Experimental Readiness Review Close Out Report

On

1kW Beam for Isotope Production Demonstration at LERF - Experiment and Target

10/4/19

Rev 4

Review Committee:

Bob May (co-chair, JLab), Tim Michalski (co-chair, JLab), Harry Fanning (JLab), Brian Freeman (JLab), Dave Meekins (JLab), John Quintana (ANL), Yves Roblin (JLab)

Charge to the Committee:

The review committee is requested to review the integration of the various components based on the material prepared and presented. In addition to making comments and recommendations on this broad view, the committee should address the following charge questions:

1. Is the run plan sufficiently detailed for effective operation?
2. Are the target and associated diagnostics ready to receive 1kW of beam?
3. Have the lessons learned from the earlier isotope run in CEBAF been adequately addressed?
4. Is the material handling plan appropriate and does it adhere to ALARA principals and JLab environmental expectations?
5. Are special emergency response guidelines needed for this beam run? If so are the plans to train laboratory staff on these new guidelines adequate?
6. Are the roles and responsibilities of the JLab staff, specifically Accelerator and Engineering divisions, clearly defined for this beam run?

Reference Information: https://www.jlab.org/indico/event/341/

Definition of Results Terminology:

- FINDINGS: Facts and figures collected by an auditor to satisfy the objectives of the audit – highlights critical issues
- COMMENTS: Inferences drawn by the reviewers from the review
- RECOMMENDATIONS: Courses of action suggested by the reviewers in line with the objectives of the charge
- NOTABLE ITEMS – areas which demonstrate a preferred process or activity or method
- OFIs – Opportunities for Improvement

Executive Summary:

Based on the information presented, the experiment is not yet ready to accept beam. There is plenty of work left to do; many details remain as "Prestart" actions, which have been listed as recommendations. There are no obvious show stoppers on progress towards the isotope production demonstration run.

Based on the sensitivity to the results of the previous run in CEBAF, a commensurate level of rigor needs to be demonstrated on the updated design and installation. This has been demonstrated in some areas while gaps exist in others. Much of the documentation needs to be completed, reviewed by SMEs, and approved for use in order to be prepared to run beam to the target. However, continued commissioning of the beamline and calibration of key instrumentation and operational parameters can continue to the 1G dump.

There are 3 topics which summarize the current state of readiness.

1) Completion of design elements and documentation of the design.
    a. There are numerous design details for the target and crucible which are still outstanding. These design details and associated documentation must be completed prior to authorizing beam on target.
    b. The final crucible is not yet fabricated for the experiment and, although the shielding design is complete, its installation is not yet complete.
    c. Aspects of integrating the target design and associated instrumentation to the EPICS control and monitoring system remain to be completed.
    d. Process documents (COO, RWP, ERG, etc.) need to be finalized and approved for use by the SMEs. They should be updated to reflect specific impacts and changes required of the Isotope Production Demonstration Experiment.
    e. To demonstrate an appropriate level of rigor for systems in the experiment, supporting documentation for the design and analyses should be completed prior to the run. Examples are the shielding design and analyses (non-RadCon) and documenting the target assembly design and analyses.
    f. Responses to Lessons Learned indicated some topics received more attention than others. There was a focus on what was perceived as high risk (shielding/transportation) areas while elements perceived lower risk (target/crucible) have less documentation supporting the details (no documented design reviews, no released drawings, little supporting analysis/validation).
2) Transportation and unpacking of the irradiated sample have received significant attention and some of the practices are notable. There are areas not yet finalized, which result from performing "dry runs". Overall, the committee has a high confidence of successful sample delivery based on the work done. Documentation of all sample handling, packing, unpacking, and transportation should be written down, reviewed and approved for use, define required PPE, and provide training for those doing the work. This work is planned to be completed prior to the run and included in the appropriate process documents.

