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Technical Progress Report
of the
Indiana University Spark Chamber Group*

December 1, 1973 to November 30, 1974

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ABSTRACT

During the contract year beginning December 1, 1973 the Indiana University Spark Chamber Group was involved in a series of major experiments designed to study various aspects of strong interaction physics. An experiment was executed to search for the production of exotic mesons utilizing the SLAC Rapid Cycling Bubble Chamber. This experiment, which established an exotic production cross section limit of ~1μb, is being followed by another experiment by us which uses the SLAC Streamer Chamber to attain an order of magnitude greater sensitivity. We completed an experiment at the ZGS which studied the large $|t|$ polarization in p-p elastic scattering by utilizing an external proton beam on a polarized proton target. Equipment from this experiment is now being used to measure the depolarization parameter in p-p elastic scattering. An experiment to measure the small $|t|$ p-p polarization has been completed using the Argonne polarized beam. We are also involved in a NAL experiment which studies forward elastic processes. Proposals have been submitted and accepted by the SPS and NAL for experiments to study backward scattering and spin effects at high energy. Final results were published from our previous πp inclusive polarization experiment.

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DISCLAIMER

PROGRESS REPORT

During the contract year beginning December 1, 1973, the Indiana University Spark Chamber Group has been involved in experiments at the Stanford Linear Accelerator Center, at the Argonne ZGS, and at the National Accelerator Laboratory. The experiments were designed to study several different aspects of the strong interactions. Our experiments at SLAC have centered on a search for the possible production of exotic mesons. Our studies at the Argonne ZGS have been focused on a determination of the role of spin in elastic and inclusive reactions. At NAL the nature of the πp, pp, Kp, and $\bar{p}p$ differential cross sections is being studied at high energies. We have also prepared a NAL proposal (which has been recently accepted) to conduct a study of spin effects in very high energy processes. Another proposal, to study backward scattering processes, has been accepted by the CERN SPS.

The SLAC Rapid Cycling Bubble Chamber, together with a downstream counter-spark chamber neutron and gamma detecting array, completed its first physics experiment (SLAC E-82) in May 1973. The film measurement for both systems was completed by December 1973 and the preliminary results presented in Chicago at the February APS meetings.[1] A more complete analysis has been finished, and these results are being submitted to the International Conference in London July 1974[2] and to Physics Letters for publication.

This hybrid system was able to selectively record 100,000 events with forward neutrons, antineutrons, or neutral K mesons. The primary motivation for the experiment was to search for the possible production of doubly charged "exotic" mesons in the process

$$\pi^+ + p \rightarrow n \text{ (forward)} + X^{++} \quad \text{at} \quad 8.4 \text{ GeV/c}.$$

From the point of view of two-component duality, this baryon exchange reaction is a favored mode for exotic meson production. Duality predicts that meson resonances in the X^{++} system should be produced with approximately the same cross sections as non-exotic meson resonances in backward-production processes (~1 μbarn at 8 GeV/c).

The results of analysis of experiment E-82 include:

a. Multiple pion mass spectra showing no exotic resonances.

b. Upper limits on the production of exotic mesons typically between 1 and 2 μbarns for all-pion final states.

c. A simple modified phase space model describing these forward neutron events quite well.

An in-depth search for exotic mesons, SLAC experiment E-103, was approved in October 1973. (Brabson is one of the two spokesmen for E-103.) The system consists of the SLAC streamer chamber with a downstream proton spectrometer to explore the reaction

$$\pi^- d \rightarrow P \text{ (forward) } X^{--} p_s \text{ at 8.5 and 14.0 GeV/c.}$$

During the spring of 1974 much of the equipment (wire spark chambers and counters) to be used in the E-103 spectrometer has been fabricated. The large streamer chamber magnet and the downstream spectrometer magnet will be mapped during the summer of 1974. Substantial modifications to the SLAC streamer chamber system itself and the installation of all downstream apparatus will also be carried out during the summer and early fall of 1974. Check-out running of the E-103 system is scheduled for November 1974 and January 1975, with data taking in February and March 1975.

