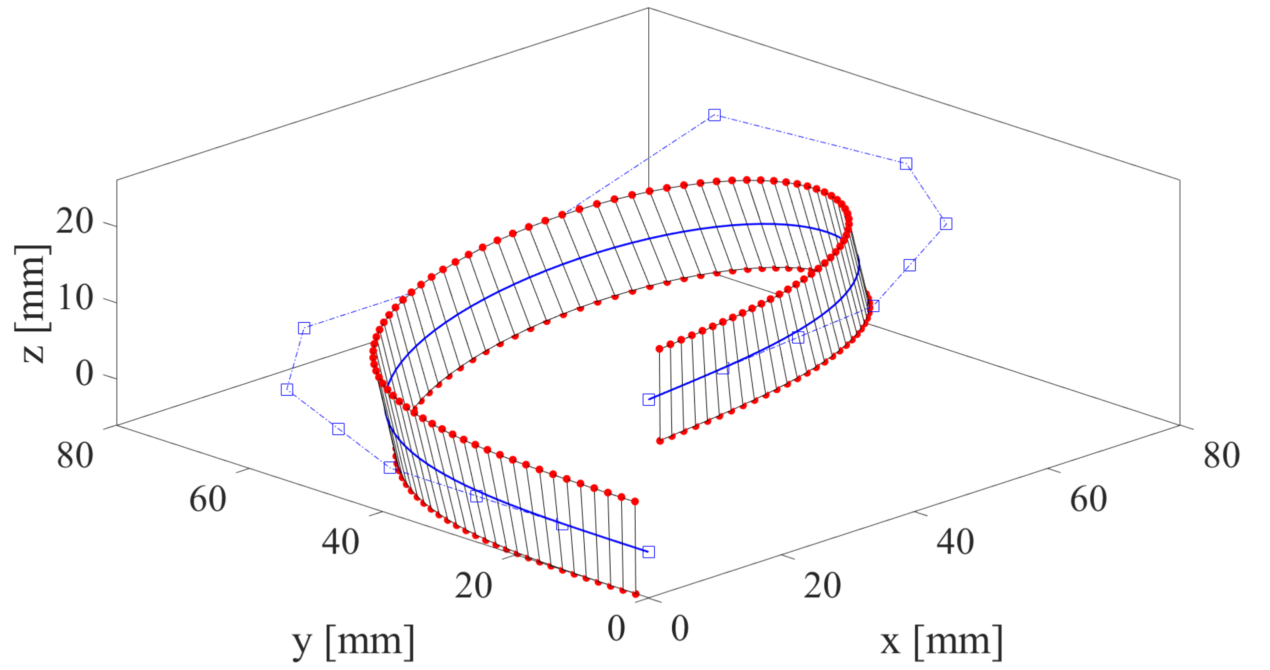
Design of a cloverleaf-racetrack dipole demonstrator magnet with dual *Re*BCO conductor

Thomas Nes, G. Kirby, G. de Rijk, M. Canale, L. Gentini, J. van Nugteren, A. Kario, H. H. J. ten Kate

CERN — UNIVERSITY OF TWENTE.

Abstract and Motivation

- Future 20+ T accelerator type magnets require *Re*BCO.
- A design of a 2-poles cloverleaf-racetrack demonstrator magnet is presented to test *Re*BCO's feasibility.
- Key is the layout of the coil-ends prohibiting degradation due to coil winding, cool down and operation.
- The cloverleaf geometry allows the beam pipe without any hard-way *Re*BCO tape bending.
- A new design tool using Bézier splines is presented.
- Use of dual tape conductor with facing *Re*BCO layers.
- No-insulation coils, so current redistribution at quench.
- Dry-wound and soldered-turns coils are compared.



