

*La tecnica delle emulsioni
nucleari nella terapia adronica*

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Motivazioni

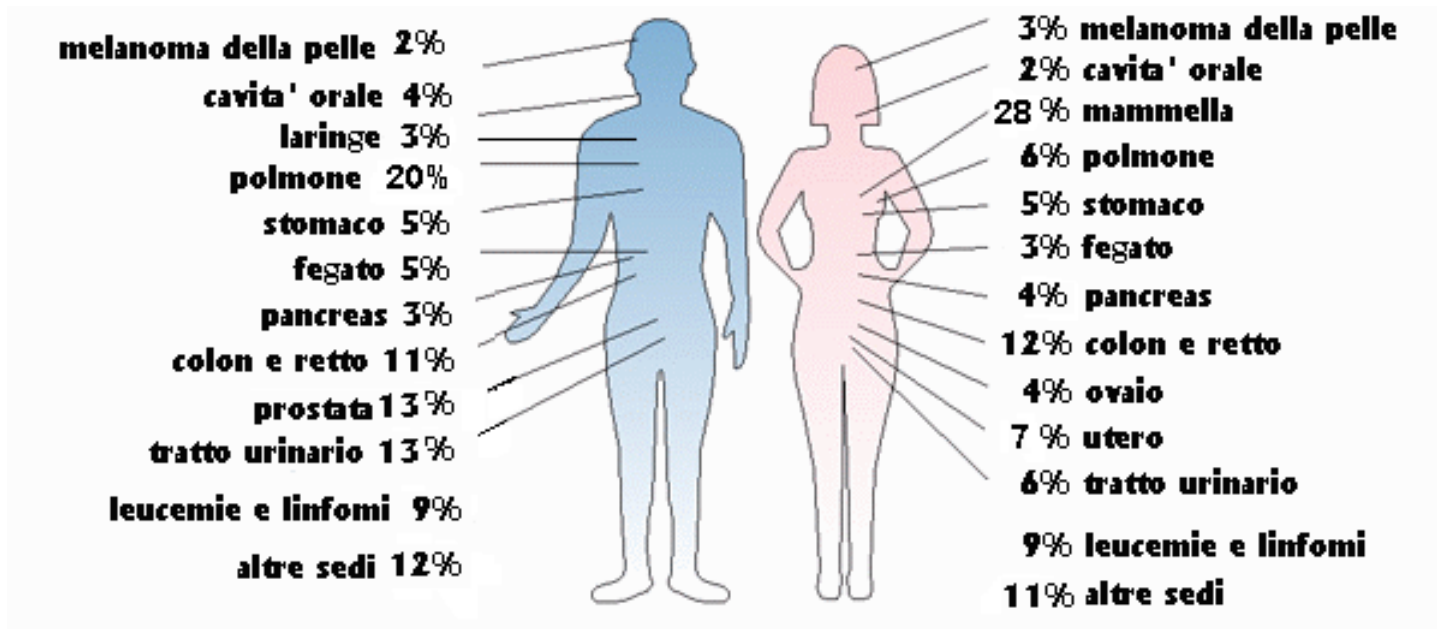
- *Incidenza della malattia*
- *Curabilità con radiazione convenzionale e con radiazione adronica*
- *Invasività ed efficacia della terapia*
- *Possibilità di migliorarne le caratteristiche*
- *Applicazioni nella diagnostica e prevenzione*

