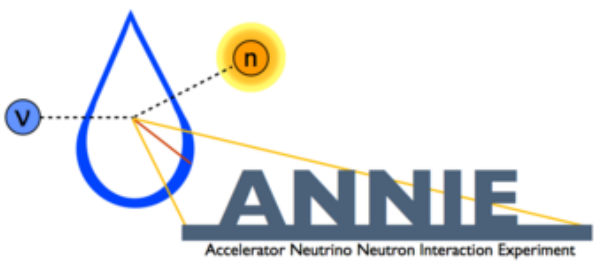
ANNIE Phase I - Status and Perspectives

New Perspectives 2016 - June 13th, 2016

Vincent Fischer

University of California, Davis

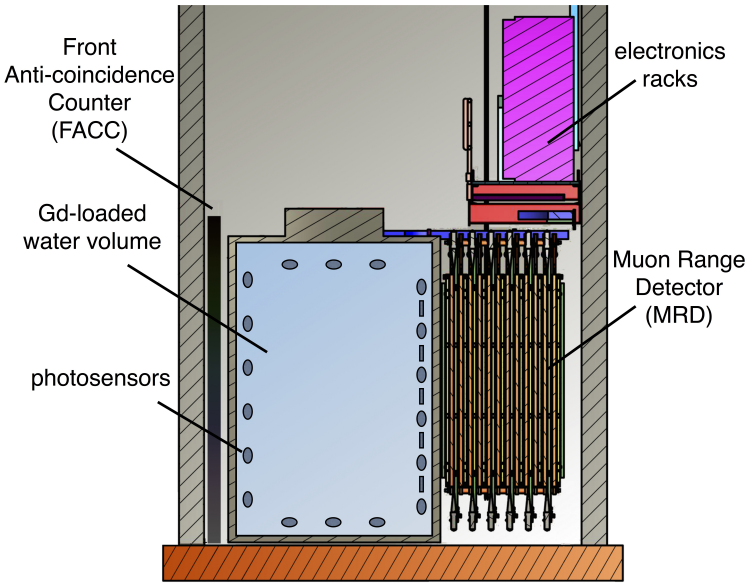
June 13th, 2016

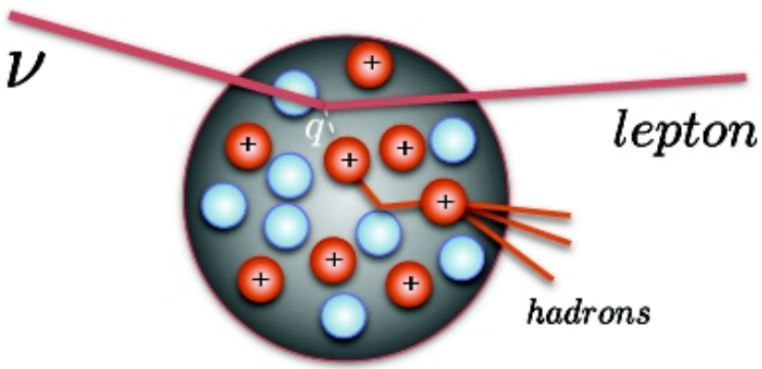


UC DAVIS
UNIVERSITY OF CALIFORNIA

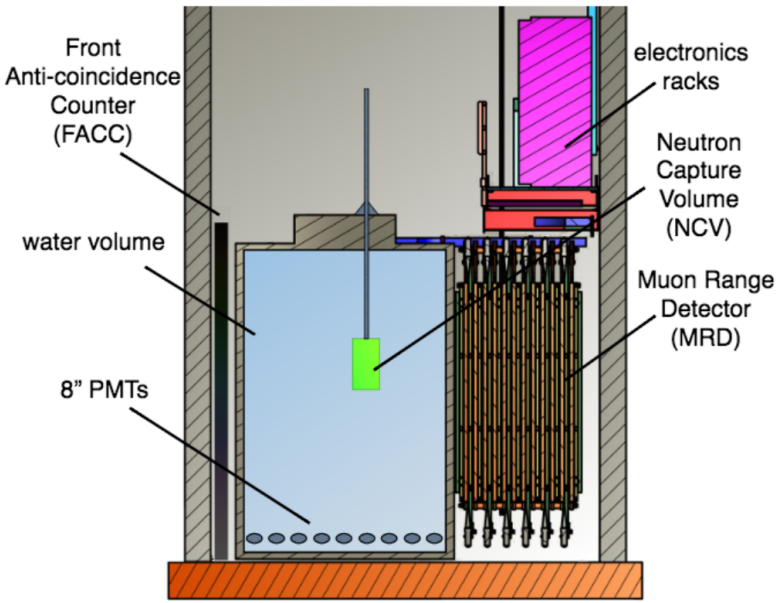
The ANNIE experiment

- **ANNIE** is the Accelerator Neutrino-Neutron Interaction Experiment
- Water Cherenkov detector placed downstream of the Booster Neutrino Beam
- Aims at measuring the production rate of neutrons from neutrino interactions in water
- Significant impact in proton decay searches and neutrino-nucleon interactions understanding





ANNIE Phase 1 - Goals



- "Proof of concept" $\rightarrow$ Measurement of the neutron background rate
- Source of neutron background:
  - **Skyshine neutrons** $\rightarrow$ Neutrons from the beam dump entering the detector
  - **Dirt neutrons** $\rightarrow$ Neutrons originating from neutrino interactions downstream of the dump
- March-May 2016: Installation in the SciBooNE hall
- Taking data since June 2016 until the 2016 Summer shutdown (end of July)
- Different detector configuration than for the Physics run

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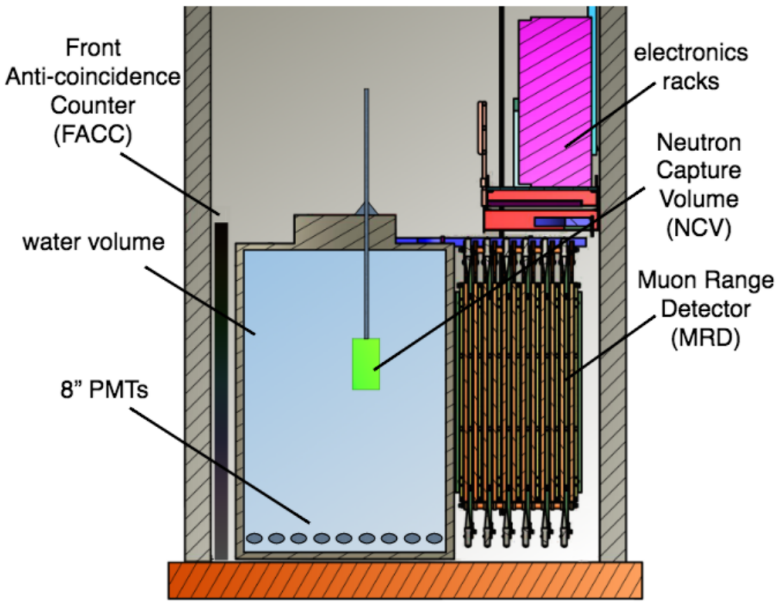

