Preparation of an Experiment to Investigate Nonlinear Beam Dynamics at the Storage Ring DELTA

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Abstract

The investigation of nonlinear beam dynamics is one of the research fields at the electron storage ring DELTA [1] [2]. Optimisation of strength and distribution of the sextupole magnets in the ring and dynamic aperture needs knowledge about phasespace structure and nonlinear resonances. For this purpose measurements of the beam position turn by turn are a very suitable.

1 The Tracking Method

Since both rings of the DELTA facility, the booster BoDo and DELTA itself are under construction at the moment, there is no possibility to use experimental data so far. All considerations are based on simulation results of measurements mainly performed with the program MAD [3]. First of all we compare the different tracking methods TRANSPORT, LIE3 and LIE4 with optical data of the BoDo ring.

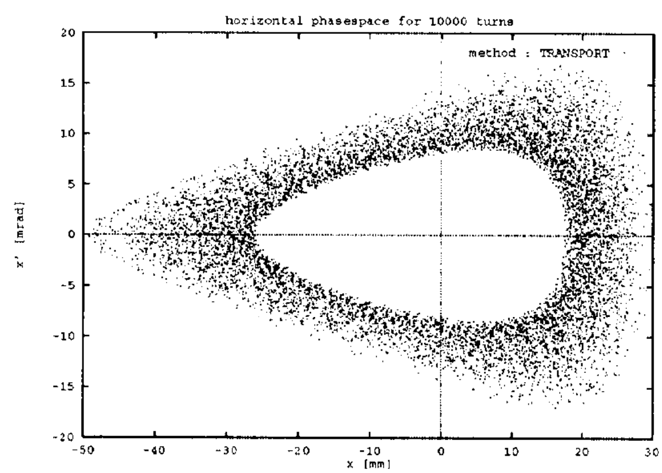

Figure 1: Horizontal phasespace with TRANSPORT

Figure 1 and 2 show the horizontal phasespace for 10000 turns with the same start parameter nearly at the limit of the dynamic aperture. The lattice contains only the separate sextupoles as nonlinear elements, but no higher multipoles due to fringe fields of the magnets. Figure 1 shows the result of the tracking method TRANSPORT. The disadvantage of the non symplectic matrix formalism is visible. The violation of Liouville's theorem produces an unphysically damping of the betatron oscillation. To get a more physical result the Lie algebra method up to third order in nonlinearities (LIE3) was used (fig. 2). The results of the phasespace calculation with the LIE4 method are the same as with LIE3 but they need a faktor three more in time.

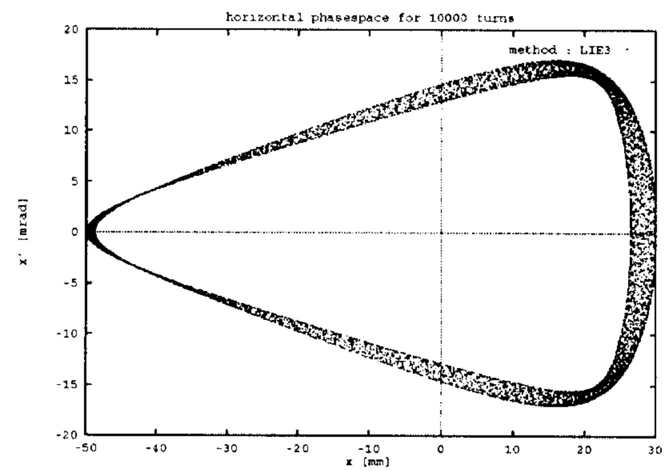

Figure 2: Horizontal phasespace with LIE3

2 Phasespace for Different Betatron Oscillations

Both the simulation and the measurements use the firing of a feedback kicker to excite a betatron oscillation. For the simulation the electron bunch is represented by 20 particles, forming a gaussian distribution with 3 σ standard deviations. The perturbation is simulated by a simple kick. The optical data of DELTA used for this simulations contain all known nonlinearities, the separated sextupole magnets, the measured multipoles in the quadrupole and dipole magnets and their fringe fields. Figure 3 and 4 show the position of the bunch for the first 10 turns at the location of BPM 1 and for the last 10 of 10000 turns. For the moderate perturbation with a 2.5 *mrad* kick the deformation of the bunch is small and it is clearly visible which particle belongs to which turn. After 10000 turns all the particles are distributed all over the phasespace ellipse because of Landau damping and a separation of turns is no longer possible. With a 4 *mrad* stimulation the first 10 turns look something different (fig. 5). The influence of nonlinearities distort the structure of the bunch after a few turns. The phasespace for the last turns