3) The committee sees no significant health or safety risks associated with the current designs for the irradiation target and crucible designs. Similarly, handling and transportation details regarding the irradiated specimen are now well understood and have mitigated prior issues. As stated in the ERR close out meeting, experience from other isotope programs indicates the risk to the isotope project lies not in safety or environmental impacts but in demonstrating a high level of rigor towards identifying and mitigating any shortcomings in the updated system design. Using the Argonne experience and standard engineering practices as a reference, the review committee feels an adequate level of rigor has not yet been demonstrated via the reviewed documentation on the experimental target and shielding. On some aspects of the shielding, there is clear, documented evidence which supports the design (such as the SCMB review and RadCon shielding effectiveness). In other aspect, the work may have been done to support a robust design, but it was not presented as evidence to the review committee. This should be completed prior to authorizing beam on target.

Aside from the ERR on the isotope experiment and target designs, the review committee would like to provide some insight into the new ERR process, defined under ES&H Manual Section 3130.

1) There are 2 considerations regarding timing of the ERR.
    a. Is the ERR done enough in advance of the scheduled run of the experiment? Time will tell if there is adequate time to implement recommendations in advance of the current run plan.
    b. Is the experiment installation and final readiness at a point where it is prepared for a final ERR? This ERR seemed a little premature, but it was helpful in identifying gaps in the experimental readiness.
2) There is an existing ERR process for experiments to be run in Halls A, B, C, and D. Terminology, expectations, and other aspects of the ERR processes should be made to be as similar as possible, to avoid confusion.
3) Review information should be provided to the ERR committee at least 2 weeks in advance of the review.

Readiness Review of Charge Elements:

In assessing the readiness of the target system, shielding system, and LERF beamline to take beam, it is clear that all the systems are not yet completed. Fabrication and installation activities remain along with finalizing details regarding instrumentation, machine protection, and prestart validation and commissioning. While none of these items appear to be a show stopper towards preparing for an isotope production demonstration run, we have highlighted specific items that are recommended as being completed prestart; identified with a **Δ**.

1) Is the run plan sufficiently detailed for efficient beam operations?

The ERR committee considers this charge element MET.

COMMENTS:

- All the steps involved in the commissioning are described in a document provided by the experiment. No particular issues have been identified for the run plan. It is allocating four hours to recover the setup previously arrived at during the initial commissioning.
- Various parameters and signals which require monitoring were discussed and will be confirmed prior to the run.
- Not all operational restrictions are currently in the existing system for the 1F beamline. Similar operational restrictions are not yet entered for the target system.

RECOMMENDATIONS:

- Commissioning procedures should be detailed in separate ATLises or beam test plans.
- Monitored parameters should be archived.
- Guidance should be given to Ops for parameters that are part of the alarm handler.
- Guidance should also be given for Fast Shutdowns that are latched, with Points of Contact clearly defined.
- Operational restrictions need to be entered in the existing system for the 1F beamline. Likewise, operational restrictions need to be entered for the target system itself. Hold points for measurements by RadCon should be incorporated into the run plan and completed measurements should be documented as part of operational records for the isotope run.
- Ensure that Operations staff have appropriately labeled Song Sheets, this should reflect labeled hardware in the machine, as well as the LERF Element Database.

2) Are the target and associated diagnostics ready to receive 1kW of beam?

The ERR committee considers this charge element PARTIALLY MET and anticipates it will be MET upon implementing the following comments and recommendations.

COMMENTS:

- The target and shielding area have been developed to provide easy access.
- The copper plate (called a raft) has lever acting clamps which actuate thermal contact on the sides of the crucible. The crucible is easy to remove with custom tongs.
- We note that significant effort has been made to ensure that personnel exposure is kept ALARA.
- Doses to personnel performing the target/crucible removal are expected to be less than 50 mrem.
- Details are still being defined for components and procedures:
  - Instrumentation and logic towards MPS, FSD, or alarm monitoring
  - Evaluation of potential heating stresses (CTE mismatch)
  - Process steps for setting up the target
  - The final crucible has not yet been fabricated
- An acceptable thermal model of the target system has not yet been developed.

