

## MEMORANDUM

Date: June 6, 2019  
To: Distribution  
From: Rolf Ent and Andrei Seryi for the Nuclear Physics Experiment  
Scheduling Committee  
Subject: Accelerator Schedule through December 2020

### Schedule

Attached is the accelerator operations schedule through December 2020. It has also been posted at [http://www.jlab.org/div\\_dept/physics\\_division/experiments/schedule.html](http://www.jlab.org/div_dept/physics_division/experiments/schedule.html). Access to the database format of the same schedule, as used by the beam accounting system, can be found at <https://cebaf.jlab.org/btm/schedule>.

The operations schedule is based on fiscal 2019 and expected 2020 funding. It may be subject to further adjustments due to actual funding and the progress of repairs and maintenance tasks. For FY2019, we have already completed the “high-energy” (gradient above one GeV/pass) portion of the schedule and preparations are underway to begin shortly a nine week Summer cycle with a gradient of about one GeV/pass. (“low-energy” cycle). Repair, maintenance and upgrade tasks for CEBAF have been prioritized and staged to support the shorter Summer down in 2019. The experiment schedule for FY2020 starts November 1, 2019 and ends May 6, 2020.

The remaining part of calendar year 2020, May 6 to December 31, is dedicated to replace one of the Central Helium Liquefiers “cold boxes”, to install new accelerating cryomodules and upgrade control systems to recover energy reach, to high priority maintenance tasks like replacement of leaking cryo-control valves and cryomodule seals damaged by radiation and, to implementing the second phase of an ongoing injector upgrade required by future experiments. The accelerator cannot be operated while these activities take place so, there are no experiments scheduled for the period May – December 2020.

The FY2019 “high-energy” run cycle was not free of challenges especially to our ability to maintain the highest possible accelerating gradient for the experimental program. Re-start of the experiment run cycle in February 2019 was delayed by about nine days to gain more accelerating gradient headroom from a few Superconducting Radio-Frequency (SRF) modules located in the North Linac. Unfortunately, the headroom proved to be not sufficient to maintain a reasonable beam trip rate and the decision was taken to lower the machine gradient by about 4%. Most of the scheduled experiments were able to absorb the change with minor impact although a few were affected more adversely. Still, despite these issues, all scheduled experiments were successfully completed.

The present schedule has Hall A taking data during the Summer 2019 to run Experiment E12-11-101 (PREX-II), followed by E12-12-004 (CREX) in the subsequent Fall run period. These experiments will utilize parity violating electron scattering to measure the neutron radii of lead and calcium, respectively. Installation of the Super Big Bite spectrometer and associated instrumentation will take place during the 2020 scheduled down in preparation for an anticipated start of the  $G_M^n$  and  $G_E^n$ -RP neutron form factor experiments. For the Summer cycle, Hall B plans to continue previous heavy photon searches (Run Group I) but with an improved detector to expand the kinematic coverage. For Fall 2019, Run Group B

will take additional data followed by a measurement to determine the structure of the free neutron at large Bjorken  $x$  with BoNuS12 (Run Group F). For the Summer run cycle, Hall C plans first to leverage the unique beam energies available to facilitate kinematic reach for longitudinal – transverse studies of pion electroproduction, with studies of the pion form factor (E12-06-101) and scaling in exclusive pion electroproduction (E12-07-105). A measurement of the proton’s generalized polarizabilities in virtual Compton scattering will follow (E12-15-001). Following completion of E12-15-001, installation of a polarized Helium-3 target will take place. Two experiments will use this target during the Fall 2019-Spring 2020 period: (a) E12-06-110 to measure the neutron spin asymmetry  $A_{1n}$  in the valence quark region; and (b) E12-06-121 to measure the neutron  $g_2$  and  $d_2$  structure functions at high  $Q^2$ . Hall C will then be brought back into configuration for standard equipment experiments. Hall D is using Summer 2019 to complete upgrading GlueX with the addition of a particle detector based on the Detection of Internally Reflected Cherenkov (DIRC). This new detector is key to study the decays of mesons and baryons to final states containing strange quarks (E12-12-002) planned for the Fall 2019 – Spring 2020 run cycle. Tables 1- 4 later in this memo, list those experiments that have been run to completion, partially run, scheduled for this run period and, those yet to be scheduled in the “12 GeV era”.

