Tracking with Compton effect

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Introduction

To construct such X-ray generator as ThomX it is necessary to predict degradation of X-ray flux of scattered beam quality and electron beam due to such phenomena:

1. Collective effect
   - Space charge
   - Resistive wall
   - Coherent Synchrotron Radiations (CSR)
2. Compton Back Scattering (CBS)
   - Randomise effect on the electron beam energy
3. Damping is negligible
   - need of longitudinal Feedback

Creating a tool

To make this study was chosen code written by A. LOULERGUE. This code was includes such stuff like:

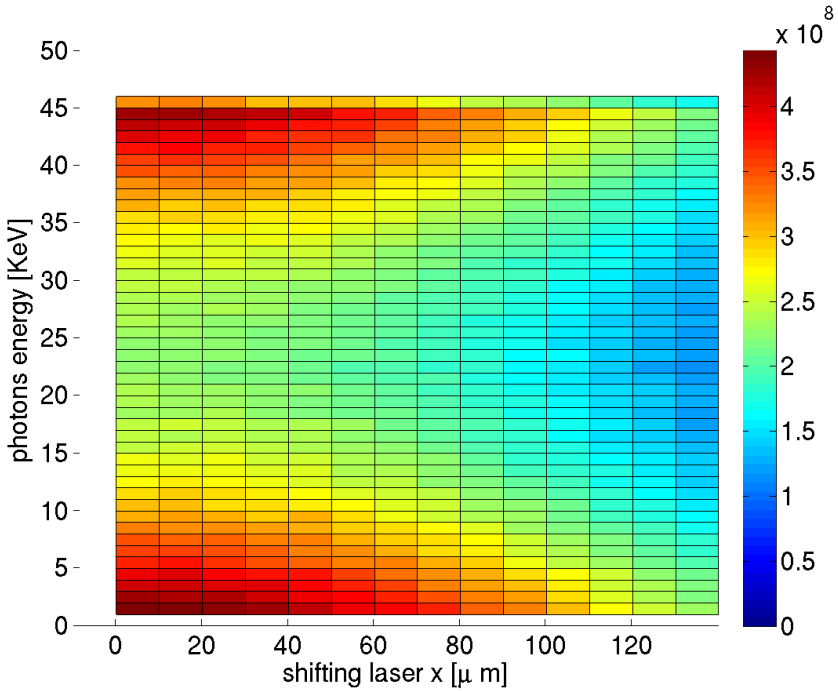
- Linear and non linear beam 6D tracking
- Collective effects

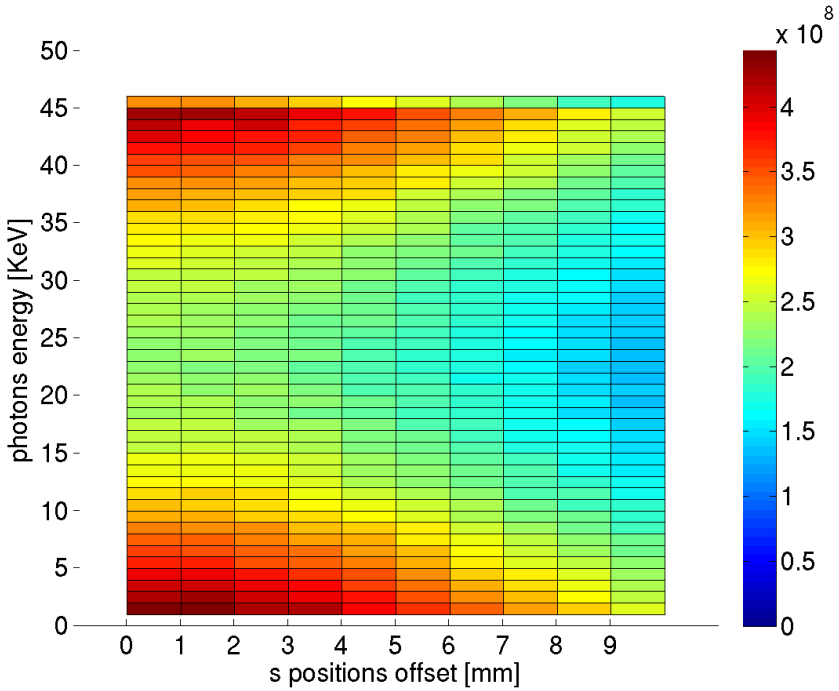
And on it was implemented some new functions for obtaining such phenomena as

