A new program for multibunch beam dynamics in recirculating machines

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Abstract

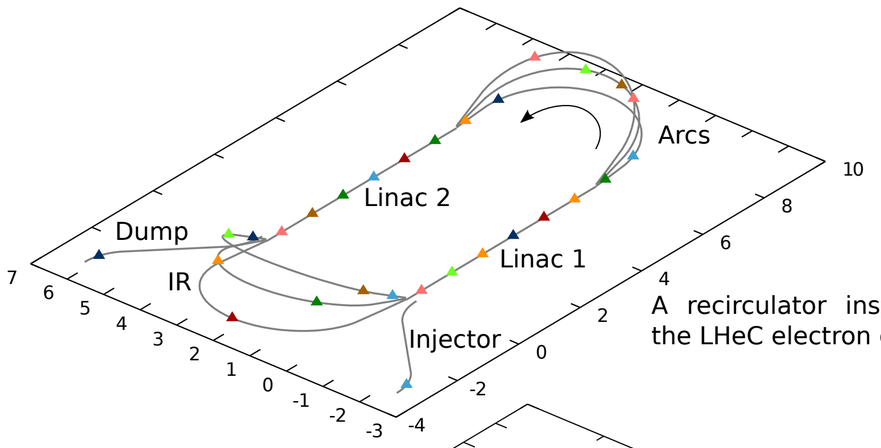
Multibunch beam dynamics plays an important role in defining the parameter space of modern particle accelerator machines. Long-range wakefields together with elements misalignments and jittering may cause the disruption of the beam.
The study of the multibunch beam dynamics is difficult in recirculating machine such as the drive beam complex of CLIC or the Linac-Ring scheme of LHeC, where bunch are shuffled along their path into the machine.
A new tracking code being developed at CERN allows to easily describe complex topologies and to correctly track particles. It's main features and first results will be presented.

Challenges in multibunch recirculation

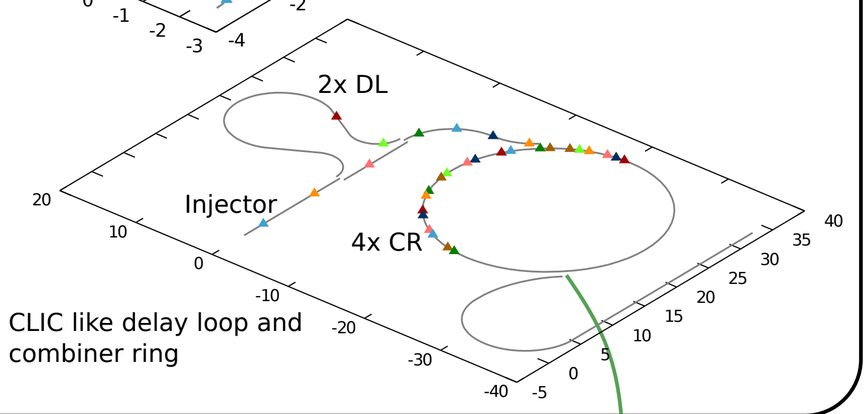
- How to describe a lattice?
- How to route the bunches through the correct elements when beamlines divide or recombine?
- How to preserve the bunch order and track multibunch effects?
- How to track in parallel taking advantages of the increasing number of coresin the CPUs without dropping collective and multibunch effects?

Main Characteristics

- 6D tracking code, for multibunch in recirculating machine, symplecticity is not needed.
- Entirely written in c++, using some of the c++11 advanced features.
- Allows a simple and modular description of complex recirculating lattices.
- Allows to track any train of bunches taking into account multibunch effects even when bunch are shuffled into a recirculating machine.
- Implements by design parallel computation taking advantages of big number of cores.
- Provides a graphical extension which allows to check the machine implementation and operation.



A recirculator inspired to the LHeC electron complex



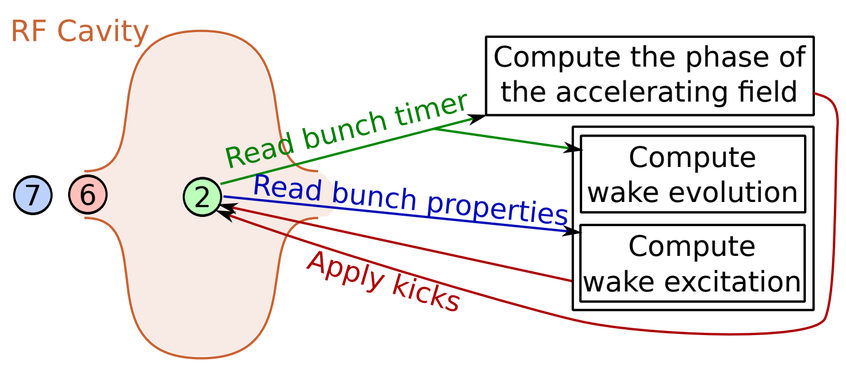
CLIC like delay loop and combiner ring

Time dependent elements

Each bunch keeps track of the absolute time since the machine was turn on.
When a bunch comes to an element, its timer can be read by the element so that it can set itself to the correct time:

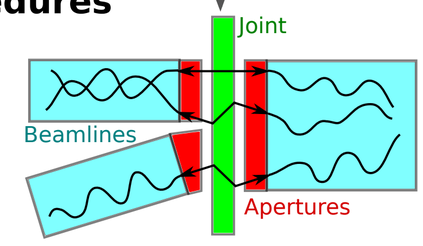
Select the correct phase of a cavity (deceleration in an energy recovery).
Apply the correct intensity at a kicker/deflector.
. . .

