Possible layout for arc cells of HE-LHC - With updates

Demin Zhou and Yuri Nosochkov

Acknowledgements:

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1. Possible layouts for the arcs of HE-LHC

➤ Arcs designed by Y. Nosochkov

- 18x 60-deg (helhc_v102)
- 20x 90-deg (helhc_v201) [Almost given up because of poor geometry fit to LHC layout]
- 18x 80-deg (helhc_v300) [Preserve resonance cancelation condition: 4x2π]

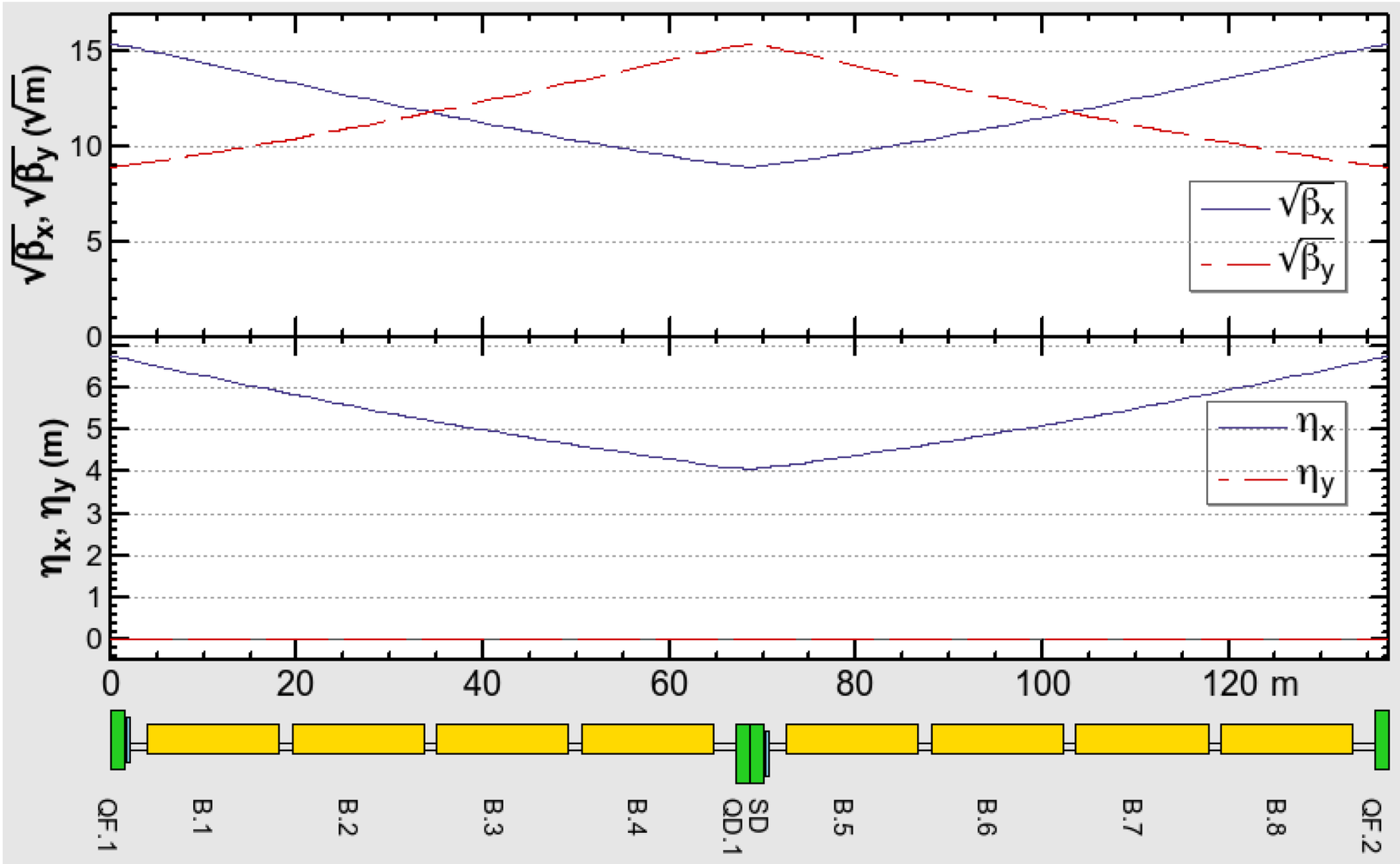
➤ Possible modifications using the same layout of helhc_v102

- 18x 90-deg [Preserve resonance cancelation condition if considering DS as a 90-deg cell: 4x2π => Add sextuples to DSs, similar as LHC]

1. Possible layouts for the arcs of HE-LHC

➤ 18x 60-deg (helhc_v102 by Y.N.)

