3D SYMPLECTIC SPACE CHARGE IMPLEMENTATION IN THE LATEST MAD-X VERSION

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We report on the advancement of the MADX-SC code finalized in 2018: featuring a 3D symplectic implementation, the use of the SigmaMatrix formalism to update the beam sigmas including the optics functions once every turn, i.e. we are considering the adaptive mode rather than the truly frozen mode. Details of the validity of the approximations are shown and the issue of noise due to the adaptive mode is discussed. Simulations have been re-done for the 2012 SC PS experiment (published 2017) and the results are compared with experimental results.
In the meantime, a significant effort has been performed to debug the complex implementations and a speed-up of a factor of 2 has been achieved. A porting of the code to the newest MAD-X version is completed and the manual has been adapted to the new code features.

3D SC Formalism

Potential

For a long bunch, $\sigma_z \gg \max(\sigma_x, \sigma_y)$, the space-charge potential can be factorized in a similar fashion

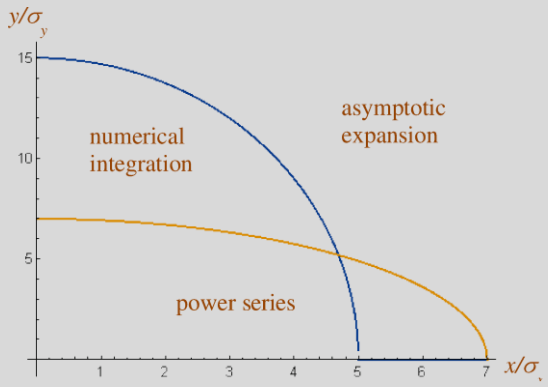
$$\phi(x, y, z, t) \cong \lambda(z - v_0 t) \cdot \Phi(x, y), \qquad (2)$$

where the two-dimensional potential function Φ can be presented in the form [7] [1]

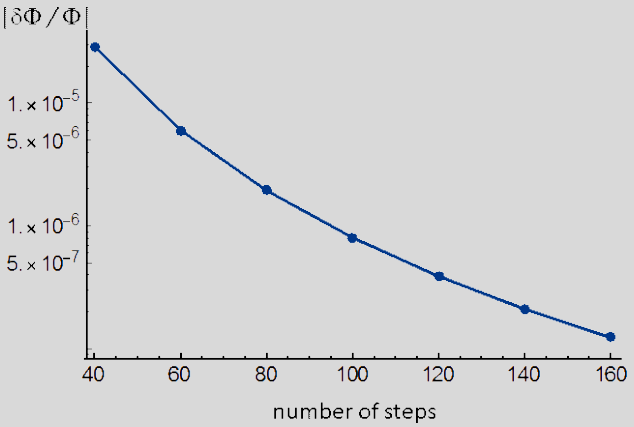
$$\Phi(x, y) = \int_0^1 \left\{ \exp\left(-\frac{x^2 t}{2\sigma_x^2} - \frac{y^2 r^2 t}{2\sigma_y^2 [1 + (r^2 - 1)t]} \right) - 1 \right\} \frac{dt}{t\sqrt{1 + (r^2 - 1)t}}, \qquad (3)$$

with $r = \frac{\sigma_x}{\sigma_y}$ for $\sigma_x < \sigma_y$.

