CONSTRUCTION OF THE SOUDAN 2 DETECTOR

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We report here on the progress in construction of the Soudan 2 nucleon decay detector which is being built at the Soudan iron mine in Minnesota. We also report the expected event rate and characteristics of low energy neutrino events, muon events, multiple muon events, and other cosmic ray phenomena which we might be sensitive to.

1. Description of the Detector.

The detector is an iron calorimeter with high density (2 g/cm^3) which emphasizes dE/dx measurement and excellent tracking. It consists of 256 identical modules with a total mass of 1.1 kilotons (Fig. 1.) Each module consists of formed steel sheets in a honeycomb pattern, with 0.5 meter drift cells read out by 2.5 m by 1.0 m proportional wires and cathode strips (Fig. 2.). Each drift cell is 14 mm in diameter and layers are separated by 1.6 mm of iron. A gas mixture of 85% Argon with 15% CO_2 will be used, and a drift field of 200 V/cm, which will give a drift velocity of 0.92 cm per microsecond. For each wire and cathode strip, the pulse height will be recorded in each of 256 time bins which are 200 ns long. Vertical and horizontal positions of hits will be determined by matching anode and cathode pulse heights. Positions along the electron drift direction will be measured in 2 mm bins using timing information. Sampling every 0.2 radiation lengths coupled with ionization information will give good event reconstruction often including particle identification. The direction from stopping tracks will be determined by the rise in pulse height at the end of a track. This will greatly aid in vertex identification, which is important in distinguishing proton decay events from neutrino interactions.

The modularity of the detector will allow calibration in a neutrino beam. We believe previous proton decay experiments indicate that this will be an important ingredient in separating proton decay candidates from neutrino induced backgrounds, as well.

To reduce the number of electronics channels required, the cathodes and anodes will be separately multiplexed by a factor of 8. Associating a module with a given hit will require demultiplexing of both anode and cathode signals, but for the simple topologies of events expected (small volume clusters of hits and tracks along straight lines) this will not be difficult.

The experiment will be located at a depth of 2200 m of water equivalent. This will shield the detector from the hadronic and electromagnetic component of cosmic ray showers, and from muons with an initial momentum of less than 700 Gev. Triggers will be caused by high energy muons, neutrino events, and radioactivity in the mine. A muon rate of 0.3 Hz is expected. Some of the muons may interact outside of the detector and give hadrons and electrons which enter the detector. Therefore a two-layer shield is being constructed around the entire detector, made out of 23 ft long aluminum proportional wire planes.

2. Trigger.

The trigger will consist of some multiplicity of hits in a local region, probably around 4 out of 16 wires. We will have the ability to finely tune the trigger in each area of the detector, which will minimize effects of radioactivity from the cavity walls while maximizing acceptance to more difficult proton decay modes, such as $p \rightarrow K^{+}\nu$.

3. Current Progress.

The first 5-ton module has been constructed and is being tested with cosmic rays. By the time of the meeting, several more will have been built and tested, so that considerable experience will have been gained on the construction and performance of the modules. The testing program will reconstruct large numbers of straight-through cosmic ray muons. We will use spatial reconstructions of the tracks to identify the individual tubes struck by each cosmic ray. We will evaluate the performance of each tube in a module to obtain statistics on efficiency, attenuation, pulse-height resolution, and position resolution. Such an analysis has already been performed on data from a 1-ton prototype of the detector and shows excellent performance, with position resolution along the drift direction limited by the flash ADC clock. A sample of stopping muon data demonstrates the direction-tagging ability of the detector. We expect to begin installing modules in the mine in November 1985 and complete installation of all 256 modules in December of 1987.

4. Cosmic Ray Capabilities.

The excellent tracking capabilities will enable this detector to do certain studies of cosmic ray physics as a byproduct to searching for nucleon decay. In particular it is desirable to try to confirm the time correlations of multiple muon events seen in the Soudan 1 detector, as well as single muons which may be coming from Cygnus X-3 and other astrophysical sources[1,2]. For single muon events, the Soudan 2 detector will have 15 times the acceptance that the Soudan 1 detector had. The multimuon acceptance should increase by more than this, the actual rate depending on the lateral spread of the muons when they reach the level of the detector. It will certainly be possible to look for Cygnus X-3 and other possible astrophysical cosmic ray sources as well. It is also possible that the multimuon event distributions will give some information about the elemental composition of cosmic rays in the 10^{14} eV energy range.

