

ANNIE: Phase I Physics Results and Phase II Plans

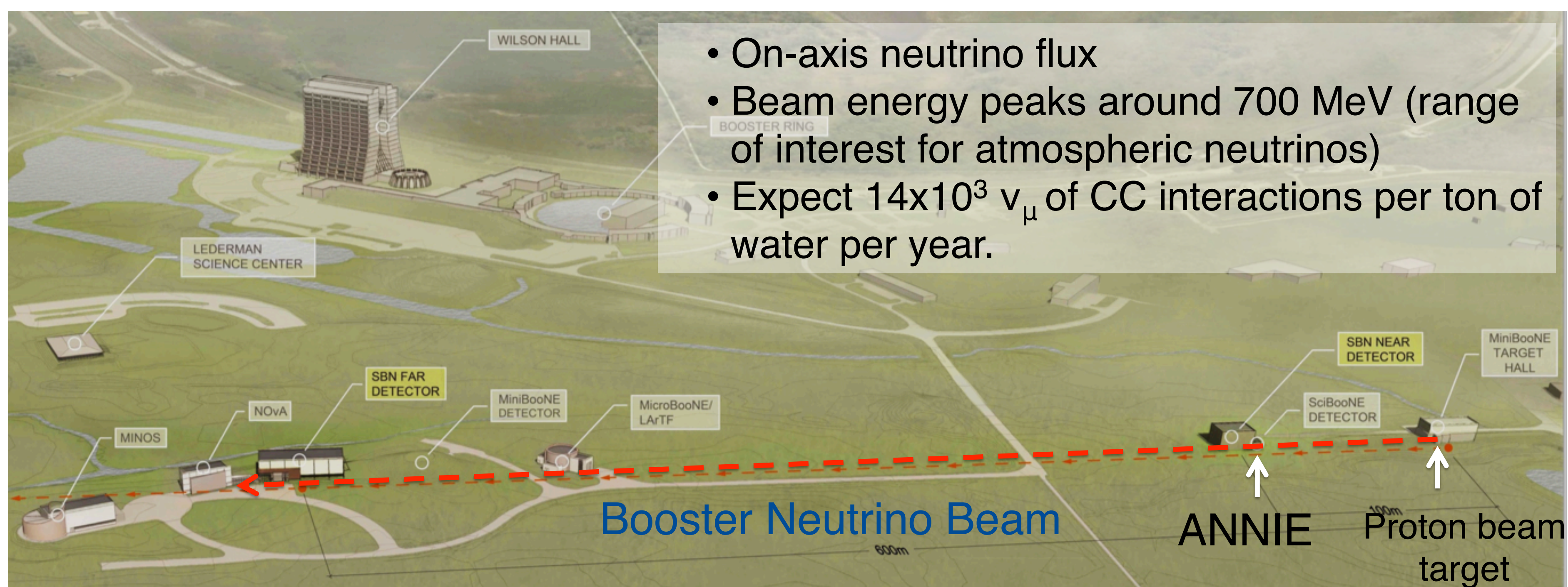
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on behalf of the ANNIE Collaboration



Accelerator Neutrino Neutron Interaction Experiment

The goals of ANNIE:

