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SPIN AND ELASTIC HADRON SCATTERING AT SUPERHIGH ENERGIES

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ABSTRACT: We consider the possibility of existence of a new mechanism which we call "the mechanism of spin dynamics" and which reveals itself in strong interactions at superhigh energies. This mechanism is shown to be important in the case of slow energy dependences of spin effects. Its experimental consequences were derived in the concrete model framework for the wide range of energies up to $\sqrt{s} = 40$ TeV. Some of them were confirmed at the CERN pp-collider.

At present some models appear in which the spin effects at fixed transfer momenta slowly change with growing energy /1,2/. In this case, as a rule, is used the ordinary eikonal representation for the regard of the hadron interaction at small angles.

Let us consider the scattering of two nucleons in the framework of the quasipotential approach /3/. The eikonal character of small-angle scattering means that the particles go not far from linear trajectories. In this case the wave function of the system satisfies the solution in the form of wick-distorted plane wave.

$$\Psi_p(r) = e^{ip2} \cdot F_p(r).$$ (1)

Solving the quasipotential equation one can obtain the ordinary eikonal representation for the scattering amplitude. However, it may be shown /4/ that the approach (1) impose on the energy dependence of quasipotentials certain limits. The limits for the quasipotentials corresponding to Born's term of scattering amplitudes

$$T(s,t) \sim \mathcal{D}(s,t); \quad T(s,t) \sim \sqrt{\frac{1}{\epsilon}} \mathcal{A}(s,t),$$

are $\mathcal{D}(s,t) \equiv \text{const}; \quad \mathcal{B}(s,t) \equiv \text{const}$. (2)

Then the spin-flip amplitude is rapidly decreasing with energy. The slow-energy dependence of spin effects can be obtained only in the case of anomalous energy dependence of the quasipotential $\mathcal{B}(s,t)$, i.e. in case, when the latter has the growing as $\sqrt{\epsilon}$ term /5/ $\mathcal{B}(s,t) \sim \sqrt{\epsilon} \mathcal{B}(s,t), \quad \epsilon \to \infty$. That is contradiction with limits (2). In this case the obtained form of scattering amplitude, can be reduced to the eikonal representation for small $\mathcal{A}(s,t)$. As a result for the spin-non-flip and spin-flip amplitudes we have

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In a superhigh energy region, where \( \frac{\sqrt{S}}{2} \beta^{(3,\nu)} \gg a(d,p) \) the double spin-flip contribution to \( \chi_{2}(d,q) \) determine the behaviour of scattering amplitudes:

\[
\frac{d^{2} \sigma}{d^{2} t} \sim \sum_{n} \left[ \Phi^{(3,\nu)}_{n} \right] ; \quad \frac{d^{2} \sigma}{d^{2} t} \sim \sum_{n} \left[ \Phi^{(3,\nu)}_{n} \right].
\]

The new mechanism of strong-interaction dynamics results in a "spin" mechanism of the total-cross-section growth, rapid growth of differential cross sections near the diffraction minimum-maximum region and some other effects. On the basis of our model peripheral parts of the eikonal phases were calculated conditioned by effects of the "meson cloud" of hadron, including the anomalous terms of the scattering amplitudes which also have a peripheral character.

In this model we have obtained a quantitative description of the differential cross-section at 4.5 GeV < \( \sqrt{S} \) < 62 GeV and 0 < \( t \) < 14 GeV\(^2\). The obtained \( S \to U \) crossing predictions for \( \bar{p}p \) scattering are in agreement with experiment.

We emphasize that the polarization behaviour at \( P_{\perp} > 100 \text{ GeV} \) is mainly determined by the anomalous term of the quasipotential.

![Fig. 1. Comparison of dynamical-model predictions for polarization with experiment.](image)

![Fig. 2. Our predictions: with and without "spin" mechanism: - - - - - Amaldi U.](image)

Note that the sign of polarization of the diffraction minimum is related with the sign of \( \text{Re} \chi_{2}^{(3,\nu)} \). The real part of \( \chi_{2}^{(3,\nu)} \) obtained in the model changes sign at \( P_{\perp} \approx 400 \text{ GeV} \). As a result, the model predicts a rapid change of polarization at \( \sqrt{S} = 28 \text{ GeV} \) (fig. 1). At these energies the polarization has a weak energy dependence and becomes positive near the diffraction minimum.

The model results for \( \sigma_{ut} \bar{p}p \) are shown in fig. 2. The main contribution to the \( \sigma_{ut} \) growth at \( \sqrt{S} \ll 100 \text{ GeV} \) is due to the standard mechanism determined by the effective-radius growth. As \( S \to \infty \) the "spin" mechanism contribution is a main contribution to \( \sigma_{ut} \) and leads to a rapid growth of the differential cross section at 1 GeV\(^2\) < \( t \) < 1.4 GeV\(^2\). As a result, \( dd/dt \) on this region at CERN \( \bar{p}p \) -collider energies increases by an order of magnitude, see Fig. 3 and Fig. 4.

Thus we conclude that the first manifestation of the new "spin" mechanism is strong-interaction dynamics is probably found. A final
Fig. 4. The role of spin mechanism in $d\sigma/dt$ our predictions at $\sqrt{s} = 2, 10$ and 40 TeV --- predictions Bourrely C. a.o. /11/ at $\sqrt{s} = 2$ and 40 TeV.

Fig. 3. Predictions of our models at $\sqrt{s} = 540$ GeV: --- --- with and without "spin" mechanism (geometrical scaling). prediction at $\sqrt{s} = 1$ TeV.

conclusion about the existence of this mechanism may be drawn at future accelerators on the basis of the polarization experiments, measurement of the energy dependence of differential cross sections near $|t| \sim 0.5 \div 1$ GeV$^2$.

References