Cosmic ray research program at QCC

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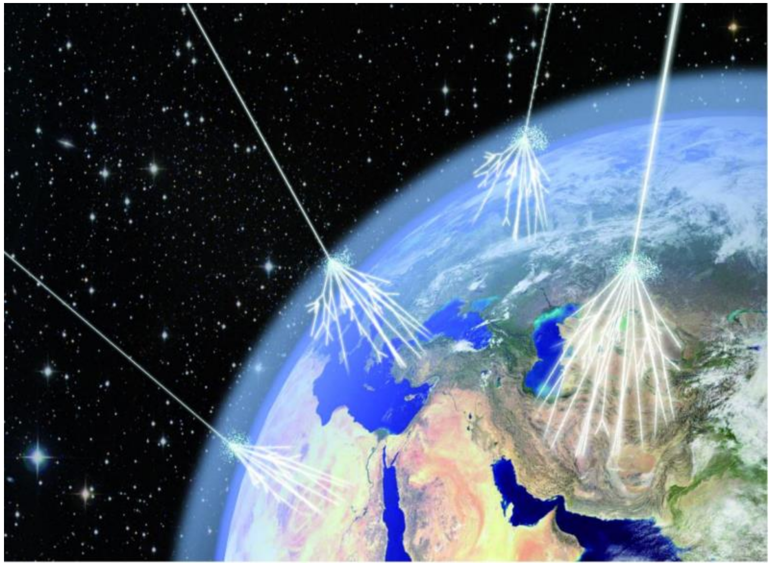
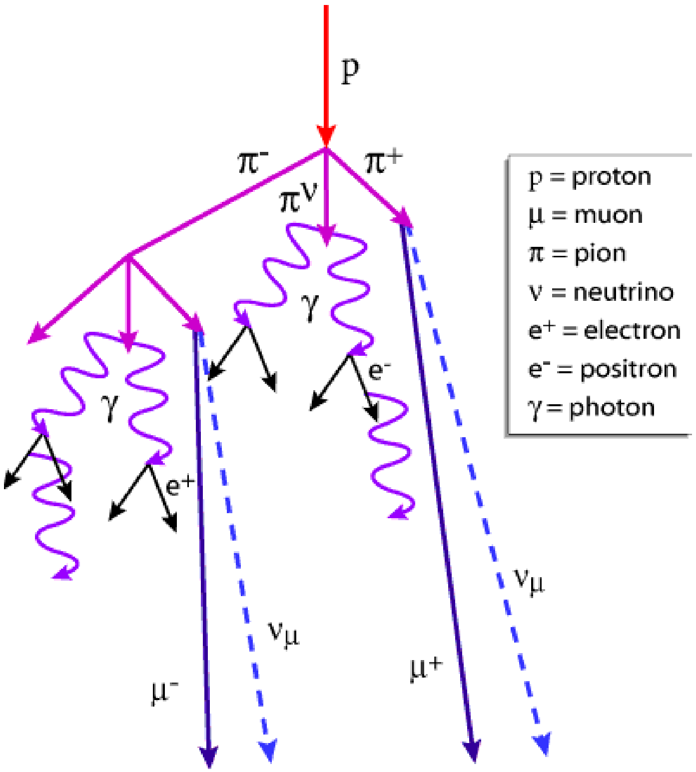
Brown-bag seminar
3-29-2017



Cosmic rays are studied in particle physics, space weather and atmospheric physics, astrophysics, solar activity, lightning, and geomagnetic field research

