Astrophysical neutrino searches with the DUNE experiment

DEEP UNDERGROUND NEUTRINO EXPERIMENT

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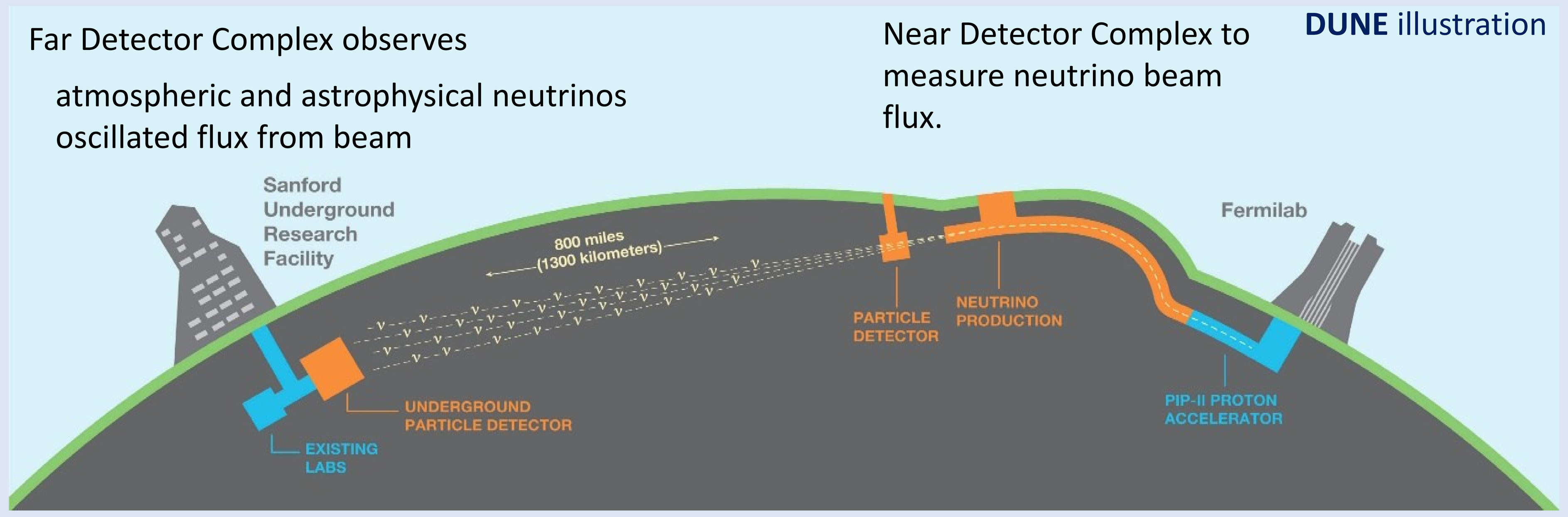
1. Deep Underground Neutrino Experiment

The Deep Underground Neutrino Experiment (DUNE) is a next-generation long-baseline experiment, hosted in the USA, that will precisely measure neutrino oscillation parameters, observe astrophysical neutrinos, and search for evidence of physics beyond the standard model.



- The Far Detector complex is situated 1.5 km underground and nominally comprises four Liquid Argon Time Projection Chamber detectors (LArTPCs), each with a fiducial mass of at least 10 kton.
- First two module designs are a vertical drift (VD) [1] detector and a horizontal drift (HD) detector [2].

4. Supernova Pointing

Reconstructing the location of the supernova neutrino burst on the sky plays a critical role in identifying the super-nova progenitor. Burst time and location is sent to the Supernova Early Warning System (SNEWS) [6] and is invaluable for coordinating multi-messenger observatories across the globe.

