Detailed report of the AETE external review, 2017/6/22, TRIUMF

Review organization

Review organizers: R. Laxdal, O. Kester (TRIUMF)
Presenters: O. Kester, P. Bricault, A. Gottberg, L. Egoriti, K. Chen, L. Kapalka, J. Chak, T. D. Goodacre (TRIUMF)
Committee members: R. Bennett (MSU), R. Catherall (ISOLDE), P. Delahaye (*chair*, GANIL), S. Rothe (ISOLDE), D. Stracener (ORNL)

See agenda at the end of the document.

Foreword

We congratulate the ARIEL team for the quality of the presentations, and for the great job which was done since the last review. The review panel appreciated the clear development strategy which was presented. The ARIEL project is definitely on good tracks. The first section of this document lists the answers to the charges as they were given as concluding remarks of the review. It additionally includes general considerations on safety aspects to answer the supplemental charge of Dr Jonathan Bagger, given during the review's opening. We give thereafter a number of additional remarks that were compiled after the review, and which we believe complete valuably the first section by providing more details on numerous aspects of the ARIEL project.

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Answers to charges (see also concluding remarks of the review, June, 22nd)

1 - Is the present design approach reasonable and credible and does it support the technical performance requirements?
Yes it is reasonable, especially considering the development of the TISA setup which will be an asset for the project. The TISA setup will allow testing of many critical aspects for the development of the facility (e.g. aspects concerning the reliability and ease of maintenance of the components) and later on will be essential for developing new techniques of RIB production.

2- What are the key technical risks? Are they being adequately addressed? Is there any obvious analysis/prototyping missing?

- The converter could become an issue if the technical solution does not meet the required performances. Tests have to be started as soon as possible and if necessary alternative places offering a similar e-beam power density have to be considered (a possible use of the ATTS was mentioned by the target group).
- The HV duct has to be developed and tested as soon as possible.
- The machine protection procedures (for example for preventing target damage after a failure of the e-beam rastering) are apparently studied very carefully. As this aspect was not really addressed in the presentations, we cannot judge the progresses in our review.
- A detailed risk analysis concerning for example the different steps involved in the target ion source handling was not presented either. We understood from discussions with the ARIEL team that this analysis is presently carried out along with the development of the different components of the facility. This detailed risk analysis could be valuably presented / summarized in the frame of a future review, when most of the details of the facility components would have been fixed.

3. Make recommendations for improvements in the design leading to: better reliability, performance, manufacturability, assembly and/or operation.

- The proposition discussed during the review for positioning the target ion source in the beam line did not seem convincing in several aspects. This operation would require a dedicated study carried out jointly by the target and remote handling groups. Decoupling the target ion source motion from the crane by placing it in the beam line, with another mechanism, should be considered. Consider automating some aspects of the target change procedure.
- The ARIEL team should provide a solution for exchanging the tip of the extraction electrode during the operational period.

Concerning delays **- is a delay necessary or can we make up ground by down selecting and moving forward.**

- At this stage it is difficult to judge whether one could cut down some of the tests required for the converter: the ARIEL team will have to figure out if this is possible once the tests are started. A motivated detailed test schedule with a decision tree could help in this matter. These tests are in any case of utmost importance for the rest of the project.
- The conical electrode for coupling the target to the RIB line sounds appropriate, other tests with other types of sealing which will not guarantee the alignment of the source may be of less relevance.
- The TISA setup could be progressively simplified/down sized once the ARIEL team is sure that the concepts are operational and mature enough.
- A delay seems unavoidable considering that some of the key people are oversubscribed, but it could be quantified by another schedule taking into account more realistic workloads per person in order to take appropriate measures. An adjustment of priorities for the project and other tasks could then be for instance proposed.
- Intensifying the collaboration with other facilities as presented, is certainly encouraged.

