IR Optics Design for the 10 TeV Muon Collider

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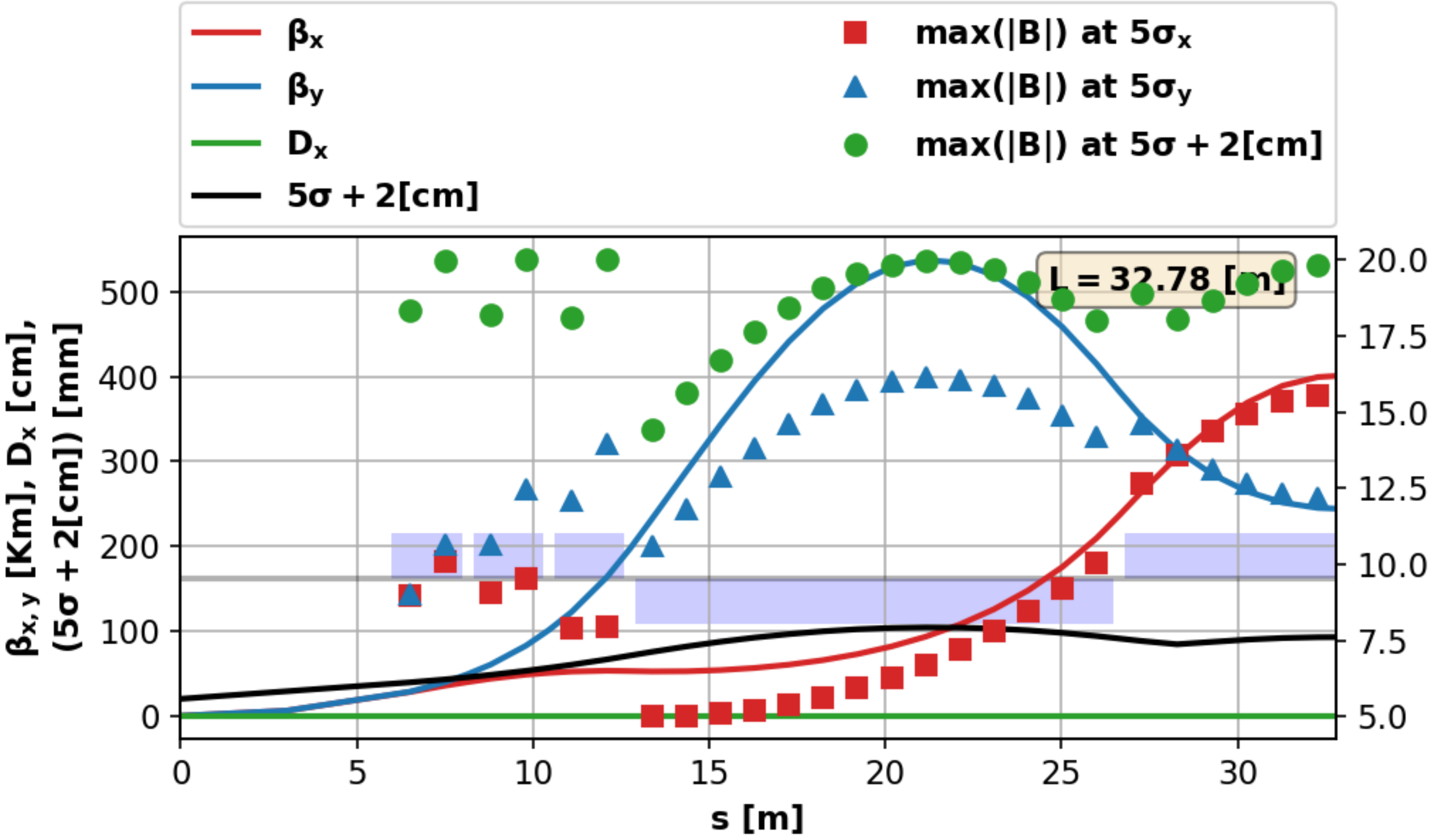
Outline

- 10TeV Muon Collider
  - Final Focusing scheme
  - Chromatic Correction scheme
  - IR Current Design
- Summary

10TeV Muon Collider - Final Focusing Scheme

- $L^* = 6$m and a triplet is used for the Final Focusing (FF).
- The maximum allowed magnetic field at the FF scheme is assumed to be the 20T.
- Due to the fast increase of the β functions right after the IP, the first magnet is splitted in three shorter ones with different gradient, reducing that way the length of the FF scheme.
- The first focusing magnets can be used to control the beta ratio (β_x/β_y) at the end of the FF scheme while the last two elements are used for the point to parallel matching ($\alpha_{x,y} = 0$ at the FF triplet end).

10TeV Muon Collider - Final Focusing Scheme



$$B\rho = 16678.205 \ [Tm]$$

$$Aperture = 2(5\sigma + 0.002) \ [m]$$

$$\sigma = \sqrt{\frac{max(\beta_x, \beta_y)\varepsilon_n}{\beta_r\gamma_r} + (D_x\delta_p)^2} \ [m]$$

$$\sigma_j = \sqrt{\frac{\beta_j\varepsilon_{nj}}{\beta_r\gamma_r} + (D_j\delta_p)^2} \ [m] \ with \ j = x, y$$

