Task A

TECHNICAL PROGRESS REPORT
OF THE
INDIANA UNIVERSITY SPARK CHAMBER GROUP*

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ABSTRACT

During the present contract year the Indiana University High Energy Physics Group completed two proton-proton polarization experiments at the Argonne ZGS accelerator and an exotics search experiment at the Stanford Linear Accelerator Center. In addition substantial efforts were directed toward preparations for experiments at the Fermi National Accelerator Laboratory to study large p_T phenomena and polarization phenomena in elastic and inclusive p-p reactions and toward preparations for an experiment at the CERN SPS to study backward pion-proton elastic scattering.

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PROPOSED TECHNICAL PROGRAM

During the 1974-1975 contract year the Indiana University High Energy Physics Group completed two polarization experiments at the Argonne ZGS and an exotics search experiment at the Stanford Linear Accelerator Center. In addition, substantial progress was made in preparing for upcoming experiments to study large p_T phenomena and polarization phenomena at the Fermi National Accelerator Laboratory and in preparing an experiment to study backward pion-proton elastic scattering at the CERN SPS. Additional details of the various efforts are discussed below.

ZGS Experiment E189:

During the summer of 1974 the group completed an experiment at the Argonne ZGS to study the Wolfenstein depolarization parameter in elastic proton-proton scattering at 3.0 and 6.0 GeV/c. This experiment was the first to explore the t dependence of this parameter at energies above 1 GeV/c. The equipment used for this experiment was principally that of our earlier experiment at the ZGS, E280. A high intensity unpolarized proton beam was incident on a polarized proton target and each of the final state elastically scattered protons was detected in a proportional chamber spectrometer. The momentum angle and time of flight measurements made with the spectrometers permitted severe constraints to be placed on each interaction. These constraints greatly discriminated against inelastic and quasi-elastic events. The depolarization was

inferred from a knowledge of the polarization of the polarized target, the conventional pp polarization parameter, and the polarization of the recoil proton beam. The polarization of the recoil protons was determined from an analysis of the left-right azimuthal double scattering asymmetry observed in a carbon analyzer. The efficiency of the analyzer (percentage of useful double-scatters) was of the order of a few percent and the analyzing power was typically 25%. This analyzer was calibrated in a special run made at the ZGS using the polarized proton beam.

The depolarization is a direct measure of the amount of unnatural parity exchange in elastic proton-proton scattering. On the basis of independent analyses the unnatural parity contributions to pp scattering have been presumed to be vanishingly small at small four-momentum transfers. Our measurements are the first to test this conclusion in a direct manner. Our results are found to be consistent with the assumption that the unnatural parity exchanges are completely negligible for t values less than $1 \text{ GeV}/c^2$.

Results from this experiment form the basis for an invited talk at the 1975 Washington Meeting of the American Physical Society (Ref. 1), for a contributed paper for the International Conference on High Energy Physics in Palermo, Italy in June 1975 (Ref. 2), for a contributed paper to the International Symposium on Polarization Phenomena to be held in Zurich in August 1975 (Ref. 3) and for a paper that has been submitted for publication in Physical Review (Ref. 4).

ZGS Experiment E377:

Approximately two years ago the Indiana Group studied the problem of polarization in pp elastic scattering at large momentum transfers at 5.15, 7.00 and 12.33 GeV/c in experiment E280 at the Argonne ZGS. That experiment employed a polarized proton target capable of polarizations of the order of 38%. In the year following experiment E280 the ZGS perfected a cryostat allowing target polarizations of the order of 80% to be obtained. Because of this significant improvement the group proposed a brief experiment to continue its study of large t polarizations utilizing the new target to better map out the structure observed previously at 12.3 GeV/c. This experiment ZGS E377 was run in November 1974 and January 1975 for a total of approximately 3 1/2 weeks. The spectrometers utilized in our previous measurements had remained in place and the setup time was minimal. The experiment resulted in a substantial reduction in the error bars on the polarization data at several points in the $|t|$ range of 1.5 to 6.5 GeV/c². The experiment independently confirmed the existence of a double zero in the polarization near -2.3 GeV/c² and it supported our earlier finding of an additional maximum in the vicinity of $t = -3.0$ GeV/c². It is our opinion that this experiment has pressed the feasibility of large t polarization measurements to its present limits. A significant improvement in the quality of the measurements would require either a considerably longer running time, a much improved polarized target or much higher beam intensities than present targets are able to withstand.

