Research Management Plan (RMP)
for the SBS projects in Hall A Jefferson Lab

Feb. 26, 2014

1 Introduction

This document describes the plans of a group of institutions within the Electro-Magnetic Form Factor (EMFF) collaboration for the management of the research efforts connected with the construction and operation of the Super Bigbite Spectrometer (SBS) for use in three Form Factor experiments. In contrast to construction, research efforts are not funded by the DOE-funded SBS construction projects but from the research funding of the individual groups involved in the SBS projects.

Research efforts include simulations of the detector performance, development and execution of calibration procedures for the spectrometer, spectrometer commissioning, development of analysis software, physics analysis and operation of the system. Successful execution of the research plan also requires design and construction of devices (dependencies) beyond the scope of the SBS construction project. The original version of this research management plan (RMP) was part of the documents required by the Office of Nuclear Physics Facilities & Project Management and Physics Research Divisions for a Joint Science/Technical, Cost, Schedule, and Management Review of the proposed Super Bigbite Spectrometer (SBS) for Hall A at the Thomas Jefferson National Accelerator Facility (TJNAF) on October 13-14, 2011. A subsequent review in November 4-5, 2013 underscored the need to update this document and to include discussion of the dependencies which are not funded as part of the SBS projects. It is not in the scope of this document to justify the physics case for the SBS. The physics justification is an ongoing process that has started with the SBS proposals for the JLab PACs and for the Science Review. This RMP addresses the activities of the participating institutions in the time between FY14 and the experimental run of GEp. FY19 is expected to be the last year of the EMFF program for the SBS[1]. The physics activities listed for the individual institutions reflect the physics interest of those institutions. The SBS projects are designed to perform the Form Factor experiments at high momentum transfer with the 12-GeV upgrade of JLab's CEBAF accelerator. The scope of the construction project is defined as building a new magnetic spectrometer in Hall A with related infrastructure, as well as a set of new detectors and trigger/DAQ electronics. The research under this RMP includes the research activity essential for the development and commissioning of the instruments as well as for the preparation and analysis of the future experimental data.

2 Research Goals

The development of an understanding of nucleon structure and the nature of quark confinement is one of the most important endeavors facing physics today. Indeed, among other things, the dynamical generation of mass within the nucleon largely answers one of the great questions facing science: What is the origin of mass? While the Higgs mechanism is often invoked in response to this question, David Gross, in his Nobel Lecture in 2004 stated, "This is incorrect. Most, 99% of the proton mass, is due to the kinetic and potential energy of the massless gluons and the essentially massless quarks, confined within the proton." During his lecture Gross at one point calls the understanding of the non-perturbative region of QCD " ... one of the most important areas of theoretical physics." The structure of the nucleon is to nuclear physics, in the early 21st century, what the structure of hydrogen was to atomic physics during the early 20th century.

While a true solution to QCD in the non-perturbative regime remains elusive, enormous progress has been made. Sophisticated phenomenological models have helped to elucidate the relevant degrees of freedom within the nucleon. Some of these models even come tantalizingly close to something approaching an analytical approach. Perturbative QCD (pQCD), while it cannot be used to calculate such underlying quantities as form factors and structure functions, can predict how certain of these quantities evolve with Q^2. Theoretical advancements such as the development of Generalized Parton Distributions (GPDs) have even

[1] Preliminary physics program on Hall A was presented in: `http://hallaweb.jlab.org/collab/meeting/2013-winter/talks/Keppel_HallACollab_Dec2013.pdf`

allowed us to understand both structure functions and form factors within a single unifying framework. In addition, lattice QCD, which may ultimately provide arbitrarily accurate numerical solutions to just about any question we may pose, has made stunning progress. Again in his Nobel Lecture, Gross notes the enormous progress in Lattice QCD in " ... achieving now reliable results that fit the low-lying spectrum to a few percent!"

One of the critical factors driving progress in understanding nucleon structure is the availability of precision experimental results at the largest possible Q^2. The observation of the surprising Q^2-dependence of G_E^p/G_M^p has generated more theoretical papers than any other result to come out of JLab. The 2007 NSAC Long Range Plan (LRP) explicitly mentioned measurements of G_E^n/G_M^n, both at JLab and at MIT/Bates. Regarding measurements of the ground-state form factors after the CEBAF upgrade, the 2007 LRP states that "Such measurements remain the only source of information about quark distributions at small transverse distance scales." Indeed, most of the current theoretical approaches to understanding nucleon structure, including phenomenological models, analysis based on GPDs and lattice calculations, require input and constraints from form-factor measurements.

Three measurements of the ground-state electromagnetic form factors are planned: one of G_E^n/G_M^n, one of G_E^p/G_M^p, and one in which a detailed comparison of G_M^n and G_M^p will be made. These three measurements, together with a very precise measurement of G_M^p using the Hall A HRS Spectrometers (not part of the Super Bigbite Program), will collectively provide precise determinations of all four nucleon form factors with unprecedented reach in Q^2. The Figures-of-Merit of these measurements represent an improvement by a factor of between 10 and 50 over all past and proposed efforts. Together with small projected systematic errors, the Super Bigbite Spectrometer will provide unique accuracy in a Q^2-regime with impressive discovery potential.

