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**Berkeley, California**

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PREDICTIONS FOR  $\pi^- + p \rightarrow n$  FROM REGGE POLES AND  $SU_3$

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May 6, 1965

PREDICTIONS FOR  $\pi^- + p \rightarrow n^0 + n$  FROM REGGE POLES AND  $SU_3^*$ Roger J. N. Phillips<sup>†</sup>Lawrence Radiation Laboratory  
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## ABSTRACT

It is assumed that the charge exchange process  $\pi^- + p \rightarrow n^0 + n$  is dominated by the R Regge pole. A prediction for the cross section is then made, by taking Regge pole parameters from a previous analysis of  $\pi N$  and  $KN$  scattering, and by invoking  $SU_3$  symmetry.

There has recently been renewed interest in Regge pole models for high-energy scattering, especially for processes in which the number of poles in the crossed channel is severely limited by selection rules.<sup>1-4</sup> One such process is  $\pi^- + p \rightarrow \pi^0 + n$  charge exchange, where of the known Regge poles only  $\rho$  can contribute; another is  $K^- + p \rightarrow \bar{K}^0 + n$ , where only  $\rho$  and  $R$  contribute;<sup>5</sup> another is  $\pi^- + p \rightarrow \eta^0 + n$ , where only  $R$  contributes. Explicit models have already been constructed for the first two processes, and the  $\rho$  couplings are found to obey the expected  $SU_3$  symmetry.<sup>4</sup> The present note is to show that, by requiring  $SU_3$  symmetry for the  $R$  couplings, we get a prediction for the third process,  $\pi^- + p \rightarrow \eta^0 + n$ .

The models of reference 4 fit available  $\pi N$  data, using the  $P$ ,  $P'$ , and  $\rho$  Regge poles.  $KN$  and  $\bar{K}N$  data are then fitted, with  $P$ ,  $P'$ , and  $\rho$  contributions restricted by the factorization principle, and with the  $\omega$  and  $R$  poles added. The best solutions are found to obey  $SU_3$  symmetry for the  $P$  and  $\rho$  couplings. The  $\pi N$  and  $\bar{K}N$  charge-exchange data are particularly valuable in determining the  $\rho$  and  $R$  contributions, although the other data are also important in this.

Now,  $R$  is supposed to belong to an  $SU_3$  octet. The coupling between this particular octet and the octet containing  $\pi$ ,  $\eta$ ,  $K$ , and  $\bar{K}$  must be pure D-type, to preserve charge-conjugation invariance.<sup>6</sup> Hence, at high energies, at which the  $\eta$ - $\pi$  mass difference has negligible effect the amplitude for  $\pi^- + p \rightarrow \eta^0 + n$  is essentially the same--apart from an extra factor  $2/\sqrt{3}$ --as the  $R$  contribution to  $K^- + p \rightarrow \bar{K}^0 + n$ .

Consider therefore the  $R$  contributions to  $K^- + p \rightarrow \bar{K}^0 + n$ , as given in reference 4. There is a helicity-flip amplitude  $B$  and a

nonflip amplitude  $A$  (following reference 7, where, however, the notation is  $B$  and  $A'$ ). The differential cross section is

$$\frac{d\sigma}{dt} = \frac{1}{\pi s} \left( \frac{m_N}{4K} \right)^2 \left\{ \left( 1 - \frac{t}{4m_N^2} \right) |A|^2 + \frac{t}{4m_N^2} \left( s - \frac{s+p^2}{1 - \frac{t}{4m_N^2}} \right) |B|^2 \right\}, \quad (1)$$

where  $s$  and  $t$  are the invariant squares of energy and momentum transfer,  $p$  is the kaon lab momentum,  $K$  is the c.m. momentum, and  $m_N$  is the nucleon mass. The  $R$  contributions to  $A$  and  $B$  are written<sup>4</sup>

$$A_R = -2C_0 \exp(C_1 t) \alpha(2\alpha + 1) \frac{1 + \exp(-i\pi\alpha)}{\sin \pi\alpha} \left( \frac{E}{E_0} \right)^\alpha, \quad (2)$$

$$B_R = -2D_0 \exp(D_1 t) \alpha \frac{1 + \exp(-i\pi\alpha)}{\sin \pi\alpha} \left( \frac{E}{E_0} \right)^{\alpha-1}. \quad (3)$$

