REINFORCE

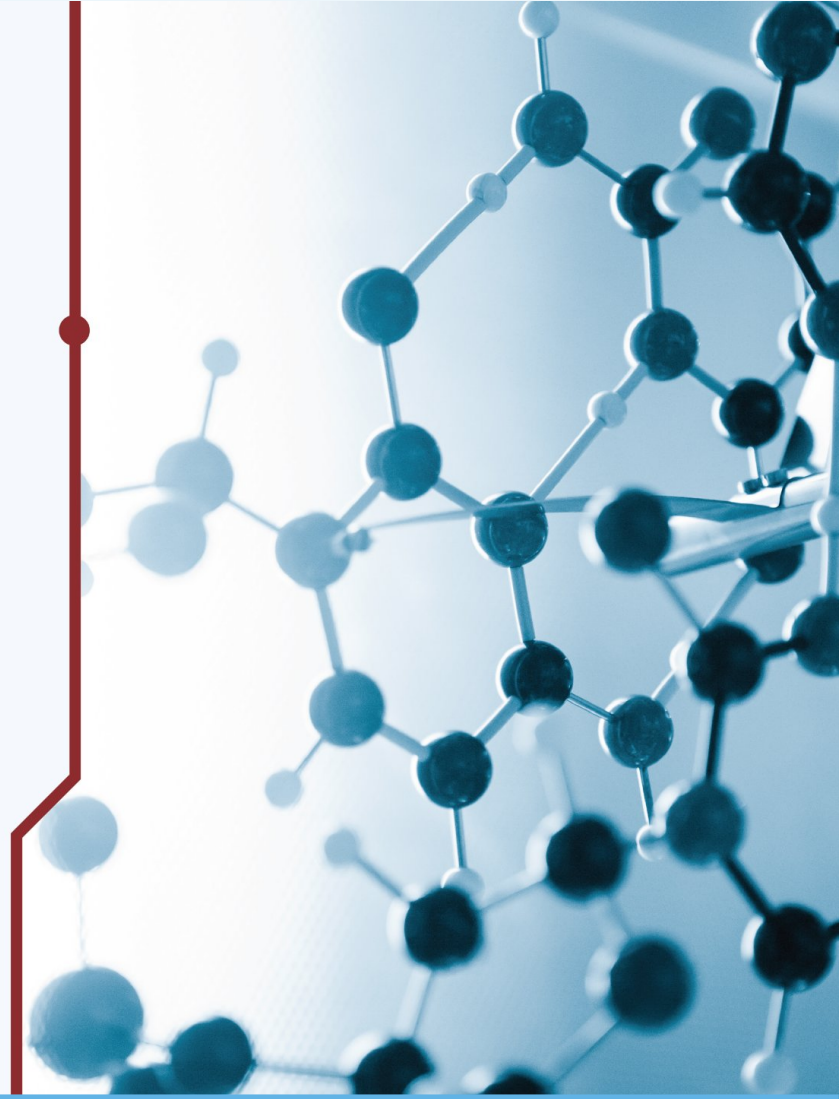
REsearch INfrastructures FOR Citizens in Europe

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
https://www.reinforceeu.eu

Science with and for Society (SWAFS)
H2020-SwafS-2018-2020

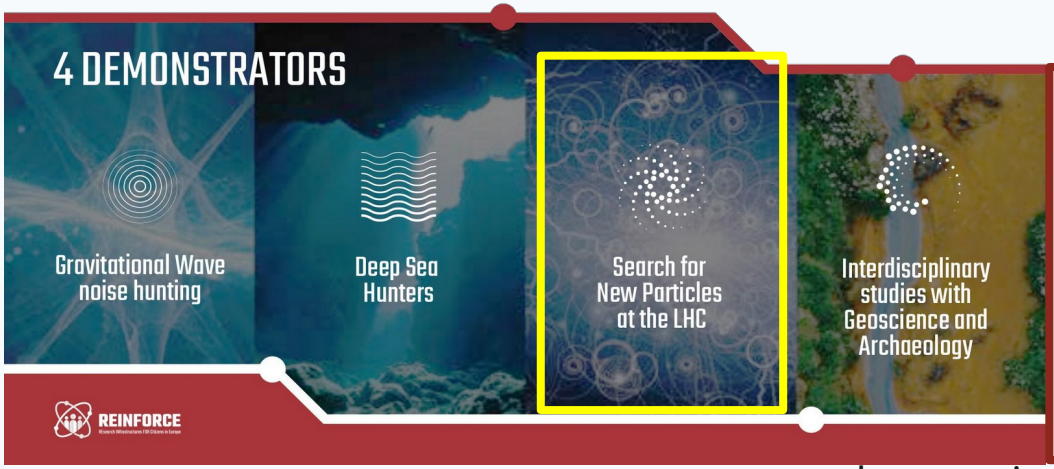
DEC 2019 – NOV 2022

REINFORCE - DEMONSTRATORS

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

Assess benefit to science

Assess benefit to society



EGO KM3NET LHC geology project

PLUS:

Explore the potential of frontier citizen science for inclusion and diversity.

