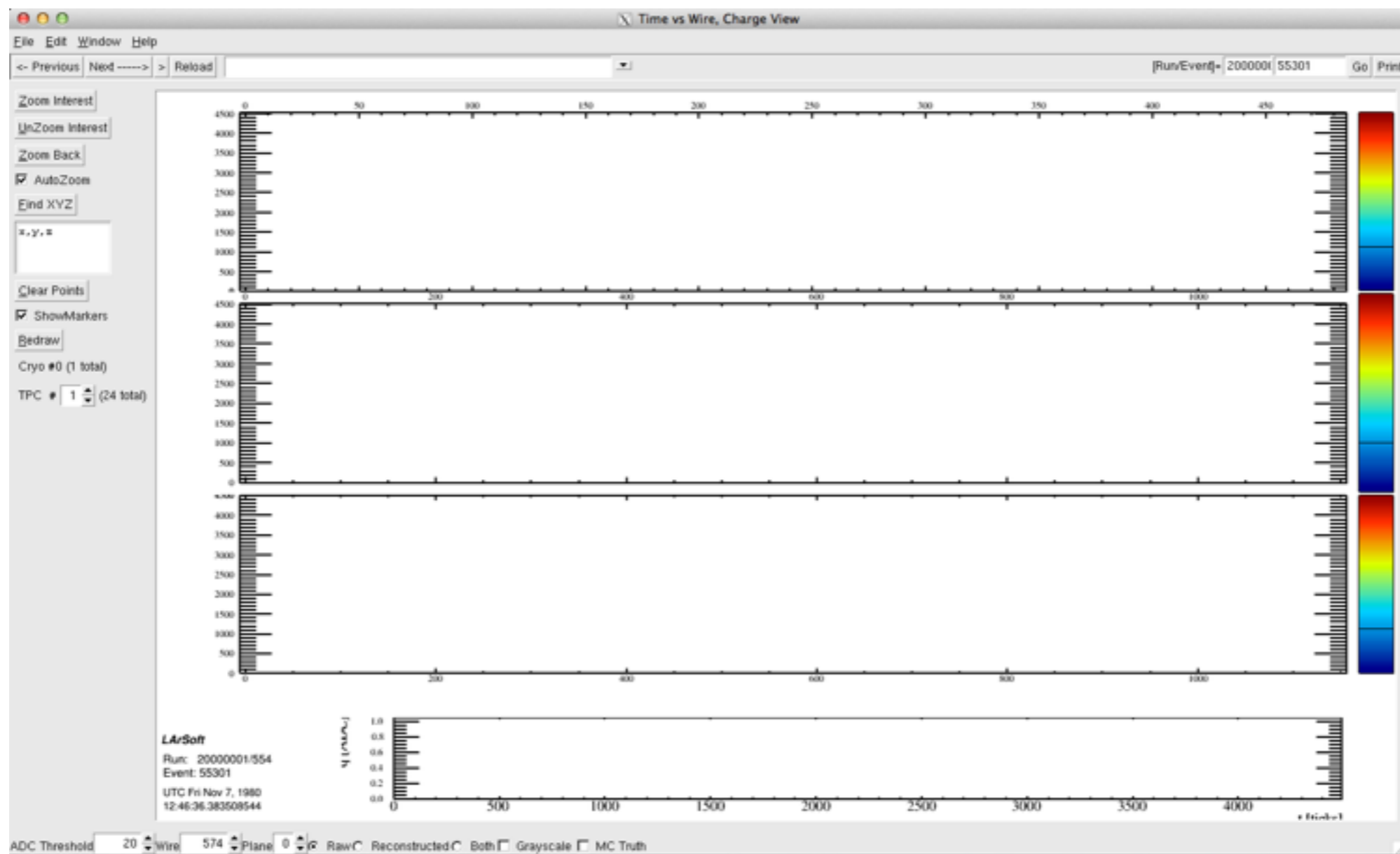
It make your experiment look great... again

And many other reasons you will find out when doing your analysis



DUNE FD Event Display

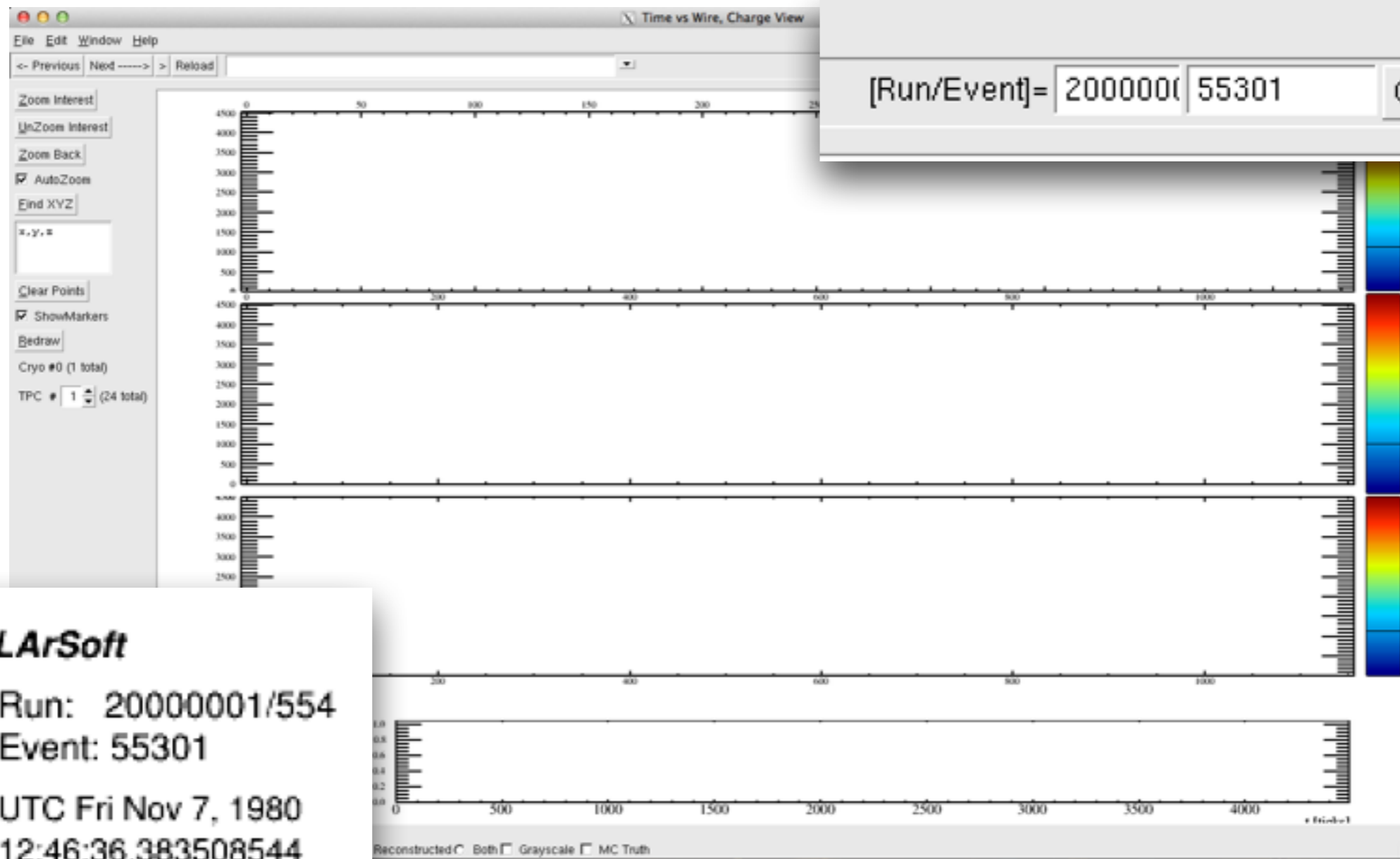
```
$ lar -c evd_dunefd.fcl myreco_file.root
```



DUNE FD Event Display

```
/pnfs/dune/scratch/dunepro/v06_02_00/reco/  
prodgenie_nu_dune10kt_1x2x6/12878103_243/  
prodgenie_nu_dune10kt_1x2x6_553_20160810T054821_gen_5b  
ae27ae-7cb4-4528-97a2-1bb6cdfc03c1_g4_detsim_reco.root
```

```
$ lar -c evd_dunefd.fcl
```

