Simulations and Studies of Electron Beam Dynamics under Compton Back-scattering for the Compact X-ray Source ThomX

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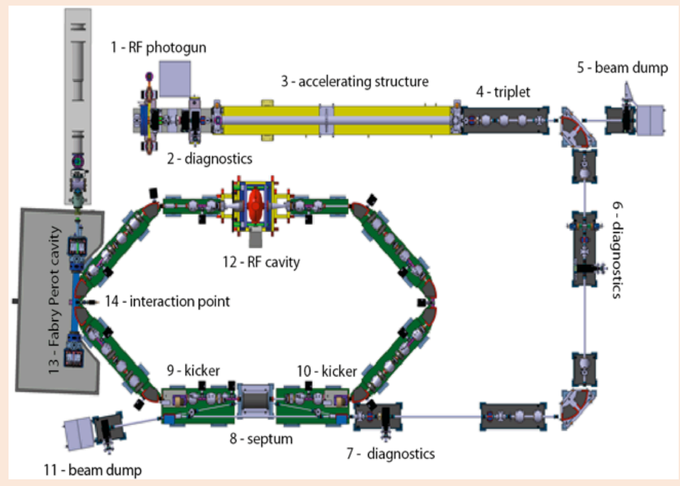
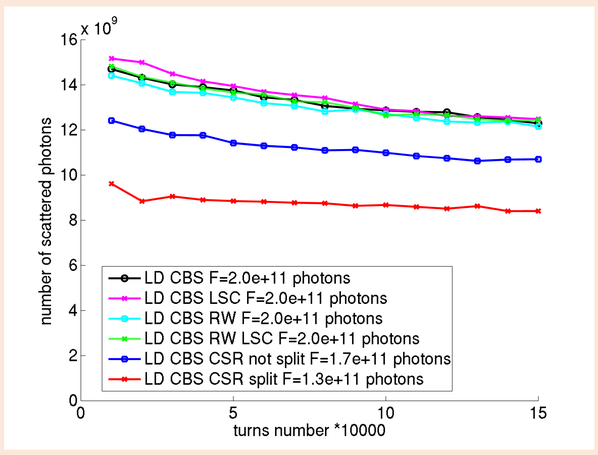
Introduction

ThomX is a project of compact X-ray source based on the Compton scattering of laser photons and relativistic electrons. The electron bunch with an energy of 50 MeV is injected in the storage ring with a circumference of 16.8 m where it collides with laser pulses in a Fabry Perot optical cavity on each turn. The beam storage time is around 400000 turns, corresponding to 20ms. ThomX is a low energy storage ring with a relatively high density beam for a small accelerator. It is necessary to predict the beam dynamics of the electrons and the degradation of the X-ray flux of the scattered beam quality and the electron beam due to:

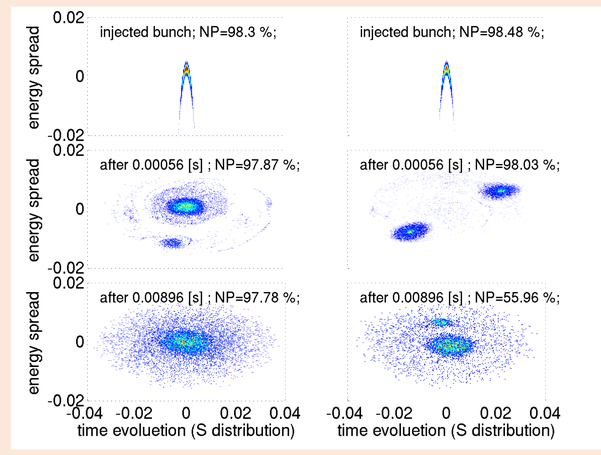
- Linear and non linear beam 6D tracking
- Collective effect
  - Space charge (LSC)
  - Resistive wall (RW)
  - Coherent Synchrotron Radiations (CSR)
- Compton Back Scattering(CBS)



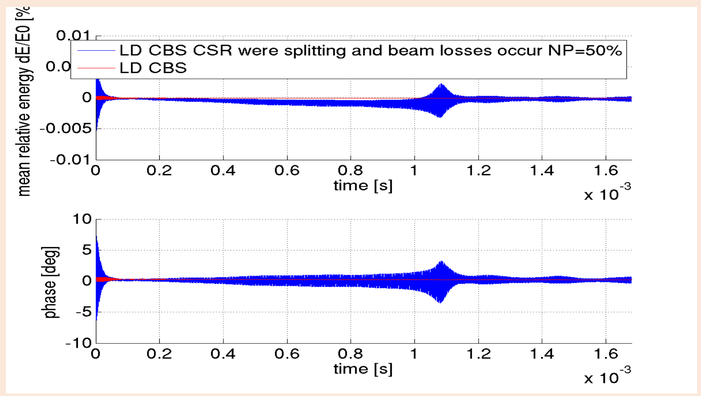
ThomX source layout.



