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(54) **Apparatus for therapy with non-charged particles.**

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FR-A- 2 295 673
US-A- 3 969 629

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Description

The present invention relates to an apparatus for therapy with non-charged particles, preferably photons, comprising a target generating by Bremsstrahlung a therapy beam and a particle filter producing uniform dose distributions. In the apparatus the therapy beam is purged or cleaned from unwanted secondary charged particles such as secondary electrons, positrons or protons.

In radiation therapy with high energy non-charged particles, in particular high energy photons and neutrons, secondary charged particles are generated both from the rear area of a bremsstrahlung generating target such as for example a thin foil of gold and from the flattening filter itself. In case of photon therapy the fluence of photons varies across the beam cross-section. This results in a non desired uneven dose distribution across the field to be irradiated. To cure this it is known to insert conical radiation filters damping the central ray of the radiation beam to a greater extent than those at the periphery. In this way the radiation beam and therefore the dose distribution is made uniform.

Particularly in connection with deep seating tumours it is required to use radiation that has its dose maximum (maximum dose absorbed in the treated volume) as deep as possible and highest possible penetrability. To achieve said objects it is known to "harden" the beam i.e. to increase the energy of the therapy beam. Beams with particles having higher energies normally require the use of large accelerators of high energy. However, with a "hardening filter" low energy non-charged particles are instead filtered out of the useful beam resulting in an increase of the mean energy of the beam.

For low to intermediate energy photons the beam quality is also influenced mainly by the air through which the beam travels since Compton electrons will be generated in the air. Thus the air itself is the principal contamination source.

From SE-A-406 240 is previously known to harden a therapy beam of photons with a flattening filter made by low atomic number, high density ceramics.

Brahme in 1976 warned against hardening the photon beam too much on the central axis as this would make the beam uniformity depth dependent. Instead Brahme suggested the use of a low atomic number filter material only at the periphery of the beam and a high atomic number on the central axis. In doing so a perfect uniformity of the beam was achieved independent of the depth in the absorbing mass.

Increasing the particle energy inevitably increases the mean energy of the secondary charged particles which are generated when the beam strikes the flattening filter. Thus normally the flattening filter itself is the dominant source of unwanted secondary charged particles at the higher energies. In connection with photon therapy said secondary charged particles are secondary electrons or positrons which will contaminate the beam with the result that the dose maximum is brought closer to the skin surface. Moreover they will contribute to an increased non-desired absorbed dose to the skin.

Another disadvantage obtained when the energy of the photons is high is that the depth dose distribution will depend on the size of the radiation field. The larger the size the nearer the skin will be the dose maximum.

In order to eliminate unwanted secondary charged particles from the useful therapy beam it is known to insert metal screens in the beam and provide such screens with a thin layer of a material with a high atomic number. Said thin layer is applied in an amount of the order of 0.1-0.2 g/cm^2. This thin layer will scatter secondary electrons generated in the metal screen. Nevertheless said scattering is unsufficient and there will still be too many secondary electrons and positrons in the useful beam.

FR-A 2 295 673 relates to a conventional flattening filter for attenuation of the intensity of the central X-rays so as to obtain a flat dose curve. The filter per se generates undesirable secondary electrons disturbing the depth dose curve. The filter is located close to the X-ray target.

US-A 3 696 629 relates to an electron filter for filtering out non wanted secondary electrons from the therapy beam. The electron filter comprises magnetic means located far from the X-ray target and arranged outside the therapy beam. A substantial magnetic field strenght must be created by the magnetic means in order to subject secondary electrons generated at the photon filter or target near the photon source of the therapy beam to a Lorenz force of sufficient magnitude to drive the secondary electrons out of the therapy beam. Such a strong magnetic field over such a large field size requires the use of large and therefore also heavy magnets. By applying the magnetic fields with alternative and opposite field directions the effect of the secondary electrons is diffused, but not very effectively.

The object of the present invention is to provide a novel apparatus for use in therapy with high energy, non-charged particles, particularly photons, avoiding the drawbacks of the previously known apparatuses using flattening filters.

This a achieved by introducing in the filter itself a magnetic field through which the contaminated beam must pass before striking the surface to be irradiated. During the passage of the filter the charged, secondary particles generated by the filter itself are subjected to a Lorenzforce deflecting said secondary particles out of the useful beam generally along a helical path.

