Optics for TME cells with longitudinally varying fields and a new CLIC DR design

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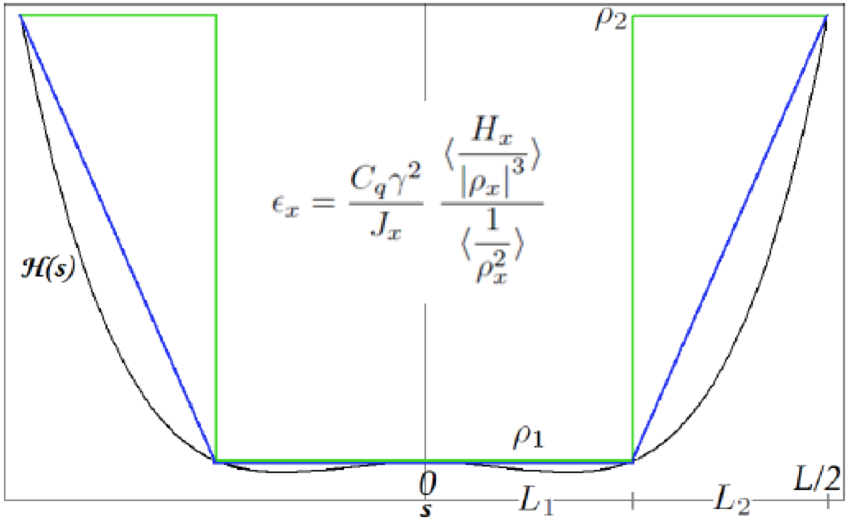
Longitudinally variable bends[1]



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Bending radii ratio

$$\rho = \frac{\rho_1}{\rho_2}$$

Lengths ratio

$$\lambda = \frac{L_1}{L_2}$$

Emittance reduction factor

$$F_{TME} = \frac{\epsilon_{TME_{uni}}}{\epsilon_{TME_{var}}}$$

$$F_{TME} > 1$$

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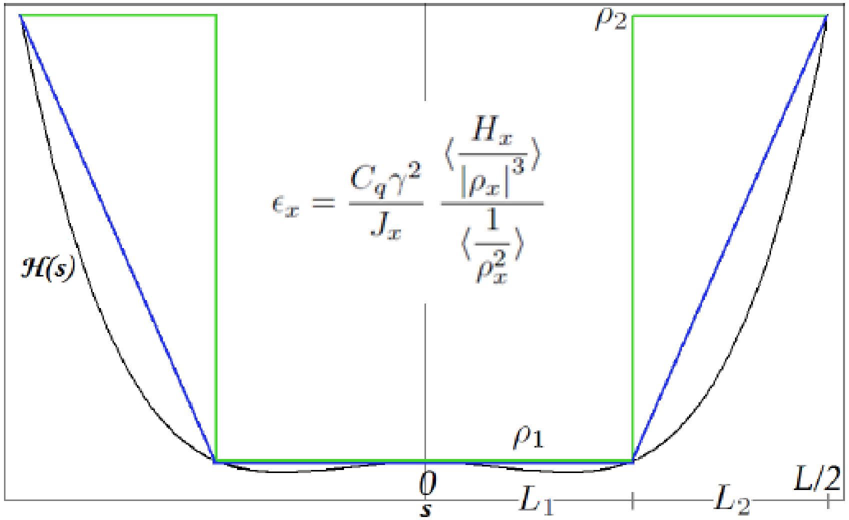

