

SUMMARY OF THE 9TH INTERNATIONAL SYMPOSIUM  
ON HIGH ENERGY SPIN-PHYSICS\*

Charles Y. Prescott

Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309

I. INTRODUCTION

Summarizing an international conference in high energy spin physics is never an easy task, because of the wide-ranging subjects in physics and technology that are involved. I have chosen to organize the topics of this conference into three broad categories relating to spin: (i) intrinsic spin; (ii) composite spin; and (iii) spin, the experimental tool. In the first category, I will briefly revisit some historical and recent developments to set a background. In the second category, composite spin, I will discuss the status and developments in several areas, including magnetic moments of baryons, hyperon polarization in high energy high  $p_{\perp}$  production, transverse polarization and asymmetries from transversely polarized targets in high  $p_{\perp}$  scattering, spin structure of the proton, and the Bjorken sum rule. In the third category, I will discuss the steady, and at times rapid, progress in spin technology. In this part I include recent progress in high energy facilities, and comment on the highlights of the Workshops. This 9th International Symposium in Bonn has surely been an important one for spin physics. Since the Minneapolis symposium on spin physics in 1988, several important breakthroughs in spin technology have occurred, promising a bright future for the field. For example, we heard at this conference that LEP is polarized and TRISTAN is polarized. Extensive simulations on LEP, HERA, and TRISTAN were reported at earlier conferences. Simulations lend very important guidance to experimenters and accelerator physicists, but now the accomplishments speak for themselves, and progress will be hastened. HERA, whose electron ring has been off while the installation of the proton ring magnets proceeds, should have opportunities in the next year to begin tests of electron polarization. The SLC expects to operate polarized beams next year. The first experimental test of a Siberian snake has occurred at the Indiana University Cyclotron Facility cooler ring. These tests were highly successful, and offer a promise of polarized protons in future proton accelerators.

\*Work supported by Department of Energy contract DE-AC03-76SF00515.

Invited talk presented at the 9th International Symposium on High Energy Spin-Physics, Bonn, W. Germany, September 10-15, 1990.

The workshops on sources and targets give this symposium series a technical backdrop that is so important to progress in the physics area. The advances in laser technologies, cryogenics, ultrahigh vacuum, surface physics, and materials are supporting strongly this steady progress in spin technology. This symposium brings together these fields for the purpose of advancing spin physics.

II. INTRINSIC SPIN

Historically, spin has been a complication of the nature of matter; but an essential complication. Classical motion, specifically the rotation of rigid bodies, contained the ideas of spin and the relationship to angular momentum. In the 1920's, studies of atomic systems led to a failure of these classical laws, and an emergence of an entire body of knowledge at the quantum level. The Pauli exclusion principle was formulated in 1925 [1]. Also in that year, Uhlenbeck and Goudsmit first hypothesized intrinsic spin as an attribute of the electron [2]. In 1926, Thomas correctly applied relativistic calculations to spin-orbit coupling in atomic systems and resolved a missing factor of two in the derived  $g$ -values [3]. In 1928, Dirac made a truly elegant synthesis of his Dirac equation for spin 1/2 particles [4]. In that formulation, solutions are four-component spinors which are interpreted as positive and negative energy states of spin  $\pm 1/2$  each. Dirac predicted the existence of the positron, and the theory became the basis for the enormously successful and precise QED.

Thus in the course of scientific history, spin arose as an essential part of particle nature in a very brief period in the 1920's. Our modern view has gone well beyond the understanding of atoms. At the high energies now available, we have investigated the nuclei, then the nucleon, and today, quarks and vector bosons which mediate the forces. Unification of electromagnetism and the weak forces is completed. We have nearly completed filling in the three generations of quarks and leptons. Only the top quark and the tau neutrino lack direct experimental observation. The recent results from LEP experiments show that  $Z^0$  decays contain three (and no more) light neutrinos, thus indirectly confirming the existence of tau neutrino [5]. Our picture today is one of spin 1/2 fermions constituting all of the known matter, and five vector bosons which mediate the forces between them:

$$\begin{bmatrix} u \\ d \\ e \\ \nu_e \end{bmatrix} \begin{bmatrix} c \\ s \\ \mu \\ \nu_{\mu} \end{bmatrix} \begin{bmatrix} (t) \\ b \\ \tau \\ \nu_{\tau} \end{bmatrix} \text{ and } [\gamma, g, W^{\pm}, Z^0]$$

