Experimental study of the electric charge of a radioactive nanometric aerosol

R. Abou-Khalil[1,2] - S. Della-Negra[3] - N. Michielsen[1]

A. Nourreddine[2] - E. Baussan[2]

(1)- *IRSN/DSU/SERAC/LPMA*
(2)- *IPHC/DRS/RaMsEs* – Université Louis Pasteur Strasbourg I
(3)- Institut de Physique Nucléaire d'Orsay (*IPNO*)

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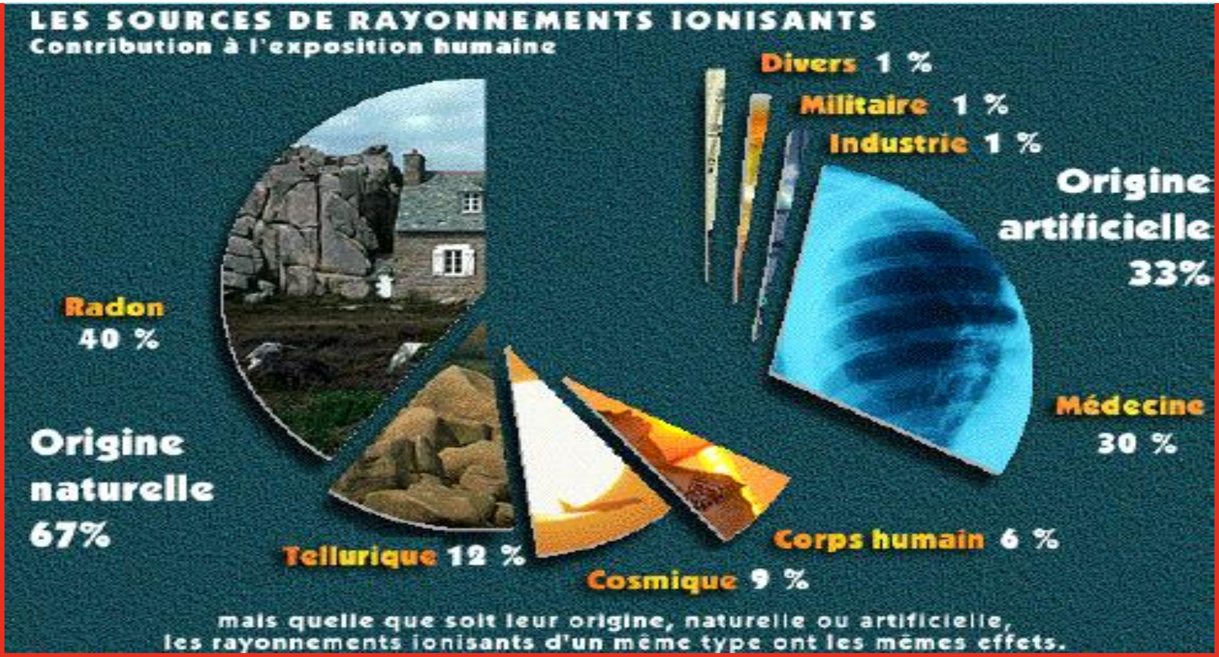
Outline

- Research goals
- Introduction
- Experimental setup
- Time-of-Flight measurements
- Results and discussion
- Conclusions and perspectives

Research goals

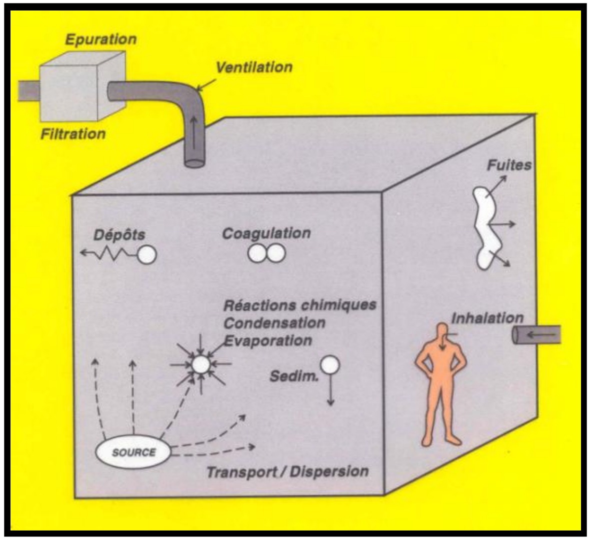


Research goals

Context

The behavior of radioactive aerosols (radon's progeny) in a medium depends on:

- Their size
- Their electric charge



Cohen *et al.* (1998) show the effect of the particles' charge on their deposition in the breathing apparatus. Their results show a deposition from 5 to 6 times greater, for 20 and 125 nm charged particles, than for neutral particles of the same size.