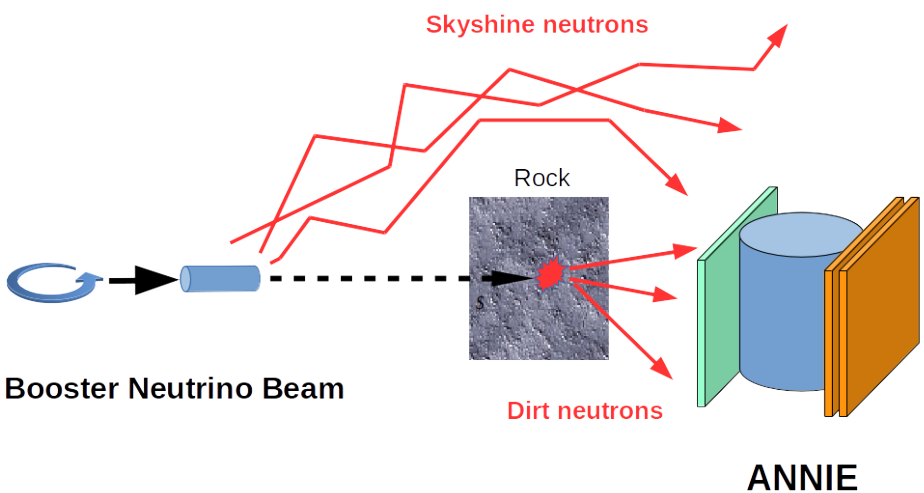

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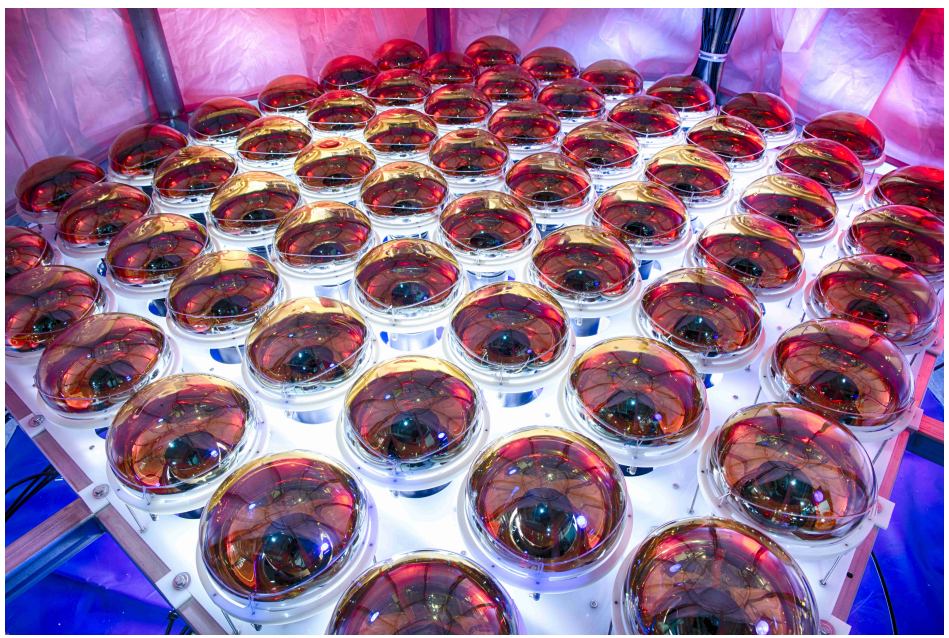
ANNIE Phase 1 - The detector

The tank

- 10x13' tank covered with a white liner for light collection
- Filled with 26-ton of ultrapure water
- Equipped with 60 8-inch photomultipliers (from SuperK, lent by UC Irvine) at the bottom



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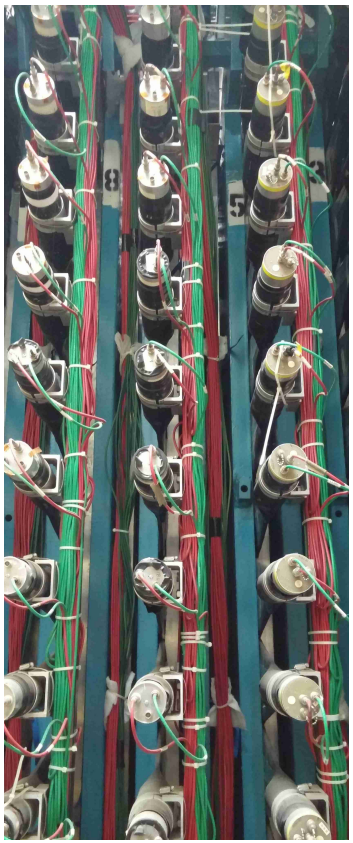

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The Muon Range Detector (MRD)

- First 2 layers in use (55 channels) instead of the 10 layers (362 channels) used in SciBooNE

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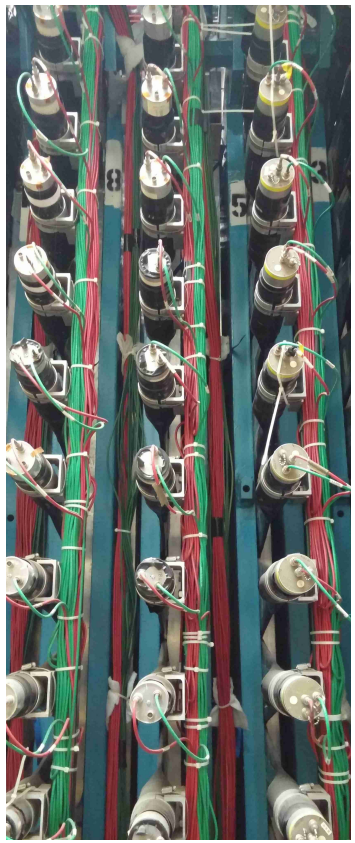