Deep mysteries remain. Why are there *three* families? What defines "familiarity"? What prevents  $\mu \rightarrow e\gamma$ ? Why do the fundamental objects have spin 1/2? Wouldn't spin 0 be more economical? What role does spin play?

It has been conjectured that the existence of three families and twelve spin 1/2 objects are too many to be fundamental. There should be a simpler and deeper level which leads naturally to answers to these questions. From questions such as these, there arises the interest in searches for a composite structure within these fundamental objects. Of the twelve fundamental fermions we know about, the electron and the muon hold special importance. Only the electron and the muon can be placed into experimental "bottles." The quarks are apparently confined. They can never be isolated. The neutrinos are uncharged, so they cannot be contained, and the tau lepton decays very rapidly. Only the  $e$  and the  $\mu$  permit us to study elemental matter at the fundamental fermion level as we understand it today.

Composite structure of a fermion should, in principle, show up as an anomalous magnetic moment. In an object which has its spin aligned, any constituent which sits at a finite radius would circulate about the center, creating circulating currents, and inducing an anomalous magnetic moment as a result. The electron exhibits an anomalous magnetic moment due to the cloud of virtual  $e^+e^-$  pairs in its vicinity. The heroic calculations of Kinoshita [6] determine the contribution of the "conventional processes" with high precision, allowing us to look at the electron more closely for non-QED contributions to its magnetic moment.

Brodsky and Drell [7] analyzed a model of an electron that is composite, consisting of a charged fermion and a neutral boson. They argue that in a simple model, the contribution to the anomalous magnetic moment  $\delta\alpha$  scales as  $m_e/m^* \cong m_e R_e$ . Existing high energy data place  $R_e < 10^{-16}$  cm, while the precise  $(g-2)_e$  place  $R_e < 2 \times 10^{-21}$  cm. The effective mass  $m^*$  corresponds to 1000 TeV! An extremely precise experimental and theoretical result at low energies can place very high energy constraints on our ideas. Such limits are extremely pessimistic to a believer in constituents of the quarks and leptons.

Avoidance of this extreme conclusion is suggested by Brodsky and Drell if chiral invariant couplings are incorporated into the model. In such cases, the linear dependence on mass is removed, leaving quadratic terms  $\delta\alpha = (m_e/m^*)^2$ . The corresponding limit on  $m^*$  is  $\approx 1$  TeV. This is a more palatable conclusion, and is the one quoted today in comparison of the theoretical and experimental  $(g-2)_e$  results. Any successful theory of compositeness of the fundamental fermions must deal with the near vanishing of both  $\delta\alpha$  and  $\delta m$ .

Although the electron  $g-2$  situation is most impressive, the muon  $g-2$  data offers the possibility for significant further understanding. Due to the mass of the muon, sensitivity to composites or other forms of "new physics" is very good. At this spin symposium, we heard only one report bearing on this important subject of intrinsic spin. That was the progress of Brookhaven's experiment AGS 821, reported by Vernon Hughes. He described

progress in the muon  $g-2$  experiment which will attempt a 20-fold improvement in the experimental value for  $g-2$ . If successful, the experiment will push composite tests up to the 5 TeV level of mass scale. These precision measurements rival the sensitivity of complementary approaches planned at the SSC. Best wishes to AGS 821 for a successful experiment and an interesting result!

