Italian National Agency for New Technologies, Energy and Sustainable Economic Development

ASSESSMENT OF THE REDUCTION OF THE RADIOXENON ATMOSPHERIC EMISSIONS BY USING A NUCLEAR-FUSION-BASED DEVICE

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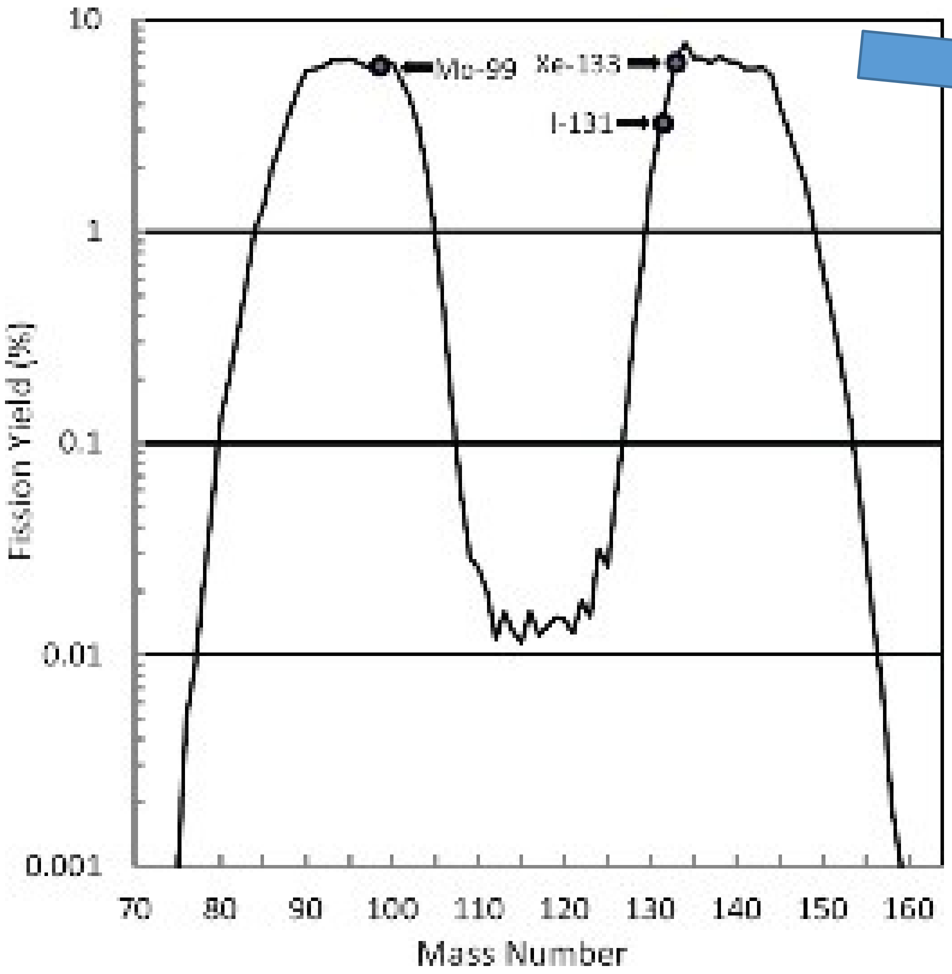
^{99m}Tc Production

^{99m}Tc is the most used tracer in SPECT (Single Photon Emission Computed Tomography) nuclear diagnostics, covering more than 80% of all the procedures worldwide, i.e. tens of millions of medical procedures annually.