Regions of good Precision

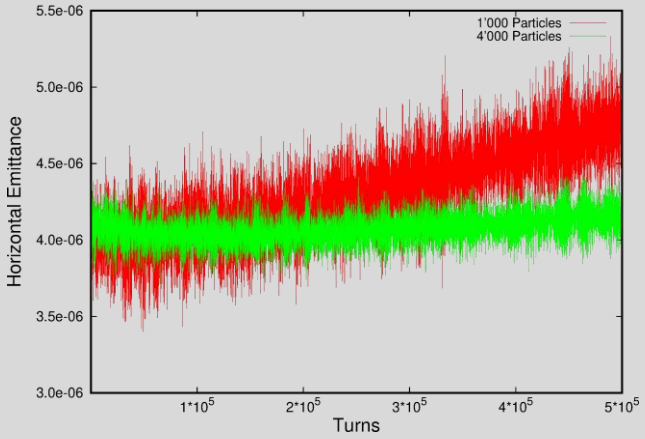


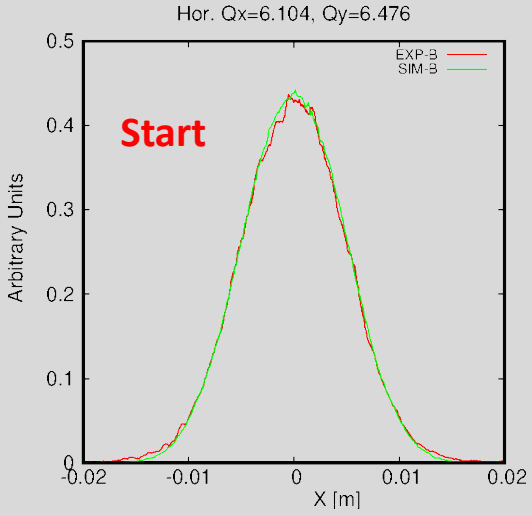
Rel. error in Φ vs. # int. steps

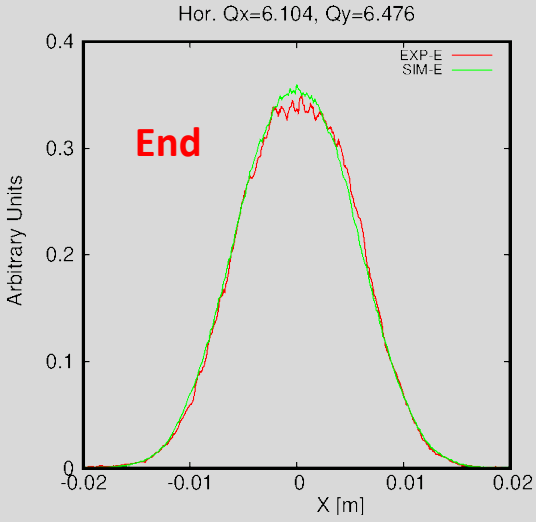


Hor. Simulation vs. Experiment

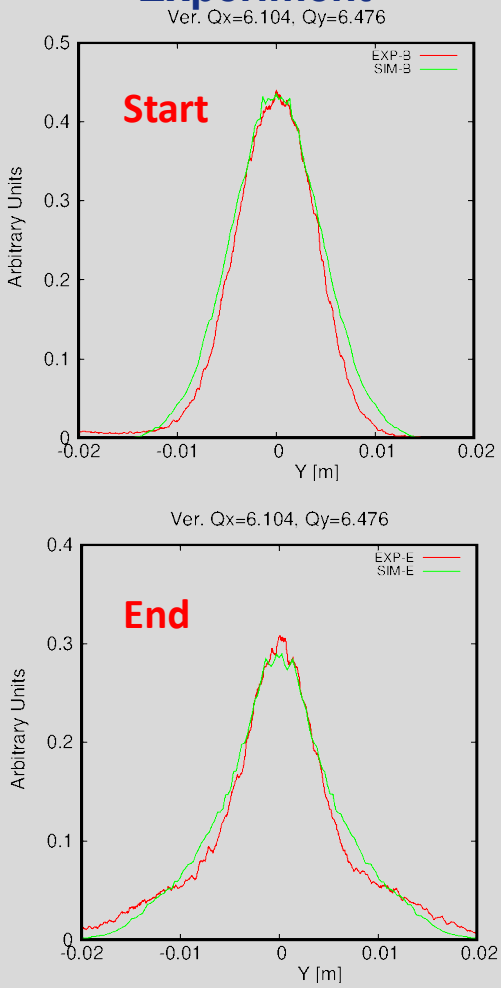
Noise on Emittance Growth







Ver. Simulation vs. Experiment



Porting to latest MAD-X Version

- First Macro based Version 2010
- Most Macros included into code 2012, complex set-up phase still needed.
- 3D symplectic SC implementation including SigmaMatrix treatment 2018
- Simulations 2019
- Debugging and Speed-up phase 2019 – 2020
- Porting to newest MAD-X 2020 – 2021
- Automation of set-up phase 2021
- Updated Manual 2021
- Running with activated SC in latest MAD-X 2021
- Speed-up in MAD-X 2021 in progress

Outlook

The finalization of the porting of the SC implementation to the latest MAD-X version will be achieved in the coming weeks. This includes a comprehensive manual that is also covering a largely simplified setting up phase to instrument the MAD-X lattice with SC kicks.

There remain a long list of items still to be tackled before the MADX-SC code could be declared complete. A few of those are: Using other distributions profiles than Gaussian; including linear coupling into the SC representation; overcoming artificial coupling when using the SigmaMatrix approach and technical issues like extending the number macro particles beyond ~16’000.