



# ANNIE: Accelerator Neutrino Neutron Interaction Experiment

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on behalf of ANNIE collaboration

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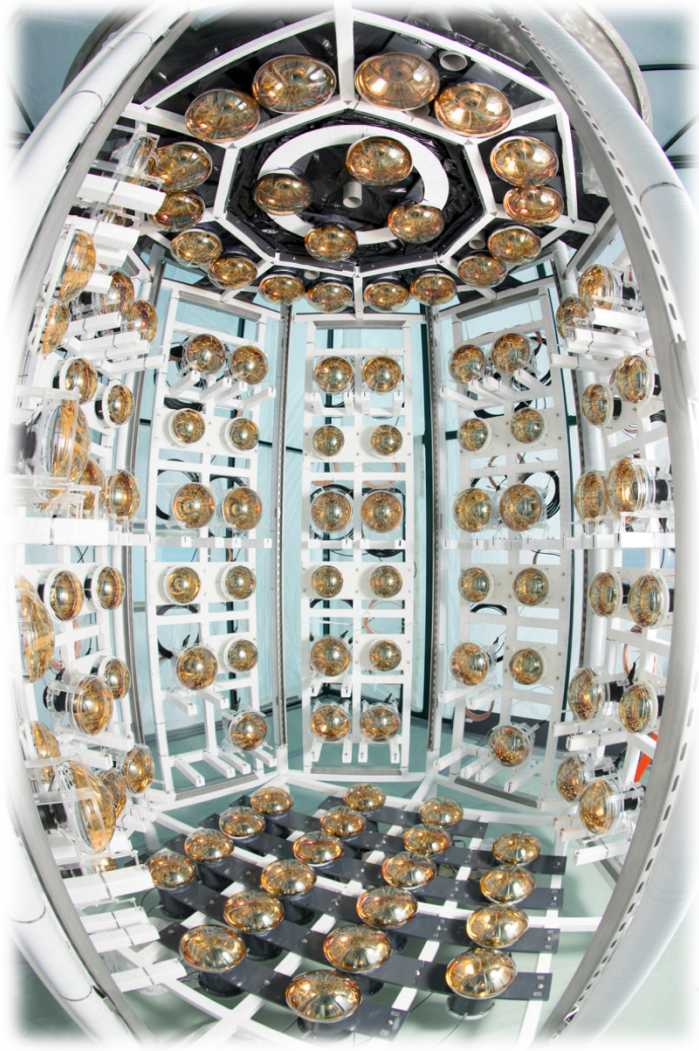
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PMG/All Experiments Meeting, Fermilab

April 2, 2020



# ANNIE: The Accelerator Neutrino Neutron Interaction Experiment



- ▶ 26-ton **Gadolinium (Gd)-loaded water Cherenkov Detector**.
- ▶ ANNIE is located on the BNB at SciBooNE Hall.
- ▶ The physics phase detector was installed in Summer 2019.
- ▶ **Main goals:**
  - Measure the beam induced final state neutron multiplicity & CC inclusive cross section on water.
  - **Demonstrate new detection technologies:**
    - ▶ **Large Area Picosecond Photodetectors (LAPPDs)**
    - ▶ Neutron tagging in Gd-loaded water.