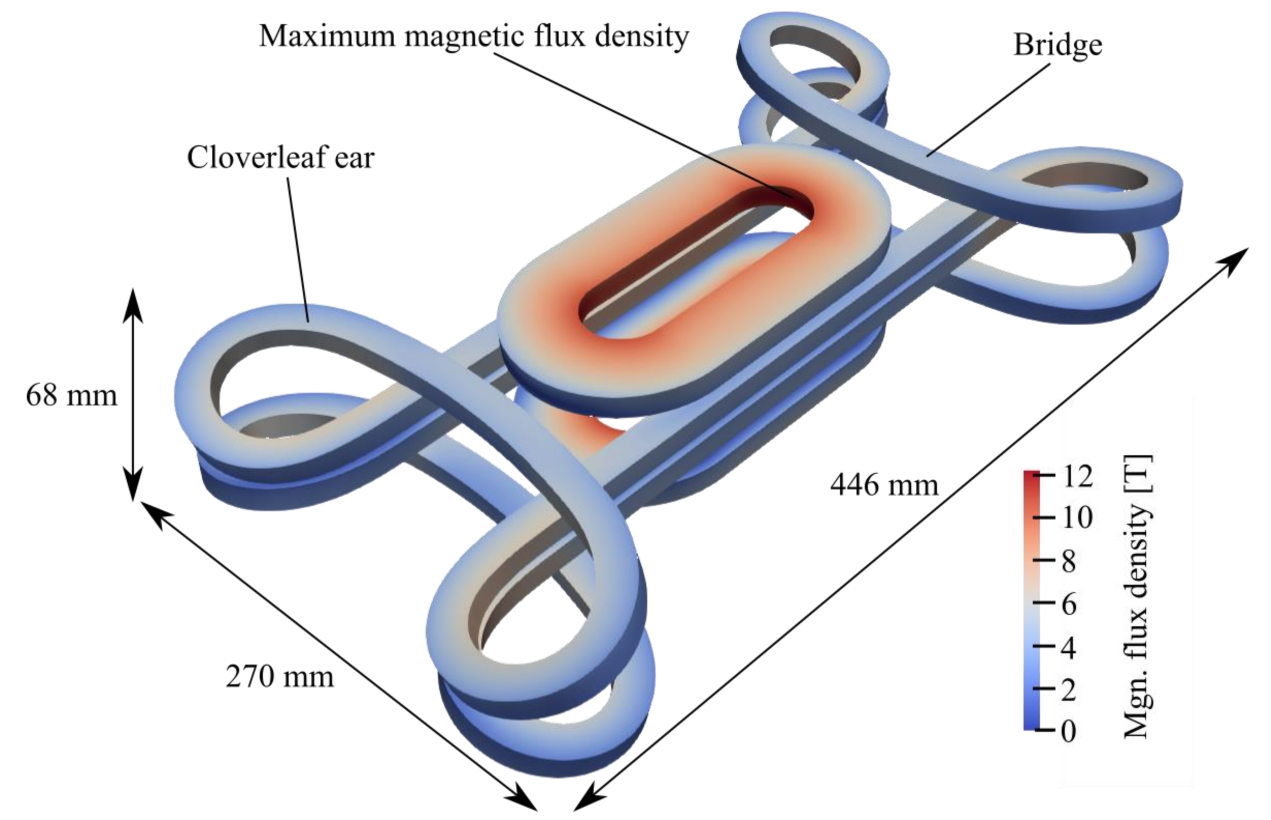
Layout of the cloverleaf ear for modelling.

