

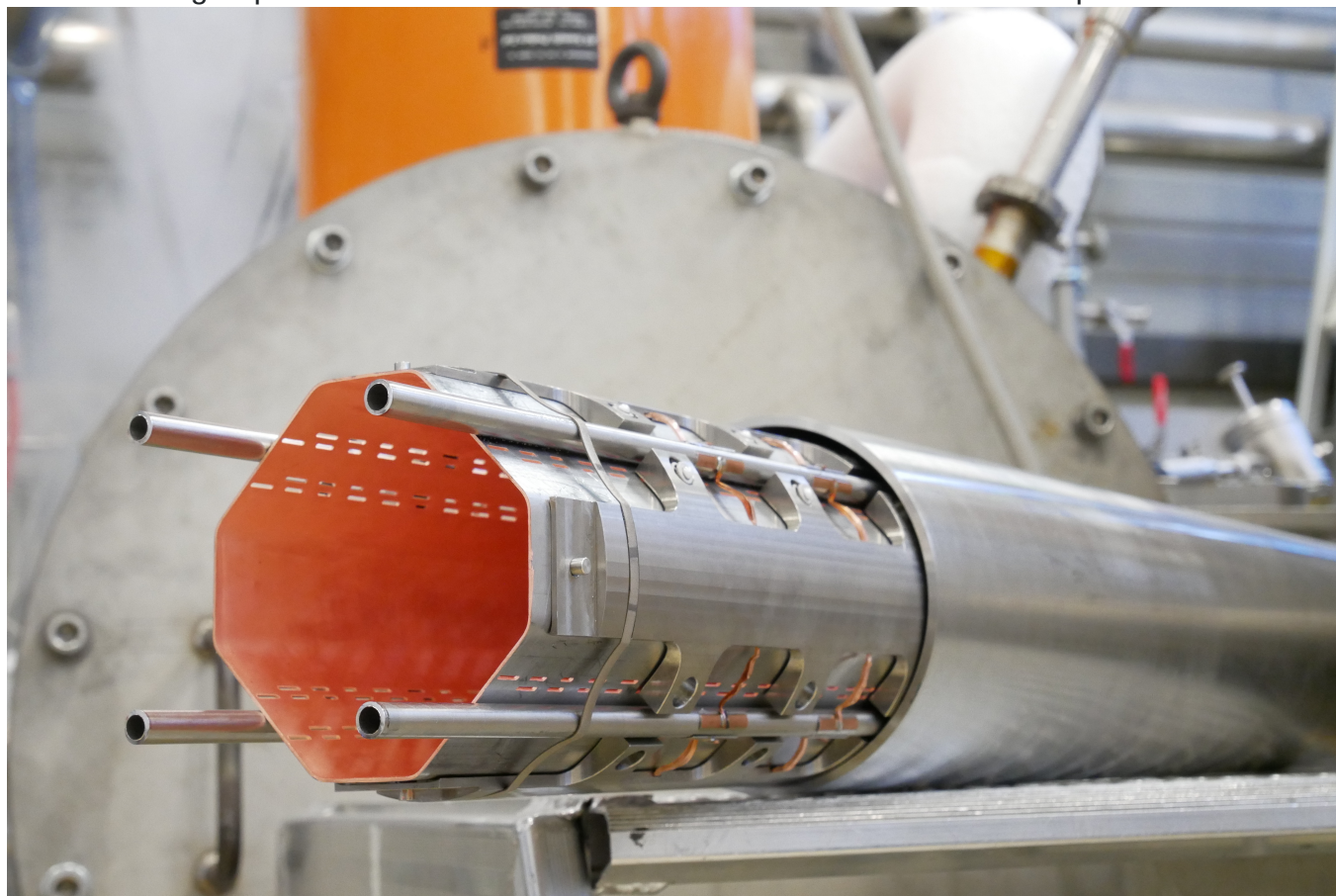
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A new generation of beam screens

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[HL-LHC](#)

The vacuum group of the HL-LHC collaboration had to innovate in a lot of aspects.



When HL-LHC was approved, the vacuum team faced a huge challenge, to create a new generation of beam screens. The LHC has already a beam screen that is already quite unique in its kind, but HL required far more strict characteristics. From one side, tungsten absorbers are integrated to intercept collisions debris leading to heat load requirements of a factor 50 higher compared with the one for LHC and for another they have much larger aperture, optimized for beam optics, inducing huge Lorentz forces during a magnet

quench of around 33 tons per meter per quadrant. A breakthrough was needed.

The shielded beam screen is a complex octagonal shaped assembly made out of a co-laminated and perforated copper and stainless steel sheet. It is equipped with tungsten blocks laid on the tube and kept in place by means of elastic rings and pins, cooling tubes and thermal links. The design is based on a thermal decoupling between the internal beam screen tube and the absorbers to keep the temperature in a thermodynamically efficient range and on a flexible assembly to ensure the transfer of the Lorentz forces induced in the absorbers to the cold bore tube. To develop the new beam screens, the team had to consider not just the 2D modelling but a full 3D modelling as the beam screen was shielded by tungsten blocks equipped with local copper thermal links.

They also had to use advanced simulation techniques considering all the factors such as the combined thermal and electromechanical behaviour. Several aspects had to be studied in detail as the transfer of heat between the beam screens and the absorber blocks in Tungsten, the cooling circuits or the thermal transfer with the cold bore.

"Thermal aspects are extremely challenging points," says Cedric Garion, responsible of the beam screen design, as in this case we are working at 60-80 K and not as for the LHC at the range of 4-20 K.

Since two years the CERN vacuum group has done a systematic campaign to validate its innovative design starting with an 80 cm model to the present 2m long prototype. This campaign has not been easy as during the 6th Annual meeting in 2016 a new requirement was added: the magnet protection scheme was complemented with a novel Coupling-Loss Induced Quench (CLIQ) system which became part of the baseline in addition to the standard quench heaters. From one day to another the new beam screen had to be able to withstand a new type of oscillatory load induced by CLIQ and work in a completely different mechanical regime.

The team reviewed in few months the consequences for the design and reworked the holding systems and the geometry of the Tungsten blocks. In a record time they were ready to test the new prototype able to resist to the new configuration with the new quench protection system.

"This summer was a really exciting moment," says Marco Morrone, one of the engineers involved in the design and in charge of the tests, as we submitted the new beam screen to extreme conditions. In fact, the prototype of the Q1 beam screen was cool down to 1.9k and subjected to currents beyond the ultimate current. The beam screen prototypes withstand magnet quenches and the results obtained were compared with the models giving a perfect fit between the simulations and what was observed.

On the other hand, thermal tests of a beam screen prototype have been carried out and have shown excellent thermal performance of this complex assembly. A very good

decoupling is observed between the absorbers and the beam screen tube, whose temperature is perfectly defined by the helium temperature. In addition, a low heat leak, below 0.5 W/m, has been measured from the massive shielded beam screen to the 1.9 K cold bore tube. These outstanding results are in very good agreement with the estimations obtained by simulations.

To obtain such good results the vacuum group had to innovate in a lot of aspects. For example, the springs on the holding system are done in additive printing. Another real challenge has been the design of the thermal links that at the same time transfer heat, warranty flexibility will resist to extreme forces. Finally the tungsten blocks are just hold to transfer forces to the cold bore. Definitively the beam screen has become a new technological jewel of HL-LHC.