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1. Research Done By S.-Y. Chu and A. W. Hendry

During the past year or so, Chu and Hendry have been studying various aspects of particle collisions in high energy physics.

Perhaps the most interesting part, however, has been the prediction and subsequent confirmation of structure in the elastic proton-proton polarization at large scattering angles. A high precision experiment to measure this polarization was performed recently by the Indiana University Spark Chamber group at the Argonne National Laboratory. In the following, the significance of the confirmation of this prediction is described.

One of the basic methods for studying how the most fundamental particles of Nature interact, is to fire a high intensity beam of them (produced by high energy accelerators and moving with enormous velocities) at a target in the laboratory. The final products of the collisions are observed and analyzed. Amongst the many collision processes possible, collisions between protons play a particularly important role - because protons form the primary beam of most accelerators and also form the most convenient target (in the form of liquefied hydrogen), the interactions between protons can be studied with great precision, far surpassing that of any other reaction. One might also expect that, as a result of the accuracy with which proton-proton collisions can be done, one might through the study of this process gain some extra insight into how the fundamental particles interact.

As the result of studying the important features of various high energy reactions, Chu and Hendry suggested some time ago that a surprisingly simple picture might be applicable to the case of proton-proton scattering, one which in fact is analogous to the well known situation when ordinary light scatters from a liquid drop. The proton is pictured as a sphere of certain size, characterized by an effective radius and a fuzzy surface. Scattering from the whole sphere gives rise to a phenomenon similar to "diffraction" in optics; scattering from the surface, on the other hand, gives rise to a much more delicate effect (the "glory effect" in optics) which is usually most easily observed at very large scattering angles. Chu and Hendry suggested that both of these two scattering mechanisms were present in proton-proton collisions, and that they should show up in a very characteristic way in a polarization experiment.

In a polarization experiment, one utilizes the fundamental fact that protons have spin one half. One way to visualize this is by thinking of a proton as a spinning top which can spin clockwise or counter clockwise about a given direction. In the actual experiment, protons in the target are made to be highly polarized, (that is, there are many more protons spinning one way than the opposite way). One then measures the number of final state protons that are scattered into a definite angle with respect to the beam direction. Next one reverses the polarization of the target proton (now more protons are spinning in the opposite way) and repeats the measurement. This is done for

many values of the scattering angle. What the simple Chu-Hendry optical-type model predicts is that, for any given value of the beam energy, there are certain definite scattering angles (determined essentially by the effective radius of interaction R between protons) for which the number of scattered protons will be the same no matter the direction of polarization of the target.

In terms of what is called the polarization parameter P for proton-proton elastic scattering, one expects P to have for any given beam energy the following shape:

The angles $\theta_1, \theta_2, \dots$ where P is predicted to vanish depend only on the beam energy and the interaction radius R .

The recent measurements of P by the Indiana University Spark Chamber Group have confirmed (at least for their highest energies) the predicted structure. It is hoped that the excellent agreement between the prediction from the simple picture and experimental data will lead in the near future to a much better understanding of how the fundamental particles interact with one another.

2. Significance of the Research Done by D. B. Lichtenberg

In experiments describing the scattering of strongly interacting elementary particles at medium energies (in the range of a few hundred million-electron volts to several billion electron volts) one of the main features has been the discovery of many resonances. These resonances show up as large increases in the number of particles scattered at certain energies. However, these resonances, which occur in high energy physics, are not nearly as narrow in width as resonances typically occurring in atomic and nuclear physics. Moreover, the resonances are superimposed on a broad background of scattering which depends only weakly on the energy.

We shall contrast the appearance of a resonance in atomic or nuclear physics with one occurring in particle physics. A typical resonance occurring in atomic physics is shown in Fig. 1a and one in particle physics is shown in Fig. 1b.

Fig. 1a) A typical resonance occurring in an atomic physics scattering experiment.

Fig. 1b) A typical resonance occurring in an elementary particle physics experiment.

It can be seen that in the atomic physics case, the resonance energy is very well defined. It is given by the value E_0 in the figure. On the other hand, it is not completely clear that the resonance energy in the elementary particles physics case is given by the center of the peak in the cross section at the energy denoted by E' . This is because the background effects may shift the peak in the intensity of scattered particles from the value it would have in the absence of the background.

Now the value of the true resonance energy, denoted by E_0 , is very important as it is a quantity which must be explained by a future theory.

For example, in the atomic physics case, Balmer's formula for the resonance energies lead to Bohr's theory of the hydrogen atom. If the measured energy did not correspond to the true resonance energy because of background effect, it might have been very difficult for Balmer to have obtained his formula, and the theory of the hydrogen atom might have been set back by many years.

Lichtenberg has been working on a simple method to obtain information about the true resonance energies in the scattering of the strongly-interacting particles. He has obtained a formula which gives the approximate energy shift of the peak in scattered intensity relative to the true resonance energy in the presence of a background. He is using this approximate formula to find the resonance energies from the experimental data. He has found that the broader the resonance and the lower the energy, the greater the shift in the resonance energy from the peak in the intensity.

According to the formula, the shift in energy is approximately proportional to the square of the width of the resonance. These results have profound implications for the unitary symmetry theory of elementary particles.

According to Gell-Mann and Okubo, the resonant energies are altered from the unitary-symmetry predictions in a definite way. The corrected values of the resonance energies, as calculated by Lichtenberg's simple formula, do not agree completely with the predictions of Gell-Mann and Okubo. This result implies that further theoretical work needs to be done. For example, it may be that, unlike the case of atomic physics, the true resonance energies are not the quantities which ought to be used in the formula of Gell-Mann and Okubo. Alternatively, the Gell-Mann - Okubo formula may need to be modified. In any case, an improved knowledge of the correct resonance energies provides very important information for a future theory of elementary-particle interactions.