Monte Carlo modelling of PMTs System for optical detection of alpha sources

Ioana Lalau[1,2] , Mihaela Parvu[2], Mastaneh Zadehrafi[1], Mihail-Razvan Ioan[1], Andrei Antohe[1], Ionel Lazanu[2]

[1]*Radioisotopes and Radiation Metrology Department, Horia Hulubei National Institute for Research and Development in Physics and Nuclear Engineering, Romania*

[2]*Faculty of Physics, University of Bucharest, Romania*

Abstract

The radioluminescence process is an alternative method to detect alpha radiation at a much greater distance than the use of standard methods in which the signal is obtained from the energy deposition inside the detection system. In this method, when alpha particles interact with nitrogen molecules from air, photons in UV domain are emitted. The goal of this work is to simulate the Optical Chamber with the PMTs System which is used for radioluminescence detection. The design of a simple system that can be used for UV photon detection was targeted. Using FLUKA Monte Carlo code, the photon fluence generated by 5 MeV alpha particles and the number of counts as a function of energy were estimated. Also, the simulated results are compared with the obtained experimental data. In order to validate the results, the ranges of the alpha particles were calculated using FLUKA and SRIM codes and a good agreement was found with the experimental data. This paper evaluates the alpha induced air radioluminescence Optical Chamber with PMTs Detection System which can be used for different applications. In particular, if the system is sensitive, it could be used to monitor the concentration of radon and their progenitors in experiments with low radioactive background.

Methodology

FLUKA (FLUktuierende KAskade) - is able to produce and propagate optical photons of Cherenkov, Scintillation and transition radiation light. [1, 2]

APPLICATIONS:

Cosmic ray physics, Neutrino physics, Accelerator design (n_ToF, CNGS, LHC systems)

Particle physics: calorimetry, tracking and detector simulation etc. (ALICE, ICARUS)

Shielding design, Dosimetry and radioprotection, Radiation damage, Space radiation, Hadron therapy

SRIM (The Stopping and Range of Ions in Matter) - a collection of software packages which calculate many features of the transport of ions in matter. [3]

Introduction. Radioluminescence

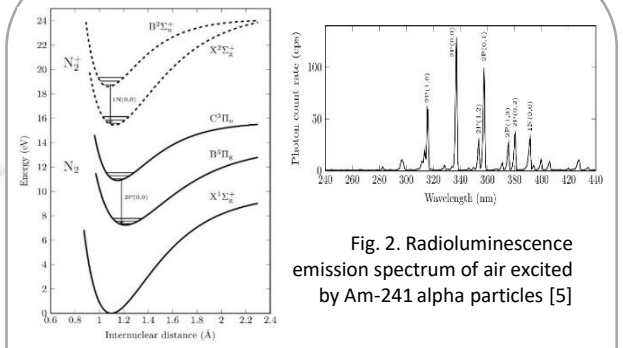

Fig. 2. Radioluminescence emission spectrum of air excited by Am-241 alpha particles [5]

Fig. 1. Selected energy levels of N_2 molecule Illustrated with Morse potential plots, using molecular constants from Lofthus and Krupenie [4]

FLUKA code validation

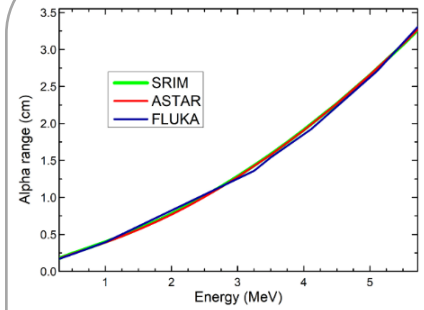

Fig. 3. Comparison between ranges of alpha particles in air estimated with FLUKA, SRIM [3] and ASTAR [6]

