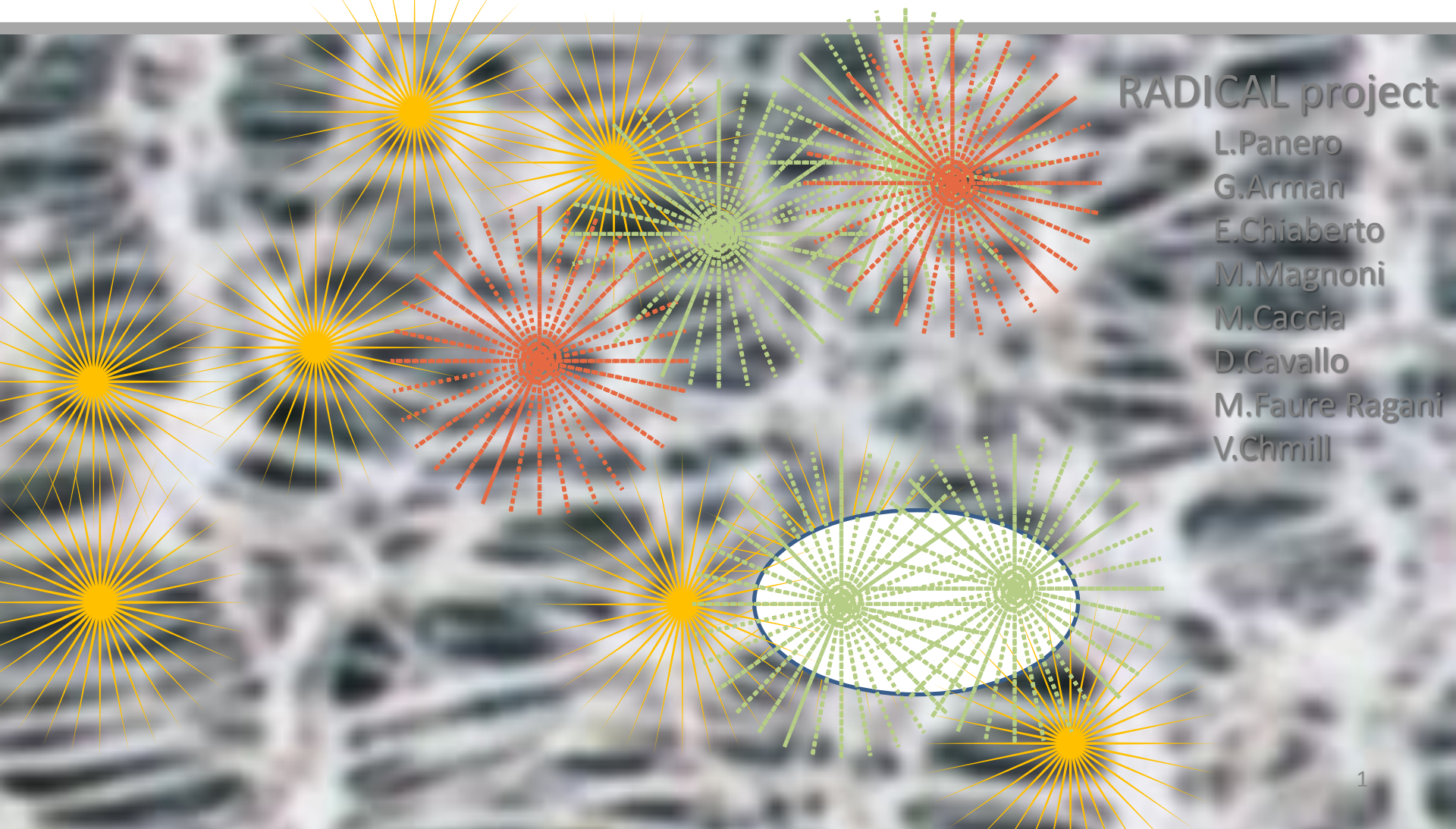


# MISURA DEL FATTORE DI EQUILIBRIO MEDIANTE CONTEGGIO BETA TOTALE



RADICAL project

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V.Chmill

$$E_{Rn} = C_{Rn} * t * DCF * F \quad (\text{dose efficace})$$

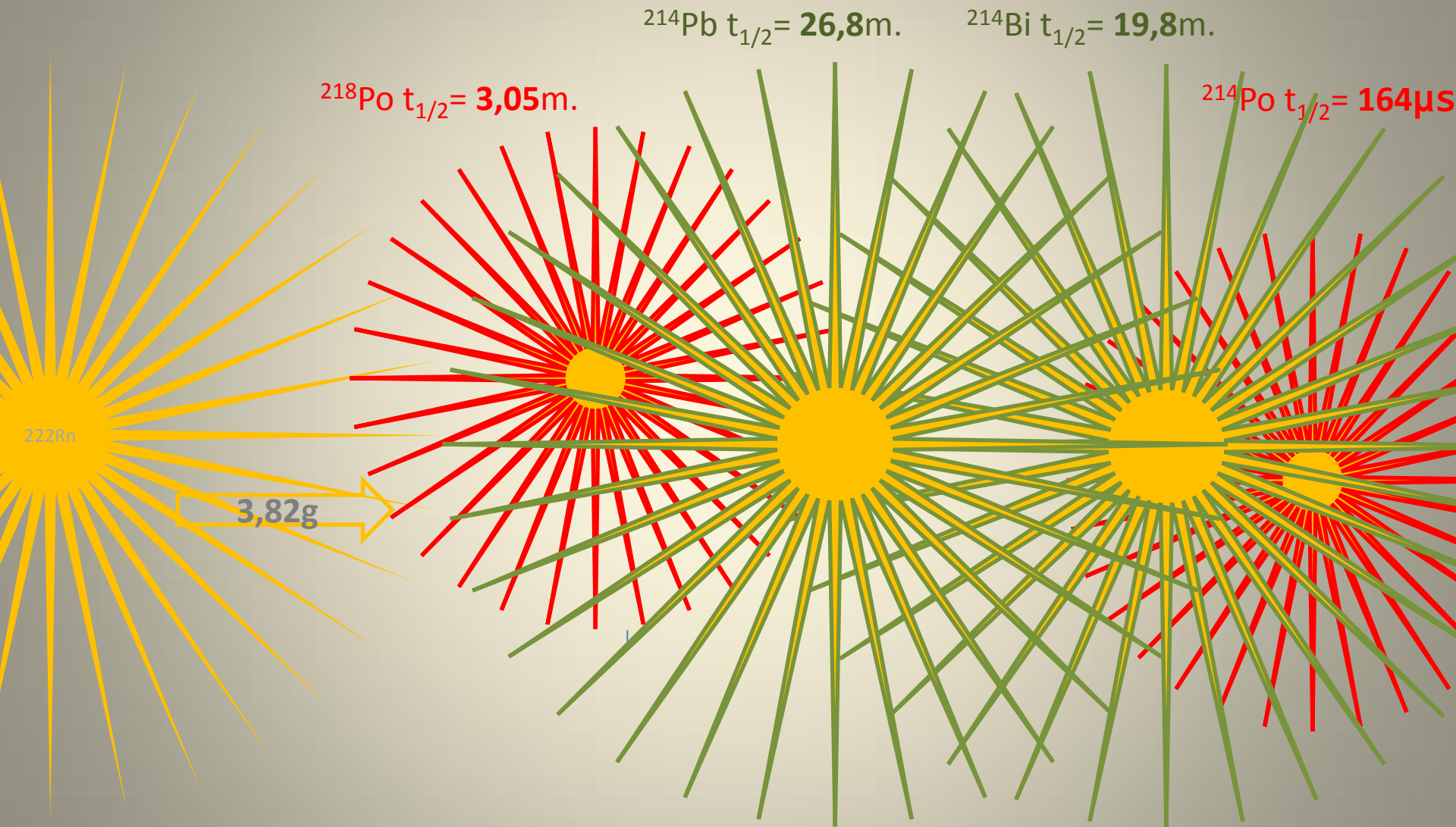
ICRP 65 /1994 :  $\langle F \rangle = 0.4$  (D.Lgs 241/2000)

**DCF** = 7.95 nSv/(Bqh/m<sup>3</sup>)  
>> D.Lgs 230/95 3nSv/(Bqh/m<sup>3</sup>)

Dose alfa  
al polmone

An anatomical diagram of the human respiratory system, including the trachea, bronchi, and lungs. A central point in the lungs is marked with a starburst of red lines, representing a localized radiation source. The diagram is rendered in a light blue, semi-transparent style against a light beige background.

