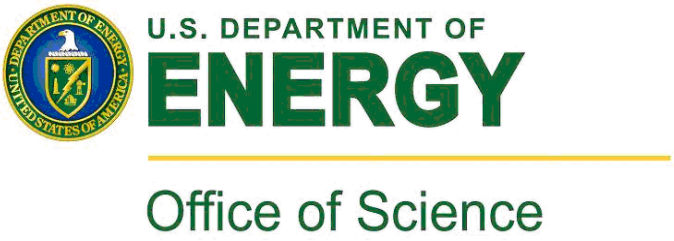

Department of Energy
Office of Nuclear Physics Report

on the

Annual Progress Review

of the

Super BigBite Spectrometer (SBS)

November 7-8, 2016

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Executive Summary

On November 7-8, 2016, the Department of Energy (DOE), Office of Science, Office of Nuclear Physics' Facilities and Project Management Division conducted an Annual Progress Review of the Super BigBite Spectrometer (SBS) program. The review was held at the DOE Headquarters in Germantown, Maryland.

The SBS program is a system of detectors to enable measurement of the elastic form factors of the neutron (GE(n)/GM(n) and GM(n)), and of the proton GE(p)/GM(p). The panel affirmed that the main SBS program continues to be of high scientific merit and remains a high priority for the scientific community. Strong interest was noted for additional uses of the equipment including the Semi-inclusive deep-inelastic scattering (SIDIS) experiment.

The SBS program has two distinct experimental configurations. In its use as a proton polarimeter it consists of the magnet followed by an array of gas-electron multipliers (GEMs) and analyzers and a position-sensitive scintillation Coordinate Detector (CDET) as the front face of a hadron calorimeter (HCAL) for proton identification. An electromagnetic calorimeter (ECAL) assists the non-magnetic CDET, and an unpolarized liquid hydrogen target is used. In the neutron detection configuration the GEMs and analyzers are not used. The CDET acts as a charged particle veto for the HCAL, an existing magnetic spectrometer is used as the electron arm, and a polarized ^{3}He gas target is used in this configuration. Several pieces of this system are external dependencies not covered within the project work breakdown structure, but were included in the review – HCAL, ECAL, and the polarized ^{3}He target.

The team responded well to last year's review, answering all recommendations. As of the review, the on-project deliverables are nearly complete. The work on the magnet was finished first in January 2016. All infrastructure items have essentially been completed and are in storage, including the magnet, its counterweight structure, the field clamps and corrector magnets, and specialized beam pipe and shielding elements. Final infrastructure elements were delivered after this review in December 2016.

CDET assembly was completed ahead of schedule in August 2016. On GEM chamber construction, the 40 GEM chambers were completed in January 2017 with spares to be delivered in May 2017. Five GEM chambers are now configured in Hall A for in-beam tests. A plan is strongly suggested for maintenance of the chambers to check on possible degradation over the long storage time anticipated (perhaps three years). On the trigger and data acquisition (DAQ) electronics, progress was made, but the panel felt that clarification of responsibilities was in order, recommending an updated org chart.

Work on the off-project dependencies was reviewed due to its importance in the overall science goals of this project. The HCAL module production has proceeded largely according to schedule, and completion is expected by February 2017. Regarding the ECAL, a proof of principal beam test of a scaled-down lead glass array was studied, and answered questions regarding the scalability of the thermal annealing of radiation damage

for this design. While no show-stoppers are anticipated, the date for a critical decision choosing the thermal annealing over the backup method of UV curing has been identified as August 2017. The panel encouraged the development of specific detailed pass-fail criteria for the annealing decision. The polarized ^{3}He target design was reviewed by TJNAF and the design of this critical component was frozen. Because the ^{3}He target is a schedule driver for the neutron measurement, its remaining milestones will need to be monitored. The gas Cerenkov and ring-imaging Cerenkov detectors are progressing well.

The project is overall on schedule, with significant portions ahead of schedule as the end of the formal project nears. The budget is on target for this stage of the project.

The project management was commended for bringing the project to this stage. More planning was recommended to ensure a successful transition to operations involving a commissioning stage, as well as the long-term storage of components such as the GEMS.

Recommendations

- Provide an updated organization chart to DOE before the next review.
- The team should consider what progress on performance is needed to reach full performance and identify them as Ultimate Performance Parameters (UPPs).
- The team should provide to DOE a plan for transition to operations before the project closeout review. The plan should describe the activities, goals, and schedule associated with demonstrating the KPP's. The plan should also include a list of milestones that capture the main activities, including off-project dependencies and demonstration of UPP's as appropriate, which need to be completed in order to accomplish the planned science program of the SBS, after project completion. These milestones will be discussed on a quarterly basis with NP.

