Status of the DUNE near detector

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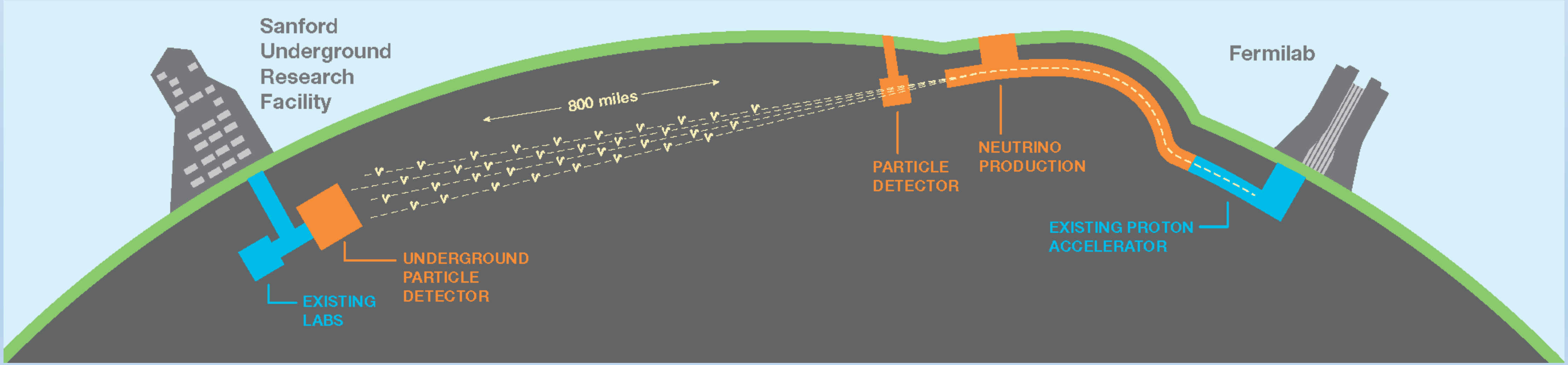
Introduction

- Brief introduction to DUNE
  - Focusing today on oscillation program but DUNE has large BSM and supernova physics programs (see talks from D. Kim, C. Alt, Y. Jwa, C. Cuesta and A. Roeth)
- What are the requirements for the near detector?
- The CDR reference design
  - How does each component of the reference design meet these requirements?

The DUNE experiment

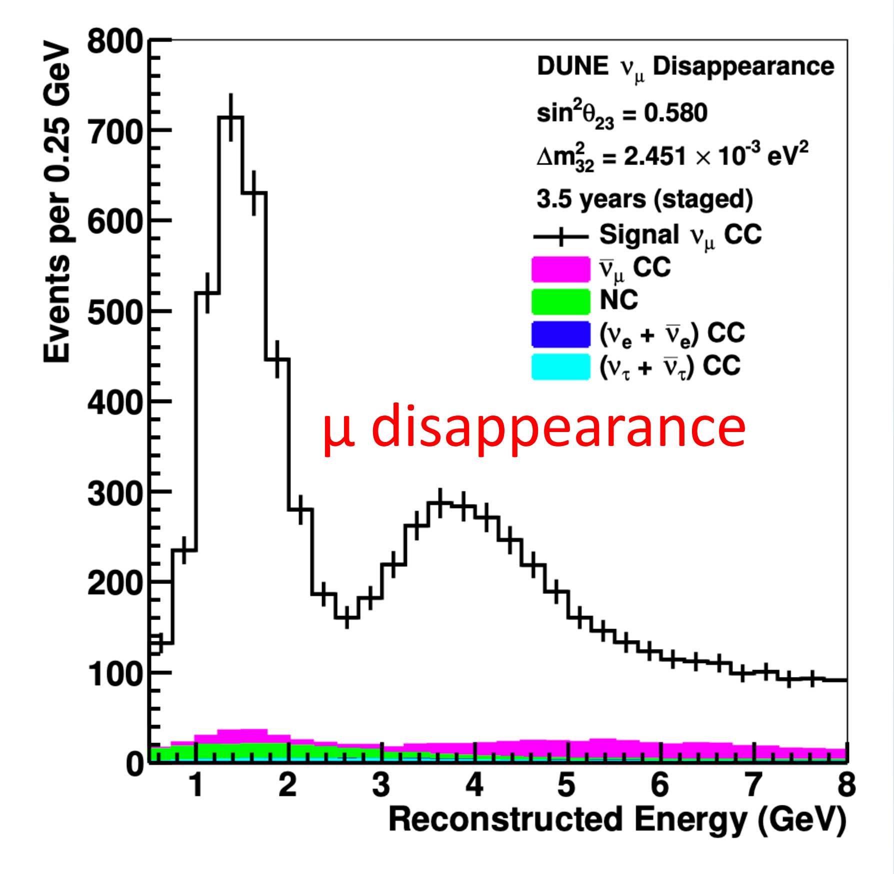
- Long-baseline neutrino experiment with 1310 km baseline
- Wide-band high-power neutrino beam (~ GeV range, >1MW)
- ~4x10 kt fiducial mass liquid-argon Far Detector
- Near Detector approximately 575 m from neutrino source
- Flagship physics topics: CP violation, mass ordering, θ_{23}, Δm^2_{32}

