Summary of “LArTPC Reconstruction Assessment and Requirements Workshops”

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UTA

Context

- Link: https://indico.fnal.gov/conferenceDisplay.py?confId=10394
- Prompted by LBNC
- Actually 2 workshops
- LBNC Mandate Expande to LBN and SBN
- Primary organizer Ruth Pordes with representatives from nearly all LArTPC experiments…

David MacFarlane

Origins of the two contiguous workshops

- Reconstruction assessment workshop:
  - Requested through the Fermilab PAC by the Long-Baseline Neutrino Committee (LBNC) as a first step along a path of focusing community attention on automated reconstruction in LAr TPCs
- Requirements workshop:
  - Community-led effort to collectively put together a shared goal of setting overall requirements for a LAr eco-system of software, hardware, and computing to guide work over the next few years
  - While strongly encouraged by the LBNC, bottoms up is a much better approach!

PAC feedback on the SBN program from June 2015

- Concerned about:
  - Pace at which automated LAr reconstruction is developing, despite being absolutely crucial to the SBN and LBN programs
  - Slow progress in coordinating the analysis across the three experiments, which is critical to the success of the SBN program and required for Stage 2 approval
  - Very aggressive SBN schedule with little flexibility
- Recommended that Fermilab continues:
  - Monitoring progress on achieving automated event reconstruction
  - Providing relevant resources and expertise towards catalyzing this effort, since it is critical to quickly demonstrate the capabilities of the LArTPC technology.

- LArTPC Reco must meet assumptions made for DUNE reach.
- Full Simulation and Automatic reconstruction for CD-2
- Need a thorough assessment for CD-2

LBNC comments on DUNE Far Detector (FD) Tas

- Comments from Sept review
  - The LBNC notes that the 80% efficiency for automated reconstruction for quasi-elastic, resonant elastic scattering and deep-inelastic scattering events is a key assumption in the projected physics reach of DUNE. Much progress in demonstrating this capability should be accomplished by the TF within the next 18 months.
  - An important part of the FDTF planning would be to lay out a common understanding of the level of reconstruction sophistication needed at various stages during the 18 months and then beyond through the DUNE design phase leading up to CD-2

- A comprehensive summary of the current status of and future plans for further development of automated reconstruction efforts:
  - Basic physics information, such as event classes and topologies, backgrounds for each experiment, performance requirements, etc.;
  - Current state-of-the-art, including quantified performance of the reconstruction;
  - Leadership for the current effort and the level of effort across the collaboration;
  - Degree to which the effort relies on common software tools, such as analysis framework development, etc. and their further development;
  - Timeline, milestones, deliverables and level of effort required for further development;
  - Linkages to hardware system development and experience with neutrino and test beam data
  - Assessment of areas of commonality with other SBN or LBN experiments; and
  - Assessment of resource limitations and impact of bringing additional targeted help, either from Fermilab or in cooperation with other science collaborations.

Assessment Workshop

Monday, October 19, 2015

09:00 - 12:30 **Reconstruction Assessment**

Convener: Dr. Ornella Palamara (Fermilab)

09:00 **Introductory Remarks** *10'*
- Speaker: Dr. David MacFarlane (SLAC National Accelerator Lab)
- Material: **Slides**

09:10 **ArgoNeuT** *30'*
- Speaker: Tingjun Yang (FNAL)
- Material: **Slides**

09:40 **Icarus (LNGS)** *30'*
- Speaker: Christian Farnese (INFN)
- Material: **Slides**

10:10 **MicroBooNE** *30'*
- Speaker: Tracy Usher (SLAC)
- Material: **Slides**

10:40 **LArIAT** *30'*
- Speaker: Jennifer Raaf (Fermilab)
- Material: **Slides**

11:10 **Break** *30'*

11:40 **Pandora software** *30'*
- Speaker: Prof. Mark Thomson (University of Cambridge)
- Material: **Slides**

12:10 **LArSoft software** *20'*
- Speaker: Dr. Erica Snider (Fermilab)
- Material: **Slides**

