Minutes – Calibration Task Force Meeting, July 10, 2018

Agenda: **https://indico.fnal.gov/event/17526**

Attendees: K. Mahn, S. Gollapinni, H. Rogers, J. Wang, R. Diurba, R. Svoboda, J. Klein, A. Fisher, M. Mooney, S. Jones, A. Reynolds, T. Junk, V. Kudryavtsev and possibly others

Talk 1: Detector Systematics in CafAna – Seb Jones presented

Seb is looking at the energy scale effects of anisotropies such as E-field distortions, space charge effects. As a first step, looking at energy scale biases based upon the true neutrino vertex coordinates. Also looking at energy scale systematics by including a Gaussian smearing to energy scale shift from inelasticity of interaction.

JK: (slide 2) what is the z coordinate used?
SJ: This is a bias in z here. True neutrino vertex, z coordinate and maximum z coordinate of the TPC. Also, considered x and y biases.

JK: Let me understand this more. How are you fitting out the bias? Using observed reconstructed energy scale? And know it has a bias?
SJ: Don't know that it has a bias on the coordinate, fit with a global energy scale.
JK: Little surprised, qualitatively, any bias, is covariant with the survival probability. Not an energy dependent bias, global scaling, maybe not? As you shift the peak of the 1st max, left or right, or first min left or right, looks like oscillations? No constraint on this at all? Fits both bias and oscillation parameters? Shouldn't the circles get bigger?
SJ: This is also profiled over the energy scale, which is why you don't see it. Including that will increase side.
JK: If trying to fit neutrino energy, error in visible energy, translates to an additional error in there. Surprised. Of course your model is ad hoc.

SG: (slide 5) what is the red contour?
SJ: Red contour, no systematic profiled over, indicating you do get the wrong parameters out.

JK: Instead of people using their own estimates on anisotropies, it would be good for the calibration task force conveners to narrow them down? Otherwise there will be infinite of them. Also, could get input from MicroBooNE or ProtoDUNE for what we think are the realistic anisotropies would be?
KM: Yes. We are working on it. We will work with Bo and Tom to generate fake data to represent realistic effects, which Seb could use to re-test. But we have to determine the parametrization.

TJ: ProtoDUNE, rather large from flow structure and also space charge effects. May learn about that, before we learn the rest?
JK: yes, that is a problem.

TJ: Some things, like a crack between APAs, that's a discontinuity not smooth. Can look for steps. Also know about cathode plane and frame boundaries. Can do some alignment.
KM: We will use some of the tools developed for ProtoDUNEs and MicroBooNE to propagate E field effects.

MM: To chase out the sub-leading effects, just putting in space charge effects, may be very helpful? Nothing specific to test for (though Bo may say otherwise) - just making sure what we measure in data is consistent with a space charge distribution in the detector. If not, then that's the sign of additional impacts, e.g. the boundary conditions aren't what we think they are (due to field cage related things, for instance). That would be me and my team - my postdoc, Hannah Rogers, will perform the SCE calibration at ProtoDUNE
KM: Thanks, we will follow up and keep an eye on it.

SJ: I have not separated particle types.

KM: Strike a balance between number of parameters.
SJ: Won't know an answer until we see the mock data first. Wouldn't like to put a number on it.

SJ: Any parameter you can provide me with, I can put it in. Trivial to put in and test that out. Can run with that and then iterate.

SG: Getting an overall bias, is a first step. Like Seb said, once we have mock data we may have a better sense. We then bring in as the next iteration the spatial dependence or momentum, and particle dependence.

KM: Exception is efficiency? Neutrons are a special case.
TJ: Neutrons which carry energy, slow, but don't capture. Few 100 MeV we care about. 10 keV neutrons, don't care? Great to calibrate what we can, but not sure we calibrate the neutron efficiency we care about?
VK: Calibrate with the neutron generator. Still need, high energy neutrons. 100 MeV neutron, and what the energy response function is.
TJ: If we can predict the true ionization there is, that provides an ionization energy scale. Doesn't tell you about neutrons, as much as the ionization energy scale.
VK: high energy neutrons, not so many materials will slow them down. Low A materials. Some component of APA frames? Unlikely to be efficiently moderated. Some may be?
TJ: See a blip somewhere where collide.
VK: Fraction of energy lost, on average, 1/20 or so, 5%. Length to the collision, average path length, may be 30cm or so? Depends on energy.
VK: if the neutron is captured, we will get a cascade of gammas. Won't know the energy. Will know the calibration if it detects those gamma rays

