

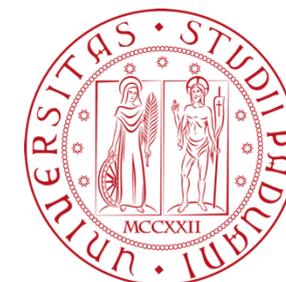
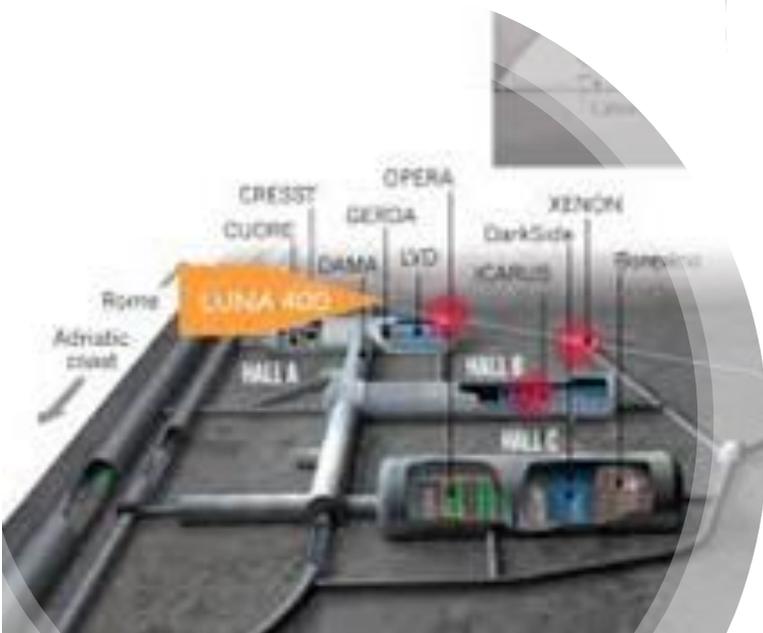


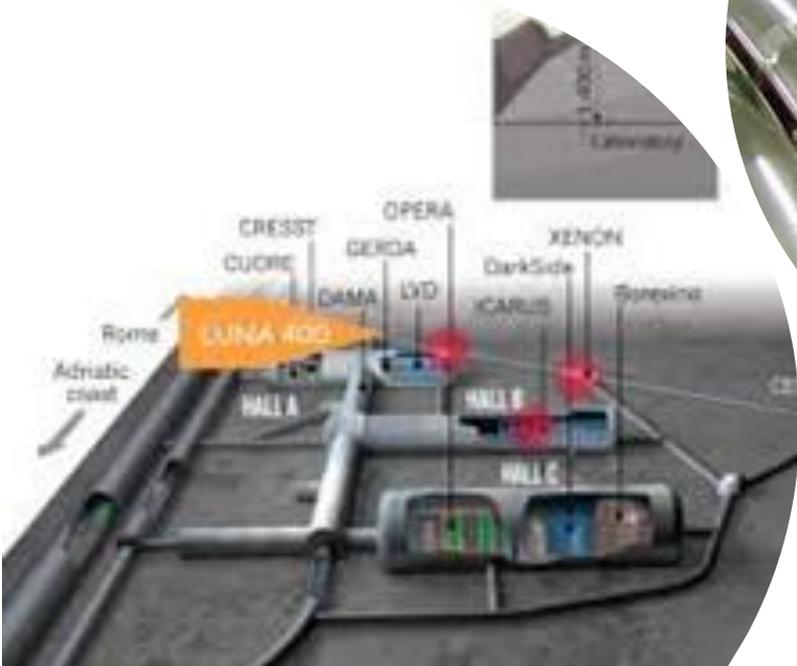
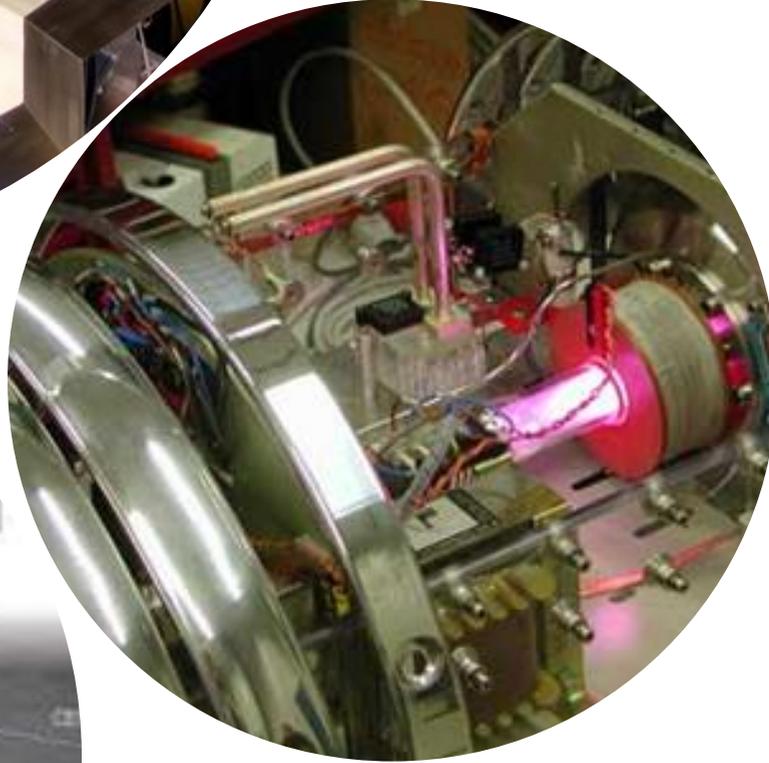
# Introduzione alla Fisica Nucleare



**Antonio Cacioli**

- Dipartimento di Fisica e Astronomia
- INFN Sezione di Padova





# Il Progetto RADIOLAB?

**Antonio Cacioli**

- Dipartimento di Fisica e Astronomia
- INFN Sezione di Padova

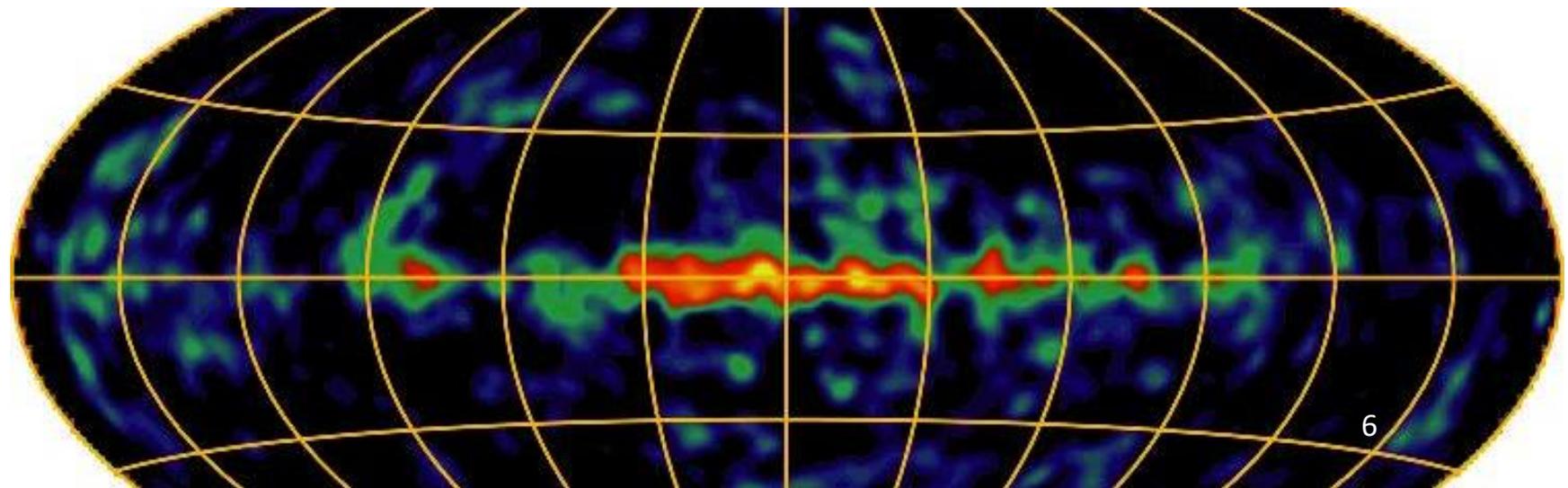


Cos'è la RADIOATTIVITÀ











the air we breath

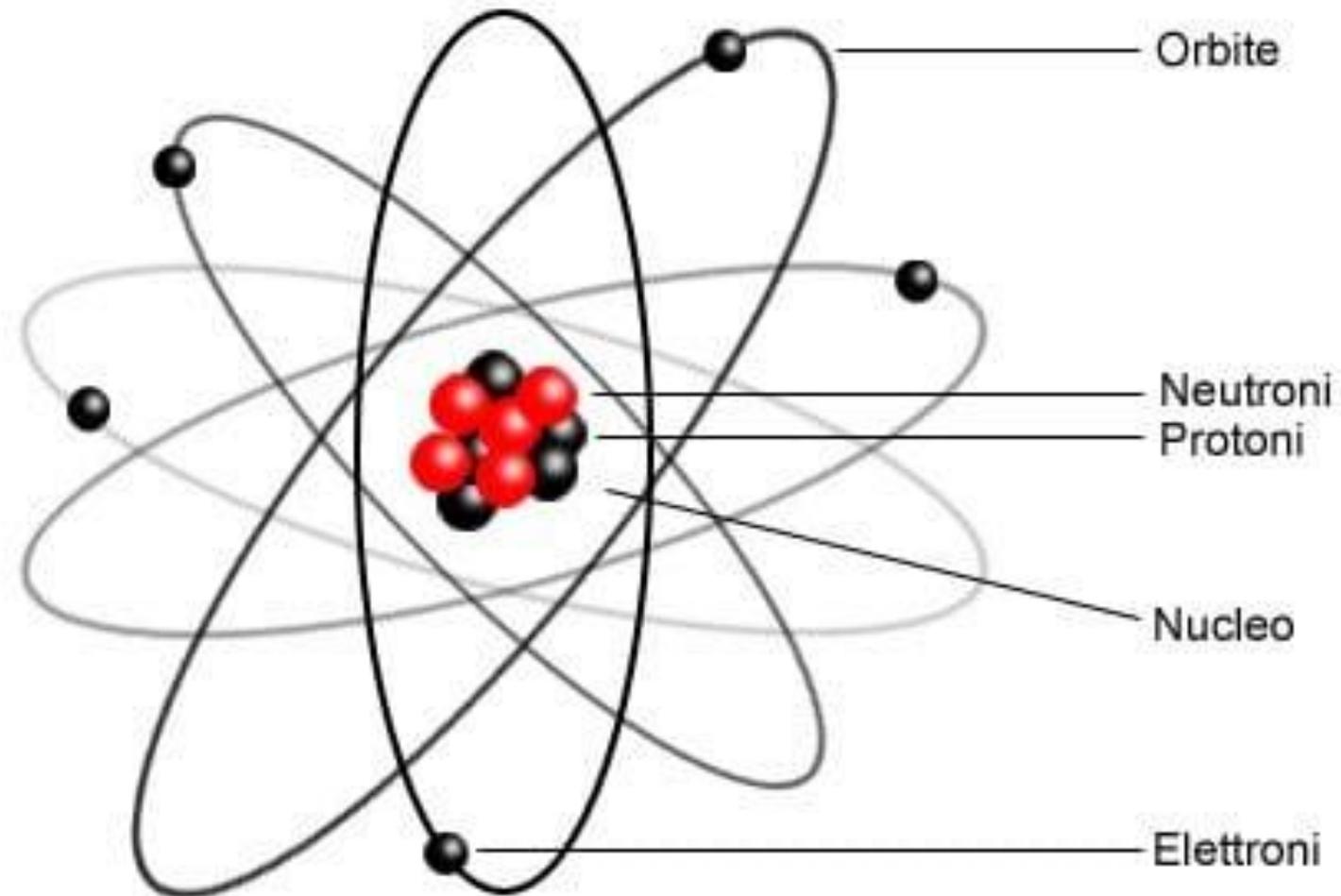
from plants

from rocks and soil

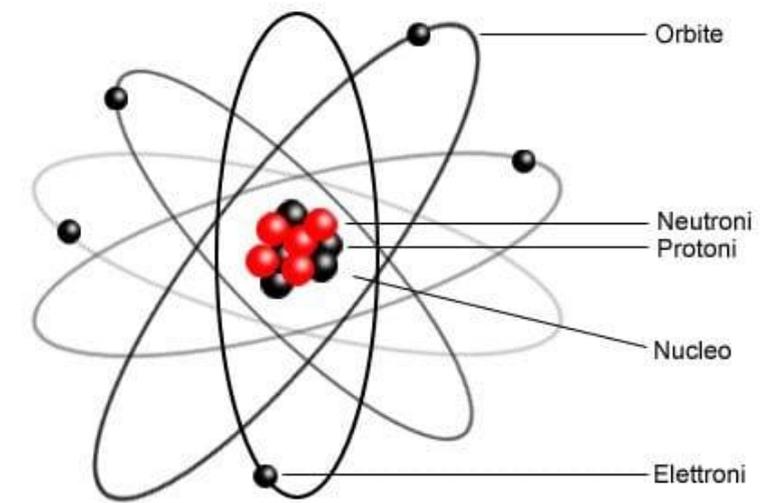
from water

Radiazioni ionizzanti sono costantemente intorno a noi

# Come è fatto un atomo?



# Come è fatto un atomo?

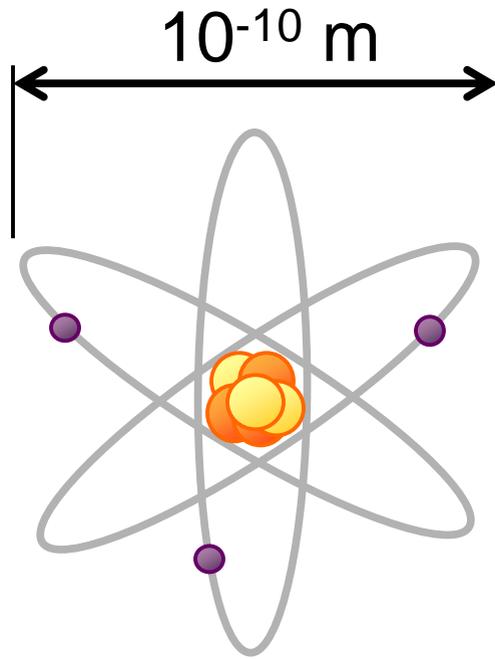


Particella	Simbolo	Carica (C)	Massa (kg)
<b>Elettrone</b>	$e^-$	$-1,6 \times 10^{-19}$	$9,1 \times 10^{-31}$
<b>Protone</b>	$p$	$+1,6 \times 10^{-19}$	$1,672 \times 10^{-27}$
<b>Neutrone</b>	$n$	<b>0</b>	$1,675 \times 10^{-27}$

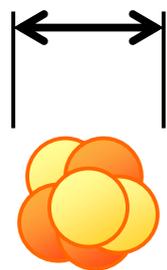
$$9.1 \times 10^{-31} = \frac{9.1}{10.000.000.000.000.000.000.000.000.000.000}$$

La massa di un protone è circa **1800** volte più grande della massa di un elettrone!

