SOME PERSPECTIVES IN THE BEAM TRANSPORT AND ANALYZING SYSTEM DESIGN FOR THE U-250 CYCLOTRON

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ABSTRACT

The existing beam transport system for the U-250 cyclotron is designed in a traditional manner. Because of this the system does not allow the full experimental possibilities of the accelerator, especially in nuclear physics investigations. Electromagnetic equipment design experience acquired by specialists of the institute may be utilized in the design of the beam analyzing system, including that of the magnetic analyzer installed in the external beam line and of the broad range spectrograph for the analysis of nuclear reaction products. Such additions will change the U-250 complex into a universal research center.

1. DESIGN CONCEPTS FOR THE BEAM TRANSPORT SYSTEM

A multichannel beam transport system is necessary for the successful realization of the research programme of the U-250 cyclotron. It is desirable for any trend of cyclotron investigations to be provided with its own beam transport channel. Omitting the discussion on scientific directions, it may be remarked that the beam transport system of the U-250 cyclotron has to have at least 10 transport channels, each with its own target device. It is not necessary to install every target in a separate room, especially for targets equipped with remote control devices for their dismantling and transport.

It's unlikely to qualify the accelerator center as universal if nuclear spectroscopy and nuclear reaction studies are not provided with the appropriate equipment. Progress in this direction is possible only for a beam transport system equipped with a magnetic analyzer for the cyclotron beam and a broad-range magnetic spectrograph for secondary-particle analysis.

2. MAGNETIC ANALYZER PROJECTS FOR THE U-250 CYCLOTRON

The criteria are widely known to appreciate the characteristics of various types of magnetic analyzers. The most important qualities of any analyzer are defined by its optical parameters and its cost. A real magnetic analyzer project makes a compromise between these considerations. High resolution force is the main desirable physical parameter for a cyclotron beam analyzer, while a large solid angle and momentum acceptance may be required for satisfactory physical results from a secondary-particle analyzer.

The production characteristics of an analyzer depend on its design features that define the costs of analyzer manufacturing, installation and instrumentation.

The main optical schemes of magnetic analyzers are widely known. It is a suitable moment to remark that in spite of their simplicity, single magnet analyzer projects with homogeneous magnetic fields are objects of the past because of their unsatisfactory physical characteristics. Similarly, an $n = 0.5$ magnetic analyzer is not a suitable construction for a modern accelerator center. This leads to the questions: What magnetic schemes are available? Are they the combinations of some magnets united in a general assembly? Evidently this direction is a perspective one although, frankly speaking, it is not "terra incognita"– various assembly analyzers are also known[1–3]. Study of these references shows the attempts of assembly-analyzer designers to achieve a workable compromise between the high optical parameters of the analyzing device and a low production cost. Everybody may estimate the results of such attempts in different ways, but it is the author's opinion that these designers deserve great respect.

Magnet assembly analyzers are seldom used as a cyclotron beam analyzing system although an example of such a project is not difficult to name[1]. In the author's opinion, a 270° magnetic analyzer may be considered an acceptable alternative to an assembly analyzer for the U-250 cyclotron beam. This type of analyzer was produced by NIIEFA in two versions:

a) as the MSP-133, an experimental model with a central radius of $R = 0.6$ m[4];

b) as the SP-017 analyzer of the U-240 cyclotron, with a central radius of $R = 2.0$ m.

The magnetic scheme of the SP-017 analyzer is shown in Fig. 1. Its basic parameters are: inhomogenity field index $n = 0.872$, central radius $R = 2$ m, design resolution force $F_p = 22600$ (at 1 mm source width). The field inhomogenity is produced by pole faces that slope at a definite angle. Sextupole lenses are installed at the magnet edges for correction of second-order aberrations.

I would like to put forward some arguments to substantiate such a selection. The main argument for its preference is the large resolution force obtained; the second one is its compactness. Some doubts may arise about the simplicity of the manufacturing procedure for the device. However, it is necessary to take into account the NIIEFA available know-how in the production and the fitting of such equipment. It is evident that the beam analyzer for the U-250 cyclotron has to realize the main design ideas of the SP-017 analyzer but not to copy one in all of the details. In the author's opinion, keeping the principles reported above will guarantee the effective design of a magnetic beam analyzer for the U-250 cyclotron.

Among the secondary-particle analyzers, the assembly ones are sufficiently extended because of their sharp optical parameters. On the other hand, the split-pole spectrograph (Enge spectrograph) is known as a design alternative for an assembly analyzer[5]. A secondary-particle magnetic analyzer was designed by NIIEFA specialists on the basis of the constructive features of the split-pole spectrograph. As a result the stepped-pole spectrograph MSP-144 has been produced at NIIEFA[6]. In this analyzer two homogeneous magnetic zones and straight boundary lines create suitable conditions for both broad-range momentum acceptance and large solid angle. Comparative characteristics of the Enge and MSP-144 spectrographs are given in table 1.

It may be seen from these data that in optical characteristics the stepped-pole spectrograph is similar to the Enge spectrograph. However, the manufacturing features of the MSP-144 make it a simpler device than a split-pole analyzer.

