COMPUTER SIMULATION OF THE SLOW BEAM EXTRACTION FROM NUCLOTRON

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Abstract

The results of modelling of particles motion during slow beam extraction from Nuclotron at the energy of 6 GeV/u are analyzed. Influence of the measured sextupole component of dipole magnets and fringe fields of the Lambertson magnets on the characteristics of extracted beam is presented. The calculations have been done using the MadX package.

INTRODUCTION

The Nuclotron, superconducting heavy ion synchrotron with iron shaped magnets, has been under operation since 1993. Physics experiments were carried out only in internal circulating beams before March, 2000. Preparation of the extraction system elements [1], their final bench tests and installation in the ring were performed in 1999. In 2000 the works were completed, and the equipment was installed into the ring and put into operation that made it possible to carry out further experiments at the extracted beams as well [2], [3].

EXTRACTION SYSTEM

System of slow beam extraction from Nuclotron includes electrostatic septum (ES), pair of Lambertson magnets (LM), 4 sextupole lenses and 4 special quadrupole lenses. The sextupoles produce 22-th harmonic of sextupole nonlinearity to excite the resonance $Q_x = 22/3$. The first pair of the lenses is located in second and sixth octants of the Nuclotron lattice whereas the second pair in fourth and eighth octants respectively. Special quadrupole lenses are used to shift the horizontal tune to the resonance vicinity. The lenses are located in the first, third, fifth and seventh octants respectively. The ES and LM are located within the fifth octant. These elements provide two-stage particle deflecting system, namely: ES in horizontal plane and LM in vertical plane to the level of existing beam-transport channels in experimental halls. The LM is superferric magnet consisting of two sections 1.5 m long each. Composition of the lattice is shown in Fig. 1.

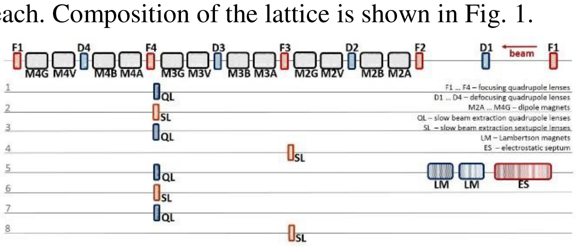

Figure 1: Composition of the Nuclotron elements.

The main task of this work is to consider how sextupole nonlinearity of dipole magnets and fringe fields of the LM disturb beam dynamics and to estimate possibility to extract the beam with high efficiency at the maximum energy. All the calculations were done for the betatron tunes $Q_x \sim 22/3$ and $Q_y = 7.4$. The gap between 3 cm and 5 cm on horizontal plane (XX' plane) is marked at each plot to show the gap of the ES. The possibility of entering this gap for the particle means its extraction.

SIMULATION AND RESULTS

At first, the case with zero nonlinearities of the structural dipoles and the other elements was considered. In this situation, there is no reason for the resonances exciting and for the extraction of the beam. Horizontal and vertical plane of the beam phase portrait at the entrance in ES are shown on Fig. 2a and Fig. 2b.

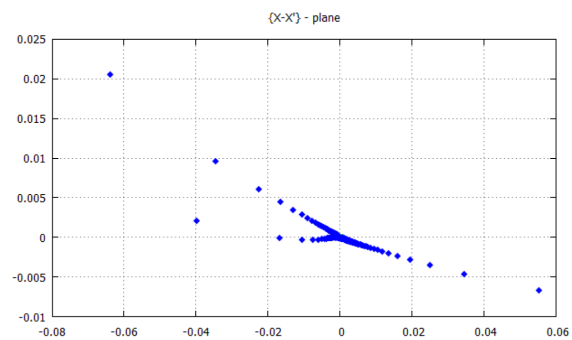

Figure 2a: XX' plane without nonlinearities

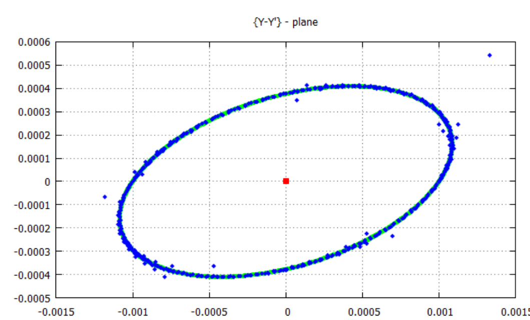

Figure 2b: YY' plane without nonlinearities.

At the next stage the sextupole nonlinearity of the dipoles was taken into account. The appearance of additional areas of stability (see Fig. 3) is observed even without switching the sextupole lenses of slow beam extraction.

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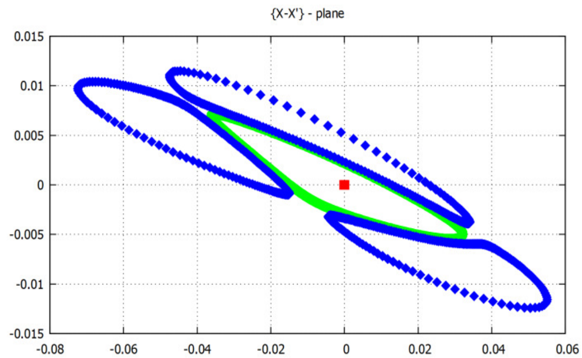

Figure 3: XX' plane with general and additional areas of stability.

