

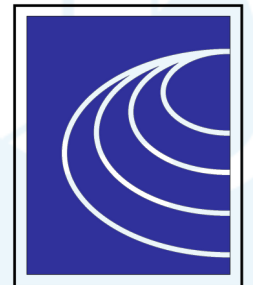
# The REINFORCE citizen-science project and the search for new long-lived particles at the LHC

**HEP 2021 - 38th Conference on Recent Developments in High Energy Physics and Cosmology  
June 19, 2021**

**Stelios Angelidakis  
on behalf of the REINFORCE consortium**



HELLENIC REPUBLIC  
National & Kapodistrian  
University of Athens



*IASA*



**REINFORCE** REINFORCE  
REsearch INfrastructures FOR Citizens in Europe

## REsearch INfrastructures FOR Citizens in Europe

<https://www.reinforceeu.eu>



## Science with and for Society (SWAFS)

H2020-SwafS-2018-2020

**DEC 2019 – NOV 2022**



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 872859.





# REINFORCE - DEMONSTRATORS

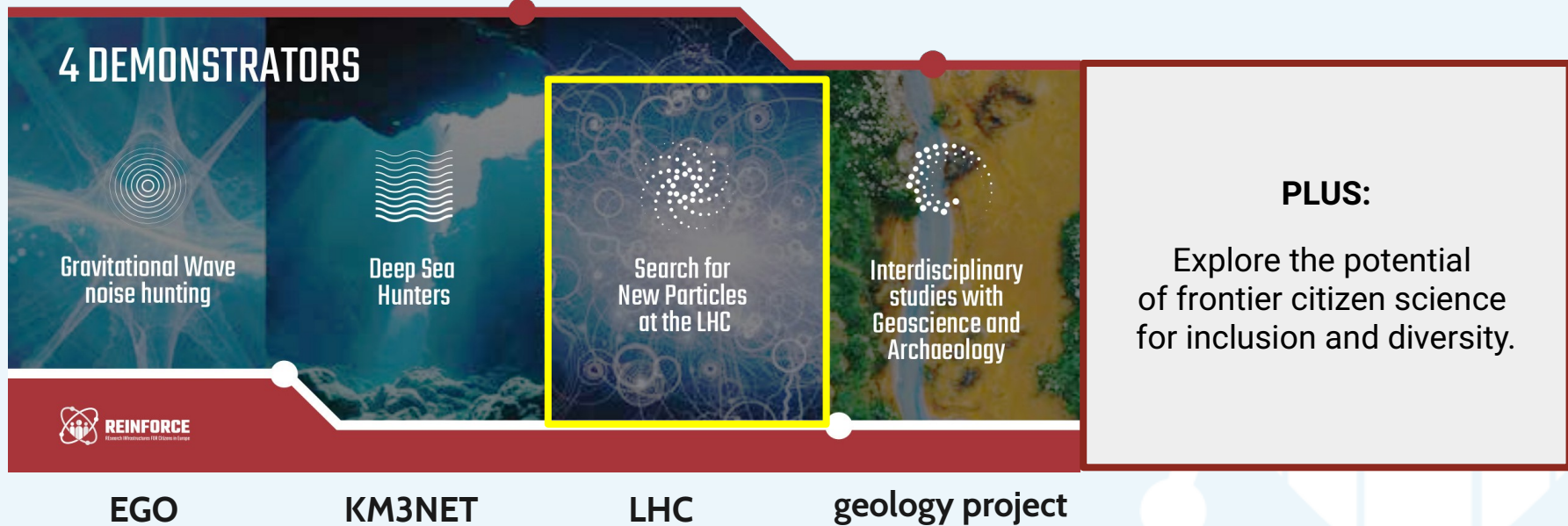
**REINFORCE:** intends to establish a community of citizens actively engaged in public-funded frontier research.



Assess the benefit to science



Assess the benefit to society



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 872859.



