THE FCC-EE HTS4 PROJECT

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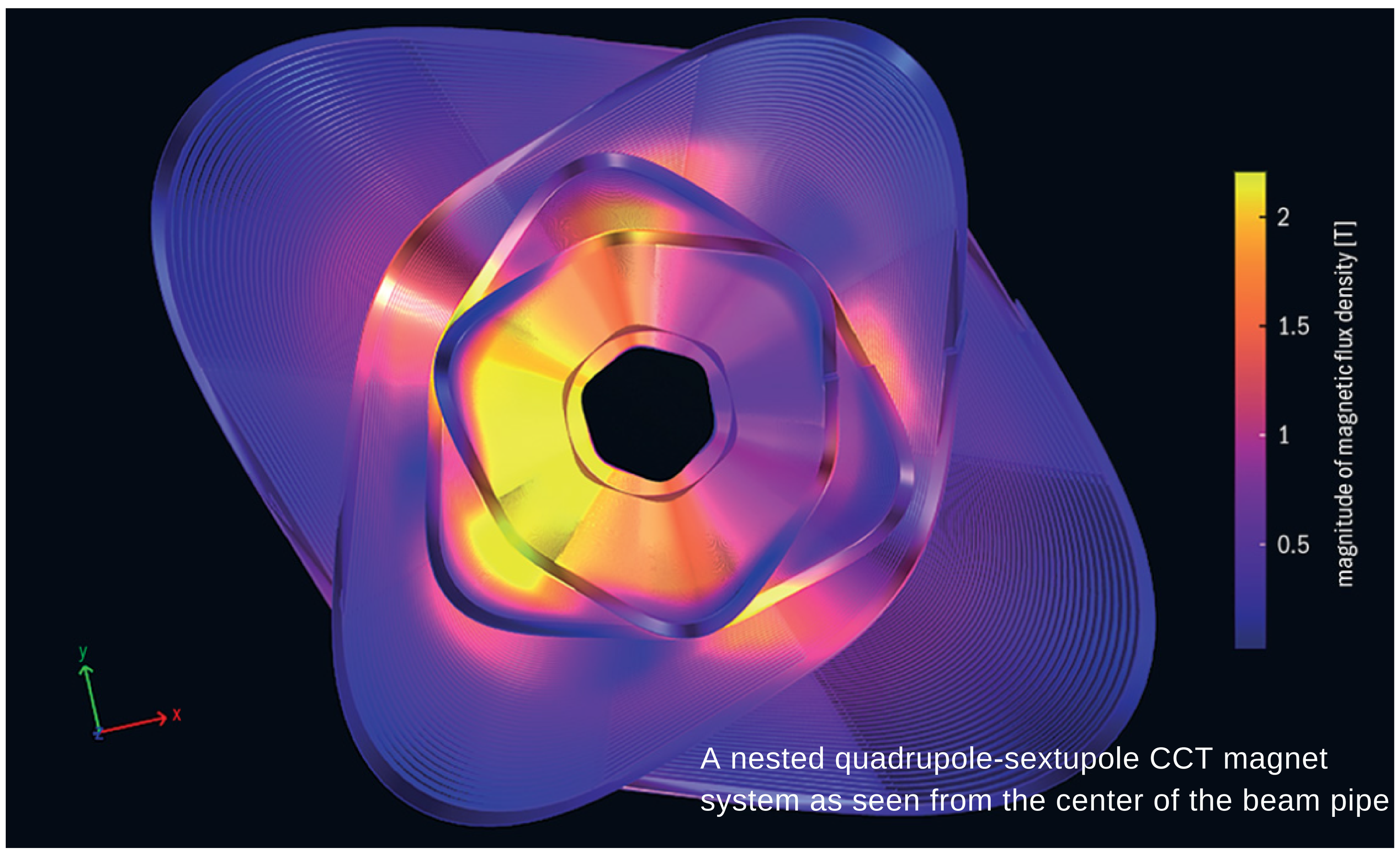
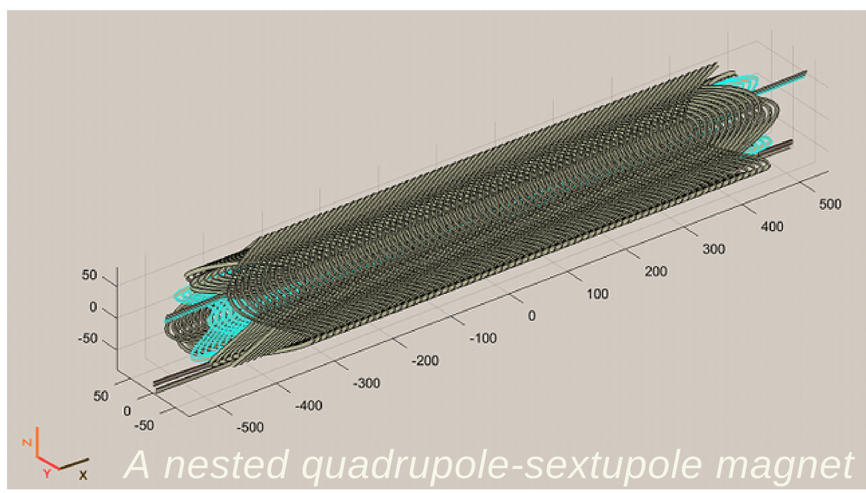
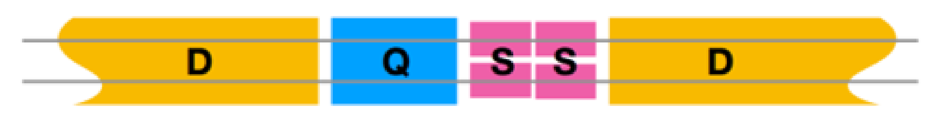