ArgoNeuT

Tingjun Yang

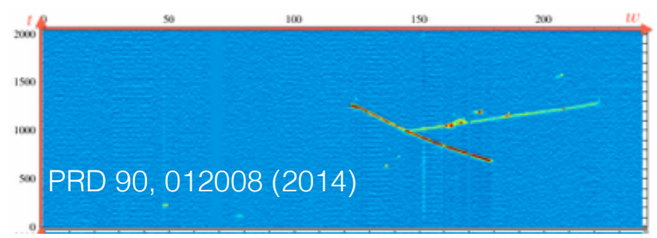
- ArgoNeuT was the first user of LArSoft after Brian Rebel et al. started this project.
- Pioneered in development and validation of simulation and reconstruction tools.
- Physics analyses done using LArSoft.

- Long list of accomplishments/ measurements:
  - Tracking, calorimetry, shower reco, PID, …
- Example: Full Auto redo for inclusive CC x-section
  - 42%/59% off for neutrino/ antineutrino
  - 5-10% Energy resolution
  - 1 degree angle resolution

- Visual scanning for some analyses

Topological Analysis 1μ+Np

- A first Topological analysis is developed by the ArgoNeuT experiment: 1μ+Np (0π)
  - Sensitive to nuclear effects
  - Observation of back-to-back proton pairs



- Analysis steps
  - automated reconstruction (muon angle and momentum)
  - visual scanning
    - hit selection
  - automated track and calorimetric reconstruction
    - Background (pion) removed

Proton angle and momentum

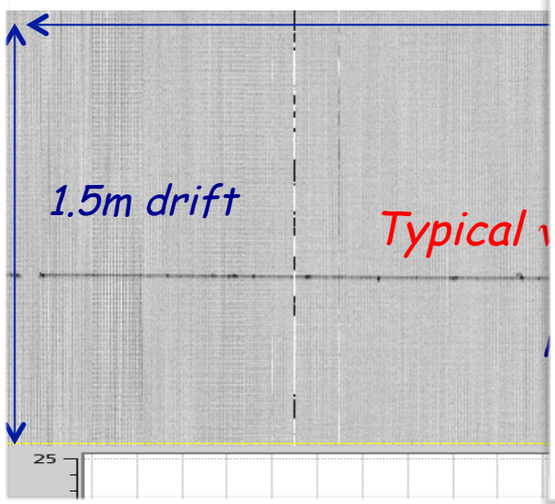
ICURUS

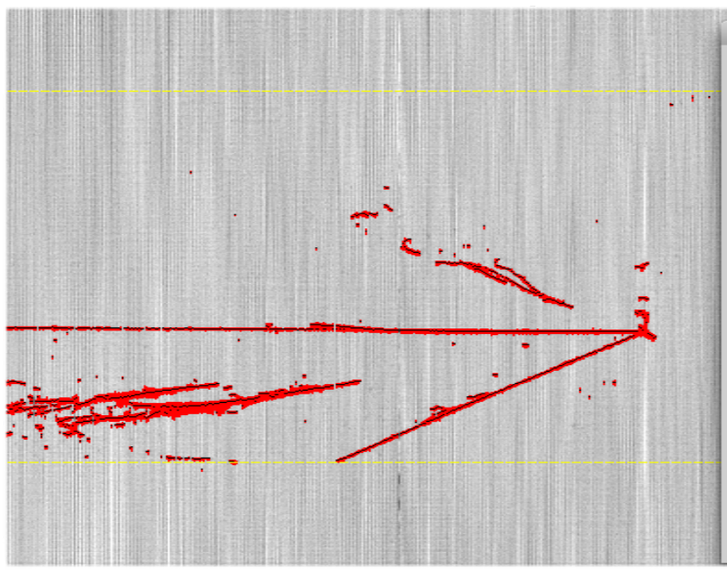
- Highlighted the importance of a powerful event display + hand scanning tool.
- QScan Demo