(moving on to energy scale systematics, slide 9)
JK: (slide 11) Fit region is from what to what? Whole histograms. Nominal goes to 500 MeV, close as the first bin. If I look at left hand plot, as you bias things one way or another. Peak shifts in that

first maximum at 4 GeV. Surprised you are able to distinguish a bias.
Bins are shifted by oscillation parameters too. Delta_m^2 and E scale do similar things? Interesting to see if the covariance matrix between those parameters? if it's 10%, baffled, but maybe wrong? If it's 90%, then I'm concerned.
SJ: This is also assuming a perfect knowledge of flux and cross section.
JK: that's OK, will do it simply. But doesn't it look like a Delta_m^2 shift?
SJ: Trying to show here is the global energy shift, with no smearing can account for it?
JK: 2% sounds big. If we can't do 2% on the E scale. Granted we may not be able to do? Can see the contour is broader when you fit for it.

KM: I think we show bias, and then say, when calibrated, we issue a correction, and still use overall parameters. Y/N?
MM: Yes, I think this sounds good. Can you send around the proposal in the minutes also so we can think more about this?
KM: Sure.

Here is the detailed summary for proposal for studies to connect calibration and LBL:
For the TDR, we need to connect the physics case of calibration to physics programs.

For the LBL studies, we provide a set of detector uncertainties:

- A parameterization
- A nominal tune and uncertainties (with no calibration information)
- An updated tune and reduced uncertainties (with calibration)

These parameters will be used in the ND+FD fits.

Suggested parameterization:

1. E Scale parameter and uncertainty for each particle type:
    - Muon
    - pions
    - protons
    - electromagnetic showers

Suggested studies to assess impact on E Scale with sample, test bias with parameters above:

2. Mock data studies
    - Include realistic E field distortions
    - Include reasonable misalignments (spatial distortions)

We want the parameterization to clearly align with proposed calibration sub-systems as best as possible. For the laser, for example, it measures the E field, and we can quantify E field impact overall from the mock data studies.

For some systems, it is not obvious there is a connection.
Neutrons: What, if any, role do we expect from neutron calibration for LBL? Two possible studies.
A). Does the current CVN selection rely on neutron tagging to separate event topologies? If yes, then a "neutron efficiency parameter" can be added.
B) It's not clear how often the LBL neutrons (100 MeV or more!) will stop and capture. (The relationship between topology, tag, and energy estimator is a challenge for the cross section uncertainties.) Has anyone studied this and can comment?

Radioactive sources: What, if any, role do we expect from RS calibration for LBL?
C) Simulate EM showers of energies relevant to DUNE. What fraction of the total energy goes into LE gammas which are arguably probed from calibration? Use this to apply to the EM energy scale. If too small a fraction, focus argument on SN program (where it is directly applicable)

EMT: What kind of parameter is useful to quantify true - reco differences probed by the EMT? Perhaps, bias tests like what Seb showed demonstrate the role of vertex mis-mapping?

Additional points of discussion (we will follow up on these in dedicated meeting when 2) are prepared:

- What the ND//ProtoDUNEs//etc. may tell us
- How correlated nue and numu (and nu // nubar) are with regard to calibration (useful projection of impact, those uncertainties often destroy one's oscillation analysis)

Talk 2: Study of 39Ar Beta Decays at MicroBooNE – Alex Flesher presented

Alex presented a summary of the method and results on 39Ar Beta decays from MicroBooNE. These results were recently made public by MicroBooNE: MICROBOONE-NOTE-1050-PUB (http://microboone.fnal.gov/public-notes/).
SG: It is clear that Ar39 has well defined spectra compared to nominal to use it for lifetime. But, there are other drift dependent effects that might skew the spectrum. I know you looked at recombination, and the shape of the spectrum is different from that of lifetime which gives you a handle to separate that effect. But, there is also space charge which can effect lifetime. Have there been studies done in simulation to address this?
MM: If field cage effect or other item, will impact it. Locally, would see different recombination. If sensitive, which is an if, then could have a well-defined way to extract it.
SG: Yes, you are right, all of that largely comes through recombination, which has a different shape dependence and can be separated. But, I was more thinking about 2-3 effects coming together and things might get masked somehow.
MM: For E field distortions, important handle. Can measure strictly with spatial offsets from tracks. Target that, without these correlations to the E scale. Then you use spatial information, make a correction or fold into simulation, and then correct it, then after that can start using E scale is unbiased by E scale.