### III. COMPOSITE SPIN

This section summarizes a very large body of work on composite objects: the baryons. It is interesting to observe that this section discusses almost exclusively the baryons, and mesons do not seem to enter the discussion seriously. The reasons are not fully obvious. With pseudoscalar mesons being spinless, and with the spin 1 vector mesons adding somewhat more complexity to the spin picture, perhaps we find it easiest to work with the spin 1/2 baryons. For whatever reason, the baryons seem to dominate this section.

#### Magnetic Moments

New contributions to this symposium consist of two results, a reanalysis of the magnetic moment of the  $\Omega^-$ , and a first measurement of the anti- $\Xi^-$  hyperon (the  $\Xi^+$ ). The reanalysis of existing data (still preliminary) reaffirmed earlier results  $\mu(\Omega^-) = -2.08 \pm 0.15$  nm. A planned experiment at Fermilab (E800) will exploit the successful techniques to improve this result substantially.

Lach discussed a new result, the magnetic moment of the  $\Xi^+$ . By the TPC theorem, the result should be equal in magnitude, opposite in sign, to that of the  $\Xi^-$ . The preliminary result,  $+0.67 \pm .022 \pm .018$ , is in good agreement with the magnetic moment of the  $\Xi^-$ ,  $-.0651 \pm .005$ . The status of quark model predictions of magnetic moments was also described. No clear simple model of magnetic moments accounts for the 20-30% deviations from static quark model expectations. Nevertheless, the simple picture of assigning magnetic moments to the valence quarks fully accounts for signs, and mostly accounts for the magnitudes of the moments. Thus, the simple picture apparently contains considerable validity.

Future progress with charmed hyperons can occur. Interest in using bent crystals to precess short-lived baryons like the  $\Lambda_c$ ,  $\Sigma_c$ , or  $\Xi_c$  exists. These ideas hold the possibility that future experiments may add more insights.

## Transverse Polarization of the Hyperons at High $p_{\perp}$

At high energies, hyperons produced at high  $p_{\perp}$  can be significantly polarized transversely to the production plane. Polarization in the plane is ruled out by parity conservation, but allowed if transverse to the plane. In a large number of processes, this polarization is large (20-30%) and of a sign determined by the hyperon's SU(6) wave function and the rule that the  $s$ -quark is negatively polarized. Heller showed a broad range of data which exhibit this behavior, and described a set of rules (in lieu of a theory, since none exists) which explain the observations. These rules, briefly summarized, assume that one or two valence quarks in the produced hyperon come from the incoming proton. An  $s$ -quark is pulled out of the sea to form the hyperon, and it is negatively polarized. Given the SU(6) wave function for the hyperon, the sign of the hyperon polarization is determined. In this picture, the  $\Omega^{-}$  pulls all  $s$ -quarks from the target sea, and lacking any information on the production plane, must therefore be unpolarized. Likewise, antihyperons are expected to exhibit no polarization. Experimental measurements show that the polarization of the  $\Omega^{-}$  and the  $\bar{\Lambda}^0$  are indeed small.

The surprising results shown at this symposium concern the  $\Xi^{+}$ . Clear evidence of nonzero polarization (10%) appears to upset the picture and rules described by Heller. Clearly some time, perhaps more data, and some thinking are needed. Since the rules represent no theory, no one is terribly concerned, but hyperons continue to provide us with interesting and puzzling behavior.

## High $p_{\perp}$ Hadron Scattering

Krisch presented two pieces of data on proton-proton elastic scattering at high  $p_{\perp}^2$ . The first set of data concern a double spin (beam and target) experiment from the ZGS, extending out to 6 (GeV/c)<sup>2</sup>. Substantial nonzero values for  $A_{nn}$  were observed. The second set of data from BNL show new results for this meeting. These results were obtained using a new polarized target capable of higher beam currents. In this case, significant nonzero values of  $A_n$  were measured. These beautiful experimental results show clear, unambiguous, nonzero asymmetries at high  $p_{\perp}^2$ .

