



# REINFORCE

REsearch INfrastructures FOR Citizens in Europe

## The REINFORCE EU citizen science project

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**on behalf of the REINFORCE consortium**

1<sup>st</sup> CREDO Workshop  
January 15<sup>th</sup>, 2024



HELLENIC REPUBLIC  
National & Kapodistrian  
University of Athens



*IASA*



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# THE REINFORCE PROJECT

- **RE**search **IN**frastructures **FOR** Citizens in Europe research and Innovation Project
- Supported by EU's Horizon 2020 Swarfs "Science with and for Society"
- ❑ **Mission** : "Minimize the knowledge gap between Large Research Infrastructures and Society through Citizen Science"
- ❑ **Goal** : "Establish a community of citizens **actively** engaged in public-funded frontier research; encourage data accessibility **for everybody**"
- 3 years long (12/2019 – 11/2022)
- **11 partners** from Argentina, Austria, Belgium, France, Greece, Italy, UK

**Four demonstrators for “discoveries”  
(GW, KM3Net, CERN, Cosmic Rays)  
Coordinated by S.Katsanevas/EGO  
This talk is dedicated to his memory**

- **REINFORCE is built on the Zooniverse platform**
- **Zooniverse is known as the world’s largest platform for online citizen science, with more than 2,5M registered volunteers**



# THE DISCOVERY DEMONSTRATORS

## GWITCHHUNTERS

Citizen scientists will look at chunks of Gravitational Wave data and identify the presence of noise which limits the sensitivity of detectors.

READ MORE

## DEEP SEA EXPLORERS

Citizens will help to improve neutrino detection algorithms, while gaining a greater insight of the unexplored deep marine environment.

READ MORE

## NEW PARTICLE SEARCH AT CERN

Citizens will be engaged in the quest of the Large Hadron Collider of CERN for the discovery of the ultimate structure of matter as well as particle theories beyond the Standard Model.

READ MORE

## COSMIC MUON IMAGES

Citizens will help explore the connections across the fields of cosmic ray physics, geology, volcanology and archaeology through the use of data and simple experimental devices.

READ MORE

A WFP fully devoted to **inclusion+diversity**  
(visually impaired, senior citizens, artistic interventions)

**PLUS:**

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

The site is [www.reinforceeu.eu](http://www.reinforceeu.eu)

# SONIFICATION OF THE DATA

[www.reinforceeu.eu](http://www.reinforceeu.eu)

About - Sonification



**REINFORCE**  
REsearch INFrastructures FOR Citizens in Europe

ABOUT ▾

DEMONSTRATORS ▾

NEWS ▾

OUTREACH ▾

PLATFORM FOR ARTISTIC INTERVENTION

PROJ

Videos

Communication Kit

Newsletter Subscription

## Sonification - Increasing the senses, increasing inclusion

### Objectives

#### sonoUno Website

The *human brain is still by far the most powerful tool for the perusal of large data sets* and, at the end of the chain, these data sets are ultimately analysed by humans. The space-physics community is in need of new methods to facilitate a more dynamic and detailed inspection of large data sets.

As part of our strategy to engage citizens in online frontier science, through our dedicated work package - *WP7 Increasing The Senses, Increasing Inclusion* - we aim to take these efforts one step further.

# CONICET DEVELOPED THE **SONOUNO\*** FOR SONIFICATION OF THE DEMONSTRATOR DATA



## Screen reader interpreter

<https://www.sonouno.org.ar/>

**CLICK HERE →**

<https://www.sonouno.org.ar/>

## Graphical interpreter

<https://reinforce.sonouno.org.ar/>

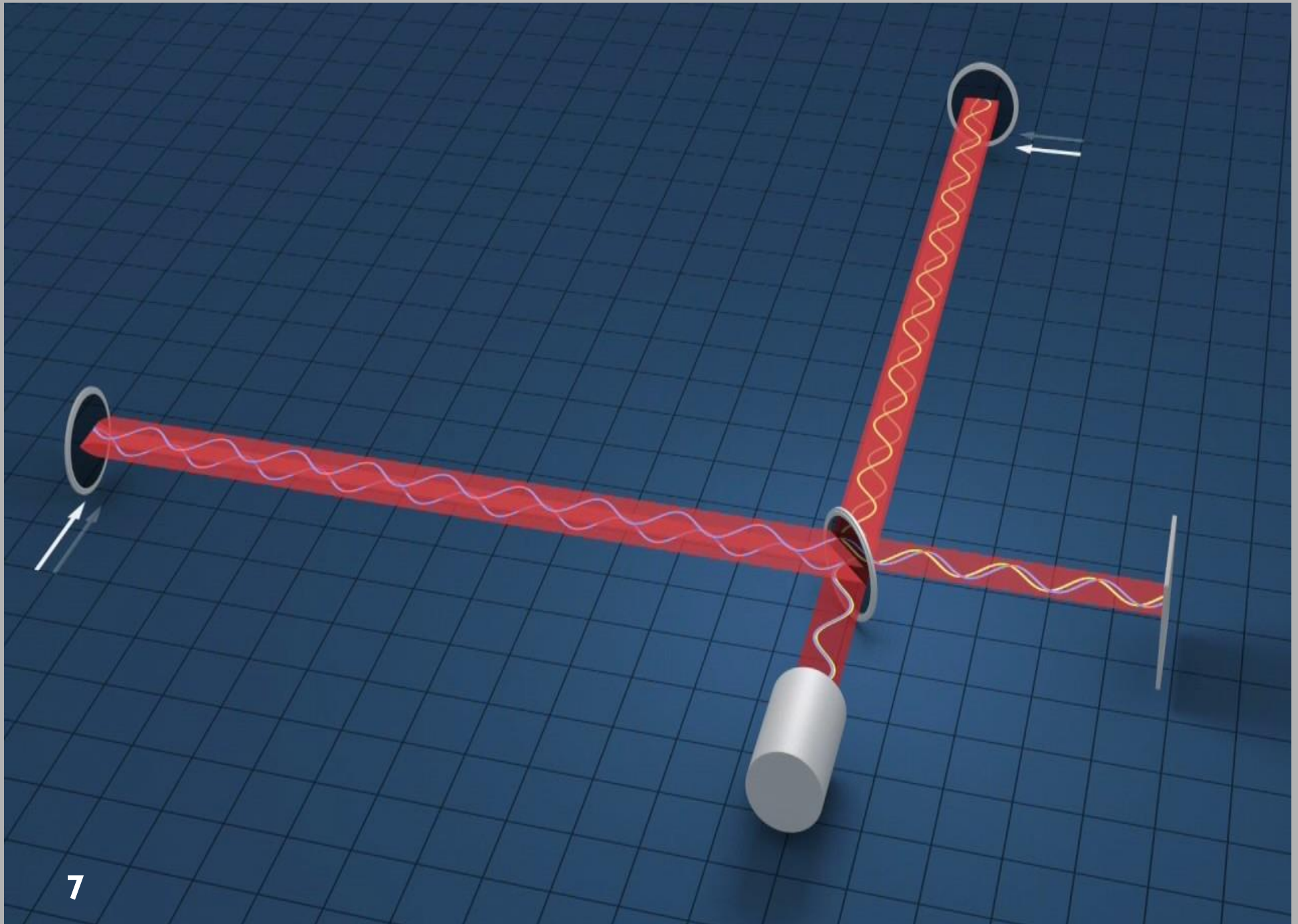
**CLICK HERE →**

<https://reinforce.sonouno.org.ar/>

\*The browser version was developed using HTML, CSS and JavaScript and uses the ARIA protocol to ensure communication with screen readers. For the sound synthesis itself, the tone.js library was selected.



# GRAVITATIONAL WAVE NOISE HUNTING (VIRGO/LIGO)



# GWitchHunters:

<https://www.zooniverse.org/projects/reinforce/gwitchhunters>



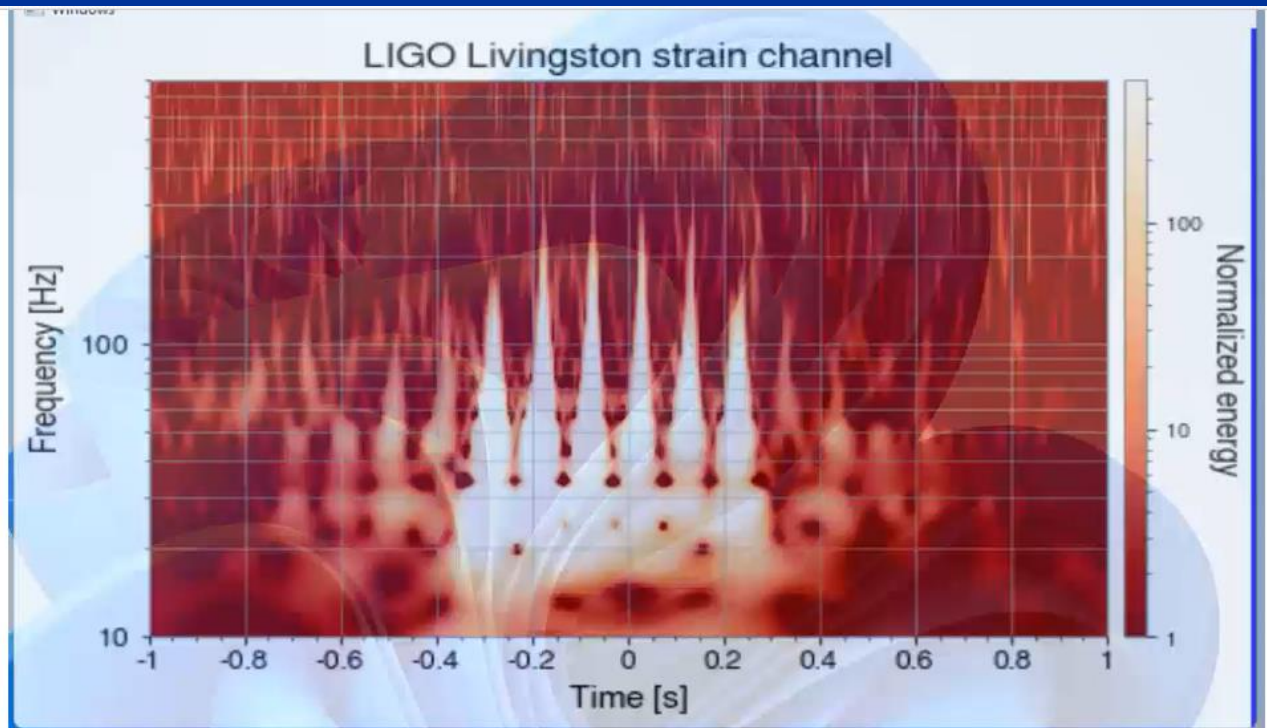
➤ Citizens recognize and classify different noise patterns