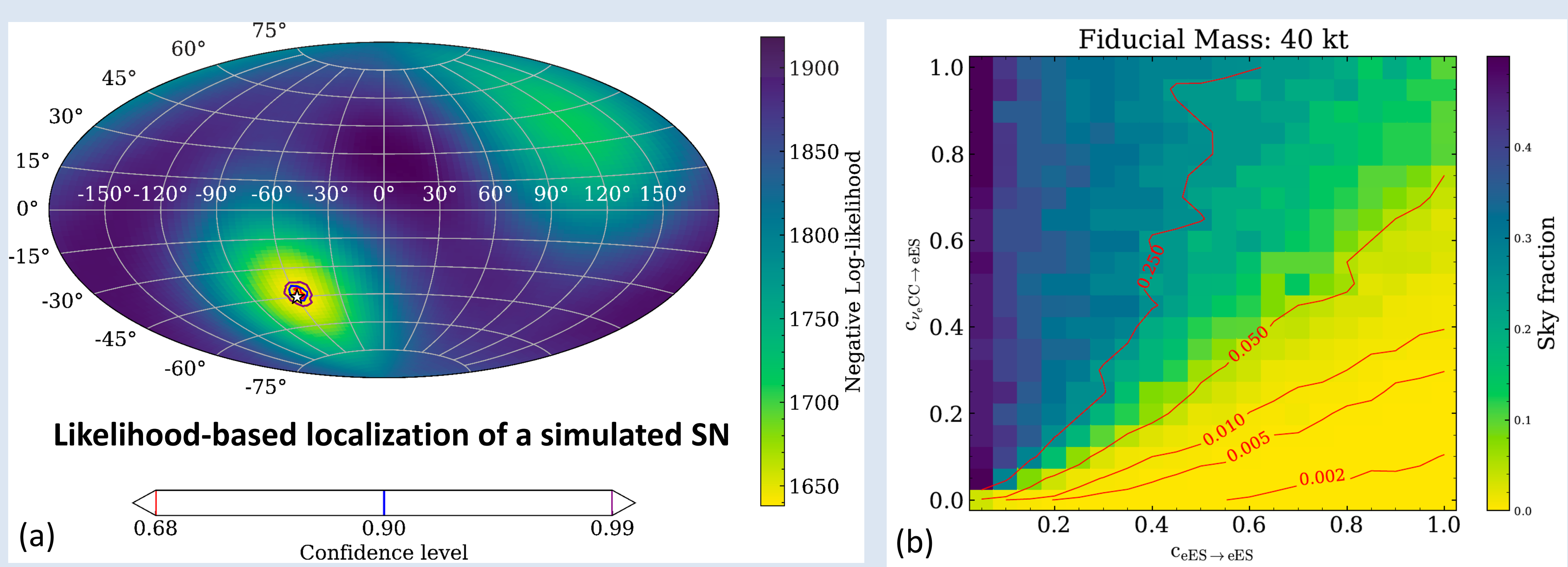
