12th International Conference on Instrumental Analysis
Modern Trends and Applications
VIRTUAL EVENT | 20-23 SEPTEMBER 2021
IMA-2021

# Optimising the remote detection systems of alpha particle emitters using Monte Carlo simulations

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*The project 19ENV02 RemoteALPHA has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.*

*19ENV02 RemoteALPHA denotes the EMPIR project reference.*

# Motivation: Emergency Response Plans

Safety standards for the protection against the dangers arising from the ionising radiation:
**The European Directive 2013/59/EURATOM**

**Article 97**

**Emergency Management System**

-*Member states should ensure that account is taken of the fact that emergencies may occur in their territory…*
-*The emergency management system shall provide for the establishment of emergency response plans…*

**Article 98**

**Emergency Preparedness**

-*Member States shall ensure that emergency response plans are established in advance for the various types of emergencies…*
-*Member States shall ensure that emergency response plans are tested and revised at regular intervals…*

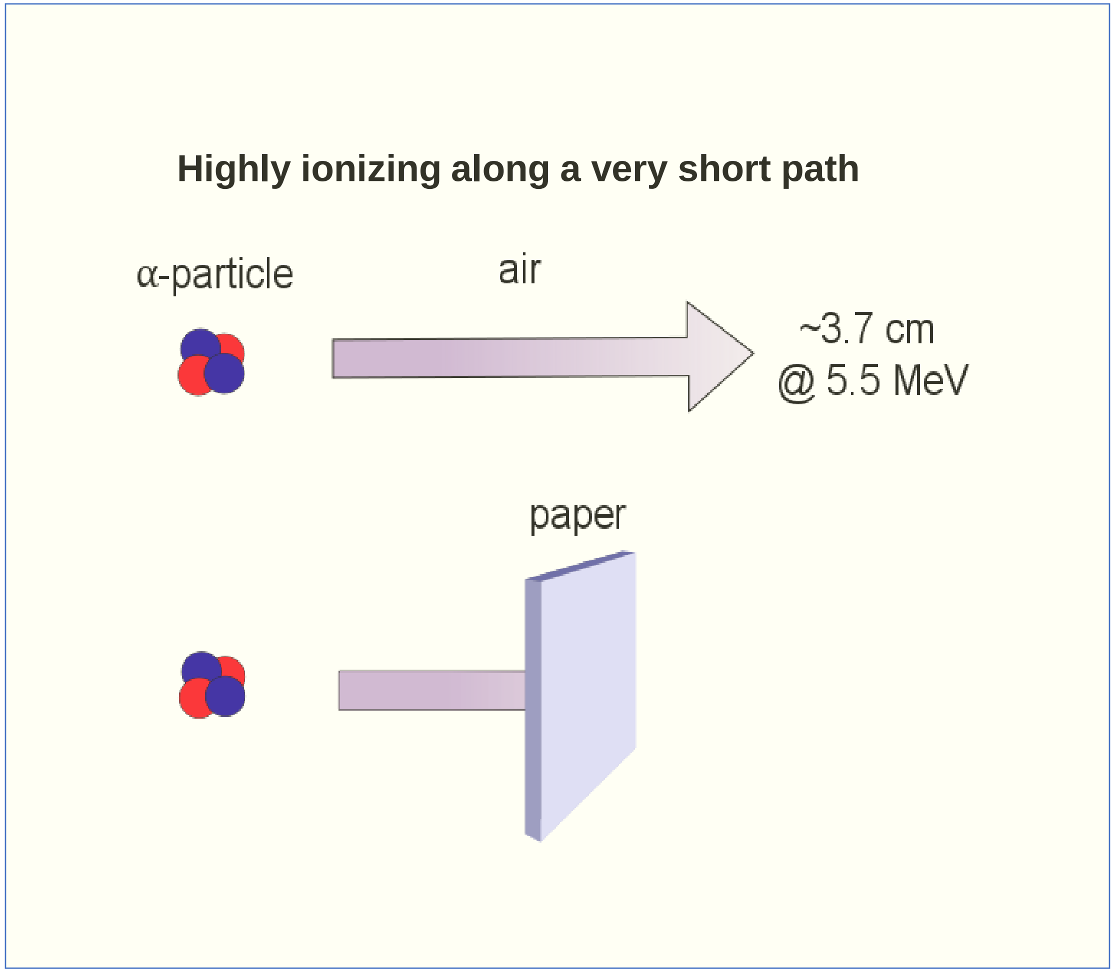
**Article 99**

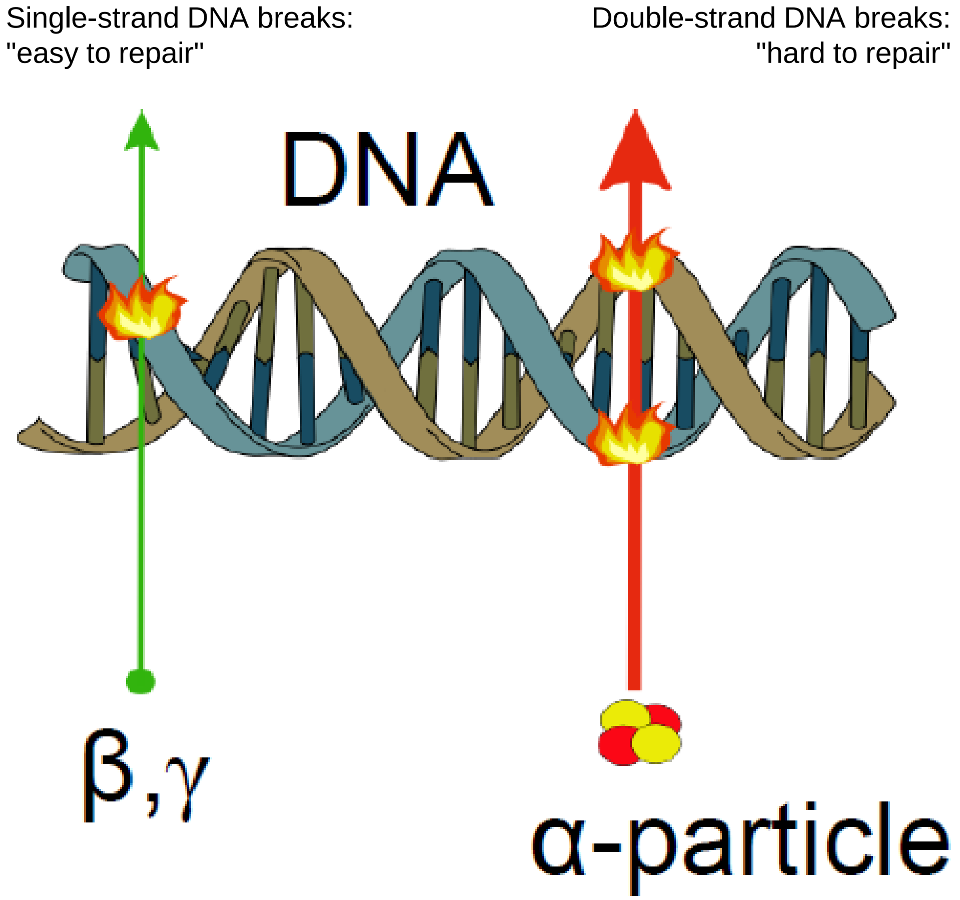
**International Cooperation**

*Member States shall cooperate with other Member States and with third countries in addressing possible emergencies on its territory which may affect other Member States or third countries…*

Possible radiological emergency:
**Accidental or deliberate dispersion of alpha emitting radionuclides in the environment**

# Alpha Particles




*DNA breaks caused by alpha, beta and gamma radiation.*

# Alpha Particles. Close Proximity Detection

http://www.argonelectronics.com/blog/the-value-of-applied-learning-for-radiation-safety-training

Traditional detection methods (proportional counter, scintillator counter, PIPS detectors) are:

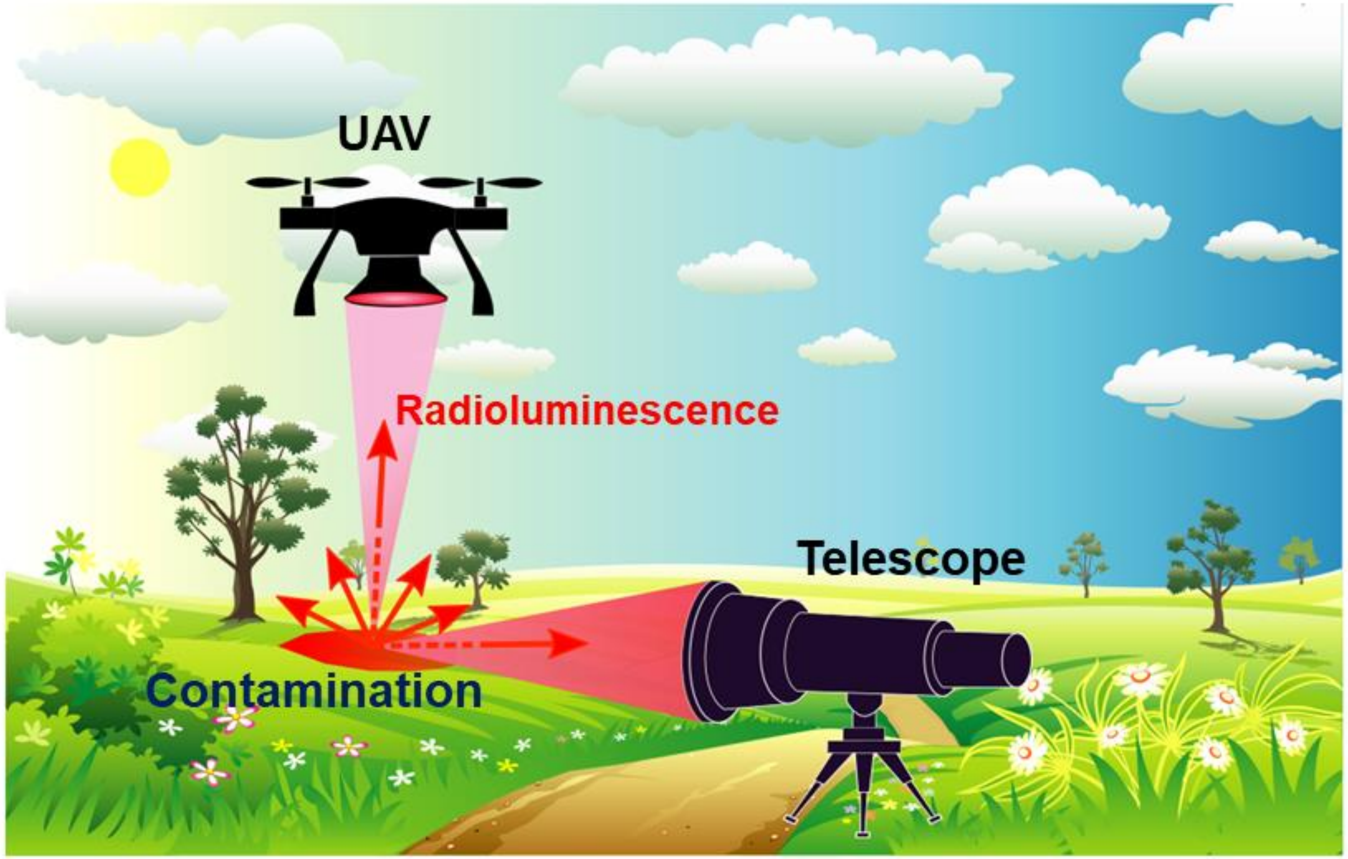
**time consuming and tedious,**

involve **scanning very close to the surface** of the contaminated area,

require the use of **personal protective equipment,**

**expose the personnel to other hazards and risks (other types of radiation, fire, etc.)**.

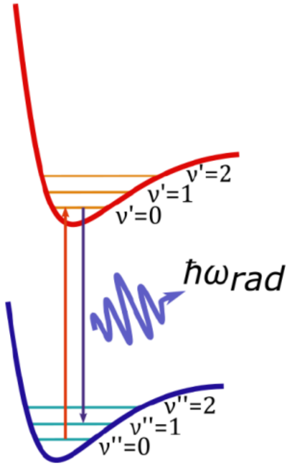