- The water cooling system is an excepted pressure system (see ESH manual 6151) and does not require a JLAB DA etc. The N2 purge system may require a JLAB DA to ensure that it meets the requirements of 6151.

RECOMMENDATIONS:

1. Δ Machine protection/Fast Shutdown signals should be employed on several indicators/switches:
    a. Cooling water flow on raft, window, and radiator. Flow switch(s) here should be employed to ensure that the flow to each element is adequate. An alternate method that assures flow is adequate to these elements is also acceptable.
    b. Temperature indicators RTDs on crucible/raft. Use both to be redundant.
    c. Flow switch on N2 if this system is considered critical. IH and RCD input may be required to determine of this flow is considered critical.
    d. Decide which Temperature indicators are critical to the run and insert into FSD. Run would then only stop when FSD conditions prevent ops.
2. Δ Documentation:
    a. Drawings for P&ID and general layout of the system should be in DCG Document Repository.
    b. Drawings for shielding should be in DCG.
        i. Signatures on drawings would then indicate approval of shielding including seismic design acceptability.
    c. Calculations that have been reviewed should be formalized and stored in the DCG repository.
3. Thermal calculations are not mature:
    a. This is acceptable for the 1 kW run with the condition that the results from the previous run are documented and clearly show that the current crucible design is acceptable as we especially note this is now a sealed container design. This should be documented appropriately.
    b. For higher power we strongly recommend a formally reviewed calculation which accurately describes the measurements made during the 1 kW run and predicts the performance at 5 kW.
    c. This model should also address radiation effects detrimental to the performance of the BN material. These effects are not expected to be significant.
4. Pressure systems:
    a. The N2 purge system may require a JLAB DA to ensure that it meets the requirements of 6151.
5. A method for blowing down the H2O cooling system should be installed. This would allow breaking water lines with minimal leakage.
6. Δ The motion system, target platform, and shielding configuration are structurally acceptable. This should be formally documented.

3) ***Have the lessons learned from the earlier isotope run in CEBAF been adequately addressed?***

The ERR committee considers this charge element ESSENTIALLY MET for the 1 kW run. Improved use of Lessons Learned is recommended for the 5 kW run and beyond.

The committee sensed some Lessons Learned drew more attention by the isotope planning team than others. Several support documents which addressed Lessons Learned items were late in getting posted. Additionally, the spreadsheet which listed actions in support Lessons Learned was modified more than once during the final days leading up to the ERR. The key to Lessons Learned is to review them early in the design process such that they can have an impact on the design. There is room for improvement at the next stage of the project.

There are 5 Lessons Learned items from the previous run which are geared more towards management responsibilities and are not directly applicable to the isotope target and experiment.

COMMENTS: Team presented ERR Committee with tabulated spreadsheet responses as well as a presentation.

1. Planning
    a. The team improved their planning process after the 2017 run using a Gantt project tool. Currently, the team is approximately 1-2 months behind their projected milestones.
    b. Planning was difficult due to low priority of Isotope program.
    c. This review is the first ERR under the revised 3130 process.
2. Review Process
    a. The team proposed a review process in August 2018 as part of the kick off meeting.
    b. While informal SME reviews were conducted for some systems (especially the new shielded hutch), no specific target/crucible design reviews were presented.
    c. Several *Review Process* Lessons Learned were not applicable to the Isotope Target and Experiment. They are Accelerator Division management items.
3. Risk Assessment
    a. The team presented a Risk Assessment (Registry), where all but the crucible transfer from the exposure hutch were mitigated to a negligible level. Risks may not be fully identified.
    b. Transportation risks to VCU have been mitigated through a point to point transfer, and appropriate DOT packaging. Several trial runs were performed to demonstrate the procedures and look at opportunities for improvement.