# La Progenie del $^{222}\text{Rn}$ a breve vita



$$F = \frac{EEC}{[Rn]} = \frac{0.105 [Po] + 0.515 [Pb] + 0.380 [Bi]}{[Rn]}$$

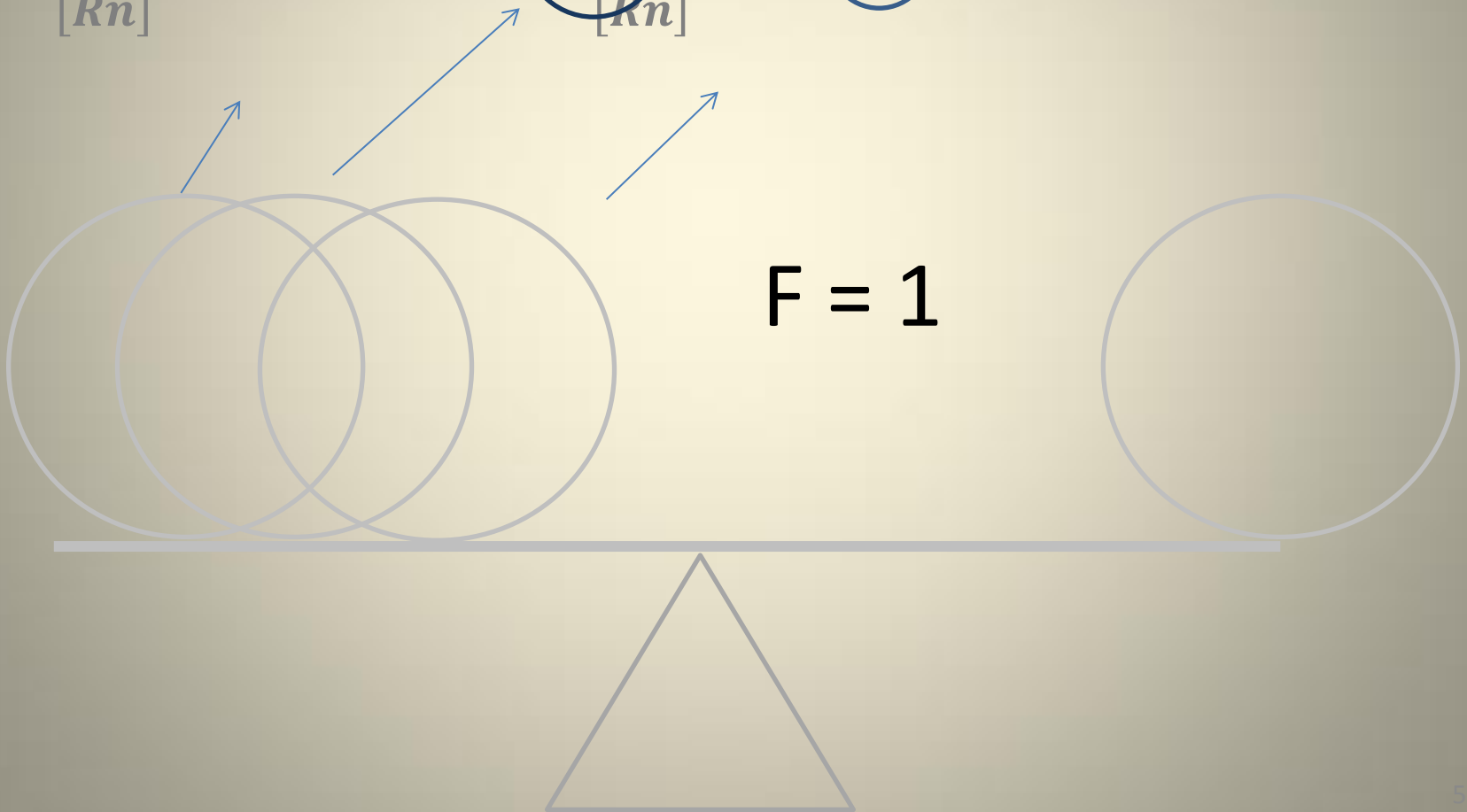
IL FATTORE DI **EQUILIBRIO**

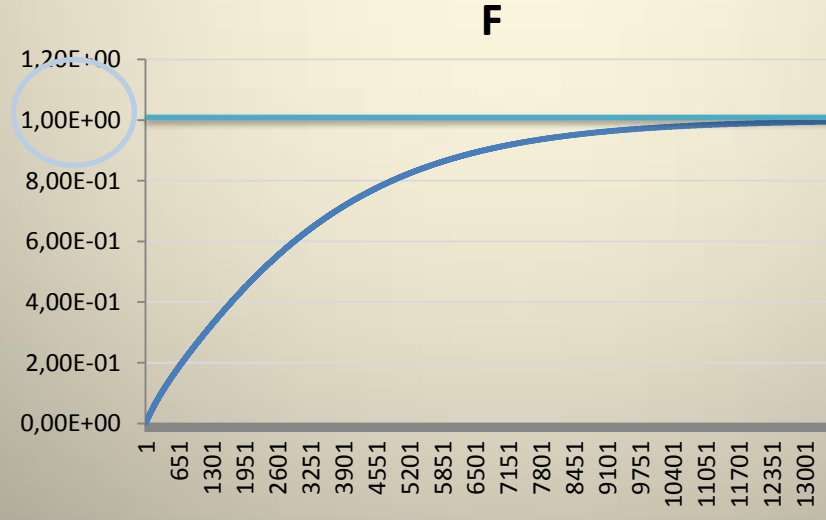
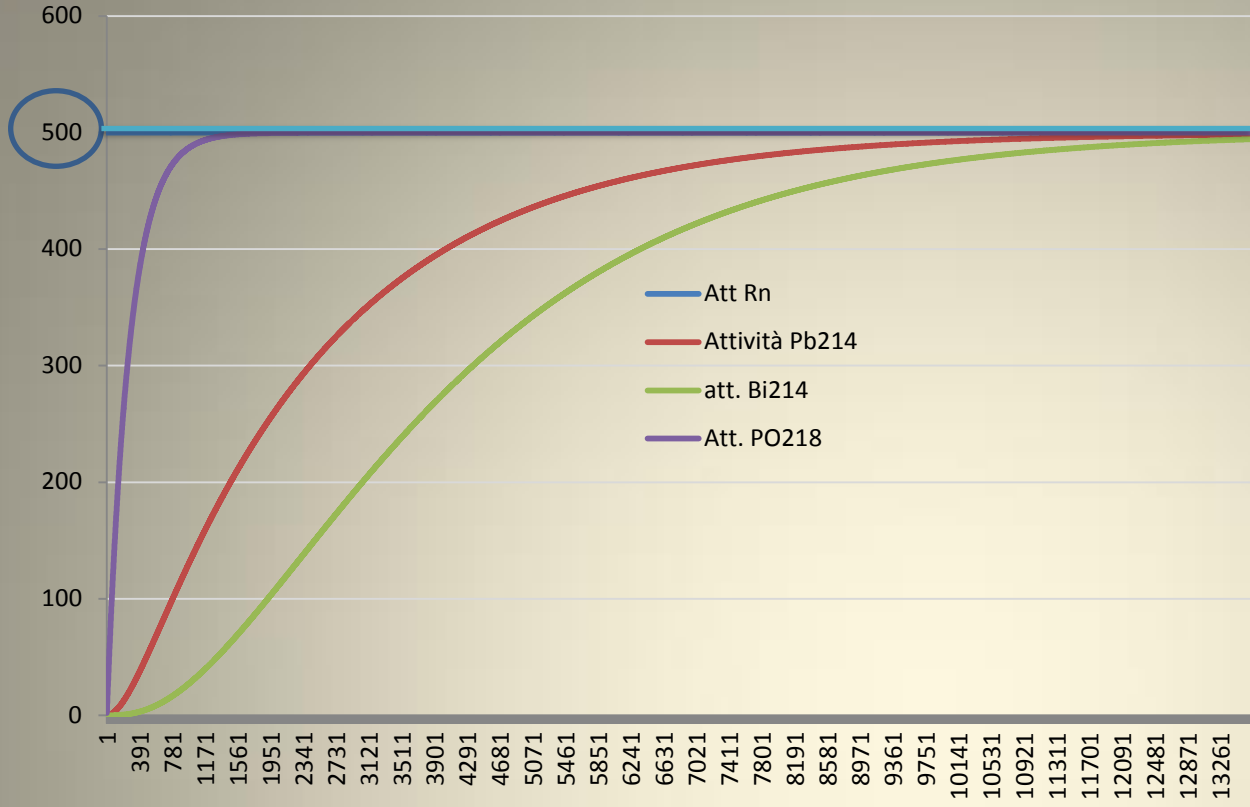


$$PAEC = \sum_j^n \frac{c_j}{\lambda_j} E_j \quad \text{N.B. } c_j / \lambda_j = N_j \text{ (atomi/m}^3\text{)}$$

$$EEC = \frac{PAEC}{\sum_j^n E_j / \lambda_j} = 0.105 [^{218}\text{Po}] + 0.515 [^{214}\text{Pb}] + 0.380 [^{214}\text{Bi}]$$

