Radon deposition : Limits of GEANT4

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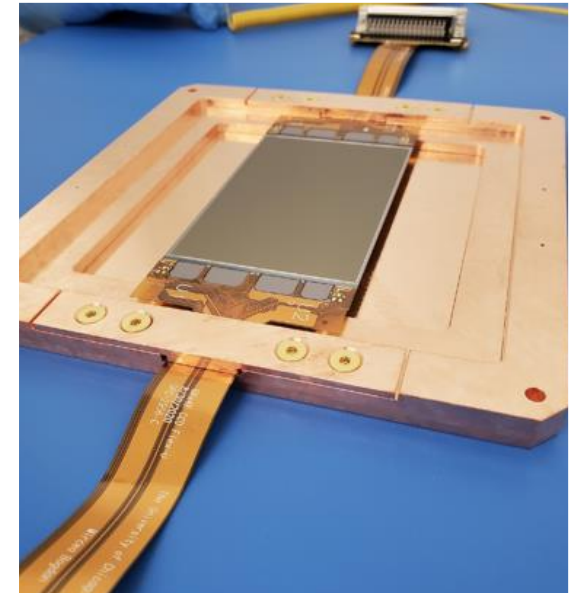
DAMIC-M experiment

Polyethylene shield

Lead shield: new and archaeological

Copper box

CCDs
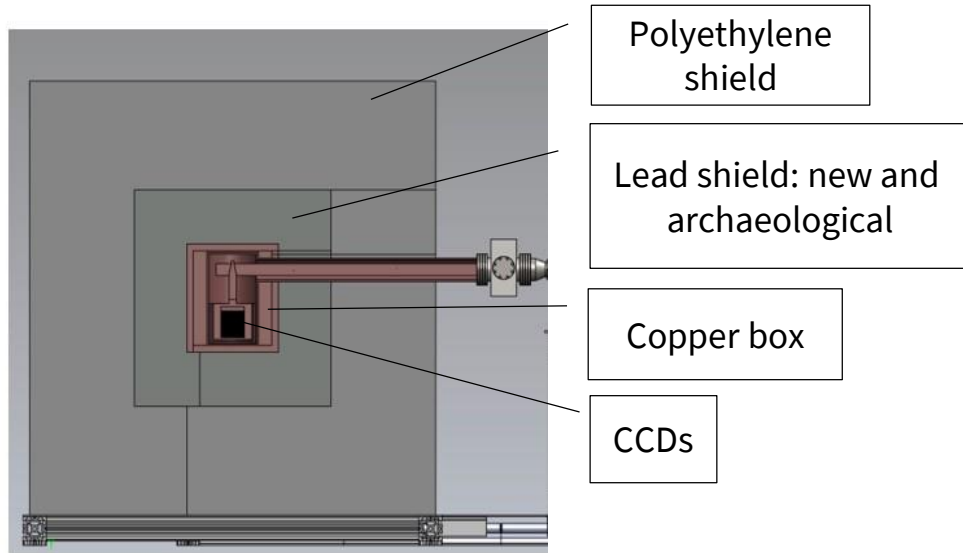
Side-view of the DAMIC-M experiment
https://damic.uchicago.edu/detector.php
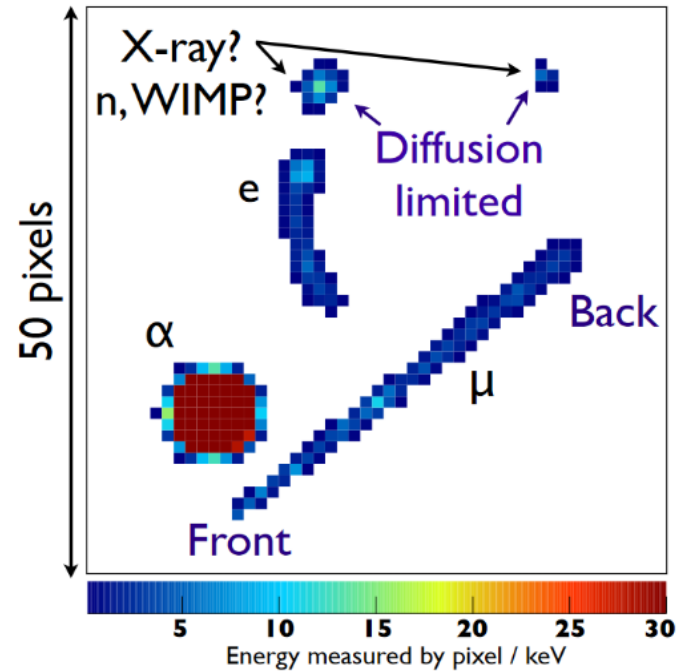
A 50x50 pixel portion of a CCD image that shows tracks of different particles
https://damic.uchicago.edu/detector.php

