

Radon daughter implantation on the surface of the component: modelling, measuring and surface cleaning

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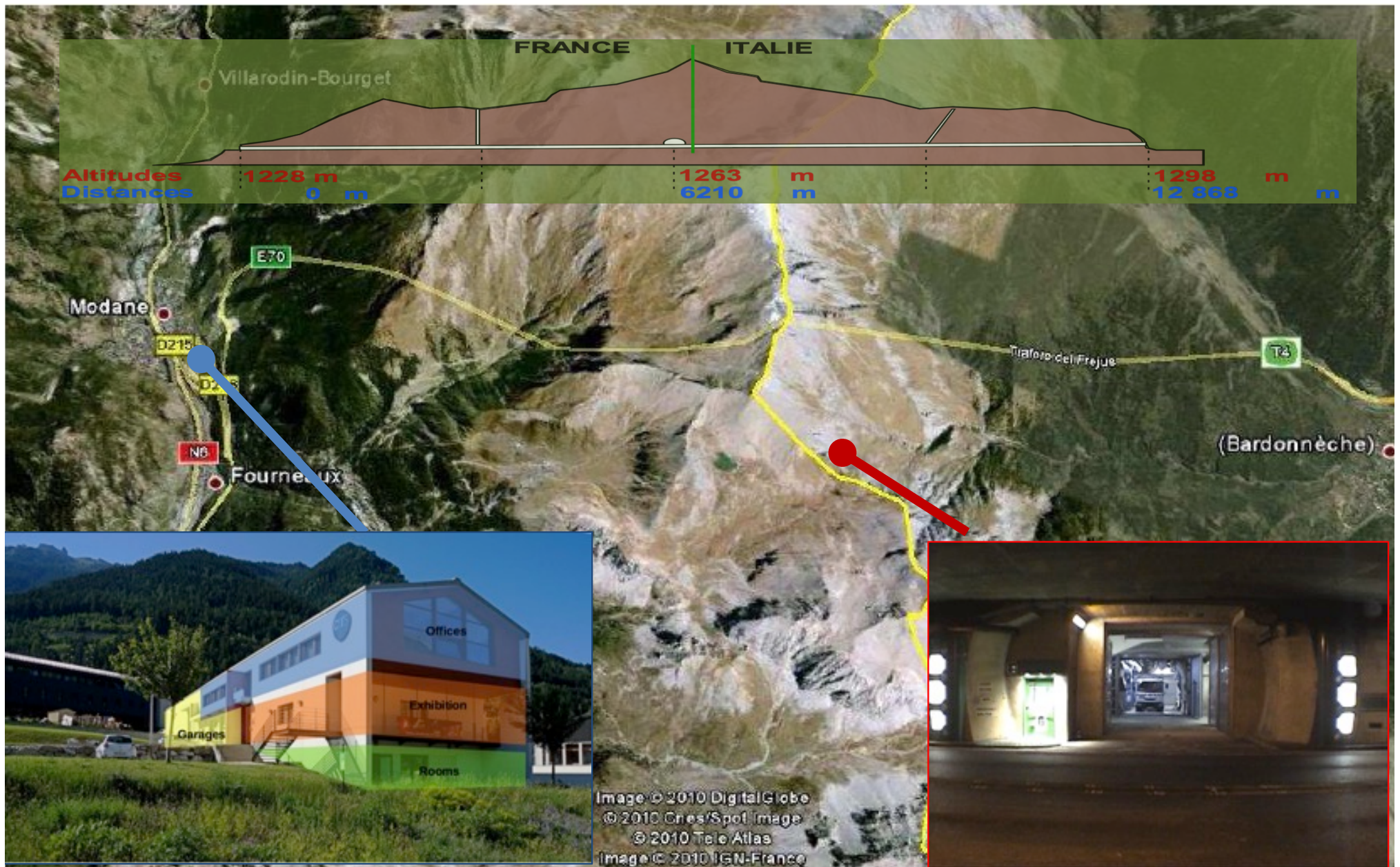


Laboratoire Souterrain de Modane



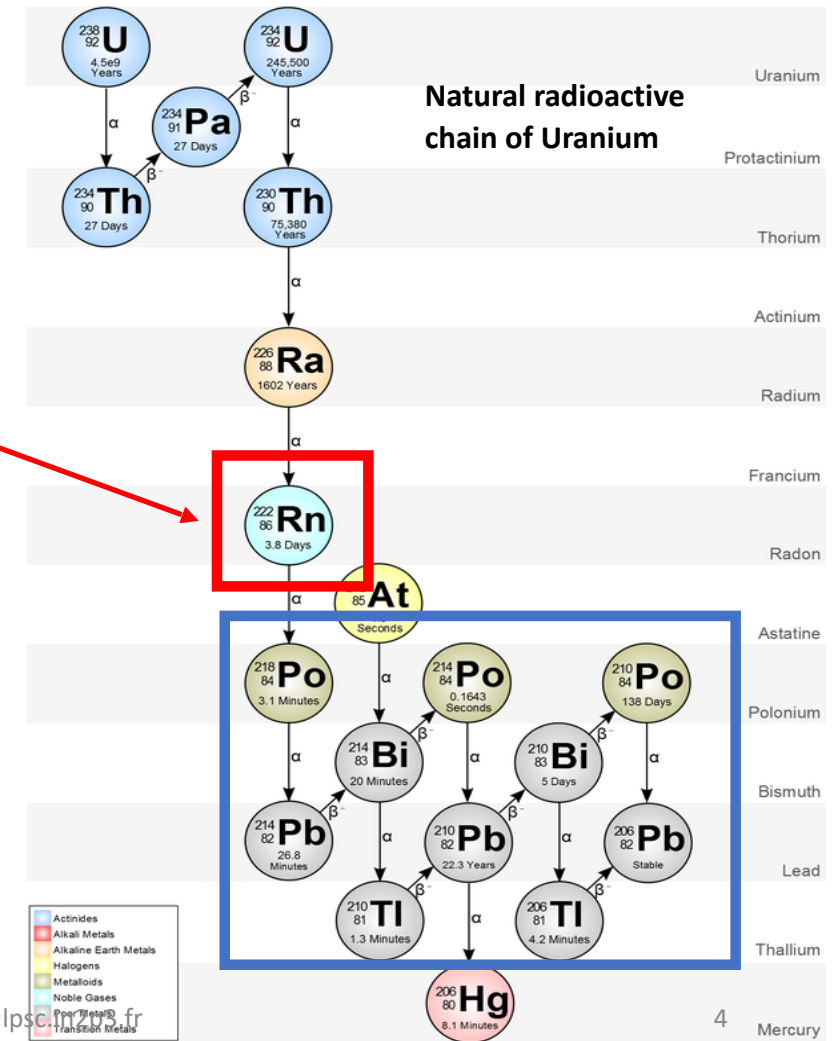
preface





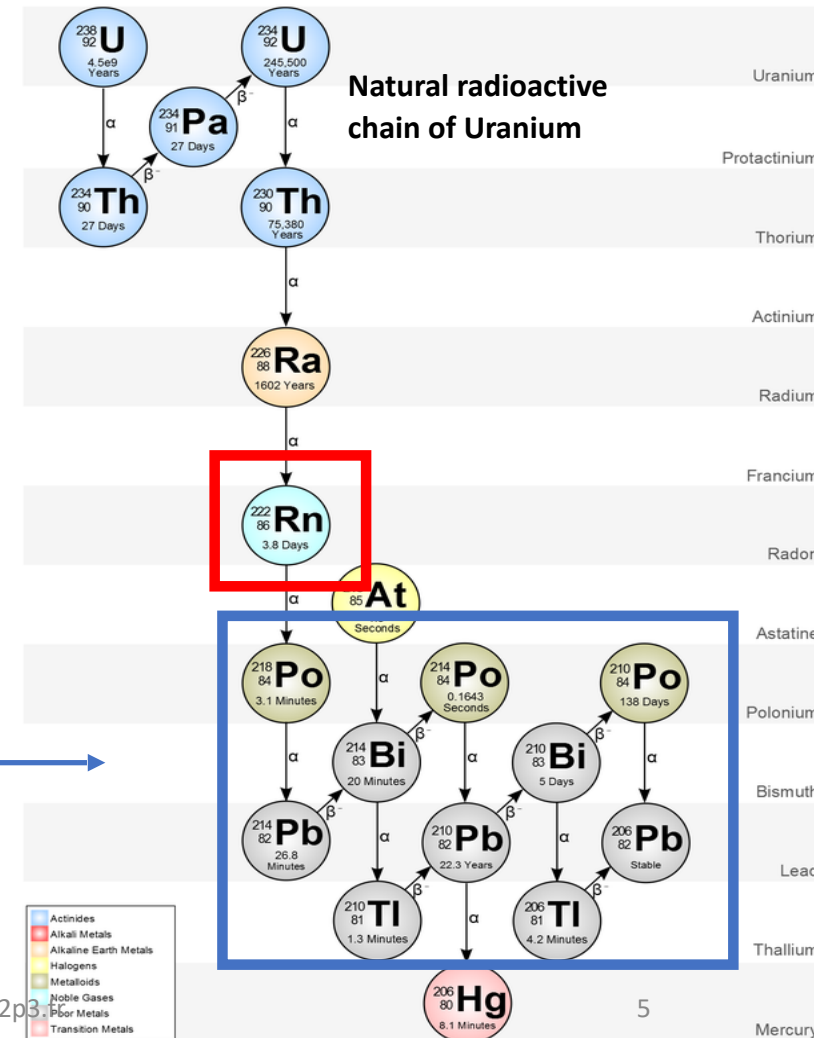
Motivation: Radon daughters as background sources

- Radon in air comes mainly from the soils and rocks emanation $\approx 50\text{-}100\text{ Bq/m}^3$
- Radon (^{222}Rn) is a noble radioactive gas with $t_{1/2} = 3.8\text{d}$



