# The CAPTAIN-MINERvA Experiment

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**Abstract**

The CAPTAIN-MINERvA experiment aims to measure neutrino-argon interactions in the few GeV energy range, which corresponds to the first oscillation maximum for DUNE. It uses the CAPTAIN LArTPC as an active target in conjunction with MINERvA to measure the neutrino interactions and will provide the only high-statistics measurement of the neutrino-argon cross section above 2 GeV before DUNE. CAPTAIN is a liquid argon TPC which is currently being built at LANL. It will be moved to Fermilab and be used in conjunction with MINERvA. Using MINERvA as the tracking detector will allow us to measure the muon energy by dE/dx and thus more completely measure the incoming neutrino energy. And, by measuring the ratio of cross sections in argon to hydrocarbon in the scintillator, we will be able to make stringent tests of nuclear effects models. Thus, through this unique combination of detectors, CAPTAIN-MINERvA will be able to study neutrino-argon interactions and serve as an important source of input for DUNE.

## The CAPTAIN-MINERvA Detector

- ❑ A liquid Ar TPC is being built at LANL.
- ❑ It will house 5 tons of liquid Ar in its active volume.
- ❑ Mini-CAPTAIN, a prototype has been built & commissioned.
- ❑ CAPTAIN will serve as the vertex detector and outgoing particles will be tracked in MINERvA.

## The CAPTAIN-MINERvA Collaboration & Future Plans

- ❑ Members of the CAPTAIN & MINERvA collaborations have joined together to form the CAPTAIN-MINERvA collaboration.
- ❑ We are comprised of 118 members from 29 institutions.
- ❑ CAPTAIN-MINERvA received Stage 1 approval from the Fermilab Director in July 2015.
- ❑ The CAPTAIN detector will be commissioned at a surface location at Fermilab in ~2017, with preparations beginning in 2016.
- ❑ We expect to take neutrino data with CAPTAIN-MINERvA beginning ~2018. One year of data (6x10$^{20}$ POT/year) in neutrino mode and one year in antineutrino mode (contingent on NuMI schedule) is expected.

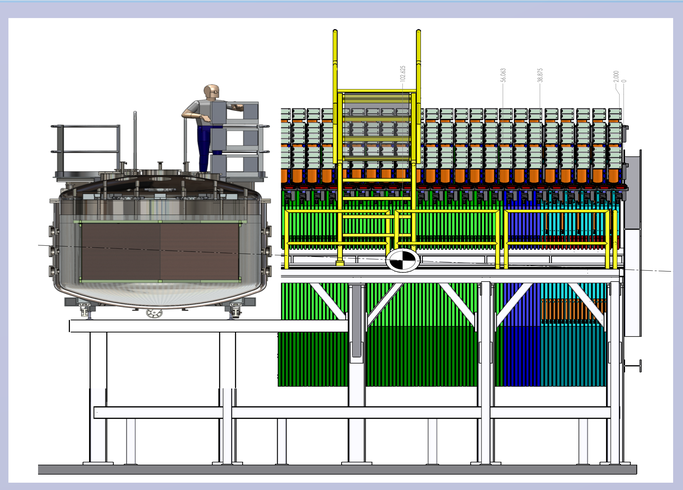


Figure 1: Proposed CAPTAIN-MINERvA detector installation

## A unique program

- ❑ Will be the only experiment making high statistics measurements of neutrino interactions on Ar in the medium energy range before DUNE.
- ❑ Will measure cross section ratios in Ar to hydrocarbon in the scintillator.
- ❑ CAPTAIN has 20 times the fiducial mass of ArgoNEUT & will see about 10 times more POT in neutrinos in 1 year.
- ❑ A unique opportunity to study events with large multiplicities - about 68% of interactions in CAPTAIN-MINERvA will have a pion in the final state; MicroBooNE's interactions will be mostly quasielastic (60%).

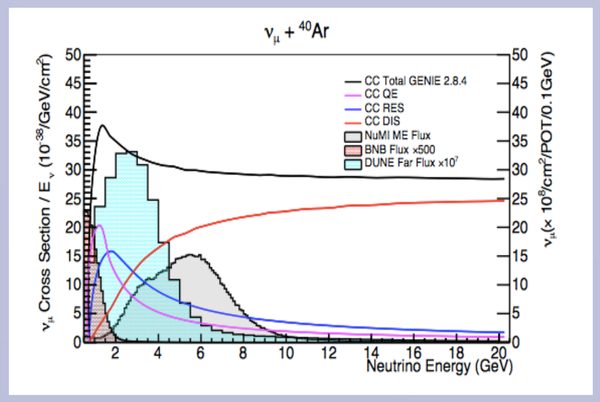


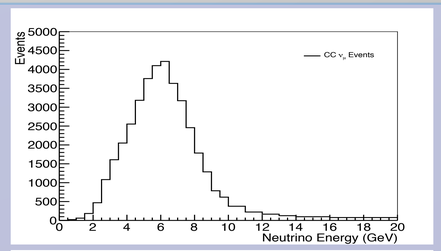

Figure 2: Unoscillated $\nu_\mu$ DUNE far flux, BNB flux at MiniBooNE, medium-energy NUMI flux at the proposed location of CAPTAIN-MINERvA, and GENIE cross sections on Argon