**Citizens will become scientists of CERN,**  
the largest particle-physics lab in the world.

**to discover New Physics with the Large Hadron  
Collider (LHC),** the most powerful collider ever built.

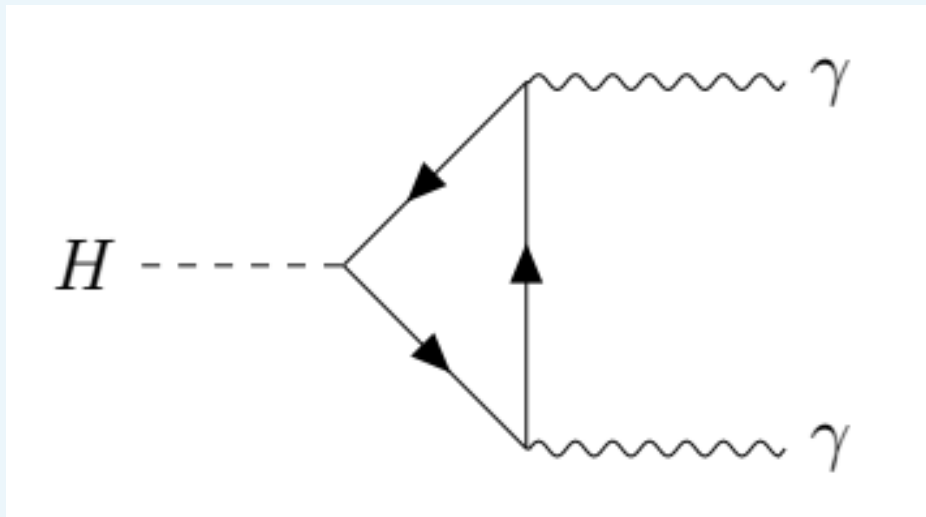




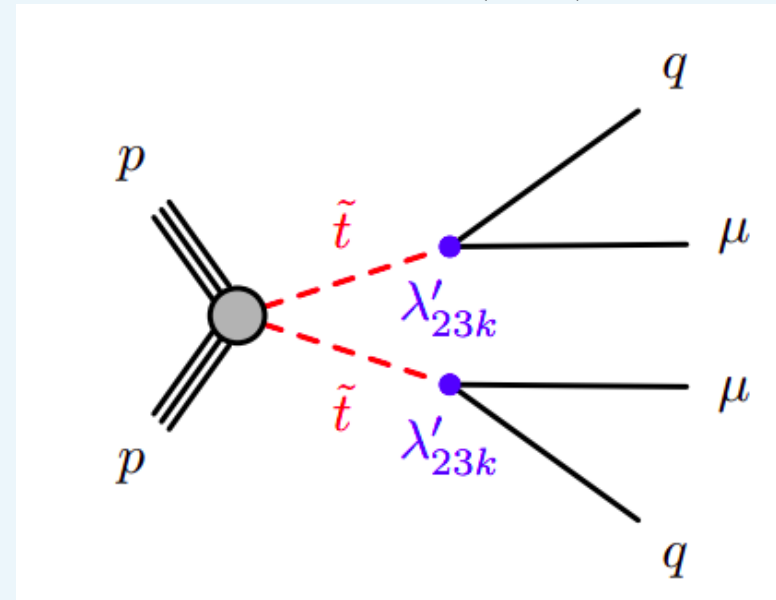
## Exploit ATLAS Data/MC to provide:

- an exciting and educating experience to citizen-scientists
- quantitative assessments on potential contribution.

### Possible subject for visual analysis: Displaced Vertices (DVs)



SM  $H \rightarrow \gamma\gamma$  with a converted photon.



SUSY scenarios with long-lived particles.



