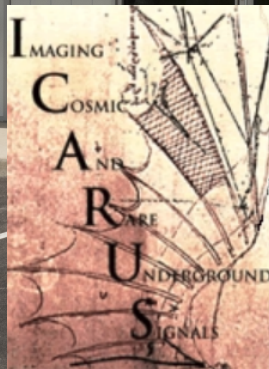


# Cosmogenic Background Suppression at the SBN Far Detector (ICARUS) with the Cosmic Ray Tagging System

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New Perspectives 2019  
Fermilab



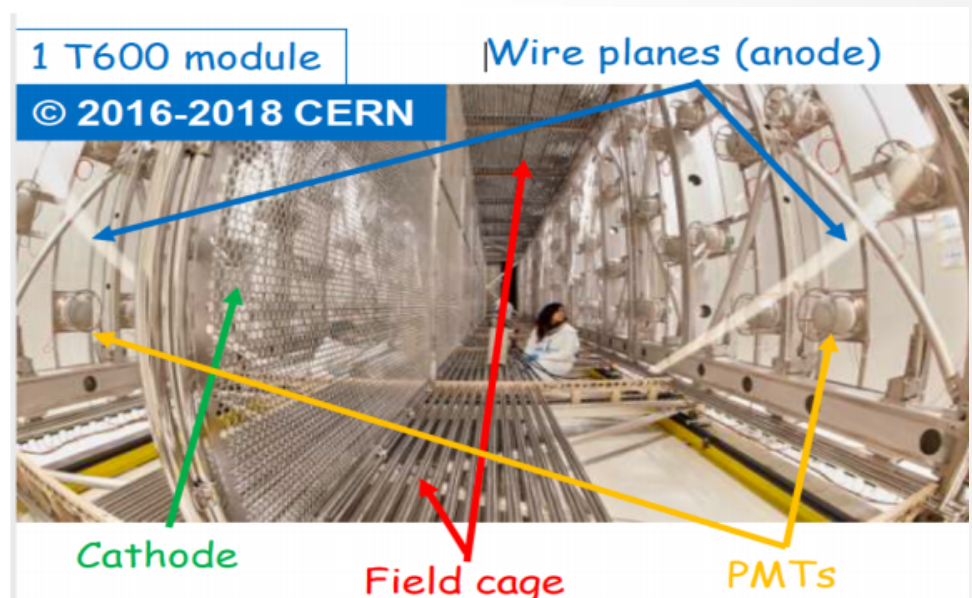
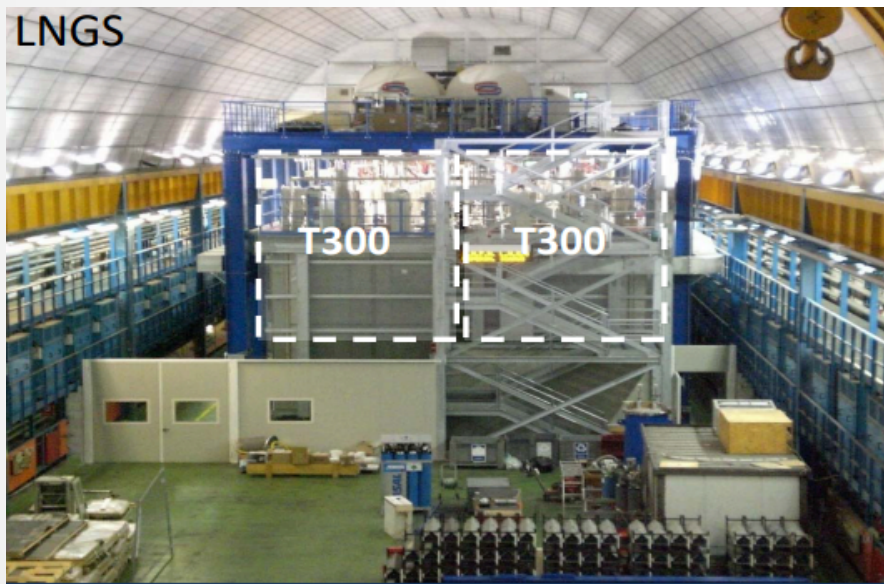
U.S. DEPARTMENT OF  
**ENERGY**