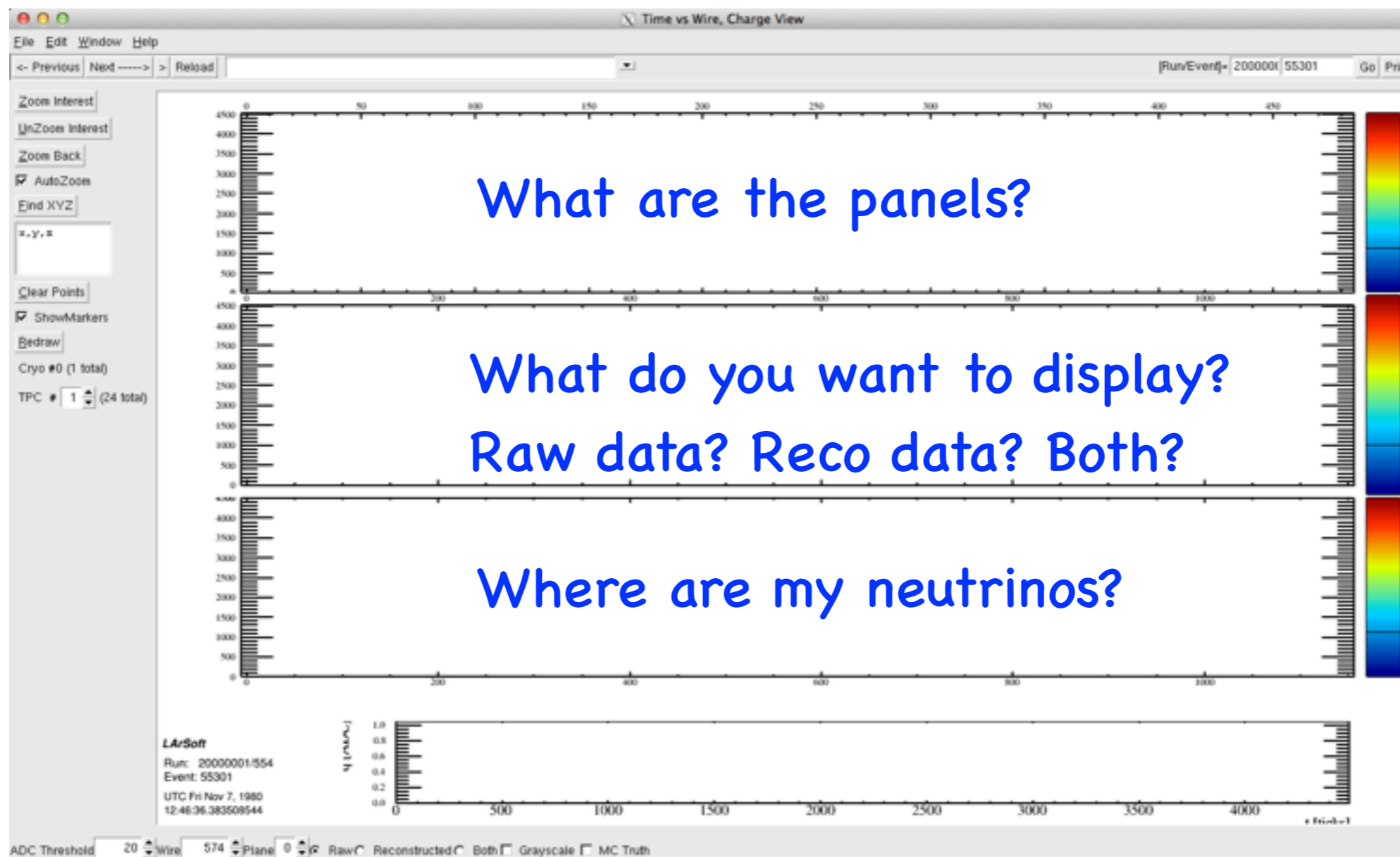


[Run/Event]= 2000001 55301 Go Print

LArSoft
Run: 2000001/554
Event: 55301
UTC Fri Nov 7, 1980
12:46:36.383508544

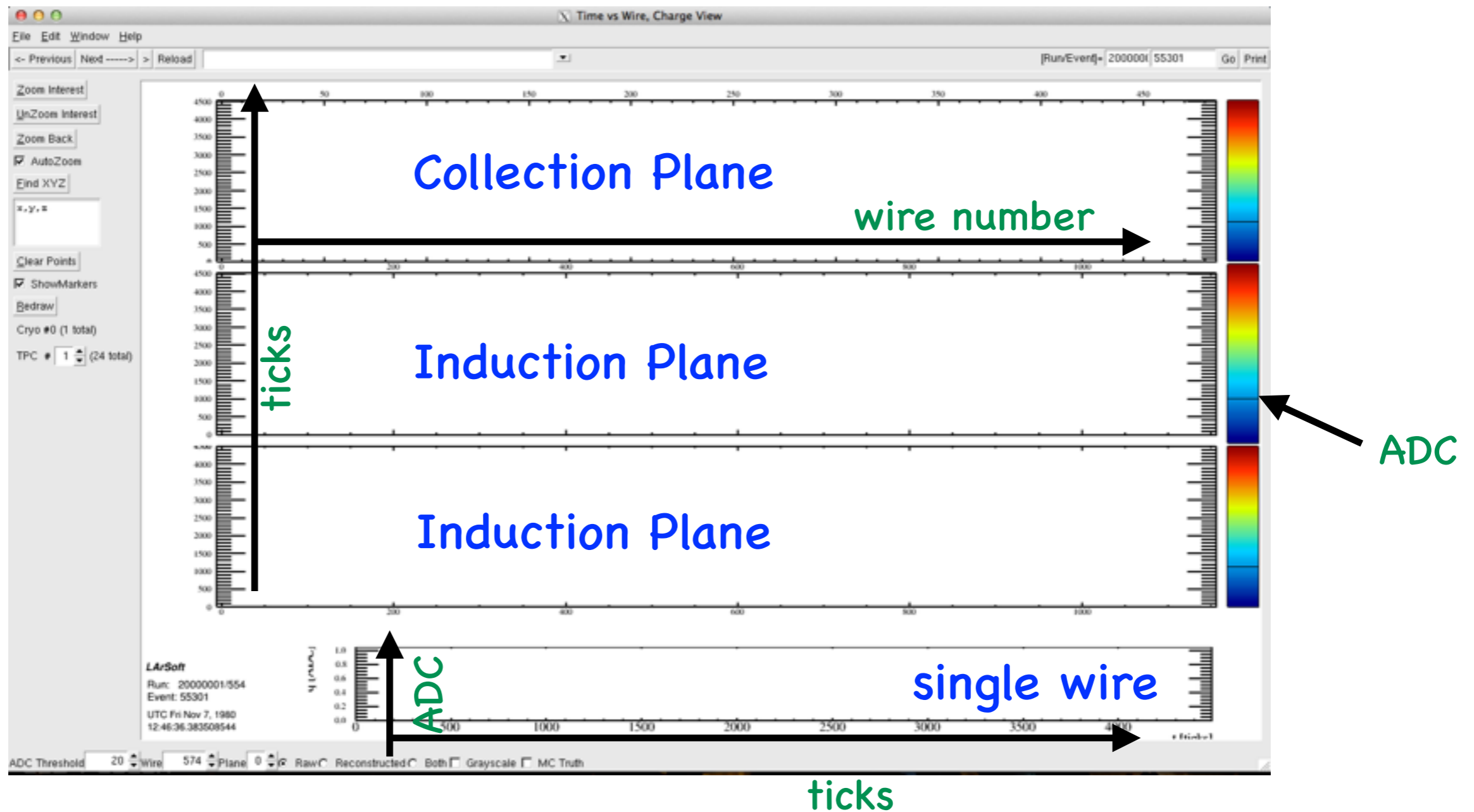
DUNE FD Event Display

```
$ lar -c evd_dunefd.fcl myreco_file.root
```



DUNE FD Event Display

```
$ lar -c evd_dunefd.fcl myreco_file.root
```



DUNE FD Event Display

```
$ lar -c evd_dunefd.fcl myreco_file.root
```

The screenshot displays the DUNE FD Event Display software interface. The main window shows a plot of the detector response with a vertical axis ranging from 0 to 4500 and a horizontal axis from 0 to 450. A color scale on the right indicates signal intensity. The interface includes a menu bar (File, Edit, Window, Help) and a toolbar with buttons for 'Configure Drawing', 'Configure Experiment Services', and 'Configure Art Services'. A 'Drawing Services' dialog box is open, showing configuration options for the plot. The dialog has tabs for 'Raw', 'Reco', 'Color', 'Analysis', and 'Simulation'. The 'Raw' tab is selected, and the following options are visible:

Option	Value
AxisOrientation	0
Cryostat	0
DrawRawDataOrCalibWires	0
MinimumSignal	20
RawDataLabel	daq
ScaleDigitsByCharge	0
StartTick	0
TPC	1
TicksPerPoint	1
TotalTicks	4492
UncompressWithPed	true

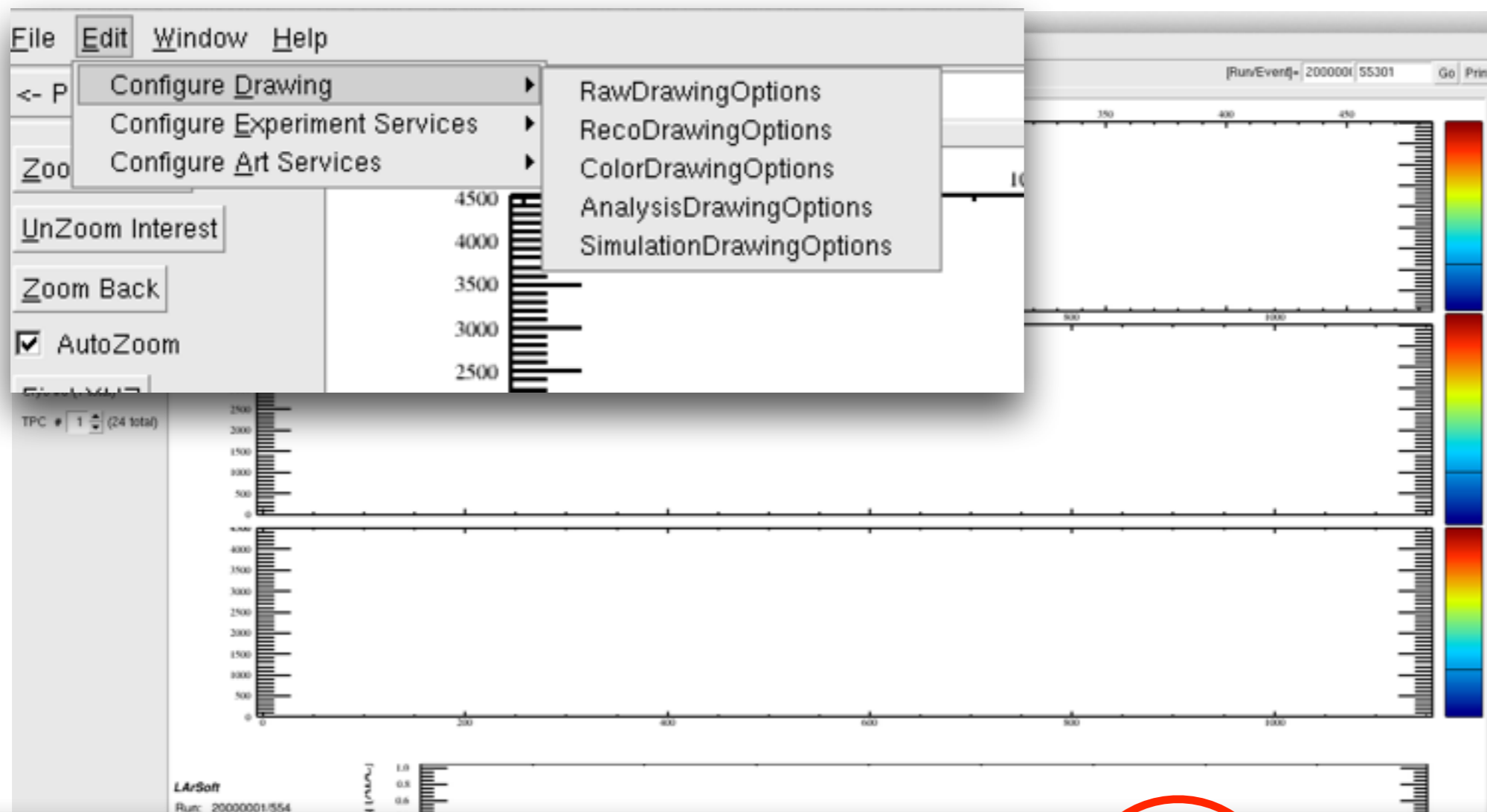
At the bottom of the main window, there is a status bar with the following information:

ADC Threshold: 20 Wire: 574 Plane: 0 Raw Reconstructed Both Grayscale MC Truth

Run: 2000001/554
Event: 55301
UTC Fri Nov 7, 1980
12:46:36.383508544

DUNE FD Event Display

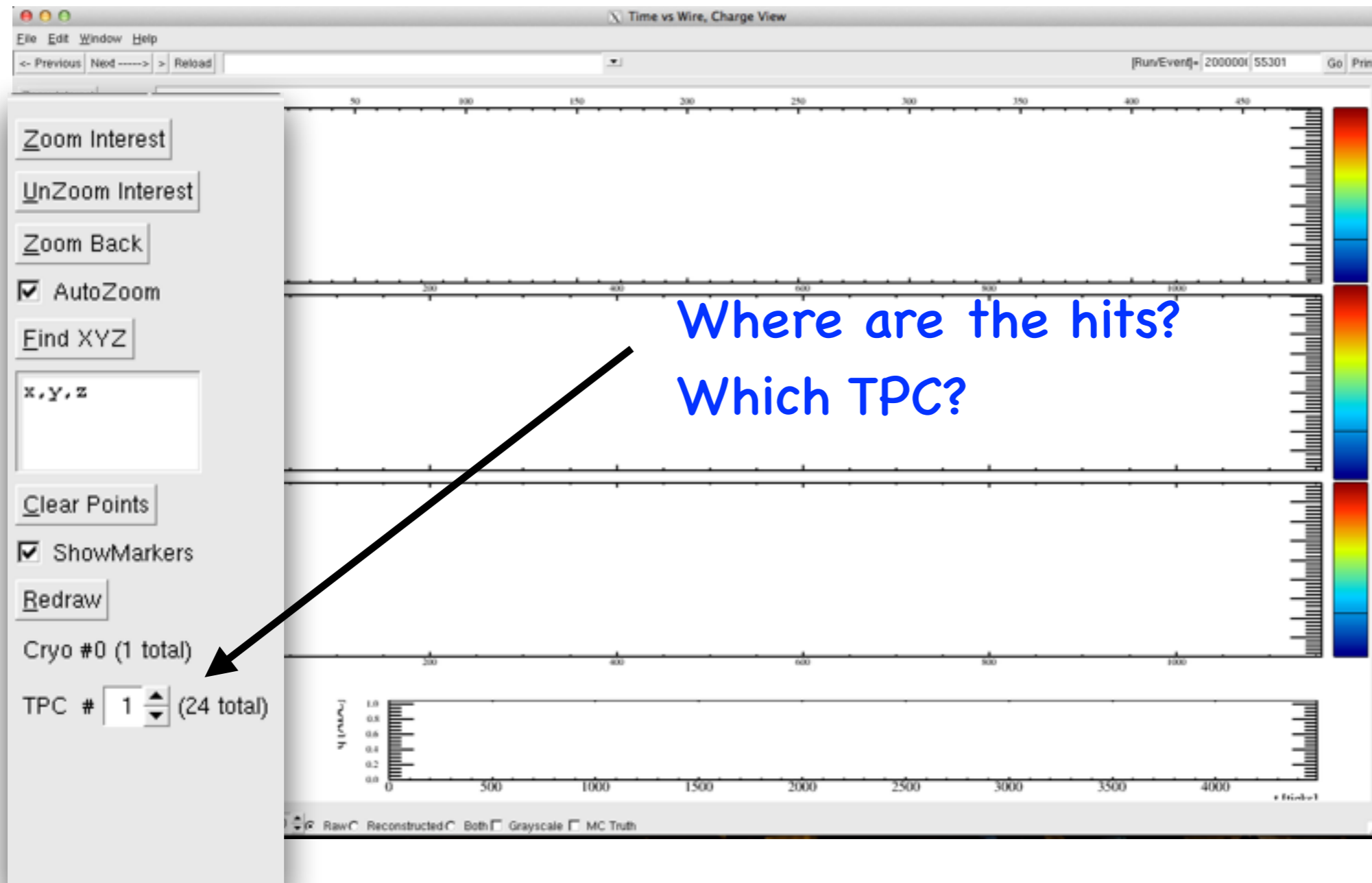
```
$ lar -c evd_dunefd.fcl myreco_file.root
```



ADC Threshold Wire Plane Raw Reconstructed Both Grayscale MC Truth

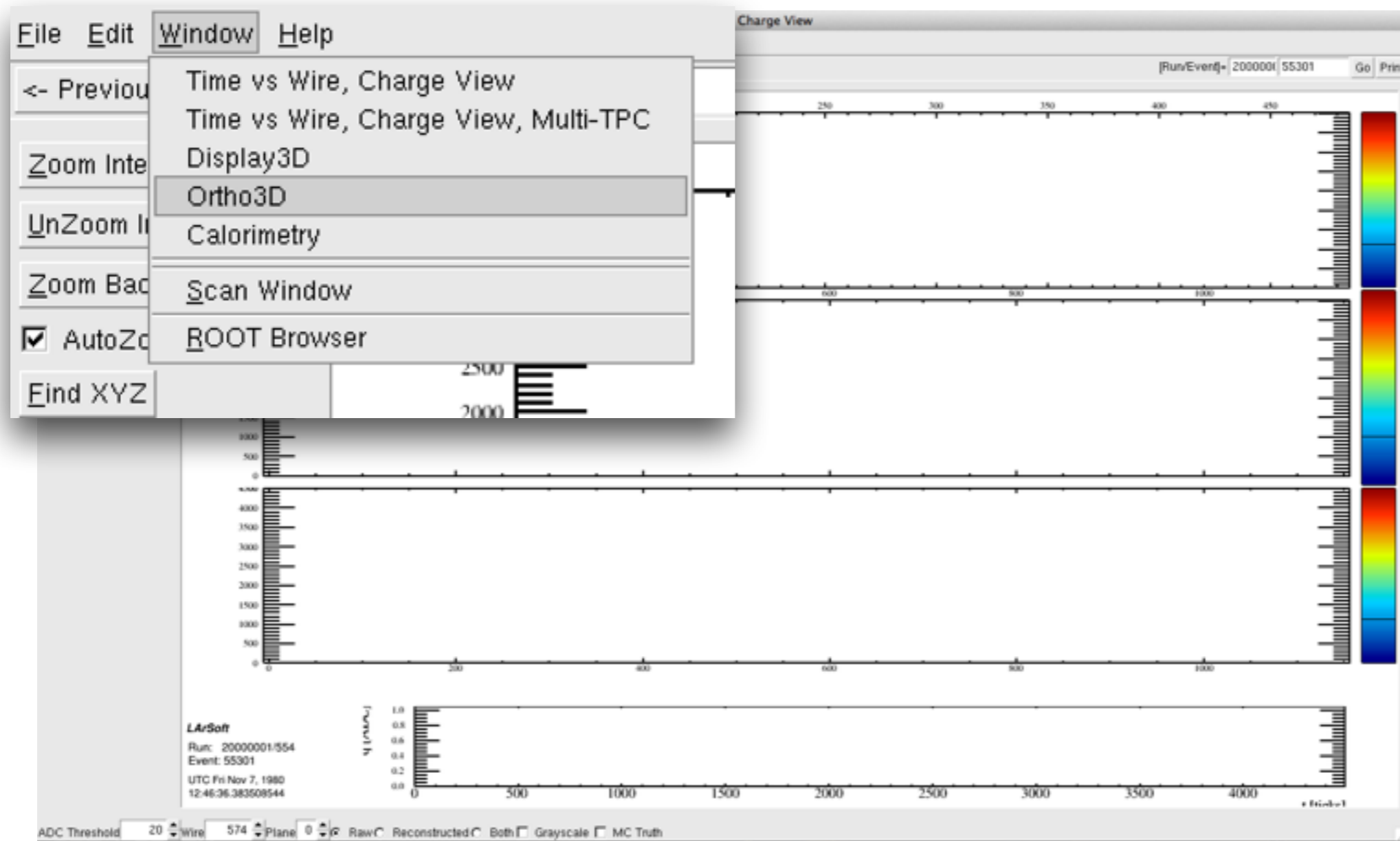
DUNE FD Event Display

```
$ lar -c evd_dunefd.fcl myreco_file.root
```



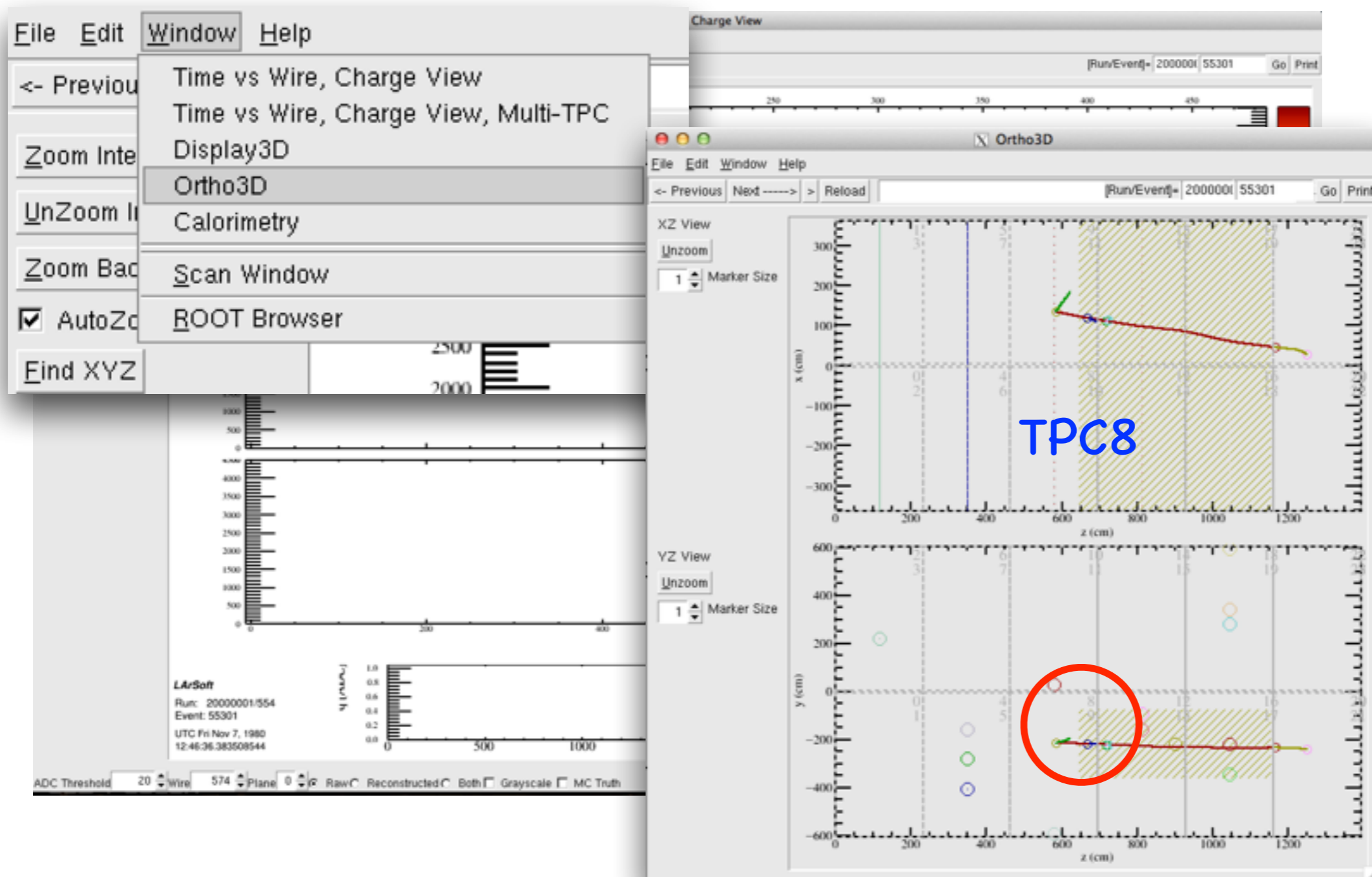
DUNE FD Event Display

```
$ lar -c evd_dunefd.fcl myreco_file.root
```