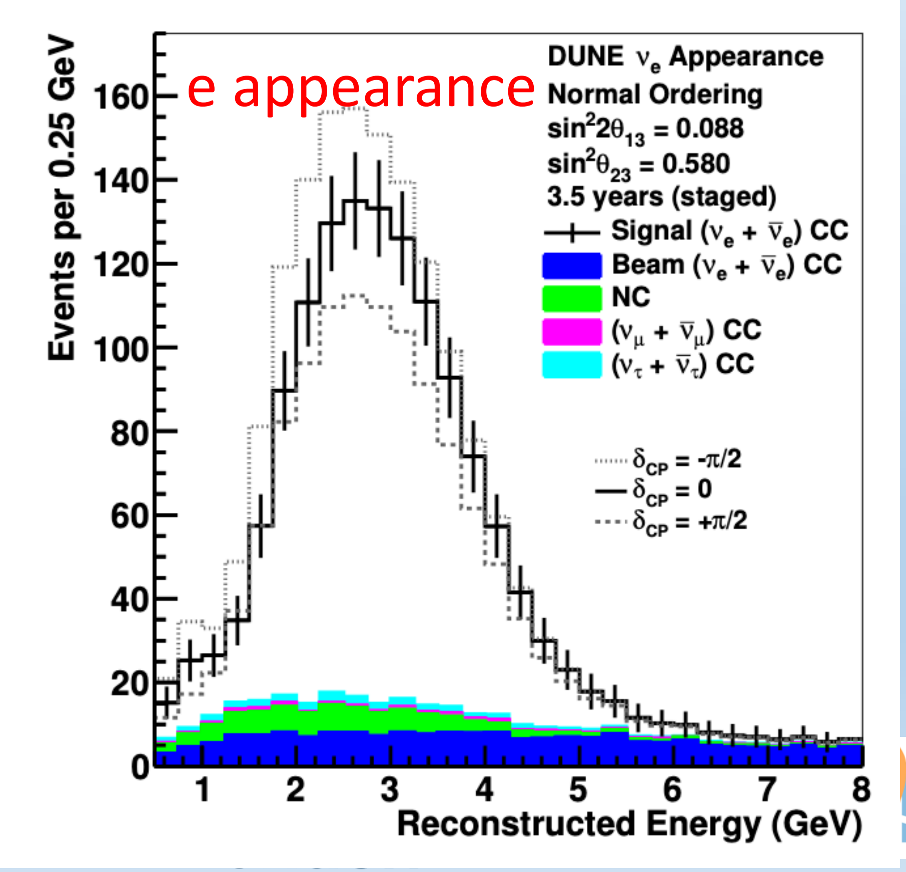


Requirements of the DUNE Near Detectors

- Predict the spectrum at the far detector

$$N(E_\nu) = \text{Flux} \times \text{Cross section} \times \text{Detector Efficiency} \times \text{Osc}$$





Requirements of the DUNE Near Detectors

$$N(E_\nu) = \text{Flux} \times \text{Cross section} \times \text{Detector Efficiency} \times \text{Osc}$$

Measure the neutrino flux	Constrain the cross-section model	Operate in high rate environment
Monitor time variation of the beam	Take measurements with different fluxes	Transfer measurements to the FD

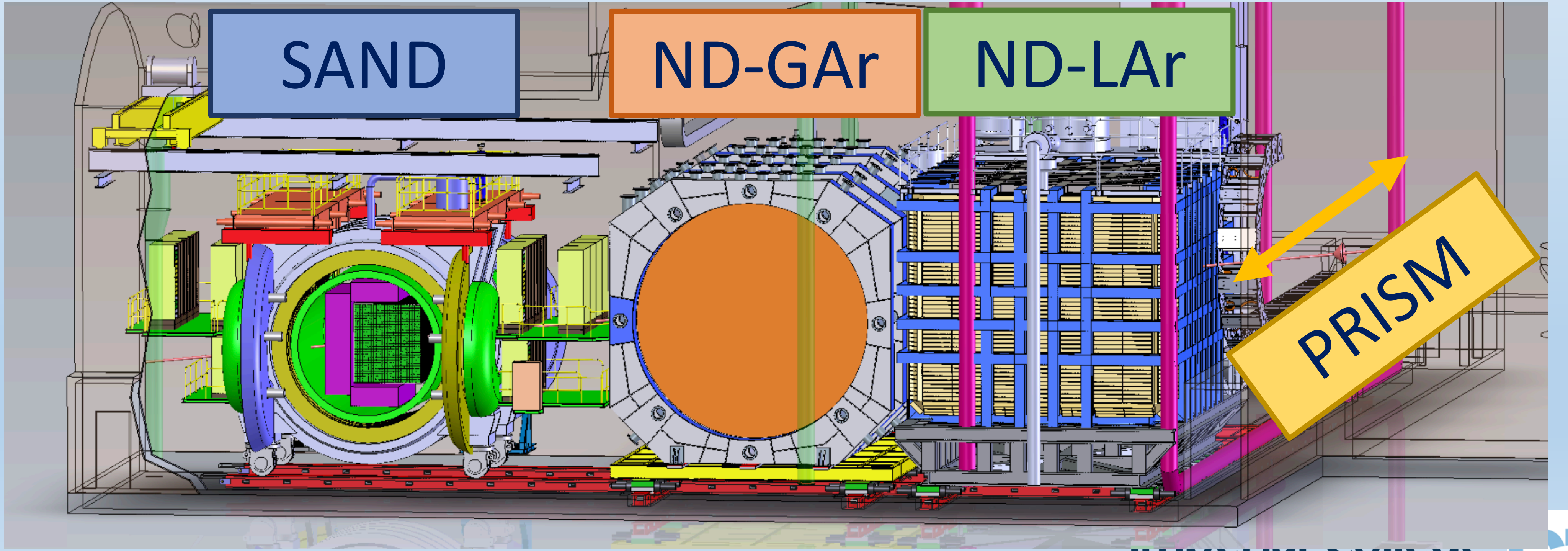
Requirements of the DUNE Near Detectors

$$N(\text{Reco vars}) = \int \text{Flux}(E_\nu, \text{time}) \times \text{Cross section}(E_\nu, \text{final state}) \times \text{Detector Efficiency}(\text{final state}) \times \text{Osc}(E_\nu)$$

