Introducing HEP to schools through educational scenarios

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The main task:

- Inform the public (general public, students, teachers, decision makers) about our research: our questions and our ways to answer them

- We should feel an obligation to do so because:
  - What we do is interesting and exciting
  - Can bridge the gap between research and education
  - Can create interest in scientific careers from younger ages
  - Can justify the money the tax payer pays...
Ways to achieve our goal

- Lectures
- Virtual Visits to an experiment (ATLAS, CMS, AMS, Icecube etc)
- Masterclasses (local or @universities)
- Hands-on
- Expositions
- Science cafes
- Multimedia material
- etc, etc

To give a good introduction to HEP need at least an one-day workshop with the interested parties.
The Tools
IPPOG International Masterclasses

Concept

- Students are in the position of a scientist
- Students are guided by a Master (lecturer or PhD student)
- Students form international collaboration
- Learn about fundamental subatomic particles and interactions, detectors, accelerators
- Active investigation: Measurements with real data from ALL LHC experiments (ALICE, ATLAS, CMS, LHCb)
Worldwide Participation

New countries for 2014:
- Australia
- Egypt
- Cyprus
- Palestine
- Romania
- Turkey

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HYbrid Pupil’s Analysis Tool for Interactions in Atlas

- Named after HYPATIA of Alexandria (370 - 418 A.D.)
- The first female mathematician/astronomer

On-line and off-line versions available for all platforms
Resources / Funding
HYPATIA developed in the framework of ATLAS outreach and EU projects (finished ones):

1) Learning with ATLAS@CERN (2009 - 2011)
   http://www.learningwithatlas-portal.eu/

2) The PATHWAY to IBSE (2011 - 2013)
   Focused on teachers
   FP7-Science-in-Society-2010-1
   http://www.pathway-project.eu/

3) Discover the COSMOS (Sept 2011 – Aug 2013)
   Focused on teachers + Students (HEP+Astronomy)
   FP7 Coordination action (UoA + CERN + TUDresden + UBirmigham)
   http://portal.discoverthecosmos.eu/

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Discover the Cosmos News

LHSee: an application for mobile phones and tablet PCs

Welcome to the Discover the Cosmos portal

The "Discover the Cosmos" coordination action aims to demonstrate innovative ways to involve teachers and students in eScience through the use of existing e-infrastructures in order to spark young people's interest in science and in following scientific careers. It aims to support policy development by a) demonstrating effective community building between researchers, teachers and students and empowering the latter to use, share and exploit the collective power of unique scientific resources (research facilities, scientific instruments, advanced ICT tools, simulation and visualisation applications and scientific databases) in meaningful educational activities, that promote inquiry-based learning and appreciation of how science works, b) demonstrating effective integration of science education with e-infrastructures through a monitored-for-impact use of eScience activities, which will provide feedback for the take-up of such interventions at large scale in Europe and c) documenting the whole process through the development of a roadmap that will include guidelines for the design and implementation of effective educational and outreach activities that could act as a reference to be adapted for stakeholders in both scientific research outreach and science education policy.

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Content of Discover the COSMOS repository/Activities

Discover the COSMOS Repository

The Discover the COSMOS Repository contains educational material in the form of educational content (photos, videos, animations, exercises, graphs, links) and of learning activities (structured lesson plans organized according to specific pedagogical models such as inquiry based Learning and Guided Research). Users can search for the educational materials in the "Explore Discover the COSMOS" section or to upload their own materials to the Discover the COSMOS Repository, using the "Share your Content" section.

Explore Discover the COSMOS

Search for Educational Content (90205)

Search for Learning Activities (625)

Share your Content

Upload Educational Content

Upload Learning Activities

moCERN

The Discover the COSMOS Repository goes mobile! Now, Discover the COSMOS Educational Content is available for mobile and handheld devices. Visit moCERN and explore the HEP resources and MoCo and explore the Astronomy repository through your mobile phone.

Visit the DISCOVER the COSMOS Camp in Second Life! Explore the Universe, the ATLAS Detector and numerous other contents of the repository through a unique immersive experience in a realistic context. From here you can download and install Second Life Viewer which is used for entering the Discover the COSMOS Camp in Second Life. Teleport to Discover the COSMOS Camp.

