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# Progress of Muon Collider Lattice Design v0.5

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With special thanks to K. Oide, P. Raimondi, D. Schulte and R. Tomas

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# Outline

- 10TeV Muon Collider (v0.5)
  - Final Focusing Scheme
  - Chromatic Correction Scheme

# 10TeV Muon Collider

TABLE I. 10 TeV center of mass energy muon collider.

| **Parameters** | **Symbol** | **Unit** | **10TeV com mc** |
|---|---|---|---|
| Particle energy | $E$ | GeV | 5000 |
| Particle momentum | $P_0$ | GeV $c^{-1}$ | 5000 |
| Luminosity per IP | $\mathcal{L}$ | $10^{34}$ cm$^{-2}$ s$^{-1}$ | 20 |
| Bunch population | $N_p$ | $10^{12}$ | 1.8 |
| Transverse normalized rms emittance | $\varepsilon_{nx} = \varepsilon_{ny}$ | $\mu$m | 25 |
| Longitudinal emittance ($4\pi\ \sigma_E\ \sigma_T$) | $\varepsilon_l$ | eVs | 0.314 |
| Rms bunch length | $\sigma_z$ | mm | 1.5 |
| Relative rms energy spread | $\delta$ | % | 0.1 |
| Beta function at IP | $\beta_x^\star = \beta_y^\star$ | mm | 1.5 |
| Beam power with 5 Hz repetition rate | $\mathrm{P_{beam}}$ | MW | 7.2 |

# 10TeV Muon Collider - In a nutshell

**1.5mm $\beta^*$**

=> ~500Km $\beta$s in the Final Focusing (FF) scheme (also large $\delta$=0.1%).

=> Enormous chromatic aberrations at the optical functions (described by Montague functions).

=> Necessity for a Chromatic Correction (CC) scheme right after the FF.

=> Need for strong sextupolar kick (beta values, dispersion, sextuple strength).

=> The CC generate large positive momentum compaction factor ($\alpha_p$) and should be controlled (keep the bunch length short) in the arcs among other parameters.

**Muon decay (short lifetime $\tau_0$~2.2μs or $\tau_{5TeV}$~0.1s)**

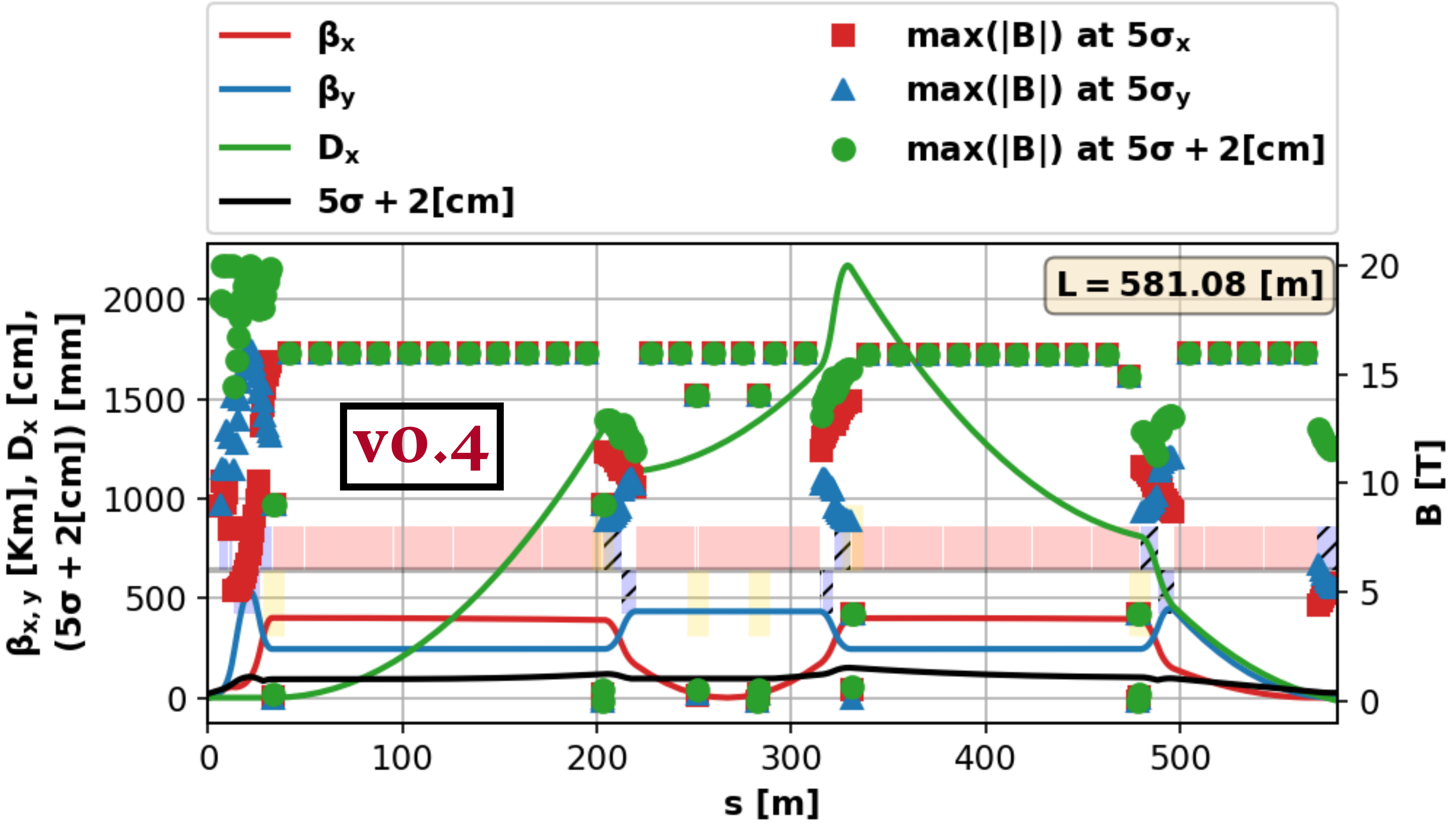
=> The resulting neutrinos even from a short straight piece of collider generate a narrow "radiation cone" that is an issue at the location, where they reach the earth surface

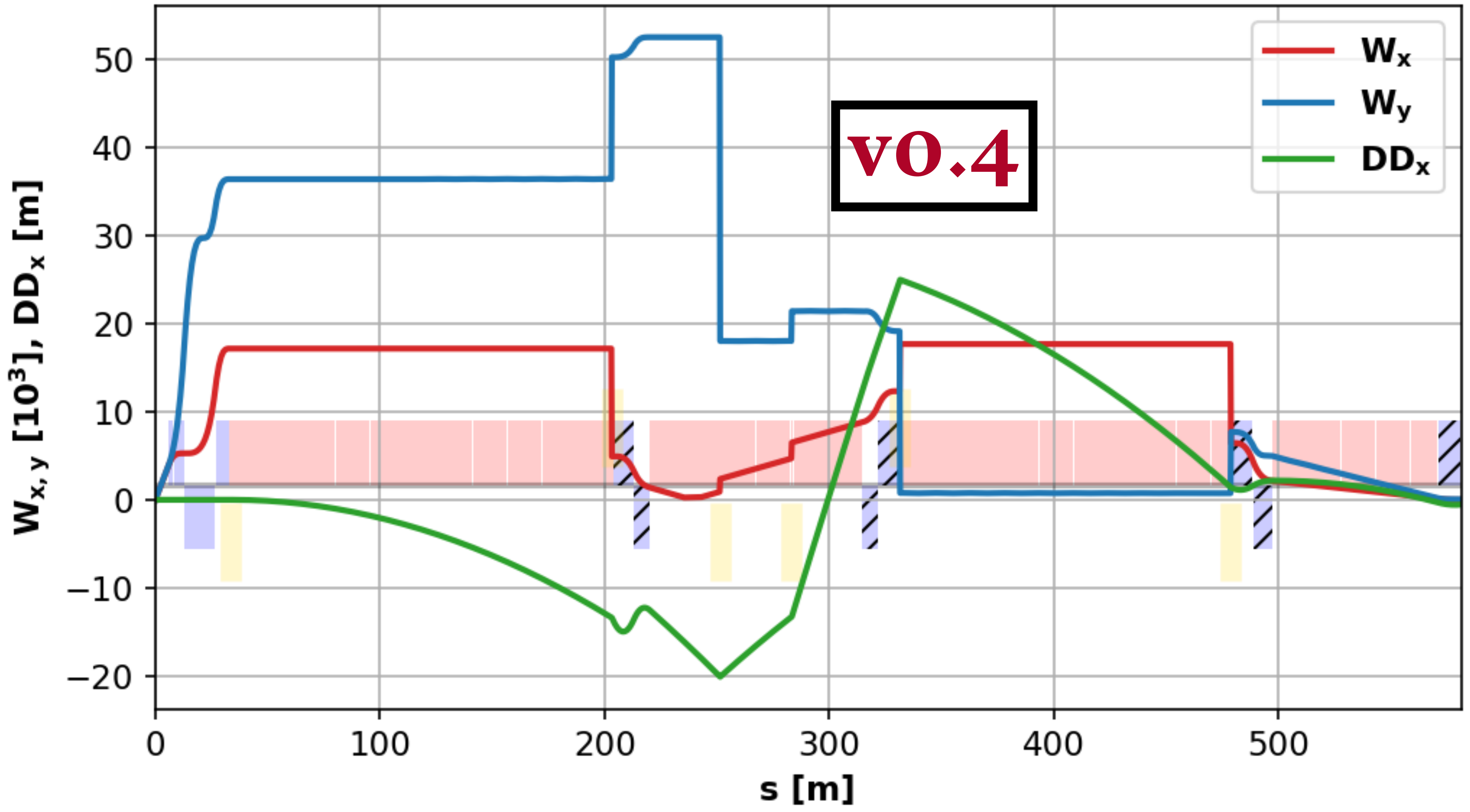
=> The planned shape of the collider is like a race track (2 straight sections for IPs)

