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SUMMARY OF THE SYMPOSIUM

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ABSTRACT

Important polarization data were reviewed at the Symposium, but there is grave danger that some accelerators will be turned off before we are finished with them. The ZGS is an important case in point. Both polarized beams and polarized targets are needed to unravel fully the quantum-mechanical amplitudes. Successful tests showed depolarization need not be serious if polarized protons are stored in storage rings. A new polarized electron source was discussed. Amplitude analysis in hadron-hadron scattering and in meson photoproduction was discussed.

INTRODUCTION

I feel as if I have taken on a nearly impossible task. I am to summarize a conference for people who, if they are here to listen to me, have probably been present as much as I have and are bound to have their own ideas about what they have heard. I suppose some may listen to me with the hope that I picked up some gem that they missed.

Well, I will try to sift out some things that seem particularly important.

I think that Marvin Marshak, who has probably put more effort into the planning of this conference than anyone else, seemed to make a sort of promise that whoever handed in his written material for the conference proceedings reasonably early would surely be mentioned in this summary talk. I think he made an understandable simplification in his desire to encourage all the speakers to get their material into his hands promptly. I have a wealth of material. I cannot keep it all in my head. I am bound to omit some very beautiful work.

While mentioning Marvin Marshak, I think I should add my thanks for his effort and for all the other people's work that has gone into making this conference a good one.

SHUTDOWN OF ACCELERATORS

One of the facts of life that underlies this whole conference is that our accelerators are disappearing long before we are ready to see them go. Very few speakers have mentioned this--I suppose it's too depressing--even though in private conversations they make it quite clear they are very much disturbed about this.

In the "good old days," when particle physics had a growing annual budget, accelerators were sometimes shut down, but only when interest in them had waned. I remember, for instance, when the 300-MeV electron synchrotron was shut down in Berkeley, about 1960.
The decision was made by Ed McMillan, who was then acting as a physicist, not a laboratory director.

I remember also the shutting down of the Cosmotron at BNL. That was a mixed situation. Many people outside BNL felt there was too much that still needed doing on the Cosmotron, but the people within the Brookhaven Laboratory felt their full effort should be devoted to the AGS.

By now we have witnessed the shutdown of PPA at Princeton, the CEA at Cambridge, and the loss of the Bevatron as a high-energy machine. The same is true of the 184-inch cyclotron in Berkeley, where my own polarization work began and prospered. (I apologize for my ignorance of the shutdown problems that I have likely not covered in parts of the world outside the United States.)

We should have learned the lesson by now that our accelerators are not going to be in service forever, and we had better get ahead with the most expeditious use of them that we can manage.

Now we are faced with the imminent demise of NINA, NIMROD, and the ZGS. NINA is scheduled to be shut down in about 1 year, and NIMROD and the ZGS are, at least on some schedules, to be shut down in 1978. And all three of these machines are actively being used in polarization experiments.

I suppose it is in the nature of polarization experiments that they are not as "dashing" as the experiments that first demonstrate new phenomena. Rather, polarization experiments are used (usually) when we want to understand a process in detail.

For example, the experiment that first demonstrated associated production was more of a milestone in physics than any of the several experiments that will be done to determine the quantum-mechanical amplitudes in the reaction \( \pi^p + K^A \). Nevertheless, we must vigorously support polarization experiments and the accelerators that make them possible if we really believe they are important, as I certainly do. I am particularly worried about the premature closing of the ZGS—with its unique polarized proton beams—before there is a reasonably full utilization of this facility for the more important problems that can be solved with its help.

Both Polarized Beams and Polarized Targets Are Needed

Several people have asked me to make some comments about the relative advantages of polarized beams versus polarized targets. The first thing that comes to my mind is that we need both, clearly. This is implicit in the p-p amplitude studies, in which it is completely central to the work to have polarized beams (of several kinds) incident upon polarized targets (of several kinds).

There are, of course, some cases in which, in principle, there could be a choice. When we study \( p + p^+ \rightarrow n + A^{++} \) we have a possible option to do it either with polarized beam or polarized target. Actually, the experimenter will usually find that one is far preferable to the other for his purpose.

