constraint equations derived from the equations of motion of the theory. Although the vacuum is simple in light-cone quantization, these vacuum zero modes thus determine the phase and physics of the theory.

There are other fundamental renormalization and gauge invariance issues that still have to be completely understood, such as how symmetries lost in the truncation can be restored, how to deal consistently with massless particles, and how to control singularities. All of these problems make the field quite exciting and challenging.

In addition to its potential for solving QCD problems, light-cone quantization has already led to many new insights into the quantization of gauge theories. Light-cone quantization not only provides a consistent language for representing hadrons as QCD bound-states of relativistic quarks and gluons, but it also provides a novel method for simulating quantum field theory on a computer and understanding features of QCD.

The appealing features of light-cone quantization for quantum field theory have brought together a new community of theorists interested in solving both the practical and formal problems. A series of conferences were held in 1991 and 1992 at Heidelberg, Aspen, Telluride, and Dallas. Two light-cone meetings in this series are being planned for this summer. Daniel Wyler of Zurich University (wyler@forty2.physik.unizh.ch) is organizing a conference from 14-18 June at the Paul Scherrer Institute near Zurich, and Antonio Bassetto (bassetto@ipdinfn) under the support of the Istituto Nazionale di Fisica Nucleare (INFN) is organizing a workshop at the Gran Sasso Laboratory from 17-27 August.

By Stan Brodsky

Proton-proton reaction rates at extreme energies

Results on proton-antiproton reaction rates (total cross-section) at collision energies of 1.8 TeV from experiments at Fermilab have suggested a lower rate of increase with energy compared to the extrapolation based on results previously obtained at CERN's proton-antiproton collider (CERN Courier, October 1991).

Now an independent estimate of the values for the proton-proton total cross-section for collision energies from 5 to 30 TeV has been provided by the analysis of cosmic ray shower data collected over ten years at the Akeno Observatory operated by the Institute for Cosmic Ray Research of University of Tokyo.

These results are based on the inelastic cross-section for collisions of cosmic ray protons with air nuclei at energies in the range10^{16-18}eV.

A new extensive air shower experiment was started at Akeno, 150 km west of Tokyo, in 1979 with a large array of detectors, both on the ground and under a 1-metre concrete absorber. This measured the total numbers of electrons and muons of energies above 1GeV for individual showers with much better accuracy than before. Data collection was almost continuous for ten years without any change in the triggering criteria for showers above10^{16}eV.

The mean free path for proton-air nuclei collisions has been determined from the zenith angle of the observed frequency of air showers which have the same effective path length for development in the atmosphere and the same primary energy. The effect of fluctuations in the longitudinal development of showers in the atmosphere has been estimated from simulations assuming no significant break in kinematical scaling up to the highest energies and that the number of secondary particles increases as the square of the logarithm of the collision energy.

The proportion of showers produced by primary protons among the observed showers is unknown at such ultra-high energies. Air showers initiated by heavier primaries generally start their cascades in the higher atmosphere. In order to optimize selection of showers which have a larger probability of being produced by primary protons, only 10% of the total showers in each energy range, those which have developed deep in the atmosphere, have been used to determine the proton attenuation length.

The upper bound on the proton-air inelastic cross-section increases with energy as $290E^{0.052}$mb in the energy range10^{16-18}eV, where E is the incident proton energy in TeV (see figure). The total cross-section for proton-proton collisions has been derived from the proton-air inelastic cross-section using conventional (Glauber) theory of multiple scattering inside the nucleus and a nucleon profile function derived from a QCD parton model using a diffraction scattering formulation.

