Jefferson Lab
Thomas Jefferson National Accelerator Facility

DRAFT

REPORT OF THE

41ST

PROGRAM ADVISORY COMMITTEE (PAC41) MEETING

May 19 – 22, 2014

The Thomas Jefferson National Accelerator Facility (Jefferson Lab) is a national physics user facility Operated by the Jefferson Science Associates, LLC, for the U.S. Department of Energy (DOE)

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Remarks from the Chair

As described in the charge, PAC41 was asked to review the list of approved 12 GeV proposals and select a "**High Impact**" subset. The purpose of this subset is to form a high-priority foundation for the first 3-5 years of production running. This period occurs after the commissioning phase, begins with early production running in mid-2015 and ends in 2020. The charge restricted our High Impact choices to a total of 600 PAC days. Applying the traditional factor of two between PAC time and Minkowski time, and assuming approximately 30 weeks of running per year, 100 PAC days amounts to 1 year of running in one hall. With the anticipated operation of 3 halls at a time, our High Impact selection constitutes a 2-year subset of the many experiments that can run in the first 3-5 years.

We applaud the stringency of the charge's 600-day limit as its intent is to leave ample room for scheduling experiments outside our selection. However, it did force us to make many painful decisions. We were provided with a scrupulously detailed database of experiments deemed capable of being ready for running by 2020; with concurrent-running overlaps removed, this starting pool amounted to ≈2500 approved PAC days of highly rated research. To reach the 600day goal, many highly valued segments of the program had to be excluded from our choices.

The primary intent of these introductory remarks is to stress that our goal was to identify a <u>strategic core</u> for the first years of the 12 GeV program, and that our High Impact designation is in **<u>no way</u>** meant to alter the scientific rating of any experiment or diminish its importance. To that end, we would like to clarify the procedure and criteria we employed.

Our activities followed the outline set by the PAC41 agenda. Prior to the meeting, a subcommittee was designated for each of the six scientific categories described in the charge, and the subcommittee members were tasked to review the pool of proposals and associated PAC reviews in each category. On the first day, we clarified our charge with the management, then split into two sets of parallel sessions where the subcommittees discussed each experiment in their area and arrived at first-pass lists of High Impact candidates. On day 2, each subcommittee chair presented these first-pass conclusions. The PAC deliberated as a group on each category, further reducing the list of candidates. Finally, the PAC considered the emerging selection of experiments as a whole. After additional discussion of each topic, we finalized our list of High Impact experiments and turned to report-writing. First drafts of the reports were completed and reviewed by the full committee by the end of Day 3. The PAC would like to thank the management for designing such a well-considered process for this unique meeting, and for the exquisite organization with which the vast sea of relevant information was provided to us.

Essential to our deliberations was reaching a consensus on the meaning of "High Impact", and this was our first topic of discussion. A precise definition is impossible, but the designation clearly incorporates some criteria that fall outside the scope of a scientific rating as its intent is focused on an early demonstration of the 12 GeV upgrade's success. Some of the High Impact criteria we considered were an experiment's ability to produce results of interest to the broader physics community, that impact other fields, that can be obtained on a relatively short time scale, that can be readily interpreted, and that highlight JLab's unique capabilities. In addition, we felt it important that the High Impact experiments be well balanced between scientific categories. We did not take the distribution of days among the halls under consideration; at the end we observed that a reasonable degree of balance had fortuitously been achieved.

What High Impact does not mean is that an experiment is of greater ultimate worth than one not receiving this label. On the contrary, many projects deemed by the PAC to be of great value to the laboratory were not included in the selection. Examples of omissions are :

- long-term projects; the SIDIS, GPD, and spectroscopy programs are prime examples, where we selected only a small "High Impact" fraction of the hundreds of approved days.

- experiments that will refine our understanding of an observable — often greatly — but where the observable's qualitative features are largely known; examples are medium-modification studies of fragmentation, and our preference in the spin program for measurements from a neutron target (^{3}He) rather than proton or deuterium targets.

- experiments that are crucial in the long term to reducing experimental and theoretical systematic uncertainties of other programs to a level commensurate with the planned statistical precision, but whose results in the short term will be meaningful only to experts.

This list is not meant to be exhaustive. We reiterate that the High Impact designation is intended to provide a strategic core program, leaving ample room for the scheduling of many other experiments. We know that the laboratory is keenly aware of the need for both rigor and patience, and will not neglect the experiments in the above categories.

In the end, we could not bring ourselves to reduce our High Impact selection below 643 PAC days. In reaching this number, we had to exclude experiments that we unanimously agreed should be included. However, as described earlier, we appreciated the reasoning behind the 600day quota. As our committee is not endowed with the intensity or focus of CEBAF, we trust that the laboratory will tolerate a 7% excess and deem that we have met our charge.

