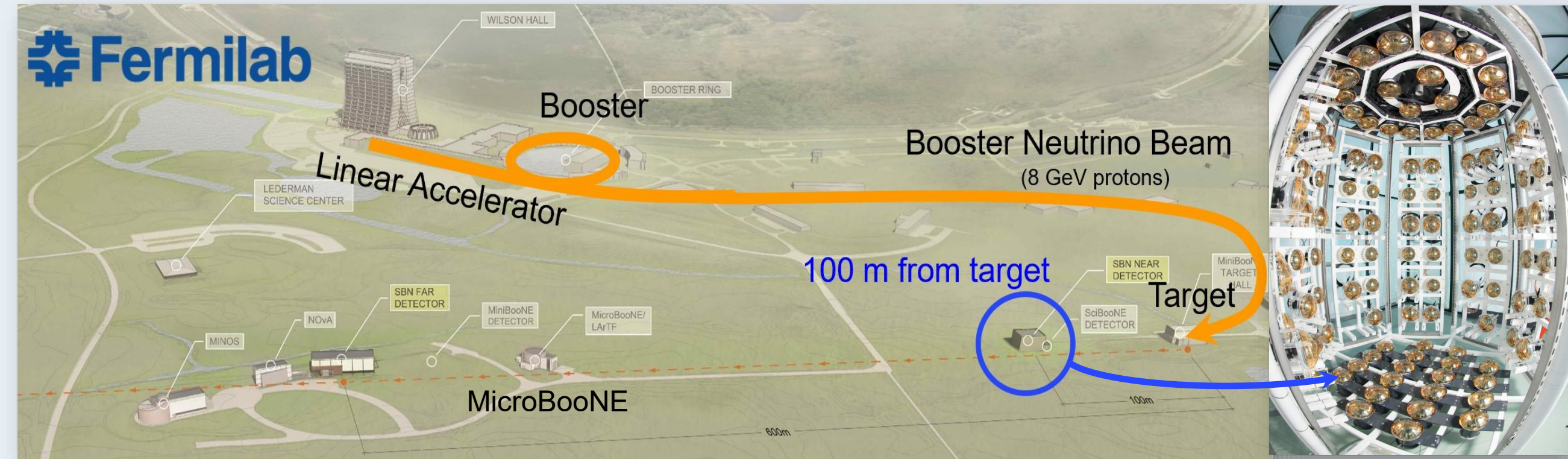


ANNIE: Accelerator Neutrino Neutron Interaction Experiment

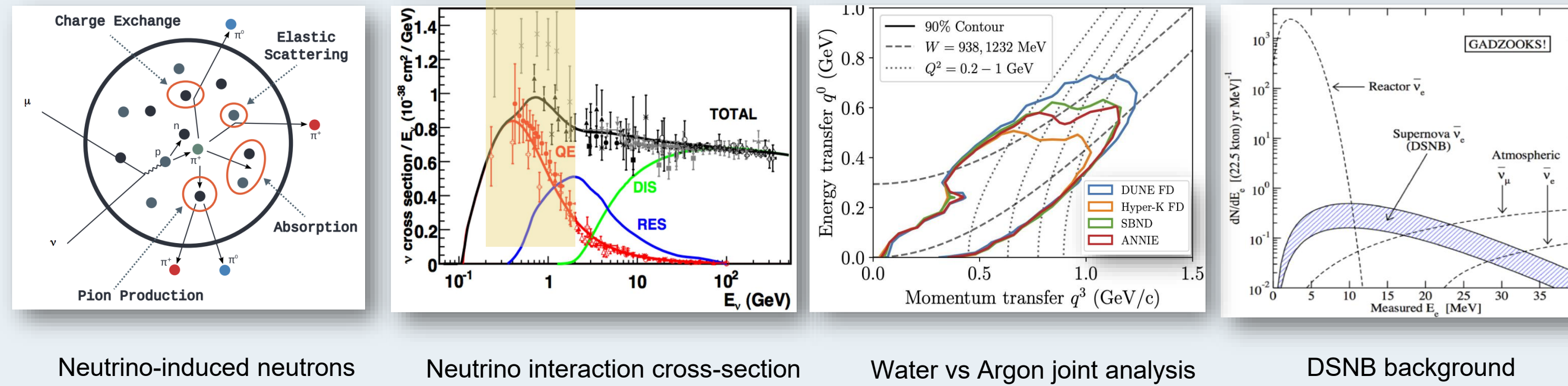
- 26-ton Gd-loaded Water Cherenkov detector, located 100 m downstream in the Booster Neutrino Beamline at Fermilab
- **Physics Goals:**
 - Neutrino-induced neutron multiplicity
 - Neutrino interaction cross sections
- **R&D Goals:**
 - Large Area Picosecond PhotoDetectors (LAPPDs)
 - Water-based Liquid Scintillator (WbLS) as a new medium



