Jefferson Lab

48th PROGRAM ADVISORY COMMITTEE (PAC 48)

August 10-14, 2020

September 25, 2020

U.S. DEPARTMENT OF ENERGY

JSA

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From the Director

Jefferson Lab
Thomas Jefferson National Accelerator Facility
Exploring the Nature of Matter

October 1, 2020

Dear Jefferson Lab Users,

It was a pleasure to see the new and exciting experimental proposals from our user community at the August 10th - August 14th Program Advisory Committee (PAC47) meeting. The September 25th Jeopardy meeting helped to emphasize that the quality of these proposals remain a testament to the tremendous scientific opportunities that Jefferson Lab's CEBAF enables for our community.

The PAC had a very heavy work load this year, reviewing 13 new proposals, 3 conditionally approved proposals, 3 run group additions and 3 Letters of Intent in addition to the 11 approved experiments up for Jeopardy. This greater than usual load along with this year's virtual meeting lead to us splitting the meetings into two separate sessions with the Jeopardy meeting being held on September 25th. Of the 16 proposals reviewed, 7 were approved while 7 received conditional approval. The science for all of our jeopardy experiments remained relevant with one experiment receiving an improved grade.

The meeting was run very efficiently and effectively even in its remote format, thanks to the efforts of the Chair, Markus Diehl and the efforts of Lorelei Carlson, Pat Stroop and Susan Brown. I thank Markus and all the PAC members for their efforts to provide expert advice to the Laboratory.

Sincerely,

Stuart Henderson
Laboratory Director

From the Chair

Markus Diehl
Theory Group
Deutsches Elektronen-Synchrotron DESY
22603 Hamburg
Germany

1 October 2020

Robert D. McKeown
Deputy Director for Science
Jefferson Lab

Dear Bob,

This letter transmits the findings and recommendations of the 48th Jefferson Lab Program Advisory Committee (PAC48). The Committee met August 10th - 14th and considered 13 new proposals, 3 conditionally approved proposals, 5 proposals for run group additions, and 3 letters of intent. Eleven experiments or run groups in Jeopardy were reviewed separately on September 25th.

Written reports on the proposals and letters of intent were prepared and reviewed by the Committee before we adjourned. 7 proposals were granted full approval, 2 proposals were approved pending a technical review by the lab (C1), and 5 proposals were approved pending review by a future PAC (C2). Two proposals were deferred. The PAC endorsed all run group additions. All experiments in Jeopardy were recommended to stay active. The PAC revised the recommended beam time for two of these experiments, and changed the scientific grade for one.

The chair of the Jefferson Lab Users Organization (JLUO) participates in all PAC sessions and is included in all communication between the PAC and the spokespersons of proposals. He represents the user community at all stages of the PAC review. We regard this as highly beneficial for both sides and would like to see this tradition continue.

After a letter of intent to PAC46 (LOI12-18-004), this year's PAC received the first two proposals for measurements with a positron beam at CEBAF. In addition, a White Paper on "An Experimental Program with Positron Beams at Jefferson Lab" appeared on the arXiv just briefly before the PAC meeting in August. The Committee sees great physics potential in a positron program. We encourage a vigorous effort to explore the technical feasibility of providing positron beams, and we are looking forward to receiving further proposals in this area. Clearly, it is difficult at the present stage to predict the characteristics of positron beams that will be achievable. Our recommendations in this report are based on the hypothesis that it will be possible to provide beams with the specifications given in the proposals.

Several of the proposals received by this PAC aim at high precision measurements, reflecting the supreme potential of the upgraded CEBAF beam and detectors. In this context, the impact of effects beyond statistics on the expected results becomes increasingly important. Therefore, we ask the authors of future proposals to provide sufficient details on how point-to-point systematic uncertainties, overall normalization errors, and theoretical uncertainties have been estimated. More generally, *the PAC urges all proponents of future experiments to carefully read and follow the "Guidelines for Proposals" on the PAC web pages.*

The TAC physics and theory reports provided to the PAC were a most valuable resource for our review, and we thank all those involved in their preparation.

Given the special situation in summer 2020, all open and closed PAC sessions were held online. We are grateful to the Jefferson Lab staff for their efforts in setting up and running the required infrastructure. This was not always easy, and our special thanks go to Susan Brown, Lorelei Carlson, and Pat Stroop, whose tireless efforts kept us afloat during the meeting.

The PAC is at your disposal for any other information or assistance we can give you. Congratulations to you, Jefferson Lab, and the user community on continued success.

With best regards,
Markus

Markus Diehl
PAC48 Chair

Introduction

The Jefferson Lab Program Advisory Committee held its 48th meeting from August 10th through August 14th, 2020 remotely. The membership of the committee is given on page 56. In response to the charge (page 57) from the JLab Science Director, Dr. Robert McKeown, the committee reviewed 13 new proposals, 3 conditional proposals, 5 run group additions and 3 Letters of Intent. The committee met again on September 25th to review the 11 experiments up for Jeopardy.

Recommendations

PAC 48 SUMMARY OF RECOMMENDATIONS								
Number	**Contact Person**	**Title**	**Hall**	**Days Req'd**	**Days Awarded**	**Scientific Rating**	**PAC Decision**	**Topic**
C12-18-005	M. Boer	Timelike Compton Scattering Off Transversely Polarized Proton	C	50			**C2**	4
C12-19-001	M. Amarian	Strange Hadron Spectroscopy with Secondary KL Beam in Hall D	D	200	200	A-	**Approved**	1
C12-19-002	T. Gogami	High accuracy measurement of nuclear masses of Lambda hyperhydrogens	A	13.5			**C2**	5
PR12-20-001	J. Bernauer	Dark Light: Search for New Physics in e+e- Final States Near an Invariant Mass of 17 MeV Using the CEBAF Injector	INJ	55			**Deferred**	6
PR12-20-002	R. Milner	A Program of Spin-Dependent Electron Scattering from a Polarized He-3 Target in CLAS12	B	30	30	A-	**C1**	4
PR12-20-003	L. Tang	Extension request for E12-17-003: Determining the unknown Lambda-n interaction by investigating the Lambda-nn resonance	A	8.5			**C2**	5
PR12-20-004	A. Gasparian	PRad-II: A New Upgraded High Precision Measurement of the Proton Charge Radius	B	40	40	A	**C1**	2
PR12-20-005	H. Szumila-Vance	Precision measurements of A=3 nuclei in Hall B	B	60	60	A-	**Approved**	5
PR12-20-006	A. Gasparian	Precision Deuteron Charge Radius Measurement with Elastic Electron-Deuteron Scattering	B	40			**Deferred**	2
PR12-20-007	W. Li	Backward-angle Exclusive pi0 Production above the Resonance Region	C	29.4	29	B	**Approved**	4
PR12-20-008	A. Puckett	Polarization Transfer in Wide-Angle Charged Pion Photoproduction	A	2	2	B+	**Approved**	4
PR12-20-009	E. Voutier	Beam charge asymmetries for Deeply Virtual Compton Scattering on the proton at CLAS12	B	100			**C2**	4
PR12-20-010	E. Fuchey	Measurement of the Two-Photon Exchange Contribution to the Electron-Neutron Elastic Scattering Cross Section	A	2	2	A-	**Approved**	2
PR12-20-011	A. Deur	Measurement of the high-energy contribution to the Gerasimov-Drell-Hearn sum rule	D	29.1	33	A-	**Approved**	3
PR12-20-012	C. Munoz Camacho	Deeply Virtual Compton Scattering using a positron beam in Hall C	C	77			**C2**	4
PR12-20-013	F. Garibaldi	Studying Lambda interactions in nuclear matter with the 208Pb(e,e'K+)208_LambdaTl	A	20	20	B+	**Approved**	5

Topic*

1 The Hadron Spectra as Probes of QCD
2 The Transverse Structure of the Hadrons
3 The Longitudinal Structure of the Hadrons
4 The 3D Structure of the Hadrons
5 Hadrons and Cold Nuclear Matter
6 Low-Energy Tests of the Standard Model and Fundamental Symmetries

C1=Conditionally Approved w/Technical Review
C2=Conditionally Approved w/PAC Review

PAC 48 SUMMARY OF JEOPARDY RECOMMENDATIONS

Number	Contact Person	Title	Hall	Days Req'd	Days Awarded	Scientific Rating	PAC Decision	Topic
E12-12-002 (GlueX-II)	M. Shepherd	An update on the GlueX II and Jefferson Lab Eta Factory experiments	D	220		A	Remain Active	1
E12-13-008 (Pion polarizability)	R. Miskimen	Measuring the Charged Pion Polarizability in the gamma gamma -> pi+ pi- Reaction	D	25		A-	Remain Active	2
RG-A	L. Elouadrhiri	CLAS12 Run Group A (RG-A)	B	200		A	Remain Active	4
RG-B	S. Niccolai	CLAS12 Run-Group B: Electroproduction on deuterium with CLAS12	B	56		A	Remain Active	3
RG-C	S. Kuhn	CLAS12 Run Group C	B	200	120	A	Remain Active	4
RG-D	L. El Fassi	Study of Color Transparency in Exclusive Vector Meson Electroproduction off Nuclei	B	60	30	B+	Remain Active	5
RG-E	W. Brooks	Quark Propagation and Hadron Formation	B	60		A-	Remain Active	5
RG-G	W. Brooks	The EMC Effect in Spin Structure Functions (CLAS Run Group G)	B	55		B+	Upgrade Rating A-	4
RG-H	M. Contalbrigo	Run Group H Jeopardy Update Document. CLAS12 Experiments with a Transversely Polarized Target	B	110		A	Remain Active	4
RG-I	T. Nelson	Search for Massive Photons at Jefferson Laboratory (HPS)	B	180		A	Remain Active	6
RG-K	A. D'Angelo	RG-K Quark-Gluon Confinement & Strong QCD	B	100		A-	Remain Active	5

RUN GROUP ADDITION SUMMARY

Number	Contact Person	Title	Hall	Topic
E12-06-106A	R. Dupre	Nuclear TMDs in CLAS12	B	5
E12-13-008A	E. Smith	Measuring the Neutral Pion Polarizability	D	2
E12-09-007A	C. Dilks	Studies of Dihadron Electroproduction in DIS with Longitudinally PolarizedHydrogen and Deuterium Targets	B	3
E12-11-007A/E12-10-006E	Y. Tian	A Precision Measurement of Inclusive g2n and d2n with SoLID on a Polarized 3HeTarget at 8.8 and 11 GeV	A	3
E12-06-117A	M. Arratia	Dihadron measurements in electron-nucleus scattering with CLAS12	B	5

Proposal Reports

C12-18-005

Scientific Rating: N/A

Recommendation: C2

Title: Timelike Compton Scattering Off Transversely Polarized Proton

Spokespersons: M. Boër (contact), D. Keller, V. Tadevosyan,

Motivation: This proposal aims to measure Timelike Compton Scattering (TCS) off the proton using a transversely polarized NH_3 target in Hall C. By measuring transverse spin asymmetries and the unpolarized cross-section, this process gives access to Compton Form Factors (CFFs), some of which are accessible in approved DVCS and TCS experiments. Assuming the applicability of factorization, CFFs can be parametrized in terms of universal Generalized Parton Distributions (GPDs). This measurement can be used to test the universality of GPDs and to obtain useful information to constrain them, in particular the GPD E, which is of considerable interest due to its relation with partonic angular momentum.