Neutrino events are expected at a rate of about 100 per year. It is possible to calculate the ν_μ/ν_e ratio, charged current to neutral current ratio, and flux as a function of energy and angle that are expected from cosmic ray neutrinos produced in the earth's atmosphere. Neutrino oscillations could change the ν_μ/ν_e ratio as a function of angle. Any new weakly interacting neutral particle might manifest itself as an excess in the apparent neutral current to charged current ratio. Any astrophysical sources of neutrinos, such as high energy particles produced in solar flares, would give neutrinos associated with a particular direction in the sky.

The detector would be sensitive to a monopole flux of 1.0×10^{-14} $cm^{-2}s^{-1}sr^{-1}$ in one year. The memory time for each event is 50 μsec, so it will be possible to see monopoles (if they ionize) with a velocity down to 2×10^{-4} c.

5. Conclusion.

A 1.1 kiloton tracking calorimeter is being constructed for use in the Soudan mine in Minnesota. As well as a tool in the search for nucleon decay, it will be possible to study cosmic ray muons and neutrinos and look for other cosmic ray phenomena.

1. J. Bartelt et al., submitted to Phys. Rev. D.
2. M. Marshak et al., Phys. Rev. Lett. 54, 2079 (1985).

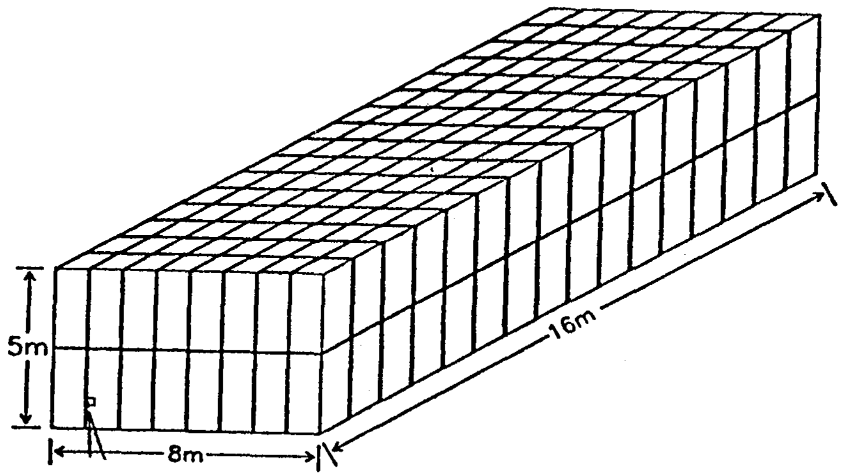

Fig. 1. Soudan 2 Nucleon Decay Detector

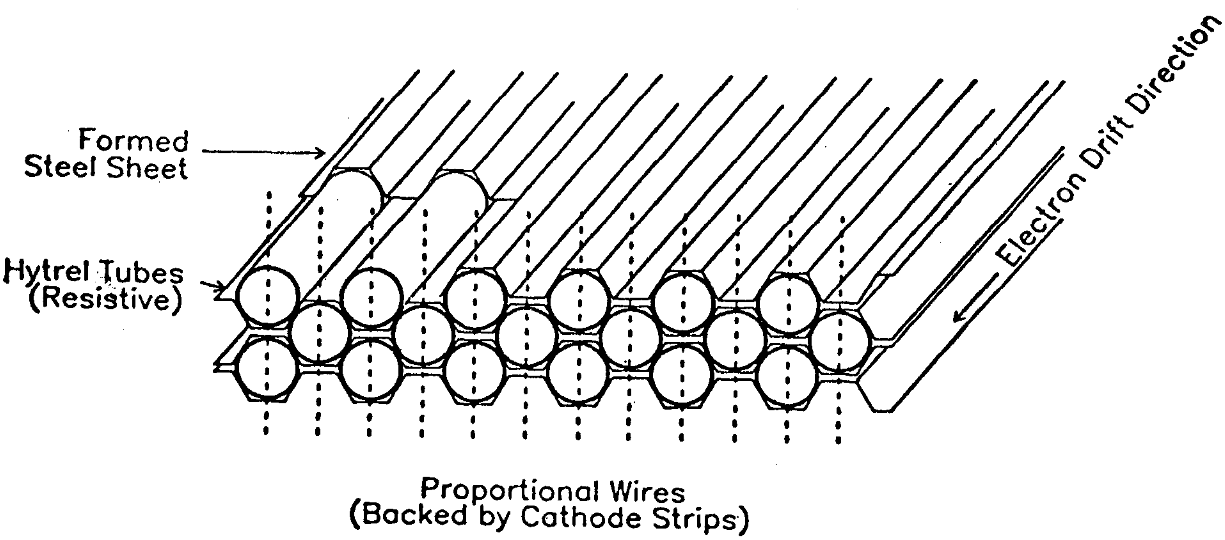

Fig. 2. Closeup of Honeycomb Pattern in Drift Chamber