



# Decoding Neutrino Interactions

A Model-Independent approach  
with DUNE-PRISM

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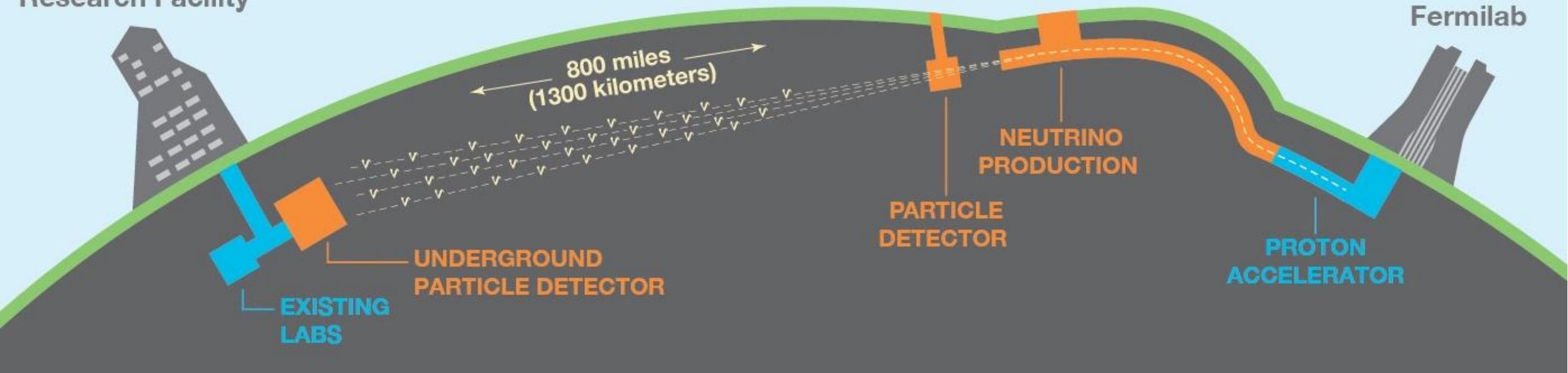


