HEAVY QUARK PRODUCTION IN SOFT HADRON COLLISIONS AT SUPERHIGH ENERGIES

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The process of heavy quark production in soft hadron-hadron collisions goes through two stages: generation of $Q\bar{Q}$-pair and subsequent interaction of these quarks with soft gluons. The generation of the $Q\bar{Q}$-pair is a hard subprocess. However the interaction of the produced heavy quarks with soft gluons is actually a strong one, it is in some way analogous to the strong interaction of the light quarks in soft production processes. This interaction changes the production cross sections $\sigma(\bar{Q}/Q)$. This effect is especially important at superhigh energies (strong-interaction shadowing).

The two-stage structure of the heavy quark production suggests a possibility of two different approaches to these processes:

1. Calculation of the hard $Q\bar{Q}$-pair production in the framework of the perturbative QCD and subsequent model estimation of the soft interactions of these quarks with gluons.

2. Description of the production of heavy quarks using the methods of the strong interaction

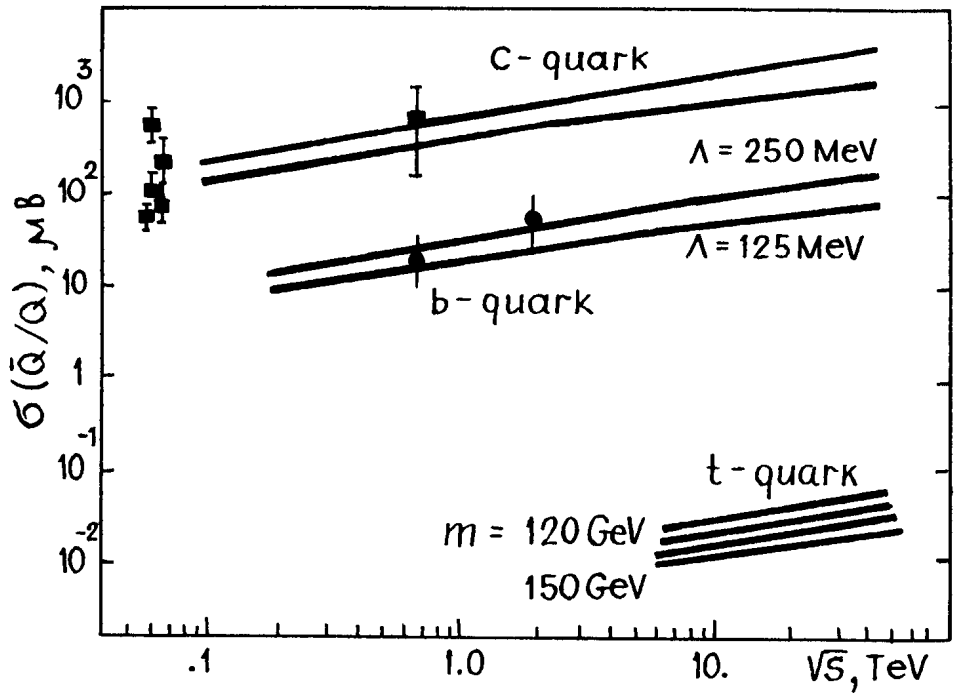

Fig. Cross sections $\sigma(pp \to \bar{Q}/Q + X)$ with Λ= 125 *MeV* and 250 *MeV* (upper and lower solid curves). Predictions of t-quark production are made for m_t= 120 *GeV* and 150 *GeV*.

phenomenology (Regge pology and resonance-reggeon duality) with the following inclusion of the specific logarithmic factors which are inherent to the hard quark production subprocesses. Such an approach was suggested in ref. [1].

Regge pology and resonance-reggeon duality leads to the following ratios of quark-antiquark pair production probabilities in the central region of hadron-hadron collision [1]

$$u\bar{u} : d\bar{d} : s\bar{s} : Q\bar{Q} = 1 : 1 : \lambda_s : \lambda_Q \qquad (1)$$

where

$$\lambda_s = \frac{m_q^2}{m_s^2}, \quad \lambda_Q = \frac{m_q^2}{m_Q^2(\ln m_Q^2/\Lambda^2)^2}. \qquad (2)$$

Here m_q and m_s are masses of non-strange and strange constituent quarks ($m_q \approx 350\,MeV$, $m_s \approx 520\,MeV$), while Q refers to c-, b- and t-quarks. The suppression parameter $\lambda_s = m_q^2/m_s^2 \approx 0.5$ refers to direct hadron production which forms the hadron spectra at large transverse momenta ($p_\perp^2 \geq 4\,GeV^2/c^2$). At small $p_\perp$ the effective suppression parameter λ_s (soft) is sufficiently less than λ_s. The hadronization of the produced quarks provides us with cascade decays of highly exsited $q\bar{q}$ states and because of this the quenching of the suppression parameter occurs in the region of small $p_\perp$: λ_s (soft) = $= C\lambda_s$ where $C < 1$. The estimates performed in rev. [1] give us $C \approx 0.3$— 0.6. The values of $\lambda_s \approx 0.5$ and λ_s (soft) = $C\lambda_s$ with $C \approx 0.45$ are in a good agreement with data [1]. In order to apply such a type of consideration to the heavy quark production probability one should take into account the momentum dependence of the QCD coupling constant $\alpha_s(m_Q^2)$. It leads to the additional suppression factor $(\ln m_Q^2/\Lambda^2)^{-2}$ in eq.(2), where Λ is the QCD scale parameter, $\Lambda = (100 - 300)\,MeV$.

Eq.(1) shows that

$$\sigma(pp \to \bar{Q}/Q + X) = \frac{\lambda_Q}{2 + \lambda_s}\sigma(pp \to \bar{q}/q + X).$$

At the same time $\sigma(pp \to \bar{q}q + X)$ determines the cross section of the produced charged particles in the central region

$$(< n_{ch} >_{pp} - 2)\,\sigma_{inel}(pp) = \frac{2\,N_{Res}}{3C}\sigma(pp \to \bar{q}q + X).$$

Here the factor 2/3 refers to the charged secondaries while the factor $1/C$ takes into account the cascade surplus of hadrons. The produced particles are low-lying reconances mainly, and the factor $N_{Res} \approx (1.5$— 2.5) gives us an increase of hadrons because of the decay of these reconances. At superhigh energies $\sigma_{inel} \approx 0.8\,\sigma_{tot}$.

The heavy quark production cross sections with $C = 0.45$, $N_{Res} = 2$, $m_c = \frac{1}{2}m(J/\Psi)$, $m_b = \frac{1}{2}m(\Upsilon)$, m_t = =(120—150) GeV and Λ = (125—250) MeV were calculated in ref. [2] and are shown in fig. The present data for $<n_{ch}>_{p\bar{p}}$ and $\sigma_{tot}(p\bar{p})$ allow to obtain the reliable values of $\sigma(pp \to \bar{Q}/Q + X)$ in the region $\sqrt{s} < 5\,TeV$ while the predictions for the region $\sqrt{s} \approx$ (5—50) TeV need the extrapolation of $<n_{ch}>$ and σ_{tot} and therefore they can contain additional uncertainties. The existing data for charm and beauty production are in a good agreement with the calculated cross sections. Let us stress that the values of heavy quark production cross sections are predicted without any unknown parameters: all the parameters which are inherent to the strong interaction phenomenology are buried into the factor $<n_{ch}>\sigma_{inel}$.

References

1. *Anisovich V.V., Huber M.G., Kobrinsky M.N., Metsch B.Ch. // Phys.Rev., 1990. D42. 3045.*
2. *Anisovich V.V. Preprint LNPI-1723. 1991. 8 p.*