



# REINFORCE

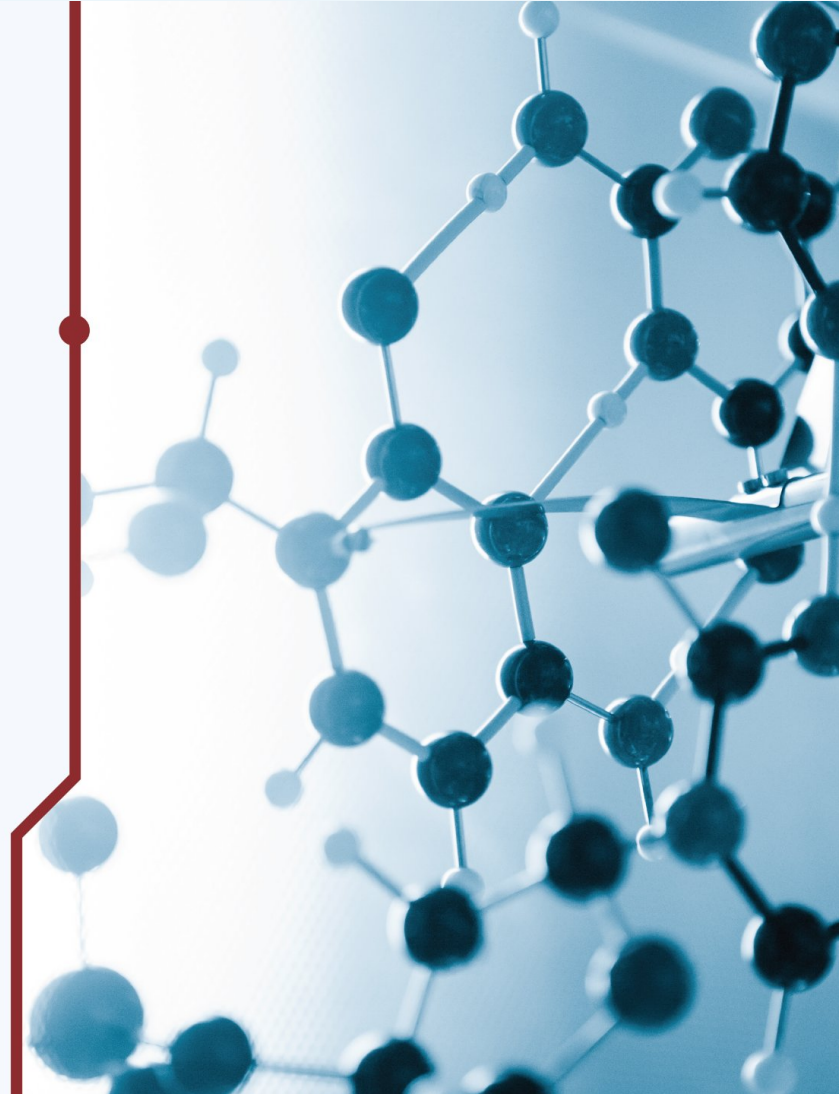
REsearch INfrastructures FOR Citizens in Europe

## Search for New Particles at CERN on the Zooniverse citizen-science platform

**Stelios Angelidakis**

HEP2023 - 40th Conference on Recent Developments in High Energy Physics and Cosmology.

5–8 April 2023





**REINFORCE**  
REsearch INFrastructures FOR Citizens in Europe

**REINFORCE**

## REsearch INFrastructures FOR Citizens in Europe

<https://www.reinforceeu.eu>



### Science with and for Society (SWAFS)

H2020-SwafS-2018-2020

**DEC 2019 – NOV 2022**





# REINFORCE - DEMONSTRATORS

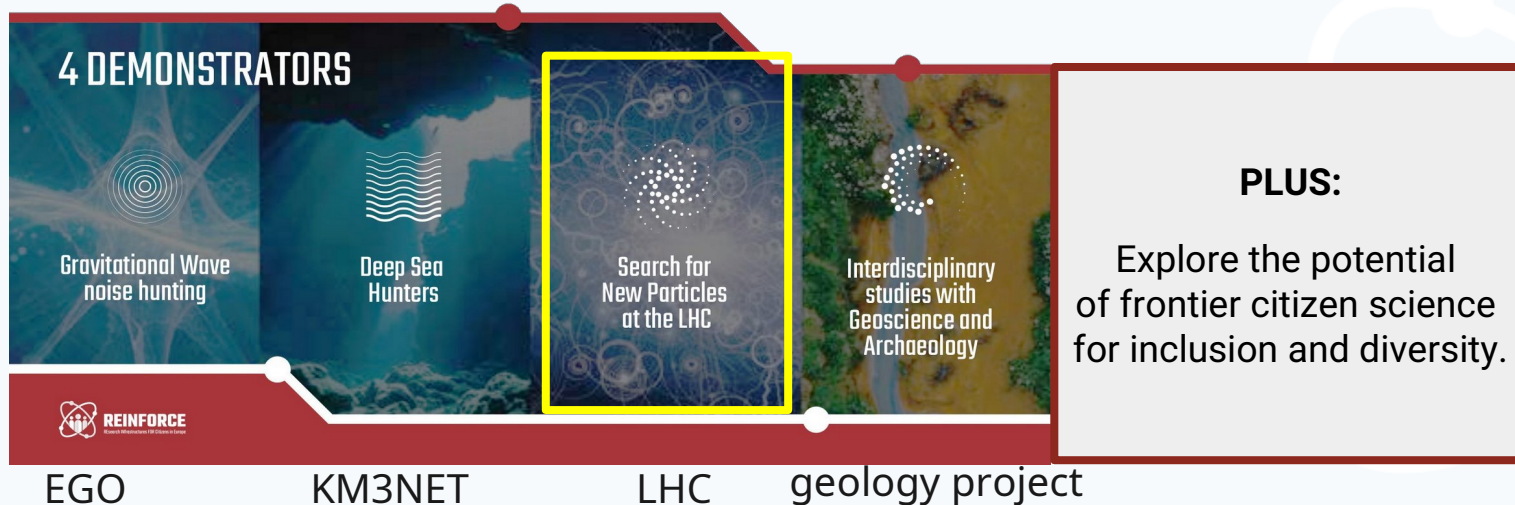
**Goal:** establish a community of citizens engaged in public-funded frontier research.



