Vision Statement for Cosmic Ray Detector

A great moment of clarity happened for me the first time I got my hands on a particle physics detector. All the vague, yet intriguing, forces of nature at the quantum level became real and made sense. For myself, it happened much too late in my education. The Fermilab cosmic ray detector system gives high school students the opportunity to make physics *real*. It's an exciting and fascinating way to learn about cosmic rays, astrophysical sources, particle physics, modern detector equipment and hands on learning that develops life-long skills in whatever career they end up pursuing.

In addition, the cosmic ray detector system allows students to conduct their own experiments and learn all which that entails, including the following: how the detector works (scintillators, pmt tubes, DAQ board, post process on the computer), how to calibrate and test a system, understanding background, measuring background signal, measuring signal to noise levels, measuring efficiency, designing an experiment, dealing with the pitfalls of doing a real-life experiment (as opposed to the normal canned experiments a la Pasco/Vernier equipment), data analysis, fitting data to non-linear curves and feeling the excitement of diving into the unknown.

I believe the cosmic ray detector setup should be used to do 'new' and interesting experiments like muon lifetime, shielding, searches for very high-energy particles, etc. The students are excited by the notion that their experiment could be relevant to increasing our knowledge of the universe. Students really step up when they are doing something 'real'.

Several years ago I did the muon lifetime experiment with a couple students using the UC Santa Cruz upper division lab equipment. We had a lot of fun and the students learned a lot about particle physics, setting up an experiment, measuring background signal, doing a background subtraction, analyzing data and understanding the statistics and what 95% C.L. really means. In this setup the students used logic units to do coincidences, vetos, and delays. They learned a lot by moving the cables between various logic units and working through the logic and studying the outputs on the oscilloscope.

Last year I received a Fermilab cosmic ray detector. Overall it is an amazing detector and a great learning tool. However, I was disappointed that so much was already done for the student on the DAQ card and so little flexibility installed (it would have been nice to have the ability either with jumpers or in code to set up the experiment themselves). I was also disappointed in the output (the string of hex numbers) and the scattered documentation of its meaning and commands.

What I did was have a student write a python code to work with the detector (just as scientist do in particle physics). He wrote a nice code that made the board user friendly and gave the experimenter options (i.e. the student decides on what he wants to do and how). He wrote another subroutine for testing the quality of the scintillator/pmt tubes and another for plateauing the scintillators and another for doing a basic experiment with the detectors. He learned a heck of a lot!

Next year, we plan to build on his code by implementing 'cuts' (so that the experimentor can require certain elements in order to accept the data, like requiring TOT to be above a certain number, requiring number of coincidences, vetos, delays, etc.). This will allow the user more flexibility so that he/she can do the muon lifetime experiment, measure efficiency, background, search for different exotic signals, etc. I do realize that the e-labs system that Fermilab setup has a data processing system but it is very limited and a complete black box to the student. I didn't feel they would learn anything except a few obscure commands. In addition, there was no way to check if it was accurate.

Writing code might not be for everyone. To accommodate the average user, I suggest that Fermilab create a visual basic or java type program so that students can make these 'cuts' on the data and see the effects right on the graph. The files are finite and there are not that many handles. This would be an easy code to write and might be done in the form of the very successful PHET simulations. This would make it easy to use for everyone and also allow maximum flexibility and limit the black box aspect. Students then share their results by writing real science papers (in the same fashion that scientists have done for centuries) that are then refereed and discussed. It seems a student scientist conference where the young experimenters could give talks and share results would then be in order.

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