Radioactivity - Radionuclides – Radiation
8th Nuclear Science Training Course with Nuclides.net
(Institut "Jožef Stefan", Ljubljana, Slovenia,
13th-15th Sept. 2006)

Wednesday, 13th September 2006

Interaction of Electrons with Matter

Mustafa Çağatay TUFAN

European Commission
Institute for Transuranium Elements
Postfach 2340, 76125 Karlsruhe, Germany

E-mail: mustafa.tufan@cec.eu.int

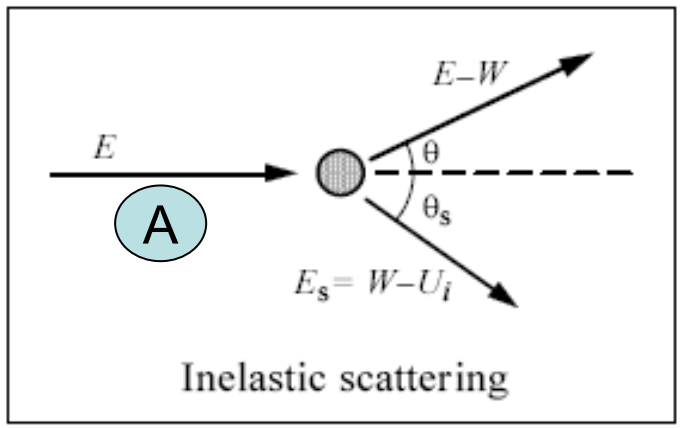
What is an electron?

- The discovery that the electron was a subatomic particle was made in 1897 by J.J. Thomson.
- Mass: $9.1093826(16) \times 10^{-31}$ kg
- Electric Charge: $-1.60217653(14) \times 10^{-19}$ C
- Electron beams are used in welding, lithography, scanning electron microscopes and transmission electron microscopes.
- They are also at the heart of cathode ray tubes.

How do electrons interact with matter?

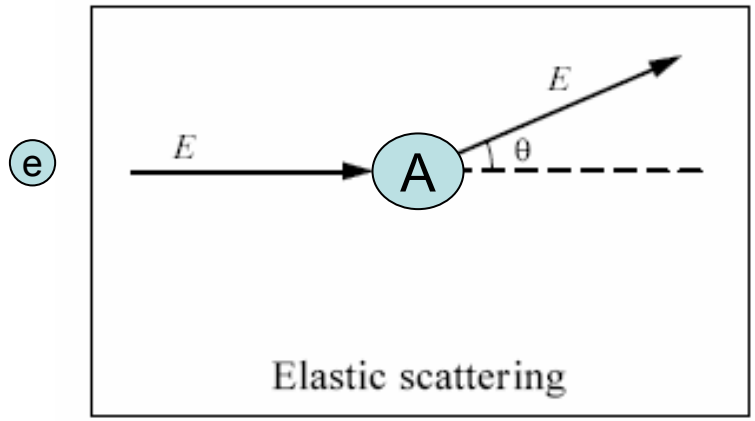
I. Inelastic scattering on atomic orbital electrons. It leads to excitations and ionizations of atoms of the medium, and is called "Collisional Stopping Power".

