C12-14-004: *Update to the JEF proposal (PR12-14-004)*

R. Edwards

This project has evolved since it was first proposed in PAC40, although the big picture is still present. The eta system and decays provides an interesting testing ground for the Standard Model. In the phase II part of the program, backgrounds can be reduced substantially to allow for new tests, or rather constraints, on chiral PT allowing for explorations of the scalar sector of QCD, SM forbidden decays, as well as constraints on a possible new gauge sector. The significant reduction of the exclusion region for new gauge bosons is intriguing, but it must be remembered, this is one of many possible extensions of the SM.

Nonetheless, the many possible SM violating channels will have large numbers of photons and thus challenging to observe, so much apparently rides on having a new FCAL-II. We agree with the PAC recommendation about the need for running concurrently. Thus, the assessment of the viability of the new FCAL will need to be judged by the PAC.

C12-16-001: *Dark Matter Search in a Beam-Dump eXperiment (BDX) at Jefferson Laboratory; and update on PR12-16-001*

D.G. Richards

This is an update to the original proposal that was conditionally approved at the last PAC in 2016. The update includes some theoretical and experimental developments since the last PAC that only strengthen the case, and the aim of the update is to address issues raised by the last PAC that are not pertinent to the theoretical justification. The original proposal was distinguished by an outstandingly thorough theoretical review, and my comments are reproduced below.

> This proposal seeks to search for, or place limits on, a class of candidate dark-matter theories and particles known as light dark matter (LDM), that is where the dark-matter fermion (or possibly scalar) has a mass ranging from a 10keV to around a GeV. The dark-matter particles are produced through their interaction via a "dark photon" in a beam dump, and then detected via their interaction, either with an electron or nucleus, in the detector.
>
> The proposal provides a truly outstanding review of the physics of LDM and in particular the various mass hierarchies of such models, i.e. on the masses of the A' and of the χ; a review of the motivation for dark matter is provided in the appendix. There is also a very clear review of current contraints on LDM parameters, namely $m_{A'}$, m_χ, and the various couplings and mixings, and the potential for this experiment to provide yet more stringent constraints, notably in the kinetically mixed and leptophlic scenarios, very well demonstrated. As a theorist, I can add little and indeed found the description incredibly informative. In any high-precision experiment such as this, crucial is a study of the backgrounds, but the team appear to have done this very comprehensively, including both background arising from the beam and cosmic backgrounds in the detector.

LOI12-17-001: *Study of J/ψ photoproduction off Deuteron*

D. Richards

This letter of intent is to add exclusive photoproduction of J/ψ near threshold from a deuteron target, as an addition to Run Group B. Broadly, the interest in J/ψ photoproduction arises from the fact that it interacts with the target primarily through two-gluon exchange and therefore has the potential to provide a window on gluonic observables and gluonic structure in the nucleon, including, for example, the gluonic contribution to the mass. Furthermore, since charmonium is relatively "compact", its interaction in nuclei can shed light on issues such as color transparency.

The challenge, as the LOI primarily addresses, is the various competing process, namely production off a quasi-free nucleon, J/Ψ production followed by final-state interactions between the nucleons, and finally J/ψ production following by its final-state interaction with a nucleon. Thus the LOI examines various detection scenarios and geometries to assess the ability to discriminate between the different mechanisms, which is important. The LOI stresses the need for more detailed simulation studies, which will be important.

To carry this letter of intent forward to a proposal, it seems to me they need to quantify the extent to which the key physics questions will in fact be addressed, and to provide a more detailed physics motivation accompanied by references; a notable absence, for example is work by Kharzeev and collaborators. To me, the most fundamental one might be the fact that the two-gluon exchange mechanism is should be "flavor-blind" and a comparison of deuteron and proton scattering data should be able to explore this, but this needs to be quantified in the proposal.

LOI12-17-002: *Search for a ϕN Bound State at Hall B*

R. Edwards

The possible existence of multi-quark states of hadrons, beyond the simple qqq and $\bar{q}$ picture, is an intriguing possibility allowed by QCD. The possible existence of hidden-charm pentaquarks states, reported by LHCb, has heightened interest in such searches. This LOI lays out a possible experiment within Hall B searching for $\bar{s}s$ contributions within nuclei, and in particular, will look for the possible existence of $\phi - N$ states. In S-wave, this might appear as a bound state. The interest in such systems is that they give us some insight on quark-gluon dynamics. There could also be resonant contributions as well in higher waves, and this might be the pattern observed in LHCb.

The lead author has carried out a series of model calculations trying to quantify the S, P, and D-wave systems for many baryon-meson systems. The initial concern I have with such calculations is that the interactions within nuclei, in particular large nuclei, might smear out significantly the simple appearance of a bound state. However, some evidence for such bound states have also been found in lattice calculations by NPLQCD, in particular in $^4He\phi$, where they found they find a substantial binding energy for the system, albeit in the $SU(3)$ limit of QCD, so large quark masses. Still, there is a strong possibility such a state will remain bound in the physical limit of QCD.

The LOI seems intriguing. However, as the authors note, there is more work needed on investigating backgrounds. The arrangement required in Hall B is a bit unusual. It appears that robust kaon id is essential.

Nonetheless, such multi-quark systems could very well be a un-common picture. Such scenarios can easily be conjectured for bosonic systems, thus there is a possible synergy with a Hall D program.