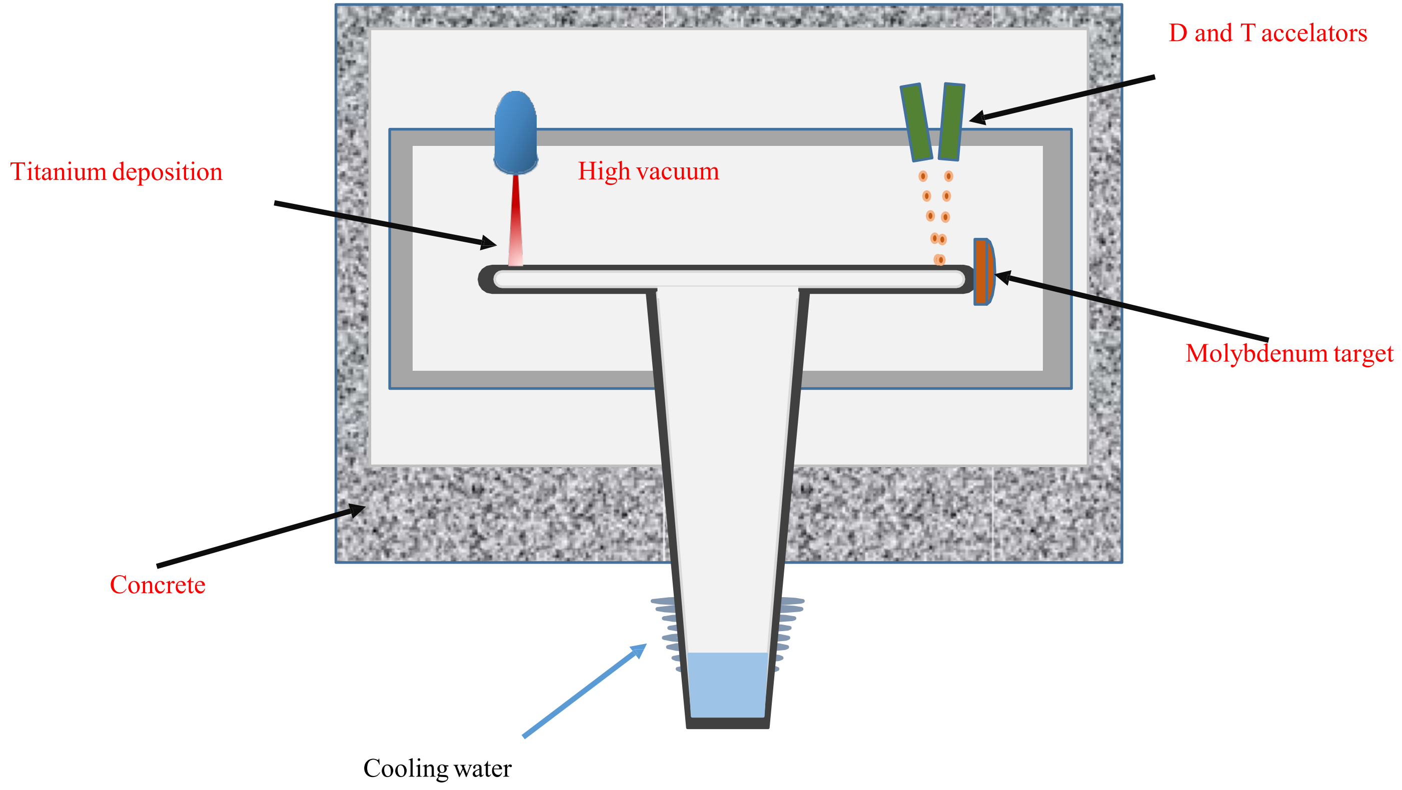
Fission Product	Half-life	Time unit	$^{235}U_f$	$^{235}U_{he}$	$^{238}U_f$	$^{238}U_{he}$	$^{239}Pu_f$	$^{239}Pu_{he}$
^{131m}Xe	11.934	d	0.05	0.06	0.05	0.06	0.05	0.07
^{133m}Xe	2.19	d	0.19	0.29	0.19	0.18	0.24	0.42
^{133}Xe	5.243	d	6.72	5.53	6.76	6.02	6.97	4.86
^{135}Xe	9.14	h	6.6	5.67	6.97	5.84	7.54	6.18

As a fission product, ^{99}Mo is produced together with many other isotopes of various elements, from which it must be purified. Among them is a large amount of radioxenon isotopes. They are periodically released.