N.C.R. Makins

PAC Days
Boldface = days designated High Impact
Parentheses = days not counting toward High Impact total

PAC41 "High Impact" Selection

Row Color
Yellow = High Impact
Green = backup expt

Exp#	Exp name	Hall	Run Group/ Days	PAC Days	PAC grade	Comments
	TOPIC 1 : SPECTROSCOPY					
E12-06-102	**GlueX** : Mapping the Spectrum of Light Quark Mesons and Gluonic Excitations with Linearly Polarized Photons	**D**		(120) approved **★90**	A	GlueX - assumed half commissioning/half physics **★plus (30) commissioning days**
	TOPIC 2 : FORM FACTORS					
E12-06-101	Measurement of the Charged **Pion Form Factor** to High Q2	**C**		**52**	A	Requires fully commissioned SHMS
E12-07-109	**GEp/GMp** : Large Acceptance Proton Form Factor Ratio Meas's at 13 and 15 (GeV/c)2 Using Recoil Polarization Method	**A**		**45**	A-	Requires SBS and high power cryo target
E12-11-106	High Precision Measurement of the **Proton Charge Radius**	**B**		**15**	A	Non-CLAS12 experiment, Prad
	TOPIC 3 : PDFs					
E12-06-113	**BONuS** : The Structure of the Free Neutron at Large x-Bjorken	**B**	F/40	(40) approved **★21** ↓	A	Requires BONuS Radial TPC upgrade **★42 days High Impact for the experiment that runs first; experiments are equally important & both are essential**
E12-10-103	**MARATHON** : Measurement of the F2n/F2p, d/u Ratios and A=3 EMC Effect in DIS off the Tritium and Helium Mirror Nuclei	**A**	Tritium target group/61	↑ **★21** (42) approved	A	
E12-06-110	**A1n HallC–3He** : Meas of Neutron Spin Asymmetry A1n in the Valence Quark Region Using an 11 GeV Beam and a Polarized 3He Target in Hall C	**C**		**36**	A	Requires high luminosity 3He
	TOPIC 4T : TMDs					
C12-11-111	**TMD CLAS–HDIce** : SIDIS on Transverse polarized target	**B**	G/110	**110** concurrent	A	Requires transversely polarized HDIce with electron beam
C12-12-009	**Dihadron CLAS-HDIce** : Measurement of transversity with dihadron production in SIDIS with transversely polarized target	**B**	G/110	(**110**) concurrent	A	Requires transversely polarized HDIce with electron beam C1 Proposal
E12-06-112	**TMD CLAS-H(Unpol)** : Probing the Proton's Quark Dynamics in Semi-Inclusive Pion Production at 12 GeV	**B**	A/139	(60) approved **★10**	A	Hall B commissioning + 10 days **★plus (50) commissioning days**
	TOPIC 4G : GPDs					
E12-06-114	**DVCS HallA-H(UU,LU)** : Measurements of Electron-Helicity Dependent Cross Sections of DVCS with CEBAF at 12 GeV	**A**	Early: DVCS & GMp/62	(100) approved **★70**	A	Hall A commissioning
C12-12-010	**DVCS CLAS–HDIce** : DVCS at 11 GeV with transversely polarized target using the CLAS12 Detector	**B**	G/110	(**110**) concurrent	A	Requires transversely polarized HDIce with electron beam C1 Proposal
E12-11-003	**DVCS CLAS–D(UU,LU)** : DVCS on the Neutron with CLAS12 at 11 GeV	B	B/90	(90) approved	A	Requires D target; central neutron detector ready in 2015 **★Backup GPD-E meas if HDIce delayed**
	TOPIC 5 : NUCLEAR					
E12-13-005	**Bubble Chamber** : Measurement of 16O(γ,α)12C with a bubblechamber and a bremsstrahlung beam	**INJ**		**14**	A-	Our guess: 2017
E12-11-101	**PREx-II** : Precision Parity-Violating Measurement of the Neutron Skin of Lead	**A**		**35**	A	Requires septum, Pb target, 1% Moller polarimetry
E12-06-105	**SRC–hiX** : Inclusive Scattering from Nuclei at $x > 1$ in the quasielastic and deeply inelastic regimes	**C**		**32**	A-	
E12-11-112	**SRC–Tritium** : Precision measurement of the isospin dependence in the 2N and 3N short range correlation region	**A**	Tritium target group/61	**19**	A-	
	TOPIC 6 : FUNDAMENTAL SYMMETRIES					
E12-11-006	**HPS** : Status of the Heavy Photon Search Experiment at Jefferson Laboratory (Update on PR12_11_006)	**B**	H/180	(155) approved **★39**	A	non-CLAS12 experiment, HPS **★25 pre-CLAS engr + 14 physics @ 4.4 GeV**
E12-10-009	**APEX** : Search for new Vector Boson A1 Decaying to e+e-	**A**		**34**	A	Requires new septum and target system