CCD in its support frame

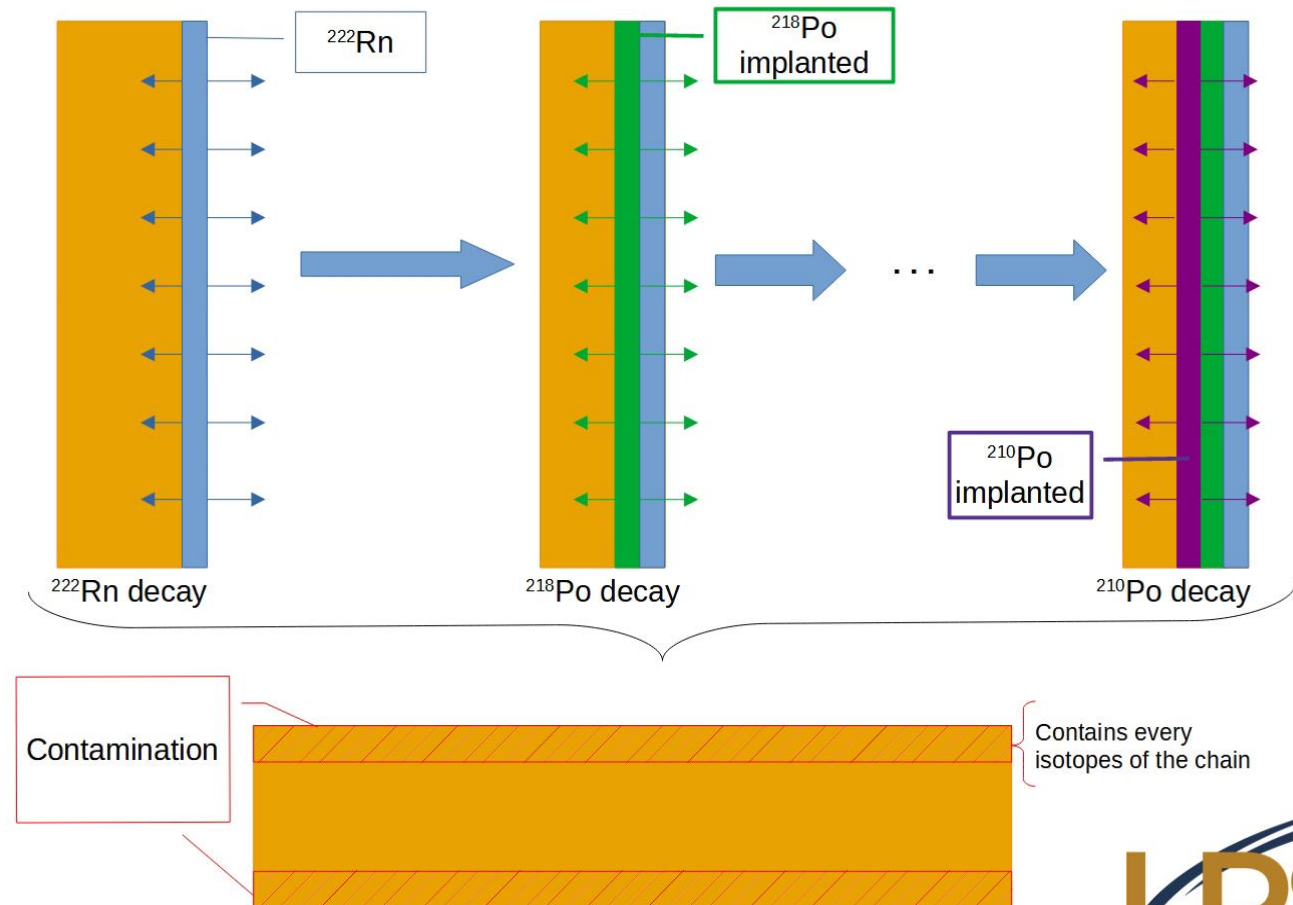# DAMIC-M Radioactive Background

- Cosmogenic contamination
- Internal contamination
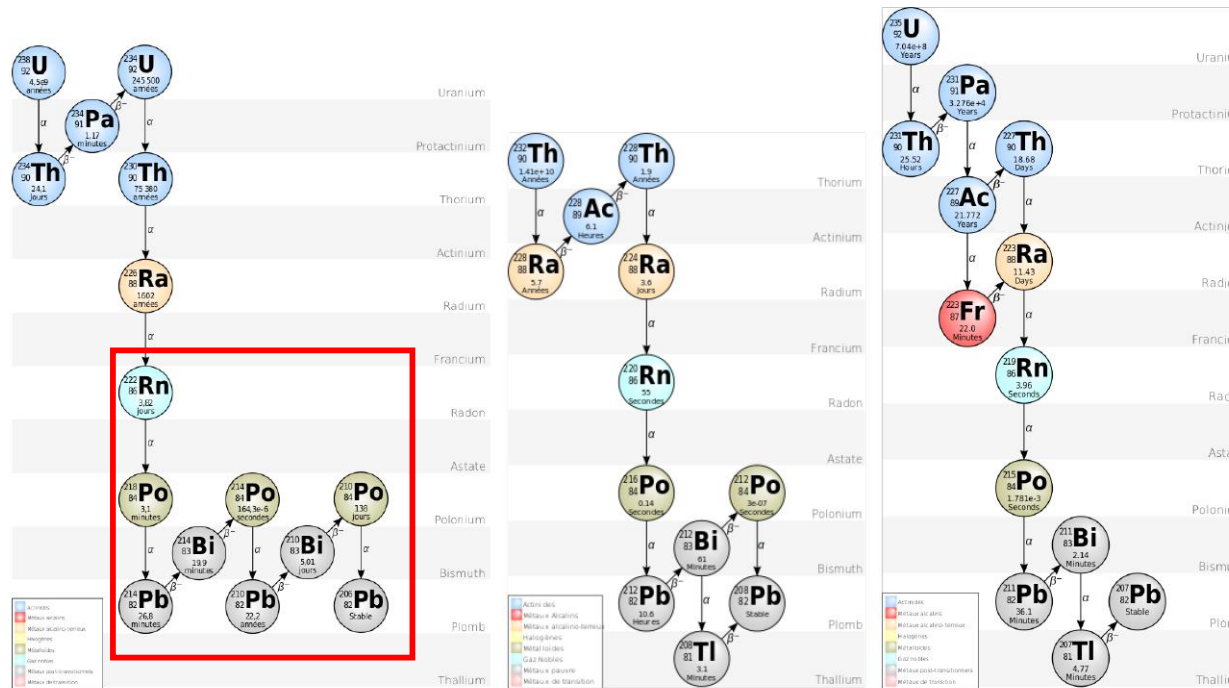
Airborne contamination due to radon daughter

Theory

- First deposition of radon or radon daughter is triggered by chemical properties
- Study of implantation using Geant4 to probe nuclear recoil
