



Mesures d'échantillons issus du démantèlement de G1 par autoradiographie digitale (MAUD)

DE LA RECHERCHE À L'INDUSTRIE

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Commissariat à l'énergie atomique et aux énergies alternatives - www.cea.fr

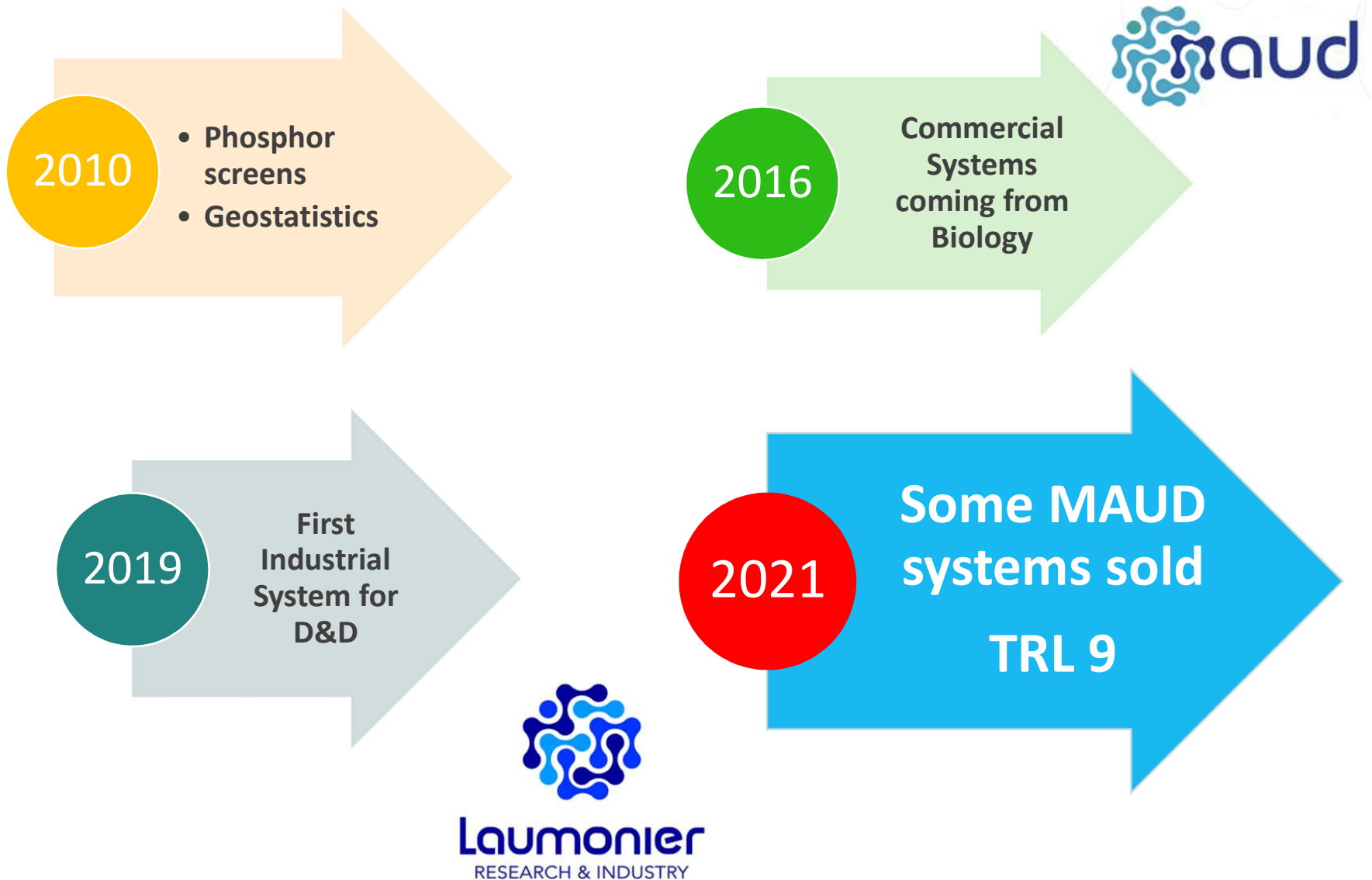


MAUD is a state funded project to improve radionuclide measurements for dismantling projects



The MAUD PROJECT is dedicated to α and β surface contamination mapping system at medium up to very small level. MAUD can be used directly on a **surface or for **sample** non destructive measurements**



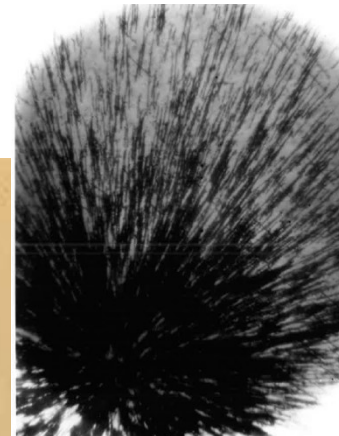


AUTORADIOGRAPHY: VERY EFFICIENT AND OLD/NEW TECHNIQUE

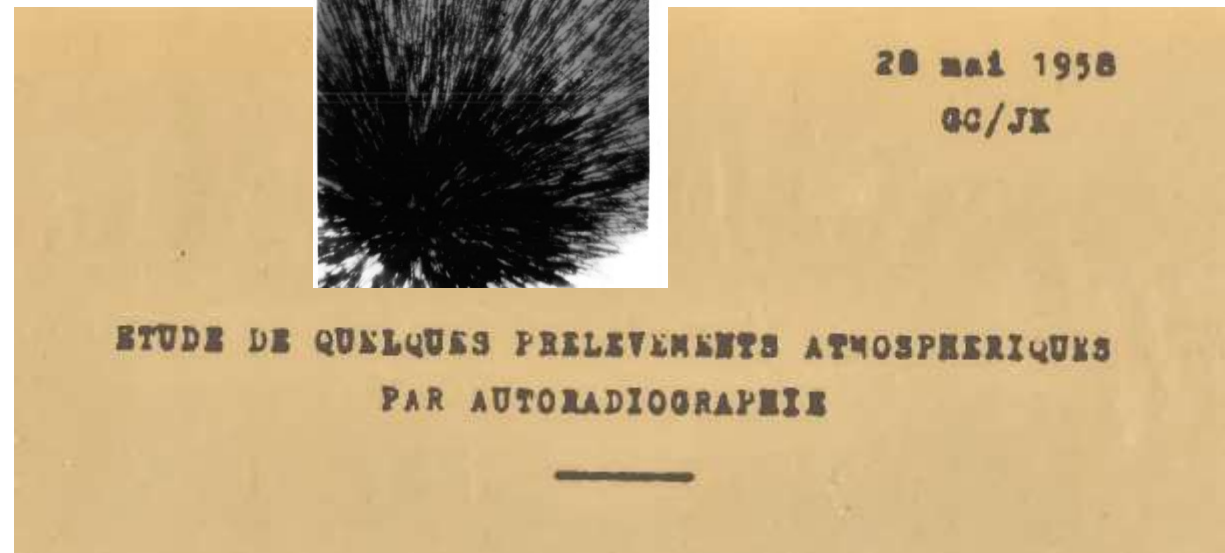


In the past, film uses to obtain an image

Image: 1896



ALPHA (1958)

