Meeting focus: TPC dE/dx calibration (MicroBooNE experience and thoughts for DUNE)

Indico link: https://indico.fnal.gov/event/15240/

Attendees: Kendall, Sowjanya, Tingjun, Matt Bass, Mike Mooney, Stephen Pordes, Glenn Horton Smith, Juergen R., Chuck Lane, Luke Corwin and possibly others.

Talk 1: Thoughts on Calibration for DUNE (with a focus on TPC dE/dx calibration)
Tingjun presented. DUNE will see about 4000 per day per 10 kt module and about 30 stopping muons per day per 10kt module. Not enough to do calibration per channel but should be okay to perform per module. The goal of calibration is uniform detector response over space and time and involves a two step approach, relative calibration (spatial and temporal calibration) and absolute calibration (converting ADCs to no. of electrons; recombination plays a role). The spatial calibration involves channel by channel, wire response and attenuation (lifetime) calibration. For channel-by-channel calibration, one can use a charge injection system to measure gain and linearity of each channel. MicroBooNE saw 1-2% variations. The non-uniformity in wire response calibration can be caused by many reasons such as shorted wires or touching wires. In MicroBooNE, the wire response non-uniformity was measured and removed using cosmic muons. This will be challenging for DUNE due to low cosmic ray rate. Laser can be helpful here. For the drift-electron lifetime calibration, MicroBooNE used cosmic muons. For DUNE, assuming there are no variations between TPCs (e.g. E-field), one can combine all cosmic muons for this calibration. Laser system can be potentially useful here. Once the spatial variations are removed, one can use cosmic muons or laser to remove temporal variations and move towards doing absolute energy calibration. In converting calibrated dQ/dx to dE/dx, one needs to know calorimetry constants and recombination. Stopping muons are typically used for this calibration. In DUNE, this will be challenging since one will need to combine stopping muon over months to get enough statistics. The angular dependence of dQ/dx complicates this process along with reconstruction challenges.

Discussion:

Kendall: on ADC to GeV conversion, is this particle dependent?
Tingjun: Yes, ADC to GeV is particle dependent.
Kendall: So, in principle, separately you need to understand number of ionization electrons liberated?
Tingjun: To the first order, one can take it from GEANT. In LArIAT, for example, people took pions and applied to proton data and got good agreement with expectation. They can do this since it is test beam and input is known.

Kendall: What is charge injection system and how does it work? Is it ex-situ?
Mike: This uses external pulser to inject charge and calibration gain and shaping time. MicroBooNE is currently working on a paper for this. One can do bench tests and also repeat it in-situ. MicroBooNE did both. For DUNE, will have a way to issue a pulsar signal and on the ASIC itself. Will be able to do this, channel-by-channel. First thing to be done and then one can use ionization signals.

Kendall: Why are shorted wires not an issue for DUNE if everything works as planned? Do we know the origin of this?
Mike: We haven't pinned all of this down for uB yet, has to do with wires touching, consistent with data. Correlation between shorted wires and tension in TPC against tension measurements in the warm.
Juergen: Do shorted wires come and go with the flow pattern?
Mike: Not clear. From other tests with a mock TPC, when in close contact, can be hard to move.

Haven't ruled out variations in time in short time scale, but on a day timescale, seem persistent.
Stephen: Combs in the DUNE TPC, harder, but not impossible to avoid touching.
Sowjanya: There are gaps between APAs, is that what you mean by combs? – gaps between frames?
Stephen: Between planes of wires, there is a comb. Long strip of G10 – so in principle cannot physically approach each other.

(On electron drift-lifetime)
Stephen: Has anybody used laser for lifetime calibration? Can be potentially hard but potentially useful.
Tingjun: ArgonTube did it and had a publication. https://arxiv.org/pdf/1304.6961.pdf
Stephen: I thought it was just a field calibration.
Sowjanya: No they did lifetime and diffusion measurements. I think this was a student's thesis.
Here is a Google drive link to thesis:
https://drive.google.com/file/d/0B0OpvqC4PIdXaEc5dEI1ZXVmWW8/view?usp=sharing
Stephen: Any picture of any evolution of a dramatic change to lifetime after initial start?
Sowjanya: Not from intentional injection, but during downtimes we saw this in uB. Example power outage or liquid argon top-ups.
Stephen: Could be an interesting thing to do for DUNE. Understand the liquid argon top-up rate in DUNE (how much oxygen is introduced by the new argon) and do some analysis of what happens to electron lifetime.
Juergen: would assume that pump changes will effect this as well.