Measurement and Feasibility: The measurement will take place in Hall C which requires the use of a Compact Photon Source and a transversely polarized NH_3 target. The recoil proton and the e^+e^- pair are reconstructed using the GEMs, a set of hodoscopes and the NPS electromagnetic calorimeter. The proposal requests 50 PAC days. This measurement requires the selection of the exclusive final state e^+e^- with an untagged bremsstrahlung photon beam. The various subdetectors are all existing and will be used in other experiments in Hall C. As the photon beam is untagged, to suppress the non-exclusive background a first and second level trigger setup is used. It is based on the energy deposition in the NPS and on timing responses of the NPS and the hodoscope as well as 2 hits out of the 3 GEMs aligning with the hodoscope info.

Issues: Some of the goals of the experiment (e.g., testing universality of GPDs) are overstated as they require many complementary experiments involving DVCS and TCS over a wide range of kinematics. To better understand the impact and complementarity of TCS measurements with respect to DVCS measurements, one should extract the CFFs from DVCS and TCS pseudo-data corresponding to the precision of the planned experiments. The presented impact study is very difficult to interpret, as the uncertainties do not represent the existing and planned data.

The proposal does not give enough details about what the signal to background ratio is, and which cuts are most effective to suppress it. A detailed discussion about the magnitude of the background would also be very helpful to understand the performance of the experiment, most importantly how the Monte Carlo simulation has been validated, so as to be sure that the absolute background level is reasonable. Furthermore, the concerns of the TAC report need to be addressed in more detail, as well as the following points:

1. The radiation load of the calorimeter is quoted to be 100 krad, which is 33 times the radiation hardness of the crystals: it needs to be shown how the radiation damage between recovery periods influences the energy calibration stability for the signal.

2. Good proton identification through the dE/dx measurement can only be achieved up to a momentum of 0.5 GeV: it should be shown how this impacts the measurement.

3. A full GEANT simulation of the electromagnetic calorimeter response for e/π simulation should be provided.

4. A more detailed description of the following critical experimental details is missing: the timing resolutions of all components, the timing requirement to suppress background, and how the GEMs are used in the trigger.

Summary: The PAC thinks that the physics case of the proposal is strong and nicely complements the extensive program of GPD-related measurements at JLab. However, in order for the experiment to be successful, the PAC feels that the issues mentioned above need to be adequately addressed.

C12-19-001

Scientific Rating: A-

Recommendation: Approved

Title: Strange Hadron Spectroscopy with Secondary KL Beam in Hall D

Spokespersons: M. Amaryan (contact), M. Bashkanov, S. Dobbs, J. Ritman, J. Stevens, I. Strakovsky

Motivation: The spectroscopy of strange baryons and mesons, including their fundamental strong interactions, are the focus of this proposal. New and unique data can be obtained with an intense K_L beam aimed at a hydrogen/deuterium target, using the GlueX apparatus to detect final state particles.

Measurement and Feasibility: The proponents have answered all questions outlined in the PAC47 report. Substantial progress has been made on the issues of simulations: details on backgrounds and background reactions have been demonstrated, a demonstration of partial wave analysis for hyperon production was given. The proponents have demonstrated the measuring technique of missing mass reconstruction, allowing them to extend the measuring range both regarding small, four-momentum transfers and isospin decomposition. No show stoppers have been pointed out by the TAC.

Issues: The PAC strongly recommends that the collaboration intensify their cooperation on two issues. (1) Coordinated leadership must be established together with the host laboratory to address the various technical issues connected with the R&D efforts and construction of the K_L beam. (2) Continuous cooperation with JPAC and associated members is recommended for the development of tools to master the challenges connected with the clean extraction of $K\pi$ scattering, the identification of the exchange processes at small momentum transfers, and the amplitude analysis for Δ final states.

Summary: The future K_L facility will add a new physics reach to JLab, and the PAC is looking forward to see the idea being materialized, in conjunction with the plans for Hall D as spelled out in the 2019 White Paper. The collaboration should now devote all its energy to turn this challenging project into an experimental facility and in parallel prepare for a successful data analysis.

C12-19-002

Scientific Rating: N/A

Recommendation: C2

Title: High accuracy measurement of nuclear masses of Lambda hyperhydrogens

Spokespersons: T. Gogami (contact), S.N. Nakamura, F. Garibaldi, P. Markowitz, J. Reinhold, L. Tang, G. M. Urciuoli

Motivation: The hyperon-nucleon interaction is of fundamental interest in the non-perturbative regime of QCD and has implications for nuclear physics as well as astrophysical problems in the development of stars. Current theoretical calculations do not correctly predict the neutron star mass limit. This has received renewed attention in the community, due to the recent limits set by gravitational wave analysis from neutron star mergers. Existing baryonic force models must be refined, and the inclusion of a three-body repulsive force via hyperon interactions is important. The specific nature of hyperon-nucleon three-body forces is debated in the theory community. Experiments providing high precision information about few-body hyperon systems are needed for theorists to refine hyperon-nucleon forces (2 and 3 body) and to determine charge-symmetry breaking terms in those forces. This not only has consequences for the description of light hyperon systems but will also be influential in constructing the neutron star equation-of-state.

Measurement and Feasibility: This proposal aims to make a precision measurement of the binding energy of ${}^{3}_{\Lambda}H$ and ${}^{4}_{\Lambda}H$. The measurements require 12 days of 4.5 GeV, 50 μA beam on gaseous targets. The binding energy is determined using the missing-mass technique, reconstructed from the scattered electron and K^+ detected in the HRS and HKS respectively. The determination of the Λ decay point requires a magnetic optics analysis. The concerns raised by PAC47 regarding a better simulation of the stated precision, the separation of the $3/2^+$ and $1/2^+$ states, as well as relating the proposed experiment to planned J-PARC experiments were satisfactorily addressed.

Issues: The PAC noted the discrepancy that the high pressure target presented in the proposal is incompatible with the geometry of the available space in the scattering chamber. There are possible solutions, where the target will have to be modified. The required re-design may affect the necessary beam time. The PAC encourages the collaboration to work with the JLab target group on a workable target for the experiment and then adjust the required beam time such that the required precision for the physics results is not compromised.

Summary: The need for new, more precise data on the binding energies of ${}^{4}_{\Lambda}H$ and the $1/2^+$ and $3/2^+$ states of ${}^{3}_{\Lambda}H$ is well motivated, and such data is eagerly awaited by the theoretical community. The main reason for this proposal to be classified as C2 is that the required beam time may be changed as a consequence of the modified design of the target.

PR12-20-001

Scientific Rating:

Recommendation: Defer

Title: DarkLight: Search for New Physics in e^+e^- Final States Near an Invariant Mass of 17 MeV Using the CEBAF Injector

Spokespersons: J. Bernauer (contact), R. Corliss, P. Fisher, R. Milner

Motivation: To search for a narrow resonance in the e^+e^- invariant mass region around 17 MeV, motivated by anomalies observed in the decays of excited states of ^{8}Be and ^{4}He, which can also be used to explain the muon g-2 anomaly. This 17 MeV resonance could be a fifth force carrier, with a suppressed proton couplings relative to the neutron.

Measurement and Feasibility: A run of 1000 hours (45 days) at the CEBAF injector (45MeV beam with 150μA current) is requested to search in the e^+e^- invariant mass region around 17 MeV in electron scattering from a tantalum target: e- Ta → e- Ta A' → e- Ta (e^+e^-). This proposal includes additional requests of 3 days for 1497 MHz accelerator commissioning and setup, and of 7 days for the commissioning of the spectrometers. This is a proposal from the existing DarkLight collaboration.

Issues: (1) The recent result on the observed anomaly in ^{4}He with an e^+e^- invariant mass also around 17 MeV are certainly encouraging. However, given that it is from the same experimental group that reported the ^{8}Be anomaly, it is unclear how much correlation this new result has with the previous 17 MeV anomaly. The interpretation of the anomaly by a fifth force carrier, whilst simultaneously satisfying the existing experimental constraints, requires a certain tuning of the couplings of the dark photon to quarks and leptons. Nevertheless, it is important to confirm or exclude a dark photon explanation of the anomaly in ^{8}Be and ^{4}He decay. (2) The experimental setup, the detector simulation, and the background considerations presented in the proposal have not been fully worked out, despite the recommendations by the previous TAC and PAC reports. (3) Given the running and maintenance schedule of JLab, the likely earliest start time of the proposed experiment would be in 2022, assuming that the funding for the spectrometer can be secured and that the detailed design of the experiments and background studies in GEANT can be worked out. Given the timelines of competing experiments worldwide, the proposed experiment might miss the optimal time window to be relevant.

Summary: Given that the experimental set and background simulations have not been fully developed, and given the JLab scheduling challenge in the near future, the PAC has decided to defer this proposal.

PR12-20-002

Scientific Rating: A-

Recommendation: C1

Title: A Program of Spin-Dependent Electron Scattering from a Polarized ^{3}He Target in CLAS12

Spokespersons: H. Avakian, J. Maxwell, R. Milner (contact), D. Nguyen

Motivation: The goals of the experiment are to measure the transverse momentum dependence of the longitudinal spin structure of the neutron and to investigate nuclear effects in SIDIS off ^{3}He targets compared to deuterium targets.

Measurement and Feasibility: The experiment will measure inclusive and semi-inclusive spin asymmetries in electron scattering off a longitudinally polarized ^{3}He target, in a fine binning of (x, z, P_T, Q^2 and φ_h) over a large kinematic range: $0.05 < x < 0.7$, $1 < Q^2 < 9$ GeV^2, $0.2 < z < 0.9$, $0 < P_T < 1.3$ GeV. The experiment will use the CLAS12 detector, including PID for $\pi^{\pm}$, $K^{\pm}$ and pion pairs. The experiment requests 30 PAC days. Similar measurements have already been approved for proton and deuterium targets in CLAS12. Feasibility, statistical resolution and systematic uncertainties have been studied, based on simulations using the full CLAS12 Monte Carlo chain. It was found that the CLAS12 spectrometer is adequate for the measurement. A new ^{3}He polarized target using metastability exchange optical pumping (MEOP) is being developed. Significant R&D for this target has to be carried out. It needs to be demonstrated that it can reach simultaneously high polarization, high target densities and sufficiently long spin relaxation times.

Issues: The proposal submitted to the PAC assumed a beam current of 2.5 μA, necessitating a new beam dump and possibly significant updates on radioprotection. In response to the TAC and the PAC, the proponents demonstrated that a beam current of 0.5 μA can still provide sufficiently high statistical precision.

A careful R&D program with realistic target densities, magnetic fields and beam load currents is needed to establish that the high target densities and polarizations required for the measurement can be achieved. A polarimeter scheme should be devised that will monitor for possible radial or longitudinal polarization dependencies (using, e.g., measurements of the inclusive double spin asymmetry A_{LL}).

To provide as much information as possible to check the applicability of a partonic interpretation of the data, it is important to provide multidimensionally binned data and polarization-averaged multiplicities where possible.

Summary: The successful development of MEOP ^{3}He targets will make it possible to pursue a highly interesting program for studying TMD quark structure of the neutron. Comparison with future results from proton and deuterium targets will provide valuable input for improving the knowledge of quark distribution and fragmentation functions, in particular their flavor dependence, and for quantifying nuclear effects. Exciting additional opportunities may arise in the future, as upgrades may make it possible to operate with transverse target polarization. The PAC recommends to continue the ongoing polarized target R&D vigorously.

