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Helicity Conservation Hypothesis and Elastic pp Scattering

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Abstract

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We propose the helicity conservation model for description of polarization effects in the elastic pp scattering at asymptotic energies. In this model the complete set of experiments will consist of only three observables. The predictions of model are compared with experimental data.

Аннотация

Четвертков М.А., Четверткова В.А., Нурушева М.Б. и др. Гипотеза сохранения спиральности и упругое pp-рассеяние: Препринт ИФВЭ 2012–23. – Протвино, 2012. – 4 с., 3 рис., библиогр.: 11.

Мы предлагаем модель сохранения спиральности для описания поляризационных эффектов в упругом pp-рассеянии при асимптотических энергиях. В этой модели полный набор опытов будет включать только три наблюдаемых. Предсказания модели сопоставляются с экспериментальными данными.

1. Introduction

Elastic pp-scattering is one of the important sources of information on the strong interaction. It requires in general 5 complex amplitudes for description. At the absence of the quantitative theory of strong interaction the goal of experimentalists is to fulfill the complete set of experiments in order to reconstruct these amplitudes directly from data. Up to now such program was completed at momentum range $1-6\ GeV/c$. With increasing energy such program becomes very challenging, since most of the measurements should be done with polarized beam and target. The additional difficulty arises from necessity to make second scattering for measuring the spin transfer tensors. For this reason one needs theoretical models for untangling nonzero observables. The recent experimental data show that the observables related to the single and double spin flip interactions tend to disappear with increasing energy. Based on such results and on some theoretical inputs we assume that at the asymptotic energies the helicity conserving interaction becomes paramount. The consequences of this helicity conservation model (HCM) are discussed.

2. Helicity conservation hypothesis

At asymptotic energies ($\sqrt{s} >> m_p c^2, m_p$ is the proton mass) there are some experimental and theoretical suggestive hints that the single and double helicity flip amplitudes may disappear. We refer to the following theoretical arguments for justification of HCM. In QCD at the region ($s, t >> m_p c^2$) perturbative interacting quark conserves its helicity. Therefore in any exclusive reaction the initial total helicity is equal to the final total helicity [1]. Though the theorem was proved for large t, we shall present later the experimental data supporting this theorem at small t too. In paper [2] the hypothesis was proposed about the approximate chirality conservation in strong interaction. We follow this approach since at high energy helicity conservation converges to the chirality conservation. In describing the data on polarization at high energy [3] the theoretical models (TM) were successfully used. The models based on the conditions that the double helicity flip amplitudes $\phi_2 = -\phi_4 = 0$, and non helicity flip amplitudes $\phi_1 = \phi_3$. We compared the model predictions with experimental data from ZGS obtained in the kinematical interval: $\sqrt{s} = 3.6\ GeV$,$0.27 \leq |t| \leq 0.83\ (GeV/c)^2$ [4]. These data include 21 observables. The next conclusions follow from these data: 1) the dominant amplitudes are ϕ_1 and ϕ_3, 2) $\phi_1 \approx \phi_3$, 3) $\phi_5 \approx (2.3 - 4.8)\%$ of ϕ_1, 4) $\phi_2 \approx (3.4 - 10)\%$ of ϕ_1, 5) $\phi_4 \approx (5.4 - 15.3)\%$ of ϕ_1. These results already support the statement that the single and double flip amplitudes are small. Comparing model predictions with ZGS and RHIC ($\sqrt{s} = 200\ GeV$), $10^{-3} \leq |t| \leq 10^{-1}\ (GeV/c)^2$ data one may note several features. The parameters P, A_{NN}, A_{SS} are not zero at ZGS but zero at RHIC as predicted by HCM. From $A_{LL} = 0$ follows $|\phi_1| = |\phi_3|$ already at $\sqrt{s} = 3.6\ GeV$. Therefore one may expect that at RHIC A_{LL} will also be zero as predicted by the TM. From TM follows $D = 1$ at any t. This condition is not confirmed by ZGS data. HCM predicts for Wolfenstein parameters the following relations $R = -D\cos\theta_2$, $R' = D\sin\theta_2$, $A = \sin\theta_2$, $A' = \cos\theta_2$. Here θ_2 is the recoil proton angle in laboratory system. In order to choice between HCM and TM it is necessary to measure precisely these observables at wide range of t. If at RHIC polarization is zero and $|\phi_1| = |\phi_3|$ then all models predict $-R = A' = \cos\theta_2$, $A = R' = \sin\theta_2$. The set of complete experiments may include: for HCM - σ, A_{LL} and D. For TM - σ, P and A_{NN}.

