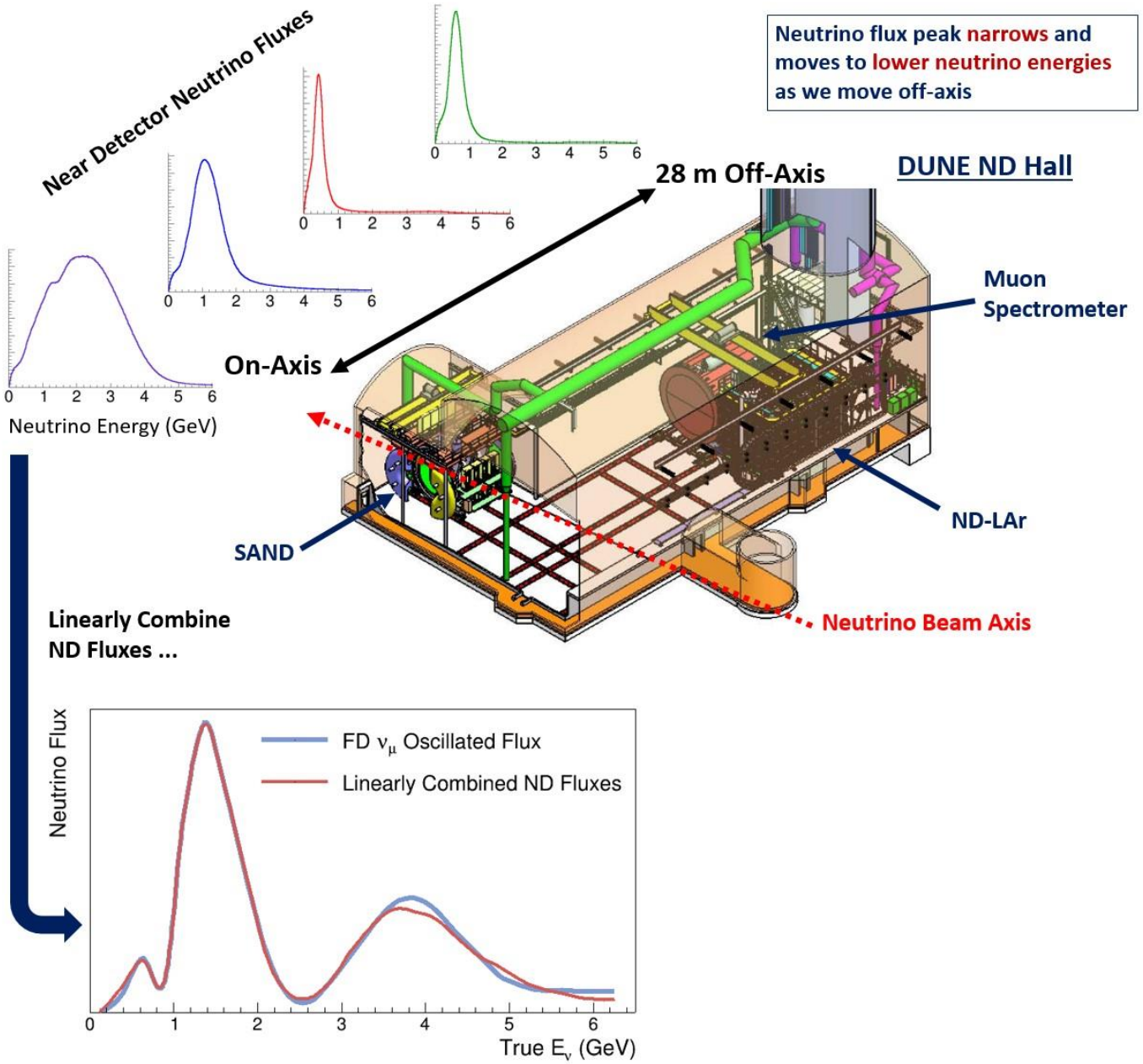
PRISM Analysis Refresher

Ciaran Hasnip
DUNE LBL Workshop
16th August 2022

Introduction to PRISM

- DUNE is an **on-axis** neutrino experiment
- But ND-LAr and TMS/ND-GAr will move **off-axis**
- Measure different neutrino fluxes
- Linearly combine off-axis measurements at the ND to produce a **data-driven** prediction of the FD event rate

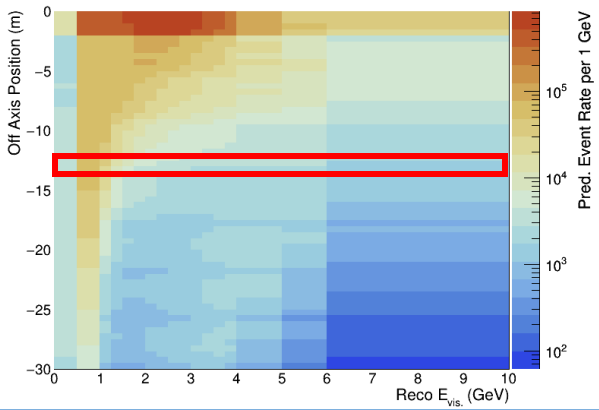


The Disappearance Analysis

Disappearance Analysis Procedure

START

1. **Subtract backgrounds** from each ND off axis slice



2. Construct **smearing matrices** for the ND and FD

3. **Unfold** each slice of ND data to **true** variable, correct for efficiency in ND slice (**ND detector systematics**)

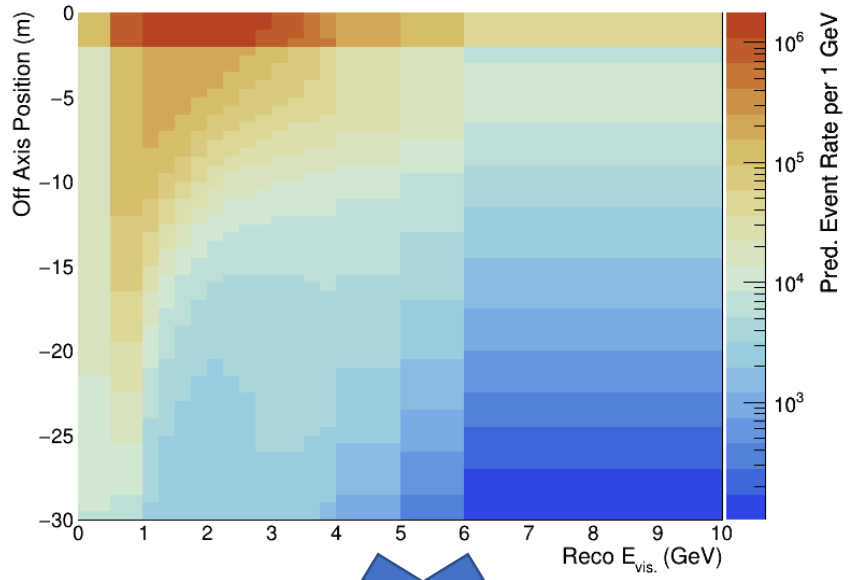
4. **Smear true variable** in each slice to **FD reco**, correct for FD efficiency (**FD detector systematics**)

