

**UNA RAPIDA GUIDA**



**2013**  
EDITION

**ARDENT**

FOR

**DUMMIES**

**ADVANCED  
RADIATION  
DOSIMETRY  
EUROPEAN  
NETWORK  
TRAINING**

**FISICA E  
RICERCA SULLE  
RADIAZIONI**



di: Silvia Puddu

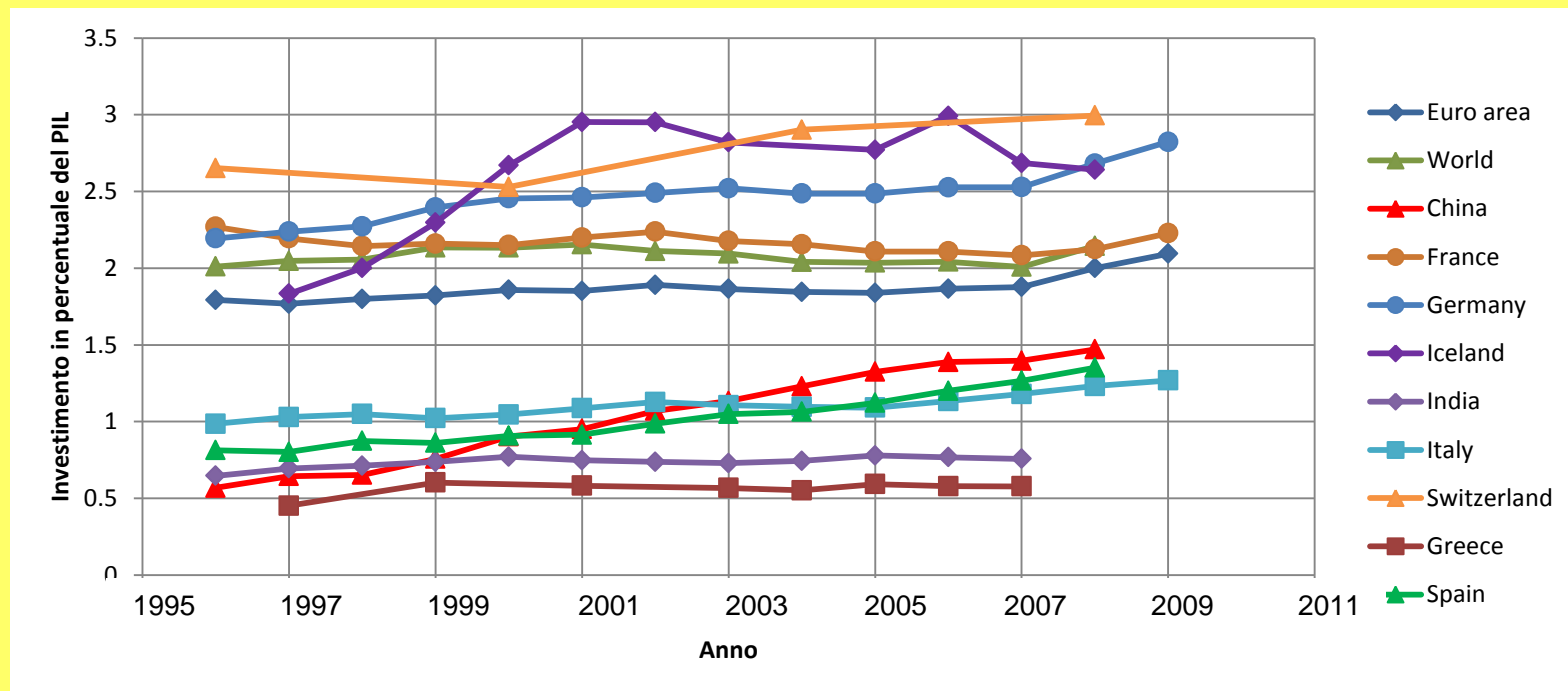
email: [silvia.puddu@cern.ch](mailto:silvia.puddu@cern.ch)

# **SOMMARIO**

- <http://youtu.be/3wtUr3iVVlw?t=1m04s>
- **Perché fare ricerca?**
- **Radioattività**
- **Interazione radiazione-materia**
- **ARDENT**
  - **Dosimetria**
    - **Rivelatori per la dosimetria dei neutroni**
  - **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.nl/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/>

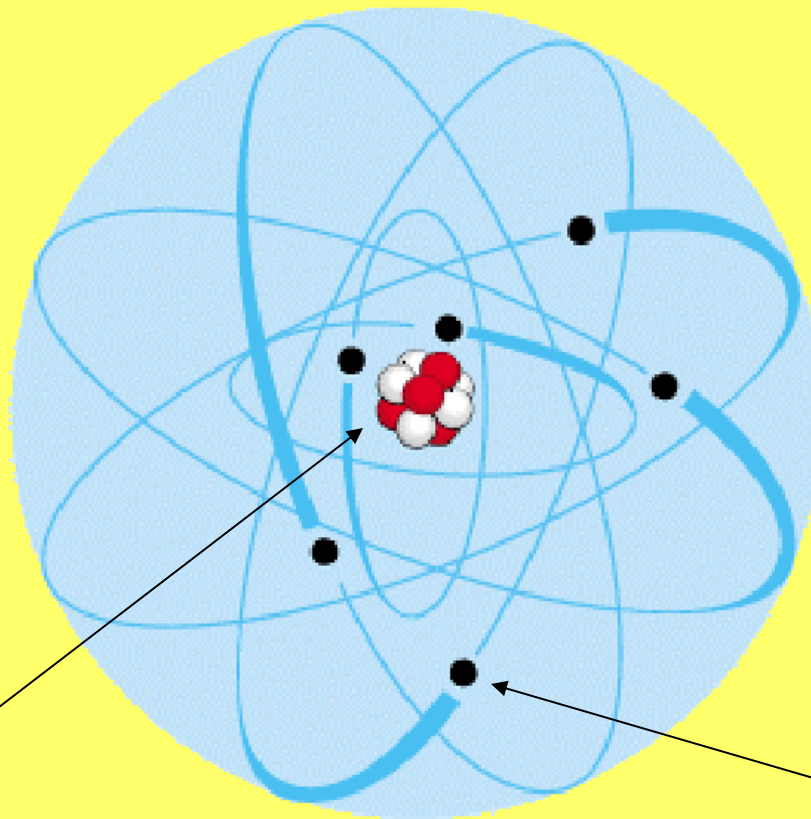
# PERCHÉ FARE RICERCA?

