## Tritium Target Safety Review Report

A tritium target is foreseen to execute four approved nuclear science experiments in Hall A at Jefferson Lab. One experiment (E12-14-009) aims to measure the ratio of elastic scattering of 3H and 3He and improve on the radius of 3H as compared to the radius of 3He. The aim is to reduce this uncertainty by a factor of five. This can then be compared with state-of-the-art nuclear science calculations. An experiment of quasi-elastic knockout of protons from 3H and 3He (E12-14-011) is a quantitative measure of the pairing mechanisms in the nucleus. The measured ratio can again be compared with state-of-the-art nuclear science calculations. A similar measurement of the ratios of quasi-elastic electron scattering off 2H, 3H, 3He, and 4He (E12-11-112) gives a count of the amount of short-range paired nucleons. The comparison of 3H and 3He will test the isospin character of this pairing. Last but certainly not least, a measurement of deep-inelastic scattering off 3H and 3He (E12-06-118) will map the ratio of proton to neutron structure functions with minimal nuclear uncertainty and will then constrain the ratio of down to up quarks in nucleons. In the kinematic limit of quark momentum fraction x 🡪 1 there are definite QCD predictions for this ratio.

The tritium target has seen a first readiness review in 2010, at which stage all comments of the committee were to be treated as recommendations. The committee would like to applaud the collaborators for the conscientious manner with which they followed up on these recommendations. What resulted is an intelligent design carefully folding in safety considerations to minimize risk and have layers of containment both for beam operations and shipping. This second review completes the evaluation of the tritium target as engineered, and acts as its final readiness review before scheduling of experiments using this target can be requested (the scientific equipment related to these four experiments will see a separate review). Some 3-6 months before the actual physics experiments, one last review is scheduled concentrating on documentation and operational procedures.

One of the prime design criteria for the target has been to minimize the amount of tritium (to 1100 Curies). The model assumption for running these experiments requiring a tritium target is to have this target at Jefferson Lab for a period of one year. The assumed run period would be an installation during one summer, run for say 6-8 months, and send the target back the next summer. Furthermore, Jefferson Lab will not be involved in filling the tritium target or in handling the tritium gas, it will come to Jefferson Lab as a completely sealed target cell system and sent back as such. *These assumptions are an intrinsic part of this second and final experiment readiness review of the tritium target.*

The committee concludes that the main emphasis should now lie on the definition of the procedures and authorities, on the certification of the calculations and the designs, on tests and simulations as part of hot checkout of equipment, and on training, education and emergency planning.

**Raising awareness of running experiments with tritium**

The committee recommends laboratory management to raise the awareness of not only staff and users but also of the public to the presence of tritium at Jefferson Lab.

The tritium target has been screened according to the National Environmental Policy Act with the Oak Ridge Compliance Officer, and will require a supplement to Jefferson Lab’s overall Environmental Assessment for the operation of CEBAF at 12 GeV. This work is in progress with Jefferson Lab’s ESH&Q Division and near completion.  This addresses some of the public awareness as the supplement, once approved, is posted on the DOE Office of Science Website.

Regarding the staff and users, we urge that the CANS system will be used to restrict Hall A to authorized personnel, and to vary this restricted list pending the activities occurring in Hall A. We also urge to consider an interruption of all Hall A’s safety awareness walkthrough certification for one year, and initiate a dedicated tritium experiments safety awareness walkthrough valid for one year, and to consider an experiment pre-briefing, which also includes stressing that any information to the public should be restricted to Jefferson Lab’s Public Affairs Office, and includes some guidance on what answers staff and users should give when probed by the public.

Regarding public awareness, consider educating the public with an article outlining first and foremost the excellent and unique science opportunities that a tritium target provides, but also pointing to the vast engineering measures taken to allow for a safe and effective operation of a tritium target at Jefferson Lab. The article should discuss that there is no exposure to the public occurring from the target being installed in the Hall. The article should perhaps also compare the radiation issues with tritium for workers with radiation levels such as those encountered in e.g. air travel, in the medical industry (like radiation therapy facilities and, for diagnostic purposes, nuclear medicine labs in hospitals), and in other nuclear applications familiar to the Hampton Roads community.

