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Authors
Chan, Chun-Fai
Chen, Chih Kwan
Rarita, William.

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COMPLEX REGGE POLES AND HIGH ENERGY SCATTERING DATA*

Chun-Fai Chan†, Chih Kwan Chen‡, and William Rarita‡

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

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ABSTRACT

For the high energy data on σ_{tot}^{pp} the proton-proton total cross section, and on ρ, the ratio of real to imaginary part of the forward elastic amplitude, including the recent ISR results, an excellent fit is obtained with P, P', ω Regge poles plus a pair of complex conjugate Regge poles. The complex poles describe the possible oscillatory behavior of the quantities σ_{tot}^{pp} and ρ. The physical meaning of these complex poles and extrapolation to future measurements of the above quantities are discussed.

The relevance of complex Regge poles to high energy scattering process was emphasized by Chew and Snider [1], who illustrated the idea with a simplified multiperipheral model. Physically, whenever the energy of the initial scattering state increases by a certain amount, a new channel opens up in the final states. In a multiperipheral model for the unitarity sum, this amounts to adding a term with one additional unit link in the multiperipheral chain of the

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† Member of the Mathematics and Computing Group; participating guest in the Theoretical Physics Group.

‡ Participating Guests, Lawrence Berkeley Laboratory.

production amplitude. This mechanism in the sum is reflected in the Regge singularity spectrum by conjugate pairs of complex poles, in addition to the leading real pole. These complex poles would describe the damped oscillations in, e.g., the total cross section.

Subsequent quantitative studies of the (more realistic) classical multiperipheral model [2,3] confirm the existence of complex poles, but their residues turn out to be so weak and the real parts of their positions so low that they could hardly produce any observable effect. Recall that this classical model contains only a low-subenergy resonating system as the unit link in the chain. More modern multi-peripheral models [4], however, include high-subenergy diffractive scattering along the chain. The unitarity sum in the classical model may be regarded as consisting of all single "fireball" events, and one now additionally includes those events consisting of two fireballs, three fireballs and so on--these events having one, two, etc. large rapidity gaps between groups of produced particles. Including multiple fireball production in the formalism, it is conceivable that the corresponding complex poles would manifest themselves experimentally when the energy is high enough to open up some of those multi-fireball "superchannels" [5]. Another candidate for a high-threshold link in the multiperipheral chain is the production of baryon-antibaryon pairs [6,7].

Motivated by these arguments, we have examined recent data on pp collisions: the total cross section σ_{tot}^{pp} and the ratio ρ of real to imaginary part of the forward elastic amplitude. We have fitted the data from about 10 GeV^2 up to the ISR region [8] with the conventional P, P', ω poles plus a pair of complex conjugate poles

P_c. In the forward direction $(t = 0)$ we have

$$\sigma_{tot}^{pp} = C_P\left[1 + 2|\beta_c| s^{\alpha_R - 1}\cos(\alpha_I \ln s + \angle\beta_c) + \beta_{P'} s^{\alpha_{P'}-1} + \beta_\omega s^{\alpha_\omega - 1}\right] , \qquad (1)$$

$$\rho = C_P\left[-2|\beta_c|\left|\cot\frac{\pi\alpha_c}{2}\right| s^{\alpha_R-1}\cos\left(\alpha_I \ln s + \angle\beta_c + \angle\cot\frac{\pi\alpha_c}{2}\right) - \cot\frac{\pi\alpha_{P'}}{2}\beta_{P'} s^{\alpha_{P'}-1} + \tan\frac{\pi\alpha_\omega}{2}\beta_\omega s^{\alpha_\omega-1}\right]\Big/\sigma_{tot}^{pp} , \qquad (2)$$

