Validity analysis of the single ion approach for TLD efficiency calculations *

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The, recently developed, single ion approach represents a basically analytical method to calculate the relative effectiveness of thermoluminescent detectors [1]. This approach computes the detector response starting from the response of a single ion of the beam. The dose contributions coming from the neighboring tracks are assumed to sum up linearly. This condition is not always satisfied and restricts the validity range of the model especially for high fluences.

In order to test this limitation relative effectiveness calculations have been performed at fixed energy for different fluence values, Figure 1. As expected, for relatively low fluences (below 10^8 cm^{-2}), the effectiveness does not change and the single ion approximation is valid. However, increasing the fluence, supra-linear and saturation effects in the inter-track region start to be significant and affect the relative effectiveness calculation.

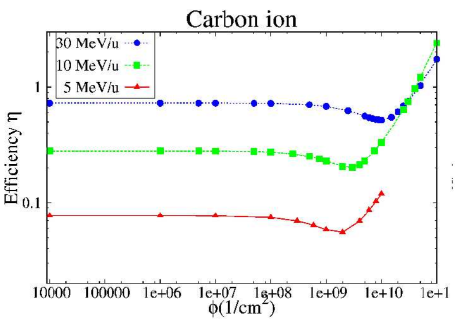

Figure 1: Relative effectiveness calculation with the single ion approach varying the fluence, for carbon ions of different energies.

Moreover, the single ion approach requires the knowledge of the radial dose distribution $D(r)$ and a parametrization of the low-LET dose-response curve for the dosimeter, $TL(D)$ [1]. In the original version of the method we adopted the sub-model implemented in ECLaT[2] and, afterwards, a robustness analysis against changes in these input models has been performed.

In Figure 2 the impact on the effectiveness calculations of two different sets of parameters for the low-LET dose-response curve is shown. The first set (dashed red line) reproduces with a good accuracy the linear region while slightly under-estimates the supra-linearity; this leads to larger values for the relative effectiveness with respect to the second set (solid blue line) which, instead, better reproduces the supra-linearity region in the dose-response curve.

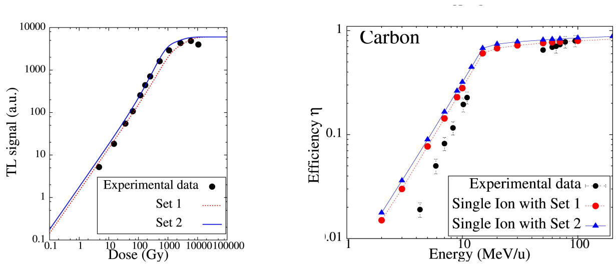

Figure 2: On the left: two possible parametrizations for the low-LET dose-response curve. On the right:relative effectiveness curves calculated with the two different parametrizations

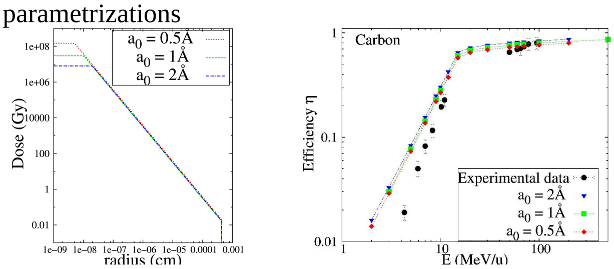

Figure 3: On the left: radial dose distributions for $10\ \mathrm{MeV/u}$ carbon ion calculated for different values of the core size a_0. On the right: the impact of the core size a_0 on effectiveness calculation for TLD-700.

Regarding the radial dose distribution the robustness of the method against changes in the core size, a_0, has been tested. On the left panel of Figure 3 the radial dose distribution around the ion for different values of a_0 is shown while, on the right one, effectiveness calculations for different radial dose distribution are compared. For the smaller core, $a_0 = 0.5$ Å, the efficiency values are lower. This observation is consistent with the fact that decreasing the core size the dose in the inner region of the radial dose distribution increases and, thus, the saturation effect is more pronounced.

We can therefore conclude that, although the single ion approach is still at the first stage of development and the single ion approximation limits its validity, it is robust against changes in the input sub-models and the approximation is verified for a wide range of flueces (up to 10^8cm^{-2}), including the fluence range used for clinical applications.

References

[1] D.Boscolo *et al.*, "TLD Efficiency calculation for heavy ions: a new approach", GSI Scientific Report 2013 (2014).

[2] O. B. Geiß , *et al.*, "Efficiency of thermoluminescence detectors to heavy charged particles". NIM B, 142:592–598, 1998.

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