

POLARIZED PROTONS AND PARITY VIOLATING ASYMMETRIES**T.L. Trueman**Physics Department
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Résumé. -

Abstract. - The potential for utilizing parity violating effects, associated with polarized protons, to study the standard model, proton structure, and new physics at the SPS Collider is summarized.

The energy of the SPS Collider makes it ideally suited to make use of the parity violating asymmetry resulting from W and Z production. The cross-sections for producing these particles are known to be substantial /1/, and if they are what we believe they are, there are strong parity violating effects in their coupling to quarks. Most notable of these is that W's can only be produced by left-handed quarks. The case for Z's is not quite so striking, because the Weinberg angle reduces the size of the vector coupling from maximal, but there is nonetheless a significant difference in their coupling to left- and right-handed quarks. The issue is then to what degree do the quarks in a polarized proton inherit the polarization of the proton? The evidence from the SLAC-Yale experiment /2/ and the preliminary results from the EMC /3/ experiment is that, in the region of $x = m/s$ of consequence at the SPS Collider, the correlation is very strong. At the relevant value of $x = .15$, the measured value of the asymmetry A_1 is about 1/3. Since

$$A_1(x) = \frac{\sum e_i^2 (q_i^+(x) - q_i^-(x))}{\sum e_i^2 (q_i^+(x) + q_i^-(x))}$$

it is clear that the quark polarization is strongly correlated with the proton polarization. Indeed, at this x the data are well described by the SU(6) relations

$$u^+(x) - u^-(x) = \frac{2}{3} u_v(x) ,$$

$$d^+(x) - d^-(x) = -\frac{1}{3} d_v(x).$$

(As x goes to 0 or to 1 the SU(6) relations have problems and theoretically there

are expected to be serious differences with these simple relations /4/ but it doesn't seem important for the issues I wish to discuss, so my quantitative remarks today will assume these simple relations.) Of course, these are not the structure functions at the proper q^2 for W or Z production. However, according to calculations done by Hochberg /5/ and by Chiapetta and Soffer /6/, the relation between the polarized and unpolarized valence structure functions are numerically well preserved by the Altarelli-Parisi /7/ equations:

The most striking asymmetry should be seen in the leptonic decays of the W. Roughly 4 to 5 times as many W^+ should be made with left-handed as with right-handed protons, while about twice as many W^- should be made with right-handed protons (yes! note the reversal here) as with left-handed. This is a real parity violating effect, proportional to the pseudoscalar $\vec{\sigma} \cdot \vec{p}$ in contrast to the observed forward-backward asymmetries /8/ - it is directly proportional to the product of the vector times axial-vector coupling. One may feel he knows what the result will be and so not be too excited about doing this, but clearly if a polarized beam is available it will be done. In any case it is a direct way of measuring the spin dependent structure functions and should complement HERA should polarized protons ultimately be made available there /9/. The structure of the proton seems to me to be of fundamental importance and it is likely that one day theory will be able to sharpen the issues here.

The formula for the asymmetry, neglecting possible polarization of the sea, is given by

$$W^+ = \int_0^1 dx (u^+(x) - u^-(x)) d\left(\frac{M^2}{xs}\right) \hat{\sigma} = \frac{2}{3} \sigma(W^+)$$

$$W^- = \int_0^1 dx (d^+(x) - d^-(x)) u\left(\frac{M^2}{xs}\right) \hat{\sigma} = -\frac{1}{3} \sigma(W^-)$$

When Paige, Tudron and I /10/ first looked at this question several years ago, we were looking for a way of pulling the hadronic jet decays of the W (Fig. 1a) out of the background (Fig. 1b). For the usual light quarks this background is a couple of orders of magnitude above the signal and we had not been able to find a satisfactory way of doing this. The fact that the polarization asymmetry is so strong makes this appear to be a good way to achieve that. The signal in the asymmetry remains very strong. The main problem is obviously to accumulate enough events so that the error in the background is smaller than the signal - the expected asymmetry is a few percent of the background for all hadronic jet pairs.

Incidentally, above the W an asymmetry due to W exchanges (Fig. 1c) remains at the percent level. Deviations from this standard model result due to quark substructure were discussed at the first Snowmass meeting and indicate that the

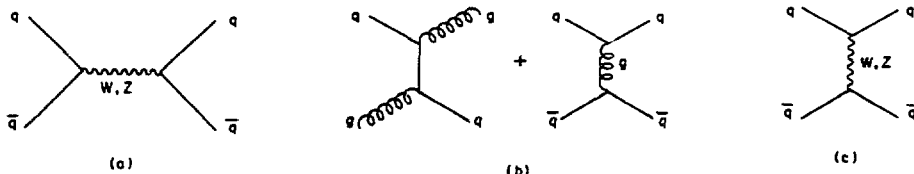


FIG. 1(a) - W, Z production and decay into light quarks;
 (b) - Principal background to (a);
 (c) - Source of asymmetry above the W and Z mass.

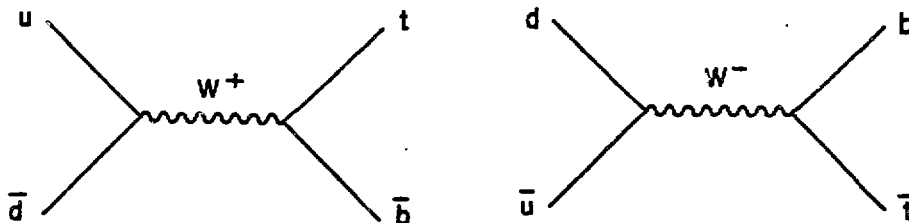


FIG. 2 - W production and decay as source of top quark.

collider could be sensitive to a substructure scale of about 1 TeV /11/. Because of the flexibility of the composite models at the present time, it is difficult to say if this is significant or not.

