Report of the review committee of the joint Japan-Canada UCN project

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Executive summary:

The review clearly found that the UCN source together with the n-EDM experiment is a program of potentially high impact and present unique opportunities. Based on what was presented, no recommendation on how to move forward could be made. The committee concluded that good progress towards a competitive program has been made, but more work still has to be done. To address the concerns of inadequate resources and contingencies, along with risks and schedule, it would be most beneficial for the collaboration to develop an integrated work-plan and agree upon milestones and periodic reviews. In the meantime, the UCN group should engage in dialogue with the involved institutes and the funding agencies, to put the project in Japan on a well-defined path that leads to a successful demonstration. A strengthening of the group would be beneficial.
The option to bring the project at the appropriate time to TRIUMF should be preserved and represents a major science opportunity for KEK, RCNP, TRIUMF, and university partners.

Introduction

The review on the joint Japan-Canada UCN project was held Sept. 20 & 21 2010 at TRIUMF on a request by the Director of TRIUMF in consultation with the Directors of KEK and RCNP. The UCN project is proposed to be located at TRIUMF and a Memorandum of Understanding (MoU) that governs that project is being prepared. During the preparation of the MoU concerns of inadequate resources and contingency available to mount a strong and competitive program arose. The committee was tasked to evaluate these concerns. Moreover, the schedule and cost uncertainties were to be evaluated and the committee was asked to identify any missing issues that may lead to significant risk in achieving the science goals. However, the scientific goal was not being questioned, and the review was not a technical review. In particular the committee was also given 10 charges. The charge and schedule of the review, and the presentations can be found on the protected web-page (password: UCN): https://indico.triumf.ca/conferenceDisplay.py?confId=1115. Additional material was also provided to the committee, such as a report of the UCN group addressing the charges, a resource-loaded Gantt chart, and a MS Project document for the UCN project. In addition to presentations from the proponents of the Japan-Canada UCN project, two presentations by directly effected experimental groups (muSR and p/n-radiation) at TRIUMF were given.

General remarks

The committee applauds the Japan-Canada UCN group for the achieved progress towards a unique high density source of ultra cold neutrons, and finds the presented experiments towards an n-EDM experiment an impressive step forward. The ultimate n-EDM experiment represents a very compelling physics case. The program aims to achieve an improvement of the current experimental limit on the neutron's EDM of $1 \cdot 10^{-26}$ ecm and in later steps by two more orders of magnitude in a staged strategy. Although Standard Model predictions clearly stay out of reach for all competing experiments of this generation, beyond Standard Model physics can potentially be well tested. EDM experiments already now probe a scale which is not yet accessible by accelerators, and while 'naïve' super-symmetric (SUSY) models have been excluded by EDM measurements, predictions of most other SUSY models mostly lie within the sensitivity range of the proposed experiment.

The project will be a novel and unique approach. The Japan-Canada UCN group has grown significantly since its start and has achieved broad support from institutions and universities, with statements of interest from graduate students and new faculty members. The committee strongly endorses the program and finds excellent potential for the group to contribute on a significant and competitive level to the worldwide efforts. The committee was impressed by the effort and creativity within the collaboration. The Japan-Canada UCN project has to be considered as an important research opportunity for KEK, RCNP, and TRIUMF, as well as for university collaborators to take on a leadership role in an exciting research field.

However, the committee finds that at this point insufficient information has been presented to make detailed recommendations with respect to the charge to the committee in terms of inadequate resources and contingency available to mount a strong and competitive program or to the schedule, risk, and cost uncertainties. The committee finds that no clear show-stoppers are identified, but a number of technical and scientific challenges lie ahead. The review was not set up to investigate the project on a technical level, however, the level of detail that was presented in a number of technical and engineering tasks, seemed potentially insufficient, while the committee ignored the technical realisations or goals in the evaluation. The committee find that technical efforts or risks are potentially underestimated, in particularly since the collaboration states that all plans or designs will still have to undergo additional approval phases. The time-lines and milestones presented by the collaboration were not always consistent, and details are unclear. Such details include, when the project would move to TRIUMF, or under which proton currents and what integrated currents tests can be performed at RCNP. It appears that significant work still has to be done, in particular in the sectors of planning and engineering. To aid in this process, the Japan-Canada UCN group should seek help and support from its partners, and the committee supports plans for such additional reviews and encourages the partner institutions to help. This will allow the collaboration to better understand the engineering risks and costs. Only then would it be possible to make detailed recommendations with respect to the charge to the committee.

As general recommendations from the committee to the Japan-Canada-UCN group, the committee finds it beneficial to the Japan-Canada-UCN collaboration to develop a coherent integrated work plan. Such a plan should include all collaboration partners and laboratory managements, and encompasses the activities spanning the entire project (including experiment) up to the proposed goal of $10^{-27/8}$ e.cm. Once the work plan is established, a well defined set of high level milestones, for both the Japanese and Canadian efforts, should be agreed upon and monitored periodically. It would be useful for the collaboration to define an organizational management structure for the entire effort outlining responsibilities and dependencies.

As a general observation, the committee finds that it would be desirable to encourage a strong engagement of all collaboration partners in the experiment as early as possible, developing intellectual ownership specifically of experimental components. This could include, in particular, involvement from Canadian university groups in the development of key components such as magnetometry or preparing precision magnetic resonance experiment tests of gas in a uniform and stable electric and magnetic field, for example, possibly at the future location in the meson hall). The committee encourages TRIUMF to support such developments for much needed R&D on the future experimental location at TRIUMF.

Detailed discussion of individual charges:

1.) Review the physics prospect of the experimental program planned for the neutron EDM. Evaluate the potential, including the schedule, to compete with other efforts around the world.

Findings

The collaboration presented a clear description of an n-EDM experiment that appears capable of an ultimate sensitivity below 10^{-26} e.cm with possible extension below 10^{-27} e.cm. An essential feature of this project is the LHe UCN source which promises extremely high UCN density at the experiment. The proposed method takes advantage of this high density by employing a cell which is considerably smaller than those used in competing experiments. Such a cell offers significant advantages in the reduction of systematic effect and in the simplicity of the overall apparatus. The smaller scale of the apparatus also allows for a “hands-on” approach to incremental development of the experimental technique.

The project also enjoys the prospect of initial operation at the lower flux source at RCNP which will allow refinement of the experiment.

The experiment plans to use a Xe co-magnetometer to compensate for magnetic field drifts. In addition, this magnetometer offers the possibility of accounting for spurious effects due to particle motion and inhomogeneous fields. A particularly attractive feature of this magnetometer is the ability to vary the mean-free-path of the Xe.

The collaboration has made significant progress to date in both the design of the experiment and in preliminary experimental efforts. The observation of a Ramsey resonance with 30 second storage is a notable achievement and is an important step on the path towards a complete experiment.

The collaboration provided a schedule for the installation of the TRIUMF UCN source and a high level overview of the RCNP experimental program.

Comments
The approach presented appears quite feasible and has a number of attractive features which make it both complementary to and competitive with other EDM projects worldwide.
It appears quite likely that this project is capable of providing an internationally competitive result on a time scale which is comparable to other efforts.
The membership of the collaboration is very strong with very extensive experience in ultracold neutron science and includes individuals with expertise in most of the technologies required in the experiment.

2.) Review, by each institution (KEK, RCNP Osaka, TRIUMF, Winnipeg), the scope of work and the resources, capital and people, needed to complete the project, including beam line commissioning to 2 micro-amps.

Findings
The individual groups share and distribute their work load in this stepwise approach.

The Japanese collaborators focus on the development of the UCN source (KEK) and the prototype of an EDM apparatus (RCNP). The collaboration presents the goal of first measurements with a prototype source and experiment. This would allow them to performed tests at RCNP with a beam of few micro-Amps (up to 10 micro-Amps), for a period of about a month at a time to eventually reach a precision of 10^{-26} e.cm. This is envisaged to be achieved by 2014. Significant contributions of equipment (e.g. a helium liquefier and beam magnets by KEK and target, shielding and moderator parts by RCNP) are provided by those institutions. Overall people assignments to individual tasks have been presented.

In parallel, the Canadian collaborators plan to set up a beam line at TRIUMF to ultimately run the UCN source at up to 40 micro-Amps. By moving the installation to the higher current beam and including the increased beam availability at TRIUMF, an improved limit on the n-EDM by 2016 should be obtained. In the presented plan TRIUMF provides the required infrastructure and manpower, together with manpower contributions and further financial contributions from U Winnipeg. As a long-term goal, the collaboration intends to significantly enhance the sensitivity of the experiment by further technical improvements. The collaboration plans to implement these new developments at a later stage, once the experiment is located at TRIUMF.

Comments:

The collaborative approach by Japan and Canada significantly strengthens the role and impact of the participating institutions in their corresponding communities.

At the current stage of the project, no detailed comments or recommendations with respect to the charge of the committee could be made based on the presented material. The global planning of several R&D efforts, engineering, project management as well as financial and manpower resources still need to be established for a more detailed consideration within the scope of further reviews.

A well defined organizational structure and an established set of milestones and communication will ensure the optimum process and reduce slippage of the schedule.

3.) Review by institution the scope of work, the cost, and the schedule for the UCN source, spallation target, septum and dipole magnet and the kicker system.

Findings
The division of work between institutions was presented along with a cost estimate and rough timeline. The basis of estimate was in most cases expert or engineering judgment, no detail or technical reviews have been carried out.

Comments
Conceptually, the plan for dividing the work seems sound. A multidirectional effort was made to minimize the cost and to establish a project structure. There appears to be opportunities for additional collaborative work to develop, particularly in areas associated with upgrades. The collaboration should continue to explore ways to increase participation from other institutions.
The sources of funding, lab contributions and manpower should be drafted into a MoU between relevant Japanese and Canadian laboratories.
In the work break down structure (WBS) the management working package (WP) is presently not defined, and should be included.

Milestones and technical reviews of all critical technologies should be incorporated into the schedule and a structure reporting to overseeing bodies, possibly such as funding agencies via laboratories participating, should be established.
The Japan-Canada UCN Project should clearly elaborate which institutions will be called upon to cover possible cost over runs or provide additional support if required.

Recommendation
Establish a more formalized management structure, after a clear understanding of the risks and responsibilities and agreement thereof is reached. Finalize and sign the MOU.

4.) Review facilities construction, cost, and schedule at TRIUMF.

Findings
A resource loaded schedule, and cost breakdown for the installation of the UCN source at TRIUMF was presented.

Comments
The construction plan seems reasonable although it appears that plans are in a state of flux and are changing as new ideas emerge. The Project team is encouraged to be conservative in its cost estimates as there are several technical areas that are still in the R&D stage.
Cost savings suggestions, such as reducing shielding on top of the pile (sky shine), should be carefully reviewed and approved before being incorporated into the plan as this has implications on operations and safety systems.
The plan should be reviewed and agreed upon by the collaboration, risks identified and contingencies provided. Technical uncertainties should be minimized, and independently reviewed.

5.) Review the cryogenics plan

Findings
The plan to incorporate an existing liquefier system and extend the capabilities and applications thereof via the purchase of a new cold box for liquefying was presented. This could in the future be used for the UCN program as well as for other 'open' applications.

Comments
The committee encourages the UCN collaboration to establish good communication with the TRIUMF and KEK cryogenic staff to optimize the cryogenic system.
In the presentation: 'UCN source at TRIUMF' a heat load of ^{3}He of 1.3 W is presented. This value only considers gamma heating. Heat leakage and incomplete heat isolation for the cryostat, should be considered and could affect the total heat load.
In the presentations, 20K D2O is cooled by cryo-coolers. However, the cryogenic design is considering cooling by a flow distribution from the liquefier. This needs to be reviewed and clarified.
In general, the proper specifications cryo-system including the heat requirements should be established and reviewed prior to purchasing.

Recommendations
Since the new UCN source will be fabricated and tested in FY2010 (April 2011), the cryogenic system, especially liquefaction capacity, should be reviewed and the test results from RCNP taken into consideration.

6.) Review the radiation issues in general and the impact of kicker failure modes.

Findings
A preliminary shielding design is presented. The concept of a retractable tungsten water cooled spallation target is illustrated.

Good electrical design of the MedAustron inspired kicker is presented with adequate components safety margin. A measurement scheme allows one to identify and prevent malfunctioning.
Comments
The spallation target can be retracted into a transport vessel that is part of the beam line. This aims at reducing dose rate during interventions and also replace components in a hot cell available at TRIUMF. Prior to the optimization of the shielding a realistic 3d model and particle tracking code needs to be established for gamma and neutron dose rate field maps and suitable shielding.

Concerning the proposed W-alloy spallation target, The figure of merit limiting the p-beam power is the gamma ray flux. Some optimization may be achieved by studying a water cooled W-alloy core for the highest hadronic shower energy density surrounded by a pure lead shielding that effectively would shield from gamma rays while being quite transparent to neutrons.
While this is not a technical review, we wanted to comment that a joint optimization of the cold neutron and spallation source materials as well as the geometry to maximize the UCN yield and minimize the gamma ray flux on the moderator could be beneficial.

The kicker design could be complemented by failure analysis, describing the impact of failure scenarios on the beam excursion and final destination should be evaluated (i.e. missed target, partial energy loss on components or incidental local heating of the metallic film that is planned to be installed to avoid static loading of the ceramic beam pipe).

Recommendations
Accessibility of components in a confined space (installation, dismantling) should be studied in more detail. Radiation issues of n-activation of experimental setup and shielding components (i.e. Co-content of shielding steel) accessibility of all components should be granted (repair exchange). Activation of cooling water and piping material should be estimated. All questions should be considered in much detail and reviewed. A worst case scenario investigation should be carried out and be reviewed.

7.) Establish the appropriate amounts of contingency per institution to achieve the schedule

Findings
For the project component in Japan:

The committee was not presented with enough information to comment on the appropriate contingency required for work on the present UCN source and EDM at RCNP.
A plan for funding the operation and upgrade work exists, based on successful application for a JSPS Grant in Aid for Specially Promoted Research. It was presented that this depends on the experiment achieving a significant result. However, as for most funding agencies, the amount of the JSPS Grant is uncertain, but could be as high as a few million CAD$.

For the project components in Canada
Project work at TRIUMF has been planned out in some detail. A Resource Loaded Schedule exists (with labor only).

Comments
Although some resources are loaded by name, the Project described this as "this person or equivalent". It is not obvious whether individuals are overloaded or that correct skill sets exist in the numbers required.
At this stage, typical projects are carrying ~40% contingency on labor. The labor contingency analysis presented by the Project indicated that there was 6.8 FTE (or 3.8 FTE depending on accounting) decrease of required labor relative to the original estimate of 33.6 FTE. This would represent a contingency of about 25%.

The Project presented a scenario whereby CFI funding could be used to substitute for TRIUMF funds in 2010-2012. This adds flexibility to the plan. The question of skill set availability still needs to be addressed. The role of Acsion was not clearly presented. They could potentially be used to supplement existing TRIUMF resources or take on specific tasks, but this needs to be better developed and defined.

Recommendations
Establish a more formal methodology for estimating contingency and estimating the risk associated with tasks and develop a mitigation plan.

8.) Review the impact on the operations of the envisaged UCN program on the existing program, in particular the muSR program (downstream of UCN).

Findings:
The UCN will have significant impact on existing programs:
Positive impact
Potential long term savings in LHe costs for CMMS users by sharing the large He liquefier with the CMMS if it can be demonstrated that the He is not activated. Note at PSI the UCN requires its own He liquefier for this very reason.

Negative impact
The UCN collaboration has estimated that the installation of the UCN can be done in an extended 6 month shutdown.

40uA diverted to the UCN 25% of the time will lead to an 7 or 8% reduction in count rates for the time differential muSR experiments at M15, M9 and M20.
It will also have a more dramatic 25% reduction in count rate for time integral measurements. This will lead to a loss in productivity for the very successful muSR program at TRIUMF.
Installation of the UCN will mean that TRIUMF loose BL1B which is currently being used to study radiation affects on materials since 1995.

Comments
Considering the amount of work for the installation in the active area around BL1A it is conceivable that the estimate of 6 months to install the program is underestimated and will take longer. More detailed studies are required and should be reviewed. This extended shut down would have considerable impact on the CMMS facility and a could lead to a potential loss in the user base.
There is large base of industrial users for radiation studies in BL1B, which will not be able to be served. Some mitigation should be considered by TRIUMF management, however the 500 MeV proton beam will be particularly hard to replace.

Installation of the UCN will mean that TRIUMF loose BL1B which has been used extensively to study radiation affects in materials since 1995. The beam is used about 4 weeks a year during cool-down periods. These activities generate some commercial revenue and result in several publications. TRIUMF is unique in that it is the only place where such a broad energy range from 20 to 500Mev can be studied in one place. Note the UCN will not affect BL2C which can be used for beams up to 110 MeV.

9.) Have the system interfaces been established?

Findings
Most system and device interfaces are straight forward technical details and only require proper specification and review.

The kicker system was well described, but the control interface was not presented.
The kicker system is linked in controls to the cyclotron and BL1A operation. Spallation target remote handling is linked also with BL1A operation. Access to the He-II cryostat and EDM areas will require beam off to UCN, which can be achieved without BL1A being off.

The septum magnet will be similar to any dipole magnet, but may have some unique features such as temperature monitoring of the septum front face – to measure spill.

Comments
If the kicker system is switched off, BL1A will operate as usual. The kicker system will require a clean notch in the beam with no bleed through in the notch, which is normally done now for ISAC. The minimum size of the notch will be set by UCN but should be

consistent with Cyclotron and ISAC requirements (tuning for temperature stability). The control implementation will not be new or difficult technology, but must be detailed. It will have to interface with the central control system (CCS) with signal distribution for such purposes as experiment triggers.

The septum magnet has specific features which will have to be specified and reviewed along with the control interface to the CCS.

Since the spallation target will be based on the one used at RCNP, the interface to the D2O cryostat and warm moderators is well-established. The spallation target will be similar to the TRIUMF beamline 1A beam dump (TNF), with monitoring of temperatures etc. This will be developed at RCNP, and brought to TRIUMF, but will have to be compatible with TRIUMF control and safety system interfaces. Special services requirements, such as un-interruptible power supply (UPS), and a closed circuit active de-ionized cooling system need to be specified. Moreover, if a failure in the UCN target occurs, the UCN will likely have to remain off until the next shutdown. Some mitigation should be considered and a plan developed and reviewed.

The shielding could reuse some smaller custom shielding that will be used at RCNP and this interface is well-established.
The UCN source system requirements for special services such as UPS, and any unique ground or “clean power” features need to be specified and reviewed.
The beam line magnet power supplies and vacuum systems are said to be made from “existing controls”, however, there are different platforms: e.g. CAMAC for BL1B magnets, and EPICS for muon channel magnets. The appropriate option needs to be defined.
The beam line and spallation target protect diagnostics, such as needed for target, kicker, septum magnet, etc. need to be defined.

10.) Are there any unresolved issues that might have significant cost or schedule implications?

Findings:
Detailed plans for the installation of the UCN source at TRIUMF have been presented. Overview plans for the Japanese efforts were shown

Comments
All plans are based on non-reviewed, best-estimate assumptions. Some critical science components have not been addressed and for some only concepts exist. No detailed studies with regard to the environmental requirements have been made, which will require more engineering resources.

Possible issues that will have cost or schedule implications could arise in the following areas (to name a few):

Xe magnetometry/ squid work

UCN source performance at higher power
Environmental considerations (electro magnetic noise, vibration, shielding, ground water activation, cooling water, etc)

Recommendations
A coherent plan with risk assessment and mitigation needs to be developed and reviewed.