Running Reconstruction Workflows by TPC

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Current Situation for ICARUS

- The ICARUS detector consists of 2 Cryostats each containing two identical TPCs

    - >50,000 total channels

    - Waveforms for each channel currently appear in a single RawDigit instance per event

- Signal processing has 3 stages beginning with above:

    - Noise Filter

    - Deconvolution

    - Hit finding (gauss hit finder)

- 3D SpacePoint creating (utilizing the Cluster3D module) used to reduce spurious noise hits on the 3 planes, takes single hit collection and outputs a new single hit collection

- Pattern Recognition, Track and Shower Recon, etc. run on the single hit collection produced by Cluster3D

Alternate Approach

- Question posed at a recent LArSoft meeting: Can you break your tasks up and run on a TPC basis?

  - Signal processing only cares about channels in a given TPC

- What about higher level processing?

  - Pattern recognition in ICARUS probably wants to be done on a Cryostat basis

    - Allow for tracks which cross the common cathode

- Goal would be to break into groups which technically could be run in parallel (eventually).

First Step: Modify Detector Sim

- To test we first need a source of RawDigits for each individual TPC and for ICARUS this comes from the Detector Simulation

    - Quickest way to test: Four instances of the detector simulation get configured

    - Each instance only outputs RawDigits for the TPC it is configured to operate on.

- Next iteration

    - Since we are looping over the full set of SimChannels anyway, one could use a single instance of detector simulation which is now capable of outputting a separate instance of RawDigits for each TPC

- In either case, the difference to the downstream recon is the InputTag that is used…

Signal Processing

- No code changes necessary at this point, can all be done by fhicl configurations

- Define a "single processing block" which consists of the noise filtering, the deconvolution and hit finding

  - Note that for the deconvolution, avoid using the SignalServices and LArFFT to try to avoid potential issues that might arise from single definitions there of FFT size, etc.

    - Currently using the Eigen package interface but can convert to anything

    - probably this needs to be explored a bit going forward

- Run four of these blocks, one for each TPC

Downstream Reconstruction

- Want pattern recognition to run on a Cryostat basis

  - Needs to get signal processing output from two TPCs

- Want to avoid having to modify Pandora at this time…

- Choose to modify Cluster3D to be able to take input from multiple signal processing producers

  - Essentially, change the art::InputTag for the input hit collection to a std::vector<art::InputTag> to allow multiple hit collections

  - This is a common them for any other changes that need to be made

- Cluster3D now outputs a single hit collection on a Cryostat basis

  - This is what is input now to Pandora, with a separate Pandora instance for each Cryostat

What Else Needs To Change?

- Similar to MicroBoone, would like to create MCParticle<—>Hit associations for streamlined truth matching in analysis

  - Similar to Cluster3D must make the art::InputTag for hits into a std::vector<art::InputTag>

  - This is in the LArAna package

- Additionally, the event display needs a similar set of changes in order to display the RawDigits, Wire and Hit information in the 2D event display

  - This is in the LArEventDisplay package

- Note that making this change requires modifying associated fhicl files

  - Technically, this is a "breaking change"

  - Various experiment fhicl files will need to change their fhicl files accordingly

Standard ICARUS "Gauss path" Reconstruction

Run the standard reconstruction over 5 simulated Cosmic Ray Events generated during the last MCC
LArSoft v08_18_00, run interactively on OSX (High Sierra)