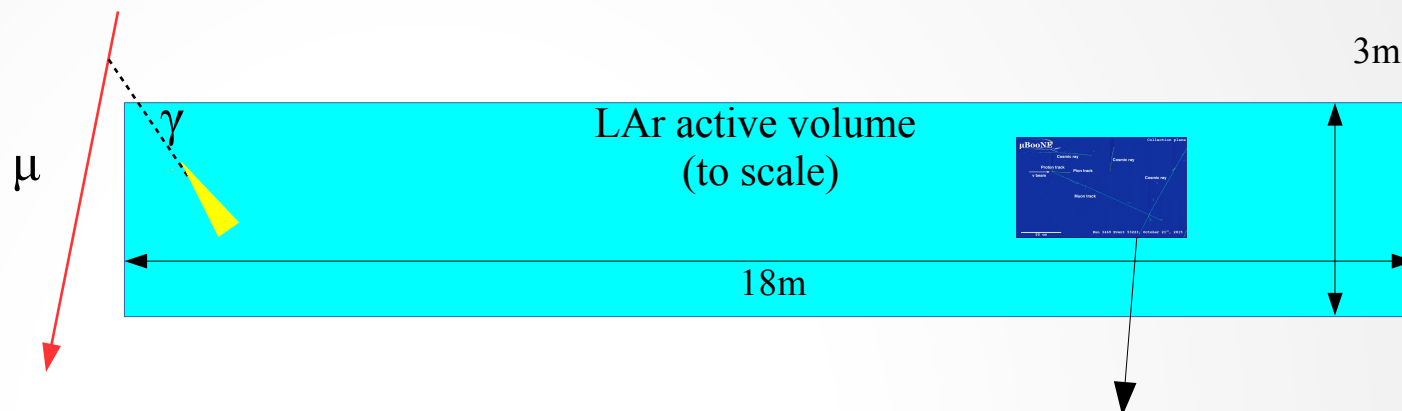
# ICARUS T600

- Short-Baseline Program Far Detector
- 2 identical cryostats, each w/2 liquid argon time projection chambers (LAr TPCs)
- With 1.5 m drift distance, 500 V/cm drift field, maximum drift time is  $\sim 1$  ms
- Photon detection system (PDS) measures prompt scintillation light, providing ns-level time information for each ionization event