The advantages offered by the invention are that the depth of dose maximum is substantially increased, for a 20 MeV photon beam about 2 cm deeper, and that the depth of penetration at the 50% level is increased, for said 20 MeV photon beam of the order of 4 cm. Up to now such deep penetrating beams are only available from high energy accelerators generating 40 MeV photons or more. Thus, by using a small and therefore low costs accelerator which is producing a 20 MeV beam and which is provided with a novel magnetic flattening filter a beam comparable to that of a 40 MeV accelerator is achieved. In a simple operation the magnetic filter may be removed from the accel-

erator which then may be used for conventional therapy purposes. Thus by adding and removing the magnetic filter one and the same accelerator can be used for medium energy as well as high energy radiation purposes. Previously two different accelerators were used for this purpose.

Various embodiments of the invention will be described below with reference to the accompanying drawings wherein

Fig. 1 is a perspective view of a magnetic flattening filter used in the apparatus in accordance with the present invention,

Fig. 2 is a perspective view of the filter shown in Fig. 1 as seen from below as seen from the radiation source,

Fig. 3 is a cross-sectional view of the main filter components included in the filter shown in Fig. 1,

Figs. 4 and 5 are cross-sectional views of different embodiments of the conical body of the magnetic filter,

Fig. 6 is a top plan view of a further embodiment of a magnetic filter,

Fig. 7 is a schematic side view of the filter shown in Fig. 6,

Fig. 8 is a top plan view of a third embodiment of a magnetic particle filter used in the apparatus in accordance with the invention and

Fig. 9 is a diagram showing depth dose curves achieved with apparatus in accordance with the invention and with an apparatus using a conventional flattening filter.

In Figs. 1 and 2 a magnetic flattening filter comprises a cylindrical housing 1 serving as a means for mounting the magnetic filter close to the Bremsstrahlung target, not shown. A flange 2 is provided around the bottom ring of the cylindrical housing. The filter is shown close to natural size.

The magnetic filter comprises a conical body 4 mounted centrally on a circular base plate 5. A ring 6 of generally the same height as a conical body 4 is mounted on the base plate 5 at the periphery thereof. As shown in Fig. 3 the conical body 4 is magnetized in the axial direction. The ring 6 is also magnetized in the axial direction but with a polarity which is opposite to that of the conical body 4. The base plate 5 is in this embodiment made of magnetically conducting material thus serving as a yoke for the magnetic field lines. Thus there is a strong magnetic field between the conical body and the ring which the particles of the beam must pass. If the non-charged particles are high energy photons secondary electrons (e-) will be generated by the filter itself and said electrons will be subjected to a Lorenz-force driving the secondary electrons out of the path of the beam along a helical path as schematically shown in broken lines in Fig. 3. Should the beam 3 also include high energy positrons (e+) these will also will be subjected to said Lorenz force and move out of the beam along the path shown by dashed lines at e+ in Fig. 3 but in a direction which is opposite to that of the negatively charged electrons.

The material used for the conical body should be capable of providing a strong magnetic field and simultaneously exhibit a high density (so as to harden the beam as much as possible). Permanent magnetic materials such as Fe, Co and alloys of samarium, cobalt and other rare earth metals are preferred. If a permanent magnetic material is used the photon beam will simultaneously be differentially hardened due to the fairly low atomic number of the magnetic materials ($Z \approx 25$, Fe, Co etc.) as compared to lead or tungsten which normally are used in flattening filters. The preferred samarium-cobalt-alloy is $SmCo_5$. This alloy is very hard and therefore difficult to machine into conical form. A conical body of $SmCo_5$ may instead be formed by cylindrical slabs 7 stacked upon each other and of successive smaller diameter as shown in Fig. 4. A non magnetic material 8 is used to fill up to a general conical form. The top portion 9 of the conical body is difficult to machine if made by said samarium-cobalt-alloy. Instead the top portion may be formed by Fe.

The conical body 4 shown in Fig. 5 is solid and made of for example ferromagnetic material. Its outer surface is provided with a thin layer 10 of a high atomic number material so as to scatter secondary, charged particle as discussed in the introductory portion of the present specification. This layer 10 may for example be gold and is applied in an amount of 0.1-0.2 g/cm^2.

The ring 6 may, as shown in broken lines in Fig. 3, be formed by several individual rings cemented or clamped together into a structural unit.