TimeTracker printout (sec)	Min	Avg	Max	Median	RMS	nEvts
Full event	565.942	823.267	1207.52	778.34	220.16	5
source:RootInput(read)	0.0043818	0.00653054	0.00741048	0.00678545	0.00111397	5
reco:rawdigitfilter:RawDigitFilterICARUS	92.3679	100.853	109.271	102.78	6.58126	5
reco:decon1droi:Decon1DROI	79.193	85.4705	92.6665	86.4804	4.84094	5
reco:gaushit:GausHitFinder	85.1896	105.376	117.58	108.771	11.3906	5
reco:gaushitsel:HitSelector	0.773882	0.981573	1.11201	1.00186	0.114171	5
reco:cluster3d:Cluster3D	100.892	192.763	411.349	145.402	113.091	5
reco:pandoraGaus:StandardPandora	48.0455	100.098	152.046	104.483	33.6162	5
reco:pandoraTrackGaus:LArPandoraTrackCreation	13.1786	34.2194	53.2131	36.9013	14.7962	5
reco:pandoraShowerGaus:LArPandoraShowerCreation	109.16	161.245	222.665	132.126	48.8112	5
reco:pandoraKalmanTrackGaus:KalmanFilterFinalTrackFitter	0.780413	1.04243	1.43419	0.9607	0.241932	5
reco:mcassociationsGaus:MCParticleHitMatching	0.849314	1.45141	2.25256	1.13115	0.590385	5
reco:ophit:OpHitFinder	7.20897	8.53227	9.66962	8.38288	0.860496	5
reco:opflashTPC0:ICARUSFlashFinder	0.57708	0.840335	1.02398	0.941036	0.183922	5
reco:opflashTPC1:ICARUSFlashFinder	0.51342	0.663781	0.862298	0.67997	0.129656	5
reco:opflashTPC2:ICARUSFlashFinder	0.0508013	0.0637668	0.075312	0.0628472	0.010138	5
reco:opflashTPC3:ICARUSFlashFinder	0.0496869	0.0624147	0.0742626	0.0630377	0.00980628	5
reco:mcophit:ICARUSMCOpHit	1.14434	1.69225	2.42074	1.43357	0.49104	5
reco:mcopflashTPC0:ICARUSMCOpFlash	0.00255607	0.00309942	0.0035628	0.00302026	0.0003443	5
reco:mcopflashTPC1:ICARUSMCOpFlash	0.00283237	0.00347519	0.00429867	0.00339032	0.000508939	5
reco:mcopflashTPC2:ICARUSMCOpFlash	0.00244812	0.00270003	0.00303954	0.00264269	0.000213211	5
reco:mcopflashTPC3:ICARUSMCOpFlash	0.00220764	0.00255968	0.00280035	0.00267948	0.000220751	5
[art]:TriggerResults:TriggerResultInserter	4.8054e-05	5.30492e-05	6.3052e-05	5.2779e-05	5.47143e-06	5
end_path:out1:RootOutput	7.779e-06	8.7402e-06	1.0267e-05	8.456e-06	8.27571e-07	5
end_path:out1:RootOutput(write)	23.4836	27.8897	33.8855	28.6195	3.73284	5

