

**UNA RAPIDA GUIDA**



**2013**  
EDITION

**ARDENT**

FOR

**DUMMIES**

**ADVANCED  
RADIATION  
DOSIMETRY  
EUROPEAN  
NETWORK  
TRAINING**

**FISICA E  
RICERCA SULLE  
RADIAZIONI**



di: Silvia Puddu  
email: [silvia.puddu@cern.ch](mailto:silvia.puddu@cern.ch)

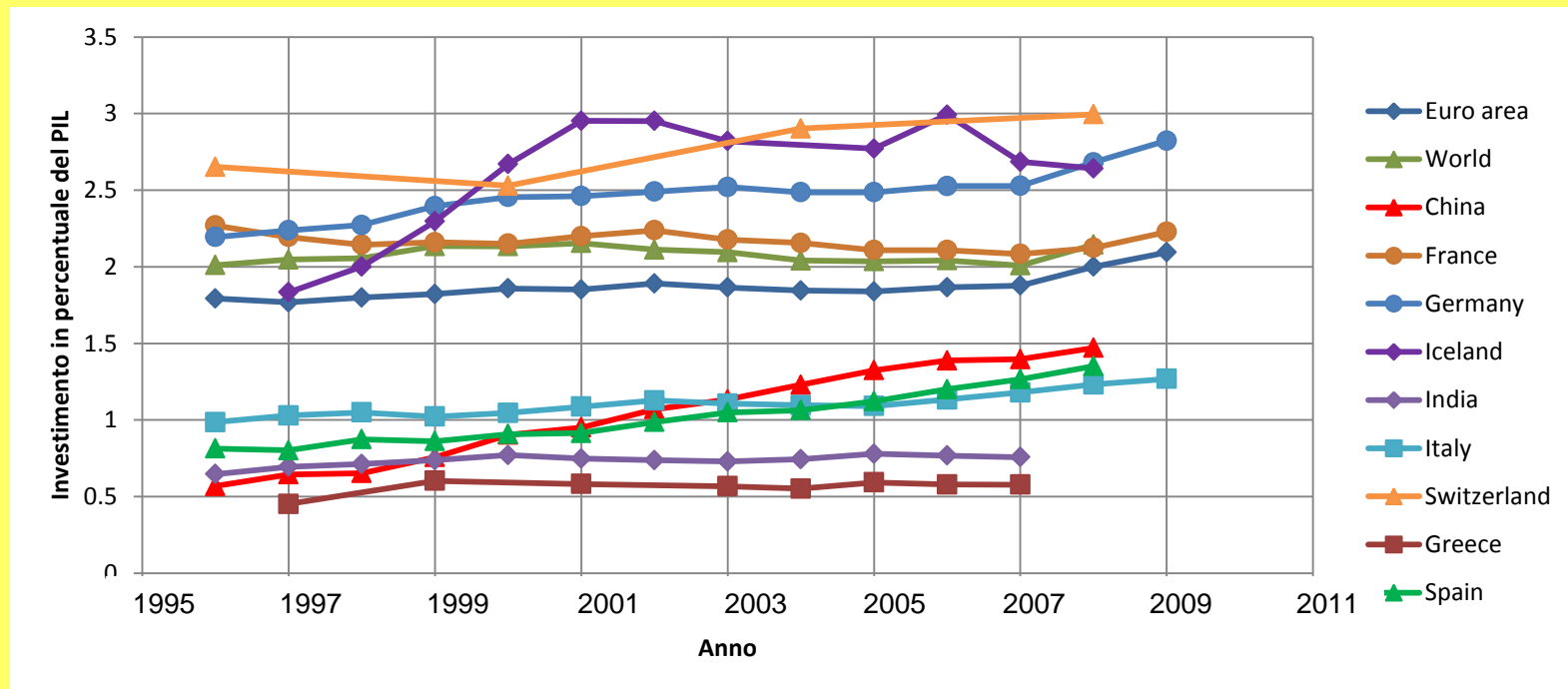
[www.txt2pic.com](http://www.txt2pic.com)

# **SOMMARIO**

- **Perché fare ricerca?**
- **Radioattività**
- **Interazione radiazione-materia**
- **ARDENT**
  - **Adroterapia**
    - **Monitor di fascio**

# PERCHÉ FARE RICERCA?

Investimento nella ricerca in percentuale del PIL (fonte: **The World Bank**).  
Spesa pubblica e privata nei vari settori della ricerca (scientifici e umanistici)



# PERCHÉ FARE RICERCA?

research  
policy

www.elsevier.com/locate/econbase

Research Policy 30 (2001) 509–532

The economic benefits of publicly funded basic research:  
a critical review

Amnon J. Salter\*, Ben R. Martin

Technology Policy Research, University of Sussex, Falmer, Brighton BN1 9RF, UK  
Accepted 9 February 2000

ELSEVIER

The increasing linkage between U.S. technology and  
science

Francis Narin\*

Kimberly S. Hamilton, Dominic Orvasco  
CPI Research Inc., 10 White Horse Pike, Haddon Heights, NJ 08033, USA

Research Policy 26 (1997) 317–330

research  
policy

<http://iupab.org/publications/value-of-fundamental-research/>

<http://hbr.org/2006/10/can-science-be-a-business-lessons-from-biotech/a/1>

<http://www.economist.com/blogs/graphicdetail/2013/02/focus-4>

<http://forumblog.org/2013/04/five-ways-technology-can-help-the-economy/>

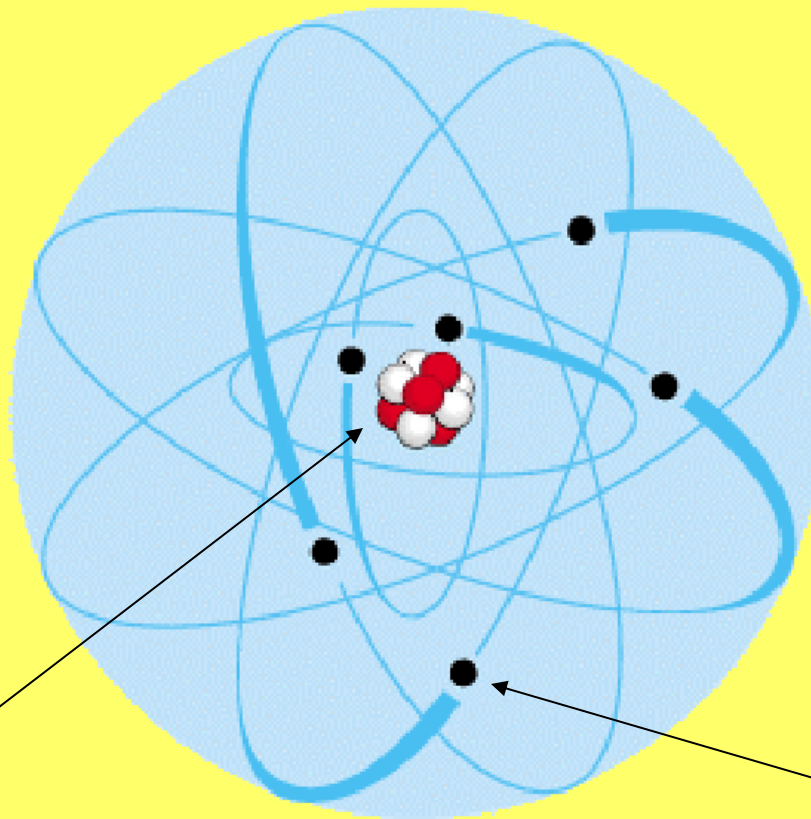
# PERCHÉ FARE RICERCA?

Può essere anche divertente...



NSS-IEEE 2012  
**Disneyland**, Anaheim  
California-USA  
...dopo la conferenza!

# **RADIOATTIVITÀ: L'ATOMO**



**Nucleo:**

**protoni + neutroni**

**Elettroni**

# RADIOATTIVITÀ: LA TAVOLA PERIODICA

Ovvero: come un chimico vede il mondo...