Supplemental charge (Dr Jonathan Bagger, section added after the review) **- Are there any safety concerns related to the project?**

- The overall layout and plan for the AETE, along with associated laboratories and test stands, incorporates designs to minimize personnel exposure during routine operations and abnormal situations. There are no particular safety issues in this regard as we could judge during the review.
- The machine protection measures that minimize the occurrence of accidental events would be valuably detailed in a future review, once the ARIEL project is more advanced. See next section.

Detailed remarks

Overall the reviewers were impressed by the quality of the work performed by the ARIEL team and the progresses made towards the objective of the project. Nevertheless, a number of questions arose during the review that are worth being addressed carefully. The remarks compiled here are meant to serve as constructive criticism for the project, i.e. they are meant to help the ARIEL team to take appropriate decisions to optimize the outcome of the project. They complement the answers to the charges as given in the previous section. Sometimes (but very rarely!) the reviewers have a slightly differing opinion about a particular aspect: in such case the pros and cons of the different solutions are left to the ARIEL team to evaluate. The remarks of the reviewers have been sorted out by items rather than by presentations. They are regrouped in five categories: converter design and tests, TISA test stand and module assembly, target production and life cycle, transport and manipulation of modules in the hot cell, and project schedule.

Converter design and tests

The converter is the central part of the ARIEL project: its performances will eventually condition the rest of the facility. Although quite elaborate, the converter concept has not yet been tested.

- As pointed out in the concluding remarks, the converter tests have to be started as soon as possible at e-beam facilities/machines with similar power density capabilities. The possibility of using a commercially available electron beam welding machine should be investigated. If not done yet, a schedule of the tests should be detailed in a note which would justify each week required for full characterization. The schedule could include a decision tree in order to optimize/minimize the efforts for achieving the technical goals.
- We note that the explosive bonding seems to be quite adapted to the deposition of a gold / heavy metal layer to the aluminum frame. Nevertheless – and if not done yet - the ARIEL team could ask for advices from experts from specialized labs to see if there might be alternative techniques (e.g. magnetron sputtering which is already widely used in industry) with potentially better performances. Whichever approach is selected, the quality controls needed for consistent bonding characteristics need to be understood and implemented.
- A fail-safe converter design has to be considered in case none of the concepts mentioned above are found satisfactory. While this design may not be optimized for conversion efficiency, it should be relatively simple to eliminate potential failure modes and to ensure some level of RIB operation.
- The machine protection measures preventing an accidental event (e.g. rastering stop or sudden degradation of converter, yielding a possible target over-heating and failure due to direct irradiation by the e-beam) would have to be studied in detail, as well as the procedure to recover from such an event (target blow out). A solution for an in-situ detection of the integrity of the Au layer would be valuably investigated. Such studies were not presented during the review.
- The development of a semi-transparent mock-up of the converter permitting comparison of CFD simulations with temperature measurements could be considered.
- The Al/Cu interface for the cooling water should be investigated.
- The thickness of the Cu piping should be designed to accommodate for erosion.

TISA test stand and module assembly

The ARIEL East Target Station consists of different modules connecting the high energy beam line to the target front end and first optics. The modular approach makes use of lessons learned from ISAC and other facilities worldwide, such as ISOLDE, SPIRAL 1 & 2 and HRIBF. The target is held under vacuum, which allows one to use more safely pyrophoric or reactive material.

Target Ion Source Acceptance (TISA) test stand

The development of the TISA test stand which consists of a full replica of this assembly to test all connections and remote handling of the individual elements has been found of high value for the project. Since the TISA will become an integral part of the process to prepare TIS modules for operation, it would be very useful for the ARIEL team to rapidly build a second simplified version of the TISA in order to pursue continuous off-line development of innovative target-ion source units beyond the commissioning phase of the facility.

Modules coupling and alignment

The coupling of the different modules is done thanks to pillow seals. Conical guides with seals are used for coupling the target – ion source to the high and low energy front ends of the target module.

