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A CRITICAL DISCUSSION OF THE EXTRACTION OF THE ρ^0 - PARAMETER AT HIGH ENERGY HADRON SCATTERING

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ABSTRACT

We propose a new and general method for the extraction of the semi-theoretical ρ-parameter from the raw dN/dt data. By using this method it is shown that the exponential form of the hadron amplitude in the diffraction peak at high energy is doubtful and that the value $\rho = 0.135 \pm 0.015$, extracted from the very precise UA4/2 dN/dt data at $\sqrt{s} = 541$ GeV, is probably wrong.

The exponential form of the hadron scattering amplitude in the diffraction peak works so well at low energies that one has a tendency to forget that it is, in fact, a *theoretical* input, without any deep justification. In particular, the semi-theoretical parameter ρ, containing the crucial information on the *phase* of the hadron amplitude is, in principle, very sensitive to the theoretical input, if new phenomena have to occur at high energies. Such new phenomena are, by definition, excluded by the exponential form, currently used by experimentalists in analyzing the dN/dt data. One gets in such a way somewhat fictious ρ-values as a result of this obvious vicious circle from logical point of view : one could infer, from a more or less good χ^2-fit of the dN/dt data, that there are no new effects just because the theoretical input excludes them.

In order to avoid such vicious circle we propose a new and general method for the extraction of the ρ-parameter from the *raw* (dN/dt) data, which has to be used in conjonction with the familiar (and useful) χ^2 - fits.

We will compute $\rho(t)$ as a function of t :

$$\rho(t_i) = \mathrm{Re}\, F_N(t_i) \,/\, \mathrm{Im}\, F_N(t_i) \tag{1}$$

where t_i are the t-values where dN/dt are measured, Im $F_N(t_i)$ are given by a theoretical model (e.g. exponential) and Re $F_N(t_i)$ are *computed* from (1) and (2) :

$$d\sigma/dt = (n/N)(dN/dt) = (1/16\pi)\, |F_c + F_N|^2 \,. \tag{2}$$

In eq. (2), F_c and F_N are the Coulomb (nuclear) amplitudes (the factor 1/s included), n is a normalisation factor and N is a *fixed* number, which will be choosed at a value convenient for drawing figures at a given energy. Namely :

$$\mathrm{Re}F_N(t_i) = -\,\mathrm{Re}F_c(t_i) \pm \sqrt{16\pi(n/N)[dN/dt(t_i)] - [\mathrm{Im}F_c(t_i) + \mathrm{Im}F_N(t_i)]^2} \,. \tag{3}$$

The quantities under the square root in eq. (3) - denoted by $A(t_i)$ - have to be positive for every t_i if the *relativistic invariance* (leading to eq. (2)) is to be respected :

$$A(t_i) > 0 \text{ , for any } t_i \,. \tag{4}$$

Let us also define the quantities :

$$\begin{aligned} C(t_i) &\equiv A(t_i) - [\mathrm{Re}F_c(t_i)]^2 \\ &= \mathrm{Re}F_N(t_i)\, [\mathrm{Re}F_N(t_i) + 2\mathrm{Re}F_c(t_i)], \end{aligned} \tag{5}$$

which are useful if $\rho(t)$ has a given sign in the experimental t-range. E.g., if

$$\rho(t_i) > 0 \text{ , for any } t_i \tag{6}$$

and

$$\mathrm{Re}F_c(t_i) > 0, \text{ for any } t_i \text{ ,} \tag{7}$$

we deduce from eq. (5) the constraint

$$C(t_i) > 0, \text{ for any } t_i \text{ .} \tag{8}$$

Let us illustrate the power of the constraints (4) and (8) by considering the $dN/dt(t_i)$ UA4/2 data at $\sqrt{s}$ = 541 GeV and the UA4/2 exponential fit[1)] leading to the "best" values :

$$\rho = \text{const} = 0.135 \tag{9}$$

and

$$\sigma_T = 62.2 \text{ mb} \text{ , } b = \text{const} = 15.5 \text{ GeV}^{-2} \text{ .} \tag{10}$$

In the UA4/2 case i = 1,... 99. The conditions (6) and (7) are automatically respected and therefore we have to use the constraint (8), in addition to the constraint (4). It has to be noted that we need only the UA4/2 σ_T and b values (10), the quantities $\rho(t_i)$ being *computed* in our method. In order to draw figures it is convenient to choose 1/N = 0.092, corresponding to n near 1 (namely, n = 1 for the best UA4/2 fit[1)], so this value can be easily visualised).

