

The color dipole approach to the Drell-Yan process

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The high center of mass energies at RHIC and LHC will allow one to study the Drell-Yan(DY) process in a kinematical region, where the dilepton mass M is much smaller than the center of mass energy \sqrt{s} . This region is the DY analog to small Bjorken- x_{Bj} DIS. In addition, coherence effects due to multiple scattering in proton-nucleus (pA) collisions can also be studied.

We developed an approach [1, 2], in which the DY cross section is expressed in terms of the same color dipole cross section as DIS. Our approach is formulated in the rest frame of the target, where DY dilepton production looks like bremsstrahlung of massive photons, rather than parton annihilation, fig. 1. The projectile quark is decomposed into a series of Fock states,

$$|q\rangle = \sqrt{Z_2}|q_{bare}\rangle + \Psi_{\gamma^*q}|\gamma^*q\rangle + \dots \quad (1)$$

The cross section for production of a virtual photon in quark-proton scattering reads then [1, 3]

$$\frac{d\sigma(qp \rightarrow \gamma^* X)}{d\ln \alpha} = \int d^2\rho |\Psi_{\gamma^*q}(\alpha, \rho)|^2 \sigma_{q\bar{q}}(\alpha\rho). \quad (2)$$

Here, $\sigma_{q\bar{q}}$ is the cross section for scattering a $q\bar{q}$ -dipole off a proton which depends on the $q\bar{q}$ separation $\alpha\rho$. The photon-quark transverse separation is denoted by ρ and α is the fraction of the light-cone momentum of the initial quark taken away by the photon.

This approach is especially suitable to describe nuclear effects, since it allows one to apply Glauber multiple scattering theory. At very high energy, the transverse separation between γ^* and q in the $|\gamma^*q\rangle$ state is frozen during propagation through the nucleus, due to Lorentz time dilatation. Therefore, partonic configurations with fixed separations in impact parameter space are eigenstates of the interaction and one can generalize (2) to nuclear targets by replacing $\sigma_{q\bar{q}}(\alpha\rho)$ with

$$\sigma_{q\bar{q}}^A(\alpha\rho) = 2 \int d^2b \left\{ 1 - \exp\left(-\frac{\sigma_{q\bar{q}}(\alpha\rho)}{2} T(b)\right) \right\}. \quad (3)$$

Here $T(b)$ is the nuclear thickness at impact parameter b .

The frozen approximation (3) is however not well justified at presently achievable fixed target energies, where the size of the $|\gamma^*q\rangle$ -state may fluctuate on length scales of the order of the nuclear radius. In pA scattering, this leads to transitions between states which are eigenstates in proton-proton (pp) scattering. We go beyond the frozen approximation by summing over all possible trajectories of the quark in the $|\gamma^*q\rangle$ -state. This summation can be formulated in terms of the Green function for a two dimensional Schrödinger equation with an imaginary potential proportional to $\sigma_{q\bar{q}}(\alpha\rho)$ [3, 4]. In the limit of very high energy of the projectile quark, one recovers the frozen approximation (3). The formulae are however too complicated to be displayed here.

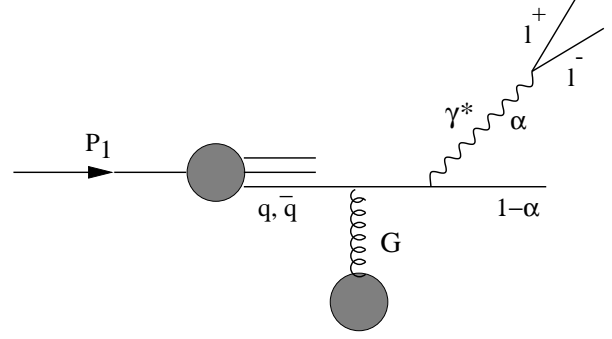


Figure 1: In the target rest frame, DY dilepton production looks like bremsstrahlung. A quark or an antiquark inside the projectile hadron scatters off the target color field and radiates a massive photon, which subsequently decays into the lepton pair. The photon can also be radiated before the quark hits the target.

Before calculating nuclear effects, we checked that the dipole approach is in agreement with DY data from pp collisions. We are able to reproduce E772 data well, without K factor [5]. The transverse momentum distribution of DY pairs in pp collisions is also calculated. The result does not diverge at zero transverse momentum due to the saturation of the dipole cross section at large separations. Note that first order pQCD leads to a divergent result.

The shadowing for DY in pA collisions at large Feynman- x_F measured at FNAL is then also well reproduced [4]. Nuclear effects on the transverse momentum distribution of the pairs are studied, too. While shadowing is predicted for dileptons with low transverse momenta, an enhancement at intermediate transverse momentum $q_\perp \sim 2$ GeV is expected. Nuclear effects vanish at very large q_\perp . For pA collisions at RHIC energies, considerable shadowing of DY dileptons is predicted for the whole x_F -range.

References

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