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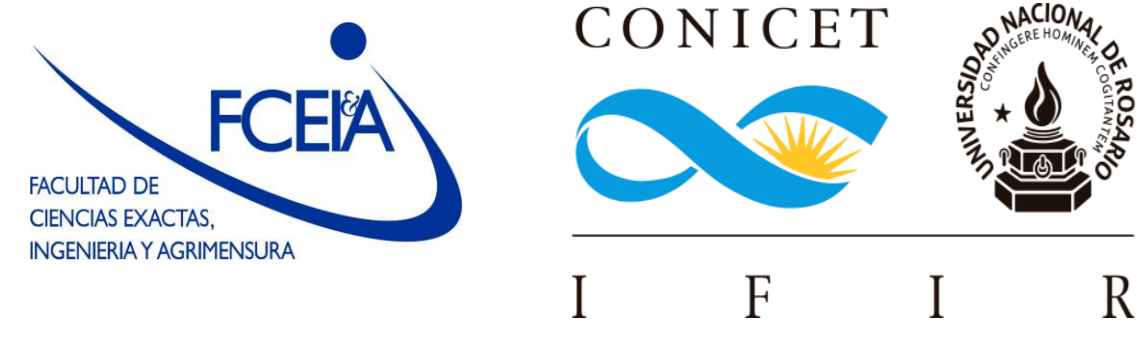
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# THEORETICAL STUDY OF W-VALUES FOR PARTICLE IMPACT ON VAPOUR AND LIQUID WATER

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## 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

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

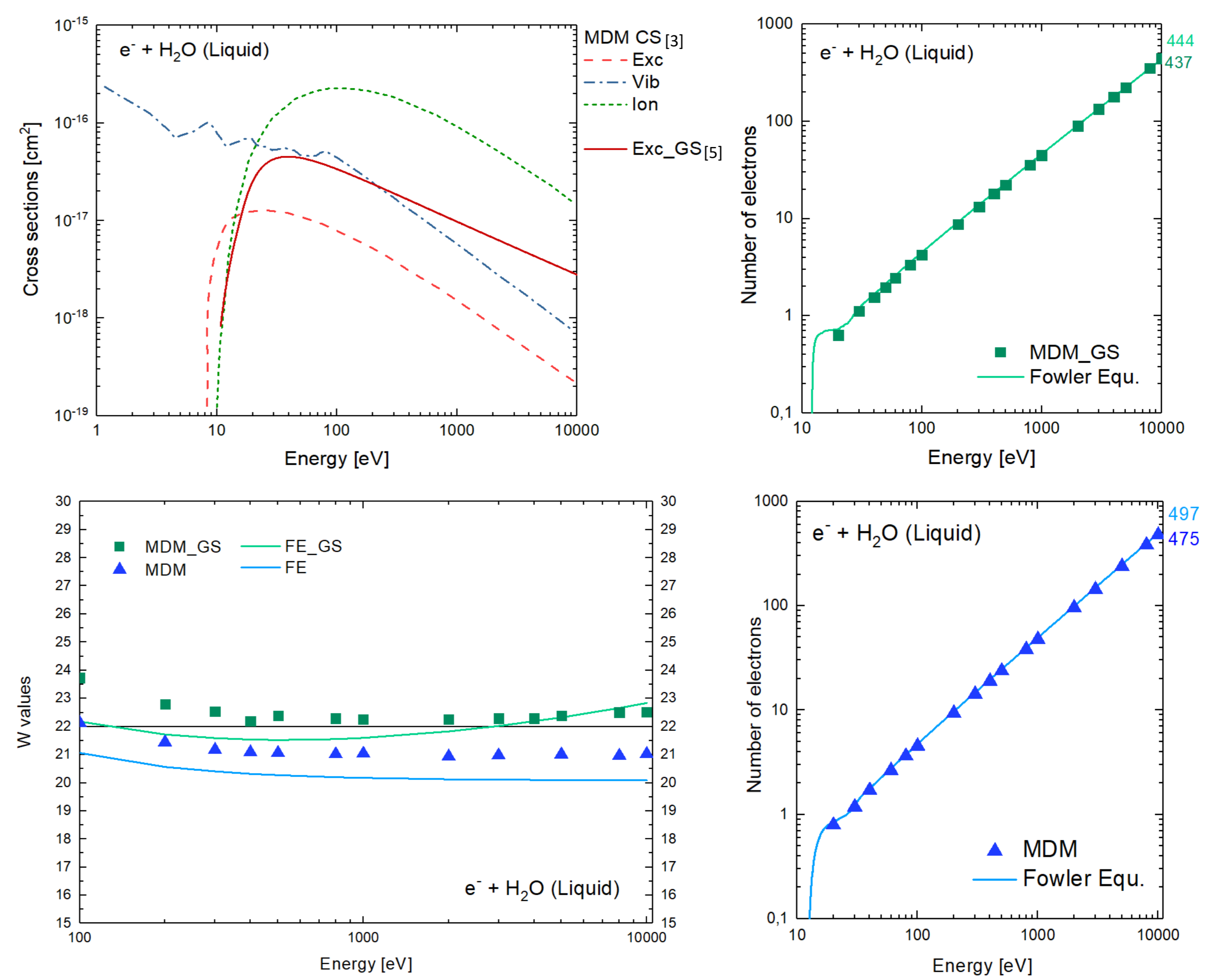
Ionization cross sections for secondary processes

