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Title: Hard edge dipole for OPAL

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1 OPAL Dipole

When defining a dipole (SBEND or RBEND) in OPAL, a fringe field map which defines the range of the field and the Enge coefficients is required. If no map is provided, the code uses a default map. Here is a dipole definition using the default map:

Example:

```
bend1: SBEND, ANGLE = bend_angle,
                    E1 = 0, E2 = 0,
                    FMAPFN = "1DPROFILE1-DEFAULT",
                    ELEMEDGE = drift_before_bend,
                    DESIGNENERGY = bend_energy,
                    L = bend_length,
                    WAKEF = FS_CSR_WAKE;
```

Please refer to the OPAL manual [1] for the definition of the field map and the default map "1DPROFILE1-DEFAULT". It defines a fringe field that extends to 10cm away from a dipole edge in both directions and it has both B_y and B_z components. This makes the comparison between OPAL and other codes which uses a hard edge dipole by default,cumbersome because one needs to carefully integrate throught the fringe field region in OPAL in order to come up with the integrated fringe field value (FINT in ELEGANT) that usually used by these codes, e.g. the ELEGANT and the TRACE3D. So we need to find a default map for the hard edge dipole in OPAL.

2 Map for Hard Edge Dipole

The proposed default map for a hard edge dipole can be:

```
1DProfile1 0 0 2
-0.00000001 0.0 0.00000001 3
-0.00000001 0.0 0.00000001 3
-99.9
-99.9
```

On the first line, the two zeros following "1DProfile1" are the orders of the Enge coeffcieint for the entrance and exit edge of the dipole. $2cm$ is the default dipole gap width. The second line defines the fringe field region of the entrance edge of the dipole which extends from $-0.00000001cm$ to $0.00000001cm$. The third line defines the same fringe field region for the exit edge of the dipole. The 3s on both line don't mean anything, they are just placeholders. On the fourth and fifth line, the zeroth order Enge coefficients for both edges are given. Since they are large negative numbers, the field in the fringe field region has no B_z component and its B_y component is just like the field in the middle of the dipole. Figure 1 compares the emittances and

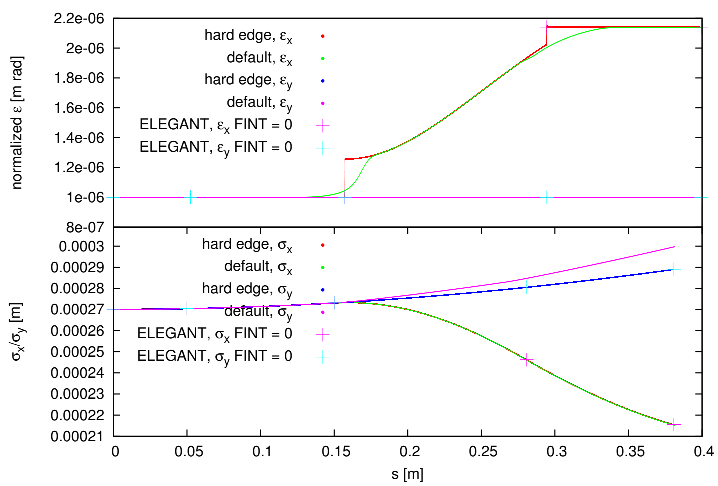

Figure 1: Compare emittances and beam sizes obtained by using the hard edge map(OPAL), the default map (OPAL), and the ELEGANT

beam sizes obtained by using the hard edge map, the default map and the

ELEGANT. One can see that the results produced by the hard edge map match the ELEGANT results when FINT is set to zero.

3 Integration Time Step

When the hard edge map is used for a dipole, finer integration time step is needed to ensure the accurate of the calculation. Figure 2 compares the normalized emittances generated using the hard edge map in OPAL with varying time steps to those from the ELEGANT. $0.01ps$ seems to be a optimal time step for the fringe field region. To speed up the simulations, one can use larger time steps outside the fringe field regions.