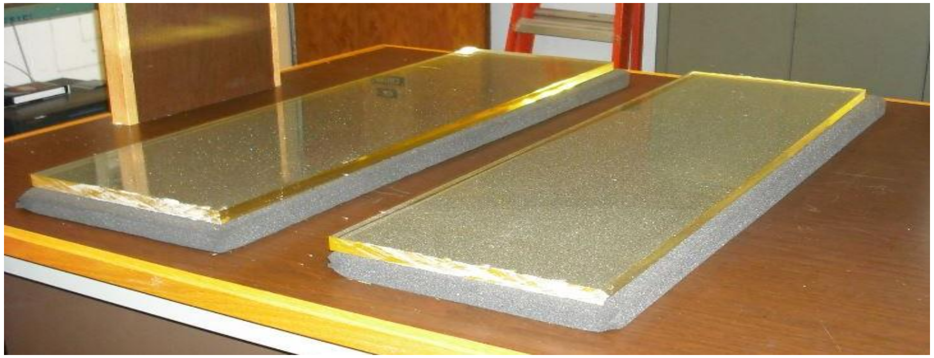
Cosmic ray shower

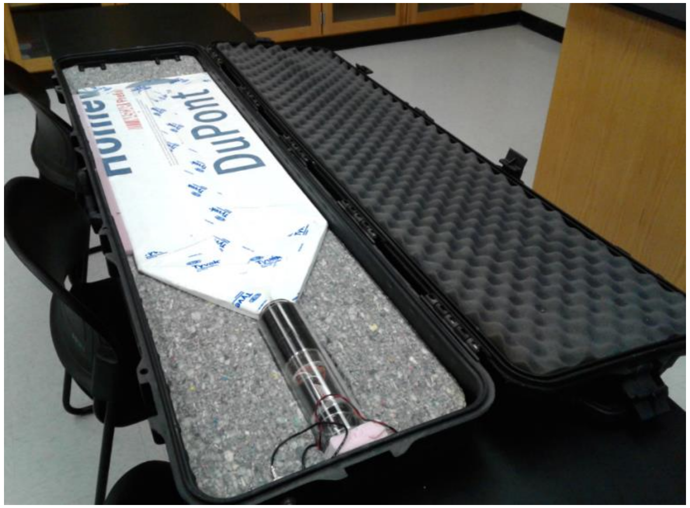
- Cosmic rays are high energy particles emitted by the sun, supernovae, and black hole regions; about 90% of the cosmic ray flux consists of protons and 9% of heavier particles, principally alpha particles.
- When a cosmic ray proton collides with a nucleon in earth's atmosphere pions are produced; charged pions decay is 26 ns (mean life time) producing muons which are detectable as they hit earth's surface.



Scintillator

- A scintillator "counter" consists of a plastic sheet of fluorescent scintillator material and a photomultiplier tube. A cosmic ray detector can consist of one or more scintillator counters connected to a data acquisition system





Scintillator fluorescent plastic

Detectors are typically made of polyvinyltoluene plastic (PVT) with fluorescent hydrocarbon molecules.

Charged muons passing through ionize PVT molecules causing them to emit faint flashes of UV light; the hydrocarbons absorb UV and re-emit longer wavelengths which pass through the plastic.

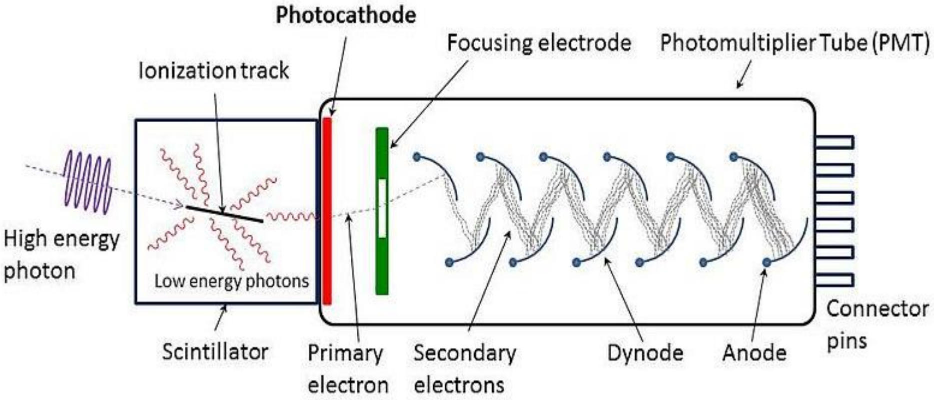
The scintillators are wrapped with foil or Tyvek construction paper containing flashes by reflecting them inward, and housed in black cases to isolate them from room lighting.

Photomultiplier tubes (PMTs)

A photomultiplier tubes is interfaced at one end of the scintillator to detect muon induced light flashes.