# Motivation: Remote detection of alpha particles




*Concept of remote detection of alpha particles.*

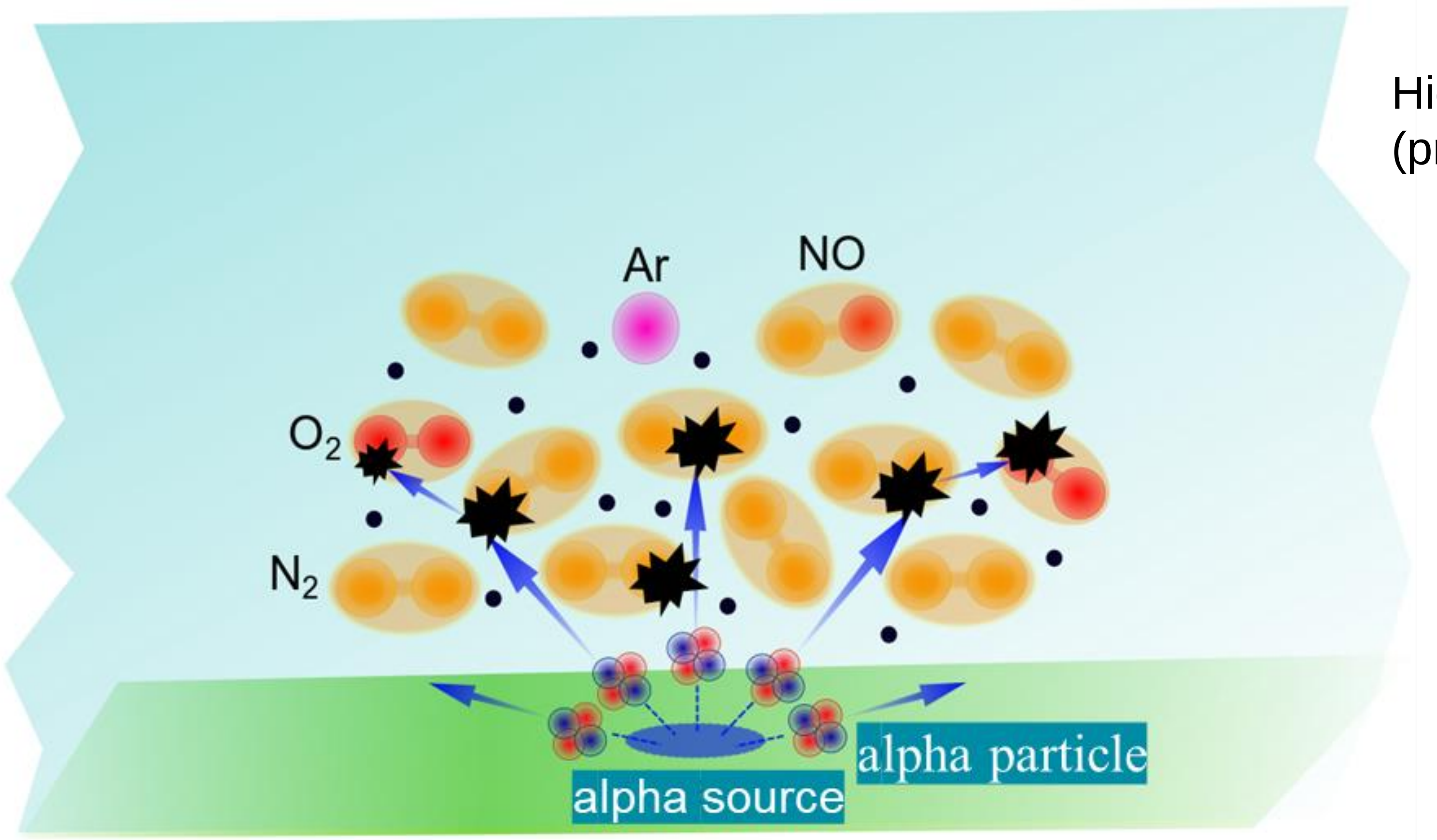
**Advantages:**

- Operators are kept out of the radiation field,
- Efficient scanning of large areas.