Assess benefit to science



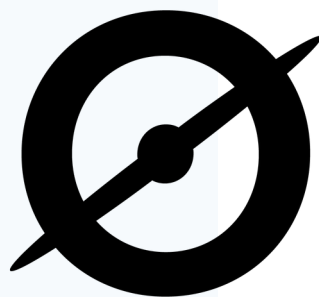
Assess benefit to society





## All demonstrators hosted by Zooniverse citizen-science platform

- Citizen friendly environment.
- Publicity boost (over 2.5M registered volunteers).



THE ZOONIVERSE WORKS

250,469,827

CLASSIFICATIONS SO FAR BY

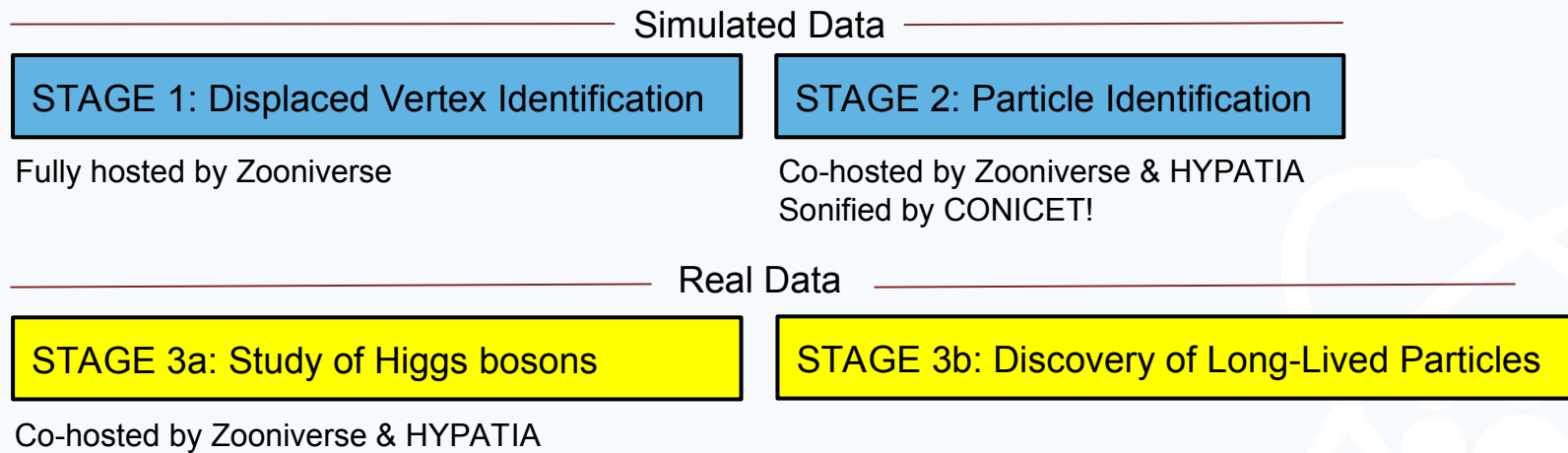
2,592,919 REGISTERED VOLUNTEERS

A **vibrant community**. Zooniverse gives people of all ages and backgrounds the chance to participate in real research with over 50 active online citizen science projects. Work with 1.6 million registered users around the world to contribute to research projects led by hundreds of researchers.





- Exploit ATLAS Open Data.
- Multitask work package (3 stages):