686,000 Classification

Different WorkFlows  
Playground level for practicing:  
Auxiliary channels (sensors)  
Run on mobile devices



# SONIFICATION OF GW GLITCHES



At the base of the sonification algorithm there is the association of frequencies with musical notes, and the signal energy with the notes intensities.

1126409678.84375\_TS\_ht\_4096\_raw data set:

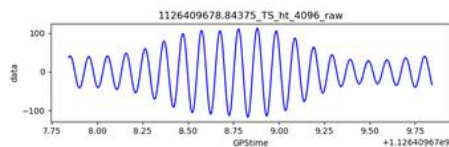
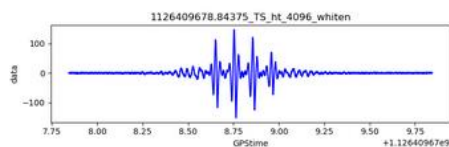


Figure 2 - Plot obtained from sonoLino with the raw data set of this glitch.



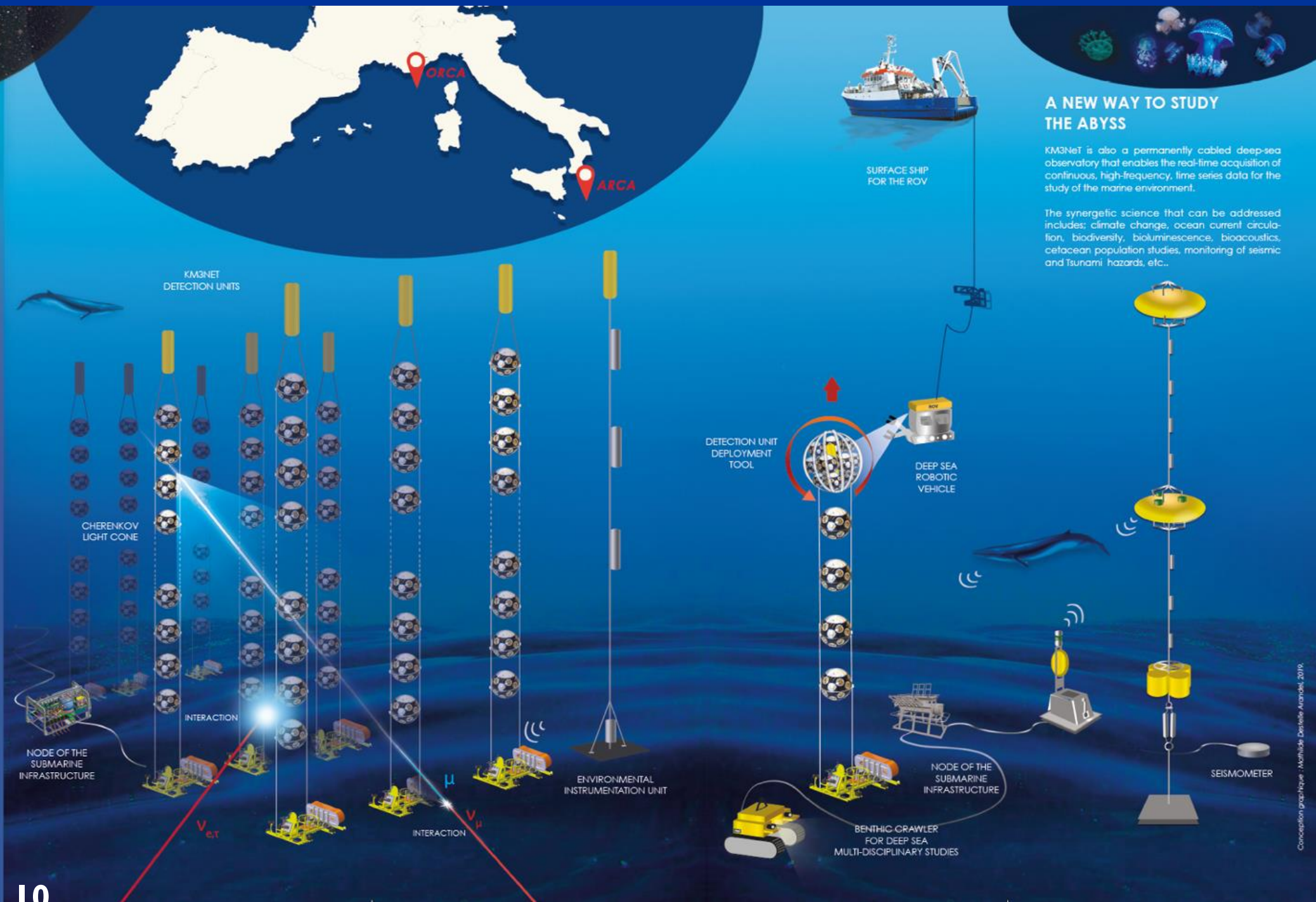
Sound 1 - Sound obtained from sonoLino with the raw data set of this glitch.

1126409678.84375\_TS\_ht\_4096\_whiten data set:



<https://www.sonouno.org.ar/glitch-1126409678-84375/>

# KM3NeT (ORCA+ARCA) NEUTRINO TELESCOPE



## A NEW WAY TO STUDY THE ABYSS

KM3NeT is also a permanently cabled deep-sea observatory that enables the real-time acquisition of continuous, high-frequency, time series data for the study of the marine environment.

The synergetic science that can be addressed includes: climate change, ocean current circulation, biodiversity, bioluminescence, bioacoustics, cetacean population studies, monitoring of seismic and Tsunami hazards, etc...

Conception graphique : Mathilde Desvigne Anankin, 2019.

# Deep Sea Explorers

<https://www.zooniverse.org/projects/reinforce/deep-sea-explorers>

PROJECTS ABOUT GET INVOLVED TALK BUILD A PROJECT NEWS

SIGN IN REGISTER



Deep Sea Explorers ✓

ABOUT CLASSIFY TALK COLLECT

Participation certificates, new results, and news from Deep Sea Explorers [here](#)

Help us to study bio-activity in the deep sea! With your help, we will better understand marine sources of noise in the KM3NeT detector, making our search for neutrinos much easier.

