ASSESSMENT EXERCISE: LONG-BASELINE PHYSICS WORKING GROUP

1/17/2017

Matthew Bass (Oxford), Mayly Sanchez (Iowa State)

Assessment Exercise Questions

1. Which assumptions from the CDR must be replaced? Which are defensible as they stand?

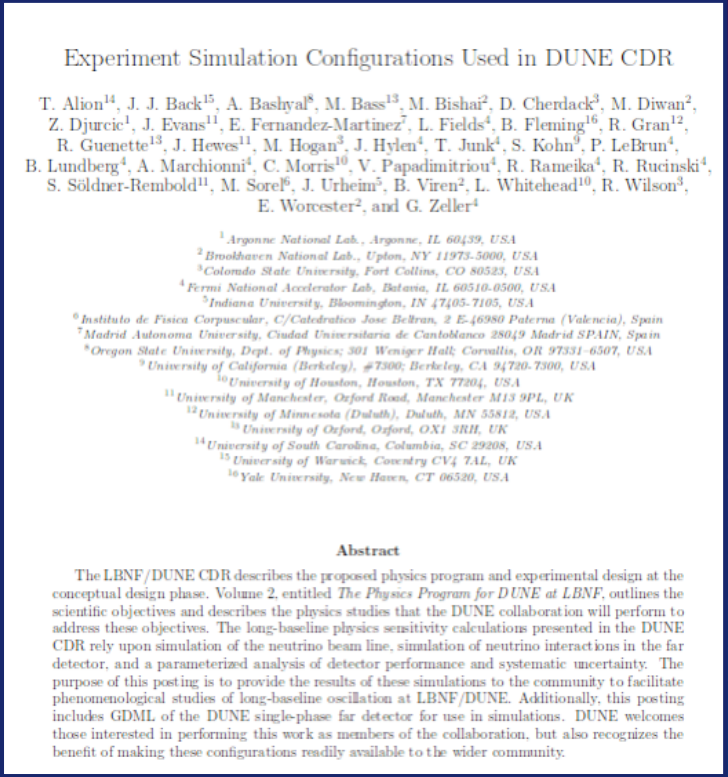
2. For each thrust of work, what is the risk it won’t demonstrate required performance in 12-16 months?

ANALYSIS ASSUMPTIONS AND UPDATES

ASSUMPTIONS FROM CDR

- **Flux**: CDR Optimized Beam: G4LBNF
- **Interactions Model**: GENIE 2.8.4
- **Detector Response and Analysis**: Fast MC
- **Systematics & Fitting**: GLoBES
- **Physics Model**: 3 flavor

These nominal assumptions are documented in the arXiv posting, "Experiment Simulation Configurations Used in DUNE CDR", arXiv:1606.09550 which includes GLoBES configurations.



Experiment Simulation Configurations Used in DUNE CDR

T. Alion[14], J. J. Back[15], A. Bashyal[8], M. Bass[13], M. Bishai[2], D. Cherdack[3], M. Diwan[2], Z. Djurcic[1], J. Evans[11], E. Fernandez-Martinez[7], L. Fields[4], B. Fleming[16], R. Gran[12], R. Guenette[13], J. Hewes[11], M. Hogan[3], J. Hylen[4], T. Junk[4], S. Kohn[9], P. LeBrun[4], B. Lundberg[4], A. Marchionni[4], C. Morris[10], V. Papadimitriou[4], R. Rameika[4], R. Rucinski[4], S. Söldner-Rembold[11], M. Sorel[6], J. Urheim[5], B. Viren[2], L. Whitehead[10], R. Wilson[3], E. Worcester[2], and G. Zeller[4]