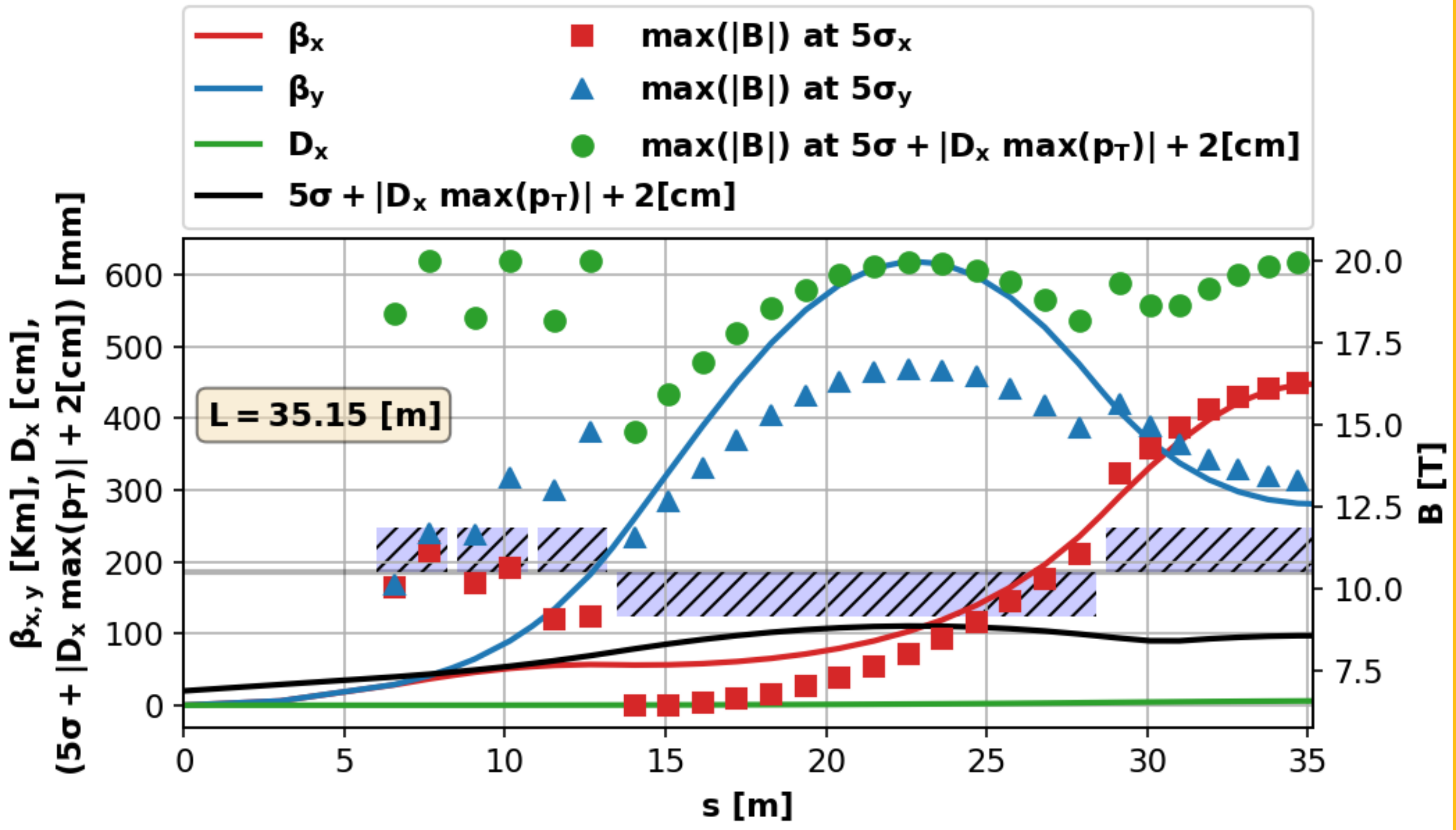
10TeV Muon Collider - Final Focusing Scheme

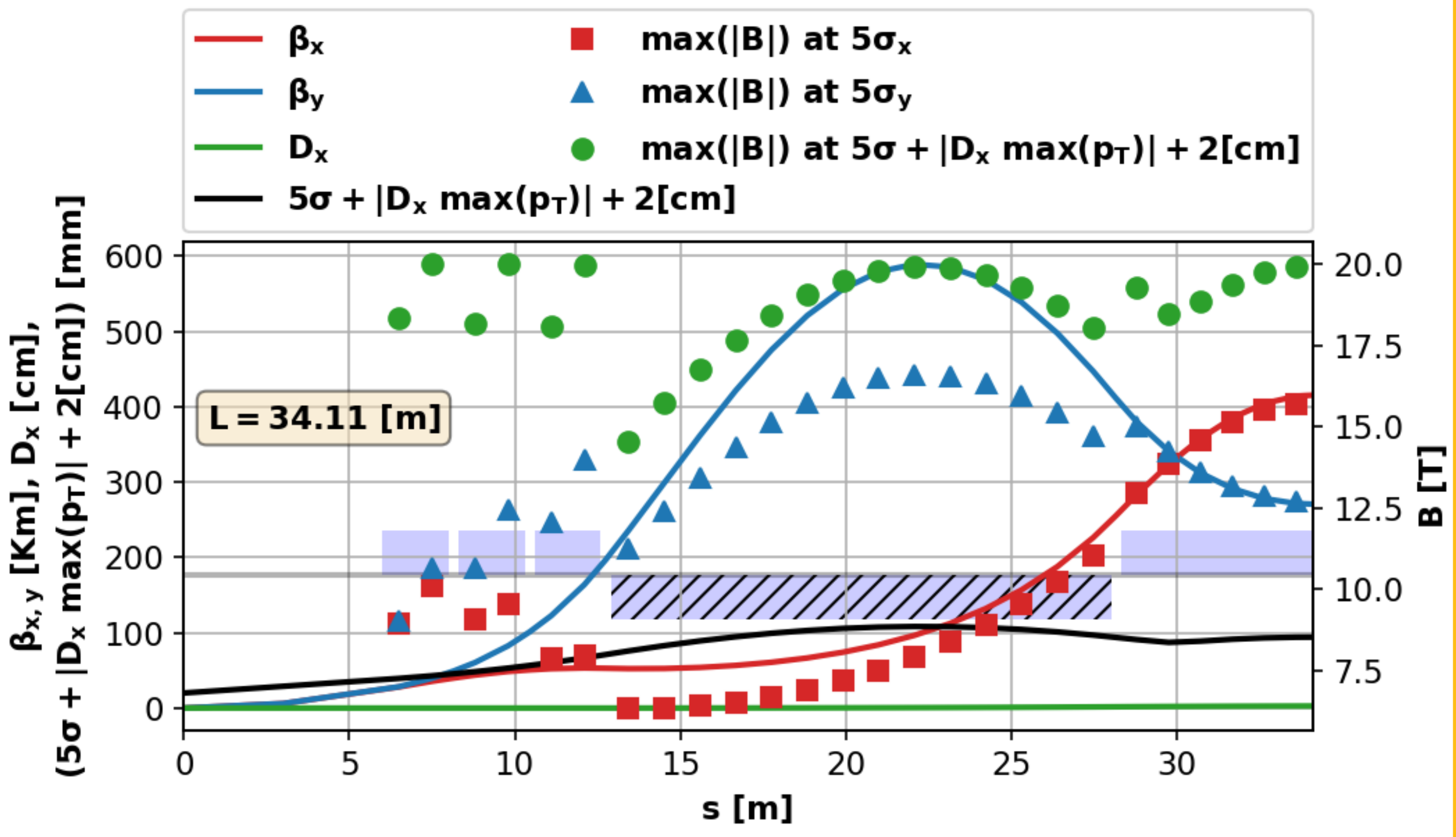
- If the 20T are not realistic and drop to 16T that is the FCC target, the same IR scheme (with similar quadrupole gradients) can be used with one or a combination of the following modifications:
  - reduction of the com energy to 8TeV, this configuration reaches the design luminosity for an 8TeV com muon collider (as β^* is inversely proportional to the energy)
  - reduction of the apertures (without significantly changing the gradients):
    - by reducing the beam envelope to 4σ+1.5cm, the luminosity degradation is negligible (less than 1%) but other consequences have to be understood
    - by increasing the β^* by a factor ~2.04 (a bit larger than (5/4)2)

