New Perspectives in Science Education
International Conference
NEW PERSPECTIVES in SCIENCE EDUCATION
Edition 4

The Interactive “HYPATIA” Tool as a Good Practice Science Education Resource of the “Go-Lab” FP7 European Project

Stylianos Vourakis[1], **Christine Kourkoumelis**[2] **and Sofoklis Sotiriou**[3]
[1,2]Physics Faculty, University of Athens, [3]Research and Development Department, Ellinogermaniki Agogi (Greece)
[1]s_vourakis@phys.uoa.gr, [2]hkourkou@phys.uoa.gr, [3]sotiriou@ea.gr

Abstract

It has been noted by various reports that during recent years, there has been an alarming decline in young people’s interest in science studies and mathematics. Since it is believed that the traditional teaching methods often fail to foster positive attitudes towards learning science, the European Commission has made intensive efforts to promote science education in schools though new methods centered on the inquiry based techniques: questions, search and answers. This should be coupled with laboratories which are very important elements in learning and practicing science.

“Go-lab” an FP7 EC project which started more than two years ago - for a four year duration - aims to put together remote labs, virtual labs and datasets/analysis tools, in order to enhance the resources available to teachers for large scale use in education.

The authors of this article have developed the analysis tool “HYPATIA” which can interactively analyze data from the ATLAS experiment at the Large Hadron Collider of CERN. HYPATA is widely used in schools throughout Europe; as an example of good practice, the students “hunt” for the recent Nobel Prize winning Higgs boson.

1. The Go-Lab project

The Go-Lab Project (Global Online Science Labs for Inquiry Learning at School) [1], [2] started more than two years ago, for a four year duration. The project is a European collaborative effort co-funded by the European Commission’s 7th Framework Programme, bringing together nineteen organizations from twelve countries. Its goal is to make remote science laboratories, their data archives and data analysis tools (collectively called “online labs”) available for use in an educational context. Go-Lab supports Inquiry Based Science Education (IBSE) tools which enable learning through a process of questioning, researching and providing answers. This “hands-on” approach towards science not only promotes analytical thinking and reasoning but also ignites the students’ interest towards science and gives them a realistic view of the tasks that a scientist has to perform. In addition it enables students of all levels of competence to take part in the learning process at a suitable pace.

1.1 Objectives

The Go-Lab objectives are three fold:

- To enable students of all ages to perform personalized scientific experiments with online labs in pedagogically structured and scaffolded learning spaces (ILSs). Social communication facilities extend the use of the ILSs and provide a means for the community to interact and enrich the available resources.
- To provide the teachers with complete and easy to use pedagogical resources through the Go-Lab portal [3] which enables the teachers to use, personalize or upload their own ILSs as well as to communicate and support each other.
- To provide the lab-owners with the opportunity to share and promote their scientific activities in a large community of potential users.

1.2 Online laboratories

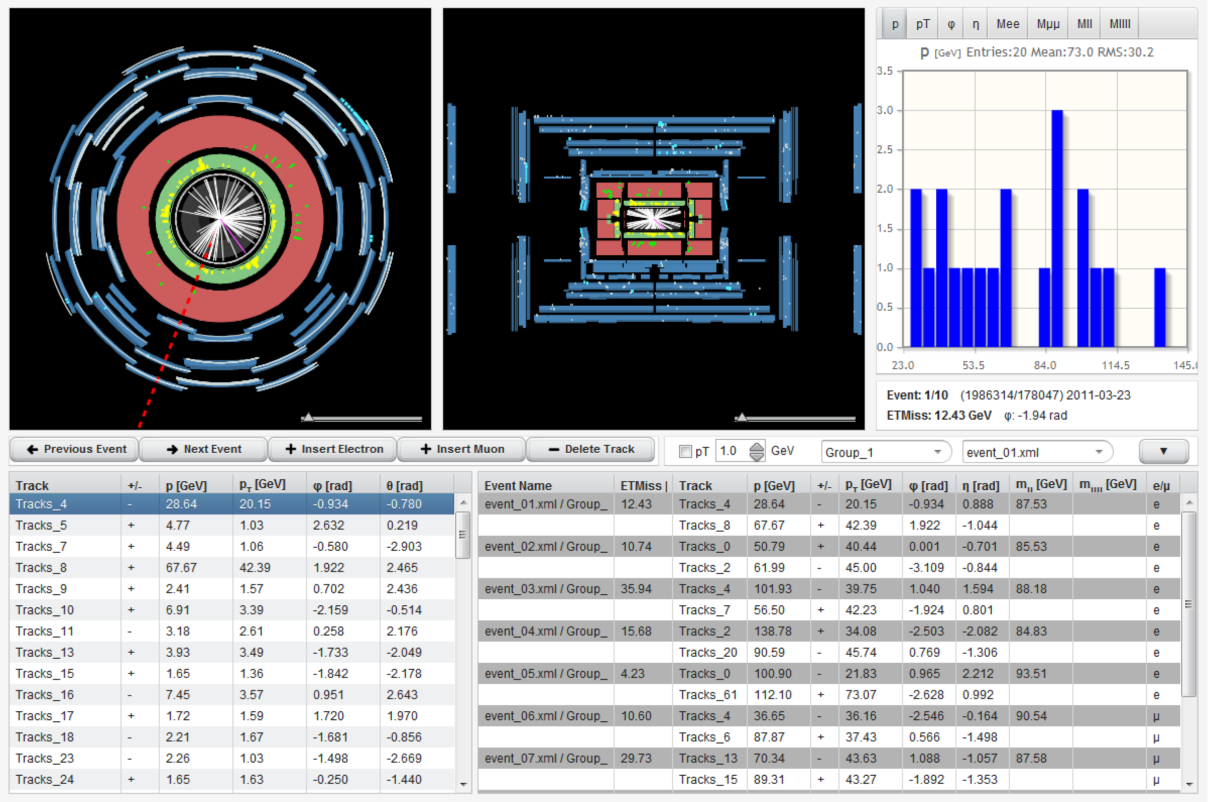
The federation of online labs is presented through the Go-Lab portal and contains pilot labs from world-renowned research organizations, such as ESA (European Space Agency), CERN (European Organization for Nuclear Research), NUCLIO (Núcleo Interactivo de Astronomia, Portugal), as well as from selected universities and institutions while new resources are constantly being added. The labs are classified as remote laboratories, virtual experiments, or data-sets/analysis tools.

