COMPUTER SIMULATION OF BEAM DYNAMICS ON JINR PHASOTRON UP TO 660 MeV ENERGY

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Project of increasing the beam intensity of the 660 MeV JINR Proton Phasotron by an external injection of the H^- beam with energy 5 MeV is now under design. Process of the beam injection was investigated formerly. Investigation of the acceleration process up to the final energy is reported in this paper. It is found that the beam losses exist along the acceleration.
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1. INTRODUCTION

For an increase in the intensity of the JINR synchrocyclotron (Phasotron) from 5 to 50 μA it is developed the project [1, 2] of the external injection of a beam. It is supposed that the beam with a current 6…8 mA and energy 5 MeV, delivered from the cyclotron, after additional bunching and neutralization ($H^- \rightarrow H^0$) is injected at the central region of the Phasotron. Carbon foil will be used in order to get proton beam ($H^0 \rightarrow p$). Some parameters of the Phasotron central region for the scheme of external injection (Fig.1) are given in Table.

Data of the Phasotron central region

Type of accelerated particle	p
Initial energy, MeV	5.0
Radius of injection, cm	27.0
Average magnetic field, T	1.2
Betatron frequencies: ν_r	1.01
ν_z	0.12
Orbital frequency, MHz	18.124
Phase width of the bunch (°RF)	20…30
Harmonic number	1
Number of accelerating gaps	2
Accelerating voltage, kV	37

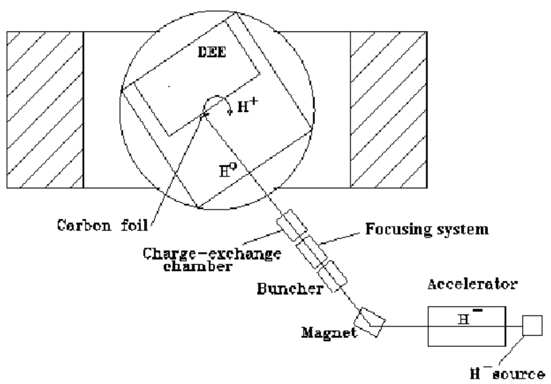

Fig.1. Scheme of the external injection

Some preliminary results concerning an efficiency of beam capture into acceleration not taking into account space charge effects were described earlier in [3, 4]. But at such high intensity of the injected beam it is necessary to know detailed information about an influence of the space-charge effects (SCE) on the particle dynamics.

More detailed investigation showed that the injection efficiency taking into account the SCE [5] is equal 49.2% (Fig.2). After 3,000 turns, 5,080 particles out of 10,000 injected ones were lost mainly due to vertical losses. It is seen in Fig.3 that the vertical losses take place mainly near injection energy.

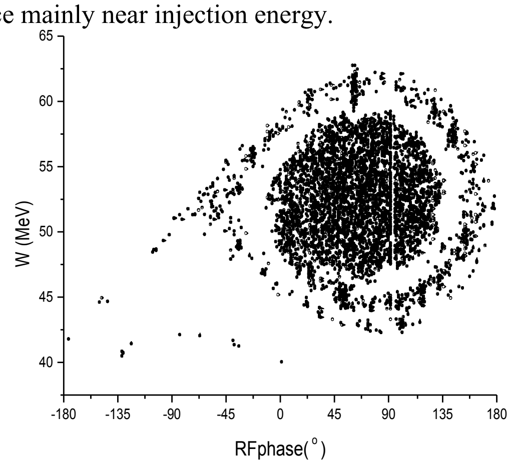

Fig.2. Position of 4,923 particles captured into acceleration on a plane (W-RFphase)

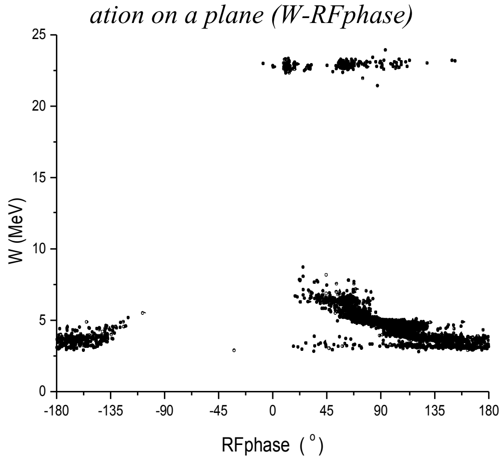

Fig.3. Position of 4,000 vertically lost particles on a plane (W-RFphase)

2. COMPUTER SIMULATION OF THE BEAM ACCELERATION UP TO ENERGY 660 MeV

Investigation of the beam acceleration process up to the final energy has two main objectives:

- to study the beam losses during the acceleration process;

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- to determine the beam quality (emittances, energy spread) at the end of acceleration before the beam extraction.

