

# TOPAS Automator

T. Campante<sup>1,a</sup>

<sup>1</sup>Faculdade de Ciências da Universidade de Lisboa, Lisboa, Portugal

Supervisor: C. Felgueiras, D. Galaviz Redondo

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**Abstract.** The TOPAS Automator was a program developed based Python with its aim to facilitate the running of simulations straightforwardly. TOPAS is a powerful tool for studying how particles like protons, electrons, and neutrons interact with different materials like tissues, organs, and detectors. However, manually setting up and running simulations can be a tedious task. With the TOPAS Automator, researchers can give the program essential instructions through the use of a GUI, and the program will create input files and run the simulations. TOPAS Automator was developed to provide an interface for the researchers to enter their requirements for the simulation, and the programs output is the simulation result. Overall, this GUI reduces the time learning the particularities of TOPAS. The project focused on the simulation of the Resistive Plate Chamber detector (RPCs), however it can be extended to any associated field such as biomedical physics and nuclear physics.

**KEYWORDS:** TOPAS, automation, GUI, interface, Tkinter, python3, simulation, neutron, RPC, detector, Geant4

## 1 Introduction

### 1.1 The automation

Let *automation* be understood as the simplification of a repetitive process through technology.

The purpose of this internship was to create an interface that obsoletes TOPAS' .txt input files. These files are usually very long and exhausting to write by hand. Now whenever someone needs to run a simulation with TOPAS, instead of opening their terminal and typing the bash commands to open it and run said file, they open the automator with python3, they use the interface and the program creates the .txt input files and runs the program automatically.

### 1.2 TOPAS MC and Monte Carlo simulations

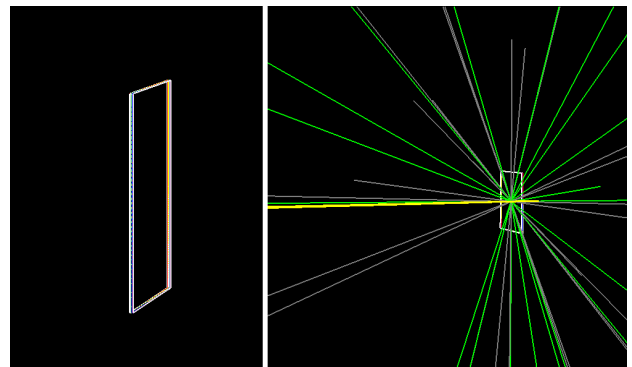
TOPAS is an advanced Monte Carlo simulation code that extends the Geant4 Simulation Toolkit [1]. [2]

Monte Carlo simulations consist of a mathematical prediction based on the probability of some event to happen. Usually, in order to have a more trustworthy estimation, the simulations are repeated on a large scale: so that the probabilities converge towards a stable distribution.

TOPAS MC is used in several fields of study, as in medical physics, radiation therapy and nuclear engineering. This framework has several functionalities: it can be used just visualize setups (figure 4), to run simulations (figure 1) and more.

## 2 About the automator

We have created an interface that collects the characteristics and the specific simulation's parameters and



**Figure 1.** Simulation example with RPCs. In this simulation there is a beam of neutrons passing through a nRPC. Yellow lines: neutrons; green lines: gammas; grey lines: other particles.

generates a .txt file that is automatically run with TOPAS. It is also possible to preview the simulation without opening the TOPAS framework. Unfortunately, this program only simulates with nRPCs and the specific setups mentioned in reference [3]. To learn more, see section 4.

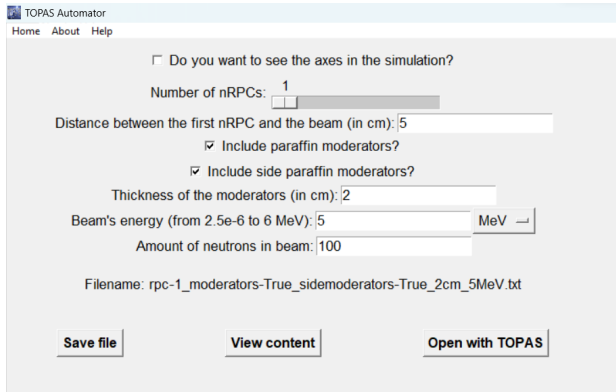
With this program, researchers can give it some instructions and let it do the hard work, such as creating the input files and running the simulations. This program can save researchers time and energy.

