Interaction region of $\mathbf{c}\tau$ project

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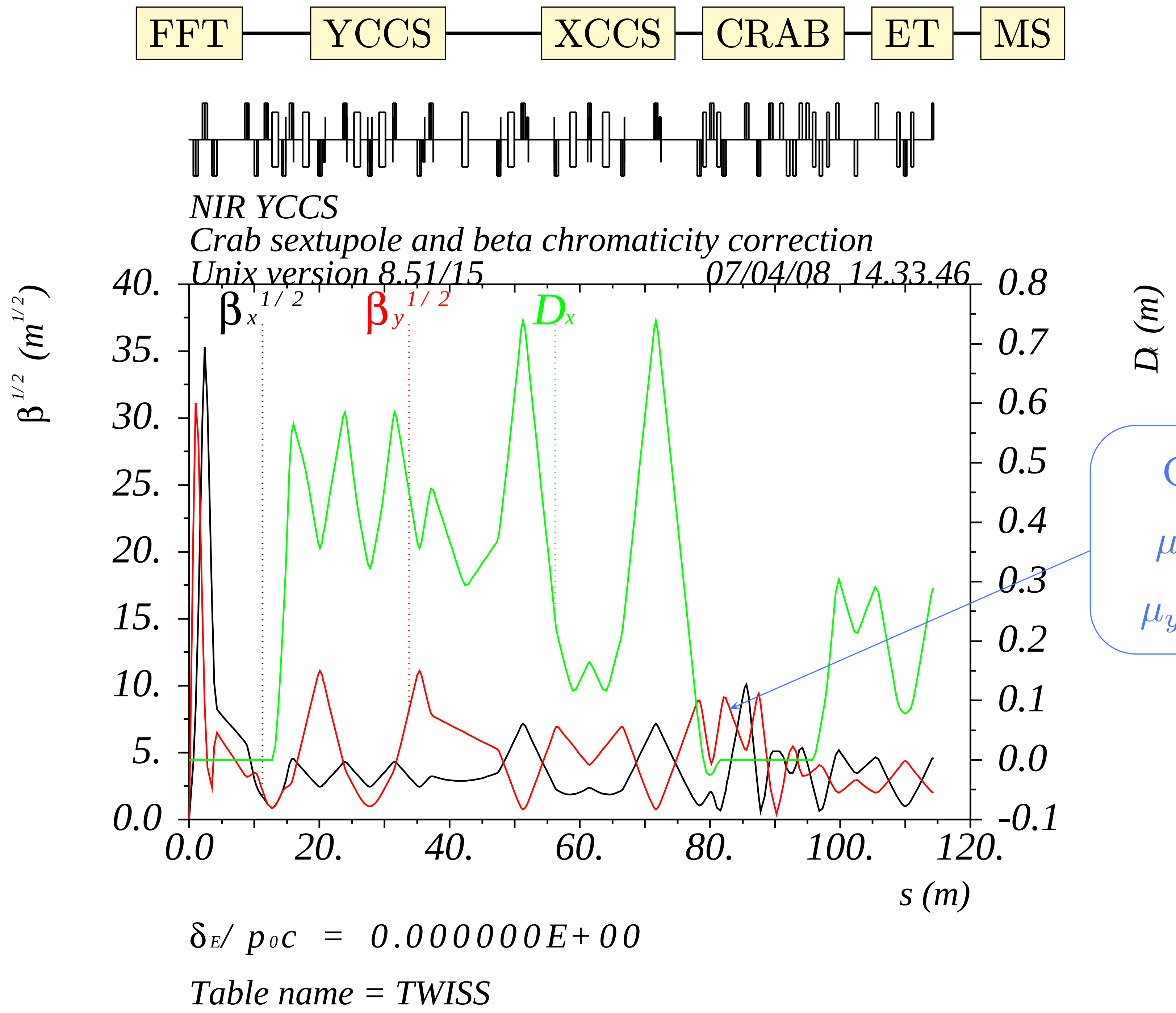
Parameters for interaction region

Energy, GeV	2
Beam current, A	1.36
Number of bunches	295
β_x, mm	20
β_y, mm	0.76
ε_x, nm rad	10
Coupling $\varepsilon_y/\varepsilon_x$, %	1
Beam length σ_z, cm	1
Crossing angle, mrad	34

Tune shift ξ_y	0.13
Particles per bunch	$7 \cdot 10^{10}$
Luminosity, $\mathrm{cm}^{-2}\mathrm{sec}^{-1}$	$1 \cdot 10^{35}$
Hour glass $\frac{\sigma_x}{\theta\beta_y}$	1.095
Piwinski angle $\varphi = \frac{\sigma_z\theta}{\sigma_x}$	12

- No bend for incoming beam.
- No longitudinal field integral over each final focus lens.
- Longitudinal field is compensated before each final focus lens.
- Interaction region length less than 100 m.
- Place for CRAB sextupole.