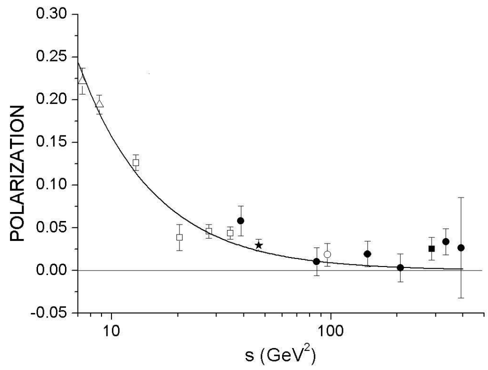

Figure 1. Polarization vs s at $-t = 0.3\ (GeV/c)^2$ (data from [3]).

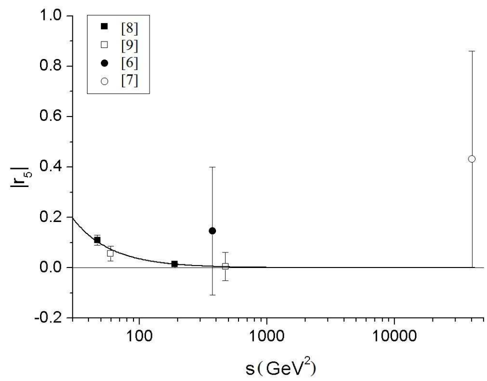

Figure 2. Reduced amplitude $|r_5|$ vs s at Coulomb–Nuclear Interference (CNI) region.

3. Polarization and $|r_5|$ versus s at fixed t

For the HCM to be applicable the polarization should become zero at high energy $\sqrt{s_a}$. The first such hint for reaching $\sqrt{s_a}$ came out from r [5]. Plotting polarization at $-t = 0.2\ (GeV/c)^2$ versus s at the interval $10 \leq s \leq 86\ GeV^2$ it was found that polarization falls down rapidly according to the power law $P = b(s/s_0)^c$, where $s_0 = 1\ GeV^2$. The power $c = -0.93$. At $s = 86\ GeV^2$ and $t = -0.2\ (GeV/c)^2$ $P = (2.23 \pm 1.8)\%$. Then one may estimate that P will be equal to 1% (zero within experimental uncertainties) at $\sqrt{s} = 15.5\ GeV$. We conditionally assume that this is the "asymptotic energy"$\sqrt{s_a}$ for polarization at $-t = 0.2\ (GeV/c)^2$. Polarization studies for wide range of s were done at $-t = 0.3,\ 0.6,\ 0.8,\ 1\ (GeV/c)^2$ [3]. The precise data at $-t = 0.3\ (GeV/c)^2$ are presented in Figure 1. We made the fit by the same formula as above and found $b = 2.73 \pm 0.95$, $c = -1.24 \pm 0.16$; $\chi^2/dof = 1.57$. Taking into accounts the uncertainties in fitted parameters we estimated $\sqrt{s_a} = 6.4 - 15.3\ GeV$. Since for rest of $-t$ points polarization changes sign we used the formula $P = a + bs^c$. The fitted parameters follow. For $-t = 0.6\ (GeV/c)^2$ $a = -0.04 \pm 0.01$, $b = 1.19 \pm 0.29$, $c = -0.88 \pm 0.13$; $\chi^2/dof = 0.65$, $\sqrt{s_a} = 3.8 - 11.1\ GeV$. For $-t = 0.8\ (GeV/c)^2$ $a = -0.07 \pm 0.03$, $b = 0.73 \pm 0.09$, $c = -0.61 \pm 0.23$; $\chi^2/dof = 1.53$, $\sqrt{s_a} = 2.3 - 49.5$. For $-t = 1\ (GeV/c)^2$ $a = -0.27 \pm 0.25$, $b = 0.70 \pm 0.27$, $c = -0.28 \pm 0.26$; $\chi^2/dof = 1.45$, $\sqrt{s_a} = 1.2 - \infty$. Comparing these data one can see that the most reliable result for asymptotic energy comes out from the smallest $-t$ value.

