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# INITIAL DATA FROM THE SOUDAN 2 EXPERIMENT

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## ABSTRACT

Soudan 2 is an 1100-ton tracking calorimeter which is being built 713 m underground to search for nucleon decay and to study neutrino and cosmic-ray physics. The detector is assembled from 256 identical 4.3-ton calorimeter modules. Each module consists of finely segmented iron and drift tubes, and records three space coordinates and dE/dx for every tube crossing. It is surrounded on all sides by a 1700 $m^2$ active shield of proportional tubes. The first atmospheric neutrino interactions and a magnetic monopole search are described. Prospects for cosmic ray studies are summarized.

## DETECTOR PERFORMANCE

Soudan 2 has excellent event reconstruction capability, particle identification and muon sign and direction determination, giving superior rejection of the neutrino background to nucleon decay. Module performance has been studied using cosmic-ray muon tracks and in a charged-particle test beam; a neutrino beam calibration is planned. Stopping muon track direction is determined correctly 83% of the time by choosing the stopping end of the track to be the one with the largest pulse height. For contained single tracks, trigger thresholds (kinetic energy at the 50% efficiency points) are 130 MeV for electrons and 85 MeV for muons. The first 550 tons of Soudan 2 are now taking physics data, with completion planned for 1992.

## NEUTRINO PHYSICS

Soudan 2 has recorded an exposure of 0.2 fiducial kiloton year in which 15 contained neutrino interaction candidate events have been identified. The rates, composition, and energy spectra of these events appear to be in agreement with Monte Carlo predictions; no candidates for nucleon decay have been found. During a 5 fiducial kiloton-year exposure Soudan 2 will record 600 contained atmospheric neutrino interactions. The excellent event characterization capabilities of Soudan 2 will allow a search for neutrino oscillations using the $\nu_\mu/\nu_e$ ratio from this sample. The measurement is sensitive to oscillations with $\Delta m^2 > 10^{-4} eV^2$ and $sin^2(2\theta) > 0.2$. In addition, a Letter of Intent has been submitted to Fermilab to search for neutrino oscillations in a 30 GeV neutrino beam aimed at Soudan 2, which is 800 km from Fermilab.

## MAGNETIC MONOPOLE SEARCH

A search for GUT magnetic monopoles is being performed using the facts that slow monopoles ionize heavily and do not make detectable delta rays in Soudan 2. No monopole candidates have been found to date, yielding a 90% confidence level upper limit on monopole flux of $6 \times 10^{-14} cm^{-2} sr^{-1} s^{-1}$ in the velocity range $10^{-3} < \beta < 0.95$.

## COSMIC RAY PHYSICS

Soudan 2 is well suited to study the question of whether astrophysical point sources such as Cygnus X-3 may be observable in the underground muon flux. Angular resolutions of less than 1° have been achieved, with future improvements expected. Ten million muons per year will be recorded by the full 1100-ton detector. A sample of about 2 million single muon tracks is currently being analyzed.

Information about the nuclear composition of the primary cosmic ray flux may be obtained from events with several parallel muons in Soudan 2. The effective area of the detector can be increased by a factor of 3.5 by counting tracks in the active shield with trajectories parallel to those in the main detector. To measure the energies of air showers which produce multiple muon events in Soudan 2, a 40 $m^2$ array of proportional tubes is being constructed on the earth's surface. Extrapolation of an underground muon bundle to the surface gives the distance from the shower core to the surface array, and the number of hits in the array then measures the shower energy. We expect to record about 7000 underground multiple muon events per year in coincidence with the surface array, for primary cosmic ray energies in the range $10^{13}$ to $10^{17}$ eV.

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