PR12-20-003

Scientific Rating: N/A

Recommendation: C2

Title: Extension request for E12-17-003: Determining the unknown Λ-n interaction by investigating the Λnn resonance

Spokespersons: L. Tang (contact), F. Garibaldi, T. Gogami, P.E.C. Markowitz, S.N. Nakamura, J. Reinhold, G.M. Urciuoli

Motivation: Theoretical studies suggest the possibility of a Λnn resonance, and that the knowledge of its excitation energy and width can provide crucial information for a better determination of the Λn interaction. Precision mass spectroscopy using the ^{3}He(e,e',K^{+})(Λnn) reaction can give information on this resonance. The experiment E12-17-003 was approved for 10 days of data collection on Λnn events plus 2 days of calibration with the H target, from which free Λ and Σ^{0} were produced. However, the statistics in E12-17-003 was such that the number of events was too small for a meaningful extraction. Therefore, it is proposed to repeat the experiment with the optimized HKS-HRS system to possibly find the Λnn resonance and the bound Σ^{0}nn state. If the latter exists, it will provide for the first time crucial information for determining the strength of the ΛN-ΣN interaction, which plays an essential role in bound A=3 hypernuclei.

Measurement and Feasibility: The optimized E12-17-003 experiment proposes to use the same HRS-HKS system that is designed for the E12-15-008 hypernuclear experiment, without a change of equipment or configuration. Only the target would be changed to a tritium target. The latter is the critical issue in this experiment.

Issues: (1) According to the technical review, the main concern is related to the target design and installation. The implementation of a tritium gas target with the HKS detector and magnet systems is likely to require a significantly new design and construction effort. Therefore, a resubmission of the proposal needs to include a discussion on target specifics. The PAC recommends to work with the target group on concrete plans on how the tritium target could be safely implemented in the experimental setup. (2) In addition, a sense of the uncertainties in the data analysis of the spectrum should be given, together with a state-of-the-art statistical analysis. In particular the statistical significance of the previous observation needs to be quantified (including the look-elsewhere-effect), as well as its impact on the proposed experiment.

Summary: Determining the properties of a possible Λnn resonance and a Σ^{0}nn bound state is an important step for determining the properties of the ΛN interaction, specifically the strength of the ΛN-ΣN transition, which may otherwise not be accessible directly. Before resubmission, the above issues must be addressed.

PR12-20-004

Scientific Rating: A

Recommendation: C1

Title: PRad-II: A New Upgraded High Precision Measurement of the Proton Charge Radius

Spokespersons: A. Gasparian (contact), H. Gao, D. Dutta, D. W. Higinbotham, E. Pasyuk, N. Liyanage, C. Peng

Motivation: Precision information on the size of hadrons can be obtained both from electron scattering and from atomic spectroscopy. It came as a big surprise that the extraction of the proton charge radius from muonic hydrogen Lamb shift measurements is in strong contradiction with the values obtained from electron-proton scattering. This 'proton radius puzzle' has triggered a large activity worldwide.

In this context, the PRad Experiment has pioneered a new technique to extract the proton radius in elastic electron scattering. Instead of using the traditional experimental technique based on magnetic spectrometry, the experiment has adopted a new calorimetric method for low Q^2 elastic scattering, using a windowless target and simultaneously recording Møller scattering for normalization of the measured cross-sections. In principle, this avoids individual point to point normalization uncertainties, which would impact the measured Q^2 spectrum.

The results obtained by this pioneering experiment (recently published in Nature) are in apparent conflict with all previous modern electron scattering experiments, especially at high values of Q^2. A new experiment with a much improved control of radiative corrections (which at the moment account for the largest part of the systematic uncertainty), with larger data sets, and which makes use of a blind analysis, is imperative to clarify the current status and to reach for the ultimate precision in *ep* scattering.

The proposed experiment aims at reducing the total uncertainty down to 0.54%, which is 3.8 times smaller than what PRad achieved, by upgrading the experimental setup.

Measurement and Feasibility: The experiment relies on the PRad setup undergoing a variety of upgrades, in particular:

1. improving the overall tracking capabilities of the setup by adding a second plane to the tracking detector,
2. adding new rectangular cross-shaped scintillator detectors to separate Møller events in the angular range 0.5^o to 0.8^o,
3. upgrading the HyCal by replacing the lead glass blocks by $PbWO_4$ and converting its readout to FADC based one,
4. improving radiative correction calculations by going to NNLO.

Three beam energies are requested, namely 0.7, 1.4 and 2.1 GeV. The lowest and highest beam energies will allow to cover the Q^2 range from 4×10^{-5} to 0.06 GeV^2. The 1.4 GeV run will serve as an important cross-check for possibly unaccounted systematics.

Issues:

- The μRWell technology (point 1 above) has never been used in a running experiment, and its reliability and radiation hardness have not been fully demonstrated. Since the main reduction on the total uncertainty arises from the addition of a second tracking station, the PAC recommends considering a second GEM station instead, further relying on the present GEM technology to reduce the risks of jeopardizing the final physics goal.
- The upgrade of HyCal (point 3 above) implies 1500 additional $PbWO_4$ crystals and a new electronic readout. The cost estimate is about $5M. While it is clear that the new readout based on FADC will strongly increase the rate of data taking (and thus reduce the statistical uncertainty), the PAC could not be convinced on the necessity of the costly replacement of the crystals for reaching the final uncertainty on the proton radius.
- The PAC strongly suggests the planning of a blind analysis to convincingly reduce possible bias stemming from the normalization and the Q^2-dependence of the form factor. In particular, all radiative correction calculations and their implementation in the Monte Carlo simulation should be fixed before the fit for the proton radius.

Summary: Given the compelling physics case and the current tension between the form factor data of PRad and all previous *ep* scattering experiments, the PAC strongly supports the request for 40 days of beam time, pending a thorough technical investigation of the actual benefits or necessity of the HyCal upgrade and the adoption of the μRWell technology.

PR12-20-005

Scientific Rating: A-

Recommendation: Approved

Title: Precision measurements of A=3 nuclei in Hall B

Spokespersons: H. Szumila-Vance (contact)**,** O. Hen, D. Meekins, D. Nguyen, E. Piasetzky, A. Schmidt, L.B. Weinstein

Motivation: Few-body systems are a unique laboratory for investigating and understanding the dynamics in nuclei, since they are sufficiently simple to allow for an exact theoretical and computational description, yet complicated enough to contain essential ingredients of a many-body system. The proposed measurements plan to constrain the theory of fundamental few-nucleon physics by measuring cross sections with high statistics over a large kinematic range on both ^{3}He and ^{3}H. Physics goals include benchmarking of few-nucleon models, constraints of the NN interaction and resulting nuclear wave functions at high momenta, scale separation of short-range correlation pairs and their formation, and the measurement of G_M^n at low and moderate Q^2.

In addition, deuterium data will be taken to complement the A=3 data. Those are also critical to the evaluation of non-quasi-elastic contributions in the measured cross sections and observables.

Measurement and Feasibility: The large acceptance and open trigger of the CLAS12 detector is used to measure inclusive and semi-inclusive hard scattering from ^{3}H, ^{3}He, and ^{2}H targets.

The target design and construction is discussed extensively in the proposal and does not seem to have any issues. The requested beam time is justified for obtaining reasonable statistics at the highest p_{miss}.

Issues: The question about systematic errors in measuring absolute cross sections in CLAS12 was adequately answered in correspondence between the proponents and the PAC.

Summary: At present, there is no experiment that probes both ^{3}He and ^{3}H across the full quasi-elastic kinematical regime. The fundamental understanding of the lightest nuclear systems and their underlying interaction need the study of both targets with equal accuracy and a more thorough evaluation of the non-quasi-elastic reaction mechanism.

PR12-20-006

Scientific Rating: N/A

Recommendation: Deferred

Title: Precision Deuteron Charge Radius Measurement with Elastic Electron-Deuteron Scattering

Spokespersons: A. Gasparian (contact), H. Gao, D. Dutta, D. W. Higinbotham, E. Pasyuk, N. Liyanage

Motivation: Precision elastic scattering can provide information on nucleon form factors. Measurements at low values of Q^2 mostly probe the electric form factor. With the shape of the form factor close to $Q^2 = 0$ revealing the charge radius square, one obtains complementary information to the one from atomic Lamb shift measurements. The latter currently dominate the measurements for deuterium, but reveal inconsistencies between electronic and muonic deuterium on the level of 3σ. The aim of the proposed measurement is to provide new and far more precise measurements of elastic *ed* scattering and to help solving the discrepancy between different $<r_d^2>$ determinations in atomic physics.

Measurement and Feasibility: The experiment plans to use the upgraded PRAD detector set-up, complemented by a new target chamber instrumented with a double-layer position-sensitive silicon recoil detector.

Issues: For *ed* scattering, radiative corrections are not known precisely and are even more difficult to calculate than for *ep* scattering. In addition, the PAC finds that the physics case outlined in the proposal is not compelling enough to anticipate the resolution of these issues. Nevertheless, valuable electron scattering data at low values of Q^2 would complement the presently scarce data set on the deuteron.

The PAC suggests to carefully address the issues on radiative corrections (where the proponents currently rely on external support, which is presently focused on new calculations for the *ep* case) and to readdress the issue of deuteron breakup reactions, using more sophisticated model descriptions.

Summary: The PAC welcomes the proposed precision measurement of elastic *ed* scattering down to very small values of Q^2 and the extraction of the deuteron charge radius complementary to atomic spectroscopy measurements. It also appreciates the further use of the innovative PRad II setup. However, the potential for interpretation for the measurement cannot be evaluated at this time, as this depends on radiative correction calculations that are not expected in the near future. Moreover, the projected precision is not high enough to have an impact on the present inconsistencies of the radius extraction using electronic and muonic deuterium. Therefore, the proposal is deferred.

PR12-20-007

Scientific Rating: B

Recommendation: Approved

Title: Backward-angle Exclusive π^0 Production above the Resonance Region

Spokespersons: W. Li (contact), J. Stevens, G. Huber

Motivation: This proposal aims at measuring backward-angle exclusive π^0 production above the resonance region with a proton target. Theoretical models to describe this process include a soft mechanism (Regge exchange) and a hard QCD mechanism in terms of so-called transition distribution amplitudes (TDAs). Since the applicability of the TDA formalism is not guaranteed, the proposal aims at checking two specific predictions: the dominance of the σ_T cross section over σ_L and the $1/Q^8$ behavior of the cross section. The idea of a *u*-channel exchange is an interesting concept that is worth exploring.

Measurement and Feasibility: The proposed measurement will take place in Hall C. Detection of backward pion production requires the use of the HMS and SHMS spectrometers for the electron and proton, respectively, whilst the pion is reconstructed with the missing-mass method. The proponents will undertake a L/T/LT/TT separation at 4 different values of Q^2, with a few additional model calibration settings. The requested time is 29.4 PAC days, with 4 different beam energies.

Issues: Spectrometers need to be at more forward angles than previously used; this group will use the settings of the Fpi-12 experiment running prior to them. Since this is an unexplored kinematic region, cross sections must be estimated in order to gauge the beam time required. We note that the Theory TAC recommendations from 2018 and 2020 are somewhat in opposition regarding the assessment of the two theory descriptions mentioned above. Because of significant theoretical uncertainties in both cases, the impact of the measurement may not be very strong.

Summary: The exploration of backward pion electroproduction is feasible, and JLab is an ideal venue at which to perform it. However, the PAC has concerns about the ultimate relevance of the proposed measurement.

