

Physics at London

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A conference of outstanding interest—a study in rapt attention.

The XVII International Conference on High Energy Physics was held at the Imperial College of Science and Technology, London, from 1-10 July. It drew together about 800 physicists from 40 countries. Known affectionately as the Rochester Conference, this biennial event is held in rotation in Europe, the USA and the USSR.

CERN COURIER's review of the last Conference held at Chicago in 1972 (Oct. p. 315) detected 'a feeling of excitement and anticipation' and closed with the words 'whether this feeling of excitement is justified and whether something very important does come up, we should know before the next Rochester Conference in two years' time'. Since that time many ideas have been upset and it is clear that the fundamental discoveries made in the past two years have more than vindicated the expectations at Chicago. With many major surprises and advances to discuss, the Conference

proved to be one of the most stimulating and exciting for a long time.

It was primarily the opening of the new accelerators and experimental facilities which prompted the sense of expectancy at Chicago and it is from these that the major discoveries have come.

The surprising results from the ISR which revealed that the total proton-proton cross section rises with energy were followed by measurements at FNAL which showed that this increase with energy is also a property of pion and kaon-proton total cross sections. The heavy liquid bubble chamber Gargamelle provided the first evidence for the existence of neutral currents and the results were soon confirmed by two counter experiments at FNAL. Experiments at the Stanford electron-positron storage ring SPEAR provided another major surprise concerning the way in which hadrons are produced in electron-positron collisions.

The SPEAR results solidly confirmed the earlier Cambridge bypass measurements which showed that the cross section for $e^+ e^- \rightarrow \text{hadrons}$ stays constant up to the highest energy investigated. These last results are in complete contradiction to the simple quark model (whether coloured or not) predictions. Other ISR surprises such as the unexpectedly large numbers of hadrons at large transverse momenta were confirmed by results from FNAL and were complemented by detailed information on the properties of individual events. Hadrons however are not the only particles produced at large transverse momenta. Experiments from the ISR and FNAL reported results which show that electrons and muons are produced in roughly equal numbers, about ten thousand times less frequently than pions. Again this number is well outside the range of simple quark model predictions. All these unexpected results were complemented by solid progress in the study of weak interactions and the more conventional subjects of hadron physics such as resonance spectroscopy and two-body reactions.

With so much happening so fast it is difficult to give a complete picture of the Conference in a short report. So let us concentrate on trying to answer briefly the main questions physicists who were not in London must now be asking their more fortunate colleagues. The many individuals whose work has contributed to this surge forward in the subject will excuse the fact that reference is made only to their Laboratory, the full list of names being rather overwhelming.

Hadrons from lepton collisions

Let us start with the SPEAR results. The main surprise lies in the fact that the cross section for $e^+ e^- \rightarrow \text{hadrons}$ is constant with energy for energies