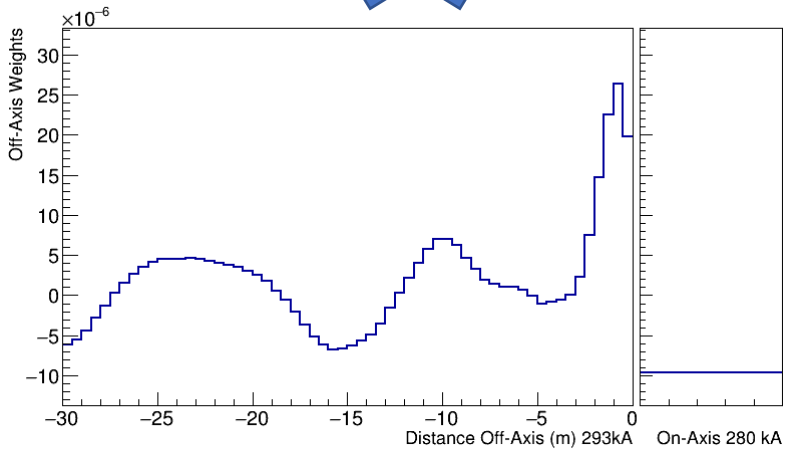
5. **Perform linear combination of extrapolated ND off-axis data**

