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V.Z.Maidikov*, V.V.Bashevoy, V.N.Melnikov

POSSIBLE MODERNIZATION OF THE U-400
CYCLOTRON FACILITIES TO PERFORM PRECISE
RIB EXPERIMENTS IN THE VICINITY
OF THE COULOMB BARRIER
(The Technical Proposal)

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*On leave from the Institute for Nuclear Research of the National Academy of Sciences of the Ukraine, Kiev, Ukraine

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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. Recent reaction mechanism investigations made in the energy region below 20 A MeV show rather high yields of exotic nuclei [1]. These results make it possible to hope that precise experiments with RIB can be performed in the same manner, as with accelerated beams of stable nuclei.

The precise RIB experiments close to the Coulomb barrier proposed here are based on the high beam intensity of the U-400 cyclotron and on that are available at its switchyard the two experimental set-ups for precise study of nuclear reactions, namely the magnetic spectrometer MSA (SP-95 magnet) [2] and the broad-range magnetic spectrograph MSP-144 [3] (Fig.1.). There are two ways of performing experiments in question.

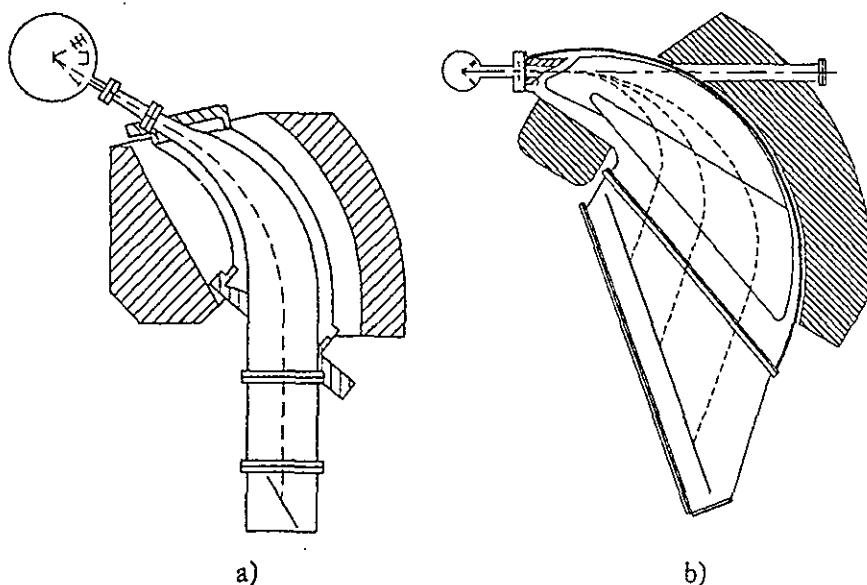


Fig. 1. Schematic view of the U-400M charged particle magnetic spectrometers: a) MSA (SP-95), b) MSP-144.

Both spectrometers belong to the same class of charged particle magnetic analyzers with the resolving power better than 10^{-3} but

with some difference in their angular and momentum acceptances. The MSA spectrometer has an angular acceptance of 3 msr and a momentum acceptance of 20% with a focal plane length of 30 cm. The MSP-144 has an angular acceptance of 5 msr and the momentum acceptance of 250% with the focal plane length of 1.5 meter. Both analyzers are installed at the first floor of the U-400 switchyard. From the second floor the beam of the cyclotron to both analyzers targets is transported through the beam Down and Commutation Set-up (DCS) [4]. The DCS consists of two 90° bending magnets, the lower one is rotatable around the vertical beam axis to direct the beam to either spectrometer or to the other set-ups located on the first floor.

The two ways of performing precise RIB experiments are defined by the location of the RIB-producing target.

