Racetrack FFAG muon decay ring for νSTORM

JB. Lagrange[1], J. Pasternak[1], Y. Mori[2]

(1): Imperial College
(2): Kyoto University

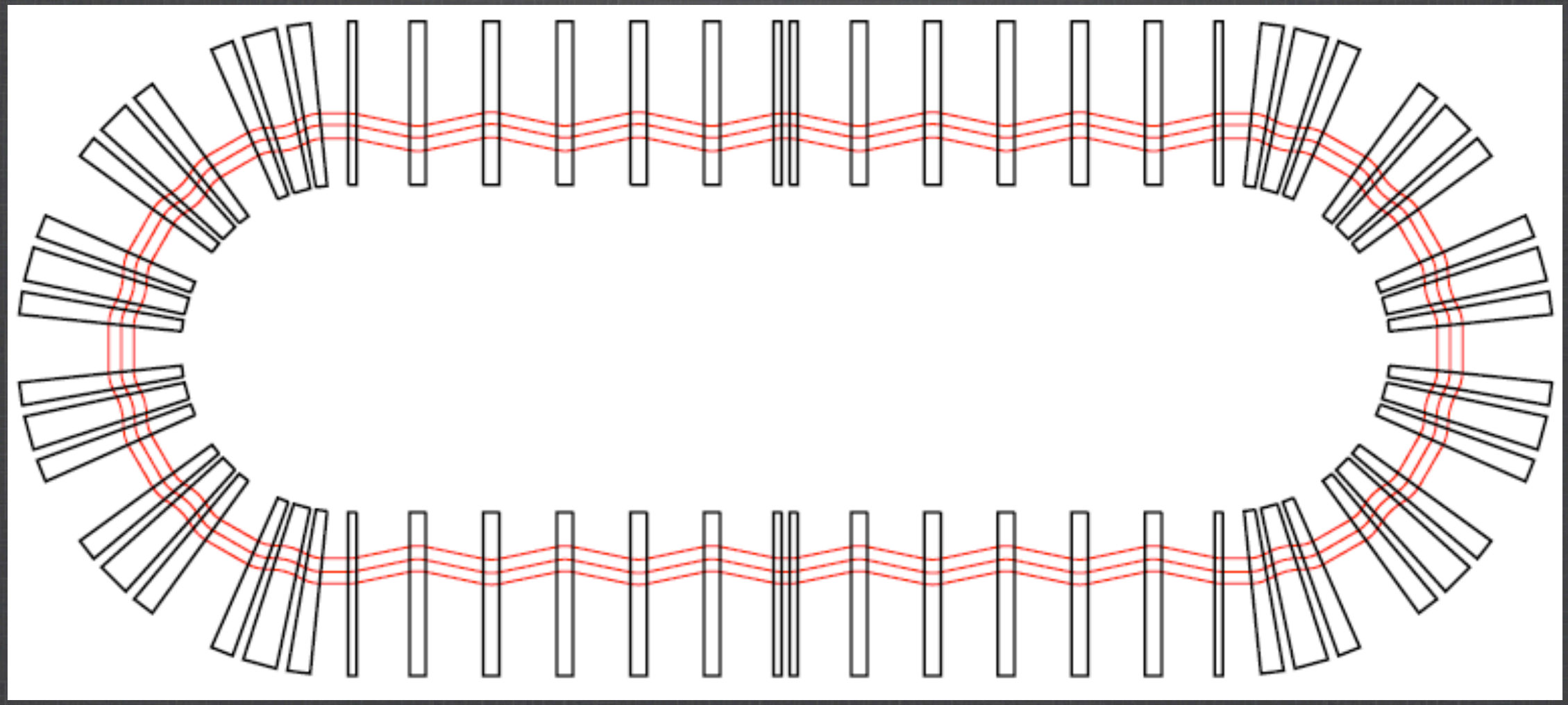
Outline

- Constraints
- “FODO-LIKE” option
- “LOW-COST” option
- Magnets
- Comparison

Outline

- Constraints
- "FODO-LIKE" option
- "LOW-COST" option
- Magnets
- Comparison

Racetrack FFAG



νSTORM Racetrack FFAG

Constraints:

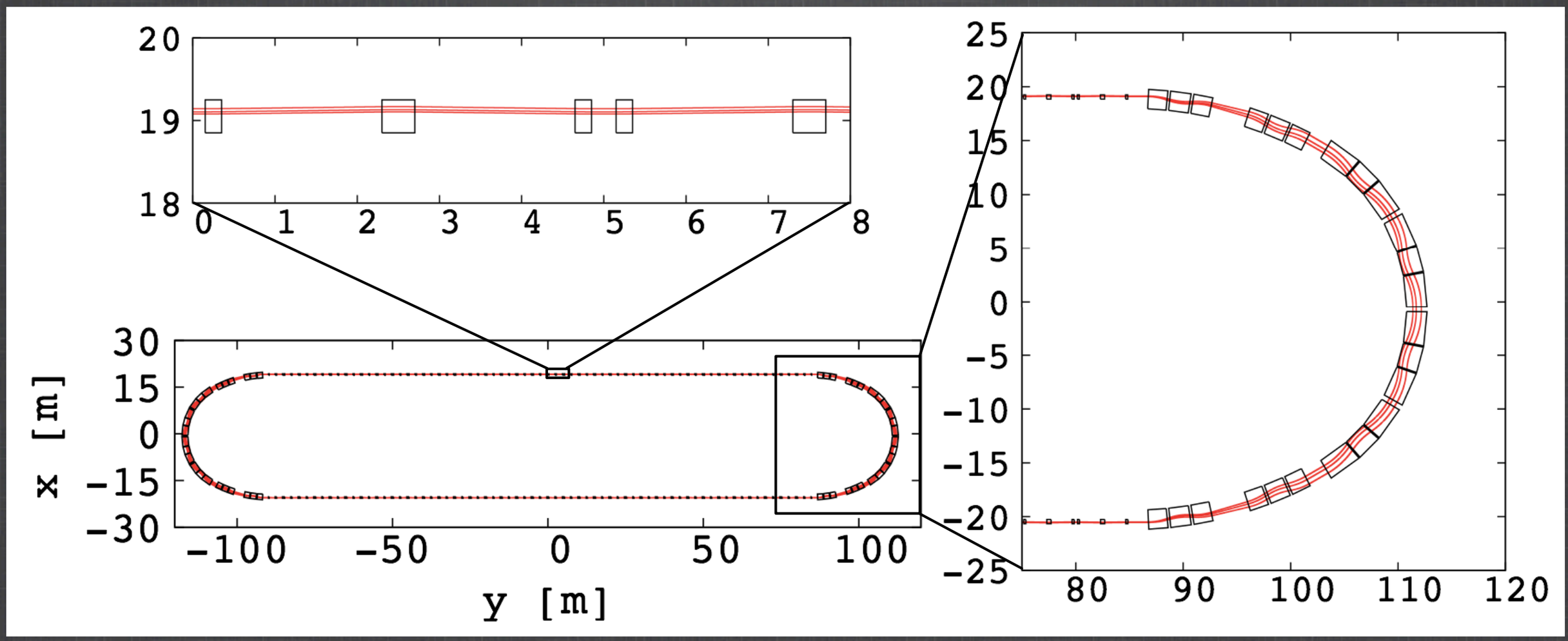
- in the straight part, the scallop must be as small as possible to keep reasonable the size of the detector. 15 mrad has been chosen as the maximum angle.
- in the dispersion matching section, a drift length of ~2.6 m is necessary for stochastic injection.
- to keep the ring as small as possible, SC magnets in the arcs are considered. Normal conducting magnets are used in the straight part.
- large transverse acceptance is needed in both planes (1000π mm.mrad).

