SCIENCE NEWS

EIGHTEENTH INTERNATIONAL COSMIC RAY CONFERENCE, BANGALORE, 1983

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THE Eighteenth International Cosmic Ray Conference was held in Bangalore during 22 August to 3 September 1983. This biennial conference is hosted by India for the second time, the first being the 8th in the series at Jaipur in 1963. About 425 delegates from all over the world, including about 135 from India presented about 1100 papers on various aspects of cosmic rays at the Bangalore Conference.

The birth centenary of Prof. Victor Hess of Austria, who discovered cosmic rays in 1912, was celebrated at this conference by holding a special symposium in his honour. Profs. Y. Sekido, M. M. Shapiro, A. E. Chudakov and J. A. Simpson gave excellent accounts of his life and research work and the impact of the discovery of cosmic rays on other areas of physics. In the plenary sessions, 8 invited talks were given by experts on topics related to cosmic rays, ranging from the radiation backgrounds and their cosmological implications to recent developments in particle detectors. Contributed papers on various aspects of cosmic rays such as the origin, acceleration, propagation, energy spectra, composition and anisotropy of primary cosmic rays, extremely energetic hadronic interactions etc—were presented in 4 parallel sessions. The conference ended with 20 Rapporteur talks in which the deliberations on various aspects of cosmic rays were summarised. Apart from the regular sessions of the conference, several informal sessions were held in the evenings on specialised topics such as antiproton fluxes, neutrino astronomy, hadronic interactions at ultra high energies, simulations of air shower cascades, history of cosmic ray research etc.

One of the highlights of the conference was the discovery of a cosmic ray source, Cygnus X-3, by a group at the University of Kiel, Federal Republic of Germany. With their air shower array, they recorded excess events of energy larger than 10^{15} eV, in the direction of Cyg X-3, with the periodicity of 4.8 hr observed at lower energies. The Leeds (UK) group presented data from their Haverah Park air shower experiment confirming the Kiel result. Since charged particles lose their direction, due to the galactic magnetic fields in traversing more than 10 kpc from Cyg X-3, these particles must be neutral, perhaps gamma rays. The Kiel group, however, find that the air showers generated by the particles coming from Cyg X-3, contain almost as many muons as in the normal cosmic rays showers, whereas the number of muons in gamma ray initiated showers is expected to be negligible. Further investigations are necessary to establish the nature of the radiation from Cyg X-3. A similar excess from the Crab nebula was reported by a Polish group with a similar muonic content, but without the periodic analysis. This result, however, was not confirmed by other groups.

In order to understand the origin and acceleration of cosmic rays, knowledge of their composition and energy spectra is essential. Several results on the spectra from direct measurements were presented at the conference. A Danish-French collaboration reported high statistics energy spectra, upto about 100 GeV/nucleon, of nuclei from lithium to iron from their experiment on HEAO-3 satellite. They confirm the earlier observations from the balloon experiment by Goddard-Max Planck collaboration, which could be understood in terms of the leaky box model of propagation of cosmic rays. The Japanese-American (JACEE) Collaboration reported energy spectra of protons and helium nuclei obtained in their balloon-borne emulsion chamber experiments in the energy range of a few TeV to a few hundred TeV. Their results are consistent with the extrapolation of spectra at lower energies obtained earlier by other groups. There is no evidence of steepening of the spectra upto about 500 TeV. The number of nuclei, heavier than helium, of total energy greater than 100 TeV is also consistent with the number expected from extrapolation of lower energy data. The preliminary results presented by the Moscow State University group indicate that while the spectra of helium and heavier nuclei agree with extrapolation from lower energies, the proton spectrum seems to be steepening at a few TeV, as suggested by an earlier Soviet satellite experiment. The steepening of the spectrum from the satellite experiment was however thought to be due to instrumental effects. An Australian balloon experiment in which a new technique involving Cerenkov radiation from iron nuclei in the atmosphere is used, suggests steepening of the iron spectrum at a total energy somewhere in the region of a few TeV to 100 TeV. Considering the preliminary nature of some of the results, the direct measurements indicate no substantial change in the primary cosmic ray composition from low energies to about 100 TeV in total energy.

