

September 2, 2014

High-Power Targetry in Support of the Intensity Frontier

H.G. Kirk, N. Simos, Brookhaven National Laboratory

K.T. McDonald, Princeton University

Introduction

The DOE-HEPAP Particle Physics Project Prioritization Panel (P5) report has given clear directions to the establishment of a robust Intensity Frontier capability in the U.S. Specifically:

Redirect specific activities and efforts at Fermilab to the PIP-II program of improvements to the accelerator complex, which will provide proton beams with power greater than one megawatt by the time of first operation of the new long-baseline neutrino facility.

The rationale for establishing this capability is to respond to two foreseen physics drivers: *i) Pursue the physics associated with neutrino mass, and ii) Explore the unknown: new particles, interactions, and physical principles.*

This scenario will require supporting R&D for the development of target systems capable of receiving the multi-MW protons beams and generating intense secondary and tertiary beams useful for the desired physics programs. Key technical issues include: i) an understanding of the influence of radiation on the physical properties of the targets as well as the surrounding supporting infrastructure, ii) management of the steady state heat load in the target, and iii) an understanding of the physical limits of the target material to disruption resulting from thermal shock.

Required R&D

Depending on the desired secondary beam to be produced, low-, mid-, and high-Z target materials need to be considered. As the beam power transcends 1 MW, solid targets, preferred for their simplicity and ease of handling, become less viable leading to the need for consideration of liquid targets as the material of choice. Due to the additional complexity of implementing liquid target systems, it is desirable to have an understanding of the limitations of solid targets as the proton drive beams increase in power and have different bunch structure requirements. R&D will be necessary to determine the limitations of various target materials as well as providing an understanding of the impact of severe radiation on the physical properties of potential target materials and in particular on the lowering of material fracture toughness. The resistance to thermal shock in the target is sensitive to various physical parameters such as heat capacity, tensile strength, coefficient of thermal expansion, and Young's modulus. Knowledge of these parameters for materials which have been exposed to various degrees of irradiation is essential and a program to measure these parameters for irradiated and non-irradiated target material should be employed. Beam tests with high-power, focused beams will be required to validate models for target disruption.

Proposed R&D

We wish to determine the limits for inducing fracturing of carbon-based targets including various polymorphs of graphite as well as carbon-carbon composites. Our strategy entails irradiation damage of carbon fiber and graphite specimens to varying degrees of proton radiation at the Brookhaven Linac Isotope Production (BLIP) facility at Brookhaven Laboratory augmented with a comprehensive post-irradiation analysis utilizing available test apparatus in the hot-cell facilities at BNL. We will determine the relevant thermal and stress/strain parameters of various samples in order to predict the limits for the fracturing of samples due to thermally induced stresses. Microscopic, post-irradiation analysis will utilize x-ray beams and diffraction techniques at the NSLS II to correlate the disruption of crystalline structures within the bulk of the test samples to the amount of radiation each sample has received.

We will utilize several methods to apply varying degrees of energy deposition in the carbon specimens. Taking advantage of the BNL Accelerator Test Facility (ATF), we will expose the samples to intense, focused laser beams as well as tightly focused electron beams in an effort to induce extreme localized transient stresses at levels that mimic high intensity frontier accelerator target conditions. The HiRadMat facility at CERN is our choice for a set of measurements utilizing an intense, focused beams consisting of 440 GeV protons from the CERN SPS which feature up to 4.9×10^{13} protons per spill along with a focused spot sizes with rms radii as small as 0.1mm.

Budget for the proposed work

Year 1		FTEs	\$K
	Effort	1.2	
	M&S		160
	Travel		20
Year 2			
	Effort	1.4	
	M&S		140
	Travel		40
Year 3			
	Effort	0.8	
	M&S		40
	Travel		20
Total		3.4	420

We firmly believe that the Accelerator R&D sub-panel should strongly indorse initiatives to study these targetry issues within the context of the General Accelerator R&D (GARD) program.