DUNE Far Detector Calibrations WG

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The Challenge

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Risk Title: The LAr Detector lacks an adequate calibration system
Risk Description: A calibration system is required to measure the neutrino energy to the required accuracy.
Detailed Risk Cause: Temporal and/or spatial variations of impurities or positive ions due to the high flux of cosmic rays.
Detailed Risk Effect: The energy deposition in the detector cannot be adequately measured.
WBS Affected: 1.4
Other WBS Affected:

Actual Start Date (when available from schedule)	**Actual Finish Date (when available from schedule)**

Initial Risk Analysis – (description of selection of impacts and probability, text length commensurate with risk complexity):

The need for a calibration has yet to be demonstrated. ANSYS simulations of fluid flow indicate that impurities and positive ions would be mixed to some extent in the cryostat. In principle, the large flux of cosmic rays would provide sufficient calibration although this has not been demonstrated. It is highly desirable to have an independent means of calibrating the detector however, for instance by providing a laser calibration system.

As a point of reference, The MicroBooNE experiment, which plans to operate on the surface with a 2.5 m drift, has decided to include a laser calibration system in the project cost.

Is there anything to do here?

Calibration Working Group

Preliminary Charge Elements

Calibration WG will:

1. Provide complete list of parameters, corrections, efficiences/acceptances to be measured
2. Generate requirements for calibration system(s)
3. Design a calibration program to meet requirements
   - May include analyses of data (cosmics, tagged events…)
   - May include explicit sources
     - Laser?
     - Cosmic tagger?
     - Radioactive sources
     - Radioactive spikes

Charge---Scope?

As it stands, charge includes

- Electronics corrections and response functions (pedestals, ADC…)
- Photon system response (light yield, timing…)
- TPC response (electron lifetime, drift velocity, diffusion…)
- Detector geometry (e.g., wire positions)
- High-level acceptances such as fiducial volume and uncertainties

Other elements of the model are *not* in our scope:

- Neutrino cross sections
- Beam flux and flavor composition
- Particle propagation through LAr

Calibration Working Group
Deliverables

- Requirements for calibration program
- Requirements for any necessary instrumentation
- Outline of how calibrations will be integrated into analysis path
- Analyses demonstrating how program will constrain parameters as well or better than physics requirements for all physics topics of interest

Path Forward

Many Questions…

- How much of detector should a laser illuminate, and how much can it reasonably do? Are we happy to get our ADC-to-energy conversion based on the agreement of 3 simulations of muon spectra?
- How are things like "fiducial volume" and/or its uncertainty measured?
- Do we need a way of independently tagging/measuring cosmics?
- Do we need low-energy calibration sources?
- How well do we need to know front-end response so that deconvolutions are accurate?
- How often do we need to measure detector response?
- How do we know mis-ID efficiencies?
- …

Answers to these and many others must be demonstrated solutions (And not "We'll just…").

Path Forward

Will start from the top-down

How have far detectors for other LBL experiments been calibrated, and how have the calibrations been used?

How have LAr-TPCs been calibrated, and how have those calibrations been used?

What are the outlines of DUNE physics analyses, and what assumptions do they make?

What uncertainties are important for DUNE physics programs?

Path Forward

A first (and inconsistent and incomplete) start on parameters:

A	B	C	D	E	F	G	H	I	J	K
Parameter/Function	**Definition**	**In-situ**	**protoDUNE**	**35 t**	**Universal**	**Calibration**	**Position Dep?**	**Time Dep?**	**Test**	
W	ionization energy	No	No	No	Yes	Benchtop	No	No	Cosmics	
C	ADC/charge map	Yes	No	No	No	Electronics cals.	Yes	Yes	Laser?	
R	electron recombination	Yes	No	No	No	Purity monitor?	Yes	Yes	Cosmics	
τ	Electron lifetime	Yes	No	No	No	Purity monitor?	Yes?	Yes?	Laser?	
A	Birk's Normalization	No?	Yes	No	Yes?	protoDUNE	No	No	cosmics	
k	Birk's constant	No	Yes	No	Yes	ICARUS?	No	No	protoDUNE	
E	electric field	Yes	No	No	No	Laser	Yes	Yes?	Cosmics?	
vd	Drift velocity	Yes	No	No	No	Laser?	Yes	Yes?	Cosmics w/ tag?	
(x,y,z)	Wire positions	Yes	No	No	No	Survey?	Yes	No?	Laser	
d	electron diffusion	Yes	No	No	No	Laser?	Yes	Yes	Cosmics?	
σt	time resolution	No	No	No	No	Clock spec.	No	Weakly	Laser	
σt0	T0 resolution	Yes	No	No	No	LED?	Yes	Weakly	Beam time profile	
N	PDS light yield	Yes	No	No	No	LED?	Yes	Yes	Stopping μs?	
ε	Trigger Efficiency/non-beam	Yes	Yes?	Yes?	No	Source?	Yes	Yes	Beam events	
Vf	Fiducial volume	Yes	No	No	No	Model prediction?	Yes	No?	Cosmics w/tag?	
ρe(E-Er)	e Energy response function	Yes	Yes	No	No	Model/protoDUNE?	Yes	Yes	protoDUNE	
$\rho\gamma$(E-Er)	γ Energy response function	Yes	Yes	No	No	Model/protoDUNE?	Yes	Yes	protoDUNE	
σr	Recon precision	Yes	Yes	No	No	Laser?	Yes	Yes	Cosmics	
Δr	Recon bias	Yes	Yes	No	No	Laser?	Yes	Yes	Cosmics	

Path Forward

Schedule

We also have to deal with project/schedule realities:

- Need to ensure calibration needs of protoDUNE are in hand
- Need to ensure that measurements by protoDUNE will provide needed calibrations input for DUNE
- Need to provide specifications for DUNE FD conventional facilities
  - How many lasers, mirrors, feedthroughs…?

These are all needed before end of this CY

Organization

- Given potential breadth of charge, we are very manpower-limited
- Some things will proceed by themselves (e.g., 35t calibrations already ongoing)
- Probably don't have time for separate subgroup phone calls
    - But "obvious" subgroups are protoDUNE, 35 t right now
    - Later might be instrumentation, in-situ analyses, etc.
- Will meet biweekly at first, may move to monthly as things settle down
- Need to define available manpower for work:
    - Cosmic-ray calibration studies
    - Tagged beam-event studies
    - Simulations of PDs (from PD WG)
    - Laser studies---how much illumination?

Organization

DUNE-FD-CALIBRATIONS

Bi-weekly phone calls at 9am CT on Thursdays.