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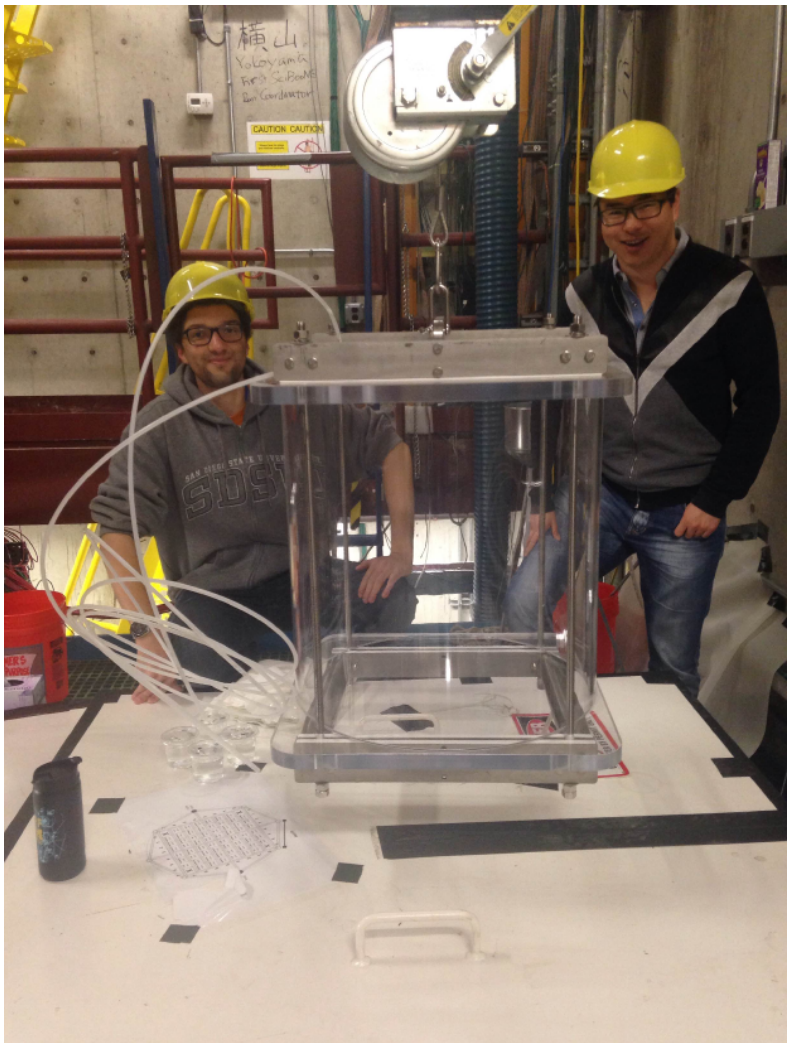

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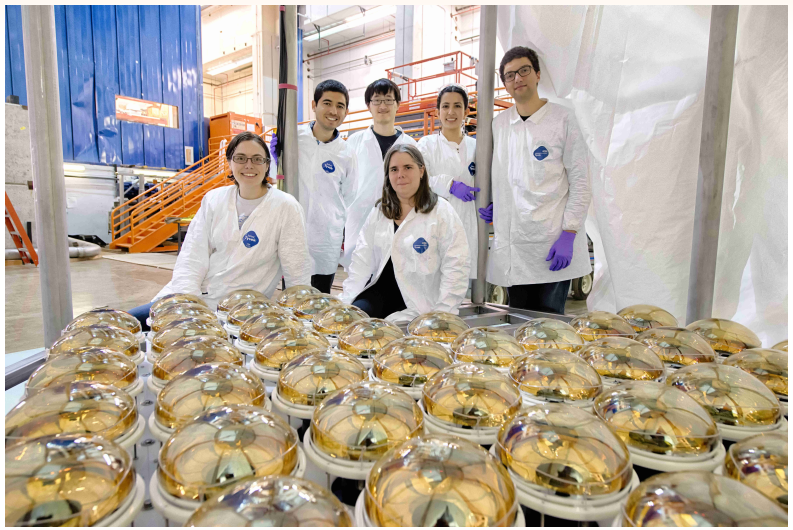
The Neutron Capture Volume (NCV)

- Neutron-sensitive subvolume within the tank
- 50x50 cm acrylic vessel (from UC Davis) filled with 100 liters of Gd-doped liquid scintillator
- Can be moved in the tank using a winch system

ANNIE Phase 1 - Tank installation



- Tank preparation and PMT installation done at the D0 Assembly Building
- Tank filled with **7000 gallons** of ultrapure water
- Water continuously flushed with nitrogen and filtered through a de-ionizing purification system
- Water quality requirement $\rightarrow$ Resistivity > 10 MΩ.m^{-1} **(0.05 ppm)**
- Water commissioning $\rightarrow$
  - Observation of muon events
  - PMT caracterization using LEDs

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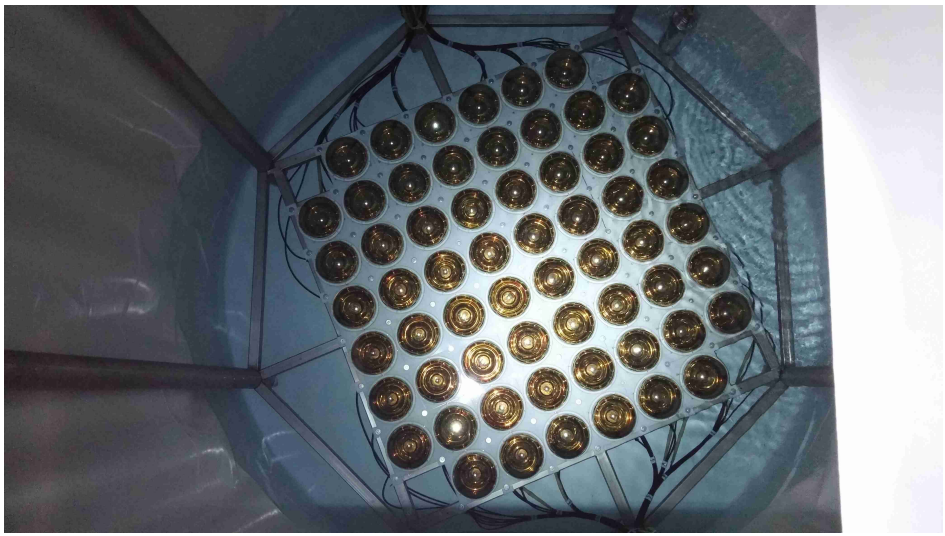

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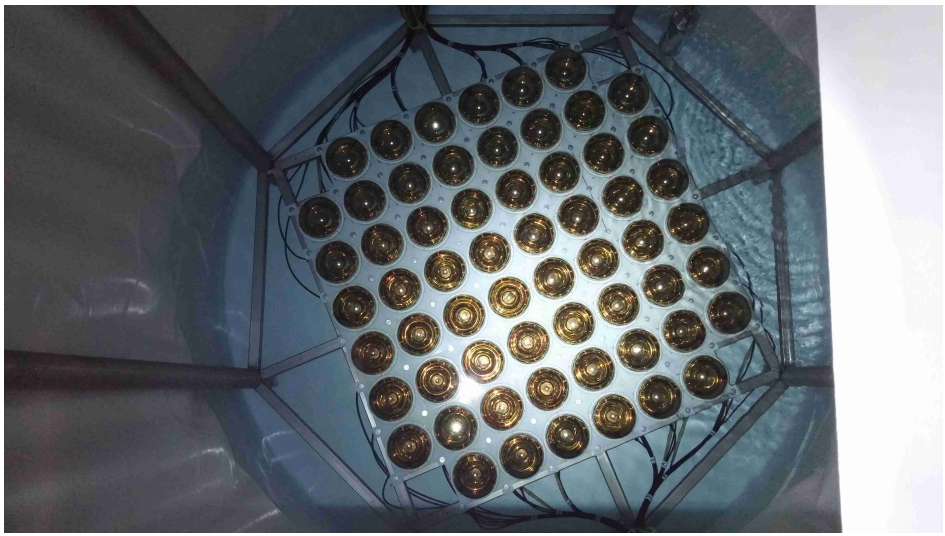

