Progress of Muon Collider Lattice Design v0.7

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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	$\varepsilon_{nx} = \varepsilon_{ny}$	μm	25
Transverse geometric rms emittance	$\varepsilon_{gx} = \varepsilon_{gy}$	nm	0.528
Longitudinal emittance (4π σ_E σ_T)	ε_l	eVs	0.314
Longitudinal geometric emittance ($\frac{\varepsilon_l c}{4\pi E_{0\mu}}$)	ε_{lg}	mm	70
Rms bunch length	σ_z	mm	1.5
Relative rms energy spread	δ	%	0.1
Beta function at IP	$\beta_x^\star = \beta_y^\star$	mm	1.5
Power per beam with 5 Hz repetition rate	P_{beam}	MW	7.2

10TeV Muon Collider - In a nutshell

1.5mm β*

=> ~840km βs in the Final Focusing (FF) scheme (also large δ=0.1%).

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

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

=> Use of dipole-sextupol kicks at areas with large betas and dispersion.

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

Muon decay (short lifetime τ_0~2.2μs or τ_{5TeV}~0.1s)

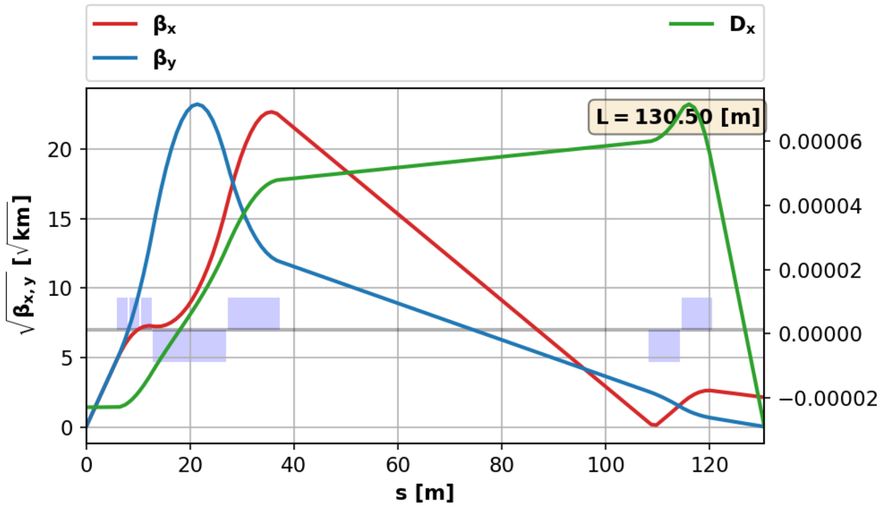
=> The resulting neutrinos even from a short straight piece of collider generate a narrow "radiation cone" that is an issue at the location, where they reach the earth surface.

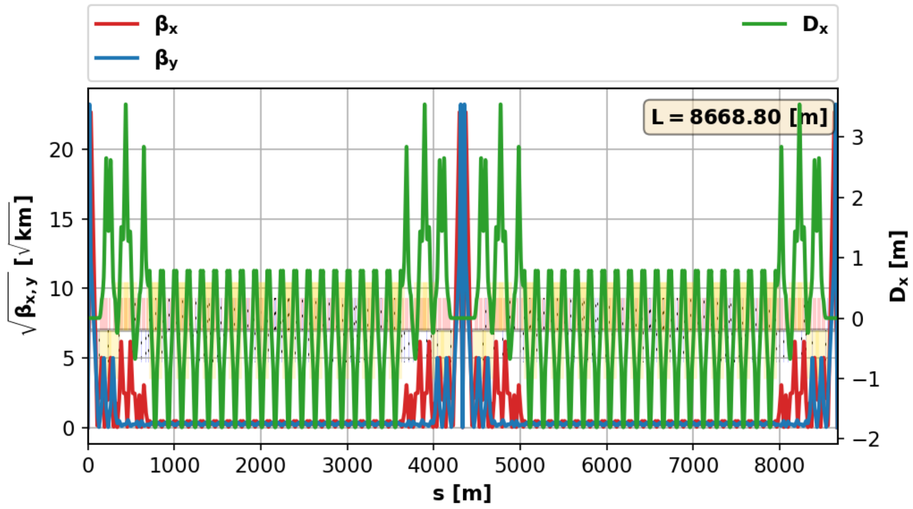
=> The planned shape of the collider is like a race track (2 straight sections for IPs).

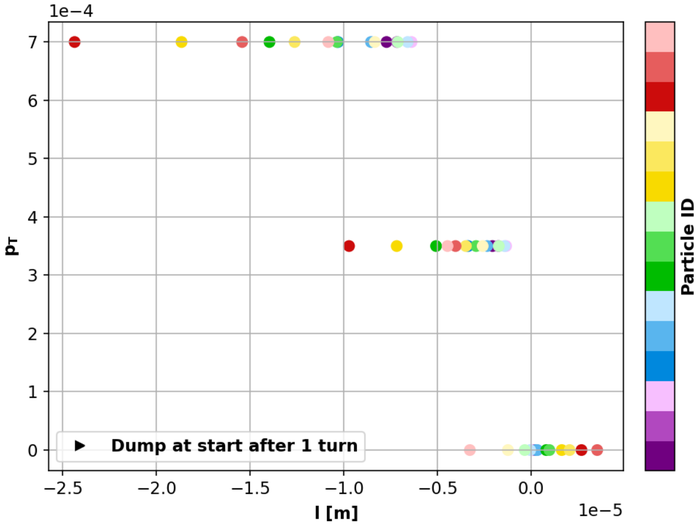
=> Extensive use of dipoles and combined function magnets.

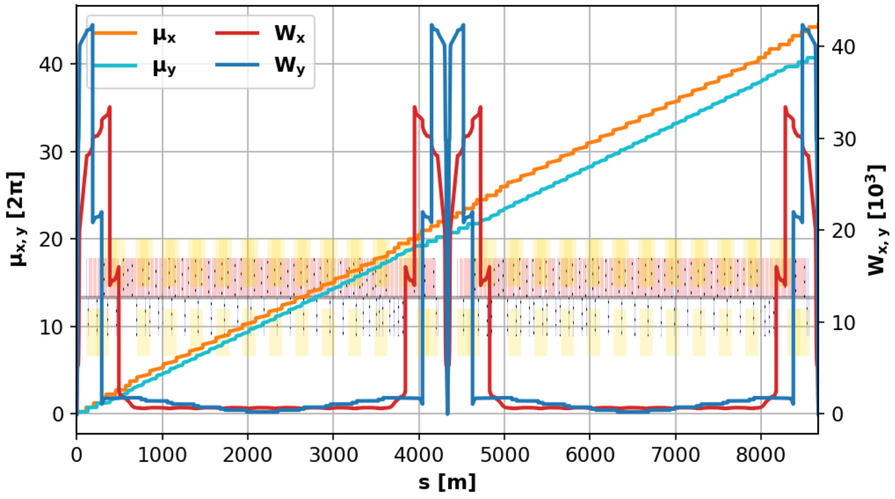
10TeV Muon Collider **v0.6** (Recap)

