eRHIC optics

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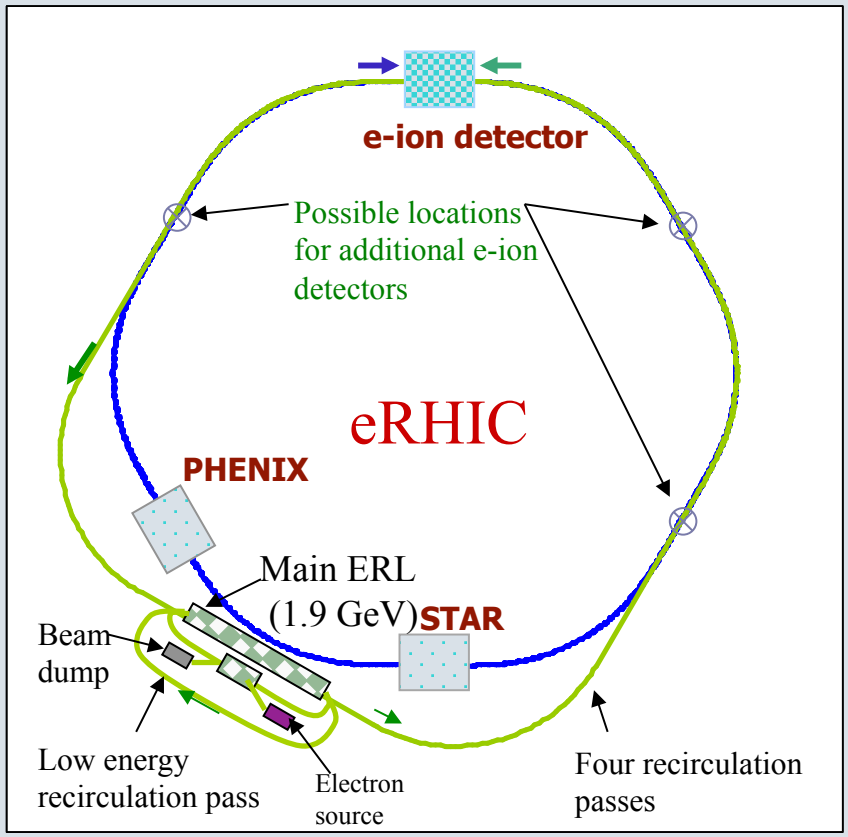
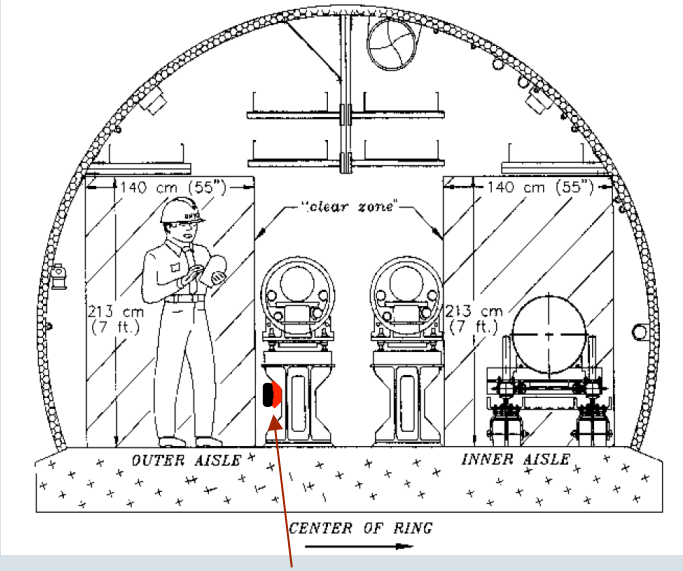
Recirculation passes in eRHIC design

At present design of eRHIC the beam passes the main linac five times during acceleration. Four of the beam recirculation passes will be placed in the tunnel. Lower energy pass can be put locally.





Possible location of the recirculation passes in the tunnel

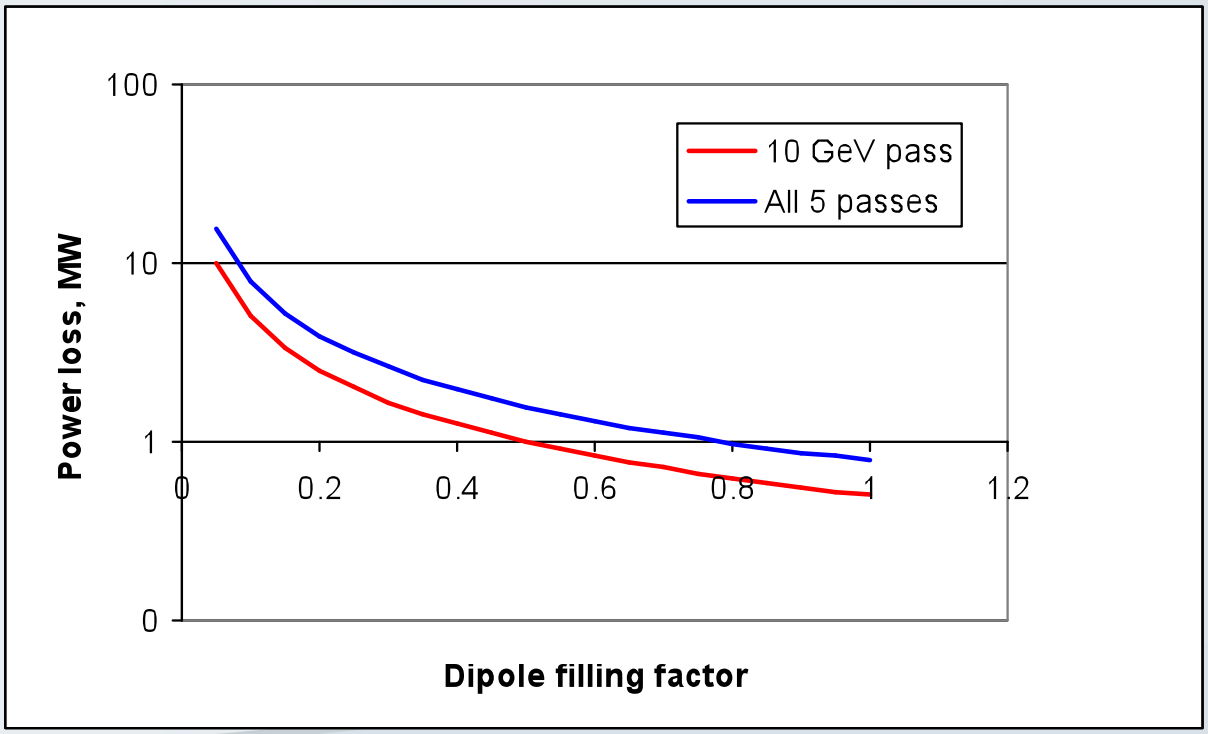
Design of recirculating passes

- Major factors affecting the design are:
- The passes are in the existing RHIC tunnel. Thus average curvature radius of the lattice is given by the tunnel curvature (R=300m)
- Synchrotron radiation. Total power loss and power load per meter. Limits the dipole magnet strength.
- Longitudinal dynamics provides additional requirements (R56, path length tuning).

Choice of the dipole filling factor

For arc consisting from several periodic cells:
dipole filling factor = $L_{dipoles}/L_{cell}$

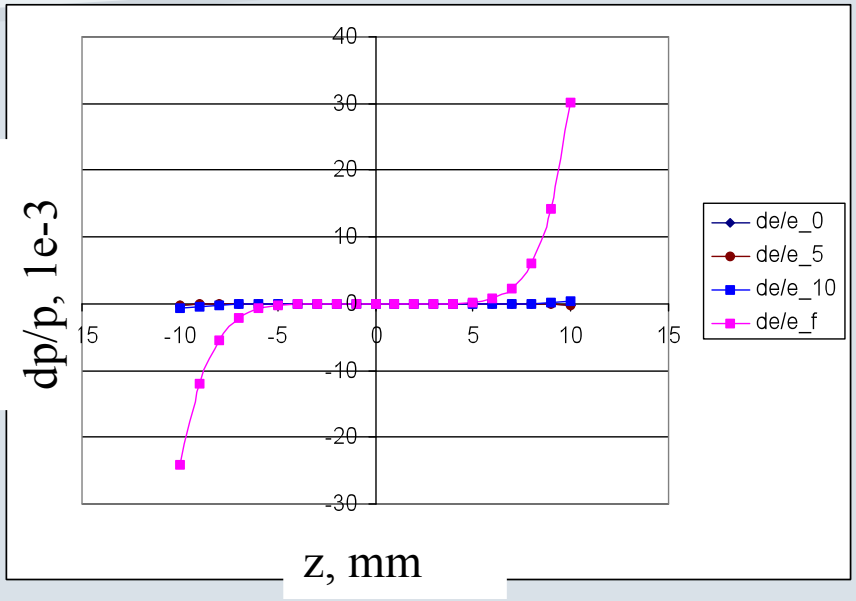
Since the average radius is defined by the tunnel, the dipole filling factor defines completely the dipole field strength.