On the schedule, each Physics Advisory Committee (PAC) day is mapped into two floor days. This factor of two accounts for Accelerator and hall efficiency due to system failures (not experiment overhead). It also accounts for a total of up to 16 hours a week of scheduled beam studies, maintenance, and RF recovery. An additional 8 hours a week is allocated for beam tuning to support program changes, beam tuning to address beam quality issues and to restore beam operations for physics post beam studies/maintenance periods. The remaining 144 hours a week, 86 %, is scheduled as research.

The Jefferson Lab Nuclear Physics Experiment Scheduling Committee developed the schedule. Committee members are: Volker Burkert, Eugene Chudakov, Rolf Ent (Co-Chair), Javier Gomez, Cynthia Keppel, Robert McKeown, Matt Poelker, Patrizia Rossi, Andrei Seryi (Acting Co-Chair) and, Mike Spata. The schedule has been reviewed and approved by the Director.

## Supplementary Scheduling Information

### Reminders

- On the schedule, daily status changes take place at the end of the owl shift (~ 7 AM) unless otherwise indicated.
- Operating one or more of Halls A, B and C at five passes together with Hall D at 5.5 passes requires a polarized gun laser frequency of 249.5 MHz for those halls. A laser frequency of 499 MHz can be used otherwise. For the same average beam current, the charge per micro-bunch when operating the laser at 249.5 MHz will be twice that of 499 MHz. For each hall, the energy, current, polarization column now also includes the laser frequency.

### The Meaning of Priority on the Accelerator Schedule

Generally, the assignment of priority to a hall means that the identified hall will have the primary voice in decisions on beam quality and/or changes in operating conditions. We will do our best to deliver the beam conditions identified in the schedule for the priority hall. It will not, however, mean that the priority hall can demand changes in beam energy that would affect planned running in the other halls without the consent of the other halls. Of course, final authority for decisions about unplanned changes in machine operation will rest with the laboratory management.

The operation of more than one hall at Jefferson Lab substantively complicates the interaction between the experimenters and the accelerator operations group. It is in the interests of the entire physics community that the laboratory be as productive as possible. Therefore, we require that the run coordinators for all operating halls do their best to respond flexibly to the needs of experiments running in other halls. The run coordinators for all experiments either receiving beam or scheduled to receive beam that day should meet with the Program Deputy at 7:45 AM in the MCC on weekdays and at the Program Deputy's discretion on weekends.

To provide some guidance and order to the process of resolving the differing requirements of the running halls, we have assigned a "priority hall" for each day beam delivery has been scheduled. We outline here the meaning of priority and its effect on accelerator operations.

### The priority hall has the right to:

- require a re-tune of the accelerator to take place immediately when beam quality is not acceptable
- insist that energy changes occur as scheduled
- obtain hall access as desired
- request that beam delivery interruptions for experiment-related operations which temporarily block normal beam delivery to all other halls take place as requested. Mott measurements of the beam polarization or pulsed operation for current monitor calibrations represent examples of such interruptions. Interruptions of this type require, at a minimum, 24 hours advance notification and coordination with the Program Deputy and the other halls.

These interruptions shall be limited by a sum rule - the total time lost to the non-priority hall(s) due to such requests shall not exceed 2.5 hours in any 24-hour period. It is, of course, highly preferred that these

measurements be scheduled at the morning meeting of the run coordinators whenever possible, and coordinated between halls whenever possible.

When the priority hall has requested a re-tune, if the re-tune degrades a previously acceptable beam for one of the other, lower priority running halls, then the re-tune shall continue until the beam is acceptable to both the priority hall and the other running halls that had acceptable beam at the time the re-tune began.

**Non-priority halls can:**

- require that a retune of the accelerator take place within 2.5 hours of the desired time (it will nominally occur at the earliest convenient break in the priority hall's schedule)
- require access to the hall within 1 hour of the desired time (again, it will nominally occur at the earliest convenient break in the priority hall's schedule)
- request that beam delivery interruptions for experiment-related operations which temporarily block normal beam delivery to all other halls occur within 2.5 hours of the desired time. Interruptions of this type require, at a minimum, 24 hours advance notification and coordination with the Program Deputy and the other halls.

