Cross Sections
WG2 overview

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Neutrino Experiments

Neutrino flux

Neutrino Energy [GeV]

Detector
Focusing on Neutrino Oscillations Experiments

Neutrino flux

Neutrino Energy [GeV]

Near Detector

Far Detector

Neutrino Energy [GeV]
Cross Section - a key ingredient for oscillations

\[ N_{\text{events}}(E_{\nu}) = \int \sigma(E'_{\nu}) \Phi(E'_{\nu}) P(E_{\nu} \mid E'_{\nu}) dE'_{\nu} \]

The flux and cross section models are convoluted.
Cross Section - a key ingredient for oscillations

\[ \frac{N_{\text{events}}^{\text{far}}(E_{\nu})}{N_{\text{events}}(E_{\nu})} = \frac{\int \sigma(E'_{\nu}) \Phi(E'_{\nu}) P(E_{\nu} | E'_{\nu}) P_{\text{osc}}(E'_{\nu}) dE'}{\int \sigma(E'_{\nu}) \Phi(E'_{\nu}) P(E_{\nu} | E'_{\nu}) dE'} \]

The flux and cross section models are convoluted.

The cross section will not cancel out
Different cross section between near/far detector due to differences in energies

It is a large and limiting uncertainty for oscillation analyses. Crucial for extraction of the oscillation parameters.
Incoming neutrino Energy Reconstruction

Cherenkov detectors:
Assuming QE interaction
Using solely the final state lepton

\[ E_{QE} = \frac{2M\epsilon + 2ME_l - m_l^2}{2(M - E_l + |k_l|\cos\theta)} \]

\( \epsilon \) is the nucleon separation energy \( \sim 20 \text{ MeV} \)

Tracking detectors:
Need good hadronic reconstruction

\[ E_{\text{cal}} = E_l + E_p^{\text{kin}} + \epsilon \]
$E_\nu$ Reconstruction: Interaction Modeling

$E_\nu = \sum E_{\text{outgoing particles}}$
$E_{\nu} = \Sigma E_{\text{outgoing particles}}$
$E_{\nu} = \Sigma E_{\text{outgoing particles}}$
E_\nu \text{ Reconstruction: Interaction Modeling}

E_\nu = \Sigma E_{\text{outgoing particles}}
$E_{\nu}$ Reco Requires Interaction Modeling

Events vs $E^l - E'^l$
E_{\nu} Reco Requires Interaction Modeling

Events

Meson Exchange

Quasi Elastic

Resonance

Deep Inelastic Scattering

E_{\nu} - E'
Next generation - High Precision Challenge

Simulation of oscillation effects in future DUNE

Need to improve modelling and reduce uncertainties
WG2 Cross Section Focus

THEORY

GENERATORS

EXPERIMENTS
WG2 Cross Section Goals

Experimental Cross section results

Theory input - new models

Generators strategies
WG2 Cross Section Goals

**Experimental Cross section results**

- 10 talks

**Theory input - new models**

- 7 talks

**Generators strategies**

- 4 talks including
  - Joint session with Oscillation WG1
    - Oscillation experiments share their modelling issues
  - Joint session with Detector WG5
    - New experiments with CS input
Planeries WG2

Towards exclusive CS measurements & modelling - Maria Benedetta Barbaro

Shallow and deep inelastic scattering - Jorge G. Morfin

Input from nuclear community - Lawrence Weinstein

SBN & μBooNE - Maurizio Bonesini

MINERvA - Michael Kordosky

- Budimir Klicek
Thank you