If there are other interesting characteristics which distinguish a potential W-decay from the background, one may not need to accumulate so many events in order to make potent use of the asymmetry. One immediately thinks of the tb decays of the W. If the recently reported UAL candidates for the t quark /12/ are truly coming from W decays there should be a clear correlation between the rate and the polarization: about 40% more should be produced with left- than with right-handed protons (Fig. 2). What's more there should be a striking difference in the sign of the lepton, the positive lepton being associated with left-handed by a factor of 5 to 1, the negative being associated with the right-handed by a factor of 2 to 1.

Obviously any other particle whose source is W-decay will show this same asymmetry. A case in point is the search for the super-symmetric partner of the W. In many models there is predicted a wino below the W mass /13/ and there can be a substantial branching ratio for W decay into this and a photino if the masses are right (Fig. 3). This would show mainly as two jets (q, q-bar, photino) with missing energy /14/. If this shows up in the asymmetry signal, it would determine the source to be W and give a measurement of the branching ratio of the W to wino + photino.

One can obviously play the same game with the Z. Although the asymmetry is not expected to be as large as with the W, it is by no means insignificant. A calculation done by Kinnunen and Lindfors /15/ shows an asymmetry of about 20%. Their calculation also shows an interesting effect in the angular distribution from the Z decay of the lepton pair: the tendency of the positron to go in the anti-proton

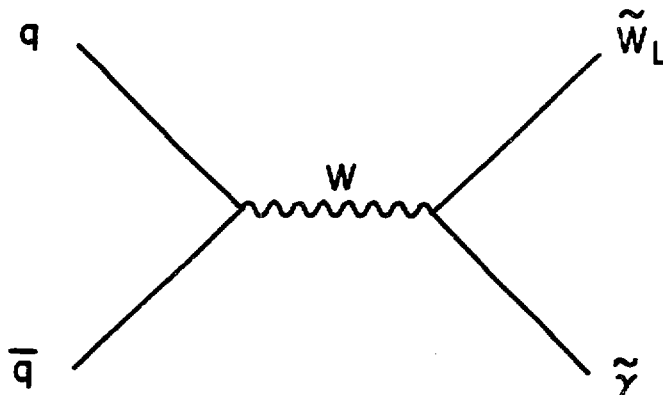


FIG. 3 - W decay as source of winos and photinos.

direction is enhanced with left-handed protons reflecting an increase in the longitudinal polarization of the Z. (This enhancement is expected to be very small in the case of W-production because, in the Drell-Yan process, the W's are produced about 99% polarized already: the only depolarization comes from W's produced by sea quarks from both the proton and the anti-proton and that is quite small at 540 GeV.) QCD corrections to this polarization have been considered by Chaichian, Hayashi, Soffer and Yamagishi in a paper submitted to this conference /16/.

I think we would all find the most interesting applications of this technique to be the new discoveries that we don't have such clear ideas about. Let's take the apparent Z to $e^+e^-\gamma$ events /17/. There are no completely satisfactory explanations of these, but there have been many different suggestions. Most of them assume that they originate from Z decay. If this is the case then there should be a 20% asymmetry in the production rate. On the other hand some people, such as Marciano /18/ and Holdom /19/, have suggested that the source is a scalar or pseudoscalar that has nearly the mass of the Z (Fig. 4). In this case the asymmetry should be different, very likely zero.

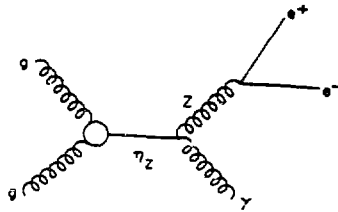


FIG. 4 - Production of η_z as possible source of $e^+e^-\gamma$.

Haber and Kane /20/ have suggested that the UA2 events of a lepton, a jet, and missing p_T /21/ could result from direct production of a wino. Since these would be produced only by left-handed quarks there would be a very large asymmetry in this signal (Fig. 5).

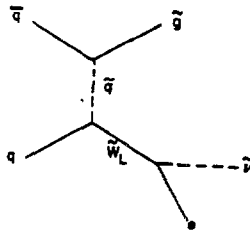


FIG. 5 - Possible source of UA2 lepton-jets events.

The mono-jet events of UA1 /22/ are another interesting case. Several authors /23/ have suggested that they result from a scalar quark. In supersymmetry there is a realistic possibility that the left- and right-handed scalar quarks are not degenerate /24/. Since one is produced from left-handed quarks and the other from right-handed, in principal there can be an asymmetry in this signal (Fig. 6). The cross-section can be large and so can the asymmetry, but I know of no detailed estimates. I find these last two possibilities especially interesting because they are the only ones that do not rely on the basic asymmetry of the vector-boson coupling.

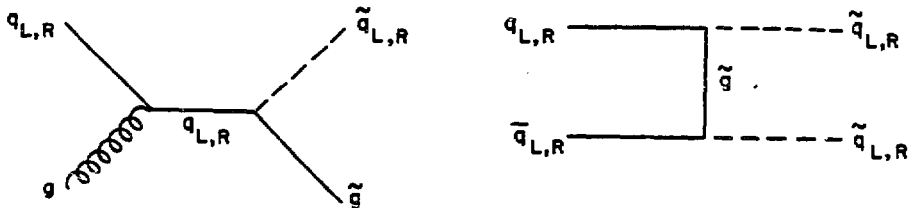


FIG. 6 - Possible source of UA1 mono-jet events.

A great many tantalizing things have been discovered at the Collider in a short time. Who knows what will be discovered next year whose nature could be unravelled with the aid of a polarized beam - perhaps a right-handed W, which would stand out like a sore thumb. Parity violation in the production process would be a very useful tool to have in our bag.

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