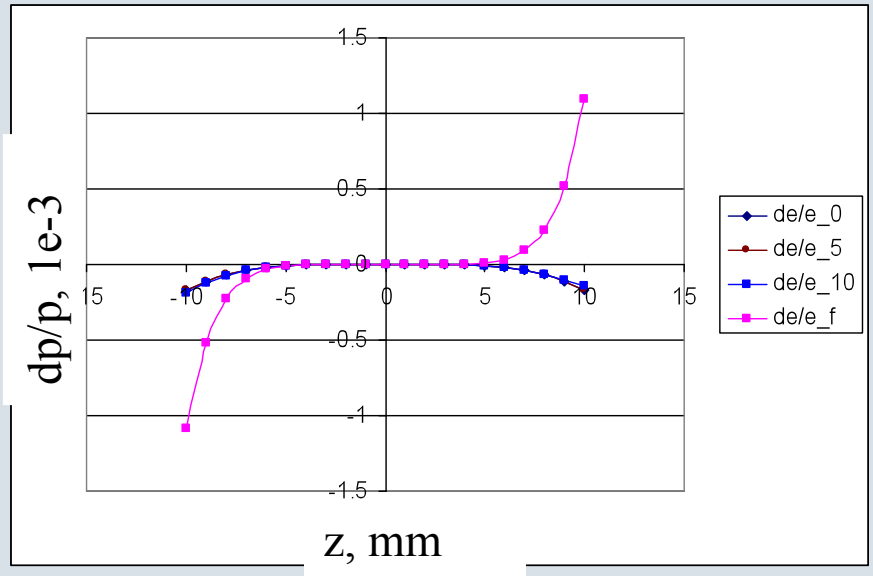
Beam power loss due to synchrotron radiation for 0.26 A beam at 10 GeV versus dipole filling factor.

Longitudinal transport

For acceleration on the crest the recirculating passes should be isochronous enough in order to have acceptable momentum spread after deceleration



R_{56}=500 mm



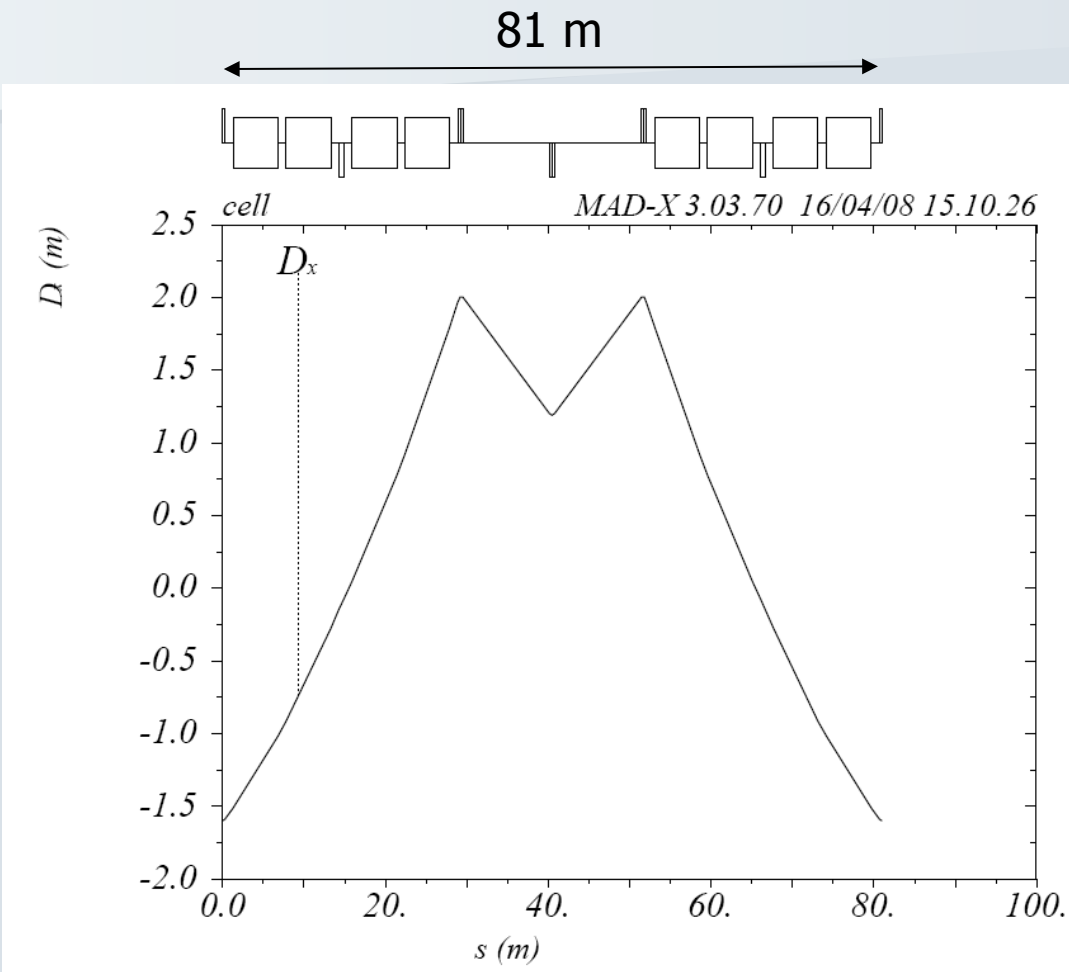
R_{56}=20 mm

3rd harmonic cavities are used in both main and pre-accelerator linacs

Possible lattice choices

- FODO cells. Very high filling factor. But large r56.
- Achromats (double or triple bend types)
- Modified FODO cells. Larger beta and dispersion functions.
- FMC cell. Flexible for the control of the r56 parameter.

Basic cell for the recirculating passes



FMC cell *(D.Trbojevic)*
Dipole filling factor: 54%
Tuned to ~0 momentum compaction

For 10GeV:
Largest gradient: 7.7 T/m
Dipole field: 1.6 kGs

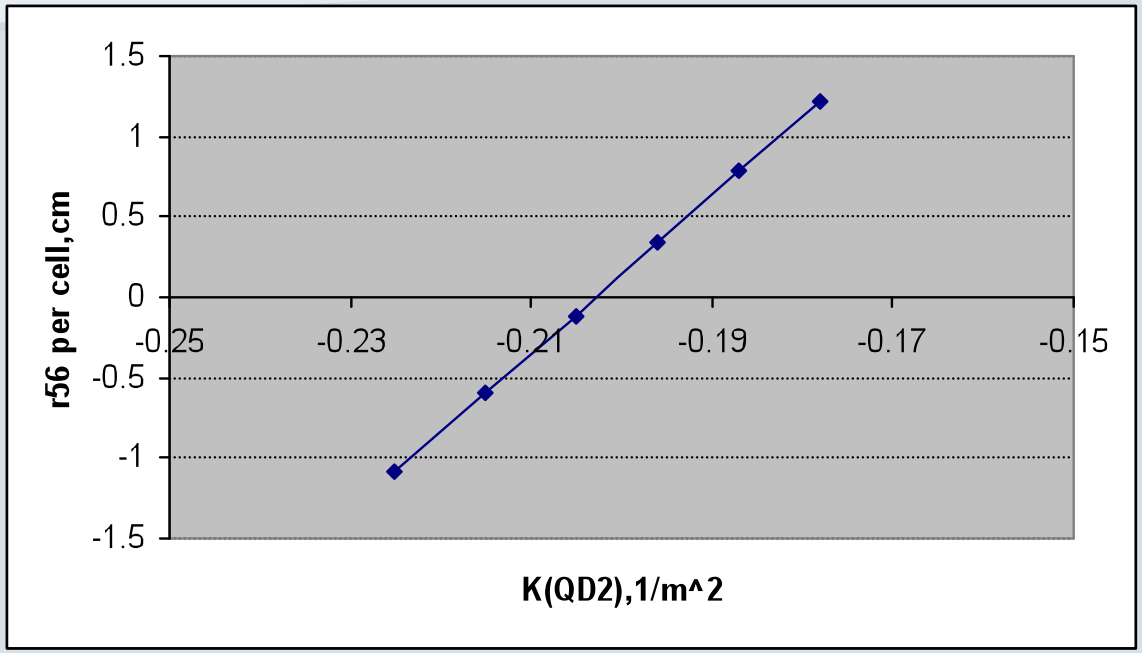
Dipole length: 5.5 m
Quad length: 0.6 m

Summary of synchrotron radiation

	I, mA	E loss on top pass, MeV	E loss on 5 passes MeV	Power loss on top pass, MW	Power loss on 5 passes MW	($\delta p/p$) rad, 1e-3	$\Delta\varepsilon$ rad, nm
10 GeV	260	4.3	6.7	1.1	1.7	0.02	0.04
20 GeV	26	69	107	1.8	2.8	0.13	1.3