## 3 Program overview

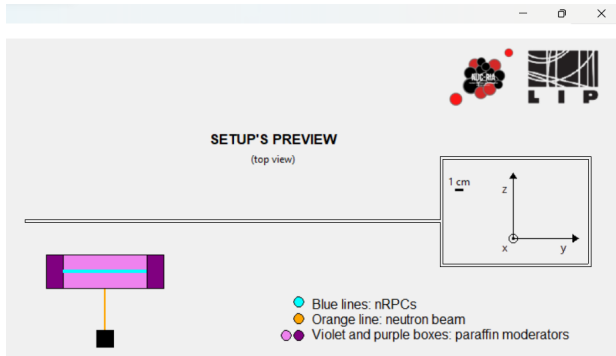
Let us inspect the developed interface.

It can be separated into 3 areas: the menu (on the top-left side), the inputs (figure 2) and the preview (figure 3).

<sup>a</sup>e-mail: tomas.campante@hotmail.com



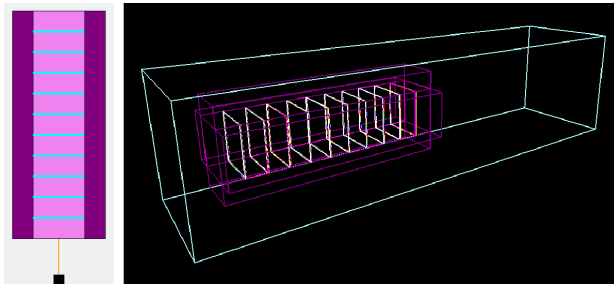
**Figure 2.** The inputs: left side of the default interface's window. Note that the menu is visible in this image (on the top-left side).



**Figure 3.** The setup preview: cropped right side of the default interface's window.

The inputs are where the user defines the parameters of the simulation. Then, he can choose to either just save the .txt file, or to either save and open it with his default .txt editor or with TOPAS.

The setup preview is a feature where the user can visualize the setup that will be open in TOPAS. This is a preview of the simulation's setup. This preview is updated at the same time the user changes the inputs.



**Figure 4.** This is the setup preview of the simulation for 10 nRPCs with moderators and side moderators with 4 cm and a distance of 7 cm between the beam and the first moderator and the TOPAS' windows for the aforementioned setup.

The menu has some functionalities, such as the About and Help buttons, that are worth highlighting. Also, if you hover over Home, it will cascade down into more buttons: Run, Reset and Exit.

In the About you can learn more about the program and its origin and its version (the program version is crucial).

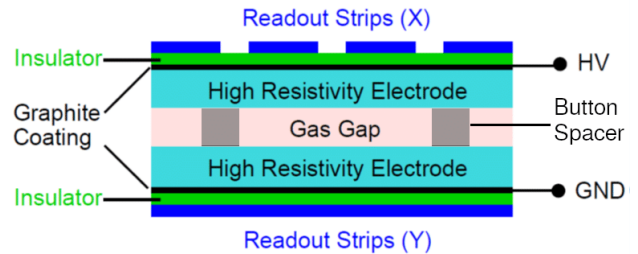
The Help window leads you to the User Guide available online (and in .pdf).

## 4 Simulations with TOPAS Automator

This program was created in order to automate the process of running several similar simulations with different parameters regarding the detection of neutrons using resistive plate chambers.