Industry

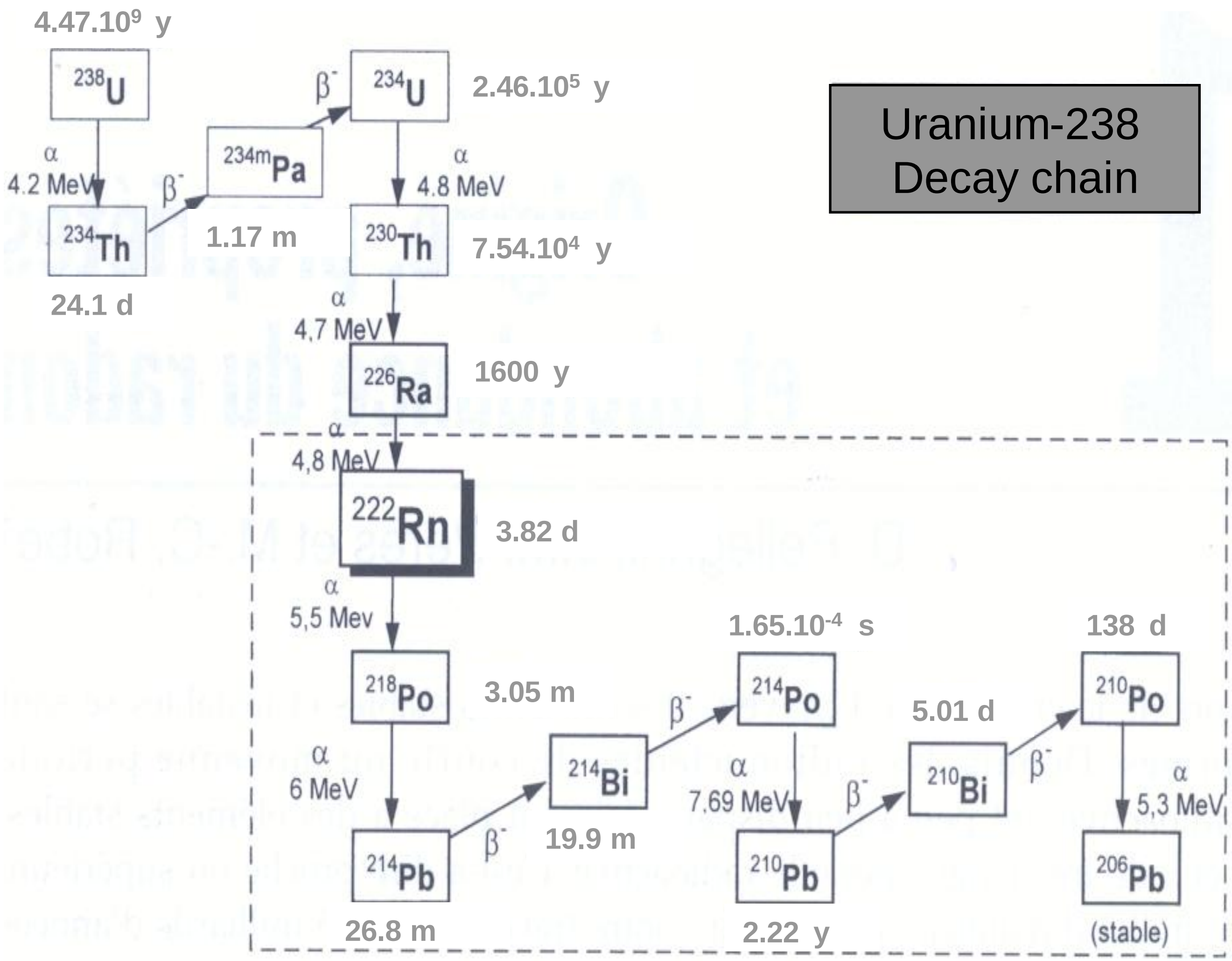
Health consequences

Deposition on surfaces and sampling systems

- Deposition in dwellings
- Deposition in the breathing apparatus