The estimated number of triggered events to be photographed in the streamer chamber is 150,000-200,000 events. We plan to measure approximately 100,000 of these events using the Indiana PEPR. To study the feasibility of this proposed measuring, we have done studies of streamer chamber film measurement using PEPR. Streamer chamber film taken during the SLAC Santa Cruz μ + d run (E-104) has been measured using PEPR, and events have been processed by the SLAC version of the downstream analysis programs TVGP, APACHE, SQUAW. Previously hand-measured μ + p events are also being processed by PEPR as an additional check on the PEPR measuring scheme. A study of enlarged film format made using PEPR shows a distinct improvement in measuring accuracy gained by the streamer chamber film format from a magnification of ×67 to a magnification of ×40. New lens systems are being installed to effect this change.

A sizeable fraction of the group's effort during the contract year was devoted to the analysis of data from our ZGS experiment E-280. This experiment employed, for the first time at high energies, an external proton beam on a polarized target to determine the polarization parameter in p-p elastic scattering. This new technique permitted the polarization to be determined essentially to 90° in the c.m.s. at 5.15 and 7 GeV/c, and out to the large $|t|$ value of 6 $(\text{GeV/c})^2$ (corresponding to $\theta_{cm} \approx 65°$) at 12.3 (GeV/c).

It has been known for some time that the behavior of the proton-proton differential cross section at momenta above 10 GeV/c is suggestive of an optical potential. By making simple physical assumptions about the contribution of the various regions of the proton to the spin-flip and non spin-flip processes, Chu and Hendry[3] have made optical model predictions for the

polarization in high energy p-p scattering. Their prediction and our 12.3 GeV/c results are in remarkable agreement. We intend to extend these 12.3 GeV/c measurements to larger t and to improve the precision of the data at smaller t by using the new ANL polarized target in a future experiment, to pose even more stringent tests on the various model predictions. Our results at 5.15 GeV/c and 7.0 GeV/c, in conjunction with the results from the polarized beam experiments planned at Argonne, will prove valuable in the attempt to isolate the various p-p helicity amplitudes at intermediate energies.

The results from this experiment have formed the basis for two conference talks (Ref. 4 and 5), a publication in Physical Review (Ref. 6), a publication in Physical Review Letters (Ref. 7), and invited seminars at Argonne National Laboratory, University of Michigan, Indiana University, and the Niels Bohr Institute. Also, papers which attempt a theoretical interpretation of the data have been written by Hendry and Abshire[8] and by Neal and Nielsen.[9]

Several frontier technical problems were dealt with in the execution of the experiment. These included problems associated with the operation of a polarized proton target in a very high intensity external proton beam and the operation of multiwire proportional chambers in a high counting-rate environment. An article based on our data on target radiation damage effects has been accepted for publication in Nuclear Instruments and Methods (Ref. 10). An Indiana University technical report has been written on the characteristics of the chambers used in the high rate application (Ref. 11).

During the present contract year a summary article was completed and published (Ref. 12) on our ZGS experiment E-307. This experiment, which was parasitic to our A_2 missing mass experiment E-266, was designed to study the polarization of the recoil proton in the reactions $\pi^{\pm}p \rightarrow pX^{\pm}$ with the mass of X in the region of the A_2 meson. The polarization was studied as a function of t for a fixed mass interval and as a function of mass for a fixed t interval. We found evidence for mirror symmetry in the polarization in the π^+ and π^- induced reactions. This result is suggestive of the dominance of the ρ exchange contribution to the proton spin-flip amplitude, as in elastic πp scattering. In addition to the above publication, papers on the results from this experiment were presented at the 1973 Meeting of the Division of Particles and Fields in Berkeley (Ref. 13) and at the Winter Meeting of the APS in Berkeley (Ref. 14).