## Exploit ATLAS Data/MC to provide:

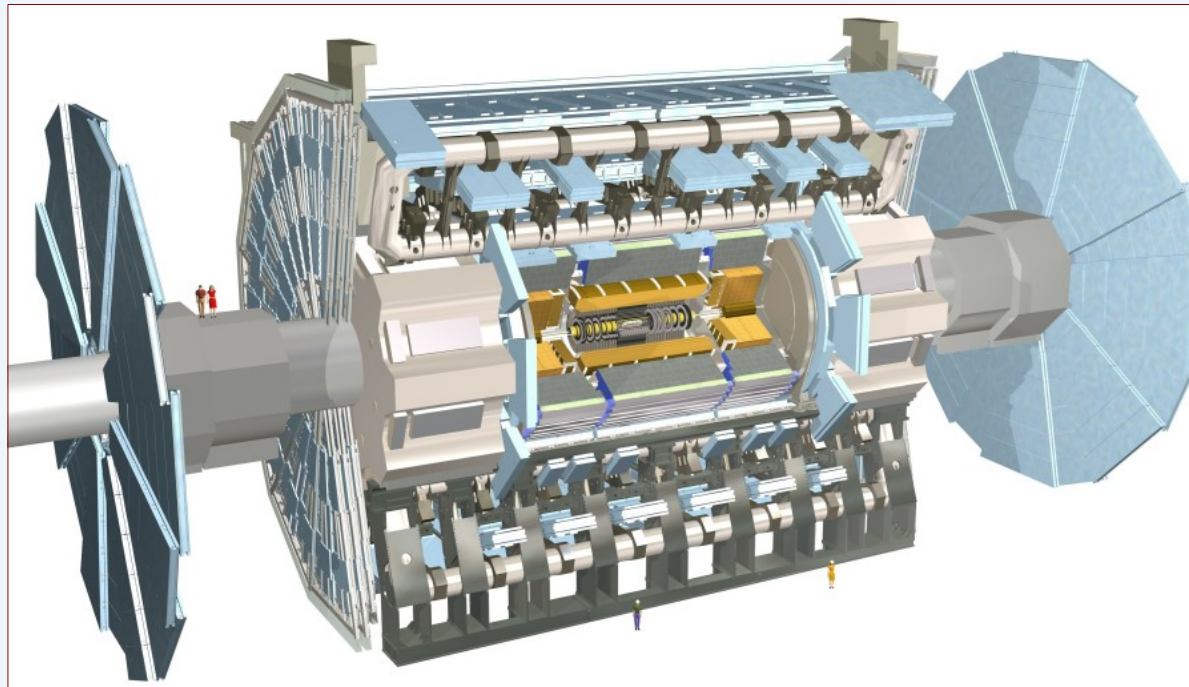
- an exciting and educating experience to citizen-scientists
- quantitative assessments on potential contribution.

**Stage - 1**  
Visual detection of  
Displaced Vertices (DV)  
- SIMULATED DATA -

**Stage - 2**  
Particle Identification  
- SIMULATED DATA -

**Stage - 3**  
Discovery  
- REAL DATA -

- **Stages 1 & 2:** will provide the main results (citizens' efficiency Vs our custom algorithm).
- **Stage 3:** gives citizens the opportunity to apply what learned on a sample of real data.



## **p-p COLLISION DATA**

A generous  $10 \text{ fb}^{-1}$  of Open Data is offered by the collaboration for exposure to the public.

Addition approval (required multiple meetings) has been given to our project to expose:

- Open Data but from special processing chains (large radius tracking),
- additional information to that already made public.



## ZOONIVERSE



**CITIZEN-FRIENDLY ENVIRONMENT & PUBLICITY BOOST**

with over 2M registered volunteers.