### 4.1 About RPCs and neutron detection

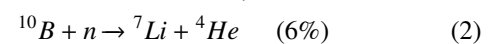
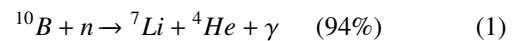
Resistive plate chambers (RPCs) are gaseous detectors currently widely used in several areas of physics (such as high-energy physics, astroparticle physics, cosmic ray research and medical imaging). Compared to others, some of the advantages of these detectors are their simple structure, low price and good spatial resolution. Moreover, as their configuration is layered, the detector becomes more flexible. [4]



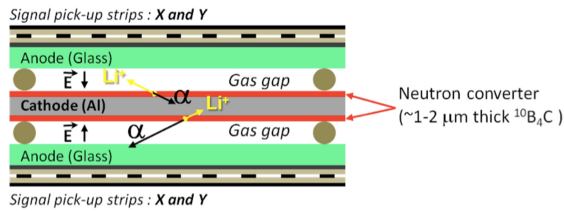
**Figure 5.** RPC constitution and its different layers.

However, RPCs only detect charged particles. Since we will be simulating with neutrons, it is necessary to induce a nuclear reaction where the neutrons react with a nucleus and generate charged particles.

Hence, enter resistive plate chambers for neutrons (nRPCs) [5]. These structures contain a layer with boron-10 - neutron converter (figure 6) [6]. When the neutrons collide with the boron, they origin the following fission nuclear processes [6]:



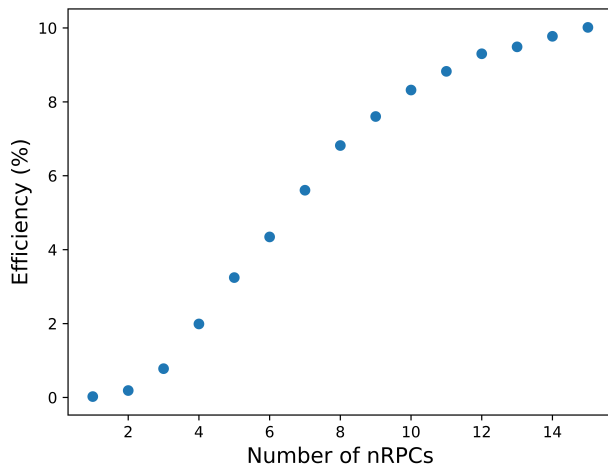
With the detection of alpha particles and lithium ions, we can deduce the presence of neutrons.



**Figure 6.** nRPC constitution and its different layers.

## 4.2 Efficiency of the detector

Firstly, it makes sense to study how the efficiency varies with the stacking of several nRPCs (figure 7).



**Figure 7.** Efficiency as a function of the number of nRPCs.

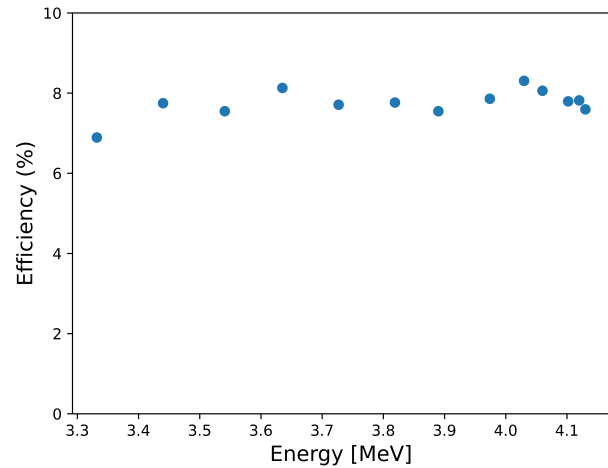
Taking a closer look at figure 7, we see that the efficiency will, virtually, increase indefinitely with the number of resistive plate chambers for neutrons in the setup. Even so, considering a tradeoff between cost and efficiency, it can be concluded that the most optimal number of nRPCs is around 10. Note that this is in agreement with the reference [7] and [8].

On the other hand, one would expect that the efficiency of the detector diminishes with the increase in the neutron's energy, due to the cross-section reduction [9]. However, simulations were conducted in order to investigate this, and the results are the following (figures 8, 9 and 10).