While both polarized beams and polarized targets are running with good polarization values, typically 70 to 90 percent, the
polarized beam offers some important advantages.

1. It is pure, uncontaminated by heavier elements.
2. In ANL practice, the beam can be alternated in polarization direction on alternate pulses, greatly reducing errors of many kinds, thus improving accuracy.
3. Polarized beams, as opposed to polarized targets, suffer no degradation from the phenomenon we call radiation damage.

There are many processes that can hardly be studied for polarization phenomena without polarized beams.

Perhaps I can best bring out this aspect by discussing how we handle elastic scattering with a polarized target, such as\[ \pi^- + p \rightarrow \pi^- + p. \]

Because our polarized proton targets are made of materials such as propanediol, they are only 10% to 15% hydrogen (by weight). A typical serious background process that we wish to reject from our sample of events is quasi-elastic scattering--scattering from a (moving) proton bound in a heavier nucleus such as carbon. By measuring something about each of the outgoing particles ($\pi^-$ and $p$) we try to select those scattering events that satisfy the kinematic relations for an initial proton free and at rest. Thus we kinematically select scattering on free (polarized) protons. If this is done carefully there may be very little background from the heavier elements in the target.

If we try to do the same thing for a process such as\[ p + p_t \rightarrow \Delta^{++} + n + \pi^0 + p + n\]
we run into trouble. The mass of the $\Delta^{++}$ is poorly defined because of its short lifetime and it is a significant bother--and expensive--to get good kinematic information about the neutron in the final state. This makes it difficult to select out this process on free hydrogen by any simple test. This example is one in which the polarized proton beam could much better be used. It would be incident upon a hydrogen target (that is almost all pure hydrogen). In fact, very good work has been done here at the Argonne Lab with the EMS (Effective Mass Spectrometer) on reactions such as this, as I will mention again shortly.

I think you can easily see that polarized beams do not replace polarized targets, nor do polarized targets replace polarized beams. Each has its essential place. In some cases it is indispensable to have both, as you may see from other examples at this conference.

**POLARIZED PROTONS IN ACCELERATORS**

Dr. Larry Ratner has given a very interesting talk about studies of the problems of maintaining the polarization of the proton beam during the accelerating process in the ZGS. One of the results he reported that I found particularly important is that in slow passage through a resonance most of the polarization is lost.

The background for this study was the hope that in slow passage through a resonance there might be a reversal of the beam polariza-
tion but little loss of polarization. The phenomenon is somewhat similar to the process often called adiabatic fast passage through a resonance in solid-state physics. One explanation of the loss of polarization—only one third of which remains in their tests—is that synchrotron oscillations cause an oscillation of the tune variable for a particular particle that is superimposed on the steady change of tune associated with the acceleration process. This causes the particle to be taken repeatedly through the resonance condition, as shown in Fig. 1.

Larry Ratner also reported a successful test showing that beam polarization could be maintained for long periods in a storage ring. They used a long—20 second—flattop in the ZGS. As long as they were situated far from a resonance, no degradation of polarization was detected. Their accuracy was such that they could say that there was surely a polarization lifetime no shorter than 30 minutes. They suspect it is much longer.

Fig. 1. Tune variable as a function of time for a particle executing synchrotron oscillations.

POLARIZED PROTON SOURCES

Everett Parker reported that many small improvements have been made in the polarized proton source for the AGS. No one recent improvement has been responsible for a great intensity improvement, but together the improvement has been significant. The intensity of the polarized proton beam is approaching one percent of that of the unpolarized beam.

T. B. Clegg told us about a new electron-beam ionizer being developed for the Saturne accelerator in France. The hope is to have intensities of $10^{11}$ polarized protons per pulse.

McKibben and Roy described the Lamb-shift source developments at LAMPF and TRIUMF. The LAMPF source will be rapidly reversible. In view of the advantages that rapid polarization reversal have conveyed on the ZGS experiments, this seems to be an important feature.

Parker also talked about the possibility of a polarized-jet target for use at Fermilab. He said it could have a luminosity of
from $10^{30}$ to $10^{31}$ cm$^{-2}$sec$^{-1}$. In view of the significant polarization dependence being seen at the ZGS in quite a variety of processes, and in view of the difficulties of using a standard polarized proton target for some of these processes, it would seem that a polarized jet target at Fermilab is going to be very important.