ENEA Sorgentina-Radiopharmaceuticals Project

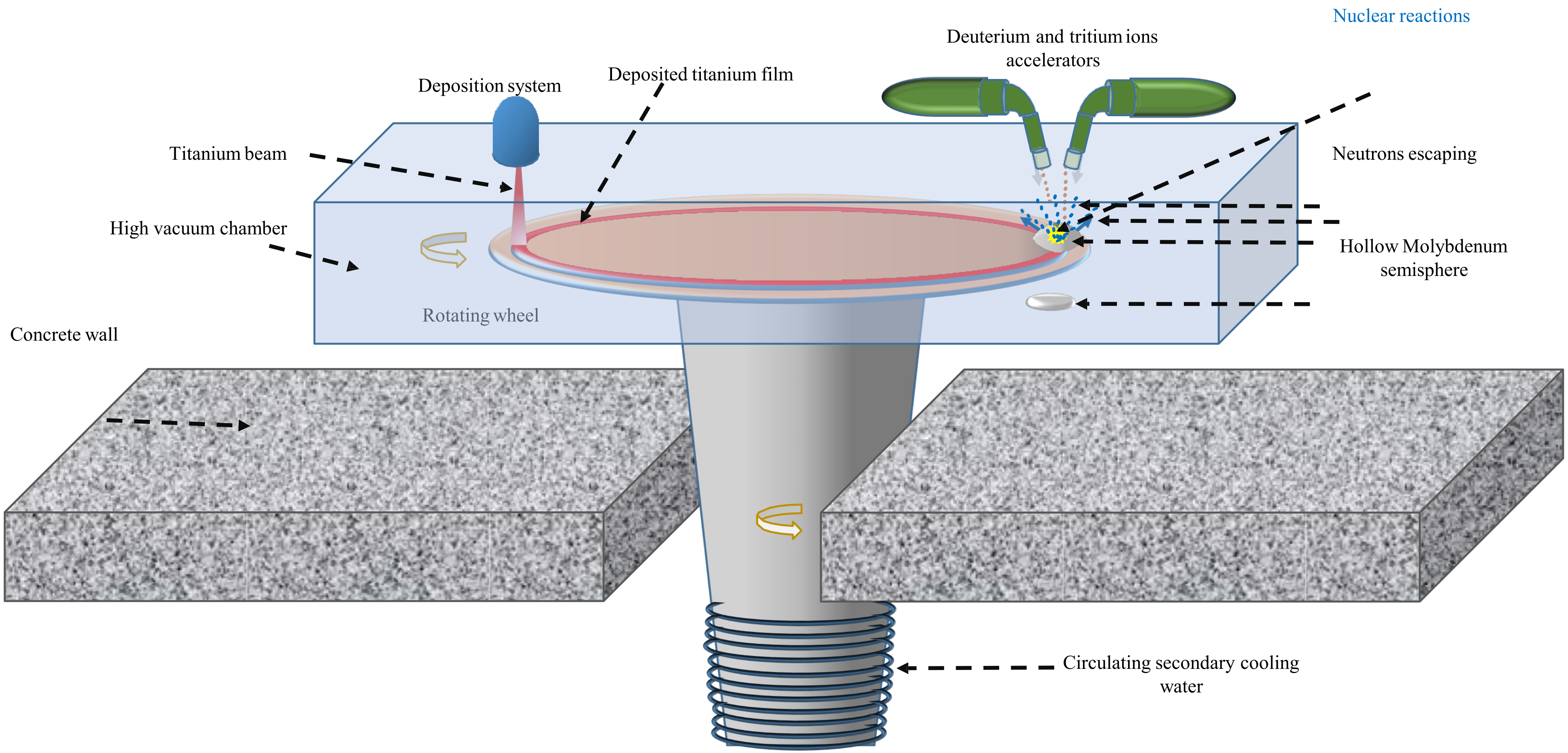
The proposed solutions relies on the use of 14 MeV neutrons from:

- deuterium-tritium fusion reaction **$D+T \rightarrow {}^{4}He + n + 17.6\ MeV$**
- and the inelastic channel **$^{100}Mo(n,2n)^{99}Mo$.**

