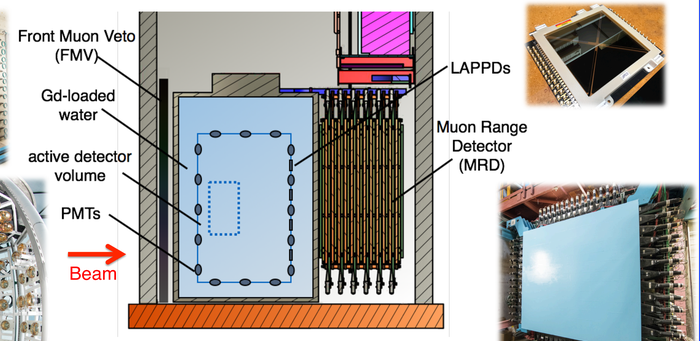
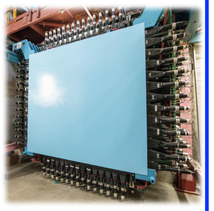
ANNIE: The Accelerator Neutrino Neutron Interaction Experiment

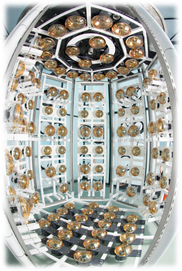
Emrah Tiras, Iowa State University
on behalf of the ANNIE Collaboration

What is ANNIE?

- It is a neutrino detector operating on the Booster Neutrino Beam (BNB) at Fermilab.
- It consists of an upstream Front Muon Veto (FMV), a Gadolinium-loaded 26 ton water Cherenkov detector, and a downstream Muon Range Detector (MRD).





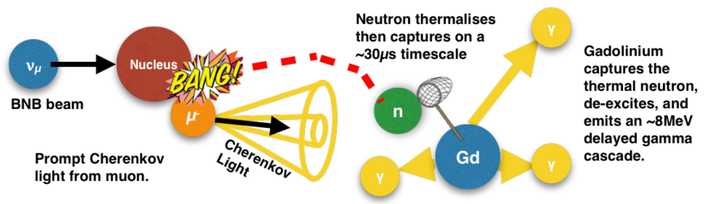


ANNIE is expected to see ~26,000 charged current muon-neutrino interactions in the fiducial volume per year.

- The water volume is instrumented with 132 PMTs and with 5 LAPPDs to be installed imminently.
- MRD consists of 11 alternating layers of plastic scintillator paddles (306 channels) with a 5 cm iron absorber between each layer to reconstruct the energy and momentum of outgoing muons.
- FMV has 2 layers of scintillator paddles and it is used to veto muons not originating in the tank.

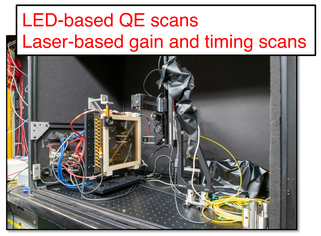
What are the goals of ANNIE?

- Measure the beam induced final state neutron multiplicity in neutrino-nucleus interactions & CC inclusive cross section on water.
- Demonstrate new detection technologies:
  - Neutron tagging in Gadolinium-loaded water
  - Large Area Picosecond Photo-Detectors (LAPPDs)
  - Possible addition of Water-based Liquid Scintillator (WbLS).

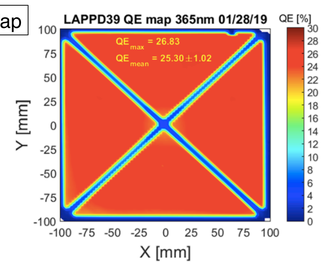


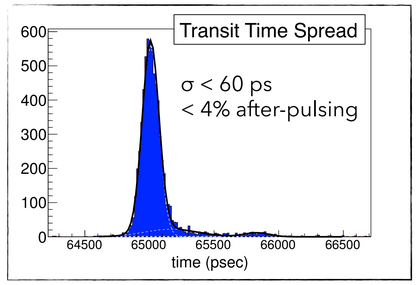
Physics Benefits of LAPPDs

- 8 inch x 8 inch MCP-based fast timing photo-detectors
- 5 LAPPDs are being characterized at Fermilab.
- LAPPDs to be installed in October 2020 - the first use of such in a working neutrino experiment.