- CBS based on code CAIN by K. Yokoya
- Intra Beam Scattering (based on Mtingwa model)
- Longitudinal Feedback
- Also was added shell for this code to have possibility run code in computational centres for almost unlimited turns number of beam in storage ring.

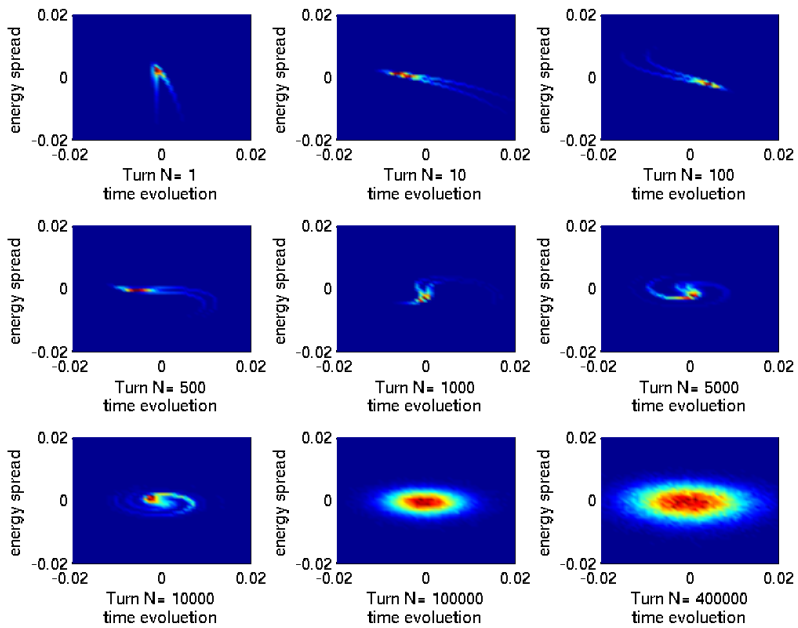
Like this we get powerful tool which give us possibility investigate beam dynamics in ThomX. And now we can look how non-linear dynamics with collective effect will influence the flux of scattered photons during CBS.