# Qualche numero: dimensioni



$10^{-15}$  m ~ 1 fm



# Qualche numero: densità

Aria

1.29 kg/m<sup>3</sup>



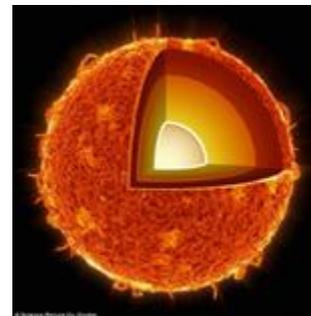
Acqua

1000 kg/m<sup>3</sup>



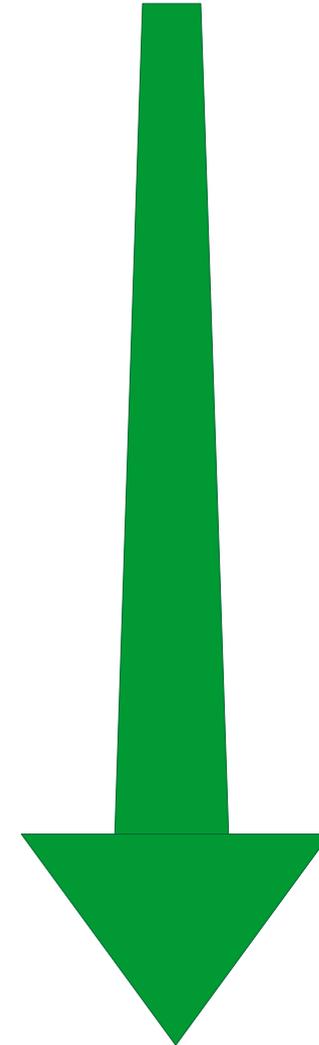
Centro del sole

10<sup>5</sup> kg/m<sup>3</sup>

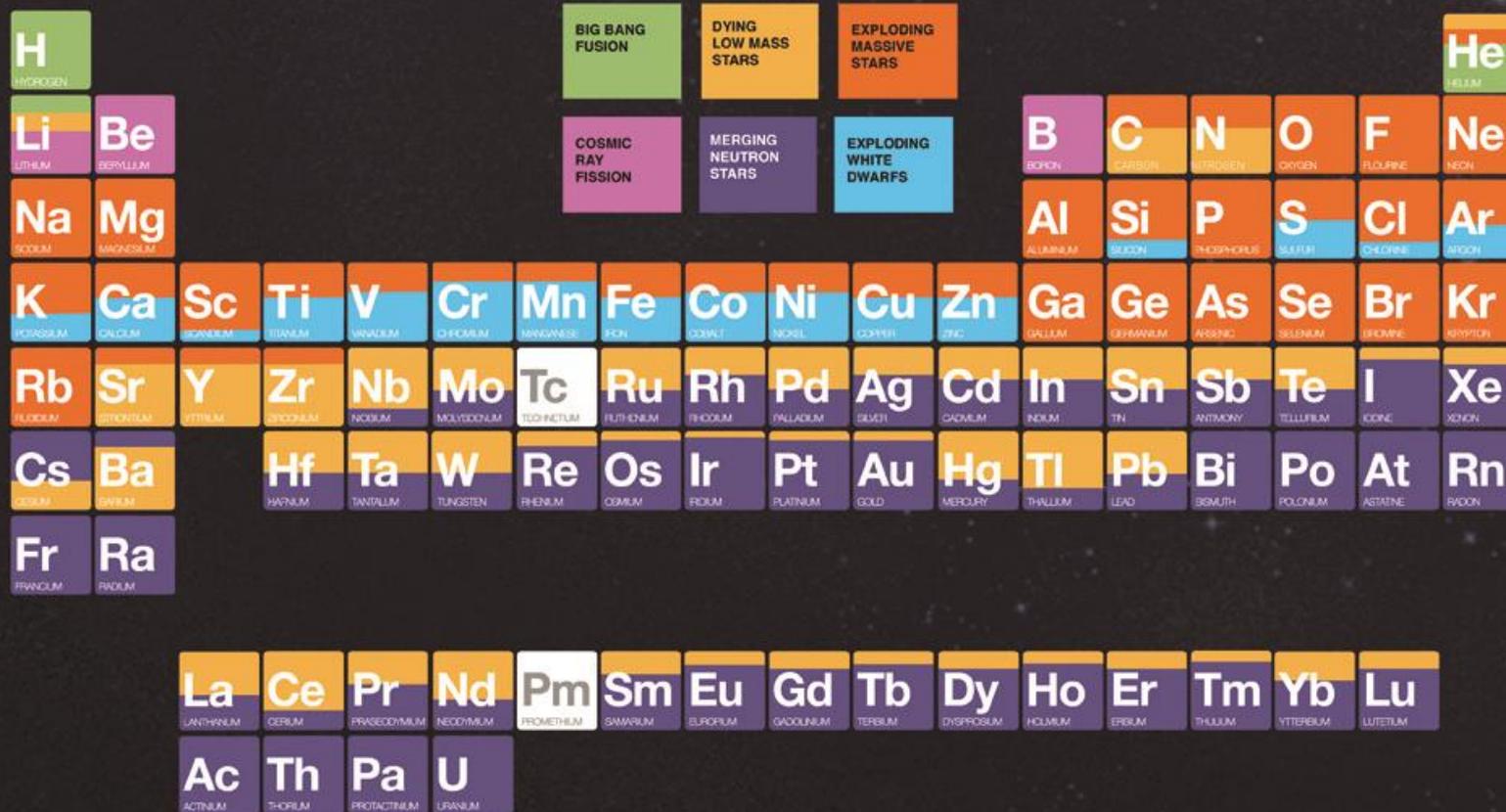


Nucleo

10<sup>17</sup> kg/m<sup>3</sup>



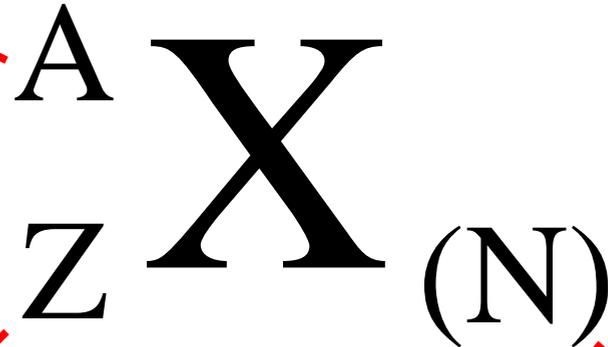
# ORIGINS: SOLAR SYSTEM ELEMENTS



1%  
9.5%  
16.5%  
73%

# Carta d'identità di un nucleo

**A = Numero di massa:**  
la somma del numero di  
neutroni e protoni nel nucleo



**Z = Numero atomico:**  
il numero dei protoni nel nucleo

**N = Numero dei neutroni:**  
il numero dei neutroni nel nucleo

$$A = Z + N$$



Numero di protoni Z





numero protoni

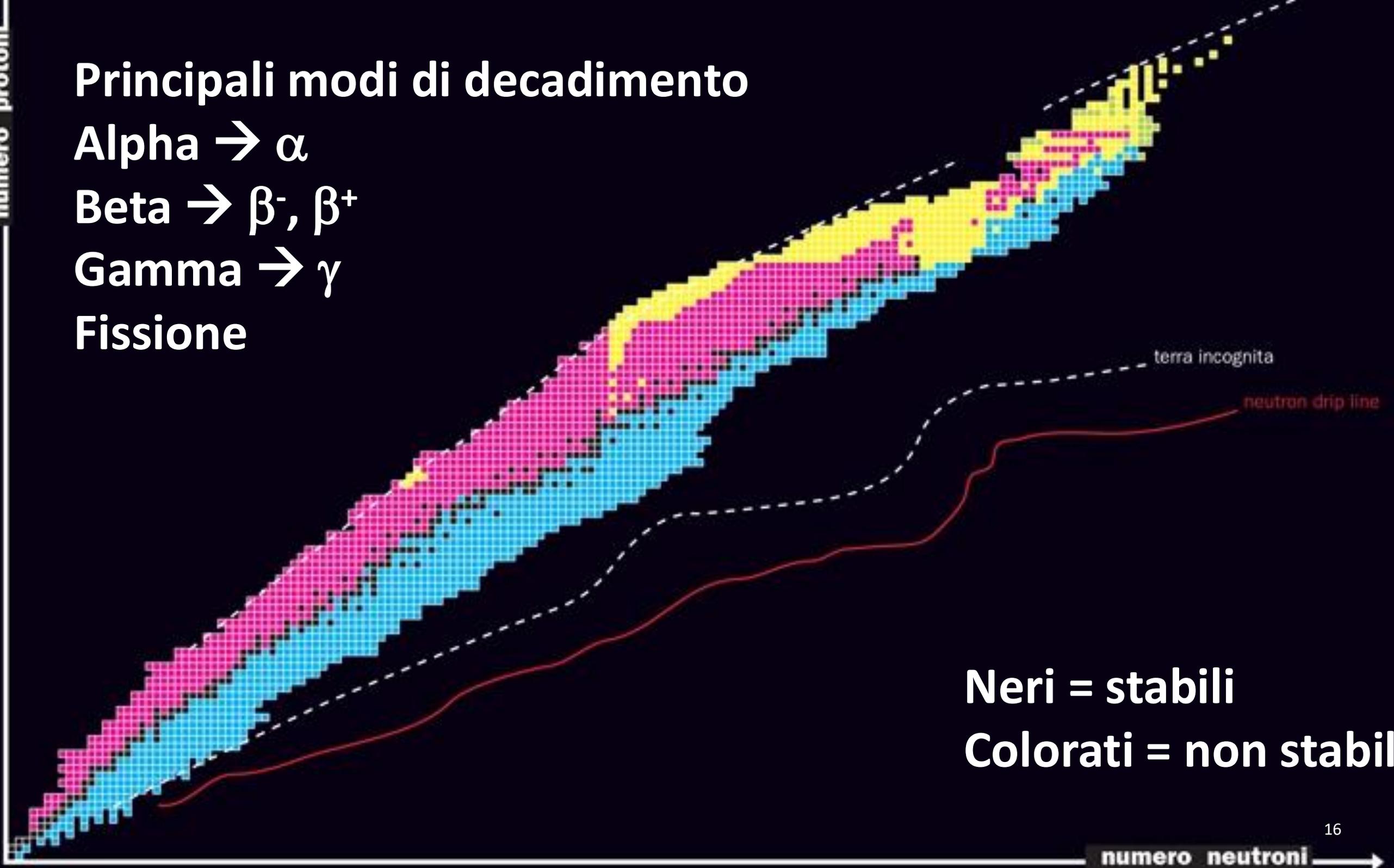
## Principali modi di decadimento

Alpha  $\rightarrow \alpha$

Beta  $\rightarrow \beta^-, \beta^+$

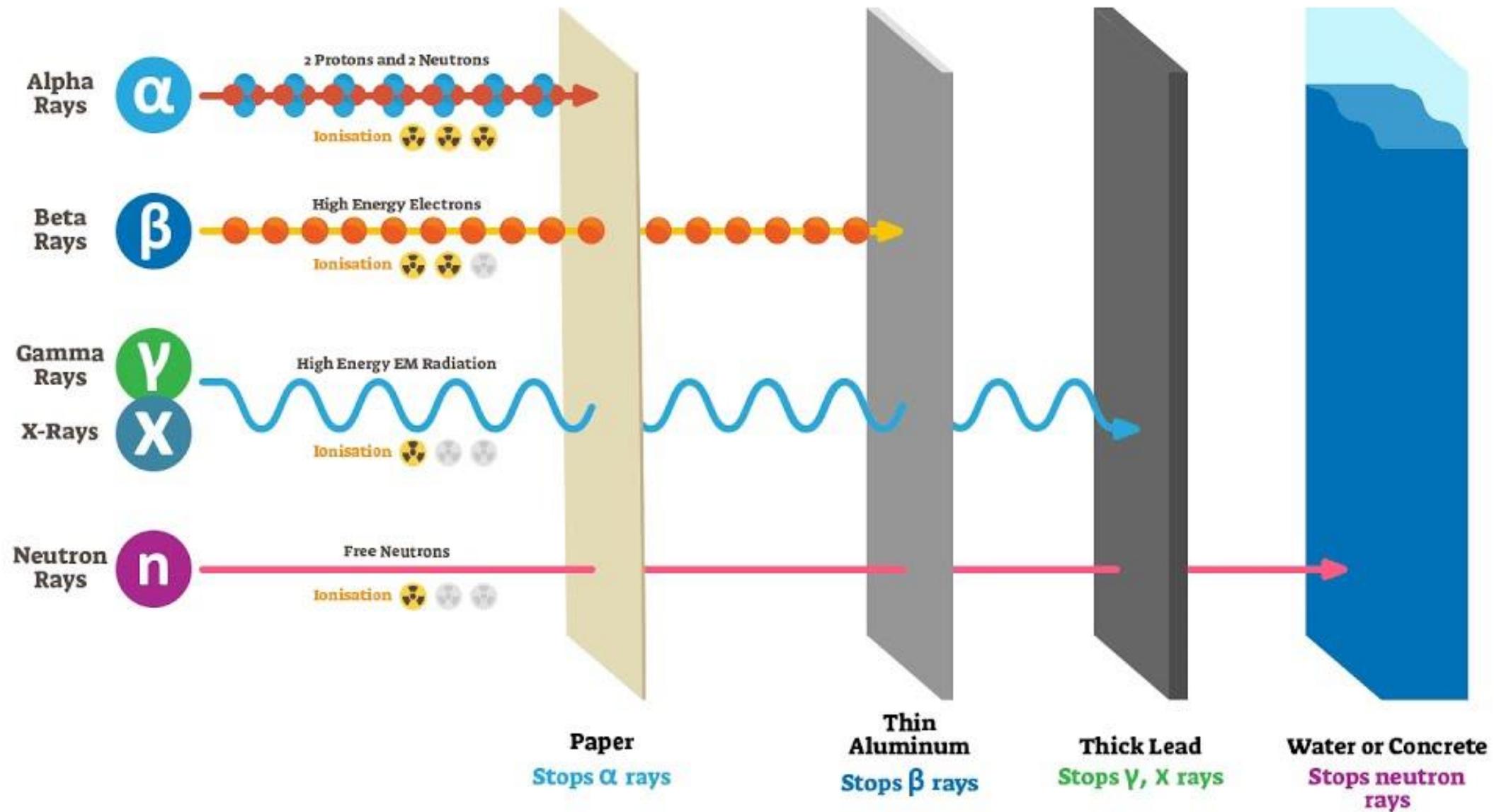
Gamma  $\rightarrow \gamma$

Fissione



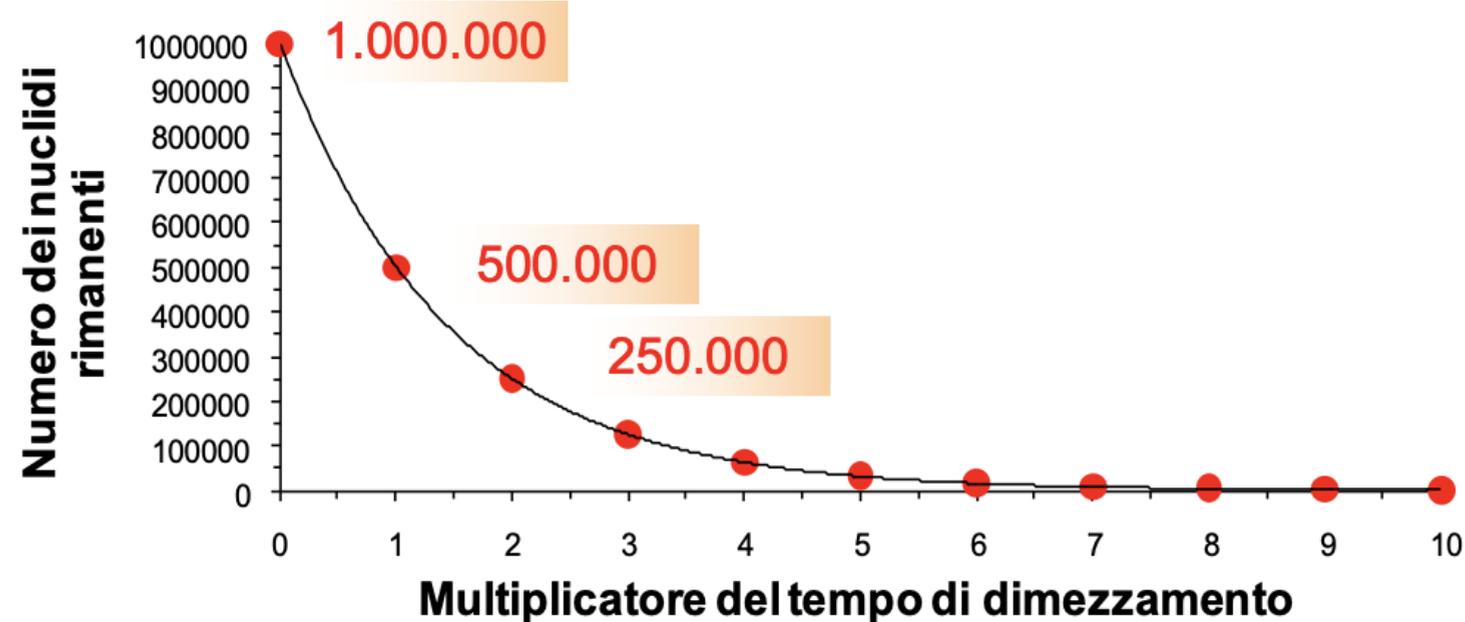
**Neri = stabili**

**Colorati = non stabili**

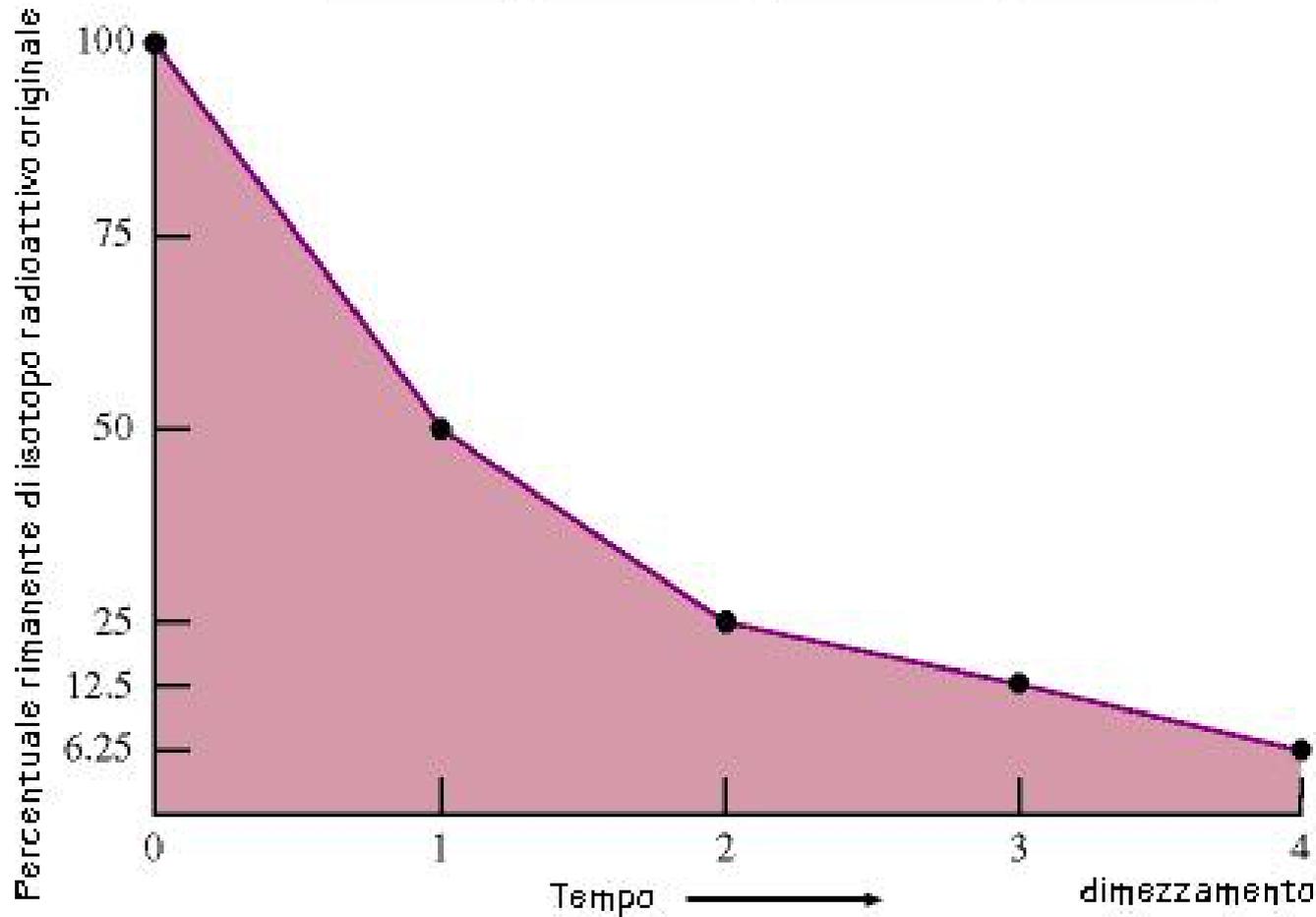


# Legge del decadimento radioattivo

$t$  è detto **vita media**, mentre  $T_{1/2}$  è detto **TEMPO DI DIMEZZAMENTO**, cioè il tempo dopo il quale la metà dei nuclei sono decaduti, e dunque la metà è sopravvissuta.