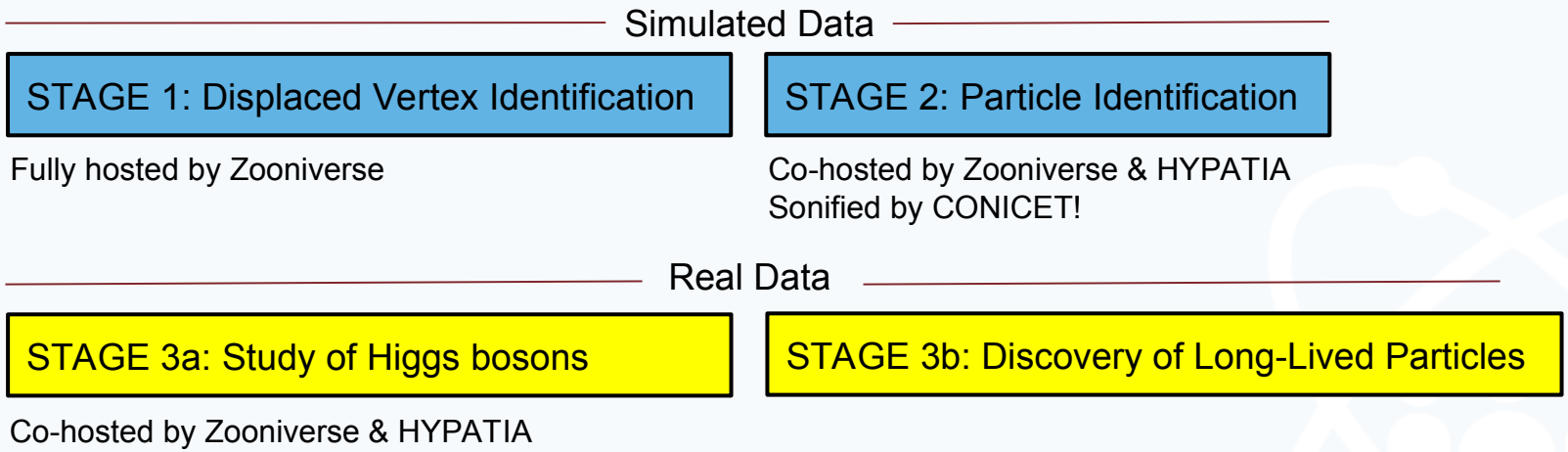
REINFORCE & Zooniverse

All demonstrators hosted by Zooniverse citizen-science platform

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

REINFORCE & LHC

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

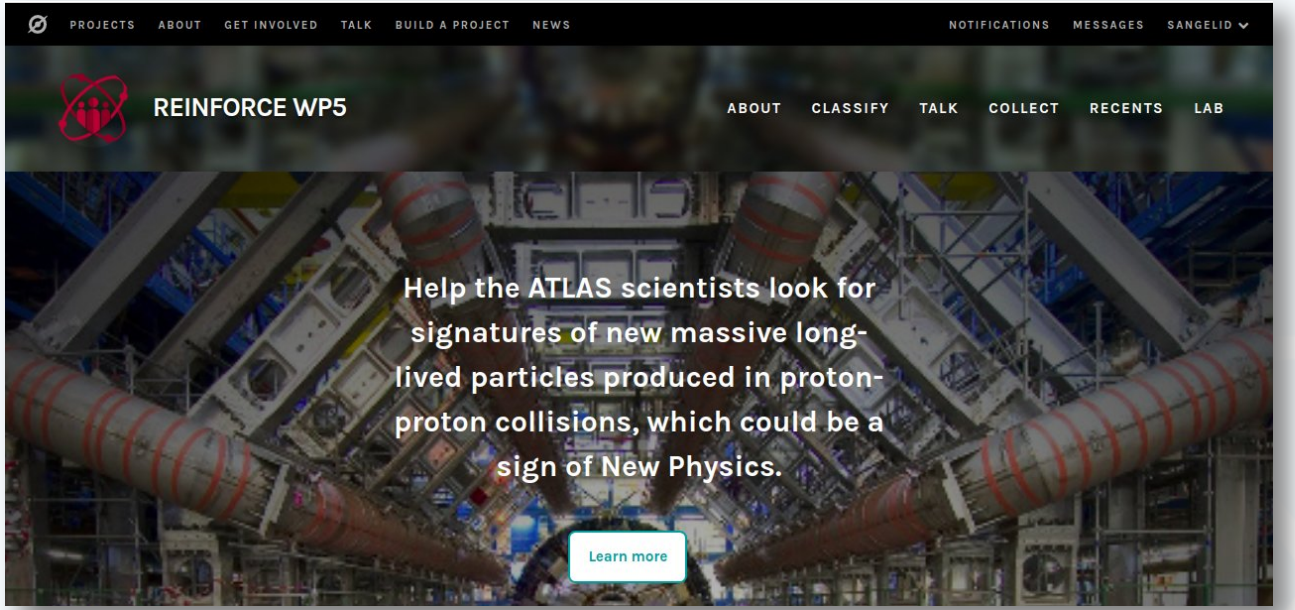


- All tasks carried out using just mouse clicks.
- Detailed but concise guidelines provided in **text, images and videos**.
- Available in **3 languages**: English, Spanish, Greek.