6. Add FD backgrounds to get **Extrapolated PRISM Prediction** in reconstructed visible energy

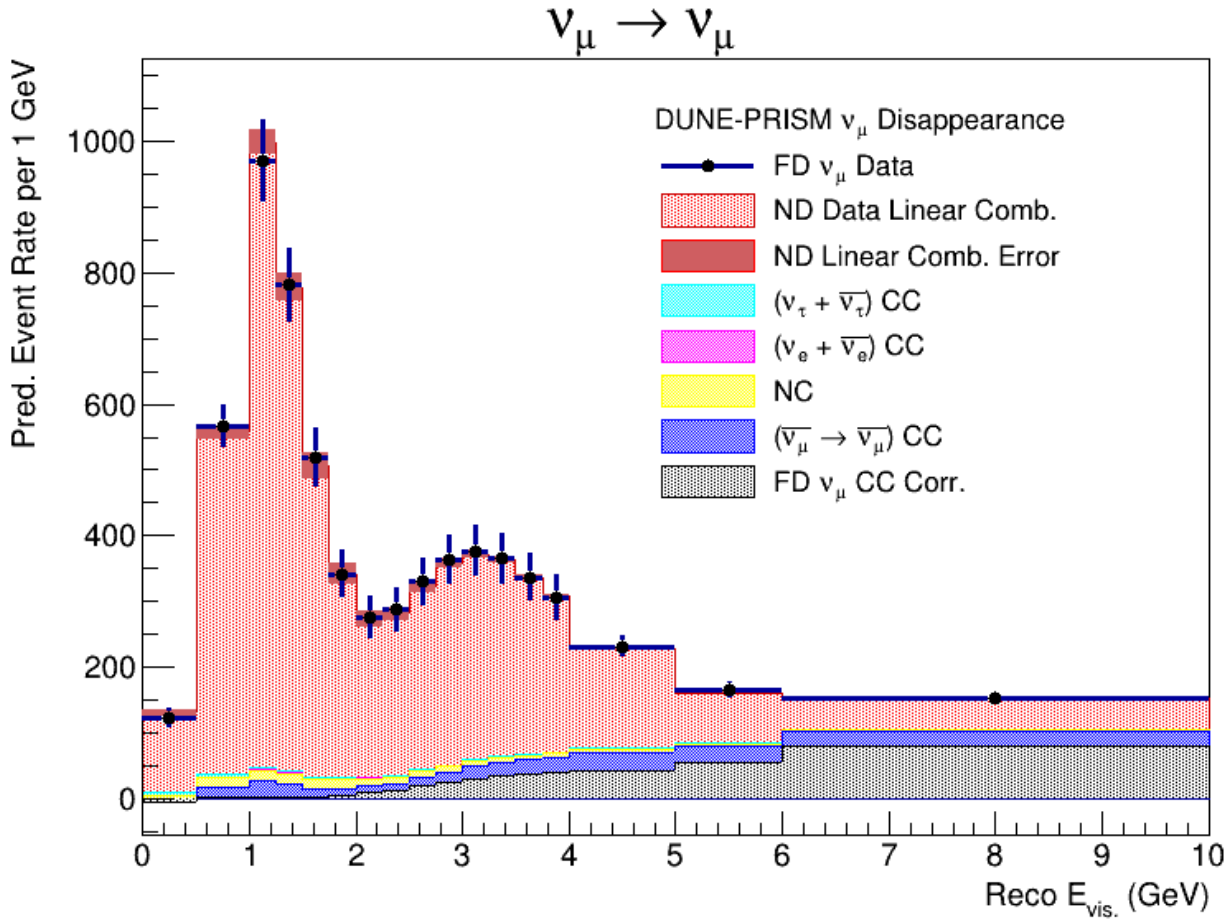
FINISH

FHC Disappearance Prediction



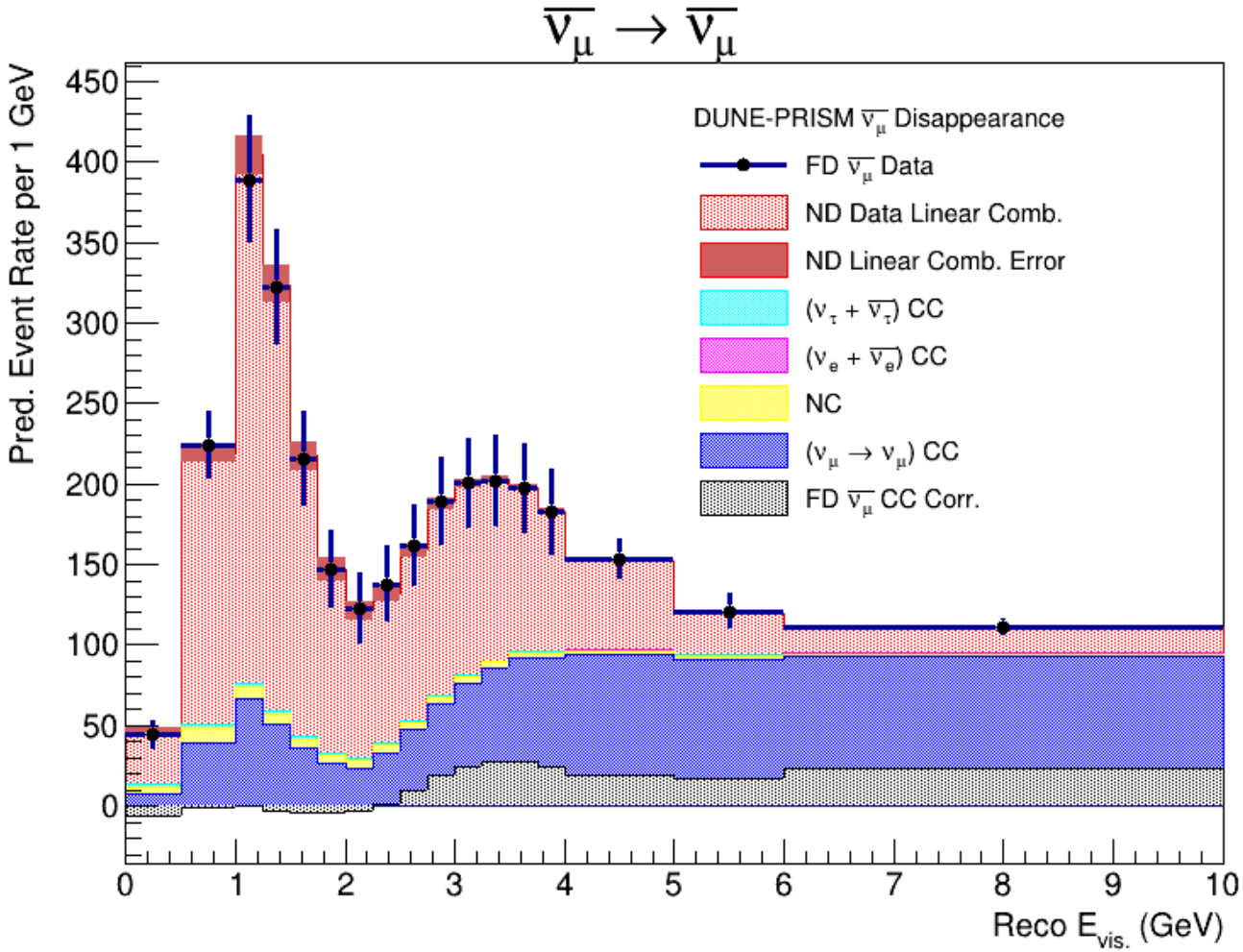


Just the RED



RHC Disappearance Prediction

- Same procedure for RHC anti-numu disappearance
- Start with **anti-numu ND data** and match to **anti-numu FD data**
- Larger **wrong-sign** background (as expected)

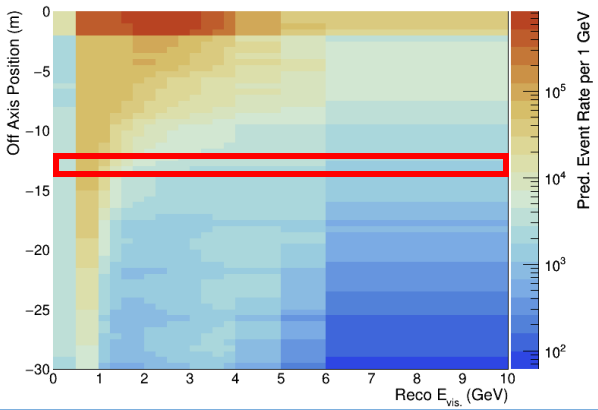


The Appearance Analysis

Appearance Analysis Procedure

START

1. **Subtract backgrounds** from each ND off axis slice



2. Construct **smearing matrices** for the ND and FD

3. **Unfold** each slice of ND data to **true** variable, correct for efficiency in ND slice (**ND detector systematics**)

4. Correct for nue/numu x-section ratio as a function of true variable

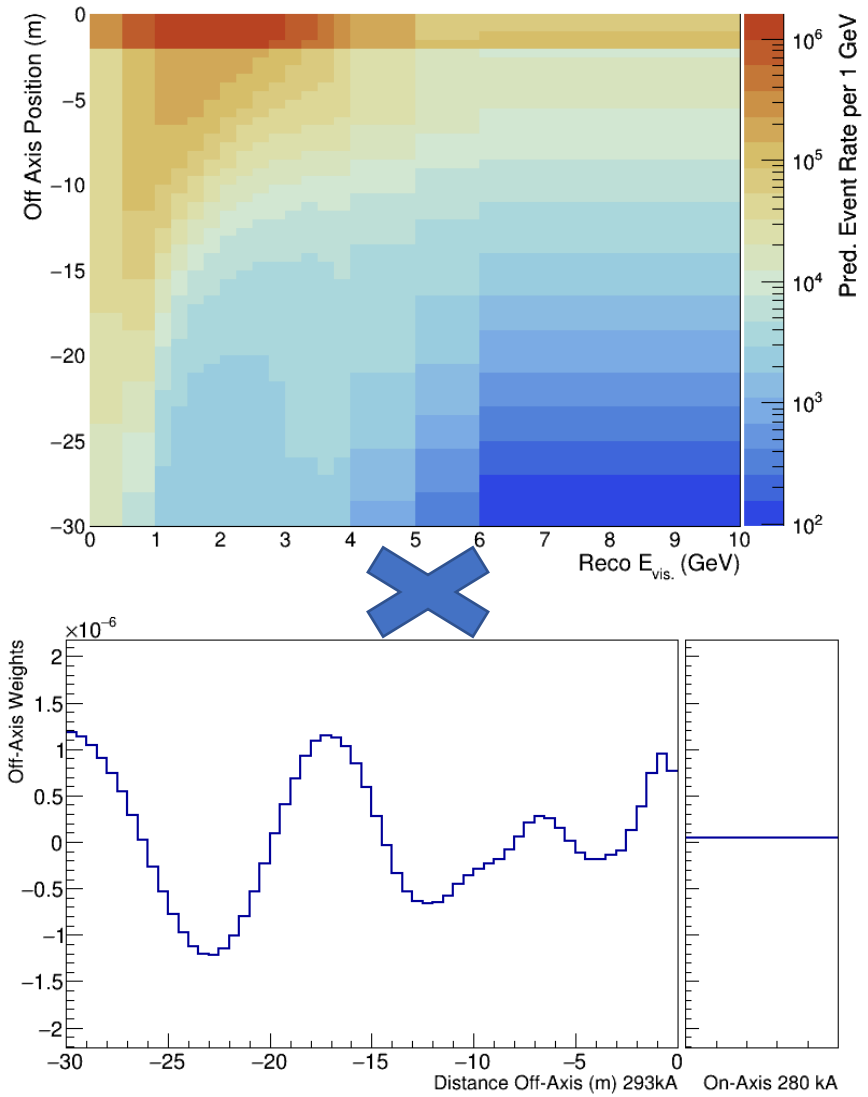
5. **Smear true variable** in each slice to **FD reco**, correct for FD efficiency (**FD detector systematics**)

