THE INR (KIEV) RADIOACTIVE ION BEAM SEPARATOR

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Abstract

The ion-optical scheme parameters of the wide-aperture high-resolution Radioactive Ion Beams Separator (RIBS) are presented. Wide angular and momentum range ($\Omega=0^0\pm1^0$, $\delta P/P=\pm2\%$) keeping by RIBS, permits to provide full accumulation of nuclei with ultra small production cross-sections and subsequent high degree separation of radioactive ions from intensive beam of bombarding particles. Two-stage scheme with analyzing magnets and electrostatic separator will be used for separation of the basic isotopes from background ions.

As a first step the existing transport line with analyzing magnet which has been installed on cyclotron for beam monochromatization will be used for separation of some radioactive ions.

1. Design of RIBS.

The RIBS was designed using the U-240 cyclotron primary beams of light and heavy ions with energies of 70 MeV and 5-10 MeV/u respectively. Secondary beams of radioactive isotopes can be produced via different nuclear reactions at the 10-100 mg/cm^2 targets. Light and middle exotic nuclei from $^3H_1$ up to $^{25}Ne_{11}$ with magnetic rigidity from 0.2 to 1.8 Tm, which corresponds to energies 20-200 MeV, can be analyzed by the device.

The location was determined by the requirement to provide experiments with radioactive beams at the experimental box N 1.

The analyzing stage of RIBS consists from two bending magnets, Quadrupole lenses, Electrostatic Separator (E/S) and Collimator (fig.1). The M1, M2 magnets using as a rigidity filter provide the accumulation of secondary beams, the deflection them at the 60^0 in M1 and 36^0 in M2 and a spatial separation from incident beam. The using of spatially separated magnets with Quadrupole in between improves considerably the focusing properties of the deflecting system.

The M1, M2 magnets have such main parameters:1) The Radii of central trajectory are 150 cm; 2) The Induction of magnetic field in the median plane changes up to 1.2 *T*, 3)The Height of vertical gap is 5 cm, 4)The Width of the effective area is 14 cm.

The particle envelopes are schematically presented for an horizontal emittance of 70 π mm mr and for an vertical emittance 50 π mm mr and beam spot 10 mm in fig.2.

The solid lines indicates the beam envelopes for the monochromatic particles, the dashed lines indicates the ray for the momentum deviation of 2% demonstrating that the maximum dispersion (+3.6 cm/%) is reached at the L2 lens location.

The lenses L2, L3 are adjusted to provide the parallel beam with Zero Dispersion at the Electrostatic Separator position. The Quadrupoles L4, L5 following the E/S determine ion- optical conditions at the focal plane where installed Collimator.

In most cases basic and background isotopes with coincident magnetic rigidity can't be separated by means of analyzing magnets only. The electrostatic separator provides an additional filtration according to the different velocities of this isotopes.

The background nuclei crossing the Electrostatic Separator are vertically deviated from basic nuclei (Fig.3). For the 280 cm dispersion at collimator position and $\Delta P/P=\pm2\%$, the beam of F^{20} have the horizontal size X_{col}=14 cm and the vertical size Z_{col}=2.5 cm. The vertical separation angle between the background and basic ion trajectories must be no less than 5 mrad to have distance between trajectories ΔZ_{col}=3 cm for good resolution.

The main parameters of the Electrostatic Separator are: effective length - 100cm, vertical gap - 10 cm, supplied voltage ±100 kV, electric field - 20 kV/cm. To compensate the beam deviation in the electrical field, the magnetic field up to 0.12 T in the ES working region was used.

This scheme allows to provide independently tuning of the momentum spread and filtration coefficient of basic ions and background admixtures because dispersion swelling of the beam and vertical deviation in E/S taking place in the transverse planes.

The nonlinear effects substantially reduce the resolving power of the separator when the beam momentum spread is larger than ±1%. In fig.3 the beam cross-sections of ^{19}F and ^{20}F isotopes in Collimator position are presented. One can see that the beam spot will be sloped and distorted and the effective vertical cross-section on the collimator will increase from 2 cm up to 4 cm.