Measure the neutrino flux	Constrain the cross-section model	Operate in high rate environment
Monitor time variation of the beam	Take measurements with different fluxes	Transfer measurements to the FD

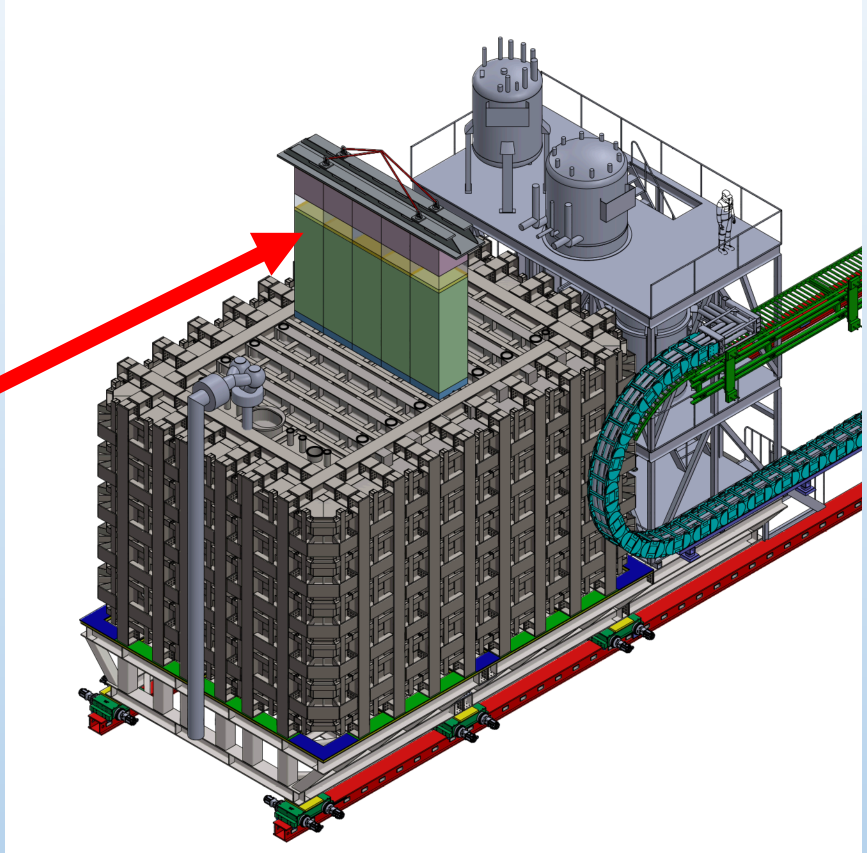
The CDR reference design

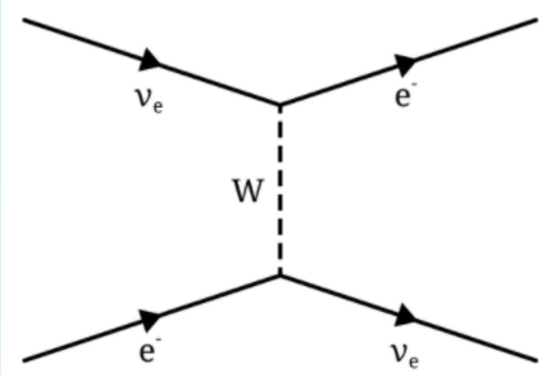
- 3 components: 2 of which (ND-LAr, ND-GAr) move off-axis giving different flux
  - ND-LAr: Liquid Argon TPC with pixelated readout (**50t**)
  - ND-GAr: High Pressure gas TPC (**1t**) + ECAL + magnet
  - SAND: 3D plastic scintillator target (**8t**) + trackers + ECAL + magnets



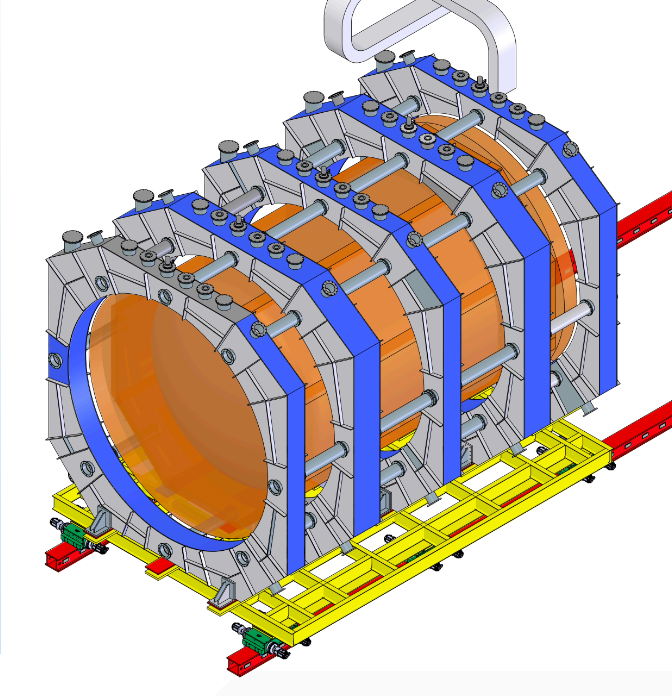
ND-LAr: Liquid Argon

- 50t fiducial mass liquid Argon TPC
  - Large event sample with same nucleus and technology as far detector
- Modular design with pixelated charge readout
  - Suitable for high rate environment
  - Allows localization of light signals
- Large mass allows ν-e scattering flux measurement
  - 6500 events per year, QCD free flux measurement