THE ZOONIVERSE WORKS

# 599,421,720

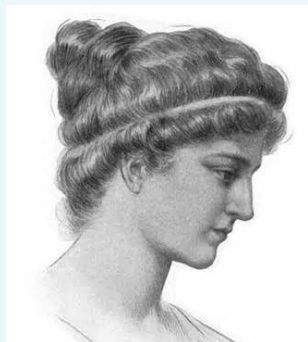
CLASSIFICATIONS SO FAR BY

**2,321,789 REGISTERED VOLUNTEERS**

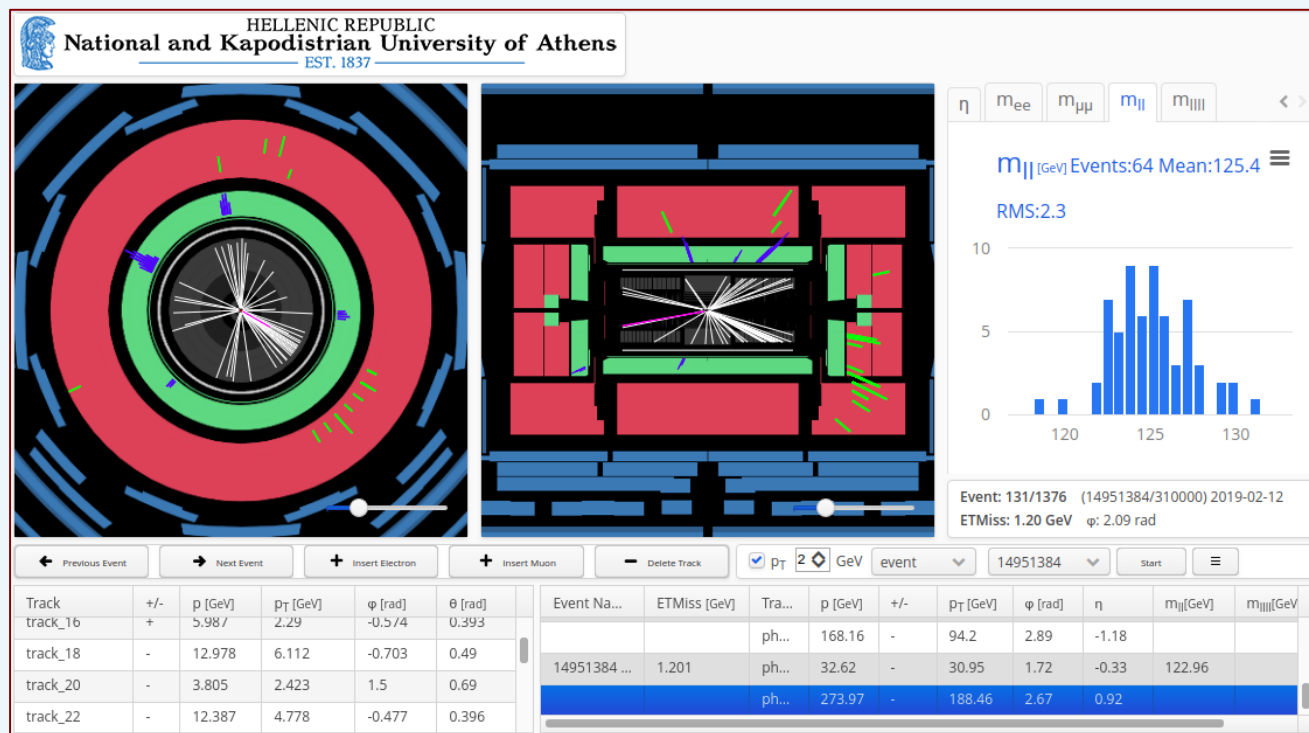
A vibrant community. Zooniverse gives people of all ages and backgrounds the chance to participate in real research with over 50 active online citizen science projects. Work with 1.6 million registered users around the world to contribute to research projects led by hundreds of researchers.

SIGN IN OR REGISTER TO GET STARTED

[Sign in](#) [Register](#)