<<< SUMMARY of "HIGH IMPACT" DAYS >>>

by Topic	1	2	3	4GT	5	6	total post-commissioning
	90	112	78	190	100	73	643
by Hall		A	B	C	D	INJ	
		224	195	120	90	14	643

Hadron Spectra as Probes of QCD

The modern theory of the strong interaction, Quantum Chromodynamics (QCD), is well tested at high energies, where the strong coupling constant α_s becomes small and perturbation theory applies. In the low energy regime, however, QCD becomes a strongly coupled theory, many aspects of which are not understood. One outstanding challenge of QCD is to understand the spectrum of its bound states. Most observed states can be understood as conventional mesons (quark-antiquark) or baryons (three quarks). However the theory also predicts more exotic forms of matter like glueballs (states made entirely of the QCD gauge bosons), multiquark states, molecules or hybrids composed of quarks and gluons. There are some indications for the existence of such states but the overall picture remains puzzling.

To address these questions Jefferson Lab has established a comprehensive meson spectroscopy program, devoted to the study of conventional states as well as the search of exotic resonances. Three experimental proposals by two collaborations have been submitted and approved, as detailed in the following table:

Experiment	Detector	Hall	Run group	PAC	PAC days	grade
E12-06-102	GlueX	D		30	120	A
E12-11-005	CLAS12	B	A/139	37	119	A-
E12-13-003	GlueX 2	D		40	200	A

The first GlueX proposal (E12-06-102) uses the baseline GlueX setup, a high-acceptance general purpose detector, to study the hadron spectrum in the light quark sector and to search for gluonic hadrons, in particular hybrid mesons, via photoproduction in Hall D. The experiment was approved by PAC 36 with a grade of A and allocated 120 PAC days, of which 30 devoted to detector commissioning, 30 for physics commissioning and 60 for the meson physics run.

The second GlueX proposal (E12-13-003) adds a level-three trigger based on a new computing farm, which will allow the experiment to run at increased luminosity, leading to an increase in statistics by a factor of 5-10 with respect to the previous proposal. With this improved setup the experiment plans to extend its sensitivity to rare processes to access more complicated decay modes. This increase in statistics, coupled with sophisticated analysis techniques, will allow the experiment to carry out a significant exploratory study of final states containing kaons and hyperons, thus enabling the investigation of the $\bar{s}s$ component of the nonets. This proposal was approved by PAC 40 with a grade of A and allocated 200 PAC days.

Experiment E12-11-005 is dedicated to the study of meson spectroscopy via quasi-real photoproduction in Hall B using the CLAS12 detector and a new Forward Tagger facility consisting of an electromagnetic calorimeter, a scintillating hodoscope and a tracking device. The experiment was approved by PAC 37 with a grade of A- and allocated a total of 119 days, of which 39 at low intensity for commissioning purposes.

The strength and impact of the hadron spectroscopy program at JLAB lies in the presence of the two experiments, which are to a large extent complementary, and whose combined effort will make JLab a worldwide center of excellence in the field of meson spectroscopy.

While it is clear that this entire program is a highlight of the JLab 12 GeV physics program, the first run of the GlueX experiment (90 days run, in addition to 30 days of detector commissioning) will already provide high impact results. The PAC urges the collaboration to implement the level-three trigger as early as possible in order to run a significant fraction of the allocated time with the upgraded setup, thus maximizing the chance of an early discovery and achieving the highest impact.

High-impact selection:

GlueX with baseline setup (E12-06-102) for 90 days + 30 days commissioning, ideally with the addition of an L3 trigger for some portion of this running time.

Transverse structure of the Hadrons

This category included 10 approved proposals on fundamental experiments of the transverse structure of pions and nucleons with a total of 356 hours of allocated beam time, 2 of them graded A, 5 A-, and 3 B+. The charge of the committee was to identify the proposals with highest impact. This was an extremely difficult task since all of these proposals are very important measurements which should be carried out and are expected to advance the field significantly. The committee selected three proposals as high impact for the reasons to be explained in the following.