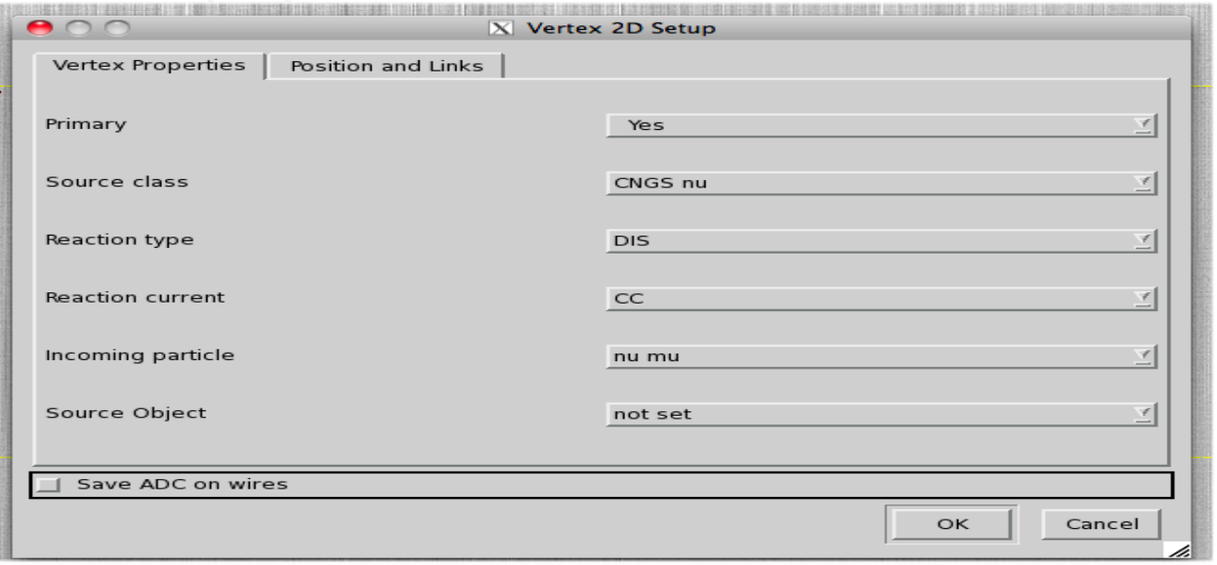
C. FARNESE

- The relatively small number of recorded CNGS neu… eraction events (~3000) allowed a semi automatic approach based … selection of events followed by a careful visual analysis of all p… …lly interesting data; the reconstructed objects can be saved/modified using a flexible ROOT-based I/O system
- The developed software framework is based on:
  - Central package (fullreco) for data decoding, basic reconstruction
  - Qt-based event display (Qscan) for visualization/scanning and human interface
  - Event loop code (AnalysisLoop) for batch analyses and ROOT I/O
  - Higher-level analysis tools (Muon momentum by MCS, EM shower reconstruction, particle identification, 3D reconstruction…);
  - Interface with FLUKA for analysis/visualization of simulated

- Qscan is a qt-based tool for a fast visualization of events in the T600:
  - the 2D projections associated to the wire planes are shown using a grey/color scale based on signal height/deposited energy;
  - the waveforms of wires and PMT signals can be displayed and fast Fourier transfo…