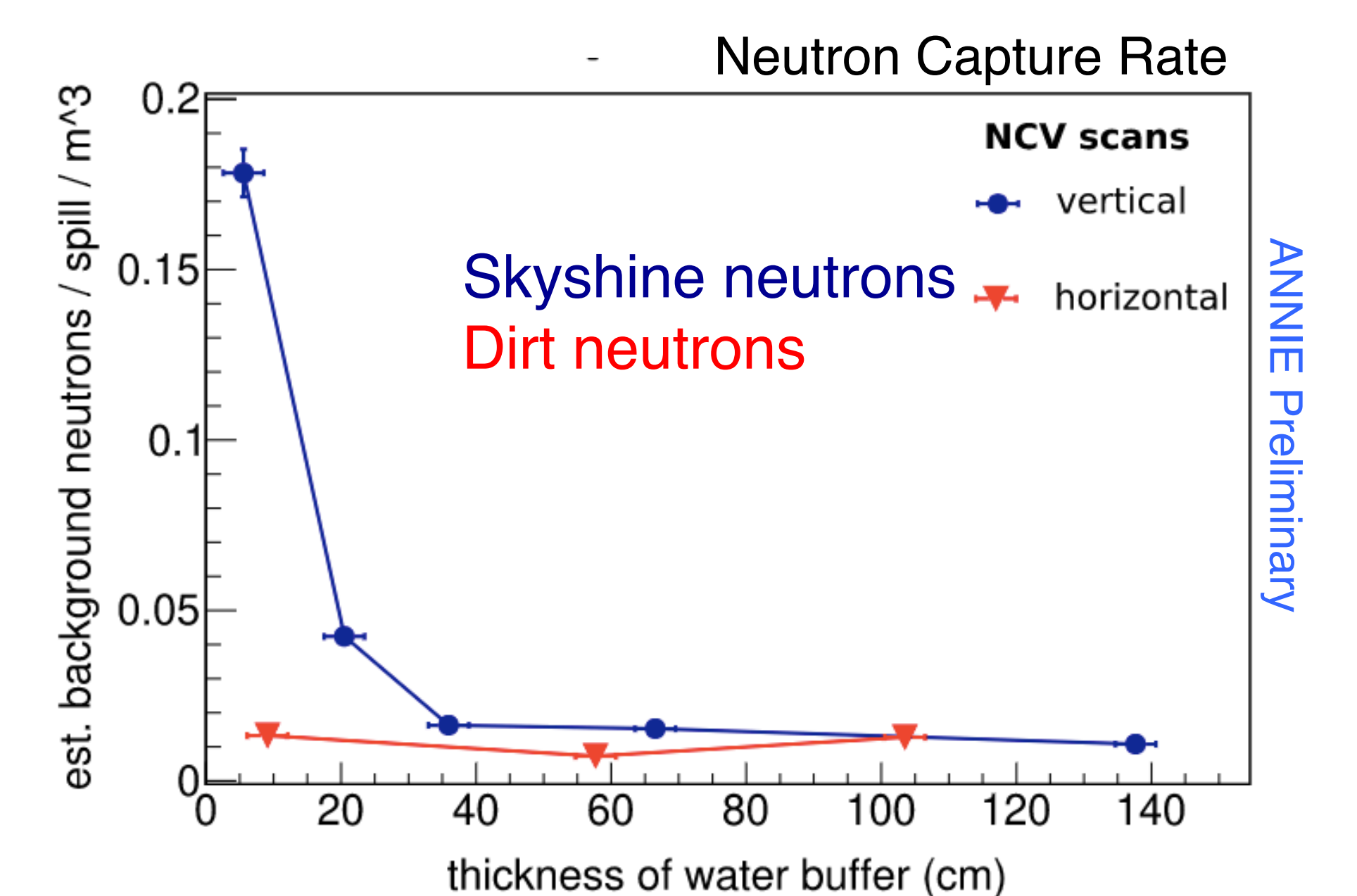
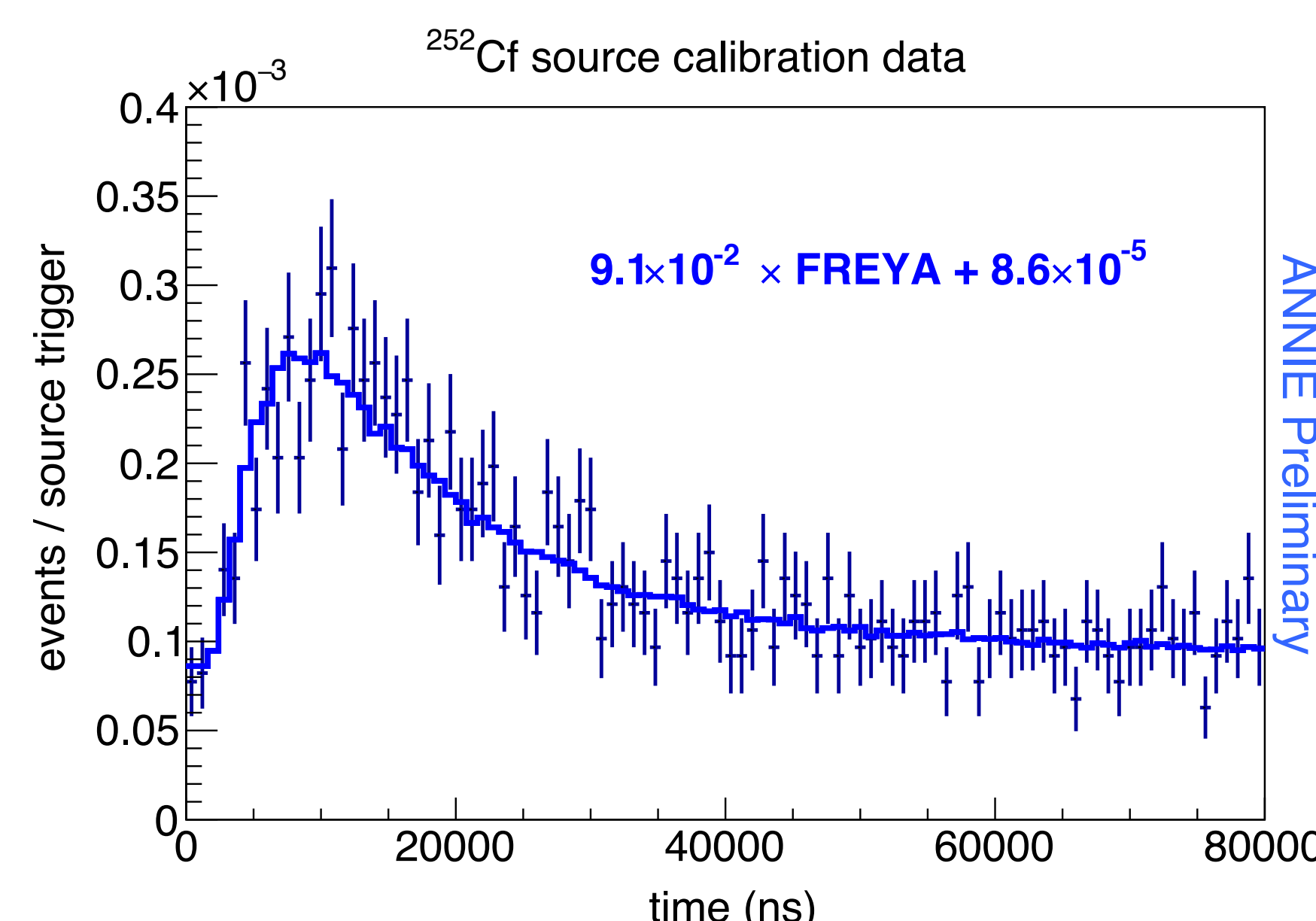
- Measuring the abundance of final state neutrons (the neutron yield) from neutrino interactions in water.
- First major application of Large Area Picosecond Photo- Detectors (LAPPDs) in a neutrino experiment.
- First Gd-loaded water Cherenkov detector to run in a neutrino beam.