The power of the positivity constraint (4), resulting from relativistic invariance, is illustrated in Fig. 1, where we draw the number of the experimental $dN/dt(t_i)$ values violating this constraint in terms of the hidden parameter n. In Fig. 1, c is denoting the central value of $dN/dt(t_i)$ at $t = t_i$ and u(d) - the highest (smallest) experimental value of $dN/dt(t_i)$ at $t = t_i$. The vertical line at n = 1 in Fig. 1 corresponds to the "best" values (9)-(10). It is seen from Fig. 1 that these values are doubtful : higher values n > 1 ($n \approx 1.05$) are prefered by the positivity condition (4). It is important to note that this remark is far from having only an academical interest : *an increase of 1% of n leads to an increase of 0.01 in* ρ ! Keeping in mind the experience we have with dispersion relations and theoretical models, such kind of increase is far from being trivial. In fact, such a tendency of ρ-values higher *than 0.135* is confirmed by the detailed study of different models fitting the UA4/2 dN/dt data[2)].

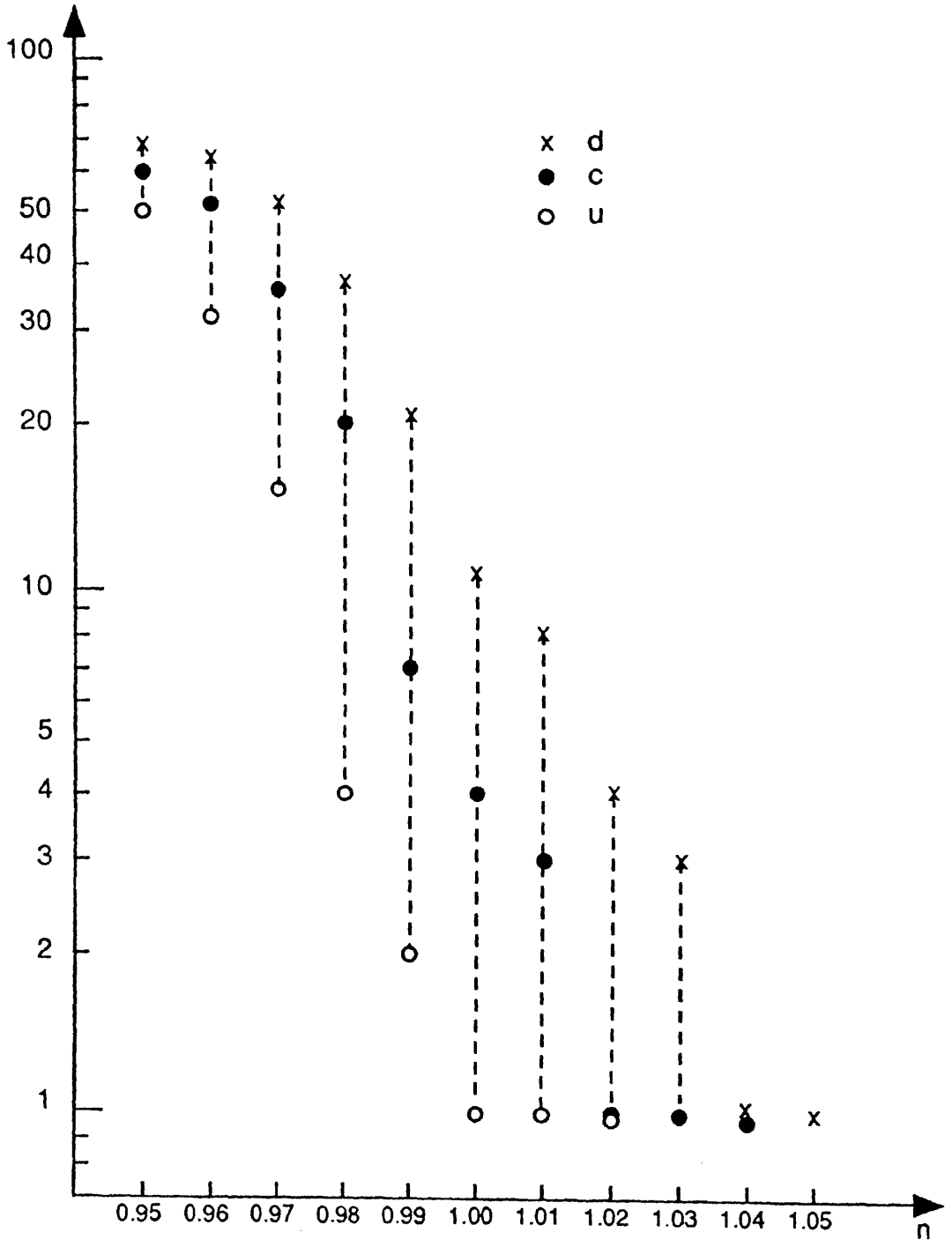

Fig. 1 . The number of $dN/dt(t_i)$ UA4/2 data violating the positivity constraint (4) (on vertical axis) in terms of the normalisation parameter n. The vertical broken lines are drawn just to guide the eye at fixed n.