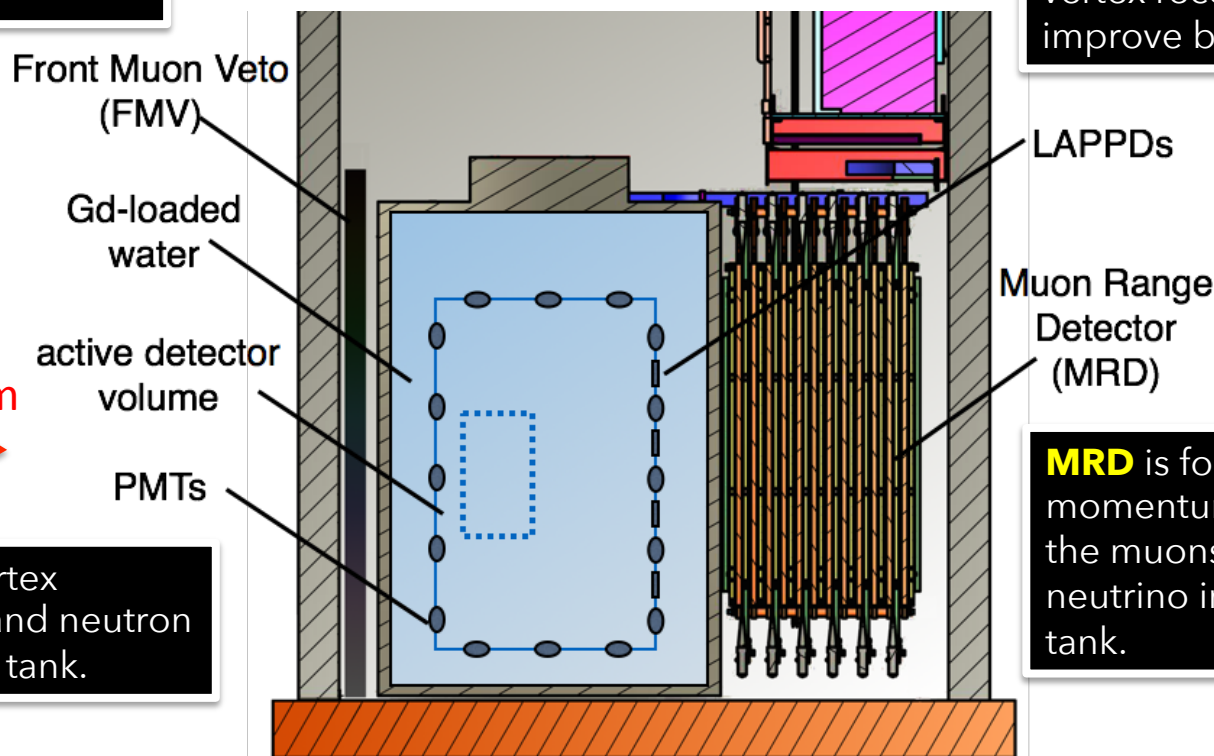




# ANNIE Detector Components

- 26 tons of de-ionized water loaded with 0.2% Gadolinium sulfate (50 kg) as an active medium to capture neutrons and study charged current neutrino interactions.

**FMV** is used to veto muons not originating in the tank.



**LAPPDs** are used for better vertex reconstruction and to improve background rejection.

Neutrino Beam  
→

**PMTs** are for vertex reconstruction and neutron detection in the tank.

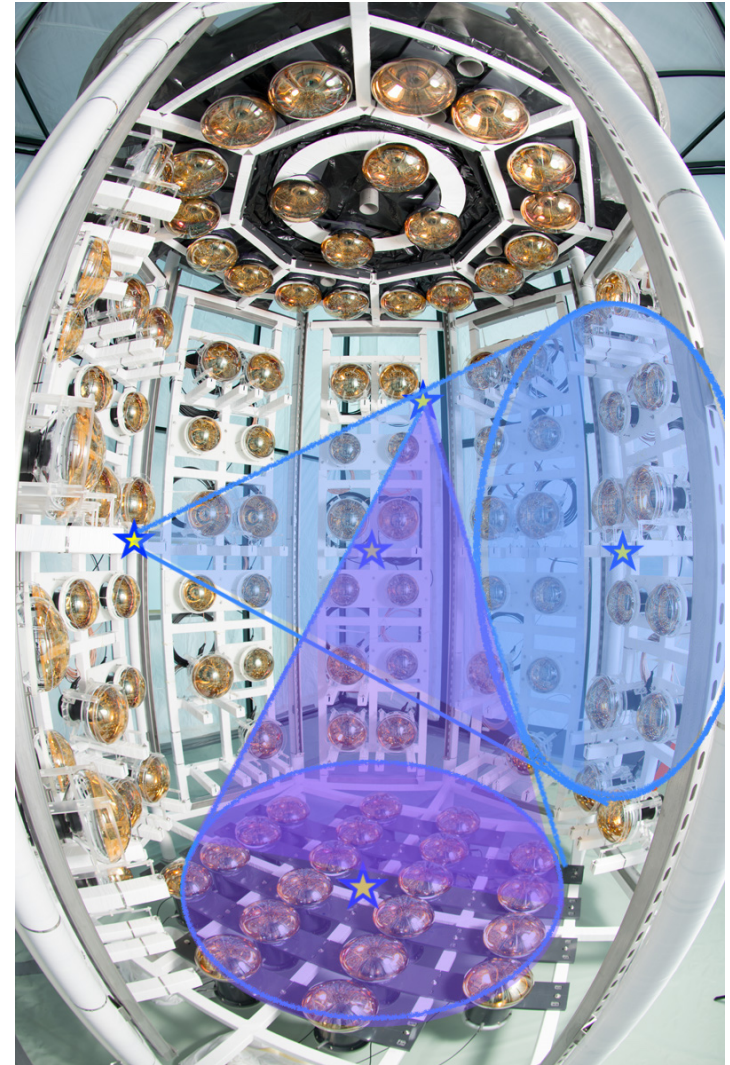
**MRD** is for measuring the momentum and direction of the muons coming from the neutrino interactions in the tank.

