Universality of cross sections of pp, pA, AA collisions

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Experimental status.

$\sigma_{pp} \sim c\, s^{\Delta}$ $\qquad \Delta \simeq 0.08 \div 0.10$

$\sigma_{\pi p} \neq \sigma_{pp}$, $\quad \sigma_{pp} \neq \sigma_{pA} \neq \sigma_{AA}$

$F_{2p}(x, Q^2) \sim \left(\frac{1}{x}\right)^{n(Q^2)}$ $\qquad n(Q^2 \simeq 10) \simeq 0.2$

$F_{2p}(x, Q^2) \neq F_{2A}(x, Q^2)$

Pre QCD ideas.

i). Dominance by Pomeron exchange

$A(s,t) \simeq s^{\alpha(t)} F(t)$;

$\alpha(0) \simeq 1 + \Delta$

$\alpha(t) = \alpha(0) + \alpha' t$

ii) $\sigma_{tot}(ab \to ab) \leq \frac{\pi}{\mu^2} \ln^2(s/s_0)$

iii). Dependence of elastic cross sections on momentum transfer t is different for collisions of different hadrons, nuclei

QCD of ultrahigh energies.

1). $\frac{\sigma_{tot}(hp)}{\sigma_{tot}(pp)} \Rightarrow 1$ $\qquad h = \pi, K \cdots p$

2). $\frac{\sigma_{tot}(hA)}{\sigma^{tot}_{pp}} \Rightarrow 1$

3). $\frac{\sigma_{tot}(AA)}{\sigma_{tot}(hp)} \Rightarrow 1$

4). t dependencies should tend to universal limit

5). $\sigma_{pp} \Rightarrow \frac{\pi}{\mu^2} \ln^2 \frac{s}{s_0}$;

$F_{2T} \Rightarrow \frac{\pi}{\mu^2} \ln^3 \left(\frac{s}{s_0}\right)$

6). Possible spontaneus violation of continious symmetries like 2 dimensional translation invariance, appearance of two dimensional „phonons".

Theoretical tools.

1. Conservation of probability.

$$A = 2s \int e^{i(q_t b)}\, \Gamma(s, b^2)\, d^2 b$$

$\mathrm{Im}\,\Gamma = \frac{1}{2} |\Gamma^2| +$ positive terms.

$$|\Gamma(s, b^2)| \leq 1.$$

2. Complexity of hadrons.

i). number of constituent in a projectile is increasing with energy

ii). Central collision becomes absorbtive

– transpancy $T \Rightarrow 0$

Probability of absorbtion $1 - e^{-\left(\sigma_{tot}\,\rho l\right) \cdot \text{number of constituents}}$

increasing with energy.

$1 - T \to 1 - \exp\left(\sigma_{tot}\,\rho l\right)$ (number of constituents)

complete absorbtion: $|\Gamma(s, b^2)| \to 1$ for $s \to \infty$

iii). In QCD the same complexity arises for the scattering of dipole consisting initially from 2 bare constituents.

3). Increase of radius with energy.

$\Gamma \sim \frac{\sigma_{tot}}{B} e^{-\mu b} \sim 1 \rightarrow \qquad \mu b \sim \ln \frac{\sigma_{tot}}{B} \simeq \Delta \ln \frac{s}{s_0}$

for $\sigma \sim s^{\Delta}$

4). Universality of interactions at large impact parameters.

i). Universality of Pomeron exchange

$\Gamma_P \simeq s^{\Delta} \exp - \frac{b^2}{2\alpha'_P \ln \frac{s}{s_0} + B_0}$

At large "b" contribution of Regge cuts should be small $\sim \Gamma_P^n$ — n number of Pomeron exchanges

ii). Dominance of 2 pion exchange because pion mass is minimal - each hadron has universal pion tail.

Thus at extreemly large energies radius of a hadron independent on a hadron, strength of interactions becomes universal : $\Gamma \simeq 1$ $\rightarrow$ so cross sections become universal.