Ions with the same ratio A/Z but different momentum will be deviated in electrostatic field on additional angle which depends on magnitude and sign of the momentum deviation from equilibrium value. The slope angle arises and the gap between isotopes decreases with increasing of secondary ion mass.

For elimination of chromatic aberrations caused by E/S will be used sloping slit with changing of angle for different nuclei.

The matching stage of RIBS (don't shown on the fig.1) consists from symmetrical triplet which forms double crossover with Zero Dispersion on the experimental device.

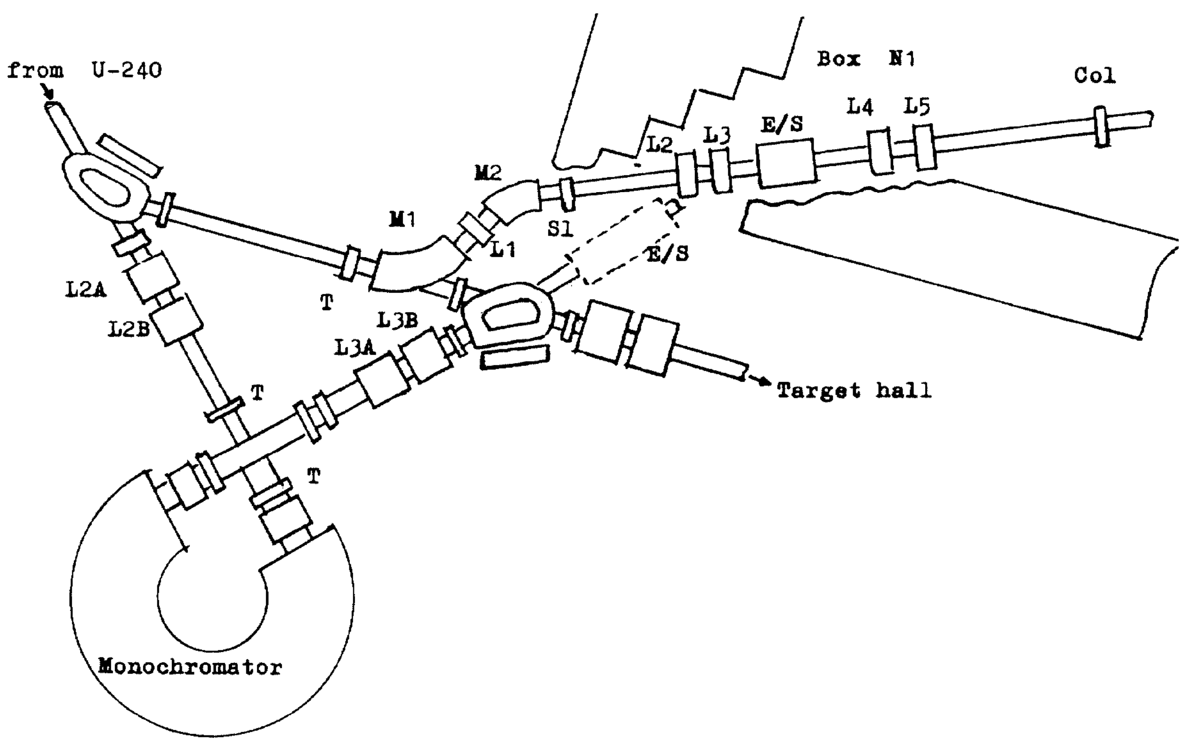

Fig.1.Layout of the Radioactive Beam Separator (RIBS) M_1-bending magnets, L_1-quadrupoles,E/S-electrostatic separator, T- targets, Col-collimator, Sl-slit.