# Calibration Systems

- ⦿ **LED Calibration** (light through fibers placed on the inner structure) is being used for:
  - Water transparency measurement.
  - PMT timing.
  - PMT gain matching studies.
- ★ **AmBe Source Calibration** through calibration ports (5x 3 inch ports on the top of the tank) is being used for:
  - Neutron capture efficiency studies.

We will also be adding:

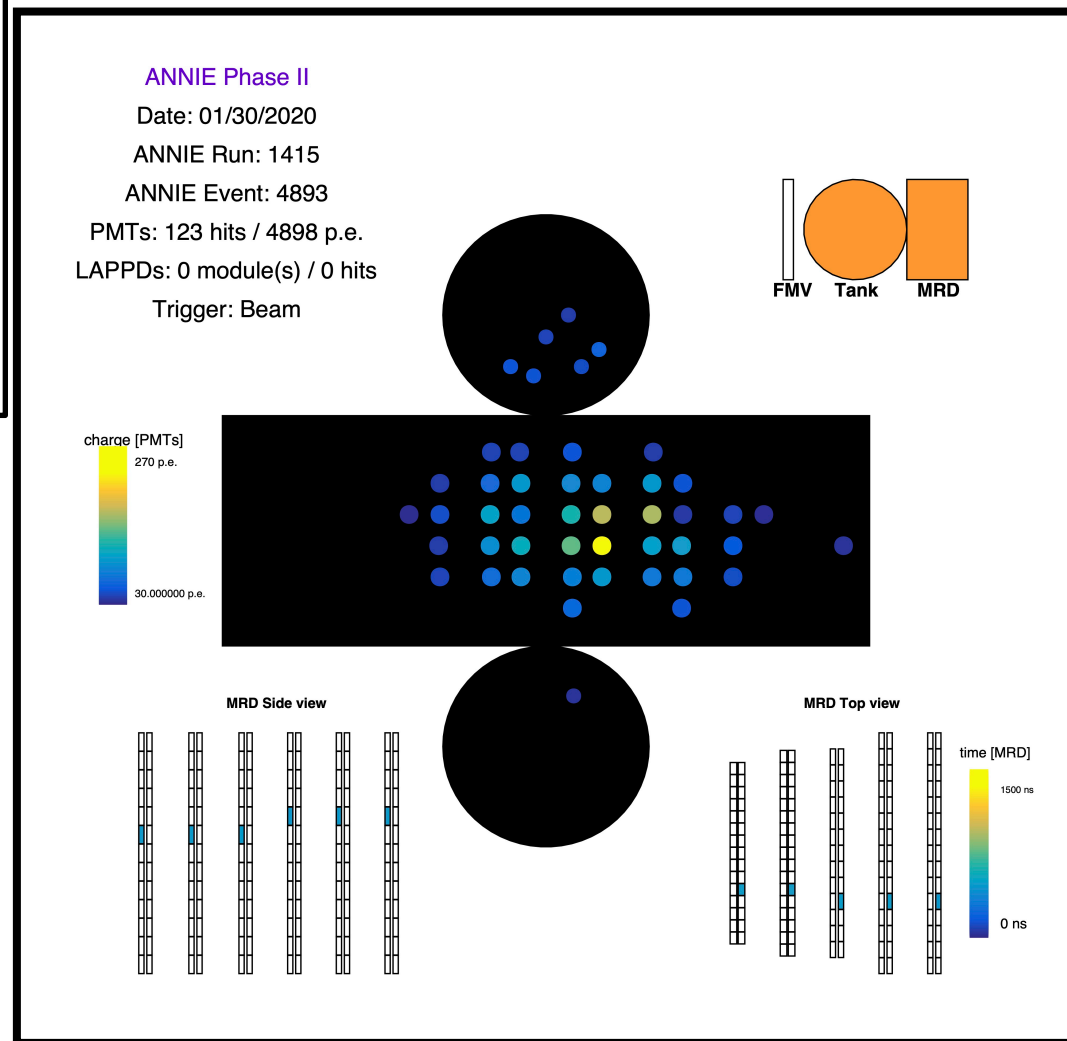
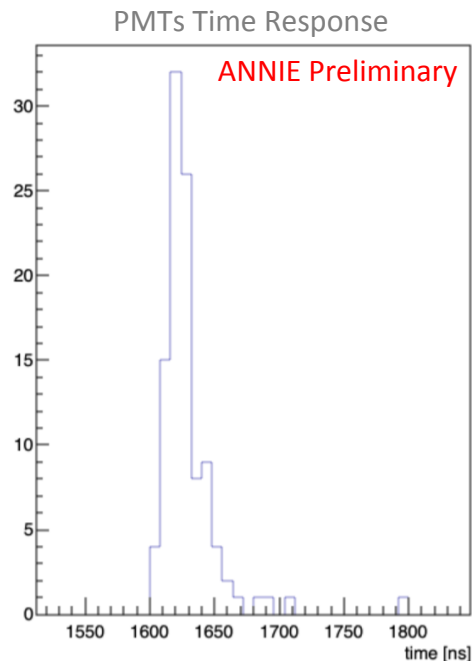
- ✧ A laserball for sub-ns PMT timing resolution.
- ✧ A standard candle for detector stability.