PR12-20-008

Scientific Rating: B+

Recommendation: Approved

Title: Polarization Transfer in Wide-Angle Charged Pion Photoproduction

Spokespersons: J. Arrington, A.J.R. Puckett (contact), A.S. Tadepalli, B. Wojtsekhowski

Motivation: This experiment plans to measure the helicity correlation parameters K_{LL} and K_{LS} for π^- photoproduction in the wide-angle regime. The nature of the interaction mechanism for this relatively simple process is not yet well understood. Theoretical studies based on GPDs suggest the dominance of twist-3 contributions and predict a sizeable and positive K_{LL} and a small K_{LS}.

Measurement and Feasibility: The measurement will take place at Hall A, using the apparatus of the GEn-RP experiment (E12-17-004), scheduled to run in 2021, with minor modifications. The proposal requests 2 PAC days. The result is expected to be measurements of the polarization observables K_{LL} and K_{LS} at well-motivated kinematic points.

Issues: Twist-3 dominance predicts K_{LL} to be roughly equal and opposite to the initial nucleon helicity correlation parameter A_{LL}, but the uncertainty on the size of K_{LL} is presently unknown. Therefore, the significance of the proposed measurement by itself is limited, but could be enhanced by a future measurement of A_{LL}.

Summary: The PAC believes that it is important to understand the basic mechanism of wide-angle pion photoproduction. This measurement by itself can give a partial contribution to this effort. It could become more relevant if combined with other measurements and if the uncertainties affecting theoretical predictions are better understood.

PR12-20-009

Scientific Rating: N/A

Recommendation: C2

Title: Beam charge asymmetries for Deeply Virtual Compton Scattering on the proton at CLAS12

Spokespersons: V. Burkert, L. Elouadrhiri, F.-X. Girod, S. Niccolai, E. Voutier (contact)

Motivation: The goal is to measure the unpolarized and polarized Beam Charge Asymmetries (BCAs) of the $e^{+/-}\, p \rightarrow e^{+/-} p\, \gamma$ process on unpolarized hydrogen with CLAS12, using polarized positron and electron beams at 10.6 GeV. The DVCS cross section can be expressed in terms of Compton Form Factors (CFFs), which in turn may be written in terms of Generalized Parton Distributions (GPDs) using factorization. Accurate determination of both real and imaginary parts of the CFFs is essential for the analysis of hard exclusive processes and the determination of GPDs. To this end, it is proposed to measure

- the unpolarized beam charge asymmetry A^{C}_{UU}, which is sensitive to the real part of CFFs,
- the polarized beam charge asymmetry A^{C}_{LU}, which is sensitive to the imaginary part of CFFs,
- the beam-charge averaged beam spin asymmetry A^{0}_{LU}, which is in particular sensitive to higher twist effects.

The combination of measurements with oppositely charged incident beams is theoretically the cleanest way to access the CFFs described above. It hence provides a highly attractive way to constrain the GPDs. The kinematic range accessible with an 10.6 GeV beam on an proton target will allow one to investigate the Q^2 dependence at fixed x.

Measurement and Feasibility: The measurements are planned with the CLAS12 spectrometer in the out-bending mode, using the regular detector arrangement with a luminosity of 0.6×10^{35} $cm^{-2}\, s^{-1.}$ The requested beamtime is 2400 hours. As a secondary e^+ beam has a much larger momentum dispersion and emittance than the primary e^- beam currently existing, one has the same $\delta p/p$ with a spot size 2-3 times larger at the target. Therefore, a target cell with 50% larger (15 mm diameter) entrance and exit windows is needed to avoid any interaction with the target structure frames. This difference in the beam parameters leads the collaboration to require equal statistics of electron and positron data using secondary e^+ *and* e^- beams.

Issues: The iTAC report concludes that "while a positron beam upgrade is a major upgrade, which will require substantial accelerator physics development, a detailed cost and implementation plan, and expensive changes to the CEBAF accelerator, a multi-Hall positron beam capability could have great potential for a future JLAB 12-GeV science program." The PAC fully agrees with this statement.

To clearly show what science would be left unaddressed without having a polarized positron beam available at JLab, the physics impact of positron beam experiments should be demonstrated more rigorously. This should include an impact study with positron beam pseudo-data and all other existing and anticipated future data with an electron beam. One would also like to see which amount of electron data alone would be needed to obtain comparable constrains on the CFFs. Furthermore, to guide the technological development of a positron source, it is important that the experiment determines clear performance requirements for the positron beam.

The PAC notes that proposal PR12-20-012 requires no electron data set with equal beam conditions for an extraction and separation of CFFs with high accuracy. It would be interesting if both groups could come to a common understanding on this issue.

Summary: The PAC recognizes the strong science case of positron beams for the GPD program at JLab. However, it feels that more rigorous simulations are needed to highlight the unique potential of the proposed experiment for constraining Compton Form Factors and eventually GPDs. Moreover, the amount of required beam time with secondary electron beams needs to be justified in a more quantitative way.

PR12-20-010

Scientific Rating: A-

Recommendation: Approved

Title: Measurement of the Two-Photon Exchange Contribution to the Electron-Neutron Elastic Scattering Cross Section

Spokespersons: E. Fuchey (contact), S. Alsalmi, B. Wojtsekhowski

Motivation: This proposal aims to provide a first measurement of the two-photon exchange contribution to elastic electron-neutron scattering

Measurement and Feasibility: This is a two-day extension to the GMn experiment E12-09-019 in Hall A, which is presently scheduled for 2021. It uses the approved beam time at 4.4 GeV of the GMn experiment together with new beam time at 6.6 GeV. A method originally used at Mainz takes ratios of d(e,e'n)p and d(e,e'p)n cross sections. With the large acceptance of the hadronic calorimeter, neutrons from *en* and protons from *ep* scattering can be detected simultaneously. The main goal is to measure the Rosenbluth slope for *en* elastic scattering at $Q^2 = 4.5$ GeV^2. The two-photon exchange contribution will be determined by comparing this to results on G_E^n/G_M^n obtained with the polarization transfer method.

Issues: Results should be presented as cross section ratios in addition to the two-photon interpretation. In this way, theorists will be able to use the data for their own interpretation.

Summary: We judge this to be a quality measurement and an efficient use of beam time.

PR12-20-011

Scientific Rating: A-

Recommendation: Approved

Title: Measurement of the high-energy contribution to the Gerasimov-Drell-Hearn sum rule

Spokespersons: M. M. Dalton, A. Deur (contact), S. Sirca, J. Stevens

Motivation: The Gerasimov-Drell-Hearn sum rule relates the integral over the doubly-polarized spin-dependent photo-production cross section off a hadron to the anomalous magnetic moment of the hadron. It may be derived in dispersion theory, where it rests on fundamental concepts such as causality, unitarity, Lorentz and gauge invariance, as well as on a "no-subtraction'' hypothesis. Whilst the integral runs all the way to infinitely large photon energy, experimental studies at LEGS, MAMI, and ELSA have so far been limited to 2.9 GeV. The proposal extends the exploration of the high-energy regime to 12 GeV. The measurement would provide valuable information on Regge phenomenology in the polarization domain in this energy range. This is well motivated and uniquely possible at JLab. An experiment planned for the 6 GeV program did not run.

This experiment will enrich the physics program of Hall D, in particular by using a polarized target. As such, the proposal is strongly endorsed by the GlueX collaboration.

Measurement and Feasibility: The experiment is to run in Hall D with a circularly polarized photon beam generated by polarized electrons impinging on a radiator. It will run in two configurations, which require two different CEBAF beam energies with 21 PAC days at the nominal CEBAF energy and 12 PAC days at an energy 1/3 to 1/2 of the nominal one. It is planned to measure photo-production off protons as well as off deuterons, so that also the neutron GDH integral could be tested. The proponents have decided to use the FROST target design, due to its easier operation and higher neutron polarization. A new version of the target will need to be built. The Hall D detection system is well suited for this measurement, thanks to its large solid angle.

Issues: The TAC report notes that the experiment is quite demanding, but that no real show-stopper has been identified. The PAC agrees with this statement. In addition, the polarized target infrastructure may be re-used in other physics programs at JLab.

Summary: The PAC recognizes the strong science case for this proposal, and recommends running with the full beam time requested in the proposal.

PR12-20-012

Scientific Rating: N/A

Recommendation: C2

Title: Deeply Virtual Compton Scattering using a positron beam in Hall C

Spokespersons: J. Grames, C. Munoz Camacho (contact), M. Mazouz

Motivation: The goal of the proposed experiment is to cleanly separate the squared Compton amplitude, $DVCS^2$, from the DVCS-BH (Bethe-Heitler) interference term in the process $e\,p \rightarrow e\,p\,\gamma$ at large Q^2. This separation allows one to disentangle the real and imaginary parts of the Compton Form Factors (CFFs), which can be expressed in terms of Generalized Parton Distributions (GPDs) using factorization. An accurate determination of both real and imaginary parts of the CFFs is essential for the analysis of hard exclusive processes and the determination of GPDs.

The combination of measurements with oppositely charged incident beams is the theoretically cleanest way to disentangle the contribution of the $DVCS^2$ term and its interference with the BH amplitude. It hence provides a highly attractive way to constrain the GPDs.

Measurement and Feasibility: To achieve high precision, the experiment will use the High Momentum Spectrometer (HMS) of Hall C together with the Neutral Particle Spectrometer (NPS), which is a high-resolution $PbWO_4$ electromagnetic calorimeter. It is proposed to measure the cross section of the DVCS reaction with positrons on unpolarized protons in a wide range of kinematics, using beam energies of 6.6, 8.8 and 11 GeV. This will allow for several values of Q^2 at given values of x.

To exploit the beam charge dependence of the cross section and separate the $DVCS^2$ from the DVCS-BH terms, these measurements will be combined with DVCS cross section measurements that use the existing CEBAF electron beam.

The proponents request 77 days of unpolarized positron beam with a current $I > 5\mu A$. At the moment when the experiment could run, the experimental setup will have been used in several other experiments and will therefore very well understood. Therefore, there are no concerns about the experimental setup, and the committee is confident that the described measurements can be performed.

Issues: The iTAC report concludes that "while a positron beam upgrade is a major upgrade, which will require substantial accelerator physics development, a detailed cost and implementation plan, and expensive changes to the CEBAF accelerator, a multi-Hall positron beam capability could have great potential for a future JLAB 12-GeV science program." The PAC fully agrees with this statement.

To clearly show what science would be left unaddressed without having a polarized positron beam available at JLab, the physics impact of positron beam experiments should be demonstrated more rigorously. This should include an impact study with positron beam pseudo-data and all other existing and anticipated future data with an electron beam. One would also like to see which amount of electron data alone would be needed to obtain comparable constrains on the CFFs. Furthermore, to guide the technological development of a positron source, it is important that the experiment determines clear performance requirements for the positron beam.

The PAC notes that proposal PR12-20-009 requires an equal-statistics electron data set for an extraction and separation of CFFs with high accuracy. It would be interesting if both groups could come to a common understanding on this issue.

Summary: The PAC recognizes the strong science case of positron beams for the GPD program at JLab. However, it feels that more rigorous simulations are needed to highlight the unique potential of the proposed experiment for constraining Compton Form Factors and eventually GPDs.