A nested quadrupole-sextupole CCT magnet system as seen from the center of the beam pipe

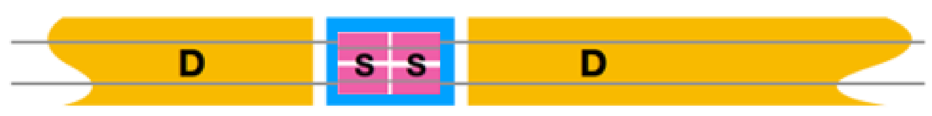
ABSTRACT

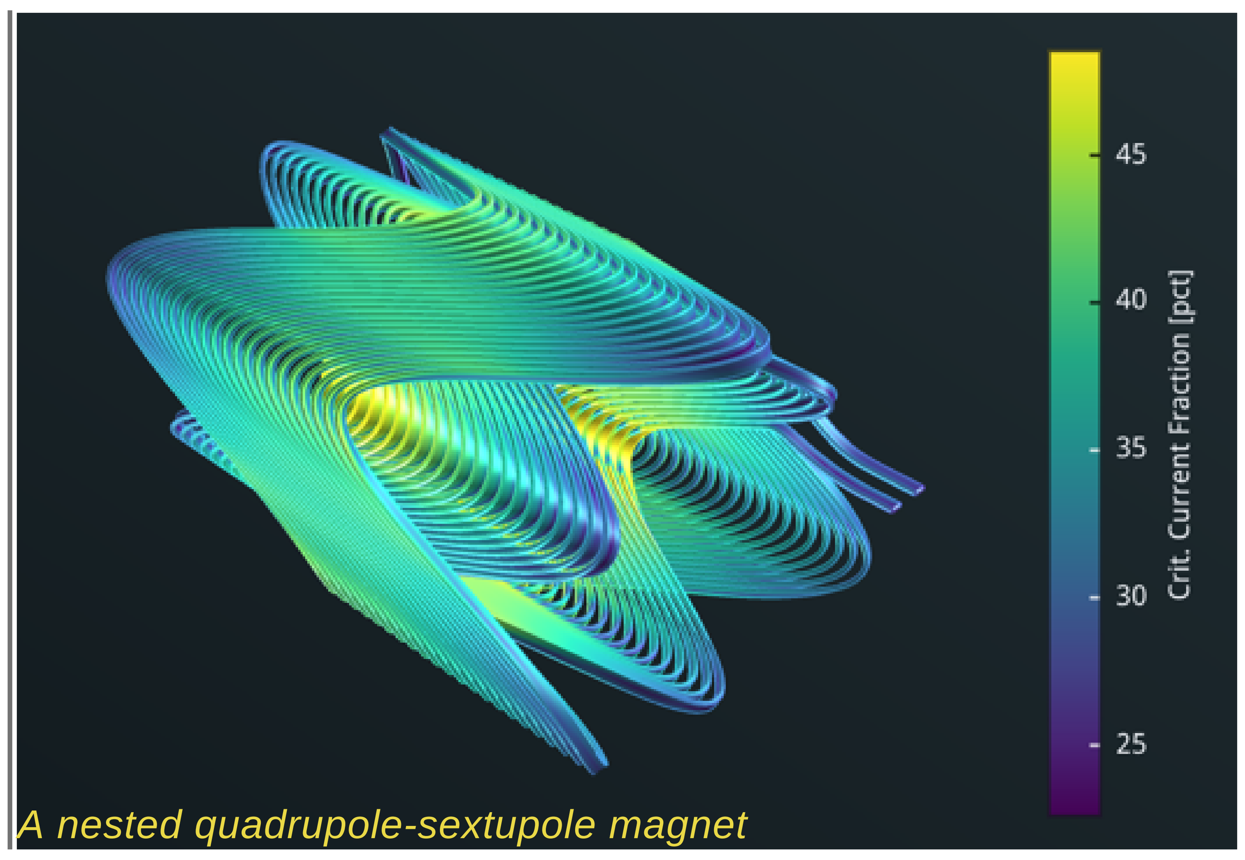
The FCC-ee HTS4 (High-Temperature-Superconducting Short Straight Section) project, a collaboration between CERN and PSI, aims at the replacement of normal conducting short straight sectors of the FCC-ee main storage ring with high-temperature-superconducting (HTS) ones. The study focuses on the construction of a 1-meter-long (full-size) prototype module, which consists of a nested quadrupole - sextupole magnet and uses high temperature superconductors (HTS, ReBCO tape), which can operate at 40K. The main pillars of this new design are minimizing power consumption, gaining luminosity and flexibility in optics and constructing a smaller and lighter system, with a vision for a more sustainable, green, cutting-edge technology with no additional costs.


