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THE MESON-BARYON ELASTIC POLARIZATION AND
THE REAL PART OF THE NON-FLIP AMPLITUDE *)

C.B. Chiu

Center for Particle Theory
University of Texas, Austin

MASTER

and

W.W. Wada

CERN - Geneva
and

Department of Physics
The Ohio State University, Columbus

A B S T R A C T

In this work we discuss briefly the strong central absorption prescription for the non-diffractive helicity-non-flip elastic two-body scattering amplitude that has recently been proposed, and present the experimental indications for this in the crossing even πp and $K^- p$ scattering amplitudes. The strong and weak versions of the prescription are also presented.

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1. INTRODUCTION

In the intermediate energy two-body scattering, it is well known that, while the Regge pole model gives an adequate description to the helicity-flip amplitude, the helicity non-flip amplitude is poorly described by the model ¹⁾⁻³⁾. For example, the Regge pole "explanation" of the crossover zero at $t \approx -0.2 \text{ GeV}^2$ in the particle-particle and particle-antiparticle elastic cross-sections leads to the violation of the pole residue factorization theorem ⁴⁾. Also, this crossover zero cannot be understood in terms of the conventional absorption correction, neither the weak nor the strong Pomeron-Reggeon double scattering cuts ²⁾.

The pattern for the success and the failure of the Regge pole model is evidently connected to the following regularities in the s channel partial wave amplitudes: in the non-flip amplitude ($n=0$) there is a large low impact parameter component, while in the flip amplitude ($n=1$), the pole contribution is naturally suppressed due to the fact that near $b=0$ the flip amplitude contains a geometric factor " b " ^{1),3),5)}. This suggests that the success of the Regge pole prediction is associated with those cases where the pole contribution has a depletion in the low b region, while the failure with those cases where there is a large central component.

At present there is no dynamical model that gives a satisfactory explanation of the above pattern. However, there are some suggestions that have been advanced in relationship to this pattern, and we review them briefly in the following.

- (1) The Dual Absorptive Model (DAM) ¹⁾. From the empirical mass-spin pattern of the prominent resonances, Harari suggested that the direct channel resonance contribution is in some universal manner concentrated in a "peripheral ring", with a radius ($r \sim 2J/m_J$) of the order of Fermi. Through finite energy duality, he then argued that the imaginary part of the asymptotic contribution to the non-diffractive scattering, $\text{Im} A_n^{\text{nd}}$, which is dual to resonances, must necessarily be "peripheral" (nd labels non-diffractive scattering and $n=0, 1, 2, \dots$ stands for the helicity change). Thus, in this view, the central partial wave suppression is associated with the intrinsic property of the s channel resonances. However, the underlying reason for the peripherality of the s channel resonances is still left to be explained. In any event, DAM has been quite successful in correlating the dip phenomena in various two-body scattering differential cross-sections for $n=0$ and

1 cases ¹⁾, although its validity for $n > 1$ is unclear at present ⁵⁾. Unfortunately, no statement on the behaviour of the real part is available from DAM.

- (2) The Strong Central Absorption Prescription (SCAP) ⁵⁾. In high-energy two-body scattering, the Regge pole exchange presumably dominates the peripheral scattering. In the central collision, however, it is assumed that the interaction mechanism differs from that in the peripheral region, in particular it is no longer governed by the Regge pole exchange. Considering hadrons as extended objects, during the central collision, there is an extensive overlap of hadronic matter and inelastic states are copiously produced. To gain insight for the two-body scattering in this region, the implication of the statistical model of multi-peripheral production may be considered ⁵⁾. During the collision, two colliding particles coalesce to form a "droplet" confined to a characteristic volume V ⁶⁾. This droplet subsequently decays into various "statistical states" with the decay probability governed by the phase space available. Thus, the probability of decaying into any two-body state is expected to be strongly suppressed. More quantitatively, if one assumes the statistical bootstrap model ^{6), 7)}, the production of a given final state in the central region should be suppressed by a factor $e^{-c\sqrt{s}}$ where $c > 0$ compared with the total production. Although this suppression has been motivated from a specific model, we believe that the effect of competing channels considered here is quite general. Thus, the following picture for the high-energy two-body scattering is suggested: a) in the central region ($b \approx 0$), the two-body production amplitude is strongly suppressed and it is essentially zero, b) as b increases, the competing channel contributions quickly die out and the coherent Regge pole exchange contribution gradually sets in, c) finally, in the peripheral region, the Regge pole contribution dominates.