10TeV Muon Collider - Final Focusing Scheme

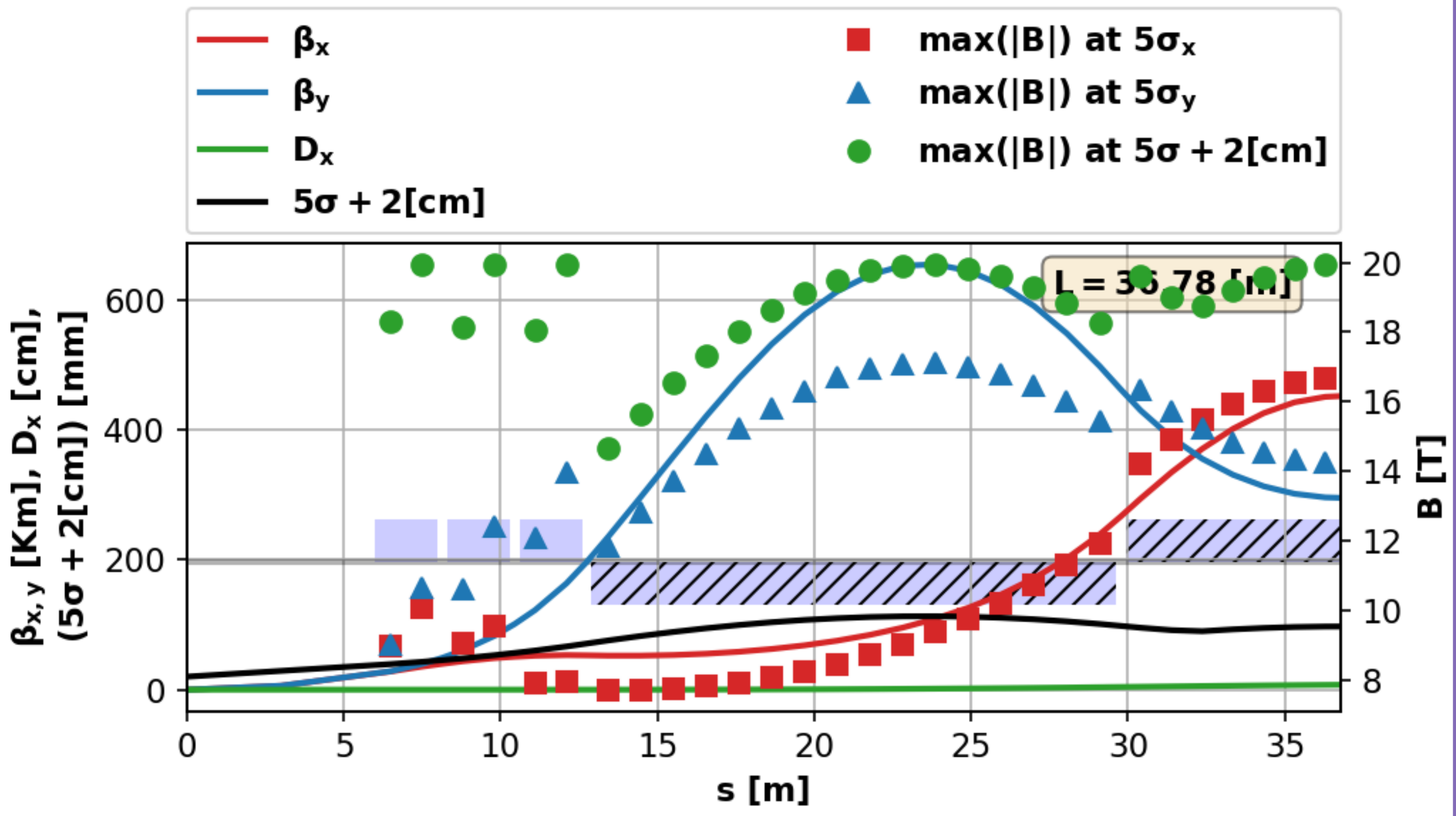
- Different FF schemes that include dipolar components or an elongated L* are designed for the mitigation of the Beam Induced Background (BIB)†.

