Regge Analysis of Correlations in the
Central Plateau*

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ABSTRACT

Recent experimental data on correlations in the central plateau are shown to be consistent with a simple Mueller Regge analysis. The charge dependence of these correlations is in remarkable agreement with both that expected from an extension of the Regge analysis of single particle production and from charge conservation sum rules. Predictions for the charge dependence of $K-\pi$ correlations are made.

Recently experiments at ISR (1,2) and NAL (3) have been conducted to measure correlations between particles produced in the central plateau. Surprisingly, these experiments have confirmed (1) the simple Mueller Regge analysis (4) predictions of short range correlations dependent only upon the rapidity difference Δy between two particles in the central region and with a correlation length L of 2., as we would expect for an intercept difference, $\alpha_P - \alpha_R$, between Pomeron and secondary Reggeon intercepts, of .5. This agreement is surprising in that the form

$$r_{ab} \exp \{-\Delta y/2.\} \quad (1)$$

describes the correlation between particles a and b not only for large Δy (of order 3.)₀ but also for small Δy , and in fact even for $\Delta y = 0$. This would be analogous, in terms of the more familiar total cross sections, to a successful description of the total cross section by secondary Regge trajectories over the s or center of mass squared energy range of .2 to 5. (BeV/c)². Thus this agreement places strong bounds on the contribution of lower Regge trajectories. When combined with the known consistency (5) of the measured approach to the central plateau with the $s^{-1/4}$ prediction of secondary Regge dominance, it suggests that a detailed Regge analysis, with P, ρ , and f trajectories, should be attempted.

Assuming simple factorizing Regge poles, the Regge analysis prediction for the dimensionless correlation between particles a and b produced in the central plateau in the reaction $c+d \rightarrow a+b$ anything is

$$C_{ab}(y_a, y_b) = \frac{1}{\sigma_{\infty}^{cd}} \left\{ \frac{d^2 \sigma}{dy_a dy_b} - \frac{1}{\sigma_{\infty}^{cd}} \frac{d\sigma}{dy_a} \frac{d\sigma}{dy_b} \right\} \quad (2)$$

$$= \sum_i \bar{\gamma}_{pi}^a \bar{\gamma}_{pi}^b \tau_i \exp \left\{ -(\alpha_p - \alpha_i) |y_a - y_b| \right\} + O(s^{-\frac{1}{4}}) \quad (3)$$

Here σ_{∞}^{cd} is the asymptotic total cross section; $\bar{\gamma}_{ij}^b$ is the double Regge coupling for a produced particle b with Reggeons i and j exchanged and $\tau_i = \pm 1$ is the signature of the Reggeon i. Note that the asymptotic prediction is independent of the incident particles c and d and that the approach to this limit is, as with single particle production, expected to be as $s^{-\frac{1}{4}}$. For either a or b a pion, G parity restricts the sum i to the ρ and f trajectories. We neglect lower trajectories with similar quantum numbers as is indicated by C's dependence on $\Delta y = |y_a - y_b|$ (1). If we define

$$r_{ab} = \lim_{s \rightarrow \infty} C_{ab}(0,0) \quad (4)$$

then

$$r_{\pi^+, \pi^+} = r_{\pi^-, \pi^-} = \left(\gamma_{pf}^{\pi^2} \right)^2 - \left(\gamma_{p\rho}^{\pi} \right)^2 \quad (5)$$

$$r_{\pi^+, \pi^-} = \left(\gamma_{pf}^{\pi} \right)^2 + \left(\gamma_{p\rho}^{\pi} \right)^2 \quad (6)$$

$$\frac{1}{2} r_{ch, \pi^0} = r_{\pi^+, \pi^0} = r_{\pi^-, \pi^0} = \left(\gamma_{pf}^{\pi} \right)^2 \quad (7)$$

$$r_{ch, ch} = 4 \left(\gamma_{pf}^{\pi} \right)^2 \quad (8)$$

where we have introduced the subscript ch to denote the sum over both π^+ 's and π^- 's. Note that the Regge analysis immediately predicts

$$r_{ch,ch} > 0 \quad (9)$$

and

$$r_{\pi^+, \pi^-} > \frac{1}{4} r_{ch,ch} > r_{\pi^-, \pi^-} \quad (10)$$

These inequalities would hold if possible lower trajectories were included.

The experimental data, with which we wish to compare eqs. (5) through (10), are the quoted values for

$$\tilde{C}_{ab}(\eta_a, \eta_b) = \sigma_I \frac{d^2\sigma}{d\eta_a d\eta_b} \left\{ \frac{d\sigma}{d\eta_a} \frac{d\sigma}{d\eta_b} \right\}^{-1} \quad (11)$$

and

$$r_{ab} = \tilde{C}_{ab}(0,0) \quad (12)$$

Here σ_I is the inelastic pp cross section and η_a is the "laboratory rapidity" of particle a. This comparison involves the following assumptions:

(a) All produced particles are pions. This is required since these experiments identify only the charges of the produced particles.