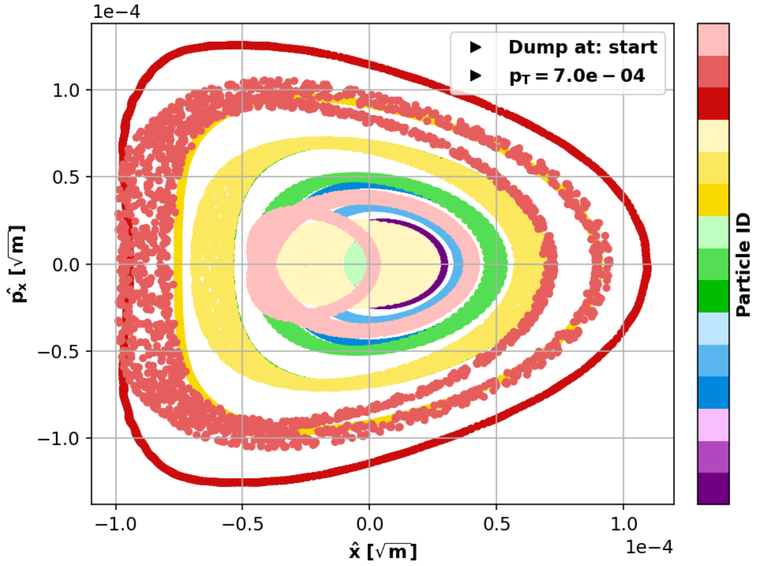
10TeV Muon Collider - v0.6











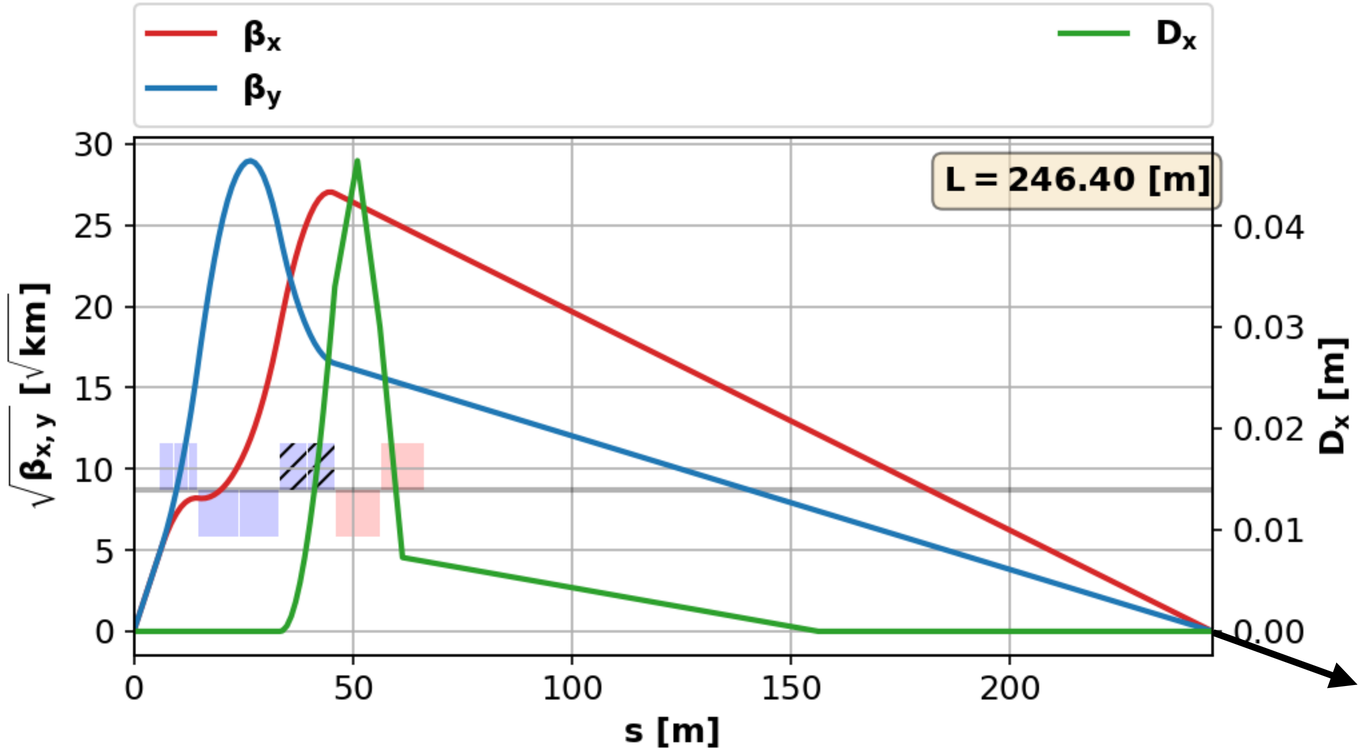
p_T [%]	DA_{min} [σ]
0.07	5
0.08	4
0.09	3
0.1	<1

10TeV Muon Collider **v0.7**
(Current design, not yet fully optimised)

10TeV Muon Collider - Final Focusing Quads

- L* = 6m and five quadrupoles are used.
- The maximum magnetic field at the magnet aperture is set to 20T.
- Due to the fast increase (decrease) of the β functions right after the IP, the first magnet is split in shorter ones with different gradient, reducing that way the length of the FF scheme.
- Inclusion of a drift section for a smoother reduction/control of the beta values (β_x,β_y) at the end of the FF scheme. This help to keep the Montague chromatic functions at smaller values in the chromatic correction section.
- Last quad is a combined function magnet while the last 2 quadrupolar components are used to control the optics in the chromatic correction section.
- Dipolar components are included (generating a dispersion bump) for the reduction of the strong beam induced background (BIB) due to the long straight section.
- Each dipolar component (>100Tm) generate ~6mrad to cancel out the dispersion bump (600m neutrino spread @ 100km from collider).

10TeV Muon Collider - Final Focusing Scheme



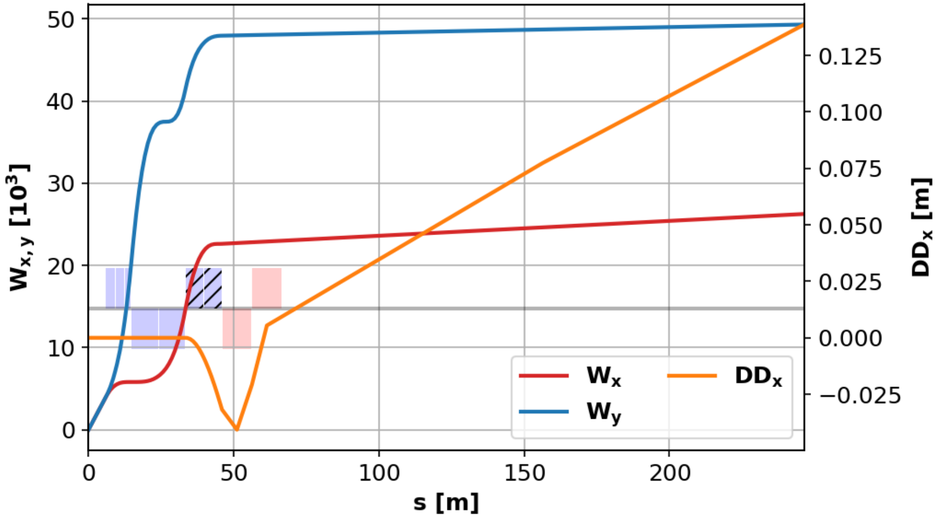
$$B\rho = 16678.205\ [Tm]$$

$$Aperture = 2(5\sigma + 0.04)\ [m]$$

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

$$\sigma = max(\sigma_x, \sigma_y)\ [m]$$

$\beta_{x,y} \sim 5cm$



Entering the CC with small βs resulted in:

- Smaller aperture
- Smaller Ws
- Smaller unwanted multipolar components
- Easier control of βs

10TeV Muon Collider - Chromatic Correction & Matching Schemes

- The maximum allowed magnetic field is assumed to be the 20T.

Chromatic Correction (CC) scheme

- The CC scheme include 2 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.

- 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.