Blocks of interaction region



CRAB:

$\mu_x = 5\pi$

$\mu_y = 5.5\pi$

❶ Map: $$R = \begin{pmatrix} R_{11} & 0 \\ 0 & R_{22} \end{pmatrix}$$ Twiss transformation: $$\begin{aligned} \beta &= R_{11}^2 \beta_0 \\ \alpha &= \alpha_0 = 0 \\ \gamma &= R_{22}^2 \gamma_0 \end{aligned}$$

❷ Simple formulae for chromaticities and $d\beta/d\delta = 0$:

$$R_{11}(\delta) = R_{11} + T_{116}\delta + U_{1166}\delta^2$$

$$\frac{d\mu_x}{d\delta} = \frac{T_{126}}{\beta_0 R_{11}} \qquad \frac{d^2\mu_x}{d\delta^2} = \frac{2U_{1266}}{\beta_0 R_{11}} - 2\frac{T_{126}T_{116}}{\beta_0 R_{11}^2}$$

$$\beta = R_{11}\beta_0 + \delta\left[2R_{11}T_{116}\beta_0\right] + \delta^2\left[(T_{116}^2 + 2R_{11}U_{1166})\beta_0 + \frac{T_{126}^2}{\beta_0}\right]$$

$$\alpha = \delta\left[-R_{11}T_{216}\beta_0 - \frac{T_{126}R_{22}}{\beta_0}\right] + \delta^2\Big[-\beta_0\Big(R_{11}U_{2166} + T_{116}T_{216}\Big) - \\ -\gamma_0\Big(R_{12}U_{2266} + T_{126}T_{226} + U_{1266}R_{22}\Big)\Big]$$

General chromaticity formulae

$$\frac{d\mu}{d\delta} = \frac{1}{2}\int\limits_0^{\Pi} \beta_0(s)\Big[S(s)D_0(s) - K(s)\Big]ds$$

$$\frac{d^2\mu}{d\delta^2} = \frac{1}{2}\int\limits_0^{\Pi} \beta_1(s)\Big[S(s)D_0(s) - K(s)\Big]ds + \int\limits_0^{\Pi} \beta_0(s)S(s)D_1(s)ds - 2\frac{d\mu}{d\delta}$$

$$\frac{\beta_1(s)}{\beta_0(s)} = \frac{1}{\beta_0(s)}\frac{d\beta}{d\delta}(s) = \quad -\frac{1}{2\sin(\mu_0)}\int\limits_s^{s+\Pi} \Big[S(s')D_0(s') - K(s')\Big]\beta_0(s')\times$$
$$\times \cos\Big(\mu_0 - 2|\mu(s') - \mu(s)|\Big)ds'$$

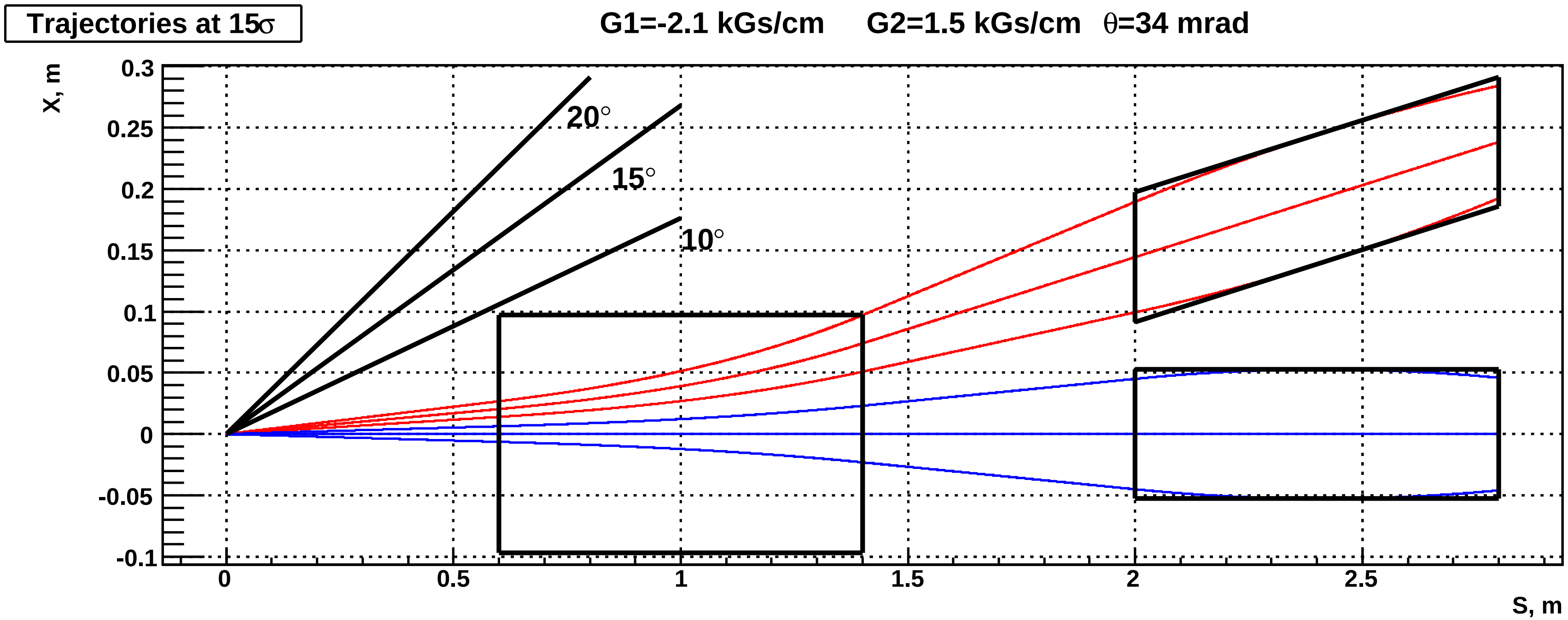
$$D_1(s) = \frac{dD}{d\delta}(s) = \quad -\frac{\sqrt{\beta_0(s)}}{\sin(\mu_0/2)}\int\limits_s^{s+\Pi} \sqrt{\beta_0(s')}\Big[S(s')D_0(s') - K(s')\Big]\times$$
$$\times D_0(s')\cos\left(\frac{\mu_0}{2} - |\mu(s') - \mu(s)|\right)ds'$$