Incidenza tumori

Incidenza dei tumori nel Veneto 1995-'96

circa 13,000 casi/anno MASCHI - circa 11,000 casi/anno FEMMINE

Percentuali per le sedi principali

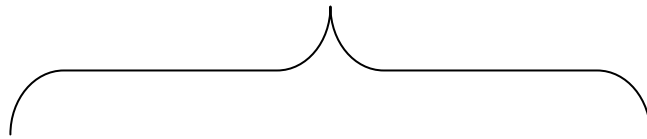


750000 morti attribuiti al cancro nella Comunità Europea nel 1985

Curabilità e terapia allo stato attuale

45% curabili

55% incurabili



22% chirurgia

18% radioterapia

5% chemioterapia

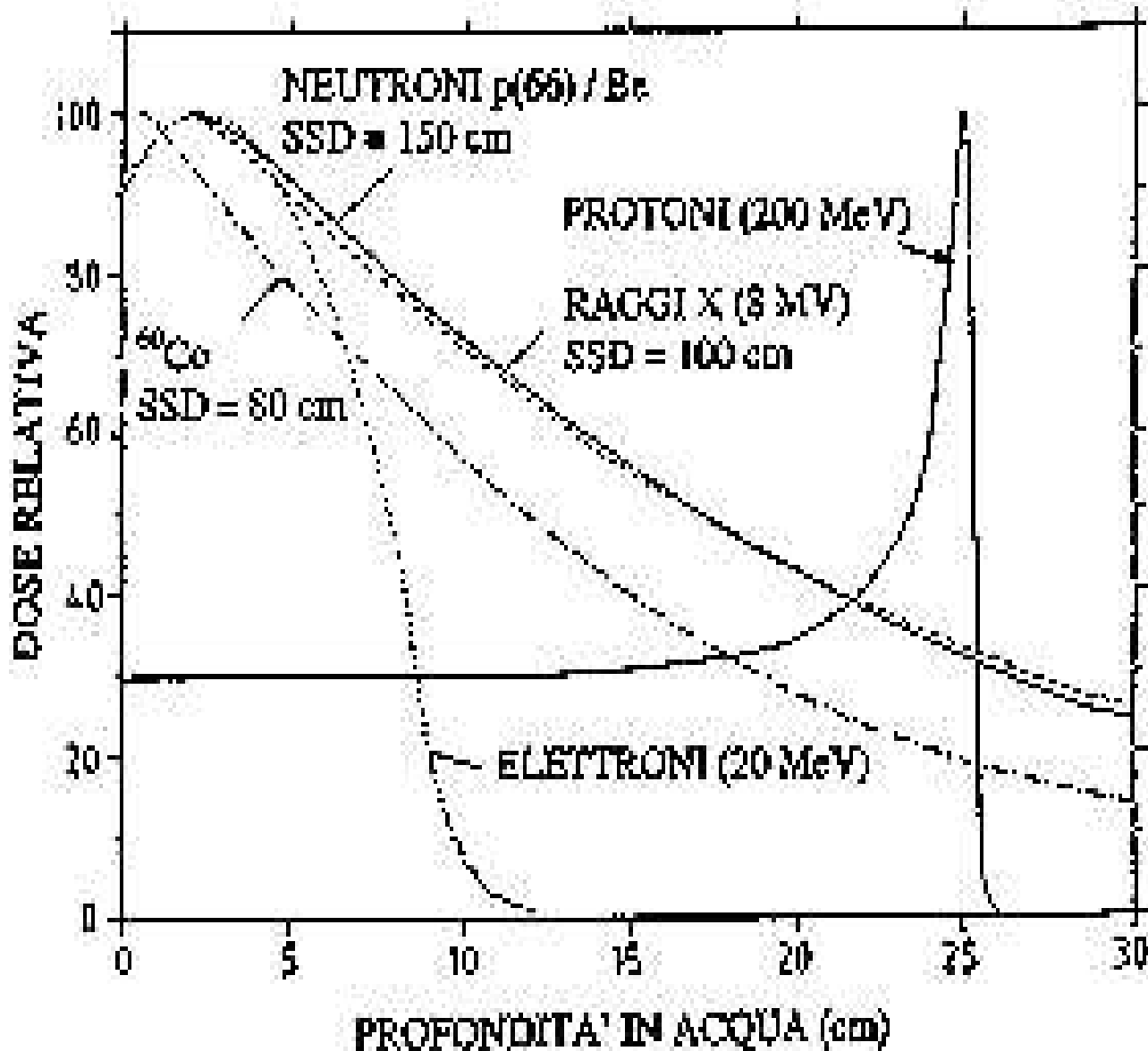


*meno invasiva
migliore tolleranza*

Cosa è la radioterapia e cosa coinvolge?

- *Cura dei tumori con radiazione*
- *Fisica per ottimizzare la radiazione*
- *Biologia per testare gli effetti sui tessuti*
- *Medicina per diagnostica e terapia*

Rilascio energetico nei tessuti

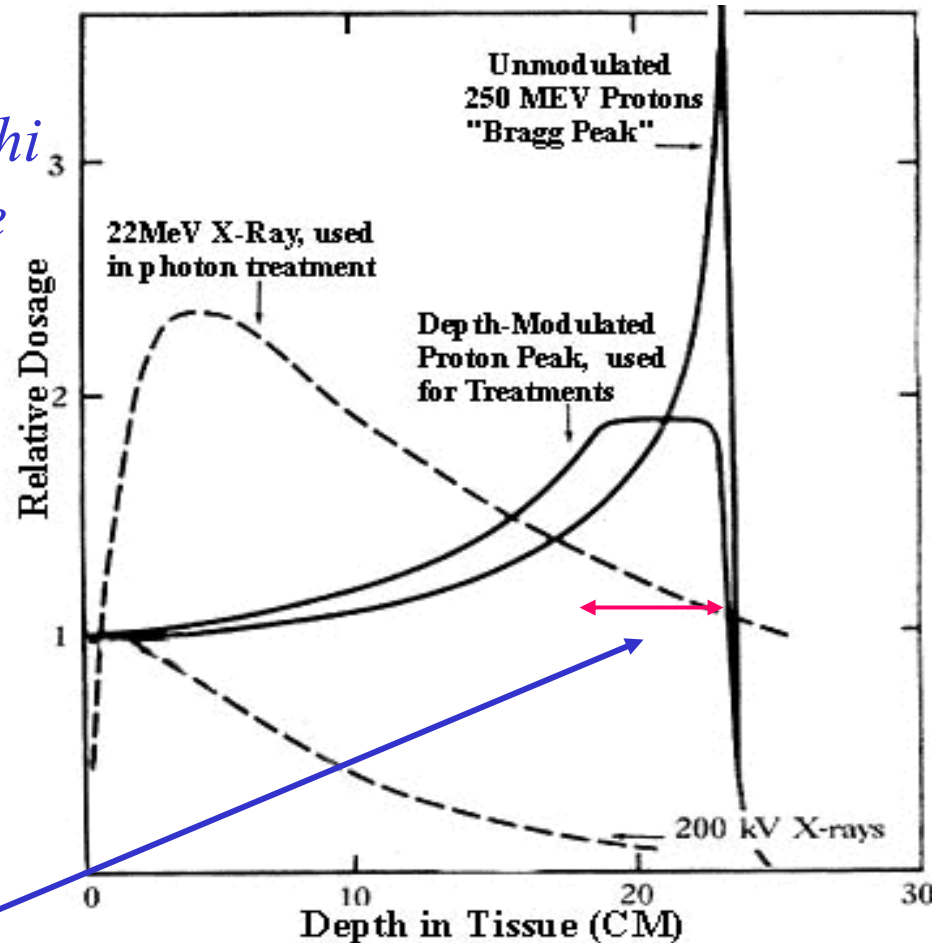


*vantaggio dei protoni
(adroni) per tumori
profondi:
cervello, base del
collo, prostata*

