Slides: <https://indico.fnal.gov/event/51519/>

### **CEvNS:** - **Sonia Bacca (Mainz)**

Yong Du (YD): Recently done a similar study in EFT frameworks. Are there projections for future topics (table on slide 6)?

SB: Clarify question related to theory or experiment?

YD: From COHERENT CsI and LAr we have detailed results, our group has done related work on results, for future targets do we have any projection for future experimental targets

Jason Newby (JN): For near term COHERENT results, deploying natGe detectors this winter and also NaI detectors with CEvNS sensitivity to Na. Those are two queued up with previous results on CsI and LAr, expect similar results

YD: I ask this question as with projections for future targets we can perform study based on those results. From our study using LAr target much better than CsI. Interested in future targets.

YD in Zoom chat: In case you were interested in our results from an EFT perspective, the paper I’m talking about is <https://arxiv.org/abs/2106.15800>

### **PVES:** **Charles Horowitz (Indiana)**

JN: Given theoretical developments and planned/current experiments, do SB and CH have any questions for each other?

CH: We measure weak FF on 48Ca, how well can Sonia extrapolate to 40Ar?

SB: Theory one can use for 48Ca same as 40Ar in terms of interactions, can connect it. Coupled cluster theory better for 40Ar. Should be able to do it quite well. If have error band, can redo with same Hamiltonian for 40Ar

CH: If we measure 48Ca to better than 1%, can you measure 40Ar to better than 2%

SB: Need to check previous calculation but likely not better than 1% but can likely do better for 40Ar.

SB: How can we nail down spin-orbit contribution?

CH: Form factors for weak currents are known, need to include consistently. Leads to numerical difference, weak-charge radius bigger than point proton-point neutron radius.

SB: This always done by theory, completely rely on theory and check understanding of two-body currents, spin-orbit terms on other nuclei.

### **Discussion:** What new PVES experiments (and additional nuclei) are needed to achieve precision in the CEvNS cross section estimate?

Rex Tayloe (RT): Understanding observables for large CEvNS detector. Has anyone worked on observables that are more than just a rate? Look at highest q^2 events to have checks on FF or PV measurements?

CH: Some kind of ratio of high vs low q^2 or some way to get FF with less sens to systematics such as neutrino energy scale. With PV, have high res spectrometer with well known E, control excited states, high q^2 leads to excited states.

JN: SB mentioned areas where theory will do better than others (closed-shell nuclei). If instrumentation-wise, driven to certain nuclei. Is there a way to categorize which nuclei we can measure to nail down FF. Be careful about choosing nuclei in categories so measurement best inform theory to extrapolate?

SB: Best case to measure, simplest is 12C, similar mass number is always good. Better control of systematic errors in theory.

SB: From experiment, is it possible to think about PVES on same nuclei as CEvNS?

CH: There are certain targets easier than other. First excited state high in energy, otherwise difficult to resolve. Ar40 needs windows (assuming gas target), probably possible with constraints on measurement time. Think about 40Ca along with Ca48.

SB: Plans at JLab to do 40Ca?

CH: In short, no.

Sergey Pereverzev (SP): On neutrino energy range: What experiments are possible at higher energy? Different ranges for neutrino energy (reactor, accel.)

JN: Demonstrated is higher energy such as pi-DAR. Asking what is best overlap with low energy and FF? Low energy affected less by FF contributions. Whole new area opens up once demonstration of reactor CEvNS physics.

SB: Theory point of view is difficult. Higher energy has inelastics, need to subtract so harder.

### **Discussion:** what new theory developments are needed to achieve precision in the CEvNS cross section estimate?

How well does validating a theory with a measurement of one nucleus extrapolate to confidence of that theory for another nucleus?

### **Low-Energy Inelastic Scattering:** (supernova/solar/piDAR/KDAR neutrinos)

### **Theory Perspective:** - **Anna Hayes (LANL)**

RT: re: charged current, advantage of setting Carbon, is order millisecond states near to Carbon, like Ni12 and boron 12. Not the case for any of the charged or neutral current for Ar, all short lived, decay. Is this true? AH: for CC, that’s true, will have to look at outgoing lepton. For NC, could see gammas, only able to see in the 10 MeV range, and other people with different detectors say they can see lower than that. I’m not an experimentalist. Will take time to figure out what the Ar detectors can see.

Offline comment (Sam Hedges): There is a meta-stable 0+ state in 40K at 1.64 MeV with a half-life of 336ns. It would be hard to detect/distinguish from the prompt charged-current signals, but it is significantly longer than the fast scintillation decay component of 40Ar. I don’t know how often this state would be populated, but it is the lowest energy state in 40K reachable through allowed transitions from a 40Ar nucleus.

### **DUNE** **Perspective:** **Erin Conley (Duke University)**

<no questions>

Offline question (J. Newby): Are accurate cross sections only required for analysis of SN data? Or are accurate cross sections needed to inform detector design or online triggering algorithms before SN occurs?

