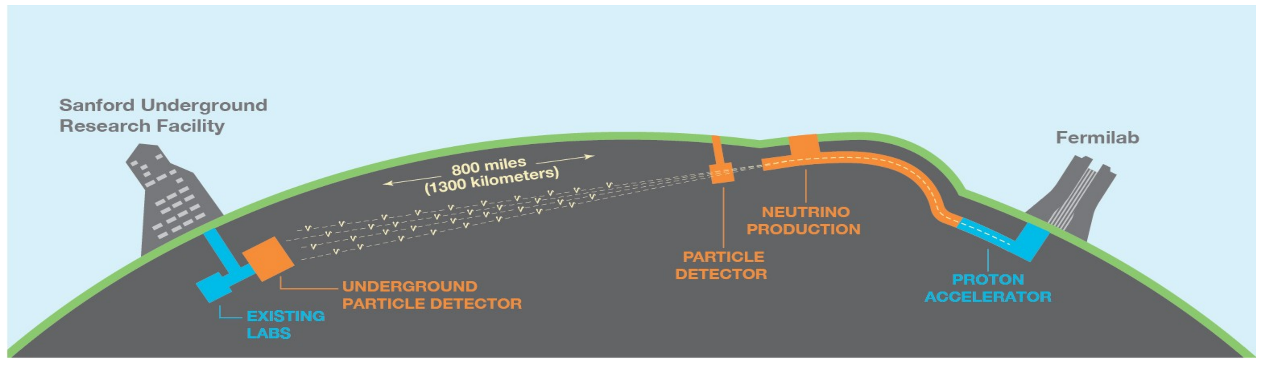
# DUNE Near Detector Choice, Cross Section Models, and Parameterization

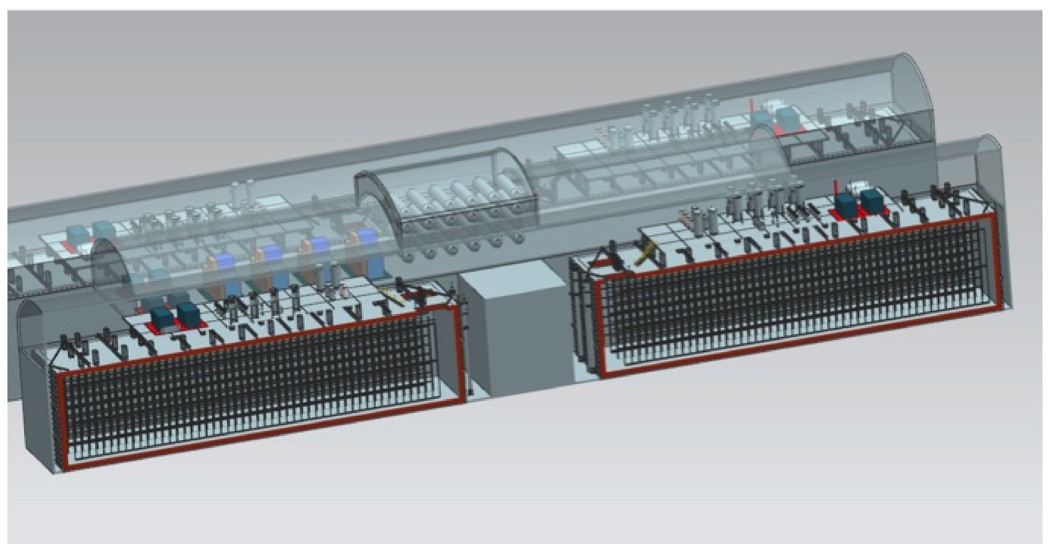
Jake Calcutt[1], for the DUNE collaboration

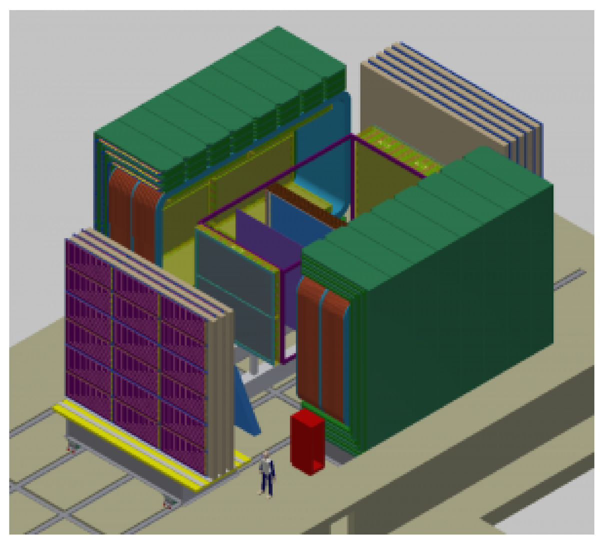
[1]Michigan State University

## The DUNE Experiment

- Next generation oscillation experiment
- Seeks to determine presence of CP-violation in oscillations
- Total systematic uncertainties are limited to <2% after a near to far extrapolation
- Motivated studies in how uncertainty parameterization affects the extrapolation and how this couples to near detector choice