MM: Also, use edge wires vs. time, to E field distortions, if you have strong E field distortions, nominal effects push charge. Even Ar39, adding up candidates per unit time, sensitivity to these distortions as well.

KM: It would be good to think about how we want to propagate electron lifetime into the LBL studies and what are the parameters.
MM: Electron lifetime measurement, field response uniformity. Impact eventually on E scale and E resolution.
KM: OK, then find a way to fold it in to E scale, E resolution. Right now, no electron lifetime measurement?
SG: Found electron lifetime was excellent on MicroBooNE, and so attenuation is negligible.
MM: Also a statement of relative needs— bigger problems elsewhere.
SG: Yes, and I think for DUNE the bigger concern is ensuring lifetime is uniform across the detector both spatially and temporally, so binned in spatial bins, in terms of uniformity, is how it could enter LBL. Make sure granular enough.
MM: In terms of the fits, could just be that as Sowjanya said is that certain effects are sub-dominant, want to reduce the number of free parameters, summarize them with a more basic variable. Not sure if we have those decisions for the TDR, or even if we can do that before data… What one could say is that if you made certain assumptions of the spatial dependence or temporal dependence. Residual bias, which propagates to E resolution in a well-defined way. Then take that level of bias, on how that impacts oscillation observables.
KM: So then, wrap it up and end the result with an E scale measurement.
MM: Impurity profiles is nice if we can get that too.
MM: Biggest priority right now is to show that it works in MicroBooNE data simulation studies. Will take most of the time. Not sure about the DUNE timeline.

TJ: If you are rolling it into E scale and E resolution, know it is from e lifetime— can't add in quadrature if they are correlated.
SG: All of this, space charge, lifetime, recombination etc. go into the E scale. But a necessary step, is to understand what are dominant for E scale. If your lifetime is bad, then that's dominant. We will need to do individual studies to understand this and then there is also the spatial and temporal dependence. And then we will also understand the impact based on the overall E scale.

MM: 2% on E scale is hard. Maybe others think it's different
KM & SG: Agreed. I think 2% is hard.

SG: Conceptually, it is clear that Ar39 is everywhere in the detector and there is a method one can use to measure the lifetime. But, have there been studies in simulation that show what granularity (spatially and temporally) that can be achieved with Ar39 for DUNE? I think it is important to quantify and demonstrate this.

MM: Better we know recombination model, for this measurement is. If we can have a separate set up— hence underground proposal. Data rate is a real concern, before discs blow up. How does that translate to precision on the measurement? Have not studied, for this number of events, what precision can achieve in terms of e lifetime?

SG: For the timeline of the TDR, I am thinking something simpler. Having just a sentence in the TDR that conceptually this is possible is not enough. We should address some of the more realistic questions here such as the achievable granularity with the method at the very least. Can we assume nominal E field for DUNE, and then certain recombination model and then say what the level achievable is? In other words, assume all conditions are ideal (also assume DAQ can support the data rate we need) and get a number for granularity and then use more realistic data rate and see where the granularity stands. We can repeat this for various scenarios and see how the granularity is impacted. And then we propagate things to LBL.

SG: Ar39 has the nice advantage of being EVERYWHERE, so providing some granularity metric will be very useful.

MM: For a number of data rates, all of which are achievable with more work. One can do a Table for spatial precision and temporal precision, and level of precision of what we can achieve for various DAQ rate scenarios (Ideal vs realistic)

SG: Yes, exactly!! for the best granularity.

MM: Yes, this is doable, but the focus currently is on MicroBooNE data, but what you are asking is just simulation. What is the TDR timeline?

SG: TDR timeline is January. First draft due and then more iteration in the following months.

KM: We can reprioritize with our current (simple) estimate for Ar39 impact on E scale, and revisit if people care more about the MicroBooNE method or improving that (too simple?) estimate.

MM: One barrier for DUNE is the appropriate noise model. A white noise model may not make it usable. It affects the smearing; Alex was showing on p28. Does October/November a good timescale to deliver the simulation work?

SG: Yes, Oct/Nov is a good target, will give us a chance to iterate before the Jan. TDR timeline.

Talk 3: Update on electron lifetime studies – Aidan Reynolds

– deferred to next week due to lack of time after the first two talks and discussion.