IMPACT PICTURE FOR POLARIZATION AND ROTATION PARAMETER
IN HIGH-ENERGY PROTON-PROTON SCATTERING

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ABSTRACT

We propose to use rigid rotation as an approximation to the hadronic matter current inside a proton. This approximation leads to predictions of the polarization and the R parameter in proton-proton elastic scattering. The angular velocity of rigid rotation may be related to the isoscalar magnetic moment of the nucleon.

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The concept of matter motion inside a hadron is due to Chou and Yang ¹⁾. Their application of this concept to the rotation parameter is intimately related to the increasing total cross-section, which has been predicted on the basis of relativistic quantum field theory ²⁾, and later verified experimentally ³⁾. It is the purpose of this note to combine the ideas of the impact picture ^{2),4)} and hadronic matter motion ¹⁾.

In order for a combination of concepts to be useful, it is necessary to derive predictions that can be tested experimentally. The simplest case to apply both the impact picture and hadronic matter motion is proton-proton elastic scattering with one of the protons polarized. This case is the simplest because we need the distributions of hadronic matter ⁵⁾ and hadronic current ¹⁾ inside only one particle, the proton. We shall assume that the target proton is polarized.

The exact hadronic matter current inside a proton is determined by strong interactions and hence expected to be complicated. For the present purpose, in order to make unambiguous predictions, we propose to study first the gross features with the simplest possible approximation, namely that the hadronic matter current is described by rigid rotation of the hadronic matter ⁵⁾. With this approximation, only one additional parameter, the angular velocity of rigid rotation, is needed to determine both the polarization and the R parameter ⁶⁾ of elastic proton-proton scattering.

In order to carry out this programme, the necessary first step is to improve the impact picture of five years ago ^{4),7)}. This improvement has been achieved recently ⁸⁾, and consists of better parametrization, proper Regge background, and more accurate experimental data used as inputs ⁹⁾. For laboratory momentum from 14 GeV/c up to that of the highest ISR energy, this improved impact picture gives a good description of proton-proton scattering, not only in the total cross-section, but also in the elastic differential cross-section. In particular, at ISR energies, there is no second dip in the vicinity of 5 GeV² ⁹⁾, a feature which has received a great deal of attention recently ¹⁰⁾⁻¹³⁾.

In the first step ⁸⁾, the protons are assumed to be unpolarized and the effect of hadronic matter current ¹⁾ is neglected. We then introduce the approximation of rigid rotation, i.e., the approximation that the matter velocity is proportional to the impact-parameter distance. The constant of proportionality must be sufficiently small so that the velocities are very much less than the velocity of light for all relevant impact parameters. We emphasize that this assumption of rigid rotation is at best a first approximation, and might need modification in the future.

In order to test experimentally whether this is indeed a reasonable approximation, we calculate the polarization and the R parameter for proton-proton elastic scattering. Let the direction of the incident proton be along the y axis, and the spin of the target proton be in the direction of the z axis. Then our assumption of rigid rotation means that

$$v_y = \omega b_x, \quad (1)$$

where b is the impact parameter, and ω is the angular velocity. Although the usual unit for angular velocity is sec^{-1} , it is much more convenient to use the unit GeV for ω .

Since, in the impact picture based on quantum field theory, crossing symmetry is satisfied, the scattering amplitude must contain both the real and imaginary parts. Therefore polarization is in general non-zero, and we can use the existing experimental data¹⁴⁾ for laboratory momenta 17.5 and 45 GeV/c to determine this parameter ω . A least square fit gives

$$\omega = -0.06 \text{ GeV}. \quad (2)$$

In Fig. 1 we show the theoretical polarization for the laboratory momentum 100 GeV/c . Note that for $|t| < 1 \text{ GeV}^2$ it gives a very small effect.

Once this parameter ω is determined by (2), the R parameter can be obtained by following the procedure used by Chou and Yang¹⁾. In Fig. 2 we show the theoretical curves for $R_{\text{lab}}(t)$ at laboratory momenta of 100, 280, and 1480 GeV/c . It is observed that, in the vicinity of the first dip, R_{lab} changes rapidly with incident momenta just above 100 GeV/c . Measurements in this energy and momentum range will give a most sensitive test of the present proposal of rigid rotation.

Details of the procedure will be described in a separate paper.

It is interesting to observe that our assumption of proportionality between the velocity of the matter and the impact distance Eq. (1) leads to a value of ω which is negative. We recall that the isoscalar magnetic moment of the nucleon is -0.06 , and hence in particular is also negative. Furthermore, with 1 GeV^{-1} as the characteristic size for a nucleon, it is natural to understand the magnitude of our value of ω in terms of this isoscalar magnetic moment.

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FIGURE CAPTIONS

- Figure 1 : Theoretical polarization for proton-proton scattering at 100 GeV/c.
- Figure 2 : Predictions of R_{lab} at 100, 280, and 1480 GeV/c.