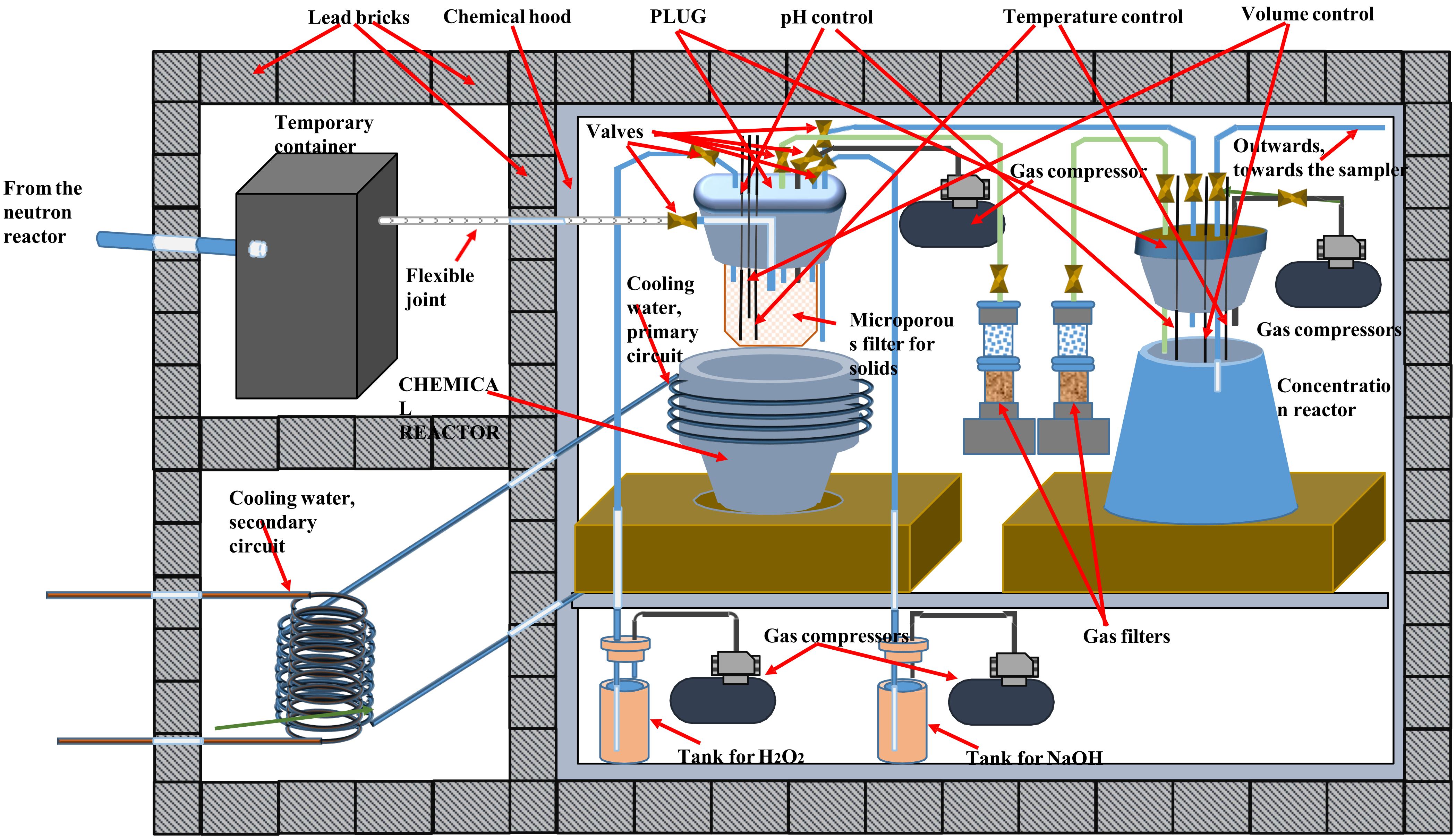


The source is composed by a rotating target, water cooled, where a layer of titanium is deposited and a mixed beam of Deuterium and Tritium, delivering a power of about 250 kW, produces mostly 14 MeV neutrons with a neutron yield in the range $5\text{-}7 \cdot 10^{13}\ s^{-1}$.

ENEA Sorgentina-Radiopharmaceuticals Project



ENEA Sorgentina-Radiopharmaceuticals Project



Technological maturity scale of a project (TRL)

TRL 1	Basic principles observed
TRL 2	Technology concept formulated
TRL 3	Experimental proof of concept
TRL 4	Technological validity in a lab
TRL 5	Technology validated in relevant environment
TRL 6	Technology demonstrated in relevant environment
TRL 7	System prototype demonstration in an operational environment
TRL 8	System completed and qualified
TRL 9	Actual system proven in operational environment

Present level

Actual target

ENEA Sorgentina-Radiopharmaceuticals Project

The ENEA's facility Sorgentina-RF will be located in the ENEA Brasimone Research Centre (BRC), in the Northern of Italy.