Modulazione della dose

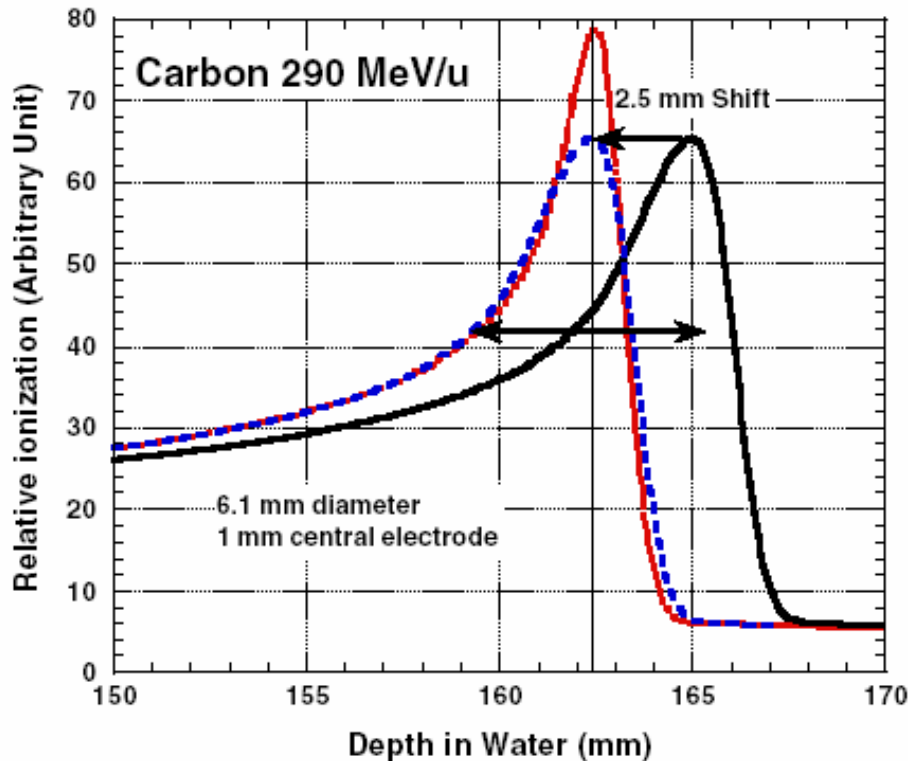
dalla sovrapposizione di picchi vicini (energie simili), viene ricavato il profilo "conformazionale"

il paziente viene ruotato in modo da evitare una forte esposizione dei tessuti circostanti

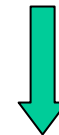


dimensioni della parte da trattare

Carbon beam



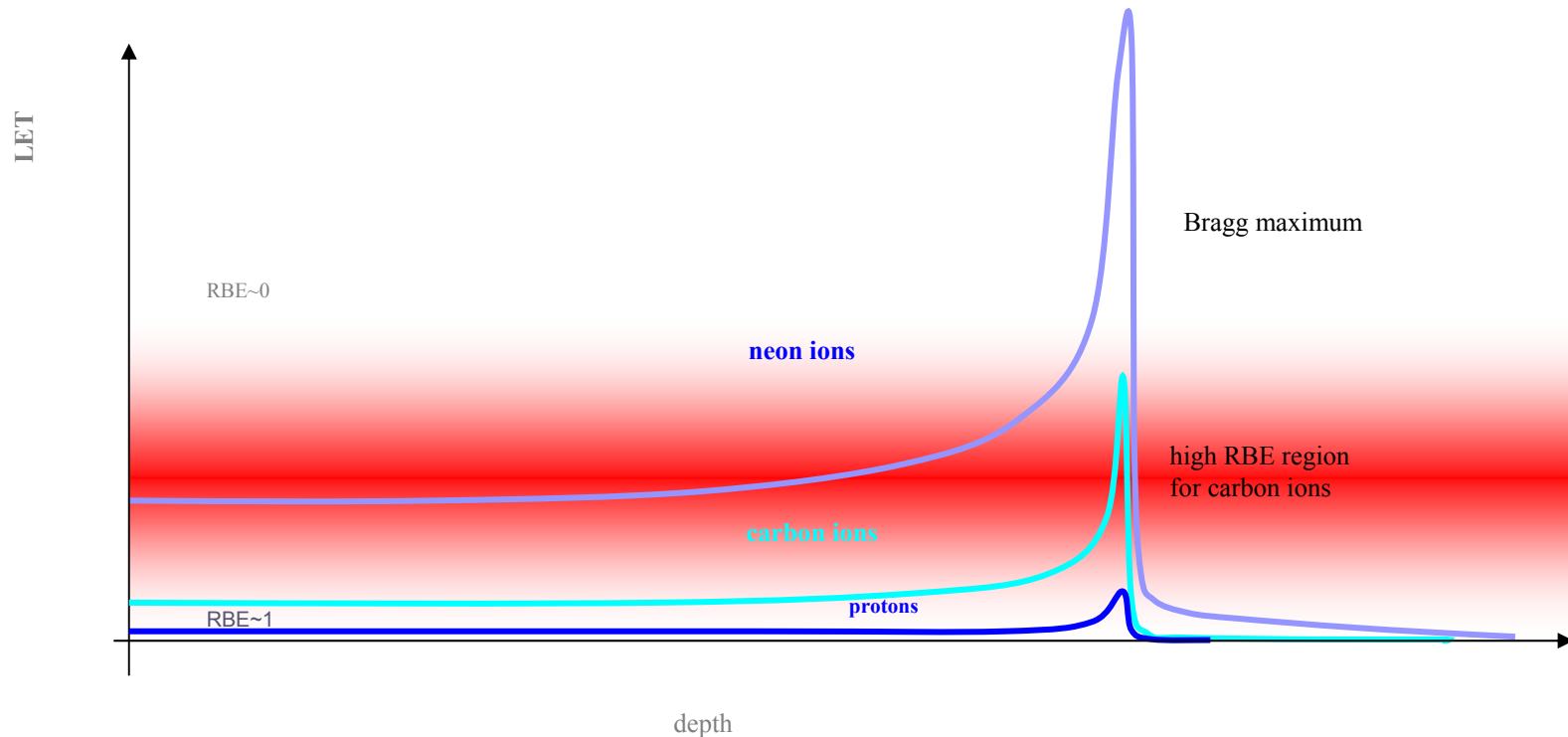
*profilo di deposito
analogo a quello dei
protoni ma maggiore
deposito di energia
per unità di lunghezza*



