

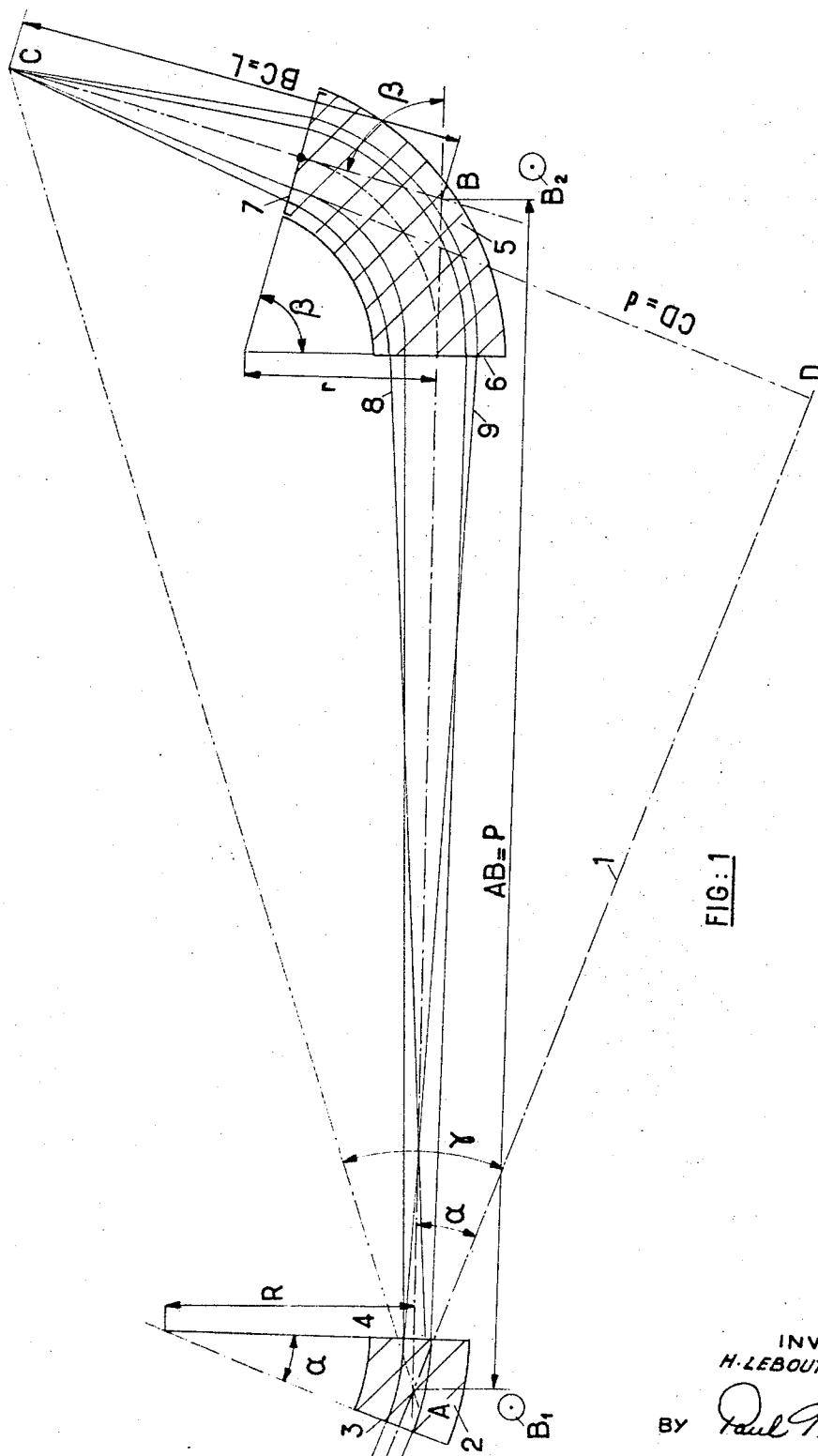
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UTILIZING TRIPLE FOCUSING MEANS

