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Low-Z High Power Targets for Neutrino Beams: Performance under Intense Proton Flux☆

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Abstract

Low-Z materials have been used in the production of intense neutrino beams and are under consideration in future multi-MW class experiments. Irradiation-induced damage and its energy correlation are discussed based on experimental, experience and simulation data.

Keywords: Irradiation damage, low-Z materials, graphite, proton energy

Low-Z targets, such as graphite, have been used extensively in the production of intense neutrino beams for neutrino experiments. The reason is three-fold : (1) the yield of useful pions parents of the neutrinos of interest from low-Z materials is well matched to the requirements of most neutrino experiments; (2) peak energy deposition in low-Z targets is lowest; and (3) graphite exhibits superior thermal and mechanical properties that are confirmed by experience data from nuclear reactors. The need for multi-MW level beams associated with proposed long baseline neutrino experiments, has prompted a rigorous effort to identify potential limitations of low-Z materials and in particular graphite grades and carbon composites.

This multi-faceted feasibility study is centered on an experimental effort [1] through which proton irradiation damage of materials at fluence levels representative of the conditions in neutrino super-beams is assessed. Concerns that anticipated material damage from high power proton beams cannot be reliably extrapolated from neutron irradiations initiated a series of irradiation damage studies using the 200 MeV proton beam from the Brookhaven Linear Isotope Producer (BLIP) facility. Special attention has been paid to various graphite grades, carbon composites, Beryllium and its Albemet alloy. Preliminary results confirmed the anticipated dissimilarities between thermal neutrons in nuclear reactors and energetic protons. Recent experience from neutrino experiments (NuMI) using graphite-based targets has provided confirmation of the experimental observations. To quantify the differences in the induced damage a series of analytical studies along with DPA (Displacement-per-Atom) model developments [2] have been initiated looking at the material damage dependency on proton energy in the range of 0.160-120 GeV and irradiation rate. The feasibility study confirmed that proton-induced damage is accelerated in the lower energies. Evaluation of the performance of the NuMI graphite target intercepting 120 GeV protons provided further evidence of the energy-damage correlation. These studies were used for lifetime predictions and target material selection for the Long Baseline Neutrino Experiment and prompted a series of dedicated irradiation damage studies at BNL.

[1] N. Simos, et al.,Target Material Irradiation Studies for High-Intensity Accelerator Beams, Nucl. Phys. B (Proc. Suppl.), 149, 259-261, (2005)

[2] N.V. Mokhov, The Mars Code System User's Guide, Fermilab-FN-628 (1995); N.V. Mokhov, S.I. Striganov, MARS15 Overview, in Proc. Of Hadronic Shower Simulation Workshop, Fermilab, September 2006, AIP Conf. Proc. 896, pp. 50-60; http://www-ap.fnal.gov/MARS/ (2007)

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