Tunable R_{56} parameter

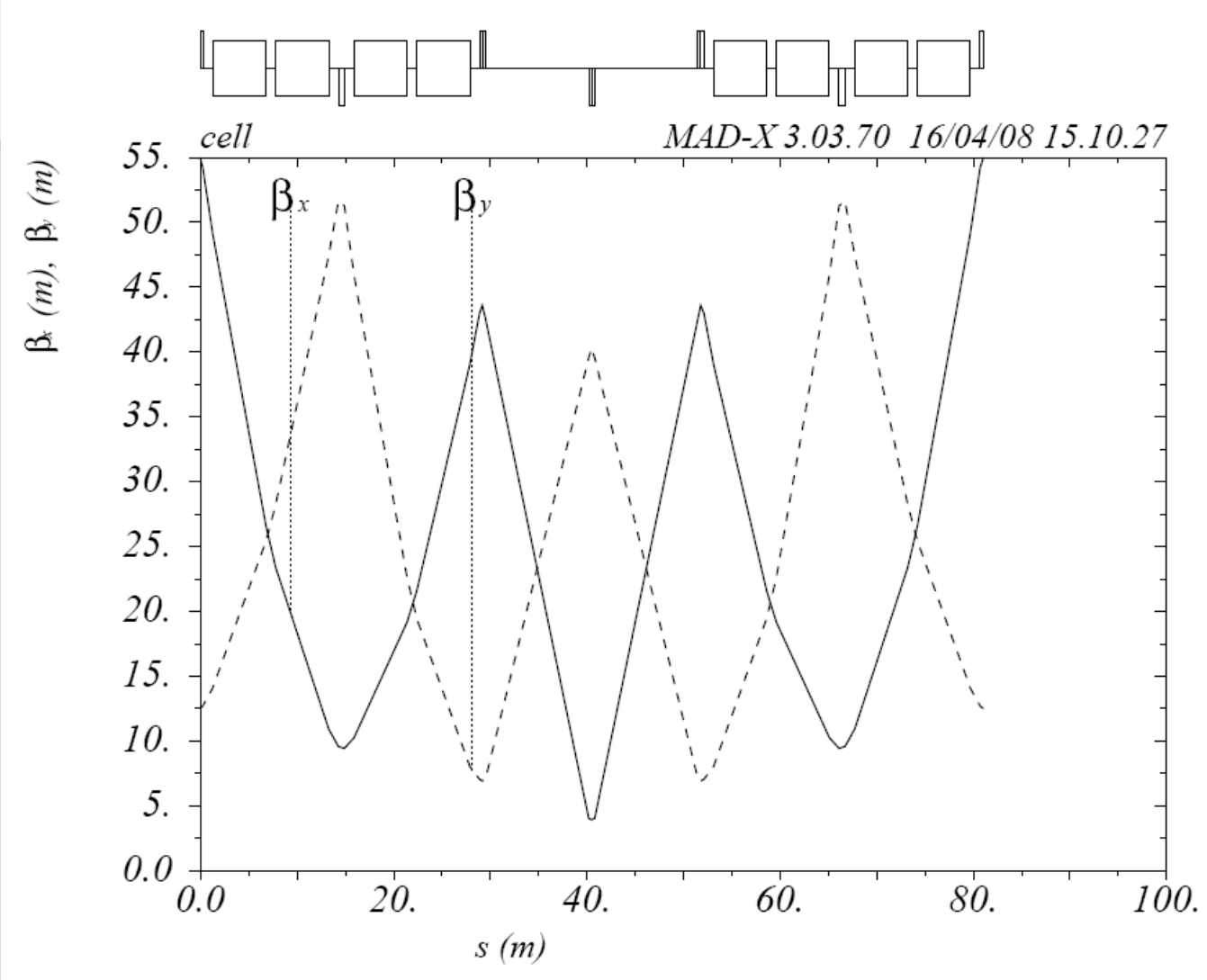
R_{56} versus gradient of QD2 quad (central quad)



Should give at least +-0.3m tuning range for R_{56} on the whole pass.
Beta_max change within 15%.

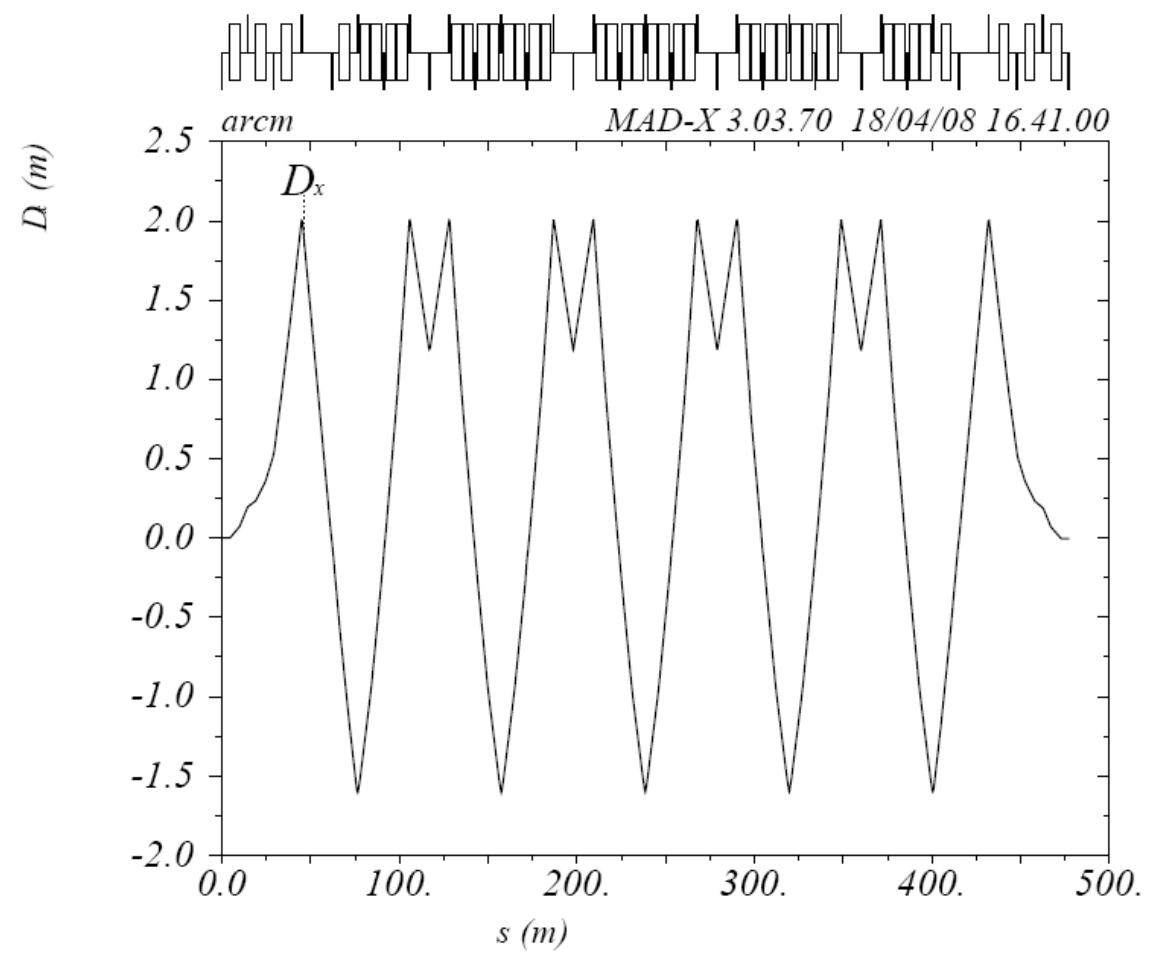
For this basic cell there are also some other ways to tune R_{56}.

Basic cell: beta-functions



Phase advances:
μ_x = 1.6π
μ_y = 1.4π

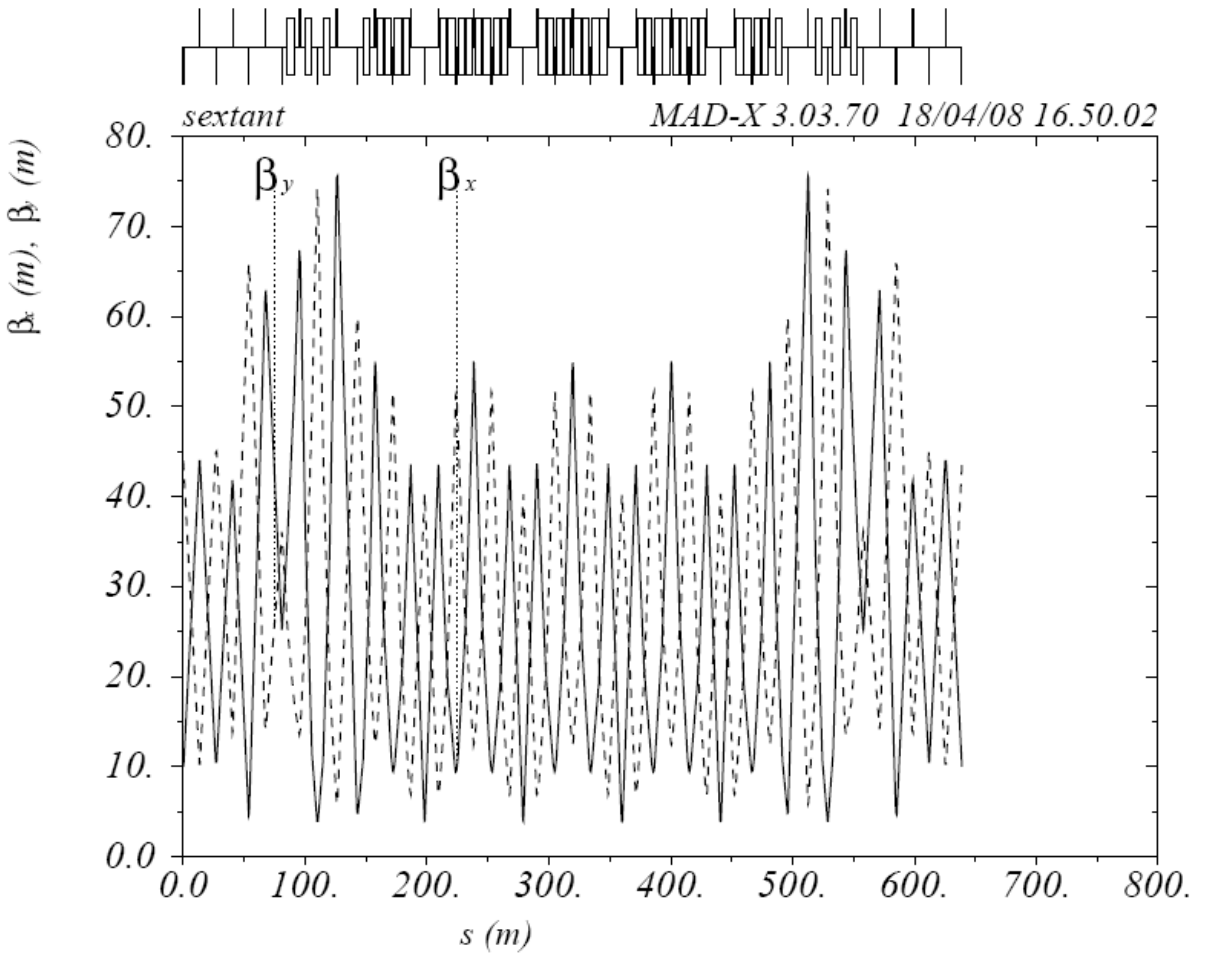
Arc lattice



4 basic FMC cells
+ matching sections

The whole arc transfer is achromatic.
R_{56}=0 and adjustable.