The question of polarization in large proton-proton scattering is an extremely interesting one from a theoretical point of view. For example, Chu and Hendry (Ref. 5) have shown that large t polarizations might be quite crucial in evaluating the validity of optical type models. Also, Neal and Nielson (Ref. 6) for example, have argued that the large t polarization in pp elastic scattering may provide a sensitive test of certain parton model predictions. Furthermore Hendry and Abshire (Ref. 7) have argued that large t polarizations should also provide very critical tests of the Regge model. Results from E377 and various theoretical analyses pertaining to the E377 data were reported at the 1975 Washington Meeting of the American Physical Society (Ref. 1), in a contributed paper to the International Conference on High Energy Physics at Palermo, June 1975 (Ref. 2), in a contributed paper to the International Symposium on Polarization Phenomena in Zurich, August 1975 (Ref. 3) and in a paper recently submitted for publication in Physical Review (Ref. 8).

SLAC Experiment E103:

In collaboration with Vanderbilt, Purdue, and SLAC, our group has been carrying out an extensive search for exotic mesons produced in backwards processes. The first experiment, E82, examined the process:

$$(1) \quad \pi^+ + p \rightarrow n(\text{fwd}) + X^{++} \text{ at } 8.4 \text{ GeV}/c$$

and set upper limits on exotic production in several channels of the order of $1 \mu\text{b}$. The final analysis of this experiment was completed by the summer of 1974 and several conference reports and publications resulted from this analysis (Ref. 9).

A second experiment (SLAC E103) completed in July 1975 has collected data on several processes:

	<u>pictures taken</u>	<u>reaction</u>	<u>beam momentum</u>
(2a)	160,000	$\pi^- d \rightarrow p(\text{fwd}) p_s X^{--}$	14 GeV/c
(2b)	45,000	$\pi^- d \rightarrow \pi^+(\text{fwd}) + \dots$	14 GeV/c
(2c)	12,000	$\pi^+ d \rightarrow \bar{p}(\text{fwd}) + \dots$	14 GeV/c
(2d)	18,000	$\pi^+ d \rightarrow \pi^-(\text{fwd}) + \dots$	14 GeV/c
(2e)	8,000	$\pi^- p \rightarrow p(\text{fwd}) + \dots$	14 GeV/c
(2f)	4,000	$\pi^- p \rightarrow \pi^+(\text{fwd}) + \dots$	14 GeV/c

with principle emphasis on manifestly exotic double negative mesons as in reaction (2a). A large acceptance proton spectrometer coupled with the SLAC streamer chamber provides an essentially complete 4π geometry detection system with 1/2% momentum resolution on the high momentum forward particle.

During the fall of 1974, the proton spectrometer wire chambers and hodoscopes were installed and interfaced to an on-line PDP-9 computer. A logic matrix for hardware momentum selection was also completed during this time. Test running of the assembled system was completed by March 1975 and the production running on the 6 reactions above was carried out from May 15 to July 15, 1975. A report of the on-line results from E103 was presented at the Argonne Conference in July, 1975.

A proposal for an extension of E103 has been submitted to study backwards produced non-exotic mesons, where a sample of 50,000 to 70,000 pictures is requested for reaction (2e) above. The existing

apparatus will remain intact until we have had the opportunity to examine the data already taken with hydrogen in the target (reactions 2e and 2f above). The approval of the extension will depend upon the results of this study. If the extension is approved, we shall probably be asked to take these data in January 1976.

During the 74-75 contract year we have been able to develop an operational measuring system utilizing the Indiana PEPR. PEPR measurement of the film taken in production running began in June 1975 as soon as data became available. We are using PEPR in a semi-automatic measuring mode (similar to POLLY) with an operator. The average event measuring rate for PEPR is presently 4.5 minutes per complete event. This rate is already sufficient to complete event measuring of film from E103 by the end of 1976.