Online labs are not a mere substitute for traditional laboratories where physical presence is required. Many studies have reported on the important advantages which the use of online labs can offer. Literature supports the idea that remote and virtual labs can not only replace direct (or face-to-face)

access to real physical laboratories but also in some cases even improve on that experience (see for example [4] and references therein).
The online labs of the Go-Lab project offer access to unique facilities that exist only in very few, or even a single place, such as the world's most powerful particle accelerator, the LHC [5] at CERN and the remotely operated telescopes used by the Faulkes Telescope Project [6]. These resources would otherwise be unavailable to the students or at the very least, considerably difficult to access, due to time, location, expertise, safety or expense constraints. Through the use of the online labs, the students are introduced to the main ideas of big science and the use of cutting-edge eScience applications without having to leave their classroom. Online labs also offer a great variety of possible experiments in different science domains (e.g., Biology, Chemistry, Environmental and Earth Sciences, Astronomy, Space, Particle Physics) in primary and secondary education that the students and teachers can select from and implement in their daily teaching schedule. This gives them the opportunity to adjust their work according to the level, interests, available time or curriculum of their class, offering an added advantage over traditional laboratories.

2. The HY.P.A.T.I.A event display

One such example developed by the authors of this article is the HY.P.A.T.I.A (HYbrid Pupil's Analysis Tool for Interactions in ATLAS) data analysis tool which offers the possibility for a 2-D interactive analysis of data collected by the ATLAS [7] experiment running at the LHC accelerator.
Two versions of HYPATIA are available. The offline version [8] offers full scientific functionality and is suitable not only for educational use but also for actual event analysis. It has been used in the International Particle Physics Masterclasses [9] since 2009 with great success. The Z-Path exercise [10] which uses HYPATIA to analyze real data from the ATLAS experiment is the most popular, performed by more than 3500 students from all over the world during the 2014 Masterclasses. Registration for this year's Masterclasses shows this preference continuing.
The online version [11], [12] has been developed as a web application. It was created as an educational tool that includes all the necessary functionality but without the added complexity of installation, for use in educational environments such as schools. It runs on all operating systems, including mobile OSs and can be used through any web browser without the need for any additional software installation. It is also currently available in four languages Greek, English, German and French.
The web application supports four different levels of complexity aimed at different analysis abilities and backgrounds of users. The first level consists mainly of the two canvas views which display cross sections of the ATLAS detector (see fig.1, left is the transverse view with respect to the LHC beams and right is the side view, along the beams). The user can browse through different events and observe the number of tracks per event and their spatial distribution in each view. This is a good starting point for entry level users, younger students, who only want to get an idea of what the ATLAS detector looks like, what the collisions of particles at unprecedented energies produce and how their products (tracks) are detected.
At the second level of the web application the information about the track momenta and their directions is added in a tabular way. The user is given instructions and examples and is then challenged to identify the different kinds of lepton tracks by using the signatures which they leave in different parts of the detector.
The third and fourth level of the HYPATIA web application (Fig. 1), give the user the ability to combine tracks in order to search for invisible short-lived particles which decay into several secondary particles.



