Radon daughter deposition modelling and measurement

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Kraków, Poland

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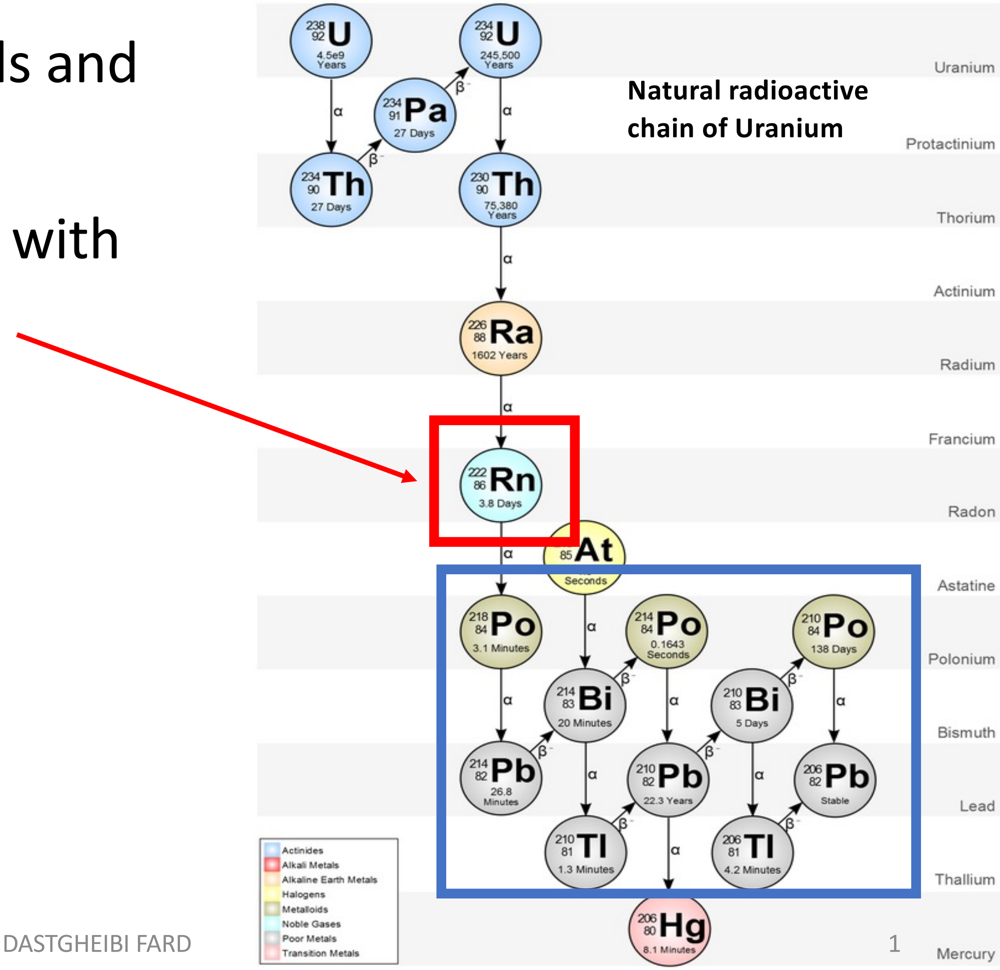
Motivation: Radon daughters as background sources

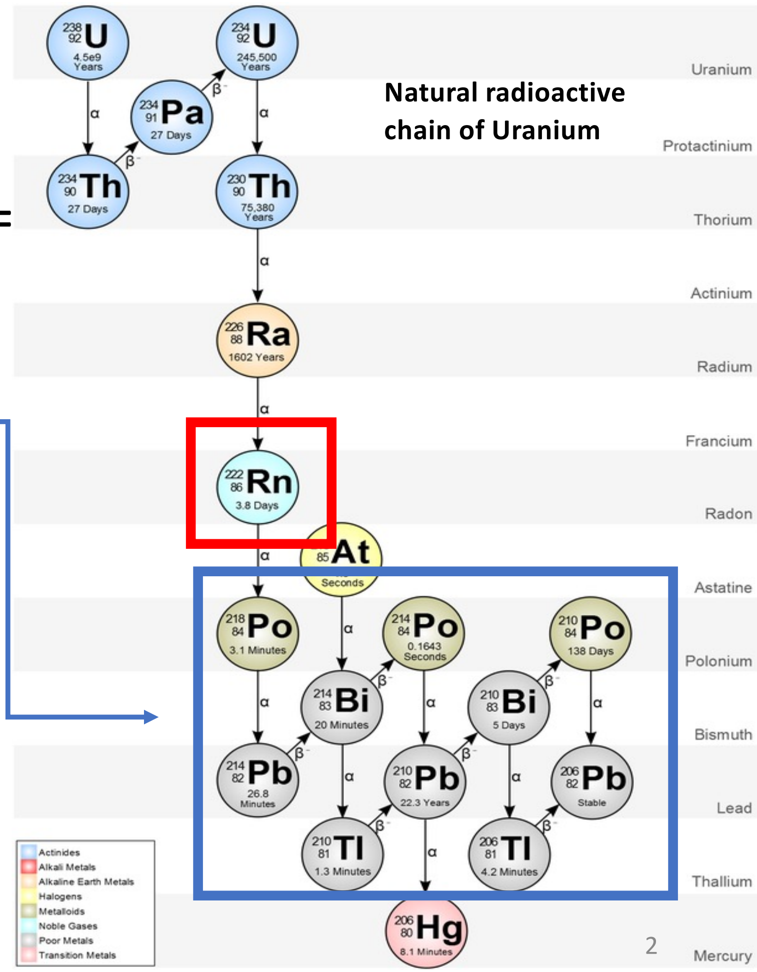
- Radon in air comes mainly from the soils and rocks emanation $\approx$ 50-100 Bq/m^3
- Radon (^{222}Rn) is a noble radioactive gas with $t_{1/2}$ = 3.8d