Nurushev showed inclusive  $\pi^0$  asymmetries from transversely polarized protons and antiprotons at Fermilab at 200 GeV/c. The asymmetries in both cases rise as  $x$  increases, for  $p_{\perp}$  values out to 2 GeV/c. He showed Serpukhov data on inclusive  $\pi^0$  production for 40 GeV/c  $\pi$  beams on polarized proton and deuterium targets. In both cases, substantial nonzero asymmetries occur at high  $p_{\perp}$ . As in the case of elastic pp scattering, the inclusive hadron data show strong transverse asymmetries at high  $p_{\perp}$ .

Tyurin discussed the status of high  $p_{\perp}^2$  spin and related theories. Perturbative QCD (PQCD) cannot explain or calculate these effects, since transverse asymmetries arise as an interference between helicity flip and nonflip amplitudes. In a massless quark theory with vector couplings, helicity flip does not occur, so transverse asymmetries cannot be calculated. The existence of such asymmetries requires ideas or mechanisms not built into PQCD. Various attempts to explain these asymmetries in nonperturbative QCD-inspired models were described. Tyurin concluded that transverse asymmetries are a crucial test for any model, and single spin asymmetries are particularly difficult for a theory to explain.

Kroll described in detail one nonperturbative calculation based on diquarks as part of the proton. He showed excellent fits to  $G_M^p$ ,  $G_E^p$ , and  $\gamma p \rightarrow \gamma p$  data. His calculations predict sizeable transverse polarization asymmetries in  $\gamma p \rightarrow \gamma p$ . This is clearly an experiment waiting to be done.

Perturbative QCD has failed to explain the high  $p_{\perp}$  asymmetries observed widely in hadron interactions. In defense of PQCD, these problems might be overcome by simple, nonperturbative extensions of PQCD. The failure of PQCD should not force us to discard either PQCD or the underlying ideas of QCD. Too many successes exist. Gluons, for example, have been seen in  $e^+e^- \rightarrow 3$  jets. Evolution of the nucleon structure functions in deep inelastic scattering occurs in a well-defined way. Phenomenological successes of QCD-inspired models of hadron interactions and  $e^+e^-$  annihilation are amazing. Because the baryons are complicated composite objects, quantitative calculations of the multibody behavior will be difficult at best, and likely to be impossible in the sense of a QED-quality precision. Future progress in this business will depend heavily on good experiments, including those which study spin effects.

## Nucleon Spin Structure

In the last few years, rapid progress has been made in the understanding of the role spin plays in the proton. The situation is not yet fully clear, but many aspects have been discussed at this meeting, and there appears general agreement on several important issues. Progress has been stimulated primarily from the CERN EMC experiment [8], which provides sufficient data at low  $x$  to evaluate an important integral,  $\int_0^1 g_1^p dx$ . The EMC data in the vicinity of  $x = 0.1$  and below fall substantially below the curve. Using these data, the integral  $\int_0^1 g_1^p dx$  has been evaluated, and surprisingly fails to satisfy the Ellis-Jaffe sum rule, achieving only about 2/3 of the expected amount. The shortfall appears to be due to the low  $x$  data, where only the EMC experiment has reported results. Where the EMC data overlap with other measurements, the agreement is excellent. Assuming these data are correct, interpretations have been made.

Brodsky, Ellis, and Karliner [10] argue that the quark contributions to the proton spin can be extracted using (i) the EMC data, (ii) an assumption that the Bjorken sum rule is valid, and (iii) the hyperon beta decay data and an assumption about SU(3) flavor symmetry. They obtain  $\Delta u = 0.74 \pm 0.08$ ,  $\Delta d = -0.51 \pm 0.08$ , and  $\Delta s = -0.23 \pm 0.08$ , where  $\Delta q = \int (q^{11} - q^{1\bar{1}} + \bar{q}^{11} - \bar{q}^{1\bar{1}}) dx$ . Furthermore, they conclude

$$\Delta u + \Delta d + \Delta s = 0.00 \pm 0.24$$

where the expectation was 1. This surprising result has been labelled the "spin-crisis," since the net quark spin in the polarized proton is apparently small. Brodsky, Ellis, and Karliner point to the Skyrme model, which predicts this result. The talk by Li at this meeting discussed that model.