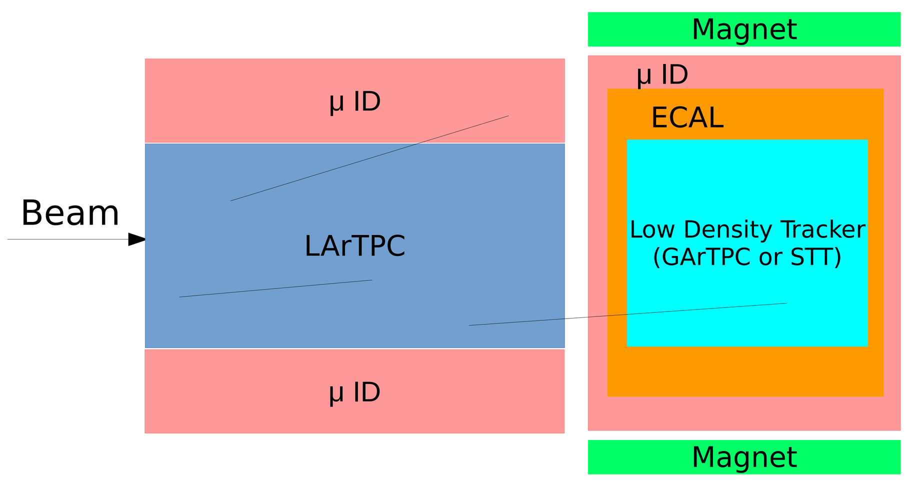


- Far detector (FD): 4-10kt LArTPC modules (left)
- Near detector (ND): several designs considered
  - Shown right: Fine-Grained Detector (FGD) from 2015 CDR
- ND goal is to constrain systematic uncertainties to <2%

## Near Detector Design

Current options for the ND consist of collections of various technologies:
- LArTPC
- GArTPC
- muon IDs
- FGD such as a Straw Tube Tracker (STT)
- Electromagnetic Calorimeter (ECAL)

- Right: sketch of one of many possible ND configurations

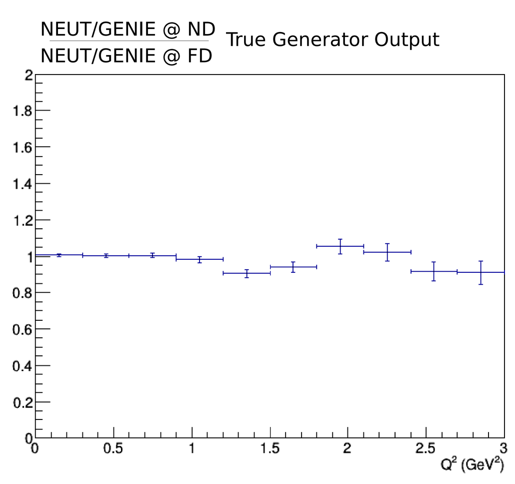


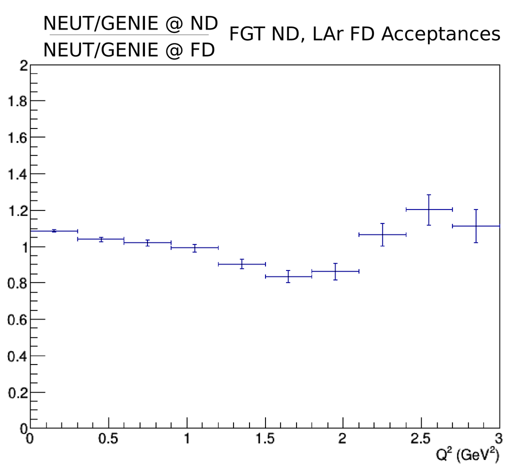

Tracks show contained muons

Each detector provides benefits to analyses

- STT: a low density tracker with very good electron ID and capability for high statistics
- GArTPC: has low momentum thresholds and high resolution
- LArTPC: detector and (nuclear) cross section uncertainties partially cancel at the FD

