PARTICLE DYNAMICS SIMULATION IN NUCLOTRON OF THE NICA COMPLEX ACCOUNTING INFLUENCE OF THE LEAKAGE MAGNETIC FIELD

I. Avvakumova, A. Kovalenko, V. Mikhaylov, A. Tuzikov VBLHEP, JINR, Dubna, Russia

Abstract

The aim of the current work was to demonstrate main parameters of beam dynamics in the Nuclotron while functioning as a part of NICA. Thereby, processes of beam circulation and slow extraction were modelled. The influence of leakage fields of injection and extraction systems septa magnets (Lambertson magnets) was demonstrated. Calculations were carried out via 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]. Systems of fast beam extraction from Nuclotron into collider and beam injection from Booster into Nuclotron are under construction now. Both of them include Lambertson magnets as well as slow beam extraction system does [4].

NUCLOTRON COMPOSITION. LAMBERTSON MAGNETS LOCATION AND PURPOSE

Nuclotron consists of 8 superperiods, or octants. Regular superperiod is shown on Fig. 1. Lambertson magnets location is also shown there.

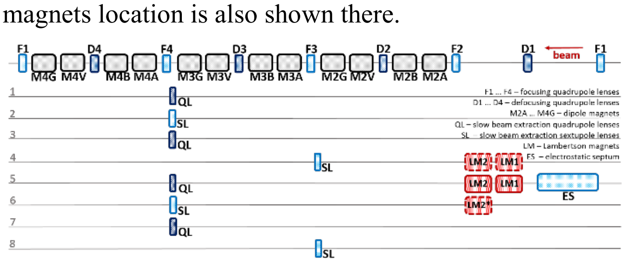

Figure 1: Composition of the Nuclotron elements.

One pair of Lambertson magnets in the fifth octant, LM1 and LM2, serve as a part of beam deflecting system during slow beam extraction process. Other three Lambertson magnets are being built now: one pair, which is absolutely the same as the existing one, would provide fast extraction from Nuclotron into collider and single Lambertson magnet is intended for injection system Booster-Nuclotron.

The aim of work is to demonstrate how leakage fields, which are produced by existing and additional Lambertson magnets, would affect beam dynamics in Nuclotron during beam circulation and slow extraction.

SIMULATION AND RESULTS

Firstly, circulating beam dynamics was observed for betatron tunes Q_x=7.40, Q_y=7.45 and at the value of guiding magnetic field about 0.45 T. This value corresponds to the energy of beam injection from Booster ring to Nuclotron. Single LM2* was expected to have significant effect on beam motion, in view of the fact that it will have it's own power supply and field value 1T.

On the figures below, results of calculations are shown. Three modes of beam circulation were considered: all Lambertson magnets are turned on and so all LM's leakage fields have effect on beam dynamics (see Fig. 2a, 2b), only couples of LM are turned on (see Fig. 2c, 2d) and all Lambertson magnets are turned on, but short-connected loops in all LM2 are turned off (see Fig. 2e, 2f).

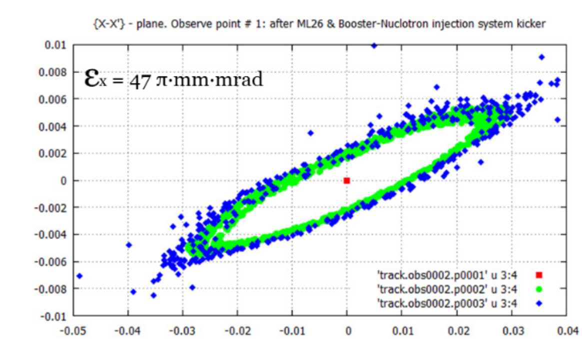

Figure 2a: XX' plane with all LM's leakage fields turned on (the first regime).

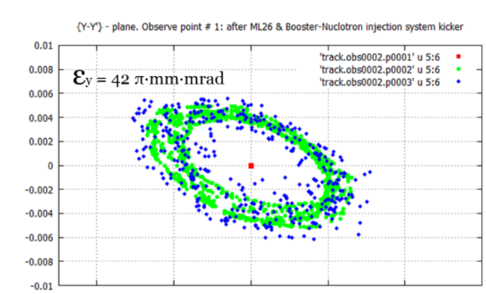

Figure 2b: YY' plane with all LM's leakage fields turned on (the first regime).

ISBN 978-3-95450-197-7

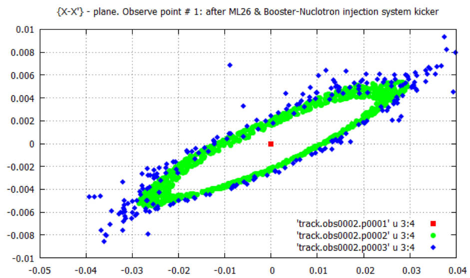

Figure 2c: XX’ plane with couple’s LM leakage fields turned on (the second regime).

