

UNA RAPIDA GUIDA



2013
EDITION

ARDENT

FOR

DUMMIES

**ADVANCED
RADIATION
DOSIMETRY
EUROPEAN
NETWORK
TRAINING**

**FISICA E
RICERCA SULLE
RADIAZIONI**



di: Silvia Puddu

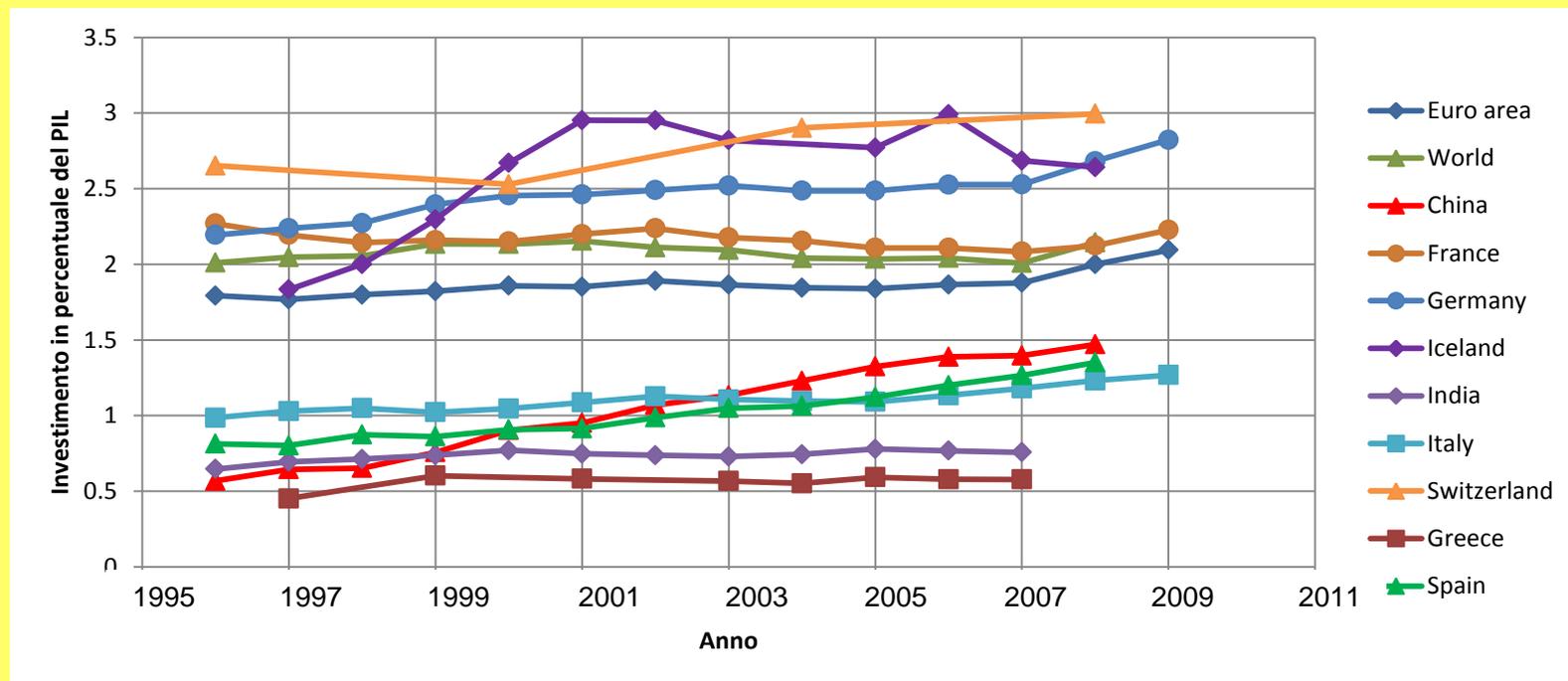
email: silvia.puddu@cern.ch

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/>

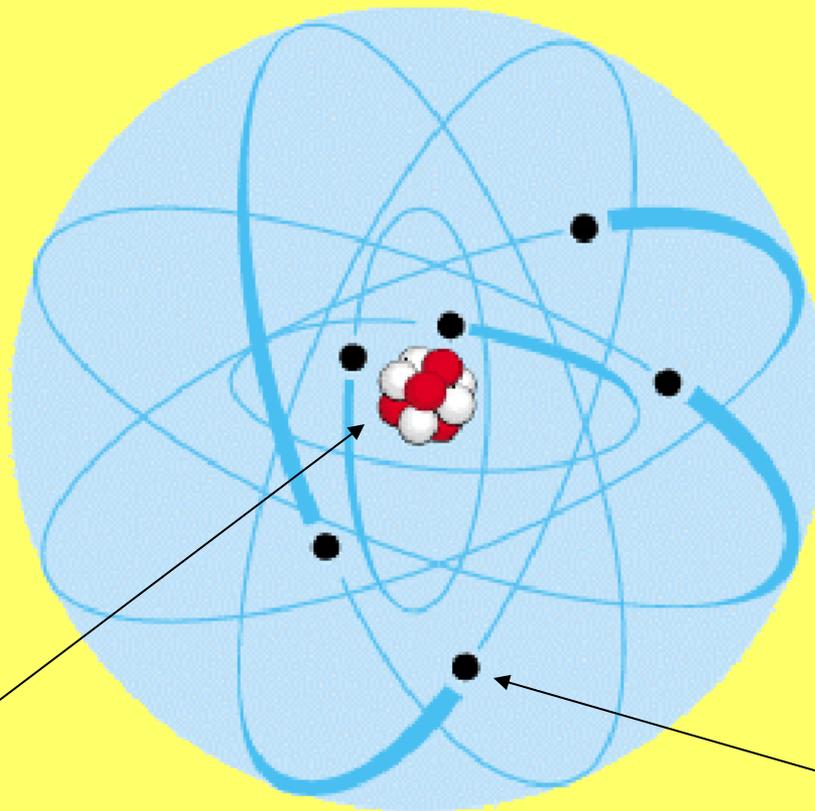
PERCHÉ FARE RICERCA?