Dieter M"ohl told us about a study at CERN of a possible polarized beam in the PS. Its greatest importance would be allowing polarized beams of protons in the ISR. Polarized protons in the SPS would seem to be out of the question for a long time, since about 1000 resonances would have to be passed through to reach 400 GeV. A polarized deuteron beam would be much more feasible, however.

**POLARIZED ELECTRON SOURCE**

A high-intensity electron source is under development at SLAC, based on GaAs plus laser light to excite electrons to energies that allow them to leave the crystal (with the help of cesium at the surface). By using circularly polarized photons one may arrange that these electrons are longitudinally polarized. Charlie Sinclair reported that there is hope of intensities of $10^{11}$ per SLAC pulse, with 50% electron polarization.

**LASER-GENERATED HIGH-ENERGY PHOTONS**

Very useful high-energy photon beams can be produced by allowing very fast electrons to make head-on collisions with optical photons. Such a beam is in use at SLAC for bubble-chamber exposures. It has the great advantage of allowing the photon polarization, as established in laser light, to be preserved in the final high-energy photons. R. H. Milburn reviewed the future possibilities, based on current laser technology. He pointed out that PEP seems to offer an excellent opportunity to exploit this method, especially with modern cavity-dumped lasers. Something of the order of $10^7$ high-energy photons per second might be had in a beam at PEP.

**PROTON-PROTON AMPLITUDE ANALYSIS**

I have for several years been fascinated by the possibility of a complete amplitude analysis of elastic proton-proton scattering. Here one concentrates on the five complex amplitudes that describe the scattering at a particular energy and angle of scattering. Jerry Thomas has pointed out a particularly clear way of seeing through the analysis process that I would like to share with you.

Thomas starts with the following set of transversity amplitudes:

$$T_1 = T_{++++} = T_{+++++}$$
$$T_2 = T_{----}$$
$$T_3 = T_{+-+-}$$
$$T_4 = T_{++--}$$
$$T_5 = T_{+-++}$$
where the subscripts $^\pm_{\text{LMD}}$ indicate spin components normal to the scattering plane of +1/2 and -1/2. The first two indices refer to final-state protons, the last two to the initial state.

There are five experiments that allow determination of the magnitudes of these five amplitudes, as follows:

$|T_1|^2 = \left(\frac{I_0}{2}\right)(1 + D_{\text{NN}} + C_{\text{NN}} + K_{\text{NN}} + 4A)$

$|T_2|^2 = \left(\frac{I_0}{2}\right)(1 + D_{\text{NN}} + C_{\text{NN}} + K_{\text{NN}} - 4A)$

$|T_3|^2 = \left(\frac{I_0}{2}\right)(1 - D_{\text{NN}} - C_{\text{NN}} - K_{\text{NN}})$

$|T_4|^2 = \left(\frac{I_0}{2}\right)(1 - D_{\text{NN}} + C_{\text{NN}} - K_{\text{NN}})$

$|T_5|^2 = \left(\frac{I_0}{2}\right)(1 - D_{\text{NN}} - C_{\text{NN}} + K_{\text{NN}})$.

Here $A = (ON,00)$, often called $P$, is the asymmetry measured with a polarized proton target (and corrected to 100% target polarization). $D_{\text{NN}} = (ON,0N)$, $C_{\text{NN}} = (NN,00)$, and $K_{\text{NN}} = (NO,0N)$. The four symbols in the bracket represent beam, target, fast scattered particle, and slower recoil. Thus $D_{\text{NN}}$ is to imply a four-fold difference is taken involving the normal (N) components of the spins of target and recoil protons, and division by the sums of counting rates gives a coefficient $D_{\text{NN}}$ that is necessarily between -1 and 1. $I_0$ is the ordinary differential cross section.

Figure 2 (Fig. 3 of the Mulera presentation to this conference) shows the Michigan determinations of the differential cross sections for states with specified transverse (normal) components of the proton spins. Although Mulera presented those results in different language, the indicated points in his figure are just the absolute squares of the transversity amplitudes $T_1$ through $T_5$, in proper order. Thus the differential cross sections based only on transverse polarization have given us the magnitudes of the five amplitudes $T_1$ to $T_5$.