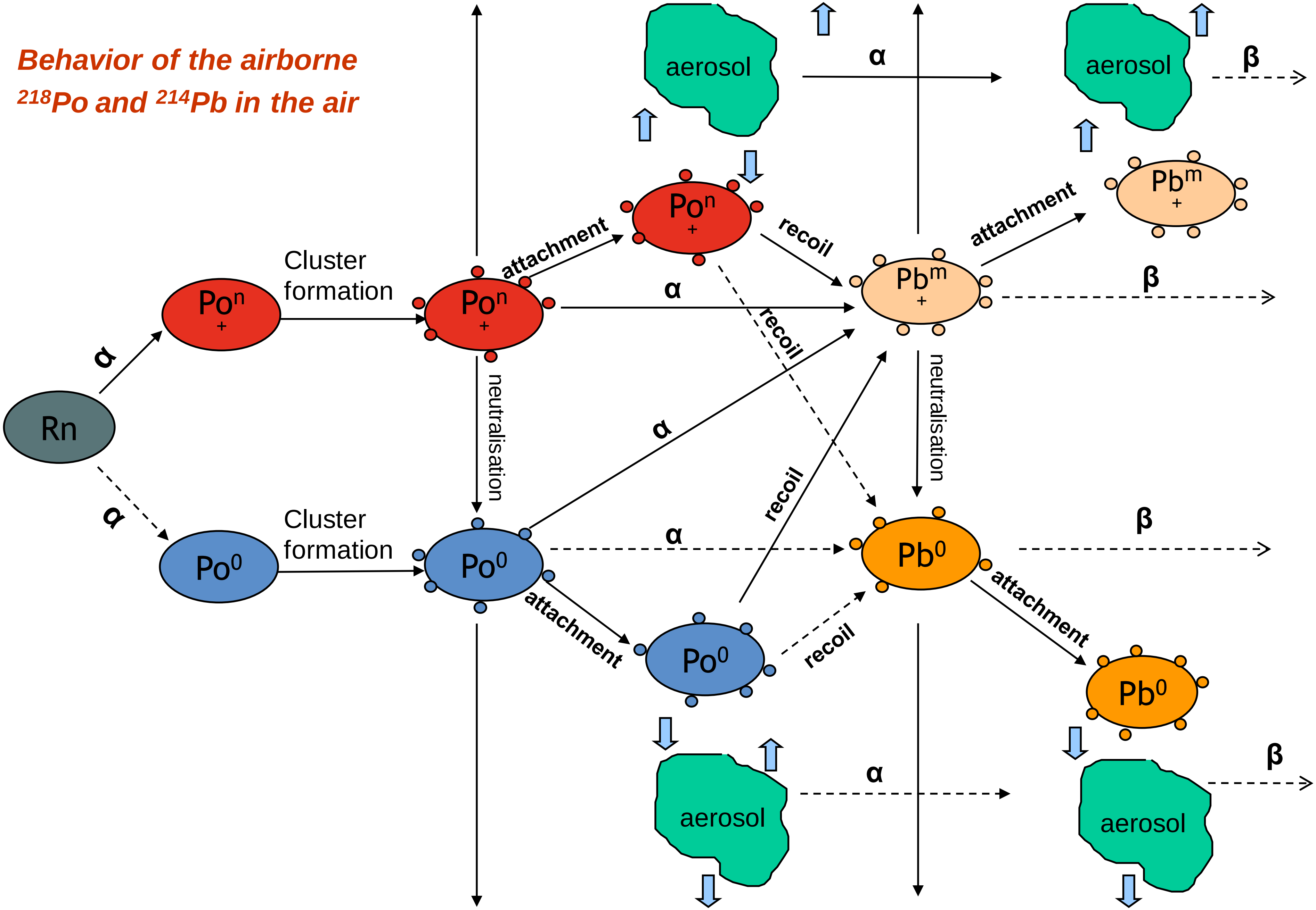
Introduction

Decay chain of Radon and its progeny



Uranium-238
Decay chain

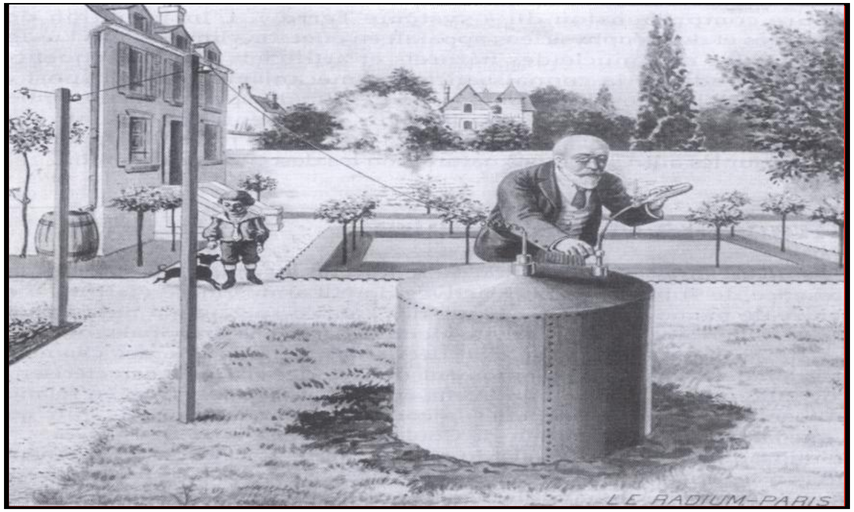
Behavior of the airborne ^{218}Po and ^{214}Pb in the air