e

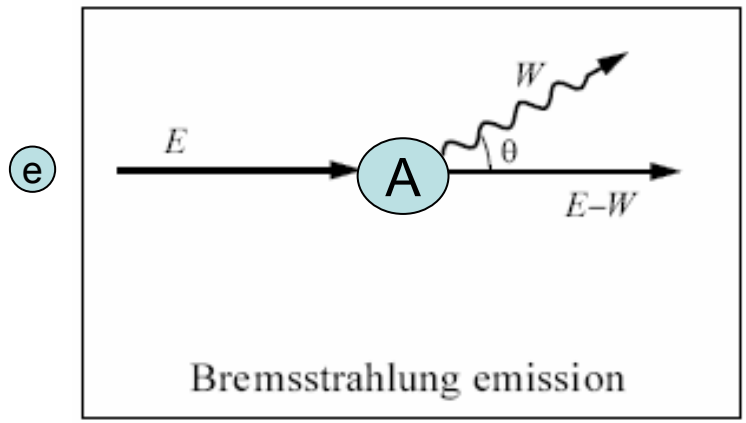


Inelastic scattering

II. Elastic scattering on atoms.
Incident electron is scattered without any change in energy.

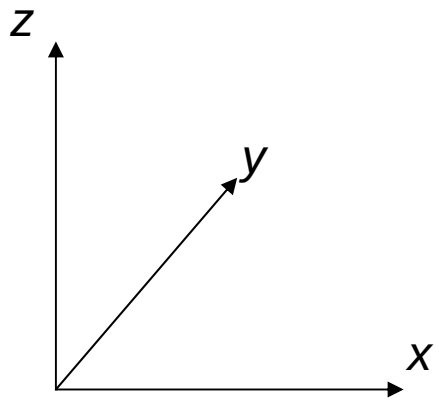


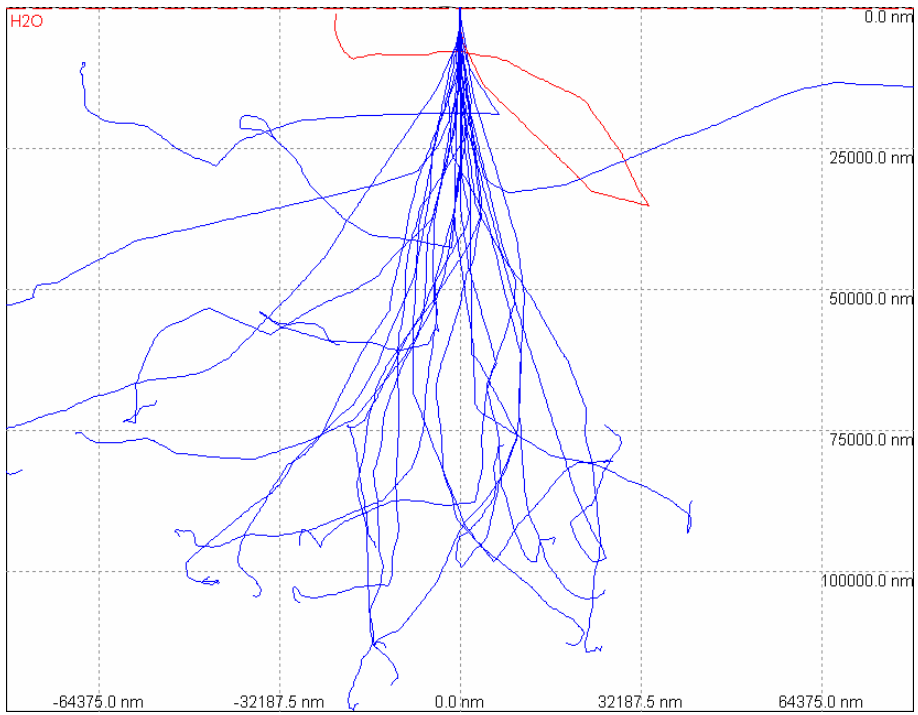
III. Inelastic nuclear scattering.
This results in radiation which is known as “Bremsstrahlung”, so the stopping power is the “Radiative Stopping Power”.