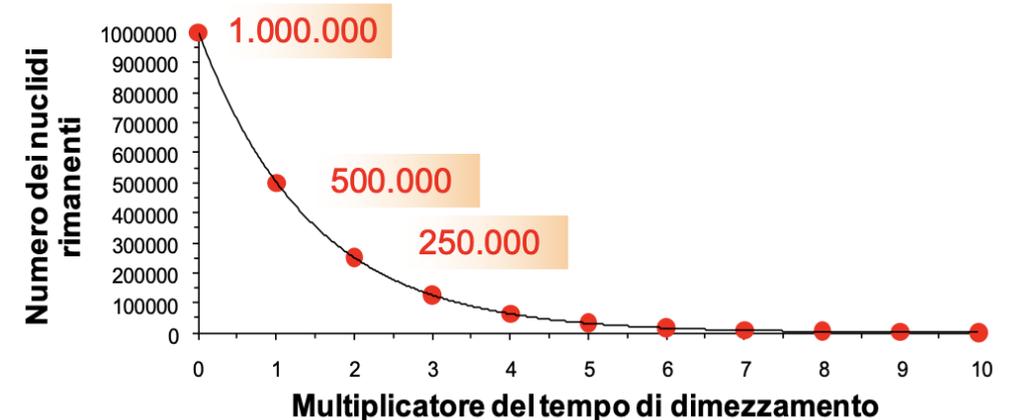
# Legge del decadimento radioattivo



Se al tempo  $t = 0$  ho  $N_0$  nuclei, quanti ne avrò dopo un tempo  $t$  ?

$$A(t) = \frac{\Delta N}{\Delta t} = \frac{N(t)}{\tau} \quad N(t) = N_0 \left(\frac{1}{e}\right)^{\frac{t}{\tau}} = N_0 \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$$

$\tau$  è detto **vita media**, mentre  $T_{1/2}$  è detto **TEMPO DI DIMEZZAMENTO**, cioè il tempo dopo il quale la metà dei nuclei sono decaduti, e dunque la metà è sopravvissuta.





the air we breath

from plants

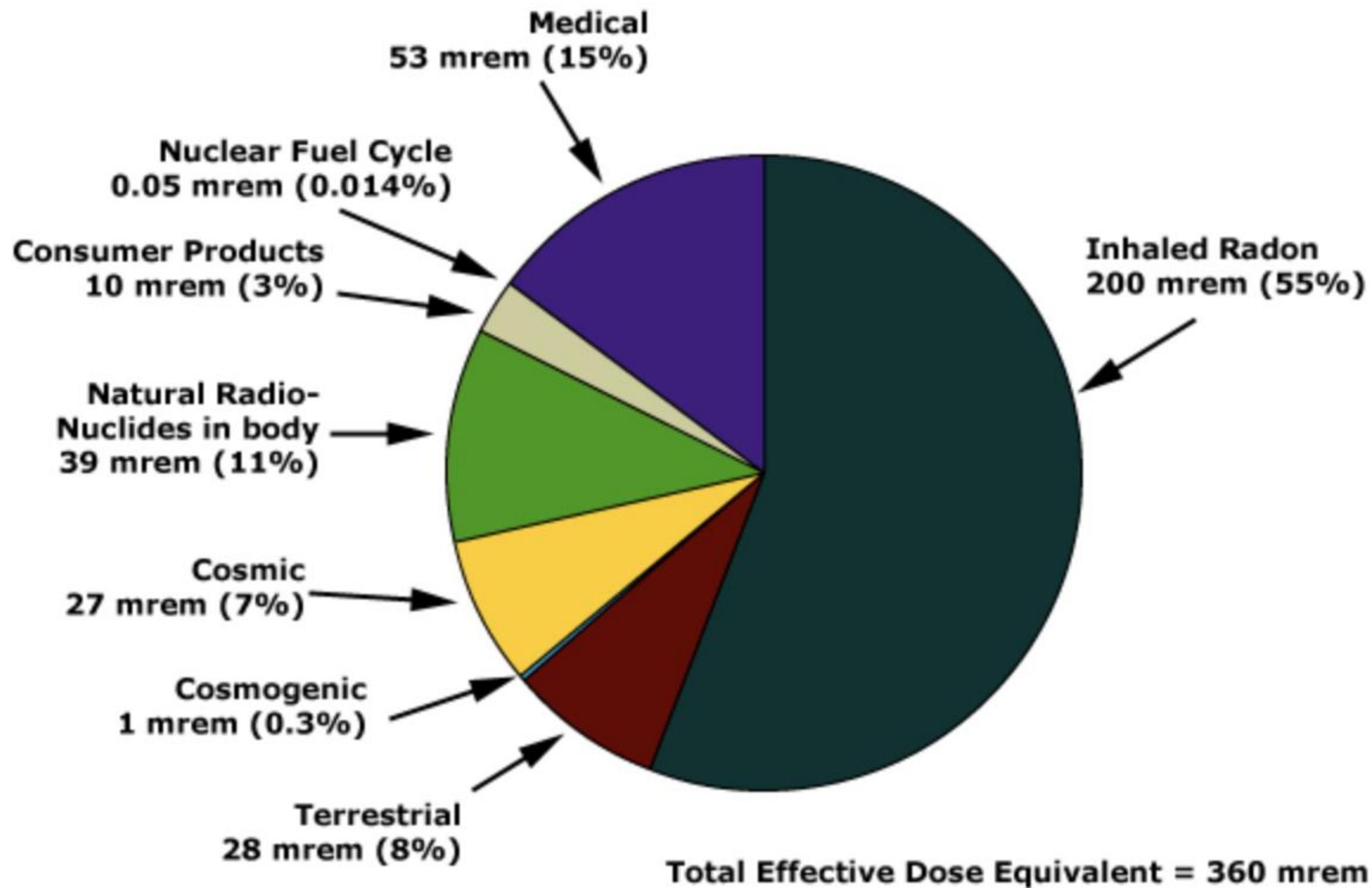
from rocks and soil

from water

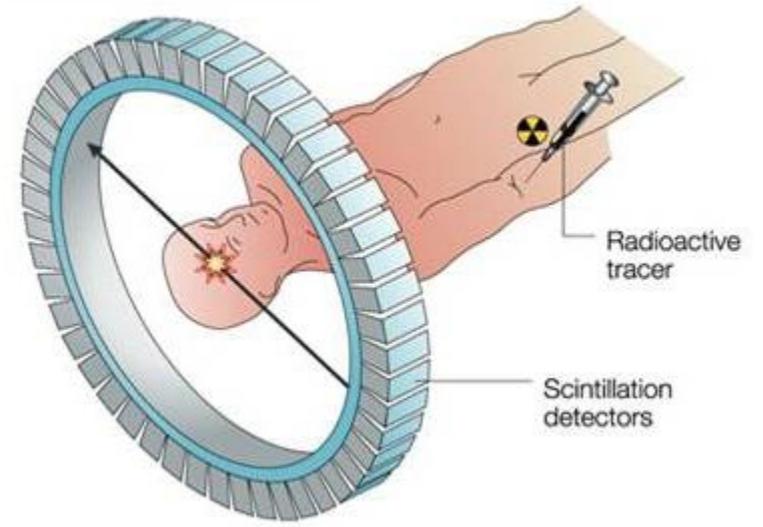
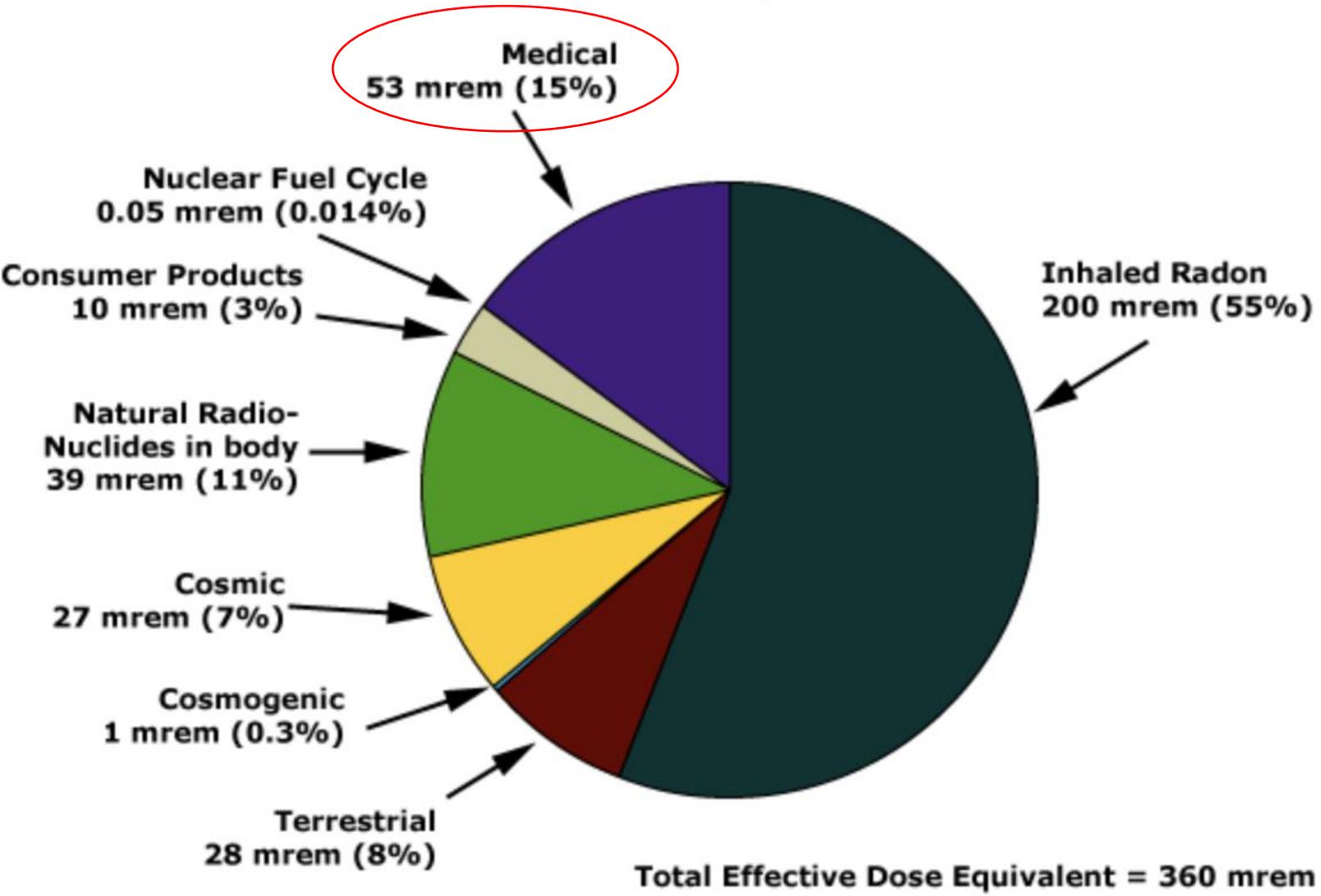
from the food we eat  
and even from our own bodies

Radiazioni ionizzanti sono costantemente intorno a noi

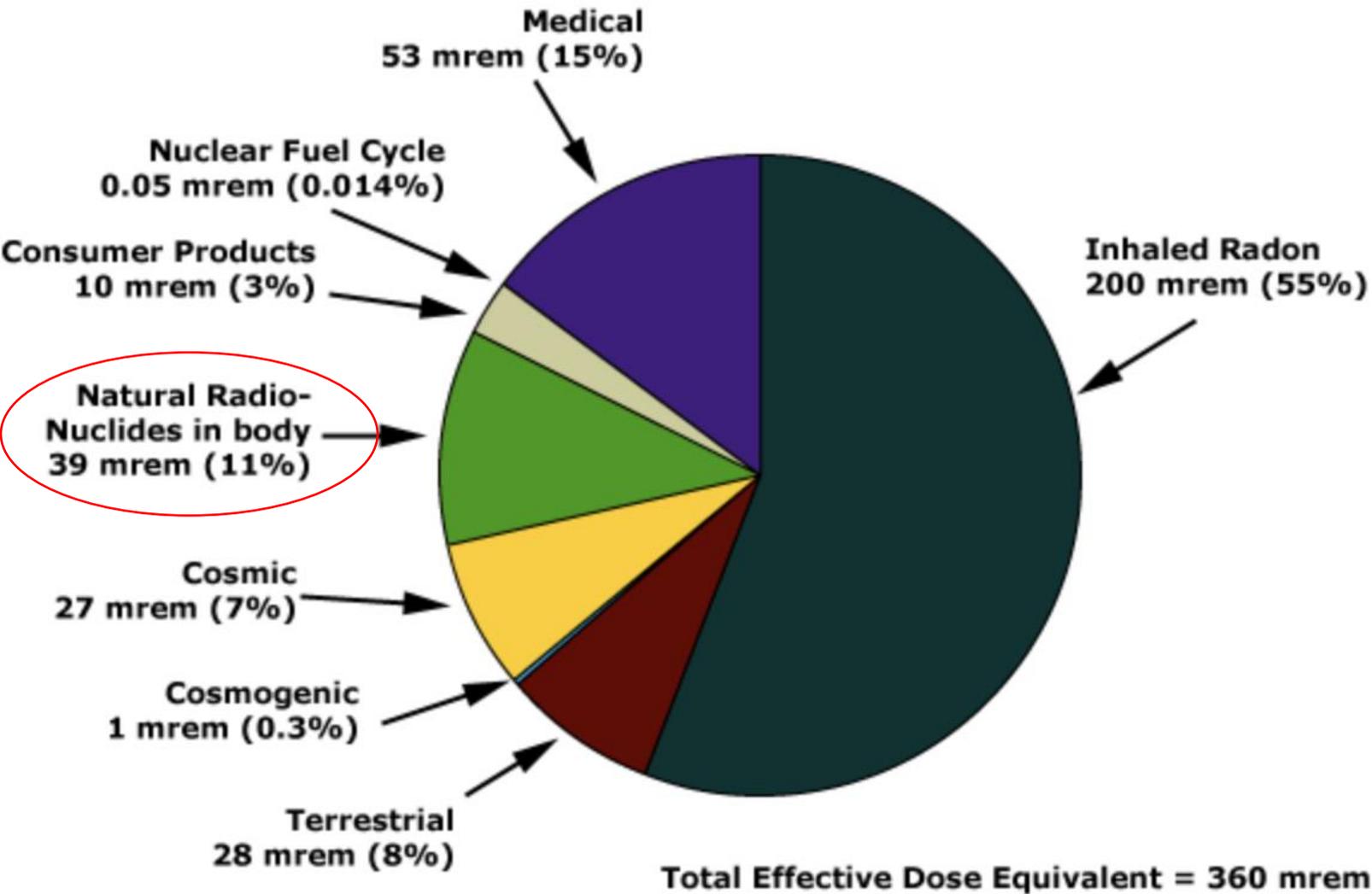
## Sources of Exposure



### Sources of Exposure

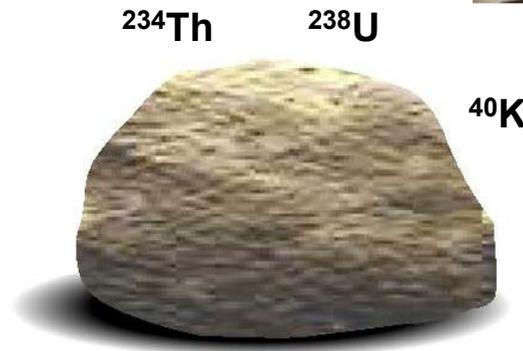
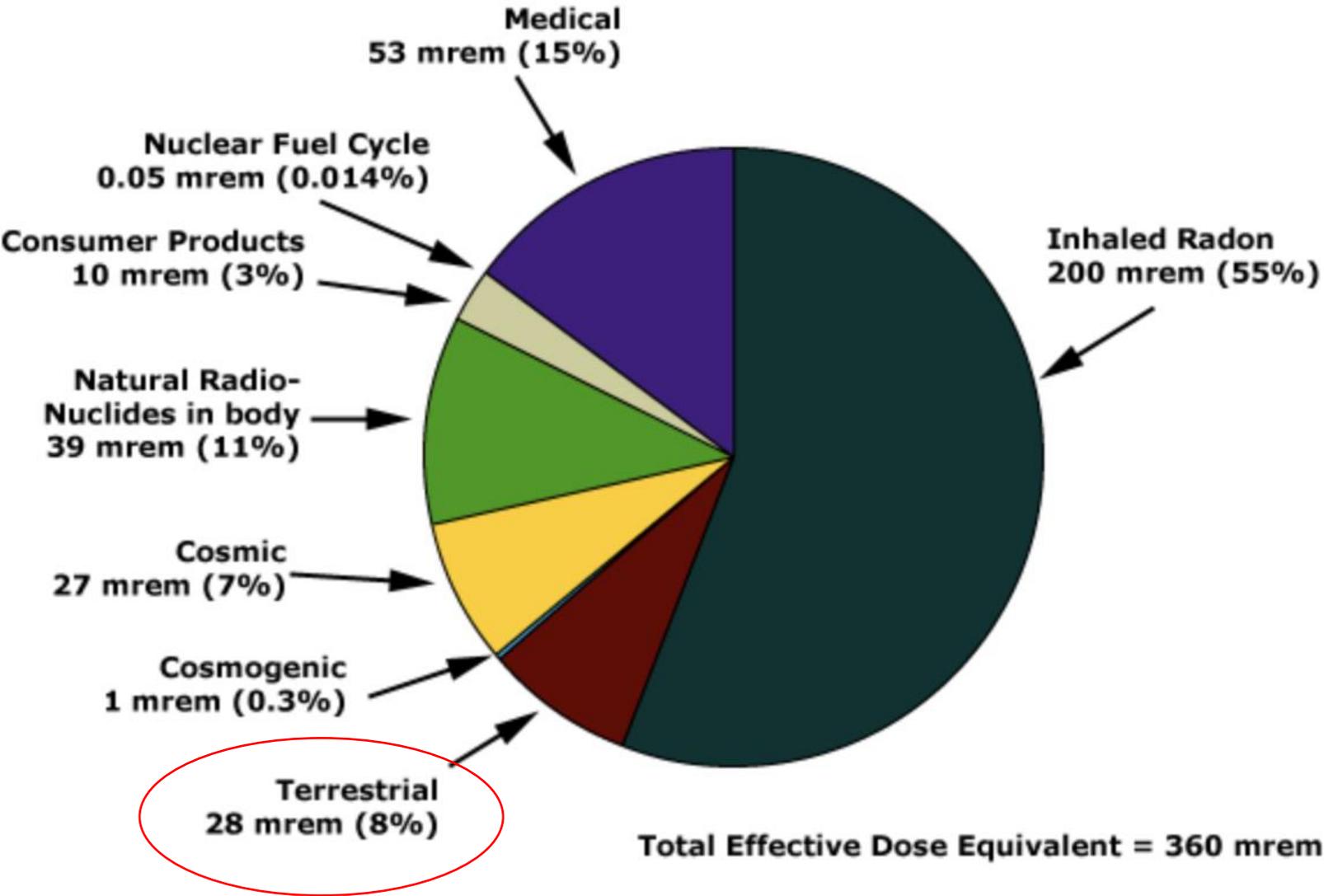