LOI12-17-003: *Studying* Λ *interactions in nuclear matter with the* $^{208}\mathrm{Pb}(\mathrm{e},\mathrm{e}'\mathrm{K}^+)^{208}\mathrm{Tl}$ *reaction*

J. Goity

This letter of intent is for Hall A and focuses on hypernuclear physics in heavy nuclei. There are several good motivations for the study of heavy hypernuclei: one is that hyperons serve as deep probes of nuclear structure, and another is the importance of hyperons in dense nuclear matter, in particular neutron stars, where they can affect the EOS which is key for understanding them. The proposed study of electroproduction of a heavy neutron rich Λ hypernucleus using ^{208}Pb as target in Hall A is thus well motivated from the scientific point of view. The improvement in resolution of the missing mass spectrum with respect to experiments carried out with pion beam will provide important more accurate information that will advance our understanding of heavy hypernuclei and possibly the role of hyperons in dense nuclear matter.

The proposed experiment with Pb target represents the natural extension of the already approved experiments with ^{40}Ca and ^{48}Ca targets. The experiment proposed in this LOI was part of a proposal submitted to PAC40, where it was recommended that the experiments with light and medium-heavy hypernuclei be submitted as separate proposals.

The proposed experiment is clearly important for the more accurate description of the physics of heavy hypernuclei, and for understanding the dynamics of hyperons in neutron rich nuclei, needed for better quantifying hyperons in nuclear matter an their effect in the EOS needed to describe neutron stars. As such, it is an important experiment for the hypernuclear physics program at Jefferson Lab. The collaboration should be encouraged to submit a proposal.

PR12-17-001 *Strange Hadron Spectroscopy with a Secondary K_L Beam at GlueX*

K. Orginos

This project intends to create a secondary K_L beam at GlueX. This is a new facility that will enable important new experiment. The authors propose to study the strange baryon sector resonances up to 2.4GeV. This is a well motivated project that will enhance our understanding of hyperon resonances. Expected future lattice QCD calculations provide a good argument for the timeliness of this experiment. Furthermore, the authors argue effectively that the improved knowledge of the hyperon spectrum may provide improved understanding of the hadronization process at RICH and LHC experiments. Finally, this facility is expected to enable experiments in the meson sector determining the pole positions and widths in systems with P-wave and S-wave $K\pi$ up to 2GeV. The authors have addressed the questions from PAC43 and provide Monte-Carlo simulation results as well argue that indeed this proposal is competitive with J-PARC. However, it is not clear that this facility can be competitive with J-PARC once J-PARC becomes operational.

PR12-17-002: *Compton Edge probing basic physics at Jefferson Laboratory: light speed isotropy and Lorentz invariance*

I. Balitsky, T. Rogers

In recent years there is a surge of interest for possible violations of Lorentz symmetry so the proposed JLab experiment on isotropy of speed of light appears to be very timely. Needless to say that in the case of observed anisotropy there is no need to worry about possible consequences for physics - there will be plenty. The proposal is to use the Hall A/C setup to put constraints on Lorentz invariance violations at several orders of magnitude greater accuracy than currently exist. It is planned to use the Compton Edge (CE) method proposed by one of the authors. This will be used to test both the light-speed isotropy and the dependence of the speed of light on velocity. However, if the result will give experimental bounds on anisotropy it would be nice to understand which models of Lorentz violation they restrict and to what extent. For example, in the discussion of SME effects due to massive vector bosons the restrictions of the parameters of the model are not discussed in the proposal. Similarly, it is not clear what will be the consequences of the improved limit on anisotropy for modern models of dark energy or dark matter. From the non-expert's point of view, it looks like that: with new JLab accuracy which is 10^2 times better than the GRAAL experiment the authors of various models just need to divide their Lorentz-violating parameters by an extra 10^2, and it is not clear how the improved accuracy is helping to distinguish between those models. Still, we think that the proposed experiment should be pursued since it will put JLab on the map of "New Physics" searches.

The CE method exploits the observation that errors in speed of light measurements are suppressed by a two factors of the Lorentz factor $(1/\gamma^2)$ relative to shifts in the position of the Compton edge. Thus, it is suggested that measurements of the Compton edge in inverse Compton backscattering off highly relativistic electrons can put stringent limits on possible variations in the speed of light. The experiment will use existing facilities. The proposal includes an extensive overview of the importance of potential Lorentz invariance violations to fields such as cosmology.

The experiment is interesting and potentially very important. Especially given that it uses existing facilities, it should therefore proceed. Feasibility is demonstrated with Monte Carlo event generator simulations, but I would be interested in a more extensive discussion of the assumptions that go into the event simulations, and how they might affect the uncertainty on any possible observations of Lorentz invariance violation. How strongly do the results rely on the specific models of Lorentz invariance described in the introduction to the paper? Also, there are some stylistic/grammar problems in the proposal. For example, after Eq.(16) is written "The common in these models...". These should be fixed.

PR12-17-003: *Determining the unknown* Λ-n *interaction by investigating* Λnn *resonance*

J. Goity, J. W. Van Orden

This proposal is for Hall A and focuses on light hypernuclear physics. The motivation and aim are to improve the current knowledge of the ΛN interaction, which is largely an open problem, with relatively limited knowledge of the Λp and no knowledge of the Λn directly from experiment. Although the ΛN interaction can be inferred to a large extent from only knowing Λp on the basis of isospin symmetry, it is of great importance to have knowledge on the isospin breaking because it can have important effects in hypernuclei and neutron matter. Isospin, or charge symmetry breaking in the strong interaction is driven by the mass difference between the u and d quarks. CSB has been determined by comparison of measurements of mirror hypernuclei $^4_\Lambda$H and $^4_\Lambda$He hypernuclei, and turns out to be larger than naively expected. Undoubtedly, the accurate understanding of ΛN interactions and CSB represents a fundamental problem in hypernuclear physics. It must be emphasized that in spite the long history of hypernuclear theory, there is still significant progress to be made, for which accurate experimental results should be of essential significance.