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 $t_{1/2}$ = 3.8d existing in air ≈ 50-100 Bq/m^3
- Radon daughters can deposit on the surfaces

of the detector components in contact with air



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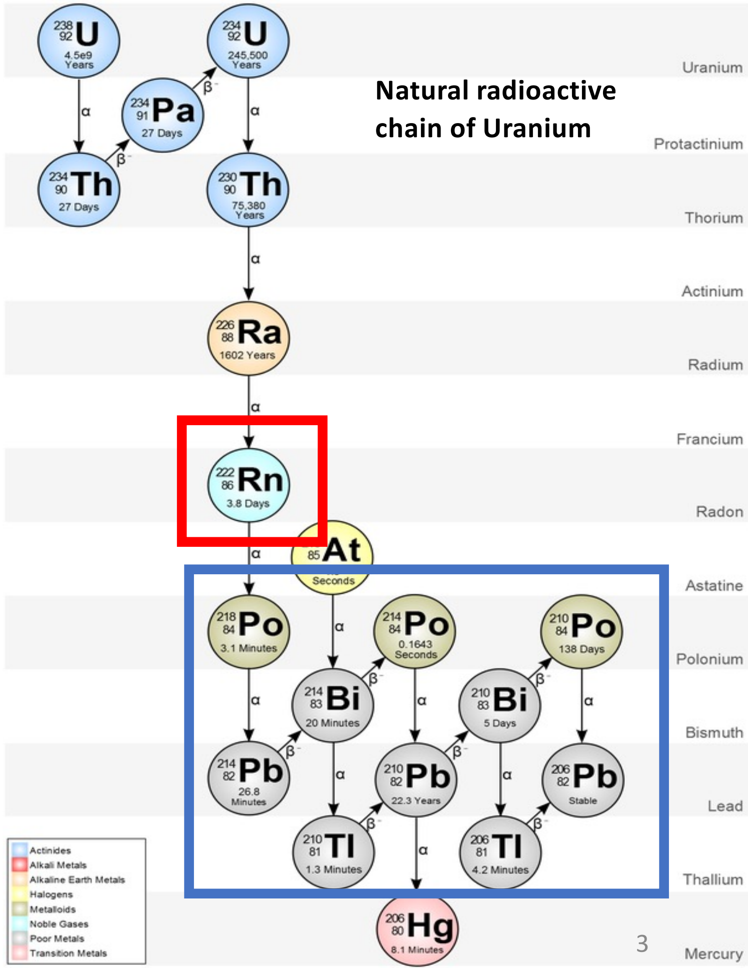
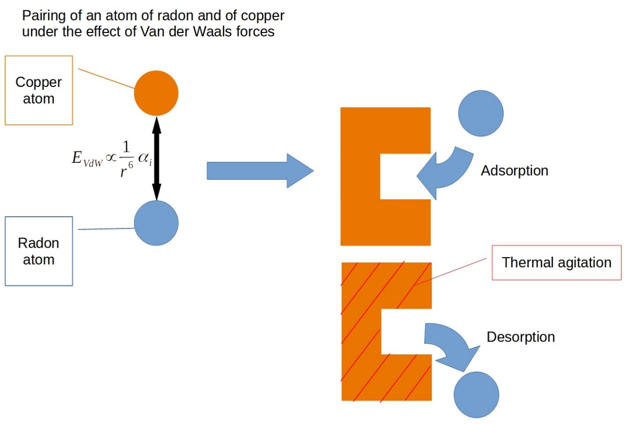
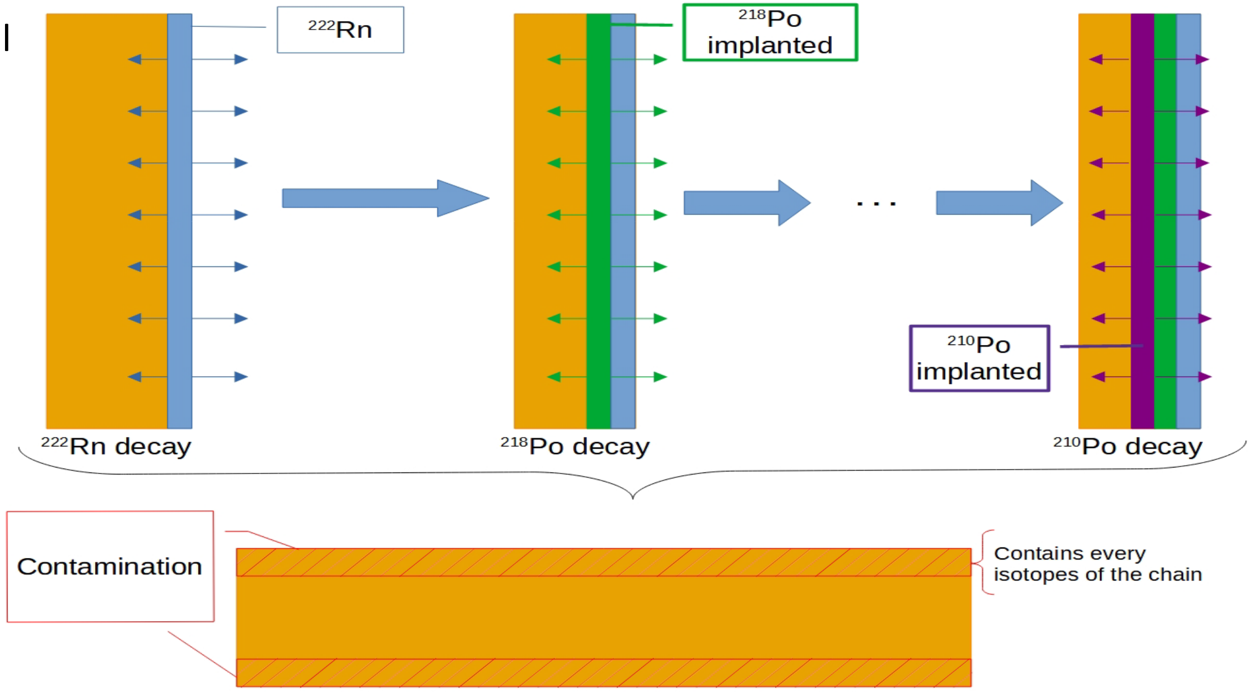
- Main concerned isotopes:
  - ^{210}Pb -> $t_{1/2}$ = 22.3 y
  - ^{210}Po -> $t_{1/2}$ = 138 d
- Possible background source for rare events detection at low masses



Radon Implantation mechanism

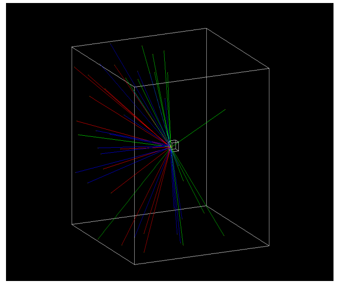
- Radon can be adsorbed on the surface
- The adsorption depends on thermodynamical parameter
- After adsorption the radon daughters decay and implant ^{218}Po by nuclear recoil

