

Relative Biological Effectiveness of Antiprotons The AD-4/ACE Experiment

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Particle beam cancer therapy was introduced by Robert R. Wilson in 1947 based on the advantageous depth dose profile of a particle beam in human-like targets (water) compared to X-rays or electrons. Heavy charged particles have a finite range in water and present a distinct peak of dose deposition at the end of their range. Early work in Berkeley concentrated on multiple ion species and revealed strong differences in effectiveness in terminating cancer cells for different ions and along the particle track. This can be expressed in terms of the relative biological effectiveness (RBE). The search for the “ideal particle” was started and early on, exotic particles like pions and antiprotons entered the field. Enhancement in physical dose deposition near the end of range for antiprotons compared to protons was shown experimentally but no data for the relative biological effectiveness were available. In 2004 the AD-4/ACE collaboration set out to fill this gap. In a pilot experiment using a 50 MeV antiproton beam we measured the ratio of cell termination between the Bragg peak and the entrance region (plateau), which can be expressed by the biological effective dose ratio (BEDR), showing an increase of cell killing capability of antiprotons compared to protons at identical energy by a factor of 4. This promising result led to a continuation of the AD-4/ACE campaign using higher energy antiprotons and adding absolute dosimetry capabilities, allowing the extraction of the RBE of antiprotons at any depth along the antiproton beam.

KEYWORDS: particle therapy, antiprotons, relative biological effectiveness (RBE)

1. Introduction

The field of particle beam cancer therapy was born in 1946 when Robert R Wilson submitted his seminal paper titled “Radiological Use of Fast Protons” to the Journal of the Radiological Society of North America [1]. He declares: “*Higher-energy machines are now under construction, however, and the ions from them will in general be energetic enough to have a range in tissue comparable to body dimensions. It must have occurred to many people that the particles themselves now become of considerable therapeutic interest*” and humbly continuous “*The object of this paper is to acquaint medical and biological workers with some of the physical properties and possibilities of such rays*”. Without any complicated math he introduces the concept of the finite range, the enhanced dose and biological effect near the end of range, and shows in his final graph a realistic depth dose distribution, including straggling.