=> Extensive use of dipoles and combined function magnets

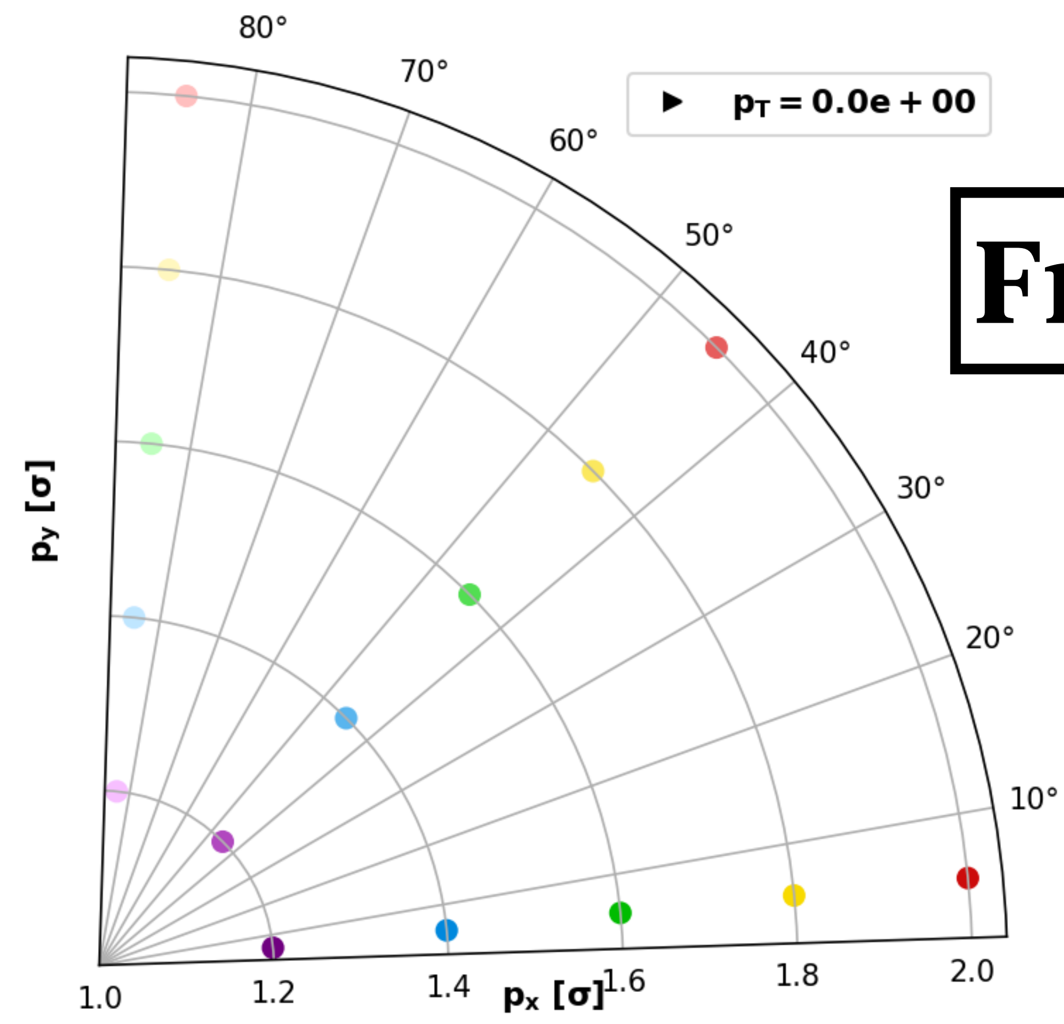
# 10TeV Muon Collider - Tracking Studies v0.4

- V0.4 CC with 1m long dipole-sextuple magnets with sextupolar components weaker than 0.2T (increase of dispersion with the addition of dipoles between sextuples of all sets).

