Minutes, Calibration Task Force Meeting, July 31, 2018:

Attendees: Kendall, Sowjanya, James Haiston, Josh K., Sean Conlon, Vitaly, Richie, Chuck, Hannah Rogers, Jose M., Juergen R., Viktor Pec, Mike Mooney, Jingbo, Bob S., and possibly others.

Josh K.'s talk:
https://indico.fnal.gov/event/17564/contribution/1/material/slides/0.pdf

VK: Seen this table before, but now not sure about data volume for cosmics. Indeed, quite uncertain, but how is it obtained?
JK: Number here is 4500 per day in 10kt.
VK: rate of cosmic is 0.05 per sec. 4500 per day? OK. Just count muons and wires crossed, will be a lower limit.
JK: Standard triggering is take it for 5.4 ms.
VK: No zero suppression?
JK: right. One day, can reduce it with zero suppression, if we find that this much data is too much. Compressed this might come to 2.5 PB/year.

JK: On neutron source, 20,000 in 10kt. Becomes an issue if that number is 100 triggers, 1000 trigger is a problem. 1M is not happening. Need to understand statistics needed. Done every day?
From Jingbo and Bob, trigger rate could be as low as .1 Hz. 10 0.1Hz triggers is OK.

RS: Talked about this with Jingbo. Typically, with each pulse, several hundred captures. 20000 per pulse.
JW: Uploaded talk, slides for this are there. 20k from trigger simulation, shoot downwards. Now we have realistic angular distribution, number is reduced.
RS: and different configurations.
JK: The more captures per trigger the better // more intense the better. Number of triggers is what is limited, because fixed block of data is better. Know there's pile up, already an issue. Not necessarily any worse.
JK: down to 10 neutrons captured, minimal. But still have the t0 (smearing is small)

JK: Understanding how the sphere of influence for spatial pile up criterion, and total statistics needed, and how frequently needed.
RS: Don't know yet.
JW: My talk will provide more details on this. We can discuss it there.

Radioactive sources
SG: Said 1 APA here. Partitioned readout scheme. Here, 2 APAs? or 1?
JK: That factor of two is not critical, in terms of order of magnitude?

Could run like neutrons, prescale it, N triggers with average trigger, but that is less than ideal, without the t0, ambiguity. If 5 of them in the volume, try the combinatorics.
Could take source trigger, and connect it to the APA, and toss them if needed

SG: Frequency this is done, 4 feedthrough, 8-hour run is a calibration campaign. Do it initially, then do just before and after the run. In terms of how often it is done, covers that need. Is that reasonable, Juergen?
JR: Right, planned to do it one at a time— one source, one feedthrough; 10Hz possible, 100Hz is ceiling, because as pointed out, don't want more than 1 event per drift window and hit pile up. Would choose source accordingly for this condition.
Have the electron tracks from Compton tracks. To make the analysis simple, can assign pair production to photon.

JK: Would like to have a talk at the DAQ workshop.
JR: OK!

JK: Front ends are also critical, assuming easily accommodated, but may need more.
SG: Other question was total per year? Responses on red ones?
JK: Yes. Pileup is an issue for source not DAQ. But total number of events, 5.4ms does matter for data selection. As a guideline, 200 TB is not crazy.
JR: Agreed. If it's much more, then it's a problem on our end.

JK: Table is a guideline— because these numbers are compressible/iterative.
JK: Will talk to Dave about the trigger primitives: nervousness about 6 PB/year, it can just be 2 PB/year.
SG: We can also check in and communicate from our side.

On Laser, actually more like windowing for Laser— not using pulses from the laser, not using pulse shapes— just apply a window around that.

Partitioning. Would be running a distinct DAQ system— not needed. But can read out distinct part of the detector— and that's easier— we can call it localization and it comes for free (like RS)

JK: Why we don't do that right away— it's not such a big win. Any given muon lights up 5, out of 150 APAs, but tail goes out quite far. Reduce 150 to 30 or 40. Factor of, at best, 30-5? For the RS source it is different.

