RESULTS ON PERIPHERAL PION-NUCLEON INTERACTIONS AT 12 AND 17 GeV/c

D. O. Caldwell (*), **E. Bleuler** (**), **B. Elsner, L. W. Jones** (***) **and B. Zacharov**

CERN, Genève

(presented by D. O. Caldwell)

Results have been obtained from a short run at the CERN proton synchrotron which give information about shortlived neutral particles which decay into a $\pi^+ - \pi^-$ or possibly a $K^+ - K^-$ pair. These particles, or resonances in the pion-pion system, were produced by observing those interactions of 12 and 17 GeV/c negative pions in a CH target in which two charged particles emerged in the forward direction with nearly all of the incident energy. In this way, it was hoped that the single diagram of Fig. 1 could be isolated, in the manner suggested by Drell [1].

In order to measure for each event the mass of the parent of the pair of outgoing high-energy particles, their angles and momenta had to be determined. It was possible, despite the large incident energy, to achieve an accuracy of $\sim$10 MeV in this mass determination by using two mesh-type [2] spark chambers separated by one meter, followed by a two-meter, 18 kG bending magnet, then two more spark chambers a meter apart, as shown in Fig. 2. The trigger

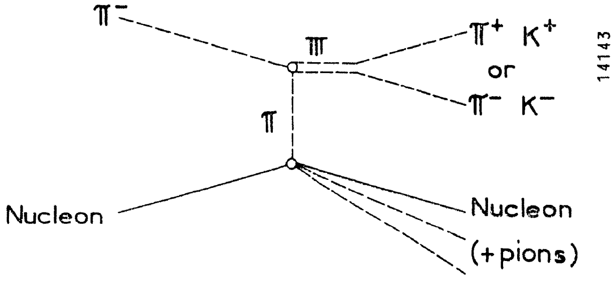

Fig. 1 Diagram which the experiment was designed to observe.

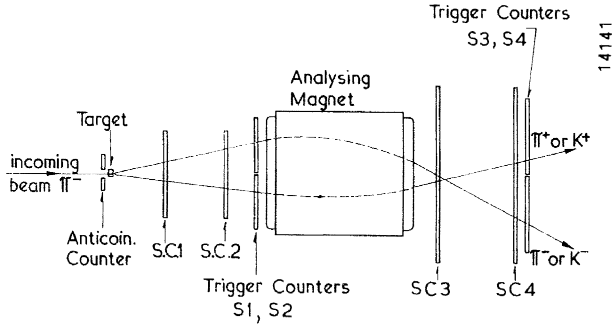

Fig. 2 Schematic lay-out of important parts of the apparatus.

counters pulsed on the spark chambers when an interaction occurred ahead of the magnet and resulted in at least two high-momentum particles beyond the magnet.

For the data presented here, there was no way of knowing for a given event whether the observed particles were π's or K's. Fortunately, however, if an assumption is made as to the mass of the observed particles and the mass of the parent particles is then calculated, the resulting mass spectrum can show sharp peaks only if the assumed masses were correct. For example, a delta-function in a dipion mass spectrum would spread over more than 100 MeV in a dikaon mass spectrum, if the π's were assumed to be K's. Here we show the results of making two assumptions as to the masses of the observed particles, that they are either pion pairs or kaon pairs. A third assumption, that one is a π and one a K does not result in decided peaks, and in particular the known K^* mass

(*) National Science Foundation Senior Postdoctoral and Ford Foundation Fellow, on leave from the Massachusetts Institute of Technology, Cambridge, Mass.

(**) John Simon Guggenheim Fellow, on leave from Purdue University, Lafayette, Ind.

***) Ford Foundation Fellow, on leave from the University of Michigan, Ann Arbor, Mich.

at 885 MeV is not observed. This result might be expected because of the much greater mass of an exchanged K as compared to an exchanged π (i.e., the interaction must be a long-range one to be observed).

If one makes the extreme assumption that in all of the 219 events the observed particles were pions, the mass ideogram of Fig. 3 or the histogram of Fig. 4 results. The peak dominating the spectrum is obviously the well-known ρ meson. Two features of this peak should be noted, however. First, the peak is at 725 MeV, a lower value than is usually given for the ρ. Second, the width is much narrower than has been reported before, being less than 50 MeV full width at half maximum, even without unfolding the effects of experimental resolution or of background. Taking these effects into account, the width would be about 40 MeV. The observation of a narrower width than is seen for ρ's produced at lower energies is made possible by our mass resolution ($\lesssim 10$ MeV r.m.s.), and may be related to the dominance of the diagram of Fig. 1, in which a pure ρ state, initially unmixed with the ω,[3] must be produced. However, a more likely reason for the narrow width is that our ρ's, which have a very high energy, travel on the average 10^{-11} cm before decaying, thus effectively eliminating final-state interactions.