Outline

- Constraints
- "FODO-LIKE" option
- "LOW-COST" option
- Magnets
- Comparison

"FODO-LIKE" OPTION

Straight: **175 m**, maximum scallop angle: **12 mrad**



Comparable straight length than FODO lattice

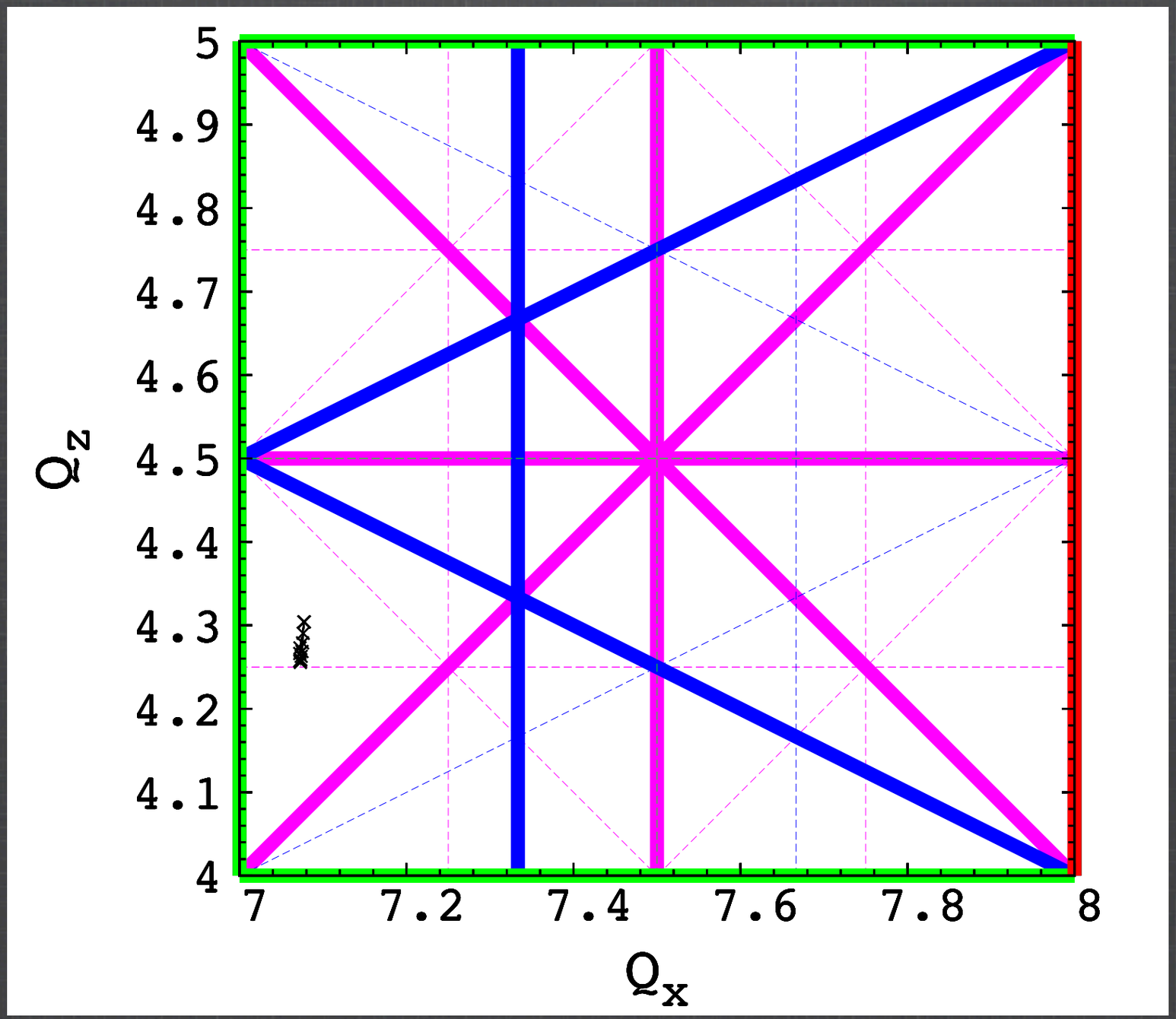
"FODO-LIKE" OPTION

Cell parameters

	Circular Section	Matching Section	Straight Section
Type	FDF	FDF	DFD
Cell radius/length [m]	17.3	36.1	5
Opening angle [deg]	30	15	
k-value/m-value	6.202	26.785	5 m^{-1}
Packing factor	0.92	0.58	0.16
Maximum magnetic field [T]	2.5	3.3	1.5
horizontal excursion [m]	1.3	1.1	0.4
Full gap height [m]	0.45	0.45	0.45
Horizontal phase advance /cell [deg]	90.0	90.0	15.8
Vertical phase advance /cell [deg]	21.1	23.7	16.8
Average dispersion /cell [m]	2.4	1.3	0.2
Number of cells /ring	4×2	4×2	35×2

