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REFERENCE DOSIMETRY IN HADRONTHERAPY: MONTE CARLO CALCULATION OF STOPPING POWER AND W-VALUES

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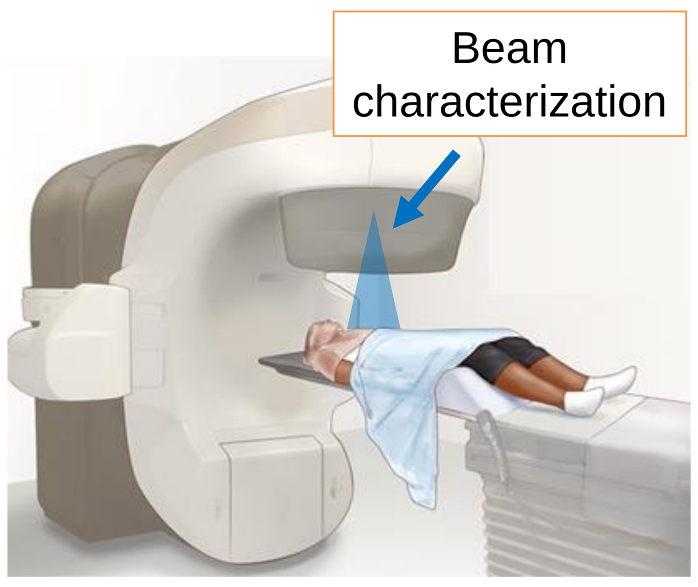
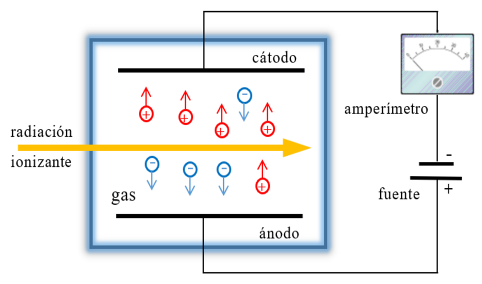
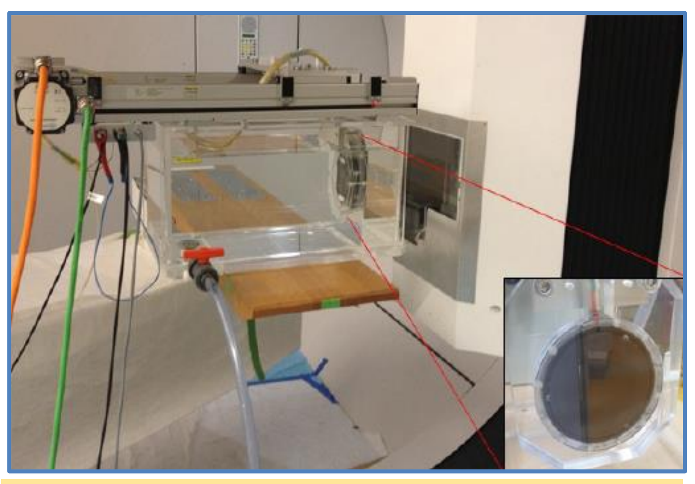
INTRODUCTION - REFERENCE DOSIMETRY - HADRONTHERAPY



Treatment Planning System

In radiotherapy, precise knowledge of the **absorbed dose** (imparted energy per unit of mass) is required for a correct prediction of clinical results. Radiation beam calibration is carried out through dosimetry under reference conditions





% Air Ionization → Dose in Liquid Water

Reference dosimetry in hadrontherapy relies on electron detection generated by the gas ionization contained in the ionization chambers [1]. This percentage of ionization is directly proportional to the absorbed dose in water.