PR12-20-013

Scientific Rating: B+

Recommendation: Approved

Title: Studying Λ interactions in nuclear matter with the ^{208}Pb (e,e' K^{+}) $^{208}_{\Lambda}$Tl reaction

Spokespersons: O. Benhar, F. Garibaldi (contact), P.E.C. Markowitz, S.N. Nakamura, J. Reinhold, L. Tang, G.M. Urciuoli, T. Gogami

Motivation: The proposal focuses on measuring the excitation spectrum of $^{208}_{\Lambda}$Tl obtained from the ^{208}Pb (e,e' K+) $^{208}_{\Lambda}$Tl reaction, in order to aid the resolution of problems associated with the role of hyper-nuclear matter in determining the maximum mass of neutron stars. A similar experiment using ^{40}Ca and ^{48}Ca targets, proposed by this group, has been approved to investigate the isospin dependence of hyperon dynamics (E12-15-008).

Using the heavier target with large neutron access provides an as good as possible proxy of matter in the interior of a neutron star. State-of-the art calculations of neutron matter with modern two- and three-body hyperon-nucleon forces indicate that the three-body forces become repulsive at high density, a feature that cannot be constrained considering only lighter systems.

Measurement and Feasibility: The measurement is proposed to take place in Hall A, using the same experimental apparatus as for experiment E12-15-008 but a cryogenic cooled Pb target. The proposal gives less specific information on the feasibility of the proposed measurement, such as details and simulations of the statistical resolution and backgrounds, as well as on the extraction of the Λ binding energy from the measurement and on the improvement with respect to the already approved E12-15-008 experiment. More information was provided in correspondence between the proponents and the PAC.

Issues: The PAC recommends the proponents to perform a state-of-the-art analysis of the results they expect to extract from the measurements, taking into account statistical and systematic errors as well as background. This should help optimizing the experiment. Also, the PAC recommends to work with the JLab target group to make a concrete plan of the target.

Summary: The proposal was presented at PAC46 and deferred. In this resubmission, issues previously raised are adequately addressed as far as the technical description is concerned. In addition, the group reached out to the relevant theory community investigating the hyperon puzzle in neutron stars with state-of-the-art approaches. For this community, the outcome of the measurements will be of interest in its own. Therefore, the remark in the PAC46 report that "it will highly valuable to see the results of the approved ^{40}Ca and ^{48}Ca measurements and their impact on ΛN and ΛNN forces" is not an issue any more, and PAC48 recommends approval.

Jeopardy Experiments

E12-12-002 (GlueX-II)

Title: An update on the GlueX II and Jefferson Lab Eta Factory experiments

Spokespersons: M. R. Shepherd (contact), A. Somov, J. R. Stevens, S. Taylor, L. Gan

Motivation: The goal of the experiment is to search for and study the spectrum of hybrid mesons with the GlueX detector enhanced by a DIRC, and to study decays of eta and eta-prime mesons with the GlueX detector after the FCAL 2 upgrade. This will allow for tests of non-perturbative QCD and may provide hints of physics beyond the Standard Model.

1) Is there any new information that would affect the scientific importance or impact of the Experiment since it was originally proposed?

E12-12-002 (GlueX with DIRC) was first approved by PAC 42 in 2014, and the JLab Eta Factory (JEF) experiment was joined (E12-12-002A) as a result of PAC 45 in 2017. The motivation of the experiment continues to be strong and is further strengthened by contemporary theoretical work. On the experimental side, this experiment should be a leader of the field once the data have been taken.

2) If the Experiment has already received a portion of its allocated beam time and/or is on the presently published accelerator schedule, the spokespersons should provide an analysis of the existing data set, the projected result for any additional time on the published schedule, and the projected result for the complete data set including all remaining unscheduled time. The goal is to show the physics impact of the respective data sets.

The approved beam time is 20 days for commissioning and 200 days for production. Among these, 14 commissioning and 38 production days have already been used. The collaboration has shown an initial analysis of the data. The FCAL 2 upgrade, which the JEF experiment requires, will be completed in 2023. In the coming years until 2023, some portion of the approved beam time will be used for the physics without the FCAL 2 upgrade.

3) Should the remaining beam time allocation and experiment grade be reconsidered?

Given the importance of the GlueX II experiment, the PAC recommends to keep the beam time allocation and scientific grading.

Summary: The PAC recommends that this experiment remain active.

E12-13-008

Title: Measuring the Charged Pion Polarizability in the gamma gamma -> pi+ pi- Reaction

Spokespersons: R. Miskimen (contact), E. Smith, D. Lawrence, I. Larin

Motivation: Measurements of hadron polarizabilities provide an important test point for effective field theories, dispersion relations and lattice calculations. Among the hadron polarizabilities, the charged pion polarizability is of paramount importance because it tests fundamental symmetries at leading order. The proposed experiment aims to extract the charged pion polarizability using the gamma gamma -> pi^+ pi^- reaction in the domain of low invariant mass $M_{\pi\pi}$ with an accuracty of 1.5% to extact the combination $\alpha_\pi - \beta_\pi$. The proposed cross section measurement will allow for a determination of $\alpha_\pi - \beta_\pi$ with an uncertainty of 0.6×10^{-4} fm^3

1) Is there any new information that would affect the scientific importance or impact of the Experiment since it was originally proposed?

Since approval the collaboration worked on developing detector upgrades, trigger upgrades, software tools for particle identification, and partial wave analysis. The collaboration also decided to change the target from Sn to ^{208}Pb.

There has been considerable progress concerning theory: new publications from Dai and Pennington (2016), and Vanderhaeghen, Danilikin et al. (2019, 2020) are available, making the motivation to carry out the experiment stronger.

2) If the Experiment has already received a portion of its allocated beam time and/or is on the presently published accelerator schedule, the spokespersons should provide an analysis of the existing data set, the projected result for any additional time on the published schedule, and the projected result for the complete data set including all remaining unscheduled time. The goal is to show the physics impact of the respective data sets.

The experiment originally requested 25 beam days, but did not run yet. There is no change in the requested beam time.

The experiment will be ready to run by 2022. With the presented technical update, this schedule seems realistic, and the experiment should be scheduled.

3) Should the remaining beam time allocation and experiment grade be reconsidered?
The beam time allocation should stay as is. The scientific rating given by PAC40 was A-, and PAC48 confirms this rating.

Summary: The PAC recommends that the experiment remain active and be scheduled in a timely fashion.

CLAS12 Run Group A

Spokespersons: L. Elouadrhiri (contact), D. Carman, S. Stepanyan, H. Avakian, M. Battaglieri, R. Gothe, F.-X. Girod

Motivation: RG-A is formed by 13 experiments grouped in five topical categories:

1. Deep Exclusive Processes (E12-06-119, E12-06-108, and E12-12-007): Study of Generalized Parton Distributions (GPDs), 3D imaging of the proton, and study of its gravitational and mechanical structure

2. Deep Inclusive and SIDIS (E12-06-112, E12-06-112A, and E12-06-112B): Study of the Transverse Momentum Distributions (TMDs) and the 3D structure in momentum space

3. Quasi-Photoproduction (E12-12-001 and E12-12-001A): Study of J/Ψ Photoproduction, LHCb Pentaquarks, and Time-like Compton Scattering (TCS)

4. Nucleon Structure (E12-09-003, E12-06-108A, and E12-06-108B): Study of nucleon resonance structure at photon virtualities Q^2 from 2.0 GeV^2 to 12 GeV^2

5. MesonEx Program (E12-11-005 and E12-11-005A): Study of meson spectroscopy in the search for hybrids

1) Is there any new information that would affect the scientific importance or impact of the Experiment since it was originally proposed?

Since the approval of the RG-A experiments, several works have been published, presenting the extraction of GPDs and TMDs with the highest currently available level of theoretical precision. Tools have been made available to extract information from data and to simulate observables, and RG-A can take advantage of them. Recent works suggest the possibilities to access new terms of the nucleon's energy-momentum tensor: RG-A experiments can provide pioneering investigations in this direction. At the same time, concerns about the applicability of the extraction formalism in the kinematics of Jefferson Lab experiments (moderate Q) have been raised: new data should serve the purpose of testing the partonic framework that underpins the interpretation of data. Careful studies of subleading twist contributions have become more important, both because of their unique physics content and because they often contaminate leading-twist observables.

Several hadron resonances have been reported in recent years from experiments at other laboratories, and some controversial results can be addressed by the RG-A experiments. Jefferson Lab has created the Joint Physics Analysis Center (JPAC), whose activities in amplitude analysis make it possible to take full advantage of hadron spectroscopy data.

Lattice QCD is providing new precision calculations of hadron properties. New studies opened the possibility to compute the multi-dimensional structure of hadrons from first principles, creating new opportunities to test and understand QCD in the nonperturbative regime.

Finally, DoE has approved the construction of the Electron Ion Collider and Jefferson Lab will be a key partner in designing, constructing, and operating it. The complementarity between JLab 12 GeV measurements and the EIC has to be fully exploited, and the experiments in RG-A can play an essential part in this endeavor.

2) If the Experiment has already received a portion of its allocated beam time and/or is on the presently published accelerator schedule, the spokespersons should provide an analysis of the existing data set, the projected result for any additional time on the published schedule, and the projected result for the complete data set including all remaining unscheduled time. The goal is to show the physics impact of the respective data sets.

RG-A collected data for roughly half of the full approved RG-A beam time. The calibration processing, and analysis of this data is already at an advanced stage. Preliminary results for beam-spin asymmetries in DVCS and meson production, for multiplicities and single-spin asymmetries in SIDIS, for TCS, J/Ψ photoproduction, and for exclusive electroproduction of hadrons have been presented to the PAC and at international meetings. The collaboration expects to have first physics results with the available statistics soon, and preparation of the first publications is underway. Given the goal to reach high statistics, it will be crucial to carefully take systematic uncertainties into account in the analysis.

3) Should the remaining beam time allocation and experiment grade be reconsidered?

To fully realize the goals of the RG-A science program, the full statistics of the approved beam time is required. For the study of GPDs and TMDs, multidimensional binning requires high statistics, and is also crucial to test the interpretation formalism. For meson and baryon spectroscopy, statistics is required for the study of rare events, e.g., the production of exotic hadrons. Sufficient precision needs to be reached in corners of phase space, for instance to achieve the significant extension in Q^2 promised by the CLAS12 12-GeV upgrade.

Summary: The PAC recommends that this experiment remain active with no change in status.

CLAS12 Run Group B
Electroproduction on deuterium with CLAS12

Spokespersons: S. Niccolai

Motivation:

1. Comprehensive study of GPD and TMDs using deuterium as a neutron target and measuring exclusive and semi-inclusive reactions. Main goals: access to the GPD E, leading to the contribution of quark angular momentum to the nucleon spin; flavor separation of GPDs and TMDs via combination of proton and deuteron observables; accurate measurement of the neutron magnetic form factor at high Q^2
2. Exclusive, near-threshold coherent and incoherent J/Ψ quasi-real photoproduction on the deuteron, to study the gluonic structure of bound nucleons and of the deuteron, and to search for isospin partners of the LHCb pentaquark
3. In-medium structure functions, Short Range Correlations, and the EMC effect, studied via proton-DIS with neutron-spectator tagging, to be compared to free-proton DIS results
4. Quasi-real ppbar photoproduction to look for ppbar resonances and to study the coherent production mechanism on deuterium

1) Is there any new information that would affect the scientific importance or impact of the Experiment since it was originally proposed?

Preliminary analysis of the experimental data taken so far demonstrates good progress and confirms the promises of the proposed experiments, including the DVCS measurements, in-medium structure functions and the EMC effect. Neutron DVCS plays a unique role to constrain the flavor structure of the GPDs. The PAC finds that recent GlueX results on near-threshold J/ Ψ production have weakened the motivation of the pentaquark search in this experiment.