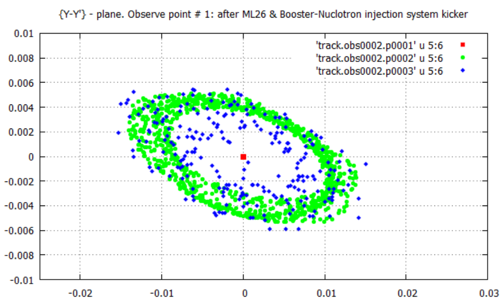

Figure 2d: YY’ plane with couple’s LM leakage fields turned on (the second regime).

Comparison of the first and the second regimes shows the effect on beam dynamics of single injection Lambertson magnet. As can be seen, setup of additional Lambertson magnets doesn’t change beam dynamics significantly.

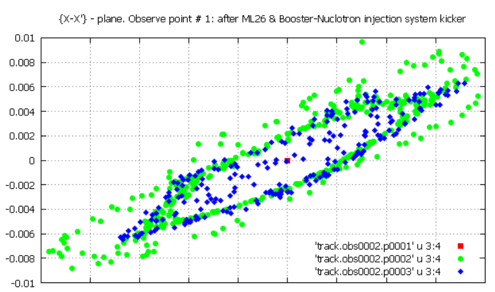

Figure 2e: XX’ plane with all LM’s leakage fields turned on; LM2’ short-connected loop is off (the third regime).

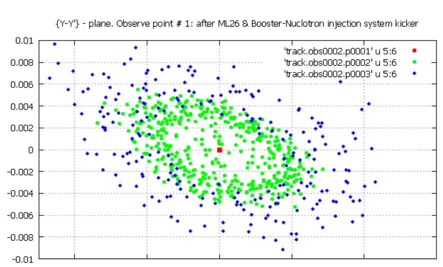

Figure 2f: YY’ plane with all LM’s leakage fields turned on; LM2’ short-connected loop is off (the third regime).

Calculation dynamics with turned off short-connected loop, which is installed in existing LM2 and is planned to be install in future LM2 and LM2*, shows that such conditions significantly change beam circulation.

Secondly, circulating beam dynamics was observed for betatron tunes Q_x=7.40, Q_y=7.45 and at the value of guiding magnetic field about 1.8 T. The field value corresponds to the maximum energy that was reached during Nuclotron runs.

Three modes of beam circulation were considered: all Lambertson magnets are turned on and so all LM’s leakage fields have effect on beam dynamics (see Fig. 3a, 3b), only existing pair of LM is turned on (see Fig. 3c, 3d) and all Lambertson magnets are turned on, but short-connected loops in all LM2 are turned off (see Fig. 3e).

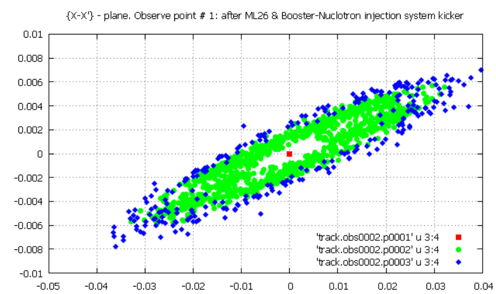

Figure 3a: XX’ plane with all LM’s leakage fields turned on (the first regime).

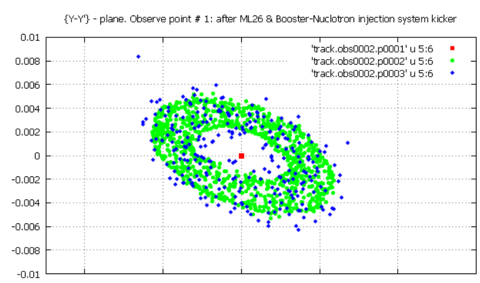

Figure 3b: YY’ plane with all LM’s leakage fields turned on (the first regime).

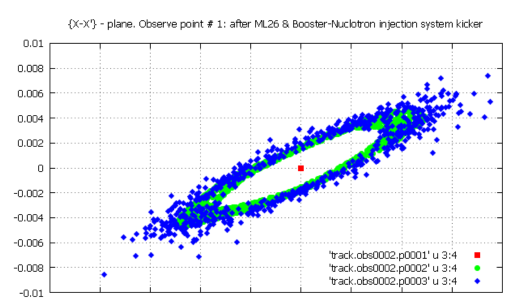

Figure 3c: XX’ plane with one existing pair of LM (the second regime).