$$F = \frac{EEC}{[Rn]} = \frac{0.105 [Po] + 0.515 [Pb] + 0.380 [Bi]}{[Rn]}$$





L'EQ

UTILI

BRIO

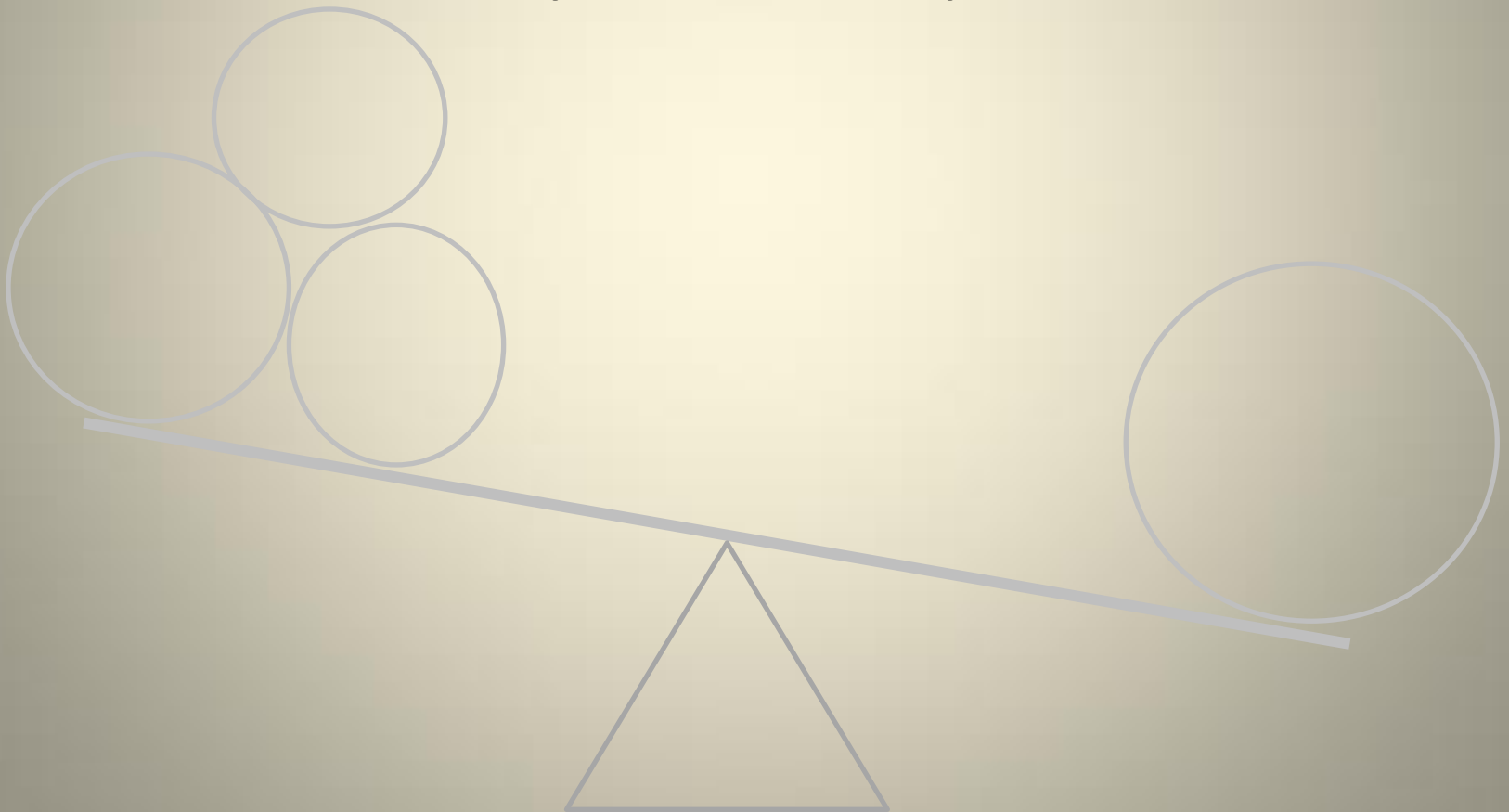
SEC

OLA

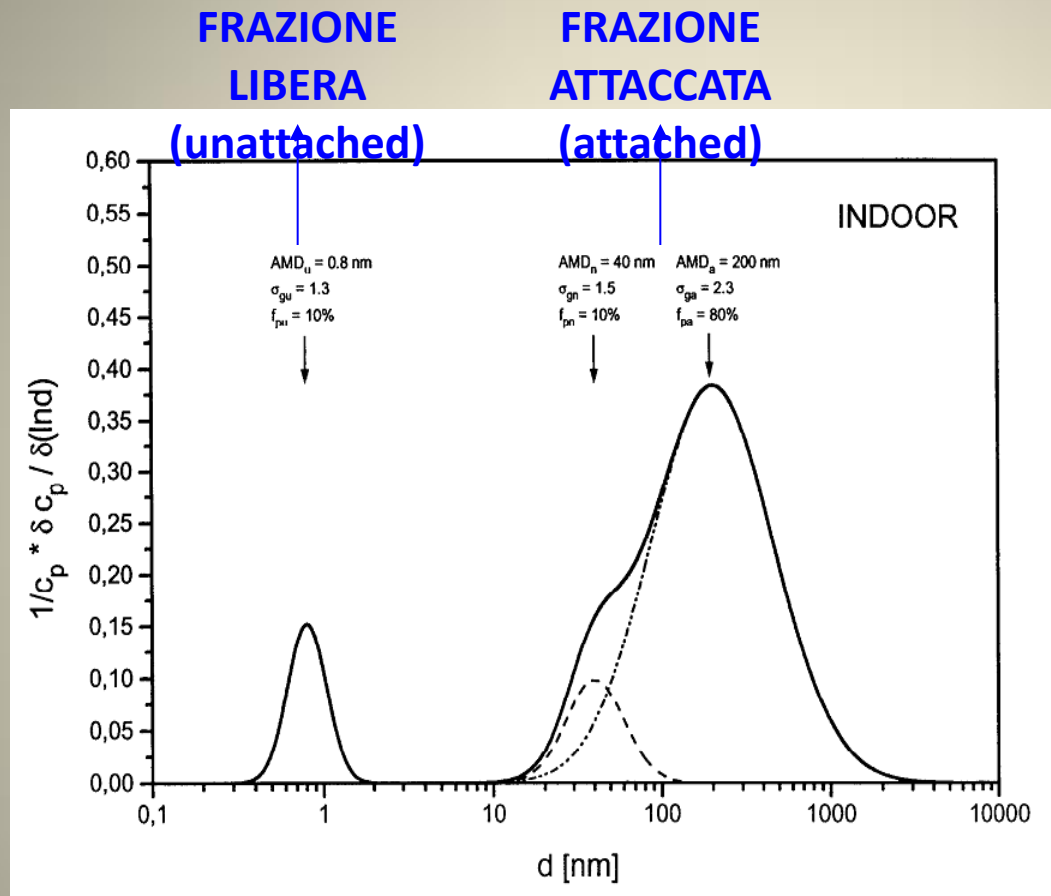
$$F = 0,4$$

ICRP 65/1994, D.Lgs 241/2000

$$0,3 < F > 0,8$$



# La distribuzione dimensionale dell'attività indoor

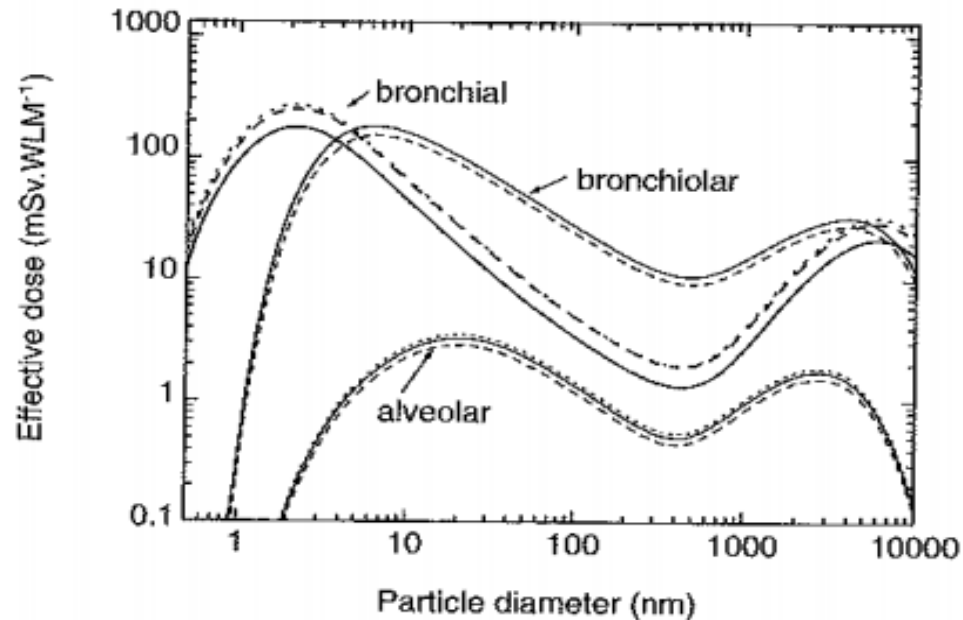


Porstendorfer, Environment International (1996)

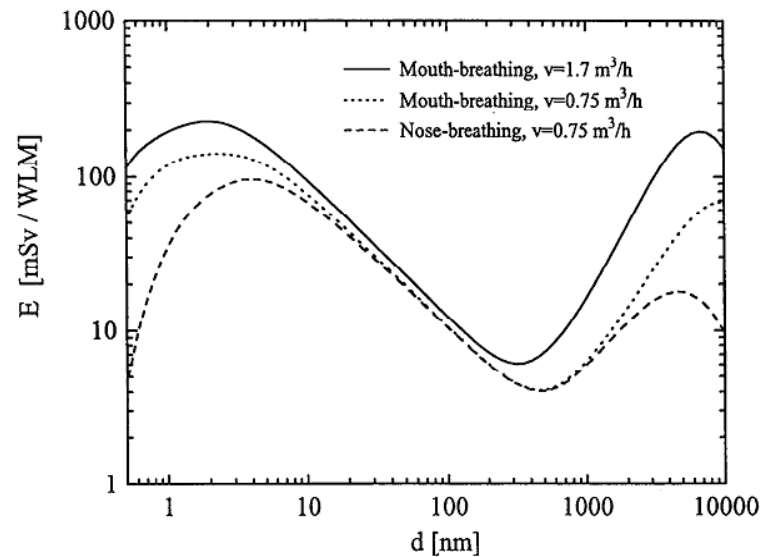
I massimo della distribuzione è compreso tra 100 nm e 500 nm dell'AMD (ACTIVITY MEDIAN DIAMETER)



Dai modelli dosimetrici  
(ICRP 66) →  
**LA DOSE dipende  
dalla dimensione delle  
particelle inalate**



Da studi epidemiologici  
→ Valore di riferimento  
**DCF = 8 \* nSv/Bqhm-3  
(ICRP 65/1994)**



Porstendorfer, Environment International (1996)

DCF (in effective dose) as function of the particle diameter obtained from model calculations (Zock 1996) based on the human respiratory tract model of ICRP 66 (target tissue: secretory and basal cells;  $w_R = 20$ ;  $w_{TBB} : w_{Tbb} : w_{TAI} = 0.333 : 0.333 : 0.333$ ;  $w_T = 0.12$ ).