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similar to figure 3. You have more or less an homogeneous distribution over the ellipse.

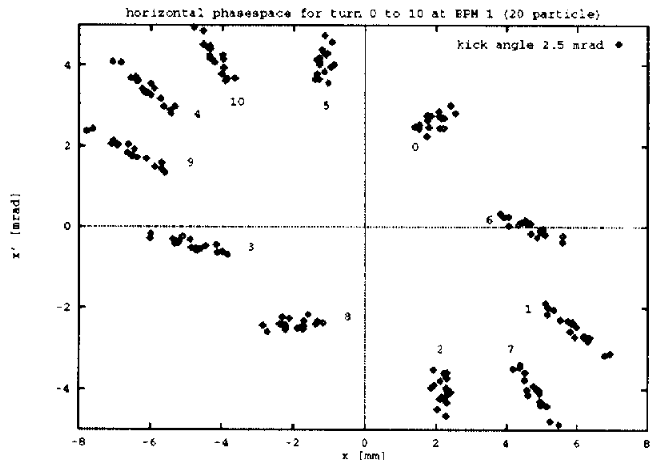

Figure 3: First 10 turns with 2.5 mrad kick

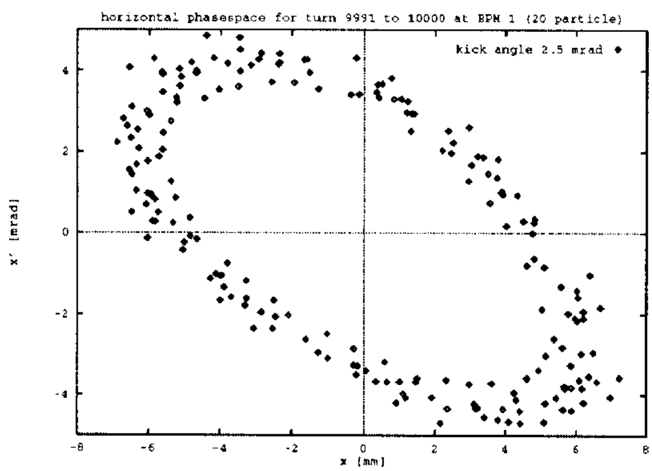

Figure 4: Last 10 turns with 2.5 mrad kick

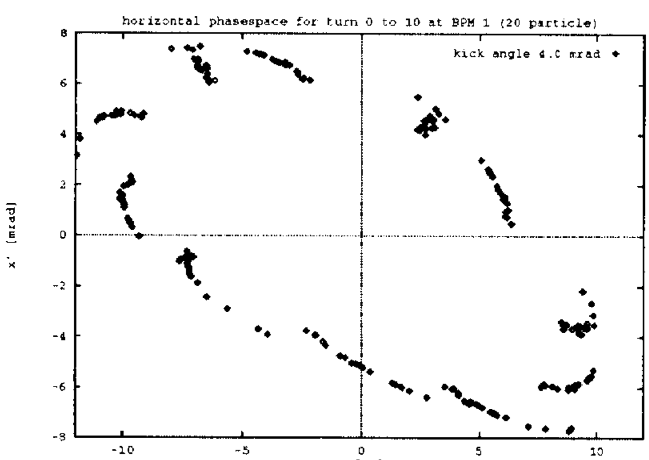

Figure 5: First 10 turns with 4.0 mrad kick

The only parameters one can get from the BPM's are are the horizontal and vertical displacement of the center of charge. It is obviously that the displacement decreases if the particles of one bunch are distributed over the ellipse more or less homogeneous. This distribution is an effekt of Landau damping. The influence of synchrotron damping is neglectible. One damping time of the DELTA storage ring at 1.5 GeV is about 10 ms and 270 ms at an energy of 0.5 GeV. As 270 ms corresponds to 675000 turns the damping for the first 10000 turns can be neglected. As one can see in figure 6 the damping is not the only effekt.