Since the Minneapolis meeting in 1988, considerable work on the assumptions leading to this conclusion has occurred. A re-analysis of the hyperon beta decay data [11] concluded that for all reasonable values of F/D, the corresponding Ellis-Jaffe sum rule prediction ranges from 0.168 to 0.210, well above the experimental value. Extrapolations to  $x = 0$  and to high  $Q^2$ -values look to be valid. Contributions to  $A_1$  from  $g_2(x)$  were analyzed in the Theory Workshop in Minneapolis in 1990 by Leader and Anselmino [12]. They concluded changes in  $\int g_1 dx$  due to  $g_2(x)$  were negligible.

QCD corrections to the Brodsky, Ellis, and Karliner result have received considerable attention. At this meeting, Rolnik and Efremov discussed aspects of on-going work relating to this issue; Dorokhov discussed possible contributions to  $\int g_1 dx$  from instanton effects. It has been shown that large gluonic spin can suppress the flavor singlet axial current matrix element, thus possibly explaining the low value for  $\Delta u + \Delta d + \Delta s$ . These arguments are somewhat controversial and rather technical. They should be left to the experts to resolve. It appears that even with the uncertainties associated with gluonic contributions, the net quark spin is small, and mechanisms for carrying net spin, such as gluons and orbital motion of constituents, must be invoked.

Brodsky, Ellis, and Karliner obtained a nonzero and negative strange quark polarization inside a polarized proton. It should be noted that the strange quarks appear to play an important role in the violation of the Ellis-Jaffe sum rule, which explicitly assumed that the strange quark contribution would be zero. Given this picture, the Ellis-Jaffe sum rule for the neutron will show violations as well (as it must if the Bjorken sum rule is preserved).

Rith described the future experiments in spin-dependent structure functions. Four experiments are planned at this time at CERN, DESY (HERA), and SLAC. They will remeasure the proton spin structure, measure the neutron spin structure, and test the Bjorken sum rule.

#### The Bjorken sum rule

$$\int (g_1^p - g_1^n) dx = \frac{1}{6} \frac{g_A}{g_V} \left(1 - \frac{\alpha_s}{\pi}\right)$$

is today regarded as a fundamental test of QCD, since its derivation stems from the principles underlying QCD. The sum rule is remarkable in that it relates deep inelastic properties of the nucleon to those of the static nucleon. Experiments in the next five years or so can test this relation to better than 10%.

Let me conclude this section. There exist extensive and high-quality data on spin-related properties of the baryons. The violation of the Ellis-Jaffe sum rule seems valid, although further experimental work is desirable to confirm the low  $x$  data and improve the overall data. There appear to be unexpected contributions arising from the strange quarks in the proton. There also appear to be hints of strange quark contributions, stemming from the sea quarks, in the analysis of magnetic moments of the baryons, and in the transverse polarization of the hyperons at high  $p_{\perp}$ . It is particularly important to confirm the EMC results at low  $x$ , where the deviation from expectations seem to occur. Of the future planned experiments, the SMC experiment at CERN is best suited to do this because of the high energies available there. The SLAC E142 experiment is particularly well suited for high quality neutron data, but cannot check the proton data because it lacks a suitable polarized proton target capable of remaining polarized in the high beam currents used. The polarized  $^3\text{He}$  target is described in the Workshop reports. The HERA (HERMES) and CERN (HELP) proposals contribute their own capabilities in important areas, and add contributions including different and possibly better systematic errors.

The spin structure data are interesting and important in their own right, but for future experiments, these data are extremely important for designing the future spin experiments at high energies in hadron facilities.