By definition $r_5 = m_p \phi_5 / \sqrt{-t}\ Im\phi_+$ — reduced amplitude, where $\phi_+ = (\phi_1 + \phi_3)/2$. This amplitude directly related to polarization in strong interaction. Therefore we parameterized it like polarization. The accumulated experimental data [6, 7, 8, 9] are presented in Figure 2. The result of fit is: $b = 25.44$, $c = -1.43$; $\chi^2/doF = 0.44$ and shown as the solid line. The estimated asymptotic energy $\sqrt{s_a} \approx 15\ GeV$ and close to one obtained from polarization data. Figure 2 presents the available experimental data on $|r_5|$.

4. The double helicity flip amplitude $Im\ r_2(0)$

The direct way of obtaining information about $Im\ r_2(0)$ at $-t = 0$ is to use the optical theorem for total cross-sections. Then we get as the ratio of spin dependent to the non dependent total cross-sections, $Im\ r_2(0) = \Delta\sigma_T / 2\sigma_0$. We are interested in energy dependence of this parameter. S dependence for σ_0 and for $\Delta\sigma_T$ as well the experimental data we borrowed from paper [10]. Recently one new point was obtained at RHIC ($\sqrt{s} = 200\ GeV$) [11]. We used it too in fit. For fit of experimental data we used the formula $Im\ r_2(0) = C\Delta\sigma_T/2\sigma_0$, where $C = 20.31 \pm 3.97$ ($\chi^2/doF = 1.05$). The solid line in Figure 3 presents the result of fit in comparison with experimental data. One can estimate that the "asymptote" is reached at $\sqrt{s_a} \approx 14\ GeV$. This number is close to what was found for r_5 in CNI region.

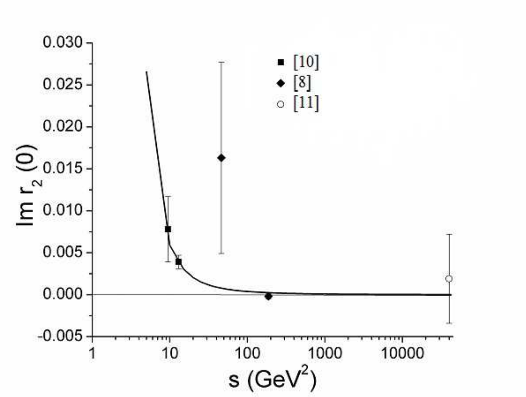

Figure 3. Amplitude $Imr_2(0)$ vs s.

5. Conclusion

For interpretation of polarization data on elastic pp - scattering at "asymptotic energy" $\sqrt{s_a}$ we propose the Helicity Conservation Model. It bases on the assumption that the single and double helicity flip amplitudes become negligible at energy $\geq$ %¸$\sqrt{s_a}$. Analyses of energy dependences of polarization at region $0.2 \leq |t| \leq 0.6$ $(GeV/c)^2$, the reduced amplitudes $|r_5|$ and $Im\ r_2(0)$ in the CNI region and $t = 0$ respectively present the obvious hint that such energy is $\sqrt{s_a} \approx 15\ GeV$. The ambiguous situation exists for polarization parameter around $-t = 1$ $(GeV/c)^2$ due to the shortage of experimental data. The model predictions are expected to be tested at the existing facilities.

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References

[1] *Brodsky S.J. and Lepage G.P.* // Phys. Rev. 1980. D.22. P.2157.
[2] *Logunov A.A., Mescheryakov V.A., Tavhelidze A.N.* // DAN USSR. 1962. 142. P.317.
[3] *Corcoran M. et al.* // Phys. Rev. 1980. D.22. P.2624.
[4] *Auer P. et al.* // Phys. Rev. 1985. D.32. P.1609.
[5] *Gaidot A. et al.*//Phys. Lett. 1976. 61.B, 103 .
[6] *Akchurin N. et al.* // Phys. Rev. 1993. D.48. P.3026.
[7] *Bültmann S. et al.* // Physics Letters 2004. B.579. P.245.
[8] *Alekseev I. G. et al.* // Phys. Rev. 2009. D.79. P.094014.
[9] *Bazilevsky A. et al.* // Journ. of Phys.: Conf. Ser. 2011. 295. P.012096.
[10] *Andreeva E.A. et al.* // Int. Journ. Mod. 1998. A.13. P.1515.
[11] *Bültmann S. et al.* // Physics Letters 2007. B.647. P.98 -103.

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