6. **Perform linear combination of extrapolated ND off-axis data**

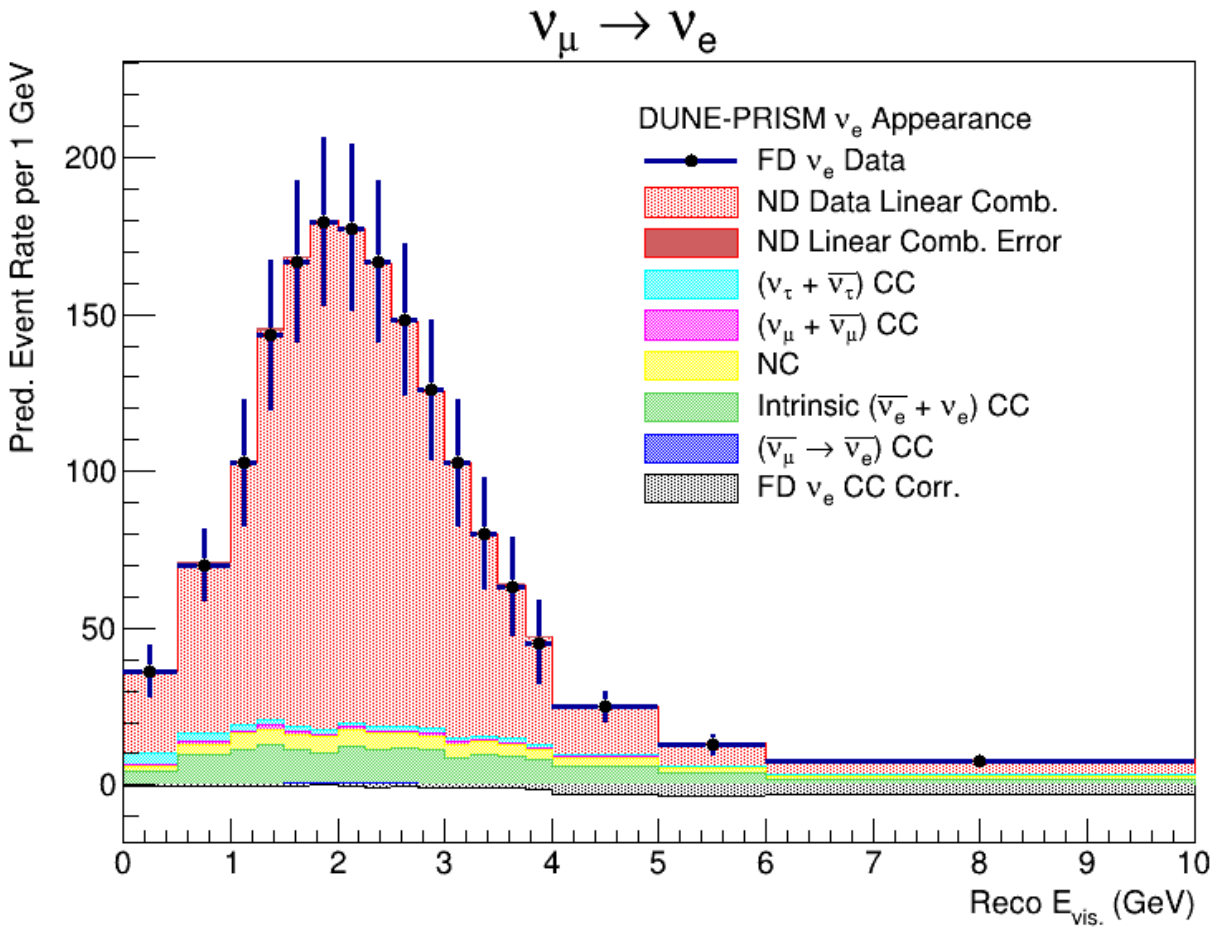
7. Add FD backgrounds to get **Extrapolated PRISM Prediction** in reconstructed visible energy