We note that for the near central collision only the non-diffractively produced two-body states enter into the incoherent statistical picture. The diffractive two-body scattering obviously cannot be treated in the same manner since it is generated by the shadow of all inelastic processes. This is in agreement with observation, i.e., typically, the s channel elastic amplitude for the shadow scattering is large.

It can easily be shown that the strong suppression of the s wave non-diffractive scattering in the $n=0$ amplitude leads to the sum rule ⁵⁾

$$\int_{-|t|_{\max}}^0 dt A_{n=0}^{nd}(s, t) \approx 0.$$

(1)

The sum rule predicts the presence of at least one zero in both real and imaginary parts of the amplitude. We refer to it as a "SCAP sum rule zero".

2. EXPERIMENTAL INDICATIONS FOR THE SCAP SUM RULE

It is well known that in the intermediate energy region a simple Regge model, in which the high-energy elastic scattering cross-section is dominated by the Pomeron contribution (assumed to be pure imaginary) in the non-flip amplitude (N) and the flip amplitude (F) is saturated by the ρ Regge pole exchange, can approximately account for the $\pi^\pm p$ polarization data in the region $0 \leq |t| \lesssim 1.4 \text{ GeV}^2$. Within this model, the polarization is given by ^{5),8)}

$$P(\pi^\pm p) \approx \mp 2 \frac{\text{Im}(N_F F_F^*)}{|N|^2 + |F|^2} \\ \approx \pm 2 \left| \sin \frac{\pi\alpha}{2} \right| \left[\frac{1}{2} \frac{d\sigma}{dt} \Big|_F (\pi^\mp p \rightarrow \pi^0 n) / \frac{d\sigma}{dt} (\pi^\pm p) \right]^{1/2},$$

(2)

where $d\sigma/dt|_F$ stands for the flip part of the charge-exchange cross-section. In general, the predictions of Eq. (2) are found to agree reasonably well with data ⁵⁾. However, in both the small $|t|$ region ($t \approx -0.2 \text{ GeV}^2$) and the large $|t|$ region ($t \approx -1 \text{ GeV}^2$) deviations of the data from the predictions of Eq. (2) are found, and we attribute these to the neglect of the real part in the non-flip amplitude.

The polarization in the elastic $K^- p$ scattering based on the similar set of assumptions is given by ^{5),8)}

$$P(K^- p) \approx \cos \pi\alpha \left[\frac{d\sigma}{dt} \Big|_F (K^- p \rightarrow \bar{K}^0 n) / \frac{d\sigma}{dt} (K^- p) \right]^{1/2}.$$

(3)

The general trend of the data is again in agreement with the prediction of Eq. (3) ⁵⁾. We attribute the observed small deviations of the data from the prediction of Eq. (3) to the neglect of the real part in the non-flip amplitude.

The polarization data thus suggest the existence of non-negligible real parts in the non-flip amplitudes of both $\pi^\pm p$ and $K^\pm p$ elastic scattering amplitudes at the energies specified.

Assuming that the flip amplitude is saturated by the Regge pole exchange, for the $\pi^\pm p$ system, the crossing-even non-flip amplitude $N^{(+)}$ contributes to the polarization formula as follows:

$$\frac{1}{4} \left[P(\pi^+ p) \frac{d\sigma}{dt}(\pi^+ p) - P(\pi^- p) \frac{d\sigma}{dt}(\pi^- p) \right] = N_y^{(+)} F_x^p - N_x^{(+)} F_y^p, \quad (4)$$

where $N_x^{(+)} (N_y^{(+)})$ is the real (imaginary) part of $N^{(+)}$, and similarly for $F_x^p (F_y^p)$, Ref. 9). The Argand plots of $N^{(+)}$ obtained from Eq. (4) at $P_{lab} = 2.74, 6$ and 10 GeV/c are shown in Fig. 1, and $N_x^{(+)}$ at the same momenta in Fig. 2 ¹⁰⁾. Notice that in the $N_x^{(+)}$ plots near $t=0$, there is a tendency of flattening in the t dependence of the curve which can be correlated to the behaviour of the pole term near $t=0$. More explicitly, here the pole terms are

$$N_x^{f^0} \propto -(1 + \cos \pi \alpha_{f^0}) \text{ and } N_x^P \propto -(1 + \cos \pi \alpha_P). \quad (5)$$