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** ← Atomic Number = Number of Protons = Number of Electrons  
**C** ← Chemical Symbol  
 CARBON ← Chemical Name  
 12 ← Atomic Weight = Number of Protons + Number of Neutrons\*

**METALS**

**NON-METALS**

1 H HYDROGEN 1																			2 He HELIUM 4													
3 Li LITHIUM 7	4 Be BERYLLIUM 9																	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 CAESIUM 133	56 Ba BARIUM 137																	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																	87 La LANTANIUM 139	88 Ce CELESIUM 140	89 Pr PRASEODYMIUM 141	90 Nd NEODYMIUM 144	91 Pm PROMETHIUM 145	92 Sm SAMARIUM 150	93 Eu EUROPIUM 152	94 Gd GADOLINIUM 157	95 Tb TERBIUM 159	96 Dy DYSPROSIUM 163	97 Ho HOLMIUM 165	98 Er ERBIUM 167	99 Tm THULIUM 169	100 Yb YBBIUM 173	101 Lu LUTETIUM 175
																		103 Ac ACTINIUM 227	104 Th THORIUM 232	105 Pa PROCTINIUM 231	106 U URANIUM 238	107 Np NEPTUNIUM 237	108 Pu PLUTONIUM 244	109 Am AMERICIUM 243	110 Cm CURIUM 247	111 Bk BERKELIUM 247	112 Cf CALIFORNIUM 251	113 Es EINSTEINIUM 252	114 Fm FERMIUM 257	115 Md MENDELIUM 258	116 No NOBELIUM 259	117 Lr LAWRENCIUM 262

**KEY**  
 ☐ - Solid at room temperature  
 ☉ - Liquid at room temperature  
 ☁ - Gas at room temperature  
 ☼ - Radioactive  
 ⬆ - Artificially Made

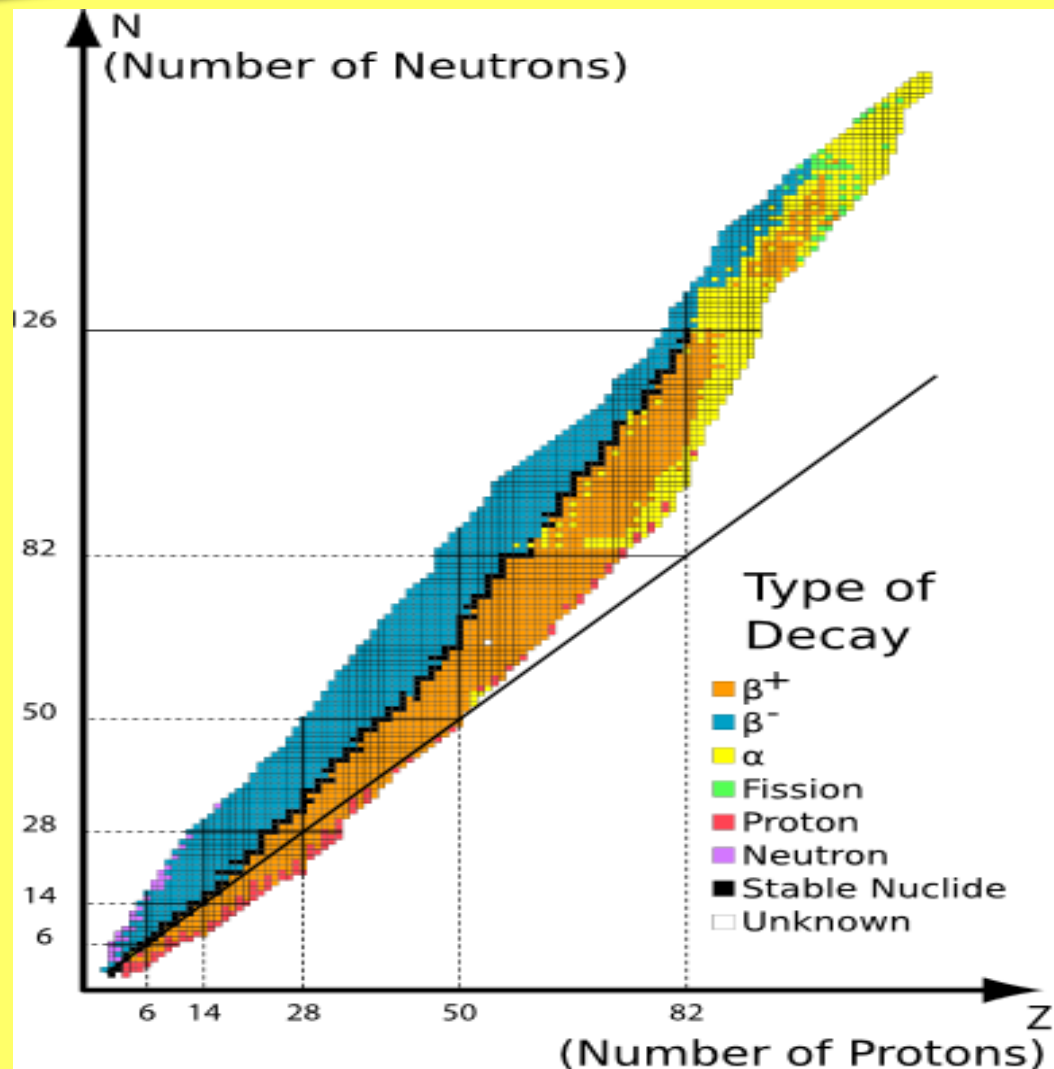
\* The atomic weights listed on this Table of Elements have been rounded to the nearest whole number. As a result, this chart actually displays the mass number of a specific isotope for each element. An element's complete, unrounded atomic weight can be found on the IUPAC Elemental web site: <http://education.jlab.org/elemental/index.html>

# 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**



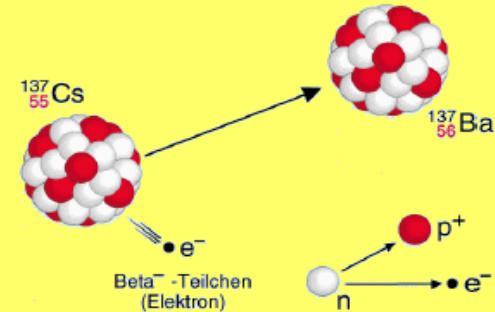


# RADIOATTIVITÀ: I TIPI DI RADIAZIONE

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

- **Carica:**

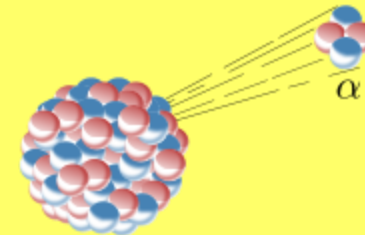
- **Particelle leggere (e.g. e-)**
  - ✓ Percorso nella materia limitato
  - ✓ Facilmente schermabili



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- **Carica:**
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    - ✓ Percorso nella materia limitato
    - ✓ Facilmente schermabili
  - **Nuclei e particelle  $\alpha$** 
    - ✓ Pesanti e molto cariche ( $n \times e^-$ )
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# RADIOATTIVITÀ: I TIPI DI RADIAZIONE