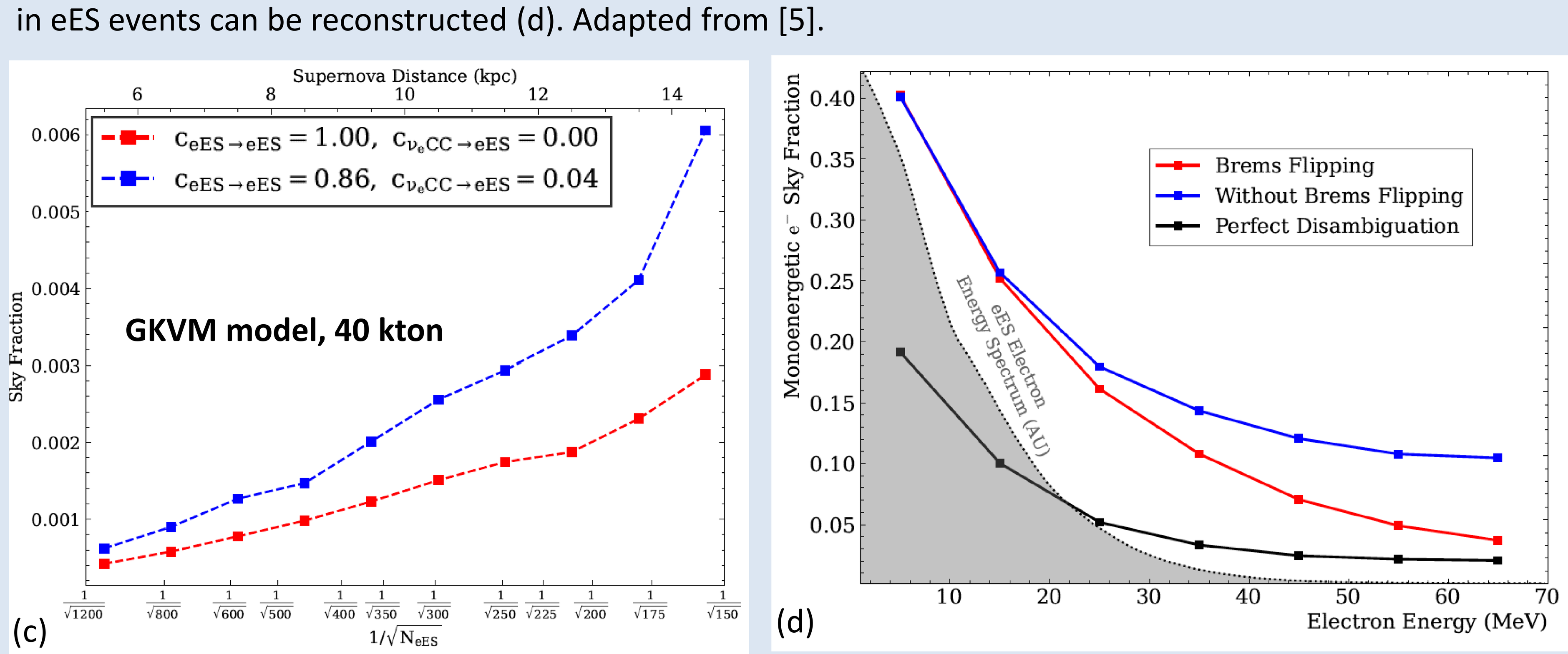