In the first case, the RIB producing target is installed at the entrance of the one of the above mentioned spectrometers, which in turn provides the RIB separation in the dispersive mode of separation. The MSA spectrometer is more preferable to be used in such mode of the RIB separation, because it has the magnetic gap twice bigger and the magnetic rigidity of analyzing particles 1.5 times higher than MSP-144. 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. Taking solid angle efficiency of about 6 msr and momentum acceptance efficiency of 20%, the MSA having dispersive mode of operation became comparable with the COMBAS separator [5]. The spectrometer is installed at 0° or at a small forward angle so as to achieve the compromise condition between the maximum RIB yield and the background problems. The physical target and detectors of the RIB reaction products are placed at the spectrometer focal plane. The energy dispersion of the spectrometer is about 1 cm/%. Thus for 1% of energy resolution one needs 1 cm focal-plane-detector spatial resolution. Therefore, excitation function measurements (for example) with RIB may be performed on the basis of the spectrometer with high precision. The optimal RIB production target for the spectrometer is 3 cm wide and 0.5 cm high. The spectrometer could operate under vacuum for light-particle RIB separation or under gas-filled condition for separating heavy reaction products.

In the second case, the RIB-production target is installed on the

second floor of the U-400 beam switchyard and the beam DCS serves as a RIB separator. To improve the DCS ion-optical properties in the RIB separation mode of operation, it is necessary to symmetrize the positions of the focussing elements at the DCS entrance and exit. Such modernized separator will have an angular acceptance of about 4 msr and a momentum acceptance of about 5%. The ion beam trajectories in such symmetrized separator are shown at the Fig. 2.

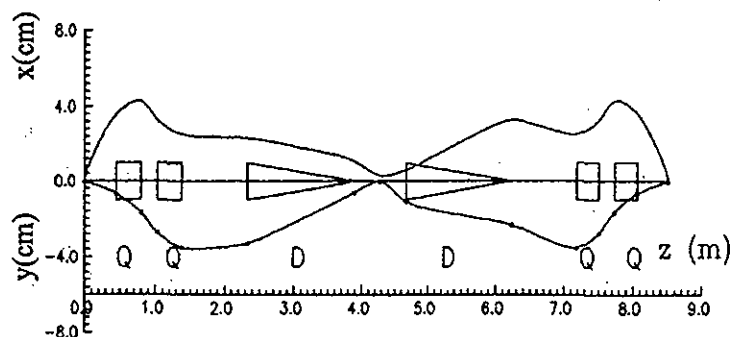


Fig. 2. Envelops of the ion beam trajectories in the separator built on the beam downing and commutation system

The RIB separated by 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 dispersion matching between the separator and the spectrograph. It may be realized by means of a beam rotator [6] introducing into the beam line between the DCS and the spectrograph. The beam path length of about 15 m between the DCS and MSP-144 permits us to install in this path the needed focussing elements together with a beam rotator. This 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 after the separator for precise nuclear reaction experiments using the magnetic spectrograph, including the differential cross-sections measurements. 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 also allows one to increase

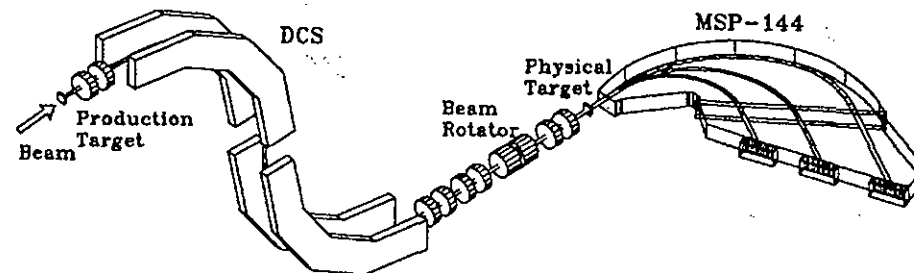


Fig. 3. The matching of the beam downing and commutation system with the spectrograph.

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.

Resume

An analysis of the ion-optical parameters of the existing facilities for precise nuclear reactions experiments at the U-400 cyclotron switchyard shows that some improvement can be made to perform RIB experiments at the Coulomb barrier of interactions. A change in the position of a dozen quadrupole lenses at the cyclotron switchyard permits one to obtain the parameters of magnetic spectrometers adequate to the modern experiments.

The ion-optical calculations of the new parameters 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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