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Perspective Article

Magnetic Errors Corrections at IR5 and IR1 by LHC Triplets and The Best Combination of A1,B1,B1

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PERSPECTIVE

This talk have the following parts that we begin with a brief description of the magnets which constitutes the Triplets in the LHC, secondly a technique to calculate magnetic errors is introduced, and then, we discuss how the total magnetic errors from two triplets can be summarized in one certain combination A1,B1,B1 to perform magnetic errors corrections. We found that although the magnets are constituted by the same materials, some are even identical to others, and accurately tests are performed for all, some locations are special to perform magnetic error corrections. This is an important task with the aim to have a precise Interaction Point (IP) measurement and equally, to have an optimal beam.

The LHC is the accelerator located at the European Laboratory for Particle Physics in CERN. It has been built to operate up to 14 TeV for proton-proton collisions, which is currently the highest energy reached in the world under these Laboratory conditions. From the bibliography, materials and dimensions of the corresponding magnets are summarized. LHC has Insertion Regions or IR, where two triplets are installed, one at each side of the collision IP; those triples are mainly quadrupole magnets. Magnetic error corrections are performed to have optimal operations and physics analysis, and one of the available methods for this task is the Action and Phase Jump method, which is convenient and developed to use few magnets.

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The LHC is the accelerator located at the European Laboratory for particle physics in CERN. It has been built to operate at high energies, up to 14 TeV, for proton-proton collisions, which is currently the highest energy reached in the world, under these laboratory conditions.

The LHC has a circumference of about 27 km, and its optics arrangement is divided in eight sectors. Four of those are where the main interaction or collisions take place, and where the main experiments are ALICE, CMS, LHCb and ATLAS, are located.

From the bibliography, materials and dimensions of the corresponding magnets to this study are summarized at the beginning of the talk, including some characteristic for every type of magnet. We emphasize in the definition of a Triplet, which is the assembly of three quadrupole magnets, used for a reduction of the optical β-functions, at each Interaction Point (IP) where the two LHC beams are expected to collide, it includes all the cryogenics necessary to keep those superconductive magnets at a temperature of 1.9 K.

LHC has four Insertion Regions or IR, where two triplets are installed, one at each side of the collision or Interaction Point (IP), those corresponding magnets are mainly quadrupoles. A list of the magnets is presented, according to their location in the LHC ring.

To fulfill a collision point, as accurately as possible, one of the goals during the LHC commissioning is to reduce the magnetic errors. This is because the magnetic devices cannot be built to have only one component in a plane without disturbing other planes, especially at the edges, therefore there are always more components presented than the expected ones. Also, during the installation and working processes of the magnets, a couple of problems could be presented by fabrication defects on their materials and a deviation from their design position along the ring. These situations cause a beam quality loss or a large uncertainty in the measurement of the particles position and hence in the determination of the collision point.

In general, the beam in an accelerator is described by the Courant-Snyder parameters; one of these is the Beta-function β,

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which is related with the amplitude of the trajectory that describes the beam. When the beam changes its characteristics an oscillation from the expected trajectory is starting to be observed and in most cases the oscillation develops large amplitude after some time, having consequently a loss of the beam. If the oscillation is produced in the transverse plane it is a called Betatron oscillation.

At the Location of the Experiments ATLAS and CMS in the LHC, we studied what is the best combination of magnets which account for all the magnetic errors at a linear level in each IR region, using just two normal quadrupole correctors (B1) and one skew quadrupole corrector (A1). For this, the LHC simulator in MAD-X is modified to measure the corresponding beam parameters.

First, in the simulator some intentional magnetic errors in all the quadrupoles are included, and then the beam parameters are measured as a result; secondly, using the APJ method a magnetic errors calculation is performed using only a combination of 2 normal quadrupole magnets and 1 skew quadrupole. According to the LHC optics, there are 30 possible combinations for each IR, and we named from 1 to 15 the ones using a skew quadrupole located at the left of the IP, and 16 to 30 the combinations with the skew quadrupole located at the right of the IP. Then, as final step, the corrections are introduced into the simulator to obtain again the beam parameters.

The described steps using the simulator are repeated for each studied combination, adding the corresponding corrections value obtained used APJ in the IR under study.

The main results which show the effectiveness of the corrections and the best obtained combination are explained. Sample plots of the β-beating obtained are presented, each one for every transverse plane. The β-beating is the traditional quantity used to established if the correction of the magnetic errors was done property, because it tells an idea of how far the expected physical beam conditions are from the measured and actual conditions of the beam in the accelerator.

A comparative plot of the RMS dispersion is presented, including all the studied combinations, to have an idea of the variations that are observed. Afterwards, we can conclude that some combinations are more effective to perform the corrections and we can determine which is the best combination A1B1B1 to perform the magnetic error corrections in the LHC regions, IR1 and IR5.