TRS 398- Int. code of practice for dosimetry

$$D_{w,Q} = M_Q \, N_{D,w,Q_o} \, k_{Q,Q_o}$$

Absorbed Dose in water for a beam quality Q

Beam quality correction factor

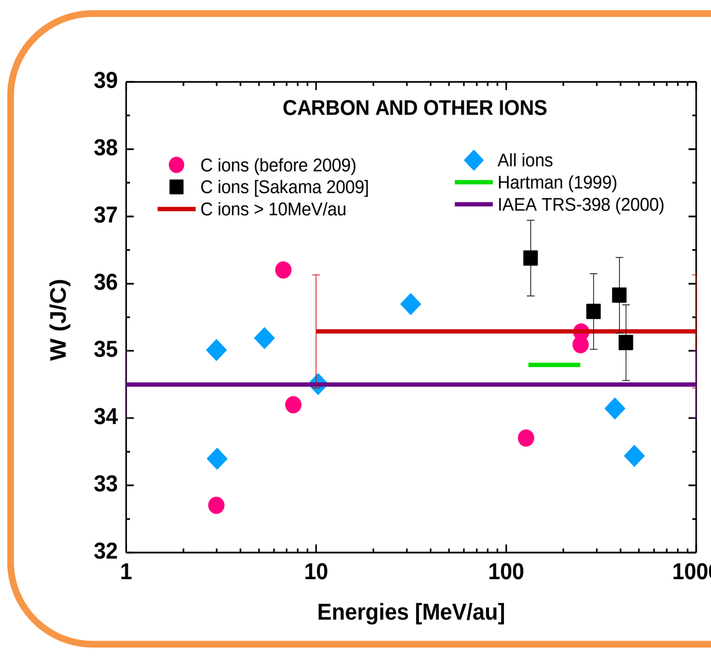
$$k_{Q,Q_o} = \frac{(S_{w/a})_Q}{(S_{w/a})_{Q_o}} \cdot \frac{(W_a)_Q}{(W_a)Q_o} \cdot \frac{p_Q}{p_{Q_o}}$$

MAJOR SOURCE OF UNCERTAINTY

Stopping Power ratio water-air

W-values Mean energy required to produce an ion-electron pair

STATE OF THE ART - Air



- International protocols assume a constant W value, independent of beam quality for high energies , due to lack of experimental data.
- TRS-398 values are based on statistical analyses of direct and indirect measurements.

THEORETICAL MODELS

In our theoretical works [2,3,4] we first studied the w-values and the stopping power by electron and proton impact on water, then we extended to air molecules. The two different methods are:

- **Continuous Slowing Down Approximation (CSDA)** [5]

$$w_{CSDA}(T) = \frac{\epsilon(T)}{\sigma_{ion}(T) + \sigma'_{ion}(T)}$$

T kinetic projectile energy, ϵ stopping cross section; σ_{ion} ionization cross section, σ'_{ion} associated with secondary processes

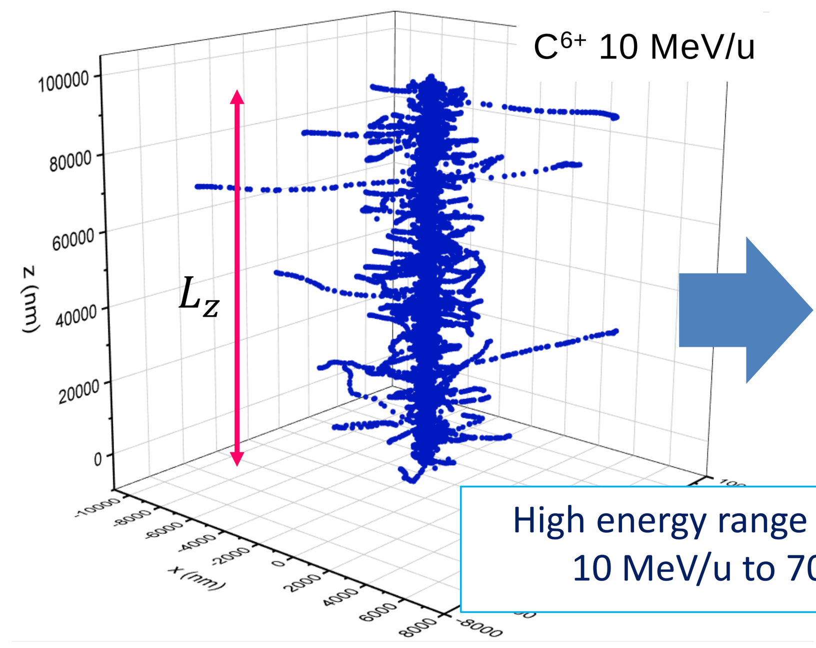
$$\epsilon(T) = \sum_n \sigma_n^{exc} \Delta E_n + \sum_i \left[\int_{E_{min}}^{E_{max}} \frac{d\sigma_i^{ion}}{dE} (E + I_i) dE \right]$$