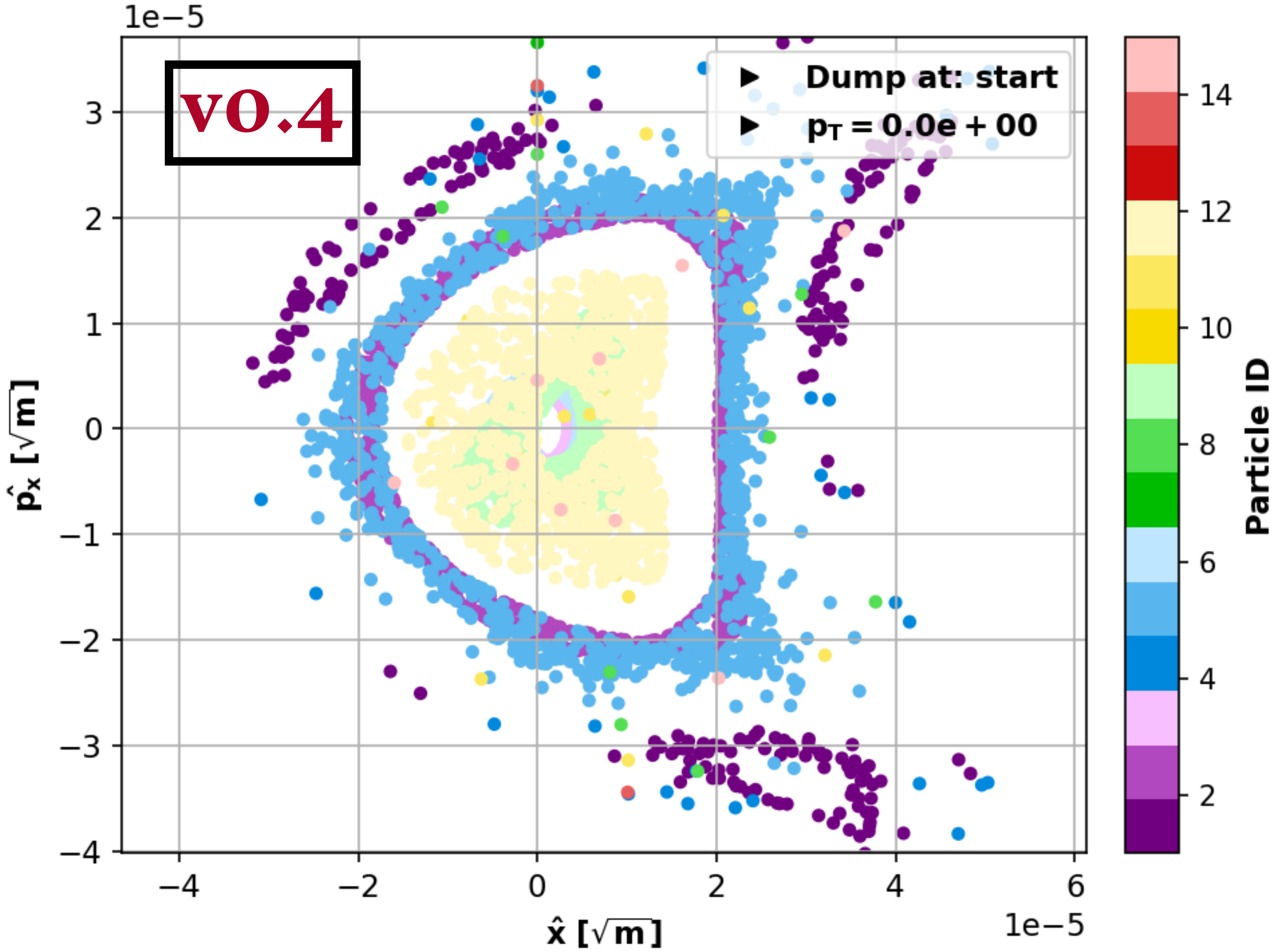


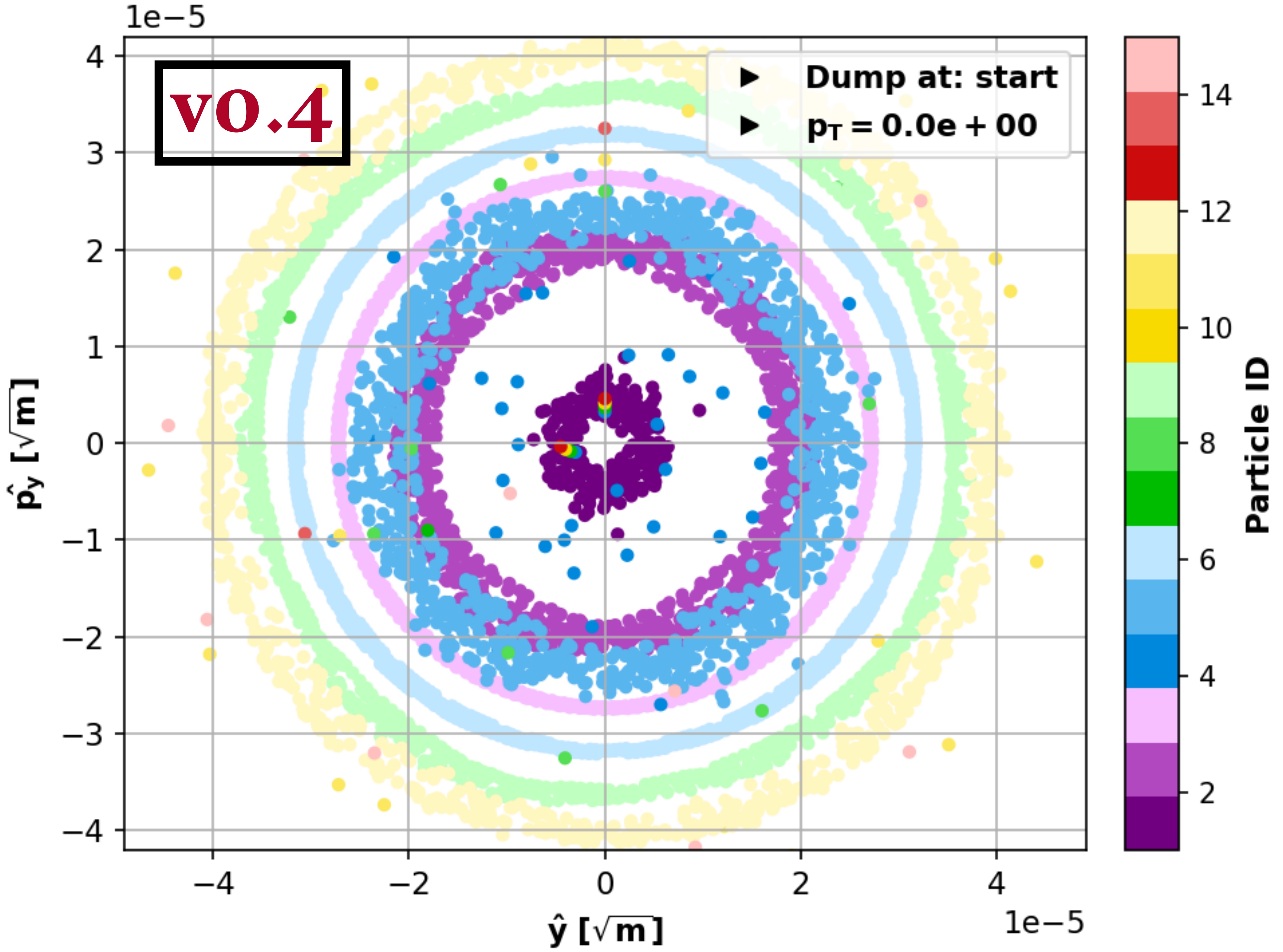



# 10TeV Muon Collider - Tracking Studies




From 1 to 2σ



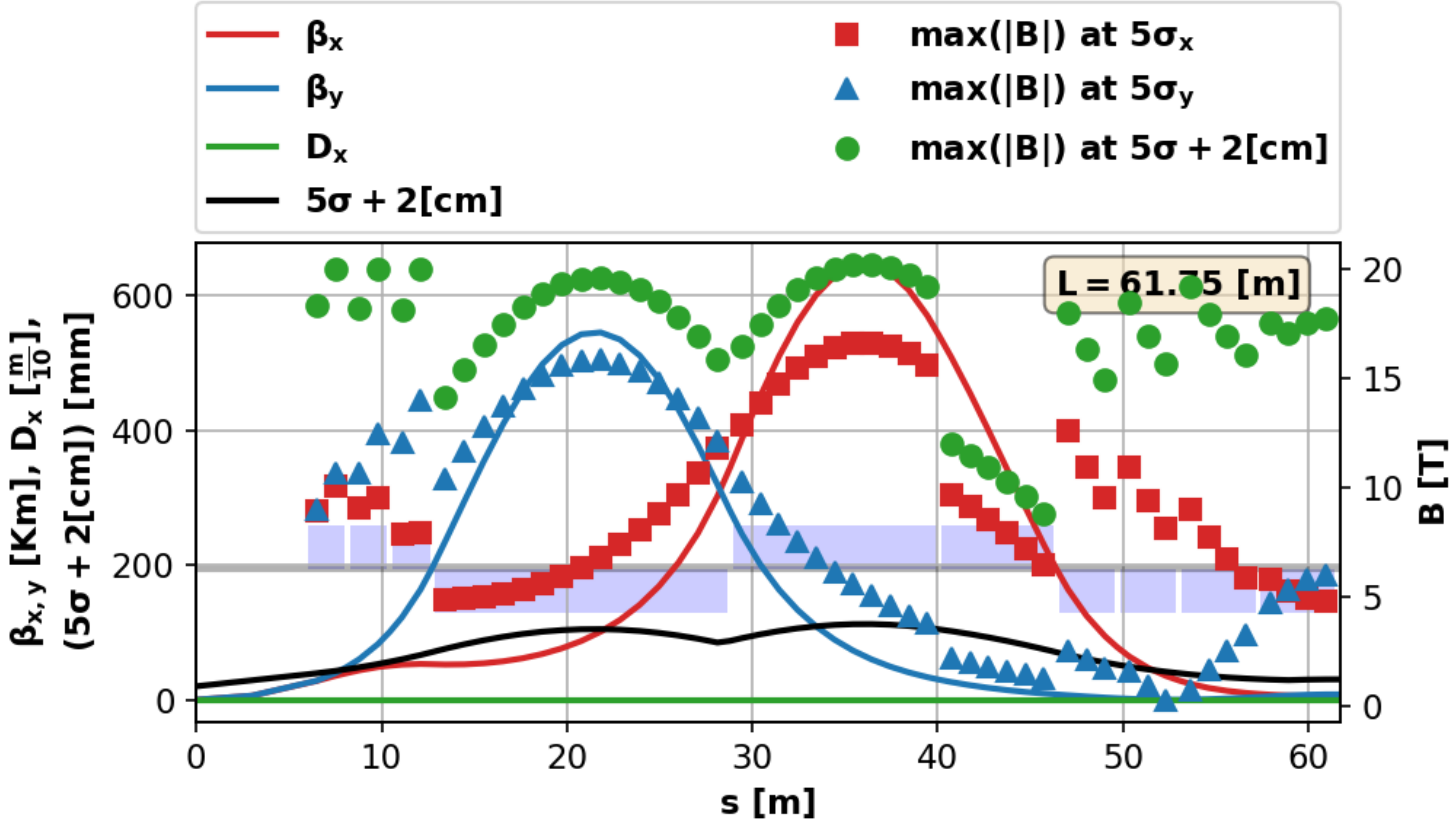
# 10TeV Muon Collider - Final Focusing Scheme