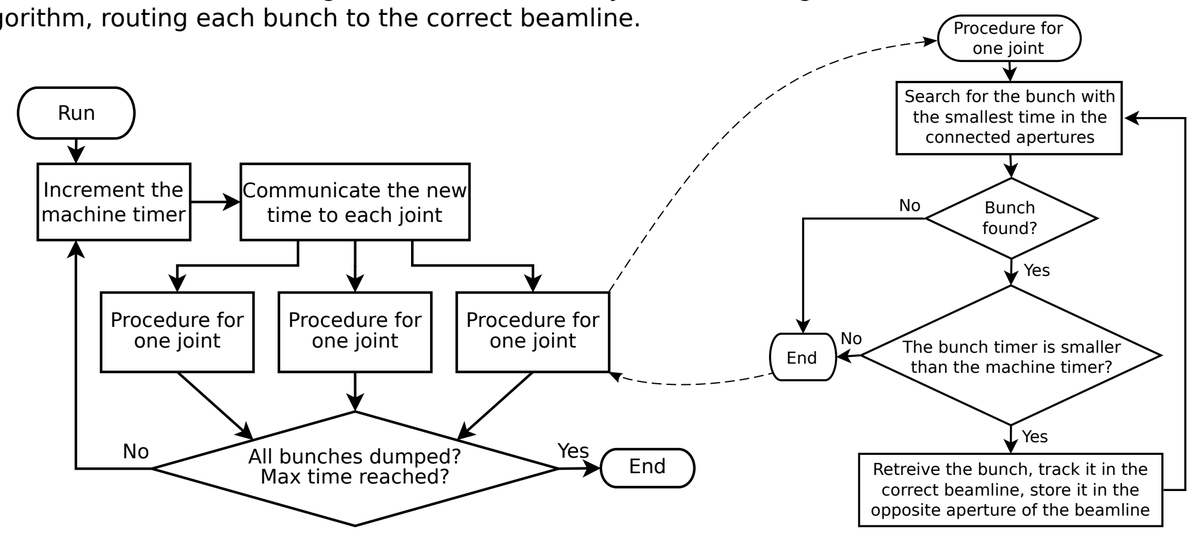
Multibunch effects are computable rigging each element with a memory of a state which is perturbed by the previous bunch and perturbs the following.



Lattice Description and Tracking Procedures

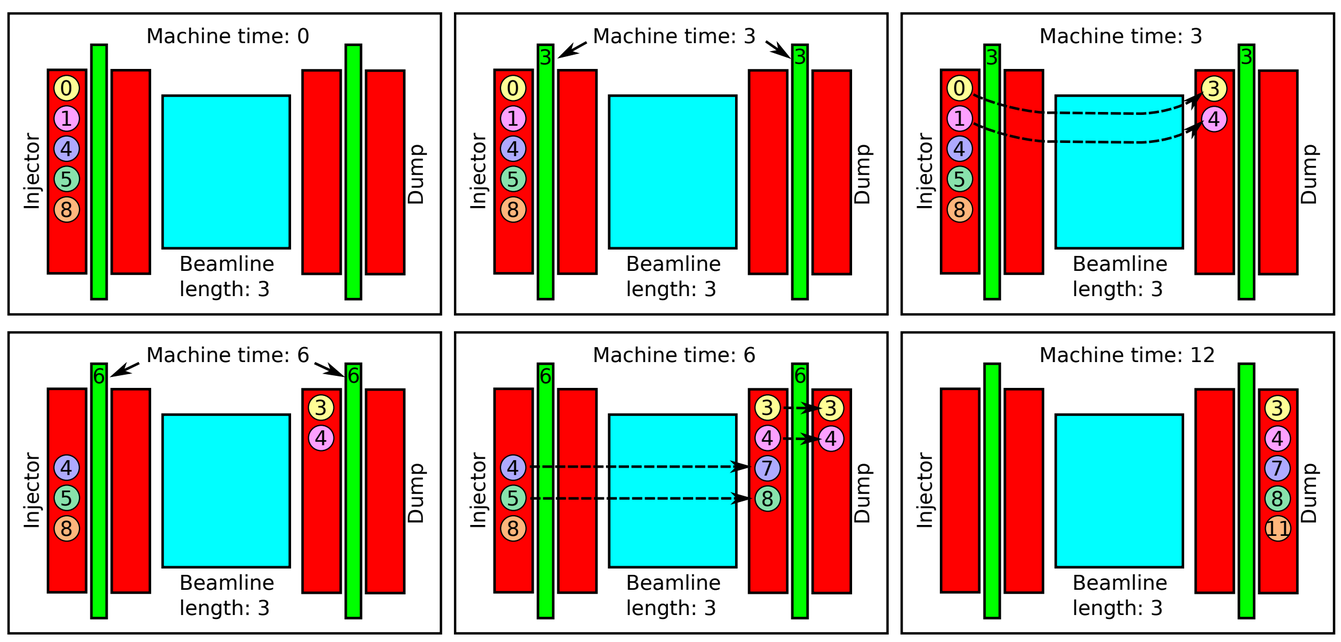
Sequences of elements are arranged in beamlines, easy to describe.
Beamlines can be attached together using apertures and joints.
Each beamline host an aperture at the beginning and one at the end. Apertures describe the positioning of the beamlines in the frame of reference of the joint. They also accumulates the bunches after the track in the correspondent beamline.
Joints connect beamlines together and are the key of the traking algorithm, routing each bunch to the correct beamline.