Introduction

On November 7-8, 2016, the Department of Energy (DOE) Office of Science, Office of Nuclear Physics (NP) held an Annual Progress Review of the Super BigBite Spectrometer (SBS). The review panel consisted of four external peer review experts: Professor Richard Majka (Yale University), Professor William Jacobs (Indiana University), Dr. Hank Crawford (Lawrence Berkeley National Laboratory), and Professor Ricardo Alarcon (Arizona State University). The review was chaired by Dr. Elizabeth Bartosz, Program Manager for Nuclear Physics Instrumentation. Other attendees included Dr. Gulshan Rai, Program Manager for Medium Energy Physics for the Office of Nuclear Physics.

Each panel member was asked to evaluate and comment on any relevant aspect of the SBS project. In particular, the purpose of this review was to assess all aspects of the project's plans—scientific, technical, cost, schedule, management, and environment, safety, and health (ES&H). The following main topics were considered at the review:

1. The significance and merit of the project's scientific goals;
2. The feasibility and merit of the technical approach for delivering the science, and the technical status of the project, including completeness of scope and fabrication progress;
3. The feasibility and completeness of the budget and schedule, including workforce availability;
4. The effectiveness of the management structure and the approach to ES&H; and
5. Other issues relating to the SBS project.

The two-day review was based on formal presentations given by the project team, separate follow-up discussions with the reviewers, and executive sessions. The second day included a question and answer session in which the project team responded to questions posed by the panel on the first day. The second day also included an executive session during which time the panel deliberated and prepared draft reports on their assigned areas of focus; a brief closeout with the SBS project team and collaborators and laboratory management occurred in the mid-afternoon. The panel members were asked to submit their individual evaluations and findings in a "letter report" covering all aspects of the charge. The executive summary and the accompanying recommendations are largely based on the information contained in these letter reports. A copy of the charge letter and the agenda are included in Appendices A and B, respectively.

Significance and Merit

Findings:

The Super BigBite Spectrometer (SBS) program involves measurement of the elastic form factors of the neutron (GE(n)/GM(n) and GM(n)), and the proton GE(p)/GM(p). Measurement of the ratio of the neutron electric to magnetic form factor is planned in a four momentum transfer range Q^2 from 1.5 $(GeV/c)^2$ up to about 10 $(GeV/c)^2$. Measurement of the ratio of the proton electric to magnetic form factor is planned in a four momentum transfer range Q2 from 5 $(GeV/c)^2$ up to about 12 $(GeV/c)^2$. Measurement of the neutron magnetic form factor is planned in a four momentum transfer range Q^2 from 3.5 $(GeV/c)^2$ up to about 13.5 $(GeV/c)^2$. A combination of the measurements allows for a SU(2) based quark flavor separation comparing u- and d-quark contributions to the form factors. These measurements are aimed at achieving a very high statistical and systematic accuracy. The SBS spectrometer setup provides the unique capability for experiments requiring high luminosity and fairly large solid angle. 3D imaging of quarks inside nucleons is the new frontier of hadron physics.

The Dyson-Schwinger equations predict a zero crossing in the ratios of GE(n)/GM(n) and GE(p)/GM(p) that can be tested at Q^2 in the domain accessible to the SBS.

Simulation and analysis such as tracking the spin rotation of particles through the spectrometer in order to extract the transverse polarization of the nucleon has been incorporated in the codes. Analysis of accidentals, by mixing events, is a work in progress. Trigger efficiency simulations are a work in progress. Radiative corrections and form factor extraction methodology in the software plan is a work in progress.

The theoretical community participated in a workshop in Trento in April 2016.

Comments:

Understanding quantum chromodynamics (QCD) requires more information about the correlations among quarks in nuclei; input that can be determined in the SBS program.

Recommendations:

- None

Technical Approach and Status

Magnet/Infrastructure

Findings:

All components for Work Breakdown Structure (WBS) 1, the magnet, were completed in January 2016. A number of components under WBS 2 (other infrastructure necessary for the set of experiments) were already completed in 2016 with the remainder to be completed by December.

The SBS infrastructure now completed and stored in the Thomas Jefferson National Accelerator Facility (TJNAF) test area includes: the 48D48 magnet and counterweight structure, field clamps and corrector magnets, scattering chambers and snouts, beam pipe and shielding as well as many other pieces. A great deal of effort has been put into making sure the designs as implemented can easily accommodate all SBS experiments in all their kinematic settings.