## Acceptance of $\nu_\mu$CC events in MINERvA & MINOS

**Simulations** (6x10$^{20}$ POT, 12.5 million CC interactions within the TPC)

- ❑ 64% of events will have a muon reconstructed by MINOS or MINERvA.
- ❑ For CC interactions, ~20% will have their hadronic energy contained within the TPC. (Neutrons are excluded under this criteria.)
- ❑ 10-15% of CC interactions will have all their hadronic energy contained AND have a muon reconstructed by MINOS or MINERvA. MINERvA will be used as a calorimeter for events where final state particles exit CAPTAIN and reach MINERvA.

| | Events w/ reco $\mu$ | Events w/ reco $\mu$ and charge |
|---|---|---|
| CCQE-like | 916k | 784k |
| CC1$\pi^\pm$ | 1953k | 966k |
| CC1$\pi^0$ | 1553k | 597k |



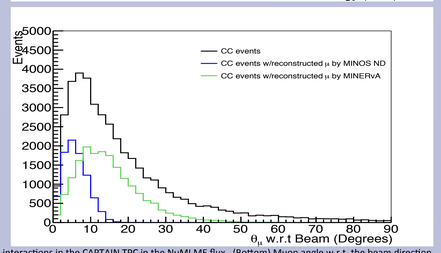
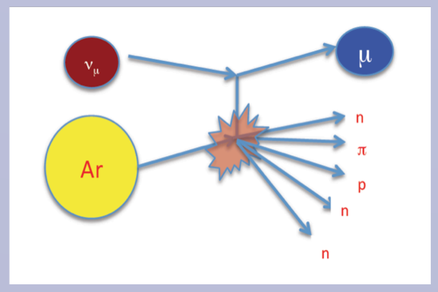




Figure 4: (Top) Incoming neutrino energy for $\nu_\mu$ interactions in the CAPTAIN TPC in the NuMI ME flux. (Bottom) Muon angle w.r.t. the beam direction

## Expected contribution to DUNE

- ❑ Uncertainty in the neutrino interaction model is a major systematic uncertainty in neutrino oscillation measurements.
- ❑ Neutrino interaction data constrains models of nuclear effects used to reconstruct the incoming neutrino energy and to predict signal & background rates.
- ❑ Currently, the interaction models used in neutrino event generators are mostly based on targets other than Ar, & there's a lack of neutrino-Ar data in the neutrino energy range relevant for DUNE.




## CAPTAIN-MINERvA's Role

- ❑ Will provide a high-statistics neutrino-Ar interactions data set in the relevant range for DUNE.
- ❑ Will extract cross section ratios, so be able to make stringent tests of nuclear effects models.
- ❑ Will study event reconstruction and particle ID in medium-energy neutrino-Ar interactions.

## Expected Physics Results

- ❑ Detailed reconstruction of the complex event topologies of final state interactions
- ❑ Measurement of CC, NC, exclusive channels in the important & poorly understood neutrino energy range where baryon resonances dominate
- ❑ Better estimation of incoming neutrino energy using muon & proton reconstructed kinematics
- ❑ Expected measurements: total $\nu_\mu$ & antineutrino CC cross-sections on Ar, ratios of CC cross sections, demonstration of $\nu_e$ detection & identification in liquid Ar

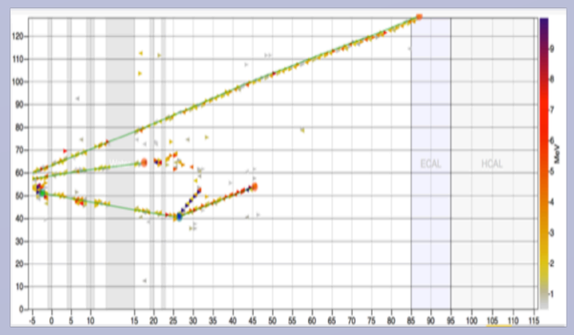



Figure 5: MINERvA event display, A. Higueraa