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PHENOMENOLOGICAL DUALITY FOR POMERON-PROTON SCATTERING

P.H. Frampton and P.V. Ruuskanen *)

CERN -- Geneva

A B S T R A C T

Data on $p + p \to p + N^*$ for 5 - 30 GeV/c at small t is extrapolated to $s \to \infty$; the Pomeron-proton forward amplitude is found to be resonance dominated, the resonances being dual to a trajectory with intercept $\alpha(0) \lesssim \frac{1}{2}$. This suggests that the Pomeron-Pomeron-Reggeon coupling is non-zero.

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*) On leave of absence from the Department of Theoretical Physics, University of Helsinki.

INTRODUCTION

There has recently been considerable interest in diffractive production of resonances and background in inclusive reactions, and in the question of how the duality concept is best generalized to these processes. In the present paper we present the results of a study of data for the process $p + p \to p + \text{any}$, in an attempt to draw conclusions about how the Harari-Freund two-component duality picture [1)] should be extended to the resonance part of elastic scattering of a Pomeron (with $t \approx 0$) on a proton.

For fixed small momentum transfer t and asymptotic energy $s \to \infty$ this process is expected to be dominated by Pomeron exchange. When the missing mass M is sufficiently large (satisfying $s \gg M^2 \gg 1$) the inclusive cross-section $(d\sigma/dt\, dM)$ is expected to approach a triple Regge limit [2)]

$$\frac{d\sigma}{dt\,dM} \sim \frac{M}{s^2}\left(\frac{s}{M^2}\right)^{2\alpha(t)} \left(M^2\right)^{\alpha_\nu(0)} \qquad (1)$$

For $s \to \infty$, $\alpha(t)$ should be the trajectory appropriate to Pomeron exchange $[\alpha(t) \approx 1$ for $t \approx 0]$ while $\alpha_\nu(0)$ is the intercept of the trajectory exchanged in the forward Pomeron-proton scattering absorptive part. In the asymptotic region of s, at fixed t, the power dependence of $(d\sigma/dt\, dM)$ as a function of the missing mass is given by the $\alpha_\nu(0)$ intercept. By extrapolating the triple-Regge form back to the resonance region this then can indicate which trajectory $\alpha_\nu(t')$ interpolates the resonance contributions in the missing mass channel.

PHENOMENOLOGY

The data are taken from Anderson et al. [3),4)] at incident momenta of 6, 10, 15, 20 and 30 GeV/c. The smallest fixed $|t|$ value presented in their data is $-t = 0.044\ \text{GeV}^2$ [see Fig. 2c of Ref. 3) and Fig. 5c of Ref. 4)].

The first step is to isolate the $s \to \infty$ component of the data in the missing mass channel, which will correspond to $\alpha(t) \approx 1$ in Eq. (1). This has been done by fitting to the data at 5 - 30 GeV/c for each value of M a form $d\sigma/dt\, dM = a(M) + b(M)s^{-p(M)}$. The resulting values of $a(M)$, which give the limiting distribution for $s \to \infty$, with their associated errors, are indicated in Fig. 1. In Refs. 3), 4) the resonance parameters of the most prominent bumps have been extracted by the usual method of fitting Breit-Wigner shapes plus a polynomial background. In this way, average values were found for the mass (M), width (Γ), forward differential cross-section (A) and t slope (B) of the observed peaks (such that $d\sigma/dt = A\, e^{Bt}$) as shown in the Table.

In the Figure the resonance contribution arising from this parametrization is plotted, and is in reasonable agreement (especially the form) with the data extrapolated to $s \to \infty$. Concerning this comparison, we note (i) that Edelstein et al.[4] quote an error ±35% on the resonance parametrization, and (ii) that the cross-sections found by Amaldi et al.[5] are consistently higher than those of Ref. 4).

As a consistency check a quadratic form $(d\sigma/dt\, dM) = A(M) + B(M)s^{-1} + C(M)s^{-2}$ was also used and the asymptotic values $a(M)$ and $A(M)$ were found to agree within errors. In this quadratic form we note that the coefficient $c(M)$ was found to increase with M, as expected for an $\alpha(t) = 0$ contribution in Eq. (1), while there was little dependence of $B(M)$ on M.

