Summary of Discussion among Conveners of the ND-TF and ND-WGs

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DUNE ND Working Group Meeting
October 8, 2015

TF-WG MEETING

- Phone meeting held on 01/Oct with longer meeting on 05/Oct.
- Present: C. Andreopoulos, S. Brice, R. Gandhi, R. Gran, K. Mahn, S. Mishra, R. Petti
- Discussion on the plans and main issues to be addressed by the TF-WGs
- General consensus among various conveners to be reflected in a coherent ND program
- Agreed a tentative agenda for the next 3 WG meetings (including today) in consonance with the TF-WG meeting

MODUS OPERANDI

✦ Compile a detailed list of ND event samples and external measurements (either from ND or from elsewhere) required to evaluate the various ND configurations:

- Optimize sensitivity for the oscillation analyses;
- Constrain systematic uncertainties.

==> Can be different for different ND configurations

✦ Evaluate the uncertainties related to the following:

- Absolute flux of ν_μ and $\bar{\nu}_\mu$
- Relative FD/ND flux as a function of energy for $\nu_\mu, \bar{\nu}_\mu, \nu_e, \bar{\nu}_e$
- Signal normalization at the FD for ν_e/ν_μ and $\bar{\nu}_e/\bar{\nu}_\mu$
- Neutrino vs. anti-neutrino asymmetry from: a) energy scale, b) topology
- Backgrounds: NC, $\nu_\mu(\bar{\nu}_\mu)$ CC, ν_τ CC, μ decays of hadrons, etc.
- Interaction models for QE, RES, DIS and coherent processes off nuclear targets

==> Pick single ND measurement for each and scale it up to the level required to match the ND-TF program

✦ Focus resources and efforts on full G4 simulation and reconstruction of various ND configurations

✦ Use existing fast MC to bootstrap the procedure:

- Optimize the set of input samples / measurements
- Define the format for the input variables (event-by-event and inclusive)
- Technical validation of the analysis framework

==> Take advantage of existing tools/knowledge to speed-up studies

==> Replace fast MC with full simulation/reconstruction as soon as available

ND REQUIREMENTS

✦ ND high level requirements (docdb #574) scrutinized during CD1 and independent technical design reviews (May-July 2015):

- Implications for a end-to-end oscillation analysis (sensitivity, uncertainties)
- Implications for ND technical specifications (detector parameters, design)
- Answer to ND questions by referees

==> Integral part of the TF-WG program

✦ Physics sensitivity studies should guarantee that each ND configuration the ND physics requirements:

- Consistency with DUNE science objectives
- Focus available resources onto the relevant ND configurations

✦ Changes in high level ND requirements should be motivated by proper sensitivity studies

✦ ND evaluation WG created to evaluate the performance of the ND configurations per the requirement document and the ND-TF tasks (focused on CPV systematics)

ND GLOBAL SCIENCE REQUIREMENTS

See details in DUNE docdb 574

- Glo-Sci-41 *ND measurements shall be of sufficient precision to ensure that the systematic error associated to FD extrapolations must be significantly less than the statistical error over the lifetime of the experiment.*
- Glo-Sci-51 *ND shall measure the absolute and relative ν_μ and $\bar{\nu}_\mu$ spectra separately.*
- Glo-Sci-23 *ND shall measure the ν_e and $\bar{\nu}_e$ contamination spectra of the beam separately in order to render the CP measurement as precise as possible.*
- Glo-Sci-24 *ND shall measure rates, kinematic distributions and detailed topologies of physics processes that could mimic signal events in FD nuclear targets with sufficient resolution so that FD oscillation measurements not limited by background predictions.*
- Glo-Sci-52 *ND shall measure CC and NC cross sections vs. hadronic energy.*
- Glo-Sci-53 *ND shall characterize exclusive and semi-exclusive processes like QE, Resonance and DIS, neutrino-electron and neutrino-proton elastic scattering.*
- Glo-Sci-54 *ND shall measure the neutrino-nucleus cross section off various targets like Hydrogen, Ar, Fe, Ca, and C etc.*
- Glo-Sci-55 *ND shall take measurements related to improving knowledge of precision electro-weak parameters.*

ANALYSIS APPROACH

- Default analysis framework for ND-TF is VALOR:
  - Fit 2D (E_vis, Y_Bj) distributions for CC and 1D E_vis distributions for NC in many different event topologies: $\mathrm{QE\ 1\text{-}trk}$, $\mathrm{QE\ 2\text{-}trk}$, $1\pi^{\pm}$, π^{0}, ν_e CC, NC, $\mathrm{etc.}$
  - Model predictions from MC including all relevant physics processes
  - Unfold fluxes and cross-sections by simultaneously fitting the key parameters describing the input MC model

- Advantages:
  - Takes into account correlations among parameters
  - Unified approach which can incorporate FD event rates
  - Maximizes the information extracted from the given set of inputs

- Issues/concerns:
  - Relies substantially upon the underlying MC model
  - Correlations and degeneracies can bias some parameters as “effective fudging” for the fitted data
  - Broad energy range in DUNE requires larger input samples/phase space coverage (higher complexity)

- Required studies:
  - Consider external inputs from exclusive measurements of fluxes and cross-sections (e.g. ND in-situ measurements, existing/past experiments)
  - Evaluate model dependence and corresponding systematics
  - Evaluate robustness vs. unexpected discrepancies between data and MC model (“unknown unknown”)
  - Study potential mitigations (e.g. different analysis techniques, present/past measurements, etc.)

- Coherent contributions from ND WG, ND Physics WG, and ND evaluation WG