Working geometry programs have been developed at Indiana during this contract year. By December 1975 we plan to have a chain of analysis programs completed through the kinematic fitting stage of analysis, which incorporate complete information from both the streamer chamber and the downstream spectrometer.

FNAL Experiments E110/260:

During the last year A. Dzierba and W. Kropac have been participating in the construction of a multiparticle spectrometer in the M6 beam line at Fermilab. This apparatus will be used initially to study large p_t physics (E260). Then production of quasi-two-body final states at low t (E110) will be explored. These studies will be carried out over a large

range of energies ($p_{\text{lab}} = 20-200 \text{ GeV}/c$). The spectrometer is being constructed by a Caltech-UICC-Fermilab-Indiana-UCLA collaboration.

All of the essential components of the spectrometer are now in place including the superconducting spectrometer magnet which arrived in June 1975. Several test runs have been made to study and calibrate the calorimeter (to be used in the high- p_t trigger), to collect track data from proportional wire chambers and spark chambers and to study high- p_t trigger rates. The first of a series of data-taking runs, which will extend over a period of ~ 1 year, will take place in the latter part of August 1975. The contribution of the Indiana group to the construction of the spectrometer is the on-line software, which is essentially complete. A. Dzierba will be actively involved in the analysis of the data during the year of data taking.

The physics goal of E260 is a global study of reactions in which one or a group of particles in the final state carry off large values of p_t (transverse momentum). The spectrometer measures the multiplicity of the reaction, measures the momentum of the forward going (0° to 120° in the c.m.) particles and identifies particle types over a large range of momenta using two threshold Cerenkov counters. Thus a very detailed study of large p_t final states can be made. We can also study large p_t final states in meson-induced reactions. (These reactions cannot be studied at the ISR.)

FNAL Experiment E313:

During the present contract year the group exerted a major effort in making preparations for its upcoming polarization

experiment at the Fermi National Accelerator Laboratory (E313). This experiment was approved last summer by the NAL Program Committee. It proposes to use the new internal target area to make polarization measurements in elastic, inelastic, and inclusive proton-proton collisions. Interactions between the circulating beam protons at NAL and protons in the jet gas target will result in recoil protons which will be detected by a spectrometer and spin analyzed in a carbon polarimeter. The building for the new spectrometer has been completed and we anticipate moving equipment into the experimental area in August, 1975. The spectrometer consists of a pair of quadrupoles and a bending magnet (all superconducting) which have been delivered from Berkeley, mapped and cooled down. It is anticipated that these magnets will be installed on the experimental floor in August 1975. The polarimeter frame has been completed and the construction of the proportional chambers and scintillation counters is in progress. The design of a special hardwired polarimeter computer has been completed and the fabrication is well underway. It is anticipated that the first beam for testing purposes will be available in October of 1975 and that by Summer 1976 the bulk of the proposed running will have been completed.

In order to have an independent review of the pertinent theory associated with the planned experiment at NAL we convened a small workshop with participants Gordon Kane from the University of Michigan, Francis Halzen from the University of Wisconsin and Geoffrey Fox from Cal Tech to discuss the various model predictions for polarizations in elastic proton-proton scattering, in pp inelastic scattering and in proton-proton

inclusive reactions. As a result of this workshop we learned that there is considerable interest in knowing the behavior of the polarization in elastic scattering in the vicinity of $t = -1.0 \text{ GeV}/c^2$ --the region of the observed dip in the differential cross section. Some models predict huge polarizations in this t region--polarizations approaching 50%. We also learned that the recoil proton coming from the reaction $pp \rightarrow X + p$ need not necessarily, according to any presently accepted theory, have a polarization which is vanishingly small at high energies. Indeed certain triple Regge predictions require the recoil proton polarization to be substantial. Our inclusive and elastic polarization measurements are expected to be the first above 50 GeV.

SPS Experiment WA5:

Experiment WA5 at the CERN Super Proton Synchrotron (SPS) will thoroughly study the essentially unexplored domain of high energy backward pion-proton elastic scattering. This major effort is a collaborative venture involving our group and a group from Saclay, France. Originally, Indiana and Saclay independently proposed experiments to do backward πp studies at Fermilab. In order to maximize the output of our efforts, we subsequently formed a research team. Because Fermilab did not have the flexibility to accomodate our experiment in a reasonable time scale, we submitted our proposal to CERN, where it was warmly received and accepted. Our experiment WA5 will be a first-generation experiment at the SPS. The SPS is expected to be completed on schedule--Fall of 1976.