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 ←

C

CARBON ←

12 ←

Atomic Number = Number of Protons = Number of Electrons

Chemical Symbol

Chemical Name

Atomic Weight = Number of Protons + Number of Neutrons*

NON-METALS										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 YTIPIUM 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																			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																			104 Rf RUFORMIUM 267	105 Db DUBNIUM 268	106 Sg SEABORGIUM 271	107 Bh BOHRIUM 272	108 Hs HASSIUM 277	109 Mt MEITNERIUM 276	110 Ds DARMSTADTIUM 281	111 Rg ROSKOPFIUM 280	112 Uub UNUNBIUM 285	113 Uut UNUNTRIUM 284	114 Uuq UNUNQUADRIUM 289	115 Uup UNUNPENTIUM 288	116 Uuh UNUNHEXTIUM 291	117 Uus UNUNSEPTIUM 286	118 Uuo UNUNOCTIUM 294																		
																		57 La LANTANIUM 139	58 Ce CELEMIUM 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 YTERBIUM 173	71 Lu LUTETIUM 175																				
																		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/>

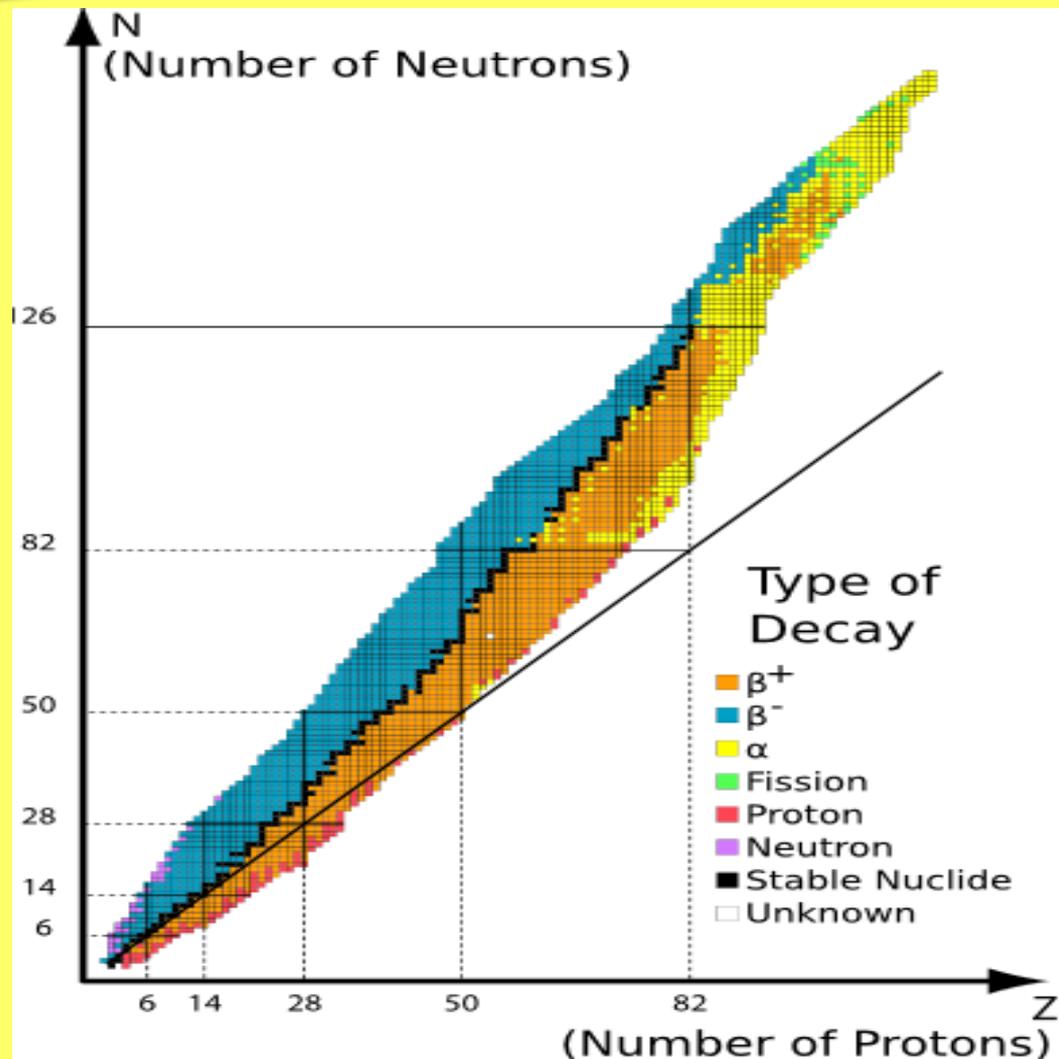
Last revised on March 21, 2008

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**

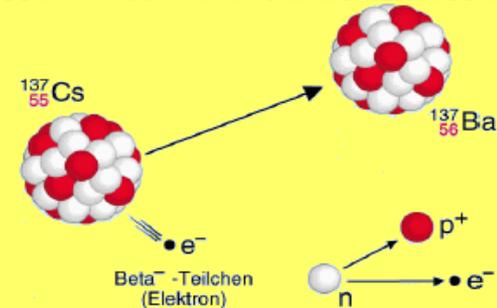


RADIOATTIVITÀ: I TIPI DI RADIAZIONE

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

- **Carica:**

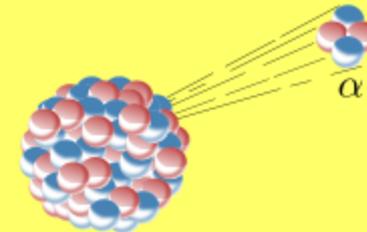
- **Particelle leggere (e.g. e-)**
 - ✓ Percorso nella materia limitato
 - ✓ Facilmente schermabili



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
 - **Nuclei e particelle α**
 - ✓ Pesanti e molto cariche ($n \times e^-$)
 - ✓ Percorso nella materia limitato
 - ✓ Facilmente schermabili



