



HAL
open science

Theoretical study of W-values for particle impact on vapour and liquid water

Veronica Tessaro, Floriane Poignant, Michael Beuve, Benoit Gervais, Mariel E. Galassi

► **To cite this version:**

Veronica Tessaro, Floriane Poignant, Michael Beuve, Benoit Gervais, Mariel E. Galassi. Theoretical study of W-values for particle impact on vapour and liquid water. 10TH INTERNATIONAL SYMPOSIUM ON SWIFT HEAVY IONS IN MATTER & 28TH INTERNATIONAL CONFERENCE ON ATOMIC COLLISIONS IN SOLIDS - SHIM-ICACS 2018, Jul 2018, Caen, France. hal-01875665

HAL Id: hal-01875665

<https://hal.science/hal-01875665v1>

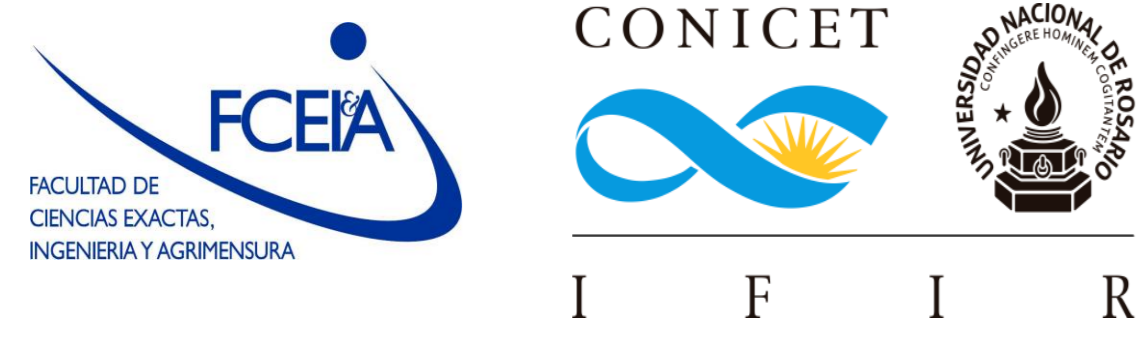
Submitted on 17 Sep 2018

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

THEORETICAL STUDY OF W-VALUES FOR PARTICLE IMPACT ON VAPOUR AND LIQUID WATER

V. Tessaro¹, F. Poignant², M. Bueve², B. Gervais³, M.E. Galassi¹



(1) Instituto de Física de Rosario (CONICET-UNR); FCEIA (UNR) Av. Pellegrini 250, Rosario, Argentina.
 (2) IPNL, Université de Lyon, CNRS/IN2P3 UMR 5822, Université Lyon 1, France
 (3) CIMAP, UMR 6252, Caen, France.



INTRODUCTION

- The knowledge of W values is crucial to radiation dosimetry using radiation chambers. W values are the link between the energy deposited in the gas by ionizing radiation, and the resulting electric charge measured. Thus, they are related directly to the energy absorbed in the medium, the dose.
- Also, extensive knowledge of the W values for different incident particles of various incident energies in gases and liquids is needed for full elucidation of radiation effects.

The aim of the present work is to study W values to improve uncertainties and provide values when experimental data are not available.

STATE OF THE ART

- W -values have been calculated using different theoretical approximations for electron impact in vapor and liquid water. Also exist experimental data for vapor water (Combecher Rad.Res 1980). The values **29,6 eV** was measured by Christophou et. al. (1971) for high energies. This was adopted as a reference value by ICRU 31 [1].
- In liquid water the W -values is **22 eV** by Mozunder.
- For proton impact there are no experimental data in water to compared, so we have to rely on theoretical or numerical calculations.
- In dry air W -values for electron and proton impact are well defined by IAEA [2] for high energies: **37.97 eV** for electrons with energy >10 keV; **34.23 eV** for protons with energy >20 MeV
- For heavy ions the W -values are consider as independent of the charge of the projectile since there is not enough experimental data. The value **34,5 eV** is set as constant by IAEA [2] for dry air.