# strumenti

*laboratorio*

**Monitore Radon**

**Campionatore di  
particolato**

**Contatore low det.level  
a gas Alpha-Beta TOT.**

**Spettrometro Gamma  
HPGe**

**Modello**

*campo*

**Monitore Radon**

**Campionatore di  
particolato**

**Contatore PORTATILE  
Alpha-Beta TOT.**

**Modello**

*il modello per il calcolo delle concentrazioni individuali della Progenie*

$$\frac{dN_i^{aria}}{dt} = \lambda_{i-1} N_{i-1}^{aria} - \lambda_i N_i^{aria} - \lambda_{rem} N_i^{aria}$$

# LA PROGENIE SU FILTRO: Modello di Raabe - Wrenn

Durante l'aspirazione dell'aria:

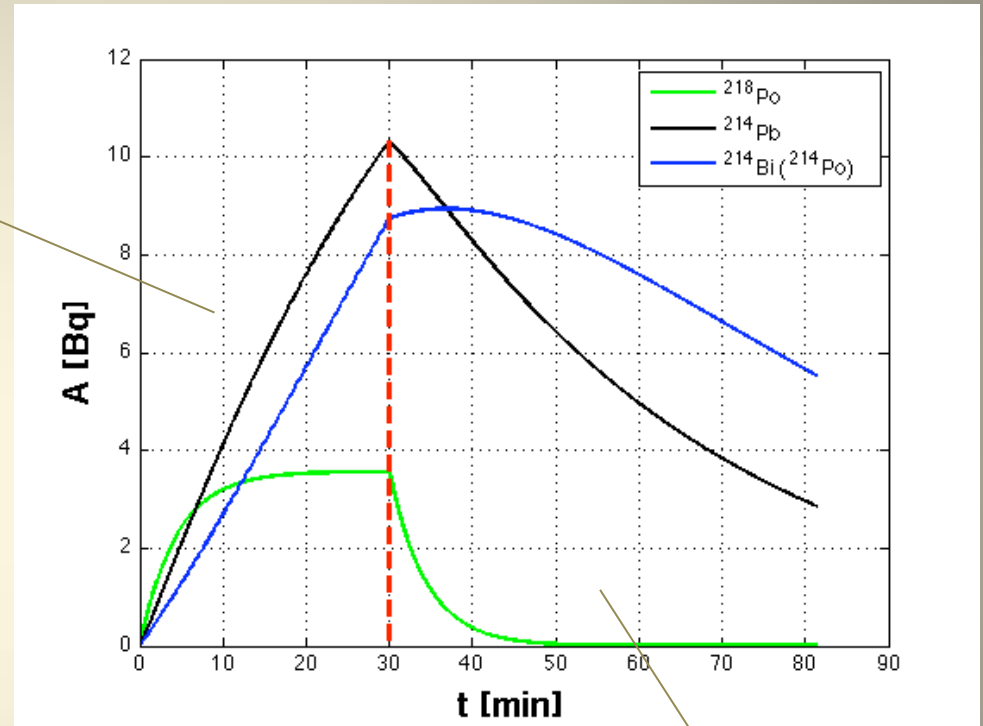
$^{218}\text{Po}$  si accumula per aspirazione e decade

$^{214}\text{Pb}$  si accumula per aspirazione,

si forma per decadimento di  $^{218}\text{Po}$  e decade

$^{214}\text{Bi}$  si accumula per aspirazione, si forma per decadimento di  $^{214}\text{Pb}$  e decade

$$^{214}\text{Po} = ^{214}\text{Bi}$$



Dopo l'aspirazione, durante la misura su filtro:

$^{218}\text{Po}$  decade

$^{214}\text{Pb}$  si accumula per decadimento di  $^{218}\text{Po}$  e decade

$^{214}\text{Bi}$  si accumula per decadimento di  $^{214}\text{Pb}$  e decade

$$^{214}\text{Po} = ^{214}\text{Bi}$$

# LA PROGENIE IN ARIA: «Room Model» di Jacobi-Porstendorfer

MODELLO A COMPARTIMENTI  
DEL COMPORTAMENTO DINAMICO DEL RADON E DELLA SUA PROGENIE  
CON DISTRIBUZIONE OMOGENEA DI ESSI  
IN ARIA E SULLE PARETI DELLA STANZA  
CONDIZIONI STAZIONARIE

LE CONCENTRAZIONI INDIVIDUALI DEI FIGLI POSSONO ESSERE ESPRESSE  
CON RELAZIONI ITERATIVE  
IN FUNZIONE DEI TRE PARAMETRI AMBIENTALI:

- VENTILAZIONE
- TASSO DI ADESIONE DEGLI IONI ALLE PARTICELLE DI AEROSOL
- TASSO DI DEPOSIZIONE DELLA PROGENIE ATTACCATA E NON ATT. ALLE PARETI (PLATE-OUT)

# Il nostro modello semplificato

Radon gas in equilibrio stazionario tra esalazione e ventilazione

Concentrazioni della Progenie diminuite da  
2 fattori ambientali o meglio “del LOCALE”:

- DECADIMENTO RADIOATTIVO  $\lambda$  = decay rate
- VENTILAZIONE  $\lambda_v$  = ventilation rate
- PLATE-OUT  $\lambda_{pl}$  = plateout rate

$$c_j = \frac{\lambda_j c_{j-1}}{\lambda_j + \lambda_v + \lambda_{pl}}$$



$$c_j = \frac{\lambda_j c_{j-1}}{\lambda_j + \lambda_{rem}}$$

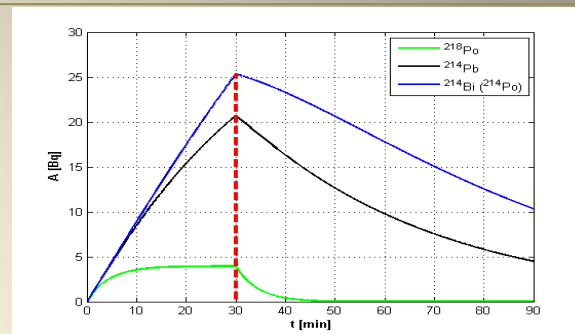
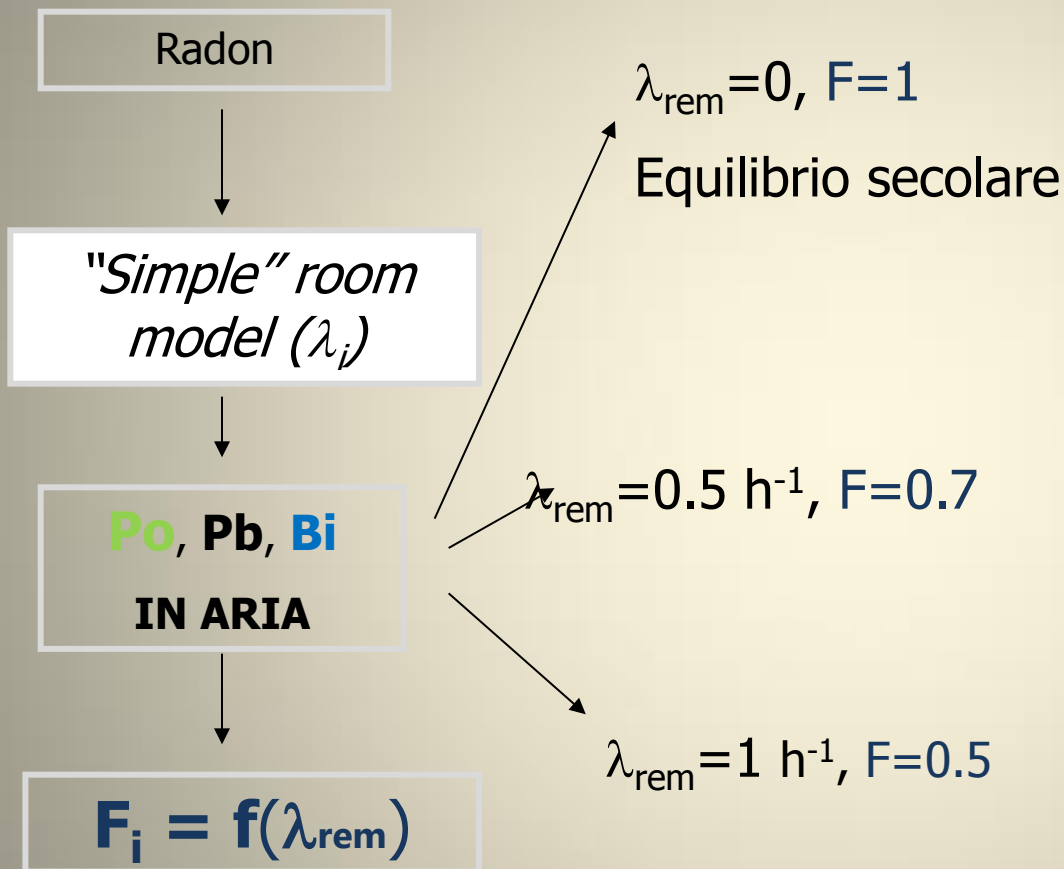


