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Journal
Physics Letters B, 44(3)

ISSN
0370-2693

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Publication Date
1973-04-01

DOI
10.1016/0370-2693(73)90226-8

INTERNAL STRUCTURE FOR THE PIONIZATION SPECTRUM

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Received 13 March 1973

Peripheral models for the inclusive $q_\perp^2$ spectrum in the central plateau region are considered in a unified treatment. The highest energy ISR spectrum for $p + p \to \pi + X$ is fit for all $q_\perp$.

By consideration of a general dynamical structure we have developed a unified treatment for the pionization spectrum which includes a variety of theoretical models [1–4]. These models have been proposed to account for different regions of the pionization data [5] which has been measured for $0.2 < q_\perp < 9.0$ GeV/c.

Peripheral theories for multiparticle production which describe the central plateau region must have a structure as indicated in fig. 1 where particle c is peripherally attached to the other produced particles. We assume that the result of squaring the amplitude and performing the inclusive sums [2, 6] produces the Regge behavior $s_1^{\alpha_{\mathrm{p}}(0)}\, s_2^{\alpha_{\mathrm{p}}(0)}$. By integrating over p_1 and p_2 we obtain the single particle spectrum or the M^2 absorptive part of the forward 3–3 amplitude. The result gives the Mueller double Regge structure, fig. 2.

To get damping in $q_\perp^2$, some form of internal damping, $\beta_{\mathrm{r}}(t_{\mathrm{r}})$ and $\beta_l(t_l)$, must be included. The various models for the pionization spectrum [1–4] differ mainly in the form for the internal damping as well as in the theoretical nature of the exchanged object.

Previously, a closed form for the single-particle spectrum has been calculated in the $s \to \infty$ limit for exponential damping in t_{r} and t_l [2]. Any other internal damping $\beta(t)$ which is non-singular and vanishes for $t \to -\infty$ can be represented as a superposition of these exponentials, $\exp(\Omega_{\mathrm{r}} t_{\mathrm{r}})$, using weight functions $B_{\mathrm{r}}(\Omega_{\mathrm{r}})$ and $B_l(\Omega_l)$:

$$\beta^2(t_{\mathrm{r}}) = \int_0^\infty B(\Omega_{\mathrm{r}}) \exp(2\Omega_{\mathrm{r}} t_{\mathrm{r}})\, \mathrm{d}\Omega_{\mathrm{r}}\,.$$

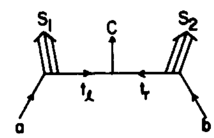

Fig. 1. Peripheral production amplitude for the central plateau region of the single particle spectrum.

Defining

$$\Omega \equiv 2\Omega_l \Omega_{\mathrm{r}}/(\Omega_l + \Omega_{\mathrm{r}})\,, \qquad \eta \equiv q_\perp^2 + m^2\,.$$

We then find [6] that the pionization spectrum can be represented as:

$$E\, \mathrm{d}\sigma/\mathrm{d}^3 q = \int_0^\infty \mathrm{d}\Omega\, C(\Omega) \exp(-\eta\Omega)\, \Psi(2, 1, \eta\Omega)$$

where $\Psi(2, 1, \eta\Omega)$ is a confluent hypergeometric function and $C(\Omega)$ is given by:

$$C(\Omega) = \int_0^\infty \mathrm{d}\Omega_l \times \int_0^\infty \mathrm{d}\Omega_{\mathrm{r}}\, \delta\!\left(\Omega - \frac{2\Omega_{\mathrm{r}}\Omega_l}{\Omega_{\mathrm{r}} + \Omega_l}\right) \frac{B_l(\Omega_l) B_{\mathrm{r}}(\Omega_{\mathrm{r}})}{(\Omega_{\mathrm{r}} + \Omega_l)^3} \exp(\Omega m^2)\,.$$

Our result for $E\, \mathrm{d}\sigma/\mathrm{d}^3 q$ agrees with the general

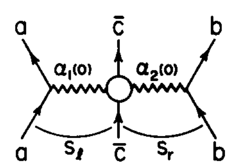

Fig. 2. Double Regge behavior in forward $a + b + \bar{c}$ resulting from Regge behavior in inclusive sums.