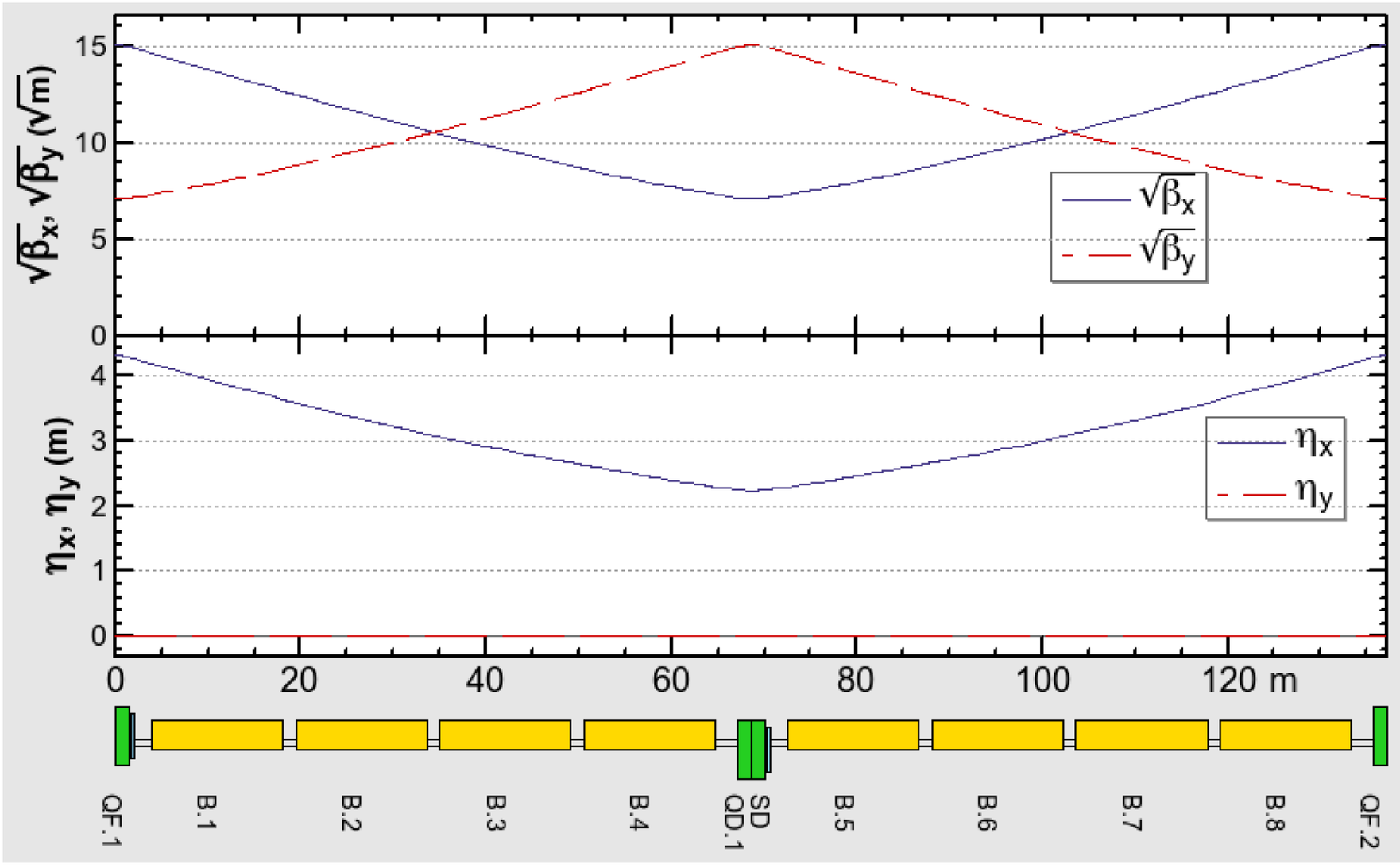
- **LB=14.18m, LQ=3.1m, LS=0.369m**
- **LBQ=2.358m, LSB=1.829m, LQS=0.16m, LBB=1.36m**



1. Possible layouts for the arcs of HE-LHC

➤ 18x 80-deg (helhc_v300 by Y.N., same geometry of helhc_v102)