Table 1
Comparative characteristics of the Enge and MSP-144 spectrographs

	Enge spectrograph	MSP-144 spectrograph
Magnetic rigidity (T-m)	1.3	1.25
Momentum ratio accepted simultaneously P_{max}/P_{min}	2.6	2.7
Solid angle (msr)	4–7	3.3–7.7
Resolution force (for 1 mm width source)	$(3-4.7)10^3$	$(3.4-4.2)10^3$

The experimental possibilities of the MSP-144 device were checked by specialists of LNR JINR (Dubna, Russia). Positive results of such checking have been expressed in the following production of four MSP-144 units for LIN JINR needs. A photograph of the MSP-144 analyzer is shown in Fig. 2. Data analysis of the stepped-pole spectrograph shows that this is an acceptable design basis of a broad-range magnetic spectrograph for the U-250 cyclotron.

3. SOME COMMON REMARKS TO THE BEAM TRANSPORT PROJECT

Generally speaking, the layout of the beam transport equipment is a problem of minor importance in comparison with the beam transport content problem. A symmetrical beam transport scheme is used in the U-250 project where switch magnets are installed in the central transport line. Because of this it is natural to arrange the analyzing-magnet equipment as some supplementary block that may be added to the available beam transport system without essential changes in the cyclotron equipment layout. It is evident that the cyclotron beam analyzer has to be arranged in such a manner as to provide their operation both together and apart.

One further remark should be made about the beam transport project. The words "some perspectives" are in the title of this report. This expression is usually said in Russian when a real possibility takes place for their creation. Someone may put a question: Is it justly for the U-250 beam transport project? The author of the report has no doubts of the expediency of this project and he would be ready to cooperate with every specialist or firm if they would have an interest in these ideas.

4. REFERENCES

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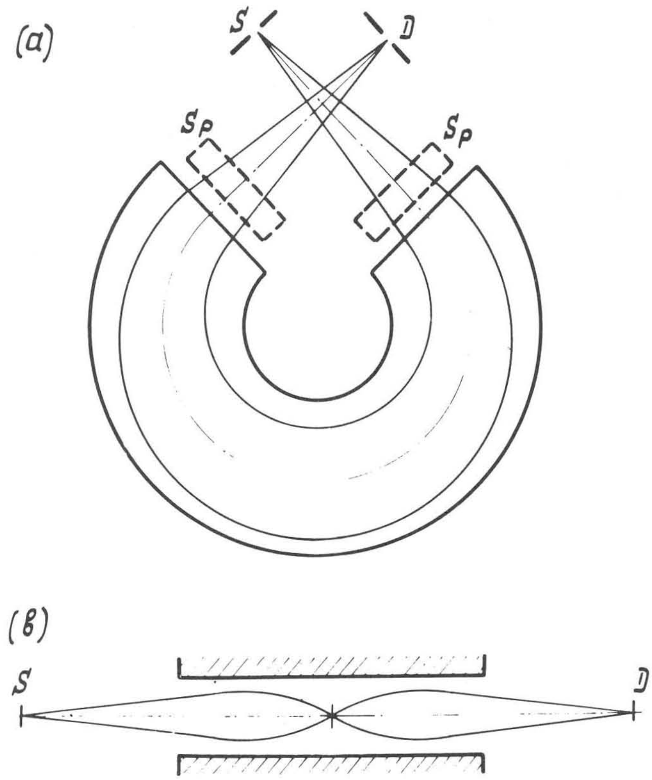

Fig. 1. Optical scheme of the 270° magnetic analyzer for horizontal (a) and vertical (b) planes. (Sp – sextupole lenses, S – source slit, D – analyzing slit).

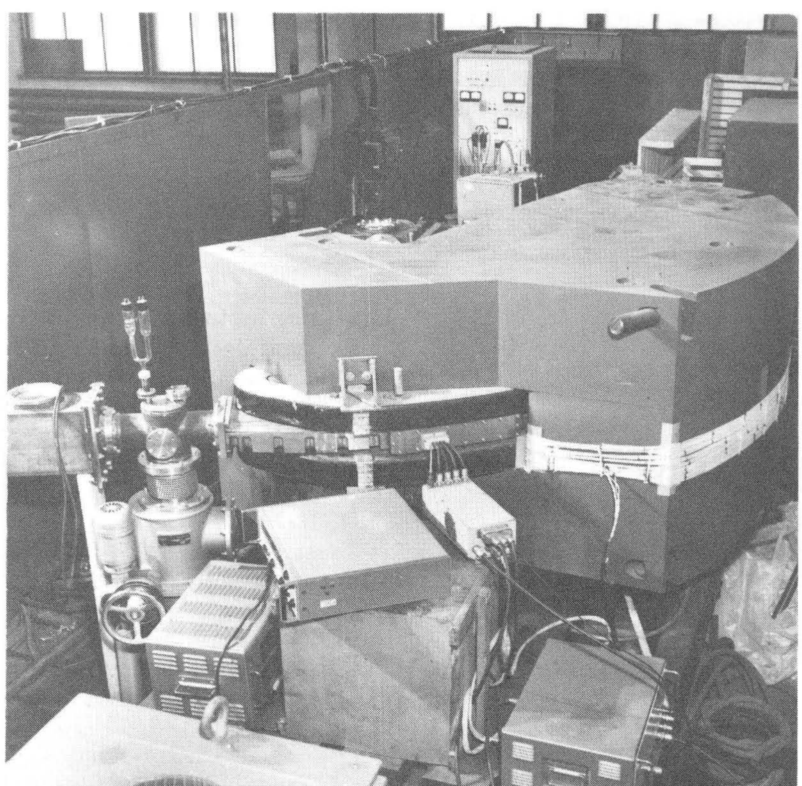

Fig. 2. NIIEFA made MSP-144 spectrograph.