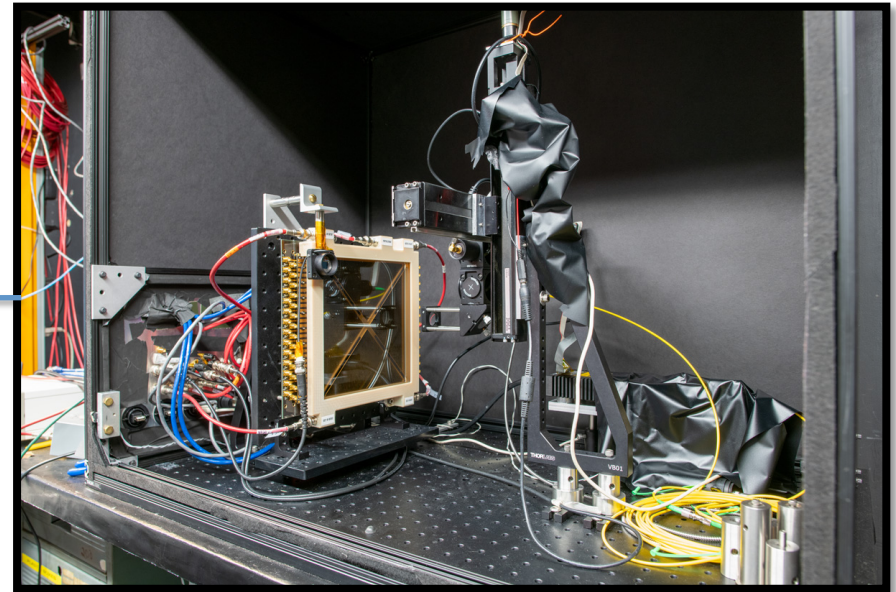
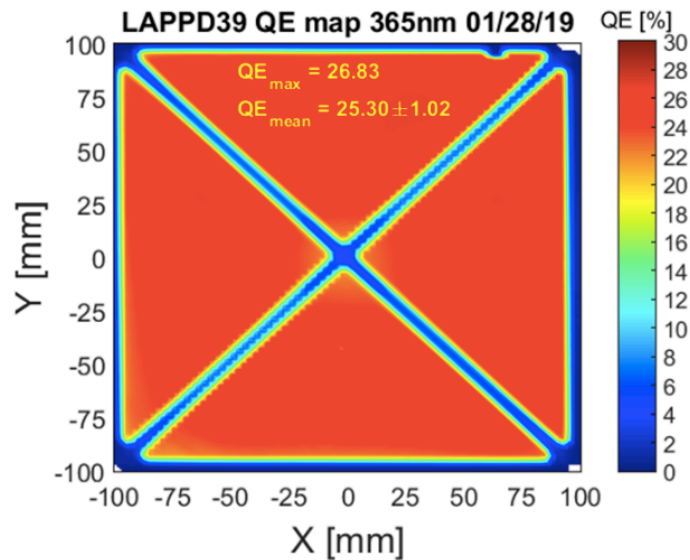