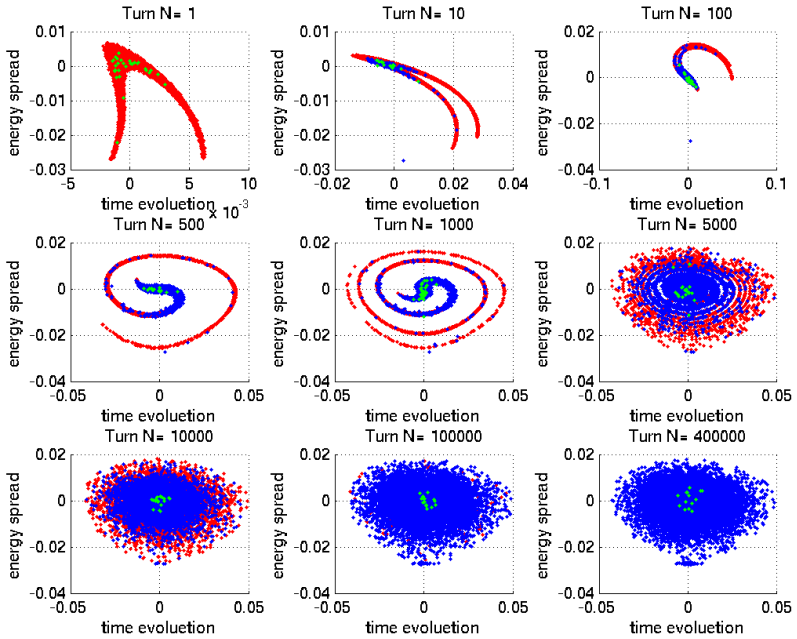
Possibility of the code



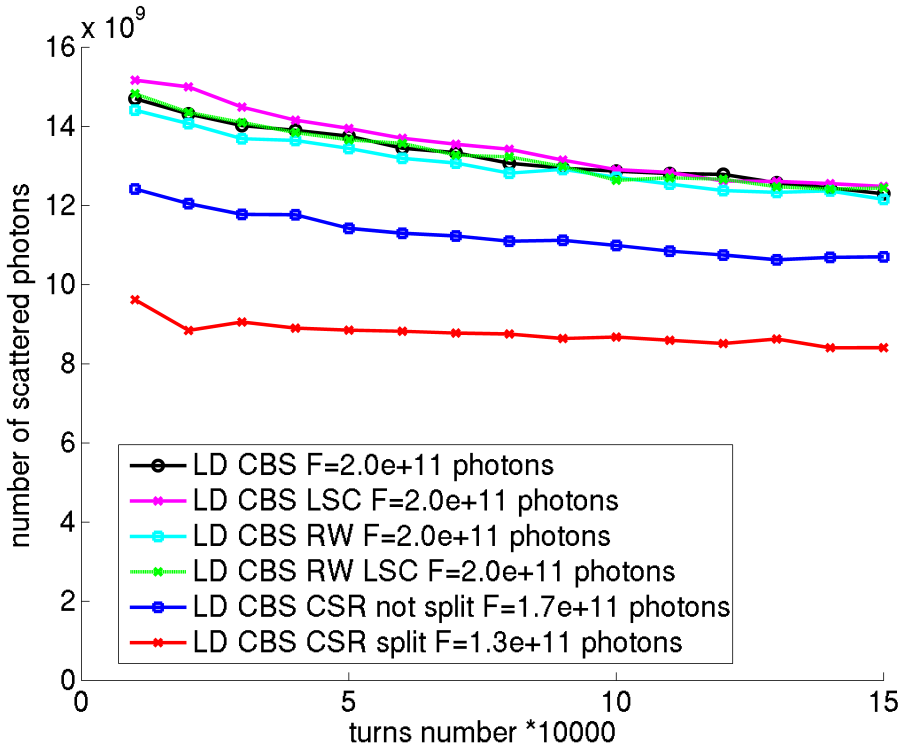


Possibility of the code





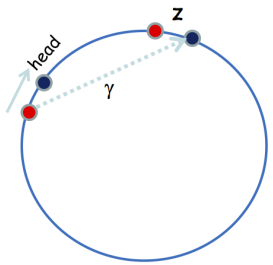
Like this we can see influence of different beam collective effects on a flux.



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.