*una ionizzazione
ogni ~ 10nm
(elica DNA ~ 2nm)*

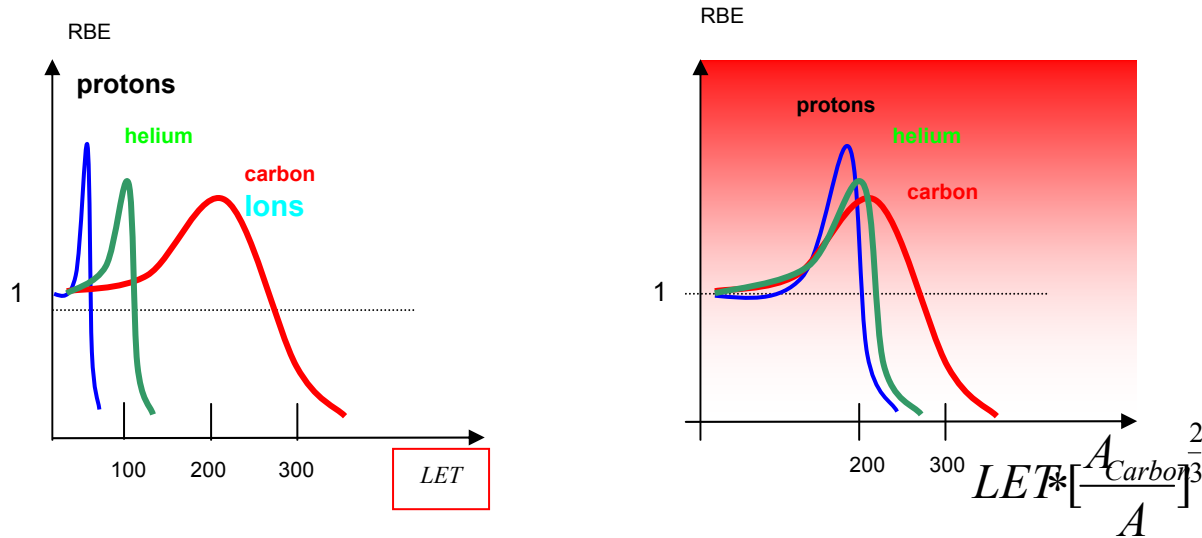
Figure 2. Simulated depth dose distribution measured by a PTW30001 cylindrical chamber. Dotted curve shows the result of the simulation for PTW30001. Solid curve is the measured depth dose distribution measured by a parallel plate ionization chamber, Markus.

Vantaggio di fasci di carbonio



LET for proton, carbon and neon ions along their path. While for carbon ions the maximum RBE is in the tumour region, neon ions produce an “overkill-effect” inside the target volume where the Bragg maximum is situated. The density of the red colour indicates the increased RBE for carbon

Efficacia biologica relativa $RBE = \frac{D_\gamma}{D_I} \Big|_{\text{same effect}}$



RBE for different ions (schematic). The decreasing RBE for too large LET is due to an overproduction of local damage (“overkill-effect”) resulting also in an effective saturation, while the denominator continuous to increase linearly. (For dose homogeneity see below). The increased RBE can be explained by the increased ionisation density which causes a cluster of produced damages (e.g. multi leason of DNA). The authors tried to parameterise proton and helium ions by scaling a formula of the maximum of RBE as a function of A

Efficacia biologica di ioni leggeri

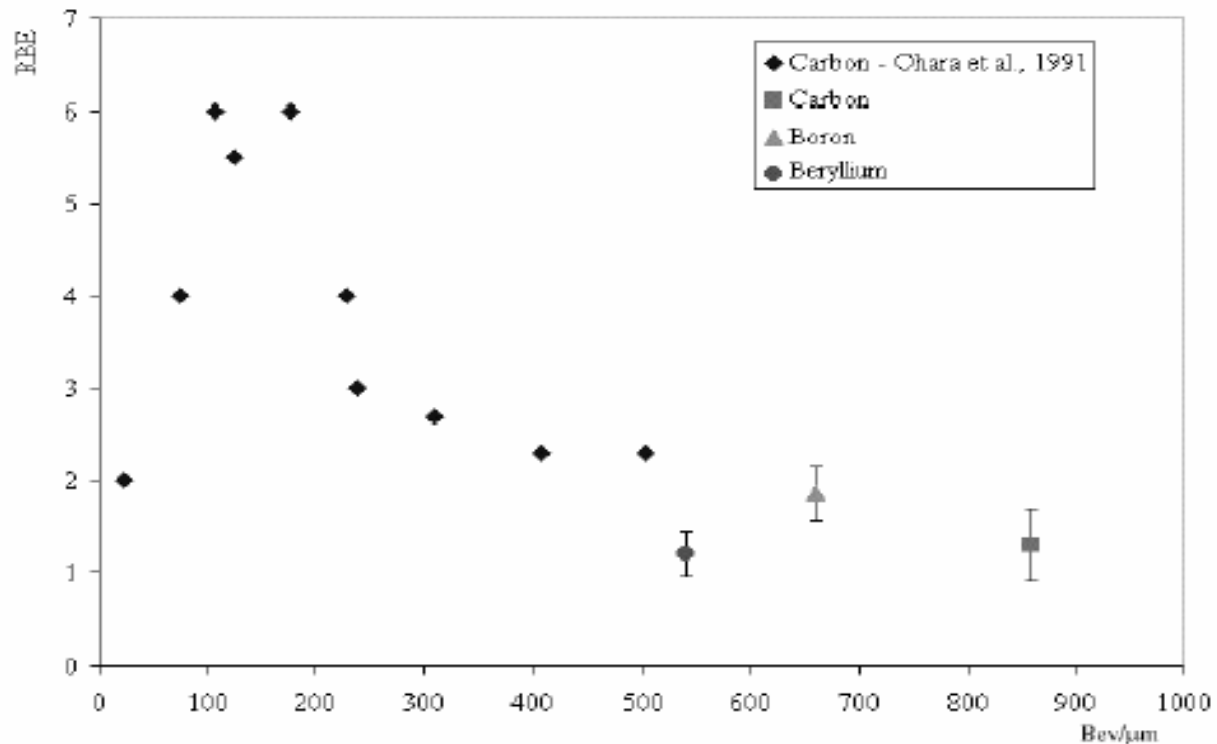


Fig. 2 – RBE vs LET: our data for B, Be, and C ion irradiation and C data from literature

Meccanismo di danneggiamento Dna

Incident X-Ray Photon



Fast Electron (e⁻)



Ion Radical

↓ 10⁻¹¹ Sec.