### Sources of Exposure

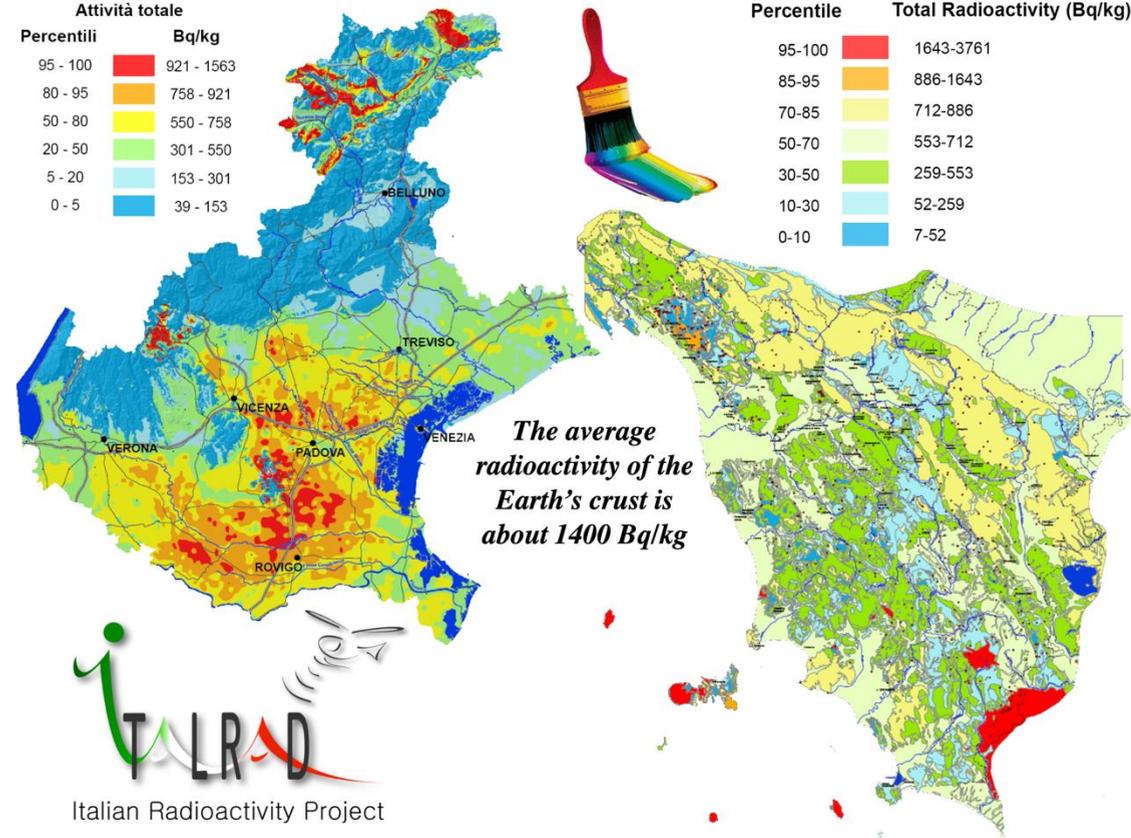
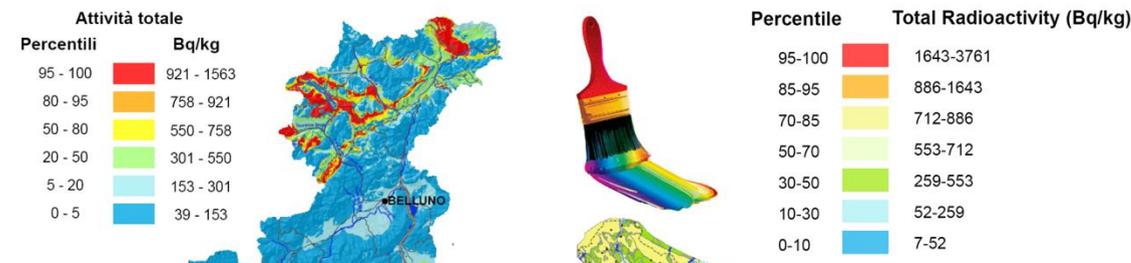


Circa 5000  
decadimenti di  $^{40}\text{K}$   
avvengono ogni  
secondo nel corpo di  
una persona di 70 kg

## Sources of Exposure



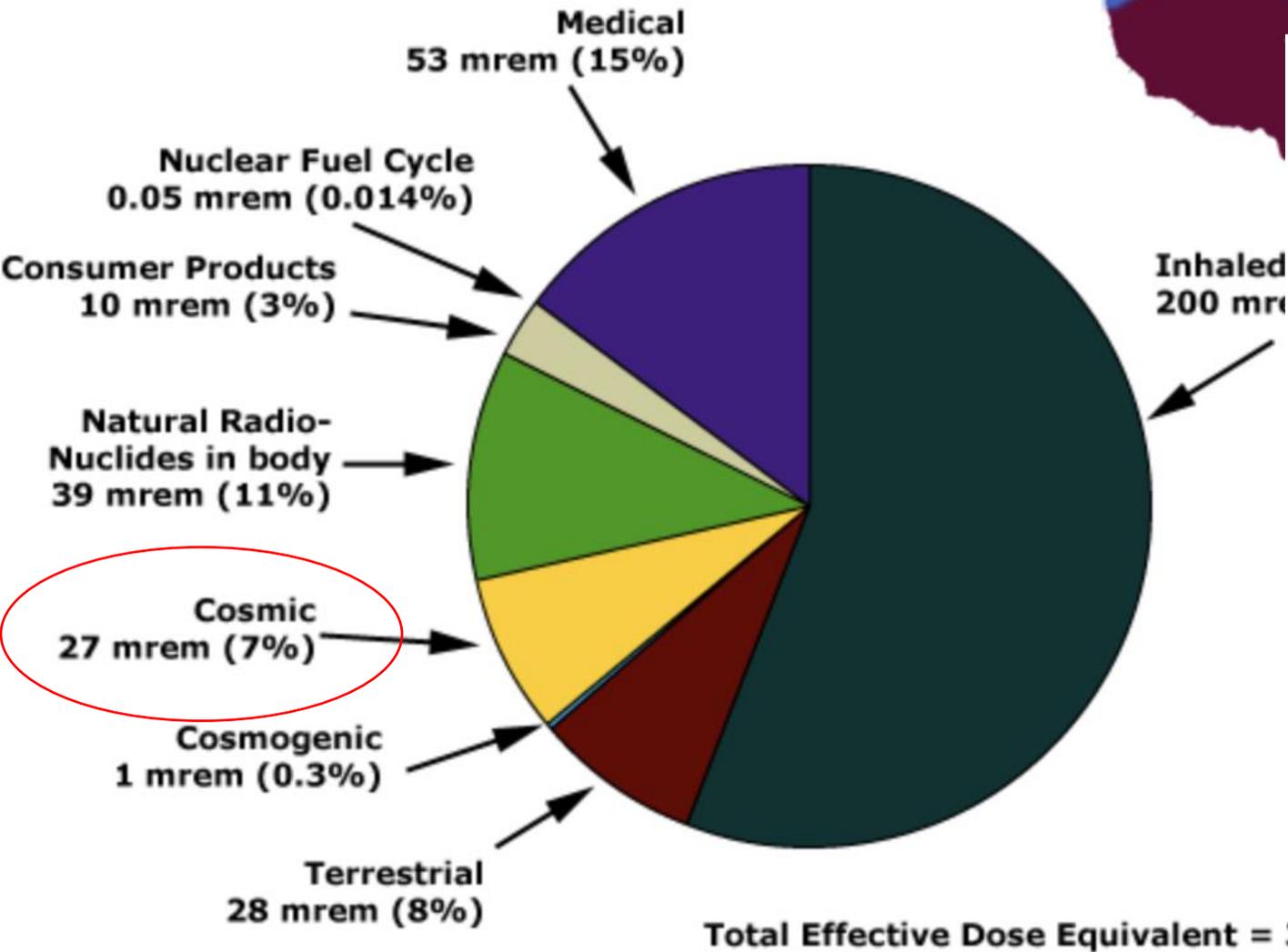
$^{234}\text{Th}$   $^{238}\text{U}$   $^{40}\text{K}$



One Transcontinental round trip flight - 5 mRem



**Sources of Exposure**



<https://jag.cami.jccbi.gov/cariprofile.asp>



FEDERAL AVIATION ADMINISTRATION  
OFFICE OF AEROSPACE MEDICINE  
CIVIL AEROSPACE MEDICAL INSTITUTE



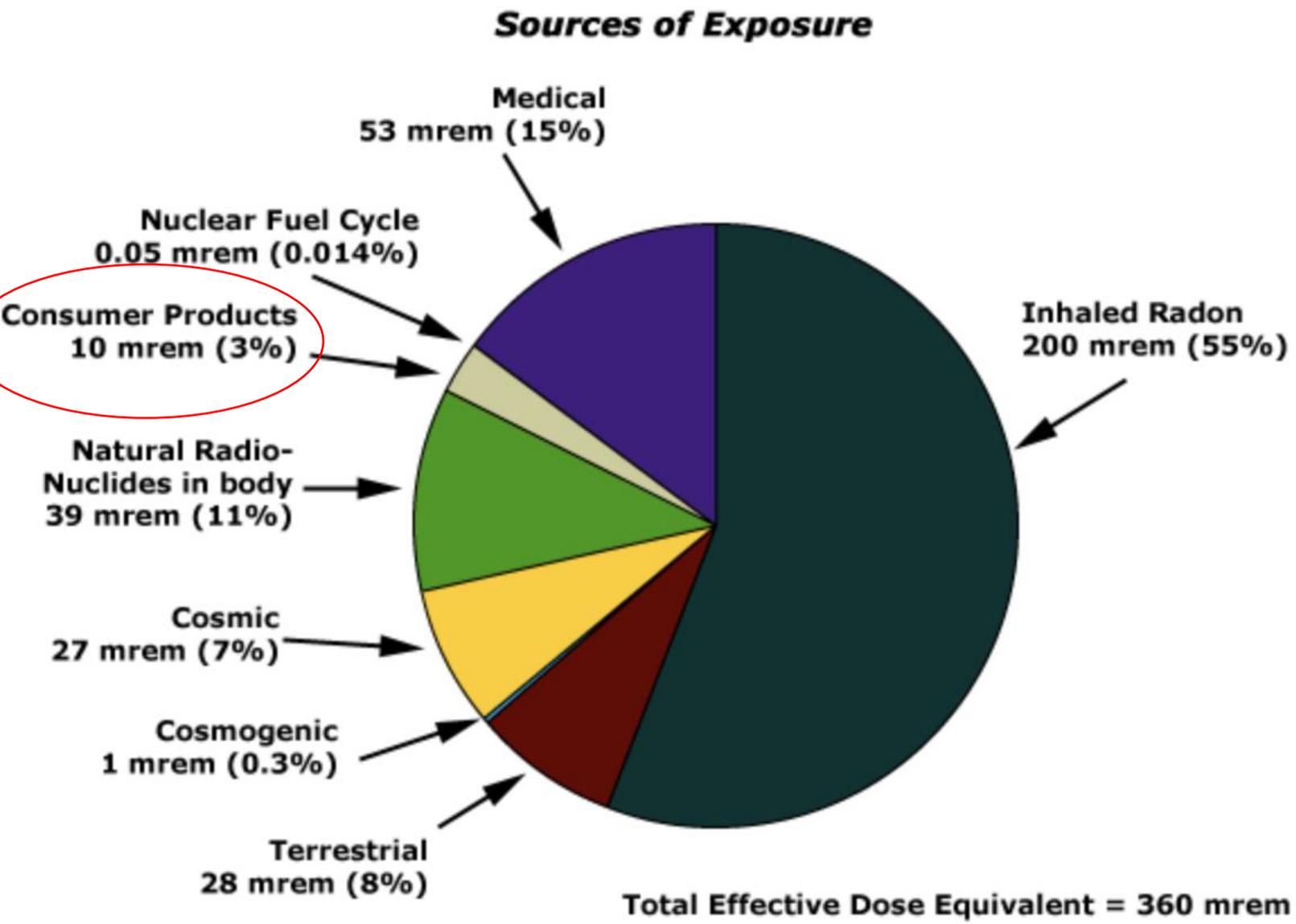
These forms require a javascript enabled browser.

Left Click on HELP For Instructions [HELP](#)

**Galactic Radiation Received In Flight**

Enter Flight Data		
Date of Flight	05/2024	01/1995 = January 1995 00/1995 = Average for 1995
Origin Code	MXP	- Enter ICAO Code or <a href="#">Look Up Origin Code</a>
Destination Code	NYC	- Enter ICAO Code or <a href="#">Look Up Destination Code</a>
Number of en route altitudes	8	
Minutes to 1st en route altitude	8	
	Continue	On the next screen you will be asked for en route altitudes, flight times and time spent in final descent..



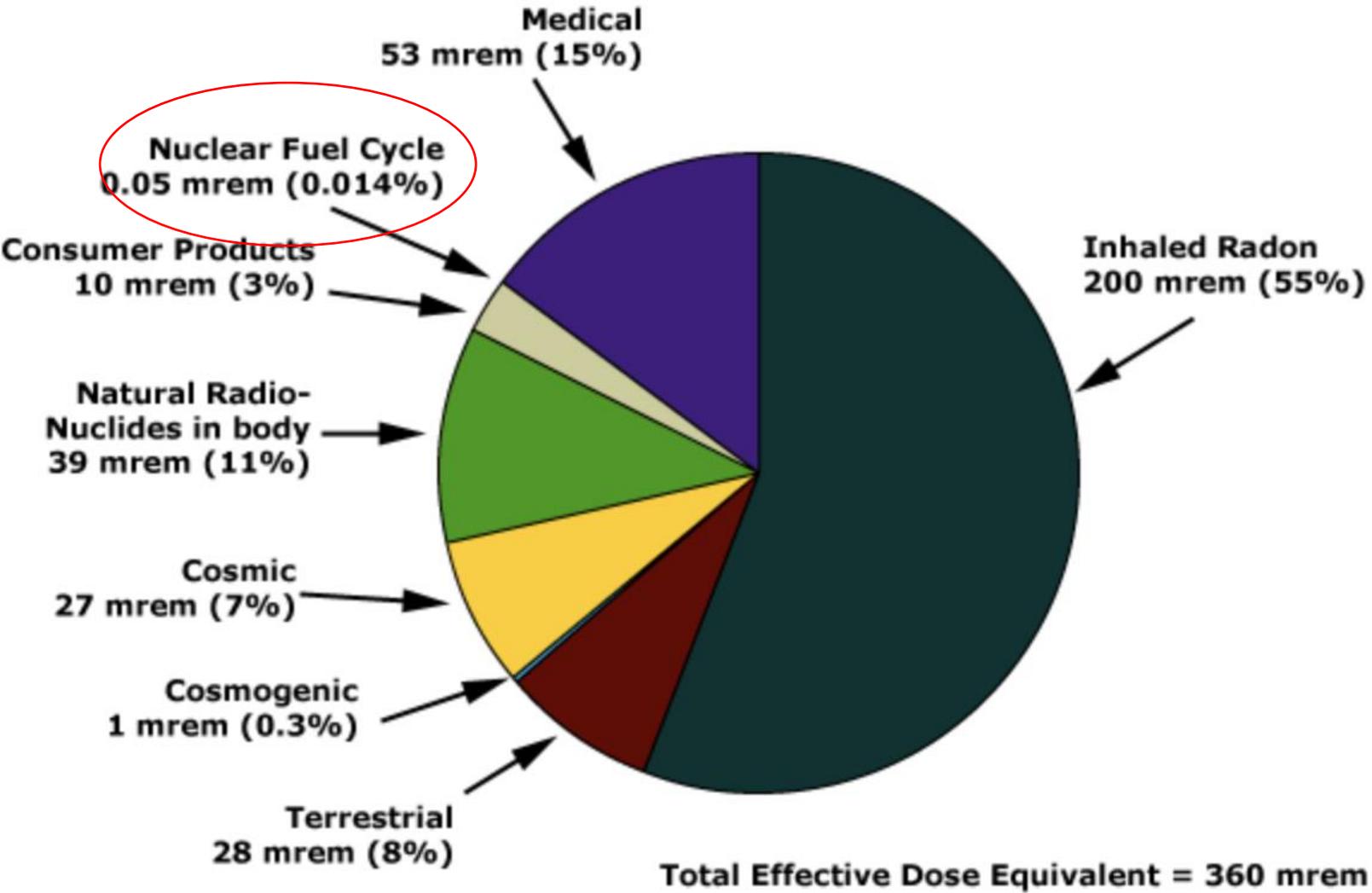


### Naturally Radioactive Foods

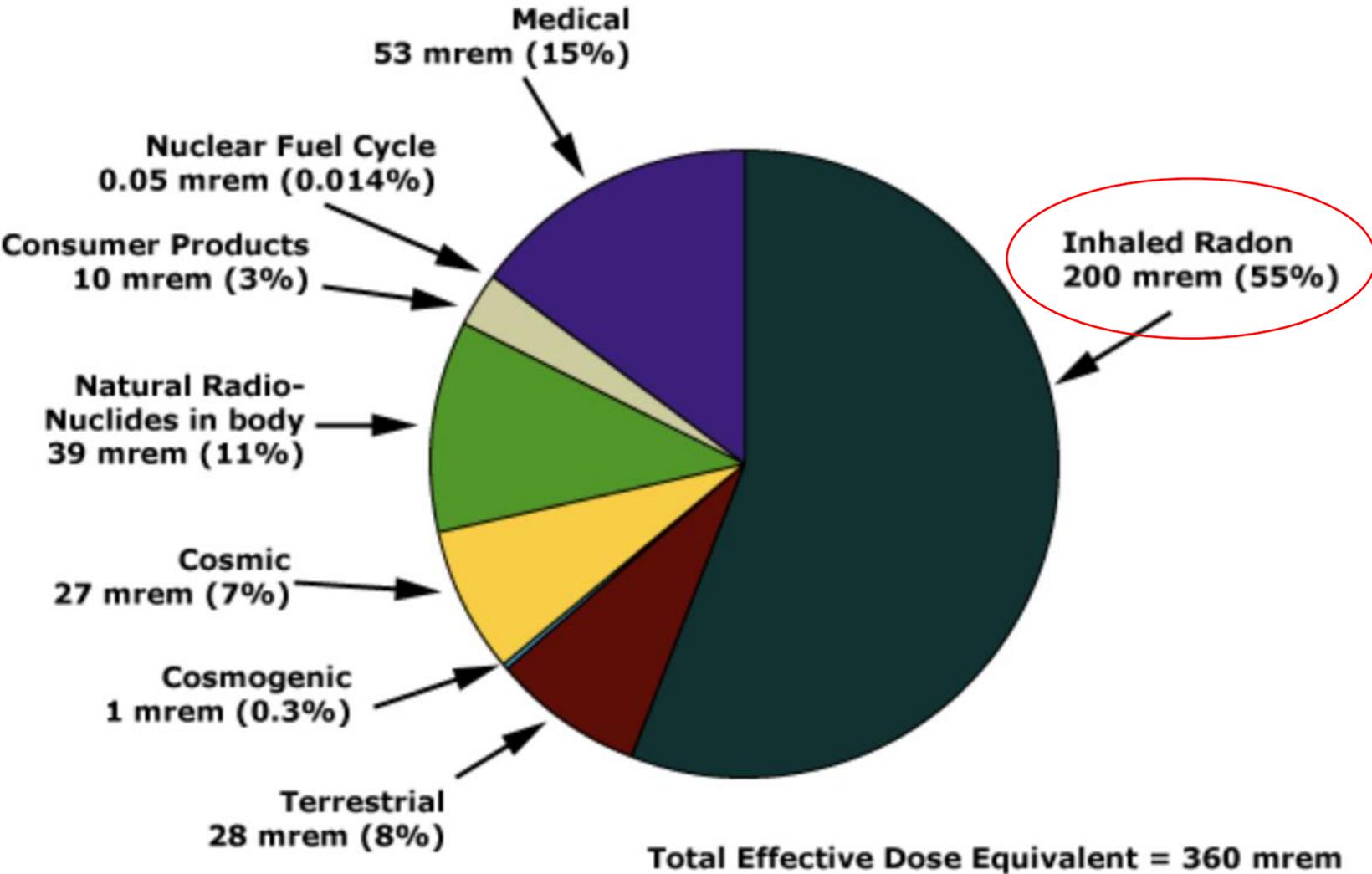
These foods naturally contain low levels of radioactive isotopes.

