Heavy quarkonia and Drell-Yan gauge boson production in the color dipole picture

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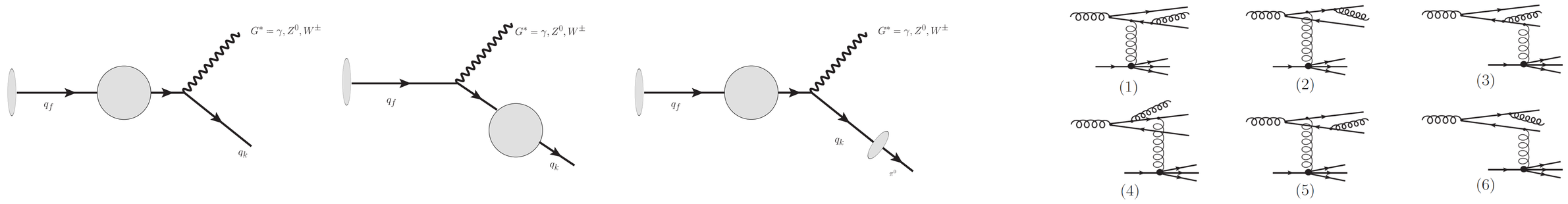
Abstract

Extensive phenomenological study of Drell-Yan (DY) and heavy quarkonia production in p-p collisions at LHC and RHIC energies within the color dipole (CD) formalism is presented. Moreover, the gauge boson (γ, Z^0, $W^{\pm}$) production in association with hadron that fragments from the incoming quark is calculated. This provides a complementary analysis tool to prompt-photon–hadron and hadron-hadron correlations within the color dipole formalism. Using Color-Singlet model (CSM) we calculate quarkonia p_T spectra and predict correlation between produced S-wave quarkonium and (semi-hard) hadron from the fragmentation of third gluon. As a very promising test of higher order pQCD in p-p collisions at modest energies we suggest to study correlations between forward high-p_T pion and J/ψ or Υ produced at mid-rapidity at RHIC energies.

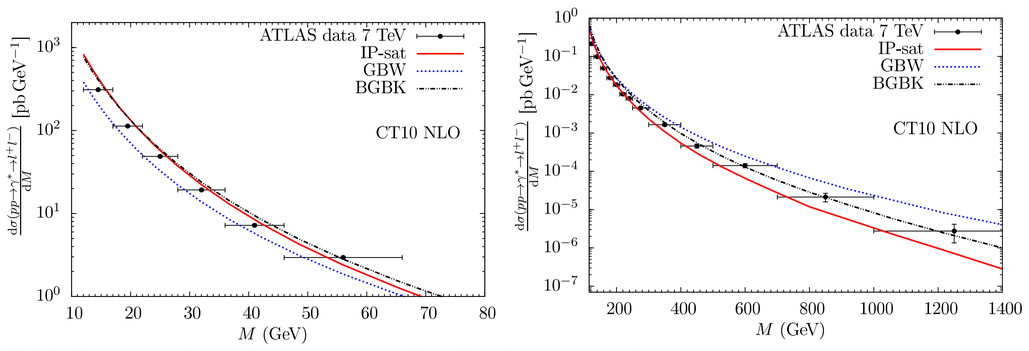
Color dipole picture of gauge boson and heavy quarkonia production

- Basic idea: although cross sections are Lorentz invariant, the partonic interpretation of the microscopic process depends on the reference frame. So in the target rest frame, the gauge boson production can be described in the dipole formalism as a bremsstrahlung process [1], rather than usually considered parton annihilation in the c.m.s. frame. CD formalism thus allows to take into account the higher-order corrections for the DY process [2].
- Replacing virtual photon with gluon one can treat G_a + p(A) → QQ , (Q=c,b) as a splitting G → QQ into dipole in the color background field of the target proton (nucleus).



