Magnetic Field Effects On Radiation Dose Distribution

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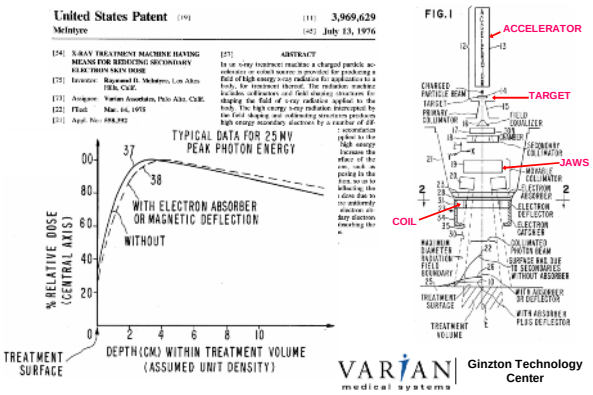
Interaction of the external beam-derived secondary electrons with magnetic fields

- Brief historical review.
- Non-uniform magnetic fields.
- Uniform MRI fields and tissue density effects.
- Treatment planning issues.
- Engineering trade-offs.
- Conclusions.

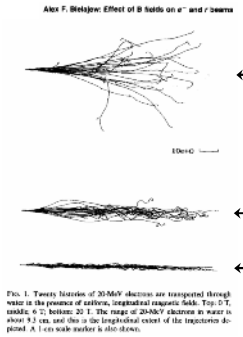
1976 McIntyre patent



Improved Monte Carlo codes

- 1978 Ralph Nelson introduced magnetic field transport to EGS3.
- 1984 Alex Bielajew developed improved method to incorporate both E and B fields in EGS4 user codes.
- AAPM Farrington Daniels Award for a paper on dose enhancement due to charge storage in electron-irradiated phantoms.
- 1993 paper by A.F. Bielajew. “The effect of strong longitudinal magnetic fields on dose deposition from electron and photon beams”. Med. Phys. 20 (1993) pp.1171-1179

Bielajew longitudinal B-field plots



20 MeV electron pencil beams

0 Tesla

6 Tesla

20 Tesla

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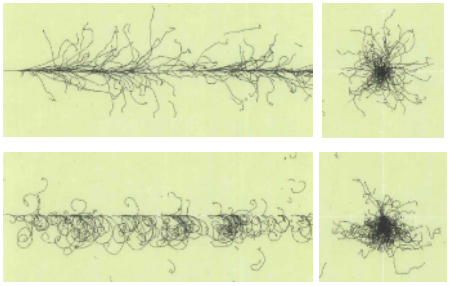
6 MeV photon beam transport in transverse B-field



0 Tesla

1.5 Tesla at 90°

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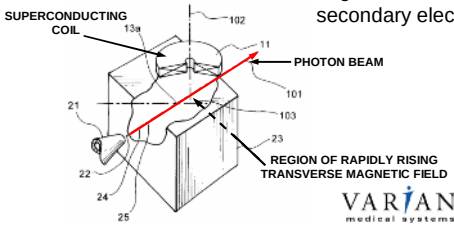
Leonard Reiffel patent

Approached by a third party who implied that there was a patent with a method for achieving proton-like dose distributions with a photon beam combined with a magnetic field to shape the secondary electron cloud



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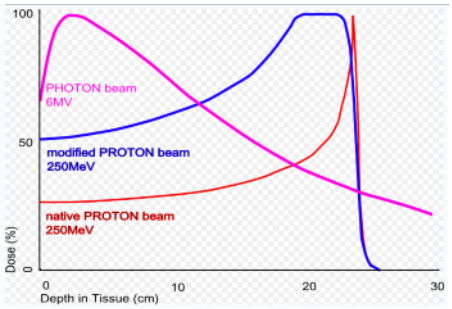
Depth dose for X-rays and protons



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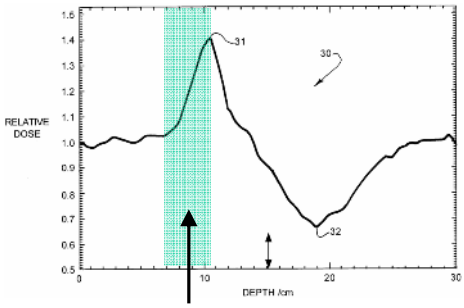
Inventor himself claimed only 40% dose enhancement



REGION OF RAPIDLY RISING TRANSVERSE MAGNETIC FIELD

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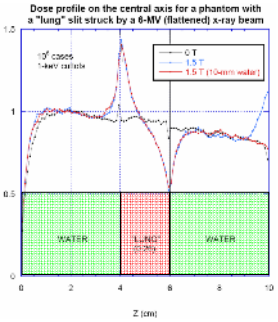
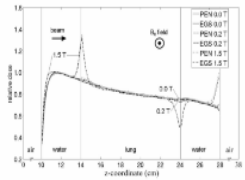
Dose deposition in transverse B-field

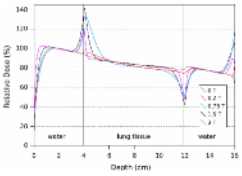
Electron Return Effects



Ralph Nelson EGS5 result



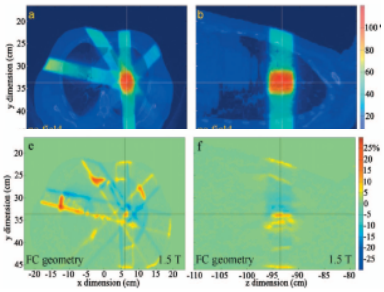
B.G. Fallone et al. Med. Phys. 35 (3) March 2008 pp. 1019-1027



A.J.E. Raaijmakers et al. Med Phys. Biol. 53 (2008) pp. 909-923

Dose Deposition

Tissue density compensation using opposed beams



B.G. Fallone et al. Med. Phys. 35 (3) March 2008 pp. 1019-1027

5-field lung treatment plan – 2 fields are 180° apart

Magnetic field vs. image quality

CT

Rifkin MD. MRI of the prostate. *Crit Rev Diagn Imaging*. 1990;31:223-262

1.5T MRI

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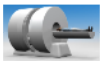
B-field/beam axis/patient axis orientations

University of Utrecht group and Viewray have the treatment beam transverse to the B-field which is aligned along the rotation axis.



Dr Fallone's group have the beam transverse to the B-field and both are transverse to the rotation axis.

Stanford have the treatment beam parallel to the B-field and both are transverse to the rotation axis.

Engineering trade-offs in combined MRI-RT Systems

- Performance tradeoffs re magnetic field orientation and field strength are complex.
- Three leading university groups pursuing widely different approaches.
- Good situation!

Acknowledgements

- The speaker would like to thank Ralph Nelson for many helpful discussions, teaching him the basics of Monte Carlo modeling, and for running the B-field transport examples shown.

Thank you for your attention