Use of optical transitions in gas molecules: **radioluminescence**

# Radioluminescence at a glance




*Schematic representation of air ionization by α-particles.*

High-energy alpha particles ionize air (predominantly molecular nitrogen).

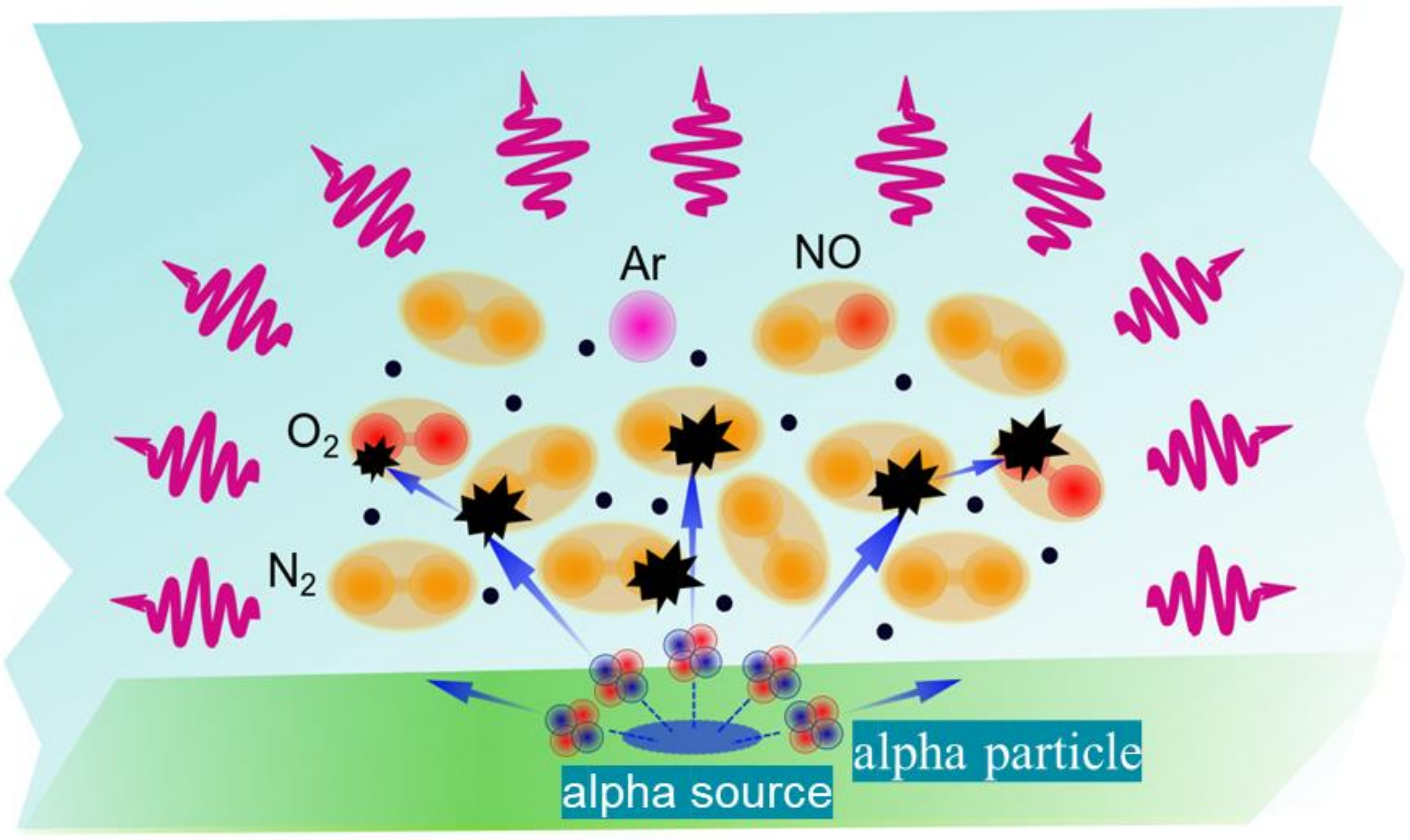
Secondary electrons excite the air molecules:

$$e^- + N_2\left(X^1\Sigma_g^+\right) \rightarrow N_2^*\left(C^3\Pi_u\right) + e^-$$

$$e^- + N_2^+\left(X^2\Sigma_g^+\right) \rightarrow N_2^*\left(C^3\Pi_u\right)$$

$X^1\Sigma_g^+, C^3\Pi_u$ → Molecular levels

# Radioluminescence at a glance




*Schematic representation of air ionization by α-particles and radioluminescence.*

Excited air molecules emit fluorescent light (radioluminescence) in the UV range between 200 nm and 400 nm.

