DUNE Physics Week Summary

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DUNE FD Joint Calibration Task Force Meeting

December 5, 2017

Calibrations@DUNE Physics Week

- We planned a rich agenda with kick-off, discussion, joint & hands-on sessions
    - The goal was to get more hands-on activity happen with DPW as a venue to recruit and engage new/more (especially younger) people for calibrations
    - While we weren't able to achieve the hands-on part, DPW served as a venue for conveners to brainstorm on how different groups should interact to achieve the goals for TDR
    - Served as a venue for good conveners retreat?

Calibrations@DUNE Physics Week

- Three main sessions with productive discussions
  - Calibrations in Technical Proposal & TDR
  - Calibrations decision making process
  - LBL+calibrations joint session
  - Reco/Sim+calibration joint session (Talk by C. Backhouse)
- One hands-on activity — Alignment with Cosmics (Talk by T. Junk)

TDR Volumes

(https://indico.fnal.gov/event/15181/session/7/contribution/25/material/slides/0.pdf)

- Multiple volumes, each volume around 150 - 200 pages

- **Volumes**
  - Volume 1: Executive Summary
  - Volume 2: Physics
  - Volume 3: Single-Phase Far Detector: Overview
    - + sub-system volumes
  - Volume 4: Dual-Phase Far Detector: Overview
    - + sub-system volumes
  - CDRs: Computing and Near Detector

Not too much worried about Volume 1, focus on volumes 2, 3 & 4

- Question 1: Where does Calibration sit in these TDR volumes?

- Question 2: What do we foresee for calibrations in the *Technical Proposal?*

Calibrations span broad

(probably easier to categorize this way for TDR purposes)

- *There is low level calibration*
  - More Detector related *(call it detector validation/performance)*
    - Broadly, relating to TPC response and photon detector response. E.g. Electronics noise, wire response, channel gain, photon gain, PDS to TPC calibration,…
    - Electron lifetime (purity), recombination (E-field), space charge, other E-field distortions, alignment, drift velocity etc.
- *There is high-level calibration* ***(More Physics related)***
    - Standard candles for Physics. E.g. Michel electrons, Calibration with Pi0s etc.
    - Energy scale, Energy resolution, Particle ID efficiencies, Various particle responses (charged hadrons, neutrons,…)
    - Another big piece: Detector systematics and their impact on LBL (and other physics)

Approach for Technical Proposal
(requires defining a calibration decision making process)

- In conjunction with collaboration input ***(venues provided e.g. upcoming collaboration meeting)***, develop a ***separate section for "Calibration Strategy" in the Technical Proposal***

    - Outline the various physics arguments and provide an overview of the proposed calibration hardware.

    - State the intentions of the collaboration for calibration hardware systems (e.g. Laser, photon calibration etc.) along with strong physics motivations

- A calibration workshop planned (in March?) to converge on calibration strategy and hardware systems by the Technical Proposal timeline

- ***Post Technical Proposal:*** Develop the systems presented in the Technical Proposal into concrete proposal for the TDR.

Volume 3: FD-SP

- **Volume 3: Single-Phase Far Detector: Overview**
  - Design Motivation
  - Cryostat and cryogenics
  - Overview of the Single-Phase Far Detector
  - ProtoDUNE-SP
  - Detector Performance
- **Volume 3A: APAs**
- **Volume 3B: High Voltage System**
- **Volume 3C: TPC Electronics**
- **Volume 3D: Photon Detection System**
- **Volume 3E: DAQ**
- **Volume 3F: Slow Controls and Cryogenic Instrum.**
- **Volume 3G: Installation and Integration**

There will be a *Calibration Strategy* chapter here

Details of the hardware will be presented in the corresponding consortium chapters of the TDR.