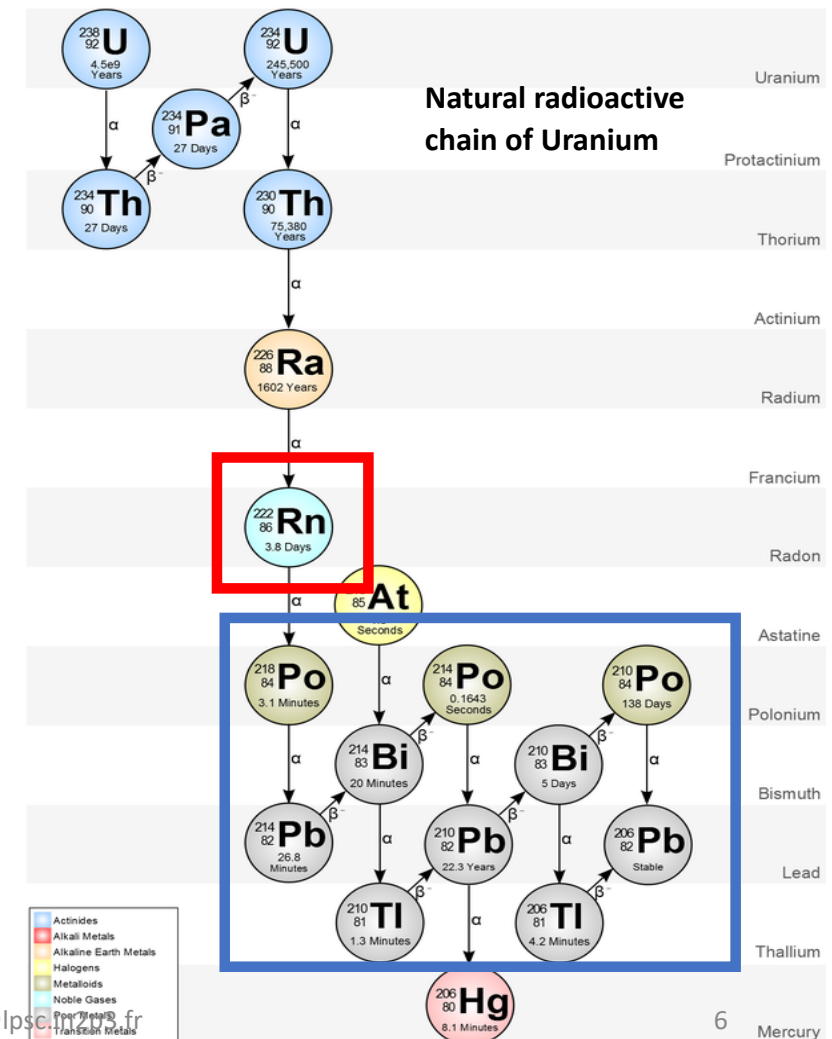
Motivation: Radon daughter like background source

- Radon comes from the soils and rocks emanation (contain U and Th)
- Radon (^{222}Rn) is a noble radioactive gas with $t_{1/2} = 3.8\text{d}$ existing in air $\approx 50\text{-}100\text{ Bq/m}^3$
- Radon daughters can deposit on the surfaces of the detector components in contact with air



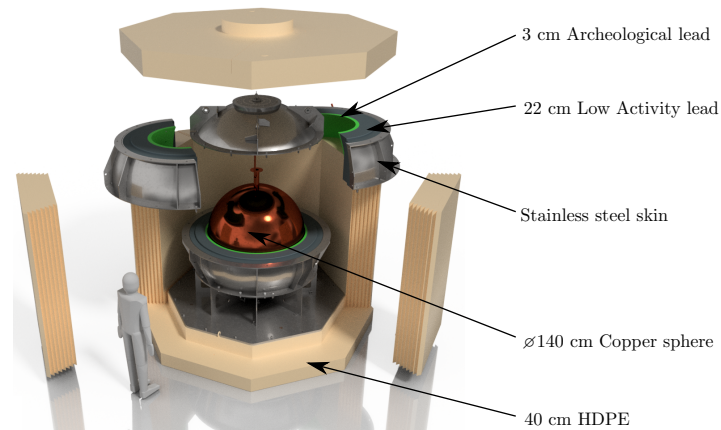
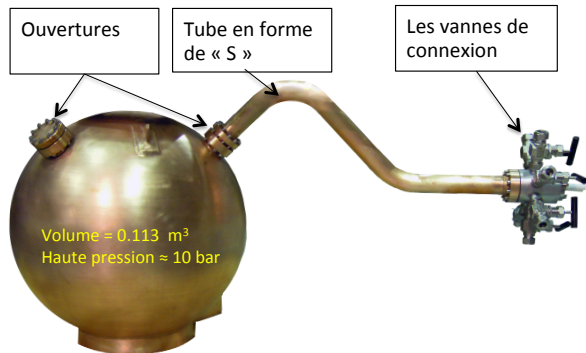
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- Radon daughters can deposit on the surfaces of the detector components in contact with air
- Main concerned isotopes:
 - $^{210}\text{Pb} \rightarrow t_{1/2} = 22.3\text{ y}$
 - $^{210}\text{Po} \rightarrow t_{1/2} = 138\text{ d}$
- Possible background source for rare events detection at low masses

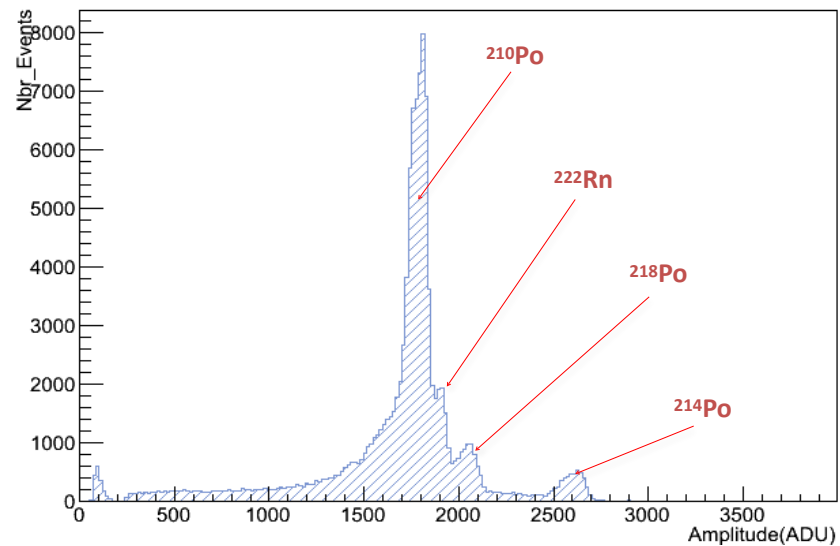
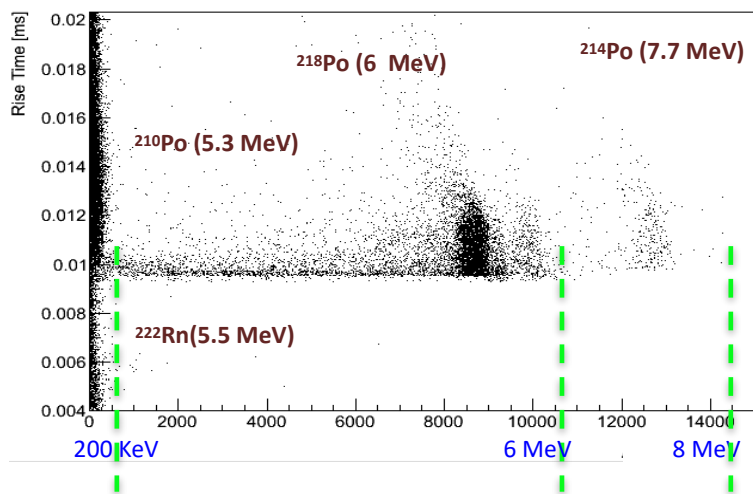