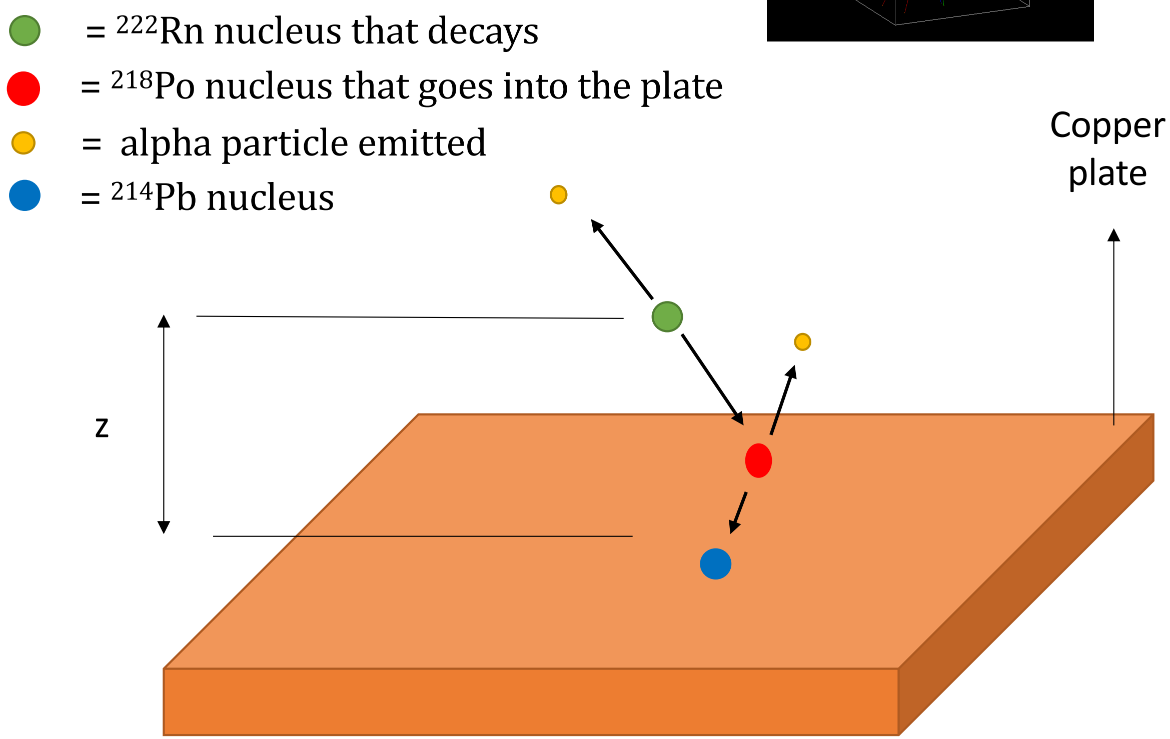




Implantation model

- 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

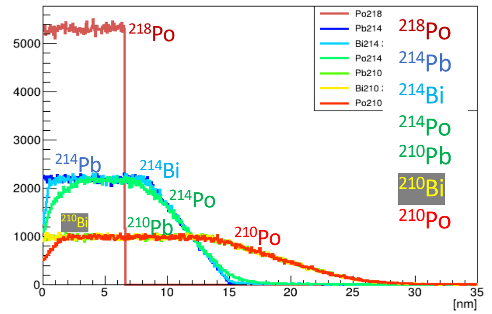




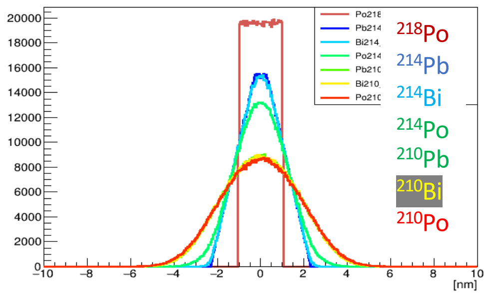
First test on Si wafer and Copper

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

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



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



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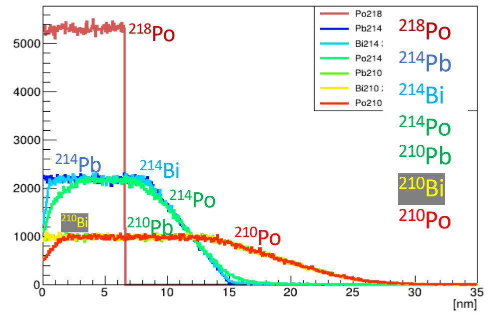

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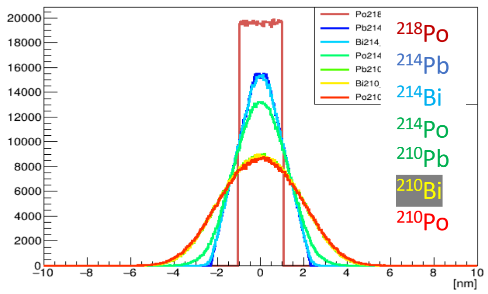
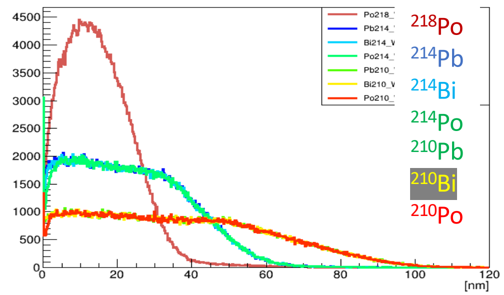
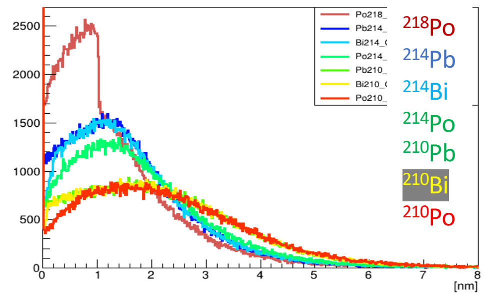


Decays at (0,0,1 nm)