- On-axis neutrino flux
- Beam energy peaks around 700 MeV (range of interest for atmospheric neutrinos)
- Expect $14 \times 10^3 \nu_\mu$ of CC interactions per ton of water per year.

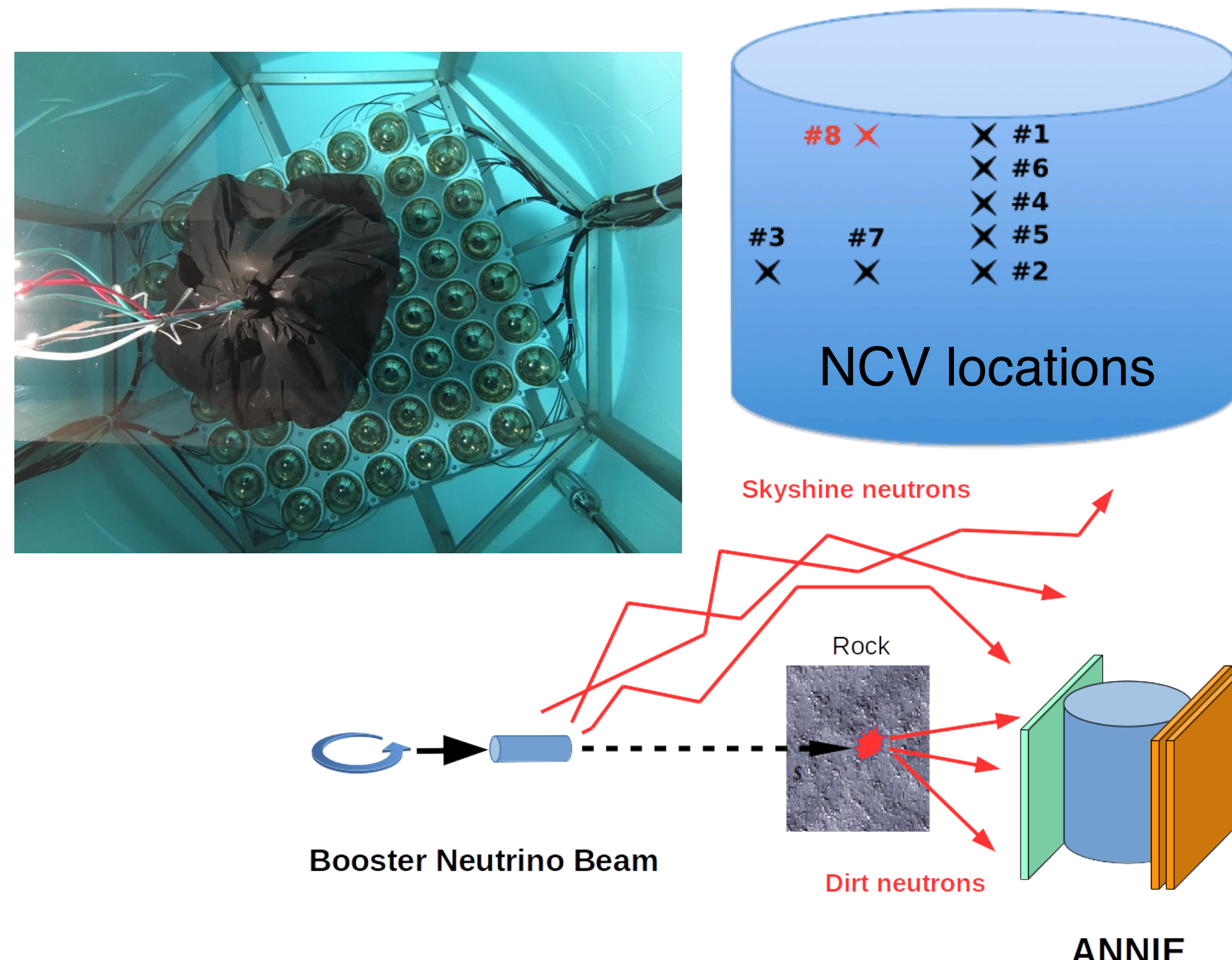
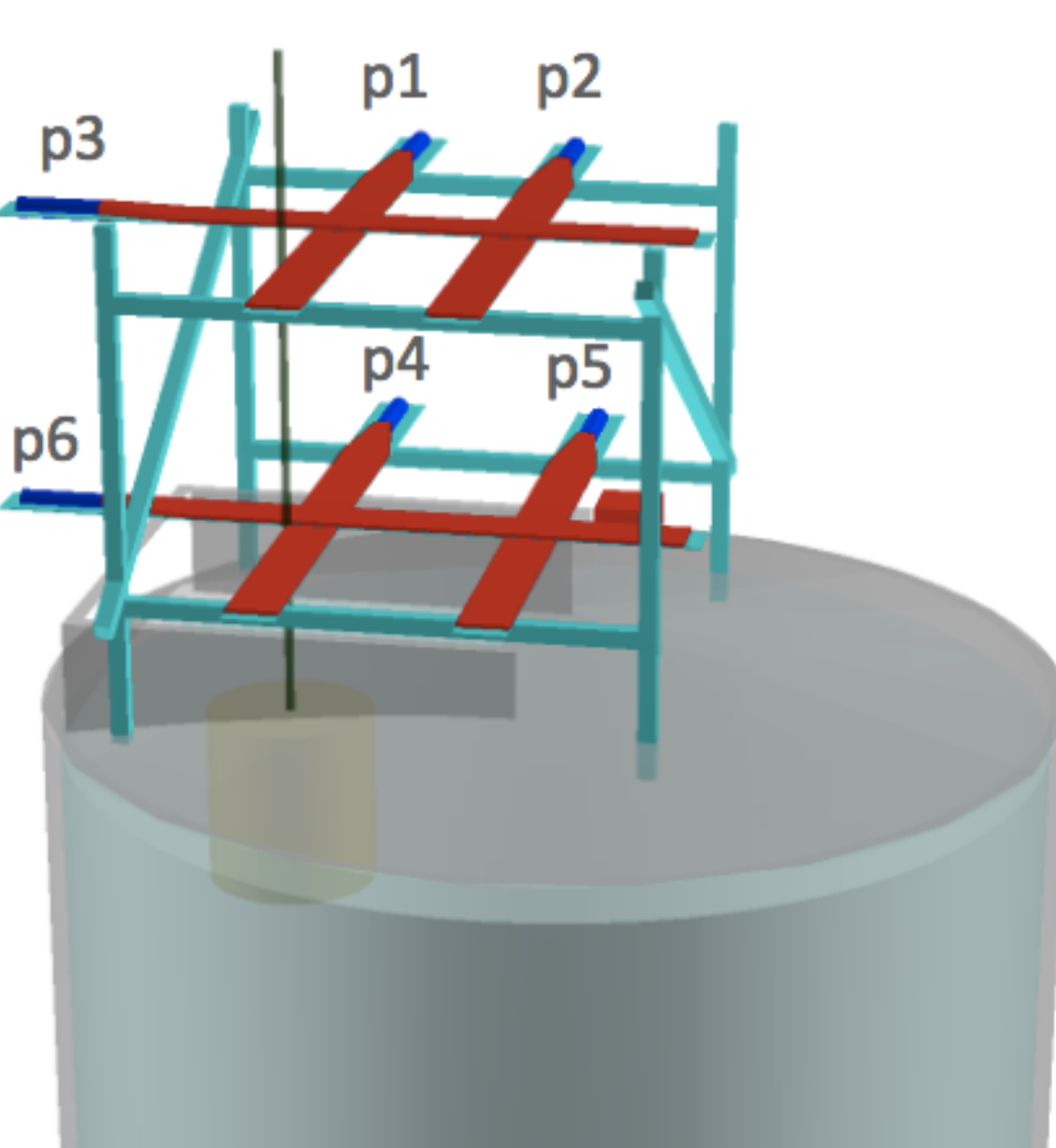
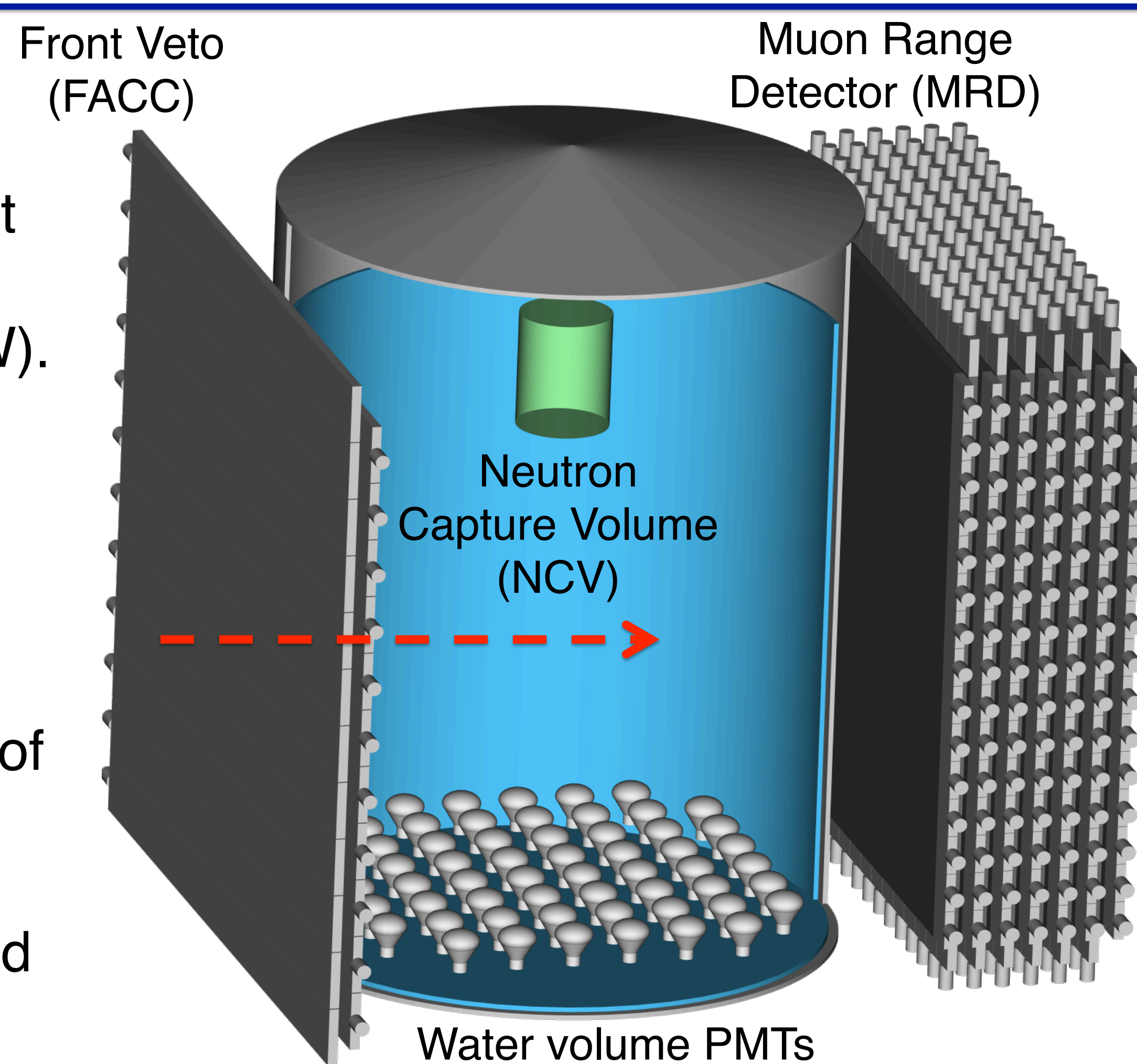
Results of Phase I