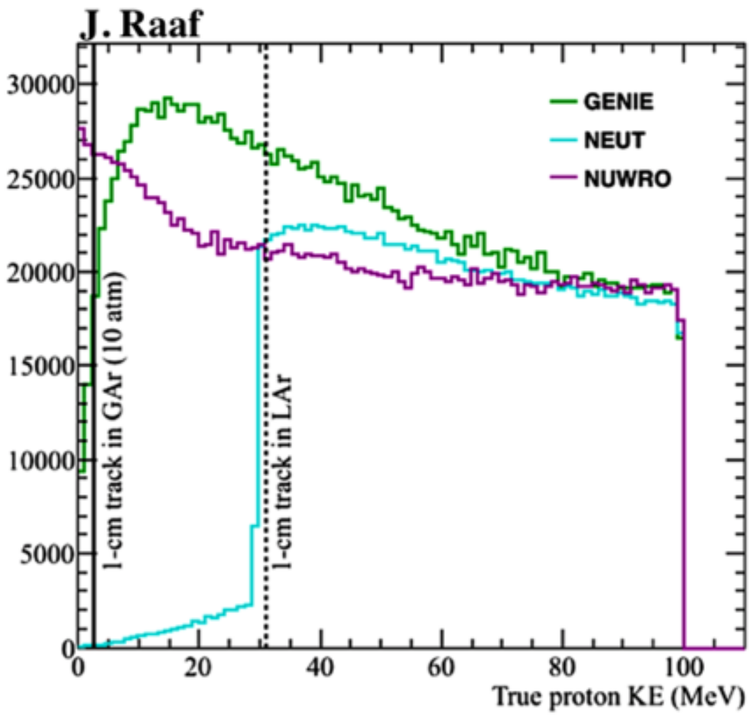




ND-GAr: Gaseous Argon

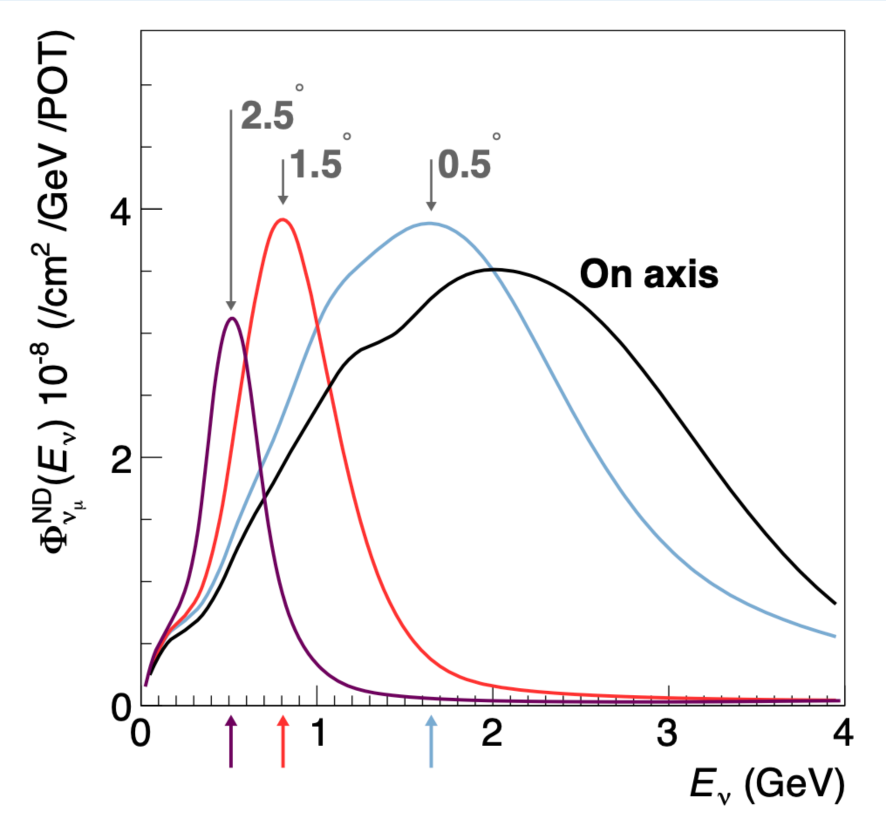


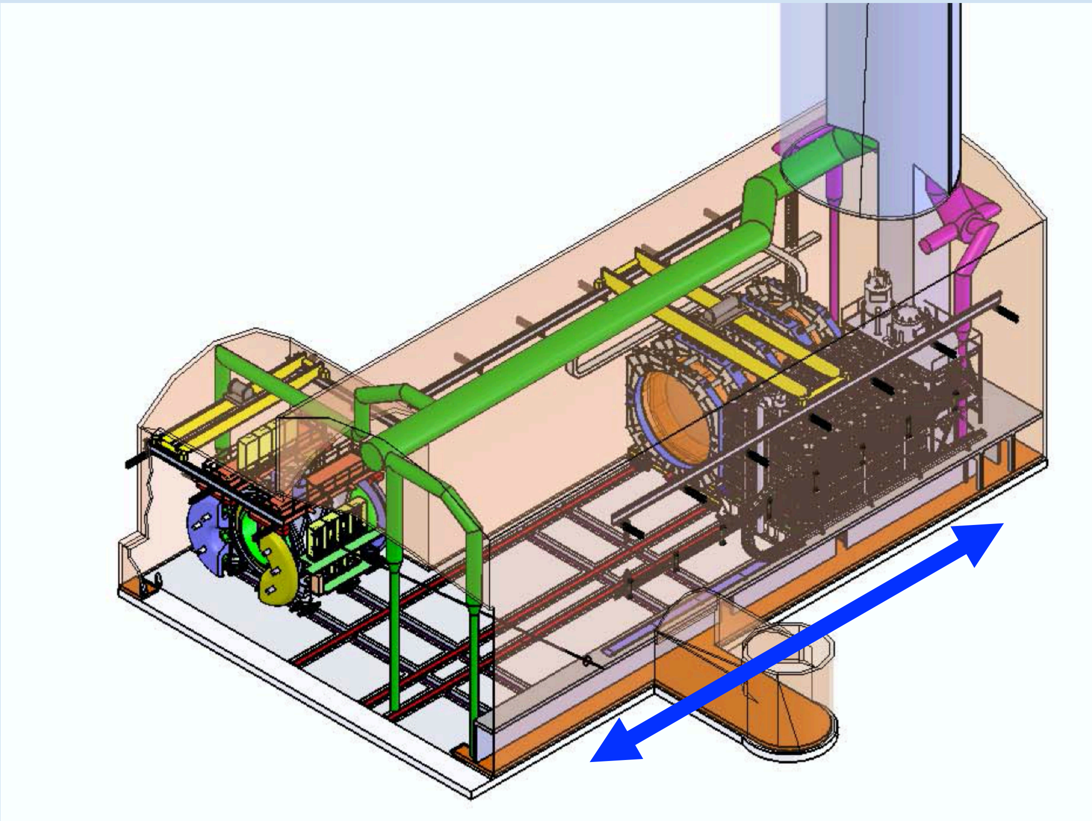
- 1 ton gas target TPC surrounded by ECAL and superconducting magnet
- Gas target has lower energy threshold than liquid
  - Models that are easily distinguishable in GAr can but not LAr can lead to biases in oscillation parameters