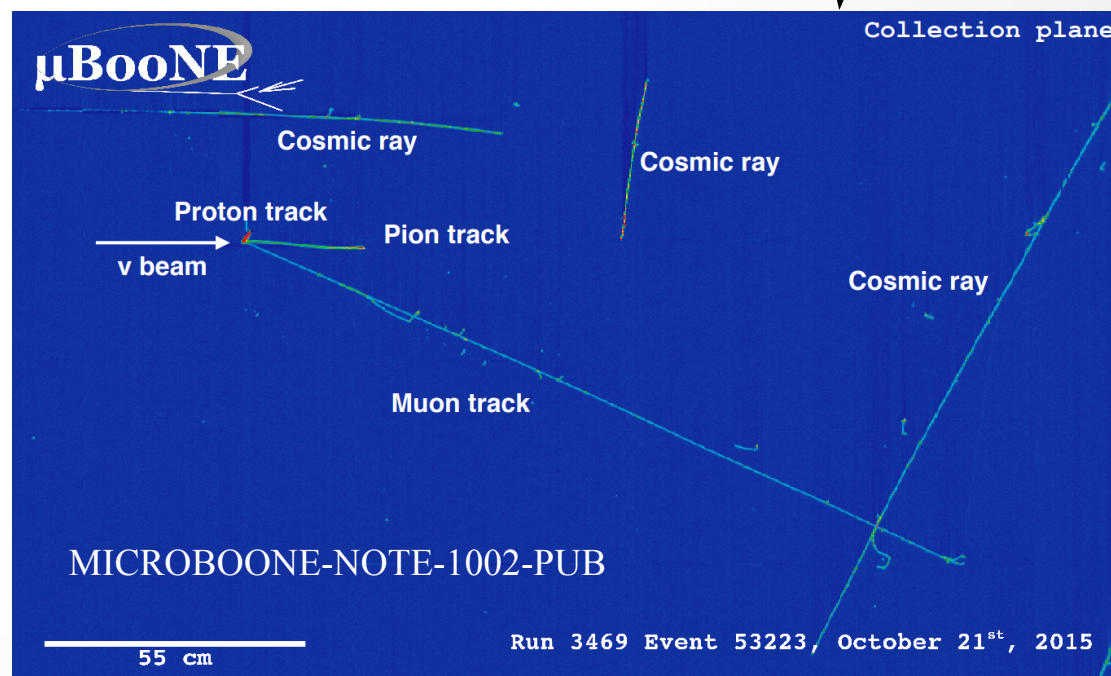




# Operating a LAr TPC on the Surface



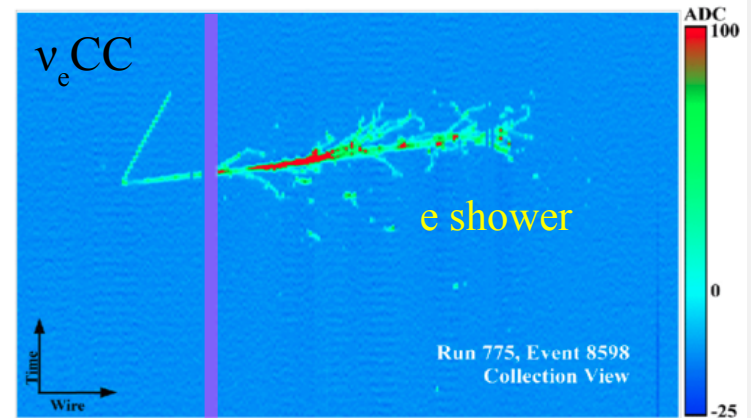
- MC predicts  $\sim 12$  cosmic  $\mu$ 's pass through active LAr per TPC readout
- $\mu$ 's passing through/near LAr produce  $\gamma$ 's which mimic  $\nu_e$  CC topology



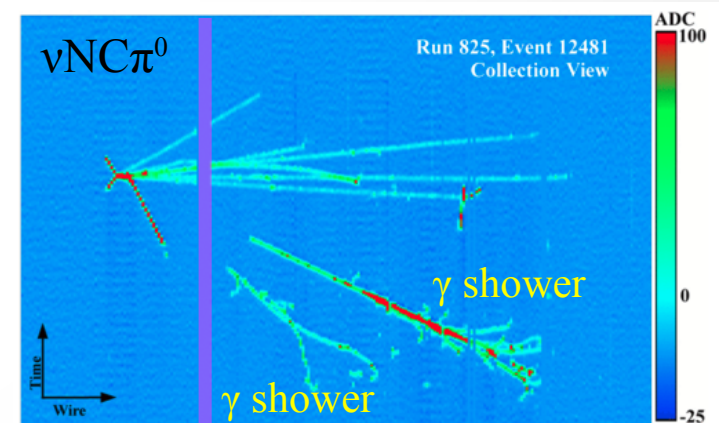


# Cosmogenic Background Suppression

- Exploit time structure of Booster Neutrino Beam
  - Each spill 1.6  $\mu$ s
  - 80 RF buckets,  $\sim 2$  ns wide, 19 ns apart
  - Up to 90% rejection
- Topological selection w/TPC
  - e/ $\gamma$  separation
  - Association with cosmic muons
- Muon tagging with external detector
  - Tags muons passing near but not through the active volume
  - Extra handle for TPC methods
  - Crucial tool to ensure signal quality