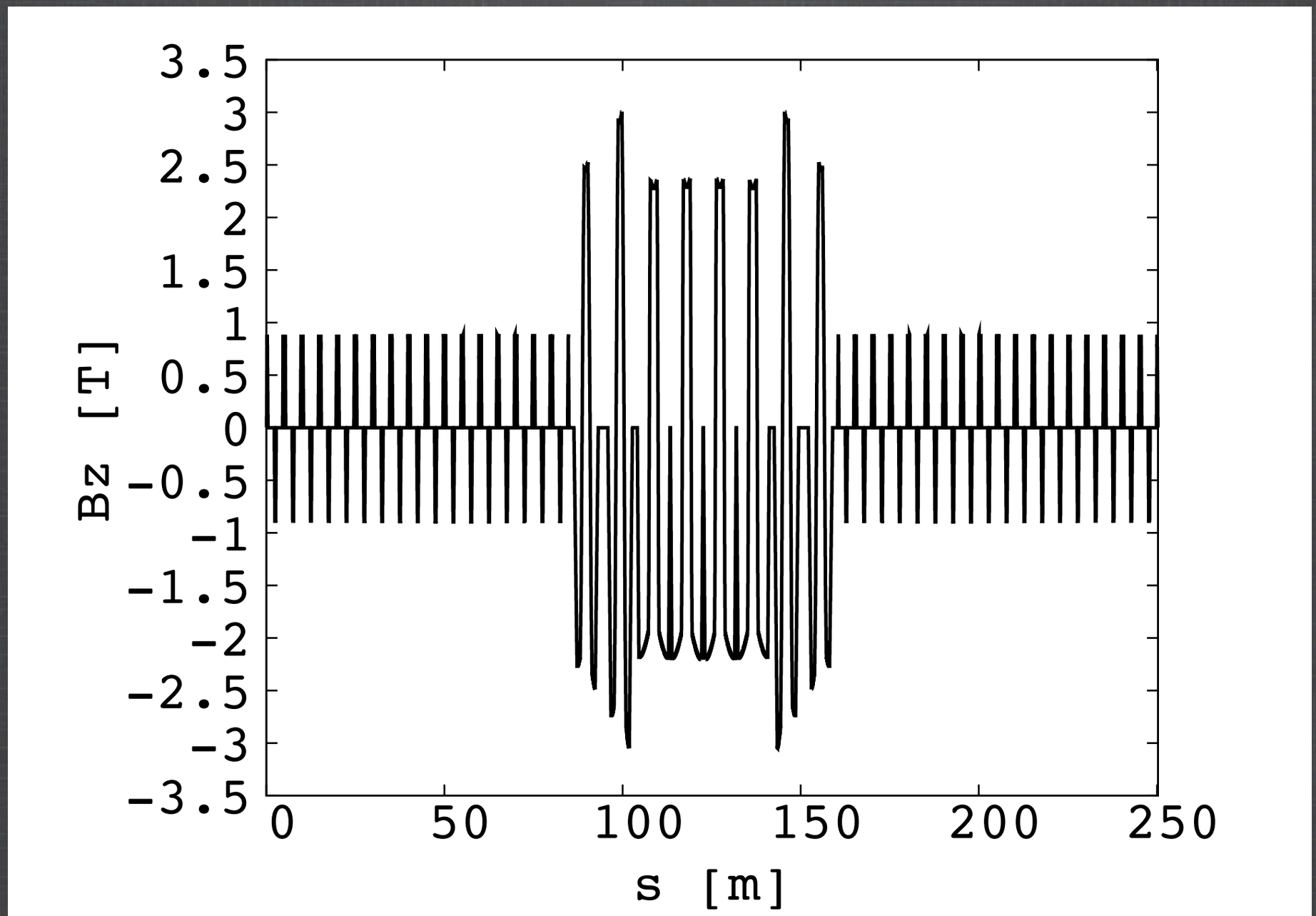
"FODO-LIKE" OPTION

Tune diagram $\frac{\Delta P}{P} = \pm 16\%$



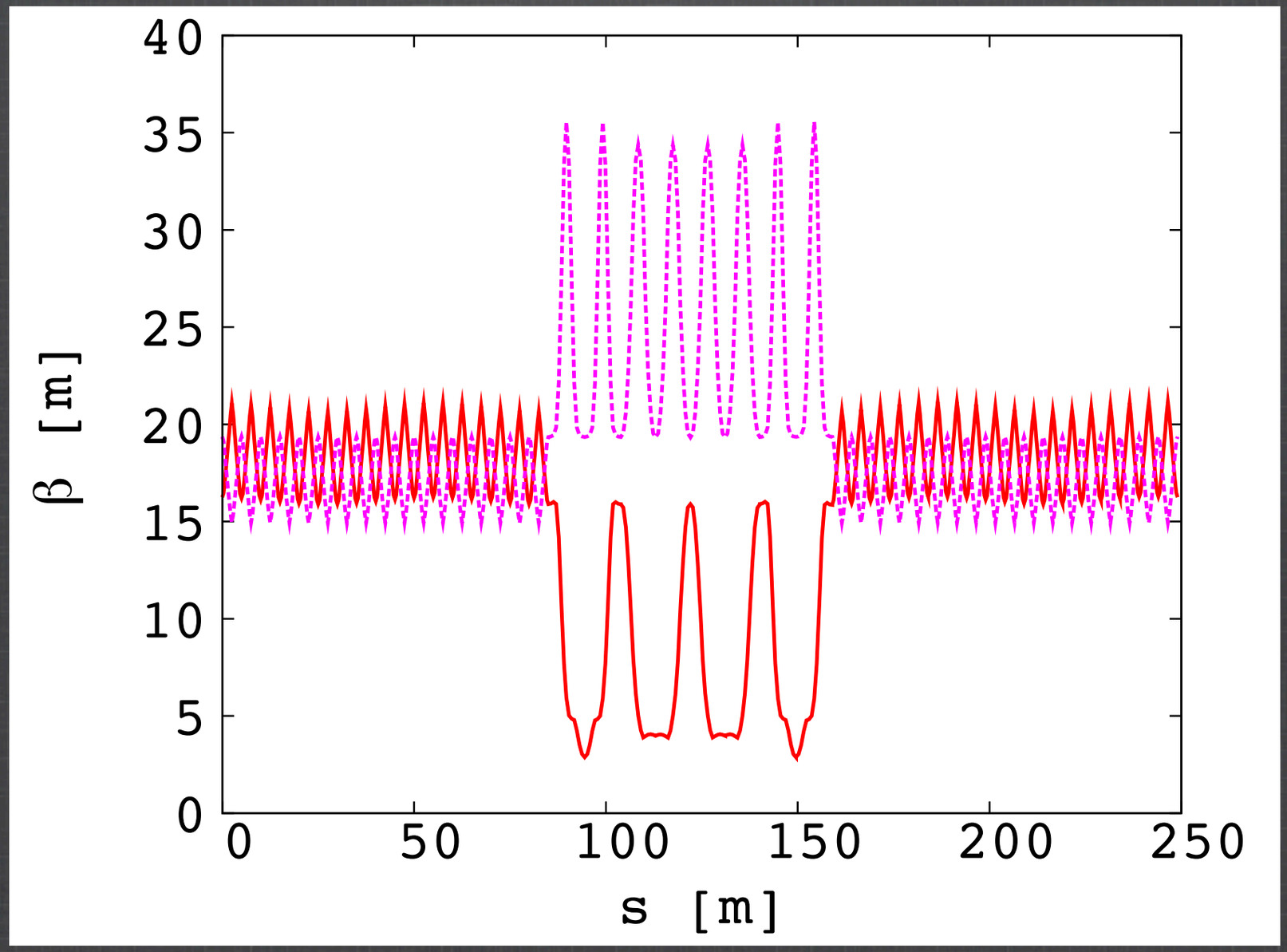
"FODO-LIKE" OPTION

Magnetic field for P_{max} (+16%)



"FODO-LIKE" OPTION

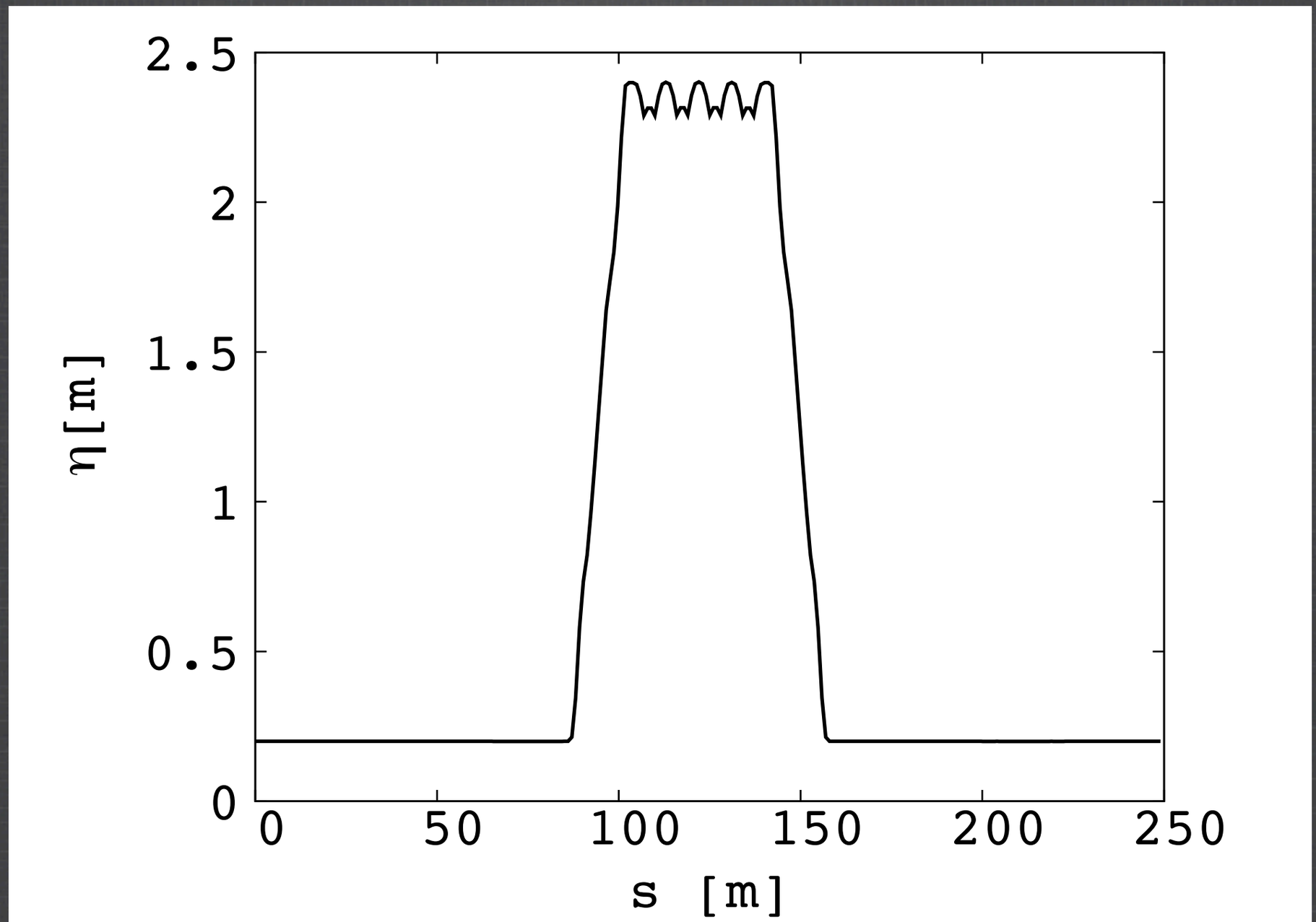
Beta-functions at matching momentum



Horizontal (plain red) and vertical (dotted purple) betafunctions for half of the ring.

