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July 31, 1963

REGGE POLE HYPOTHESIS AND π -p DIFFRACTION EXPERIMENTS*

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July 31, 1963

Recent experiments at 5-20 BeV^{1,2} have shown a substantial shrinkage with increasing energy of the forward peak width for p-p elastic scattering whereas only a slight shrinkage was observed for π -p scattering. At first sight this result seems to contradict the prediction of the Regge pole hypothesis and the opinion has been expressed that a reasonably simple superposition of Regge-poles is unlikely to fit all the experimental data. The purpose of this letter is to show that when other available experimental and theoretical information is employed the existing π -p data is in fact entirely consistent with a simple Regge pole representation. In particular we present a two-parameter fit to the elastic π -p scattering.

The behavior of the total π -p cross sections has made it clear for a long time that to represent the 5-20 BeV region the Pomeranchuk trajectory must be supplemented by at least one further trajectory, the simplest possibility being the P' of Igi.³ Furthermore, without any firm basis, it has often been assumed that all trajectories are linear with slopes near 1 BeV^{-2} in magnitude, even after the discovery of the f^0 particle gave evidence to the contrary.^{4,5} In a previous paper⁶ the authors used dispersion theory together with the mass and width of the

f^0 to estimate the slope of the Pomeranchuk trajectory as between 0.3 and 0.4 BeV^{-2} in the region of interest ($-0.8 \text{ BeV}^{-2} \lesssim t < 0$), while with similar but more conservative arguments Pignotti⁷ placed a firm upper bound of 0.6 BeV^{-2} on the slope. Appreciable curvature also was indicated by our study. We propose here to employ the Pomeranchuk trajectory already deduced by us in Ref. 6 and shown in Fig. 1. The detailed shape of the P' trajectory is less important and, for lack of other information, we shall take it parallel to the P . The ρ -meson contribution will be neglected since it contributes with opposite signs in π^+p and π^-p scattering where the cross sections are known experimentally to be almost identical.^{1,2}

A related but somewhat oversimplified proposal has already been made by Desai⁸ to fit the π -p and p-p data. With respect to π -p he assumes that the Pomeranchuk trajectory alone is sufficient and that its slope is negligibly small. To assume such a flat trajectory however, is unrealistic from the point of view of the f^0 particle; furthermore the least squares fits to the data of Foley et al.^{1,2} ($d\sigma/dt$ vs. $\log(s/\text{BeV}^2)$) are not exactly horizontal lines. We have already remarked on the necessity for including P' as well as P .

The differential cross section for π -p scattering can be written as:⁹

$$\frac{d\sigma}{dt} = \frac{1}{16\pi s^2} \left\{ (4M^2 - t) |A'|^2 + \frac{t}{(4M^2 - t)} [4M^2 - ts - (s - M^2 - 1)^2] |B|^2 \right\} \quad (1)$$

in pion mass units, where $s = 2EM + M^2 + 1$ if E is the lab energy of

the pion. In our two-pole approximation we have

$$|A'|^2 = \left[\beta_{A'P}(t) E_P^{\alpha_P(t)} \frac{1 + \cos \pi \alpha_P(t)}{\sin \pi \alpha_P(t)} + \beta_{A'P'}(t) E_{P'}^{\alpha_{P'}(t)} \frac{1 + \cos \pi \alpha_{P'}(t)}{\sin \pi \alpha_{P'}(t)} \right]^2 + \left[\beta_{A'P}(t) E_P^{\alpha_P(t)} + \beta_{A'P'}(t) E_{P'}^{\alpha_{P'}(t)} \right]^2 \quad (2)$$

and we propose to neglect the helicity-flip term proportional to $|B|^2$.

An analysis we have made of the experimental shape of the forward peak indicates that this term is small for $|t| \lesssim 0.8 \text{ BeV}^2$, a point that can eventually be checked with polarization measurements. Using the same arguments as Desai,⁸ we have taken the residues to be of the form

$$\beta_P(t) = \beta_P(0) e^{t/a}$$

where

$$\beta_P(0) = \frac{\sigma_N^{\text{Total}}(\infty)}{N} = 20.67 \text{ mb} \approx 1.0 \text{ m}_\pi^{-2}$$

and

$$\beta_{P'}(t) = \beta_{P'}(0) e^{t/b}.$$

Such an exponential dependence is reasonable for not too large a value of momentum transfer. (Neither $\alpha_P(t)$ nor $\alpha_{P'}(t)$ vanish in the region of interest.) Igi¹⁰ gives a relation between $\alpha_{P'}(0)$ and $\beta_{P'}(0)$.

