EXECUTIVE SUMMARY: TARGET SOLENOID MAGNETIC DESIGN

For the Target and Capture magnet system, we aim at developing an alternative solution to the hybrid US-MAP (featuring 5 resistive coils and 19 SC coils, 2.4 m bore diameter [1-3]) made of 23 SC HTS-based solenoids of 1.2 m bore diameter.

To achieve this goal (in particular, a peak field of 20 T on the channel axis) we intend to deploy an HTS conductor operating in the 20-30 K range. In this way we eliminate the Joule losses [1-3], we reduce the magnet cooling power ($T \approx 20$ K, $DT \approx 3$ K) and/or we can tolerate higher heat loads (reducing nuclear heat shielding).

It is worth noticing that these magnets design offers some strong synergies with tokamak fusion magnets since for the *Central Solenoid Coils*: Higher B→ higher flux → higher reactor availability factor, whereas for the *Toroidal Field Coils*: Higher T→ larger acceptable heat load → compact shield → cost.

The highlights of the proposed design are as follows:

- The requirement on the magnetic field profile on the channel axis derived by using the Sayed-Berg formula [4] is matched within 4% accuracy over 16 m channel length. Such field profile call for a total magneto-motive force of about 95 MAt;
- The conductor is based on the VIPER-like cable [5] made of 4-6 HTS tapes stacks with a central cooling hole and steel jacket as structural element. The maximum operating current is $I \approx 61$ kA;
- The same conductor is used to wind 23 solenoid coils (each 1.2 m inner diameter) grouped in 3 sections of about 8 coils each. A gap of 300 mm separates adjacent sections whereas a 20 mm gap is kept between coils for insulation;
- The required 20 T peak field on channel axis [4] translates in a peak field on the HTS cable of B=20.9 T. The coils magnetic energy is 1.1 GJ (x3 lower that in [1], and the HTS cable length is about 8.7 km. The total winding mass winding mass is about 115 t;
- The stresses in structural elements within 316 LN limits ($\sigma_Y \approx 1000$ MPa) and in the HTS tapes are being investigated to be minimized. At the moment we achieve a shear stress of $\tau \approx 30$ MPa;
- The coils operating at $T \approx 20$ K, $p \approx 20$ bar, requires about 15 W of pumping power to remove about 150 W of nuclear heat;
- The conductor exhibits very high stability margins ($\Delta T \geq 10$ K);
- Detection & dump for quenches in low field/current most challenging (→long detection times) but seems compatible with hot-spot temperature limit ($T_{HS} \approx 150\text{-}200$ K).

Such innovative, high performing magnet design needs further engineering and integration studies (nuclear and magnetic shielding layout, joints layouts, cooling, etc.) and, more importantly, few key R&D risk mitigation actions to produce short conductor samples and coils mock-ups to validate winding procedure, high field performance, etc.

1. R.J. Weggel, N. Souchlas, H.G. Kirk, V.B. Graves, K.T. McDonald, A TARGET MAGNET SYSTEM FOR A MUON COLLIDER AND NEUTRINO FACTORY, TUPS053 Proceedings of IPAC2011, San Sebastián, Spain
2. R.J. Weggel, N. Souchlas, H.K. Sayed, J.S. Berg, H.G. Kirk, X. Ding, V.B. Graves, K.T. McDonald, DESIGN OF MAGNETS FOR THE TARGET AND DECAY REGION OF A MUON COLLIDER/NEUTRINO FACTORY TARGET TUPFI073 Proceedings of IPAC2013, Shanghai, China
3. C. Rogers, Overview of target, capture and cooling complex, https://indico.cern.ch/event/1147941/
4. H.K. Sayed and J. S. Berg, Optimized capture section for a muon accelerator front end, PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 17, 070102 (2014)
5. Zachary S Hartwig *et al* 2020 *Supercond. Sci. Technol.* **33** 11