Technical Progress Report

of the

Indiana University Spark Chamber Group[†]

December 1, 1972 to November 30, 1973

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The principal experimental effort of the Indiana Spark Chamber Group during the period beginning December 1, 1972 has been the installation, tuning, execution, and analysis of ZGS experiment E-280. This experiment measures the large-angle polarization in $pp \rightarrow pp$ at 5.15, 7.0, and 12.3 GeV/c. We also finished analyzing ZGS experiments on the rare $K^- K_L^0$ decay of the A_2^- meson and on the proton polarization in the inclusive processes $\pi^\pm p \rightarrow pX^\pm$. We completed taking data for a collaborative SLAC experiment to search for exotic mesons in $\pi^+ p \rightarrow nX^{++}$. Finally, we proposed an experiment to measure small angle pp polarization using the ZGS polarized proton beam, a collaborative experiment to study $\pi^- d \rightarrow p_s pX^{--}$ at SLAC, and an NAL experiment to measure the s -dependence of $\pi^- p$ backward elastic scattering.

ZGS experiment E-280 is designed to study with high precision the polarization in large-angle elastic proton-proton scattering at 5.15, 7.0 and 12.3 GeV/c. The experiment is unique in that a polarized proton target is utilized in an external proton beam. The gain in rates and resolution that results from this arrangement has permitted a substantial extension in the t range for high statistics p - p polarization data. A double-arm, variable position, multiwire proportional chamber spectrometer detects both final state protons. The momentum of each proton is measured with a resolution of $\sim \pm 6\%$, and the apparent scattering angle of each proton is determined with a resolution of $\sim \pm 2.0$ mr. In addition, the relative and absolute time-of-flight of each final state proton is determined for each event with a resolution of $\sim \pm 0.7$ ns.

Equipment for this experiment was moved to Argonne in October, 1972. Installation of our electronics trailer, the polarized proton target, the beam line magnets, the fast logic, and all elements of the spectrometers was completed by January, 1973. Test runs to study the beam, target and chamber characteristics were conducted between January and mid-March. Data taking runs began in mid-March and the last running cycle is expected to terminate near the first of September.

We have completed all measurements at 5.15 and 7.0 GeV/c and are now in the process of taking the last few data points at 12.3 GeV/c. Results from the 5.15 GeV/c data have been presented at the 1973 APS Division of Particles and Fields Conference in Berkeley¹ and a paper has been submitted to Physical Review for publication.² Analysis of the 7.0 and 12.3 GeV/c data is in progress.

At 5.15 GeV/c we have found that a minimum occurs in the polarization near $t = -.8 \text{ (GeV/c)}^2$, the polarization rises from this minimum until a maximum is attained near $t = -1.8 \text{ (GeV/c)}^2$, and then the polarization monotonically decreases until the value of zero is reached at $t \approx -4.0 \text{ (GeV/c)}^2$ --the 90° c.m. point. Our measurements represent the first to cover the entire angular distribution ($> 30^\circ$ c.m.) at a high energy.

The E-280 spectrometer with its associated hardware and software has proven itself as an extremely powerful system for studying two-body polarizations. Its effective data accumulation rate is substantially greater than that of any previously assembled high energy polarimeter.

During the current contract year we have finished analyzing a series of ZGS experiments (E-266 and E-307) on the A_2 meson. The analysis of the A_2 missing-mass data from $\pi^\pm p \rightarrow A_2^\pm p$ at 4 GeV/c was completed near the end of the previous contract year and a Physical Review Letter based on these data appeared on December 18, 1972.³

In this experiment the recoil proton was observed in a high-precision magnetic spectrometer. Because of the very good mass resolution and high statistics of this experiment, we were able to show with conviction that the A_2 does not exhibit a "dipole" shape. A thorough study of the possibility of exotic A_2 properties hiding in our data was examined, with negative results, and a technical report on this study was issued.⁴

A novel pedestrian-approach paper on our A_2 missing-mass results was also prepared.⁵

A study of the production and decay properties of the A_2 meson was made by analyzing 474 rare $A_2^- \rightarrow K^- K_L^0$ events obtained in a subsequent phase of E-266. The final-state proton in $\pi^- p \rightarrow A_2^- p$ was analyzed as in the missing-mass experiment and another magnetic spectrometer was used to measure the vector momentum of the K^- from $A_2^- \rightarrow K^- K_L^0$. A novel trigger selected events of interest to be recorded on magnetic tape for subsequent analysis. Because of the minimal background under the A_2 in the final data sample, we were able to measure the A_2 spin density matrix elements. Our result deviates significantly from a simple vector meson or f_0 t-channel exchange prediction. In particular, we find that

the element, $\rho_{00} = .19 \pm .05$. A nonzero ρ_{00} requires unnatural spin-parity exchange, such as the B meson. A paper on this work has been accepted for publication by Physical Review.⁶

The analysis of data from our ZGS experiment E-307 was completed during this contract year. In this experiment the polarization of the recoil proton in the reactions $\pi^{\pm} p \rightarrow pX^{\pm}$ was measured for masses M_X between 1200 and 1400 MeV and for t values between $-.8$ and $-.2$ (GeV/c)². This, to our knowledge, represents the first such measurement of polarization in an inclusive process. By examining the polarization as a function of missing mass, averaged over all t , one may search for any substantial asymmetries which might be due to differences between the two halves of the A_2 meson. By examining the polarization as a function of t , averaged over all masses, one may look for evidence for various production mechanisms.

