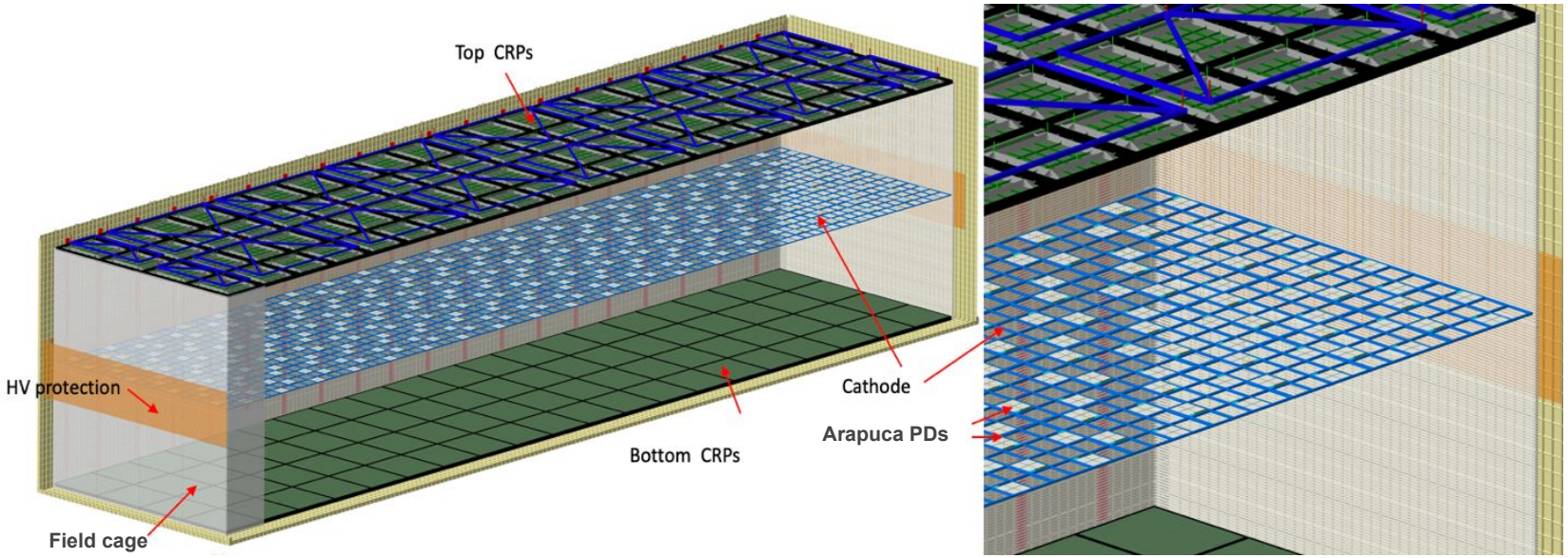
LBNC review summary and future plans for the group



Dominic Brailsford, Laura Paulucci

FD sim/reco WG meeting

24 October 2022

FD sim/reco

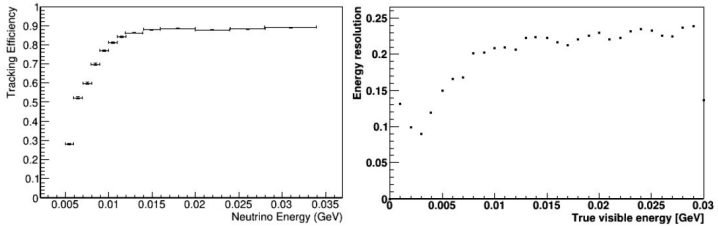
- L. Paulucci is the new FD sim/reco convener
  - Brings expertise from low energy + PDS
- Going forwards, we plan to better incorporate PDS sim/reco activities into this working group
- Recent activities:
  - Vertical Drift TDR
    - Thank you to everyone who has contributed work/plots to the TDR
    - The relevant sections of the physics chapter now have a complete draft
  - LBNC review

LBNC review

- Breakout talk presented 6th October by Laura
  - PDS and TPC low energy sim/reco
  - LBL-motivated TPC sim/reco
- Well presented by Laura!
- Good engagement from the reviewers during the talk

LE Physics: LE events with TPC

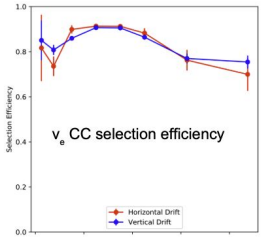
- Sample: MARLEY (ν_e CC): 5-30 MeV range, in 1 MeV steps, order 10^4 events for each energy, no backgrounds
- Tracking efficiency: identify reco tracks and check if track is well reconstructed
- Energy resolution: analysis of track with highest charge + blips in time and position coincidence

