An Astroparticle Physics Research Project for High School Students

Mark Pearce
KTH Particle Physics
Aims of SEASA

High school students have only a cursory exposure to the most stimulating and open questions in physics today (ie: the stuff hidden away in the final chapter of the textbook...)

The SEASA project aims to stimulate high school students into choosing the science program and to pursue science or engineering at university

How? ...

... through hands-on experience of forefront science and technology
Cosmic rays... 

...linking the very large to the very small
• Above ~ $5 \times 10^{19}$ eV, space becomes opaque to cosmic ray protons
• Sources of CR with energies above the GZK limit must be 'close', < 50-100 Mpc
• No known acceleration sites for such high energies...

$p + \gamma_{\text{cmb}} \rightarrow \Delta^+ \rightarrow p + \pi^0$

$\rightarrow \Delta^+ \rightarrow n + \pi^+$
Where are they from?

How are they produced and accelerated?

How can they reach us?

### 'Bottom-up'?
- Ordinary hadrons accelerated to ultra-high energies... GRBs?

### 'Top-down'?
- Cosmic rays are born energetic... super-heavy decays / topological defects

New laws of physics at high energies?
Detecting Cosmic Rays

Top of Atmosphere

Ground
Ground Airshower Detector Array

$10^{19}$ ev shower

The lateral shower profile is measured
AGASA
Akeno Giant Air Shower Array

111 scintillators + 27 muon detectors
Flux $\times 10^{30} \text{ (eV}^{-1}\text{ m}^{-2}\text{ s}^{-1}\text{ sr}^{-1})$

$\log_{10}(E)$ (eV)

- HiRes-2 Monocular
- HiRes-1 Monocular
- AGASA

20% energy variation

by Douglas Bergman
The Pierre AUGER Observatory

- angular speed variation determines geometry
  - monocular mode needs long tracks

- Issues:
  - fluorescence yield
  - Cherenkov subtraction
  - atmospheric transmission

- Stereo!
- Hybrid!

from Fly’s Eye 1985
1600 water Cherenkov detectors with 1.5 km spacing on 3000 km²
4 stations with 24 fluorescence telescopes
(1) Scintillator detectors...
(2) Timing system...
$t_1 = t_2 = t_3$?
The GPS Constellation

- 24 satellites
- 6 orbital planes
- 4 satellites per plane
- 20200 km altitude / 55° inclination

- Anywhere on the earth ⇒
  - 4 satellites above horizon

4 satellites ⇒ lat. / long. / height / time
1 satellite ⇒ time (if position known)

*Clinton's turns off 'Selective Availability – May 2000'*
Event time = 10 ns x n + yy/mm/dd:hh/mm/ss

100 MHz counter

Start  Stop

GPS

Pulse per second ('PPS')

1 2 3 4

Secs
The diagrams illustrate the distribution of time differences between GPS 1 and GPS 2, with separate plots for 'Corrected' and 'Raw' data. The horizontal axis represents the trigger number, while the vertical axis shows the time difference in nanoseconds. The corrected data shows a narrower and more defined peak compared to the raw data, indicating reduced variability and improved accuracy.
Time evolution of difference for corrected data, with satellite changes (red=card 1, green=card 1 - card 2)

# of satellites
Analog front-end

Analog

Digital

~10ns

V_{ref}

School 1

GPS

PPS

RS232

Ethernet

School 2

School 3

School 4

School 1

Analog
t_1
t_2
t_3

Digital

Programmable Logic Array

Single Chip Computer (Linux)
Shower Direction
Also:
- Germany
- Poland
- Portugal
- UK
- ...

Mark Pearce - KTH Stockholm -
ALTA -- A Collaboration between local area high schools and the University of Alberta in the area of cosmic ray research


~30 Schools Involved
7(9) FULL Detector systems operating with data being recorded.

Size of planned Auger detector
• School arrays in the US benefit greatly from recycled parts from ‘professional’ arrays...

• Hands-on work programs for students (& teachers)
• Co-ordinated workshops
• Several arrays are now taking data and seeing showers!
### Curriculum Topics Available in CROP

#### Classroom Curriculum
- History of cosmic rays
- Charged particles in matter
- Scintillators & photomultiplier tubes
- Cosmic ray energy spectrum
- Julian calendar, UTM, galactic coordinates
- Global positioning system
- Ionizing particle detectors
- Calorimeters and showering
- Particle zoo and Standard Model
- Tour of particle accelerators
- Random events, probability
- Monte Carlo simulations
- Lightning protection

#### Lab Curriculum
- Polishing, cleaning scintillator
- Gluing PMT and wrapping scintillator
- Assembling high-voltage supply
- Oscilloscope lesson
- Turning on counters, source tests,
  finding/fixing light leaks
- Measure counter efficiency, high voltage plateau
Research Possibilities...

- Large, time correlated array with local pointing
  - Study of Ultra-high energy cosmic rays
  - Correlations between multiple primaries
  - Time structures in shower arrivals
  - Unknown effects...
A distributed data acquisition system – not only for cosmic rays...

... stand-alone or correlated to cosmic rays

Temperature / humidity
Background radiation
Siesmograph
Air quality
Magnetic field
etc. etc.

Ethernet
Summary

• Next step: deploy a scintillator station on the roof and identify showers...

• ... then deploy a second station to check GPS time correlation

• Expansion to high schools depends critically on the funding received

• MAY make a significant contribution to physics...

• ... WILL help to motivate students to study physics!
http://www.particle.kth.se/SEASA