Four Reggeon Couplings in Two Particle Inclusive Data*

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Abstract

Motivated by theoretical studies of Reggeon field theories with direct four Reggeon couplings, we consider the phenomenological implications of such a coupling. In particular, we calculate the contribution to two particle inclusive reactions of a direct four Reggeon coupling, and show that: (a) they are accessible at presently available energy, (b) they give rise to dramatic effects, (c) the data seem to show evidence of these effects, and (d) the coupling appears large.

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Much of the work in Regge theory in the past few years has been of a very formal nature, addressing itself to the question of consistency. Most recently the Reggeon calculus of Gribov has been converted into a field theory.[1] Once Regge theory had been cast in a field theoretic language it was natural to depart from the Regge behavior dictated strictly by fits to data and ask what other trajectories and coupling might be handled with this new technique. One of the most interesting departures is the four Reggeon coupling,[2] and it is the one we will study here. The reasons for our interest are many: (1) In a Reggeon field it is a relevant variable, that is, it can affect the ultra high energy behavior of the theory, or the approach to it. (2) By studying coupled ladder Feynman diagrams, which is after all the basis of Gribov calculus, it has recently been shown that such coupling should be of order one.[3] (3) The four Reggeon coupling is measurable with present accelerators. (4) Its size can be estimated from present data, at ISR.

The inclusive reaction where the four Reggeon coupling will enter is $a+b \to c+b+X$ (Fig.1a) Consider the kinematics of this process.

$$P_a = (m,000) \quad ; \quad P_b = m(\mathrm{ch}Y,00,\mathrm{sh}Y);$$

$$P_c = (\mu_c \mathrm{ch}y_c, \vec{q}_c, \mu_c \mathrm{sh}y_c) \quad ; \quad P_d = (\mu_d \mathrm{ch}y_d, \vec{q}_d, \mu_d \mathrm{sh}y_d).$$

The kinematic region of interest for the four Reggeon coupling is:

$$s \text{ large, } M_1 \text{ large, and } M_2 \text{ large, } (s/M_1^2) \text{ large and } (s/M_2^2) \text{ large,}$$

$$t_1 \text{ small, } t_2 \text{ small,}$$

where

$$s = (P_a + P_b)^2 = m^2 e^Y$$

$$t_1 = (P_a - P_c)^2 = 2m^2\left(1 - \frac{\mu_c}{m} \mathrm{ch}y_c\right)$$

$$t_2 = (P_b - P_d)^2 = 2m^2\left(1 - \frac{\mu_d}{m} \mathrm{ch}(Y-y_d)\right) .$$

$$M_1^2 \cong m^2 e^Y\left(1 - \frac{\mu_d}{m} e^{-(Y-y_d)}\right) = (P_a + P_b - P_d)^2$$

$$M_2^2 \cong m^2 e^Y\left(1 - \frac{\mu_c}{m} e^{-(y_c)}\right) = (P_a + P_b - P_c)^2$$

$$M^2 \cong m^2 e^Y\left(1 - \frac{\mu_d}{m} e^{-(Y-y_d)}\right)\left(1 - \frac{\mu_c}{m} e^{-y_c}\right) = (P_a + P_b - P_c - P_d)^2 \ .$$

For convenience, we also use

$$x_1 = \frac{\mu_d}{m} e^{-(Y-y_d)}$$

$$x_2 = \frac{\mu_c}{m} e^{-y_c} .$$

Now consider the diagram for the two-particle inclusive process in the limit given above. The diagram is shown in Fig.1b. Summing over intermediate states X implies a discontinuity of a two Reggeon elastic amplitude.[4] One contribution to the two Reggeon elastic amplitude is a direct four Reggeon coupling as shown in Fig.1b. The Regge behavior of this diagram is given by

$$\frac{d\sigma}{dP_c dP_d} = \frac{1}{s}\left(\frac{s}{M_1^2}\right)^{2\alpha(t_2)}\left(\frac{s}{M_2^2}\right)^{2\alpha(t_1)}\left[y(t_1 t_2)\right]\beta_{ac}^2(t_1)\beta_{bd}^2(t_2)$$

where $dP = d^3P/E$, and where $y(t_1 t_2)$ is the discontinuity of the four Reggeon coupling.[6] We have only considered one trajectory here but the extension to many is straightforward. The kinematic region for this diagram is clearly within experimental reach. This four Reggeon diagram is very likely the principal contribution in this region of small M^2. However, it will also remain for large M^2, since the four Reggeon coupling is a basic coupling in the theory. In the large M^2 region there is another diagram which contributes; the double triple Regge diagram (DTR) (Fig.1c.). This diagram contributes

$$\frac{d\sigma}{dP_b dP_d} = \frac{1}{s}\left(\frac{s}{M_1^2}\right)^{2\alpha(t_2)}\left(\frac{s}{M_2^2}\right)^{2\alpha(t_1)}(M^2)^{\alpha(o)}\, g(t_1)g(t_2)\beta_{ac}^2(t_1)\beta_{bd}^2(t_2).$$