# How DUNE works ...



Sanford Underground Research Facility

Fermilab

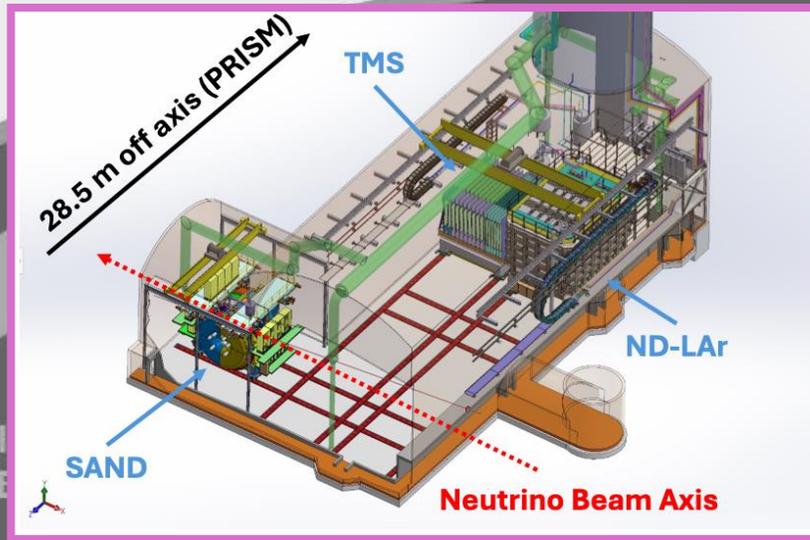


# How DUNE works ...



Sanford Underground Research Facility

Fermilab



PARTICLE DETECTOR

PROTON ACCELERATOR

DUNE-PRISM

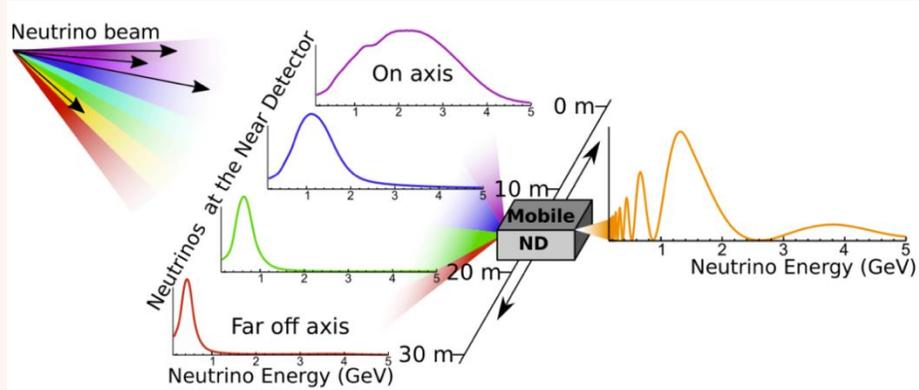
Movable Near Detector

↑ Systematics control

↑ Robust oscillation results

# Making fair neutrino comparisons

## Neutrinos come in:



$$\Phi_{\nu_{\mu},j}(E_i)$$

$$\Phi_{\nu_e,j}(E_i)$$

## Measure Event Rates:

$$R_{\nu_e} \quad R_{\nu_{\mu}}$$

$$R(E) \approx \Phi(E)\sigma(E)$$

## Flux Matching:

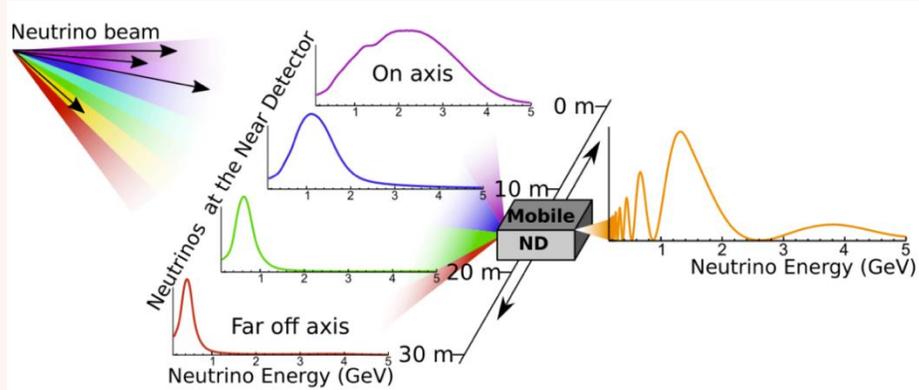
$$\Phi_{\nu_e}(E_i) = \sum_j c_j \Phi_{\nu_{\mu},j}(E_i)$$

$$R_{\nu_{\mu}}^{\text{LC}}(E) = \sum_j c_j (R_{\nu_{\mu}}(E))_j$$

$$\frac{R_{\nu_{\mu}}^{\text{LC}}(E)}{R_{\nu_e}(E)} = \frac{\sigma_{\mu}(E)}{\sigma_e(E)}$$

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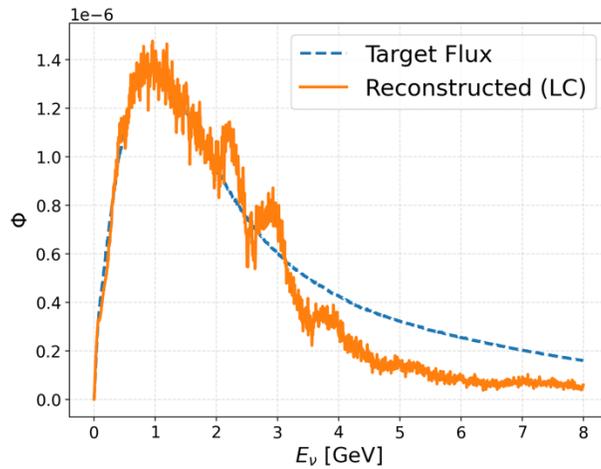
$$R_{\nu_{\mu}}^{\text{LC}}(E) = \sum_j c_j (R_{\nu_{\mu}}(E))_j$$

$$\text{DR} = \frac{\sigma_{\mu}(E)/\sigma_e(E)}{\sigma_{\bar{\mu}}(E)/\sigma_{\bar{e}}(E)}$$