- We have detected neutron captures from both a calibration source and the beam.
- Preliminary estimates based on measurements below the surface indicate neutron backgrounds in less than 2% of spills
- Backgrounds are acceptable and can be mitigated with < 2 ft of buffer.



Phase I of ANNIE

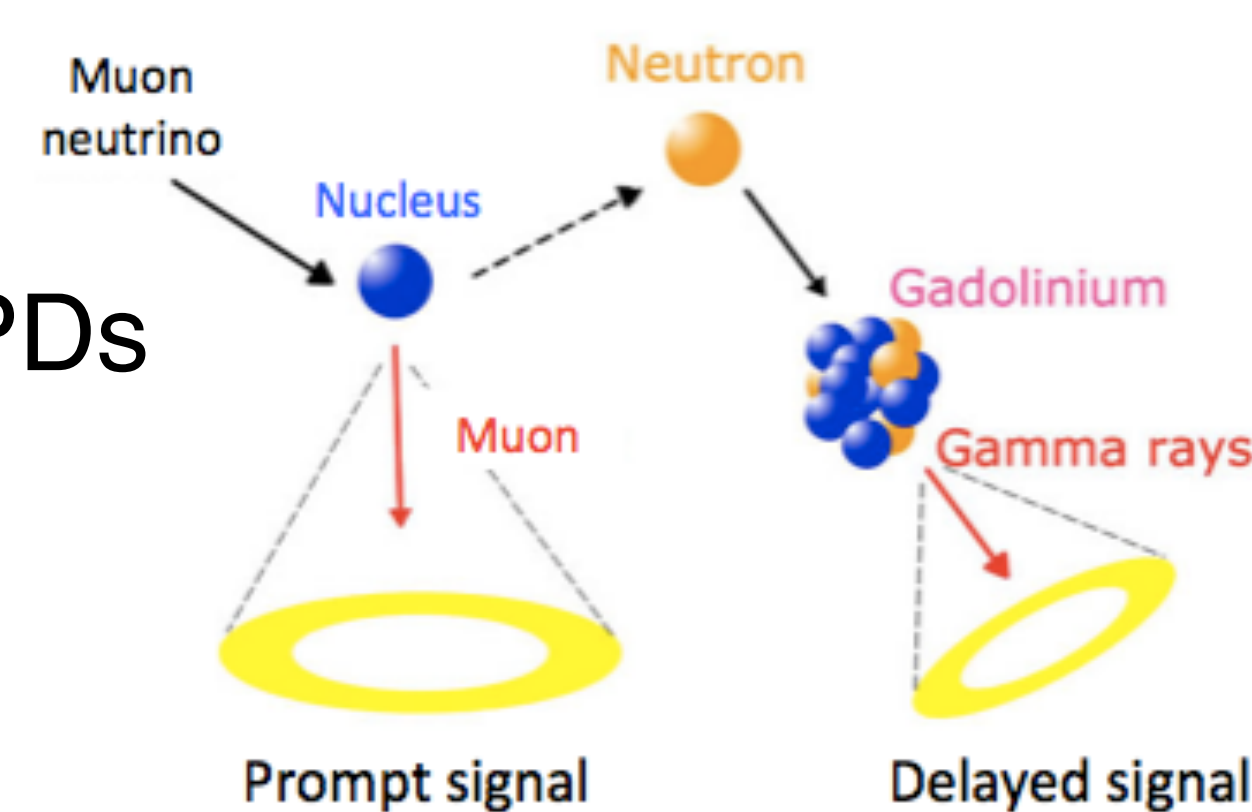
- Steel cylindrical tank, 10 ft x 13 ft and 8 m under the ground.
- 26 tons of ultra-pure water (UPW).
- NCV, a movable acrylic vessel holding 25 gallons of Gd-loaded liquid scintillator.
- FACC paddles veto muons not originating in the tank.
- Sixty 8 inch PMTs at the bottom of the tank.
- MRD consists of 11 alternating layers to measure the energy and direction of stopped muons.
- The first two layers of the MRD are instrumented only during Phase I.



- The goal of Phase I was measuring and understanding beam-induced neutron backgrounds.
- There are two potential background neutron sources in ANNIE:
 - 1 Sky-shine neutrons from the beam dump
 - 2 Dirt neutrons from the rock
- We measured the background neutron flux at different locations in the tank.
- Also we measured the neutrons from a calibration source, ^{252}Cf .

