SIMULATIONS FOR THE FRANKFURT FUNNELING EXPERIMENT*

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Abstract

Beam simulations for the Frankfurt Funneling Experiment are done with RFQSim and FUSIONS. RFQSim is a particle dynamic program to compute macro particle bunches in the 6D phase space through a RFQ accelerator. Behind the RFQ the simulation software FUSIONS calculates both beam lines through a r.f. funneling deflector. To optimise beam transport of existing and new funneling deflector structures FUSIONS is presently being developed. The status of the development of FUSIONS and the results will be presented.

INTRODUCTION

The Frankfurt Funneling Experiment consists of two multicusp ion sources, a Two-Beam RFQ accelerator and a funneling deflector to bend both beam lines to a common beam axis [1, 2].

The principle of funneling is displayed in fig. 1. The r.f. deflector bends alternately both beam lines to a common beam axis. In cells with even numbers the electric field bends the bunches of both beam lines in the correct direction, but not in the odd cells. To reduce this effect the odd cells are enlarged in aperture and a drift tube can be placed in the gap (shaded rectangle). The beam has now the frequency $2f_0$.

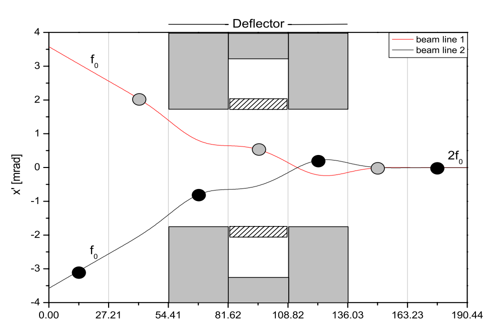

Figure 1: Funneling demonstrated at a 3 cell deflector.

THE SIM CODES

RFQSim

Beam dynamic transport through the RFQ accelerator is done by *RFQSim*. *RFQSim* is a particle simulation program especially for RFQ accelerator structures. It transports macro particle bunches in the 6-dimensional phase space segmentally through the RFQ and more than 15 transport modules such as bunchers, quadrupole, lenses and drift tubes. These modules can be placed before and behind the accelerator.

DefGen

To calculate a beam resp. two beams through a funneling deflector a potential distribution matrix of the deflector is required. The distribution with fringe ranges is computed by *DefGen* [3]. It's a Laplace 3D-solver using the technique of successive over-relaxation. *DefGen* generates two kind of matrices: a structure matrix $\Theta(x, y, z)$ and a potential matrix $\Phi(x, y, z)$. The structure matrix Θ contains additional information about the matrix elements, e.g. drift tube, electrode, space.

FUSIONS

FUSIONS (**Fu**nneling **S**imulation for **Ion** Beam**s**) is a particle dynamic program to simulate two beam lines through a r.f. funneling deflector. It's a further development of *DefTra* with a window based GUI. *FUSIONS* needs a particle distribution file from *RFQSim* and both matrices from *DefGen*.

The bunch of each beam line is transported segmentally in the 6 dimensional phase space through the structure matrix including fringe ranges. The number of segments correlates with the number of meshes along the z axis of the potential matrix Φ. On the basis of the present position on the mesh of the Φ matrix of each macro particle and the corresponding r.f. phase the three electric field components for each particle is determined. The momentum of the three coordinates is calculated and transfered to the particle. It is transported to the next segment. After all particles of the macro bunch are calculated in this segment the routine repeats the calculation for the next segment. This is done over all segments.

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SIMULATIONS WITH THE 15 CELL DEFLECTOR

Our Two-Beam RFQ accelerator is driven at a frequency of $f = 54$ MHz. The whole experimental set-up is scaled in He^{+} instead of Bi^{+} of the first funneling stage of a HIF driver. The deflector is placed approximately 0.5 m behind the RFQ in the beam crossing point. We have two different kind of funneling deflectors: a single cell and a multi cell deflector. Only one deflector is used during the experiment. The following investigations are done with our new 15 cell deflector.