A ZGS experiment (E-364) measuring the polarization in pp scattering at small momentum transfers was completed in the past year. It involves a collaboration between Indiana University, Ohio State University, Argonne National Laboratory, and University of Chicago. The results of one run have been analyzed completely. A second run is presently being analyzed, and the results will be published shortly. The results from the first run show a smooth decline of polarization to 0 at t = 0 but no unusual features.

NAL experiment E-7 is a collaboration between University of Michigan, Argonne National Laboratory, Fermi National Accelerator Laboratory, and Indiana University. The experiment is now taking data measuring the differential cross sections for $\pi^{\pm}p$, $K^{\pm}p$, pp, and $\bar{p}p$ elastic scattering between 50 GeV/c and 200 GeV/c. Preliminary results have been presented

at the 1974 Rochester Conference held in London. New features of these reactions have been found, and it is apparent that some features of lower energy data such as the dip in the K-p cross section persist to 200 GeV/c.

Several years ago the Indiana University Spark Chamber Group submitted a proposal to the Argonne ZGS for an experiment to study the D parameter in elastic proton-proton scattering. Because of internal scheduling considerations for the group's experiments, we have only recently assigned a high priority to the execution of this particular experiment. The physics interest in the measurement of D has been recently heightened by the possibility of measuring other conjugate spin correlation parameters with the Argonne polarized beam. A coordinated set of spin parameter measurements may now permit the isolation of the momentum transfer dependence of the various helicity amplitudes in p-p elastic scattering at intermediate momenta.

The experiment (E-189) to measure D is presently being installed at the ZGS. Data taking is expected to begin near July 1, 1974 and to terminate by mid-August. The setup is practically identical to that of our experiment E-280, except for the addition of a carbon polarimeter to determine the polarization of the recoil proton. A high intensity unpolarized proton beam will strike a polarized target, and both the recoil and scattered protons will be detected and momentum analyzed. Knowledge of the target polarization, the elastic polarization parameter, and the polarization of the recoil proton allows the determination of the Wolfenstein D parameter. Measurements will be made at 3.0 GeV/c and 6.0 GeV/c for $|t|$ values out to ~1.5 $(\text{GeV/c})^2$.

We plan to utilize the techniques which we have developed in our recent experiments with carbon analyzers to make measurements of the elastic, inclusive and inelastic recoil proton polarization at NAL energies. A formal proposal (P-313) with this goal has recently been submitted to and accepted by the NAL Program Committee. The experiment will utilize the planned expanded CO internal target area. A spectrometer, which has been designed for the p-p angular distribution measurements of NAL experiment E-198, would be used to select the desired recoil protons from beam-jet gas target interactions. The polarization of the recoil protons would be determined to an accuracy of ~1% by a small carbon polarimeter located downstream of the spectrometer. The elastic polarization would be measured at several momenta between 30 and 400 GeV/c for several t values in the interval $.2 < |t| < 2.5$ $(GeV/c)^2$. The polarization of the recoil proton in N^* (1520) and N^* (1688) production would be studied for $|t| \lesssim 1$ $(GeV/c)^2$ at several momenta. In the inclusive reaction $p + p \rightarrow p +$ anthing, high precision measurements are planned at selected points in the region near $x = -1$. Depending on the development of the NAL schedule, these measurements could be the first polarization measurements at very high energies. Although all spin effects are expected to become small at high energies, extrapolation of the present data still allows for the existence of experimentally detectable elastic polarization at quite high momenta at large $|t|$. These measurements would serve to test model predictions for the high energy elastic polarization, to examine the similarity of the N^* processes to the elastic process, and also to attack the question of whether spin plays a significant role in inclusive reactions.

The principal investigators covered by this contract (R. Heinz and H. Neal) have devoted 100% of their time during two summer months and approximately 40% of their time during the academic year to this research project. It is anticipated that these percentages will apply for the remainder of the contract year. To the best of our knowledge compliance with the contract requirements has been complete.

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