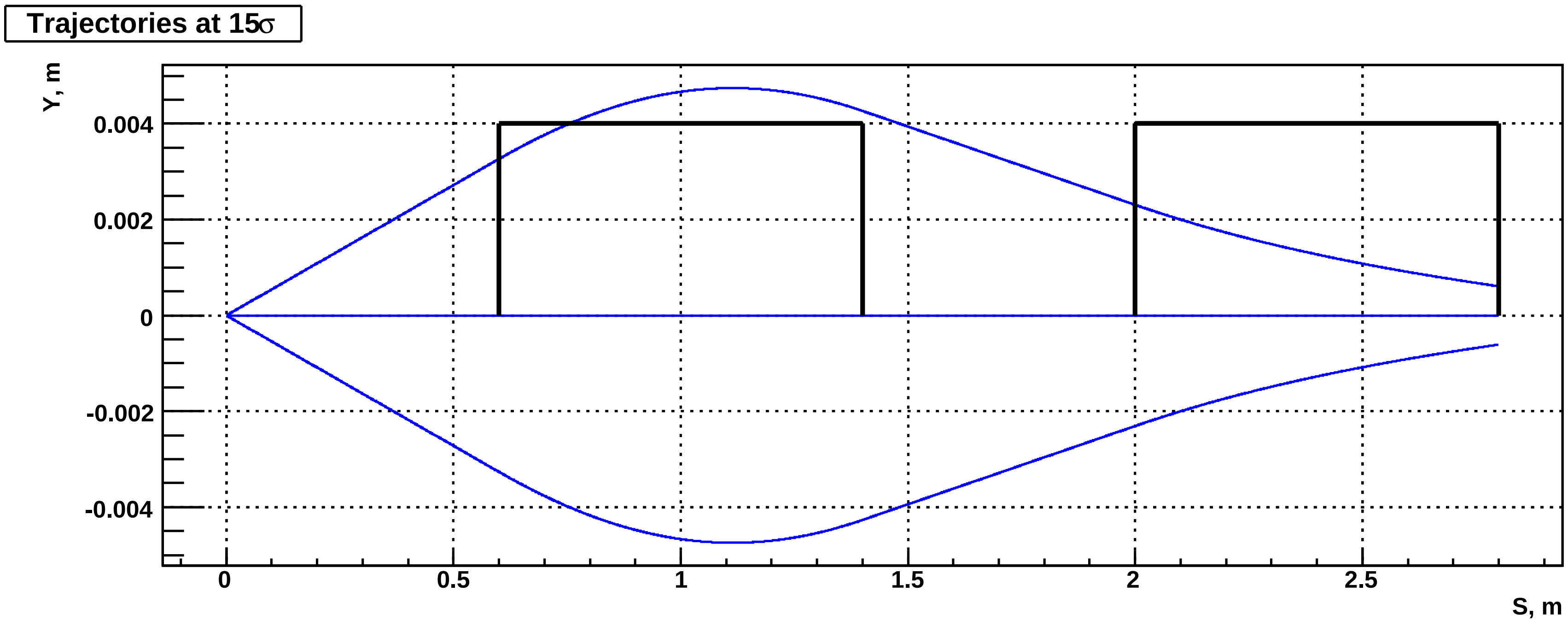
T. Sen and M. Syphers "Second Order Chromaticity of the Interaction Regions in the Collider"