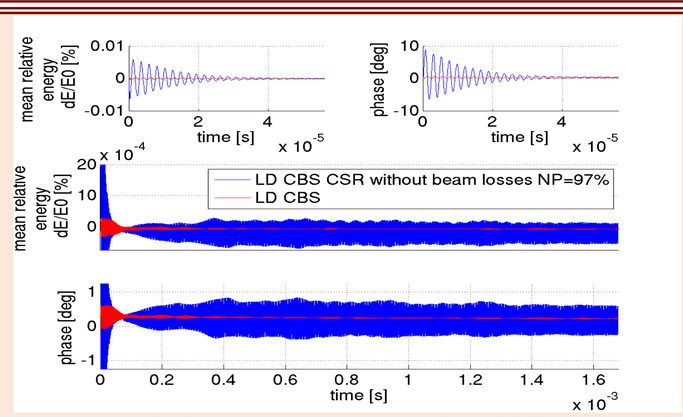
Compton backscattering flux for different beam dynamics effects. In the case of the CSR simulations, if the beam did not split 97% of the particle survived (blue) and 50% survived in the case the beam did split (red). F is the total flux integrated over 150000 turns.



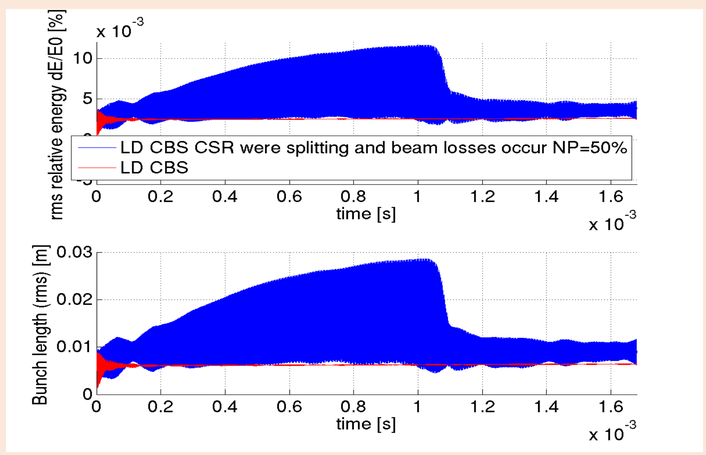
Evolutions of longitudinal phasespace. Left is for CSR without splitting and losses. Right is for CSR with split bunch leading to ~ 50% losses of particle.



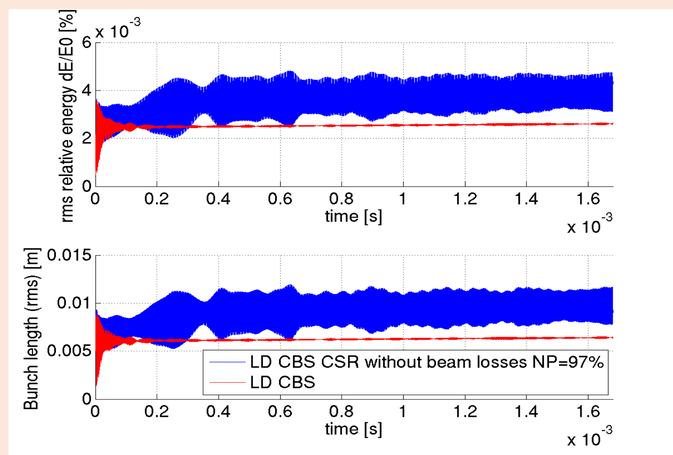
Oscillations of mean relative energy spread and phase of the electron beam in case of destructive effect of CSR wake field(blue) with simulations made without collective effect (red).



Oscillations of mean relative energy spread (middle) and phase (bottom) of the electron bunch over the total duration of the injection and zoom over the first 50 μs (top) with simulation effect of CSR wake field with simulations made without collective effect. NP is number of remaining macroparticles in %



Oscillations of rms relative energy spread and longitudinal bunch length of the electron beam in case of destructive effect of CSR wake field (blue) with simulations made without collective effect (red).



Oscillations of rms relative energy spread and longitudinal bunch length of the electron beam with simulation effect of CSR wake field (red) with simulations made without collective effect (red).

In this work we show the influence of collective effects on beam dynamics in the ThomX electron storage ring and their impact on flux of Compton scattered photons. The largest impact is the effect of Coherent Synchrotron Radiations (CSR) in the first turns. It has destructive effect and it increases the amplitude of oscillations and grows energy spread and longitudinal length of the bunch. To prevent this negative impact of CSR there are two possibilities. One of them is to reduce the initial charge of the injected beam but this will also reduce the flux. Another way is to operate the injection with different setting as: an energy offset to compensate the first turn CSR losses and running the linac slightly off-crest in order to fix the bunch lengthening and to escape from CSR risks. The last method gives us the possibility to damp the amplitude of oscillations and to relax destructive effect of CSR.