Radon and rare events experiences

NEWS-G Dark Matter Experiment

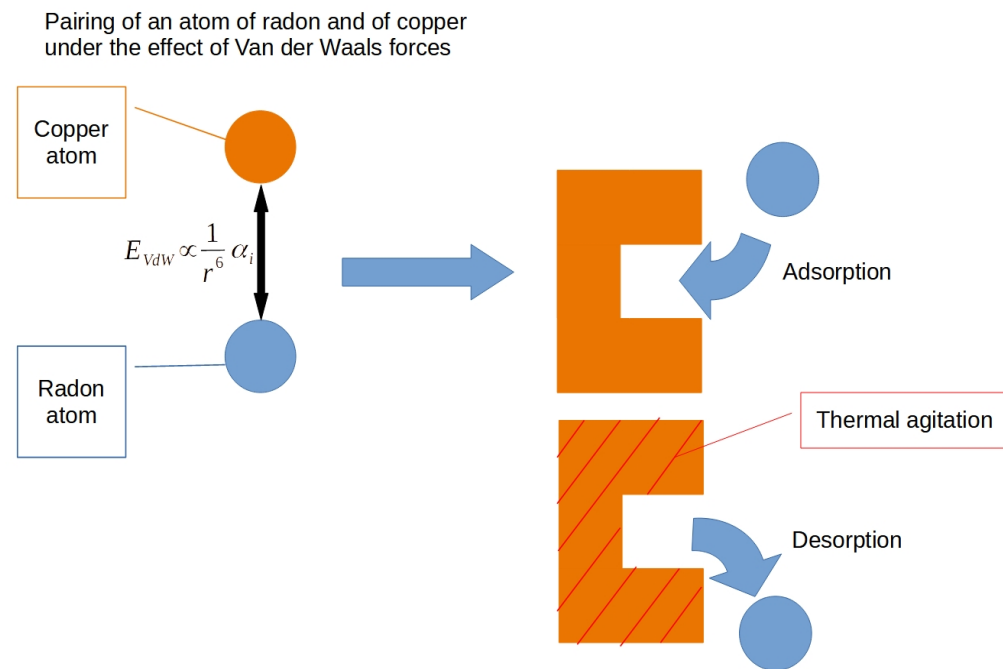


Ar + CH₄ (2%) P = 300 mbar



Radon Implantation mechanism

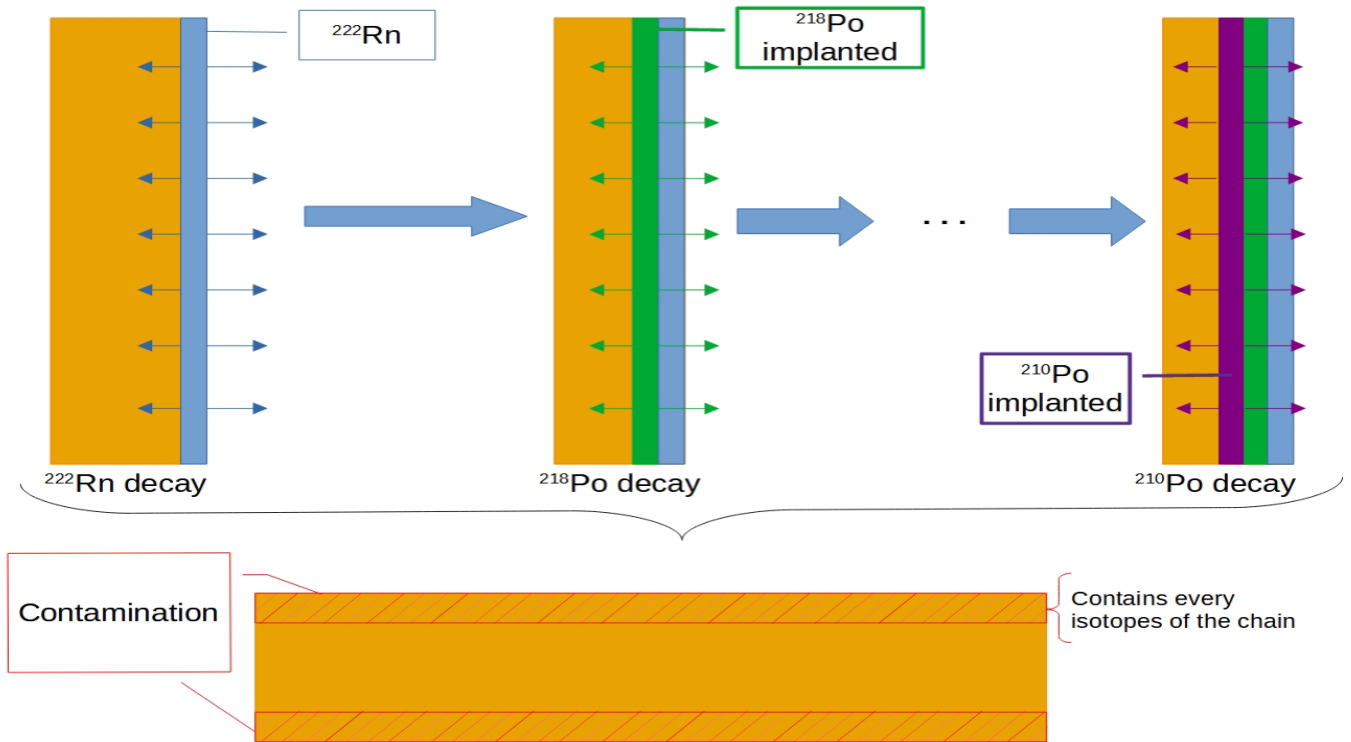
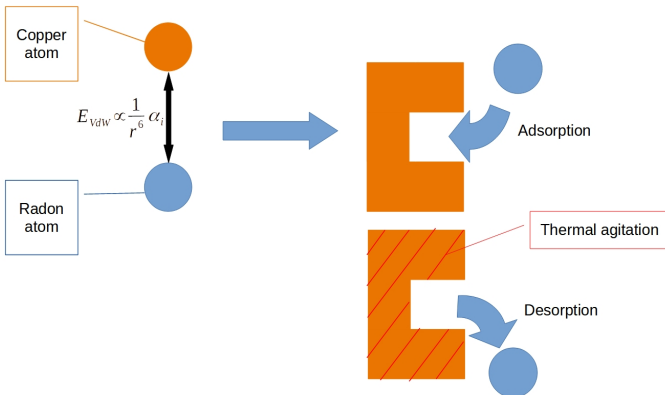
- Radon can be adsorbed on the surface
- The adsorption depends on thermodynamical parameter
- After adsorption the radon daughters decay and implant ^{218}Po by nuclear recoil



Radon Implantation mechanism

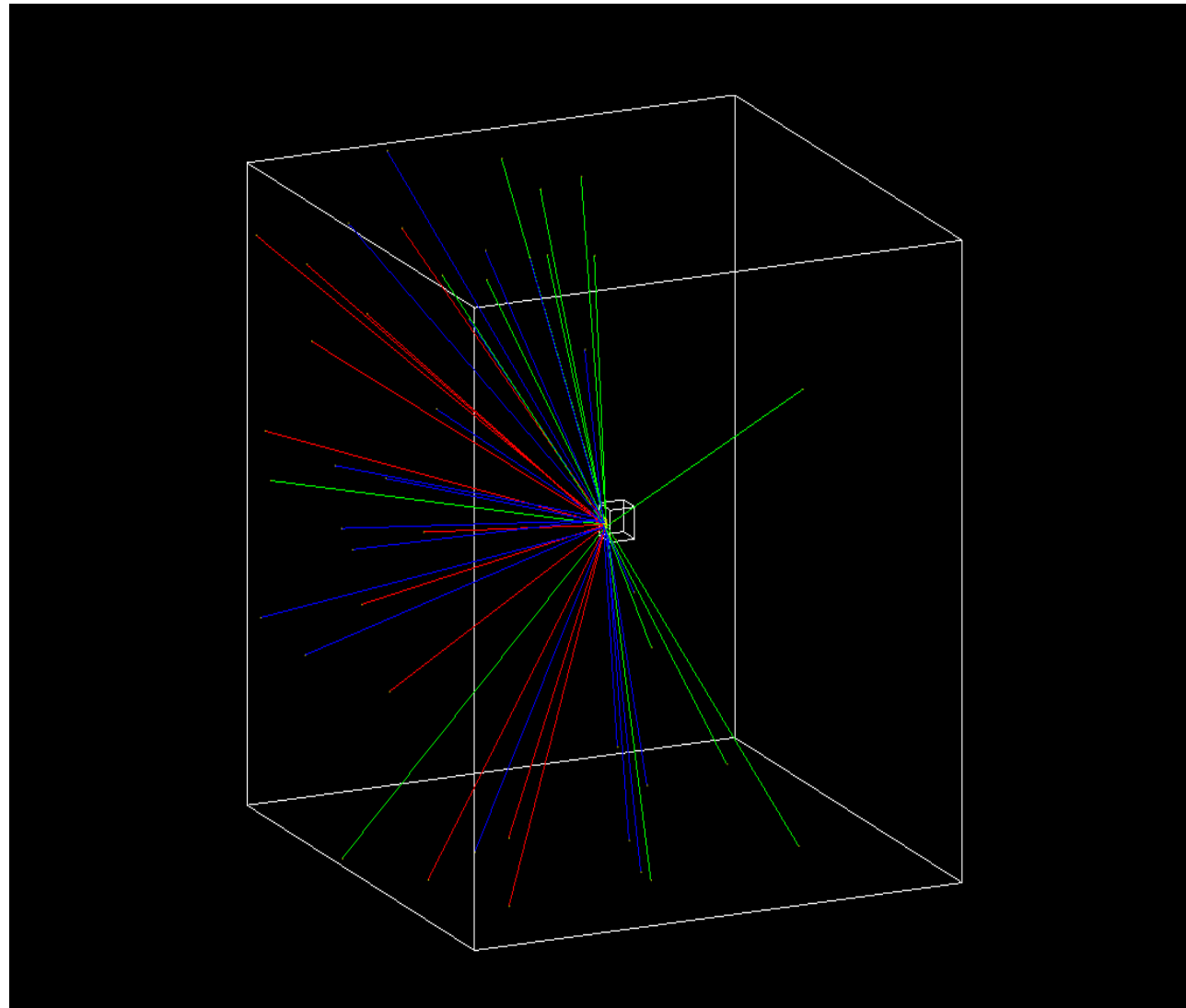
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Pairing of an atom of radon and of copper under the effect of Van der Waals forces



Implantation model

- Implantation modelled through GEANT4
- Copper plate (cube) used as a detector [GEANT4 rdecay01 example]
- Full ^{222}Rn decay chain monitored
- ^{222}Rn @ $z=0$ of copper plate
- Recorded final step depth per nucleus



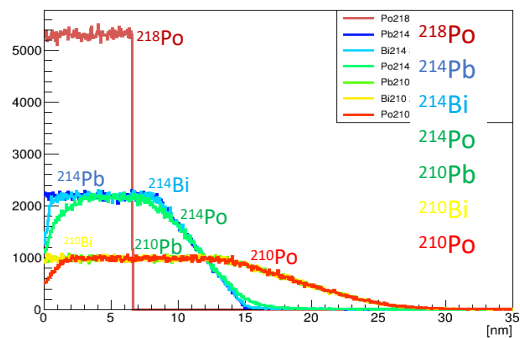
First test on Si wafer and Copper

Decay at (0,0,0) and inside the copper plate

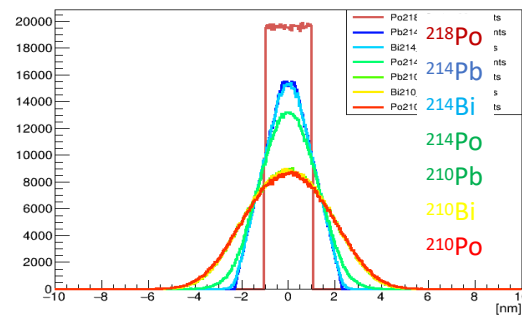
Decay inside the copper plate

Decays at (0,0,1 nm)

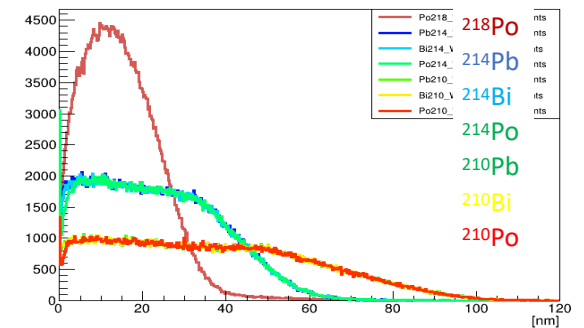
^{222}Rn decay (1E6) on the Si wafer surface