FINISH

FHC Appearance Prediction

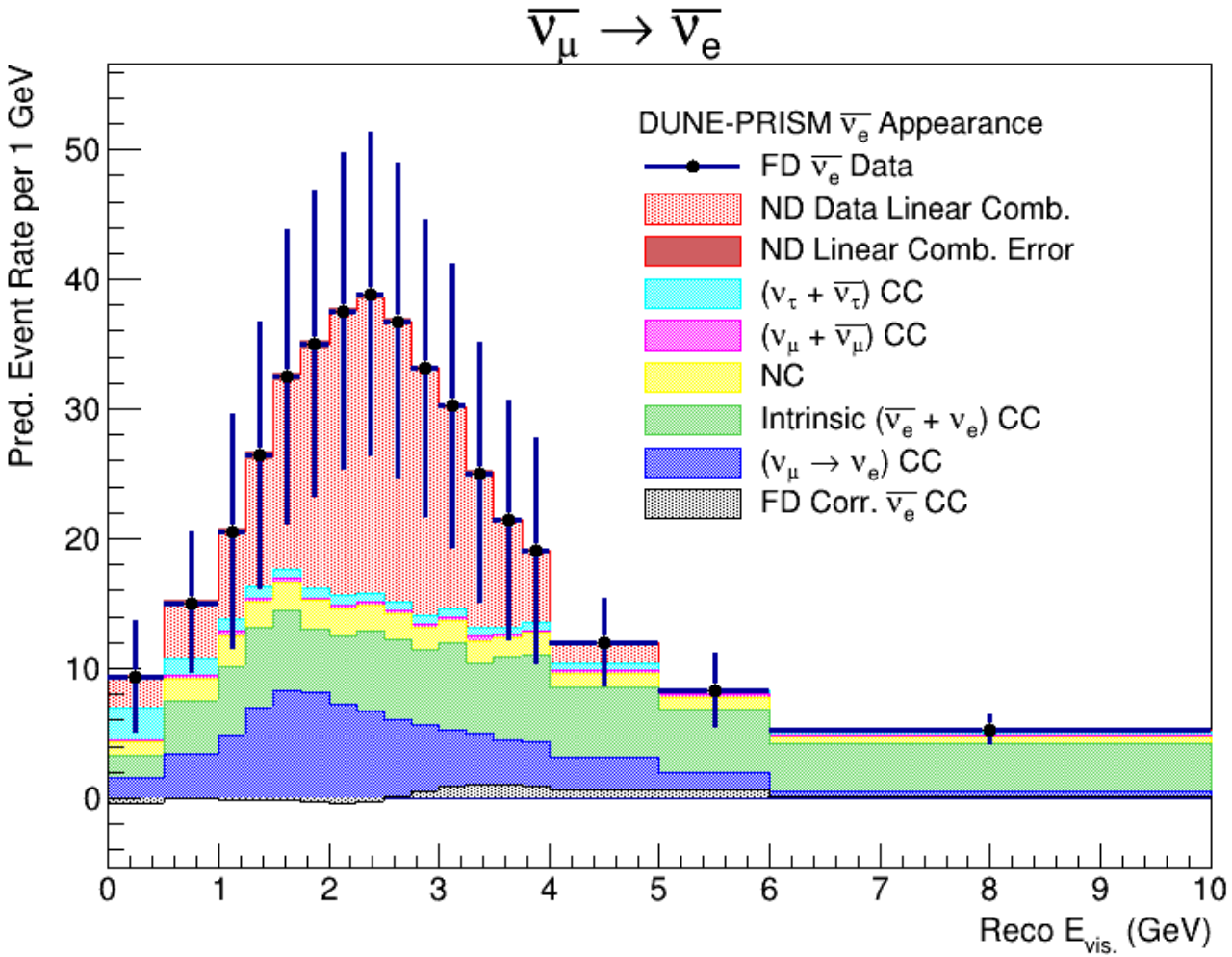


Just the RED



RHC Appearance Prediction

- Same procedure for RHC anti-nue appearance
- Start with **anti-numu ND data** and match to **anti-nue FD data**
- Large background components
  - Intrinsic (**green**) and WS (**blue**) can be data driven

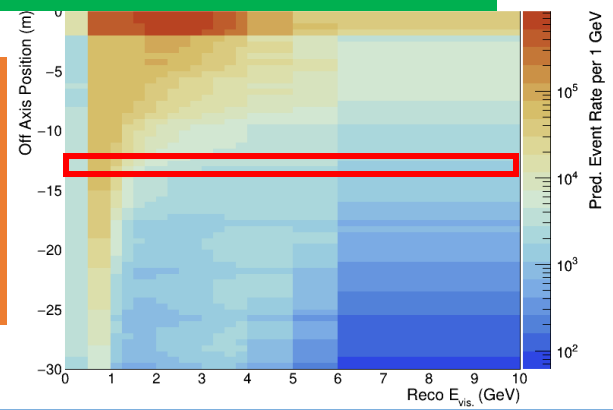


Systematics and Oscillation Fits

Systematics in a PRISM Analysis

START

1. **Subtract backgrounds** from each ND off axis slice



2. Construct **smearing matrices** for the ND and FD

3. **Unfold** each slice of ND data to **true** variable, correct for efficiency in ND slice (**ND detector systematics**)

All **systematics affect everything else**

4. **Smear true variable** in each slice to **FD reco**, correct for FD efficiency (**FD detector systematics**)

***Only* flux systematics affect this stage**

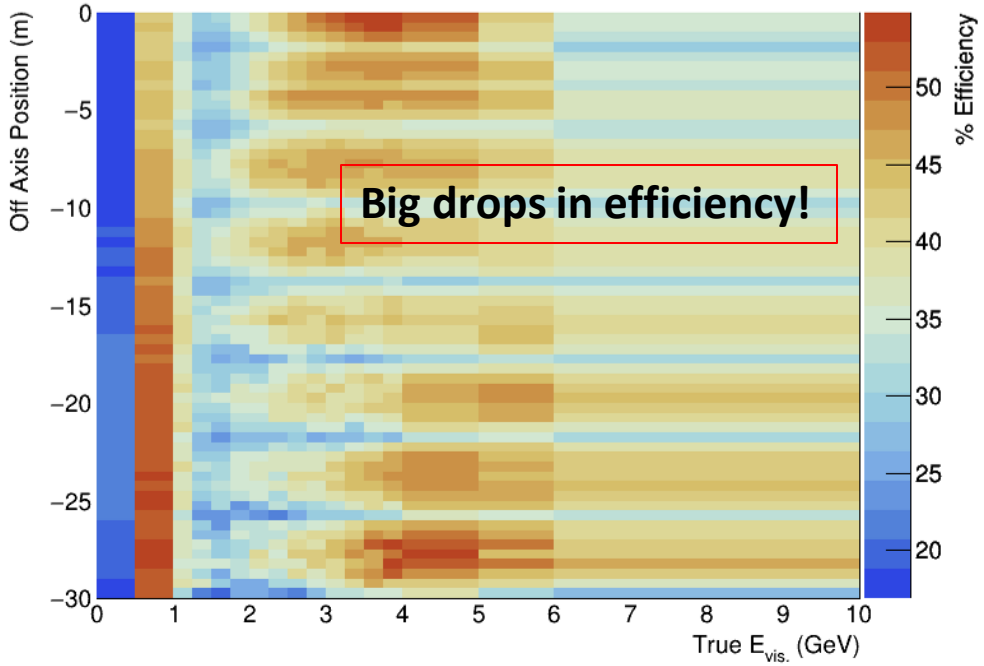
5. **Perform linear combination of extrapolated ND off-axis data**

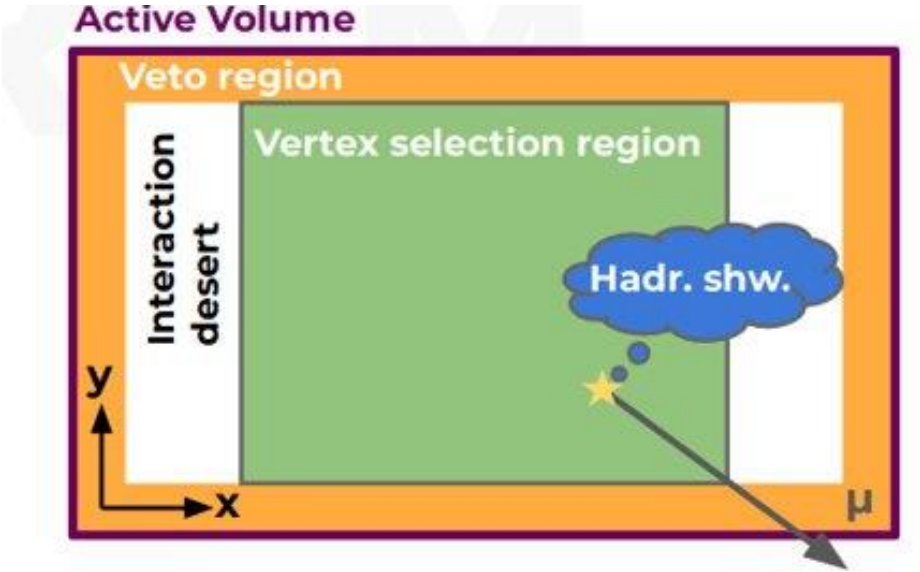
6. Add FD backgrounds to get **Extrapolated PRISM Prediction** in reconstructed visible energy