- The pillow seals are under tests. The first results are very encouraging: the pillow seals seem relatively simple to implement and reliable.
- At the RIB front end, the use of conical guides guarantees a good and fixed positioning of the ion source with respect to the rest of the beam line. The tolerances are to be absorbed by the flexibility of the connectors. While the use of a conical guide was found to be satisfactory at ISOLDE, this solution would have to be tested for ARIEL: One of the reviewer notes that such guides being used together with other pins to align the target vessel with both the high energy and low energy front ends thanks to two different tables, they may create problems of over-constrained alignment. If not successful the use of spherical guides which can accommodate small angular misalignments could be considered. In the accidental event of a target vessel being stuck in the target module, the target module can be decoupled and moved to the hot cell thanks to the pillow seals. But this operation should remain marginal.
- The target vessel coupling to the RIB front end is done by means of a lead screw. Such mechanism should integrate a clutch in order to avoid unnecessary forcing. The weight and rigidity of the power cables strongly influence the mobility of the connectors. In general, the forces that are required to couple the target unit should be studied and the stability of the HV insulating structure holding the coupling table should be demonstrated. The alignment has to be preserved after repeated coupling and decoupling cycles. Such aspects would have to be evaluated on the dedicated test stand.
- The target vessel coupling requires implementing position detection (end switches) for monitoring the position of the extraction electrode and coupling table, and ideally several cameras well positioned to avoid ambiguous scenarios where an intervention would have to be scheduled. This aspect was not detailed during the review, but should carefully be taken into account. The procedure for repairing or recovering a stuck target vessel could also have been better detailed.
- The stiffness of the TISA test stand structures supporting the modules, low and high energy front ends and target vessels has to be similar to the one of the production beam line in order to predict actual performances and in order to prevent all sorts of reliability and misalignment issues. To this intent the stiffness should be calculated for both structures and eventually adjusted by the use of suitable supports.
- The supports at the RIB and e-beam front ends seem to result in a downward force at the target itself. This should be verified and the installation of an insulated support under the coupling table should be considered.
- The effect of dilatation due to target/ ion source heating should be also evaluated, and if relevant taken into account for the alignment of the optical elements with the electron and ion beam axes.
- Similarly, the effect of dilatation over the relatively long support structures of the modules should be evaluated.
- The peek turnbuckles aligning the extraction electrode may suffer the consequences of long and intense exposure to high radiation (they could be creeping over time). Methods for detecting a faulty misalignment due to the ageing of the turnbuckles should be considered.

High Voltage chase

The high voltage chase will make use of a radiation-hard resin used in the ITER project. The design of the chase allows for relatively easy replacement. This chase will carry cooling water, different high current and voltages through different types of pipes high voltage or power cables. It must be able to resist a non uniform heat load, especially in the case of incidental events (e.g. short circuits). This chase being one of the critical items for the project, it is advised to build a prototype and start the tests of the concept as soon as possible, to allow for possible adjustments such as dimension modifications which may impact the design of the target module. The tests should include different realistic resistive heating scenarios as differences in thermal loads might produce unforeseeable expansion / contraction and loss of contact for cooling.

Target ion source production and life cycle

The success of ARIEL and its capability to attract a wide user community will mainly rely on the beam time availability, and on continuous improvement of the isotope yields and variety. In order to achieve the goal of 3000h of beam time per target station and year, the production and life cycle of Target Ion Source (TIS) units has to be carefully planned and optimized. The production process should be flexible enough to permit various kinds/versions of TIS units, and a parallel R&D effort should be pursued in order to improve the beam variety, as well as beam intensities, and beam purity. The target vessel exchange process needs to be fast and reliable. A rapid target exchange also permits minimizing the exposure time of reactive materials to air. ARIEL will make use of a crane for the exchanges, which will take about 8 hours with possible optimizations. For comparison, at ISOLDE, target exchanges can be done physically in less than 1 h. It is not uncommon to change twice the target the same day in order to eliminate possible issues with a target unit, or contribute to the diagnosis by means of elimination of possible issues with the technical infrastructure. This allows the use of dedicated diagnostic targets. The typical time from beam to beam is 2 days, as it is aimed at ARIEL.