The proposed experiment would use a tritium target for the reaction $\gamma^*\ ^3\mathrm{H} \to K^+\Lambda nn$ (such a target will be available for other prior experiments, which is a great advantage). Measuring the observables of the three body Λnn system can provide valuable information on the Λn interaction. Of particular interest is the possibility of determining CSB in a complementary way to what has been done so far, and in itself, if resonant behavior or even binding is observed, this three body system will become of paramount importance. For instance the possibility of an Efimov state for the Λnn system is not ruled out and if it is found it would represent a major discovery. This is particularly important in view of reported results from the GSI HypHI experiment, where indication of a bound or resonant state has been suggested. Since this indication has attracted a lot of theoretical attention, it is important to have new experimental results to confirm or invalidate those observations, if possible with more accurate measurements.

The advantages of the proposed electroproduction experiment in Hall A are clearly articulated in the proposal. From a practical point of view, the tritium target will be already installed for previous experiments, a great logistic advantage. The proposed experiment addresses fundamental aspects of hypernuclear physics, which are of relevance for understanding CSB in mirror light Λ hypernuclei, and also eventually in hypernuclear physics in neutron rich nuclear matter. This would be an important experiment in the Jefferson Lab hypernuclear program.

PR12-17-004: *Measurement of the Ratio* G_E^n/G_M^n *by the Double-Polarized* $^2\boldsymbol{H}(\vec{e}, e'\vec{n}\,)$ *Reaction*

W. Melnitchouk, R. Schiavilla

The proposed experiment aims at extracting the ratio of neutron electric to magnetic form factors by measuring the longitudinal (P_z) and transverse (P_x) polarization transfer observables in the reaction $^2\mathrm{H}(\vec{e}, e'\vec{n})$. The measurement would be carried out at a four-momentum transfer squared Q^2 of 4.5 GeV^2, and would extend our empirical knowledge of this ratio, which is presently limited up to Q^2 of 3.4 GeV^2.

The neutron (and proton) electromagnetic form factors are among the most fundamental quantities characterizing the extended structure of baryons. They are a crucial testing ground for models of baryon structure and provide important constraints, via sum rules, for the modeling of GPDs. These form factors are also essential input in calculations of electroweak structure and response of nuclei. From this perspective, the scientific relevance of the proposed experiment is high.

There are also two competing, and already approved, experiments to measure the ratio G_E^n/G_M^n: the first scatters longitudinally polarized electrons from a polarized ^{3}He target (E12-09-016); the second uses the same process of the present proposal (E12-11-009). Both of these experiments have a much higher reach in Q^2 (10 GeV^2 and 7 GeV^2, respectively). The relative merits of this proposal versus E12-11-009 in particular rest in the experimental aspects concerning improvements in understanding the analyzing power and systematics for small-angle recoiling protons.

PR12-17-005: *The CaFe Experiment: Isospin Dependence of Short-Range Nucleon Pairing in Nuclei*

J. W. Van Orden, W. Melnitchouk

The object of this proposal is to extract the percentage of correlated *np* and *pp* pairs in a variety of nuclei using the $(e, e'p)$ reaction. This is motivated by results obtained from the Hall B data mining program. This analysis is based on the integration of reduced cross sections over ranges of missing momentum below and above some value characterized by a Fermi momentum, which is chosen such that the lower integration range is characterized by the "mean-field" contribution and the upper by the effects of short-range correlations. The results of this analysis are shown in Fig. 1 as a function of neutron excess for the measured nuclei, and then interpreted as a fraction of correlated nucleon pairs normalized to ^{12}C in Fig. 3. The proposed measurements extend this work to include additional nuclei. These are chosen to fill in gaps in the previous work and to include some nuclei for which *ab initio* calculations of the ground state wave functions are available. Ultimately, the objective is to determine the percentage of correlated pairs in the various nuclei.

The assumption here is that a careful choice of kinematics can lead to a minimization of exchange currents and final state interactions (FSI) and two-body currents. If these effects are indeed quite small, this motivates a factorization of the cross section allowing the isolation of nuclear momentum distributions. The momentum distributions can then be related to target wave functions. Calculations for the deuteron have shown that while kinematics can be found which tend to minimize the final state interactions, the contribution of FSI is not negligible and varies considerably with the choice of bound state wave function. As a result, the experimental separation of the ground state components will be subject to a nontrivial error. Furthermore, the proposed kinematics given in Table 1 of the proposal would give x_{Bj} for central values of slightly less than one, rather than at larger values of x_{Bj}, significantly greater than one, where FSI and two-body current effects are expected to be minimized.

The fundamental theoretical problem with this work is that the quantities that are to be obtained from these experiments are not quantum mechanical observables. It is not possible, in principle, to measure momentum distributions or correlated pair fractions from the $(e, e'p)$ reaction, and at present there are no credible calculations of this for the range of nuclei at the proposed kinematics. It is possible to obtain these quantities from calculated wave functions, but the wave functions are not observables. The challenge for the authors of this proposal is therefore to demonstrate that a theoretically sound interpretation of the results of the measurements can be obtained, that would be well-defined in the context of field theory (QCD or some low-energy effective theory).

This said, even though the information extracted from the proposed experiment are, of necessity, only qualitative, the trends shown are interesting and should, hopefully, stimulate theoretical efforts for calculating reactions on non-symmetric nuclei. Indeed, this is a major problem for the interpretation of neutrino oscillation experiments utilizing argon detectors.

PR12-17-006: *Electrons for Neutrinos: Addressing Critical Neutrino-Nucleus Issues*

R. Schiavilla, J.W. Van Orden

The present proposal aims at carrying out a systematic study of electron scattering off ^{4}He, ^{12}C, ^{16}O, ^{40}Ar, and ^{208}Pb for incident electron energies ranging from 1 GeV to 8.8 GeV with the CLAS12 detector in Hall B. Because of the large acceptance of this detector system, including its enhanced neutron detection capabilities, it will make it possible to identify hadrons (pions, protons and, most importantly, energetic neutrons) produced in the reaction, and to isolate specific reaction mechanisms, such as quasi-elastic scattering and quasi-free resonance production as well as more complicated processes, for example multi-nucleon knock-out.