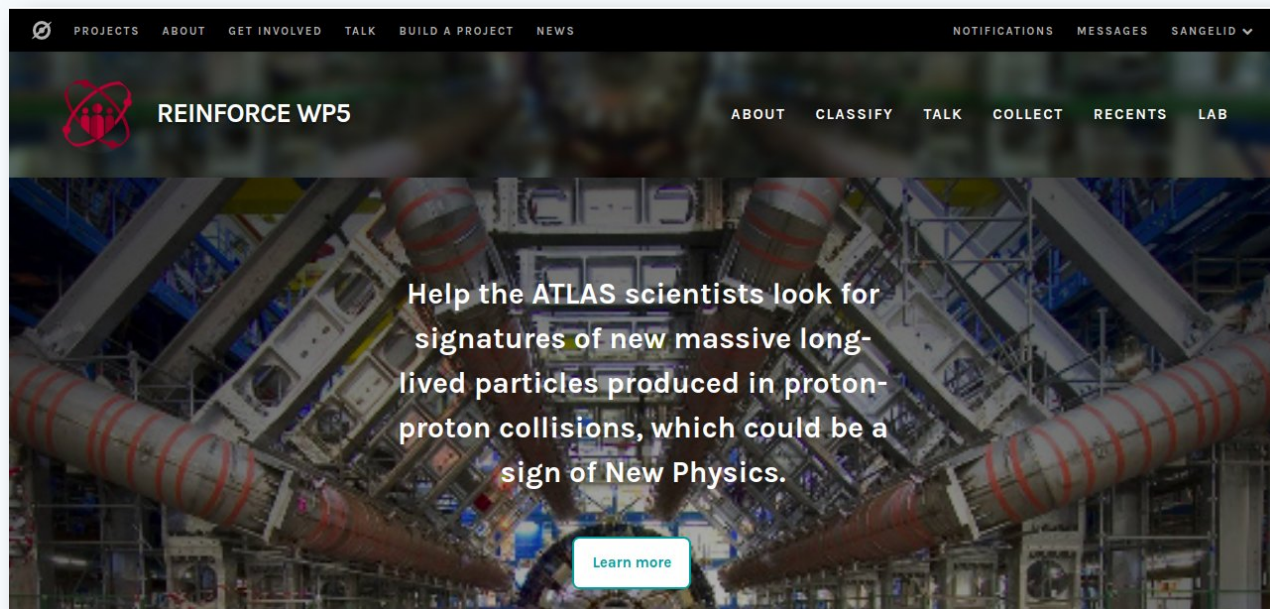
- All tasks carried out using just mouse clicks.
- Detailed but concise guidelines provided in **text, images and videos**.
- Available in **3 languages**: English, Spanish, Greek.



# The project on Zooniverse

**Homepage** with links providing information about:

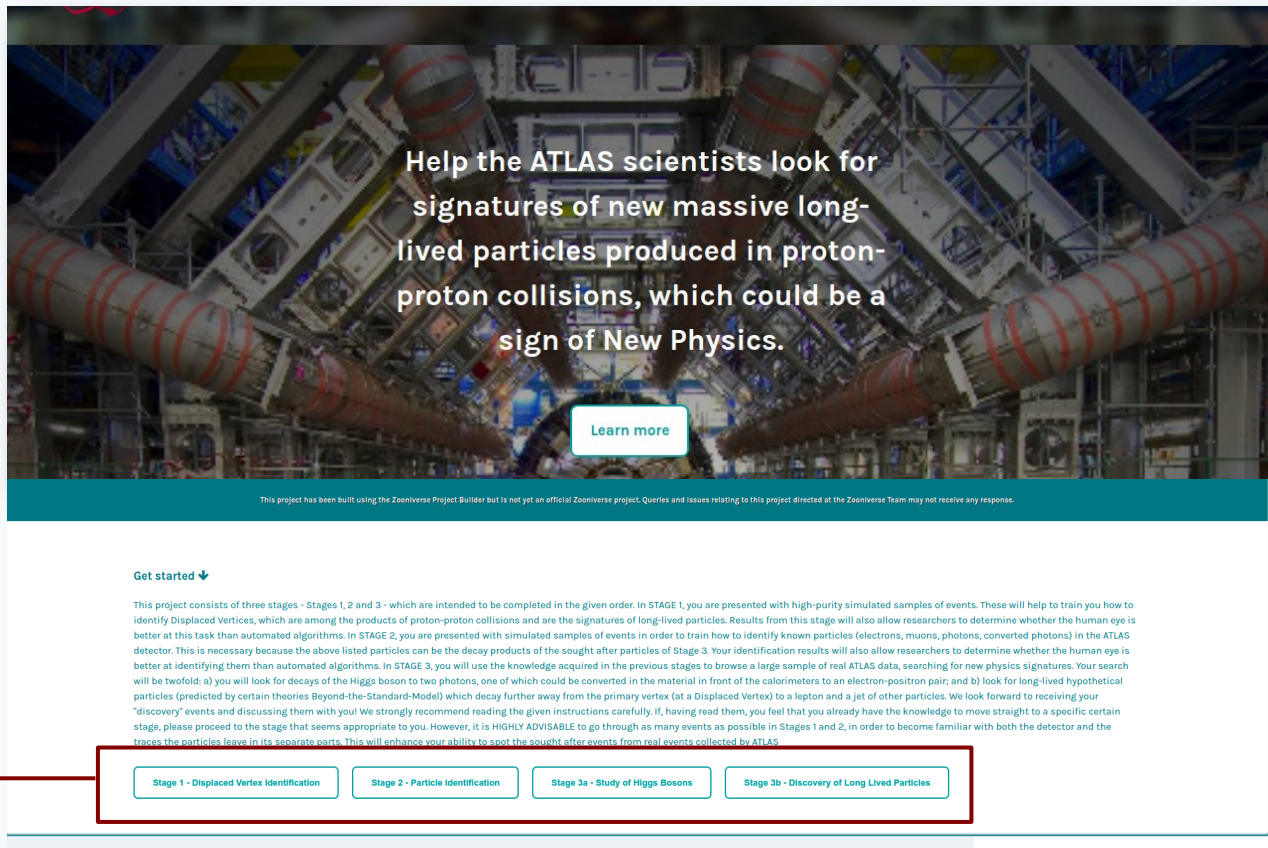
- physics (related to the project);
- the ATLAS experiment;
- the group.



# The project on Zooniverse

**Homepage** with links providing information about:

- physics (related to the project);
- the ATLAS experiment;
- the group.



Help the ATLAS scientists look for signatures of new massive long-lived particles produced in proton-proton collisions, which could be a sign of New Physics.

[Learn more](#)

This project has been built using the Zooniverse Project Builder but is not yet an official Zooniverse project. Queries and issues relating to this project directed at the Zooniverse Team may not receive any response.