[1] *Argonne National Lab., Argonne, IL 60439, USA*
[2] *Brookhaven National Lab., Upton, NY 11973-5000, USA*
[3] *Colorado State University, Fort Collins, CO 80523, USA*
[4] *Fermi National Accelerator Lab, Batavia, IL 60510-0500, USA*
[5] *Indiana University, Bloomington, IN 47405-7105, USA*
[6] *Instituto de Fisica Corpuscular, C/Catedratico Jose Beltran, 2 E-46980 Paterna (Valencia), Spain*
[7] *Madrid Autonoma University, Ciudad Universitaria de Cantoblanco 28049 Madrid SPAIN, Spain*
[8] *Oregon State University, Dept. of Physics; 301 Weniger Hall; Corvallis, OR 97331-6507, USA*
[9] *University of California (Berkeley), #7300; Berkeley, CA 94720-7300, USA*
[10] *University of Houston, Houston, TX 77204, USA*
[11] *University of Manchester, Oxford Road, Manchester M13 9PL, UK*
[12] *University of Minnesota (Duluth), Duluth, MN 55812, USA*
[13] *University of Oxford, Oxford, OX1 3RH, UK*
[14] *University of South Carolina, Columbia, SC 29208, USA*
[15] *University of Warwick, Coventry CV4 7AL, UK*
[16] *Yale University, New Haven, CT 06520, USA*

Abstract

The LBNF/DUNE CDR describes the proposed physics program and experimental design at the conceptual design phase. Volume 2, entitled *The Physics Program for DUNE at LBNF*, outlines the scientific objectives and describes the physics studies that the DUNE collaboration will perform to address these objectives. The long-baseline physics sensitivity calculations presented in the DUNE CDR rely upon simulation of the neutrino beam line, simulation of neutrino interactions in the far detector, and a parameterized analysis of detector performance and systematic uncertainty. The purpose of this posting is to provide the results of these simulations to the community to facilitate phenomenological studies of long-baseline oscillation at LBNF/DUNE. Additionally, this posting includes GDML of the DUNE single-phase far detector for use in simulations. DUNE welcomes those interested in performing this work as members of the collaboration, but also recognizes the benefit of making these configurations readily available to the wider community.

FLUX

- Currently using “CDR Optimized Design” as the nominal beam flux
- **Updates needed**
  - G4LBNF simulation based on engineered beam design
  - Preliminary flux is available; being optimized and validated
- **Considerations**:
  - This is expected to happen outside of LBLPWG effort (beam group)
  - Will be last update to flux before TDR

INTERACTIONS MODEL

- **Updates needed**:
  - GENIE (2.12) tune deemed “modern enough” to be defensible
    - Includes several 2p2h models
    - NDTF is using GENIE 2.10.6 which includes phenomenological MEC-2p2h
  - GENIE 3.0 planned for Q2 2017; GENIE 4.0 in Q4 2017
  - Need to consider whether other model improvements are also required
- **Considerations**:
  - This is likely to happen outside of LBPWG effort but should be monitored
  - If we have particular requests that are not going to be part of the nominal GENIE tune, DUNE will need to contribute some effort and we will need to start early enough to validate the tune and incorporate it into LArSoft