Theoretical Models

$W=T/N \rightarrow$ mean energy required to form an ion pair upon the complete slow down of ionizing particles

To calculate this parameter, *inelastic cross sections* and the *cumulative counting of all the processes* induced by the incident and secondary particles are necessary. As the contribution of secondary electrons to the calculation is of crucial importance for all types of incident particles (electrons, ions, etc.), we started studying W -values by electron impact on liquid and vapor water.

For the *cumulative counting processes* we use two theoretical models:

- 1) MDM Monte Carlo simulation [3] \rightarrow track event-by-event of all generated particles
- 2) Analytic method of Fowler Equation [4] \rightarrow Continuum Slowing Down Approximation

$$W(T) = T / \int_1^T dT' / w(T') \rightarrow w(T) = \frac{\epsilon(T)}{\sigma_{ion}(T) + \sigma'_{ion}(T)}$$

Differential w value

$$\epsilon(T) = \sum_n \sigma_n^{exc} \Delta E_n + \sum_k \left[\int_{E_{min}}^{E_{max}} \frac{d\sigma_k^{ion}}{dE} (E + I_k) dE \right]$$

CS stopping power

$$\sigma'_{ion}(T) = \sum_k \left[\int_{E_{min}}^{E_{max}} \frac{d\sigma_k^{ion}}{dE} J(E) dE \right]$$

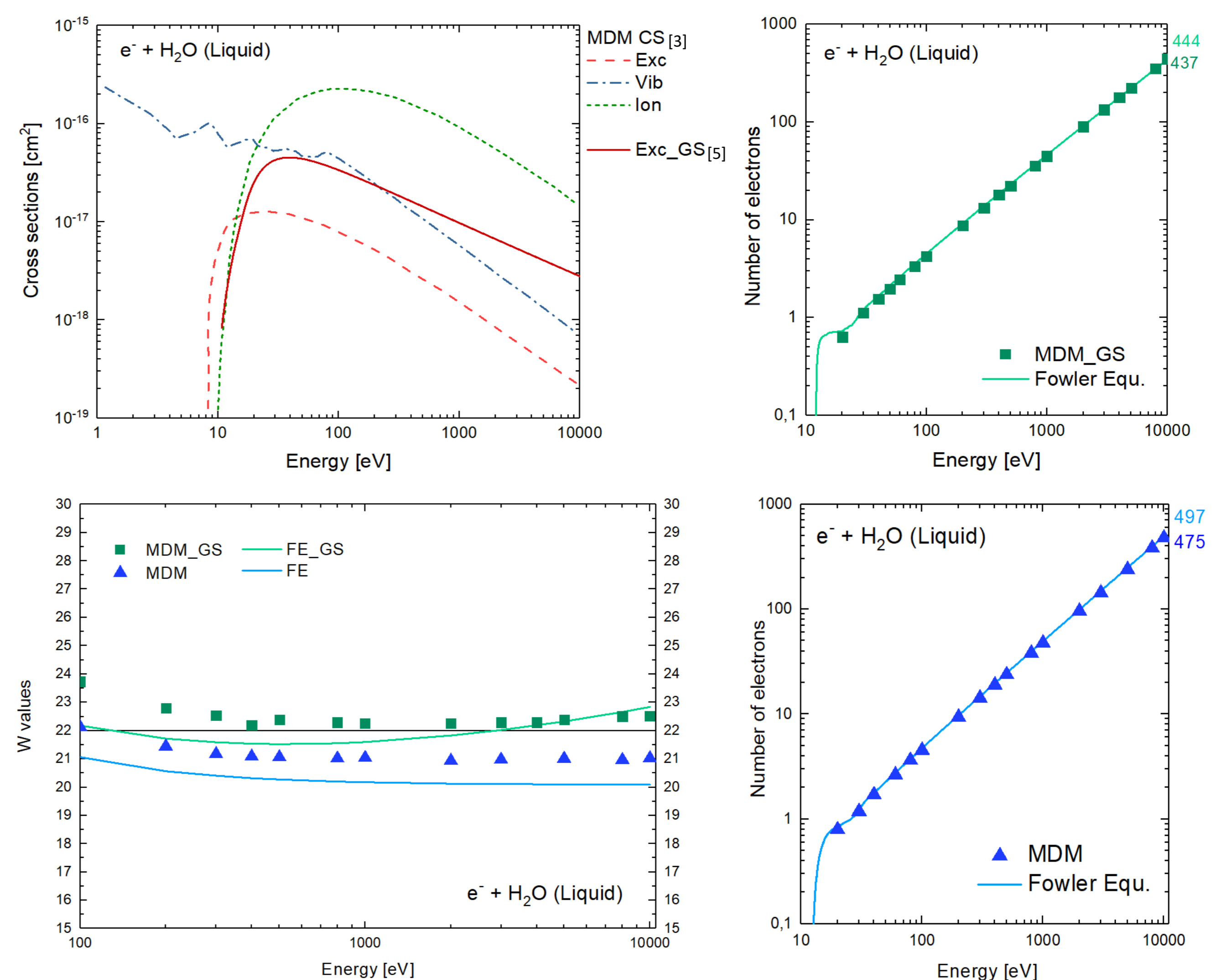
Ionization cross sections for secondary processes

