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PREDICTIONS OF MESON-CLOUD MODEL FOR ELASTIC HADRON SCATTERING

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Recent experimental results on elastic $\pi^- p$ -scattering[1], $\bar{p}p$ -scattering[2-4], and the data on pp -scattering[5] at high energies in a wide range of momentum transfers allow the verification of predictions of different models of high-energy hadron scattering[6]. However, most of the models cannot quantitatively reproduce all basic properties of experimental data in a unique way.

In this note we discuss results of the scalar meson-cloud model[7,8] for elastic pp-, $\bar{p}p$-, and πp -scattering at high energies in a wide region of momentum transfers. Consider high energy scattering of two spinless particles with identical masses within the Logunov-Tavkhelidze quasipotential approach[9]. The hypothesis of smoothness of the local quasipotential[10] gives the eikonal representation for the leading asymptotic term of the scattering amplitude

$$T(s,t) = \frac{is}{16\pi^3} \int d^2\rho \, e^{i\vec{\Delta}\vec{\rho}} \left(1 - e^{i\chi(\rho,s)}\right). \qquad (1)$$

The smoothness of the quasipotential is related to the dynamics of two-particle interactions and means that at high energies hadrons behave as loose extended objects with a finite size. Our model assumes the existence of a central part of a nucleon, where valence quarks are concentrated, and of a meson cloud, which in the first approximation consists of π -mesons only. A variant of such a model was considered earlier in paper[11]. The consideration of diagrams of the simplest form, which describe scattering of the central part of one hadron on the meson cloud of another hadron allows one to show that their contribution into the eikonal phase at large impact parameters has the form[8]

$$\frac{1}{i}\chi(\rho,s) \sim \frac{1}{\rho^3} e^{-2\rho\sqrt{\mu_\pi^2 + \frac{M_\rho^2}{\mu_\pi^2}\frac{1}{\rho^2}}} \sim e^{-\mu_{eff}\rho}$$

The computer integration reveals that at distances of an order of the hadron size $\mu_{eff} \sim 0.6$ GeV and decreases with growing energy.

The total eikonal phase which includes also the contribution of scattering of the central parts of hadrons on each other is well approximated by the expression[8]

$$i\chi(\rho,s) = -h \exp(-\mu(s)\sqrt{b^2(s)+\rho^2}), \qquad (2)$$

where h, b, μ are the effective coupling constant, the effective radius of the central part of interaction, and the effective mass, respectively.

The quasipotential corresponding to (2) is a smooth function of the relative distance, and hence, the leading term of the scattering amplitude is correctly defined by formula (1). The scattering amplitude can be calculated explicitly[7]; it is an analytic function of t. The energy dependence of the parameters in (2) has been chosen on the basis of the hypothesis of geometrical scaling[12]

$$\mu(s) = \mu_0/\text{æ}(s); \quad b(s) = b_0 \cdot \text{æ}(s); \quad \text{æ}(s) = (1+\alpha(\ln s - \tfrac{i\pi}{2}))^{1/2}.$$

This corresponds to the energy dependence of μ obtained in the model.

In the framework of the proposed model, with inclusion of inelastic effects, a quantitative description is obtained for the data on pp -scattering in a wide region of momentum transfers: $0.4 \leq |t| \leq 1.4$ GeV^2 at energies $\sqrt{s} \geq 23.4$ GeV ($\chi^2/\bar{\chi}^2 = 541/449 = 1.21$, for three varied parameters μ_0, b_0, h). The model qualitatively reproduces the behaviour of the scattering cross sections at small momentum transfers and predicts a smooth decrease of the differential-peak slope[7], that has been fortified experimentally at FNAL.

To get a quantitative description for small transfer momenta and the region of lower energies, we take into account the contribution of more heavy particles into the meson cloud and the terms of order $1/\sqrt{s}$ in the scattering amplitude. Then, the eikonal phase of pp -scattering may be taken in the form

$$\chi^{pp}(\rho,s) = \chi_0^{pp}(\rho,s) + \chi_1^{pp}(\rho,s)$$
$$\chi_0^{pp}(\rho,s) = i\left(h e^{-\mu(s)\sqrt{b^2(s)+\rho^2}} - \left(h_1 + h_2\frac{\rho^2}{b^2(s)}\right)e^{-\mu_1(s)\sqrt{b^2(s)+\rho^2}}\right) \qquad (3)$$
$$\chi_1^{pp}(\rho,s) = \frac{iA - B}{\sqrt{s}} e^{-\rho^2/R^2}$$

The second term in χ_0 represents the sum of contributions of inelastic effects and particles with mass ≥ 0.7 GeV into the meson cloud. As a result, $\mu_1 \sim 2\mu$. The χ_1 is of the Gaussian form, as the effects of the hadron mesonic cloud can be shown to be small in correction terms of the eikonal phase.