Here  $\alpha$  is the  $R$  trajectory,  $E = (p^2 + m_K^2)^{1/2}$  is the total kaon lab energy, and  $E_0$  is an arbitrary scale parameter, taken for convenience to be 1 GeV;  $C_0$ ,  $C_1$ ,  $D_0$ , and  $D_1$  are coefficients which parameterize the residue functions. The trajectory  $\alpha$  is given the form

$$\alpha(t) = -1 + [1 + \alpha(0)]^2 / [1 + \alpha(0) - \alpha'(0)t], \quad (4)$$

where  $\alpha(0)$  and  $\alpha'(0)$  are the value and slope at  $t = 0$ . In reference 4, the various parameters for  $R$ , as well as other relevant Regge poles, are determined by least-squares fitting to  $\pi N$ ,  $KN$ , and  $\bar{K}N$  data.

Using these R Regge pole parameters, a prediction for  $\pi^- + p \rightarrow n^0 + n$  can immediately be made. Table I shows a set of parameters, representing a slightly modified<sup>8</sup> form of Solution I of reference 4; Fig. 1 shows the predicted cross section at 10 GeV/c.

Let us consider how much uncertainty attaches to this prediction.

(i) SU<sub>3</sub> Symmetry

If SU<sub>3</sub> symmetry fails for the R couplings by 10%, we may expect a 20% effect in the predicted cross section. This symmetry also enters indirectly, via the analysis of pole parameters. The numbers in Table I are a best fit if exact SU<sub>3</sub> symmetry is assumed for the  $\rho\bar{K}K$  and  $\rho\pi\pi$  couplings: if this relation is relaxed by 10%, the best fits predict cross sections that differ by less than 20% on the whole.

(ii) The Helicity-Flip Amplitude

The cross-section predictions are rather sensitive to this amplitude. If it increases by 20%, the dip at  $t = 0$  becomes more pronounced; if it decreases by 20% the dip vanishes. Our solution happens to lie in a rather sensitive intermediate region.

(iii) Model Dependence

The four different models in reference 4 all give similar predictions for the R contribution, which suggests there is not much uncertainty in this respect.



(iv) Energy-dependence

The cross section  $d\sigma/dt$  behaves like  $E^{2\alpha-2}$ ; hence for our model it behaves like  $E^{-1.4}$  at  $t = 0$  and like  $E^{-2}$  near  $t = -0.5(\text{GeV}/c)^2$ . There is some uncertainty in  $\alpha$ , and hence in the energy dependence, but this should scarcely affect our prediction at 10 GeV/c, which is effectively normalized to the nearby  $K^-p$  charge-exchange measurements at 9.5 GeV/c.

We understand that experimental data on  $\pi^- + p \rightarrow n^0 + n$  have recently been taken and are being analyzed, by the MIT/Pisa and Saclay/Orsay groups.<sup>9</sup> The results should throw much light, both on the R-Regge pole model and on the applicability of  $SU_3$  symmetry in this context.

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FOOTNOTES AND REFERENCES

- \* Work done under auspices of the U.S. Atomic Energy Commission.
- † Permanent address: A.E.R.E. Harwell, Berks., England.
- ‡ Visiting scientist.
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- 7. V. Singh, Phys. Rev. 129, 1889 (1963).
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- 9. Janos Kirz (Lawrence Radiation Laboratory) R. K. Logan (Massachusetts Institute of Technology), and P. Sonderegger (Centre d'Etudes Nucleaires, Saclay), private communications.

Table I. Parameters for the R-Regge pole in K-N scattering

$\alpha(0)$	$\alpha'(0)$ [(GeV/c) <sup>-2</sup> ]	$C_0$ (mb x GeV)	$C_1$ (GeV <sup>-2</sup> )	$D_0$ (mb)	$D_1$ (GeV <sup>-2</sup> )
0.32	0.80	3.1	0.4	-29	2.4

FIGURE CAPTION

Fig. 1. Predicted  $\tau^- + p \rightarrow \eta^0 + n$  cross section at 10 GeV/c.