Free Radical

↓ 10⁻⁴ Sec.

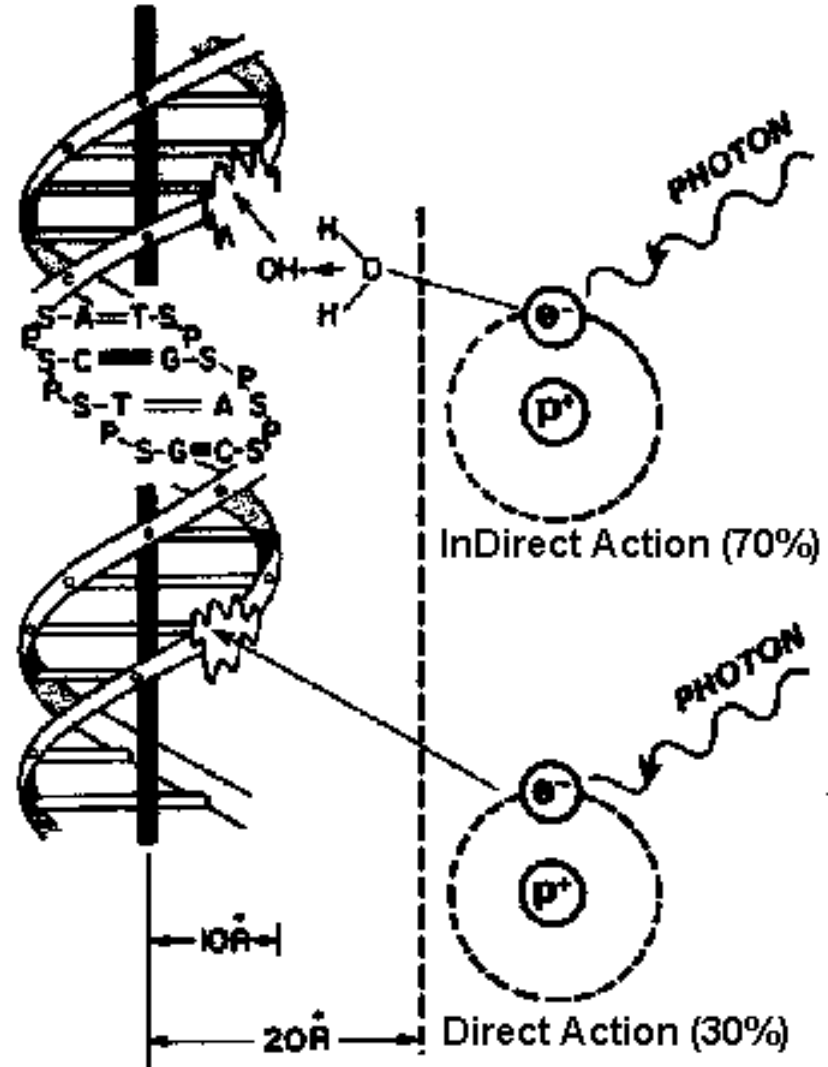
Chemical Changes



Breakage of Bonds

↓ Hours-Years

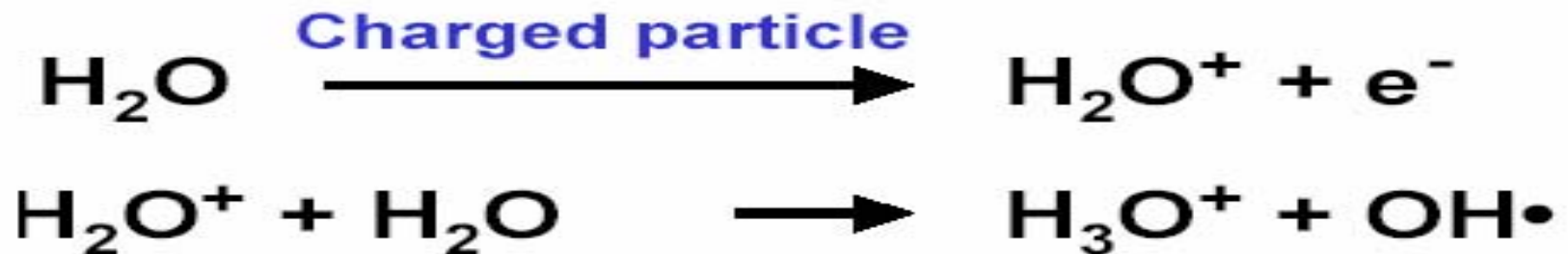
Biological Effects



Meccanismo di danneggiamento

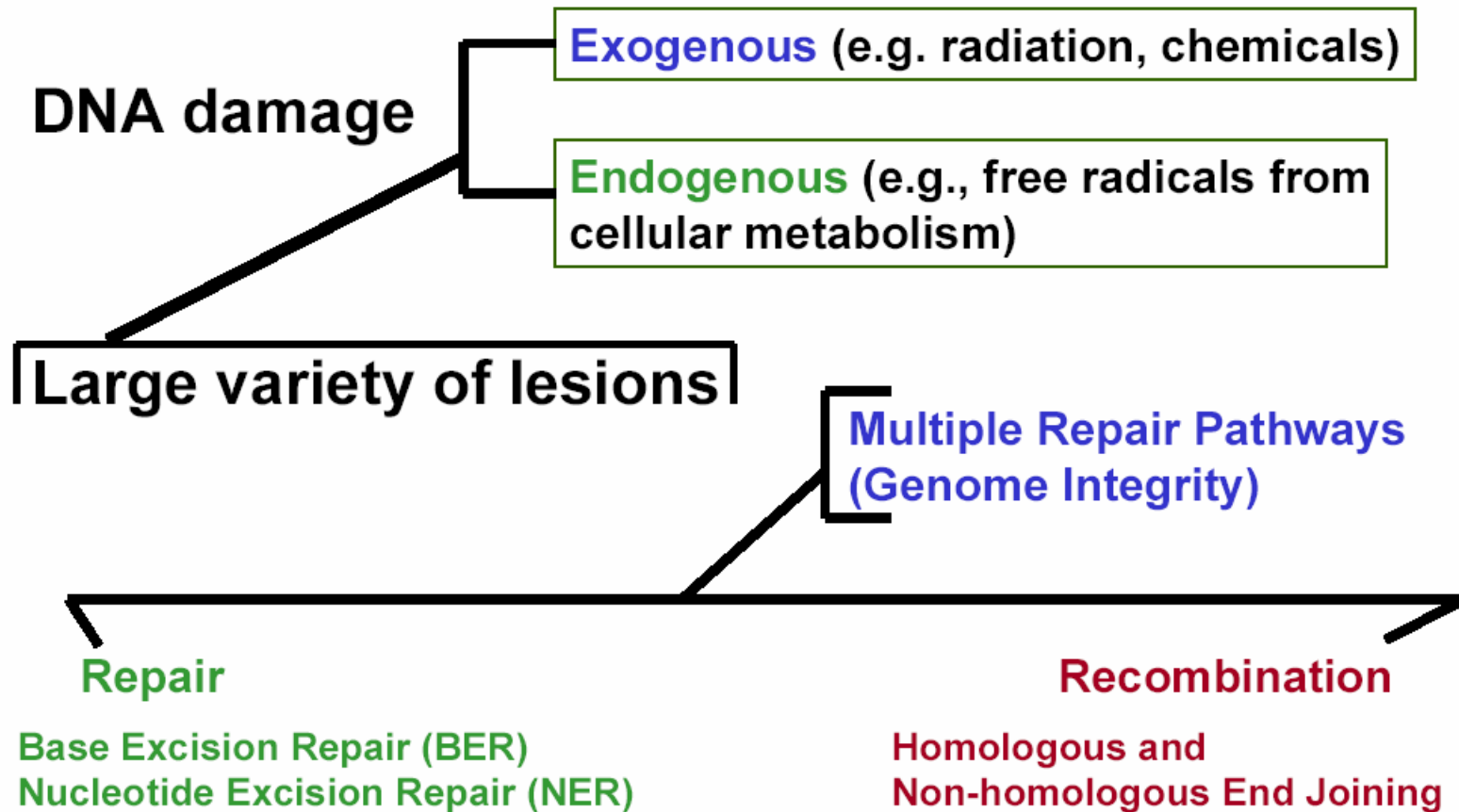
Dna

Figure 1.8. Direct and indirect actions of radiation. The structure of DNA is shown schematically. In direct action a secondary electron resulting from absorption of an x-ray photon interacts with the DNA to produce an effect. In indirect action the secondary electron interacts with, for example, a water molecule to produce a hydroxyl radical (OH•), which in turn produces the damage to the DNA. The DNA helix has a diameter of about 20 Å (2 nm). It is estimated that free radicals produced in a cylinder with a diameter double that of the DNA helix can affect the DNA. Indirect action is dominant for sparsely ionizing radiation, such as x-rays. *S*, sugar; *P*, phosphorus; *A*, adenine; *T*, thymine; *G*, guanine; *C*, cytosine.



Meccanismi di “difesa” del DNA

DNA Damage Repair and Recombination



PET

What is PET?

Positron Emission Tomography, or PET, is a procedure that allows a physician to examine the heart, brain, and other organs. PET images show the chemical functioning of an organ or tissue, unlike X-ray, CT, or MRI which show only body structure

What Can PET Detect?

Coronary Artery Disease

PET imaging is unique in its ability to determine whether a patient's heart muscle will benefit from coronary artery bypass surgery.

PET can monitor the irradiation procedure. When e.g. the carbon beam penetrates through the tissue, positron emitting isotopes (^{11}C and ^{10}C) are generated by nuclear fragmentation of the primary ions. They stop nearly in the same region as the Isotopes do and therefore their detection allows the irradiation monitoring.

Application to tumors

PET imaging is very accurate in differentiating malignant from benign growths, as well as showing the spread of malignant tumors. PET imaging can help detect recurrent brain tumors and tumors of the lung, colon, breast, lymph nodes, skin, and other organs. Information from PET imaging can be used to determine what combination of treatment is most likely to be successful in managing a patient's tumor.