- Studied in the frame of DAMIC-M radon deposition
- Intern Theo Dubroca
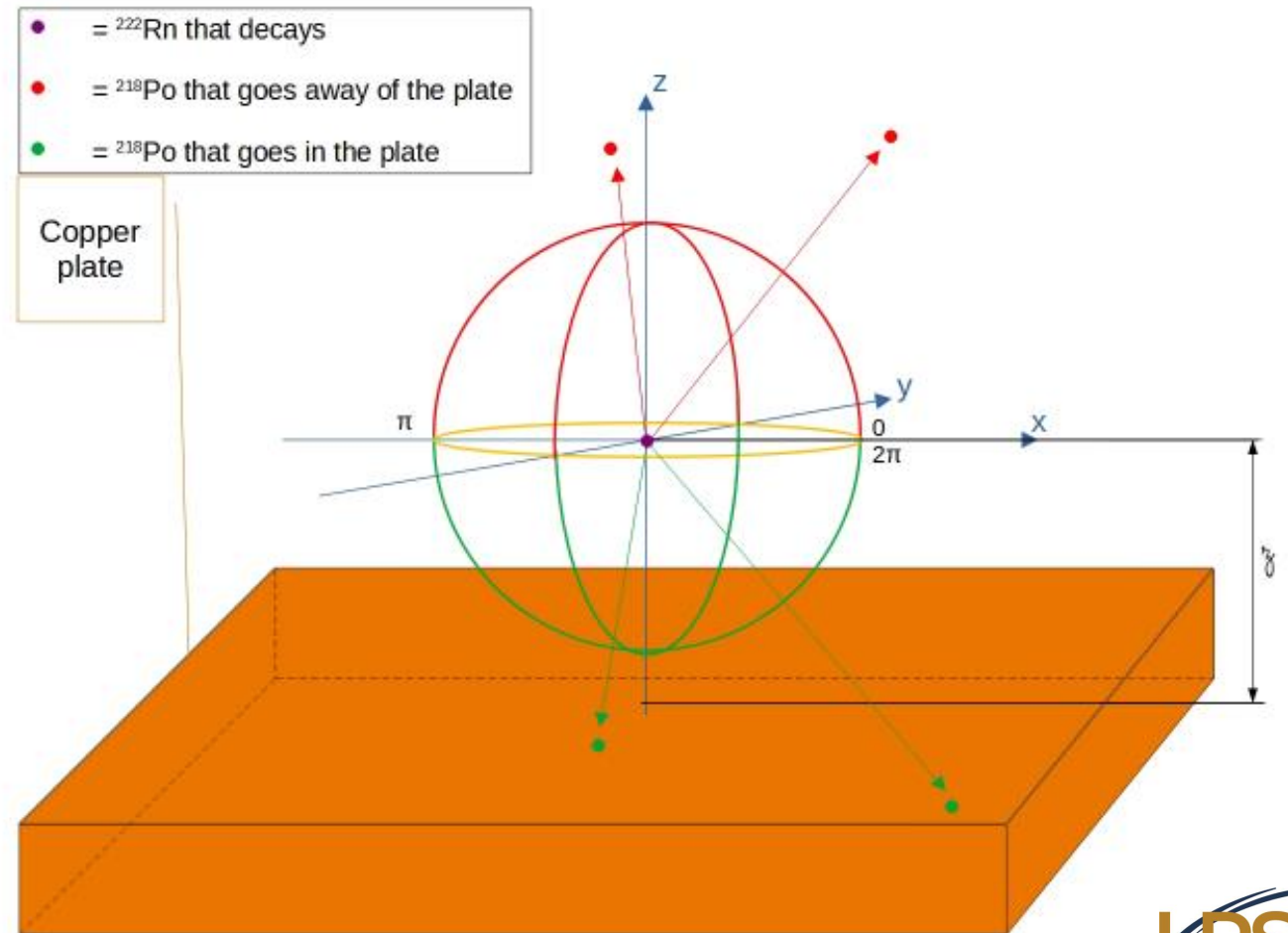
Radon implantation model

Modelisation Radon daughters:

- On the surface
- In the bulk (z tbd)
- Define a function for each isotope according the obtained curve

An internal new contamination

Which impact for detector ?