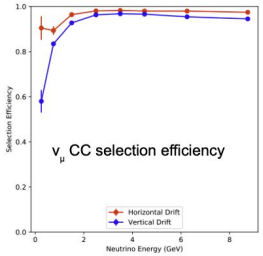


5 06 Oct 2022 D. Brailsford & L. Paulucci – VD Sim and Reco Status

Convolutional Visual Network

- Deep learning-based, neutrino flavour tagger
  - Uses all readout planes to perform event classification: CC ν_μ, ν_e, ν_τ and NC
- Used to select neutrinos in the Horizontal Drift TDR analysis
- Retrained for the 30° Vertical Drift
- Selections tuned to maximise efficiency X purity
- Comparable performance with some minor remaining differences between VD/HD





	ν_e		ν_μ	
	Efficiency	Purity	Efficiency	Purity
VD	84.3%	82.8%	93.7%	93.2%
HD	85.6%	87.5%	96.5%	93.7%

12 06 Oct 2022 D. Brailsford & L. Paulucci – VD Sim and Reco Status

LBNC review

- Talk was included in the FD2 closeout report's R&D highlights

R&D highlights: The committee continues to be impressed with the rapid and thoughtful progress.

- **Simulation and reconstruction**: The FD2VD simulation is running with updated CRP strip orientation, realistic field cage, not yet final PDS detector location. Technical advances made production much faster. Comparisons with HD produced for VD TDR. Studied low-energy physics efficiency, SNB triggering.

- Comments were generally positive, with some recommendations for further study

- The simulation and reconstruction has had much less time for detailed study for VD than for HD, but it is showing comparable performance. There are outstanding items requiring deeper understanding
  - the lack of expected improvement in PDS resolution with higher visible energy
  - lower CVN efficiency than HD, especially for low-energy muon neutrino CC events

- PDS sim is under review

- The recommendation for the CVN works nicely into what our future direction needs to be

Future plans: Horizontal Drift production

- The past year has been focussed on VD performance relative to the 2018 HD-TDR baseline
- LBL-motivated TPC reconstruction in VD now approaching that baseline
- The last few residual differences may be due to an out-of-date benchmark
  - Not doing an apples-to-apples comparison
- It is now time to revisit preparing/running a new HD production to provide a new benchmark
  - This should bring both TPC and PDS into the modern era

Future plans: Horizontal Drift production

- Previously, HD production preparation reached the validation stage (R. Cross)
  - One last minor issue related to shower reconstruction length remained unsolved. We can accept this discrepancy and push forward
- Timeline
  - Re-prepare software/fcl: 1 month
  - First part of production: 1 month
    - Up to hit reconstruction
    - Both HD and VD events
    - ~O(1 million events)
  - Tune CVN, Pandora, calorimetry constants: 1 month
  - Second part of production: 1 month

