PROCEEDINGS OF SCIENCE

PER me si va ne la fisica recente (Particle Escape Room)

Simone Venturini,[a,b,*] **Chiara Aimè,**[a,b] **Arianna Armanetti,**[a] **Daniele Aurelio,**[c] **Ettore Budassi,**[a,b] **Davide Gianatti,**[a] **Diego Maragnano,**[a] **Paolo Montagna,**[a,b] **Michele Pirola,**[a,b] **Davide Santostasi,**[d] **Simone Restelli**[a] **and Luca Zatti**[a]

[a] *Dipartimento di Fisica, Università di Pavia, Via Agostino Bassi 6, Pavia, Italy*
[b] *INFN Sezione di Pavia, Via Agostino Bassi 6, Pavia, Italy*
[c] *IIS Faravelli, Via Edmondo de Amicis, 35, Stradella, Italy*
[d] *Liceo Ginnasio Statale B. Cairoli, Via Cairoli, 27, Vigevano, Italy*
E-mail: physics4teenagers@unipv.it, simone.venturini01@universitadipavia.it, paolo.montagna@unipv.it

In recent years, outreach activities have acquired great importance among the three university missions for the involvement of the non-expert community. In this context, the "Physics4Teenagers" outreach group of the Physics Department of Pavia University, in Northern Italy, designed the "PER me si va ne la fisica recente" experience. In physics promotion, our major target are usually high school students with a particular focus on the choice of their future studies. With this in mind, we decided to exploit a new format: the educational escape room. Based on the success of recreational escape rooms, this format has acquired great visibility in the last decades, combining entertainment with learning goals. Besides, it allows for the development of soft skills such as collaboration and critical thinking through hands-on activities. We created a journey through the history of particle physics from the atomic theory of Democritus to the discovery of the Higgs boson, which completes the Standard Model. Furthermore, we pushed the boundaries of our map towards the questions that remain unsolved in this theory, such as the problem of dark matter, neutrino masses and oscillations, and unification of forces. At the end of the escape room, we asked the participants for feedback and suggestions through a satisfaction questionnaire. The good results in both occasions confirm the suitability of the format and the effectiveness of the friendly and informal attitude.

41st International Conference on High Energy physics - ICHEP2022
6-13 July, 2022
Bologna, Italy

*Speaker

PoS(ICHEP2022)1164

1. Introduction

Outreach activities have recently grown in importance with the specific goal of including and involving the non-expert community into the scientific world [1]. The Physics4Teenagers outreach group of the University of Pavia Physics Department [2] takes part in the effort of designing new ways to do so, in parallel with more canonical seminars and laboratory activities.

To this aim, we designed the "PER me si va ne la fisica recente" educational Escape Room and proposed it as a non-formal teaching method on various occasions through 2021 and 2022: within the National Genova Science Festival (edition 2021), with more than one thousand participants; in two scientific high schools near Pavia for at least two weeks, specifically aimed at the students of said schools; within the "TenDaysPhysics4Teenagers" summer school at the Pavia Physics Department, aimed at fourth-year high-school students; in the "Collegio Cairoli" in Pavia, addressed both to the non-expert community and to a group of high-school teacher coming from all over Italy, reaching almost 200 people; within the didactic course "Preparazione di Esperienze Didattiche" at the Physics Department of the University of Pavia.

2. The Escape Room

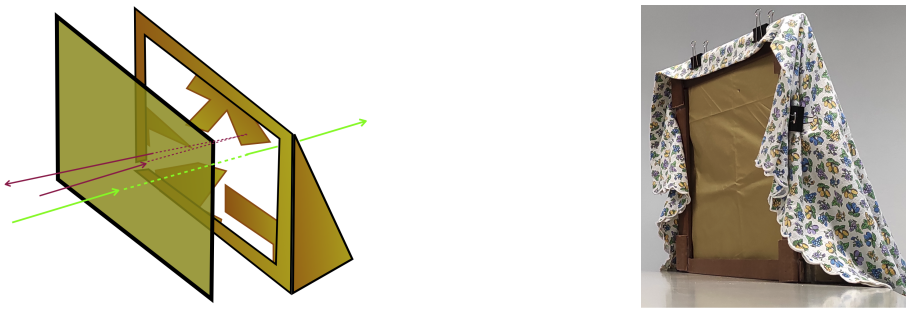
The idea of the escape room is to guide the audience into building the Standard Model (SM) through a historical perspective: all the pieces of the "puzzle" are being gathered by the participants through the reproduction of famous experiments or physical reasoning that led the physicists in history to make their discoveries.

The journey starts with Democritus, with his atomistic idea. Democritus, performed by us, plays the role of Virgilio in the "Divina Commedia" guiding the audience through the most important steps of particle physics history in the first room. The ultimate goal of Democritus is to show how his concept of "atom" changed over the centuries, thanks to the scientific discoveries.

Among the most important historic steps, the following have been reproduced: the Newton's prism, the discovery of electric materials, the Rutherford experiment, the Chadwick experiment, the cosmic rays and antimatter discovery, the internal structure of hadrons, the Higgs' mechanism and the Higgs' boson. Each step has been accompanied with home-made experimental setups, quiz and riddles realized to intrigue the participants and help them to understand in a playful way the scientific progresses. We report here just two of these experiences.

