



1st FCC-hh design meeting

Thursday 15th September 2022, 14:00 – 15:30

Chair: Massimo Giovannozzi

Speakers: Wolfgang Bartmann, Massimo Giovannozzi, Gustavo Pérez Segurana

Participants: Wolfgang Bartmann, Massimo Giovannozzi, Katsunobu Oide, Gustavo Pérez Segurana, Thys Risselada

AGENDA

Meeting actions	1
General introduction (Massimo Giovannozzi)	1
1. Layout and optics for PL (Gustavo Perez Segurana)	3
2. Layout and optics for PB (Wolfgang Bartmann)	3

MEETING ACTIONS

Massimo to seek further input about the choice of into which aperture Beam 1 should be injected in PB.

Gustavo to compile a table of hardware parameters of the injection system in PL to compare to PB.

GENERAL INTRODUCTION (MASSIMO GIOVANNOZZI)

Massimo introduced this series of meetings that have as objective the review of ongoing activities related to FCC-hh and the sharing of information between contributors. This meeting series will take place every 4-6 weeks depending on needs and the nominal time slot is Thursday 2 pm-3:30 pm.

A series of short-term goals were presented in the context of the mid-term review of the FCC study taking place during the second half of 2023 and the 2023 FCC Week:

- Updated FCC-hh layout under the baseline scenario, including the injection lines.
- Integration study of the injection lines in the FCC tunnel.
- Completion of the design of the collider optics with new designs for collimation and extraction/dump insertions.
- Development of R&D plans, schedule, and deliverables for Nb3Sn, high-temperature superconducting (HTS) and hybrid magnets for FCC-hh

A summary of the on-going activities followed.

With regards to the transfer lines in the ring tunnel, there was an attempt to change the geometry of the jumper to reduce the vertical separation between the plane of the circulating beam and that of the transfer line. However, this did not seem efficient due to a great increase in complexity design for a marginal gain. The magnet design of dipoles and quadrupoles for the transfer line consists of two options: normal-conducting and permanent magnets. Next step is to finalize the design and attempt a costing.

On the topic of the optics design of the FCC-hh ring, there has been great progress on PB and PL (see other talks presented below). Dogleg geometry has been reviewed for PF and PH with preliminary loss maps produced, to be followed up including the collimators in PB. A study is being carried out aiming at optimizing the regular cell length and the dispersion suppressors. Lastly, the alternative combined-function optics layout study is progressing, studying the damping properties of the lattice.

All the current studies are based on the V1.0 layout, which will be shortened by 68 m to match the harmonic number of FC-hh and its injector. As a result, the 2160 m insertions will be reduced to 2143 m. After completion of the studies for the V1.0 layout, the change to the V2.0 should be easy to do.

The question of in which aperture the beam is injected in PB (inside or outside) remains open with no arguments presented to decide.

Studies regarding the beam screen are ongoing regarding multipoles generated by the HTS coating layout, its behavior during a quench, and its operating temperature to minimize power consumption.

Discussion:

- **Wolfgang** asked if there had been any input from machine protection on the discussion of which aperture corresponds to the beam injected in PB. **Massimo** responded in the positive and that so far, no arguments had been presented either way from machine protection experts. Additionally, since many target parameters are kept similar to those of the CDR, it is still unclear what (if any) new particular points would be of concern for machine protection. It was agreed to rediscuss with a finalized layout to review any general potential issues.

1. LAYOUT AND OPTICS FOR PL (GUSTAVO PÉREZ SEGURANA)

Gustavo presented the design of the PL insertion hosting the injection for Beam 2 and the RF section.

The injection is purely vertical, as we are assuming the transfer line geometry will follow that of the arc directly below its corresponding aperture. Furthermore, the optics of the transfer line and that of the arc underneath will perfectly match. Notably, this insertion consists of the injection section (with space for the downwards bend of the injected beam, space for the septa magnets, kicker and TDI), two doglegs to change the intra-beam distance for the rf cavities, and matching sections at either end to match to the dispersion suppressors.

Optics and horizontal dispersion were presented, highlighting the fact that the doglegs have been made achromats. The geometry of the injection section was presented in more detail showing the margins kept for the apertures and element strengths fall within the specifications from the CDR as well as the constraints related to the TDI ($\sqrt{\beta_x\beta_y}$ and phase advance).

Finally, checks with respect to the beam aperture and quadrupole settings were presented.

Discussion:

- **Wolfgang** asked if the injection line is achromatic. **Gustavo** responded that it is not achromatic and will add the impact of the leaking vertical dispersion to future analysis.

2. LAYOUT AND OPTICS FOR PB (WOLFGANG BARTMANN)

Wolfgang presented the design of PB hosting the injection of Beam 1 and dump systems. These two systems were shown to be combined in the 2.16 km straight section with more complicated hardware, failure scenarios and operation; but with no fundamental performance limit identified.

The design of PB pivots around overlaying the constraint optics between kicker and absorber for both injection and dump systems. Consequently, the most critical failure would be at injection, which would impact all extraction elements.

The kick strength factor has been reduced by a factor of 1.8, which also reduces the miss-kicked trajectory offset. HW parameters for the extraction are not far from the CDR, except for apertures. The impact of an injection failure scenario results in 5 mm extra MKD clearance, 27 mm extra at quadrupole and MSD protection will need careful design.

Next steps for the development include studies of different failure scenarios of injection and extraction elements, including global machine protection studies; cross-checks on hardware parameters between IPB and IPL, iterating designs to aim for a single type of injection hardware and compile a list of HW parameters to check for impact on previously chosen technologies and generate a rough cost estimate.

Discussion:

- **Wolfgang** noted that although both IPB and IPL MKI deflections had been reduced with respect to the CDR values, in their current design would require different kicker designs highlighting a first iteration objective. **Massimo** asked whether the quadrupoles strength has been checked against specifications and the aperture is within specs. **Wolfgang** replied hinting at the need of a final verification of these two aspects.

Reported by Gustavo Pérez Segurana