IS THE INELASTIC CHARGE-EXCHANGE CONTRIBUTION CONSTANT AT THE LARGE x AND SUPERHIGH ENERGIES ?

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Abstract. The mechanism explaining the decrease of the inelastic charge-exchange contribution at $x \simeq I$ and $s \to \infty$ has been proposed.

I. Introduction.

It is customary to think that inelastic charge-exchange (CEX) processes with pions $\pi^{\pm} h \to \pi^{0} X$ and with nucleons do not decrease with energy growth and along with the processes of the diffraction dissociation (DD), play an important role in production of leading hadrons and γ-quanta. Sometimes it is motivated by lack of obvious energy-dependence of the RRP-term of the triple Regge expansion of the cross-section for the inclusive reactions[I]. At the same time already from Regge-pole parametrisation of the total cross-section, σ_{ab}^{tot}, one can see that the contribution of the reggeon exchange ($R \neq P$) into σ_{ab}^{tot} as a whole decreases with the growth of total energy $\sqrt{s}$, as $I/\sqrt{s}$, providing the rapprochement of the total cross-sections of the particle and antiparticle interactions[2].

In this report we shall point out concrete factors, which are responsible for CEX-contribution decrease at $s \to \infty$ and work near the kinematical limit of the reaction $pp \to nX^{++}$.

2. Points of departure and formulas.

When discussing the relative contribution of the CEX and DD near the kinematics limit two factors should be taken into account: the limited value of the mass of the particle beam ($M_X^2 \neq const \cdot s$ at $s \to \infty$) and the dual meaning of the M-dependence in the formula of the triple Regge expansion:

$$s\frac{d^2\sigma}{dt\,dM_X^2} = \sum_{ijk} G_{ijk}(t)\, s^{\alpha_i(t)+\alpha_j(t)-1} (M_X^2)^{\alpha_k(0)-\alpha_i(0)-\alpha_j(0)}$$

- the terms with $\alpha_k(0)=I$ give the background of the resonances in resonance mass region and the terms with $\alpha_k(0)=1/2$ give the resonances itself as a certain function of M.

Near the kinematical limit one may represent the ijk-term contribution as

$$\frac{d\sigma^{ijk}}{dM_X^2} = \int_{-\infty}^{t_{max}} dt \left(\frac{d^2\sigma}{dt\,dM_X^2}\right) = f_{ijk}(s, M_X^2)\cdot T(s, M_X^2),$$

-where $T(s,M_X^2)$- is the result of integration of the t-dependence of the process:

$$T(s,M_X^2) = \int_{-\infty}^{t_{max}} dt\, G_{ijk}(t) \left(\frac{s}{M_X^2}\right)^{(\alpha_i' + \alpha_j')t} \simeq \frac{\lambda_1}{B_{ij1}} + \frac{\lambda_2}{B_{ij2}}$$

Here the two component form of the $G_{ijk}(t)$

$$G_{ijk}(t)=\sum_{\ell}^{2}\lambda_{\ell}e^{\mu_{\ell}t}, \qquad B_{ij\ell}=\mu_{\ell}+(\alpha_i'+\alpha_j')\ln\left(\frac{s}{M_x^2}\right)$$

and small value of $t_{max}\simeq\frac{m_p^2}{x}(1-x)^2$ in the region of $x\simeq I$ ($I-x\equiv M_x^2/s$) are used. $T(s,M_x^2)$ is a weak (logarithmic) dependence of its arguments, and the behaviour of the triple Regge contributions is determined mainly by the F_{ijk}-function, the explicit form of which is given in the table for different sets of ijk. (Only two trajectories are considered: $\alpha_R(t)=1/2+t$ and $\alpha_P(t)=1+\varepsilon+\gamma t$ $(\varepsilon=0.06,\ \gamma=0.3)$).

To elucidate differences in CEX- and DD-behaviour near the kinematical limit we have considered the integral cross-section of the PPR- and RRR-contributions as a function of the upper limit for the integration over the mass.