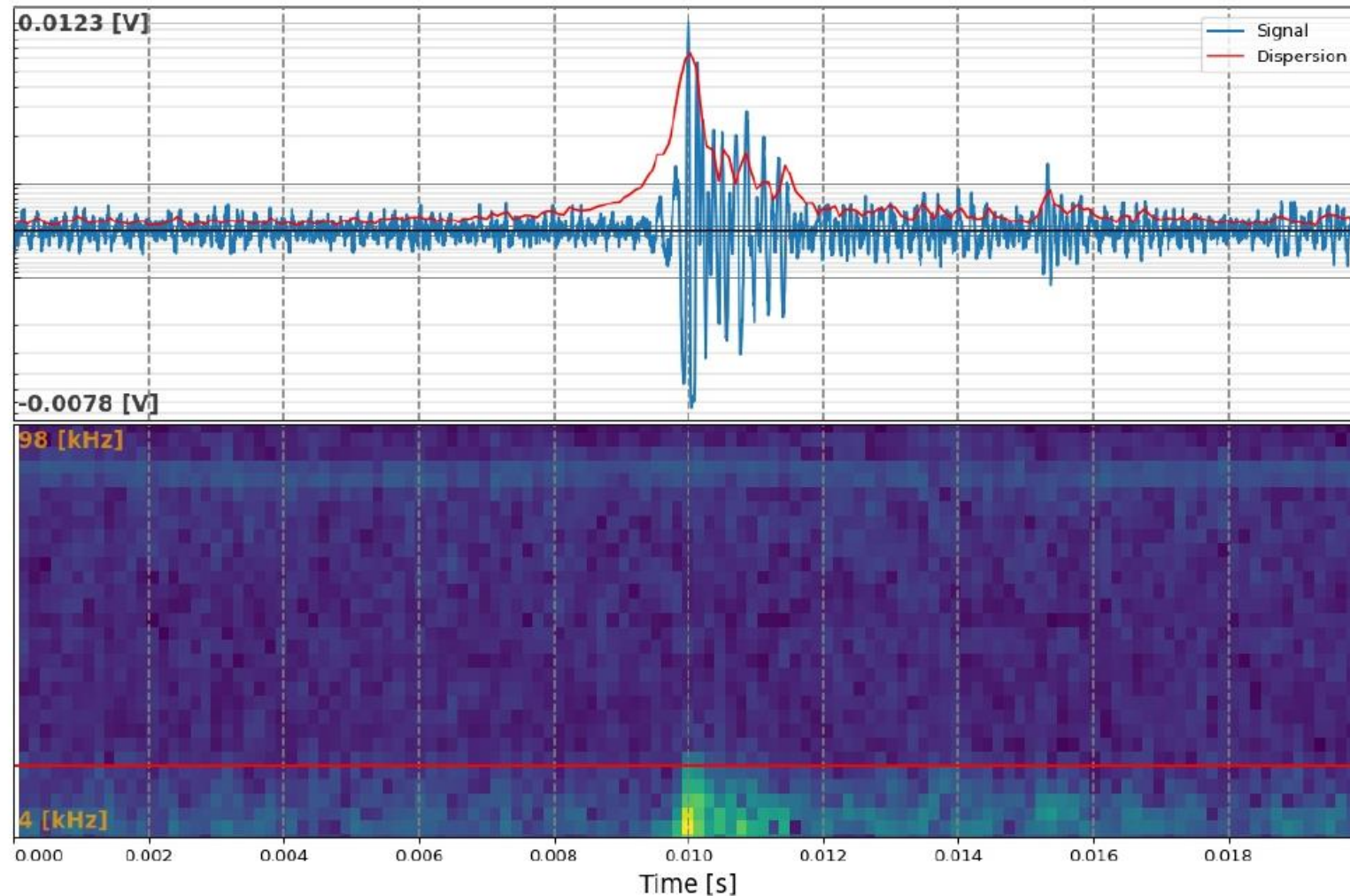
➤ Hunt what is not a neutrino

170,000 Classification

2 WorkFlows:  
[Bioluminesce](#)  
[Bioacoustics](#)



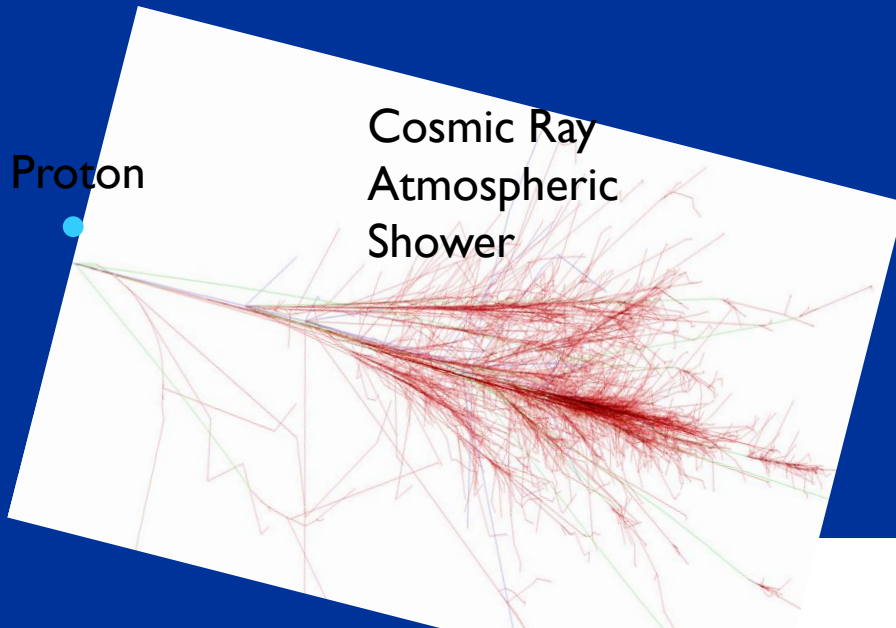
# SONIFICATION OF DEEP SEA NOISE



A click (millisecond-range soundwave) from a sperm whale

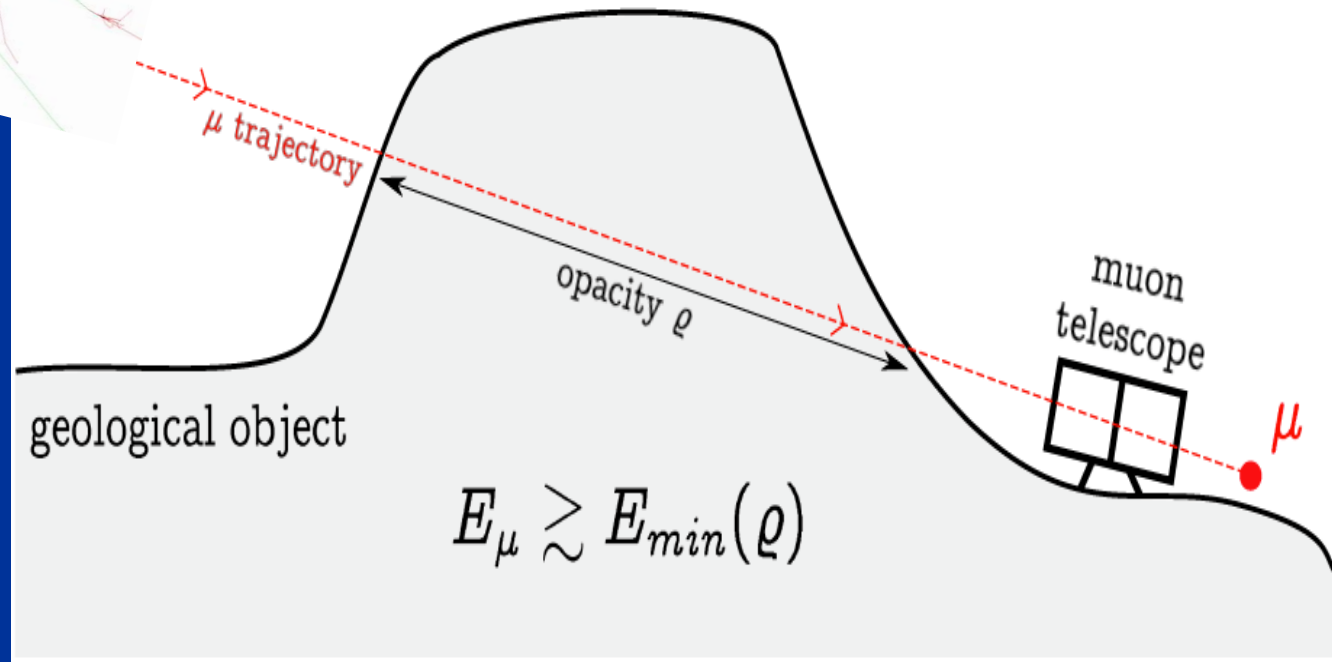
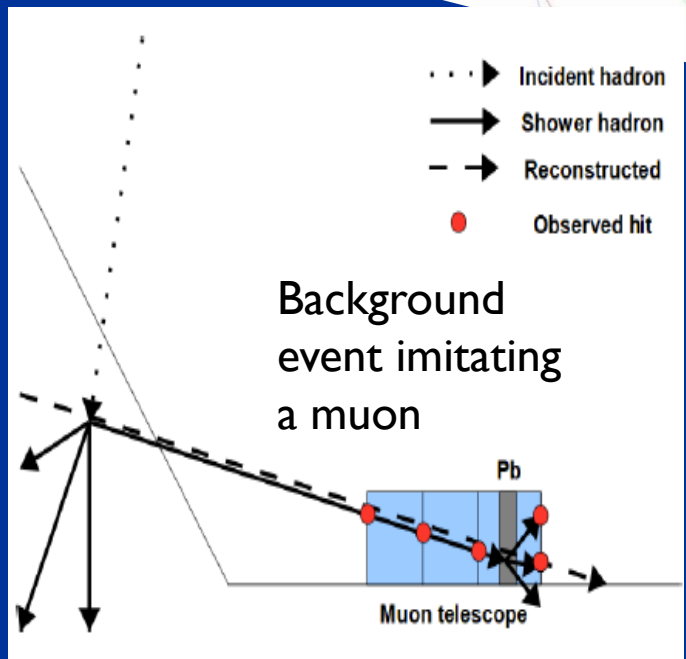
<https://www.youtube.com/watch?v=pkiGdZu5gEo>

# MUOGRAPHY (COSMIC RAYS) OVERVIEW



Use muons to reveal internal structure of :

- Volcanoes
- Civil Infrastructures
- Archaeological sites





# Cosmic Muon Images

<https://www.zooniverse.org/projects/reinforce/cosmic-muon-images>



Cosmic Muon Images ✓

ABOUT

CLASSIFY

TALK

COLLECT

Using Muon Tomography we can probe the internal structure of massive objects, like volcanoes, with particles from stars and galaxies far far away... help us identify these particles inside our detectors

