NCCU proposal to NSF for a low energy positron facility at the Jefferson Lab FEL: Technical Feasibility Committee Report

Final Report, Submitted 2013-02-12

Committee

An *ad hoc* committee was convened by J-Lab Director Montgomery to review the technical feasibility of a proposal to establish a positron generation and related experimental user facility at the J-Lab Free Electron Laser (FEL). Members were: Pavel Degtiarenko, J-Lab; Joe Grames, J-Lab; Javier Gomez, J-Lab; Tommy Hiatt, J-Lab; John Sutherland, East Carolina University (chiar).

Charge

The committee was charged by Director Montgomery with evaluating the technical feasibility of a development program being proposed by a group of investigators lead by Dr. Branislav Vlahovic, NCCU, to be submitted to the Major Research Instrumentation program at NSF. The committee was not concerned with the scientific case for developing a high-flux positron source or for the administrative issues involved with developing and managing a user program.

Summary

The proposal is to develop and test apparatus to use the electron beam generated by the superconducting linear accelerator of the J-Lab FEL to generate a beam of positrons with a high flux; the goal is a flux of 10^{10} e^{+}/sec delivered to a laboratory on the floor above the FEL vault. Issues of particular interest are: generation and transport of the positron beam, mechanical design and costing for development and installation, radiation shielding, and management of the design, installation and.

The consensus of the committee is that most of the technical problems might be overcome if adequate resources are provided, although the target required to achieve the design flux may represent a significant development project in which achieving success, and hence meeting the design flux specification, is not certain. We are concerned, therefore, both with the prospects for achieving the proposed performance and the adequacy of the proposed budget and available personnel for achieving the stated goals. Much of our concern stems from the very short time that has been available for J-Lab personnel to explore the numerous technical issues inherent in this proposal. Endorsing the present proposal would represent a significant commitment by J-Lab in the absence of appropriate estimates of the resulting costs. However, delaying submission of the proposal to NSF until the next cycle would improve the situation only if the time is used for appropriate and detailed consultations between the university teams and J-Lab personnel.

Positron Generation and Transport

High power electron linac: The proposal requires an electron beam ~100 MeV and up to 1 milliAmps. The existing JLAB FEL is ideally suited for this proposal. However, the beam optics from FEL extraction to positron conversion target are not complete or shown. This risk is small and surmountable.

High power conversion target: The required power deposited into the target by the electron beam to produce sufficient positron intensity is very high, 10's of kW. Concepts and estimates to mitigate the power density by rotating a solid target and by rastering the incoming electron beam are sensible. However, the proposed configuration is not yet highly developed and thus there is a high risk associated with engineering the target and evaluating whether the presented positron collection efficiency is attainable.

Raster system: The raster system is a sensible approach to reduce the power density at the target, however, no details are presented with regard to the impact on the outgoing particles (primary beam, e+ or e^- pair production, secondaries) which are meant to be collected or eliminated. Without demonstration (simulation or calculation) it is difficult to imagine this sensitivity, or even the exact implementation. The risk is therefore high.

Solenoid transport system: The proposed solenoid transport system is typical of low energy positron sources for coupling positrons from a radioactive moderator to the target. The application here to the linac based source is novel and appears an encouraging route. However, limited simulation result are presented, and the exact integration baseline to the target is not given. As with the raster system, it is difficult to ascertain the sensitivity to collection efficiency, and therefore the risk is also high.

Moderator: Solid neon moderators have been used applied to activated sources with efficiency approaching 10^{-2}. However, details of the implementation, even if directed outside of the proposal, make it is difficult to understand overall impact and risk to the project. A less effective metal moderator with efficiency of ~10^{-3} may be used, but this is not mentioned in the proposal.

Electrostatic Transport: Electrostatic transport systems have been applied in low energy positron sources successfully. It is likely that a suitable transport system could be developed. However, details of the system were not provided for review so it is difficult to ascertain risk, even if low, for the desired implementation.