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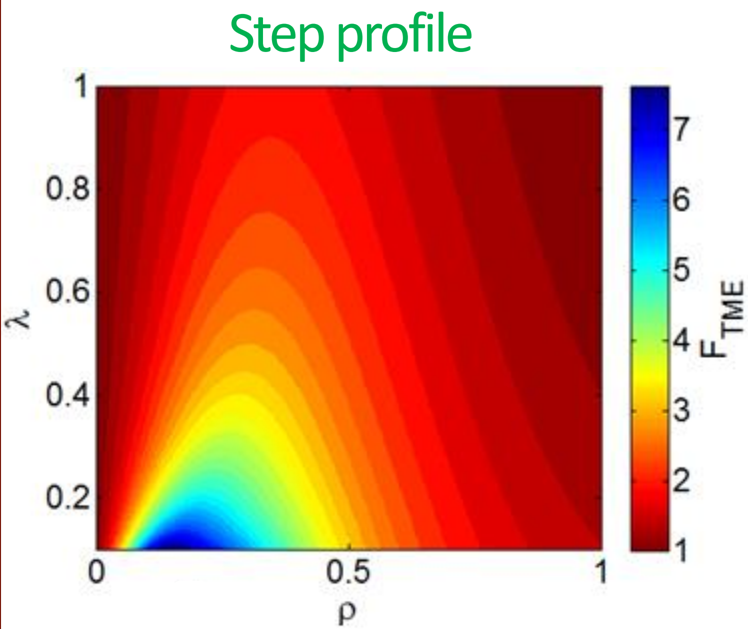
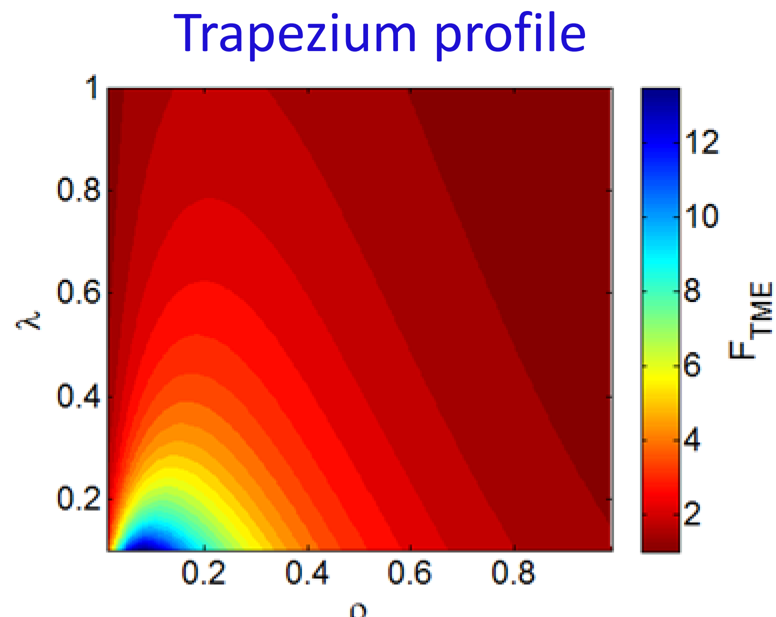
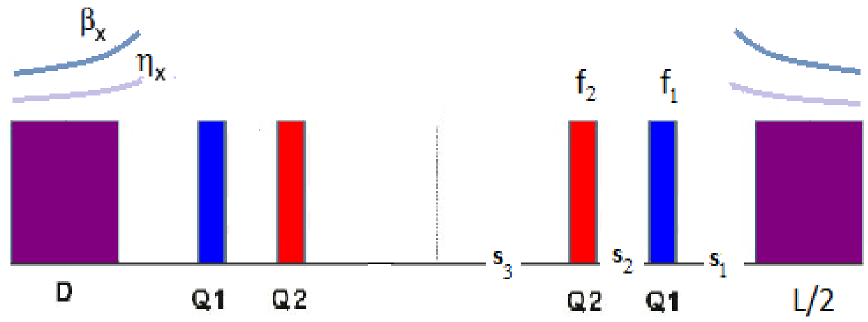




The parameterization of the emittance reduction factor F_{TME} with the bending radii ratio ρ and the lengths ratio λ, always for λ>0.1.

Optimization of the arc TME cell



Aiming to reduce the DR's circumference, it is necessary to find the optimal phase advances for which:

- $\gamma\varepsilon_x$ <500nm, ε_l<6 keVm
- adequate dynamic aperture (low chromaticities)
- quadrupole strengths<100 T/m
- compact cell

Fixing the dipoles' characteristics: bending radii ratio ρ and lengths ratio λ, dipole's length L and bending angle θ or else the total number of dipoles N_d

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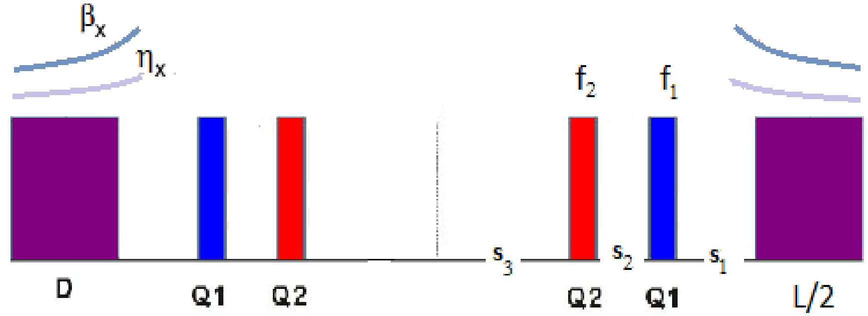

