Absence of multiple-dip structure in *pp* elastic scattering*

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The recently noted discrepancy between many models of *pp* elastic scattering and the data at $|t| \gtrsim 2$ GeV^2 could be due to the neglect of diffractive dissociation. A model which includes such effects exists and shows remarkable agreement with the data.

In a recent Letter,[1] Sukhatme compared models of high-energy *pp* elastic scattering with the latest data obtained at the CERN intersecting storage rings (ISR) by the CERN-Hamburg-Orsay-Vienna (CHOV) collaboration.[2] He concluded that none of the models could provide a convincing explanation of the slope and smoothness of the differential cross section in the momentum-transfer region $2 \lesssim |t| \lesssim 8$ GeV^2.

We would like to point out two things. First, a plausible reason for the failure of the models considered by Sukhatme is that none of them allows in a realistic way for the existence of diffractive-dissociation processes. Second, there is in fact at least one current model[3] which does this and is thereby able to give a good quantitative account of all the available ISR elastic-scattering data, as well as correctly predicting the form of diffractive-dissociation cross sections.

Several recent papers have dealt with the way in which diffractive dissociation is related to elastic scattering by unitarity.[3-5] The basic assumption, which can be justified on rather general grounds,[5] is that diffractive dissociation can be taken into account by introducing "diffraction eigenchannels" $|ij\rangle$ which undergo only elastic or nondiffractive scattering, the corresponding elastic amplitudes being dominated by their absorptive parts $\sigma_{ij}(s,b)$ (s is the c.m. energy squared, b is the impact parameter). If P_{ij} is the probability of the incident $|pp\rangle$ system being in eigenchannel $|ij\rangle$, the elastic cross section is

$$\sigma_{el} \propto \int d^2b \left(\sum_{i,j} P_{ij}\sigma_{ij}\right)^2 = \int d^2b \, \langle \sigma_{ij} \rangle^2, \quad (1)$$

while the diffractive dissociation cross section σ_d is given by

$$\sigma_{el} + \sigma_d \propto \int d^2b \sum_{i,j} P_{ij}\sigma_{ij}{}^2 = \int d^2b \, \langle \sigma_{ij}{}^2 \rangle . \quad (2)$$

Hence

$$\sigma_d \propto \int d^2b \, \langle (\sigma_{ij} - \langle \sigma_{ij} \rangle)^2 \rangle . \quad (3)$$

Given the large observed values of σ_d,[6] one is forced by Eq. (3) to the conclusion that the eigenchannel amplitudes σ_{ij} have a wide variety of forms. Therefore at large t the elastic differential cross section

$$\frac{d\sigma}{dt} \propto \left(\sum F_{ij}\right)^2 + (\text{small real parts})^2, \quad (4)$$

where

$$F_{ij}(s,t) = P_{ij} \int b \, db \, J_0(b\sqrt{-t})\sigma_{ij}(s,b), \quad (5)$$

receives contributions from a variety of σ_{ij}'s which do not necessarily dominate near $t=0$. The result is that structure beyond the first dip tends to be washed out and there is no simple relationship between the small-t and large-t regions of the type discussed by Sukhatme, even when the individual amplitudes F_{ij} have simple forms.

In the model of Ref. 3, we took the eigenchannels $|ij\rangle$ to consist of pairs of eigenstates representing orthonormal combinations of the proton and two diffractive excitations, making six distinct eigenchannels ($i,j=1,2,3$). The eigenchannel impact-parameter profiles $\sigma_{ij}(s,b)$, with varying amounts of absorption specified by the eikonal prescription, are shown (at $\sqrt{s}=53$ GeV) in Fig. 1a. These lead to the amplitudes F_{ij} shown in Fig. 1b. The resulting prediction of the elastic differential cross section is shown in Fig. 2, together with the CHOV data. The model parameters were determined by a fit to earlier data at $23 < \sqrt{s} < 62$ GeV covering a smaller range of t, so the large-t behavior is a genuine prediction.[7]

It may be seen from Fig. 1b that F_{12}, the most important amplitude near $t=0$, exhibits the characteristic features of the models discussed by Sukhatme,[1] viz. zeros (and associated dips in $d\sigma/dt$) at $|t| \approx 1.2$, 4, and 8 GeV^2; but Eq. (3) tells us that a single eigenchannel cannot dominate at all t, for this would necessarily give $\sigma_d = 0$. We find in fact that the amplitudes F_{11} and F_{22} are also important[8] at large t, leading to the shift of the dip in $d\sigma/dt$ to $|t| = 1.35$ GeV^2, the characteristic shape of the secondary maximum, and the absence of a dip at $|t| \approx 4$ GeV^2. At $|t| \approx 8$ GeV^2, on the other hand, all three important amplitudes have nearby zeros, giving a distinct dip in $d\sigma/dt$. It is not clear whether this dip will remain in a more realistic model with more than two diffractive excitations of the