TIS unit production

To simplify a demanding line production process, the TIS unit should be assembled from standard pieces whose procurement could be outsourced. The production team would therefore only be responsible for the assembly process as a function of beam demand. Even with this standardized approach there will always be minor changes and adjustments to meet specifications. The persons responsible for the different aspects of target production (ion source development, target material, TRILIS, production team) should work closely together and define an approval process before accepting a target design, i.e. the continual production of prototype targets should be avoided if line production deadlines are to be maintained.

TIS conditioning

The ARIEL Thermal Test Stand (ATTS) and Pumping and Heating Investigation (PHI) stands are presently used for the development of the TIS units. Beyond the development phase – in routine operation - the TIS units will have to be conditioned in the PHI stand before being tested on the TISA stand and then put on-line. Together with the TISA, the use of the PHI and ATTS stands is paramount to assuring target production, preparation, and continuous TIS R&D. Considering the relatively low cost of the ATTS and PHI stands, the production of a third device (another ATTS or PHI stand) should be envisaged: it would ease the target material preparation (which can block a device for up to a week), it would ease future target R&D, and would be essential in the case of a failure of a device. The third stand could be used in such a way as to minimize the potential for cross-contamination between actinide and non-actinide material testing.

TIS unit exchange

Preliminary ideas were presented for lifting the target vessel down to the canyon. The solution shown makes use of a kind of 'bracket' attached to the crane. Such a solution may not be satisfactory for several reasons:

- It is not clear how the pre-alignment of the target vessel to its receptacle in the target module would precisely be done with such a system. The required precision seems well beyond the capability of the crane (+-3mm compared to x cm).
- The target vessel has to be handled with care as its components are often very fragile (such as the UCx pellets) so that any shock due to dangling would potentially be harmful.
- The use of the crane to perform such a careful operation would most probably prevent a rapid target exchange, especially if an additional lifting tool attached to the crane is required.

Alternatively to the use of the crane, a solution based on a dedicated lifting robot or mechanism attached to the canyon and to which the crane would pass the target vessel could be valuably investigated. It is strongly advised that the target and crane groups work together on the different possible concepts in order to optimize the reliability and rapidity of the target exchange process, as the beam time availability is meant to be one of the primary assets of ARIEL. In the context of a shortage of resources, the evaluation of the impact on resources of each concept could be part of the decision making process. Alternatively, outsourcing the realization of the concept could be considered.

Extraction electrode

- At each target vessel exchange, the extraction electrode has to be retracted into the RIB front end. This operation has to be monitored by different means such as potentiometers and micro-switches as in ISOLDE, and if possible by means of cameras, which would be most useful in case of difficulties. A strategy for recovery has to be investigated in case of a failing operation (e.g. electrode stuck in place).
- The extraction electrode tip has been found to be often polluted by the target material at ISOLDE. A plan for routine periodic replacement of the tip and occasional emergency replacement during the operational period should be envisaged.

- The spacing between the extraction electrode and conical sealing has to be large enough in order to avoid discharges. At ISOLDE traces of sparks are regularly observed on the inner aperture of used target units.

Transport and manipulation of modules in the hot cell

Module and target transport via the crane

The double-girder overhead bridge crane seems arguably to be a safe way to transport the different modules and concrete blocks in the ARIEL hall (e.g. transport from the TISA to the canyon, from the canyon to the hot cell, or from the hot cell to the storage vault or canyon…). It has two motors in redundancy for the bridge, trolley and main hoist. It is equipped with three cameras. Similar cranes are used in routine operation for ISAC and the meson hall. The crane group has definitely a long experience in using such equipment for performing difficult tasks requiring both precision and calm.
Different improvements in the crane operations are considered to speed up the target exchange: combining the shield block and target access plug, implementing preprogrammed positions for the crane and / or dynamic anti-swing systems, and optimizing the speed of the bride and trolley. We understood that the last optimizations (preprogrammed positions and anti-swing systems especially) are commercially available, and that they would additionally permit saving operator's time and gaining in reliability by automating some of the steps required in the target exchanges. Nevertheless and according to the estimates, it is not clear to all the reviewers that these latter would be very beneficial with regards to the limited time gain and probable costs to implement. All these aspects are left to be evaluated by the ARIEL team.