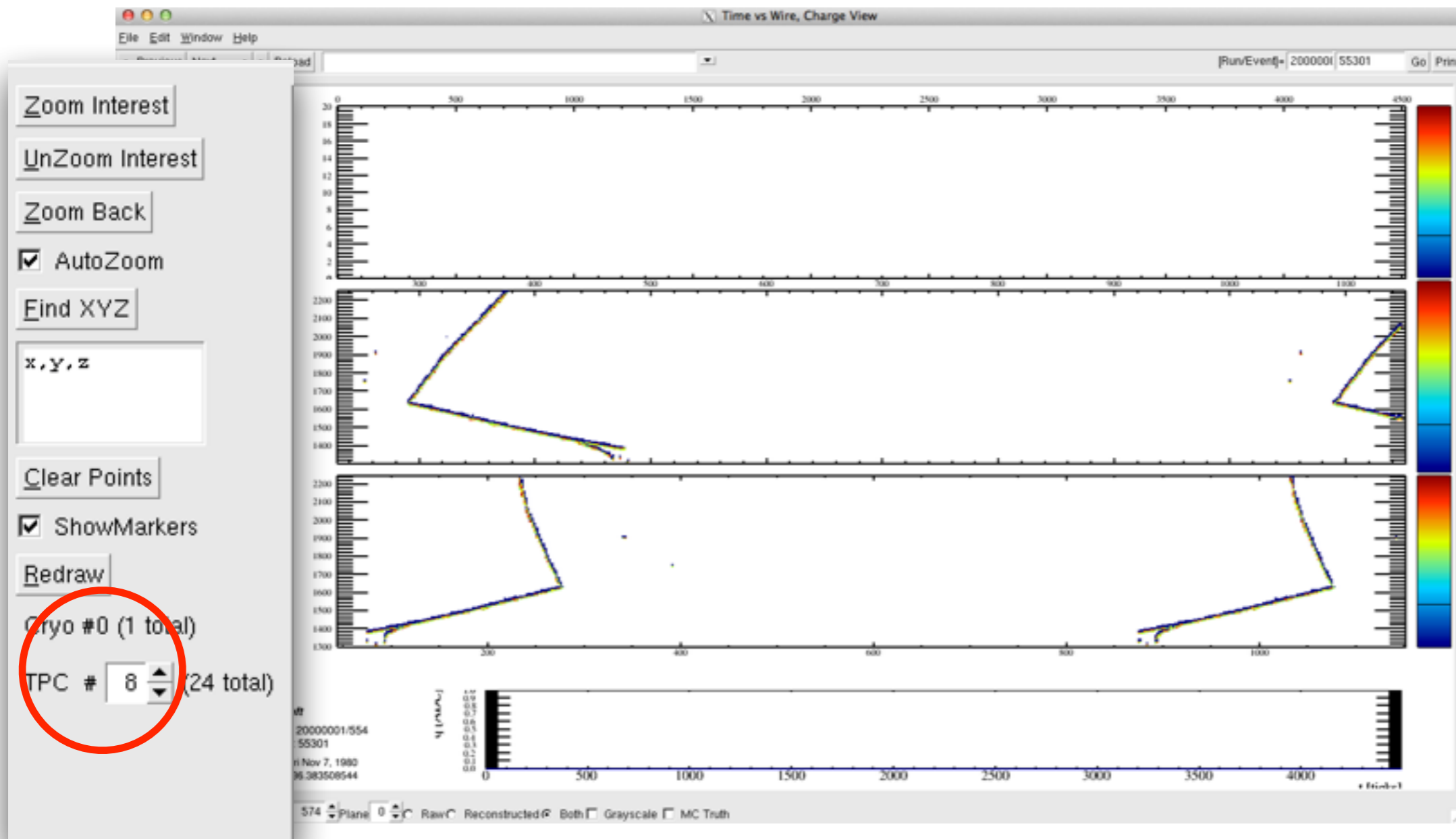
DUNE FD Event Display

```
$ lar -c evd_dunefd.fcl myreco_file.root
```



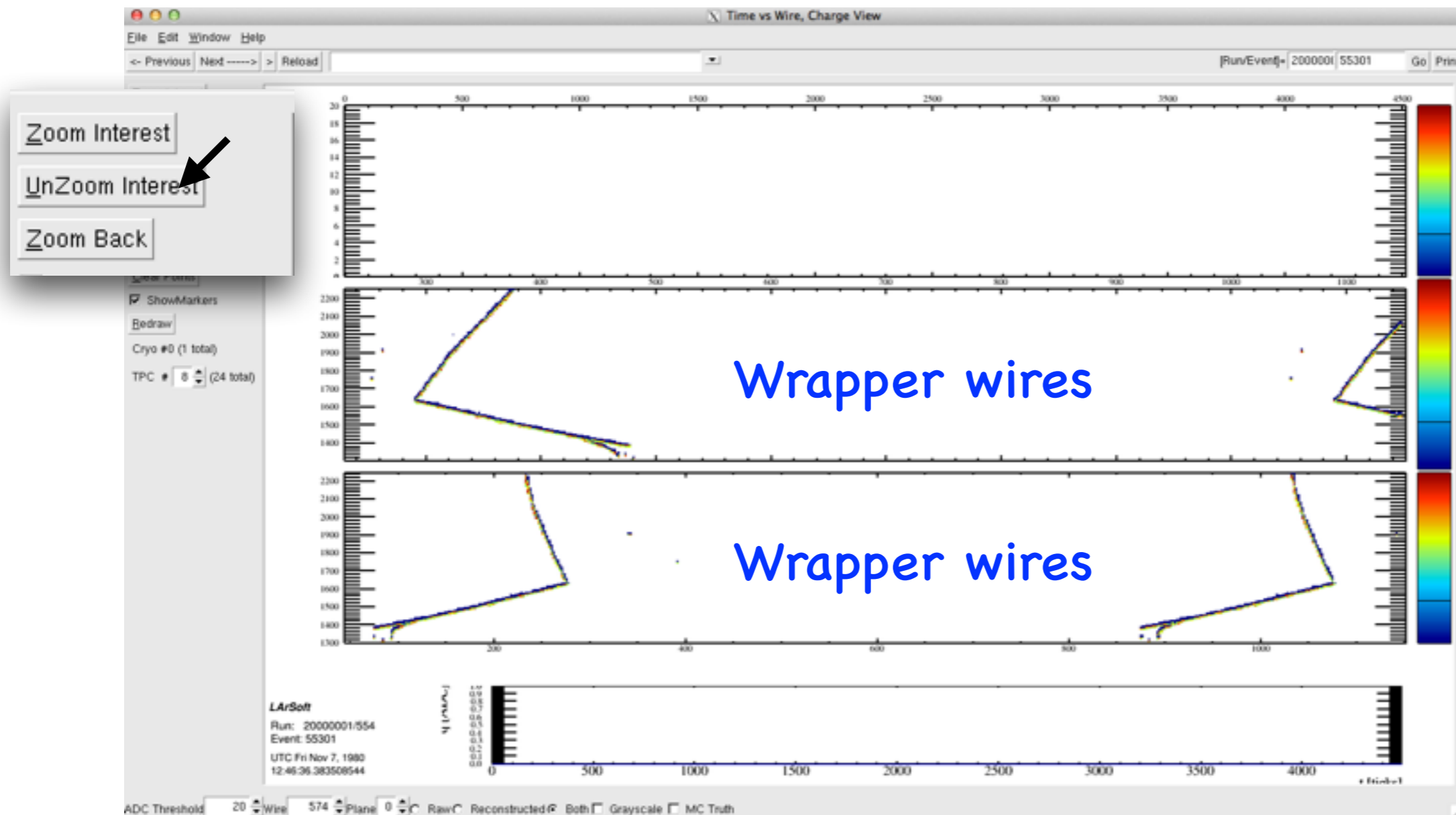
DUNE FD Event Display

```
$ lar -c evd_dunefd.fcl myreco_file.root
```