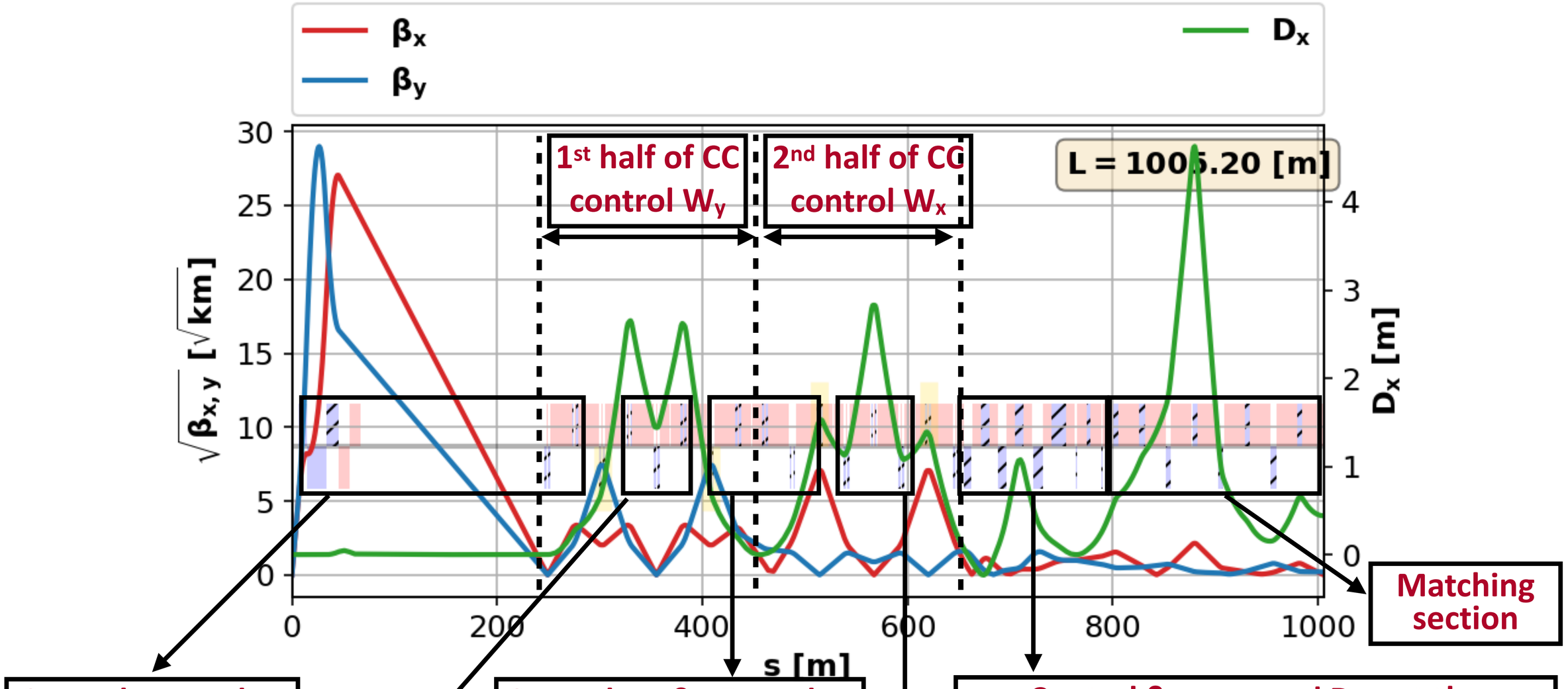
Matching scheme (CC-Arc)

- The $\beta_{x,y}$, $\alpha_{x,y}$, D_x and D_{px} are matched by controlling the strength of six dipole-quadrupole and the dipole length separating the dipole-quadrupole magnets.

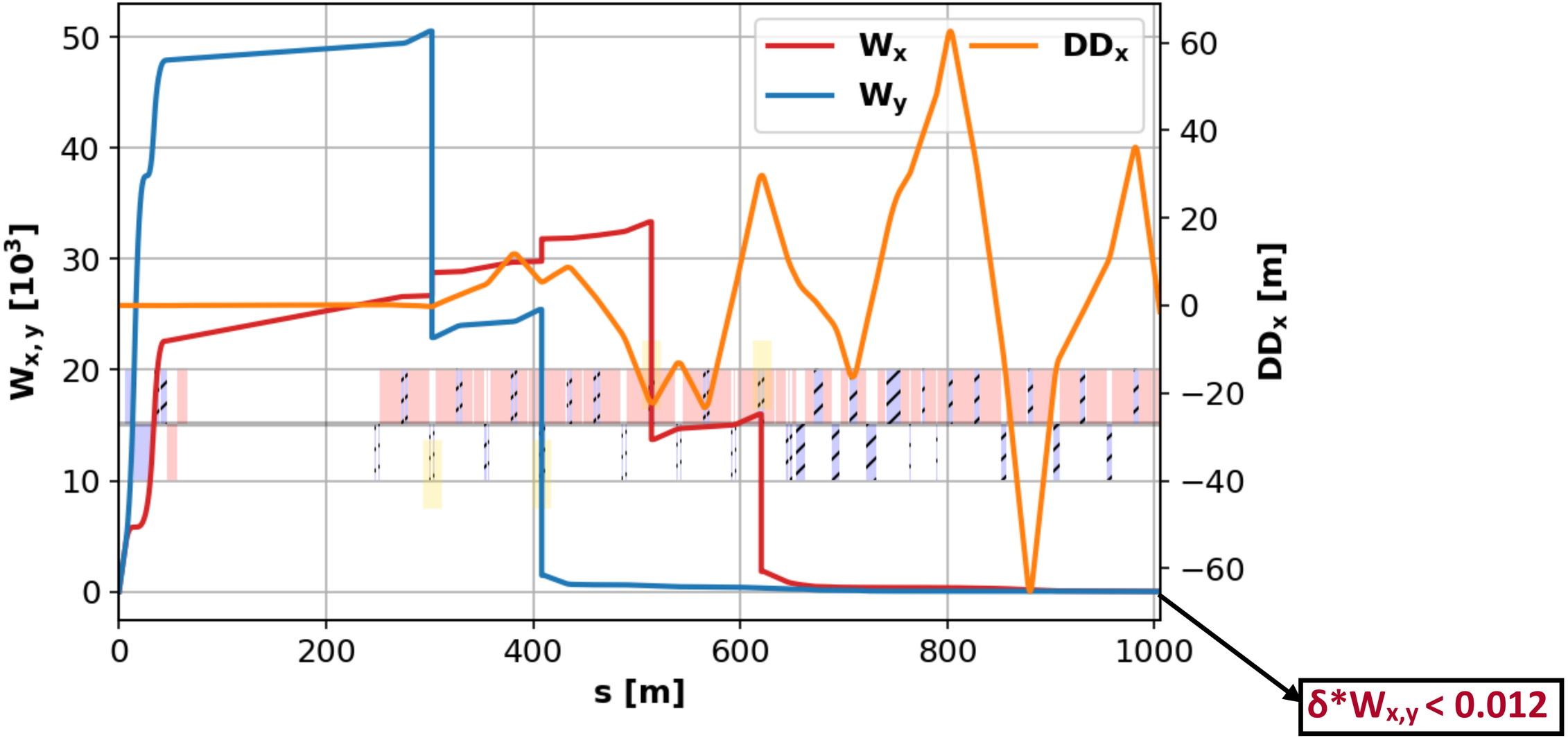
- The matching to the arc optical functions is facilitated by controlling the optics value at the entrance of matching section with a set of pre-matching combined function magnets.

- The working point is also controlled (not yet with great flexibility).