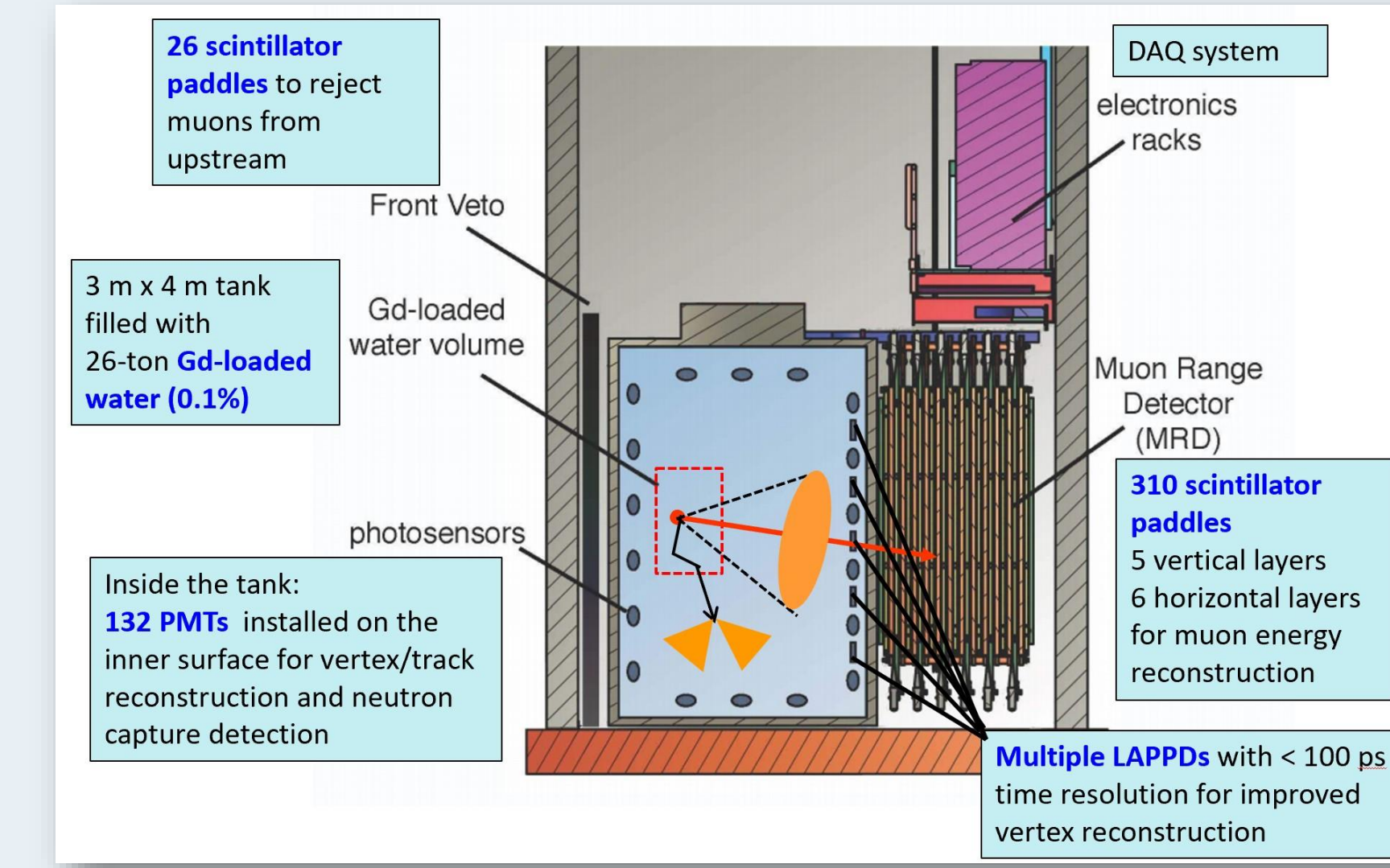
~10,000 Charged current neutrino events per ton of target water per year expected at ANNIE hall!

ANNIE Physics

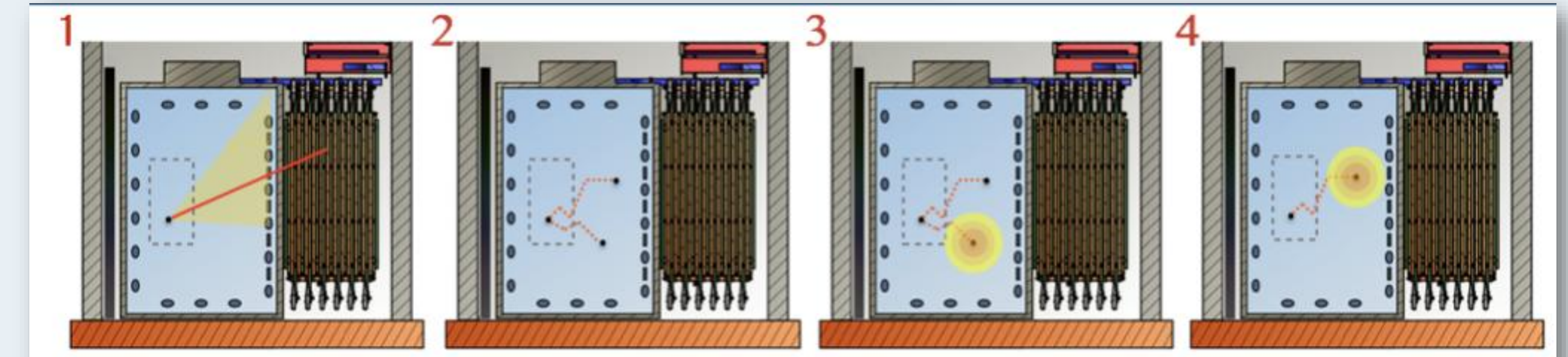
- Measure **final-state neutron multiplicity** in water
 - Refine neutrino-nucleus interaction and nuclear effect models
 - Reduce neutrino energy reconstruction uncertainties for oscillation experiments
- Measure **charged-current and neutral-current neutrino cross sections**
 - Improve interaction modeling and constrain systematic uncertainties
- Compare **neutron multiplicity in water (ANNIE) with proton multiplicity in argon (MicroBooNE)**
 - Study nuclear effects across different target media
- Demonstrate **Gd-based neutron tagging**
 - Enhance background rejection for proton decay and Diffuse Supernova Neutrino Background (DSNB) searches



