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Exclusive central diffractive production of scalar and pseudoscalar mesons; tensorial vs. vectorial pomeron

Piotr Lebiedowicz [a], Otto Nachtmann [b], Antoni Szczurek [a,c,*]

[a] Institute of Nuclear Physics PAN, PL-31-342 Cracow, Poland

[b] Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, D-69120 Heidelberg, Germany

[c] University of Rzeszów, PL-35-959 Rzeszów, Poland

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ABSTRACT

We discuss consequences of the models of "tensorial pomeron" and "vectorial pomeron" for exclusive diffractive production of scalar and pseudoscalar mesons in proton–proton collisions. Diffractive production of $f_0(980)$, $f_0(1370)$, $f_0(1500)$, η, and $\eta'(958)$ mesons is discussed. Different pomeron–pomeron–meson tensorial coupling structures are possible in general. In most cases two lowest orbital angular momentum–spin couplings are necessary to describe experimental differential distributions. For $f_0(980)$ and η production reggeon–pomeron, pomeron–reggeon, and reggeon–reggeon exchanges are included in addition, which seems to be necessary at relatively low energies. The theoretical results are compared with the WA102 experimental data. Correlations in azimuthal angle between outgoing protons, distributions in rapidities and transverse momenta of outgoing protons and mesons, in a special "glueball filter variable", as well as some two-dimensional distributions are presented. We discuss differences between results of the vectorial and tensorial pomeron models. We show that high-energy central production, in particular of pseudoscalar mesons,

* Corresponding author at: University of Rzeszów, PL-35-959 Rzeszów, Poland.
E-mail addresses: Piotr.Lebiedowicz@ifj.edu.pl (P. Lebiedowicz), O.Nachtmann@thphys.uni-heidelberg.de (O. Nachtmann), Antoni.Szczurek@ifj.edu.pl (A. Szczurek).

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could provide crucial information on the spin structure of the soft pomeron.

1. Introduction

Double pomeron exchange mechanism is known to be responsible for high-energy central production of mesons with $I^G = 0^+$. While it is clear that the effective pomeron must be a colour singlet the spin structure of the pomeron and its coupling to hadrons is, however, not finally established. It is commonly assumed that the pomeron has effectively a vectorial nature; see for instance [1–3] for the history and many references. This model of the pomeron is being questioned in [4,5]. Recent activity in the field concentrated rather on perturbative aspects of the pomeron. For instance, the production of heavy objects (χ_c mesons [6,7], Higgs bosons [8], dijets [8], W^+W^- pairs [9], etc.) has been considered in the language of unintegrated gluon distributions. Exclusive $\pi^+\pi^-$ [10,7,11] and K^+K^- [12] pairs production mediated by pomeron–pomeron fusion has been a subject of both theoretical and experimental studies. Particularly interesting is the transition between the nonperturbative (small meson transverse momenta) and perturbative (large meson transverse momenta) regimes. Here we wish to concentrate rather on central exclusive meson production in the nonperturbative region using the notion of effective pomeron. In general, such an object may have a nontrivial spin structure.

In the present analysis we explore the hypothesis of "tensorial pomeron" in the central meson production. The theoretical arguments for considering an effective tensorial ansatz for the nonperturbative pomeron are sketched in [4] and are discussed in detail [5]. Hadronic correlation observables could be particularly sensitive to the spin aspects of the pomeron.

Indeed, tests for the helicity structure of the pomeron have been devised in [13] for diffractive contributions to electron–proton scattering, that is, for virtual-photon–proton reactions. For central meson production in proton–proton collisions such tests were discussed in [3] and in the following we shall compare our results with those of Ref. [3] whenever suitable.

There are some attempts to obtain the pomeron–pomeron–meson vertex in special models of the pomeron. In [3] results were obtained from the assumption that the pomeron acts as a $J^{PC} = 1^{++}$ conserved and non-conserved current. The general structure of helicity amplitudes of the simple Regge behaviour was also considered in Refs. [14,15]. On the other hand, the detailed structure of the amplitudes depends on dynamics and cannot be predicted from the general principles of Regge theory. The mechanism for central production of scalar glueball based on the "instanton" structure of QCD vacuum was considered in [16–19].

In the present paper we shall consider some examples of central meson production and compare results of our calculations for the "tensorial pomeron" with those for the "vectorial pomeron" as well as with experimental data whenever possible. Pragmatic consequences will be drawn. Predictions for experiments at RHIC, Tevatron, and LHC are rather straightforward and will be presented elsewhere.

The aim of the present study is to explore the potential of exclusive processes in order to better pin down the nature of the pomeron exchange. Therefore, we shall limit ourselves to Born level calculations leaving other, more complicated, effects for further studies. Nevertheless, we hope that our studies will be useful for planned or just being carried out experiments.

Our paper is organized as follows. In Section 2 we discuss the formalism. We present amplitudes for the exclusive production of scalar and pseudoscalar mesons and we also briefly report some experimental activity in this field. In Section 3 we compare results of our calculations with existing data, mostly those from the WA102 experiment [20–25]. In Appendices A and B we discuss properties and useful relations for the tensorial and vectorial pomeron, respectively. In Appendices C and D we have collected some useful formulae concerning details of the calculations. Central production of mesons with spin greater than zero will be discussed in a separate paper.