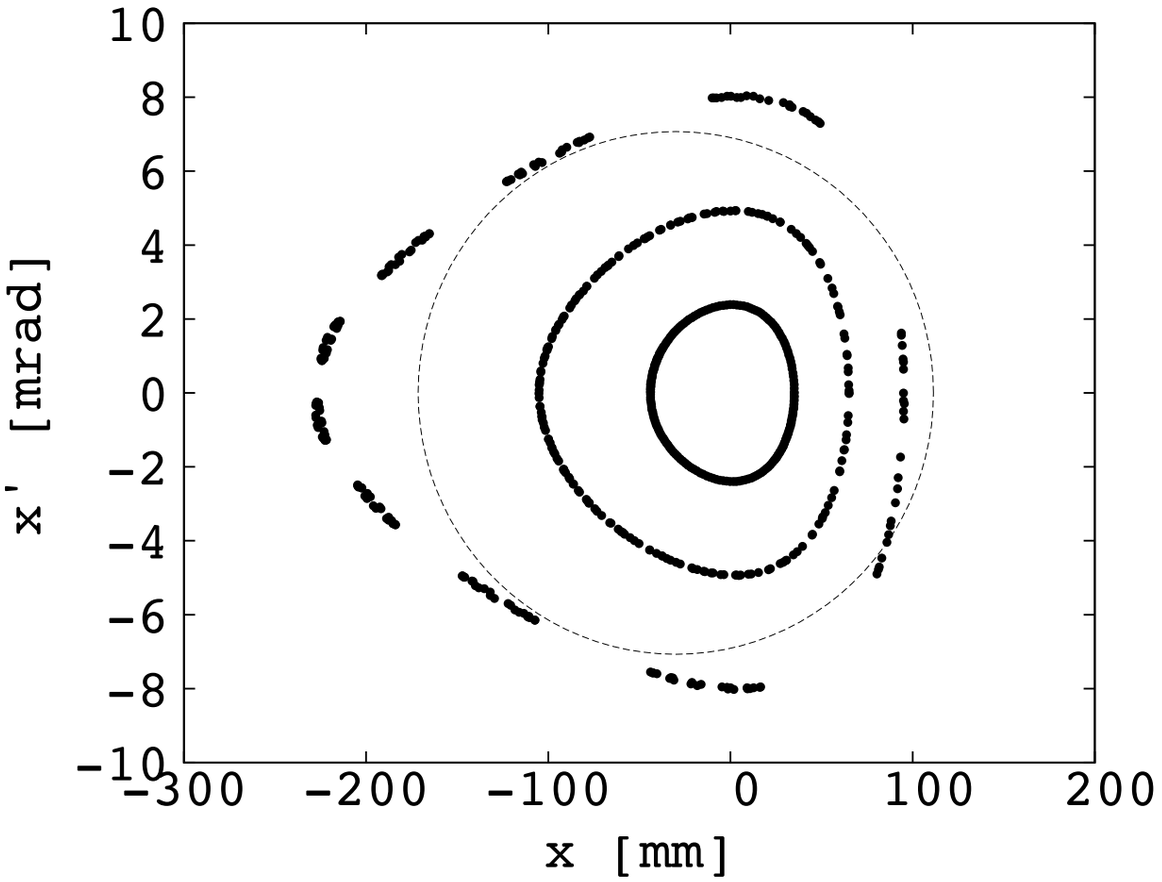
"FODO-LIKE" OPTION

Dispersion function at matching momentum

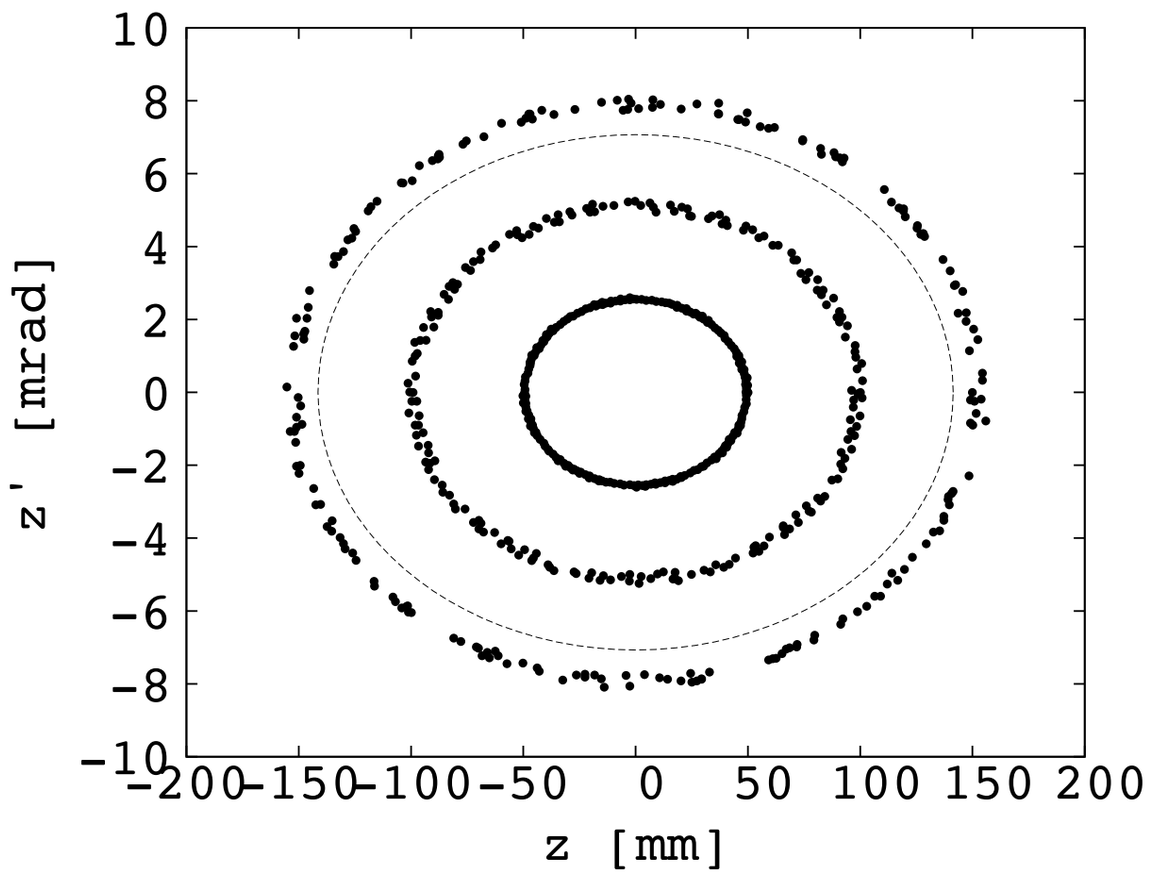


"FODO-LIKE" OPTION

Transverse acceptance



Maximum horizontal stable amplitude over 100 turns



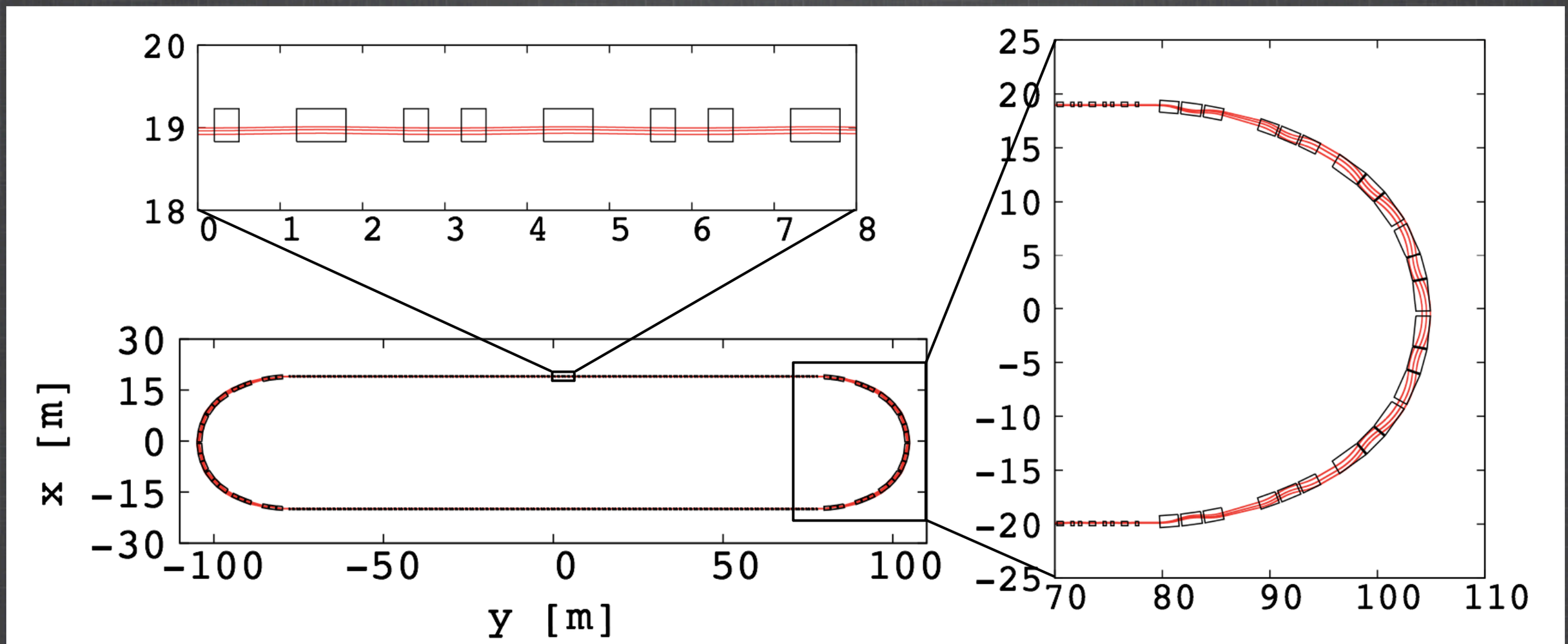
Maximum vertical stable amplitude over 100 turns

Outline

- Constraints
- "FODO-LIKE" option
- "LOW-COST" option
- Magnets
- Comparison

"LOW-COST" OPTION

Straight: **156 m**, maximum scallop angle: **13.9 mrad**



Short straight length for a cheaper lattice.