Manipulations of modules in the hot cell

The mockup for the remote handling of the modules will be very beneficial as it would allow testing the alignment procedures and repairs/maintenance operations in the hot cell. If not done yet, a list of all possible operations in the hot cell should be done. A schedule for the construction of the mockup would have been worth discussing during the review as such test stand could impact the design of the different modules composing the TISA.

Project schedule

If not done yet, a detailed plan would have to be developed for the layout and implementation of laboratories and test stands, with a discussion of priorities. This concerns among others the TISA stand, the labs for production of actinide targets and pyrophoric materials.
The Gantt chart shown during the review has been constructed in order to achieve the objectives in due time. Compared to the original plans, there has been a significant extension (more than 2 years) to the schedule for the first experiments using beams from the AETE. Many resources are oversubscribed, showing that it will be difficult to complete the project on schedule. There are still a number of detailed designs to be completed. In some cases, solutions for critical aspects have yet to be finalized. Some of the resources are already committed by other laboratory responsibilities. It is proposed to construct a second Gantt chart with a realistic work load for the resources, to better identify milestones which are on the critical path of the project. Decisions could then be taken based upon this more realistic chart for e.g. outsourcing part of the development work, simplifying some developments, tests, hiring temporary staff, in order to contain the unavoidable schedule drift. The list of critical milestones should then be tracked all along the project duration. Weekly project meetings and more frequent interactions within specific design teams are believed to be essential for the success of the project.

Other remarks on the organization of the review

The reviewers warmly thank the ARIEL team for the very nice and efficient organization of the review. The committee was pleased with the format of the review, including the overview talks and the detailed presentations on critical aspects. The talks were informative, clear, well presented, and provided the review committee a very good update of the status of the project. There was adequate time for detailed discussions on aspects of interest.
A couple of suggestions were made by one of the committee member for an even more efficient review:

- Presentations could have been sent one week before the review to permit a better preparation of the committee and to optimize the quality of exchanges during the review.
- More time could have been left between the presentations for reviewing their content.

- One could have considered allocating some time to review the detailed mechanical designs at a CAD workstation using the CAD software.
- Powerpoint presentations could be preferred to pdf as the slide show mode is more natural for such kind of documents. Pdf files sometimes do not display correctly in such a mode.

Annex: Agenda of the review

Time	Title	Presenter
	Wednesday, June 21	
	Start of AETE International Review	
9:00 AM	Welcome and Charge	Oliver Kester
9:10 AM	Status of the AETE Development Program	Pierre Bricault
10:05 AM	Design Process and Concept Validation Tests I	Alexander Gottberg
10:55 AM	**Coffee Break**	
11:20 AM	Design Process and Concept Validation Tests II	Alexander Gottberg
12:15 PM	**Lunch break**	**Committee and speakers**
1:15 PM	Electron-to-Gamma Converter Aspects	Luca Egoriti
2:05 PM	Target Station Service Remote Connections	Kevin Chen
2:45 PM	Target Exchange	Jason Kapalka
3:25 PM	**Coffee Break**	
3:50 PM	RIB beam modules design and plan	Jason Chak
4:30 PM	Target Station Prototyping	Thomas Day Goodacre
5:20 PM	Closed session	Committee
6:20 PM	**End of day**	
6:50 PM	**Dinner**	Committee and Speakers
	Thursday, June 22	
9:00 AM	Tour	Alex/Pierre
9:45 AM	Homework/Discussion if required	Alex/Pierre plus
10:30 AM	Review Committee Closed session	Committee
12:00 PM	Close-out	All
12:30 PM	**End of AETE International Review**	