BLonD and its application to MC RCS RF system

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Beam Longitudinal Dynamics - BLonD

BLonD macro-particle tracking code has been developed at CERN since 2014.

Kick and drift equations:

\[ \Delta E_{n+1} = \Delta E_n + qV_n \sin(\omega_{RF,n}\Delta t_n + \varphi_{RF,n}) - (E_{d,n+1} - E_{d,n}) + E_{other,n} \]

\[ \Delta t_{n+1} = \Delta t_n + T_{rev,n+1} \left[ (1 + \alpha_{0,n+1}\delta_{n+1}) \frac{1 + \delta_{n+1}\beta_{d,n+1}^2}{1 + \delta_{n+1}} - 1 \right] \]

\[ \delta_n = \frac{\Delta p_n}{p_{d,n}} = \frac{\Delta E_n}{\beta_{d,n}^2 E_{d,n}} \]

Optimized and tested for various applications with a single RF station. → Multiple RF stations are required in MC RCS due to a large energy change per turn.

Plot from K. Iliakis et.al, BLonD++: Performance Analysis and Optimizations for Enabling Complex, Accurate and Fast Beam Dynamics Studies.
Multiple RF stations in BLonD

Ring object contains several section and each section has one RF system
Each section applies kick and drift:

$$\Delta E_{n+1} = \Delta E_n + q V_n \sin(\omega_{RF,n} \Delta t_n + \varphi_{RF,n}) - (E_{d,n+1} - E_{d,n}) + E_{other,n}$$

$$\Delta t_{n+1} = \Delta t_n + T_{rev,n+1} \left[ (1 + \alpha_{0,n+1} \delta_{n+1}) \frac{1 + \delta_{n+1} \beta_{d,n+1}^2}{1 + \delta_{n+1}} - 1 \right]$$

First identified issue: the step $n \rightarrow n + 1$ corresponds to one turn, not to one section!
Bunch will be immediately lost from the bucket

→ Redesign of BLonD modules (e.g., Ring and RF_station) is required
Possible but not realistic solution

Without redesigning BLonD one can define a ring with a circumference $C / N_{st}$ and use a single RF station only.
Drawback: intensity effects will not be properly modelled

Initial mismatch is due assumption of continuous synchrotron motion in the matching routine
Possible but not realistic solution

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Summary

Present version of BLonD needs to be modified to properly model longitudinal beam dynamics in MC RCS → redesign of *Ring* an *RF_station* objects is required

Inclusion of collective effects requires significant effort, in particular:

• short range wakes (RF cavities + RW impedance),
• long range wakes due to fundamental mode including possible feedback and feedforward systems (also impact of counter-rotating bunches)

After all can we properly separate longitudinal and transverse beam dynamics?
Thank you for your attention!