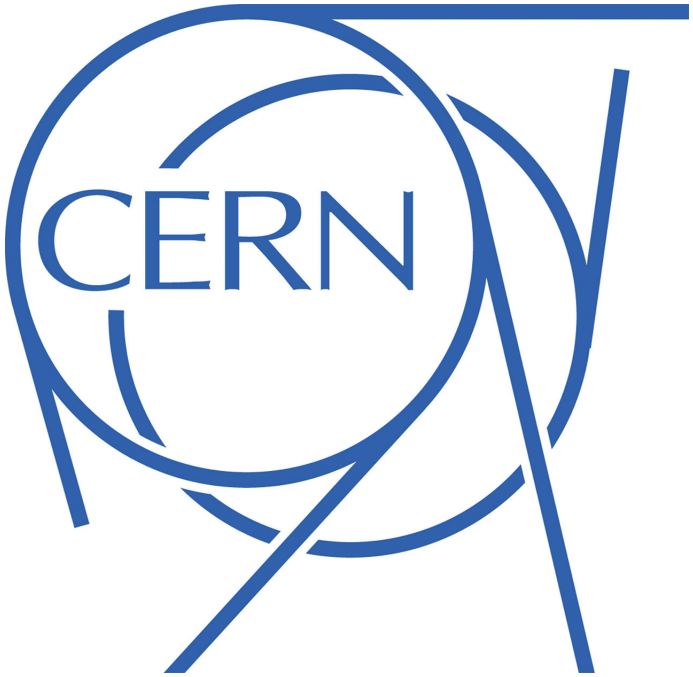

CERN Non-Member State Summer Studentship 2021

Accelerators and Beam Physics department

Supervisors: Frank Schmidt and Angeles Faus-Golfe

FODO cells simulations with MadX

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1 Introduction

In an accelerator the structure formed by the magnets is well known as lattice. The most simple and stable configuration is the FODO cell, which is formed by focusing lens, dipole magnet, defocusing lens and dipole magnet, in that exact order as shown in figure 8.

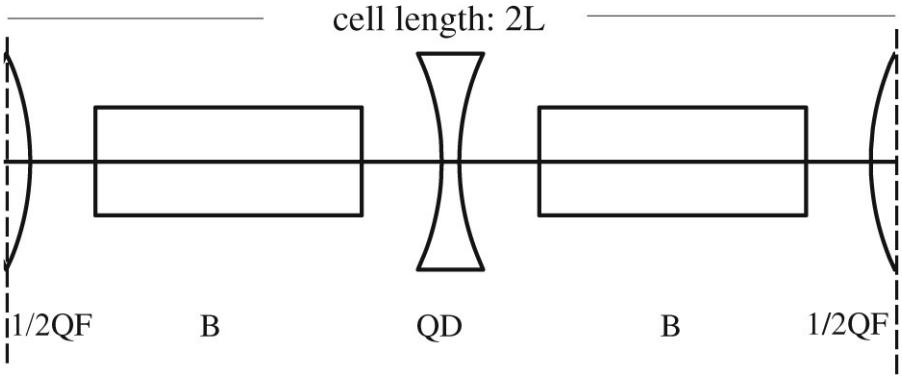

Figure 1: Composition of a FODO cell

Homogeneous magnetic fields are used to guide the beam on a closed orbit and focusing fields are used to keep the particles close together. Dipole magnets are used to cause the bends in the design orbit of the particles. Meanwhile the quadrupole magnets' function is to focus the beam and prevent it from diverging. The magnetic focusing field depends linearly on the particle amplitude (the distance of the particle from the design orbit). The amplitude function, β, represents the width of the beam divided by the emittance. If Beta is low, the beam is narrower, "squeezed". If Beta has large values, the beam is wide and straight. It has units of length and it can be

related to the distance from the focus point to where the beam width is twice as wide as in the focus point.