4. Skills Mix
    a. The Isotope team has a variety of relevant skill mixes.
    b. The Accelerator Operations Department assumed responsibility for resuscitating the LERF.
    c. RadCon was involved in shipping and shielding analysis; quite thorough.
    d. Missed opportunity in not effectively engaging Mechanical Engineering in some of the design/documentation activities.
5. Safety
    a. The crucible has been modified to address beam charging (i.e. grounded graphite plug)
    b. Dry runs with the VCU team conducted including clear instructions.
    c. RadCon will develop crucible retrieval and packaging procedures based on dry runs in the LERF prior to the run.
6. Documentation
    a. While much of the required documentation for the ERR exists, it is incomplete.
    b. While concepts for critical processes involving the target were presented, procedures related to target readiness have yet to be developed.
    c. Documentation related to the target and crucible design and manufacture is not ready. While documentation may follow a graded approach, documentation is objective evidence that an appropriate level of rigor is being applied.
    d. OSPs/THAs used during the last experiment were not refreshed in advance of this review.

RECOMMENDATIONS:

1. Some items called out in the Lessons Learned after the previous run were not fully addressed and could have been utilized to improve the process. Examples: no formal reviews between previous run and ERR (several SME reviews were held but not yet formally documented), documentation of the target and crucible component/assembly design, documentation of the validation of the target and crucible component/assembly (to include analyses, inspection, testing). Implement the Lessons Learned from the initial run and the upcoming 1 kW run to improve both the design and demonstrated level of rigor for the 5 kW run and beyond.
2. Continue to develop the Risk Registry to include all risks associated with the process (gallium contact with personnel, gallium contact with experimental setup, irradiated gallium spill, time schedule, funding schedule, etc.).
3. Future schedule planning for the isotope run at 5 kW should include time to review and document updates to the target design and analysis. As a minimum, a thermal analysis based on the 1 kW results is required. Additionally, an ERR of the 5 kW installation, the

1 kW irradiation and isotope separation results, and additional lessons learned must be planned for.

4) ***Is the material handling plan appropriate and does it adhere to ALARA principals and JLab environmental expectations?***

The ERR committee considers this charge element PARTIALLY MET and anticipates it will be MET upon implementing the following comments and recommendations.

COMMENTS:

1. Multiple trial runs on the packing, unpacking, and transportation have been performed.
2. It is clear that significant effort and trials have been invested in the development and validation of material handling, especially on the transportation to VCU.
3. The plan for packaging the Gallium/Cu^{67} after it has been irradiated is comprehensive and well thought out.
4. While steps on the insertion of Gallium into the crucible was provided in the presentation, it would be beneficial to have it included within a procedure which governs all phases of Gallium material handling (pre-irradiation, post irradiation, pre-shipment, etc.). A video of the process was identified in a presentation.
5. Certain aspects of Gallium material handling were explained to be included in a work specific Radiation Work Permit (RWP) under development, but could be called out in the RWP by referencing the OSP covering all stages of the Gallium material handling.

RECOMMENDATIONS:

1. **Δ** Continue to use information from mock-ups and trial runs (especially after shielding is finalized) for development of material handling procedures with specific roles and responsibilities throughout the entire process before commencing with Isotope run.
2. **Δ** Ensure all material handling steps are documented, reviewed, approved, identify appropriate PPE, and personnel performing the work are trained. Some of these procedures are stated to be included in the experiment RWP.
3. Continue to develop containment protocols for worst case scenario where irradiated Gallium/Cu^{67} is spilled.
4. During cool down period for isotope target, recommend leaving the state of the LERF vault in Power Permit and only taking vault to Controlled Access for RadCon or emergent tasks under RadCon supervision.

5) ***Are special emergency response guidelines needed for this beam run? If so are the plans to train laboratory staff on these new guidelines adequate?***

The ERR committee considers this charge element MET.

COMMENTS:

1. Emergency Response Guidelines (ERG) dated 6/4/19 was available for review. They are complete and consistent with the content in other ERG documents.
2. The language in the ERG says "Isotope production takes place in the Low Energy Recirculator Facility (LERF)." There is no mention of the unique operational issues or hazards associated with Isotope production.