# Seems Easy Enough... Until the Degrees of Freedom Kick In

## Performing the Fit

- Binned values: Minimization



Best fit possible

Large weights  
Erratic behaviour

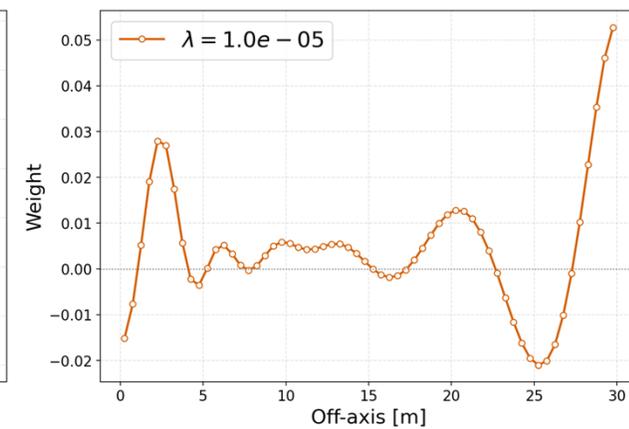
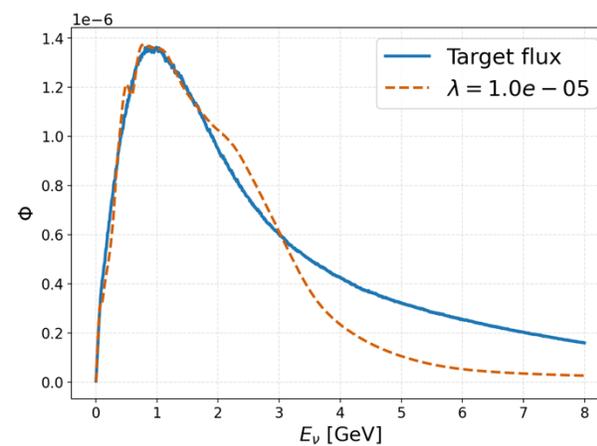
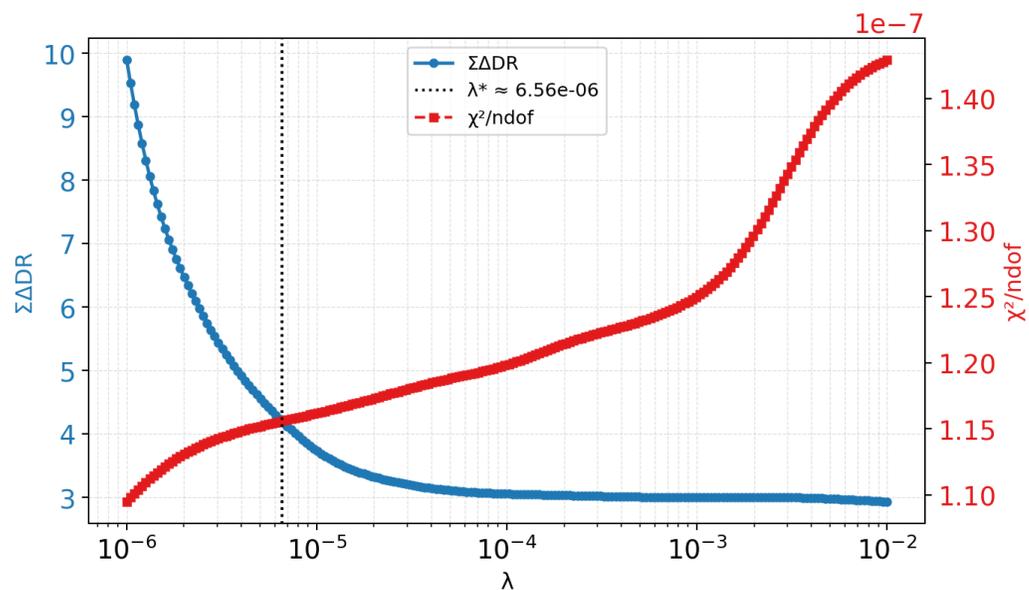
$$\min_{\vec{c}} \left\| \Phi_{\nu_e}(E) - \Phi_{\nu_\mu}(E) \vec{c} \right\|^2$$