The intercept $\alpha_\nu(0)$ determines the M dependence, from Eq. (1). When extrapolating, in M, the asymptotic form to the resonance region the appropriate threshold and pseudothreshold factors were included as follows

$$\frac{d\sigma}{dt\,dM} \propto \frac{M}{s^2}\left(\frac{s}{\sqrt{(t-(M+M_p)^2)(t-(M-M_p)^2)}}\right)^{2\alpha(t)} \left(M^2-M_p^2\right)^{\alpha_\nu(0)} \qquad (2)$$

to ensure sensible behaviour for $M \to M_p$. The resonance curve has been extrapolated to the unphysical point $t = 0$, and then compared to the form of Eq. (2), putting $\alpha(0) = 1$ for the Pomeron. In Fig. 2, the curves corresponding to $\alpha_\nu(0) = 0, \frac{1}{2}, 1$ are indicated. These curves are normalized so that the area below them is equal to the area below the resonance curve between $M = 1.30$ GeV and $M = 1.81$ GeV. For semi-local duality to be good within the measured range of M, the $\alpha_\nu(0) = 0$ curve is slightly better than the $\alpha_\nu(0) = \frac{1}{2}$ curve, and certainly both are much better than that for $\alpha_\nu(0) = 0$; we conclude that $\alpha_\nu(0) \lesssim \frac{1}{2}$ is favoured.

To extend such an analysis to larger negative values of t there are two obstacles.

(i) The slope of the Pomeron trajectory $\alpha(t)$ is unknown. This means that to separate the Pomeron contribution by its different s dependence, one would need to extrapolate using an unknown power $2(\alpha(t)-1)$ of s.

(ii) The different diffractively produced resonances have markedly different t slopes (see the Table). This fact is difficult to incorporate into the simple duality scheme considered here, since according to the triple-Regge formula the slopes can have only a mild dependence on M.

DISCUSSION

The fact that only the resonance part survives the $s \to \infty$ limit indicates that the forward elastic Pomeron-proton absorptive part is almost entirely resonance dominated (for a Pomeron with squared mass $t \approx 0$).

From the M dependence of this absorptive part (for $t = 0$) we conclude that the resonances are dual to a trajectory with $\alpha_\nu(0) \lesssim \frac{1}{2}$ [we expect the P' trajectory with $\alpha_\nu(0) \approx \frac{1}{2}$]. In terms of Pomeron ($\mathbb{P}$) couplings this means that at $t = 0$ the $\mathbb{P}\mathbb{P}R$ coupling is certainly non-zero. The most straightforward generalization of the Harari-Freund ansatz seems to give a consistent picture : for the Pomeron ($t = 0$) external line the direct channel resonances are dual to a normal Regge exchange, while there is very little direct channel background which can be attributed via duality to a very small value [6] of the $\mathbb{P}\mathbb{P}\mathbb{P}$ coupling. This picture is that which emerges from dual loop considerations [7], but not in all duality schemes [8]. The background in the missing mass channel falls away at $t = 0$ as s^{-p} with $0.95 < p < 1.25$, consistent with an $\alpha(0) \approx \frac{1}{2}$ exchange and the smallness of $\mathbb{P}\mathbb{P}\mathbb{P}$ coupling, as pointed out by Edelstein et al. [9]. These authors also find evidence for a significant $\mathbb{P}\mathbb{P}\mathbb{P}$ coupling when $|t|$ is larger.

For $t < 0$ the different t slopes of the resonance isobars in diffraction dissociation have been discussed, for example, by Frautschi and Margolis [10] in a multiple scattering model where, however, the resonances of smaller slope (1520, 1690, 2190,...) decouple from the input Pomeron pole.

To reconcile this with the present discussion, one must regard the Pomeron as a complex (but factorizable) exchange : nevertheless, the markedly different t behaviour of the 1400 really remains a mystery in either picture.

In conclusion, at $t = 0$ there is a consistent picture emerging which is compatible with the triple-Regge ansatz, although the latter cannot be checked in detail. Higher energy data (from, e.g., forward proton spectra at ISR) will be essential to check the extrapolation of the Pomeron-proton amplitude to higher M values.

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	$N^*(1400)$	$N^*(1520)$	$N^*(1690)$	$N^*(2190)$
M (GeV) =	1.411	1.501	1.690	2.160
Γ (GeV) =	0.188	0.140	0.133	0.250
A (mb.GeV^{-2}) =	5.8	0.90	1.60	0.37
B (GeV^{-2}) =	16.5	4.8	4.8	5.1

TABLE : Average values for the resonance parameters, taken from Ref. 4).