At such conditions, switching of special sextupole lenses for slow beam extraction gives no the expected positive effect. There is no general or partial stable areas, however there is bending of the particle trajectories at Q_x = 22/3 (Fig. 4 and 5a, 5b).

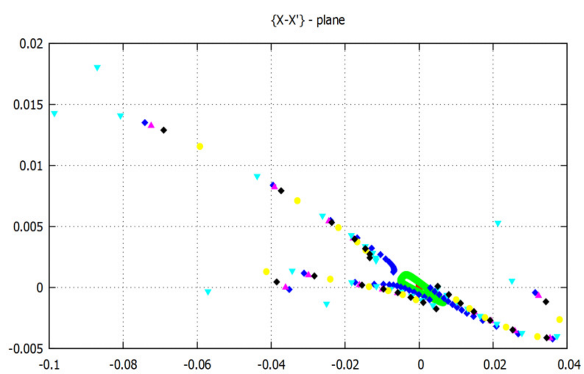

Figure 4: Bending of the trajectories caused by the sextupoles switching on.

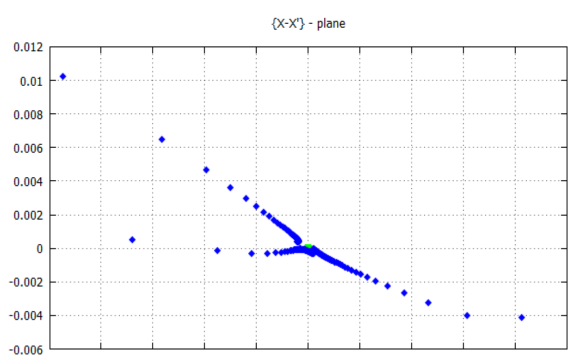

Figure 5a: XX' plane with the slow extraction sextupoles, Qx = 22/3.

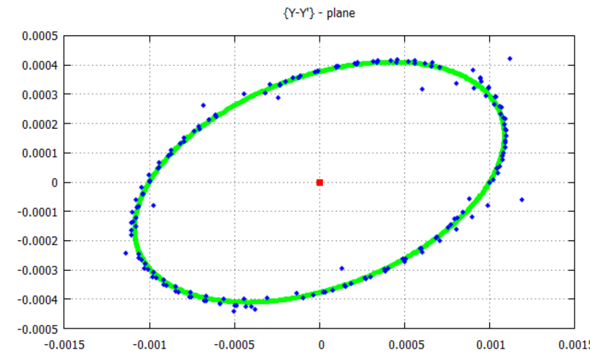

Figure 5b: YY' plane with the slow extraction sextupoles, Qx = 22/3.

The situation is improved a little bit if we shift the work point from the resonance. This case is shown at Fig. 6a calculated at Qx = 22/3 + 0,01. Phase portrait in YY' plane for the conditions mentioned above is shown in Fig. 6b.

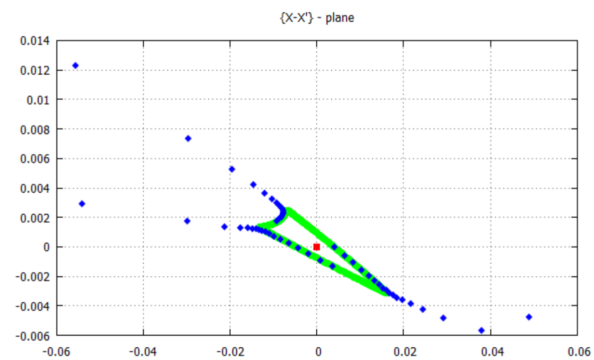

Figure 6a: XX' plane with the sextupoles nonlinearity at Qx = 22/3 + 0,01.

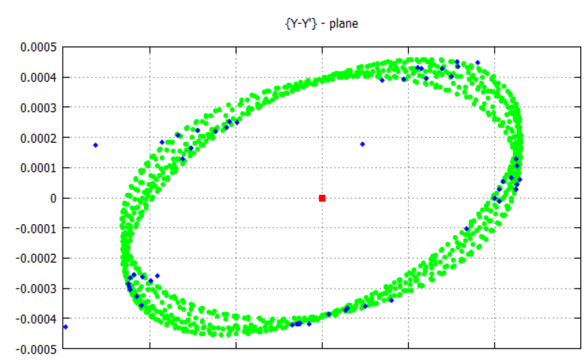

Figure 6b: YY' plane with the sextupoles nonlinearity at Qx = 22/3 + 0,01.

Influence of the LM fringe fields together with the sextupoles nonlinearity was considered in the next step. The modelling shows that directly at the resonance point (Qx = 22/3) the beam can enter to the ES gap, and slow beam extraction is possible (Fig. 7a and 7b).