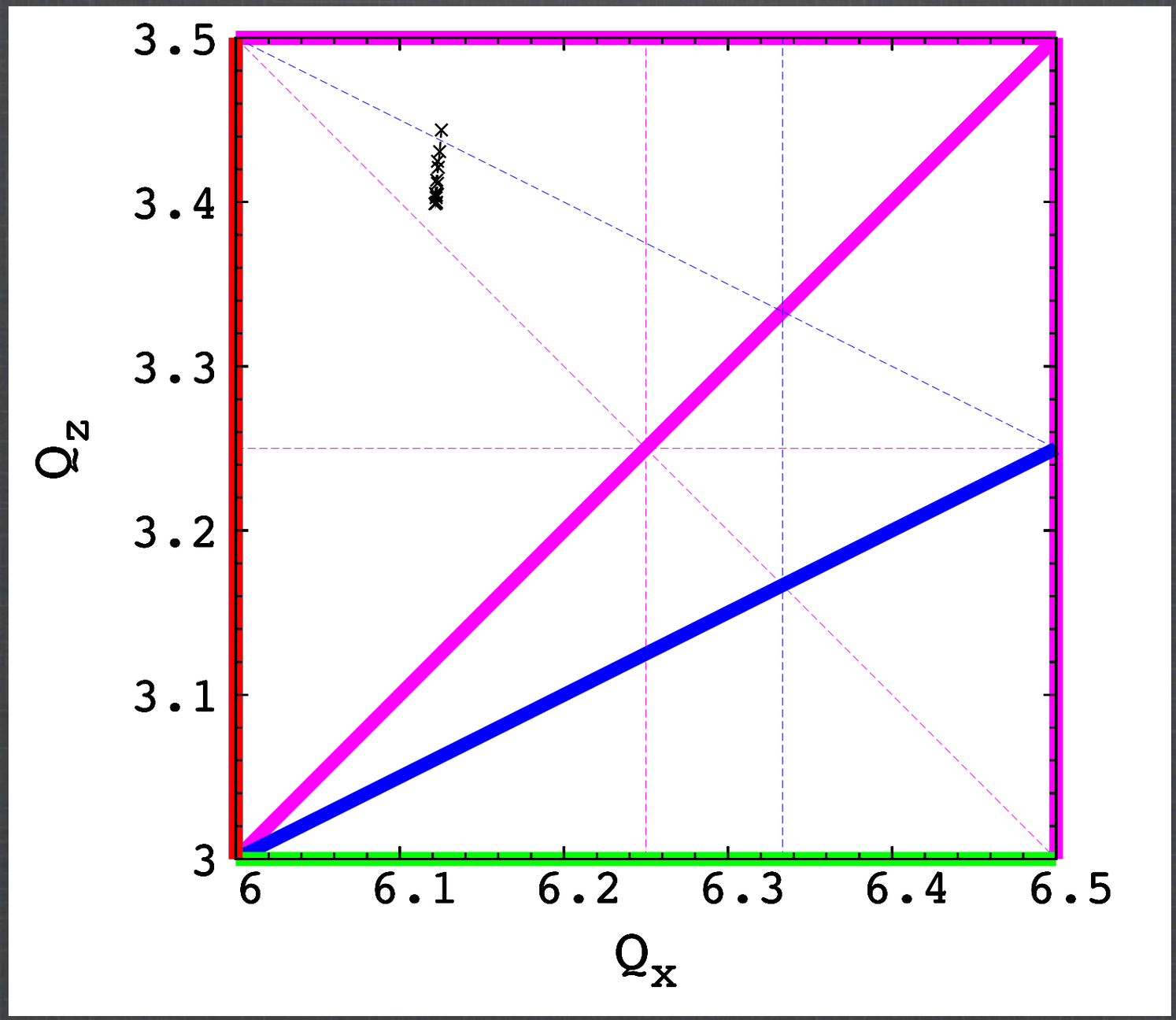
"LOW-COST" OPTION

Cell parameters

	Circular Section	Matching Section	Straight Section
Type	FDF	FDF	DFD
Cell radius/length [m]	17	36.15	3
Opening angle [deg]	30	15	
k-value/m-value	6.21	26.83	4 m^{-1}
Packing factor	0.92	0.58	0.4
Maximum magnetic field [T]	2.9	3.8	1.7
horizontal excursion [m]	1.35	1.1	0.65
Full gap height [m]	0.45	0.45	0.45
Horizontal phase advance /cell [deg]	90.0	90.0	7.3
Vertical phase advance /cell [deg]	19.1	21.9	8.6
Average dispersion /cell [m]	2.4	1.3	0.25
Number of cells /ring	4×2	4×2	52×2