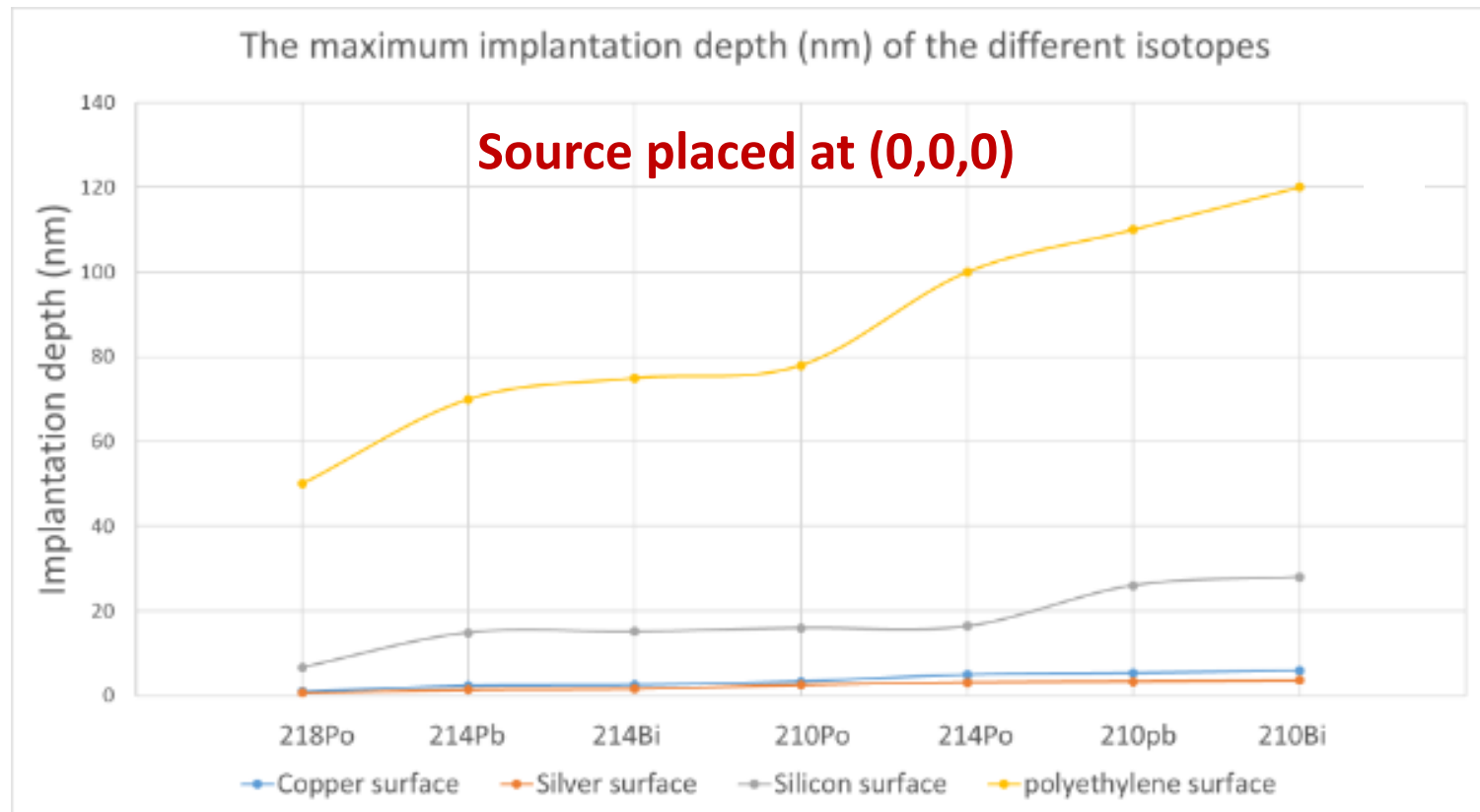
^{222}Rn decay (1E6) in the center of Copper



^{222}Rn decay (1E6) Si wafer



First test: More materials where tested



Further simulations were performed for other materials in order to compare the maximum implantation depth results for different densities.

Implantation depending on the ρ and Z

$$\rho_{Ag} > \rho_{Cu} > \rho_{Si} > \rho_{PE}$$

And

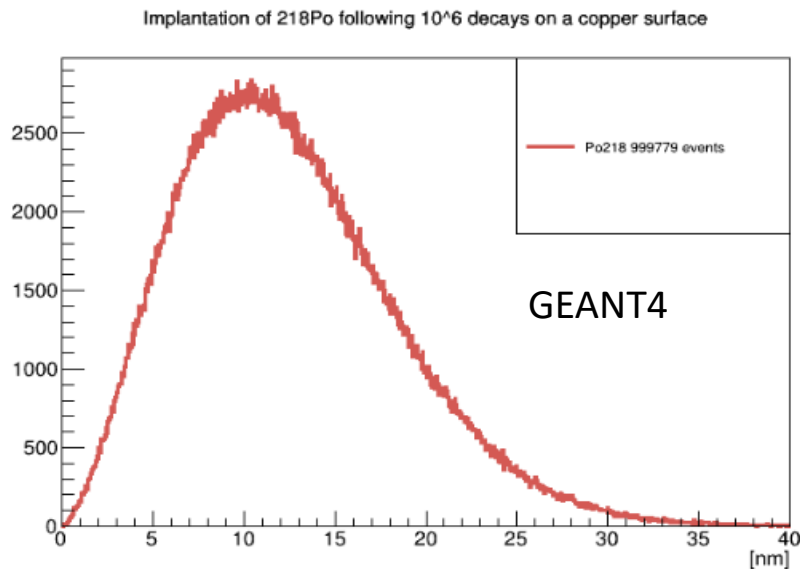
$$Z_{Ag} > Z_{Cu} > Z_{Si} > Z_{PE}$$

Maximum implantation depth for each isotope from the ^{222}Rn decay chain

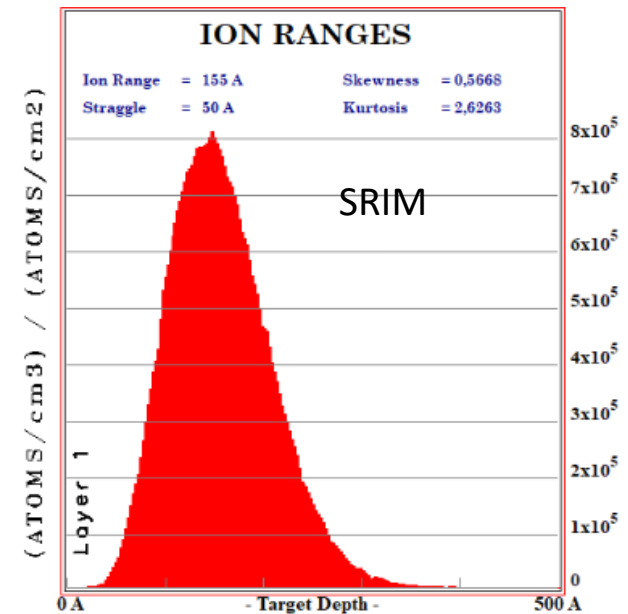
Geant4 / SRIM

- To compare the GEANT4 results with SRIM, only ^{218}Po isotope was simulated

^{218}Po sent as a beam on the surface of the copper with its recoil energy = 101keV



GOOD AGREEMENT

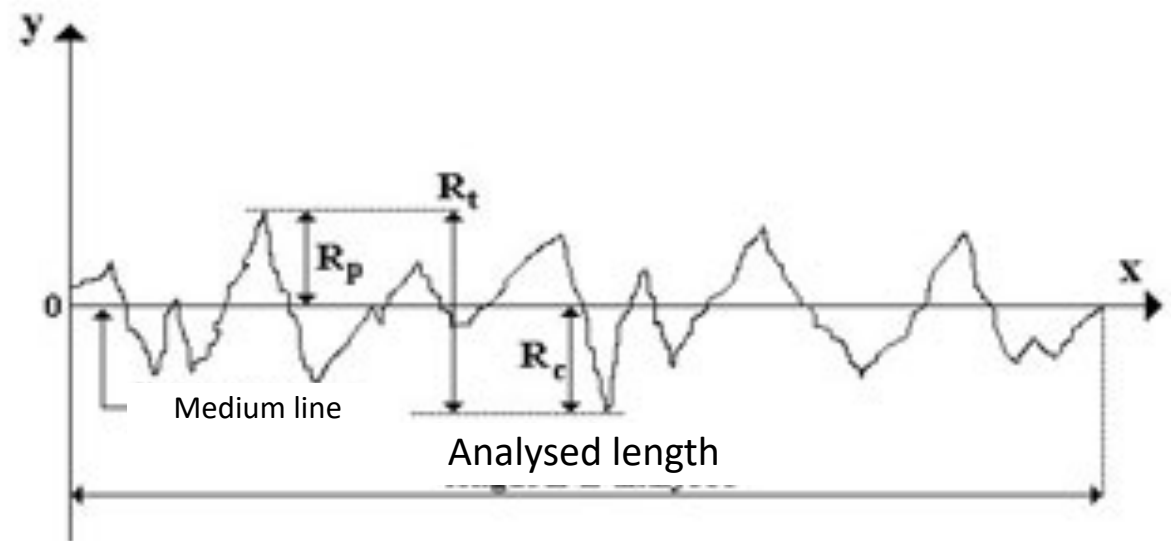


Surface Modelling

- Real surface of the materials is with some roughness
- It can be modelled as

Where :

- R_p = the maximum height of a peak
- R_c = the maximum height of a deep
- R_t = peak-to-peak height



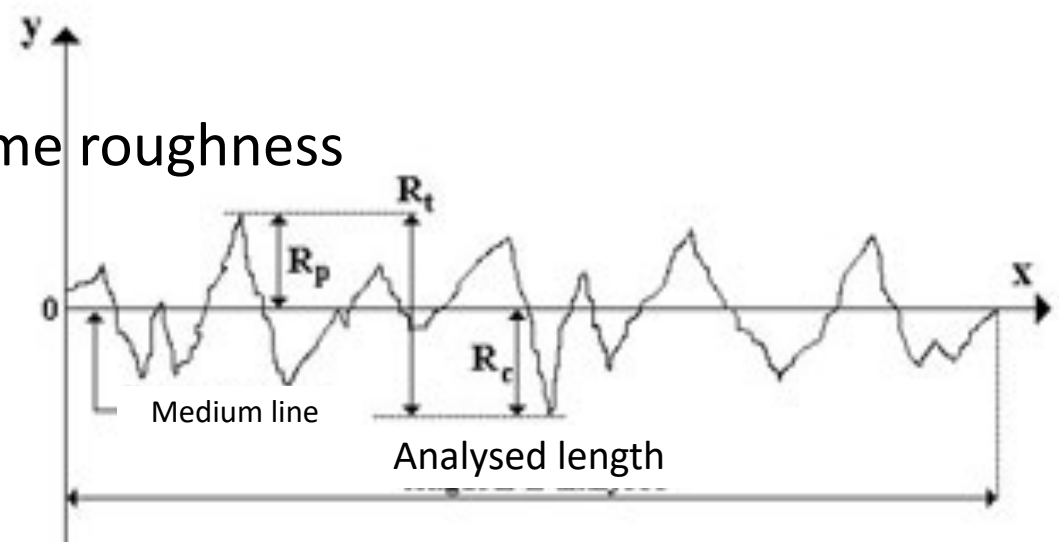
R_p , R_c and R_t : roughness measurement parameter