In Fig. 6 a second magnetic filter embodiment is shown. Here the conical body 4 and the ring 6 are transversally magnetized, i.e. the lines of the magnetic fields are extending in a direction perpendicular to the central axis of the magnetic filter. In Fig. 6 the beam strikes the base of the conical body from a point situated below the plane of the paper and the secondary charged particles are also in this embodiment subjected to the Lorenz force moving the charged particles out of the path of the useful beam along a helix path as schematically indicated by the dashed lines in Fig. 6.

In Fig. 7 the transversal magnetization of the filter members of Fig. 6 are shown. A base plate 5 similar to that of Fig. 3 may be used for the filter shown in Fig. 6. It is however also possible to use a base plate of non-magnetic conductive material if the magnetic field is closed by way of a magnetic yoke in the form of two opposing pole shoes 11, 12 interconnected with a pole piece 13 as shown in Fig. 8. In the Fig. 8 embodiment of the magnetic filter the ring has accordingly been replaced by the pole pieces 11, 12 surrounding the conical body 4. In the Fig. 8 embodiment it is accordingly possible to mount the conical body 4 on a base plate 5 which must not be magnetically conductive.

The magnetic field in this configuration can be continously varied by adding a winding 14 supplied with direct current in order to establish the magnetic field. The purpose of this will be explained below.

In the embodiments described thus far magnetic yokes have been used in order to have a magnetic field which is as strong as possible. Theoretically, however, it is possible to refrain from a magnetic yoke and instead close the magnetic field lines at

infinity. This results in a weaker magnetic field but is theroetically possible using the principles of the present invention. In this most simple form of an electron filter the filter is just a permanent magnet.

If low energy non-charged particles are used for therapy purposes and no particle intensity filtration is required in order to have a uniform beam, then it is possible to reduce the magnetic filter to a single magnetized slab of uniform thickness. The direction of the magnetization may either be transversal, like the embodiments shown in Figs. 6 and 7, or axial, as shown in Figs. 2 and 3.

The slab will subject the secondary. charged particles generated in the slab to a Lorenz force moving the secondary charged particles out of the treatment beam along helical paths.

In Fig. 9 depth dose curves are shown. Curve A has been recorded with the magnetic filter described in Figs. 1-4 and curve B has been taken with a conventional flattening filter made of lead. In both cases 20 MeV photons were used for the beam and the size of the radiated field was 20×20 cm^2. Comparing curve A with curve B it is apparent that the dose maximum of curve A is situated 4.2 cm below the surface while with the conventional lead filter the dose maximum is situated about 2.2 cm below the surface. Thus the depth of dose maximum is about 2 cm deeper if the magnetic flattening filter in accordance with the invention is used. This has been indicated with Δ D. Comparing the penetration of the beam it is obvious that, for a given dose, the penetration of the beam in which the magnetic filter is used is about 4 cm deeper than that which is achieved when a conventional filter is used. This difference has been indicated as p in Fig. 9. In Fig. 9 there is a shaded area. This shaded area represents - as far as the position of the dose maximum is concerned - the non desired effect of the secondary electrons and positrons if they were present. From Fig. 9 it is also apparent that by reducing the strength of the magnetic field Δp will also reduce. Conversly, increasing the strength of the magnetic field through which the non wanted changed particles must travel will increase Δp. Accordingly by varying the magnetic field, for example by providing an electro magnet around the conical body 4, the penetrability of the beam may be varied.

Claims

1. Apparatus for therapy with non-charged particles, preferably photons, comprising a target generating by Bremsstrahlung a therapy beam and a particle filter comprising magnetic means for subjecting charged unwanted particles, particularly secondary electrons, to a Lorenz force moving said charged particles out of the therapy beam, characterized in that said magnetic means are located close to the target generating said therapy beam and that said magnetic means are located within the therapy beam.

2. Apparatus in accordance with claim 1, characterized in that said magnetic means is a magnetized slab of uniform thickness.

3. Apparatus in accordance with claim 1, said filter comprising a conical body (4) for flattening and hardening the irradiation beam (3), characterized in that the conical body is magnetic so as to form said magnetic means.

4. Apparatus in accordance with claim 3, characterized by a ring (6) surrounding the conical body (4), said ring being magnetized with a polarity opposite to that of the central conical body, and a base plate (5) of magnetically conducting material on which the conical body and the ring are mounted, said plate serving as a magnetic yoke.