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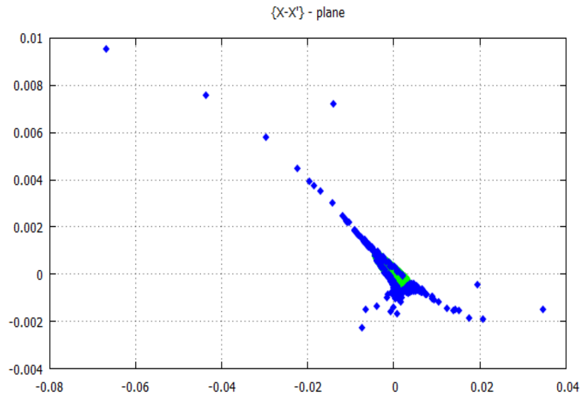

Figure 7a: XX' plane with the sextupoles nonlinearity and the LM fringe fields at Qx = 22/3.

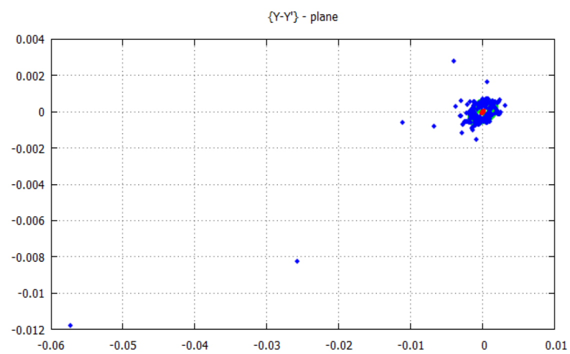

Figure 7b: YY' plane with the sextupoles nonlinearity and the LM fringe fields, Qx = 22/3.

However, trajectories of the beam motion in the limits of resonance tuning (Qx = 22/3 + 0,01) and with both sets of nonlinearities (sextupole nonlinearity and fringe fields of Lambertson magnets) show that slow beam extraction occurs under these conditions with very low efficiency (Fig. 8a, 8b and 9).

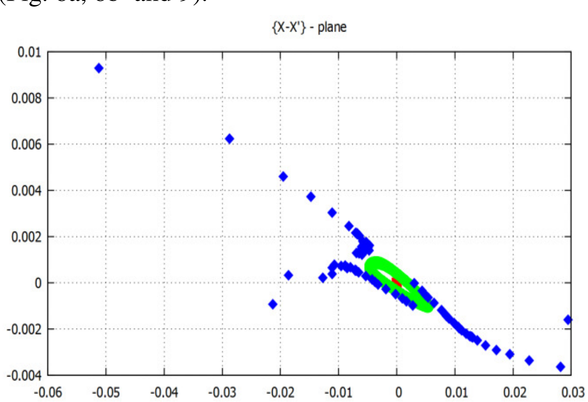

Figure 8a: XX' plane with the sextupoles nonlinearity and the LM fringe fields at Qx = 22/3 + 0,01.

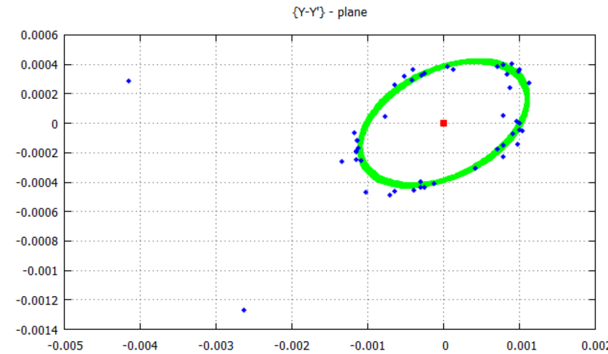

Figure 8b: YY' plane with the sextupoles nonlinearity and the LM fringe fields, Qx = 22/3 + 0,01.

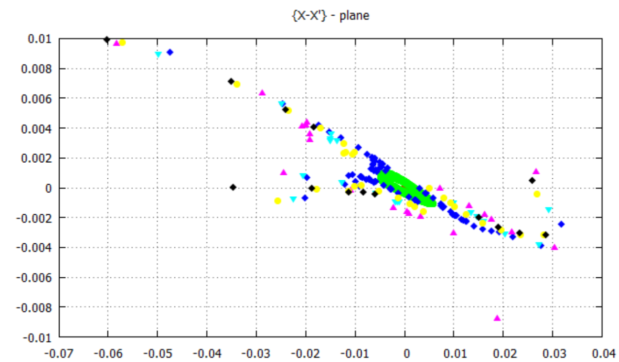

Figure 9: XX' plane with the sextupoles nonlinearity and the LM fringe fields at Qx = 22/3 + 0,01.

CONCLUSION

The obtained data demonstrate the necessity of further analysis of slow beam extraction process at Nuclotron and especially at the maximum magnetic field in lattice dipoles (2 T and over). The measured values of the sextupole component of the Nuclotron structural dipoles were used in the presented set of calculations. Nevertheless, the decapole component exists in the dipole magnetic field and its distribution was measured also. Thus, the work will be continued.

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