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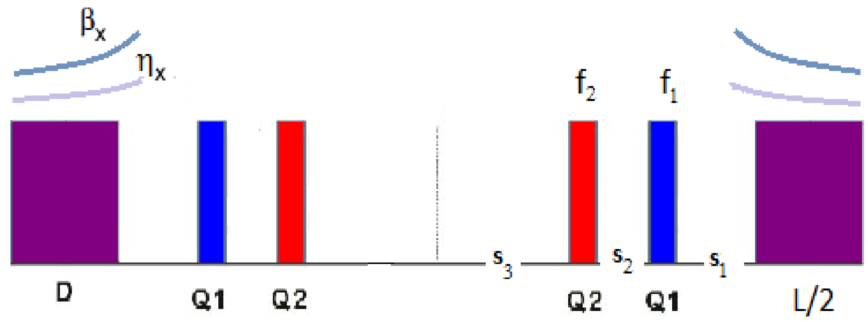

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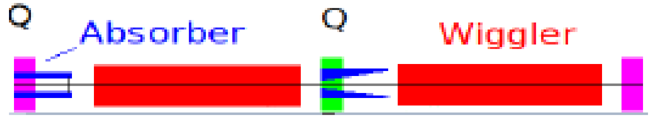
The optimal solutions are found to be N_d=96 for the step and N_d=90 for the trapezium profile.

Optimization of the wiggler FODO cell



Results obtained after the optimization of the arc TME cell.

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When increasing the wigglers' peak field B_w up to a certain point, the emittance and the IBS effect are lowered (see F. Antoniou talk "Lattice Design of Intrabeam Scattering dominated LERs")[3].

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Based on the technological restrictions, a new working point for the damp. wiggler is proposed to be at 3.5T (prev. 2.5T), with 49mm period length[4]

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Removing some FODO cells from the existing straight section (N_{FODO}=13 per section) is possible.

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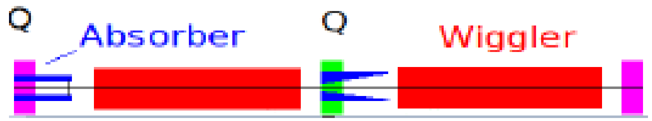

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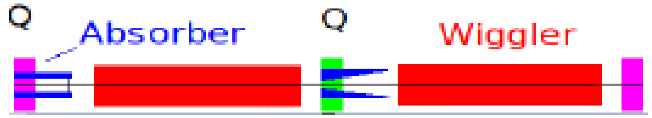