Electron Tracks

-z is the incident direction of electrons

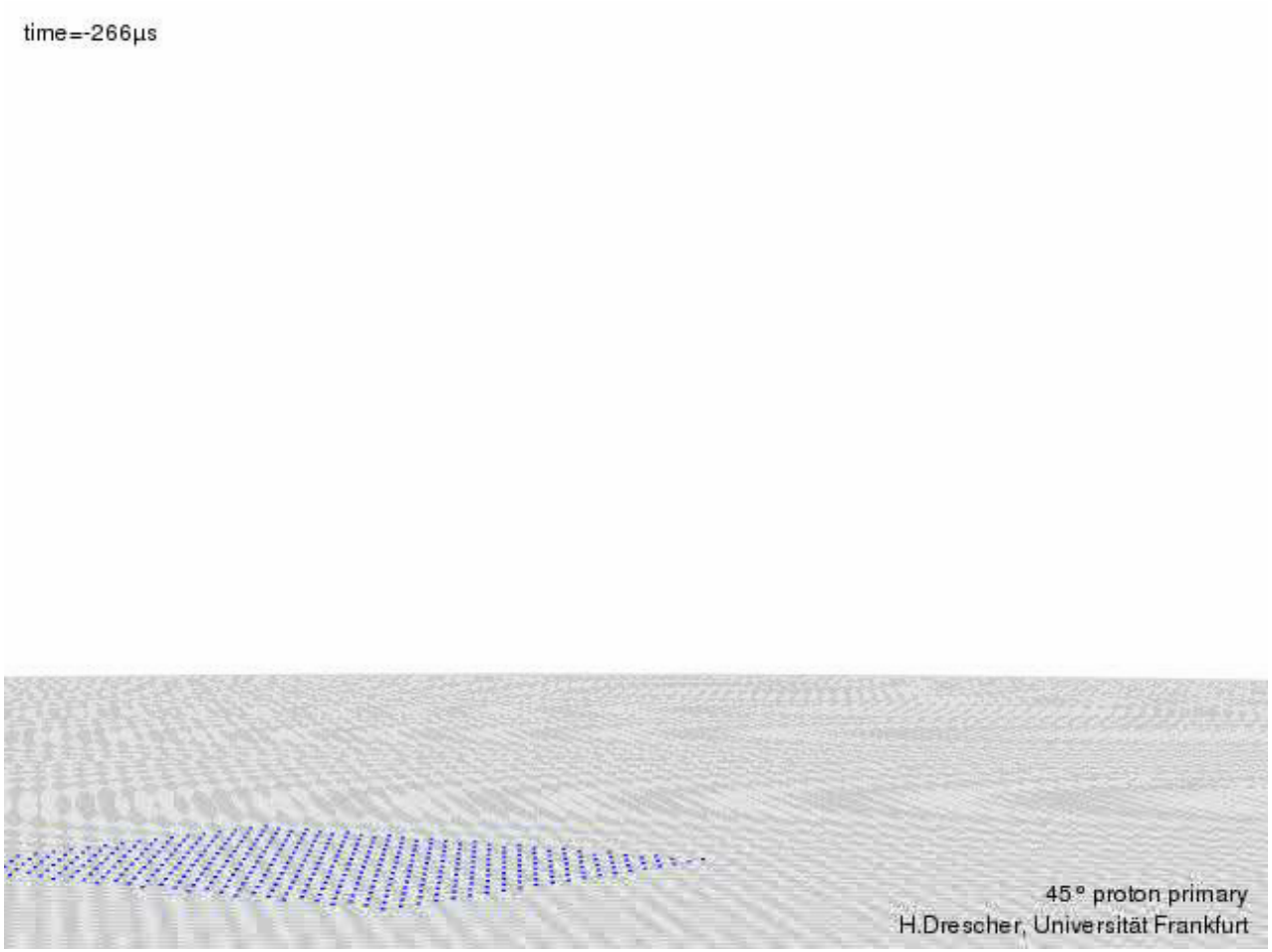




Have you ever seen electron interactions with matter?

Aurora Borealis,
interaction of electrons with oxygen and molecular nitrogen.

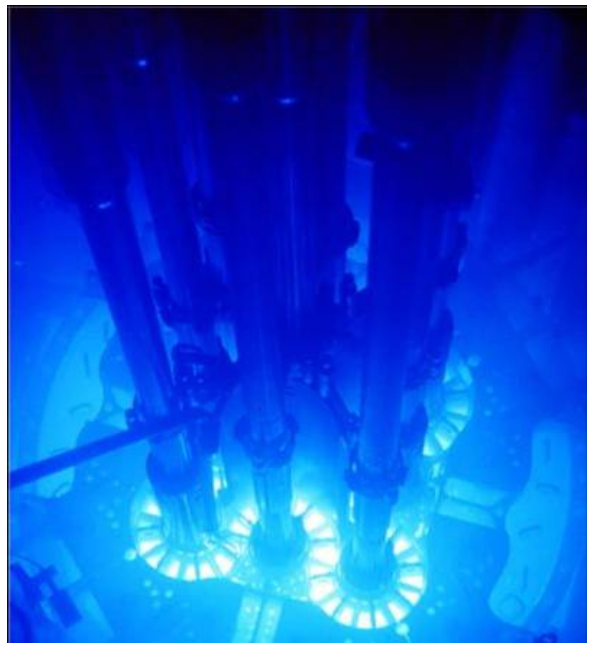
What else happens when the solar wind comes to the earth?