Principles applied for interaction region

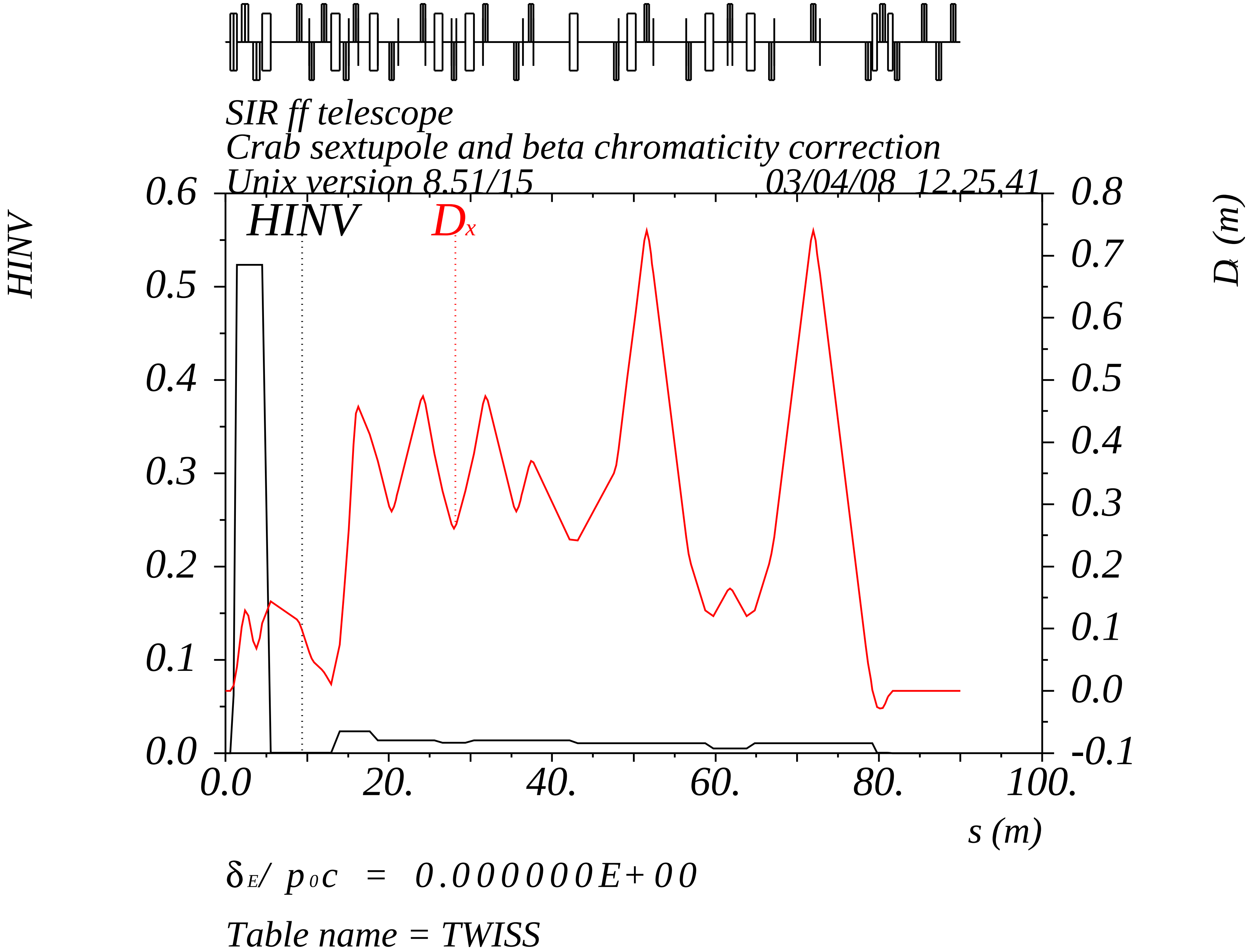
- Telescope because of easy tuning and simplicity of chromatic analysis.
- Two pairs of sextupoles at $n\pi$ phase advance from two FF lenses respectfully and $-I$ map inside the pair.
- CRAB sextupole at $\mu_x = \pi m$ and $\mu_y = \pi(2n+1)/2$ from IP and zero dispersion.
- Additional sextupoles: low beta functions but high beta chromaticity, high second order dispersion, weaker than main sextupoles.
- Octupoles: high beta and dispersion.