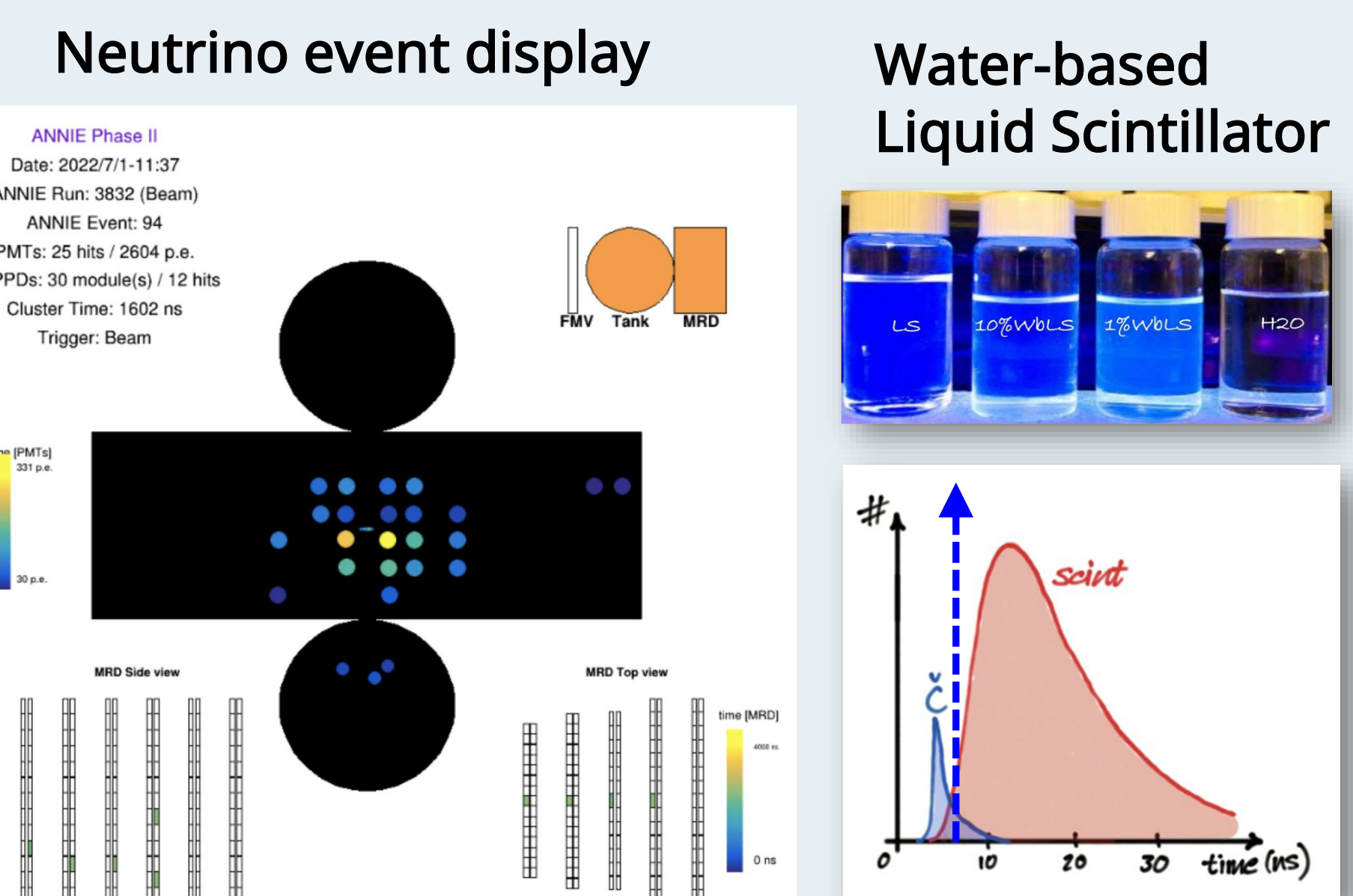
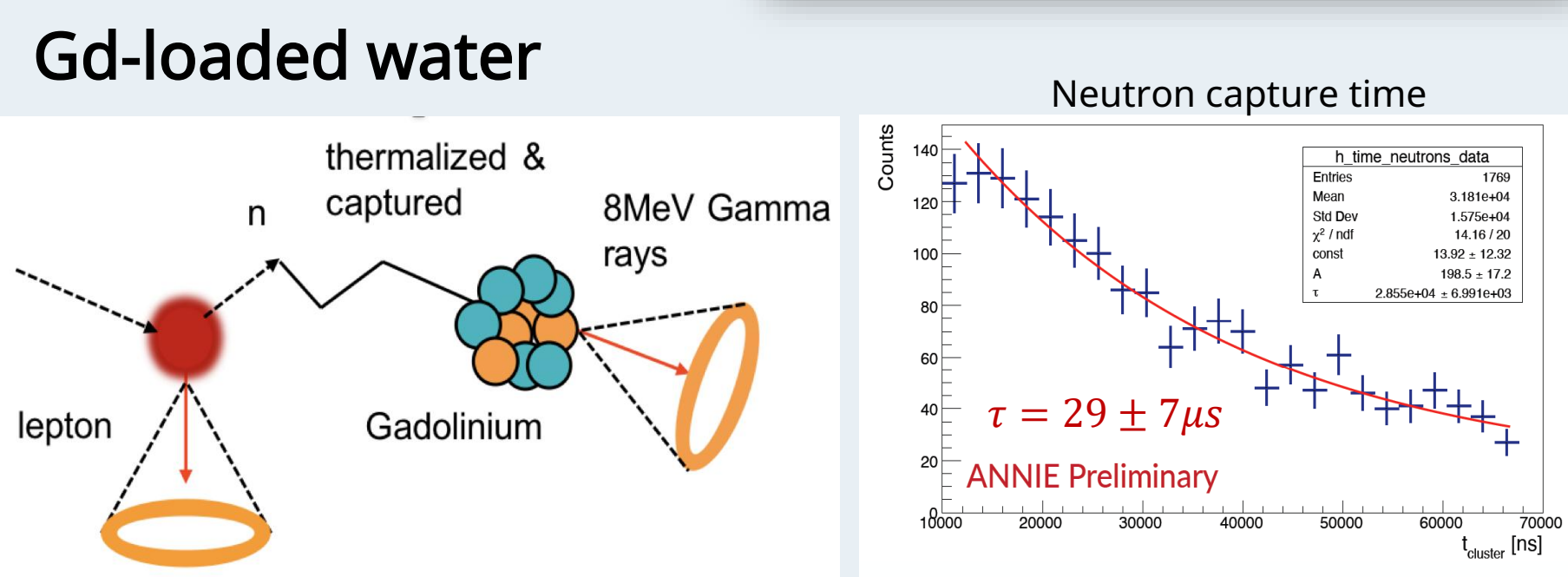
