DESIGN OF MAGNETS FOR THE TARGET AND DECAY REGION OF A MUON COLLIDER/NEUTRINO FACTORY TARGET*

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Abstract

The baseline target concept for a Muon Collider or Neutrino Factory is a free mercury jet within a 20-T magnetic field being impacted by an 8-GeV proton beam. A pool of mercury serves as a receiving reservoir for the mercury and a dump for the unexpended proton beam. Modifications to this baseline are discussed in which the field at the target is reduced from 20 to 15 T, and in which the magnetic field drops from its peak value down to 1.5 T over 7 rather than 15 m.

INTRODUCTION

The baseline target concept for a Muon Collider or a Neutrino Factory is a free jet of mercury impacted by a 4-MW, 8-GeV proton beam at 50 Hz within a 20-T magnetic field [1]. The magnetic field is produced by a coaxial array of cryogenically cooled superconducting (SC) coils and water-cooled resistive magnets. During operation, the Target Module resides within a shielding module that protects the SC coils from the impinging radiation. The arrangement of these modules inside a cryostat is shown in Fig.1.

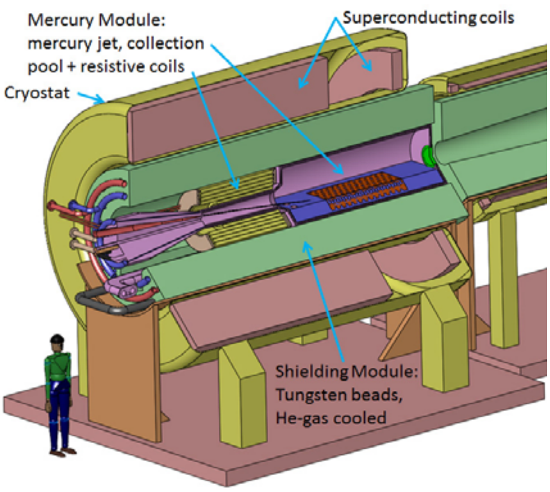

Figure 1: Neutrino Factory/Muon Collider Target System.

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The baseline target module, sketched in Fig. 1, has the complexity that the mercury double-containment vessel must pass through the small bore of the 5-T resistive coil that augments the 15-T field from the outer superconducting coils to bring the field on target to 20 T. Recent studies [2] have showed that the Target System can still deliver a good yield of pions/muons with only a 15-T magnetic field around the target, provided the transition magnets between the high field on the target and the low (1.5 T) field in the subsequent beam transport is reoptimized. This paper presents configurations of the magnets of the Target System that are compatible with this revised scenario. See [3] for discussion of options for the Mercury Module.

ALTERNATIVE MAGNET CONFIGURATIONS

The baseline configuration of the Target-System magnets has 20 T on the target but only 1.5 T in the solenoids of the constant-field Decay Channel (with superconducting coils) that begins 15 m downstream of the target [4], as shown in the top of Fig. 2. Alternative configurations in which the constant-field Decay Channel begins only 7 m downstream of the target are shown in the middle and bot-

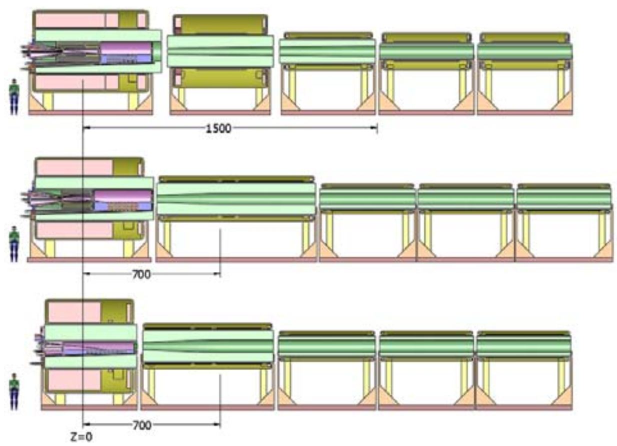

Figure 2: Vertical sections of Target-System magnet configurations with 20 T (top, middle) or 15 T (bottom) at the target, which ramp the magnetic field down to 1.5 T over 15 m (top) or 7 m (middle, bottom).