where, as usual the scale parameter is set equal to $1\ \mathrm{GeV}^2$, $|\beta_c|$ is the absolute magnitude of the residue of the complex pole, measured against C_P: the Pomeranchuk pole residue, $\angle\beta_c$ is the argument of the complex residue and $\alpha_c = \alpha_R + i\alpha_I$ is the pole position. We have put the Pomeranchuk pole $\alpha_P = 1$ for simplicity [9]. Before going to the data, one point deserves to be emphasized. If α_I is large enough such that $e^{-\pi\alpha_I} \ll 1$ (say, $\alpha_I \gtrsim 0.5$), then it is easy to see that $\angle\cot\frac{\pi\alpha_c}{2} \approx -\frac{\pi}{2}$, so that the real part of the amplitude oscillates $\sim\frac{1}{4}$ cycle ahead of the total cross section.

With inclusion of $\sigma_{tot}^{p\bar{p}}$ data to fix the ω residue, an excellent fit is obtained with the following values of the parameters

C_P	$\lvert\beta_c\rvert$	$\angle\beta_c$	$\beta_{P'}$	β_ω	α_R	α_I	$\alpha_{P'}$	α_ω
43.8	0.13	-0.26	0.30	-0.91	0.8	0.6	0.5	0.4

with $\chi^2 = 67.7$ for 75 data points. The plots are shown in the figure. Examining these values, we can see that the previously established picture of P, P', and ω remains roughly the same. Our value of $\beta_{P'}$ is a bit small, because part of its previously assumed role is now accounted for by P_c. The complex poles P_c have quite a small residue as expected. We have two further remarks:

(1) Another adequate fit $(\chi^2 = 70)$ has a smaller α_I, $(\alpha_I = 0.2)$. The corresponding curve for, say, σ_{tot}^{pp} rises further than that shown in the figure, but now $\alpha_{P'}$ is close to 1. In the energy range depicted this solution of our model is similar to models with an explicit (absorptive) Pomeranchuk cut.

(2) If α_R is reduced as far as 0.4 with $|\beta_c|$ and $\angle\beta_c$ properly chosen, the values of the other parameters remaining roughly unchanged, we still get a reasonable fit $(\chi^2 \approx 140)$.

Obviously the most distinctive feature of our fit is that by extrapolation σ_{tot}^{pp} reaches a maximum (at about $3 \times 10^4\ \mathrm{GeV}^2$), and then decreases. This is contrary to all fits heretofore proposed [10].

The values of the parameters shown above are compatible with results from current studies of detailed multiperipheral models [7,12]. If we extend the results of the model of Gaisser and Tan [7] (Fig. 2 in their paper), we would obtain a σ_{tot}^{pp} similar in behavior to that shown in our figure. While quantitative connection to specific model details is not attempted here, we emphasize that it is the threshold opening of large-mass multiperipheral clusters (e.g., fireball [11] and/or $N\bar{N}$ pairs [6,7]) that generates oscillatory components in the amplitude which can be described by complex Regge poles. Whatever the threshold mechanism one would observe the oscillation in ρ

earlier than that in σ_{tot}. Furthermore, one might also expect oscillations in the "slope parameters" of the forward elastic peak, in the mean pion multiplicity [13], (thus the height of the pionization plateau [14]), etc. All these considerations apply also to other reactions such as πp, Kp--with the same period of oscillation, although the phase and the amplitude of oscillation will be different.

We have put major emphasis on the fit shown in the figure, because it is consistent with past as well as present Regge-pole pictures of strong interactions. If, as suggested by one analysis of cosmic-ray events [15], the values of σ_{tot}^{pp} beyond ISR energies lie much higher than the curve shown in our figure, the other solution (mentioned in the first remark above) is favored.

In conclusion, if future accurate and reliable data show that σ_{tot}^{pp} continues to increase (even after 10^5 GeV^2), it is likely that there are still new channels opening up to sustaing the growth, and the present version of the multiperipheral model is in trouble. On the other hand, experimental verification of oscillations would constitute an important encouragement for the presently-understood multiperipheral mechanism.

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FIGURE CAPTION

Fig. 1. Total cross sections and the ratios of real to imaginary part of the forward elastic amplitudes.