2) If the Experiment has already received a portion of its allocated beam time and/or is on the presently published accelerator schedule, the spokespersons should provide an analysis of the existing data set, the projected result for any additional time on the published schedule, and the projected result for the complete data set including all remaining unscheduled time. The goal is to show the physics impact of the respective data sets.

Preliminary analyses have been shown for neutron DVCS, and also for incoherent proton DVCS and coherent deuteron DVCS. Results for other channels are also well underway.

3) Should the remaining beam time allocation and experiment grade be reconsidered?
No.

Summary: The motivation to complete the neutron DVCS measurements is very strong. The efforts of the collaboration to measure additional DVCS channels are commended by the PAC. The motivation for the pentaquark search may not be as strong as claimed. The analysis of data already taken is going well. The PAC recommends to maintain the remaining beam time allocation.

CLAS12 Run Group C

Spokespersons: S. Kuhn (contact), H. Avakian, C. Keith, S. Niccolai, F. Sabatié, W. Armstrong

Motivation: Run Group C (RG C) comprises six approved experiments with the CLAS12 spectrometer in Hall B, each scattering polarized electrons from longitudinally polarized protons or deuterons to determine the flavor structure of nucleons. This includes unpolarized PDFs, helicity PDFs, TMDs and GPDs.

E12-06-109: Longitudinal spin structure of the nucleon

E12-06-109a: DVCS on the neutron with a polarized deuterium target

E12-06-119b: DVCS on a longitudinally polarized proton target

E12-07-107: Spin-orbit correlations with a longitudinally polarized target

E12-09-009: Spin-orbit correlations in kaon electroproduction in DIS

E12-09-007b: Study of partonic distributions using SIDIS kaon production

1) Is there any new information that would affect the scientific importance or impact of the Experiment since it was originally proposed?

Since the experiments have been approved, a lot of new data that constrains unpolarized PDFs, helicity dependent PDFs, and TMDs has been published by COMPASS and the RHIC experiments. Several of this data covers the same x but higher Q^2 compared with RG C, which make the theoretical interpretation of the data significantly easier. In the light of these developments, it is necessary to re-assess the scientific impact of the RG C measurements. The PAC would like to see a corresponding impact study, based on pseudo-data representing the expected experimental performance. This study should consider all the relevant existing data. The improved understanding of kaon production at 12 GeV and its sensitivity to strangeness should be considered as well in this context. There is no change of the scientific importance of the DVCS part of the Run group.

2) If the Experiment has already received a portion of its allocated beam time and/or is on the presently published accelerator schedule, the spokespersons should provide an analysis of the existing data set, the projected result for any additional time on the published schedule, and the projected result for the complete data set including all remaining unscheduled time. The goal is to show the physics impact of the respective data sets.

No data has been taken, but all components of the experiment are on track to be ready by early 2022. A request for beam scheduling was submitted in August 2019 for 182 calendar days (91 PAC days, or roughly 1/2 of the total approved beam time for RG C). This request was accepted with the sole proviso that running on any nuclear targets can be demonstrated not to harm the CLAS12 central silicon vertex detector. A beam test to address this question was conducted in February 2020, and the results appear to alleviate any concerns about running nuclear targets in CLAS12. The scheduling request for the remaining 94 PAC is planned for later after tradeoff

between raster size, luminosity, and target length for the DVCS part of the proposal have been clarified.

3) Should the remaining beam time allocation and experiment grade be reconsidered?

Yes, the PAC suggests to reduce the beam time to 120 days as requested for the DVCS part of the Run Group. The forward tagger should be available for this run. For the remaining beam time, the Run Group should return to the PAC with an updated impact study for the measurements on PDFs and TMDs as specified above.

Summary: The PAC approves 120 days of running with focus on the DVCS part of the Run Group including the forward tagger. For the remaining beam time, the proponents should come back to the PAC after the significance of the different experiments addressing PDFs, helicity PDFs and TMDs has been reevaluated.

CLAS12 Run Group D
Study of Color Transparency in Exclusive Vector Meson Electroproduction off Nuclei

Spokespersons: L. El Fassi (contact), W. Armstrong, K. Hafidi, B. Mustapha, M. Holtrop

Motivation: Experiment E12-06-106 (RG-D) aims to study the color transparency (CT) phenomenon in exclusive ρ^0 electro-production of nuclei, using the CLAS-12 spectrometer in Hall B. Through the use of different nuclear targets, the proponents aim at investigating space-time properties of small size configurations of a quark-antiquark pair.

1) Is there any new information that would affect the scientific importance or impact of the Experiment since it was originally proposed?

This experiment was endorsed by PAC30 in 2006. It was reviewed by PAC36 and granted 60 PAC days in 2010.

Initially, the experiment was proposed to run on ^{12}C,^{63}Cu and ^{118}Sn targets. When Hall B decided to merge this experiment and the experiment E12-06-117 on color propagation (CP) into a common run, Cu was changed to Fe to accommodate the CP measurement. Since ^{56}Fe cannot be run in the solenoid field of CLAS12, the proponents have changed back to the original program and presented a run plan with ^{63}Cu instead of ^{56}Fe. Theoretical calculations show that the kinematics for both nuclei are close, and updated experimental simulations confirm that the nuclear transparency of Fe will be not so different from Cu.

Additionally, a new foils assembly has been built, and the share of beam time amongst the target has been updated correspondingly.

2) If the Experiment has already received a portion of its allocated beam time and/or is on the presently published accelerator schedule, the spokespersons should provide an analysis of the existing data set, the projected result for any additional time on the published schedule, and the projected result for the complete data set including all remaining unscheduled time. The goal is to show the physics impact of the respective data sets.

The experiment has not yet received any beam time.

3) Should the remaining beam time allocation and experiment grade be reconsidered?

Yes. There has been no substantial progress in the theory of CT since this proposal was approved by PAC36, due to the paucity of new data. The results of this experiment may help to stimulate new theory efforts in CT. Both PAC30 and 36 expressed concerns about the difficulty in establishing an unambiguous experimental signature of CT, and about the impact of such a measurement on theory, which is reflected in the grading B+ of the experiment. PAC48 shares the above concerns. In addition it is not clear to the committee whether the measurement will be jeopardized by systematics.

Summary: The PAC recommends that this experiment be allocated half of the beam time (30 PAC days) and make use of the possibility to increase statistics by running together with other experiments.

CLAS12 Run Group E
Quark Propagation and Hadron Formation

Spokespersons: W. Brooks (contact)

Motivation: Run Group E consists of Jefferson Lab experiment E12-06-117 "Quark Propagation and Hadron Formation". The experiment will make use of nuclear targets to gain substantial new insights into the propagation of QCD color through strongly interacting systems. There are two essential thrusts of these studies:

1. to characterize the fundamental QCD subprocesses of color propagation and hadron formation in quark fragmentation,

2. to greatly expand our knowledge about the color structure of nuclei by using the struck quark as a colored probe of the medium. By studying the strength of the interaction between the colored quark and the nuclear medium using the transport coefficient, one can gain quantitative understanding of the color structure of bound nucleons via color charge form factors.

1) Is there any new information that would affect the scientific importance or impact of the Experiment since it was originally proposed?

The Run Group E was originally approved in 2006 and later given the scientific rating of A− by PAC36 in 2010. Since then, a large amount of *pA* data at LHC and RHIC has been obtained. Looking at jet-substructure and ultra-peripheral collisions (UPC), the same or similar questions to those above can be answered. It is worrisome that this data are not mentioned and that the proponents do not discuss how the anticipated CLAS data are complementary and what they add uniquely to the question how hadron formation is modified in the nuclear medium.

2) If the Experiment has already received a portion of its allocated beam time and/or is on the presently published accelerator schedule, the spokespersons should provide an analysis of the existing data set, the projected result for any additional time on the published schedule, and the projected result for the complete data set including all remaining unscheduled time. The goal is to show the physics impact of the respective data sets.

Run Group E has not yet received any beam time. There are no technical issues with this experimental setup as it uses standard CLAS-12 equipment. A new version of the dual target, where a deuterium cryotarget is mounted just upstream of the solid target, has been built and reviewed. The final conclusions from the readiness reviews are still outstanding and need to be resolved before scheduling the experiment.

3) Should the remaining beam time allocation and experiment grade be reconsidered?

The PAC maintains both the recommended beam time and scientific grade.
However, the committee strongly recommends that before running Run Group E, the proponents should publish the 6 GeV data. This will ensure that the collaboration has gone through all systematic corrections and uncertainty determinations. The result of this exercise should help clarify whether the 12 GeV goals are realistic. To obtain the high-precision data envisaged for

Run Group E, it is important that one understands the difference in acceptance and detector responses for *ep* and *eA* very well. To ensure this, the PAC recommends a Monte-Carlo vs. data challenge, which will indicate whether special calibration runs are needed. The physics questions addressed by this experiment remain important, but it remains to be seen in detail what can be achieved by this Run group after folding in the now known CLAS-12 performance and acceptance effects.

Summary: The PAC recommends to run the Run Group E experiments as proposed when a significant part of the 6 GeV data is published and when the laboratory management is convinced that the systematic effects, especially for baryon measurements, can be controlled such that the stated goals can be achieved. The scientific grade should remain A−.

CLAS12 Run Group G
The EMC Effect in Spin Structure Functions

Spokespersons: W. Brooks (contact), S. Kuhn

Motivation: In 1983, the European Muon Collaboration at CERN reported the modification of DIS cross sections per nucleon in DIS off nuclear targets. The results can be interpreted as nuclear effects on the quark and gluon structure of the free nucleon. The effect has been clearly established in unpolarized experiments that have been carried out since EMC. However, an agreement on the physical mechanisms that lead to the *A*-dependence of nucleon quark and gluon distribution has not be reached.

E12-14-001 is a proposal to carry out the first measurement of spin dependent nuclear effects by comparing DIS cross sections from polarized ^{6}LiH (free proton) and ^{7}LiD (bound proton) targets. Model calculations indicate that leading explanations of the EMC effect predict differences in the spin dependent DIS cross sections large enough to be detected in the experiment. Results on the spin dependent EMC effect have the potential to discriminate between competing explanations of the EMC effect observed in unpolarized scattering experiments.

The results from E12-14-001 will provide important information for the planning of future measurements at the EIC, and it would hence be helpful to have results in the early stages of EIC detector and machine design and planning.

1) Is there any new information that would affect the scientific importance or impact of the Experiment since it was originally proposed?

The precision of *A*-dependent unpolarized quark and gluon distributions has been further improved. Alternative explanations of the EMC effect still await experimental discrimination. Additional model calculations of spin dependent effects support the ability of E12-14-001 measurements to discriminate between several of the leading theoretical explanations. EIC has been approved. The results from E12-14-001 will be helpful to guide the simulations and planning for its *eA* program.

2) If the Experiment has already received a portion of its allocated beam time and/or is on the presently published accelerator schedule, the spokespersons should provide an analysis of the existing data set, the projected result for any additional time on the published schedule, and the projected result for the complete data set including all remaining unscheduled time. The goal is to show the physics impact of the respective data sets.

The experiment has not run yet.

3) Should the remaining beam time allocation and experiment grade be reconsidered?

Yes. Given the above assessment, the PAC increases the grade of the experiment to A–.