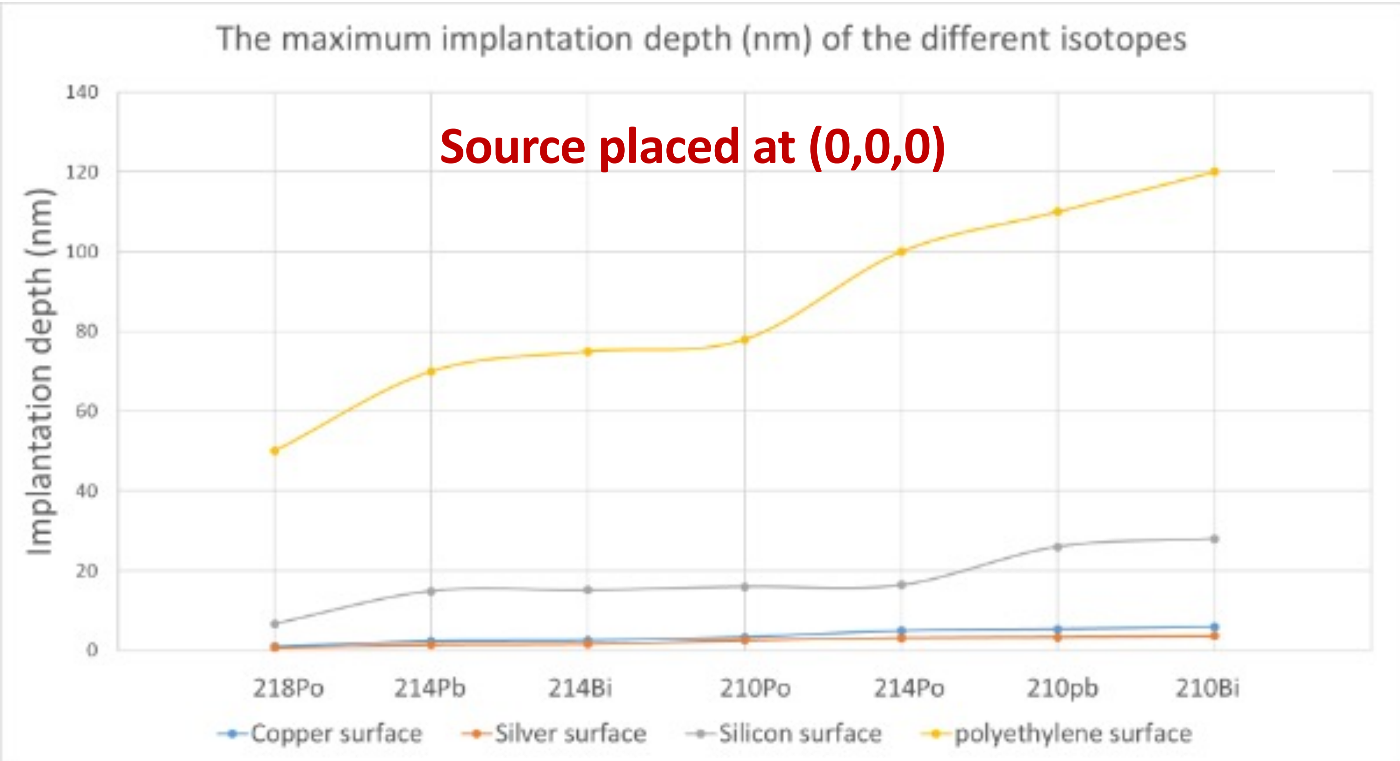
^{222}Rn decay (1E6) Si wafer



^{222}Rn decay (1E6) Copper



First test: More materilas where tested



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

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

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

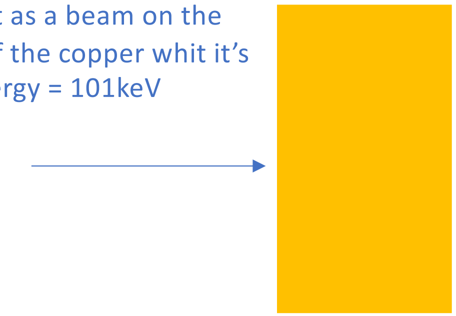
And

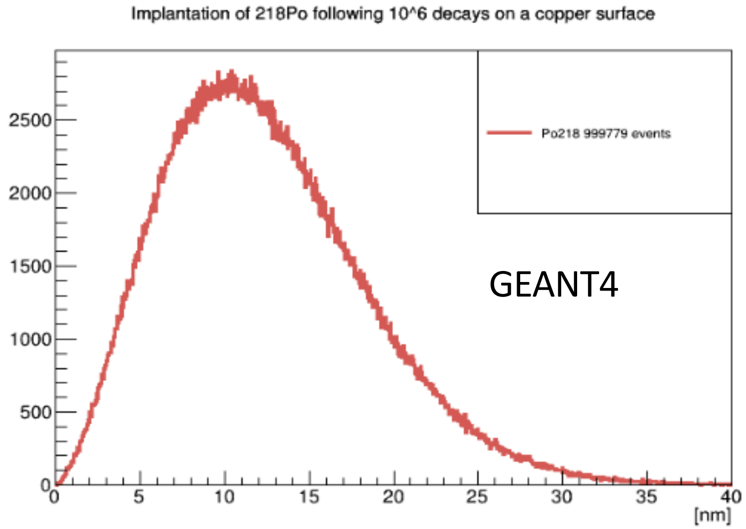
$$Z_{Ag} > Z_{Cu} > Z_{Si} > Z_{PE}$$

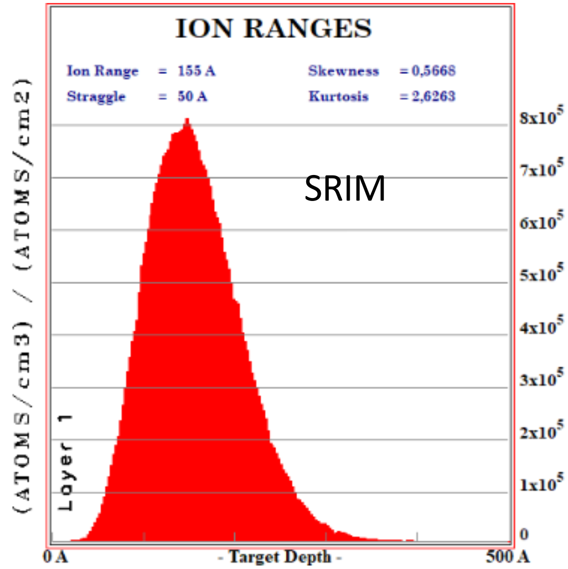
Geant4 / SRIM

- 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 whit it’s recoil energy = 101keV







