Transverse momentum distribution in Pomeron-Pomeron collisions at the CERN ISR

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Abstract. Proton-proton interactions which result in a central cluster of mass $M_x$ and two quasi-elastically scattered protons are generally described by Pomeron-Pomeron scattering. A study of this process at ISR energies with the Split Field Magnet detector is carried out in terms of transverse momentum behaviour for the centrally produced system of particles. The inclusive $p_T$ distribution for central hadrons is measured up to 3 GeV/c. For $p_T < 1.2$ GeV/c, the $p_T$ distribution is exponential. Using a subsample of exclusive events, this exponential shape is shown to originate from a phase-space-like decay of $M_x$ when convoluted with a transverse component of the Pomeron momentum. In the high $p_T$ range, the shape of the $p_T$ distribution strongly depends on Feynman-$x$ of the scattered protons in a way that can be described by hard parton scattering.

1 Introduction

An important concept in "soft" hadronic physics is that of the Pomeron, hypothesized in Regge theory to explain the elastic scattering of hadrons: the Pomeron trajectory is the Regge trajectory associated with the exchange of the quantum numbers of the vacuum. In quantum chromo dynamics (QCD) a satisfactory understanding of the actual mechanism of "Pomeron exchange" does not yet exist, because of the difficulty in performing calculations in the "non-perturbative" regime of soft hadronic collisions. However, there are suggestions that Pomeron exchange could be described by multi-gluon exchange with possible quark and gluon loops [1, 2] (Fig. 1 a).

Data on diffractive scattering are usually interpreted with optical or geometrical models and no investigations intended to reveal the role of partons have been done. Only recently an ISR experiment studying the fragmentation of a diffractive system produced in $pp$ interactions has claimed evidence for Pomeron interaction with a single valence quark in the beam proton [3].

In the following we study the pion $p_T$ distribution in the process

$$pp \rightarrow ppX, \quad X \rightarrow \pi^\pm + ...$$

($\sqrt{s}$=62 GeV), where the particles in system $X$ have rapidities $|y|<1.5$ and the final-state protons have Feynman-$x$ $|x_f|$ near 1. This process is expected to be dominated by double Pomeron exchange (DPE), with the centrally produced particles created in the Pomeron-Pomeron collision as in the scheme of Fig. 1 b). For convenience we use the label DPE and...
4.2

Fig. 1. a Example of gluon ladders and quark loops which may sum to produce a Pomeron trajectory. b Double Pomeron exchange in pp → ppX. c Uncorrected (π⁺π⁻) invariant mass distribution for the reaction pp → ppπ⁺π⁻ at √s = 62 GeV from [6]

The data have been processed with the standard SFM programs for full event reconstruction. Only events with two positive forward tracks at large Feynman-x (|xf| > 0.7) in opposite directions have been accepted for further analysis. A requirement of a good event vertex determination has also been applied. Our final sample consists of 200000 events compatible with reaction (1). The average proton |xf| is 0.93; the central cluster X has an average multiplicity of about five charged particles, all at small rapidity (|y| < 1.5) [5]. Proton momenta are measured with a precision of Δp/p ≈ 7% on the average. The data cover a range of proton 4-momentum transfer squared |t| between 0.08 and 1.5 GeV².

3 Data analysis

3.1 Pion Pₜ distribution in pp → pp π⁺π⁻

Out of the main sample, a subsample of 12500 exclusive events (4-constraint kinematic fits) with only two central pions of opposite charges has been extracted to study the process

pp → pp π⁺π⁻,

which has been discussed in a recent paper [6]. The average proton |xf| is 0.97. In particular, the (π⁺π⁻) invariant-mass spectrum (Fig. 1c) between threshold and 1.7 GeV/c² has been studied: a significant f₁⁰ (JPC=2++) signal appears above a large low-mass continuum with no sign of p₀ (JPC=1⁻⁻) production. Other experiments have shown data with similar features [7], partly in a complementary range of proton 4-momentum transfer [8] (see also Fig. 4 (d)). The data exhibit contributions from s and d wave excitation only, the former being mainly responsible for the low-mass continuum.

Figure 2a shows the pₜ π distribution for central pions in the rest frame of the (π⁺π⁻) system for different mass slices of M(π⁺π⁻). pₜ π is the transverse momentum with respect to the incident Pomeron direction, i.e. the direction of the proton momentum transfers. Superimposed on the data are the expectations for a two-body decay into pions for a mass Mₜ at rest. We have assumed pure s wave behaviour from threshold up to 1 GeV/c² and also in the region above 1.5 GeV/c². In the range 1 to 1.5 GeV/c² a superposition of s and d (m = 0) waves in the percentages obtained from a fit to the mass spectrum [6] has been used ((47 ± 8)% d-wave). An estimate of the detector angular acceptance has been included. A good description of the data is obtained up to 1.5 GeV/c².

In the highest mass bin the distribution is well reproduced in the higher pₜ range, while an excess is ob-