At energies beyond 10^{14} eV, results on the primary spectra and composition have to necessarily come from ground based observations of extensive air showers (EAS) generated by cosmic rays because of the extremly low fluxes. Earlier experiments have already shown that the primary cosmic ray spectrum steepens at a few times 10^{15} eV. This is confirmed by the Samarkhand group in USSR who reported measurements of Cerenkov radiation in EAS which can be related to primary energy with less uncertainty. Results from EAS experiments at Haverah Park in UK., Yukutsk in USSR, Narabri in Australia and Akeno in Japan show that the spectrum beyond the bend continues smoothly upto 10^{19} eV. Above 10^{19} eV the spectrum becomes flatter as reported by the Haverah Park, Yakutsk and Sydney groups. The highest energy cosmic ray reported has an energy of 2.10^{20} eV.

Information on the cosmic ray composition is more difficult to obtain at these energies since most of the air shower parameters are sensitive to the composition as well as the behaviour of hadronic interactions, which is also unknown at these energies. New methods, relatively independent of models of hadronic interactions, of analysis of fluctuations of various components of EAS and their correlations, developed in the last few years along with improved experimental measurements have, nevertheless, thrown some light on the composition at these energies. From an analysis of the fluctuations of low energy muons, a Soviet group working at the Tien Shan mountain station, suggest that the composition upto 10^{17} eV is nearly same as at lower energies. The group from Tata Institute of Fundamental Research, India, working at Kolar Gold Fields finds that the variation of the number of high energy muons with shower size (total number of particles) is slower in the region 5.10^5–2.10^6 particles compared to that below and above this region. They argue that it is difficult to understand this result in terms of changes in the behaviour of hadronic interactions and suggest that the composition of primary cosmic rays becomes lighter, perhaps predominantly protons, at energies greater than $\sim 5.10^{15}$ eV. It remains to be seen whether the Soviet results can be reconciled with this. Earlier results on the depth of shower maximum from measurements of atmospheric Cerenkov radiation in EAS, have suggested that the composition at 10^{15}–10^{16} eV is predominantly heavy. Improved bias-free measurements reported at this conference by the Samarkhand and Japanese groups have shown that the depth of shower maximum is deeper in the atmosphere than indicated by the earlier measurements, supporting the composition inferred from the muon measurements. There is, thus, no compelling evidence for a heavy-enriched composition at these energies.

The implications of these results on the acceleration and propagation of cosmic rays, are not yet clear. The time-honoured rigidity cut-off model, which leads to certain features in the primary energy spectrum and gradual enrichment of heavy nuclei with primary energy in the region 10^{14}–10^{16} eV does not seem to be favoured, unless a new source of cosmic rays, perhaps predominantly protons, starts dominating at an appropriate energy. A model, in which the nuclei are lost due to photo-nuclear disintegrations near the source, however, seems to agree well with data. The astrophysical conditions under which this can occur remain to be investigated. Obviously further experimental study of the important region of 10^{14}–10^{17} eV is needed. At the highest energies, the cosmic ray spectrum continues, perhaps becomes even flatter, beyond the Greisen-Zatsepin cut off energy of $\sim 3.10^{19}$ eV due to interactions with the universal microwave radiation, if these particles are of extragalactic origin. The sources of these cosmic rays, therefore, cannot be farther than 100 million light years, the mean-free path for interaction with microwave radiation. If they are of galactic origin, they should be predominantly Fe nuclei to be confined in the galaxy. Results on the fluctuations of depth of shower maximum indicate that cosmic rays of this energy are predominantly protons and analysis of arrival directions of the showers indicates an excess flux from north galactic latitudes suggesting local or nearby superclusters as the sources.