One sextant



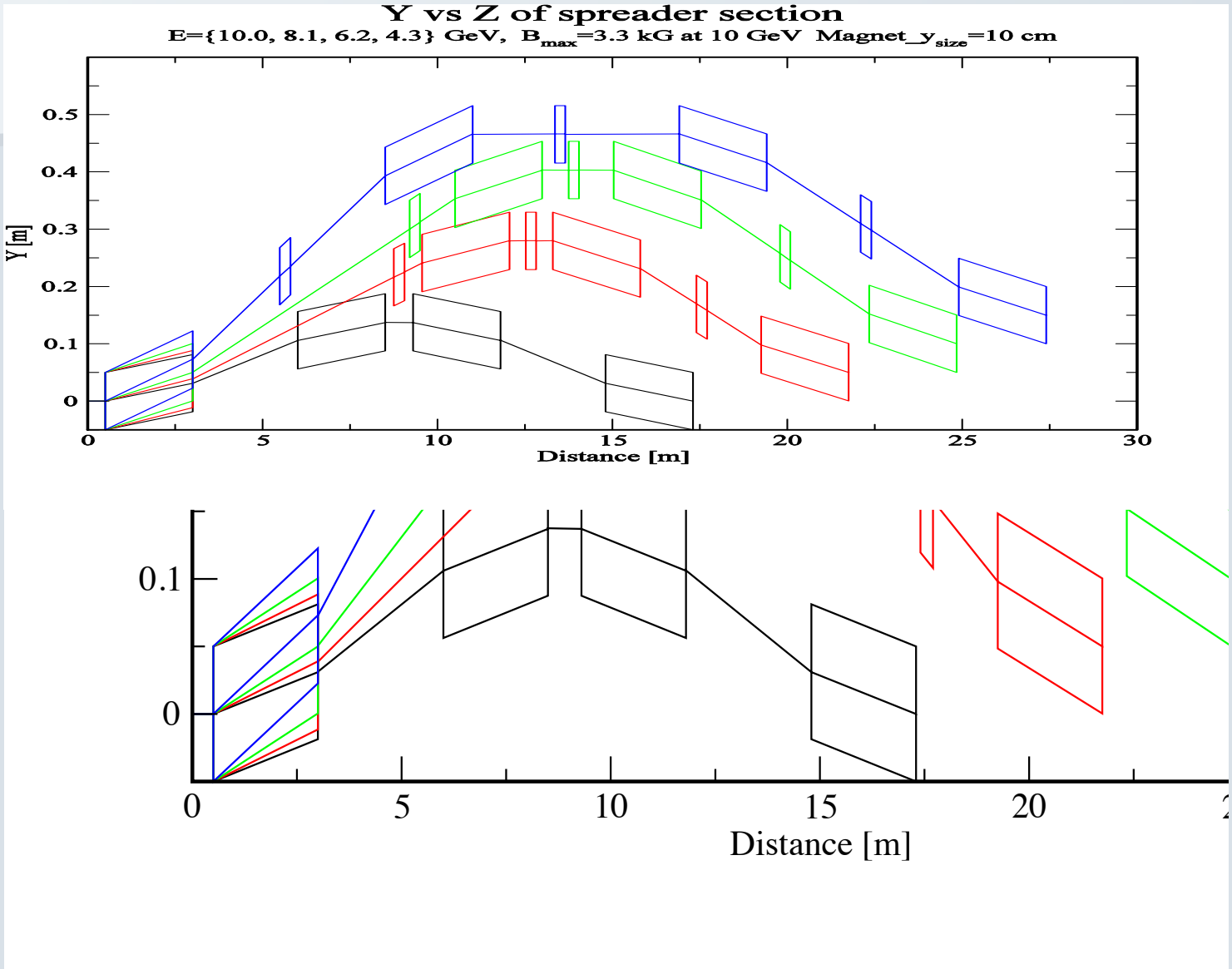
Arc+ straights with no IR

Separated functions:

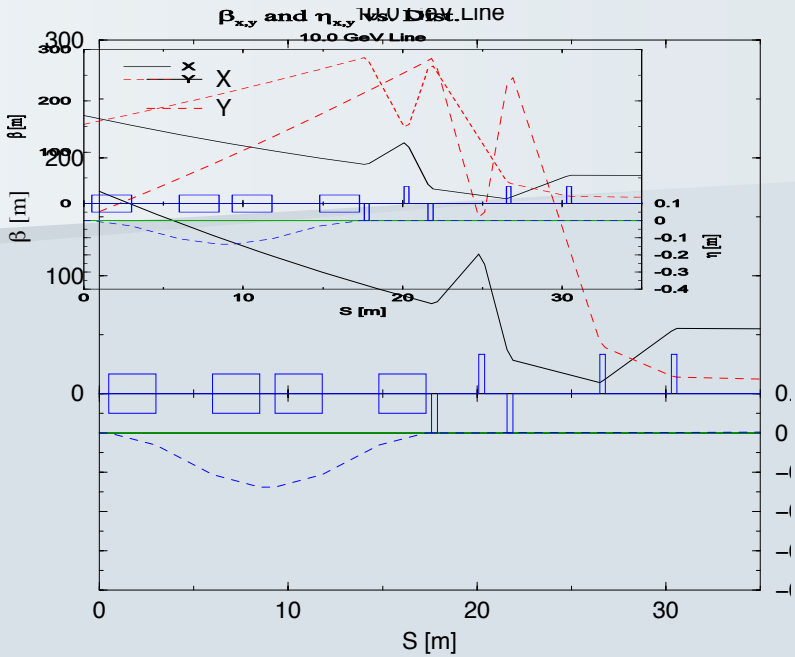
- R_{56} tuning: arcs
- Phase trombone: straights
- Path length tuning: in area of IR insertion (IR12)