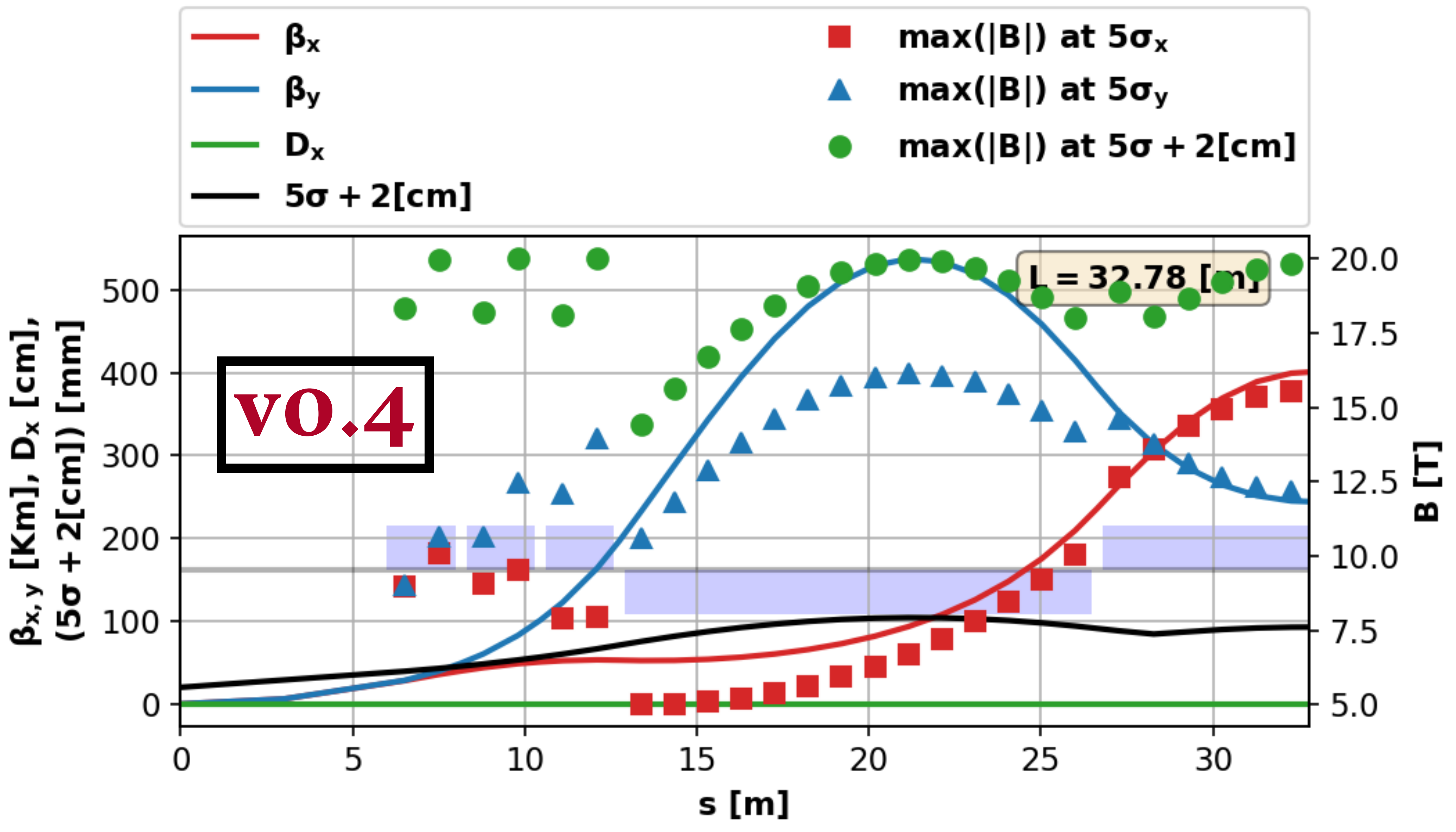
- $L^* = 6m$ and a triplet is used for the Final Focusing (FF).
- The maximum allowed magnetic field at the FF scheme is assumed to be the 20T.
- Due to the fast increase (decrease) of the β functions right after the IP (at the end of FF scheme), the first (last) magnet is split in shorter ones with different gradient, reducing that way the length of the FF scheme.
- The quadrupoles in the FF scheme are used to control the beta values ($\beta_x$,$\beta_y$) at the end of the FF scheme as well as to obtain a point to parallel matching ($\alpha_{x,y} = 0$) at the end of the FF scheme.