The ability of non-priority halls to request retunes and accesses shall be limited by a sum rule - the total time lost to the priority hall due to such requests shall not exceed 2.5 hours in any 24-hour period. (To facilitate more extended tuning associated with complex beam delivery, with the agreement of the run coordinators for all operating halls, the sum rule may be applied over a period as long as three days, so long as the average impact is less than 2.5 hours/day.) In the event that two non-priority halls are running, the 2.5 hours shall be split evenly between them in the absence of mutual agreement on a different split.

**All Halls:**

Can negotiate with other halls, and with the Accelerator and Physics Division for changes in scheduled energy changes (either direction).

**Initial Tune-up of New Beams:**

Normally one and one half shifts (12 hours) is set aside for tune-up whenever a new beam setup is being tuned (for unusual beam setups more time may be scheduled explicitly for tuning at the discretion of the scheduling committee). It is understood that beam tune-ups shall *always* be done in the order that the accelerator operations group believes will minimize the *total* time needed to tune *all* scheduled beams (i.e., the "priority hall" beam is not necessarily tuned first). In the event that obtaining the new beam setup requires more than the scheduled time, the Accelerator Program Deputy is authorized to spend up to one additional shift of tuning in an effort to deliver all scheduled beams instead of just the "priority hall" beam.

**Maintenance/Beam Studies.** Accelerator Division may request up to sixteen hours per week. Users will be consulted in deciding how these sixteen hours per week are placed on the calendar, i.e. five shorter or three long blocks of time.

## Scheduling Status of Experiments

**Table 1 - Completed Experiments**

Experiment	Hall	Contact	Beam Req. Submitted
E12-06-102	D	C. Meyer	1-Aug-2014
E12-07-108	A	B. Wojtsekhowski	20-Aug-2014
E12-09-002	C	K. Hafidi	2-Jul-2015
E12-09-017	C	R. Ent	2-Jul-2015
E12-10-002	C	S. Malace	21-Aug-2014
E12-10-103	A	G. Petratos	1-Sept-2014
E12-11-106	B	A. Gasparian	22-Jun-2015
E12-14-011	A	L. Weinstein	24-Jun-2015
E12-14-012	A	C. Mariani	26-Jun-2015
E12-17-003	A	L. Tang	27-Jul-2017

**Table 2 - Partially Completed Experiments**

Experiment	Hall	Contact	Beam Req. Submitted
Run Group A	B	L. Elouadrhiri	1-Jul-2015
Run Group B	B	J. Gilfoyle	31-Jul-2016
Run Group I	B	S. Stepanyan	27-Jul-2017
Run Group K	B	A. D'Angelo	13-Jul-2017
E12-06-107	C	D. Dutta	6-Aug-2014
E12-06-114	A	C. Hyde	6-Aug-2014
E12-09-011	C	T. Horn	2-Jul-2015
E12-10-003	C	W. Boeglin	6-Aug-2014
E12-10-008	C	D. Gaskell	6-Aug-2014
E12-10-009	A	B. Wojtsekhowski	27-Jul-2016
E12-10-011	D	A. Gasparian	1-Aug-2017
E12-11-008	LERF	P. Fisher	6-Jul-2015
E12-11-112	A	D. Higinbotham	30-Jul-2014
E12-14-009	A	D. Higinbotham	29-Jun-2015
E12-16-007	C	Z.E. Meziani	27-Jul-2017

**Table 3 - Scheduled Experiments**

Experiment	Hall	Contact	Beam Req. Submitted
Run Group B	B	J. Gilfoyle	31-Jul-2016
Run Group F	B	S. Bueltmann	28-Jul-2017
Run Group I	B	S. Stepanyan	27-Jul-2017
E12-06-101	C	G. Huber	1-Aug-2016
E12-06-110	C	X. Zheng	30-May-2018
E12-06-121	C	B. Sawatzky	30-May-2018
E12-07-105	C	T. Horn	1-Aug-2016
E12-11-101	A	K. Paschke	28-Jul-2017
E12-12-002	D	C. Meyer	23-May-2019
E12-12-004	A	S. Riordan	28-Jul-2017
E12-15-001	C	N. Sparveris	19-Jul-2017