Modeling the cloverleaf ear for best performance

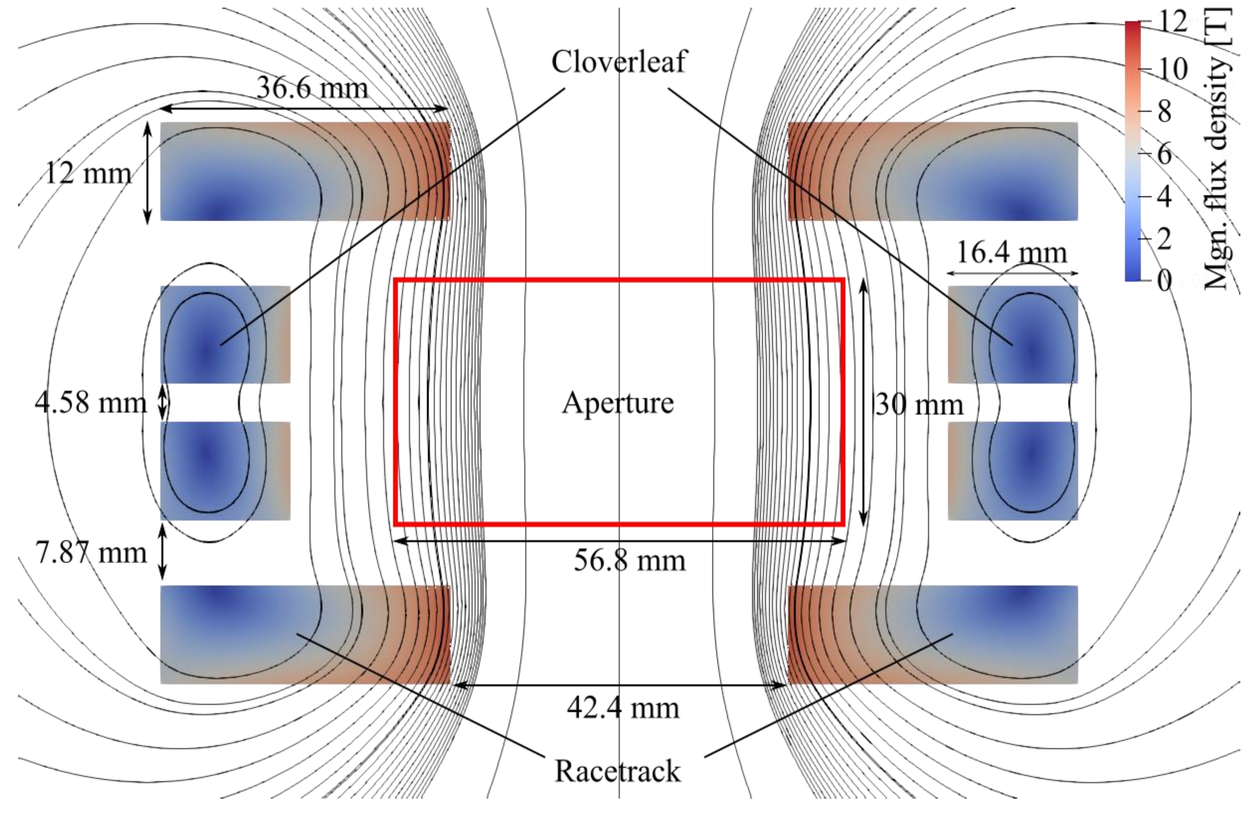
- *Re*BCO tape cannot be bend over the thin side of the tape (hard-way bending).
- Cloverleaf shape allows windings to be passed over the particle beam pipe without hard-way bending.
- Surface is modelled by applying differential geometry to a Bézier curve tracing the shape of the cloverleaf.

Electromagnetic design

- Magnet consists of 2 cloverleaf coils and 2 racetrack coils.
- Block-coil configuration to align tape with magnetic field for higher performance.
- Coils are wound non-insulated for quench protection.
- To keep the charging times low, a dry-wound coil is preferred over a soldered coil, which has a lower transverse resistance.