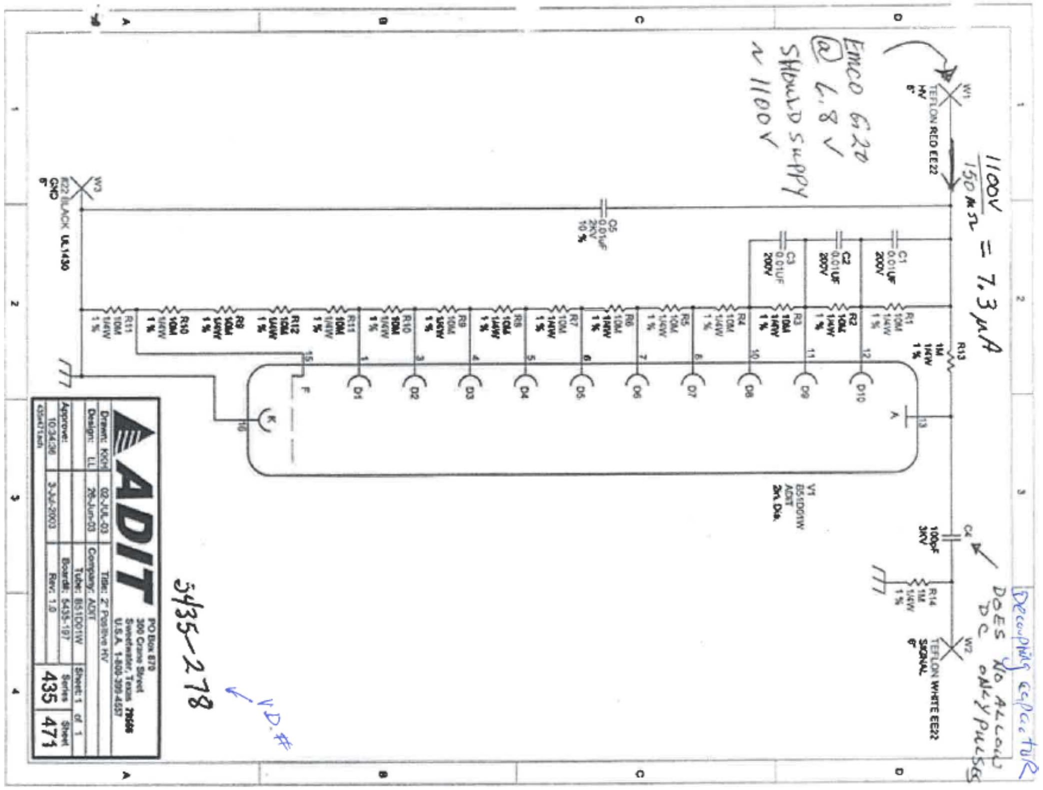
Each PMT has a cesium based photocathode which converts incident photons into electrons via the photoelectric effect.

Internal electrodes held at high voltages convert these electrons into a pulse of current which is fed into the data acquisition system.



Photomultiplier tube voltage divider circuit provides gain and determines if can detect continuous light as well as fast pulses

Each PMT uses a voltage divider circuit to distribute high voltage to the electrodes. The anode has a capacitor on its output to isolate the high voltage from the signal; this limits the PMT output to pulses removing any DC component.