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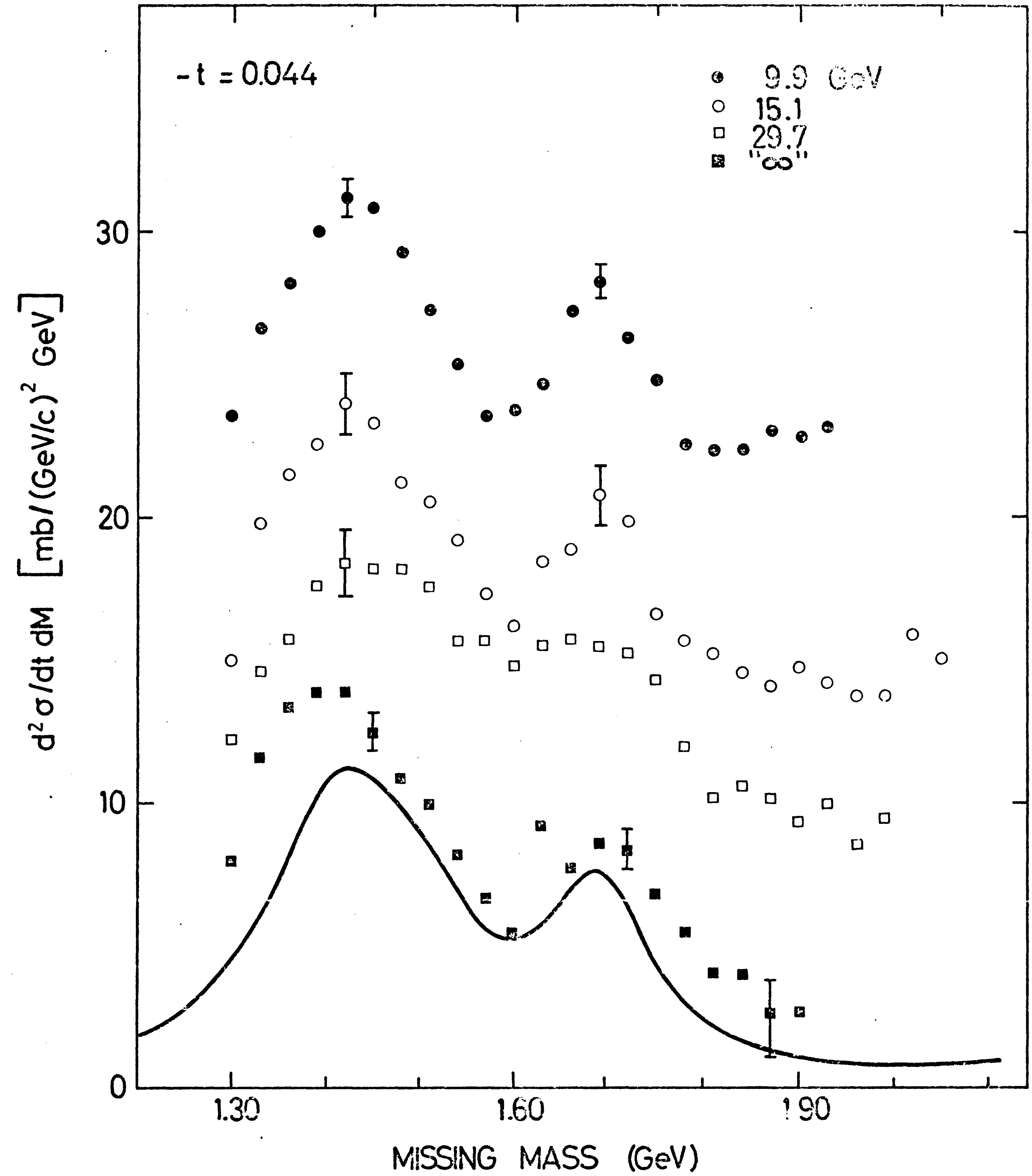
FIGURE CAPTIONS

Figure 1 Data points for $d^2\sigma/dt\,dM$ versus M for $p + p \to p + \text{any}$ at 9.9, 15.1 and 29.7 GeV/c at fixed $t = -0.044$ GeV^2 from Refs. 3) and 4). The points marked by crosses are obtained by extrapolation to $s \to \infty$. The solid curve is the contribution of the resonances alone, using the average resonance parameters obtained in Refs. 3) and 4).