Future plans: Full geometry

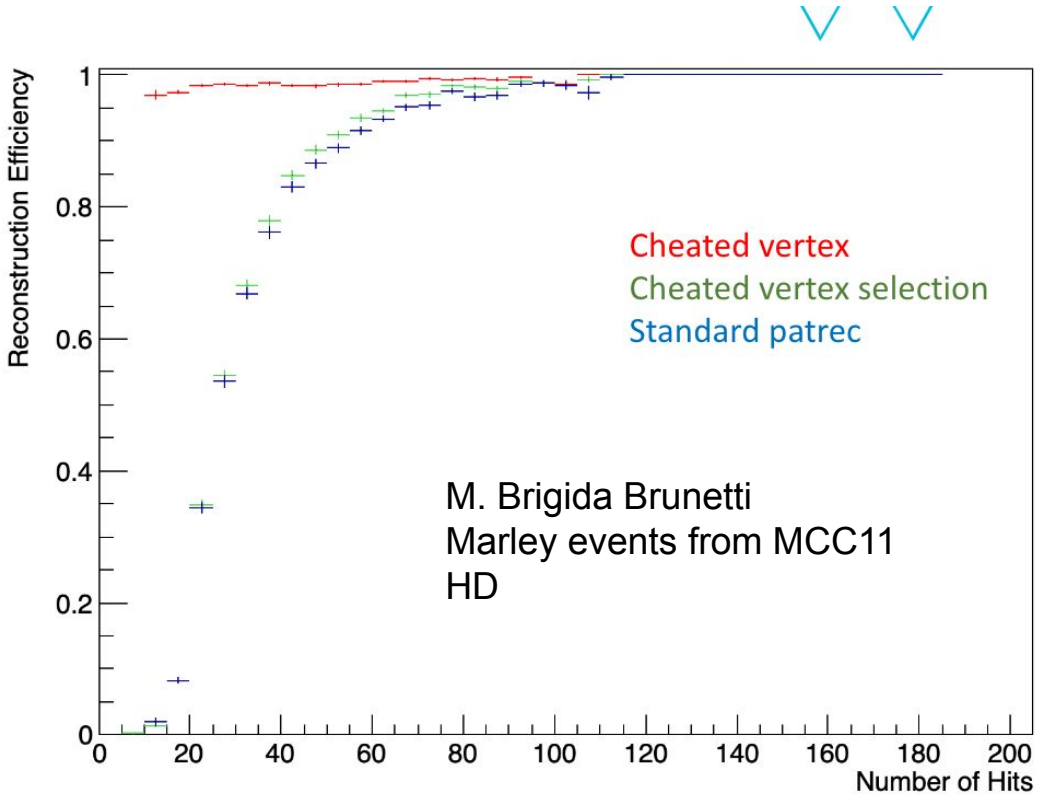
- HD and VD currently use ‘workspace’ subsets of the full geometry due to scaling issues
- Key issue is memory footprint from immense size of raw digits output from the detector simulation
- Other issues are expected to be
  - Run time
  - File size
- Memory can be addressed by processing subsets of the detector through the detector signal simulation/signal processing in wirecell, rather than holding entire operation in memory
- It’s possible we may also need more extreme solutions when scaling up
  - e.g. only saving channels containing true signal
- This will need to be another primary focus going forwards, as this is highly desirable across the physics working groups

Future plans: Energy reconstruction

- Management/LBL would like to move away from the MC correction-based energy reconstruction used for both the HD/VD TDR
  - Needed to harmonise the energy reconstruction with the ND/PRISM
- This updated energy reconstruction method could be:
  - As simple as dropping the correction but keeping the lepton+hadronic blob energy reconstruction philosophy
  - As complicated as 3D reconstructing all particle in the event and summing each particles momenta/energy (or even more complicated)
- Separately, there are studies underway to combine TPC+PDS to maximise energy reconstruction performance (see. G. Brunetti's talk today)

Future plans: Low energy reco with Pandora

- The low energy reconstruction (in both HD and VD) makes use of outdated/unsupported algorithms
  - e.g. trajcluster + pmtrack
- Pandora has been in use in multiple groups as the primary means of pattern recognition+3D reconstruction for awhile now
- Pandora has never been developed/optimised for low energy events
  - LE event signature very different from any ‘high energy’ topology
  - This will, most likely, require targeted algorithm development rather than a simple retune
- M. Osbiton (New Warwick PhD student) is picking up this development



Future plans: Energy reco with backgrounds

- Updated background model for both HD and VD
  - Decay0 model (more details here): LAr bulk (39Ar, 42Ar, 85Kr, 222Rn and their decay chains) + cathode (drifted 42K, 40K and 238U decay chain) + CRPs (60Co and 238U decay chain) + PDS (222Rn decay chain) + external sources (gammas and neutrons from surrounding rocks)
- Obvious impact on LE physics
- Need to evaluate the impact on energy reconstruction for beam events, specially on
  - Hadronic component
  - NC events use the calorimetric sum of all hits

Summary

- New convener: L. Paulucci
- Recent burst of VD activities resulting in a completed TDR chapter and successful LBNC review
- The group can now shift focus to update the HD production
- Other priorities going forward:
  - Full geometry
  - Energy reconstruction
  - LE reconstruction with Pandora
  - Impact of backgrounds
  - Validation system development (A. Chappell, see backup)
  - Your ideas here

Validation system and automating future studies

- We are periodically asked, '*Can you study changing FEATURE/PARAMETER in the vertical drift simulation?*'
  - Our answer is usually '*no*'

- Any such study usually relies on 3 pieces of work
  1. Altering FEATURE/PARAMETER in the simulation
  2. Simulating/reconstructing events using the altered codebase
  3. Making plots using the simulated events

- We can borrow from a well-established validation system in HD (**developed by R. Cross, V. Di. Benedetto**) to mostly automate such studies
  - This would reduce the active work to step 1) and automate step 2) & 3)
  - https://wiki.dunescience.org/wiki/DUNE_Computing/DUNE_CI_Setup_and_Usage

x