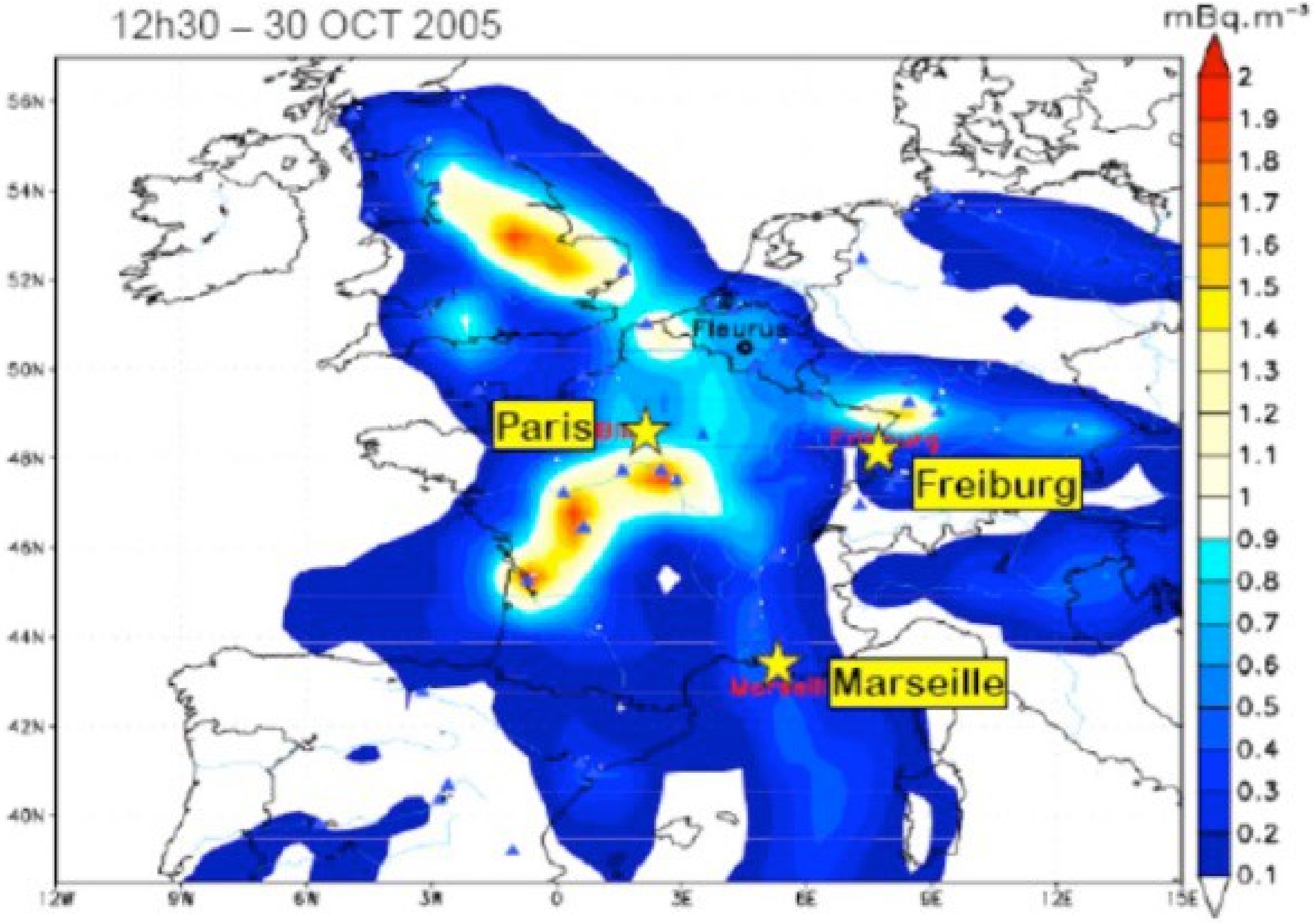
Activities of noble gas radionuclides generated from the fission Mo-99 production on the weekly production of 2,000 6-day Ci.

Inert gas radionuclides	Activity (Ci) at 24 hr EOB
Kr-85	2.65×10^{-1}
Kr-85m	2.27×10^{1}
Kr-87	3.93×10^{-3}
Xe-131m	2.36×10^{0}
Xe-133	2.63×10^{3}
Xe-133m	1.11×10^{2}
Kr-85	2.65×10^{-1}
Xe-135	1.04×10^{3}
Xe-135m	5.94×10^{1}
Inert gas total	3.86×10^{3}

EOB, end of bombardment.

To obtain an equivalent quantity of 99Mo, a hypothetical traditional reactor, placed in northern Italy, would release a large quantity of Xe.

