Chapter 1

Operation concept

1.1 Operation and performance

1.1.1 Filling patterns

Hannes

1.1.2 Bootstrapping injection scheme

Xavier + Hannes

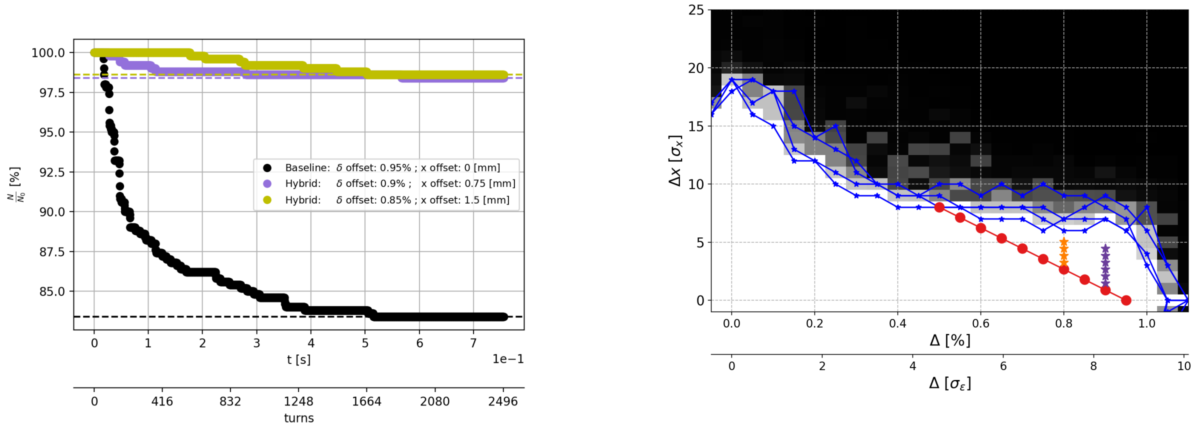
Including the Bartosik-Carli injection scheme for e-cloud mitigation in booster and collider, which is our new baseline

1.1.3 Top-up injection

Y. Dutheil status first draft, to be discussed with ABP

The top-up injection scheme described in Sec. **??** was simulated assuming a perfect lattice, with no consideration of collective effects or machine imperfections. However, in practice, lower than expected injection efficiencies and significant penalties on injection performance at higher circulating currents have been major challenges at other lepton colliders [**?**, **?**].

While the baseline injection scheme has a unique setting for on-axis injection, it is possible to use a hybrid injection scheme in the range of injected beam energy offset between $0.7\,\%$ and $0.95\,\%$ (see Fig. **??**). The hybrid injection scheme has to maintain a constant physical distance between injected and circulating beam at the injection point due to the septum thickness. While the optics remains unchanged, this results in a geometrical condition in the DA-MA plane which is represented as red dots in Fig. 1.1b. Above and to the right of this line, injection is physically possible but limited by DA and MA. Below and to the left of this line the injection is geometrically not possible.



(a) Scan of injection efficiency for different betatron offsets.

(b) Quarter quadrant representation of the DA/MA with markers denoting the injection settings modelled.

Fig. 1.1: Collider injection efficiency at various betatron offsets for the hybrid injection scheme and their corresponding location in the DA/MA for the Z mode.

The injection efficiency for different hybrid schemes, different betatron offsets, is simulated and the most promising results, showing improved efficiency over the baseline (on-axis injection), are plotted in Fig. 1.1a. In these simulations, the weak-strong model of the beam-beam interactions is used. Figure 1.1b shows that a range of injection settings are possible between the geometrical constraints represented as the red dots and the DA and MA limits of the lattice shown as the blue lines [**?**].

This validates the feasibility of the present injection concept, but in the absence of comprehensive tracking that includes both errors and collective effects it is not possible to assure at this stage that high injection efficiency can be reached and maintained up to nominal intensity. Therefore, the present feasibility study establishes an injection efficiency goal of 80 % based on the status of the concept and experience from other facilities [**?**, **?**]. This injection efficiency goal is used in the feasibility study for the sizing of injector chain, see Tab. Hannes parameter table.

1.1.4 injection requirements

The top-up injection scheme strongly relies on an injected beam considerably smaller than the circulating one (see Fig. **??**). This beam size provided by the booster (see Tab. ref to hannes table must be maintained up to the nominal intensity, but also along all the bunches of the injected trains, and over time. The beam transfer systems for both the booster extraction and collider injection have to ensure a high level of stability and reproducibility to prevent beam jitter from increasing emittances and reducing injection efficiency.

1.1.5 Refilling after abort

Hannes + Jacqueline

1.1.6 Optics commissioning strategy

Ballistic optics etc, flow chart. **Rogelio + Jacqueline+Christian**

1.2 Changing operation modes

1.2.1 Switching between Z, WW, and ZH modes

Ivan + Ghislain

The ability to easily switch between Z, WW and ZH modes of operation depends upon some conditions and requirements.

The 400 MHz cavities and cryomodules must all be installed in their final location from the start of operation; this represents 33 cryomodules on either side of Point H. This is a constraint for the early procurement and installation of all cryomodules but could be advantageous to avoid staging the installation of the cryogenics systems and to avoid later interventions in the tunnel for installation of cryomodules.

At the Z and W operating points, the incoming beam from the arc is coming from the outer aperture and first goes through the 33 cryomodules on the incoming side of the insertion; it is then deviated towards a bypass line that goes around the other 33 cryomodules on the outgoing side of the insertion, before being brought back towards the inside aperture of the outgoing arc. Hence the two counter-rotating beams are crossing at the middle of the RF insertion.

With the scheme of reverse phase operation for the 400 MHz RF, the switch between the Z and WW modes of operation involves only a reconfiguration of the RF system; the beamlines and beam paths stay the same.

The crossing of the beams in the middle of the insertion is done over a long length to avoid string dipole bends that could generate synchrotron radiation towards the cavities. The adverse effect of this shallow horizontal crossing is that the electron and positron beams share a common vacuum chamber over a certain length, which, in turn, generates long-range beam-beam interactions that would be very detrimental at the Z and WW modes of operation. For this reason, we have proposed that the horizontal crossing should be supplemented by a vertical bump in opposite directions for both beams, such that they can be in separate vacuum chambers over the horizontal crossing avoiding all long-range beam-beam interactions.

The separation scheme and recombination at the Z and WW operating points involve only magnetic dipoles; the only point of attention being that the dipoles should not generate synchrotron radiation towards the RF cavities and ancillary equipment and that any synchrotron radiation generated should be minimal, both in terms of power radiated and critical energy of the photons.

1.2.2 RF upgrade for $\mathrm{t\bar{t}}$

Franck+Ivan

1.3 Operation requirements

1.3.1 Physics requirements

1.3.2 Target availability and efficiency

1.3.3 Machine protection requirements

1.3.4 Initial alignment and field error tolerances

1.3.5 Beam-based alignment, optics correction, emittance and IP tuning

1.3.6 Beam diagnostics requirements

1.3.7 Injection requirements

1.3.8 Vacuum tolerances

1.4 Availability

1.4.1 Simulation Model

1.4.2 Performance of the Baseline Design

1.4.3 R&D Opportunities

1.5 Operational Model

1.6 Preliminary requirements on technical systems