Discover the COSMOS Tutorials

The Discover the COSMOS consortium has produced a series of video tutorials on particle physics, astronomy, astrophysics and high energy physics subjects. To access these tutorials click here.

~ 95,000 items in Educational content
~ 630 educational scenaria (HEP/Astronomy)

HEP tool-box
- HYPATIA
- MINERVA
- CAMELIA
- CERNland
- LHCgame

5,000 teachers and 31,000 students reached
850 impl. activities in schools
2,000 schools continuing
Activities supported by the new EU projects:

- Go-Lab (Nov.2012 - Nov.2016, 20 partners)
  
  http://www.go-lab-project.eu/

- Inspiring Science Education (ISE) (April 2013 + 40mo, 31 partners)
  
  http://inspiring-science-education.org/
CERN Council updated the European strategy for particle physics at the European Commission meeting

• “Discover the COSMOS” and “Go-lab” were one of the ten “talking” points presented as “on-line labs” to CERN council, ministers and EU officials

• The Strategy report brochure distributed under chapter “society and skills” stated:

  Discover the Cosmos and the Go-Lab project are new ways of bringing frontier science to schools; there have been remote masterclasses for students from around the continent.
More Details on HYPATIA
The IPPOG downloadable IMC version hypatia.phys.uoa.gr (works in all operating systems)

Reconstructs invariant masses of short-lived particles

Used in Z-path (Z → ll, H → 4l and H → γγ)
UoA started using LHC data with HYPATIA in 2007 “unofficially” (HYPATIA developed with help from ATLAS outreach)

IMC: Official start 2009

Number of “Z-path” classes from 9->$67

Z-path is the most popular

- 199 IMC 2014 Masterclasses (Fermilab: 29)
  - ALICE: 14
  - ATLAS W: 51
  - **ATLAS Z: 67 (13)**
  - CMS: 46 (19)
  - LHCb: 21

Constantly improving the software as needs arise

2014 numbers of IMC

*U.Bilow+K.Cecire, Zeuthen 2014 IPPOG Report*
2013 change:
Added the Higgs histograms
- $\gamma\gamma$ invariant mass plot
- 4l invariant mass plot

2014 change:
Separated the 4l Higgs invariant mass plots
- $2e2\mu$
- $4\mu$
- $4e$
On-line: http://hypatia.iasa.gr (works on mobile phones, tablets etc) English, French, German, Greek

Short event files:
Z, “home made” H-\(\rightarrow 4l\)
+ Extensive help
+ hidden solutions to the questions

- Anybody can try it online and spent from few minutes to hours and adjust level of difficulty
- Can also use it as a basis of building educational scenaria
Main page with four questions, each with increasing level of difficulty (from 12 yrs)

Do you want to make histograms of the new particles and learn about their width (Heisenberg uncertainty principle)?

Do you want to discover invisible particles? (Z⁰, 91 times heavier than the proton)?

Do you want to learn how to identify tracks and distinguish electrons from muons?

Do you want to learn what happens when protons of the highest energy in the world collide with protons of the same energy?
New HYPATIA feature: Track thickness proportional (log scale) to their $P_T$. 
The following four HYPATIA lesson plans were developed for Go-lab using the full Inquiry Based path: Orientation, Conceptualization, Investigation, Conclusion, Discussion.

1. Conservation of momentum
2. Measurement of the magnetic field using the giant ATLAS detector
3. Discover the Z boson
4. Hunt for the Higgs boson
Conservation of Momentum

34 GeV

1 GeV

3 GeV

7 GeV

39 GeV
Measurement of Magnetic Field

\[ B(T) = \frac{p_T (GeV/c)}{0.3 \times R(m)} \]

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For the rest of HYPATIA’s HEP scenario: 

1) Discover the Z boson 
2) Hunt for the Higgs boson 

One needs to:

I. Identify electrons and muons by their different signatures in the detector 

II. Calculate invariant masses of short-lived particles Z’s or H’s decay particles 

III. Make histograms and measure width 

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Goal I: Learn a few things about the interaction of particles with matter
Goal II: The Z and Higgs bosons decay immediately so we observe their decay products

