1 Comparison of NK and HBT approaches to interference and perpendicular momenta in vector meson production

In [1](KN) the problem is studied for the first time. In a similar approach, the interference is studied in [3](HBT) using the semiclassical as well as the Glauber approaches. The differences between the Glauber and semiclassical results are minimal, so let us concentrate on the differences between KN and HBT.

For simplicity, let us take the case y=0. There are perpendicular momenta of the photon and the 'pomeron', there is an impact parameter b . There has to be a convolution over perpendicular momenta and an integration over b. These ingredients are present in the KN and HBT approaches. It seems that the convolution is done in a somewhat different way. Maybe the differences are small in practice, but it would be good to understand the difference in the concepts of the two approaches in some more detail.

2 KN formulae

There is a photon perpendicular momentum (KN;eq. 1) (no impact parameter b!)and a pomeron perpendicular momentum given in KN;eq.2. (If the photon momentum would be strictly in the z-direction, this eq. 2 of KN would give the perpendicular momentum distribution, dashed line in KN, Fig.2.). The convolution smears out the minima, otherwise it is not a big effect.

The $A+\gamma \rightarrow A+V$ cross section is obtained from the elementary $\gamma+p$ cross section and a Glauber calculation. It is only known numerically, see esp. eq. 15 of [2] Now the impact parameter is introduced: (p. 2331 of KN) The impact parameter dependent photon spectrum

$N(\omega, b) \propto |\int d^2Q_\perp \vec{Q_\perp} F(Q^2) \exp -i\vec{b}\cdot\vec{Q_\perp}/Q^2|^2$

is multiplied with $\sigma(\gamma A...)$. (The photon energy is fixed by the requirement $y = fix = 0$).

In this way, the impact parameter b enters and an amplitude $A(p_\perp, b) = \sqrt{\sigma...}$ is defined (y=0). The interference is done essentially in eq. 4 of KN. It may be written as

$$\sigma(b) \propto |A(p_\perp, b) - \exp i\vec{b}\cdot\vec{p_\perp} A(p_\perp, b)|^2 \tag{1}$$

Finally, the integration over b is done.

More details are given in [4] The b-dependent equivalent photon spectrum is given in eq. 1 (no dependence on perpendicular momentum of the photon!). The convolution is explicitly given in eq. 4. It is written for a $\gamma + A \rightarrow A + V$ total cross section, but one can also do it for the differential cross section which depends on $k_\perp$, the vector meson perpendicular momentum, or the scattering angle.

Interference is taken into account according to eq. 7.

3 HBT approach

The convolution is done for the b-dependent amplitudes. In eq. 9 of HBT a simple analytical form for the nuclear photoproduction cross section is assumed (from the current in eq. 9, HBT one obtains directly this cross section). In eq. 7 and 10 the vector meson production amplitude is obtained by the convolution.

A related approach is in Sect. II.A. of [5], with two omissions: (i)the interference is not treated and (ii): the photon momentum is in the z-direction. Eq. 2.15 of [5]corresponds to eq. 4 of [4]. It has the same approximation: the photon momentum is perpendicular to the z-axis. This approximation is not done in eq. 10 of [3], this leads to a more general formula. The interference is done in eq. 15 [3]. Again, this is somewhat more general than eq. 7 of [4], but contains this formula as a limit. See the remarks following eq. 15 of [3].

4 comparison

Up to now, one can only make numerical comparisons.

In my (Gerhard Baur) opinion, the difference of KN and HBT can most easily be seen in eq. 10 of [3]. If the last exponential is approximated by $exp{-}R_V^2 v_\perp^2$ one would obtain a separation into a differential cross section for vector meson production and a b-dependent equivalent photon number, like in eq. 4 of [4]. So the best thing would be to compare a full calculation of a_V, eq. 10 of [3] to this approximate calculation. Kai Hencken could do this, but he is overburdened with other work for the time being.

4.1 Direct connection of KN and HBT

Under quite realistic assumptions one can see a direct connection of KN and HBT. In KN the equivalent photon spectrum is given in the point nucleus limit ($F = 1$), so the impact parameter has to be restricted to $b > b_{min}$. One could very well put the formfactor of a nucleus with radius R and extend the integration over b from 0 to ∞. The Gaussian shape of the photonuclear cross section, see eq. 9 HBT, is for simplicity, in order to compare with KN one could assume that they also use this shape.

Now the integration over b in eq. 6 of HBT is from 0 to ∞. For the untagged case, $f_{00} = 1$. The absolute square $|a_V|^2$ in eq. 6 of HBT can be written as a double integral $\int d^2Q_\perp \int d^2Q'_\perp$.

Now the integration over d^2b can be done analytically and one obtains a delta function i.e. $Q_\perp = Q'_\perp$, at least for the absolute square of the direct and exchange term. The interference term seems more complicated. I still have to check the factors, but now the remaining integral over $d^2Q_\perp$ in eq. 6 of [3] looks like the folding done in KN. The actual formula is not given in KN, but it is the procedure which leads to the solid curve of Fig. 1 in [1].

Anyway, the forthcoming ECT^* workshop in Trento January 2007 would be a good occasion to discuss this matter.

References

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