Of course, for large M^2 this diagram will dominate the four Reggeon diagram because of the $(M^2)^{\alpha(o)}$ dependence. Now at low M^2 this diagram probably provides a background in some dual sense to the four Reggeon diagram.

The correlation function R is defined by

$$R = \frac{\sigma \frac{d\sigma}{dP_c dP_d}}{\frac{d\sigma}{dP_c}\frac{d\sigma}{dP_d}} - 1 .$$

In this kinematic region $d\sigma/dP_c$ is given by the triple Regge form,

$$\frac{d\sigma}{dP_c} = \frac{1}{s}\left(\frac{s}{M_2^2}\right)^{2\alpha(t_1)}\left(M_2^2\right)^{\alpha(o)}\beta_{ac}^2(t_1)\bar{\beta}(o)g(t_1)$$

and $\sigma = \bar{\beta}(0)^2$. Thus the contribution to R from both the DTR diagram and the four Reggeon diagram is

$$R = \frac{y(t_1 t_2)}{g(t_1)g(t_2)}\,\frac{1}{M^2} = \frac{y(t_1 t_2)}{g(t_1)g(t_2)}\,\frac{1}{s(1-x_1)(1-x_2)} .$$

The value of the DTR diagram is one, and it cancels the one in the expression for R.

In Fig.2a we plot R, calculated with $P_\perp = 0$, $y/g^2 = 10$ and $s = 540\ (\mathrm{GeV})^2$, $\Delta y_1 = Y - y_d$ and $\Delta y_2 = y_c$. We see that the contours rise as we move into the lower right hand corner of the y_c y_d plot. In Figs. 2a and 2b we show the Pisa-Stony Brook two particle correlation data[5] displayed as countours; the rising of contour in the lower right hand corner is clear at both energies. In addition we see that the structure is deeper in the corner at higher energy, as is predicted by the 1/s in the expression for R. Furthermore, as we move away from the corner in both graphs we see that there is a relatively large area where R is approximately zero. This again is in agreement with our expression for R, since as we move away from the corner M^2 increases rapidly and R drops to zero (the contribution of the DTR diagram).

The fixed multiplicity contour plots, Figs. 2c and 2d, also show the structure we have described. In fact, in the Pisa-Stony Brook data the effect seems stronger here. We should note that the data is a function of $\eta = -\log \tan \theta/2$, which necessarily introduces some uncertainties. In order to estimate the size of the four Reggeon coupling we look at a slice of data crossing the contours which is shown in Fig.2b.

While the data is somewhat eratic, we would estimate that for $\sqrt{s} = 23$; $R \approx .3$ $y_c \approx .5$ and $Y\text{-}y_d \approx .2$. If we take $\langle P_\perp \rangle$ to be about .35 GeV., then $\mu/m \cong 1.15$ and $x_1 = .7$ and $x_2 = .94$ and we find that

$$\frac{y(t_1 t_2)}{g(t_1)g(t_2)} \cong 9.5.$$

While this is at best an order of magnitude result, two things appear clear: (a) The data show a peaking in the corner indicating a four Reggeon coupling. (b) The four Reggeon coupling is at least as big as the triple Regge coupling, and probably larger.

References and Footnote

1. H. D. I. Abarbanel and J. Bronzan, Phys. Rev. D 9, 2397 (1974), and references therein.

2. H. D. I. Abarbanel and J. Bronzan, CALT-68-428; W. A. Bardeen, J. W. Dash, S. S. Pinsky, V. Rabl, FNAL preprint in preparation.