#### IV. SPIN, THE EXPERIMENTAL TOOL

In this part, I summarize the very broad subject of technology of spin. This section includes accelerator facilities utilizing polarized beams; the workshops covering polarimeters, targets, and sources; and Siberian snakes. The Workshops have been summarized for us, so I will only add a few comments on the highlights.

We heard of two significant firsts for  $e^+e^-$  circular rings. Polarized beams have been observed for the first time at LEP and at TRISTAN. Blondel reported on the observation of transverse polarization at LEP. The data were taken at a beam energy of 46.5 GeV, with the detector solenoids off and only a single beam in the ring. The degree of transverse

polarization was 9-13%. During the 14-hour run in which measurements were taken, depolarizing bumps were introduced into the orbit, and then removed. The polarization decay and buildup occurred as expected with the expected time constants. Blondel described plans to build and install spin rotators of the Richter-Schwitters type at the four LEP detectors. Decisions to proceed with the construction are needed soon in order to prepare for polarized physics in late 1993. A series of machine physics studies is needed in order to increase the polarization to a higher level. In the meantime, transverse polarization can be used to calibrate the LEP energy scale to obtain a more precise value of the  $Z^0$  mass.

Horikawa described the first observation of polarization at TRISTAN. The polarimeter, based on a Compton back-scattered photon technique, is similar to that used at LEP, and earlier at other storage rings. Clear up-down asymmetries were seen and translated into an estimated 37% polarization. The experimenters also measured a longitudinal component to the polarization. This component indicates that the spin vector was not completely normal to the plane of the ring, and is of considerable interest to machine physicists who study spin dynamics in storage rings.

Barber discussed plans at HERA to measure polarized electrons. His lecture on the simulation of spin in electron storage rings of high energies was very instructive. He showed that obtaining polarized beams in these storage rings is a delicate business, requiring considerable experimental input as well. The recent results from LEP and TRISTAN will make further progress possible, and in fact much more rapid. The HERA ring has been down since September 89 to allow for installation of the proton ring. Barber anticipates resumption of electron beam running in 1991, so studies of polarization may be possible during the coming year.

It is my personal view that HERA offers our best chance for seeing new physics beyond the Standard Model in the near future. Why do I believe this? Because deep inelastic scattering has been so productive in the past. For example, quarks first showed up in inelastic  $ep$  scattering as a surprisingly large cross section exhibiting scaling behavior pointing to scattering from point-like constituents. Gluons were first seen in  $\nu N$  and  $eN$  inelastic scattering as scale-breaking behavior at high energies and high  $Q^2$ . Neutral currents first showed up in  $\nu N$  interactions in Gargamelle. And the minimal form of  $SU(2) \times U(1)$  as predicted by Weinberg and Salam was confirmed by inelastic  $\nu N$  and polarized  $eD$  scattering. HERA extends the kinematic territory by 10-fold in the center-of-mass energy and 100-fold in  $Q^2$ . I believe history will repeat and that new physics will emerge from the experiments at HERA. Polarization should play a significant role, as well. We all look forward with excitement to the adventure about to begin at DESY.

Moffett described the status of polarization at the SLC. The majority of the polarization system is already installed, and finishing touches are underway with the gun and polarimeters. Early tests should begin in the Spring of 1991.

The program of spin physics at intermediate energies is very broad. We heard presentations on these programs, which cover electronuclear physics and p-nuclei interactions at energies from 800 MeV to 6 GeV. Highlights included ELSA, the 3.5 GeV stretcher ring (now operating at 2 GeV) here at Bonn described in a talk by Anton, a report that the Mainz microtron MAMI is now operating (congratulations!), and beautiful extensive data on polarized p-n scattering from Saturne II (Lehar). Kowalski described the parity violation experiment in elastic  $eC$  scattering at Bates, in which impressive control of systematic effects were obtained, and nonzero asymmetries consistent with the Standard Model were observed. De Botton described the importance of testing the Dreil-Hearn-Gerasimov sum rule in light of the current interest in the Ellis-Jaffe sum rule and the Bjorken sum rule.