(On absolute energy calibration)
Sowjanya: You mentioned LArIAT used pions, can you expand on it?
Tingjun: Right. They had low statistics for stoppers. With a test beam, there are more handles to do this since the momentum is known. For DUNE, have to rely on things known well. Stopping power of a muon which is well known.

(On Recombination)
Kendall: is there any dependance on space or time for recombination? Or just via E field?
Tingjun: Recombination parameterized as a function of electric field. Should be constant in time and space except for the E field dependance.
Mike: Recombination may have some angular dependence w.r.t. the drift direction. But, not seen in ArgoNeut. Sowjanya's team is working on this.
Sowjanya: Yes, the theory predicts it. Currently unclear, we are looking into it.

Sowjanya: Is laser essential for this aspect (TPC response) of the program? I know it depends on the timeline and how often we want to do stability monitoring, but what is your opinion?
Tingjun: Laser system great to remove time dependence of detector response. No ideas how reliable it is for spatial or channel-by-channel calibration. Cosmic stopping muons are probably our best handles for energy.
Mike: Ar39 is a good idea to explore more. Unless noise is super high, then should be able to see and use.
Chuck: If you have tunable intensity and steering, when have another calibration can cross check it. Experience based in scintillator.
Stephen: What is the range for laser in meters? The experience from uB is pretty sobering.
Chuck: Point is that the laser is still flexible and a new piece of information. Other calibration sources are very limited around the detector. Cross calibration is huge for confidence building.
Stephen: What is the realistic future for the laser? And also what is the effort.

Sowjanya: We did setup the Feedthrough functionality to be flexible for laser. We still need to understand the funding scenario for this, but that is a different question.

Kendall: Tingjun, what keeps you up at night?
Tingjun: Worried limited young people; not many working on DUNE.
Kendall: What are the enticing problems in your opinion?
Tingjun: There is an immediate need to finish the physics TDR. Short timescale, need improvements on reconstruction, calibration, very hard to have those accomplished.
Stephen: do you think recombination from ArgoNeut and ICARUS are adequate?
Tingjun: No. We are working to do more on uB on this.
Sowjanya: E-field dependance on recombination parameters is not understood. ICARUS and ArgoNeuT are at same E-field. Also, angular dependance needs study.
Juergen: HV and purity are an issue. If we have reduced volume due to either of those issues, then needs in-situ measurement if not done before for that E-field.

Mike: Another use for the Ar39, study wire response as a function of wire number. In case of sagging a little bit, E-field between planes are different. Could do and show.
Tingjun: Need to rely on something we understand. Needs additional sources.
Sowjanya: What are the other low level things we can use Ar39 for? Lifetime, wire response?
Mike: lots of stuff. Diffusion. Have heard some people say we need to nail this down. On the DAQ side, worried about if plans they make are commensurate with the calibration needs as well.
Sowjanya: Agreed this is a good point and something we need to watch and communicate our needs.
Juergen: Ar39, for a 3.5 m drift, for the most part will only be useful away from APA.
Mike: Will depend on the e lifetime. Calibration would assume uniform population in x direction.
Juergen: But, even 3 ms is not enough. One will have to increase the light threshold and you already lose most of it.
Mike: Can be folded into the measurement— agreed it maybe more limited.

Sowjanya: Diffusion, agreed, doesn't change dramatically with E field, and also model dependent. In situ is really hard. Does DUNE requires insitu?
Tingjun: Has to be studied— maybe change HV to study it? Consider worst case scenarios.
Sowjanya: Recombination though, the E-field may vary and we have to do in-situ. The hard part is we are making calibration hardware choices for DUNE right now and we don't have enough information to do it and this will impact what we can do in-situ.
Juergen/Mike: Try to find a way to avoid shutting doors.
Jurgen: The laser folks suggested photonic crystals.
Mike: Sad that ProtoDUNE doesn't have laser system. Lost opportunity

Sowjanya: Maybe we should ask the “what keeps you up at night” more formally, maybe conduct a survey?
Mike: What is the strategy for calibration for the technical proposal?
Sowjanya: For TP, we will have a 2-page strategy. We will open this up at the January collaboration meeting followed by a calibration workshop in March.

Juergen: Would like to provide a quick update on source calibration studies. We are making progress, before we have shown studies for inside active volume, now we made changes to geometry (and photon libraries) to include outside the field cage response. The main emphasis now is to cut down radioactive source signals from radiological backgrounds. Will present an update at future meetings.

Kendall/Sowjanya: No more meetings through the new year. Happy holidays!