**Table 4 - New Experiments to be Scheduled**

Note that partially completed experiments are also considered for re-scheduling  
 (\*\*\*) = TBD pending ERR completion)

Experiment	Hall	Contact	Beam Req. Submitted
Run Group C	B	S. Kuhn	***
Run Group M	B	O. Hen	***
E12-06-105	C	D. Day	28-Jul-2017
E12-09-019	A	B. Wojtsekhowski	31-Jul-2017
E12-13-003	D	C. Meyer	29-Jul-2016
E12-13-007	C	R. Ent	***
E12-13-010	C	C. Muñoz Camacho	***
E12-14-003	C	B. Wojtsekhowski	***
E12-14-005	C	D. Dutta	***
E12-17-004	A	B. Sawatzky	***
E12-17-005	C	O. Hen	31-Jul-2017

## Accomplishments and Expectations

### Accelerator

CEBAF achievements since the last memo include establishing low energy spread beam for the Hall-A hyper-nuclear experiment (E12-17-003). The measured energy spread sigma is maintained below  $5e-5$  as per the user specification. Achieving this low energy spread requires establishing precise phasing of the cavities with respect to the beam arrival (sub  $\frac{1}{4}$  degree of 1497 MHz phase). Continuous monitoring of the energy spread is accomplished through a new synchrotron light monitor at a dispersive location in the Hall-A line. Fast feedback and the Master Oscillator modulator (MoMod) applications are now 100% functional and contribute to the ability to maintain the low energy spread.

The beam energy as measured by the 1<sup>st</sup> and 2<sup>nd</sup> Arcs has not agreed with the energy derived by the electron spin precession and the Hall-A 9<sup>th</sup> dipole measurements at the 0.25% level. A cross calibration was performed during facility development that consisted of sending beam through to Arc2 and Hall-A with the South linac off. This enabled Arc1, Arc2 and Hall-A string to measure the same beam. In addition Hall-A was able to gather some elastic scattering data with this same beam to provide absolute determination of the energy. This data is still being analyzed. Having proper energy calibration will enable the Wien filter angle to be set properly and minimize the amount of beam time spent performing spin dances in the future.

CEBAF 4-hall beam delivery is now routine: the hardware is working well and the new injector and separator configuration to enable 4-hall operations are well understood. This capability has some constraints that are described at the end of this section.

The highest-impact beam studies performed over the last year have focused on the testing of developments that reduce the time required for accelerator setup and tuning. New tools have been tested that enable the automated collection of optics data. When released for general use these will save hours of optics matching between accelerator segments with each machine setup. The second principal development of general interest is an automated tool to improve phasing of the RF cavities.

Each end-station has an Accelerator Physicists Experimental Liaison (APEL) that serves to aid the Nuclear Physicists in beam related issues during all phases of an experiment, proposals, commissioning, operating and analysis. The APELs with input from the end-station scientist, injector, and diagnostics have developed a beam parameter table for the 12 GeV era (JLAB-TN-022). Experiments requiring more stringent beam parameters should consult the APEL of the end-station in question. What is not in this document is that there are additional constraints that need to be applied during the scheduling process. Most of these constraints derive from the new 4-hall system and are as follows:

- 4-hall operations requires at least one of the original halls (ABC) to receive 5<sup>th</sup> pass beam.
  - It is strongly preferred that the original halls be A or C. Coupling B-D, while possible, places additional constraint on B & D currents.
  - Any of the original halls receiving 5<sup>th</sup> pass beam concurrently with Hall-D will receive beam with a 249.5 MHz repetition rate.
  - 499 MHz repetition rate is available when a hall is receiving pass 1-4 beam.

- Hall-D must be at 249.5 MHz repetition rate whenever an original hall is simultaneously receiving 5<sup>th</sup> pass beam.
- Hall-D can only receive 499 MHz beam when only two of the original halls are receiving beam on the lower passes (1-4).

