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ENERGY-LOSS SPECTROMETER FOR PRECISE RADIOACTIVE ION BEAM EXPERIMENTS IN THE VICINITY OF THE COULOMB BARRIER

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The energy-loss spectrometer – very effective set-up for precise nuclear reactions study based on magnetic analysis of primary beam and charged particle nuclear reaction products have been proposed. Based on existing magnetic analyzers, it may increase the magnetic spectrograph efficiency of about two orders of its value in comparison with achieved up to now with no loss of its resolving power.

During the last years the main interest in radioactive ion beam (RIB) 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.

The DRIBS project realization [1] will give rise to rather unique possibility of precise experiments with RIB can be performed in the same manner as with accelerated beams of stable nuclei. According to this project, the U-400 cyclotron serves as a post-accelerator of RIB produced at the U-400M cyclotron and at the MT-25 microtron.

Possibility for precise RIB experiments close to the Coulomb barrier proposed here is based on the available at the U-400 cyclotron switchyard experimental set-up for precise study of nuclear reactions, namely the broad-range magnetic spectrograph MSP-144 [2] (Fig. 1.).

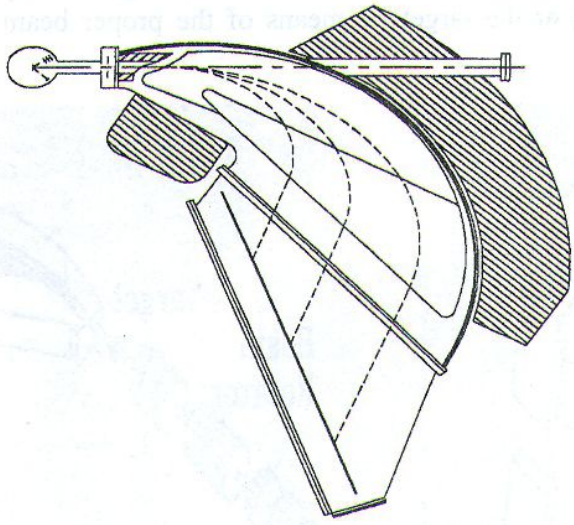

Fig. 1. Schematical view of the charged particle magnetic spectrograph MSP-144.

The MSP-144 spectrograph has a solid angle acceptance of about 5 msr and the momentum acceptance of 250 % with the focal plane length of 1.5 meter. The energy dispersion of the spectrograph is about 1 cm/%.

It is installed at the first floor of the U-400 beam switchyard. From the second floor the cyclotron beam to the spectrograph target is transported through the beam Downing and Commutation Set-up (DCS) [3]. The DCS consists of two 90° bending magnets, the lower one is rotatable around the vertical beam axis to direct the beam to either spectrograph ore to other set-ups

located on the first floor. The DCS could serve as a monochromator of accelerated beam directed onto the spectrograph target.

Last time in the experimental practice of precise nuclear reactions study by means of charged reaction products magnetic analysis often use the "dispersion matching" [4 – 6] between the beam monochromator and magnetic spectrometer. Such matching permits one to increase the overall efficiency by a few orders of magnitude remaining the main advantage of magnetic spectrometer – very high energy resolution.

But in our case, for the reason of the ortogonality of dispersive planes of monochromator and spectrograph the RIB passed through the DCS may be further focused onto the MSP-144 spectrograph target with beam intensity loss of about 90%. To avoid this loss it is necessary to realize the momentum loss operation mode by means of dispersion matching between the separator and the spectrograph. It may be realized by means of a beam rotator [7] introducing into the beam line between the DCS and the spectrograph (Fig. 2). The beam path length of about 15 m between the DCS and MSP-144 permits one to install in this path the needed focussing elements together with a beam rotator. Such rotator consists of five standard quadrupole lenses so as to turn the vertically oriented DCS dispersion plane to the horizontal plane, where the dispersion plane of the spectrograph is situated. In this way it is possible to use practically the total RIB energy and angular spread (even in the multiturn mode of the beam extraction from the cyclotron) for precise nuclear reaction experiments using the magnetic spectrograph, including the differential cross-sections measurements.

Moreover, such matching strongly eliminates (to a few orders of magnitude) the parasitic background of scattered particles at the spectrometer focal plane and other detectors by means no collimating using in the target vicinity.

Additional advantage of the monochromator – spectrometer matching is the arising opportunity for the compensation of the kinematic broadening of the spectrograph spectral line by the beam spot defocusing at the target by means of the proper beam line tuning for the better resolution obtaining.