5. Apparatus in accordance with claim 4, characterized by two pole shoes (11, 12) arranged on opposite sides of the conical body (4) and of polarities opposite to that of the magnetic conical body (4), said pole shoes being interconnected by a magnetically conducting member (13) so as to form a closed magnetic structure.

6. Apparatus in accordance with any of claims 3-5, characterized in that the conical body (4) is of solid material, preferably a magnetized samarium cobalt alloy ($SmCo_5$) and that the envelope surface thereof is provided with a layer (10) of high atomic number material to scatter secondary, charged particles and to increase the effect of the magnetic field.

7. Apparatus in accordance with any of claims 3-6, characterized in that the conical body (4) comprises slabs (7) of cylindrical bodies of solid material, preferably a magnetized samarium-cobalt alloy ($SmCo_5$), said slabs being stacked one upon each other and being of successive smaller diameter, said slabs on their perephery surface being covered by a layer (8) of non-magnetic material filling up to a general conical form of the central body, the envelope surface thus provided being smooth.

8. Apparatus in accordance with claim 6 or 7, characterized in that the conical body and the ring are magnetized in the axial direction.

9. Apparatus in accordance with claim 6 or 7 characterized in that the slabs of the conical body and the ring are magnetized in a direction which is perpendicular to the central symmetry axis of the conical body.

10. Apparatus in accordance with claim 6 or 7, characterized in that the ring is of iron and is provided with a winding (14) so as to form an electromagnet the magnetization of which is variable, thereby making it possible to continously change the penetration depth of the the therapy beam.

Patentansprüche

1. Therapiegerät für nicht-geladene Teilchen, insbesondere Photonen, mit einem Target, welches durch Bremsstrahlung einen Therapiestrahl erzeugt, und mit einem Partikelfilter, der eine Magnetanordnung aufweist, um geladene unerwünschte Teilchen, insbesondere Sekundärelektronen, mit einer Lorenzkraft auf dem Therapiestrahl zu entfernen, dadurch gekennzeichnet, daß die Magnetanordnung nahe an dem den Therapiestrahl erzeugenden Target und innerhalb des Therapiestrahls angeordnet ist.

2. Therapiegerät nach Anspruch 1, dadurch gekennzeichnet, daß die Magnetanordnung eine magnetisierte Platte konstanter Dicke aufweist.

3. Therapiegerät nach Anspruch 1, wobei der Filter einen konischen Körper (4) zum Glätten und Härten des Bestrahlungsstrahls (3) aufweist, dadurch gekennzeichnet, daß der konische Körper magnetisch ist und die Magnetanordnung bildet.

4. Therapiegerät nach Anspruch 3, dadurch gekennzeichnet, daß ein den konischen Körper (4) umgebender Ring (6) vorgesehen ist, der mit zu dem konischen Körper entgegengesetzt gerichteter Polarität magnetisiert ist, und daß eine Basisplatte (5) aus magnetisch leitendem Material vorgesehen ist, auf der der konische Körper und der Ring angeordnet sind und die als magnetisches Joch dient.

5. Therapiegerät nach Anspruch 4, dadurch gekennzeichnet, daß zwei Polschuhe (11, 12) vorgesehen sind, die auf gegenüberliegenden Seiten des konischen Körpers (4) angeordnet und mit entgegengesetzter Polarität zum konischen Körper (4) ausgerichtet sind, und daß die Polschuhe zur Bildung einer geschlossenen Magnetstruktur über eine magnetisch leitende Brücke (13) miteinander verbunden sind.

6. Therapiegerät nach Anspruch 3 bis 5, dadurch gekennzeichnet, daß der konische Körper (4) aus festem Material, insbesondere aus einer magnetisierten Samarium-Kobalt-Legierung ($SmCo_5$), besteht, und daß seine wirksame Oberfläche mit einer Schicht (10) eines Materials mit hoher Atomzahl bedeckt ist, um geladene Sekundärteilchen abzulenken und die Wirksamkeit des magnetischen Feldes zu verbessern.