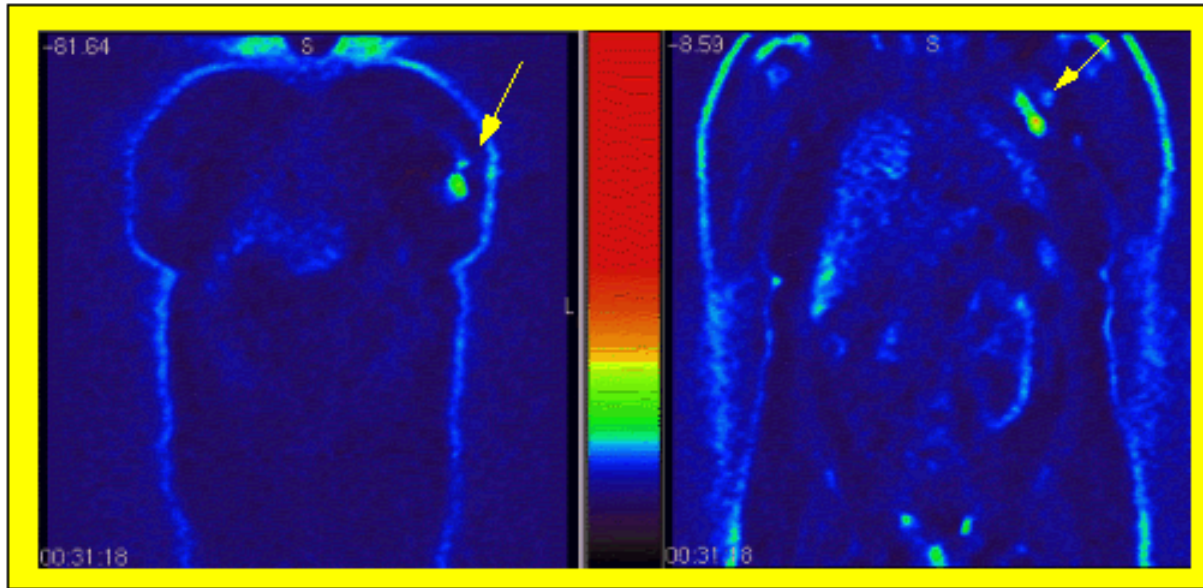


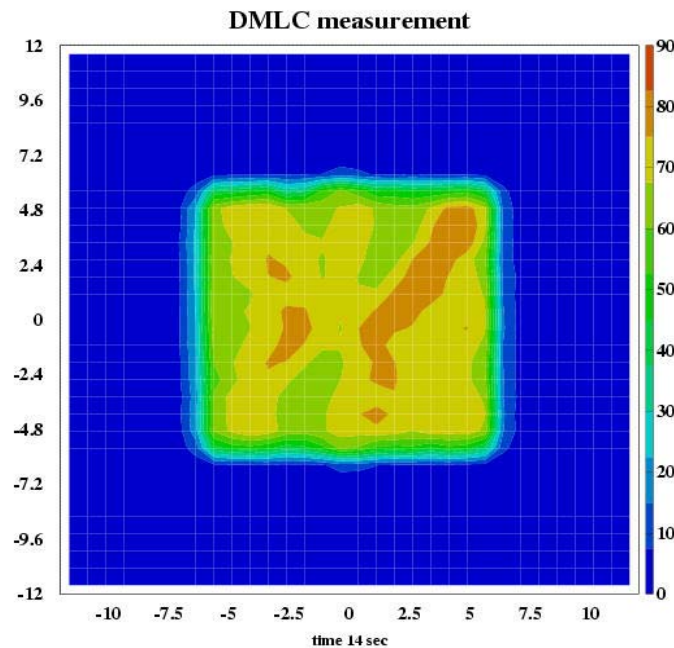
Image showing malignant breast mass That was not revealed by conventional imaging techniques such as CT, MRI, and mammogram

Image of same patient with enlarged left axillary lymph nodes (indicated by arrows), which through biopsy were found to be metastatic (spread from another location). The whole body scan reveals a mass in the left breast (indicated by arrow), that was malignant and subsequently removed.

Measuring *DURING* treatment

DMLC = Dynamic Multi-leaf Collimator

Deposited
dose as
function of
time

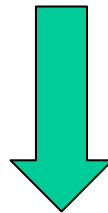


Time: 14 sec

Courtesy of [R. Cirio \(University and INFN Torino\)](#)

Spazio a miglioramento

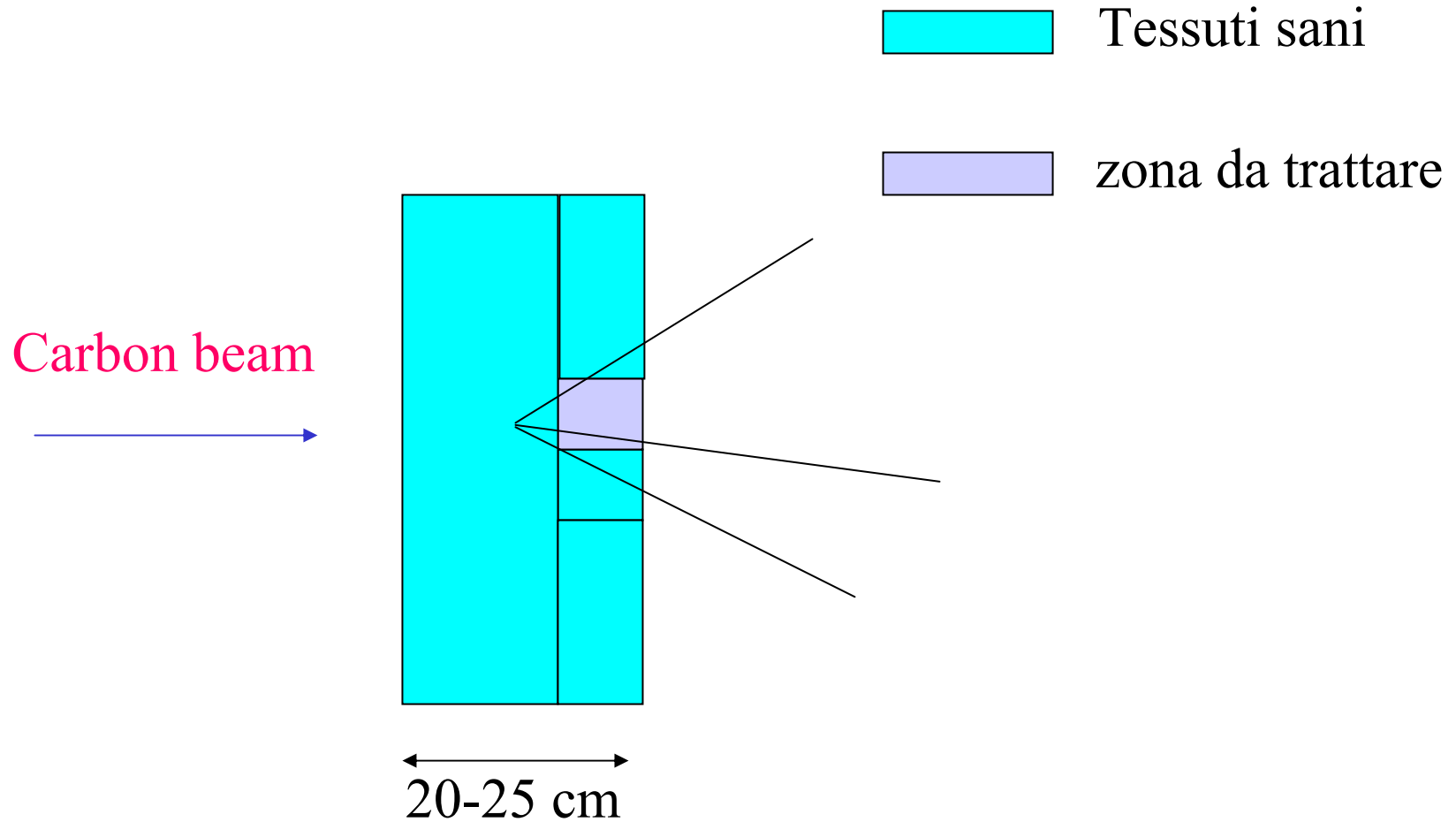
- *Conoscenza della radiazione secondaria*
- *Conoscenza degli effetti biologici*