# First neutrino candidates recorded in January 2020

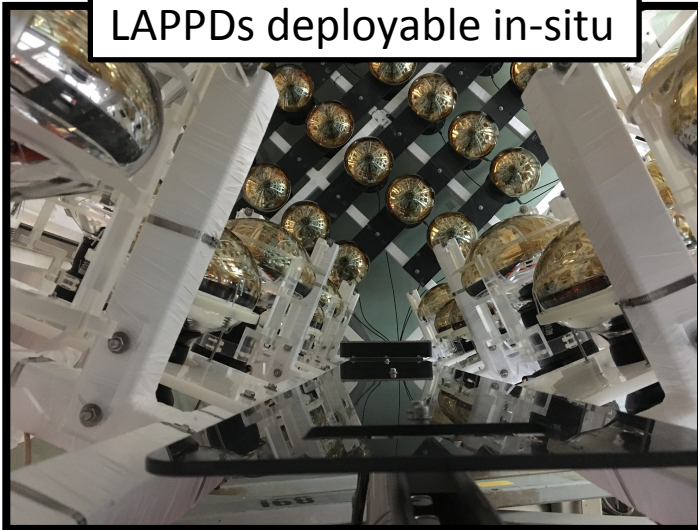
- The event display shows:
  - Good beam candidate event.
  - Outgoing muon in the tank.
  - Well defined track in both MRD views.
  - PMT response times are well clustered.



# LAPPD Characterization at Fermilab



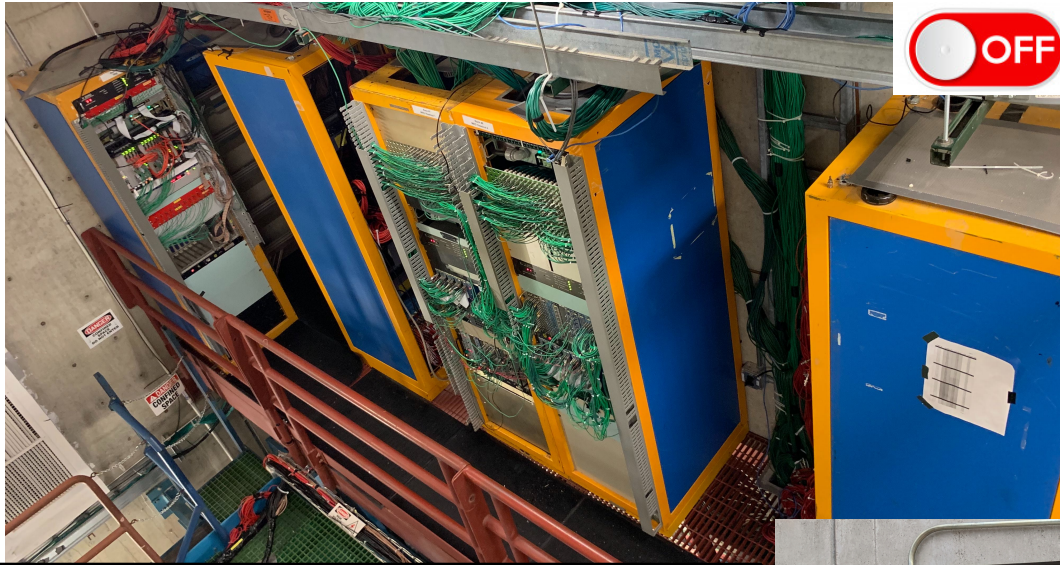
LAPPDs deployable in-situ



- ▶ We have been testing 5 LAPPDs at our test setup at Lab-6.
- ▶ They meet our specifications for physics data-taking (i.e. QE > 20%)
- ▶ LAPPDs are being readied to deploy into the tank.