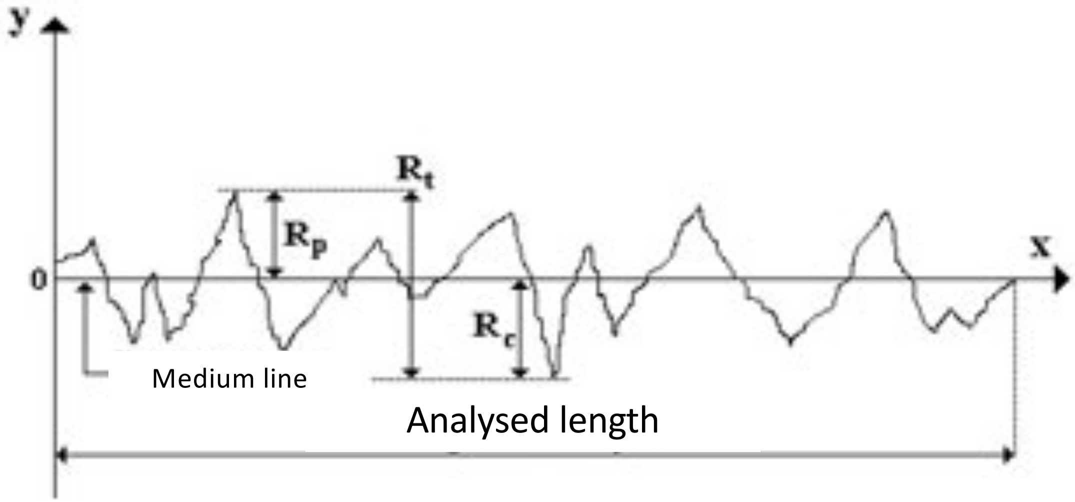
GOOD AGREEMENT

Surface Modelling

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

Where :

  - Rp = the maximum height of a peak
  - Rc = the maximum height of a deep
  - Rt = peak-to-peak height



R_p , R_c and R_t: roughness measurement parameter

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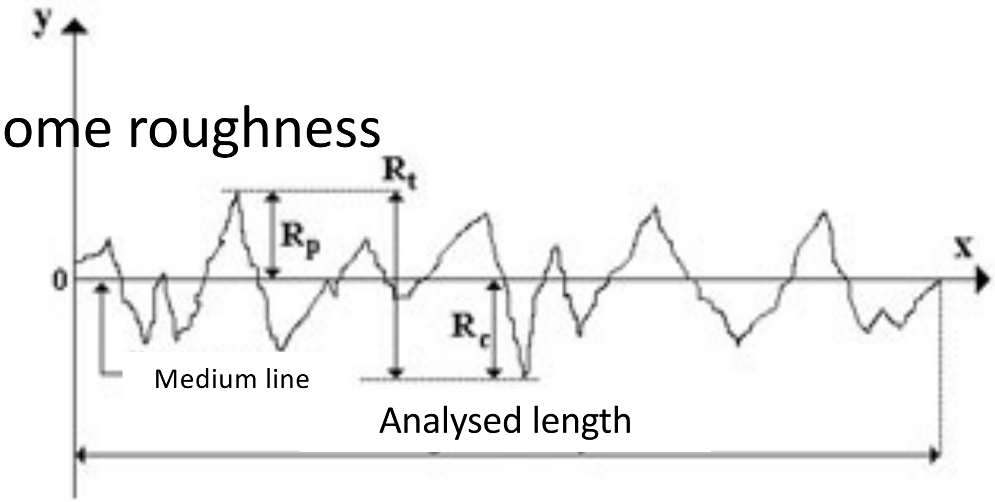

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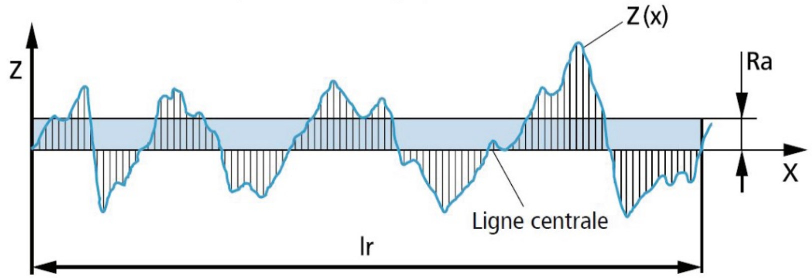

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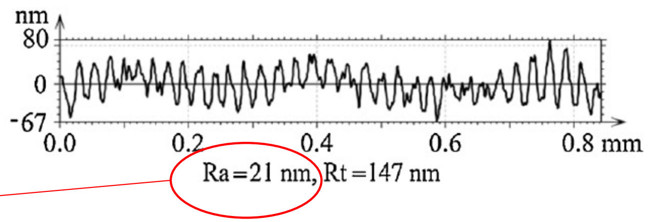
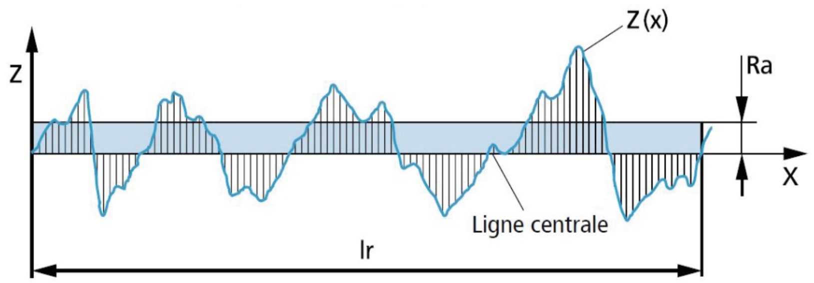


