QuarkNet Day at SLAC

Cosmic Ray Detectors

Intro to cosmic rays

- What are cosmic rays?
- Where do they come from?
- What is known about cosmic rays at the surface of the Earth?

What are cosmic rays?

- Different forms of matter/energy traveling through space
- Primary "cosmic rays" include protons & nuclei of heavier elements
- Secondary ("processed" by Earth's atmosphere) are mostly muons and electrons (from showers)
- Other forms include: photons (radio waves, microwaves, visible light, x-rays, gamma rays) neutrinos, other charged particles, exotics (dark matter, dark energy)

Where do they come from?

- Many sources: supernovae, black holes, stellar collapse/expansion,…
- The magnetic fields in the universe "stir them up"
- Difficult to associate with specific sources
- They appear isotropic to observers

What is known about cosmic rays at the surface of the Earth?

- Mostly muons (≈70/m^2/s/sr [PDG])
- Zenith angle distribution ~$\cos^2\theta$ (grazing muons decay in the atmosphere)
- Energies vary over many orders of magnitude

QuarkNet Cosmic Ray Detector

- (look to your left!)

How does it work?

- Charged particles traverse scintillating plastic where molecules are excited; de-excitation produces flash(es) of light.
- Light bounces around in plastic and strikes Photomultiplier Tube (PMT).
- Photo cathode on PMT absorbs light and releases one or more electrons (photoelectric effect)
- Dynodes (electrodes) at HV accelerate electrons and multiply their numbers (secondary electron mission)
- Voltage/current pulse exits PMT and enters Base circuit where it is transmitted into the logic board
- Signal is compared with a pre-established threshhold; a trigger is formed by requiring a coincidence between two counters.
- Signals are digitized (converted into numbers) and sent to computer via serial port
- Computer records and histograms each event

Experiment #1 - Cosmic Ray incident rate vs. zenith angle

- Measure incident cosmic ray flux at Earth's surface at various incoming angles
- Compare with known distribution

Experiment 1: Basic steps

- Assemble and adjust apparatus; record setup information
- Initialize logic board and check basic functionality
- Place counters in vertical orientation, collect ~1000 data; record information
- Rotate detector 45 degrees, then 90 degrees and repeat above step
- Analyze data and plot results

Assembly

- Exercise *extreme care* handling detectors! Treat them like your grandmother's delicate crystal goblets.
- You must have a computer with a serial port (running Windows) to follow these instructions
- Detailed instructions on web (soon), http://www.slac.stanford.edu/quarknet/CRD.
- We will perform this assembly as a group project in just a few minutes

Check Basic Functionality

- Use PC to configure logic board with the commands `WC 0 01` and `WC 0 02` to verify each counter is working (watch scaler). [channels 0 and 1]
- Configure logic board with the command `WC 0 13` which requires a *coincident* signal from both counters.
- Orient detectors vertically and as close together as possible (about 33 inches), reset on-board scaler and count for 2 minutes. You should expect to see between ~ 10 counts.

Sample Data Recording Sheet

		Experiment 1 WORKSHEET					
Measure incident cosmic ray flux at surface of the Earth as a function as azimuth angle							
Date:							
Time:							
Name(s):							
	TOP	BOTTOM					
Detector #							
Base #							
Channel #							
Threshhold (mV)							
Dial setting							
Detector orientation							
Number of counts							
Start time							
End time							
Time period (End-Start)							
Counts/min							
Uncertainty							

Statistics

- Cosmic rays strike the earth randomly in a way described by the Poisson distribution.
- The uncertainty associated with the randomness in a counting experiment of this type is estimated by taking the square root of the number of counts.
- Since the number of counts rises faster than the square root, one benefits from collecting as much as practicable.

Analyze Results

- Convert the number of counts from hexadecimal to decimal
- Calculate the number of counts/minute and the statistical error for each position of the detector.
- Plot the number of counts/min (x-axis) vs. the angle θ (y-axis). Include error bars to indicate uncertainty
- Plot the number of counts/min vs. $\cos^2\theta$, along with error bars. Why is this plot more interesting?
- What other sources of uncertainty can you imagine?