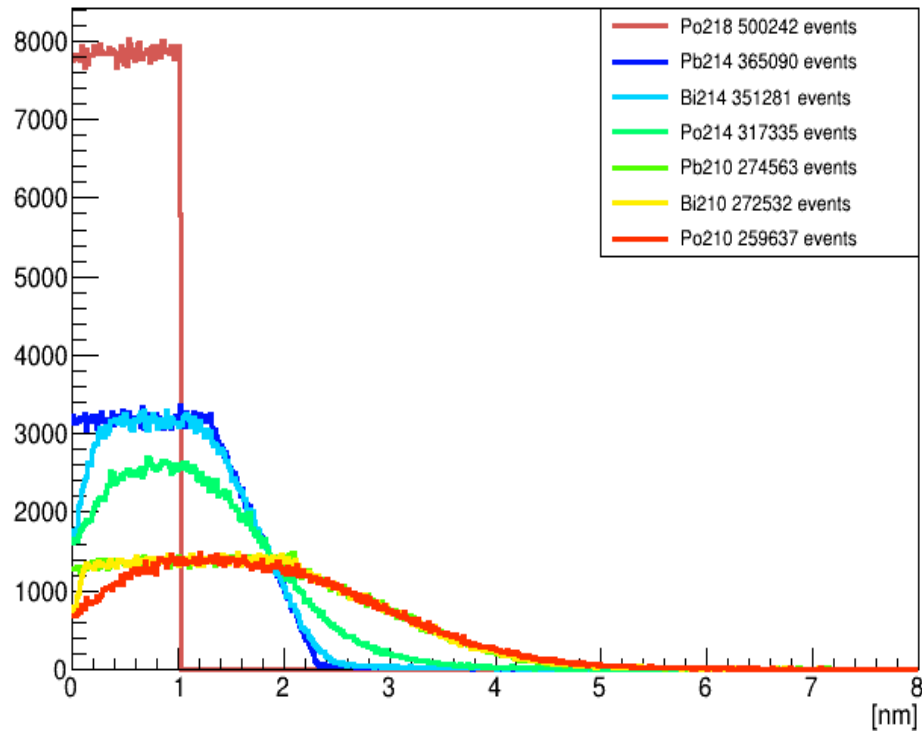These information will be an input for DAMICM background simulation

Simulation

- Geometry
- Deposition of an ion on the surface of material
- Position (0,0,0)on the surface and material below
- Full decay
- Record of the position of each nucleus daughter
- Plot projection on z axis
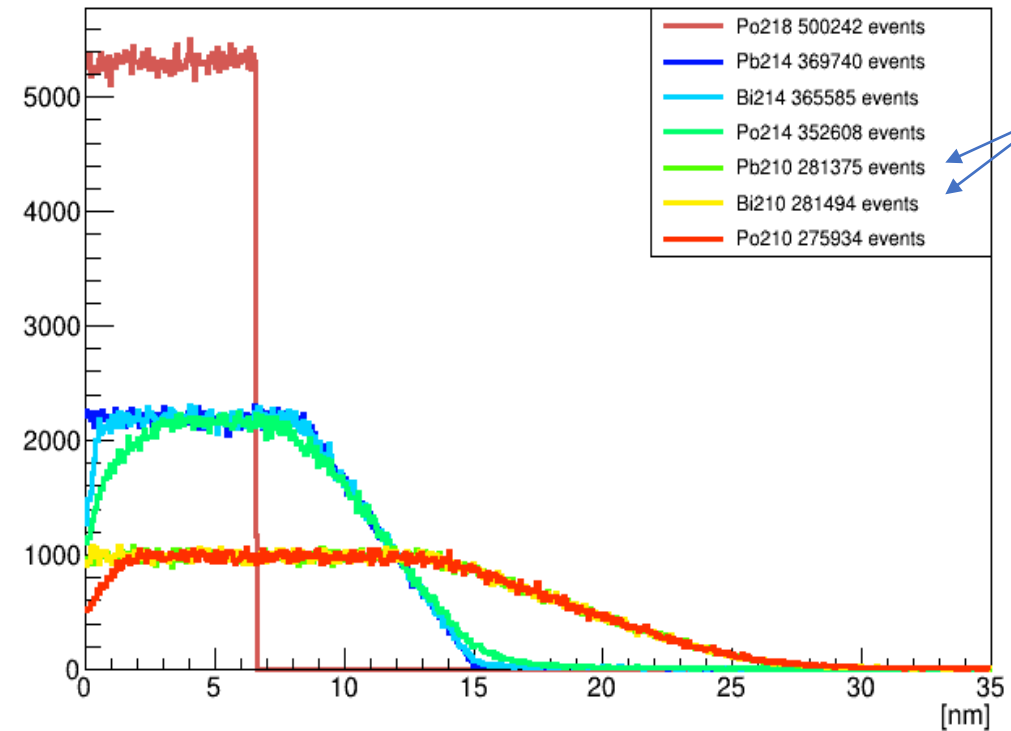- Code Given by A Brossard on behalf of News-g collaboration