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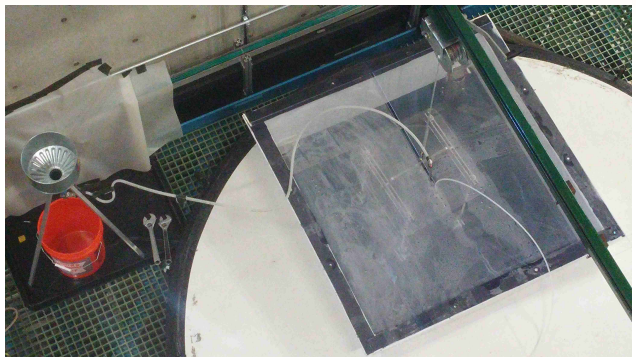
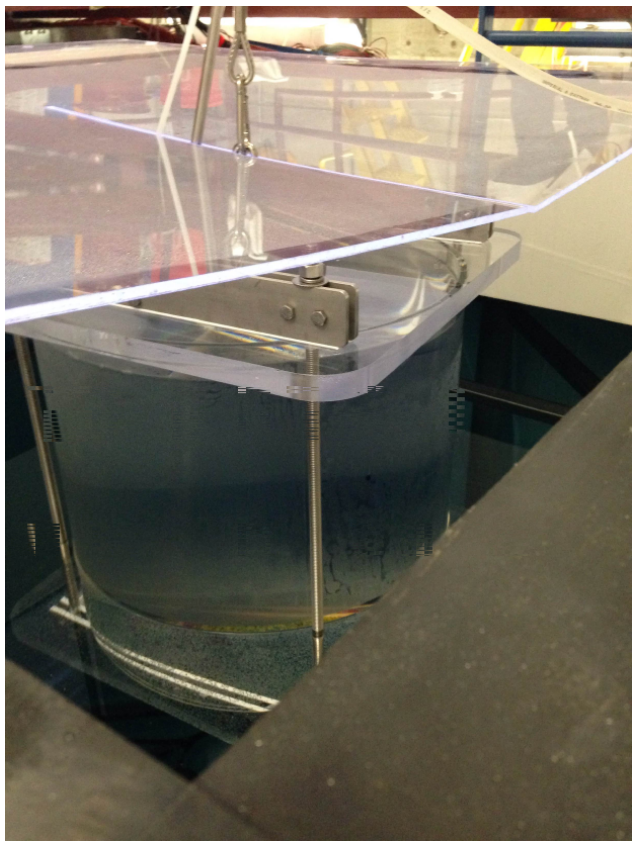




- **100 liters** of EJ-335 liquid scintillator ordered from the Eljen company

  → **Pseudocumene-based** (high light yield), **0.25% Gd-doping** (high neutron capture cross-section)

- Filling safely performed in collaboration with ES&H and the Fire Dept.

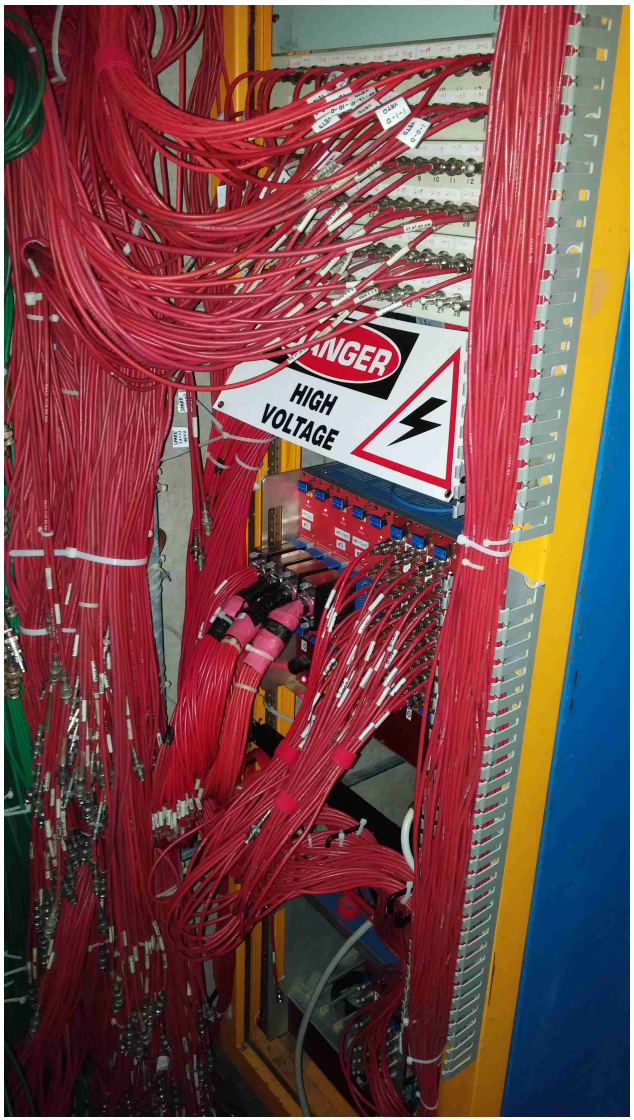
- Using the winch, the NCV can be moved in the vertical direction and along the beam direction

  → **Allows a measurement of the neutron rate at different locations within the tank**

ANNIE Phase 1 - Electronics and Data Acquisition

High voltage system

- Experts: University of Sheffield, UK
- 81 negative channels (veto, MRD) and 60 positive channels (tank PMTs)
- LabVIEW-based web interface for remote monitoring and control



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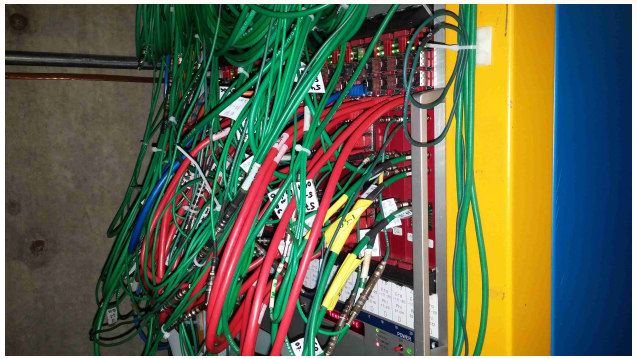