The less general condition (8) leads to the same conclusions. The corresponding figure is practically identical to Fig. 1 (simply, the situation is even worse for $n < 1$).

The consideration of the χ^2-fit errors in eqs. (9)-(10) do not alter our general conclusions. *The exponential form of the hadron scattering amplitude in the diffraction peak at high energy is doubtful. Moreover, there is a strong* (ρ, σ_T, n) *correlation generally favoring values of* ρ *higher than* $\rho = 0.135$.

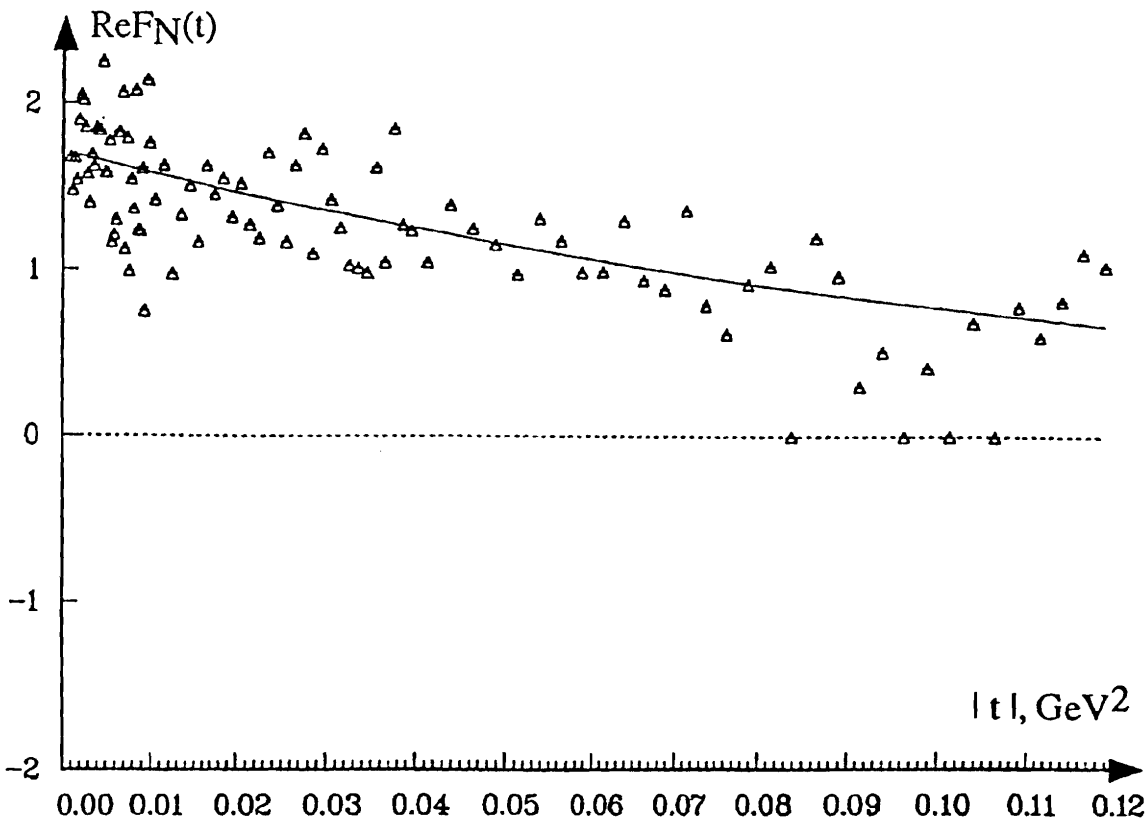

Fig. 2. Comparison between $ReF_N(t_i)$ computed from eq. 4 (Δ) and the real part given by the exponential UA4/2 model[1] (solid line). The triangles on the 0-axis correspond to the violation of the positivity constraint (4) (here only the central points are indicated).

These conclusions are reinforced by the direct comparison between $ReF(t_i)$ as computed from eq. (3) (triangles in Fig. 2) and the corresponding real parts as given by the exponential UA4/2 model[1] (the solid line in Fig. 2). It is clearly seen from Fig. 2 that there is too much structure in ReF(t) as when compared with the

smooth exponential form. If this structure corresponds or not to *oscillations* is an open problem and will be studied elsewhere[3]. The possibility of such oscillations was also mentioned by T.T. Wu at this conference[4].

References

1) UA4/2 Collab., C. Augier et al., Phys. Lett. B316 (1993) 448 ; B315 (1993) 503.
2) P. Gauron, talk at this conference.
3) P. Gauron, B. Nicolescu and O. Selyugin, work in progress.
4) T.T. Wu, talk at this conference.