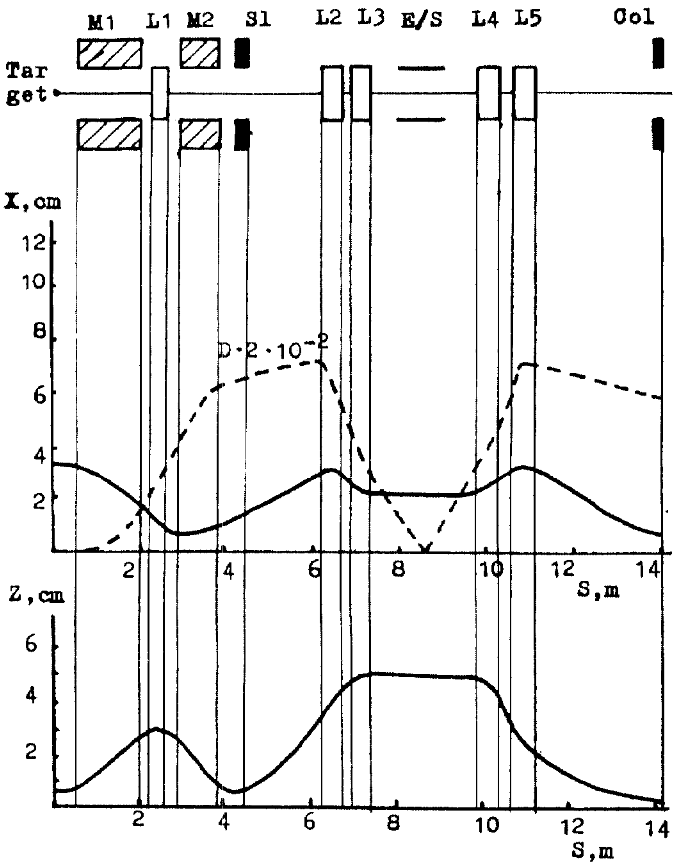

Fig.2. The horizontal (x), vertical (z) and dispersion envelopes of the RIBS: solid lines- contours of the monochromatic beam, dashed lines - ray of the beam with momentum deviation δP/P=2% .

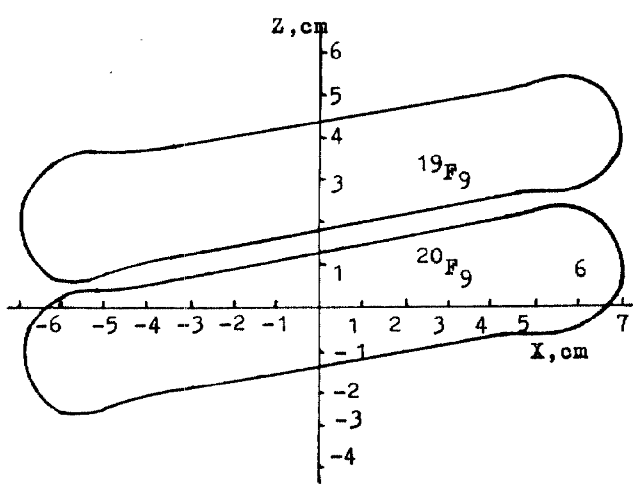

Fig.3. Beam cross-section on collimator for the ^{19}F and ^{20}F isotopes.

2. Monochromator.

As a first step of radioactive nuclei experiments the 270^0 analyzing magnet with Radius of central trajectory 2 m will be used. Now this device working as Monochromator of the primary beams. Target will be installed on distance 3.36 m or 0.90 m in front of entrance of Monochromator and after A/Z separation will be transport to Experimental box N 1 (dashed lines on fig.1). The E/S will be installed after Quadrupoles L3A, L3B at position where the beam is parallel in two planes and Dispersion equal Zero.

The radial gradient of magnetic field is provided by quadrupole coils and determined by the requirements to transmit without losses to experimental target the secondary beam with maximum emittance (50 π mm mr) and momentum range δP/P=±2% .

Compensation of the second-order aberrations will be achieved by two independently tuning sextupole lenses.

3. Conclusion

The Radioactive Ion Beam Separator is supposed to use for the investigations of nuclear reactions with the light exotic nuclei. In the future, the RIBS can be used for the production and subsequent transmission of Radioactive Ions in the Heavy Ion Storage Ring. Their electron cooling, accumulation and acceleration to the energies 3-300 MeV/u will be done in the Storage Ring.

References

1. M.G.Nagayenko. BETRAMF - the computer code for the calculation and optimization of magnetic-optical systems in the first-order approximation. Preprint B-0614, NIEPA, Leningrad, 1984.
2. M.G.Nagayenko. TOREX- the computer code for the calculation of aberration coefficients in the magnetic systems. Preprint E-0665, NIEPA, Leningrad, 1984.