Figure 4.1. Burst localization (a) depends on) how well eES and ν_e CC interactions can be distinguished (b), the number of ν_e elastic scattering (eES) interactions (c), and how well the direction of the primary electron in eES events can be reconstructed (d). Adapted from [5].



With electron ES (eES) classification efficiency of 86% and a ν_e CC misclassification rate of 4%, the estimated pointing resolution is 4.3° for 68% of sky-coverage for the full detector and 8.7° for 1 HD module [5].

2. Astrophysical Neutrinos with the DUNE Far Detectors

Core-collapse supernovae (CCSNe) produce a massive flux of neutrinos of all flavors that carry away 99% of the gravitational binding energy of the star.

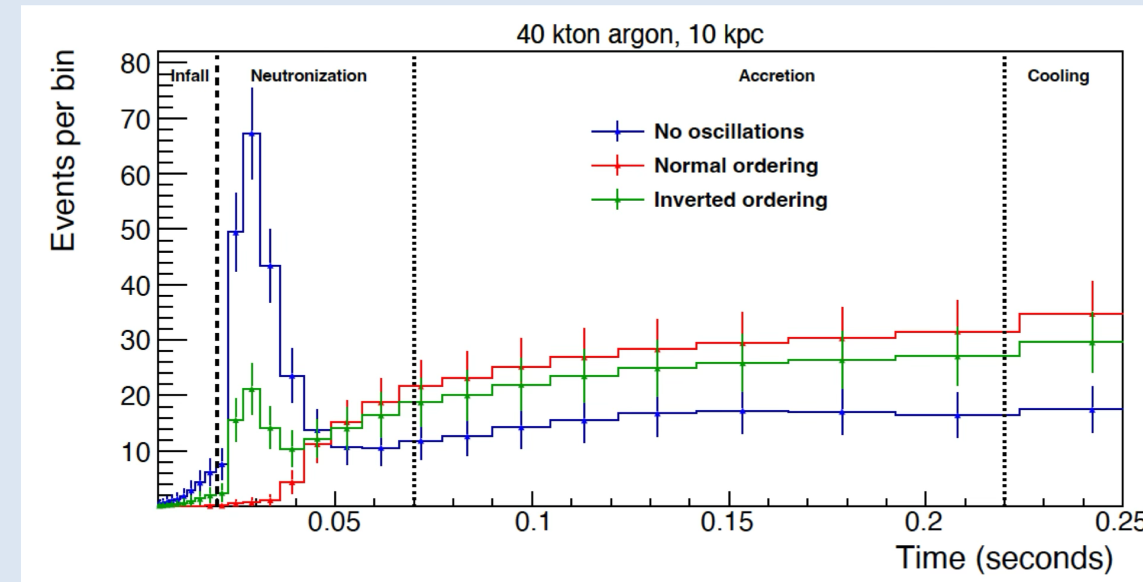


Figure 2.1: Predicted burst time profile, as observed by DUNE, of the Garching electron capture SN model. From [3].

- Neutrino flux precedes electromagnetic (EM) radiation.
- Neutrino flux visible even if EM component obscured by dust or absent (i.e. black hole formation).
- Information about the core-collapse mechanism, SN evolution, neutrino mass ordering, and flavor oscillation is imprinted on flavor-separated spectrum and burst time profile.

- DUNE's sensitivity to the ν_e component complements other neutrino detectors.
- 1-3 SN/century are expected in our Galaxy.
- It is vital DUNE triggers effectively on a Galactic SN.

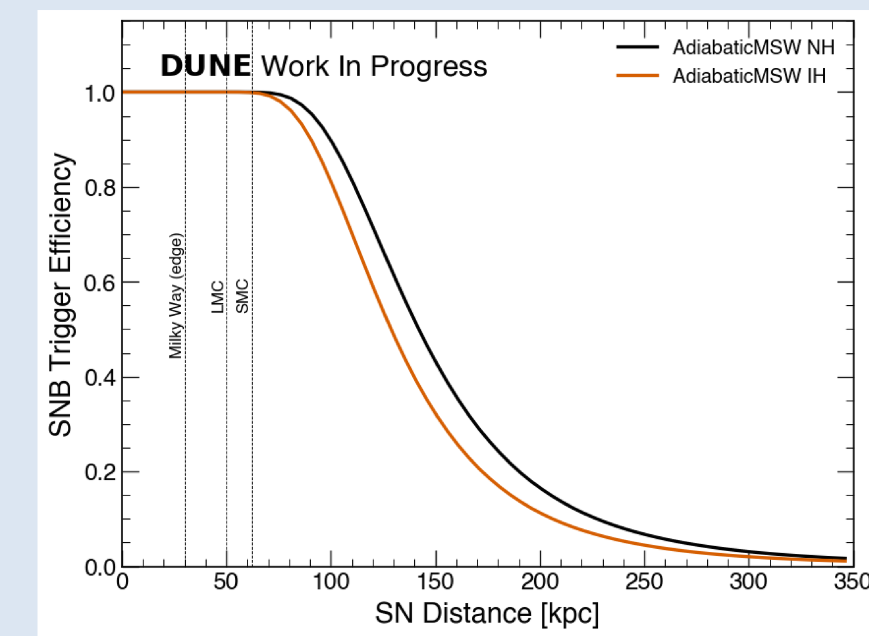


Figure 2.2: SNB trigger efficiencies vs. distance for a single HD module for E_ν>10 MeV. Core-collapse SN model from [4].

- Astrophysical neutrino signatures like the Diffuse Supernova Neutrino Background and solar hep and ^{8}B neutrinos are also of interest.