Surface Modelling

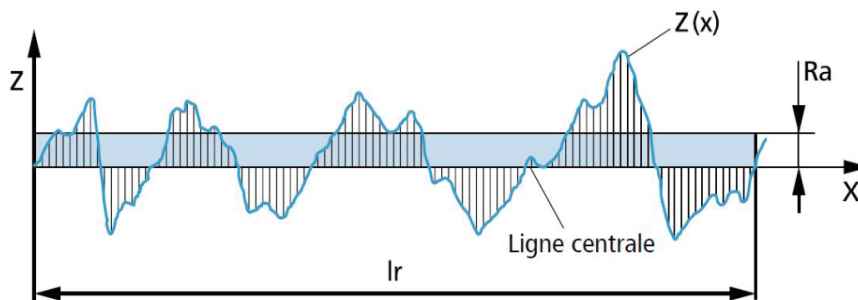
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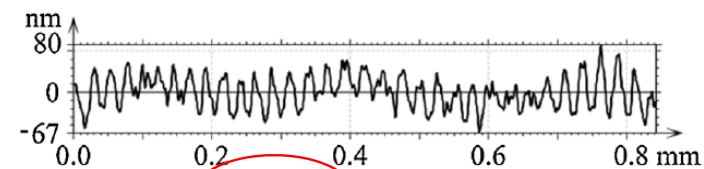
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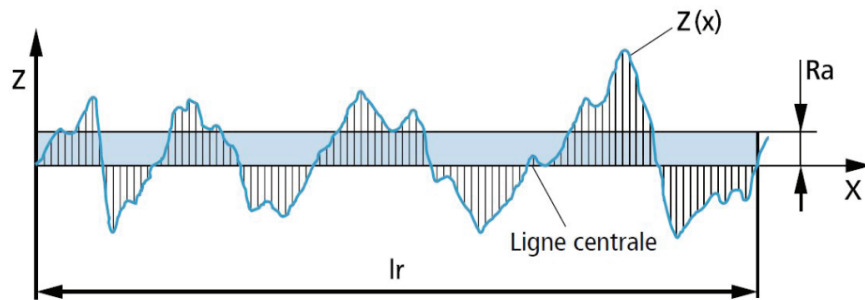
R_a = the mean half peak for a considered surface = 21 nm



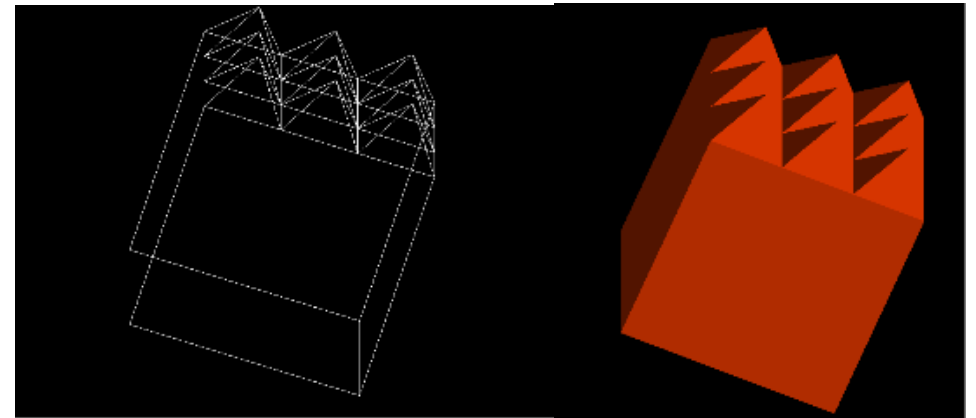
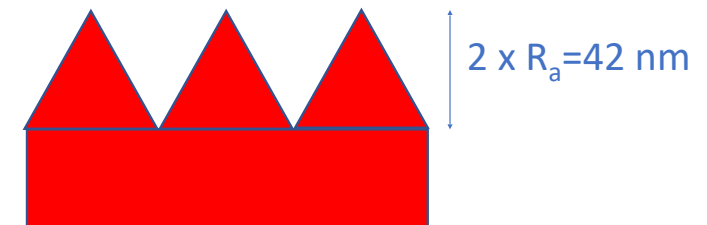
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Surface Modelling

- Surface modelled as the pyramids
- 9 pyramids with 42nm high over a cube



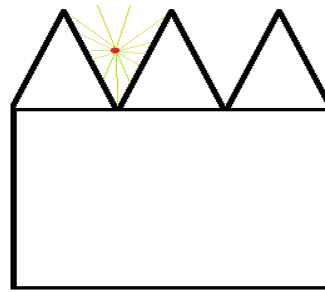
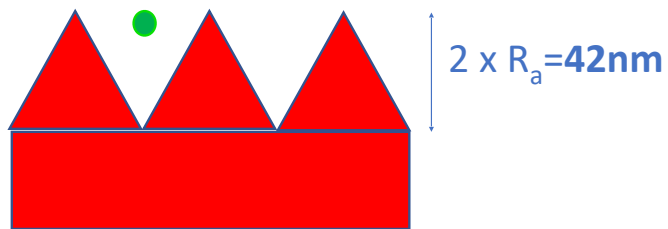
R_a = the mean half peak for a considered surface = 21 nm



Surface Modelling

- Surface modelled as 9 pyramids with **42nm** high over a cube

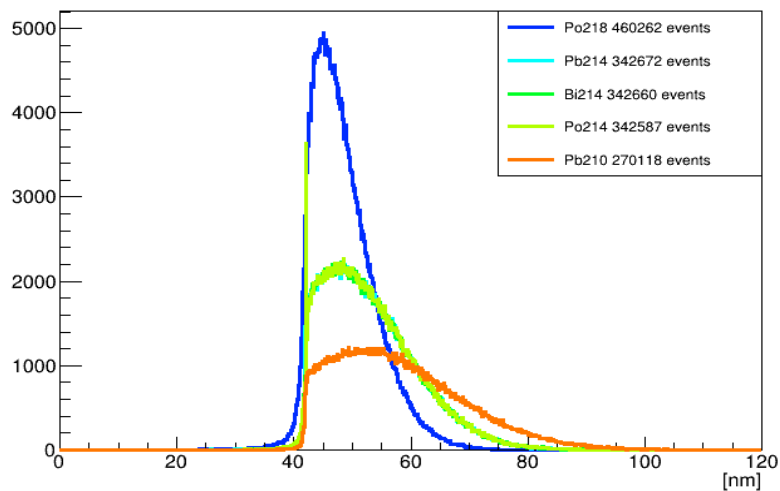
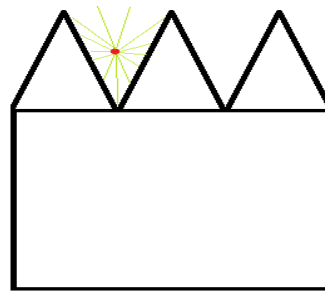
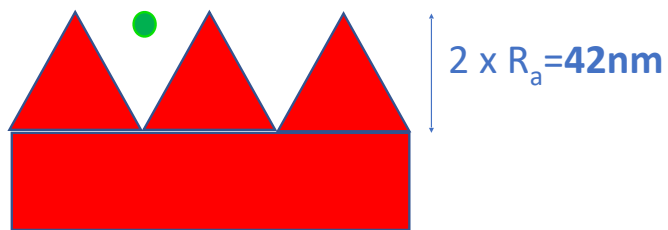
Decay : point $z=0$, iso



Surface Modelling

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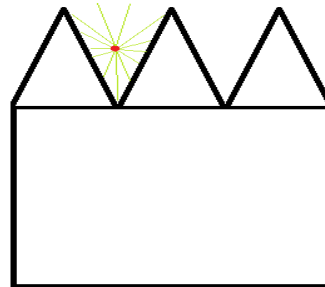
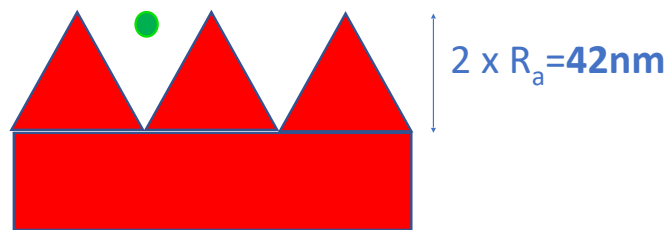
Decay : point $z=0$, iso



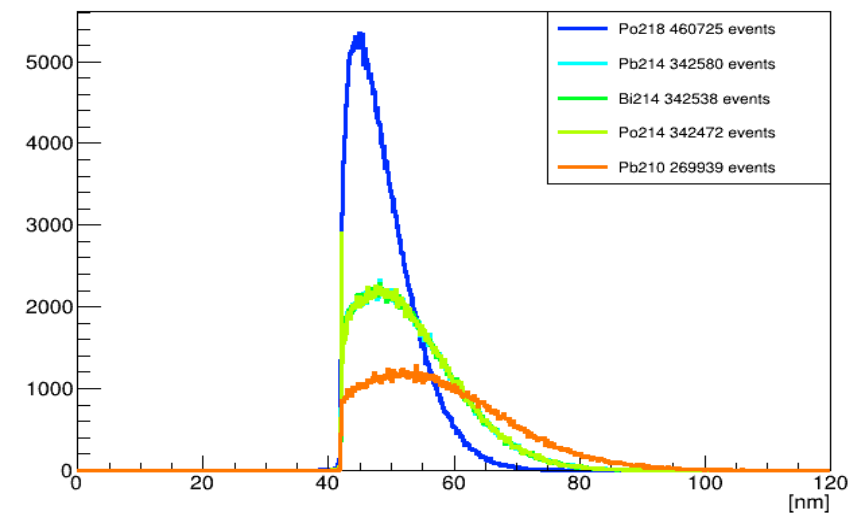
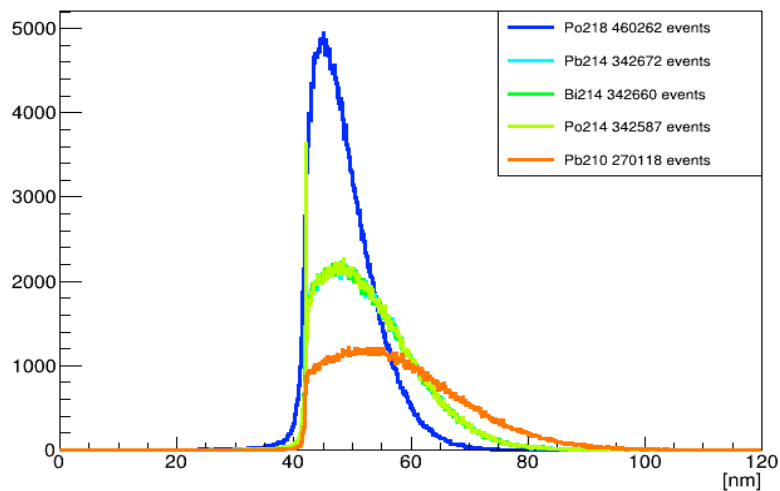
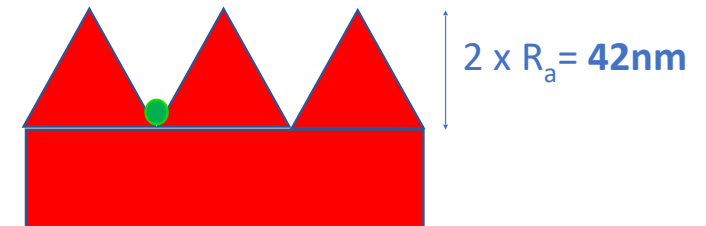
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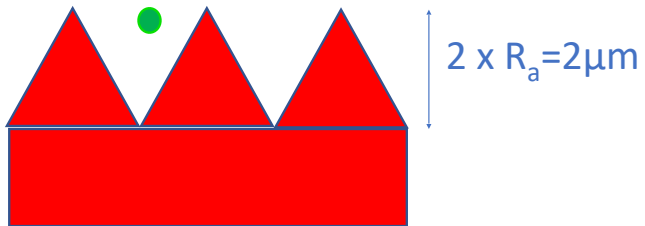