A nested quadrupole-sextupole magnet



Comparison between a nested quadrupole-sextupole magnet and a traditional one





A nested quadrupole-sextupole magnet

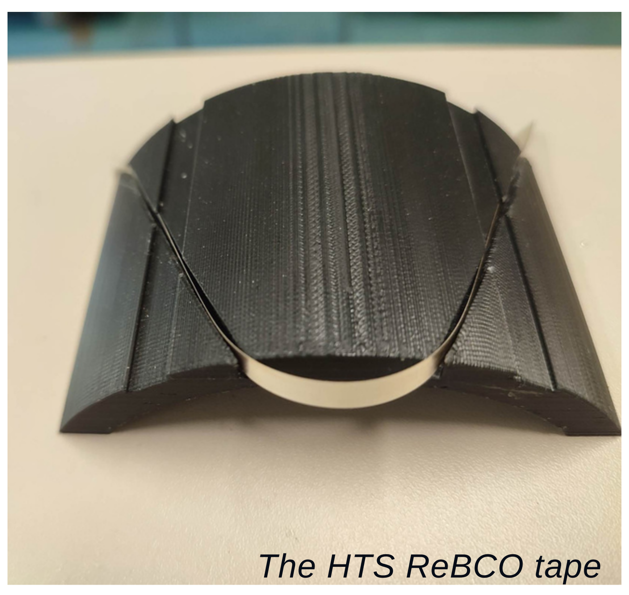
WHY HTS?