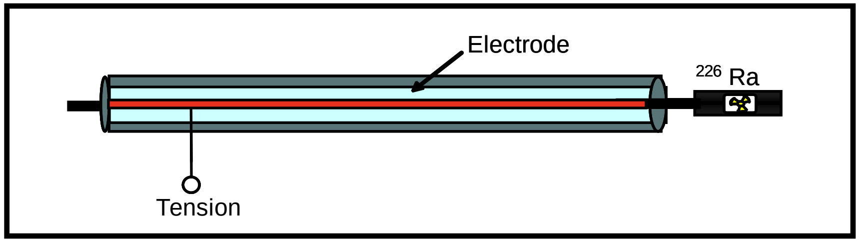
Literature review

The electric charge of radon progeny has two forms: total charge fraction and charge distribution

Pierre & Marie Curie 1904, were the first to measure the electric charge of radon's progeny



Wellisch 1913, was the first to measure the total charge fraction of ^{218}Po using a Zeleny Tube:



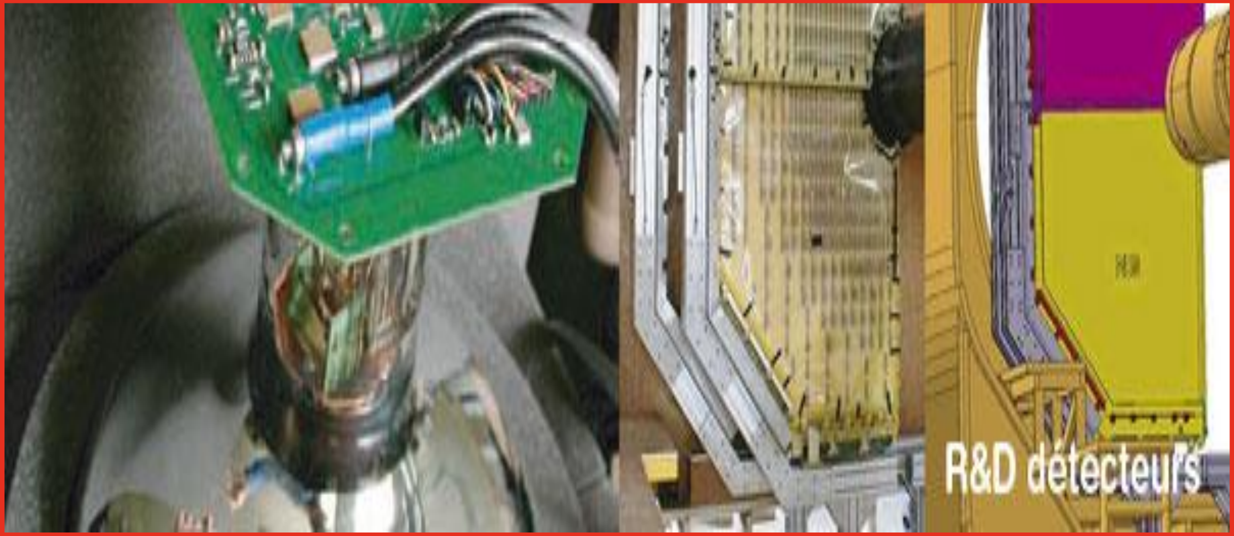
$$f_{chrg} = \frac{C_c}{C_n + C_c}$$

→

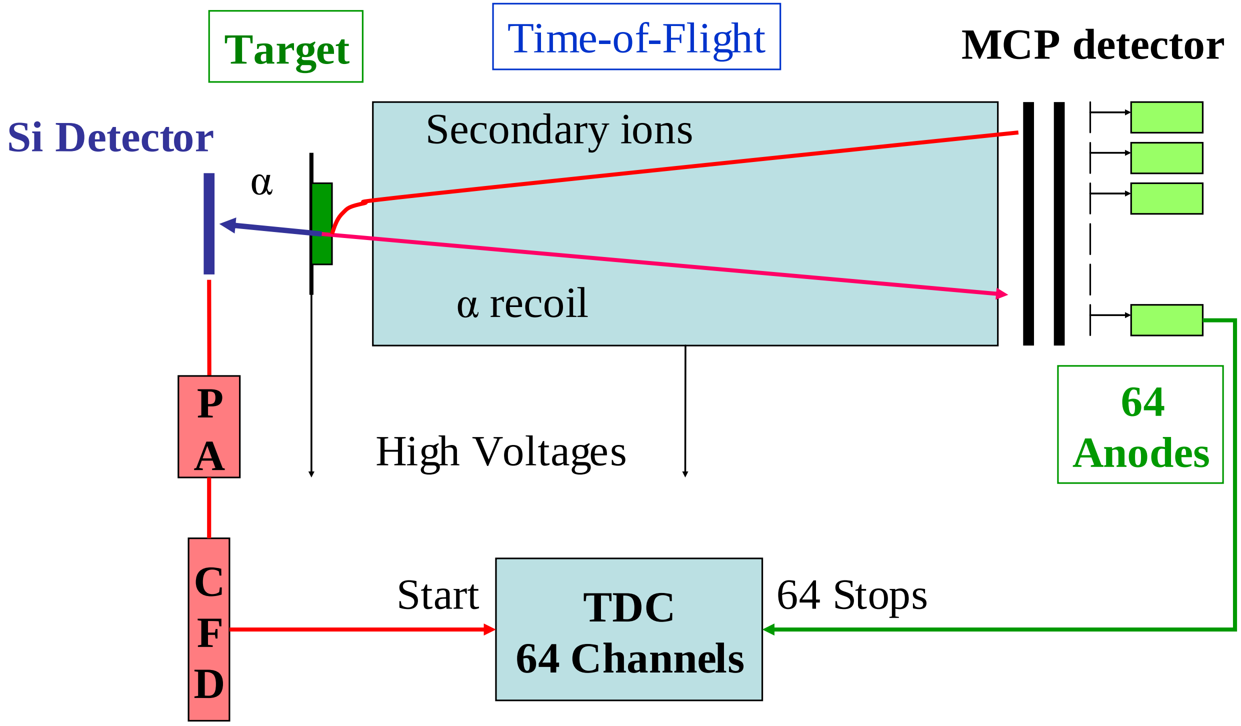
88% positive
12% neutral

All results in the literature concerning radon's progeny treated the total charge fraction, but none of them studied its charge distribution state.

Experimental setup



ACCELERATION CHAMBER



- PA: Preamplifier
- CFD: Constant Fraction Discriminator
- MCP: Micro Channel Plates
- TDC: Time Digital Converter

Time-of-Flight measurement

- Time-of-Flight of ^{218}Po before its detection by the Micro Channel Plates is:

$$\boxed{T = T_a + T_L}$$

T_a: Time-of-Flight in the accelerator chamber 10 mm (10^{-8} s)
T_L: Time-of-Flight between the accelerator chamber and the MCP 46 cm ($>10^{-7}$ s)

- Velocity and kinetic energy of the recoiling ions $^{218}Po^q$ while applying a differential potential ΔU in the acceleration chamber:

$$\boxed{V_q = \gamma T_a + V_r} \Rightarrow \boxed{E = q\Delta U + E_r}$$

γ: Acceleration of ^{218}Po due to the differential potential
V_r and E_r: Velocity and energy recoil of ^{218}Po