R_a = the mean half peak for a considered surface = 21 nm

Surface Modelling

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



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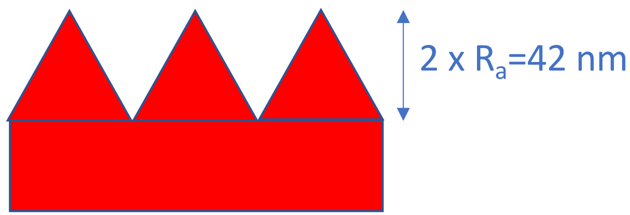
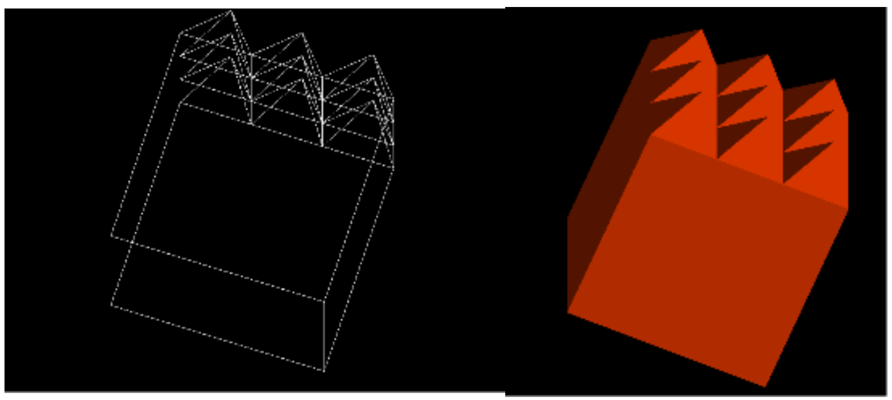
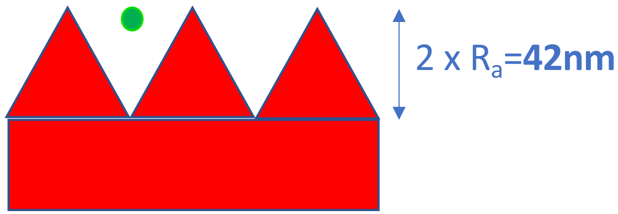


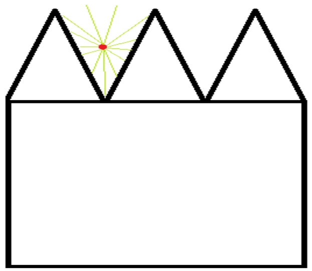


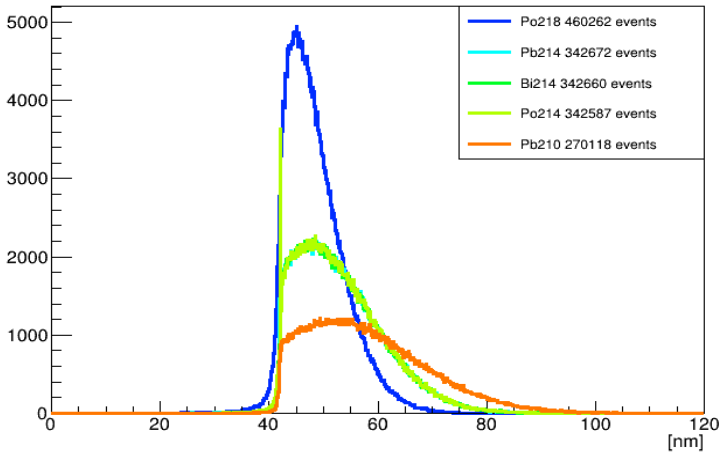
Surface Modelling

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

Decay : point z=0, iso







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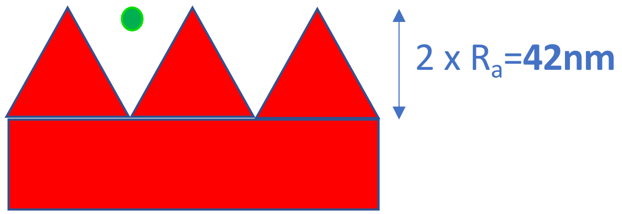
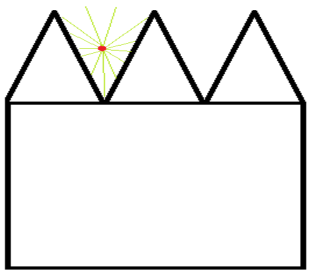
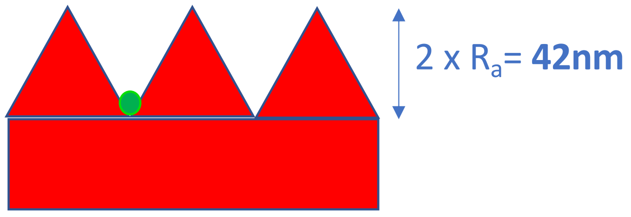
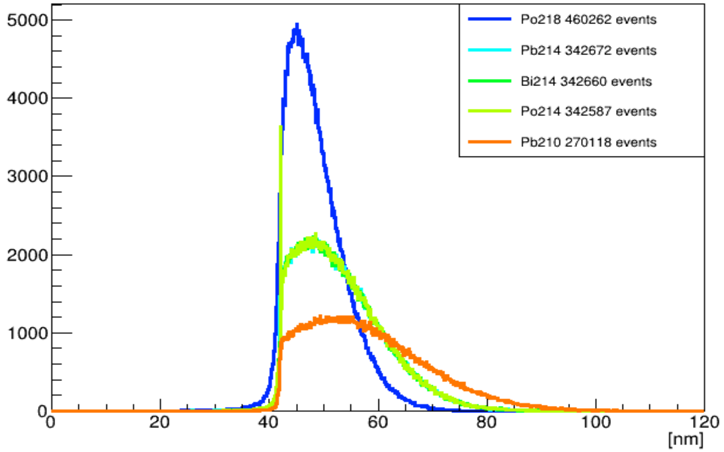
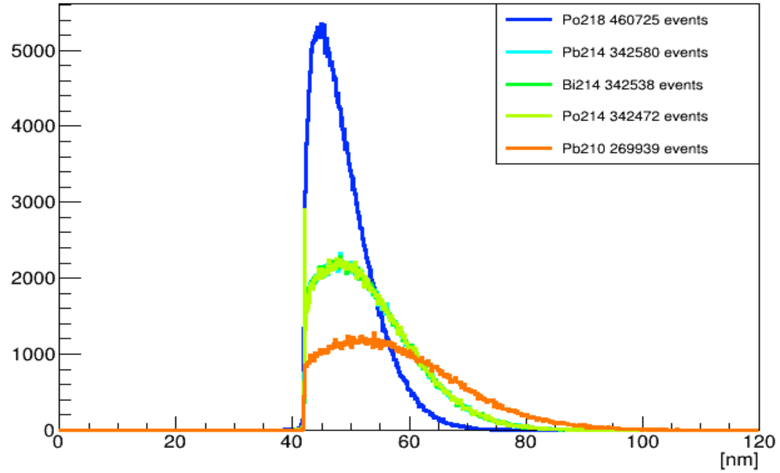