* Supported in part by the National Science Foundation Technical Report #73–14.

analytic representation found by Zakrewski [7] on the basis of analyticity arguments and Regge behavior alone. This is to be expected since the approach we have used (from ref. [2]) possesses the correct analyticity consistent with double Regge behavior and has no simultaneous discontinuities in the overlapping variables s_l and s_r (Steinmann relations). Our general structure provides the physical meaning of the arbitrary weight function, $C(\Omega)$, in terms of the internal damping functions $\beta(t)$.

In a fortcoming publication [6] a variety of models which generate behaviors $\exp(-aq_\perp^2)$, $\exp(-bq_\perp)$ and $q_\perp^{-n}$ are calcualted. One of these is a simple AFS model with pion propagators giving the internal damping, but which gives too slow a falloff in $q_\perp$. We have also formulated the single particle spectrum from the peripheral production of a resonance which then decays to two pions [8]. The large η behavior of the decay pions has the same power law or exponential behavior as the produced resonances.

Here we present one form of internal damping which successfully fits all the pionization data from $q_\perp = 0.2$ to 9.0 GeV/c. Parametrizing a power law internal damping with an effective mass μ, we let

$$\beta_l(t) = \beta_r(t) = (t-\mu^2)^{-2}$$

which results [6] in:

$$C(\Omega)\,\alpha \exp(m^2\Omega)\,\Omega^3 \exp(-2\mu^2\Omega)\,W_{1/2,1/2}(4\mu^2\Omega)$$

where $W_{1/2,1/2}$ is a Whittaker function [9]. The integral over Ω has asymptotic behavior:

$$E\,\mathrm{d}\sigma/\mathrm{d}^3q \xrightarrow[\eta\to\infty]{} 1/\eta^4 \text{ or } 1/p_\perp^8$$

in agreement with the large $q_\perp$ data [5] and with the results obtained from parton models [4]. In fig. 3, the fit to all the highest energy ISR pionization data for pp $\to \pi + X$ is shown using an effective mass $\mu = 0.485$ GeV. The fit covers nine orders of magnitude in cross section.

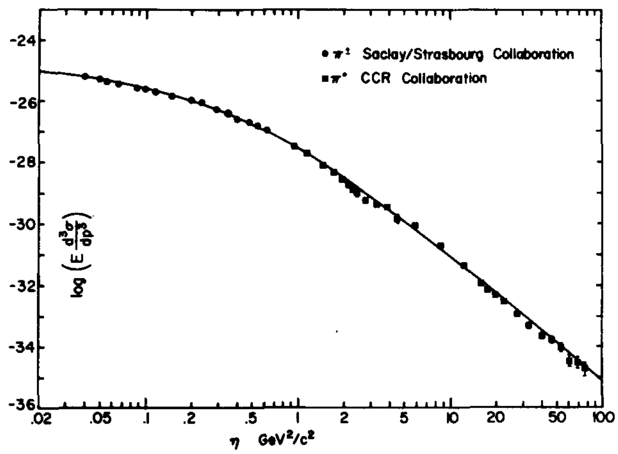

Fig. 3. Fit to the $\sqrt{s} = 53$ GeV/c ISR data for $p + p \to \pi + X$ for power law internal damping.

References

[1] A. Amati, S. Fubini and A. Stanghellini, Nuovo Cim. 26 (1962) 896.
[2] D. Silverman and C-I. Tan, Nuovo Cim. 2A (1971) 489; D. Silverman, U.C. Irvine preprint 73-5.
[3] L. Caneschi and A. Pignotti, Phys. Rev. Lett. 22 (1969) 1219.
[4] S.M. Berman, J.D. Bjorken and J.B. Kogut, Phys. Rev. D4 (1971) 3388;
J.F. Gunion, S.J. Brodsku and R. Blankenbecler, Phys. Lett. 39B (1972) 649; SLAC preprint SLAC-PUB-1053; Phys. Lett. 42B (1972) 461.
[5] R. Cool et al., (CERN/Columbia/Rockefeller Collaboration);
M. Banner et al., (Saclay/Strasbourg Collaboration); 16th Int. Conf. on High energy physics, Batavia, Ill., Sept. 1972.
[6] M. Barnett and D. Silverman, U.C. Irvine preprint.
[7] W.J. Zakrzewski, Phys. Lett. 40B (1972) 645.
[8] M. Barnett and D. Silverman, U.C. Irvine preprint.
[9] I.S. Gradshteyn and I.M. Ryzhik, Table of integrals, series and products (Academic Press, New York, 1965) pp. 1059–1063.