CSR mitigation in the FCC-ee injector bunch compressor

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Abstract

Coherent Synchrotron Radiation (CSR) encountered in the FCC-ee injector bunch compressor can lead to transverse emittance dilution, undulating some of the emittance reduction from the damping ring. The bunch compressor is required to reduce the RAMS bunch length from 5 mm to 0.5 mm, prior to injection into the linac. This is achieved through a dogleg comprised of two triple-bend achromats (TBA) tailored to accomplish the compression. Despite the fact that the final bunch length is relatively long compared to FEL linacs (for example, where CSR is a commonly encountered problem), CSR is still capable of increasing the transverse emittance by 30% if left unchecked. Through careful optics design, the CSR-kick encountered in each dipole can be cancelled and the CSR-induced emittance growth can be significantly reduced.

FCC-Injector Bunch Compressor

Immediately following the second turnaround loop, before the beam is injected back into the linac, the bunch is compressed from 5 mm to 0.5 mm. The possibility of using one or both of these turnaround loops for bunch compression was investigated however the impact of CSR-induced emittance growth was unmanageable, without the inclusion of CSR compensation schemes such as those described in References [1-4]. Instead the required bunch compression is performed by dogleg bunch compressor. By delaying the bunch compression, and leaving the bunch length to be longer in the turnaround loop, makes the bunch less susceptible to CSR effects.

- Isochronous and achromatic loops (after damping ring and near 1.5 GeV section of linac)
- Followed by accelerating structure and dogleg compressor

Bunch compressor

```markdown
<table>
<thead>
<tr>
<th>Section</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 GeV</td>
<td></td>
</tr>
<tr>
<td>Turnaround loop</td>
<td></td>
</tr>
<tr>
<td>Acceleration structure</td>
<td></td>
</tr>
</tbody>
</table>
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This layout has three benefits:

1. It allows for a reasonably large R56 value.
2. There is no parasitic compression.

- Sadmodolos strengths optimized for chromaticity, rather than for T56E. However the resulting T56E is close to optimal anyway. Therefore there is no need for a harmonic cavity.

4. ABB bunch length strong dogleg.

References:


CSR Mitigation

After passing through all of the dipoles, the off-momentum particles (in each slice) return to the initial trajectory. Therefore, minimizing the emittance growth.

- A bunch compressor was present for the FCC-ee injector. Notably, the bunch compressor is a dogleg bunch compressor comprised of two TBAs, for a positive $\nu_{BC}$ and favorable $\nu_{T56}$.
- CSR kicks encountered in each dipole can be cancelled to large extent, reducing the CSR-induced emittance growth from 85.8% to 6.8%.

Conclusion

- The aim to reduce the total kick at the end of the BC.
- Below is the CSR kick $\Delta \nu_{x}$ and $\Delta \nu_{x'}$ from dipole 1 propagated to the end of the dipole.
- This variation in the slice Twiss parameters creates a different mean kicks in $\nu_{x}$ as shown in Fig. 5. In addition, the slice variation in the beta function can create atypical CSR kicks.
- CSR kicks in a propagated to the end of the dogleg.

Atypical CSR kicks encountered in dipole 2 and 5 due to slice variation in $\nu_{x}$.

- Slice variation of dipoles 2 and 5.

Below is the kick $\Delta \nu_{x}$ from dipole 6 and 7, which are in the dogleg.

- The non-zero dispersion and energy chirp, creates a variation in slice twiss parameters in the middle of each TBA.

- This variation in the slice Twiss parameters creates a different mean kicks in $\nu_{x}$, as shown in Fig. 6. In addition, the slice variation in the beta function can create atypical CSR kicks.
- CSR kicks in a propagated to the end of the dogleg.

References