$$J(E) = P_{ion}(E) + \sum_n P_n^{exc}(E) J(E - E_n^{exc}) + \sum_k \left[\int_{E_{min}}^{(E-I_k)/2} \frac{d\sigma_k^{ion}}{dE'} \frac{1}{\sigma_T(E)} \{J(E - E' - I_k) + J(E')\} dE' \right]$$

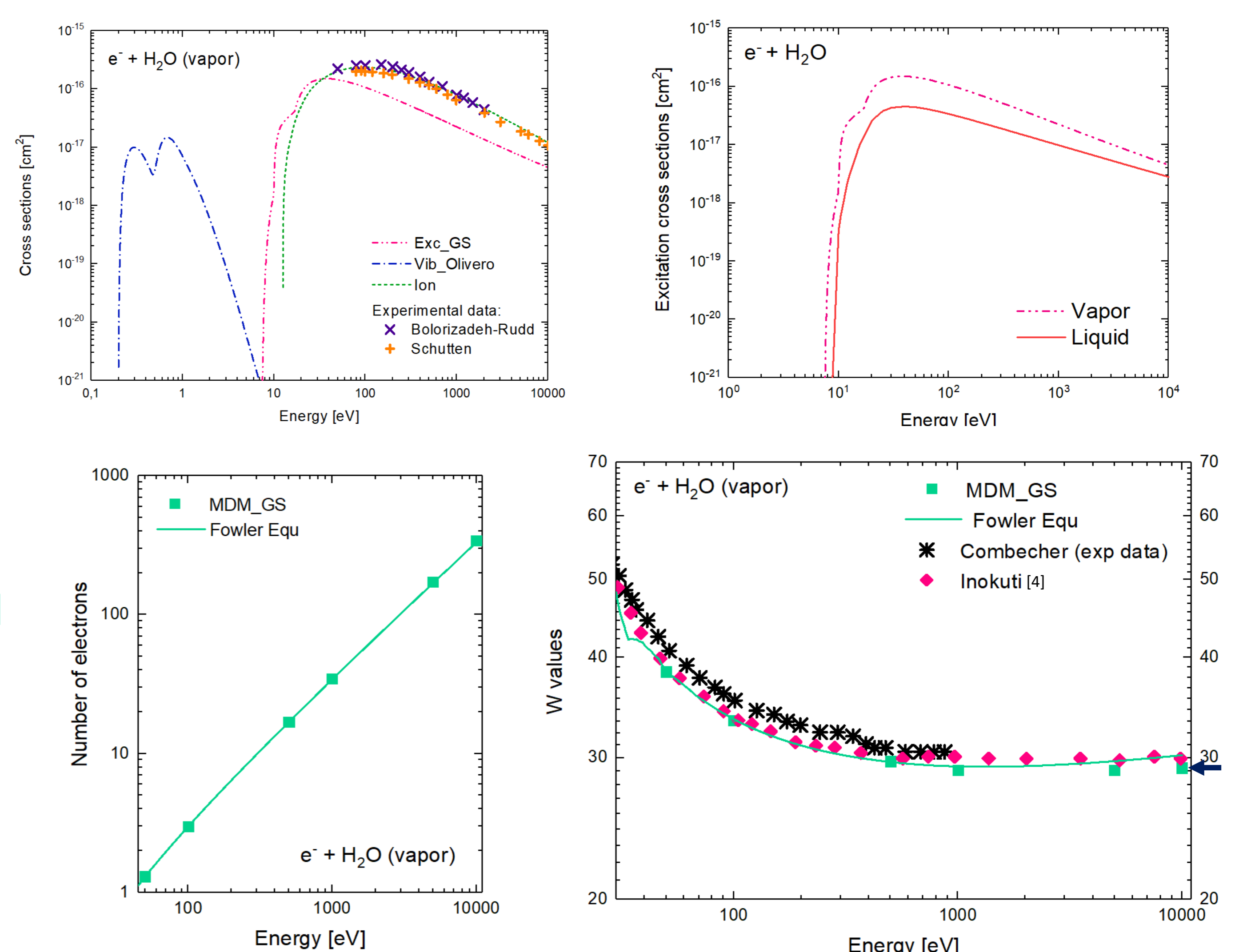
Number of electrons generated

ELECTRON IMPACT