FINISH

ND Efficiency Correction

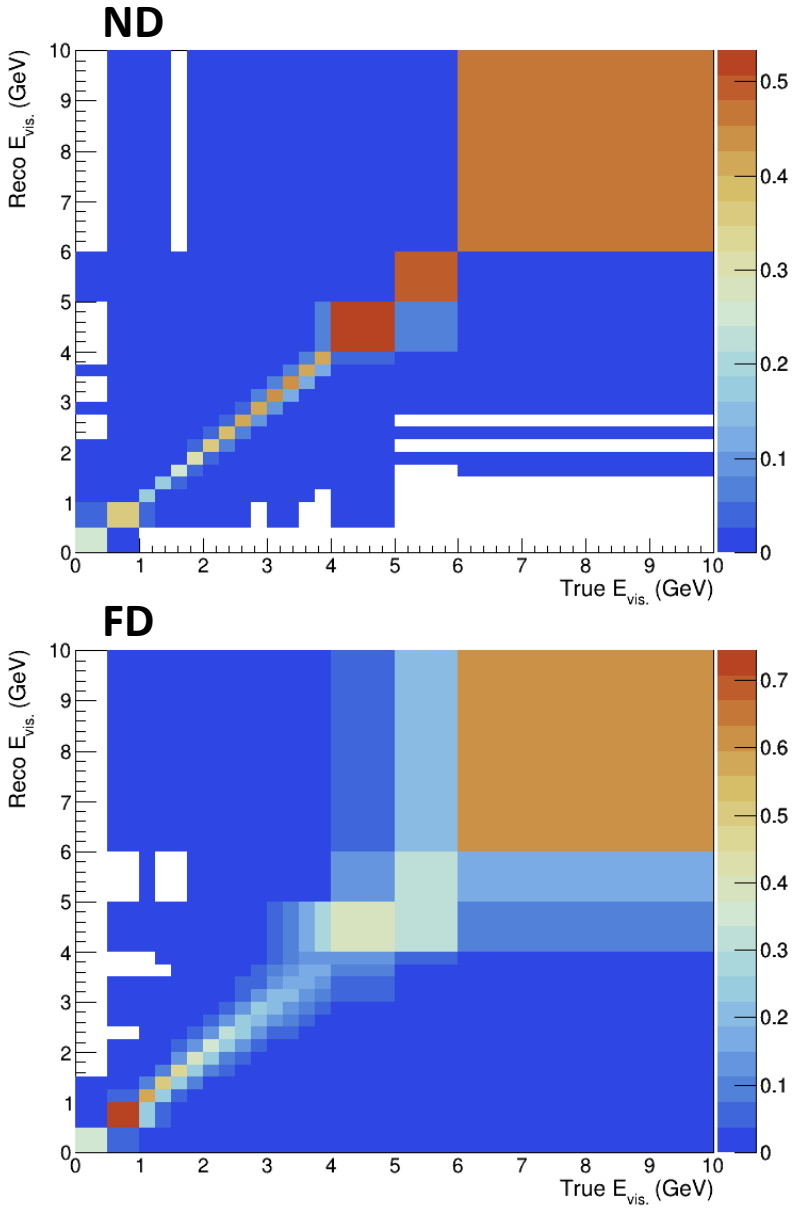
- The **geometric efficiency** in the **ND** corrected for using the MC – **Entirely model dependent!**
- Primary way **cross-section uncertainties** enter PRISM analysis currently
- Data-driven **efficiency correction**
  - Replace MC-based efficiency correction
  - Event-by-event efficiency correction based on detector geometries
  - See talk from **Wei Shi** next!