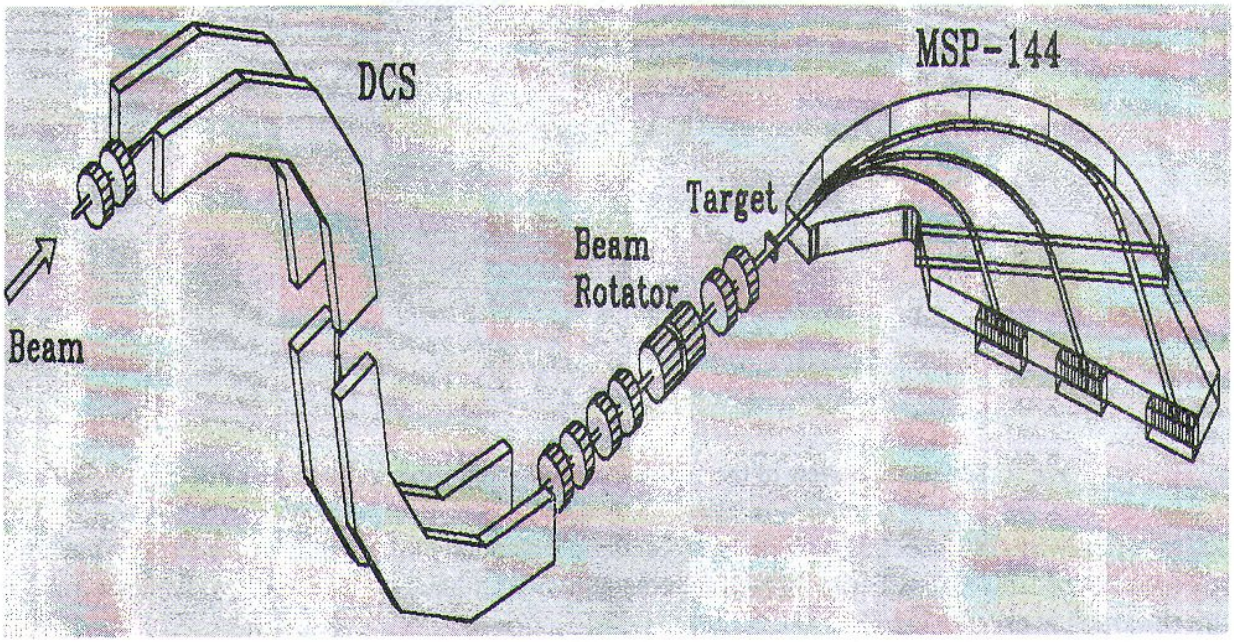

Fig. 2. The matching of the beam downing and commutation system with the spectrograph.

The overall resolving power of such a tandem will be better than 1000, which is determined by the DCS resolving power (higher order calculations will make its more accurate definition). The efficiency of this tandem depends on the matching quality of DCS and spectrograph parameters.

The dispersion matching of DCS and MSP-144 by means of a beam rotator introducing also allows one to increase the total spectrograph efficiency by a factor of about 100, in comparison with the efficiency achieved up to now, in traditional experiments with accelerated beams of stable nuclei. Moreover, the dispersion matching strongly simplifies the background problems at the spectrograph owing to no collimation used in the vicinity of the spectrograph target.

Such monochromator-spectrometer matching is very important for the rare events in nuclear reactions investigation, for precise ultrasensitive accelerator-based mass spectrometry (AMS) and in experiments with radioactive nuclei beams having low intensity and rather large energy spread.

Resume

Analysis of the ion-optical parameters of existing facilities for precise nuclear reactions experiments at the FLNR, JINR U-400 cyclotron beam switchyard shows that some improvements can be made to perform RIB experiments at the Coulomb barrier of interactions. A change in the position of a dozen guadrupole lenses at the cyclotron switchyard permits one to obtain parameters of magnetic spectrometer adequate to the modern experiments.

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СПЕКТРОМЕТР ВТРАТ ЕНЕРГІЇ ДЛЯ ПРЕЦИЗІЙНИХ ЕКСПЕРИМЕНТІВ З ПУЧКАМИ РАДІОАКТИВНИХ ІОНІВ ПОБЛИЗУ КУЛОНІВСЬКОГО БАР'ЄРА

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Запропоновано варіант створення спектрометра втрат енергії для проведення прецизійних експериментів з пучками радіоактивних іонів поблизу кулонівського бар'єра в рамках реалізації проекту ДПРІ (дубненські пучки радіоактивних іонів). Спектрометр втрат енергії реалізується на базі існуючих на циклотроні У-400 Лабораторії ядерних реакцій Об'єднаного інституту ядерних досліджень магнітних аналізуючих приладів: широкодіапазонного магнітного спектрографа МСП-144 і магнітів зниження й комутації пучка прискорювача шляхом відповідного узгодження їх іонно-оптичних параметрів. Таке узгодження дозволяє підвищити реальну ефективність спектрографа на два порядки, порівняно з раніше досягнутою, без погіршення його енергетичної роздільної здатності.

СПЕКТРОМЕТР ПОТЕРЬ ЭНЕРГИИ ДЛЯ ПРЕЦИЗИОННЫХ ЭКСПЕРИМЕНТОВ С ПУЧКАМИ РАДИОАКТИВНЫХ ИОНОВ ВБЛИЗИ КУЛОНОВСКОГО БАРЬЕРА

В. З. Майдиков

Предложен вариант создания спектрометра потерь энергии для проведения прецизионных экспериментов с пучками радиоактивных ионов вблизи кулоновского барьера в рамках реализации проекта ДПРИ (дубненские пучки радиоактивных ионов). Спектрометр потерь энергии реализуется на базе существующих на циклотроне У-400 Лаборатории ядерных реакций Объединенного института ядерных исследований магнитных анализирующих приборов: широкодиапазонного магнитного спектрографа МСП-144 и магнитов снижения и коммутации пучка ускорителя путем соответствующего согласования их ионно-оптических параметров. Такое согласование позволяет повысить реальную эффективность спектрографа на два порядка, по сравнению с ранее достигнутой, без ухудшения его энергетической разрешающей способности.