RADIOATTIVITÀ: I TIPI DI RADIAZIONE

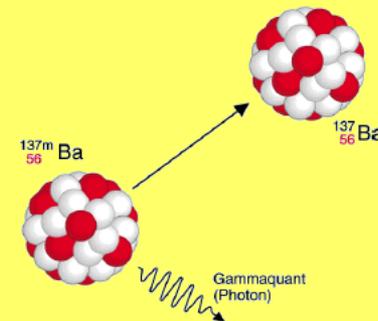
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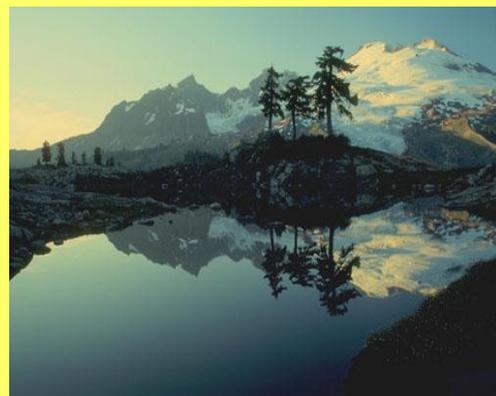
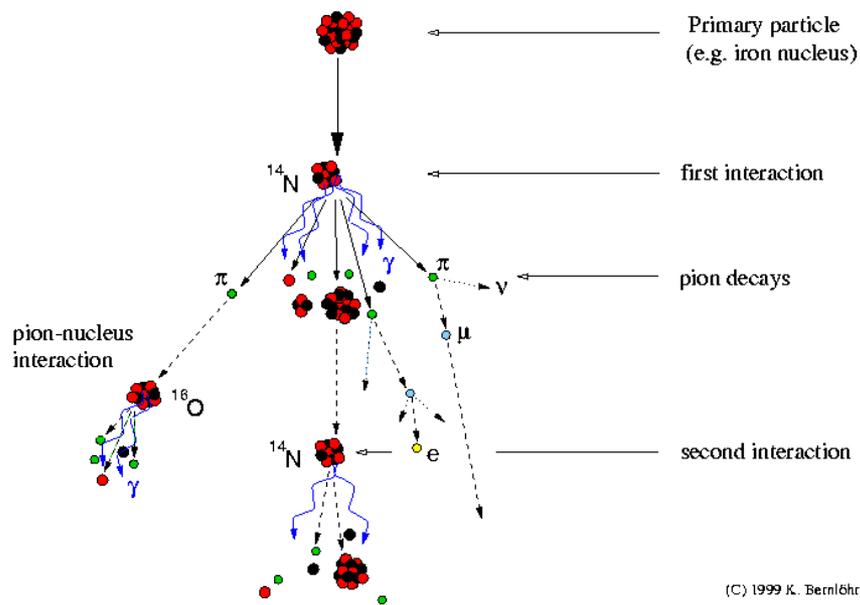
- **Neutra:**

