APEX Experimental Readiness Review
April 7, 2016

Review Committee: V. Burkert (chair), P. Degtiarenko, E. Folts, C. Keith, B. Manzlak, Q. Sun, K. Welch.

The committee reviewed the APEX experiment and experimental equipment as proposed by the APEX collaboration according to the documentation available and based on the presentations given to the committee. The committee commends the collaboration for the excellent presentations and the preparatory work that entered into them. The presented material was reviewed to address the **nine charge items** given to the committee and the presenters prior to the review. The answers to the charges are presented below and separated into **Answer, Findings, Comments, and Recommendations.**

Charge 1: *Have the EHS&Q considerations been properly included in the design of the equipment?*

Answer: *Conditional YES*

Findings: All equipment is reviewed by JLab staff and documented according to ESH&Q policies

- Documentation can be found in DocuShare
- Drawings of new equipment can be found on the web

  https://userweb,jlab.org/~wines/APEX/

Comments:

Applicable EH&S considerations was given to the equipment that was presented with these exceptions.

The analysis report and the presentation should be maintained with consistency; for example, the vacuum system is Category II in the analysis report while it is Category I in the presentation. This shall be rectified with a clarification memo from the project engineer to the review committee.

The collaboration is well on its way as it relates to equipment design and that the collaboration understands that the remaining equipment shall be designed in accordance with all relevant EH&S policies, codes and or standards. This specifically applies to the downstream correctors, septum magnet support plates, LCW requirements, shielding and supports. Furthermore, the collaboration understands that at the next equipment readiness review its remaining equipment shall be reviewed, unless specifically requested earlier by physics division senior management.

The experiment design includes a significant amount of lead shielding to be located downstream of the target area, for protection of electronics. If the desired protection can be achieved without the use of lead, the collaboration should consider alternative materials, since this shielding will almost certainly become activated.

Recommendation: Design and install lockable radiation barrier around target for 1 R/hr field.

Charge 2: *Has the thermal performance of the target material been assessed? Is the cooling system adequate for its safe and efficient operation? What is the target change/decommissioning plan?*

Answer: *Partially*

Findings: For the entirety of its experimental program, the APEX experiment will utilize a system of solid foils mounted to a single target ladder with vertical motion capability. These will comprise a set of carbon foils and tungsten wires for optics studies, and a set of three production targets. Each production target is a series of 8 cm long, 2.5 cm wide tungsten or tantalum ribbons. The ribbons are approximately 18 μm thick and equidistantly spaced over a length of about 50 cm. In this manner, the production target is thick (up to 5% radiation length) but is relatively immune to secondary scattering. The length of the ribbons is required to provide the necessary vertical acceptance for the experiment. The anticipated maximum beam current is 120 μA, imparting a power of 7.5 W to each ribbon and a total beam heat load of about 75 W. The target ladder will use the motion mechanism from the Hall A waterfall target and will be installed in the standard Hall A cryotarget vacuum chamber.

A detailed Finite Element Analysis (FEA) has been performed to assess the cooling requirements for the target system. The FEA indicates that the 1.5 x 5 mm^2 rastered electron beam will heat the central portion of the tungsten ribbon to a temperature of approximately 2400 K, about 1300 K below its melting point. The analysis demonstrates that active water-cooling of the target ladder is unnecessary, as 90% of the heat imparted to the ribbon will be dissipated by blackbody radiation. The remaining heat will have a negligible impact on the aluminum target holder. Based on the FEA, the cooling requirements for the safe and efficient operation of the APEX target appear to have been met by the current target design.

Since all the foils and ribbons required for the complete program will be installed onto the target ladder, there will be no need to access this potentially high radiation area for routine target work. At the completion of the experiment, the target ladder will be removed from the scattering chamber and placed in a secure location. Once the radiation levels have reached an acceptable level, the system will be dismantled and included in a routine radiological waste shipment.

Comments: The review committee commends the APEX collaboration for their detailed thermal analysis of the target performance with beam on. However, no analysis was presented for the behavior of the target during the repeated thermal cycling between 300 - 2400 K that it will experience throughout the experiment. There is concern that the ensuing stresses and embrittlement of the ribbons will cause them to break. The loss of one foil simply reduces the detector rates by 10%. However, the experiment could be seriously jeopardized if this problem is endemic. An estimate of foil lifetime due to oxidation was given, but supported only by "numbers in the literature": 10 hours with a poor vacuum (10^{-2} torr) and up to 1000 hours at 10^{-6} torr.

Beyond its design, there seemed to be some confusion over the responsibilities of constructing and installing the target and its control systems. It is assumed (and advised) that Hall A/C scientist Silviu Covrig Dusa will oversee these duties. Due to the high radiation character of the experiment, the collaboration should consider adding a series of electrical switches to the motion mechanism to indicate the position of the target ladder. These should be interlocked with the accelerator's FSD system.

The recent redesign of the target/ladder arrangement is a significant improvement over the original design operationally and from an ALARA perspective. The new design is intended to allow execution of the experiment without any manual changes of targets or maintenance that would require work around or in the target chamber, provided there are no failures of target foils or other components. Since target foil performance cannot be guaranteed, some contingencies must be considered. For example, the target foil/holder design allows for changing individual foils via a single bolt on each holder. In addition the collaboration should consider constructing a second, identical ladder to facilitate a fast switch of the entire target assembly, should the need arise.