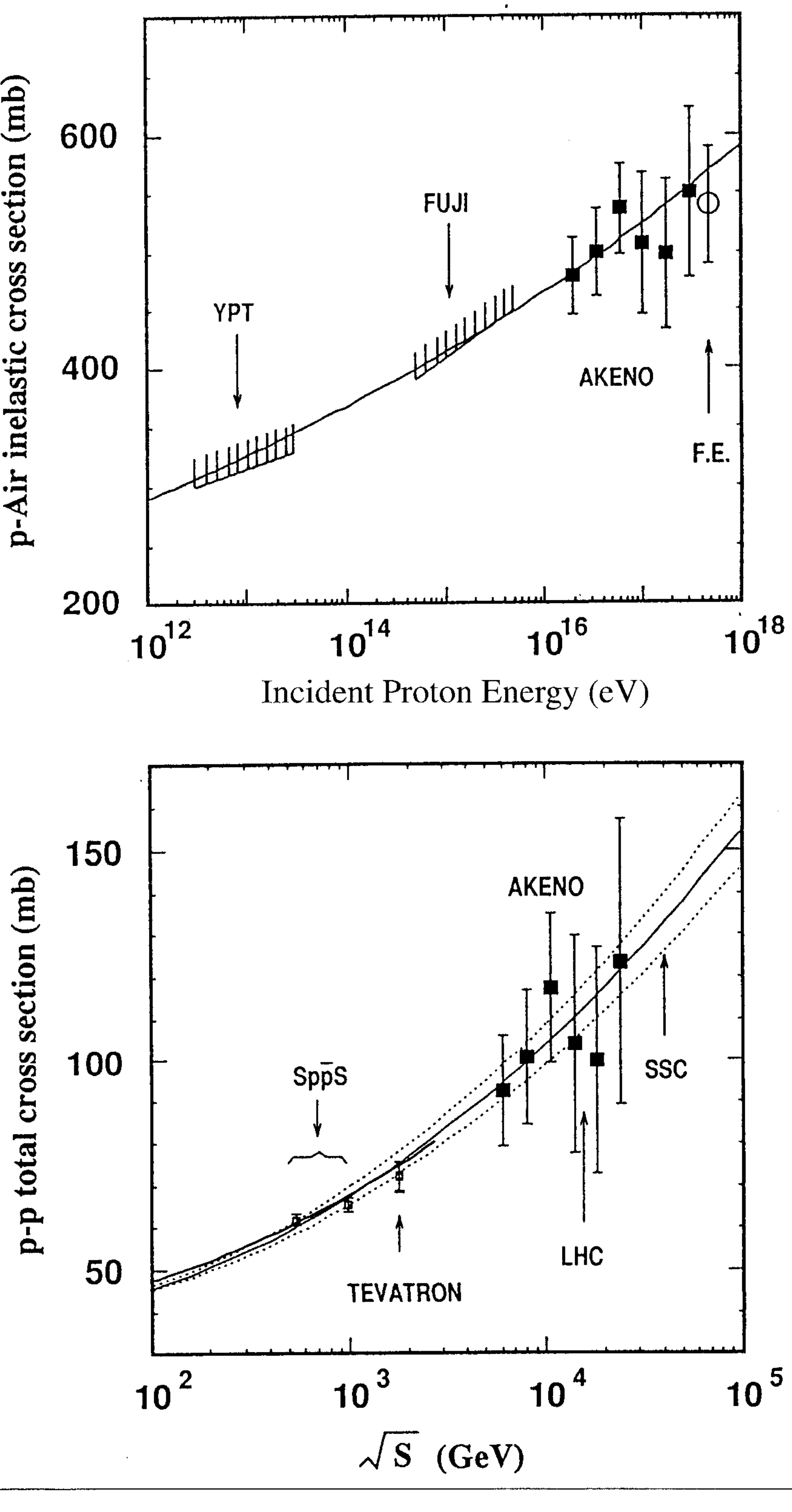
The total cross-section is found to vary as $38.5+1.37\ln^2$(collision energy/10GeV)mb. These fit fairly well with results from CERN's proton-antiproton collider at 540GeV and 900GeV and from Fermilab's Tevatron collider at 1.8TeV, although the Tevatron value is a little smaller than what is expected from the best fit to the Akeno results.

The observed frequency attenuation length depends on the fluctuation of air shower development