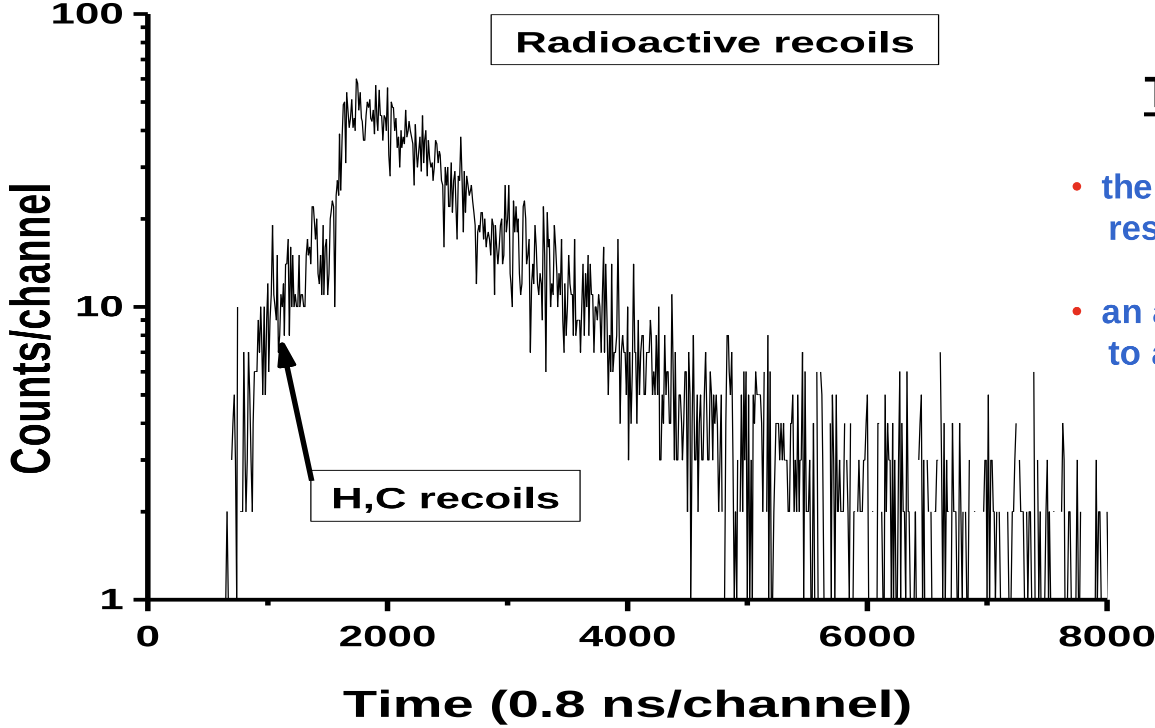
- Velocity V_q is constant for all the L distance, this implicates that:

$$\boxed{T_L = \frac{L}{V_q}} \Rightarrow \boxed{T_L = \left(\frac{M}{2}\right)^{1/2} .(E)^{-1/2}.L}$$

M: atomic mass unit of ^{218}Po

Results and discussion

Time-of-Flight measurement obtained without differential potential to define the recoiling ^{218}Po ions spectrum



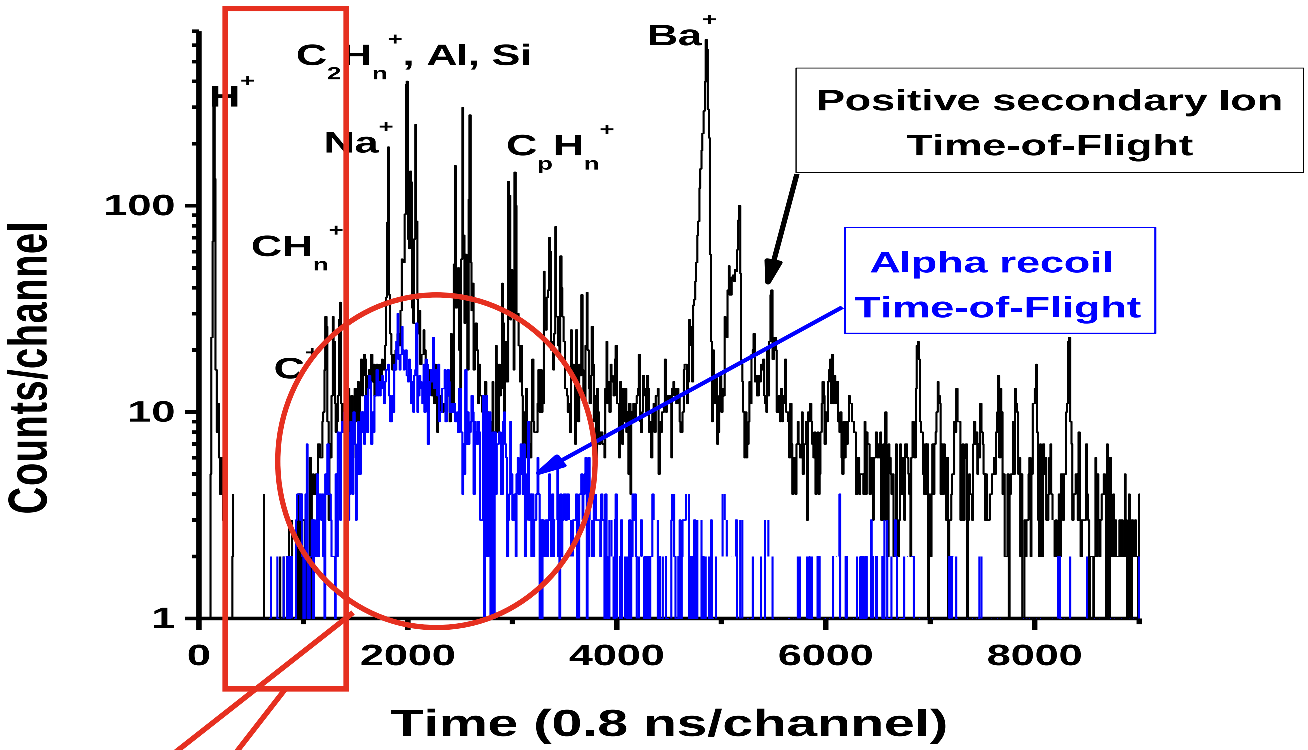
The centroid peak represents:

- the mean velocity of the recoiling ion ^{218}Po resulting from the energy loss in the matter
- an average energy loss of 40 keV, equivalent to a layer of 10 - 20 nm of the organic deposit

The longest Time-of-Flight is attributed to ions that lost about 90 keV in a material about 40 to 50 nm thick

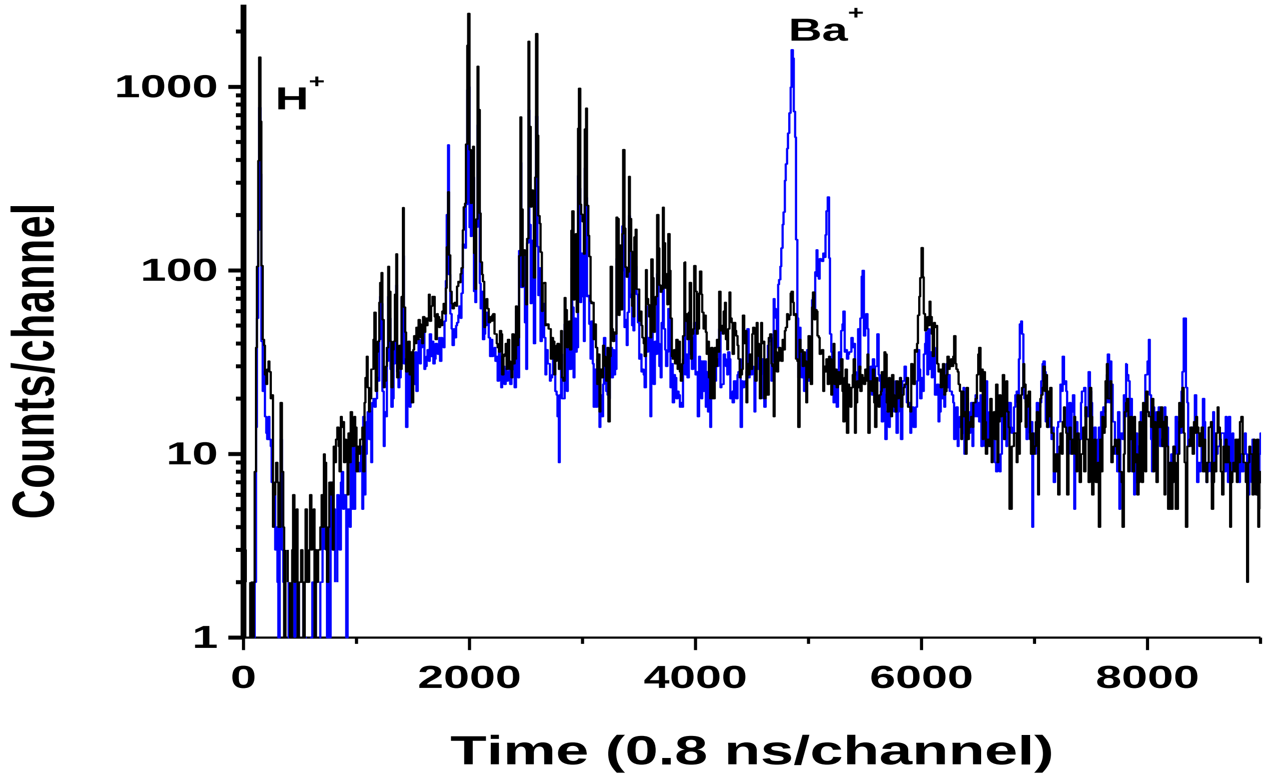
We can also note the presence of light elements such as hydrogen and carbon atoms; these are ejected by the radioactive recoil colliding the organic molecules of the source deposit