Charged pion form factor (E12-06-101)

The pion form factor is an object of fundamental theoretical interest, especially at larger values of Q^2 where one can study non-perturbative dynamics of QCD. Due to the simple structure of the pion, perturbative QCD makes an exact prediction for the absolute value of the form factor at $Q^2 \to \infty$, thereby providing a benchmark for models used to calculate the structure of hadrons. A variety of models at the interface between non-perturbative and perturbative QCD make predictions about the behavior of the form factor, differing in both absolute value and shape, at the scale of a few GeV^2. The proposed new measurements will explore the unknown region up to Q^2 of 6 GeV^2 and will have high impact on hadronic structure physics.

Charge radius of the proton (E12-11-106)

This proposal addresses the "proton charge radius puzzle" stemming from a 6 σ discrepancy between a new measurement of the Lamb shift in muonic hydrogen and existing data (Lamb shift in ordinary hydrogen and electron scattering experiments. The experimental proton radius result from the muonic hydrogen Lamb shift is significantly smaller than present electron-based determinations. The goal of the JLab experiment is to measure the proton charge radius to an unprecedented precision by extending present form factor data significantly down in Q^2 to 10^{-4} GeV^2. A careful test of the charge radius extraction from electron scattering is among the most timely and important high-impact measurements in physics.

Electric to magnetic form factor ratio of the proton (E12-07-109)

The electric and magnetic form factors of the proton and neutron, and their Q^2-dependence, are fundamental quantities, the measurement of which is a key part of the JLab mission. The corresponding 6 proposals in this subgroup represent a well-founded and coherent program to measure and separate all electric and magnetic form factors of proton and neutron. The committee emphasizes the need to pursue all of these experiments with high priority, which will also allow a flavor decomposition. The selection of the proton form factor ratio was based on the following argument: The first measurements of G_E/G_M using the recoil polarization technique revealed a surprising linear decrease with Q^2, completely unexpected from the former Rosenbluth separation results. It is of highest importance to clarify whether this trend continues at higher Q^2, leading to a zero-crossing or a gradual flattening out. The expected data will strongly constrain models and at the same time provide critical constraints for the parametrization of GPDs.

The committee considers the form factor ratio on the neutron (E12-09-016) of equal importance but thinks that the higher impact to a broader community will come from the proton.

High-Impact Selections:

E12-06-101, Hall C, 52 days

E12-11-106, Hall B, 15 days

E12-07-109, Hall A, 45 days

The sub-committee on **Longitudinal Structure** discussed 12 experiments, 11 approved and 1 conditionally approved. 4 of them were rated A, 7 A- and 1 B+.

All 12 experiments were considered to be of high scientific quality. The general consensus was that the most timely results, and those most likely to have immediate impact among the scientific community working on the longitudinal structure of the nucleon, concern the large-x behavior of the partonic distributions, both unpolarized and polarized. The sub-committee identified 4 experiments dealing with the study of the large-x structure of the nucleon, two with unpolarized targets and two with longitudinally polarized ones. Unfortunately, a further selection had to be made.

Unpolarized d/u

The proposed experiments with unpolarized targets will lead to the determination of the F_{2n}/F_{2p} ratio at large-x values. The committee considers these n/p measurements to have extremely high impact. The d(x)/u(x) parton distributions are of interest not just to the nuclear community, but are also important in high energy physics where they make important contributions to electro-weak physics. The large-x behavior of the valence quark distributions is still widely unknown due to interference from nuclear effects. The BONUS12 (E12-06-113) and MARATHON (E12-10-103) experiments propose to address these nuclear effects in complementary and highly robust fashion. They will both address this science with much greater precision and theoretical clarity than previous measurements and will be able to crisply distinguish between theoretical models.

The Committee identifies the measurement of the $x \rightarrow 1$ limit of d/u as having extremely high impact. At least 40 PAC days are necessary to measure this important quantity. The committee finds no basis on which to select one experiment over the other as the first to run, and feels that both experiments must ultimately be performed.

Longitudinally Polarized Targets

The two experiments (E12-06-109 and E12-06-110) with longitudinally polarized targets will give results on $\Delta q/q$, for u and d quarks, in the large-x region. There are several different model predictions for this ratio at x=1, which must be confronted with experiment in order to fully understand the valence quark spin contribution. Again, both experiments are considered by the committee to be of very high quality; however, the limited total amount of days available for "high impact" designation forces a choice, and the Committee favors the experiment measuring A_{1n} with the ^3He target, as less data are currently available than for A_{1p} or A_{1d}.

The Committee designates experiment E12-06-110, "Measurement of Neutron Spin Asymmetry A_{1n} in the valence quark picture, as "High Impact" with 36 PAC days.