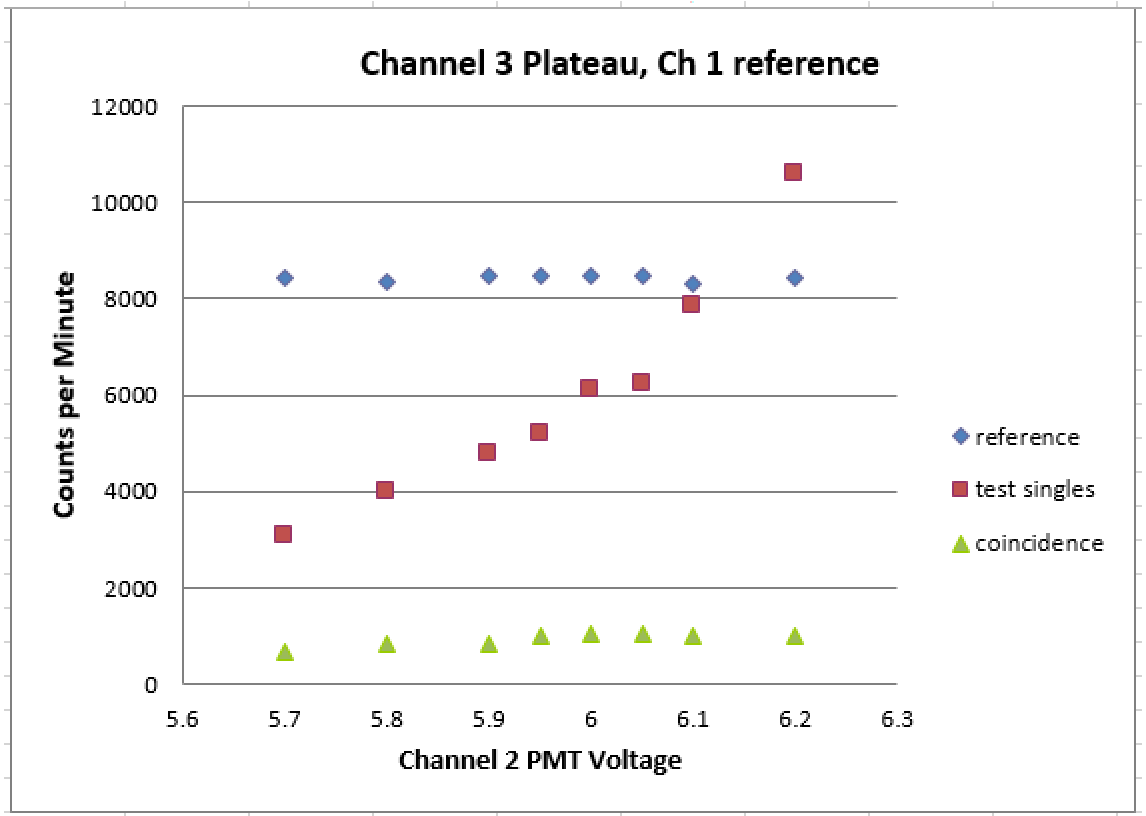
Plateauing photomultiplier tubes

- PMTs are sensitive and each operates at a slightly different voltage; if the voltage is too low it doesn’t detect all muons, if it’s too high it pulls electrons off the cathode generating a lot of noise. It is critical to find their optimal operating voltages in a plateau calibration.

- In the procedure two scintillator counters, each with its own PMT, are stacked one above the other such that incident muons go through both counters within a very small window of time (a muon travelling at close to the speed of light travels about 1 foot per nanosecond);

- one PMT is held at a fixed voltage while the voltage to the other PMT is incremented in small steps; the goal is to find the voltage at which both PMTs put out coincident pulses within a very short time window