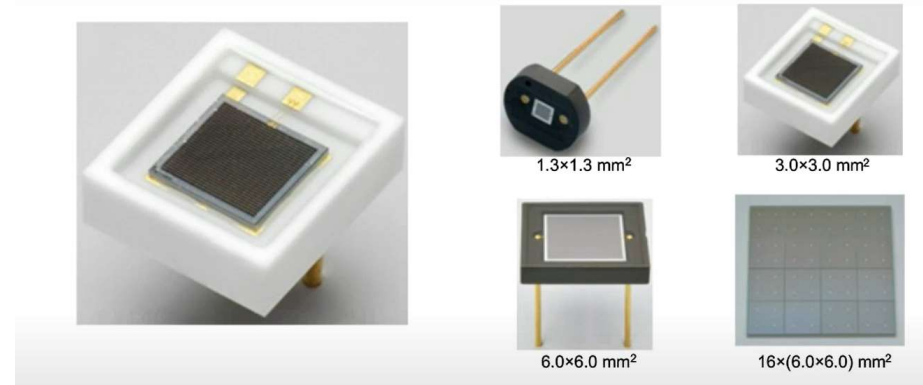


Today new photon detectors: the SiPM (Silicon PhotoMultiplier)

Standard photon detector

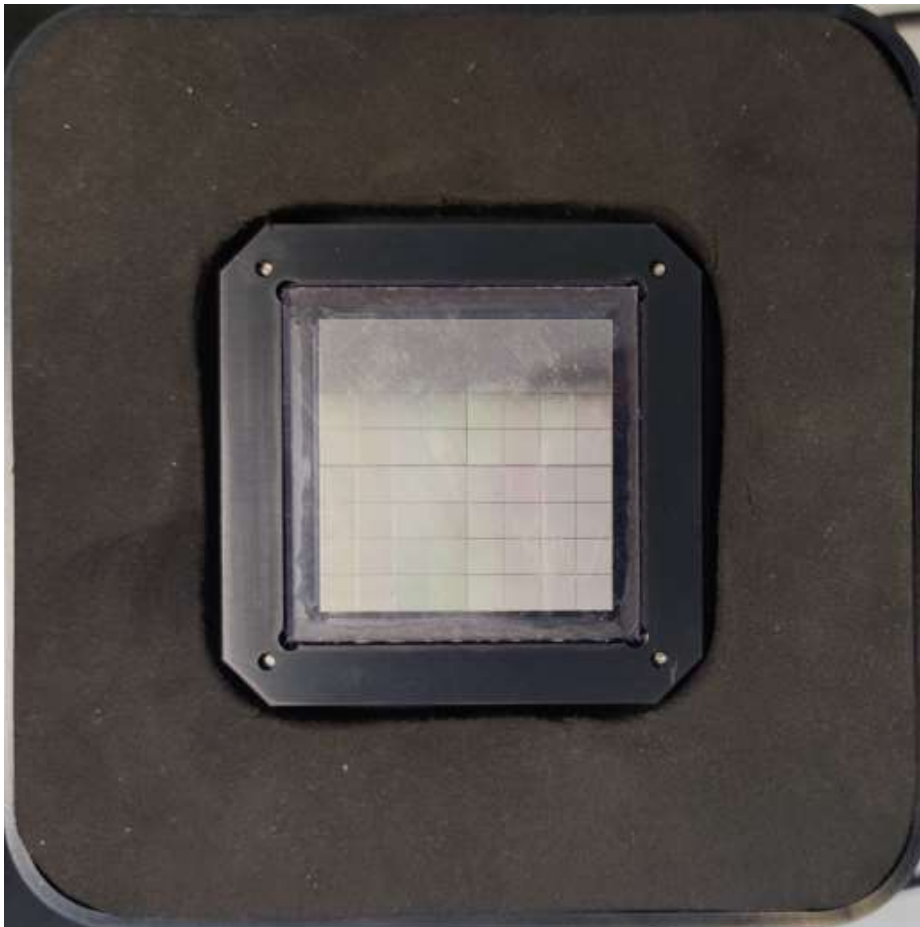
Photo Multiplier Tube (PMT)

Sensitive to photons
High Gain
Fragile
Operating Voltage use: 1000V

SiPM**Silicon PhotoMultipliers**

Sensitive to photons
Small Si detectors
High Gain
NOT Fragile
SiPM in Matrix form
Operating Voltage use 50-60V
Not destroyed by high photon flux

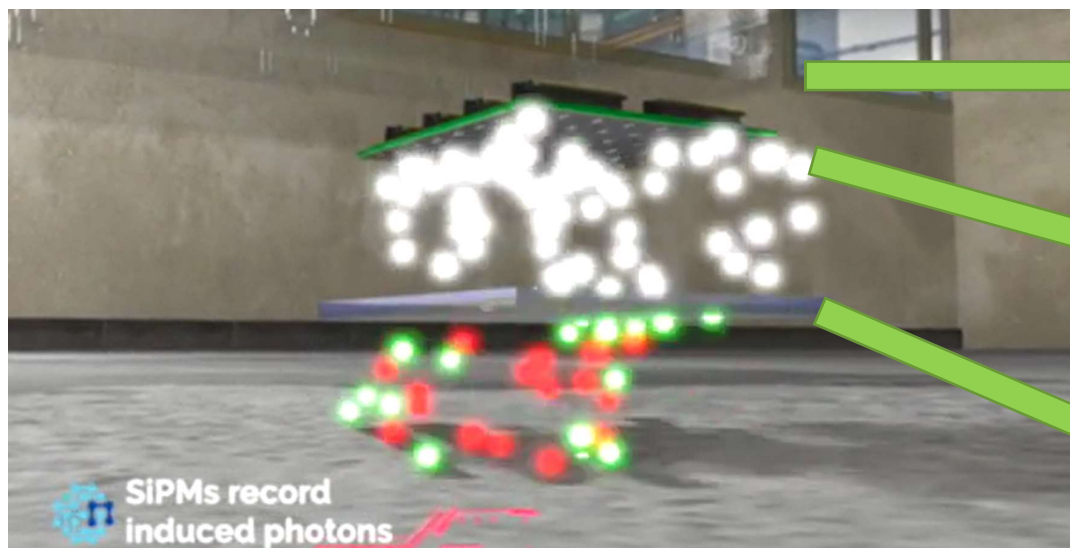
64 SiPM, 4 matrices of 16 individual SiPM



With new electronics, it is possible to have comparable gains for the 64 SiPM!