From this point on in the p-p analysis I will divide out the factor $I_0$ in certain quantities by inserting $I_0 = 1$.

Having determined the magnitudes of the amplitudes $T_i$ we wish to introduce other experiments to determine the relative phases of the amplitudes. To make our expressions as simple as possible we set the phase of $T_4$ to be $\eta_4 = 0$. This makes $T_4$ real and positive--our arbitrary choice for the moment. We now add the experimental quantities $C_{SS} = (SS,00)$, $C_{LL} = (LL,00)$, and $C_{SL} = (SL,00)$. Here $L$ indicates a longitudinal spin component, and $S$ indicates a component perpendicular to both $L$ and $N$. In terms of the transversity amplitudes $T_i$ these are:

$C_{SS} = -(1/2) \text{Re}(T_1 + T_2)T_4^* - \text{Re} T_3T_5^*$

$C_{LL} = 1/2 \text{Re} (T_1 + T_2)T_4^* - \text{Re} T_3T_5^*$

$C_{SL} = \text{Im} (T_1 - T_2)T_4^*$.

These quantities are particularly important because rather accurate measurements on these can be made--2 to 4 percent. Data for $C_{SS}$ are in hand, reported at this conference and are shown in Fig. 3. $C_{LL}$ and $C_{SS}$ should be determined in the future, but for purposes of
Fig. 2. Michigan-St. Louis-ANL results for differential cross sections for initial and final spin states with definite normal spin components in p-p elastic scattering. These are just the absolute squares of the amplitudes $T_1$ through $T_5$, in proper order.

In illustration we will insert some theoretical guesses so as to allow this analysis to continue.

Adding the expression for $C_{SS}$ and $C_{LL}$ we determine $\cos(\eta_3 - \eta_5)$, and thus determine $(\eta_3 - \eta_5)$ up to a two-fold ambiguity.

By subtracting the expression for $C_{SS}$ from that for $C_{LL}$ we determine $\cos(\eta_1 + \eta_2)$, hence $\eta_1 + \eta_2$ up to a second 2-fold ambiguity. Once a choice has been made for $(\eta_1 + \eta_2)$ the equations determine $\eta_1$ and $\eta_2$ completely.
By adding the measurement (SN,OS) we learn one thing about \( \eta_5 \), subject to a third 2-fold ambiguity.

Adding (SOOS) and (OSOS) (also called R) adds some information but, both being of limited accuracy, they do not change the picture drastically, so we remain with an 8-fold discrete ambiguity.

To analyze this 8-fold ambiguity it is helpful to transform to another set of amplitudes through the relations

\[
\begin{align*}
T_1 &= N_0 - N_2 - 2iN_1 \\
T_2 &= N_0 - N_2 + 2iN_1 \\
T_3 &= N_0 + N_2 \\
T_4 &= -U_0 - U_2 \\
T_5 &= U_0 - U_2.
\end{align*}
\]

While we are defining these new amplitudes we may also wish to write down their expression in terms of the usual helicity amplitudes

\[
\begin{align*}
N_0 &= \frac{1}{2}(\phi_1 + \phi_3) \\
N_1 &= \phi_5 \\
N_2 &= \frac{1}{2}(-\phi_2 + \phi_4) \\
U_0 &= \frac{1}{2}(\phi_1 - \phi_3) \\
U_2 &= \frac{1}{2}(\phi_2 + \phi_4).
\end{align*}
\]

The names N and U have come from the fact that at very high energy these amplitudes correspond to the exchange of natural-parity and unnatural-parity particles.

Inspection of these 8 solutions shows that four have large \( N_0 \) and four have large \( N_2 \), which is much less likely, but in the spirit of this analysis should be taken as a serious possibility until proved otherwise.