10TeV Muon Collider - Chromatic Correction & Matching Schemes



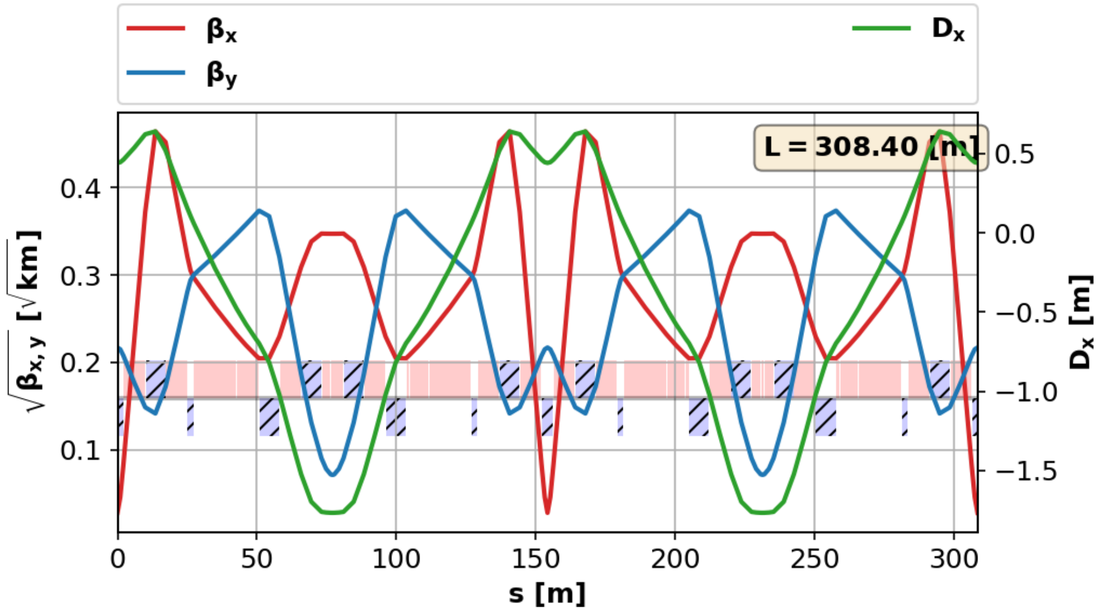
10TeV Muon Collider - Chromatic Correction & Matching Schemes

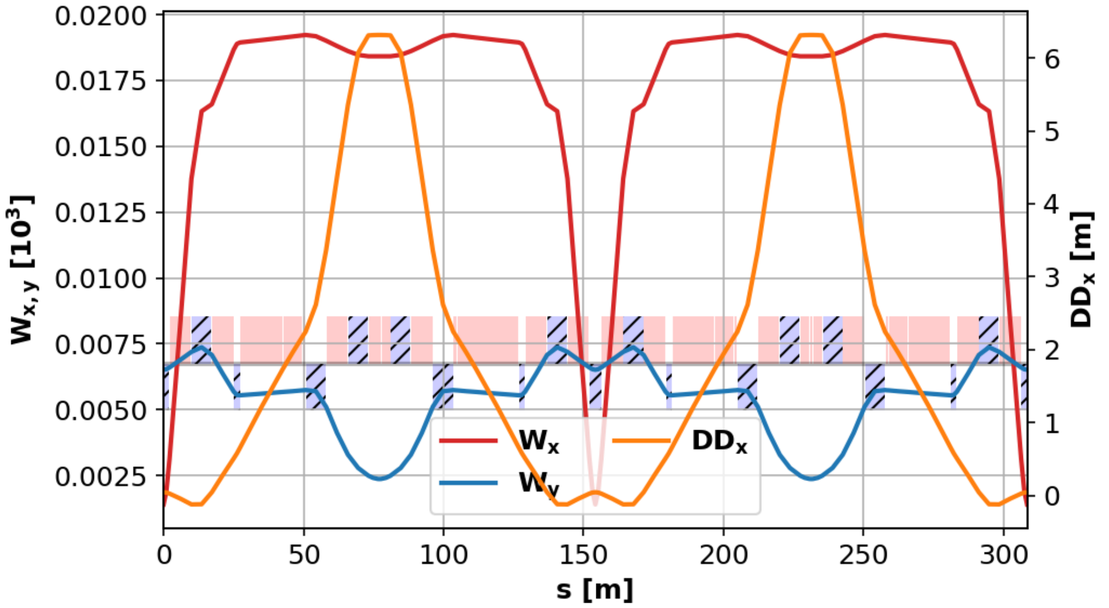


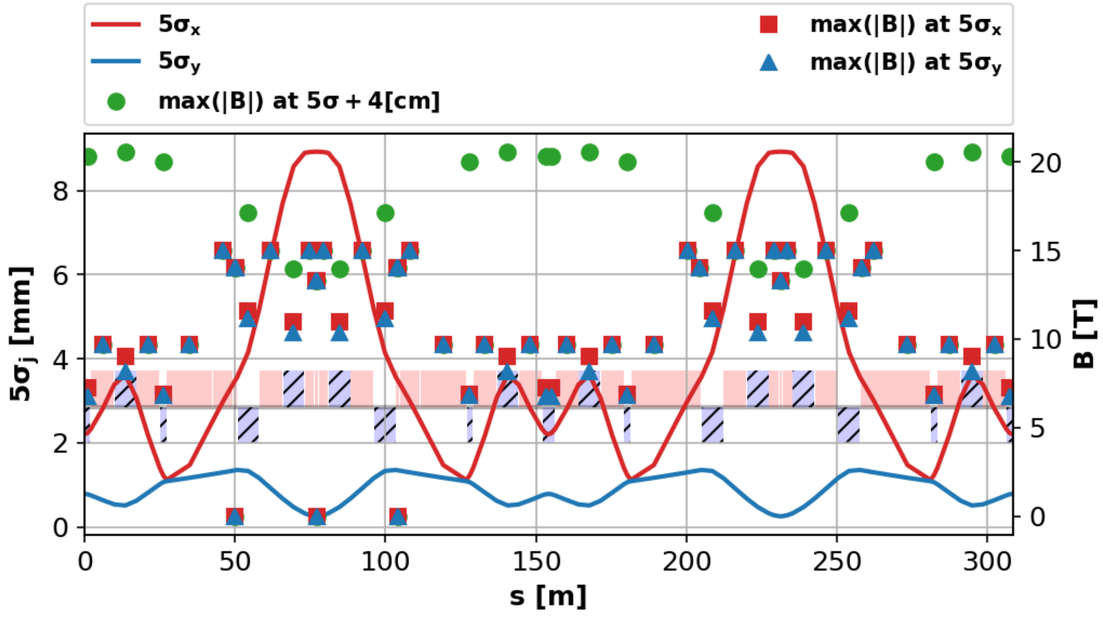
10TeV Muon Collider - Arc

- The CC scheme produces a large positive contribution to the momentum compaction factor (α_p) and phase slip ($\eta_p \sim \alpha_p - 4.5 \times 10^{-10}$) thus, a negative contribution from the arcs is generated in order to keep η_p small and stay below transition ($\eta_p, \alpha_p < 0$).
- The maximum allowed magnetic field is assumed to be the 20T and is planned to be reduced to 16T in future iterations.
- Each arc section consist of repeated Flexible Momentum Compaction (FMC) cells (each one is made out of 2 FODO cells).
- The integrated strength of a set of dipoles located at areas with negative dispersion controls the α_p while with another set of dipoles, the 2π closing of the trajectory is controlled.
- The linear chromaticity at x and y planes is controlled with a set of combined function dipole-sextupole magnets separated by a -I transform.
- The phase advance per FMC cell is $3\pi/2$ (-I transform every second cell).