With the normal trajectory parameters $\alpha_{f^0} \approx 0.5 + t$ and $\alpha_P \approx 1 + \alpha_P' t$ where $\alpha_P' \approx 0.3 \sim 0.4$ as indicated by the Serpukhov data ¹¹⁾, both factors in Eq. (5) increase away from $t=0$. We separate the non-diffractive and diffractive terms and write

$$N_x = N_x^P + N_x^{nd}, \quad (6)$$

with the parameterization of the Pomeron taken from Ref. 12), where $\alpha_P' = 1 + 0.37t$. The quantities N_x , N_x^P and N_x^{nd} are all illustrated in Fig. 2. Notice in particular that for N_x^{nd} the SCAP sum rule zeros are present at $P_{lab} = 2.74, 6$ and 10 GeV/c. The first case is not sensitive to the Pomeron contribution assumed, while the latter two cases are more sensitive to it. The crudeness of the data and the lack of precise knowledge on N_x^P prevent us from making

a more quantitative test on the SCAP sum rule. Also, it is interesting to note that for the large $|t|$ region, the N_x^{nd} shown differs from the expectation of the Regge pole model. Barring accidental zero in the Regge residue function, the pole model predicts $N_x^{f0} < 0$ for all $|t|$ [see Eq. (5)], while the data change sign at around $t \approx -0.5 \text{ GeV}^2$.

The quantities $N(K^-p)$ for $P_{lab} = 2.74 \text{ GeV}/c$, N_x and N_x^{nd} for K^-p case for $P_{lab} = 2.74$ and $10 \text{ GeV}/c$ are respectively shown in Figs. 3 and 4¹³⁾. In the small $|t|$ region, N_x is negative, which is correlated to the fact that the polarization predicted on the basis of the simple Regge model [see Eq. (3) and Ref. 5] is systematically larger than the data, although the errors are quite large in general. In the large $|t|$ region (e.g., $|t| \geq 0.8 \text{ GeV}^2$) accurate data are available only at $2.74 \text{ GeV}/c$, so only the corresponding N_x and N_x^{nd} values are shown. In the interval $0.7 \leq |t| \leq 1.0$, there are two possible solutions (see Fig. 4). Solution I, with $N_x > 0$ and $N_y > 0$ for all t values considered, is the conventional choice. For example, $N_y > 0$ is assumed in the work of Ref. 1). Furthermore, for this solution, there is a sign change in N_x , where a similar sign change also occurs in the πN case. We prefer this solution. Near $t=0$ the t dependence of N_x^{nd} is consistent with the Regge pole behaviour, i.e., $N_x^{f0+\omega} \propto -\cos \pi\alpha$, although, unfortunately, the data are rather poor. However, in the large $|t|$ region, N_x^{nd} again does not follow the trend of the Regge pole model. The pole model predicts that $N_x^{f0+\omega} < 0$ for $\alpha > -\frac{1}{2}$, or $|t| < 1$, while the observed N_x^{nd} has a SCAP sum rule zero and changes sign at around $t = -0.6 \text{ GeV}^2$.

3. THE STRONG VERSION OF THE SCAP vs. THE WEAK VERSION OF THE SCAP

In Section 1 and in Ref. 5) we discussed the motivation for the SCAP from a purely geometric point of view not involving any selection in the s channel quantum numbers. There is an alternative way to motivate SCAP that does incorporate some quantum number selection rules, leading to a less restrictive SCAP sum rule. To distinguish between the two cases, we shall refer to the version discussed in Section 1 [and Ref. 5] as the strong version of the SCAP, and the alternative prescription as the weak version of the SCAP.