- Citizens perform the difficult task of track finding even in ambiguous cases

202,000 Classification

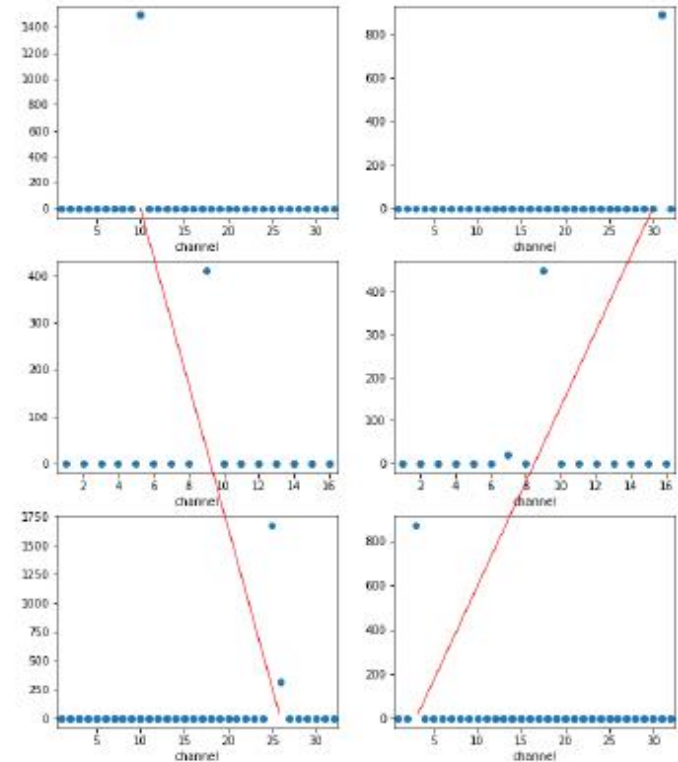
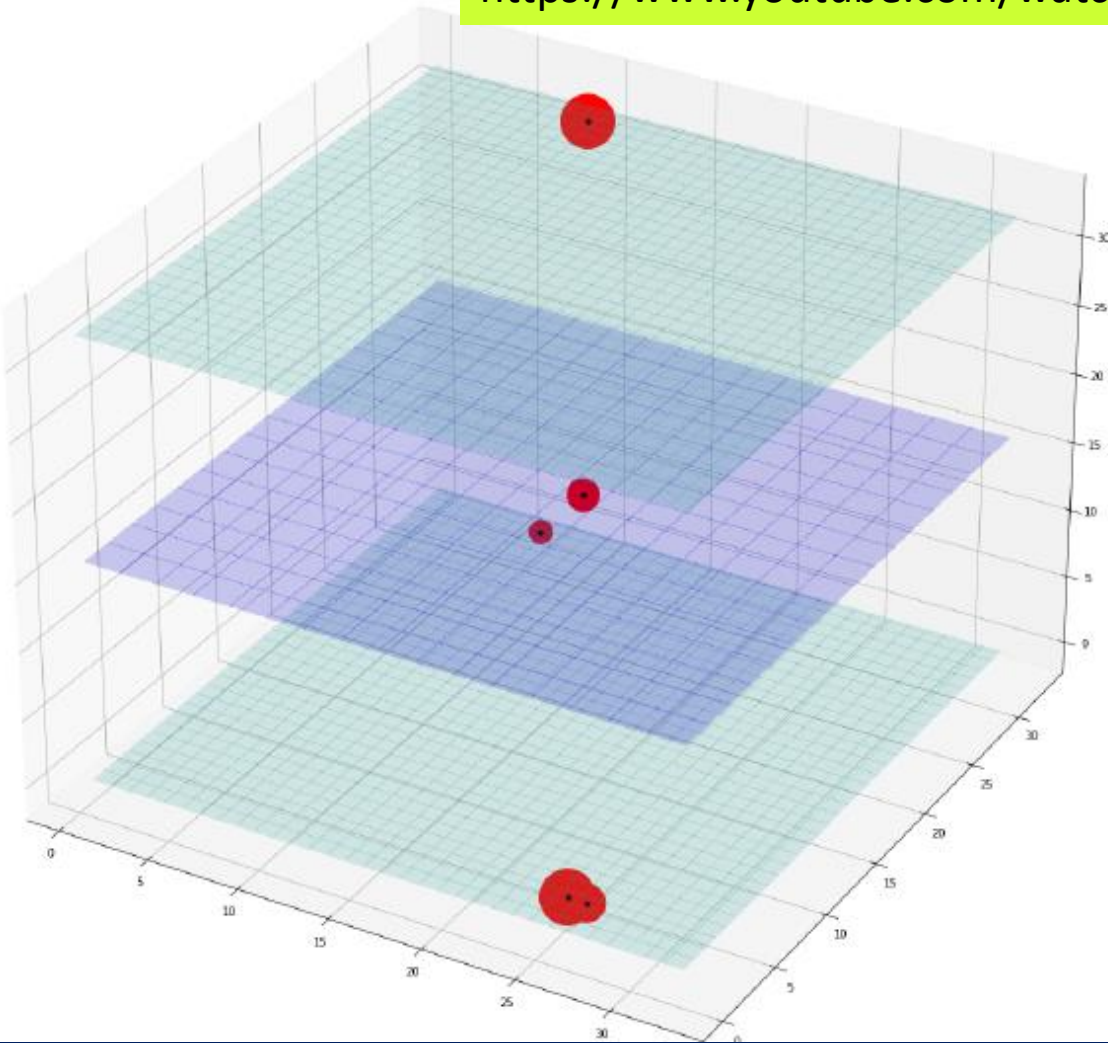
2 WorkFlows:

Introductory – Simple events

Advanced – Complicated Events

# SONIFICATION OF COSMIC RAYS

<https://www.youtube.com/watch?v=EYhcdyO2w2I>



**The note heard correspond to deposit of energy in the channel**  
Top and bottom -> 32 channels->one note for two close-by channels  
Middle 16 channels-> 16 piano notes

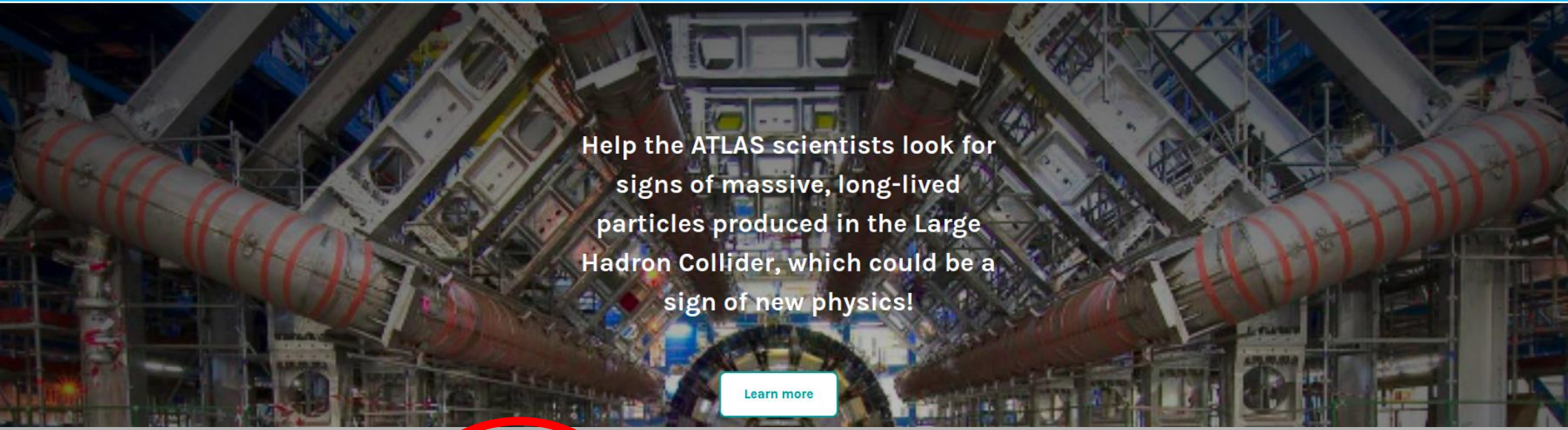


# New Particle Search at CERN

<https://www.zooniverse.org/projects/reinforce/new-particle-search-at-cern>



Please give us your feedback using this short Google form <https://forms.gle/jDBtb3skzZr123ew5>



### Get started ↓

The project consists of three stages, intended to be completed in the given order. In Stage 1, you will identify Displaced Vertices, which are the signatures of long-lived particles. In Stage 2, you will identify the signatures of known particles (muons, photons) in the ATLAS detector. In Stage 3 you will: search for Higgs boson decays to a pair of photons and look for long-lived particles decaying far from the beam collision point.

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.

365,000 Classifications since Oct 21

Four different workflows  
simulation  
Real data from ATLAS Open Data Set

# VISUAL INSPECTION OF DISPLACED VERTICES

The workflow is split in 3 stages

simulated data  
human Vs machine-based algorithms

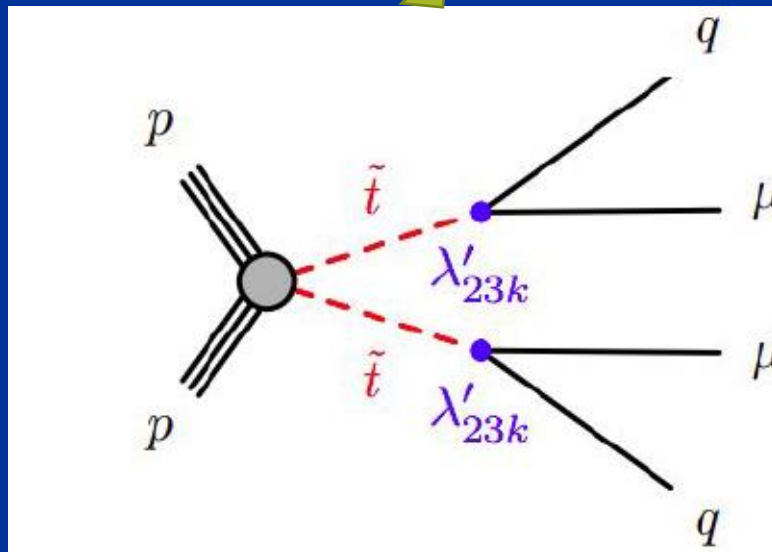
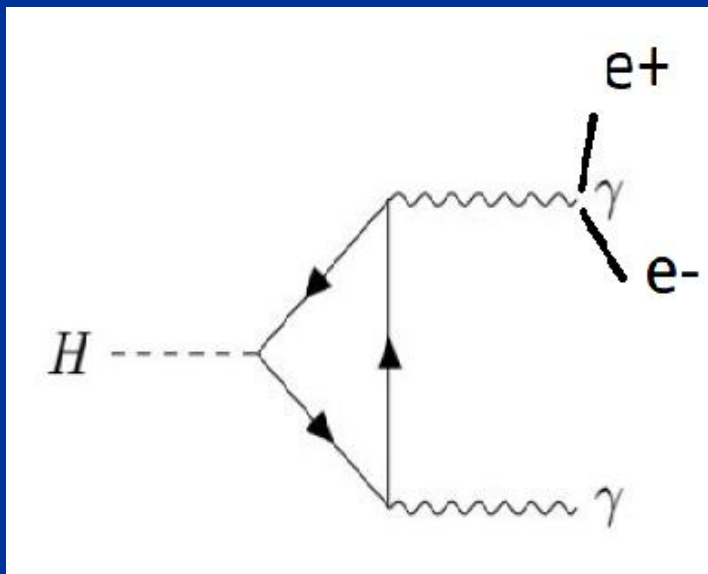
Stage 1  
Displaced Vertex Identification