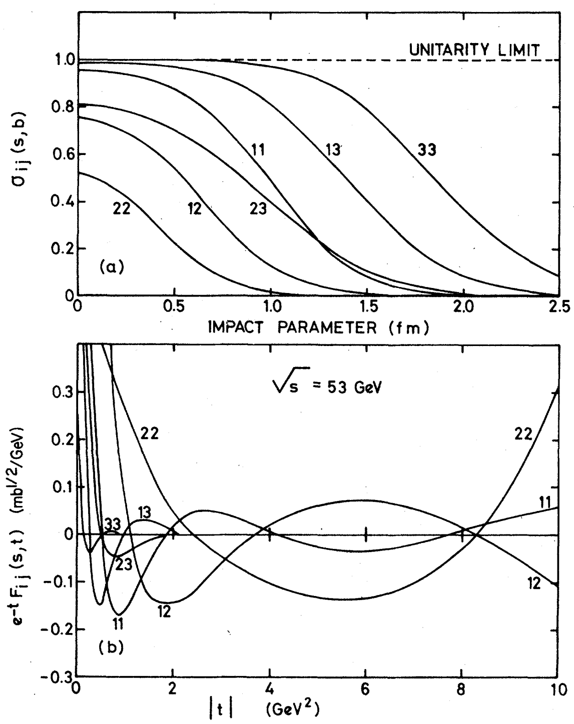

FIG. 1. (a) Impact-parameter profiles (total overlap functions) for the diffractive eigenchannels $(i,j=1,2,3)$ in the model of Ref. 3. As indicated, the normalization is such that the unitarity limit for each eigenchannel is $\sigma_{ij}=1$. (b) Contributions to the elastic amplitude obtained by taking the Fourier-Bessel transform of the impact-parameter profiles in (a). The normalization is such that the constant of proportionality in Eq. (4) is unity when $d\sigma/dt$ is measured in mb/GeV^2. Each contribution is multiplied by e^{-t} to render the large-t structure visible.

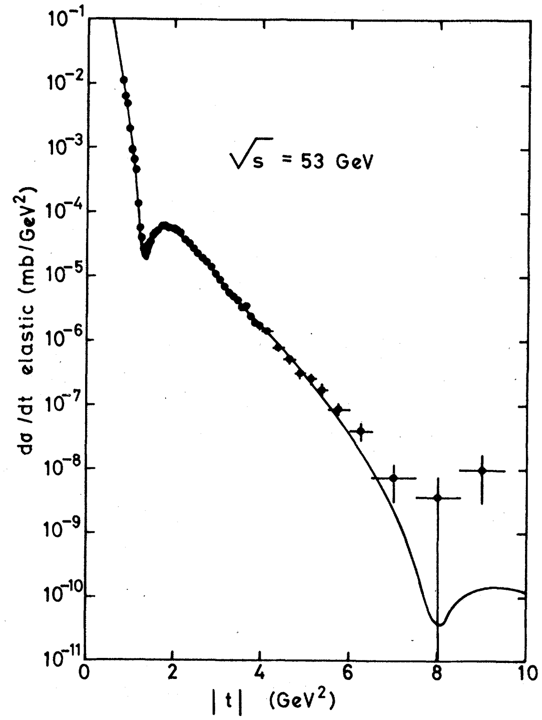

FIG. 2. *pp* elastic differential cross section at $\sqrt{s}=53$ GeV. Data are from Ref. 2. The curve shows the prediction of Ref. 3. See also Ref. 7.

proton. The data hint at such a dip, which, if it exists, would be a powerful constraint on the structure of the amplitudes F_{ij} and hence on diffractive processes in general.

In conclusion, we would like to stress that our main intention is *not* to show that a complicated set of amplitudes (such as those in Fig. 1) can be concocted to agree with the elastic data. Rather, it is to point out that the large value of the diffractive-dissociation cross section appears to force such complications upon us, removing any obvious link between the small-t and large-t behavior. We regard it as somewhat surprising but encouraging that the simple scheme proposed in Ref. 3 to take account of this effect turns out to agree with the elastic data over such a wide range of t.

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[6]Triple-Regge analyses suggest that at high energies $\sigma_d \approx \sigma_{el} \approx$ 7–8 mb. See D. P. Roy and R. G. Roberts, Nucl. Phys. B77, 240 (1974), and R. D. Field and G. C. Fox, *ibid.* B80, 367 (1974).

[7]The data of Ref. 2 generally fall 15–30% lower than expected from our good fit to the earlier CHOV data at $\sqrt{s}=23$ and 62 GeV [N. Kwak *et al.*, Phys. Lett. 58B, 233 (1975)], suggesting some incompatibility between the normalizations at different energies. The curve in Fig. 2 was therefore normalized by eye to the height of the secondary maximum in the data.

[8]The amplitudes involving eigenstate 3, i.e., F_{13}, F_{23}, and F_{33}, were associated with a geometrically larger impact-parameter distribution, as shown in Fig. 1(a), and therefore contributed significantly only at $|t| \lesssim 1$ GeV^2.