Cosmic ray detectors for high schools in France
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CNRS/IN2P3 detectors for educational activities related to particle physics

The well-recognized « Cosmodétecteur »

The new « COSMIX » case

« COSMAX »: a data analysis framework for Fermi-GLAST data – γ ray sky

Outlook

Cosmic rays

The « Refuge des Cosmiques » (Chamonix valley) awarded « EPS historic site » in 2012
→ Long tradition of cosmic ray studies in France

2012 CNRS/IN2P3 exhibit: « The mistery of cosmic rays »

http://www.in2p3.fr/physique_pour_tous/informations/manifestations/expo_RC/expo_RC.htm
Cosmic ray detectors for high school education

- After some years of eclipse, topic related to particle physics – special relativity, \( \mu \) lifetime, \( \beta \) decay, etc. – are back in the French high school physics curriculum
- How to give students a taste of the « infinitely small »?
  - Watching the sky opens a window onto the « infinitely large »
  - No particle detector equivalent to a simple refractive telescope

→ Cosmic rays are an invaluable educational tool!

- Allow the students to sense (elementary) particles
- Give a feeling of the problems raised by their detections

- CNRS/IN2P3 labs involved for many years in projects based on cosmic ray detections
  - Examples: « Cosmophone », « Cosmic arch »

- In the following, focus on 3 educational projects targeting high school students and their teachers

The « Cosmodétecteur »

- Designed and built by José Busto and his team at the CNRS/IN2P3 « Centre de Physique des Particules de Marseille » (CPPM)
- 3 scintillator plates with a photomultiplier on top
- A DAQ system to trigger on 2fold- or 3fold-coincidences
  - To remove background
- A Labview interface to steer the detector, monitor data taking and record data (ascii)
- A movable « cosmic wheel » to look at the cosmic muon zenithal distribution

Full price about 8,000 €, including a laptop & a transportation box
Additional detector elements

- A Cherenkov radiator
- A scintillator tube to measure the muon lifetime in a light guide

→ Used to show that μ’s come from above

→ A μ enters the scintillator (1st signal) and stops An e⁻ is emitted when it decays (2nd signal)

Example of histogram for $t_2-t_1$
[Measured by high school students]

Measured μ lifetime = 2.26 μs
[PDG: 2.19 μs]
Partnership with « Sciences à l’École »

• « Sciences à l’École » is a project from the French Education ministry which is promoting Science in high schools and higher education

• Action based on three main pillars
  ▪ **Financial support to projects** bringing scientists to classes or creating resources
    → LUNAP: « The Universe within easy reach »
    → CDC: « Researchers in classes »
  ▪ **Loan of scientific equipments to high schools**
    → Cosmic ray detectors: « Cosmos at schools »
    → Other programs: astronomy, seismology, genetics, meteorology
  ▪ **Science challenges for groups of students**
    → National: physics Olympiads, « C.Genial » (« That’s brilliant »)
    → International: EUCYS, CASTIC, physics Olympiads

www.sciencesalecole.org
Educational activities based on the «Cosmodétecteur»

- To measure the angular distribution of muons
- To measure the muon lifetime
- To highlight the radioactivity of some products ($^{40}$K, etc.)
- To use the Cherenkov effect to find the muon direction
- To study particle showers
- To study how particles interact with matter

**A hands-on experience**
- Calibration
- Discrimination
- Coincidence

![Raw muon angular distribution](image1)

**«Plateau» measurement of a photomultiplier**

![Figure 4: Distribution zénithale des muons](image2)
Educational activities based on the « Cosmodétecteur »

- All teachers who receive a « Cosmodétecteur » follow two training sessions
  - 5 days at CERN: French Teacher program sponsored by the CNRS/IN2P3
  - 3 days at CPPM to be trained in the detector

- In addition, meetings among teachers are organized to exchange information about their experience and the educational activities developed with the detector

- Each teacher receiving a « Cosmodétecteur » on loan benefits from
  - an educational leaflet which includes an introduction to particle physics, a description of the detector, info about operations and data analysis, such as a list of experiments to carry out
  - advices from a CNRS/IN2P3 physicist who acts as a mentor
  - support from the teacher educational authority

- With the new curriculum, the detectors are used during regular teaching hours and not just for research projects or hands-on activities
Circulation of the « Cosmodétecteur »

- A network of 46 high schools from 18/26 regional education authorities
- 1,100+ students

- Once they have been trained, teachers train colleagues
  - From their high school
  - From their area (teacher training sessions)

