

Dispersion analysis (with BDSIM and RF-Track) of LhARA stage 1 beamline with vertical arc

WP6 LhARA meeting

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Dispersion calculation

- If N is sufficiently large (at least $>1e5$) and the initial dispersion is zero:
Covariance bunch dispersion $\rightarrow$ finite-difference line dispersion

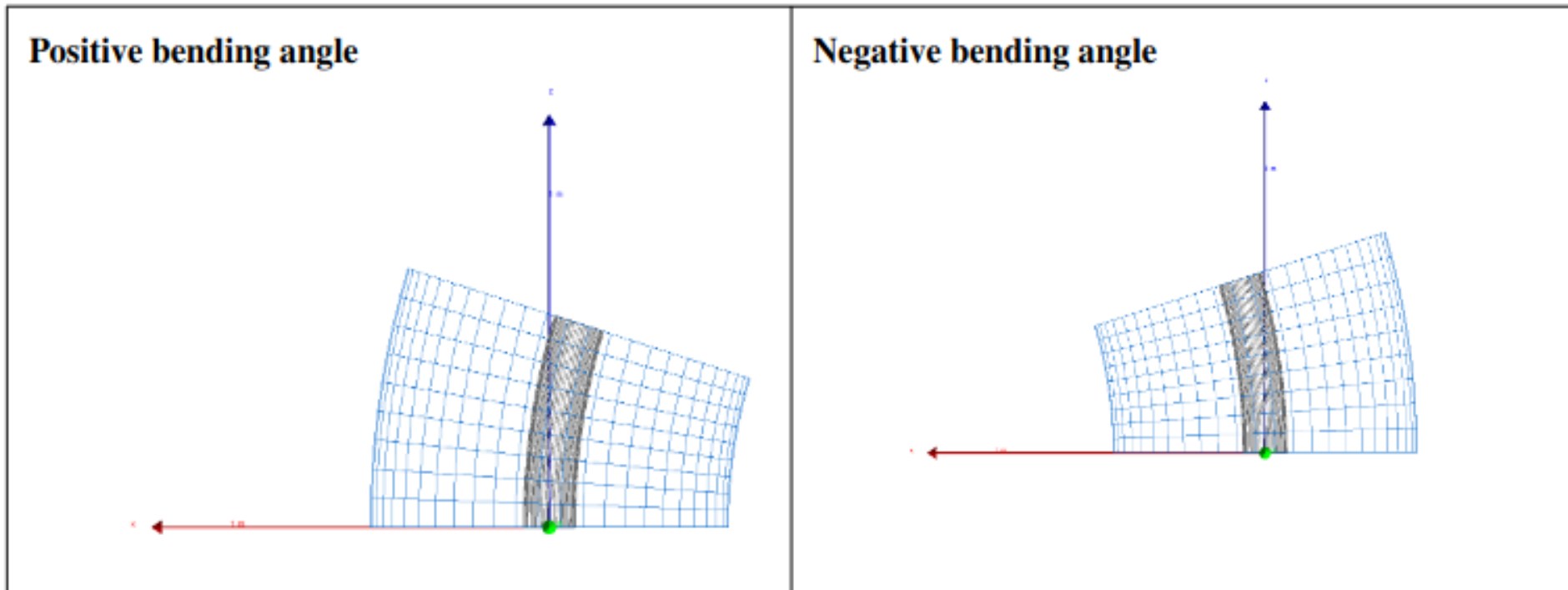
- If the initial dispersion is non-zero:
Total bunch dispersion = line-generated dispersion + propagated initial dispersion $\neq$ true line dispersion

- Collimators are changed to drifts for finite difference calculation:
 $D_x(s) = ((x_+(s)) - (x_-(s))) / (2\Delta)$ where Δ is the relative momentum deviation from the reference momentum

Bending angle convention from BDSIM doc

The two images below show the direction of bending for positive and negative angles:

- A positive angle will bend toward negative X in the x-z plane (local coordinates).
- A negative angle will bend toward positive X in the x-z plane (local coordinates).
- Note: X-axis is red, z-axis is blue, y-axis is green and points towards you.