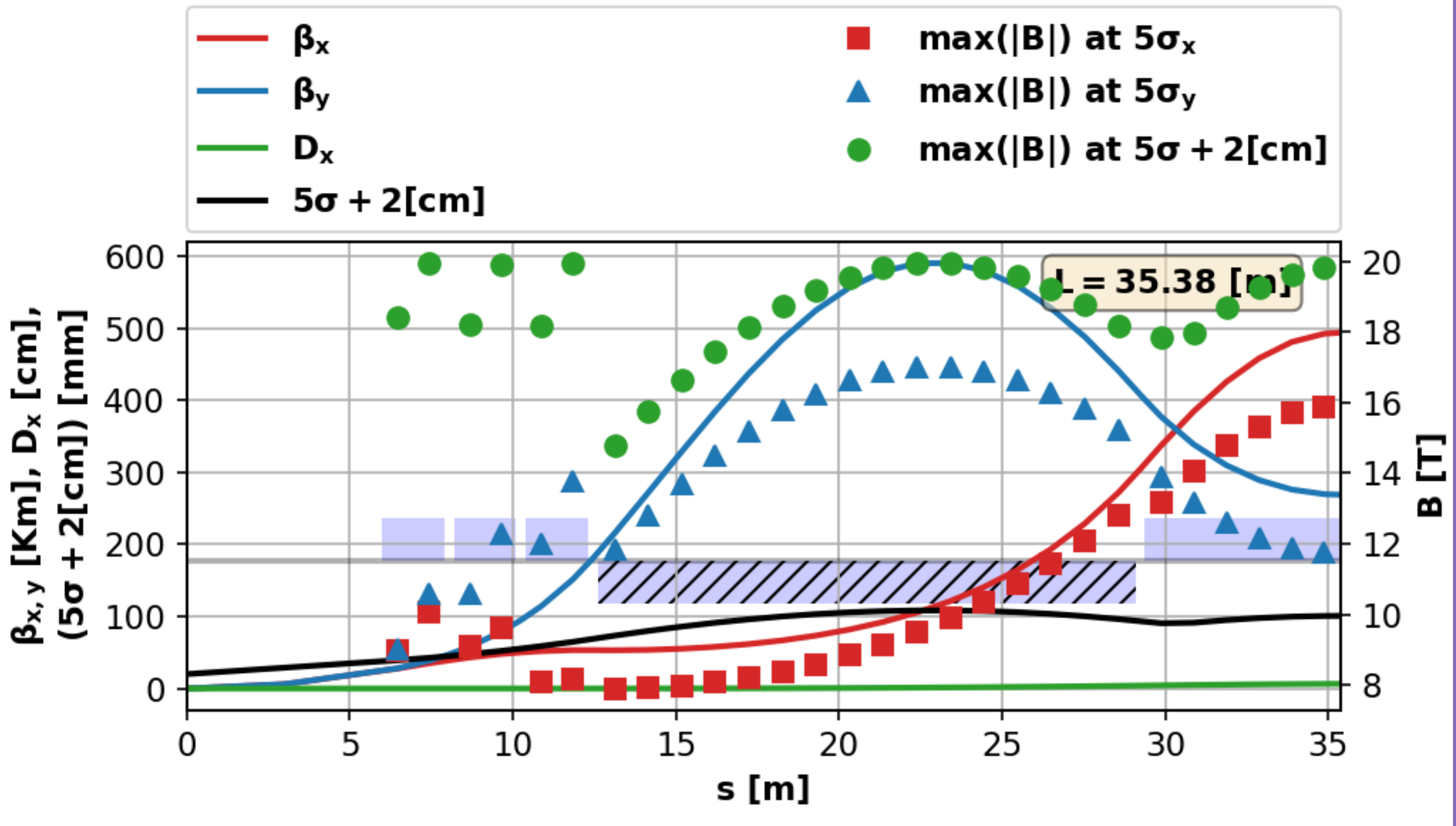
B_d = 2T



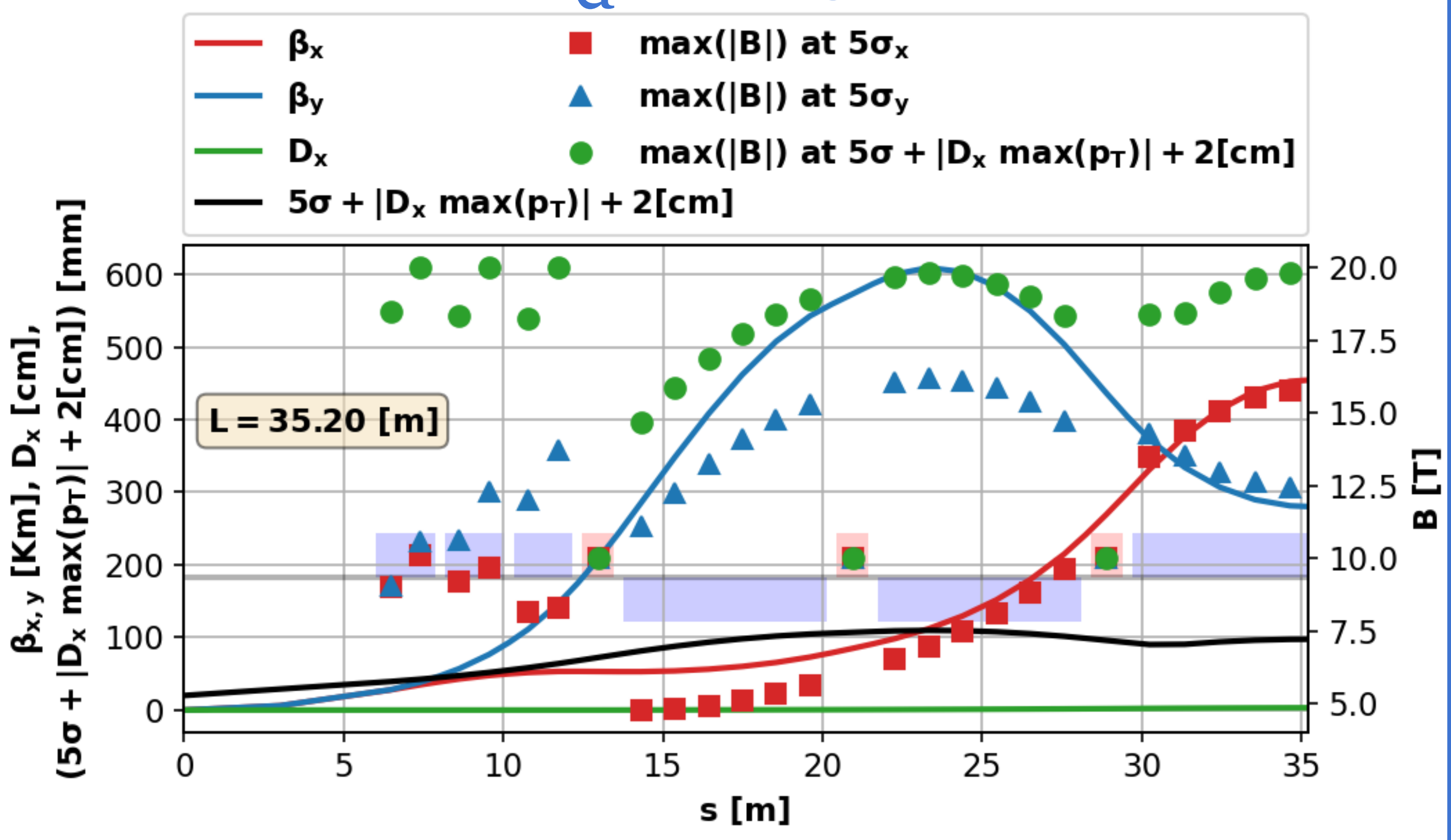


B_d = 4T

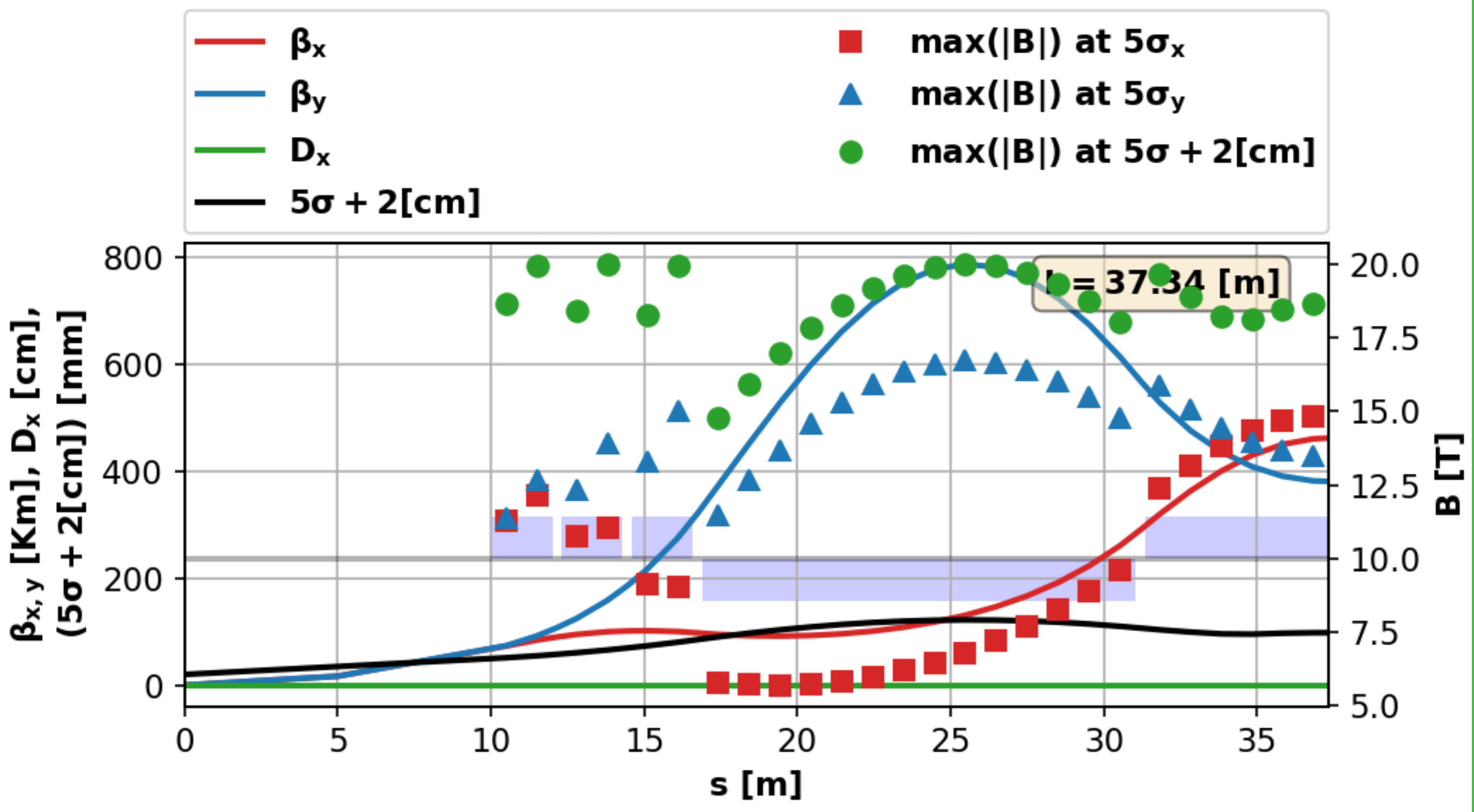




B_d = 10T



L^* = 10m

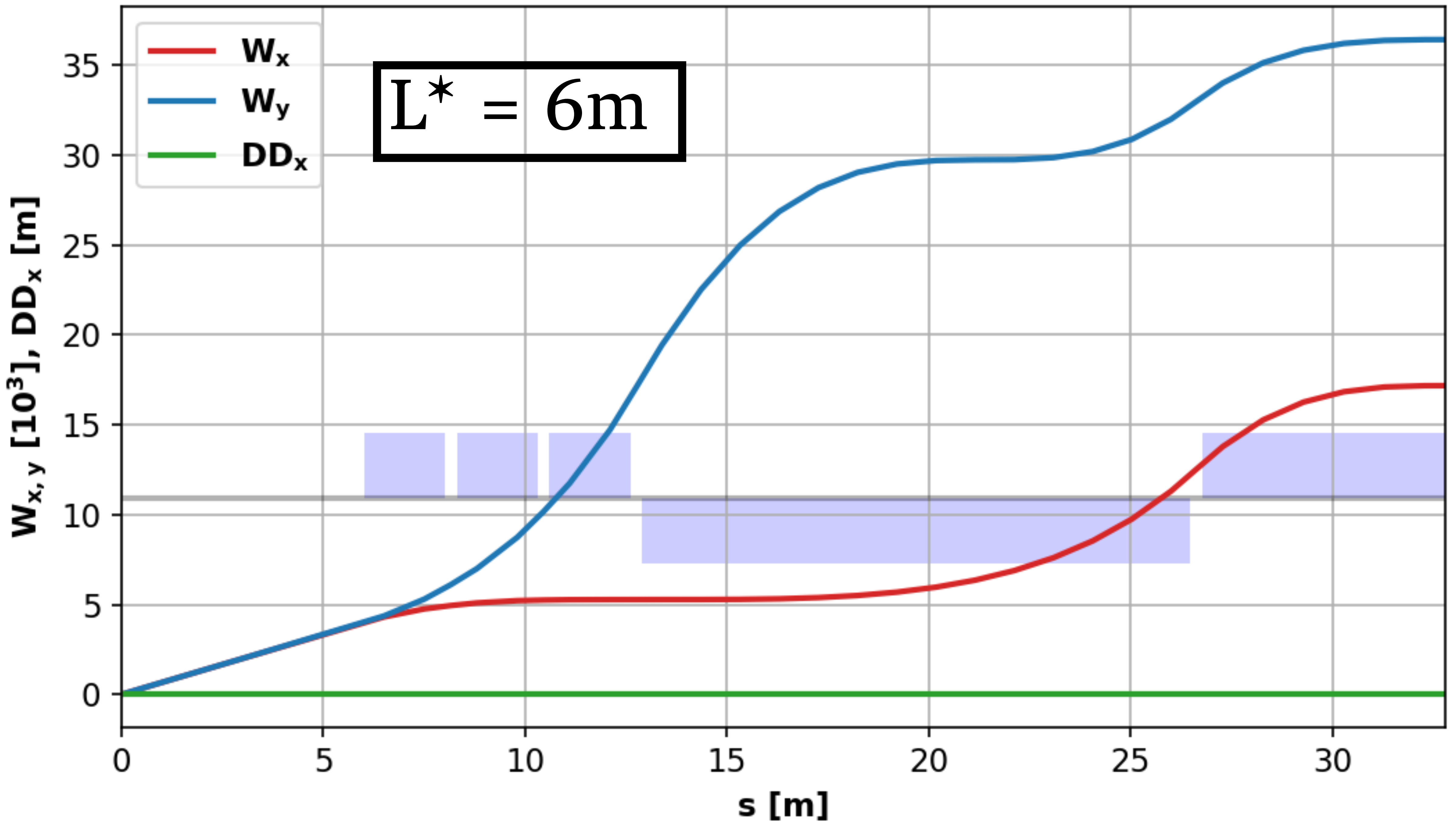


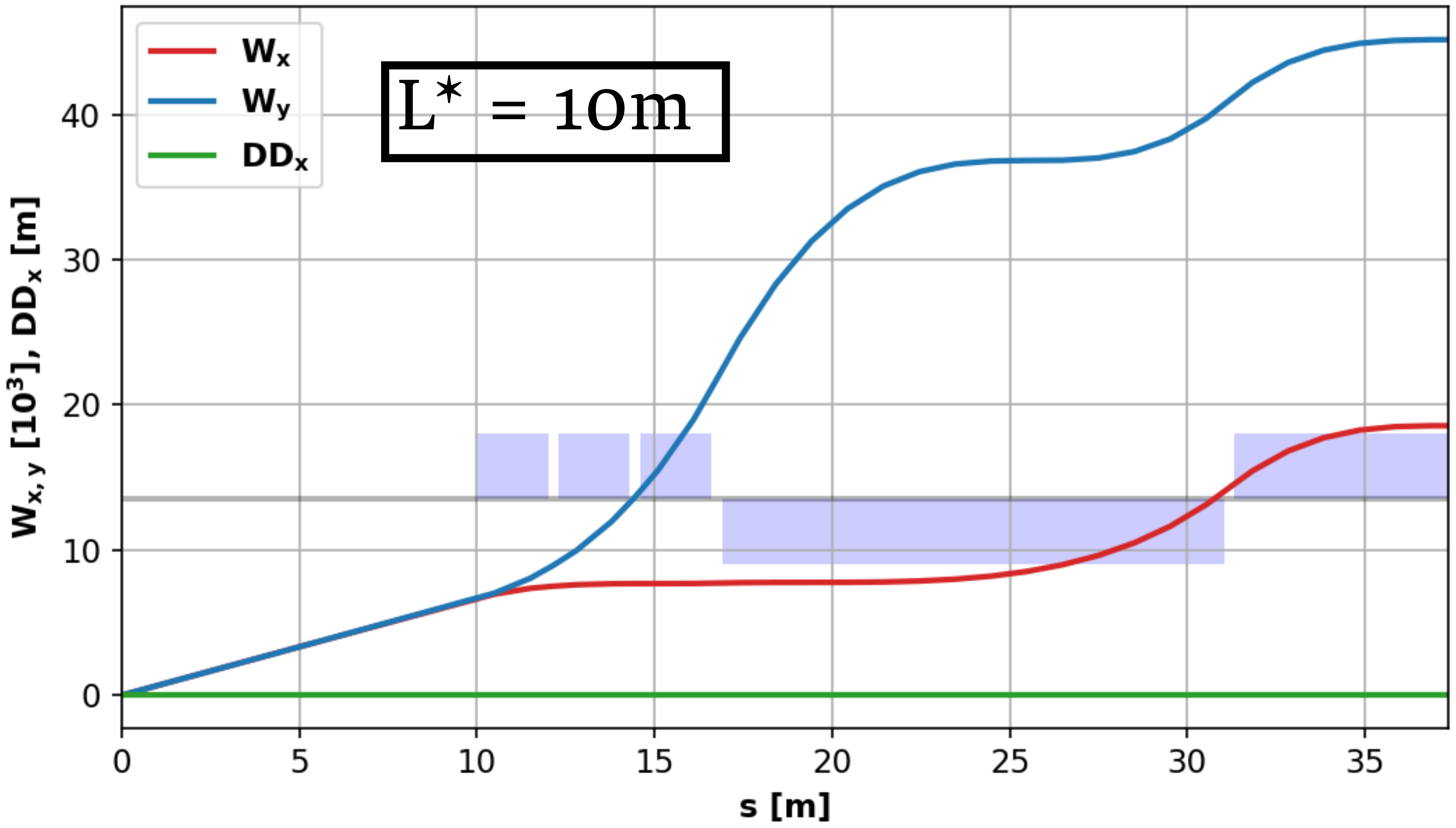
†see “Machine-induced background studies for the 10 TeV Muon Collider”

10TeV Muon Collider - Final Focusing Scheme

- Due to strong focusing quadrupoles (β^*=1.5mm), the Montague chromatic functions ($W_{x,y}$) that describe the optics perturbation for off-momentum particles w.r.t on-momentum one are significantly large.