The only proof of the existence of anti-matter in the Universe is its detection in cosmic rays. A few years ago an American group reported a finite flux of anti-protons in the energy region of a few GeV, which could, however, be understood as due to production in nuclear interactions of high energy cosmic ray protons with interstellar matter. At the last Conference in Paris, another American group reported a finite flux at energies of a few hundred MeV, which is too high to be accounted for by interstellar production because of high energy threshold. At this Conference, an Indian group working at TIFR reported a few anti-proton events in agreement with the high flux. Further investigations are necessary to establish the flux and understand its origin.

Even though the energies available at accelerators for the study of hadronic interactions, are rapidly increasing with time ($\sim 10^{14}$ eV equivalent laboratory energy at present), cosmic rays are still the only source of particles with extremely high energies (upto $\sim 10^{20}$ eV), particularly for studying hadron-nucleus and nucleus-nucleus interactions. Several discoveries in particle physics have been made in the past using cosmic rays, *e.g.* the discovery of μ, π, κ and charm mesons, the increase of inelastic cross-sections with energy, enhanced production of baryons at high energies etc. Since the energy available in cosmic ray interactions is very large, any new particles existing in Nature can be produced in these interactions and if their production cross-section is large enough and if they are reasonably long lived, they can be detected in cosmic ray experiments. Searches for various types of new particles have been reported at this Conference, all with negative results. The upper limits at 90% confidense level are $3.10^{-4}\,m^{-2}\,d^{-1}\,sr^{-1}$ for tachyons and $5.6\times 10^{-6}\,m^{-2}\,d^{-1}\,sr^{-1}$ for slow-moving monopoles predicted by the grand unification theories (GUT). The few events, with large energy deposit and large delay with respect to highly relativistic particle front, attributed to heavy mass particles reported earlier, turned out to be a false alarm as a detailed study of these events in an Indian experiment and exposure of the instrument to accelerator beams in USA have shown them to be due to fluctuations of the more abundant low energy hadrons. No new results on free quarks have been reported. Search for the exotic events like Centauro, Charm and Geminion events discovered earlier by the Brasil–Japan group have been reported. The Centauro events, a majority of which were first suggested by an Indian group to be due to fluctuations in the development of atmospheric cascades, have not been observed in the Pamir and Fuji collaboration experiments. Chiron and Geminion events, which are interpreted by the Brasil–Japan group as multi-particle production events and pair production events respectively with large transverse momentum (2–3 GeV/c) and without pion production, have been observed by other groups. Simulation of atmospheric cascades, however, show that the Geminion events could be understood as due to fluctuations in the usual pion production process if 50% of the inelastic cross section is due to the production of high P_t jets. Similar calculations are necessary for understanding the chiron events.

Estimates of the inelastic cross-section of protons on air nuclei upto 10^{18} eV, from measurements on extensive air showers were reported at this conference. The Akeno air shower group in Japan found $\sigma_{p\text{-air}} = 290\,E^{0.066\pm 0.005}$ mb in the energy range 10^3–10^6 TeV from the frequency attenuation of showers with fixed number of muons and electrons after making allowance for the possible presence of nuclei in primary cosmic rays. This is an upper bound considering the uncertainties in the details of particle production at these energies. Assuming geometrical scaling and Glauber theory, they estimate the *p-p* cross-section to be $38.5 + 0.46\ln^2(S/100)$ mb with S in GeV^2. From the fluctuations in the depth of shower maximum, the Fly's eye group in USA estimated the *p*-air cross-section to be 500 mb at 10^{18} eV. Both these measurements are consistent with the extrapolation of the dependence given by Yodh, Pal and Trefill, about a decade ago, in the few TeV energy region from unaccompanied hadron fluxes at mountain altitudes.