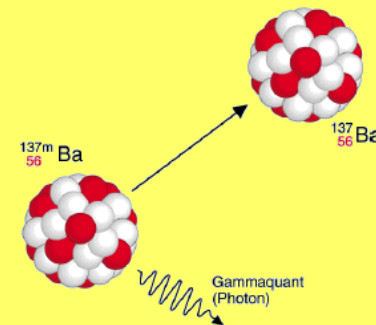
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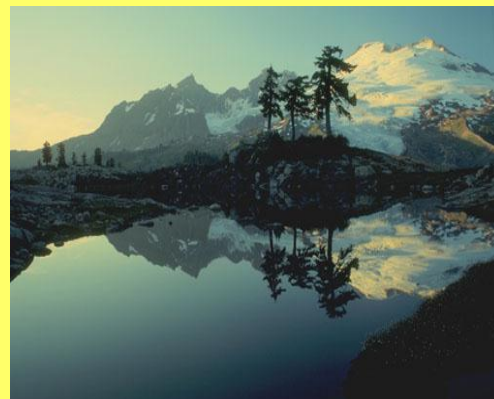
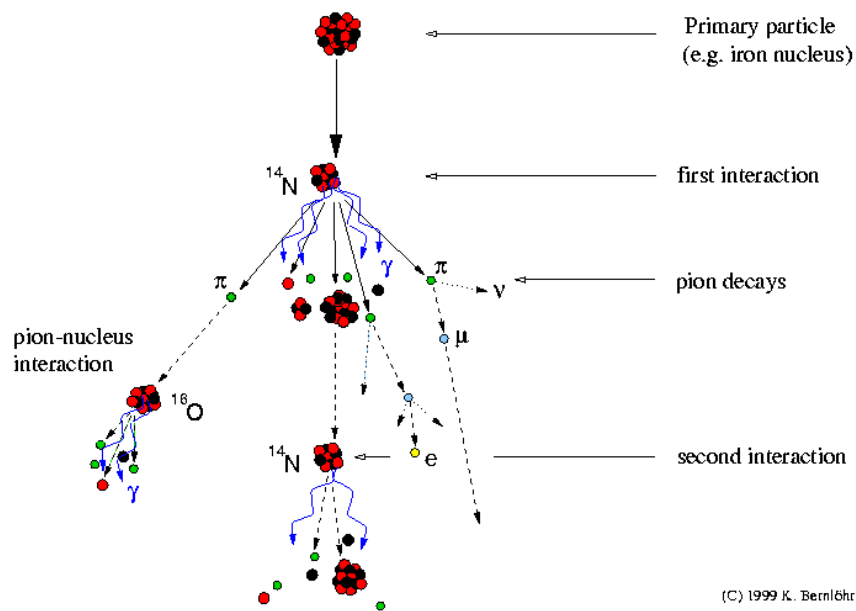
- **Neutra:**

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

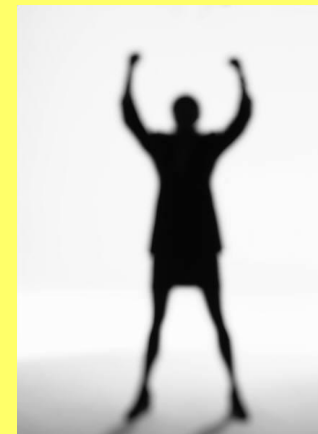


# RADIOATTIVITÀ: FONTI NATURALI DI RADIAZIONE

Development of cosmic-ray air showers



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

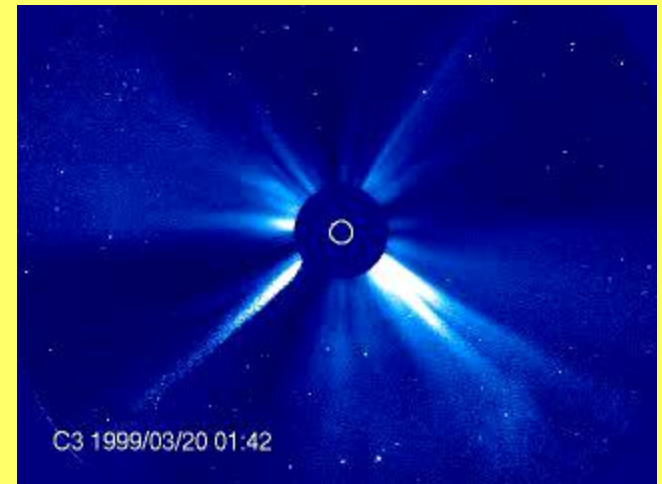
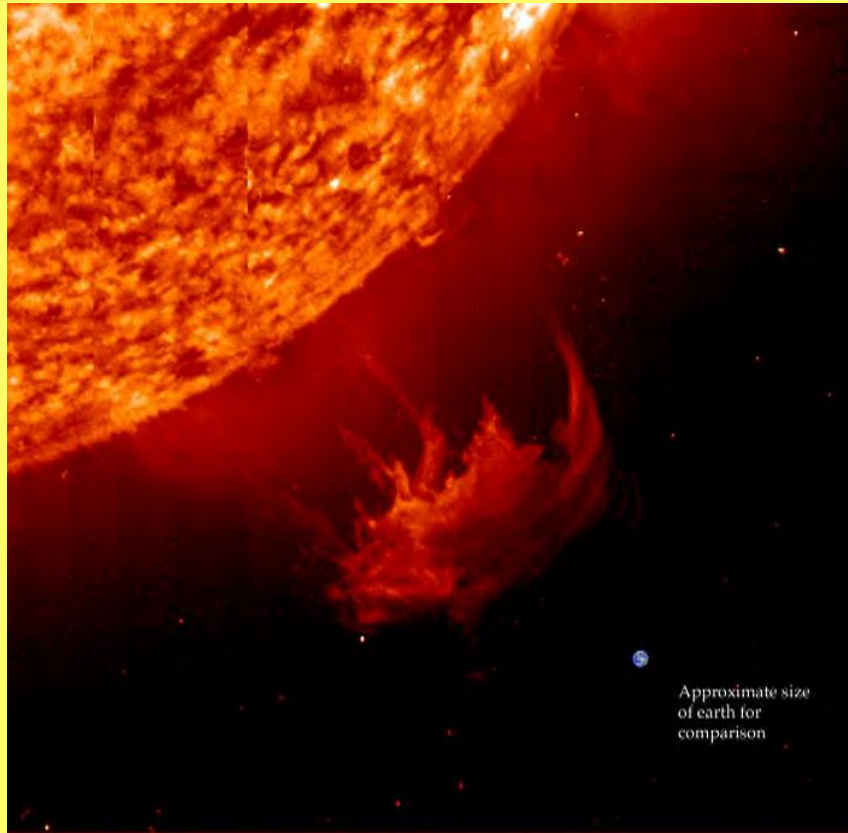


**Isotopi  
radioattivi di  
elementi  
naturalmente  
presenti nel  
corpo umano:  
 $^{14}\text{C}$ ,  $^{40}\text{K}$ ....**