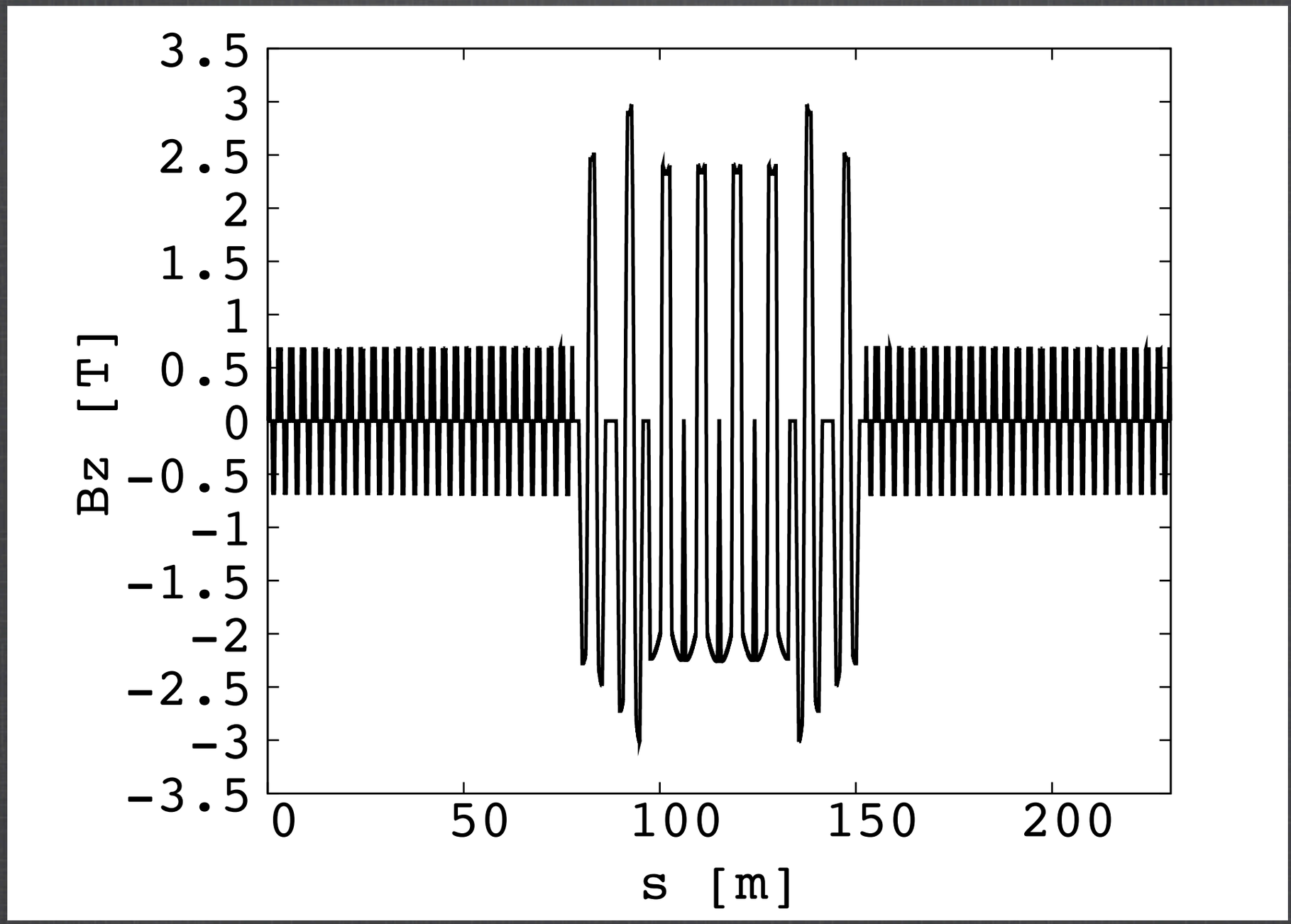
"LOW-COST" OPTION

Tune diagram $\frac{\Delta P}{P} = \pm 16\%$



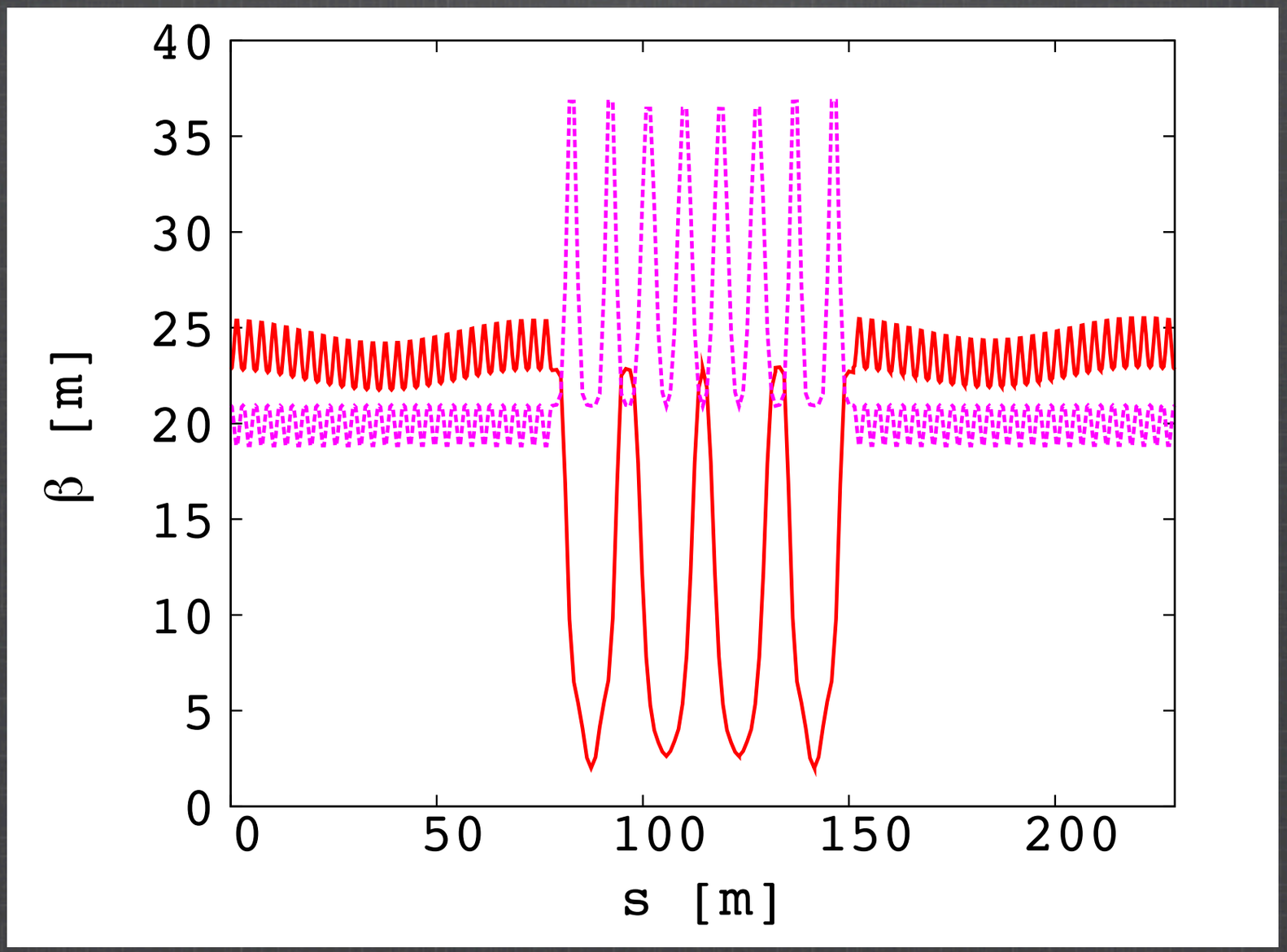
"LOW-COST" OPTION

Magnetic field for P_{max} (+16%)



"LOW-COST" OPTION

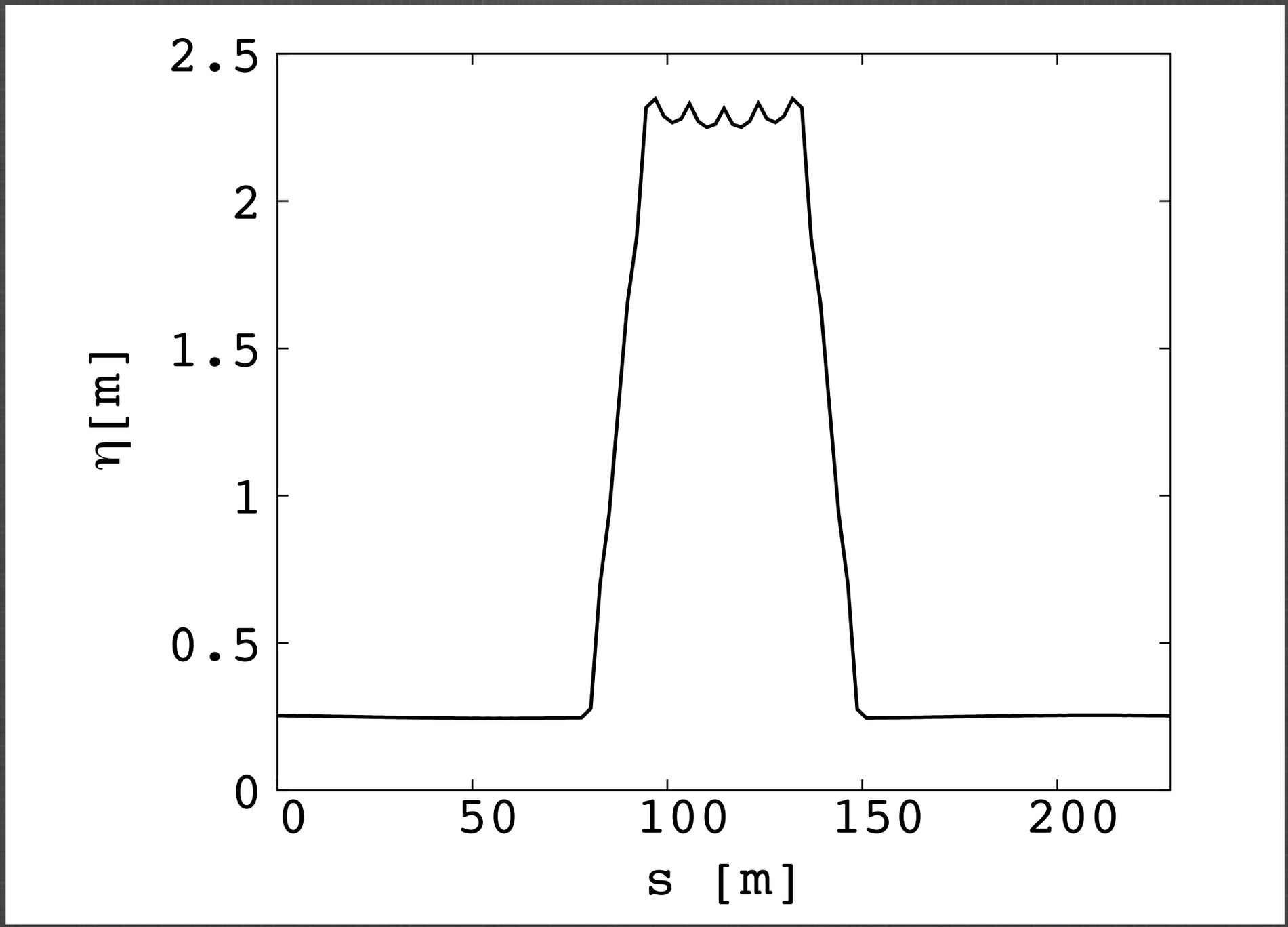
Beta-functions at matching momentum



Horizontal (plain red) and vertical (dotted purple) betafunctions for half of the ring.