Bulk of the high energy cosmic ray measurements are sensitive to scaling in the fragmentation region of hadronic interactions. There were several indications, in the past, of scaling violation in this region, but not conclusive because of the uncertainties in the primary cosmic ray composition at ultra high energies. Detailed analysis of accelerator data from ISR and $\overline{P}$–P collider experiments, presented at this conference by a U.K.–Polish collaboration showed that the degree of scaling violation increases with energy. Using supercritical Pomeron theory and additive quark model, a Soviet group has shown that scaling in the fragmentation region will be violated in hadron-nucleus interactions, which are relevant for cosmic ray studies, even if it is valid in hadron-hadron collisions. Both the groups showed agreement of some of the experimental data with scaling violation models.

It is being speculated that at extremely high energies, particularly in nucleus–nucleus collisions where matter can be compressed beyond the nuclear densities, phase transition from hadronic matter to quark matter can occur and quark-gluon plasma (QGP) may be produced. The onset of QGP is characterised by very high multiplicities, direct production of gamma rays and enhanced production of strange particles and baryons. Because of the possible presence of energetic nuclei in the primary beam, this phenomenon can be looked for in cosmic ray experiments. In fact, attempts are being made to explain some of the unusual cosmic ray phenomena in terms of the formation of QGP. At this conference, a few isolated unusually high multiplicity events have been reported from balloon-borne emulsion chamber experiments. A Japanese contribution at this conference has shown that most of these and other similar events can be understood in terms of the multichain model of nucleus–nucleus interactions without invoking QGP. Nevertheless, this is a very exciting area in which contributions can come only from cosmic ray experiments in the near future. Further investigations are, obviously, extremely important.

Search for proton decay, predicted by the grand unification theories, has been reported by several groups. The only positive results are from the Indo-Japanese collaboration working at Kolar Gold Fields and the Italian group working in the Mont Blanc tunnel. The Indo-Japanese group reported 3 candidate events, fully confined in their detector, one of which is suggested to be of $e^+\pi^\circ$ mode. They argue that the probability that these events are due to neutrino interactions is very small and estimate a lifetime of 10^{31} years for proton assuming them to be due to proton decay. The Italian group reported one confined event attributable to proton decay, which is consistent with the above lifetime. The Irvine–Michigan–Brookhaven collaboration from USA, using a water Cerenkov detector, which is sensitive to the $e^+\pi^\circ$ mode, however, has not seen any events attributable to proton decay, whereas about 10 events are expected with the above lifetime. Whether this discrepancy is due to the different types of detectors used in the different experiments or due to systematics in one of the experiments, is not clear. Results from other experiments are lower limits consistent with the above lifetime.

ANNOUNCEMENTS

THE INSTITUTE OF PHYSICS, LONDON

The Council of The Institute of Physics, 47, Belgrave Square, London SW1X 8QX, has made the following awards for 1984. The presentation of the awards will be made in London on 2 May 1984.

Gutherie Medal and Prize to Professor M J Seaton of the University College, London, for his many outstanding contributions to atomic and molecular physics, atmospheric physics and astrophysics.

Glazebrook Medal and Prize to Dr P E Trier of Philips Electronics Ltd, London, for his activities in organizing and encouraging research and development in the electronics industry as Director of the Mullard Research Laboratories and subsequently Director of R&D in the UK Philips Group.

Duddell Medal and Prize to Dr P G LeComber of the University of Dundee, for his outstanding work in the field of amorphous semiconductors.

Rutherford Medal and Prize to Professor P W Higgs of the University of Edinburgh and Professor T W B Kibble of Imperial College of Science and Technology, London, jointly, for their contributions to theoretical elementary particle physics and particularly the concept of spontaneous symmetry breaking in gauge theories.

Charles Vernon Boys' Prize to Dr J Klein of the University of Cambridge and the Weizmann Institute, Rehovot, for his outstanding contributions to experimental macromolecular physics.

Maxwell Medal and Prize to Dr D W Bullett of the University of Bath, for his outstanding contributions to the theory of bonding in solids.

Paterson Medal and Prize to Dr I A Shanks of Unilever Research, Bedford, for his contributions to the applications of liquid crystals and his several inventions in the field of displays.