Comments:

The panel is very pleased to see the end in sight of the design/fabrication and readiness of all the SBS infrastructure items in WBS 1, and many of the engineering-related items such as shielding enclosures, beamline supports, and magnet correctors within WBS 2, on time and on budget.

Testing of the functionality of the items has been part of the process (e.g., ability to move some of the heavy components around). Assembly of the many intricate beam line shielding pieces will be tested in November, a commendable plan. Regarding implementation of the detector support hardware, attention has been paid to making positions verifiable by survey and reproducible at the mm level upon detector replacement.

The panel notes that a comment from the 2015 review resulted in an estimation and plan to address any transverse beam transport issues into the dump, and these plans were discussed in the pre-brief materials.

The panel affirms the WBS 1 Key Performance Parameter (KPP) is complete, as well as the relevant KPP from WBS 2.

Recommendations:

- None

Target and Detectors: ^{3}He, HCAL and ECAL, CDET

Findings:

Following initiation of fabrication in March of 2015, progress on HCAL module production has advanced and has largely adhered to the anticipated schedule. At present, 75% of the 288 required modules have been completed, with 169 of those already delivered to TJNAF. Completion of the hadron calorimeter (HCAL) module assembly is expected by February 2017.

In response to recommendations during the last review, a write up of the C16 "proof of principle" beam test of thermal annealing for the electromagnetic calorimeter (ECAL) lead glass was generated. North Carolina Central University has received a supplement from the National Science Foundation (NSF) for the construction of the full scale ECAL. The NSF supplement is for equipment and does not include contingency or workforce support beyond that already funded by the existing NSF operations grant to that university.

Construction of a C200 prototype for the thermal annealing studies was initiated. In conjunction with the above, a document outlining 3 options for dealing with the ECAL radiation damage (use of Pb glass with UV curing, with thermal annealing, or the use of the fiber 'spaghetti' calorimeter (SPACAL) from Brookhaven National Laboratory, BNL) was generated and reviewed/discussed via email with a subset of SBS review panel members.

The path forward as presented at this review follows on with the thermal annealing solution with UV curing as a backup; a critical decision point in August 2017 has been identified for a final decision.

The work on the C200 prototype to identify and implement scalable solutions for thermal annealing has been ongoing and a summary of the work and preliminary conceptual design report (CDR) were generated.

CDET assembly was completed August 2016. The target design including metal endcaps is complete. The ^{3}He target will be pumped continuously with 240W of laser power. The intrinsic relaxation time of the target is expected to be approximately 40 hours based on his calculations of a glass-metal design. The relaxation time caused by the beam is ~30 hours and so it will dominate. The current laser power saturates the polarization of the intended 6L gas volume.

Comments:

The HCAL detector is nearing completion with work on the crane-able assemblies to begin in spring 2017 and fiber optics based pulser system to be installed in the summer 2017. The fabrication of this subsystem dependency seems to be well in hand and anticipated to be ready for use for the SBS. A caution to the above is the question if the HCAL iron channels stray magnetic fields to cause a problem with photomultiplier performance. A simulation/test of this possible problem should be performed.

The super module (3x3 Pb glass block assemblies) ECAL concept appears to answer many questions regarding a scalable design for the ECAL thermal annealing.

Comparison of C200 test setups with simulated results from the COMSOL program have allowed for understanding and improving details of the super module structure with optimal heating and cooling. This has been a very encouraging development. In the current test implementation, the desired temperature profile along the length of the lead glass is achieved and correctly simulated in COMSOL, giving important confidence in the design process.

Continued tweaking of design components is ongoing to optimize thermal gradients and mechanical performance; no show-stoppers are known or anticipated.

Although a decision point for the annealing method is not until August of 2017, it is important to continue to test and finalize issues as quickly as possible, as aspects of the full ECAL construction (parts procurement) already begin in early 2017. While general criteria for success of the fully stacked ECAL in thermal annealing mode are that it operates with appropriate temperature profiles and mechanical stability over week long type test running periods, specific detailed pass/fail criteria should be developed to ensure success.

As epilogue to the C16 test, any investigations that would further solidify the conclusions from those results would of course strengthen the thermal annealing underpinning beyond the test of principle already carried out.

The panel commends the project team for completing CDET ahead of schedule. The panel compliments the ^{3}He team for accomplishing the design review and freezing the design of this critical component.