## HYPATIA



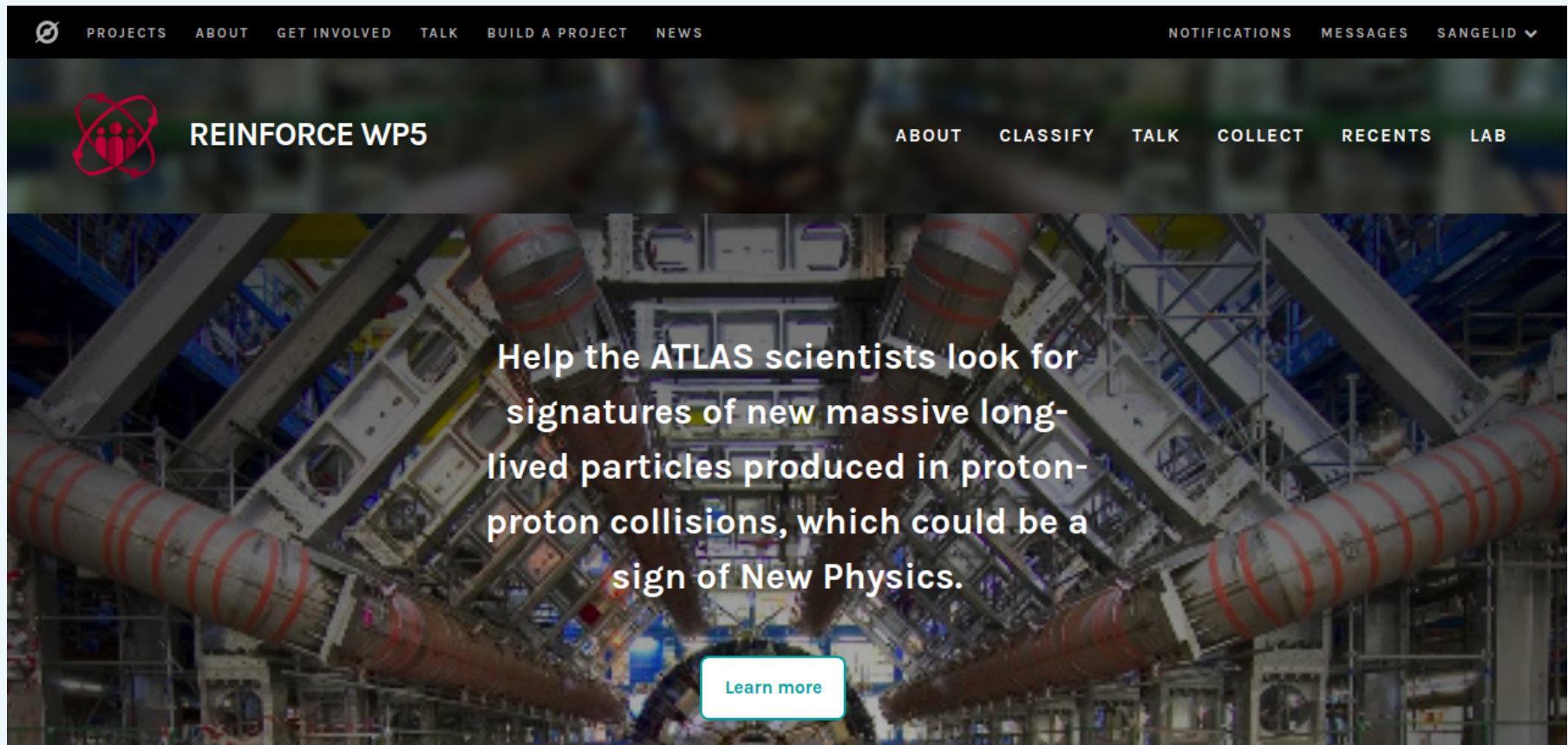
## VISUAL DATA-ANALYSIS FRAMEWORK

successfully used for many years in IPPOG Masterclasses & other outreach actions.



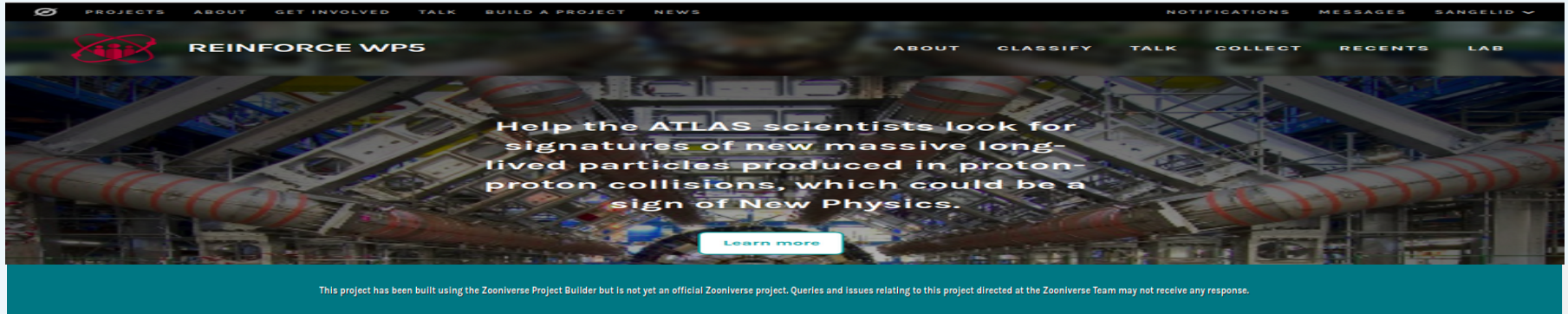
# The project on **ZOONIVERSE**





**Homepage** with links providing lots of information about:

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



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 ADVISED 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 help you to spot the sought after particles in the events collected by ATLAS.

