# Modeling secondary particle tracks generated by high-energy protons in water

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**Synopsis** We present interaction probability data of low-energy secondary electrons and positrons produced due to the proton impact. The probability distribution functions serve as input data for the Low Energy Particle Track Simulation (LEPTS) approach which allows one to include the effect of low-energy species in medical applications of radiation and in ion-beam cancer therapy, in particular.

The Low Energy Particle Track Simulation (LEPTS) code [1] is a powerful complementary tool to include the effect of low-energy electrons and positrons in medical applications of radiation. In particular, for ion-beam cancer treatments it provides a detailed description of the role of the secondary electrons abundantly generated in the vicinity of the Bragg peak, as well as the possibility of using transmuted positron emitters ($^{11}$C, $^{15}$O) as a complement for ion-beam dosimetry.

In this study, we present interaction probability data, derived from experimental and theoretical studies, of low-energy secondary species produced due to the proton impact. The probability distribution functions, which serve as input data for the model, are also complemented with a comprehensive review of experimental [2] and theoretical [3, 4] cross sections available in the literature. We will also update the corrective factors for solid and liquid environments calculated by means of the IAM-SCAR method [5, 6]. Using these data, single electron and positron tracks in liquid water and pyrimidine have been simulated to provide information about energy deposition as well as the number and type of interactions taking place in any selected "nanovolume" of the irradiated area.

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## References

[1] F. Blanco *at al* 2013 *Eur. Phys. J. D* **67** 199

[2] M. E. Rudd, Y.-K. Kim, T. Märk, J. Schou, N. Stolterfoht, and L.H. Toburen, *Secondary Electron Spectra from Charged Particle Interactions* (International Commission on Radiation Units and Measurements, Bethesda, MD, 1996) (ICRU 55)

[3] P. de Vera, R. Garcia-Molina, I. Abril, and A. V. Solov'yov 2013 *Phys. Rev. Lett.* **110** 148104

[4] P. de Vera, R. Garcia-Molina, and I. Abril 2015 *Phys. Rev. Lett.* **114** 018101

[5] F. Blanco and G. García 2003 *Phys. Rev. A* **67** 022701

[6] F. Blanco and G. García, 2004 *Phys. Lett. A* **330** 230

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