Summary: Almost 40 years after the discovery of the EMC effect, there are still no spin dependent measurements. Such measurements may have a significant impact on the theoretical understanding of the EMC effect. The experiment should run as soon as the target and the Moller shield become available. PAC42 approved the experiment for 55 days and asked for clarification on the possibility to reach a 3% control of the target polarization. This issue has been addressed by the proponents. The uncertainties shown in the submitted document have not been updated with the latest information on Hall B beam and instrumentation performance. However, the proposed measurement follows well established experimental methods, and the PAC does not request an update of the simulation studies.

The PAC recommends to change the grading from B+ to A–. The PAC also recommends to run the experiment as soon as possible, so that the results from E12-14-001 will be available during the planning phase of the *eA* program at the EIC.

CLAS12 Run Group H
Experiments with a Transversely Polarized Target

Spokespersons: M. Contalbrigo (contact)

Motivation: This run group contains a comprehensive set of measurements for GPD and TMD studies with a transversely polarized target in Hall B. It is uniquely important for the JLab 12 GeV program.

1) Is there any new information that would affect the scientific importance or impact of the Experiment since it was originally proposed?

As detailed in the TAC Theory Report, theoretical work in recent years has sharpened the limitations of interpreting SIDIS measurements in terms of parton distributions (PDFs or TMDs). The PAC recommends a concerted effort of experiment and theory to identify observables that can help to elucidate these questions in the kinematics accessible at CLAS12.

2) If the Experiment has already received a portion of its allocated beam time and/or is on the presently published accelerator schedule, the spokespersons should provide an analysis of the existing data set, the projected result for any additional time on the published schedule, and the projected result for the complete data set including all remaining unscheduled time. The goal is to show the physics impact of the respective data sets.

This experiment has not run.

3) Should the remaining beam time allocation and experiment grade be reconsidered?

No.

Summary: The scientific motivation of the run group remains very strong. The target development is key to the success of the experiments and well underway. The PAC confirms the C1 status of the run group and encourages the proponents to work with the Lab management to make sure the target is ready for the proposed experiments.

CLAS12 Run Group I
Search for Massive Photons at Jefferson Laboratory (HPS)

Spokespersons: T. Nelson (contact), S. Stepanyan, M. Holtrop

Motivation: The aim of the experiment is to search for heavy photons over a wide range of couplings, $\varepsilon^2 > 10^{-10}$, and masses, 20 MeV< $m_{A'}$< 220 MeV, using a compact, large-acceptance forward spectrometer consisting of a silicon microstrip vertex tracker (SVT), a scintillation hodoscope (SH), and a $PbWO_4$ electromagnetic calorimeter (ECal).

1) Is there any new information that would affect the scientific importance or impact of the Experiment since it was originally proposed?

The landscape of heavy photon searches has evolved since the first HPS proposal. While a significant fraction of parameter space at large ε has been ruled out by fixed target and collider experiments, new target regions, motivated by hidden sector scenarios of light dark matter, have emerged. The parameter space that HPS will probe using a displaced vertex search with 2 GeV to 5 GeV electron beams lies in the most desirable region. There is stiff competition for this parameter space from experiments coming online in 2021-2023 at CERN and FNAL. Therefore, running HPS is time-critical in order to be first to either discover a new force or significantly constrain allowed parameter space for light dark matter theories.

2) If the Experiment has already received a portion of its allocated beam time and/or is on the presently published accelerator schedule, the spokespersons should provide an analysis of the existing data set, the projected result for any additional time on the published schedule, and the projected result for the complete data set including all remaining unscheduled time. The goal is to show the physics impact of the respective data sets.

HPS has used 45.5 PAC days of the approved 180 days for the engineering and first physics runs combined, and the collaboration expects to use 27.5 PAC days during the scheduled 2021 run.

HPS completed two engineering runs in 2015 and 2016 with 1.1 GeV and 2.3 GeV beams, respectively. The engineering runs established excellent beam conditions. The SVT was successfully moved into the nominal data taking position, and all systems worked as designed. The 2015/2016 data was the basis for the resonance search and a displaced vertex search, with results appearing in PhD theses, analyses notes, proceedings, and journal publications. The searches do not exclude new parameter space for the minimal A′ production model, but demonstrate significant improvements to both analyses. The 2015 and 2016 run also motivated key upgrades to the apparatus prior to the physics runs.

In the first physics run with the upgraded detector in the summer of 2019, HPS collected roughly 45% of the expected physics-quality data at 4.56 GeV. The collaboration expects to release the first physics result from this data in early 2021. While little or no new sensitivity is expected, the resonance search forms the basis for the displaced vertex search, which should follow within a year, and should offer a window into highly motivated parameter space.

After maintenance and repairs, which are ongoing, the HPS detector will be ready for the next physics run scheduled in the summer of 2021 with a 3.7 GeV electron beam.

3) Should the remaining beam time allocation and experiment grade be reconsidered?

The collaboration proposes that future physics operations include 10 PAC weeks at ≈ 4 GeV and 6 PAC weeks at ≈ 2 GeV. The PAC endorses this scenario and recommends maintaining the remaining time allocation (135 days) as well as the experiment grade A.

Summary: The PAC recommends the approval of 135 PAC days of beam time for running with beam energies from ≈ 2 GeV to ≈ 4 GeV.

CLAS12 Run Group K
Quark-Gluon Confinement & Strong QCD

Spokespersons: A. D'Angelo (contact), V. Burkert, D. Carman, L. Elouadrhiri, F.-X. Girod, R. Gothe, V. Mokeev

Motivation: RG-K is formed by 3 experiments with 2 major themes:

1. Deep Exclusive Processes (E12-16-010B): Study of Generalized Parton Distributions (GPDs) and study of its gravitational and mechanical structure

2. Nucleon Structure (E12-16-010 and E12-16-010A): Study of nucleon resonance structure with emphasis on new structures

Run group K is an extension of run Group A, using the same apparatus but lower beam energies and a reversed magnetic field. The reversed field gives access to lower Q^2 than possible with RG A. Much of the physics justification and data analysis are then strongly linked. The need for lower energy results to complement core results makes sense, as any new phenomenon should evolve with energy. Different beam energies are needed to constrain the Compton amplitude to interpret DVCS data.

1) Is there any new information that would affect the scientific importance or impact of the Experiment since it was originally proposed?

The field has evolved since the proposals were originally approved. New baryon resonances have been reported, and E12-16-010 and E12-16-010A have the goal of testing and extending these claims. The DVCS data from the 6 GeV era have been published and provide strong evidence for the value of E12-16-010B studies.

2) If the Experiment has already received a portion of its allocated beam time and/or is on the presently published accelerator schedule, the spokespersons should provide an analysis of the existing data set, the projected result for any additional time on the published schedule, and the projected result for the complete data set including all remaining unscheduled time. The goal is to show the physics impact of the respective data sets.

Run Group K received a small fraction of its allotted beam time. They have calibrated and analyzed that data, and the results are encouraging.

3) Should the remaining beam time allocation and experiment grade be reconsidered?

No.

Summary: The PAC recommends that this experiment remain active with no change in status.

Run Group Additions

E12-06-106A

Title: Nuclear TMDs in CLAS12

Spokespersons: Z.-E. Meziani, H. Szumila-Vance, R. Dupré (contact)

Motivation: There is a large program of measuring transverse momentum dependent parton distribution functions (TMDs) on nucleons. This proposal wants to extend this program to nuclei so as to explore an essential aspect of QCD studies, the effect of the nuclear medium on the dynamics and motion of quarks and gluons. These measurements are a natural extension of the program of measuring collinear nuclear parton densities and fragmentation functions. Like in the nucleon case, the tool to be used is semi-inclusive deep inelastic scattering (SIDIS).

Measurement and Feasibility: This proposal complements the already approved physics program of CLAS12. In order to perform these studies, it is planned to use the targets and beam time already approved for Run Group D, with the only addition being the use of beam polarization. In this way, the beam time is optimized.

Summary: There is no question that the proposed measurements are interesting if one can really interpret them in the TMD framework. There are a couple experimental hurdles that need to be well controlled, namely acceptance and radiative corrections. It is especially important that the acceptance corrections and radiative corrections be applied in a combined Monte Carlo method, because they do not factorize. In parallel to the experimental program, it would be good to see a theoretical development to interpret the data and to provide an understanding whether factorization holds in the kinematic regime and how much of the data is really in the current fragmentation region.

E12-13-008A

Title: Measuring the Neutral Pion Polarizability

Spokespersons: E. Smith (contact), M. Ito, B. Zihlmann, R. Miskimen, I. Larin

Motivation: This proposal aims to provide a first measurement of the π^0 electric polarizability

Measurement and Feasibility: The experiment will use 20 days existing beam time and the same apparatus as the charged pion polarizability experiment in Hall D. This uses the GlueX detector with an additional radiator and additional shower counters. The experiment uses the Primakoff method to measure the $\gamma\gamma \rightarrow \pi^0 \pi^0$ cross section. Getting an accurate normalization of the cross section must be a priority.

Summary: This is a well-justified measurement with existing apparatus.

E12-09-007A

Title: Studies of Dihadron Electroproduction in DIS with Longitudinally Polarized Hydrogen and Deuterium Targets

Spokespersons: H. Avakian, C. Dilks (contact), O. Soto

Motivation: The goal of this proposal is to measure dihadron correlations in SIDIS off longitudinally polarized hydrogen and deuterium targets. This measurement can provide useful information to constrain twist-three parton distribution functions, dihadron fragmentation functions, and fracture functions.

Measurement and Feasibility: The proposal is an addition to Run Group C in Hall B and is fully endorsed by the CLAS collaboration. The measurement *per se* is feasible, but the interpretation in terms of partonic distributions needs to be carefully assessed.

Summary: The PAC considers the proposal a valuable addition to Run Group C, especially because it can be useful to study higher-twist contributions, the limits of applicability of twist-three factorization (both collinear and TMD), and the separation of current and target fragmentation. The PAC recommends to provide results for all observables suitable to confront those issues (for instance, multidimensional binning of data and polarization-averaged multiplicities).

E12-11-007A/E12-10-006E

Title: A Precision Measurement of Inclusive g2n and d2n with SoLID on a Polarized ^{3}HeTarget at 8.8 and 11 GeV

Spokespersons: Chao Peng and Ye Tian (contact)

Motivation: Precision study is proposed of the fundamental spin structure function $g^n_2(x,Q^2)$ for the neutron. This would quantify higher twist contributions to $g^n_2(x,Q^2)$ by determining the 3rd moment, dn^2 (Q^2), of a properly chosen linear combination of $g^n_1(x,Q^2)$ and $g^n_2(x,Q^2)$. The measurement would provide a test of the Burkhardt-Cottingham sum rule.

Measurement and Feasibility: The proposal aims at the measurement of longitudinal spin asymmetries in inclusive DIS from a polarized ^{3}He target using the SOLID detector. The feasibility of this measurement has been established through careful Monte Carlo simulation studies of inclusive DIS and SIDIS with different targets and the SOLID detector. There are no concerns with regard to the experimental feasibility.

Summary: The cross section in inclusive DIS is described by four fundamental structure functions, $g_1(x,Q^2)$, $g_2(x,Q^2)$, $F_1(x, Q^2)$ and $F_2(x,Q^2)$. It is highly important to characterize these four structure functions over a large kinematic area with high precision for protons and neutrons, using targets of polarized protons, deuterium, and ^{3}He. Measuring g_2 and d_2 offers the exciting opportunity to determine the size of the higher twist contribution to g_2.