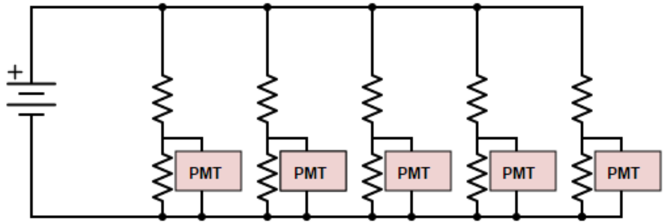
Plateau calibration

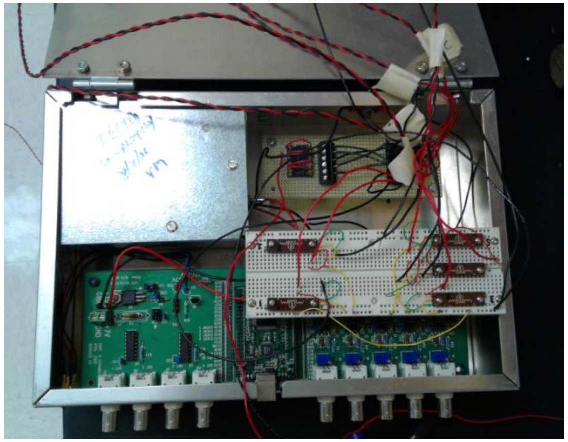


PMT power circuit

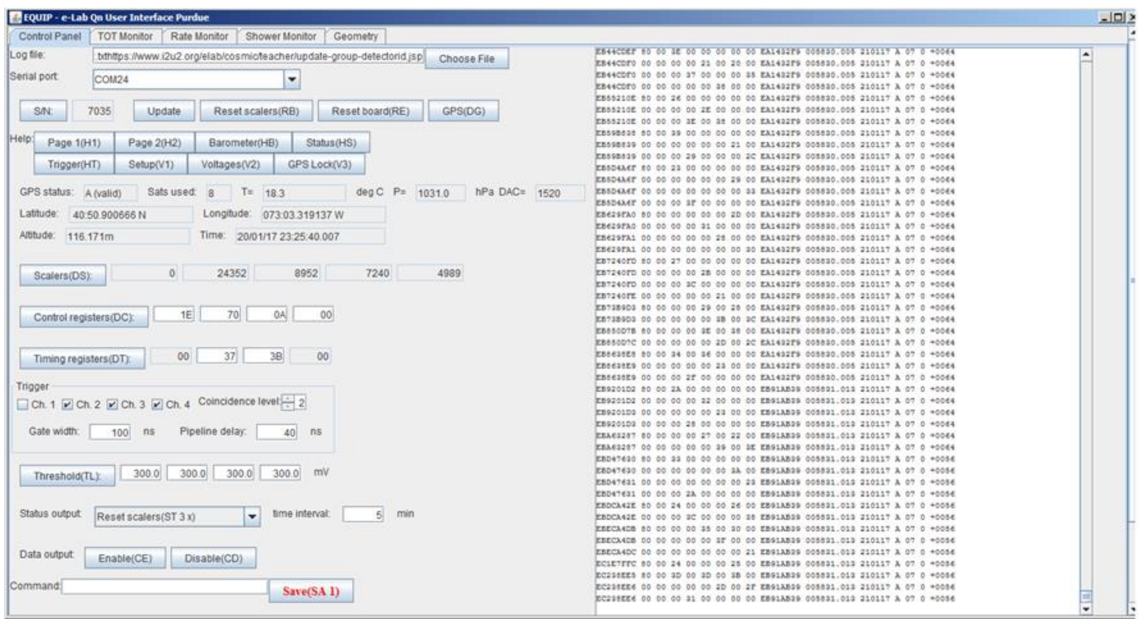
Low voltage DC to high voltage DC converters, which operate at 5 to 7 volts, are used to provide high voltage to PMTs; thus three low voltage variable regulated DC power supplies were used to power up the three PMTs.

Shown below is a voltage divider circuit that was built to be used for future cosmic ray measurements; the circuit distributes five manually adjustable voltages, each with 0.05V resolution, to five PMTs from a single power supply. Each PMT produces a load on the circuit thus low resistance potentiometers of 100Ω were used to minimize variation in V_{out}.