(Frankfurt, Strikman, Zhalov 05)

$$\sigma_{tot} = \int d^2b \;\; 2\,\mathrm{Im}\,\Gamma \approx \int d^2b \;\; \theta(b_{PT} - b)$$

Independent on target, on projectile:

$$1 = \frac{\sigma_{\pi p}}{\sigma_{pp}} = \frac{\sigma_{Kp}}{\sigma_{pp}} = \frac{\sigma_{pA}}{\sigma_{pp}} = \frac{\sigma_{AA}}{\sigma_{pp}}$$

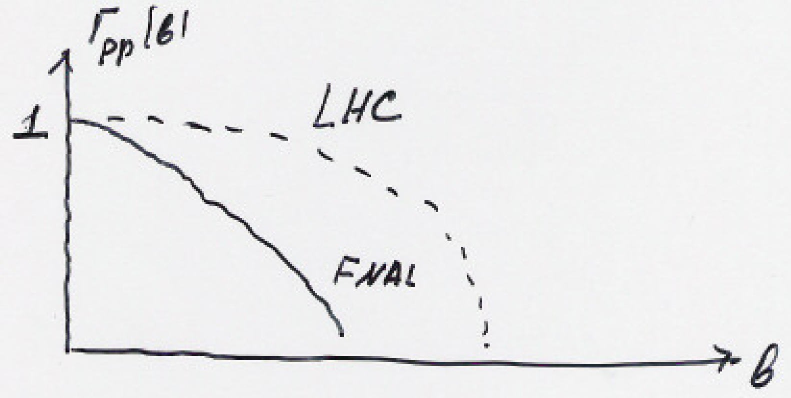
Onset of universality limit occurs at different energies.

Requires huge energies comparable to Planck scale. May appear important in the theory of black holes.

$$\frac{F_{2A}(x, Q^2)}{F_{2p}(x, Q^2)} \Rightarrow 1 \qquad \text{for } x \to 0$$

How to observe such universality in Lab.

This universality of cross sections will be revealed in elastic pp collision.



Thus at achievable energies major effect is increase with energy of the radius of soft and hard processes, blackening of interaction and increase with energy Q^2_{max} – narrowing region of applicability of QCD evolution equation.

Structure functions:

$$F_{2N}(x,Q^2) \Rightarrow \frac{1}{\mu^2} \ln^2\left(\frac{\sigma_d}{\sigma_0}\right) \ln s/s_0$$

$$\frac{F_{2A}(x,Q^2)}{F_{2N}(x,Q^2)} \Rightarrow 1 \qquad x \to 0$$

$$F_{2N} \Rightarrow \frac{Q^2}{12\pi^2} \sum_i e_i^2 \, \sigma_d \ln \frac{s}{s_0}$$

Within the black limit:

$$\frac{dF^{\gamma^*_x + T \to X + T}}{dM^2 \, d\Omega_x} = \frac{\pi R_A^2}{12\pi^2} \, \frac{Q^2 M^2}{(M^2+Q^2)^2} \, \frac{d\sigma(e\bar{e} \to X)/d\Omega_x}{\sigma(e\bar{e} \to \mu\bar{\mu})}$$

Significantly less steep decrease with Q^2 than in LT, mostly diffraction into jets.

For $|X\rangle = |\rho\rangle$ cross section should be $\sim \frac{1}{Q^2}$ instead of $\frac{1}{Q^6}$.

Spontaneous violation of two dimensional translation symmetry (TSV).

Series over rescatterings have the form:

$\sum c_n (-1)^n s^{n\Delta}$ and therefore are unstable

i) elastic eikonal approximation explore divergency of series but can not remove all tachyon singularities in the angular momentum plane.

ii) Investigation of Pomeron models (D. Amati et al) of hard processes at $x \to 0$ in QCD (B. Blok and L. F.) found TSV.

TSV reveal itself.

i). in the appearance of two dimensional „phonons"

ii) in the event by event fluctuations

Transverse radius of a proton will differ at each event. (cf. ferromagnetism)