2.1 Neutron Electromagnetic Form-Factor Ratio G_E^n/G_M^n up to $\mathrm{Q}^2 = 10\ \mathrm{GeV}^2$

The GEn experiment (E12-09-016), which was first approved in January of 2009 by PAC34, will measure a double-spin asymmetry in quasi-elastic scattering of polarized electrons from a polarized ^{3}He target using the reaction $^3\overrightarrow{\mathrm{He}}(\vec{e}, e'n)pp$. The scientific rating (A-) and beam time allocation for GEn (50 days) were assigned by PAC35. We have adjusted the experimental plan and projected accuracies to accommodate the allocated beam time (see Fig. 1).

A schematic representation of the experimental setup is shown in Fig. 2. The scattered electron will be detected using a modified version of the BigBite spectrometer. The BigBite detector package includes the GEM tracking system that is being built as part of the Super Bigbite Spectrometer projects. The recoil neutron will be detected using a large segmented hadron calorimeter that will also be used in the proton arm of GEp. For GEn, the Super Bigbite magnet itself will be located between the target and the hadron calorimeter, and will make it straightforward to distinguish between charged and neutral quasi-elastic events.

GEn will require an increase in effective usable luminosity over E02-013 of more than an order of magnitude. It should also be noted that E02-013, when it was performed, had already achieved more than an order-of-magnitude increase in effective luminosity over earlier experiments to measure G_E^n. The gains in E02-013 were due largely to three factors:

- the use of a highly-optimized polarized ^{3}He target,
- the ability to collect excellent statistics using the open-geometry dipole spectrometer BigBite, and
- the use of what was then the world's largest dedicated neutron detector.

The additional gains needed for GEn will be achieved by:

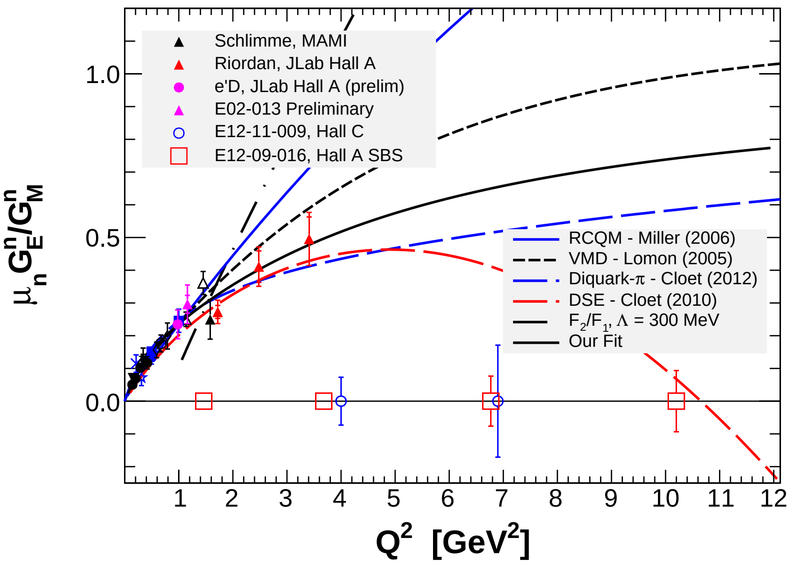

Figure 1: Shown are existing data and projected errors for measurements of the ratios of the electric and magnetic form factors of the neutron. The projected errors for the measurements made with the Super Bigbite Spectrometer are shown by the open red squares. We show published data including those of Madey *et al.*, and the results of E02-013. We also show the projected errors of the present GEn in an approved 50-day run, and E12-11-009 in a 60-day run with SHMS (open blue points).

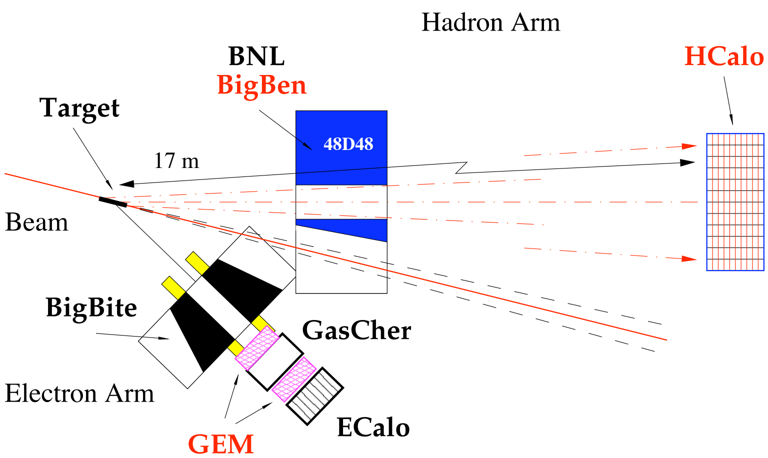

Figure 2: Shown is a schematic representation of the setup that will be used for both the GEn (E12-09-016) and the GMn experiments (E12-09-019). The target will be polarized ^{3}He for GEn and deuterium for the GMn experiment, most other components are identical.