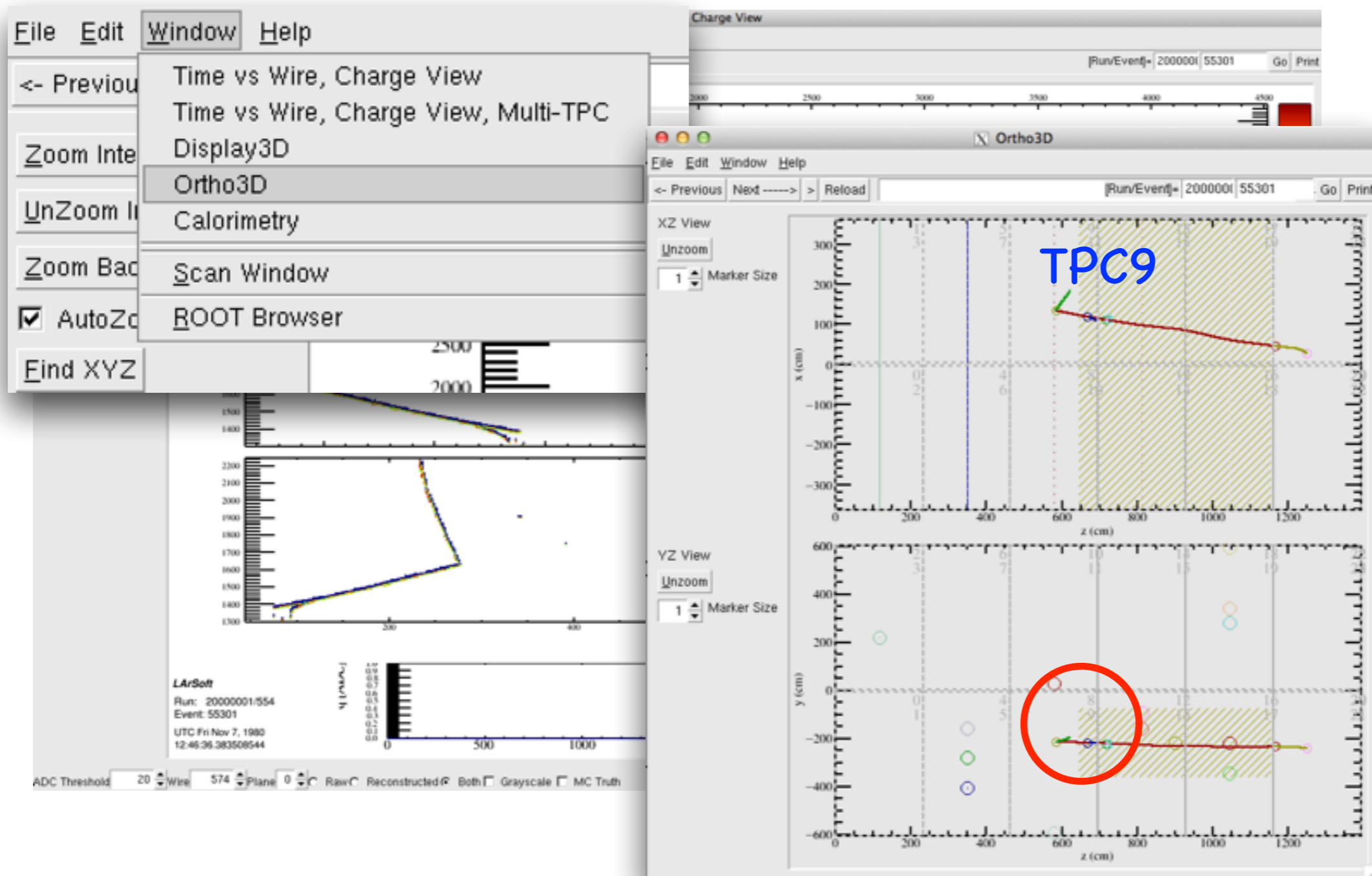
DUNE FD Event Display

```
$ lar -c evd_dunefd.fcl myreco_file.root
```



DUNE FD Event Display

```
$ lar -c evd_dunefd.fcl myreco_file.root
```



DUNE FD Event Display

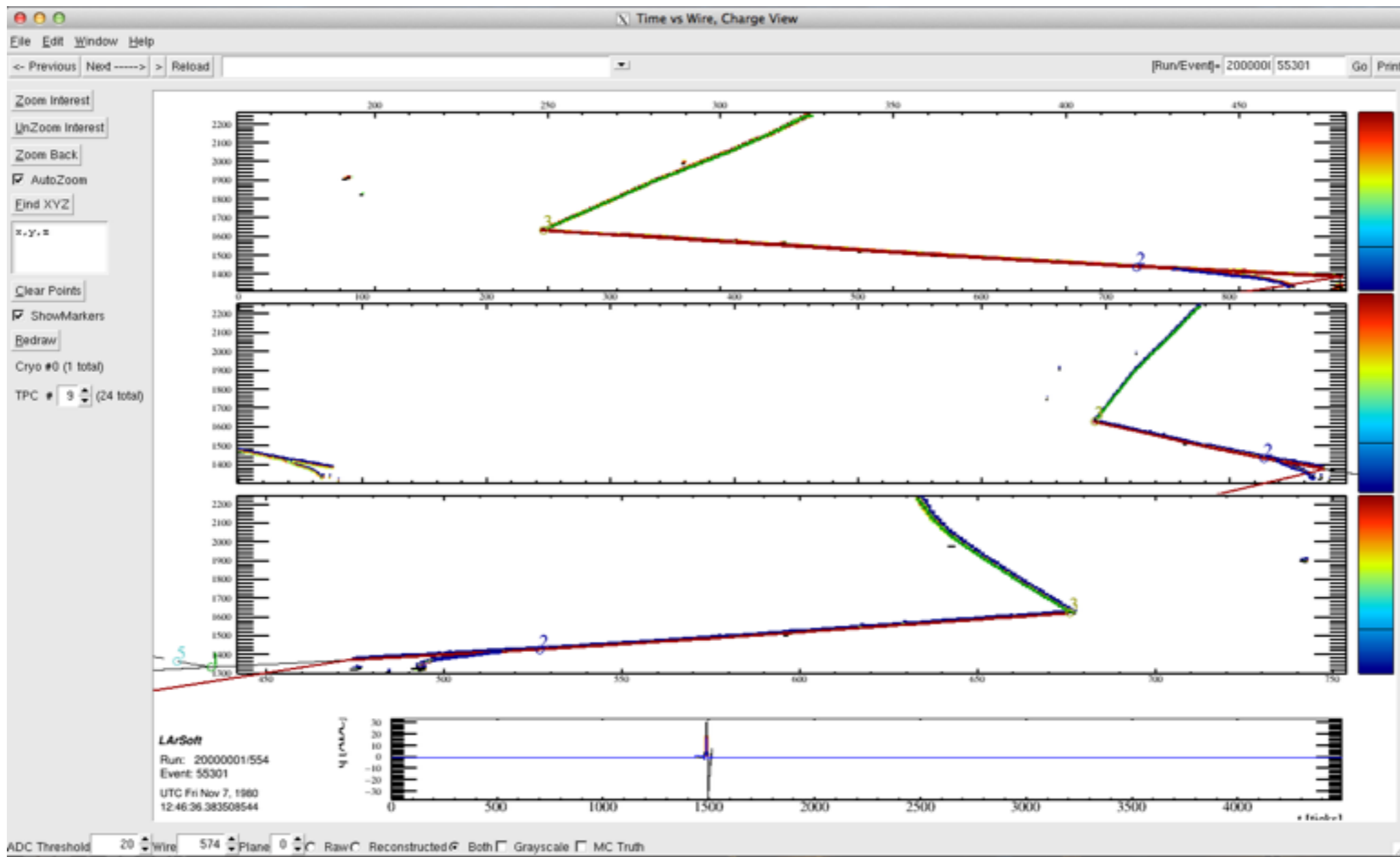
```
$ lar -c evd_dunefd.fcl myreco_file.root
```

The image shows a screenshot of the DUNE FD Event Display software interface. The main window is titled "Time vs Wire, Charge View" and displays two plots. The top plot shows a wire charge distribution with a peak at approximately 4500. The bottom plot shows a track reconstruction with a peak at approximately 1500. The interface includes a menu bar (File, Edit, Window, Help) and a toolbar with buttons for "UnZoom Interest", "Redraw", and "Cryo #0 (1 total)". A "TPC # 9 (24 total)" dropdown menu is highlighted with a red circle. The "Drawing Services" dialog box is open, showing a list of drawing options and their values. An arrow points to the "Apply" button at the bottom of the dialog.

Option	Value
DrawTracks	1
DrawVertices	1
EndPoint2DModuleLabels	0
EventModuleLabels	0
FlashMinPE	0
FlashTMax	1e9
FlashTMin	-1e9
HitModuleLabels	[lineclusterdc]
OpFlashModuleLabels	[opflash]
PFPModuleLabels	[pandora]
ProngModuleLabels	0
SeedModuleLabels	[seedfinder]
SelectedHitColor	6
ShowerModuleLabels	[showerreco]
SpacePointModuleLabels	[spacepts]
TrackModuleLabels	[gmtrack]
TrkVtxCosmicLabels	0
TrkVtxFilterLabels	0
TrkVtxTrackLabels	0
UseHitSelector	false
VertexModuleLabels	[gmtrack]
WireModuleLabels	[caldata]

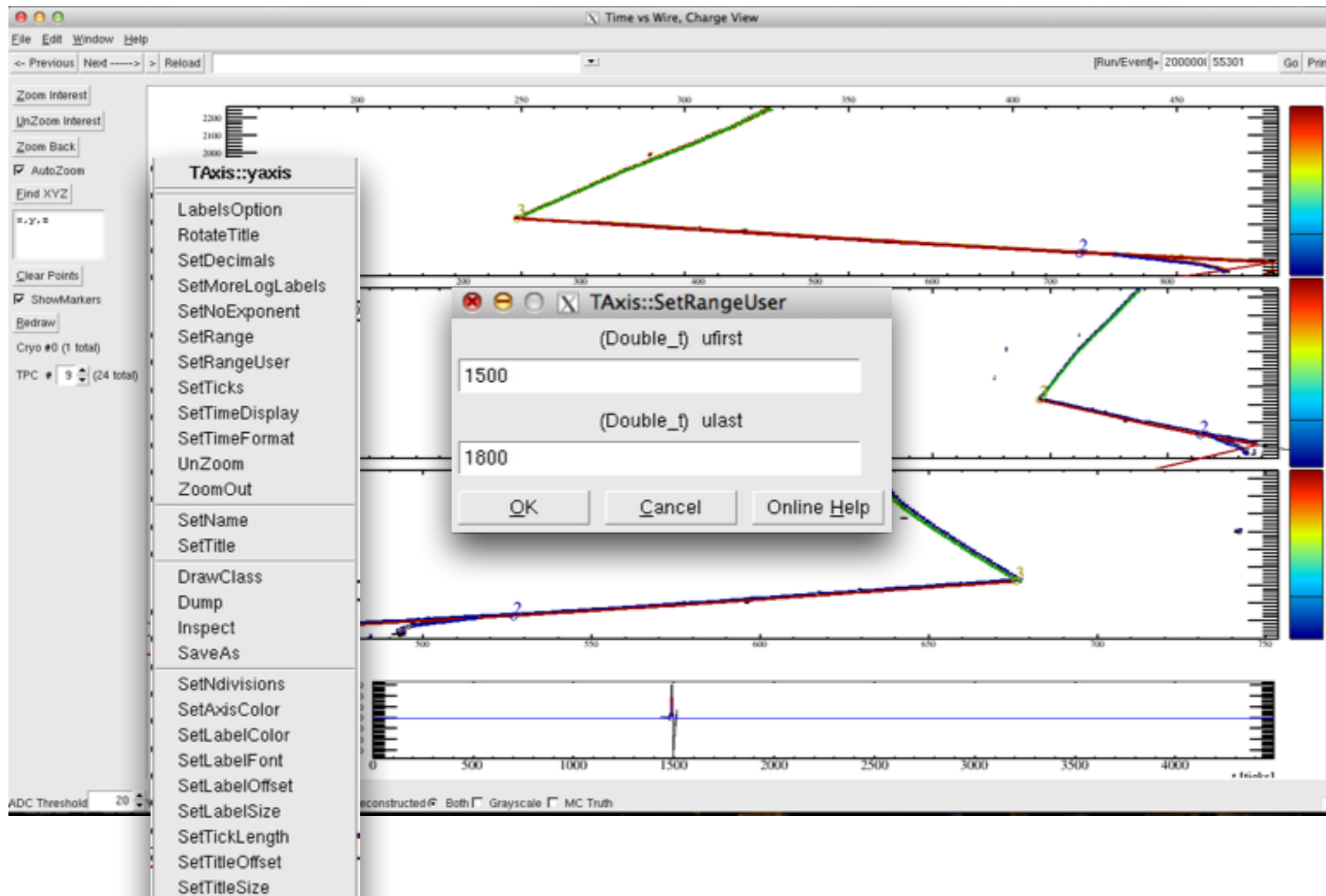
DUNE FD Event Display

```
$ lar -c evd_dunefd.fcl myreco_file.root
```