Stage 2  
Particle Identification

ATLAS open data  
identification of interesting events

Stage 3a  
Study of Higgs Bosons

Stage 3b  
Discovery of Long Lived Particles



Higgs  $\rightarrow \gamma\gamma$  with one converted photon

SUSY scenaria with long-lived particles (ex RPV)

# Stage 1 : Displaced Vertex Identification

New Particle Search

Feedback

Hits

- Displaced vertices found: (2 matches)

Feedback provided after each event

SELECT RECENTS LAB

TUTORIAL

displaced vertices that you see any displaced vertices,

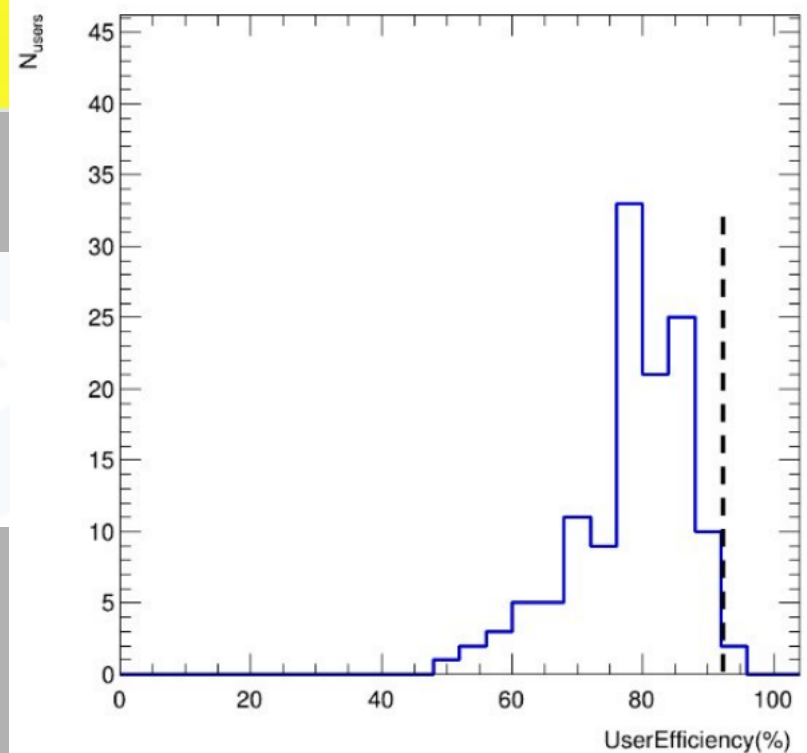
it you have read the provided at the help link

2 of 3 required drawn

HELP WITH THIS TASK?

Done

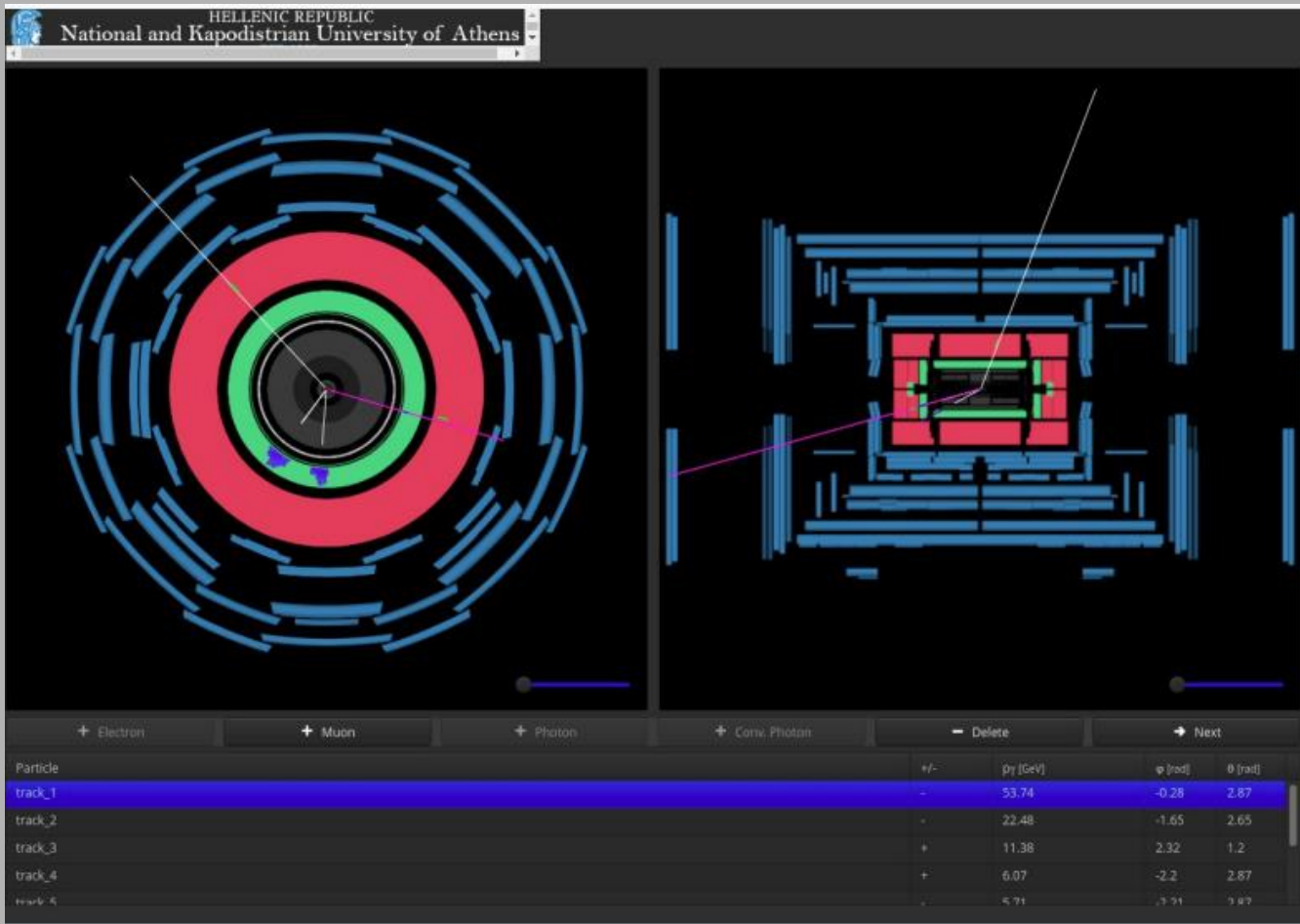
- **User consensus efficiency: 93%**  
(combined user response per event)
- **Efficiency of automated algorithm: 94%**





# Stage 2: Particle Identification

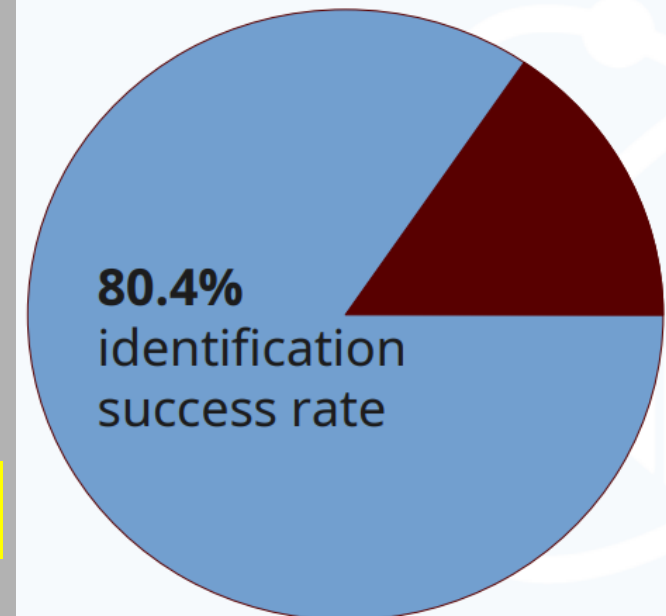
Users have to learn how to identify  
 $e, \mu, \gamma, \gamma \rightarrow e^+e^-$  conversions



An ML algorithm compares users identification results with the “truth” information