Vacuum System: The proposal does not have a baseline vacuum system or design, consequently this is a high risk to the success of the project.

The motivating arguments for a low-energy intense positron source were well made. However, neither a table listing the experiment beam requirements nor positron source beam specifications was given, making it difficult to judge the technical risk vs. facility success of the project (positron source + experiments). It is recommended that a document providing a technically complete baseline with calculations for each system be developed which includes all systems, with baseline specifications, simulations and estimates. The present proposal would likely benefit from this proposal and be significantly stronger.

Mechanical Design and Costing

There has been some coordination between the NCCU-lead team and the FEL regarding the mechanical design and costing effort, but it has not produced a defensible technical design or costing scenario as far as basis of estimates, contingency, risk and manpower are concerned. There is an issue with the costs associated with the G&A and those costs appear that they will either make or break the $4M budget. This should be resolved before going forward with a proposal. The budgeted personnel amount was presented as $1.46M, using an average of $100K per man year the labor profile works to about 15 people assigned to the project for its duration, or < 4 people per year for the duration of the 4 year project. The amount of work to conduct an engineering, design and installation effort for a project of this level of complexity may need significantly more resources assigned.

There was no risk chart shown, which does not provide the panel the ability to assess the collaborations' understanding of the risks associated with the design. For instance does the design and fabrication of the magnet arrangement to transport the beam upstairs carry a higher risk than designing and fabricating the rotating target? It was mentioned that the design of the labyrinth in the 'costed design' is 'questionable'. Having less complex concepts like this in a questionable state doesn't lend credibility to the design and costing of more complex systems in the proposal.

The technical work to design and build the components and the systems for this project is exciting and challenging, but the scope work was not demonstrated to be fully vetted. It will be imperative that the NCCU-lead collaboration continue to work closely with the FEL staff to complete the development of the design and fully understand and defend the risks, costs and complications of the mechanical components, systems and installation.

Radiation Shielding

The preliminary radiation safety assessment of the positron source and the proposed experimental setup in FEL at JLab indicates that it is feasible to build it without causing significant radiological problems for the FEL and its operations. The results of analytical evaluations and more detailed Monte Carlo simulation of the proposed setup are given in the Appendix 2 of the main Proposal document. The target, vacuum chamber, and the beam dump enclosure can be shielded sufficiently enough not to disturb FEL vault environment. Proper shielding of the positron moderator at the end of the positron line upstairs in the Laboratory space is also achievable. The results of the simulation indicate to a very high level of material activation inside the target enclosure after planned runs, making the area inaccessible for months after the run. So special measures on reliability and radiation hardness should be taken in the design of all equipment in the enclosure. This issue haven't been addressed in the proposal. Significant effort in radiological optimizing of the setup will be needed in parallel with the engineering design efforts, and should be included in the project budget cost. (The latest corrections of the budget include that). The design of the vault must include measures providing radiologically safe mechanism for cooling down the target, beam dump, and the shielding walls to take away the 30 kW of beam power delivered to the enclosure. Using of either gas or liquid coolants should include isolated heat exchange loops to avoid leaks of activated coolant. It seems that money requested in the budget for the radiological part of the task are

reasonable. So the general assessment would be that the project is not "ready to go", but feasible with more detailed design work to do.

Technical Management

Based on the documents provided, we believe that most of the technical issues could be resolved given adequate resources involving both funding and key personnel. The incomplete and fluid descriptions of the proposed budget and division of responsibilities are, therefore, of concern. The successful design, installation and testing of a high flux positron facility will require extensive participation by J-Lab staff. Not enough attention has been paid to determinations of the extent, nature and costs of these activities. In addition, the insufficient attention has been paid to the quantitative technical requirements that the resulting project is expected to achieve. Some members of the committee are also concerned because successful completion of the CEBAF energy upgrade is critical for the future of the institution, J-Lab should not be entertaining new, technically demanding projects that will divert significant investments in technical personnel and resources that are not directly associated with it's core mission.