Summary of High Impact Selections

- d/u : 42 days for BONUS12 (E12-06-113) or MARATHON (E12-10-103)
- $\Delta q/q$: 36 days for A_{1n} from a ^3He target in Hall C (E12-06-110)

The subcommittee on the **3D structure of hadrons – TMD** discussed 8 experiments, 6 approved and 2 conditionally approved. 3 of them were rated A, 4 A- and 1 B+.

The Committee considers the study of the 3-dimensional structure of the nucleon as a key goal of JLab scientific activity. The 8 proposals can be grouped into 3 requiring a transversely polarized target, 3 with unpolarized targets and two with longitudinally polarized targets.

The basic way of accessing the TMDs, from which the 3-D imaging of the proton can be achieved, is Semi-Inclusive Deep Inelastic Scattering (SIDIS) off a transversely polarized target. In that area, the Committee considers the experiment C12-11-111, *SIDIS on transverse polarized target*, as the "master experiment" with high impact. It is conditionally approved depending on the availability of the transverse polarized HD-Ice target.

Along with this experiment, in the same run group, the proposal C12-12-009, *Measurement of transversity with dihadron production in SIDIS with transversely polarized target*, is also considered as a high impact experiment. It leads to a novel determination of the so far poorly known transversity distribution (which is not strictly a TMD, but is typically grouped in this category).

The Committee identifies C12-12-009 (Transversity with dihadron) and C12-11-111 (SIDIS with transverse polarized target) as High Impact experiments.

The experiments with unpolarized targets can give crucial information on the intrinsic motion of quarks and, through the study of azimuthal asymmetries, on the Boer-Mulders function, relating the transverse polarization of quarks inside an unpolarized nucleon to their intrinsic motion. The B-M functions are expected to give new information on the orbital motion of quarks.

The Committee identifies E12-06-112, "Probing the proton's quark dynamics in Semi-Inclusive pion production at 12 GeV", as a High Impact experiment that requires 10 PAC days beyond the 50 commissioning days.

The Committee considers all other experiments as important and with high scientific quality, but has to remain within the limited total amount of days available for "high impact" designation.

Summary of High Impact Selections

- SIDIS with transverse polarized target in Hall B (*C12-11-111*) for 110 days
- Transversity from dihadron production in Hall B (*C12-12-009*) for 110 days *Note: the above two experiments run concurrently with each other and with C12-12-010 from the GPD high impact selection*
- SIDIS with unpolarized hydrogen target in Hall B (*E12-06-112*) for 10 days plus 50 commissioning days

Highlights of the Generalized Parton Distributions Program

Motivation: Generalized Parton Distributions (GPDs) provide an unprecedented way to describe the nucleon as a 3-dimensional object. The GPD program is at the heart of the scientific motivation of the 12 GeV upgrade of JLab. Deeply virtual Compton scattering (DVCS) is the cleanest 'golden' channel to study GPDs, and there is a series of highly rated approved experiments aimed at a complete set of measurements, as well as investigation of specific channels in meson electroproduction. The understanding of Deep Exclusive Scattering (DES), i.e. the exclusive electroproduction of a photon or meson, on the nucleon at large momentum transfers Q^2 and in the near-forward direction is facilitated by a QCD factorization theorem. It permits a rigorous separation of the perturbatively calculable hard scattering on a parton from the non-perturbative nucleon structure functions encoded in GPDs. This will enable the extraction of 3D images of the nucleon, mapping out the longitudinal quark momentum and transverse position dependence. The JLab 12 GeV facility will be in a unique position to provide an experimental test of the factorization and establish the Q^2 scaling regime for hard exclusive reactions in the valence region. The primary goals of the different deep exclusive experiments reflects the complementarity between the different Halls :

1) A measurement of beam spin asymmetries and cross sections in Hall A (E12-06-114) will provide a precision test of scaling for selected kinematical points.
2) A survey over a wide kinematic range of unpolarized and polarized DVCS observables in Hall B (E12-06-119, E12-11-003, C12-12-010, E12-12-001) will provide an unprecedented DVCS data set.
3) The experiment E12-13-010 will use the unique setup of Hall C supplemented by a new Neutral Particle Spectrometer (NPS) to provide a precision measurement of the cross section at different beam energies in order to perform an L/T separation. Such data will enable extraction of the real part of the Compton form factors without any assumptions.
4) It is also worthwhile to mention meson electroproduction, where a first test of factorization with L/T separation can be accurately performed, notably for charged pions (E12-07-105).

We identified two major high-impact physics highlights in the GPD program:

1) Test of factorization/scaling from precision absolute cross sections, providing a transverse imaging of nucleon substructure

The PAC identifies, as a first major highlight in this program, the Hall A DVCS experiment (E12-06-114), using a polarized electron beam on an unpolarized proton target for 70 days. It will allow a precision test of scaling through measurement of DVCS absolute cross sections.