2 MAD-X

MAD-X is a general purpose beam optics and lattice program that helps you generate and test accelerator designs. It is multiplatforms, very flexible and easy to extend, made for complicated applications and really powerful. MADX-specific commands serve to describe, optimize and simulate a machine with several thousand elements eventually with magnetic elements shared by different beams, like in colliders. In the introduction were explained several components of an accelerator structure that can be greatly simplified with this program. It is also capable of simulate and test a lot of different beam approaches. It was developed by CERN over the past few decades as a virtually standalone coding language that is quite simple to use once you understand the basics.

3 Simulations

The document <fodo.mad> uses the following fodo cell: focusing quadrupole, small drift, dipole, small drift, defocusing quadrupole, small drift, dipole, small drift, focusing quadrupole. The information of the beam contains the type of particle, its energy, current and relative energy spread. Changing any of the mentioned values does not make a difference in the resulting plot. The alpha function, also known as correlation function, represents the slope of the beta function and the variation of only this element does not make any difference either.

There are two parameters that cause changes in the resulting plot: the beta function, β, and the phase function, μ. If the phase advanced is changed to a higher value in both μ functions, the β_y function peak reaches very high values and the β_x function also reaches higher values but not as higher as in the β_y function. This makes the beam wider in the y direction than the x direction but, in general, definetely more extensive.

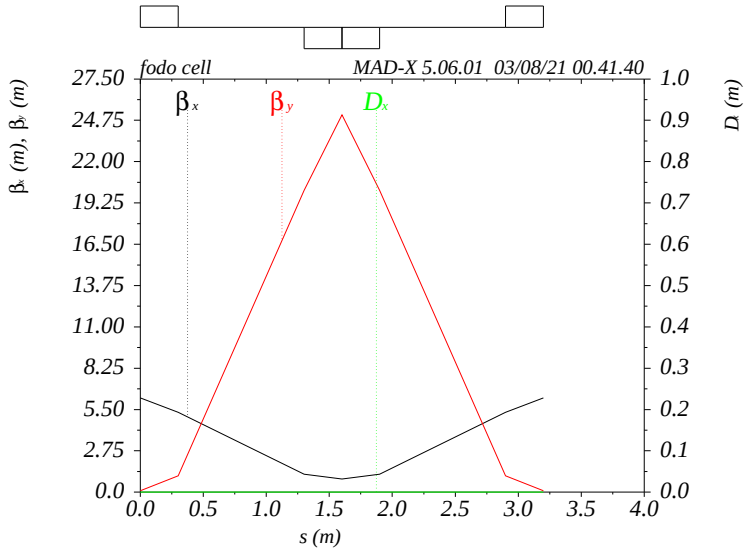

Figure 2: Variation of the phase function, μ, to a higher value

In comparison, if the phase advanced is changed to a lower value, both β_x and β_y reach their peaks and valleys at the exact same values. The peak value is lower that the value without the change, but the valley value is higher.

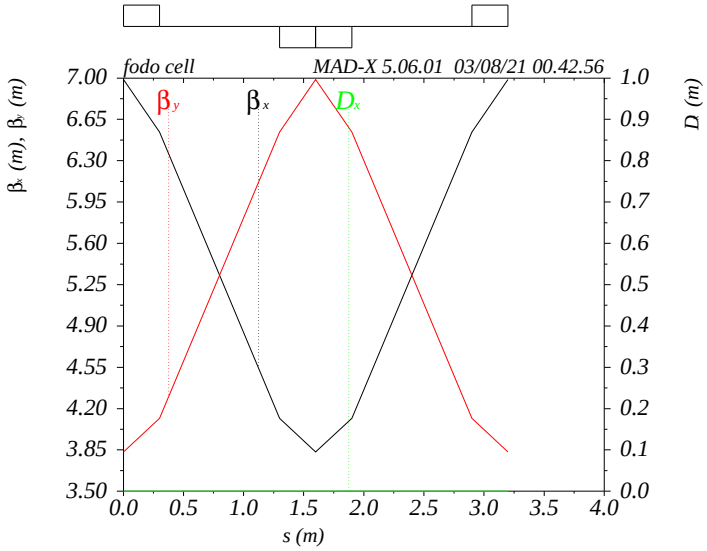

Figure 3: Variation of the phase function, μ, to a lower value

Changing just one of the two μ values to a lower value, gives a lower peak but with a bit higher dispersion. If the changed value corresponds to the μ_x, β_x plot will get higher values than the β_y plot. If the changed value corresponds to the μ_y, it is the opposite.