- Key for hadronic final states which are hard to distinguish in ND-LAr and far detector that contribute to visible energy differently e.g. multi-π
- Not all muons are contained in ND-LAr so ND-GAr also acts as spectrometer for these



PRISM

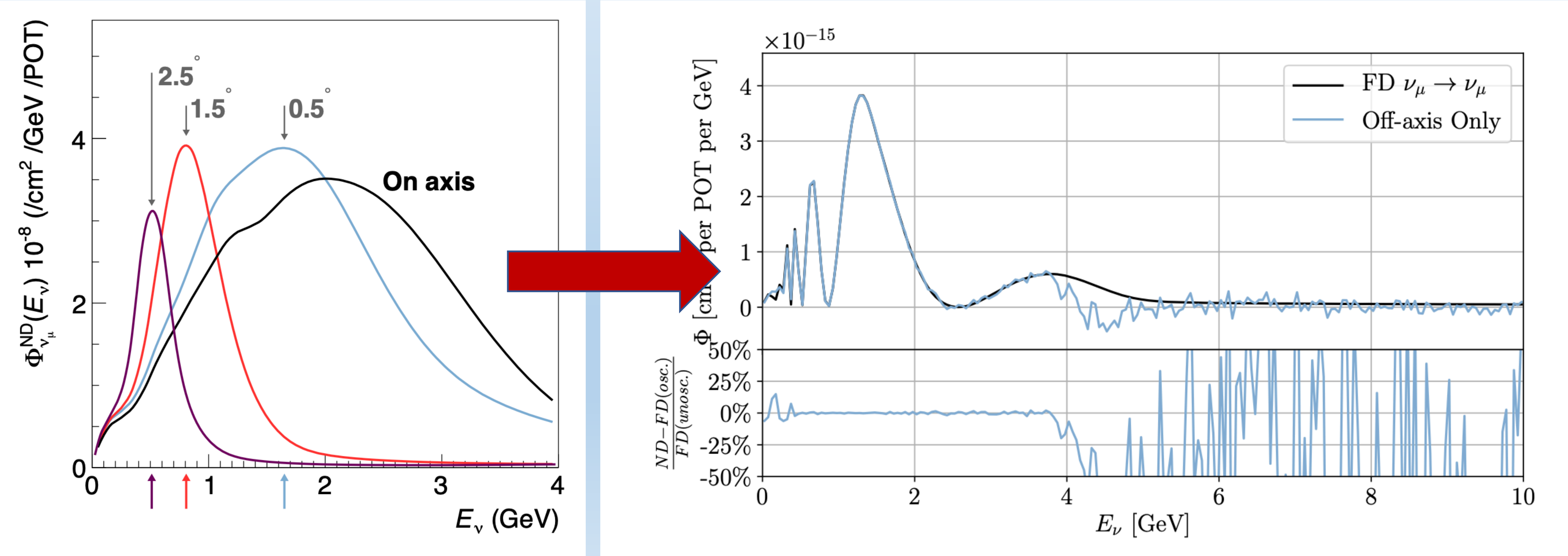
- Use off-axis effect to sample multiple fluxes using same detectors
- Allows isolation of flux, cross-section and detector effects on rate





