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Future Circular Collider

PUBLICATION

Recommended collider follow-up R&D: Milestone M3.7

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MILESTONE REPORT

RECOMMENDED COLLIDER FOLLOW-UP R&D

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Abstract:

This milestone documents the gap analysis between findings of the study, towards a realization project: Portfolio of suggested R&D topics related to the domain of the interaction point, experimental area and machine detector interface design elements and associated technologies.

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Delivery Slip

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1. PHASE ADVANCE SCAN INCLUDING BEAM-BEAM EFFECTS

1.1. MOTIVATION

Initial studies of the dynamic aperture (DA) at collision energy including non-linear field errors in the final focus triplets of the high luminosity interaction regions showed inconclusive results as the FCC-hh lattice evolved. A systematic study of the changes revealed that the phase advance between the interaction regions is a major contributor to the dynamic aperture. Consequently, a scan to find the optimum phase advance was established as a powerful tool to maximise the DA. However, studies of beam-beam effects showed that the optimum phase advance found with non-linear magnet errors decreased the DA with beam-beam effects.

1.2. OBJECTIVES

The goal of the work is to establish tracking studies that include the most relevant factors for the dynamic aperture at collision, i.e. head-on and long range beam-beam effects and the magnet errors of the final focus triplets. This will ensure that the predictions for the dynamic aperture are realistic and that the results of phase advance scans are applicable to the real machine.

1.3. COLLABORATION WITH UNIVERSITIES AND RESEARCH CENTRES

The activities on tracking studies at collision energy have so far been split into effects of non-linear magnet errors studied at the John Adams Institute, University of Oxford (UK) and CERN (international organisation), as well as beam-beam studies conducted by the EPFL (Switzerland). A collaboration of these institutes has already produced a single study combining both effects. This study should be used as a basis for a systematic scan of the phases between the high luminosity interaction points in order to maximise the dynamic aperture.

2. OPTIMIZED RUNNING SCENARIO

2.1. MOTIVATION

Large parts of the studies conducted on the interaction region have assumed a static setup with constant $\beta^*$and constant crossing angles. Only recent beam stability studies have shown the need of a collide & squeeze scheme. A squeeze scenario was developed to mitigate stability issues. However the shrinking of the emittance due to radiative damping, as well the intensity burn-off open up possibilities to modify this squeezing scheme in order to increase the luminosity production.

2.2. OBJECTIVES

The goal is to arrive at an operational scenario that is optimized for luminosity production under the premise that the optics at the interaction point change dynamically with the evolution of the beam parameters.

2.3. DESCRIPTION OF WORK

The main way of increasing the luminosity production per run is to squeeze the beat function at the IP β^*below the current “ultimate” parameter of 0.3 m. While the aperture of the final focus triplet already allows smaller β^*, the parameters of the arc sextupoles were chosen to compensate the chromaticity of the Ultimate optics. In order to squeeze beyond the ultimate β^* without significant changes to the arcs it is worth to study the possibility of an HL-LHC-like Achromatic Telescopic Squeezing scheme (ATS). Another point is the radiation load from collision debris in the triplet: While it appears manageable in the static case, it is strongly connected to the crossing angle. Consequently squeezing beyond the ultimate β^*should not increase the angle. The dynamic adaption of the crossing angle to the shrinking emittance and intensity should not only allow for smaller β^* with the same triplet aperture but also allow to keep the radiation load in the final focus triplet constant or even decrease. Thus the optimization comprises 4 tasks:

1. Development a scheme for the reduction of the crossing angles as the transverse emittance and the beam intensity evolve during the run
2. Study the possibility and effectiveness of an HL-LHC-like Achromatic Telescopic Squeezing scheme (ATS) in order to
3. Explore the reduction of β^* below the ultimate parameter of 0.3m in the later stages of the run
4. Quantify the change of the radiation load as the crossing angle and β^* (and consequently the luminosity) evolve over the run and arrive at a more realistic estimate for the long term exposure per integrated luminosity

Task 1) mainly comprises of beam-beam studies with changing emittance and intensity. It should ideally result in a minimum normalized beam to beam separation as a function of the emittance and intensity in order to allow modelling a beta squeeze scenario.

Task 2) should result a toolkit to use an ATS scheme in the FCC-hh. Also it should give a minimum β^* at which the chromaticity can still be corrected in order to set a technical limit for the beta squeeze.

Task 3) should arrive at a squeezing scenario optimizing the luminosity production rate while adhering to the limits obtained from tasks 1) and 2).

Task 4) will keep the estimates of the radiation load up to date with the evolving operational scenario. It should also check whether small changes in the operational scenario might reduce the radiation dose for the full integrated luminosity below the damage limit, making a magnet replacement unnecessary and thus potentially reducing the duration of long shut downs.

2.4. COLLABORATION WITH UNIVERSITIES AND RESEARCH CENTRES

The responsibility for the beam-beam studies of Task 1) should remain with the EPFL as it has before. The development of an ATS scheme should happen in close collaboration between CEA of and CERN. These two institutes have both involvement in the development of the FCC-hh lattice and expertise in the ATS scheme of HL-LHC. Work at CERN has already provided the basis for the tasks 3) and 4) making it the ideal candidate for further work in that direction.

3. IMPACT OF HTS ON IR DESIGN AND LUMINOSITY

3.1. MOTIVATION

The application of High Temperature Superconducting (HTS) materials for accelerator magnets is a promising option to increase the magnet strengths. From the view of the interaction region design, the most important applications are the the arc sextupoles needed for chromaticity correction that are currently the bottleneck to reach smaller β^*, as well as the final focus triplet quadrupoles that could arrive at stronger gradients or larger apertures, thus reducing the minimum β^* further or reducing the maximum beta functions, increasing the dynamic aperture.

3.2. OBJECTIVES

Efforts should be made to come up with designs such magnets in order to get reasonable estimates for the achievable field strengths for arc sextupoles and larger aperture triplet quadrupoles. With this information the lattice of the interaction region can be improved and the gain in luminosity estimated. The impact of the radiation debris from the collisions on the HTS magnet should closely monitored. The latter will likely require studies of the quench limits of the HTS material.

3.3. COLLABORATION WITH UNIVERSITIES AND RESEARCH CENTRES

Experts at CEA Saclay have suggested the development of HTS magnets for the triplet region, making this institute a good candidate for collaboration on this topic. The integration of the magnets in the IR and arcs should be done in close collaboration of the by the WP3 group at CERN and the WP1 optics experts from CEA.