Vertical section optics

Rick Baartman

6 Nov. 2008

– Typeset by FoilTeX –

Model Ingredients

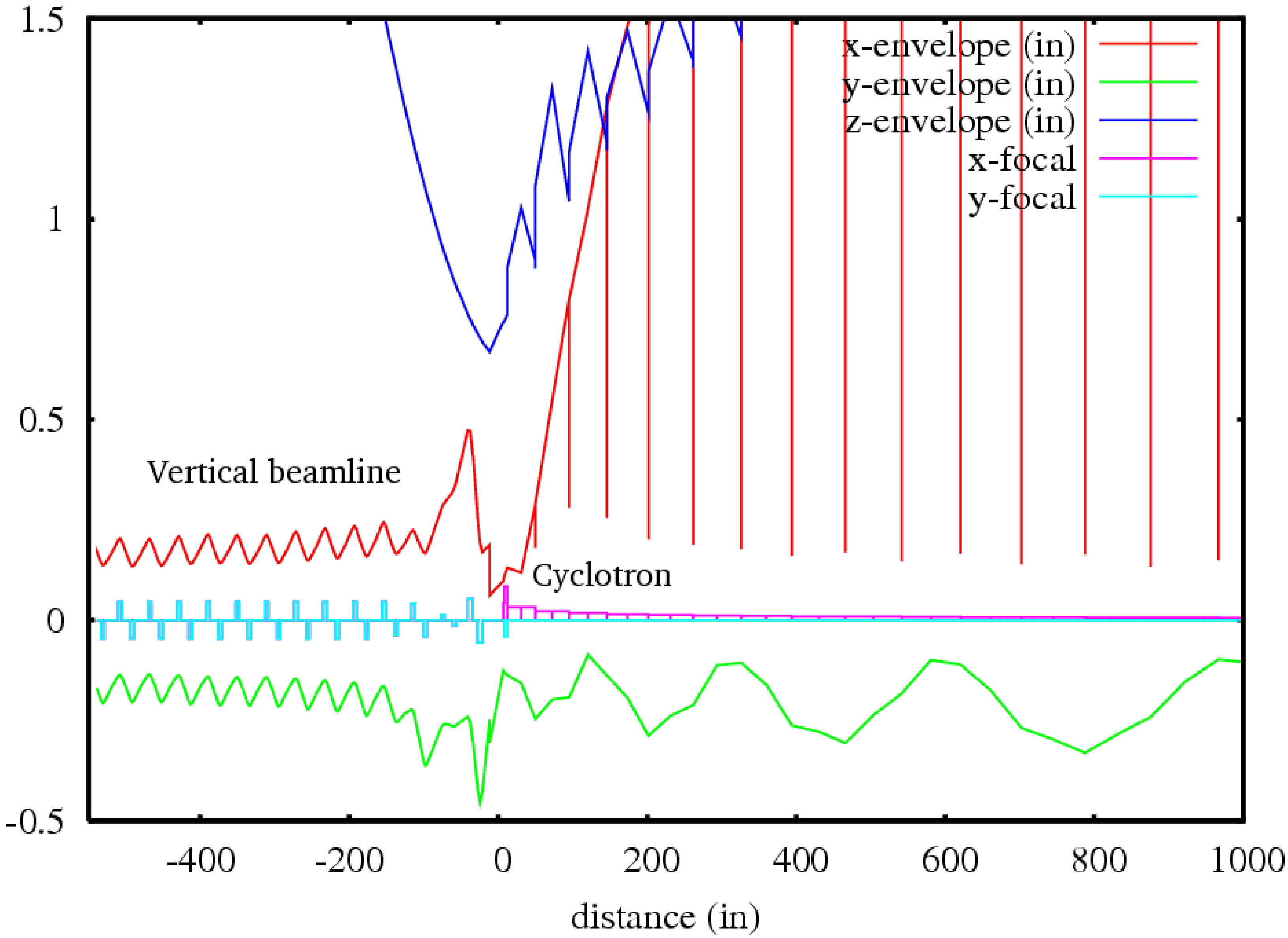
- Space charge of bunches in 3D space (no images); 22 pC per bunch (times 23 MHz = 500 μA); normalized emittance = 0.3 μm.
- Electrostatic quads with first order fringe field effects.
- Axial magnetic field from Larry from Ewart.
- Canonical inflector equations of motion so that space charge effects are calculated also through the inflector. I.e. not just using a transfer matrix to transport through inflector. (Axial field couples x and y, inflector also couples z, so in general, there is an ellipsoid at some orientation floating through and exiting the inflector. Have to rotate reference frame to the ellipsoid's axes, calculate the elliptic integrals giving the space charge forces along the axes, then transform back to lab frame. This is done at every RK step. Typically $4,000$ RK steps to get to first turn.)