As an aside, I point out, following Jerry Thomas, that in the forward direction there is evidence that \( N_0 \) is the large amplitude.
We now know the unpolarized cross section $\sigma_{\text{Total}}$ as well as the two polarization-dependent cross sections $\Delta\sigma_T = \Delta\sigma_{\text{Transverse}} = \sigma(\uparrow\downarrow) - \sigma(\uparrow\uparrow)$, the difference of cross sections of transversely polarized protons, spins antiparallel minus spins parallel, and $\Delta\sigma_L = \Delta\sigma_{\text{Longitudinal}} = \sigma(\uparrow\downarrow) - \sigma(\downarrow\downarrow)$, the difference of cross sections of longitudinally polarized protons, spins antiparallel minus spins parallel. Both of these are known at 2 GeV/c, where $\Delta\sigma_T$ is 6 mb, $\Delta\sigma_L$ is -9 mb, both much smaller than $\sigma_{\text{Total}}$. Some results for $\Delta\sigma_T$ at other beam momenta are shown in Fig. 4, received from W. Dragoset of the Rice-Michigan-Houston collaboration. The dominance of $N_0$ seems definite when one looks at the relations:

$$\sigma_{\text{Total}} = (4\pi/k) \text{Im } N_0$$
$$\Delta\sigma_T = (4\pi/k) \text{Im } (U_2 - N_2)$$
$$\Delta\sigma_L = (4\pi/k) \text{Im } U_0,$$

in which $k$ is the c.m. wave number.

![Fig. 4. $\Delta\sigma_T$, the total-cross-section difference between antiparallel and parallel transverse spins in p-p scattering versus incident momentum.](image)

While these forward relations are interesting, they are not strictly necessary to our complete analysis. The experimental quantity $(L_0, OS)$, also called $D_{LS}$, can be expected to distinguish the large-$N_0$ cases from the large-$N_2$ cases. This experimental quantity has as its largest term $\sin \theta_R (|N_0|^2 - |N_2|^2)$, $\theta_R$ being the recoil proton angle in the laboratory system. The Monte Carlo technique bears out our expectation, and we have reduced the discrete ambiguities from 8 to 4.

Similarly, $(N_0, OS)$ has a large term proportional to $\sin \theta_R \text{Im } N_0N_2^*$. The Monte Carlo bears out the expectation that
the 4-fold ambiguity is then reduced to 2-fold when (NS,OS) is measured.

In the test case there remains a difficult 2-fold ambiguity based on a question of whether $U_2$ or $U_0$ is the more significant. Since both amplitudes are small, one might feel it was not too important to resolve the closely lying ambiguous cases. With some luck or better accuracy on certain key experiments one may eliminate the last shred of ambiguity.

I think you can see that this job really can be done. Most of the work is already done at 6 GeV/c and seems guaranteed to be successful. Using the guessed input to complete the experimental set of measurements, we arrive at the amplitudes shown in Fig. 5 for 6 GeV/c beam momentum and $t = -0.3$. The two parts of the figure show the 2-fold ambiguity that would remain in this hypothetical case if no further measurements were made. Clearly the two sets of amplitudes are very close to each other.

![Diagram](image)

Fig. 5. Proton-proton scattering amplitudes as calculated, based mostly on experimental data but using theoretically estimated values of $C_{LL}$ and $C_{SL}$. When the latter two experiments are completed, a more realistic calculation can be done. Parts (a) and (b) represent the remaining 2-fold ambiguity. This calculation is based on $-t = 0.3(\text{GeV/c})^2$ and incident momentum 6 GeV/c. The amplitude $N_0$ is arbitrarily assumed pure imaginary. The case presented is from private communication by Jerry Thomas.
It is quite important that these techniques be used to complete the work at 6 GeV/c and to get the solution to the highest practicable beam momentum--11.7 GeV/c. They should constitute one of our best tests of whether we understand scattering amplitudes at high energy.

**CHARGE EXCHANGE REACTION IN π-N SCATTERING**

The Rutherford Laboratory has given us some very impressive data sets on pion-nucleon scattering in the past and another contribution from that same source was presented by Tony Parsons, this time on differential cross section and polarization (actually asymmetry) in π^-p → π^0n. Their data are quite extensive. I include here only an example of the results, at 1355 MeV/c, as Fig. 6. The solid curve shows the Saclay 1974 phase-shift result, adjusted without the benefit of these data points. It is my impression that the fit is amazingly good. It strongly suggests that the Saclay 1974 solution is excellent and needs only the most minor adjustment in this energy region.

