Development of Superconducting Magnets for Future Accelerators

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INFN participation to H2020 EuroCirCol project

Following the idea that relevant R&D activities are necessary for future accelerators , in particular, for hadron colliders at the highest energy, in the last years the Italian Institute for Nuclear Physics (INFN) has actively participated to the European H2020 EuroCirCol project aiming at developing a conceptual design of a hadronic Future Circular Collider (FCC). In particular, the activities of INFN sections in Genova and Milano LASA were focussed on the design of a twin aperture Nb_3Sn superconducting magnet able to generate a magnetic field of 16 T in 50 mm bore. The magnet designed by INFN has a cos-theta layout and since the beginning it was conceived to be assembled involving a bladder and key process.

Meanwhile the EuroCirCol project was going on, it was recognised that the development of high field magnets (crucial for FCC or other High Energy Hardon Collider) requires significant resources and time. Moreover, it was realised that the involvement of the industry could led to significant benefits when moving from the early phases of the R&D to the construction of magnet models and prototypes.

From EuroCirCol to the dipole magnet model development (Falcon_D)

On this basis, a new project, jointly funded by CERN and INFN, has recently started aimed at the construction of a single aperture short model. The objective of this program (Falcon_D, acronym of Future Accelerator post-LHC Cos-theta Optimised Nb_3Sn Dipole) is the development in collaboration with industry of the needed technologies and the demonstration of the soundness of the INFN design.

The basic choices for this model were:

1) Lay-out – Single aperture, comparable coil cross section with EuroCirCol design, length 1.5 m maximum (simplified but at the same time significant structure).
2) Magnetic field -The minimum target is the first step beyond 11T (as this value is the consolidated state-of-art for accelerator dipoles), i.e. 12 T at 1.9K. This is also a reasonable target considering the involvement of the industry. The ultimate field of about 14 T could be achieved being the short sample limit 15.8T.

Under these conditions a two layers dipole (one double pancake) is feasible starting with existing wires. Even if we need two coils for the aperture, we have planned the construction of a significant number of coils (up to 8) for maximising the chances to achieve the target. This activity is planned to last another four years and it is already clear that new models shall be developed and built as next steps.

Beyond Falcon_D

The first step beyond Falcon_D should be the construction of a single aperture model able to generate 16 T in the same aperture. This would require the coils are two double pancakes and can be considered a significant step forward.
The second step would be the construction of a double aperture model magnet, i.e. a model of the EuroCirCol magnet.
Once model constructions have demonstrated the feasibility of these magnets, the construction of long prototypes should start.

HTS

In parallel with Nb_3Sn model, developments of HTS magnet has already started in INFN with the aim to put the basis of this technology for further increase of the magnetic field for accelerator beyond 16T. R&D activities, smaller wrt Falcon_D, are going on for first developments of superconducting magnets in the canted cosine-theta configuration involving Bi-SCCO wire in a collaboration frame with the SPIN Laboratory of Italian Council for Research (CNR). We think that this R&D line should be progressively increased in next future. It is remarkable that this technology is of interest also for low magnetic field applications (medical and energy).

Fast cycled magnets

The present envisaged projects for a future Muon Collider demand for fast cycled superconducting magnets. The INFN laboratories involved in superconducting magnets developments have a consolidated experience on this matter after the design, construction and test of a 4.5 T, 100 mm bore prototype magnet for FAIR SIS300, able to be ramped up to 1 T/s. In addition we are also collaborating in the FAIR SIS100 project. We think that our experience puts a solid basis for further developments to higher ramp rate magnets.

References

1) Baseline Design of a 16 T cos theta Bending Dipole for the Future Circular Collider
By: Valente, Riccardo; Bellomo, Giovanni; Caiffi, Barbara; et al.
IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY Volume: 29 Issue: 5 Article Number: 4003005 Published: AUG 2019DOI: 10.1109/TASC.2019.2901604

2) Preliminary Design of the Recombination Dipole for Future Circular Collider
By: Pampaloni, Alessandra; Bersani, Andrea; Caiffi, Barbara; et al.
IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY Volume: 29 Issue: 5 Article Number: 4000504 Published: AUG 2019 DOI: 10.1109/TASC.2019.2892725

3) Update on Mechanical Design of a Cos theta 16-T Bending Dipole for the Future Circular Collider
By: Caiffi, Barbara; Bellomo, Giovanni; Fabbricatore, Pasquale; et al.
IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY Volume: 28 Issue: 4 Article Number: 4006704 Published: JUN 2018 DOI: 10.1109/TASC.2018.2805918

4) Conceptual Design of a 16 T cos theta Bending Dipole for the Future Circular Collider
By: Marinozzi, Vittorio; Bellomo, Giovanni; Caiffi, Barbara; et al.
IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY Volume: 28 Issue: 3 Article Number: 4004205 Published: APR 2018 DOI: 10.1109/TASC.2018.2795533

5) Quench Protection Study of the Eurocircol 16 T cos theta Dipole for the Future Circular Collider (FCC)

By: Marinozzi, Vittorio; Bellomo, Giovanni; Caiffi, Barbara; et al.
IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY Volume: 27 Issue: 4 ArticleNumber: 4702505 Published: JUN 2017 DOI: 10.1109/TASC.2017.2656156

6) The EuroCirCol 16T Cosine-Theta Dipole Option for the FCC

By: Sorbi, Massimo; Bellomo, Giovanni; Caiffi, Barbara; et al.
IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY Volume: 27 Issue: 4 Article Number: 4001205 Published: JUN2017 DOI: 10.1109/TASC.2016.264298

7) Measurements and Analysis of the SIS-300 Dipole Prototype During the Functional Test at LASA

By: Sorbi, M.; Alessandria, F.; Baldessari, G.; et al.
IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY Volume: 24 Issue: 3 Article Number: 4002205 Published: JUN 2014 DOI: 10.1109/TASC.2013.2283814

8) AC Losses Measurement of the DISCORAP Model Dipole Magnet for the SIS300 Synchrotron at FAIR

By: Volpini, G.; Alessandria, F.; Bellomo, G.; et al.
IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY Volume: 24 Issue: 3 Article Number: 4000205 Published: JUN 2014 DOI: 10.1109/TASC.2013.2280733

9) The Curved Fast Ramped Superconducting Dipoles for FAIR SIS300 Synchrotron: From First Model to Future Developments

By: Fabbricatore, P.; Alessandria, F.; Bellomo, G.; et al.
IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY Volume: 23 Issue: 3 Article Number: 4000505 Part: 2 Published: JUN 2013 DOI: 10.1109/TASC.2012.2229332