^{133}Xe in the atmosphere

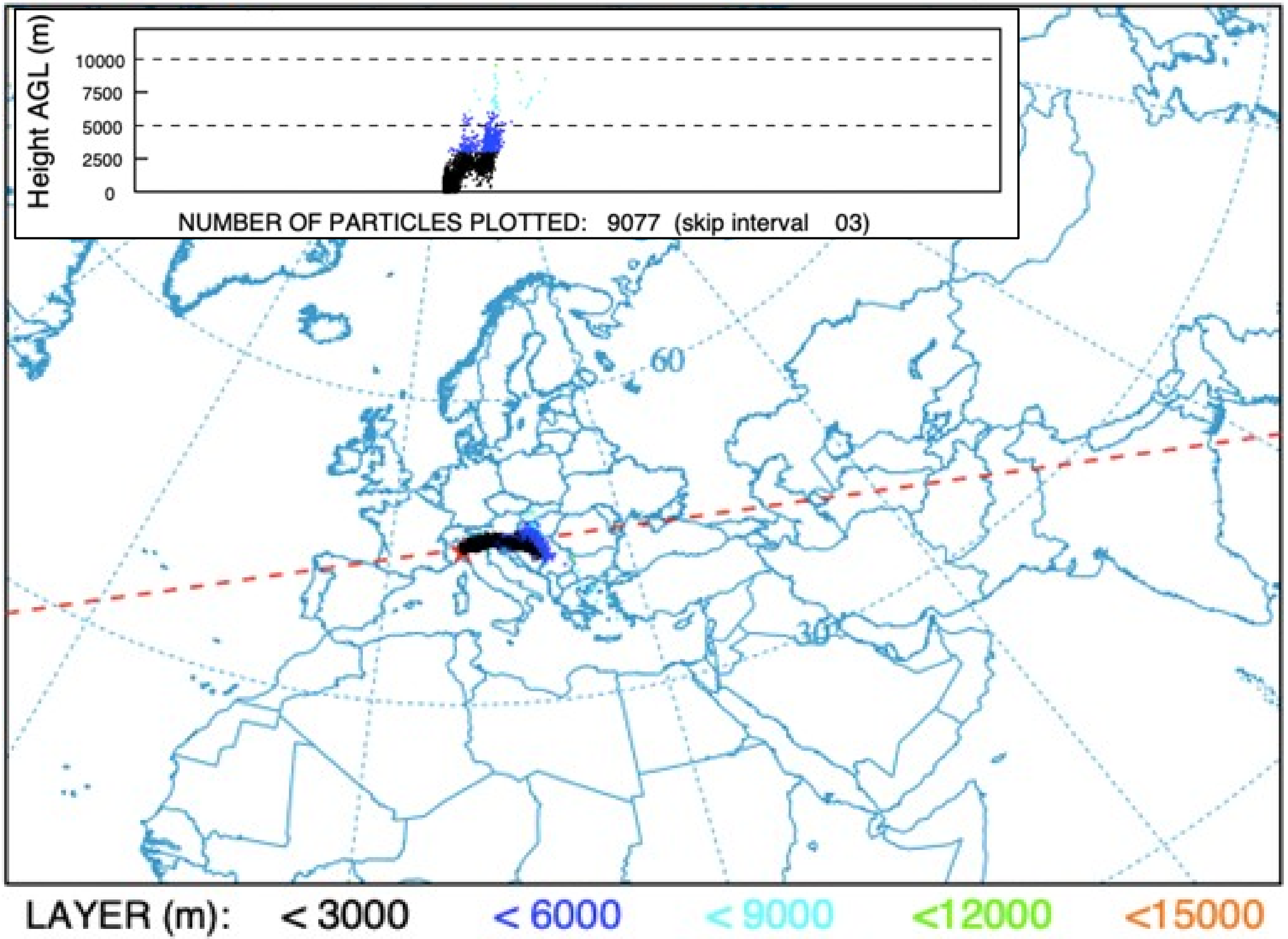


ex: 1hr average concentration in Xe-133

Nuclear power plants give a continuous ^{133}Xe release: for instance Fleurus releases up to 5 TBq/day.