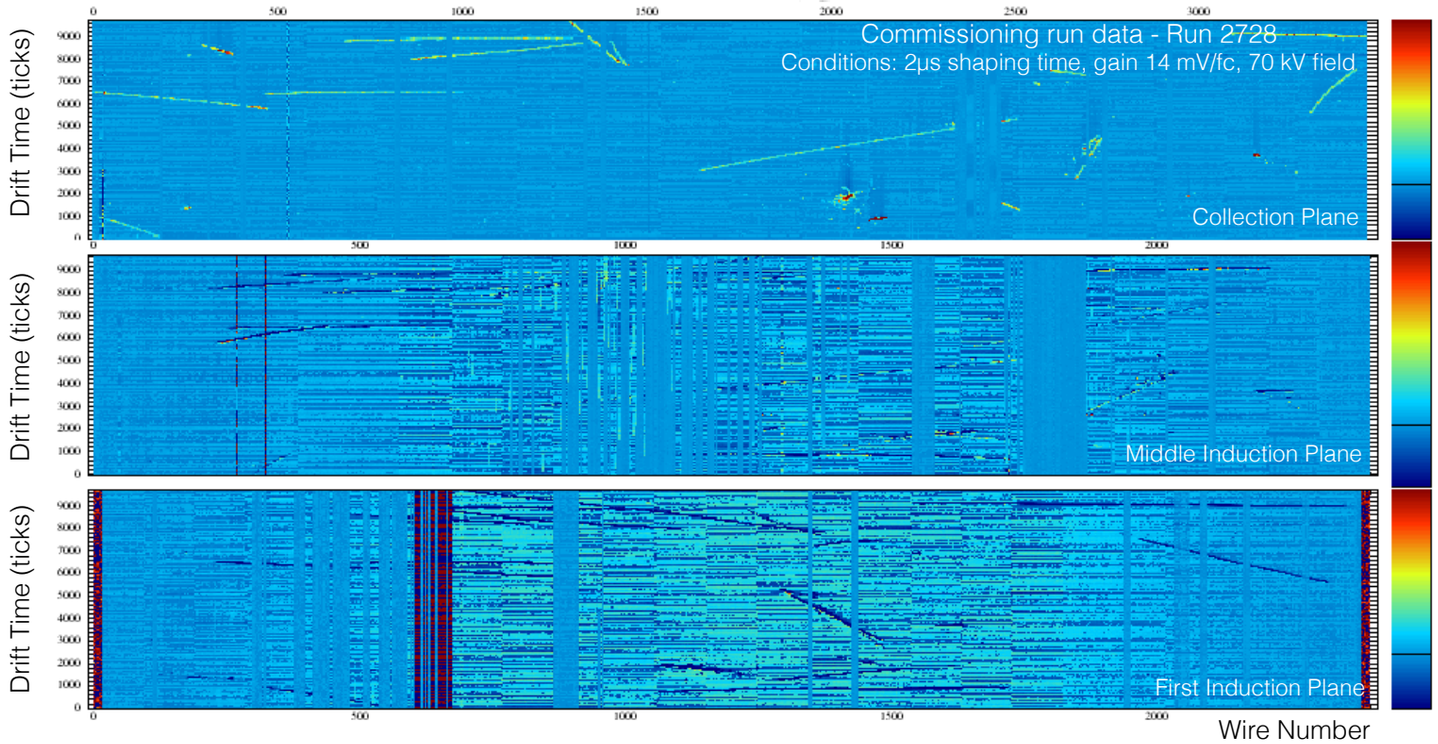


MicroBooNE Commissioning

Tracy Usher

- Bringing complex detectors online for the first time is rarely a smooth process
  - In particular, there are almost always surprises
- Two issues directly impacting reconstruction
  - Dead channels
    - Tend to be in groups as opposed to the assumed isolated dead channels one might have studied in developing algorithms
  - Noisy channels with several different signatures
    - “zig-zag” - high frequency tick-to-tick oscillations in randomly distributed short bursts
    - “correlated” - low frequency (~20 kHz) correlated across wires
    - “chirping” - transient issue, switching between “dead” and “live” with large baseline excursions
    - “high noise” - steady state very high rms noise - effectively dead channels for recon
- Redirection of reconstruction resources to address these issues
  - Attacking noise issues by developing algorithms ain
  - Developing more sophisticated channel status infor
  - Pattern recognition algorithms will need to be able t