- LB=14.18m, LQ=3.1m, LS=0.369m
- LBQ=2.358m, LSB=1.829m, LQS=0.16m, LBB=1.36m



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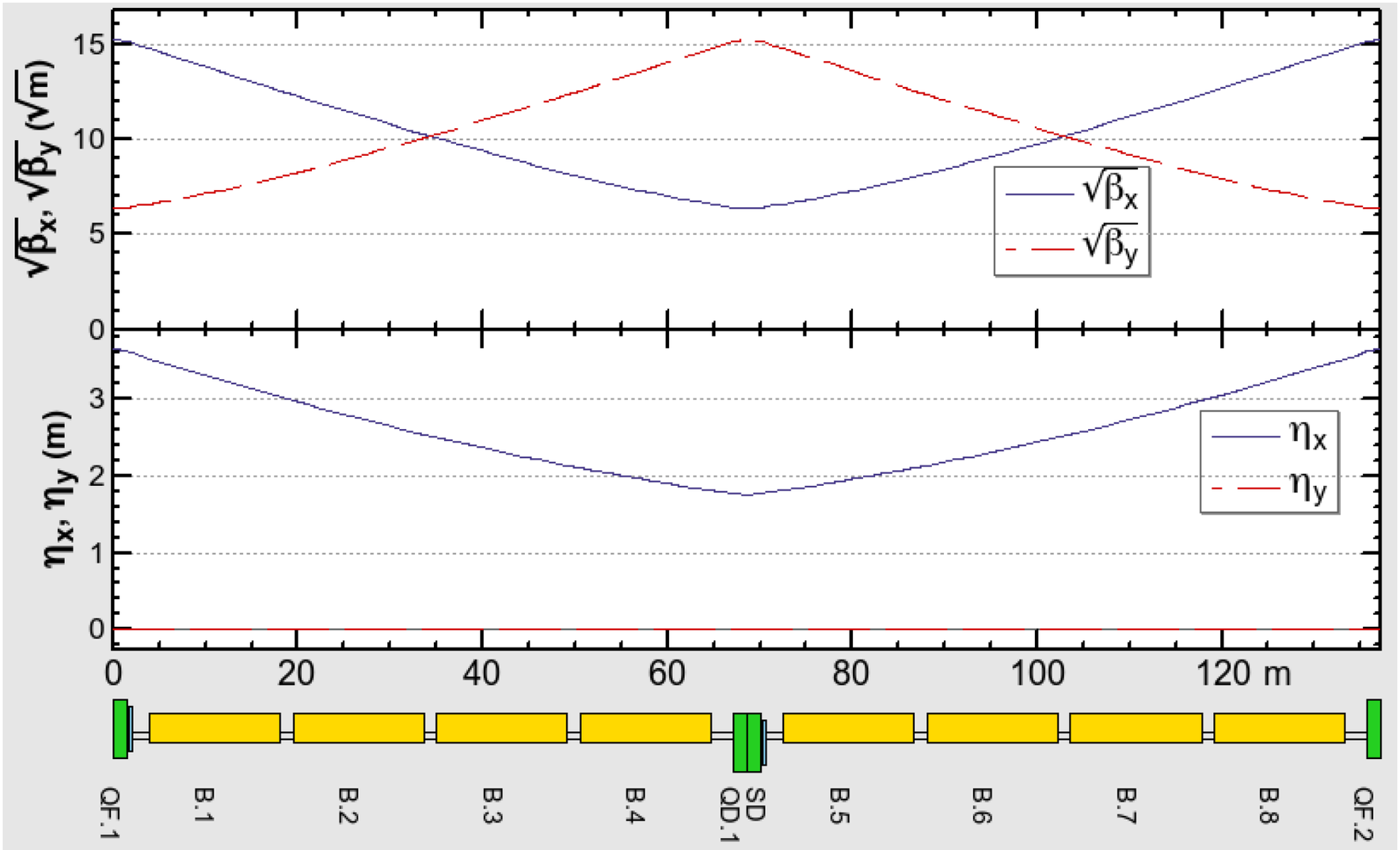
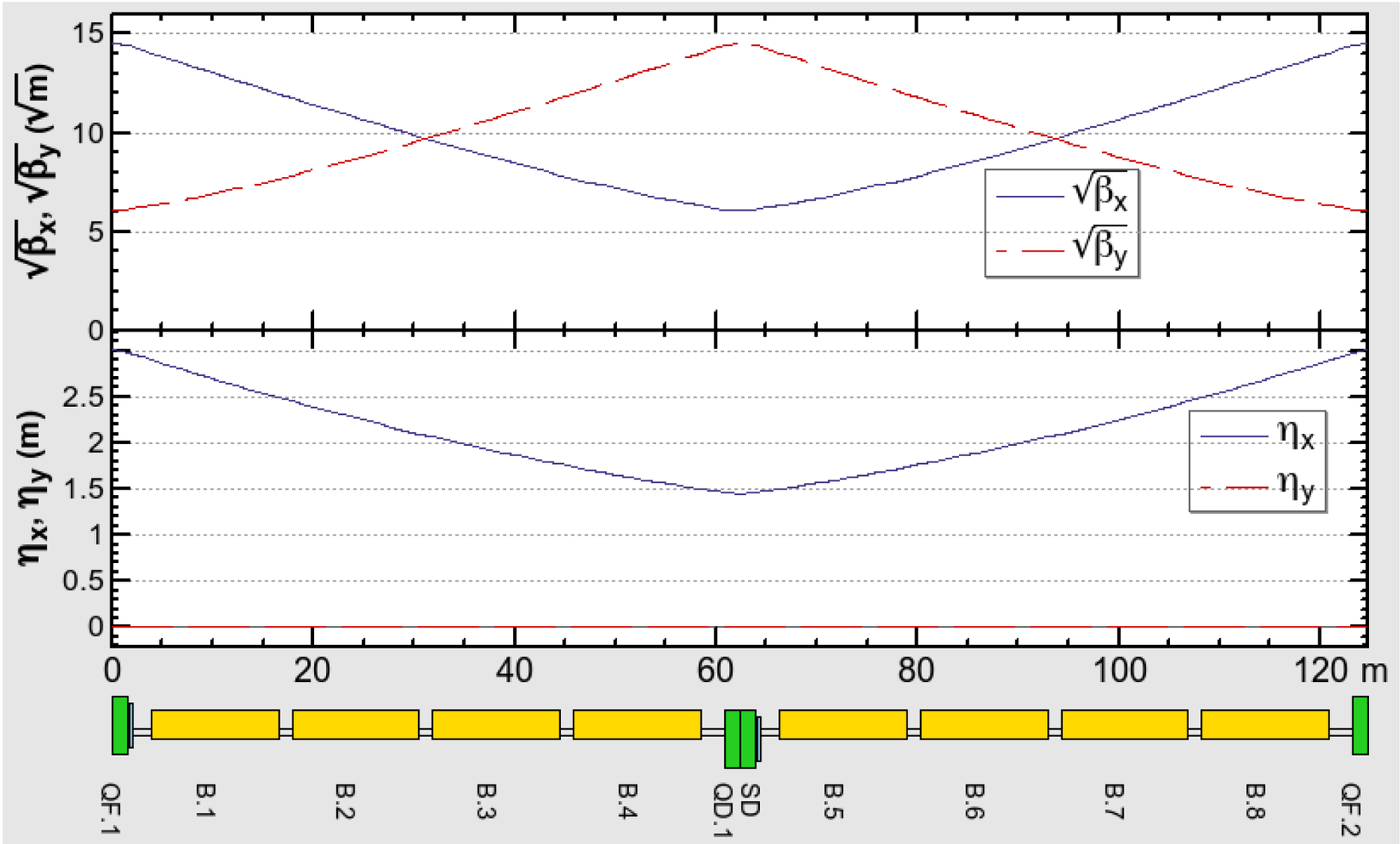