3. B. M. McCoy, T. T. Wu, FNAL - 74/88-THY.

4. A. Mueller, Phys. Rev. D 2, 2963 (1970).

5. G. Bellettini, Stony Brook Conference on High Energy Collisions, 1973, p. 9.

6. In principle $y(t_1t_2)$ can depend on M^2; however, we have no reason to expect this dependence to be large.

Figure Captions

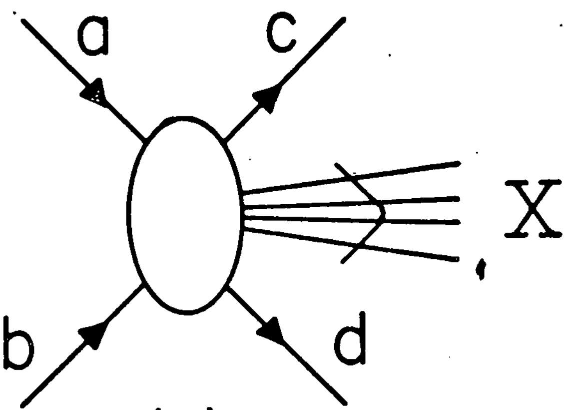
Figure 1. (a) Two particle inclusive process $a+b \rightarrow c+d+X$. (b) The four Reggeon coupling contribution to the two particle inclusive process. (c) The double triple Regge contribution to the two particle inclusive process.

Figure 2. (a) Calculated value of $R(y_c, y_d)$ with the ratio of the four Reggeon coupling to the triple Regge coupling squared equal to 10. (b) Pisa-Stony Brook two particle correlation for $\sqrt{s} = 23$ and 62 GeV with $\eta_1 = -4.42$ and η_2 in the range 4 to 5.

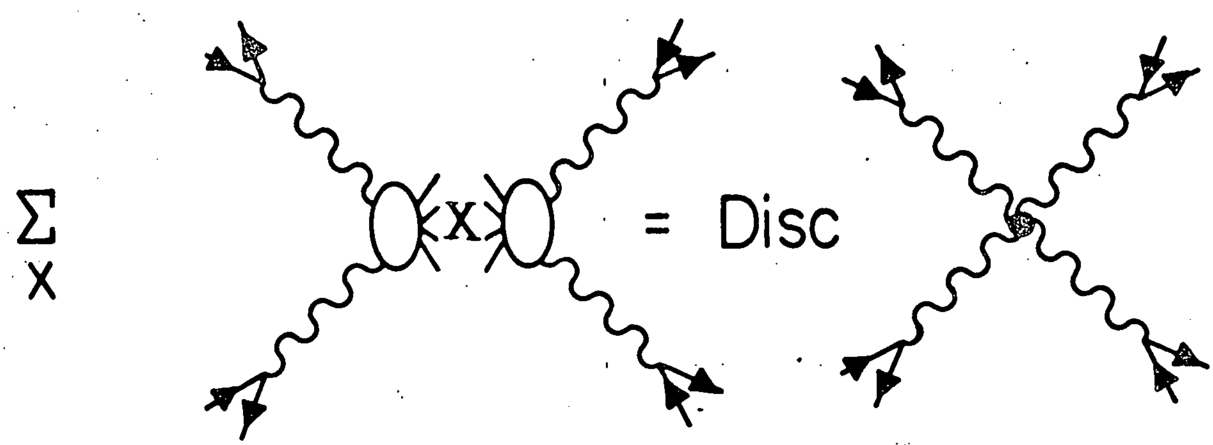
Figure 3. Pisa-Stony Brook two particle correlation contours of constant $R(\eta_1 \eta_2)$. (a) $\sqrt{s} = 23$ GeV. (b) $\sqrt{s} = 62$ GeV.

(c) fixed multiplicity $\sqrt{s} = 23$ GeV.

(d) fixed multiplicity $\sqrt{s} = 62$ GeV.



(a)