- a further upgraded polarized ^{3}He target that will be able to tolerate beam currents in excess of 60 μA while delivering even higher polarization,
- greatly increased rate-handling capability using GEM technology,
- the use of the Super Bigbite magnet to greatly simplify the identification of charged events,
- a neutron detector (hadron calorimeter) with suppression of background by more than a factor of 200,

and of course,

- the higher beam energy available from the upgraded CEBAF.

Polarized ^{3}He Target The polarized ^{3}He target, the heart of the experiment, provides effectively polarized neutrons. In order to reach the effective design luminosity, several key innovations are required. These are:

- the use of metal end-caps with the glass target cell to sustain up to 60 μA beam currents,
- a "double barrel" convection design to allow for more rapid polarization times and sustained 60% polarization,
- increasing the overall pumping laser power and increasing the number of pumping chambers,
- the use of spectrally narrowed lasers.

In addition to the target itself, the design of a suitable target chamber and polarimetry system is required. The primary criterion for such a chamber is to have a sufficiently uniform holding field gradient which is required to maintain high-quality polarization and to minimize polarization losses in adiabatic fast passage in EPR polarization measurements. A pulsed-NMR system is also required for "online" monitoring of the polarization. All of these innovations are underway through the efforts of collaborators in the Cates group at the University of Virginia.

Monte Carlo Simulation Monte Carlo simulations are an intrinsic part of any experimental effort and for a large-scale project such as Super Bigbite, must be designed to meet a wide variety of needs. In particular, these include:

- evaluation of rates, acceptances, and figures-of-merit,
- quantification of specific backgrounds and intrinsic detector rates,
- understanding quality of spectrometer optics and tracking,
- understanding quality of particle identification.

Geant4 represents the state-of-the-art software package in particle physics to meet these needs. However, a considerable amount of infrastructure must be developed on top of these, such as defining specific configurations and output formats. Our collaboration has adopted a framework to be able to represent all the experiments and configurations within this project and integrate with CERN's ROOT analysis software suite.

GEM Instrumentation The inclusion of GEM chambers into the Bigbite detector stack is a major component of being able to perform sufficiently high precision electron tracking. For GEn, the hit rates on the GEMs from background are expected to be significantly less than the lower angle, higher luminosity GEp measurement. These chambers will be in a configuration of the four "front tracker" chambers for GEp in front of the gas Cerenkov followed by a single chamber behind from the "polarimeter tracker". These components are being developed by the UVA and INFN groups for use in all the SBS experiments.

2.2 Proton Form-Factor Ratio Measurements up to Q^2= 12 GeV^2 using Recoil Polarization

Introduction The experiment GEp (E12-07-109) was approved by PAC32 in August of 2007 and was the experiment that provided the original motivation for the Super Bigbite Spectrometer. It will measure the Sachs Form Factors ratio G_E^p/G_M^p of the proton using the polarization-transfer method in the reaction $p(\vec{e}, e'\vec{p})$. The polarization of the recoil proton will be measured using a large-acceptance spectrometer, based on the Super Bigbite magnet, that will incorporate a double polarimeter instrumented with GEM trackers and a highly-segmented hadron calorimeter.

The electron will be detected in coincidence by a electromagnetic calorimeter that is sometimes referred to as "BigCal". PAC35 allocated 45 days of beam time for the proposed measurement and recommended a maximum value of $Q^2 = 12$ GeV^2.

These parameters were used to readjust the original plan of measurements which will be made at three values of Q^2 : 5, 8, and 12 GeV^2 , while achieving an error in the ratio G_E^p/G_M^p of 0.07. The projected results are shown in Fig 3, in which we show results from earlier G_E^pmeasurements, and the anticipated errors for the present GEp experiment. The excellent precision that GEp will obtain even at 12 GeV^2 is clearly evident.

Additional measurements at even higher values of Q^2 will be evaluated after SBS commissioning.