The set of proposed measurements is critical for the current and future neutrino physics program in the US and elsewhere. Neutrino oscillation experiments compare the interaction rates between near and far detectors to reduce the systematic uncertainty associated with ignorance of flux, nuclear effects, and cross-section details. This does not reduce these uncertainties to zero, however, for the simple reason that the neutrino fluxes in the near and far detector are not identical (see Fig. 1 in the proposal) and his difference ensures that any uncertainty in neutrino cross-sections, nuclear effects, or flux will still play a role in the final systematic error accounting. For this reason oscillation experiments must incorporate accurate modeling of neutrino- and antineutrino-nucleus interactions even if they have multiple detectors.

These oscillation experiments aim at few percent-level measurements of neutrino event rates and precise measurements of the energy distribution of events. In order to meet these goals, a detailed understanding (at the % level!) is required not only of neutrino and antineutrino cross sections on nuclear targets, but also of nuclear effects that can alter final-state particle composition and kinematics and hence distort the inferred incident neutrino energy.

The way the neutrino experiments make use of their knowledge of neutrino interactions is to implement models for the above processes in event generators. These generators must simulate all particles produced in an interaction over the entire available phase space for the beam energies in question. So far, event generators have only been tested against inclusive (e, e') data. The data provided by the present proposal will permit the testing and calibration of these generators in semi-inclusive channels. This is crucial, since current and future neutrino detectors, notably the liquid Argon TPC in DUNE, are capable of detecting, beyond the out-going lepton, all final-state charged hadrons. Additionally, the CLAS12 capability to detect neutrons will provide critical benchmarks to validate the modeling of neutron emission and neutron multiplicity by event generators, an issue that impacts the difference between neutrino and antineutrino cross sections and hence the determination of the CP-violating phase. Event generators currently in use differ dramatically in their predictions of neutron multiplicities (see Fig. 11).

PR12-17-007: *Probing QCD in the nuclear medium with real photons and nuclear targets at GlueX*

A. Accardi, C. Weiss

The proposal describes a program of measurements of photonuclear reactions $A(\gamma, X)$ and $A(\gamma, XN)$, with X a meson-baryon state carrying a significant fraction of the photon momentum, at incident photon energies in the range 3-12 GeV, and at angles corresponding to high-momentum transfer scattering processes on the nucleons in the target ($|t, u| > 2\,\mathrm{GeV}^2$). The measurements are to be performed with the Hall D tagged photon beam and several nuclear targets (^{2}H, ^{2}He, ^{12}C, ^{40}Ca), using the GlueX spectrometer in its standard configuration. The central idea is to induce high-momentum-transfer exclusive processes on the nucleons in the nucleus, $\gamma + N \to M + N'$ (with $N, N' = p, n$ and $M = \pi, K, \rho, \phi, \omega$), and to compare the results in different nuclear environments at the same nucleon-level kinematics. The physical effects to be studied in this way are: (a) the transition from the "hadronic" to the "pointlike" component of the photon as a function of the hardness of the nucleon-level process; (b) color transparency in meson and baryon production; (c) nucleon-nucleon short-range correlations in the initial state. The different effects are to be separated through the choice of appropriate final states (mesons, baryons), choice of kinematics (light-cone momentum of initial nucleon, t of nucleon-level subprocess), and judicious comparison of the results from different nuclei (nuclear ratios, A dependence). The program relies extensively on experience gained with previous studies of color transparency and short-range correlations in high–Q^2 electroproduction on nuclei and aims to recruit high–t photoproduction for the study of these effects, broadening the set of tools and opening up new areas for experimental study.

The role of photon structure in exclusive photoproduction processes is a basic question of hadronic physics. It is expected that with increasing t (above $\sim$ 1-2 GeV^2) the "hadronic" component becomes suppressed and only the "pointlike" component remains. Observing the transition at the quantitative level is important for understanding the onset of scaling behavior in exclusive $2 \to 2$ processes and the region of applicability of a QCD-based description. In existing measurements on the proton this question is tied up with the overall modeling of the reaction mechanism. The proposed experiment would observe the disappearance of the hadronic component through its different nuclear absorption compared to the pointlike component, which would provide a direct and independent test. The results could provide new insight into the mechanism of high–t exclusive processes, which are an essential tool for short-range nucleon structure at JLab.

Color transparency — the reduced interaction of small-size color singlet configurations (size $\ll$ hadronic size $\sim$ 1 fm) with hadronic matter — is a fundamental prediction of QCD. Among other aspects, it is a necessary condition for the QCD factorization theorem for high–Q^2 exclusive processes. Experiments so far have focused on observing CT in high–Q^2 electroproduction of mesons and nucleons on nuclei, with some success for mesons, but little indication of CT for nucleons. The proposed program would use high–t exclusive photoproduction to study CT for mesons and baryons. This setup allows one to use the entire photon energy up to 12 GeV for "squeezing" the configurations (large t) and "freezing" them as they propagate through the nucleus (large P_{hadron}), which would increase the chances to observe CT signals compared to electroproduction, particularly in the baryon sector. The results could have a major impact on CT studies.

The observation of short-range nucleon-nucleon correlations in nuclei and their marked isospin dependence (pn vs. pp/nn) in $A(e,e'p)$ and $A(e,e'pN)$ is widely recognized as one of the most important results of the JLab 6 GeV program. Further electroproduction experiments are planned with 12 GeV to confirm the universality of SRCs and their possible connection with the EMC effect. The proposed experiment aims to observe SRCs in high–t exclusive photoproduction, making use of the steep s–dependence of the elementary process. A demonstration of this method would be a major breakthrough and would open up new possibilities for SRC studies (universality, isospin dependence, momentum/size dependence). This part of the program will likely require further theory input, in order to separate initial-state modifications from final-state interactions in such exceptional configurations. The proponents have strong theory support and should continue to address these questions specific to SRCs.