Figure 2 Resonance curve drawn for $t = 0$, and triple-Regge plots made for $\alpha_\gamma(0) = 1$ (-----), $\alpha_\gamma(0) = \frac{1}{2}$ (———) and $\alpha_\gamma(0) = 0$ (-.-.-.-.-), using Eq. (2) of the text.



-t = 0.044
9.9 GeV
15.1
29.7
"∞"
30
20
10
0
d²σ/dt dM [mb/(GeV/c)² GeV]
1.30
1.60
1.90
MISSING MASS (GeV)

FIG.1

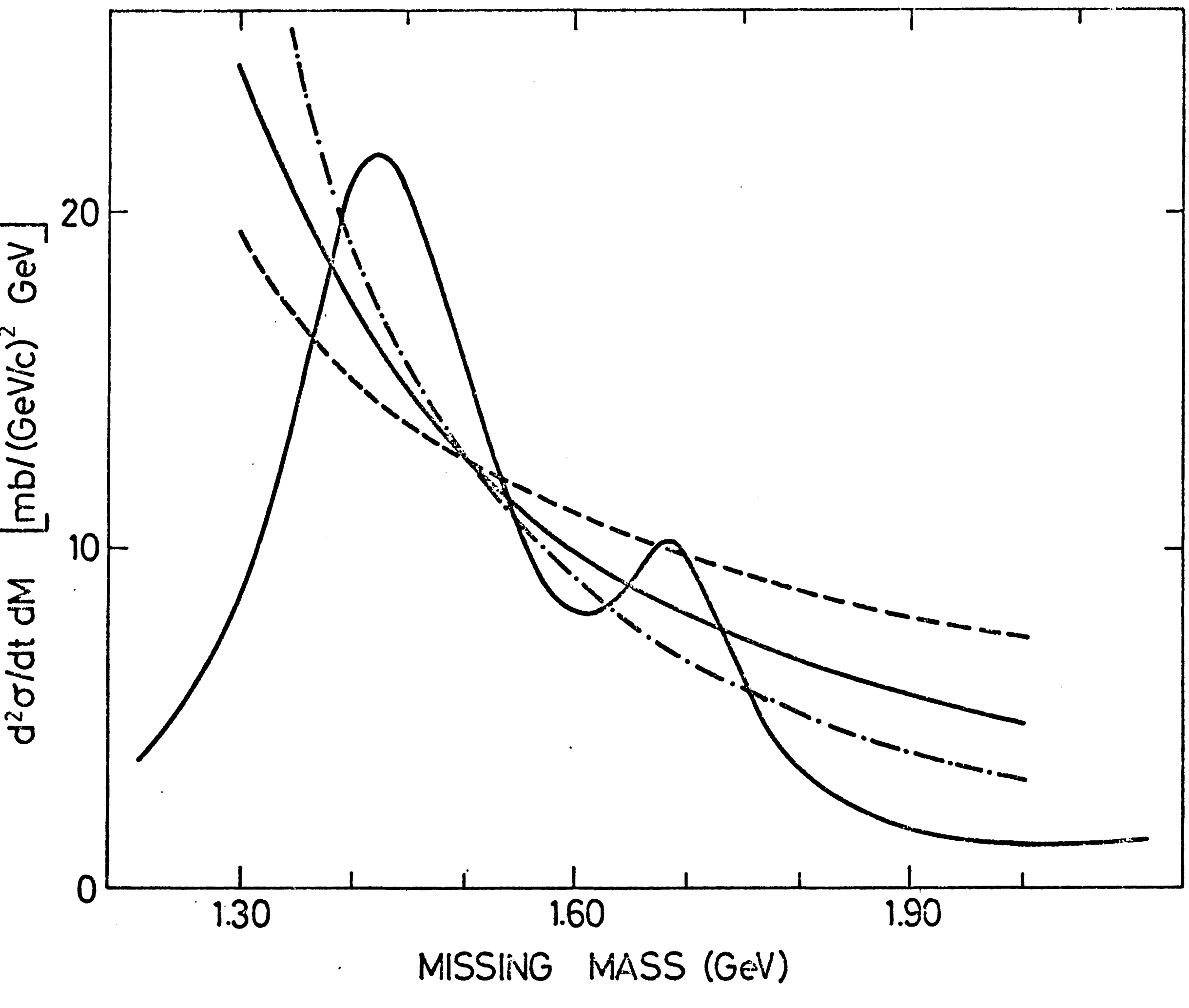


FIG.2