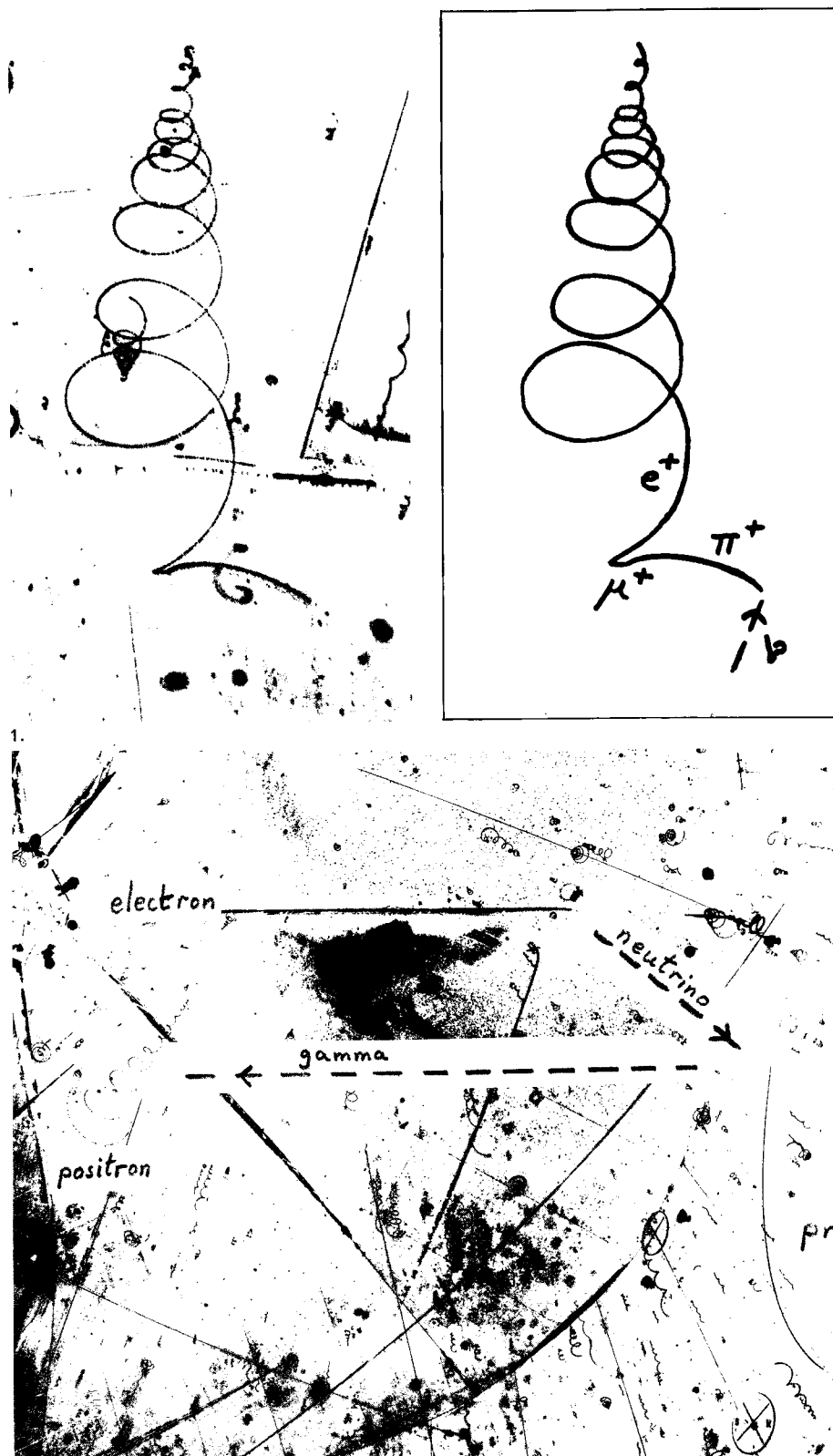


The Argonne neutrino experiment using the 12 foot bubble chamber, filled with either hydrogen or deuterium, gives very clear information on the existence of neutral currents.

Neutral current evidence from Argonne:

1. A neutrino interacts with a proton to give a neutron, a positive pion and an outgoing neutrino. Only the positive pion is seen since the other particles produced in the interaction are uncharged.

2. A neutrino interacts with a proton to give an outgoing proton and neutrino plus a neutral pion which can be identified via its subsequent decay into two gammas at least one of which is seen materializing as an electron-positron pair.



above 3 GeV. The expected mechanism for this process is one in which the electron-positron pair annihilate into a virtual timelike photon which then materialises into hadrons. Care is taken in the experiments to exclude contributions from the competing process in which the hadrons are produced by photon-photon interactions in a double Bremsstrahlung diagram. The one photon annihilation process can also lead to a final state consisting of two oppositely charged muons whose cross section is predicted by QED to fall as the inverse of the center of mass energy squared. Parton models which have been so successful in describing the SLAC results on deep inelastic lepton scattering can then predict the ratio $e^+ e^- \rightarrow \text{hadrons} / e^+ e^- \rightarrow \mu^+ \mu^-$ to be a constant equal to the sum of the squares of the parton charges. With quark partons this constant is $2/3$, coloured quarks would give 2 and an SU3 octet of quarks would give 4. Experimentally this ratio turns out not to be a constant and, more surprisingly, at the highest energies available it reaches a value of 6!

A second big surprise from the SPEAR results is that single hadron energy distributions only show the type of scaling expected from deep inelastic electron scattering for large secondary hadron energies. At lower secondary hadron energies the distributions show a behaviour which is very similar to that of hadrons produced in very high energy proton-proton collisions. A third SPEAR result appears to have provoked intense theoretical activity. It was observed that as the energy of the e^+ and e^- beams is increased the fraction of that energy going into the observed charged particles decreases. Hence a large proportion of the energy must be going into neutral particles.

All these results proved to be a disaster for the hitherto successful

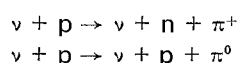
New total cross section data from the Fermi Lab. (black dots) show a general rise with increasing energy for various incident particles on protons. Additional proton-proton cross section measurements made at the CERN ISR lie off the figure to the right (see next figure).

quark-parton model. However this is clearly not a disaster for physics. Experimentalists would be very upset if a new facility exploring unknown areas of nature *didn't* produce unexpected results.

