ANNIE: New Developments in Neutrino Detection

Franklin Lemmons – SDSM&T
For the ANNIE Collaboration

Abstract

The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a 26-ton water Cherenkov neutrino detector along the Booster Neutrino Beam (BNB) at Fermilab. Its primary physics goals are the measurement of final-state neutron yield of neutrino interactions and of charged-current cross section of muon neutrinos. ANNIE is also a prime staging ground for up-and-coming technologies in neutrino detectors. One such technology is Water-based Liquid Scintillator (WbLS), a novel detector medium aimed at combining the advantages of Cherenkov and scintillation detectors. ANNIE has recently deployed a target 366L vessel of WbLS in its tank. This talk will detail the experiment and its recent activity, up to and including this deployment.

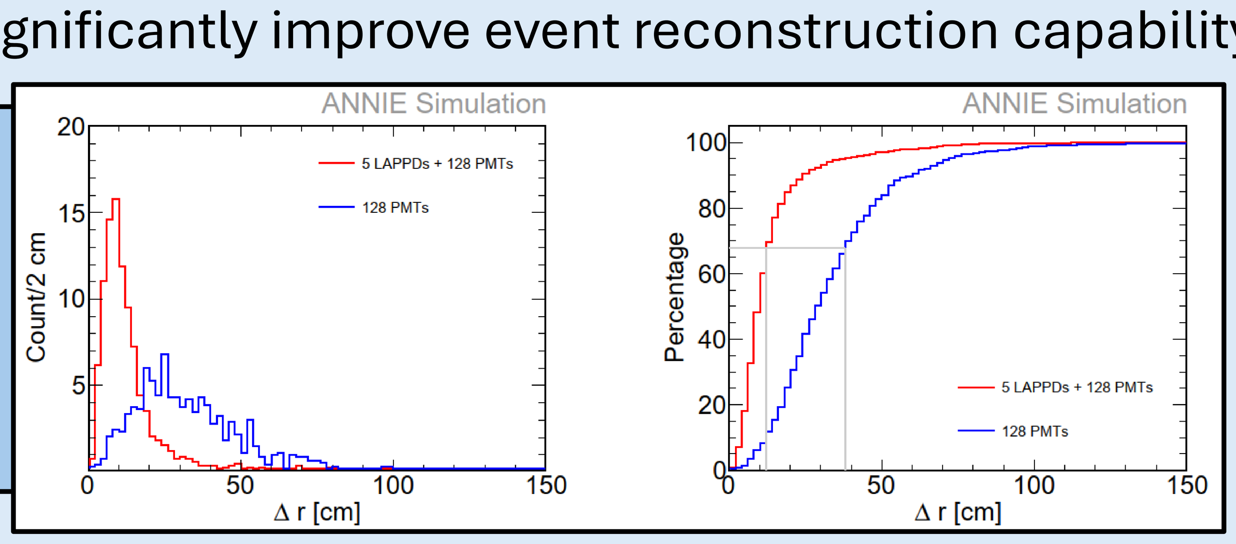
Physics Motivation

- Understanding the full scope of neutrino-nucleus interactions is crucial to making precise neutrino energy measurements
  - Precise measurement of neutrino cross-section are needed in a variety of targets and energy ranges
  - Account of final state hadrons is needed to fully understand interactions
- ANNIE provides measurements of neutrino events on water
  - Measurement of final-state neutron multiplicity
  - Measurement of CCQE and NCQE cross sections
  - These measurements will aid in background rejection for proton decay and DSNB searches

New Technology

- Gd-doped Water
  - Gd resonance allows for neutron captures after only ~30 μs
  - Deexcitation gamma ~8 MeV allows for capture detection
- Large Area Picosecond PhotoDetectors (LAPPDs)
  - 20x20cm, Sensitive to photon position on surface
  - ~50ps time resolution
  - Expected to significantly improve event reconstruction capability