Numerical estimations of the CEX- and DD- contributions have been carried out using the parametrisation of $G_{ijk}(t)$ from [3].

3. Results of the calculation and discussion.

If only the terms with k=P and $i\neq j$ are taken into account, then the relative contribution of the CEX does not depend on the energy of the interaction and decreases with the growth of x:

$$R\equiv\sigma^{ex}_{RRP}/\sigma^{DD}_{PPP}\cong(1-x)^{1+2\varepsilon}$$

Then, the DD-contribution predominates over the CEX one, beginning with $x\simeq 0.85$ (fig.I).

However, it is impossible to extrapolate this dependence into the point x = I, without falling into contradiction with the experimental data. Near the kinematical limit of the inclusive reaction $hh\to hX$ the relation σ^{ex}/σ^{DD} is determined by cross-section of the relevant quasi-two-particle reactions:

$$\frac{\sigma^{ex}}{\sigma^{DD}}\xrightarrow[M_x^2\to M_{Res}^2]{}\frac{\sigma(pp\to n\Delta^{++})}{\sigma(pp\to pN^*)}=Const(M^2)\frac{s^{2[\alpha_R(0)-1]}}{s^{2[\alpha_P(0)-1]}}\equiv c\cdot s^{-(1+2\varepsilon)}.$$

Such behaviour is described by the terms with k = R and i = j or, alternativelys, by the two-reggeon- approximation, which effectively takes into account the resonance and background contributions into the reggeon-hadron amplitude.

The ratio of the cross-section σ^{ex} to σ^{DD}, which is expressed via the contributions of the RRR- and PPR-terms, behaves as $\sim I/s$ with the limited upper value of the mass M

$$r\equiv\sigma^{ex}_{RRR}(s,M)/\sigma^{DD}_{PPR}(s,M)\cong Const(M^2)\cdot s^{-(1+2\varepsilon)}$$

However, on energy dependence, the relevant behaviour of the x-distributions (terms with k = R) does not join with the regime of the terms, which are dual to background (k = P) (fig.I.). To guarantee the smooth transition between them one should take into account the interference terms with $i\neq j$ and different k. The s- and M-dependences of the crossed terms at a given k obey the rule

$$\text{inter}=\sqrt{\text{diff}\cdot\text{nondif}}$$

The accounting of the interference leads to that, the energy-dependent form of the x-disrtibutions (the contribution of the terms with $k=R$) extends from the vicinity $x \simeq I$ to the broader region of $x<I$*). At large M_X, when only terms with $k=P$ become essential, the cross-section will depend only on x, and the scaling regime is reconstructed (if $\varepsilon=0$). The effect of the scaling reconstruction at large M is known[4].We accent our attention on the factors, which break it down at small M_X.

4. Conclusions.

When prognosing the x-distribution behaviour in superhigh energy region ($s\to\infty$) it is impossible to neglect non-scaling terms with $k=R$, extrapolating the scaling behaviour of the terms with $k=P$ to the point $x=I$.

In the resonance and nearresonance mass region the diffractive and non-diffractive processes, $hh\to hX$, behave in essentially different way. The energy dependence of resonance diffractive production is approximately the same as for elastic scattering processes (one can expect even a weak growth ($\varepsilon\neq 0$!) of the contribution of the reaction $pp\to pN_i^*$), whereas the non-diffractive channel decreases as $\sim I/s$, involving the neighbour regions of the x-spectrum, owing to the action of the interference terms (with $i\neq j$), which decrease only as $\sim I/\sqrt{s}$ **).

All this taken together should lead to the gradual decrease of the CEX-contribution with energy growth at $s\to\infty$, which begins close to $x=I$ and extends then to the region of the smaller x.

The study of the CEX processes in the experiments with cosmic ray particles is usually carried out at not too high energies ($E_0 \lesssim I0^{12}-I0^{14}$ eV) and in the limited region of moderately large x ($x\lesssim 0,7$ - $0,8$). Apparently, this is not enough to detect the considered effect. It is interesting to observe the CEX-behaviour directly in the region of the utmost large x.