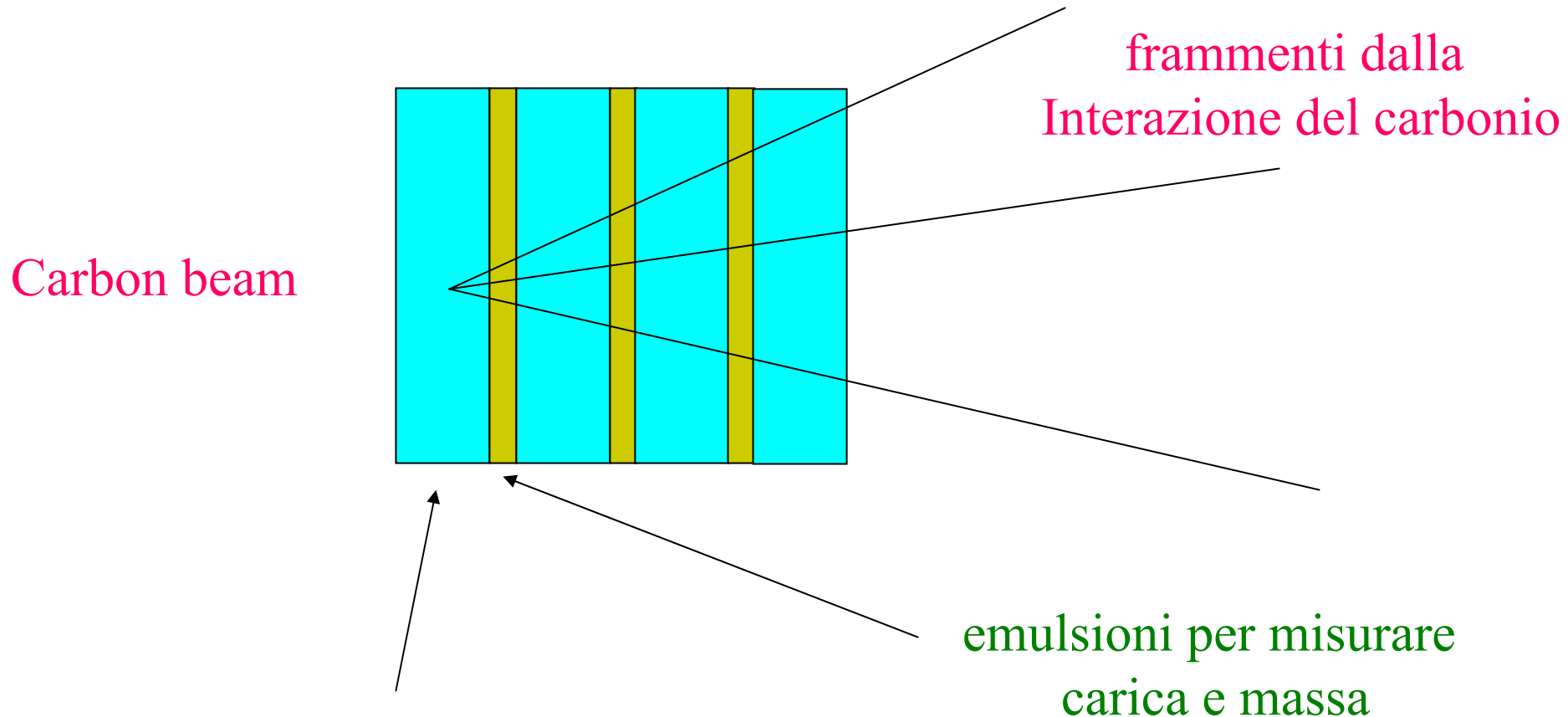
nel seguito ci concentriamo sugli aspetti della radiazione

La frammentazione crea lunghe code nel deposito di energia

Radiazione secondaria: frammentazione



Simulare il corpo umano



Plastica: stessa densità dell'acqua (corpo umano)

Misura di carica e massa

- *La densità di grani lungo la traccia è $\propto Z^2$*
- *La diffusione angolare mi consente di ricavare $p\beta$*
- *Dalla misura combinata, noto β , ricavo p e quindi la massa*
- *(A,Z) determina la natura dello ione*

Conclusioni e prospettive

- *La terapia adronica è già una realtà in diversi paesi (Giappone, Germania, USA)*
- *Un centro (CNAO) è in via di costruzione a Pavia!*
- *Le emulsioni nucleari possono dare un contributo per migliorare la comprensione della radiazione e la conseguente efficacia della terapia*