- **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}C , ^{40}K**



**Raggi Cosmici:
 ^{14}C , ^3H , ^7B , μ , π ,
 ρ , n ...**

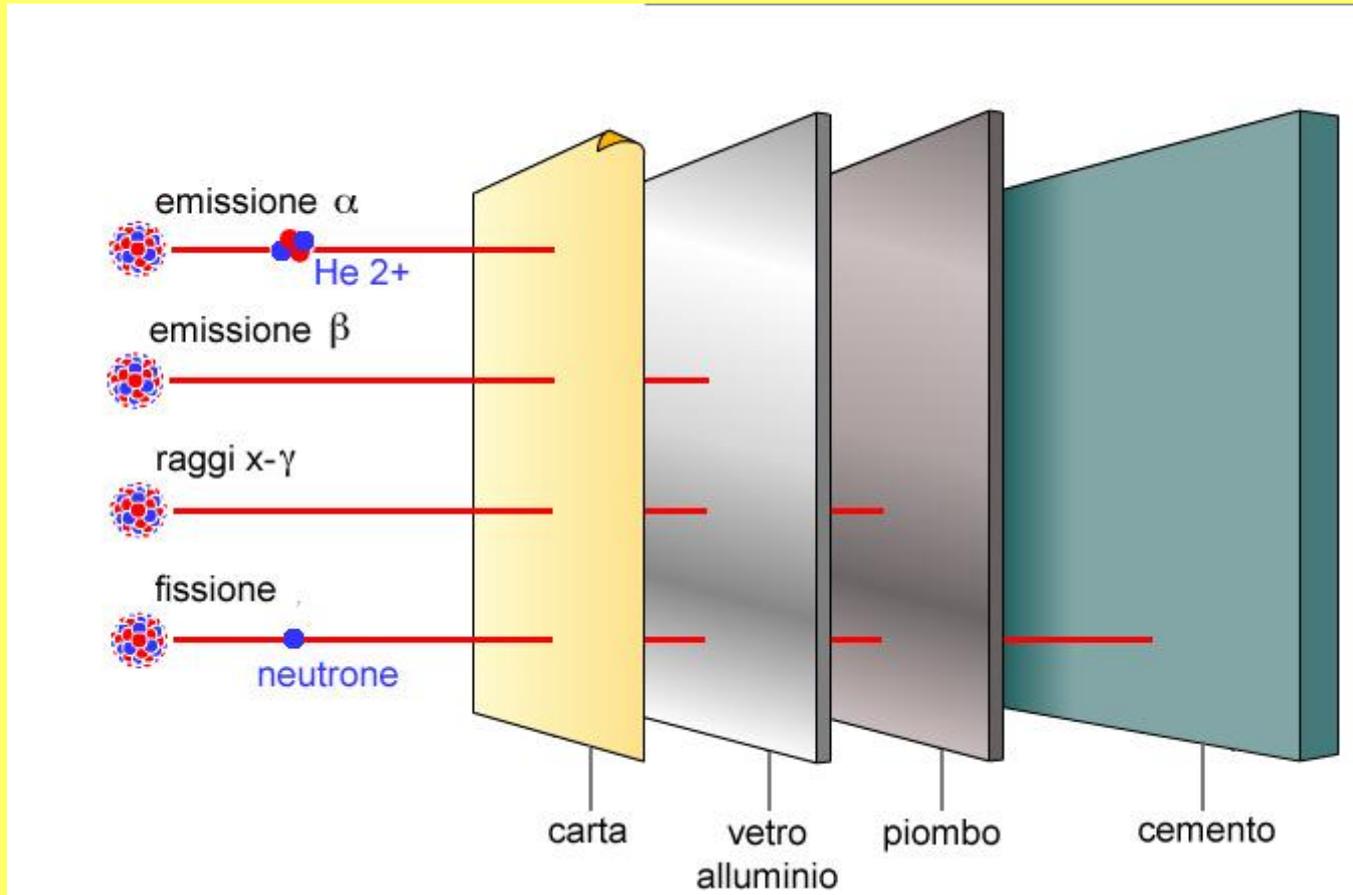
RADIOATTIVITÀ: FONTI NATURALI DI RADIAZIONE, RAGGI COSMICI



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

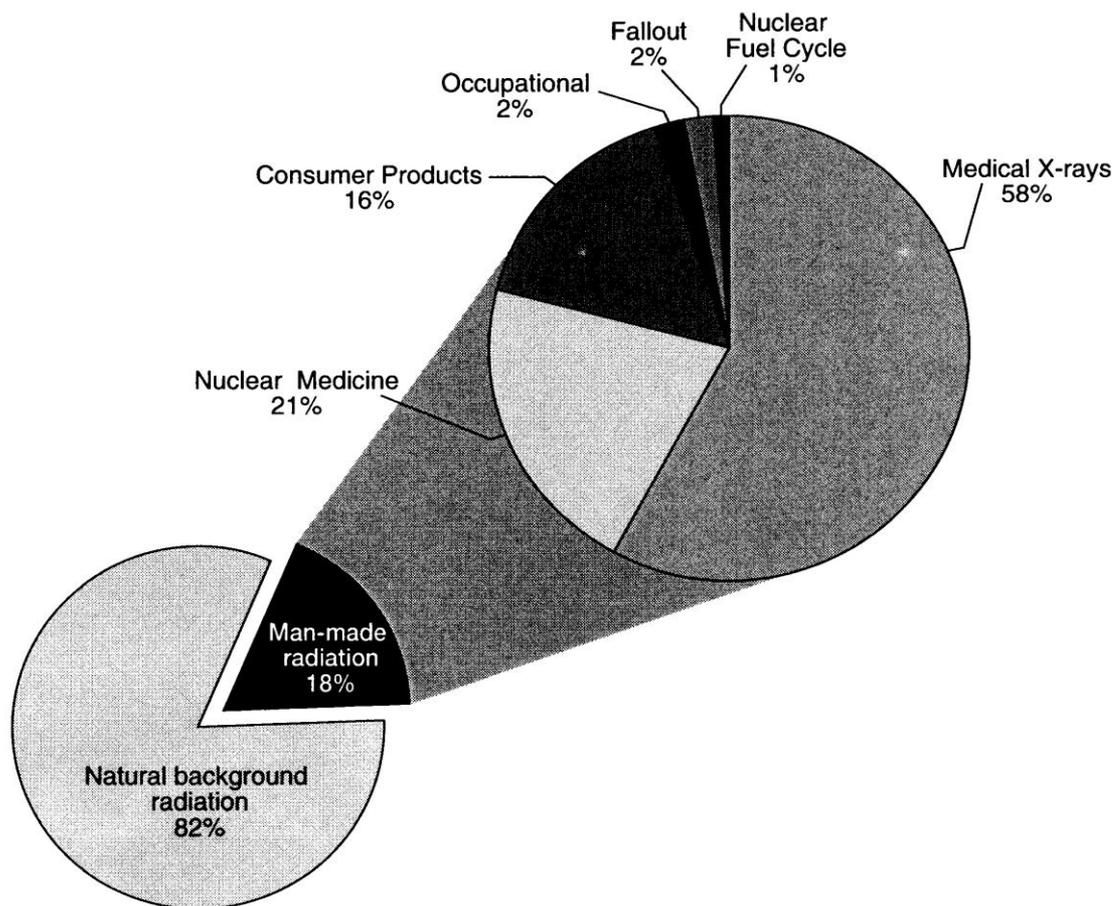
$$H = \sum_R w_R D_R \rightarrow 1Sv = 1J/kg$$

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**

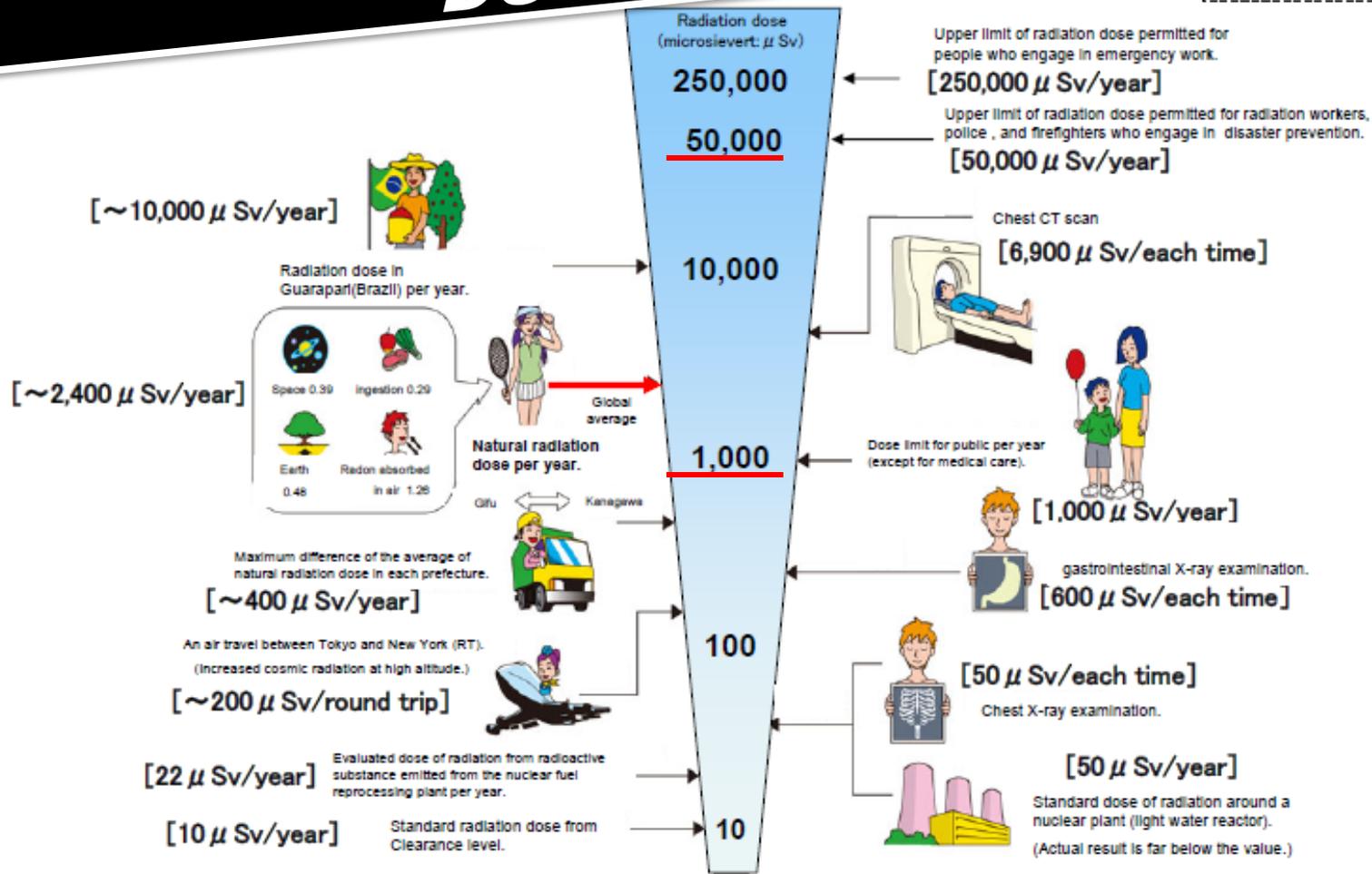
ARDENT DOSIMETRIA

La radioattività naturale vs Attività umane:



ARDENT DOSIMETRIA

※Unit : μSv

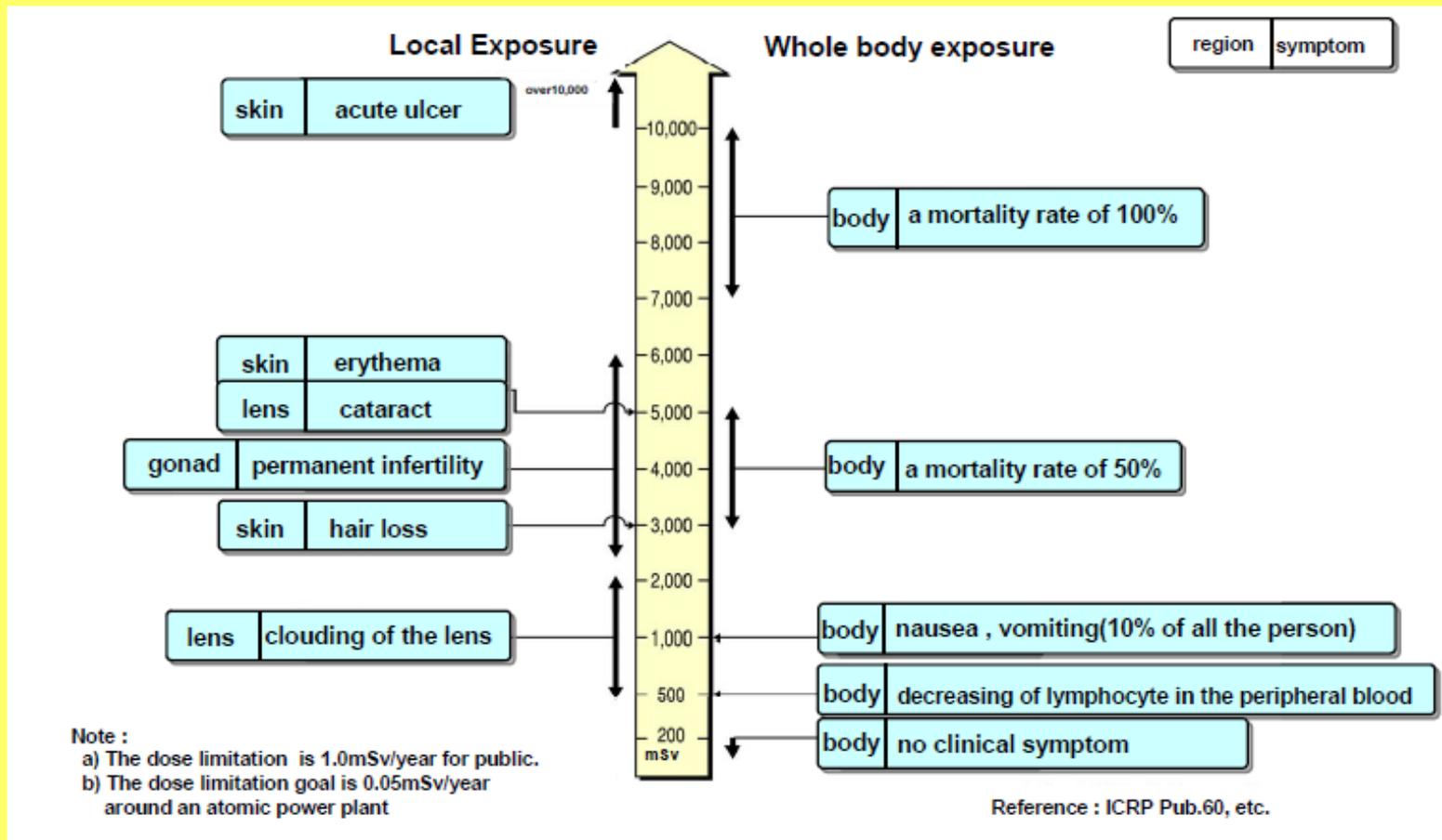


(Ref) Average dose rate at the monitoring post of Tokyo (9:00~17:00, 15, March) : $0.144 \mu\text{Gy/h} = 1261 \mu\text{Gy/y}$

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

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

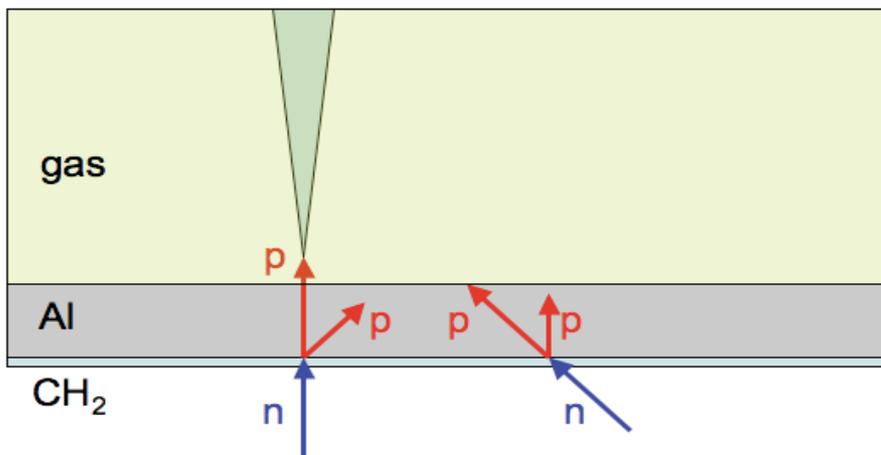
La dose efficace annua media ricevuta dal personale di volo è
circa **3 mSv**