# Currently in **Standby Mode**



- All the PMTs, VME and HV systems are powered down.
- Water filtration/recirculation system is working. It's remotely controlled and being monitored 24/7.
- The water volume is being flushed by Nitrogen to prevent bacterial growth in the tank.
- We are keeping an eye on things and weekly checks performed by ND.



# SUMMARY

- ▶ Physics Phase detector was installed in Summer 2019.
- ▶ Beam data taking started in January 2020 and ANNIE is in “standby mode” since March 20.
- ▶ Until March 20, ANNIE was able to take some usable neutrino beam physics data as well as AmBe source measurements at four different locations in the tank. Analysis on these data has started.
- ▶ 5 LAPPDs characterized at Fermilab being readied for installation.



30+ Collaborators from 14 institutions in 3 countries (🇺🇸 🇩🇪 🇬🇧) | Picture: Spring 2020 Col. Meet.



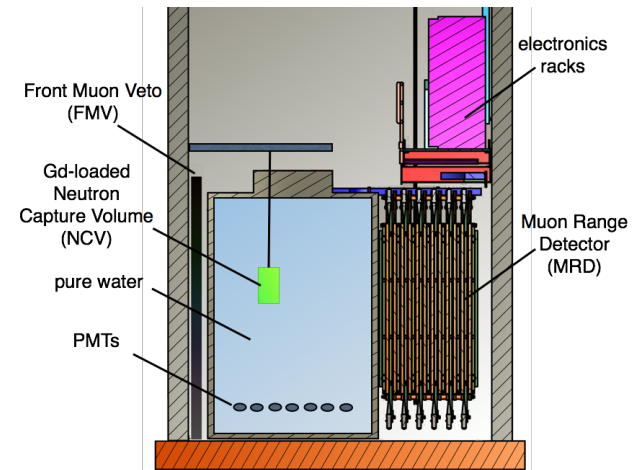
## **BACKUP SLIDES**

# Timeline of ANNIE

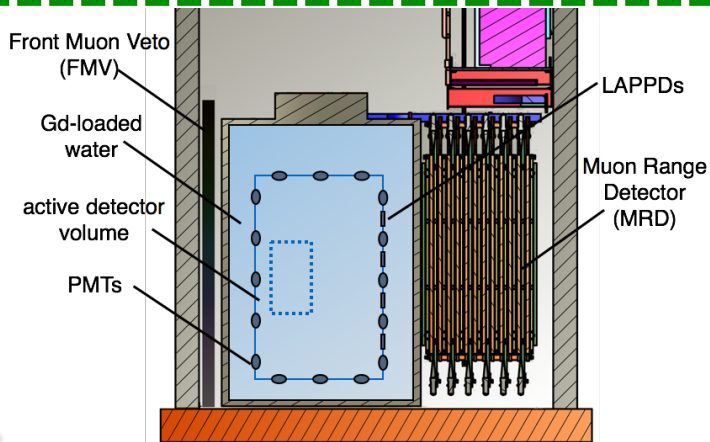
## Background Measurements

(arXiv:1912.03186 and submitted to JINST)

- Partially instrumented detector
- Feasibility demonstration
- Beam induced background neutron flux was measured to be  $<0.02$  neutrons/beam-spill/m<sup>3</sup>.



Fall 2019



## Physics Phase

- First Gd-doped water Cherenkov detector in a neutrino beam.
- Neutron multiplicity and CC-inclusive meas.
- First LAPPD deployment in a neutrino beam.

2021

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## Testing new tech for future experiments

- Testbed for a new active medium (WbLS), LAPPDs and other technologies.