Due to the small energy gain in the Phasotron (near 25 keV per turn) the acceleration process continues for 37,000 turns. To have appropriate computer time consumption we have used in our calculations only 2,000 particles (instead of 4,920) and did not take into account space charge effects. Even with these conditions and using PC with 2 GHz processor the time consumption was about 120 hours.

These 2,000 particles used in calculation were chosen from the 4,920 captured into acceleration ones by the uniform random selection. Main results of calculations are shown in Fig.4-11.

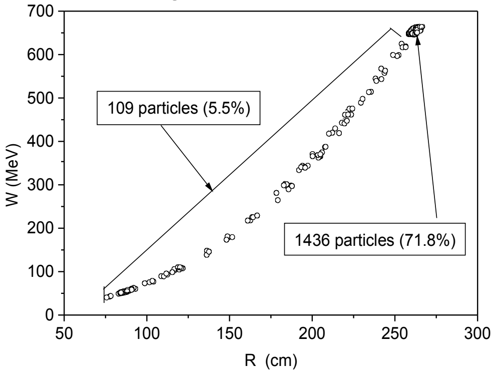

Fig.4. Final particles position on a plane (R-W)

It is seen from Fig.4 that the phase losses are distributed uniformly along the all acceleration cycle. Number of particles inside separatrix is equal to 1,436 (71.8% of 2,000).

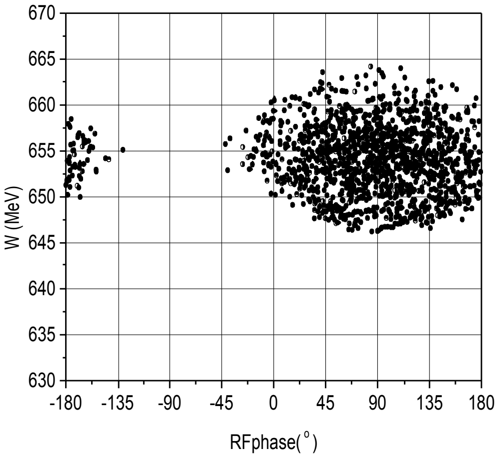

Fig.5. Final particles position on a plane (W-RFphase)

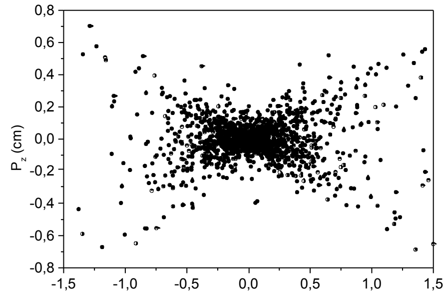

Fig.6. Final particles position on a vertical phase plane

The Fig.6 illustrates the vertical position and angle of each particle at the end of acceleration, which are entirely determined by the vertical free oscillations.

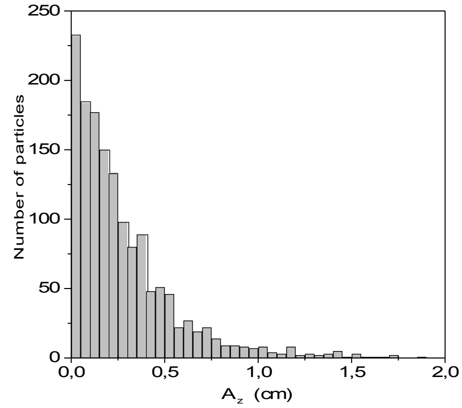

Fig.7. Final distribution of the particles vertical amplitudes

The amplitude distribution of these oscillations is shown in Fig.7. More than 95% of particles have vertical amplitudes less than 1 cm.

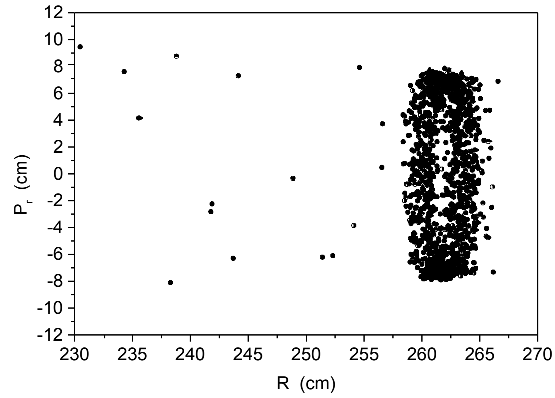

Fig.8. Final particles position on a radial phase plane

The radial particles position (Fig.8) is determined not only by the free oscillations but also by the synchrotron oscillations. A special procedure was used to separate the free oscillations amplitude. Free oscillation amplitude distribution at the end of acceleration is shown in Fig.9. Main part of the particles has the amplitudes less than 1 cm.