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Filed March 15, 1966

Sheet / of 2



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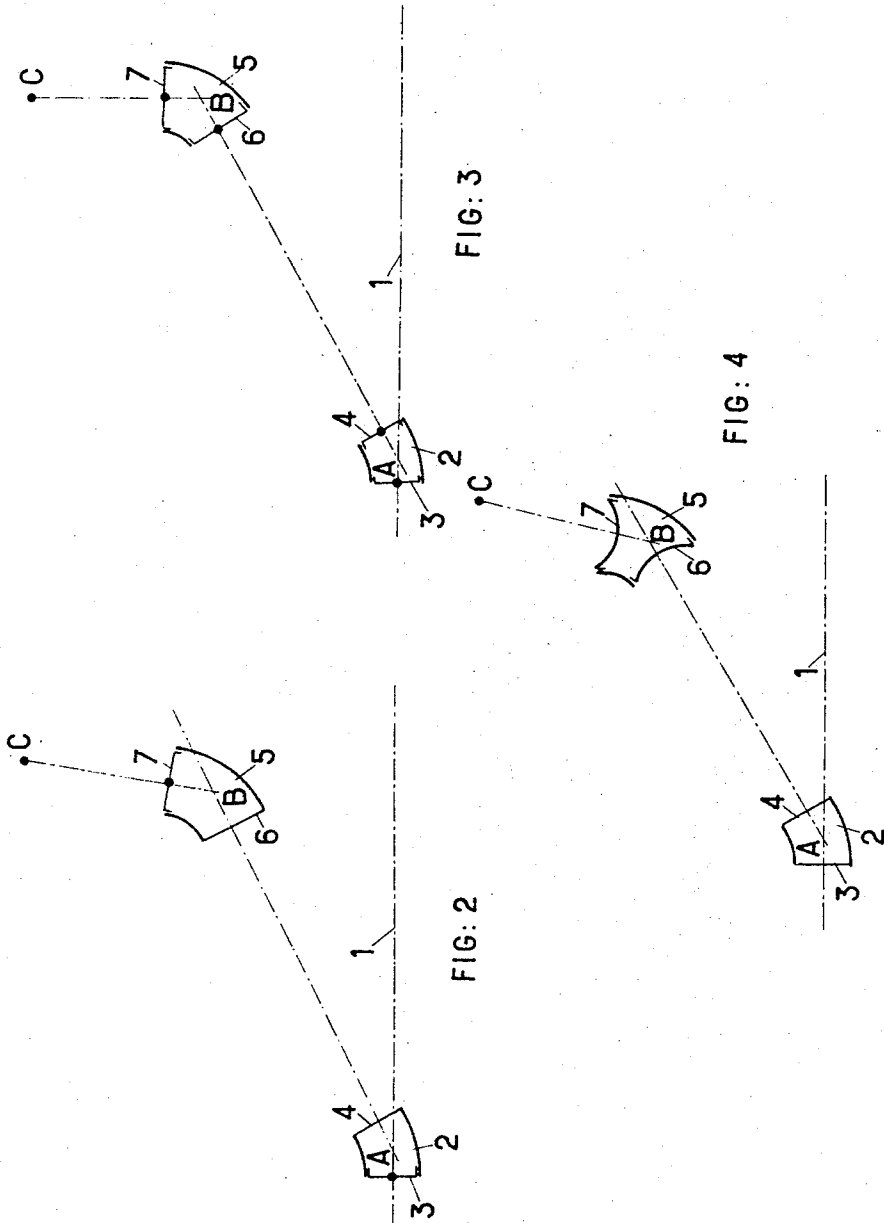
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DEVICE FOR DERIVING A BEAM FROM A PARTICLE ACCELERATOR UTILIZING TRIPLE FOCUSING MEANS

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7 Claims

ABSTRACT OF THE DISCLOSURE

A device for deriving an accelerated beam from a particle accelerator and directing it toward a target off the axis of the accelerator using only two sectoral magnets. The invention relates to the selection of the parameters of the magnets to obtain a triple focusing of the beam on the target, i.e., a focusing with respect to the various energy levels of the particles in the beam and a focusing along the path to the target in two mutually perpendicular planes.

The present invention relates to a beam deriving device, and more particularly to a device for deriving the accelerated beam of a particle accelerator in such a manner that it is deflected onto a target lying outside of the normal path followed by the accelerated beam.

In the operation of charged particle accelerators, it is usual to derive a beam from the path normally followed by the accelerated beam along a predetermined axis, and to direct this derived beam against a target located out of alignment with said axis at any convenient site within the accelerator room to permit observation work by a physicist, the location of said target being thus defined by a pair of coordinates with respect to the derivation point. The particles are guided along such path from the derivation point by a combination of magnetic devices including at least one deflecting magnet. The effect of such a magnet is, firstly, a defocusing of said particles due to their different energy levels, i.e., a splitting of the path of the original beam containing, as is well known, a spectrum of particles of different energies, into a multitude of different paths, one path each for particles of one and the same energy, and secondly, a defocusing of particles of a predetermined energy in two mutually perpendicular planes, conveniently termed horizontal and vertical planes, respectively. The problem therefore arises as to how to refocus the particles of different energy level and also in the horizontal plane and in the vertical plane, and moreover how to achieve this triple focusing action so that the triple focus point will fall into coincidence with the location of the target, i.e., that the energy focus, the vertical focus and the horizontal focus would find themselves precisely on the target.