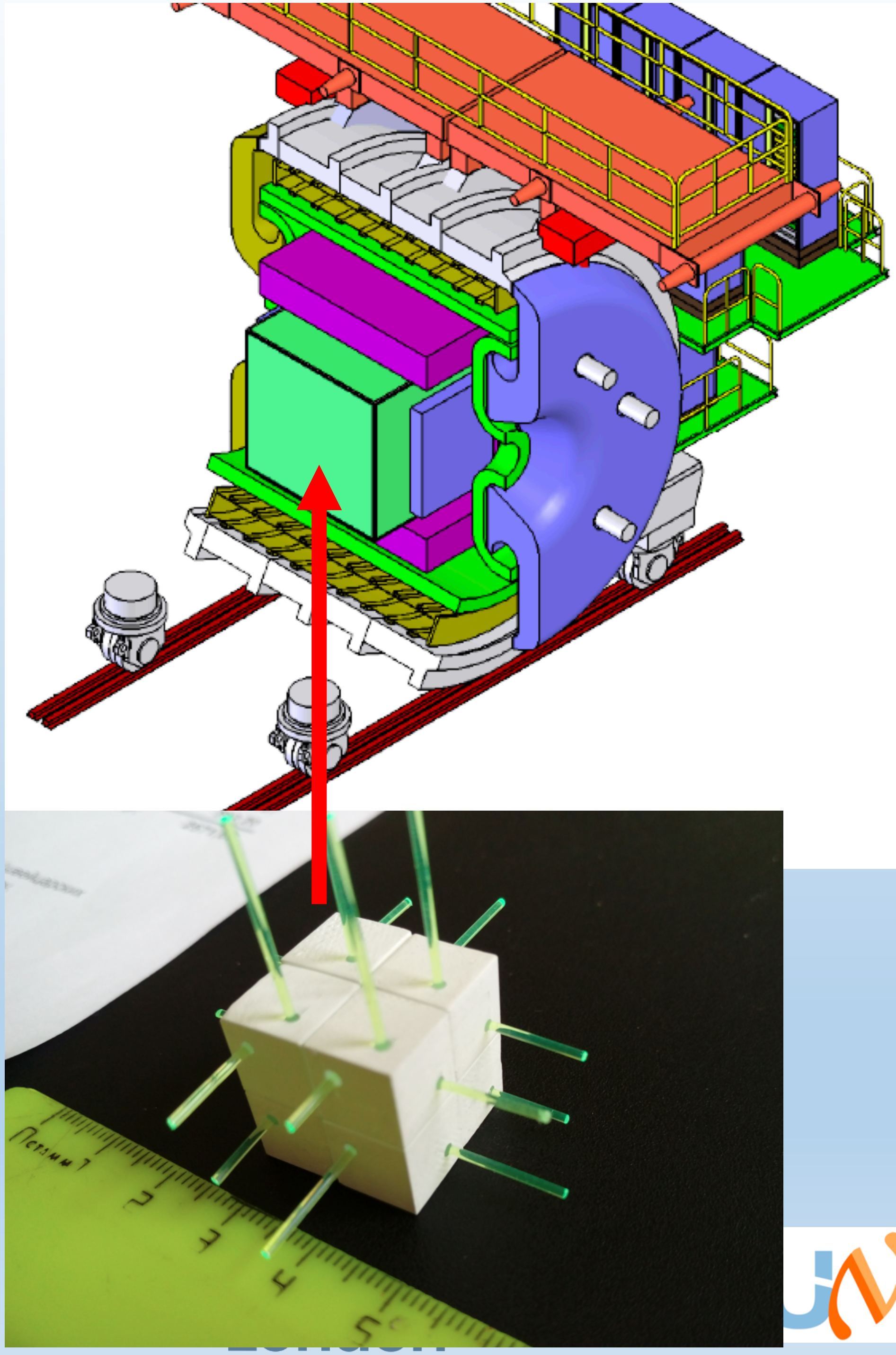
PRISM

- Use off-axis effect to sample multiple fluxes using same detectors
- Allows isolation of flux, cross-section and detector effects on rate
- Linear combinations of these fluxes allows reproduction of oscillated flux