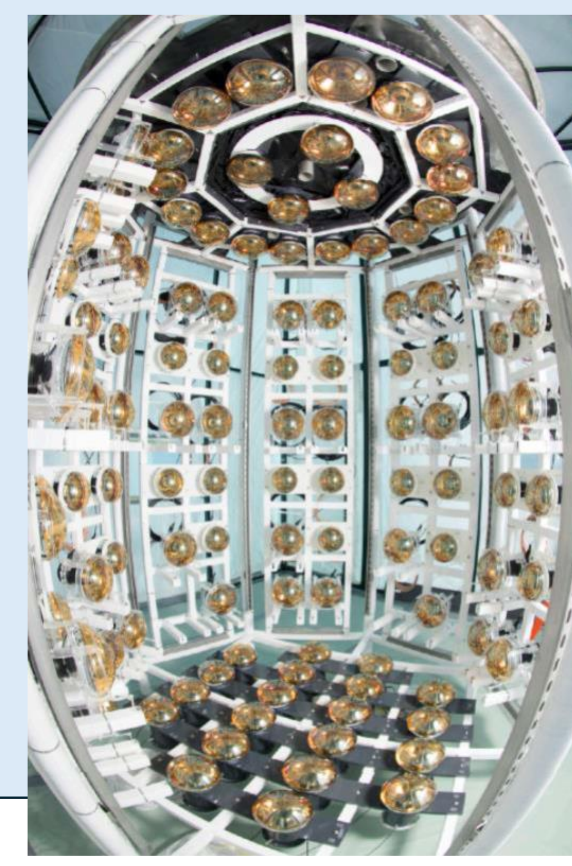
Left: Reconstructed event vertices compared with simulated true positions
Right: Cumulative distribution of the same; 1σ resolutions: ~40cm improved to ~10cm with 5 LAPPDs

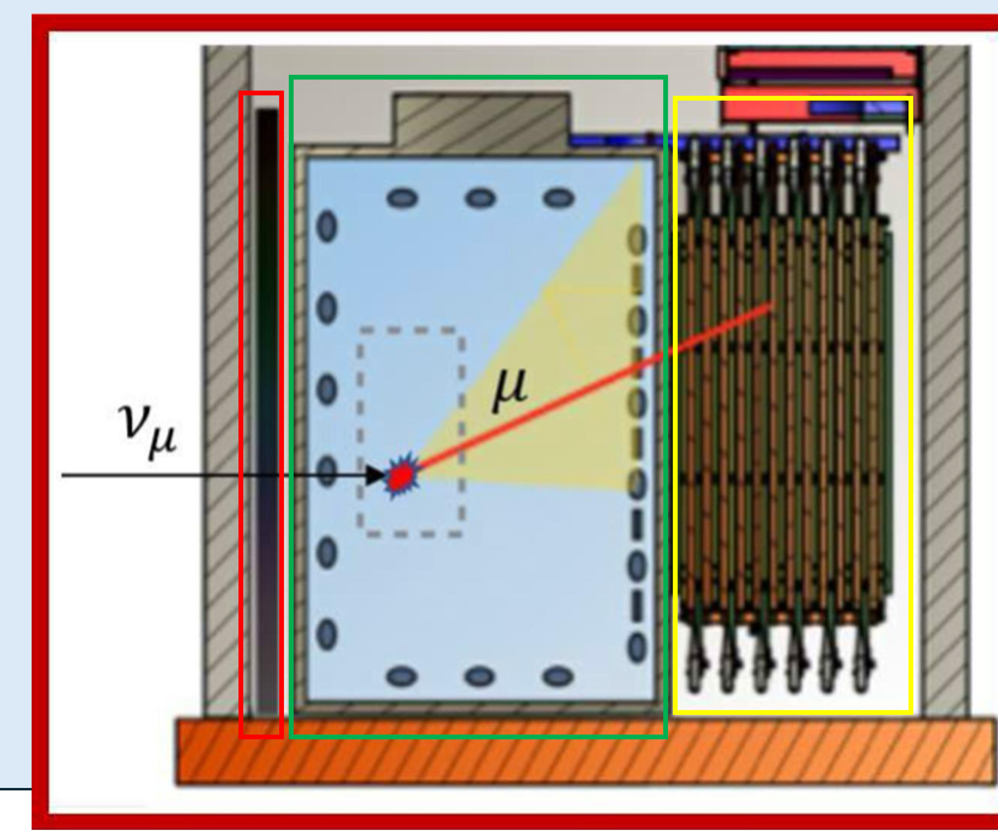


- WbLS
  - Scintillating oil suspended in water
  - Adds isotropic scintillation light to directional Cherenkov signal
  - Separation of scintillation and Cherenkov allow enhanced reconstruction