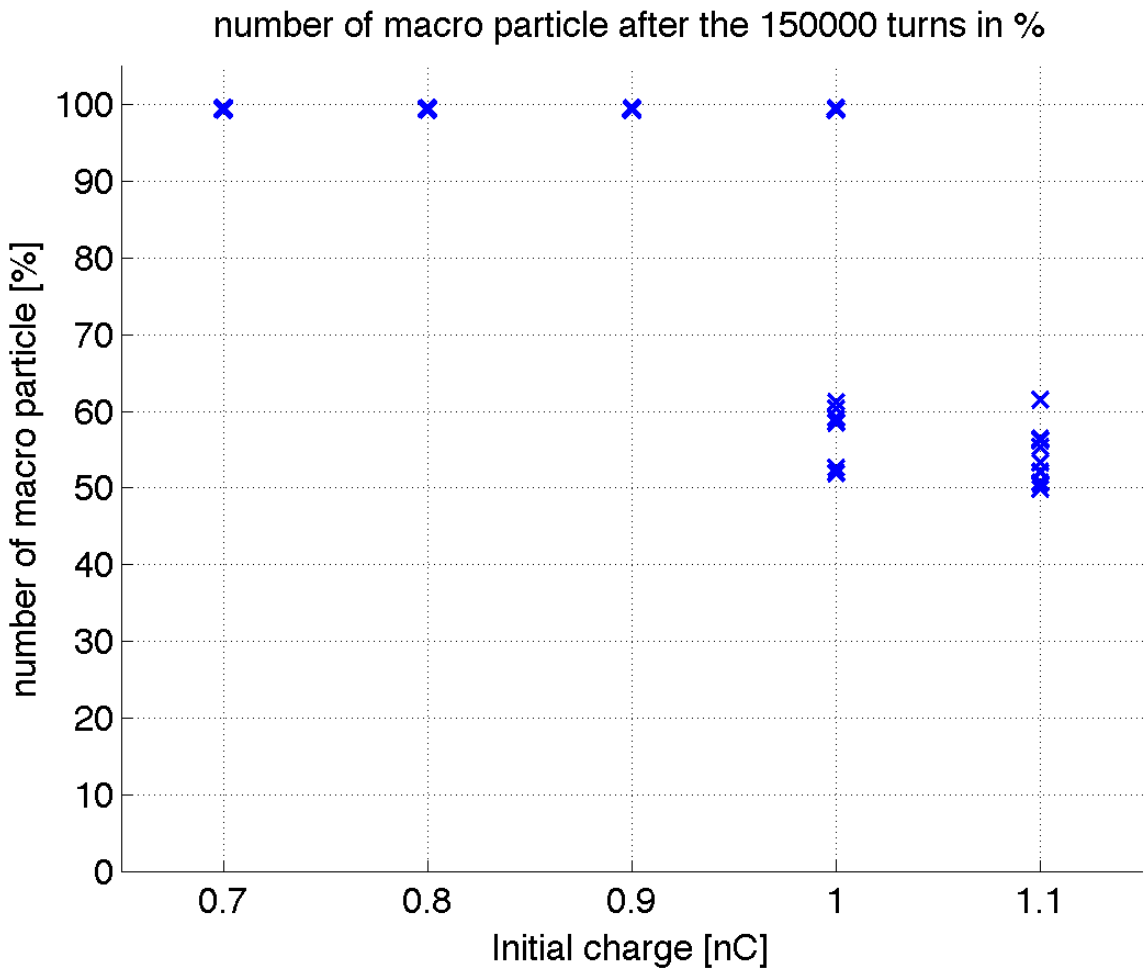
Coherent Synchrotron Radiations Instability (CSR)

CSR is a phenomenon that originates from coherent emission of electromagnetic waves radiated by ultrarelativistic electrons and create wake field that provide on beam instability. It start be significant when wavelength of Synchrotron Radiations becomes comparable with the size of the bunch. In case of ThomX $\lambda \approx 1[mm]$ and $\sigma_t = 4[ps]$