# 10TeV Muon Collider - Final Focusing Scheme

$$B\rho = 16678.205\ [Tm] \qquad Aperture = 2(5\sigma + 0.02)\ [m]$$

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

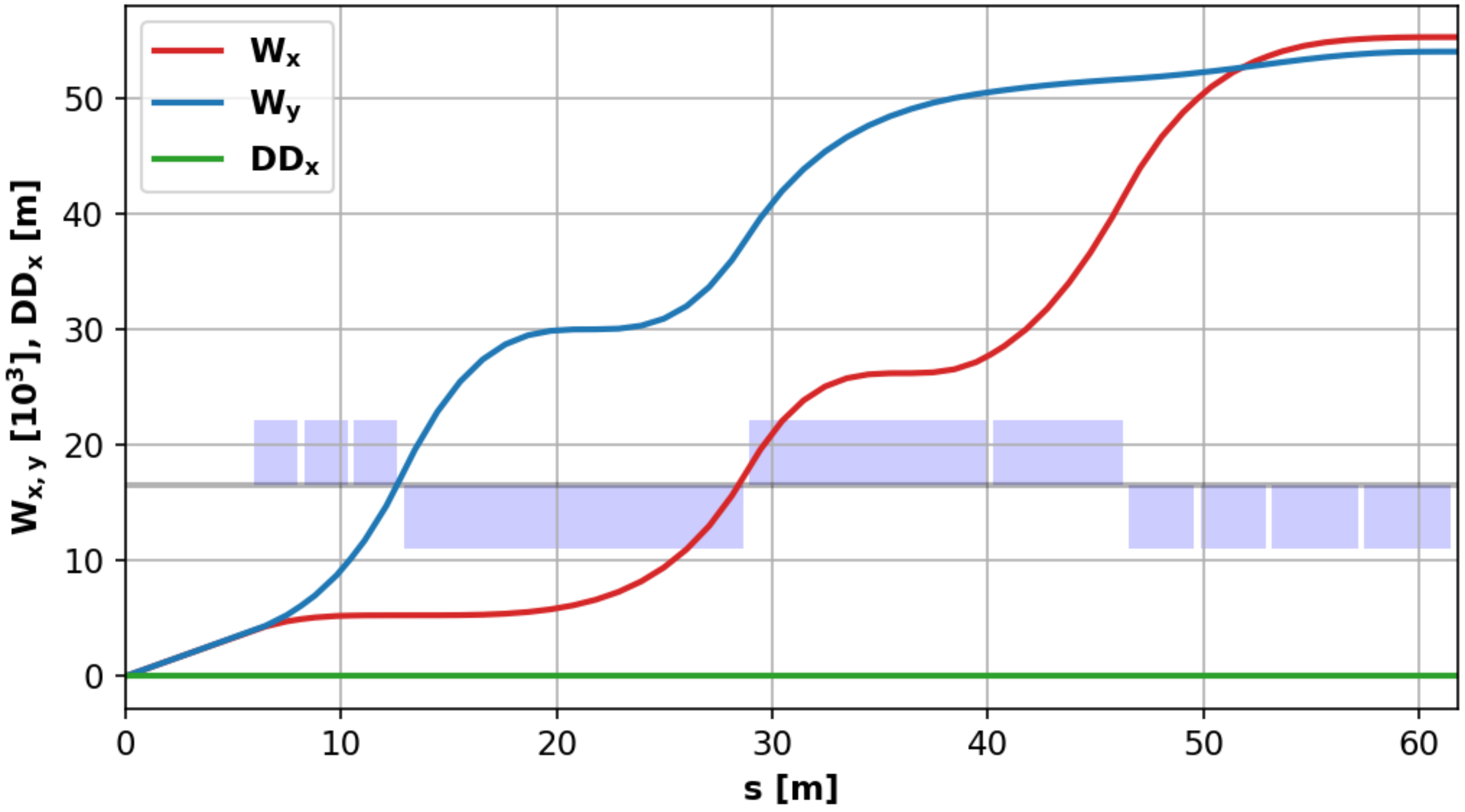


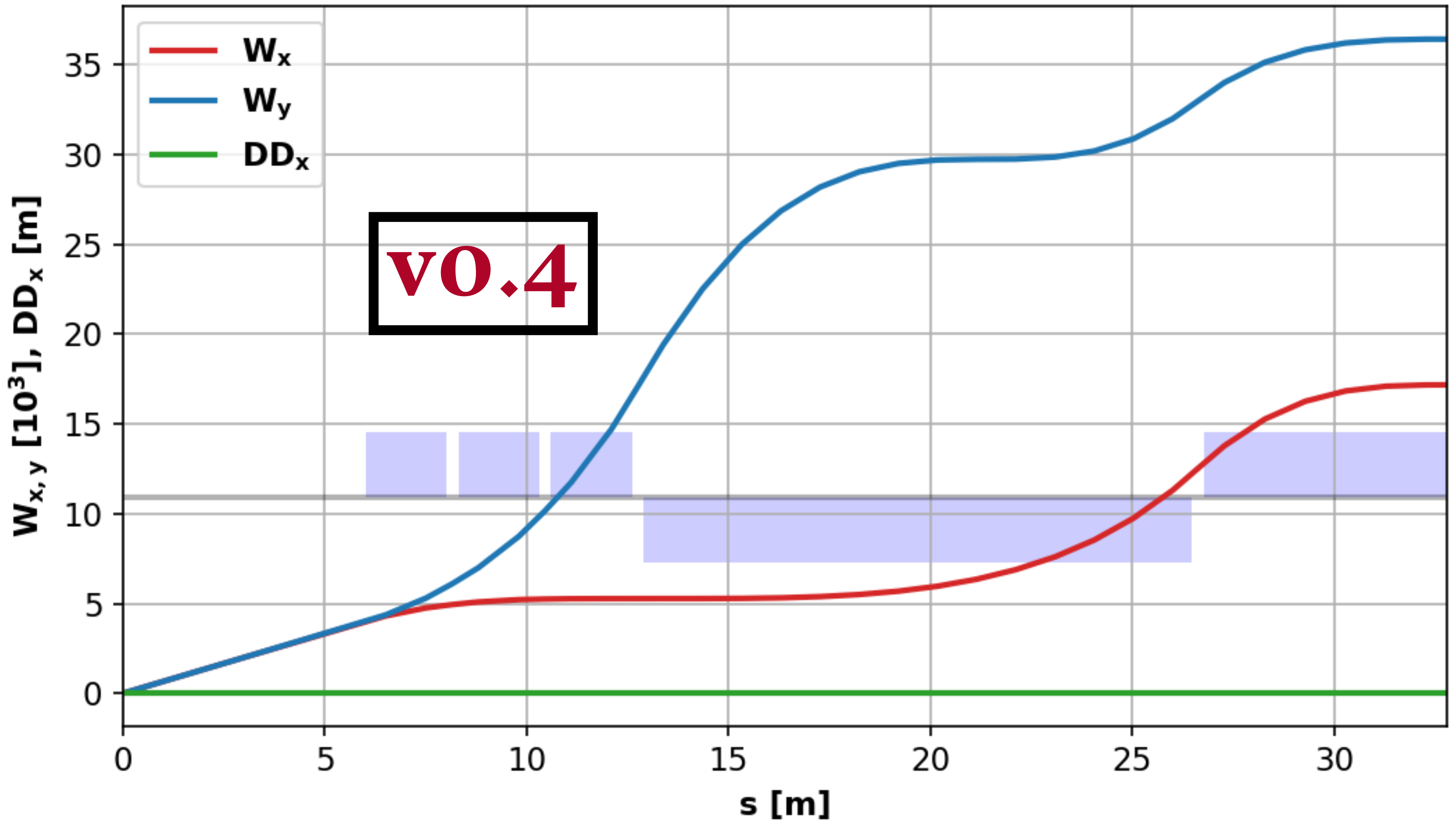



# 10TeV Muon Collider - Final Focusing Scheme

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

- Together with the large momentum spread ($\delta=10^{-3}$), these W values indicate enormous chromatic effects that should be compensated in order to avoid performance degradation.



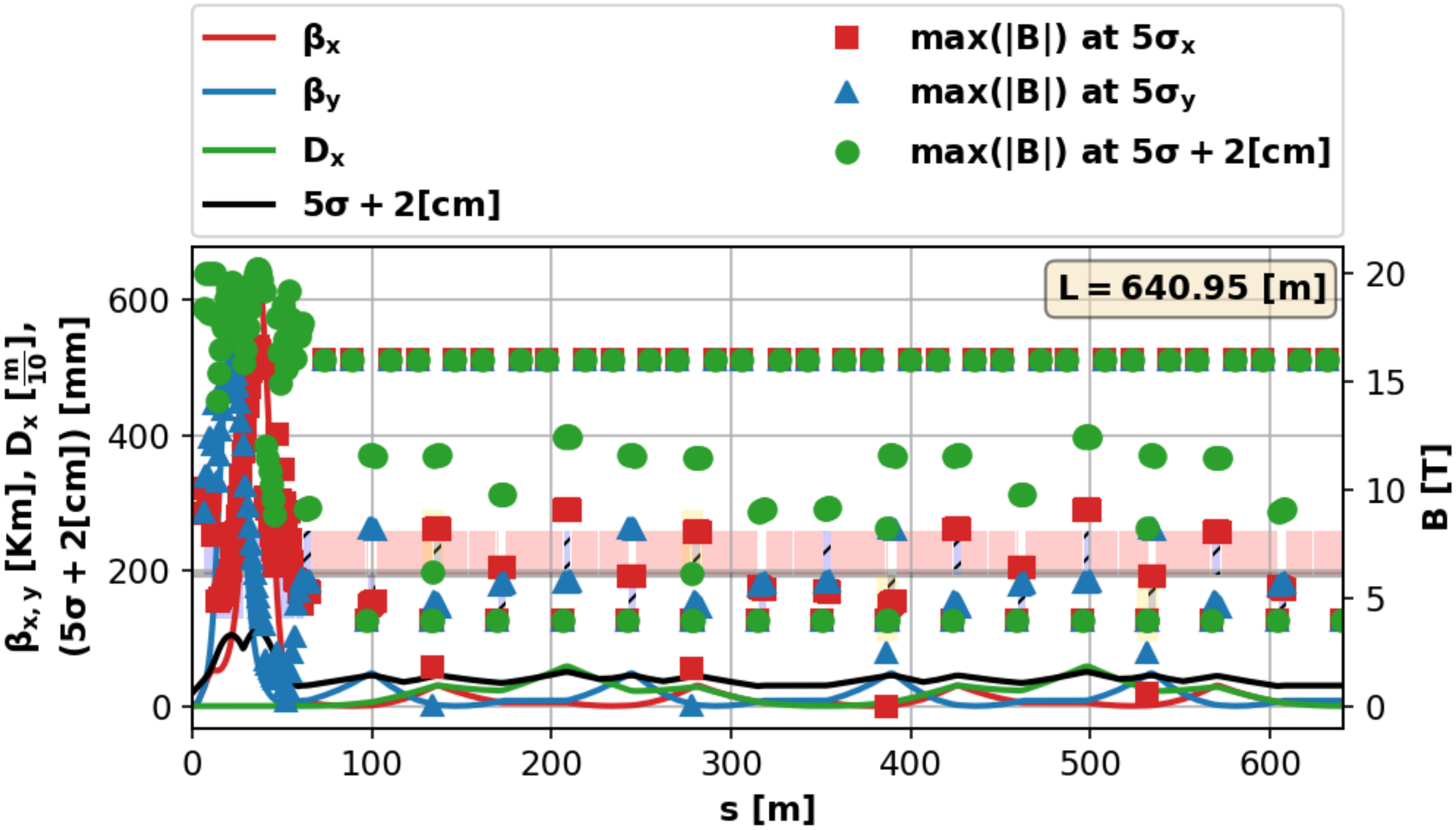
# 10TeV Muon Collider - Chromatic Correction Scheme