We have chosen $\alpha_P(0) = 0.5$ and correspondingly $\beta_P(0) = 2.4$. With Eqs. (1) and (2) we have tried to fit all the π -p data using the two parameters

a and b . The best fit was obtained for the following values

$$a = 24.6 m_{\pi}^2$$

$$b = 14 m_{\pi}^2$$

and is shown by the solid lines in Figs. 2 and 3 against the experimental data of Foley et al.² and Brandt et al.¹¹

With regard to still higher energies we predict that as the P' effect dies out the rate of shrinkage of the π -p forward peak will increase by about a factor two to the asymptotic rate determined uniquely by the slope of the Pomeranchuk trajectory at $t = 0$.¹² At the same time the rate of shrinkage of the p-p forward peak should decrease by about a factor two to approach this same limit.

Finally we would like to remark that to fit p-p scattering at currently accessible energies in terms of $P + P' + \omega$ no essential difficulty should arise since Desai⁸ has already succeeded in finding a fit with zero-slope trajectories. Our task can only be easier than his.

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FOOTNOTES AND REFERENCES

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- † American Colleges Fellow.
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 12. An increase of lab energy by a factor four will reduce the effect of P' by a factor two if $\alpha_p(0) = 0.5$; giving a 50% increase over the currently observed rate of shrinkage.

FIGURE CAPTIONS

Fig. 1. $\text{Re } \alpha(t)$ vs. t for the Pomeranchuk trajectory from Ref. 6.

Fig. 2. Differential cross-section data for π^+ -p scattering of Foley et al. and the fit obtained with the present calculation.

Fig. 3. Differential cross-section data for π^+ -p scattering of Brandt et al. at 10 BeV lab energy and the fit obtained with the present calculation.

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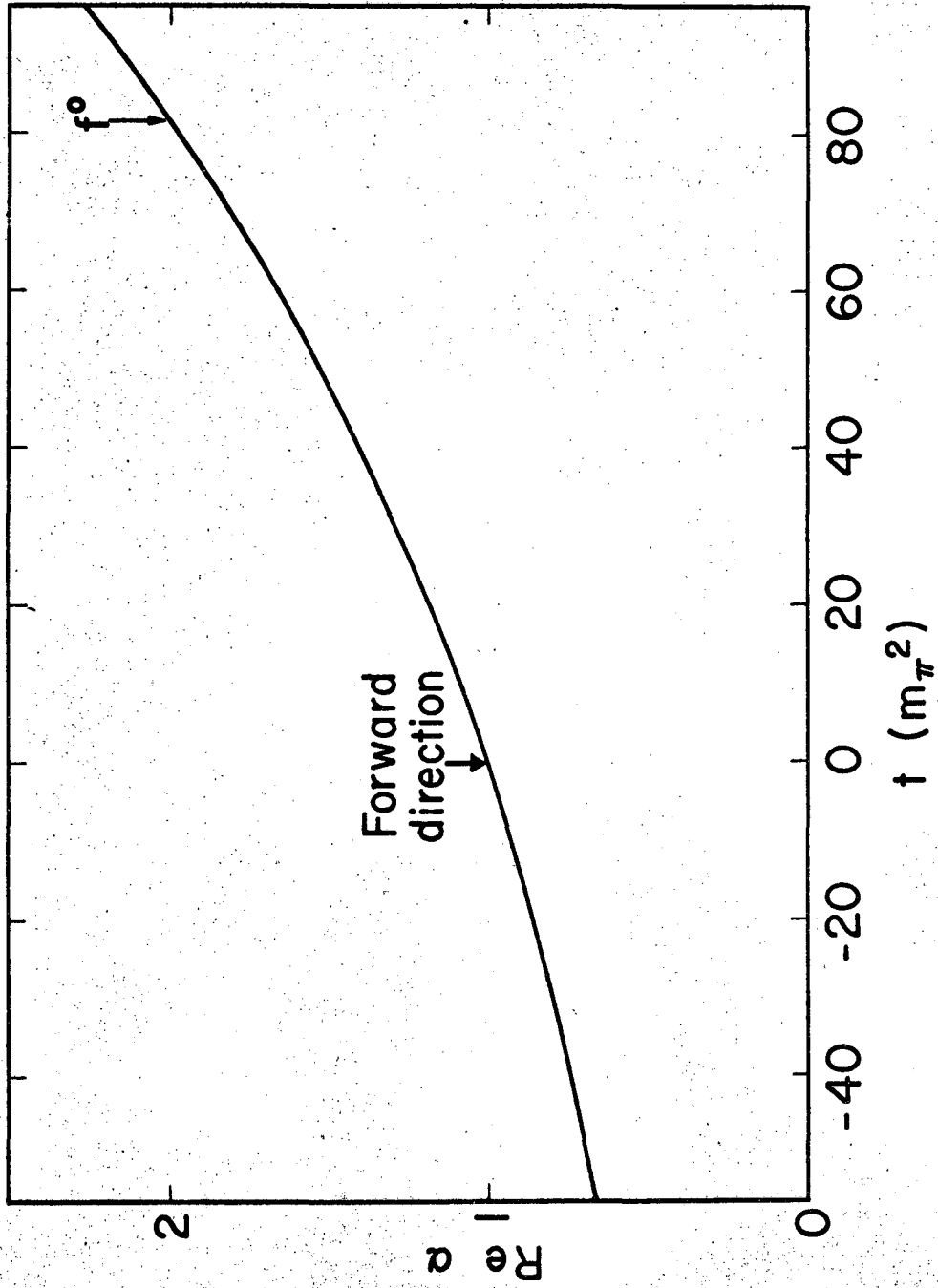


