Work Package 6

Text taken from "description of work" (Annex 1 of the proposal)

The inner triplets in the high luminosity regions are critical components for controlling the luminosity of the collider, the most important performance index for a collider after the collision energy. The luminosity depends critically on the beam current and on the so-called β^* at the collision point. However, while the beam current depends on the whole ring and the chain of injectors, the β^* depends mainly on the optical properties of the interaction region. So, acting on the low-β quadrupoles is the most effective way to increase the luminosity in a fast and relatively inexpensive way in a circular collider. Furthermore, a triplet with a sufficiently large aperture can help a lot in attaining or passing the design beam current in the LHC which is today limited, among other things, by a severe problem of collimator aperture.

These above-mentioned triplets consist of a set of 16 high-gradient quadrupoles which focus the beams at the experimental collision points. Each of the four triplets is composed of a string of 4 quadrupoles equipped with magnet corrector packages and other important equipment (like absorbers, cryogenic distribution feed boxes, etc.) As the luminosity increases in the first years of the LHC operation, these quadrupoles will become the main bottleneck to the machine performance. A further increase in luminosity will therefore require the replacement of these quadrupoles by a more advanced design with a larger aperture.

With this in mind, a new inner triplet layout has been recently proposed [LHC Project report 1000], which serves as a basis for this WP work. In this proposal, each triplet is composed of four quadrupoles all of the same cross section with an inner bore of 130 mm and with two different magnet lengths: 8 and 9 m. For comparison, the present layout features quadrupoles of 70 mm wide aperture, with two different lengths, two different cross sections and different operating currents. In the new design the operating current will be the same, allowing the triplet to be powered in series. This design allows room for reducing physical bottle-necks occurring in other critical component of the machine (e.g. the collimation aperture).

In this suggested design option, the peak field, which essentially remains unchanged, is limited by the intrinsic properties of the NbTi, i.e. less than 10 T of peak field. However, the energy and the forces considerably increase with respect to the present design and reach limits so far unexplored for NbTi quadrupoles. These reasons, as well as the necessity to qualify the procedures and the actual field quality, all demand that at least one short model (one-meter-long), be manufactured and cold tested before proceeding to the construction and test of a full scale prototype.

Objectives

- designing the NbTi quadrupole for the interaction regions of the LHC upgrade for higher luminosity.
- manufacturing and cold testing a one meter long model of NbTi quadrupole to qualify the procedure retained and the actual field quality

- constructing and testing a full scale prototype made of a complete quadrupole with the cryostat and the correctors, as a basis for preparing the manufacture of the 16 quadrupoles needed for the high-luminosity interaction regions S-ATLAS andCMS2.

Description of work

Task 6.1 Design of advanced Nb-Ti superconducting quadrupole: The 130 mm aperture poses considerable problems of mechanics and force containment, with forces and energy even larger than in the LHC main dipoles. The design package will review all these aspects: magnetic, mechanical, coil positioning and stability, protection and thermal behaviour. The thermal design will be reviewed and the insulation scheme will be possibly upgraded with respect to the one used for the LHC. The superconductor, fine filament high quality NbTi, high RRR copper stabilized, will be fully qualified both as cable and as coil package for thermal and mechanical properties (like elastic modulus, ultimate strength, insulation creep limit, etc.).
The design of the complete cold mass will be carried out, including the corrector magnet package. The principle choices on corrector magnet technology will be done following the freezing of the optics lay-out. The cryostat, interface and interconnections will be carefully studied and optimized for a working temperature of 1.9 K.
All these issues will also be studied in view of the higher radiation level and heat deposition that the increased luminosity will generate in the triplet equipment.
CERN is the leading institute and will coordinate the effort. CEA-Saclay and CERN will be in charge of the magnet design with contributions from CIEMAT and STFC. CIEMAT and STFC will be in charge of the corrector design and CERN and CNRS-IN2P3 will be in charge of cryostat design.

Task 6.2 Construction and testing of short models: This task concerns the construction and test in cryogenic conditions of a 1 meter long model quadrupole magnet and one short model corrector model magnet. This will allow qualifying the coil manufacturing procedure, the mechanical assembly procedure, the coil stability as well as the field quality in real operation conditions. The task is composed of the design and construction of the necessary tooling, as well as its installation and qualification. After that, for the quadrupole model, the coil winding and curing with a new insulation scheme will be tested and applied to the coils (1 or 2 spare coils are foreseen). The mechanical assembly will be carried out, either in a vertical assembly, according to the classic technique in CEA-Saclay style, or in a horizontal assembly.
Once assembled and fully instrumented, the bare quadrupole magnet will be cold tested and measured from low field up to full power. For the correctors a single magnet short model will be separately made and cold tested.
The coil manufacturing will be led by CEA-Saclay, in collaboration with CERN, while CERN will take care of the cold mass assembly and of the cold test at its own premises. CIEMAT and STFC will do the design and manufacturing of the corrector magnet short model and the cold test will be done at CERN

Task 6.3 Construction and testing of a full-scale prototype: This task has the objective to manufacture and fully test a complete prototype quadrupole. The final, effective proof of the system proposed for this new interaction region triplet will be the construction of a prototype (the length is still to be defined: in the range from 5 m to 10 m, input from task 1) and its successful test of all aspects: quadrupole magnet, correctors and the thermal and mechanical behaviour of the cryostat. The content of this task starts with the design and construction of the tooling according to the magnet and the cryostat design decided in task 1 followed by the test of the long magnet winding procedure and the curing and collaring stages. Once the coils have been collared, the selected procedure for the cold mass assembly, already tested in the task 2, will be applied on the long prototype, with specific tooling suitably designed and installed. The corrector package will be manufactured separately and then integrated into the cold mass. The cryostat with improved features will then be manufactured and the cold mass assembled into it. Finally the magnet will be tested in the unique cold test facility of CERN, where complete tests will be done to assess the suitability of the magnet for the new interaction region of LHC in terms of field quality, quench behaviour and safety.

CERN will provide the necessary guidance and coordination for the global effort. CERN will manufacture the long prototype magnet, with contributions from CEA-Saclay, STFC and CIEMAT. The correctors will be manufactured by CIEMAT and STFC. CNRS-IN2P3 will assist CERN in manufacturing the cryostat and the tooling for the assembly of the magnet into the cryostat.