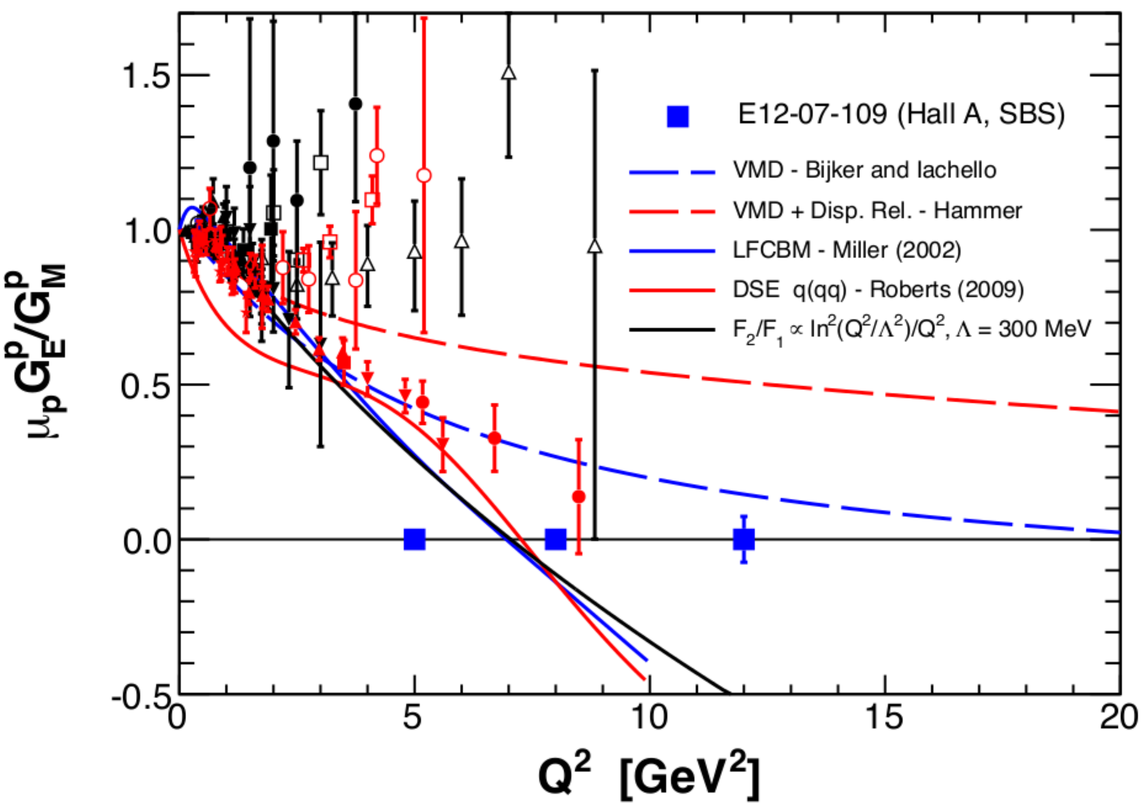

Figure 3: G_E^p/G_M^p existing measurements and expected statistical accuracy for the GEp experiment. The projected errors for the measurements made with the Super Bigbite Spectrometer are indicated by the filled blue squares, corresponding to 45-day run with the recommended highest value of momentum transfer 12 GeV^2.

Equipment A schematic representation of the experiment is shown in Fig. 4.

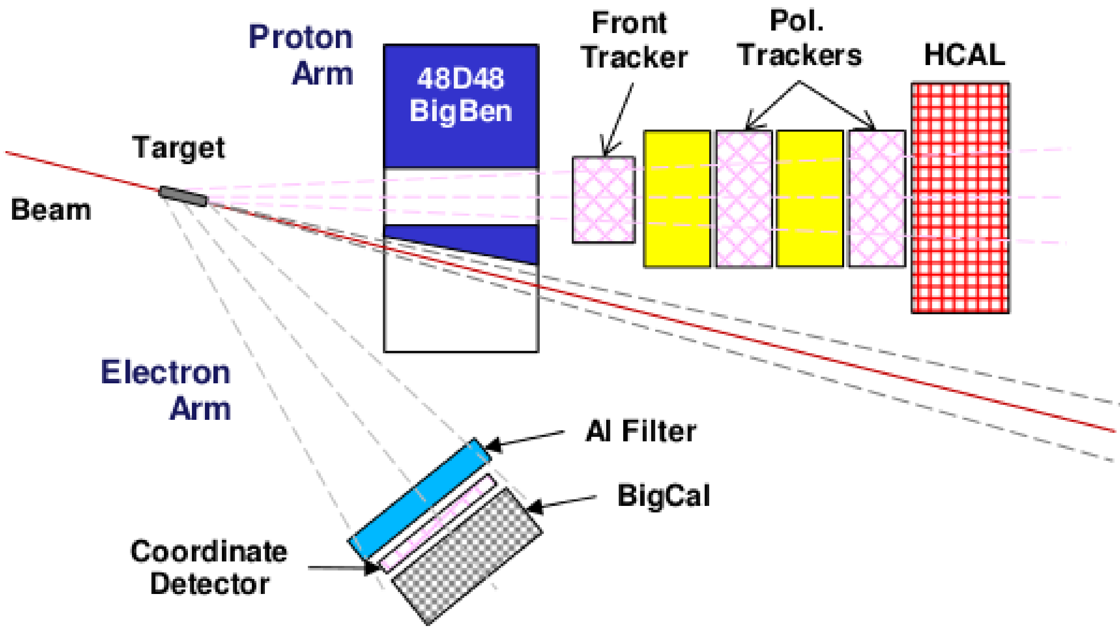

Figure 4: GEp schematic layout with the proton and hadron arm.