Decay : point $z=-42$ nm, iso

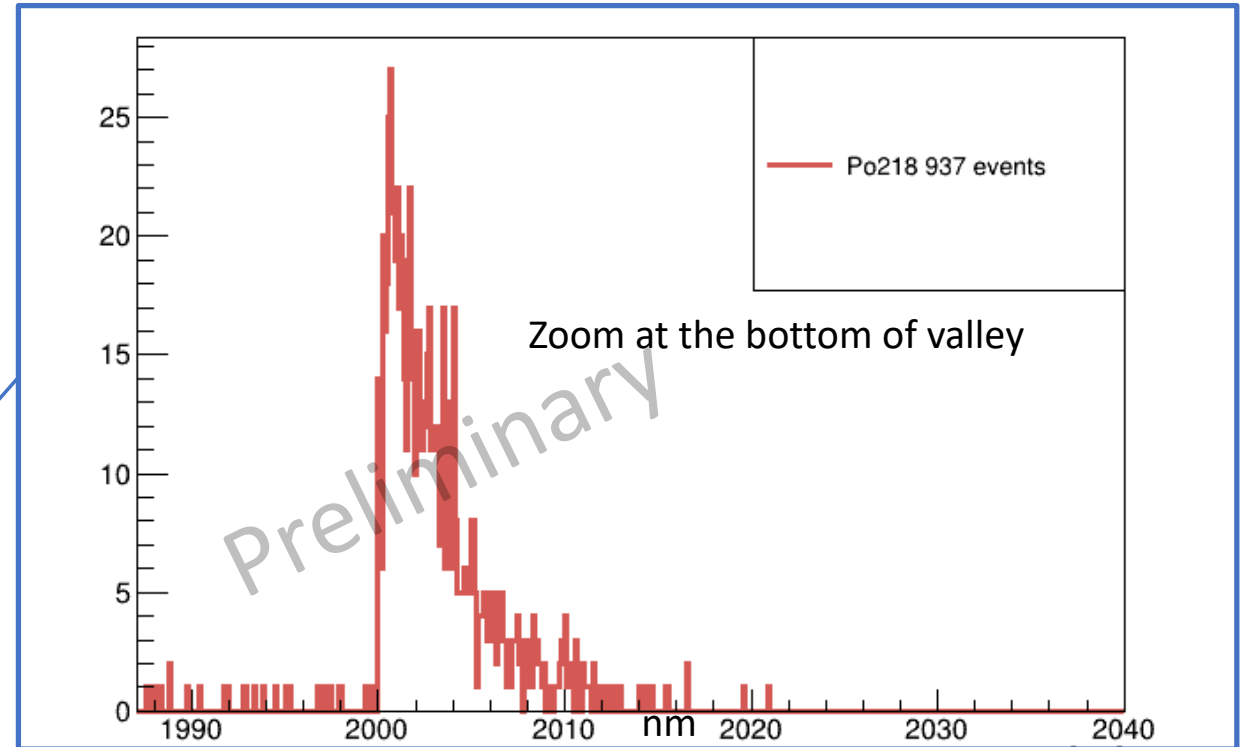
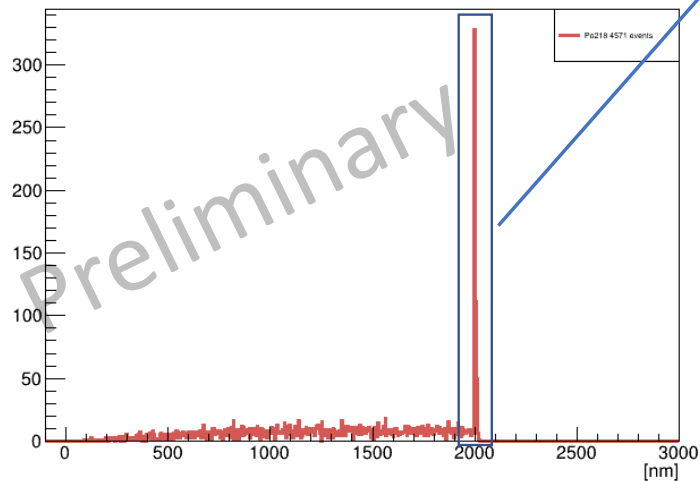


Surface Modelling

Decay : point $z=0$, iso

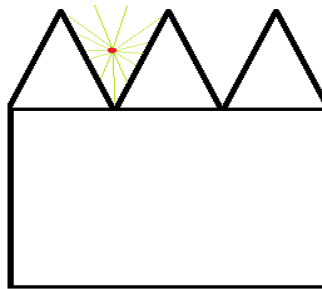
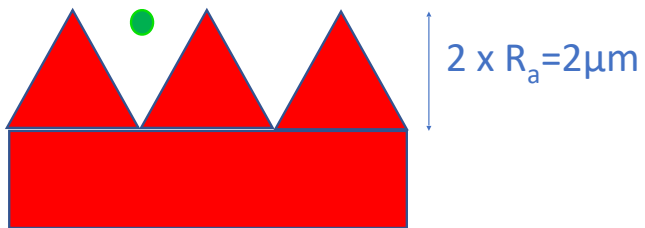


Decay of ^{218}Po at $z=0$, between 2 pyramids, implantation depth

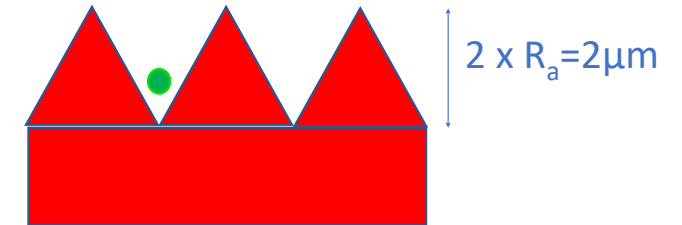


Surface Modelling

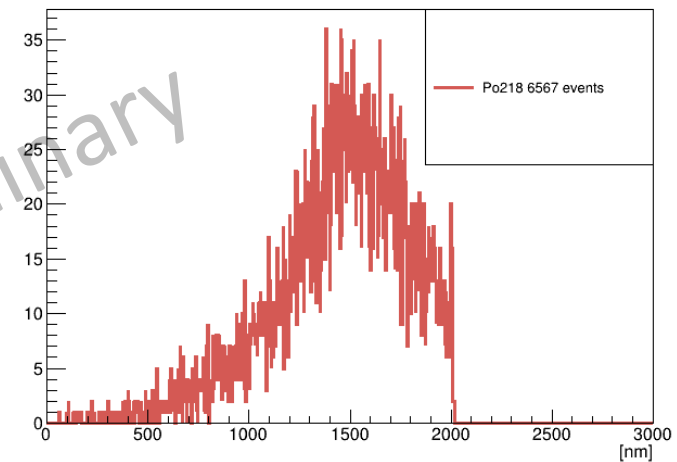
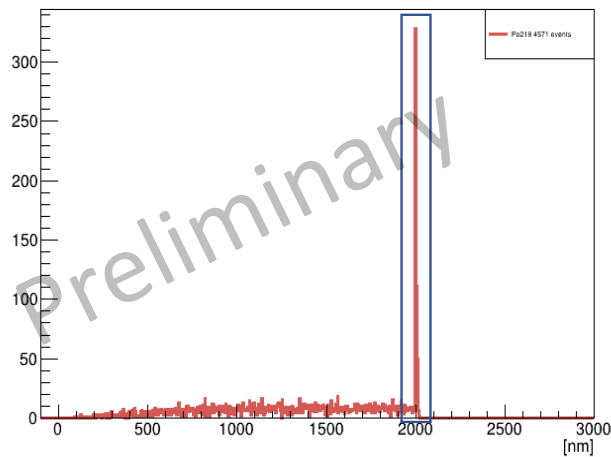
Decay : point $z=0$, iso



Decay : point $z=-1,5$, iso

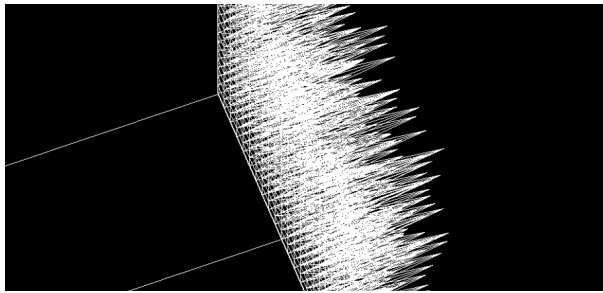


Decay of ^{218}Po , between 2 pyramids, implantation depth



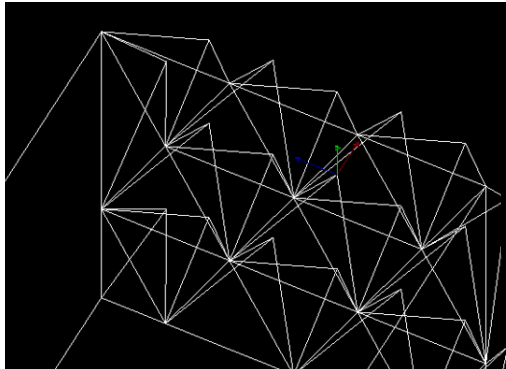
Other surface models

Pyramids



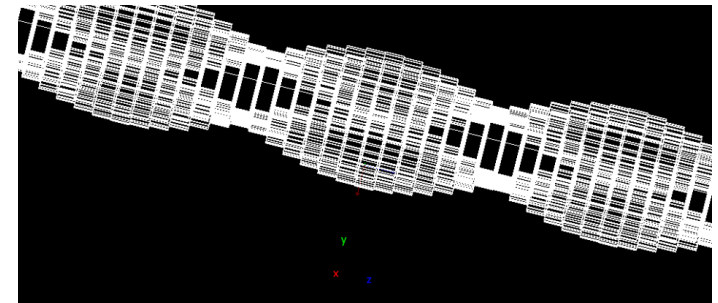
- 30x30 Pyramids with random heights
- Height randomly distributed between 1 and 5 times 2 μm

