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HIGHLIGHTS OF THE INDIANA UNIVERSITY SPARK CHAMBER PROGRAM IN 1973*

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The Indiana University Spark Chamber Group has recently completed a major experiment at Argonne National Laboratory to study the spin dependence of proton-proton interactions at high energies. It has been known for many years that the proton, which is generally regarded as one of the most "fundamental" particles in nature, possesses spin. This spin is analogous to the spinning of the Earth about its axis. One central question in the field of high energy physics concerns the mechanism through which the proton spin affects the interaction of protons with other elementary particles. The answer to this question is of fundamental importance to the formulation of a complete theory of particle interactions and is required for a full description of many phenomena in nuclear and subnuclear physics. In order to make a high precision study of spin effects in the proton-proton scattering process, it is necessary to bombard a target composed of protons whose spins have been aligned in a given direction with an intense beam of protons and to detect and analyze the interactions which result.

The Indiana experiment utilized the high energy external proton beam of the Argonne National Laboratory Zero Gradient Synchrotron (ZGS) accelerator. This accelerator produced a beam of ten billion protons per

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second, each proton having an energy of up to twelve billion electron volts. At such high energies the protons had a velocity approaching the velocity of light. This beam was directed onto a proton target which had been polarized using the technique of dynamic nuclear orientation. When an elastic collision between a beam and target proton occurred, the interaction was detected by a scintillation counter-proportional chamber system and recorded by an on-line computer. The difference in the scattering probability for different target spin orientations is directly related to the spin dependence of the proton-proton forces. This experiment extended the exploration of spin effects to substantially larger values of momentum transfer than previously possible and has provided striking verification of a theory recently proposed by two Indiana University theoretical physicists, Professors S. Y. Chu and A. W. Hendry.

The results, interpreted in terms of the Chu-Hendry model, imply that the proton can be thought of as a sphere with a radius of approximately one tenth of a millionth of a millionth of an inch, and that flipping of the proton spin occurs predominantly when two colliding protons pass through each other with their centers separated by this radius. There exists evidence from other experiments that the proton itself consists of other particles called partons. The posssible connection between the observed polarization behavior and the existence of partons is being explored.

The Indiana University High Energy Group is also involved in an experimental search for the so-called exotic mesons. Exotic mesons are those which cannot be made up of simple quark-antiquark pairs. Up to the present there is no conclusive evidence for the existence of these exotic mesons. In fact, the description of almost all observed mesons fits nicely into a model called the "simple quark model," where each meson is made of a quark plus an antiquark.

The quark idea, formulated in 1964 by M. Gell-Mann and G. Zweig, envisions all the observed strongly-interacting particles as being made up of three "super-fundamental" particles, the quarks, along with their antiparticles. Mesons (strongly interacting particles with integral values of the intrinsic spin) are made up of two quarks, while baryons (strongly interacting particles with half-integral spin) are made up of three quarks.

How can you tell if a meson is or is not made of two quarks? (i.e. whether it is or is not exotic) Since quarks have electric charge of either 1/3 or -2/3 (and antiquarks have charge -1/3 or +2/3), then any meson of charge 2 (or -2) is automatically exotic. No combination of two quarks can add up to charge 2.

We have launched two experiments to search for such mesons of charge 2 (X^{++} or X^{--}). Theoretically, they should be most easily produced in a process such as

$$\pi^{+} + p^{+} \rightarrow n_{forward} + X^{++}_{backward}$$

The Stanford Linear Accelerator Center (SLAC) has recently completed the creation of the world's fastest bubble chamber (Rapid Cycling Bubble Chamber). Using this detector as our target of protons, we recently completed a 100,000 picture experiment in search of events of the above process. Each picture taken contained a forward neutral particle (largely neutrons) giving a large sample of possible X^{++}'s, seen in the RCBC. These data are being examined, and the high energy community is anticipating results with considerable interest.

A second experiment will search for the charge 2 exotic X^{--} using a different detecting system called a streamer chamber. The streamer chamber can be made sensitive quickly enough that one can wait until after an interesting event has occurred to decide to make the chamber sensitive. By selecting events of interest (those with a possible X^{--}), one can make a detailed search, one which is ten times as sensitive as the X^{++} search. To create X^{--} mesons, the process

$$\pi^- + n \rightarrow p^+_{forward} + X^{--}$$

will be used.

Just as the periodic table of elements is determined by the way the constituents of the nucleus (protons and neutrons) interact, the table of fundamental particles is determined by the way the constituents of the fundamental particles (quarks) interact. Therefore, the existence (or nonexistence) of exotic mesons lies at the heart of our understanding of fundamental particle physics.