2) Determining the nucleon helicity-flip GPD *E*, providing access to the quark total angular momentum of the nucleon

Once the scaling for Deep Exclusive Scattering is established, the highest goal of the GPD program is understanding of the nucleon's angular momentum carried by quarks, through the measurement of the nucleon helicity-flip GPD (called *E*). Although the nucleon helicity-flip GPD *E* decouples in the forward limit, its normalization yields the large anomalous magnetic moment of the nucleon. (The latter measurement in 1933, through the Nobel Prize winning experiment of Otto Stern, provided the first glimpse of the proton's substructure.) With the help of Ji's angular momentum sum rule, the second moment of this GPD *E* allows access to the angular momentum of the proton.

> 1) Experimentally, the most direct access to the proton GPD *E* is achieved with a transversely polarized target. With the 11 GeV beam, the CLAS12 detector in combination with the HD-Ice target, as proposed in C12-12-010, will offer a unique opportunity to access these observables.
>
> 2) If the transversely polarized target is not ready in time to be used together with the high flux electron beam, we recommend the alternative solution to accessing the GPD *E*: measuring DVCS on the neutron using an unpolarized deuteron target with CLAS12 as proposed in E12-11-003. This experiment will provide a different flavor combination of the GPD *E*. In both cases, the large acceptance of CLAS12 will allow every observable to be measured in a wide kinematical domain, providing an extensive mapping of these three-dimensional distributions.

The PAC selects as the second major highlight in this program the access to the nucleon helicity-flip GPD E, sensitive to the nucleon angular momentum, through measurement of the DVCS asymmetries on a transversely polarized target (C12-12-010, 110 days). If delays in the development of the HD-Ice target make it unfeasible for this experiment to run in the first 3-5 years, the PAC recommends prioritizing a measurement of a different flavor combination of the GPD E using DVCS on an unpolarized deuteron target with CLAS12 (E12-11-003, 90 days).

Summary of high impact selections:

- 70 days E12-06-114 in Hall A (scaling test)
- 110 days C12-12-010 in Hall B (nucleon angular momentum)
  Note: the above experiment runs concurrently with C12-11-111 and C12-12-009 from the TMD high impact selection.

Hadrons and Cold Nuclear Matter

Research at Jefferson Lab after the 12 GeV upgrade will have a key role in exploration of nuclear structure and in exploration of QCD effects in nuclear matter. There are 12 approved experiments related to this effort within the timeframe of the committee's charge, for a total of 412 PAC days. These cover a diverse set of topics from experiments to understand stellar evolution to measurement of the weak charge distribution in lead nuclei. All contain the potential for highlights. The PAC selected the subset we deemed of highest impact within this part of the Jefferson Laboratory program. These experiments are:

PREX-II

Determination of the neutron skin of neutron rich nuclei in parity-violating electron scattering is a new capability with guaranteed high impact for many parts of the broader physics community. PREX-II is a follow-up measurement to PREX-I that ran in 2010 and demonstrated the technique to measure the neutron radius in ^{208}Pb. PREX-II is designed to achieve the originally proposed experimental precision in R_N of ±1 %, which is a factor of 3 better than PREX-I. In addition to being a fundamental test of nuclear theory, a precise measurement of R_N pins down the density dependence of the symmetry energy of neutron rich nuclear matter, which has implications for neutron star structure, heavy ion collisions, and atomic parity violation experiments.

CREX is the analogous measurement on a ^{48}Ca target with a further factor of three increase in precision. Calculations for this nucleus are more mature than for Pb and are eagerly awaited by the nuclear theory community to discriminate among nuclear structure models and to quantify the importance of 3-neutron forces and the symmetry energy effects in particular. These results will inform models of neutron star cooling.

We selected PREX-II over CREX to be classified as high impact because of its more direct connection to astrophysics and because of the importance to reach ±1 % precision in the ^{208}Pb neutron radius determination. The PAC recognizes PREX-II and CREX as highly complementary in their implications, and stresses that their full impact will require the completion of both experiments.

$^{16}O(\gamma,\alpha)^{12}C$

The low energy cross section for $^{12}C(\alpha,\gamma)^{16}O$ determines the evolution of high mass stars and is responsible for the carbon to oxygen ratio in stars that in turn determines the observed abundances of most elements in the Universe. The reaction cross section still remains unknown more than forty years after its importance was realized. This experiment finally would measure the cross section with high enough precision at low enough energies so that a reliable extrapolation can be made the region of astrophysical interest. Given the importance of the reaction to stellar evolution and nucleosynthesis, the impact of a successful measurement will be extremely high.