Decay : point z=-42nm, iso







Surface Modelling

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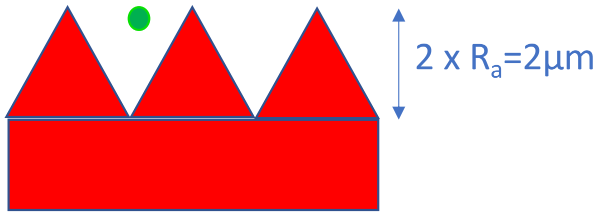
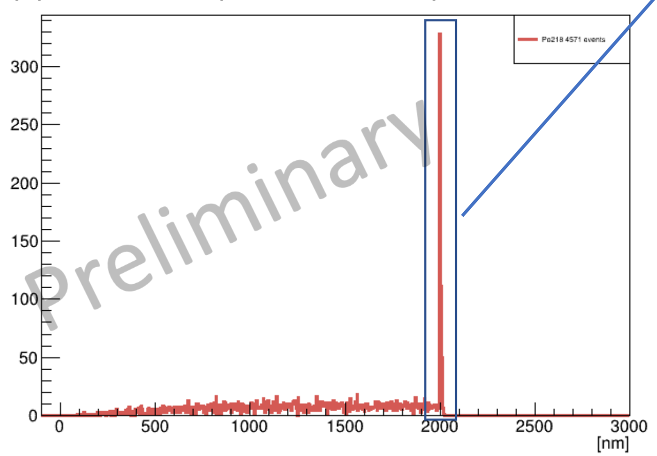
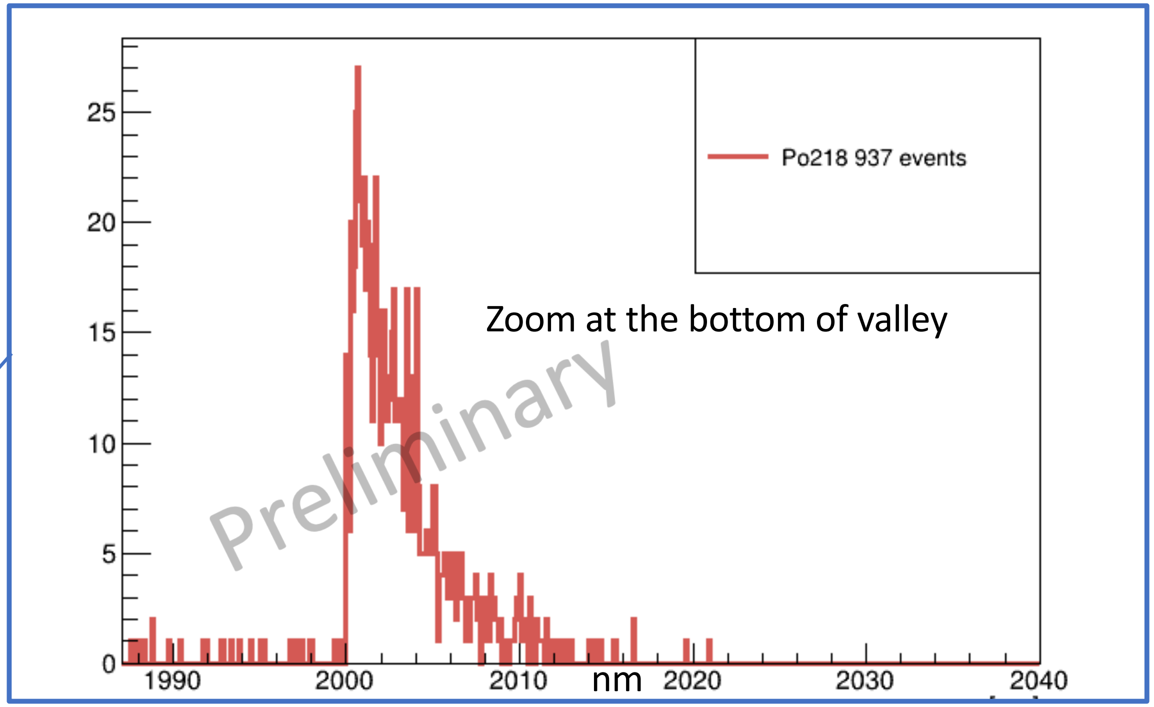


Decay of ^{218}Po at z=0, between 2 pyramids, implantation depth





Surface Modelling

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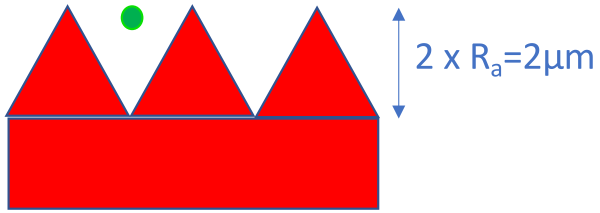
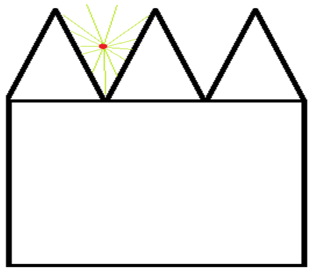
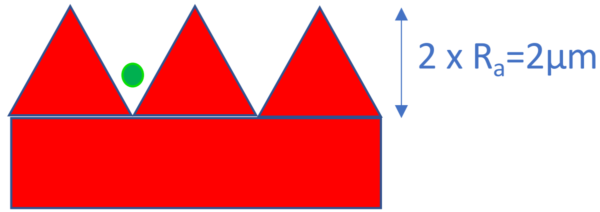
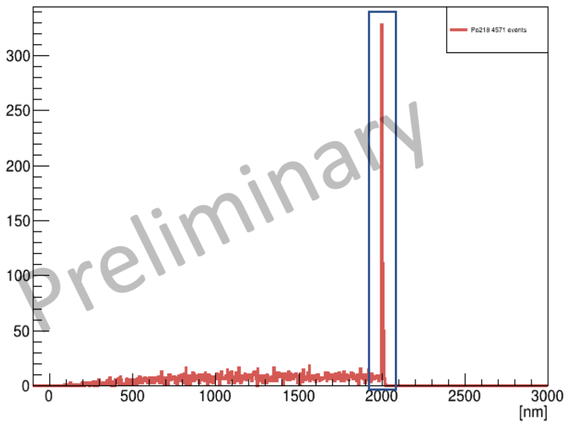