Final lens trajectories



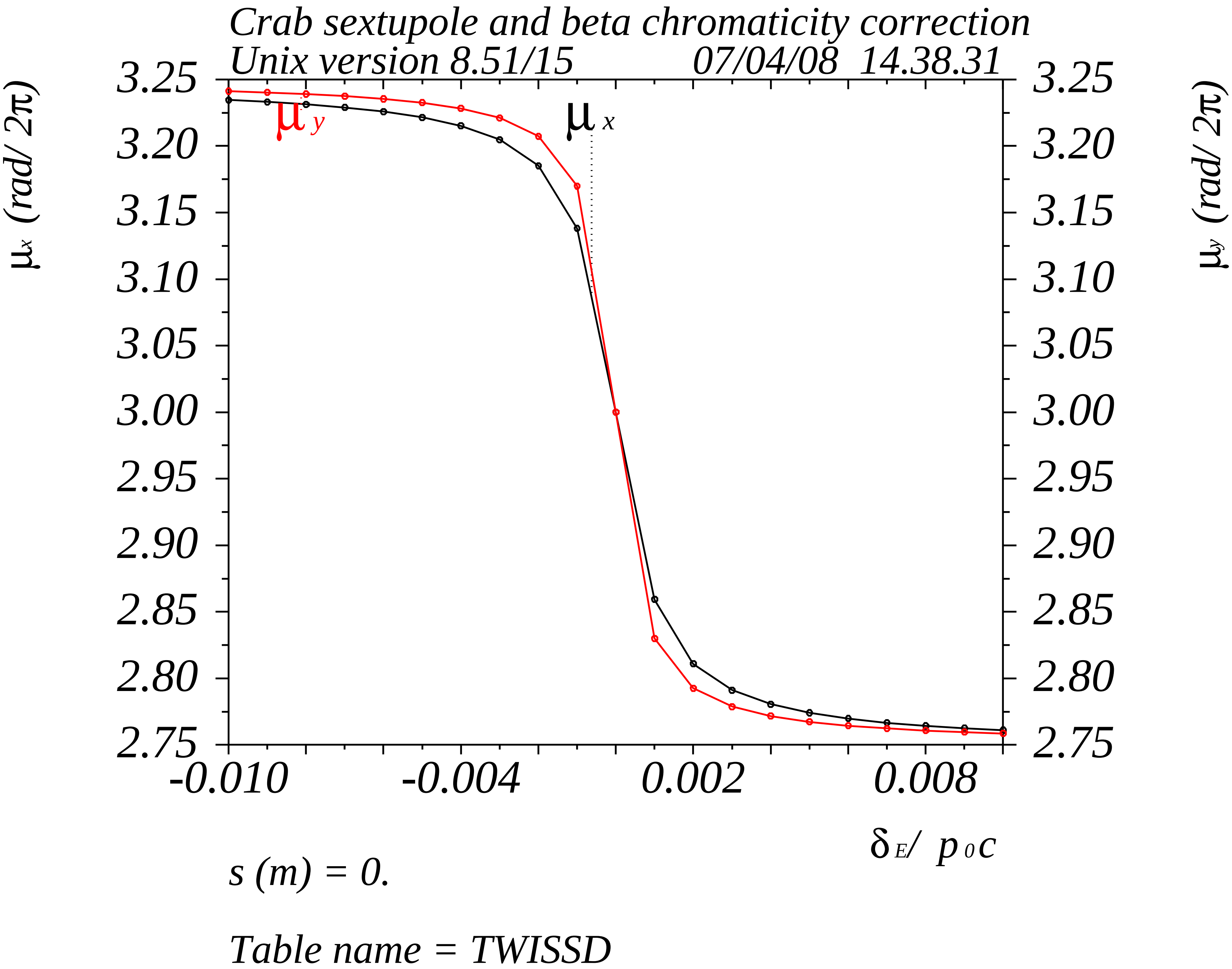


H invariant

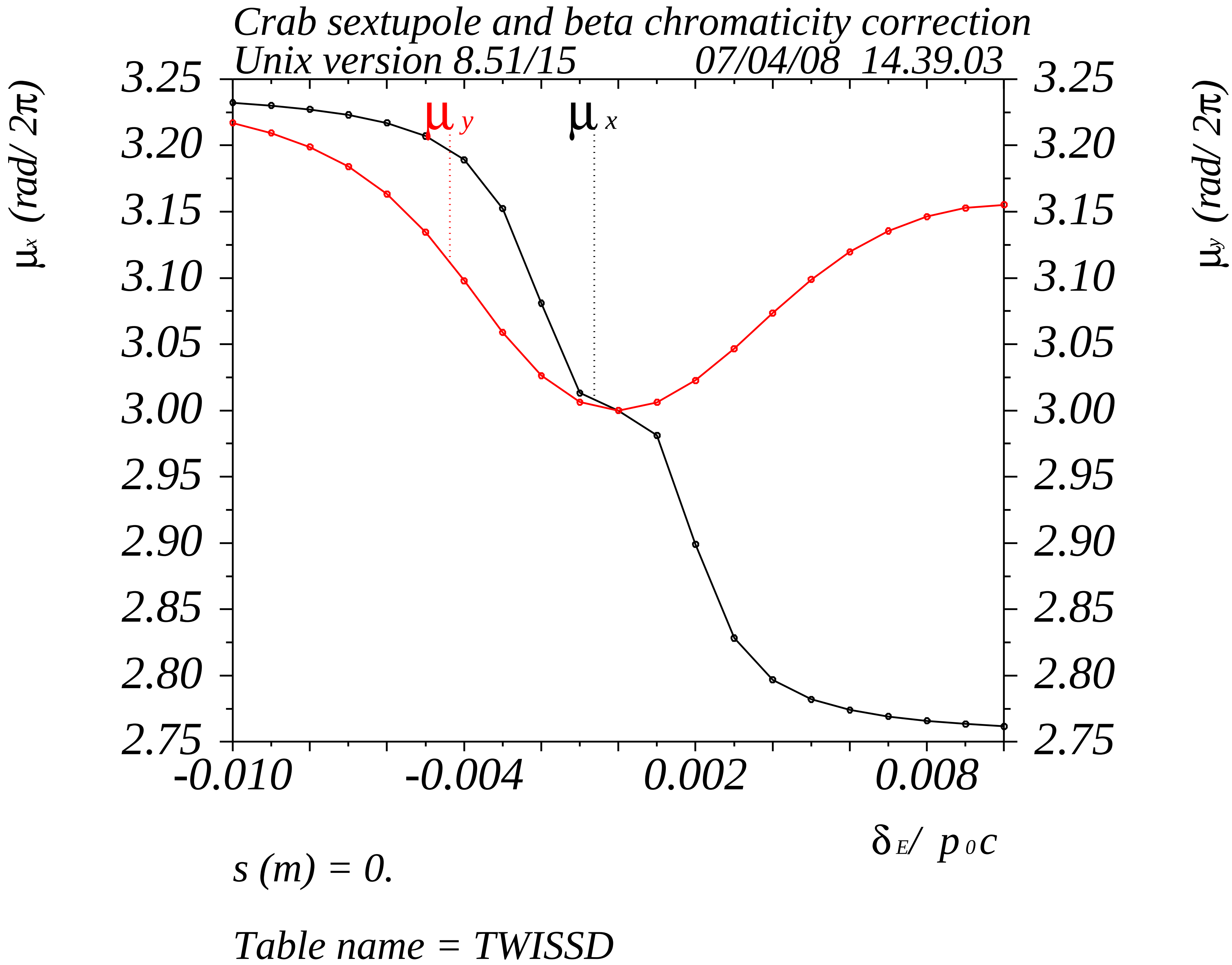


SIR ff telescope
Crab sextupole and beta chromaticity correction
Unix version 8.51/15
03/04/08 12.25.41
HINV
D_x
HINV
D_x (m)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
0.0
20.
40.
60.
80.
100.
s (m)
$\delta_E/\ p_0c\ =\ 0.000000E+00$
Table name = TWISS

