HIGH-RESOLUTION SPECTROMETER FOR "SALO"-PROJECT

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The spectrometer of the high resolution for the project "SALO" is calculated. The spectrometer consists of two quadrupole lenses and two dipole magnets and has the length of $11.306\,m$. Spectrometer has resolution 4.74×10^{-5} and solid angle $4.9\,msr$. Parameters of calculated spectrometer are comparable with spectrometer in the Hall A Jefferson's laboratory.

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1. INTRODUCTION

In NSC KIPT the project "SALO" [1] is developed. This project plans to create the electron accelerator which will give out a bunch with energy of $750\,MeV$, with a diameter $0.2\,mm$, angular divergence 5×10^{-5} radian and momentum disorder 10^{-4}. The spectrometer is necessary for carrying out nuclear-physical researches on the accelerator with such parameters with the momentum resolution comparable with prospective value of momentum disorder of a beam. Spectrometer calculation was spent by means of program TRANSPORT [2]. The spectrometer will be established in an existing premise in which spectrometers of the $SP-103$ and the $SP-02$ [3] are already located, and it will define its sizes. The basic influence on the sizes of a spectrometer will be rendered by energy of a beam of the accelerator. In connection with limitation of financial resources the decision on the maximum use of the existing equipment in complex of $2\,GeV$ electron linear accelerator (existing spectrometers and other elements) is accepted.

2. RESULTS OF CALCULATIONS

The scheme $QQDD$, where Q - a quadrupole lens, and D - a dipole magnet, has been chosen for the construction of a spectrometer with the resolution better than 10^{-4}. The choice of such scheme was motivated by requirements of the high momentum resolution at the 10^{-4} level, a large solid angle and a convenient arrangement in the existing hall. Calculation was made by means of the program TRANSPORT [2]. During the calculation the basic geometrical parameters were determined taking into account the size of the existing facilities. For the purpose of economy of the financial expenses the magnet of the spectrometer $SP-103$ [4] is used as the first dipole magnet in $QQDD$ spectrometer. It was calculated for electron scattering investigations with the energy up to $2.3\,GeV$. Its length along the central trajectory is $2.817\,m$ and the solid angle it is equal to $1.739\,msr$. The installation of two quadrupole lenses before a $SP-103$ magnet will allow to increase the solid angle the spectrometer. Two of the quadrupole lenses were installed in front of the first dipole magnet to achieve the desired angular acceptance that define of the solid angle of the spectrometer. The quadrupole lenses were chosen with a length of $0.5\,m$ and the field on the pole of $1.3\,T$. The second dipole magnet with the central trajectory length equal to $1.1\,m$ should be manufactured. This length was defined for particle energy of $750\,MeV$ and the field in the vertical aperture of magnet of $1.2\,T$. The vertical aperture size in a magnet was chosen equal to $8\,cm$, as well as in the $SP-103$ magnet. Each magnet has the bending angle of 30°, thus the bending angle of a spectrometer will be equal to 60°. The distance from the target to the detector along the central trajectory is calculated to be $11.306\,m$.

For scattering particles on a target and taking off under corners $45\,mrad$ in a bending plane of a spectrometer and $27.2\,mrad$ in a plane of a perpendicular of bending plane focusing of the first order a point in a point has been carried out. Such focusing it was realized by selection of angles ε_1 and ε_2 for both magnets. These angles are defined as the angles between the direction of movement of the central trajectory and a normal to the magnet border in the points of this trajectory entrance into and exit from the magnet. Angles ε_1 and ε_2 are considered positives if the center of curvature of the central trajectory and an external normal to the magnet border are on opposite sides of the central trajectory, and negatives, if they are on the same side. An entrance angle of the first dipole magnet is $\varepsilon_1 = 55.012°$, and the exit angle is $\varepsilon_2 = -68.233°$. For the second dipole magnet $\varepsilon_1 = -23.59°$ and $\varepsilon_2 = 54.22°$. Variation of the matrix elements of the first or-

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der in the bending and vertical planes is shown in Fig.1 for whole particle trajectory from the target to the detector along the central trajectory (axis z). The z-dependence of the spectrometer's first-order transfer matrix elements is shown in Fig.1.