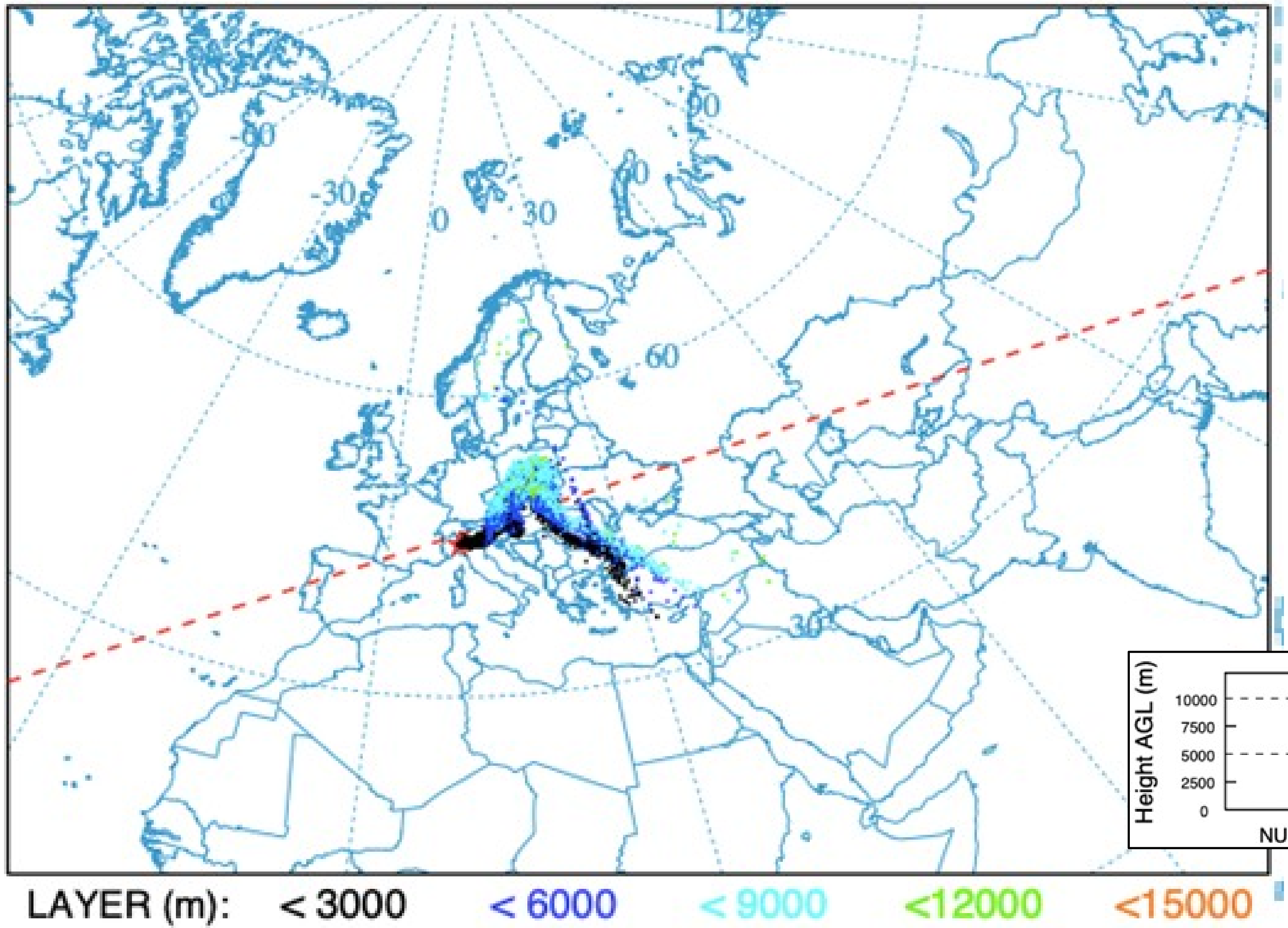
The result is an almost continuous baseline on the order of 1 mBq/m3 as measured in Paris, Freiburg and Marseille

Hysplit Model Transport Simulation

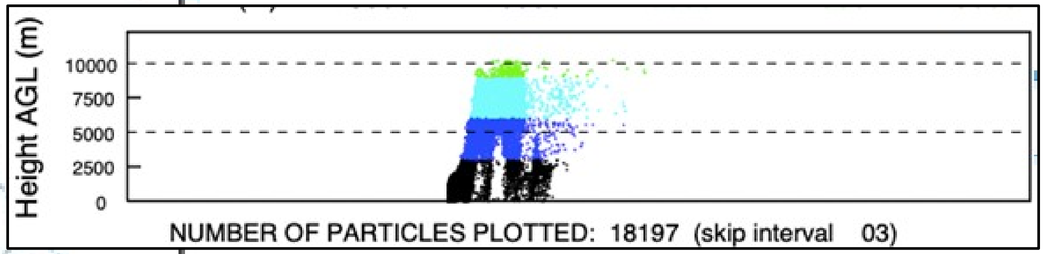


It is possible to show that the ^{133}Xe produced by a hypothetical fission facility located in the North of Italy would be detected by the SEP63 IMS station according to the local atmospheric conditions.