RECOMMENDATIONS:

1. To make the distinction of this application of the LERF for Isotope Production Demonstration, consider adding specific information to the ERG regarding the isotope experiment such as:
    a. Extended time in Controlled Access post irradiation
    b. Temporary decommissioning of Rapid Access System during isotope runs, etc.

6) ***Are the roles and responsibilities of JLab staff, specifically Accelerator and Engineering Divisions, clearly defined for this beam run?***

The ERR committee considers this charge element MET.

COMMENTS:

1. Many roles are clearly defined, however there was some inconsistencies in the COO document, such as shift leaders and crew members from the experiment.
2. In many cases there is clear ownership of equipment. It was mentioned that some equipment instrumentation still needs to be handed to Engineering, but has not yet been done.

RECOMMENDATIONS:

1. **Δ** Clearly define roles in COO, look for inconsistences in the document versus what is written in the LOD.
2. **Δ** Current COO captures the basics required for the document. Additions are required to make it Isotope Experiment specific.
3. Clearly define points of contact for all equipment that is not owned by Engineering.
4. Consider having one point of contact, the dual run coordinator roles (accelerator and experiment) will get confusing. There should be one point of contact.

Notable Items:

1. The RadCon process and documentation of the shielding design was well thought out and provides a measure of thoroughness which gave confidence to the reviewers. The analysis reports are maintained in a centralized system.
2. Dry runs and documentation of the shipping and unpacking procedures has led to a much improved process. It has been accomplished in advance of the actual need on the upcoming isotope production demonstration run.
3. Detailed calculations for dose rates were presented and are well done.
4. It is clear to the committee that a significant amount of work has been accomplished to move the design and installation to the state described in the review material and witnessed during the tour.

Opportunities for Improvement:

1. Several HPI (Human Performance Improvement) opportunities were highlighted during the review and the tour. JLab should look to add this to the system development and review process. Examples: Eliminate risk of dropping (look at means of transferring the crucible without lifting it up), eliminate risk of leaking during handling and shipment (turn the specimen into a solid by dropping temperature to < 29 degrees).
2. The Beamanizer is a LabView data acquisition system for image data to measure the beam size and to do emittance measurements. The program runs on a Window 7 Computer that will need to go to Windows 10, and some work will need to happen to move to the new system.

Commentary on the ERR Process:

COMMENTS:

1. In August, 2018, an expectation of IDRs, FDRs, and ERR was stated. This ERR is the first formal review on the project. Less formal reviews are not documented. *(The only reviews held during the 1+ year of advancing the design were less then formal and not documented in many cases. The reviews which were held were with individuals or small groups of SMEs. While they yielded benefit for the project, the question remains on whether broader and more intentional reviews during the process would have better prepared the design for the ERR?)*
2. Timing of this ERR appears too close to the planned run date (November). Time available for any updates or implementing recommendations is very short.
3. Lots of data to review, submitted to the committee on Sunday; continued changing up through the middle of the day of the review.
4. Need to make sure process documentation and documentation readiness is part of any ERR charge.
5. The expectation is that a near final draft(s) of the ESAD, RSAD, COO is/are ready by the time of the review.
6. This is the first ERR for the Isotope Production Demonstration. Is the expectation that multiple ERRs should/will be required for small experiments (consistency with Physics ERR)?

RECOMMENDATIONS:

1. Need to have ERR consistency across the lab for all experiments (expectations, terminology, timing)
2. ERR should be held more in advance of scheduled experimental run.
3. Review information should be provided to the ERR committee at least 2 weeks in advance of the review.Consider having a key individual perform a preliminary assessment of readiness for an ERR – People, Process, and Equipment

Consider adding a technical appendix to ES&H Manual Chapter 3130 that provides a suggested set of metrics for a successful ERR (what are the necessary outcomes), process steps including internal reviews and timing to prepare for the ERR, suggested timeline for process steps, expected level of completion for design documentation and records of closeout of internal review recommendations at the time of the ERR, deadlines for completion of required documentation.