- **Beam**: Requested beam energies of 4.4 and 11.0 GeV at the highest longitudinal polarization (85% assumed in the proposal) and large current (75 μA assumed in the proposal).
- **Target**: The production target will be based on the standard Hall A high power LH2 cryotarget. After the successful G0 and Qweak targets, there is a consistent effort at JLab to standardize the hydrogen target performance for the 12 GeV program. The goal is to obtain not more than 1% density loss over 20 cm with beam of 100 μA and 2 mm square raster. Target design largely exploits Computational Fluid Dynamics (CDF); the first identified solution is under investigation. Thin carbon foils will be used for the calibration of optical and spin-transport studies in the proton arm.
- **Electron Arm**: The electron arm is based on a coordinate detector, CDET, made of an array of thin scintillator plates coupled to existing PMTs donated by FNAL and a calorimeter, ECAL, assembled from the existing lead-glass blocks used in previous experiments. The blocks need to be reconfigured for the higher Q^2 geometry, higher radiation operation and use with a PMT-based coordinate detector.
  - **ECAL**: The Electron Calorimeter requires development of an efficient method of annealing radiation damage for which two concepts are under investigation. The UV-light-based concept is well known, but requires a ten-fold increase in the UV intensity. A potential complication of very high UV intensity would be PMT photocathode damage by the large amount of light. Maintaining the calorimeter blocks permanently at high temperature is a new concept which would require a light guide between a hot lead-glass block and a room-temperature PMT.
  - **CDET**: The development of the Coordinate Detector is well advanced and a report is available at: https://userweb.jlab.org/ bogdanw/CDET_V3.pdf
- **Proton Arm**: The SBS spectrometer is used as the proton arm, set at a central scattering angle of 16.9 degree. It incorporates a large acceptance dipole Magnet, a primary particle GEM tracker, a double polarimeter instrumented with GEM trackers and a highly segmented hadron calorimeter.

- **Magnet**: The 48D48 spectrometer magnet is being reconfigured for this use as part of the SBS program.
- **Front Tracker**: The Front Tracker will be made of six 40×150 cm^2 chambers. Each chamber is composed of 3 adjacent GEM (Gas Electron Multiplier) modules of 40×50 cm^2 active area with two dimensional (x/y) readout. The tracker will sit immediately downstream of the dipole magnet. The modules will operate with an Argon and CO_2 gas mixture (70/30) and high voltage up to 4300 V. The GEMs are designed to provide spatial resolution down to 70 μm on each hit and to operate with a large background flux (up to 400 khits/cm^2). The readout electronics is designed to sustain 10 kHz trigger rate with 50% channel occupancy. The Front Tracker may benefit from the addition, in front of the dipole magnet. of two small 10×20 cm^2 microstrip silicon planes with 50 μm pitch. These are under development by the INFN Rome group; impact of this silicon detector on the SBS tracking is under evaluation.
- **Polarimeter**: Composed basically by two polarimeters in series; each polarimeter includes a CH_2 block followed by tracking chambers based on GEM technology.
- **HCAL**: Described in section 2.3

- **Trigger and DAQ**: Covered in the SBS program.

2.3 Precision Measurement of the Neutron Magnetic Form Factor up to Q^2 = 13.5 GeV^2

The Hall A GMn experiment was approved in January of 2009 by PAC34 to make measurements up to a Q^2 of 13.5 GeV^2. G_M^n will be extracted from a precision measurement of the ratio of the unpolarized elastic cross sections of the two processes $d(e, e' p)n$ and $d(e, e' n)p$. It will use essentially the same apparatus as GEn, with the exception that the target will be the Hall A liquid deuterium cryotarget. The schematic representation of the experimental setup was given above in Fig. 2.

Like the other Super Bigbite Spectrometer form-factor measurements, the G_M^n measurement in Hall A will provide excellent accuracy and reach in Q^2, well beyond all competing efforts. The GMn experiment will require only 25 days of running to measure the approved kinematic points. An extension to higher Q^2 would be possible with the same equipment if additional beam time is subsequently approved. The existing data for G_M^n, together with the projected errors for both the Hall A and the CLAS12 experiments, are shown in Fig. 5. While the magnetic form factor of the neutron has previously been measured up to 10 GeV^2, the few data that exist above 4.5 GeV^2 have uncertainties of about 10-20%. The GMn experiment in Hall A will provide sufficient accuracy to bring new understanding to this subject, including combining with the other nucleon form factor measurements to effect the decomposition of the u- and d-quark distributions.

Hadron Calorimeter, HCal-J A 12×24 module calorimeter is being built at Carnegie Mellon Univ. with contributions from INFN Catania and JLab. Each module will have a face of roughly 15 cm square and consist of 40 layers of iron interspersed with 40 layers of scintillator, read out by a wavelength shifter plate running through the center of the module. This detector is expected to have excellent spatial resolution ($\approx$3 cm for an 8 GeV/c nucleon) providing the angular resolution required for rejection of events which are not quasi-elastic. It will have an efficiency of well over 90% for neutrons and a slightly higher efficiency for protons. The excellent match in efficiency will greatly reduce systematic errors in the ratio of cross sections of interest. A significant advantage of such a calorimeter over a scintillation detector is that the large expected energy-deposited allows the use of a high threshold, greatly reducing background trigger rates at the high luminosity of the experiment.