dead wires

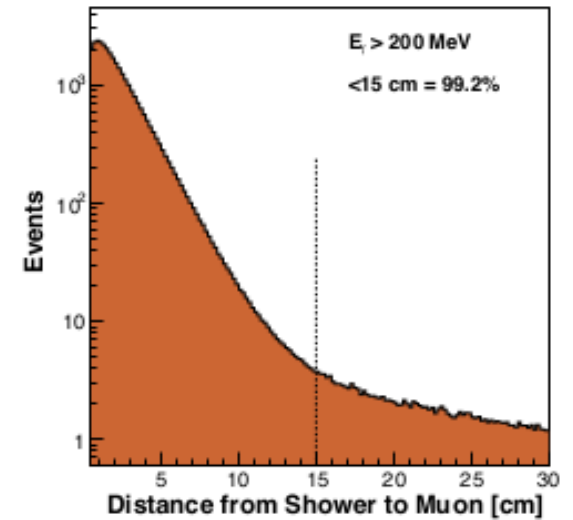
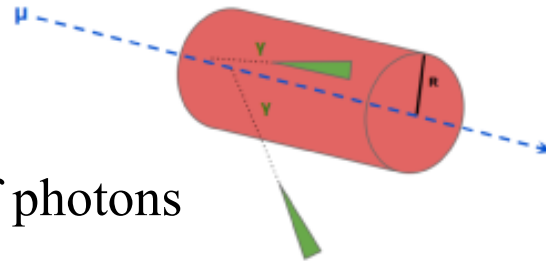


ArgoNeuT Phys. Rev. D 95, 072005

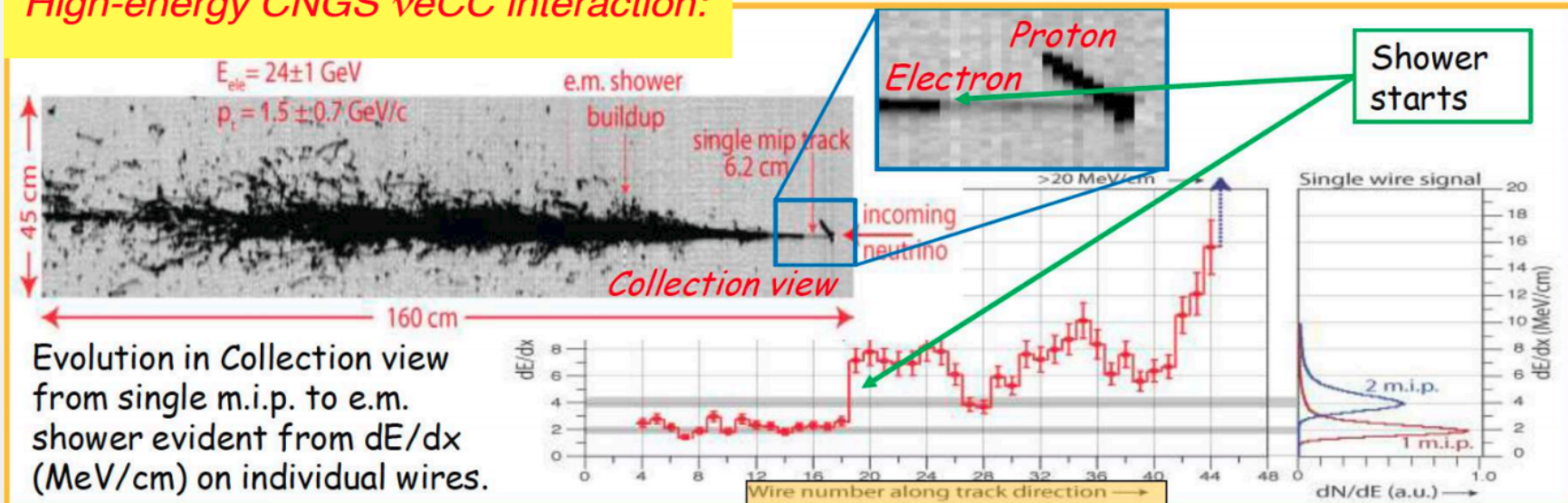


# TPC Selection

- Ionization density ( $dE/dx$ ) in first few cm of EM shower
  - Cut at 3.5 MeV/cm rejects  $\sim 94\%$  of pair producing photons
- Distance of vertex from  $\mu$  track
  - Cut at 15 cm rejects 99% of photons
- In 3 years running, leaves  $\sim 100$  events (not enough!)