Fig. 2 shows the potential distribution with fringe ranges of the first 5 cells of the 15 cell deflector in top view. The cross section is at the beam axis. The drift tubes in the wider apertures (odd cells) have a radius of $r = 15mm$ and a length of $l = 16mm$.

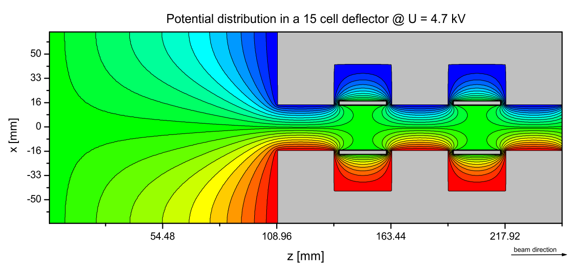

Figure 2: Intersection of the first cells of the deflector.

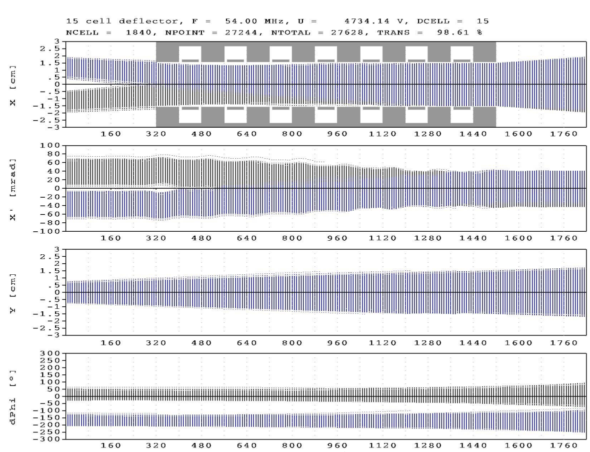

Figure 3: Beam trace of the 15 cell funneling deflector.

Two bunches each of $1.38 \cdot 10^{4}$ macro particles are entering the deflector with a phase shift of 180 degree (fig. 3). The first graph shows the beam transport in top view. The deflector is schematically plotted. The second graph shows the angle of the x component. In the last graph the phase of the two beams is drawn.

The angle reduction from $x' = 37.5$ mrad to $x' = 0$ mrad of the stable particle is shown in fig. 4. Fig. 5 illustrates the electric field components during the transport for the stable particle. In both figures the blue rectangle marks the deflector area.

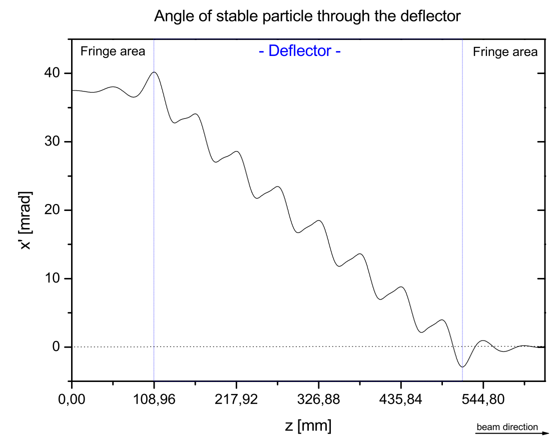

Figure 4: The angle of the x component of the stable particle is decreased from $x' = 37.5$ mrad to $x' = 0$ mrad.

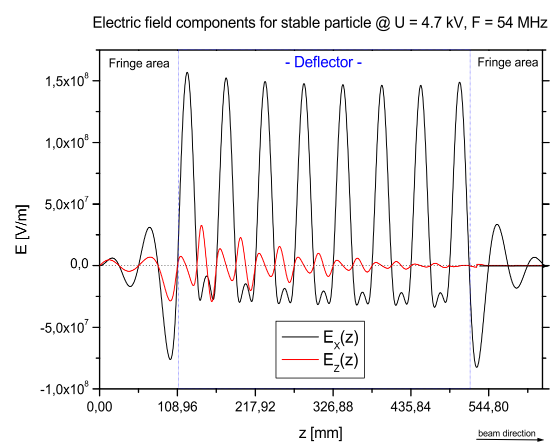

Figure 5: Electric field components, $E_x(z)$ and $E_z(z)$, for a stable particle.