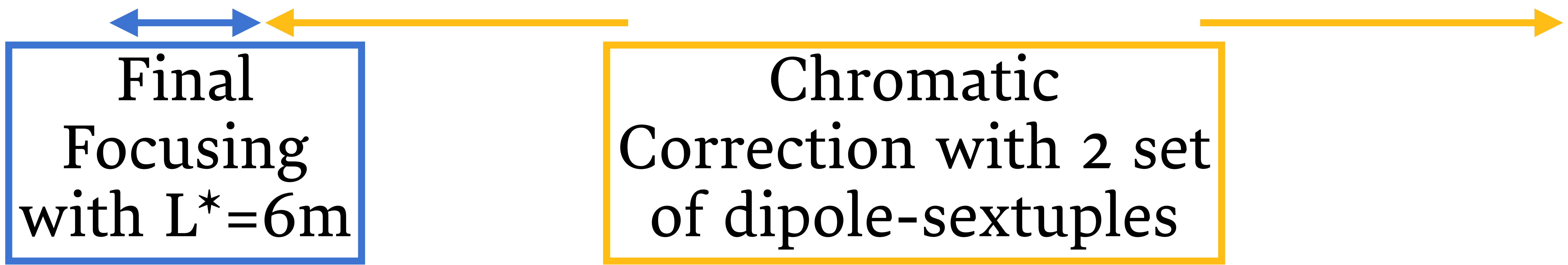
- In order to address the chromatic phenomena before entering the arcs, the Chromatic Correction (CC) schemes is designed and placed right after the FF quads.
- The maximum allowed magnetic field is assumed to be the 16T.
- The CC scheme include 2 sets (doublets) of combined function dipole-sextupole magnets and each set is placed at positions with large $\beta_q$, where q=x or y, for the correction of the $W_q$ at the end of CC scheme.
- Each set include a pair of dipole-sextupole magnets with the same $k_2$ and are separated by -I transform at x and y planes for the compensation of the RDTs excited by the sextupolar component.
- The $D_x$ and $D_{px}$ are also controlled in the CC scheme (by generating a $2\pi$ phase advance at the x plane) facilitating the matching between the CC and arc optics.

# 10TeV Muon Collider - Chromatic Correction Scheme

Colour code for lattice elements:

- Red dipoles
- Blue quadrupoles
- Hashed blue dipole-quadrupoles
- Red + Gold dipole-sextupoles (all 1m long)



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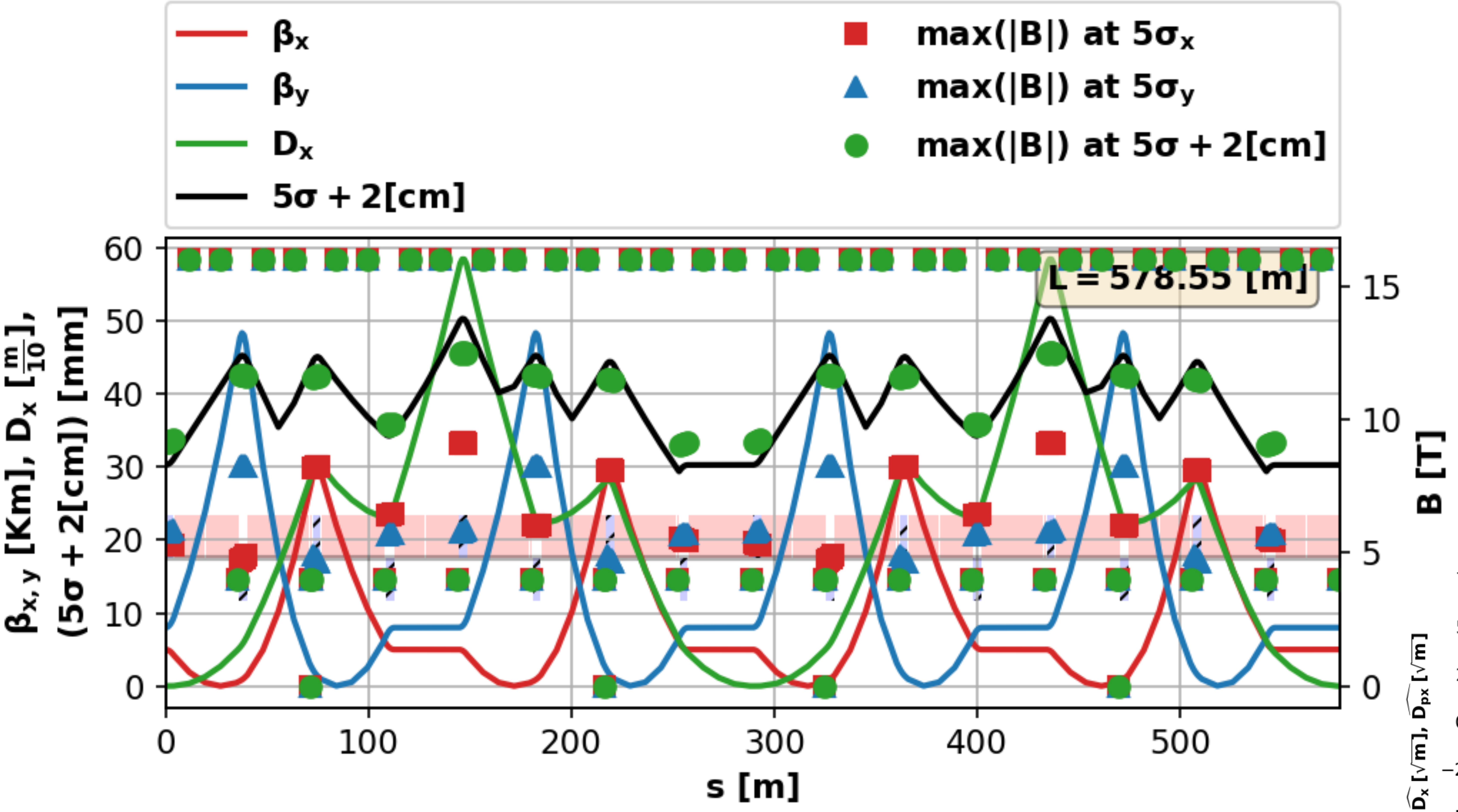