Green track : photons

Blue track : ions (radioactive or not), alphas

Red track : electrons
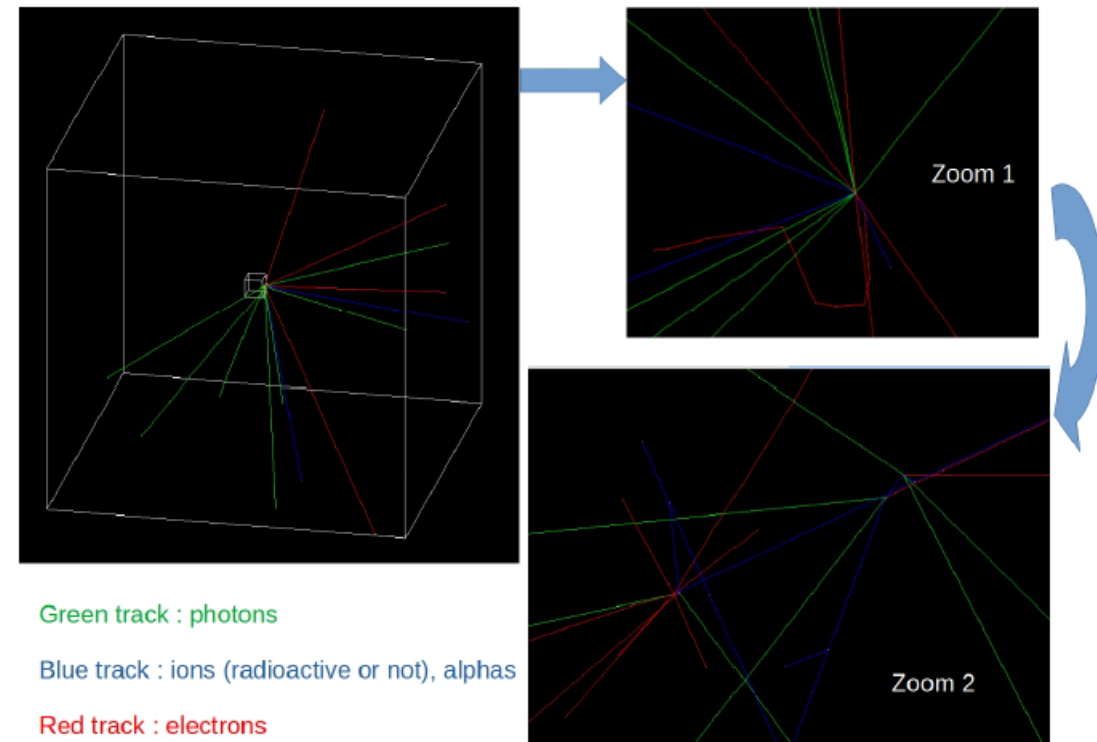
First results source on the surface

Position of decays following 10^6 decays of ^{222}Rn on surface of Cu

Po218	500242 events
Pb214	365090 events
Bi214	351281 events
Po214	317335 events
Pb210	274563 events
Bi210	272532 events
Po210	259637 events

Position of decays following 10^6 decays of ^{222}Rn on surface of Si

|	
Po218	500242 events
Pb214	369740 events
Bi214	365585 events
Po214	352608 events
Pb210	281375 events
Bi210	281494 events
Po210	275934 events