1. Possible layouts for the arcs of HE-LHC

➤ 20x 90-deg

- **LB=12.625m, LQ=3.1m, LS=0.369m**
- **LBQ=2.36m, LSB=1.831m, LQS=0.16m, LBB=1.36m**



1. Possible layouts for the arcs of HE-LHC

➤ **FCC tech: 16 T@B, 400 T/m@Q, 7800 T/m²@S**

	LHC-like	18x60⁰	18x80⁰	18x90⁰	20x90⁰
Arc cell phase advance [deg]	90/90	60/60	80/80	90/90	90/90
Arc cell length [m]	106.958	137.233			124.8
K1 [m⁻¹]	0.027	0.0148	0.019	0.021	0.023
$\beta_{max/min}$ [m]	181.3/31.5	236.7/79.5	227.7/50.0	233.0/40.4	211.7/36.8
$\eta_{max/min}$ [m]	2.2/1.1	6.7/4.1	4.3/2.2	3.6/1.8	3.0/1.5
Dipole length [m]	14.3 [x6]	14.18 [x8]			12.625 [x8]
Dipole field [T] @13.5TeV	16.06	15.59			15.92
Quad. gradient [T/m] @13.5TeV	391.7	214.8	276.2	303.9	334.7
Sext. gradient [T/m²] @13.5TeV	4883	866	1824	?	2940
Filling factor	0.802	0.827			0.809