**Get started ↓**

This project consists of three stages - Stages 1, 2 and 3 - which are intended to be completed in the given order. In STAGE 1, you are presented with high-purity simulated samples of events. These will help to train you how to identify Displaced Vertices, which are among the products of proton-proton collisions and are the signatures of long-lived particles. Results from this stage will also allow researchers to determine whether the human eye is better at this task than automated algorithms. In STAGE 2, you are presented with simulated samples of events in order to train how to identify known particles (electrons, muons, photons, converted photons) in the ATLAS detector. This is necessary because the above listed particles can be the decay products of the sought after particles of Stage 3. Your identification results will also allow researchers to determine whether the human eye is better at identifying them than automated algorithms. In STAGE 3, you will use the knowledge acquired in the previous stages to browse a large sample of real ATLAS data, searching for new physics signatures. Your search will be twofold: a) you will look for decays of the Higgs boson to two photons, one of which could be converted in the material in front of the calorimeters to an electron-positron pair; and b) look for long-lived hypothetical particles (predicted by certain theories Beyond-the-Standard-Model) which decay further away from the primary vertex (at a Displaced Vertex) to a lepton and a jet of other particles. We look forward to receiving your "discovery" events and discussing them with you! We strongly recommend reading the given instructions carefully. If, having read them, you feel that you already have the knowledge to move straight to a specific certain stage, please proceed to the stage that seems appropriate to you. However, it is HIGHLY ADVISABLE to go through as many events as possible in Stages 1 and 2, in order to become familiar with both the detector and the traces the particles leave in its separate parts. This will enhance your ability to spot the sought after events from real events collected by ATLAS.

[Stage 1 - Displaced Vertex Identification](#) [Stage 2 - Particle Identification](#) [Stage 3a - Study of Higgs Bosons](#) [Stage 3b - Discovery of Long Lived Particles](#)

**Each button launches the respective stage**



# Stage 1 – Displaced Vertex Identification

Citizen scientists are invited to identify any displaced vertex in the displayed event using their mouse pointer.

Stationary image of the ATLAS inner detector (transverse & longitudinal view).



Tracks are colored to allow association between the two views.

SUSY MC samples (stop  $\rightarrow$  DV +  $\mu$ ).

The track selection mimics the one used by ATLAS to reconstruct DVs (plus additional criteria for visualization).

Tracks from the PV have been removed.

Please make sure that you have read the detailed instructions provided at the help link below.

Displaced vertex 0 of 0 required drawn

NEED SOME HELP WITH THIS TASK?

Done & Talk

Done





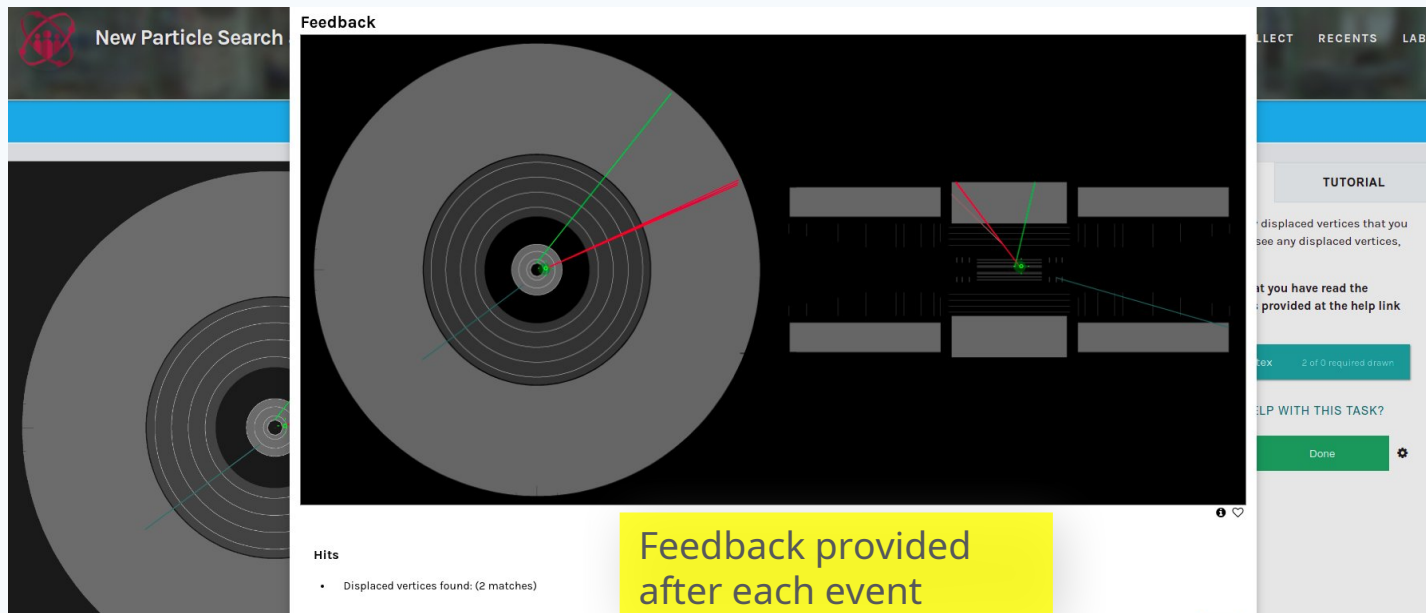
# Stage 1 – Displaced Vertex Identification

Citizen scientists are invited to identify any displaced vertex in the displayed event using their mouse pointer.