Augmentation of number of event theoretically impossible

Recoil penetration is Z and density dependent

30/11/21

Depth improbably low

```
{
    if (Z > 1.e-6)  h_Amplitude->Fill(Z/10.);
}
```
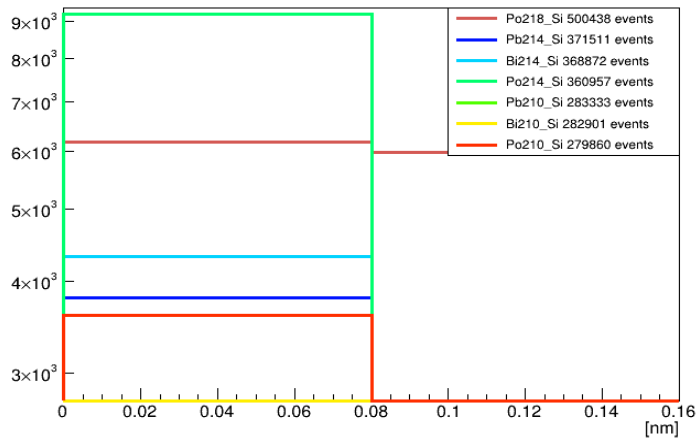
Histograms of the implantation depth are drawn without the condition :
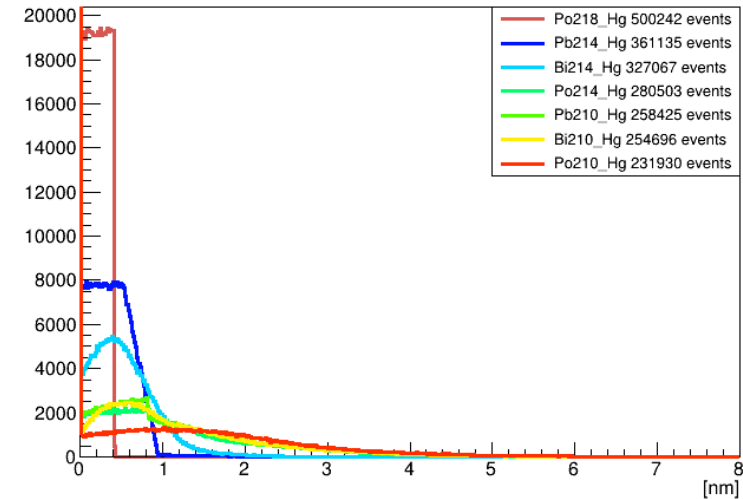"if z > 1E-6 " allowing to see unexpected surface event.
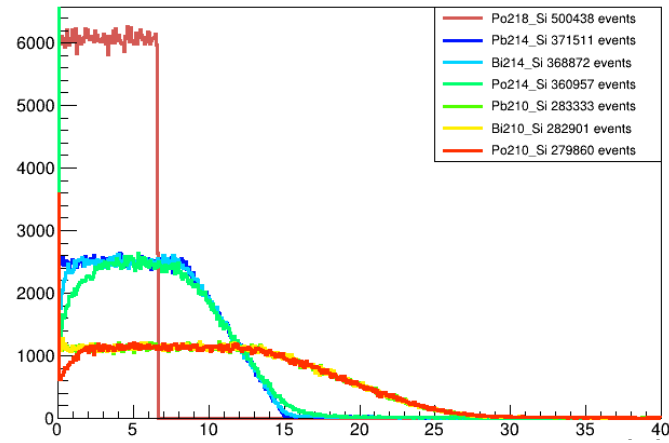
Phenomenon enhanced by using high Z material
First position of nuclei are improbable , below 0,1 nm meaning less than 1 atom
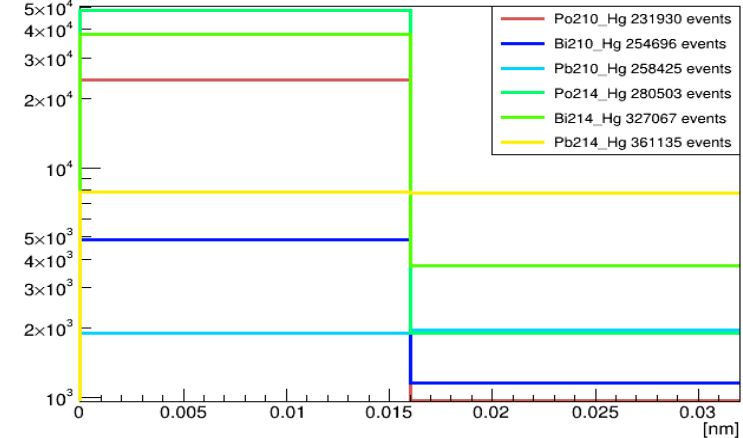
Interaction with surface

- Changing decay position to (0,0,1) nm

- New shape of the curve

Position of decays following 1E6 decays of ^{222}Rn at 1nm from the surface of water

Legend:
- Po218_Water 433955 events
- Pb214_Water 343840 events
- Bi214_Water 343202 events
- Po214_Water 340954 events
- Pb210_Water 269580 events
- Bi210_Water 269425 events
- Po210_Water 268555 events