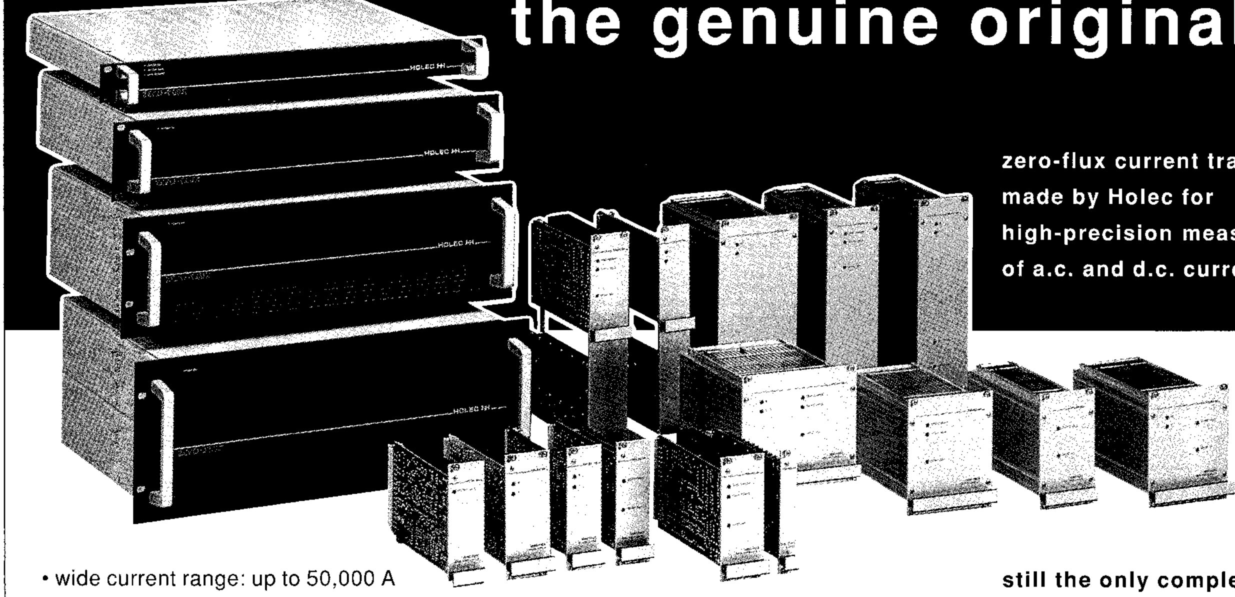

We Go to Great Lengths...

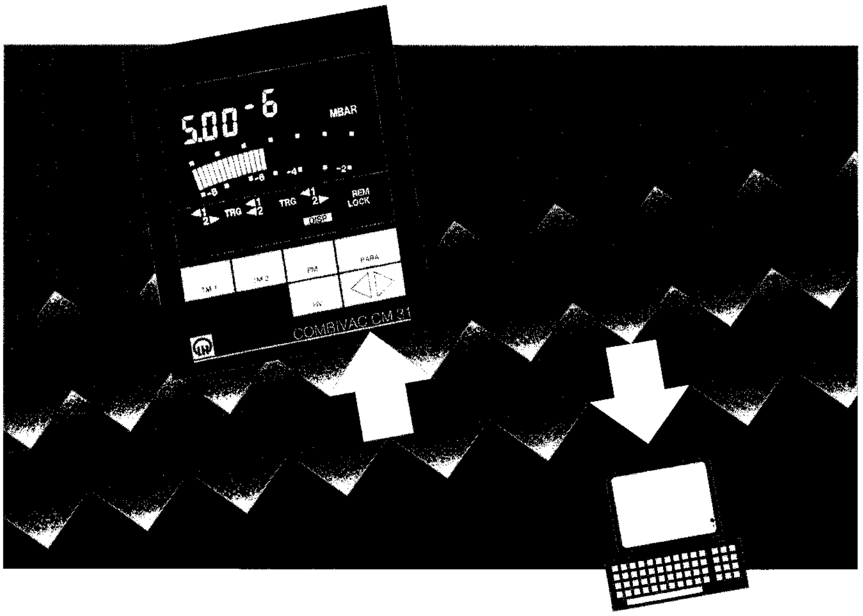
and therefore is dependent on details of ultra-high energy interactions . The total proton-proton cross-section is expected to be slightly smaller if there is a significant breakdown of scaling.

From Motohiko Nagano



Top, reaction rates seen by the Akeno cosmic ray experiments compared to other measurements. The Fly's Eye experiment (FE) has used a somewhat different method. Lower bounds on the cross-section have also been determined from measurements on the surviving proton flux (YPT) and the Mt. Fuji emulsion experiment (FUJI). Below Energy dependence of the total proton-proton cross-section deduced from the cosmic ray data compared with proton-antiproton results at lower energies.




5.00 -6
MBAR
TRG
REM LOCK
DISP
PARA
COMBIVAC CM 31