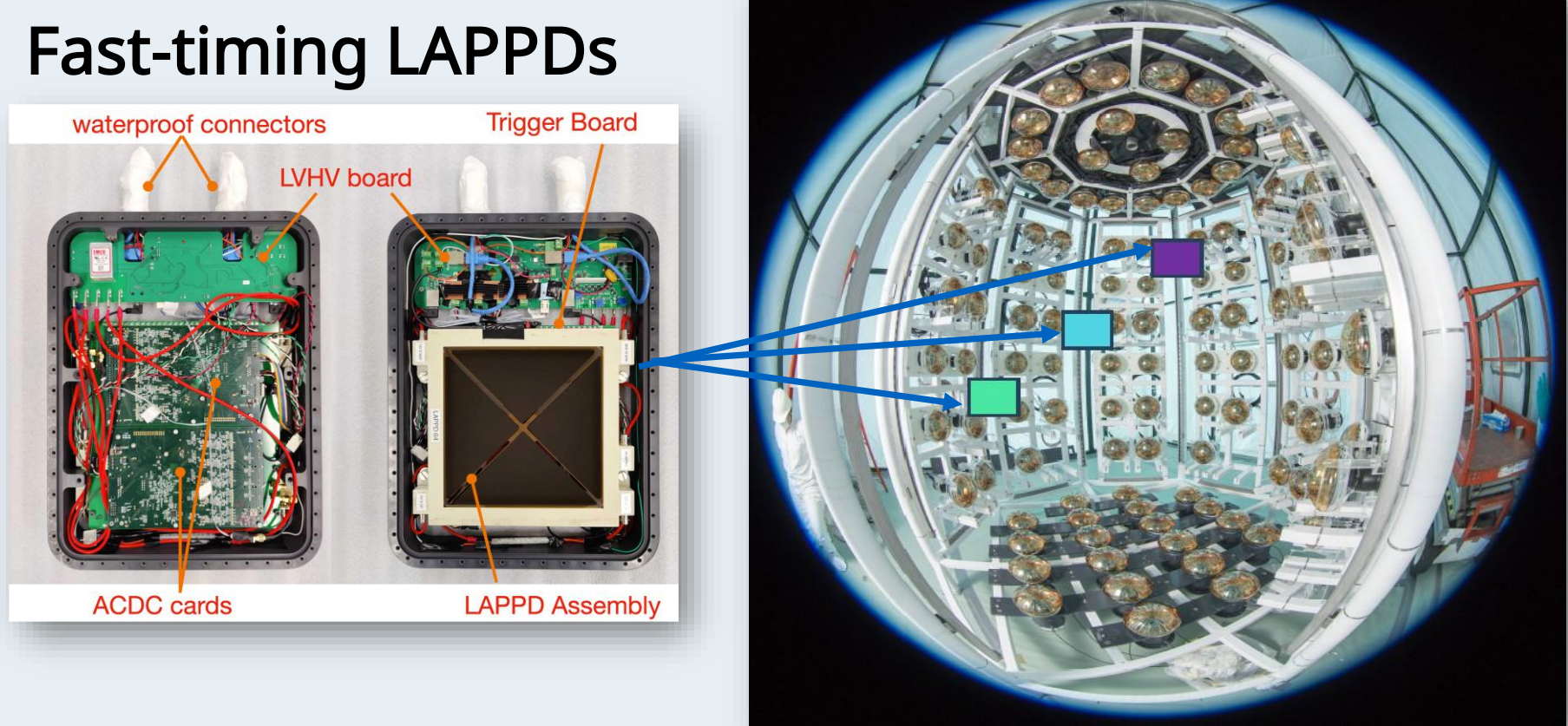
ANNIE Detector Strategy