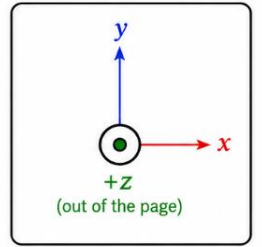
Dispersion in vertical arc

BDSIM doc: A positive *tilt* angle corresponds to a clockwise rotation when looking along the beam direction as we use a right-handed coordinate system

Ex.: LHA_LEL_MAG_DIP_02: sbend, $l=0.8$, $\text{angle}=\pi/4$, $\text{tilt}=-\pi/2$;

- Positive angle: rotation towards -x
- After negative tilt applied: towards -x becomes towards +y (upward)
- Implication for dispersion: positive energy shift should have $\Delta y < 0$
=> **negative D_y**

View along beam direction
(looking from upstream
toward downstream, along +z)



Dispersion computed with MAD-X (from CDR): same tilt convention: why is $D_y > 0$ here?

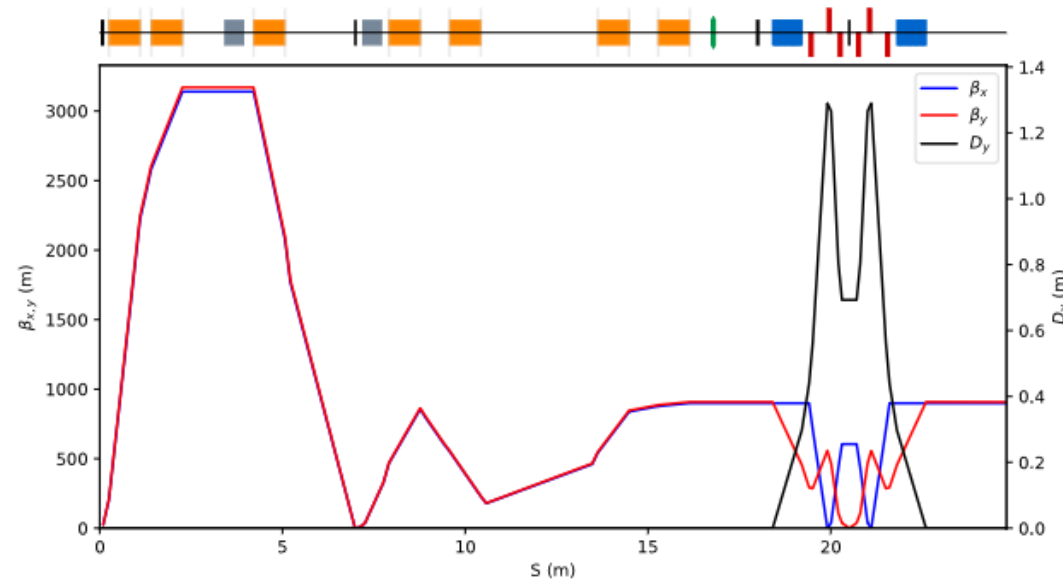


Figure 2.4: Horizontal (β_x , blue) and vertical (β_y , red) Twiss β functions and vertical dispersion (black) along the Stage 1 beam transport line (s) from the nozzle exit to the *in-vitro* end station for the 30 mm spot size configurations. The survey at the top of the plots shows the locations of the Gabor lenses/solenoids (orange), RF cavities (grey), collimators (black), octupole (green), dipoles (blue), and quadrupoles (red).