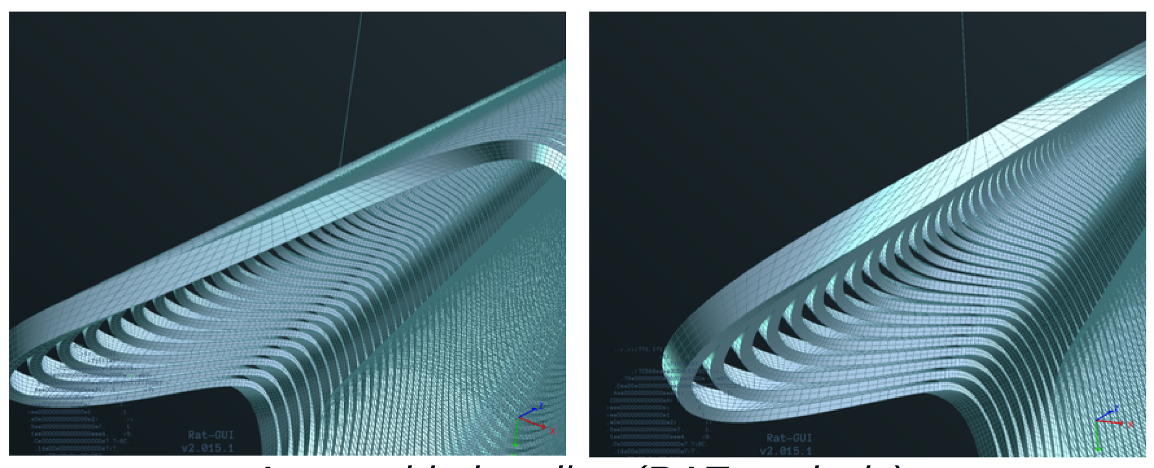
The main drawbacks of normal conducting technology are consumed electricity through Ohmic losses and energy spent on removing extra heat. Superconductors seem to be a better solution. Conventional superconductors need to be cooled below ~5K, consuming large amounts of energy. HTS magnets can operate up to 90K, can be made lighter and can also be nested, resulting in 7% increase in packing factor and thus luminosity. The system also provides increased flexibility in the optics design, since any phase advance can be chosen with no penalty and there is no requirement for fixed polarity e-/e+ quadrupoles. Moreover, we are hoping to build the system within the same cost envelope as the traditional system (considering the expected cost of HTS tapes in 20 years). FCC-ee is expected to use ~20,000 km of HTS.

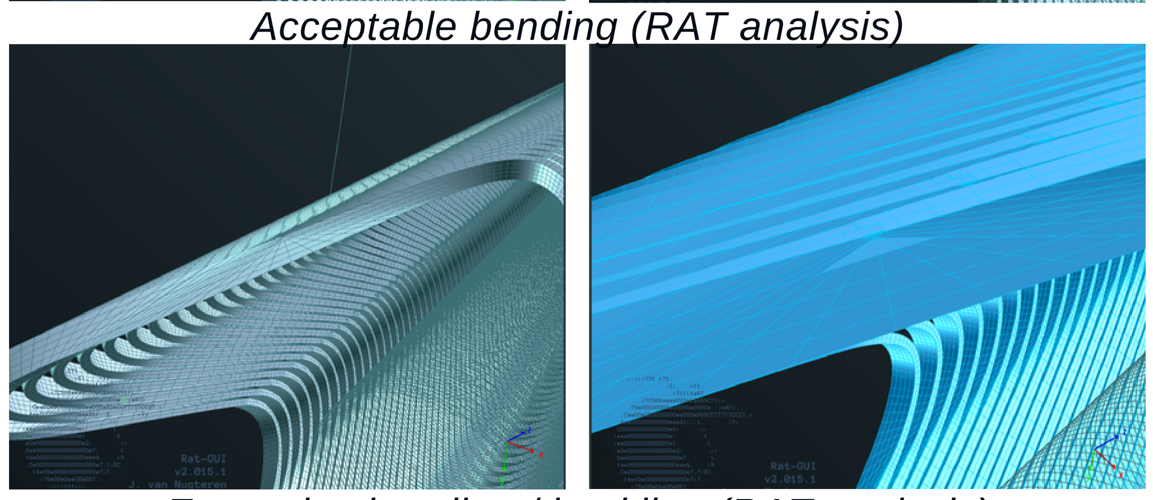
FRENET-SERRET SERIES

The HTS ReBCO tape, due to its particular geometry, cannot be bent in every direction, without breaking or buckling. Thus, a thorough analysis, with the use of Frenet–Serret formulas, was done, resulting in finding a feasible, mathematical solution, according to which a CCT (canted-cosine-theta) magnet can be constructed, without hard-way bending.

The first demonstrator will be a CCT magnet, without, though, rejecting the possibility of using traditional magnets (cosine theta) in the end. The Frenet-Serret framework is expected to provide a feasible solution for traditional magnets as well, but this needs to be further investigated.