- Neutrino interactions are reconstructed using the Cherenkov light pattern in the water tank and the muon track length in the MRD.
- Final-state neutrons thermalize and are captured on Gd, producing delayed 8 MeV gamma-ray signals tens of microseconds later, measured by the PMTs

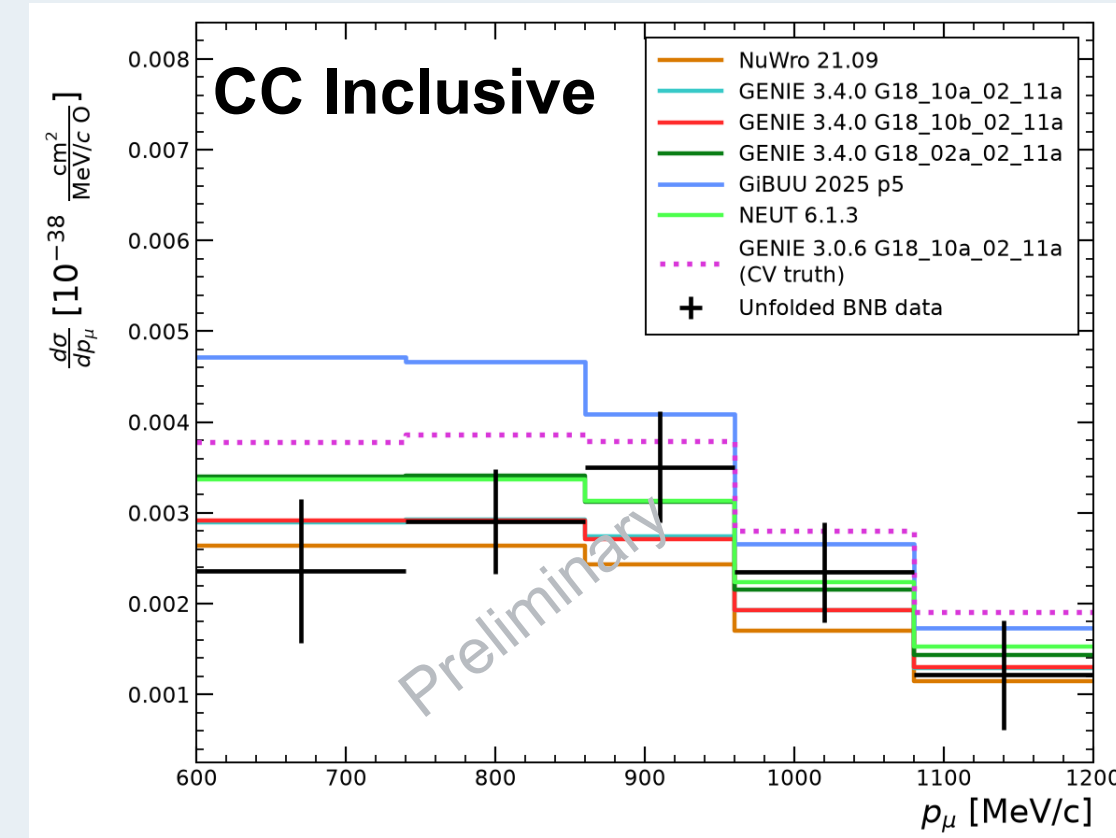


ANNIE R&D

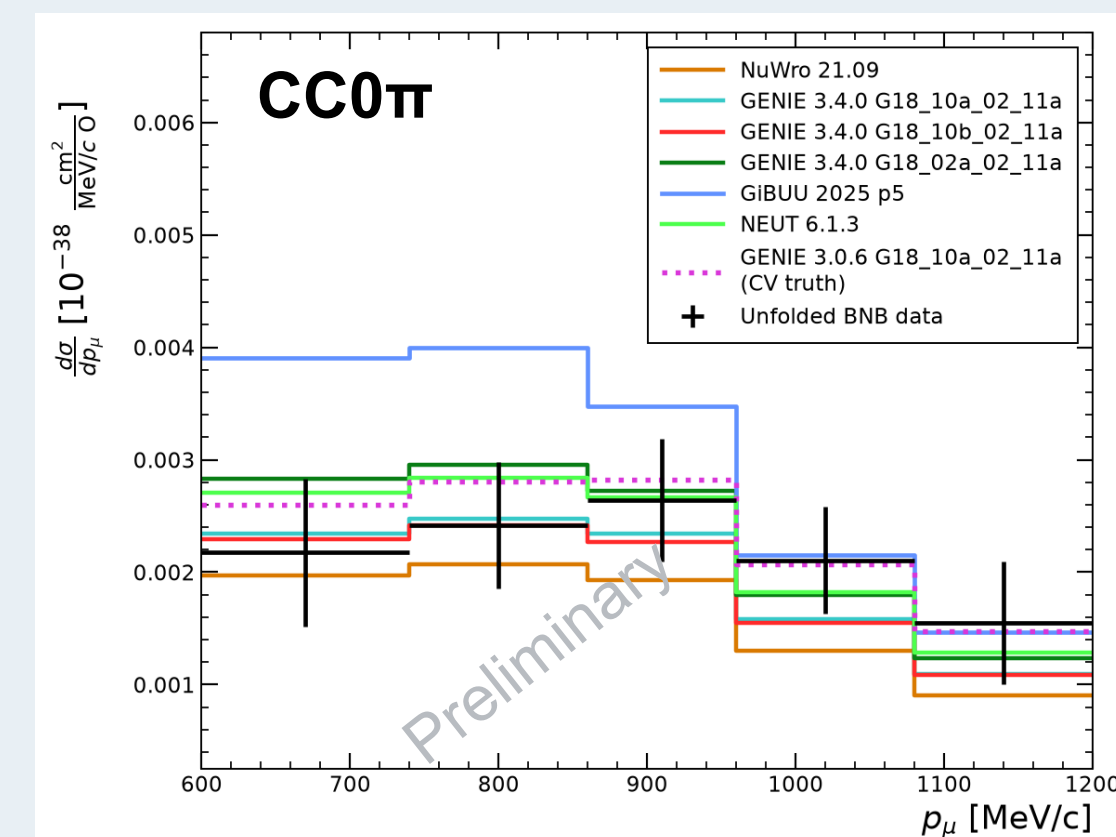


Neutrino Cross Section Results

CC analysis: full data, 1.7×10^{20} POT

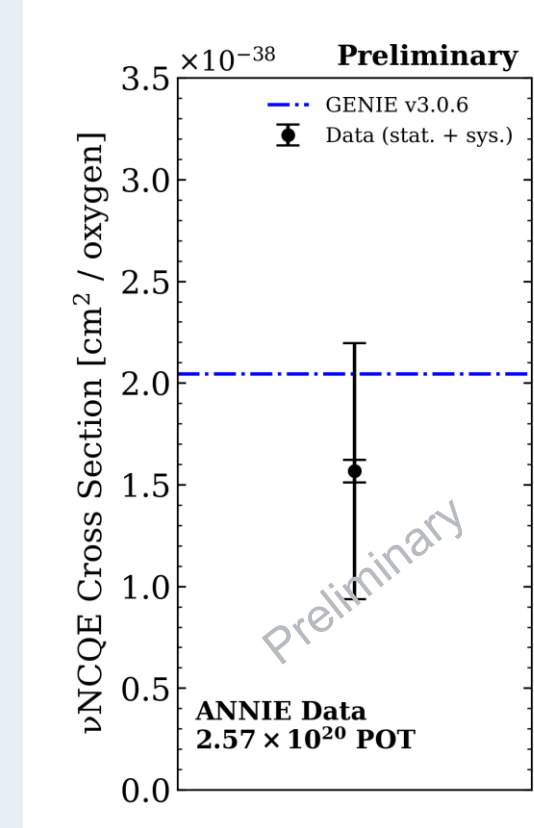


- CC-Inc event selection:
1. Prompt timing cluster
 2. Fiducial vertex
 3. MRD-matched muon track
 4. Event quality cuts
 5. CC-Inclusive: No restriction on hadronic final state
 6. Accepts CCQE, 2p2h, RES, and DIS events



- CC0π event selection:
1. Basic cuts are same as CC-inc 1-4
 2. No final state pion signatures
 3. Selects CC0π topology

