DEVELOPMENT OF LEBT AND BEAM DYNAMICS STUDY IN AN INITIAL RFQ PART (INPUT RADIO MATCHER) FOR A HEAVY ION HIGH CURRENT GSI-HSI-RFQ

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Different variants of the LEBT for a Heavy Ion RFQ (GSI-UNILAC) were numerically investigated. The requirements for initial matching conditions for the RFQ structure have been defined. The optimization of an unmodulated input radio matcher (IRM) with a lowed slope of beam envelope was carried out with the use of the optimizing code ABC developed. The beam dynamics simulation with the use of the method of macroparticles was performed for the input radio matcher in comparison with the codes DYNAMION and PROTON. The comparison with data obtained from envelope equations and simulations was carried out.

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1. LEBT DEVELOPMENT

The LEBT development was made for different variants of the input radio matchers with different initial matching conditions taking into account an emittance growth in the LEBT and sensitivity for initial Twiss parameters of beam and particles distributions at the matcher entrance after the LEBT.

1.1. MAIN PARAMETERS OF GSI-HSI-RFQ

The main parameters of the RFQ [1] are presented in Table 1.

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

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 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

1.2. MATCHING CONDITIONS IN DIFFERENT VARIANTS OF INPUT RADIO MATCHERS

Different profiles for the IRM rods are shown in Fig.1. The parameters of beam emittance and matching parameters for different variants of dynamical matchers, calculated with the ABC program [2,3], are shown in Fig.2 and Table 2.

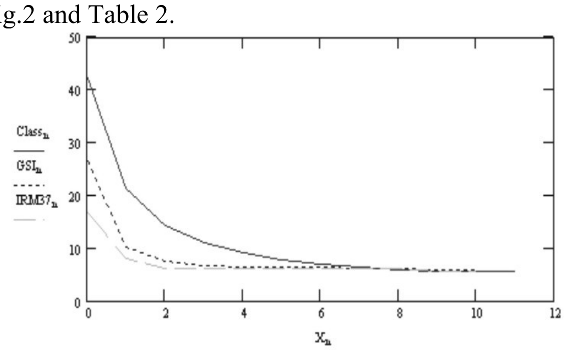

Fig.1. Profiles for the rods of the IRM matcher

The “IRM37” matcher with a monotonous electrode profile was specially developed with the use of the modernized code ABC [3] to provide reduced slopes of matched beam envelopes.

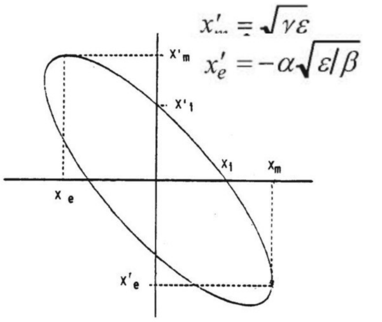

Fig.2. Parameters of beam emittance

***Table 2**. Matching parameters for IRM entrance*

IRM	Classic	GSI	IRM37
Current (U+4), mA	55	55	55
$\varepsilon_{x,y}$, mm mrad	330	330	330
$\alpha_{x,y}$	3.24	1.161	0.75
$\beta_{x,y}$, mm/mrad	0.25	0.115	0.0995
X\`m, Y\`m (mrad)	119.5	82.2	72.1
X\`e, Y\`e (mrad)	114.5	62.3	37.3

1.3. OPTIMIZATION OF THE LEBT WITH THE USE OF THE TRACE-3D CODE

The LEBT optimization was performed with the use of the TRACE-3D code for initial matching conditions calculated for different matchers. Two basic schemes were developed. The first one includes four quadrupoles, the second one includes only one solenoid. The results are presented in Fig.3 and Fig.4 for the “IRM37” matching conditions and in Table 3 and Table 4 as well. As it can be seen from Table 4, the “IRM37” matcher in the scheme with one solenoid has an advantage in a shorter length of the LEBT and less maximal envelope size.

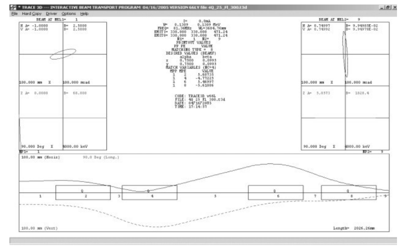

Fig.3. Beam dynamics in the scheme with four quadrupoles

Table 3*. Main parameters of LEBT (4 quadrupoles)*

IRM	Classic	GSI	IRM37
Length of LEBT, mm	1654.2	1618.3	2026.3
R_{max} , mm	100.8	77.6	87.5
Quadr. Length, mm	300		
Max Gradient, T/m	10		

In this table, R_{max} is the maximal size of the beam envelope.

