

# Alternate Uses of Off-axis Data in LBL Sensitivity Studies: Discuss



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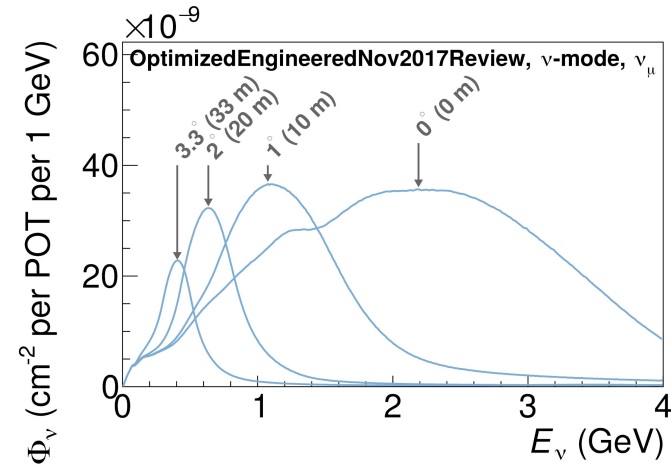
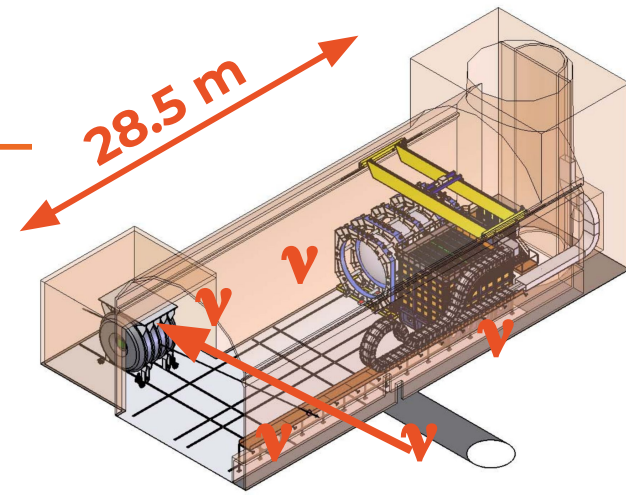
DEEP UNDERGROUND  
NEUTRINO EXPERIMENT

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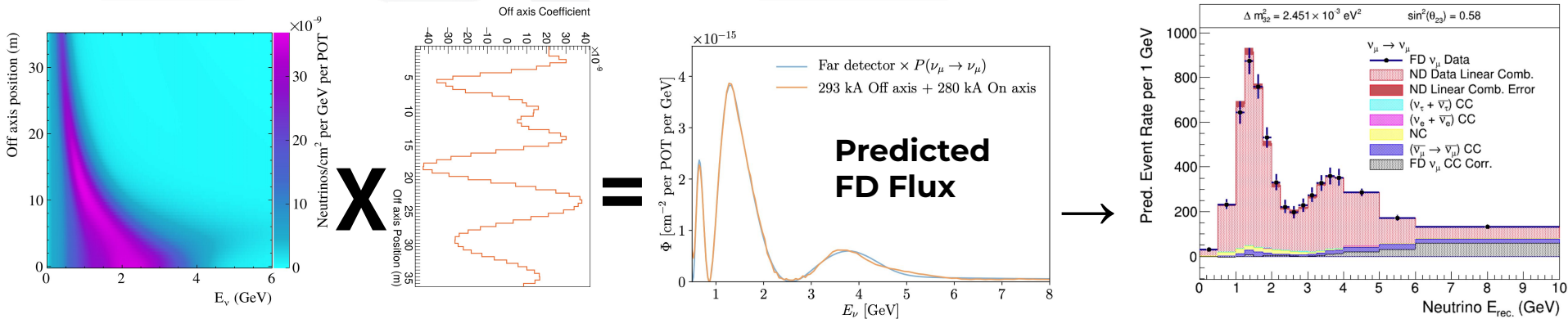
# DUNE-PRISM

- Mobile ND can take data at a range of positions  
=> exposed to different neutrino energy spectra
- This is generically 'extra' information compared to a fixed ND
  - How best to use it?



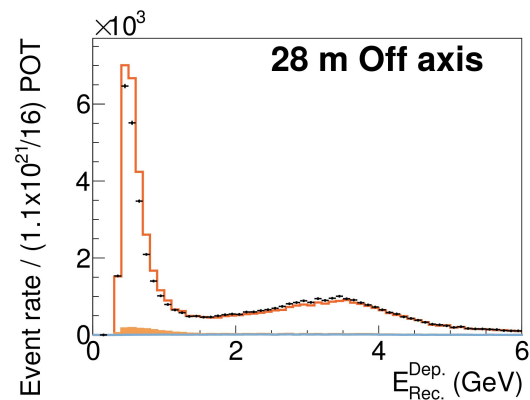
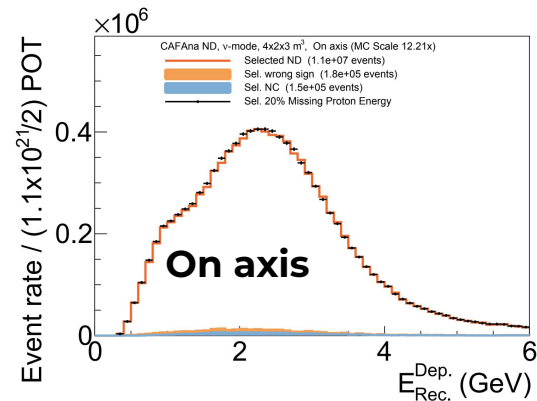
# Linear Combination Analysis

- Expected to be very model independent, if:
  - We can get the ND -> FD smearing correction working
    - It's just detector effects, much easier than hard-scatter and hadron transport modelling
  - We can get the ND -> FD Efficiency correction working
    - It is again, largely just understanding the detector differences and can be studied and applied in data
  - Background rates are small and relatively well predicted
- Current approaches here are ML-based and progressing!



