High Intensity Proton Irradiation Facility

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Introduction

Fermilab plans to upgrade its accelerator infrastructure to deliver 2.4 MW 120 GeV proton beam for DUNE. The Booster Replacement (BR) will replace the current 8 GeV booster with a new accelerating facility (see LOI by contact author Jeffrey Eldred, Fermilab). Technology options for this upgrade include an extension of the PIP2 superconducting Linac, a rapid cycling synchrotron (RCS) as well as combinations thereof. High intensity, lower energy proton beams from initial acceleration stages, PIP2 and the BR, will be available for other experiments. The potential exists to produce lepton beams as well. Fermilab is engaging the community to explore the physics potential enabled by PIP2 and the BR, and to inform technology choices and to maximize science output. In addition to this proposal to create an irradiation facility for detector development for future colliders, we are also submitting an LOI for an irradiation facility for targets (contact author is Frederique Pellemoine, Fermilab), as well as an LOI for a new test beam area as part of the same complex upgrade (contact author Evan Niner, Fermilab). The goal is to develop these facilities in a homogeneous and complementary way together.

Physics Goals, Motivation, and Setup

The goal is to create a high-intensity proton irradiation facility at the BR to benefit future collider detector developments. The current Fermilab Irradiation Test Area (ITA), which is near completion, at the end of the LINAC, is designed for fluences needed for the HL-LHC detector upgrades. However, for future collider detectors doses up to two orders of magnitude higher are expected. It is paramount that detector elements under development can be tested for radiation hardness to these levels. Currently, there is no facility in the world, that would allow such tests at a reasonable timescale. It is desirable to reach on the order of 10^{18} protons within a few hours. The exact beam energy is less relevant as long as it is stable and well known. The Fermilab Booster Replacement seems like an ideal candidate to serve such a facility with its high intensity proton beam. The proposal is to build a tangential arm to set up an experimental hall where devices under test (DUT) can be placed for irradiation under controlled conditions.

The beam size at the DUT should be tunable and on the order of a few millimeters to five centimeters. A pulsed beam might be preferable if not necessary for cooling and readout reasons; a continuous beam would likely overheat the DUT and make cooling very challenging. Although this needs some R&D to determine exactly which beam structure would be preferable at these high rates. Even with a pulsed beam, cooling of the DUT will be one of the main challenges. A similar time structure to the current LINAC could be suitable. The main particle type that is needed would be protons, but being able to switch to electrons, or even ions at times, would be beneficial.

It would be good to have an adjacent, shielded counting room, where users could sit and operate and monitor their DUTs. This would require some user infrastructure, such as cables, power supplies, or cooling, to be placed either in the experimental hall or the adjacent counting room. Cables would be run between the two. There should be a cold, dark box for the DUTs available that can be moved in and out of the beam, including the ability to perform beam scans. Beam monitoring data need to be made available to the users as well. The irradiated DUTs would be handled by radiation technicians or a robot and stored cold until they can be retrieved by the users.

Timescales, R&D needs, and similar facilities
Likely, cooling of the DUTs is the main challenge and some R&D needs to go into finding a solution. Similarly, having robotic control of handling the box that contains the DUTs and that needs to move in and out of the beam would be highly desirable. This could be either addressed by a commercial solution or by in-house development. The timescale by which such a facility is needed would realistically be somewhere in the late 2020s. Before then, detector components aimed to sustain these kinds of radiation levels will likely not be ready for testing.