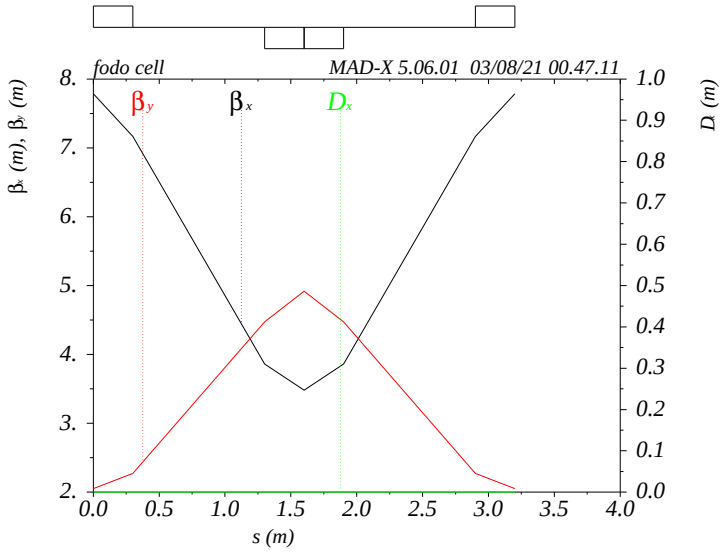

Figure 4: Variation of μ_x to a lower value

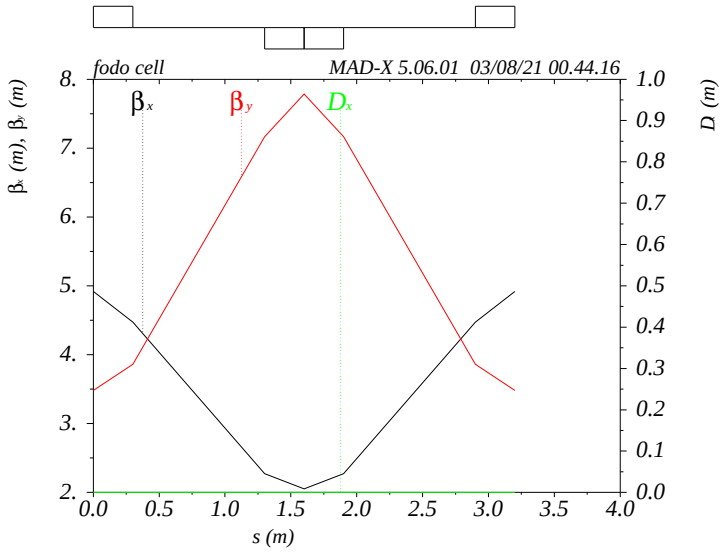

Figure 5: Variation of μ_y to a lower value

The best plots are obtained when the phase advanced in the x direction is changed to a bit higher value. With that, the obtained plots have lower peaks and valleys. The values of β_x are slightly lower but the values of β_y are considerably lower.

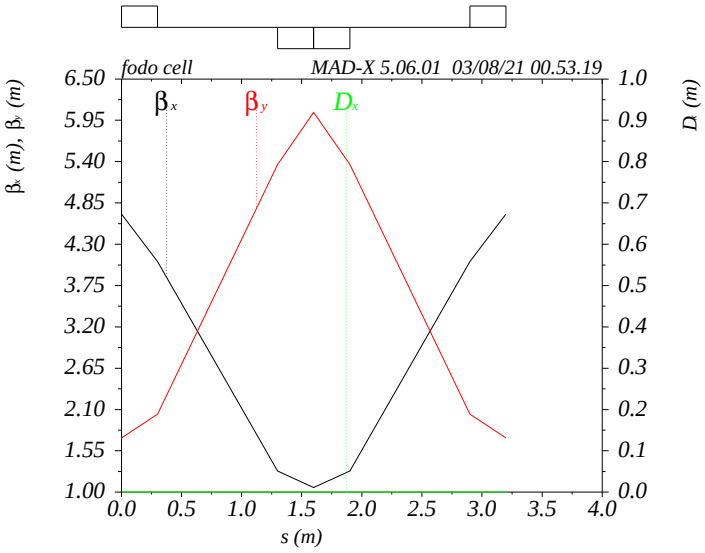

Figure 6: Variation of μ_x to a higher value

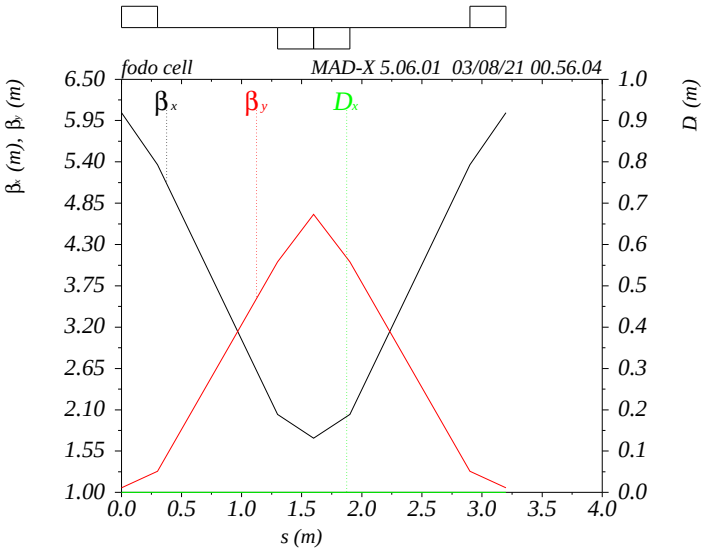

Figure 7: Variation of μ_y to a higher value

At last I ran a loop file consisting on a 5 times loop of the next fodo cell: marker, focusing quadrupole, small drift, bending magnet, small drift, defocusing quadrupole, marker, defocusing quadrupole, small drift, bending magnet, small drift, focusing quadrupole, marker.

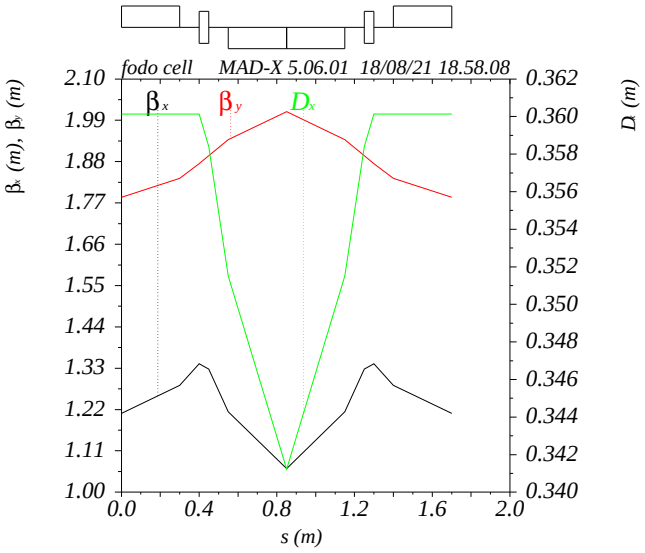

Figure 8: FODO loop

This last graph has a very different behaviour than the previous ones. It is clear that the dispersion decreases as the β_y increase. The β_x appears to have a unique behaviour as it has one valley every two peaks and, also, it happens that both β_x and D_x valleys concur.

4 My CERN experience

Even with the covid pandemic and the summer internship held online, I really enjoyed a lot this opportunity. I feel like I gained a much broader knowledge of accelerators and beam physics. Unfortunately, I felt that the time was not enough for me to fullfill the expectations my supervisors had about me. I also ran into personal and health problems that decreased my usual work performance. This really made me sad because I think it was going to be the perfect chance to demonstrate my full abilities. Although that I gave the most I could and learnt a lot about things I did not know. Besides that, I had an amazing time attending the lectures, social activities, virtual visits, etc.