The Detector

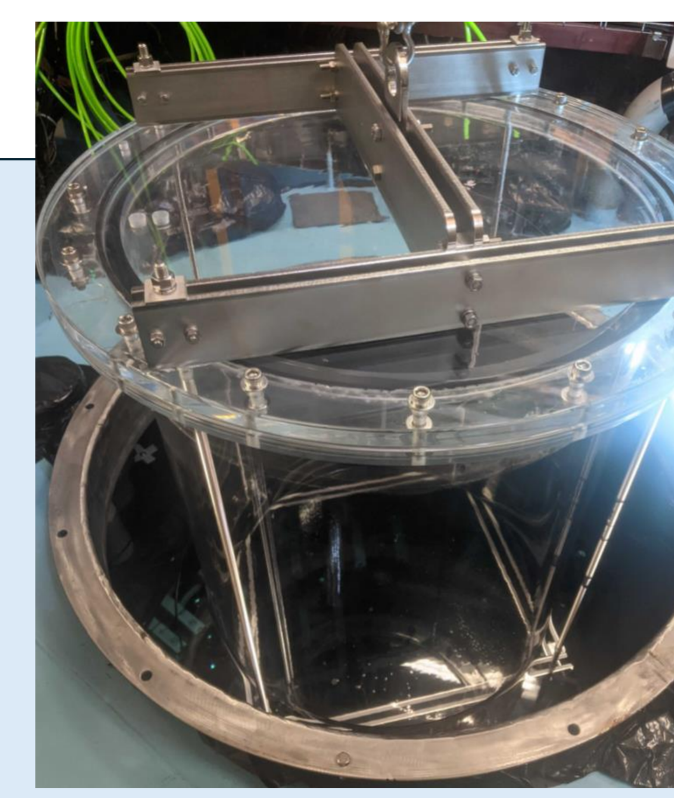
- Front Muon Veto (FMV)
  - Single panel of scintillator material
  - Rejects neutrino events not originating from within the tank volume
- Tank Volume
  - Gd-loaded water outfitted with photodetector array
  - Cherenkov signals from resultant leptons
  - Deexcitation gammas after neutron capture on Gd
- Muon Range Detector (MRD)
  - 12 panels of scintillator material interspersed with iron layers
  - Iron slows outgoing muon, to measure penetration depth
  - Depth and direction are used to reconstruct muon momentum and energy