Average over 5 events is 823 seconds/event

Multi TPC Workflow, ICARUS "Gauss path" Reconstruction

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================================================================================================
TimeTracker printout (sec)                        Min          Avg          Max        Median          RMS     nEvts
================================================================================================
Full event                                    525.492      710.293      984.098        652.8      153.639         5
------------------------------------------------------------------------------------------------
source:RootInput(read)                       0.00115396   0.00411243   0.00795376     0.002642   0.00282208       5
reco:rawDigitFilterTPC0:RawDigitFilterICARUS   19.0226      25.5514      29.542       26.2337      3.49873        5
reco:decon1DroiTPC0:Decon1DROI                 18.471       22.0303      25.6086      22.1814      2.31865        5
reco:gaushitTPC0:GausHitFinder                 16.1732      28.9808      45.4263      26.3005      9.53103        5
reco:rawDigitFilterTPC1:RawDigitFilterICARUS   22.63        24.6383      25.9724      25.2076      1.23772        5
reco:decon1DroiTPC1:Decon1DROI                 18.915       21.3009      23.2214      21.7094      1.45969        5
reco:gaushitTPC1:GausHitFinder                 19.044       24.5358      30.8052      23.5487      4.70707        5
reco:cluster3DCryo0:Cluster3D                  18.1833      87.7152     173.111       64.8248     53.8357         5
reco:pandoraGausCryo0:StandardPandora           8.2372      51.9392      92.6491      43.912      30.0557         5
reco:pandoraTrackGausCryo0:LArPandoraTrackCreation  1.8147   10.6237      17.5575      10.544       5.79323        5
reco:pandoraShowerGausCryo0:LArPandoraShowerCreation  6.24194  44.9597     92.6106      34.8613     29.1861        5
reco:pandoraKalmanTrackGausCryo0:KalmanFilterFinalTrackFitter  0.224669  0.563483  0.771985  0.574253  0.195574   5
reco:rawDigitFilterTPC2:RawDigitFilterICARUS   23.4938      25.0968      26.9566      25.483       1.32011        5
reco:decon1DroiTPC2:Decon1DROI                 20.1951      21.3577      22.759       21.4874      0.972929       5
reco:gaushitTPC2:GausHitFinder                 19.1808      26.0135      30.3274      27.922       4.26467        5
reco:rawDigitFilterTPC3:RawDigitFilterICARUS   24.287       25.1301      26.9485      24.6266      0.996928       5
reco:decon1DroiTPC3:Decon1DROI                 20.5206      21.552       24.1336      20.8402      1.32377        5
reco:gaushitTPC3:GausHitFinder                 22.362       27.8157      39.541       26.9248      6.20577        5
reco:cluster3DCryo1:Cluster3D                  32.743       77.991      149.546       66.1108     42.1615         5
reco:pandoraGausCryo1:StandardPandora          15.2551      48.8887      92.8232      52.439      29.5974         5
reco:pandoraTrackGausCryo1:LArPandoraTrackCreation  2.37127   8.74895     14.1789       9.6548      5.07653        5
reco:pandoraShowerGausCryo1:LArPandoraShowerCreation  18.5691  46.5477     91.8248      39.2429     26.9761        5
reco:pandoraKalmanTrackGausCryo1:KalmanFilterFinalTrackFitter  0.293568  0.475007  0.63737  0.524886  0.143657   5
reco:mcassociationsGausCryo0:MCParticleHitMatching  0.000159006  0.00128753  0.00571135  0.000189845  0.00221195  5
reco:mcassociationsGausCryo1:MCParticleHitMatching  0.000112673  0.000150404  0.000232034  0.000137049  4.21141e-05  5
reco:ophit:OpHitFinder                          7.56021      8.38549      9.69811      8.00508      0.846766       5
reco:opflashTPC0:ICARUSFlashFinder             0.587727     0.853286     1.01367      0.932681     0.168257       5
reco:opflashTPC1:ICARUSFlashFinder             0.506939     0.668529     0.862104     0.685193     0.128355       5
reco:opflashTPC2:ICARUSFlashFinder             0.0503889    0.0612948    0.0728717    0.061032     0.00835941     5
reco:opflashTPC3:ICARUSFlashFinder             0.050217     0.0620022    0.0732102    0.0645793    0.00941111     5
reco:mcophit:ICARUSMCOpHit                      1.1612       1.68151      2.27415      1.47963      0.431661       5
reco:mcopflashTPC0:ICARUSMCOpFlash             0.00273609   0.00348586   0.00447351   0.00334453   0.000595245    5
reco:mcopflashTPC1:ICARUSMCOpFlash             0.00311391   0.00366075   0.00420946   0.00358236   0.000424891    5
reco:mcopflashTPC2:ICARUSMCOpFlash             0.00248992   0.00281544   0.00339542   0.00277922   0.000334882    5
reco:mcopflashTPC3:ICARUSMCOpFlash             0.00240827   0.00274778   0.00324632   0.00268888   0.000308312    5
[art]:TriggerResults:TriggerResultInserter     5.3132e-05   0.000233715  0.000953602  5.3593e-05   0.000359944    5
end_path:out1:RootOutput                       8.397e-06    9.6672e-06   1.3837e-05   8.627e-06    2.09347e-06    5
end_path:out1:RootOutput(write)                22.3818      26.0995      30.2112      26.7662      2.64849        5
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Average over 5 events is 710 seconds/event

Summary

- ICARUS would like to move to the scheme of handling signal processing on a TPC basis, downstream reconstruction on a Cryostat basis

- The current set of needed changes in LArSoft affect

  - LArAna - MCParticle<—>Hit creation

  - LArReco - Cluster3D

  - LArEventDisplay - input source info for 2D drawing

    - Note that with this update there is also a beginning OpHit and OpFlash display for the 3D display

- The above are, unfortunately, "breaking changes"