Paving



- Hard to model
- No effect to implantation

Complex model

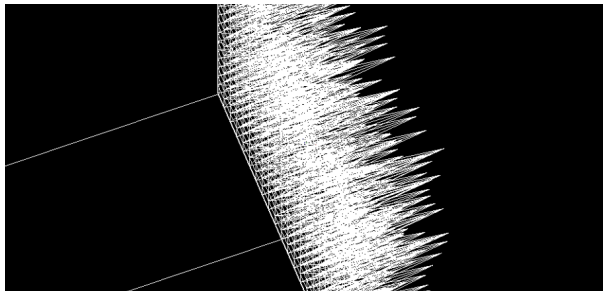


- Voxel put together to model the surface
- Height depends to angle ($\sin_y$ & $\cos_x$)

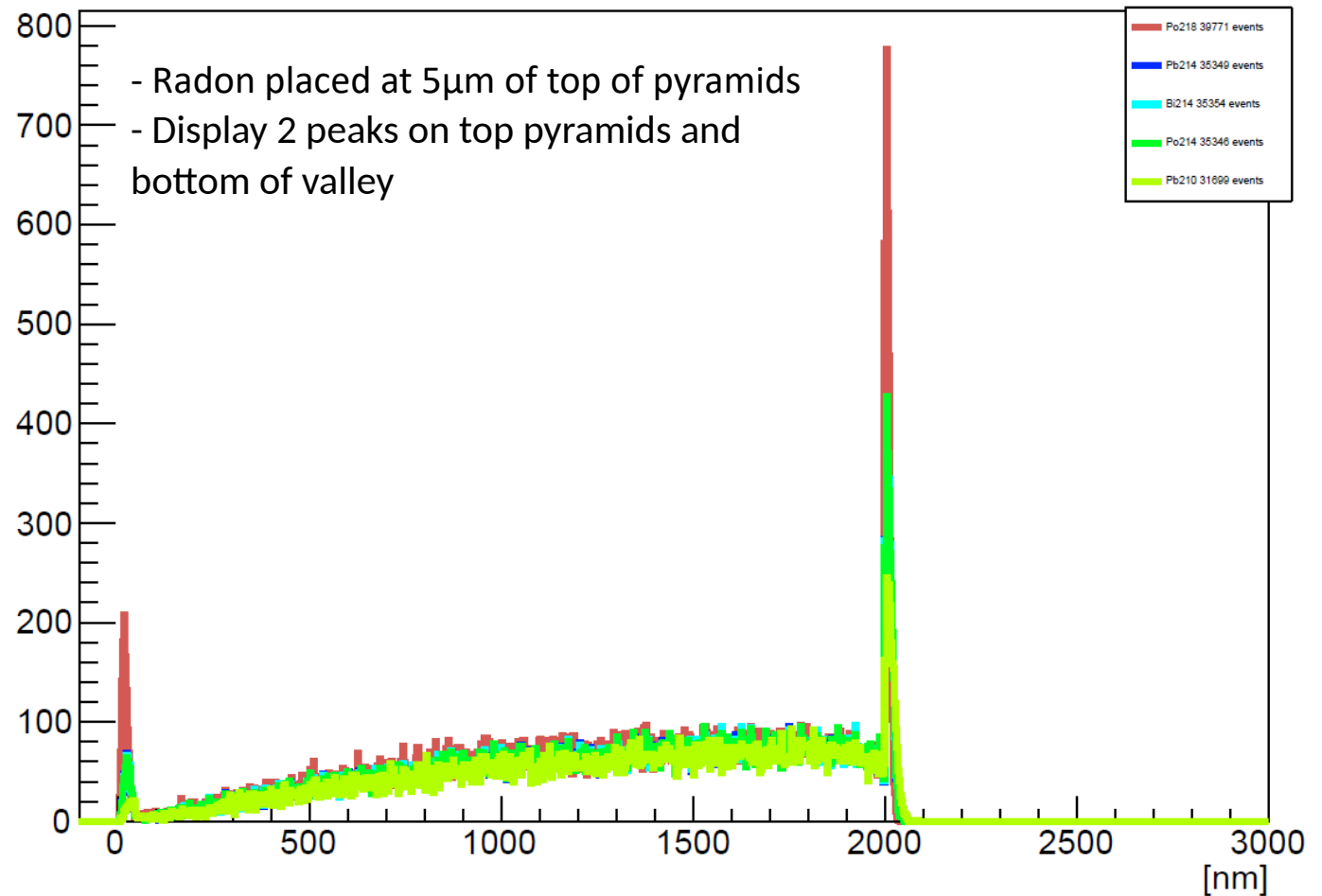
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Other Surface Modelling

Pyramids

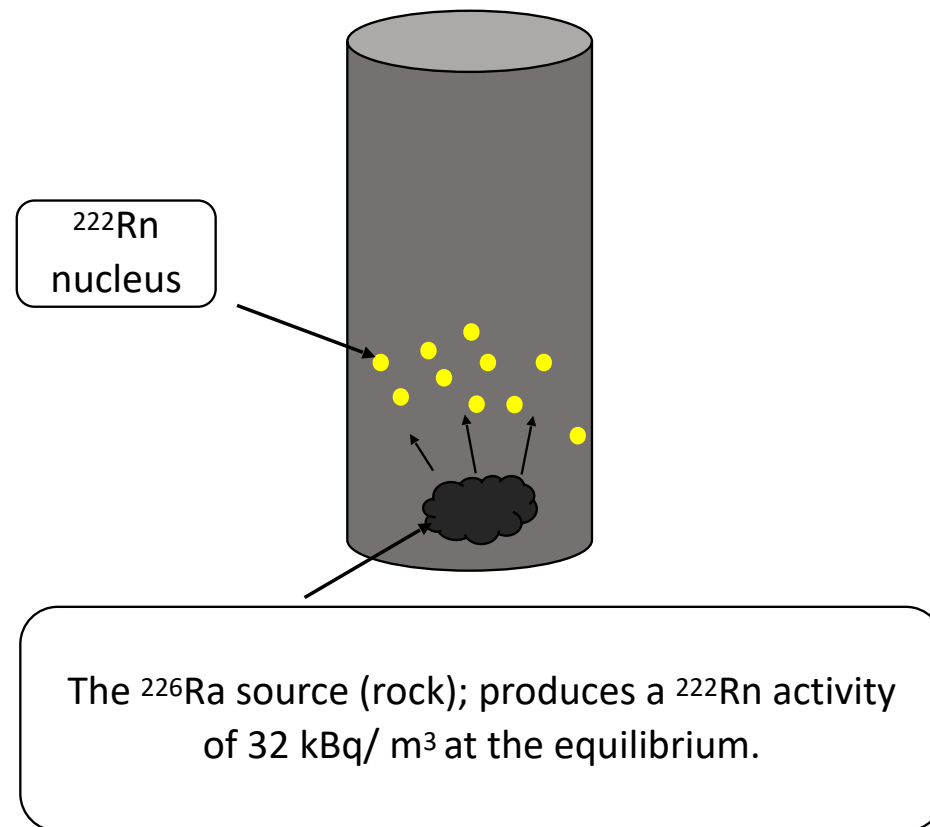


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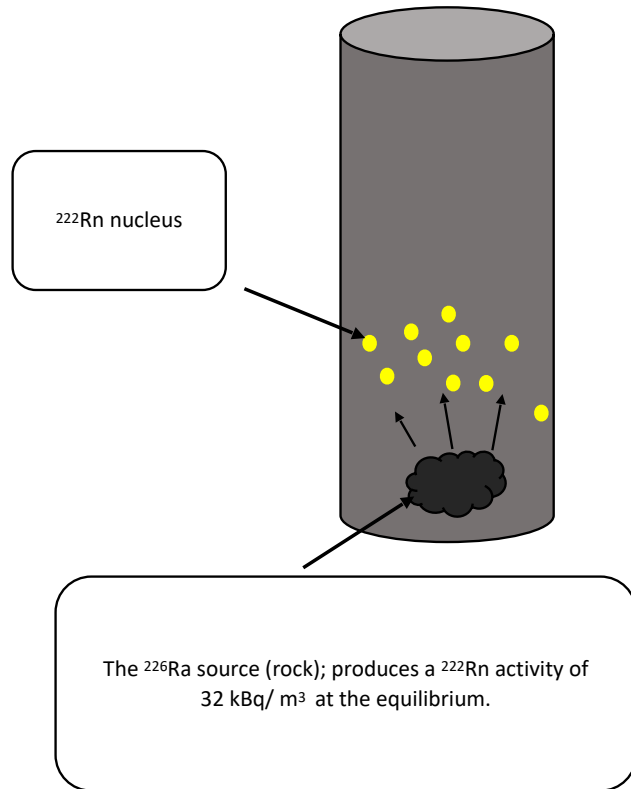


“Radonisation” Samples @ CPPM

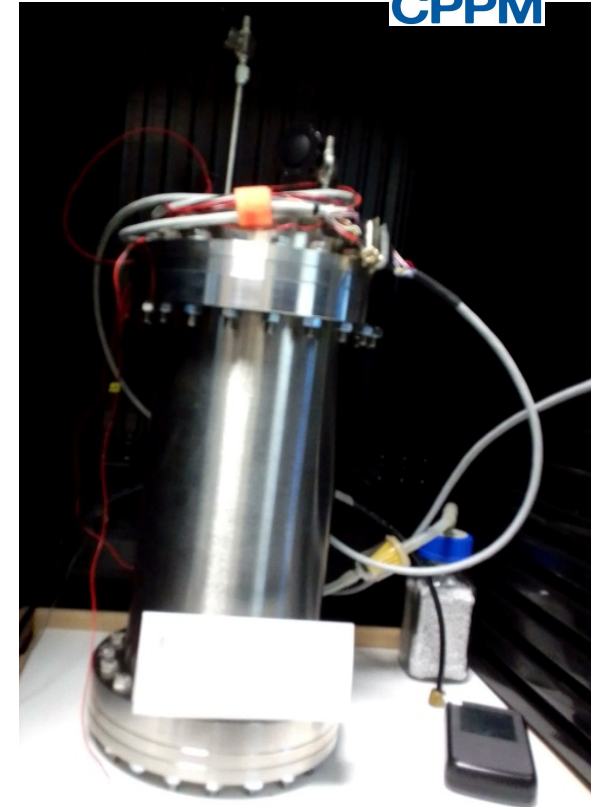
“Radonisation” Chamber



“Radonisation” Samples @ CPPM



a) Support of the samples



b) “Radonisation” chamber

“Radonisation” Samples @ CPPM

The experiment is carried out at the particle physics center of the Marseille University (CPPM) with Pr. José Busto.