# Traditional + Off-Axis Samples

- The most direct extension to a 'traditional' fixed-ND analysis would be to just add an additional 'off axis position' axis to any fit spectra
  - The naive expectation is that the extra off-axis data will more tightly constrain various free parameters in a fit:
    - Give artificially tight constraint in 'asimov'
    - Give unacceptable GOF at ND in fake-data study
  - Not clear how to proceed in this instance for sensitivity studies
    - How we would proceed with data is very person-power intensive, it is not likely that this is worth chasing for sensitivity studies.
  - Ideas for how to do this are very welcome!



# A Third Idea

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- ~~Stolen~~ Borrowed after discussions with NuPRISM/Hyper-K analysers
- Make up some granular freedoms in important interaction kinematics and fit them to off axis near detector data:

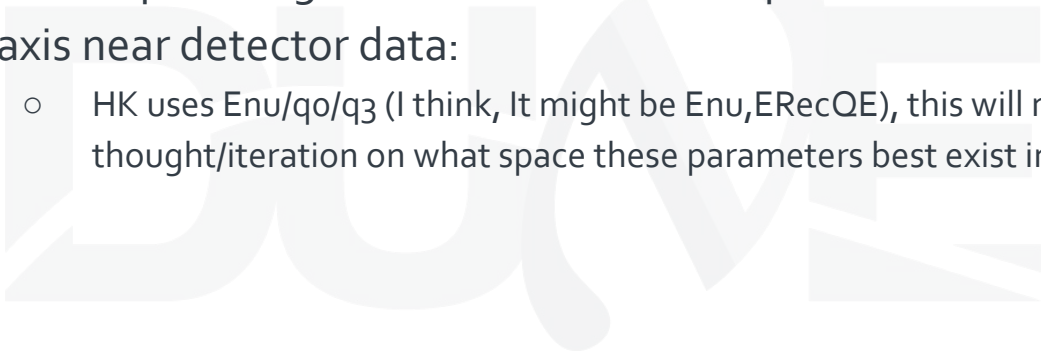
DUNE



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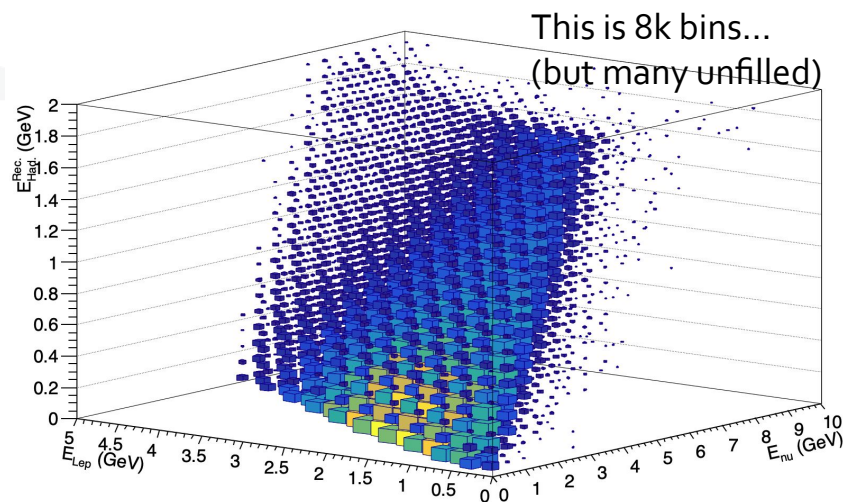
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  - HK uses  $E_{\nu}/q_0/q_3$  (I think, It might be  $E_{\nu}, E_{\text{RecQE}}$ ), this will not be best for DUNE, would require some thought/iteration on what space these parameters best exist in



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  - These then become 'correction' factors to the model that can be extrapolated to the Far Detector prediction
    - As these parameters exist in interaction kinematics, expect the smearing between true and observed to allow a lot of degeneracy in analysis bins => build up a big correlation matrix of constraints in correction factors which represents model-dependent freedom around the MC model
    - Can be made less model-dependent by using MC with an 'expanded generation phase space'
  - Kinematic/binning choice becomes important
    - Can also add inter-parameter continuity constraints to keep total xsec smooth in corrected kinematics
    - Naturally extends to separating by neutrino species (and target material – could include SAND data)
  - If granular enough, expect that it might lessen the 'chi2 of a billion' problem with many ND bins.
  - Effectively bolts on to existing analyses – but adds potentially many (many) new parameters





# Your Idea Goes Here

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- ...
- There is a lot of space for tweaks and improvements to these three approaches and also fundamentally new approaches!



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- There is a lot of space for tweaks and improvements to these three approaches and also fundamentally new approaches!
- Possibly stupid idea I just thought up:
  - Do 'traditional' ND+FD analysis but the ND sample is linearly combined. Still a pure model-based extrapolation, but having similar flux ND and FD 'targets' model constraints to important regions of phase space
    - (A usual problem is that we get most constraint from the ND peak, which is the FD trough)
    - Less bins, so less 'chiz of a billion problem'.
    - Might be a nothing burger! Tell me if you think it is.

# A Note on Messaging

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- This discussion is not meant to suggest that the full PRISM analysis plan is not the main goal for a flagship LBL!
  - It is just trying to have a slider between 'fully model dependent with more bins' and 'model independent but complex' that allows us to show off the power of off axis data before all of the PRISM ND->FD extrapolation tools are read.
- We might have to be careful about how we frame such studies to not insinuate that