# il nostro modello

DALL'ARIA AL FILTRO

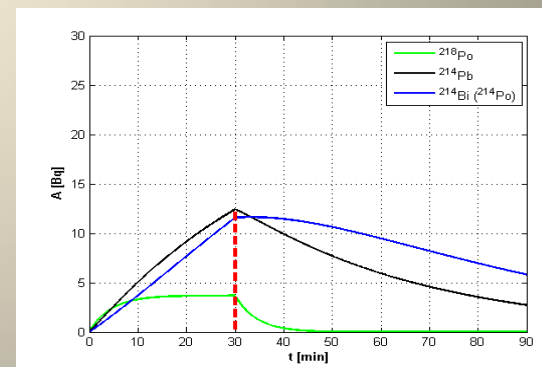
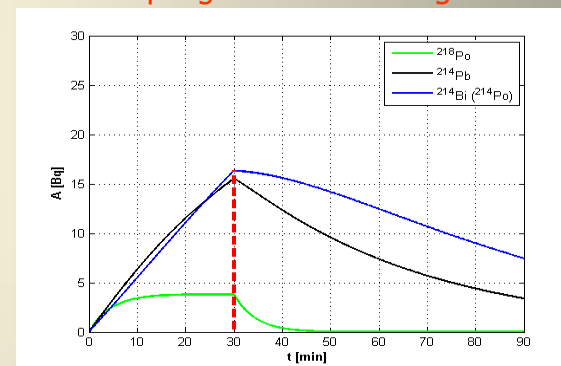
(Room Model)

Raabe-Wrenn



sampling

counting



CALCOLO

$C_j$  da  $C_{Rn}$ :

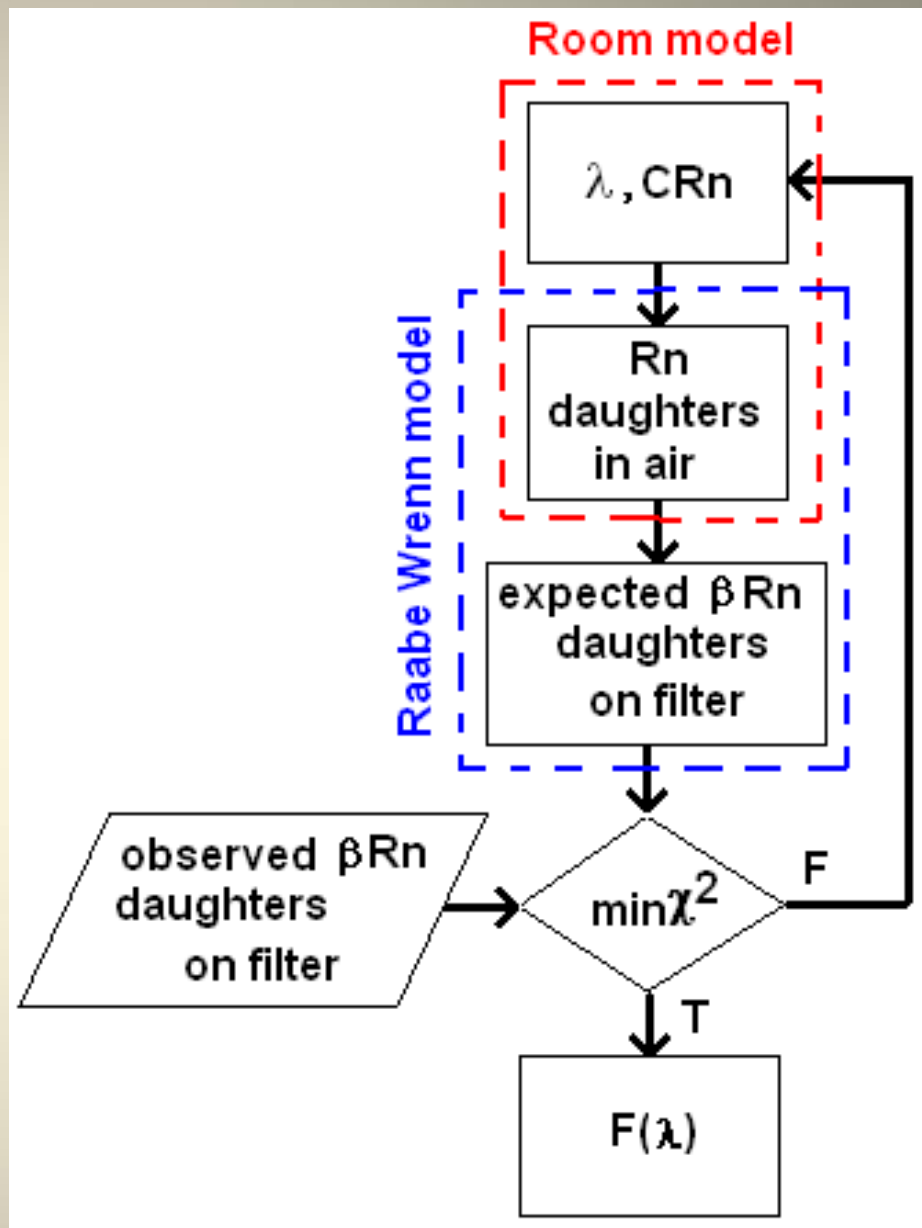
con

processo

iterativo =  $f(\lambda_{rem})$



$F = f(\lambda_1, \lambda_2, \lambda_3, \lambda_{rem})$

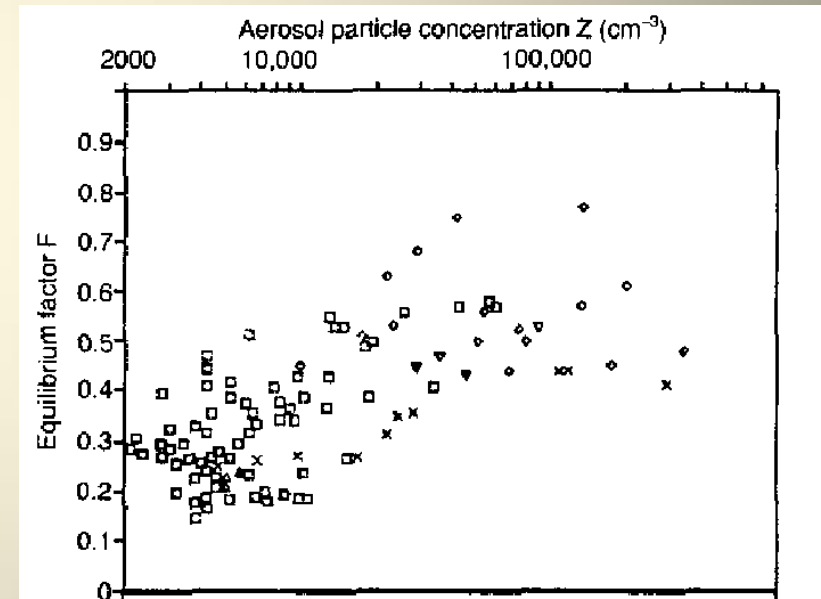
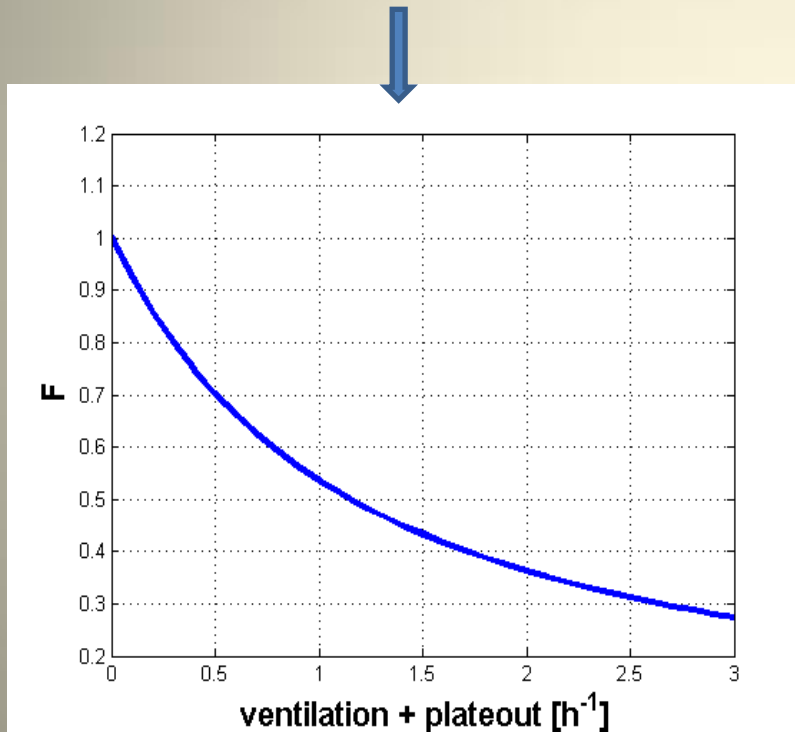


# Fattore di equilibrio F

dipende in modo diverso da:

- Ventilazione
- Plate-out

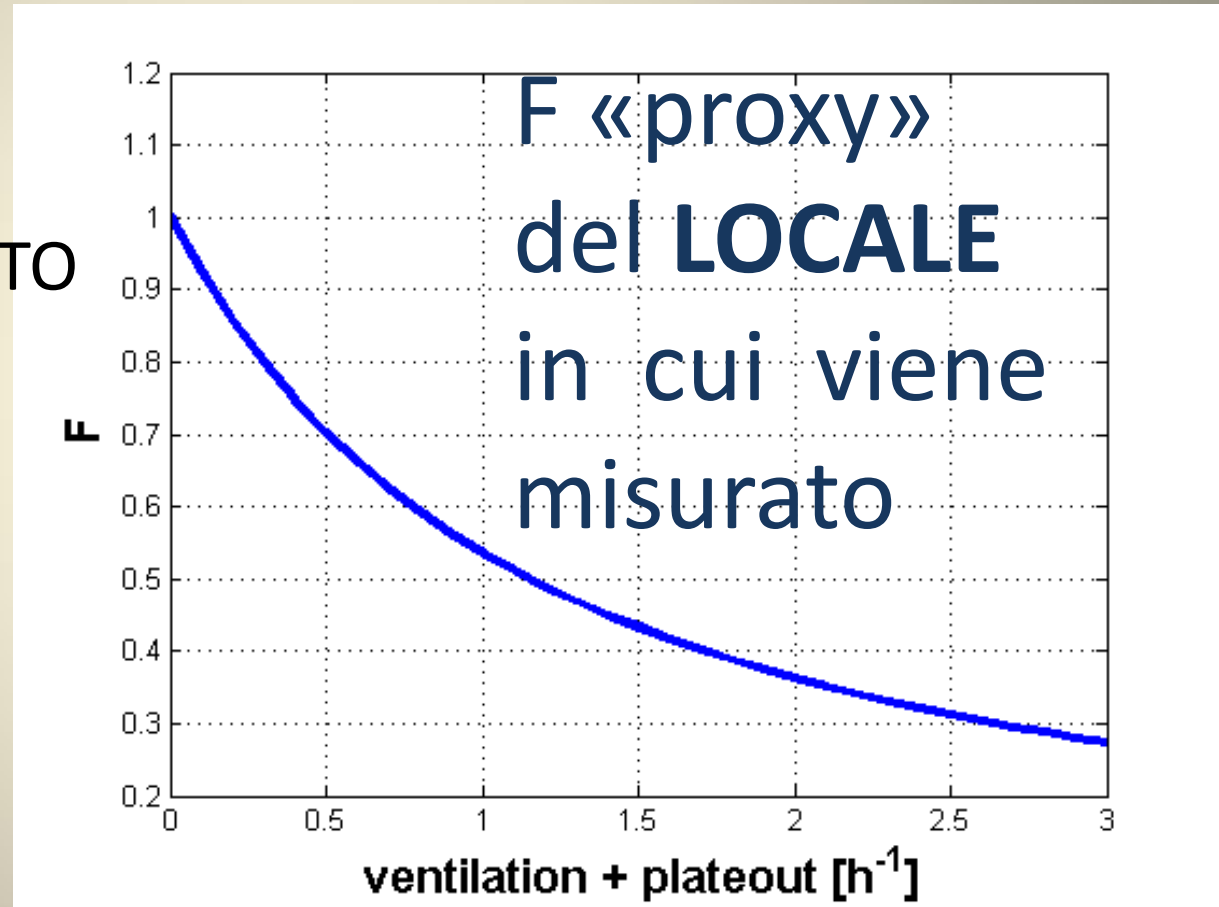
Caratteristiche Aerosol



J.Porstendorfer, RPD (1992)

# F FUNZIONE ESPONENZIALE della $\lambda_{rem}$

I CALCOLI  
DIMOSTRANO  
CHE **F**  
E' BEN APPROSSIMATO  
SEMPLICEMENTE  
CONSIDERANDO  
UNA DIPENDENZA  
DEL 1° ORDINE  
DA UN TASSO DI  
RIMOZIONE UNICO  
E IDENTICO  
PER CIASCUN FIGLIO



# Il conteggio $\alpha\beta$ TOT.

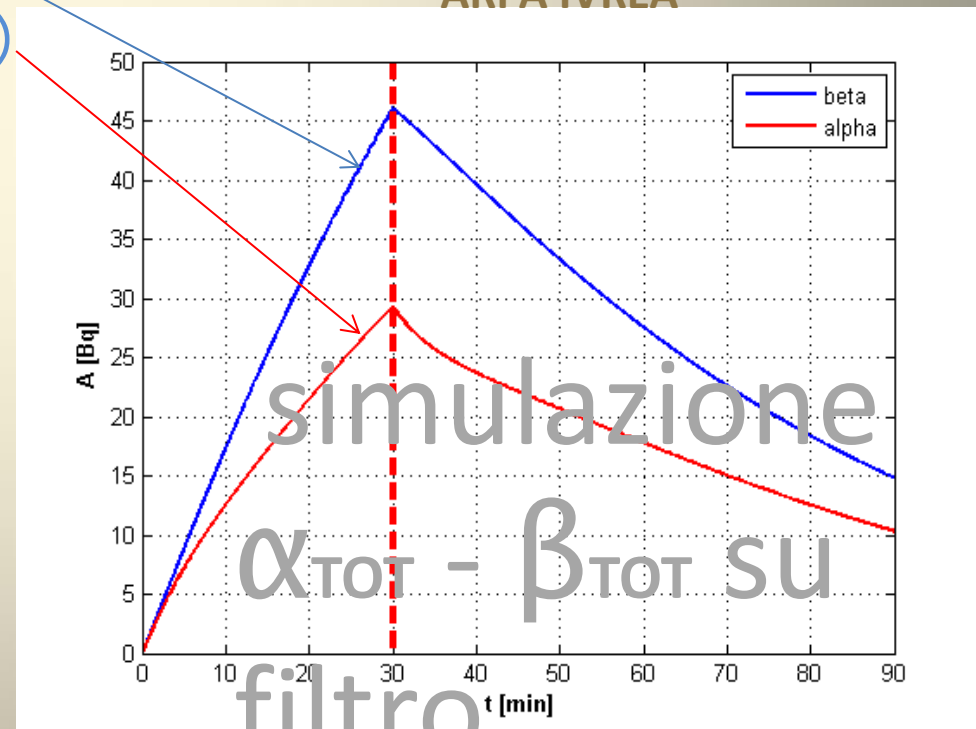
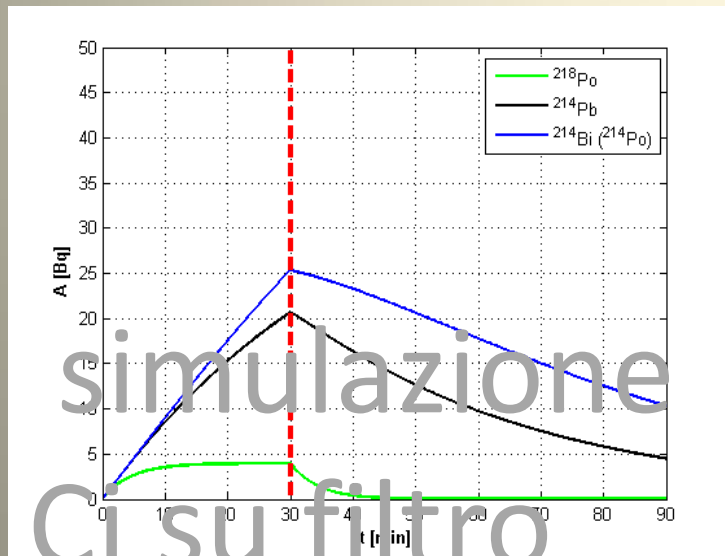
- Low-level gas proportional counter (Ar90%-10%CH<sub>4</sub>)
- Low detection limits: (i.e. alpha <sup>241</sup>Am: 12 mBq for 1 hour counting, beta <sup>90</sup>Sr: 22 mBq for 1 hour counting)
- Pb shielding and guard counter to account for background



Berthold LB-770  
ARPA IVREA

$$\text{Beta TOT} = \text{Pb} + \text{Bi}$$

$$\text{Alpha TOT} = {}^{218}\text{Po} + {}^{214}\text{Po}(=\text{Bi})$$



# Risultati in laboratorio

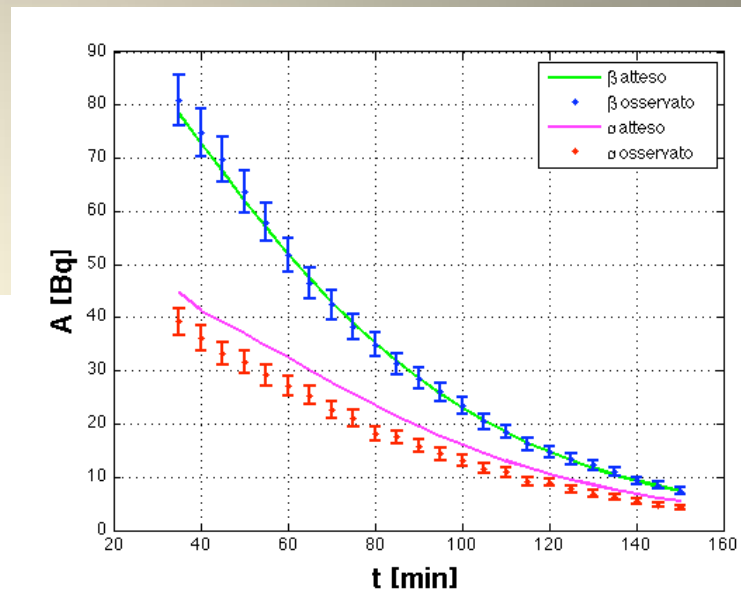
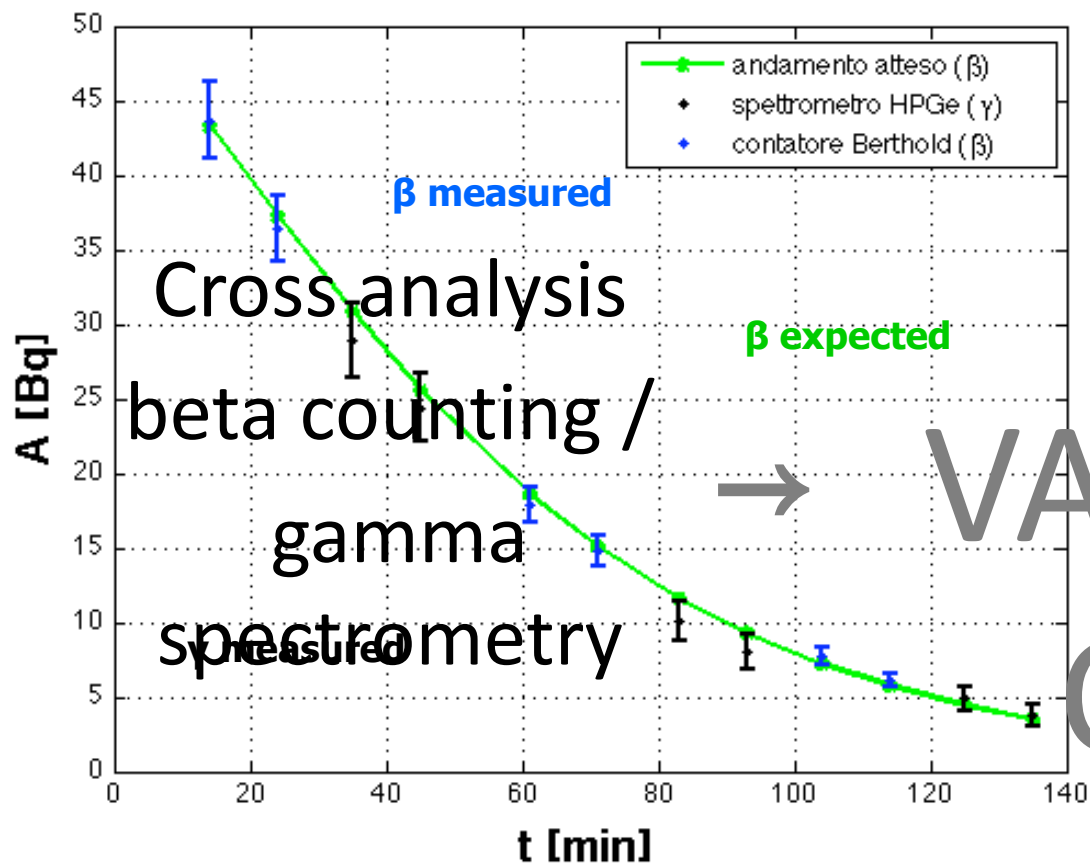
I/min	T (min)	Rn (Bq/m <sup>3</sup> )	$\lambda$ ( h <sup>-1</sup> )	F
9	30	288±63	0.64±0.13	<b>0.66±0.18</b>
9	30	261±42	0.65±0.12	<b>0.64±0.12</b>
9	30	100±33	1.60±0.20	<b>0.42±0.16</b>
9	120	250±40	1.00±0.13	<b>0.54±0.10</b>
8	30	99±31	1.55±0.18	<b>0.42±0.16</b>
5	30	108±26	1.30±0.17	<b>0.47±0.14</b>
5	30	105±21	1.00±0.16	<b>0.54±0.16</b>
5	30	107±22	1.10±0.17	<b>0.51±0.15</b>