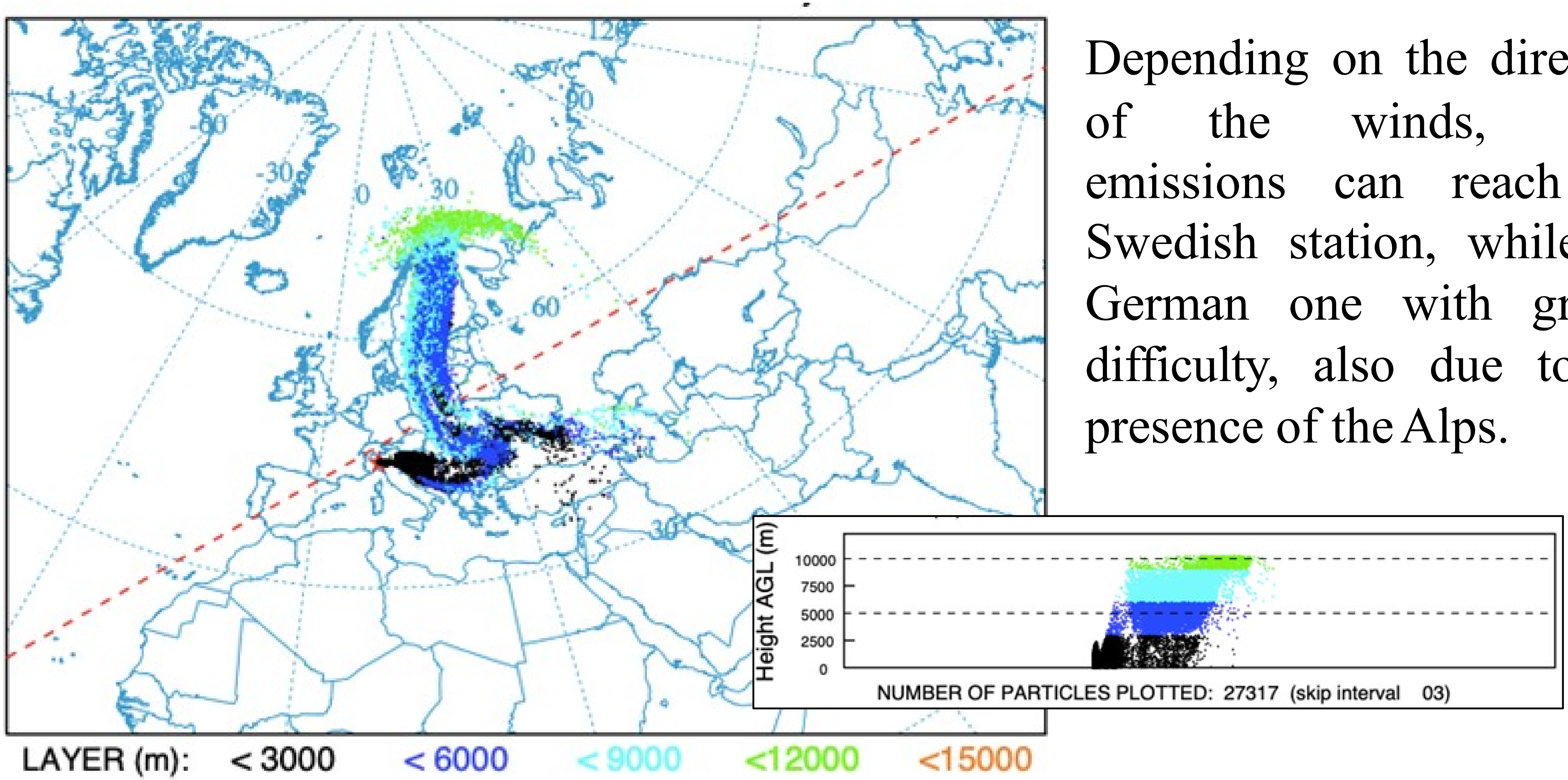
Hysplit Model Transport Simulation



From atmospheric transport simulations, it can be seen that the emissions reach a level that can be easily detected by some detection stations.



Hysplit Model Transport Simulation



Depending on the direction of the winds, these emissions can reach the Swedish station, while the German one with greater difficulty, also due to the presence of the Alps.

CONCLUSIONS

"ENEA Sorgentina – RF project" is designed to achieve the following objectives:

- To create a small-scale prototype with regional funds (power 250 Kw, neutron yield 7 * 10 ^ 13 n / s) including a neutron source, radio-chemistry and auxiliary systems (radiation protection, tritium treatment, thermal evacuation, manipulation ... .)
- To fine-tune the engineering of the individual sub-systems and the system engineering
- To make the neutron source available for research on new radiopharmaceuticals and for studies on the behavior of materials.
- (Alternatively) to convert the prototype into a small production center that will cover the ^{99}Mo needs for 7 million inhabitants

Finally, it can contribute to reduce the radioxenon background.

THANK YOU

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