- Together with the large momentum spread (δ=10^{-3}), these W values indicate enormous chromatic effects that should be compensated avoiding performance degradation.





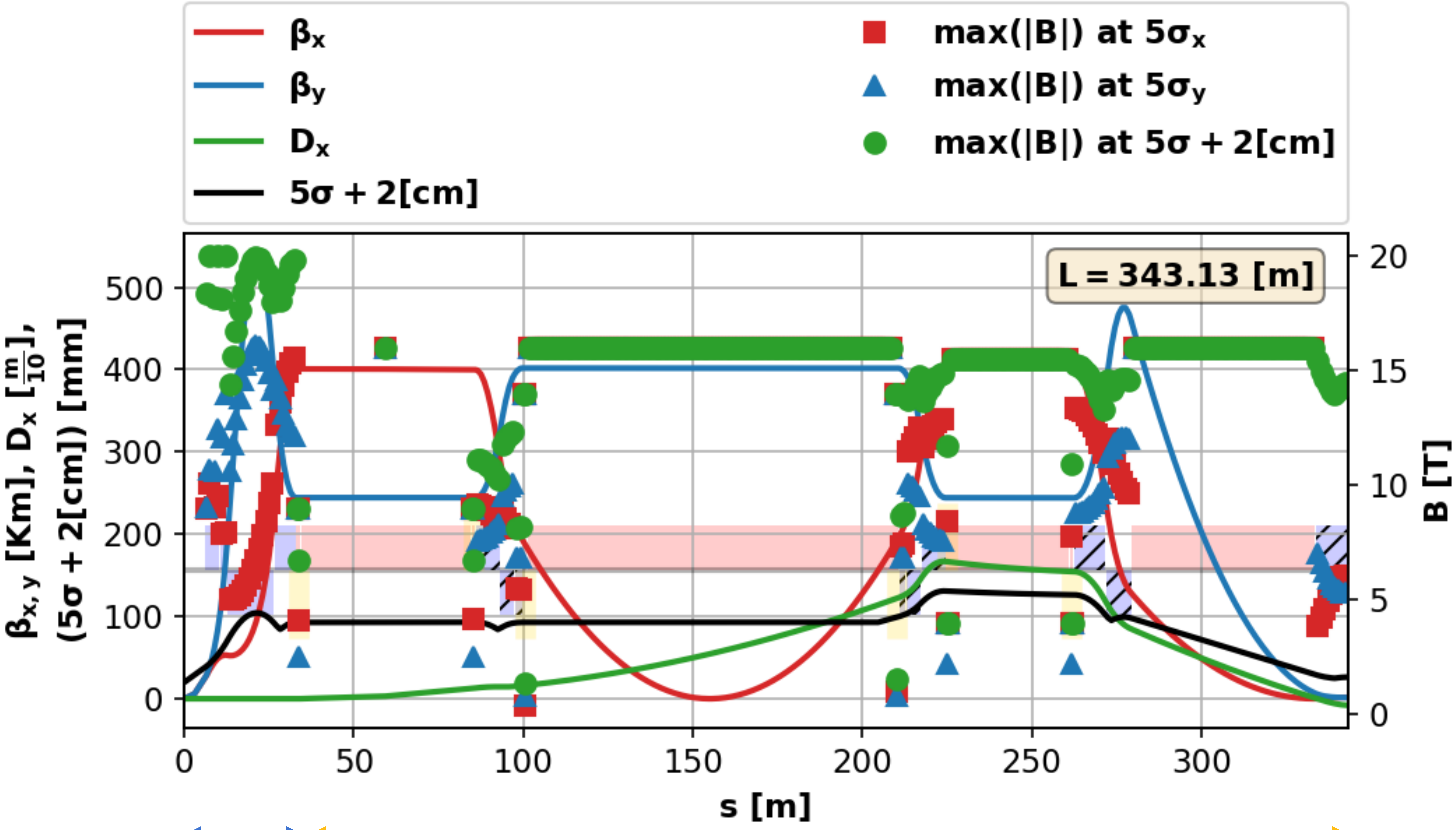
10TeV Muon Collider - Chromatic Correction Scheme

- In order to benefit from the large $\beta_{x,y}$, the Chromatic Correction (CC) schemes is designed and placed right after the FF quads.
- The maximum allowed magnetic field is assumed to be the 16T.
- The CC scheme include 3 sets (doublets) of combined function dipole-sextupole magnets and each set is placed at positions with large β_q, where q=x or y, for the correction of the W_q at the end of CC scheme and the correction of the DD_x at the IPs.
- Each set include a pair of dipole-sextupole magnets with opposite polarity (k_2,-k_2) when are separated by an identity like transformation and with the same k_2 when are separated by -I transform at x plane for the compensation of the RDTs excited by the sextupolar component.