The interpretation of the proposed measurements relies on a self-consistent framework relating several effects and phenomena in QCD and short-range nuclear structure: CT, SRCs, and the EMC effect. The framework has been very successful as a guidance for previous electroproduction experiments and their interpretation, and has led to predictions that were later confirmed by traditional nuclear structure calculations (e.g. characteristic differences in the proton and neutron momentum distributions in nuclei and their connection to SRCs). The proponents should continue their efforts to reach out to the low-energy nuclear structure community and communicate their results in terms that can relate to other nuclear structure calculation frameworks (e.g., nuclear EFT interactions). The same is advisable in order to reach out to the DIS and perturbative QCD community. The proposed program could become a focal point for future joint efforts combining high-energy probes and low-energy nuclear structure, verify the assumptions of the current interpretation framework, and spur further and deeper theoretical understanding of the interplay of these two energy regimes.

PR12-17-008: *Polarization observables in Wide-Angle Compton Scattering at large* s, t *and* u

C. Weiss, A. Radyushkin

The proposed experiment would measure the initial–state helicity/spin correlation observables A_{LL} and A_{LS} in wide-angle real Compton scattering (WACS) on a polarized proton, $\vec{\gamma}\vec{p} \rightarrow \gamma' p'$, at squared center-of-mass energies $8\,\mathrm{GeV}^2 < s < 20\,\mathrm{GeV}^2$ and center-of-mass scattering angles $\theta_{\mathrm{cm}} = 70°, 90°$ and $110°$. The measurement is to be performed with an untagged bremsstrahlung photon beam, using a novel technique for electron-photon beam separation. The scattered photon is detected with the neutral particle spectrometer (NPS); the recoil proton with the BigBite spectrometer in Hall C. The experimental setup has been redesigned compared to the previous 6 GeV WACS experiments and the approved 12 GeV experiments (E12-14-003, E12-14-006) and optimized for the purpose of initial-state spin asymmetry measurements. The physics goals of the proposed new experiment complement and extend those of E12-14-003 (WACS cross section) and E12-14-006 (helicity transfer K_{LL}) and strengthen the overall impact of the 12 GeV WACS program.

WACS is an exclusive process probing short-range nucleon structure and QCD interactions, whose theoretical description is closely related to that of the elastic nucleon form factors at $|t| \sim$ few GeV^2. Measurements of WACS provide critical tests of the high–t reaction mechanism and can identify structures not accessible in elastic scattering alone, related to spin and orbital angular momentum in the nucleon's valence quark component. At $|t| \sim$ few GeV^2 WACS is expected to proceed mainly by way of Compton scattering from a single quark ("handbag graph"), whose emission/absorption by the proton is mediated by non-perturbative interactions and described by high-t generalized parton distributions (GPDs), similar to the structures measured in high-Q^2, low–t processes such as DVCS. The pQCD hard scattering mechanism, in which all three valence quarks participate in the hard reaction through perturbative gluon exchange, is expected to become dominant only at much larger t. The recently developed framework of soft–collinear effective theory (SCET) consistently combines the contributions of the different mechanisms, provides a factorized QCD-based description, and permits computation of sub-asymptotic corrections. Overall, the theoretical description of WACS is at a level comparable to that of high-Q^2 exclusive processes such as DVCS and supports detailed experimental studies.

Polarization observables provide particularly sensitive tests of the reaction mechanism. An earlier measurement of the polarization transfer K_{LL} in Hall A experiment E99-114 at $\theta_{\rm cm} = 120°$ was able to clearly discriminate between the "handbag" and the hard scattering predictions and is widely regarded as one of the most important experimental results in exclusive reactions coming out of the JLab 6 GeV program. The more recent measurement by E07-002 came up with an equally large K_{LL} asymmetry at a smaller angle $\theta_{\rm cm} = 70°$, which challenges all present QCD-based pictures of the reaction mechanism and calls for further clarification. The 11 GeV experiment proposed here (together with E12-14-003 and E12-14-006) thus takes place within a lively discussion and could make significant contributions to our understanding of the WACS reaction mechanism. The asymmetries A_{LL} and A_{LS} allow one to separate the different helicity components of the high–t quark GPDs (vector, axial vector, tensor), as well as possible quark helicity–flip contributions to the amplitude due to chiral symmetry breaking. The kinematic settings of the proposed experiment have been carefully chosen in order to maximize the physics impact.

The extraction of the WACS signal relies on the subtraction of the background of coplanar photons from $\pi^0 \to \gamma\gamma$ decays (where the second photon remains undetected). The background is estimated by extrapolating the measured exclusive π^0 production cross section to the new energy range. Since this cross section has a very steep energy dependence ($d\sigma/dt \sim s^{-7}$) there is likely considerable uncertainty in this extrapolation, leading to an uncertainty in the estimate of the dilution factor. Furthermore, since it is planned to measure WACS spin asymmetries, the estimates should allow for the possibility of a spin dependence of the π^0 cross section. While these questions can ultimately only be answered from the new data themselves, by reconstructing the π^0, it might be worth refining the uncertainty estimates already at this stage. This in particular as the dilution factor is expected to be largest ($D \sim 6$) in the kinematic settings that require the most beam time (L4/S4). We recommend that the proponents consult with theorists regarding the assumptions about the π^0 background and possible refinements of the uncertainty estimates.