A snapshot of the two bunch lines is displayed in fig. 8. Each bunch is in the middle of its cell. Because of the long drift of approximately 41 cm through the funneling deflector and the lack of focusing elements inside the deflector the beam radius increases. The emittance graphs in fig. 6 and fig. 7 show clearly the situation. Furthermore the phase width increases from $\Delta\Phi = 38°$ to $\Delta\Phi = 70°$.

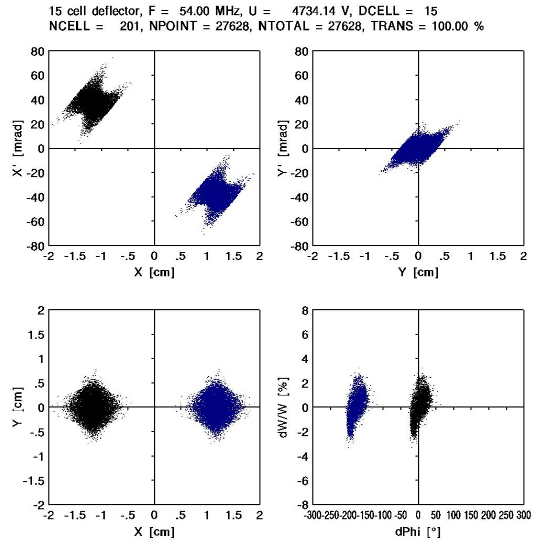

Figure 6: Emittances of both bunches before entering the funneling deflector.

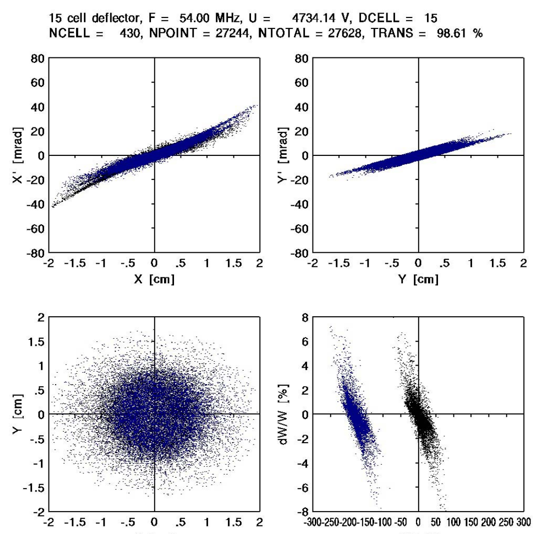

Figure 7: Emittances of both bunches leaving the deflector.

CONCLUSIONS

The development of the simulation software *FUSIONS* is still in progress. Several analysis routines and a space charge routine have to be integrated to the software.

The simulations show clearly that the beam has to be focused before it enters the next RFQ accelerator. This has to be verified with further investigations and simulations. For this purpose *RFQSim* has to be adjusted to accept the beam data of *FUSIONS*.

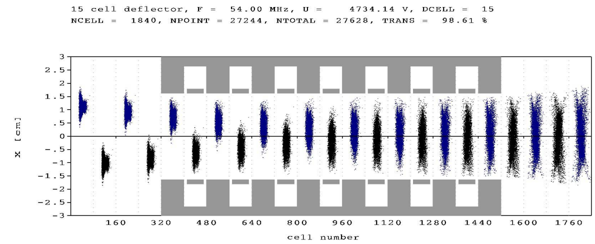

Figure 8: Bunch trace through the funneling deflector in top view.

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