(b) Knowledge of $\frac{d\sigma}{dy}_a$. We have taken the values of these directly from the fits of reference 5.

(c) The neglect of the non-asymptotic terms in eq.(3). An estimate of the possible error here can be made if we note that the dimensionless single pion production cross section, $\sigma_{\infty}^{-1} \frac{d\sigma}{dy}$, is predicted in ref.5 to rise by 30% from NAL energies to its asymptotic limit.

(d) Knowledge of the ratio $\sigma_{\infty}^{pp} / \sigma_I^{pp}$ which we have set equal to 1.2.

Note that this calculation is independent of any problem with the differences between the true and laboratory rapidities y and η . In Table I we list the measured $\tilde{r}_{ab}$ and the calculated r_{ab} for the data of ref.2.

The inequalities, eqs.(9) and (10), can be immediately verified from Table I, as can the approximate validity of the relation

$$r_{ch,ch} = 2 r_{ch,\pi^0} \quad (13)$$

These values for r imply

$$\left(\gamma_{Pf}^{\pi} \right)^2 = .28 \quad \left(\gamma_{P\rho}^{\pi} \right)^2 = .10 \quad (14)$$

The errors in the above determination can be estimated by noting that if correction (d) above had not been applied the results would be .18 and .08 respectively.

A strong check on the consistency of the above analysis can be made by comparing these values for γ_{Pf}^{π} and $\gamma_{P\rho}^{\pi}$ to those needed to describe the $s^{-\frac{1}{4}}$ approach to asymptopia for single pion production

in the central region. For γ_{pf}^π this check is ambiguous, as the single pion spectra for different incident particles are inconsistent with a unique value; however, eq.14 is in reasonable agreement with the value $\gamma_{pf}^\pi = -.4$ required for pp scattering. For $\gamma_{p\rho}^\pi$, eq.(14) is in good agreement with the value of $\gamma_{p\rho}^\pi = .31$ used in ref.6. Here, in addition to these spectra,... there is the charge conservation sum rule (6) assuming ρ dominance:

$$\left(\gamma_{p\rho}^\pi \right)^2 = \frac{\alpha_p - \alpha_\rho}{.4} \gamma_{pp}^\pi \quad (15)$$

which, for $\gamma_{pp}^\pi = .75$ (5) and $\alpha_\rho = .5$, is in excellent agreement with eq.(14).

The tests of Regge theory and dominance embodied in eqs.(14) and (15) can be alternatively viewed as a measurement of an effective intercept difference $\delta_\rho = \alpha_p - \alpha_\rho$ averaged over all trajectories with the quantum numbers of the ρ . Letting λ denote the sum over isovector, even G-parity trajectories, eqs.(5) and (6) generalize to

$$\frac{1}{2} (r_{\pi^+, \pi^-} - r_{\pi^-, \pi^-}) = \sum_\lambda (\gamma_{B\lambda}^\pi)^2 \quad (16)$$

and eq.(15) to

$$\sum_\lambda \frac{(\gamma_{p\lambda}^\pi)^2}{\alpha_p - \alpha_\lambda} = \frac{1}{4} \gamma_{pp}^\pi \quad (17)$$

Then

$$\delta_\rho = 2(\gamma_{PP}^\pi)^{-1} (r_{\pi^+, \pi^-} - r_{\pi^-, \pi^-}) \quad (18)$$

defines an experimentally measurable effective intercept difference, which, for the values used above, is .53, thus confirming ρ dominance of the sum over λ . A similar analysis can be performed for the isoscalar, even G parity exchanges. Here, due to the absence of a sum rule analogous to eq. (17), the integrated charged particle correlation, $f_2^{\text{ch, ch}}$, must be used:

$$f_2^{\text{ch, ch}} = 8 \sum_{\sigma} \frac{\gamma_{P\sigma}^2}{\alpha_P - \alpha_\sigma} \ln s + \text{constant} \quad (19)$$

where σ runs over all isoscalar, even G-parity trajectories.

Similar charge conservation sum rules, extended to allow for strange particle production, (7), imply:

$$\gamma_{P\rho}^K / \gamma_{P\rho}^\pi = .5 \quad \gamma_{PP}^K / \gamma_{PP}^\pi \quad (20)$$

Accepting the value of .1 for the asymptotic K^-/π^- ratio in the central region we then predict

$$r_{K^-, \pi^+} - r_{K^-, \pi^-} = 2 \gamma_{P\rho}^\pi \gamma_{P\rho}^K = .010 \quad (21)$$

Here the smaller size is mostly due to the suppressed K production.

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References

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TABLE I

Reported values for $\tilde{r}_{ab}$ compared to the calculated r_{ab} for ref. 2.

ref.	ab	$\tilde{r}_{ab}$	r_{ab}
3	+, -	.80	.35
3	ch, ch	.60	1.11
3	-, -	.35	.15
2	ch, π^0	.62	.57