7. Therapiegerät nach Anspruch 3 bis 6, dadurch gekennzeichnet, daß der konische Körper (4) zylindrische Platten (7) aus festem Material, insbesondere aus einer magnetisierten Samarium-Kobalt-Legierung ($SmCo_5$), aufweist, die aufeinandergestapelt sind und schrittweise abnehmende Durchmesser aufweisen, und daß die Platten auf ihrer Umfangsfläche eine Schicht (8) unmagnetischen Materials tragen, die den zentralen Körper zu einem im wesentlichen konischen Körper ergänzt, dessen Oberfläche dann glatt ausgebildet ist.

8. Therapiegerät nach Anspruch 6 oder 7, dadurch gekennzeichnet, daß der konische Körper und der Ring in axialer Richtung magnetisiert sind.

9. Therapiegerät nach Anspruch 6 oder 7, dadurch gekennzeichnet, daß die Platten des konischen Körpers und der Ring in einer senkrecht auf der zentralen Symmetrieachse des konischen Körpers stehenden Richtung magnetisiert sind.

10. Therapiegerät nach Anspruch 6 oder 7, dadurch gekennzeichnet, daß der Ring aus Eisen ist und mit einer Windung (145) versehen ist, so daß er einen Elektromagneten bildet, dessen Magnetisierung variabel ist, wodurch es möglich ist, die Eindringtiefe des Therapiestrahls kontinuierlich zu verändern.

Revendications

1. Appareil pour traitement thérapeutique avec des particules non chargées, de préférence des photons, comprenant une cible qui génère par rayonnement de freinage un faisceau de traitement et un filtre de particules comportant des moyens magnétiques pour soumettre les particules chargées indésirables, en particulier les électrons secondaires, à une force de Lorenz qui déplace les dites particules chargées hors du faisceau de traitement, caractérisé en ce que lesdits moyens magnétiques sont placés près de la cible engendrant ledit faisceau de traitement et en ce que lesdits moyens magnétiques sont placés à l'intérieur du faisceau de traitement.

2. Appareil suivant la revendication 1, caractérisé en ce que lesdits moyens magnétiques sont constitués d'une plaque aimantée d'épaisseur uniforme.

3. Appareil suivant la revendication 1, ledit filtre comprenant un corps conique (4) pour l'aplatissement et le durcissement du faisceau d'irradiation (3), caractérisé en ce que le corps conique est magnétique de manière à constituer lesdits moyens magnétiques.

4. Appareil suivant la revendication 3, caractérisé par un anneau (6) entourant le corps conique (4), ledit anneau étant aimanté avec une polarité opposée à celle du corps conique central, et une plaque de base (5) en matière magnétiquement conductrice sur laquelle sont montés le corps conique et l'anneau, la dite plaque servant de culasse magnétique.

5. Appareil suivant la revendication 4, caractérisé par deux pièces polaires (11, 12) placées sur des côtés opposés du corps conique (4) et de polarités opposées à celle du corps conique magnétique (4), les dites pièces polaires étant interconnectées par un élément magnétiquement conducteur (13) de façon à former une structure magnétique fermée.

6. Appareil suivant l'une quelconque des revendications 3 à 5, caractérisé en ce que le corps conique (4) est en matière massive, de préférence en alliage samarium-cobalt ($SmCo_5$) aimanté, et en ce que sa surface extérieure comporte une couche (10) de matière de nombre atomique élevé pour disperser les particules secondaires chargées et pour augmenter l'effet du champ magnétique.

7. Appareil suivant l'une quelconque des revendications 3 à 6, caractérisé en ce que le corps conique (4) comprend des plaques (7) de corps cylindrique en matière massive, de préférence en alliage samarium-cobalt ($SmCo_5$) aimanté, lesdites plaques étant mutuellement superposées et étant de diamètre progressivement décroissant, lesdites plaques éant revêtues sur leur surface périphérique par une couche (8) de matière non magnétique de garnissage jusqu'à une forme générale conique du corps central, la surface extérieure ainsi obtenue étant régulière.

8. Appareil suivant la revendication 6 ou 7, caractérisé en ce que le corps conique et l'anneau sont aimantés dans la direction axiale.

9. Appareil suivant la revendication 6 ou 7, caractérisé en ce que les plaques du corps conique et de l'anneau sont aimantées dans une direction qui est perpendiculaire à l'axe central de symétrie du corps conique.

10. Appareil suivant la revendication 6 ou 7, caractérisé en ce que l'anneau est en fer et il est pour-

vu d'un enroulement (14) de manière à constituer un électro-aimant dont l'aimantation est variable, ce qui permet de modifier en continu la profondeur de pénétration du faisceau de traitement.