# In laboratorio: Alpha-beta Vs. Gamma Spectrometry

Efficienze  $\alpha\beta$ :

- $\varepsilon_{\text{alpha}} = 0.37 \text{ cps/Bq}$
- $\varepsilon_{\text{beta}} = 0.47 \text{ cps/Bq}$



VALIDAZIONE  
CALIB.  $\beta$



Misura

Beta TOT. in camp

# Misuratore Alpha-Beta TOT. in campo



(LUDLUM MEASUREMENTS - TX, USA)  
ARPA IVREA

## Modello 3030P Dual channel $\alpha\beta$ counter

Rivelatore Built-in PIP'S

$\epsilon_{\alpha}$  ( $4\pi$ ): 39%  $^{239}\text{Pu}$

$\epsilon_{\beta}$  ( $4\pi$ ): 23%  $^{99}\text{Tc}$

Fondo acc. in campo  $10\mu\text{R/hr}$  :

10 min cont.fondo  $\alpha$  : 0.6 cpm

10 min cont.fondo  $\beta$  : 27,6 cpm

Crosstalk acc. ( $10\mu\text{R/hr}$  field) :

alpha to beta crosstalk ( $\leq 5\%$ ) : 1,50%

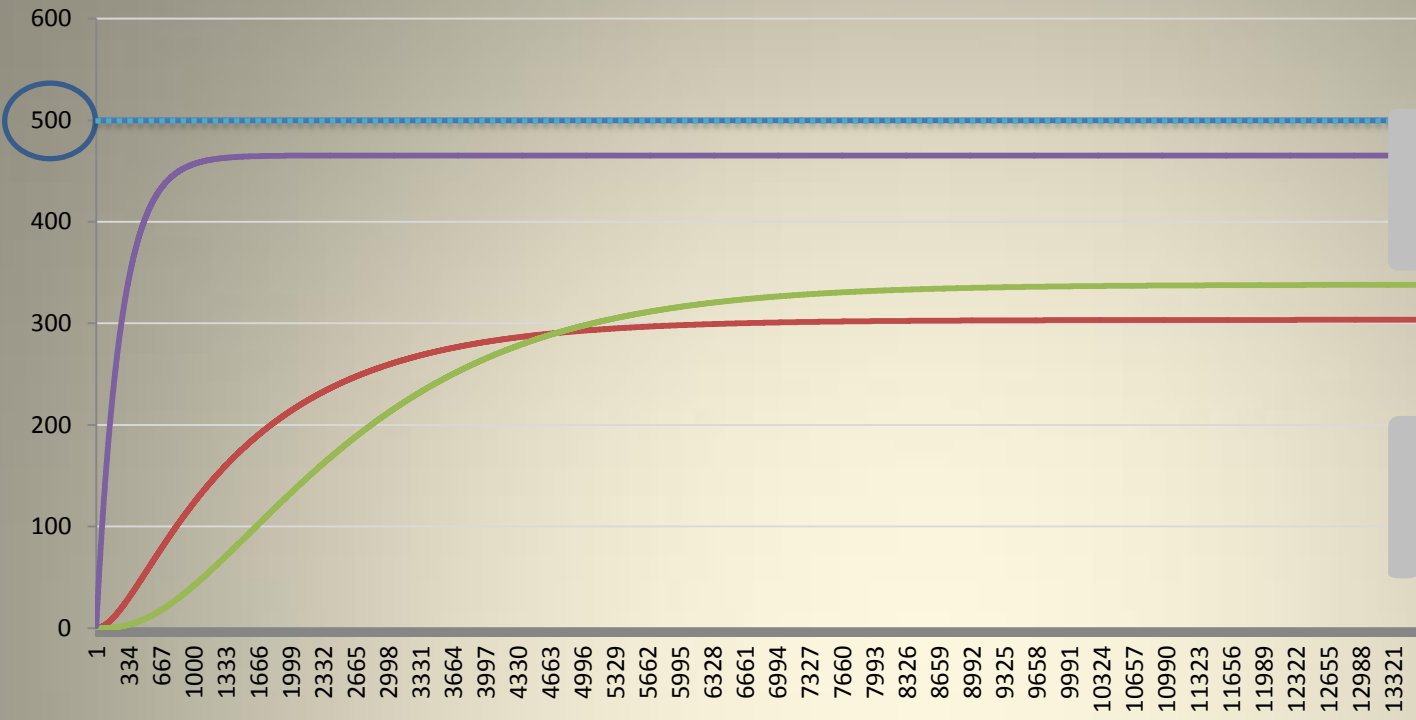
beta to alfa crosstalk ( $\leq 0.1$ ) : 0,000%

CALIBRAZIONE : Fondo  $\leftrightarrow$   $\epsilon$   $\leftrightarrow$  crosstalk

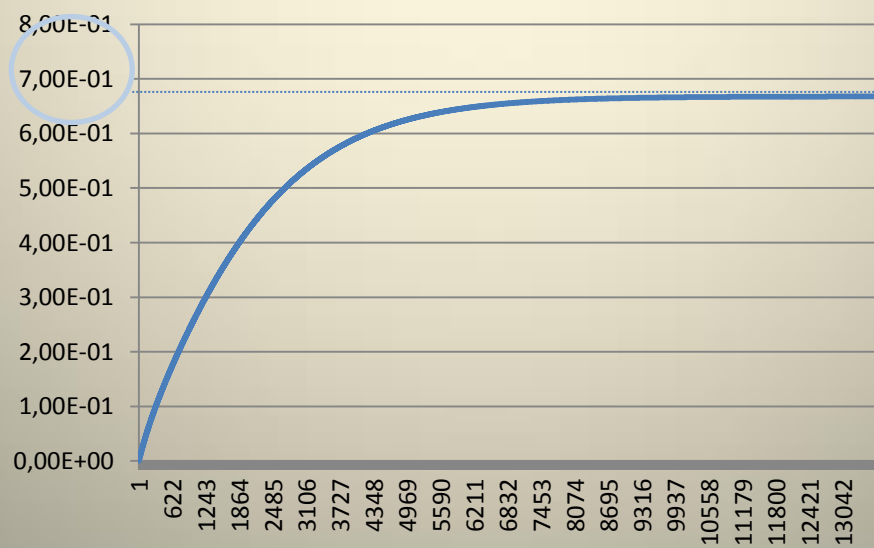
# PROTOCOLLO DI MISURA IN CAMPO DEL FATTORE DI EQUILIBRIO F

- Monitore Radon in continuo RADIM5B (count int. 1h)
- Filtro Millipore AA 0,8 $\mu$ m – d=37mm
- Tempo campionamento aerosol : 30 min
- Flusso aria : 9 l/min
- Conteggio Beta tot. : Counting interval = 5 min  
Conteggio : 8 - 12 cicli
- Modello di calcolo esteso alla  $C_{Rn}$  variabile