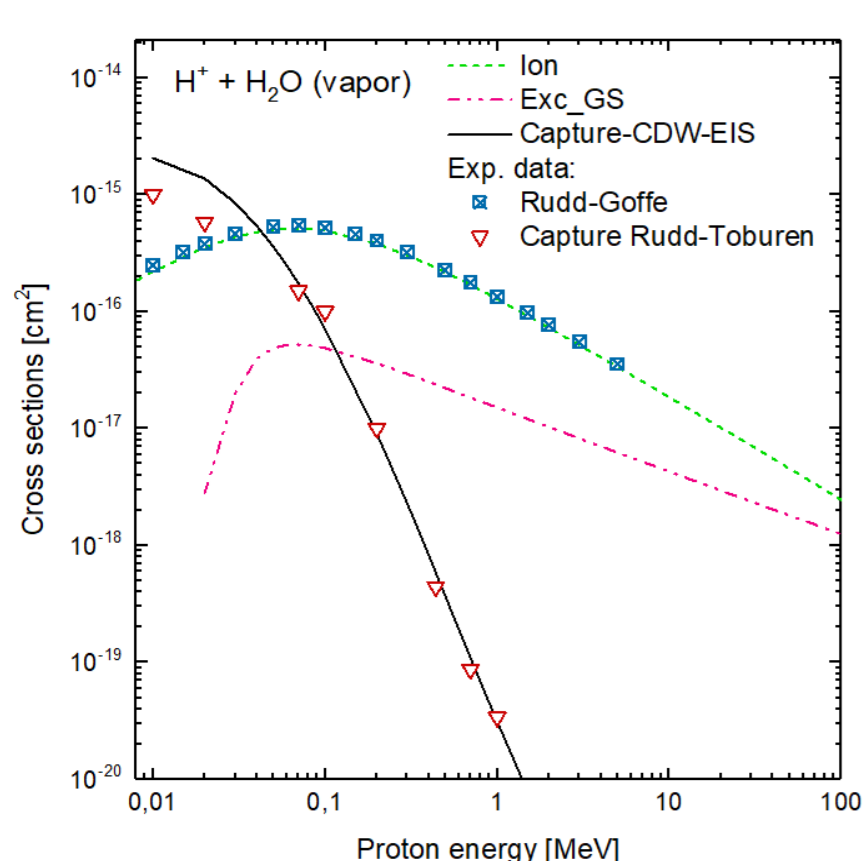
Liquid water



Vapor water

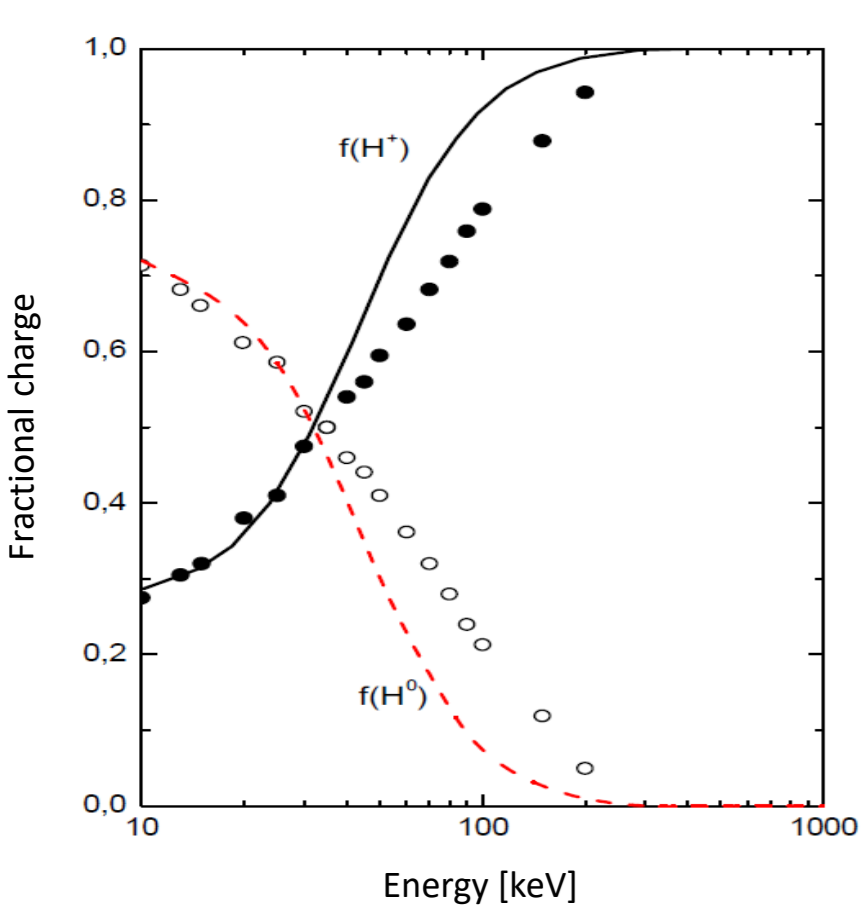
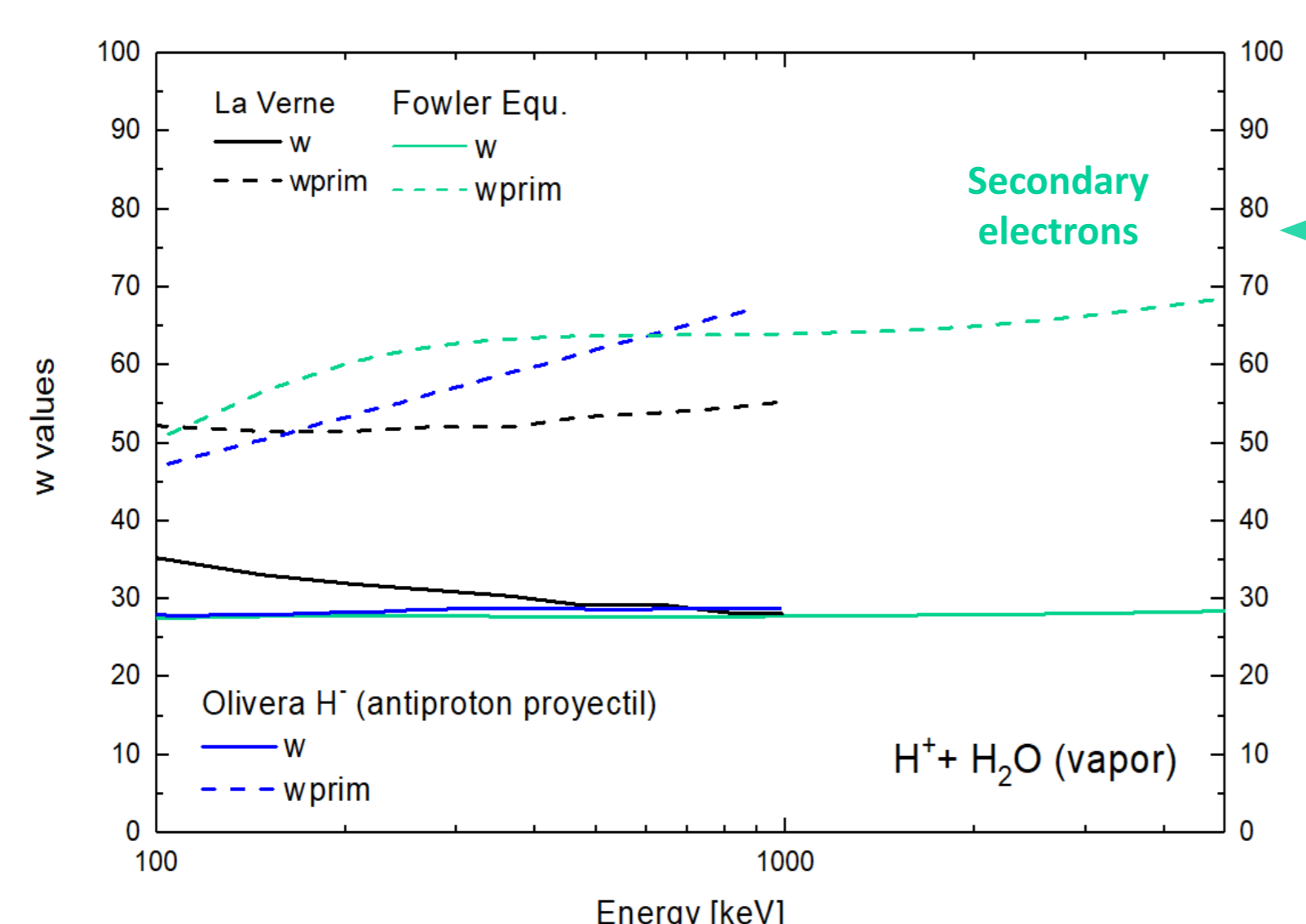