NC analysis: full data, 2.6×10^{20} POT

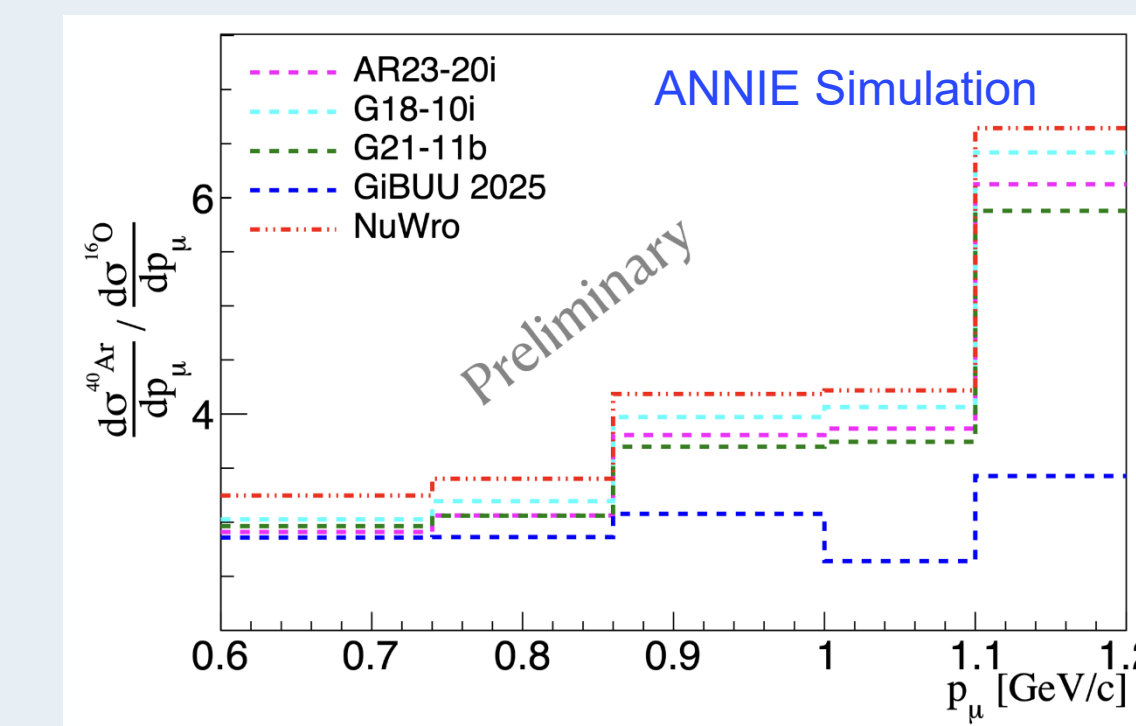


- NC event selection:
1. Timing cluster in prompt window
 2. No FMV hit or MRD track
 3. Fiducial vertex
 4. De-excitation gamma energy between 5 and 12 MeV
 5. Anisotropy topology cut

Joint Cross Section Analysis

provides input to DUNE and Hyper-K. (Data unblinding underway)

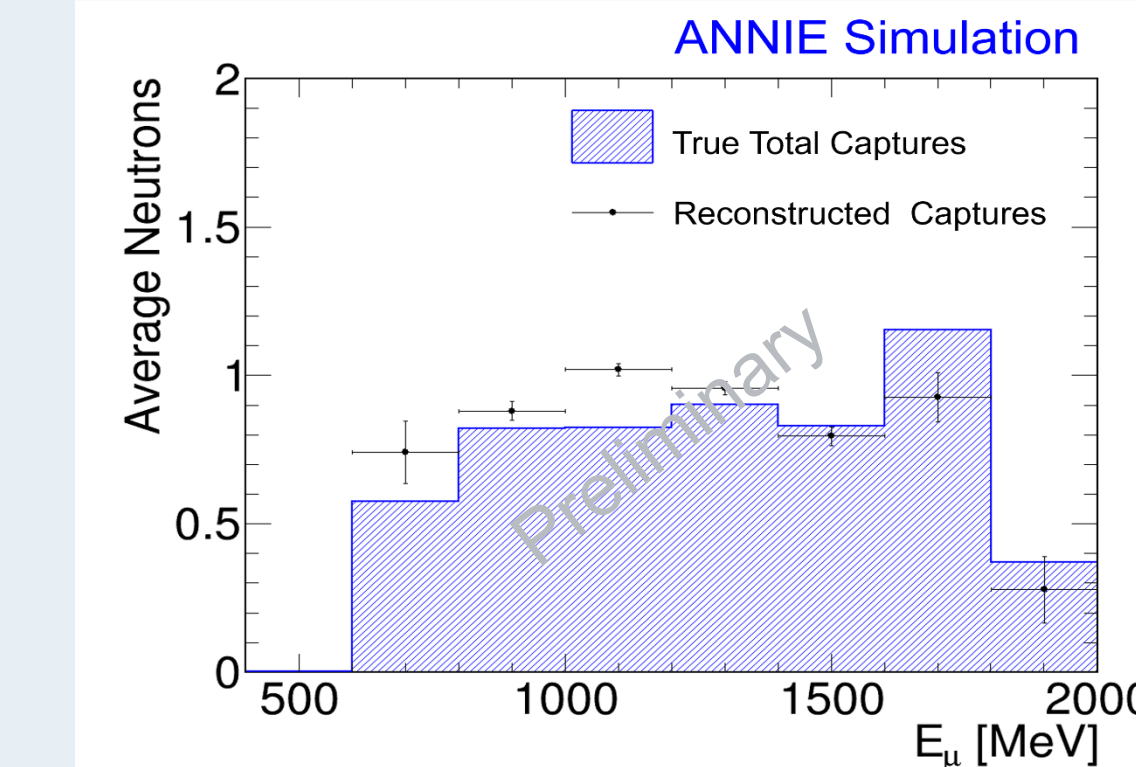
MC simulation: CC0π cross section ratio oxygen (ANNIE) vs argon (MicroBooNE)