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

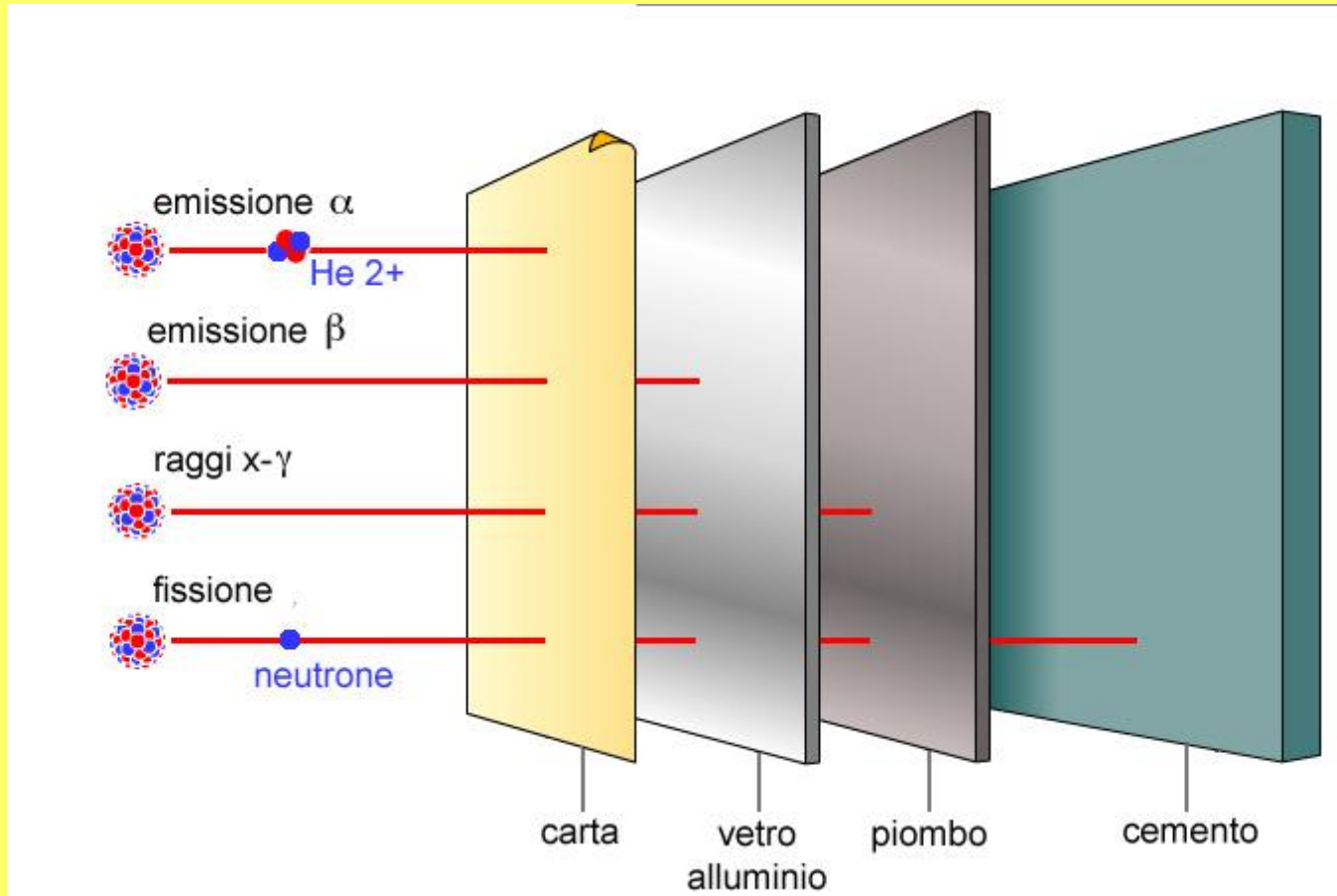
# **RADIOATTIVITÀ: FONTI NATURALI DI RADIAZIONE, RAGGI COSMICI**



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

SOHO – Solar and Heliospheric  
Observatory

# INTERAZIONE RADIAZIONE MATERIA: MATERIALI



# INTERAZIONE RADIAZIONE MATERIA: ORGANISMO

Cosa non  
succede ☹ ...



# INTERAZIONE RADIAZIONE MATERIA: ORGANISMO

## Effetti deterministici



11/05/2013

## Effetti Stocastici



Silvia Puddu

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# 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: ADVANCED RADIATION DETECTION EUROPEAN NETWORK TRAINING

Marie Curie initial training network under EU FP7 –  
4M€

- **7 full partners**

- CERN, Svizzera
- AIT, Austria
- Czech Technical University – IEAP, Repubblica Ceca
- Jablotron Alarms, Repubblica Ceca
- Politecnico di Milano, Italia
- MI.AM, Italia
- IBA Dosimetry, Germania

- **5 partners associati**

- ST Microelectronics, Italia
- Università di Erlangen, Germania
- Università di Huston, USA
- Univerità dell'Ontario, Canada
- Università di Wollongong, Australia



# ARDENT DOSIMETRIA

Qualche equazione...

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

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

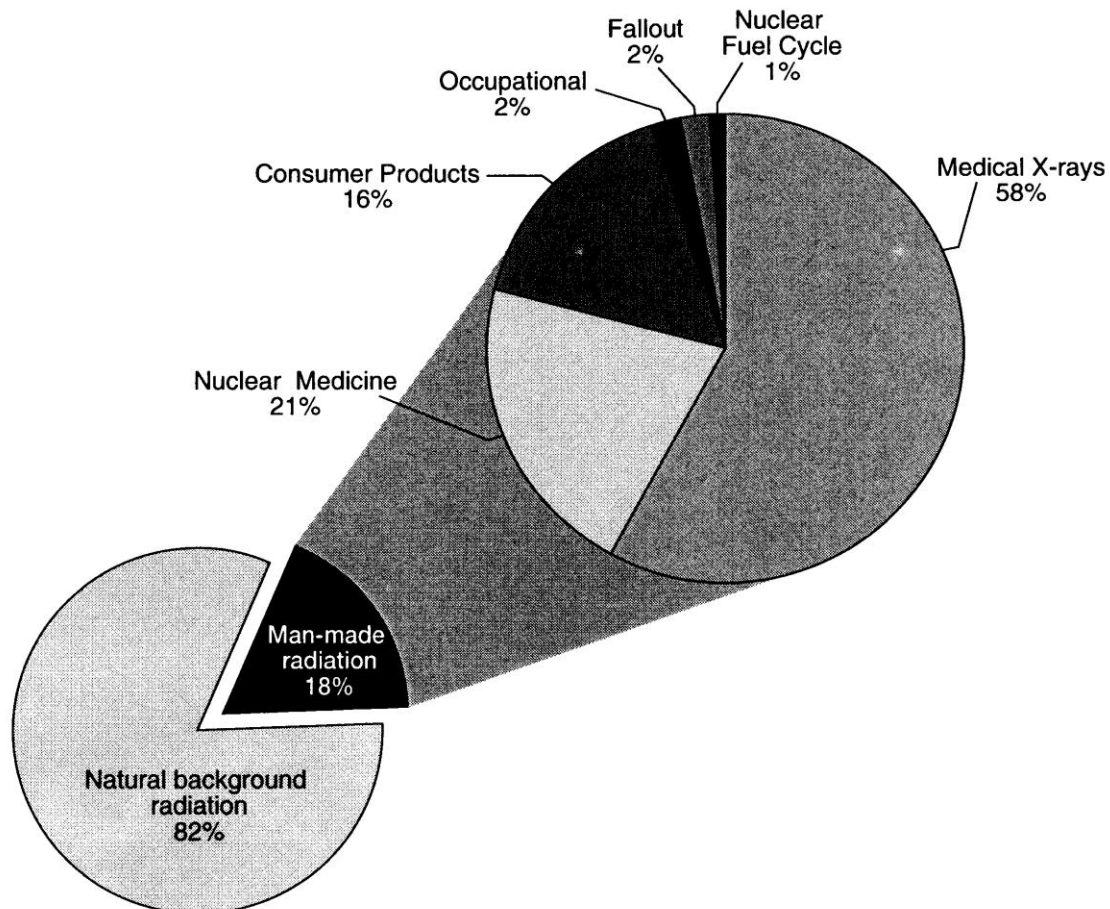
**Dose equivalente:** serve a stimare il danno provocato tenendo conto della differente pericolosità delle radiazioni