# Stage 1 – Displaced Vertex Identification

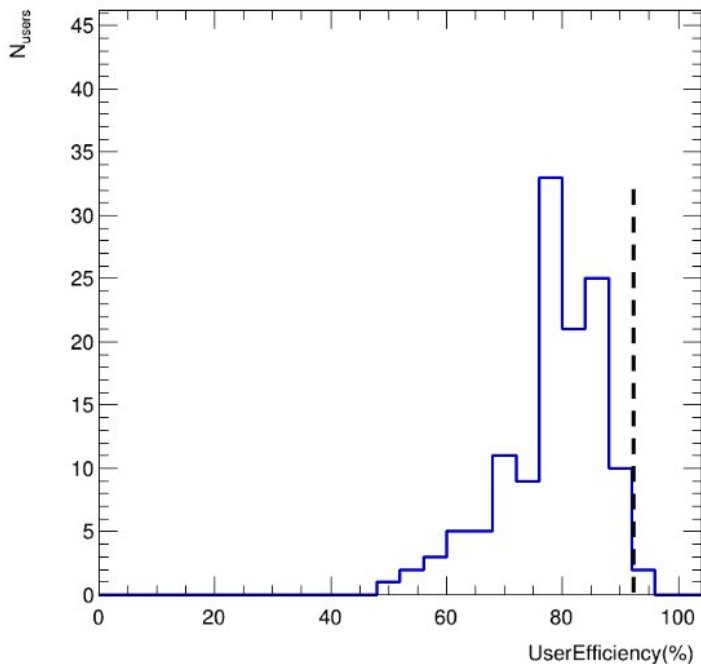
Citizen scientists are invited to identify any displaced vertex in the displayed event using their mouse pointer.



- Citizens' data are collected by Zooniverse and provided to us for analysis/evaluation.
- Citizens' performance were compared to an automatic algorithm performing the same selection.



# Stage 1 – Displaced Vertex Identification




## Citizens Performance Assessment:

- considering only the most active users ( $\geq 200$  classifications,  $\geq 50\%$  efficiency)
- Individual user average efficiency:  $\sim 79\%$
- **User consensus efficiency: 93%**  
(combined user response per event)
- **Efficiency of automated algorithm: 94%**



## Stage 2 – Particle Identification

HYPATIA takes over from Zooniverse:

**REINFORCE WP5**


ABOUT CLASSIFY TALK

Tutorial and Help page are provided

This Stage of the Demonstrator uses an external web event display called "HYPATIA" to identify different kinds of particles.

Click here for detailed instructions

Link to load HYPATIA



<http://atlas.ch>


TASK **TUTORIAL**

[Click here to open HYPATIA](#)

NEED SOME HELP WITH THIS TASK?

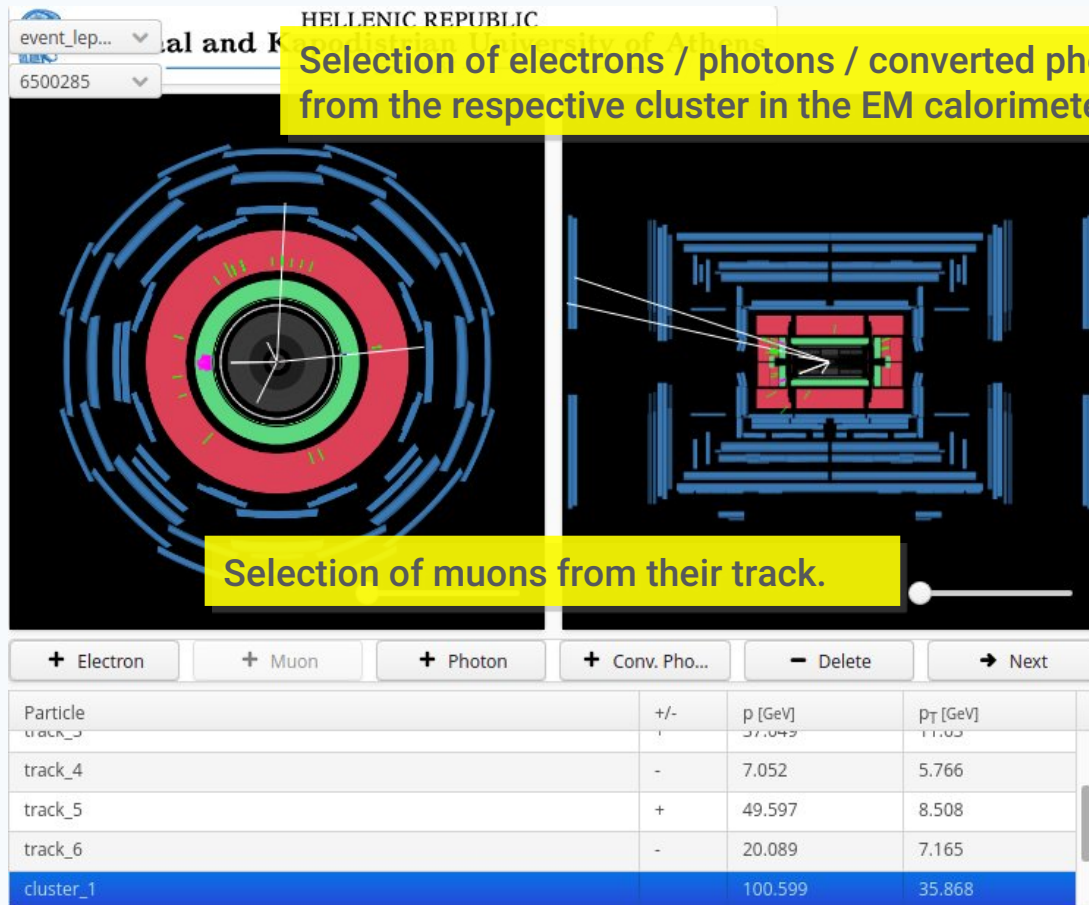
Done & Talk

Done





## Stage 2 – Particle Identification



	+/-	p [GeV]	p <sub>T</sub> [GeV]	e/μ/γ
cluster_1		100.6	35.87	e
track_3	+	37.05	11.63	μ
track_1	-	85.52	18.57	μ

substantial adjustment of the official HYPATIA to provide more realistic cases.