Recommendations:

- None

Trigger and DAQ Electronics

Findings:

The SBS trigger has 2 levels. The Level 1 trigger uses information from only the ECAL discriminators. The Level2 trigger uses geometrical information from both the ECAL discriminators and from the HCal Fast Analog-to-Digital converters (FADCs.)

The GEM readout effort is investigating ways to reduce data volume using both the crude tracking available from HCal geometry and the timing information that allows coincidence of time slices in x and y.

The GEMs have a 4 micro-sec pipeline but the shaping of the signals gives ~300 ns pulses which are sampled every 25ns and their analog amplitude stored. The raw data is first transferred to the multi-purpose digitizer (MPD) where it is zero-suppressed. The remaining data represents about 60% occupancy which are then passed to the sub-system processor (SSP) where they are selected based on the geometry of the trigger and individual hit waveforms fit to get the t_0 for the pulse. All zero suppressed data from ECal is sent to the event builders after a L2 trigger.

A timing diagram was presented during the discussion period on the second day.

Comments:

The project did not present a clear responsibility or organization chart of either the trigger or data acquisition (DAQ); the workforce appears to consist of small FTEs for numerous people. While Ron Gilman is identified in the PMP as the head of the trigger system, the former technical point of contact at the Laboratory (Camsone) was presented at 0.2 full-time equivalent (FTE) on the project.

The software for waveform fitting, geometrical selection, and comparing x,y hit times is not yet written and is now timely. The panel is glad to see the DAQ/trigger timeline explicitly presented.

Recommendations:

- Provide an updated organization chart to DOE before the next review.

GEM Progress

Findings:

WBS 3 is the production of 40 Gas Electron Multiplier (GEM) chambers which are expected to be completed in January 2017. Eight spare modules are expected to be completed in May 2017.

The yield of components and finished chambers passing quality assurance (QA) and meeting specifications throughout the project has been high. Five chambers are installed in Hall A for testing. The optical link to the SSP is under testing. The full order of MPD and APD cards has been delivered. University of Virginia (UVa) will order 13 more MPDs with UVa funds, to ease the cabling.

Comments:

The panel commends the group on bringing this part of the project to near completion. The panel also commends the effort to store and operate chambers in Hall A. This will allow both testing in a realistic environment and development of calibration and analysis (track finding) software.

A plan should be developed for maintenance of the chambers while in “storage” and for checking on possible degradation over time. The panel was not clear on who is funding the rear tracker electronics or what acceptance criteria is being tracked.

Recommendations:

- None

Budget and Schedule

Findings:

The high level budget and schedule were presented. The completion date for WBS 1 was met as expected by January 2016 and all expenditures were completed $44,000 over budget. The WBS 2 budget was underspent by $14,000. The completion date for WBS 2 is January 31, 2017; all milestones have been completed and about $14,000 of the contingency remains. The completion date of WBS 3 is February 1, 2017; all milestones are completed except for the assembly and testing of the last GEM modules expected by November 30, 2016. There is $26,000 in contingency remaining in WBS 3.

Significant progress has been achieved in the following project dependencies: hadron calorimeter, front tracker GEMS, and the GRINCH.

The thermal annealing of ECAL has been modeled with COMSOL and a solution has been proposed for the entire device. Funding for the construction of the annealing scheme has been secured from National Science Foundation (NSF) to NCCU.

All the dependency projects, being carried out at outside institutions, have tracked milestones, but their schedules are not clear.

Comments:

There have been significant advances in the project since the last review. The experimental configurations for the GM(n) measurement were presented and TJNAF should be commended for addressing it at this juncture. It is quite encouraging that TJNAF will conduct a readiness review of the GM(n) experiment.

The dependency projects ECAL and polarized ^{3}He target continue to drive the overall schedule. The ^{3}He target is needed for the neutron form factor measurements and on the present schedule is expected to be ready for beam in January of 2019. The Laboratory workforce has been allocated to start the logistics of implementing the ^{3}He polarized target into Hall A.

An overall workforce plan was not presented formally. The workforce as discussed for individual WBS elements seems adequate to complete the project.

Recommendations:

- None

Management and ES&H

Findings:

The recommendations from the last review were addressed in a timely and satisfactory manner. To keep track of the project, the Project Manager (PM) works closely with Hall A management and the collaboration.

Environment, Safety and Health (ES&H) is fully integrated into the design, fabrication, and installation of the overall SBS project.