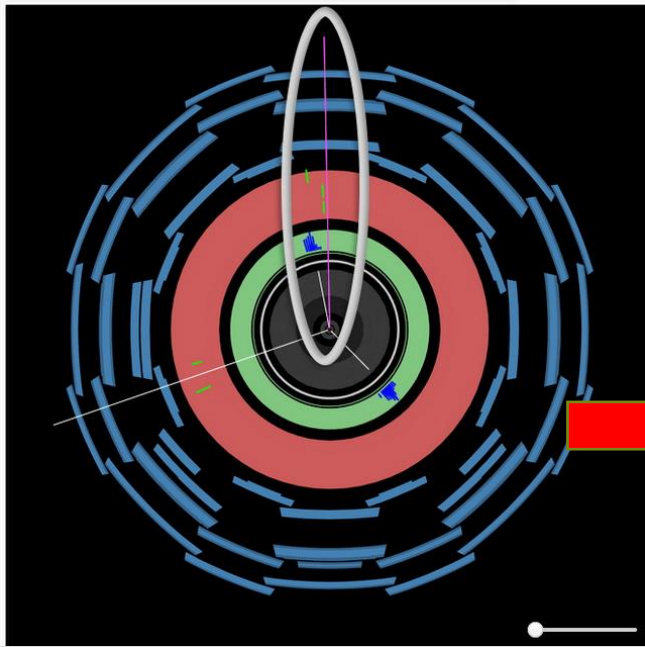


36690 Classifications



Data=Products of pp collisions sonified by CONICET

# HOW TO IDENTIFY PARTICLE TYPE BY SOUND(1/2)

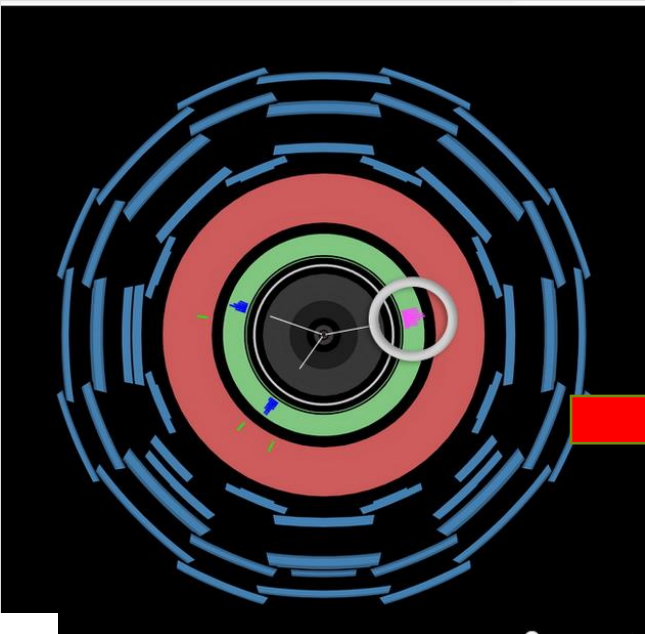


## Selection of a muon

A muon is a long track which reaches the outer layers of the detector

✓ Tracks :continuous sound (D6, 2sec)

✓ Long tracks (muons) :continuous sound 4 sec,



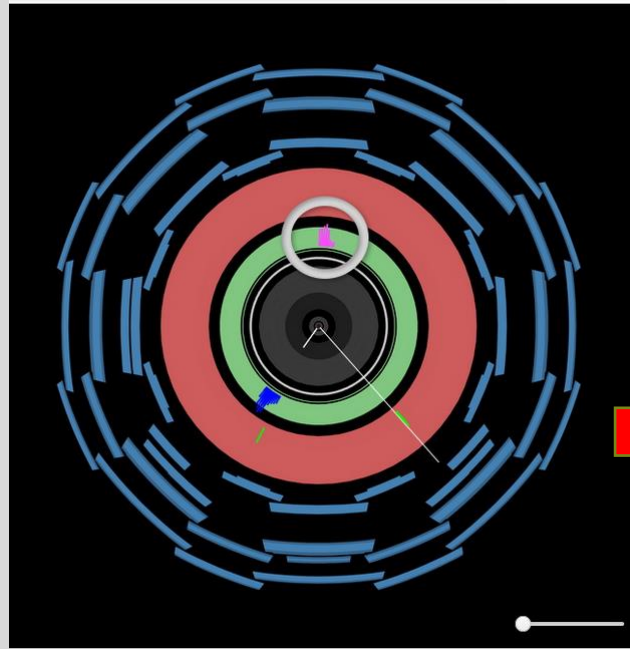
## Selection of an electron

An electron leaves a track+a cluster of energy

✓ Tracks :continuous sound (D6, 2sec)

✓ Clusters: short sounds volume related to energy

# HOW TO IDENTIFY PARTICLE TYPE BY SOUND (2/2)

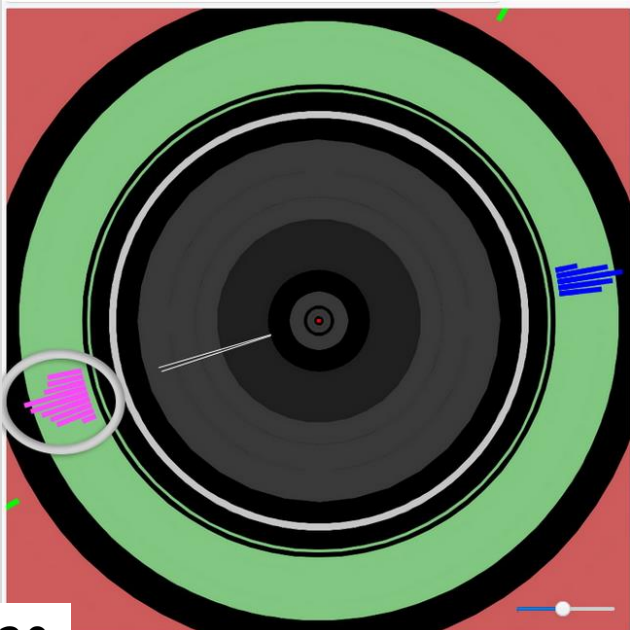


## Selection of a photon

A photon gives a cluster of energy and NO track associated with it

✓ No track: silence 2 sec

✓ Clusters: short sounds volume related to energy



## Selection of a converted photon ( $\gamma \rightarrow e^+e^-$ )

A converted photon converted photon (the most difficult case) gives two CLOSE-BY tracks and a (double) cluster of energy

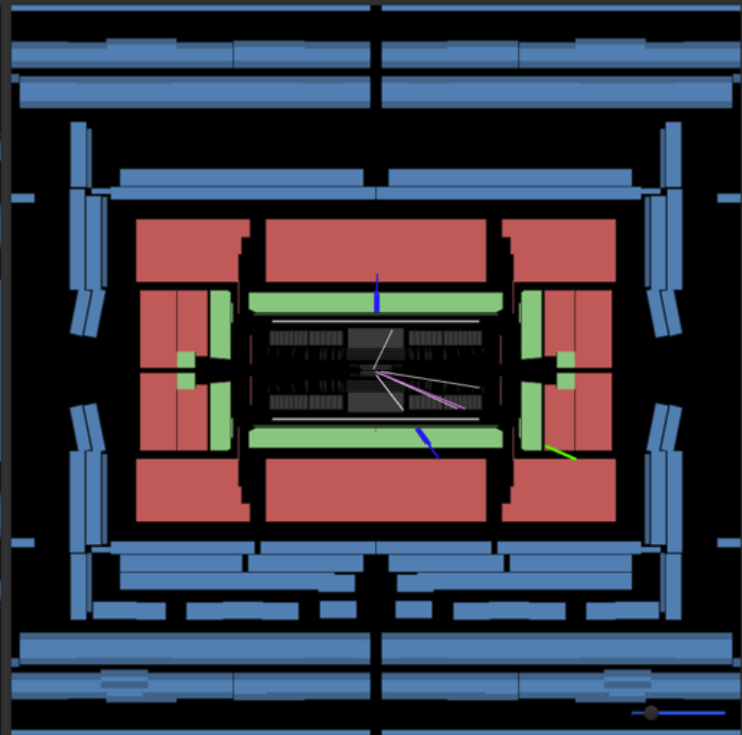
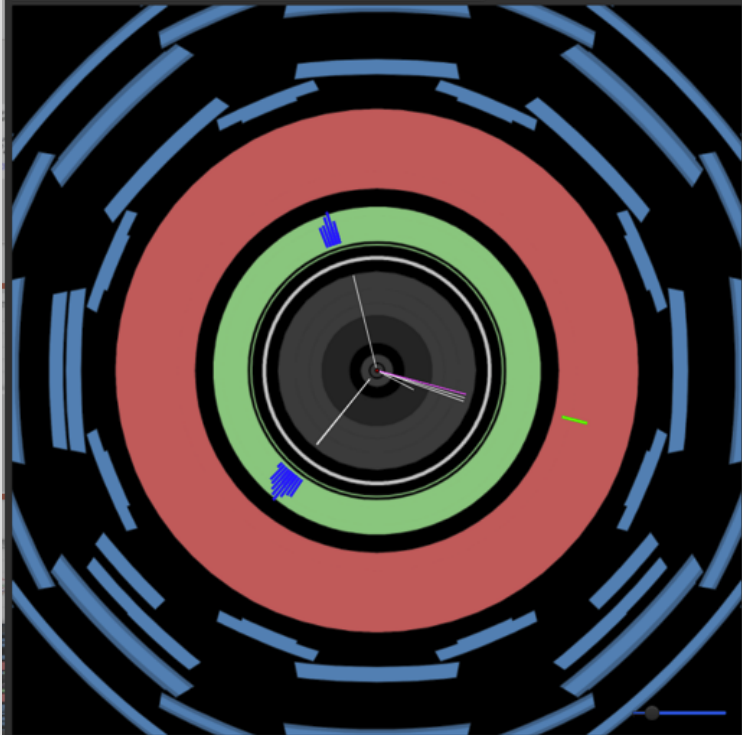
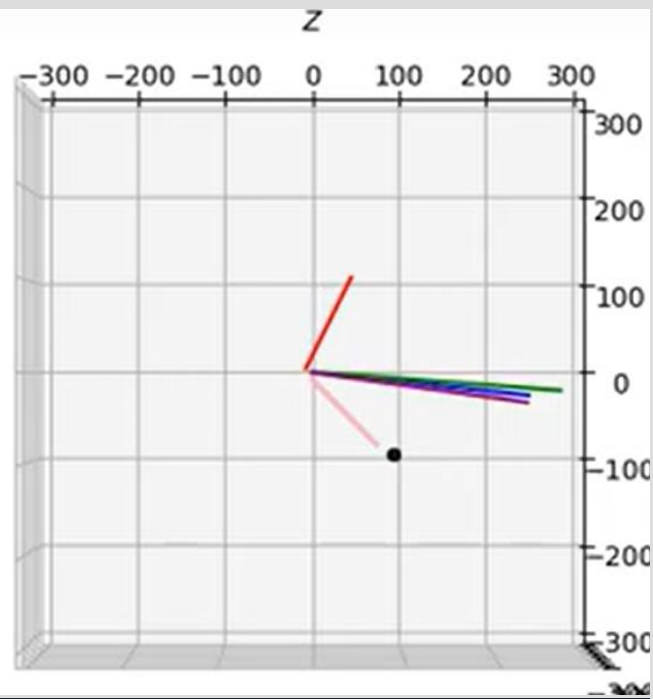
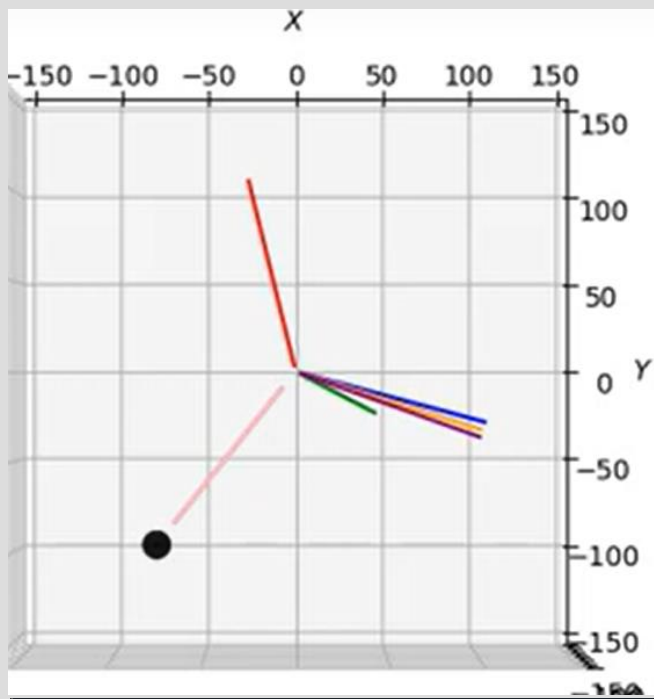
✓ Double tracks: (conversions) two continuous sounds of dif. freq. D6+C6