<u>Range in air:</u>

α-particles → ~ 0,037 m
UV light → 500 m

# EMPIR Project: RemoteALPHA

RemoteALPHA

**General objective**: Remote and real-time optical detection of alpha-emitting radionuclides in the environment

**Partners:**

PTB
Messen ▪ Forschen ▪ Wissen

Tampere University

Leibniz Universität Hannover

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

IFIN-HH

BUDAPEST FŐVÁROS KORMÁNYHIVATALA

SZENT ISTVÁN UNIVERSITY

**Alfa Rift Oy**

**Collaborator:**

Australian Government

ANSTO

# Technical Workpackages

**RemoteALPHA: 01.09.2020 - 31.08.2023**

| | |
|---|---|
| **WP1** | New instruments for the optical detection of alpha emitters in the environment |
| **WP2** | Calibration system for the novel radioluminescence detector systems |
| **WP3** | Mapping alpha contamination in the environment using UAVs |
| **WP4** | Feasibility study on laser-based techniques for alpha emitter detection |

Research Mobility Grant

Research activity:
Optimising the optical configurations for the detection of alpha-induced radioluminescence, by using MC simulations

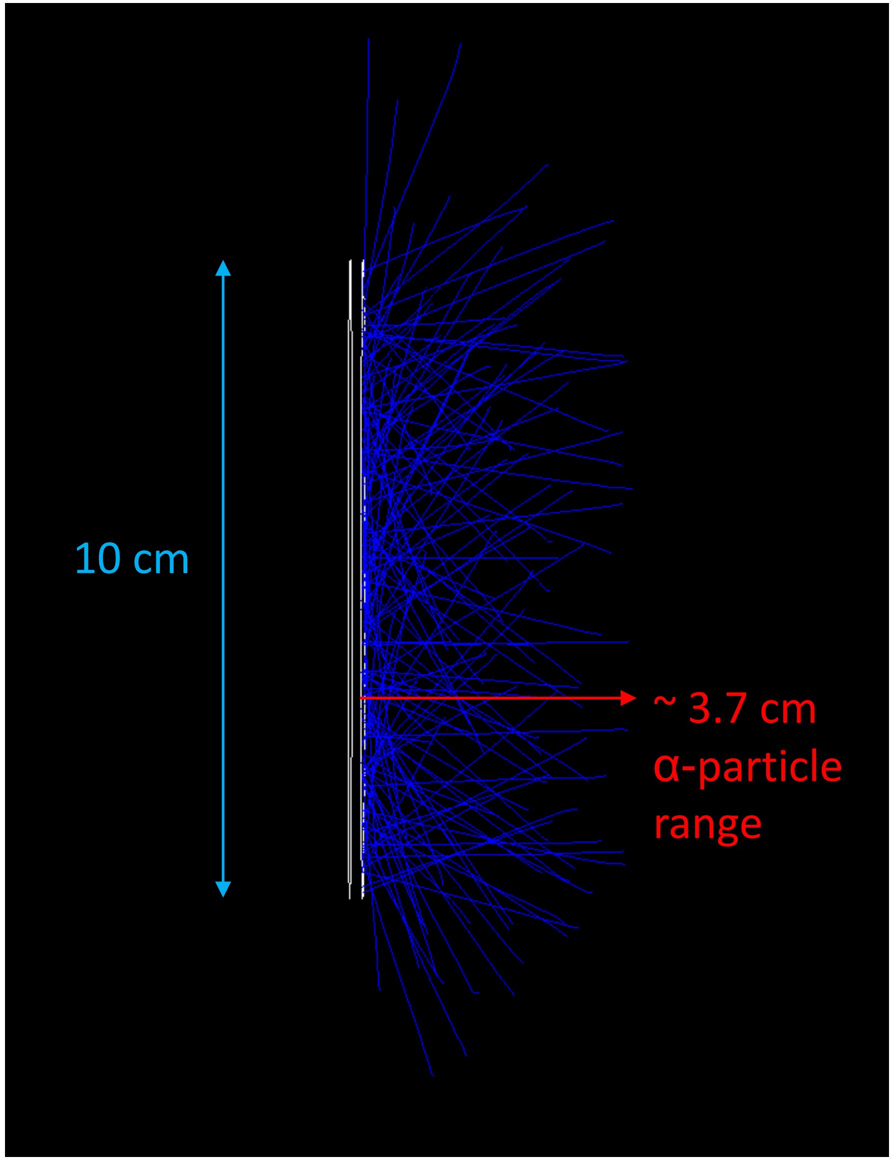
Task 1:
Modelling the radioluminescence emitting volume from a Am-241 radioactive source, using MC simulations