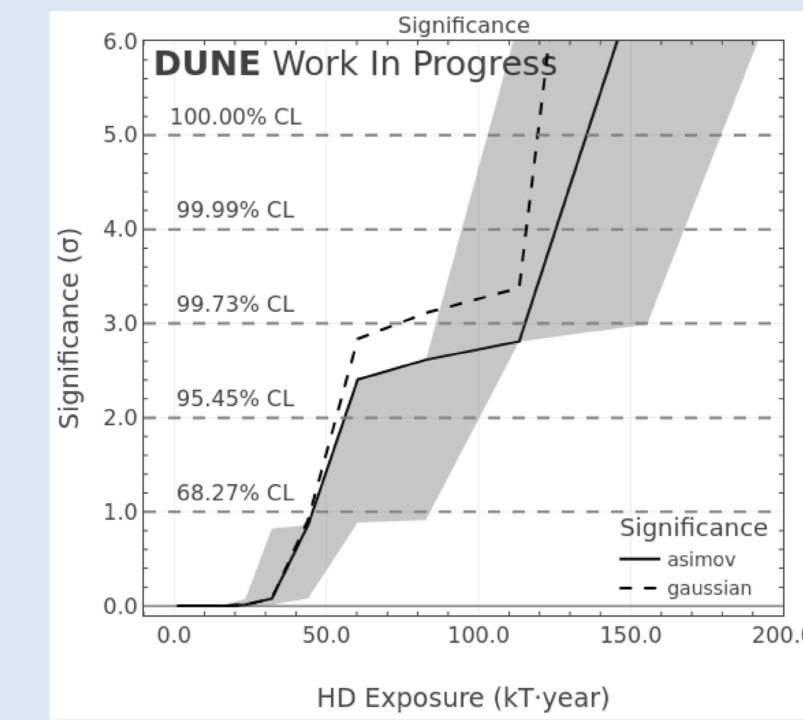


Figure 2.3: projected sensitivity of the first HD module to hep neutrinos. Projections are sensitive to fiducial cuts and assumptions about radiological backgrounds.

3. Low-Energy Neutrino Detection and Reconstruction

Low-energy (<100 MeV) neutrinos produce small, localized signatures in the detector that are challenging to reconstruct.

The dominant supernova neutrino detection channel in DUNE is ν_e charged-current (CC) on LAr. The electron track is used to estimate the incoming ν_e energy [2]. Rarer elastic scattering (ES) interactions provide the best information about incoming neutrino direction [2,3].