The coefficient A was defined from the total pp scattering cross sections. The coefficient B can be determined on the basis of local dispersion relations[13] from the total $\bar{p}p$ -scattering cross sections, and

$$B \sim 2A. \qquad (4)$$

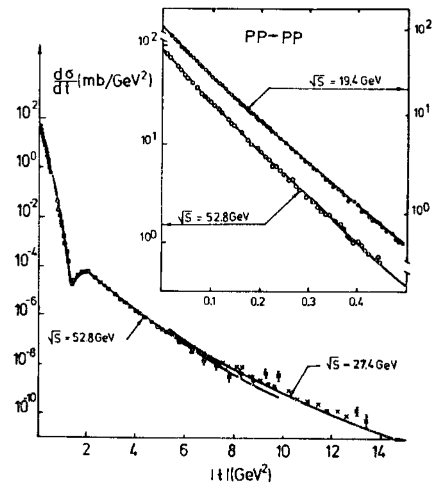

Fig. 1. Differential cross sections of pp -scattering at small ($\sqrt{s}$ = 52.8 GeV and 19,4 GeV) and large ($\sqrt{s}$ = 52.8 GeV and 27,4 GeV) momentum transfers (data are taken from[5]).

Thus, we have analysed the experimental data on differential cross sections by varying 7 parameters in $\chi(\rho,s)$. Including into consideration all the known data on elastic pp -scattering at energies $\sqrt{s} \geq 19,4$ GeV and momentum transfers $0 \leq |t| \leq 14.2$ GeV^2, we have obtained the quantitative description of experimental data ($\chi^2/\bar{\chi}^2 = 1305/1060 = 1.23$). The corresponding curves in the region of small and large momentum transfers are drawn in Fig. 1 for several energies.

The $\bar{p}p$ -scattering amplitude can be defined by using the $s \rightleftarrows u$ crossing symmetry, without changing the obtained parameter values; and from (3) we find

$$\chi_0^{\bar{p}p}(\rho,s) = \chi_0^{pp}(\rho,s)\ ;\ \chi_1^{\bar{p}p}(\rho,s) = \frac{iB-A}{\sqrt{s}}\, e^{-\rho^2/R^2} \quad (5)$$

The predictions obtained for $\bar{p}p$ -scattering cross section (Fig. 2) are in good agreement with the recent experimental data in the regions of small and large momentum transfers at energy P_L = 50 GeV/c [2] and P_L =1850 GeV/c [3], resp. The strongly marked diffraction minimum in $\bar{p}p$ -scattering at $\sqrt{s}$ = 50 GeV/c is due to the fact that in the region of the minimum the essential contribution in the differential cross section comes from the amplitude real part which for $\bar{p}p$ -scattering is approximately half as large as that for pp -scattering.

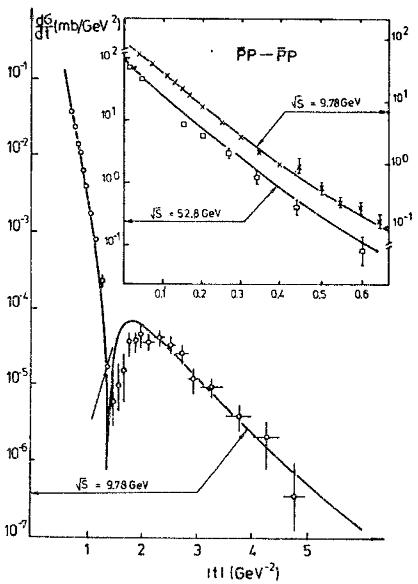

Fig. 2. Model predictions for the $\bar{p}p$ -scattering (model parameters are taken from the analysis of data on pp -scattering) for small ($\sqrt{s}$ = 52.8 GeV and 9,78 GeV) and large ($\sqrt{s}$ = 9,78 GeV) momentum transfers (o are from [3,4], x from [2]).

Note that the meson-cloud model applies also for the high energy meson-nucleon scattering. In this case minimal changes should be made, that does not influence essentially the eikonal-phase shape, which, as in the case of pp -scattering, can be approximated by the expression (2), the effective mass being of the same order: $\mu_{eff} \simeq 0.6$ GeV. Within this model we predicted the diffraction minimum in $\pi^- p$ -scattering in the region 3 - 4 GeV at energy P_L = 200 GeV [8], that was verified experimentally at FNAL. Theoretical curves obtained by analysing the experimental data available on $\pi^- p$ -scattering at P_L = 200 GeV [13,14] and $0.07 \le |t| \le 2.35$ GeV and preliminary data [1] on $\pi^- p$ -scattering in the region of large momentum transfers are shown in Fig. 3.