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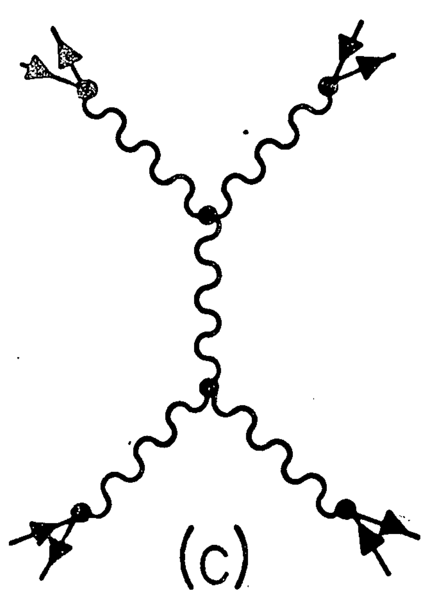
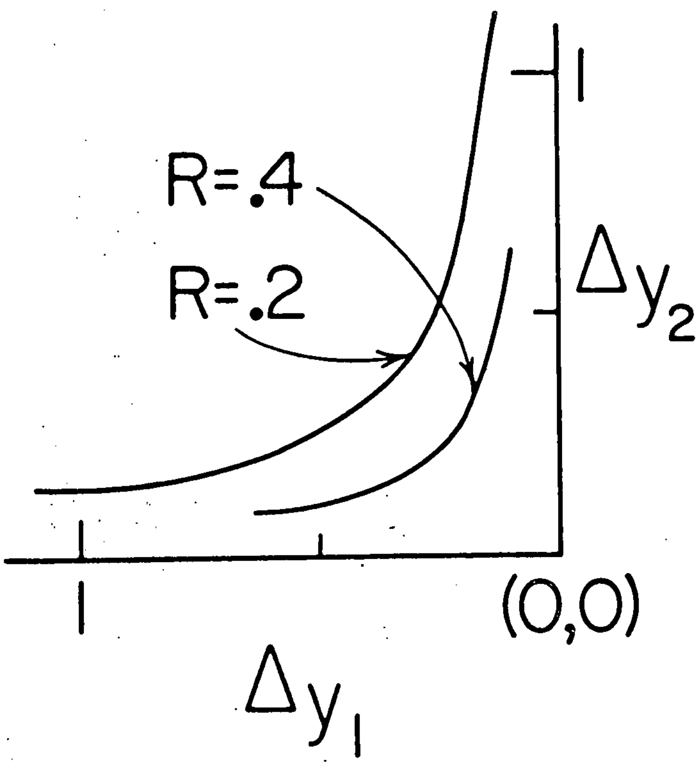
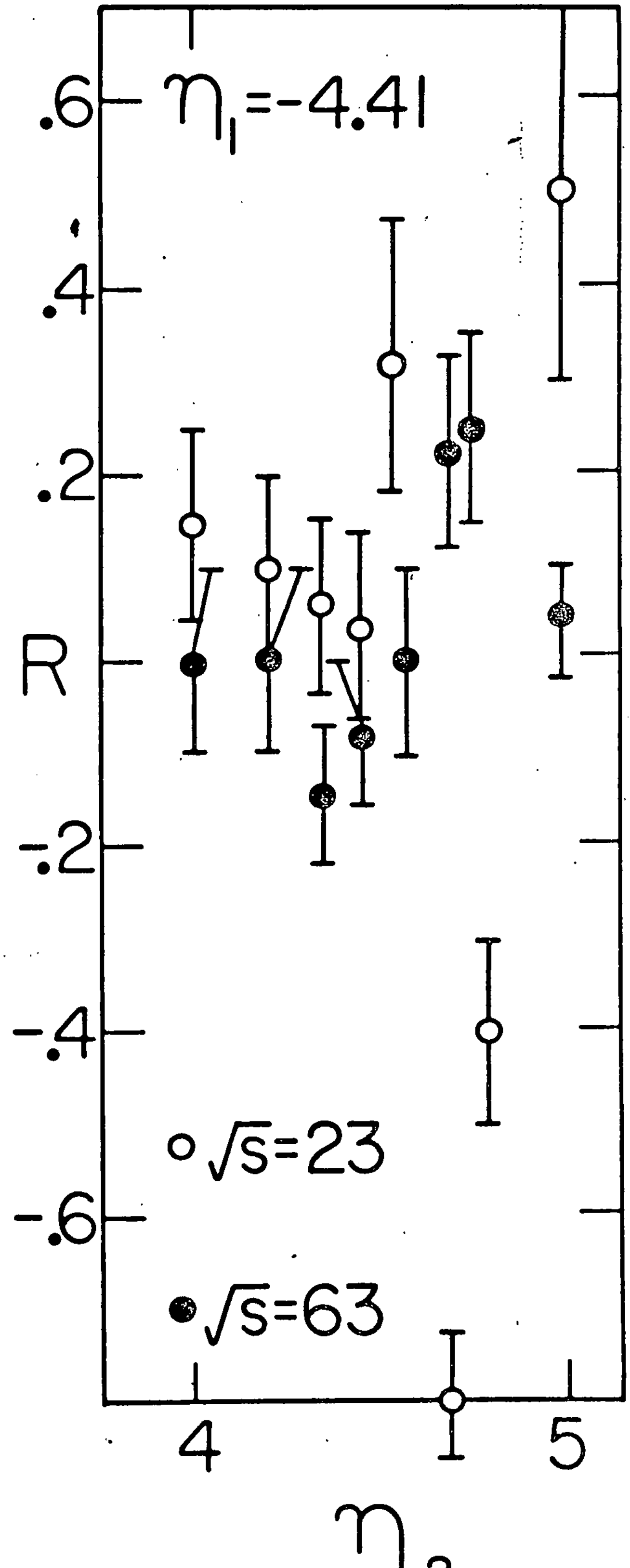