**PIEON-NUCLEON ELASTIC SCATTERING**

At small momentum transfer the pion-nucleon amplitudes are rather well known at about 40 GeV/c incident momentum from the results from Serpukhov. Ludwig Van Rossum has reported on the polarization in π^±p → π^±p, as well as R measurements for π^-p → π^-p. The polarization results agree at least roughly, as they have for a long time, with the idea that the polarization P has opposite sign for π^±p and π^-p elastic scattering because the polarization derives from interference between p-exchange and other amplitudes. The opposite sign is then automatic since the p contribution reverses sign when one goes from π^+p to π^-p initial states.

The R measurements have their simplest approximate description in the statement that they agree roughly with s-channel helicity...
conservation. This means that in the center-of-mass system a proton that arrives with spin direction perpendicular to its motion leaves the collision with its spin perpendicular to its motion. Fig. 7(a) shows the c.m. view with s-channel helicity conservation. It is rather an amusing exercise in Lorentz transformations to show that the c.m. momentum diagram of Fig. 7(a) does indeed correspond to the diagram of Fig. 7(b) when viewed from the lab system. The component of spin of particle 4 in the direction perpendicular to its motion is $-\cos \theta_p$ in this case. The experimental numbers are not far from the case illustrated.

\[ \text{Component of spin of recoil proton that is measured for } R \text{ measurement} \]

\[ \text{Initial target spin} \]

\[ \text{Final target spin} \]

\[ \text{(s-channel helicity conserved)} \]

\[ \text{Spin direction of recoil proton if s-channel helicity is conserved} \]

Fig. 7. Illustrations of spin directions in $\pi$-p scattering for the case of strict s-channel helicity conservation. (a) is the c.m. view, (b) the lab-system view of the same process. Although the diagram is inspired by 40-GeV/c data the illustrations are for 6 GeV/c incident lab. momentum. The quantity $-t$ is chosen as 0.5 (GeV/c)$^2$.

ANTIPROTON-PROTON ANNihilation INTO 2 MESONS

Alan Astbury presented a report on a very beautiful experiment on annihilation of antiprotons on polarized protons leading to a 2-pion or 2-kaon final state. The work is a collaboration between University of London, Daresbury, and the Rutherford Laboratory. Beam momenta range from 1.0 to 2.2 GeV/c. As an example, their
asymmetries at 1.90 GeV/c are shown in Fig. 8. For some reason unknown the asymmetries are for the most part positive. In analyzing their results they find new resonances. They find a 3- resonance at a mass of 2.14 GeV, a 5- resonance at 2.36 GeV, and a 4+ resonance at 2.40 GeV. In view of the rather small cross section of 100 microbarns for annihilation into 2 pions, their results seem very impressive.

Fig. 8. Example of the data presented by Alan Astbury on asymmetry in $\bar{p} + p \rightarrow n^+ + n^-$, from a U. London-Daresbury-Rutherford Lab collaboration.

POLARIZATION EFFECTS IN INELASTIC SCATTERING

Only in recent times has it been plainly apparent that a great deal of very valuable information is to be derived from inelastic processes that derive from polarized initial states. Perhaps we have concentrated on elastic scattering on polarized protons because the conventional polarized targets, containing heavier elements, were more suitable for elastic scattering, in which kinematics could be used to isolate the processes occurring on free (polarized) hydrogen. With the advent of the polarized proton beam at the ZGS it has been possible to study a multitude of inelastic processes induced by polarized protons.

Since I find myself on rather unfamiliar ground I will not pretend to give an adequate account of the analysis of these inelastic processes. But I can point out that the large asymmetries observed in inelastic processes in some cases strongly suggest that the polarization effects are interesting, important, and potentially very informative on the matter of reaction mechanisms.

The data of Wicklund et al. on the reaction $p_+ + p \rightarrow \Delta^{++} + n$ constitute a good example. The data are shown in Fig. 9. The
measurements are made with the Effective Mass Spectrometer. Although they have similar results at other beam momenta, only their results at 6 GeV/c are shown. Notice the large asymmetry. Furthermore, it seems remarkable that the asymmetry is small at small values of $-t$, where one would expect the pion exchange to be important, and becomes large in a range in which the pion exchange should be unimportant.