10TeV Muon Collider - Chromatic Correction Scheme

Colour code for lattice elements:

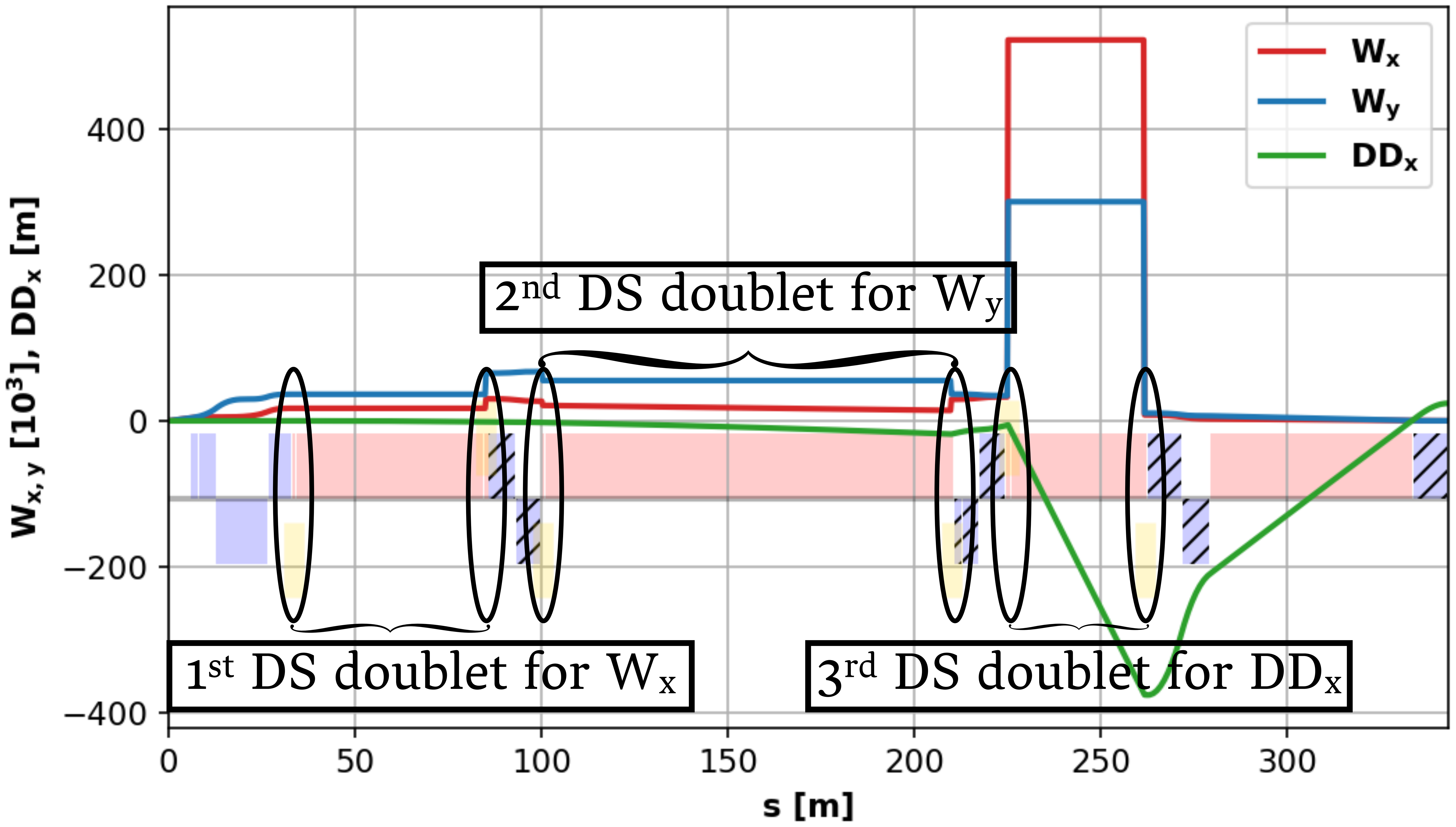
- Red dipoles
- Blue quadrupoles
- Hashed blue dipole-quadrupoles
- Red + Gold dipole-sextupoles