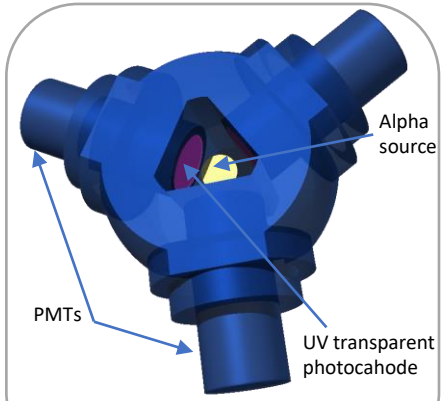

Fig. 4. PMTs System for radioluminescence detection

Simulations and Results

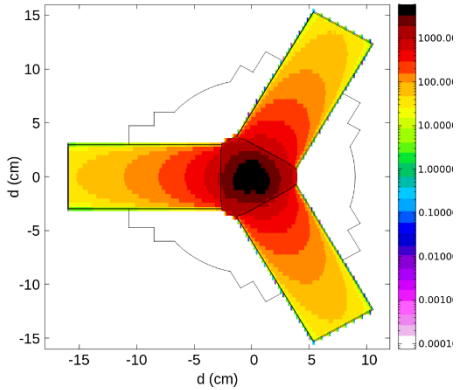

Fig.5. Radioluminescence photons distribution inside the PMTs

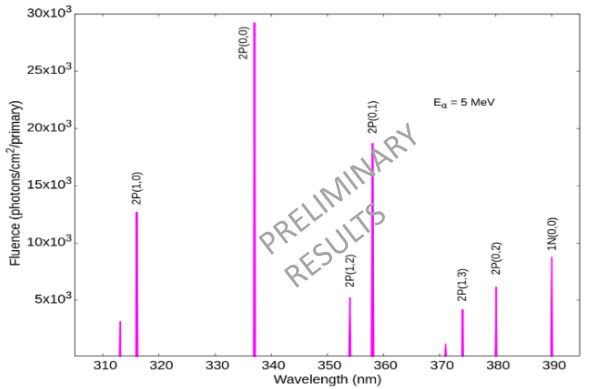

Fig. 6. Fluence induced by alpha particles in air

Conclusions

➔FLUKA code it's a useful tool in radiation physics

➔Integrating the number of photons obtained from simulations, we obtained the total number of photons which is far greater than the experimental data; further study needs to be done to obtain results in good agreement with the experimental data (one has to consider QE of the photocathode, geometry factors, etc.)

➔The results show that the setup with 3 PMTs may be a good approach in detecting radioluminescence photons induced by alpha particles

Acknowledgements:

This 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.

This work was performed also with the financial support of the contract no. 02/2020, PNCDI III 2015-2020, Programme 5, **Module CERN-RO**.

References

1. "FLUKA: a multi-particle transport code" A. Ferrari, P.R. Salla, A. Fasso and J. Ranft, CERN-2005-10 (2005), INFN/TC_05/11, SLAC-R-773

2. "The FLUKA Code: Developments and Challenges for High Energy and Medical Applications" T.

3. http://www.srim.org/

4. A. Lofthus and P. H. Krupenie, "The spectrum of molecular nitrogen," Journal of Physical and Chemical Reference Data, vol. 6, no. 1, pp. 113 – 307, 1977.

5. Sand, J. (2016). Alpha Radiation Detection via Radioluminescence of Air. (Tampere University of Technology. Publication; Vol. 1449)

6. Berger, M.J., Coursey, J.S., Zucker, M.A., and Chang, J. (2005), ESTAR, PSTAR, and ASTAR: Computer Programs for Calculating Stopping-Power and Range Tables for Electrons, Protons, and Helium Ions (version 1.2.3). [Online] Available: http://physics.nist.gov/Star [2021, November 18]. National Institute of Standards and Technology, Gaithersburg, MD.

15th INTERNATIONAL SYMPOSIUM ON RADIATION PHYSICS (ISRP-15)

Kuala Lumpur – Malaysia, 6 — 10 December 2021

The authors declare that they have no conflict of interest.