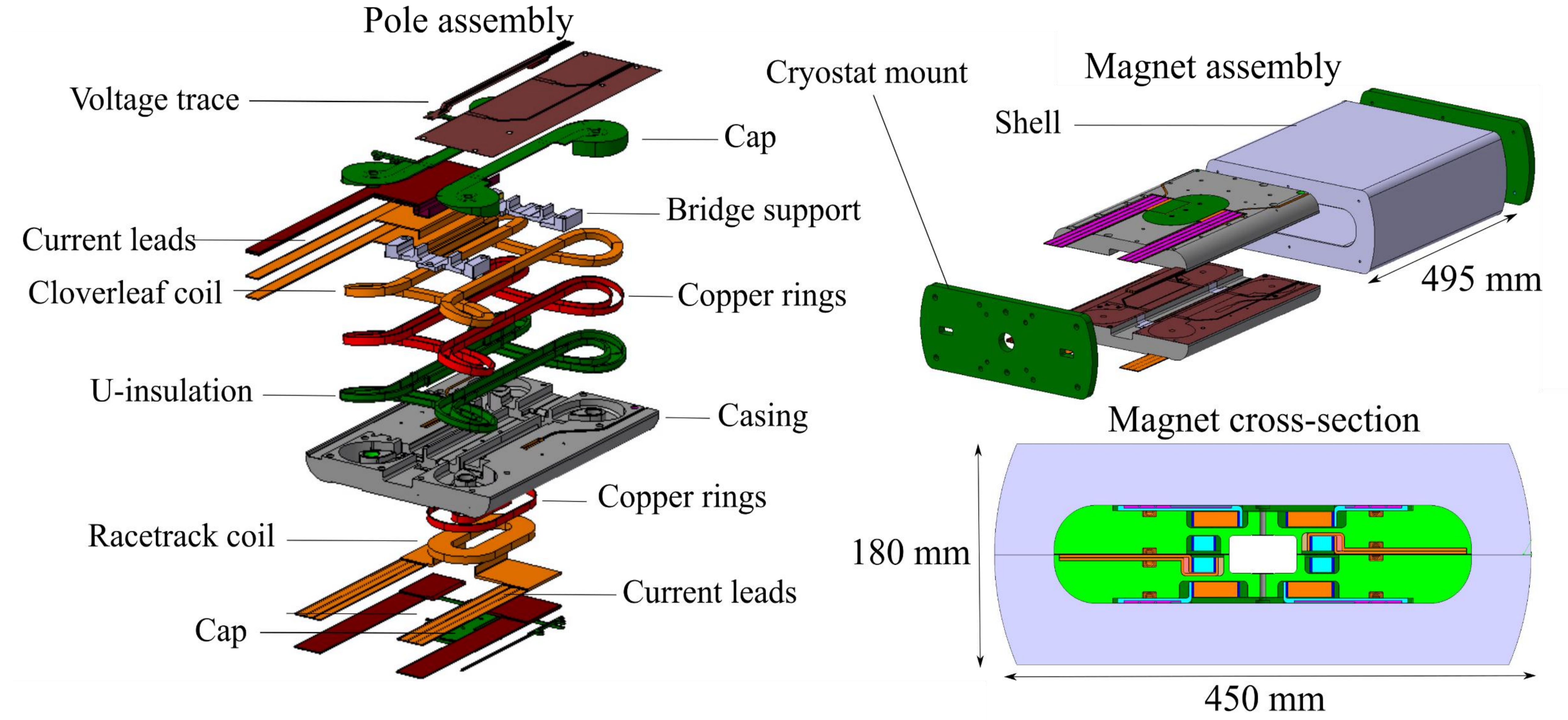
3D view of the cloverleaf coil windings.



Cross-section of the coil windings showing sizes

Mechanical design

- The coils are in a casing, capable of taking the Lorentz forces when powering the coil.
- Due to the large minimum quench energy of *Re*BCO, no pre-compression needed to prevent conductor movement.
- The coils are insulated from the former using a 3-D printed plastic U-channel sitting around the coils.
- The two poles of the magnet are enclosed in an aluminium alloy shell holding the poles together and allowing for easy magnet assembly in a cryostat.
- The magnet is constructed in a modular way.