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

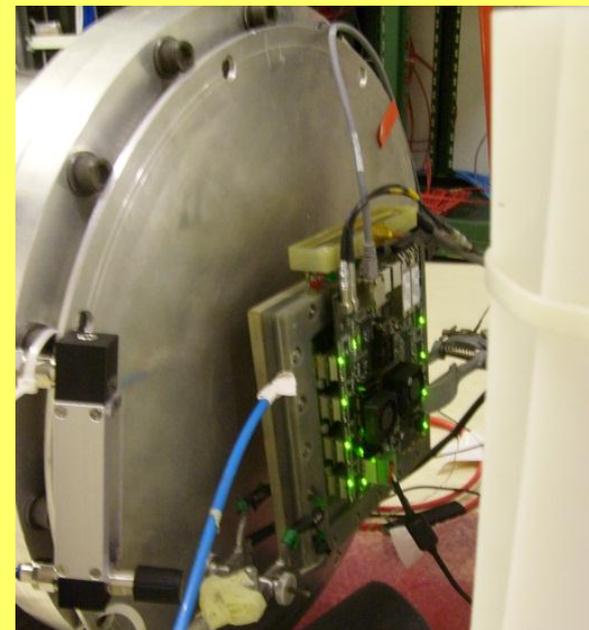
ARDENT DOSIMETRIA-RIVELATORI

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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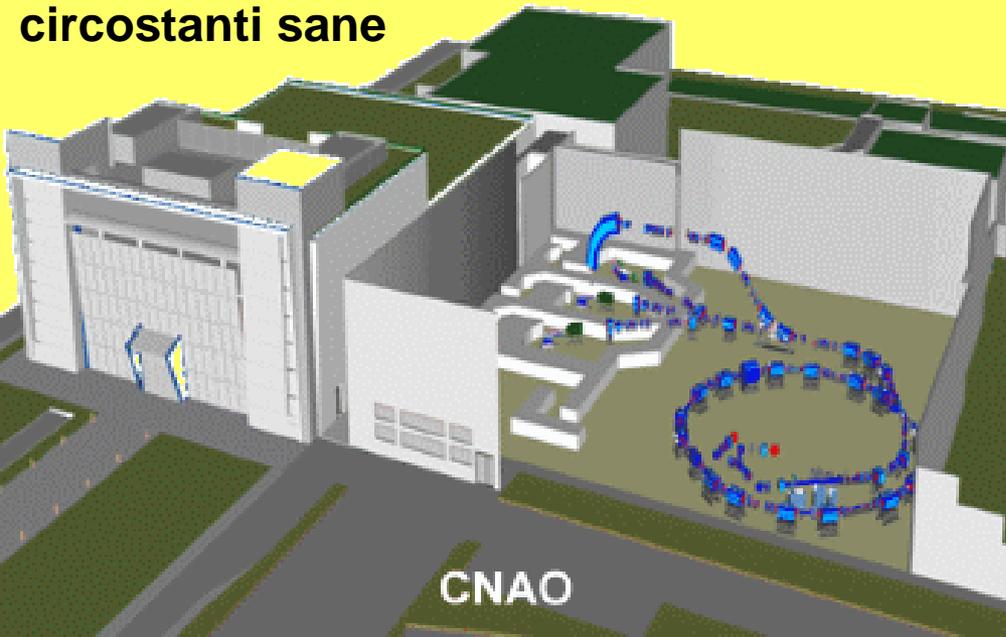
ARDENT ADROTERAPIA

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 riesce a trattare **localmente** i tumori.

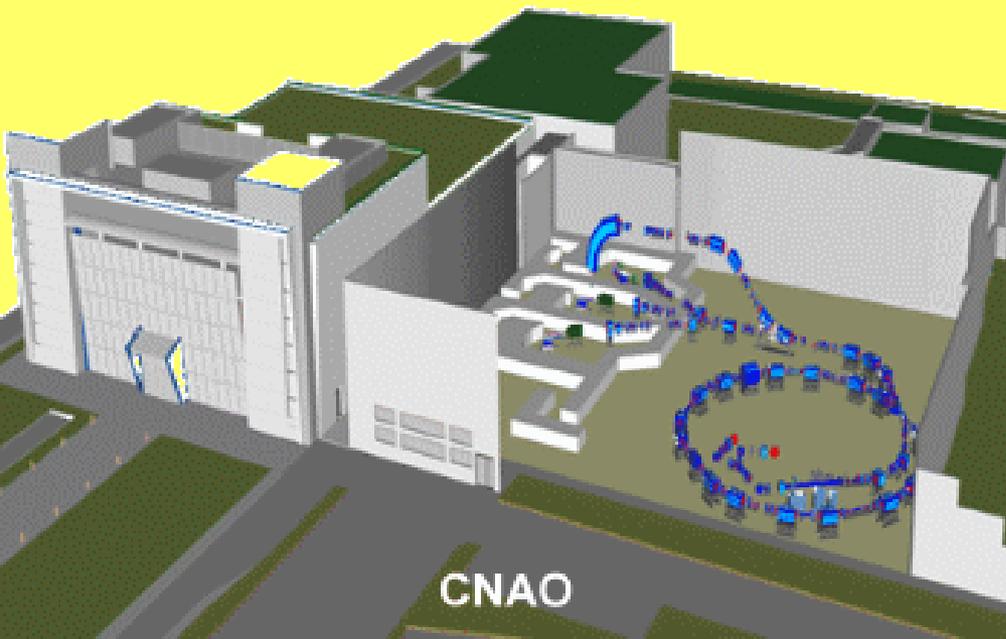
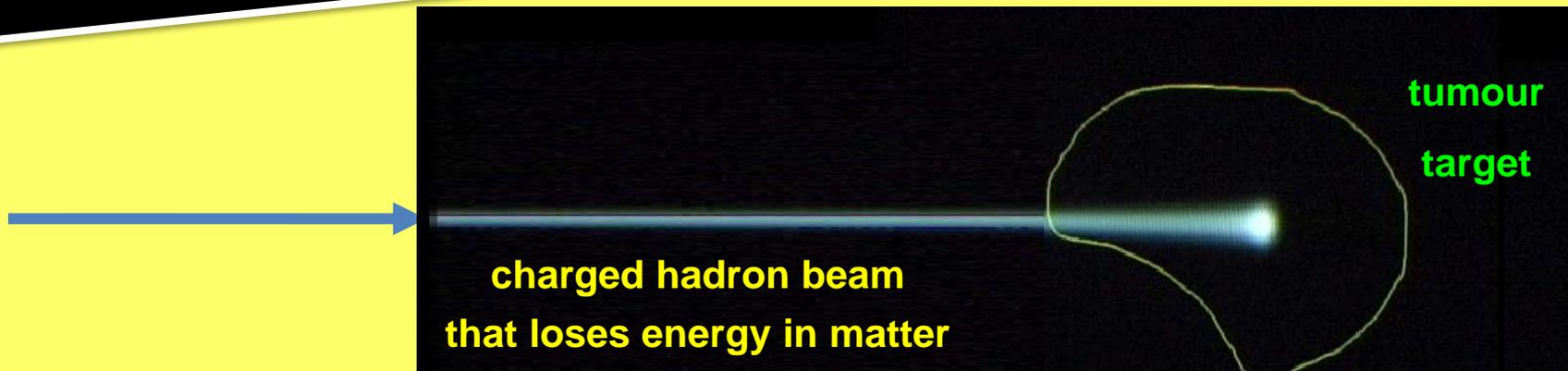
La radiazione viene assorbita soprattutto dal tumore, riducendo il danno alle zone circostanti sane