Event: 1/10 (1986314/178047) 2011-03-23
ETMiss: 12.43 GeV φ: -1.94 rad

Track	+/-	p [GeV]	p_T [GeV]	φ [rad]	θ [rad]
Tracks_4	-	28.64	20.15	-0.934	-0.780
Tracks_5	+	4.77	1.03	2.632	0.219
Tracks_7	+	4.49	1.06	-0.580	-2.903
Tracks_8	+	67.67	42.39	1.922	2.465
Tracks_9	+	2.41	1.57	0.702	2.436
Tracks_10	+	6.91	3.39	-2.159	-0.514
Tracks_11	-	3.18	2.61	0.258	2.176
Tracks_13	+	3.93	3.49	-1.733	-2.049
Tracks_15	+	1.65	1.36	-1.842	-2.178
Tracks_16	-	7.45	3.57	0.951	2.643
Tracks_17	+	1.72	1.59	1.720	1.970
Tracks_18	-	2.21	1.67	-1.681	-0.856
Tracks_23	-	2.26	1.03	-1.498	-2.669
Tracks_24	+	1.65	1.63	-0.250	-1.440

Event Name	ETMiss |	Track	p [GeV]	+/-	p_T [GeV]	φ [rad]	η [rad]	m_{ll} [GeV]	m_{llll} [GeV]	e/μ
event_01.xml / Group_	12.43	Tracks_4	28.64	-	20.15	-0.934	0.888	87.53		e
		Tracks_8	67.67	+	42.39	1.922	-1.044			e
event_02.xml / Group_	10.74	Tracks_0	50.79	+	40.44	0.001	-0.701	85.53		e
		Tracks_2	61.99	-	45.00	-3.109	-0.844			e
event_03.xml / Group_	35.94	Tracks_4	101.93	-	39.75	1.040	1.594	88.18		e
		Tracks_7	56.50	+	42.23	-1.924	0.801			e
event_04.xml / Group_	15.68	Tracks_2	138.78	+	34.08	-2.503	-2.082	84.83		e
		Tracks_20	90.59	-	45.74	0.769	-1.306			e
event_05.xml / Group_	4.23	Tracks_0	100.90	-	21.83	0.965	2.212	93.51		e
		Tracks_61	112.10	+	73.07	-2.628	0.992			e
event_06.xml / Group_	10.60	Tracks_4	36.65	-	36.16	-2.546	-0.164	90.54		μ
		Tracks_6	87.87	+	37.43	0.566	-1.498			μ
event_07.xml / Group_	29.73	Tracks_13	70.34	-	43.63	1.088	-1.057	87.58		μ
		Tracks_15	89.31	+	43.27	-1.892	-1.353			μ

Fig. 1: *HY.P.A.T.I.A web application, fourth level*

2.1 Exercises

Four exercises have been developed for HYPATIA. They are available at the GoLab repository [13] as ILSs and follow the five stages of inquiry based learning (orientation, conceptualization, investigation, conclusion and discussion).

2.1.1 Discover the Z boson

In this exercise [14] the students study the leptonic decays of the Z^0 boson –one of the carriers of the weak force- into pairs of electron-positron or muon-antimuon. First they learn how to identify electron or muon tracks using their characteristic signatures on the various ATLAS subdetectors. They also learn about the concept of invariant mass and how to combine multiple tracks in order to infer the existence of a short-lived initial particle. Using the criteria given to them, they identify the Z^0 decay products and verify their selections by calculating the corresponding invariant mass. They also create histograms based on their result and in this way calculate the mass and width of the Z^0 boson. Finally they can discuss their results after comparing their findings with the values given in the bibliography and explain any resulting deviations.

2.1.2 Hunt for the Higgs boson

Based on the experience gained from the previous exercise the students take their search one step further and attempt to identify Higgs boson decays [15] into a pair of Z^0 particles which in turn decay into pairs of leptons ($H \rightarrow 4l$). In order to simplify the exercise, the events used consist of two real Z^0 boson decays superimposed into a single event. This way the students can use the experience gained from the previous exercise. However, since the events are not genuine Higgs decays, the resulting mass of the Higgs bosons is 182 GeV, higher than the discovered Higgs mass of 125,4 GeV. This exercise is always a student favorite because of the recent publicity of the Higgs discovery and subsequent Nobel Prize awarded to P.Higgs and F.Englert who predicted its existence more than 50 years ago.