SG: OK for LBNC?
JK: thinks so. Before, had issues which didn't add up. Committees get crazy.

SG: The DAQ document that was circulated, has it been updated with most recent details?
JK: Can update it with the new numbers.

JM: How about laser?
JK: We window, go from 100mus vs. 5.4 ms. May get another factor for only lighting up 10 APAs. But real question is if 800,000 pulses enough 4x a year. If we need 5x that number, we need to do more.
JM: One track for voxel, right? crossing tracks.
JK: Yes. Get to use many tracks reused.
JM: Every single voxel gets two crossing tracks.
JK: Yes, that is my understanding.
SG&KM: Yes, that is the goal.

MM: for trigger primitives, is it 12 bits for 39Ar? What does it actually have?
JK: 12 x4, includes time, charge, time over threshold, channel, timestamp (may be in time). Timestamp will roll over. if useful, may need to insert distinctive timestamp, which increases the number.
MM: If it's possible to take a localized region of the waveform? Or set of statistics?
JK: if you can do it with 4 samples and no more than that, it's OK. Picked 12 bits, exactly size of a single sample for that reason.
4 samples by itself, it's free. But more than 4 samples from waveform— 10 samples, multiply by 2.5.
MM: Don't need full dynamic range though.
JK: But could toss the top 8 bits. Then calculate how many samples getting— needs work and effort on that.

Mike Mooney's talk: Thoughts on Rn-222 Source injection

JR: proposed it in July last year, proposed Rn 220. Rn222 gives long lived isotopes.
MM: Rn222 is what they said in the close out report. So, I am presenting thoughts on it.
JK: Wouldn't worry about lead, out of equilibrium.
JR: Still get an alpha. Someone should calculate the rate.
JK: Is that thoron? That's short lifetime, worry would be not get it in in time? Harder to make?

MM: to be clear, I'm not suggesting Rn220 is not good— just addressing the question in the report.
CL: Can buy sources for either one easily.
MM: Also need to figure out how to see regions of the detector.

VK: agree with comments so far. Total circulation time, in order to be uniformly distributed, should be circulated, of order of days. Even Rn222 may not be convenient.
JK: As calibration of circulation, then nice?
VK: What circulation time assumed?
JK: Days. Concern about Rn in simulation— will be hard to see, then not have a radon problem vs. normal triggering.
VK: Need to be careful of the remnants.

Fluid flow mapping

JK: Comment on dark matter. Correct that some have gain, like DEAP or MiniClean is just light— but issue of pileup we have is just so much higher. Much slower detector in the end. They may not realize that. Could say, OK, crank up alpha source, just stands out easily. But already have a hot source— 10 MBq.
MM: If free charge was different, then can do it.
JK: They have a great photon system; we don't have it. Because then, they have timing to see things. BiPo (Bismuth-Polonium) coincidence. If all you're trying to see, could use random trigger, enhanced number of charge deposits in the detector than normal?
MM: Just looking at location. Statistically see it.
JK: Any given APA, 50x smaller than that— more events than before, then see it moving along. But energy calibration bar is much much higher.

JK: Forget about the lead. It's a blob of charge on top of another charge. Could say, larger charge? maybe see it that way?
MM: Some distance in the TPC.
JK: but don't have a t0.
MM: Need light from alpha and beta to do it.
Can say, if we've met our requirement, then maybe say tag light from these decays.
Short time coincidence on the wire which arrives earlier

JK: If you can do it well enough and do electron lifetime all the time.
If didn't have it, live without it. Unless there is something we don't understand. Then we would want to see eddy or dirty argon sitting in one spot.

MM: Continuous readout, even with random triggers?
JK: Could do with primitives. Depends on if you care about vertically. Along detector easy enough to do.

Worth studying and talking about more, but other complications like Pb plating out?