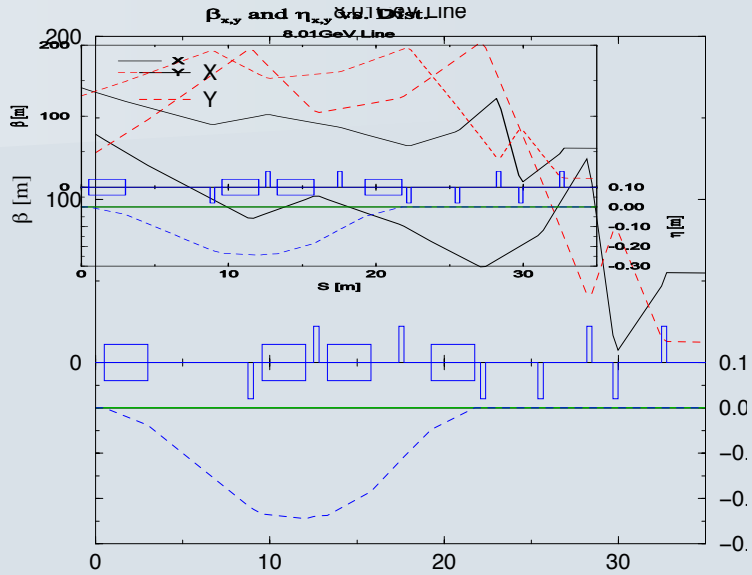
Achromatic Spreader

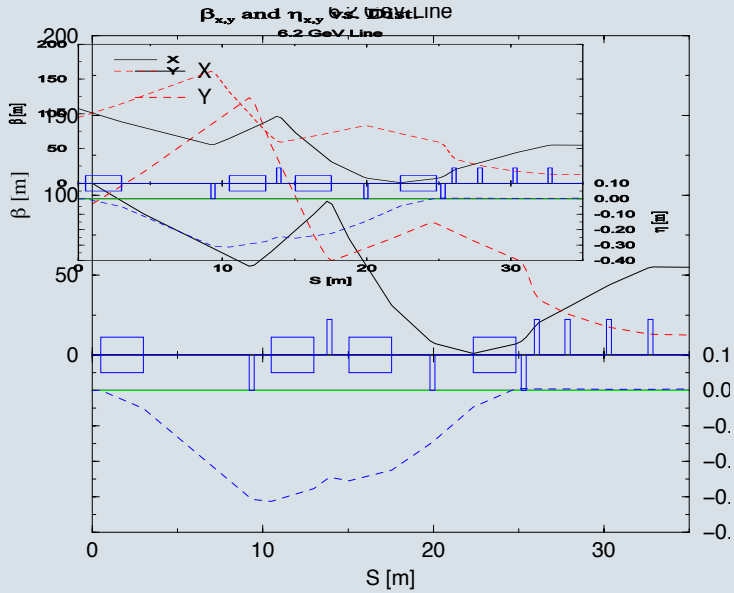
N.Tsoupas

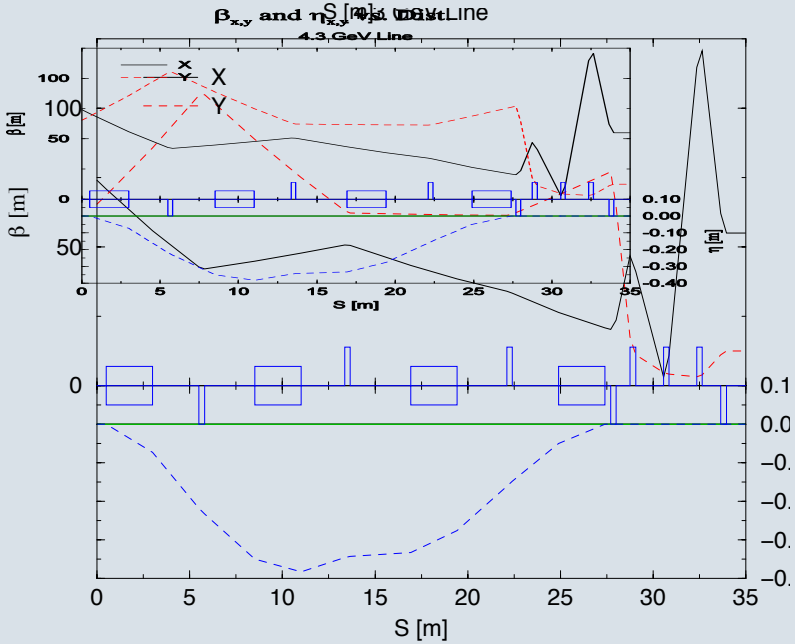


Beam parameters and dispersion for each line of the separator

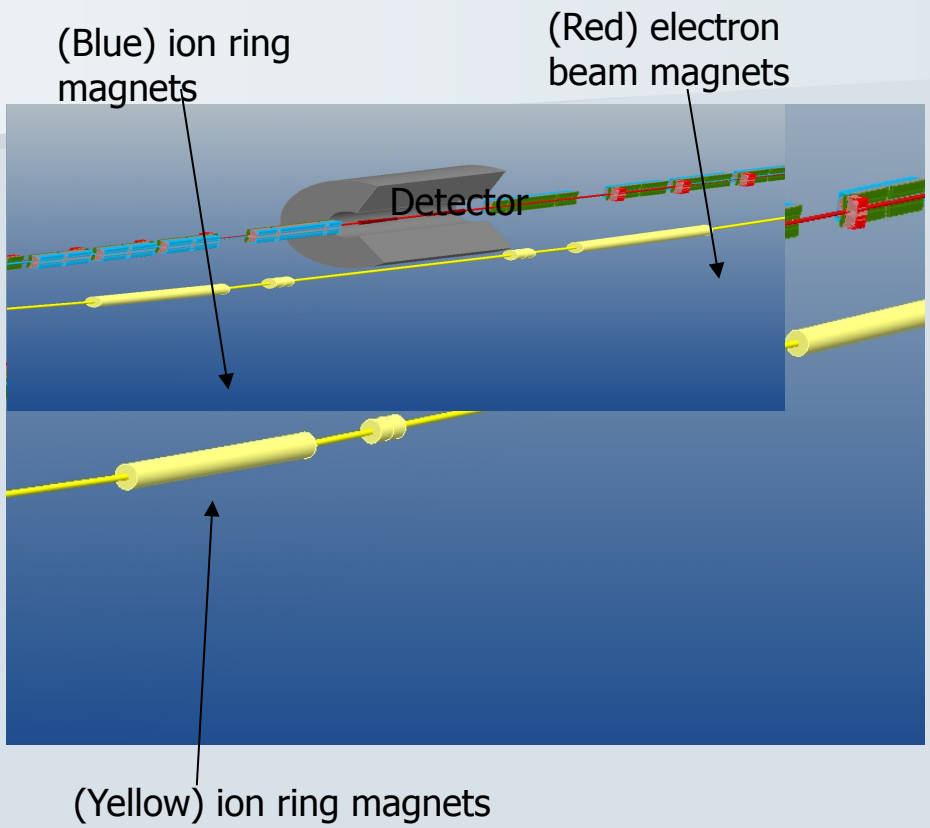








Interaction Region Design

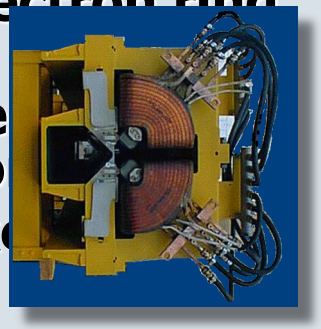


C.Montag's talk at the Parallel session

Present IR design features:

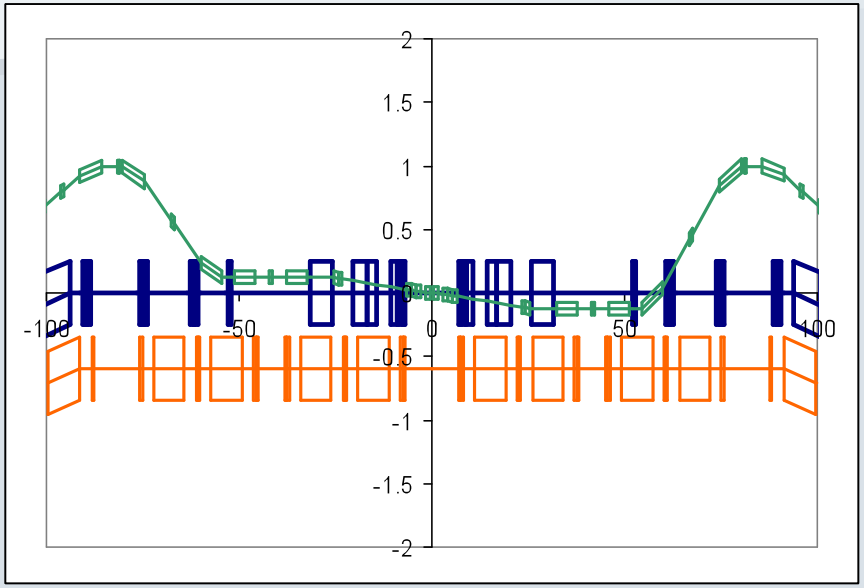
- **No crossing angle at the IP**
- **Detector integrated dipole: dipole field superimposed on detector solenoid.**
- **No parasitic collisions.**
- **Round beam collision geometry with matched sizes of electron and ion beams.**
- **Synchrotron radiation emitted by electrons does not hit surfaces in the detector region.**
- **Blue ion ring and electron ring magnets are warm.**
- **First quadrupoles (e beam) are at 3m fro**
- **Yellow ion ring mak vertical excursion.**