## HOW IT IS DONE (DETAILS)

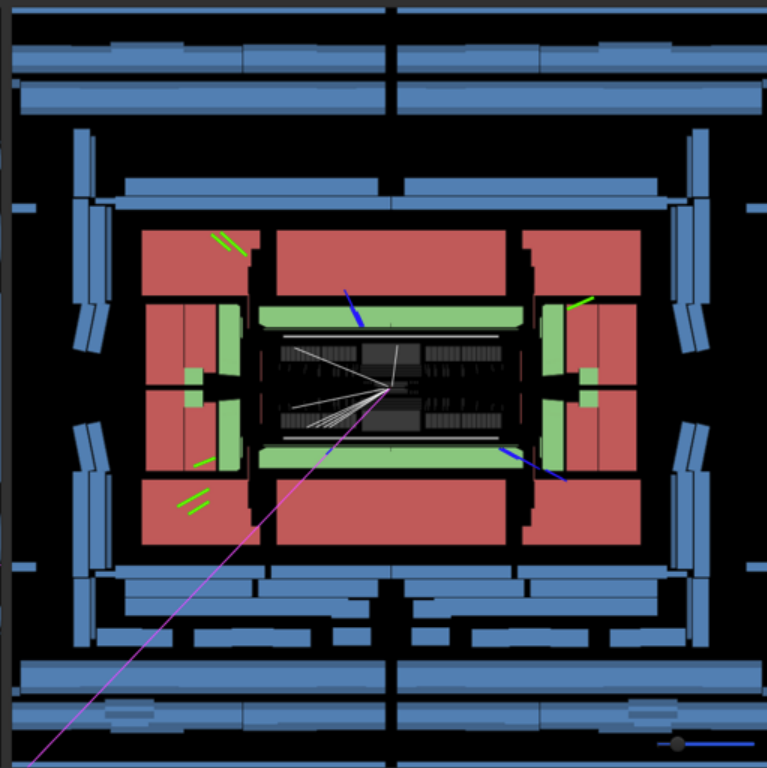
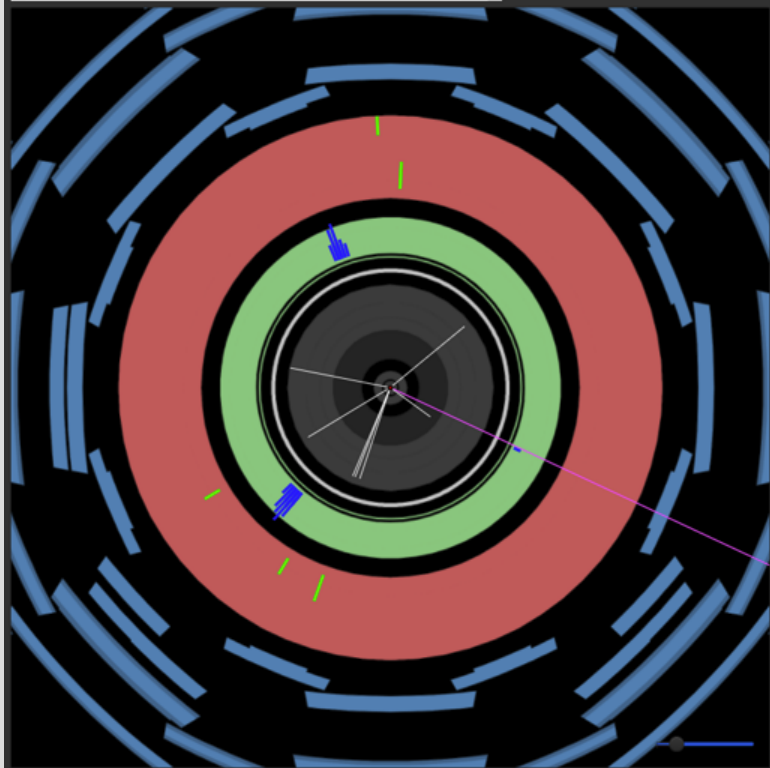
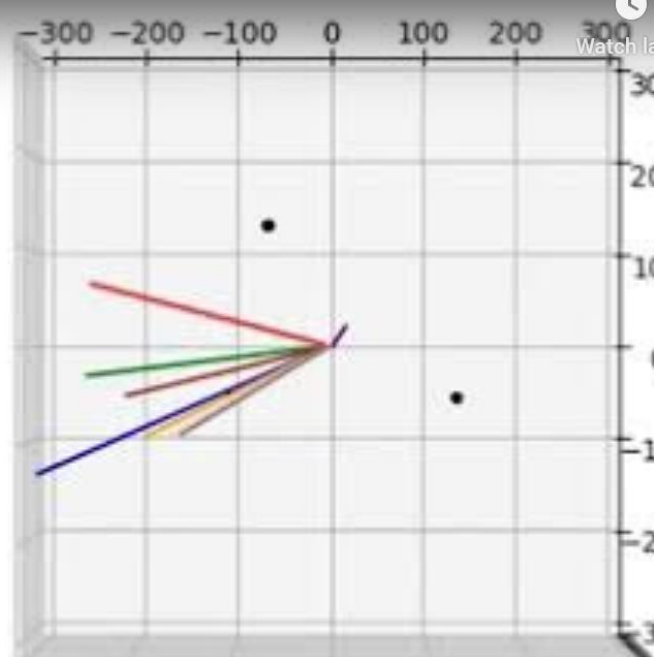
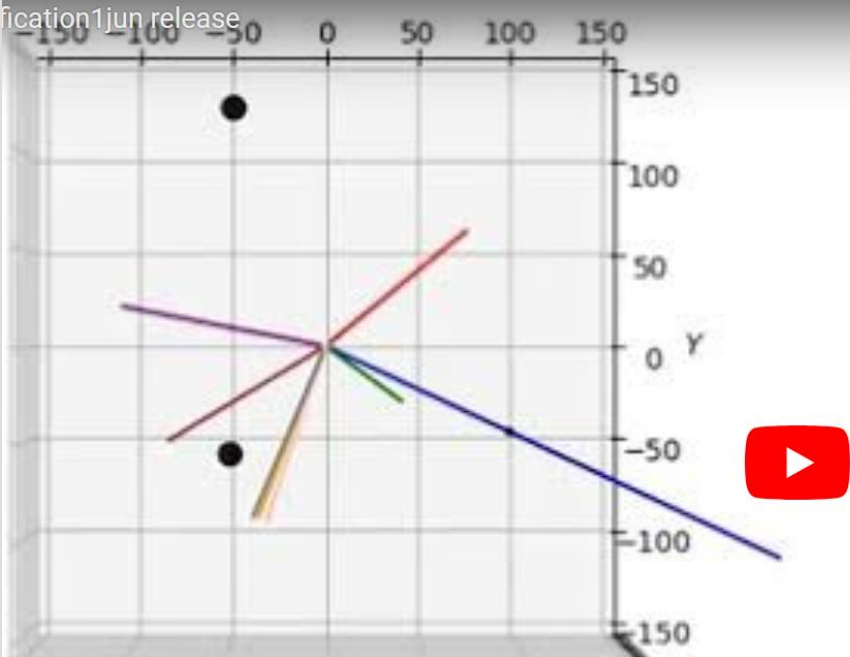
The various ATLAS subdetectors are used.