## High-energy CNGS $\nu eCC$ interaction:

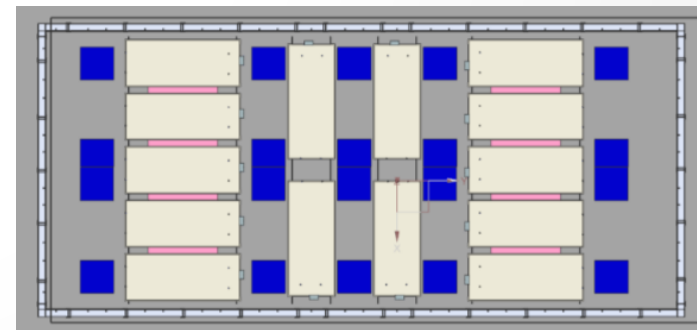
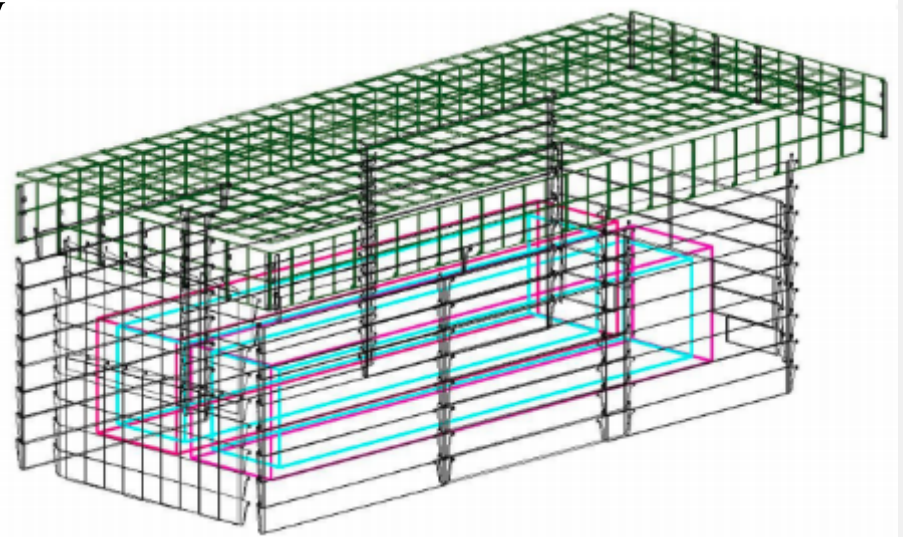




# Cosmic Ray Tagging System

Three subsystems providing ~95% tagging efficiency

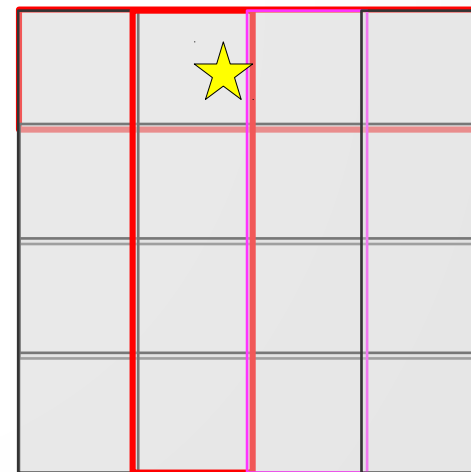
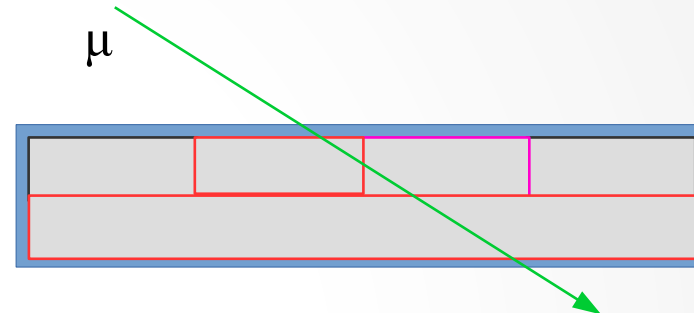
- Top
  - X-Y configuration
  - Single ended readout
- Sides (mix of configurations depending on wall)
  - X-X or X-Y
  - Single or dual ended readout
- Bottom
  - X-X configuration
  - Single ended readout