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.

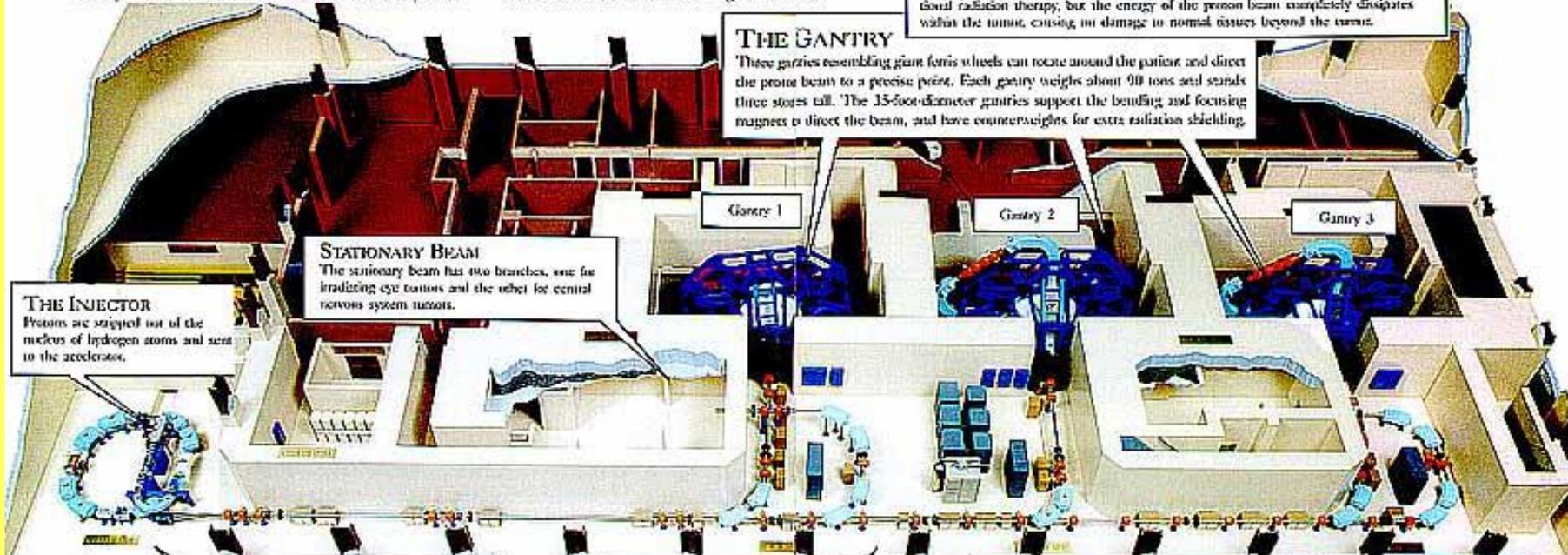
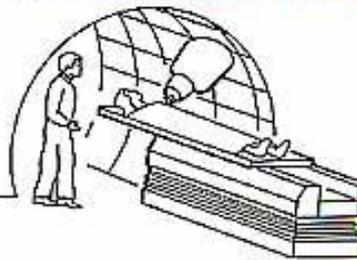
BEAM TRANSPORT SYSTEM

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.

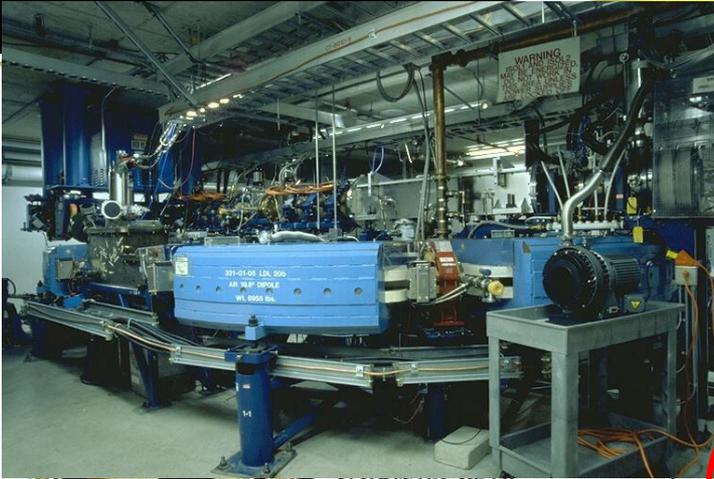
WHAT THE PATIENT SEES

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

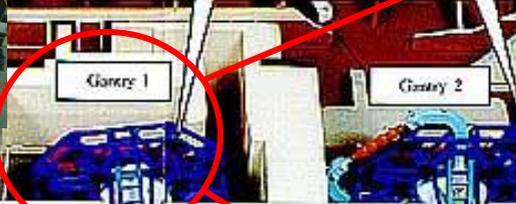
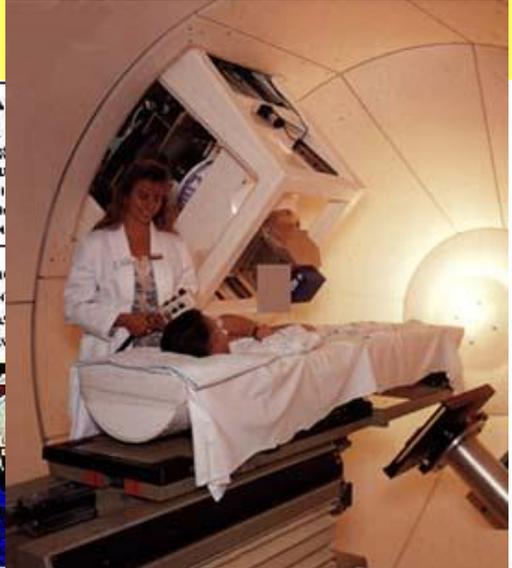
It contains the world's smallest synchrotron accelerator Laboratory. It is as large as up to 100 patients in a 10-hour day. It is used for training and research.