- Brazil nuts
- Lima beans
- Bananas
- Carrots
- Potatoes
- Lite salt
- Red meat
- Beer
- Water
- Peanut butter

### Sources of Exposure



### Sources of Exposure



**RADON**

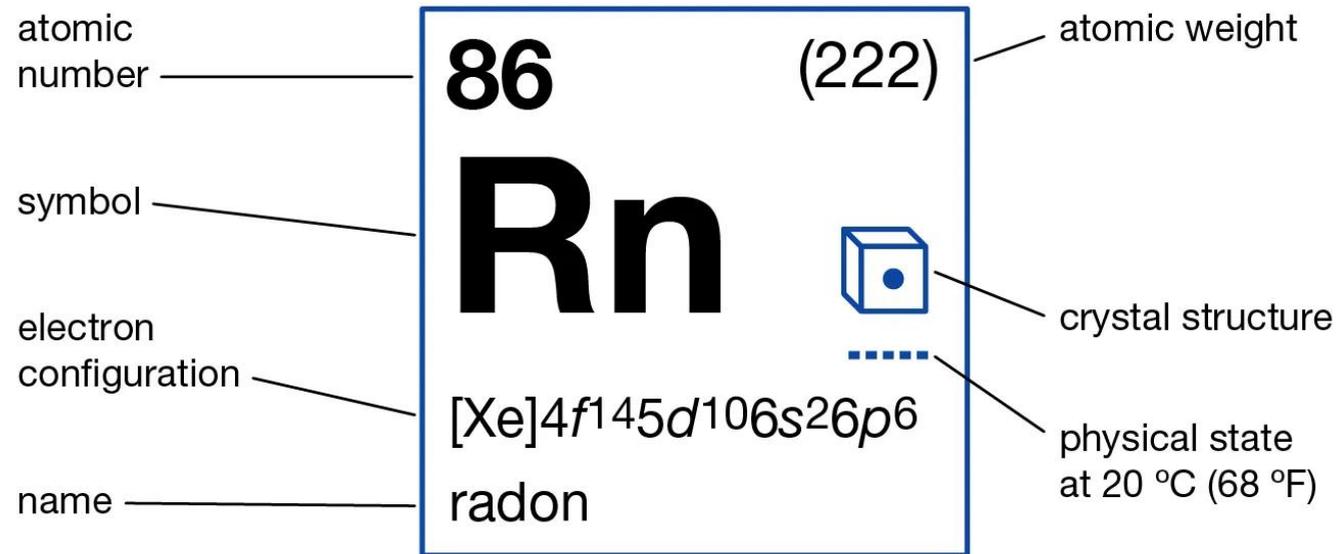
Die zweithäufigste Ursache für Lungenkrebs

**Il radon è inquadrato al secondo posto, dopo il fumo, come causa per l'insorgenza di tumori polmonari.**

(foto: Radon, Ufficio federale d. sanità pubblica di Berna, CH).

# Da dove viene il radon?

## Radon



 Noble gases	 Gas
 Face-centred cubic	

( ) indicates the mass of the longest-lived isotope.

# Radioattività primordiale

- **Primordiale** – esistente già prima della creazione della Terra

Nuclide	Tempo di dimezzamento	Abbondanza isotopica naturale
$^{235}\text{U}$	$7.04 \times 10^8 \text{ yr}$	0.7% dell' uranio totale
$^{238}\text{U}$	$4.47 \times 10^9 \text{ yr}$	99.3% dell' uranio totale
$^{232}\text{Th}$	$1.41 \times 10^{10} \text{ yr}$	100% del torio totale
$^{40}\text{K}$	$1.28 \times 10^9 \text{ yr}$	0.012% del potassio totale
$^{87}\text{Rb}$	$4.75 \times 10^{10} \text{ yr}$	48.6% del rubidio totale

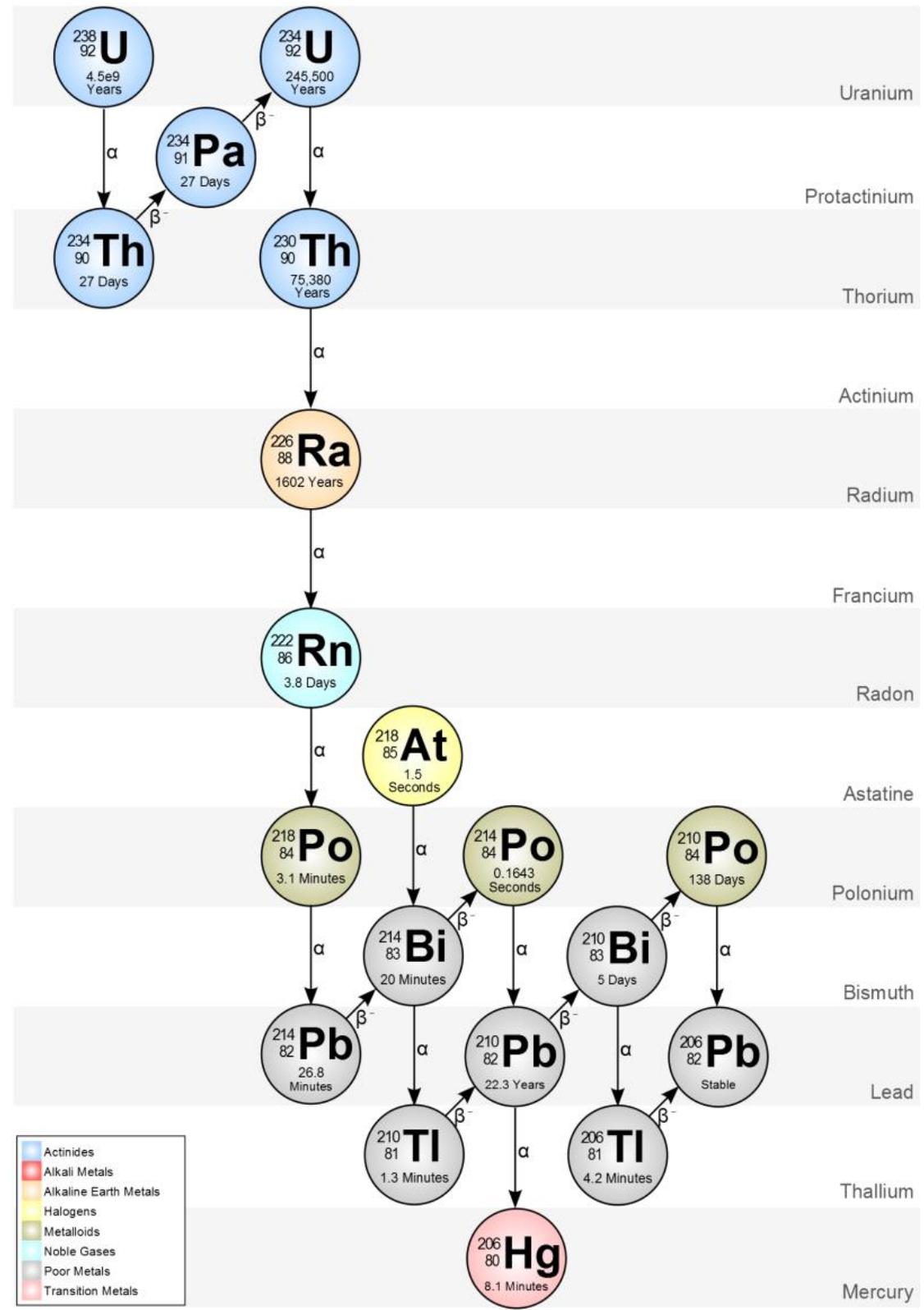


# Catena Uranio-238

Il Radon è un gas e può uscire dalla roccia dove si è formato e venire respirato

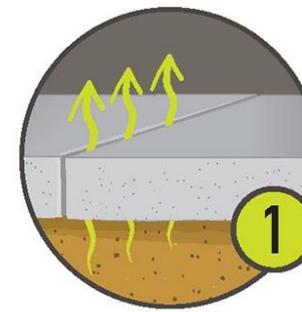
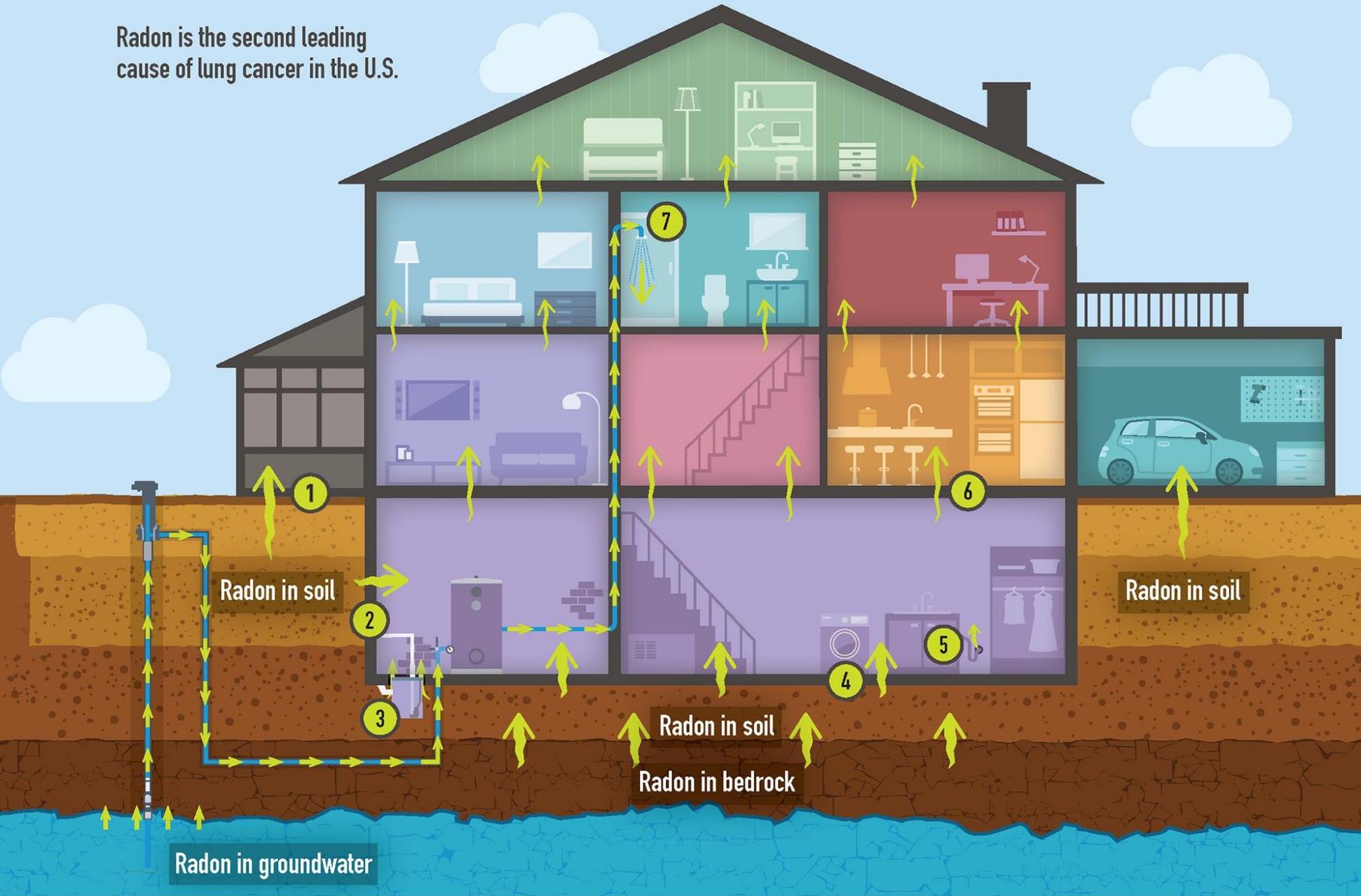
Entrando nei nostri polmoni può raggiungere parti meno protette del nostro corpo. Inoltre i suoi figli possono fare anche danni di tipo chimico

Dopo quanto tempo si esaurisce il radon messo dentro un recipiente sigillato?



# Gets into Your Home

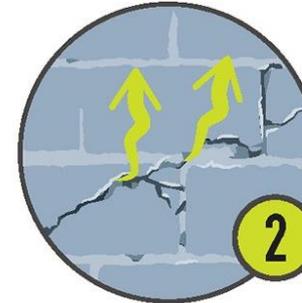
Radon is the second leading cause of lung cancer in the U.S.



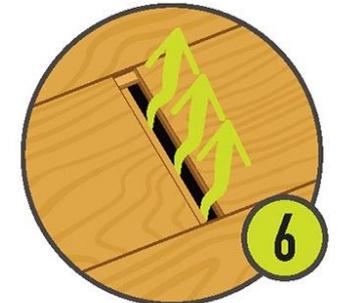
Construction joints



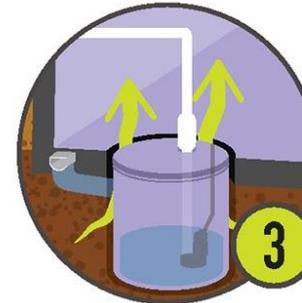
Gaps around service pipes



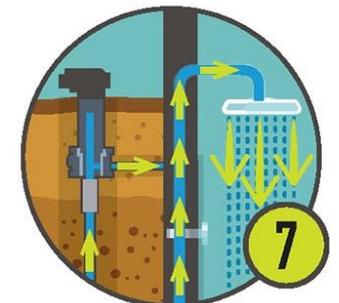
Cavities and cracks inside walls



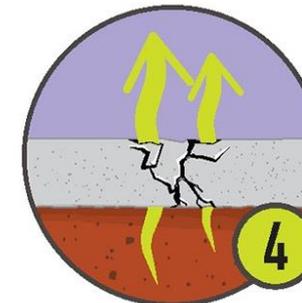
Gaps in suspended floors



Sump pump



Private wells and groundwater supplies\*



Cracks in solid floors

\* High radon levels in the water supply are more likely when its source is groundwater such as private wells or a public water supply system that uses groundwater. Most public water supplies are sourced from surface water (lakes, rivers, and reservoirs).

While it is never safe to affirm that the future of Physical Science has no marvels in store even more astonishing than those of the past, **it seems probable that most of the grand underlying principles have been firmly established and that further advances are to be sought chiefly in the rigorous application of these principles to all the phenomena which come under our notice.** It is here that the science of measurement shows its importance — where quantitative work is more to be desired than qualitative work. An eminent physicist remarked that the future truths of physical science are to be looked for in the sixth place of decimals.

Albert Michelson in 1894

E adesso un po' di storia

# Scoperta della radioattività

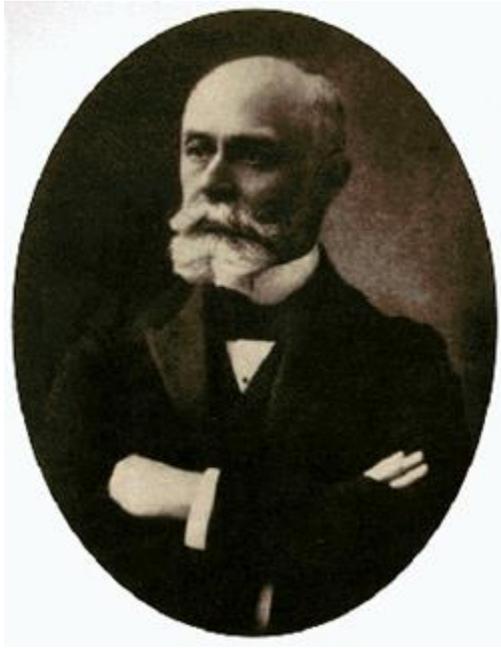


**1895:** Röntgen scopre i raggi X, facendo esperimenti con tubo catodico

Röntgen si accorse che inserendo un oggetto tra l'emettitore dei raggi X e una lastra fotografica era possibile fissare le immagini ottenute, e conservarle nel tempo.



# Bequerel e i coniugi Curie



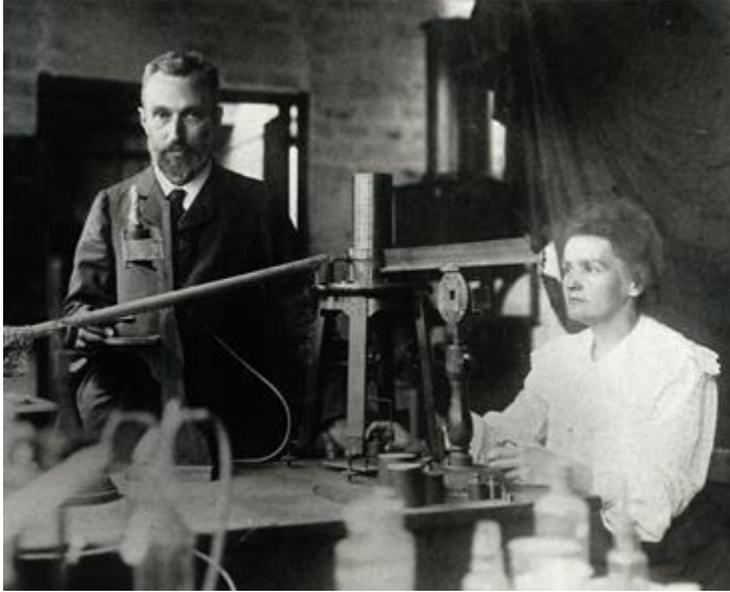
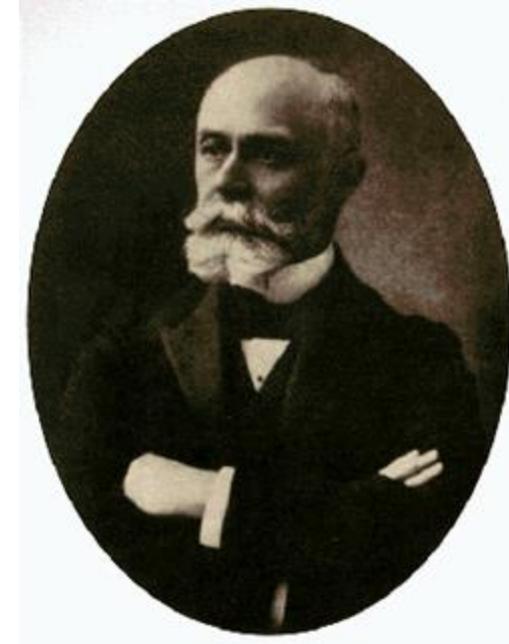
**1896:** Becquerel scopre la radioattività



Becquerel scoprì che i sali di uranio emettevano spontaneamente raggi di natura ignota, in grado di impressionare una lastra fotografica.

**1896:** Becquerel scopre la radioattività

## Bequerel e i coniugi Curie



**1900-1908:** Marie Curie scopre il radio e il polonio e sviluppa metodi efficaci per separare il radio dai minerali di uranio.