simplified menu (suitable for particle identification)

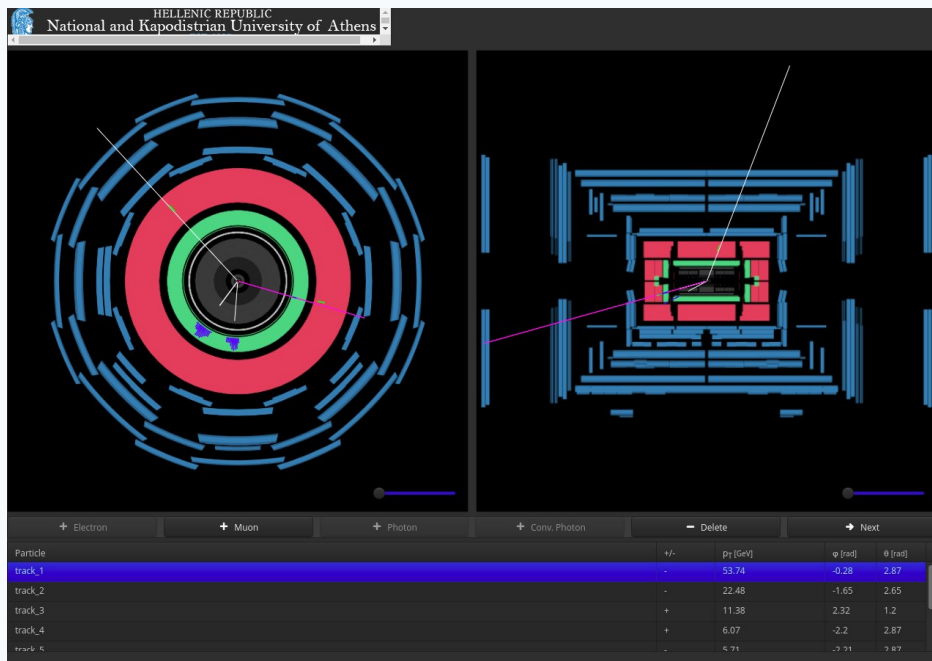
In this stage we use SM MC samples ( $H \rightarrow \gamma\gamma$ ,  $H \rightarrow ZZ^* \rightarrow 4l$ )



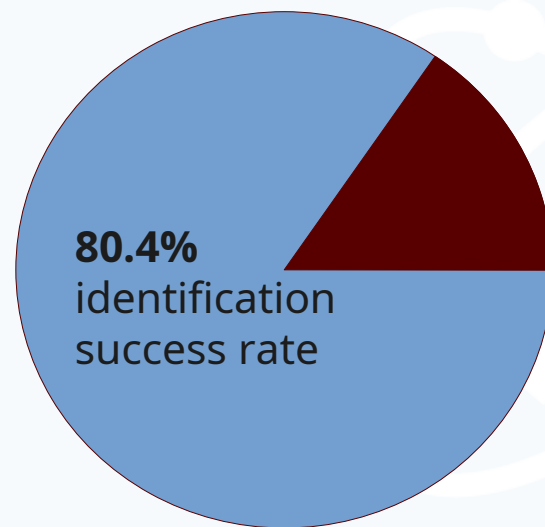


## Stage 2 – Particle Identification

- Hosted by HYPATIA (re-directed from Zooniverse)
- Citizens have identified photons, converted photons, electrons, muons.
- Citizen performance is close to that of a ML-algorithm in some cases.