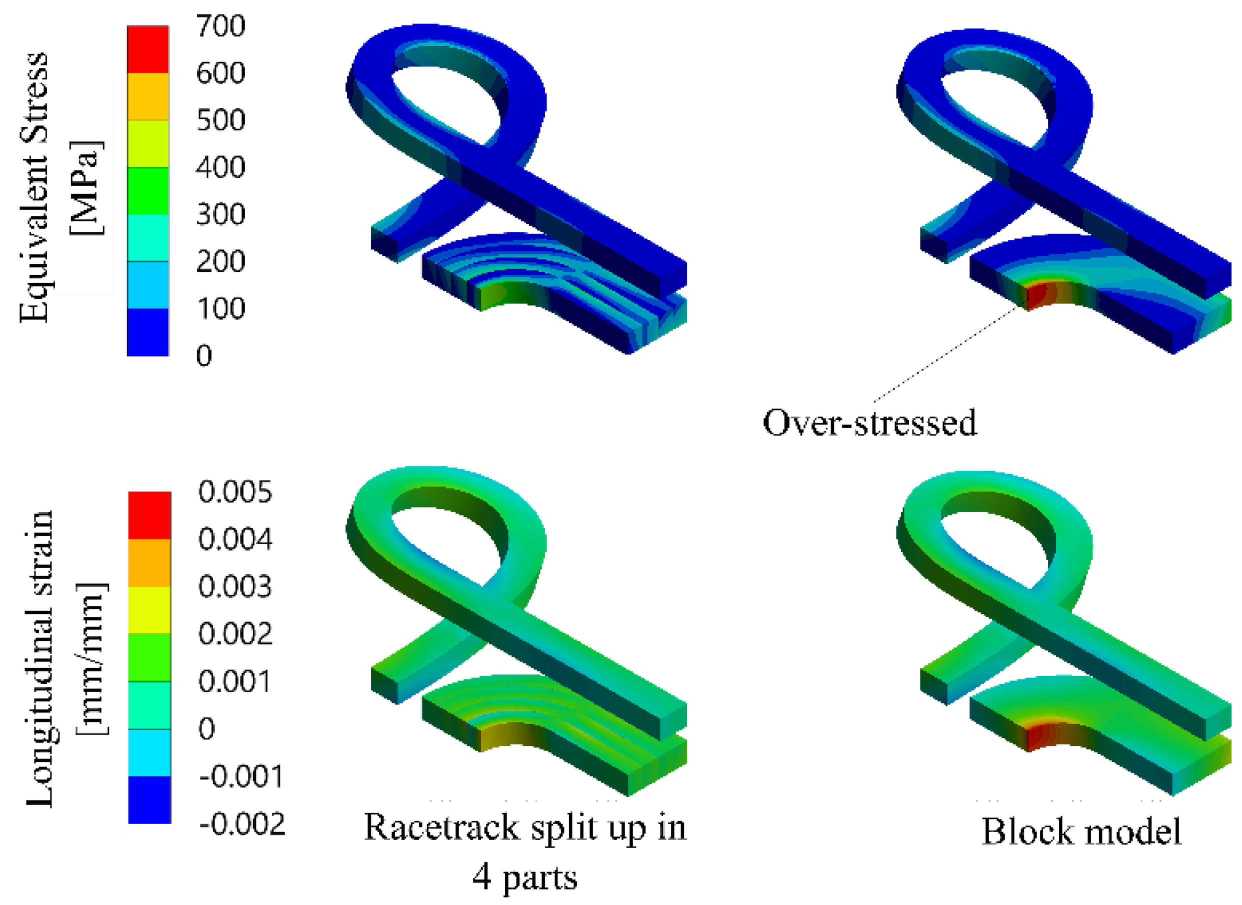
Exploded view and cross section of the magnet showing the various parts.