HERA type half quadrupole used for proton beam focusing

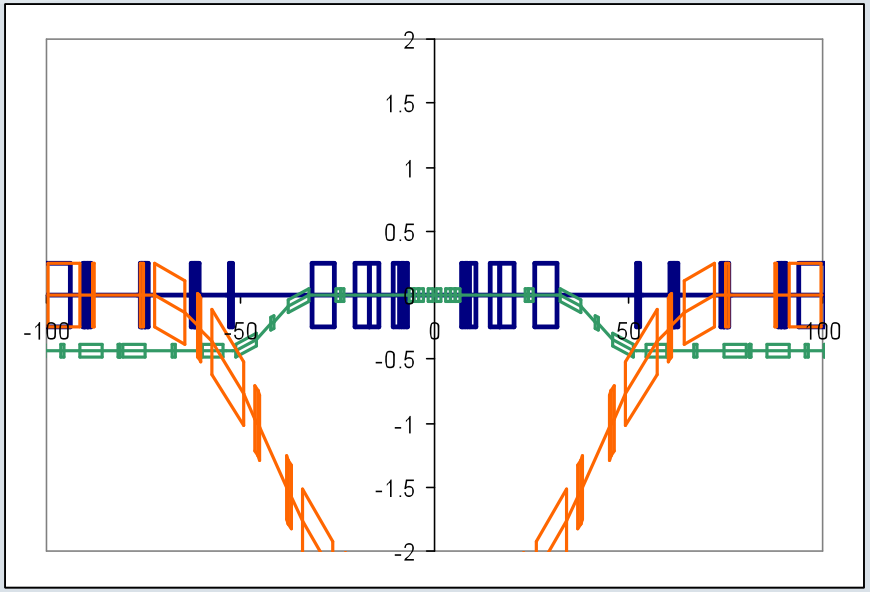


Interaction Straight Layout

H-plane

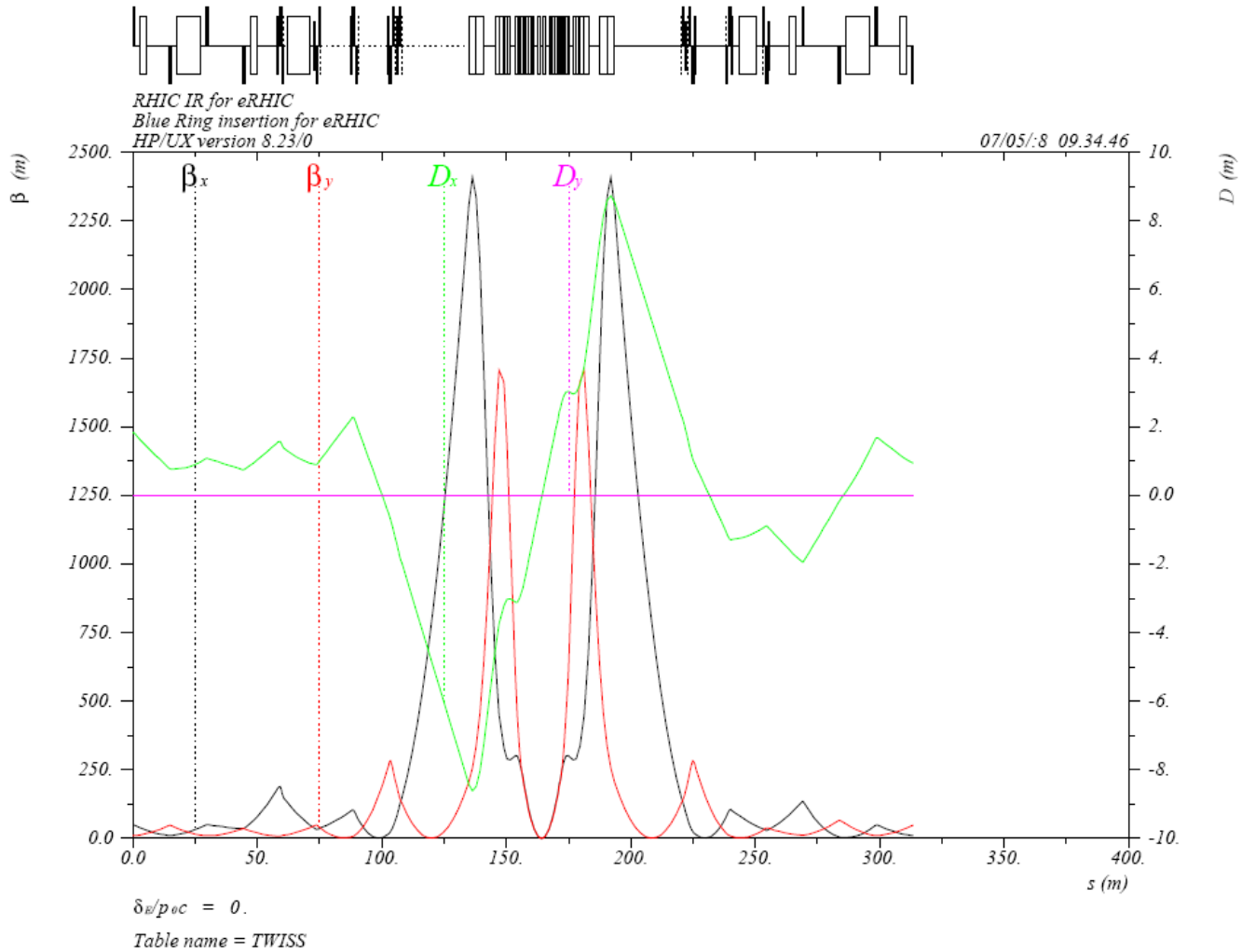


V-plane



Presently considered geometry of the interaction region straight.
Dispersion matching is not perfectly optimized yet.

Electron lattice function in the IR



Linac design

- Structure: Cryostats with superconducting RF cavities interleaved with quadrupoles.

- Lattice variants:
  - FODO lattice – smaller number of magnets

    Doublet or triplet lattice – approximately equal horizontal and vertical beam size through lattice and cavities.

  - Focusing challenge: the same linac is passed by the beams of different energies. The focusing should be adequate for the whole energy range.

    The energy recovering linac also requires quadrupole gradient symmetry relative to the center of the linac.

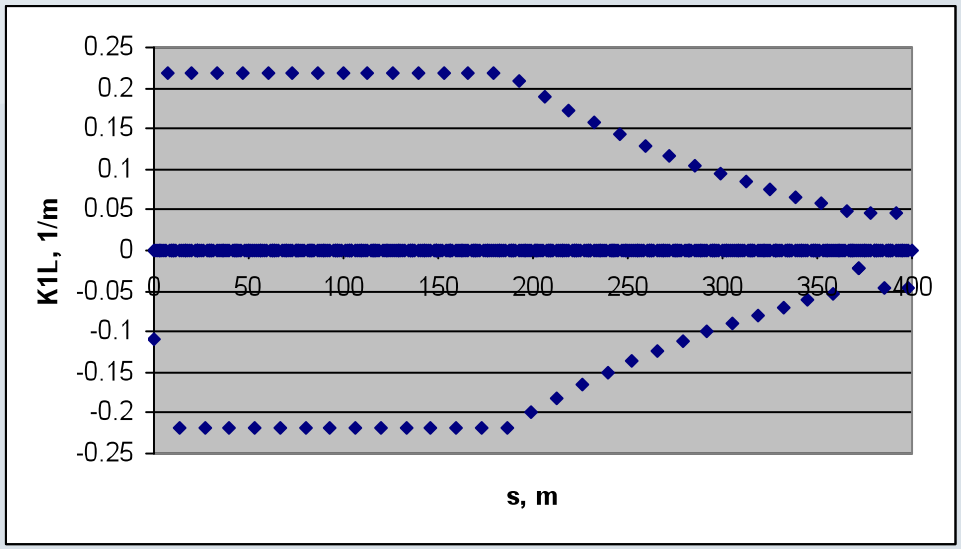
    Two choices have been considered:

    Constant gradient – same T/m gradient in all quadrupoles. Focusing strength reduces along the linac.

    Graded gradient – gradient in T/m increasing linearly on first half of the linac, then decreasing linearly on second half.

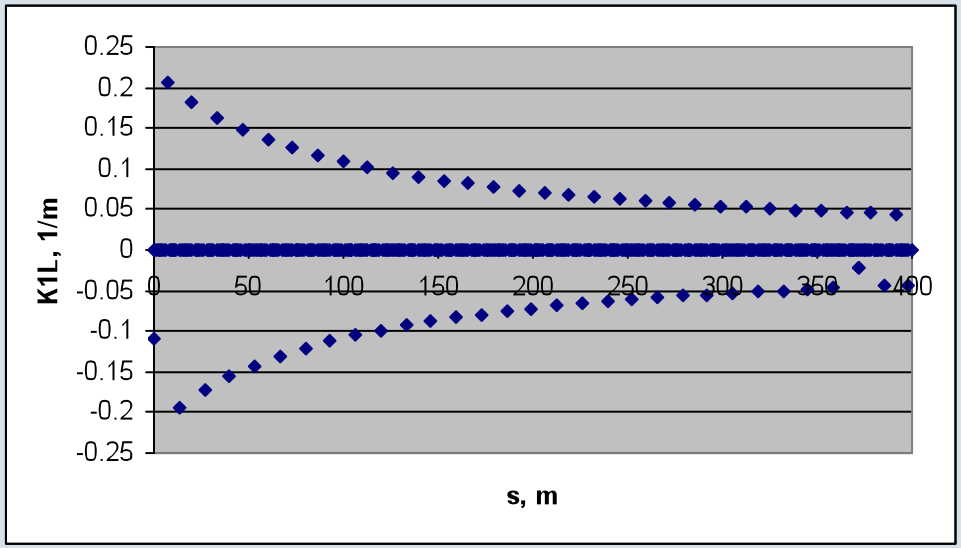
Integrated normalized gradients on first linac pass for two types of linac lattice

Graded gradient

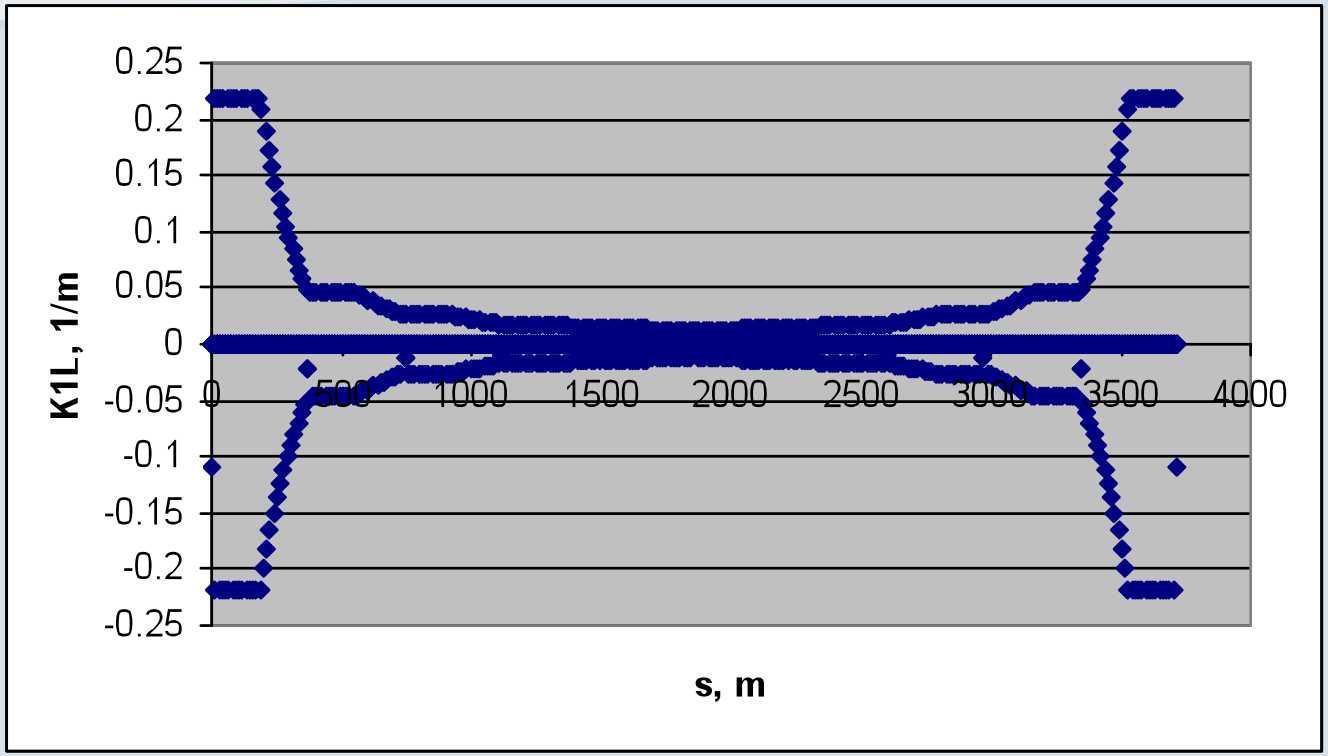


0.5GeV → **2.4 GeV**

Constant gradient



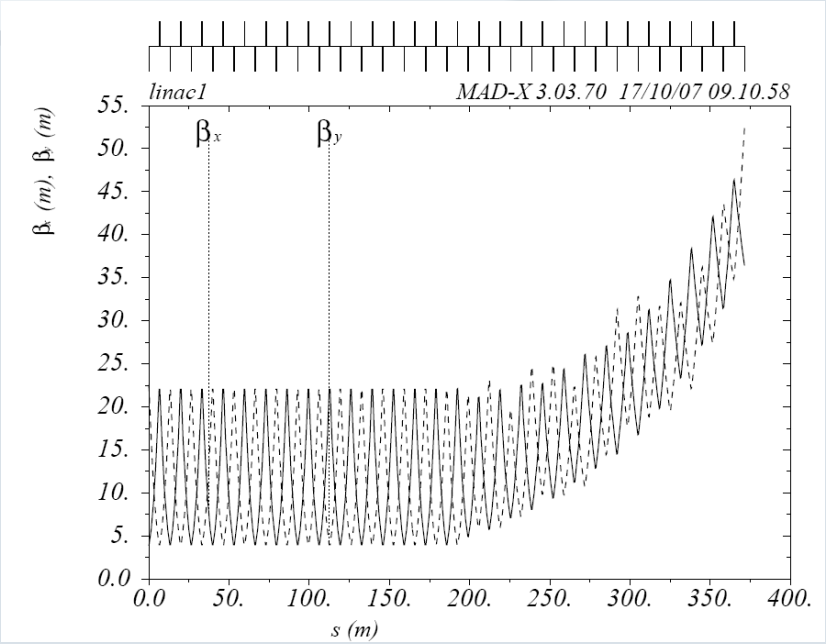
Integrated normalized gradient along the linac passes for graded gradient lattice (for 90 degree first cell)