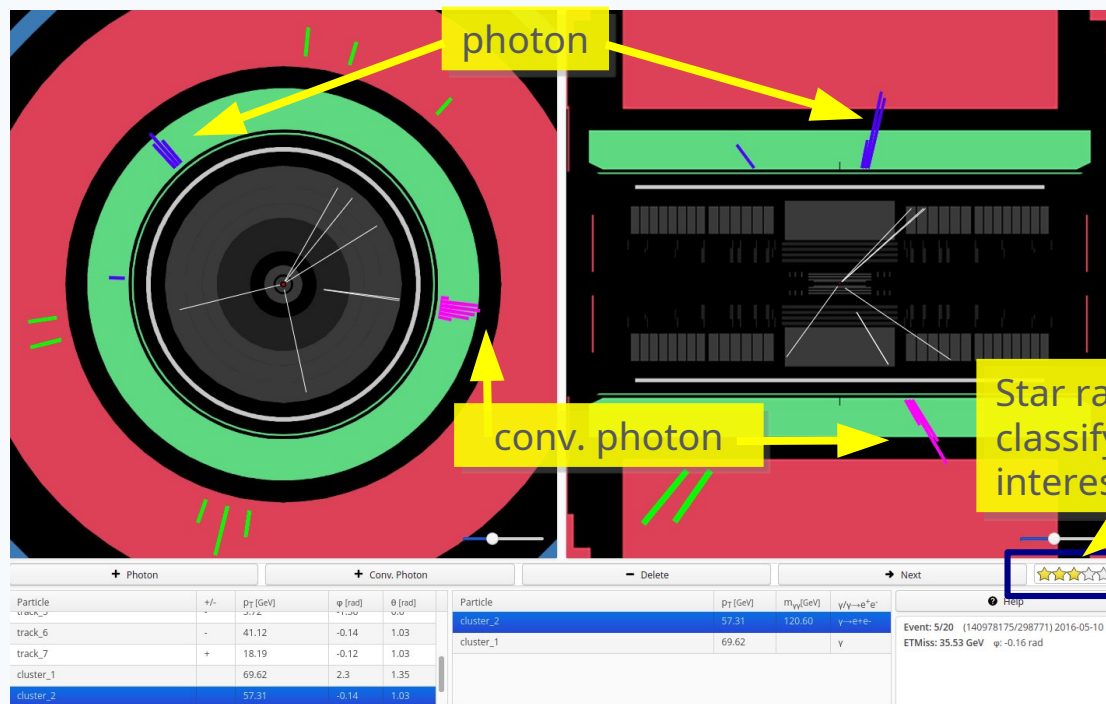


### 36690 Classifications





## Stage 3a – Study of Higgs Bosons ( $H \rightarrow \gamma\gamma$ )



Using real ATLAS data with event preselection as in  $H \rightarrow \gamma\gamma$  searches.

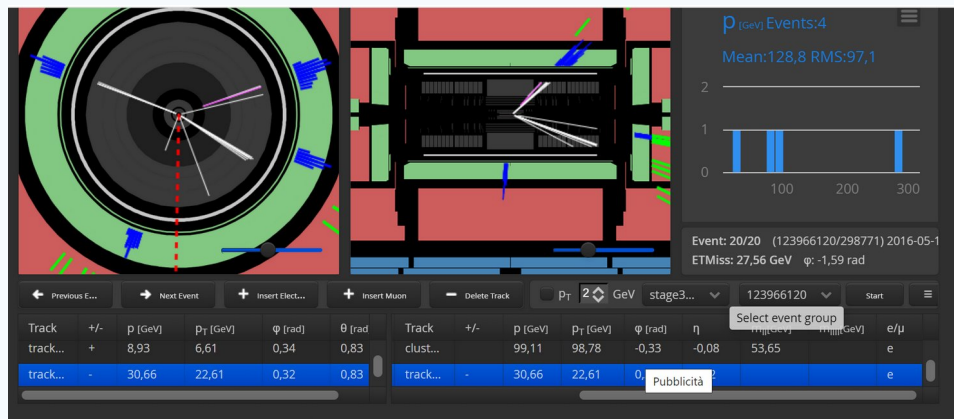
Citizens search for and select pairs of photons (including converted photons) consistent with Higgs decay products.

Star rating system to classify events according to interest level.

- Citizens' data are collected by HYPATIA for analysis/evaluation.
- High rated events are discussed on the project's discussion board.