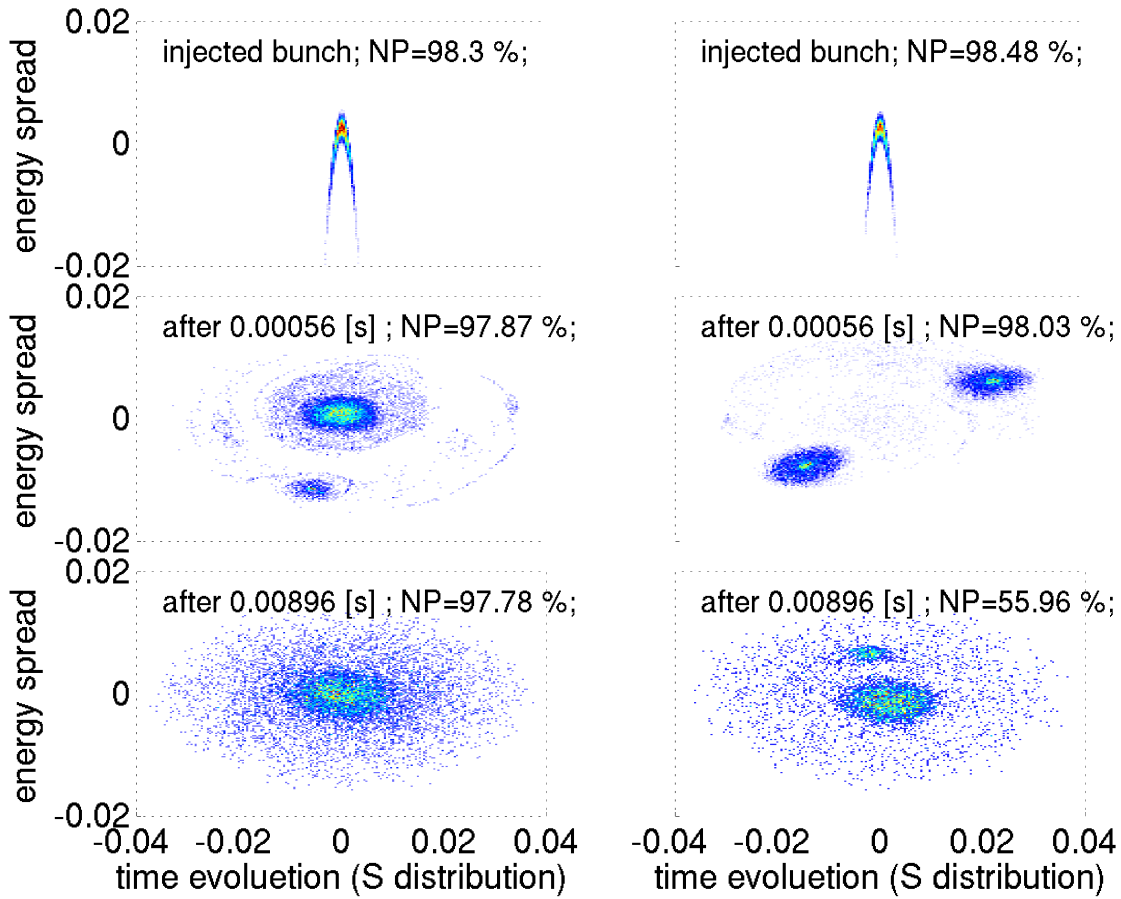


For simulations effect of CSR in free space we will take the electrical tangential field presented by Merphy and Krinsky $E_\phi = -\frac{4}{3}\frac{e\gamma^4}{\rho^2}\frac{d\nu(\mu)}{d\mu}$ and apply it as wake field to the bunch: $W(s) = \frac{e}{\rho^{2/3}}\left(-\int_{-\infty}^{\infty} ds' \frac{1}{(s-s')^{1/3}}\frac{d}{ds'}(n(s'))\right)$

