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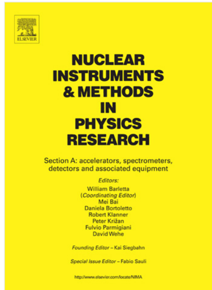

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A bulk superconducting MgB_2 cylinder for holding transversely polarized targets

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Abstract

An innovative solution is being pursued for the challenging magnetic problem of producing an internal transverse field around a polarized target, while shielding out an external longitudinal field from a detector. A hollow bulk superconductor can trap a transverse field that is present when cooled through its transition temperature, and also shield its interior from any subsequent field changes. A feasibility study with a prototype bulk MgB_2 superconducting cylinder is described. Promising measurements taken of the interior field retention and exterior field exclusion, together with the corresponding long-term stability performance, are reported. In the context of an electron scattering experiment, such a solution minimizes beam deflection and the energy loss of reaction products, while also eliminating the heat load to the target cryostat from current leads that would be used with conventional electromagnets.

Keywords: Bulk superconductor, MgB_2, HDice, superconducting shield, trapped field, zero–field cooling

1. Introduction

The determination of the spin-dependent amplitudes in a reaction between non-zero spin particles always requires measurements with different orientations of the target polarization. In the case of spectrometers that are not accompanied by large magnetic fields at the target, such as those incorporating torodial magnets, elaborate changes to a cryostat are usually required to provide holding fields for different target spin orientations. For spectrometers with strong magnetic fields in the target region, changing the natural target spin alignment becomes a formidable problem. The latter arises in the study of transverse spin effects with an 11 GeV electron beam in Hall-B of Jefferson Laboratory, where a transversely polarized hydrogen target must be placed within the longitudinal field of the central solenoid of the CLAS12 detector system [1, 2, 3]. We describe here a novel solution to such problems.

A hollow bulk superconductor is able to provide a transverse holding field inside, while adjusting its internal currents to shield any outside field [4, 5]. The latter feature is an important improvement with respect to a conventional coil-based magnetic solution. Additional advantages include minimal space needed to fit within the target cryostat, maximal field compactness to reduce electron beam deflection in the transverse field, the absence of cryogenic load from current leads and the ability to operate without a copper stabilizer, which reduces the energy–loss of particles traversing the material. The particular choice of MgB_2 for the superconducting material results in a small mass and Z in the path of reaction products, which further minimizes their energy–loss. Polarized hydrogen targets inherently require low temperatures, and as a result, the cooling of an MgB_2 cylinder to 4K can be readily incorporated within the target cryostat. Finally, for the planned set of transverse experiments with polarized HD in the CLAS12 detector, the necessary eld manipulation is straightforward to accommodate within the installation procedure of the HDice frozen-spin polarized target [6, 7].

The choice of magnesium diboride as the superconductor is motivated by its high critical current, critical field and transition temperature (39 K), by its availability in suitable shapes, as well as by its low density and low average-Z [8, 9]. Over the relevant temperature and field regime, it operates as a hard type–II superconductor, despite the presence of two coherence lengths.

The details of an apparatus to test the transverse magnetic behavior [7, 10] of MgB_2 cylinders are given in Section 2. The measurements are presented in Section 3, while conclusions are summarized in Section 4.

2. A test bed for an MgB_2 prototype cylinder

The design of the system has been described earlier [7], but additional details of the as-constructed setup are given here. Figs. 1 and 2 provides an overview.

2.1. Mechanical refrigerator

The superconducting cylinder is cooled by a cold head (Edwards 6/30). The lowest temperature that has been reached is 11.1 ± 0.1 K. The sample temperature is controlled by resistive heating of the cold head. The cold

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