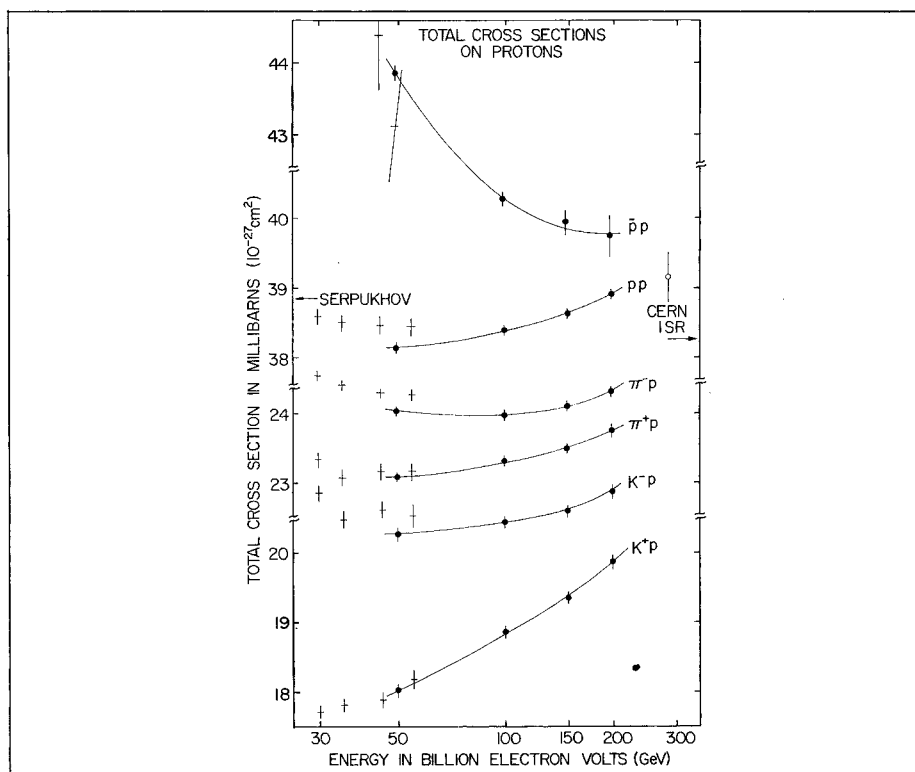
Neutral currents

Let us now turn to neutral currents whose birth was consecrated at this Conference. The necessity of neutral currents or heavy leptons (or both) emerged as a result of the attempts to renormalise the theory of weak interactions so as to cure its diverging high energy behaviour. The first evidence of neutral current interactions was the observation at CERN of events of the type $\nu_\mu + \text{nucleon} \rightarrow \nu_\mu + \text{hadrons}$ in the large heavy liquid bubble chamber Gargamelle. It was the absence of a charged muon in the final state which provided the evidence for the existence of neutral currents. A thorough discussion of the experimental evidence from Gargamelle was presented at this Conference and at the same time results were confirmed by two experiments at FNAL. The results can be presented in terms of the ratio of neutral to charged current events which turns out to be about 20 % for neutrino and 40 % for antineutrino induced reactions. The next stage will obviously be the detailed experimental study of their properties.

New confirmation of the existence of neutral currents in weak interactions came from Argonne. An Argonne/Concordia College/Purdue University team used the twelve foot bubble chamber filled with hydrogen or deuterium to look for two types of interaction

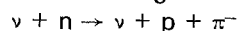


In the first type only the positive pion is seen emerging from the interaction; in the second type the proton and at least one electron-positron pair from



the neutral pion decay is seen emerging.

In 700 000 pictures they have twelve clear examples of neutral current interactions. The use of the hydrogen chamber has the advantage over the CERN and FNAL information in being able to identify all the produce of some interactions. The team is now working on interactions



in which everything about the interaction can be measured — the neutrino energy, the momentum transfer, the proton/pion masses and so on.