**The Periodic Table of Elements**

6 ←

C

CARBON ←

12 ←

Atomic Number = Number of Protons = Number of Electrons

Chemical Symbol

Chemical Name

Atomic Weight = Number of Protons + Number of Neutrons\*

<b>NON-METALS</b>										<b>METALS</b>																																																																																												
1 H HYDROGEN 1			2 He HELIUM 4	5 B BORON 11	6 C CARBON 12	7 N NITROGEN 14	8 O OXYGEN 16	9 F FLUORINE 19	10 Ne NEON 20	11 Na SODIUM 23	12 Mg MAGNESIUM 24	13 Al ALUMINUM 27	14 Si SILICON 28	15 P PHOSPHORUS 31	16 S SULFUR 32	17 Cl CHLORINE 35	18 Ar ARGON 40	19 K POTASSIUM 39	20 Ca CALCIUM 40	21 Sc SCANDIUM 45	22 Ti TITANIUM 48	23 V VANADIUM 51	24 Cr CHROMIUM 52	25 Mn MANGANESE 55	26 Fe IRON 56	27 Co COBALT 59	28 Ni NICKEL 59	29 Cu COPPER 64	30 Zn ZINC 65	31 Ga GALLIUM 70	32 Ge GERMANIUM 73	33 As ARSENIC 75	34 Se SELENIUM 79	35 Br BROMINE 80	36 Kr KRYPTON 84	37 Rb RUBIDIUM 85	38 Sr STRONTIUM 88	39 Y YTIUM 89	40 Zr ZIRCONIUM 91	41 Nb NIOBIUM 93	42 Mo MOLYBDENUM 96	43 Tc TECHNETIUM 98	44 Ru RUTHENIUM 101	45 Rh RHODIUM 103	46 Pd PALLADIUM 106	47 Ag SILVER 108	48 Cd CADMIUM 112	49 In INDIUM 113	50 Sn TIN 119	51 Sb ANTIMONY 122	52 Te TELLURIUM 128	53 I IODINE 127	54 Xe XENON 131	55 Cs CESIUM 133	56 Ba BARIUM 137	57 La LANTANIUM 139	58 Ce CELESIUM 140	59 Pr PRASEODYMIUM 141	60 Nd NEODYMIUM 144	61 Pm PROMETHIUM 145	62 Sm SAMARIUM 150	63 Eu EUROPIUM 152	64 Gd GADOLINIUM 157	65 Tb TERBIUM 159	66 Dy DYSPROSIUM 163	67 Ho HOLMIUM 165	68 Er ERBIUM 167	69 Tm THULIUM 169	70 Yb YBBIUM 173	71 Lu LUTETIUM 175	72 Hf HAFNIUM 178	73 Ta TANTALUM 181	74 W TUNGSTEN 184	75 Re RHENIUM 186	76 Os OSMIUM 190	77 Ir IRIDIUM 192	78 Pt PLATINUM 195	79 Au GOLD 197	80 Hg MERCURY 201	81 Tl THALLIUM 204	82 Pb LEAD 207	83 Bi BISMUTH 209	84 Po POLONIUM 209	85 At ASTATINE 210	86 Rn RADON 222	87 Fr FRANCIUM 223	88 Ra RADIUM 226	89 Ac ACTINIUM 227	90 Th THORIUM 232	91 Pa PROCTINIUM 231	92 U URANIUM 238	93 Np NEPTUNIUM 237	94 Pu PLUTONIUM 244	95 Am AMERICIUM 243	96 Cm CURIUM 247	97 Bk BERKELIUM 247	98 Cf CALIFORNIUM 251	99 Es EINSTEINIUM 252	100 Fm FERMIUM 257	101 Md MENDELIUM 258	102 No NOBELIUM 259	103 Lr LAWRENCIUM 262

**KEY**

- Solid at room temperature
- Liquid at room temperature
- Gas at room temperature
- \* - Radioactive
- † - Artificially Made

\* The atomic weights listed on this Table of Elements have been rounded to the nearest whole number. As a result, this chart actually displays the mass number of a specific isotope for each element. An element's complete, unrounded atomic weight can be found on the IUPAC Elemental web site: <http://education.jlab.org/elemental/index.html>

<http://education.jlab.org/>

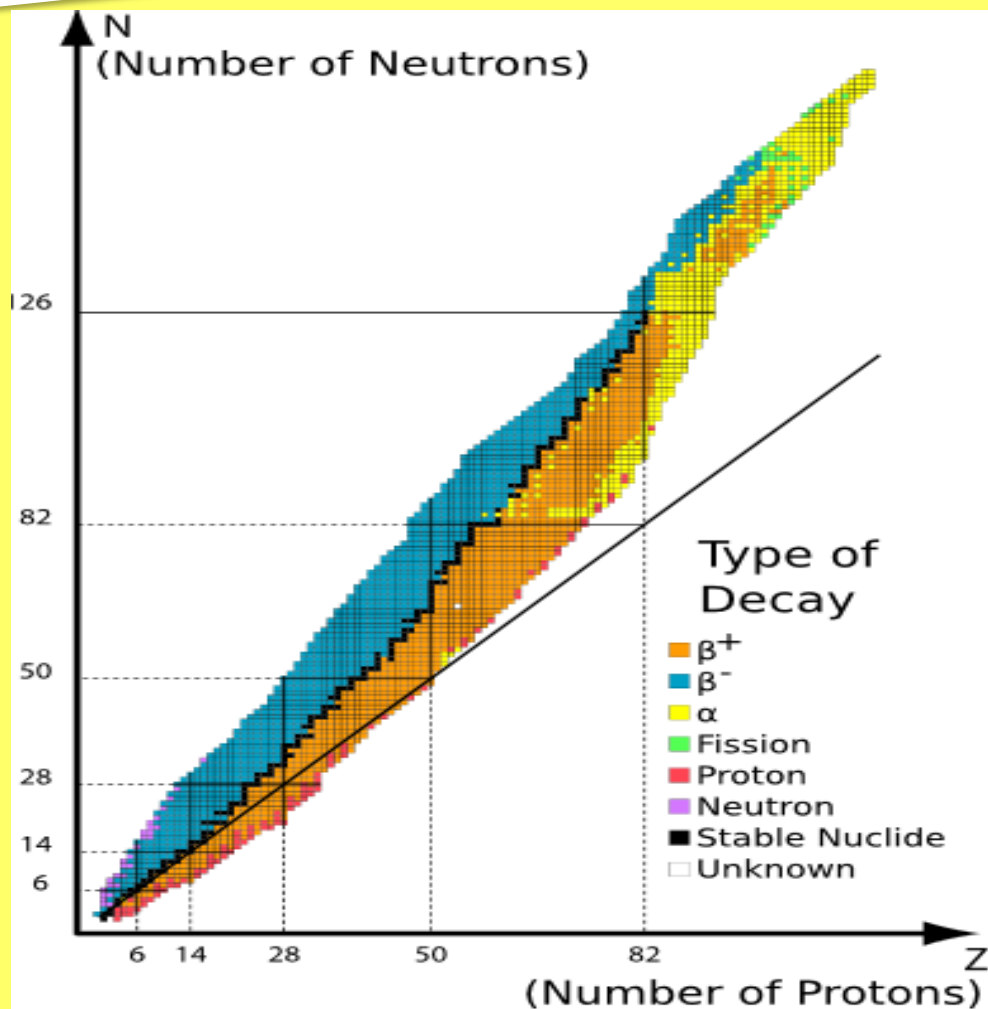
Last revised on March 21, 2008

# RADIOATTIVITÀ: LA TAVOLA DEI NUCLIDI

Ovvero: come un fisico nucleare vede il mondo...