# Simulation geometry

**Silver plate**:
- 5 cm radius
- 1 mm height

**Radioactive source**:
- $Am^{241}$
- 5 cm radius
- 10 μm height
- 5.5 MeV energy of emitted α-particle

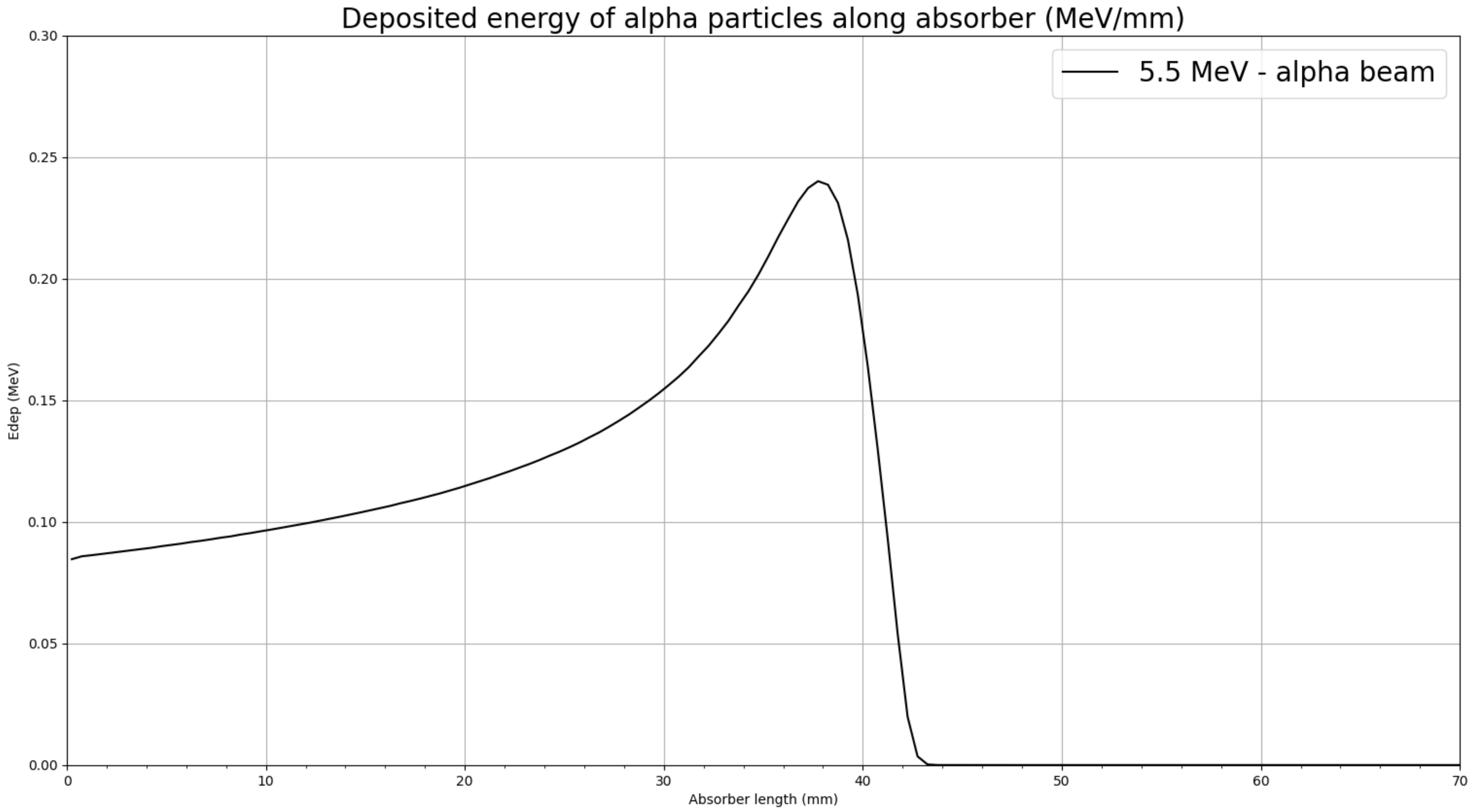
**Detector volume**:
- 50 m cube length
- Air at NTP




The range of alpha particles describe the volume from which the radioluminescence photons are emitted