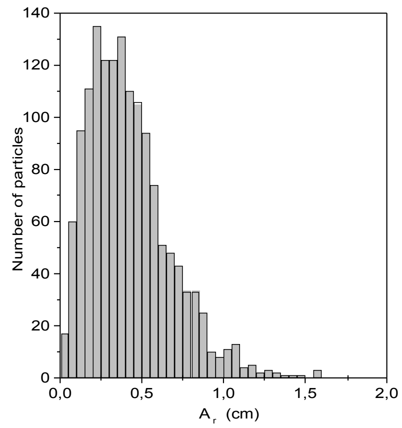

Fig.9. Final distribution of free radial oscillation amplitudes

In Fig.10 it is shown the distribution of the vertical beam losses on radius and in Fig.11 a dependence of the free oscillations frequencies on radius. It is evident the coincidence of the maximum beam losses radial position showed in Fig.10 and minimum of the vertical oscillation frequency Q_z (Fig.11).

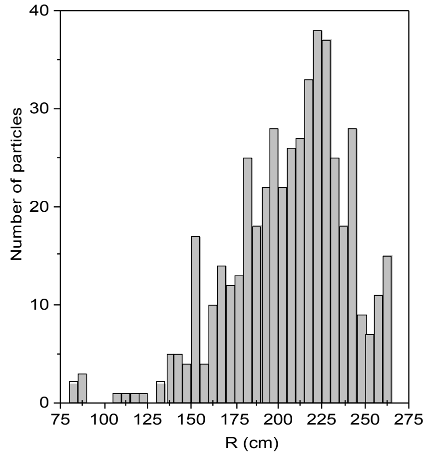

Fig.10. Vertical losses dependence on radius

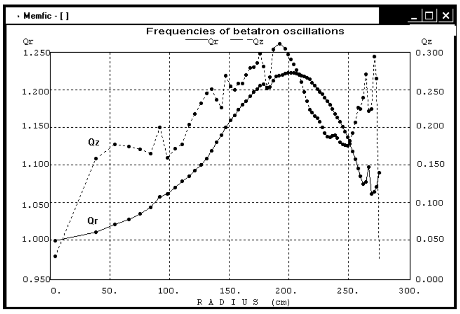

Fig.11. Free oscillation frequency dependence on radius

3. CONCLUSIONS

Computer simulation of the beam dynamics along the whole acceleration cycle demonstrates the almost 28% of beam losses including the 22.7% vertical losses and the 5.5% phase losses. The final beam intensity is equal 21.5 μA as follows from this simulation. The vertical beam losses along acceleration could be avoided by increasing the vertical oscillation frequencies within the (200…250) cm radial range.

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КОМПЬЮТЕРНОЕ МОДЕЛИРОВАНИЕ ДИНАМИКИ ПУЧКА В ФАЗОТРОНЕ ОИЯИ ДО ЭНЕРГИИ 660 МэВ

Л.М. Онищенко, Е.В. Самсонов

Проект увеличения интенсивности пучка протонного Фазотрона ОИЯИ на энергию 660 МэВ с помощью внешней инжекции H^- ионов с энергией 5 МэВ находится в стадии разработки. Процесс инжекции пучка был исследован ранее. В настоящее время проводятся исследования ускорения пучка до конечной энергии. Обнаружено, что потери пучка существуют вдоль всего цикла ускорения.

КОМП'ЮТЕРНЕ МОДЕЛЮВАННЯ ДИНАМІКИ ПУЧКА У ФАЗОТРОНІ ОІЯД ДО ЕНЕРГІЇ 660 МеВ

Л.М. Онищенко, Є.В. Самсонов

Проект збільшення інтенсивності пучка протонного фазотрона ОІЯД на енергію 660 МеВ за допомогою зовнішньої інжекції H^- іонів з енергією 5 МеВ перебуває в стадії розробки. Процес інжекції пучка був досліджений раніше. Зараз проводяться дослідження прискорення пучка до кінцевої енергії. Виявлено, що втрати пучка існують уздовж усього циклу прискорення.