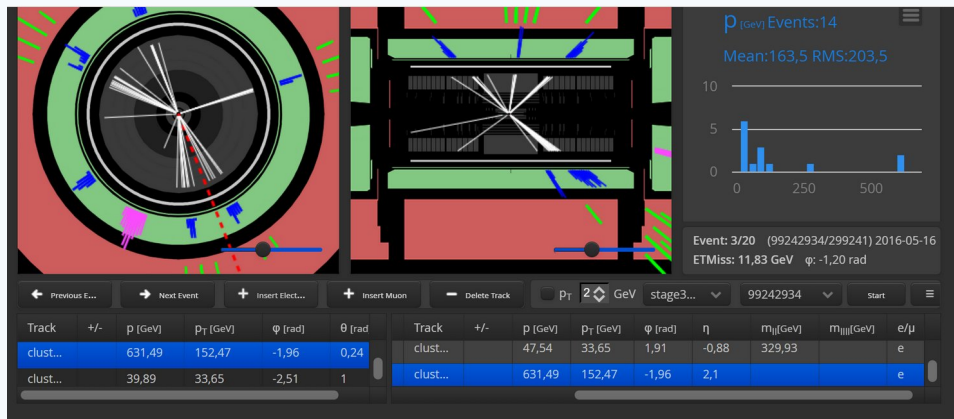


## Stage 3a – Study of Higgs Bosons ( $H \rightarrow \gamma\gamma$ )



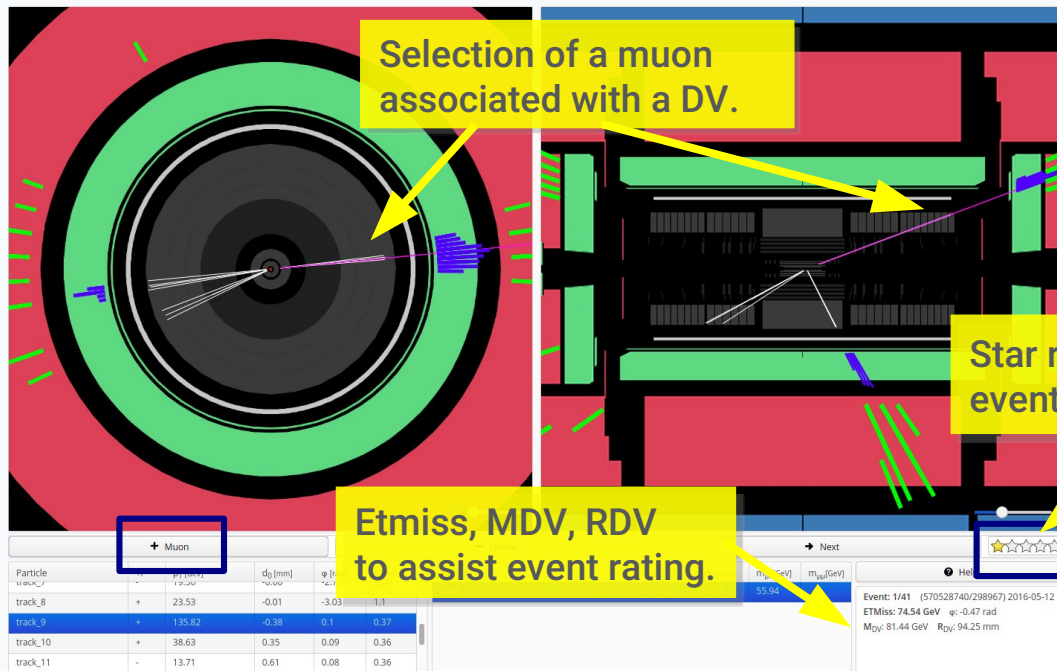
**Citizens identified Higgs photon products (21369 photons classified).**

Also, they have identified interesting cases and rated with 5 stars certain events containing additional leptons, which is interesting for the study of rare Higgs decays.



The additional activity is understood. The leptons are mostly part of a larger group of particles called “hadronic jet”.

## Stage 3b – Discovery of Long Lived Particles



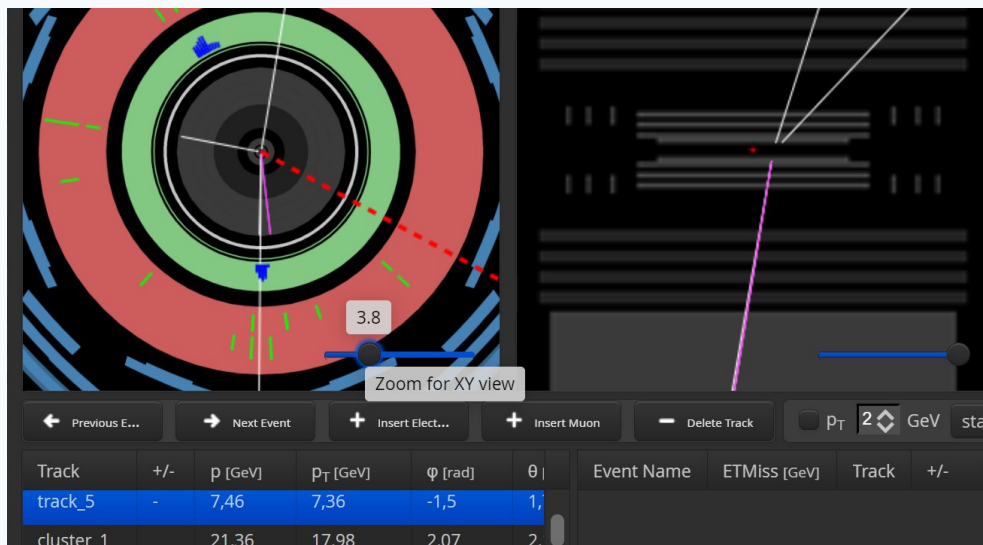
Using real ATLAS data (RPVLL stream).

Citizens search for muon-jet DVs:

- mark the lepton associated with the DV,
- rate the event (low  $\rightarrow$  high interest).

- Citizens' data are collected by HYPATIA for analysis/evaluation.
- High rated events are discussed on the project's discussion board.

## Stage 3b – Discovery of Long Lived Particles



$m_{DV}=41$  GeV  $R_{DV}=166\text{mm}$   $p_{T\mu on}=21\text{GeV}$

**Citizens correctly classified 46502 displaced vertices.** Most are located on a detector surface.

Also, they identified certain interesting cases, which they rated with 5 stars.



Those events are indeed interesting. However, known processes or errors in the reconstruction sometimes produce such results.





## Statistics gathered in the period: October 19, 2021 – November 30, 2022 (end of project)

- 1962 registered users (over 2300 registered users today).
- 365,000 classifications in all three stages of the project.
- 2852 posts on the Zooniverse Talk forum
  - Technical questions regarding the given tasks
  - Specific questions about the theory behind WP5
  - General questions on physics
  - Ideas for improvement





- The project engaged and still maintains the interest of a large number of citizens in the analysis of high-energy physics data collected by the state-of-the art ATLAS detector.
- **Stage 1:** The comparative study showed that citizen consensus (combination of individual measurements) can be used as a precision measurement.
- **Stage 2:** Showed that citizens can perform technical tasks involving complicated concepts and tools.
- **Stage 3:** Citizens visually inspected a large number of collision events, identified issues in the reconstruction process, provided out-of-the box thoughts.
- **REINFORCE was taken into account by CERN in two parts of its nine-part Open Science Policy and Implementation (<https://openscience.cern/>), released on October 2022.**





# Conclusions



**More than 2K citizens participated to the project.**



**The project...**

- will remain active on Zooniverse; we will be monitoring the talk session and possibly add new ATLAS Open Data as soon as they are released.
- will be used for the promotion of citizen-science: e.g. presentations at conferences or referenced at specialized articles.
- will be used for educational purposes: e.g. visits to schools and masterclasses.

**Additional Information and News on the project website:**

<https://www.reinforceeu.eu>

