

June 11, 1968

G. R. LAMBERTSON

3,388,359

PARTICLE BEAM FOCUSSED MAGNET WITH A SEPTUM WALL

Filed Jan. 31, 1967

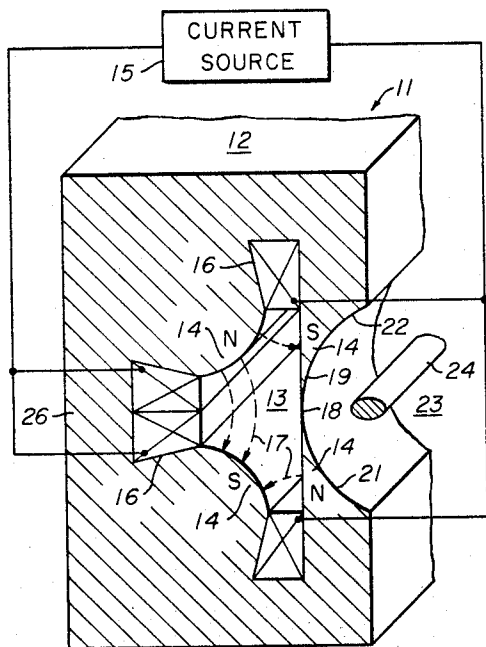


Fig. 1.

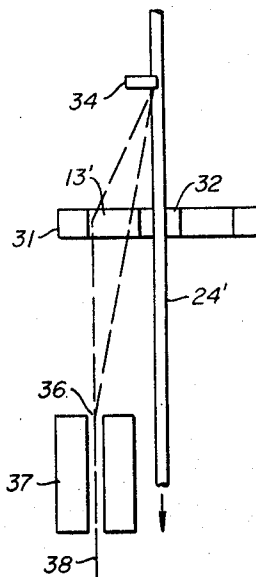


Fig. 2.

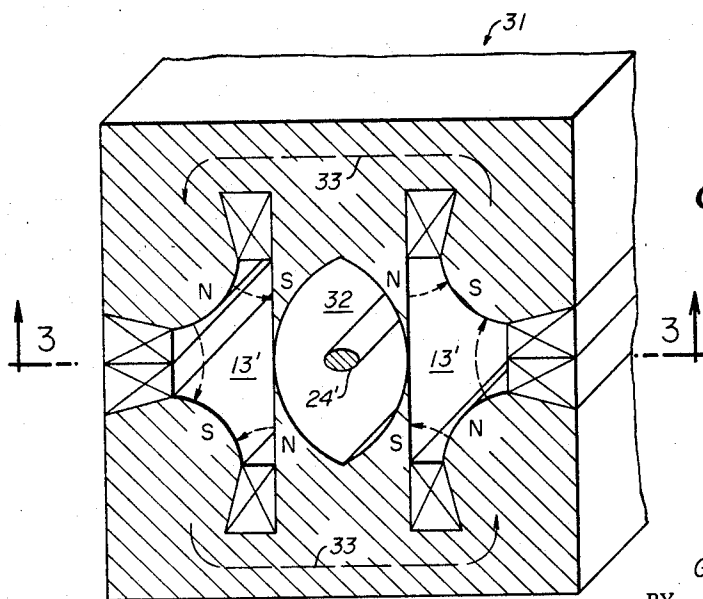


Fig. 2.

INVENTOR.
GLEN R. LAMBERTSON
BY
Roland A. Anderson
ATTORNEY.

1

3,388,359

PARTICLE BEAM FOCUSsing MAGNET WITH A SEPTUM WALL

Glen R. Lambertson, Oakland, Calif., assignor to the
United States of America as represented by the United
States Atomic Energy Commission
Filed Jan. 31, 1967, Ser. No. 613,047
7 Claims. (Cl. 335—210)

ABSTRACT OF THE DISCLOSURE

This invention is a quadrupole electromagnet specifically designed for focussing a maximum number of secondary particles as are emitted in diverging paths from a target bombarded by the primary beam of a high energy particle accelerator. The compact physical structure of the magnet alleviates spatial congestion of the target region of the accelerator, in that one wall of the magnet contains a thin septum which allows the beam focussing field of the magnet to be disposed near the primary beam and the target without physically or magnetically interfering therewith.

BACKGROUND OF THE INVENTION

This invention relates generally to magnets and more particularly to a quadrupole magnet for focussing a high energy charged particle beam. The invention described herein was made in the course of, or under contract W-7405-eng-48 with the Atomic Energy Commission.

The present magnet was designed for use in conjunction with high energy particle accelerators such as a synchrotron. While there is no inherent characteristic which would limit the magnet to use with particle accelerators, the subsequent description will indicate how the magnet is particularly advantageous when used with a synchrotron.