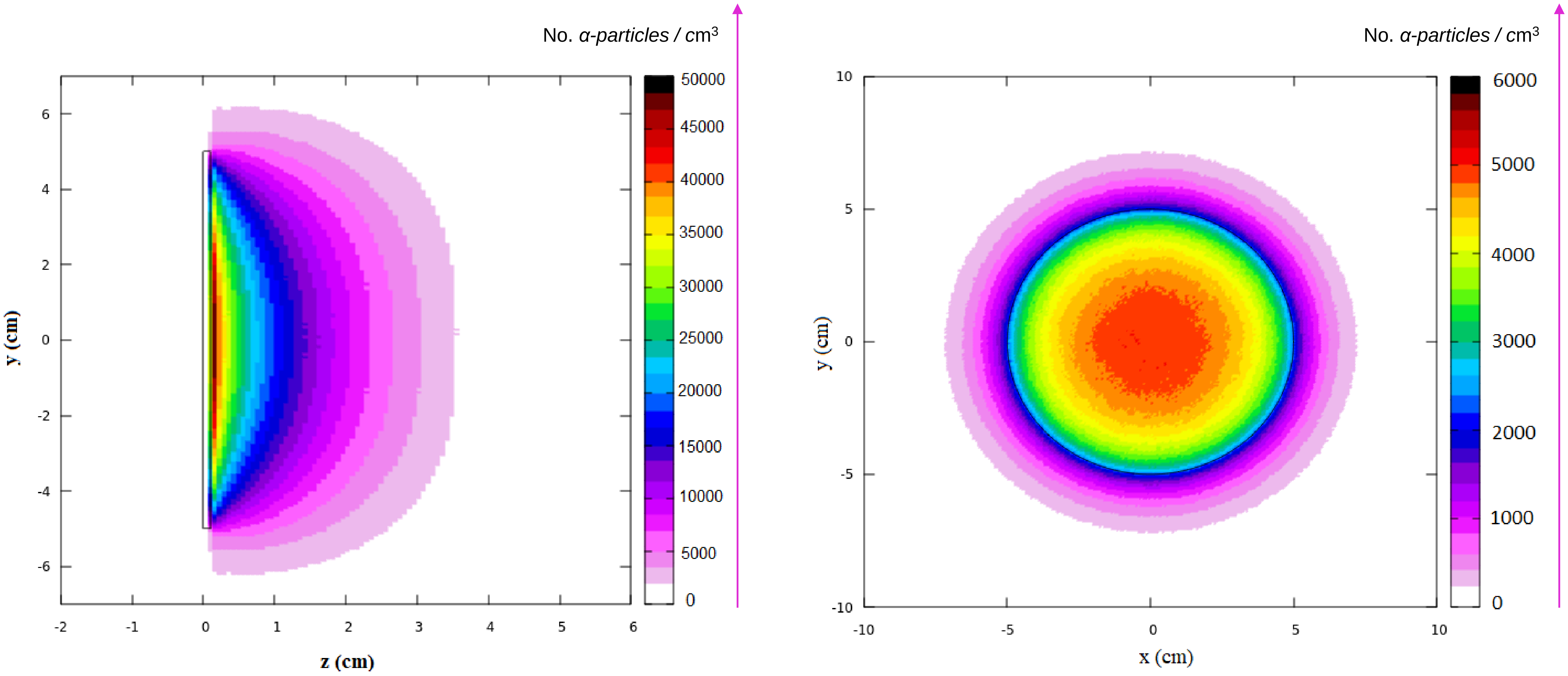
*Trajectories of the α-particles emitted by the radioactive source simulated with Geant4*