blue: electrons/ positrons
cyan: photons
red: neutrons
orange: protons
gray: mesons
green: muons

"Blue Lagoon"
Light of the Reactor

- Nothing has velocity greater than light's velocity in vacuum.
- Fission products which are produced in the reactor decay and produce high-energy beta particles.
- Speed of light in water is approx. 2.3×10^8 m/s.
- Speed of beta particles with kinetic energy of 0.26 MeV exceeds 2.3×10^8 m/s.



What do we calculate?

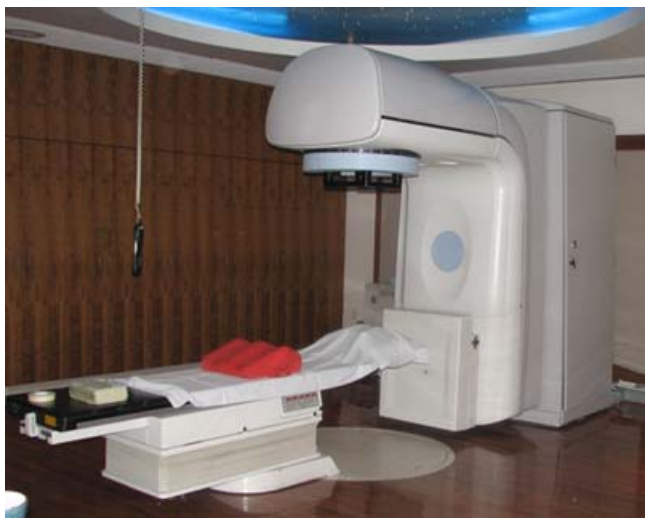
- Stopping Power, or energy loss of particle in unit path length when it passes through matter.
- Range, distance travelled by the particle in the stopping medium.

Why do we need to know this?

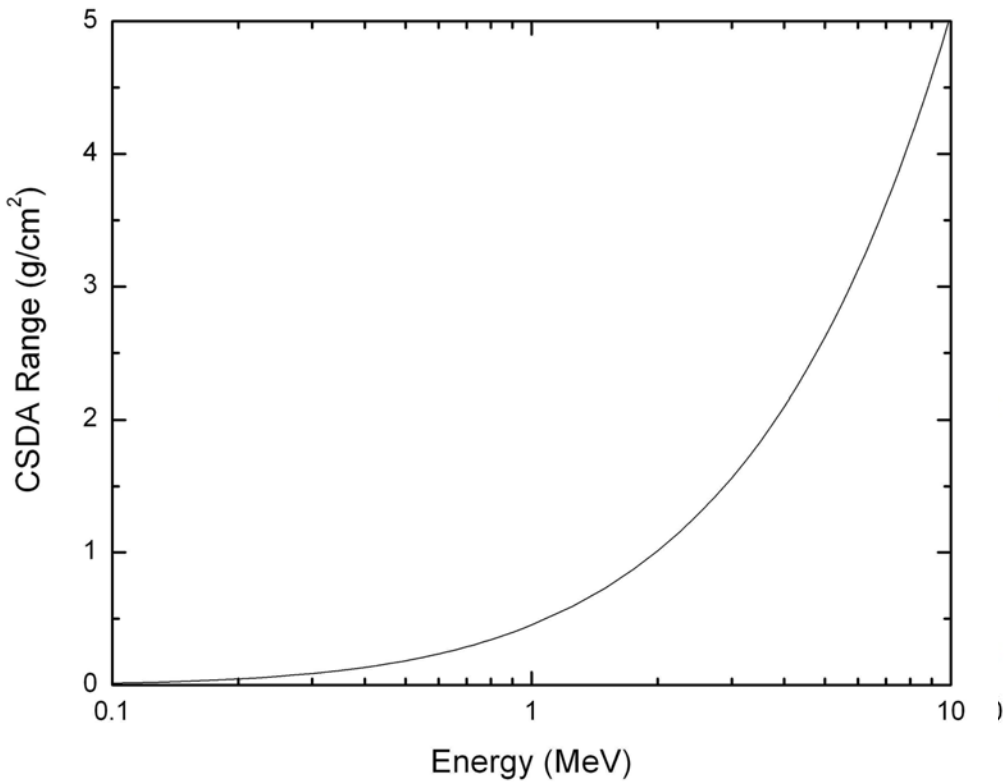
- One can estimate the damage to the medium due to the ionizing radiation.
- This is more important especially in the fields of Radiotherapy, Surface Analysis and Radiation Protection.