References

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*) It is even better to consider together the three - and one-reggeon formulas for one-particle distribution in the incident hadron fragmentation region.

**) By parameterisation of the $G_{ijk}(t)$ the role of the interference terms is not always taken into account , as e. g. in[3].

Table

	ijk	$d\sigma^{ijk}/dM^2$ $\varepsilon = 0$	$d\sigma^{ijk}/dM^2$ $\varepsilon \neq 0$
diff	PPP	I/M^2	$s^{2\varepsilon}M^{-2(I+\varepsilon)}$
	PPR	I/M^3	$s^{2\varepsilon}M^{-(3+4\varepsilon)}$
nond	RRP	I/s	$s^{-I}M^{2\varepsilon}$
	RRR	$I/(sM)$	$s^{-I}M^{-I}$
inter	PRP	$I/\sqrt{sM^2}$	$s^{\varepsilon}/\sqrt{sM^2}$
	PRR	$I/(M^2\sqrt{s})$	$s^{\varepsilon}/\sqrt{s}\cdot M^{-2(I+\varepsilon)}$

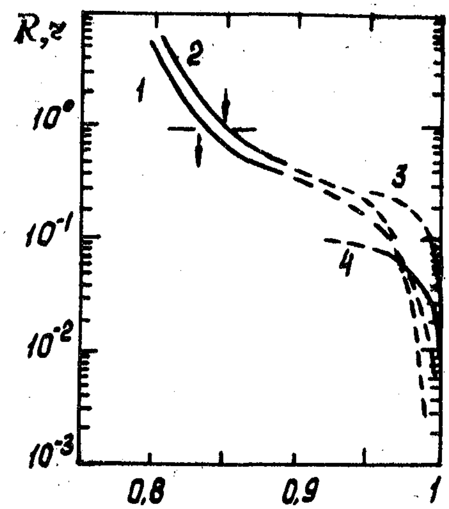

Fig. I.

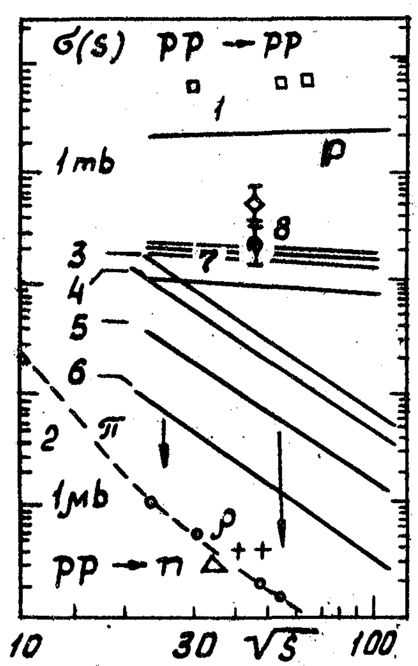

Fig.2.

Figure captions.

Fig.I. The behaviour of the x- distribution. I-the ratio R for $3I \leq \sqrt{s} \leq I00$ at $\varepsilon = 0.06$; 2- the same at $\varepsilon = 0$; 3,4- the ratio r for $\sqrt{s} = 3I$ and I00, respectively.

Fig.2. The behaviour of the contributions with k = P and i = j near the kinematical limit ($M_x \to m_p$). I-the elastic scattering cross-section and the contribution of the P-pole (without accounting for the interference with f- and ω - poles); 2- the cross-section of the reaction $pp \to n\Delta^{++}$ (π- and ρ-regimes) from [6]; 3 - 6 — $\sigma^{RRR}(s, M_x^2)$ for M =I0; 7.I; 3.2: and I.4, respectively; 7-σ^{PPR}(s,M) for the same values of M ; 8 - the contribution of the reaction $pp \to pN_i^*$ from [7].