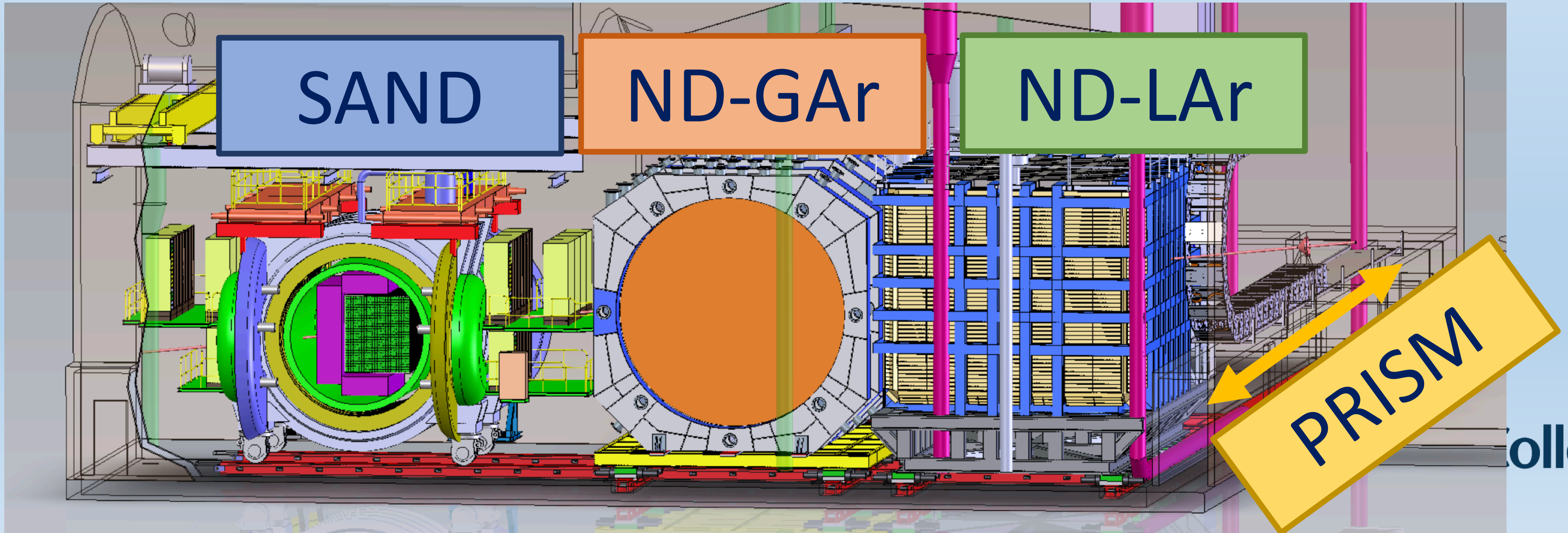
SAND

- Necessary to have a fixed beam monitor to measure beam's time stability
  - Key lesson from previous experiments
- Wide band flux necessitates spectral measurement
- 3D segmented plastic scintillator target surrounding by low density tracker and ECAL serves this purpose



Summary

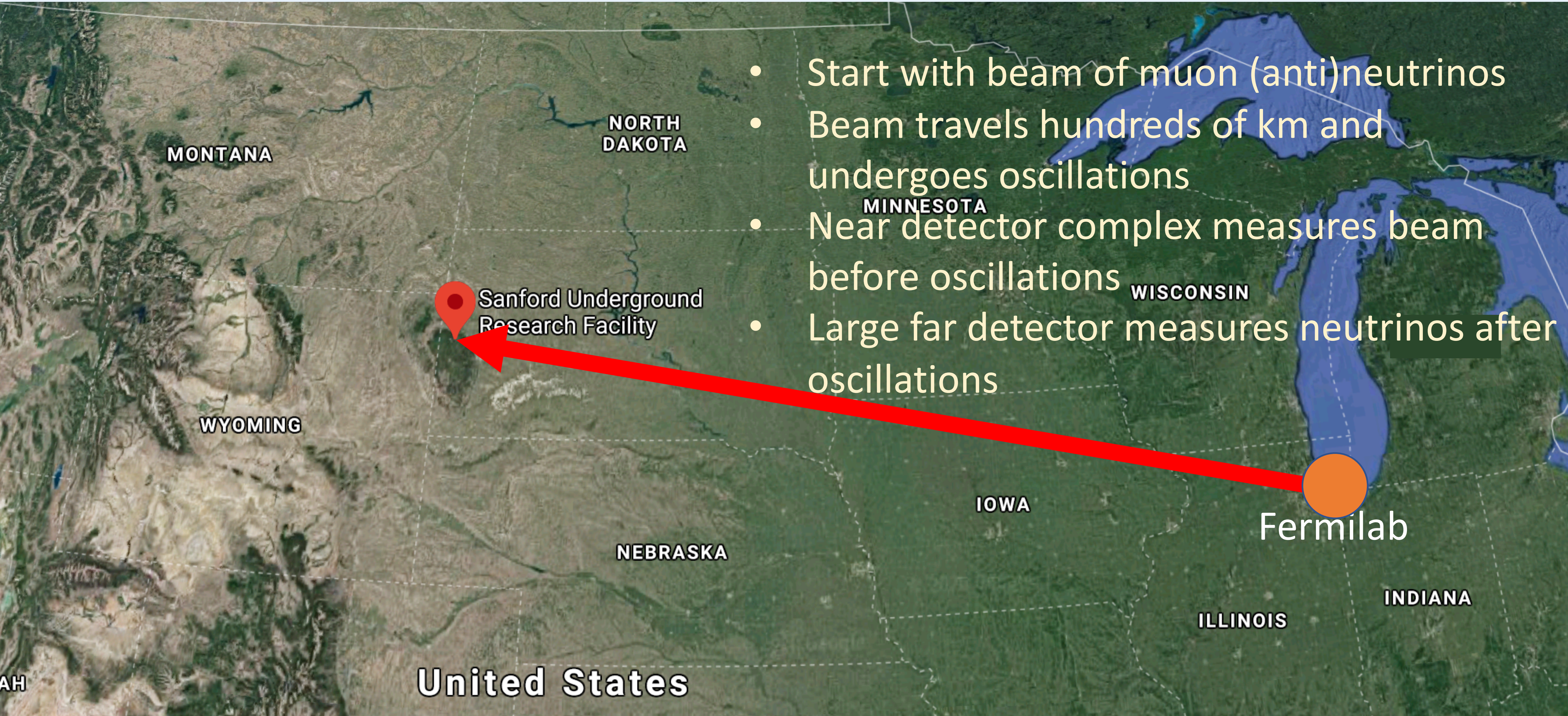
- DUNE ND reference design focusses on achieving oscillation physics goals
- 3 components + PRISM gives ability to constrain non-oscillation components of spectrum prediction to prevent biases
  - ND-LAr: High statistics detector with same technology as FD
  - ND-GAr: Low-threshold magnetised detector for powerful cross-section constraint
  - SAND: On- axis spectrometer beam monitor



Backup

Long-baseline neutrino experiments

- Start with beam of muon (anti)neutrinos
- Beam travels hundreds of km and undergoes oscillations
- Near detector complex measures beam before oscillations
- Large far detector measures neutrinos after oscillations