Time-of-Flight spectra for secondary and recoiling ions



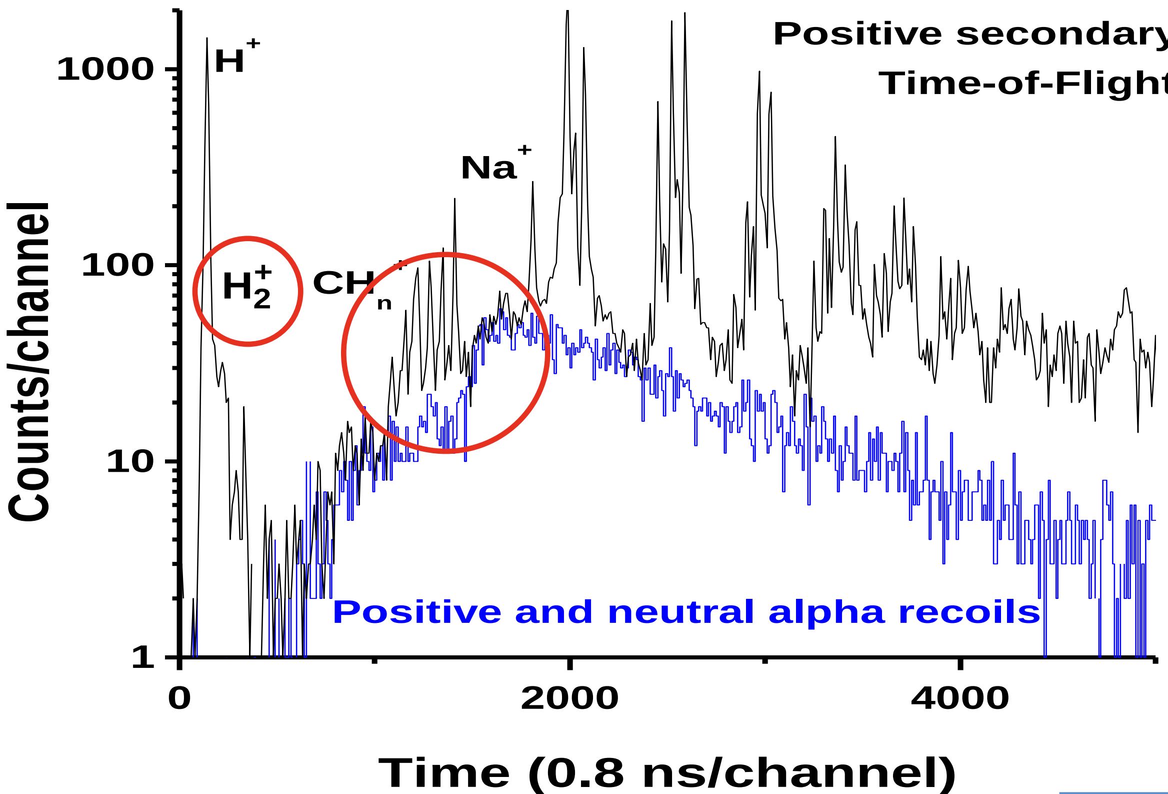
- Time-of-Flight spectra show small differences, which reveal the neutral and singly positive charged states of recoiling ions
- No multi-charged ions greater than +10 appear, otherwise they would have been located between H and C peaks

Time-of-Flight spectra for secondary ions for two different ^{226}Ra sources



The secondary ion emission for both sets of measurements differ by the presence or not of barium in the source solution; the second set lacks the barium peak because the decrease of the concentration in the solution

Time-of-Flight spectra for secondary and recoiling ions



To adjust the Time-of-Flight deficit, a contribution of 10 keV was attributed for 20% of the recoiling ^{218}Po atoms.

20% singly charged ^{218}Po

To fill the gap near the peak CH_n^+, the same rough estimation was made:

6% multicharged ^{218}Po
Maximum +10 charges
Average +5 charges

Conclusions and perspectives

Conclusion and Perspectives

✓ These results show, for the first time, the charge distribution state of a radon progeny (^{218}Po): 74% neutral, 20% singly charged, 6% multicharged (with a maximum +10 and an average +5), they confirm the decay of ^{218}Po to the ground state

✓ These results show how the energy loss (10 - 100 keV) in the matter emits a high secondary ions yield and how it neutralizes recoiling ions

✓ Otherwise, we can notice the large influence of the matter (barium) and the medium surrounding the emitting source

✓ We must mention as well that our results can not be compared to those of the literature (88% of ^{218}Po positively charged, Wellisch) as we measured the charge distribution in the vacuum and not in the ambient air (Wellisch)

✓ These data are interesting because they show several ways of matter's ionization, and will help investigations on the electric charge of radioactive element attached to nanometric aerosols

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Thank You!