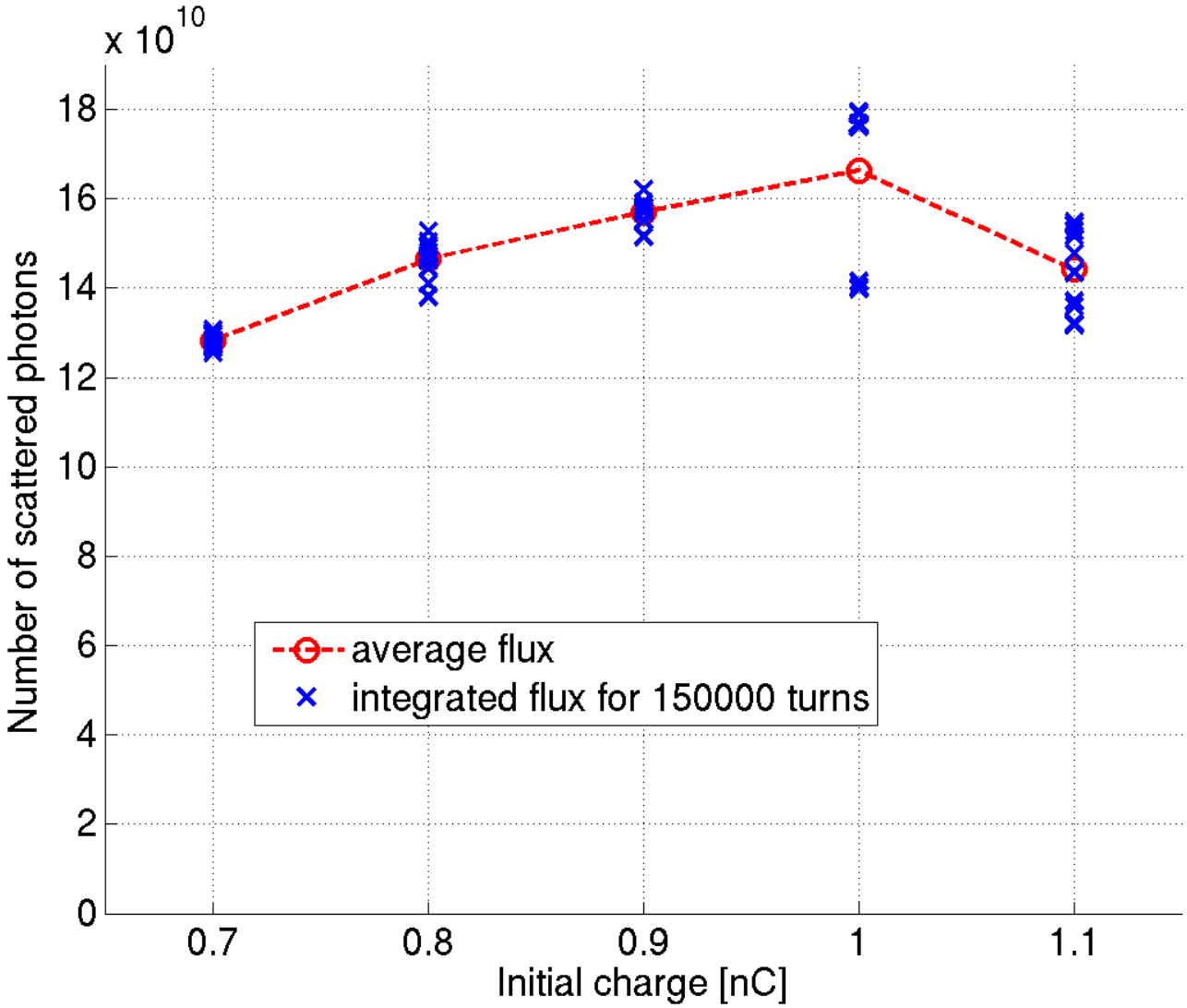
As we can see from formula value of influence of CSR linearly depend from initial charge of bunch. On this plots presented particle losses during tracking simulations for different initial charge of the bunch.



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



The number of Compton scattered photons for different initial charge of the injected bunch.