E12-06-117A

Recommendation:

Title: Dihadron measurements in electron-nucleus scattering with CLAS12

Spokespersons: M. Arratia (contact), A. El Alaoui, K. Joo

Motivation: The proposed addition to the CLAS12 Run Group E physics program is to study di-hadron angular correlations in nuclear DIS. Evidence of angular correlations has been seen in CLAS6, in particular the suppression of back-to-back pion pairs. The increase in beam energy and luminosity, as well as the improved instrumentation of the CLAS12 detector will allow one to confirm and further elucidate the nature of this effect. The proposed measurements will be complementary to those at the future EIC, as they explore a different kinematic range. This is crucial for a full understanding of QCD effects in nuclei.

Measurement and Feasibility: The experiment is planning to measure azimuthal correlations of di-hadron production in deep-inelastic scattering off nuclei (deuterium, C, Fe and Pb). Key observables to be determined are the multiplicity ratio R_h and the conditional modification factor R_{2h}, as defined in the proposal.

Preliminary results from CLAS6 have been compared with the GiBUU transport code, and qualitative agreement was observed. The proposed measurements would also allow one to improve the description of hadron production in this transport code.

This proposal does not require additional beam time, nor any modification of the detector or trigger. The already approved experimental setup of Run Group E is well suited for this proposal.

Issues: It is mentioned in the proposal that the results can provide valuable input to neutrino oscillation programs such as DUNE, for which multi-pion production in DIS off argon dominates the total cross section. The PAC encourages the collaboration to present the results of the measurements also in the form of pion kinematic distributions, so that it is useful for neutrino oscillation experiments.

Summary: The PAC recommends Run Group E to integrate this proposal into their running plan.

Letters of Intent

LOI 12-20-001

Title: Measurement of the Neutral Pion Transition Form Factor and Search for the Dark Omega Vector Boson

Spokespersons: A. Gasparian

Motivation: Two experiments are proposed. The first is to measure the neutral pion transition form factor (TFF) in the Q^2 range from 0.001 to 0.1 GeV^2. This will help to narrow down the uncertainties of the hadronic light-by-light (HLbL) contribution to the muon anomalous magnetic moment, g-2. The second proposed experiment is the search for a hidden sector vector boson (dark omega), coupled to matter via the baryonic current, in the 140 – 620 MeV mass range.

Measurement and Feasibility: The two proposed experiments will run concurrently and use the PRad-II setup in Hall B. The measurement of the neutral pion TFF is via the Primakoff reaction with virtual incident photons. The virtual Primakoff scattering cross section can be distinguished from the nuclear coherent and incoherent reactions, which was shown to work in the PrimEx-II data. The second experiment is to search for dark omega in the direct electroproduction on a silicon target in the forward direction of 10.5 GeV electron beam. The dark omega decays into a neutral pion and a photon, leading to a bump in the three-photon invariant mass distribution. An initial design of the experiments, as well as preliminary estimates of their acceptance, resolution, uncertainties, backgrounds, and sensitivity have been worked out. The results of this exercise are encouraging.

Issues: (1) For the neutral pion TFF measurement: given the recent progress in lattice QCD calculations, the authors are encouraged to put their anticipated results for the neutral pion TFF more closely into the context of the efforts to control the uncertainty on the HLbL contribution to the muon g-2. Ideally, this should include an estimate of how much the measurement would decrease that uncertainty. (2) For the search of the dark omega: while it is useful to search for such gauge boson in the three-photon final state, the motivation for the specific model considered in the proposal is relatively weak. (3) On the experimental side: the detailed experimental layout and detector design need to be carefully worked out, along with a full Monte Carlo simulation of backgrounds.

Summary: Both proposed experiments will provide insight in the search for new physics beyond the Standard Model. The authors are encouraged to sharpen their theoretical motivation, to develop a detailed design of the experiments, and to perform comprehensive background studies. Given the status of the physics motivation for each proposed experiment, the PAC recommends to prioritize the neutral pion TFF measurement when detector setup and optimization are considered.

LOI 12-20-002

Title: Measurement of the neutron charge radius

Spokespersons: N. Sparveris (contact), M. Paolone, Z.-E. Meziani, M. Jones, A. Camsonne

Motivation: Present evaluations of the charge radius square $\langle r_n^2 \rangle$ of the neutron use low energy neutron scattering on diamagnetic materials (inverse kinematics). The various experiments agree rather well with each other, apart from a few outliers that follow statistical fluctuations. However, as charge radius square measurements are often affected by unknown systematics, the proponents of this LoI intend to use standard kinematic electron-nucleon scattering and to derive $\langle r_n^2 \rangle$ from the slope of the electric form factor $G_E^n(Q^2)$ at $Q^2=0$. Although the expected accuracy for this measurement will not really impact the present knowledge of $\langle r_n^2 \rangle$, it would constitute a systematic check of all previous measurements.

Measurement and Feasibility: The experiment aims at determining the electric form factor $G_E^n(Q^2)$ at very small Q^2 from electric and Coulomb quadrupole transitions of the proton to the Δ. The reaction e p $\rightarrow$ e $\Delta^+ \rightarrow$ e p π^0 is reconstructed, using the double arm spectrometer in Hall C running at a beam momentum of 1.3 GeV/c and reconstructing the π^0 through missing mass. The measurement technique builds on many similar measurements that were performed in the past at larger values of Q^2. Normalisation is a key issue, as different Q^2 values require different settings of the magnetic spectrometers. Using asymmetries in the proton polar angle with respect to the virtual photon, the electric and quadrupole p $\rightarrow \Delta$ transition form factors can be extracted. From these, the electric form factor G_E^n is obtained using relations derived for the large-N_c limit of QCD, where N_c is the number of colors.

Issues: (1) The theory TAC report points out that the large-N_c relations just mentioned are valid only at tree level. In the language of chiral perturbation theory, they receive corrections from pion (and kaon) loops. The one-loop contributions have been computed for G_E^n [Phys. Rev. D 101 (2020) 054026], but no corresponding analysis for the p $\rightarrow \Delta$ transition is currently available. These loop contributions could substantially modify the large-N_c relations in the region of very low Q^2, which is crucial to determine the slope of G_E^n at $Q^2=0$ but outside the region in which the proposal has corroborated the validity of the relations using existing data. A reliable estimate of theoretical uncertainties of the proposed method to determine $\langle r_n^2 \rangle$ thus requires further studies. (2) The physics TAC report points out technical issues related to the operation of the HMC spectrometer for low-momentum protons. These need to be addressed and resolved by the proponents.

Summary: The PAC regards the proposed measurements at very small Q^2 as very interesting, However, the committee suggests that the proponents seek close cooperation with theory on the issue of pion loop corrections laid out above. They should re-evaluate the uncertainties with respect to the $\langle r_n^2 \rangle$ extraction and - if necessary - consider putting the main emphasis of this measurement on the p $\rightarrow \Delta$ transition form factors.

LOI 12-20-003

Title: Sub- and Near-threshold Production of J/Ψ Mesons from a Deuterium Target at SoLID

Spokespersons: H. Gao

Motivation: The LOI proposes measurements of sub-threshold and near-threshold real photoproduction and quasi-real photoproduction (low Q^2 electroproduction) of a J/Ψ meson from a 15-cm liquid deuterium target, using SOLID with the same experimental configuration as the approved experiment E12-12-006. By comparing the J/Ψ N → J/Ψ N scattering amplitude - accessed by photo-producing the J/Ψ off one nucleon and then having it rescattered off the other nucleon - with modern LQCD calculations, the experiment may allow for an extraction of the J/Ψ N potential. In addition, based on the prediction by Hatta and collaborators (PLB 803 (2020) 135321), the experiment aims at probing short-range correlations (SRC) in deuterium by sampling the large relative momentum part of the deuteron wavefunction, accessed by producing the J/Ψ below the J/Ψ N kinematic threshold.

Measurement and Feasibility: The proposed measurements will use an identical experimental configuration as the already approved experiment E12-12-006, except for the deuterium target. Both quasi-real photoproduction (low Q^2 electroproduction) and real photoproduction will be used, so as to maximize event counts. The experiment as briefly outlined in the LOI seems feasible.

Issues: The extraction of the J/Ψ N potential necessarily contains model dependence. Additional calculations could allow one to study this dependence.

The theory TAC report suggests further detailed model studies as a prerequisite for a reliable estimate of the theoretical uncertainty of the proposed method, because coupled multiple subprocesses will lead to the same final state.

The results should be presented in a model independent way (J/Ψ and nucleon kinematic distributions) so that any other researcher can interpret the data. Any further analysis by the proposers can have significant model dependence. Extensive simulations to determine explicit uncertainty estimates for backgrounds, as well as a realistic precision estimate of the proposed measurement must be given in a full proposal.

Summary: The proposed experiment provides a timely and interesting science case that nicely extends the JLab 12 GeV program of measurements of charm production near threshold. The authors are advised to follow the suggestions of both the TAC physics and theory reports, to perform detailed simulation studies and to examine more carefully the theoretical uncertainties.

Program Status

12 GeV Approved Experiments by Physics Topics

Topic	Hall A	Hall B	Hall C	Hall D	Other	Total
Hadron spectra as probes of QCD	0	2	1	4	0	**7**
Transverse structure of hadrons	7	3	3	1	0	**14**
Longitudinal structure of hadrons	1	3	7	1	0	**12**
3D structure of hadrons	5.5	9	6.5	0	0	**21**
Hadrons and cold nuclear matter	9	6	7	1	0	**23**
Low-energy tests of the Standard Model and Fundamental Symmetries	3	1	0	1	1	**6**
Total	**25.5**	**24**	**24.5**	**8**	**1**	**83**
Total Experiments Completed	**9.0**	**9.7**	**7.3**	**1.5**	**0**	**27.5**
Total Experiments Remaining	**16.5**	**14.3**	**17.2**	**6.5**	**1.0**	**55.5**

12 GeV Approved Experiments by PAC Days

Topic	Hall A	Hall B	Hall C	Hall D	Total
Hadron spectra as probes of QCD	0	219	11	740	**970**
Transverse structure of hadrons	152.5	85	146	25	**408.5**
Longitudinal structure of hadrons	19	170	211	29	**429**
3D structure of hadrons	361	812	225	0	**1398**
Hadrons and cold nuclear matter	240	275	205	15	**735**
Low-energy tests of the Standard Model and Fundamental Symmetries	547	180	0	79	**806**
Total Days	**1319.5**	**1741**	**798**	**888**	**4746.5**
Total Days - (includes MOLLER)	**845.5**	**1741**	**798**	**888**	**4272.5**
Total Approved Run Group Days (includes SoLID)	**1319.5**	**966**	**755**	**688**	**3728.5**
Total Approved Run Group Days (includes MOLLER)	**845.5**	**966**	**755**	**688**	**3254.5**
Total Days Completed	**256.5**	**323**	**173**	**206**	**958.5**
Total Days Remaining	**589**	**643**	**582**	**482**	**2296**

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Review new proposals, previously conditionally approved proposals, and letters of intent for experiments that will utilize the 12 GeV upgrade of CEBAF and provide advice on their scientific merit, technical feasibility and resource requirements.

Identify proposals with high-quality physics that, represent high quality physics within the range of scientific importance represented by the previously approved 12 GeV proposals and recommend for approval.

Also provide a recommendation on scientific rating and beam time allocation for proposals newly recommended for approval.

Identify other proposals with physics that have the potential for falling into this category pending clarification of scientific and/or technical issues and recommend for conditional approval. Provide comments on technical and scientific issues that should be addressed by the proponents prior to review at a future PAC.