The accelerator energy for the operations to date has been 1050 MeV/linac, i.e. 40 MeV/linac below design. The energy margin during the Fall 2018 campaign was inadequate to support robust operation as there was little or no margin in the North Linac. Beam physicists have explored and implemented the option to run the Spring 2019 program with asymmetric linacs in order to gain some margin in the North Linac. A C100 cryomodule has been removed from CEBAF and is presently being refurbished in the SRF TestLab. The goal is to have this first refurbished C100 cryomodule installed in CEBAF in Aug/Sep 2019 and have it participate in the Fall 2019 beam operations. When removed from CEBAF the C100 module was delivering 72 MeV of integrated gradient, if it returns as a C100 it will be 108 MeV capable (98 MeV operable, representing a gain of 26 MeV).

A plan for returning CEBAF back to the design energy, 1090 MeV/linac, has been developed and the first C75 module will be ready for installation in Summer 2020. Beam delivery at 1090 MeV/linac is projected for Fall 2021, after 3 C75 modules have been installed, refurbished P1 cryomodule and one more refurbished C100 cryomodule have been installed. Following these cryomodule installations, additional C75s will be produced and installed, at the pace that will be defined taking into account mitigation measures which are under development (such as plasma processing), to increase and maintain the margin so that CEBAF can support robust beam delivery at these energies.

## Hall A

Hall A ran five experiments using the tritium target apparatus during the Fall 2017, Winter/Spring 2018, and Fall 2018 run periods: (1) E12-010-103 (“MARATHON”), a measurement of the neutron to proton structure function ratio which will enable knowledge of the elusive down to up quark ratio; (2) E12-14-011 which leverages the asymmetric A=3 nuclei  $^3\text{H}$  and  $^3\text{He}$  to verify predictions suggesting that high momentum distributions in nuclei are dominated by short distance correlated pairs of different type nucleons; (3) E12-11-112, also using the asymmetric A=3 nuclei to perform a precision test of the isospin dependence of the two nucleon short range correlations, extending such measurements into a regime where three nucleon short range correlations may be observed; (4) E12-17-003, which will determine the unknown  $\Lambda n$  interaction which is critically important to understanding charge symmetry breaking in the strangeness nuclear physics sector; and (5) E12-14-009, aimed at the elastic form factor ratio in the mirror nuclei. With the completion of the tritium program, Hall A then ran in Spring 2019 the APEX experiment, a search for a new gauge boson ( $A'$ ) with sub-GeV mass that couples to ordinary matter. Installation and running of the PREX-II (E12-11-101) and CREX (E12-12-004) experiments will follow in Summer and Fall 2019. These experiments will utilize parity violating electron scattering to measure the neutron radii of lead and calcium and have important implications for nuclear structure including three neutron forces, atomic parity violation, and astrophysics. Following PREXII/CREX, installation for the SuperBigBite spectrometer program will follow. This multi-faceted program includes four measurements of the proton and neutron form factors, a semi-inclusive measurement aimed at transverse momentum distributions within the nucleon, and tagged measurements of pion and kaon structure



functions. The plan is to start with elastic scattering measurements of the neutron magnetic and electric elastic form factors  $G_M^n$  (Experiment E12-09-019) and  $G_E^n$ -RP (Experiment E12-17-004).

