BEAM DYNAMICS SIMULATION WITH THE USE OF MACROPARTICLE «PROTON» CODE IN DIFFERENT VARIANTS OF INPUT DYNAMICAL MATCHERS IN A HEAVY ION HIGH CURRENT RFQ STRUCTURE

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Beam dynamics simulations with the use of macroparticle method were performed for two cases of input dynamical matchers for RFQ. It is done a comparison with data obtained from the envelope equations. These simulation results are in agreement with other simulation and theoretical ones.

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1. INTRODUCTION

Beam dynamics simulations with the use of macroparticle PROTON code [1] were performed for two input dynamical matchers with different electrode profiles for KV and Gauss initial particle distributions. The first case, "RM37", was optimized for a beam current 55 mA and the second one, "IRM37-400", was optimized for the current 400 mA. Both cases with monotonous electrode profiles were developed with the use of modernized ABC code [2,3] to provide reduced slopes of input matched beam envelopes. The "IRM37-400" matcher provides almost constant value of dynamical matching coefficient and low sensitivity to difficult controlled initial site of a fringe field within a wide range of beam currents.

The simulations were performed using 5000 macroparticles in one central bunch and two virtual neighboring ones. Statistics includes 100% of the particles. Space charge forces were calculated with the use of a particle-particle method and a fast two-level-tree algorithm. Integration of motion equations was evaluated by the Runge-Kutta scheme of 4-th order involving 200 steps of integration during one RF period. The testing channel consists of 39 RFQ cells with 12 matching ones and analytical set of field. The main parameters of .RFQ [4] are shown in Table 1.

***Table 1**. Main parameters of RFQ-GSI*

Ions	U^{+4}, U^{+3}
Input beam current (U^{+4}), mA	37
Input beam current (U^{+3}), mA	18
Full beam current, mA	55
Beam charge neutralization in LEBT, %	100
Beam energy (U^{+4}), keV/u	2.2
Full energy of ion (U^{+4}), MeV	0.52
Input beam emittance, mm.mrad	330

2. BEAM DYNAMICS WITH KV DISTRIBUTION

The results of beam dynamics simulation for initial KV distributions are shown in Figs.1-4.

"IRM37" "IRM37-400"

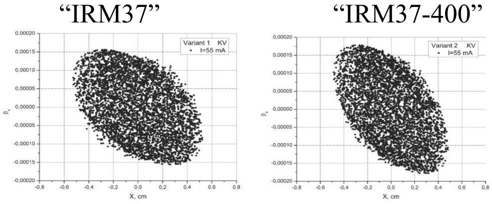

Fig.1. Input emittances

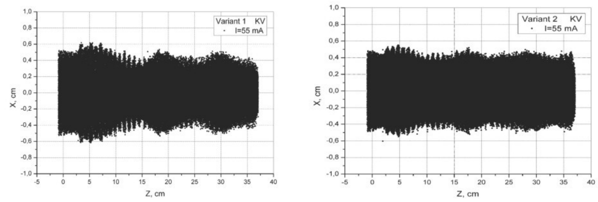

Fig.2. Beam envelopes in plane X

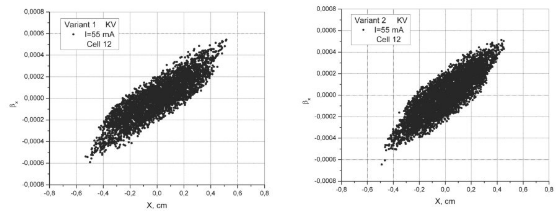

Fig.3. Output emittances in plane X

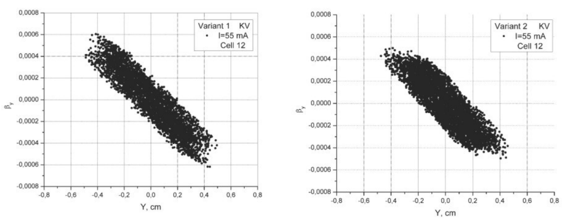

Fig.4. Output emittances in plane Y

3. BEAM DYNAMICS WITH GAUSS DISTRIBUTION

The results of beam dynamics simulation for initial Gauss distribution are shown in Fig.5-8 for "IRM37" and "IRM37-400" matchers.

