Antishadowing and Multiparticle Production

S. M. Troshin, N. E. Tyurin

Institute for High Energy Physics,

Protvino, Russia

Rational form of unitarization
leads to prediction of the antishadow
scattering mode.
Appearance of this mode is expected beyond
the Tevatron maximum energy.
The region of the LHC energies is the one
where antishadow scattering mode is to be
presented.
This mode can be revealed at the LHC
directly measuring $\sigma_{el}(s)$ and $\sigma_{tot}(s)$
(and not only through the analysis of impact
parameter distributions).
Antishadowing leads to self–damping of the
inelastic channels and dominating role of
elastic scattering,

$$\sigma_{el}(s)/\sigma_{tot}(s) \to 1$$

at $s \to \infty$.
Many models and experimental data suggest
power dependence on energy of mean
multiplicity.

What about consistency of antishadowing with rising mean multiplicity?

$$\mathrm{Im} f(s,b) = |f(s,b)|^2 + \eta(s,b)$$

$$F = U + iUDF$$

unitarity is satisfied provided

$$\mathrm{Im} U(s,b) \geq 0$$

$$f(s,b) = \frac{U(s,b)}{1 - iU(s,b)},$$

inelastic overlap function

$$\eta(s,b) \equiv \frac{1}{4\pi}\frac{d\sigma_{inel}}{db^2}$$

is a sum of n–particle production cross–sections at the given impact parameter

$$\eta(s,b) = \sum_n \sigma_n(s,b),$$

where

$$\sigma_n(s,b) \equiv \frac{1}{4\pi}\frac{d\sigma_n}{db^2}, \quad \sigma_n(s) = 8\pi \int_0^\infty bdb\sigma_n(s,b).$$

Inelastic overlap function

$$\eta(s,b) = \frac{\mathrm{Im}U(s,b)}{|1 - iU(s,b)|^2}$$

Unitarity: $|f(s,b)| \leq 1$

"black disk" limit: $|f(s,b)| \leq 1/2$

Imaginary part of U-matrix
is sum of inelastic channel contributions:

$$ImU(s,b) = \sum_n \bar{U}_n(s,b),$$

n runs over all inelastic states and

$$\bar{U}_n(s,b) = \int d\Gamma_n |U_n(s,b,\{\xi_n\}|^2$$

$U_n(s,b,\{\xi_n\})$: $h_1 + h_2 \to X_n$
Im$U(s,b)$ itself is a shadow of the inelastic processes.
Self–damping of the inelastic channels:
increase of Im$U(s,b)$ results in decrease $\eta(s,b)$
when Im$U(s,b) > 1$ Inclusive cross–section

$$\frac{d\sigma}{d\xi} = 8\pi \int_0^\infty bdb \frac{I(s,b,\xi)}{|1 - iU(s,b)|^2}.$$

$$I(s,b,\xi) = \sum_{n\geq 3} n \int d\Gamma_n |U_n(s,b,\xi,\{\xi_{n-1}\})|^2$$

and

$$\int I(s,b,\xi)d\xi = \bar{n}(s,b)\mathrm{Im}U(s,b).$$

$\sigma_n(s,b)$:

$$\sigma_n(s,b) = \frac{\bar{U}_n(s,b)}{|1-iU(s,b)|^2}$$

Probability

$$P_n(s,b) = \frac{\sigma_n(s,b)}{\sigma_{inel}(s,b)}$$

is

$$P_n(s,b) = \frac{\bar{U}_n(s,b)}{\mathrm{Im}U(s,b)}. \qquad (1)$$

Cancellation of unitarity corrections in the ratio of cross-sections $\sigma_n(s,b)$ and $\sigma_{inel}(s,b)$. Mean multiplicity in the impact parameter representation

$$\bar{n}(s,b) = \sum_n nP_n(s,b)$$

does not affected by unitarity corrections and should not be proportional to $\eta(s,b)$.
Cancellation of unitarity corrections does not take place for the quantity $\bar{n}(s)$.
Quark model for the hadron scattering based on the ideas of chiral quark models
Hadron consists of constituent quarks embedded
into quark condensate
Overlapping and interaction of peripheral clouds occur at the first stage of hadron interaction
Nonlinear field couplings transform kinetic energy to
internal energy (mechanism of such transformations was discussed
by Heisenberg and Carruthers)
Massive virtual quarks appear in the overlapping region and effective field is generated
Their hadronization leads to production of secondary particles

$$\tilde{N}(s,b) \propto \frac{(1-\langle k_Q\rangle)\sqrt{s}}{m_Q}\, D_c^{h_1}\otimes D_c^{h_2},$$

Since the quarks are constituent

$$\bar{n}(s,b)=\alpha\tilde{N}(s,b), \qquad (2)$$

with a constant factor α

Mean multiplicity $\bar{n}(s)$:

$$\bar{n}(s)=\frac{\int_0^\infty \bar{n}(s,b)\eta(s,b)bdb}{\int_0^\infty \eta(s,b)bdb}.$$

Antishadowing with peripheral profile of $\eta(s,b)$ suppress the region of small impact parameters and main contribution to the mean multiplicity is due to peripheral region of $b\sim R(s)$

Condensate distribution:

$$D_c^h \sim \exp(-b/R_c).$$

Mean multiplicity

$$\bar{n}(s,b) = \tilde{\alpha}\frac{(1-\langle k_Q\rangle)\sqrt{s}}{m_Q}\,\mathrm{exp}(-b/R_c).$$

$U(s,b)$ is a product of the averaged quark amplitudes

$$U(s,b) = \prod_{Q=1}^{N}\langle f_Q(s,b)\rangle$$

Power-like dependence of the mean multiplicity $\bar{n}(s)$ at high energies

$$\bar{n}(s) \sim s^{\delta}, \qquad (3)$$

where

$$\delta = \frac{1}{2}\left(1 - \frac{\xi}{m_Q R_c}\right).$$

Two free parameters in the model, $\tilde{\alpha}$ and R_c: δ has value $\delta \simeq 0.2$, which corresponds to effective mass

$M_c = 1/R_c \simeq 0.3 m_Q$, i.e. $M_c \simeq m_\pi$.
It means that condensate distribution in the hadron is broad
does not coincide with the distribution of charged matter
The value of mean multiplicity expected at the LHC maximum energy ($\sqrt{s} = 14$ TeV) is about 110 ($\sigma_{tot} \simeq 230$ mb and $\sigma_{el}(s)/\sigma_{tot}(s) \simeq 0.67$)

No limitations follow from the general principles
of theory for the mean multiplicity,
besides the well known one based on the energy conservation law. Obtained power–like dependence which takes into account unitarity effects could be considered as a kind of a saturated upper bound for the mean multiplicity.