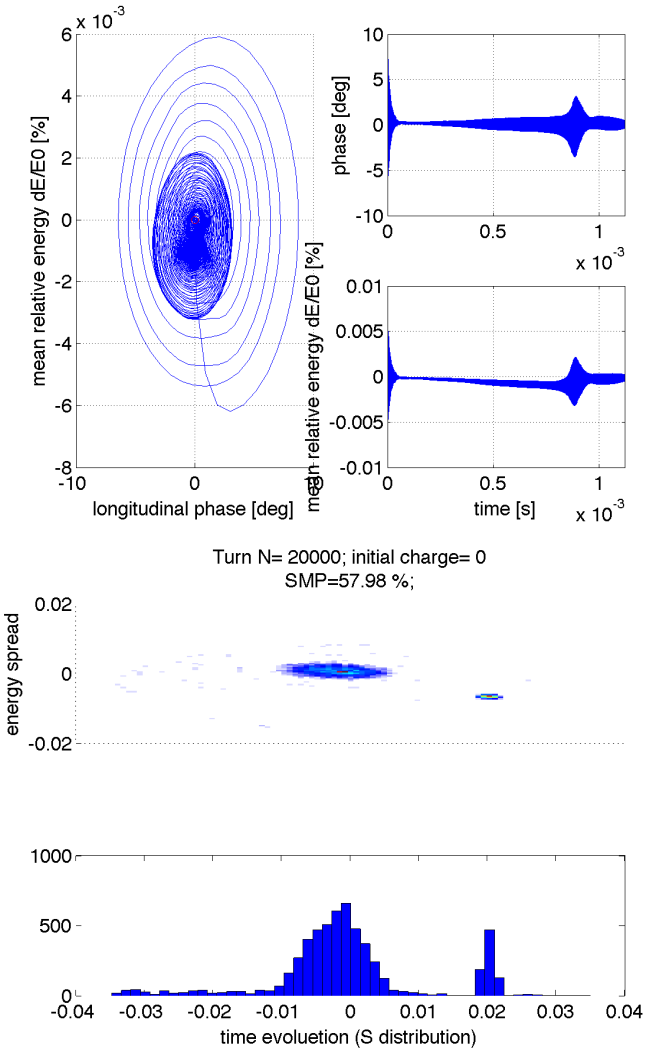


How to reduce destructive effect of CSR on the beam?

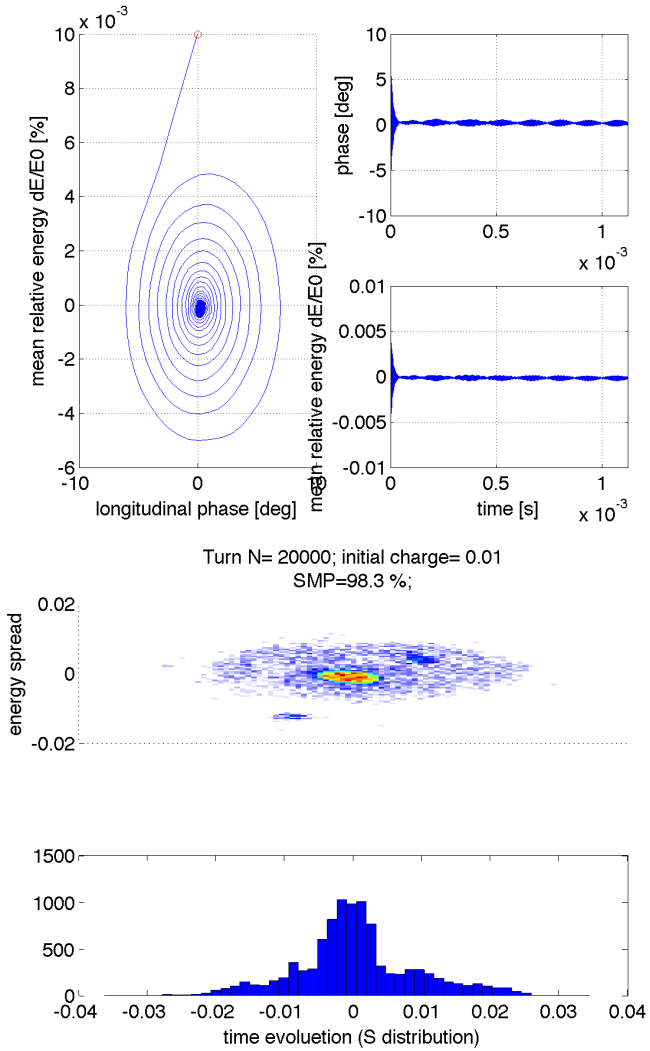
- Reduce the initial charge of bunch.
  - \+ Easy to realize.
  - \- Reduce flux of scattered photons.
- Add initial linac energy offset.
  - \+ Save flux of scattered photons.
  - \- Realizations depends of injections tuning of machine.

Influence of injection linac energy offset

energy spread offset = 0



energy spread offset = 0.01



Conclusion

As we can see phenomena of Coherent Synchrotron Radiation can have very strong effect on the stability of electron beam and as a consequence have influence on flux of scattered photons.

Future plans

- Optimise parameters for ThomX to maximise flux of scattered photons and stabilise beam.
- Continue investigations of other collective phenomena as:
  - Space charge
  - Resistivity wall

Thank for your attention.