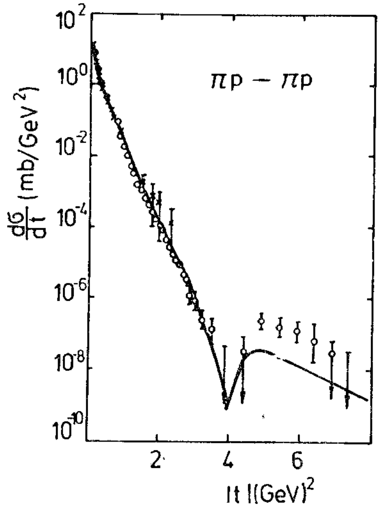

Fig. 3. Model predictions for πp -scattering at large momentum transfers ($\sqrt{s}$ = 19.4 GeV) from the analysis of data ●, x [14,15], o-data [1]

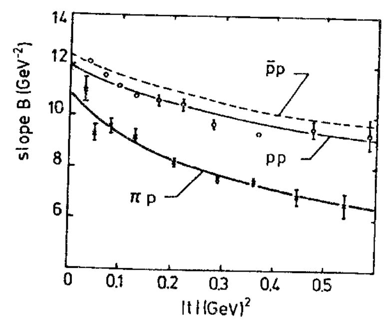

Fig. 4. Change of the diffraction-peak slope in the region of small t for $\bar{p}p$, pp, and πp -scattering at $\sqrt{s}$ = 19.4 GeV(x are data from [15]).

According to the model the diffraction-peak slope for different processes of hadron-hadron scattering changes smoothly in the region of small t (Fig. 4).

So, the simplest spinless meson-cloud model provides the unique description of hadron--hadron scattering at high energies in a wide region of momentum transfers. The model results are as follows: i) smooth change of the diffraction-peak slope at small momentum transfers, ii) the only diffraction minimum in pp - and $\bar{p}p$-scattering at $|t| \sim 1.4$ GeV^2 and in πp -scattering at $|t|$=3.5 - 4.2 GeV^2; iii) small slope of differential cross sections after the second diffraction maximum defined by the effective radius of the central part of the interaction, $b(s)$, which for pp -scattering at energy $\sqrt{s}$ = 60 GeV equals about half hadron radius ($b \sim 0.48$ fm).

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References

1. Baker W. et al. Phys.Rev.Lett., 1981, v. 47, p. 1683.
2. Gordoni G. et al. CERN-EP/81-138, Geneva, 1981.
3. Asa'd Z. et al. CERN-EP/81-26, Geneva, 1981.
4. Ayres D.S. et al. Phys.Rev. D, 1977, v. 15, N 11, p. 3105.
5. Schubert K.R. In: Landolt-Börnstein, New Series, v. I/9a, 1979.
6. Zotov N.P., Rusakov S.V., Tsarev V.A. Particles and Nuclear 1980, 11, p. 1160.
7. Goloskokov S.V., Kuleshov S.P., Seljugin O.V. Yad.Fiz., 1979, 31, p. 741.
8. Goloskokov S.V., Kuleshov S.P., Seljugin O.V. In: Int. Conference on High Energy Phys., Lisbon, Portugal, 1981, vol. 5D, p. 224.
   Goloskokov S.V., Kuleshov S.P., Seljugin O.V. JINR, E2-81-441, Dubna, 1981.
9. Logunov A.A., Tavkhelidze A.N. Nuovo Cim., 1963, 29, p. 380.
10. Alliluev S.P., Gershtein S.S., Logunov A.A. Phys.Lett., 1965, 18, p. 195.
11. Pumplin J., Kane G.L. Phys.Rev., D, 1975, 11, p. 1183.
12. Dias de Deus J. Nucl.Phys., 1973, B59, p. 231.
    Buras A.J., Dias de Deus J. Nucl.Phys., 1974, B71, p. 481.
    Goloskokov S.V., Kuleshov S.P., Seljugin O.V. Yad.Fiz., 1980, 32, p. 492.
13. Bronzan J.B., Kane G.L., Sukhatme U.P. Phys.Lett., 1974, 49B, p. 272.
    Gerdt V.P., Inozemtsev V.I., Meshcheryakov V.A. Yad.Fiz., 1976, 24, p. 176.
14. Akerlof C.W. et al. Phys.Rev., 1976, D14, p. 2864.
15. Schiz A. et al. Phys.Rev., D, 1981, 24, p. 26.

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Голоскоков С.В., Кулешов С.П., Селюгин О.В. E2-82-109

Предсказания модели, учитывающей мезонную шубу адрона для упругих адронных реакций.

В бесспиновой модели, учитывающей эффекты мезонной шубы адрона, получена единая картина описания упругого $pp-$, $\bar{p}p-$, πp-рассеяния при высоких энергиях в широкой области передач импульса.

Работа выполнена в Лаборатории теоретической физики ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1982

Goloskokov S.V., Kuleshov S.P., Seljugin O.V. E2-82-109

Predictions of Meson-Cloud Model for Elastic Hadron Scattering

Within a spinless meson-cloud model, a unique description is obtained for elastic $pp-$, $\bar{p}p-$, and πp-scattering at high energies in a wide region of momentum transfers.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

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