## Hall B

Run Group A, a collection of 13 individual proposals, continued taking data at 10.6 GeV beam energy and highly polarized electron beam starting from September 27 until November 26, 2018. A total charge of 111mC was accumulated. This run was followed by a short, opportunistic RGK data taking period for 3 individual proposals that ran at the beam energies of 7.5 GeV and 6.5 GeV, covering the remaining period of 18 calendar days until holiday break, and accumulated an integrated charge of 50mC. After the completion of short RGK, the BAND detector was re-installed in preparation for RGB. This run group serves 7 individual proposals, all using liquid deuterium as target material. During the 2019 Spring run of RGB two beam energies were used that differed by 4%, 10.6 GeV at the beginning of the run, and 10.2 GeV during the later part of the run. The change to the lower energy was related to accelerator issues that prevented a steady operation at the higher energy. During the lower energy part more stable beam was delivered to the experiment. The total accumulated charge during this run was 93mC and the ABUs are equivalent to 22.5 PAC days. Following RGB, a 21 days extension of RGA commenced, which was scheduled to (partially) compensate for lost beam time in the Fall of 2018. RGA completed the Spring run with a total of 13 ABU days and an accumulated charge of 61mC. Integrated over the entire 2018/2019 period, RGA has used the equivalent of 55 PAC days, corresponding to about 40% of the entire approved beam time of 139 days for RGA. The 2019 Summer schedule shows HPS scheduled for 63 days from June 17 through August 18 at 4.5 GeV beam energy. Following the Summer break, RGB is scheduled to continue data taking for another 48 days from November 1 through December 19 at the planned beam energy of 10.5 GeV. Following the RGB run, the BONUS12 tracking detector will be installed inside the CLAS12 solenoid magnet during the first weeks of January 2020. This requires first the removal of other detectors that are part of the standard equipment of the CLAS12 Central Detector. BONUS12 has assigned a run period of 80 days, starting January 22, and ending April 10, 2020. This will cover the entire approved beam time of the experiment.

There are currently no plans of operating the accelerator for physics during the remainder of CY 2020. Candidates for the spring operation in CY 2021 are the continuation of RG-K (ERR completed, and beam time requested) with some 70 days, or one of the nuclear target run groups (D or E) with some 60 calendar days. The latter still will have to pass the ERR before they will be able to ask for beam time.

## Hall C

After completing a first round of experiments chosen to both produce science and calibrate the new SHMS and re-commission the existing HMS spectrometers, Hall C continued with running Experiments E12-09-017 and E12-09-011, semi-inclusive pion and kaon electroproduction measurements aimed at confirming the potential for Jefferson Lab to study the proton's 3D momentum tomography, including with strange quarks. Experiments E12-09-002, a search for charge symmetry violating quark distributions via measurement of the  $\pi^+/\pi^-$  ratio in semi-inclusive deep-inelastic scattering, and E12-16-007, a search

for the LHCb charmed “pentaquark” using photoproduction of  $J/\Psi$  at threshold, were included in this run group. For the Summer 2019 run cycle, Hall C plans first to leverage the unique beam energies available to facilitate kinematic reach for longitudinal – transverse studies of pion electroproduction, with studies of the pion form factor (E12-06-101) and scaling in exclusive pion electroproduction (E12-07-105). A measurement of the proton’s generalized polarizabilities in virtual Compton scattering will follow (E12-15-001). Hall C is preparing to then run in Fall 2019 Experiment E12-06-110, a measurement of the neutron spin asymmetry  $A_{1n}$  in the valence quark region and Experiment E12-06-121, a measurement of the neutron  $g_2$  and  $d_2$  structure functions to access to the neutron color polarizability. These two experiments utilize a polarized Helium-3 target, which will be installed in Hall C late Summer/early Fall 2019. Hall C then plans to return to standard equipment configuration with cryogenic and solid targets.

## **Hall D**

During the Fall run of 2018 Hall D finished the data taking for E12-06-102 at the regular energy. Then, at lower energies of the accelerator, the CompCal detector for E12-10-011 was installed and tested. During the first 2 weeks of the Spring 2018 run a half of the DIRC detector for E12-12-002 was commissioned. After that the E12-10-011 experiment (PRIMEX-eta) ran for 53 calendar days, with Aluminum radiators, mostly at 200nA. The Hall D solenoidal magnet was off for the PRIMEX-eta running. For the first 15 days the electron beam energy was 11.6GeV, for the rest it was 11.2GeV. Most of the data were taken with a LHe target, while a Be target was also used for calibration purposes. In summer 2019 the second half of the DIRC detector will be installed. The second phase of the GlueX experiment E12-12-002 is scheduled to run in the fall of 2019 and in the spring 2020 using in total about 30% of the total time approved for this experiment. During the summer-fall 2020 shutdown Hall D plans to do a part of the modifications to the downstream platform needed for the E12-13-008 (pion polarizability) experiment. The plans are to run the 2-nd run of E12-10-011 in spring 2021; and to continue E12-12-002 in the fall 2021.