Response is similar for the whole surface detector

TECHNICAL CHOICES WITH MAUD



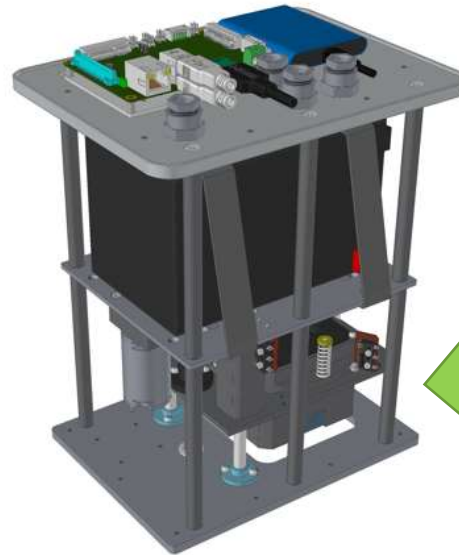
Dedicated electronics, to measure all **64 SiPM** independently and at the same time. Development of new ASICs configurations

64 SiPM (Silicon PhotoMultipliers)

Plastic Scintillator sensitive to radioactivity. => Photons productions.

But: all is in close contact. Sample on the scintillator, the scintillator on the SiPMs, the SiPM on the electronics.