Step 1 : Transport in vacuum

Step 2 : Transportation process

Step 3 : bounce back or
go through the surface

Step 4 : Multiple Coulomb Scattering (MSC)
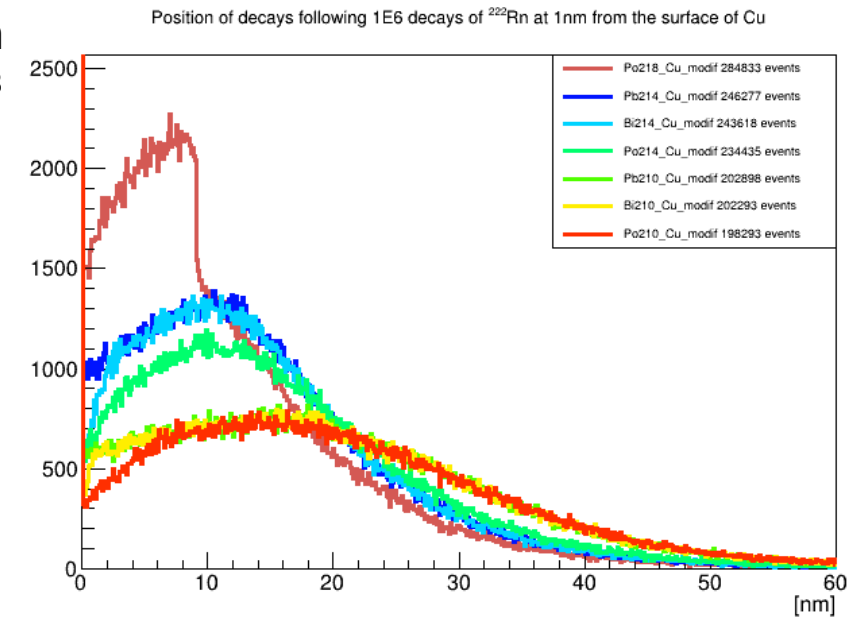processes