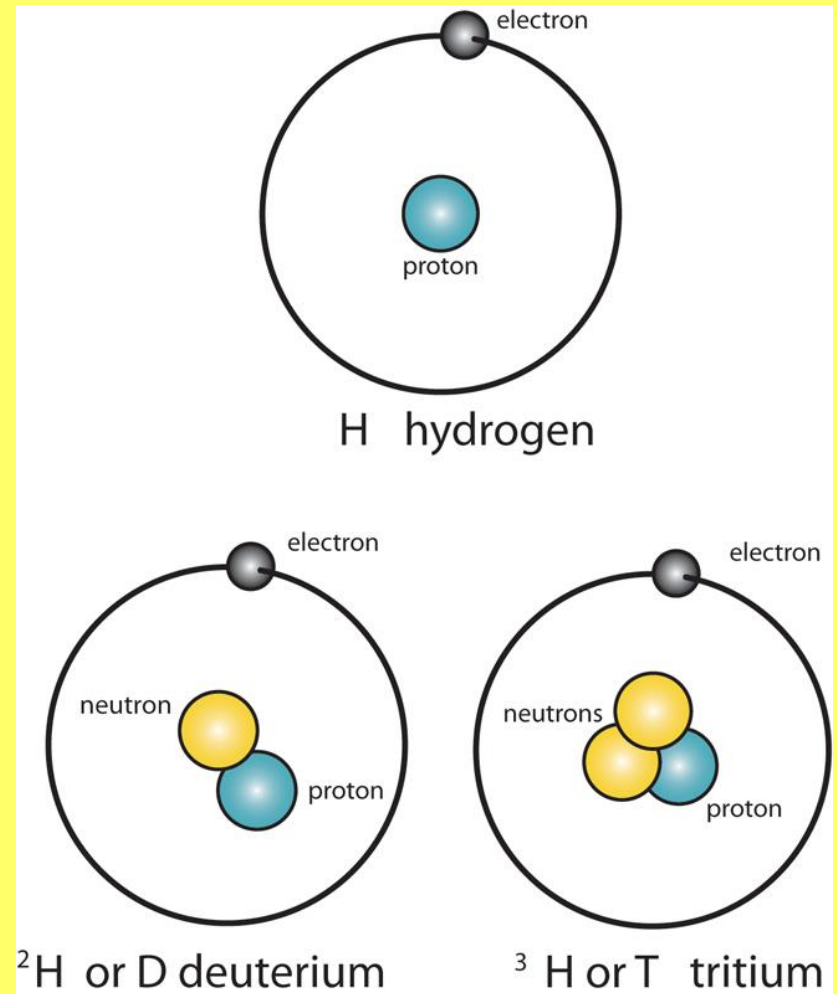
I Nuclei possono avere degli **isotopi**: stesso elemento chimico (stesso Z) ma differente numero di massa (A)

Gli isotopi possono essere **instabili e decadere** emettendo **radiazioni**





# RADIOATTIVITA': ISOTOPI

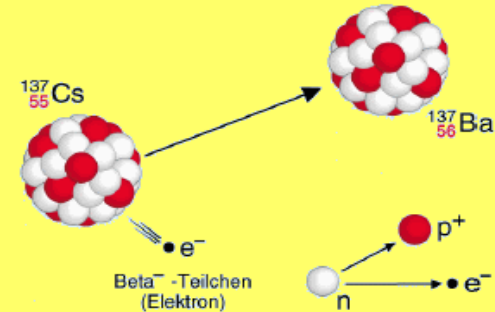


# RADIOATTIVITÀ: I TIPI DI RADIAZIONE

Distinguiamo principalmente tra radiazione **carica** e radiazione **neutra**

- **Carica:**

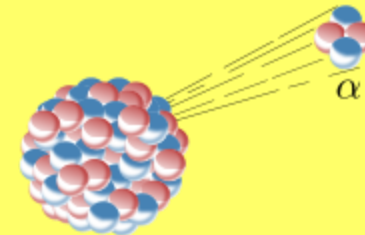
- **Particelle leggere (e.g. e-)**
  - ✓ Percorso nella materia limitato
  - ✓ Facilmente schermabili



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- **Carica:**
  - **Particelle leggere (e.g. e-)**
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  - **Nuclei e particelle  $\alpha$** 
    - ✓ Pesanti e molto cariche ( $n \times e^-$ )
    - ✓ Percorso nella materia limitato
    - ✓ Facilmente schermabili



# RADIOATTIVITÀ: I TIPI DI RADIAZIONE

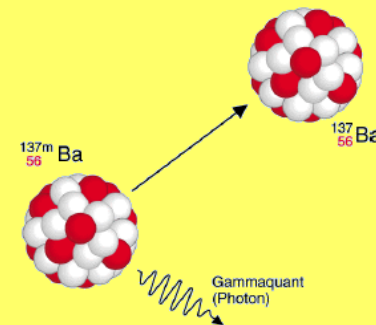
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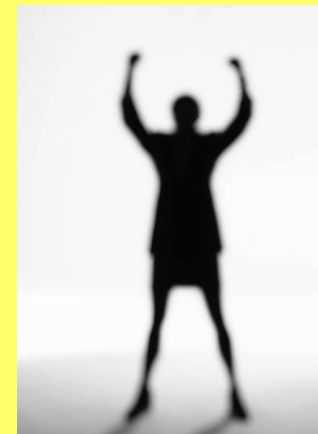
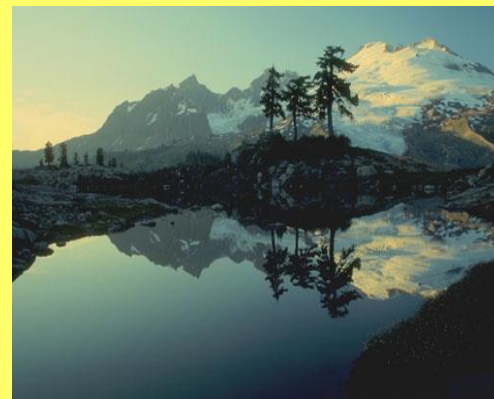
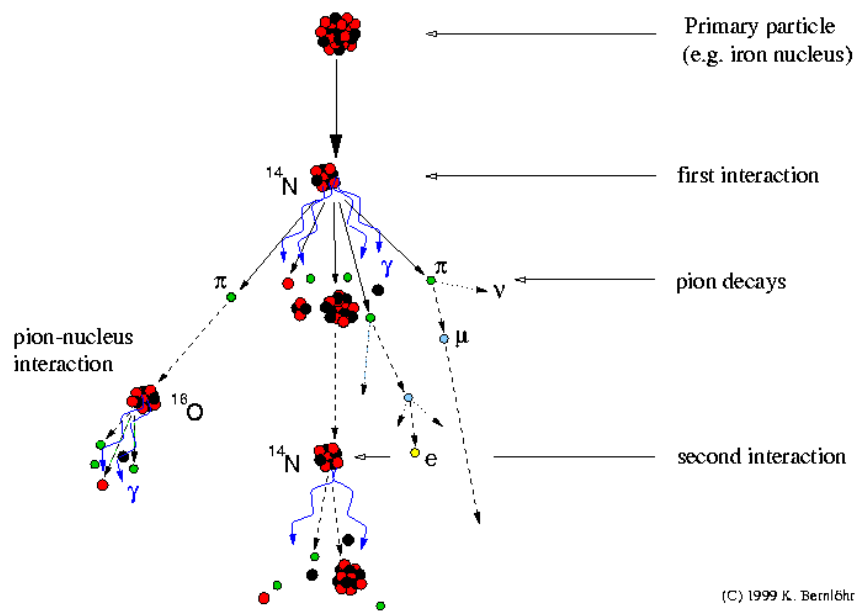
- **Neutra:**

- **Fotoni**
  - ✓ Molto penetranti
  - ✓ Difficili da schermare
- **Neutroni**
  - ✓ Molto penetranti
  - ✓ Difficili da schermare