Backward π^+p and π^-p elastic scattering at high energy (25-125 GeV/c) holds promise of providing exciting insights into the nature of strong interactions. With only a single important dynamical mechanism (baryon exchange) interpretation of the data and observation of significant effects is greatly facilitated. We cover the u region from 0 to -1.3 GeV/c^2 and perhaps will see parton effects at large $|u|$.

WA5 activities during the current contract year have involved extensive detector development and, currently, the design and construction of those detectors which will be provided by us. Major development work in multiwire proportional chambers (MWPC) was done to investigate MWPC instantaneous rate capability and its dependence on sense wire pitch, chamber gap, sense wire diameter, and chamber gas mixture. Studies were done with radioactive sources and with an intense NAL beam. Our data expose the essential cause of the dead time--residual ions. A simple formula, $\epsilon = 1 - RD$, characterizes the chamber efficiency (ϵ) as a function of the beam flux/area (R) and the chamber dead time parameter (D). Our best D is $\sim 3 \mu\text{s mm}^2$, implying our ability to take fluxes of $\sim 10^4/\text{sec/mm}^2$ with $\epsilon \sim 97\%$. MWPC development has been done on amplifiers (resulting in an original design) and on desensitizing specified MWPC regions. Our scintillation development has concentrated in the areas of fiber optics light pipes, special high-rate, low-power, compact bases, and the utilization of an inexpensive automobile industry photomultiplier for rather large scintillator hodoscopes.

The experimental detectors include beam hodoscopes (provided by Indiana), a forward proton spectrometer (upstream half provided by Indiana, downstream by Saclay) and a massive recoil pion vertex spectrometer (built by Saclay). The Indiana detectors will be ~95% completed by September 1975. Beginning September 24, 1975 we will test our equipment at the CERN PS (South Hall). Our experiment will be assembled in the SPS West Area next summer.

The principal investigators covered by this contract (R. Heinz and H. Neal) have devoted 100% of their time during 11 summer weeks 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.

REFERENCES

1. H. A. Neal, presented at the 1975 Washington Meeting of the APS; COO-2009-97.
2. G. W. Bryant, M. Corcoran, R. R. Crittenden, S. W. Gray, R. M. Heinz, H. A. Neal and D. R. Rust, presented to the International Conference on High Energy Physics, Palermo, Italy, 1975; COO-2009-100.
3. G. W. Bryant, M. Corcoran, R. R. Crittenden, S. W. Gray, R. M. Heinz, H. A. Neal and D. R. Rust, presented to IV International Symposium on Polarization Phenomena in Nuclear Reactions, Zurich, Switzerland, 1975; COO-2009-103.
4. G. W. Abshire, M. Corcoran, R. R. Crittenden, S. W. Gray, R. M. Heinz, H. A. Neal and D. R. Rust, submitted to Physical Review; COO-2009-91.
5. S.-Y. Chu and A. W. Hendry, Physical Review D6, 190 (1972); COO-2009-31.
6. H. A. Neal and H. B. Nielsen, Physics Letters 51B, 79 (1974).
7. G. W. Abshire and A. W. Hendry, submitted to 1974 Washington Meeting of the APS; COO-2009-79.
8. G. W. Bryant, M. Corcoran, R. R. Crittenden, S. W. Gray, R. M. Heinz, H. A. Neal and D. R. Rust, submitted to Physics Review D; COO-2009-101.

9. M. S. Alam, et al., contributed to July 1974 XVII International Conference on High Energy Physics, Imperial College, London, England; COO-2009-76.

B. B. Brabson, presented to the 1974 APS/DPF Williamsburg Conference Williamsburg, Virginia; COO-2009-88.

M. S. Alam, et al., Phys. Letters 53B, 207 (1974); COO-2009-106.

M. S. Alam, et al., presented to the 1974 XVII International Conference on High Energy Physics, Imperial College, London, England; COO-2009-84.