Second review of Babyiaxo magnet – L. Quettier – 6/11/2020

After a first review of the Babyiaxo magnet was held in May 2019, and a second review was organized on 30 October 2020.

Since the first review, a very important design work was accomplished with some important technical modifications. The new design is a superconducting NbTi magnet, indirectly cooled and it is operated in driven mode.

- Magnetic design and conductor

The magnet is based on a simple design, which limits the technical risks. The magnet consists of a long quadrupole, with a common coil configuration. Each coil is composed of a set of flat double pancakes enclosed into an aluminum casing.

The initial conceptual design of the magnet coils was based on using an 8-strand NbTi/Cu Rutherford cable co-extruded with a high purity aluminum stabilizer. Early 2020, the use of an existing conductor available at the Institute for Nuclear Research in Russia (INR) has been explored. This conductor is 30 years old, and was developed for the MELC project that was never been completed.

A complete and detailed characterization of the conductor is on-going (visual inspection, verify of unit lengths...). However, critical measurements already performed show an average degradation of 20% compared with the initial conductor specification. After some design evolutions, this 20% degradation of Jc looks acceptable, although a small reduction of the FoM may be required at the end. However, the coil and casing designs will have to be adapted if the unit lengths are not sufficient, and if joints are required.

The magnet will use resistive joints, and two different techniques have already been confirmed that a "face to, face" method gives better resistance results. The resistance could still be decreased by increased the joint length, but this could requires additional space outside the casing, or some local casing design modifications.

But this new conductor option looks viable, especially in regards of the cost saving that it represents.

- Cryogenics

The cryogenic design presented during the previous review has been strongly improved, and my concerns from the first review were correctly addressed. The magnet is indirectly cooled and it is designed with a 2K temperature margin. There are now 7 crycoolers (instead of 5 in the previous design), plus two cryo-fans, as well as a specific loop for the cool-down phase.

The estimated cryogenic budget looks convincing and the magnet should have now a sufficient temperature margin. However, the final thermal losses will strongly dependent of the manufacturing work quality (especially of the MLI installation), and of the losses created the current leads and the resistive joints. A port for an additional cryocooler should be foreseen somewhere in the cryostat to minimize the risk.

- Electrical design and protection

The plan is now to operate the magnet in driven mode at 3kA, with HTS current leads. The use of a new conductor leads to a larger inductance. The magnet protection relies on a classical protection method, and even with a degraded conductor, maximum voltages in case of quench and hot spot are acceptable (besides, the quench back effect is not taken into account and will certainly help with the quench propagation across the coils).

- Mechanical design

A detailed mechanical analysis was presented. The cold mass design and the mechanical supports of the thermal shield and of the cold mass are based on classical technologies, and they look perfectly appropriate in terms of peak stresses and deformations.

Constraints have also been thoroughly investigated at specific locations, which lead to some local reinforcements.

Temporary rods will be designed and added during the transport from the manufacturing site to DESY.

Earthquake scenarii are not taken into account, as it is considered as a low risk in DESY area.

- Coil manufacturing and magnet integration

The magnet design is based on classical manufacturing techniques and it does not require any specific development. Most of them have been already used for the other magnets. The magnet fabrication will be entirely managed at CERN, by CERN, with a possible support of external subcontractors for the winding and the final integration. The project will benefit from existing tools from the Atlas magnet fabrication.

The strategy is to build only a small demonstrator to validate the winding tooling and the procedures, but there is no plan of dummy nor spare coil. Besides, there will be no individual test of the coils at cryogenic temperature before the integration into the cryostat.

Due to the new conductor and its round corners, a Vacuum Pressurized Impregnation is strongly recommended instead of using a prepreg, or a wet winding technique. This impregnation method could be imposed to the magnet coil supplier in the magnet specification.

Additional resistive joints between the coils will be needed if the conductor unit lengths available are too short. In this case, the mechanical design will have to be modified. It will also impact the manufacturing method, especially if the joints have to made inside the winding pack or inside the coil casing. Cooling of these joints will have also to be carefully studied.

- Project organization and next steps

The CERN team has completed an impressive design work and there is no potential short-term showstopper, but the conductor performances and the available unit lengths need to be confirmed as soon as possible in order to finalize the design.

The Babyiaxo magnet project is well advanced and the current design is based on reliable techniques, which help to get an affordable cost. However, the project relies on the strong involvement of CERN, and especially of the magnet detector group. This CERN commitment shall be officially formalized as soon as possible to clarify the detailed contribution and responsibility of CERN and of the Babyiaxo collaboration, and to secure the CERN resources to be involved in this project.

A new design review should be held once the project will have been officially approved and when the conductor will have been validated.