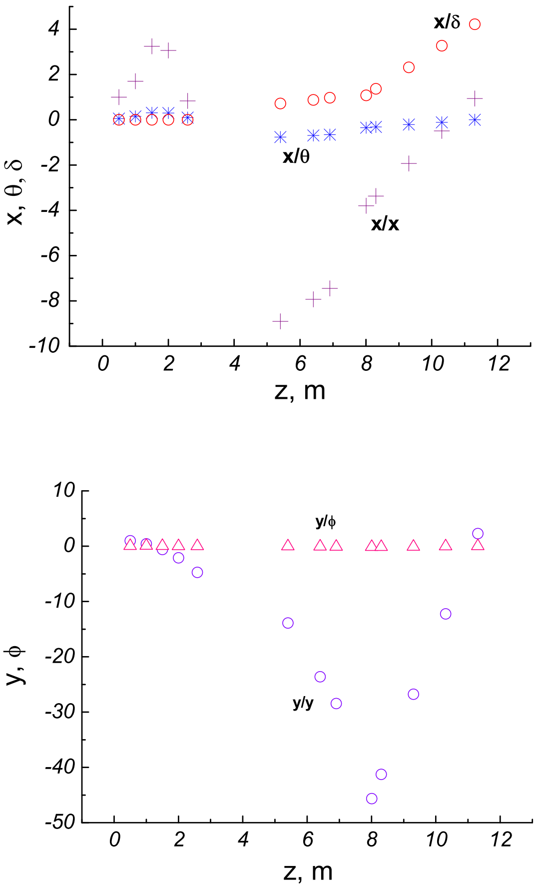

Fig.1. *Variation of matrix elements of the first order along the central trajectory: top is the bending plane (horizontal), and bottom in the vertical plane*

Matrix elements $\langle x|\theta\rangle$ and $\langle y|\phi\rangle$ remain small: ($\leq$ 0.8) for $\langle x|\theta\rangle$ and ($\leq$ 0.15) for $\langle y|\phi\rangle$ all over the trajectory in the spectrometer. These matrix elements are used to determine the contribution of the angle of divergence at the entrance of the spectrometer to the beam sizes at X and Y axis in the spectrometer. The values of $\langle x|\theta\rangle$ and $\langle y|\phi\rangle$ ensure the maximum angular capture in a horizontal plane $\theta = 45\,mrad$, using the existing pole width of the $SP - 103$ which is equal to $73\,cm$ at its exit. The value $\langle y|\phi\rangle$ guarantees angular capture in the vertical plane $\phi = 27.2\,mrad$ for the vertical aperture of the magnet equal to $8\,cm$.

The focusing of the second order was carried out by means of the radiuses of a curvature of entrance and exit borders of dipole magnets. The entrance border of the first dipole magnet has the radius of curvature $1/R_1 = -1.0\,m^{-1}$, i.e. the border has a concave form, and the exit border is rectilinear. For the second dipole magnet the entrance border has a convex form with the radius of curvature $1/R_1 = -1.048\,m^{-1}$, and the exit border has a concave shape with radius of curvature $1/R_2 = -0.3102\,m^{-1}$. The variation of the beam size along the trajectory from the target to the detector for the scattered particles captured by the spectrometer are shown in Fig.2 for monochromatic electron beam $0.2\,mm$ in diameter on the target. It is seen from the figure that the maximum size in X direction (horizontal plane) is at the exit of the first magnet, and in Y direction (vertical plane) is at the exit of the second magnet. The size in X direction at the exit of the first magnet is smaller than the pole width of the existing magnet. The size in Y direction at the exit of the second magnet doesn't exceed the vertical aperture of $8\,cm$ in this magnet.

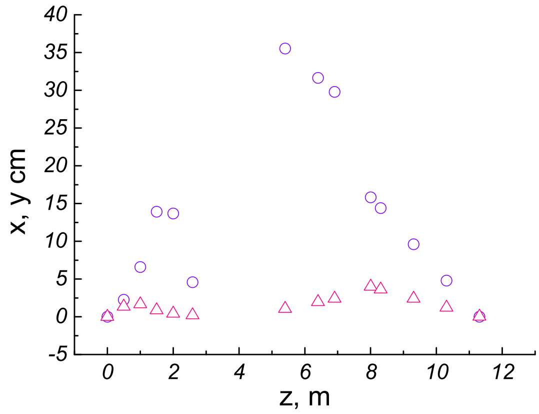

Fig.2. *The maximum deviation from the central trajectory of scattering particles in a spectrometer on the way from the target to the detector. Squares are the deviation values in X direction, and circles are the deviation values in Y direction*

The image size on the detector in X direction is $0.02\,cm$, and in Y direction is $0.046\,cm$. These sizes are defined by the sizes of a beam on a target. The momentum dispersion is equal to $4.222\,cm/\%$. This gives the resolution of 4.74×10^{-5} under the assumption that the detector system guarantee the spatial resolution of $200\,\mu m$.

For the non-monochromatic beam with the energy spread of $\pm 10^{-4}$ the size in Y direction remains the same as for the monochromatic beam and the image size in X direction becomes equal to $0.094\,cm$ which gives the resolution of 2.23×10^{-4}. In this case the main contribution to the spectrometer resolution is given by the momentum spread of the beam at the accelerator exit. With the reduction of the momentum spread of the accelerated beam it will be possible to approach to the spectrometer resolution of 4.74×10^{-5}. The design first-order transport matrix is:

$$
\begin{pmatrix} x_d \\ \theta_d \\ y_d \\ \phi_d \\ \delta_d \end{pmatrix} = \begin{pmatrix} 0.944 & 0.000 & 0.000 & 0.000 & 4.222 \\ 14.388 & 1.059 & 0.000 & 0.000 & 9.519 \\ 0.000 & 0.000 & 2.282 & 0.000 & 0.000 \\ 0.000 & 0.000 & 145.206 & 0.438 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 & 1.000 \end{pmatrix} \times \begin{pmatrix} x_m \\ \theta_m \\ y_m \\ \phi_m \\ \delta_m \end{pmatrix}. \quad (1)
$$