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- Veto and each MRD layer combined using a CAMAC DAQ and sent to the trigger board

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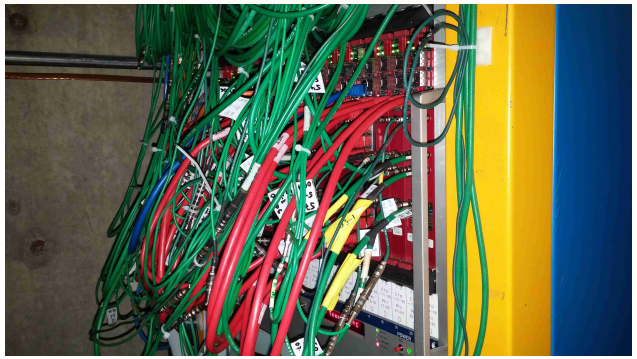

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Trigger system

- Experts: Iowa State University
- Primary mode: Beam trigger
- Possibility to use an external trigger for cosmics searches or LED calibration

ANNIE Phase 1 - Light calibration

- **Goals**:
  - Monitor the PMT response to Cerenkov and scintillation light
  - Control the light attenuation in water
  - Monitor the PMT gain in-situ and continuously
- **4 LEDs** attached to the top of the tank
- One blue and one green LED on each side, one equipped with a teflon diffuser
- Can be plugged in directly to a pulse generator $\rightarrow$ Very easy to use

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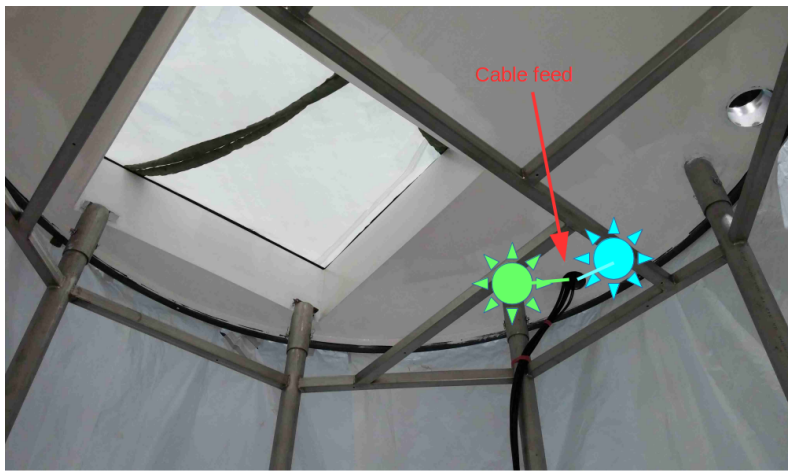

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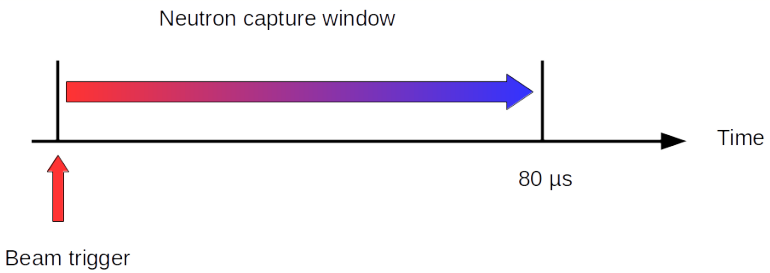

- Neutron capture search: All waveforms after a beam trigger recorded for 80 μs
- **Event definition** $\rightarrow$ Coincidence of 5 or more PMT pulses above a certain threshold and within a given time window
- Background reduction: Comparison between cosmic muon, beam muon and neutron capture events
- Possibility to separate Cerenkov and scintillation light using pulse shape analysis

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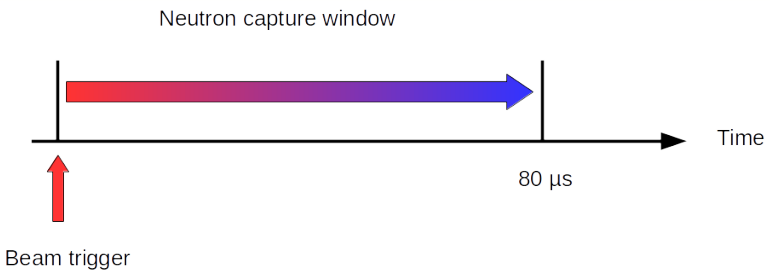

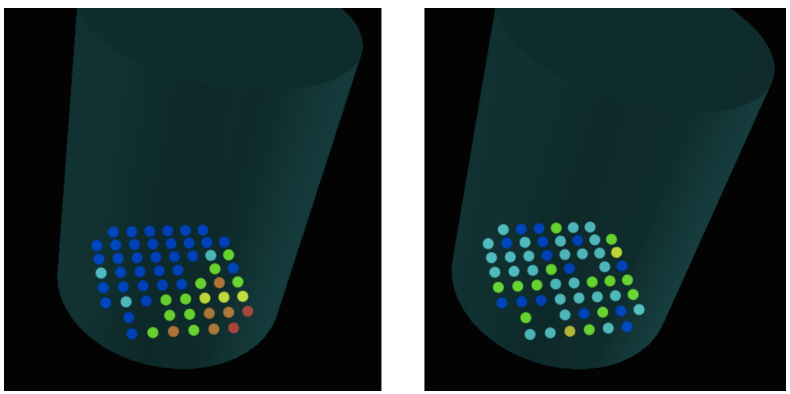

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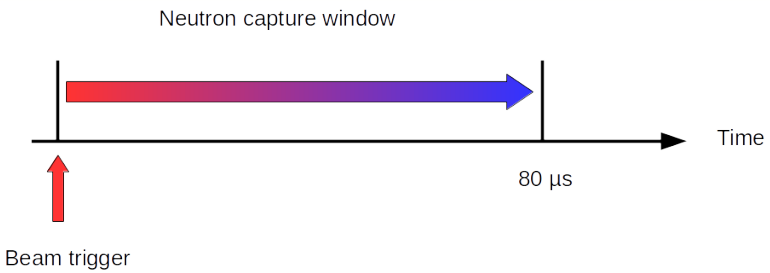