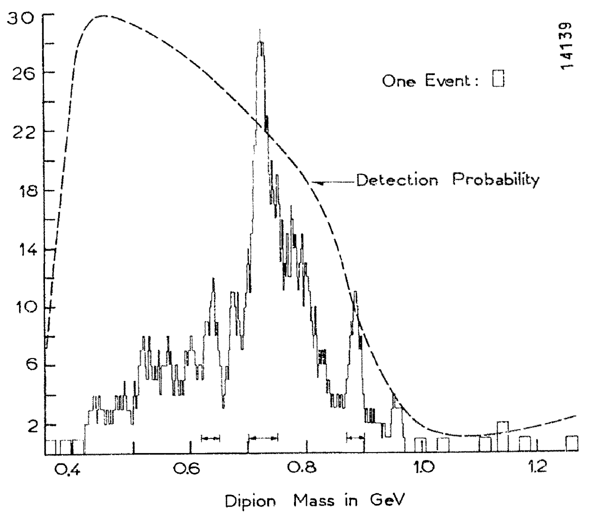

Fig. 3 Ideogram of all 219 events plotted as dipions.

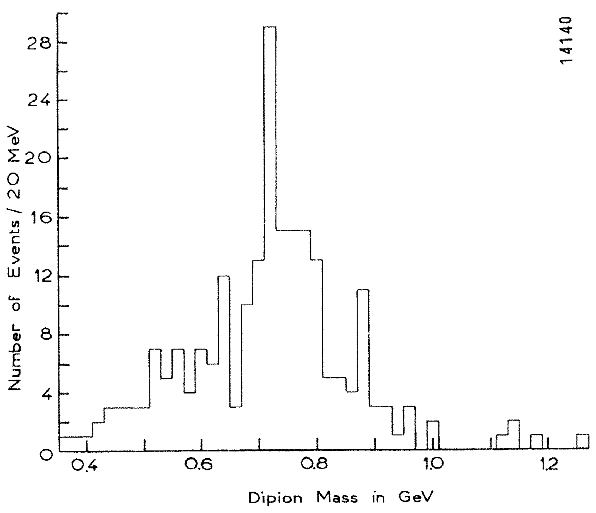

Fig. 4 Histogram of all 219 events plotted as dipions.

The next most prominent feature of Fig. 3 or 4 is a peak at 885 MeV with a width determined by the experimental resolution. There is about a 3% chance that this peak is a statistical fluctuation. Note that in order not to misrepresent the statistical inadequacies of the data, the variation of detection probability with mass has not been corrected for, but is shown in the figures. Hence the peak at 885 would be much more prominent if such a correction were made. Should further work confirm the existence of this dipion, its mass, which is the same as that of the K^*, may indicate an interesting symmetry, since a new $K-\pi$ state has recently been found [4] which has about the same mass as we find for the ρ.

This dipion mass spectrum also provides a little evidence for a peak near 635 MeV, also of a width determined by experimental resolution. The statistical significance of this peak is very dependent upon the value chosen for the " background ", but if one takes values from the immediate neighbourhood of the peak, there is about a 5% chance it is a fluctuation. If this dipion state exists, it may have some relation to the tripion state recently found [5] at about the same mass.

Finally, one notes that there is no evidence for the ζ^0, although our detection probability reaches a maximum in the region of the mass of the charged ζ.

Certainly all 219 events are not pion pairs, and one must inquire as to the effect of kaon pairs on the dipion mass spectrum. To see what dikaon background there may be, the events are replotted in Fig. 5 as if all except those giving dipion masses in the ρ peak (700 to 750 MeV) were dikaons. These 165 events show some structure and one may ask whether this can be related to the 885 and 635 MeV dipion peaks. If the 25 events in those peaks are also removed from