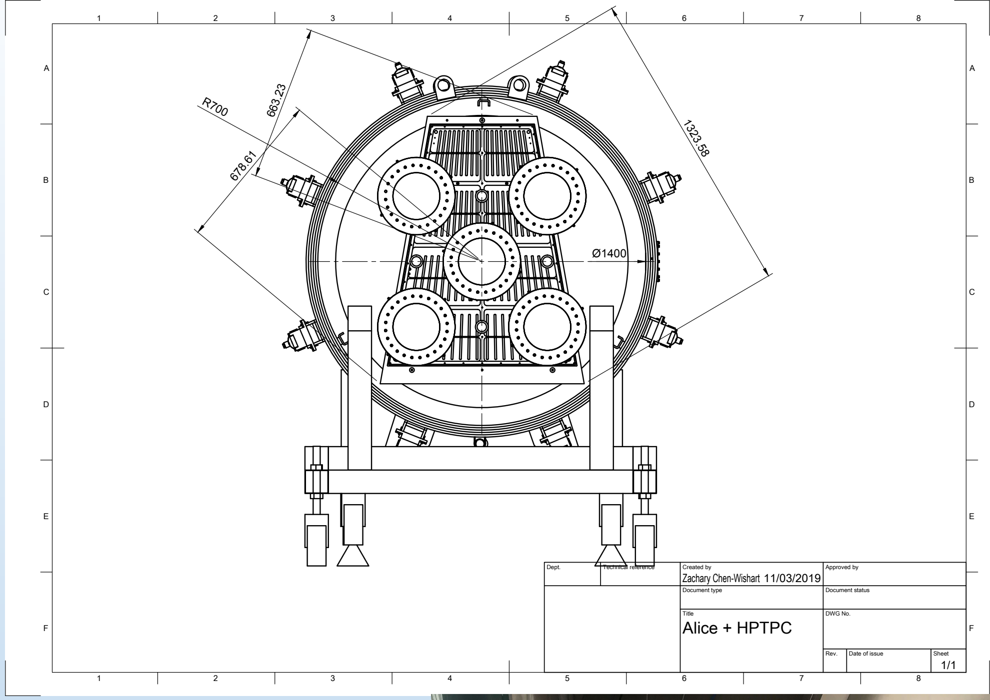


DUNE Near Detector HPTPC

- ALICE experiment is upgrading their TPC during LS2
- DUNE detector will use readout chambers (ROCs) from ALICE as their amplification stage
  - Two types of ROCs, small inner (IROCs) and larger outer (OROCs)
- ROCs use wire chamber design which gives better amplification for same voltage

UK Prototype tests for DUNE

- UK HPTPC prototype is only vessel plus field cage available large enough to test OROCs
- Detector now back at Royal Holloway in larger lab ready for upgrade
- Working with DUNE HPgTPC group, one of the OROCs is being tested in London



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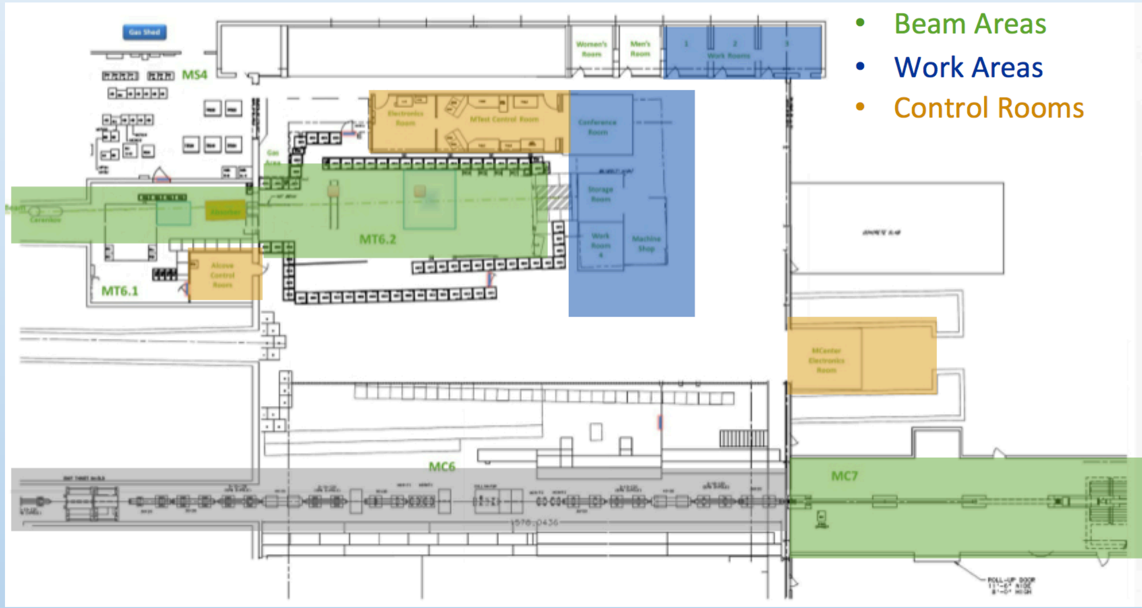
OROC+FNAL beam test

- Test beam facility at Fermilab has beamlines suitable for several month run
- Beam energy is lower than T10 O(200 MeV) so complicated techniques to reduce energy will not be necessary
- UK OROC test stand will be transported to FNAL for beam test in ~~Summer/Autumn 2020~~ whenever FNAL beam comes back after COVID-19…



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