PROTON IMPACT – FOWLER EQUATION



For high-energy particles in thin media, only a fraction of the particle energy dE is deposited in a medium, so it is necessary to consider the differential w value, $w = dE/dN$. Preliminary results: The Fowler Equation model validity is from 500keV (charge exchange is negligible).

$$w = \frac{f(H^+) \Sigma^+ + f(H) \Sigma}{f(H^+) \{\sigma^+ + \sigma'^+\} + f(H) \{\sigma + \sigma'\}}$$



CONCLUSIONS & PERSPECTIVES

Electron impact:

- There was no appreciable difference including the vibrational excitation and attachment processes.
- The calculations have a strong dependence on the cross sections considered.
- Both models are in good agreement with other theoretical models and experimental data (vapor water).

Proton impact:

- For proton impact, the preliminary results are comparable to those of electrons, at high energies, as many authors suggest. Although heavy charge should be studied. In the future we will research if there is a dependence on the charge and energy of the projectile.

The next step is to improve Monte Carlo MDM code to simulate the impact of fast ions, not only in liquid water but also in air and other gases that constitute the radiation detectors. Regard the Fowler Equation, we will incorporated the charge exchange to study an extend range of energies.

Acknowledgements

This work was partially supported by the following institutions: Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Universidad Nacional de Rosario (UNR) (PID-ING 515 and AVEdocente), LABEX PRIMES (ANR-11-LABX-0063) of Université de Lyon, within the program 'Investissements d'Avenir' (ANR-11-IDEX-0007) operated by the French National Research Agency (ANR). We also acknowledge the financial support by ITMO Cancer in the framework of Plan Cancer 2009–2013.

Referencias:

- [1] ICRU REPORT 31. Average Energy Required to Produce an Ion Pair.
- [2] International Atomic Energy Agency (IAEA), *Technical Report Series TRS-398* (2000).
- [3] Gervais et. al., *Radiation Physical and Chemistry Vol 75* (2006).
- [4] M.Inokuti, *Ionization Yields in Gases under Electron Irradiation*, Radiat. Res. Vol.64 6-22 (1975).
- [5] A.Green, R.Stolarski, *J. of Atm. and Ter. Phy.* Vol.34, p.1703-1717 (1972).