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FRAGMENT-SEPARATOR AT THE U-400 CYCLOTRON (The Technical Proposal)

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During the last years the main interest in Radioactive Ion Beam experiments has been shifted to the intermediate and high energy region, since in these experiments RIB are produced mainly using projectile fragmentation reactions. Thus the traditional nuclear reaction studies in the vicinity of the Coulomb barrier are scarce as for the use of RIB. But many reaction mechanism investigations made in the energy region below 20 AMeV show rather high yields of exotic nuclei [1 - 3]. These results make it possible to hope that such experiments at the Coulomb barrier of the interactions with RIB can be performed in the same manner, as with accelerated beams of stable nuclei.

The possibility of RIB experiments close to the Coulomb barrier proposed here is based on the high beam intensity of the U-400 cyclotron and on the available at its switchyard experimental set-up for precise study of nuclear reactions, namely the charged particle magnetic spectrometer MSA (SP-95 magnet) [4]. The low energy fragment-separator for the exotic nuclides separation could be created on the basis of this spectrometer.

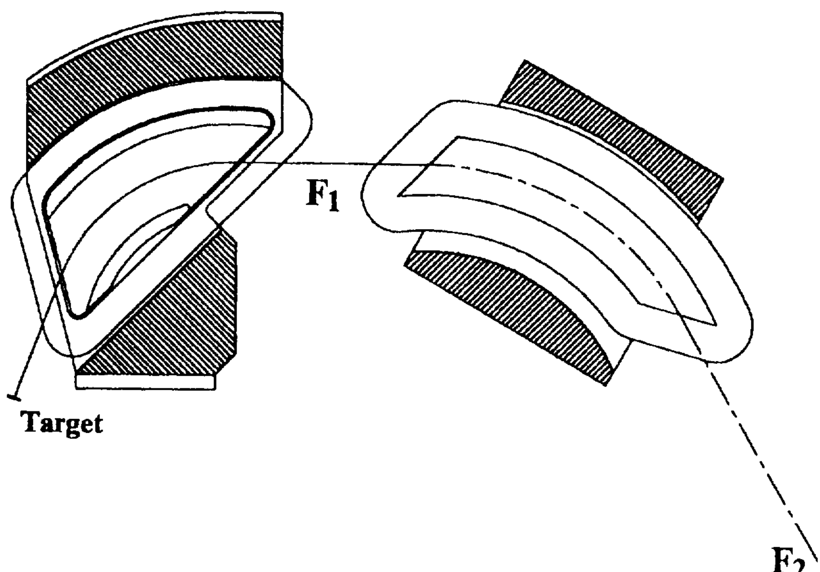

Fig.1 The plot of the proposal fragment-separator

The MSA spectrometer has a resolving power of about 10^{-3} having an angular acceptance of 3 msr and a momentum acceptance of 20% with a focal plane length of 30 cm. The momentum dispersion of the spectrometer is 1.255 cm/% with the bending angle of the central particle trajectory of 70° and the bending radius of 1.26 m. The horizontal magnification in the dispersive plane is about 0.45, the vertical magnification - about 4. The focal plane of the spectrometer is located at the angle of about 60° with respect to the central particle trajectory.

The angular acceptance of the spectrometer may be increased by a factor of about 2 by means of shortening the entrance spectrometer drift space between the target and the magnetic field boundary. With this increase of the solid angle the resolving power of the spectrometer deteriorates only slightly.

The dispersion of the spectrometer could be compensated by means of the available SP-97 bending magnet installed at the MSA exit as it is shown in Fig. 1. The SP-97 magnet has a particle trajectory deflection angle of about 60° with the bending radius of 2 m, therefore the whole separator, built with these two magnets became only nearly symmetrical due to the difference in deflection angles and bending radii. For this reason the compensation of the dispersion is not complete. The resulting dispersion at the final focus of such separator could be of about 0.3 cm/% in momentum. The angular dispersion at this focal point is still rather large - of about 20 mr/%.

Some asymmetry takes place also in the vertical focussing: The vertical focussing in the SP-95 magnet is accomplished by means of pole faces rotation to the angle of $61^{\circ}30'$ at the entrance and of $-43^{\circ}48'$ at the exit of magnetic gap. For the SP-97 magnet these angles need to be of about 45° and of about -60° correspondingly. But the asymmetry in the horizontal plane seems to be more important, causing an additional aberrations. The compensation of the most important aberrations could be accomplished by the proper shaping of the curvature of the entrance and the exit faces of SP-97 magnet pole pieces or/and the additional multipole element introducing into the separator. The higher order calculations will clarify this problem.