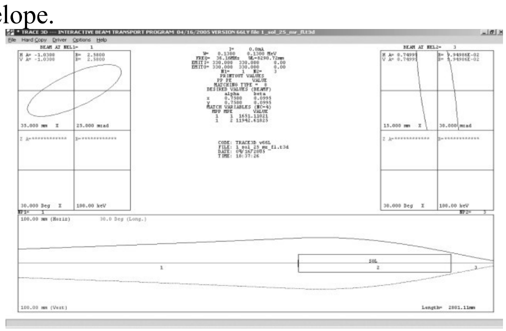

Fig.4. Beam dynamics in the scheme with one solenoid

2. BEAM DYNAMICS STUDY IN THE INPUT RADIO MATCHER "IRM37" DEVELOPED

The beam dynamics simulation was carried out with the use of the DYNAMION code [4, 5] for a beam current 55 mA and 5,000 macroparticles. In the last version of the code, a possibility of field calculation on a 3D grid was introduced. The necessary parameters of rods were set automatically in the ABC code after the matcher optimization. Simulations were made for KV and Gaussian initial particle distributions. A mismatch coefficient was calculated according to the ref. [6]. The results are presented in Figs.5-8.

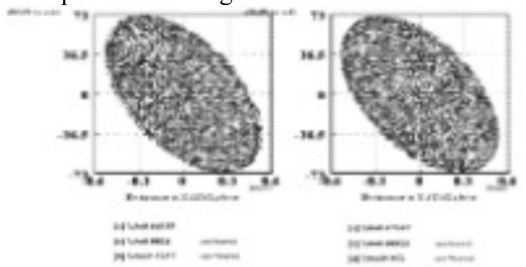

Fig.5. Initial phase space ellipses

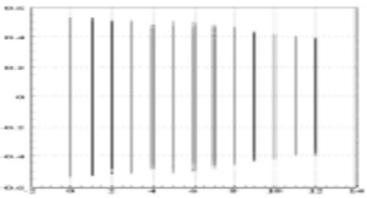

Fig.6. Envelope in IRM37" matcher

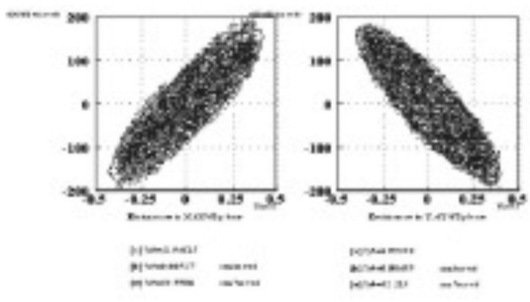

Fig.7. Phase portraits after the "IRM37" matcher (KV distribution). Emittance growth – 14.9%. Mismatch coeff. – 1.46

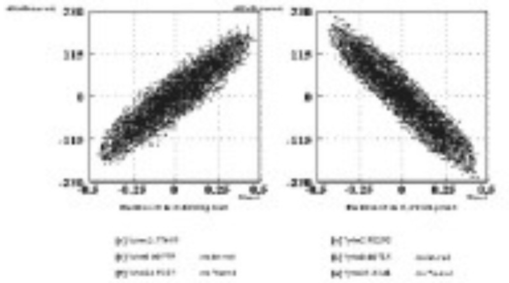

Fig.8. Phase portraitures after the "IRM37" matcher. (Gauss distribution). Emittance growth – 7.9%. Mismatch coeff. – 1.9

The data processing was performed for 90% of macroparticles. The transmission for both particle distributions is 100%. As it is follows from the results presented, the simulations with the DYNAMION code are in an agreement with the PROTON code results [7] and theoretical data.

3. BEAM DYNAMICS STUDY IN THE LEBT FOR DIFFERENT INITIAL MATCHING CONDITIONS

3.1. BEAM DYNAMICS IN THE LEBT FOR THE INPUT RADIO MATCHER "IRM37"

The results of beam dynamics simulation with the DYNAMION code for a beam current 55 mA in the LEBT with one solenoid, optimized for the "IRM37" matching conditions, are shown in Fig.9. As it can be seen from these results, the emittance growth in the LEBT (214%) is very high.

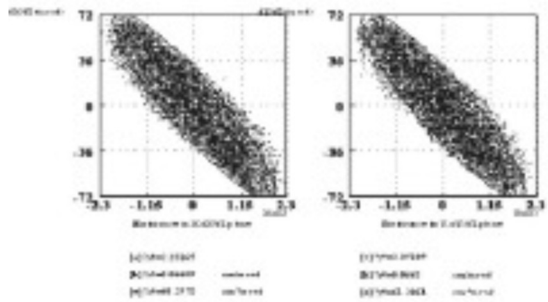

Fig.9. Phase portraits after LEBT for "IRM37" matcher. Emittance growth – 214%

3.2. BEAM DYNAMICS IN THE SHORT LEBT WITH ONE SOLENOID

According to the simulation results for the "IRM37" matching conditions it is necessary to develop a LEBT with a reduced emittance growth and formulate required initial conditions for the next IRM. The results obtained are shown in Figs.10-11 and Table 4.