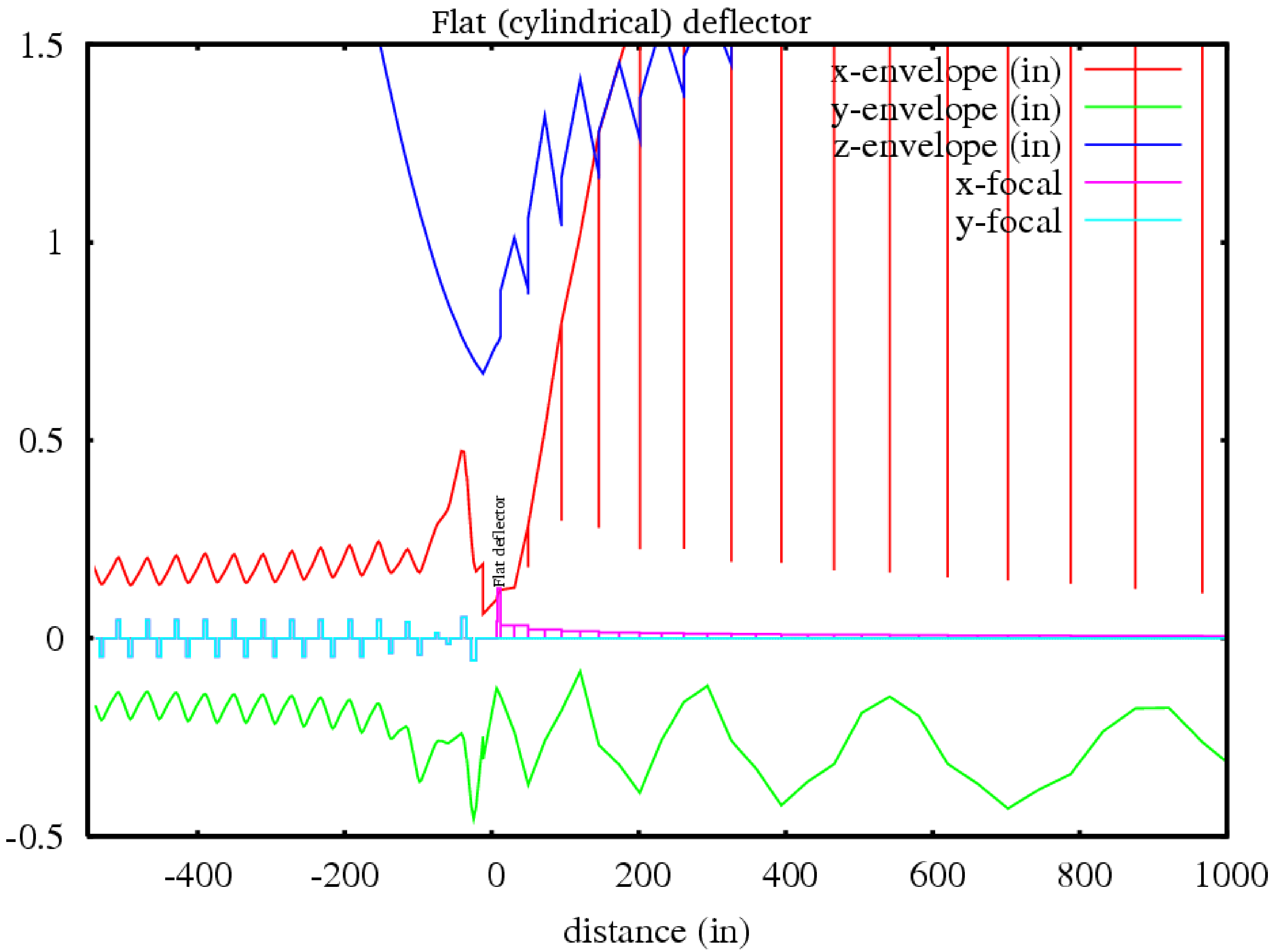
- Dee gaps in cyclotron give correct longitudinal and transverse kicks. (Unlike TRACE3D...) So electric focusing automatically included.
- BUT. It's only a linear calculation so e.g. tune cannot vary along bunch; best that can be done is to make a number of calculations at different rf phases.
- Variation of magnetic component of vertical tune with energy is stored in a function (taken from 1972 data).
- Variation of rf phase with energy due to isochronism bump also from 1972 data.
- The fitting function to minimize is average beam size over first 20 turns. Radial beam size is calculated with dispersion component removed: we don't care if the turns get broad, only if an energy slice gets broad.