PR12-17-009: *Precision Deuteron Charge Radius Measurement with Elastic Electron-Deuteron Scattering*

A. Radyushkin, J.-W. Qiu

Experiment proposal PR12-17-009 “Precision Deuteron Charge Radius Measurement with Elastic Electron-Deuteron Scattering” intends to reach a half-percent accuracy in essentially model independent extraction of the deuteron charge radius with the goal to address the “deuteron charge radius puzzle”, that attracts now a lot of attention. This “puzzle” is a recent addition to observations (muon $g-2$, and proton radius puzzle) related to possible violation of electron-muon universality. The latter is one of the assumptions of the standard models, and deviations from it motivate searches for “physics beyond the standard model”.

There is discrepancy in the proton and deuteron charge radii obtained from the study of electronic vs muonic atoms. For electrons, an independent way is to use electron scattering. However, the uncertainties in existing measurements are too large to have an impact on resolving the discrepancy. The proposal is for an electron scattering experiment that is capable to extract the deuteron radius with higher precision than achieved so far. The proposed tool is to use the Möller scattering cross section and also to apply another complementary method of extracting the deuteron radius from the ratio of $e-d$ to $e-p$ scattering.

Having the higher precision is critically important for the success of the proposed experiment. Since the same collaboration just completed a similar high precision electron scattering experiment aiming to address the “proton radius puzzle”, their experience on achieving the proposed precision will be very valuable for this new experiment. Although their data on the “proton radius puzzle” experiment is still being analyzed, it would help determine the time to run the experiment if more definite statements to show their ability to achieve the precision of the measurement, especially, from the experiment that they just completed.

Summarizing, the proposed experiment has a solid physics case, aiming at ambitious goals of investigating effects related to core assumptions of the standard model. More specifically, the results of the proposed measurement may contribute to the resolution of the “deuteron radius puzzle.”

PR12-17-010: *Photoproduction of vector bosons on nuclei with GlueX*

J.-W. Qiu, I. Balitsky

The present proposal aims to use the GlueX detector to study the photoproduction of light vector mesons ρ, ω, ϕ on a set of nuclear targets: C, Si, Sn, and Pb in the large photon beam energy range between 6 GeV and 12 GeV. The primary goal of the proposed experiments is (1) to measure nuclear transparency of ω mesons in incoherent photoproduction on various nuclear targets and to extract the total cross section of longitudinally polarized ω mesons on a nucleon, $\sigma_L(\omega N)$; (2) to measure spin density matrix elements for ω mesons to separate production of longitudinally and transversely polarized ω mesons, providing an independent way to extract $\sigma_L(\omega N)$; and (3) to measure the nuclear transparency of various light mesons, such as ρ, ω, ϕ, to study its beam energy dependence.

With the variation of nuclear targets, measuring the nuclear transparency of meson photoproduction, $A_{eff}/A = \sigma_A/A\sigma_N$, or more specifically, the absorption of mesons in production off nuclei, can help extract meson-nucleon cross sections to study interactions of transversely and longitudinally polarized mesons with nucleons. While the coherent photoproduction provides the better information on the total cross section of the transversely polarized vector mesons V_T with nucleons $\sigma_T = \sigma(V_T N)$, the proposed measurement of ω meson photoproduction in the incoherent region will provide a unique opportunity to extract the total cross section for longitudinally polarized vector meson $\sigma_L = \sigma(\omega_L N)$ for the first time. While the knowledge of $\sigma_T(VN)$ and $\sigma_L(VN)$ is very important for studying the hadron physics and strong interactions, it is also important in the interpretation of the effect of color transparency in the electroproduction of vector mesons off nuclei.

With the variation of both beam energies, the proposed measurements could provide good information on the beam energy dependence of the nuclear transparency to shed light on a long-standing puzzle: the disagreement between the earlier experimental results and the existing theory predictions. The predicted decrease of nuclear transparency as beam energy increases has not been observed. The better measured beam energy dependence, and the range of the available beam energies could be very valuable for understanding the quantum fluctuation of the photon to its various hadronic components and the life time of such quantum fluctuation.

In addition to the focused measurements mentioned above, the data acquired with the experiment could also be used to study several other related and interesting strong interaction physics topics, as mentioned in the proposal. The proposed measurements seem to be robust and could be carried out without making any changes to the GlueX detector, other than changing the targets.

PR12-17-011: *The Parity Violation Parton Distribution Function (PVPDF) Experiment: a new experimental constraint on PDFs*

W. Melnitchouk, A. Accardi

The proposed experiment would measure the parity-violating DIS asymmetry from a proton at intermediate x values in order to provide an additional constraint equation that would allow one to unambiguously extract the strange quark PDF, $s(x)$. In this x range ($0.1 < x < 0.5$) there are essentially no data that directly constrain $s(x)$, which are free from theoretical assumptions whose validity is unclear.

The potential implications of such a measurement are widespread, ranging from a better understanding of the nonperturbative sea in the proton, to a more reliable determination of the strange-quark helicity PDFs. It would also provide important input into analysis of transverse momentum dependent PDFs in upcoming JLab experiments. The measurement would complement ongoing experiments at the LHC from which information is extracted on the strange quark PDF at very small values of x ($\sim 10^{-3}$).

The theoretical interpretation of the eventual data should be straightforward, especially with the expertise that has been developed at JLab in recent years in global QCD analysis.

PR12-17-012A: *Tagged EMC Measurements on Light Nuclei*

T. Rogers

This proposal was reviewed by me and C. Weiss in 2016. Our main concern was that the proposal contained an overstatement of the ability remove final state interactions (FSIs) entirely. The new proposal has sufficiently soften these claims. The have directly responded to our previous comments. Thus, we recommend that the experiment proceed. Apart from this issue, the rest of the proposal remains the same as in 2016, and our comments remain the same. Thus, we copy the previous report here:

% % %

The proposal is to use spectator tagged deeply inelastic scattering to probe the theoretical treatments of nucleon off-shellness, final state interactions (FSIs), and their relationship to the EMC effect. The targets are light nuclei (D and ^{4}He) and the detected spectators are low energy p, ^{3}H and ^{3}He. The proposed strategy is to exploit the ALERT detector's capability to identify low energy and wide angle hadrons, and the large acceptance of CLAS12, to distinguish regions of phase space where FSIs are expected to be large from regions where it is small.