**Charge Item 1. Review the conceptual design of the Tritium Target design from an operational safety point of view, including the vent system to safely remove the Tritium from the scattering chamber/hall.**

**Findings:**

* The conceptual design is sound and thorough, and is based on reasonable, conservative estimates

**Comments:**

* We agree with “freezing” the design of the target and not allowing changes without an AD-level review/approval.
* We support the goal that the final target ladder configuration be finalized by March 1, 2016.
* No changes to the target ladder shall be allowed during the running of the four experiments.

**Recommendations:** None

**Charge Item 2. Review the tritium target design as engineered and its anticipated performance characteristics.**

**Findings:**

* The tritium target design is based on the primary consideration to provide gas targets for accurate nuclear physics comparison of 3He and 3H nuclei while minimizing safety risks in terms of operating parameters such as pressure, Curies, beam current, days of operation, and beam trips.
* Target design is based on tritium handling by Savannah River Tritium Enterprise (SRTE) personnel to minimize handling of tritium gas at TJNAF.
* Target system design includes a sealed tritium target cell filled at SRTE and shipped to TJNAF. The tritium target cell is designed, constructed and pressure tested at TJNAF and sent to SRTE.
* Design of target system is relying on three layers of tritium containment or confinement for the period tritium is in Hall A. These layers include, target cell, scattering chamber and the Hall A exhaust system. Safety analysis has been developed to determine radiation impact on personnel from any release scenario. The system is designed to minimize dose resulting from these release scenarios.
* Detailed thermodynamics and mechanical analyses of the target cell with beam on, including tritium, helium and hydrogen targets at more than twice the operating pressures of each target cell, have been performed.
* Pressure testing of the cells has resulted in burst pressures well above operating pressures. The gas cell design pressure is about 1000 psi with actual operating pressures at 200 psi for tritium and 500 for He/H2 at room temperature. Operating pressure for tritium with no beam is about 30 psi at 40k.
* Included in the design studies are cyclic loading and thermal effects of full current when raster is off.

**Comments:**

* Design of the target system is optimized in favor of minimizing safety risks over a general desire to maximize physics count rates and physics output for the one year period considered for tritium target experiments.
* It is important that detailed schematics of vacuum systems and exhaust systems presented today be checked or certified for functionality of what they are intended for. The as-built systems need to be simulated/tested before tritium target cell arrival from SRTE.
* The anticipated release dose relies on proper functioning of systems and correctly following of applicable procedures established for each release scenario. In the worst case scenario when no procedure is followed and all safety systems failed, a modest dose rate of 1.5 rem is anticipated. It is important that operational procedures are well established and followed by all personnel.
* All pressure system analyses provided during the review need to be reviewed and approved prior to February 1, 2016.
* Stress corrosion testing of pre-cracked Aluminum samples should be evaluated after 4, 8 and 12 months as planned and information should be utilized to determine the range of safe life-cycles of target cells.

**Recommendations: None**

**Charge Item 3. Review the Installation Plan including safety checkout plans both prior to installation (specifically including the transportation of the target to JLab), during installation, and after installation has been completed.**

**Findings:** None

**Comments:**

* Savannah River will provide advice on bioassay, emergency response.
* The transportation requirements for shipping the container must be fully understood and implemented with respect to flammable gas and radioactive material requirements.
* Arrange for just-in-time delivery of the cell to minimize the potential for outgassing within the shipping container.

**Recommendations:**

* Perform a dry-run with helium to validate design of packaging methodology. Consider dry-running forklift and installation operations as well.
* Receiving should be done directly by the RadCon department. Inspection requirements will be defined with respect to acceptable limit of tritium contamination/outgassing.
* Keep shipping container staged nearby for potential storage needs. Evaluate need for alternate storage location.
* Institute CANS for access control, evaluate for the Green Door.
* Develop Hot Checkout Tool for Tritium Target with 2 layers of “hands-on” verification.
* Define restrictions/requirements during installation, changeover of equipment and post installation
  + Staffing levels
  + Access controls/CANS
  + Training requirements
  + Crane usage
  + Local emergency response
  + Et Cetera

and present at the equipment-related readiness review.