# RADIOATTIVITÀ: FONTI NATURALI DI RADIAZIONE

Development of cosmic-ray air showers



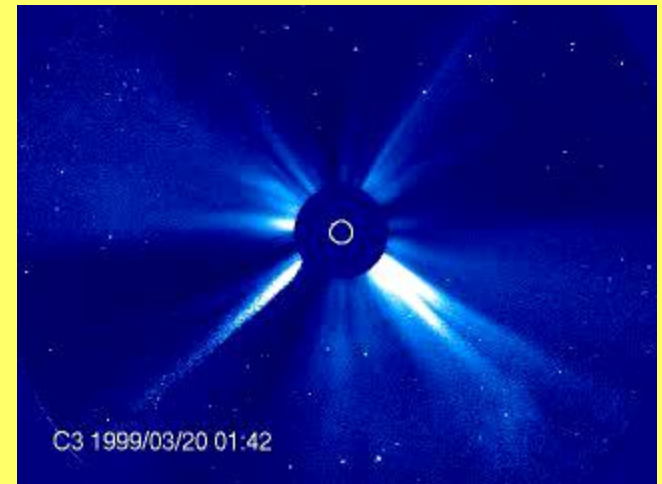
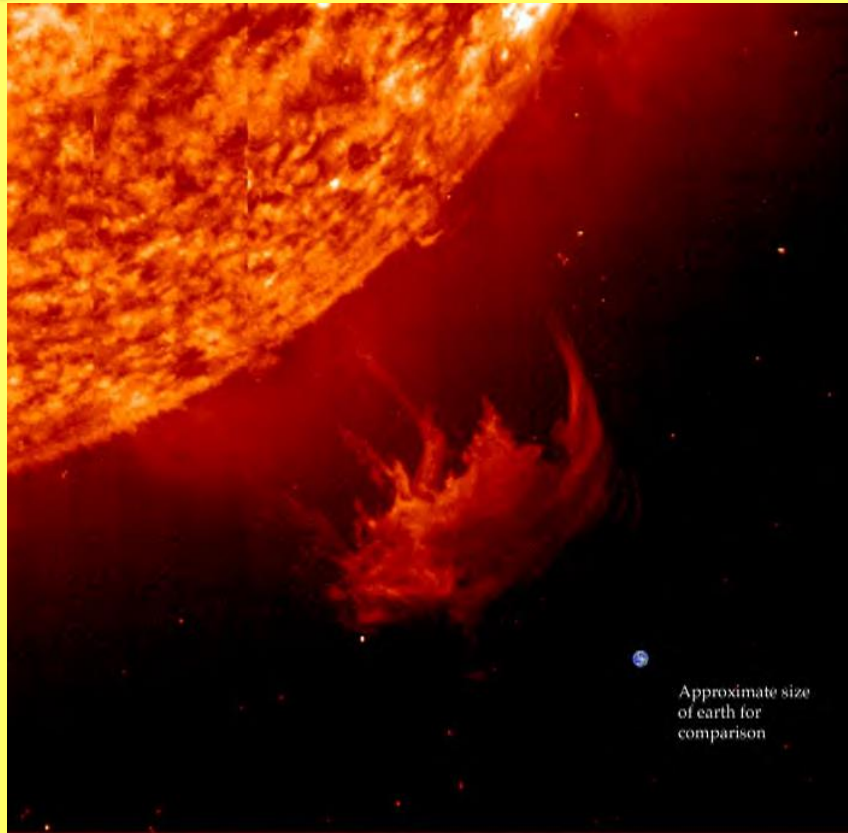
**Radionuclidi  
presenti nella  
crosta terrestre:  
U, Th, Rn, Ra....**

**Isotopi  
radioattivi di  
elementi  
naturalmente  
presenti nel  
corpo umano:  
 $^{14}\text{C}$ ,  $^{40}\text{K}$ ....**



**Raggi Cosmici:  
 $^{14}\text{C}$ ,  $^3\text{H}$ ,  $^7\text{B}$ ,  $\mu$ ,  $\pi$ ,  
 $\rho$ ,  $n$ ...**

# **RADIOATTIVITÀ: FONTI NATURALI DI RADIAZIONE, RAGGI COSMICI**



## Coronal Mass Ejections and planet transit 20 Marzo – 10 Aprile 1999

SOHO – Solar and Heliospheric  
Observatory

# INTERAZIONE RADIAZIONE MATERIA: MATERIALI



## LA PENETRATION DES RAYONNEMENTS



Réalisé par CHURCHILL

# INTERAZIONE RADIAZIONE MATERIA: ORGANISMO

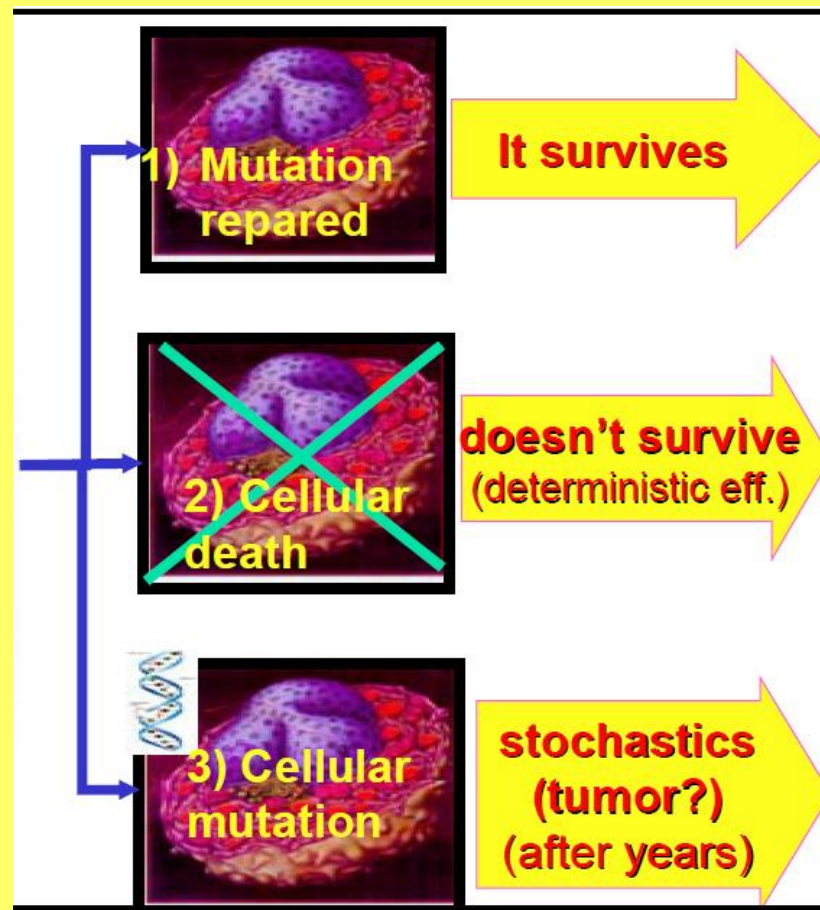
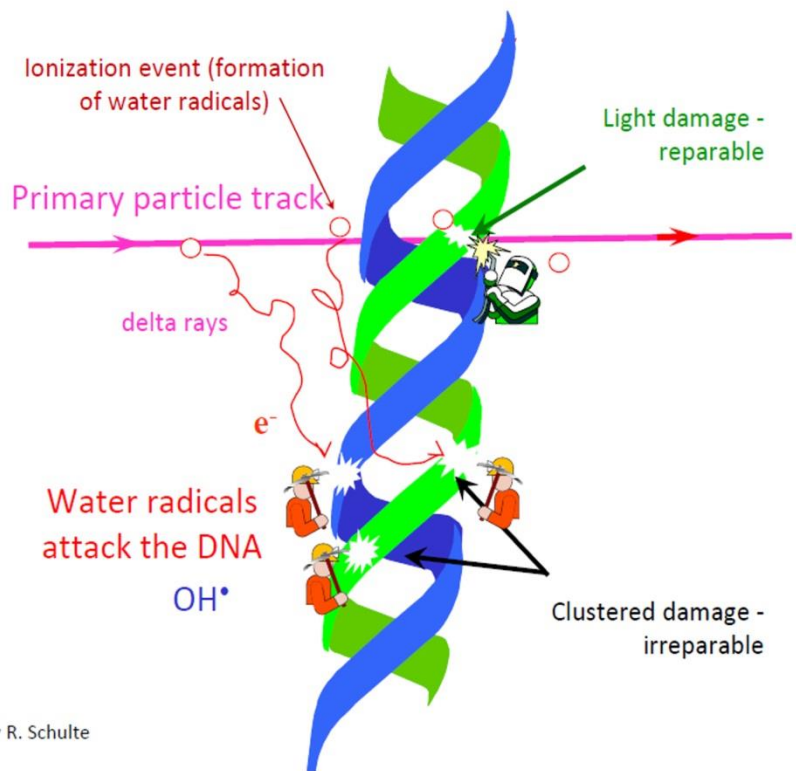
Cosa non  
succede ☹ ...





# INTERAZIONE RADIAZIONE MATERIA: ORGANISMO

- Effetti Stocastici
- Effetti deterministici



# INTERAZIONE RADIAZIONE MATERIA: ORGANISMO

- **danni al corpo umano deterministici**

Per danni deterministici si intendono quelli la cui frequenza e gravità **variano con la dose.**

- **danni al corpo umano stocastici**

I danni somatici stocastici comprendono **le leucemie e i tumori solidi.**

In questa patologia è in funzione della dose solo la **probabilità di accadimento, e non la gravità del danno.**

- **danni genetici stocastici**

Fino ad oggi **non è stato possibile** rilevare una correlazione tra l'esposizione alle radiazioni dei genitori e le malattie ereditarie della progenie rispetto a soggetti non esposti.

# ARDENT DOSIMETRIA

Qualche equazione...