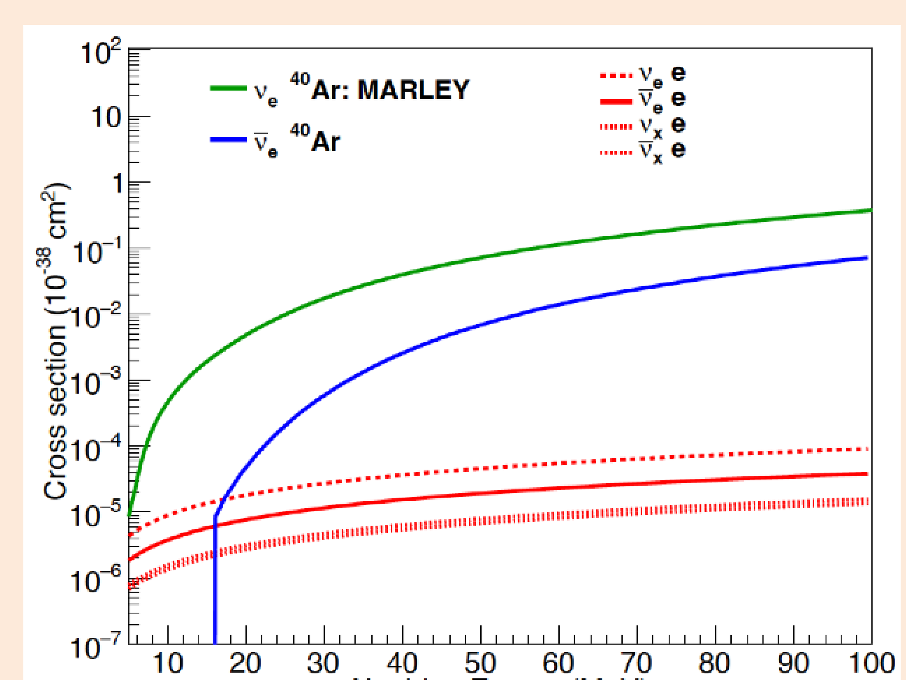


Figure 3.1: Relevant ν cross-sections on LAr. From [3].

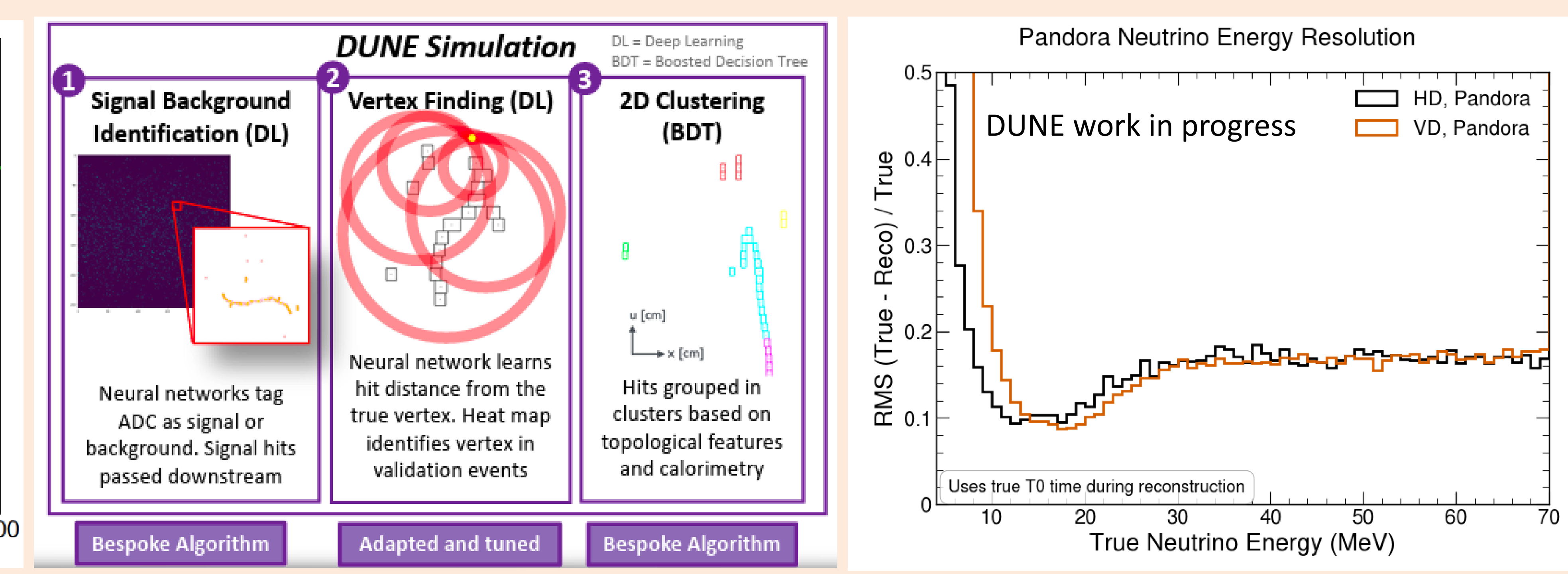


Figure 3.2: Performance of a new multi-algorithm pattern recognition reconstruction chain (left) optimized for low-energy interactions that improves reconstruction efficiency, energy resolution (right) and improves on the direction reconstruction shown in Panel 4.

References and Acknowledgements

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