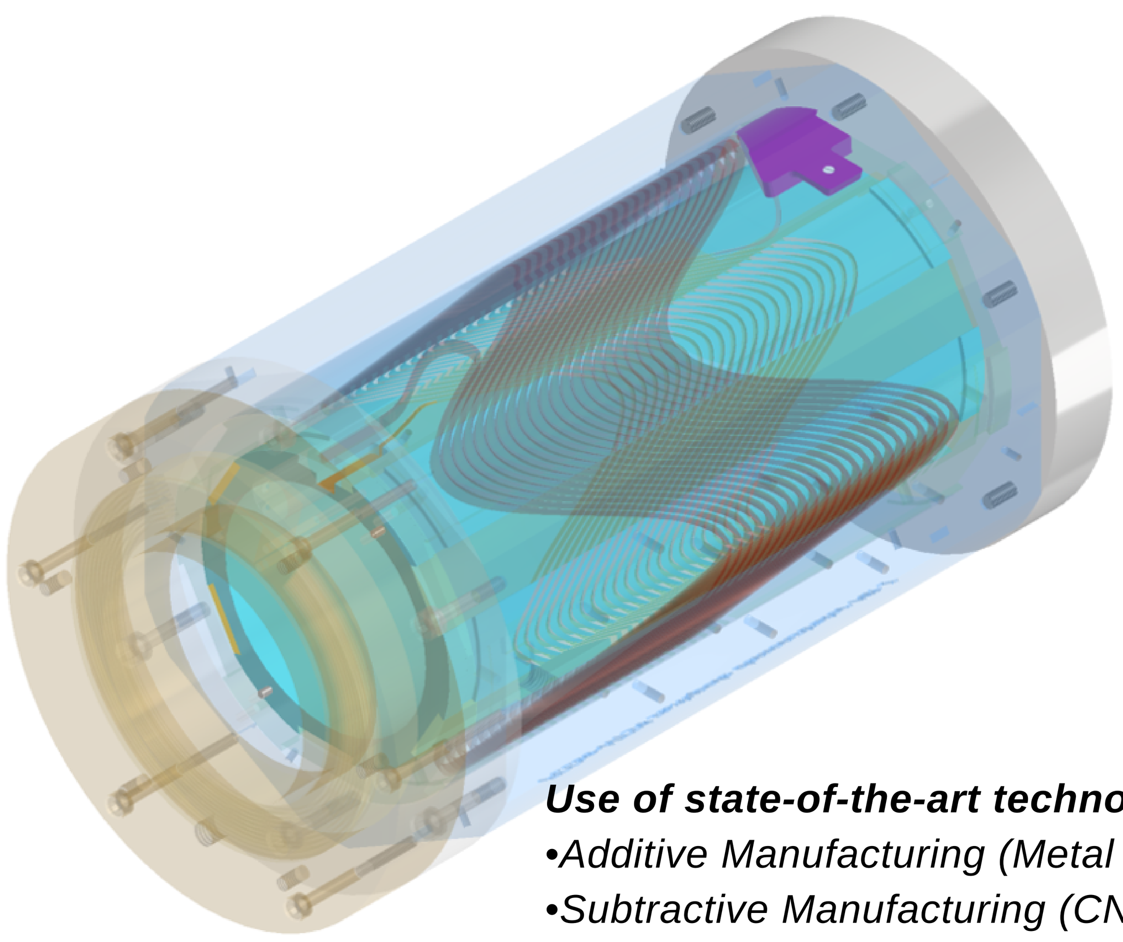

The HTS ReBCO tape


Acceptable bending (RAT analysis)


Excessive bending / buckling (RAT analysis)

FCC-EE - CPES

The CPES (Cryogenic Power Electronic Supply), a collaboration of ETHZ and PSI, is a parallel project, which focuses on cryogenic power supplies, instead of traditional room temperature ones, and investigates the possibility of moving the power supply inside the cryostat, with the aim of reducing heat losses.


Use of state-of-the-art technologies
•Additive Manufacturing (Metal 3D printing)
•Subtractive Manufacturing (CNC milling)

WORK IN PROGRESS

We are working on demonstrating the efficacy and feasibility of HTS4 project, in the following areas:

- Magnetic analysis
- Thermal analysis – heat loads
- Resistive wall impedance analysis
- Cost estimation
- Design of a demonstrator and prototype