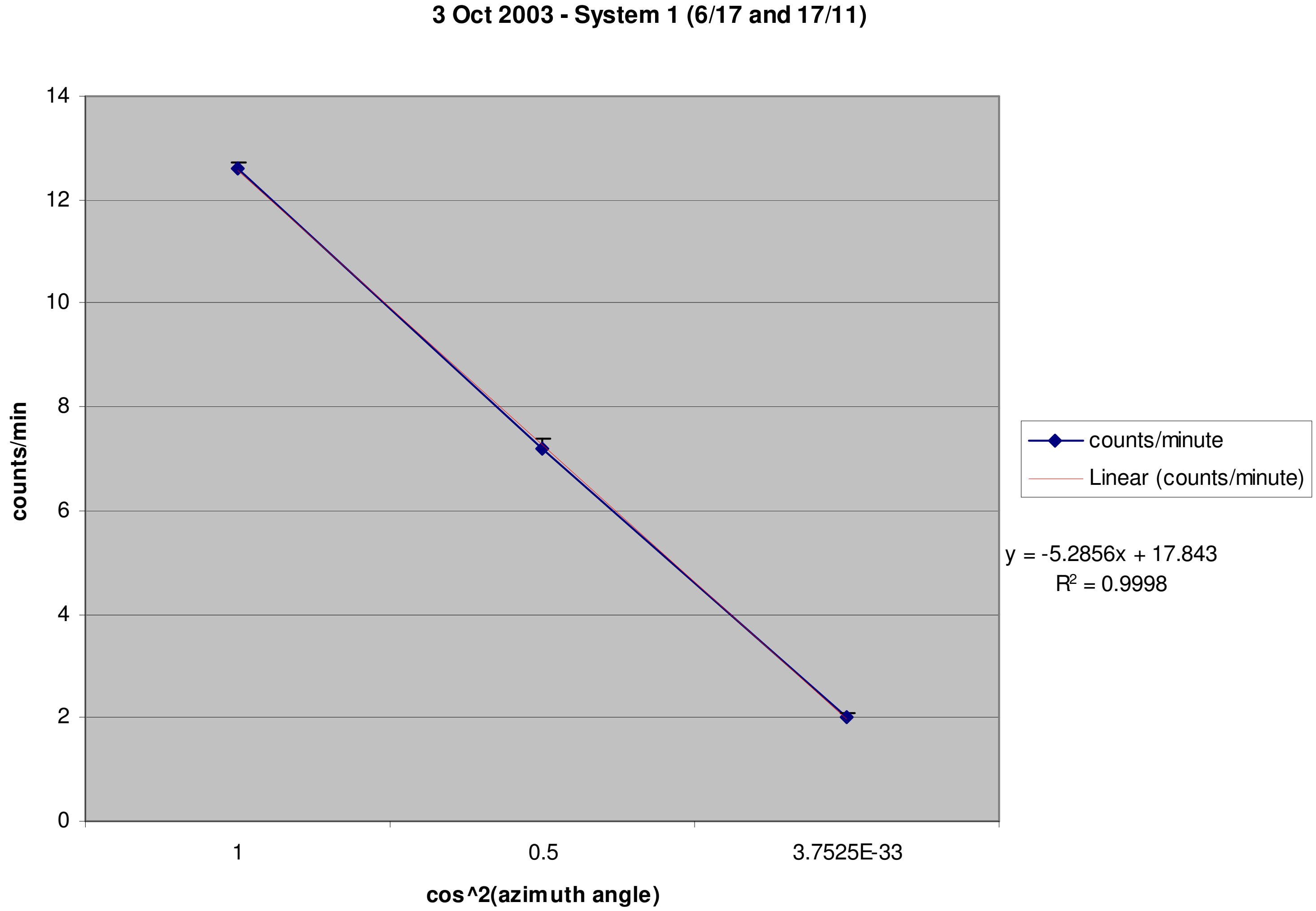
Break for Lunch

- I need a helper to carry CRD parts
- Extra copies of Interaction Point

My Results

Board	TH1	TH2	TH3	TH4	TOP	BOT	(counter/base)
37	0.5	0.5	0.5	0.5	6/17	17/11	
Test 1		Start time: 4:30pm 10/2/2003					
Orientation	0	45	90				
Start	16:30	8:18	11:00				
Stop	8:08	11:00	13:24				
Counts	10305	1165	760				
sqrt(counts	101.513546	34.1321	27.57				
frac err	0.0098509	0.0293	0.036				
Time (min)	818	162	375				
Cnt/min	12.5977995	7.19136	2.027				
error	0.12409969	0.21069	0.074				
cosine thet	1	0.5	4E-33				

Graph of Results



Expected number of Cosmic Rays

- Willy's program (soon on web)

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Width 15.24 cm
Length 17.78 cm
Distance 78.74 cm
Number of events 100000

Had 2049 hits out of 100000 cosmics

Accepted cosmic ray fraction:  0.02049 ± 0.000452659
Cosmic ray rate through top panel:  281.806 /min
Cosmic ray rate through both panels: 5.7742 ± 0.127562 /min
Simple estimate (wl/d2 formula):  7.81604 /min
```

Lending Policy

- Three (or four?) systems released today
- First users will be pioneers! Help with docs
- Duration? 1 month? 3 months?
- Reporting damage/breakage (but please take care!)
- Resources:
  - Web (http://www.slac.stanford.edu/quarknet/CRD)
  - Email to Tom (dragon@slac.stanford.edu) or Willy (wglp09@slac.stanford.edu)
  - (last resort) phone Tom (650-926-3160)

Future

- Possible new experiments (e/m showers, muon lifetime, large array telescope)
- Advanced student projects (extend CRAnE, statistical analysis, utilize GPS time, barometer, design new experiment with apparatus, …)
- Need *YOUR* help with feedback, ideas, and documentation