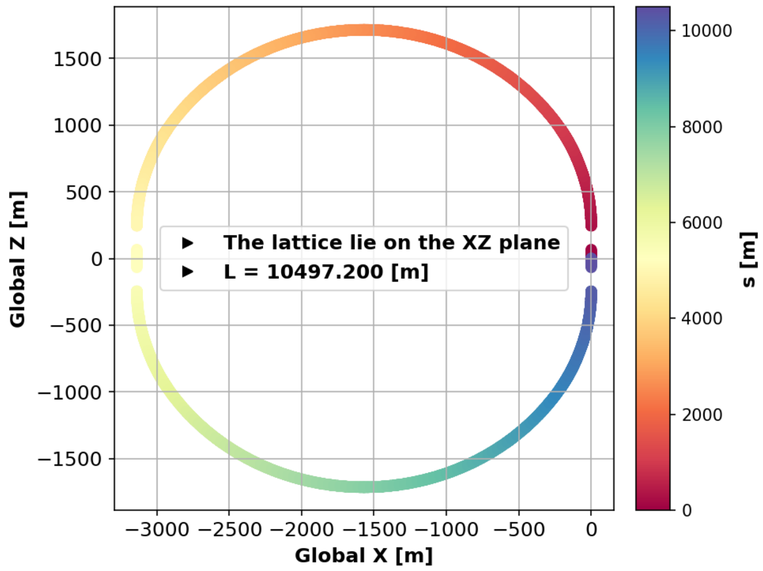
10TeV Muon Collider - Arc

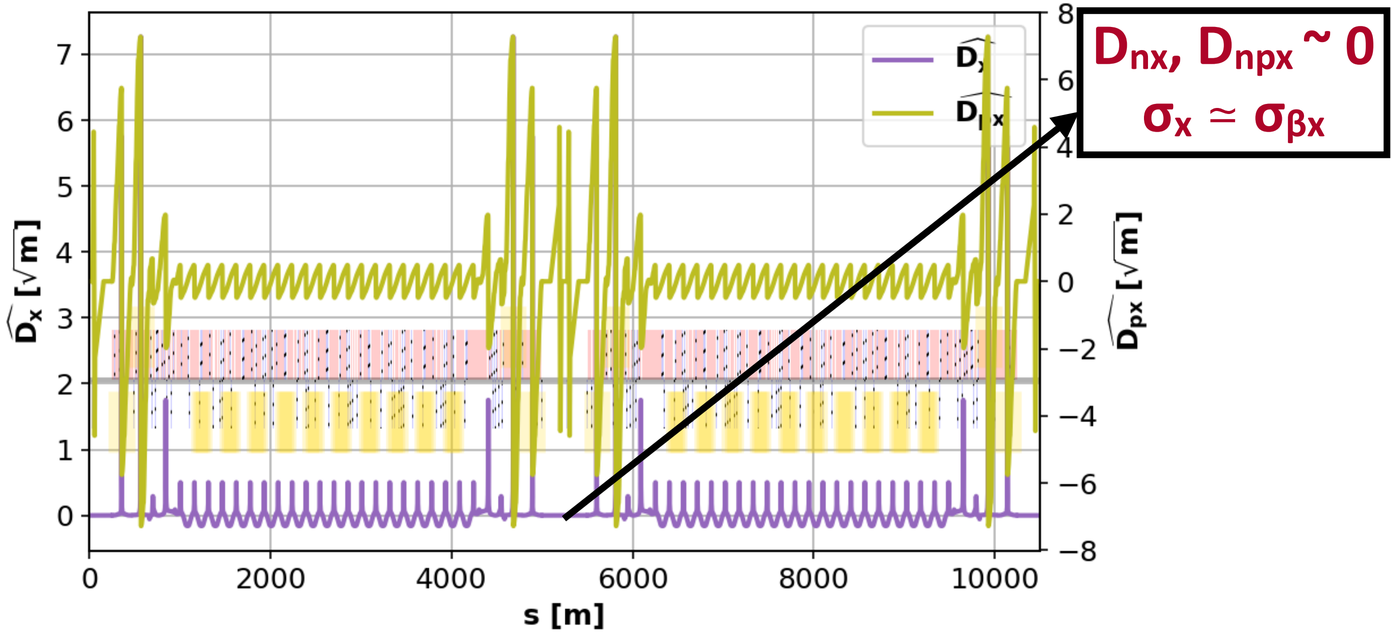


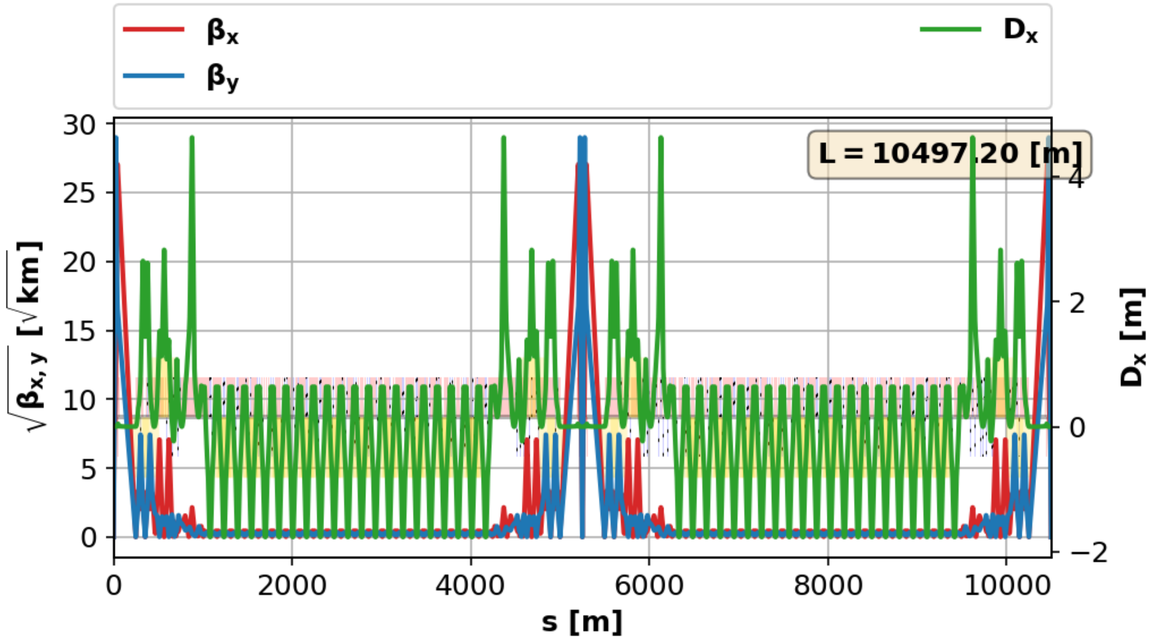


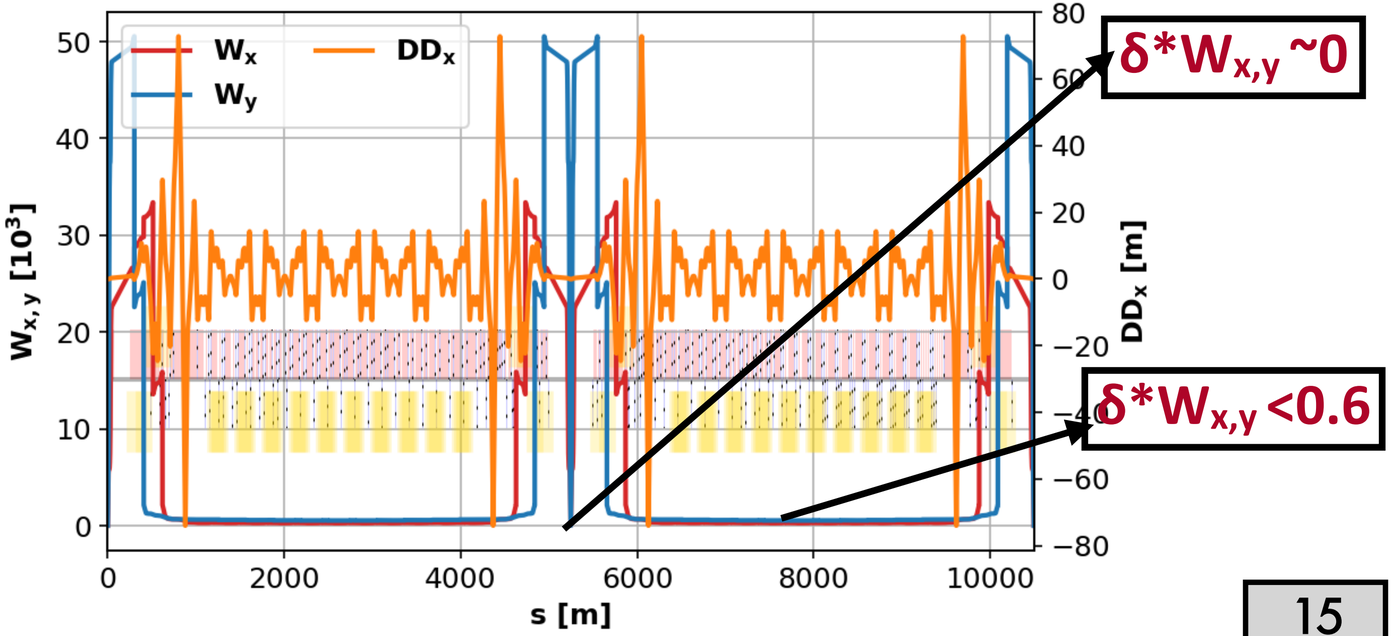


10TeV Muon Collider - Full Lattice





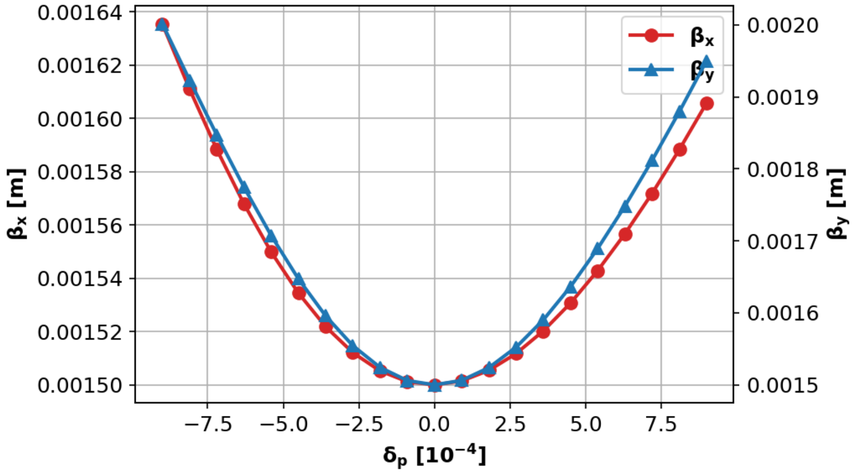


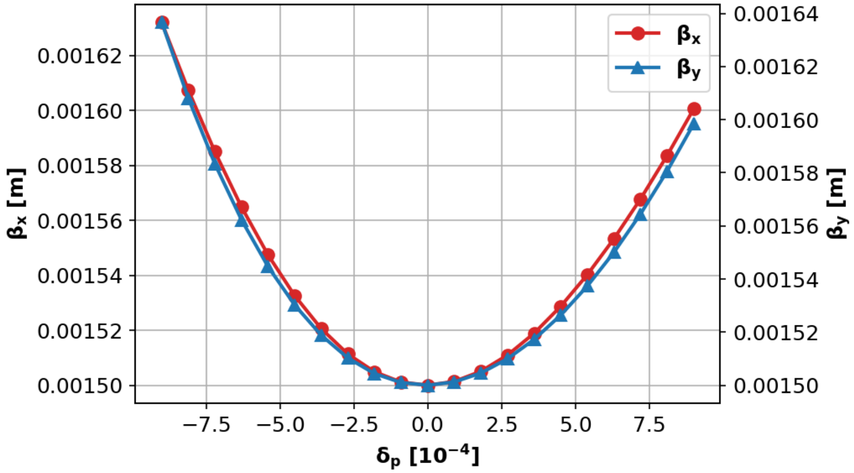