MAPPING

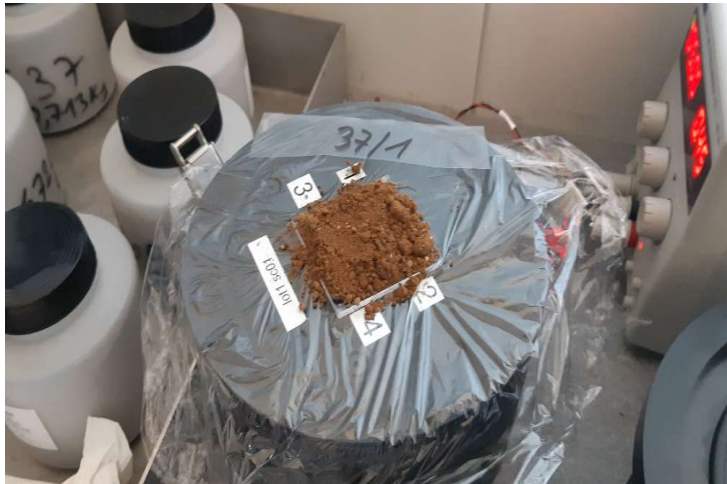


System with battery

MAUD detector

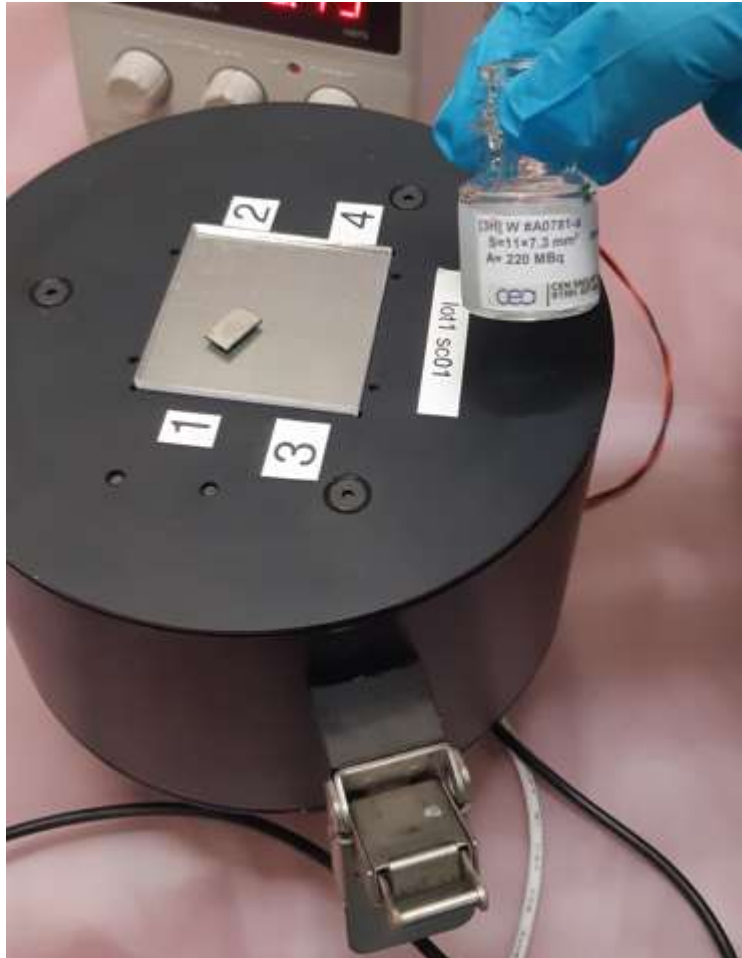
SAMPLE MEASUREMENTS

Used for G1 reactor samples

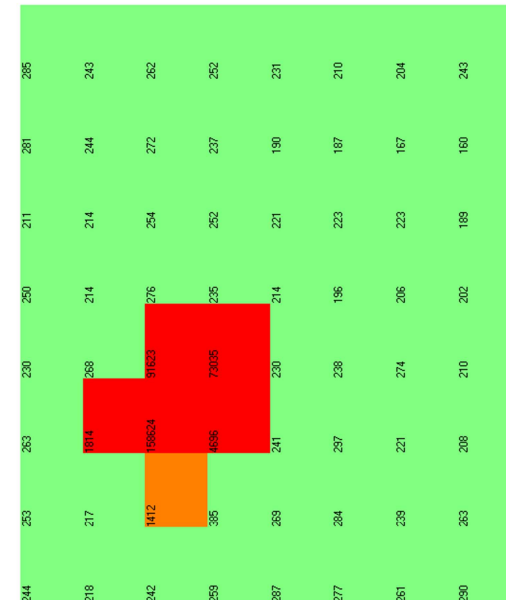


This setup: to control potential contamination of soils

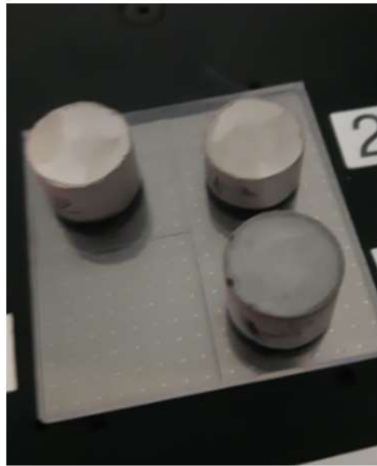
W matrix with tritium on surface



Tritium 220 MBq on the whole surface



Acquisition Time: 3 minutes

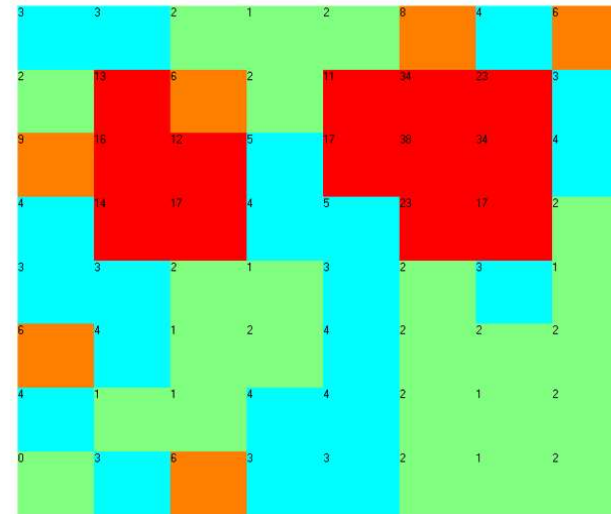


Small sample made of concrete with Uranium on surface

Activity: **less than 1 Bq / cm²**



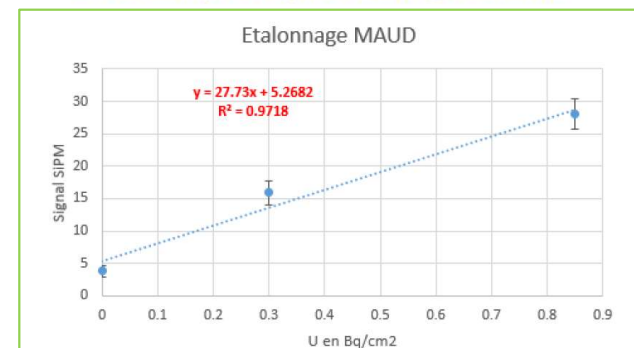
Acquisition Time = 3 minutes
Results of the activity measurement
Number of triggers



Two samples with **Uranium** on surface.

One sample representing a blank

Linearity with sample activity

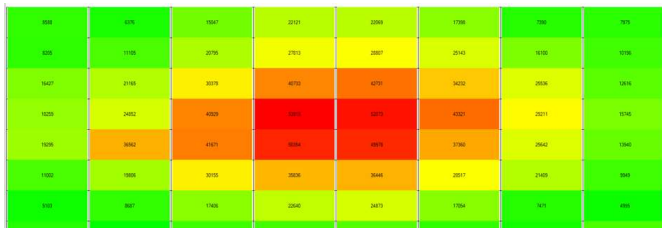


Sr-90 (3254 Bq (4 π))



Sources on
MAUD detector.

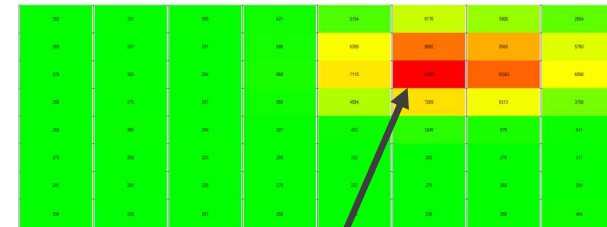
Pu-239 (160 Bq (2 π))



Sr-90 (3254 Bq (4π))

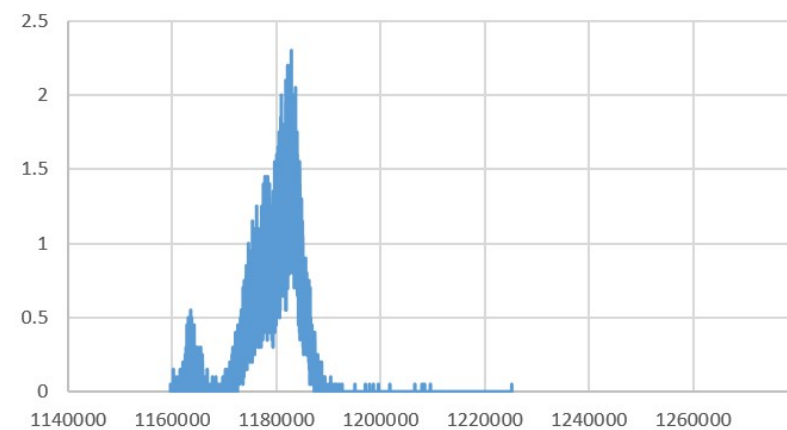
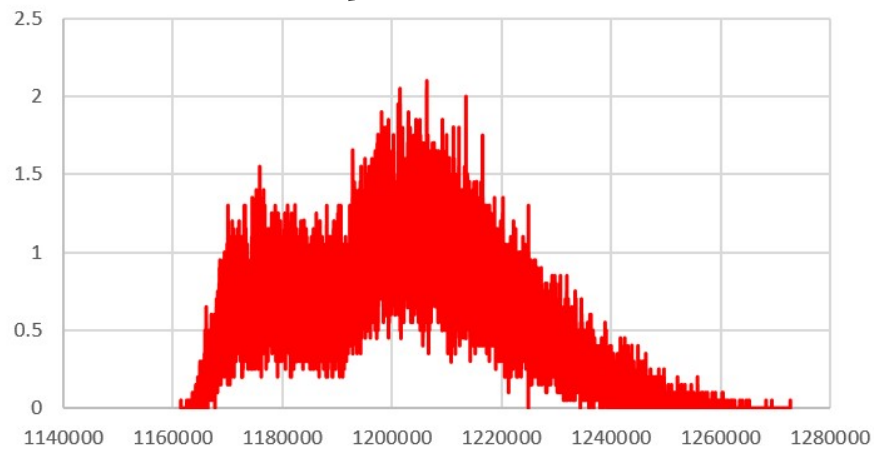