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



STATIONARY BEAM

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

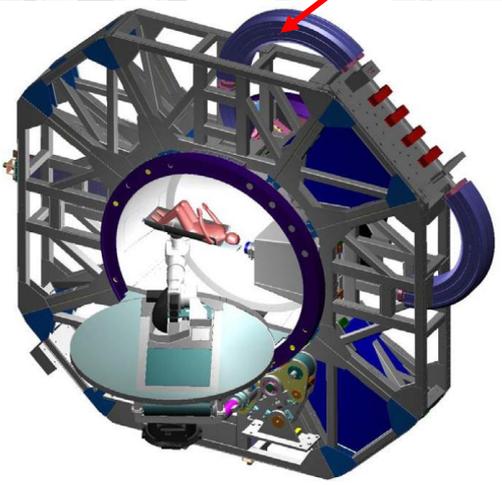
THE INJECTOR

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



SYNCHRO

The synchrotron is 20 feet in diameter and is located in a vault. The ring is 1.5 miles long. It is a 3 field reaches scattered beam while proton ring. The system uses energy quarter second million electron

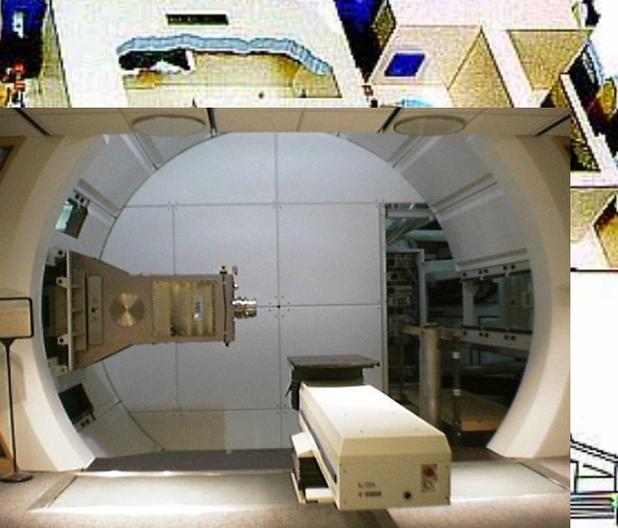


TRANSPORT SYSTEM

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 magnets are located at many points. Variations from the design are made to adjust the magnets which automatically

WELLS

The patient is placed in a chair. After the patient is positioned, the patient will be treated. The patient is then moved to the other procedure.



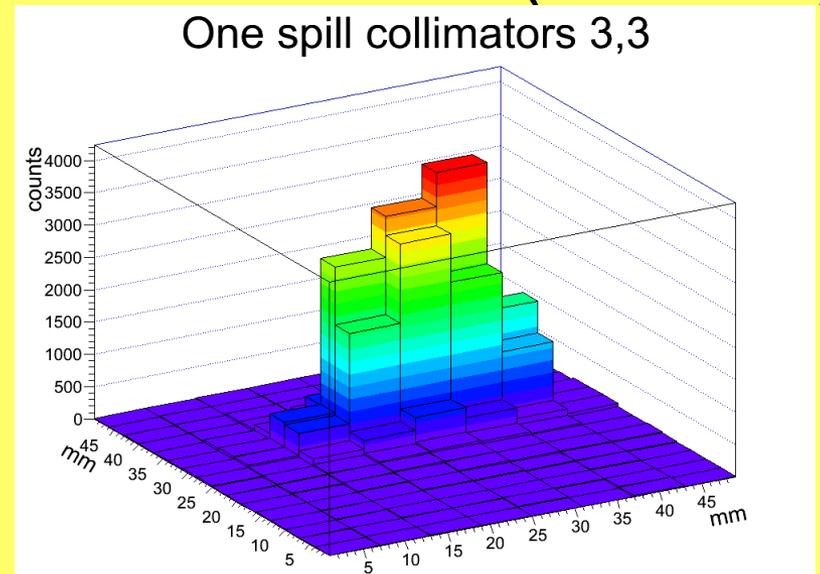
Steel-reinforced concrete walls are up to 13 feet thick.
1/05/2018

ARDENT ADROTERAPIA - DETECTORS

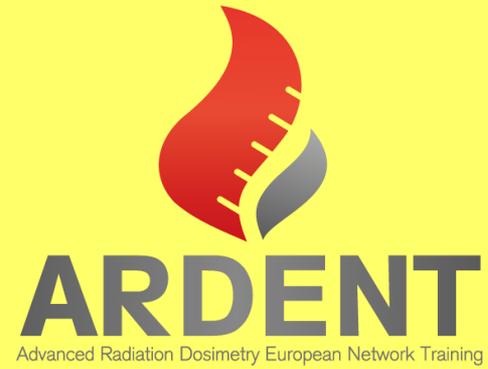
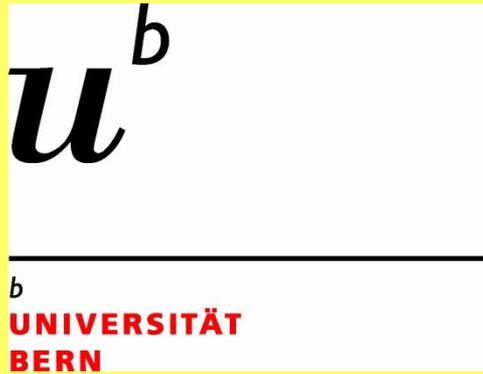
In questo caso le particelle sono **protoni** o **ioni pesanti** (^{12}C) quindi **cariche**.
Il detector per il monitoraggio del fascio deve essere:

- 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