In one very common mode of operating a synchrotron, a primary beam of charged particles is accelerated to a high energy and used to bombard a target to release secondary particles from the target. The secondary particles knocked from the target diverge over a relatively wide angle, but the path of a majority of the particles is close to the primary beam. To effectively utilize such secondary particles it is nearly always required that the particles be focussed into a narrow pencil-like beam. Conventional quadrupole focussing magnets which have a thick core structure around a focussing channel, cannot be disposed near the target since the magnet cannot be allowed to interfere, either physically or magnetically, with the primary beam. Therefore, the conventional focussing magnet must be spaced away from the target but, because of such spacing, the magnet must have a wide aperture to collect the diverging secondary beam. Consequently, the conventional magnet is necessarily large and takes up considerable space in the target area, which is usually already overcrowded with apparatus.

SUMMARY OF THE INVENTION

The present invention is a quadrupole type magnet having a longitudinal channel therethrough in which there is provided a beam focussing magnetic field. One side of the channel is a thin septum, thereby permitting the magnet to be positioned with the septum immediately adjacent the orbit of the primary particle beam of the synchrotron. Thus a beam focussing channel may be provided adjacent the orbit of the primary beam since there is no thick core

2

to physically interfere with the primary beam and since no external magnetic field is generated. Therefore the magnet may be positioned very near the target so that a large portion of the diverging secondary beam can enter the beam focussing channel without requiring a large aperture to collect and focus the particles. The size of the magnet structure may be relatively small but provides results equivalent to those of a large magnet of conventional construction.

It is an object of the present invention to provide a means for reducing the size and cost of a particle focussing magnet.

It is another object of the present invention to provide a means for reducing congestion in the target region of a particle accelerator.

It is another object of the present invention to provide charged particle focussing means which may be disposed immediately adjacent other objects or regions without physical or magnetic interference therewith.

BRIEF DESCRIPTION OF THE DRAWING

The invention will best be understood by reference to the drawing of which:

FIGURE 1 is a cross-section view of a beam deflection focussing magnet.

FIGURE 2 is a cross-section view of another embodiment of the invention having two beam focussing channels, and

FIGURE 3 is a plan view showing the position of the magnet of FIGURE 2 with respect to the target region of a synchrotron, the magnet being shown in greatly reduced size and in section as indicated by lines 3—3 in FIGURE 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGURE 1, there is shown a section view of a septum magnet 11 having an iron core 12 with a longitudinal beam focussing channel 13 therethrough. Inwardly facing magnetic poles 14 in the core 12 define the channel 13 which, in section, has an approximate triangular shape with current conducting coils 16 being disposed longitudinally within the channel at the apices of the triangle. The connections to the current carrying coils 16 are arranged so that adjacent north and south poles will be formed when the conductors are carrying current as from a current source 15. In FIGURE 1 the poles 14 of magnet 11 are successively marked with an N or an S to show a typical polarity arrangement. The magnetic field directions between the various poles of the magnet are indicated by arrows 17, such field direction following the conventional configuration of a quadrupole magnet. The mid-point along one wall of the channel 13 is a longitudinal thin septum 18. Of poles 14, a north pole 21 and south pole 22 on each side of the septum 18 have, in section, an outwardly facing concave surface 19 with parabolic shape. The vertex of the parabolically shaped surface coincides with the center of the septum 18, which could theoretically have zero thickness at such center position. By utilizing such pole shape, the flux density in all portions of the poles 21 and 22 on each side of the septum 18 is equal and there are no concentrations of flux at any one region therein. Using highly permeable iron, the flux will be carried without appreciable saturation and the region 23 near the surface 19 will approach zero magnetic field. The magnetic field intensity in the channel 13 has a near zero value along the middle of the septum 18 and increases in value from the septum to a maximum at the opposite coils 16. The core 12 has a flux return path 26

around the coils 16 opposite the septum 18. It should be noted that a parabolic shape for the concavity obtains the most open space possible in region 23 for an adjacent beam orbit. However, if all of such open space is not necessary, different concavity shapes may be utilized without affecting the operation as long as no core material is removed which would lie back of the theoretically perfect parabolic surface. In practice, only a rough approximation of the parabolic shape would ordinarily be required.

In use, the primary beam 24 of an accelerator can be directed longitudinally through the region 23, there being no magnetic field from the septum magnet 11 which would tend to deflect such primary beam. Secondary particles entering the channel 13 are focussed in that particles passing through the channel near the zero field region near septum 18 receive no deflective force but particles passing through the intense magnetic field near coils 16 are deflected by a force acting toward the septum 18, thereby concentrating all the secondary particles entering the channel 13 at a distant focal point.

If two magnets 11 as described in FIGURE 1 are combined with the concave surfaces 19 facing, as shown in FIGURE 2, a magnet 31 is provided having a central channel 32 free of any magnetic field. A primary high energy charged particle beam 24' may be accelerated around a closed orbit which passes through the field free channel 32. It will be noted that the flux return portion 26 of the iron core in FIGURE 1 has been eliminated in magnet 31 of FIGURE 2. The omission of such iron core return path is permissible since in the magnet of FIGURE 2, the path for magnetic lines (indicated by arrows 33) is through the opposite channel 13' and the iron core return path 26 of FIGURE 1 is no longer necessary. However, in such a core structure the magnetic fields across the two channels 13' are necessarily in opposite directions. If like directed magnetic fields are required in the two channels 13' then such return path 26 must be retained.