## Parameterization

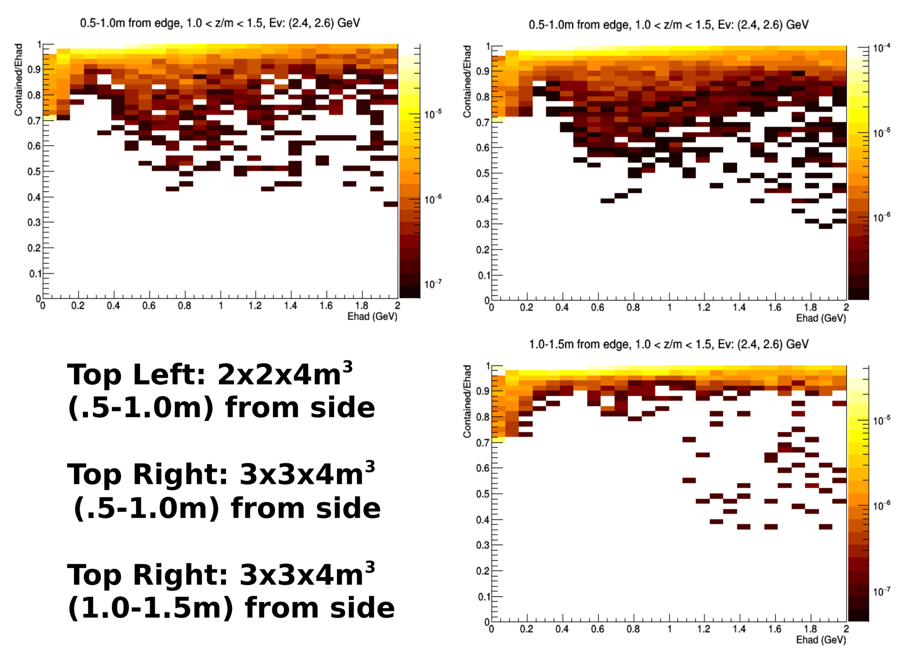



Ratios of simulated events from different MC generators serve as model variations

- A subsequent ratio of this between the ND and FD gives an approximation of a near to far extrapolation.
- Shows that detector effects couple to model variations and can affect cross section model constraints
- Motivates an investigation into particle acceptance/containment in the ND

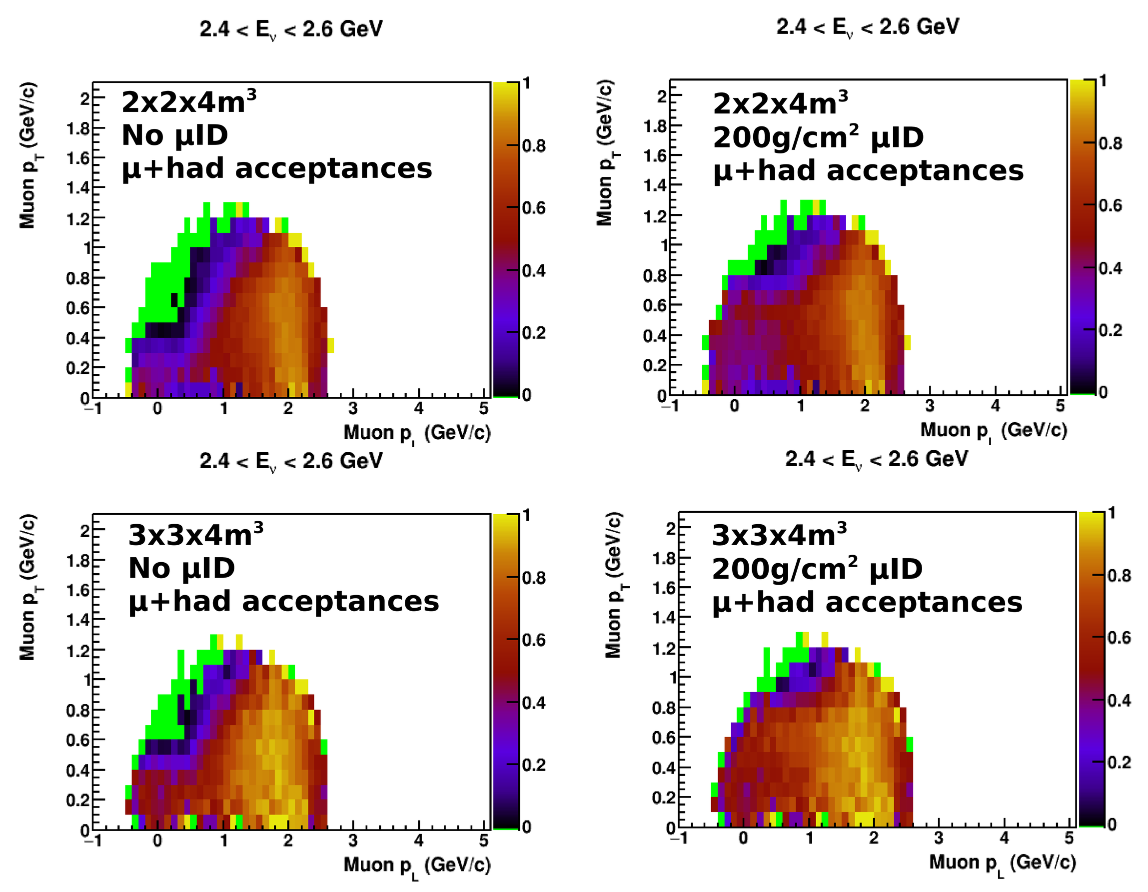
## Hadron Containment In LAr




One factor driving the detector size requirement is the ability to contain hadrons

- Needed for good reconstruction of neutrino energy and FSI model constraints
- Increasing size of detector allows higher hadronic containment for inner-most events

## Muon Containment In LAr




To limit effects from detector differences, the ND must have $4\pi$ containment of muons like the FD

- Need to reduce area with 0% containment of muons and hadrons (shown in green above)
- Increasing the size of the detector, as well as adding side muon IDs successfully reduces the area with 0% containment
- Adding muon IDs to the smaller detector is cheaper than increasing the size
  - Muon IDs do nothing for hadron containment, though increasing size will benefit this

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