(c)



(a)



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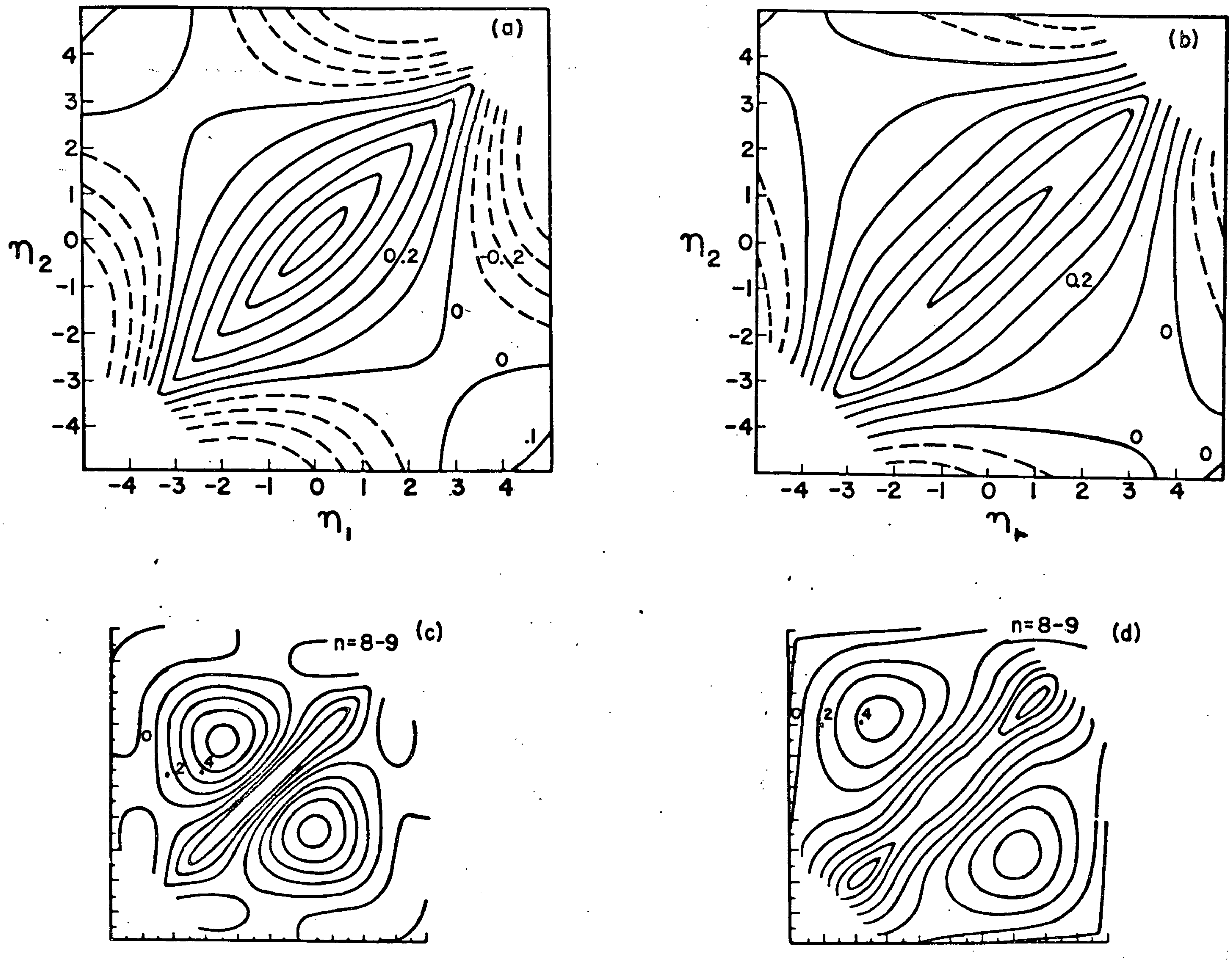
(a)
(b)
(c)
(d)
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n=8-9
0.2
-0.2
0
.1
.2
.4
η2
η1
4
3
2
1
0
-1
-2
-3
-4