The HYPATIA image is transformed to an acoustical/visual representation is based on the existence (a continuous sound of two seconds) or not (a silence of two seconds) of the track in the inner detector, the existence (a characteristic sound of one second) or not (a silence of one second) of the cluster in the calorimeter (the volume of the sound represents the energy), and the existence of a track beyond the inner detector (in this case the initial continuous sound length changed from two seconds to four seconds)

[https://www.youtube.com/embed/Foa\\_8fT2NYY?start=1&end=57](https://www.youtube.com/embed/Foa_8fT2NYY?start=1&end=57)







+ Photon				+ Conv. Photon			- Delete				→ Next		★☆☆☆☆	
Particle	+/-	$p_T$ [GeV]	$\phi$ [rad]	$\theta$ [rad]	Particle	$p_T$ [GeV]	$m_{\gamma\gamma}$ [GeV]	$y/\gamma \rightarrow e^+e^-$				Help		
track_1	+	30.71	-0.44	2.33								Event: 9/20 (860195431/208967) 2016-05-12		

# Stage 3b - Neutral long-lived particle-hunting

The screenshot shows a web-based interface for particle detector simulation. At the top, there are navigation links: ABOUT, GET INVOLVED, TALK, BUILD A PROJECT, and NEWS. The main area is split into two panels: a top-down view of the detector on the left and a side-view cross-section on the right. Both views show a central beam pipe surrounded by concentric layers of detector components, color-coded in blue, red, and green. A particle track is visible in both views, with a white line representing the path and colored segments indicating interactions. Below the panels is a control bar with buttons for '+ Muon', '- Delete', and '+ Next'. A star rating system is visible in the bottom right corner, circled in red. Below the control bar is a data table with two sections. The left section lists particle tracks with columns for +/-, p<sub>T</sub> [GeV], d<sub>0</sub> [mm], φ [rad], and θ [rad]. The right section shows event summary statistics: Event: 1/41 (570528740/298967) 2016-05-12, ET<sub>miss</sub>: 74.54 GeV φ: -0.47 rad, M<sub>DV</sub>: 81.44 GeV R<sub>DV</sub>: 94.25 mm. A green circle highlights the d<sub>0</sub> [mm] column in the table and the event summary statistics.

Particle	+/-	p <sub>T</sub> [GeV]	d <sub>0</sub> [mm]	φ [rad]	θ [rad]
track_1	-	38.17	-0.01	-3.01	1.1
track_2	+	17.81	0.00	-2.67	2.64
track_3	-	22	-0.01	-2.98	1.1
track_4	-	20.1	-0.01	-3.01	1.1
track_5	+	24.02	-0.02	-2.71	2.65

Event: 1/41 (570528740/298967) 2016-05-12  
 ET<sub>miss</sub>: 74.54 GeV φ: -0.47 rad  
 M<sub>DV</sub>: 81.44 GeV R<sub>DV</sub>: 94.25 mm

- Citizens are advised to look at  $M_{DV}$ ,  $R_{DV}$ ,  $p_T$  and  $d_0$  of the event and rate it accordingly with stars
- Every time they select a muon: the  $M_T$  of muon  $p_T$  and the  $ET_{miss}$  is calculated ( $m_{\mu\nu}$ )

# CONCLUSIONS

- ❑ REINFORCE made available Open Data from Large Research Infrastructures for education and citizen research, extended inclusion through sonification of data samples.
- ❑ About 12,000 citizens are involved, with 1,600,000 classifications in all four demonstrators
- Comparative studies show that the power of citizen's performance (often similar to ML algorithms).
- The demonstrators will remain open on zooniverse platform

# PARTENERS



**theLisboncouncil**  
think tank for the 21<sup>st</sup> century



Thank you



**Back-up**

# The idea behind our WP (New Particles@CERN)





[https://www.zooniverse.org/projects/reinforce/new-particle-search-at-cern\\*](https://www.zooniverse.org/projects/reinforce/new-particle-search-at-cern)



WP5 on Zooniverse



4

-  To have citizens focus on visual inspection of events
-  To train them to locate **displaced vertices** which they may do better than ATLAS (HiggsHunters example)
-  To train them to recognize characteristic signatures of electrons, muons, photons and converted photons **using the online HYPATIA event display**
-  Finally, by combining the above: to let them make **possible discoveries of “new physics”**

\*Translations: English, Greek, Spanish



# THE SCIENTIFIC METHODOLOGY/EVENT DISPLAYS

Design algorithms/methods  
on simulated data



Apply on real data

- Train citizens on simulated data
- Evaluate citizens' performance
- Compare with automated algorithms



Apply on real data

Stage 1: Fully hosted by Zooniverse

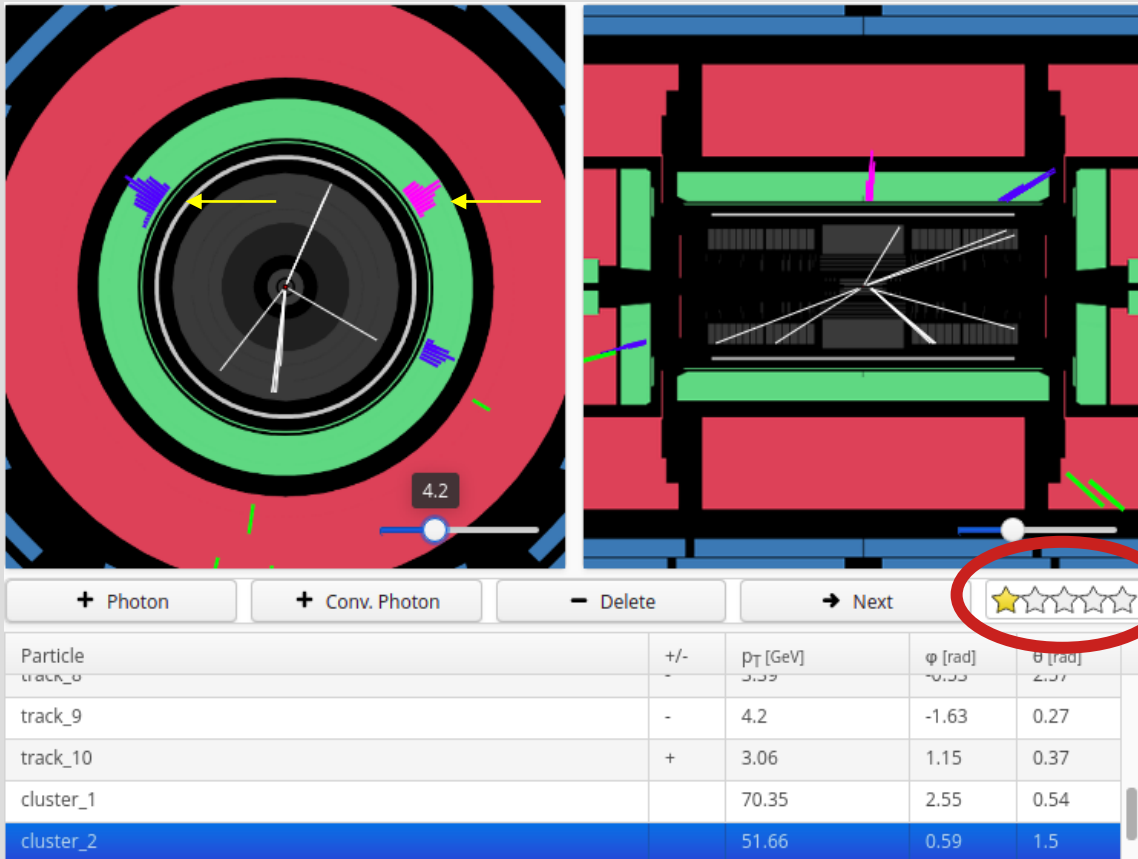
Stages 2, 3a,b: Co-hosted by Zooniverse and online HYPATIA

Stage 2: **Sonified** by CONICET

All tasks carried out by using only mouse clicks

# Stage 3a - $H \rightarrow \gamma\gamma$ STUDY (using HYPATIA)

## Event Handling



Event: 1/170 (39081409/297730) 2016-04-28  
ETMiss: 9.08 GeV  $\phi$ : -2.53 rad  
DV Mass: -

Particle	$p_T$ [GeV]	$m_{\gamma\gamma}$ [GeV]	$\gamma/\gamma \rightarrow e^+e^-$
cluster_1	70.35	126.30	$\gamma$
cluster_2	51.66		$\gamma$

**Citizens search for  $H \rightarrow \gamma\gamma$  candidates\*:**

- select the candidate photon pair,
- rate the event (low  $\rightarrow$  high interest).

**Highly rated events** are discussed on the project's discussion boards.

Potential statistical processing of user outputs may be carried out by our team alone.

\*All ATLAS open data pre-selection cuts have been applied to the sample