The weak SCAP

It is well known that both the statistical bootstrap model and the dual resonance model share a common feature in the energy dependence of the total level density ^{6),7),14)}. In particular, in both models, for large s the level density increases exponentially as a function of $\sqrt{s}$. However, in the dual resonance model, the intermediate states appear only in those s channel states with non-exotic quantum numbers. For example, the resonant states appear in the so-called "moving phase channels" (with the t channel Regge pole phase $-e^{-i\pi\alpha}$), e.g., $\pi^- \pi^+ \rightarrow \pi^- \pi^+$ and $K^- p \rightarrow K^- p$, but not in the exotic channels or the so-called "real phase channels", e.g., $\pi^+ \pi^+ \rightarrow \pi^+ \pi^+$ and $K^+ p \rightarrow K^+ p$. Thus, the statistical states, which appear in the original argument of the SCAP ⁵⁾, can a priori be specified by two alternatives: one is to include both the non-exotic and exotic states, ¹⁵⁾ and the other to take only the non-exotic states. The former leads to the "strong SCAP" discussed in Section 1, while the latter to the "weak SCAP" which predicts only one SCAP sum rule, i.e., for the case of the moving phase channel,

$$\int_{-|t|_{\max}}^0 dt A_{n=0}^{\text{moving}}(s,t) \approx 0.$$

(7)

The sum rule here should not be applied to the case of the real phase, nor for those channels associated with the pure even or odd signature, since these channels contain the "real phase" components. The choices here should eventually be determined by the multiparticle production information, although these choices can presumably be inferred from the two-body scattering data.

Of the two cases studied in Section 2, the weak SCAP sum rule is relevant only for the $K^- p$ case. It does not impose any specific constraints of the type of the sum rule on the t dependence of the quantity $\text{Re } N^{nd(+)}(\pi N) \equiv N^{nd(+)}(\pi N)$ considered in the previous section, neither on the quantity $\text{Im } N^{x(-)}(KN)$ considered by Davier and Harari ¹⁾. This is because these two amplitudes are associated with pure even ($N^{nd(+)}(\pi N)$) and odd ($N^{(-)}(KN)$) signatures. From the very presence of the SCAP sum rule zero in the $\text{Re } N^{(+)}_{nd}(\pi N)$ demonstrated in Fig. 2 and the observed peripherality of $\text{Im } N^{(-)}(KN)$ shown in Ref. 1), it is suggestive that the strong SCAP is in fact operative here. On the other hand, Ringland and Roy have determined the quantity $\text{Re } N^{(-)}(\pi N)$ based on the $\pi^- p \rightarrow \pi^0 n$ polarization data ¹⁶⁾. From their results, it appears that the partial waves of $\text{Re } N^{(-)}(\pi N)$

have a large central component ¹⁷⁾, contrary to the expectation from the strong SCAP. Unfortunately, due to the large errors in the polarization data, especially for $|t| > 0.5 \text{ GeV}^2$, and the uncertainty of the $\text{Im} N^{(-)}(\pi N)$ assumed in the analysis, their amplitude at $b=0$ may have a considerable uncertainty. Evidently, further elastic and charge-exchange polarization data are needed to provide more stringent test on the validity of the strong version of the SCAP predictions.

We have also looked into the situations for $K^- n \rightarrow \pi^- \Lambda$ and the $\pi^+ p$ backward scattering, both of which have been regarded as providing suggestive evidences for a large central component in N_x^{nd} . For the former case ³⁾ we found that, actually, the data are not incompatible with the presence of the SCAP sum rule zero in N_x^{nd} due to the presence of a sizable flip amplitude (implied by the large polarization data ¹⁸⁾) and due to the fact that the presence of some imaginary part in the non-flip amplitude is expected. In the $\pi^+ p$ backward scattering, the Regge pole model has been most successful in explaining the differential cross-section data ¹⁹⁾ for $|u| < 0.5 \text{ GeV}^2$. It is crucial to note that there it is the imaginary part that dominates and the Regge pole description is insensitive to the detailed behaviour of the real part so long as it is relatively small in magnitude. Thus, the particular aspect of the Regge pole model that predicts a large central component for the real part has not been directly tested by the data.