**F = 0,66**



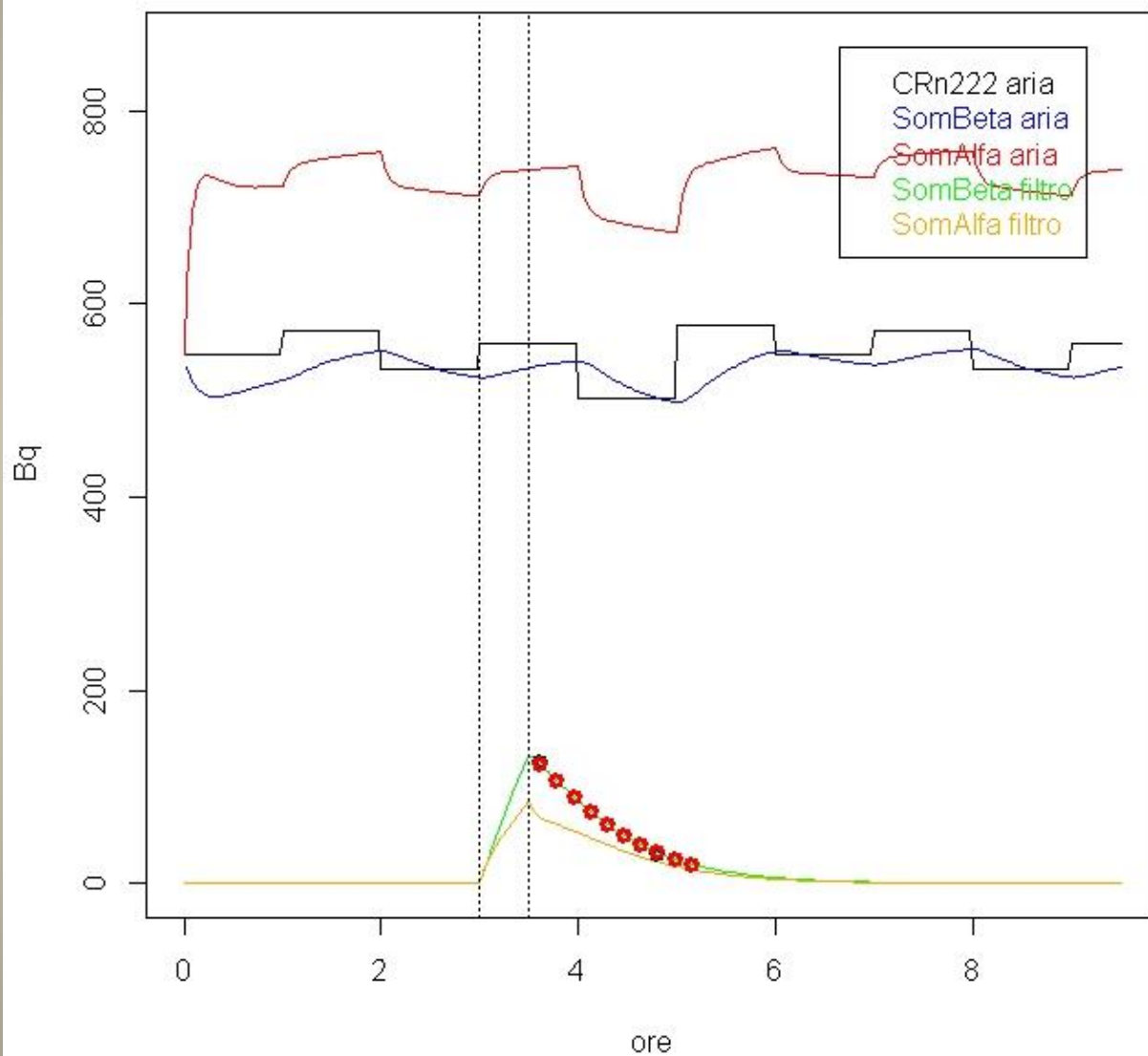
E. S.  
NON  
ESIS  
TE!?



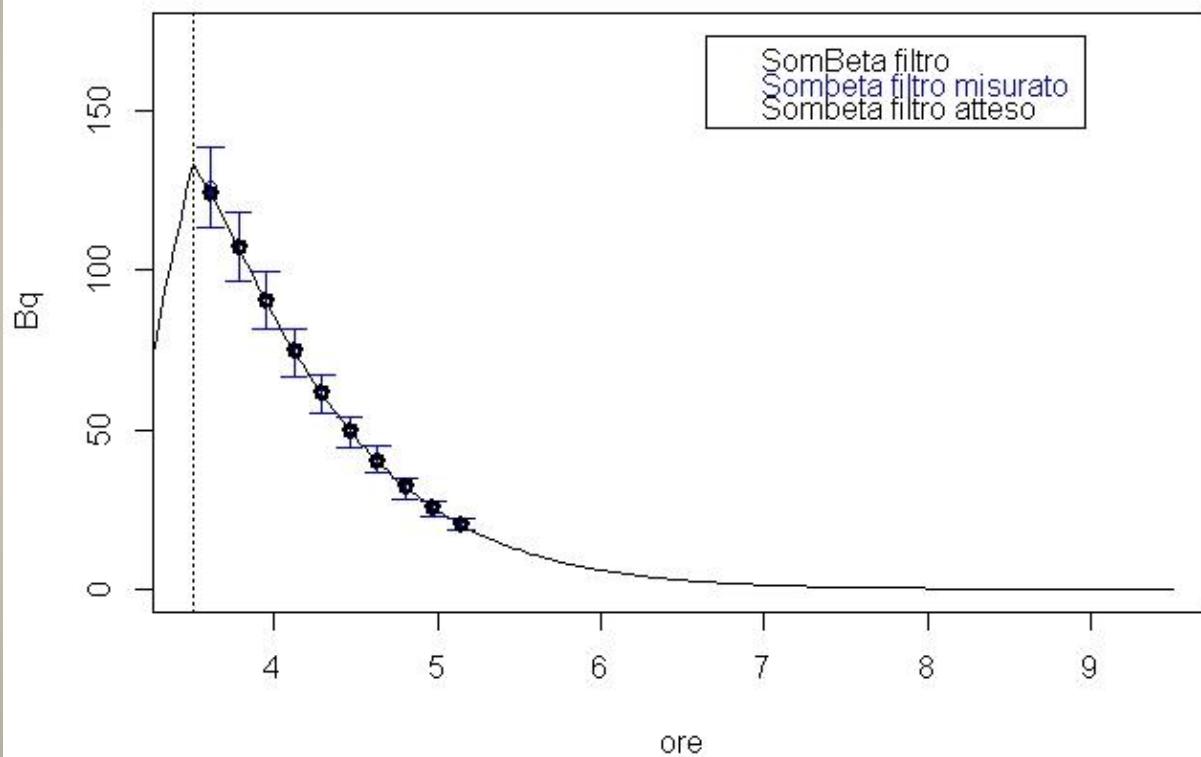
# F da misure $\beta$ in campo

	LUDLUM 3030P			
	$\lambda_{\text{rem}}(\text{h}^{-1})$	F	$C_{\text{Rn}}(\text{Bq}/\text{m}^3)$	$\chi^2$
IVREA	$0.96 \pm 0.22$	<b>0.55</b>	$560 \pm 52$	0.01841
BOSSEA1	$0.1 \pm 0.15$	<b>0.92</b>	$770 \pm 79$	0.00997
BOSSEA2	$0.04 \pm 0.14$	<b>0.96</b>	$762 \pm 78$	0.01864

### prodotti di decadimento filtro prima durante dopo il prelievo



### andamento attività post prelievo e misure effettuate e attese



## IL FUTURO PROSSIMO

# MISURA IN CAMPO DI RADON E PROGENIE

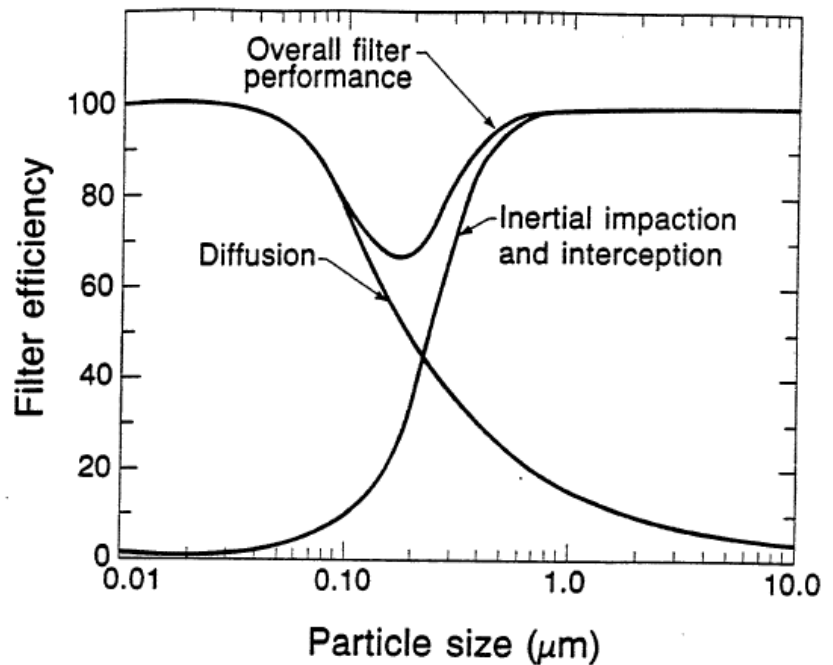


A.R.P.A. VALLE D'AOSTA

## SARAD EQF 3220

### 3 Si detectors :

- Progenie unattached
- Progenie attached
- Radon gas ( $^{222}\text{Rn}$  e  $^{220}\text{Rn}$ )



# Dose conversion factor (DCF)

$$E = R_n * T * F * \text{DCF}$$

- $\text{DCF} \approx a * f_{\text{free}} + b * f_{\text{att}}$ 
  - $a, b = \text{coefficients}$   $a > b$
  - $f_{\text{free}} \approx 10\text{-}20\% f_{\text{att}}$