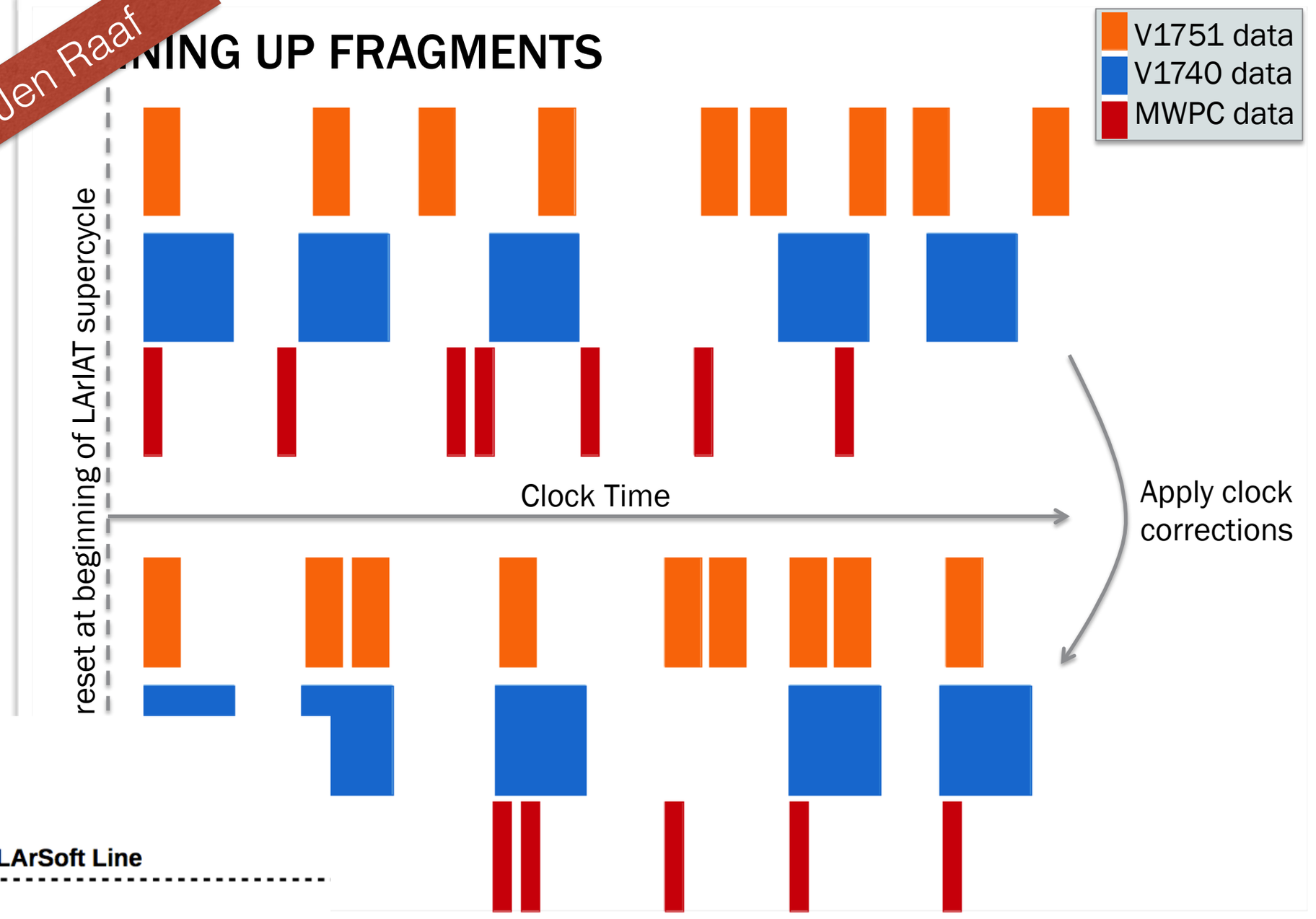
Reminded us that noise can significantly increase data volume…