The short-range character of the nuclear force and short-range nucleon correlations in nuclei

A highlight of the JLAB 6 GeV program was the discovery that neutron-proton pairs dominate short-range correlations, SRC, in nuclei. This is a fundamental piece of information important for achieving a comprehensive model of nuclei. Knowledge of short-range correlations and consequently the resulting high-momentum components of the nucleon wave functions is also important information for experiments that use nuclei, for example in neutrino scattering, that rely on accurately known nuclear properties. There were two experiments the PAC identified as providing results of particularly high impact in this area.

Experiment E12-06-105 would measure inclusive electron scattering on a series of targets from ^{3}He to Cu and determine the ratios of nucleon structure functions in the x>1.5 region. This data set is critical for revealing the nature of 2N SRCs and extends these studies to the 3N regime and potentially to the 4N region. The range of targets, especially for A≤12 where *ab initio* calculation of nuclear structure is possible, will map out in detail the nuclear structure dependence in the 2N region, and make a first study of the A-dependence in the 3N region.

Experiment E12-11-112 will yield a precision test of the isospin dependence of two and three-nucleon short-range correlations by comparison of results from mirror nuclear ^{3}He and ^{3}H targets. The experiment will provide confirmation of our understanding of the dominance of np pairs in nuclei. By extension of measurements to x>2 it will provide the very first information on the isospin structure of the 3N interaction at short range.

Summary of High Impact Selections

- *E12-13-005 $^{16}O(\gamma,\alpha)^{12}C$ with 14 days at the injector to fill in a piece of the puzzle, missing for 40 years, needed for modeling of the evolution of massive stars and chemical composition of the Universe.*

- *E12-11-101 (PREX-II) for 35 days in Hall A to make an accurate measurement of the neutron radius in ^{208}Pb and determine the neutron skin of this nucleus. The result will have a direct bearing on our understanding of neutron stars.*

- *E12-06-105 for 32 days in Hall C for a systematic study of the short-range 2,3, and 4-nucleon correlations in atomic nuclei. The result will provide critical insight into the structure of atomic nuclei and information necessary for the use of nuclei properties in many fields.*

- *E12-11-112 with 19 days in Hall A will provide fundamental information on 2N and 3N interactions in atomic nuclei at short range and guide development of interactions used as the basis for ab initio nuclear theories.*

Fundamental Symmetries

The experiments in this category address key properties of QCD and the electroweak interactions, as well as the dark matter sector, and are highly relevant for the high energy and astro-particle physics communities. Most of the corresponding approved PAC days were not considered as these fall outside the first 3 to 5 years of the 12 GeV era. Of the three remaining experiments:

The PAC identifies HPS (E12-11-006) and APEX (E12-10-009) to have the potential to reshape our picture of the fundamental interactions of the universe and their symmetries.

The recent surge of interest to search for intermediate mass (MeV to GeV) vector bosons is motivated from astrophysical anomalies and their possible connection to dark matter. Furthermore, they may explain the deviation in the muon anomalous magnetic moment (g−2). Existing limits, as well as APEX and HPS, are based on producing such bosons from electron bremsstrahlung.

APEX and HPS are complementary. Both would use the CEBAF electron beam incident on a high-*Z* target. APEX detects $e^+ e^-$ pairs in the HRS, while HPS is a dedicated facility with silicon tracking detectors immersed in a large volume dipole magnet. APEX needs to tune the spectrometers to different settings to cover different mass regions and takes a very high beam current. HPS uses only low current beam, but is sensitive to much broader kinematics at a time. The signal is a peak in the $e^+ e^-$ invariant mass, so good momentum and angle resolution are important for optimizing the signal over a copious QED background. HPS has an additional very crucial feature, namely the ability for vertex reconstruction, that allows it to explore regions of extremely weak coupling, where the new particle travels a macroscopic distance before decaying. Although the production cross section here is small, the QED background should be negligible.

Similarly, there is complementarity with respect to the parameter space. We consider both the full APEX run and the early running of HPS as high impact experiments. APEX will carve out a large unexplored area in the mass/coupling parameter space, with $\alpha'/\alpha \gtrsim 10^{-7}$ and masses between 60 and 500 MeV. HPS would extend this region to somewhat lower masses, albeit with less sensitivity to the coupling, and also add an entirely new region with $2\times10^{-8} \lesssim \alpha'/\alpha \lesssim 4\times10^{-10}$. Probing all of this parameter space which covers the non-excluded part addressing the muon g−2 would have impact reaching far into the greater physics community.