Initial proton beam dispersion (after the nozzle)

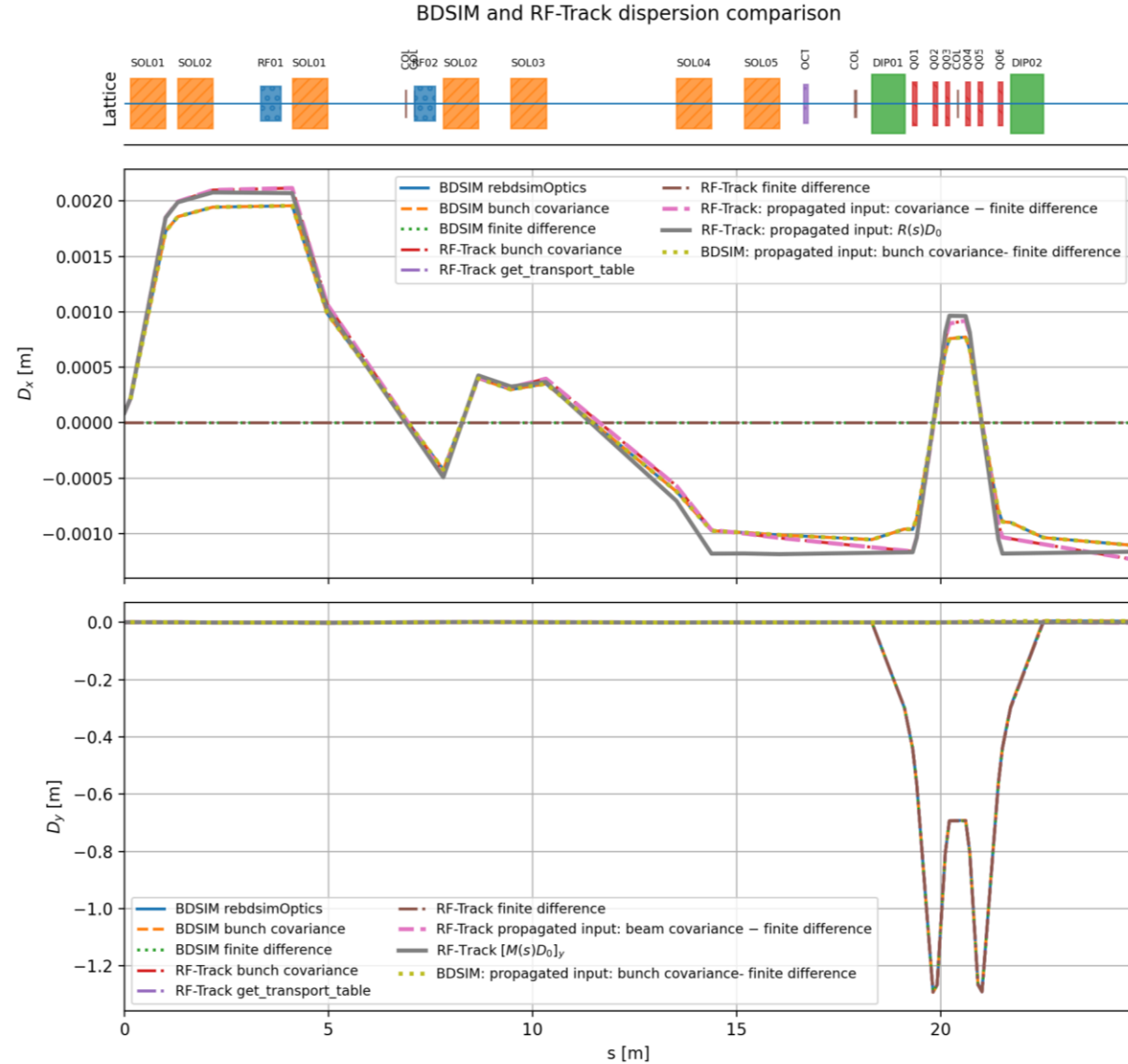
- Bunch entrance dispersion

$$Dx0 = 8.89224285071e-05 \text{ m}$$

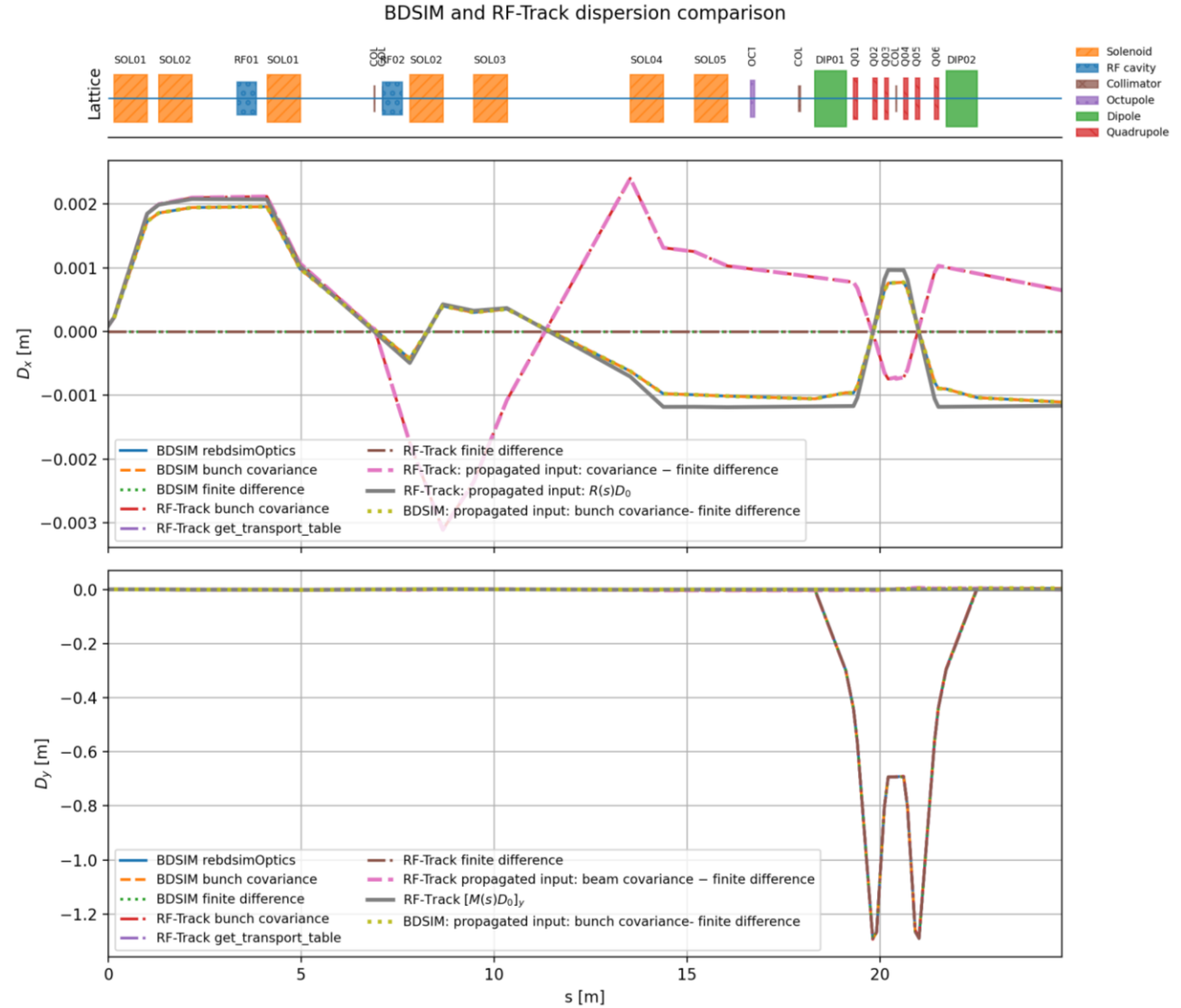
$$Dxp0 = 0.000886873749246 \text{ rad}$$

=> can it be neglected in calculation of line dispersion? (Only visible on Dx plot)

Results: solenoid used



Collimators changed to drifts



With collimators