Short-Baseline neutrino oscillation searches with the ICARUS detector at FNAL

The SBN program to search for sterile neutrinos
- The Short-Baseline Neutrino (SBN) program aims to confirm or definitively rule out the existence of sterile neutrinos at the eV mass scale as hinted by some experimental results [1-3] by measuring the \( \nu_e \) appearance and the \( \nu_{\mu} \) disappearance oscillation channel on the Booster and NuMI neutrino beams at Fermilab
- Liquid Argon Time Projection Chambers (LAr TPCs) at Near (110 m) and Far (600 m) positions along the \( \nu_e \) Booster Neutrino Beam (\( E_e \sim 1 \text{ GeV} \)) at Fermilab
- SBN will cover the allowed parameter region \( \Delta m^2_{\nu_e-\nu_{\mu}} \) with 5σ sensitivity in 3 years (6.6 x 10^20 POT)
- Additionally, it will provide high-statistic samples of \( \nu_e - \nu_{\mu} \) cross-section measurements extremely useful for the upcoming DUNE experiment

A new experimental challenge
ICARUS operates at shallow depth. The high rate of cosmic ray induced signal (background) is mitigated by:
- 3 m of concrete overburden reducing the rate of cosmic neutrons and \( \gamma \) by a factor 200 and muons by 25%
- Photons originated by the residual muon rate (~ 10 in 1 ms TPC readout) can mimic \( \nu_e \) signal interaction \( \rightarrow \) Cosmic Ray Tagger (CRT) system identifies in time and space particles to distinguish cosmos entering the detector from particles originated inside the TPC

Cosmic Ray Tagger
- Three subsystem ensuring 4m coverage of the detector: Top, Side and Bottom CRT
- Side CRT made of 8 inner and outer vertical layers on lateral walls: 1 scintillator plane/layer of 20 scintillator strips each with 1 WLS fiber readout by SiPM (at both end 8 m strips, at the same side 5 m strips)
- Top CRT will intercept 80% of cosmic ray flux: 123 modules, 2 x 2 m each, 84 horizontal installed below the overburden and 39 in vertical position on west, east, north and south rim
- Each Top CRT module composed of 2 orthogonal scintillator planes of 8 bars each:
  - 2 WLS fibers grooved on each bar + SiPM at one end of each fiber
  - Front End Board trigger: quadruple coincidence
- Top CRT modules assembled and tested at LNF and re-tested at Fermilab before installation
- Top CRT modules technical specifications:
  - Mean efficiency ~ 96 %
  - Time resolution 2-3 ns and spatial granularity of ~ 20 cm

The Far Detector ICARUS T600
- The SBN Far Detector, ICARUS T600, was run at LNGS Lab from 2010 to 2013 as the first and largest LArTPC ever operated collecting 8.6x10^21 POT statistics from the CNGS neutrino beam
- ICARUS is a self-triggering detector:
  - two identical modules 19.6 (L) x 3.6 (W) x 3.9 (H) m^3 each with a total (active) LAr mass of 760 (476) ton
  - Charged particles from neutrino interactions ionize the LAr producing \( e^- \) drifting in 1 ms (\( E_e = 500 \text{ V/cm} \) along 1.5 m drift length) towards three parallel anode wires with different orientation (0°, ± 60°).
  - Combining wire coordinate at different drift time \( \rightarrow \) 3D track reconstruction with resolution of ~ 3 mm
  - Scintillation light detected by photomultipliers to provide the event time

References