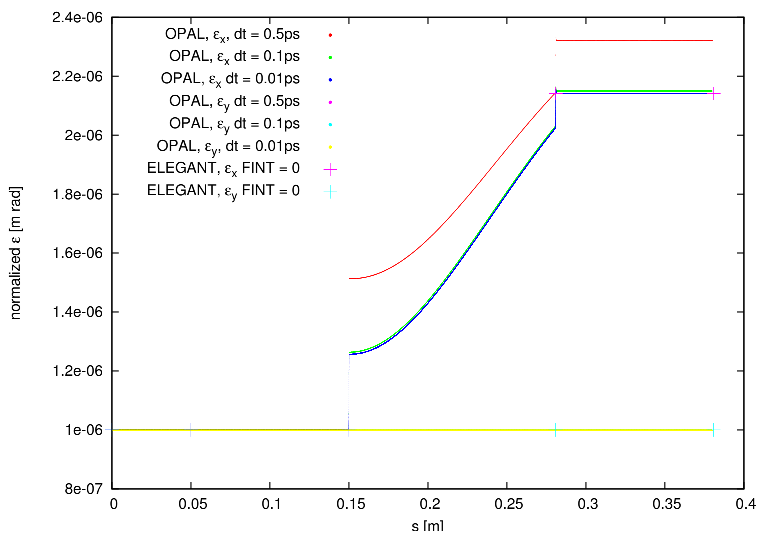

Figure 2: Horizontal and vertical normalized emittances for different integration time steps

Figure 3 and 4 examine the effects of the fringe field range and the integration time step on the simulation accuracy. Figure 4 is a zoom-in plot of Figure 3. We can conclude that the size of the integration time step has more influence on the accuracy of the simulation.

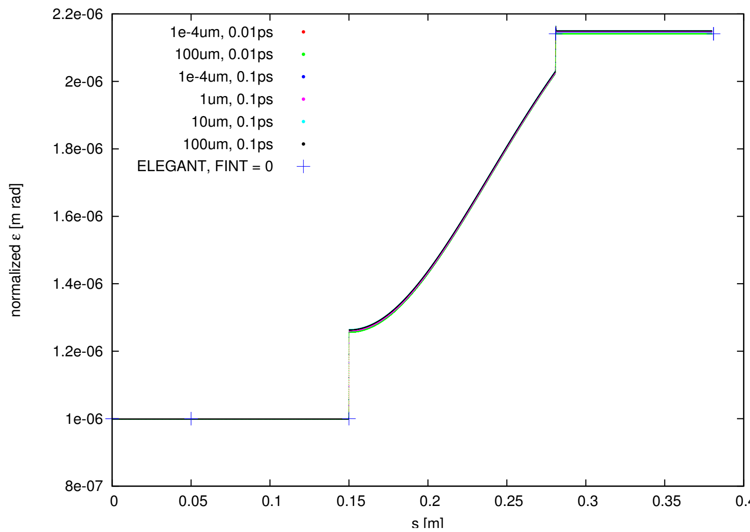

Figure 3: Normalized horizontal emittance for different fringe field ranges and integration time steps

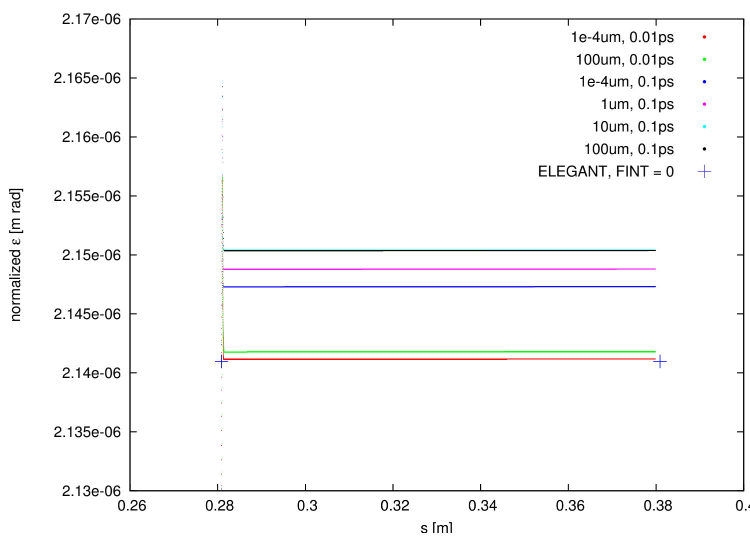

Figure 4: Zoom in on the final emittance in Figure 4

References

[1] A. Adelmann et al., The OPAL Framework, User's Reference Manual, 2014