HARD SCALES
AND HIGH ENERGY DEPENDENCE

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• It is banal but necessary to say that the study of the collision energy dependence of experimentally measured physical characteristics is one of the main ways to verify (and to invent!) various ideas on mechanisms of particle interactions and on their structure. For instance, the total cross-section behaviour at high energy is believed to reflect some global geometrical characteristics of the collision process, while the average multiplicity signals on the efficiency of transformation of the collision energy into the masses of particles produced in final states.

In so-called hard processes we meet the situation when an additional ("hard") scale (beyond the collision energy) is present. In deeply inelastic scattering the hard scale is associated with virtuality of the exchanged electro-weak bosons (γ, W, Z). In purely hadronic processes the hard scale is provided by high-p_T hadrons or jets, or by masses of heavy quarks produced in the collisions. With these additional scales, what will be the energy evolution of observable quantities (cross-sections, multiplicities, inclusive densities etc.) in comparison with their usual, "no-scale" counterparts?

• Since mid 90s it became clear after the first HERA results that in presence of an additional hard scale the energy dependence of the (virtual) photon-proton total cross-section and that of the exclusive vector meson production changes drastically: the cross-section rise significantly steeper with energy growth [1].

At present (June 1998) no simple and commonly shared explanation has been suggested. To our opinion such a behaviour could be a kind of a transient threshold-like phenomenon, and the steep rise will be smoothly converted into a slow energy dependence characteristic for "no-scale" high-energy processes [2]. Nonetheless by no means we consider the problem closed.

• If we concern highly inelastic, multiple production processes it makes sense to consider first the most simple characteristic of the final states, i.e. the average multiplicity.

The question of influence of a hard scale on energy evolution of average multiplicities was addressed for the first time in the ever famous paper by C.N. Yang and his collaborators [3]. Taking use of some general ideas on mechanisms of extended particle fragmentation in the course of violent collisions the authors of ref. [3] made a qualitative prediction that, e.g. the average multiplicity in deeply inelastic scattering will grow with photon virtuality (at fixed invariant hadronic mass). In a sense the higher virtuality is the more effective multiple production becomes.

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A dozen years after that prediction we managed to give a quantitative measure of such a growth on the basic of perturbative QCD and some general considerations on hadron constituent composition [4]. It appeared that this effect is very slow, the slowness being a result of two circumstances: slow dependence of the QCD running coupling on the scale, and the composite (nonperturbative) structure of the nucleon.

Experimental data for the space of more than a quarter of century were somewhat controversial [5]. Recent data from HERA [6] still are not accurate enough to discern this rather a fine effect. The problem is of great importance of principle, and more precise data are badly needed.

• The last issue we have to mention is the influence of mass on high energy behaviour. At first sight at high enough energies masses are not very essential, and their effect dies-off with energy growth. In most cases it is really so. There are, however, some spectacular mass effects which seem to persist even at highest energies achieved.

Consider, for instance, multiple hadron production in e^+e^--annihilation. The generic mechanism corresponds roughly to the "primary" $\bar{q}q$ pair (which couples directly to γ/Z) and its gluonic bremsstrahlung (with final convertion of gluons and quarks into the observed hadrons). Experimentally it is possible to extract from the data the average multiplicities $< n >$ corresponding to a definite flavour of the primary $\bar{q}q$ pair. According to naïve expections the difference between $< n >_{\text{light}}$ and $< n >_{\text{heavy}}$ disappears at high energies (this is really the case for some other observables).

However, calculations based on QCD [7] lead to an asymptotically constant, finite difference which appears to be close to experimental data.

The most recent measurements at LEP II [8] agree with this theoretical conclusion. Nonetheless, the physical reason for such a behaviour is not clear. In principle it could be related to questions of principle on the rôle of mass in physics.

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