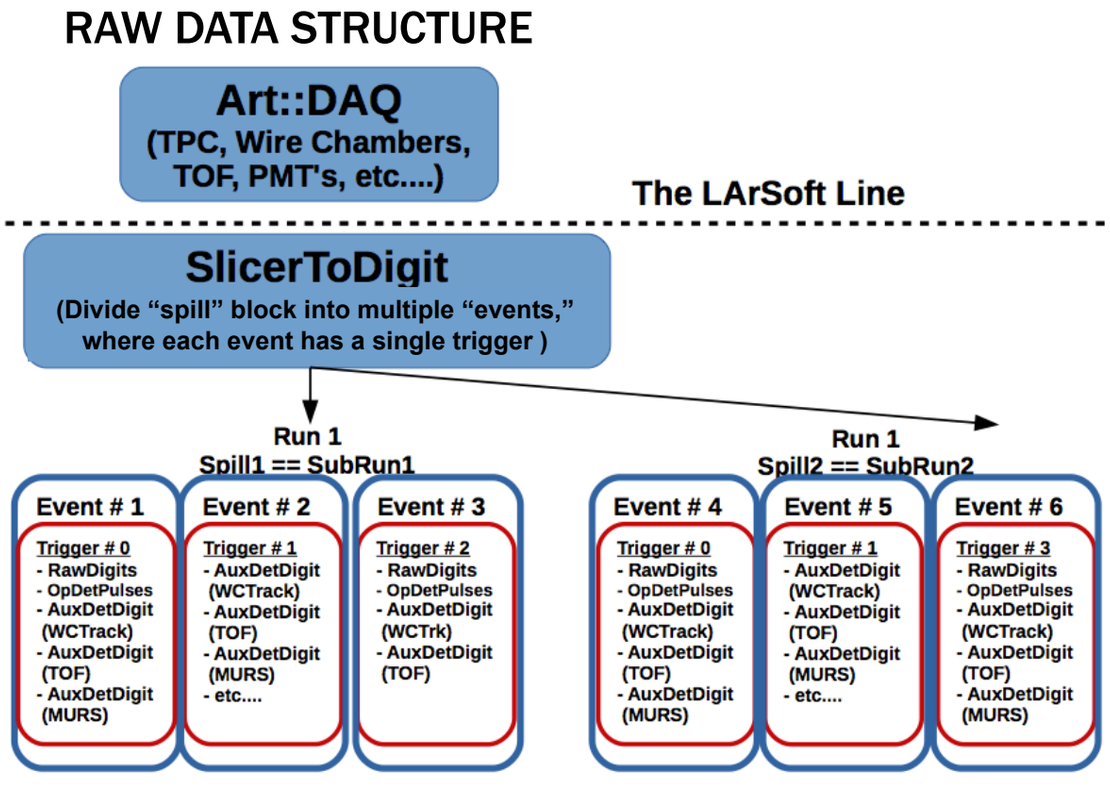


LArIAT

Jen Raaf

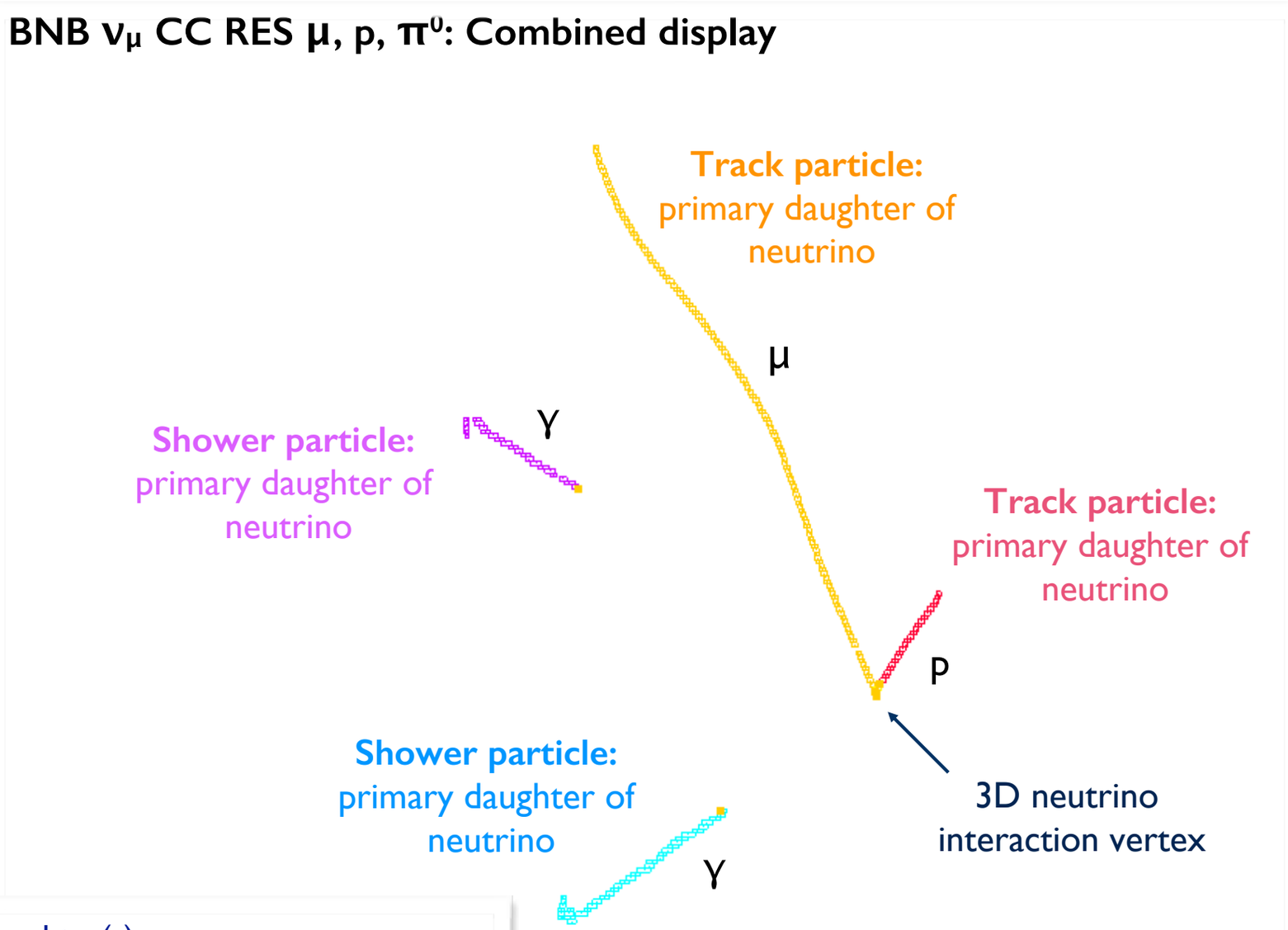
- Reminded us the importance of timing across different detectors….