Erin Conley: Hi Jason, I think that accurate cross sections would certainly be useful for detector design (photon detectors come to mind) and triggering, but I really couldn’t say how useful or what they would inform on. I humbly ask experts to chime in here

<10min break>

### **10s of MeV and KDAR (236 MeV) Neutrino Scattering Measurements**: **Taritree Wongjirad (Tufts)**

<no questions>

### **10s of MeV and 236 MeV Electron Measurements at MAMI and MESA: Luca Doria (Mainz)**

Joshua Barrow: Tell me more about the target. I’m unfamiliar with it. Super cool. LD: Yes, it’s a jet. It comes in at low temp and high pressure. It’s close to gas liquid transition. Called “Laval nozzle”. Then, supersonic expansion. In this process, gas creates lots of clusters of atoms/molecules, increases density even more. Electron beam goes right to the gas stream. Only material in exit windows of the target, which are very thin. JB: You don’t have to do Al subtractions except for windows? LD: Nope, no subtraction not even for the windows. Last week, we did an empty target measurement, no stream, and saw no background. We still need to be careful-- not hit catcher, beam has halo, etc. But, technical issues. Seems to work fine, and hope it will stay there! So we can take the data before the target will be sent to the other accelerator.

Afroditi P: this is quite exciting, p17. I’d like to comment-- for comparison to GENIE, use latest, identified issues in previous iteration-- electrons for GENIE has evolved. And important for uB and NOvA. LD: Artur made this-- and results may not be too different between versions. Of course, we are happy to try before publication. AP: They will be different-- and can see it change in the resonance channels-- consistent w/ latest model. LD: Agreed.

AP: Slide 18, do we understand what’s happening at lowest energy transfer? LD: almost an online analysis, for this workshop. The stuff here-- artifact of fine binning. I did wide binning. AP: thank you! JB: Interesting to see here what Vishvas sees in this energy regime. VP: Yes, we expect giant resonances not covered. As Luca said, it was a fast analysis, and we expect peaks here.

JB: FYI, misspelled GiBUU. LD: Argh! Sorry. I was communicating with Ulrich.

### **Discussion:** What electron scattering measurement (and what nuclei) can be considered to achieve precision in this energy region?

KM: kickoff! Connect Erin to Taritrees talk. We see lots of facilities, and sensitivity to the interaction model. Do we have sufficient measurements to validate this?

TW: We don’t have ANY measurements at ALL. That’d be great. I also appreciated Anna’s talk about gamma energies. LArTPC is great, but slow, and surface can add complications.

 -> Need to clarify how we get at the gamma energy spectrum for these measurements.

EC: To my knowledge, it seems like COHERENT and CCM are evolving toward LAr detectors that will partially focus on nueCC cross section measurements. That might be years down the line, and I personally don’t know of any near-term plans for measurement.

KM: Re: the DUNE based studies, do we see where measurements are going to clarify uncertainties in the sensitivity studies? Example: how key is the gamma features in their view?

EC: Hello, the smearing matrix we developed for the paper (i.e., the DUNE-like detector performance assumption) included all energy from de-excitation gammas. That’s certainly an optimistic scenario. To be totally transparent, we used the “visible energy” definition from<https://arxiv.org/pdf/2010.02393.pdf> (Eq 72 on page 17). Hopefully DUNE will be able to reconstruct this much of the SN events, but I admit it’s a very optimistic assumption.

I hope this somewhat answers your question; please let me know if I haven’t.

KM: other measurements for the LE regime? JN: We touched on oxygen xsec for SN energies. Heavy water detector which will measure deuterium, measure the oxygen CC. But, with limited statistics for that detector. First measurement and then could be scaled to larger.

JB: If we want to inform CEvNS style LE interactions, is it useful to look at electron scattering (ES) for that? Is the propagator similar or different?

VP: CEvNS is different from others-- for that we get in PVES, form factor, neutron radii which is directly input to ground state. And, directly input to any nuclear model. For inelastic scattering, more states in nucleus-- then have vector and axial part, and vector part is constant. At MAINZ, will be useful for nuclear models at this energy. The theory predictions are SO different from each other. \*\*VP, please edit\*\*. Model predictions, some robust models, but very different predictions.

AH: I agree, especially for excited states, would

=> give Q dependance of the vector current

Better than q=0 which is all we have now.

AH: Ideally, be able to measure those photons in neutrino neutral current. I don’t know how hard that is. Detector dependant. Here are the gamma rays you will see. If not, electron scattering would greatly constrain theory. Right now, those gamma ray states strongly excitated would be informed.

KM: In my limited experience, detector model can conflate our interpretation for neutrino interactions (we try to run test beams to constrain the detector model, but particles out of the interaction can create secondary interactions resulting in backgrounds) T2K paper: <https://journals.aps.org/prd/abstract/10.1103/PhysRevD.100.112009> <https://arxiv.org/abs/1910.09439>

AH: In 10 MeV e+/e- may see that. KM: yes, I think so.

