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A HIGHLY FOCUSING BETA SPECTROMETER

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Bei Wahl von geeigneten Feldparametern[4]) läßt sich mit einem Magnetfeld der Form $H = H_0 a/(r \sin \vartheta)$ ein hochauflösendes doppelfokussierendes β-Spektrometer konstruieren. In dieser Arbeit werden Grundlagen und Konstruktion eines Eisen-β-Spektrometers mit dem Feldparameter $K = 0.309894$ und 6 Trochoidenumläufe beschrieben, das einen maximalen Bahnradius von 25 cm aufweist.

Zur Bestimmung der theoretischen Eigenschaften des Spektrometers wurden die Bildfehler der Fokussierung und die apparative Linienform numerisch ermittelt. Wie diese Berechnungen zeigen, ist auch für ausgedehnte Quellen eine Transmission von 1.87% zu erwarten, welche über einen großen Bereich der Auflösung, $\delta p/p$, praktisch konstant bleibt und bei $\delta p/p = 10^{-4}$ immer noch 1.3% beträgt.

Die Eigenschaften des Spektrometers wurden im Energiebereich von 75 keV bis 660 keV experimentell geprüft. Die Resultate bestätigen die theoretischen Erwartungen weitgehend; die geringere Transmission bei hohen Auflösungen kann durch die störende Wirkung der restlichen Feldfehler erklärt werden. Die beste erreichte Auflösung beträgt $\delta p/p = 3.5 \times 10^{-4}$; bei $\delta p/p = 5 \times 10^{-4}$ beträgt die gemessene Transmission 0.68% und die zugehörige Luminosität 2×10^{-4} cm^2.

Die Ergebnisse zeigen, daß für $\delta p/p \geqq 5 \times 10^{-4}$ die Transmission und Luminosität dieses Spektrometers die Werte aller existierenden doppelfokussierenden Spektrometer übertreffen.

1. Introduction

In the field of β-spectroscopy, the best resolutions can still be attained by means of electron-optical systems, i.e., monochromators. In general, instruments of this kind make use of highly focusing magnetic fields in order to produce the image of a source at a detector. In the low energy range electrostatic focusing offers its special advantages.

Assuming that a magnetic field focuses particles in an ideal manner, the *resolution* of the instrument is given by its dispersion and the geometry of the source with respect to the detector. The *transmission* of a spectrometer – defined as the ratio of the number of particles reaching the detector to the total number of emitted monochromatic particles – is therefore given by the limits of the solid angle within which the particles are permitted to start, the so-called "opening angle". This in turn depends upon the spectrometer construction.

In most cases, however, focusing is imperfect, the coordinates of the focus depending on the source dimensions and the opening angle. Hence the focus of an ideal point source has a finite size thereby determining the maximum attainable resolution. Errors in focusing are functions of the opening angle which in turn determines the transmission. The transmission is therefore a function of the resolution. It is the relation between these two quantities which measures the quality of a β-spectrometer. Another characteristic quantity is the luminosity of a spectrometer, which is defined as the product of transmission and source area. Contrary to the transmission, the luminosity is dependent on the size of the instrument.

Among the various types of precision instruments[1]), the best results have been attained by the well-known $\pi\sqrt{2}$ double focusing type of β-spectrometer[2,3]) in which the field is shaped so as to vary as $\rho^{-\frac{1}{2}}$. This spectrometer yields a good theoretical figure of merit, does not, however, possess a particularly large value of the transmission at high resolutions. In view of these circumstances, developments in this field of research may turn out to be very useful.

The attractive properties of a field varying as $1/r$ predict results[4-9]) which are essentially superior to those existing to date. The aim of the present paper is to report on the design, construction and performance of a β-spectrometer based on the characteristics of this type of magnetic field.

2. Theory

2.1. Main features of an $1/r$-field

A detailed description of the properties of a magnetic field having the form

$$H = H_0 a/(r \sin\vartheta), \tag{1}$$

(r,ϑ,φ) being a right-handed system of spherical polar coordinates, has already been given by Hofmann[4]). The main characteristics of this field can be summarized as follows:

Charged particles in the magnetic field perform orbits in form similar to that of trochoids. Double focusing is obtained after $m \geqq 2$ trochoidal revolutions,