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);
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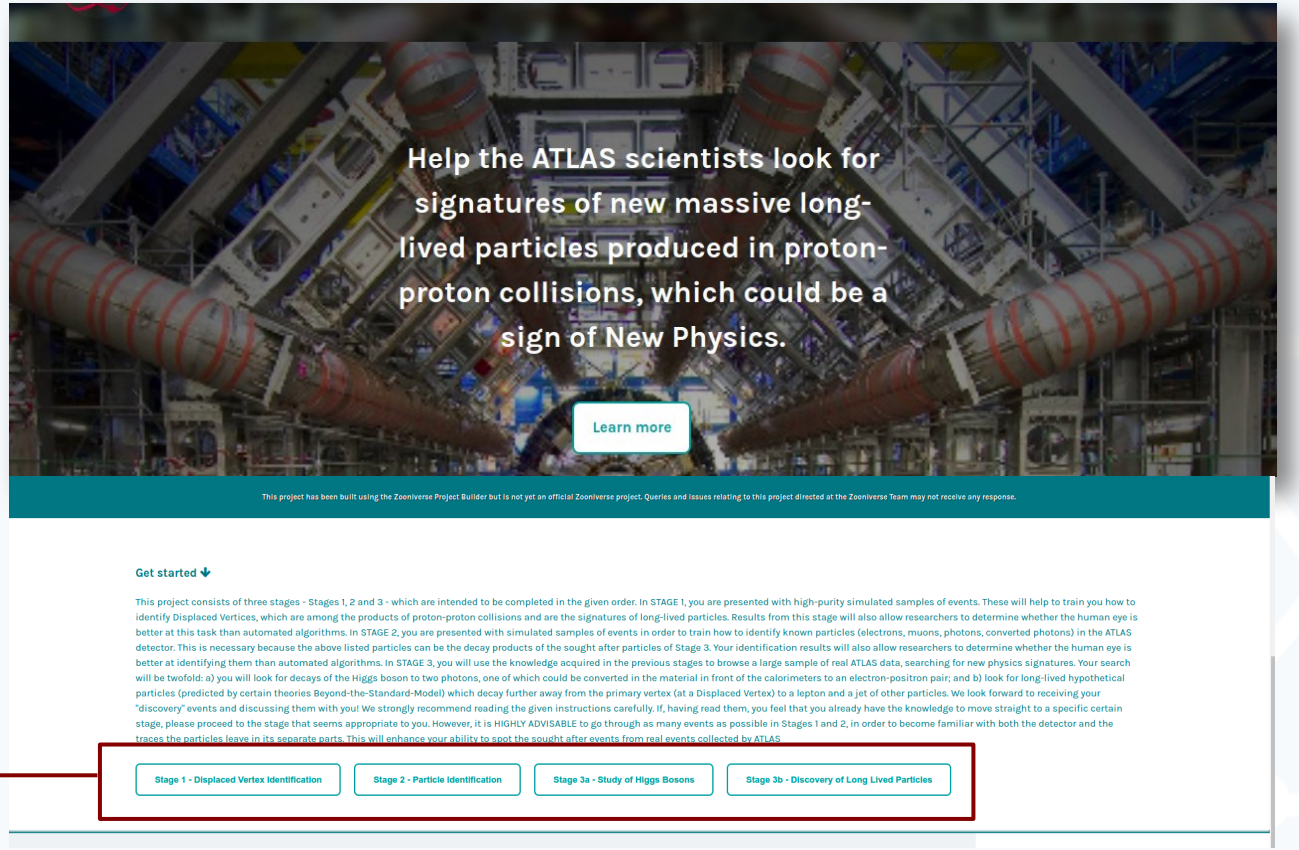
- the group.

Each button launches the respective stage



Stage 1 – Displaced Vertex Identification

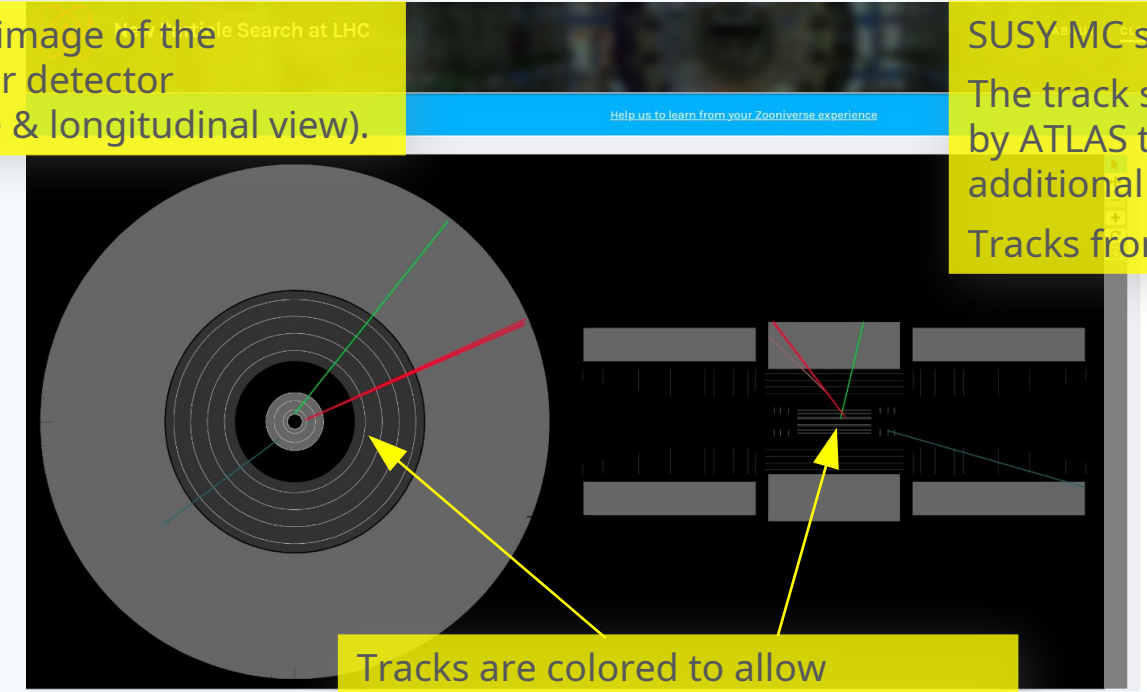
Citizen scientists are invited to identify any displaced vertex in the displayed event using their mouse pointer.