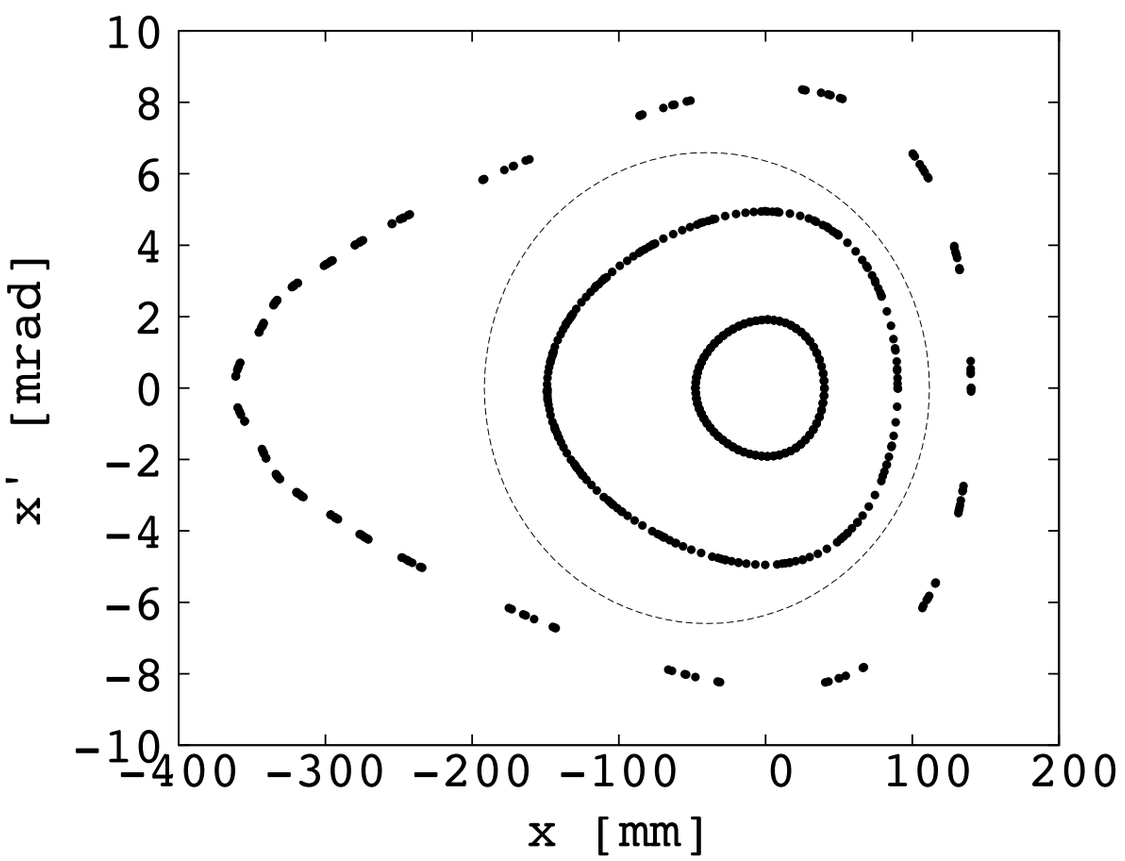
"LOW-COST" OPTION

Dispersion function at matching momentum

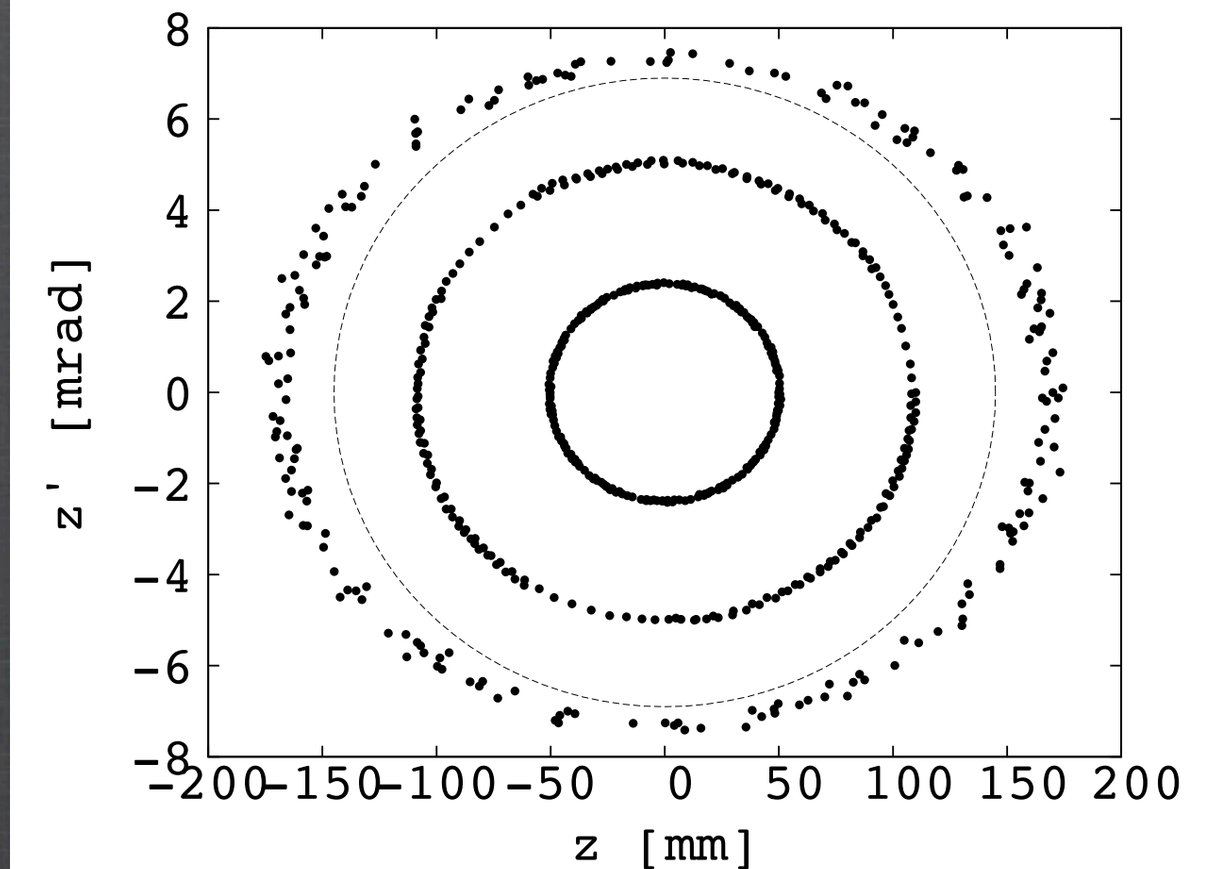


"LOW-COST" OPTION

Transverse acceptance



Maximum horizontal stable amplitude over 100 turns

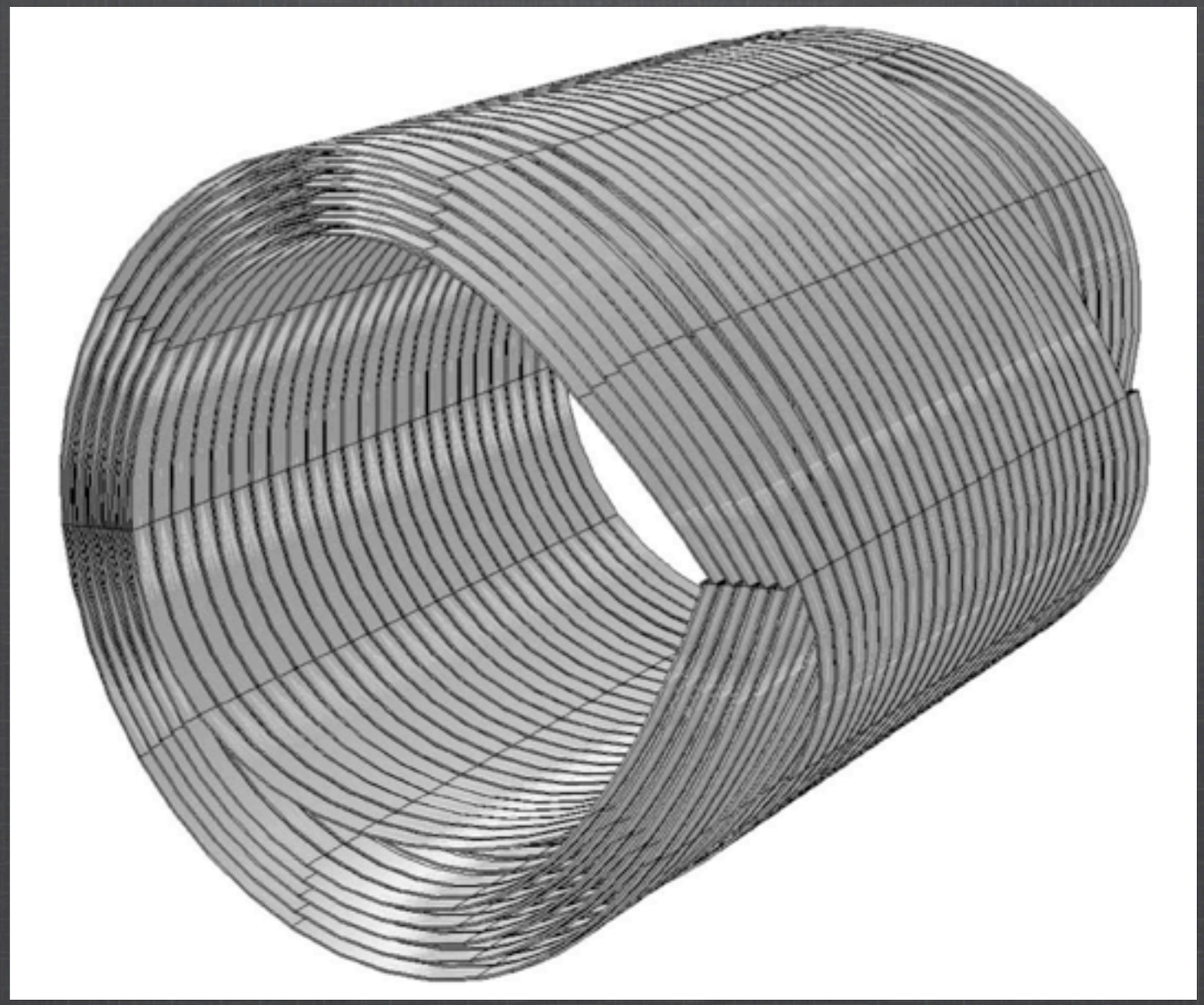


Maximum vertical stable amplitude over 100 turns

Outline

- Constraints
- "FODO-LIKE" option
- "LOW-COST" option
- Magnets
- Comparison

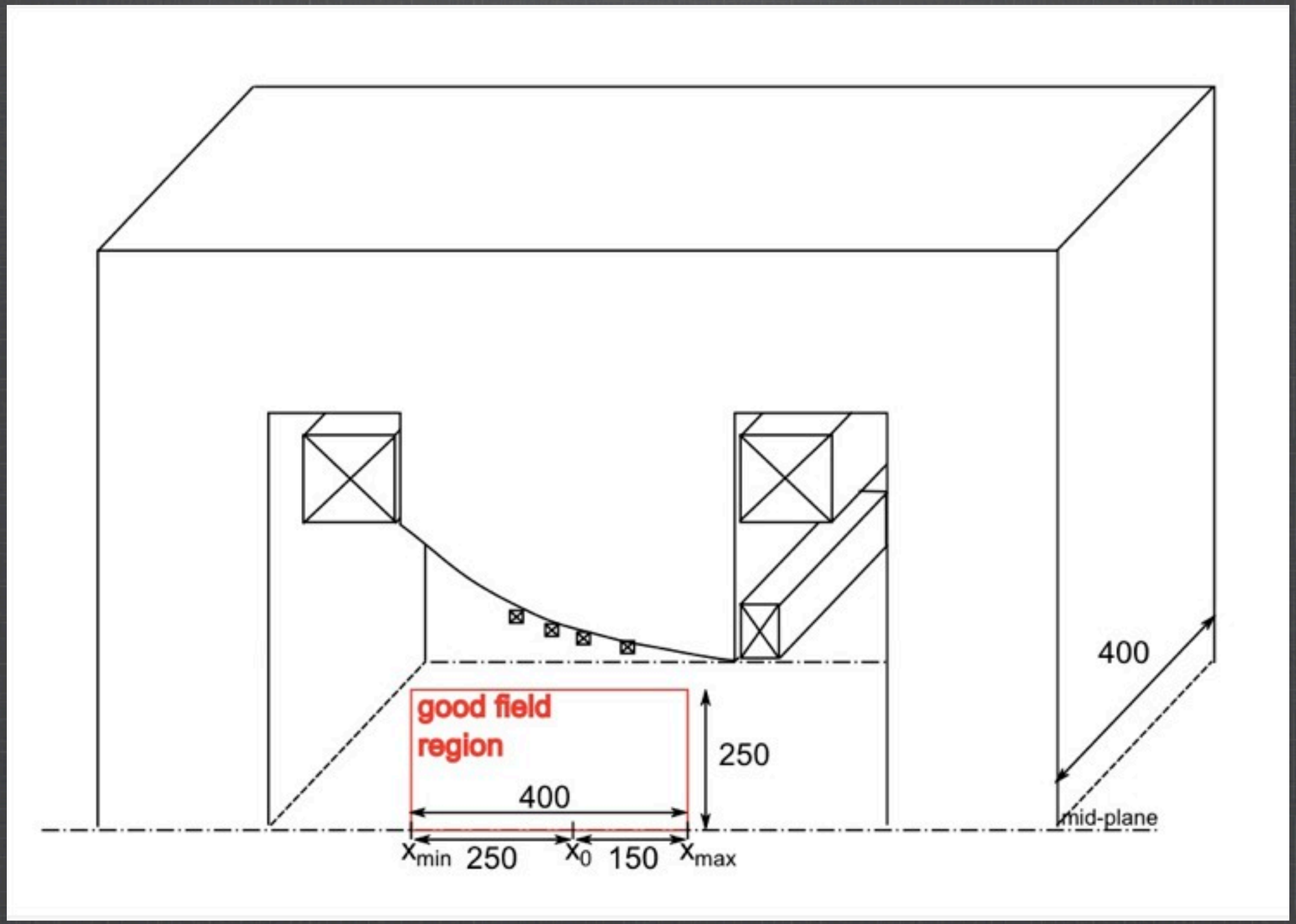
Superconducting magnets



PAMELA "F" magnet

The Advantages and Challenges of Helical Coils for Small Accelerators—A Case Study, H. Witte *et al*. *IEEE, 22 (2), 2012*.

Straight FFAG magnets



Outline

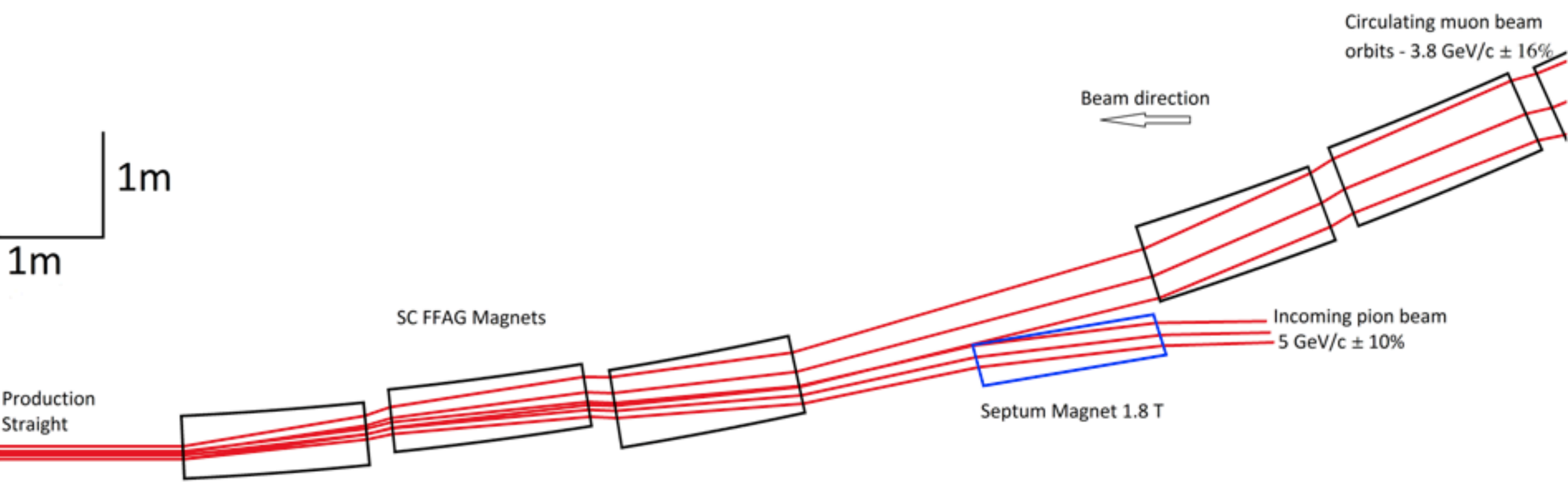
- Constraints
- “FODO-LIKE” option
- “LOW-COST” option
- Magnets
- Comparison

Comparison

Parameters	FODO (Jun. 2013)	RFFAG "FODO-like"	RFFAG "low-cost"
$L_{straight}$ [m]	185	175	156
Circumference [m]	480	500	460
Dynamical acceptance A_{dyn}	0.6	0.95	0.95
Momentum acceptance	±10%	±16%	±16%
π/POT within momentum acceptance	0.094	0.171	0.171
Fraction of π decay in one straight (F_s)	0.48	0.47	0.43
Straight-circumference ratio (Ω)	0.39	0.35	0.34
A_{dyn} x π/POT x F_s x Ω	**0.011**	**0.027**	**0.024**

Stochastic Injection

Preliminary results



Stochastic injection principle (J. Pasternak)

Summary

- Promising results for racetrack FFAG ring as a muon decay ring for NuSTORM.
- Quite flexible regarding the circumference.
- Large momentum acceptance compared with FODO lattice.
- Cost may not be higher than FODO solution.
- Larger momentum acceptance (±25% achieved previously) for wider magnets.

Future plans

- Enge functions fringe field fall-offs (ongoing).
- Study of the scallop effect on the neutrino flux.
- Injection study.
- Error studies (field quality, alignments).
- Investigate feasibility of the arc magnets.
- Cost/performance comparison with FODO solution using cross-checked code (Zgoubi).

Thank you for your attention