Final Focusing with L*=6m

Chromatic Correction with 3 set of dipole-sextuples

10TeV Muon Collider - Chromatic Correction Scheme

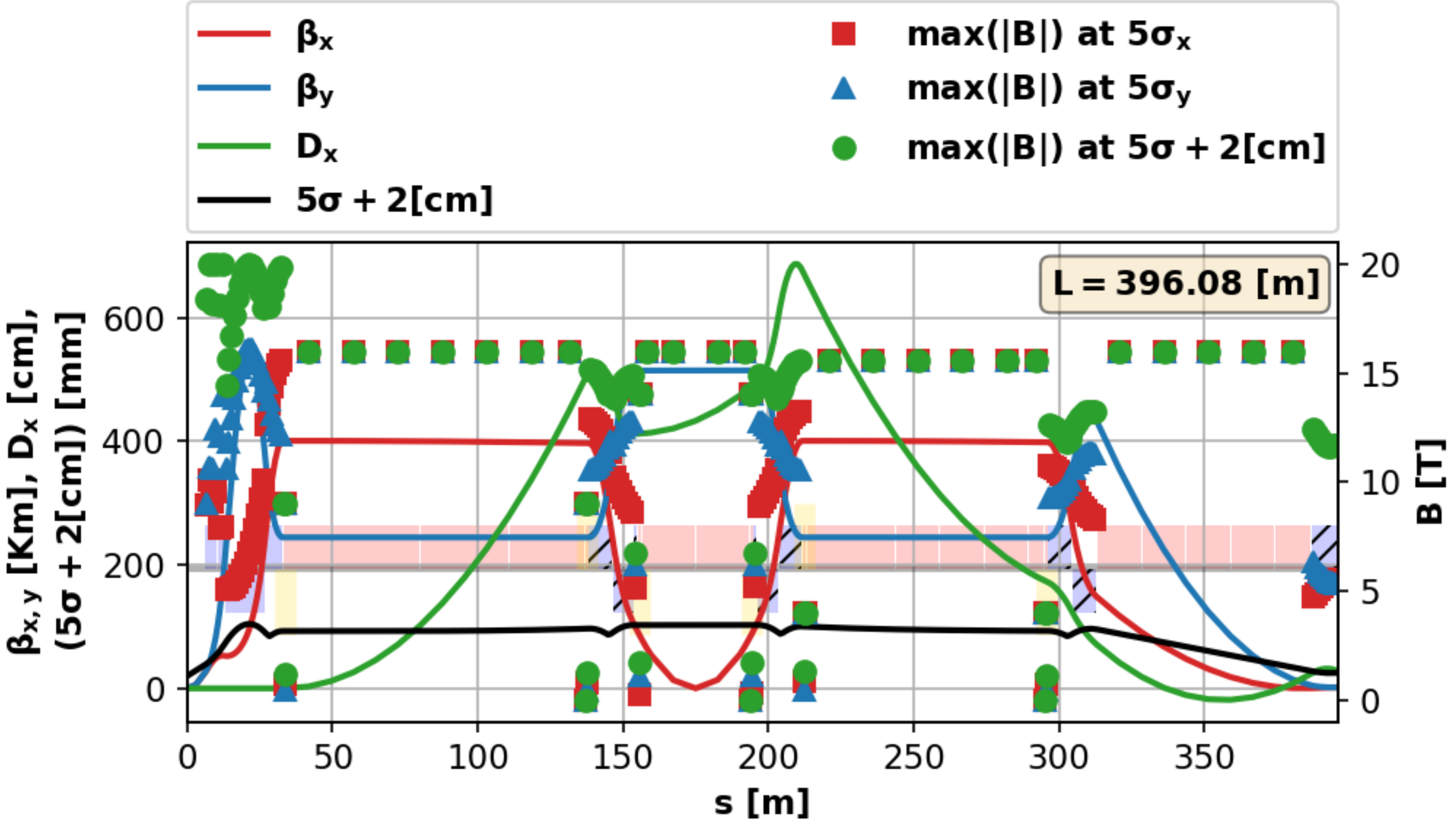


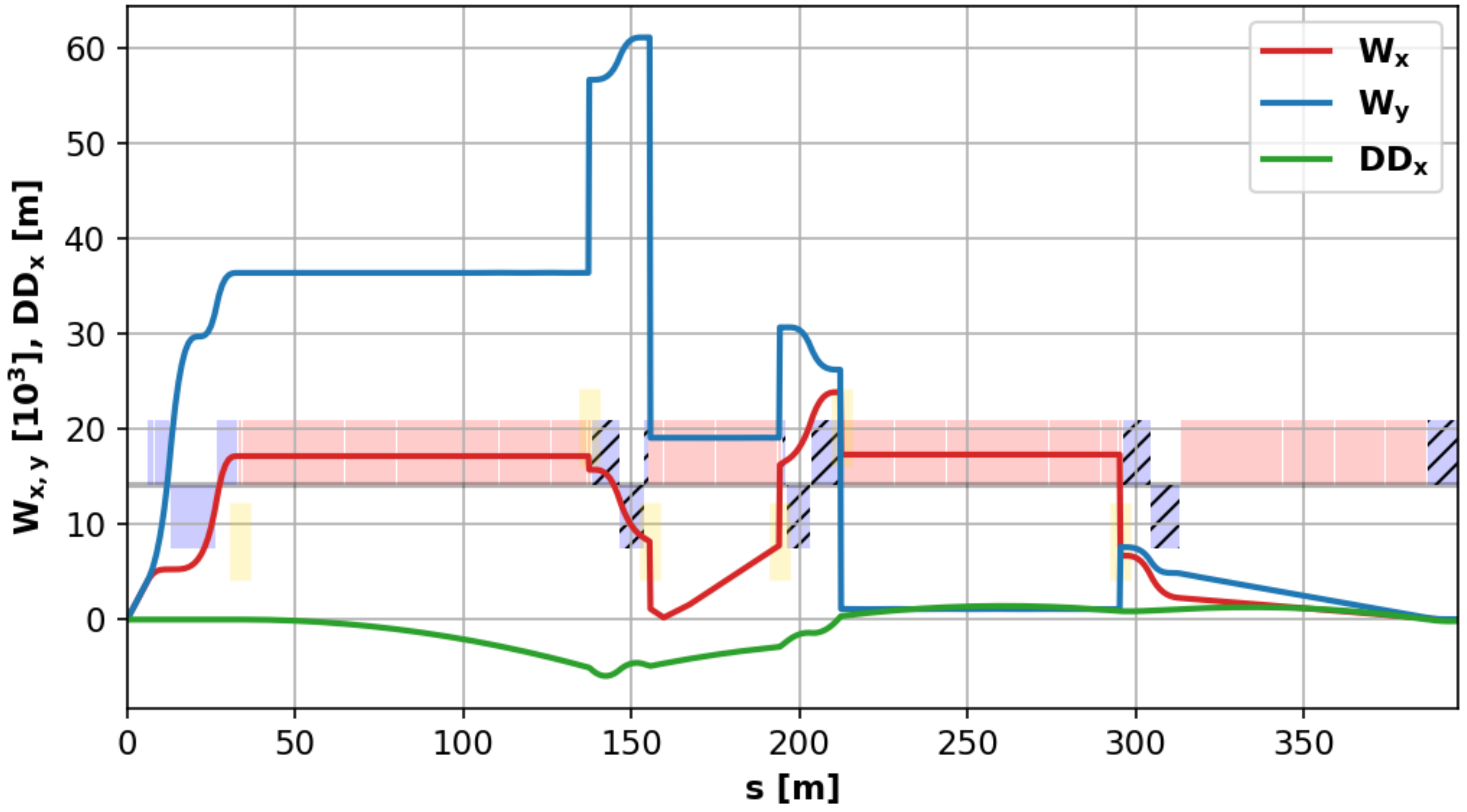
Final Focusing with L^*=6m

Chromatic Correction with 3 set of dipole-sextuples

10TeV Muon Collider - IR Current Design

- New design that aims to address the issues revealed from the tracking studies as well the information/restrictions coming from the WP2, WP5, WP6 and WP7.
  - All magnets are up to 15m long.
  - The minimum dipolar field in the combined function magnets is 4T.
  - The dipole-sextuple magnets are 1m long and the sextupolar field is up to 2T.
  - ...





Summary

- Different Final Focusing schemes that aim to mitigate the BIB are diveloped.
- The presented Final Focusing and Chromatic Correction schemes are shared with the FLUKA team for studying the radiation issues.
- Each section of the collider relies on the information/restrictions constantly coming from the WP2/5/6/7 thus, the ring is constantly updated.

Thank you for your time!

All the **presented studies** are **work in progress** thus, any input is very welcome.

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