Fig. 1.

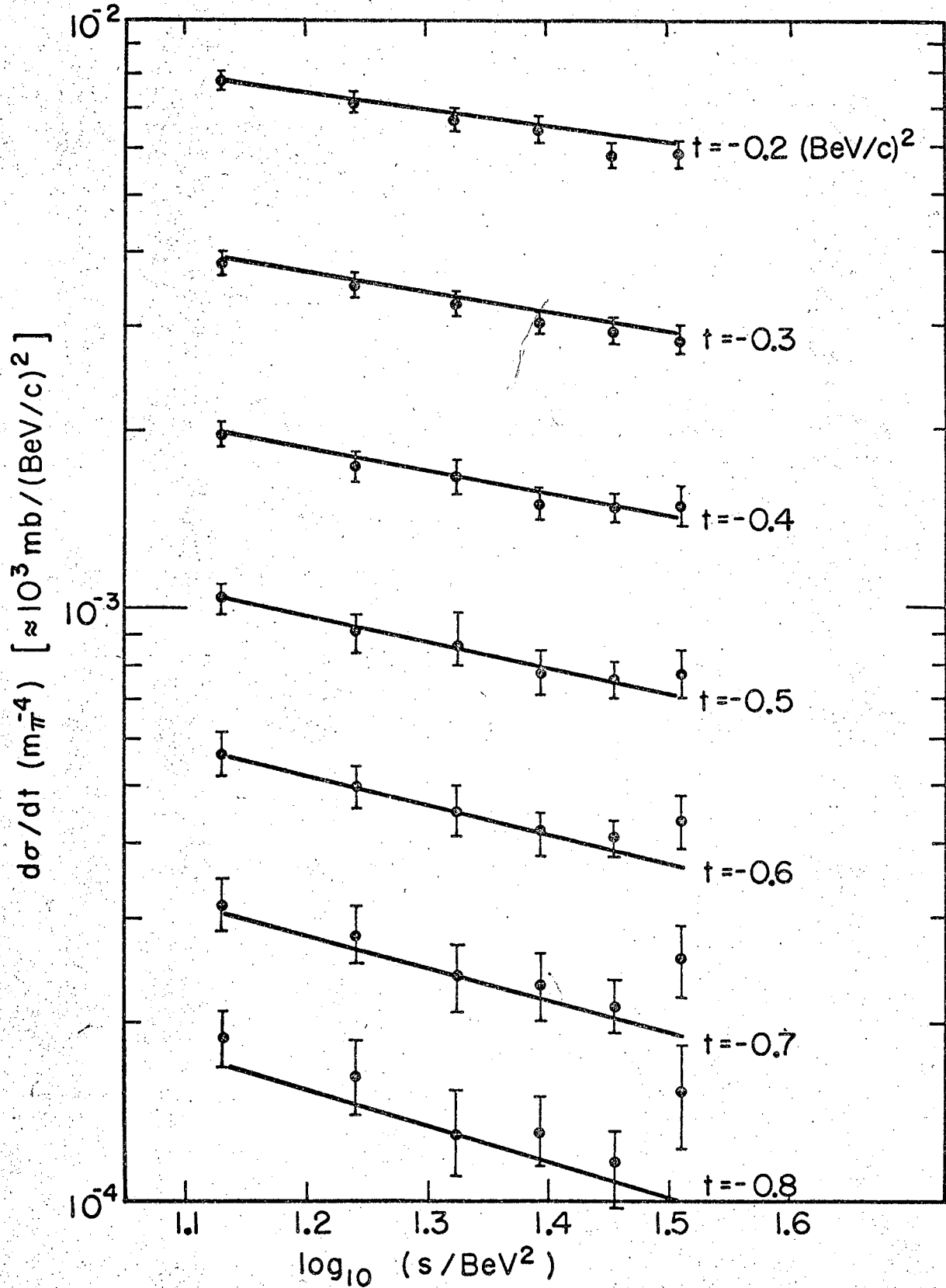
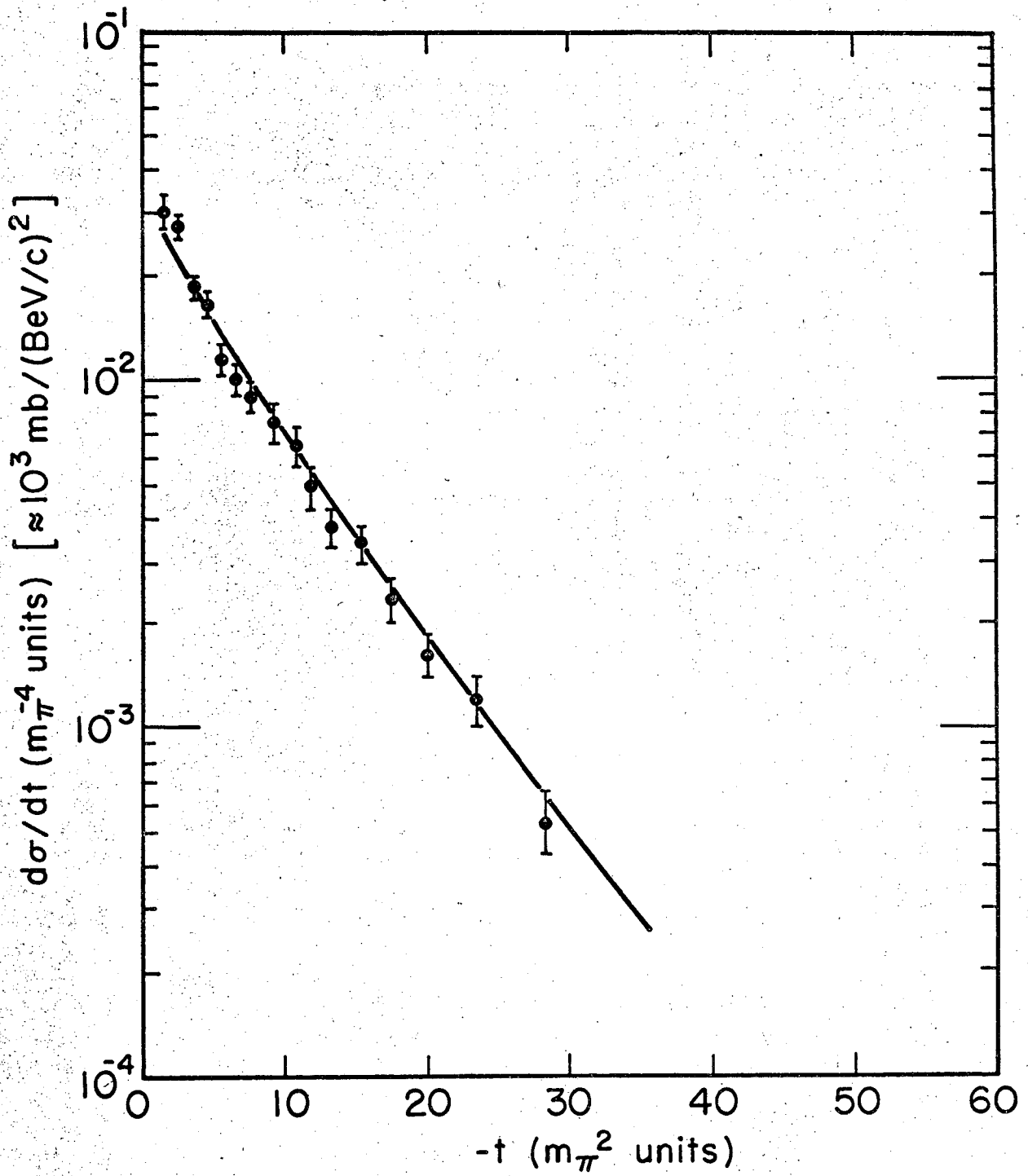


Fig. 2.



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Fig. 3.

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