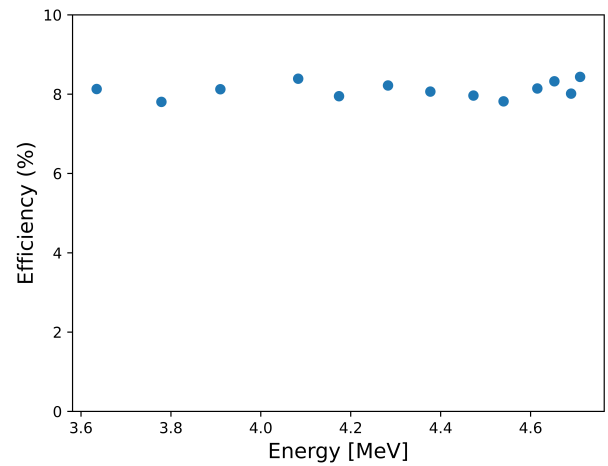
Where on the x-axis is the energy of the neutrons and on the y-axis is the efficiency of the detector.

For these simulations, the setup had 10 nRPCs with moderators of 1 cm and a sample of 20000 neutrons.

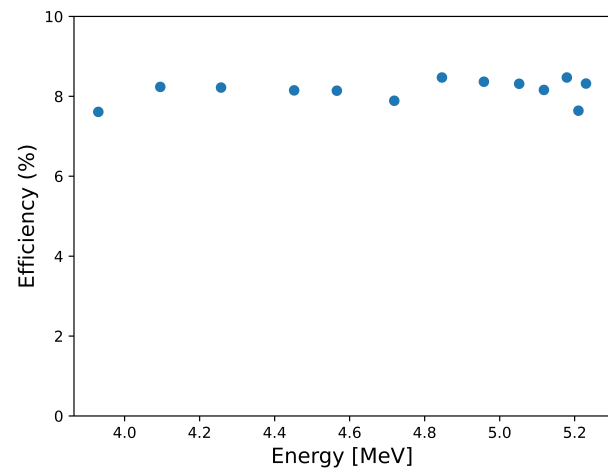
Analyzing the figures 8, 9 and 10 we get some promising results, as the efficiency stays about constant



**Figure 8.** Initial kinetic energy of the deuterium-deuterium reaction of 1 MeV (see figure 11).

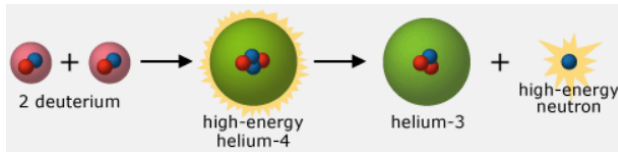


**Figure 9.** Initial kinetic energy of the deuterium-deuterium reaction of 1,5 MeV (see figure 11).



**Figure 10.** Initial kinetic energy of the deuterium-deuterium reaction of 2 MeV (see figure 11).

for different arrays of energy.



**Figure 11.** The  $D(d,n)^3\text{He}$  reaction creates neutrons by colliding two deuterium. In this experiment, both deuterium have the have initial kinetic energy. Image retrieved from <https://undsci.berkeley.edu/teach-resources/products-of-deuterium-fusion/>.

## 5 Documentation and Download

Following up on the program, it was also written an User Guide [10] and a download page [11] that links to the GitHub repository [12] (mouseover for hyperlinks).

## 6 For the future

In January 2024, my supervisors, Carolina Felgueiras and Daniel Galaviz, are going to CNA in Seville to perform the experiment that we have been simulating (and automating) in this internship. Until then, there is more work to be done regarding simulations, data processing and data analysis.

## Acknowledgements

I would like to thank my supervisors, Carolina and Dani, for guiding me through this process and always being available to clarify my questions.

Also, a huge thanks to the NUC-RIA group members and fellow interns for providing an excellent work environment.

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