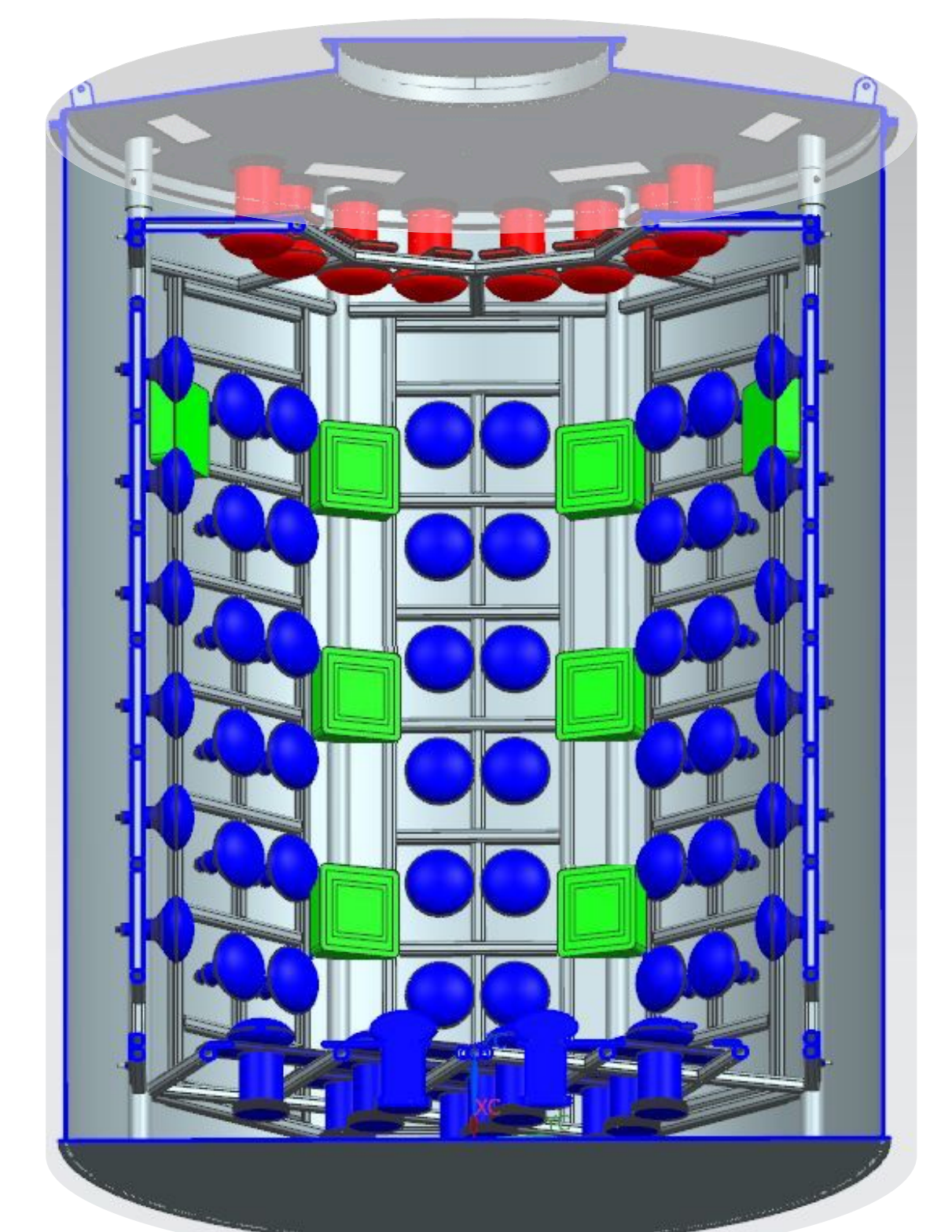
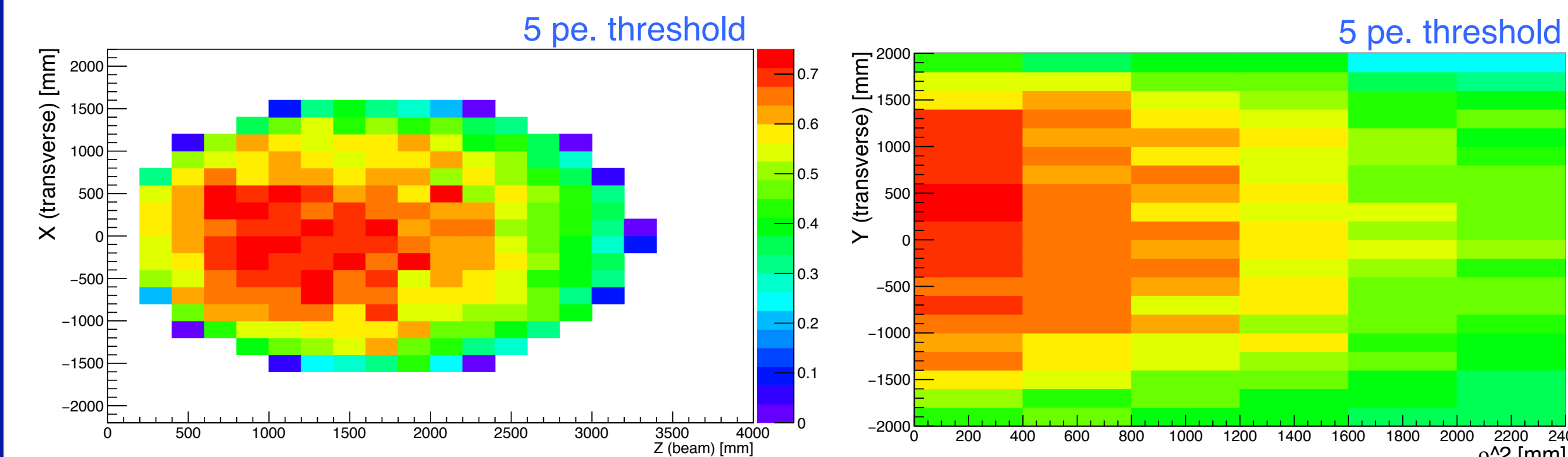
Phase II Plans

- Gd-loaded (0.2%) water tank instrumented with a combination of conventional PMTs (~125) and LAPPDs (~5).
- Fully refurbished MRD, 310 active channels for full muon reconstruction during Phase II.