Fig. 9. Data of Wicklund et al. on the reaction $p^+ + p \rightarrow \Delta^{++} + n$ at 6 GeV/c incident lab momentum, showing quite large asymmetries.

The Effective Mass Spectrometer has also been used, by Diebold et al., to study elastic p-p scattering and p-n scattering. They are particularly able to observe collisions with rather small momentum transfer. Their data for p-p and p-n scattering at 11.8 GeV/c are shown in Fig. 10.

Fig. 10. Preliminary data of Diebold et al. on polarization in elastic p-p and p-n scattering at 11.8 GeV/c.

PION PHOTOPRODUCTION ON NUCLEONS

In reactions such as $\gamma + p \rightarrow \pi^+ + n$ and $\gamma + p \rightarrow \pi^0 + p$ the differential cross section $I_0$ has been extensively measured, and this
is to a great extent augmented by measurements of $P$, the final-state nucleon polarization, $\Sigma$, the asymmetry induced by using transversely polarized incident photons, and $T$, the asymmetry induced by polarization of the nucleon target in the initial state. (In hadron-hadron scattering we usually call the last quantity $A$. ) Althoff has presented data on the asymmetry $T$ based on measurements in the 700-MeV region.

History tells us that it is exceedingly important to know the photoproduction amplitudes in as much detail as we can. Barker, Donnachie, and Storrow have answered the question of what additional measurements are needed to fully determine the amplitudes. They refer to three classes of further experiments: beam-recoil, beam-target, and target-recoil, referring to which two particles have their polarization monitored in the further experiments. They say that 3 more experiments are needed, only 2 of which can come from the same class.

I apologize for touching so lightly on photoproduction. Its importance would warrant much more comment.

LOOKING INTO THE FUTURE

Only fools look into the future of physics, but this is one of those occasions when perhaps one should try to see what may be coming. Here are some scattered thoughts as to what we may expect—or what we may wish to think about.

1. I expect to see polarized protons accelerated in the accelerator at the KEK laboratory in Japan. The Japanese physicists have shown that combination of persistence, care, patience, and ingenuity that would allow them to tackle successfully the full amplitude analysis of a variety of polarization phenomena that we cannot hope to handle at the ZGS before its scheduled shutdown. (There will still be an enormous amount of physics to do if the ZGS gets an extension of its life of a year or two.)

2. I expect to see complete analyses of p-p and p-n elastic scattering at both 6 and 12 GeV/c based on data taken at the ZGS before its demise. The p-p analysis is well advanced. The p-n scattering we know less about at this time.

3. I hope and expect to see $R$ measurements (OS,OS) at much higher values of $-t$. These experiments will not be easy. They will require great skill and imagination in the design of apparatus. They may, very likely, involve polarized target magnets that are designed from the beginning to serve also as analyzing magnets.

4. We will be using polarized $\Lambda$ beams. A report on two methods of obtaining polarized $\Lambda$ beams has already been presented at this conference by M. Sheaff.

5. We will have polarized photon beams at Fermilab.

6. We can confidently expect that we will be using polarized $e^+$ and $e^-$ beams at PEP. I base my optimism on something that Charlie Sinclair told me—he knows of a diagnostic method that will measure the extent of polarization of either beam.

7. Dilution refrigerators for polarized targets are definitely in. Niinikoski's report that you can cool the lattice much better
with a dilution refrigerator will be enough to force us to learn how to make dilution refrigerators. Cooling polarized targets by evaporation of $^3$He is hereby pronounced passé.

8. The big question: will we have polarized protons accelerated at Fermilab or in the SPS? One answer is that it seems hopeless unless we find a good diagnostic that will tell quickly how much polarization the beam has while in the machine. Another answer is probably that accelerating polarized deuterons looks much more tractable. We could do a great deal with the polarized protons and polarized neutrons that can be derived from high-energy polarized deuterons.

In conclusion let me say thank you for listening, and thanks to the many conference participants who have given me private lessons and lots of good suggestions.
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