

# Cell Inactivation by Beryllium, Boron and Carbon Ions at the Low-energy Irradiation Facility of the Naples University

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## Abstract

The 3MV HVEC TTT-3 Tandem accelerator at the University of Naples, already used for radiobiological studies with protons and alpha particles, was set up for irradiation of biological samples with low energy carbon, boron, and beryllium beams. Radiobiological characterisation and study of these ion beams is essential in hadrotherapy to understand, for example, the possible biological effect of the target fragmentation products. Furthermore in space radiation biology we need to know the biological effects of heavy ions, a component of cosmic radiation that can contribute to the radiobiological risk when long sojourns in space are concerned. V79 Chinese hamster cells were irradiated with the different ions and the resulting cell inactivation data are reported.

KEYWORDS: Ion beams, high LET, cell inactivation.

## 1. Introduction

Radiobiology of heavy ions has recently attracted increasing interest in particular for its applications in two important fields. The first one is radiotherapy, where use of heavy ions could be more advantageous compared to protons, mostly in terms of the higher RBE for cellular inactivation [1]. The second one is space radiation biology: in fact, cosmic radiation has a heavy ion component, and the understanding of its radiobiological effects is crucial for risk evaluation in space [2]. The 3MV HVEC TTT-3 Tandem accelerator at the University of Naples, already used for radiobiological irradiation with proton and helium beams, was then tuned for irradiation of biological samples, at low energy, with several ion beams (at present C, B, Be).

In order to study the biological effect of the fragmentation products that take place at radiotherapy carbon beam it was necessary to characterise the beams from a radiobiological point of view.

Survival measurements have been carried out on V79 Chinese hamster cells, with C, B and Be beam, and RBE has been evaluated for these ions.

## 2. Material and Methods

The Tandem accelerator in Naples has been set up for delivering ion beams for radiobiological studies. The beam line is at an angle of 30° with respect to the switching magnet, positioned after an analyser magnet providing the desired charge selection. A 2 mm diameter collimator followed by a 1 mm collimator collimates the selected beam. The beam is then scattered by a gold foil with a thickness of 0.2 µm, in order to homogeneously irradiate the sample whose diameter was 1 cm. Beam is finally extracted in air through an aluminised Mylar window (2 µm thick) supported by very thin wires.

Beam fluence was continuously recorded by a set of four silicon detectors put around the beam exit window. The beam monitor was calibrated with CR39 plastic detector located at the sample holding on the beam during the sample change.

V79 Chinese hamster cells have been grown and irradiated in suitable glass wells with a 3 µm Mylar base in order to obtain the dose-response curve for the three different ions.

## 3. Results and Discussion

The described system was able to deliver beryllium, boron, and carbon ions at a rate of 1 Gy/min.

The spatial uniformity of the beam was checked counting the number of tracks in 9 different fields (area of 1.12 10<sup>-4</sup> cm<sup>2</sup>) of the plastic detectors.

The energy distribution of the different beams was determined both in vacuum, and after extraction in air with a silicon detector. We carried out six different experiments (two for each ion beam) for measuring cell survival. Incident energies for beryllium, boron and carbon were respectively 5.3, 6.6 and 7.3 MeV corresponding to LET values, at the cell mid-plane, of 660, 542 and 859 keV/µm.

Inactivation data were fitted with a linear-quadratic model ( $S = S_0 \exp(-\alpha D - \beta D^2)$ ) and the quadratic term was found compatible with zero for all the three ions, as expected when highly ionising particles are involved. Survival curves are shown in Figure 1.

RBE has been evaluated in two different ways: As  $\alpha/\alpha_\gamma$  representing the effectiveness at very low doses, and as the ratio between 2 Gy, the reference  $\gamma$  ray dose, which is commonly used in radiotherapy, and the ion dose producing the same inactivation level. Irradiations with  $\gamma$ -rays from a <sup>60</sup>Co source were reported in a previous work [3].

In Table I we report our results (including the inactivation cross sections).

