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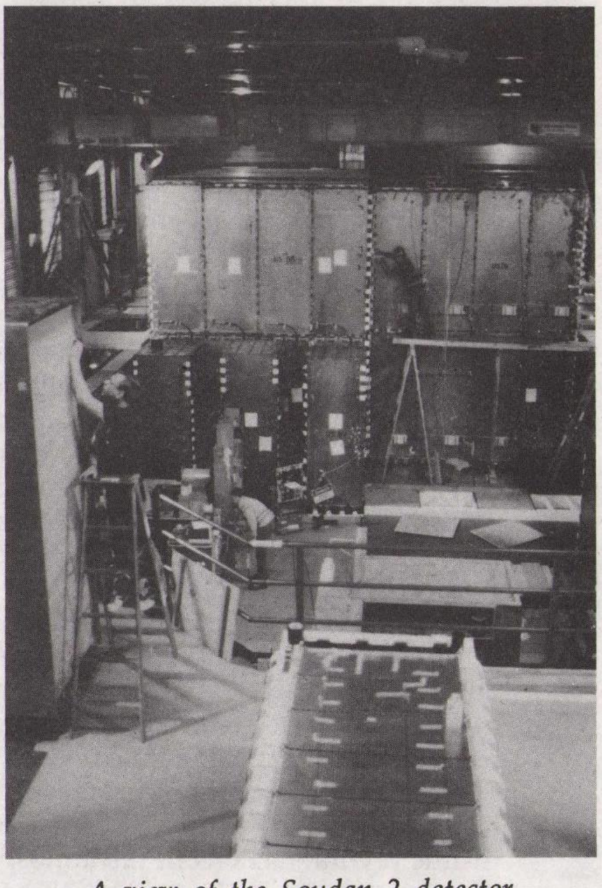
Proton Decay and the Soudan 2 experiment

What is matter made of?

We all learnt at school that matter is made up of atoms. Atoms consist of light electrons orbiting a heavy nucleus made up of protons and neutrons (collectively called nucleons). Over the past 20 years particle physicists have discovered that a nucleon is made of three more elementary particles called quarks. Quarks in normal matter come in two different types, "up" and "down". The difference between the proton and neutron is due to the different combination of quarks inside them. On the other hand we cannot find any substructure in the electron, which still appears as elementary as when it was first discovered at the beginning of this century. The present "standard model" of particle physics thus envisages all normal matter to be made up of just three different types of particles, two quarks and an electron.



A view of the Soudan 2 detector

Is matter stable?

Quarks are heavier than electrons and there is no energetic reason why quarks should not change into electrons, with catastrophic results to the nucleon that contains them. We know, however, that this does not happen often in nature, since matter still exists from the beginning of the universe, 15 billion (1.5×10^9) years ago. Other more stringent tests can be made from nature that set limits of around 1,000,000,000,000,000,000,000,000, (10^{24}) years for the lifetime of protons and neutrons.

What does particle theory predict?

The history of physics has been a process of explaining more and more phenomena with fewer and fewer basic particles and forces. In this spirit many "Grand Unified Theories" have been put forward that combine the electron and quarks into one theory. These theories generally predict that quarks will transform into electrons but very slowly. The lifetime of a nucleon (defined as the time in which 63% of the nucleons have decayed) would be more than 10^{30} years.

How can we detect such rare decays?

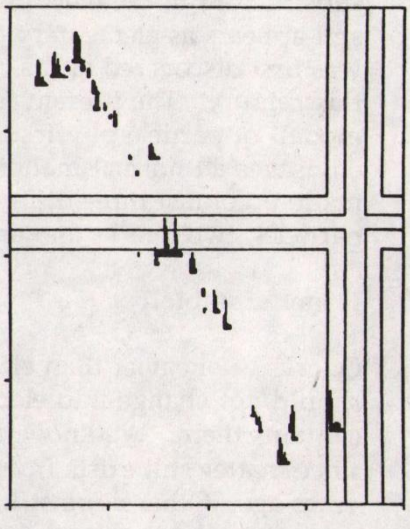
1000 tons of matter contain 6×10^{32} nucleons. If we watch this amount of matter continuously and if the lifetime of the nucleon is 6×10^{32} years, then on average we will see one of them decay per year. The Soudan 2 detector is designed to be able to spot this one decay. How the detector works is described in another leaflet. The experiment will run for five year and establish, at this level, whether or not ordinary matter is slowly decaying.

What will a decay look like?

The way in which a proton or neutron decays depends on the details of the theory but in general the decay will produce an electron and other particles, such as pi mesons, containing quarks and antiquarks. The total mass of the proton is converted into the mass of the decay particles and their energy of motion. This energy will be dissipated as the particle passes through the detector leaving particle "tracks". From the characteristics of the tracks the nature of the initial nucleon and the manner of its decay can be reconstructed.

What can be confused with a nucleon decay?

The detector is shielded against accidental background processes produced by cosmic rays by building it half a mile underground. The remaining background comes from the highly penetrating neutrinos produced by cosmic ray interactions in the atmosphere. We expect to detect about 100 of these interactions per year. The ultimate sensitivity of the experiment depends on the ability of the detector to distinguish this process from nucleon decay. The Soudan 2 detector will be able to do this better than any other experiment currently planned or running.



A background neutrino interaction

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.