Target changes would most likely involve working in a high radiation area and contamination area. The collaboration/Hall need to ensure that personnel responsible for this work are identified and appropriately trained (RW-II). Residual radiation levels around the target/septum region may exceed 1 rem/hr whole body, which requires invoking positive physical access control. A lockable barricade should be planned for as part of the target platform configuration.

Decommissioning/disposal of the targets is manageable within the scope of JLab's radioactive waste program. The targets will need to be stored for some period to allow for decay to levels allowing routine disposal procedures. Details such as location or possible shielding for such storage, and decay time allowed before removal of the targets from the chamber need to be worked out with RadCon.

A spare target foil assembly and a quick disconnect for the target mount should be considered.

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Recommendations: The collaboration should implement a program to address concerns about the viability of the tungsten ribbons due to repeated thermal cycling. The option of using a high power (100 W) laser to locally heat the ribbon was mentioned by the collaboration. Another and potentially simpler option, would be to use a DC electric current to heat the ribbon, suitably shaped to localize the heat into a 1.5 x 5 mm^2 area.

The collaboration should develop estimates of who, when, and how often personnel will require access to the target area. This information is to be passed on to the Jefferson Lab Radiation Control Group for ALARA planning and development of a suitable Radiation Work Permit.

Charge 3: *Has the magnetic shielding of the beam line required to operate the septa magnet been evaluated?*
Answer: *YES*

Findings: The beam pipe uses 1006 steel. The adjustable corrector magnets are used upstream and downstream of the septum magnet to reduce the field effects on the beam line. The spectum field is well compensated with the use of septum correctors. The TOSCA model should be less than 2% difference from the measured field based on the past experience.

Comments: Ownership of the septum and corrector magnets is not clear.
The adequacy of the magnetic field shielding should be checked if the measured magnetic field is more than 2% different, such as 10%, from that of TOSCA model.

Charge 4: *Are the radiation levels expected to be generated in the hall acceptable? I.e. has the impact of the radiation generated in the hall equipment and infrastructure been properly calculated and mitigated?*
Answer*: YES*

Findings: The radiation environment in this experiment was studied using Geant4 MC simulation package. The detailed model of the APEX experiment allowed evaluation of the radiation damage to electronics in the Hall. Optimization of the target and beam line setup made it possible to significantly lower such damage as compared with the previous high luminosity PREX-I experiment.

Several benchmark comparisons with the available limited data and other simulation models give us reasonable confidence that the final configuration is safe to run from the point of view of prompt radiation and radiation damage expected in the Hall.

Radiation budget is evaluated; expected radiation production at CEBAF boundary is acceptable. Target activation during the run is also evaluated and found significant enough to implement extra controls around the Interaction chamber.

Available data was well presented but no mitigation measures were included.

Comments: Due to proximity to beam line and the possibility of hot spots, a separate cooling system for corrector magnets should be considered.

The new Hall A beam dump tunnel design should be included in the Geant4 model to evaluate possible radiation backscattering from the beam diffuser and the beam dump.

The committee suggests that, as a way to summarize the results of the ALARA approach to the planning of the experiment, the Collaboration prepared a dedicated ALARA document that would itemize the risks of personal radiation exposure and of radiation damage to electronics during and after the experiment, and list the mitigation measures to minimize such risks, that would include target and beamline design, corresponding radiation shielding elements, operating and post-operating procedures, etc..

Charge 5: *What is the status of the equipment towards operation? What are the completion/commissioning schedule and tasks***?**

Findings: Equipment requirements are known with some final design work remaining in the target system, magnets and magnet supports but nothing that can't be accomplished given a priority on manpower.
Schedule and an example of the pre-beam checklist were available though not presented.
Recommendations: none

Charge 6: *Have all the jobs that need to be done to safely mount the equipment been identified and defined adequately?*
Answer: *NO*

Findings: none
Comments: see charge #1.
Recommendations: See recommendations to charge #2.

Charge 7: *Has the equipment ownership, maintenance and control been defined during beam operations?*
Answer*: Mostly*

Findings: Ownership was presented but not always clearly defined.

Comments:
Consider limit switches to back up potentiometer and encoder for target position.
The responsibility for the MPS (ion chamber position) was not covered.

Charge 8: *Are the responsibilities for carrying out each job identified, and are the manpower and other resources necessary to complete them on time in place?*
Answer: *Mostly*

Comment: Target system responsibilities are not fully defined.
Engineering/design group is highly loaded and delivery of parts by the start of installation could be difficult.

Recommendation: Assign responsibility for placement of the beam line protection Ion Chambers at the strategic locations around the beam line.

Charge 9: *Are the specific documentation and procedures to operate safely and efficiently the detector, in place and adequate? This includes demonstrated readiness for full rate capability and expedient analysis of the data.*
Answer: *YES*

Findings: The required safety documentation (COO, ESAD, RSAD, ERG) has been mostly identified but exists only in draft form, in part with outdated internal link. A specific experiment run checklist was not specified.

HRS related documentation is available in 3 web-based documents.

The readiness for full rate capability has already been demonstrated with an existing data acquisition system. The 4KHz DAQ capability with 10% dead time is achievable.

Improvements are planned to further reduce dead time through TDC sparsification and reduced data volume.

Good use is made of data from test run.

Comment: The specific documentation should be completed well before the experiment is scheduled to run.

Recommendation: none