2.1 Rutherford Experiment

Rutherford experiment has been reproduced macroscopically with recycled and inexpensive material. Basically, a wooden stand has been constructed, with unevenly-shaped wooden pieces arranged in casual positions inside a wooden frame (see Figure 1). A sheet of glided tissue paper has been placed in front of the stand. Participants, in the role of Rutherford, shoot alpha-particles (plastic bullets) at a gold foil (the glided tissue paper) with a particle accelerator (a toy gun).



(a) **(b)**

Figure 1: The design (panel (a)) and the realization (panel (b)) of the Rutherford experiment.

The result of the experiment is that some alpha-particles pass through the gold foil, and others, hitting the wooden pieces, are bounced back. This implies the inappropriateness of the Thomson atomic model and the theorization of the Rutherford planetary model.

2.2 Cosmic Rays and Antimatter

The discovery of the antimatter dates back to 1932, when Carl David Anderson detected unexpected particle tracks in his cloud chamber, as having been created by a particle with the same mass as the electron, but with opposite electrical charge: the positron. In our escape room, the participants can understand the behaviour of particles in presence of magnetic fields, by playing with a home-made console. Such a device (see Figure 2), simulating the Anderson cloud chamber, shows the traces of different particles in magnetic fields, according to the trajectories due to the Lorentz force. The modulus and the verse of the magnetic field, as well as the masses and the charges of the particles detected, can be changed by moving knobs. By doing so, muons, pions and positrons are discovered by the audience.

(a) **(b)**

Figure 2: Our home-made console (a) interfaces with a Python program, showing the output on a screen (b).

This activity is a typical example of non-formal teaching method, since it permits to recover three vary basic features of the Lorentz force, without studying any physical law: the trajectories of charged particles in vacuum are circles, if a constant magnetic field is applied; opposite charges travel in opposite directions; the radii of curvature are bigger for heavier particles, or for weaker magnetic fields.

At the end of the first part, the participants must complete the SM puzzle, with the cards gained during the experience, recognizing the gauge bosons, the leptons and the quarks. Only by sorting their particles by growing mass, they are authorized to cross the threshold that leads to the world beyond the SM (the second room). When the SM puzzle is complete, Democritus fulfills his task and, unable to answer the questions left unsolved by the SM, gives way to a modern and scientific version of the dantesque Beatrice, the Curiosity, that in the second room tries to shed light on three open problems: dark matter and dark energy; neutrino oscillations; gravitational force and graviton.

3. Results of the satisfaction questionnaire and Conclusions

The participants were asked to complete a satisfaction questionnaire related to the escape room: the questions regarded how interesting and useful the activity was perceived. The results of the questionnaires are very promising and prove the suitability of the format, as one can appreciate by looking at the answers to one of the questions coming from the Genova Science Festival and the 2022 TenDaysPhysics4Teenagers summer school, shown in Figure 3. It is important to mention that the two samples of people that filled in the questionnaires of Figure 3 are substantially different: the 2022 stage was specifically addressed to high school students that intend to pursue a STEM university path. On the other hand, during the Genova Science Festival, the Escape Room attendees ranged from teenagers to families, without any *a priori* sampling.

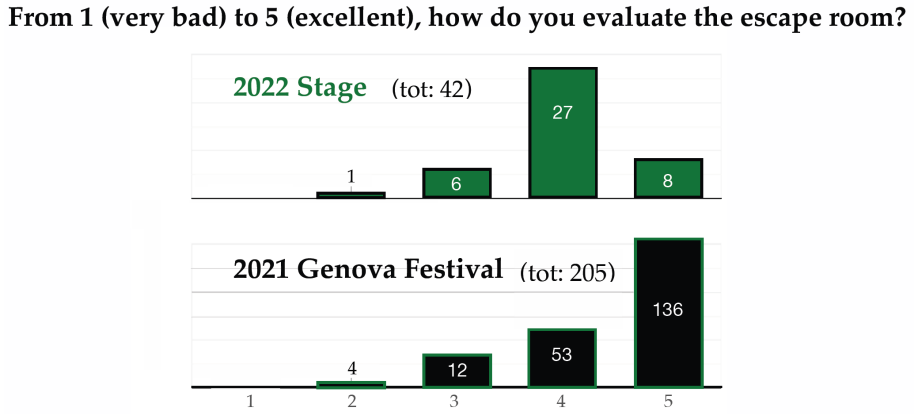


Figure 3: Answer to one of the questions in the satisfaction questionnaire from 2022 Stage attendees (top) and Genova science festival participants (bottom).

Besides the satisfaction questionnaires, we are planning to build also a didactic effectiveness questionnaire for the next preparation of the escape room with a pre- and post- physics test on the subjects that are discussed, in order to test the effectiveness of the Escape Room format.

References

[1] Sanchez, Eric, and Maud Plumettaz-Sieber. "Teaching and learning with escape games from debriefing to institutionalization of knowledge." International conference on games and learning alliance. Springer, Cham, 2018.

[2] https://fisicapaviaeducational.it/phys4teens/