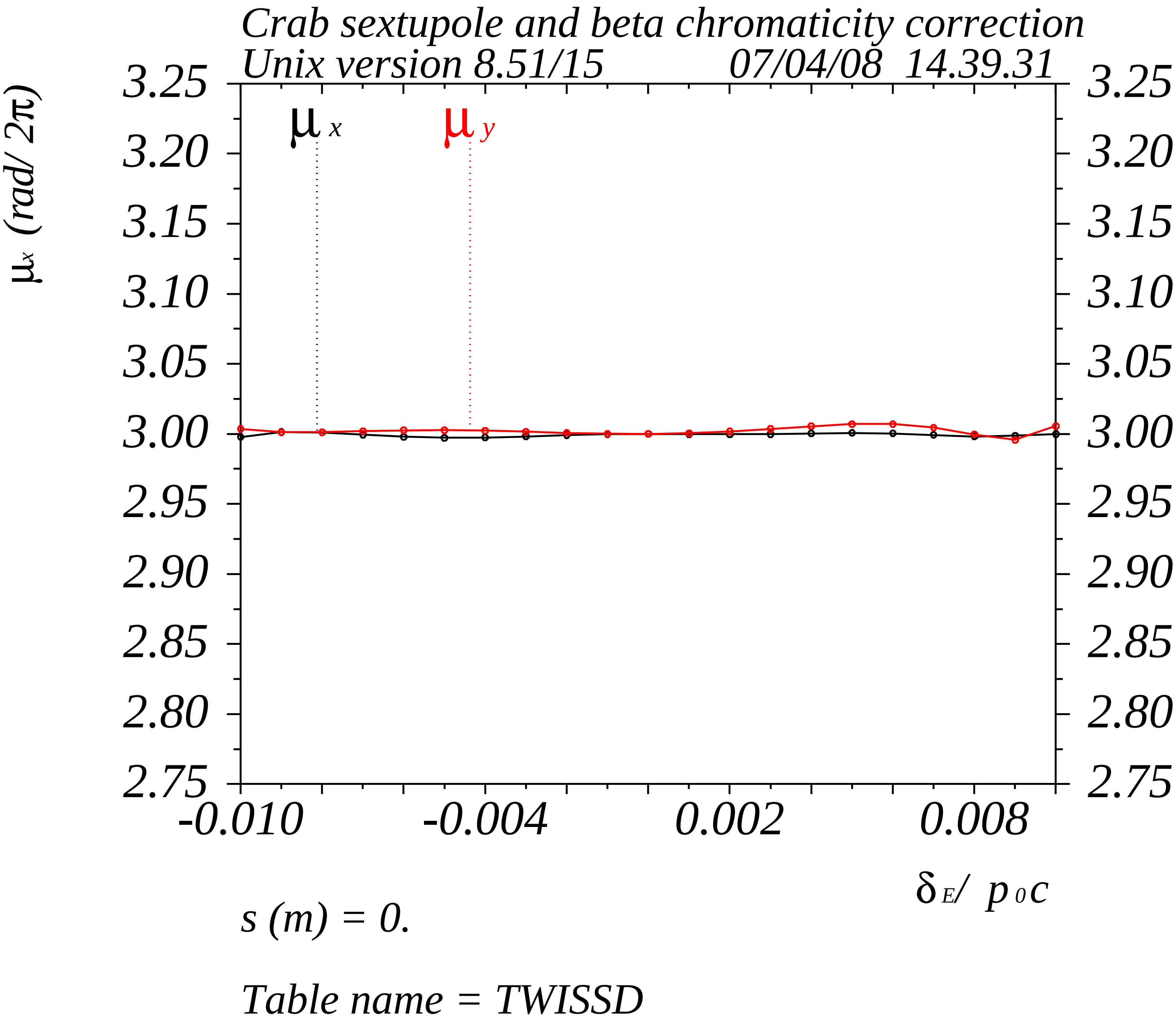
NIR Sextupoles OFF



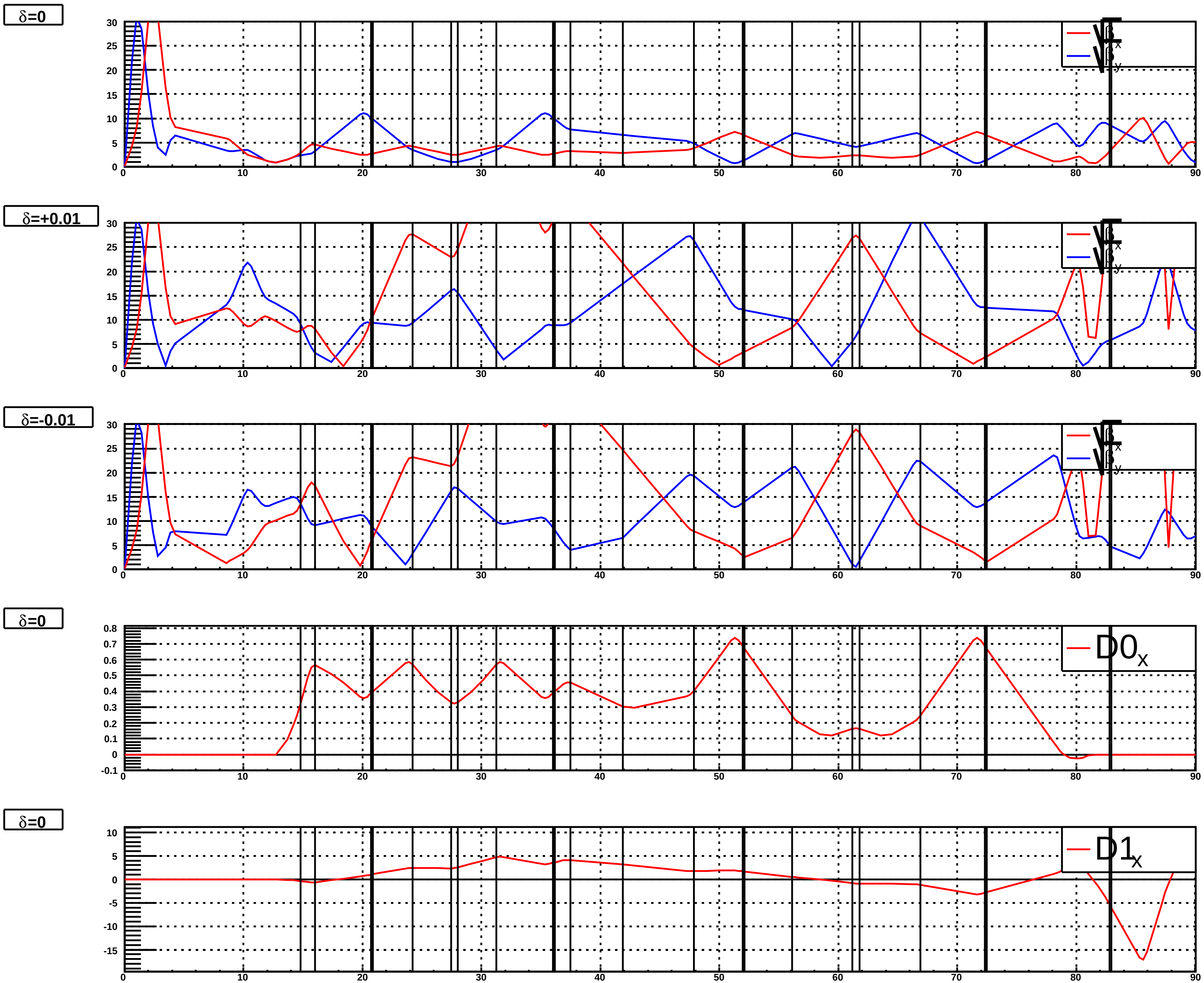
NIR Main Sextupoles ON



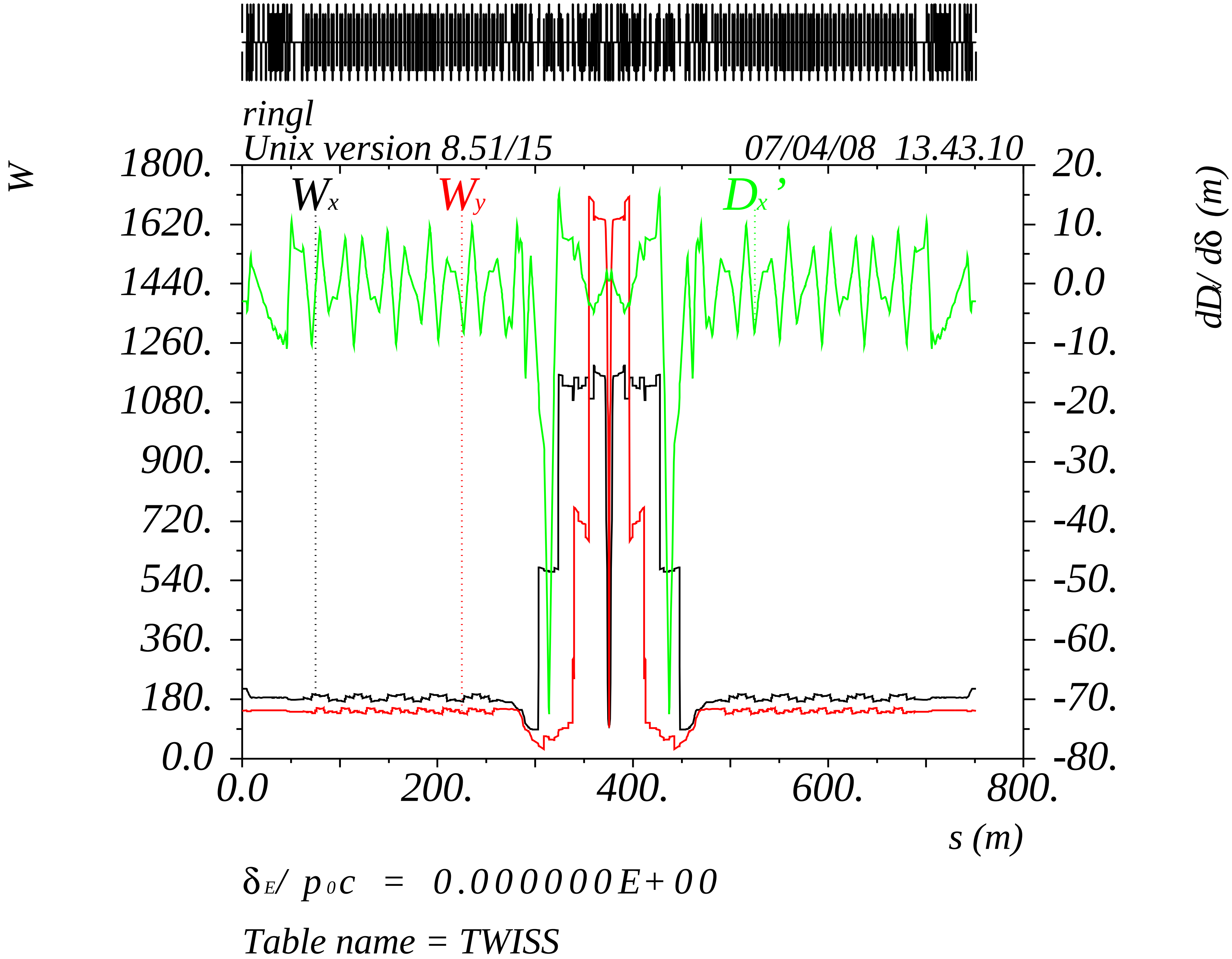
NIR Main & Additional Multipoles ON



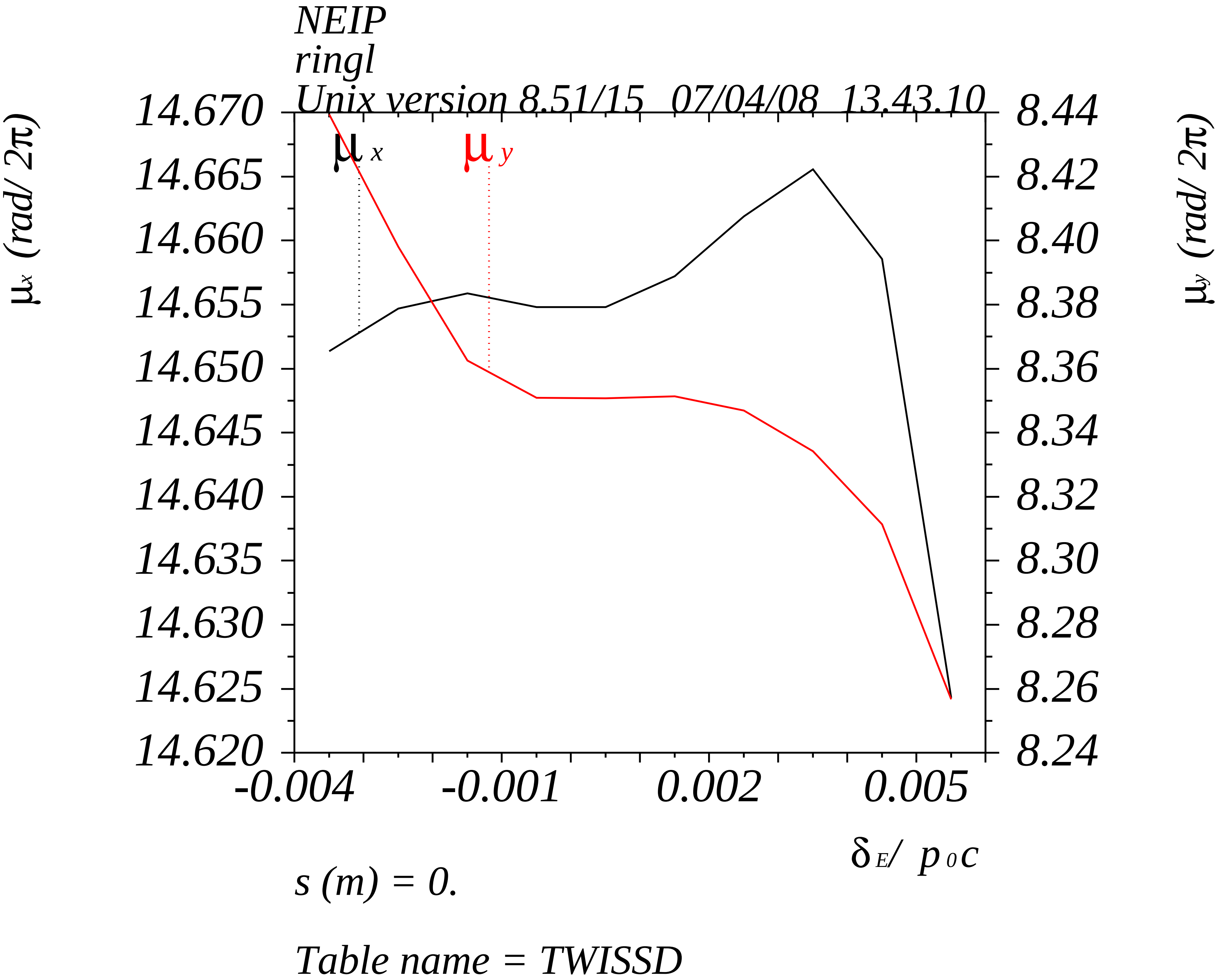
Nonlinear elements NIR



NIR and ring chromatic functions



NIR and ring μ dependance on δ



Conclusion

- Designed interaction region provides luminosity of 10^{35} $\text{cm}^{-2}\text{sec}^{-1}$ with not extreme parameters.
- There is freedom in beam-beam tune shift, which allows to decrease coupling coefficient and increase luminosity.
- The presented interaction region satisfies all geometrical constraints.
- Obtained energy acceptance of the Super-ct-factory is small and requires further optimization of the nonlinear chromaticity correction in interaction region and in the arcs.