"IRM37" "IRM37-400"

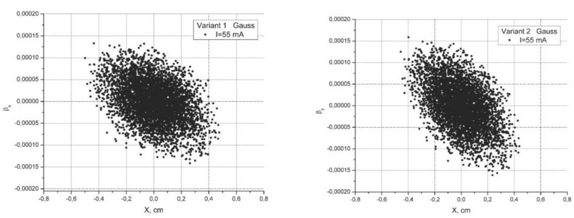

Fig.5. Input emittances

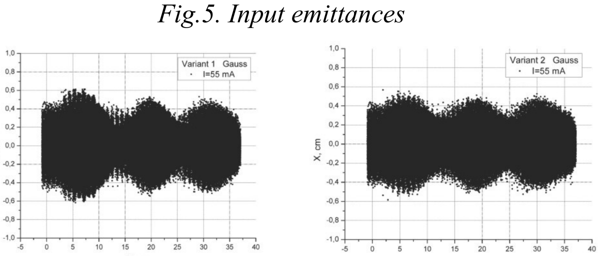

Fig.6. Beam envelopes in plane X

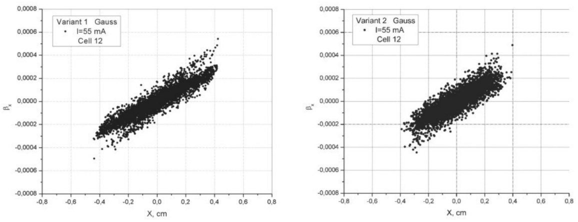

Fig.7. Output emittances in plane X

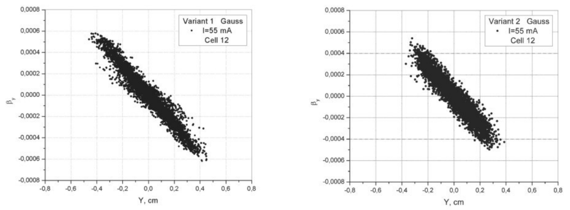

Fig.8. Output emittances in plane Y

4. OUTPUT TWISS PARAMETERS

The parameters of beam emittance obtained from simulations and matched parameters, calculated with the use of ABC program, for both cases of dynamical matchers are shown in Table 2 and Table 3. The matching coefficients, calculated according to Kapchinsky method [5], are shown in Table 4 and Table 5.

***Table 2**. Twiss parameters for IRM output*

KV	IRM37	IRM37-400	Matched
α_x	2.254	1.771	1.90
α_y	-1.397	-1.539	-1.90
β_x	0.003882	0.003569	0.00421
β_y	0.003697	0.003395	0.00421

***Table 3**. Twiss parameters for IRM output*

Gauss	IRM37	IRM37-400	Matched
α_x	3.607	2.417	1.90
α_y	-1.301	-1.237	-1.90
β_x	0.005606	0.004135	0.00421
β_y	0.004760	0.003751	0.00421

***Table 4.** Input matching coefficients*

Units	IRM37		IRM37-400	
	k_x	k_y	k_x	k_y
KV	1.170	1.173	1.170	1.173
Gauss	1.040	1.008	1.040	1.008

***Table 5.** Output matching coefficients*

Units	IRM37		IRM37-400	
	k_x	k_y	k_x	k_y
KV	1.686	1.372	1.271	1.240
Gauss	2.564	2.194	1.732	1.636

Current density is generated up to ≈780 mA/cm·mrad for KV beam and ≈1990 mA/cm·mrad for Gauss beam. Required current rms density is 768 mA/cm·mrad.

The results from PROTON code simulations are in agreement with the results obtained by DYNAMION code [6,7] and other theoretical data.

5. EMITTANCE GROWTH AND BEAM TRANSMISSION

The results for rms emittances and beam losses, obtained from beam dynamics simulation for initial KV and Gauss distributions are shown in Figs.9-12 for "IR-M37" and "IRM37-400" matchers. The dependences of beam transmission and output beam current on input beam current for "IRM37" and "IRM37-400" matchers for KV beam are shown in Fig.13 and Fig.14.