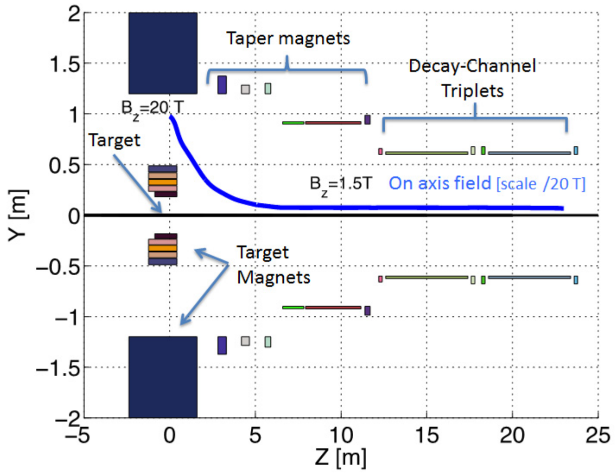

Figure 3: Magnet-coil layout and axial-magnetic-field profiles for the configuration that tapers from 20 to 1.5 T over 7 m.

tom of Fig. 2, with peak fields of 20 and 15 T, respectively. A sketch of the coils of the middle configuration of Fig. 2 is shown in Fig. 3, along with the on-axis field profile. The third alternative, with only 15 T on the target, would permit a much simpler design of the Mercury Module.

The stored energies in the Target-System magnets are large: 3.3 GJ for the baseline configuration, and 2.9 GJ for the configurations where the constant-field Decay Channel begins 7 m downstream of the target.

Figure 4 shows axial-field profiles of Target-System magnet configurations that ramp down to 1.5 T at 7 m downstream of the target. The desired field profile is shown in black, following the form $B(z) \propto 1/(1 + az^2 + bz^6)$ [6]. For a 20-T peak field, the contribution is shown in red

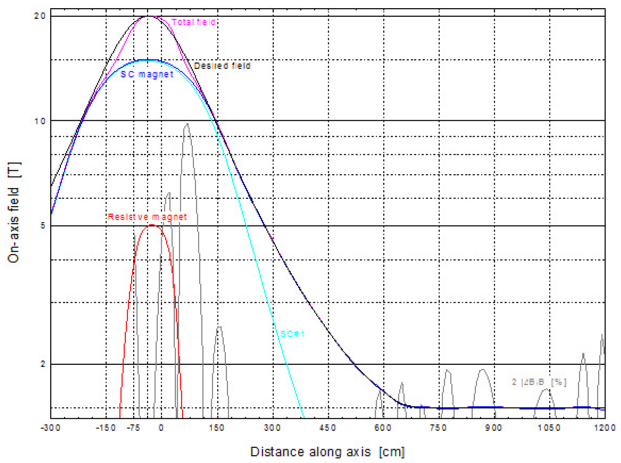

Figure 4: Axial-field profiles of Target-System magnet configurations that ramp down to 1.5 T at 7 m downstream of the target.

for the resistive coils, in turquoise for the first, large superconducting coil, in blue for the superconducting coils, and in magenta for the total. The field error (grey), plotted as $2|\Delta B|/B$, is 4.9% at $z = 70$ cm and 1.2% at 1,190 cm, where $z = 0$ is at the downstream end of the beam-target interaction region.

STOP BANDS IN THE DECAY CHANNEL

The constant-field Decay Channel extends to $z \approx 70$ m downstream of the target, at which point an RF Buncher and Phase Rotator manipulate the muon beam into a bunch train at final frequency of $\approx$ 200 MHz [5], as appropriate for injection into the subsequent Muon Accelerator. The superconducting coils of the Decay Channel are in 5-m-long triplets, with each triplet with its own cryostat. The field perturbations at the ends of each triplet can lead to stop bands, *i.e.*, reduced transmission of particles of particular longitudinal momenta.