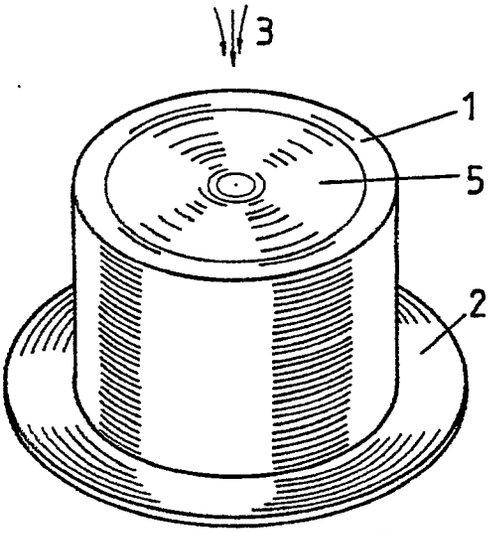


Fig 1

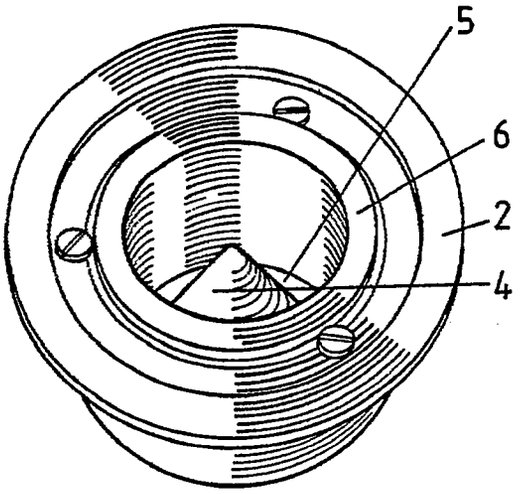


Fig 2

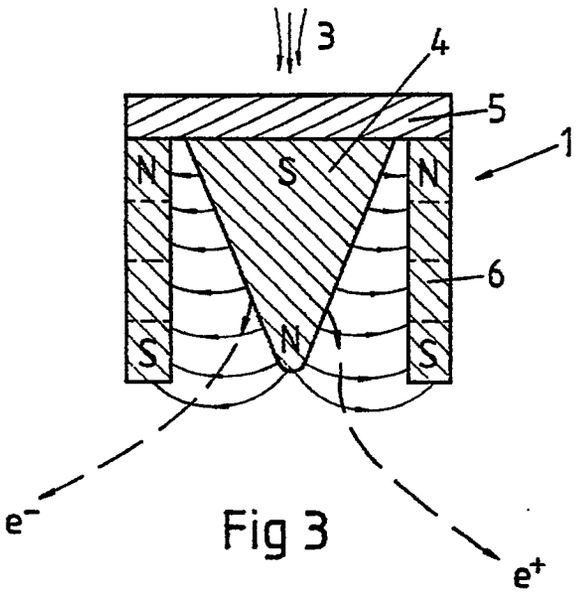


Fig 3

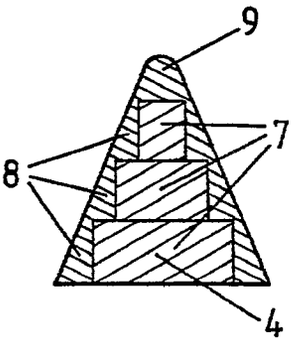


Fig 4

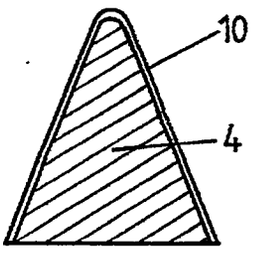