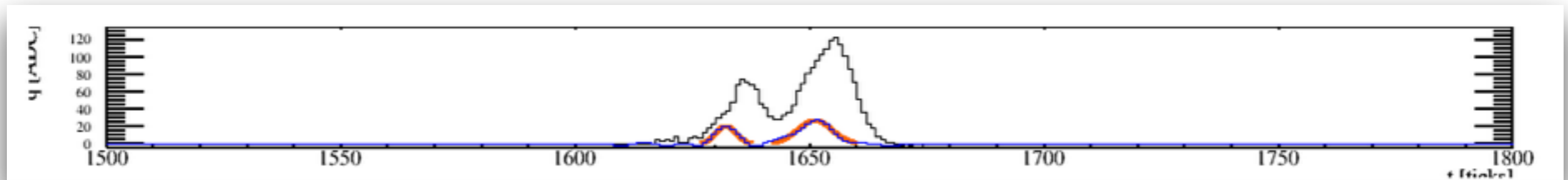
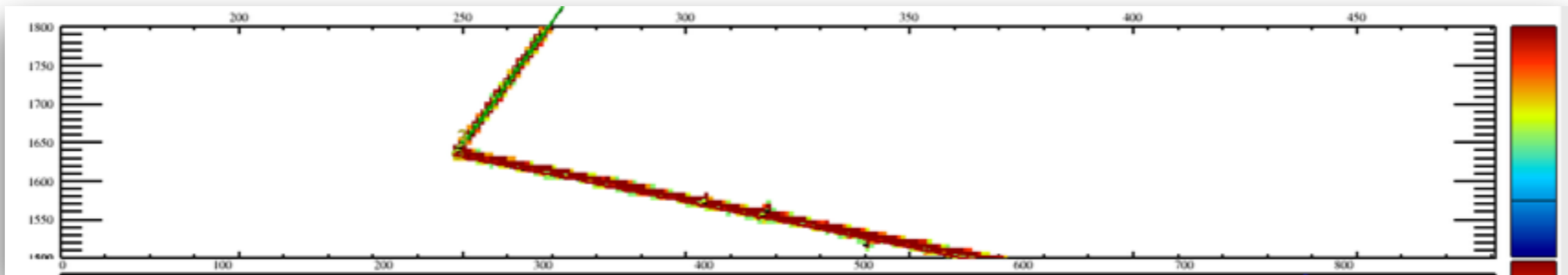
DUNE FD Event Display

```
$ lar -c evd_dunefd.fcl myreco_file.root
```



DUNE FD Event Display

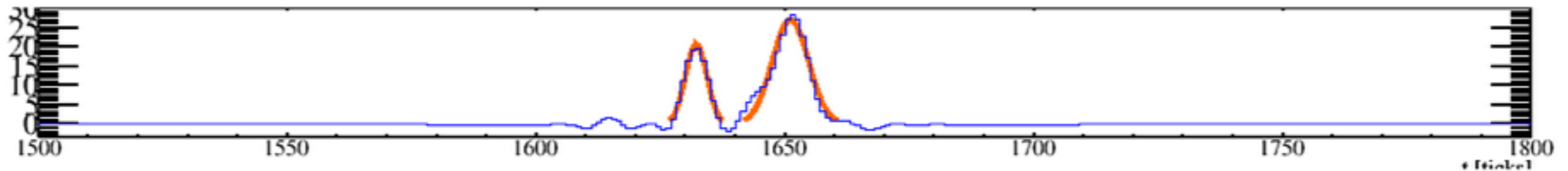
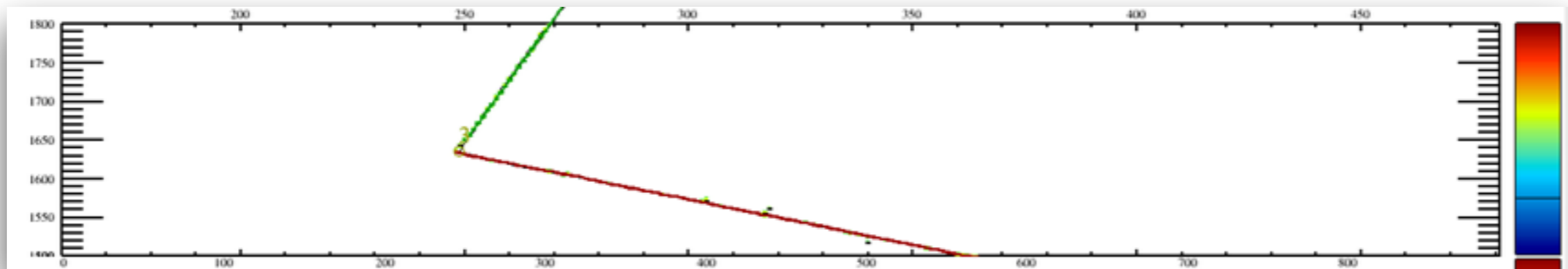
```
$ lar -c evd_dunefd.fcl myreco_file.root
```



ADC Threshold Wire Plane Raw Reconstructed Both Grayscale MC Truth

DUNE FD Event Display

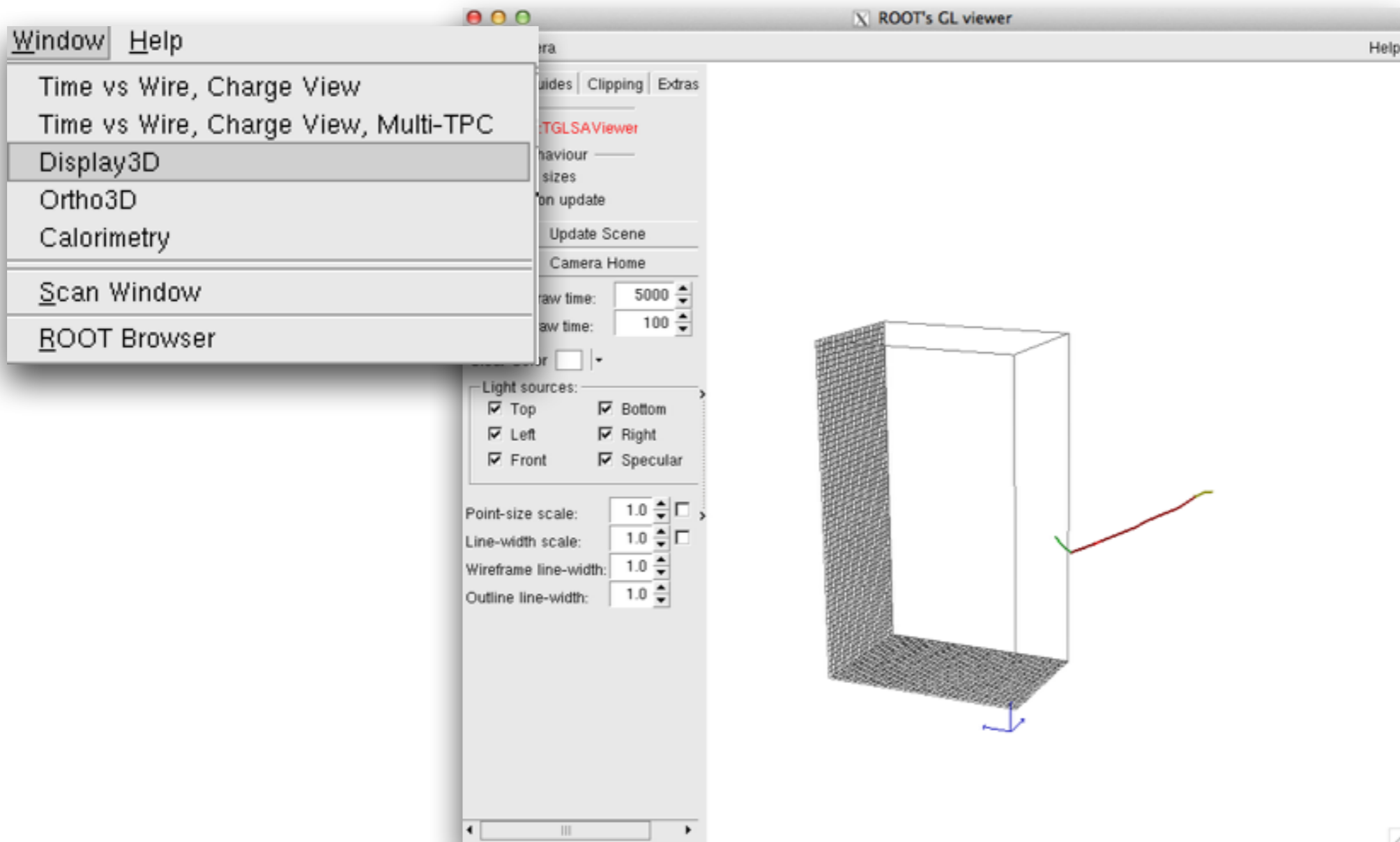
```
$ lar -c evd_dunefd.fcl myreco_file.root
```



ADC Threshold Wire Plane Raw Reconstructed Both Grayscale MC Truth

DUNE FD Event Display

```
$ lar -c evd_dunefd.fcl myreco_file.root
```



PART II

Check Out & Build DUNETPC



Log in

```
$ ssh -XY user@dunegpvmXX.fnal.gov
```

Source DUNE software

```
$ source /grid/fermiapp/products/dune/setup_dune.sh
```

```
$ cd /dune/app/users/username
```

```
$ ups list -aK+ dunetpc
```

```
"dunetpc" "v06_05_00" "Linux64bit+2.6-2.12" "debug:e10" ""  
"dunetpc" "v06_05_00" "Linux64bit+3.10-2.17" "debug:e10" ""  
"dunetpc" "v06_05_00" "Linux64bit+3.10-2.17" "e10:prof" ""  
"dunetpc" "v06_06_00" "Linux64bit+2.6-2.12" "e10:prof" ""  
"dunetpc" "v06_06_00" "Linux64bit+2.6-2.12" "debug:e10" ""
```