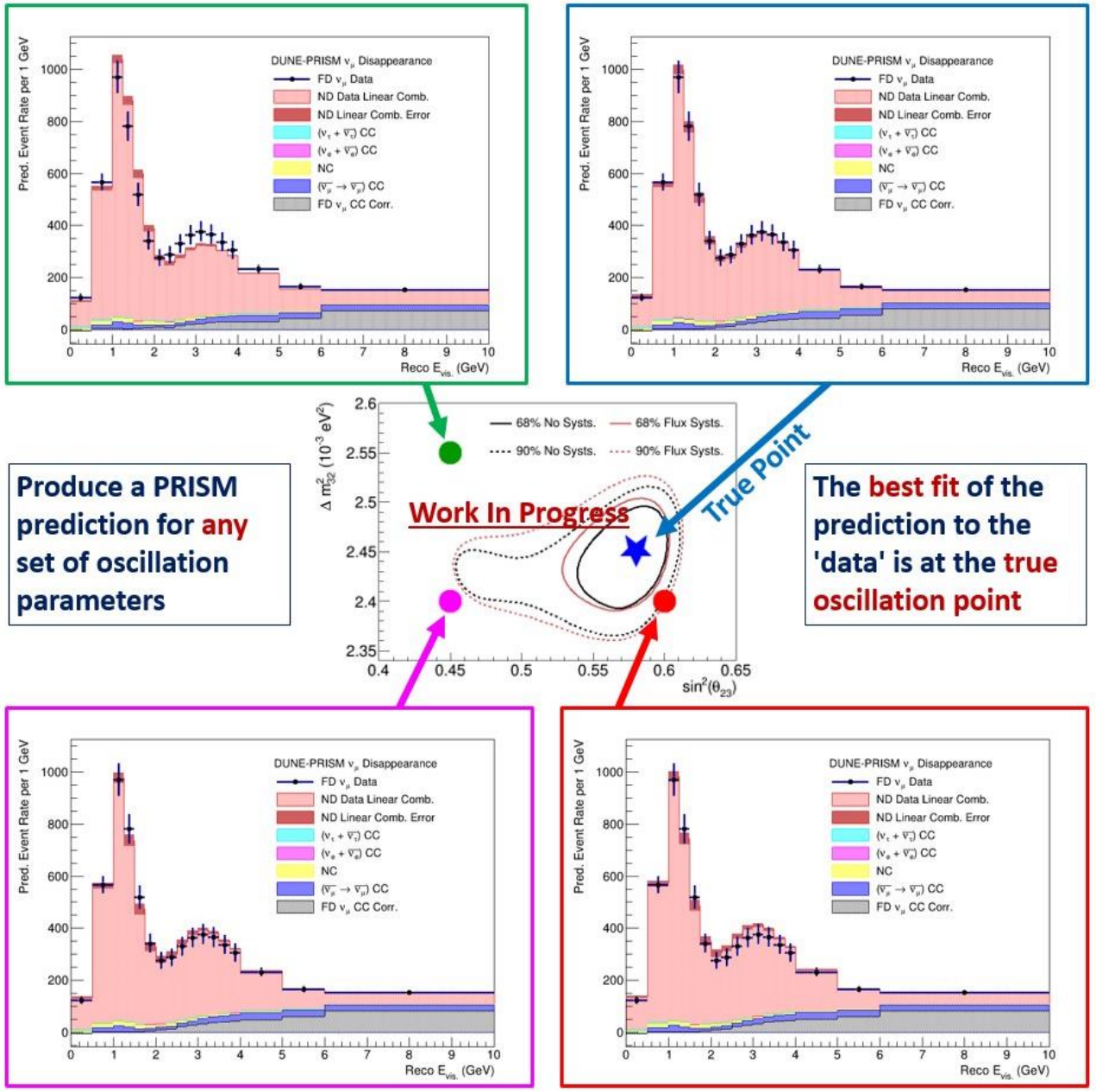
Resolution Correction

- Current method for correcting for ND/FD detector differences uses **MC to unfold and smear ND data**
- Proposal for a **ML-based ND to FD translation**
  - See talk by **Alex Wilkinson** next
- I.e., no more smearing matrices or unfolding



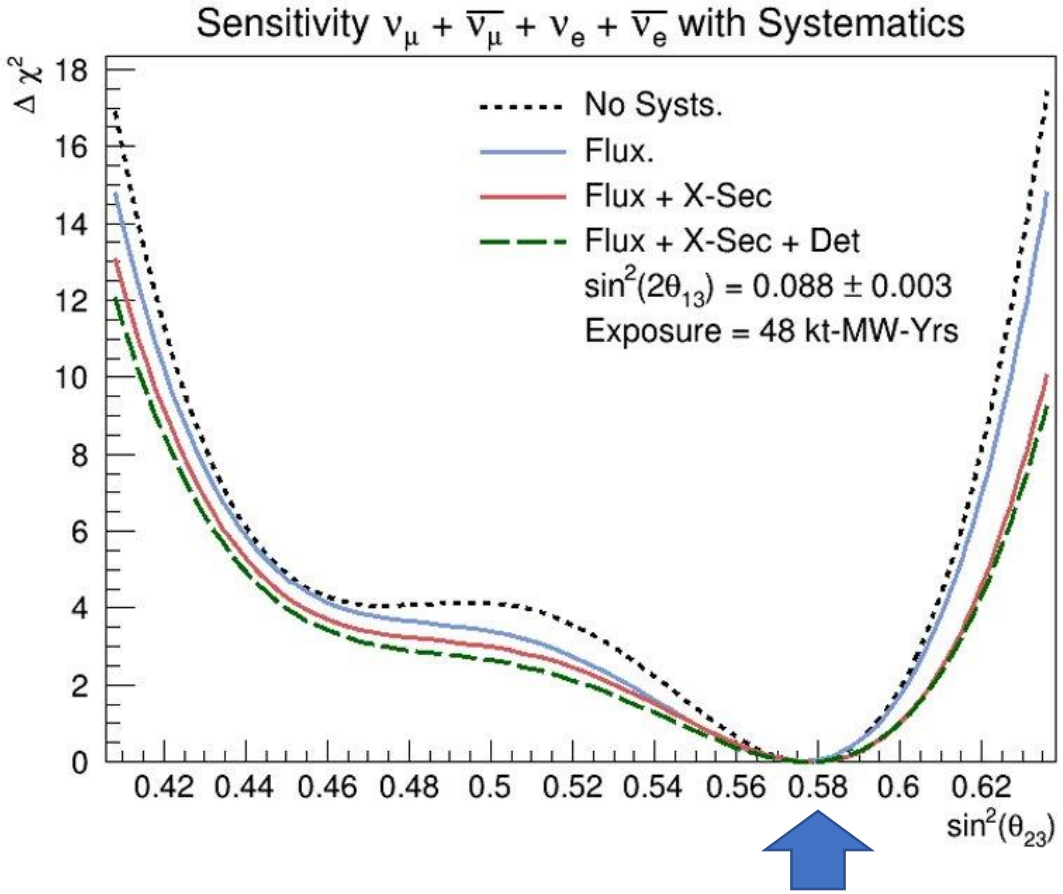
Oscillation Fits with PRISM

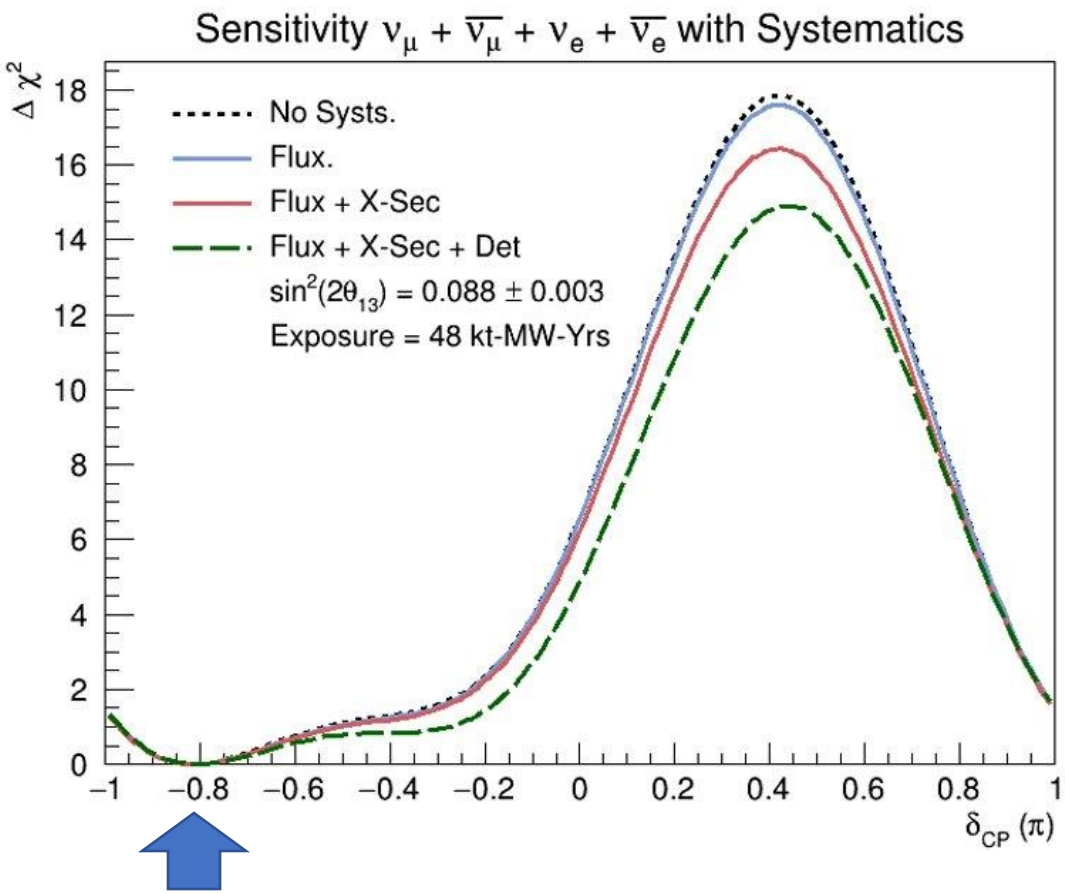
- PRISM analysis implemented in **CAFAna**
- Fit **prediction** to **'data'** using MINUIT2 at each point in oscillation parameter space