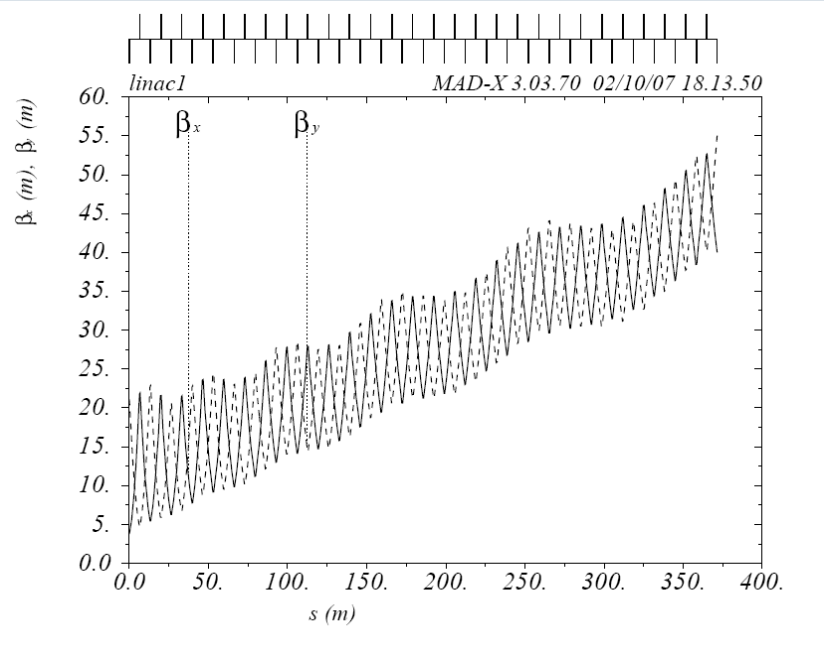
0.5 GeV → 10 GeV → 0.5 GeV

Beta-functions on first linac pass (0.5 -> 2.4 GeV), 90 degree first cell

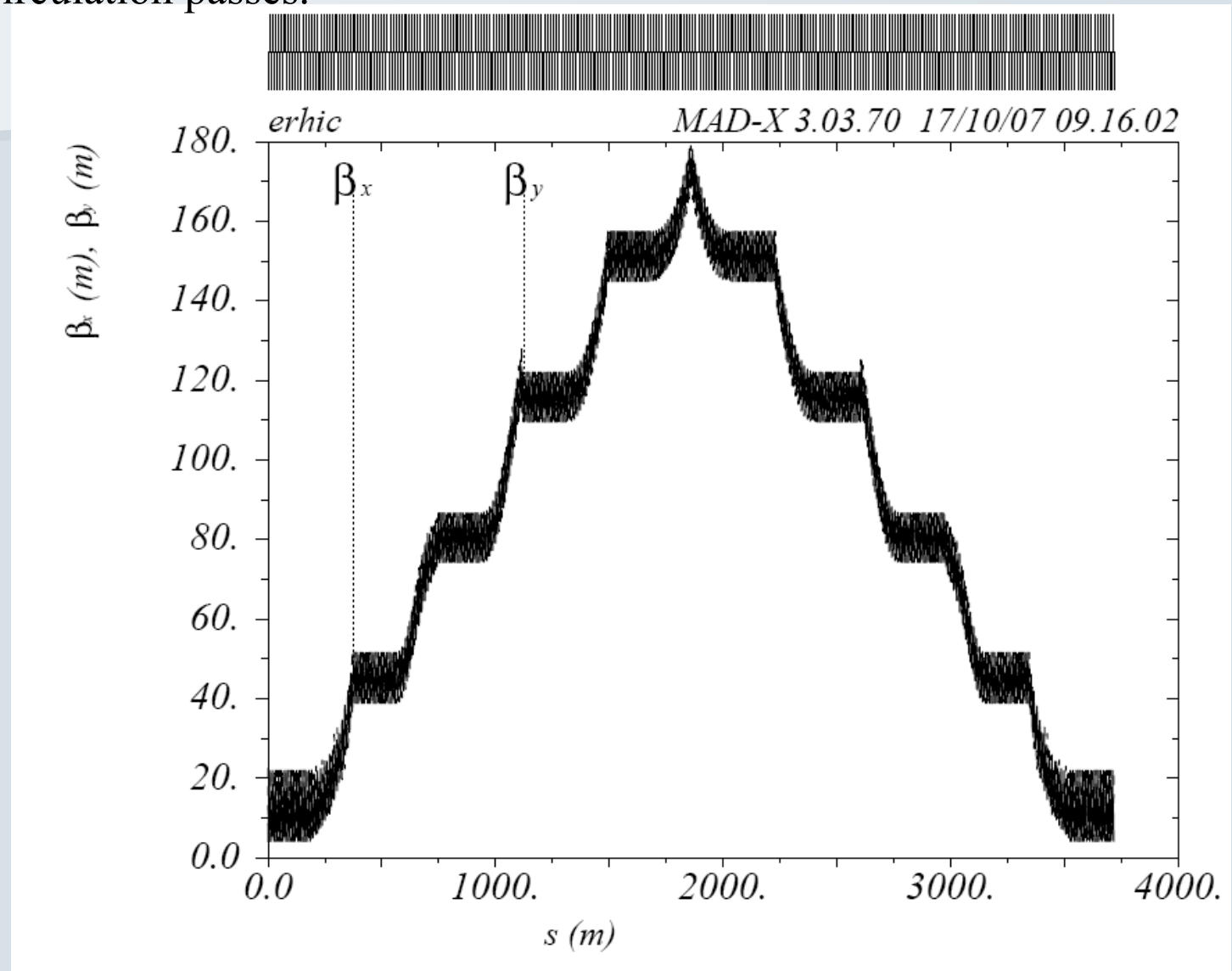
graded gradient



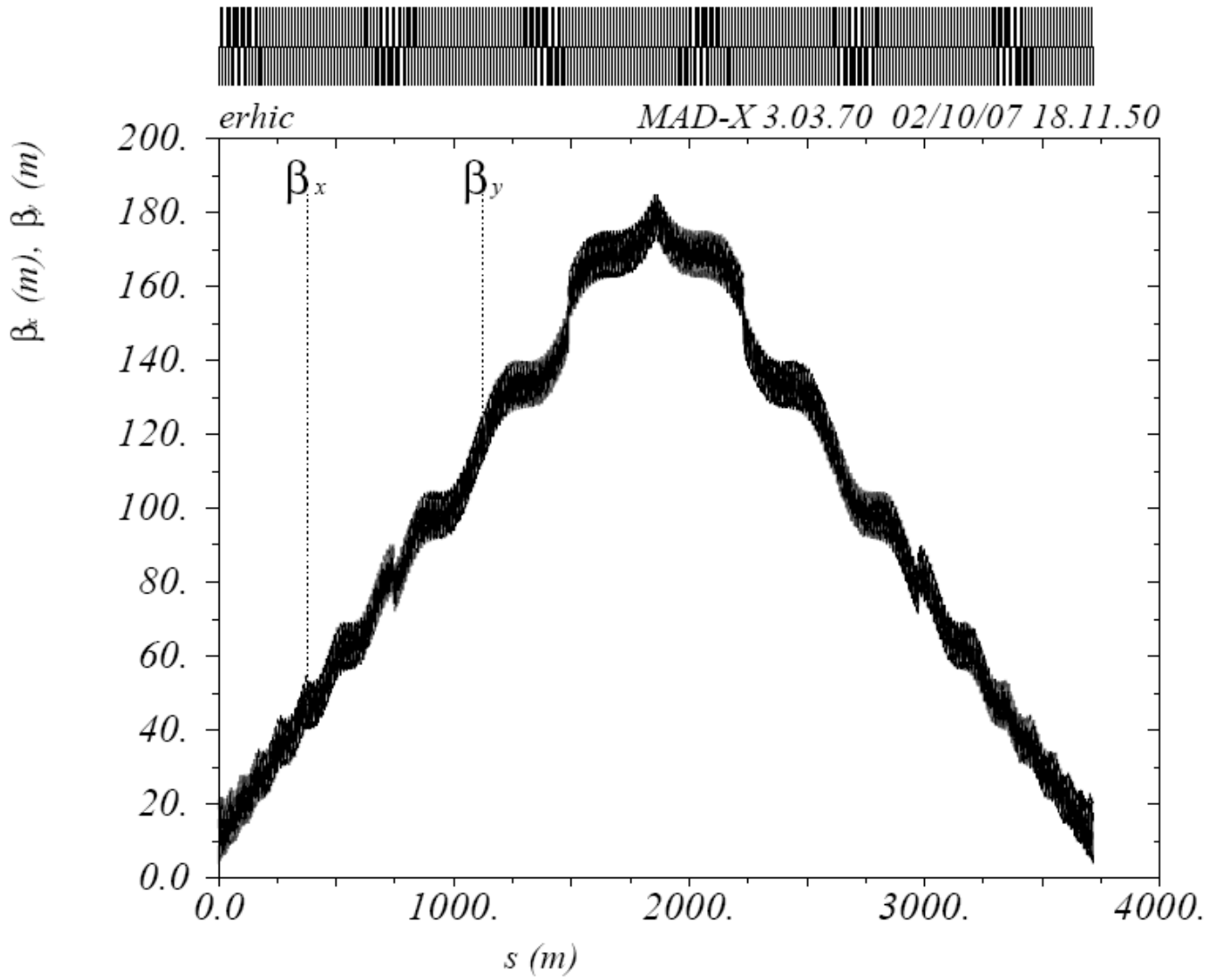
constant gradient



Beta-functions in linac passes; graded gradient, 90 degree first cell
General mirror symmetry (R(β1,α1->β2,α2)=R(β2,-α2->β1,-α1)) for recirculation passes.