The ion-optical properties of the separator at the intermediate dispersive focal point F1 between dipole magnets are determined by the SP-95 dipole. With the dispersion of 1.255 cm/% and the horizontal magnification of about 0.45 the first order resolving power of the separator in momentum would be about $3.6 \cdot 10^{-3}$. But for the most experiments with the RIB the main problem is the RIB intensity when the resolving power is desirable but often is not obligatory. Moreover, the FLNR has an another possibility for precise nuclear experiments in the vicinity of the Coulomb barrier, including the experiments with RIB [5].

Taking solid angle efficiency of about 6 msr and momentum acceptance efficiency of 20%, this separator became comparable with the COMBAS separator [6]. Having the magnetic rigidity of the particles to be analyzed of about 2 Tm, that corresponds to the AE/q^2 value of about 200, it will supplement the COMBAS performance at the lower energy region.

The separator will be installed at 0° or at some forward angle with respect to the primary beam, so as to achieve compromise conditions between the maximum RIB yield and the minimum of background contaminations from the primary beam particles. The optimal RIB production target for the separator is 5 cm in width and 0.5 cm in

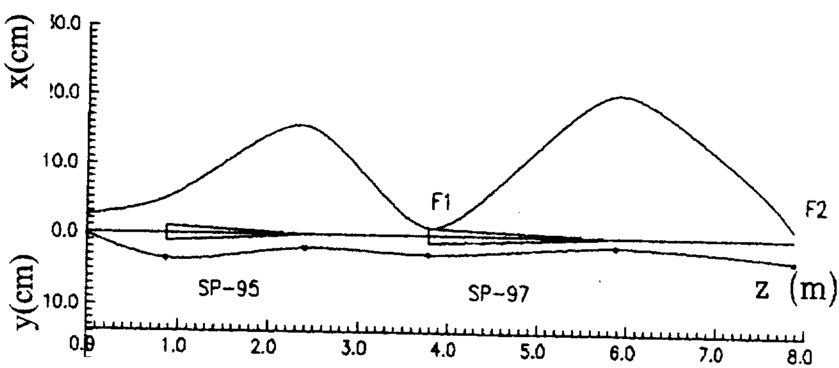

Fig. 2. Envelopes of the ion beam trajectories in the separator in the horizontal X and the vertical Y planes for the production target dimensions 5x0.5 cm and the angular acceptances $\Delta\Theta = \pm 50$ mr and $\Delta\varphi = \pm 30$ mr.

hight. With such producing target dimensions its luminosity and the overall separator transmission will be much higher than in the case of the circular target. The physical target and detectors of the RIB reaction products are placed at the final quasiachromatic focal point. The magnification coefficient of the whole separator in the horizontal plane is about 0.5, in the vertical plane - about 10. Thus, the producing target image at the final focus will be the spot with about 3x5 cm dimensions, covering the total momentum acceptance of the separator.

The envelopes of ion beam trajectories in the proposed separator are shown in Fig. 2.

For the separation of heavy reactions products the vacuum chamber of the separator could be filled by the gas at low pressure for the equilibration of their ionic charge state distributions.

The main parameters of this SP-95-SP-97 separator are listed at the Table in comparison with that of the COMBAS separator [5] and the separator on the basis of the U-400 beam downing and commutation system (DCS) [6].

Table

Parameter	COMBAS	SP-95-SP-97	DCS
Magnetic rigidity Bρ [Tm]	4.6	2	1.3
Solid angle Ω [msr]	6.4	6	4
Momentum acceptance [%]	20	20	5
Resolving power Rp/Δp	4360	2800	2900
Total length [m]	14.5	7.8	9

Resume

The ion-optical calculations together with graphical modeling show some possibility to create the low-energy fragment-separator for the RIB experiments performing at the Coulomb barrier of interactions at the U-400 cyclotron. Combination of two available magnetic dipoles SP-95 and SP-97 without any additional focussing elements at the cyclotron switchyard permits one to obtain the parameters of the RIB separator adequate for the modern experiments performance. Of course, the SP-97 magnet needs some improvement of its magnetic and ion-optical properties.

The ion-optical calculations of parameters of the separator were performed using the TRANSPORT computing code (version of 1975) [7] on the 386PC/AT computer. Graphical modeling was made on the SUNSPARCstation [8] in the AutoCAD environment [9].

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Майдиков В.З., Башевой В.В. E13-98-105
Фрагмент-сепаратор для циклотрона У-400
(Техническое предложение)

Проведенные ионно-оптические расчеты и графическое моделирование позволили предложить конструкцию низкоэнергетического электромагнитного фрагмент-сепаратора на пучке циклотрона У-400, состоящего только из двух магнитных диполей СП-95 и СП-97. Это позволит проводить ядерно-физические эксперименты с пучками радиоактивных ионов вблизи кулоновского барьера взаимодействия.

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Fragment-Separator at the U-400 Cyclotron
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The investigation has been performed at the Flerov Laboratory of Nuclear Reactions, JINR.

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