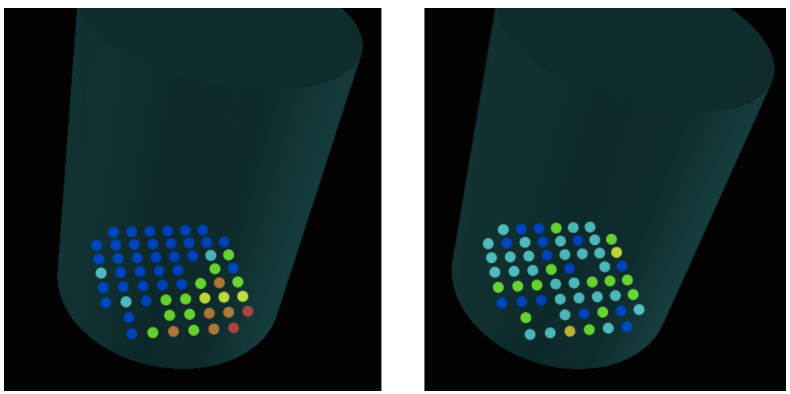

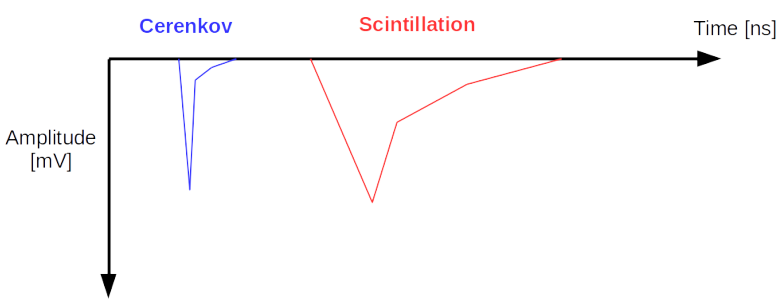

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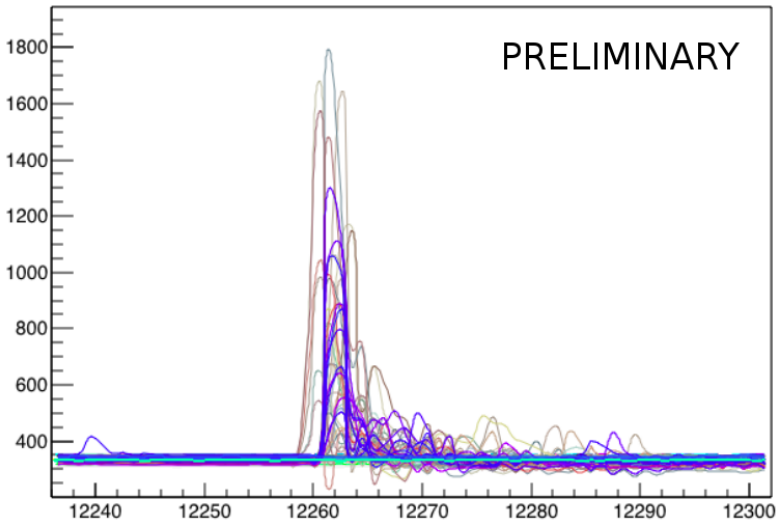
ANNIE Phase 1 - First data

- **First muon** observed during the water commissioning phase
- Excess of events observed in coincidence with the RWM signal from the BNB
- Neutron captures $\rightarrow$ Excess of events (exponential shape) after beam signal
- Pattern observed in the very first data taken with the NCV $\rightarrow$ Neutron captures, Michel electrons



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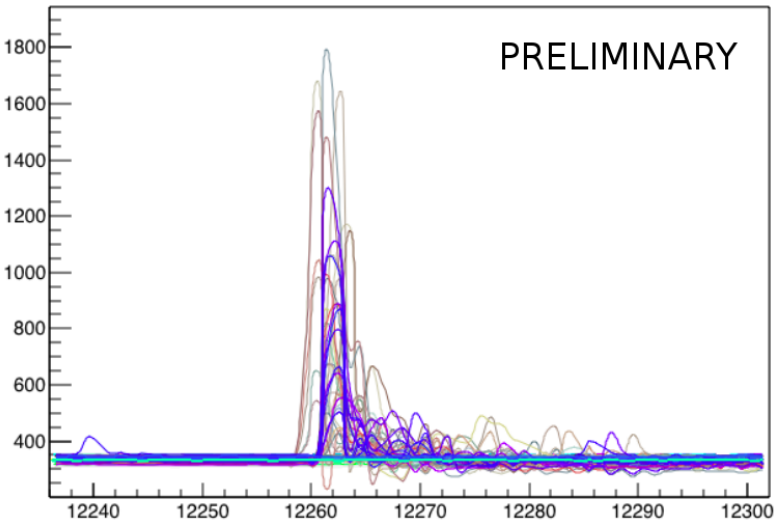

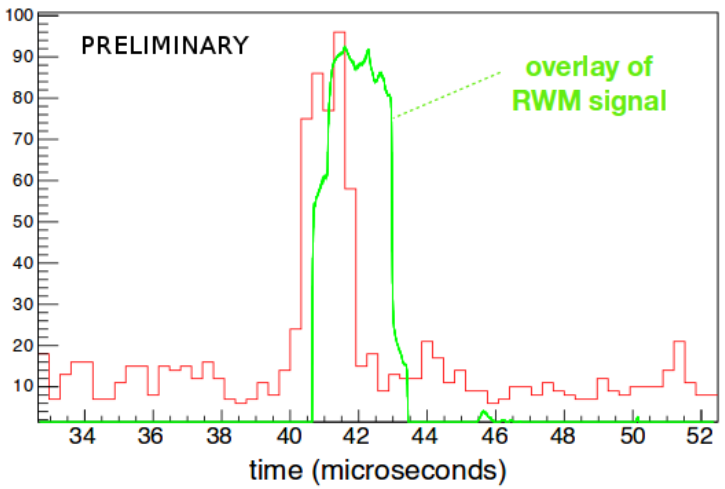

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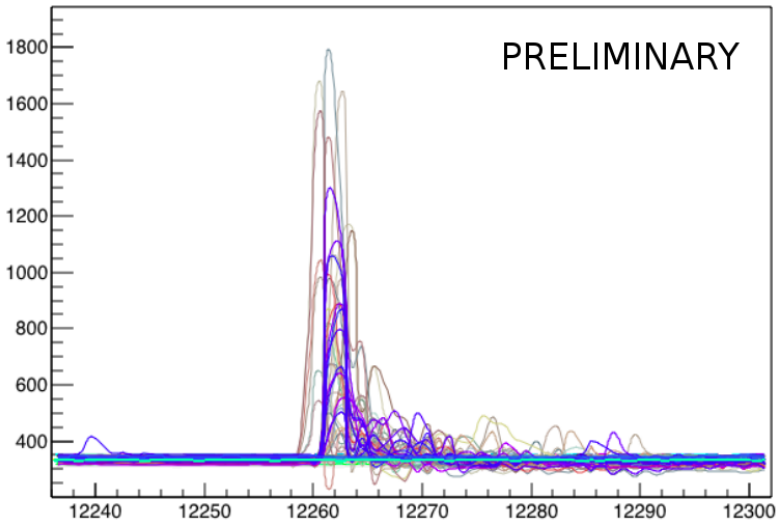