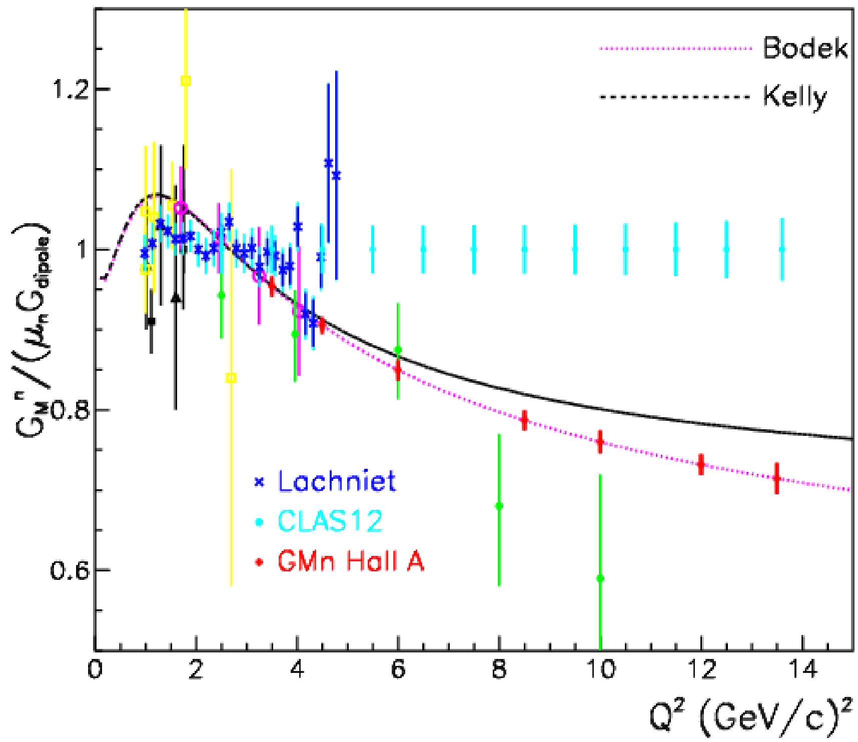

Figure 5: Published G_M^n data together with the projected accuracy for Q^2-points of the CLAS12 G_M^n experiment (E12-07-104) in a 30-day run, and the projected accuracy for Q^2-points of the Hall A G_M^n experiment (E12-09-019) in a 25-day run that will be performed using the Super Bigbite Spectrometer. The Bodek (BBBA) parametrization of the nucleon form factors was used to calculate of the projected statistics.

A high-speed wavelength shifter is being used to improve the timing of this calorimeter compared to previous designs. This requires the use of unusual scintillator which provides a harder spectrum by avoiding the POPOP dye typically used to increase attenuation length. This custom scintillator is being mixed and extruded for us at the FNAL facility. The resulting improvement in time resolution will be particularly useful for background rejection in the GEn measurement.

Coordinate Detector The Idaho State and St. Mary's Univ. groups are collaborating with JLab on construction of a two-plane coordinate detector. Each is comprised of 2400 horizontal scintillator strips 5 mm thick and 60 cm long read-out by wavelength-shifting fibers driving multi-anode PMT's. The strips are arranged to give an active area of 3.0×1.2 m^2 for each plane. The detector was originally conceived to provide high-rate tracking ability for the electron arm of the GEp experiment. It will first be used by the GEn and GMn experiments for charged-particle identification at the entrance face of HCal-J. It will provide auxiliary information for neutron/proton identification along with the track deflection given to protons by the 48D48 dipole magnet.

2.4 Additional experiment

Semi-Inclusive Deep Inelastic Scattering Experiment E12-09-018, approved for 64 beam-days by JLab PAC38 in August 2011, will study transverse target single-spin asymmetries in the semi-inclusive electroproduction of charged and neutral pions and charged kaons on a polarized ^{3}He target in the DIS regime. The BigBite spectrometer will detect scattered DIS electrons in the valence region at x values ranging from 0.1-0.7 and Q^2 values from 1-10 GeV^2. The SBS will detect high-energy hadrons at low-to-moderate transverse momentum $P_{h\perp} \lesssim 1$ GeV and large values (0.2-0.7) of the fraction z of the virtual photon energy imparted to the observed hadron. The large acceptance of SBS and BigBite spectrometers will provide wide coverage of all kinematic variables of the SIDIS reaction, including the azimuthal angles ϕ_h of the hadron production plane relative to the electron scattering plane and ϕ_S of the target polarization relative to the electron scattering plane. Complete coverage of ϕ_S is achieved by taking data for as many as eight different orientations of the target polarization, always perpendicular to the beam direction. The azimuthal single-spin asymmetries corresponding to the Collins and Sivers effects will be extracted in a fine three-dimensional grid of x, z and $P_{h\perp}$ at each of two different beam energies (11 and 8.8 GeV), providing a wide Q^2 coverage at fixed x. The results will have a substantial impact on global TMD analysis and will achieve a statistical figure-of-merit for neutron asymmetries 100 times greater than that of the HERMES experiment for proton asymmetries. The only additional equipment required by E12-09-018 relative to that already approved for the form factor experiments is a refurbished RICH detector from the HERMES experiment, needed for charged hadron identification in SBS.