1. Possible layouts for the arcs of HE-LHC

➤ General scaling laws

- **Assume ideal FODO cell [thin-lens, 100% filling factor]**

$$\sin(\Phi/2) = \frac{1}{4}\mathrm{K_1 L_{cell}}$$

$$\beta_{\pm} = \frac{2\left(1 \pm \mathrm{K_1 L_{cell}}/4\right)}{\mathrm{K_1}\sqrt{1-\left(\mathrm{K_1 L_{cell}}/4\right)^2}}$$

$$\mathrm{B}\rho = \mathrm{P}_0/e$$

$$\eta_{\pm} = \frac{4}{\rho \mathrm{K_1^2}}\left(1 \pm \mathrm{K_1 L_{cell}}/8\right)$$

$$K_{2\pm} = \frac{K_1}{\eta_{\pm}}$$

Note:
Sextupole strength for chromaticity correction ONLY in arc cells.
IRs and DSs require higher K_2

1. Possible layouts for the arcs of HE-LHC

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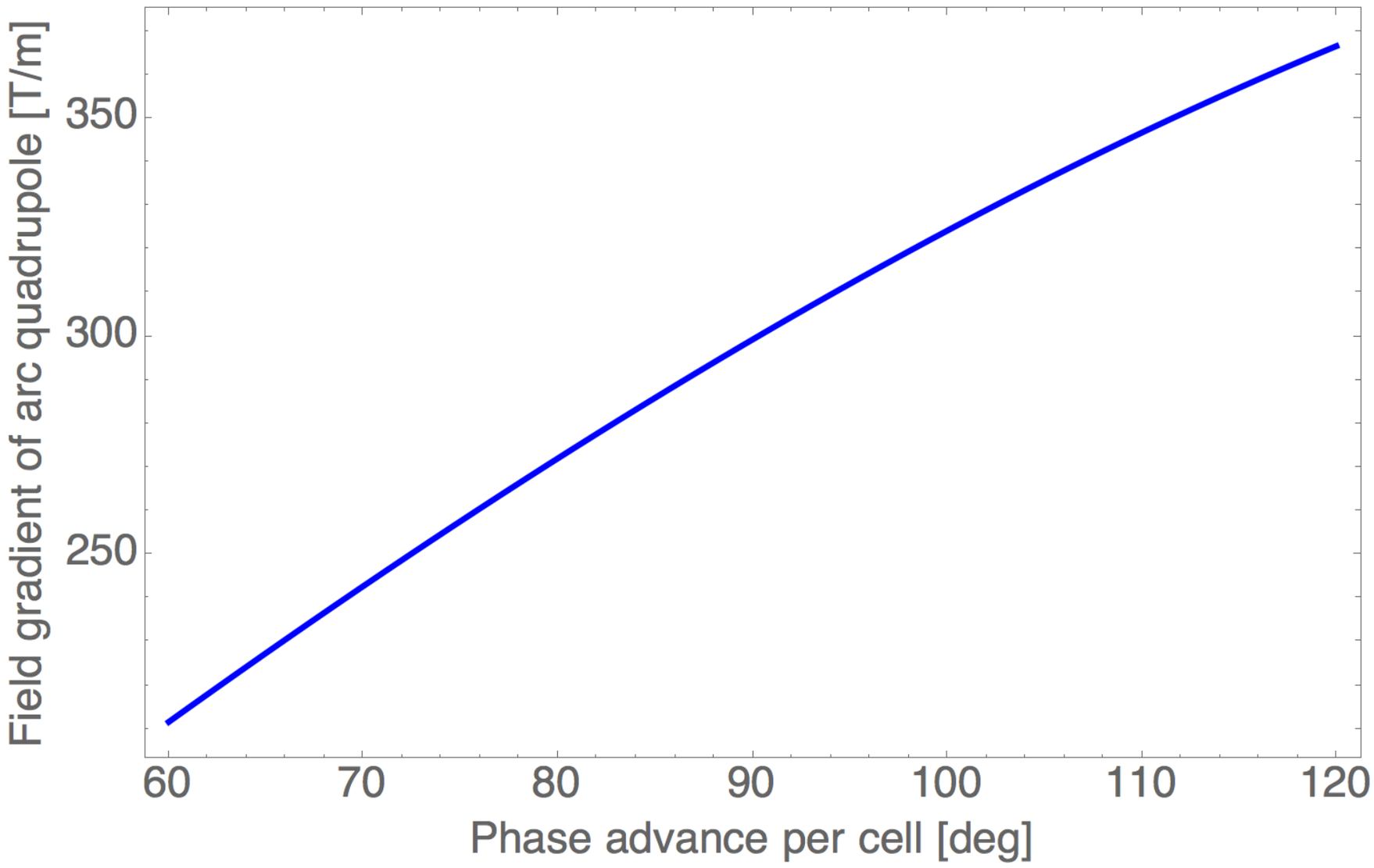
- **Assume ideal FODO cell [thin-lens, 100% filling factor]**
- **Use 18x60 layout:**

