TDR discussion for Calibration

Sowjanya, Kendall

DUNE Physics Week
November 15 - 17, 2017
Fermilab

TDR Structure

- Mark's slides: https://indico.fnal.gov/event/15615/contribution/0/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

- Question 1: Where does Calibration sit in these volumes? Currently it is not clear.

TDR Structure

- Mark's slides: https://indico.fnal.gov/event/15615/contribution/0/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 volumes? Currently it is not clear.

Keep in mind: Calibrations span broad

(But, 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)

Keep in mind: Calibrations span broad

(But, probably easier to categorize this way for TDR purposes)

- **There is low level calibration**
  - More Detector related *(call it detector validation/performance)*

Most importantly, we need a "Calibration Strategy" plan to tie all this together and understand the impact of detector calibration & Systematics on LBL (and other physics).

This is a bigger question, will touch on that today but would like to focus on TDR organization for Calibration

- **Th**
  - 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)

Keep in mind: Calibrations spans broad

- **There is low level calibration**
  - More Detector related *(call it detector validation/performance)*

> ***How & where all these calibration pieces fit into the TDR?***
>
> The goal is of course not to overburden the TDR with too many details. But, ensure all important pieces are touched and gives a full picture

- **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)

Volume 3: FD-SP (Mark's slide)

- **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**

Same for Volume 4: FD DP

Ideas for Detector System Volumes

Volume 3: FD-SP

- **Volume 3: Single-Phase Far Detector: Ove**
  - 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 I**
- **Volume 3G: Installation and Integration**

And also the DP

- Detector Performance is a prime piece here.
- Cryogenic Instr. also a prime piece? description of calibration systems?
- In a way, all detector systems will include some piece of (low level) calibration. We need a plan to distribute things.
- Will also need to include “select” detecter performance pieces from ProtoDUNE
- Provide how things project for DUNE with “realistic” studies

Volume 2: Physics (Mark's slide)

- **Volume 2: Physics**
  - DUNE Physics goals (primary, secondary, ancillary)
  - Far Detector Reconstruction
  - Long-Baseline Neutrino Oscillations
  - Supernova Neutrinos
  - Nucleon Decay
  - Beyond the SM Physics
  - Other Topics
  - Near Detector Physics

How do we integrate calibration into the Physics volume?

This needs more thought!

We will have one section on Reconstruction and Tools/ Method. It would make sense to have a section on (high level) Calibration. Other thoughts?

There is also the Technical Proposal?
(what do we foresee for calibrations in TP?)

- *Will broadly follow the "same" structure as TDR, but compressed, Timeline is also close (April 2018)*
  - We can in principle follow the same strategy for calibrations as for TDR
  - Timeline of TP makes some choices easy:
    - *Won't have ProtoDUNE data* (but maybe some validation of systems will be available). The "detector performance" part will not be much
    - *The design for calibration systems for DUNE FD will not have been finalized.* So, can' t go too much into those details.
  - We can present arguments/strategy for Calibration and some MC studies to show impact on LBL (hard to guarantee since we might also focus on calibration hardware driven studies to follow the timelines for the project).
  - Maybe a better way is to discuss about calibration hardware and not so much of a full strategy?
- *Other thoughts?*

Question 2:
Calibration path to TDR

Calibration Quantities

(Note: There are strong correlations b/n these 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>

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?

Calibration Quantities

Big question here: Are Cosmics enough for all this?

- 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

Calibration Initial thoughts on Strategy

- **Develop a refined list of things that need calibration along with available sources to address them**
  - Goal: get a number next to each quantity based on literature survey, prior measurements, best estimates etc. — *We need a starting point*
  - *Close eye on MicroBooNE/ProtoDUNE analyses & results; Lessons learned from other experiments;*
    - *Need to be careful in extrapolating detector related (low level) results from other experiments; extrapolation is okay for physics quantities to a large extent.*
- **From this list, identify**
  - *What are the lowest hanging fruits?* Universal constants? (e.g. argon Ionization energy?)
  - *ex-situ measurements, past experiments?* recombination? Calculable (diffusion?)
  - Propagate them to physics, confirm and push out the door.

Calibration Initial thoughts on Strategy

- Need tools that can propagate calibration uncertainties to physics and make our suite of plots.
    - What are those final set of measurements that require in-situ measurements?
    - How do we achieve them? (calibration devices needed)
        - What are those quantities that are never measured before? Does it require a specific calibration source?
    - Which quantities have biggest impact on physics?
- Additionally, develop methods for high level standard candles
- Collaborate with FD Simulation/Reconstruction and LBL conveners for developing tools & ways to propagate detector parameters to assess physics impact

Calibration Initial thoughts on Strategy

- Other thoughts?
    - Issues with envisioned path to TDR?