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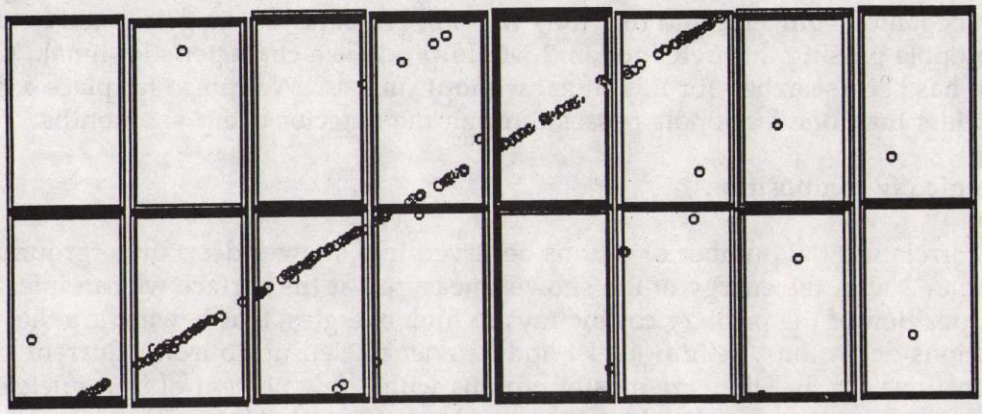
RUTHERFORD APPLETON LABORATORY

SCIENCE AND ENGINEERING RESEARCH COUNCIL

Muon Astronomy in Soudan 2

An underground telescope?

Soudan 2 detects particles called muons that are the remnants of particle showers produced when high energy cosmic rays hit the earth's atmosphere. About 1 muon will cross the full detector every 2 seconds with energies greater than can be produced in the biggest earthbound accelerator. Some interesting astronomical properties of the primary cosmic rays can be inferred from these remnants. Because of their high energies the muons preserve the direction of the incident cosmic ray particle. If the cosmic ray comes directly from an astronomical object then the muon will still point towards the object and can in principle, be associated with it just like a particle of light being detected in a conventional telescope.



Side view of the Soudan 2 detector being crossed by a cosmic ray muon

How are Cosmic rays produced?

Cosmic rays are naturally occurring high energy particles that arrive at the earth from outer space. It is believed they can be produced in natural accelerators that utilise the intense magnetic fields occurring in very dense stars such as neutron stars or black holes. These cosmic accelerators can make beams of particles which rotate with the star. If the beam strikes material surrounding the star (for

example the disks of material often found in binary star systems) then it can produce beams of secondary neutral particles, photons or neutrinos. These are especially interesting since being neutral they are not deflected by the galactic magnetic field which scrambles the directions of charged cosmic rays. Muons produced by interactions of these particles may point directly to their sources.

Do muons point towards Cygnus X-3?

One possible cosmic accelerator is the binary star system called Cygnus X-3. About five years ago several groups claimed to observe muons coming from Cygnus X-3. The well known radio and x-ray signals from Cygnus X-3 have a characteristic 4.8 hour period caused by the orbital rotation of the binary star system. It was claimed that this period was also visible in the muon data. This caused much excitement and controversy since the observation could not be explained with known physical principles. Since then other experiments have failed to observe Cygnus X-3, while others have confirmed the early observations and claimed to observe other sources. The situation is currently far from settled but Soudan 2 with its large area and high rate of observing muons will be able to make a definitive test over the next five years.

Search for magnetic monopoles

All known magnetic poles exist in pairs, a north and south pole. It is theoretically possible to have an isolated pole. Some theories predict that such poles, called magnetic monopoles, would have been produced in the big bang that began our universe and that they will still be found in our galaxy today. A monopole passing through Soudan 2 would produce a characteristic signal. Our data has been searched for this signal without success. We can so far place a limit that less than one monopole passes through the detector every six months.

Cosmic ray composition

By correlating the number of muons observed in a shower deep underground in Soudan 2 with the energy of the shower measured at the surface we can infer the composition of the primary cosmic rays at high energies, that is what are the fractions of protons, helium nuclei and heavier nucleii up to iron. Current indications are that they are mostly protons with a few percent of iron nucleii. These compositions shed light on the accelerating mechanism and the composition of stellar matter.

Calibrating the detector

A mundane but vital use for the muons passing through the detector is to maintain the detector calibration both for positional and ionisation measurement accuracy.

For more information on this project, please contact Peter Litchfield, Soudan 2 group, tel (0235) 446265 or Esther Peacock, RAL Press & Public Relations section, tel (0235) 445777.

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