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

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**

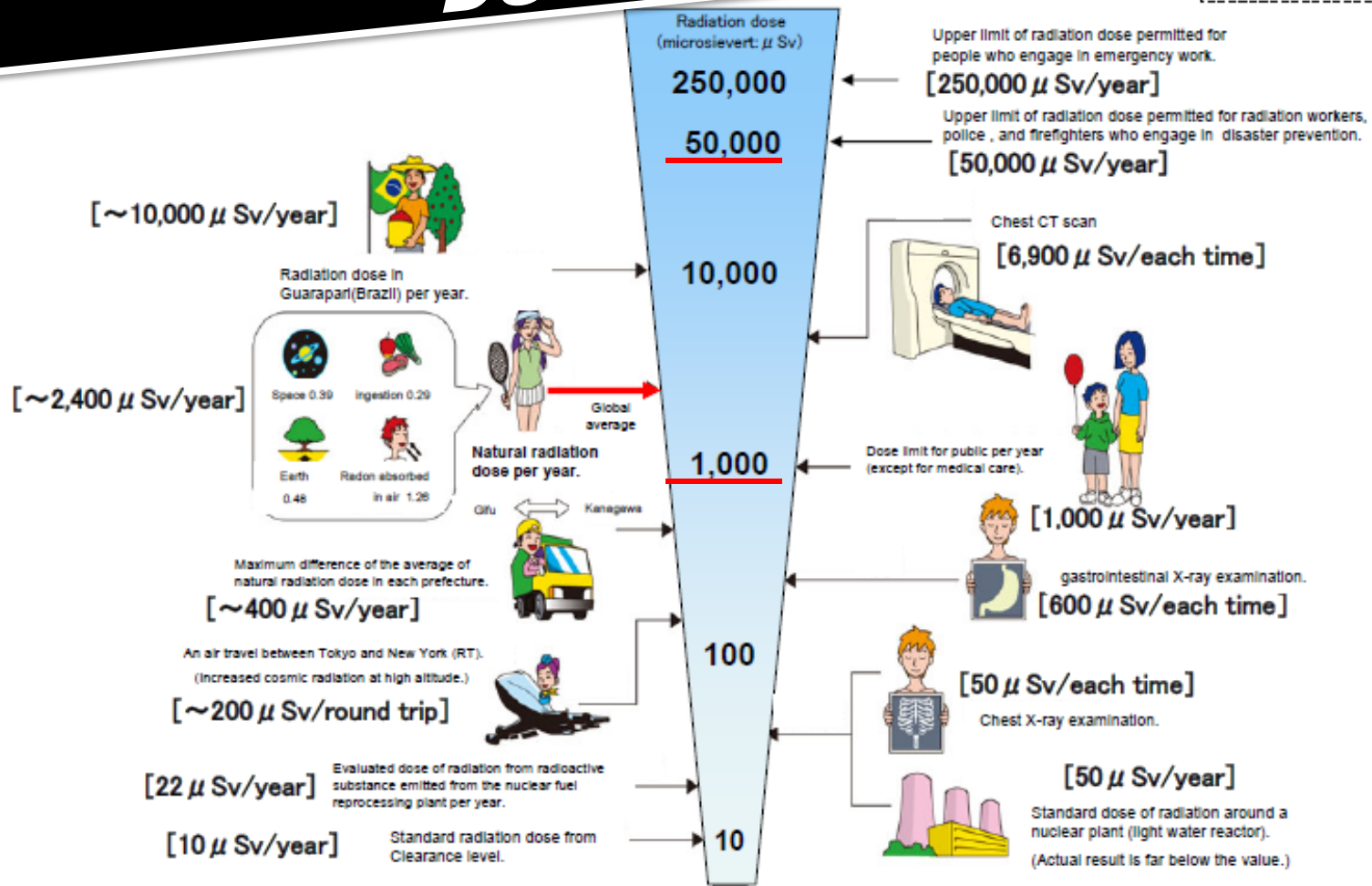
# ARDENT DOSIMETRIA

La radioattività naturale vs Attività umane:



# ARDENT DOSIMETRIA

※Unit :  $\mu\text{Sv}$

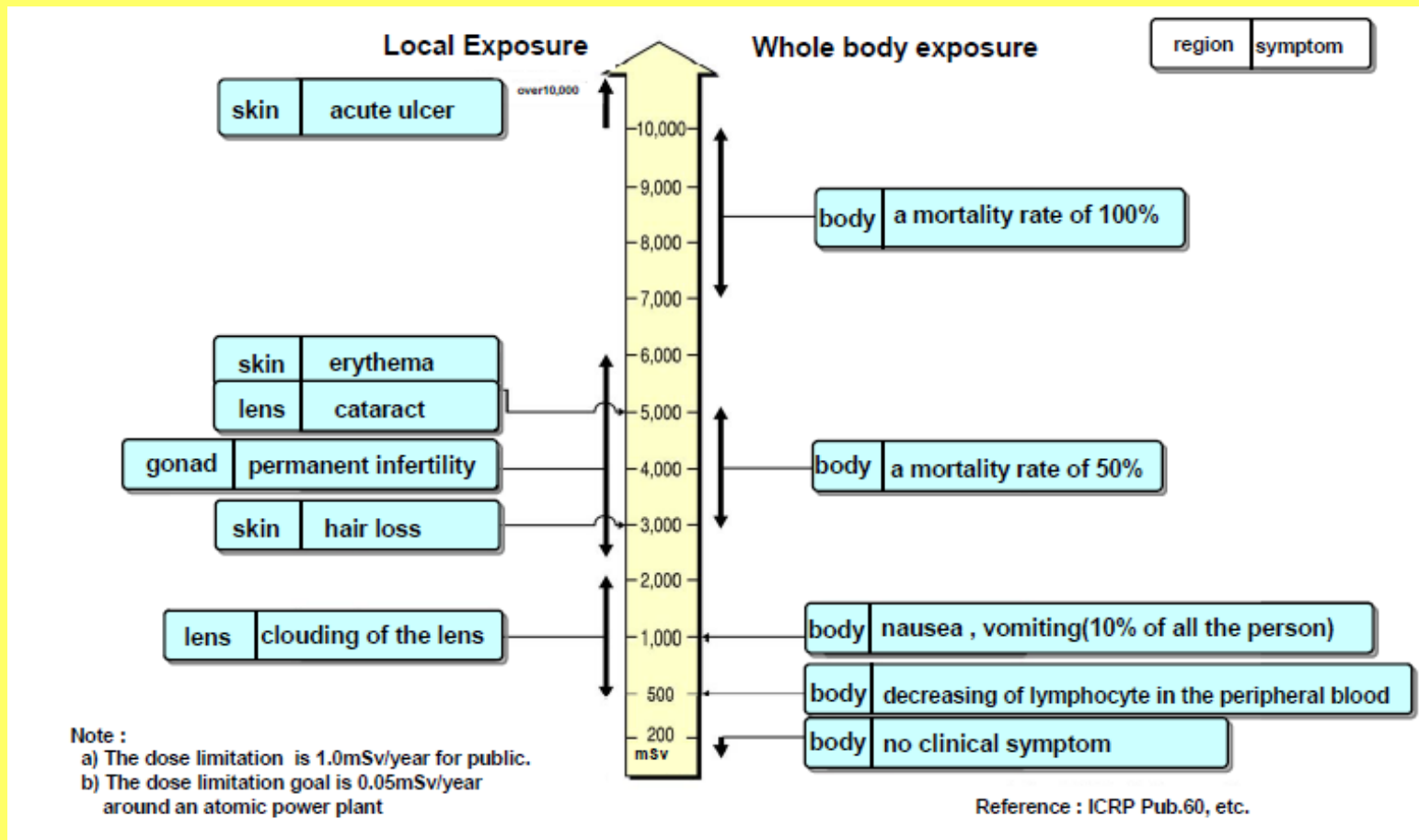


(Ref) Average dose rate at the monitoring post of Tokyo (9:00~17:00, 15, March) :  $0.144 \mu\text{Gy}/\text{h} = 1261 \mu\text{Gy}/\text{y}$