L_{cell}=137.233 m, L_Q=3.1 m, $L_B=L_{cell}/2$, L_S=0.369 m, E=13.5 TeV



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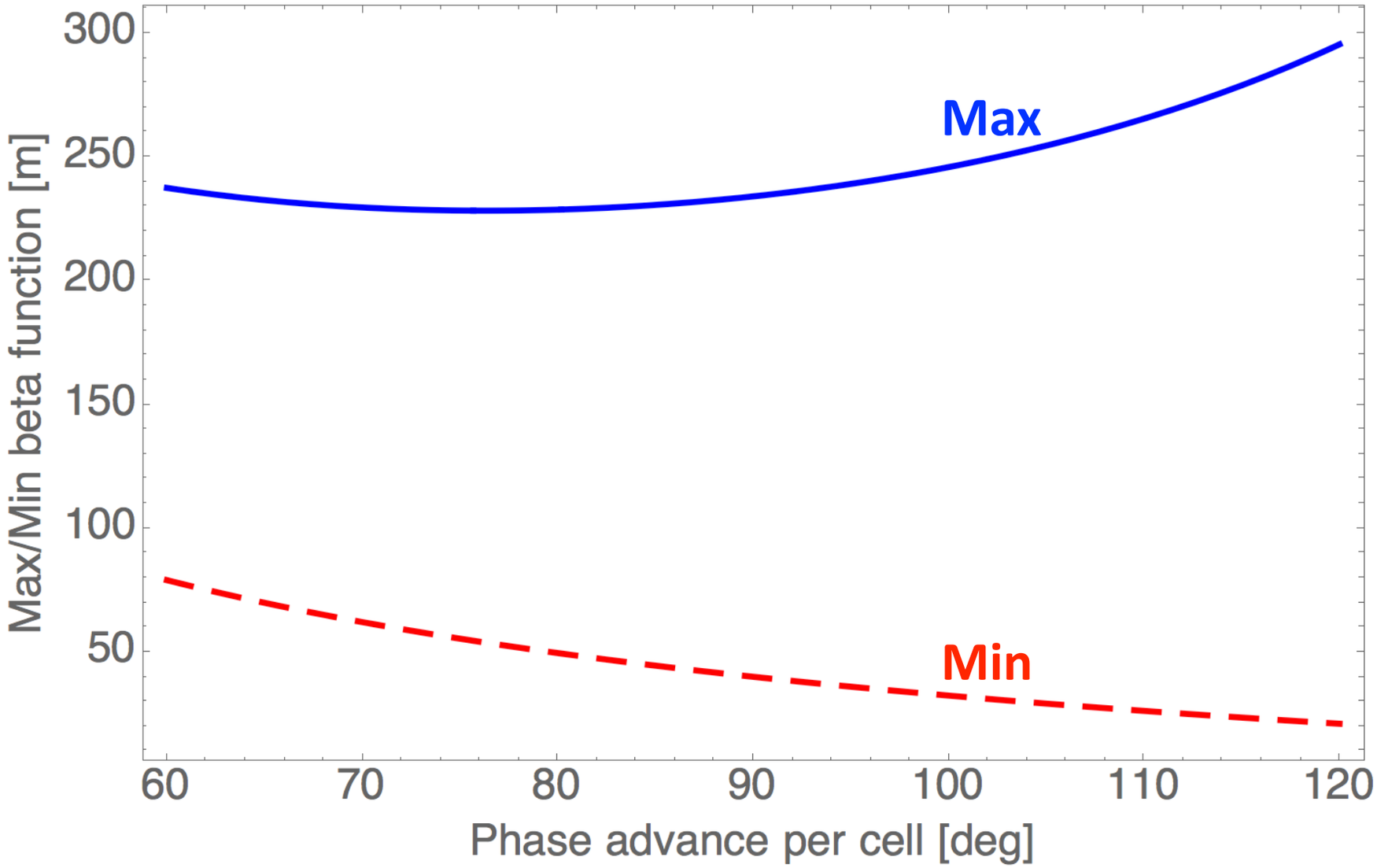

