Positron induced chemistry in biological medium

Is energy deposition by high energy particles the right measure of tissue damage?

In radiation therapy most studies and predictions of the effects on living matter were based on energy deposition by a beam of high energy particles. It was assumed that all effects including the biological damage, and especially damage to the DNA, were proportional to the energy loss. Recent studies of the effect of individual electrons on organic molecules of high complexity such as DNA [1,2] have revealed that dissociative electron attachment (DEA) may be the primary cause of damage. Furthermore it is most efficiently done by low energy electrons, with the cross sections for the process often peaking at energies just above thermal energy.

Thus we turn the focus from energy deposition of the primary positron beam to the effects of the secondary electrons which are typically formed with low to moderate initial energies (~< 20 eV). In addition, we base our production rates of the secondary electrons on the accurately measured and compiled cross sections to form a complete set [3]. It is assumed that the material of the cells is mainly water. We add the process of dissociative excitation for methane [4] to ten percent of the molecules to represent organic molecules in the tissue. The collisions leading to dissociative excitation represent dissociative processes with high energy loss (several eV).

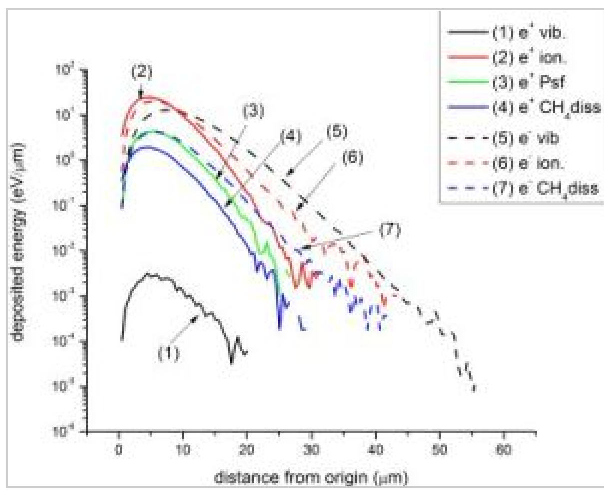

Figure 1. Expand for caption details.

Why did we not include the cross sections for low energy dissociative attachment? Well, we did actually, but the problem is that below 5 eV electrons are most likely hydrated. As the modeling of transport and collisions of hydrated electrons is still uncertain we do not show the data. It still remains a major goal, but high energy threshold dissociation also plays a role in inducing chemistry (and biochemistry) in the irradiated medium.

Calculations show that primary positron-induced dissociative processes are far fewer than those induced by secondary electrons (see Figure 2). The latter process extends also further in space and time. The chemical reactions resulting from the effect of the initial radiation may be followed and, in particular, if all issues of hydrated electrons are solved, one would be able to predict even the damage to the DNA, single and double strand breaks. Those predictions can be (as is the case here) based on an exact transport/collision model (Monte Carlo) and on accurately measured binary collision data rather than on semi-empirical relations associated with energy deposition only. Comparing Figures 1 and 2 we see that high-energy loss processes dominate (as expected) the energy loss, while some of the low-energy processes dominate the number of scattering events.

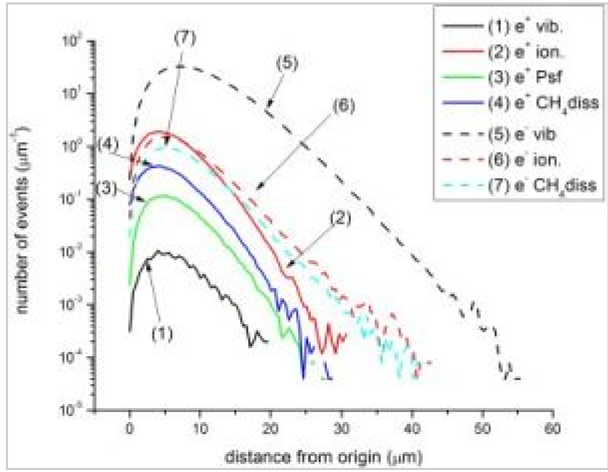

Figure 2. Expand for caption details.

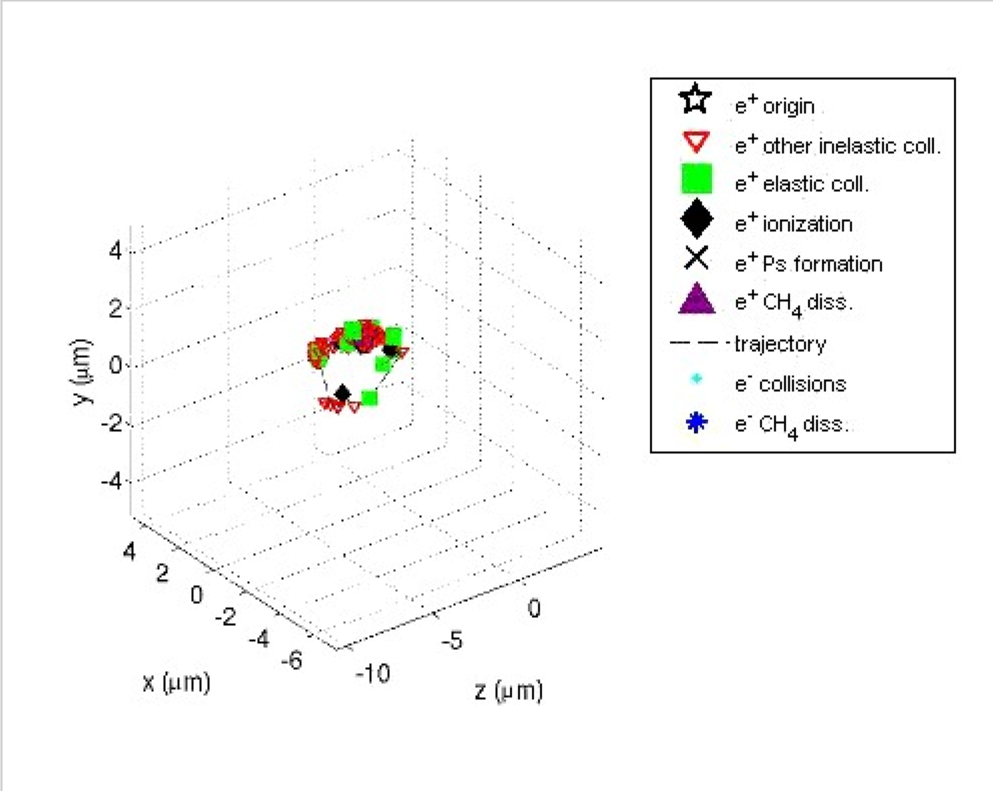

Figure 3. Animated figure - expand for full caption details.

Figure 3 shows an example of the positron trajectory, including the points of collisions resulting from an initial positron (with energy 800 eV) and collisions of the produced secondary electrons.

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References

[1] Huels M A *et al* 2003 *J. Am. Chem. Soc.* **125** 4467

[2] Anderson E K *et al* 2014 *J. Chem. Phys.* **141** 034306

[3] Banković A *et al* 2012 *New J. Phys.* **14** 035003

[4] Šašić O *et al* 2004 *New J. Phys.* **6** 74

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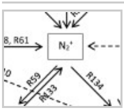

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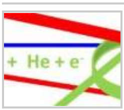

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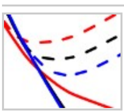

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