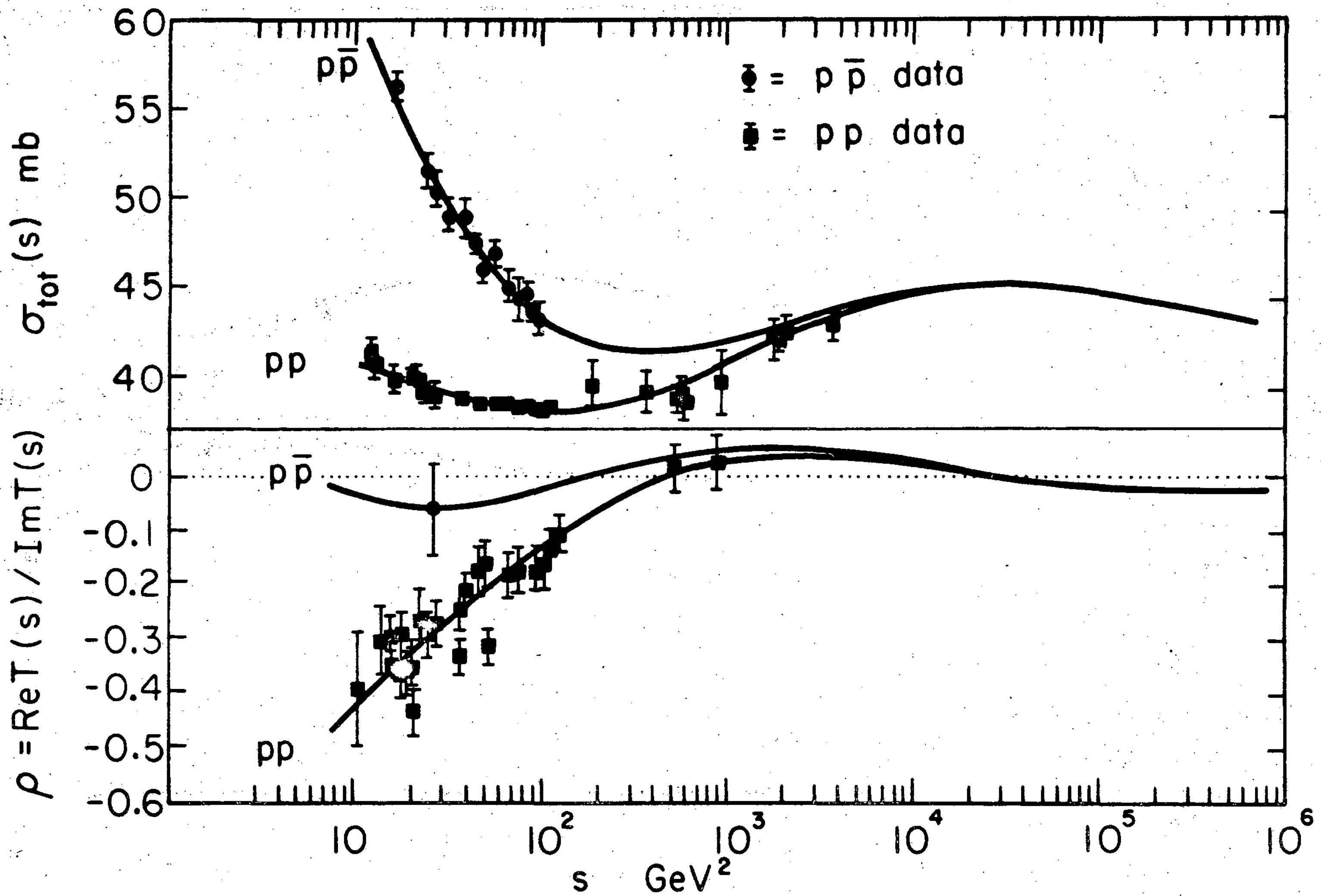

Fig. 1

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