- Teachers get a « Cosmodétecteur » for 3 years and usually make it circulate in their school and locally

First prize at the 2010 French physics olympiads

☆ and ●: high schools equipped before 2013
◆: high schools equipped in 2014
Prospects for the « Cosmodétecteur »

- Strengthen the teacher network
  - Online forum to exchange feedback and information
  - 2 days of joint data taking organized in 2014

- Organization of more formations for teachers

- Produce new ressources related to particle physics

- Create synergy between educational/outreach projects
  - For instance Masterclasses
  - or « Passeport pour les deux infinis »
  - All gathered in the « Ecole des deux infinis »
    at the CNRS/IN2P3 level

A virtual « Cosmodétecteur » in a virtual world designed by a physics teacher
The « COSMIX » detector

• A portable cosmic muon detector
  ▪ Compact and light
  ▪ Plug-and-play
  ▪ Robust
  ▪ Background-free data

• Developed at a CNRS/IN2P3 lab, the « Centre Etudes Nucléaires de Bordeaux Gradignan », (CENBG) by Benoit Lott and Denis Dumora

→ Quick and easy introduction to cosmic rays to audiences which do not have access to a « cosmodétecteur »

• Various applications
  ▪ High schools
  ▪ Outreach talks
  ▪ Museums, laboratory open days, etc.
The « COSMIX » case

- Two l×w×h = 16×3×2 cm³ CsI(Tl) bars from Amcrys
- Hamamatsu PIN diodes
- Consumption ~300 mA
- 5V power (e.g. from laptop)
  - 7000 mAh battery for mobile measurements
- Cost ~1000 €
  - Reduced by a factor ~2 by recycling existing detectors (Fermi-GLAST R&D) and electronics
- Case
  - Weight < 4 kg
  - Dimensions: ~44×36×12 cm³
Experiments

• Energy deposit: ~12 MeV for cosmic muons >> background particles
→ All analog signals come from muons

• Two data-taking modes:
  Single rate
  ~1 evt/s
  Coincidences
  [One bar is movable]
  ~0.4 evt/s

• All high schools have scopes nowadays

• DAQ system based on an Arduino micro-controller and a SD memory card
  ▪ Event counting + data recording (ascii format → easy offline analysis)
Cosmic ray rates vs. altitude

Private plane flight up to 1,800 m

Commercial flight up to 10,000 m

Pressure drop w.r.t. ground [hPa]

COSMIX rate [/minute]

Paris subway

Altitude [m]

Scintillator bar rate [/minute]
Circulation of « COSMIX » detectors

• 2013: 3 test cases (2 funded by « Sciences à l’Ecole ») – circulated around Bordeaux
  ▪ More than 1,000 students from 15 high schools used them
    → Feedbacks helped improving the design
  ▪ One prototype now in the Réunion island
  ▪ Another one is running in this room… 😊
    → Come and have a look at it during the break!

• 2014: first « mass production »
  ▪ 10 cases for the « Ile de France » region (Paris area)
  ▪ 8 for CNRS/IN2P3 labs
  ▪ 12 more (TBC by the end of the month)
    for the « Aquitaine region » (Bordeaux area)

• Enough crystals to make 12 more such cases – next year

• Plan is to create a collaborative website to allow « COSMIX » users to exchange data taken in various conditions – from the Eiffel tower to an underground lab!
Another project: « COSMAX »

- **COSMAX: COSMic ACCelerators** – same developers as COSMIX
- Provide access to the very variable gamma ray sky using Fermi-LAT data
- Production of time-resolved maps or animations
- Data: public, all-sky, easy to grasp, readily available
- Study of many transient phenomena (blazars, gamma ray bursts, pulsars)
- Same tool and data than the scientific community
- COSMAX is based on a suite of tools installed on a ready-to-use VMware Linux machine for windows – or directly working on Linux

Outlook

• CNRS/IN2P3 and partners are developing educational projects based on particles coming from the cosmos: (charged) cosmic rays and photons
  ▪ Part of a global outreach effort targeting teachers, students and the general audience

• The well-recognized « Cosmodétecteur » project started a decade ago, in collaboration with « Sciences à l’Ecole »
  ▪ Large cosmic detectors loaned to selected teachers
  ▪ Associated support: advices, ressources, etc.

• The new « COSMIX » detector
  ▪ Mobile and easy to use to introduce cosmic rays to audiences w/o access to the « Cosmodétecteur »

• The « COSMAX » sofware project for γ-rays
  ▪ Fermi data are « simple » and easy to manipulate

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