**Stage 1**

**Stage 2**

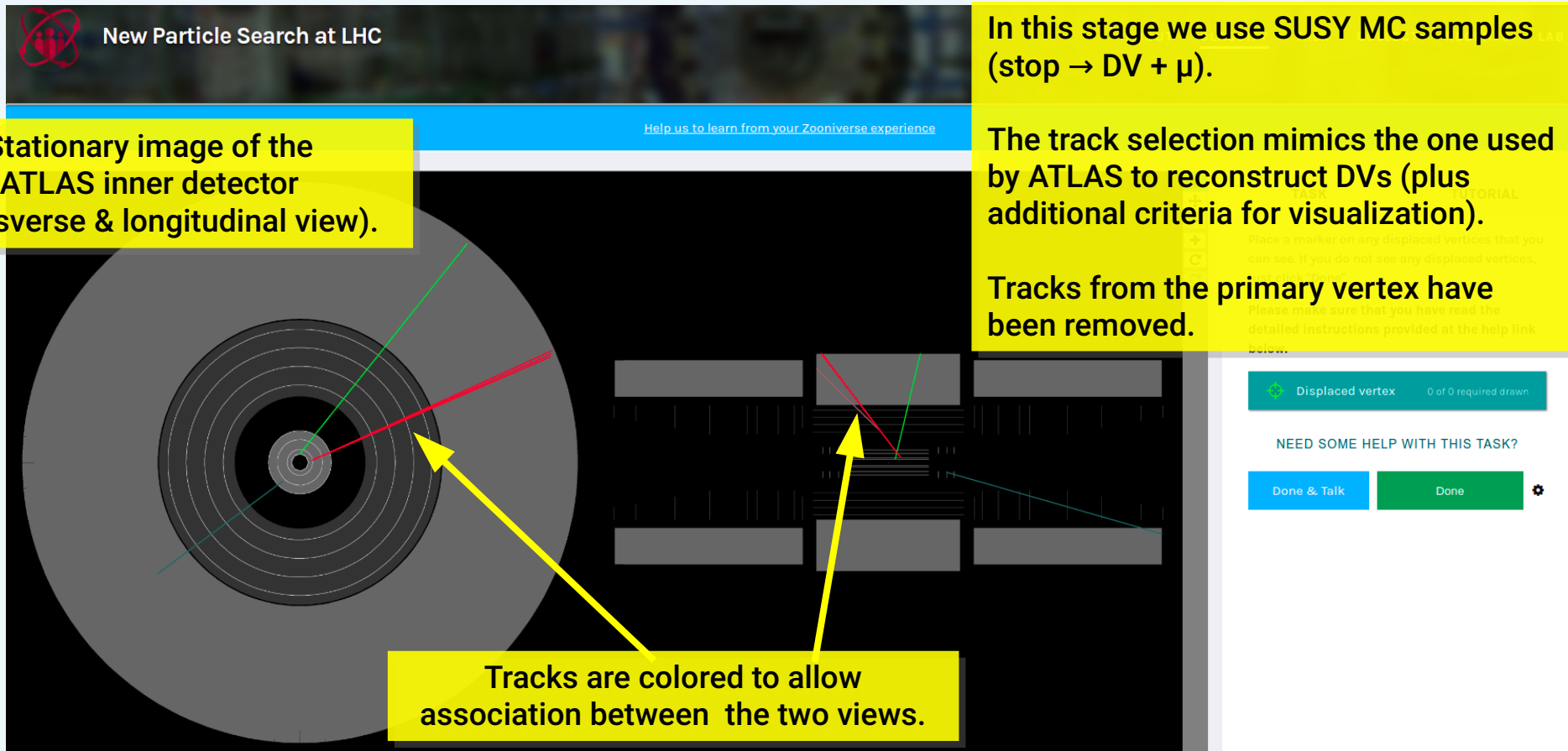
**Stage 3a**

**Stage 3b**

- Stage 1 - Displaced Vertex Identification
- Stage 2 - Particle Identification
- Stage 3a - Study of Higgs Bosons
- Stage 3b - Discovery of Long Lived Particles

**Each button loads the respective stage.**

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



**New Particle Search at LHC**

Help us to learn from your Zooniverse experience

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

**In this stage we use 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 primary vertex have been removed.**

**Tracks are colored to allow association between the two views.**

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.