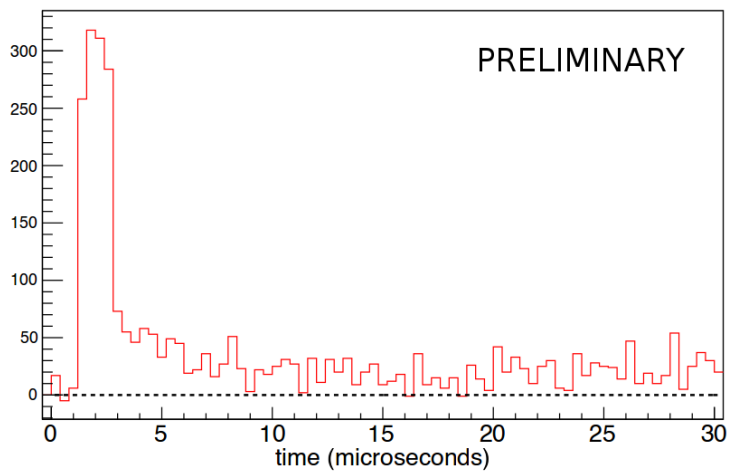

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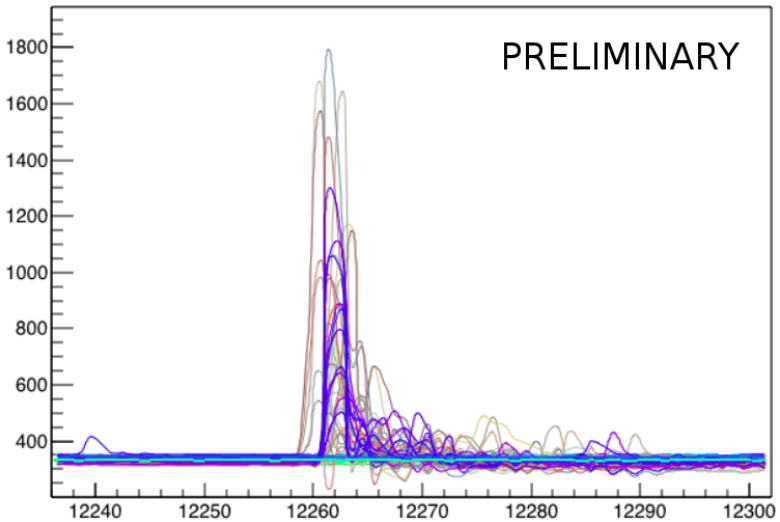
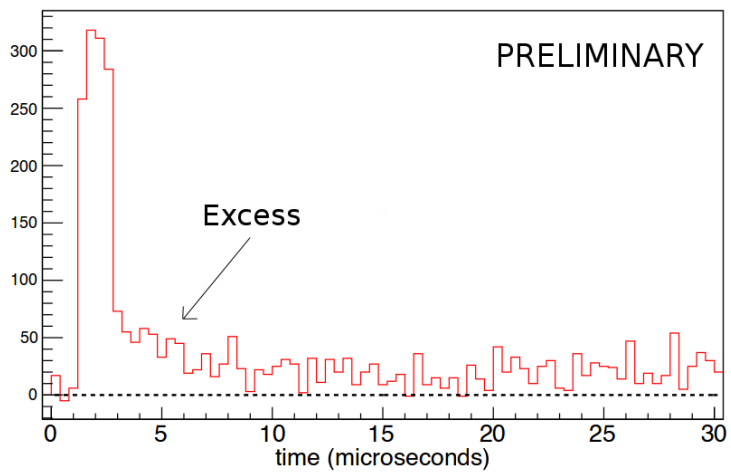
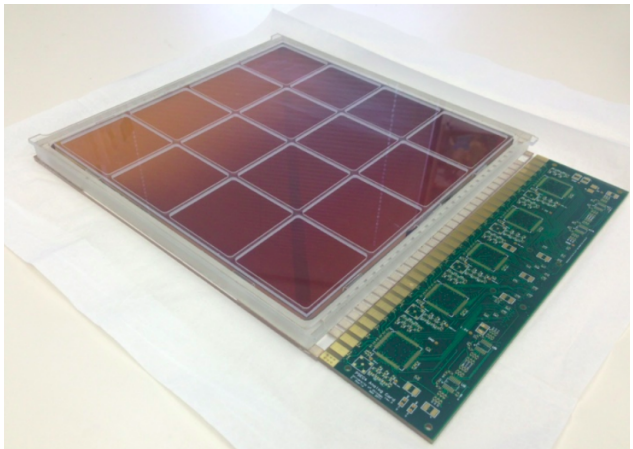




ANNIE Phase 1 - The future



- Data taking can continue even without beam $\rightarrow$ Cosmic data
- Design studies in progress to install small **LAPPDs** in the tank in a near future
- Possibility of adding **Gadolinium** to the water under investigation
- This **ANNIE 'Phase 1b'** will take place right after the Summer shutdown

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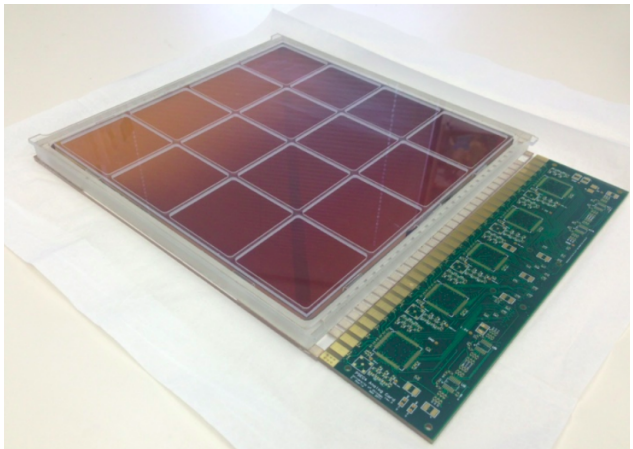