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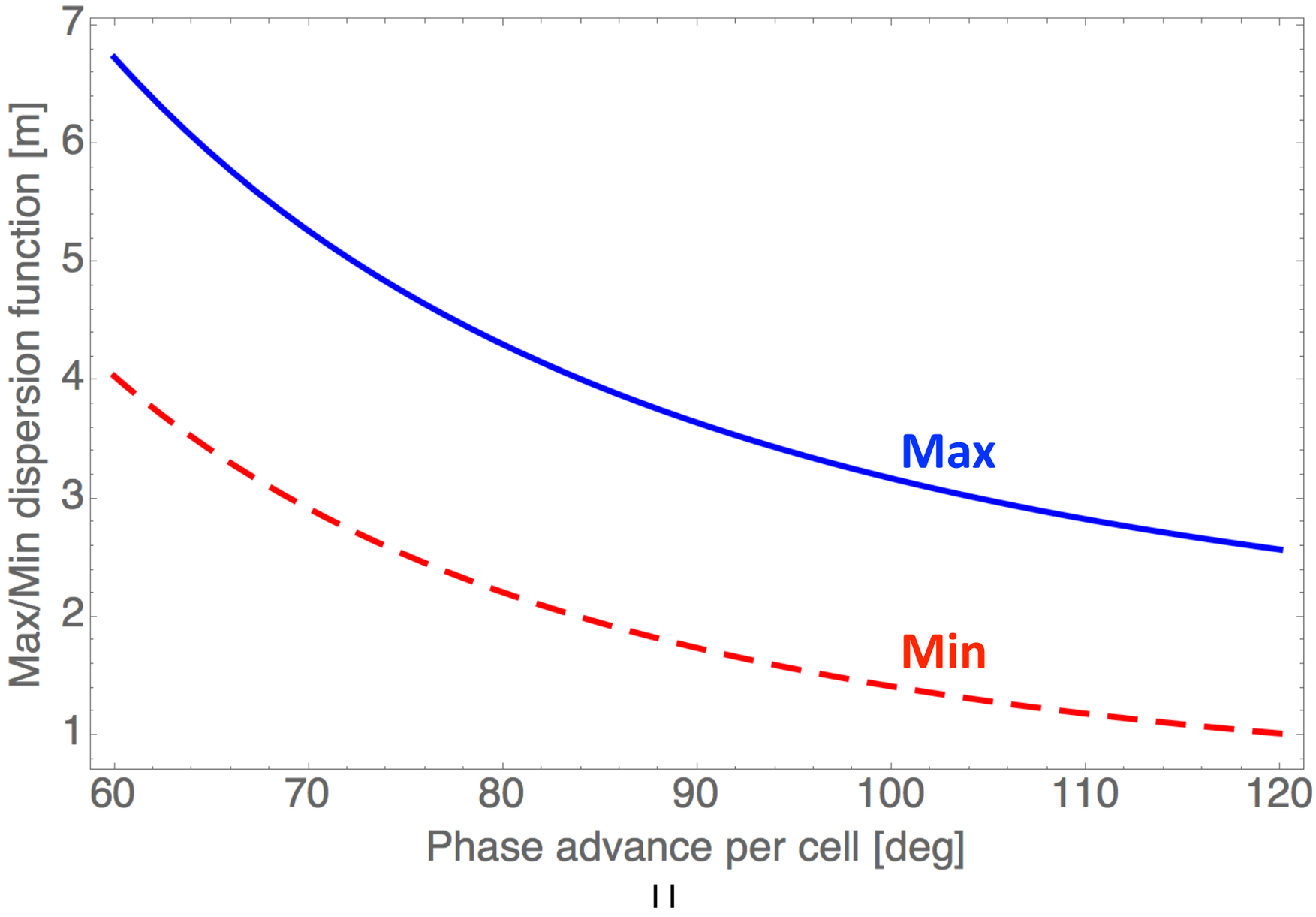