The screenshot displays the 'New Particle Search at LHC' web application. The main interface features a large circular detector diagram with concentric circles and a central point. A red line and a green line are drawn from the center to the outer edge. A 'Help' link is visible in the top right. A 'Brief tutorial' window is overlaid on the detector diagram, containing the following text:

In *New Particle Search at LHC*, you will identify **displaced vertices** in the ATLAS inner detector. The inner detector is represented in two different ways, which are shown next to one another.

On the left half of the image is the transversal view of the detector, represented by a series of concentric circles. On the right half of the image is the longitudinal view of the detector.

A 'Continue' button is at the bottom of the tutorial window. A 'Link to a detailed HELP section:' box lists:

- video instructions
- examples
- training cases

The task panel on the right has tabs for 'TASK' and 'TUTORIAL'. The 'TASK' tab contains the following instructions:

Place a marker on any displaced vertices that you can see. If you do not see any displaced vertices, just click "Done".

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

A progress bar shows 'Displaced vertex' with '0 of 0 required drawn'. Below this is a section titled 'NEED SOME HELP WITH THIS TASK?' with 'Done & Talk' and 'Done' buttons.





# STAGE 1 – Displaced Vertex Identification

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

The screenshot displays the 'New Particle Search at LHC' interface. It features two main views: a circular top-down view on the left and a rectangular side-view on the right. A yellow callout box with the text 'Marking the position of a displaced vertex in both views.' has two arrows pointing to a specific vertex in both views. On the right side, a sidebar contains a 'TASK' section with a 'Displaced vertex' task (2 of 0 required drawn) and a 'TUTORIAL' section. A blue box highlights the zoom and drag controls in the sidebar, with a yellow callout box stating 'Zoom & drag functionalities.' and an arrow pointing to the controls. Below the task section, there is a 'NEED SOME HELP WITH THIS TASK?' section with a 'Done & Talk' button and a 'Done' button.



# STAGE 1 – Displaced Vertex Identification

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

**Feedback**

**Hits**

- Displaced vertices found: (2 matches)

**Feedback is provided for each processed event.**

OK

**TUTORIAL**

displaced vertices that you see any displaced vertices,

at you have read the provided at the help link

2 of 0 required drawn

HELP WITH THIS TASK?

Done

- Citizens' data will be collected by Zooniverse and provided to us for analysis/evaluation.
- Citizens' performance will be compared to an automatic algorithm that we are developing.



HYPATIA takes over from Zooniverse:

The screenshot shows the REINFORCE WP5 interface. At the top, there is a navigation bar with the REINFORCE logo, the text "REINFORCE WP5", and menu items "ABOUT", "CLASSIFY", and "TALK". A yellow callout box points to the "CLASSIFY" and "TALK" items, stating "Tutorial and Help page are provided".

The main content area is split into two panels. The left panel has a black background with white text: "This Stage of the Demonstrator uses an external web event display called 'HYPATIA' to identify different kinds of particles." Below this is the ATLAS EXPERIMENT logo and the URL "http://atlas.ch". A yellow callout box labeled "Link to load HYPATIA" points to a blue arrow that points from the text to the right panel.

The right panel has a white background and is titled "TUTORIAL". It contains a blue link that says "Click here to open HYPATIA". Below the link is a box with the text "NEED SOME HELP WITH THIS TASK?". At the bottom of the panel are two buttons: "Done & Talk" (blue) and "Done" (green), along with a gear icon for settings.



Interactive display of the ATLAS detector (transverse & longitudinal view).

event lep...  
6500285

HELENIC REPUBLIC

Selection of electrons / photons / converted photons from the respective cluster in the EM calorimeter.

Selection of muons from their track.