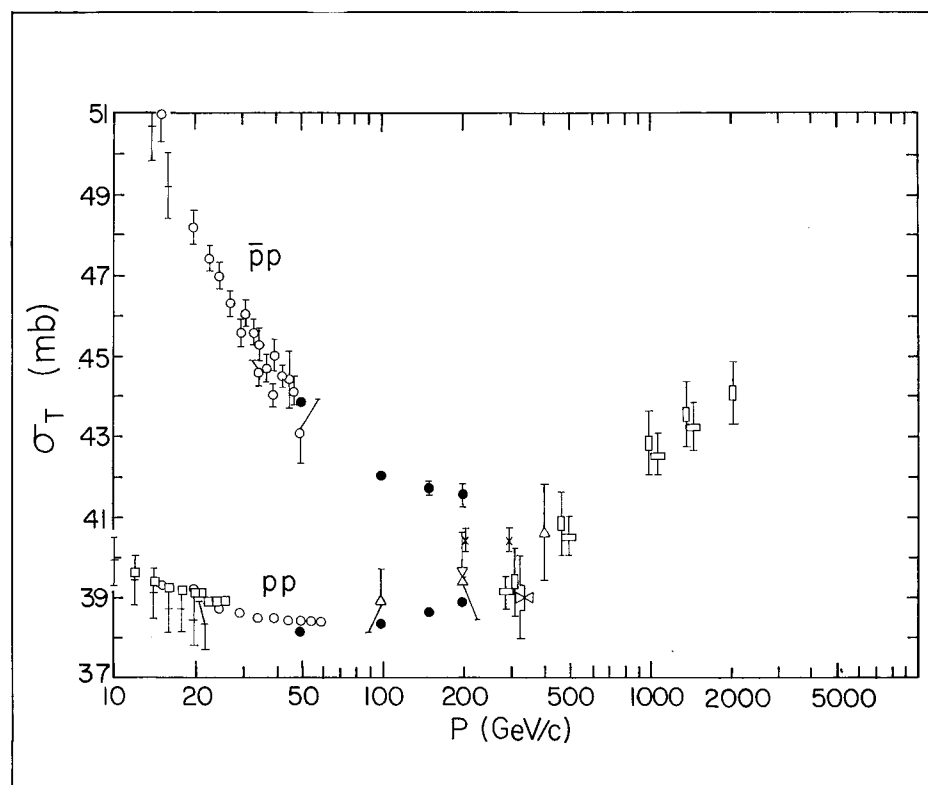
Need for charm

The successful prediction of neutral currents has strengthened theorists' confidence in renormalisable models and they are now predicting the existence of a new quantum number, charm. It is the experimental absence of strangeness — changing neutral currents in conjunction with the need to renormalise certain diverging weak interaction processes involving quarks which leads to the necessity of charm. During the next two years we shall certainly witness an intense experimental activity in the search for charmed particles.

Hadron interaction cross sections

Turning to hadronic interactions many results were presented which would

have been thought exciting in any ordinary year. Total cross section measurements for $\pi^\pm$, $K^\pm$, p and $\bar{p}$ on proton and deuterium targets were presented by groups from FNAL. All except the pp cross section show a rise over the FNAL energy range and the pp results interpolate smoothly between the Serpukhov and ISR points. The $p\bar{p}$ cross sections flatten out with increasing energy and thus avoid crossing the rising pp points. The very basic theorem according to which particle and antiparticle cross sections should approach each other as the energy is increased is beautifully satisfied by the new results. In fact the difference between the two is very well described by a $1/\sqrt{s}$ behaviour as predicted by Regge models. On the other hand it seems unlikely that data at presently accessible energies will be able to distinguish between models predicting different functional dependences for the rise in the cross section. As was stressed by the rapporteur all available data can be fitted by a $\ln s$ or $(\ln s)^2$ rise or even a power law in s . Experimental attempts to pin down the mechanism responsible for the rise led to apparently contradictory results. Groups from the ISR and FNAL studying the pionisation and diffractive components of proton-proton interactions separately claimed that the contribution to the total cross section of their respective kinematic regions could account for



the rise. We thus seem to witness the parts adding up to more than the whole unless of course the two observations are the result of the same mechanism.

High transverse momentum particles

Staying with the ISR the first results from Split Field Magnet experiments were presented and included measurements of elastic pp scattering at high momentum transfer. The variation with energy of the position of the dip in the cross section first reported at the Chicago Conference tends to support a simple picture of geometrical scaling i.e. the proton behaves like a 'grey disk' whose radius increases with energy.

Some very important results on high energy two-body reactions were presented by groups working at Serpukhov and FNAL. They reported measurements of $\pi^-p \rightarrow \pi^0 n$ and $\pi^-p \rightarrow \eta n$ at momenta up to 100 GeV/c which,

when combined with recent precise measurements at the CERN PS, lead to beautifully straight ρ and A_2 Regge trajectories.

The report on the observation of unexpectedly large numbers of particles at high transverse momentum was one of the highlights of the Chicago Conference two years ago. As has often been stressed high transverse momentum events may be the manifestation of pointlike constituents in the proton. It is therefore extremely important to study in detail the properties of subevents, in particular the quantum numbers of the emerging particles, the effective mass distributions and the correlations among them.