- 1) Covered Copper sample with 1 plastic bag.
- 2) Covered Copper sample with 2 plastic bags.
- 3) Covered Copper sample with 3 plastic bags.
- 4) Bare silver sample.
- 5) Bare copper sample.
- 6) Bare polyethylene sample.
- 7) Bare scintillator sample.

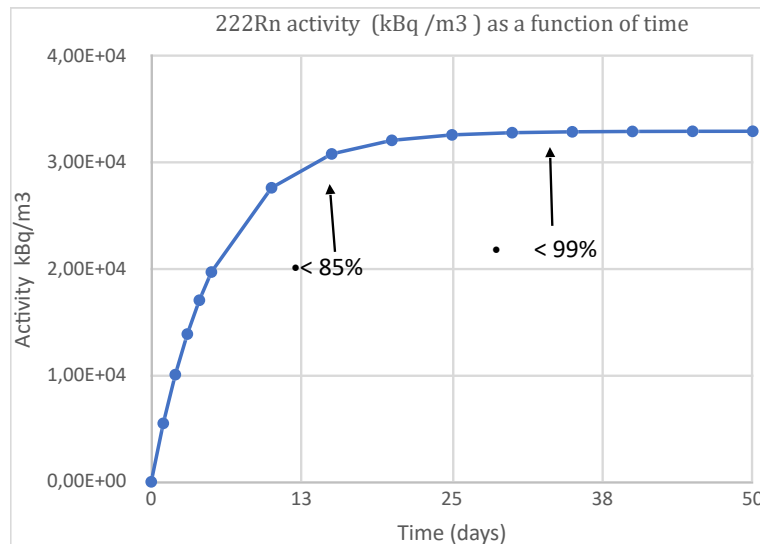
batch	Temperature °C	Humidity %
A	18	59
B	18	100
C	45	59
D	45	100

The samples used for the measurements with a size of 3x3 cm

Temperature and humidity conditions during measurements

“Radonisation” Samples; 1st Results

^{222}Rn activity evolution over time



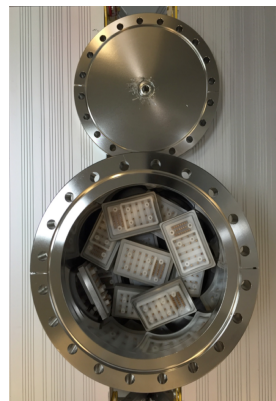
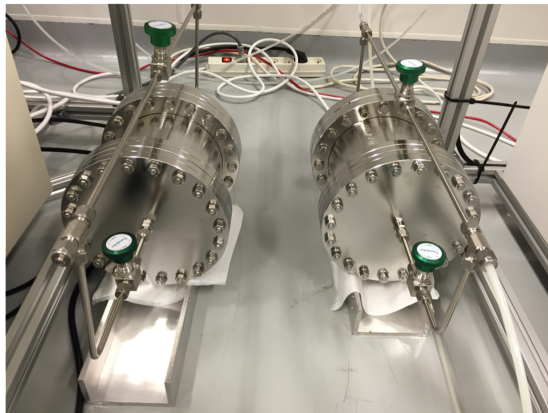
illustrates the evolution of ^{222}Rn activity as a function of time in the measurement chamber.

- The results from our measurement are under analysis
- Other experiments were done for DARKSIDE. The results: using the several layers of plastic show:
 - 1 foil layer decrease by factor 3.6
 - 2 foil layers decrease by factor ≥ 160
 - 3 foil layers decrease by factor ≥ 160 (detection limit)

Measurement

Emmanation

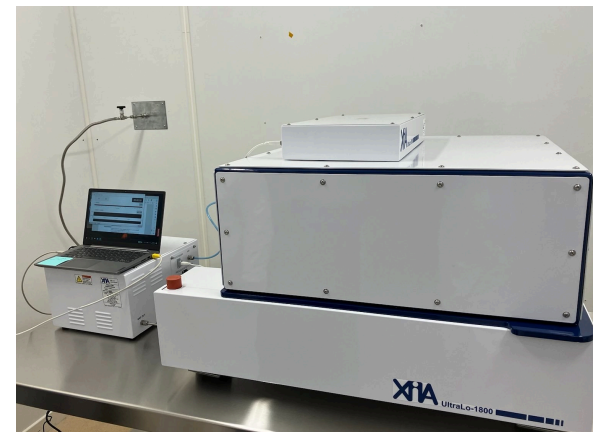
- *All detector components and construction materials are tested for their radon emanation levels*
- *small samples with large surfaces*
- *Sensitivity (@90% CL): $^{214}\text{Po} < 0.09 \text{ mBq per sample}$*



Fang Xie, HEPP and APP Conference 2018

Surface contamination measurement by XIA,

- *Boil-off Argon gaz from Liquide Argon is used as a target*
- *By measuring rise time ($t_{\mu} - t_0$), surface event are distinguished*
- *Sensitivity of $0.0011 \pm 0.0003 \text{ alpha/cm}^2/\text{h}$*



Mitigation: Anti-radon air facility

Examples of LSM former radon free air facility

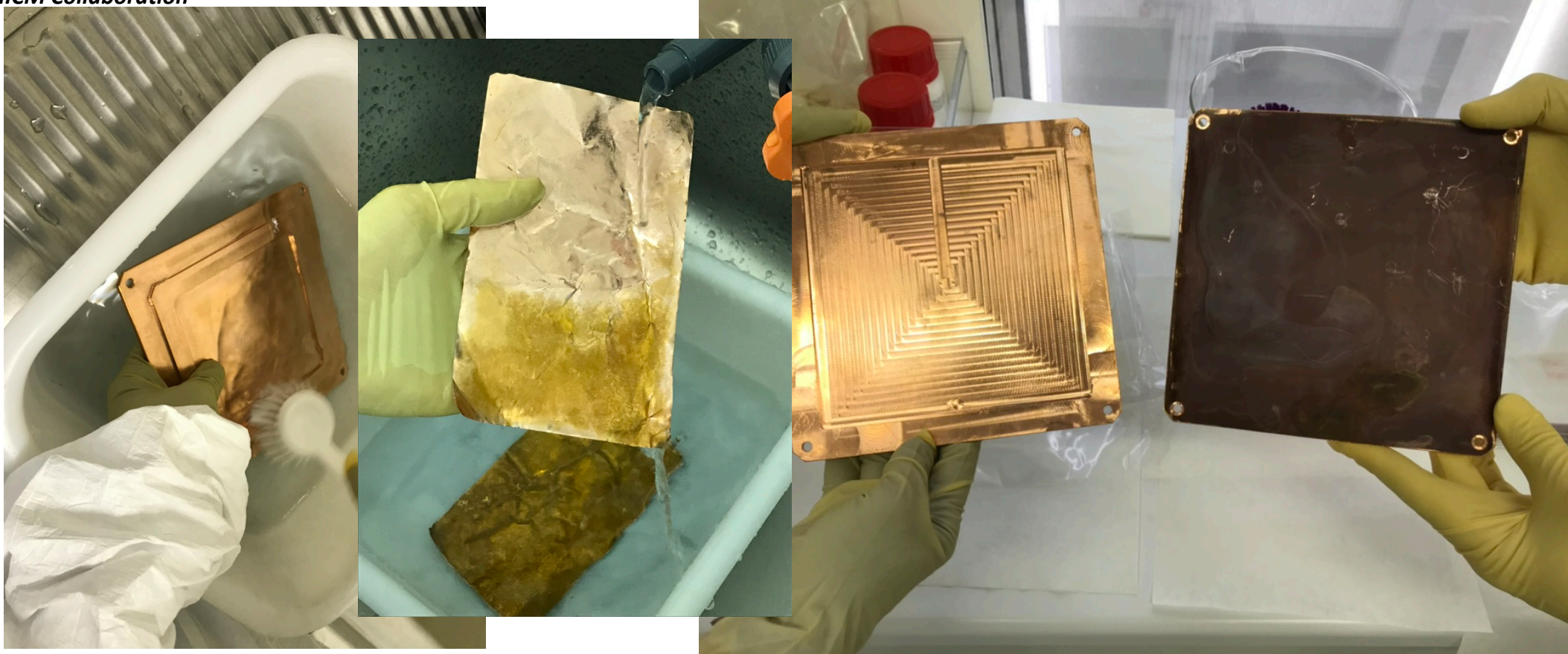


- 500 kg Charcoal
 - Flux: $\approx 250 \text{ m}^3/\text{h}$ anti-radon air
 - Activity:
 - Before facility $\approx 15\text{-}20 \text{ Bq}/\text{m}^3$
 - After facility $\approx 15 \text{ mBq}/\text{m}^3$
-
- It is impossible to provide the anti-radon air to whole the lab or experiences s area, In the most of the case, a tent is installed around the detector and anti-radon air is circulating.

Mitigation: Cleaning

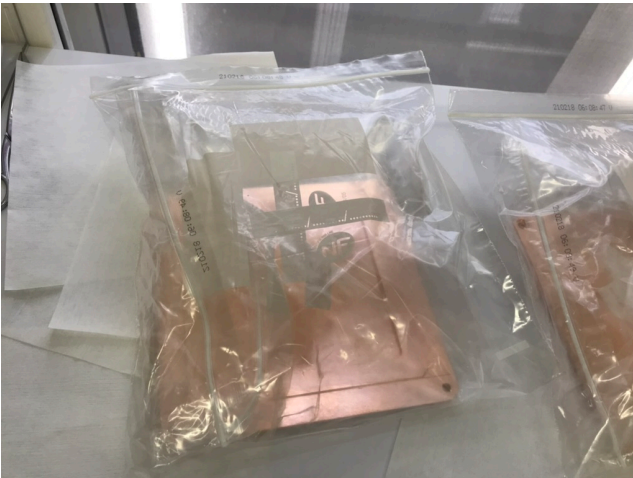
Copper chemical cleaning

DAMICM Collaboration



Mitigation: Packing

DAMICM Collaboration



- **Packing**
 - 3 layers of zip bag plastic is used
 - The cleaned/packed components storage inside of a clean box
 - Box is protected with the plastic film

Summary

- Radon is a noble gas existing in air. Radon or its daughters can become a background source for rare events experiments
- Today there is no model for Radon daughters implantation
- In this work we find implantation depth of a few nm up to several tens of nm
- Simulation of implantation performed with GEANT4 in good agreement with SRIM
- Surface modelling ongoing to have a more accurate model of depth distribution
- Comparison with experimental implantation in real material
- Radon measurements: emanation, diffusion and surface
- Mitigation: Anti-radon air, cleaning and packing



سپاس
Sépâsse
(Persan)

Thanks

Merci

謝謝

"Mési"

(Créol)

Danke

Grazie

Gracias

Dziękuję

धन्यवाद