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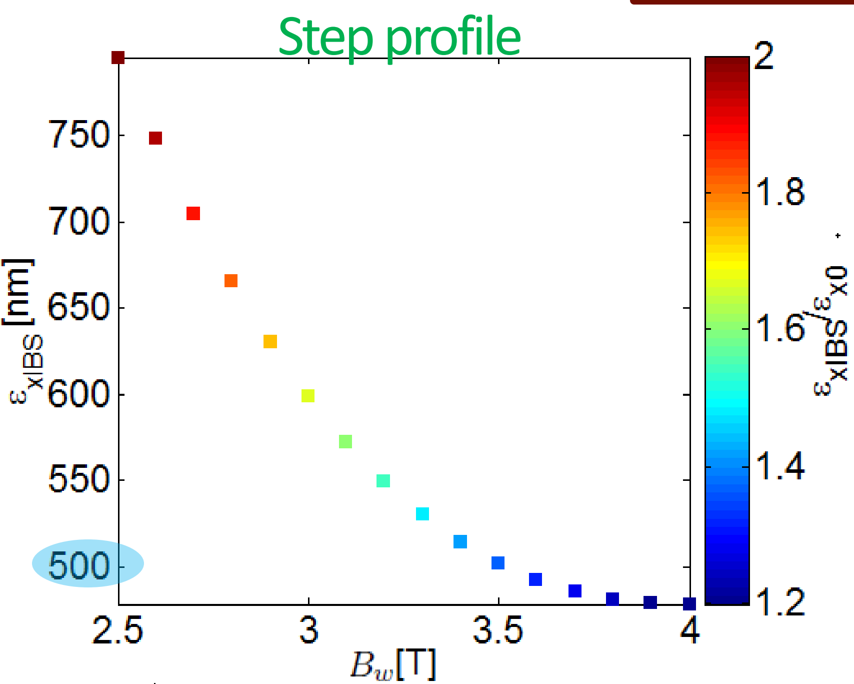
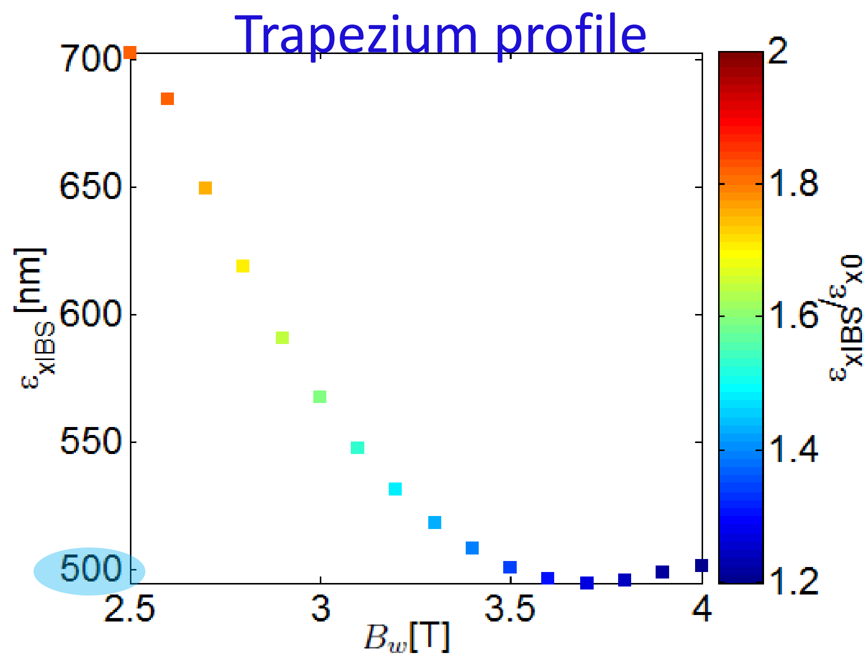




Parametrization of the steady state emittance and the IBS effect with the wiggler's peak field B_w

Design parameters for the main DRs, E=2.86 GeV

Parameters, Symbol [Unit]	uniform	step	trapezium
Number of arc cells/wigglers	100/52	96/40	90/40
Circumference, C [m]	427.5	374.1 (-14.3%)	359.4 (-18.9%)
Dipole field (max/min), B [T]	0.97/0.97	1.77/1.01	1.77/0.72
Horiz./Vert. chromaticities ξ_x/ξ_y	-113/-82	-135/-76	-126/-72
Wiggler peak field, B_w [T]	2.5	3.5	3.5
Wiggler length, L_w [m]	2		
Wiggler period, λ_w [cm]	5.0	4.9	4.9
Damp. times, (τ_x, τ_y, τ_l) [ms]	(2.0, 2.0, 1.0)	(1.2, 1.3, 0.6)	(1.2, 1.2, 0.6)
Mom. compaction, α_c [10^{-4}]	1.3	1.3	1.2
Energy loss/turn, U [MeV]	4	5.7	5.7
Norm. horiz. emittance , $\gamma\varepsilon_x$ [nm-rad] *	681	502	500
Norm. vert. emittance, $\gamma\varepsilon_y$ [nm-rad]	5.0	4.9	4.9
Energy spread (rms), σ_δ [%]	0.12	0.13	0.13
Bunch length (rms), σ_s [mm]	1.8	1.6	1.6
Long. emittance , ε_l [keVm]	5.9	6.1	6.0
IBS factors hor./ver./long.	2.2/1.5/1.2	1.4/1.5/1.1	1.4/1.5/1.1
RF Voltage, V_{RF} [MV]	5.10	7.25	6.97
Stationary phase [^{o}]	51.4	51.3	54.2

***Both lattices[5] reach the target emittances including IBS, as calculated by the Bjorken-Mtingwa formalism through MADX. Using the Piwinski form., the original design[6] (with the uniform dipoles) was also reaching the target horizontal emittance.**

References

[1] J. Guo and T. Raubenheimer, proc. of EPAC 2002, Paris (2002).
Y. Papaphilippou, P. Elleaume, PAC 2005, Knoxville (2005).
R. Nagaoka, A.F. Wrulich, Nucl. Instrum. Methods Phys. Res., Sect. A 575, 292 (2007).
C.-x Wang, PRST-AB 12, 061001 (2009).
C.-x Wang, Y. Wang, Y. Peng, PRST-AB 14, 034001 (2011).