In Radiotherapy

- We directly deal with the human patients.
- We must be careful.
- It is most important to know stopping power and range in water and tissue.
- Beta emitters or LINAC are used as a source.
- The Linear Energy Transfer (LET) is similar to the stopping power except that it does not include the effects of radiative energy loss (i.e., Bremsstrahlung) or delta-rays.

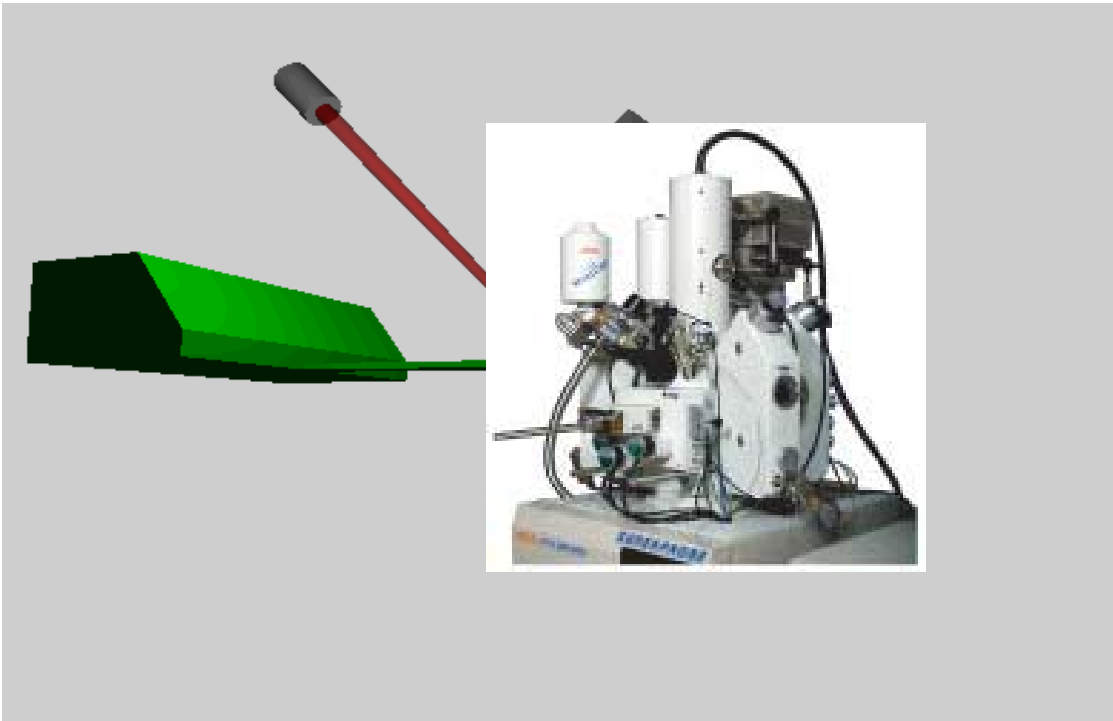


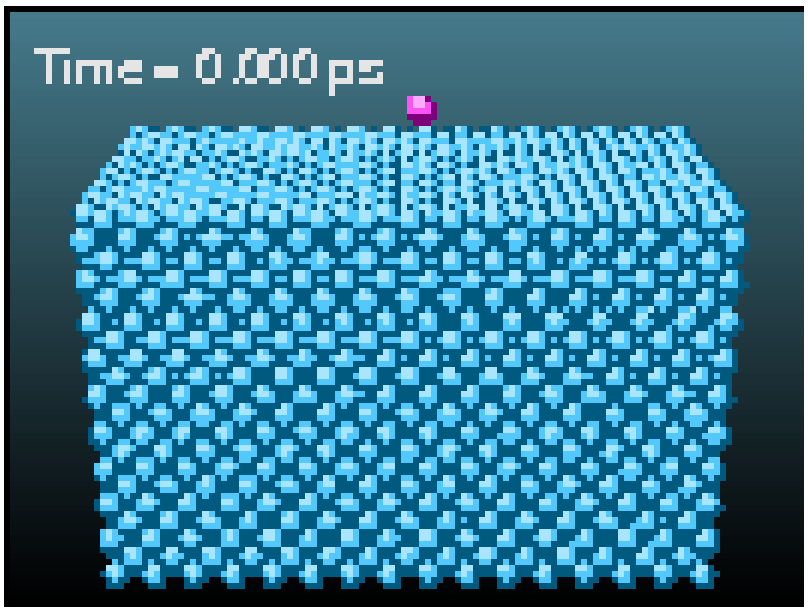
Stopping Power and Range in Water(Liquid)

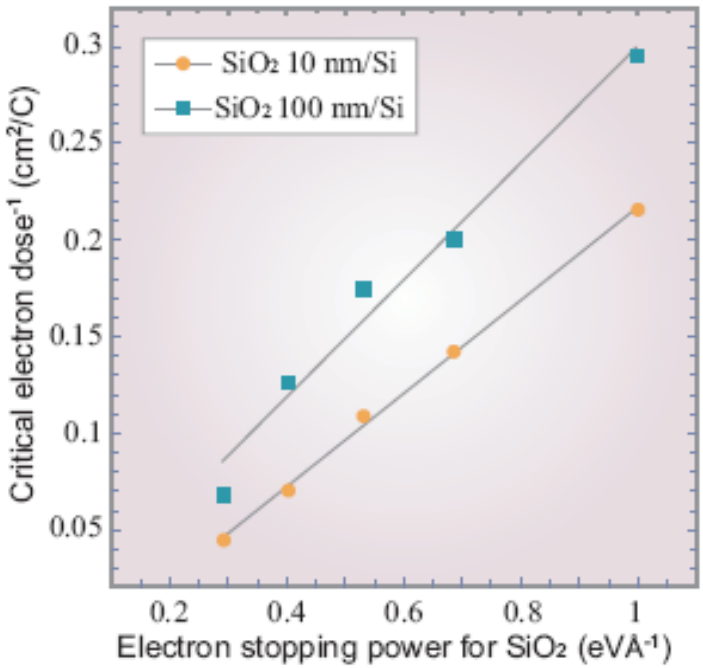


In Surface Analysis

- Generally SEM or STM is used.
- Both of them use electron beams.
- Nobody wants to damage newly produced matter, but we want to know about its surface.







Range Module in Nucleonica

Selected Relevant Publications

- Rohrlich, F., Carlson, B.C., 1954. *Positron–electron differences in energy loss and multiple scattering*. Phys. Rev. 93, 38–44.
- Gümüs H., 2005. *Simple stopping power formula for low and intermediate energy electrons*. Radiation Physics and Chemistry 72, 7–12
- ESTAR: 2003. *Stopping Power and Range Tables for Electron* http://physcs.nist.gov/PhysRefData/Star/Text/ESTAR.html.
- F. H. Attix, *Introduction to radiological physics and radiation dosimetry,* Wiley&Son, New York, 1986.
- ICRU, Report No. 37, 1984. *Stopping powers for electrons and positrons*. International Commission on Radiation Units and Measurements, Bethesda, MD.