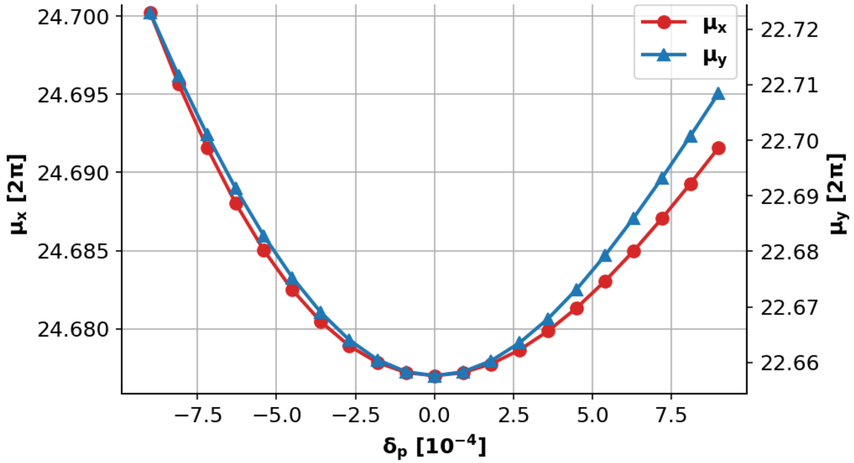
10TeV Muon Collider - Full Lattice

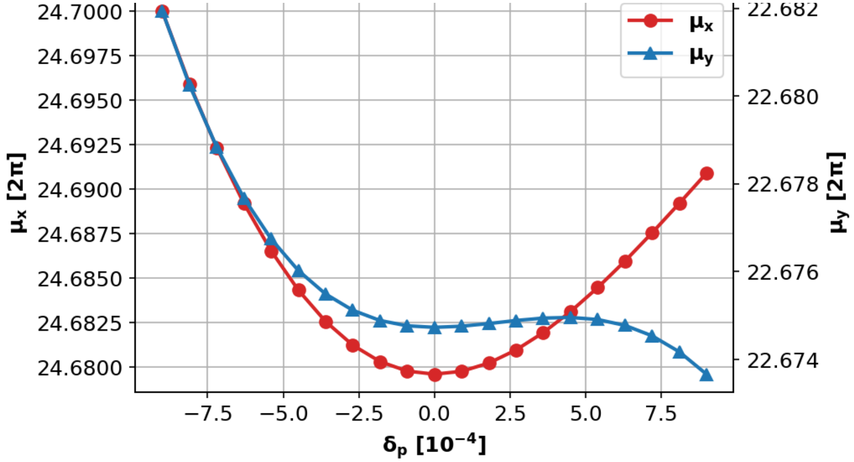
$\mu_{y,IP->SD}$ [2π]	$\mu_{x,IP->SF}$ [2π]	$\xi_{x,y}$	$Q_{x,y}$	α_p
0.75	1.75	2.6E-05	0.354	1.6E-05
		-4E-05	0.315	

$\mu_{y,IP->SD}$ [2π]	$\mu_{x,IP->SF}$ [2π]	$\xi_{x,y}$	$Q_{x,y}$	α_p
0.75 - 3E-5	1.75	4E-05	0.359	1.6E-05
		-2.2E-05	0.349	