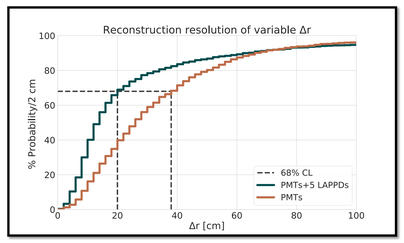


QE Map

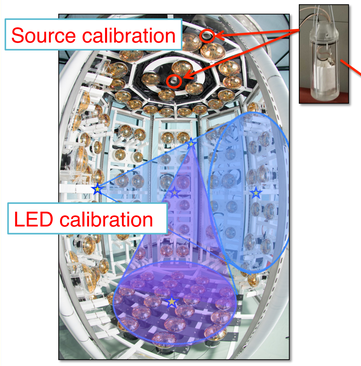


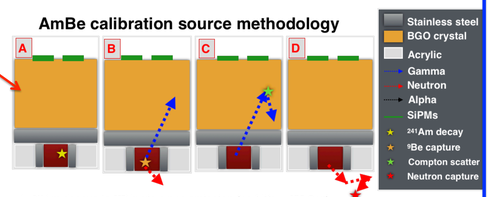


- LAPPDs are used for better vertex reconstruction and to improve background rejection.
- The addition of 5 LAPPDs greatly improves reconstruction of muon track parameters.
- Multi-track reconstruction, non-forward physics and addition of WbLS will require more LAPPDs spread isotropically.



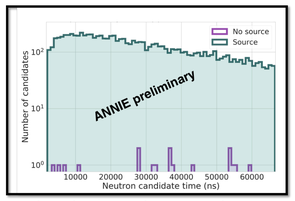
Neutron Capture Calibration Results





A. ^{241}Am decays to ^{237}Np via alpha emission (half-life = 432.2 yr).
B. ^{9}Be can capture the emitted alpha to produce ^{12}C* and a neutron. ^{12}C* produces a prompt 4.44MeV gamma.
C. 4.44 MeV gamma can Compton scatter in the BGO crystal - this gives us a trigger seen by the SiPMs.
D. Neutron thermalises in ANNIE and is captured on Gd.

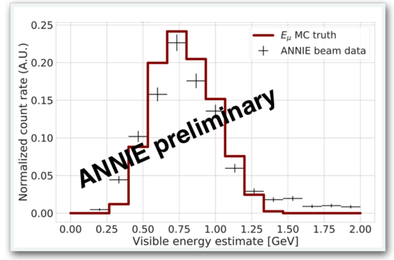
- To probe the neutrino-nucleon interactions we need to reconstruct final-state muons and have a high neutron capture detection efficiency.

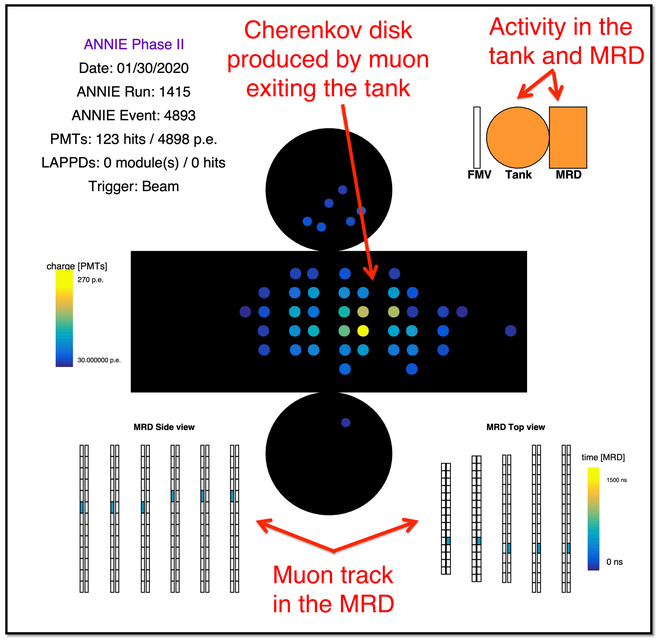


Reconstructed neutron capture candidates

Preliminary Beam Data Results

- ANNIE has detected its first neutrino interactions.
- PMT response times are well clustered.
- In addition to the ability to detect the delayed neutron capture, reconstruction of the interaction vertex is under development.





Conclusions

- ANNIE will measure the neutron multiplicity as a function of momentum transfer for ν_μ interactions - vital for the next generation of neutrino experiments.
- The detector is now operational and has demonstrated the ability to detect both the prompt Cherenkov signal and delayed neutron signal of neutrino-nucleon interactions.

Acknowledgement

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