- Higgs → $b + \bar{b}$ (b quark and its antiquark)
- Higgs → $\tau^+ + \tau^-$ ($\tau$ lepton and its antiparticle)
- Higgs → $\gamma + \gamma$ (two photons, also called gammas)
- Higgs → $W^+ + W^-$ ($W$ boson and its antiparticle)
- Higgs → $Z^0 + Z^0$ (Two Z bosons)

- $Z \rightarrow e^+e^-$
- $Z \rightarrow \mu^+\mu^-$

$e^+ + e^- + e^+ + e^-$
$e^+ + e^- + \mu^+ + \mu^-$
$\mu^+ + \mu^- + e^+ + e^-$
$\mu^+ + \mu^- + \mu^+ + \mu^-$
Goal III: Invariant mass calculation of Z(H)
Done automatically by HYPATIA (but if there is time students can try out the calculation)

\[ m^{(Z)}_0 = \sqrt{(m^{(1)}_0)^2 + (m^{(2)}_0)^2 + 2 \left( \frac{1}{c^4} \cdot E_1 \cdot E_2 - \frac{1}{c^2} \cdot \vec{p}_1 \cdot \vec{p}_2 \right)} \]

Goal IV: Mass Histogram

- Is there a peak??
- How many events lie outside the peak?
- At which mass does the peak correspond?
- What is the width and why is it non-zero?
We do not expect to achieve all the goals BUT in one school we had ALL the participating 15 year old students “discover” the hidden Higgs events
Activities / Impact
Local Masterclasses, e-Masterclasses & Virtual Visits

- **Masterclasses @schools ("mini" ones)**
  - 50 schools all over Greece (Komotini to Crete)
  - Students learn how actually science goes
  - Listen to lectures
  - **Follow a virtual visit to ATLAS control room**
  - Analyse events with the HYPATIA on-line tool

- **e-Masterclasses**
  - Dutch (9) & Polish (43) students (Nov.12)
    - “Learn how actually science goes”
    - Teachers’ role (e.g. HST12 participants)
    - Targeting extended group visits
  - **Synergies with local-level MCs**
    - + CERN Hangouts (Polish students)
    - + CERN Mini Expo (Santiago de Compostela)

- **VV with a cluster of schools**
  - CMS (10), ATLAS (10+2 from Cyprus)

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Masterclasses and VV in Greece (last two years)

31 ~50 schools

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Masterclasses and VV in Europe (last two years)
Increase of CERN Visits by GR High Schools

As an example:

- “Odysseus' Comrades” team from Varvakios Pilot School in Athens won the “beam line” competition
- Their teacher A.Valadakis has followed many of our masterclasses, has used HYPATIA in the school and brought his students to CERN several times
CERN OPEN DAYS
September 28th-29th 2013
A crowd of about 3,000 visited the “Discover the COSMOS” and “Go-lab” stand in 24 hours and got a demonstration of our resources.
Six large screen PC’s and four ipad’s were set-up to run: MINERVA, HYPATIA, “Collisions”, LHC game and CERNland.
The upgrade of the CERN “mini-expo” visit to Greece 2011-2012, followed by visits to Spain/Serbia/Cyprus

- **Alexandroupolis**
  - 8-18 December 2011 (4000 students, 80 teachers)
  - TOWN OF 50,000 people!!

- **Kavala**
  - 10-29 February 2012 (3500 students, 70 teachers)

- **Volos**
  - April 2012

- **Patras**
  - May 2012

- **Athens**
  - 10-27 November 2011 (6000 students, 500 teachers)

- **Heraklion**
  - 12-27 March 2012 (3000 students)

- ~14,000 students visited
~650 teachers trained in concurrent workshops
Mini EXPO Spanish tour
9 months, 9 cities

- Public lectures (Higgs)
- Guided tours
- Training of teachers (mostly in the framework of PATHWAY)
CERN expo visit in Greece 2014
One month in Athens (May 2014) in Eugenides foundation (science museum plus planetarium)

~ 11,200 visitors
~ 4000 students from 92 schools
Trained ~120 teachers in HYPATIA workshops
HYPATIA “demo” running during the exhibition
Conclusions

- Have been interacting with teachers and students in order to introduce HEP in schools for several years
- Have reached thousands of teachers and students
- With help from ATLAS, five EU outreach programs and feedback from our school activities we developed the HYPATIA tool
- Off-line and on-line versions available and several full lesson plans

Please join us in our efforts and share your enthusiasm for your research with others