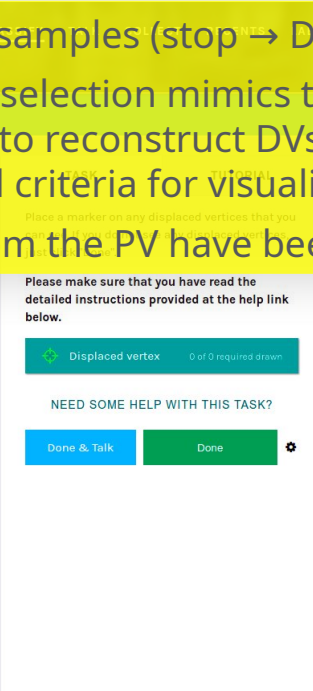
Stationary image of the ATLAS inner detector (transverse & longitudinal view).

SUSY MC samples (stop → DV + μ).

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

Tracks from the PV have been removed.





Tracks are colored to allow association between the two views.

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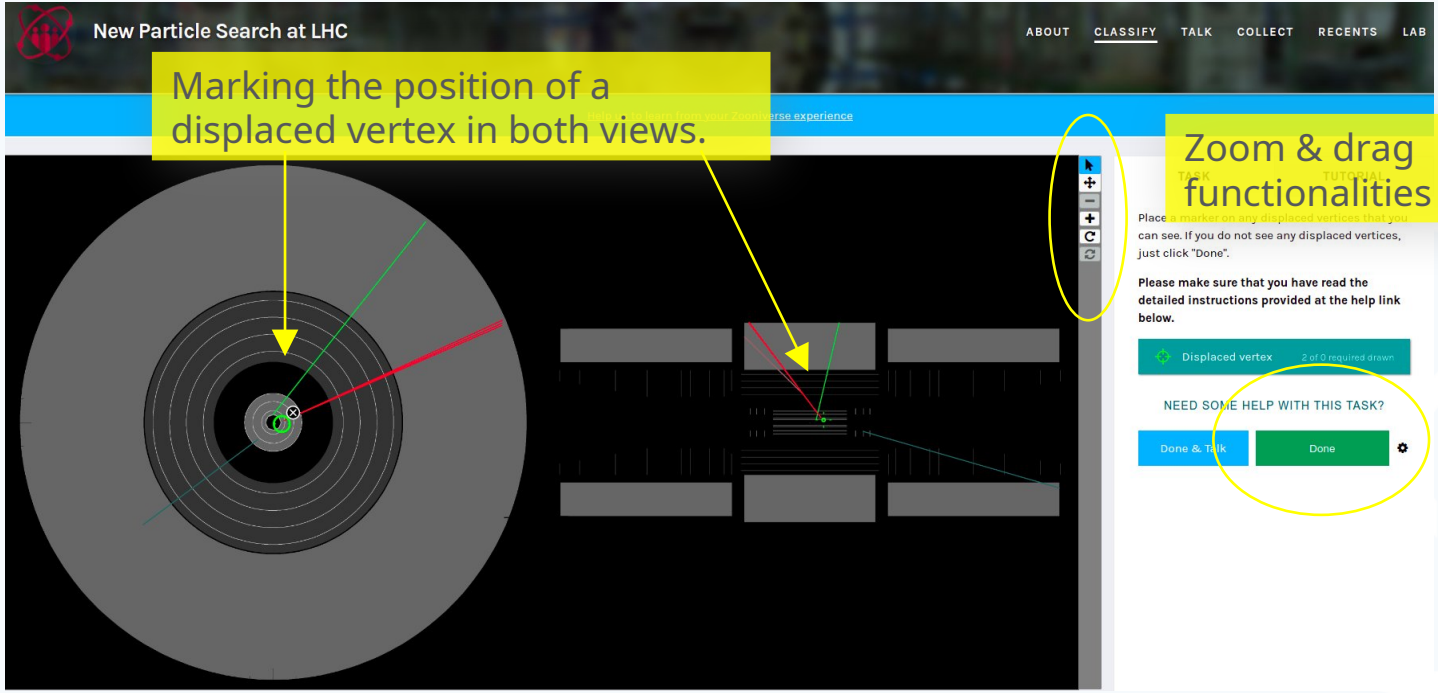