* Define radiological controls, including bioassay requirements (RadCon)
* Educate NNFD on the hazards of Tritium so as to assist them in preparing to respond to an emergency event (Emergency Manager)
* Develop/Implement public information campaign for employees and public (Lab Leadership) on science case and engineered safety controls. Have contextual information ready in case of incident.

**Charge Item 4. Review both the passive and active control and safety systems.**

**Findings:**

* Tritium target is a static pressurized Al cell
* Target gas pressure is 200psi at 295K
* Target gas operating pressure is 30psi at operating temperature (40K).
* The target cell, with covers installed, was tested to failure at 5500psi. The target cell without covers, as in the operations phase, was tested to failure at 2900 psi.
* The target ladder has 5 gas cells, 1 empty cell, 5 solid targets, and two alignment/optics locations.
* There are no identifiers on the six gas/empty cells.

**Comments:**

* The decision to use a static gas cell has resulted in a design with minimal active controls.
* The control of Hall access during "restricted" access needs to address the issue with the door between the accelerator and the Hall.
* Consider physical keys on the target cells/ladder to ensure that each target cell can only be mounted at one location.
* Consider adding unique identifiers (aka color/names) to the target gas cells.
* Safety controls must be considered in the Facility Safety Assessment Document.

**Recommendations:** None

**Charge Item 5. Review the estimates provided of the impact of a catastrophic failure of the target, either during installation or operation, on the general environment and on Hall A specifically.**

**Findings:** None

**Comments:**

* Hall A and Hut are considered “Confinement”, not “Containment” per DOE Handbook on Tritium Handling and Safe Storage.
* Consider the collateral damage if the adjacent cell has a catastrophic failure.

**Recommendations:**

* Re-do/check certain aspects of atmospheric dispersion at site boundary, evaluate building wake turbulence (Rad/Con).

**Charge Item 6. Review the modification to the beam line for the operation of the Tritium Target including the Beam Shutdown systems.**

**Findings:**

* The T2 target does not require any modifications to the beam line outside of the scattering chamber.
* Scattering chamber modifications include a new target ladder and a new Be entrance window.
* Scattering chamber does not include an exit window (until the dump window).
* The design does include a slow valve at the start of the downstream beam line.

**Comments:**

* Explore using OTR from the Be window as a beam diagnostic.
* The large number of administrative elements involved in maintaining the required beam size, beam current, target cell locations will require establishing detailed procedures and comprehensive training of relevant staff.

**Recommendations:**

* Determine the maximum thickness and location for an exit window that does not negatively impact the physics program

## Appendix: Tritium Target Safety Review - Charge to the Committee

Jefferson Lab requests that the Tritium Target Safety Review Committee:

1. Review the conceptual design of the Tritium Target design from an operational safety point of view, including the vent system to safely remove the Tritium from the scattering chamber/hall.

2. Review the tritium target design as engineered and its anticipated performance characteristics.

3. Review the Installation Plan including safety checkout plans both prior to installation (specifically including the transportation of the target to JLab), during installation, and after installation has been completed.

4. Review both the passive and active control and safety systems.

5. Review the estimates provided of the impact of a catastrophic failure of the target, either during installation or operation, on the general environment and on Hall A specifically.

6. Review the modification to the beam line for the operation of the Tritium Target including the Beam Shutdown systems.

## Appendix: Tritium Target Safety Review – Committee Members

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Includes feedback from:

Patty Hunt (TJNAF DOE Site Office) – Observer (absent)

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## Appendix: Tritium Target Safety Review - agenda

0800-0850 Closed Session

0900-0910 P. Rossi

Welcome and Charge

0910-0930 D. Higinbotham

10 min High level overview of the 4 Physics Experiments

10 min questions

0930-0950 R. Holt

10 min Experimental needs and Target/Experiment Compatibility

10 min questions

0950-1105 D. Meekins

50 min Target Design, includes Cell Design, Vacuum System and Vent/Exhaust

25 min questions

1105-1130 Break

1130-1230 D. Meekins

40 min Failure Modes and Mitigation, includes Response to Recommendation of 2010 Review

20 min questions

1230-1330 Lunch/Executive Session

1330-1600 Executive Session