# Series-Connected Hybrid Magnetic Shielding Conceptual Design for the Helmholtz Centre Berlin for Materials and Energy

T. A. Painter, M. D. Bird, I.R. Dixon, T. Xu, Y. Zhai (NHMFL)
H. Ehmler, J. Heinrich, P. Smeibidl (HZB)

## Introduction

The NHMFL is designing and constructing two SCH magnets, which are the first of the next generation of high-field hybrid magnets made possible from technical advancements in $Nb_3Sn$ superconducting wire and enhancements to the integrated design of the combined superconducting outsert and resistive insert since the NHMFL 45 T Hybrid magnet was constructed [1]–[4]. A feature of the originally proposed SCH design was a CIC NbTi shield coil located concentric with the main field insert and outsert coils. The NbTi shield coil reduced the fringe fields at both the HZB facility, where the adjacent spin echo test station located 15.65 m from the SCH requires fields of < 0.5 G, and the NHMFL facility, where the adjacent magnet test cells located 3 m from the SCH must be shielded to less than 100 G.

An additional requirement of the HZB SCH is that it rotate through a 30$^o$ angle to allow maximum exposure to neutron diffraction angles. The benefit of a concentric shield coil is that it cancels the fields everywhere external to the system regardless of the SCH rotation. However, by targeting a smaller shielding area around the adjacent spin echo test station, it was conceivable to reduce the strength of the shield coils by locating them closer to the shielded region and potentially save costs, which was the tact taken in our cost-reduction investigation.

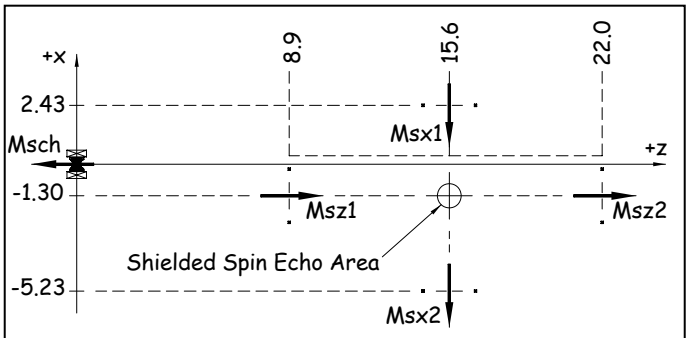


Fig. 1: The plan view of the HZB neutron scattering facility shows the orientation of the local coils required to shield the spin echo test station.

## Lower-Cost, Alternate Shield Design

The final position of the local shield coils are shown in Fig. 1, where coils SZ1 and SZ2 are the shield pair designed to cancel the z-component of the SCH fringe fields and coils SX1 and SX2 are the shield pair designed to cancel the x-component of the SCH fringe fields.

The challenge in seeking alternate solutions for local shielding was the magnitude of fringe field changes in the x and z directions throughout the full 30$^o$ range of SCH rotations. The x- and z-components change by approximately 1.0 G and 0.5 G respectively in a manner that prevents a single shield or a single shield pair at any orientation to maintain the fringe fields to less than 0.5 G at all rotations. However, two pairs of shields orthogonally located around the spin echo facility were sufficient to meet the requirement.

Calculation of the conductor costs using air-cooled copper current densities of 1 x $10^6$ A/m$^2$ for coils SX1 and SX2 and NbTi current densities of 1 x $10^8$ A/m$^2$ for coils SZ1 and SZ2 indicate a nominal savings of just under $300k if the alternate shield option is selected.

## Conclusions

An alternate shield coil design which targets shielding at the adjacent HZB spin echo facility has been shown to meet the fringe field requirement. The nominal conductor cost for the alternate four-shield coil option is calculated with conservative estimates of current density to be 11.4% of the CICC NbTi shield conductor cost resulting in a nominal savings in conductor costs of just under $300k if the alternate shield option is selected.

## References

[1] Bonito-Oliva, A., *et al.*, IEEE Trans. Appl. Supercond., **18** (2), 529-535 (2008)
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[3] Bird, M.D., *et al.*, Supercond. Sc. and Tech., **17** (8), 19-33 (2004)
[4] Miller, J.R., *et al.*, IEEE Trans. Appl. Supercond., **14** (2), 1283-1286 (2004)