Nei suoi esperimenti notò che la pechblenda, minerale contenente soltanto piccole quantità di sali di uranio, manifestava una radioattività maggiore di quella dei sali di uranio: ne dedusse la presenza di qualche specie chimica ignota. Con vari procedimenti chimici riuscì a separare il polonio e il radio la cui radioattività risultava rispettivamente 400 e 1.000.000 di volte superiore a quella dei sali di uranio puri.



# Applicazioni possibili?

Luis A. Campos

# RADIUM

and the secret of  
LIFE

CRÈME  
COLD-CREAM  
POUR PEAUX SÈCHES  
CRÈME  
MAURESQUE  
FOND DE TEINT  
POUDRE  
SAVON  
LAIT DE TOILETTE  
DÉMAQUILLANT  
ROUGE À LÈVRES  
DENTIFRICE

# THO-RADIA

MÉTHODE  
SCIENTIFIQUE  
DE  
BEAUTÉ

EN PHARMACIE EXCLUSIVEMENT



### CERTIFICATE

SHOE-FITTING TEST DATA FOR \_\_\_\_\_

1. ANKLE ROLL    GOOD     FAIR     POOR

2. WEIGHT DISTRIBUTION

LEFT    RIGHT

\_\_\_\_% BALL    \_\_\_\_%

\_\_\_\_% OUTER    \_\_\_\_%

\_\_\_\_% HEEL    \_\_\_\_%

RIGHT WAY    WRONG WAY

3. X-RAY FITTING TEST

LEFT    RIGHT

GOOD   

FAIR   

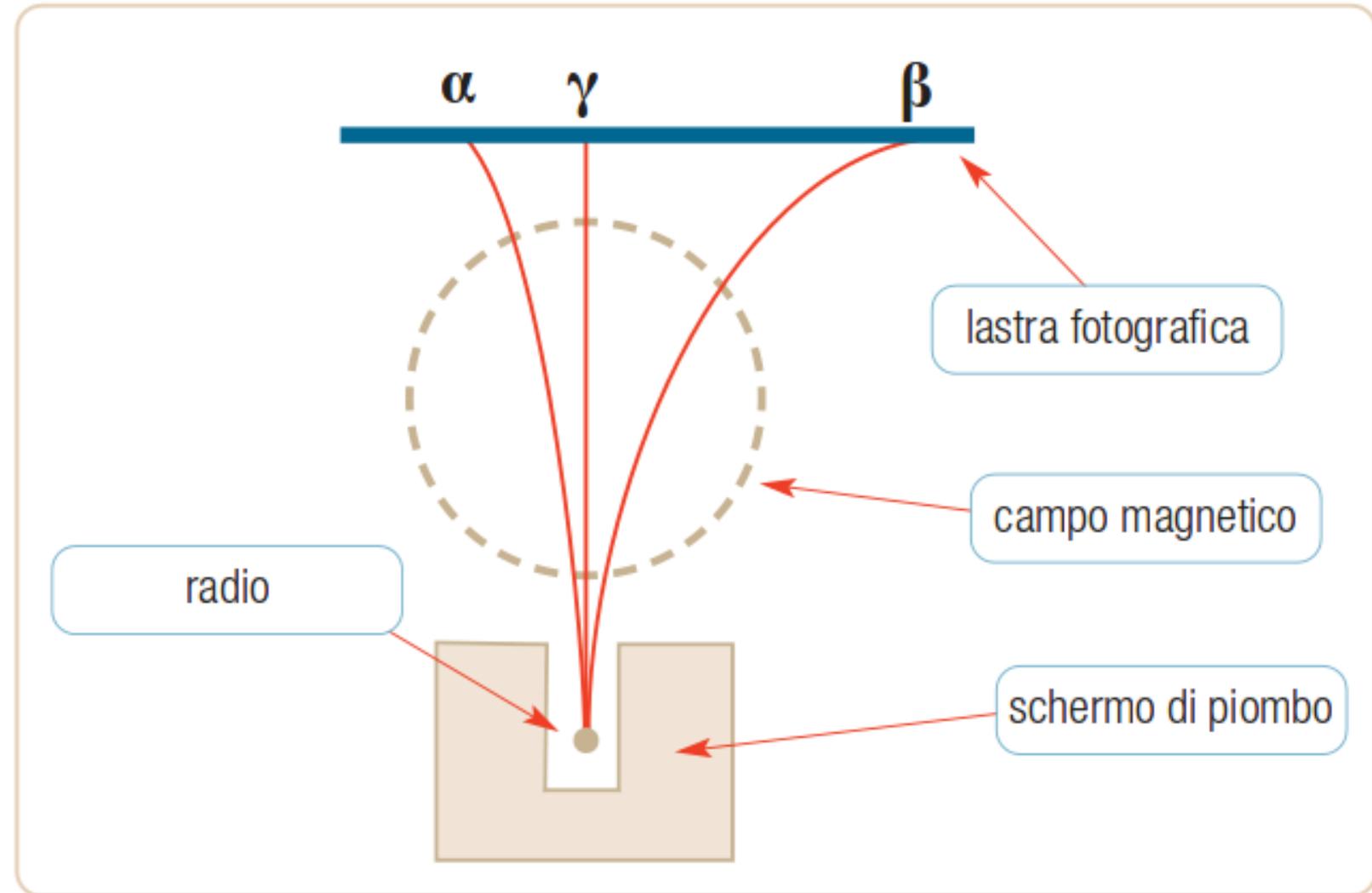
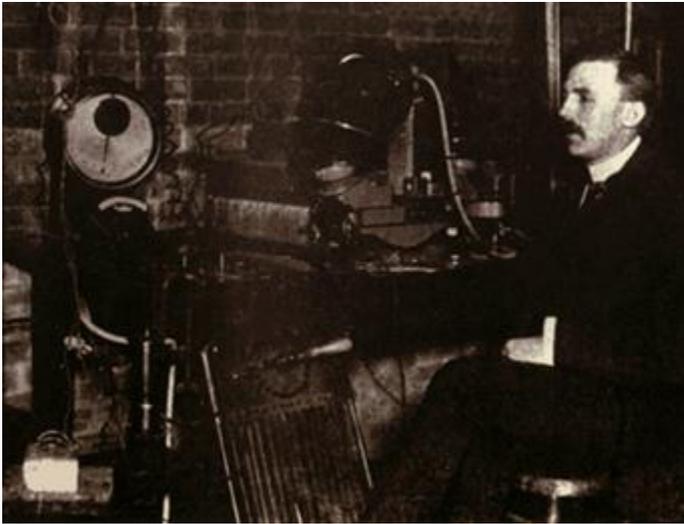
POOR   

RIGHT WAY    WRONG WAY

**This scientific way of approaching the problem of poorly-fitted shoes eliminates guesswork. Now you can see for yourself!**

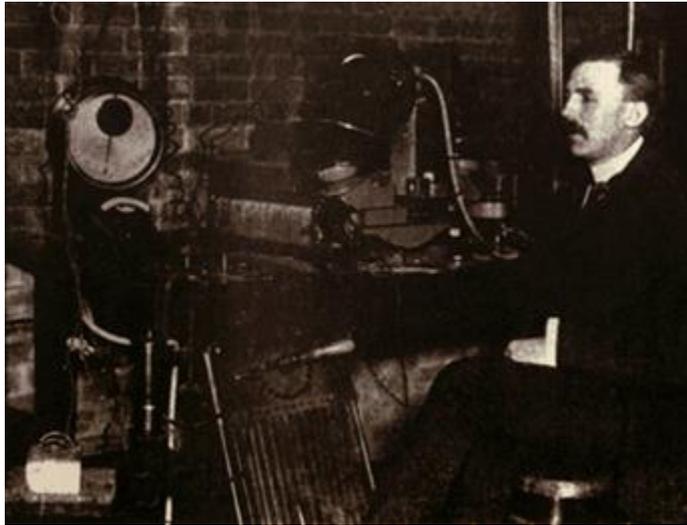
# Tipi di radiazioni

1897: Rutherford scopre i raggi alfa, beta e gamma



# Tipi di radiazioni

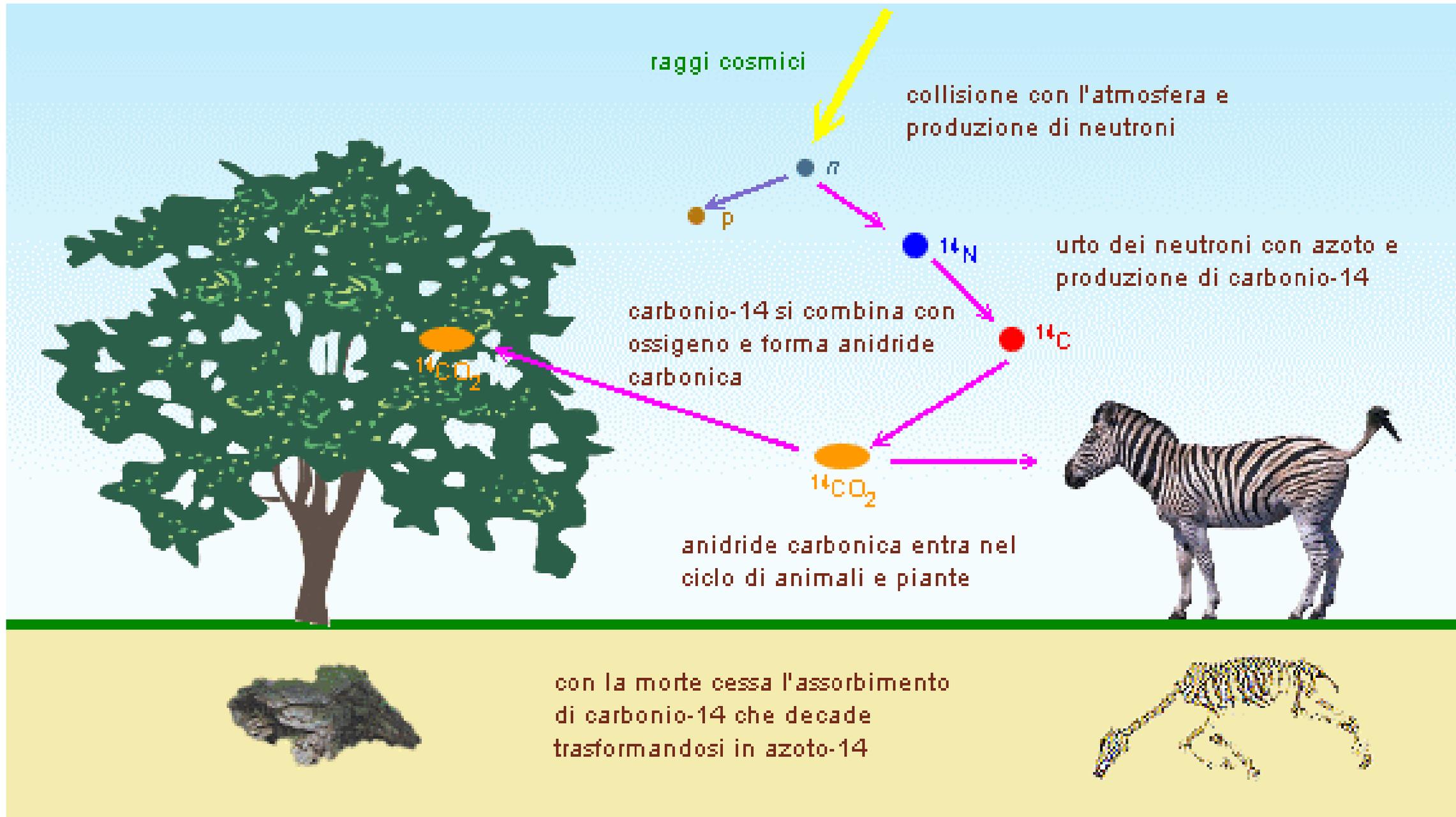
1897: Rutherford scopre i raggi alfa.



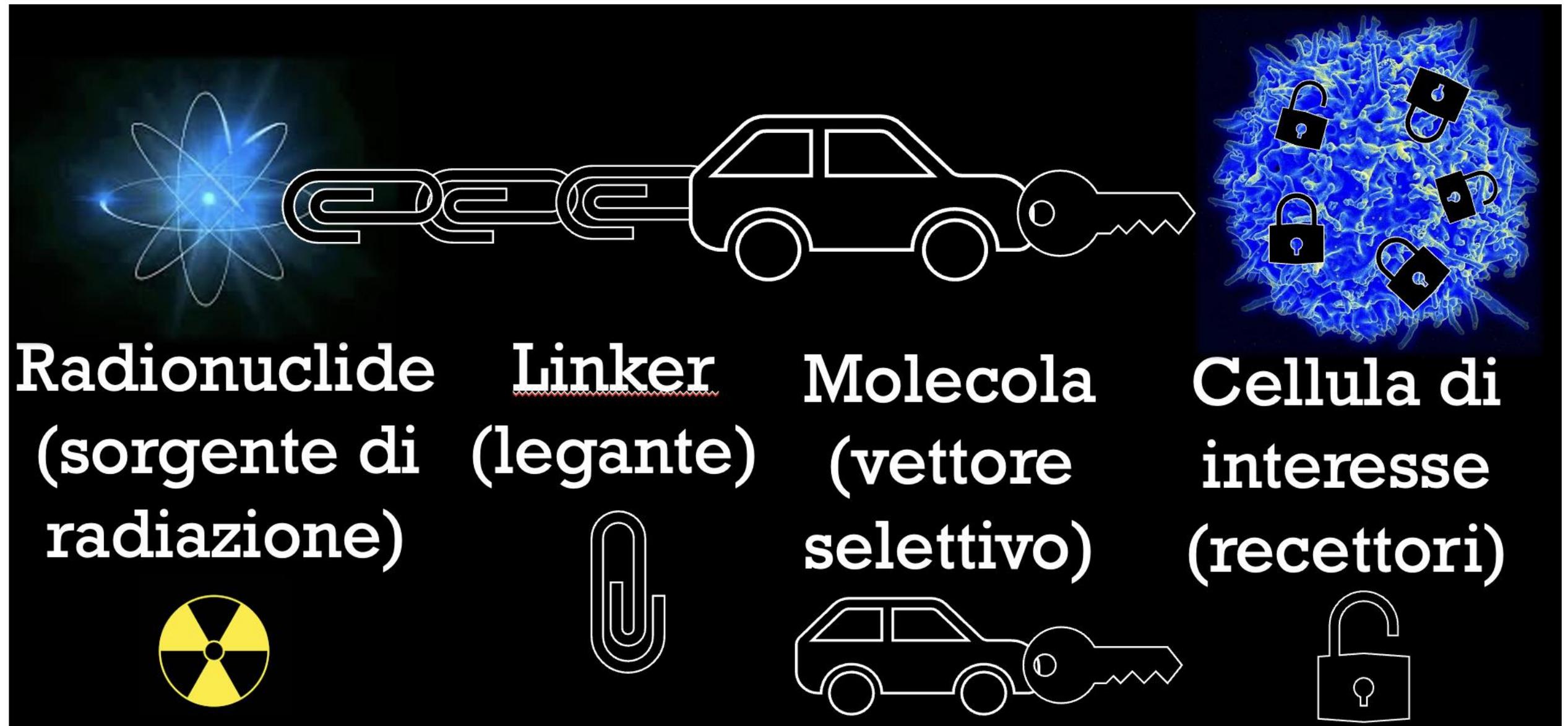
Ne deriva che le particelle beta sono elettricamente cariche negative, le particelle alfa trasportano cariche positive (e hanno massa maggiore delle particelle beta) e i raggi gamma sono elettricamente neutri

# Applicazioni

# Applicazioni: datazione con $^{14}\text{C}$



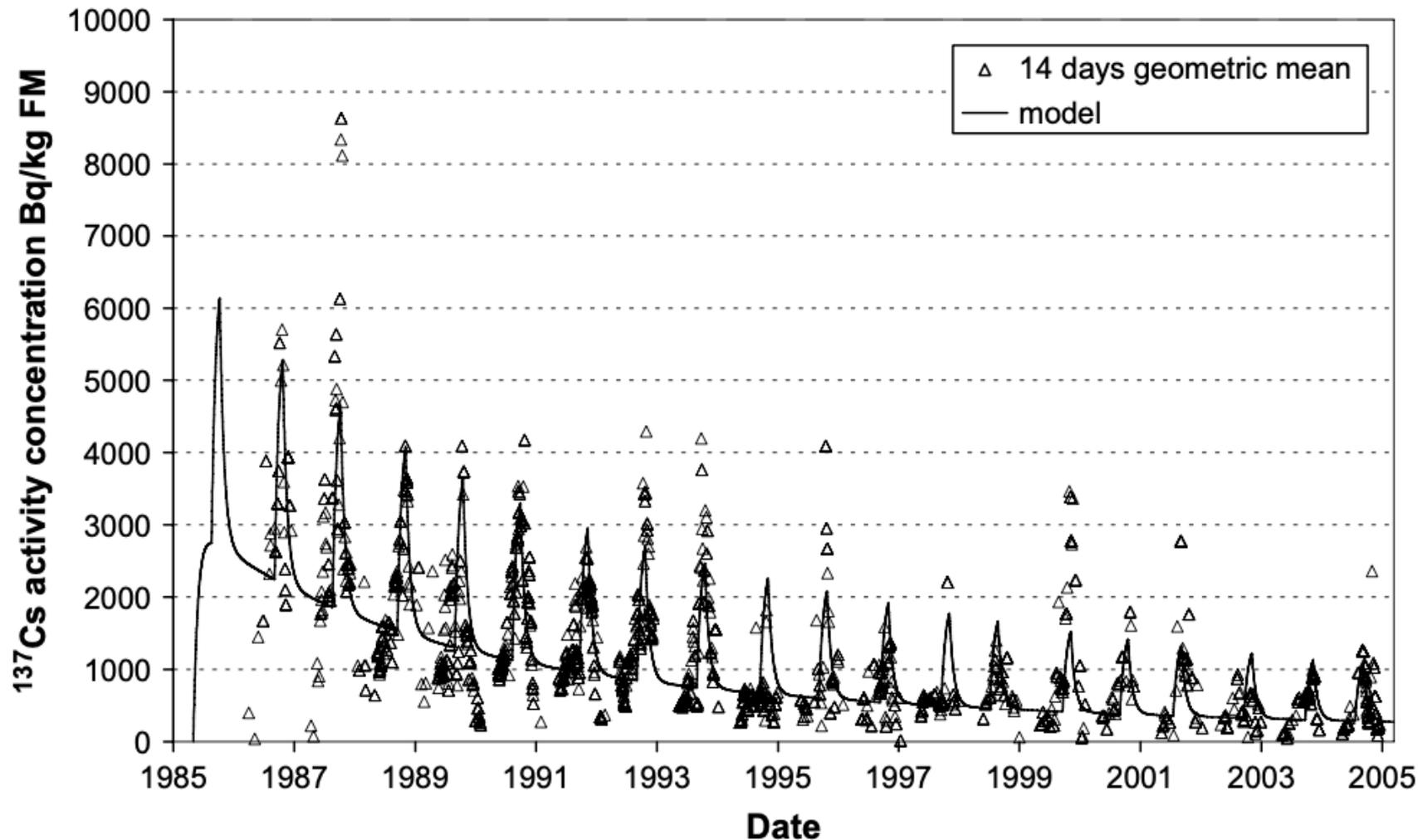
# PET: Positron Emission Tomography



# Fun facts

# Uno studio interessante con i caprioli

Studio su circa 20 anni



Journal of Environmental Radioactivity 100 (2009) 241–249



Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: [www.elsevier.com/locate/jenvrad](http://www.elsevier.com/locate/jenvrad)