Pu-239 (160 Bq (2π))



For Pu and Sr sélection of results with the highest number of triggers

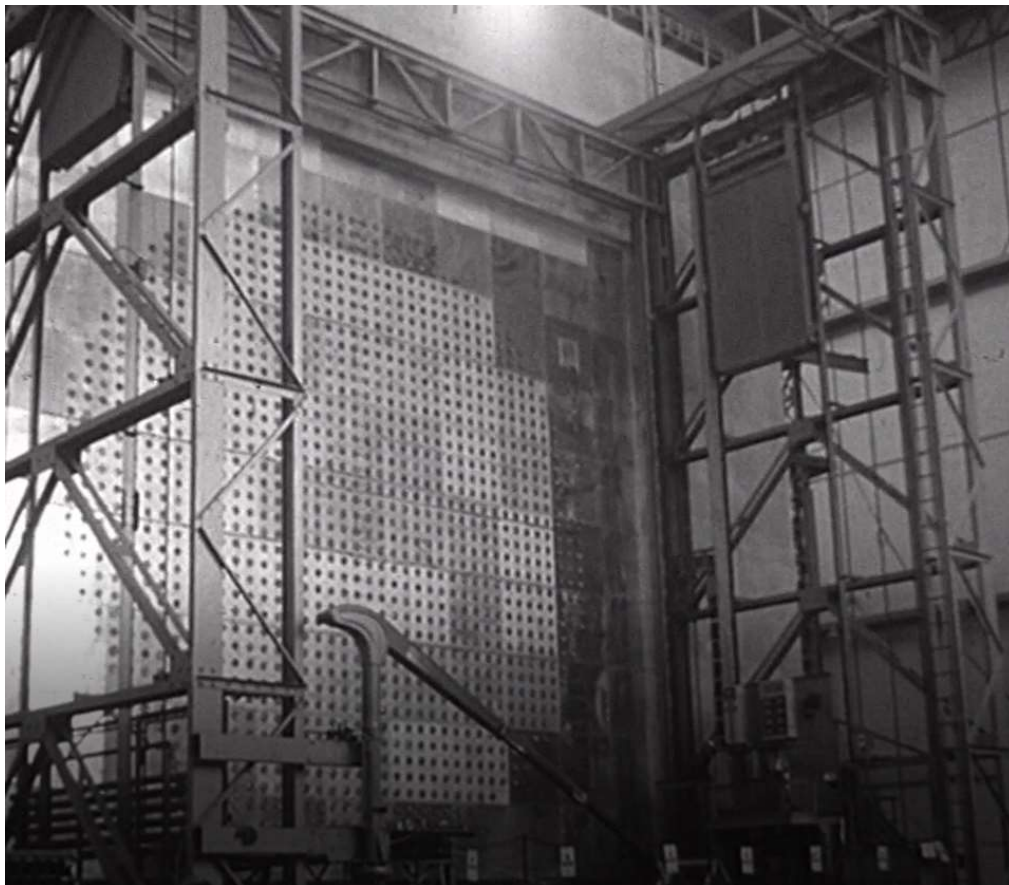
SiPM signal is different for the Sr-90 and Pu-239



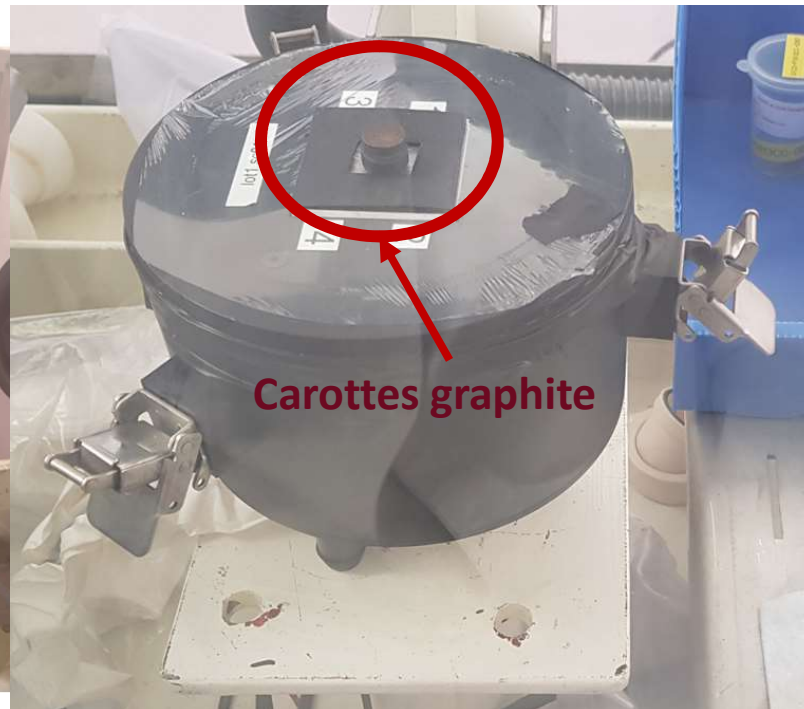
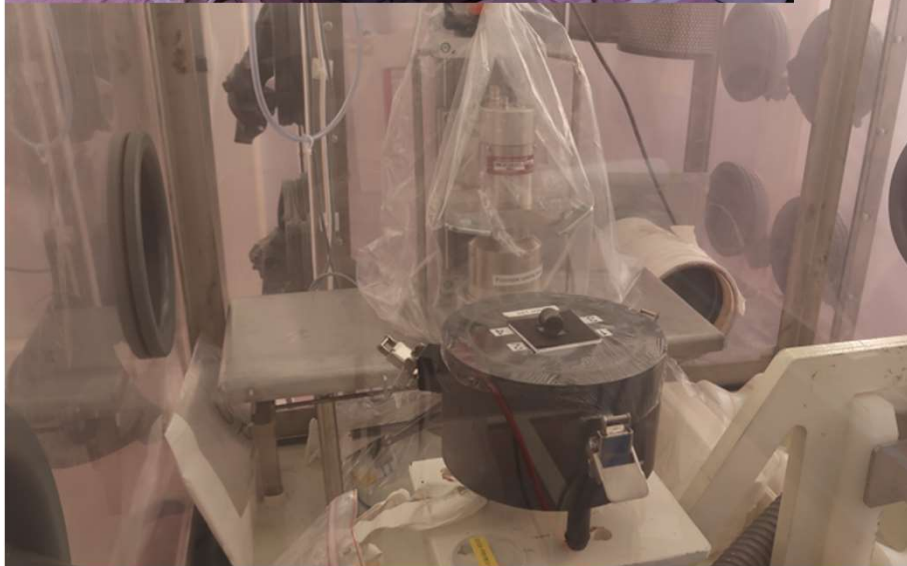