+ Electron   + Muon   + Photon   + Conv. Pho...   - Delete   → Next

Particle	+/-	p [GeV]	p <sub>T</sub> [GeV]
track_3	-	37.049	11.63
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 <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 → γγ, H → ZZ\* → 4l)



HELENIC REPUBLIC  
National and Kapodistrian University of Athens  
EST. 1837

event lep...  
6500285

Particle	+/-	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

**Selections are stored by HYPATIA**

+ Electron   + Muon   + Photon   + Conv. Pho...   - Delete   → Next

Particle	+/-	p [GeV]	p <sub>T</sub> [GeV]
track_3	+	37.049	11.63
track_4	-	7.052	5.766
track_5	+	49.597	8.508
track_6	-	20.089	7.165
cluster_1		100.599	35.868

- Citizens' data will be collected by HYPATIA for analysis/evaluation.
- Citizens' performance will be compared to a machine-learning algorithm that we are developing.





HYPATIA takes over from Zooniverse:

The screenshot shows the REINFORCE WP5 interface. At the top, there is a navigation bar with 'ABOUT', 'CLASSIFY', and 'TALK' options. A yellow callout box points to the 'TUTORIAL' tab, stating 'Tutorial and Help page are provided'. Below the navigation bar, there is a main content area with a dark background. On the left, there is a logo for 'ATLAS EXPERIMENT' with the URL 'http://atlas.ch'. The main text reads: 'This Stage of the Demonstrator uses an external web event display called "HYPATIA" to identify different kinds of particles.' Below this, there is a link: 'Click here for detailed instructions'. A yellow callout box points to this link, stating 'Link to load HYPATIA'. A blue arrow points from the text 'to identify different kinds of particles.' to the 'Click here for detailed instructions' link. On the right side, there is a 'TASK' and 'TUTORIAL' tab interface. The 'TUTORIAL' tab is active. Below the tabs, there is a link: 'Click here to open HYPATIA'. A yellow callout box points to this link, stating 'Link to load HYPATIA'. Below the link, there is a question: 'NEED SOME HELP WITH THIS TASK?'. At the bottom, there are two buttons: 'Done & Talk' and 'Done', along with a settings gear icon.



# STAGE 3A – Study of Higgs bosons

**photon**

**converted photon**

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

Citizens will 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.

+ Photon					+ Conv. Photon					- Delete		→ Next	
Particle	+/-	$p_T$ [GeV]	$\phi$ [rad]	$\theta$ [rad]	Particle	$p_T$ [GeV]	$m_{\gamma\gamma}$ [GeV]	$\gamma/\gamma \rightarrow e^+e^-$					
track_6	-	41.12	-0.14	1.03	cluster_2	57.31	120.60	$\gamma \rightarrow e^+e^-$	Event: 5/20 (140978175/298771) 2016-05-10				
track_7	+	18.19	-0.12	1.03	cluster_1	69.62		$\gamma$	ETMiss: 35.53 GeV $\phi$ : -0.16 rad				
cluster_1		69.62	2.3	1.35									
cluster_2		57.31	-0.14	1.03									

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



The interface displays a top-down view of a particle detector with tracks originating from a central point. A yellow callout points to a specific track labeled 'track\_9'. Below the detector view is a table of particle tracks and an event summary panel.

**Selection of a muon associated with a DV.**

**Using real ATLAS data (RPVLL stream). Citizens will search for muon-jet DVs:**

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

**Star rating system to classify events according to interest level.**

**Information (E<sub>miss</sub>, MDV, RDV) to assist event rating.**

Particle	Charge	p <sub>T</sub> [GeV]	d <sub>0</sub> [mm]	φ [rad]	θ [rad]
track_8	+	23.53	-0.01	-3.03	1.1
track_9	+	135.82	-0.38	0.1	0.37
track_10	+	38.63	0.35	0.09	0.36
track_11	-	13.71	0.61	0.08	0.36

Event: 1/41 (570528740/298967) 2016-05-12  
 ET<sub>Miss</sub>: 74.54 GeV φ: -0.47 rad  
 MDV: 81.44 GeV RDV: 94.25 mm

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



**After tens of meetings (collaboration / advisory board / EU review board / ATLAS)**

- The platform is finalized and will deploy in the next months.
- Citizen data will be collected for about a year.
- Analysis of citizens' data will follow.

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

<https://www.reinforceeu.eu>



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