Magnet parameters

Parameter	Value	Parameter	Value
Center magnetic field	4.7 T/kA	Length cable/tape per cloverleaf	143/286 m
Maximum field on conductor	6.1 T/kA	Length cable/tape per racetrack	80/160 m
Tape thickness	0.1 mm	Total tape length	894 m
Tape Width	12 mm	Number of cable turns cloverleaf	82
Number of tapes in cable	2	Number of cable turns racetrack	183

Mechanical modelling

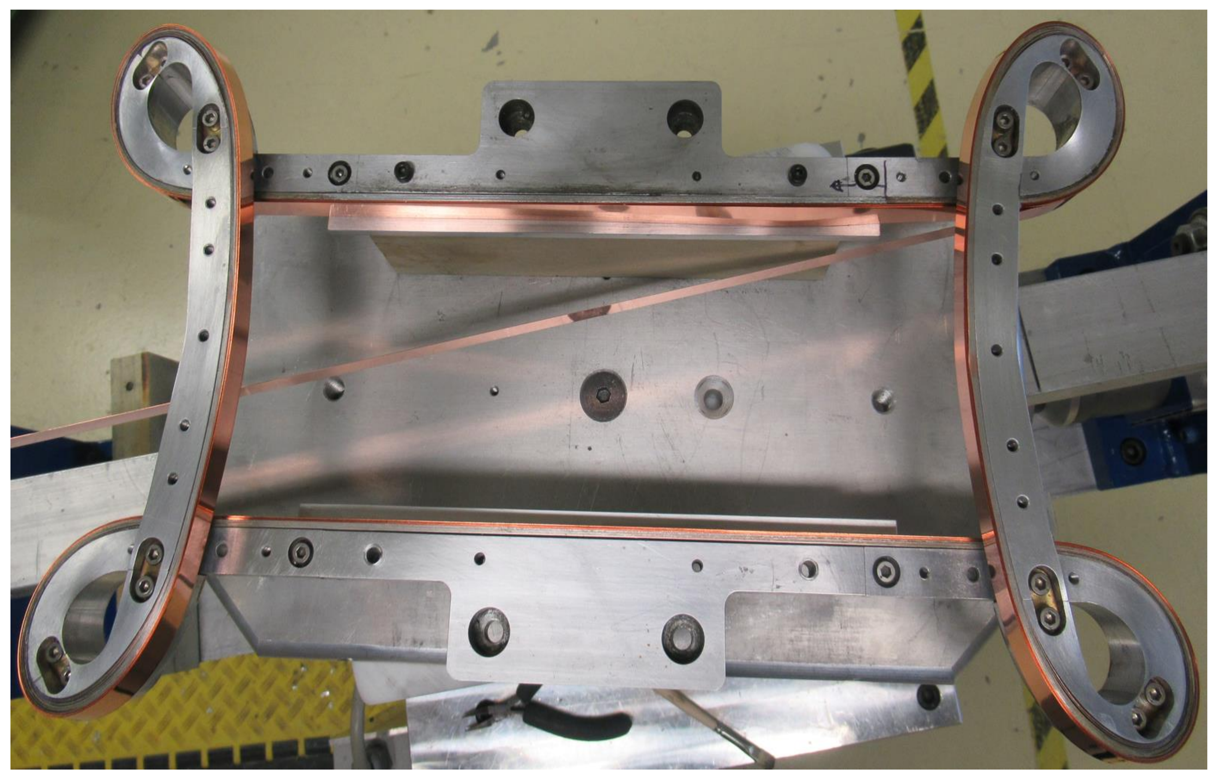
- ¼ of magnet modelled in ANSYS, cooling to 4.2 K, current at 2 kA.
- Soldered case: both coils modelled as single block, turns cannot slide.
- Dry-wound case: racetrack coil split into 4 parts that can slide.
- Mechanical model conclusion: dry-wound coil has lower mechanical stress and strain over soldered one, due to the ability of the turns to slide relatively to each other.



ANSYS ¼ pole model result: stress and strain.

Winding trials done

- Cloverleaf winding comes with complications, due to its unique 3D shape.
- Cable to pass under the winding mandrel twice when winding a full turn. Achieved by placing the winding mandrel on two removable legs.
- It works, more to come!



Unconventionally winding a 500 mm long cloverleaf coil comprising 2 straight legs & 4 ears,