Finally, we summarize the situation in the magnitude of the real part of the non-flip partial wave amplitude $|N_x^{\text{nd}}|$ near $b=0$. This is given in the Table with the columns listing relevant four cases: the "real phase", the "moving phase", the even and odd signature cases, while the rows refer to the various theoretical models. According to the Regge pole model, for a nominal trajectory $\alpha = \frac{1}{2} + t$, the quantity $|N_x^{\text{nd}}|$ at $b \approx 0$ is relatively large for all cases, except for the case of moving phase. In this last case, due to the presence of a zero at $\alpha = -\frac{1}{2}$ or $t = -1$, its magnitude is reduced compared with the other three cases. The weak SCAP predicts that the relevant quantity is zero for the case of the moving phase, and is unknown for the other three cases. The strong SCAP predicts that it is universally suppressed for all four cases. No statements are available from the dual absorption model. As far as the data are concerned, accepting the assumptions of our analysis, we have determined the quantity $N_x^{\text{nd}}(K^- p)$ which corresponds to the case of the moving phase and the quantity $N_x^{\text{nd}}(\pi N)$ to the even signature case. The t dependence of the quantities obtained are encouraging, and the presence of the SCAP sum rule zeros is in agreement with the strong SCAP. We have also commented on the other data

such as those for $\pi^- p \rightarrow \pi^0 n$, $K^- n \rightarrow \pi^- \Lambda$ and $\pi^+ p \rightarrow p \pi^+$ scattering. At this stage, the data are not incompatible with the strong SCAP prediction. Further polarization data and the amplitude analysis work are needed to provide a more stringent test for the SCAP proposed.

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TABLE

	Real Phase (-1)	Moving Phase ($-e^{-i\pi\alpha}$)	Even Signature ($1 + e^{-i\pi\alpha}$)	odd Signature ($1 - e^{-i\pi\alpha}$)
Regge pole model	large	large (reduced)	large	large
Weak SCAP	?	~ 0	?	?
Strong SCAP	~ 0	~ 0	~ 0	~ 0
Dual Absorption	?	?	?	?
<p>—— The SCAP sum rule zero has been observed.</p> <p>? Not predicted by the model.</p>				

Real part of the non-flip amplitude, $|\operatorname{Re} N(b, s)|$, near $b = 0$.

FIGURE CAPTIONS

Figure 1 :

The Argand diagrams for $N^{(+)}$ obtained by solving Eq. (4) at $P_{lab} = 2.74, 6$ and 10 GeV/c. The error bars shown include uncertainties from both the polarization data and the elastic differential cross-section data. For the data used, see Ref. 10). The quantity $N_x^{(+)}$ at $t=0$ was obtained from the $\pi^{\pm}p$ total cross-sections and the N_x/N_y data at $t=0$ for the $\pi^{\pm}p$ elastic scattering. For the latter, see W. Rarita, R.J. Riddell, C.B. Chiu and R.J.N. Phillips, Phys.Rev. 165, 1615 (1968).

Figure 2 :

The quantities N_x (extracted from $\pi^{\pm}p$ polarization and the differential cross-section data) and N_x^{nd} and N_x^P at $P_{lab} = 2.74, 6$ and 10 GeV/c. N_x^P is taken from Ref. 12). Notice that there is the SCAP sum rule zero at each of the three energies. .

Figure 3 :

The Argand diagram for the non-flip amplitude N for K^-p elastic scattering extracted from the expression

$$P(\bar{K}p) \frac{d\sigma}{dt}(\bar{K}p) = 2 (N_y F_x^{j+A_2} - N_x F_y^{j+A_2})$$

at $P_{lab} = 2.74$ GeV/c. The error bars shown include uncertainties from both the polarization data and the elastic differential cross-section data. For the data used, see Ref. 13).

Figure 4 :

The quantities N_x and N_x^{nd} extracted from the K^-p polarization data at $P_{lab} = 2.74$ and 10 GeV/c with N_x^P obtained from Ref. 12), together with the SU(3) singlet assumption for the Pomeron, i.e., $N_x^P(KN) = N_x^P(\pi N)$. Both solution I and a portion of Solution II are illustrated. Error bars shown include polarization errors only. Points plotted are the midpoints of the error flags. Notice the presence of the SCAP sum rule zero in N_x^{nd} .

FIG.1a

FIG.1b

FIG.1c

FIG. 2a

FIG.2b

FIG.2c

FIG. 4