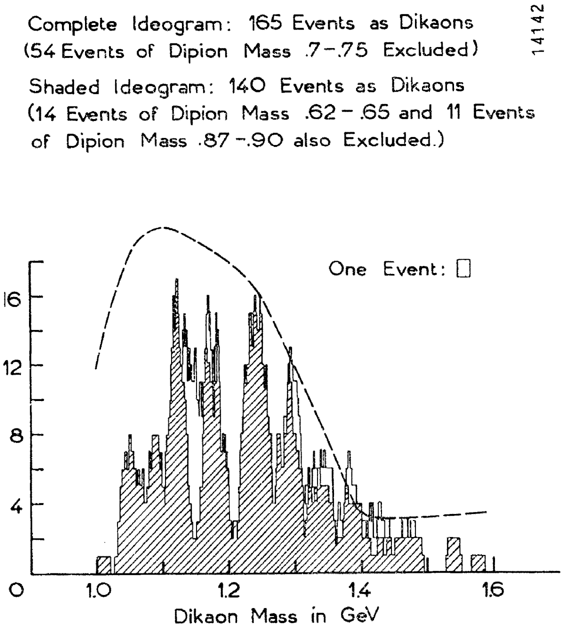

Fig. 5 Ideogram of 165 events and of 140 events as dikaons, after subtracting dipion backgrounds.

the sample, the shaded ideogram results. The peaks at 1120, 1175, 1245, and 1293 MeV are remarkably sharp, but one cannot claim that they represent dikaon states on the basis of such a dubious subtraction procedure. Nevertheless, should dikaon states be providing a background in the dipion spectrum, these peaks are the most likely sources, and hence it is of interest to see what effect they could have on the dipion spectrum. Thus if one removes from the entire sample of 219 events those which give dikaon masses in the four peaks and then plots the remaining 102 events as dipions, the ideogram of Fig. 6 results. It is seen that nearly all of the events could be assigned to narrow peaks in either the dikaon spectrum or the dipion spectrum.

It seems clear that whether or not the background in the dipion spectrum is predominantly due to incorrectly identified dikaons, the diagram of Fig. 1 must be the dominating process. Because of poor statistics and various experimental and theoretical uncertainties, a quantitative comparison with a one-pion exchange model is difficult. However, the cross section for ρ^0 production is not more than a factor of five less than predicted [1] by that model and is $\sim$25 μb/nucleon for momentum transfers $<3m_\pi c$ and an incident π^- of 17.2 GeV/c. Also the momentum-transfer spectrum, which we could measure to an accuracy of only $\sim\frac{1}{2}m_\pi c$, and the ρ angular distribution, which could be measured to $\sim$1 milliradian, are at least in qualitative agreement with the model.

Accelerator time for this experiment will be obtained right after the Conference, and it is hoped that many of the uncertainties in the above results can be resolved with the new data, which will be acquired with improved apparatus, including threshold Čerenkov counters to separate π's from K's.

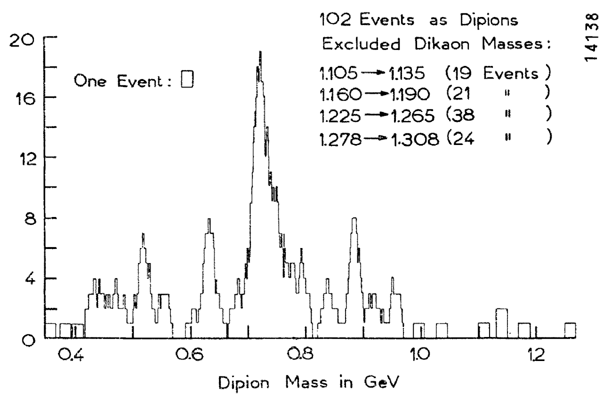

Fig. 6 Ideogram of 102 events as dipions, after subtracting possible dikaon background.

LIST OF REFERENCES

1. S. D. Drell, Phys. Rev. Letters *5*, 278 and 342 (1960), Rev. Mod. Phys. *33*, 458 (1961).
2. G. Culligan, D. Harting and N. H. Lipman, CERN 61-25 (1961).
3. J. Bernstein and G. Feinberg, BNL 6122 (to be published);
   S. Glashow, Phys. Rev. Letters *7*, 469 (1961);
   G. Feinberg, Phys. Rev. Letters *8*, 151 (1962);
   J. C. Taylor, Phys. Rev. Letters *8*, 219 (1962).
4. G. Alexander, G. R. Kalbfleisch, D. H. Miller and G. A. Smith, Phys. Rev. Letters *8*, 447 (1962).
5. E. Pickup, D. K. Robinson and E. O. Salant, Phys. Rev. Letters *8*, 329 (1962).