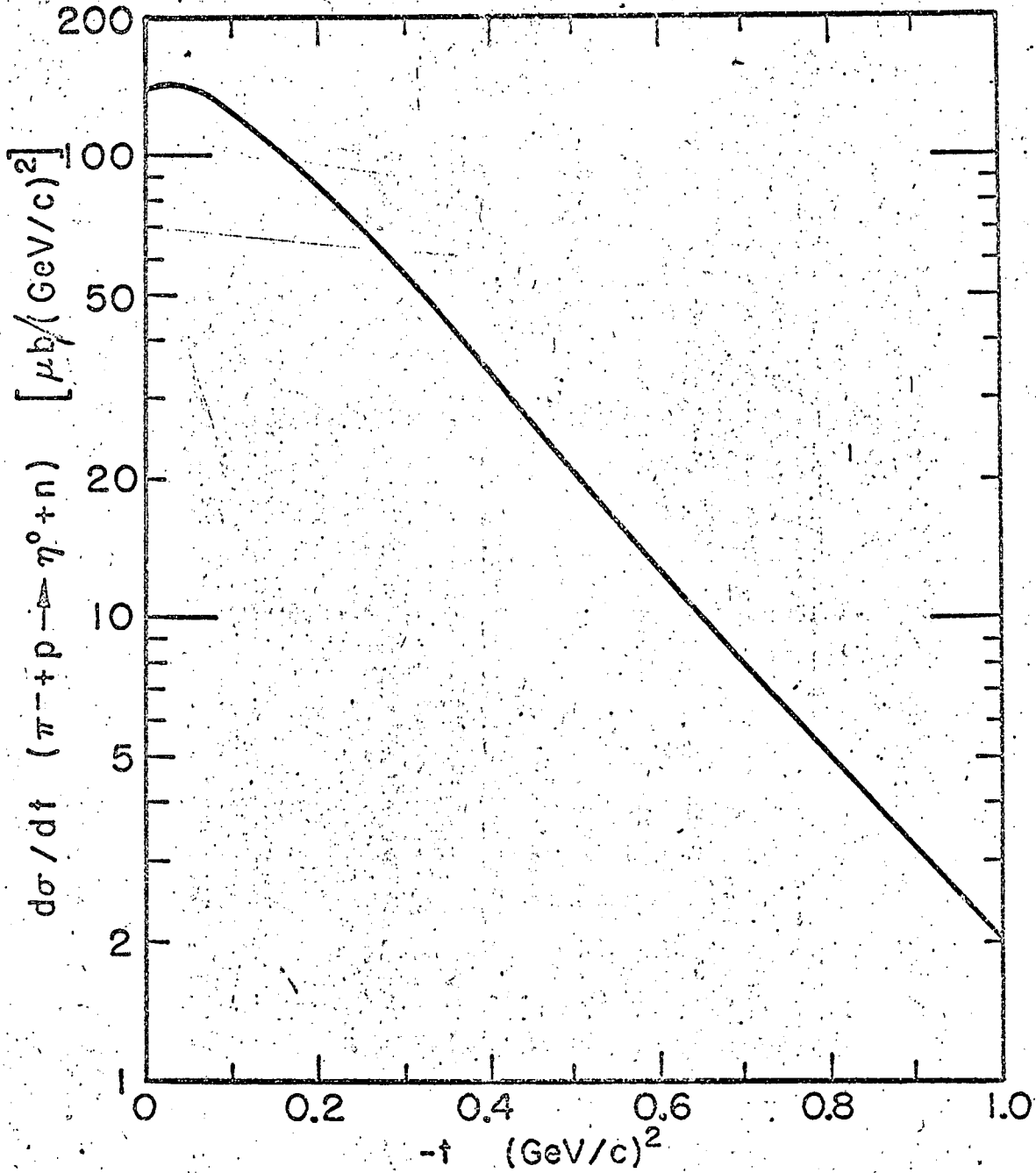


Fig. 1

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