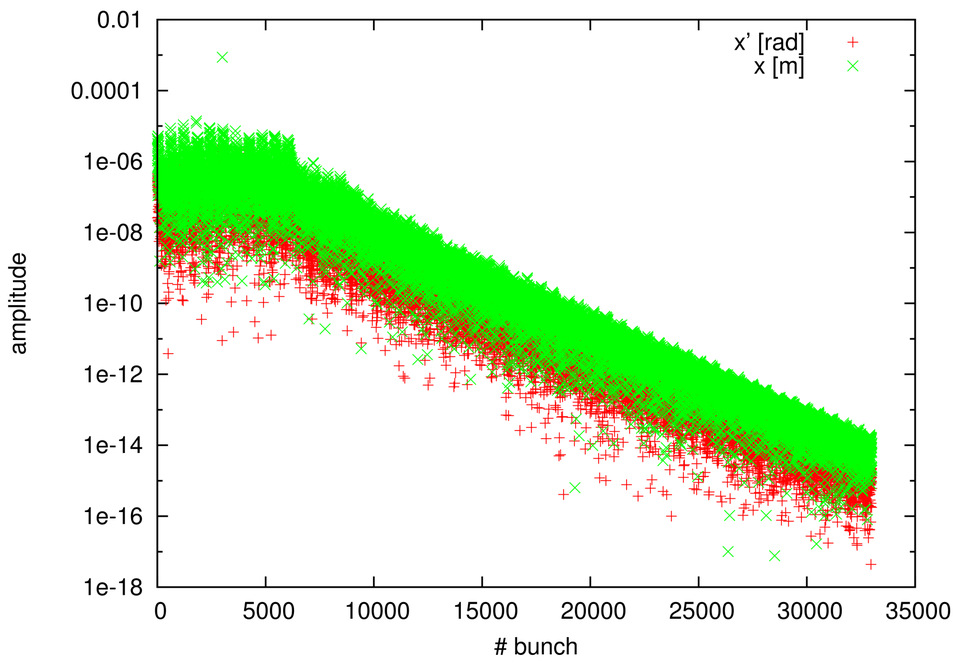
Machine Timing and Operation Example

- Each bunch contains a timer which refers to moment when the machine is turn on. Example: when the second bunch enters the machine its timer indicates the distance from the first bunch (it is possible to adjust the spacing between bunches at the injector, acting on their timers).
- Bunch timer is increased when they travels through lengthy elements.
- At each step the machine time is advanced by the time taken by the slowest bunch to travel the sorter beamline, this guarantees the bunch order to be preserved and allows to apply the advancing algorithm for each joint in parallel without further synchronisation.



First results: long range wakefield instability in the LHeC electron facility

In the LHeC electron complex 3600 bunches circulate at the same time. Bunches that are consecutive in space have turned the facility for different times, thus they have different characteristics (energy, phase-space shape, ...).
After having filled the machine with 3000 bunches perfectely aligned, the bunch #3001 is injected with an offset of 1 mm. The plot shows the amplitude of the bunches at the exit of the machine. Long-range wakefields propagate the excitation carried by bunch #3001 to all other bunches.
In this framework it's possible to test many values of beam current, varing both bunch charge and spacing, investigating the required detuning factor and verify if the excitation is damped or amplified, determining the beam stability.



Conclusions

A new tracking code for recirculating machines is being developed at CERN. Its main goal is to provide a tool for computing multibunch effect in complex topologies taking advantages from parallel processing.

The new concepts adopted have been proved to work and the stability of the electron facility of LHeC has been investigated. Efforts are being tacken to extend its functionality and flexibility, including more physical effects and improving the usability.