Neutron Detection Efficiency

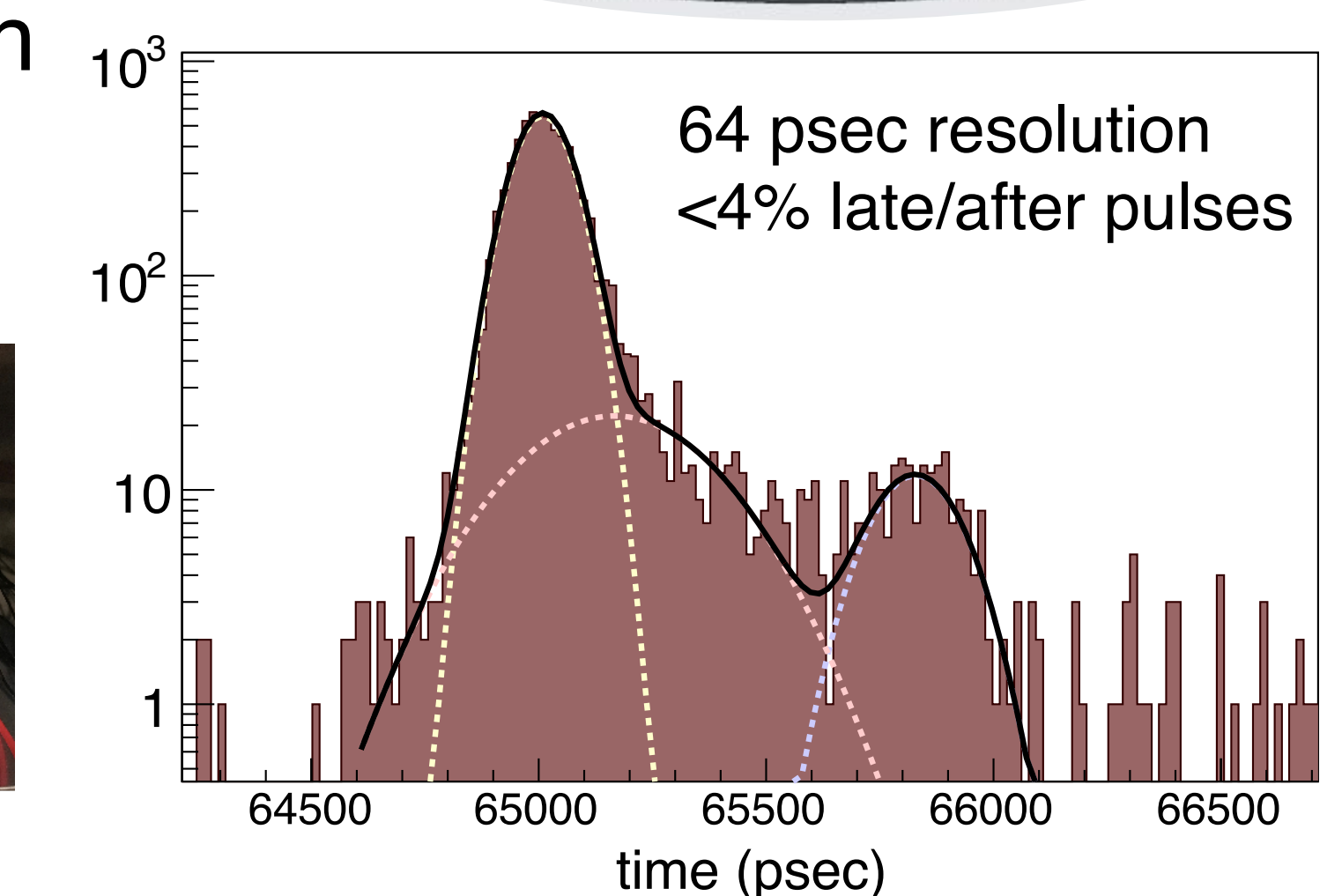
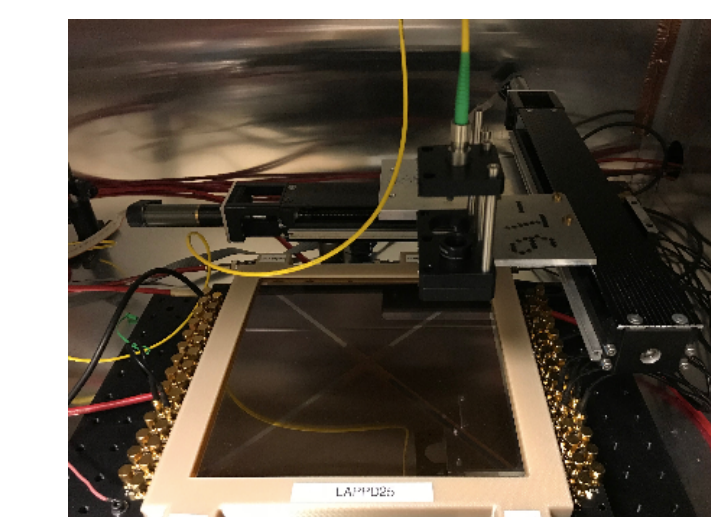
- The detector is large enough to fully contain neutrons
- Requested PMT coverage is sufficient to efficiently detect neutrons.



Enabling Technology

LAPPDs are 8" x 8" imaging photodetectors, with specifications of:

- ~60 picosecond single-PE time resolution
- < 1 cm spatial resolution
- > 20% QE (target)
- > 10^6 gain
- low dark noise (<100 Hz/ch)



Vertex Reconstruction and Fiducialisation

- LAPPDs show substantial improvement in precision for vertex reconstruction.
- LAPPDs help to understand the topology of the events.