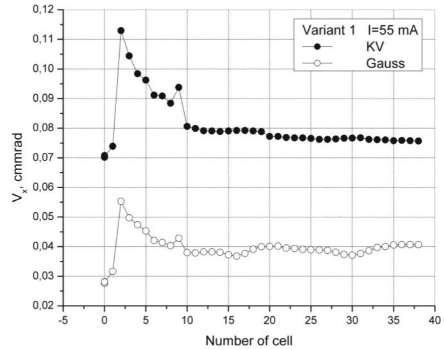

Fig.9. Normalized rms emittances in plane X for "IR-M37" matcher

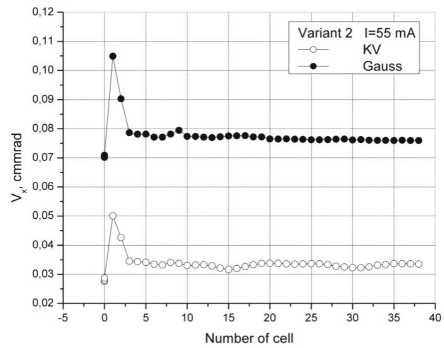

Fig.10. Normalized rms emittances in plane X for "IRM37-400" matcher

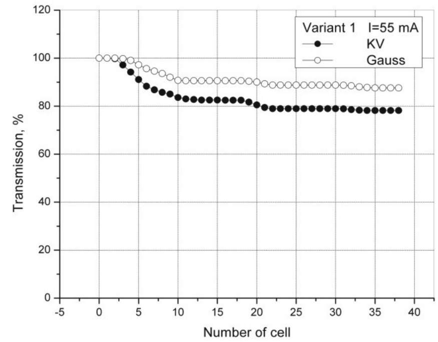

Fig.11. Beam transmission for "IRM37" matcher

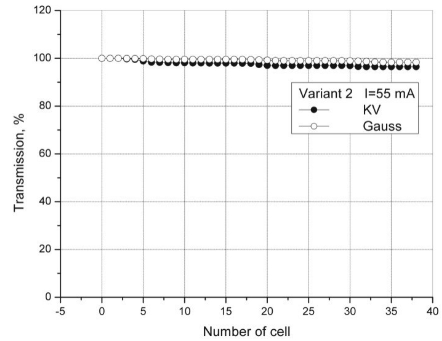

Fig.12. Beam transmission for "IRM37-400" matcher

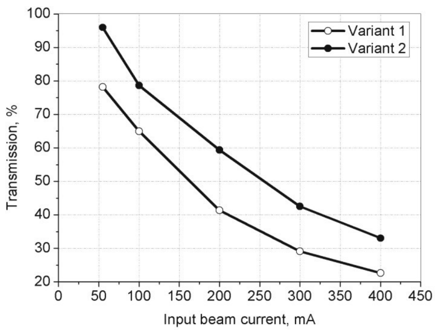

Fig.13. Dependences of beam transmissions on input beam current for "IRM37" and "IRM37-400" matchers for KV beam

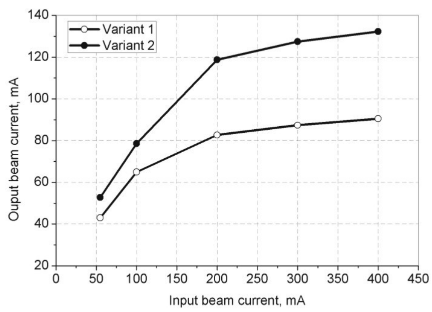

Fig.14. Dependences of output beam currents on input beam current for "IRM37" and "IRM37-400" matches for KV beam

6. CONCLUSION

The beam dynamics simulations with the use of the macroparticle method and the PROTON code were performed for two cases of input dynamical matchers for RFQ for KV and Gauss beams. The comparison with data obtained from the envelope equations and by DYNAMION code simulations, has shown that the results from simulations with the use of PROTON code are in agreement with others. Twiss parameters for KV beam are close to the theoretical values calculated for a beam current of 55 mA. To obtain better agreement between calculated and theoretical data, a special procedure for initial particle distribution generation is required. This procedure will provide exact initial matching conditions according to required current density and investigations of beam matching for different initial distributions. The second case of matcher, optimized for beam current of 400 mA, has improved dynamics for all the parameters under investigation including reduced sensitivity for initial particle distributions with respect to the first case. Further improvement of beam dynamics in high current region requires special optimization procedure for reducing emittance growth and particles losses, which may be realized by joining ABC and PROTON codes into one program.

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ЧИСЛЕННОЕ ИССЛЕДОВАНИЕ ДИНАМИКИ ПУЧКА МЕТОДОМ КРУПНЫХ ЧАСТИЦ С ИСПОЛЬЗОВАНИЕМ ПРОГРАММЫ «PROTON» В РАЗЛИЧНЫХ ВАРИАНТАХ ВХОДНОГО ДИНАМИЧЕСКОГО СОГЛАСОВАТЕЛЯ В ТЯЖЕЛОИОННОЙ СИЛЬНОТОЧНОЙ СТРУКТУРЕ ПОКФ

И.А.Воробьёв

Численное исследование динамики пучка методом крупных частиц выполнено в двух вариантах входного динамического согласователя для ПОКФ. Сделано сравнение с данными, полученными по уравнениям для огибающих. Результаты численного моделирования находятся в соответствии с данными других расчётов.

ЧИСЕЛЬНЕ ДОСЛІДЖЕННЯ ДИНАМІКИ ПУЧКА МЕТОДОМ ВЕЛИКИХ ЧАСТОК З ВИКОРИСТАННЯМ ПРОГРАМИ «PROTON» У РІЗНИХ ВАРІАНТАХ ВХІДНОГО ДИНАМІЧНОГО УЗГОДЖУВАЧА У ВАЖКОІОННІЙ ПОТУЖНОСТРУМОВІЙ СТРУКТУРІ ПОКФ

І.А.Воробйов

Чисельне дослідження динаміки пучка методом великіх часток виконано у двох варіантах вхідного динамічного узгоджувача для ПОКФ. Зроблено порівняння з даними, отриманими по рівняннях для обгинаючих. Результати чисельного моделювання відповідають даним інших розрахунків.