Comments:

The PM, with his unique blend of scientific and technical expertise, has done a great job in bringing the project close to completion. The Project and Laboratory have also managed well to drive the SBS dependencies to sound design and contractual solutions.

A plan for transition to operations should be developed including physical protection of the stored equipment, planning adequate workforce for developing the trigger software, and on line and off line software and analysis.

Recommendations:

- The team should consider what progress on performance is needed to reach full performance and identify them as Ultimate Performance Parameters (UPPs).
- The team should provide to DOE a plan for transition to operations before the project closeout review. The plan should describe the activities, goals, and schedule associated with demonstrating the KPP's. The plan should also include a list of milestones that capture the main activities, including off-project dependencies and demonstration of UPP's as appropriate, which need to be completed in order to accomplish the planned science program of the SBS, after project completion. These milestones will be discussed on a quarterly basis with the ONP.

Appendix A: Charge Letter

Thank you for agreeing to participate as a panel member for the Annual Progress Review of the Super BigBite Spectrometer (SBS) for Hall A at the Thomas Jefferson National Accelerator Facility (TJNAF). This review is being organized by the Department of Energy (DOE) Office of Nuclear Physics Facilities and Project Management Division and is scheduled to take place at TJNAF on November 16-17, 2015. A list of the review panel members and anticipated DOE participants is enclosed.

Each panel member is being asked to evaluate and comment on any relevant aspect of the SBS project. In particular, the purpose of this review is to assess all aspects of the project's plans—scientific, technical, cost, schedule, management, and environment, safety and health (ES&H). The following main topics will be considered at the review:

a. The significance and merit of the project's scientific goals;
b. The feasibility and merit of the technical approach for delivering the science, and the technical status of the project, including completeness of scope and fabrication progress;
c. The feasibility and completeness of the budget and schedule, including workforce availability;
d. The effectiveness of the management structure and the approach to ES&H; and
e. Other issues relating to the SBS project.

Each panel member is asked to review these aspects of the SBS project and write an individual "letter report" on his/her findings. These letter reports will be due at DOE two weeks after completion of the review. The review will be chaired by Dr. Elizabeth Bartosz, Program Manager for Nuclear Physics Instrumentation. As Chairperson, she will accumulate the "letter reports" and compose a final summary report based on the information in the letters. We take care to keep the identity of the reviewers confidential in the summary report. It would be convenient if you would prepare your response in a form suitable for transmittal to the proponents devoid of potentially identifying information. The cover letter may include other remarks you wish to add.

The project team has been asked to provide relevant background materials prior to the review. This documentation, along with a current agenda, will be distributed in the near future. If you have any questions about the review, please contact Dr. Bartosz at (301) 903-0189, or E-mail: Elizabeth.Bartosz@science.doe.gov. If you have any questions regarding local travel or lodging, please contact Pat Stroop at TJNAF at (757) 269-7553, or E-mail: stroop@jlab.org.

I greatly appreciate your willingness to assist us in this review. It is an important process that helps our office to understand the status of the project. I look forward to a very informative and stimulating review.

Sincerely,

Jehanne Gillo
Director
Facilities and Project Management Division
Office of Nuclear Physics

Enclosure

Appendix B: Agenda

November 7-8, 2016

Monday, November 7 – Plenary Sessions at the Department of Energy, Germantown, MD (Room: E-401)

8:30 – 9:15	Executive Session
9:15 – 9:40 (15+10)	SBS Science Update and Overview (Ian Cloet)
9:40 – 10:30 (35 +15)	SBS Project: Cost, Schedule, and Management (Jones)
10:30 – 10:45	Break
10:45 – 11:30 (30+15)	Dependency overview (Keppel)
11:30 – 12:15 (30 +15)	WBS 2.2 & 2.3 – Beamline support, Electronics hut etc. (Wines)
12:15 – 1:20	Executive session
1:20 – 2:05 (30+15)	WBS 2 – Neutron Form Factor: CDet (Monaghan)
2:05 – 2:50 (30+15)	WBS 3 – Proton Form Factor: GEM (Liyanage)
2:50 – 3:15 (15+10)	ECal (Riordan)
3:15 – 3:30	Break
3:30 – 3:55 (15+10)	Polarized 3He target (Cates)
3:55 – 4:20 (15+10)	DAQ (Cisbani)
4:20 –	Executive session

Tuesday, November 8 – Plenary Sessions at Germantown, MD

8:30 – 9:30	Q&A
9:30 – 11:00	Breakout Sessions, if needed
11:00 – 2:30	Executive session
2:30	Closeout