Shadowing Effects on Vector Boson Production*

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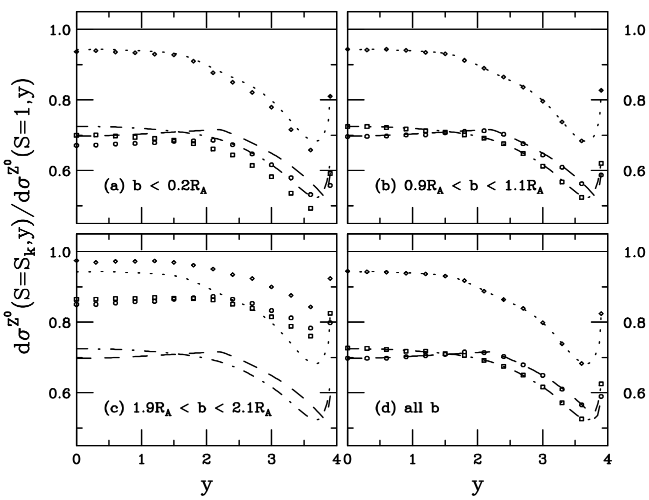
The Z^0 was proposed as an alternative reference process for quarkonium suppression at the LHC. There are two difficulties with using the Z^0 as a baseline for quarkonium suppression: the large mass differences, $m_{Z^0} \gg m_\Upsilon, m_{J/\psi}$, and the difference in production mechanisms, predominantly $q\overline{q}$ for the Z^0 and gg for quarkonium. Both these differences are important as far as nuclear effects are concerned. However, the differences that reduce the value of the Z^0 as a baseline process are the same that make it an interesting object of study itself—the Z^0 provides a unique opportunity to study quark shadowing at high Q^2. Therefore, we examine the possible effects of shadowing on Z^0 production as well as W^+ and W^- production which are also quark dominated. The impact parameter dependence of the shadowing effect will also be shown.

The electroweak production and decay channels of the massive vector bosons make them excellent candidates for shadowing studies since no hadronic final-state rescattering is possible. The Z^0 itself, with a 3.37% branching ratio to lepton pairs, will be easily observable by reconstructing the peak. Full reconstruction of the leptonic $W^\pm$ decays, $W^\pm \to l^\pm\nu$, is not possible due to the missing energy given to the undetected neutrino but charged leptons with momenta greater than 40 GeV should be prominent. This technique has been used at the Tevatron to measure the asymmetry between W^+ and W^- production through their lepton decays since this asymmetry is sensitive to the ratio f_d^p/f_u^p at intermediate values of x and high Q^2. If the charged leptons from $W^\pm$ decays can be identified in heavy ion collisions, such asymmetry measurements may also be employed at the LHC to reduce systematics and obtain a more meaningful determination of the Q^2 dependence of quark shadowing in the nucleus.

The table gives the total cross sections in the CMS and ALICE central acceptances $|y| < 2.4$ and $|y| < 1$ respectively for no shadowing and with three shadowing parameterizations. The cross sections are larger than the virtual photon mediated Drell-Yan cross sections at lower masses. The results, given for Pb+Pb collisions, are integrated over impact parameter in units of nb/nucleon pair.

Detector	σ_1 (nb)	σ_{S_1} (nb)	σ_{S_2} (nb)	σ_{S_3} (nb)
		Z^0		
CMS	15.41	10.87	10.96	14.26
ALICE	6.22	4.35	4.49	5.86
		W^+		
CMS	20.85	14.39	14.54	18.93
ALICE	8.13	5.52	5.73	7.44
		W^-		
CMS	21.84	15.08	15.26	19.83
ALICE	8.35	5.66	5.89	7.64

The figure compares the ratios of Z^0 production in Pb+Pb collisions with three shadowing parameterizations to Pb+Pb collisions with no shadowing as a function of rapidity. The isospin effects wash out the differences between the W^+ and W^- distributions in the ratios so that the results are essentially identical for the two charged vector bosons. Therefore the ratios are shown only for the W^+. The results are shown for several impact parameter bins, the most central bin, $b < 0.2R_A$, an intermediate impact parameter bin around $b \sim R_A$, and a peripheral bin around $b \sim 2R_A$. It is clear that by neglecting the impact parameter dependence of shadowing, one may make an overestimate of the effect in peripheral collisions, an important point if using the Z^0 as a baseline in different transverse energy bins. Note also that the integration over all impact parameters is equivalent to the average shadowing.



Once the basic nuclear shadowing effects on vector boson production have been understood, they can perhaps be used to study other medium effects in heavy ion collisions by comparing the leptonic and hadronic decay channels. The hadronic decays of the vector bosons, $\sim 70\%$ of all decays of each boson, may be more difficult to interpret. While the width of the Z^0 decay to l^+l^- is not expected to be modified in the quark-gluon plasma, the Z^0 has a 2.49 GeV total width and will decay in any quark-gluon plasma to two jets through $Z^0 \to q\overline{q} \to$ jet + jet in ~ 0.1 fm. Therefore, the decay jets could be modified in the medium which may still be progressing toward thermalization and will be subject to rescattering and jet quenching. Thus a comparison of a reconstructed Z^0 in the dilepton channel where no nuclear effects are expected since leptons do not interact strongly and medium-modified jets should result in a broader width for the $q\overline{q}$ channel than the l^+l^- channel. In addition, the Z^0 could be used to tag jets through the $q\overline{q} \to Z^0 g$ and $gq \to Z^0 q$ channels to study the jet properties in the quark-gluon plasma.

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