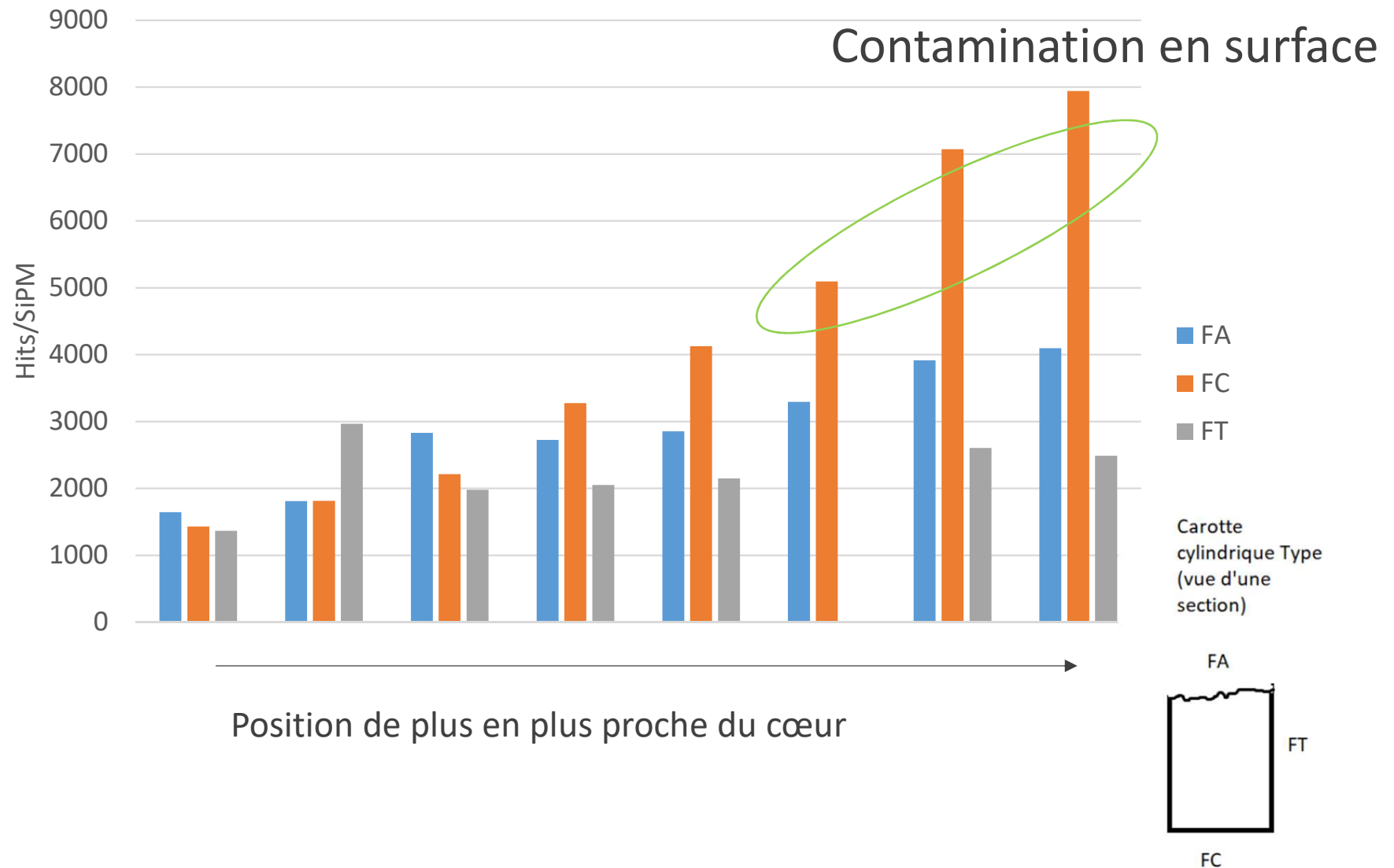
Application to G1 reactor samples

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- Construit en 1955 (CEA Marcoule)
- A l'arrêt depuis 1968
- Programme d'investigations et de prélèvements des différentes parties du réacteur est en cours
- 48 carottes graphites extraites du cœur du réacteur
- Détermination de l'activité des radioéléments présents (majoritairement des émetteurs beta pur):**
 - Généralement réalisée de manière destructive dans les laboratoires d'analyse : opérations couteuses et très chronophages.
 - Solution de tri et d'identification des carottes d'intérêt: MAUD





FA

Hits sum : 69261 Max : 4661 Min : 0 RSD : 0,8901125 Mean : 1082,203

1058	998	1042	1079	0	0	0	1317
918	822	1006	1066	1289	1094	0	1231
912	1012	1278	2236	0	1321	1275	0
881	931	2359	4661	4658	1384	1189	1447
783	986	2147	3809	3359	0	0	0
881	799	1226	1457	0	0	0	1333
906	896	967	941	1015	1046	1205	1173
910	909	919	985	1021	0	1224	0