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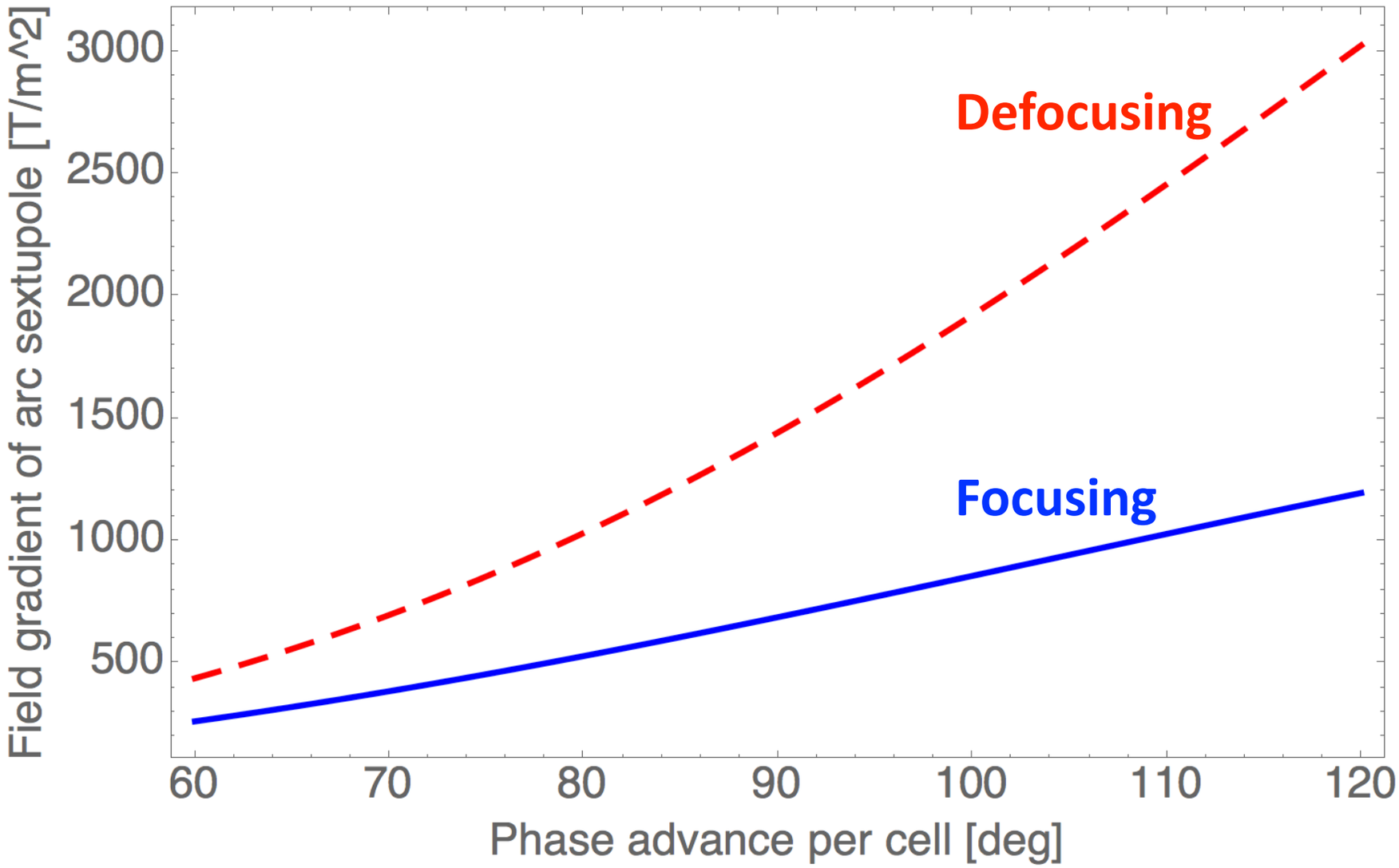

2. Strategy for HE-LHC design

➤ Task distribution

- Arc cells and DSs
- IR1 and IR5: Main experiment IRs
- IR3 and IR7: collimation
- IR4 and IR6: RF and beam dump
- Full lattice: Global matching&optimization/chromaticity correction/toolkits
- Beam-beam issues
- Collective effects
- … …

2. Strategy for HE-LHC design

➤ Iterative design process

- Step 1: Create arc cells, adjust DSs, matching to SLHC IRs [respect to LHC geometry]
- Step 2: IR design/update, repeat Step 1
- Step 3: Global matching&optimization/chromaticity correction
- Step 4: DA calculations with errors
- Step 5: Check challenges (technical and beam physics), if hit show-stopper, restart from Step 1
- Step 6: Collimation and other sub-system design/update (electron lens, crab cavity, etc.)