Seasonality of  $^{137}\text{Cs}$  in roe deer from Austria and Germany

U. Fielitz<sup>a</sup>, E. Klemt<sup>b</sup>, F. Strebl<sup>c</sup>, F. Tataruch<sup>d</sup>, G. Zibold<sup>b,\*</sup>

<sup>a</sup> Environmental Studies, Thomasberg 33, D-37115 Duderstadt, Germany

<sup>b</sup> Hochschule Ravensburg-Weingarten, University of Applied Sciences, Doggenried Str., D-88250 Weingarten, Germany

<sup>c</sup> Div. Radiation Safety and Applications, Austrian Research Centers GmbH – ARC, A-2444 Seibersdorf, Austria

<sup>d</sup> Research Institute of Wildlife Ecology, University of Veterinary Medicine Vienna, Savoyenstr. 1, A-1160 Wien, Austria

Due effetti:

Aumento della concentrazione in  
autunno → funghi

Decrescita esponenziale correlata con  
la dispersione del  $^{137}\text{Cs}$  nel corso degli  
anni (piogge e altri effetti)

## Measurement and comparison of individual external doses of high-school students living in Japan, France, Poland and Belarus—the ‘D-shuttle’ project—

N Adachi<sup>1</sup>, V Adamovitch<sup>2</sup>, Y Adjovi<sup>3</sup>, K Aida<sup>4</sup>, H Akamatsu<sup>5</sup>, S Akiyama<sup>6</sup>, A Akli<sup>7</sup>, A Ando<sup>8</sup>, T Andrault<sup>9</sup>, H Antonietti<sup>3</sup>, S Anzai<sup>10</sup>, G Arkoun<sup>3</sup>, C Avenoso<sup>11</sup>, D Ayrault<sup>9</sup>, M Banasiewicz<sup>12</sup>, M Banaśkiewicz<sup>13</sup>, L Bernardini<sup>11</sup>, E Bernard<sup>7</sup>, E Berthet<sup>11</sup>, M Blanchard<sup>3</sup>, D Boreyko<sup>14</sup>, K Boros<sup>15</sup>, S Charron<sup>16</sup>, P Cornette<sup>9</sup>, K Czerkas<sup>15</sup>, M Dameron<sup>11</sup>, I Date<sup>17</sup>, M De Pontbriand<sup>3</sup>, F Demangeau<sup>9</sup>, Ł Dobaczewski<sup>18</sup>, L Dobrzyński<sup>19</sup>, A Ducouret<sup>3</sup>, M Dziejdzic<sup>20</sup>, A Ecalle<sup>9</sup>, V Edon<sup>9</sup>, K Endo<sup>21</sup>, T Endo<sup>21</sup>, Y Endo<sup>21</sup>, D Etryk<sup>12</sup>, M Fabiszewska<sup>18</sup>, S Fang<sup>4</sup>, D Fauchier<sup>9</sup>, F Felici<sup>7</sup>, Y Fujiwara<sup>10</sup>, C Gardais<sup>9</sup>, W Gaul<sup>20</sup>, L Gurin<sup>9</sup>, R Hakoda<sup>22</sup>, I Hamamatsu<sup>6</sup>, K Handa<sup>10</sup>, H Haneda<sup>10</sup>, T Hara<sup>10</sup>, M Hashimoto<sup>1</sup>, T Hashimoto<sup>8</sup>, K Hashimoto<sup>21</sup>, D Hata<sup>1</sup>, M Hattori<sup>10</sup>, R Hayano<sup>23</sup>, R Hayashi<sup>22</sup>, H Higasi<sup>5</sup>, M Hiruta<sup>6</sup>, A Honda<sup>6</sup>, Y Horikawa<sup>8</sup>, H Horiuchi<sup>24</sup>, Y Hozumi<sup>17</sup>, M Ide<sup>25</sup>, S Ihara<sup>8</sup>, T Ikoma<sup>24</sup>, Y Inohara<sup>22</sup>, M Itazu<sup>24</sup>, A Ito<sup>8</sup>, J Janvrin<sup>9</sup>, I Jout<sup>11</sup>, H Kanda<sup>5</sup>, G Kanemori<sup>5</sup>, M Kanno<sup>10</sup>, N Kanomata<sup>10</sup>, T Kato<sup>24</sup>, S Kato<sup>24</sup>, J Katsu<sup>5</sup>, Y Kawasaki<sup>21</sup>, K Kikuchi<sup>4</sup>, P Kilian<sup>26</sup>, N Kimura<sup>25</sup>, M Kiya<sup>10</sup>, M Klepuszewski<sup>15</sup>, E Kluchnikov<sup>14</sup>, Y Kodama<sup>5</sup>, R Kokubun<sup>10</sup>, F Konishi<sup>22</sup>, A Konno<sup>6</sup>, V Kontsevov<sup>2</sup>, A Koori<sup>6</sup>, A Koutaka<sup>6</sup>, A Kowol<sup>27</sup>, Y Koyama<sup>4</sup>, M Kozioł<sup>13</sup>, M Kozue<sup>1</sup>, O Kravtchenko<sup>14</sup>, W Kruczała<sup>12</sup>, M Kudła<sup>28</sup>, H Kudo<sup>29</sup>, R Kumagai<sup>24</sup>, K Kurogome<sup>25</sup>, A Kurosu<sup>29</sup>, M Kuse<sup>25</sup>, A Lacombe<sup>3</sup>, E Lefaillet<sup>3</sup>, M Magara<sup>17</sup>, J Malinowska<sup>26</sup>, M Malinowski<sup>18</sup>, V Maroselli<sup>7</sup>, Y Masui<sup>29</sup>, K Matsukawa<sup>29</sup>, K Matsuya<sup>17</sup>, B Matusik<sup>20</sup>, M Maulny<sup>9</sup>, P Mazur<sup>27</sup>, C Miyake<sup>29</sup>, Y Miyamoto<sup>4</sup>, K Miyata<sup>1</sup>, K Miyata<sup>5</sup>, M Miyazaki<sup>30</sup>, M Molęda<sup>20</sup>, T Morioka<sup>1</sup>, E Morita<sup>24</sup>, K Muto<sup>1</sup>, H Nadamoto<sup>5</sup>, M Nadzikiewicz<sup>28</sup>, K Nagashima<sup>29</sup>, M Nakade<sup>22</sup>, C Nakayama<sup>25</sup>, H Nakazawa<sup>17</sup>,

Y Nihei<sup>4</sup>, R Nikul<sup>2</sup>, S Niwa<sup>8</sup>, O Niwa<sup>30</sup>, M Nogi<sup>6</sup>, K Nomura<sup>29</sup>, D Ogata<sup>8</sup>, H Ohguchi<sup>31</sup>, J Ohno<sup>24</sup>, M Okabe<sup>17</sup>, M Okada<sup>22</sup>, Y Okada<sup>6</sup>, N Omi<sup>25</sup>, H Onodera<sup>10</sup>, K Onodera<sup>25</sup>, S Ooki<sup>21</sup>, K Oonishi<sup>29</sup>, H Oonuma<sup>10</sup>, H Ooshima<sup>8</sup>, H Oouchi<sup>1</sup>, M Orsucci<sup>11</sup>, M Paoli<sup>11</sup>, M Penaud<sup>9</sup>, C Perdriset<sup>9</sup>, M Petit<sup>9</sup>, A Piskowski<sup>15</sup>, A Płocharski<sup>15</sup>, A Polis<sup>13</sup>, L Polti<sup>3</sup>, T Potsepnia<sup>14</sup>, D Przybylski<sup>12</sup>, M Pytel<sup>28</sup>, W Quillet<sup>9</sup>, A Remy<sup>3</sup>, C Robert<sup>9</sup>, M Sadowski<sup>19</sup>, M Saito<sup>10</sup>, D Sakuma<sup>1</sup>, K Sano<sup>5</sup>, Y Sasaki<sup>24</sup>, N Sato<sup>4</sup>, T Schneider<sup>32</sup>, C Schneider<sup>3</sup>, K Schwartzman<sup>2</sup>, E Selivanov<sup>14</sup>, M Sezaki<sup>25</sup>, K Shiroishi<sup>21</sup>, I Shustava<sup>14</sup>, A Śniecińska<sup>28</sup>, E Stalchenko<sup>14</sup>, A Staroń<sup>27</sup>, M Stromboni<sup>7</sup>, W Studzińska<sup>26</sup>, H Sugisaki<sup>17</sup>, T Sukegawa<sup>21</sup>, M Sumida<sup>22</sup>, Y Suzuki<sup>17</sup>, K Suzuki<sup>10</sup>, R Suzuki<sup>10</sup>, H Suzuki<sup>10</sup>, K Suzuki<sup>6</sup>, W Świdorski<sup>18</sup>, M Szudejko<sup>33</sup>, M Szymaszek<sup>27</sup>, J Tada<sup>34</sup>, H Taguchi<sup>22</sup>, K Takahashi<sup>4</sup>, D Tanaka<sup>5</sup>, G Tanaka<sup>29</sup>, S Tanaka<sup>24</sup>, K Tanino<sup>4</sup>, K Tazbir<sup>13</sup>, N Tcesnokova<sup>14</sup>, N Tgawa<sup>5</sup>, N Toda<sup>6</sup>, H Tsuchiya<sup>17</sup>, H Tsukamoto<sup>8</sup>, T Tsushima<sup>1</sup>, K Tsumumi<sup>25</sup>, H Umemura<sup>8</sup>, M Uno<sup>24</sup>, A Usui<sup>25</sup>, H Utsumi<sup>29</sup>, M Vaucelle<sup>9</sup>, Y Wada<sup>17</sup>, K Watanabe<sup>4</sup>, S Watanabe<sup>22</sup>, K Watase<sup>29</sup>, M Witkowski<sup>26</sup>, T Yamaki<sup>21</sup>, J Yamamoto<sup>4</sup>, T Yamamoto<sup>17</sup>, M Yamashita<sup>22</sup>, M Yanai<sup>21</sup>, K Yasuda<sup>22</sup>, Y Yoshida<sup>1</sup>, A Yoshida<sup>21</sup>, K Yoshimura<sup>25</sup>, M Żmijewska<sup>15</sup> and E Zuclarelli<sup>7</sup>

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Come misurare la radioattività  
ambientale?

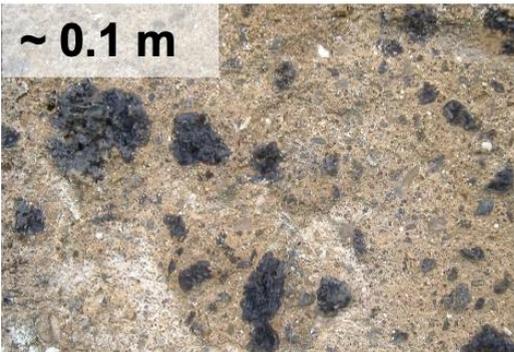
Ma non il Radon

# Possibili metodi di indagine

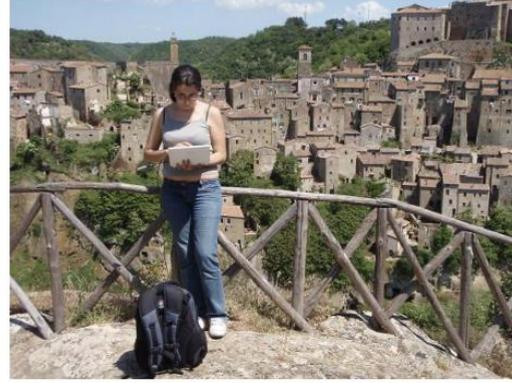
... in laboratorio



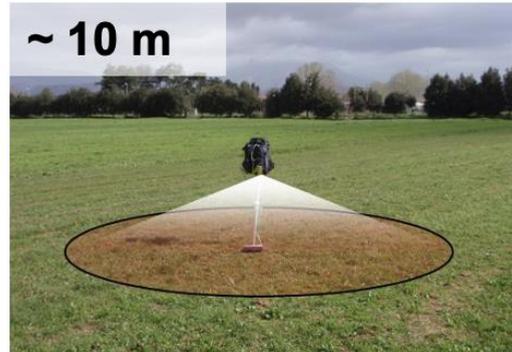
~ 0.1 m



... in situ



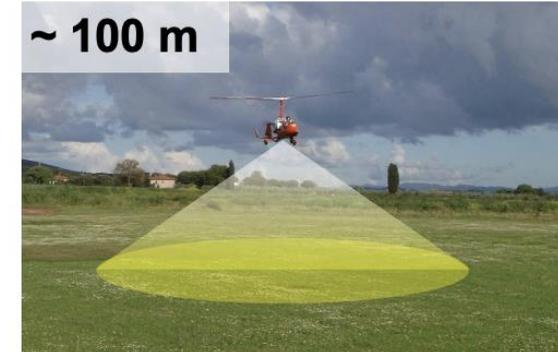
~ 10 m



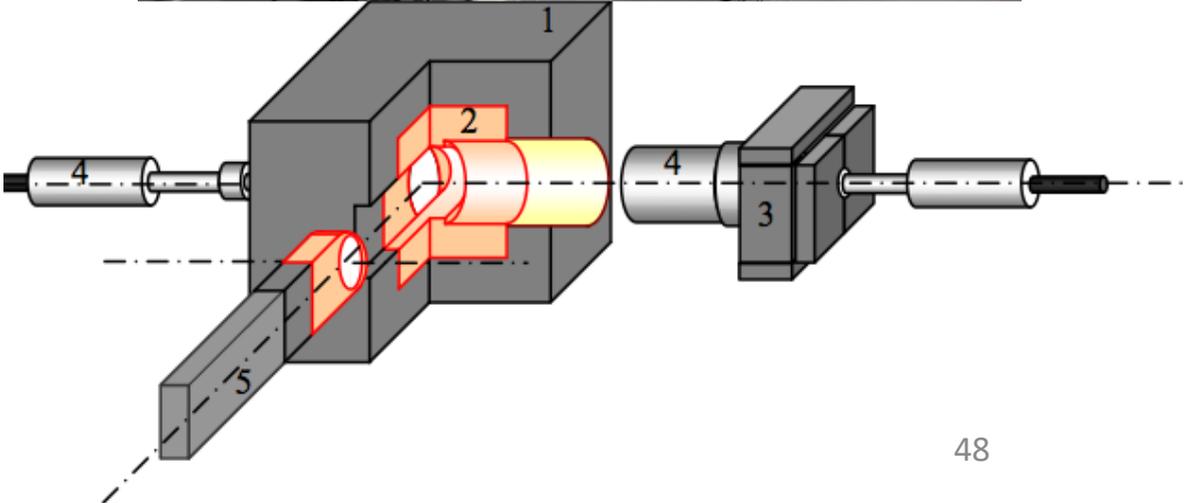
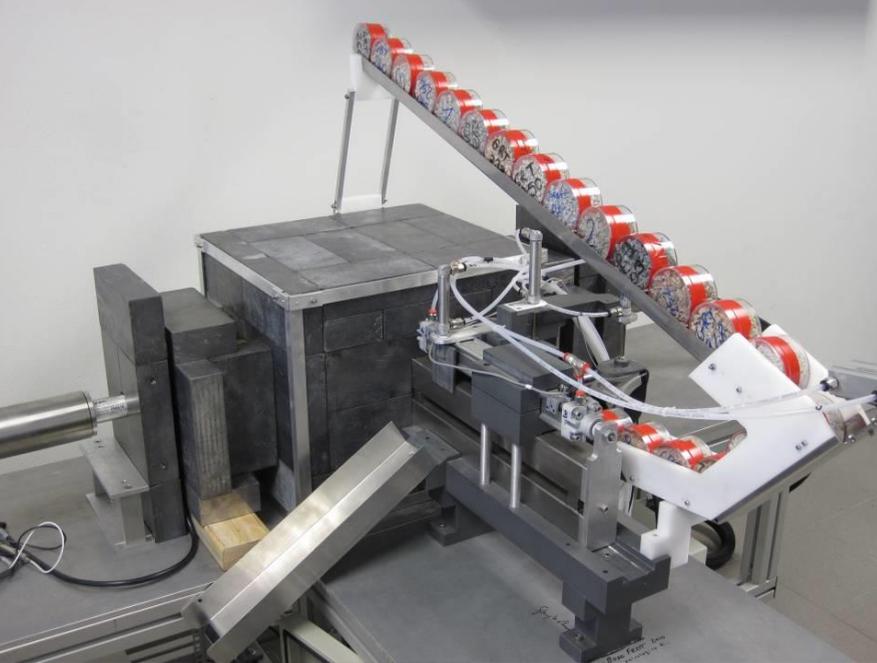
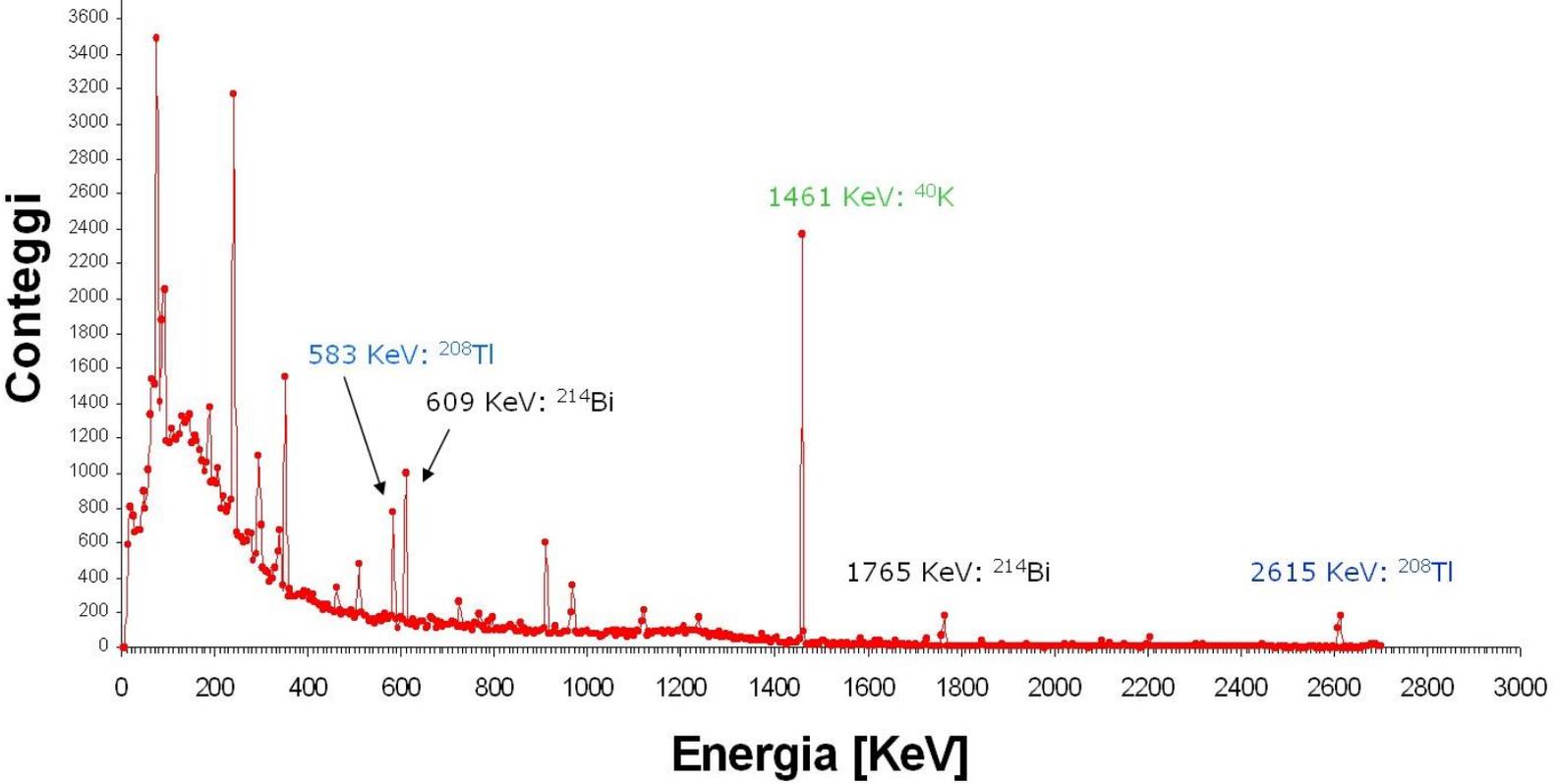
... in volo