JK: If on the LBNC, would wonder why the free charge doesn't apply. Argument for the factor of 2 in gain. Worried why it is. Put aside scintillation only. But Dark Side. Someone has to say, Dark Side 20k will deploy a radon source, what mistake isn't the case for us?
MM: How do they do that?
JK: Electro luminescence provides gain at the top. Doesn't help if you are trying to distinguish alpha from Ar39
Light readout is much better.
JR: S2 to S1 ratio is different.
MM: Can use BiPo beta, correlated with alpha, so this is what I'm looking for, then use light/S1 to find it.
JK: So then, LBNC developed these calibration— this argument doesn't affect it.
If using depleted argon, then they don't have Ar39.
MM: if using alpha for energy scale studies.

JK: Much better light detection. Crisp and clear.

JR: Single electron efficiency is really different?
JK: Everything we claim, no place say why we can't see 100 keV electrons. People show 100 keV deltas off CR. Then people ask, why not G5 DM experiment.
Then say not that good, contradicts it.
MM: What is missing in all this is S1/S2 PID. Not doing it with free charge.

JR: Compare light efficiency of a DM, very different for what we can detect here. PDS is two different beasts.
JK: Yes. our charge response is fine for a detector this big. Without the light, makes it hard.
MM: Light and gain.

KM: Fluid flow circulation, how does a program look like this?
VK: any way we could discriminate from Alphas and Ar39, always there?
JK: Have to put in a lot hotter source than 39, locally. Given APA, not 10 MHz, 10kHz.
VK: fluctuations for where the flash happens. difficult.
MM: To get the rate above the Ar39 background. Confusing light.
VK: To get the rate above, probably impossible, but to make sure ID signal for source using, from alphas. Betas is more problematic— Bi is maybe OK? Few MeV signal. But then with intensity smaller than Ar39. Ar39 flashes fluctuate. Difficult thing.
MM: Even if alpha is 10x light. Ar39 near anode, and this by cathode, ambiguous.

JR: We are also identifying the radio purity requirements. Rn222 violates this. Reasonably small amount on this, or large light signal. May be problem, of days or so, to have a very strong source.

KM: suggested response is: thank LBNC for the suggestion, initially discounted but going back to it. Have to address concerns:

- Radio purity requirements (under study)
- Visibility of signal and triggering relative to 39Ar
- Photon system is quite different than DM experiments in terms of coverage and efficiency

Neutron generator report - Jingbo

Assumed 50cm port diameter in simulations and considered also the manhole.

SG: Roughly 20cm which is correct, but heard back from the cryostat engineer that it is 21.5cm inner diameter port to be exact.

JK: Coincidence of neutron is low with SN. But if run at beam events, will use neutrons, and so energy lost to neutrons. Capture as well as scatter. If running for a long time, then could get an

accidental from the neutrons from this 200us tail. Should calculate the pile up, 10^-4? Should be sure we have a number.
JK: DAQ prefers to do the triggering, that OK?
JW: Yes.

JK: If it's 100 neutron captures per pulse, then 6x10^4, compare to the 2x10^6 cosmic rate. Limits how often we can do this. 1x a month is maybe OK?
Ultimately the number of triggers. 6x10^6 is what is important to understand.
If pileup limited, really want 1 neutron per APA per 5.4 ms, then if that limited then…
how many total triggers.
JW: Next slide!
SG: Per pulse right?
JK: 1000 per m^3, per pulse, if 100 captures per pulse, that's 10^4 triggers, and that's not so bad.

JM: Time between generator and the capture?
From simulation?
JW: yes.
Moderation time is not included, nor reflector. For this, just shoot 73 KeV neutrons into LAr.

JM: This average, did a quick calculation of travel time/velocity and how long takes to cover half of the detector. Of order 1ms? Average may be heavily biased by large number of neutrons which capture close to source? But, we really want the ones farther away. Maybe 120us is maybe underestimate?
JW: good point.