**Dose assorbita:** energia ceduta dalla radiazione per unità di materia.

$$D = dE / dm \rightarrow 1Gy = 1J/kg$$

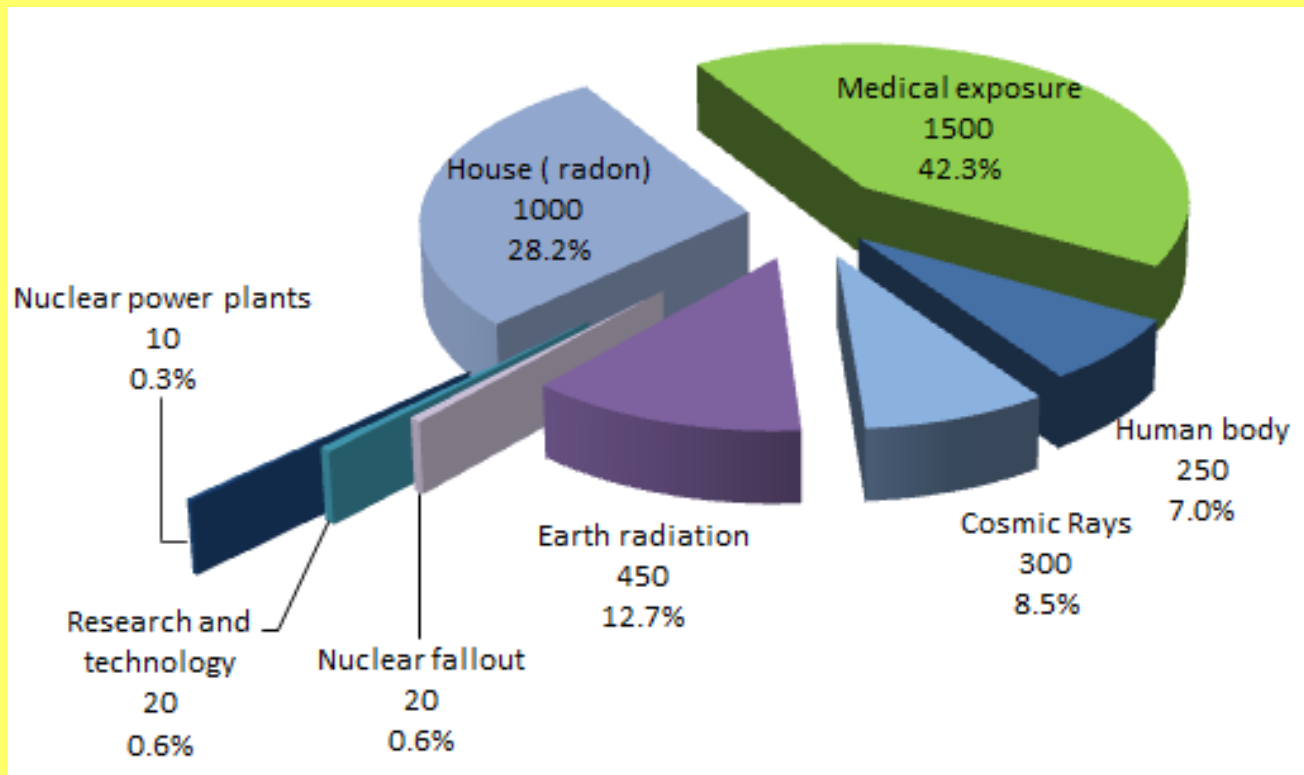
**Dose equivalente:** serve a stimare il danno provocato tenendo conto della differente pericolosità delle radiazioni

$$H = \sum_R w_R D_R \rightarrow 1Sv = 1J/kg$$

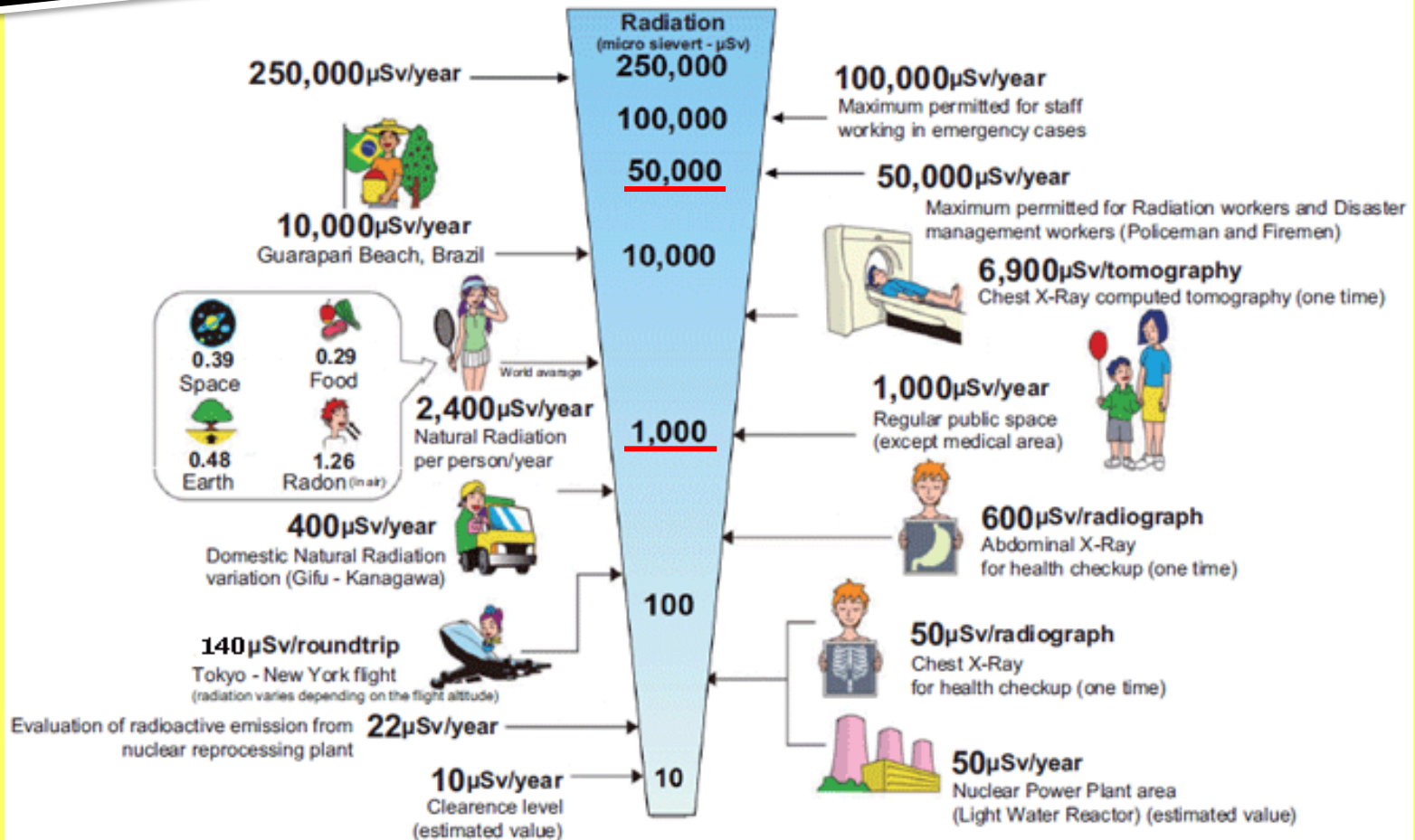
Il fattore  $w_R$  dà un peso ed è differente per ogni tipo di radiazione:  
 $\gamma, \beta, \mu, w_R = 1$ ;  $p w_R = 5$ ; nuclei  $w_R = 20$ ; neutroni dipende dall'**energia**

# ARDENT DOSIMETRIA

La radioattività naturale vs Attività umane:



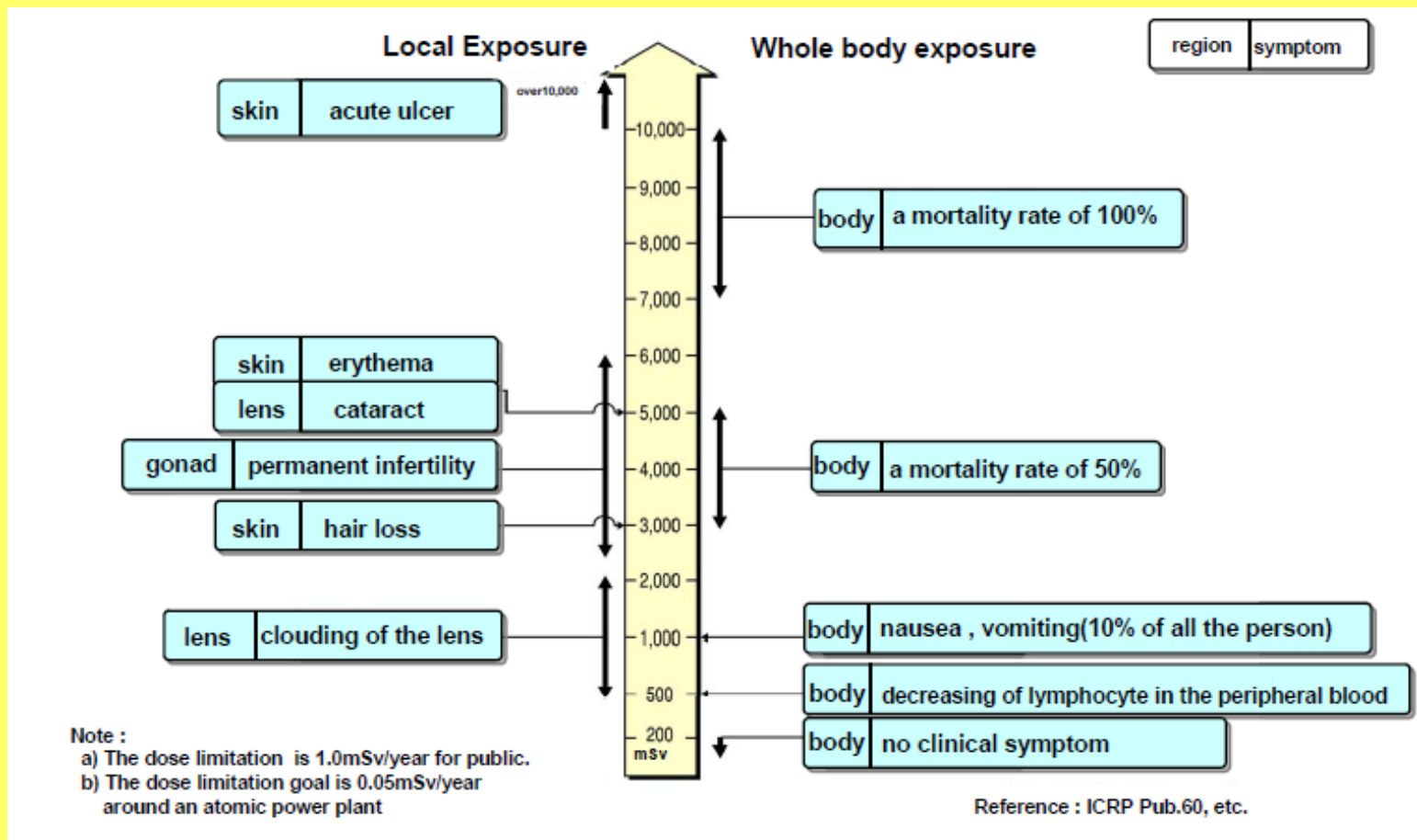
# ARDENT DOSIMETRIA



Source: Ministry of Education, Culture, Sports, Science and Technology of Japan

# ARDENT DOSIMETRIA

## Dose assorbita ed **effetti deterministici**



# **ARDENT DOSIMETRIA**

Dose assorbita ed **effetti stocastici**: tumori

La probabilità di ciascun individuo non esposto ad agenti cancerogeni, di sviluppare un tumore è del **20%**

L'assorbimento di **1 Sv** aumenta questa probabilità del **4%** per raggiungere una probabilità del **24%**

Per **100 mSv** (100 volte la dose annua) la probabilità aumenta del **0.4%** per un totale del **20.4%**

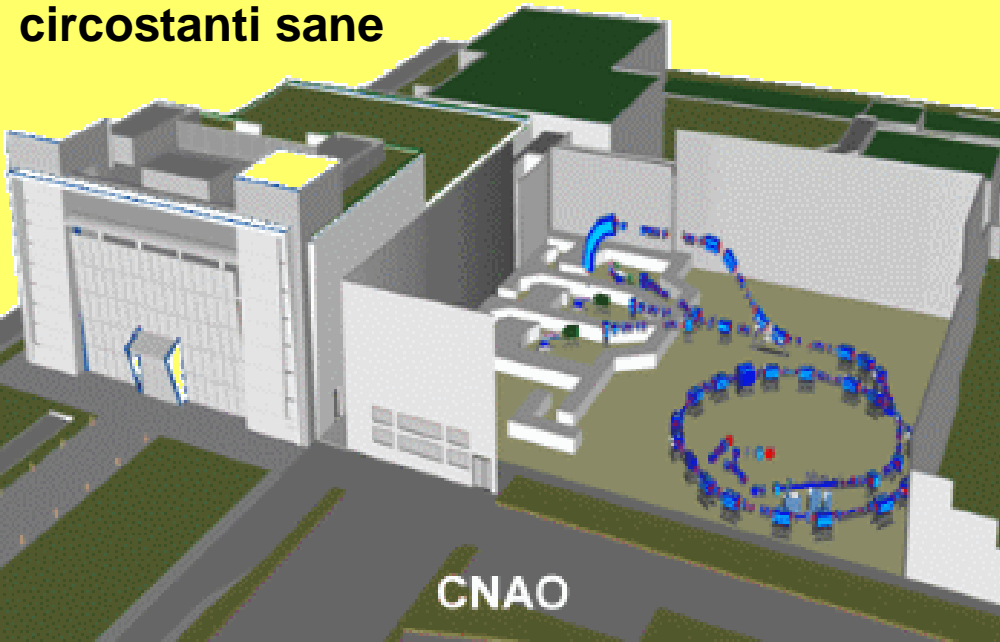
# ARDENT ADROTERAPIA

Le **cellule sane** hanno, entro un certo limite, la **capacità di riparare** il danno dovuto alle radiazioni

Le **cellule tumorali** invece non riescono a riparare il danno e **muiono**

Con l'**adroterapia** si riescono a trattare **localmente** i tumori.

La radiazione viene assorbita soprattutto dal tumore, riducendo il danno alle zone circostanti sane

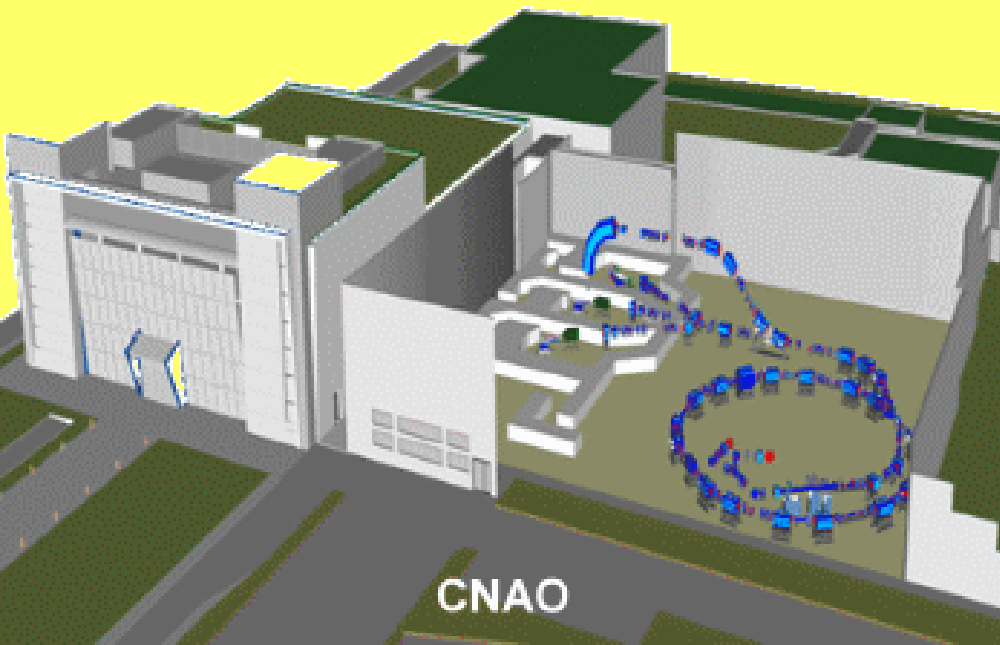
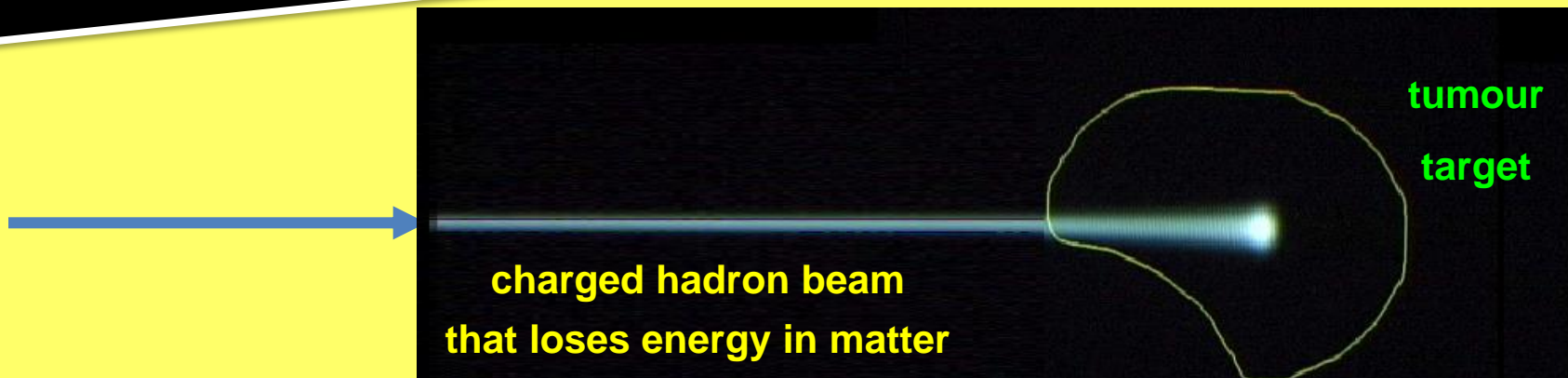