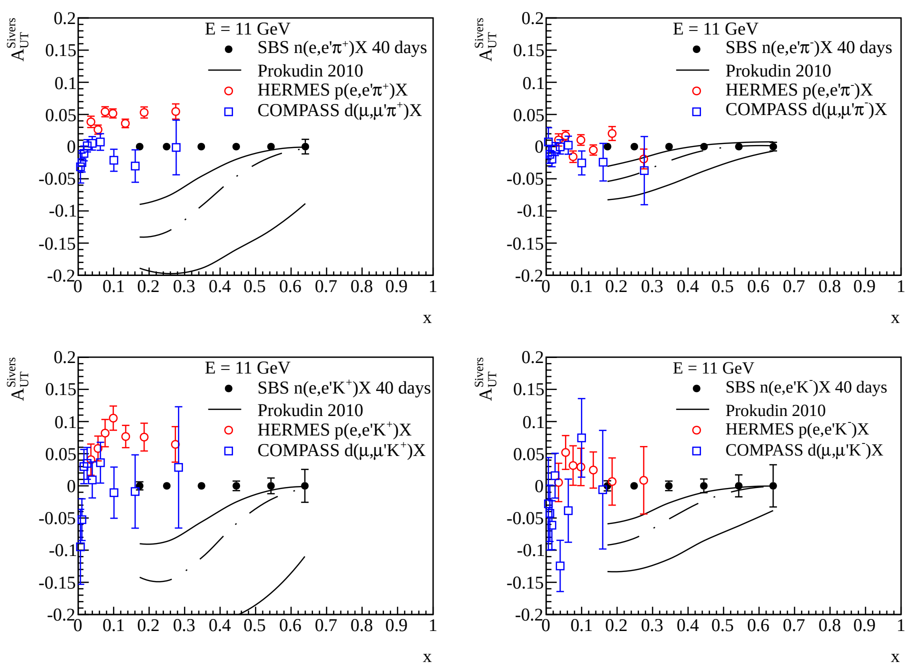

Figure 6: Projected uncertainties from E12-09-018 in the azimuthal moments of the SIDIS cross section corresponding to the Sivers effect in the $\mathbf{n}(e, e'h)X$ reaction as a function of x, integrated over z, Q^2 and $P_{h\perp}$. Projected uncertainties are compared to data from previous experiments on proton (HERMES) and deuteron (COMPASS) targets, as well as the prediction (with uncertainty band) of a model-dependent global analysis by A. Prokudin.

3 RMP Milestones

The milestones in this document are research milestones that are derived from a technically feasible project time line. We will update those milestones as the project time line will be refined, especially by including a realistic funding profile.

The following project milestones are foreseen:

Table 1: Major milestones of the SBS dependencies and related activities

Month / yr.	Milestone Description
6/14	HCal-J detailed design complete
7/14	Develop concept for annealing ECal blocks
8/14	Select ^{3}He target cell design for high luminosity
8/14	GRINCH design complete and components ordered
9/14	Front tracker electronics in production
9/14	HCAL-J design review
10/14	Start HCal-J module construction
1/15	GRINCH fully assembled and tested for gas and light tightness
7/15	ECal design review
9/15	GRINCH installed and tested
2/16	Four GEM front tracker chambers complete and available at JLab
3/15	HCal-J module assembly 50% complete
5/16	ECal electronics ready
9/16	GRINCH ready
6/16	Simulated-beam bench test of selected ^{3}He cell design
9/16	All (6) GEM front tracker chambers complete and available at JLab
9/16	HCal-J construction complete
1/17	Design for ^{3}He target hardware and instrumentation complete
6/17	GEn polarized ^{3}He target ready
9/17	ECal ready

A tentative plan of experiments in Hall A is a subject of ongoing analysis by the Hall A collaboration. Results of that analysis could change the schedule of experiments and dates of the research milestones. The actual experimental schedule will be defined in the future, largely by the beam availability.

4 List of tasks

The following is a list of the research tasks only, it does not include DOE-funded tasks for the construction of the SBS systems. The research tasks include simulation and commissioning required for: Magnet, Beam line, GEM chambers, Lead-glass calorimeter, Hadron Calorimeter, Trigger, DAQ, and the analysis software. Some of the tasks involve more than one component. For example, the division between general software tasks and tasks related to an individual detector component is somewhat arbitrary.