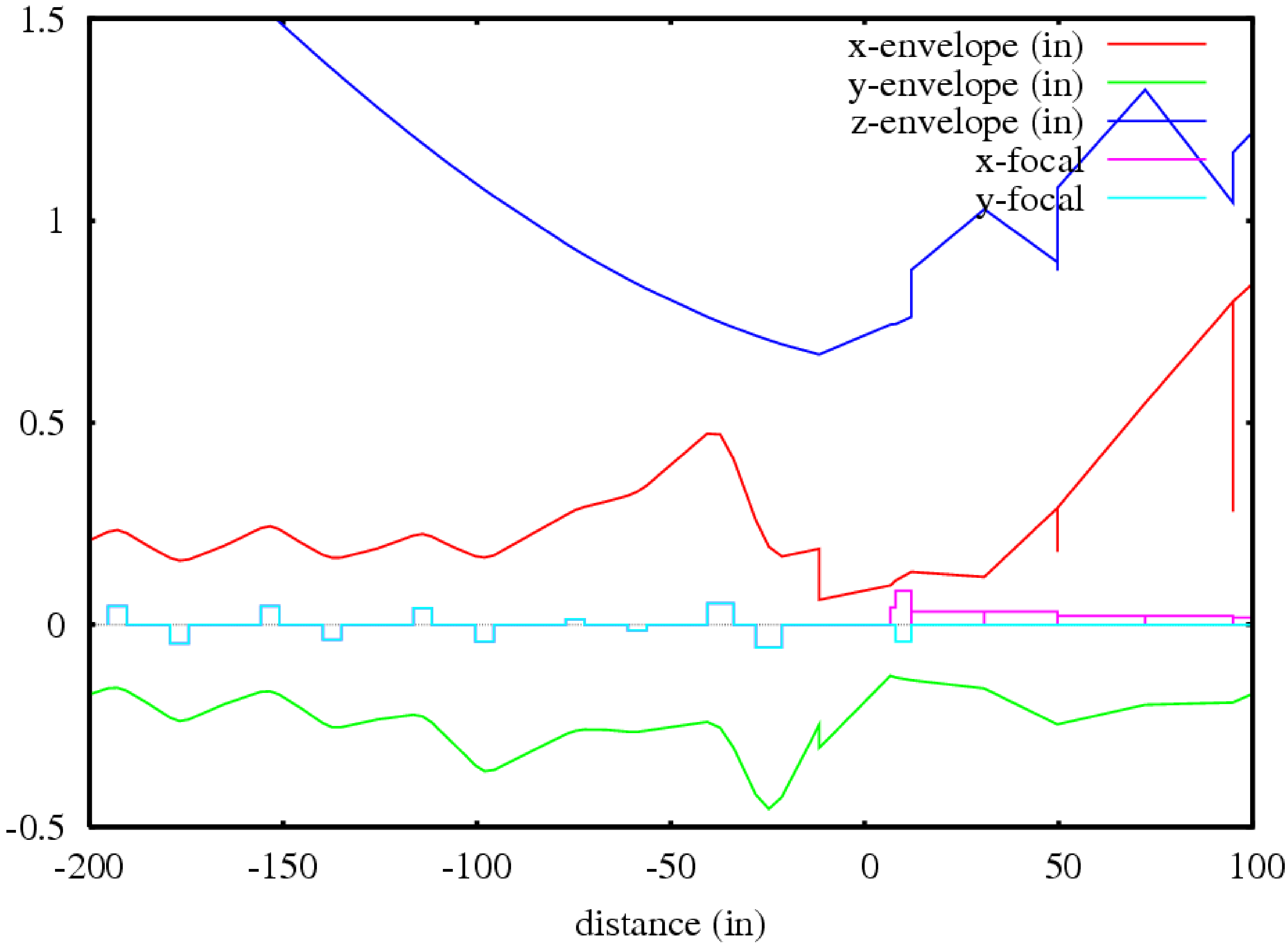
Optics Optimization

All possible parameters were varied: periodic section voltage, rotation angle between quads and inflector, locations of 6 matching quads. But the final configuration is strikingly similar to the current one. Same periodic section (except that quads are slightly paired as doublets), same (lack of any extra) rotation angle. In addition, have the following advantages over the current beamline:

- Matching knobs reduced from 9 to 5 (it helps, not having a chopper section).
- All quads well below 5 kV.
- Beam size in inflector is well within the electrodes even for the high ~ 7 mA peak current.


1.5
1
0.5
0
-0.5
-400
-200
0
200
400
600
800
1000
distance (in)
x-envelope (in)
y-envelope (in)
z-envelope (in)
x-focal
y-focal
Vertical beamline
Cyclotron


Flat (cylindrical) deflector
1.5
1
0.5
0
-0.5
-400
-200
0
200
400
600
800
1000
distance (in)
x-envelope (in)
y-envelope (in)
z-envelope (in)
x-focal
y-focal
Flat deflector



x-envelope (in)
y-envelope (in)
z-envelope (in)
x-focal
y-focal
1.5
1
0.5
0
-0.5
-200
-150
-100
-50
0
50
100
distance (in)

The matching can be described qualitatively as follows. The inflector/deflector and first gap represent tight size constraints. To focus into them, need large beam in the last doublet. The voltage in this last doublet is kept below 4 kV by extending them to 6 inches length. All other quads are 4 inches.

Unavoidably, the beam at the injection gap is too small to match well, especially vertically where focusing is weak. This is the reason there is a factor 2 to 3 emittance growth. We see here vertical size is about 0.25 in, so $\epsilon_n = y^2\nu_y/R_\infty \sim 0.8\,\mu$m compared with the $0.3\,\mu$m input normalized emittance.

Radially, there is a strong gap-crossing resonance blowing up the turn widths. This can be corrected with a phase bump, but anyway does not matter for an H^- machine.

The radial beam size with dispersion removed (look at the bottoms of the red spikes) is roughly half the vertical since the vertical tune is roughly 1/4 the radial.

Collimation, Steering

A mismatched beam oscillates in size according to its phase advance per cell. The chosen 3 kV periodic section voltage gives roughly 45° per cell, so beam halo cleanup collimators should be placed two periods apart. Steerers should be placed accordingly.