du

Centro Nazionale di  
Adroterapia Oncologica,  
Pavia



# ARDENT ADROTERAPIA



Centro Nazionale di  
Adroterapia Oncologica,  
Pavia

# ARDENT ADROTERAPIA

## A NEW TOOL FOR CONTROLLING CANCER

The Lova Linda University Medical Center Proton Treatment Center is the first in the world to offer proton therapy, designed to treat cancerous tumors without harming surrounding healthy tissue. The center cost \$10 million, took four years to

design and build, and contains the world's smallest synchrotron built by Fermi National Accelerator Laboratory. It is as large as some hospitals, can serve up to 100 patients in a 10-hour day, and is a model for worldwide training and research.

### HOW A PROTON BEAM WORKS

The beam enters the body at a low absorption rate and increases in intensity at a specific point, called the Bragg peak. A series of protons are focused on the tumor, giving it the highest concentration of radiation, killing the cells of the tumor. Not only is the dose of radiation in normal tissue sharply reduced, compared to conventional radiation therapy, but the energy of the proton beam completely dissipates within the tumor, causing no damage to normal tissues beyond the tumor.

### THE GANTRY

Three ganties resembling giant ferris wheels can rotate around the patient and direct the proton beam to a precise point. Each gantry weighs about 90 tons and stands three stories tall. The 15-foot-diameter ganties support the bending and focusing magnets to direct the beam, and have counterweights for extra radiation shielding.

### STATIONARY BEAM

The stationary beam has two branches, one for irradiating eye tumors and the other for central nervous system tumors.

### THE INJECTOR

Protons are stripped out of the nucleus of hydrogen atoms and sent to the accelerator.

### SYNCHROTRON (ACCELERATOR)

The synchrotron is a ring of magnets, about 20 feet in diameter, through which protons circulate in a vacuum tube. As the magnetic field in the ring is increased, the energy of the protons is also increased. When the magnetic field reaches the value corresponding to a prescribed beam energy, the field is held constant while protons are slowly extracted from the ring. The system accelerates protons to a minimum energy (70 million electron volts) in one-quarter second and to maximum energy (250 million electron volts) in one-half second.

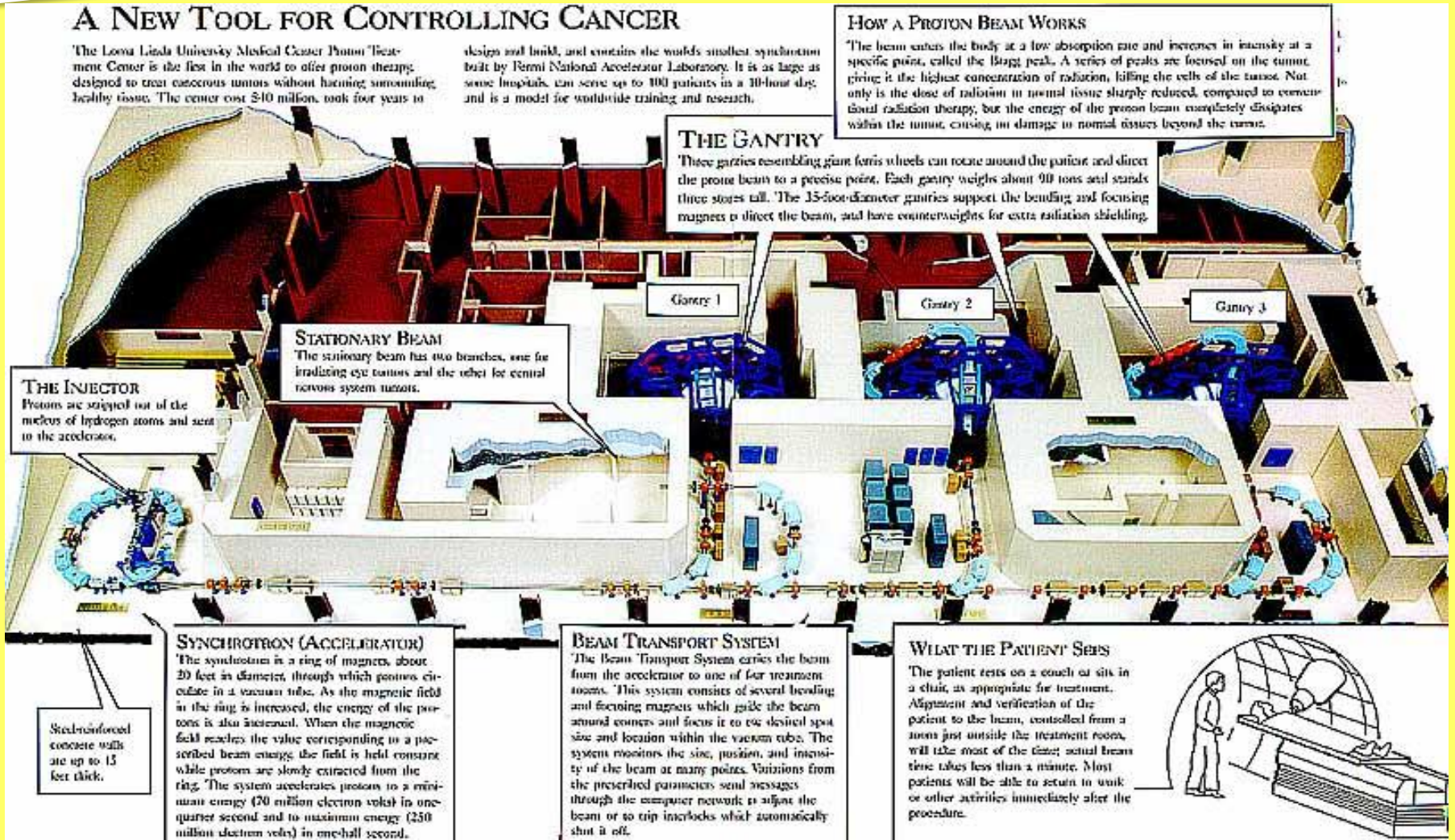
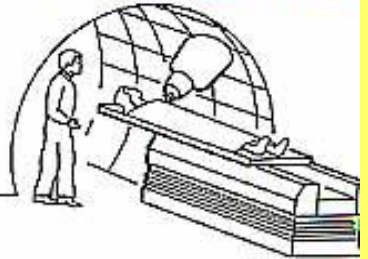
Steel-reinforced concrete walls are up to 15 feet thick.