Similar Structure for Volume 4: FD Dual Phase

Volume 2: Physics TDR Structure

Current Outline

- **Executive Summary**
- **Introduction to LBNF and DUNE**
- **Scientific Landscape**
- **Tools and methods employed**
- **Standard neutrino oscillation physics program**
- **GeV-scale non-accelerator physics program**
- **Supernova neutrino bursts and physics with low-energy neutrinos**
- **Precision physics with the near detector**
- **Additional opportunities for Beyond-Standard-Model physics**
- **Summary and conclusions**

There will also be a section in the Physics Volume of the TDR discussing the physics-process based calibration measurements and the assumed systematic uncertainties that will be propagated to the physics

Discussion with Reco/Sim group: Tools & Interfaces

(https://indico.fnal.gov/event/15181/session/7/contribution/27/material/slides/0.pdf)

Many Calibration quantities

TPC response model
- Argon ionization energy
- Electron drift velocity
- t_0 offsets
- Electron lifetime
- Recombination parameters
- Electric field
- Longitudinal and transverse electron diffusion
- Wire positions/geometry
- Wire field response
- Channel gain
- Overall electronics analog transfer function
- Electronic crosstalk
- Electronics noise, including correlated noise
- ADC linearity (differential and integral).

Photon detector response model:
- <similar list here>

(See Backup for more)

High level quantities
- Position reconstruction biases
- Direction reconstruction biases
- Energy scale
- Energy resolution
- Particle ID efficiencies
- Noise removal efficiencies
- …
- …

Particle response
- Charged hadron propagation
- Neutron response
- …

- Is this list complete?
- Position/time dependance?
- Needed precision?
- How to constrain? How much can you relay on external measurements?

Many Calibration sources

- Purity Monitors
- Temperature monitors
- Survey
- Current monitors
- υ_μ CC events
- Michel electrons
- Stopping muons
- Stopping protons
- Muon Crossers, APA/CPA piercers
- Ar^{39}
- Laser system
- CRT tagger
- Other radioactivity
- Michel electrons
- υ_μ CC events
- π^0 mass peak
- Other decays (K^0s…)
- Tagged events

What else??

- Keep in mind each source comes with its own challenges
- Best Strategy: Option of multiple ways to calibrate

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C. Backhouse talk today

- There are needs from both simulation & reco side from calibration. Good to factorize calibration and reconstruction

- Develop tools (e.g. fhicl knobs) & interfaces (both at sim/reco levels) that propagate calibration quantities into LBL to assess impact

Interfacing with the LBL group
lots of challenges!

(https://indico.fnal.gov/event/15181/session/1/contribution/30/material/slides/0.pdf)

- Challenge: Build a master list of systematics that calibration constrains
    - Separate by in-situ and external knowledge (e.g. protoDUNE)
- Challenge: Decide method for inclusion. What is parametrizable and what is not? Can we re-use a given parameter for multiple effects
    - Take a test case fully through the chain; ideas for space charge, Energy scale effects
- Challenge: Deadline for inclusion (TDR ~ Jan 2019). Likely can only include a small set of fully propagated effects
- Challenge: Systematics seem to cancel more than we expect! Why?
    - LBL checks: confirm Energy scale with no fit parameter produces bias

https://indico.fnal.gov/event/15181/session/1/contribution/31/material/slides/0.pdf *(from M. Bass)*

- Two Main Fitters for LBL:
  - *GLoBES* — current baseline
  - *CAFAna* — relatively new; under validation

Systematics studies

Bottom-up: re-run entire simulation/reconstruction chain with sim/detsim/physics parameters varied, rerun selections & sensitivity analysis for each variation

Resource intensive
Ready to go in both CAFAna and GLoBES

E.g. Wire spacing study

Top-down: shape, normalization systematics or modify smearing to account for underlying detector/physics effect

Difficult to relate to underlying parameters?
Ready to go in both CAFAna and GLoBES

E.g. Energy bin level systematics

Reweighting: reweighting events to account for parameter variations

Reweighting not in place in larsoft
Some reweighting possible with CAFAna

Next Steps for TF

- Our last ***FT proposal for calibrations*** is currently being discussed with the cryostat team — ***goal to finalize by this month***.

- Next meetings focused on defining a calibration strategy and hardware needed by the Technical Proposal timeline

  - ***Goal:*** Present a calibration strategy at the January collaboration meeting to get collaboration wide input and key criticisms/questions

  - Not all studies can be done; we will still be driving on arguments, past experience and future projections;

- Plan for a ***calibration workshop in March*** to refine strategy and address key concerns raised — converge on a strategy for TP