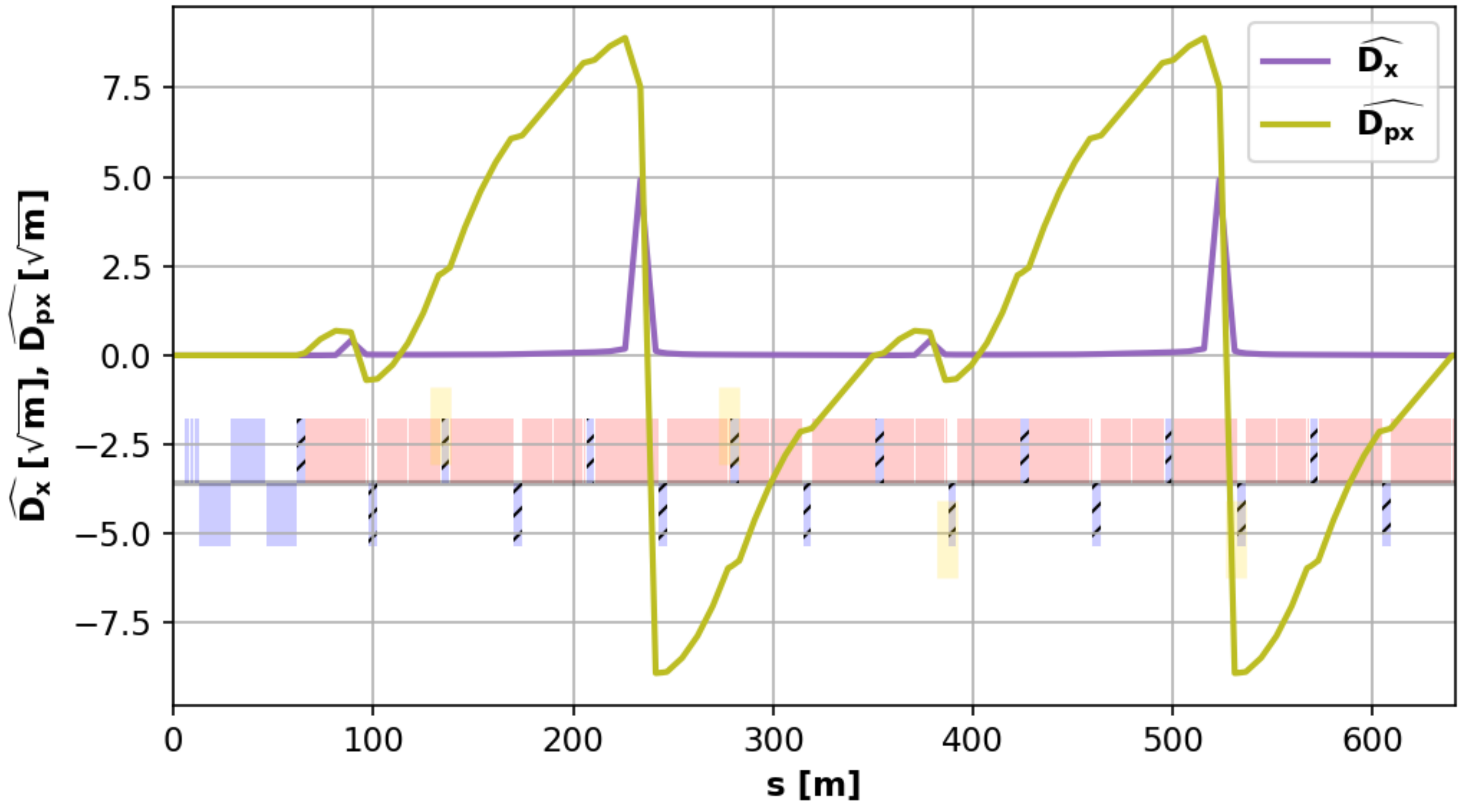

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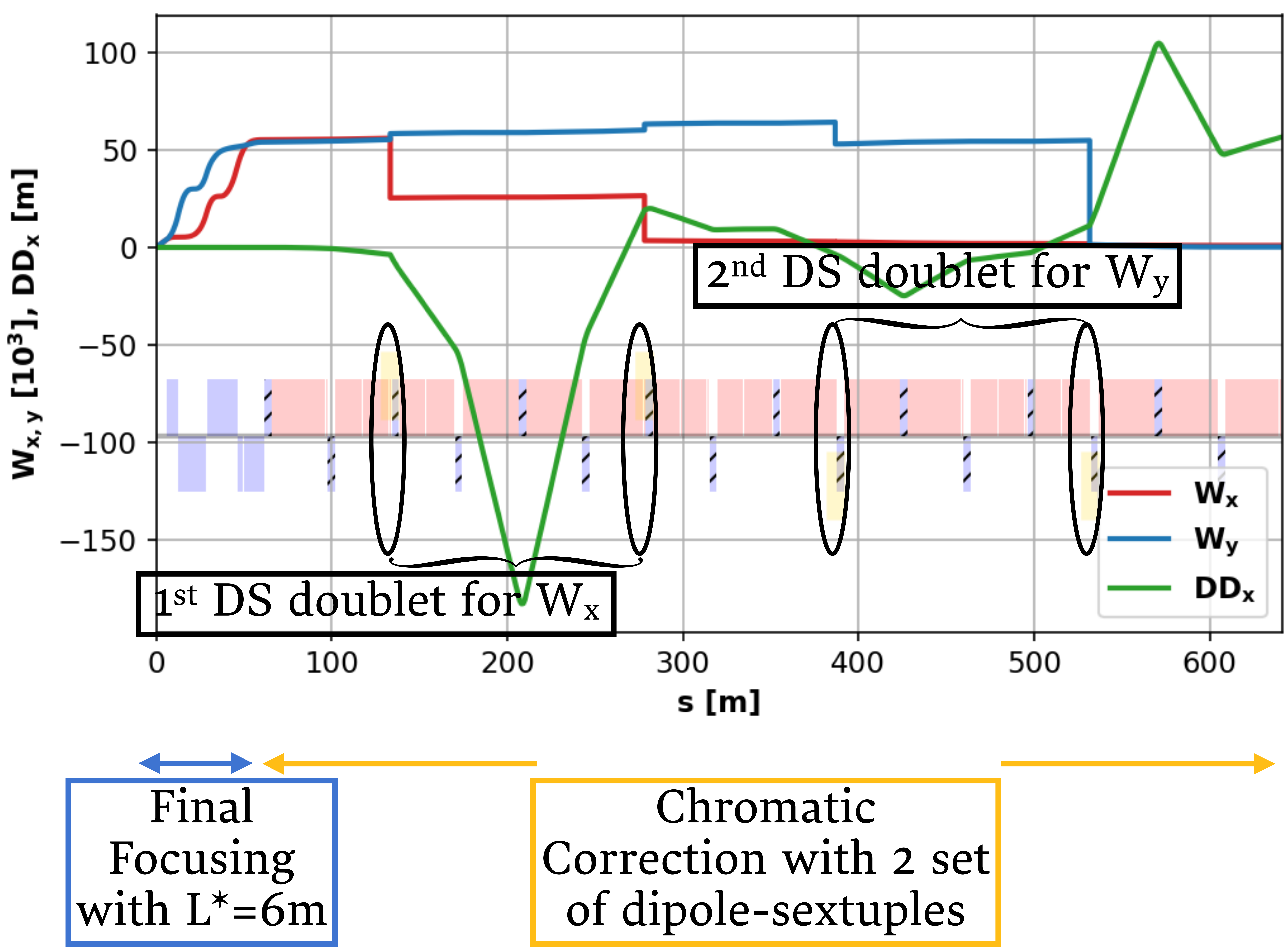

# Thank you for your time!

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

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# Backup

# 10TeV Muon Collider - Final Focusing Scheme

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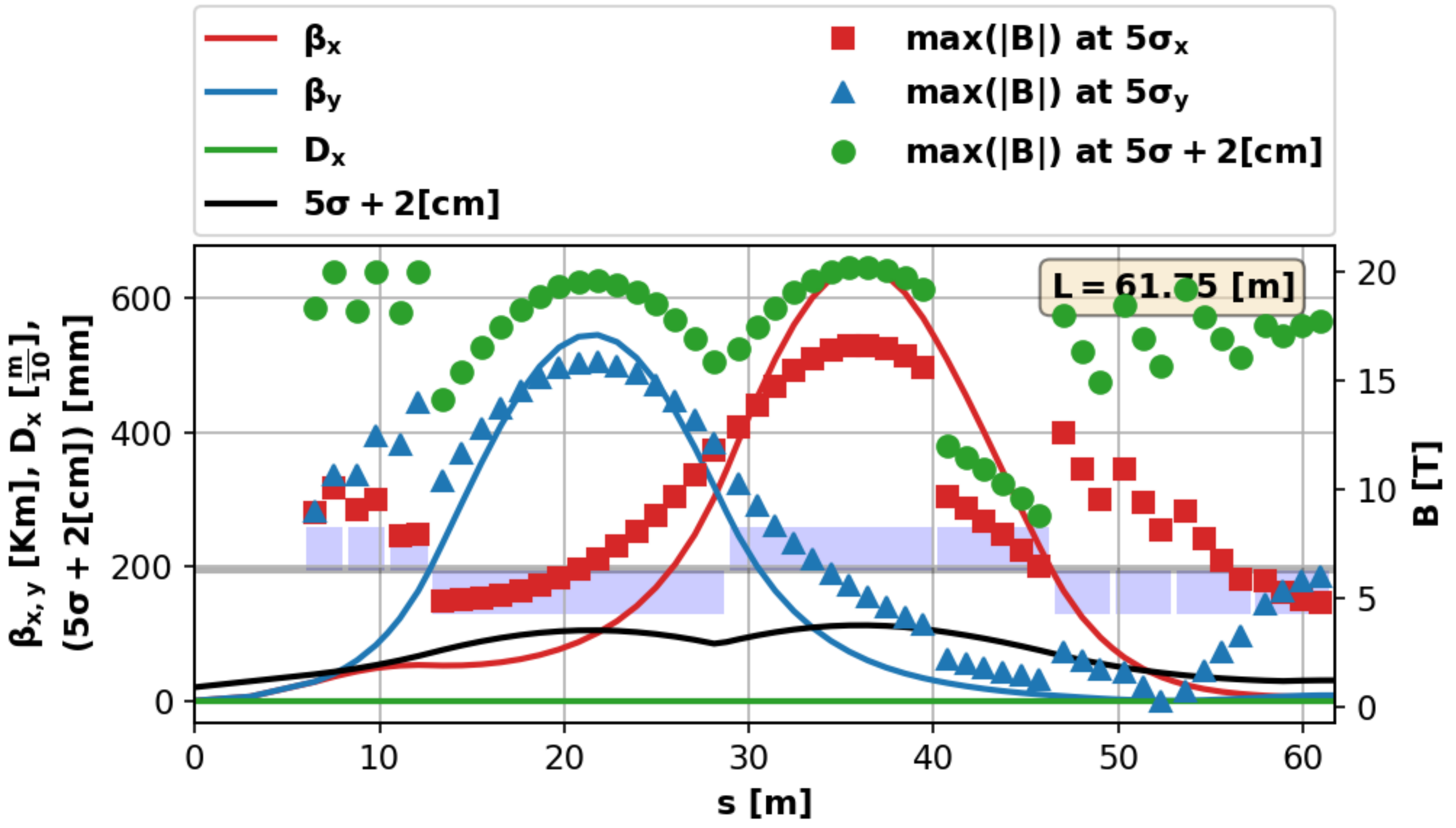