Check Out & Build DUNETPC



Set up

```
$ setup dunetpc v06_05_00 -q e10:prof
```

```
$ mkdir dunetpc_mydev
```

```
$ cd dunetpc_mydev
```

```
$ mrb newDev
```

(multiple repository builder)

```
building development area for larsoft v06_05_00 -q e10:prof
MRB_BUILDDIR is /dune/app/users/higuera/test/build_slf6.x86_64
MRB_SOURCE is /dune/app/users/higuera/test/srcs
INFO: copying /grid/fermiapp/products/larsoft/larsoft/v06_05_00/
IMPORTANT: You must type
           source /dune/app/users/higuera/test/localProducts_larsoft_v0
NOW and whenever you log in
```

```
$ source localProducts_XXXX/setup
```

```
$ cd srcs
```

```
$ mrb g -t v06_05_00 dunetpc
```


Check Out & Build DUNETPC



Build

```
$ cd ../build_slf6_XXXXX
```

```
$ mrbsetenv
```

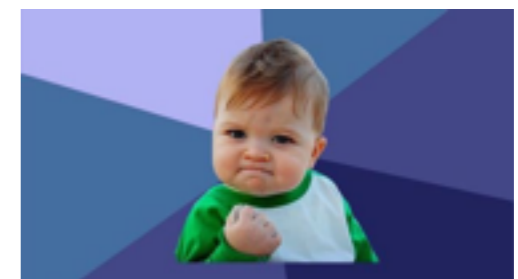
```
$ mrb i -j4
```

```
$ cd ..
```

```
$ mrbslp
```

```
local product directory is /dune/app/users/
10_prof
----- this block should be empty -----
```

You have setup and compile DUNETPC



Within DUNETPC



```
<dunegpvm10.fnal.gov> ls  
CMakeLists.txt  dune  fcl  releaseDB  test  ups  
<dunegpvm10.fnal.gov> █
```

Algorithms: class performs some or all the operations required for a task
Framework module: class manages and coordinates its algorithms in order to produce and deliver a result to the framework

```
<dunegpvm10.fnal.gov> ls  
AnaTree          Daq              Gaps             OpticalDetector  SpaceCharge  
ArtSupport       DataPrep         Geometry         PhotonPropagation SpaceChargeServices  
CFilter          DetSim           HitAnalysis      Protodune        T0Reco  
CMakeLists.txt  DuneCommon      HitFinderDUNE   RawdataDisplay  TrackFinderDUNE  
CTree            DuneInterface   LArG4            RecoAlgDUNE     TrackingAna  
CalData          EnergyStudies   MuonCounterTimes RunHistory       Utilities  
ClusterFinderDUNE EventFilters     MuonCounters    ShowerAna       daqinput35t  
DAQTriggerSim   EventGenerator  NearlineMonitor  SimFilter  
DUNEPandora     FDSensOpt       OnlineMonitor    Simulation  
<dunegpvm10.fnal.gov> █
```

Within DUNETPC

fHiCL (Fermilab Hierarchical Configuration Language)



```
<dunegpvm10.fnal.gov> ls  
CMakeLists.txt dune fcl releaseDB test ups  
<dunegpvm10.fnal.gov> █
```

```
<dunegpvm10.fnal.gov> ls  
CMakeLists.txt dune35t dunefd protodune  
<dunegpvm10.fnal.gov> █
```

← projects

```
<dunegpvm10.fnal.gov> ls  
CMakeLists.txt detsim g4 gen mergeana reco  
<dunegpvm10.fnal.gov> █
```

Within DUNETPC



```
<dunegpvm10.fnal.gov> ls  
CMakeLists.txt  detsim  g4  gen  mergeana  reco  
<dunegpvm10.fnal.gov> █
```

```
<dunegpvm10.fnal.gov> ls  
CMakeLists.txt  detsim  g4  gen  mergeana  reco  
<dunegpvm10.fnal.gov> cd mergeana/  
<dunegpvm10.fnal.gov> ls  
CMakeLists.txt  
standard_ana_dune10kt.fcl  
standard_ana_dune10kt_1x2x6.fcl  
standard_ana_dune10kt_1x2x6_hist.fcl  
standard_ana_dune10kt_3mmpitch_1x2x6.fcl  
standard_ana_dune10kt_3mmpitch_1x2x6_hist.fcl  
standard_ana_dune10kt_3mmpitch_workspace.fcl  
standard_ana_dune10kt_3mmpitch_workspace_hist.fcl  
standard_ana_dune10kt_45deg_1x2x6.fcl  
<dunegpvm10.fnal.gov> █  
  
standard_ana_dune10kt_45deg_1x2x6_hist.fcl  
standard_ana_dune10kt_45deg_workspace.fcl  
standard_ana_dune10kt_45deg_workspace_hist.fcl  
standard_ana_dune10kt_dp.fcl  
standard_ana_dune10kt_dp_hist.fcl  
standard_ana_dune10kt_hist.fcl  
standard_ana_dune10kt_workspace.fcl  
standard_ana_dune10kt_workspace_hist.fcl
```

AnalysisTree



```
<dunegpvm10.fnal.gov> ls
AnalysisTree.fcl AnalysisTree_module.cc CMakeLists.txt HowToUseAnalysisTree.txt
<dunegpvm10.fnal.gov> █
```

```
1153 class AnalysisTree : public art::EDAnalyzer {
1154
1155 public:
1156
1157     explicit AnalysisTree(fhicl::ParameterSet const& pset);
1158     virtual ~AnalysisTree();
1159
1160     /// read access to event
1161     void analyze(const art::Event& evt);
1162     // void beginJob() {}
1163     void beginSubRun(const art::SubRun& sr);
1164     void endSubRun(const art::SubRun& sr);
1165
1166 private:
1167
1168     void HitsPurity(std::vector< art::Ptr<recob::Hit> > const&
1169     double length(const recob::Track& track);
1170     double driftedLength(const sim::MCParticle& part, TLorentzVec
1171     double driftedLength(const sim::MCTrack& mctrack, TLorentzVec
1172     double length(const sim::MCParticle& part, TLorentzVector& s
1173     double bdist(const TVector3& pos);
1174
1175     TTree* fTree;
1176     TTree* fPOT;
```

AnalysisTree



```
1166 private:
1167
1168 void HitsPurity(std::vector< art::Ptr<recob::Hit> > const& hits, Int_t& trackid,
1169 double length(const recob::Track& track);
1170 double driftedLength(const sim::MCParticle& part, TLorentzVector& start, TLorentz
1171 double driftedLength(const sim::MCTrack& mctrack, TLorentzVector& tpcstart, TLoren
1172 double length(const sim::MCParticle& part, TLorentzVector& start, TLorentzVector&
1173 double bdist(const TVector3& pos);
1174
1175 TTree* fTree; ←
1176 TTree* fPOT;
1177 // event information is huge and dynamic;
1178 // run information is much smaller and we still store it statically
1179 // in the event
1180 std::unique_ptr<AnalysisTreeDataStruct> fData;
1181 // AnalysisTreeDataStruct::RunData_t RunData;
1182 AnalysisTreeDataStruct::SubRunData_t SubRunData;
1183
1184 std::string fDigitModuleLabel;
1185 std::string fHitsModuleLabel;
1186 std::string fLArG4ModuleLabel;
1187 std::string fCalDataModuleLabel;
1188 std::string fGenieGenModuleLabel;
```

GENIE info

Beam info

Recon info (hit, cluster, tracks, showers, etc)

AnalysisTree



```
CreateBranch("mcevts_truth",&mcevts_truth,"mcevts_truth/I");  
CreateBranch("nuPDG_truth",nuPDG_truth,"nuPDG_truth[mcevts_truth]/I");  
CreateBranch("ccnc_truth",ccnc_truth,"ccnc_truth[mcevts_truth]/I");  
CreateBranch("mode_truth",mode_truth,"mode_truth[mcevts_truth]/I");  
CreateBranch("enu_truth",enu_truth,"enu_truth[mcevts_truth]/F");  
CreateBranch("Q2_truth",Q2_truth,"Q2_truth[mcevts_truth]/F");  
CreateBranch("W_truth",W_truth,"W_truth[mcevts_truth]/F");  
CreateBranch("X_truth",X_truth,"X_truth[mcevts_truth]/F");  
CreateBranch("Y_truth",Y_truth,"Y_truth[mcevts_truth]/F");  
CreateBranch("hitnuc_truth",hitnuc_truth,"hitnuc_truth[mcevts_truth]/I");  
CreateBranch("nuptyx_truth",nuptyx_truth,"nuptyx_truth[mcevts_truth]/F");
```

GENIE info

Beam info

Recon info (hit, cluster, tracks, showers, etc)

Within DUNETPC



```
<dunegpvm10.fnal.gov> ls  
CMakeLists.txt  dune  fcl  releaseDB  test  ups  
<dunegpvm10.fnal.gov> █
```

```
<dunegpvm10.fnal.gov> ls  
CMakeLists.txt  dune35t  dunefd  protodune  
<dunegpvm10.fnal.gov> █
```

```
<dunegpvm10.fnal.gov> ls  
CMakeLists.txt  detsim  g4  gen  mergeana  reco  
<dunegpvm10.fnal.gov> █
```


Within DUNETPC



```
<dunegpvm10.fnal.gov> ls  
CMakeLists.txt  detsim  g4  gen  mergeana  reco  
<dunegpvm10.fnal.gov> █
```

```
<dunegpvm10.fnal.gov> ls  
CMakeLists.txt  detsim  g4  gen  mergeana  reco  
<dunegpvm10.fnal.gov> cd mergeana/  
<dunegpvm10.fnal.gov> ls  
CMakeLists.txt  
standard_ana_dune10kt.fcl  
standard_ana_dune10kt_1x2x6.fcl  
standard_ana_dune10kt_1x2x6_hist.fcl  
standard_ana_dune10kt_3mpitch_1x2x6.fcl  
standard_ana_dune10kt_3mpitch_1x2x6_hist.fcl  
standard_ana_dune10kt_3mpitch_workspace.fcl  
standard_ana_dune10kt_3mpitch_workspace_hist.fcl  
standard_ana_dune10kt_45deg_1x2x6.fcl  
<dunegpvm10.fnal.gov> █  
  
standard_ana_dune10kt_45deg_1x2x6_hist.fcl  
standard_ana_dune10kt_45deg_workspace.fcl  
standard_ana_dune10kt_45deg_workspace_hist.fcl  
standard_ana_dune10kt_dp.fcl  
standard_ana_dune10kt_dp_hist.fcl  
standard_ana_dune10kt_hist.fcl  
standard_ana_dune10kt_workspace.fcl  
standard_ana_dune10kt_workspace_hist.fcl
```