### BEAM TRANSPORT SYSTEM

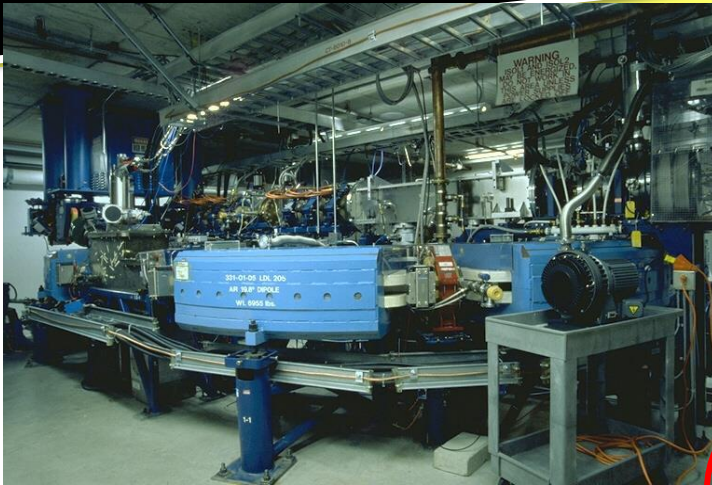
The Beam Transport System carries the beam from the accelerator to one of four treatment rooms. This system consists of several bending and focusing magnets which guide the beam around corners and focus it to the desired spot size and location within the vacuum tube. The system monitors the size, position, and intensity of the beam at many points. Variations from the prescribed parameters send messages through the computer network to adjust the beam or to trip interlocks which automatically shut it off.

### WHAT THE PATIENT SEES

The patient rests on a couch or sits in a chair, as appropriate for treatment. Alignment and verification of the patient to the beam, controlled from a room just outside the treatment room, will take most of the time; actual beam time takes less than a minute. Most patients will be able to return to work or other activities immediately after the procedure.



# ARDENT ADROTERAPIA



## CANCER

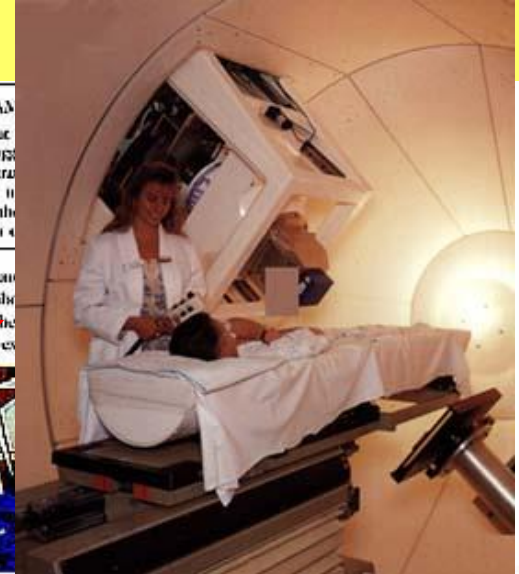
It contains the world's smallest synchrotron accelerator Laboratory. It is as large as up to 100 patients in a 10-hour day: ride training and research.

## HOW A PROTON BEAM

The beam enters the body at a specific point, called the Bragg peak, giving it the highest concentration. Only the dose of radiation is used for radiation therapy, but the rest is absorbed by the body, causing no harm.

## THE GANTRY

Three gantries resembling giant ferris wheels can rotate around the proton beam to a precise point. Each gantry weighs about three stories tall. The 15-foot-diameter gantries support the magnets to direct the beam, and have counterweights for equilibrium.



## THE INJECTOR

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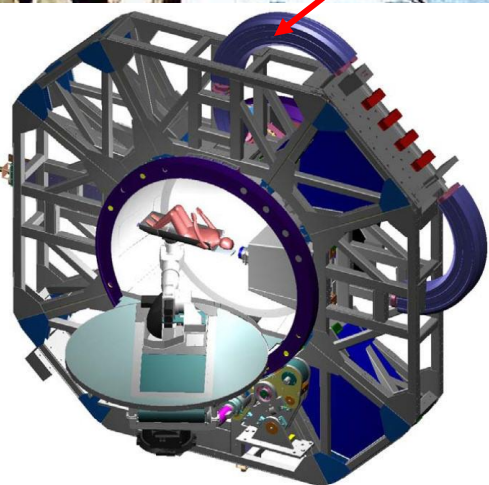
## STATIONARY BEAM

The stationary beam has two branches, one for irradiating eye tumors and the other for central nervous system tumors.

Steel-reinforced concrete walls are up to 13 feet thick.  
16/10/2013

## SYNCHRO

The synchrotron is 20 feet in diameter and 10 feet in height. The ring is 100 feet in diameter and 3 feet thick. The beam reaches the target while passing through the ring. The system uses energy from a quarter of a million electrons.

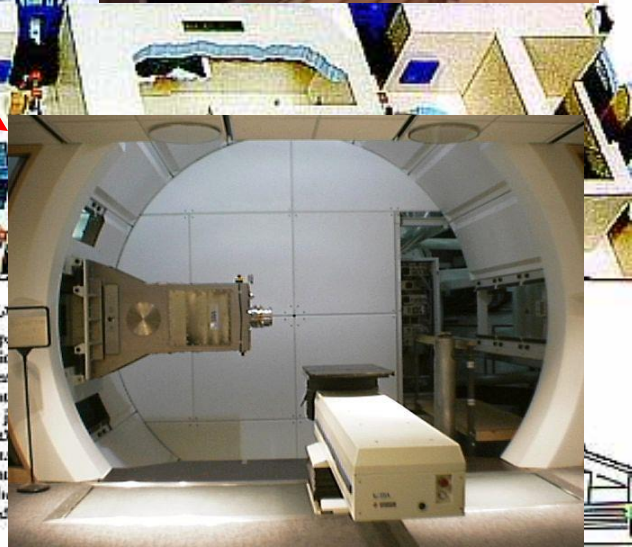


## TRANSPORT SYSTEM

The transport system carries the beam from the injector to one of four treatment rooms. It consists of several bending magnets which guide the beam and focus it to the desired spot within the vacuum tube. The size, position, and intensity of the beam are controlled at many points. Variations from the design are corrected by a computer network to adjust the interlocks which automatically

## WELLS

The patient is placed in a chair. After the patient is positioned, the beam will be directed to the patient or other procedures.

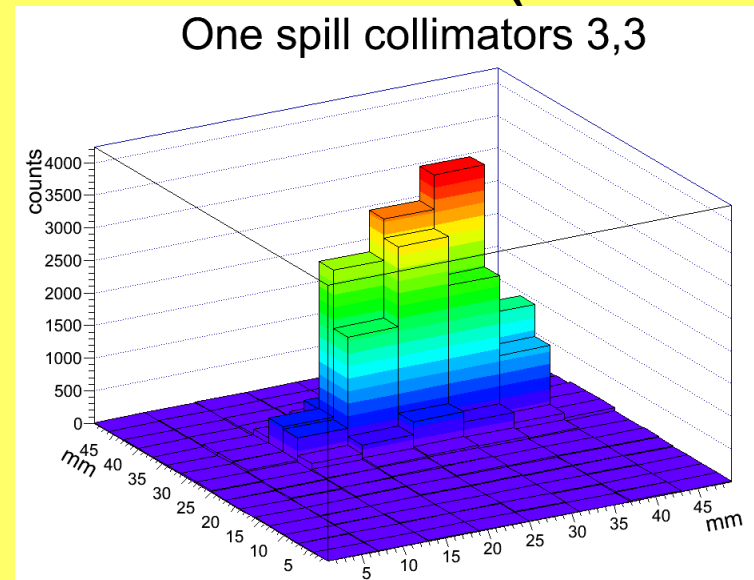


# ARDENT ADROTERAPIA - DETECTORS

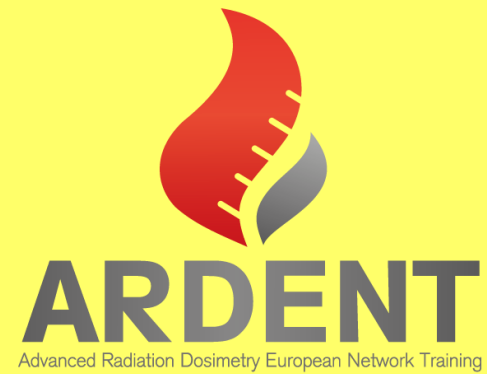
In questo caso le particelle sono **protoni** o **ioni pesanti** ( $^{12}\text{C}$ ) quindi **cariche**.  
Il detector per il monitoraggio del fascio deve essere:

- resistente alle radiazioni
- non deve interferire col fascio stesso (causando perdite o cambiamenti nella forma )

Finora abbiamo utilizzato la GEM per monitorare fasci di neutroni (nTOF-CERN)  
e di particelle cariche (CERF-CERN)



**GRAZIE A...**



# ***GRAZIE A...***

- Il Politecnico di Milano e il Prof. S. Agosteo per l'organizzazione e lo spazio dedicatoci
- I miei relatori: Dr. M. Silari e Dr. F. Murtas per il materiale scientifico
- Il Dr. F. Varrato per la bibliografia su ricerca ed economia