Fig 5

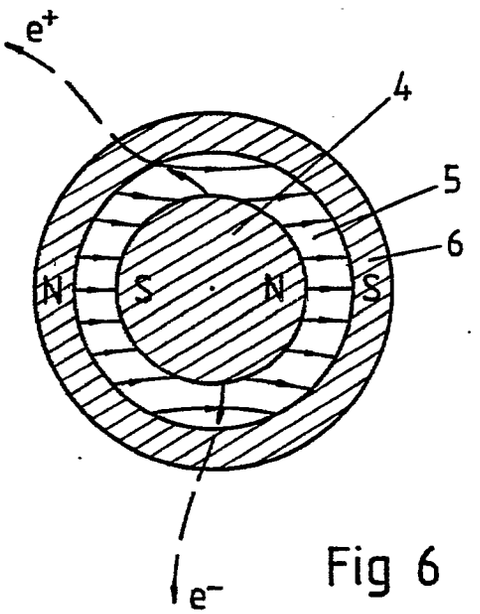


Fig 6

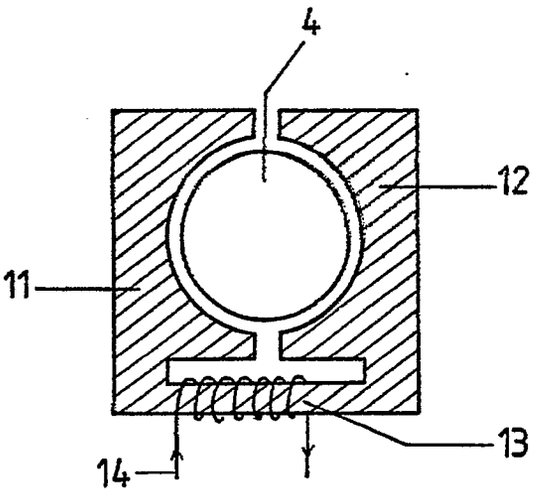


Fig 8

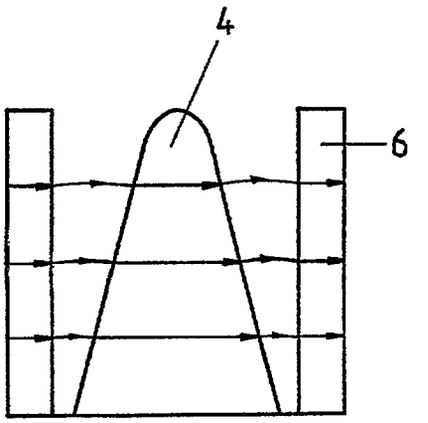


Fig 7

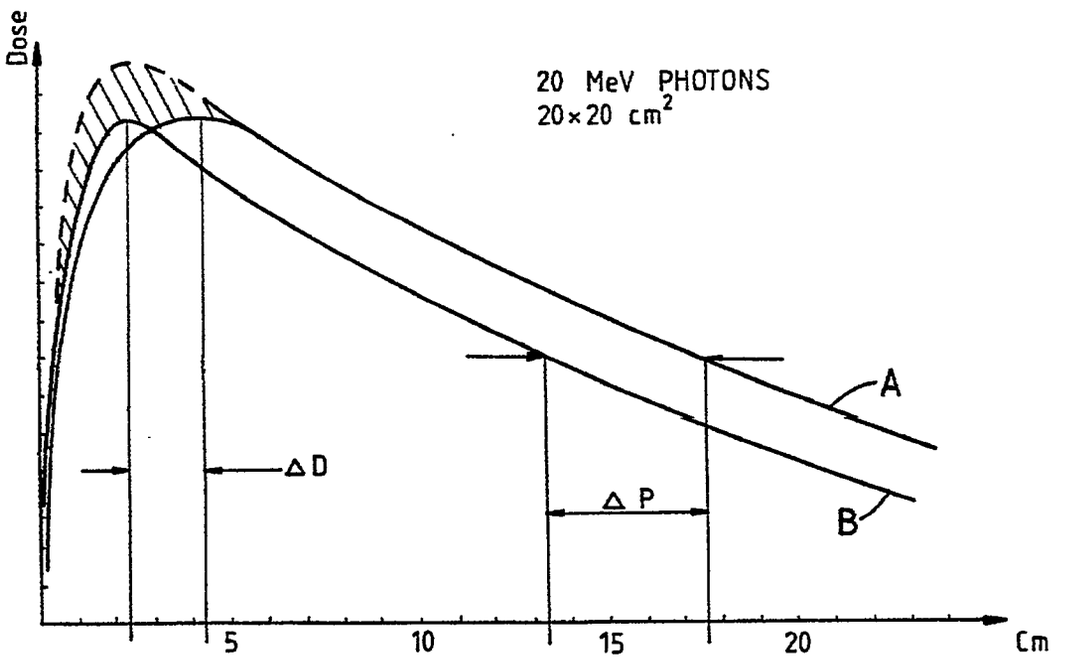


Fig 9