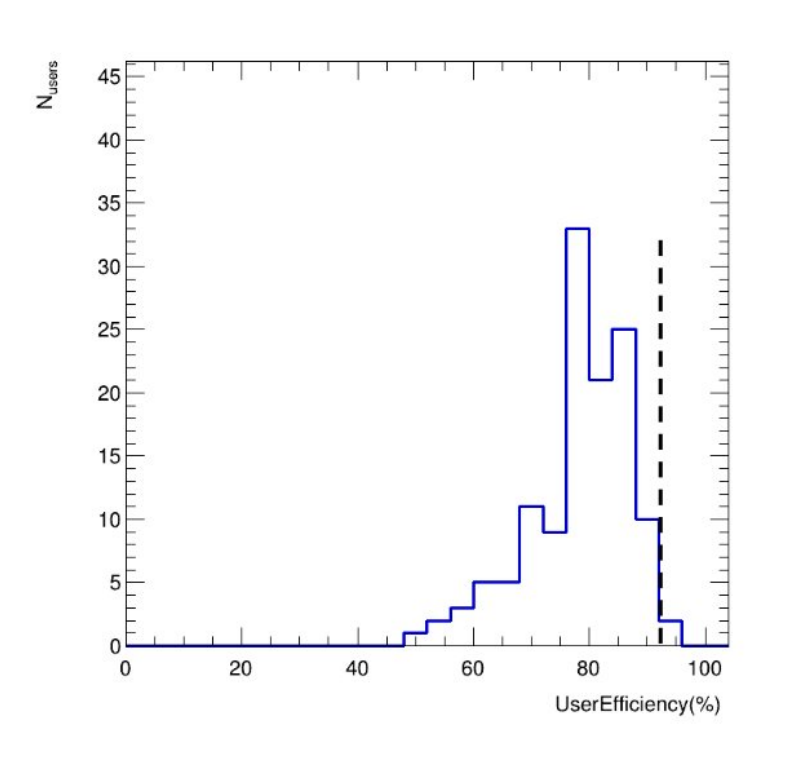
Stage 1 – Displaced Vertex Identification

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

Feedback provided after each event

- 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

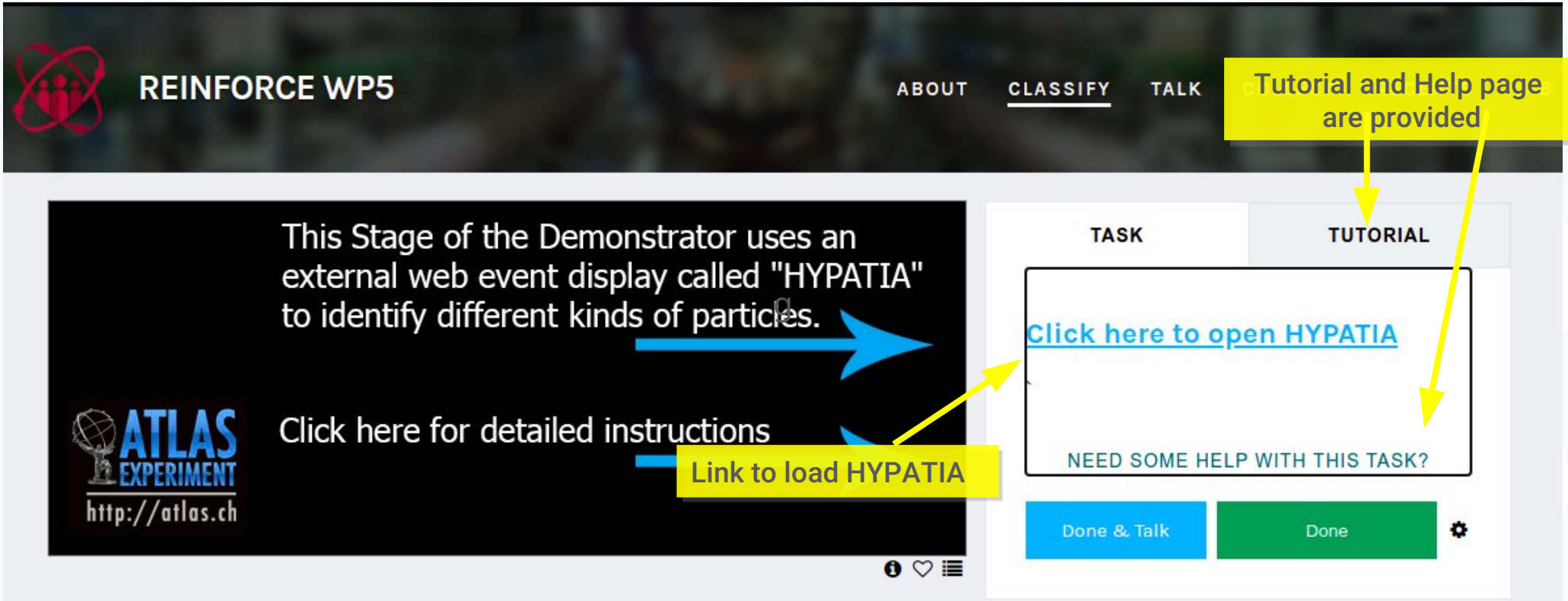


Citizens Performance Assessment:

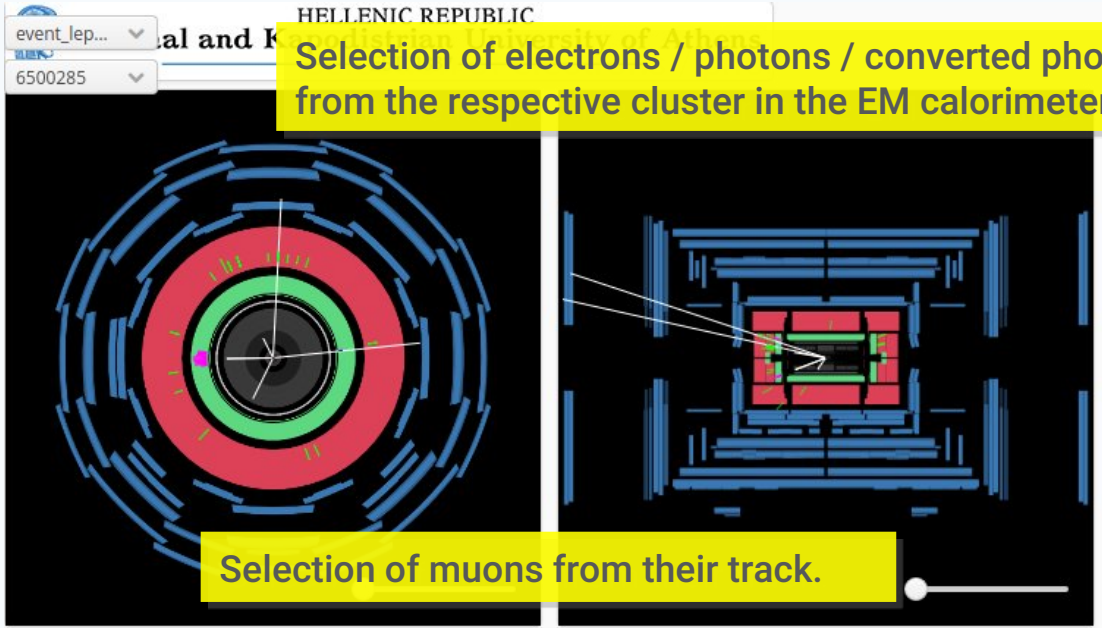
- considering only the most active users (>=200 classifications, >= 50% efficiency)
- Individual user average efficiency: ~79%
- **User consensus efficiency: 93% (combined user response per event)**
- **Efficiency of automated algorithm: 94%**

Stage 2 – Particle Identification

HYPATIA takes over from Zooniverse:



Stage 2 – Particle Identification



Particle	+/-	p [GeV]	p_T [GeV]
track_4	-	7.052	5.766
track_5	+	49.597	8.508
track_6	-	20.089	7.165
cluster_1		100.599	35.868

Particle	+/-	p [GeV]	p_T [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

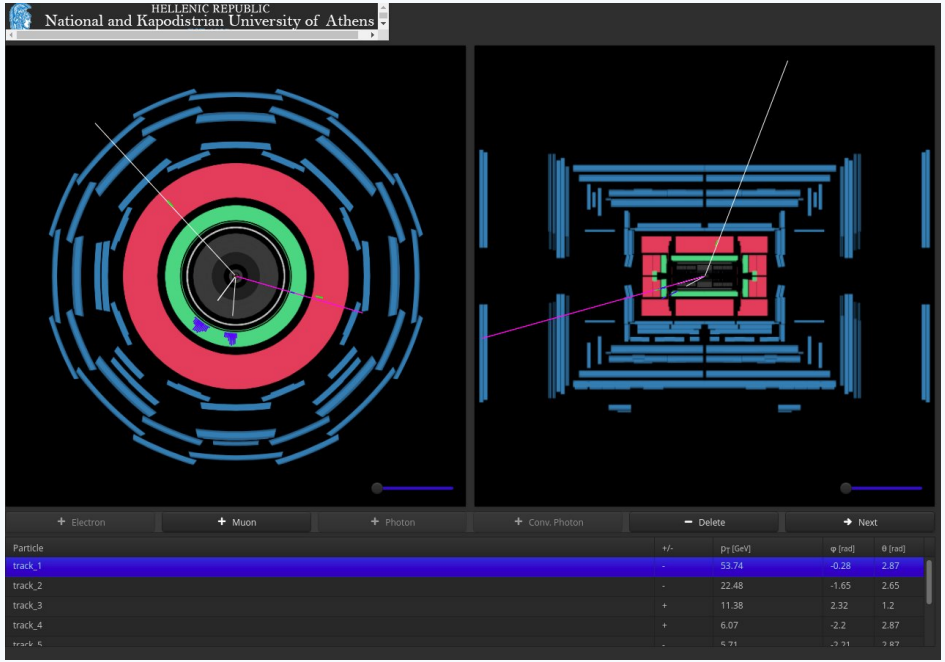
substantial adjustment of the official HYPATIA to provide more realistic cases.