The apparatus for this experiment was basically that of our A_2 experiment, E-266; a carbon polarimeter was added as the last element in the proton arm to allow the polarization of the recoil proton to be determined. This permitted missing mass and polarization data to be recorded simultaneously. Great care was taken to avoid false asymmetries due to instrumental biases.

The results of the experiment were presented at the 1973 Meeting of the American Physical Society Division of Particles and Fields⁷ and a paper has been submitted for publication in Physical Review.⁸ We find

no evidence for substantial polarization differences in the two halves of the A_2 meson. The polarization of the recoil proton as a function of t is consistent with mirror symmetry in the two cases $\pi^+ p \rightarrow pX^+$ and $\pi^- p \rightarrow pX^-$. One possible interpretation of this observation is that ρ exchange is the dominant contributor to the spin flip amplitude for these inclusive processes, just as is the case for elastic scattering.

The SLAC Rapid Cycling Bubble Chamber (RCBC), together with a downstream counter-spark chamber neutron and gamma detecting array, successfully completed its first physics experiment (E-82) in May 1973. This experiment is an Indiana, Purdue, SLAC, Vanderbilt collaboration. The primary Indiana contribution to the experimental apparatus was the neutron and gamma detectors. This search for exotic mesons in the reaction $\pi^+ p \rightarrow n_{\text{forward}} X^{++}$ comprises $\approx 120,000$ triggered events at 8.4 GeV/c incident π^+ momentum. The sensitivity level of the experiment (≥ 50 events/ μb) is great enough to detect the existence of resonance structure in the X^{++} system at the sub-microbarn level. By August 15, 1973 approximately 35% of the entire data sample had been measured. Four-constraint untriggered events in the bubble chamber are well understood and prove that the RCBC operates as a normal bubble chamber with a 70μ setting error. Proper correspondence between bubble chamber and spark chamber geometry has been established, and the first large sample of jointly measured pictures will be processed by the first of September. Besides the expected forward neutrons and K^0 mesons, it seems that there is also

a suitable sample of anti-neutron events in the reaction $\pi^+ p \rightarrow \bar{n} pp$. Results on the existence or nonexistence of exotic X^{++} mesons should be available soon after the complete data sample has been measured. The projected date for the completion of measurements is December 1973. Interesting physics will also be forthcoming from the forward K^0 data sample.

Physics Letters articles have appeared on backward $\pi^- p$ and $\bar{p}p$ experiments which Professor Brabson collaborated on at CERN prior to this contract year.^{9,10} Professor Crittenden and Mr. J. Krider issued a report outlining important aspects of their development of multiwire proportional chambers for use in the group's A_2 and pp polarization experiments.¹¹

During the past three months we have designed three experiments which have led to experimental proposals at SLAC, the Argonne ZGS, and NAL. These experiments are expected to be performed subsequent to the end of this contract year. The SLAC proposal (E-103) is for the Indiana-Purdue-SLAC-Vanderbilt collaboration to use the SLAC streamer chamber and a downstream spectrometer to study $\pi^- n \rightarrow px^{--}$, utilizing a deuterium target. Professor B. Brabson is one of the two spokesmen for this experiment. The ZGS proposed experiment P-364 will use the polarized proton beam and much of the apparatus from our pp large-angle polarization experiment to measure small t polarizations in pp elastic scattering. During the next contract year we also plan to execute ZGS experiment

P-189, which will measure the depolarization parameter in pp-pp. The NAL experiment will test the s-dependence of various models by determining the cross section for $\pi^- p \rightarrow \pi^- p$ at 180° from 15 - 75 GeV/c. A letter-of-intent for this experiment has been submitted, and a proposal has been prepared.

During the period September, 1972 to June, 1973, Professor R. Crittenden was on sabattical leave at the College de France in Paris. Professor K. Hinotani from Tenri University, Tenri, Nara, Japan spent his 1972-73 academic year on leave at Indiana University and worked with our research group. Professor C. Ankenbrandt resigned in July, 1973. The faculty members currently associated with the Indiana Spark Chamber Group are Professors B. Brabson, R. Crittenden, R. Heinz, and H. Neal. In addition a faculty-level research scientist, D. Rust, works with the group. (The principal investigators, Heinz and Neal, devoted 100% of their time during two summer months and 40% of their time during the remainder of the contract year to this project.) The university contributes a research physicist (J. Krider), a technician (B. Martin), and 82% of D. Rust to the group. The NSF Science Development Program supports an electronics engineer (S. Ems) for the group. Other group members include three students (G. Abshire, M. Alam, and M. Corcoran) and a senior technician (H. Petri). Our postdoctoral position is currently vacant due to the recent resignation of S. Levy.

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