Introducing HEP to high-school and university students through the ATLAS event analysis tools

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The HEP main challenge:

How can we provoke students’ curiosity for HEP? (which in most countries is absent from the national curriculum)

- So far a lot activities for high school students (IPPOG’s International Masterclasses, mini-masterclasses, virtual visits to the experiments, Quarknet, etc etc)
- The students get engaged in hands-on experimentation directly connected to top-level real-time research and discoveries
- EU outreach projects developed a lot of material which is ready to be used in the duration of a school lesson
- At University level enhance labs with research tools
The running EU outreach projects +CREATIONS

- Go-Lab (Nov. 2012 - Nov. 2016, 20 partners)
  - Online science laboratories for the large-scale use in schools
    - [http://www.go-lab-project.eu/](http://www.go-lab-project.eu/)
      - 385 on-line labs
      - 343 Inquiry Learning Spaces
      - 37 Apps
      - In all STEM curricula subjects in 10 languages

- Inspiring Science Education (ISE) (40mo, ending 31/7, 31 partners)
  - eLearning tools for 5,000 schools in 14 countries
      - 120 Demonstrators (in all STEM curricula subjects)
      - +Harvested existing repositories with 278,000 educational resources (mainly ODS and DtC)
      - In two years has reached 2750 schools
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)

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.

moCERN

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 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 and continuing
Developing an Engaging Science Classroom

- 36 months, 1,8 ME, 7 WPs
- Coordinator: University of Bayreuth
- This week summer school for teachers@Marathon

16 Partners
CERN (Art@CMS), UoB, IASA, STFC + Quarknet +Science Opera etc

http://creations-project.eu/

http://creations.ea.gr/
#1. All material in the Universe is made of very small particles
HEP applications
The main tool: HYPATIA
Best practice

• Offline version used by IPPOG’s Z-path http://hypatia.phys.uoa.gr/
• Online version http://hypatia.iasa.gr/

has been used since 2010 in about 150 Greek schools across the country

Local Masterclasses, e-Masterclasses & Virtual Visits
Students learn “how science actually works” (half day)
➢ Listen to lectures
➢ Follow a virtual visit to the ATLAS control room
➢ Analyse events with the HYPATIA on-line tool
➢ Scenarios for different ages are available
ISE HYPATIA demonstrator +PISA assessment questions
Masterclasses and VV in Greece (last two years)
Tested demonstrator (February 2015-May 2016) in **76 schools** at seventeen different locations (urban, sub-urban and rural schools) ~**270 students**

Problem solving competence -> Higher than “PISA”
In addition developed material for University students since most resources were addressed to high-school

**Decided to target University students**

- Up to now very few universities had such lab courses addressed to their students
- University of Athens has been one of the few, BUT was using small set of ATLAS data
- Need experimental data (real and MC)
- Multiple groups have shown interest in obtaining larger datasets
- So an effort was launched by the ATLAS Outreach Data and Tools group to define the data and is about to get approval for 1fb\(^{-1}\) data (an ATLAS note under preparation)
- Have developed a batch process event analysis which optimizes cuts for the Higgs→4l search
Methods of analyzing large event samples

We investigated (and worked) on several options

– Offline HYPATIA (the IMC version) too slow, data files too large
– Root analysis, more or less ready but we didn’t develop it further
– Online HYPATIA analysis (which won the “best visualized experiment award” by the online labs IEEE consortium). Fully developed
University Student analysis using HYPATIA (1)

Use the large datasets to process events in batch mode for:

- teaching data analysis strategies such as selection optimization, histogramming and statistics
- detector and accelerator physics

HYPATIA has been running on event-by-event display mode -> modification to run large datasets
University Student analysis using HYPATIA (2)

After **visually** inspecting some events

- Process many events in **batch jobs** (which have some minimum defaults cuts)

- A GUI opens to set manually **cuts** like $p_T$, $d_0$, $|z_0-vrtx|$, isolation, invariant mass range

- Inspect histos (signal/real data and MC) → rerun, etc

  - Run on 2 leptons (look for Y, Z, Z’)
  - Run on four leptons (Higgs)
Implemented in the online HYPATIA
EXERCISE VI - Event batch processing

Using large samples (consisting of thousands) of events, study the histograms and select the appropriate parameters which will allow you to separate the signal (Higgs boson decays) from the background.

Detailed instructions

http://hypatia.iasa.gr/en/exercise.html#part6

- Comes with a full 10-page instruction manual
- Event files are built-in (converted from mini-trees provided by the ATLAS event tool group) For the moment are password protected (till the official release)
- **Runs VERY fast (300k events in < 1 sec)**
- And questions to the students for their write-up
When the “batch processing” mode is chosen a GUI opens up where the student can select and optimize various cuts and check histograms of significance, signal/background etc.

Higgs 4l analysis (MC signal and bkg files)
Optimization technique

Optimize cuts by “N-1” method

Use MC samples for both signal and background

- Apply all cuts except the one under study and plot its distribution
- Determine the optimum cut value by looking at the significance plots

\[
\text{significance} = \sqrt{2 \cdot (S + B) \cdot \ln \left( 1 + \frac{S}{B} \right) - S}
\]

- Iterate for all cuts
- Plot invariant mass of 4 leptons and try to maximize signal/bkg
Examples of cut optimization based on the significance for isolation and impact parameter

Track Isolation

Muon $d_0$ significance
Indicative results:
Indicative results:

Before cut optimization between 120-130 GeV
Signal/Background: 1/2

After cut optimization
Reduction of background >10
Loss of signal ~20%
Indicative results:
The first implementation to the 3rd year physics students labs was done on Winter 2015 semester
About 60 students – interested in particle and nuclear physics - participated in lab
It involved two 3 hour parts:
- Visual inspection of 50 events, identification of e’s, μ’s, Z’s and ZZ events
- The batch analysis described here

The results are VERY encouraging!! All students performed very well and liked the lab!
Will add the real data set and do comparisons
Resume next fall
BACK-UP
How can we attract students interest in science education (STEM and STEAM)?
(Their interest is decreasing with age)

In general:

- Train teachers in intergrading IBSE in the classrooms
  -> gradually change their teaching approach
- Promote use of existing ICT, new methodologies and new eLearning tools ready to be used in the classroom
- Resources should be linked to the curricula
- Build teacher communities
- Engage learner in scientifically oriented questions
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</table>

*muon P_T threshold is high (>25 GeV) but will be fixed