# Simulation results

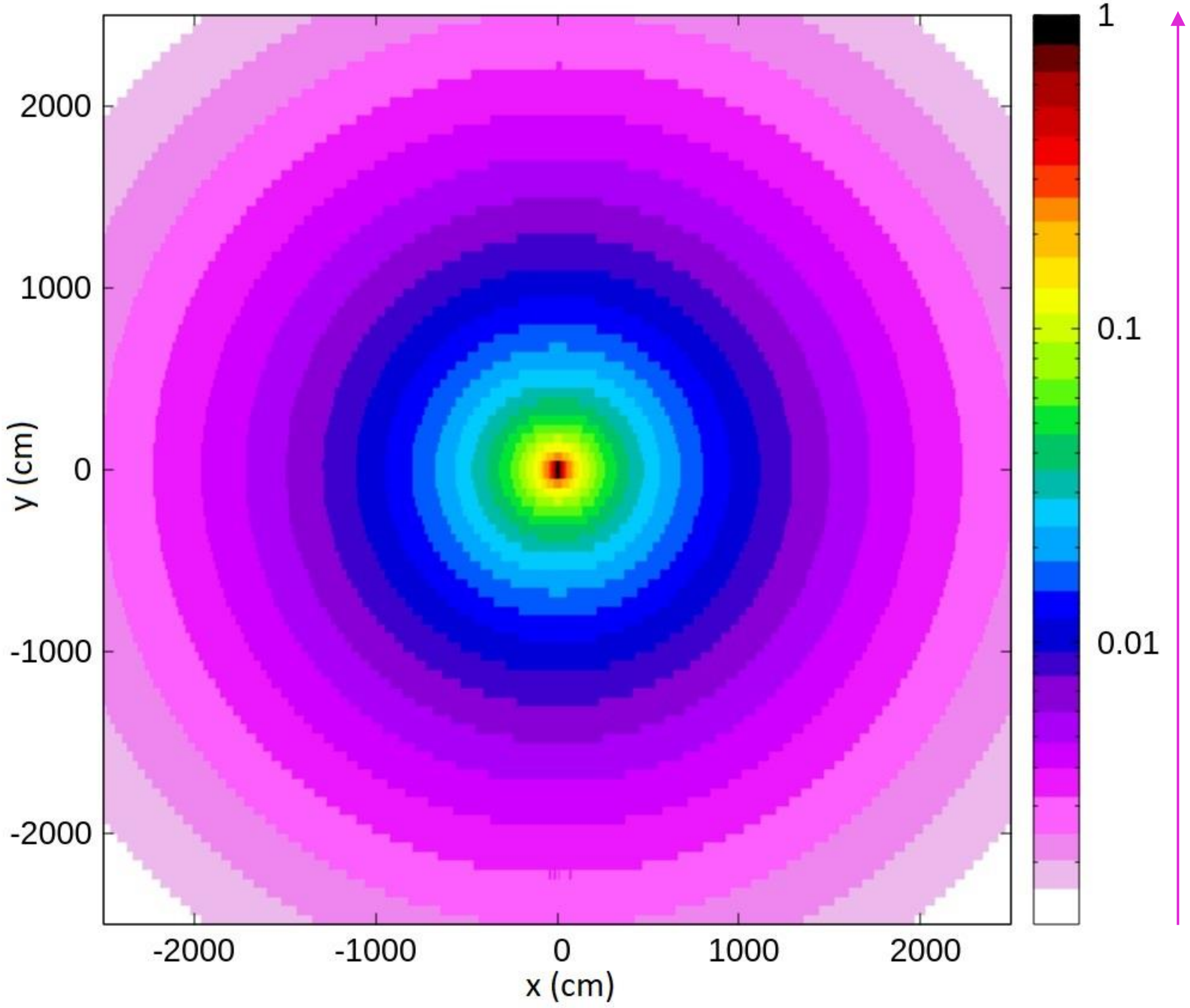



*Geant4 simulation of the Bragg curve for 5.5 MeV α-particle beam ($10^6$ events) at NTP conditions*

# Simulation results

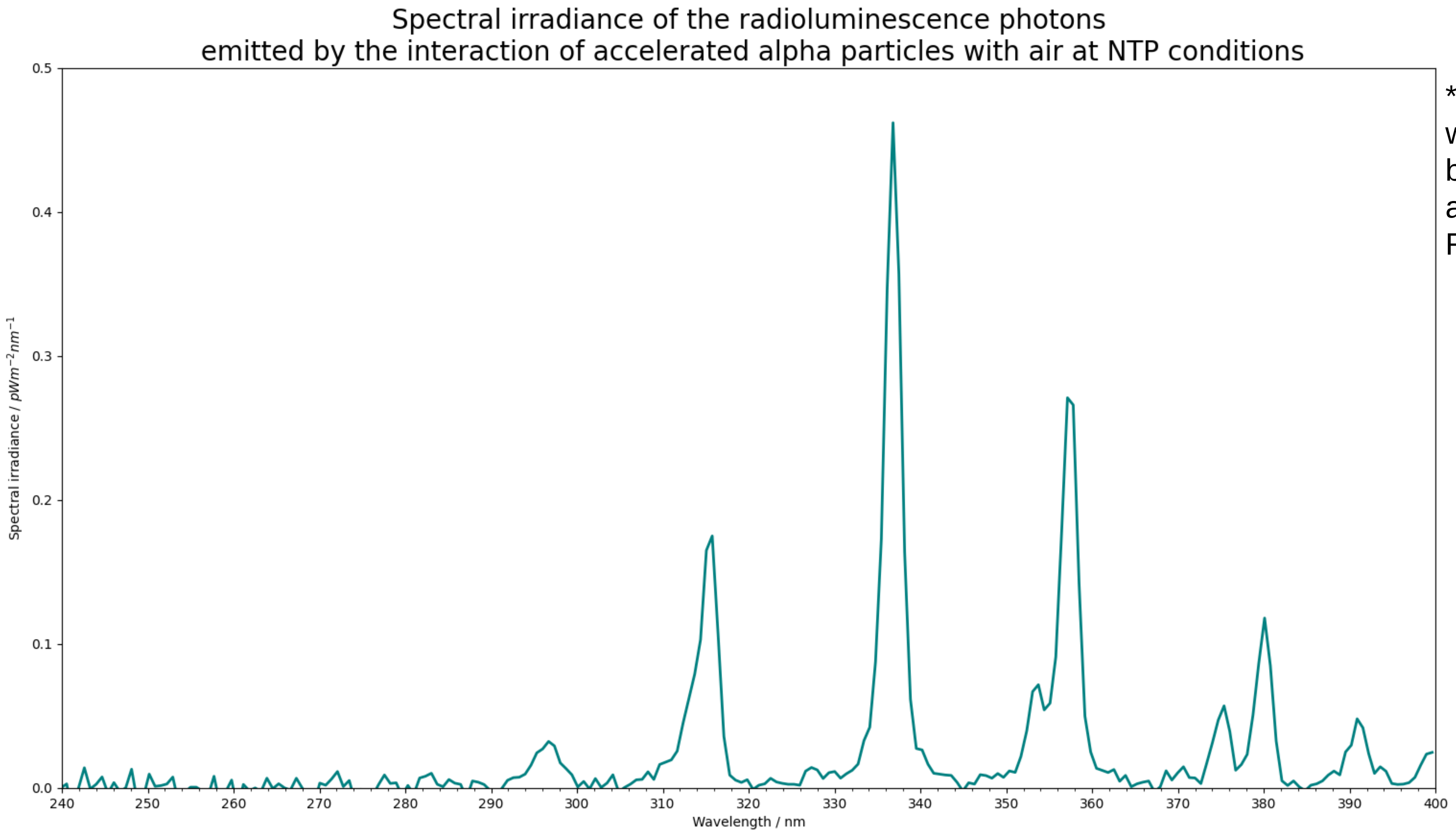



*The radioluminescence emitting volume of the $Am^{241}$ source (front and side view) simulated with FLUKA at NTP conditions*




No. of radioluminescence photons / *α-particle* / cm$^3$

!!!!!!!!!!!!!!




*This measurement was taken during beamtime at the PTB accelerator facility, by the RemoteALPHA team

!!!!!!!!!!!!!!

Further developments of the Geant4 simulation: Task2: UV spectrum

*Spectroscopic measurement of the radioluminescence photons emitted by accelerated alpha particles in air.*

# Acknowledgements

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