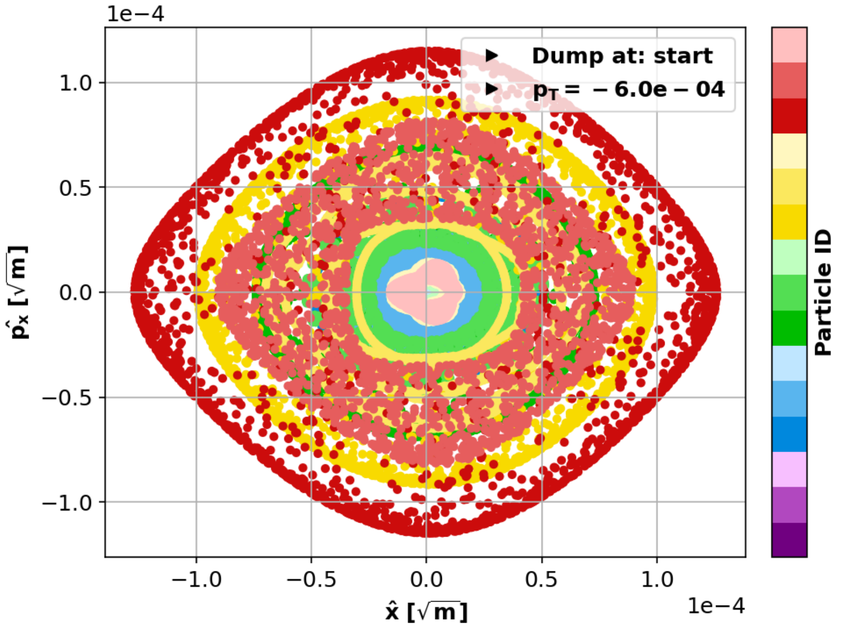


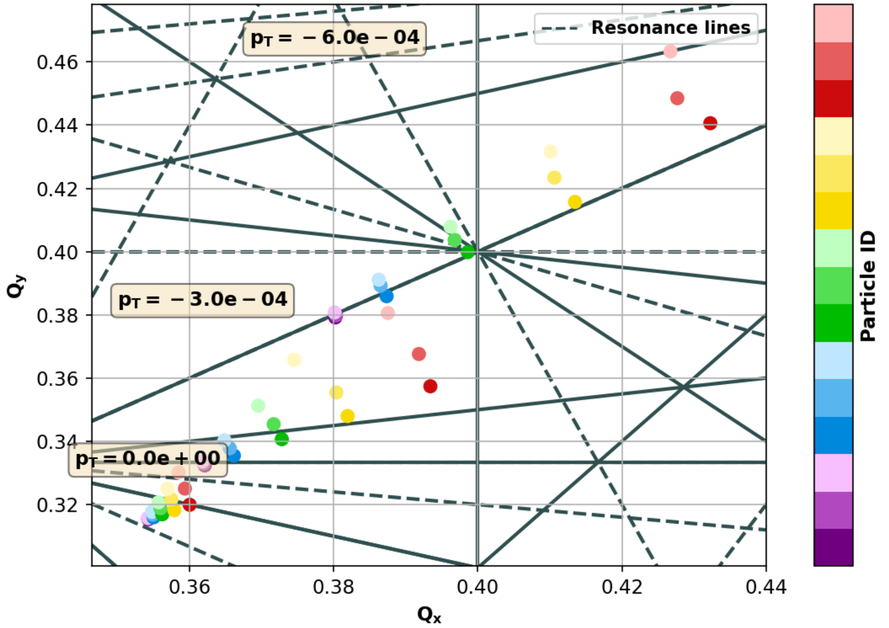






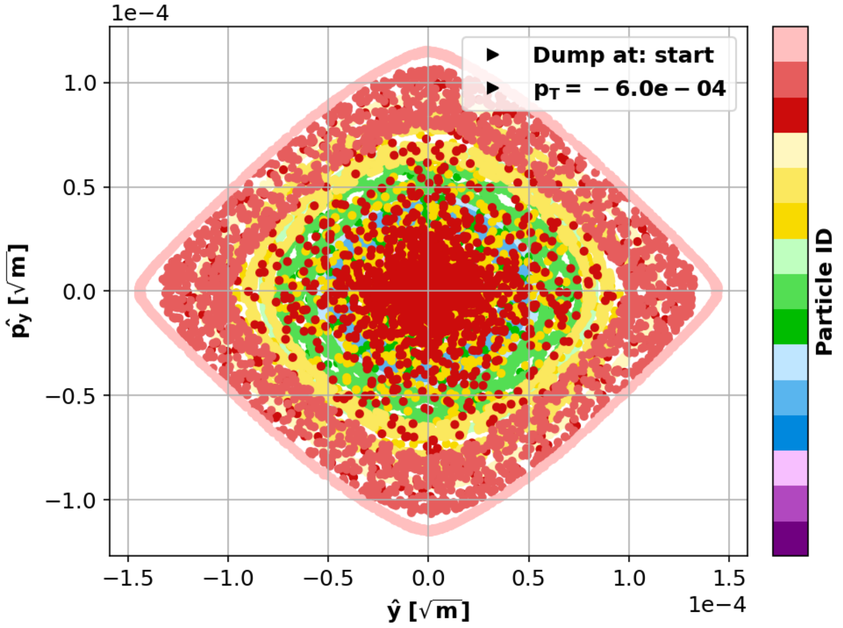
10TeV Muon Collider - Tracking Studies

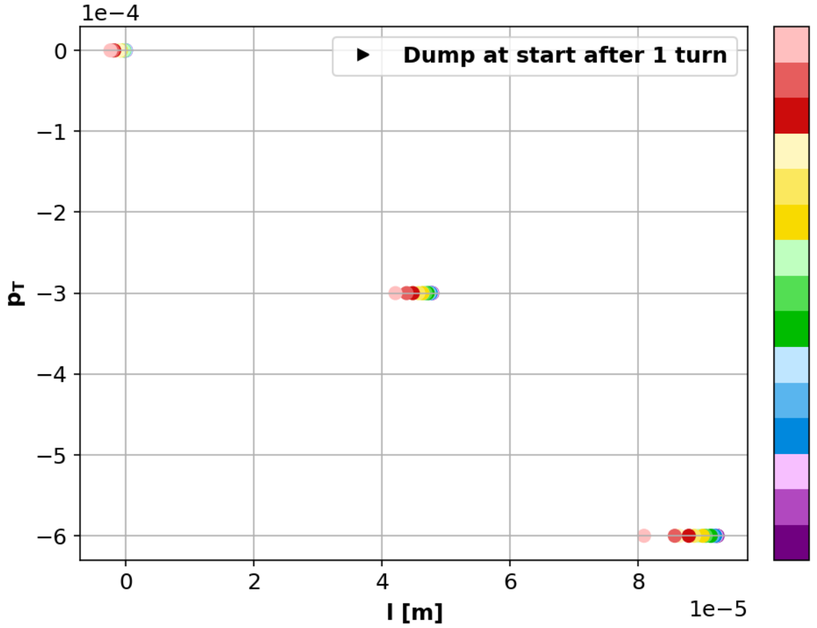


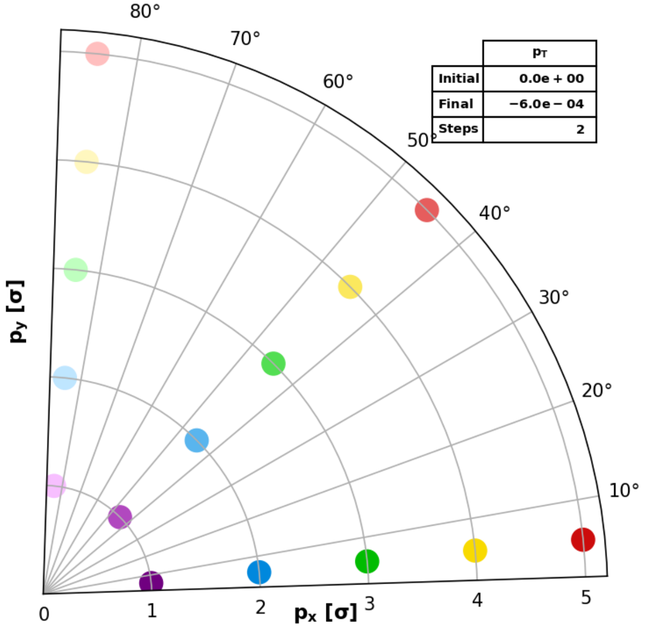


p_T [%]	p_T [σ_{pT}]	DA_{min} [σ]
-0.06	-0.6	5
-0.08	-0.8	4

$\xi_{x,y}$	$Q_{x,y}$	α_p
2.6E-05	0.354	1.6E-05
-4E-05	0.315	







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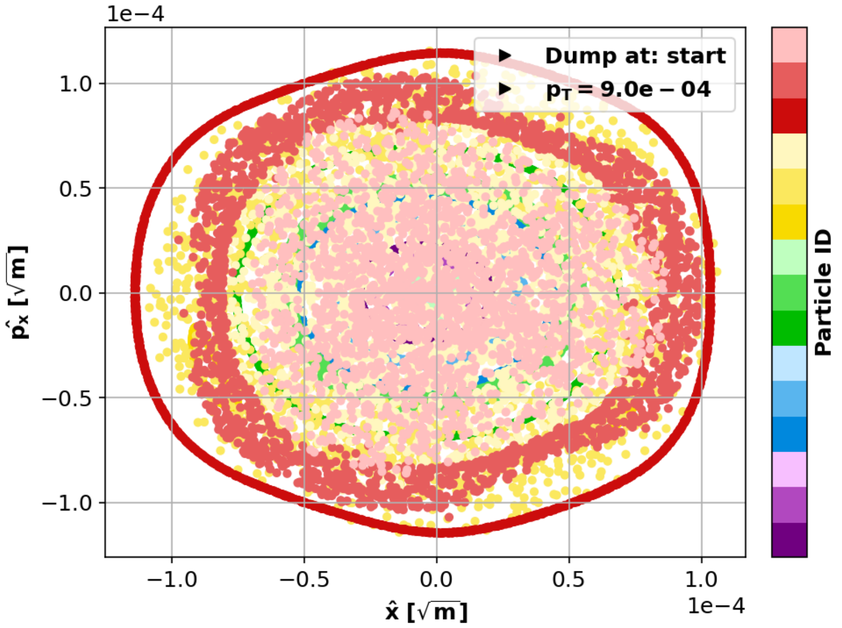