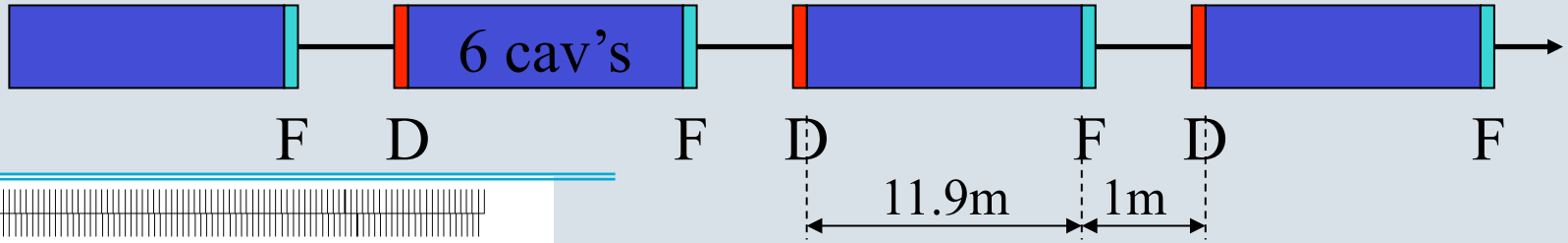
Beta-functions in linac passes for 90 degree first cell optics
for constant gradient lattice

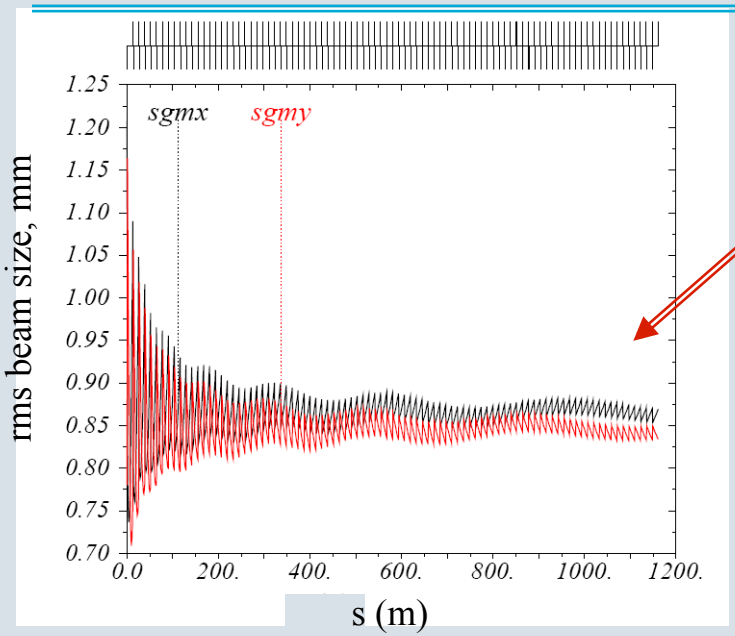


Compact linac design

Suggested by E.Pozdeyev

Increased number of 700MHz cavities inside one cryostat to 6 cavities.
3rd harmonic cavities (2 per cryostat) for the momentum spread minimization.
Cavity gradient: 19.5 Mev/m; Average acceleration rate: 8.2 MeV/m;
Total length of 1.9 GeV linac: 232m (instead of ~360m in the previous design).

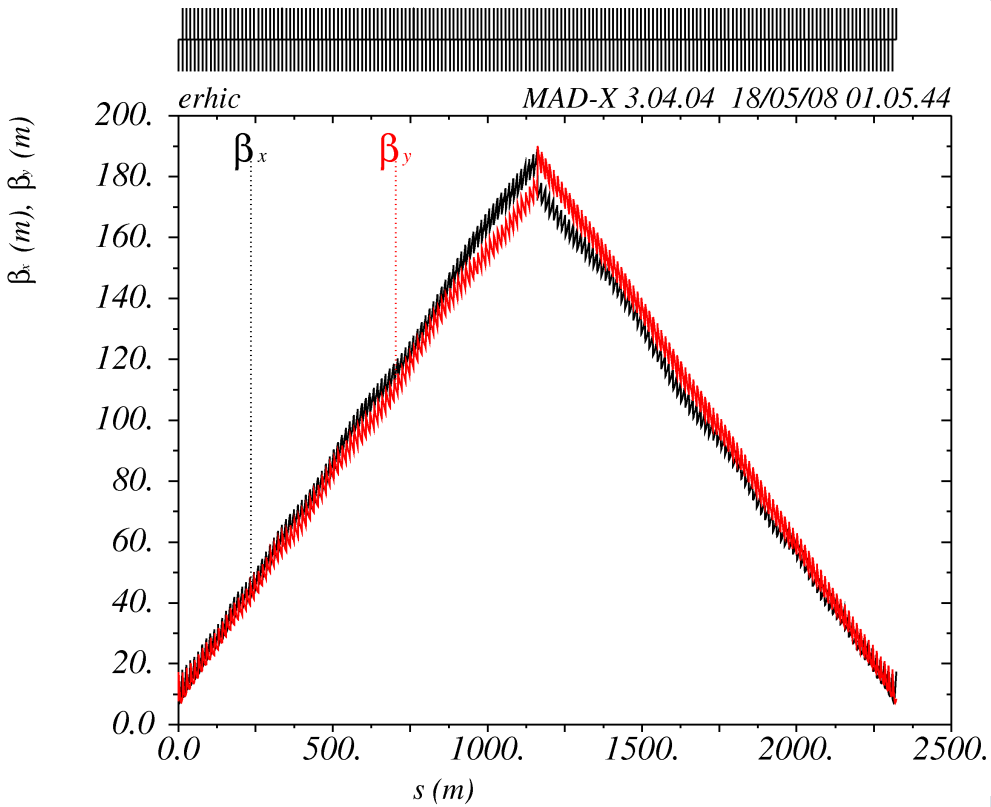




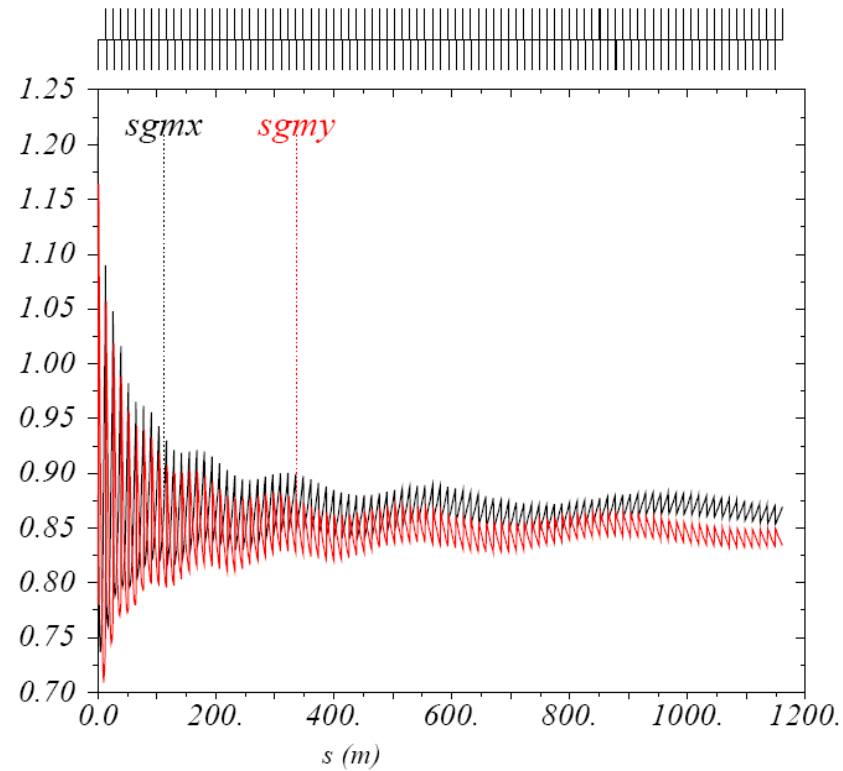
Evolution of rms beam sizes along the linac on all acceleration passes. Recirc.passes are presented by Unit matrix.
Doublet focusing (90º phase advance per cell)
Constant quadrupole gradient.

Compact linac design makes more realistic a design option with linac(s) placed inside the RHIC tunnel

Optical Functions and Beam Size



β-functions in the linac (m)
5 up + 5 down,
unity recirculations (not shown)



Beam size in the linac (mm)
5 passes up
unity recirculations (not shown)