( $1\text{Gy} \doteq 1\text{Sv}$ )

# 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 DOSIMETRIA

La dose efficace annua media ricevuta dal personale di volo è  
circa **3 mSv**

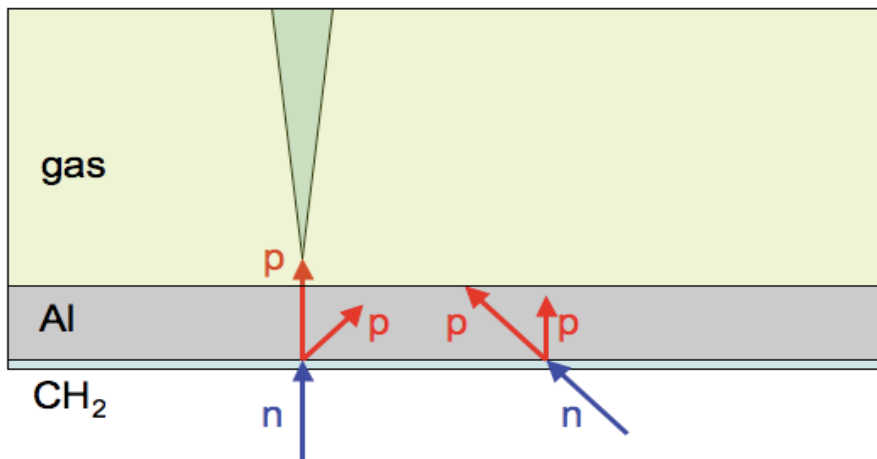


La dose totale ricevuta durante un volo A / R Milano - Los Angeles è di  
circa **100  $\mu$ Sv**. In buona parte è dovuta ai neutroni



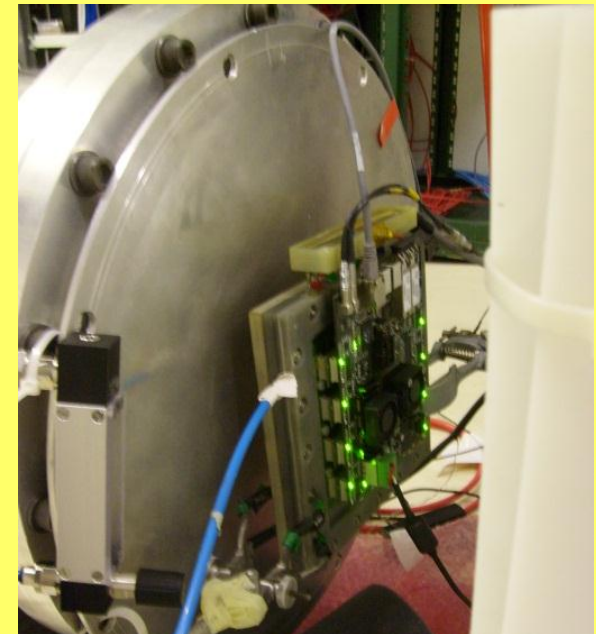
# ARDENT DOSIMETRIA-RIVELATORI

Per rivelare i neutroni bisogna prima **convertirli in radiazione carica** (protoni o alpha ad esempio). Fatto ciò, la radiazione carica può essere rivelata da una **zona attiva** del rivelatore (e.g. gas) e dirci quanti neutroni sono entrati nel rivelatore. Il convertitore che si utilizza dipende dall'energia del neutrone. Le **GEM** sono rivelatori a gas sviluppati al CERN (in particolare le triple sono state fatte tra INFN Frascati e INFN Cagliari), di cui, col progetto ARDENT, si stanno studiando le applicazioni in dosimetria.



11/05/2013

Silvia Puddu



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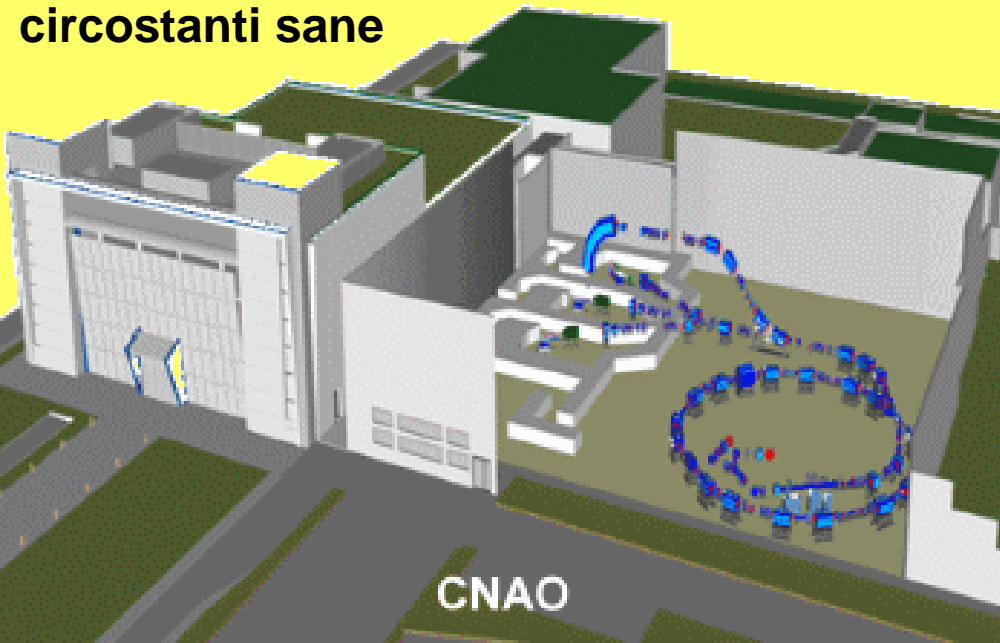
# ARDENT ADROTERAPIA

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.