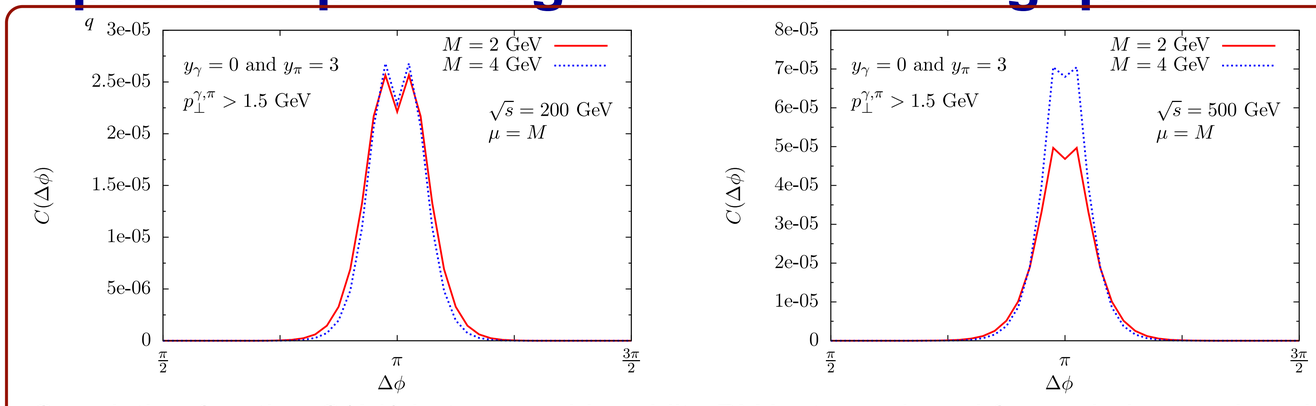
- First two diagrams on the left represent the process of a gauge boson irradiated by a quark (antiquark) of flavor *f* after/before the interaction with the target color field (shaded circle), respectively. For the $W^{\pm}$ radiation $q_k \neq q_f$. In the high energy limit, each of the two graphs factorizes into a production vertex for the gauge boson times an amplitude for scattering a quark off the target. The quark scatters at different impact parameters depending on whether the gauge boson is irradiated after of before the scattering. The universal dipole-target cross section σ_{qq} is determined by the low-x DIS data and provides a unified description of inclusive and diffractive observables in e-p processes as well as for in DY, prompt photon and heavy quark production in hadron-hadron collisions. Diagram in the middle representing the gauge boson - pion production in the CD picture provides higher-order correction to DY process.
- In the CSM one needs at least 3 gluons to be coupled to the quark line in order to produce $\{Q\,Q\}_{1+}$ state (see diagrams (1) - (6) on the right).

DY gauge boson production results



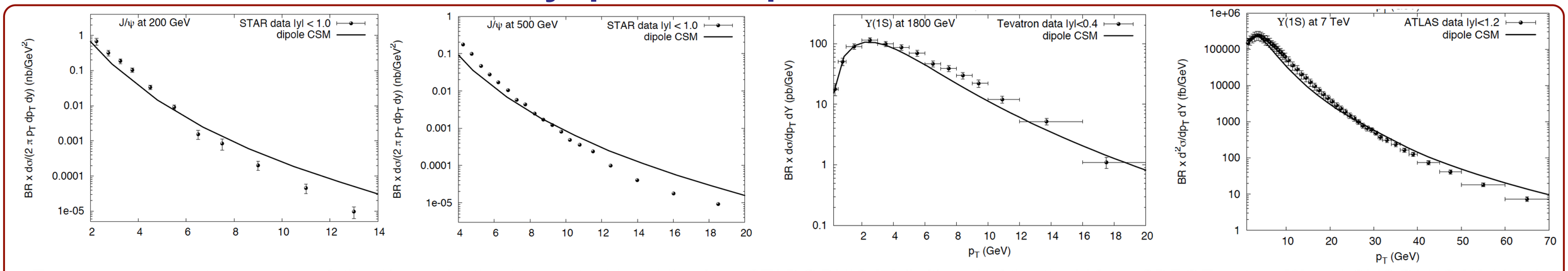
DY dilepton invariant mass distributions for the kinematical ranges of low (left panel) and high (right panel) invariant mass of the dileptons. Calculations [3] based on three different parametrizations of dipole cross section [4,5] are compared to data of the ATLAS Collaboration [5].

Azimuthal correlations between DY lepton pair and pion fragment of radiating quark



Correlation function C(Δϕ) between mid-rapidity DY lepton pair and forward pion produced in pp collisions at RHIC (√s = 200 GeV, left and √s = 500 GeV, right) assuming that factorization scale μ is given by the dilepton invariant mass M (right).

Heavy quarkonia production results



Transverse momentum spectra of the J/ψ production in p-p at mid-rapidity, from STAR@RHIC [7] (left) and of the the Υ from CDF@Tevatron [8] and CMS@LHC [9] (right).

- In the CD picture incoming gluon is collinear and moves along the z-axis. Momentum transferred to it by color background field of the target proton is predominantly longitudinal one (exchanged gluons have typically soft transverse momenta $k_T \sim m_G$). By momentum conservation, the J/ψ transverse momentum p_T is close to that of the radiated gluon. ⇒**Transverse momentum correlation between produced S-wave quarkonium and (semi-hard) hadron from the fragmentation of third gluon.**

References

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Summary

1. The dipole formalism provides of DY production of gauge bosons and quarkonia was presented.
2. Parameter-free calculations of J/ψ and Υ differential transverse momentum cross section performed within dipole CSM approach provide substantial improvement over previous CS NLO calculation
3. Further test of the model will come from expected quarkonim–(semi-hard) hadron correlation. J/ψ and quarkonium production in association with the leading forward hadron.

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