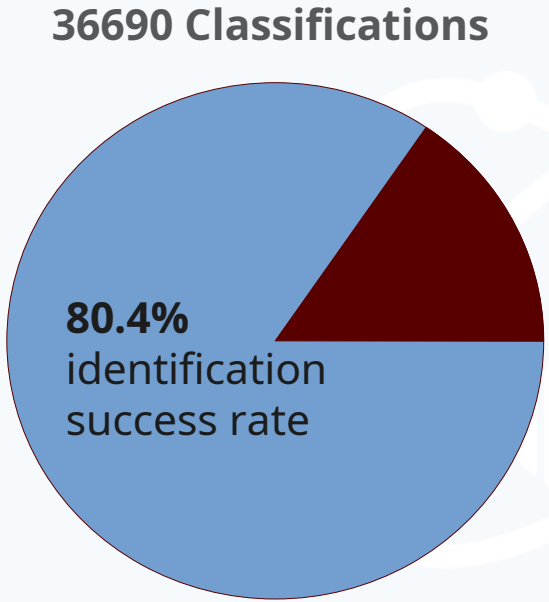
simplified menu (suitable for particle identification)

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

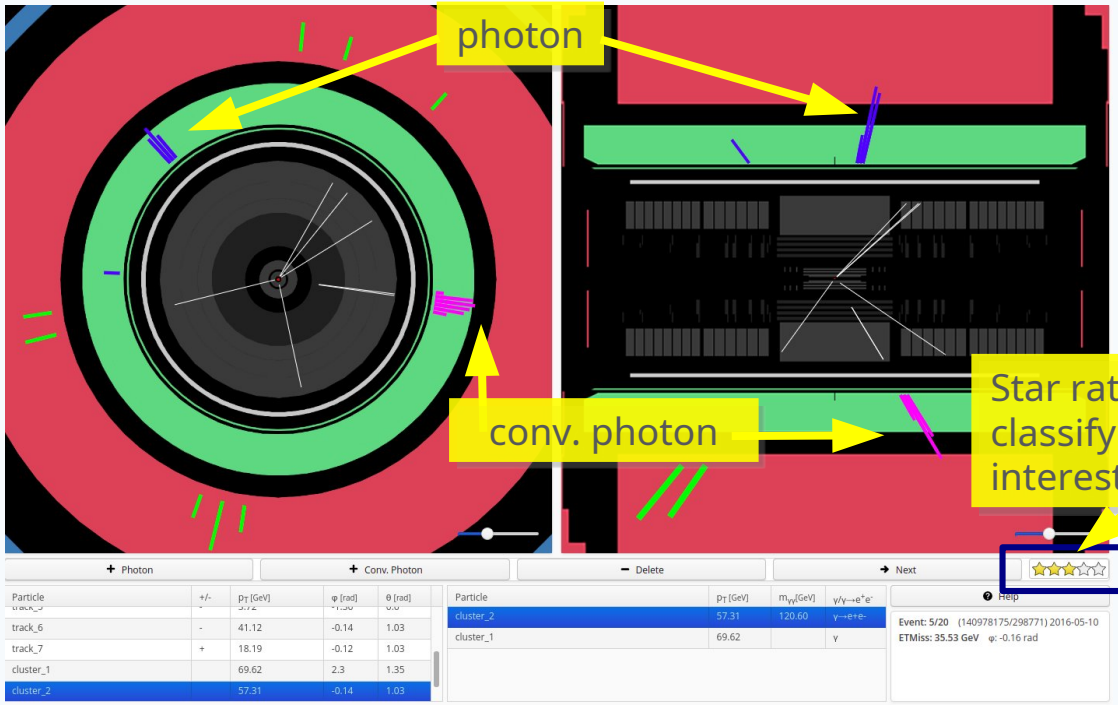
Stage 2 – Particle Identification

- 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.





Stage 3a – Study of Higgs Bosons (H→ γγ)