The committee stresses the competitive environment of such searches. In addition to the successful APEX test run, there is a very recent result by the A1 experiment at MAMI which covers the sensitive region of the test run, and also most of the region related to the solution of the muon g−2. There are also ongoing analyses at various $e^+ e^-$ colliders.

This shows that HPS and APEX are extremely timely experiments and should be executed as soon as possible.

In addition, we feel it is appropriate to comment on the third experiment (E12-10-011) which is highly relevant for the understanding of chiral symmetry breaking. It will provide by far the most precise measurement of the partial decay width $\eta \to \gamma\gamma$, thereby resolving a long-standing discrepancy between existing determinations from the Primakoff effect (as in this experiment) on one hand and from $e^+ e^-$ colliders on the other. As the normalizing decay it enters all η branching ratios and (when combined with $\eta' \to \gamma\gamma$) permits the extraction of the η-η' mixing angle and the SU(3) singlet decay constants, playing a unique role in the breaking of chiral and in the context of the axial U(1) symmetry. Furthermore, when combined with the $\eta \to 3\pi$ branching ratio it constrains the strange to light quark mass ratio without complications from the poorly known electromagnetic correction entering the analogous quantity derived from the pseudoscalar masses.

The PAC believes this is very compelling physics and hopes it will be scheduled in a timely fashion.

High Impact Selections:

• *APEX (34 days in Hall A)*

• *HPS (25 days commission run plus 14 days of running at 4.4 GeV in Hall B)*

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AGENDA

PAC 41

May 19 – 22, 2014

CEBAF Center L102-104
Monday, May 19, 2014

09:00 – 10:00 **Executive Session**
- **Charge**
- **Discussion**

10:00 – 12:00 **EXECUTIVE PARALLEL SESSIONS**

- **The Hadron Spectra as Probes of QCD** — A110
  Bettoni, Thoma, Vanderhaeghen, Arrington
- **The Longitudinal Structure of the Hadrons** — L102
  Schellman, **Anselmino**, Arends, Martin, Kunne
- **Low-Energy Tests of the Standard Model and Fundamental Symmetries** — CC 210
  Erler, Napolitano, Sherrill

12:00 – 13:00 **Lunch** — L102/104

13:00 – 17:00 **EXECUTIVE PARALLEL SESSIONS**

- **The Transverse Structure of the Hadrons** — A110
  Bettoni, **Arends**, Thoma
- **Generalized Parton Distributions** — B207
  Arrington, **Vanderhaeghen**, Kunne, Makins
- **Transverse Momentum Distributions** — L102
  Anselmino, Schellman, Martin
- **Hadrons and Cold Nuclear Matter** — CC 210
  Erler, **Sherrill**, Napolitano

15:00 – 15:30 All Groups will meet for a Coffee Break in L102/104

AGENDA

PAC 41

May 19 – 22, 2014

CEBAF Center L102-104
Tuesday, May 20, 2014

EXECUTIVE PLENARY DISCUSSIONS

08:30 – 09:30
- **The Hadron Spectra as Probes of QCD**
  Bettoni, Thoma , Vanderhaeghen, Arrington

09:30 – 10:30
- **The Longitudinal Structure of the Hadrons**
  Schellman, **Anselmino**, Arends, Martin, Kunne

10:30 – 12:00
- **Low-Energy Tests of the Standard Model and Fundamental Symmetries**
  Erler, Napolitano, Sherrill

12:00 – 13:00 **Lunch**

EXECUTIVE PLENARY DISCUSSIONS

13:00 – 15:00
- **Transverse Momentum Distributions**
  Anselmino, Schellman, Martin

15:00 – 15:30 **Coffee Break**

15:30 – 17:00
- **Generalized Parton Distributions**
  Arrington, **Vanderhaeghen**, Kunne, Makins

AGENDA

PAC 41

May 19 – 22, 2014

CEBAF Center L102-104
Wednesday, May 21, 2014

EXECUTIVE PLENARY DISCUSSIONS

08:30 – 10:30	• **The Transverse Structure of the Hadrons** Bettoni, **Arends**, Thoma	
10:30 – 11:00	**Coffee Break**	
11:00 – 13:00	• **Hadrons and Cold Nuclear Matter** Erler, **Sherrill**, Napolitano	
13:00 – 14:00	**Lunch**	
14:00 – 17:00	**Global Discussion**	
18:00	**PAC Dinner**	Atrium

AGENDA

PAC 41

May 19 – 22, 2014

CEBAF Center L102-104

Thursday, May 22, 2014

09:00 – 11:00	**Report Writing**
11:00 – 12:00	**Closeout**
12:00 – 13:00	**Lunch**