Main sources of uncertainty in quark and gluon fragmentation functions into hadrons and photons

Monique Werlen, LAPTH

April 8, 2008

A precise knowledge of the QCD hadron and photon production is necessary while searching for low mass Higgs signals at LHC/Tevatron. Uncertainties on this background must therefore be asserted with care, in particular those due to the measurement of fragmentation functions. In the calculation of inclusive hadron and photon cross sections in pp collisions with the PHOX package, a set of NLO event generators at parton level for large pt PHOton, hadron and/or jet X-sections [1], uncertainties on fragmentation functions (FF) do matter compared to those from scales and parton distribution functions (PDF) at RHIC and LHC energies [2]. FF are obtained from fits to inclusive cross sections assuming a functional form at a given scale M_{F0} and evolving it to the scale of the data. The sources of uncertainties are both experimental and theoretical. Experimental uncertainties are due to statistical error, in particular for the large momentum fraction z of the parton in e^+e^- data. But also systematic effects are contributing as in the data normalization or in the extrapolation (evolution) needed to cover the full z (Q^2) range. Matching theory and data due to binning and cuts settings may also be an issue. Theoretical uncertainties come from the choice of the functional form for the selected z range, the choice of scales, the order of the theory (leading, next-to-leading NLO, resummation) and further parameters like PDFs and α_s.

As shown for the first time in [3], NLO fits to $e^+e^- \to \pi^0 X$ data from PEP and PETRA constrain the quark fragmentation into neutral pions while those to $pp \to \pi^0 X$ from ISR and UA2 constrain the gluon fragmentation. BFGW [4] sets of FF into unidentified charged hadrons have been obtained from LEP and PETRA data choosing optimized scales: a rough approximation of the large z resummation ([5]). Gluon parameters are quite sensitive to the functional form chosen for the quark distribution. A full statistical error analysis is performed while estimation of the "theoretical error" as previously detailed can be obtained by comparison to other FF sets. Important discrepancies with the BKK set [6] have been shown, specially at large z while the gluon FF at $z > 0.5$ is found much higher, in accordance with the UA1 data, than in the Kretzer set [7]. Large scale instabilities (specially at low $\sqrt{s}$ and low p_T) affect the phenomenology of inclusive production of pion [9]. Theoretical estimates rely on extrapolations of the FF outside ($0.75 < x < 0.9$) of the region where they are actually constrained ($0.1 < z < 0.7$) by the data [10]. A preliminary study [13] with JETPHOX shows that the p_T imbalance hadron-jet correlation cross-sections at RHIC energy may be used to constrain the FF into hadron in the high z region. For $p_T(h) > 25$ GeV and $p_T(jet) > 30$ GeV, the three set (BFGW, KKP[8], Kretzer) give quite different predictions: BFGW systematically higher than KKP while Kretzer a factor two lower.

Thanks to recent data from PHENIX and D0 spanning a large $x_T = 2p_T/\sqrt{s}$ range, inclusive prompt photons cross sections from $\sqrt{s} = 23$ GeV to $\sqrt{s} = 1.96$ TeV are now well understood in the NLO QCD framework [11]. Photons can be produced either directly or via a parton-to-photon FF. The later becomes important at low p_T and high $\sqrt{s}$. Uncertainties on the photon FF are mainly due to the uncertainty on the gluon FF as quantified by the BFG sets I and II [12]. BFG I reduces the cross section by up to 10% (a factor 2.5) at $p_T = 3$GeV at RHIC (LHC) energy compared to BFG II [2]. As shown in [13] the photon-jet correlation at RHIC energy may also be used to constrain the photon FF. Fixing the jet and varying the photon momenta allows a direct measurement of the photon fragmentation at low z, a region barely accessible in the LEP experiments.

References

[1] see http://www.lapp.in2p3.fr/lapth/PHOX_FAMILY/main.html

[2] F. Arleo et al., [arXiv:hep-ph/0311131].

[3] P. Chiappetta, M. Greco, J. P. Guillet, S. Rolli and M. Werlen, Nucl. Phys. B412 (1994) 3 [arXiv:hep-ph/9301254].

[4] L. Bourhis, M. Fontannaz, J. P. Guillet and M. Werlen, Eur. Phys. J. C19 (2001) 89 [arXiv:hep-ph/0009101].

[5] M. Cacciari and S. Catani, Nucl. Phys. B 617 (2001) 253.

[6] J. Binnewies, B. A. Kniehl and G. Kramer, Phys. Rev. D52 (1995) 4947.

[7] S. Kretzer, Phys. Rev. D62 (2000) 054001 [arXiv:hep-ph/0003177].

[8] B. A. Kniehl, G. Kramer and B. Potter, Nucl. Phys. B582 (2000) 514

[9] P. Aurenche, M. Fontannaz, J. P. Guillet, B. A. Kniehl and M. Werlen, Eur. Phys. J. C13 (2000) 347 [arXiv:hep-ph/9910252].

[10] T. Binoth, J. P. Guillet, E. Pilon and M. Werlen, Eur. Phys. J. C24 (2002) 245. [arXiv:hep-ph/0111043]

[11] P. Aurenche, M. Fontannaz, J. P. Guillet, E. Pilon and M. Werlen, Phys. Rev. D73, 094007 (2006) [arXiv:hep-ph/0602133].

[12] L. Bourhis, M. Fontannaz and J. P. Guillet, Eur. Phys. J. C2 (1998) 529 [arXiv:hep-ph/9704447].

[13] Z. Belghobsi, M. Fontannaz, J.Ph. Guillet, G. Heinrich, E. Pilon and M. Werlen, in preparation