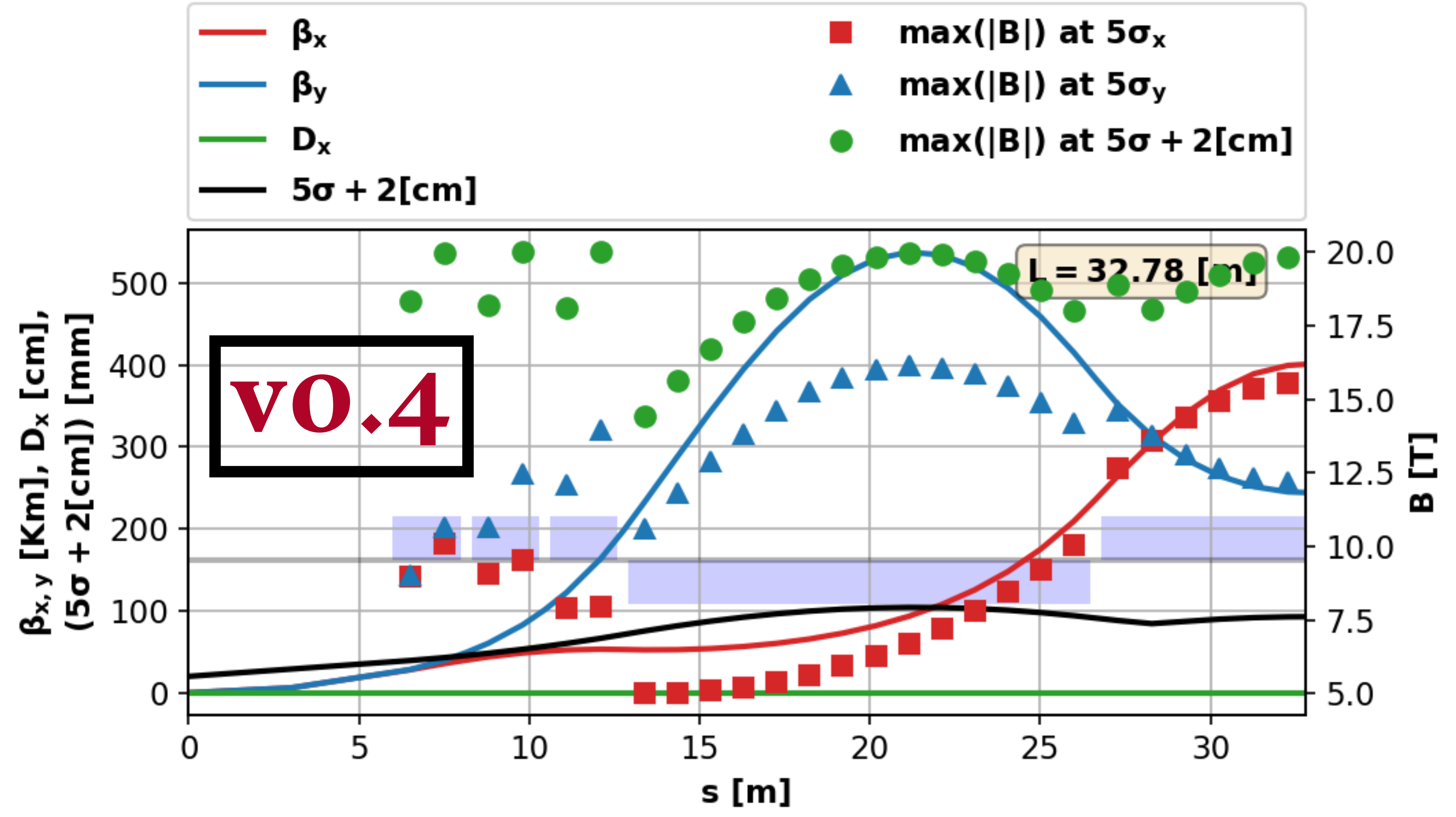


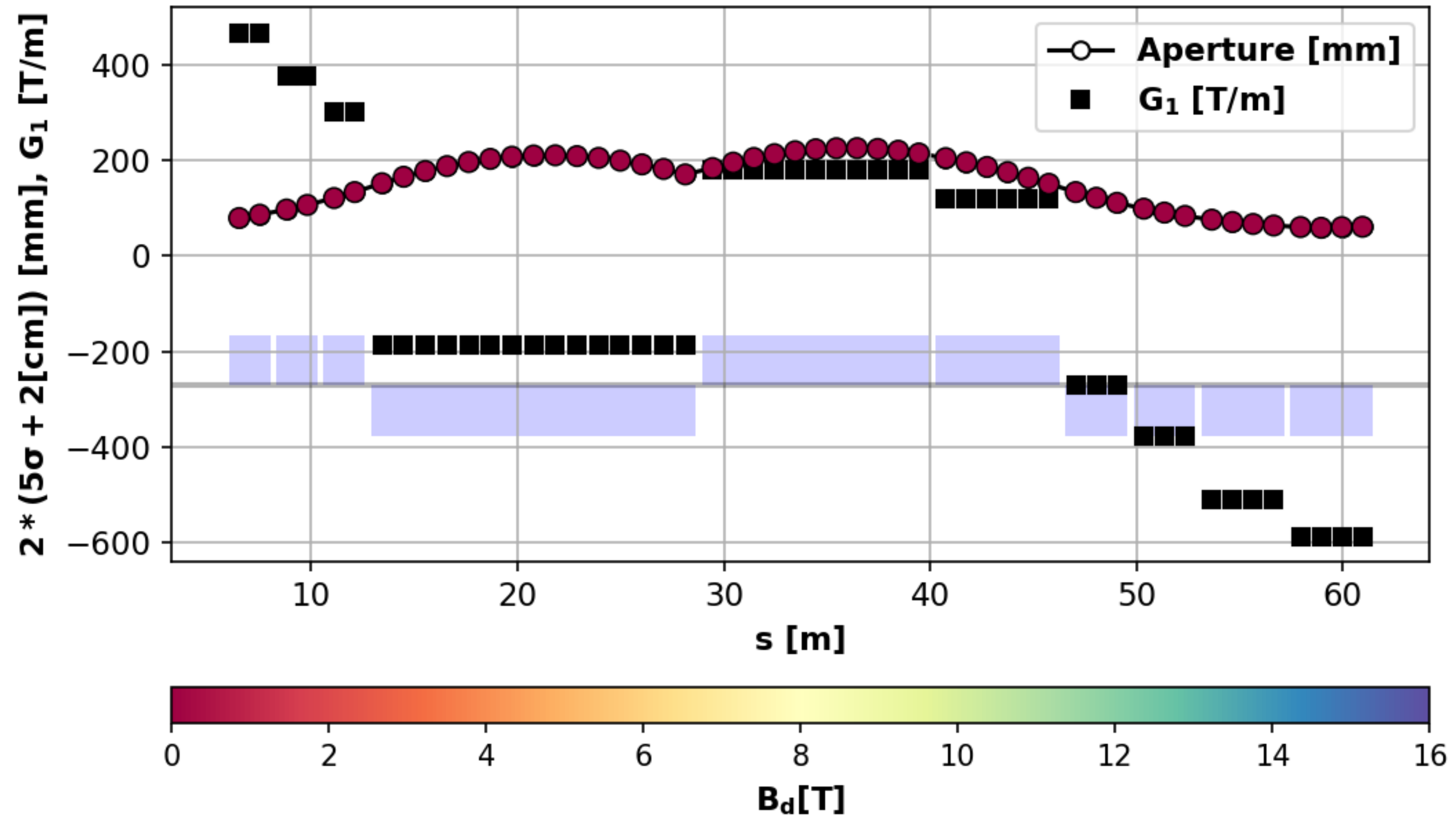

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