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

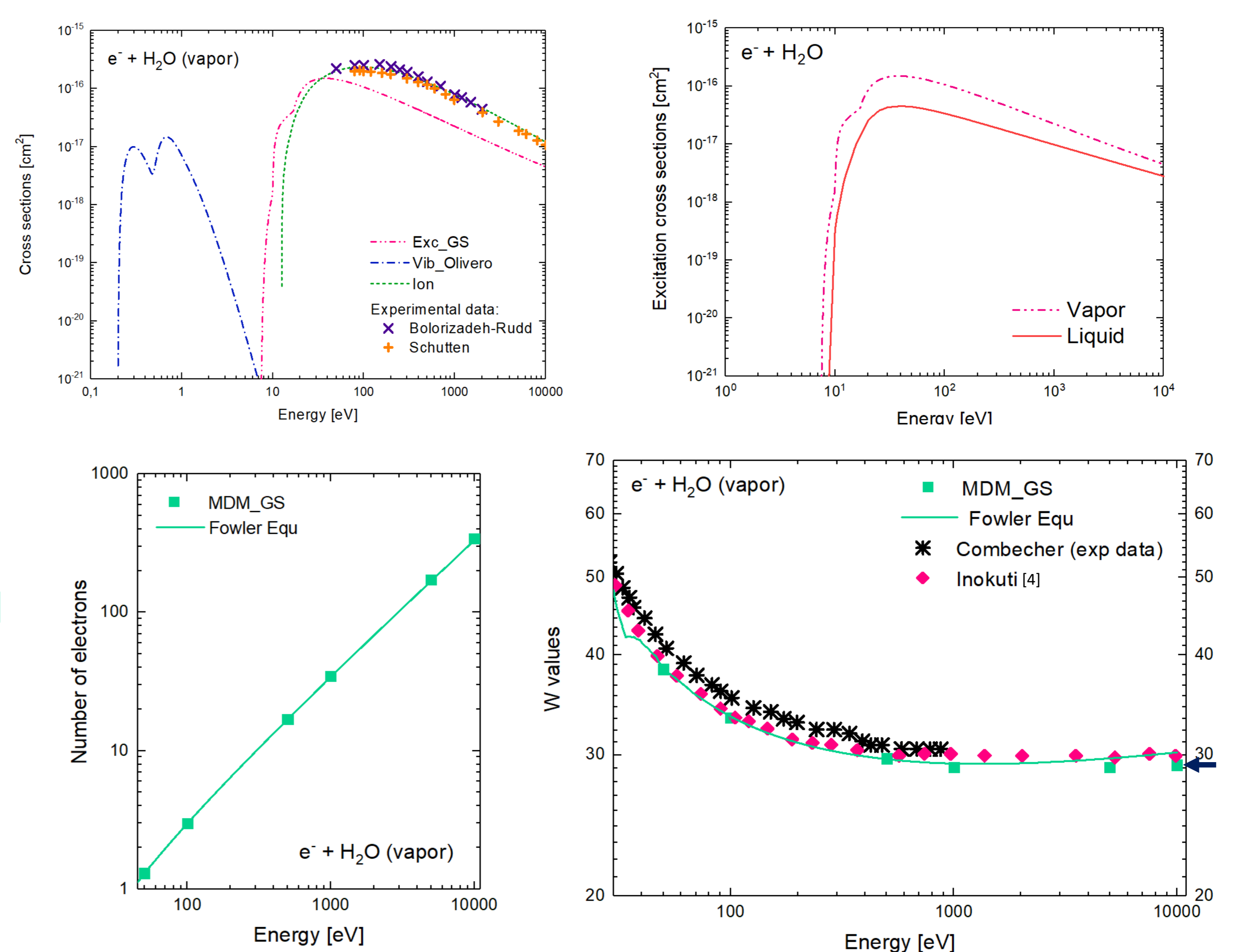
Number of electrons generated

## ELECTRON IMPACT