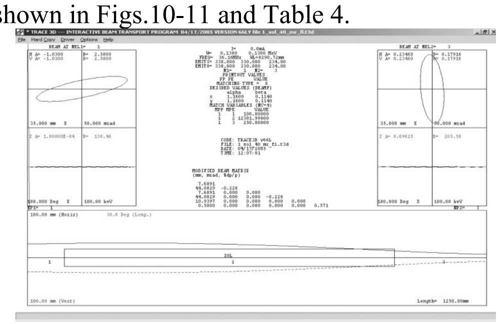

Fig.10. Beam dynamics in the short LEBT with one solenoid

Table 4. Main parameters of LEBT (1 solenoid)

IRM	Classic	GSI	IRM37	44 mrad
Length of LEBT, mm	4734.8	2913.2	2801.1	1250.0
R_{max}, mm	84.6	55.88	52.85	31.4
Solenoid Length, mm	750	800	900	900
Max Field, T	1.29	1.28	1.2	1.2

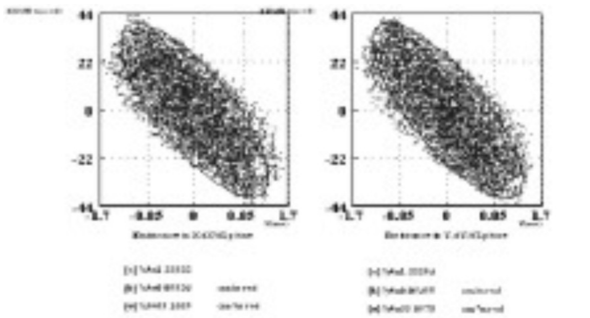

Fig.11. Phase portraits after the short LEBT for the "44 mrad" matcher. Emittance growth – 18%

As it can be seen from these results, the emittance growth in the LEBT was reduced down to 18%. But this result has required a low maximal emittance angle of 44 mrad that is near to a beam crossover.

4. CONCLUSION

The investigations of the different variants of the LEBT for the Heavy Ion RFQ (UNILAC) with the TRACE-3D code showed that for reducing the emittance growth in the LEBT it is necessary to have a beam crossover at the RFQ entrance. The electrode profiles of the input RFQ matcher with such properties may differ from traditional ones. The beam dynamics simulations for the "IRM37" dynamical matcher with the method of macroparticles in the code DYNAMION are in an agreement with the theoretical results, obtained from the envelope equations, and with the results from the code PROTON.

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РАЗРАБОТКА LEBT (СИСТЕМЫ ТРАНСПОРТИРОВКИ ПУЧКА НИЗКОЙ ЭНЕРГИИ) И ИССЛЕДОВАНИЕ ДИНАМИКИ ПУЧКА В НАЧАЛЬНОЙ ЧАСТИ СТРУКТУРЫ ПОКФ (ВХОДНОМ ДИНАМИЧЕСКОМ СОГЛАСОВАТЕЛЕ) ДЛЯ ТЯЖЕЛОИОННОГО СИЛЬНОТОЧНОГО УСКОРИТЕЛЯ GSI С ПОКФ

И.А. Воробьёв, В.И. Першин, Т.Е. Третьякова, С.А. Высоцкий, С.Г. Ярамышев, W. Barth

Численно исследованы различные варианты LEBT для сильноточного ускорителя с ПОКФ (UNILAC). Определены требования к начальным согласованным условиям в структуре ПОКФ. Оптимизация немодулированного входного динамического согласователя со сниженным углом наклона огибающей пучка выполнена с применением разработанной программы ABC. Численное моделирование динамики пучка методом крупных частиц сделано во входном динамическом согласователе в сопоставлении по программам DYNAMION и PROTON. Сделано сравнение с данными, полученными по уравнениям для огибающих и численного моделирования.

РОЗРОБКА LEBT (СИСТЕМИ ТРАНСПОРТУВАННЯ ПУЧКА НИЗЬКОЇ ЕНЕРГІЇ) І ДОСЛІДЖЕННЯ ДИНАМІКИ ПУЧКА В ПОЧАТКОВІЙ ЧАСТИНІ СТРУКТУРИ ПОКФ (ВХІДНОМУ ДИНАМІЧНОМУ УЗГОДЖУВАЧІ) ДЛЯ ВАЖКОІОННОГО ПОТУЖНОСТРУМОВОГО ПРИСКОРЮВАЧА GSI З ПОКФ

І.А. Воробйов, В.І. Першін, Т.Е. Трет'якова, С.А. Висоцкій, С.Г .Ярамишев, W. Barth

Чисельно досліджені різні варіанти LEBT для потужнострумового прискорювача з ПОКФ (UNILAC). Визначено вимоги до початкових узгоджених умов у структурі ПОКФ. Оптимізація немодульованого вхідного динамічного узгоджувача зі зниженим кутом нахилу обвідна пучка виконана із застосуванням розробленої програми ABC. Чисельне моделювання динаміки пучка методом великих часток зроблено у вхідному динамічному узгоджувачі в зіставленні по програмам DYNAMION і PROTON. Зроблено порівняння з даними, отриманими по рівняннях для обвідних і чисельного моделювання.