JK: For the DAQ, don't care—- not the same for the calibration. Latency wasn't the neutron capture time. Latency to the source vs. time neutrons exit. Does it warm up for 10 ms? 5 secs later?

JM: Full time produced a neutron to the far part of the detector. If cutting at 5.4ms, then blinding self?
JK: Think it can't be that long though. They'd have to bounce a long time.
JW: Longest in simulation is 1ms. Will check.
JK: More like water than heavy water.

How much illuminated? Long neutron lifetime, don't know for each capture, don't know how far travelled. May have trouble along the electric field.

JK: Move source?
JW: That's one solution.
JW: Best case is to run LArSoft— right now Geant4.

VK: When saying neutron lifetime is 120us, does it include Thermalization // diffusion // capture.
JW: defined time as between neutron appearance and disappearance. Dominated by capture time.

CL: cross section for Ar40, is 0.66 Barns.
VK: Hydrogen is .33 barns. Looks reasonable, about 100us then.
JK: yes, like water. Travel far, but then once thermalize its capture time.
Thermalizing in LAr, vs. room temperature water. Capture cross section goes like 1/velocity.
=> Consider temperature.

JK: if decide 10 captures per pulse then in trouble.
How many runs expected, not sure?

JW: If decide to use manhole, need to submit request to design engineer.
KM: Won't be able to adjust the first cryostat re: manhole in center.
SG: Yes, it is close to impossible to request additional ports at this point.

MM: How arriving at the number?
JW: No analysis for this, but the assumptions are here. If you can localize, for 1 cubic meter, then so many neutrons.
JW: May be hard to localize along field capture. Will need to run LArSoft to refine this.

MM: Do you have everything in LArSoft? Or need development?
JW: Just need a neutron gun. If capture is done right, can use that.

JK: Won't update table, until hear from Jingbo and Bob re: pileup. Numbers are the same right now. If they decide 20k is too many, 200 is acceptable, then noticeable change.
JW: OK.

JR: Did Jingbo and Bob calculate how long can run before activation of Ar? Will activate Ar37 and 39. But not sure what run time is significant.
JW: Not done yet. But we think the DD generator of 2.5 MeV.
JR: Look at Q value for Ar36 and 38— 8-9 MeV?
VK: As trying to capture neutrons, and main contributors will be Ar40. But 36 and 38, also captured on those.
JR: yes. But then activate Ar37, half-life of a month.
VK: Thermal neutrons will activate. May not be a problem, but need to be sure.
JK: Ar39 can't be an issue— 200-year half-life. Others are different and we should consider.

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Other discussion:
Someone: I had one other question, apologies, can send an email. Is there any discussion of if the PDS DAQ requirements go up if we use them for calibration? So far we have not considered that in our DAQ budget.
is using PDS for say, Radioactive source tagging a deal breaker? I assume their data rate is lower than the TPC but I have no idea.

JK: The calculations so far assume that the PDS is a negligible data source. The reason is that it will almost certainly be zero-suppressed (because there really isn't useful waveform information) and because the total number of channels is relatively tiny. I don't know how that will change for calibrations…so it is a good question.

What are radio purity requirements?

JR: <10 mBq/ kg requirement on Rn-222 as e.g. on slide 19 of my summary talk at the DUNE collaboration meeting in Rapid City on May 20, 2016:
https://indico.fnal.gov/event/10612/other-view?view=standard

BTW it strikes me as insane to inject Rn-222. I'm currently gamma-screening the protoDUNE molecular sieve and copper getter material for radon parents, as well as light detectors for radon daughter plate-out and the ARAPUCA materials. No dark matter experiment I'm aware of would inject Rn-222 unless they want to ruin their detector at the end... short-lived Rn-220 (aka thoron) is the typically injected isotope which does not leave long-lived daughters in the detector

Thanks! It is currently a problem that radio purity has fallen through the cracks in the reorganization structure of DUNE. The way I addressed this in the meantime is that in pretty much every consortium I have taken the responsibility for radio purity and materials screening...