5 Statement by the Hall A leader

The Hall A collaboration of over 70 user institutions has endorsed the research program of the SBS and will support the operation of the experiments. The core group of the electromagnetic form factor collaboration (EMFF) consists of about 30 physicists and has been one of the most active groups within the Hall A collaboration. After the completion of the SBS hardware, the SBS program will become a high priority for scheduling - consistent with the timeline and the milestones listed in this document as well as in the Project Management Plan. With the operation of SBS, the EMFF collaboration is expected to grow significantly. Beyond the form factor program, new experiments have been proposed and are planned to be proposed that will utilize the SBS equipment to continue a successful physics program into the future.

6 Institutional Responsibilities

The tables list the responsibilities and the manpower available for the research tasks connected with the construction and operation of the SBS. We start with an overview detailing the responsibilities of all institutes and then list the responsibilities and tasks of the individuals. The manpower listed is sufficient to perform all the tasks listed in the task list. In addition to this manpower, the EMFF collaboration as a whole will be involved in the physics analysis of data derived from the SBS detector.

The core of the collaboration, Thomas Jefferson National Accelerator Facility, the University of Virginia, Carnegie Mellon University, the College of William and Mary, the University of Glasgow (Scotland), Norfolk State University, Rutgers the State University of New Jersey, the National Institute of Nuclear Physics (INFN) (Italy), has recently successfully completed the E04-108 and E02-013 experiments at JLab.

The international part of the Super Bigbite collaboration plays a very important role in the project. It includes the groups from INFN (Italy) and Glasgow (Scotland). Efforts of the INFN group (Dr. E. Cisbani *et al.*) are concentrated on development of the GEM-based front tracker and associated electronics, for which INFN approved the full requested funding of 720k Euro. The Glasgow group (Hall-A Spokesperson Dr. J. Annand) is developing a front-end electronics for the large PMT arrays, which will be used in several Super Bigbite experiments.

Detailed Institutional Responsibilities

The tables below are based on the committed resources within the existing base grants from the funding agencies. Due to the standard duration of these grants, the given grant typically spans about 3-4 years, somewhat short for the SBS projects. However, the commitments from spokespersons in the collaborative institutions reach at least through 2018. The committed manpower is sufficient to bring the SBS spectrom-

Table 2: Institutional Responsibilities

Jefferson Lab	Magnet Trigger & DAQ Coordination of the experiment preparation
Col. of William & Mary (Perdrisat)	ECAL Physics/ECAL data analysis
Col. of William & Mary (Averett)	GRINCH GRINCH data analysis
CMU	Hadron calorimeter GEM tracker data analysis Physics/HCal data analysis
Glasgow	Development of the PMT front-end BigBite Timing Hodo Neutron polarimetry analysis
Rutgers	Trigger in GEp FADC/FPGA data analysis Physics analysis
INFN/Rome	Front Tracker detector & readout GEM simulation software Track reconstruction software Physics/GEM tracker data analysis
INFN/Catania	Front GEM module design & coordination Simulation of the GEM tracker GEM data analysis HCAL-J light collection
UVa (Cates)	Polarized ^{3}He target
UVa (Liyangage)	Polarimeter GEM detectors & readout GEM data analysis
NSU	Physics data analysis Contribute to ECal construction
Idaho State Univ.	Coordinate Detector
Univ. of Connecticut	RICH detector contribute to Monte Carlo
St. Mary's Univ.	Coordinate Detector construction FastBus testing
Yerevan Phys. Inst.	Spectrometer operations
North Carolina A&T	GRINCH photon detection

eter to a stage of detector commissioning and readiness. According to many years' practice in Hall A, the manpower required in the following stage (experiment running and analysis) will be easy to find within a wider Hall A collaboration. However, we expect that the core EMFF collaboration will be have sufficient resources for running the experiments.

The Jefferson Lab FTE calculation is for four years, and represents actual total time for SBS research. We note that the potential staff research time (25% scientist, 75% postdoc), as differentiated from operations time, does not include work that is funded in the program management plan.

Table 3: FTE $\times$ years

Institution	Faculty	Staff	Postdoc	Grad. Student	Undergrad.
Jefferson lab		2.2	2.3		
W&M (Perdrisat)	2.5		3.75		0.3
W&M (Averett)	1.5		2.5	3.0	
Carnegie Mellon Univ.	2.0	3.0	3.0	3.0	5.0
Univ. of Glasgow	1.5	2.5	1.5	3.0	
Rutgers Univ.	0.6		1.1	0.5	
INFN/Rome	2.5	4.0	1.5	1.0	
INFN/Catania	2.0	4.0	1.0	2.0	
U.Va. (G. Cates)	1.1	1.5	2.5	2.5	
U.Va. (N. Liyangage)	1.25		3.0	7.5	
Norfolk State Univ.	1.0		1.0		1.0
Idaho State Univ.	1.0			3.0	
Univ. of Connecticut	2.5			4.0	
St. Mary's Univ.	1.25			6.0	2.7
Yerevan Phys. Inst.	1.5	1.5			
North Carolina A&T	2.0			5.0	5.0