[2] Y. Papaphilippou et al., ``Conceptual design of the CLIC damping rings'', TUPPCO86, proc. of IPAC'12, New Orleans, USA (2012).

[3] F. Antoniou, PhD thesis, NTUA, (2013)
D. Schoerling et al, PRST-AB 15, 042401 (2012).

[4] L. Garcia Fajardo, ``Nb3Sn prototype progress'', CLIC Workshop, CERN, Geneva (2015).

[5] S. Papadopoulou, F. Antoniou and Y. Papaphilippou, Emittance reduction with variable bending magnet strengths: Analytical optics considerations, preprint (2015).

[6] F. Antoniou, PhD thesis, NTUA, (2013).

Thank you!

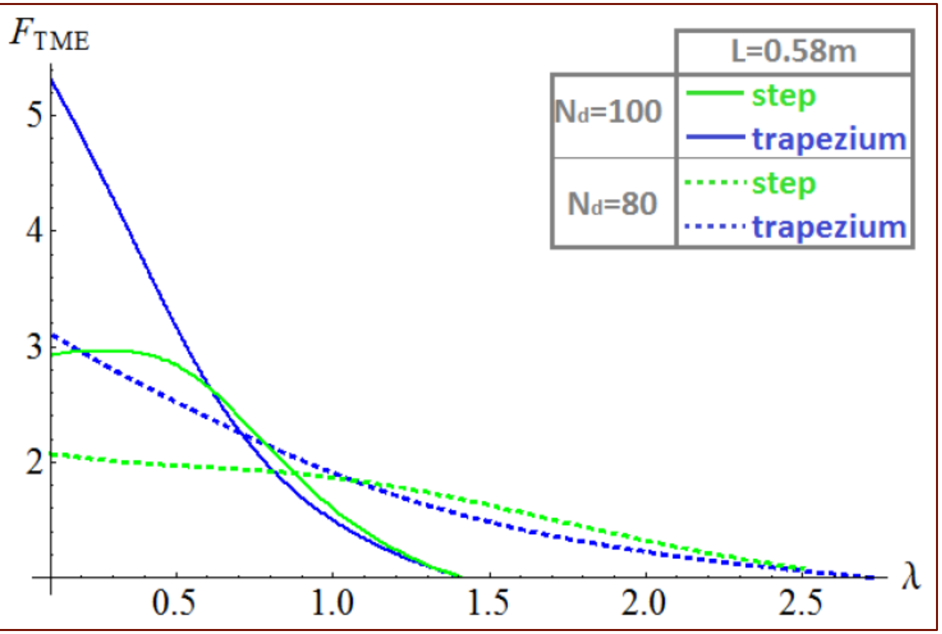
Fixing the dipole's characteristics (bending angle, length and minimum bending radius)

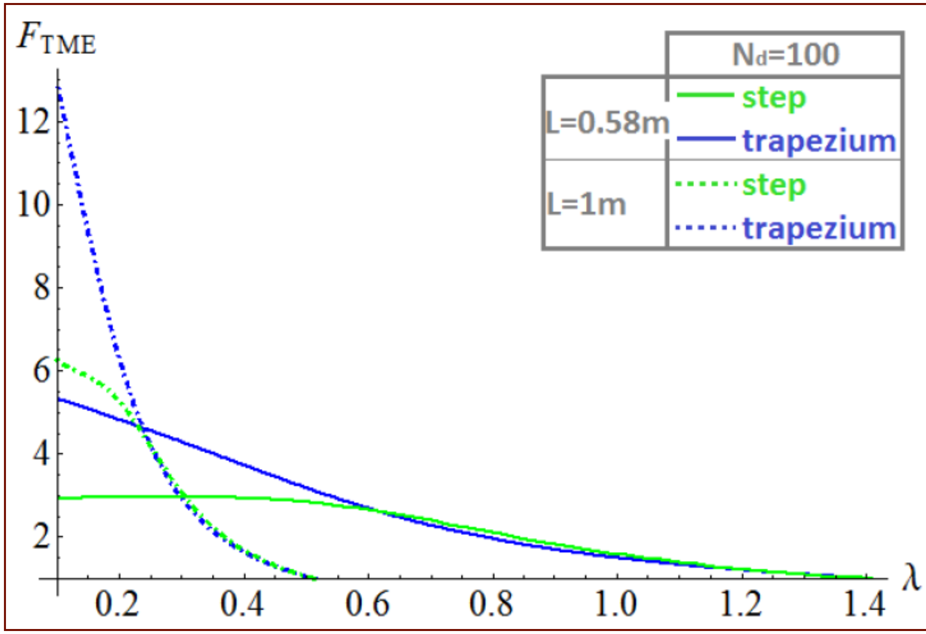
step → $\theta = \dfrac{L(\lambda+\rho)}{\rho_1(1+\lambda)}$