AnalysisTree



```
$ cd /dune/app/users/XXXX/XXXX/srcs
```

```
$ mkdir myjob
```

```
$ cp standard_ana_dune10kt_hist.fcl ../../../../  
myjob/
```

```
<dunegpvm10.fnal.gov> ls  
CMakeLists.txt detsim g4 gen mergeana reco  
<dunegpvm10.fnal.gov> cd mergeana/  
<dunegpvm10.fnal.gov> ls  
CMakeLists.txt  
standard_ana_dune10kt.fcl  
standard_ana_dune10kt_1x2x6.fcl  
standard_ana_dune10kt_1x2x6_hist.fcl  
standard_ana_dune10kt_3mpitch_1x2x6.fcl  
standard_ana_dune10kt_3mpitch_1x2x6_hist.fcl  
standard_ana_dune10kt_3mpitch_workspace.fcl  
standard_ana_dune10kt_3mpitch_workspace_hist.fcl  
standard_ana_dune10kt_45deg_1x2x6.fcl  
standard_ana_dune10kt_45deg_1x2x6_hist.fcl  
standard_ana_dune10kt_45deg_workspace.fcl  
standard_ana_dune10kt_45deg_workspace_hist.fcl  
standard_ana_dune10kt_dp.fcl  
standard_ana_dune10kt_dp_hist.fcl  
standard_ana_dune10kt_hist.fcl  
standard_ana_dune10kt_workspace.fcl  
standard_ana_dune10kt_workspace_hist.fcl  
<dunegpvm10.fnal.gov> █
```

AnalysisTree



```
$ lar -c standard_ana_dune10kt_1x2x6_hist.fcl  
myfile.root -n 10
```

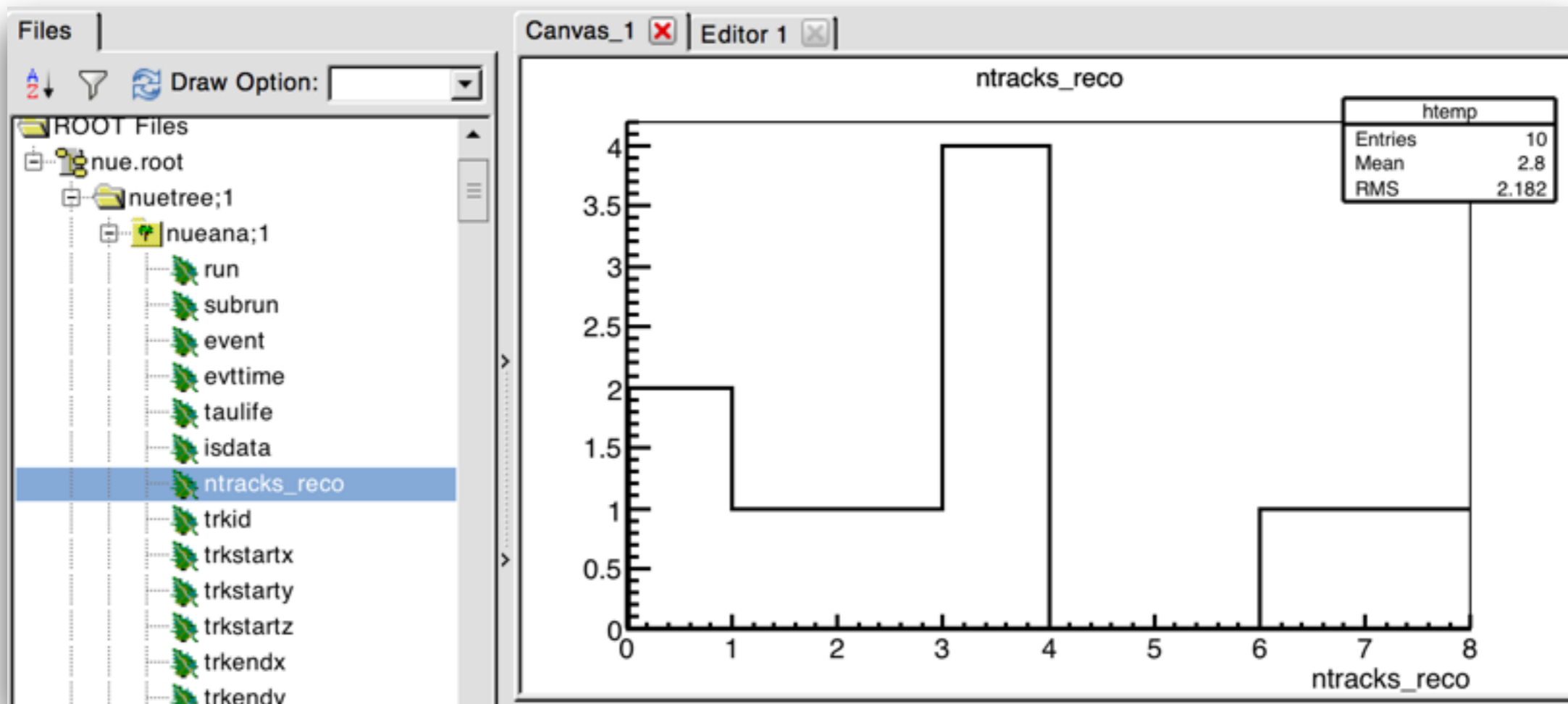
```
<dunegpvm10.fnal.gov> lar -c standard_ana_dune10kt_1x2x6_hist.fcl /pnfs/dune/scratch/dunepro/v06_02_00  
/reco/prodgenie_nu_dune10kt_1x2x6/12878103_243/prodgenie_nu_dune10kt_1x2x6_553_20160810T054821_gen_5ba  
e27ae-7cb4-4528-97a2-1bb6cdfc03c1_g4_detsim_reco.root
```

```
TFile**      nue.root  
TFile*       nue.root  
TDirectoryFile*      nuetree nuetree (NueAna) folder  
KEY: TTree   nueana;1      analysis tree  
KEY: TTree   pottree;1     pot tree  
KEY: TDirectoryFile  nuetree;1      nuetree (NueAna) folder  
KEY: TDirectoryFile  nuetreedc;1    nuetreedc (NueAna) folder
```

AnalysisTree



Walk through the nueana TTree



PART III

DUNE Repositories



As software repositories are designed to include useful packages

DUNE

Deep Underground Neutrino Experiment top-level project

DUNE NDTF

DUNE NDTF software repository, and wiki for documentation.

dunebsm

Searches for Beyond the Standard Model Physics with DUNE

dunefgt

DUNE Fine-Grained Tracker Near Detector

dunelbl

DUNE Long-Baseline Physics Code and Documentation

dunendk

DUNE Nucleon Decay Code and Documentation

dunetpc

Project for DUNE LArTPC simulation, reconstruction and analysis

duneutil

HighLAND

Code and Documentation for the HighLAND analysis framework

ProtoDUNE

The project to build prototype for the DUNE detector data management, workflow management and analysis

ProtoDUNE Data Management

ProtoDUNE data management project

SAMDUNE

Subproject of ProtoDUNE to make changes to SAM needed to build data management, workflow and analysis for ProtoDUNE and then for DUNE

WA105

Dual-Phase TPC in a charged-particle beam at CERN

<https://cdcvns.fnal.gov/redmine/projects/>

DUNE Repositories



Lets checkout dunendk

```
<dunegpvm10.fnal.gov> mrb g dunendk
git clone: clone dunendk at /dune/app/users/higuera/tutorial/srcs
NOTICE: Running git clone ssh://p-dunendk@cdcvs.fnal.gov/cvs/projects/dunendk
Cloning into 'dunendk'...
remote: Counting objects: 76, done.
remote: Compressing objects: 100% (72/72), done.
remote: Total 76 (delta 23), reused 0 (delta 0)
Receiving objects: 100% (76/76), 60.93 KiB | 0 bytes/s, done.
Resolving deltas: 100% (23/23), done.
Checking connectivity... done.
ready to run git flow init for dunendk
Already on 'master'
Your branch is up-to-date with 'origin/master'.
Using default branch names.
Already on 'develop'
Your branch is up-to-date with 'origin/develop'.
Branch develop set up to track remote branch develop from origin.
Already up-to-date.
NOTICE: Adding dunendk to CMakeLists.txt file
NOTICE: You can now 'cd dunendk'
```

DUNE Repositories



Lets checkout dunendk

```
<dunegpvm10.fnal.gov> git checkout feature/higuera  
Branch feature/higuera set up to track remote branch feature/higuera from origin.  
Switched to a new branch 'feature/higuera'  
<dunegpvm10.fnal.gov> ls  
CMakeLists.txt  dunendk  fcl  ndksens  releaseDB  test  ups  
<dunegpvm10.fnal.gov> cd
```


DUNE Repositories

Lets checkout dunendk



```
53 namespace DUNE{
54
55 class NDKAna : public art::EDAnalyzer {
56 public:
57
58     explicit NDKAna(fhicl::ParameterSet const& pset);
59     virtual ~NDKAna();
60
61     void beginJob();
62     void endJob();
63     void beginRun(const art::Run& run);
64     void analyze(const art::Event& evt);
65
66     void reconfigure(fhicl::ParameterSet const& pset);
67
68     void Process(const art::Event& evt, bool &isFiducial);
69     void truthMatcher( std::vector<art::Ptr<recob::Hit>> track_hits, const simbc::MCParticle *MCparticle,
70 double myPrange( double track_range );
71 double truthLength( const simbc::MCParticle *MCparticle );
72 void cal( std::vector<const anab::Calorimetry*> cal, double &dEdx, double &range, double &res_range, c
73 bool insideFV(double vertex[4]);
74 void reset();
75
76 private:
77
78     // the parameters we'll read from the .fcl
79     std::string fMCTruthModuleLabel;
80     std::string fTrackModuleLabel;
81     std::string fOpFlashModuleLabel;
82     std::string fShowerModuleLabel;
83     std::string fHitsModuleLabel;
84     double fPIDA_endPoint;
85     bool fSaveMCTree;
86
87     TTree *fEventTree;
88
89     // Event
90     int Event;
91     int Run;
92     int SubRun;
93
94     //MC truth
95     double MC_vertex[4];
96     int MC_npart;
97     int MC_id[MAX_TRACKS];
98     int MC_pdg[MAX_TRACKS];
99     int MC_mother[MAX_TRACKS];
```

DUNE Repositories



Lets open a terminal . . . and do so typing

```
#include <stdio.h>
int main(void)
{
    int count;
    for (count = 1; count <= 500; count++)
        printf("I will not throw paper airplanes in class.");
    return 0;
}
```



The End