# Fixing the chaos: regularization

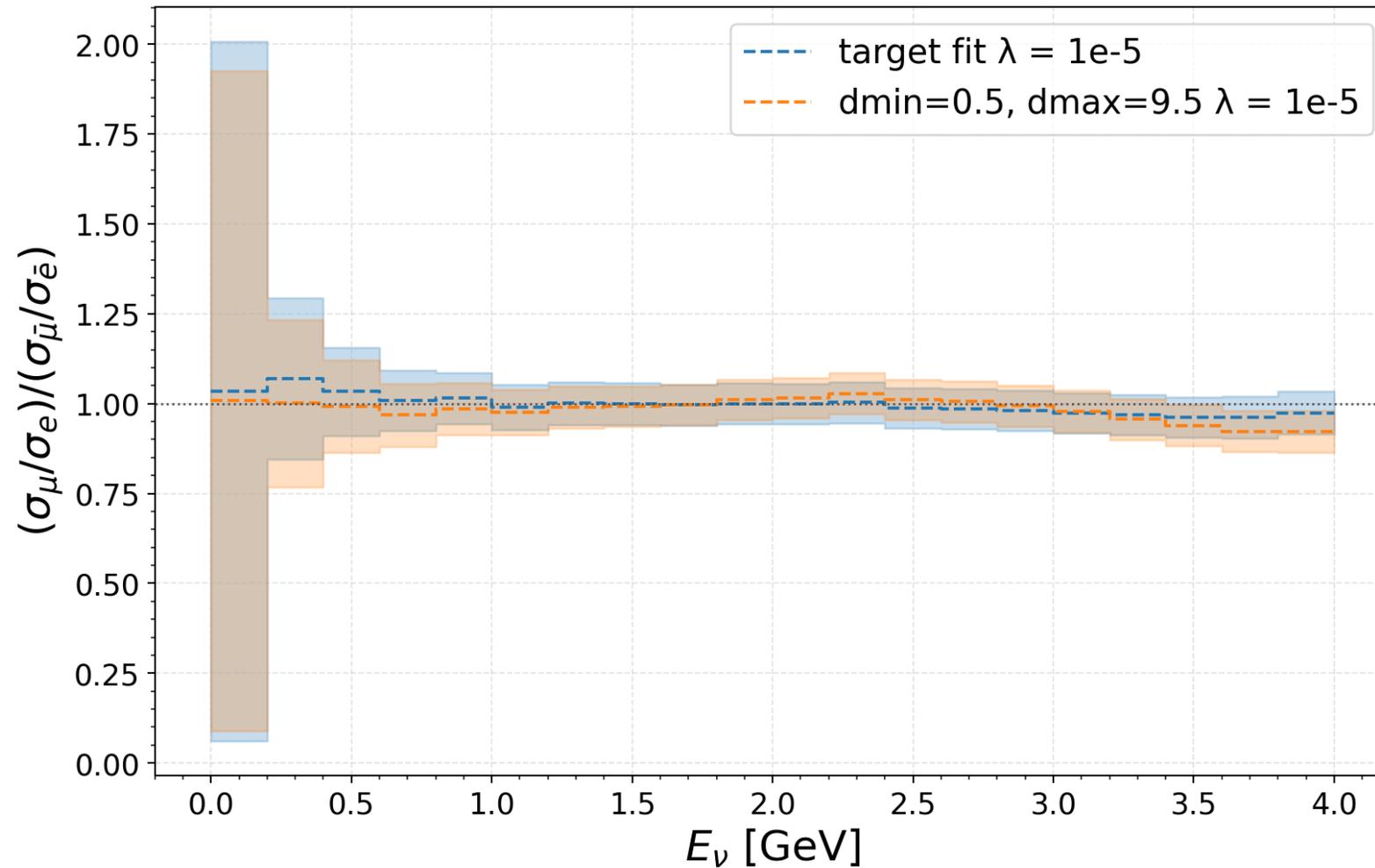
$$\min_{\vec{c}} \left\| \Phi_{\nu_e}(E) - \Phi_{\nu_\mu}(E) \vec{c} \right\|^2 + \lambda \left\| \vec{c} \right\|^2$$

Choose  $\lambda$



$\uparrow \lambda \longrightarrow \downarrow \text{Uncertainty} \quad \uparrow \chi^2$

# Results double cross section ratio



DUNE-PRISM turns  
**detector motion** into a  
*data-driven* lens on  $\sigma(E)$