DETECTOR RESPONSE & ANALYSIS

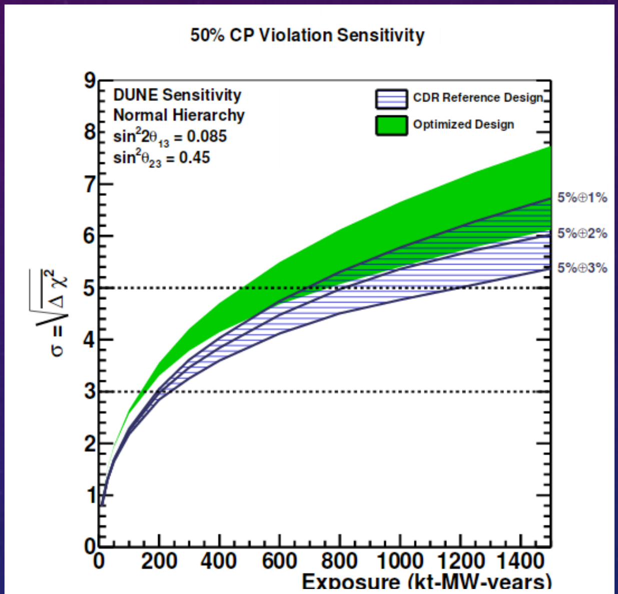
- **Updates needed**: LArSoft simulation and analysis to replace Fast MC
- **Considerations**:
  - This is the primary focus of LBPWG
  - **Simulation and selection** exists
    - LArSoft based simulation and reconstruction: GENIE, GEANT4, FD Simulation, Reconstruction
    - **Selections**: TMVA ν_e and ν_μ selections; CNN-based selections being developed
    - Energy reconstruction under development
  - Results are reasonable, but are significantly worse than assumed in Fast MC (particularly in NC background rejection)
  - Need to define "required performance" in terms of efficiency and background rejection.
    - Example: using CDR setup, can multiply NC background by factor of 10 with only moderate reduction in CPV sensitivity. We have been saying roughly 80% efficiency for 1% NC background acceptance is the goal -- but is somewhat worse than that good enough? Simple to study, but should be quantified so we know what the goal is.
    - General guess is that this will converge to "good enough" for CPV sensitivity but probably not to 80%,1%
- Note: if, for some reason, it doesn't converge as a full analysis, **fallback position** could be to do LArSoft MC studies justifying Fast MC inputs and then doing final analysis with Fast MC. Obviously not our first choice.

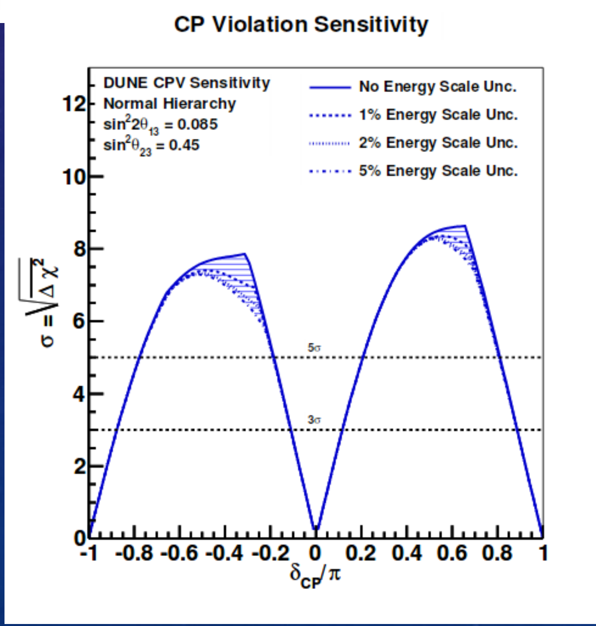
SYSTEMATICS - IMPLEMENTATION

- **Updates needed**: Improved systematics treatment to include **shape effects**, possibly individual sources of systematic uncertainty. Three ways to do this:
  - **Covariance matrix** *a la* SBN proposal. Entries in matrix are still ad hoc and have to be justified but our perception is that this "sells" better. **Minimum** option.
  - Validate Fast MC inputs against LArSoft analysis and use existing **Fast MC reweighting tools** to evaluate impact of individual uncertainty. **Intermediate** option.
  - Develop tools within **LArSoft** to reweight or vary individual parameters such that **full systematic treatment** happens in the same framework as official sensitivities. **Best** option.
- **Considerations**:
  - **Choice** of options coupled to discussion of **fitter** development (discussed later)
  - Not difficult to include **covariance matrix** in MGT or LOAF. Some inquiry required to figure out how difficult this would be in LArSoft
  - Additional work is required for Fast MC reweighting
  - FastMC/LArSoft method will almost certainly not converge using all flux and cross-section parameters for FD only – if we assume constraints on variations from the ND (eg: taking the VALOR constraints) and reasonable limits on sample to sample variations in the 4-sample fit, it can probably converge.