# CRT Reconstruction

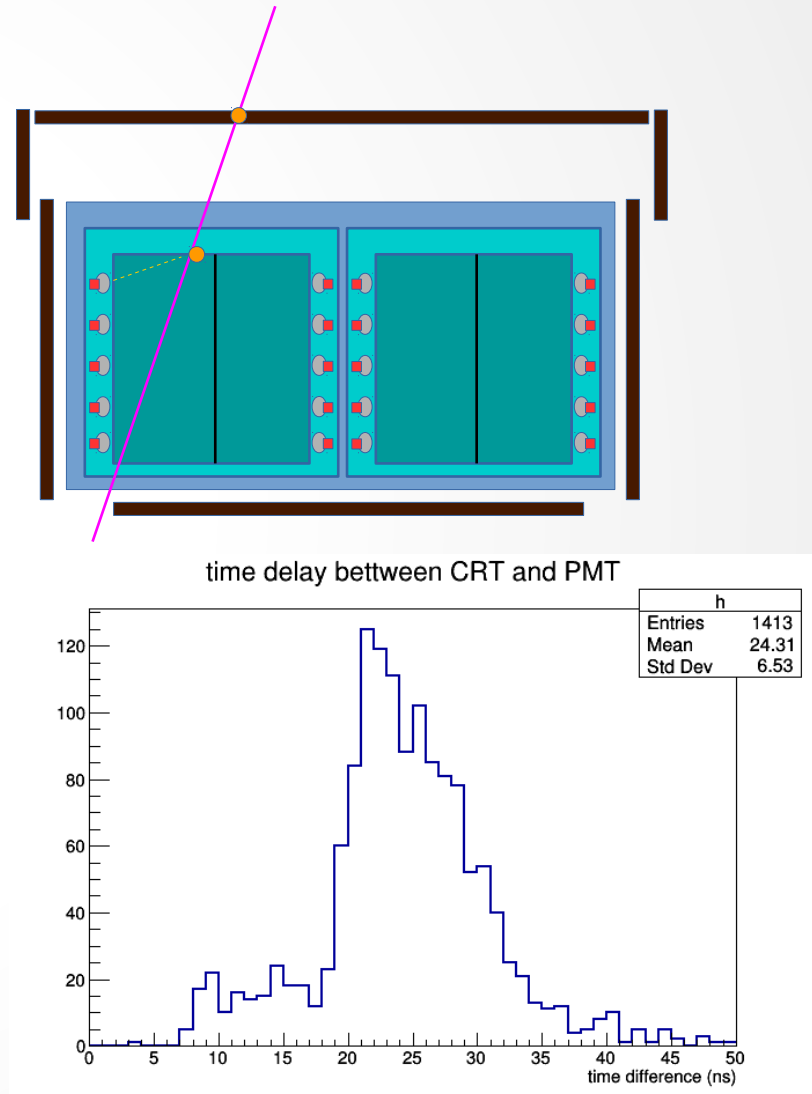
- From channel mapping, light output, and time stamps, extract point and time of CRT crossing
- Hit reconstruction method depends on CRT subsystem/configuration
  - Position resolution 3cm-2m
  - Time resolution 3-7ns





# Background Rejection with CRT

- Event Veto
  - Veto all events with CRT hit in time with beam spill
  - Sacrifices  $\sim 5\%$  of  $\nu_e$  CC events
  - Sacrifices  $\sim 20\%$  of  $\nu_\mu$  CC events
- Track Veto
  - Differentiate between ingoing and outgoing muon tracks using TOF between CRT and LAr
  - Reject all activity associated with ingoing tracks
  - Feasibility depends on CRT, PDS time resolution
  - Truth level study looks promising



# Current and Future Work

- Development of cosmogenic muon track veto method with full detector simulation and reconstruction chain is underway
- Partial CRT system commissioning this summer with test of CRT hit reconstruction
- ICARUS TPC commissioning/first data end of 2019
- Full CRT system early 2020, deployment of background suppression methods to follow