Model descriptions of the EMC effect rely on assumptions about nucleon off-shellness and on estimates of the rate of final state interactions. The typical physical picture is that of a single hard scattering off a single target nucleon, factorized from the nuclear remnants (the proposals' Fig. 1.1). To understand the EMC effect, it is crucial to test this picture. The proposed experiment aims to provide such tests by examining the ratio (R of Eq. (1.3)) of cross sections with the same remnant kinematics for the nuclear remnant but with different A.

The analysis of the proposed measurements relies on the validity of the spectator mechanism, which assumes that the nuclear modification of the $A \to A - 1$ "tagged" structure function is entirely due to nuclear binding effects in the initial state and described by the nuclear momentum distribution. It is claimed that the observation of an intact $A - 1$ recoil nucleus implies the absence of FSIs. These assumptions are generally not warranted. The DIS final state produced on the active nucleon contains slow hadrons (with momenta of approximately a few 100 MeV in the nuclear rest frame), which are fully formed inside the nucleus and interact with the remnant with hadronic cross sections. Initial-state modifications due to nuclear binding and FSI effects produced by such hadrons are generally of the same order. While FSIs can be minimized in backward kinematics, it remains unclear how effectively this can be done for a complex nucleus with many possible configurations of the active nucleon relative to the remnant system. The selection of "large" recoil momenta on the nuclear scale, P_{A-1} 100-400 MeV, with the goal of displaying the nuclear binding effects, generally put the active nucleon in configurations close to the remnant system, where FSI are not suppressed. While the proposed measurements would certainly be interesting, their interpretation is likely much more complex than envisioned in the proposal. It would require very substantial theory support in the form of modeling of the FSI and calculation of the $A \to A-1$ decay functions in the presence of FSI. The proposal needs to state the science motivation more clearly.

The proposal also explains how methods for treating deuterium can be extended to heavier nuclei, and how the techniques can be utilized to test the flavor dependence of nuclear effects, particularly in the anti-shadowing regime.

To summarize, we believe the experiment will likely have important impacts on the theoretical picture of the EMC effect. However, the theoretical case needs to be sharpened.

PR12-17-012B: *Tagged Deeply Virtual Compton Scattering Off Light Nuclei*

I. Balitsky

The GPD program is one of the main goals of scientific program of the 12 GeV upgrade of JLab. The deeply virtual Compton scattering (DVCS) is the most straightforward channel for this program. The main goal of this experiment is to study incoherent DVCS on a nucleon contained inside a nucleus and determine the size of "off-forward EMC effect" - the ratio of bound nucleon's GPD in ^{2}H and ^{4}He to a free nucleon's GPD. The tagging of the recoil spectator particles gives us a handle on experimental study of final state interactions and a possibility to (dis)prove various models of these interactions. The experiment is proposed in a run group with two other measurements aimed at understanding of the structure of ^{4}He.

My comment to the previous version of this proposal was that the unchanged momenta of final nucleons were interpreted as an absence of final-state interactions (FSI). However, I noted that the nucleon scattering amplitude (he elliptic black blob in the right Fig. 1.4 diagram) may have sizable zero momentum transfer limit which may be interpreted as final-state interaction that does not change the momenta of the tagged nucleons but can change the amplitudes and cross sections. Judging from a new Appendix A, the authors of new proposal are aware of the problem and suggest to solve it using model calculations. Based on these model calculations, the authors claim that the *significant* FSI can be identified in the experiment. At this point I do not have further questions and I think the experiment should be pursued.

PR12-17-012C: ***Nuclear Exclusive and Semi-Inclusive Measurements with a New CLAS12 Low Energy Recoil Tracker***

R. Schiavilla

The present proposal is part of a comprehensive program to study the partonic structure of the ^{4}He nucleus through measurements of Deeply Virtual Compton Scattering (DVCS) and Deeply Virtual Meson Production (DVMP). Its specific focus is on (i) extending the DVMP measurements on ^{4}He to detect π^0 production in the final state, (ii) measuring coherent DVCS on the deuteron, and (iii) measuring DVCS in ^{4}He resulting in its three-body breakup.

The DVMP process is generally parametrized in terms of a number of chiral-even and chiral-odd generalized parton distributions (GPDs). In the case of a spin-zero target, such as ^{4}He, there is a single chiral-even and a single chiral-odd GPD at leading twist, and two chiral-even ones at twist three. Thus determination of these GPDs in a relatively dense system, at least in its central region, such as ^{4}He will provide information on the extent to which they are modified *in medio*.

In a spin-one target, such as the deuteron, there are nine GPDs that characterize the coherent DVCS cross section. Sum rules relate combinations of these GPDs to the charge, quadrupole, and magnetic form factors measured in elastic electron scattering off the deuteron. The present measurements would provide information on these GPDs complementary to that extracted from measurements on the nucleon. In particular, it would seem, but it is not clearly stated, that the authors will be able isolate the so-called H_3 GPD.

The last measurement deals, rather than with coherent DVCS, with DVCS resulting in a three-body breakup of ^{4}He with a final deuteron being detected along with the other recoil particles. It might be interesting to explore whether it is experimentally feasible to measure the breakup into two deuterons (rather than a deuteron and two nucleons). In a PWIA picture this would appear to be as quasi-free deuteron DVCS in ^{4}He. A comparison with the proposed measurements above could in principle shed further light on *in medio* modifications, as well as deviations from the PWIA picture.