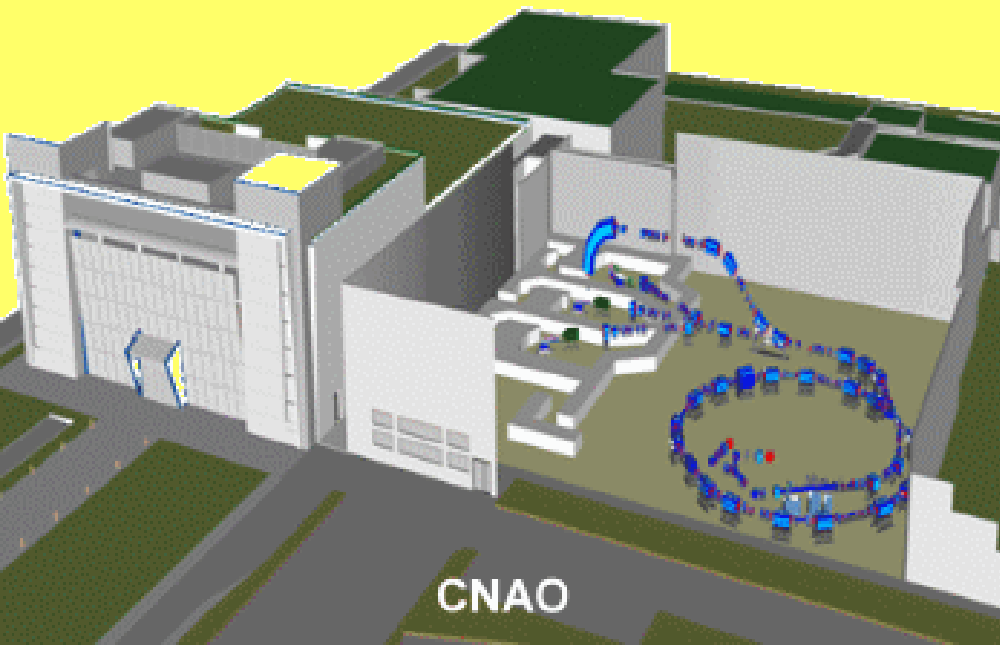
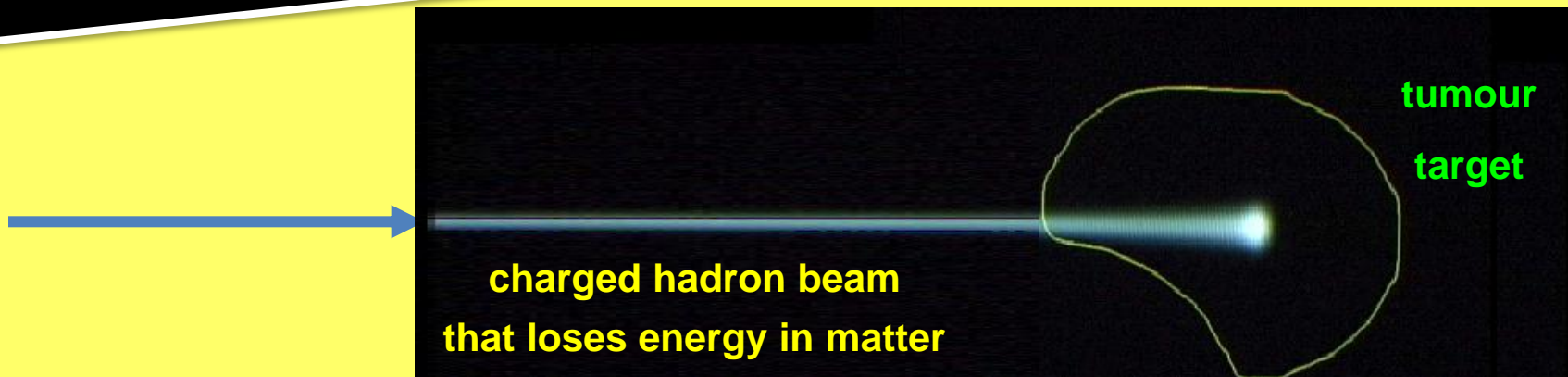
La radiazione viene assorbita soprattutto dal tumore, riducendo il danno alle zone circostanti sane



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 35-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.

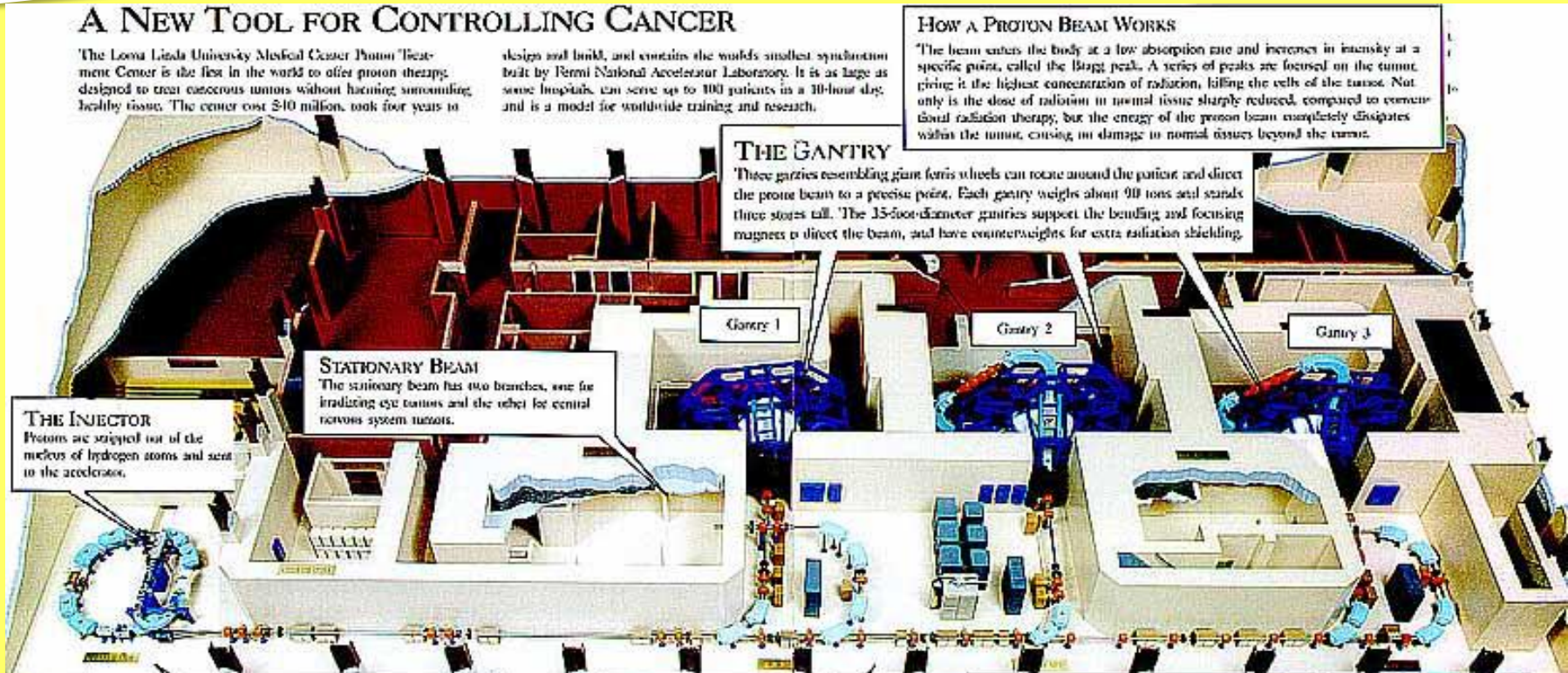
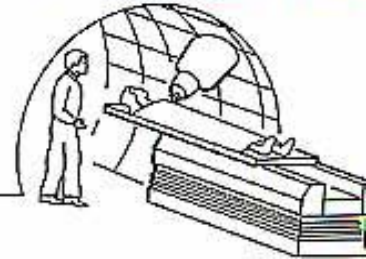
### BEAM TRANSPORT SYSTEM

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.