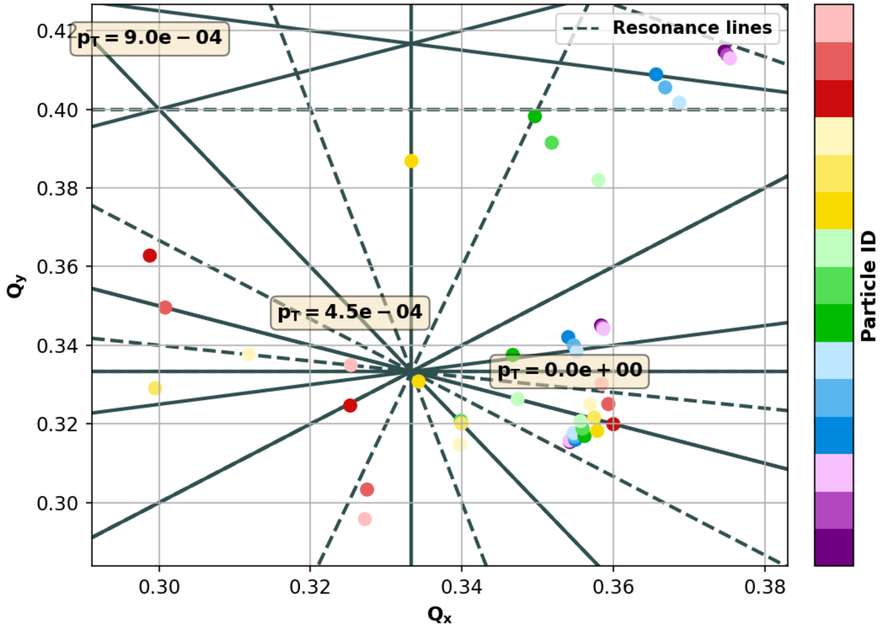

p_T [%]	p_T [σ_{pT}]	DA_{min} [σ]
0.09	0.9	5
0.15	1.5	4

$\xi_{x,y}$	$Q_{x,y}$	α_p
2.6E-05	0.354	1.6E-05
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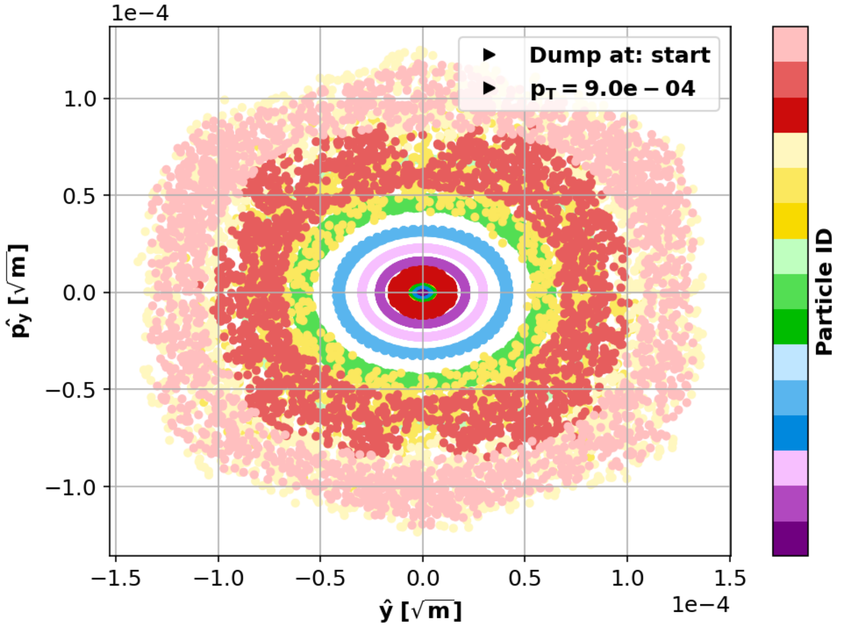

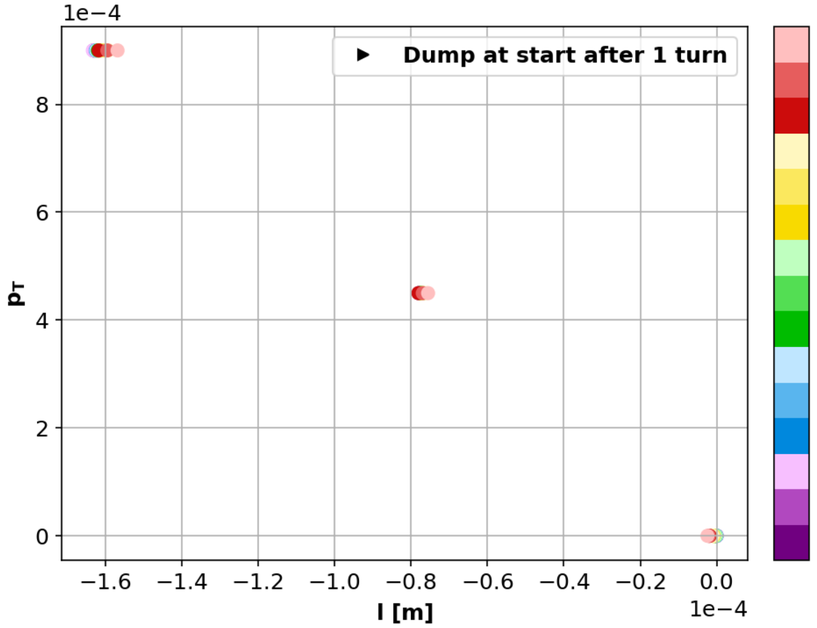

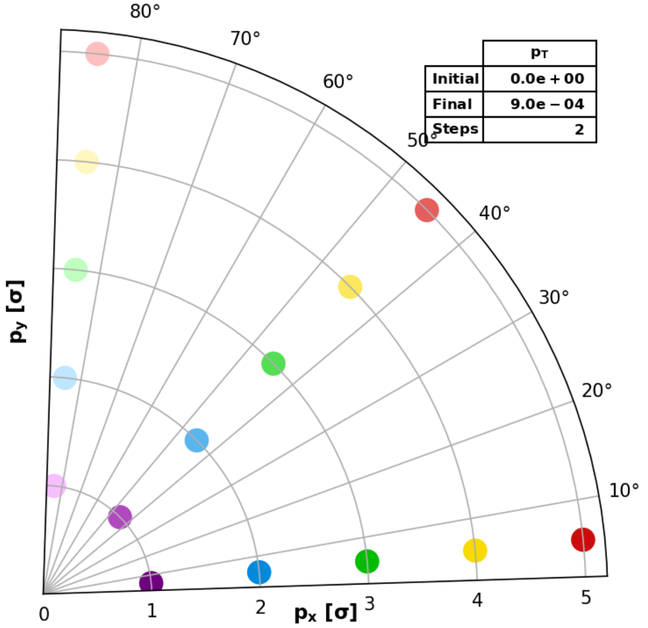

Comments - Discussion

Thank you for your time!

The presented studies are work in progress.

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