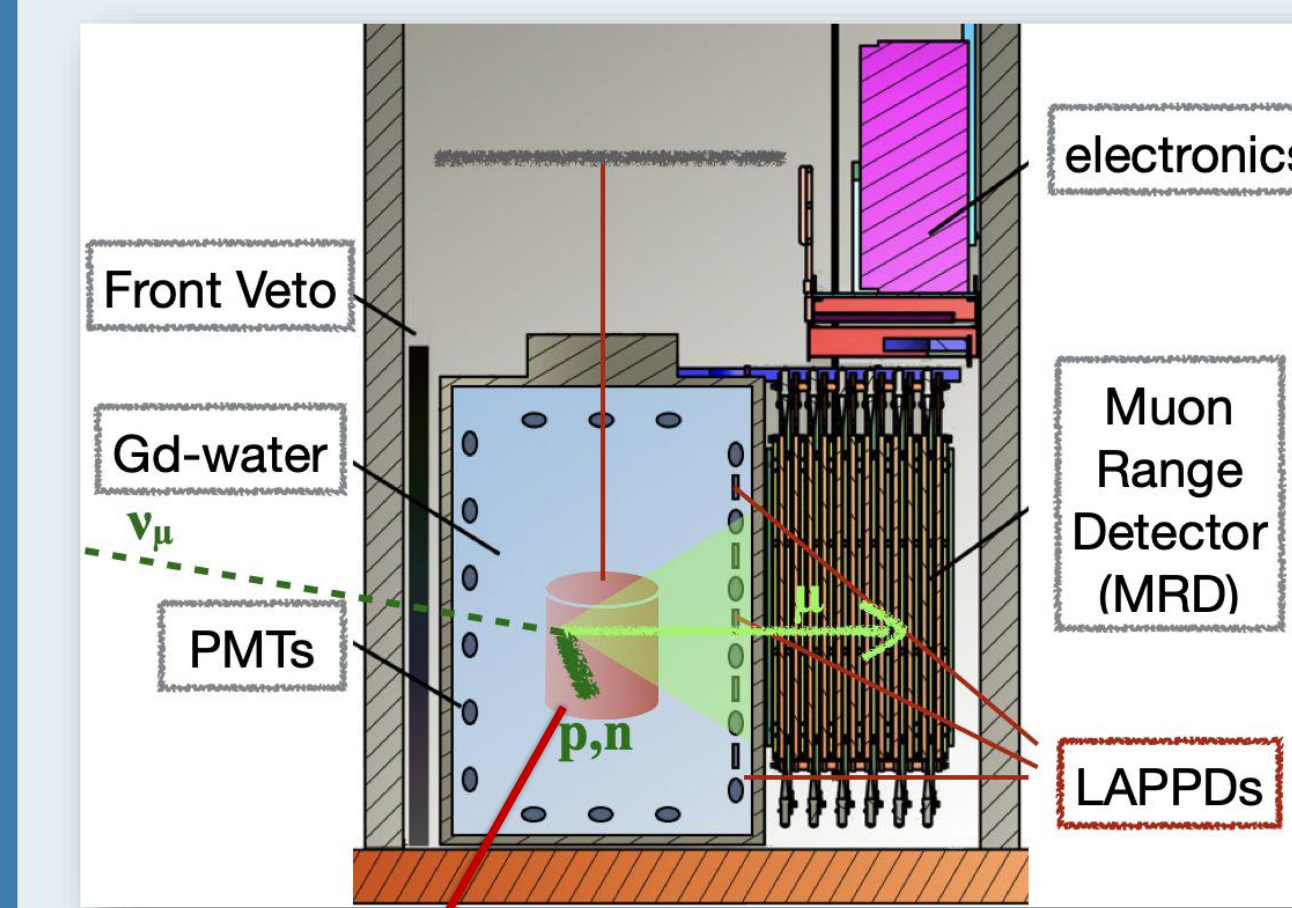
Neutron Multiplicity Analysis

Neutron capture multiplicity VS muon kinematics (Data unblinding underway.)