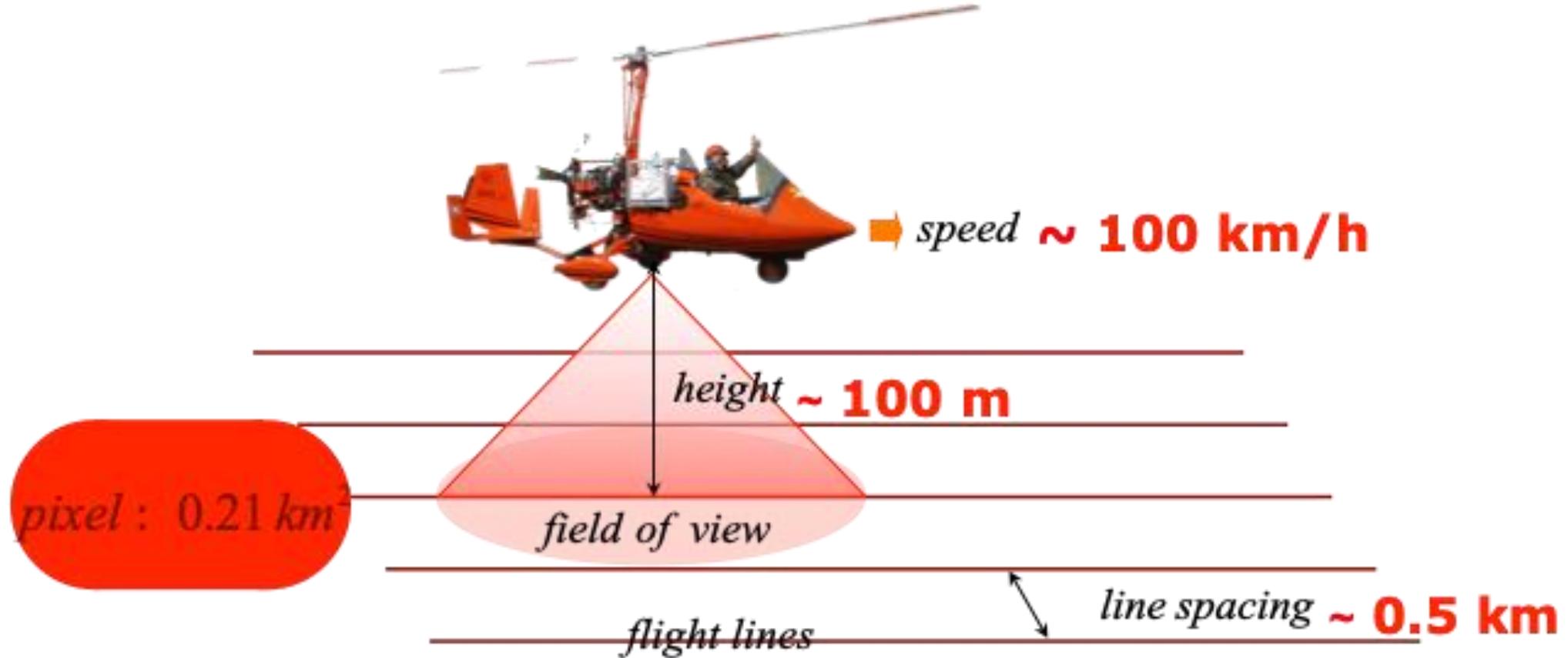
~ 100 m

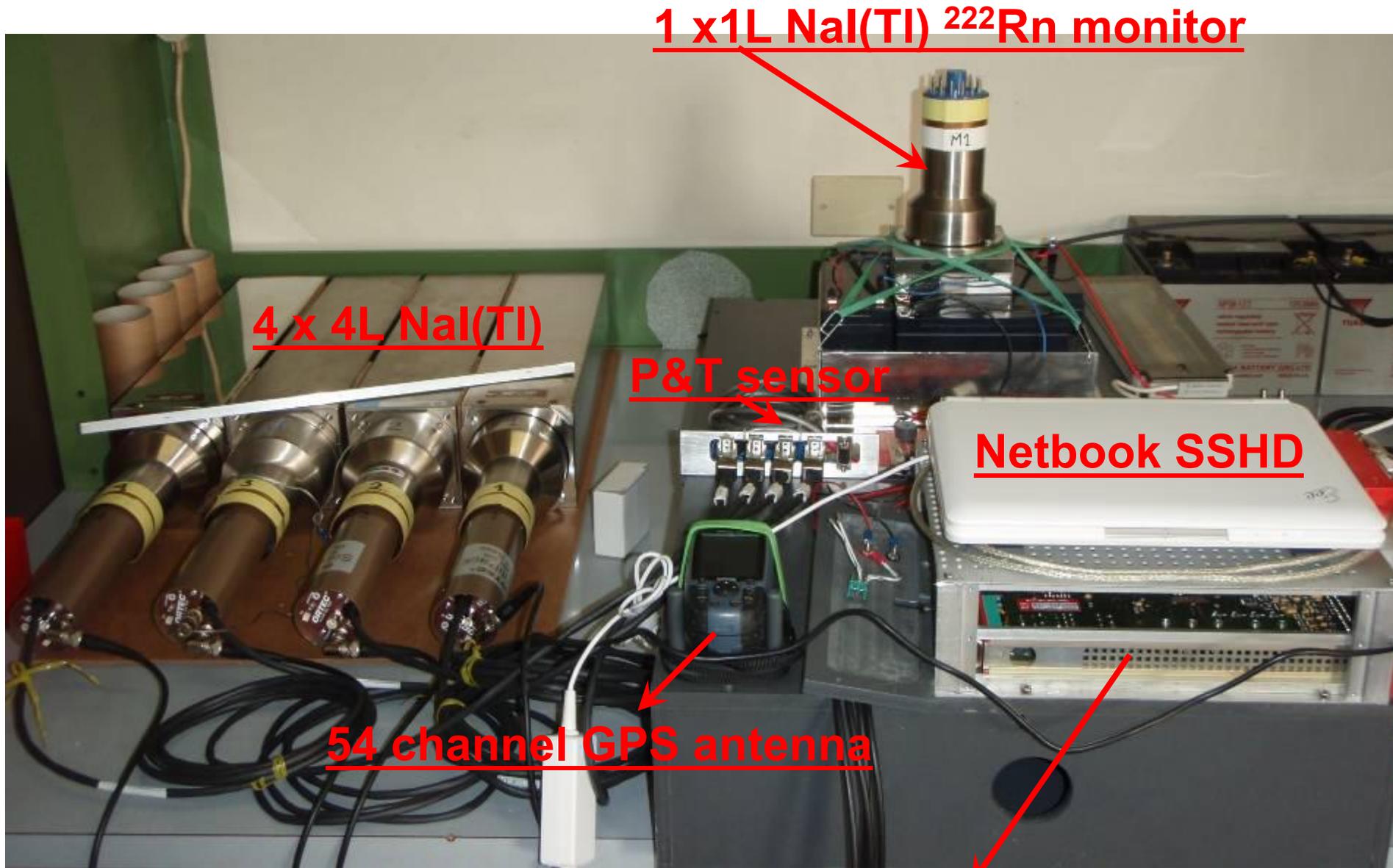


# Strumenti in laboratorio



# Setup in volo





1 x 1L NaI(Tl)  $^{222}\text{Rn}$  monitor

4 x 4L NaI(Tl)

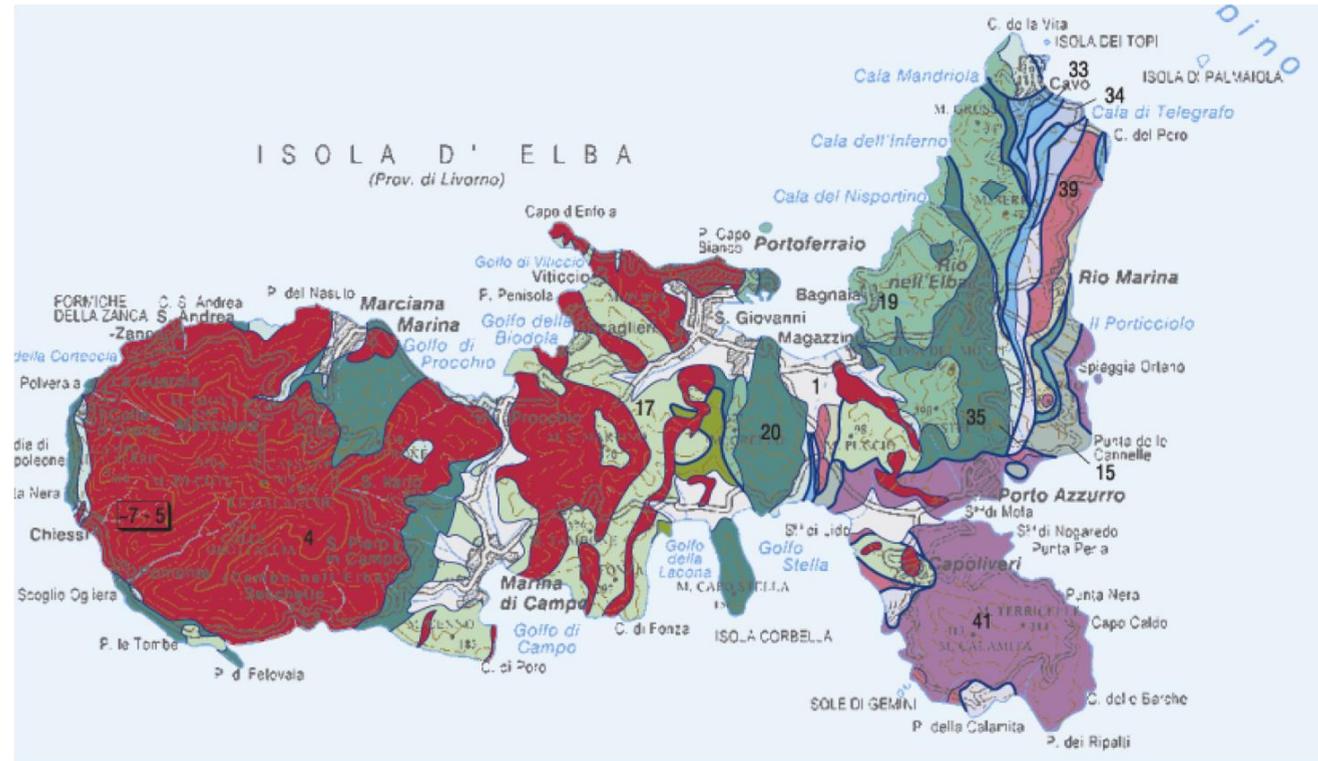
P&T sensor

Netbook SSHD

54 channel GPS antenna

4 channel ADC with MCA CAEN module

# Volo su Isola d'Elba



73 formations latitudinally oriented which are also representative of the Tuscany Appennini in a relatively small island (225 km<sup>2</sup>)

3<sup>rd</sup> June 2010

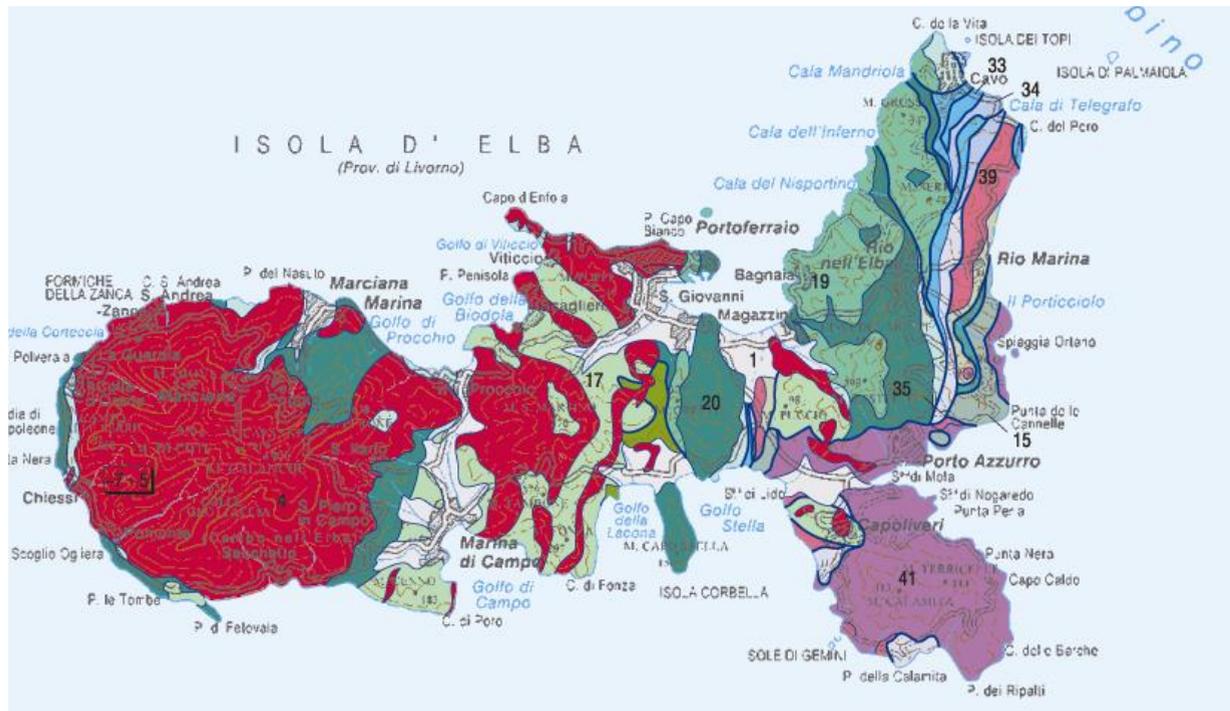
2.2 h

225 km<sup>2</sup>

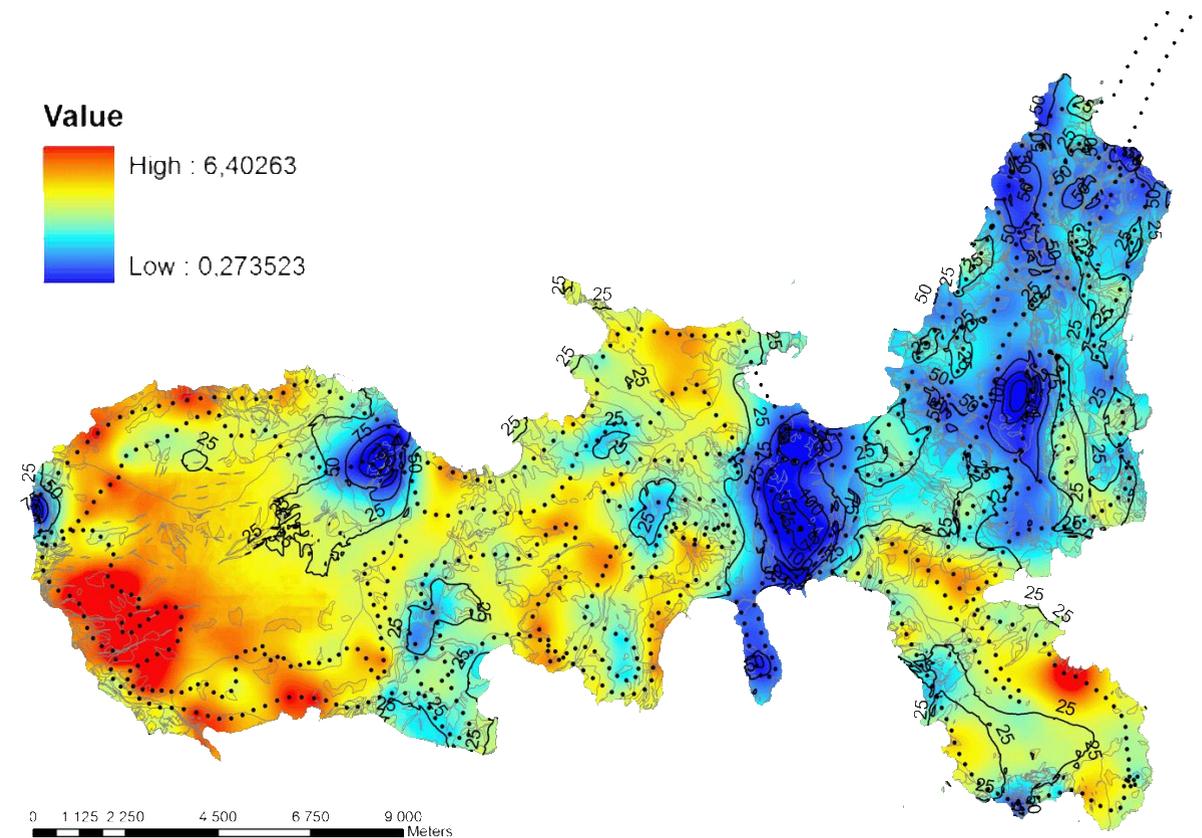
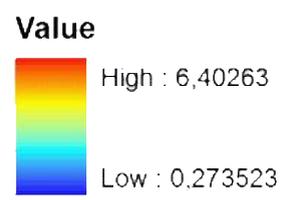
~100 m altitude

no good weather





### Legend



# Mappe della Toscana e del Veneto