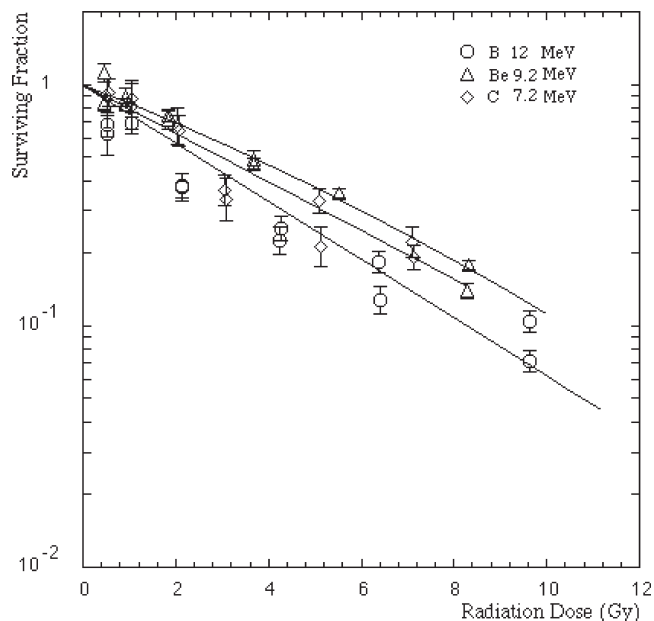


Fig. 1 – V79 cell line inactivation curves following B, Be, C irradiation

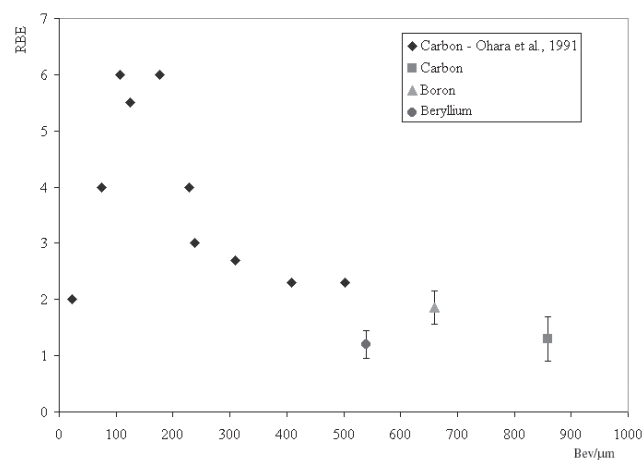


Fig. 2 – RBE vs LET: our data for B, Be, and C ion irradiation and C data from literature

**Table I** – RBE and cross-section values after irradiation of V79 cells with C, B, and Be ions.

	carbon	boron	beryllium
LET (keV/μm)	859	660	540
RBE (2Gy/γ/D <sub>isoeffect</sub> )	1.30±0.40	1.85±0.30	1.20±0.25
RBE (α/αγ)	1.53±0.85	1.85±1.00	1.15±0.56
σ (μm <sup>-2</sup> )	31.6±9.6	29.3±8.0	14.9±2.2

In Figure 2, the 2 Gy RBE(2Gy/D<sub>isoeffect</sub>) is plotted together to carbon data from literature [4]. In the case of carbon ions it can be seen that our result confirms the RBE decreasing at high LET values in good agreement to data from literature. No data exist in literature about boron and beryllium.

REFERENCES

- [1] Golovkov M, Aleksandrov D, Chulkov L, Kraus G and Schardt D. Fragmentation of 270 A MeV carbon ions in water. *Advances in Hadrontherapy*. U Amaldi, B Larsson, Y Lemoigne Eds. Elsevier 1997; 316
- [2] Durante M. Biological dosimetry in astronauts. *La Rivista del Nuovo Cimento* 1996; 19; 3-12
- [3] Belli M, Bettega D, Calzolari P, Cera F, Cherubini R, Dalla Vecchia M, Durante M, Favaretto S, Gialanella G, Grossi G, Marchesini R, Moschini G, Piazzola A, Poli G, Pugliese M, Sapora O, Scampoli P, Simone G, Sorrentino E, Tabocchini MA, Tallone L and Tiveron P. Inactivation of Tumoral and Normal Human Cell irradiated with Low Energy Protons. *Int J Radiat Biology* 2000; 76; 831-840.
- [4] Ohara H, Kanai T, Ando K, Kasai K, Itsukaichi H, Fukutsu K, Kawachi K and Sato K. Studies on physics and biology of carbon beams of Riken and Nirs. *Proceedings of the Nirs International Workshop on Heavy Charged Particle Therapy and Related Subjects*. 1991: 13-22