The Workshop's summaries covered electron sources (Reichert), ion sources (Mori reported on the KEK workshop in February 1990), gas targets (Steffens), and solid targets (Mango). In addition, an exciting workshop on Siberian snakes and related machine physics was summarized by Wienands.

The Workshops are an important feature of the Spin Symposia. They bring together scientists involved in the technology of spin and the physics of spin. It is an excellent opportunity to exhibit recent progress and to pick up new ideas. It is truly a mixing of atomic, nuclear, intermediate energy, and high energy interests. The advances in technology are impressive. Progress is enhanced by the underlying advances in lasers, magnets, cryogenics, high vacuum, materials sciences, and surface physics. The technical underpinning promises a bright future for the advance of spin physics.

Progress on Siberian snakes has been especially important and deserves special comment. We saw here in Bonn the first report on Siberian snakes at work. A collaboration of physicists from Indiana, Michigan, and Brookhaven installed and tested a Type I snake at the Indiana University Cyclotron Facility cooler ring. This snake consists of a single solenoid surrounded by compensating quadrupoles, four skew quads, and four regular quads. The cooler ring has an imperfection resonance ( $G\gamma = 2$ ) at 108 MeV and an intrinsic resonance ( $G\gamma = \nu_y - 3$ ) at 177 MeV. A polarimeter was added to measure radial and vertical components of the beam polarization remaining after polarized beams were injected from the cyclotron. As predicted, the operation of the snake eliminates these depolarizing resonances. In addition, they reported elimination of a synchrotron resonance, evidence for a Type III partial snake, measurement of the spin tune, and observation of a snake-induced "snake resonance."

This outstanding achievement provides us the proof-of-principle needed for snakes. The future could be very bright. A design for the SSC, consisting of 24 snakes for each of the SSC main rings was described by Steffen. The injection complex for the SSC has been studied and could be relatively easily adapted with snakes. Polarized protons at 20 on 20 TeV would be an exciting future for spin physics indeed!

This symposium at the University of Bonn has been highly successful, and a highly successful part of a long series beginning at Argonne Lab in 1974. Our next meeting in Nagoya, Japan in 1992 promises to be an exciting one as well.

Spin remains a fundamental property of matter, and in many respects a deep mystery. These symposia celebrate the many manifestations of spin and carry forth the message that spin is a very important part of experiment and theory. We look forward to the unravelling of these mysteries, and the challenging steps required to accomplish a better and deeper understanding of our universe.

#### REFERENCES

- [1] W. Pauli, *Zeits. f. Physik* **31**, 765 (1925).
- [2] G. E. Uhlenbeck and S. Goudsmit, *Naturwiss.* **13**, 953 (1925); *Nature* **117**, 264 (1926).
- [3] L. H. Thomas, *Nature* **117**, 514 (1926).
- [4] P. A. M. Dirac, *Proc. Roy. Soc.* **A117**, 610 (1928).
- [5] F. Dydak, *Proc. XXVth Int. Conf. on High Energy Physics, Singapore, 1990*, to be published.
- [6] T. Kinoshita et al., *Phys. Rev. Lett.* **52**, 717 (1984).
- [7] S. J. Brodsky and S. D. Drell, *Phys. Rev.* **D22**, 2236 (1980).
- [8] The EMC Collaboration, J. Ashman et al., *Phys. Lett.* **B206**, 364 (1988).
- [9] J. Ellis and R. L. Jaffe, *Phys. Rev.* **D9**, 1444 (1974).
- [10] S. J. Brodsky, J. Ellis, and M. Karliner, *Phys. Lett.* **B206**, 309 (1988).
- [11] P. G. Ratcliffe, *Phys. Lett.* **B242**, 271 (1990).
- [12] E. Leader and M. Anselmino, *Proc. VIIIth Int. Sym. on High Energy Physics, AIP Conf. Proc.* **187** (1989).

#### DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

**END**

**DATE FILMED**

01 / 10 / 91