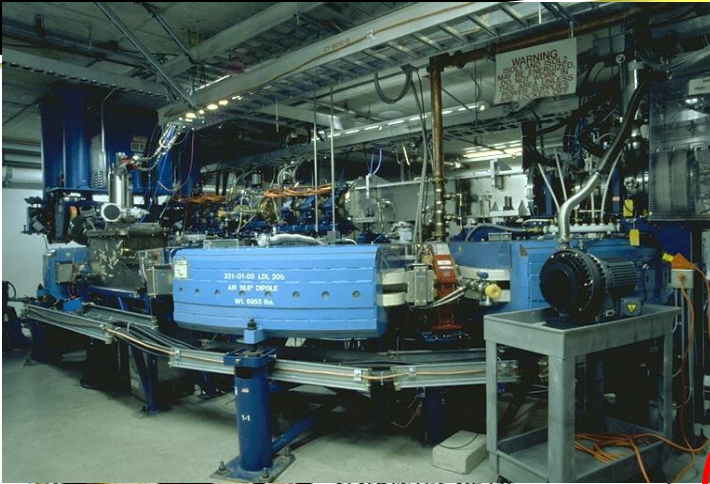
### WHAT THE PATIENT SEES

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.

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



# ARDENT ADROTERAPIA



## CANCER

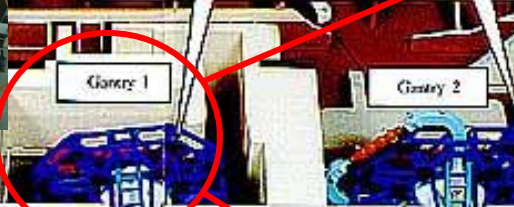
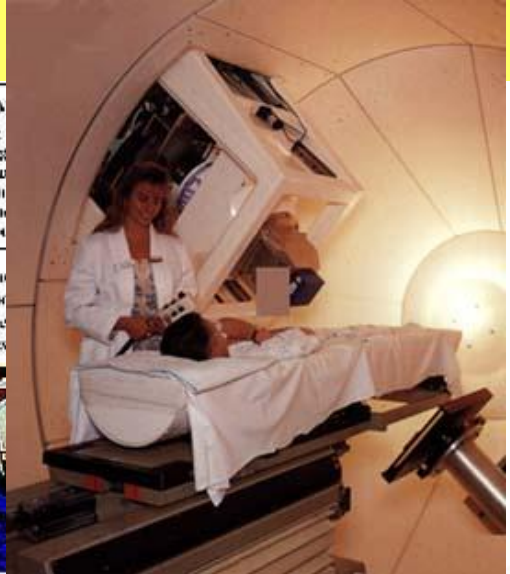
It contains the world's smallest synchrotron accelerator Laboratory. It is as large as up to 100 patients in a 10-hour day, for training and research.

## HOW A PROTON BEAM

The beam enters the body at a specific point, called the Bragg peak, giving it the highest concentration. It is only the dose of radiation that is used for radiation therapy, but the rest of the beam is absorbed within the tumor, causing no damage.

## 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.

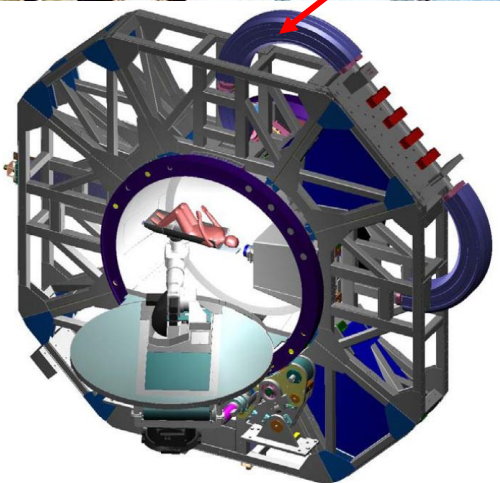


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## THE INJECTOR

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## SYNCHRO

The synchrotron is 20 feet in diameter and is located in a vault. The ring is 1.5 miles long and reaches a speed of light while proton ring. The system uses energy from a quarter section of a million electrons.

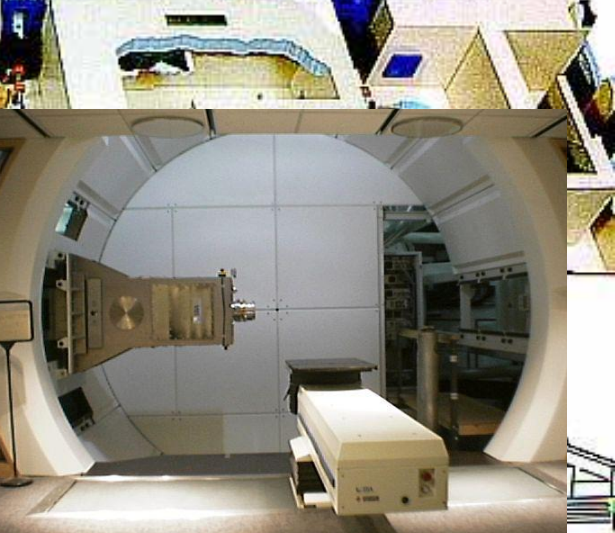
Steel-reinforced concrete walls are up to 13 feet thick.  
1/05/2018

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

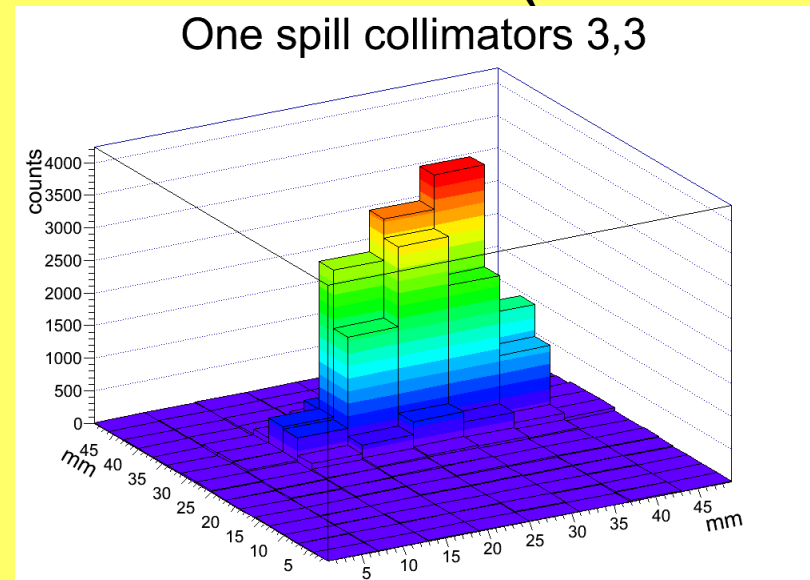


# ARDENT ADROTERAPIA - DETECTORS

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 )

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



**GRAZIE A...**



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

- Il Liceo Scientifico L.B. Alberti e l'istituto Tecnico e Liceo Scientifico delle Scienze Applicate M. Giua, per aver ospitato i seminari
- La Professoressa Fois e mio padre (Prof. Puddu) per l'organizzazione a Cagliari
- 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