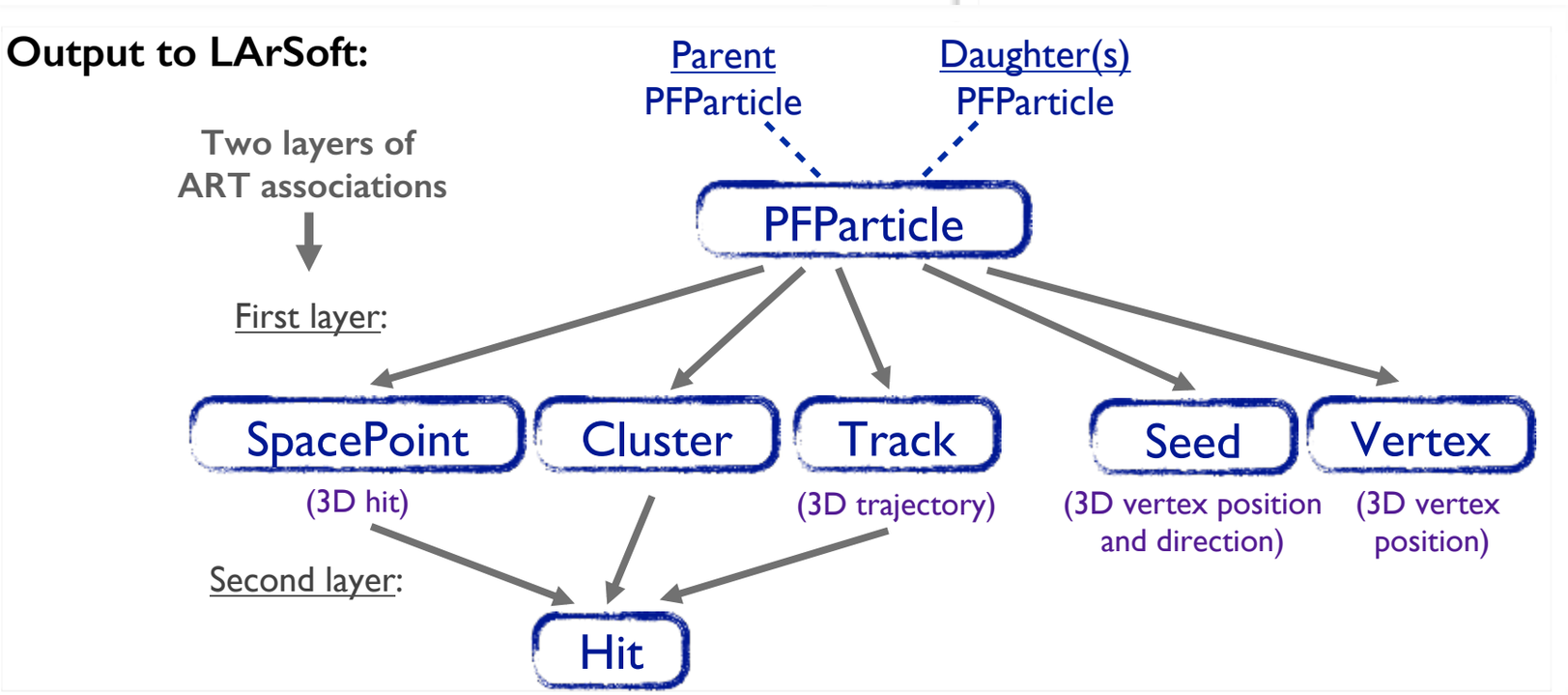




Pandora

- Impressive performance…
- Don't forget Pandora gives fully recoed topologies in PFParticle.





Requirements

Organization

Topic 1. Non-beam reconstruction and analysis (includes cosmic ray removal)

- Reconstruction, analysis and simulation
- Systematics and constraints
- Cosmic Ray Removal - from LarTPC alone, combining information from other detectors
- Scintillation light efficiencies
- Cosmic Ray analysis - for those experiments doing this

Topic 2. Beam reconstruction and analysis

- Reconstruction, analysis and simulation
- Systematics and constraints
- Beam particle identification - including electron, muon, hadron, pizero, ...
- Track, shower, vertex identification

Topic 3. Overarching Analysis strategies (largescale to individual events), light detection systems and external detectors
(cosmic ray taggers etc.)

Potentially includes:

- Dataset management
- Meta-data management
- Analysis techniques
- Analysis toolkits
- Analysis workflows
- Real-time/Data Acquisition
- "Anything r

Topic 4. Human interactions, computing systems, software and interfaces

- Visualization
- Scientific and development workflows - including human components
- Regression and validation software/processes
- New computer hardware architectures - short, medium, long term, multi-threading
- Software frameworks and interfaces
- Organization of common/shared components, including policies

- 4 x 4 Simultaneous sessions, each on one topic.
- Participants rotate through all topics.
- Roles assigned:
  - Leader
  - Scribe
  - Note taker
- Document Editted live on Overleaf

My Impression

- The session allowed extremely useful brain storming…
- Very positive and cooperative environment across experiments.
- We need to understand the roles and responsibilities of experiments, LArSoft, and other resources.
    - e.g. Understand the model of algorithm development in an experiment, passing ownership to LArSoft (?), and then supported for all experiments.
- Awareness of Analysis and User requirements was very encouraging (LArSoft vs LArLite).
- We have a huge number of: physics goals, tasks, required capabilities, requirements, use cases.
- The topic organization wasn't necessarily ideal… nonetheless the WS was very effective.
    - Rather difficult to overview the requirements…
- Attempting to organize now… Erica is restructuring the document…
- I'll try to present an overview of the requirements, once I can wrap my head around how to organize them….

Starting document… new document on the way.

Contents

Next Steps

- Currently working on the workshop report…
  - Aim for end of November.
- Next step is very difficult:
  - assess what requirements are already met.
  - work out the details of how to meet the requirement
  - establish a workplan…