Copper
plate

^{218}Po

Imperfection in the shape

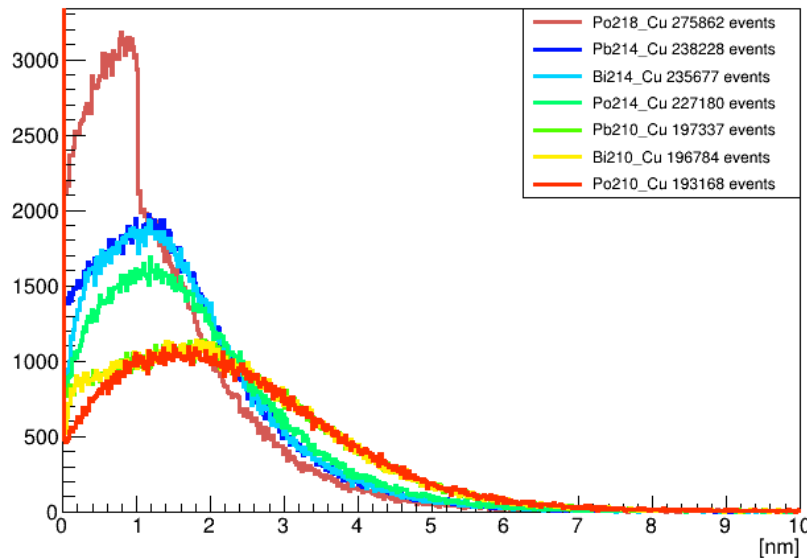- Discontinuity for higher Z

- Independant from density
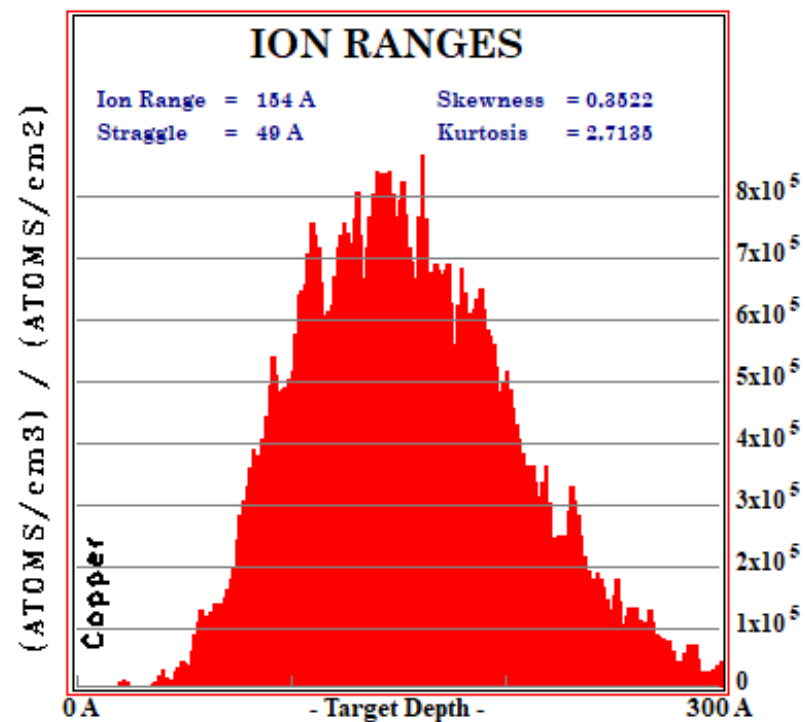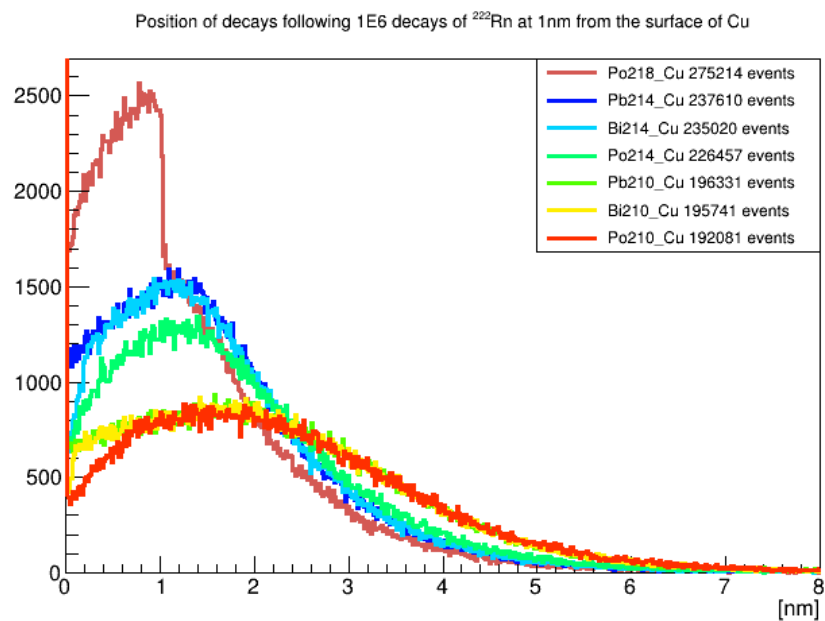
Copper
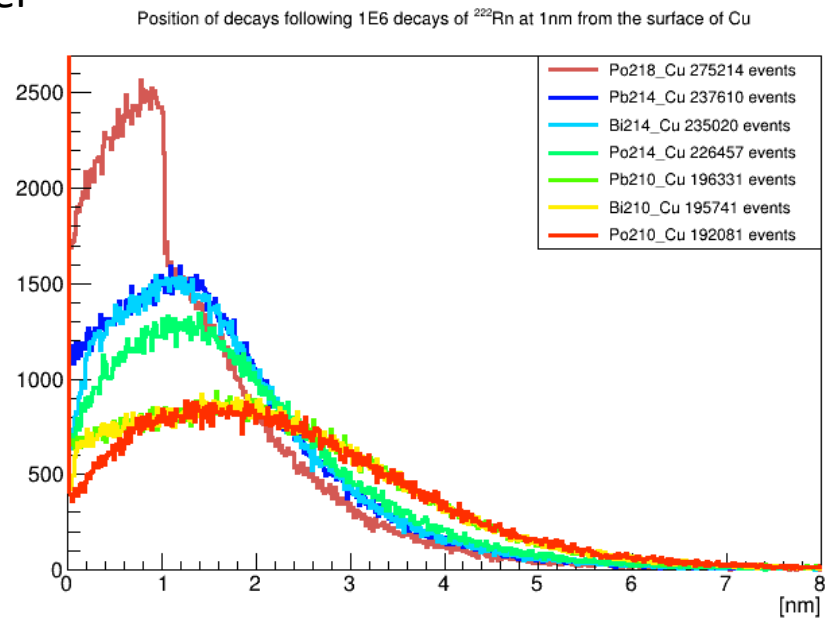
*Copper with
$\rho = 1.0$ g.cm^{-3}

Forcing G4step

- Using a step max (any) will reproduce (0,0,z) decay point

- Console shows that Compton scatering process is used instead of MSC process producing smoother but not continuous curves

G4stepmax
forced to 1μm

Comparison GEANT4 vs Srim

Position of decays following 1E6 decays of ^{222}Rn at 1nm from the surface of Cu

- Po218_Cu 275214 events
- Pb214_Cu 237610 events
- Bi214_Cu 235020 events
- Po214_Cu 226457 events
- Pb210_Cu 196331 events
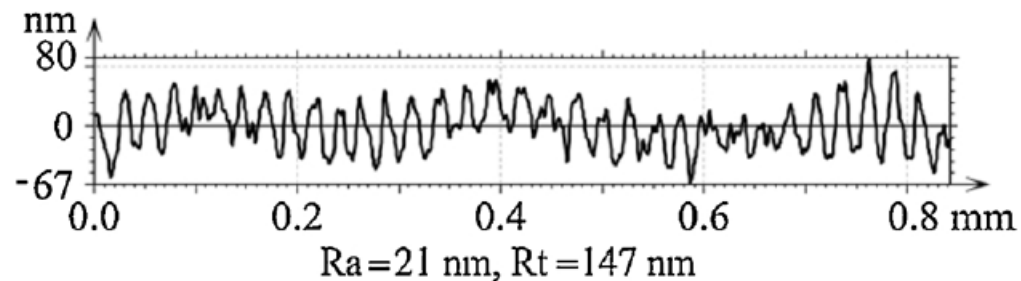- Bi210_Cu 195741 events
- Po210_Cu 192081 events

^{218}Po depth range in copper – SRIM 2013

Simulation and reality

- Simulation uses a infinitely flat surface
- Real copper side view for example (optimised OFHC)

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Ra=21 nm, Rt=147 nm

- Reproducing these shape in GEANT 4

Conclusion

- Dependences from starting decay point on results of ion implantation
- Propagation through surface turns on complex simulation mecanism
- Decay can also be properly tracked by set a UserStepMax
- Questions arose about the surface roughness of material compared to penetration of ions
- How to calibrate the results at low energy
- Thanks to Mariangela for the support