- **Monte Carlo code: MDM-Ion**

$$w_{MDM-Ion}(T) = \frac{\overline{E_{lost}}}{\overline{N_{tot}}} \qquad S_{MDM-Ion} = \frac{E_{loss}}{L_z}$$

E_{lost} energy lost by the ion projectile

N_{tot} total number of electrons created, L_z path length of the ion track

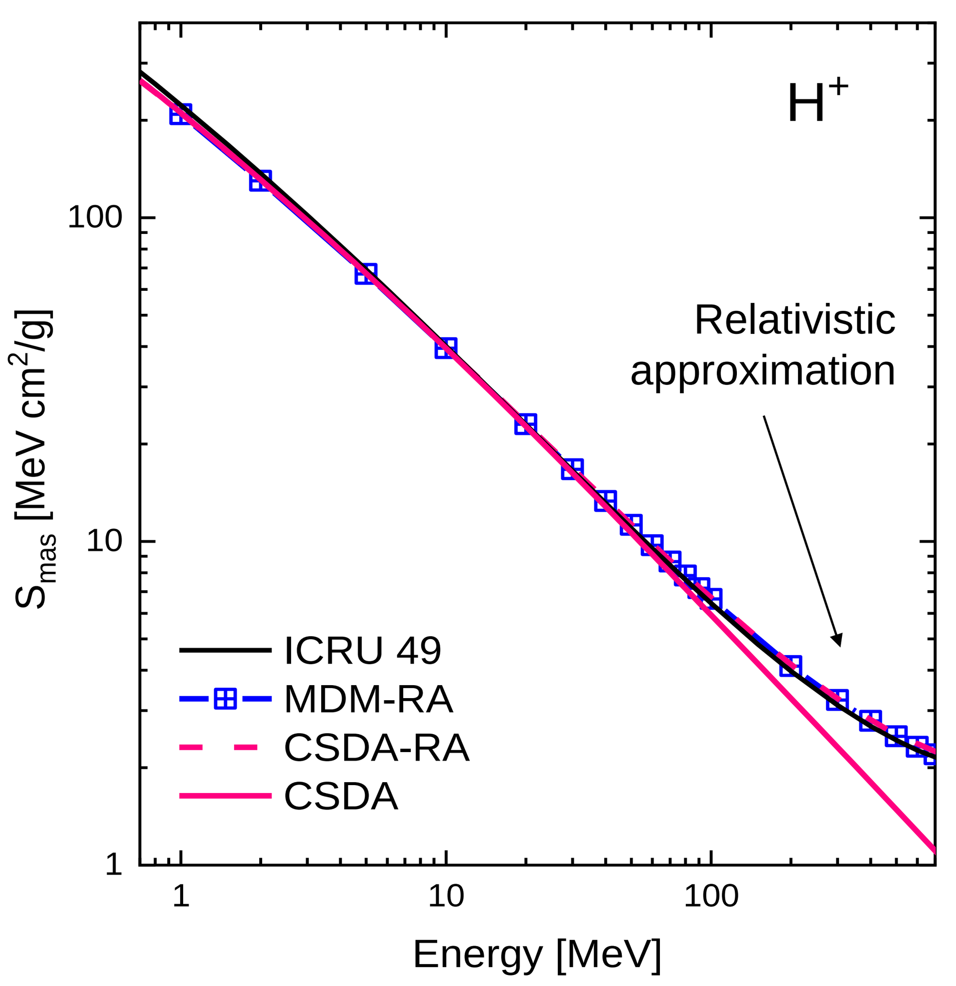


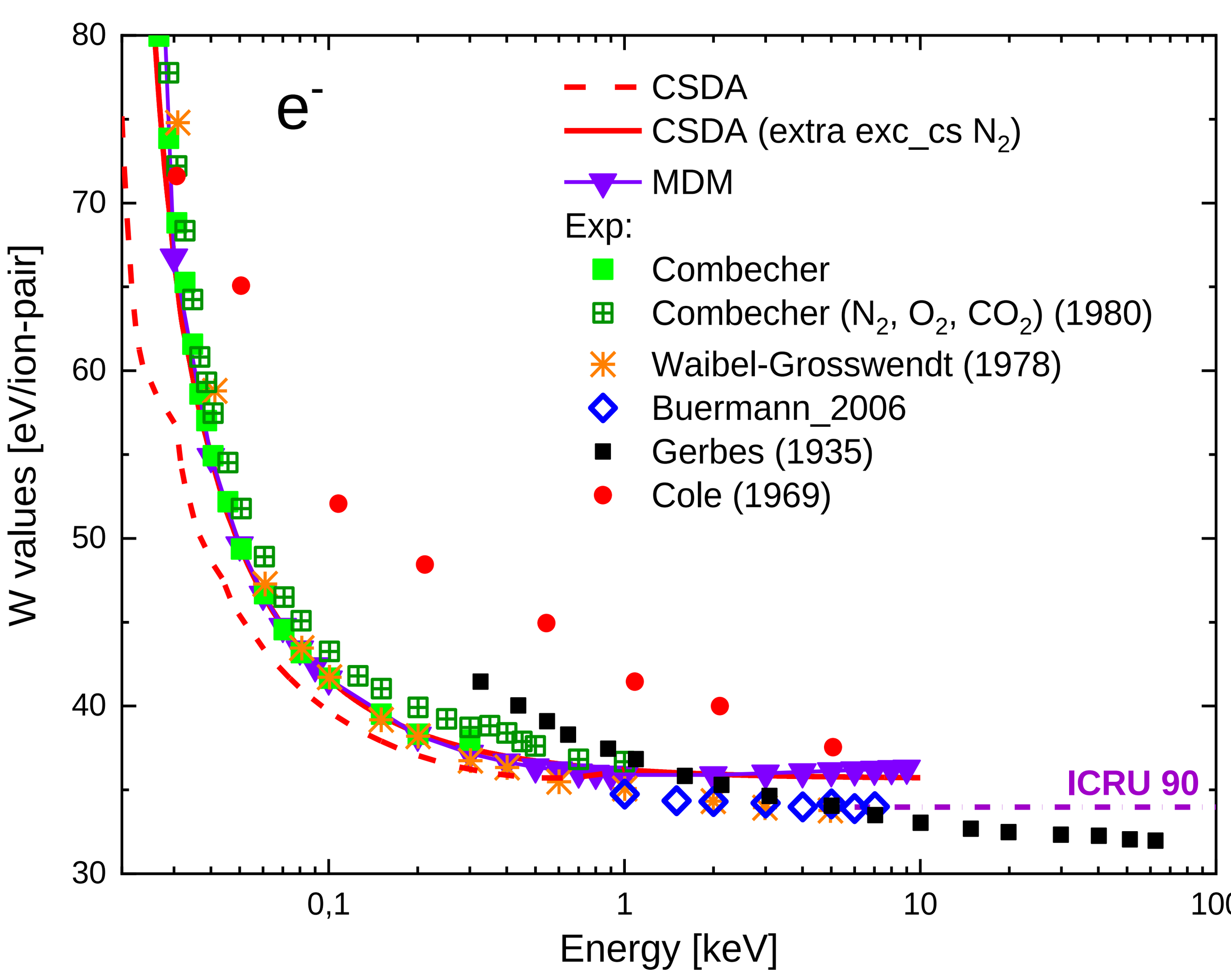
Monte Carlo MDM-Ion simulation

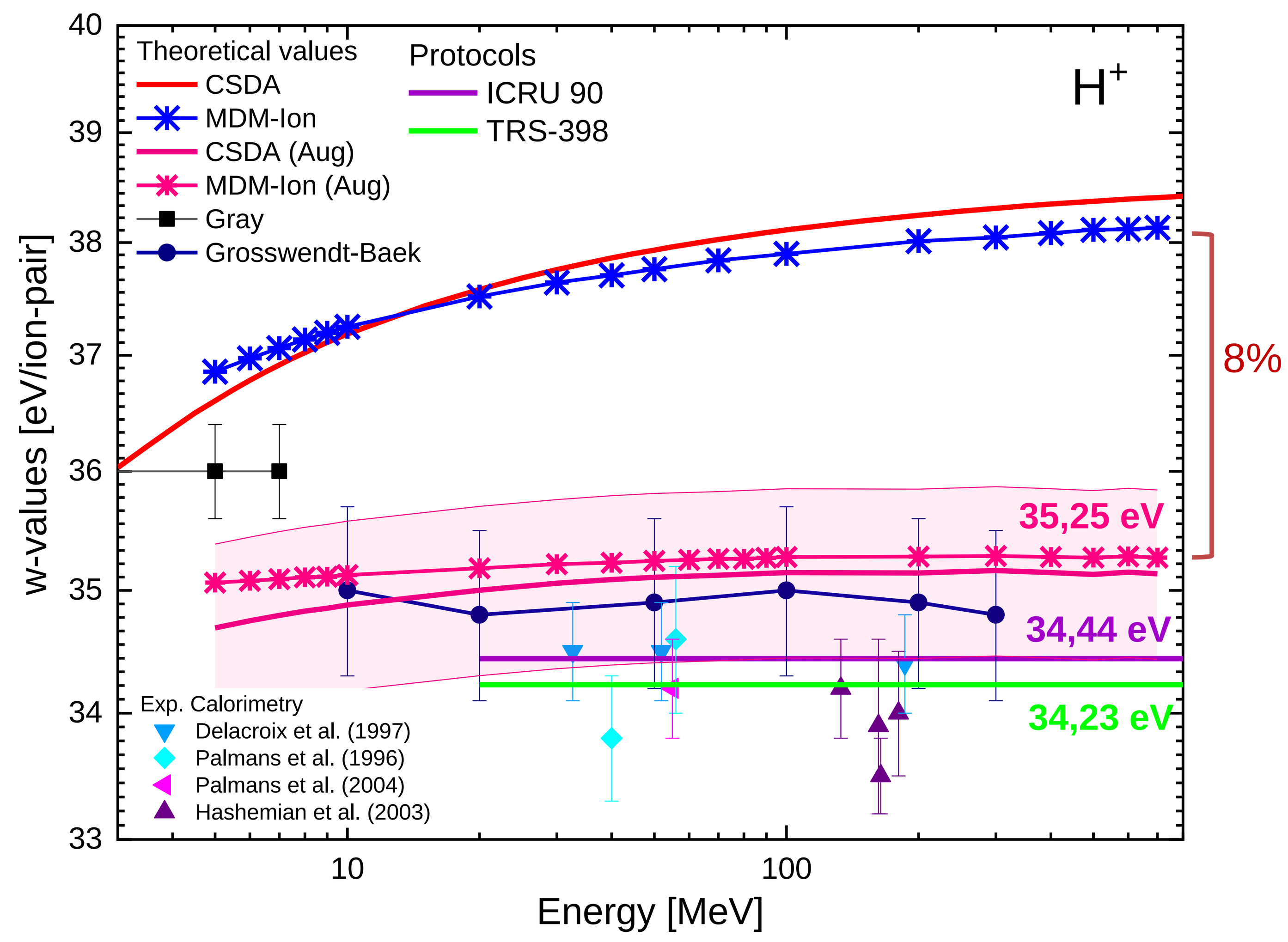
Each point represents an inelastic interaction: electronic excitation or ionization, which are the most relevant processes for dose deposition.

High energy range studied from 10 MeV/u to 700 MeV/u

RESULTS: Stopping Power and w-values on AIR = N_2 0.76 + O_2 0.24







CONCLUSION AND FUTURE WORK

Theoretical models show good agreement with experimental data and other simulations. The stopping power agrees very well with the recommended data when the relativistic approximation (RA) is applied. Calculated *w*-values strongly depend on post-collisional Auger emission—neglecting this process leads to discrepancies of up to 8%—as well as on the excitation cross sections employed. A relative difference of approximately 2% is observed with respect to the recommended reference data (ICRU 90, TRS-398). In addition, the *w*-value appears largely independent of the projectile type, tending toward a constant value at high energies.

REFERENCES

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[2] Tessaro V. et al. NIMB (2019).
[3] Tessaro V. et al. Physica Medica 88 (2021).
[4] Doctoral thesis by Tessaro V. (2022).
[5] Inokuti, M. Radiation Research 64 (1975)

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