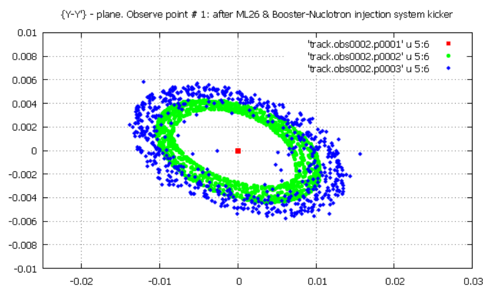

Figure 3d: YY' plane with one existing pair of LM (the second regime).

Comparison of the first and the second regimes shows the effect on beam dynamics of all three additional Lambertson magnets. As can be seen, the setup of them changes beam dynamics significantly.

Calculation dynamics with turned off short-connected loop shows that stability criteria of betatron oscillation is disturbed, so there is no closed orbit for such conditions. Therefore, ion acceleration in Nuclotron to high energies is impossible without short-connected loops work.

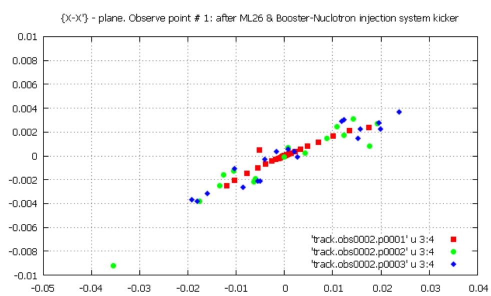

Figure 3e: XX' plane with all LM's leakage fields turned on; LM2' short-connected loop is off (the third regime). There is no closed orbit!

Finally, possibility of the slow beam extraction was observed. Slow extraction in Nuclotron is carried out on the third order resonance. Calculations were done for two modes: Q_x=22/3, Q_y=7.38 (see Fig. 4a, 4b) and Q_x=22/3, Q_y=7.45 (see Fig. 4c, 4d).

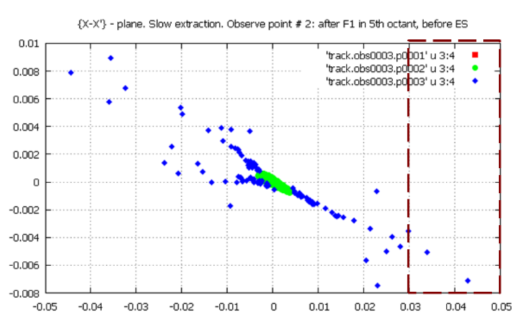

Figure 4a: XX' plane, Q_x=22/3, Q_y=7.38.

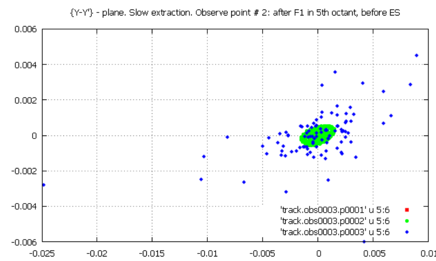

Figure 4b: YY' plane, Q_x=22/3, Q_y=7.38.

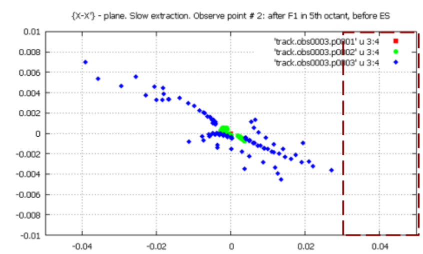

Figure 4a: XX' plane, Qx=22/3, Qy=7.45.

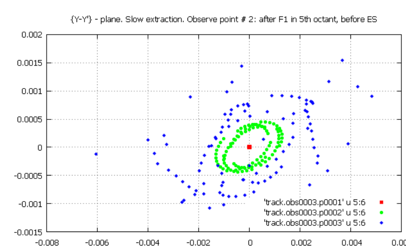

Figure 4b: YY' plane, Qx=22/3, Qy=7.45.

CONCLUSION

The obtained data demonstrate that on the energy of beam injection from Booster into Nuclotron single Lambertson magnet doesn't make any critical effect on beam dynamic. At the maximum energy leakage fields of Lambertson magnets cause considerable effect on beam dynamics, but don't produce beam loss while turning off short-connected loops in LM2 causes beam loss. Beam slow extraction is possible even after additional Lambertson magnets setup.

REFERENCES

[1] I. Issinsky, V. Mikhaylov, V. Shchepunov, "Nuclotron lattice", EPAC'90, Nice, June 1990, p.458 (1990).

[2] A. Kovalenko, "Nuclotron: status and future", EPAC 2000, Vienna, June 2000, p.554 (2000).

[3] N. Agapov et al. "Slow beam extraction from Nuclotron", PAC'01, Chicago, March 2001, p.1646 (2001).

[4] A. Butenko et al. "Transport channels, injections and extraction systems of the accelerating NICA complex", PEPAN Letters 7 (2016), p.1507.

ISBN 978-3-95450-197-7