Results from the ISR and FNAL show very high production ratios of kaons, protons and antiprotons to pions. Thus for example at $p_\perp \sim 6$ GeV/c and $E_{\text{Lab}} \simeq 400$ GeV they find $K^+/\pi^+ \simeq 0.7$. Another important

result from the ISR concerns the multiplicity of particles associated with one of large $p_\perp$. In the hemisphere opposite to the large $p_\perp$ particle the multiplicity grows by a factor of 4 between $p_\perp \sim 0.7$ and 3.7 GeV/c. This is independent of the incident energy. In the hemisphere towards the large $p_\perp$ particle the multiplicity is strongly energy dependent and at the lower energies decreases with increasing $p_\perp$. At the highest energies it becomes independent of $p_\perp$. An intriguing result of the same experiment was that triggering on one π^0 with large $p_\perp$ enormously increases the chances of finding nearby another π^0 with a similar $p_\perp$. The effective mass spectrum of the two pions does not show any obvious resonant structure.

The study of large transverse momentum phenomena is still at a very early stage and, as the rapporteur on the subject pointed out, we cannot yet draw any real conclusions but many questions have been raised which need further detailed experimental study.

Pointers to the future

Extrapolating forward from the discoveries of the past two years it is not too optimistic to predict that the next two will be at least as exciting. We may well have seen at this Conference the first hints of some of the forthcoming sensations. At least three results first reported at this Conference were received with the sort of reaction which suggests that they are good candidates for tomorrow's major story, though at present all three are, to varying degrees, subject to confirmation.

Firstly, the results mentioned earlier from a number of FNAL and ISR experiments observing single lepton production at large transverse momenta. Is this observation, and the

52nd Session of CERN Council

The Council met on 26, 27 June under the Presidency of Professor W. Gentner

difficulties of parton models to explain it, related to the SPEAR results on $e^+ e^- \rightarrow$ hadrons or are we seeing very substantial production of ϕ mesons which then decay to lepton pairs? This is undoubtedly the firmest of the three results to be discussed and in the next two years several experimental searches for lepton pair production at high transverse momentum will be made.

The second very interesting result was the observation at FNAL of two neutrino induced reactions with not only a μ^- in the final state but also a μ^+ . Both events occurred at the highest neutrino energies and we may be observing the onset of a new process.

Thirdly, another experiment at FNAL studying deep inelastic muon scattering from a nuclear target shows some weak indication of a deviation with the scaling which would have been expected from lower energy deep inelastic lepton scattering. The breakdown of scaling at high energies would indicate that some new process was taking place involving the existence of a fundamental length. However this is a very difficult experiment to perform needing a thorough understanding of the systematic errors.

Three hints then from the Conference which could lead to an even more interesting Rochester Conference in two years' time. How widespread was the sense of expectancy that the next two years will witness very important discoveries? Well, one rapporteur went on record as being prepared to bet any physicist a crate of wine that by the next Conference charmed particles with masses below 12 GeV will have been found.

So we can make one firm prediction for the next Rochester Conference. There will either be excitement among physicists at a discovery of great importance or a number of professionally despondent but inebriated physicists.

At the June Council Session the Directors General presented reports of progress at the two CERN Laboratories. W. K. Jentschke mentioned some recent physics results from the 28 GeV proton synchrotron and the intersecting storage rings. As covered in the report of the London Conference, there is further evidence for neutral currents from the neutrino experiments with the Gargamelle heavy liquid bubble chamber. Another example of neutrino-electron scattering has been seen and over two hundred events on nucleons are now confirmed. In addition, an experiment with a proton beam into the chamber has checked that the estimate of the background, which could result in other events being confused with neutral current events, is correct.

While the existence of neutral currents is supporting evidence for the attempt to unify the interpretation of weak and electromagnetic interactions,

a subversive new type of interaction remains the only way to explain the behaviour of the neutral kaon. The so-called superweak force has been postulated to account for the disrespect of the neutral kaon for the symmetry of charge and parity in Nature. Since the combined symmetry of charge, parity and time is still believed to be good, the violation of charge-parity implies a violation of time symmetry to restore the balance. The superweak theory makes rather precise predictions as to how the symmetry of time will be broken.

The network of survey reference points on the Laboratory II site is being extended to meet the geodetic needs of the accelerator and of its North Experimental Area. The work has been greatly eased by the use of a geodolite, on loan from the Fermi Laboratory, which is a distance measuring instrument using a modulated laser beam. It is capable of accuracies of one part in a million over distances longer than could previously be measured in one stage at CERN.



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