E12-12-001A: *Near threshold J/ψ photoproduction and study of LHCb pentaquarks with CLAS12*

C. Weiss, J.-W. Qiu

This Run Group Proposal aims to extend measurements of J/ψ photoproduction on the proton near threshold and study possible resonances in the J/ψ–p channel, using the run conditions of the approved CLAS12 experiments E12-12-001 [untagged photoproduction of dilepton pairs, $e + p \to e'(\text{undetected}) + p' + (l^+l^-)$, with $l = e$ or μ] and E12-11-005 [tagged photoproduction, or quasi-real electroproduction, $e+p \to e'(\text{detected})+p'+(l^+l^-)$]. The comparison of different reconstruction methods for the J/ψ–p exclusive final state, and the possibility of reconstructing the J/ψ using both e^+e^- and $\mu^+\mu^-$ decay modes, will allow for cross-checks and good control of the systematics. Comparison with the forthcoming Hall D measurements in exclusive J/ψ photoproduction will allow for further tests and greatly strengthen the overall impact of JLab's results on J/ψ production near threshold.

J/ψ photo- and electroproduction near threshold proceeds through high-momentum gluon exchange between the produced $c\bar{c}$ pair and the nucleon, and offers the possibility of measuring nucleon form factors of gluonic operators at invariant momentum transfers $|t| \sim$ 1–2 GeV^2 (at threshold the kinematically required minimal momentum transfer is $|t_{\min}| = 2.2\,\text{GeV}^2$). The theoretical description of the process — the precise nature of the gluonic operators, and the dynamical mechanisms governing the high–t gluonic form factors — are a very active field of research. J/ψ production near threshold represents a unique window on gluonic structure at JLab energies and can probe gluonic dynamics very different from that in diffractive processes at small x. The measurement of high-t gluonic form factors also complements the JLab program in traditional electromagnetic form factors and quark GPDs. The proposed measurements would provide important new information for this field of research and should be encouraged.

Recent experiments at LHCb have observed signals indicative of a resonance in the J/ψ–p channel, which have caused great interest and engendered much theoretical work. Near-threshold bound states of heavy quarkonia with the nucleon would test the interaction of heavy quarkonia with hadronic matter at low relative momenta ($\ll 1$ GeV), which is related to fundamental questions regarding long-range color interactions in QCD. The most favorable kinematics for studying these interactions is in the J/ψ–p final state in exclusive J/ψ production near threshold, where the system has a small energy in the center-of-mass frame. Two putative resonances observed by LHCb (at 4380 MeV and 4450 MeV) are within the kinematic reach of the proposed 11 GeV experiment and could be explored in this way. Confirmation of these resonances through an independent photoproduction experiment would have a major impact on this field, and, if observed, could provide crucial insight into the production mechanism.

The discussion of J/ψ photoproduction in the proposal refers to the picture of diffractive production known from small x and uses the approximation of vector meson dominance. These concepts are likely not applicable in photoproduction near threshold, where the minimum momentum transfer to the target is large ($|t_{\rm min}| = 2.2\,\mathrm{GeV}^2$ at threshold, see above) and the relevant configurations of the $c\bar{c}$ pair are very different from those in low–t J/ψ–nucleon interactions. However, since cross section data from previous experiments are available at $E_\gamma \geq 11$ GeV to anchor the calculations, these conceptual issues should not affect the rate estimates presented in the proposal. We encourage the proponents to continue to work with theorists regarding the theoretical interpretation of the near-threshold data. Likewise, some of the estimates of the resonance production rates presented in the proposal rely on questionable assumptions and seem unrealistically large. This, however, should not detract from the merits of a measurement in this energy region, as even a negative result would have would have a major impact on our understanding.

E12-10-006B: *Measurement of Deep Exclusive* π^- *Production using a Transversely Polarized* ^{3}*He Target and the SoLID Spectrometer*

A. Accardi

This run group proposal is an update of that submitted to PAC44, and has satisfactorily addressed all the remarks in last year's report.

It aims primarily at a measurement of the $A_{UT}^{\sin(\phi-\phi_s)}$ asymmetry, and, secondarily, of the $A_{UT}^{\sin\phi_s}$ asymmetry in Deeply Exclusive π^- production on (bound) neutrons, utilizing currently available transversely polarized ^{3}He targets. The goal is to provide access to the $\tilde{E}$ GPD through an unseparated measurement of transverse and longitudinal photon double spin asymmetries.

This proposal is meant to complement proposal PR12-12-005, that envisaged a Rosenbluth-type separation of the $A_L^{\perp} \propto \tilde{E}$ contribution to the $A_{UT}^{\sin(\phi-\phi_s)}$ asymmetry. Achieving the desired statistics for a precise enough separation requires, however, the development of a new generation polarized Helium target (currently being developed at New Hampshire U.) to provide the required high luminosity levels. Since this is a completely new technology, no timeline has been established for that experiment. This proposal aims, instead, at providing shorter term results than PR12-12-005, with an unseparated measurement, that builds on pioneering HERMES results in exclusive π^+ production on proton targets and does not need additional beam time compared to E12-10-006. It is thus an interesting measurement, worth pursuing.

C12-15-006A *Measurement of Kaon Structure Function through Tagged Deep Inelastic Scattering (TDIS)*

K. Orginos

This project intents to measure Kaon parton distribution functions PDFs while the approved pion-TDIS project is running. It requires no additional run time or detector modifications. In that sense, if the pion-TDIS project runs there is no reason for this measurement not to run. However, we would like to point out that the the systematics of the meson PDFs these projects intent to extract are not well understood not allowing a clear interpretation of the experimental data obtained in both projects.