FT

Hits sum : 81173 Max : 3116 Min : 736 RSD : 0,3796595 Mean : 1268,328

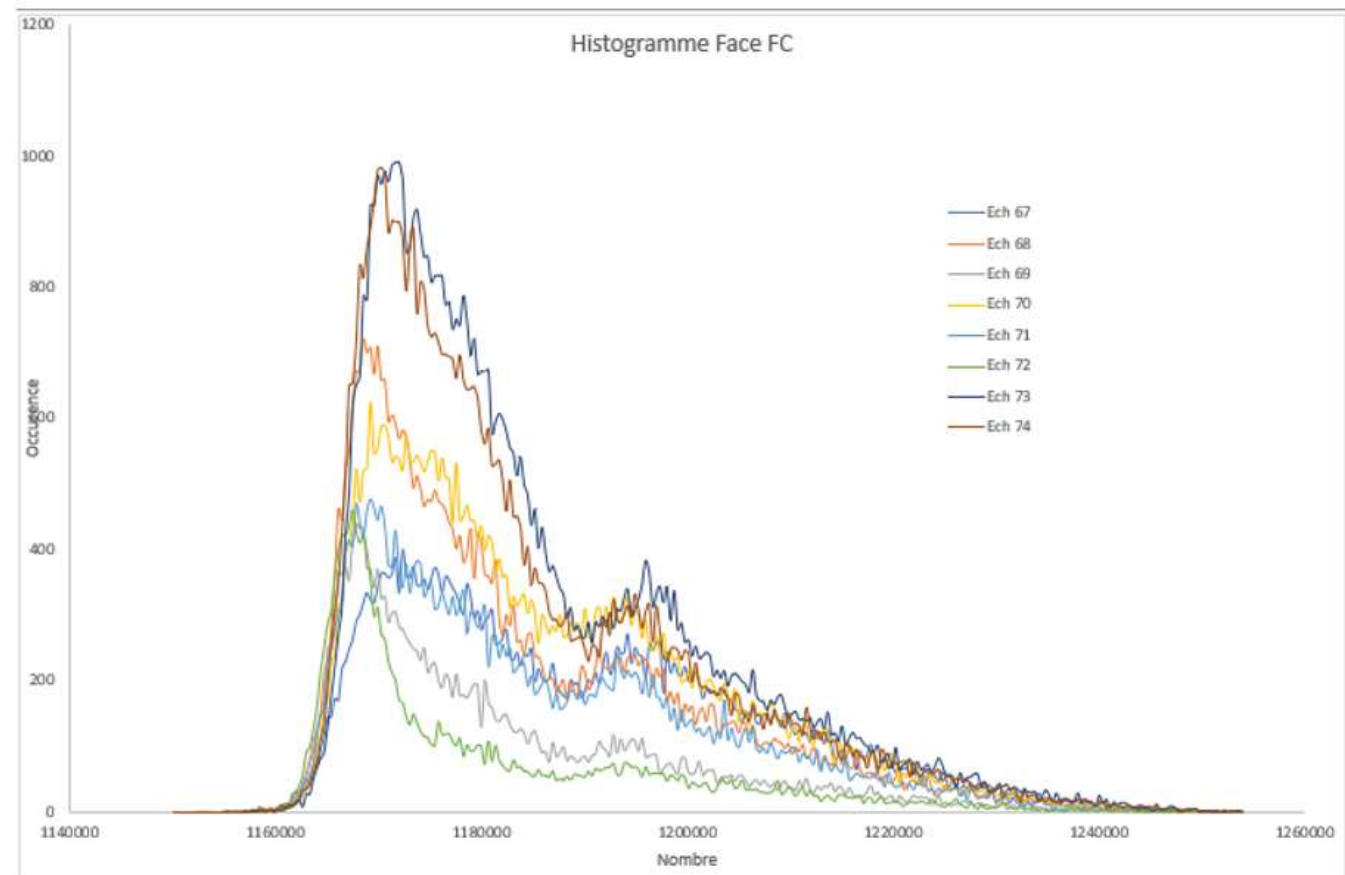
1055	980	946	1069	1123	1116	1151	1389
883	339	937	1073	1255	1139	1121	1248
908	857	1029	1504	2035	1400	1359	1326
841	796	1545	2703	3116	1995	1301	1470
763	876	1422	2538	2711	1857	1592	1225
834	736	1172	1466	1498	1391	1385	1386
950	896	976	926	935	1074	1320	1352
901	883	942	852	1020	1117	1259	1369

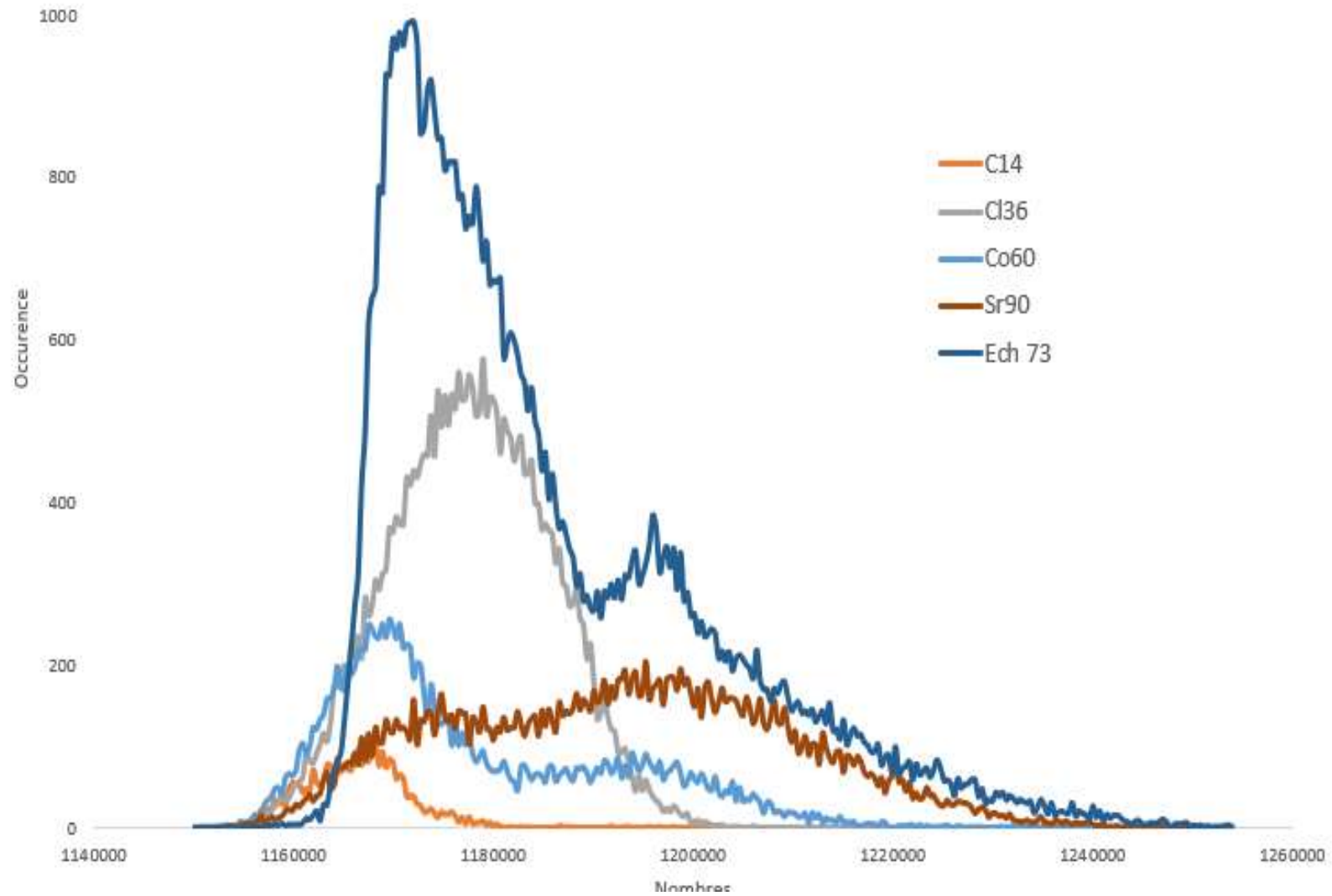
FC

Hits sum : 107739 Max : 9643 Min : 774 RSD : 1,061433 Mean : 1683,422

1211	986	1007	1053	1092	1050	1007	1513
970	813	920	1013	1248	1046	960	1153
919	888	1326	2875	2258	1210	1146	1185
824	849	4221	9643	6812	1363	978	1282
819	1144	4258	8232	6082	1410	1277	1069
918	774	1543	2817	1855	1167	1242	1229
951	837	921	1004	932	990	1116	1157
964	865	910	904	1016	1050	1106	1389

