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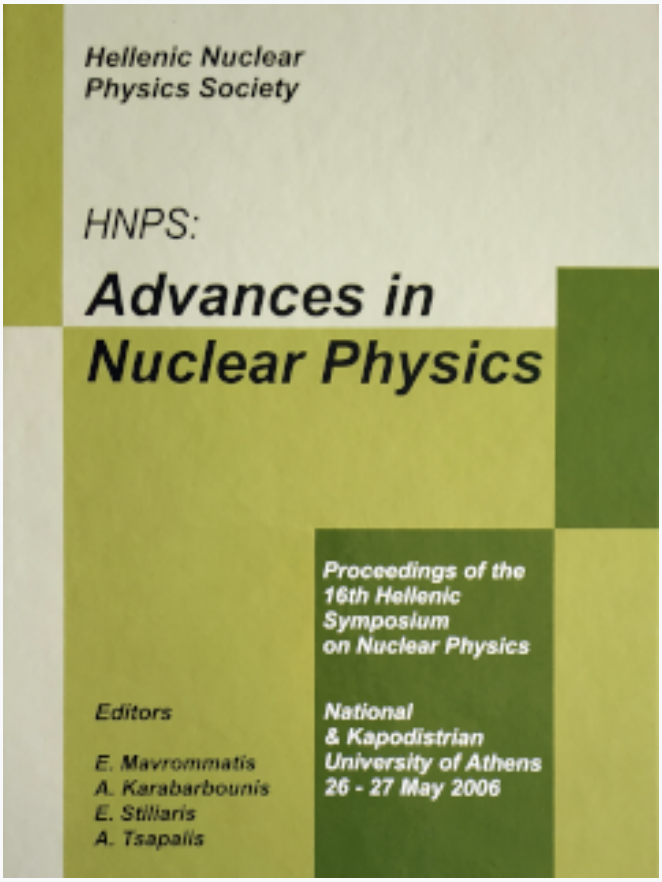

Feasibility study of the use of antiprotons and other heavy particles in therapeutic and diagnostic applications

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Cancer is the second cause of death in the western community. Physics among other sciences works on the solution of this difficult puzzle. Applications of Physics on Medicine, whose contribution is regarded as extremely significant for the fight against cancer are Computer Tomography (CT), Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET), Photon-Electron beams (Linacs) and relatively recently, Hadron beams for cancer treatment.

Intense interest is also being observed nowadays about hadrons' accelerators with application on cancer treatment despite the high cost of these accelerators. Further we are going to examine the reasons which justify this interest.

This work was done by using the Monte Carlo code, FLUKA.

The following pictures illustrate the improvement of the isodose curves when the irradiation is done by protons (fig.1b) than by photons (fig.1a).

The refinement of the isodose curves can be easily explained from the Figure 2.

Heavy charged particles deposit the maximum of their energy at the end of their path, forming the Bragg peak. The exact point of the Bragg peak depends on the energy of the beam and therefore the maximum of the dose can be delivered to the target. Furthermore we can extract from the above picture the following conclusion: the largest peak is formed by antiprotons, the second peak by protons and the last one by carbon-12 ions. Another

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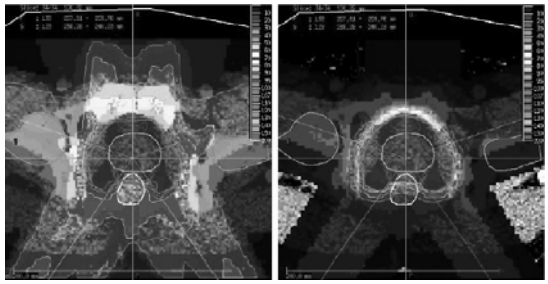

Figure 1. Irradiation of a prostate with (a) IMRT (Intensity Modulated Radiotherapy) and the same irradiation with (b) IMPT (Intensity Modulated Proton Therapy).

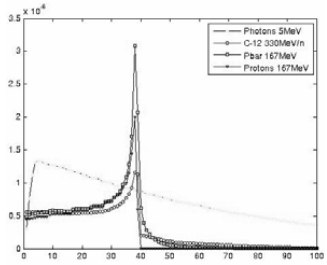

Figure 2. Depth dose curve of Photons, Carbon-12 ions, Antiprotons and Protons.

conclusion is that after the Bragg peak the antiprotons and the carbon ions form a 'tail' contrary to the protons. The 'tail' is formed due to the fragmentation of the beam (for ^{12}C ions) and the target, because of the nuclear reactions. The lighter ions that are produced move deeper inside the matter and deposit their energy after the Bragg peak.

We will go on with the presentation of another comparison which helps us decide which beam has the best dosimetric characteristics among photons, carbon ions, antiprotons and protons. An irradiation was done with the same way for all the above beams. Region 2 is the target and regions 1 and 3 are the healthy tissues. Table 1 presents the doses that the healthy tissues receive when 1Gy dose is delivered to the target. From Table 1 we conclude that the beam with the best dosimetric characteristics is this of the antiprotons.

Furthermore antiprotons provide the opportunity of real-time imaging during the treatment, contrary to protons' and carbon ions' beams. Real time imaging could be based on the annihilation of positrons which are produced during the annihilation of antiprotons. Both annihilations last less than a few 10^{-9} sec and therefore imaging is possible during cancer's treatment. The mean kinetic energy of the positrons is aproximetely 1.4MeV (fig. 3) and therefore they are annihilated in the area in which they where produced and consequently the image will be from that area.

Table 1.Healthy tissues' dose for each beam.

Beams	*Reg.*1 (*Gy*)	*Reg.*3 (*Gy*)
Protons	0.6	0.05
Antiprotons	0.5	0.032
^{12}C	0.83	0.097
Photons 10MeV	1.1	0.72

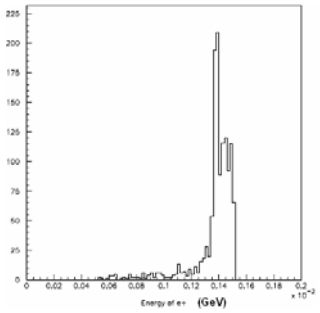

Figure 3. Energy spectrum of the positrons which are produced by the annihilation of the antiprotons at rest.

The reason which prohibited until now the usage of antiprotons in clinical routine, is the fact their production is very expensive (very powerful accelerators are needed). But in the near future this won't be a problem, because portable antiproton traps have already been constructed (fig. 4).

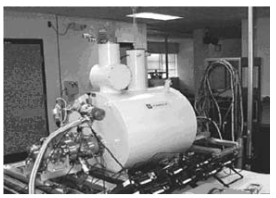

Figure 4. Portable antiproton trap, able to transfer 10^{12} antiprotons.

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