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- First data looks very promising
- Huge effort undergoing on analysis
- Precise simulations of the beam (muons and neutrons generation) and the detector (response to neutron capture) are required
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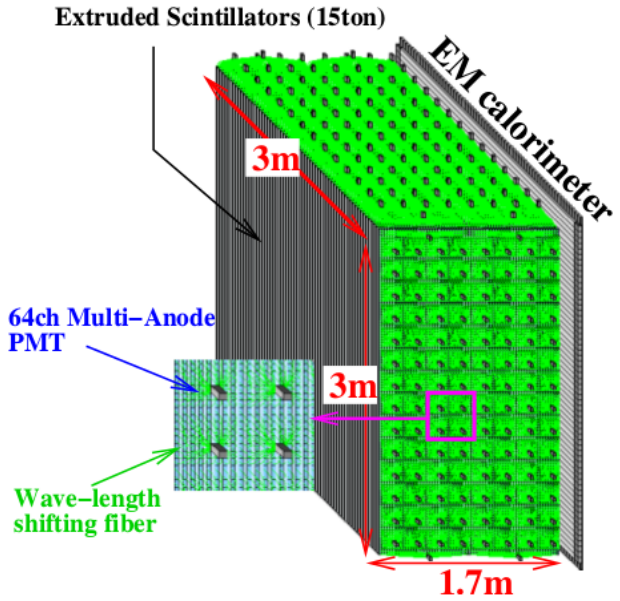
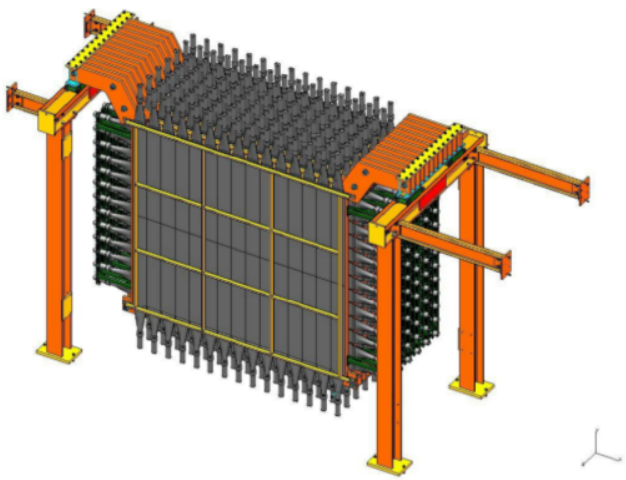
Thank you for your attention !

Back-up

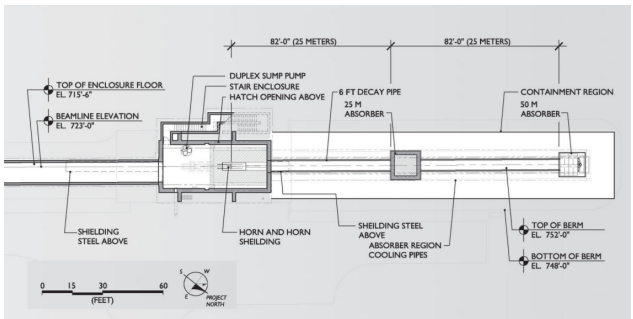
SciBooNE

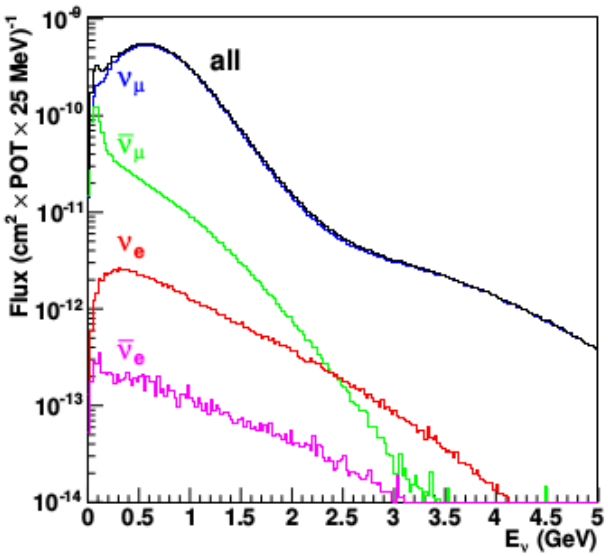




- SciBar: Scintillator tracking detector (14'000 bars, 14 tons)
- Electron Catcher: 2 planes of calorimeter (lead and scintillating fibers)
- Muon Range Detector
- Measurement of CC-QE, CC-$\pi^{\pm}$, CC-π^{0}, NC-ES cross-sections

Booster Neutrino Beam



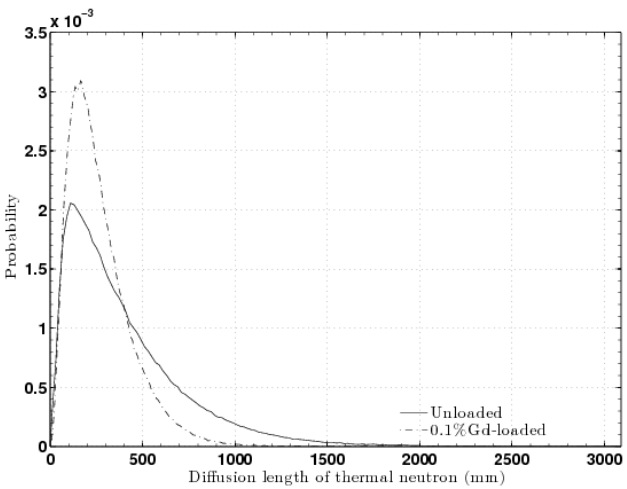


- 8 GeV protons from Booster beam
- Beryllium target, reversible horn polarity
- Mean neutrino energy of 700 MeV
- Composition: 93 % of ν_μ, 6.4 % of $\bar{\nu}_\mu$ and 0.6 % of $\bar{\nu}_e$ and ν_e

Neutron capture on H/Gd

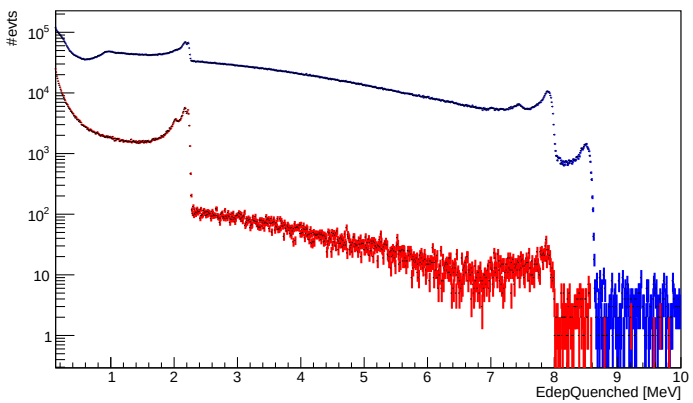
n-H capture

- Capture time: $\sim$ 200 μs
- 2.2 MeV emitted in one gamma
- Higher accidental background (natural radioactivity)



n-Gd capture

- Capture time: $\sim$ 20 μs (0.25% Gd-loading)
- $\sim$ 8 MeV emitted in several gammas
- High background reduction
- Smaller diffusion path length



Liquid scintillators

- Scintillation: Process by which ionization produced by charged particles excites a material and light is emitted by fluorescence
- Liquid scintillators: Organic molecules diluted in an optically-inert liquid (mineral oil,..)
- Basically: Charged particle ionizes liquid $\rightarrow$ Excites molecules that de-excites emitting light
- This light is detected using photomultiplier tubes (PMT's) that amplify it into a detectable current