trapezium → $\theta = \dfrac{L(\lambda(-1+\rho)+\rho\log\rho)}{\rho_1\ (-1+\rho)(1+\lambda)}$

$F_{TME}(\rho,\lambda)$

⇒ $\lambda(\rho)$ or $\rho(\lambda)$ ⇒ $F_{TME}(\rho)$ or $F_{TME}(\lambda)$

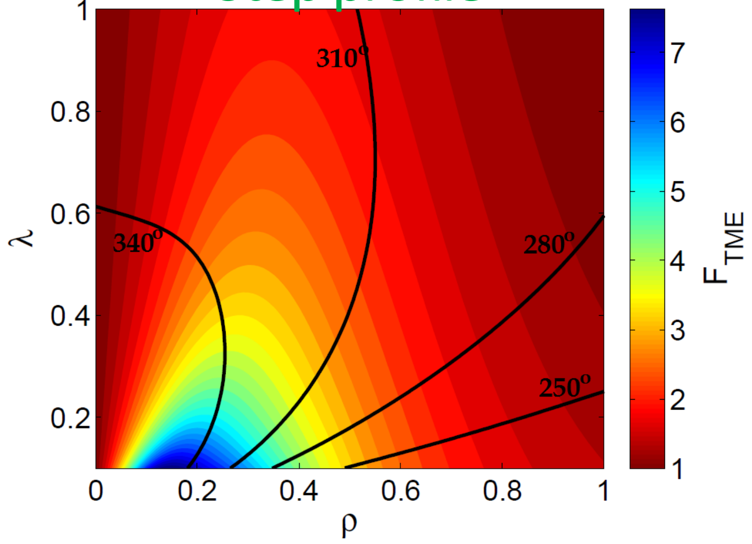




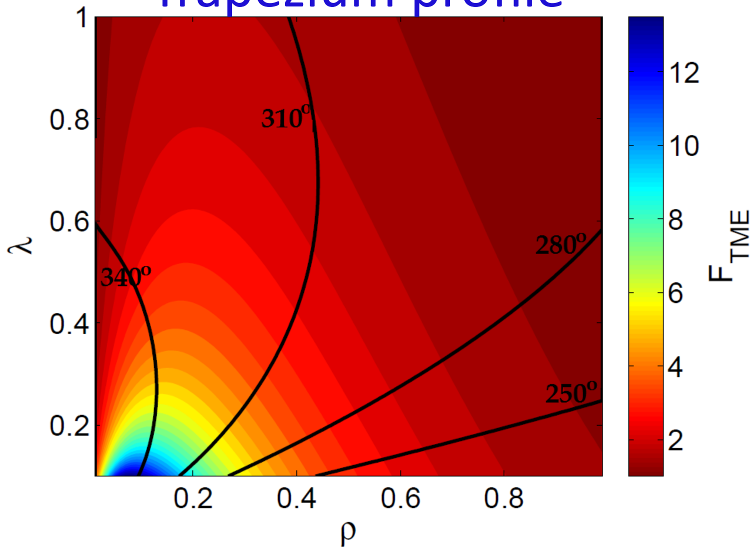
↓N_d ⇒ ↓F_{TME}

↓L ⇒ ↓F_{TME}

Step profile



Trapezium profile



The parameterization of the emittance reduction factor F_{TME} with the bending radii ratio ρ and the lengths ratio λ, always for λ>0.1. The black contour lines correspond to different values of the horizontal phase advance.