SYSTEMATICS - STUDIES

- Systematics studies currently in CDR
  - ν_e signal normalization uncertainties
  - Energy scale: N[E]→N[(1+a)E] model
- Studies needed for TDR
  - Replace qualitative/grouped normalization systematics with detailed breakdown and systematic errors "budget" including shape and normalization
  - This depends heavily on the availability of inputs, propagation method, and fitter





FITTER

- **Updates needed**: functionality to treat systematics for chosen method
- **Considerations** for each possible option
  - **MGT (GLoBES-based):**
    - Possible to include expanded systematics treatment
    - Requires some conversion from Fast MC/LArSoft inputs to MGT format; Elizabeth is familiar with conversion scripts
    - Would need to be supported, documented, and made available for general use – documentation and availability exists, needs updating
    - Matt and Elizabeth familiar with framework, has been used by others in DUNE
    - We should always maintain an updated GLoBES configuration to enable sanity checks, BSM physics studies, and collaboration with theorists
  - **LOAF:**
    - Possible to include expanded systematics treatment
    - Requires no conversion from Fast MC/LArSoft inputs
    - Would need to be supported and documented for general use – not currently available
    - Only Dan familiar with framework; he does not have time to support
  - **VALOR:**
    - Complicated and sophisticated treatment of systematics including joint ND fit
    - Requires no additional conversion from Fast MC/LArSoft inputs
    - Well supported; would need to be documented and made available for general use

More discussion on this at the collaboration this

MODEL ASSUMPTIONS

- **Updates needed**: consider impact of possible BSM effects on 3ν fits?
- **Considerations**:
  - Elizabeth gets this question all the time – we need to have an answer, but perhaps the answer should come from the BSM group or from phenomenology rather than LBPWG
  - If this falls in BSM group, some effort to make sure that, in addition to studying sensitivity to BSM effects, they study impact of allowing the possibility of BSM effects on 3ν fits, and that the comparison to the standard sensitivities is apples-apples, which means keeping our fitter and inputs synced with theirs
  - If we use the MGT fitter, not difficult to include GLoBES-based BSM models; some work already done

TDR STRUCTURE

CDR TABLE OF CONTENTS (LB CHAPTER)

Currently:
- Sensitivity methods
- Oscillation probabilities
- Flux inputs
- Detector response (FastMC)
- Oscillation parameter priors

TDR Updates:
- Describe new, LArSoft based inputs to sensitivity computations
- ν_μ/ν_e event selections
- CVN Selections
- Neutrino energy reconstruction
- Oscillation parameters
- Event spectra

CDR TABLE OF CONTENTS (LB CHAPTER)

Currently:
- Sensitivity plots for MH, CPV, and oscillation parameter resolutions

TDR Updates:
- Sensitivities should be updated with new inputs
- Plots updated to match new sensitivity plot format

CDR TABLE OF CONTENTS (LB CHAPTER)

Currently:
Far detector samples and the effects of uncertainties on these samples and the resulting sensitivities. A lot of text justifying estimates of uncertainties that were used in lieu of full systematics treatment.

New layout:
- Far detector samples
- Constraints from ND analyses
- Uncertainties
  - Flux
  - Interactions
  - Detector
- Sensitivity effects of uncertainties

CDR TABLE OF CONTENTS (LB CHAPTER)

Currently:
Describes differences between CDR and optimized beam flux configurations. Studies sensitivities wrt to these fluxes.

TDR Updates:
This section should be updated to compare CDR beam design to engineered beam design wrt to LB oscillation sensitivity.

CDR TABLE OF CONTENTS (LB CHAPTER)

As discussed previously, this section will be moved to a “Beyond the Standard Model Physics Searches” chapter. This should include a subsection on how the BSM affects the SM measurements.

CDR TABLE OF CONTENTS (LB CHAPTER)

Currently:
High-level discussion of the requirements, based on neutrino oscillation sensitivity, for the beam, FD, and ND.

TDR Updates:
This becomes integrated into the previous sections as a description fo the final design chosen.

SUMMARY

- Significant work to be done for TDR :
  - Working close with other groups beam and simulation for model selection
  - Converging on detector response and analysis
  - Adding capabilities to deal with detailed systematic uncertainties (including shape and normalization)
  - Converging on and optimizing fitting framework
- TDR changes have been identified