In FIGURE 3 there is shown the magnet 31 of FIGURE 2 as it would be typically disposed with respect to a synchrotron high energy primary beam 24 and a target 34. The magnet 31 is disposed along the orbit of the synchrotron so that the primary beam 24 passes through the field free channel 32 while being accelerated. As generally utilized, the target 34 is then bombarded by the beam 24'. In usual practice, the target is either rapidly inserted into the path of the beam 24' or is fixed at one side of the beam orbit and the beam deflected slightly toward the target so that the primary beam 24' impinges thereon. The secondary particles are released in diverging paths in the same general direction as the primary beam 24', thus it is desirable to position the focusing magnet as close to the target as possible to receive a maximum number of secondary particles. The secondary particles enter the channel 13' and are directed toward a common focal point 36. A magnet 37 is provided for forming the secondary particles into a beam 38 and the secondary particle beam then will have a preferred narrow pencil-like configuration suitable for various uses as is well known in the art. By using the double septum magnet of FIGURE 2, beams of secondary particles can be extracted from both sides of the primary beam simultaneously, thus the double septum magnet 31 may be advantageous in some instance over the single septum magnet 11.

While the magnet has been described in the quadrupolar form, it is possible to use the septum construction with a sextupole, octopole or other magnet configuration with an even number of poles. The septum magnet may be used in ways other than as shown in FIGURE 3, for instance, to aid in separating a non-homogeneous particle beam in which the components have been unequally deflected due to differences in charge, mass, or velocity into separate components.

Many variations are possible within the spirit and scope

of the invention and it is not intended to limit the invention except as defined in the following claims.

What is claimed is:

1. In a septum magnet for focusing charged particles, the combination comprising:

(a) a magnet core structure having an even number and at least first, second, third, and fourth successively numbered pole faces defining the walls of a longitudinal channel, said first and second poles being adjoining and having extremities tapered in thickness toward a septum therebetween, and

(b) means magnetically polarizing every other one of said poles around said channel in a first polarity and polarizing the remainder of said poles in the opposite polarity.

2. A septum magnet as described in claim 1, said first and second poles have mutually aligned flat surfaces facing said channel, the tapered extremities of said first and second poles together forming an outwardly facing longitudinal concavity having in section an approximate parabolic configuration.

3. A septum magnet as described in claim 1 wherein said core structure has four poles and wherein said means magnetically polarizing has a conducting means disposed in said channel between said first pole and said fourth pole and further conducting means disposed between said second pole and said third pole, and further conducting means disposed between said third and fourth poles, connection means for said conductors providing for current flow in one direction through said conductors adjacent said first and second poles and for current flow in the opposite direction through said conductors between said second and third poles.

4. In a septum magnet for focusing charged particles, the combination comprising:

(a) a long magnet core structure having three longitudinal channels therethrough, a first of said channels being disposed between a second and a third of said channels and separated therefrom by thin septums in said core structure, said core structure further having an even number and at least first, second, third and fourth poles facing inwardly into each of said second and third channels, said first and second poles in each channel being joined by one of said septums, and

(b) means magnetically polarizing every other one of said poles around said second channel in a first polarity and polarizing the remaining poles around said channel in the opposite polarity, said means further magnetically polarizing every other one of said poles around said third channel in a first polarity and polarizing the remaining poles around said channel in the opposite polarity.

5. A septum magnet as described in claim 4 wherein said two poles joined by a septum in said second and third channels each have mutually aligned surfaces facing each said respective channel, each side of said first channel having in section an approximate parabolic configuration.

6. A septum magnet as described in claim 4 wherein said core structure has a pair of longitudinal gaps therein, a first gap extending between the exterior of said core and said second channel and a second gap extending between the exterior of said core and said third channel, said magnetic polarizing means providing oppositely directed magnetic fields in said second and third channels whereby flux through one channel around said gap thereof is returned through the other channel around said gap thereof.

7. A septum magnet as described in claim 6 wherein said magnetically polarizing means has a first set of current conductors disposed longitudinally in said first gap and a second set of current conductors disposed in said second gap, additional conductors being disposed within each of said second and third channels between

said two poles therein joined by said septum and adjacent poles facing into said channel, connection means for said conductors providing for current flow in one direction through said conductors associated with said two poles in said second and third channels and for current in the opposite direction for the remainder of said conductors.

References Cited**FOREIGN PATENTS**

698,867 12/1940 Germany.

5 BERNARD A. GILHEANY, *Primary Examiner*.
GEORGE HARRIS, Jr., *Examiner*.