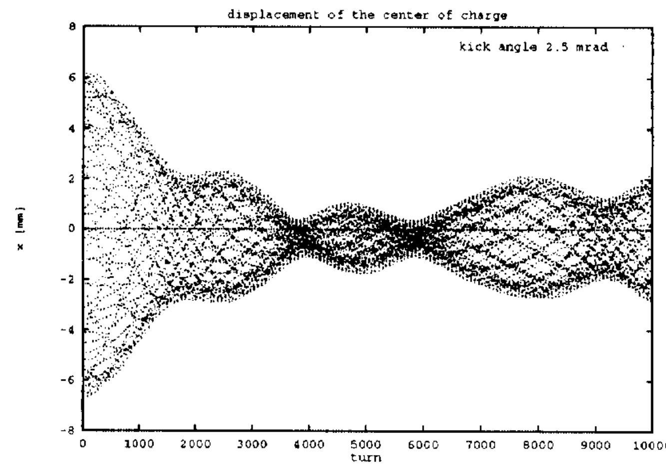

Figure 6: Displacement of the center of charge versus turn for 2.5 $mrad$ kick

For moderate beam perturbation a periodic damping and excitation of the center of charge is visible. Damping to a minimum means that the particles are more or less equal distributed all over the ellipse. Excitation means a concentration of the particles in one part of the ellipse. With a 4 $mrad$ perturbation every structure and every damping and stimulation mechanism is lost.

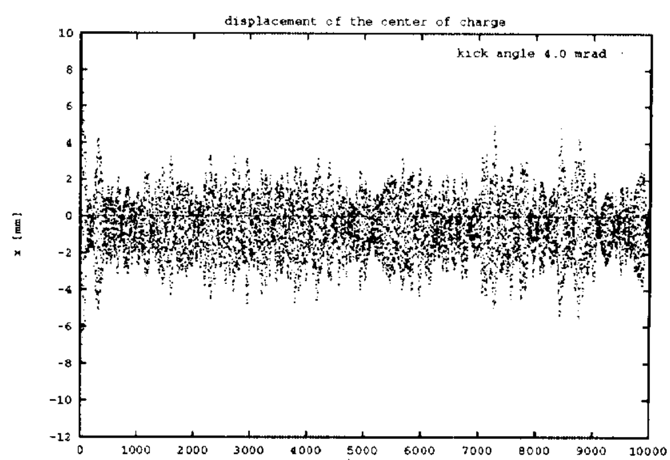

Figure 7: Displacement of the center of charge versus turn for 4 $mrad$ kick

The monitor signal looks like electronic noise but nevertheless it contains information about the optics. If one looks at the fourier spectrum of the displacement (fig. 8,9) one can see in case of linear optics small peaks at the location of the horizontal tune Q_X and at $2*Q_X$. In the nonlinear case the main peaks are broader and have many additional small peaks. One can also detect a tune shift depending on the stimulation kick.