This problem has already been resolved in the device according to a copending application Ser. No. 8,043 filed on Feb. 11, 1960 by Jacques Pinel, now U.S. Patent No. 3,287,584, issued Nov. 22, 1966, and assigned to the same assignee.

In the device of this application, a guiding system for the derived beam was proposed, comprising a combi-

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nation of two deflecting magnets having lines of force parallel but of opposite sense, and of one or two quadrupolar magnetic lenses.

However, such combination includes a relatively large number of components, and is therefore relatively expensive.

Accordingly, it is an object of the present invention to provide a triple focusing device affording a comparable result with less expense, hence having a more limited number of components.

Another object of the present invention is a beam deriving device for operating on a beam from a particle accelerator, wherein triple, i.e., energy, vertical and horizontal, focusing is attained in a common point located on a target positioned somewhere out of alignment with the axis of the accelerator, with the use of only two deflecting magnets exclusive of any other magnetic optical components along the path of particles between the accelerator and the target.

These and other objects, features and advantages of the present invention will become more obvious from the following description when taken with the accompanying drawing which shows, for purposes of illustration only, several embodiments in accordance with the present invention, and wherein:

FIGURE 1 is schematic plan view of a beam deriving device ensuring triple focusing action in accordance with the present invention;

FIGURE 2 is a view, similar to FIGURE 1, showing a development of the present invention wherein some faces of the deflecting magnets have been made orientable;

FIGURE 3 is a view similar to FIGURES 1 and 2, showing a further development according to the present invention, wherein all faces of the deflecting magnets have been made orientable, and

FIGURE 4 is a view similar to FIGURES 1, 2 and 3, showing a still further development of the present invention wherein some orientable faces of the deflecting magnets have a concave shape.

In all figures, there is shown a beam deriving device including only two deflecting magnets without any further components such as a magnetic lens, the lines of force of these magnets being parallel and moreover, in contrast with the device described in the aforesaid copending application, being of the same sense. Furthermore, the sizes and locations of these magnets are defined by six parameters, two of which are selected freely and the remaining four being determined from a set of four equations which will be given below, in dependence on the coordinates of the target and of said two freely selected parameters.

Referring now more particularly to FIGURE 1, the line 1 passing through points A and D represents the axis which is followed by charged particles issued from or moving within an accelerator (not shown). It will be assumed that it is desired to derive from this axis at A a beam to be guided toward a target located at the point C having two coordinates with respect to A, i.e., having its location given by its distance from the axis 1 ($CD=d$) and by the angle $CAD=\gamma$. A first sectoral magnet 2 is placed in such a manner that the point A is within the gap thereof. This magnet includes an input face 3 and an output face 4, the face 3 being normal to the axis 1 and the face 4 being normal to the desired path of the beam after deflection caused by the magnet 2. The angular opening of the

sector occupied by the magnet 2 is α , so that the particles are deflected therein by an angle α with an average radius of curvature R . At a point B along the deflected path is located a second sectoral magnet 5 having an input face 6 normal to the line AB, and an output face 7 having means to rotate it so as to change its orientation. The sector of the magnet 5 occupies an angle β and the particles are deflected therein, with respect to the line AB, by this angle β with an average curvature radius r .

The lines of force of both magnets 2 and 5 are parallel and of the same sense. Admitting that the particles are negatively charged (electrons), for deflecting these particles in the plane of the drawing and in the counter-clockwise sense, the lines of force must be perpendicular to the drawing and directed toward the viewer, which is denoted by the circles B_1 and B_2 .

A calculation made with the present invention has established that for the paths leaving the magnet 5 to pass through the point C, and for the energy focus, the horizontal focus and the vertical focus to be brought into coincidence at this very point C, the following conditions must be met at least approximately.

The size and the location of magnets 2 and 5 being defined by the following six parameters.

R =radius of curvature of the average path of particles within the magnet 2;

r =radius of curvature of the average path of particles within the magnet 5;

α =deflection angle of the magnet 2 with respect to the axis 1;

β =deflection angle of the magnet 5 with respect to the direction of the preceding deflection;

P =distance AB;

L =distance BC;

any desired two of these six parameters are selected freely provided limiting conditions $R > r$ and $\alpha < \beta$ are satisfied, while the four remaining parameters can be determined readily as they must satisfy, according to the invention, a set of the four following equations:

$$\frac{1}{r} - \frac{1}{R} = \frac{1}{P \sin \beta} \quad (1)$$

$$\sin \beta - \sin \alpha = \frac{L \sin \alpha}{R} \quad (2)$$

$$P \cos \alpha + L \cos (\alpha + \beta) = d \cot \gamma \quad (3)$$

$$P \sin \alpha + L \sin (\alpha + \beta) = d \quad (4)$$

For purposes of adjusting more finely the coincidence between the three mentioned focusing points and the point C located on the target, it is possible to rotate the face 7 for experimentally achieving the desired result. Moreover, it is possible to assist this adjustment by using a magnet 5 with varying gap width, i.e., a so-called field-gradient magnet.

The induction in each of magnets 2 and 5 is calculated according to the known formula:

$$B_1 = \frac{E}{300R} \text{ or } B_2 = 300r \quad (5)$$

wherein E is the mean energy of the energy band of the particles to be guided toward the target, in MeV.

B_1 or B_2 is the respective induction, in Tesla, and R or r is the respective curvature radius, in meters.

According to the development of the present invention shown in FIGURE 2, wherein the same reference numerals are used to denote similar elements as in FIGURE 1, the input face 3 of the magnet 2 is also orientable. This feature makes it possible to adjust coincidence between horizontal and vertical focus in the event of inaccuracies in the manufacture of the magnets or in their positioning.

FIGURE 3 showing a further development of the present invention, differs from FIGURE 2 merely by the

fact that the output face 4 of the magnet 2 and the input face 6 of the magnet 5 have also been shown as orientable. Adjusting these intermediate faces makes it possible to determine with great flexibility a compromise between the positions of the faces 3 and 7 concurring in an optimum of triple focalization at C. As well known to those skilled in the art, the same effect could be achieved by selecting for the polar pieces of the magnet 2 a suitable profile to form a field gradient magnet with varying width of its gap.

FIGURE 4, showing a still further development of the present invention, differs from FIGURE 1 by the fact that the output face 7 of the magnet 5 has been given a concave shape. The same feature is shown for the input face 6 thereof, which, for instance although not necessarily, has been also made orientable. The exact profile of the concave faces will be determined graphically by those skilled in the art with a view of obtaining achromatic focalization within a broad energy passband, starting from a widened path of the beam within the magnet 5, as comprised between extreme or limiting trajectories 8 and 9 traced in FIGURE 1.

It is obvious that all schematic showings as described are susceptible of many constructive embodiments within the knowledge of those skilled in the art, and we therefore do not wish to be limited to the particular examples shown and described herein, but intend to cover all such changes and modifications as are encompassed by the scope of the appended claims.

We claim:

1. A deriving system for charged accelerated particles normally following a direction along a predetermined axis, for guiding said particles from a derivation point on said axis toward a target located at a point defined by a pair of coordinates d and γ with respect to said derivation point, comprising: a first sectoral magnet located to act on said particles at said derivation point to deflect them by an angle α with respect to said axis and to curve their mean path with a radius of curvature R , whereby said particles follow a deflected linear path forming said angle α with said axis; a second sectoral magnet located along the path of said particles between said first magnet and said target; said second magnet having lines of force parallel and of the same sense as said first magnet, and being located to act on said particles at a point spaced from said derivation point by a distance P along said deflected linear path, and spaced by a distance L from said target, to deflect the particles by an angle $\beta > \alpha$ with respect to said deflected linear path and to curve their mean path with a radius of curvature $r < R$, whereby said particles follow a further linear path passing through said target; a set of four parameters among said six parameters α , β , R , r , P , L being selected to at least meet a set of four equations:

$$\frac{1}{r} - \frac{1}{R} = \frac{1}{P \sin \beta}$$

$$\sin \beta - \sin \alpha = \frac{L \sin \alpha}{R}$$

$$P \cos \alpha + L \cos (\alpha + \beta) = d \cot \gamma$$

$$P \sin \alpha + L \sin (\alpha + \beta) = d$$

in dependence on the two remaining parameters and of said coordinates of the target.

2. A system as claimed in claim 1, wherein each of said first and second magnets has an input face and an output face, and wherein means are provided for varying the angle of inclination of the output face of the second magnet with respect to the path followed by said particles within said second magnet.

3. A system as claimed in claim 2, further comprising means for varying the angle of inclination, with respect

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to particle path, of at least one of three magnet faces including the input and output faces of said first magnet and the input face of said second magnet.

4. A system as claimed in claim 2, wherein the output face of the second magnet has a concave shape.

5. A system as claimed in claim 4, wherein the input face of the second magnet has a concave shape. 5

6. A system as claimed in claim 5, wherein means are provided for varying the inclination angle with respect to the particle path, of the input face of the second magnet. 10

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7. A system as claimed in claim 1, wherein at least one of said first and second magnets is of field-gradient type.

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