### **Discussion:** What theory developments are needed for the 10s MeV region?

KM: generator support needed? JB: Number of generator theory intersections needs to be larger. If there’s an important model, we need to get that in. from GENIE side, have not looked so hard at LE validation. Don’t know what it looks like.

 => Clarify or revisit, is MARLEY enough?

VP: MARLEY still has limitation of person power limitation.

=> Echo main concern, generator at all energies, and specifically this, need people support.

VP: Anna’s talk, at higher energies, even 20 MeV, GT strength is not enough. Need more operators. So, it’s limited region of workability. As far as GENIE is concerned, CRPA model, managed to put into GENIE. Not officially in yet-- paper: <https://arxiv.org/abs/2110.14601>.

SB: Re: MARLEY vs. other theories, where we can see it at log scale? Seems like not? well constrained from theory point of view.

VP: Taritree had a slide, angular distribution p20. MARLEY has only GT strength operator, and in CRPA, if put whole operator, then it induces change as scattering angle.

SB: Also, let’s establish a range of theoretical uncertainties. (each curve needs an error bar, or it’s hard to say what’s right). It’s not trivial to do-- for ab initio, putting a lot of effort into this. Count every possible source of uncertainty. But, major shift to consider this.

SB: LE regime is where ab initio could add. My group is focused on QE region. Need to do expansion in low Q of multipoles. Can change interaction, can make bands.

AH: Theoretical error bars is very difficult. Problem is, if you consider all that comes in, error bar which is so large, that calculation is useless. If self confident-- can be too small.

KM: We can expose where experimental inputs did come in-- form factors are a great example.

AH: Yes. And, if we use only beta decay, only at q2=0, then that’s a driving factor.

AA: going to exclusive measurements is a high priority-- CLAS will also add here.

SH: Brought up about transitions for MARLEY and pion decay at rest-- that was my comment.

AA: Specific parameters or specific processes needed? CLAS for example, will make transparency measurements. JB: Most of the time, when looked at code, scattering nucleons have minimum kinetic energy, 50-100 MeV. Still have FSI at these low energy transfer-- does anyone look at that? Is it relevant? VP: it depends, for some LE scattering, photons knocked out, so not so much an issue. And some case neutron or proton, yes it matters.

KM: What will CRPA get out of the KDAR? Seems powerful for that. VP: Interesting region, mix of QE from LE, transition region. Any measurement, of fixed neutrino energy, as exclusive as possible. Energy of outgoing muon and scattering angle. Looks like LE, 236 MeV, but actually probing for MiniBooNE excess. For GeV beam, significant phase space, in this kinematic region.

=> VP: it may not be possible, but if we could see the LE excitations peak? Not sure if any detectors CAN do this, or have the resolution to do it, but that would be quite interesting. But, I suspect it may be the sum of bins.

 TW: LAr TPC, may get percent level of muon energy. If calorimetric. KM: I’m more cautious here about what has been achieved, but good to pose the question and answer it.

### **White Paper Discussion: Vishvas and Jason**

### Unified electron scattering white paper? (<https://www.overleaf.com/4212219177vsnmhzfkmtfg>): discuss outline, solicit contributions

SB: Is it one white paper? Or two? VP: plan is one unified WP relating electrons to neutrinos for all energies. SB: Makes sense.

KM: <Comments, add. Some overlap in physics, certainly overlay in need to better exchange and have connection between NP and HEP>

JB: Exec summary may need to be more, 1 page may be too small.

VP: If we have two separate WP, repeat a lot, same issues. Shortens length if put together.

I think that it should be mentioned at Sections 5 or 6

=> Ask Horowitz where they should go.

Tomalak: Sorry, have some audio troubles. How about covering pion production on nuclei for neutron skin? I.e., https://arxiv.org/pdf/1904.12269.pdf or https://arxiv.org/pdf/1504.08347.pdf

 => Add this as a subsection. Thanks for the good idea!

JB: MIT Tau group will contribute. KM: Yes, thank you thank you!

SB: Can offer to help section 3.2. => invite Chuck to help, give Sonia details. Thanks!

YD: Probably I can help with CEvNS (its implications on EFTs)

 => Send Yong the link. Thanks!

KM: Where does KDAR live? VP: Yes, only as motivation. KDAR should live in motivation-- section 3.

 => 3.2 section on KDAR. Taritree says he can help. Thanks!

KM: And also in topical group report as well.

VP: Sign up Luca for 6.2? LD: yes, sure.

SB: Theory paper as well? VP: yes, there is also a theory white paper. topical convener

 => Clarify the theory white paper overlap. Nominal plan is to put our material here

SB; i’m not clear on the Snowmass-- I see what is in the theory white paper-- will not be 100%, focused on theory, and this is more on the experiment.

----- session ends ---

Add offline notes here: