KURRI-FFAG collaboration meeting

"Design of the Injection Line into the INFN Molecular H2+ 800 MeV High Power Cyclotron"

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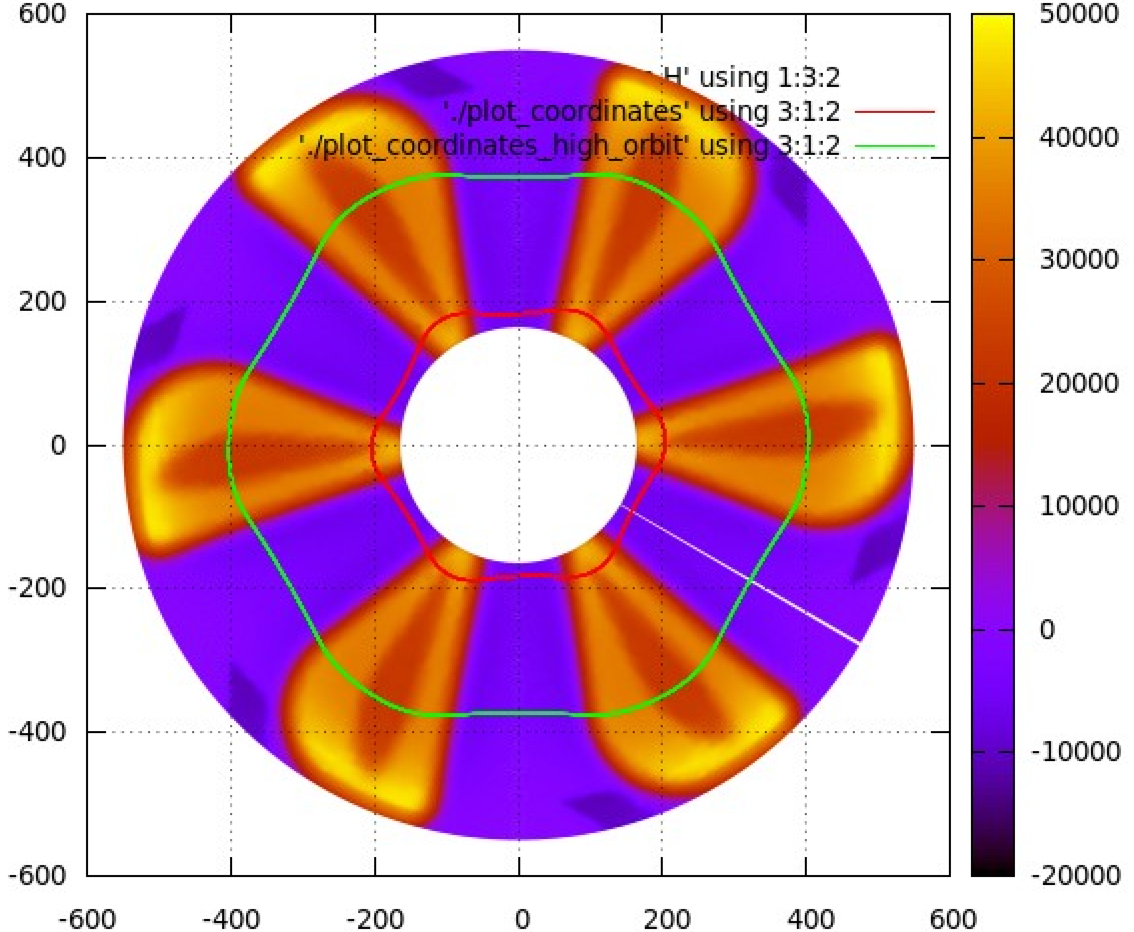
BNL C-AD

August 1st 2013

Injection design:

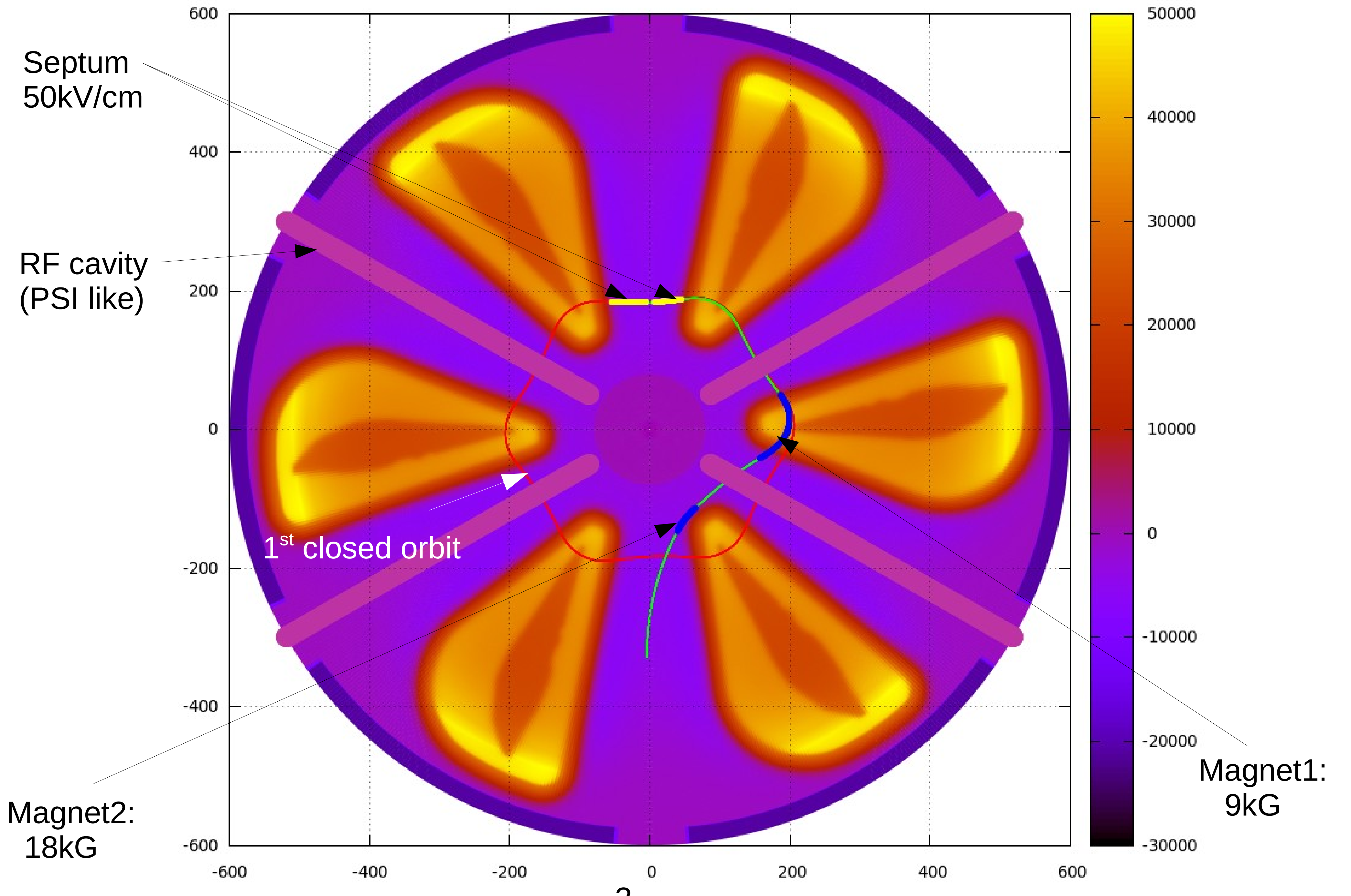
Cylindrical Frame (r,θ,z)
Origin: the center of the machine



Plot of the closed orbits

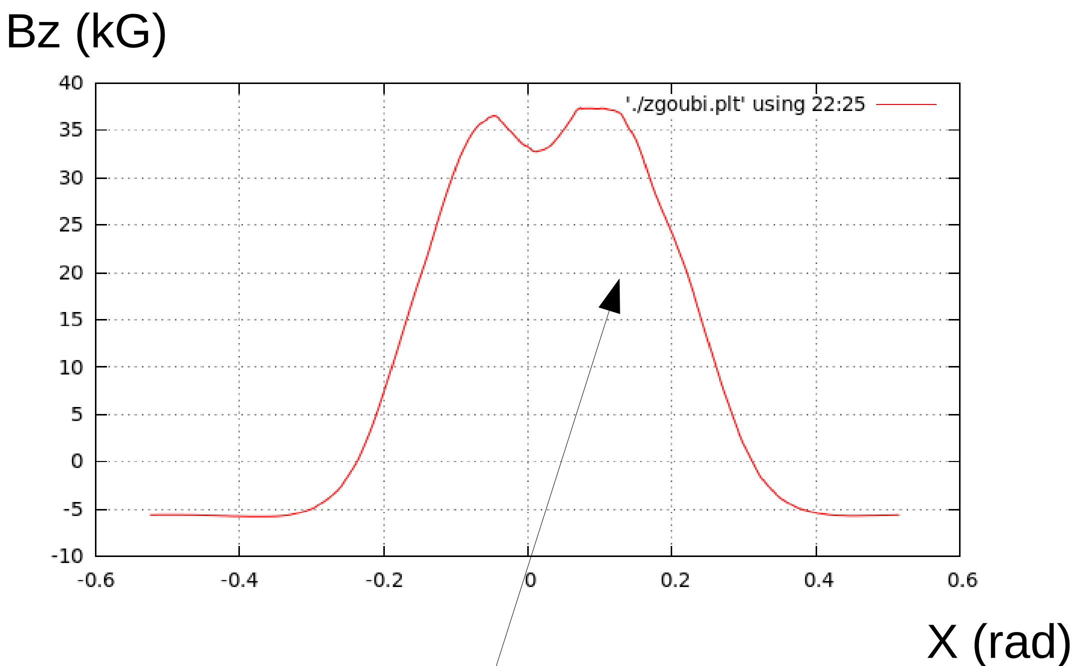
- at injection (60MeV/n)
- at high energy (340Me

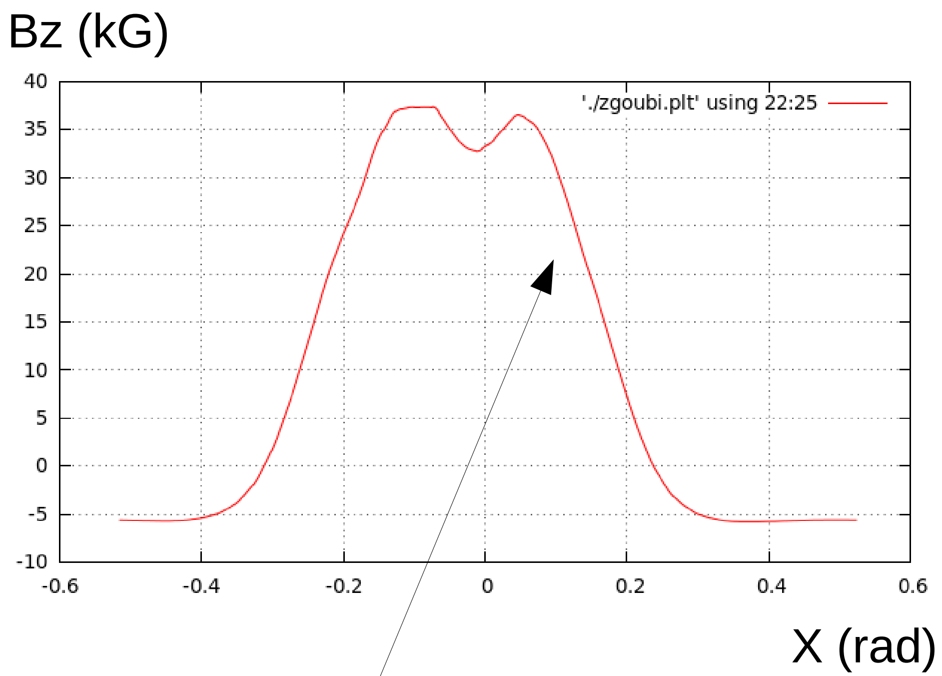
Accelerate an average of 2mA of H2+ up an energy of 800 MeV/n



Septum
50kV/cm
RF cavity
(PSI like)
1st closed orbit
Magnet1:
9kG
Magnet2:
18kG
600
400
200
0
-200
-400
-600
-600
-400
-200
0
200
400
600
50000
40000
30000
20000
10000
0
-10000
-20000
-30000

Tracking backwards





- Original field map

Field map backwards

Septum: why?

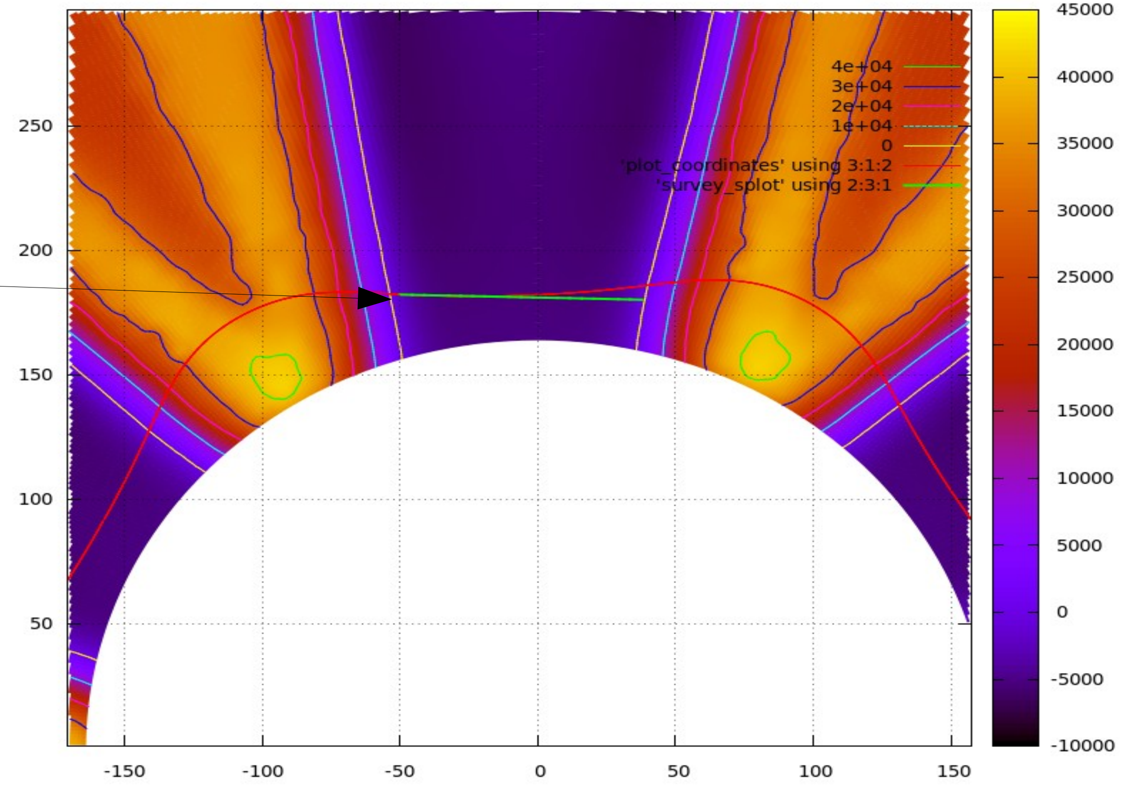
- We estimate the transverse separation of the turns before and after crossing the electrostatic deflector: $\Delta R = 1.71$ cm
- We compute the radial dispersion function as well and find: $\Delta R = \pm 0.675$ cm for an energy spread max set to ± 0.75 %.
- That gives us almost 1cm to place the septum.

How to place the septum?

- We must be tangent at the entrance point (matching point)

Tracking backwards

Choice to place the septum in the drift in order to have a margin regarding the sparking limit



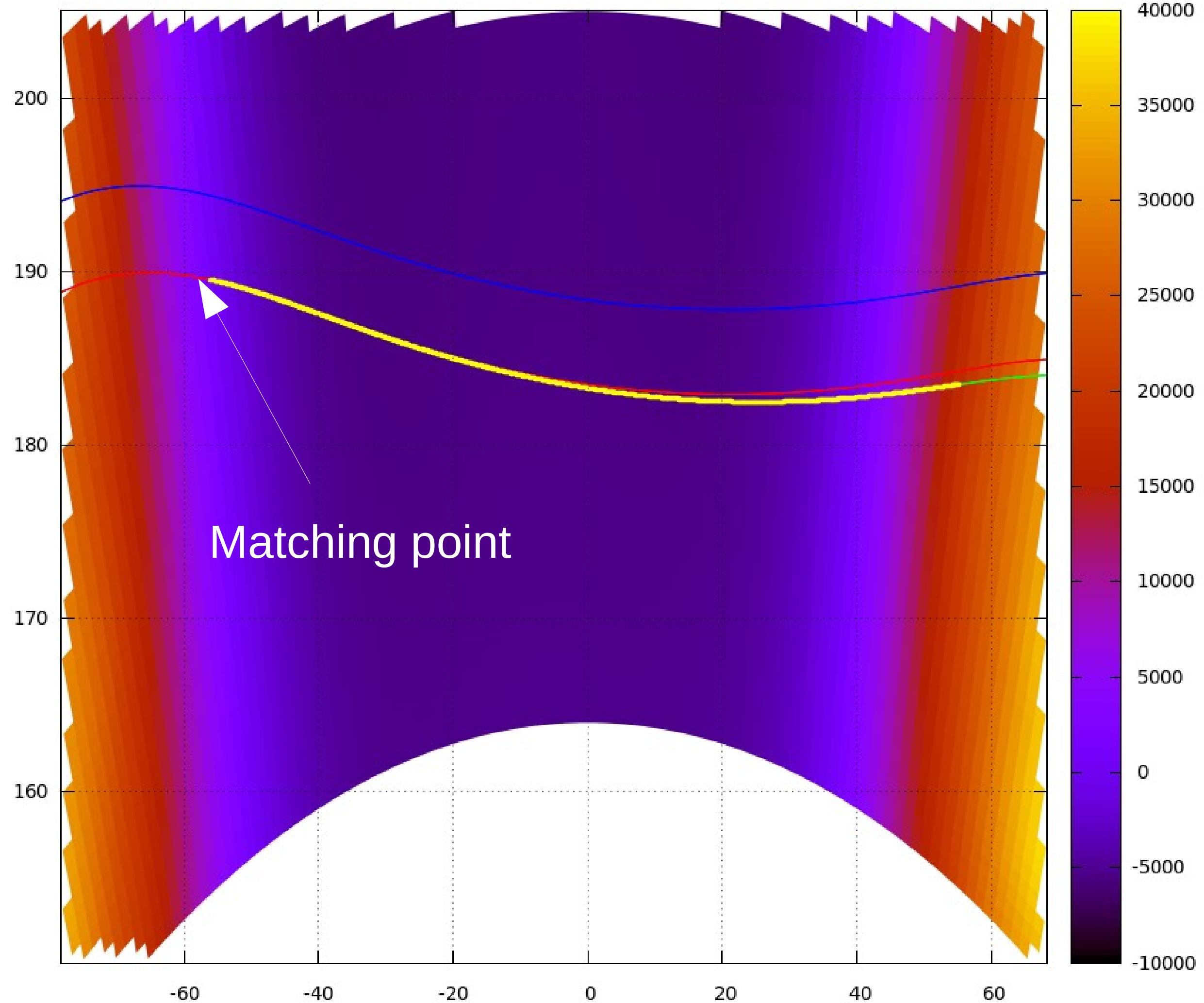
- Compute the matching parameters at this location

Electrostatic Deflector 1/2

- Septum design: compute the equivalent magnetic field to the septum:
  B_sept=E/v ~ 0.48 kG
  where E=50kV/cm
  and v=0.3425893214
  then account for the change in the field map at the location of the septum
- Length ~ 1.15m

- Magnetic field of the septum assumed to be constant: that means that the septum has to be tailored according to the beam trajectory

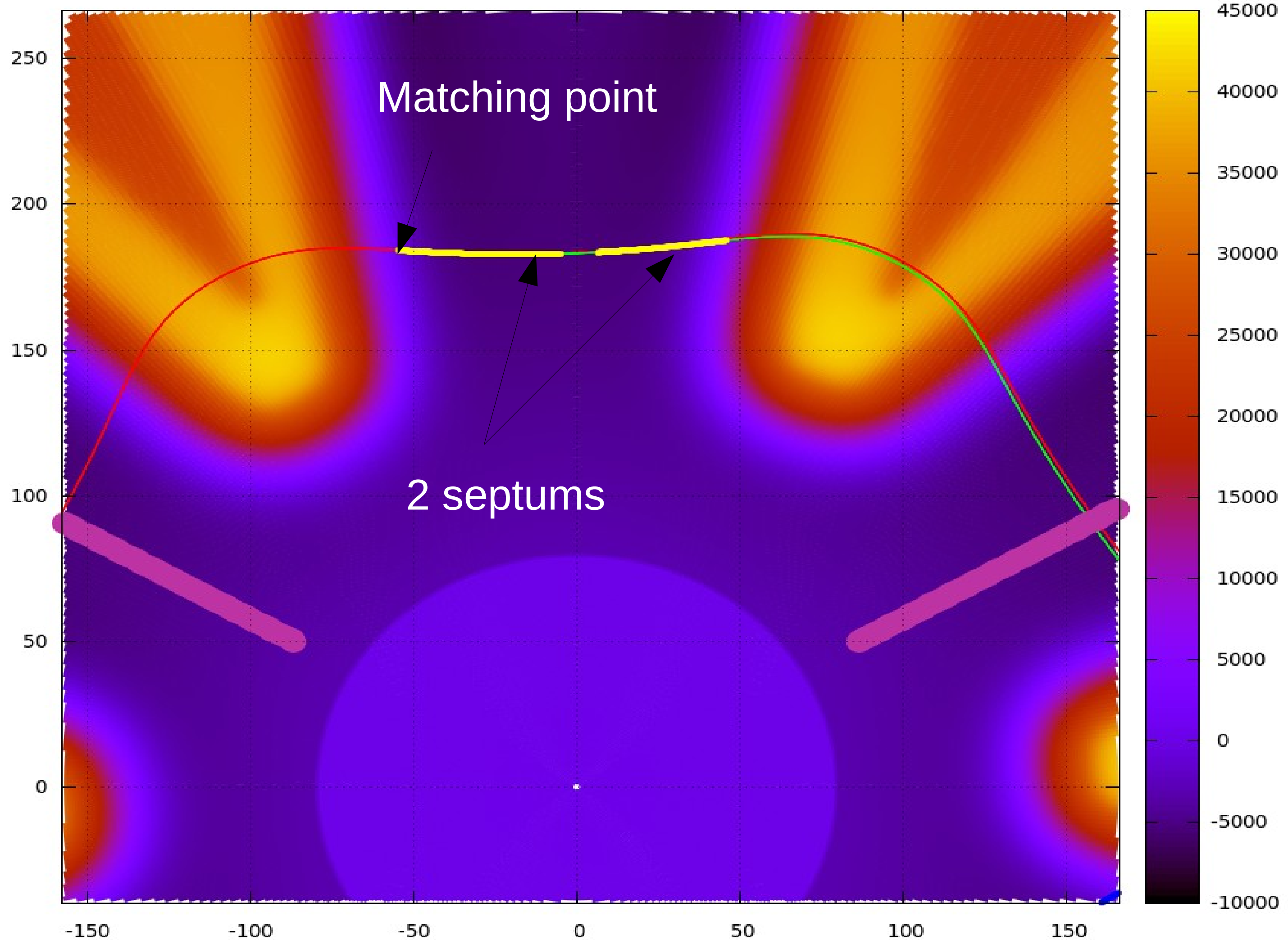
- Arcing problem ?



The Yellow curve shows the septum location

Electrostatic Deflector 2/2

The septum was divided into two elements in order to follow the bending curvature of the beam

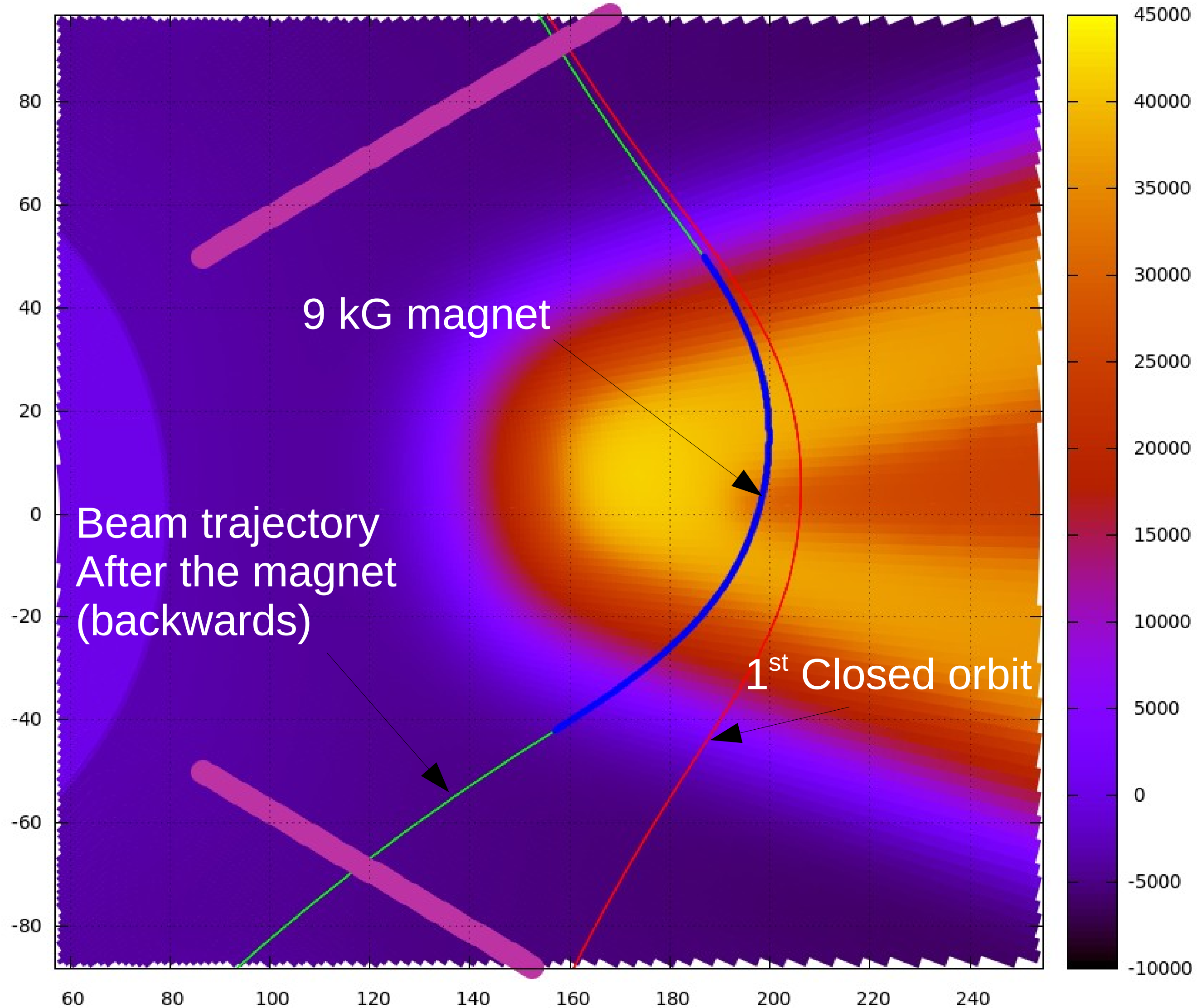


Plot of the particle trajectory through the 2 septums (the green curve): the first equilibrium orbit is shown with the red curve.

1st magnet

- Permanent magnet
- Distortion of the magnetic field of the main magnets ?

- <u>Answer:</u>
- We will restore the symmetry by introducing the same distortion in the 6 sectors



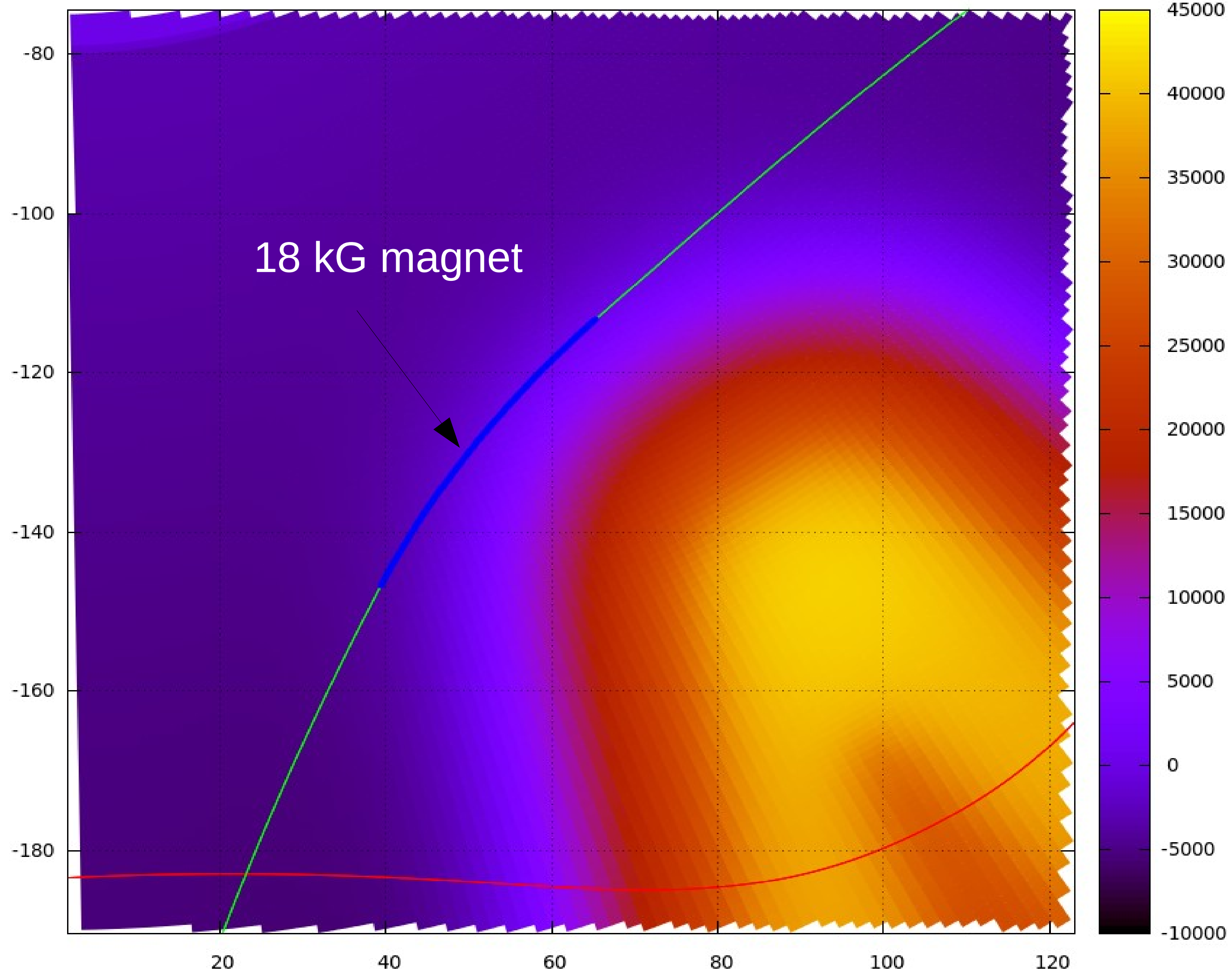
2^{nd} magnet

Inside the drift

Enough space

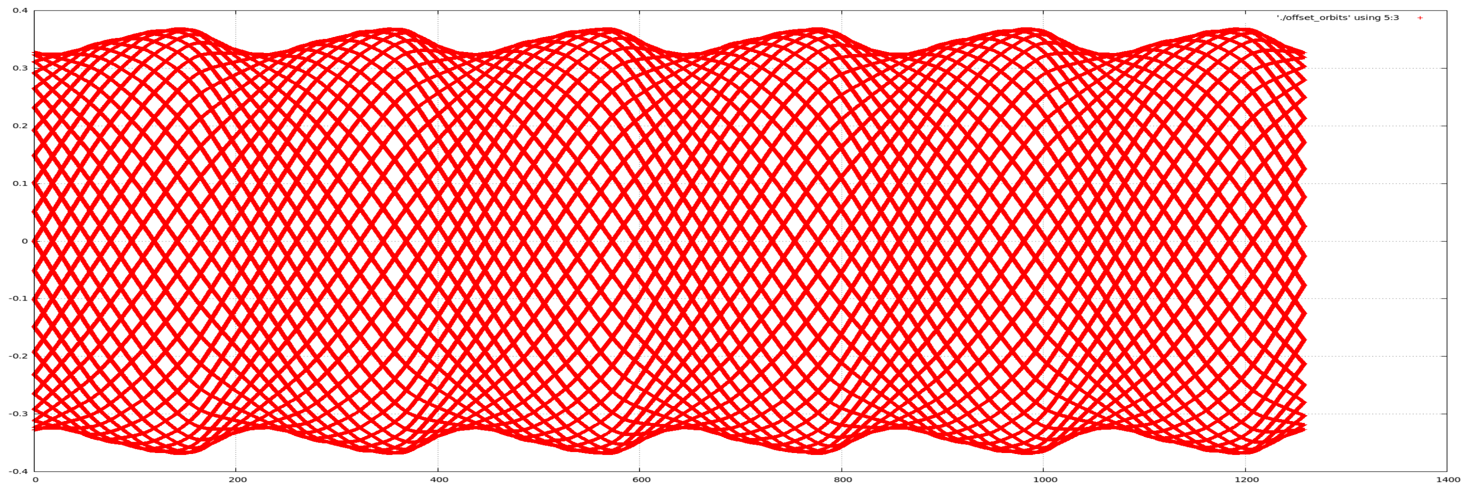
- Length ~ 0.4 m

- But the key point is the gradient

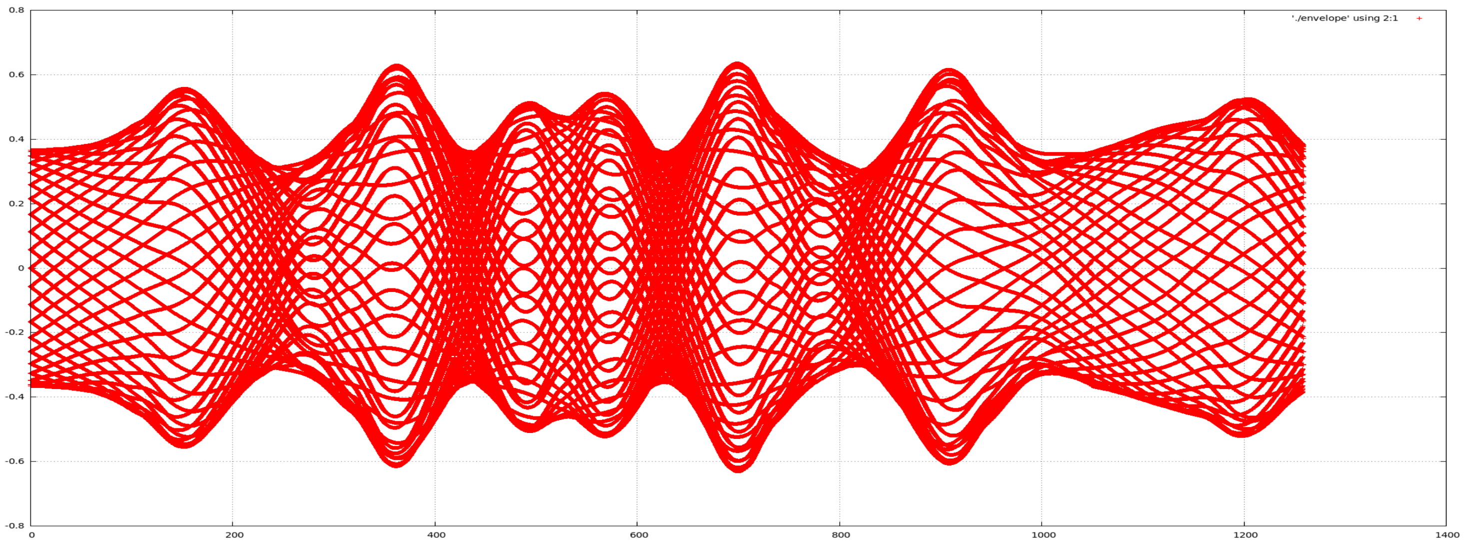


Beam envelope for the closed orbit at injection

- In the vertical plane



- In the horizontal plane



MADX

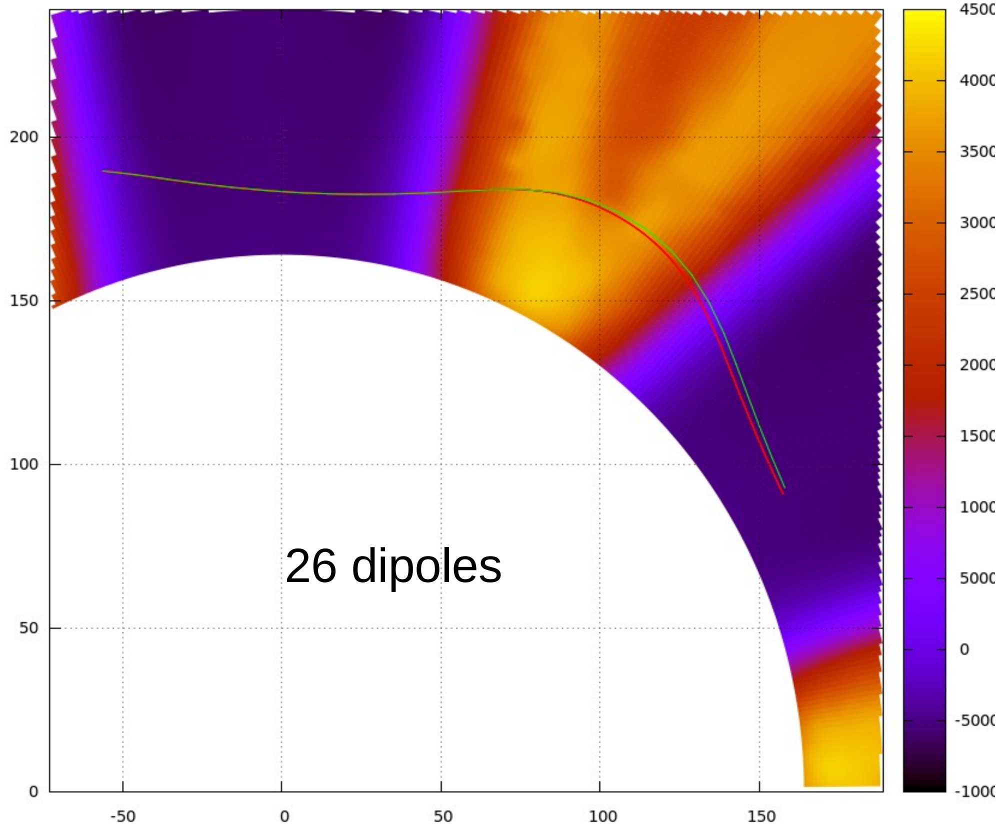
- Simulate the magnetic field by using a set of dipoles: (sector bending magnets)

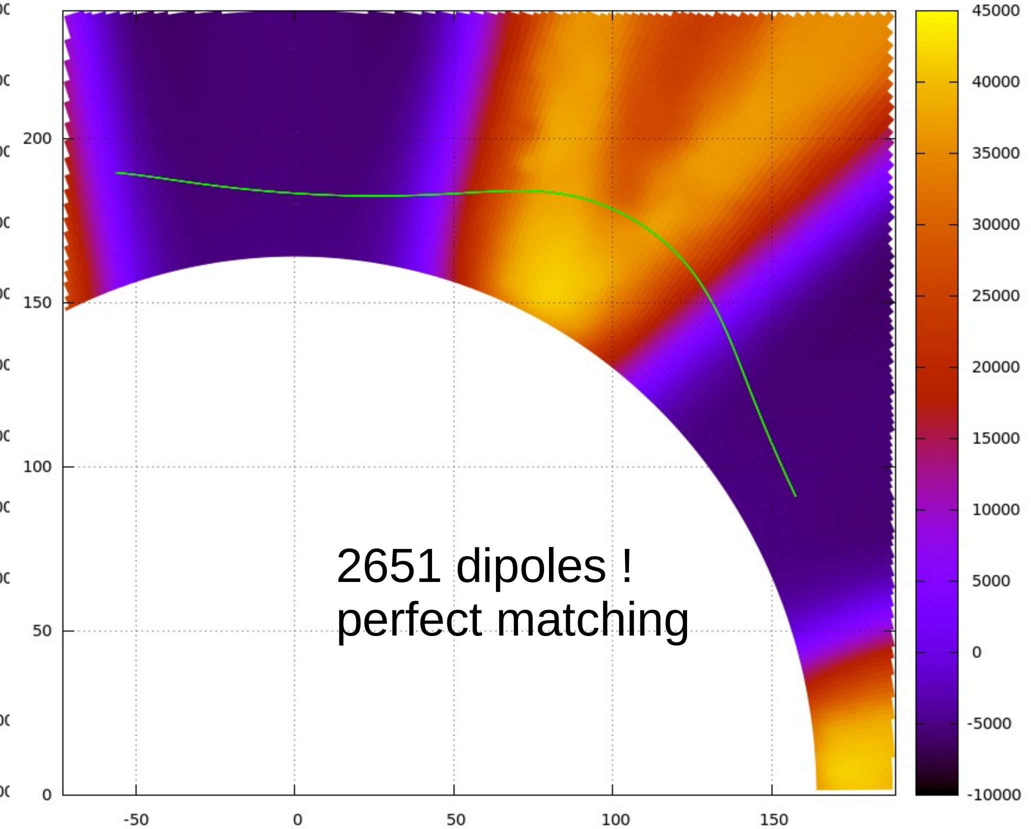
  1) compute the length of each dipole

  2) compute the bending angle as well

- We have to get the same trajectory and the same Twiss parameters with both codes (zgoubi and MADX)

Trajectory matching: zgoubi vs MADX

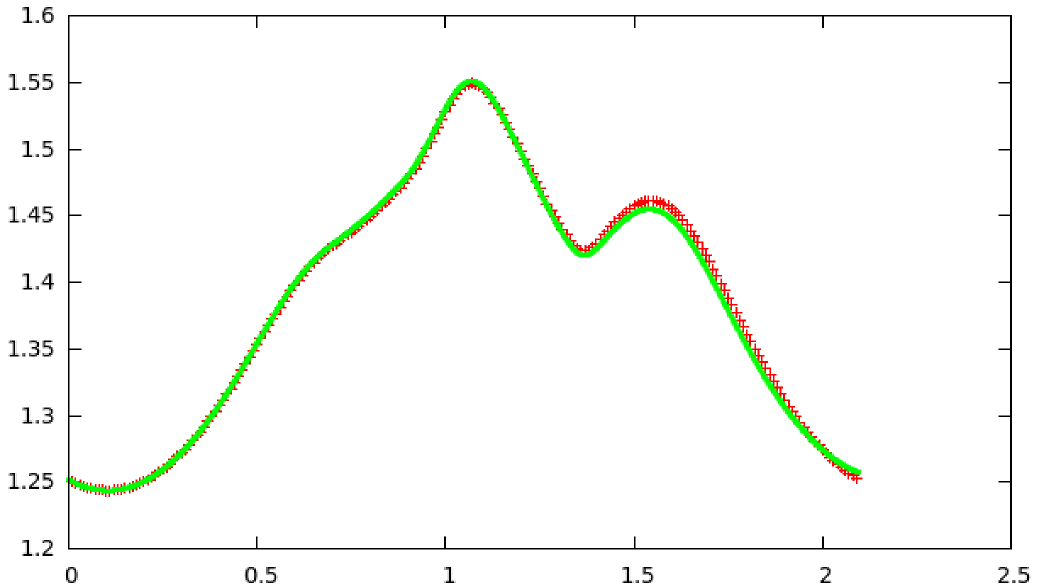




- The red curve shows the result of tracking with zgoubi, and the green one shows the result of MADX (when using survey)

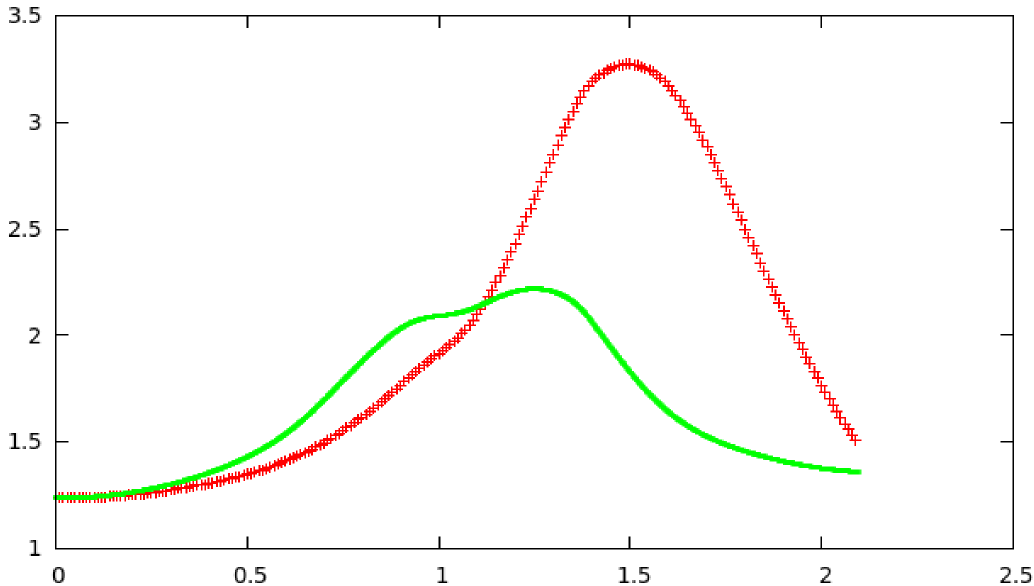
Twiss parameters matching ?

β(m) vertical plane



s(m)

β(m) horizontal plane



s(m)

The green curve shows the result from zgoubi, ad the red one the result from MADX

Result after accounting for the gradient (quadrupole component of the field)
and computing the edge angles according to the hard edge approximation.

That works quite well for the vertical plane, yet there is a problem in the horizontal one

What might be the origin of the problem

- Error computing the transfer matrices ?
- Symplectic condition not satisfied in the horizontal plane:

$$\det(x) = 1.0721$$

$$\det(z) = 1.00000000001$$

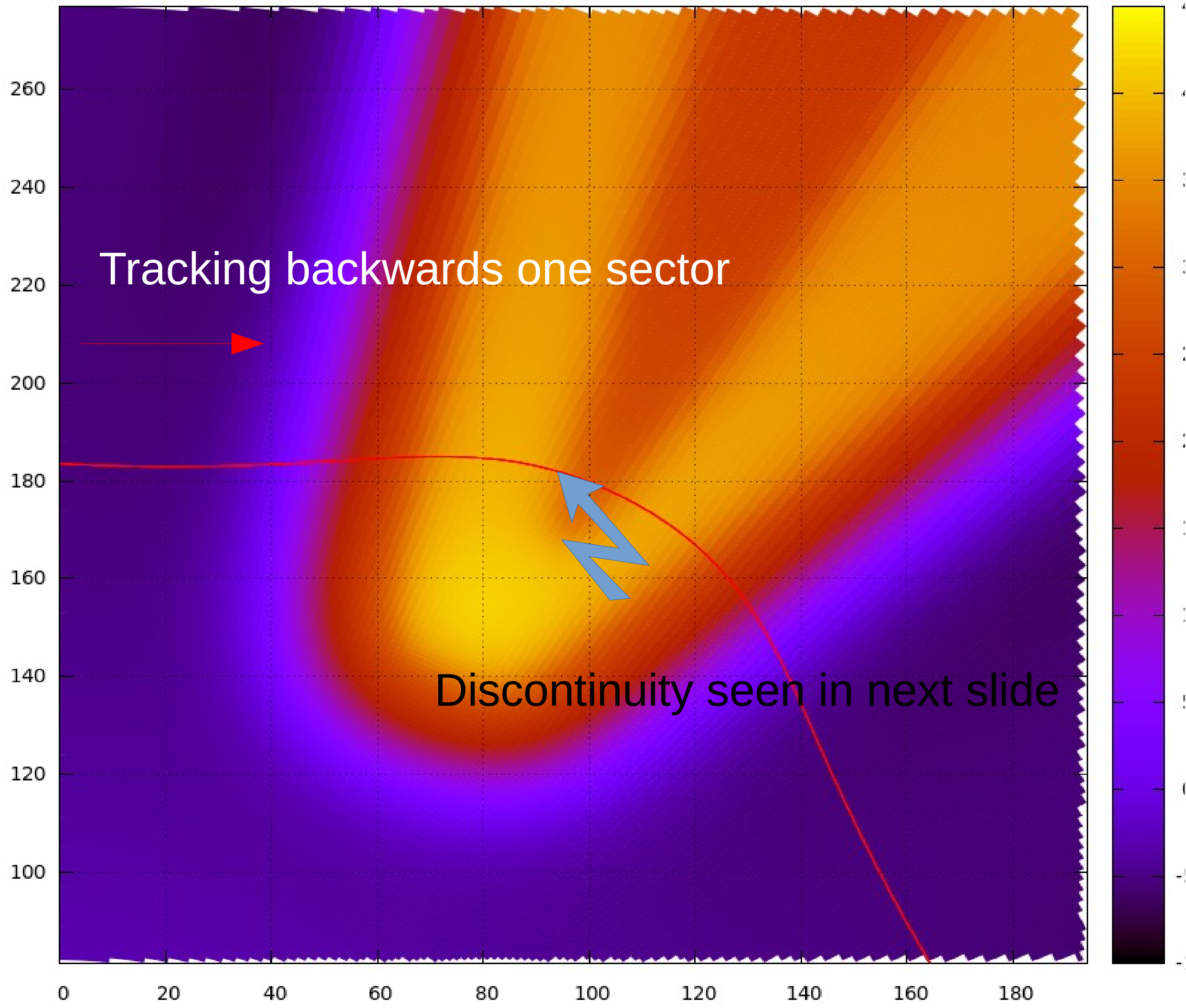
- The MADX simulation is based on computing the symplectic matrices.

Symplectification of the matrices 1/2

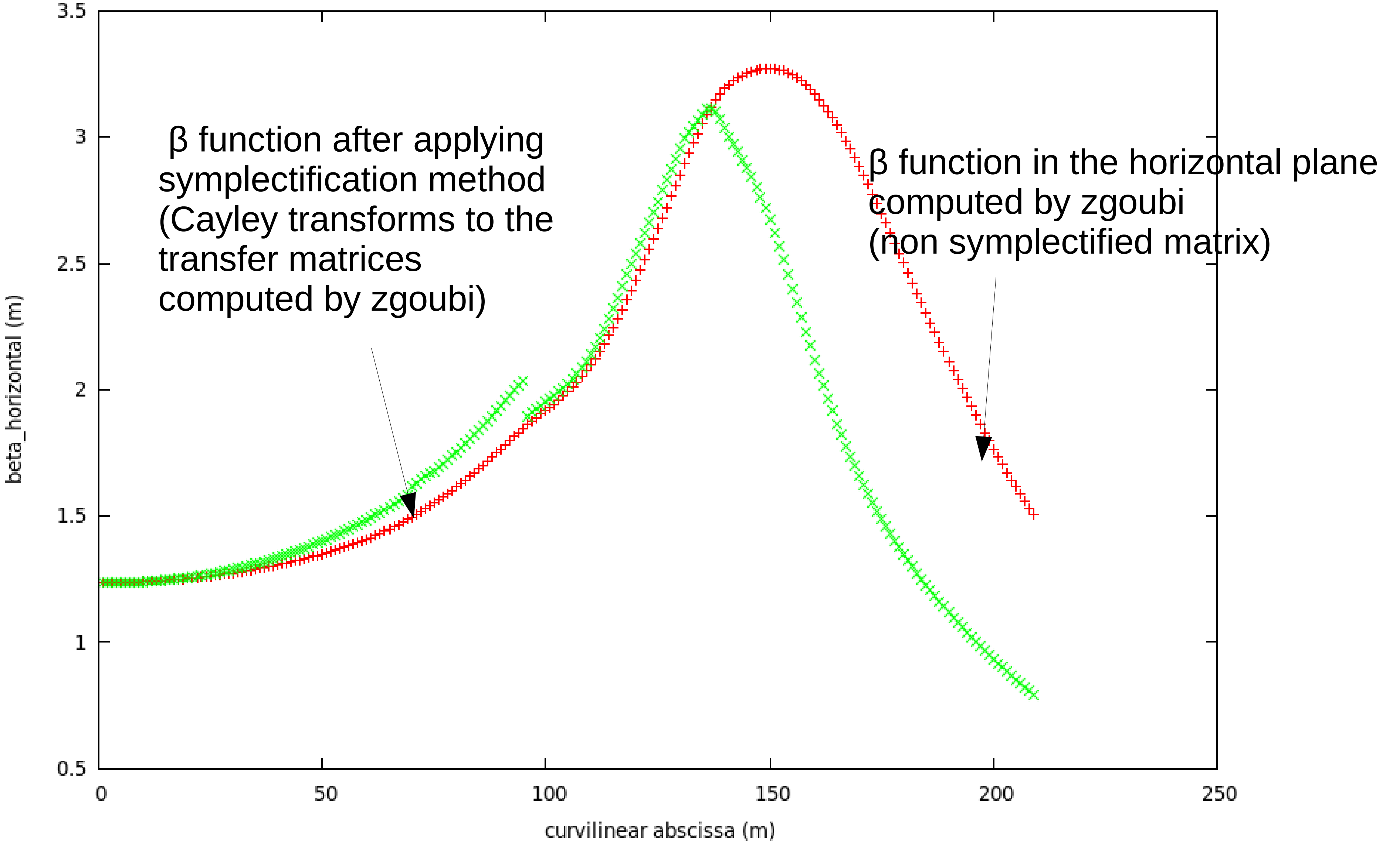
- Using <u>Cayley transforms</u>:
  A symplectic matrix can
  be written in the form
  M= (I+SW)(I-SW)^-1
  if and only if W is a
  symmetric matrix,
  and where S is defined by: $S=\begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}$

- We apply two Cayley transforms
  in order to symplectify the matrices
  computed by zgoubi and we obtain:

  det(x)=1.000000000000001
  instead of 1.0721



Symplectification of the matrices 2/2



- Thank you for your attention