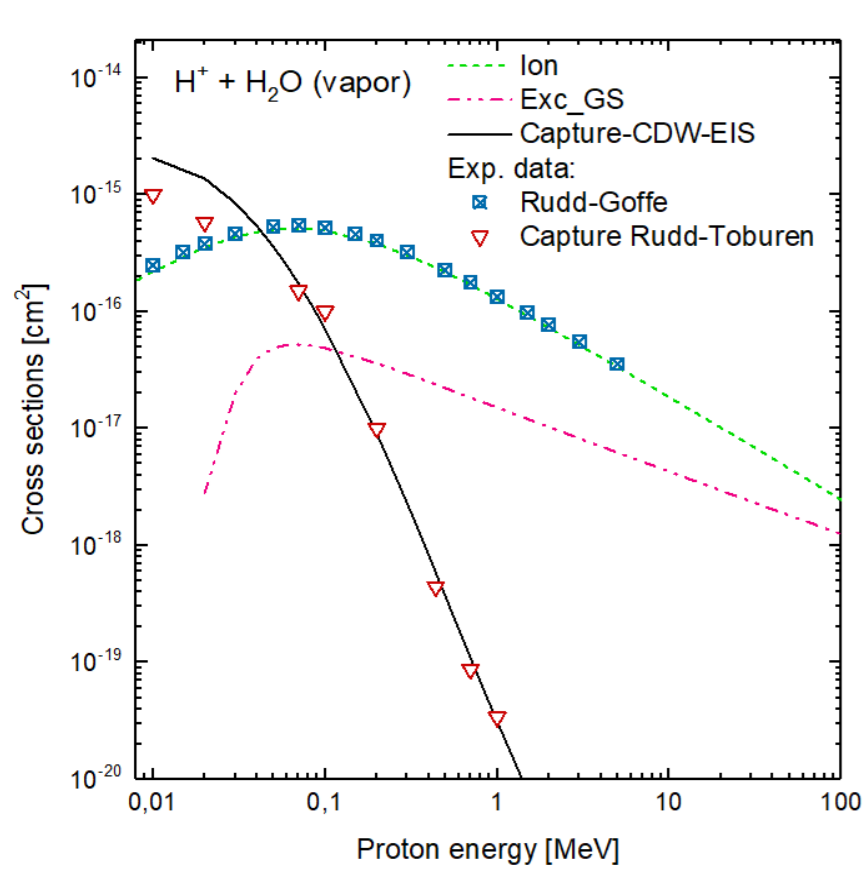
### Liquid water



### Vapor water

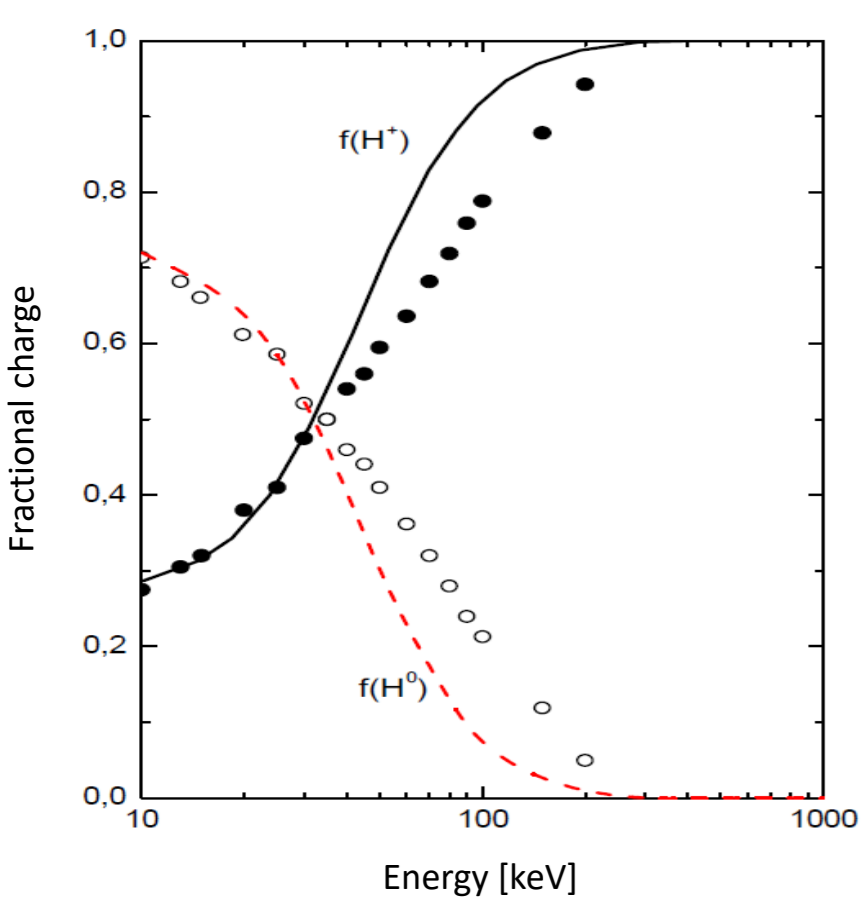
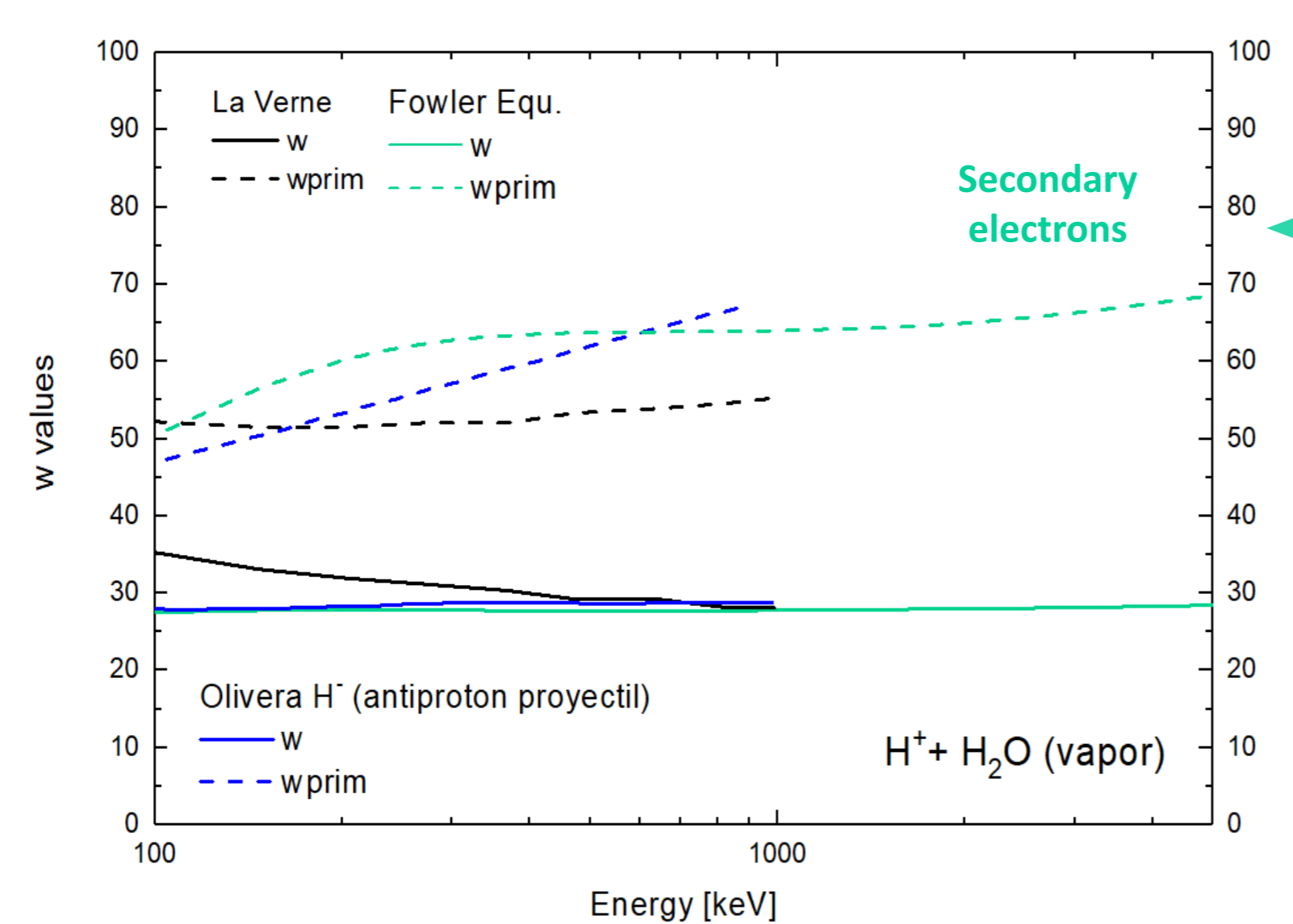


## PROTON IMPACT – FOWLER EQUATION



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.

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