2.1.3 Conservation of momentum

This exercise [16] is suitable for younger students and demonstrates a conservation principle that is part of any school curriculum. Specially selected events with only a few tracks are used so that the students can easily add their momenta using the two different vector addition methods they learn at school and the information given by HYPATIA. Since momentum is conserved in the transverse view, the students can compare their results to the missing momentum (ETMiss) [17] calculated by the application and discuss any differences that may occur. This demonstrates that fundamental physics principles, such as the conservation of momentum, apply to subatomic particles in exactly the same way as they do to the macroscopic world.

2.1.4 Magnetic field measurement

This is another exercise [18] that is directly linked to school curricula. It uses a newly developed functionality of HY.P.A.T.I.A and demonstrates how the Lorenz force that is exerted on charged particles moving in a magnetic field curves the particles' trajectories. Students can use the curvature of the tracks at the central part of the ATLAS detector to measure their arc radius and through the Lorenz force, calculate the intensity of the magnetic field in the central solenoid. This has also been tested at several schools with great success.

3. Conclusions

The Go-Lab project has been presented in science fairs and festivals like the Vilnius ICT2013 fair [19], the 2013 CERN Open days [20], or the "Science sets sail" Open Day in Chania [21] in dedicated stands. Thousands of visitors were given the opportunity to use workstations in order to get aquatinted with the Go-Lab HEP pilot resources, such as HYPATIA. Moreover, in a special session of the CERN Council in Brussels on the 30th of May 2013, dedicated to the update of the European Strategy for Particle Physics, the Go-lab project was presented as an exemplary online lab federation during the accompanying events. In one of the main outcomes of the meeting, the brochure "Accelerating science and Innovation - Social benefits of European research in Particle physics" in the chapter "Society and skills", it is reported that "The Go-Lab project (together with the Discover the COSMOS project [22]) are new ways of bringing frontier physics to schools; there have been remote masterclasses for students from around the continent" [23].

HYPATIA and the ILSs based on it have been presented as hands-on tools in a number of workshops and events held at schools all around Greece and abroad. It has been extensively used by students with great success. Together with other initiatives of the Go-Lab project, they have contributed to a significant increase in the interest of young students towards CERN as indicated by the 54% increase in the number of Greek high school students visiting CERN during the 2013-2014 school year compared to two years prior. This is a good example of the kind of impact such initiatives can have on the way young students view science and develop their interests.

4. Acknowledgements

This publication is partially funded by the European Union in the context of the Go-Lab project (Grant Agreement no 317601) under the Information and Communication Technologies (ICT) theme of the 7th Framework Programme for R&D (FP7). This document does not represent the opinion of the European Union, and the European Union is not responsible for any use that might be made of its content.

References

[1] [Online] http://www.go-lab-project.eu/frontpage
[2] De Jong T, Sotiriou S & Gillet D, Innovations in STEM education: the Go-Lab federation of online labs, Smart Learning Environments 2014, 1:3 doi: 10.1186/s40561-014-0003-6
[3] [Online] http://www.golabz.eu/
[4] De Jong, T., Linn, M. C., & Zacharia, Z. C. Physical and virtual laboratories in science and engineering education. Science, 340 (2013) p.305-308
[5] [Online] http://lhc-machine-outreach.web.cern.ch/lhc-machine-outreach
[6] [Online] http://www.faulkes-telescope.com
[7] [Online] http://atlas.ch
[8] [Online] http://hypatia.phys.uoa.gr/
[9] Johansson K.E. et. al. European particle physics masterclasses make students into scientists for a day. Phys. Educ., Vol. 42 (2007) p. 636
[10] [Online] http://atlas.physicsmasterclasses.org/en/zpath.htm

[11] [Online] http://hypatia.iasa.gr
[12] Kourkoumelis C. and Vourakis S., HYPATIA - An online tool for ATLAS event visualization, Phys. Educ., Vol. 49 (2014) p. 21-32
[13] [Online] http://graasp.eu/
[14] [Online] http://graasp.eu/spaces/547311d94c09ae2e54912a81
[15] [Online] http://graasp.eu/spaces/547311df4c09ae2e54912b4c
[16] [Online] http://graasp.eu/spaces/547310b74c09ae2e54911101
[17] [Online] http://hypatia.iasa.gr/en/help.html#missingtransversemomentum
[18] [Online] http://graasp.eu/spaces/547311f14c09ae2e54912ca1
[19] [Online] https://ec.europa.eu/digital-agenda/en/ict-2013-conference
[20] [Online] http://opendays2013.web.cern.ch/app
[21] [Online] http://www.iox.gr/cultural/50-other/269-2014-07-31-08-06-52.html
[22] [Online] http://www.discoverthecosmos.eu
[23] [Online] http://cds.cern.ch/record/1551933/files/Strategy_Report_LR.pdf