Oscillation Fits with PRISM

Some examples of 4-signal-channel fits with systematics:





Conclusions and Aims for Workshop

- Have a working PRISM analysis with 4 signal channels and systematics
- The geometric efficiency correction and ML near-to-far translation are on-going efforts (see the following talks)
- Attempting to implement new flux uncertainties from the beam group
- Discuss plans to prevent PRISM code falling behind the main CAFAna code
- Need a lot of ND MC for the PRISM analysis at many off-axis positions – how do the needs of PRISM fit into plans for future ND MC productions?

Thanks for Listening!

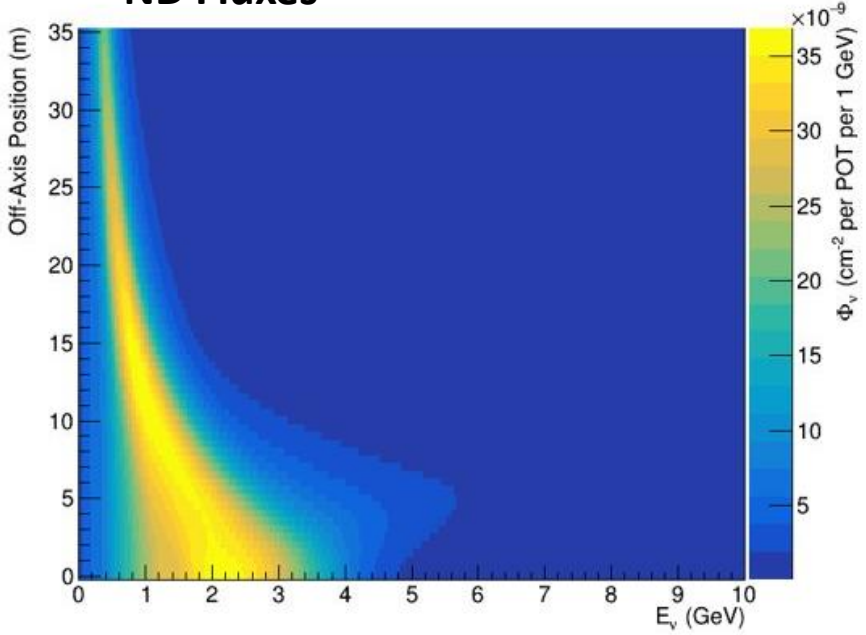
Backup

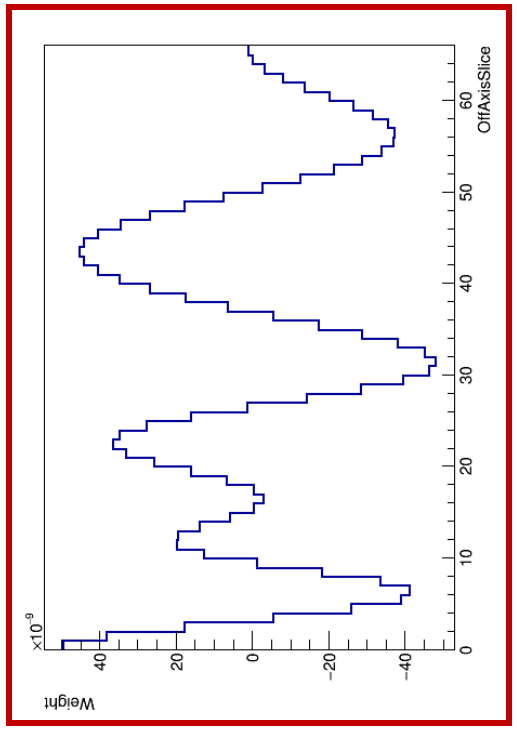
Linear Combination

- Match the ND numu fluxes to the FD oscillated flux
- Just solving a linear algebra problem with the flux model
- Mathematically, this is **N***c* = *F* – we solve for *c*!

N.B. we can match to **any target shape**, not just the oscillated prediction

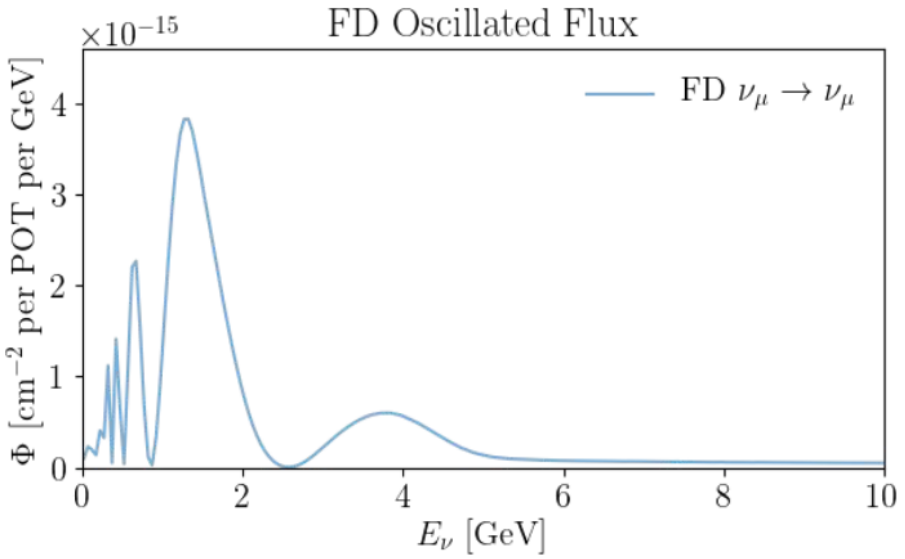
ND Fluxes





=

NuFit 4.1, $\Delta|M^2|_{32} = 2.52\times10^{-3}$ eV, $\sin^2(\theta_{23}) = 0.525$



Linear Combination

- Coefficients calculated **independently** of cross-section model
- Apply these coefficients to **measured ND events rates** to predict **FD event rate**
- Any unknown or poorly modelled cross-section effects are naturally included in the FD prediction