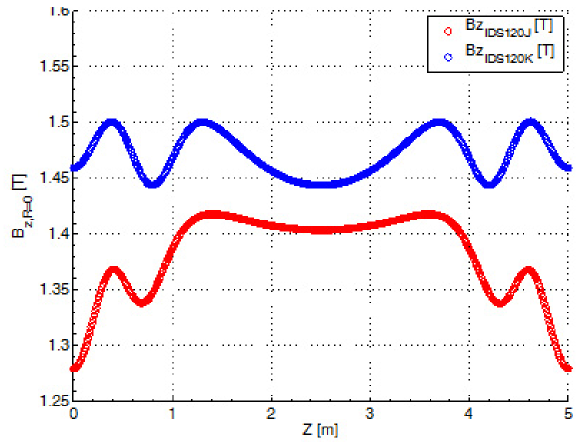

Figure 5: Axial magnetic field profiles for the 5-m-long modules of the IDS120j (red) and ISD120k (blue) configurations.

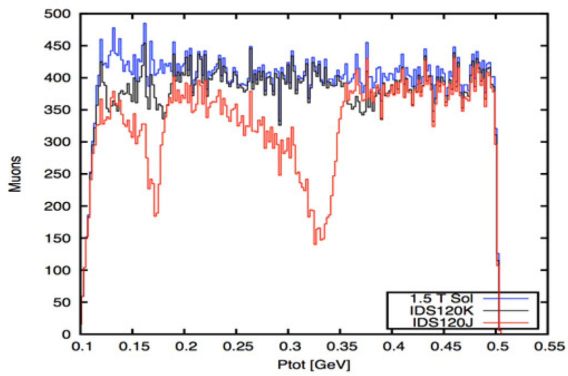

Figure 6: Transmission of particles to the end of the Decay Channel for an ideal 1.5-T solenoid (blue), the IDS120j (red) and the IDS120k (green) configurations.

Indeed, the first design of the Decay-Channel triplets for the baseline configuration, with axial-field profile shown in red in Fig. 5, led to significant loss of transmission around momenta of 165 and 330 MeV/c, as shown by the red curve in Fig. 6, according to an ICOOL simulation [7]. However, revision of the triplet coils so as to deliver the axial-field profile shown in blue in Fig. 5 largely mitigated this issue, as confirmed by the green curve in Fig. 6.

The coils for the Decay-Channel triplets have been slightly redesigned for the new Target-System configurations in which the constant-field region begins 7 m downstream of the target, with axial-field profile as shown in Fig. 7. These triplets also have only minor loss of transmission, as shown in Fig. 8.

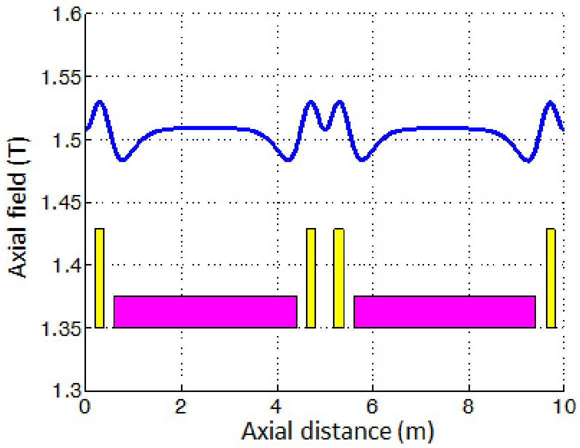

Figure 7: Axial magnetic field profile for the 5-m-long modules of the configuration that tapers from 20 to 1.5 T over 7 m.

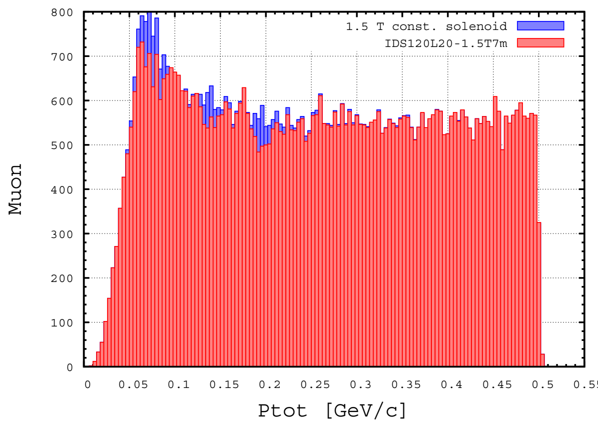

Figure 8: Transmission of particles to the end of the Decay Channel for an ideal 1.5-T solenoid (blue), and the configuration (red) that tapers from 20 to 1.5 T over 7 m.

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