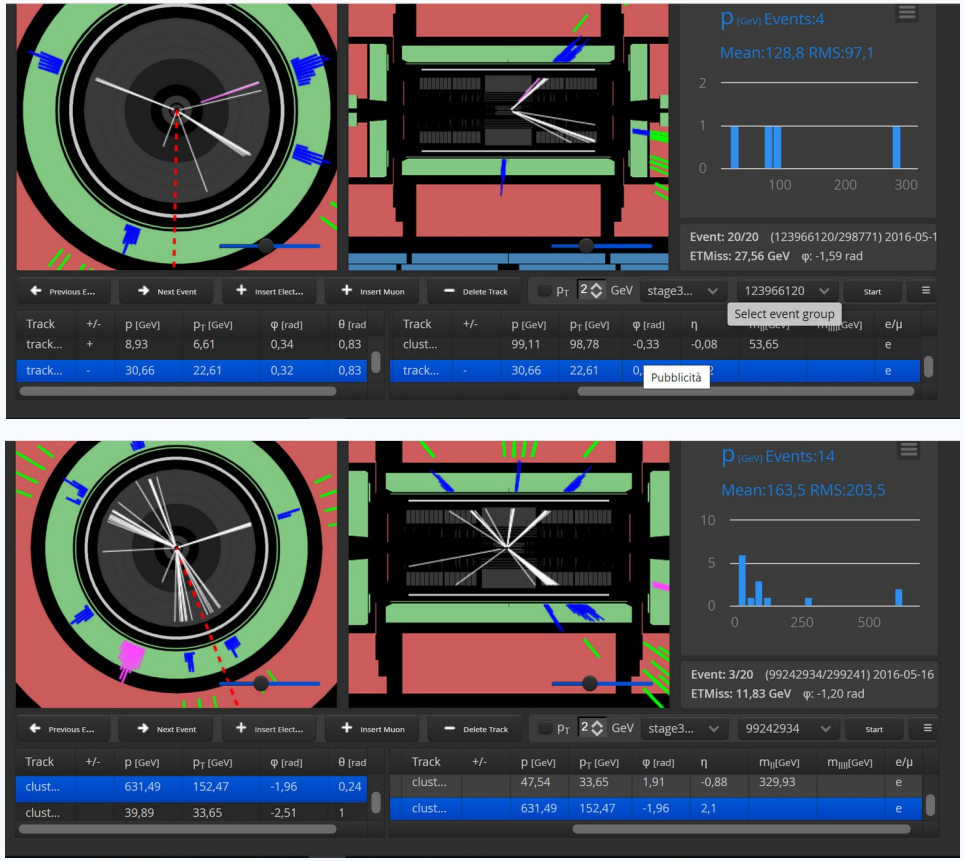


Using real ATLAS data with event preselection as in H → γγ searches.

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

- 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→ γγ)



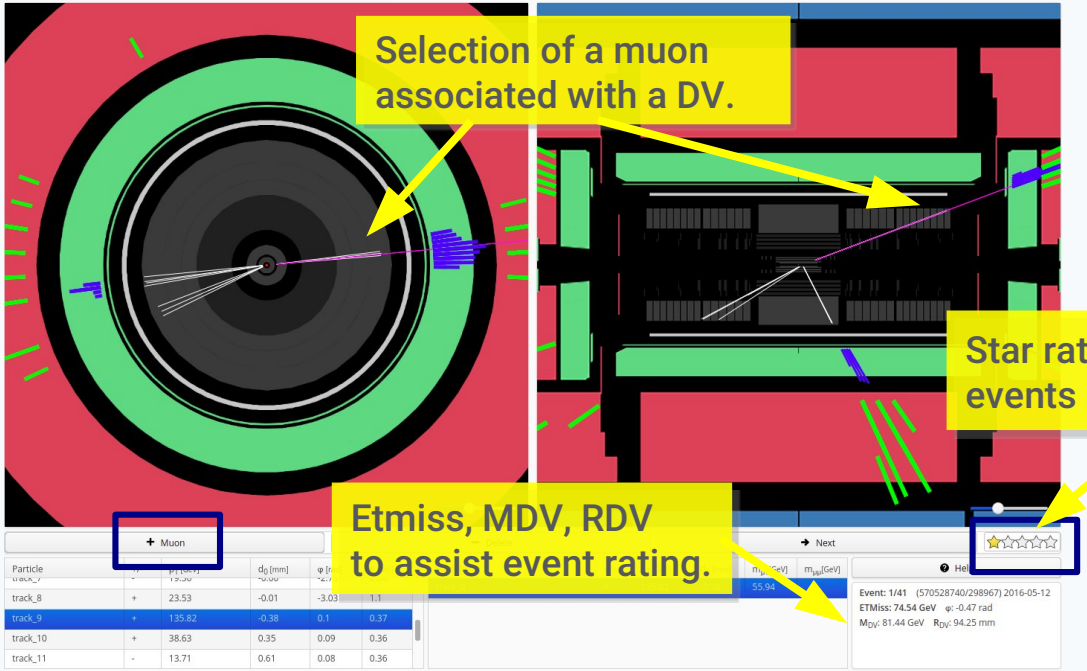
Citizens identified Higgs photon products (21369 photons classified).

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



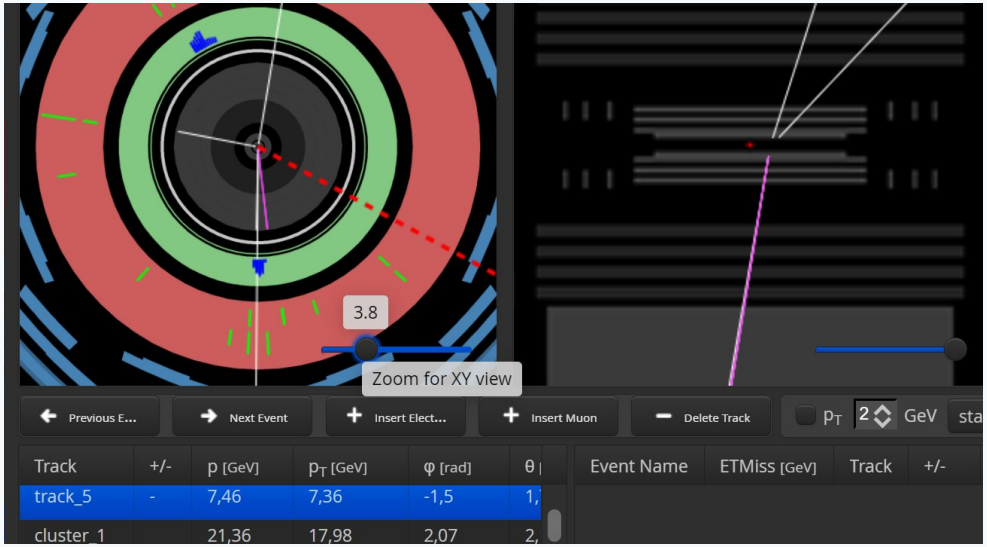
Using real ATLAS data (RPVLL stream).

Citizens search for muon-jet DVs:

- mark the lepton associated with the DV,
- rate the event (low → 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}=166mm p_{Tmuon}=21GeV

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.

Some statistics

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

Impacts

- 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