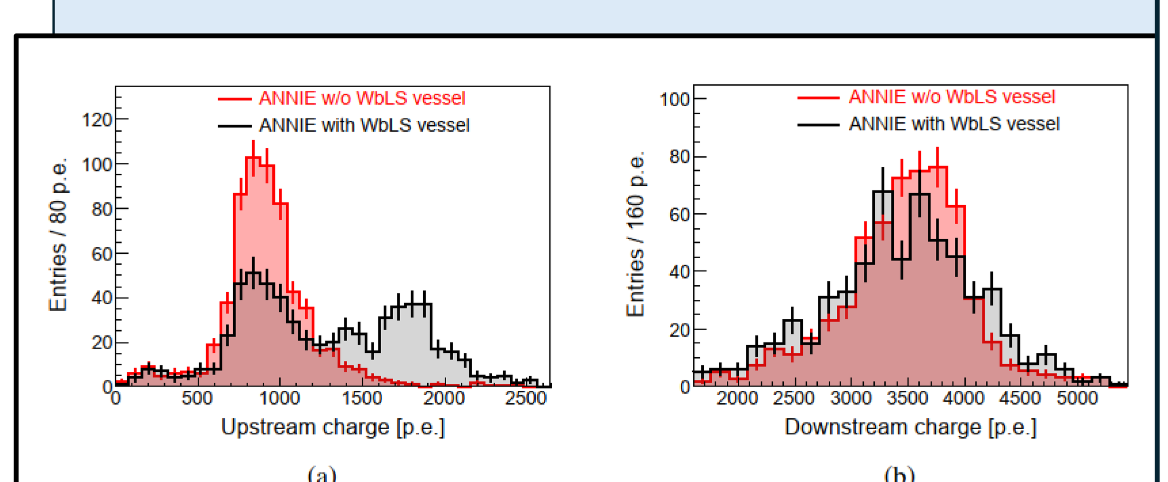




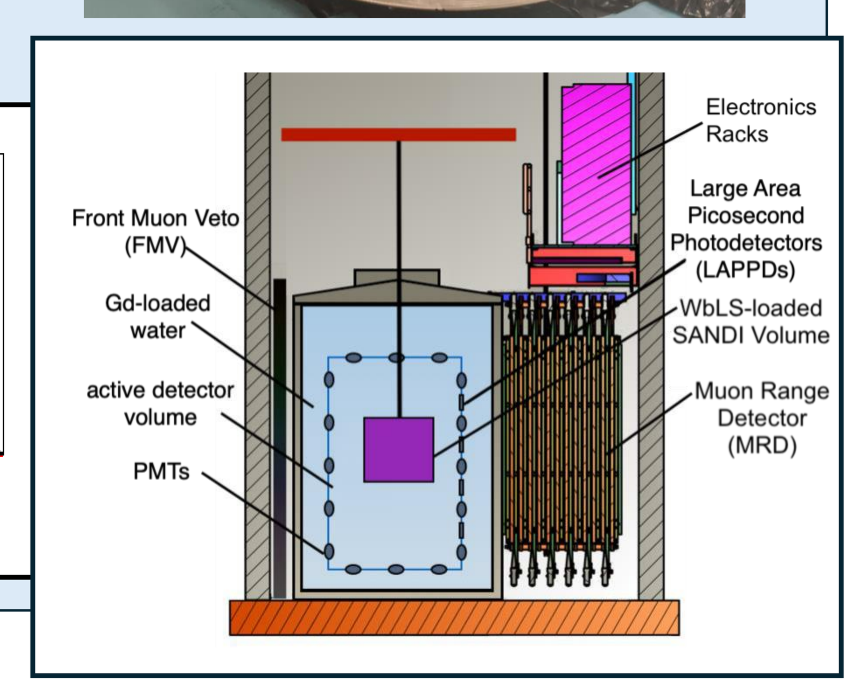
SANDI Deployment

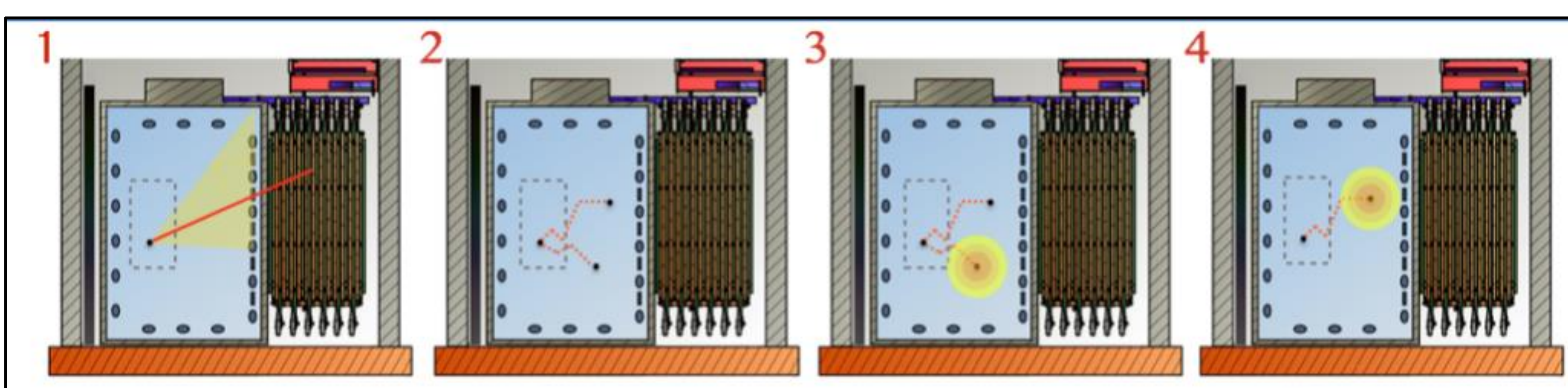
- Scintillator for ANNIE Neutrino Detection Improvement (SANDI)
  - 366L vessel of WbLS material suspended in ANNIE tank volume
  - Combined data collected for about two months.
  - Upstream PMTs saw notable increase in charge
  - Further analysis is ongoing

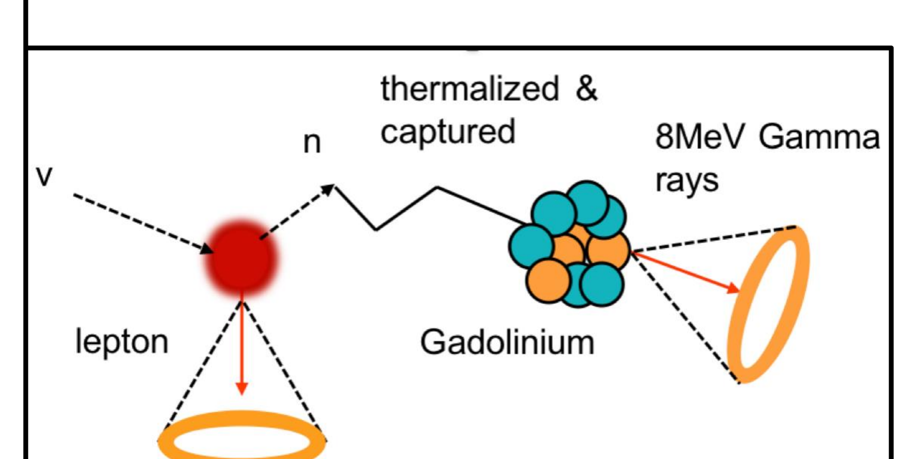




Comparison of upstream and downstream charge distributions before and after SANDI deployment







Left: Process of neutron detection in ANNID: 1) Neutrino interacts with water nucleus, resulting in a charged lepton (usually muon) and other particles, including neutrons. 2) Generated neutrons drift through the tank, losing energy to collisions in medium. 3,4) Thermalized neutrons capture on Gd nuclei, releasing gammas. Right: the same process depicted at the particle scale.