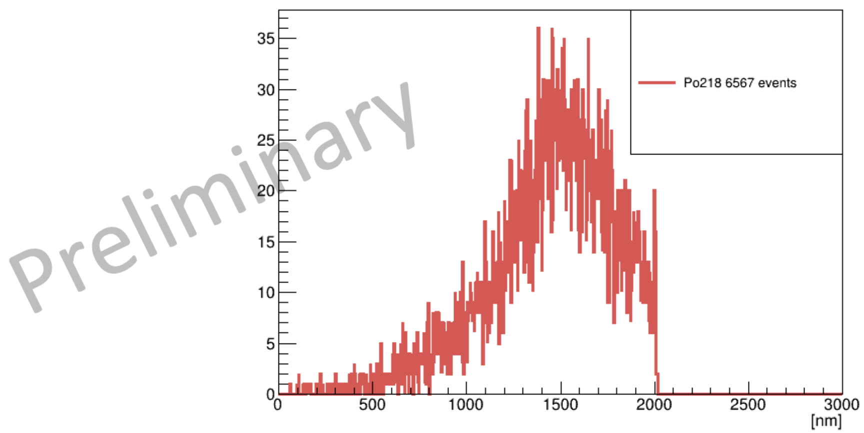


Decay : point z=-1,5, iso



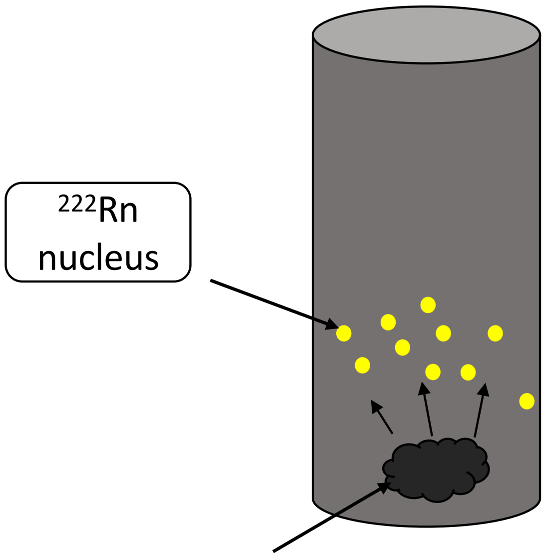
Decay of ^{218}Po , between 2 pyramids, implantation depth





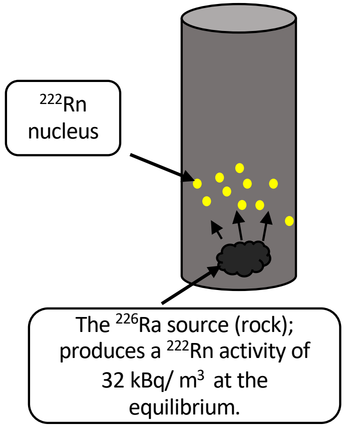
Experiment: “Radonisation” Chamber@ CPPM

“Radonisation” Chamber

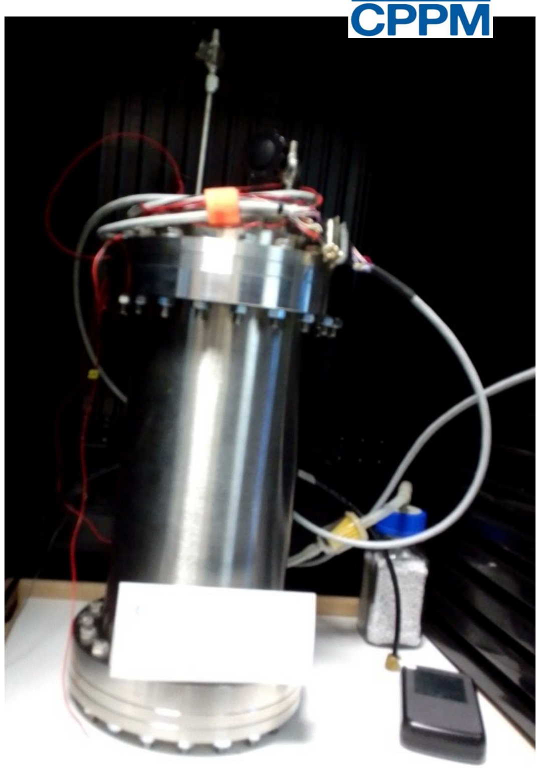


The ^{226}Ra source (rock); produces a ^{222}Rn activity of 32 kBq/ m^3 at the equilibrium.

Experiment: Samples “Radonisation” @ CPPM



a) Support of the samples



b) “Radonisation” chamber

Experiment: Samples

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

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

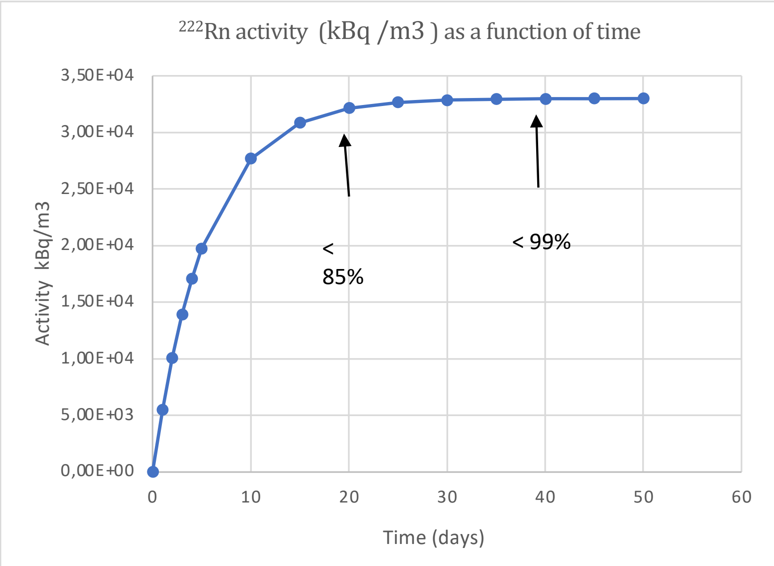
1) Covered Copper sample with 1 plastic bag.
2) Covered Copper sample with 2 plastic bags.
3) Covered Copper sample with 3 plastic bags.
4) Bare silver sample.
5) Bare copper sample.
6) Bare polyethylene sample.
7) Bare scintillator sample.

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

Temperature and humidity conditions during measurements

Experiment: 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)

Summary

- 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 perform 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

سپاس
Sépâsse
(Persan)

谢谢

Gracias

謝謝

Dziękuję

Merci

Thanks

Grazie

“Mési"

(Créol)

Danke

धन्यवाद