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Quadrupole magnets for FCC-ee

by Panagiotis Charitos (CERN)

FCC-ee quadrupole magnets

First tests of a twin quadrupole magnet for FCC-ee took place last summer in CERN's new magnetic measurement laboratory.

Last summer, the first measurements of a twin quadrupole magnet for a future 100 km circular lepton collider (FCC-ee) were taken at CERN’s new magnetic measurement laboratory profiting from the excellent capabilities offered in the new building (Building 311).

Contrary to previous designs for twin aperture quadrupoles, currently used for example in the LHC cleaning insertions, the design team opted for a mechanically and magnetically coupled twin quadrupole. This approach, also implemented for the FCC-ee dipoles, offers significant energy savings and reduces the number of coils, thus simplifying the construction of these magnets, finally decreasing their cost.

To meet the beam requirements, the magnet team came up with a design as shown in Figure.1. The two apertures have opposite polarities, allowing for both focusing and defocusing gradient for the two beams. For each aperture, there are four poles, but there are only two coils in total. This innovative design thus creates a flux in the central yoke parts, while the sides act as return legs for the field. The top and bottom halves of the yoke are kept together with a non-magnetic spacer in the centre.

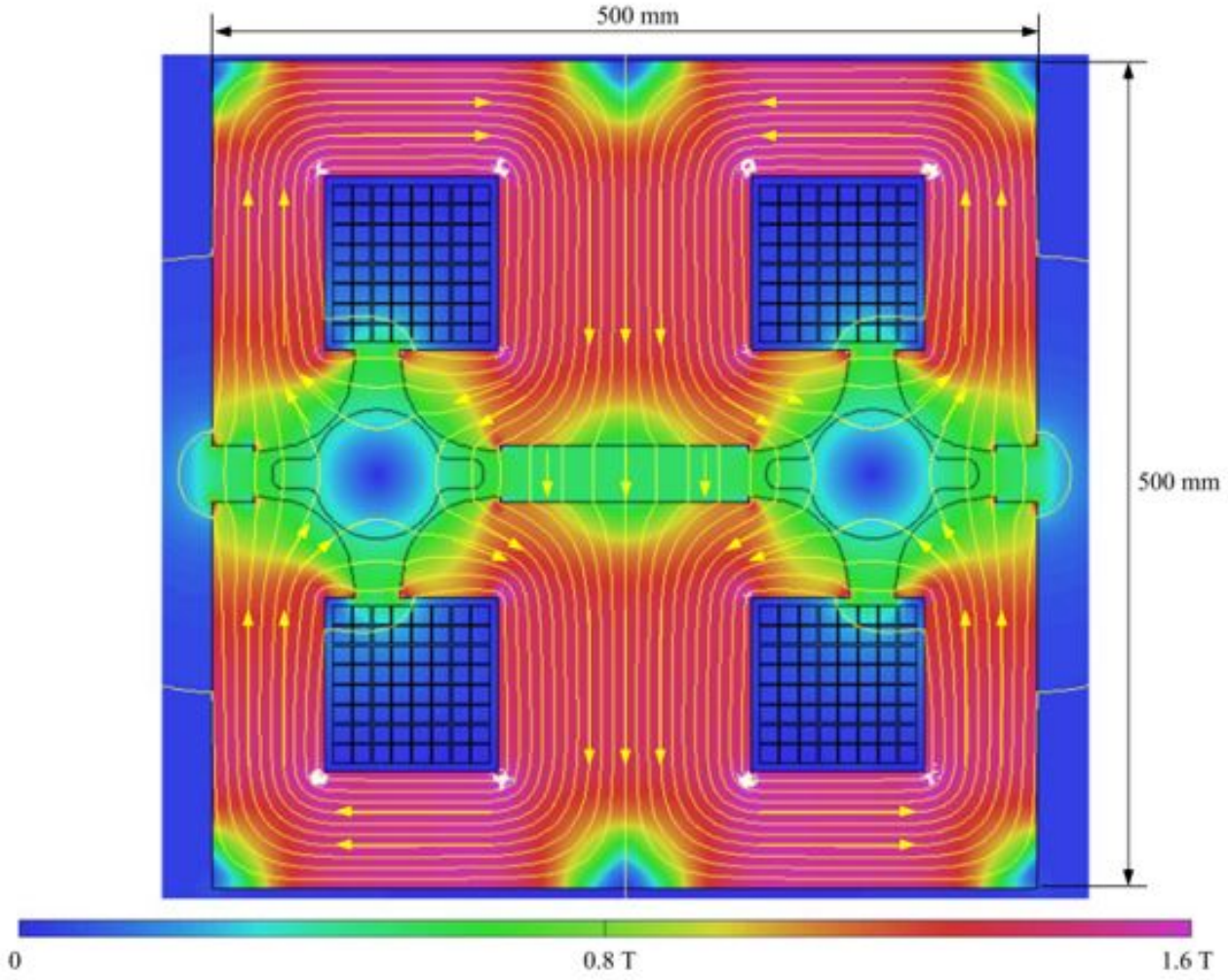

Fig. 1: magnet design cross-section (Credits: Attilio Milanese@CERN)

As Attilio Milanese, a CERN expert that leads the design effort explains: “The inter-beam distance dictates the overall cross-section of the twin quadrupole; the coil is dimensioned to keep the current density, and consequently the power consumption, reasonably low. The magnetic coupling between the two apertures brings a 50% saving in power consumption with respect to a traditional design”. It has been estimated that thanks to the novel design, at the highest beam energies of 175 GeV foreseen for FCC-ee, the total power for the quadrupole magnets can be kept below 30 MW. Finally, the new design puts the coil far from the midplane radiation.

To understand the performance and future industrialization needed for FCC-ee, a short model has been constructed and tested at CERN (see Fig.2). The team measured the strength

of the integral field, the field quality, and the magnetic axis for different current levels. As Carlo Petrone, in charge of these tests explains: "It was one of the firsts magnets tested in our new measurement laboratory. Additional effort was required due to the commissioning phase of the instrumentation to yield accurate magnetic measurement results. Furthermore, to fully qualify the FCC-ee twin-quadrupole magnet, different magnetic measurement systems have been used at different current cycles. This was required to achieve the accuracy required for taking decisions on the future design improvements".

First results have been promising about the efficiency of this design and match very well the simulated data with a precision of 1% up to 200 amperes excitation current. The two apertures provide a similar magnetic field quality, within 0.1‰, even before individual trimming.

In the next months, the team will further analyze the data, explore in detail all the parameters of the new design and make any necessary improvements towards the final conceptual design of the FCC-ee quadrupoles as key components of this machine.

Fig. 2: FCC-ee quadrupole test magnet installed on the magnetic measurement bench in the laboratory 311 at CERN. (Credits: Stephan Russenschuck,

CERN)