The carried out calculations show that in the construction of the first magnet it will be necessary to change the angle and the radius of a curvature of the pole face at the entrance and at the exit of the magnet. As the pole face in a $SP-103$ magnet at the same time are the walls of the vacuum chamber it will be necessary to change the form of the vacuum chambers at the entrance and at the exit of the magnet and accordingly the form of the magnetic screens which affect the form of the fringing field. The existing magnetic screens reduce the length of the fringing field [4,5] and make them almost linear. Therefore the parameters of the linear distribution of the fringing field from the program TRANSPORT [2] were used in spectrometer calculation.

The basic characteristics of the high resolution spectrometer for the project "SALO" are presented in the Table.

	NSC KIPT Calculation	Jefferson Lab Operating [6]
Configuration	Horizontal bend, $QQDD$	Vertical bend, $QQDQ$
Bending angle	$60°$	$45°$
Optical length	$11.306\,m$	$23.4\,m$
Momentum range	$0.3...1.0\,GeV/c$	$0.3...4.0\,GeV/c$
Momentum acceptance	$-4.5\% < \delta p/p < +4.5\%$	$-4.5\% < \delta p/p < +4.5\%$
Momentum resolution	4.74×10^{-5}	1×10^{-4}
Momentum dispersion	4.2	12.4
Angular acceptance in the bending plane	$\pm45\,mrad$	$\pm60\,mrad$
Angular acceptance perpendicular this plane	$\pm27.2\,mrad$	$\pm30\,mrad$
Solid angle	$4.9\,msr$	$6.0\,msr$

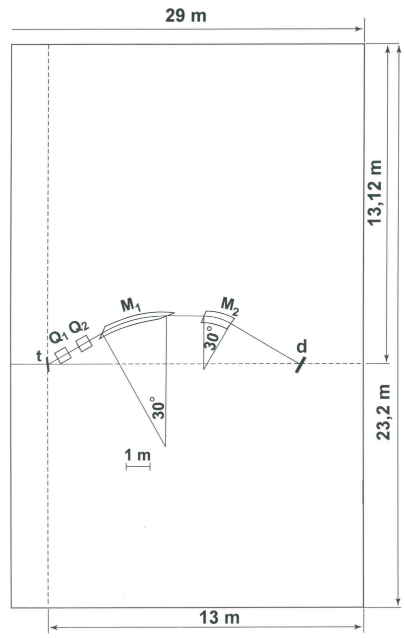

Fig.3. *A schematic arrangement of a spectrometer in an existing hall. All the sizes long are given in meters*

The information about the spectrometer of the hall A of Jefferson laboratory [6] at the electron accelerator with energy of $4\,GeV$ is also given. The calculated value of the momentum resolution of our spectrometer is a bit better, and the solid angle is somewhat smaller than the spectrometer of Jefferson laboratory has.

The spectrometer position in the existing hall is presented in the Fig.3. It is seen from the Fig.3 that there are more than two meters to place the the detecting system.

3. CONCLUSIONS

Calculation of electronic optics of a magnetic spectrometer with enough big solid angle and the high momentum resolution, consisting of two quadrupole lenses and two dipole magnets have been carried out. The maximum deviation of the scattered particles from the central trajectory in a spectrometer is shown along all way from the target to the detector. Creation of such spectrometer will allow to study an electron - and photonuclear reactions with the high momentum resolution.

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СПЕКТРОМЕТР ВЫСОКОГО РАЗРЕШЕНИЯ ДЛЯ ПРОЕКТА "SALO"

В.М. Хвастунов, В.В. Деняк

Рассчитан спектрометр высокого разрешения для проекта "SALO". Спектрометр состоит из двух квадрупольных линзы и двух дипольных магнитов и имеет длину 11.306 м. Спектрометр имеет собственное разрешение 4.74×10^{-5} и телесный угол 4.9 мср. Параметры рассчитанного спектрометра сравнимы с параметрами спектрометра в зале A лаборатории Джефферсона.

СПЕКТРОМЕТР ВИСОКОГО РОЗРІШЕННЯ ДЛЯ ПРОЕКТУ "SALO"

В.М. Хвастунов, В.В. Деняк

Проведені розрахунки спектрометра високого розрішення для проекту "SALO". Спектрометр складається з двох квадрупольних лінз та двох дипольних магнітів і має довжину 11.306 м. Спектрометр має власне розрішення 4.74×10^{-5} і тілесний кут 4.9 мср. Параметри розрахованого спектрометра близькі до параметрів спектрометра в залі A лабораторіі Джефферсона.