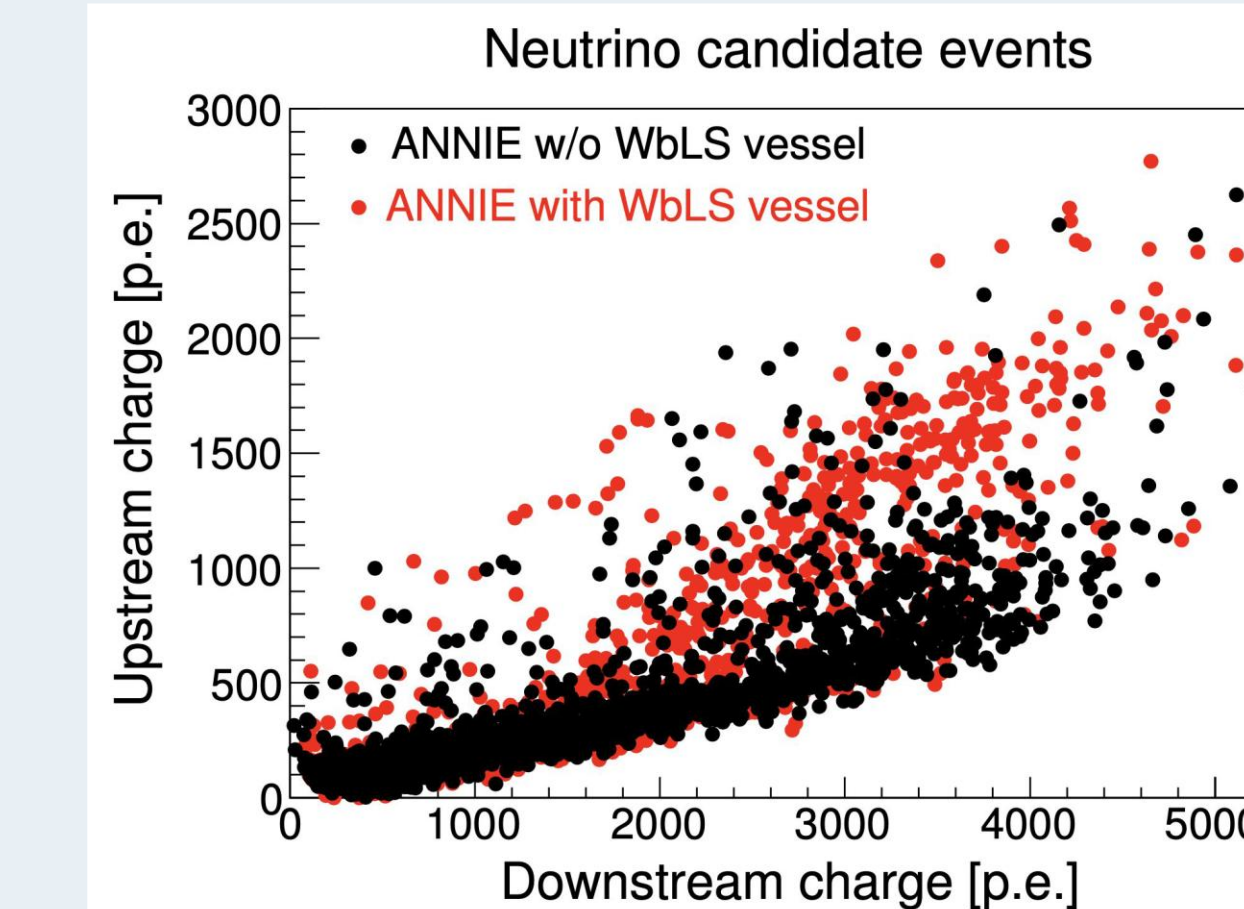
MC simulation: #neutrons VS muon energy



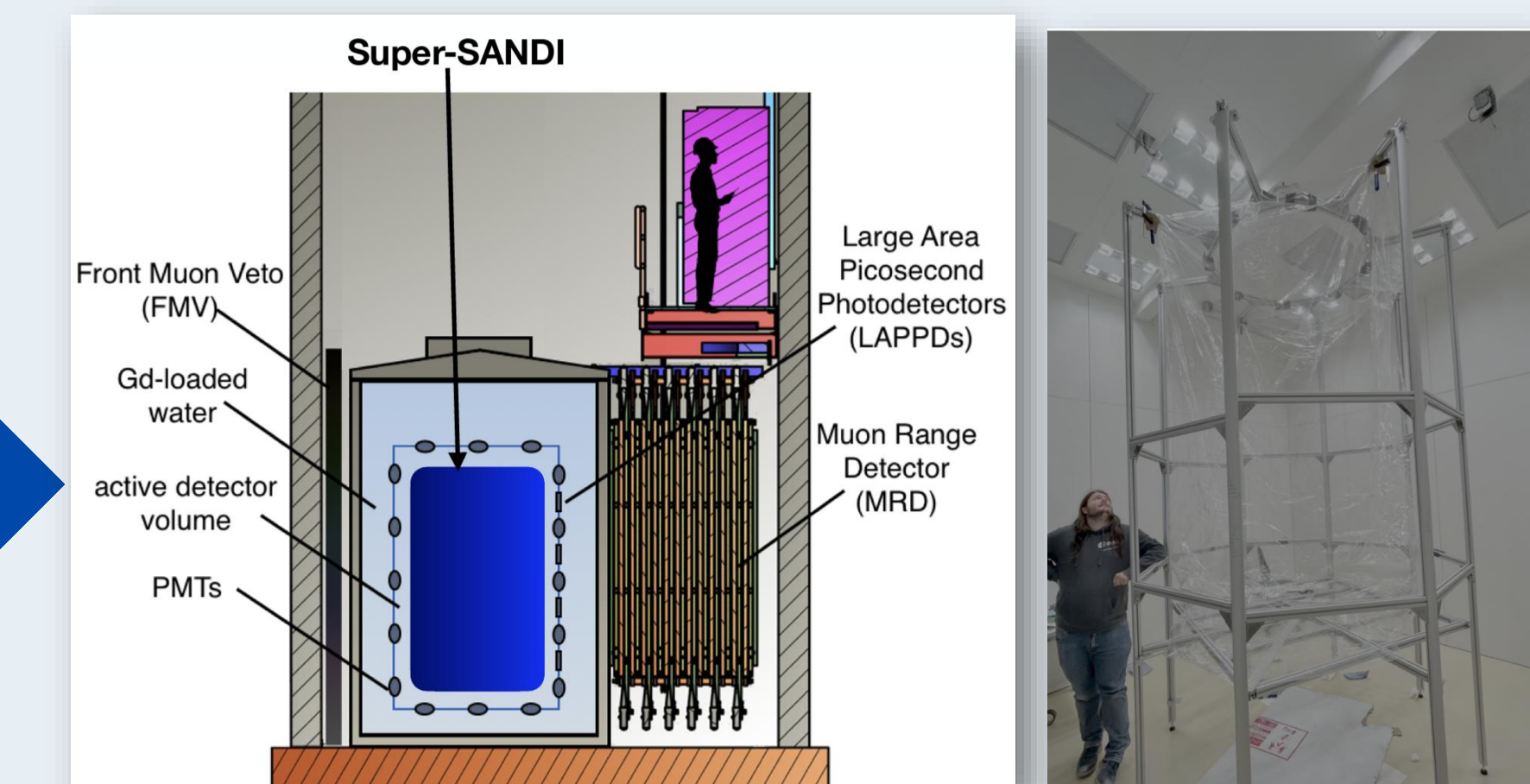
Hybrid Detection with Water-based Liquid Scintillator



Scintillator for ANNIE Neutrino Detection Improvement (SANDI) ~3'x3' acrylic vessel containing 356 kg of WbLS



First WbLS experiment in neutrino beam! (light yield increased by >x1.4)



- Super-SANDI: Full WbLS deployment in ANNIE with Gd + LAPPDs, X20 larger than SANDI
- WbLS: candidate technology the fourth far detector in DUNE (Module of Opportunity) and the chosen technique for the future THEIA detector