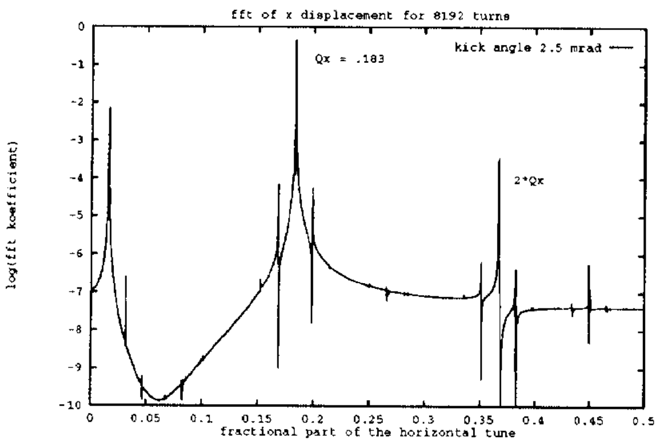

Figure 8: fft of the displacement with 2.5 *mrad* kick

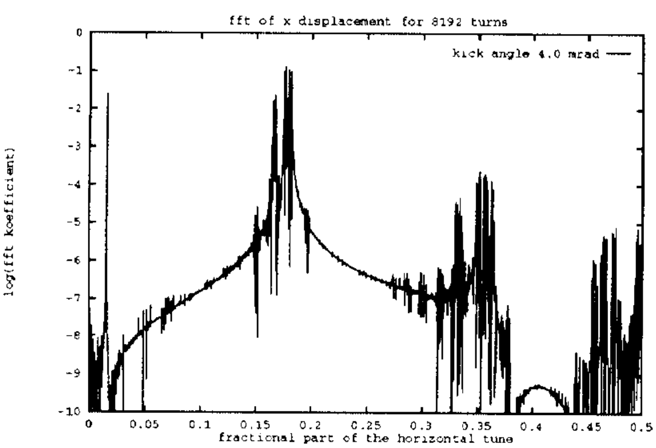

Figure 9: fft of the displacement with 4 *mrad* kick

3 Reconstruction of the Phasespace

To calculate the phasespace from the monitor signals which can only measure the displacement of the beam but not the derivative, one has two possibilities. First you can use the betafunctions, the gradient of the betafunctions at the location of the two beam position monitors and the phase advance between them from other measurements to calculate the derivatives with the help of the matrixformalism. This method has disadvantages. The optics parameter are only known with an accuracy of about a few percent and that is not enough for precise statements about the phasespace. Furthermore the matrixformalism takes into account only linear elements of the optics and neglects all nonlinearities. Therefore it is better to use the measured magnetic field distribution between the monitors with all higher multipoles. Doing this it is possible to solve the Lorentz equation using a series expansion of the magnetic field. At this X_1 at BPM 1 is a fix parameter and X_1' will be vary til X_2 at BPM 2 is matched. X_2' is fixed automatically by this 'shooting' method.

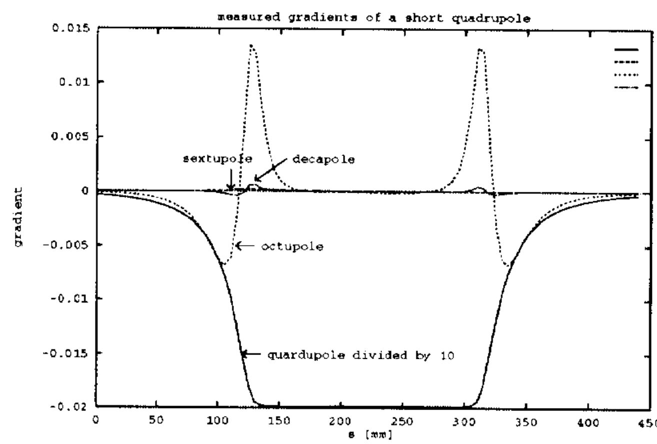

Figure 10: Example of measured gradients of a short quadrupole [4]

4 Conclusion

Measurements of the pasespace turn by turn are useful to study damping mechanisms, tuneshifts due to nonlinearities and resonace widths as one can see before. Before an experiment can be designed some theoretical considerations are nessesary. Therefore, tracking programs are very helpfull. The influence of magnet misalignments, accuracy of BPM monitors will take into account next. The analysis of the monitor data will be improved to extract informations as most as possible.

References

[1] N. Marquardt, Report on DELTA One Year Before Routine Operation, This Conference.

[2] DELTA Group, DELTA Status Report (August 1990), unpulished

[3] F. C. Iselin, H. Grote, The MAD Programm Version 8.4, CERN/SL/90-13

[4] F. Brinker, Phd. Thesis, to be published