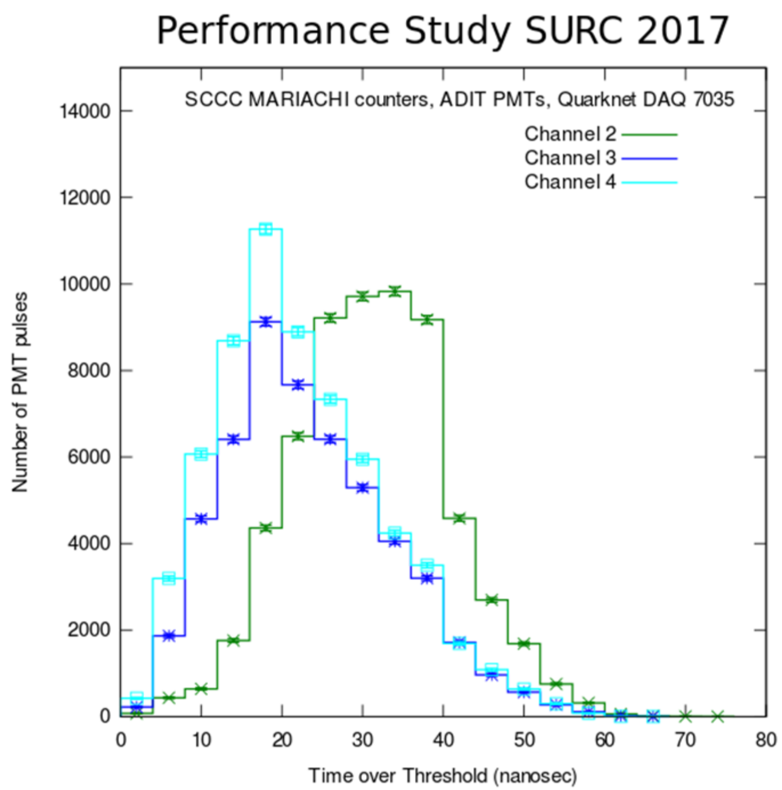


Cosmic Rays Detected in the SCCC Science Building



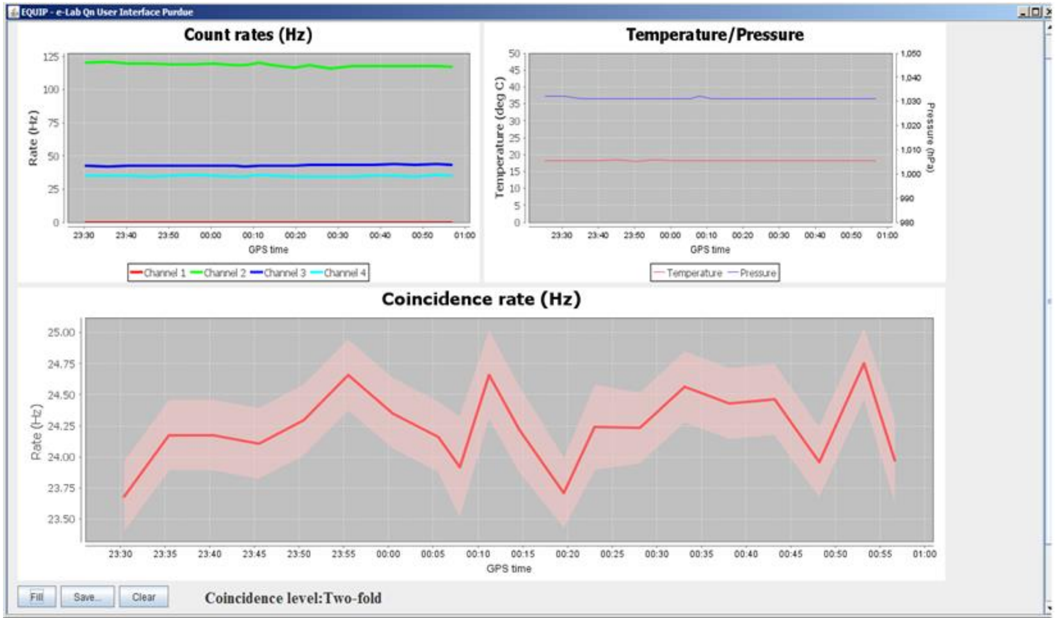
PMT pulse shapes

Individual PMT pulse shapes evaluated in Time over Threshold distributions



Cosmic rays measured as the coincidence count rate, at 24 Hz

Also shown are individual PMT count rates, temperature and pressure monitor data



1.5 hours of coincidence data was recorded which resulted in 129,600 potential cosmic rays detected:

$$\frac{24}{sec}\, x\, \frac{60sec}{min}\, x\, \frac{60min}{hour}\, x\ 1.5hours =$$

129,600 potential cosmic rays detected

Cosmic ray flux: results, error, and conclusion

The coincidence rate obtained while plateauing the PMTs was 17Hz, thus comparing the two values:

difference = [(24-17)/17] x 100 = 41%

If 17Hz is accepted as the expected rate than 91,800 would be the expected number of cosmic rays, thus:

[(129,600-91,800)/91,800] x 100 = 41% difference

The SCCC MARIACHI scintillator panels were measured to be 2,511 cm^2; the Quarknet scintillator panels measure about QCC 827 cm^2 and have a typical coincidence rate of 10Hz, thus comparing them:

expect = 10 x (2511/827) = 30 Hz coincident rate,

[(30-24)/24] x 100 = 25% difference

The cosmic ray rate and flux will be measured again at SCCC and QCC for improved accuracy and results compared.