For other samples, other radionuclides observed







Conclusions and perspectives

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MAUD: Digital AUtoradiography Measurement

- Commercialized new detector
- Non destructive and robust technique
- Mapping use
- Sample measurements
- Very sensitive system

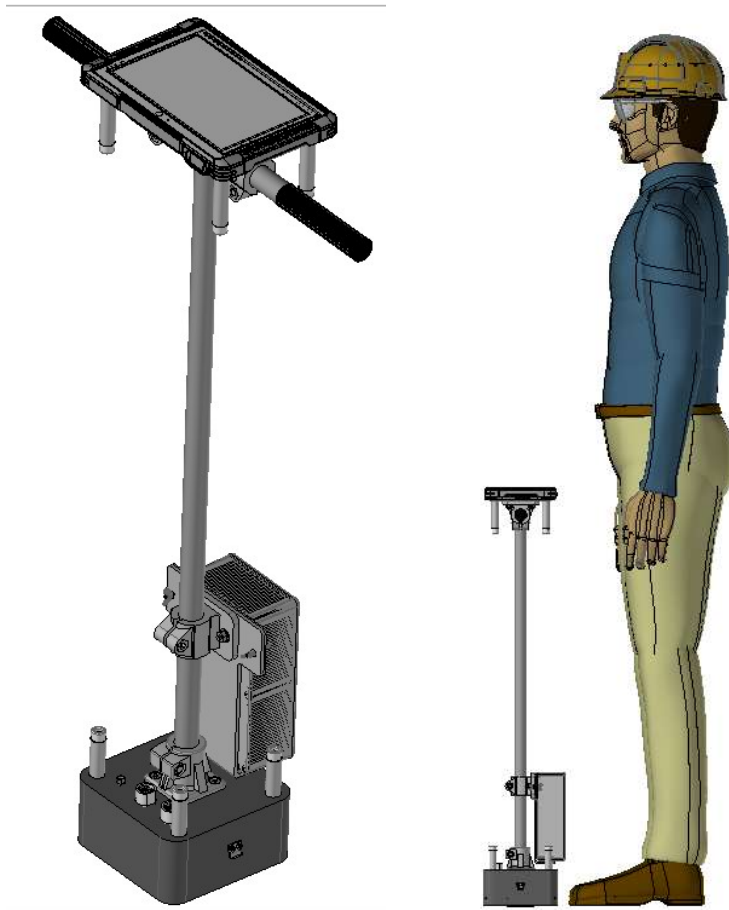
Application au démantèlement de G1

- Classement des échantillons selon leur niveau de radioactivité
- Observation des différences selon les faces de l'échantillon
- Identification de contamination potentielle

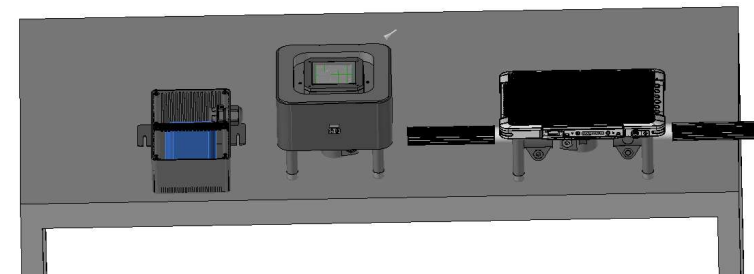


Future développements en cours aux Ateliers Laumonier

Utilisation en format sur site



Utilisation sur plan de travail





MAUD patent
number (2020)



(11) Veröffentlichungsnummer:

(11) Publication number:

(11) Numéro de publication:

EP 3 746 812 A0

MAUD awards in 2020

▶ <https://www.iaea.org/newscenter/news/robots-drones-and-artificial-intelligence-for-advanced-decommissioning-and-environmental-remediation-winners-of-the-iaea-2020-crowdsourcing-challenge>

▶ (YOU TUBE)



The screenshot shows the IAEA website interface. At the top left is the IAEA logo (International Atomic Energy Agency). To the right are links for 'Press centre', 'Employment', and 'Contact'. Below the logo is a navigation menu with 'TOPICS', 'SERVICES', 'RESOURCES', 'NEWS & EVENTS', and 'ABOUT US'. A search bar is located to the right of the menu. Below the navigation is a breadcrumb trail: 'Home / News / Robots, Drones and Artificial Intelligence for Advanced Decommissioning and Environmental Remediation: Winners of the IAEA 2020 Crowdsourcing Challenge'. The main heading of the article is 'Robots, Drones and Artificial Intelligence for Advanced Decommissioning and Environmental Remediation: Winners of the IAEA 2020 Crowdsourcing Challenge'.

MAUD presented in **WNE 2021**

De la recherche à l'industrie - MAUD, dispositif de mesure



What is MAUD (Digital AUsoradiography Measurement) ?

MAUD (Digital AUsoradiography Measurement) is a cutting-edge camera for in situ alpha & beta radiation detection, difficult to measure. The objective is to assess the potential alpha and beta contamination (in Bq/cm²) of a surface in a facility to be dismantled.

Complement: Detection

Journal of Radioanalytical and Nuclear Chemistry (2022) 331:1075–1089
<https://doi.org/10.1007/s10967-021-08172-2>



Development of a compact alpha and beta camera for dismantlement applications

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Table 4 Detection efficiency and minimum detectable activity measured with the radioactive sources

Isotope	Radiation	Detection efficiency (%)	Minimum detectable activity (Bq/cm ²)
³ H	β	0.15 ± 0.05	92
¹⁴ C	β	38.1 ± 0.4	0.36
²³⁹ Pu	α	45.7 ± 1.3	0.30
¹³⁷ Cs	γ + β	6 ± 1.3	2

Springer