PROCEEDINGS OF SCIENCE

Direct photon and heavy-quark production in p-A and A-A collisions

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We show that the associated production of a prompt photon and a heavy-quark jet (charm or bottom) is a versatile process that provides us with the opportunity to study the structure of the proton and the nucleus (in proton-nucleus (p-A) collisions) as well as the mechanisms of heavy quark energy loss (in nucleus-nucleus (A-A) collisions). Future p-A measurements of this process at the LHC should allow one to disentangle the various nPDF sets currently available. In heavy-ion collisions, the photon transverse momentum can be used to gauge the initial energy of the massive parton which is expected to propagate through the dense QCD medium produced in those collisions. The two-particle final state provides a range of observables through the use of which a better understanding of parton energy loss processes in the massive quark sector can be achieved, as shown by the present phenomenological analysis carried out in Pb-Pb collisions at the LHC.

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1. p-A Collisions

Unlike the PDF for a gluon inside an unbound proton, the nuclear gluon PDF is largely unconstrained due to lack of available data. This is demonstrated in the large uncertainties of the currently available nPDF sets (nCTEQ [1, 2, 3], HKN07 [4], EPS09 [5]) and the differences between them as presented in Fig.1. There are several process one can use to constrain the gluon nPDF. We have shown in Ref.[6] that $\gamma + Q$ production is an excellent probe of $g^A(x, Q^2)$, and that measurements of this process once applied to a global fit can help to greatly reduce the gluon nPDF uncertainty, as evidenced by Fig.7 and Fig.11 of said reference.

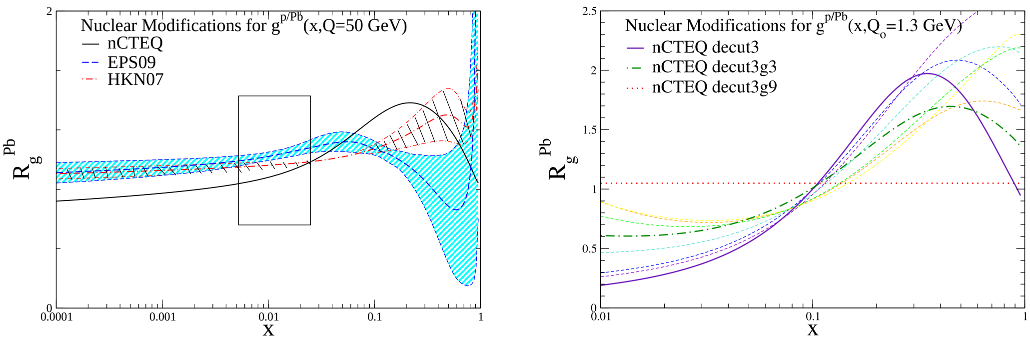

Figure 1: a) R_g^{Pb} at $Q = 50$ GeV for nCTEQ decut3, EPS09 + error band, HKN07 + error band, the box exemplifies the x-regions probed at the LHC. b) R_g^{Pb} at $Q_0 = 1.3$ GeV for different nCTEQ decut3, decut3g1-decut3g9 fits.

2. A-A Collisions

It is currently our understanding that a state of hot & dense QCD matter - Quark Gluon Plasma (QGP) - is created in nucleus-nucleus collisions (Au-Au at RHIC & Pb-Pb at the LHC) [7, 8]. One way to study the properties of this matter state is to quantify the energy lost by colored particles traversing it. This is known as jet quenching and has been observed at both RHIC [9] & the LHC [10]. By focusing on two-particle final states one has a much more versatile access to quantifying the energy loss, as compared to the study of a single inclusive process. Furthermore, if one of the final-state particles is medium insensitive, it can act as a gauge of the initial energy lost by the parton γ+*jet* [11] or γ+*hadron* [12]. Currently it is expected that light partons loose more energy than heavy ones: $\varepsilon_g > \varepsilon_q > \varepsilon_c > \varepsilon_b$, with the heavier quarks loosing less energy due to the 'dead-cone effect'[13]. Therefore by varying the final state one can verify this hierarchy. Here we focus on comparing the $\gamma + b$ & $\gamma + c$ spectra.

We apply the energy loss, ε_Q, to the heavy quark energy on an event by event basis using the numerical code from Ref.[14], so that: $E_Q^{med} = E_Q^{vac} - \varepsilon_Q$. It can be assumed that the parton does not change its initial direction while traversing the medium, therefore we apply the energy loss to the heavy quark four-vector using the simple kinematic relation:

$$p^{vac} = p_T(\cosh y, \vec{e}_T, \sinh y) \rightarrow p^{med} = [p_T - \varepsilon](\cosh y, \vec{e}_T, \sinh y). \quad (2.1)$$

In Fig.2a) we present the effect of the medium on the LO differential cross-section versus $p_{T,\gamma}$ & $p_{T,Q}$ in vacuum and in medium, where the parameters describing the medium used are $\hat{q} = 6.25$ GeV/fm^2 and $\omega_c = 50$ GeV. The medium effects show up in the difference between $\frac{d\sigma^{\gamma+c;med}}{dp_{TQ}}$ (red dashed line) and $\frac{d\sigma^{\gamma+c;vac}}{dp_{TQ}}$ (red solid line), while the $\frac{d\sigma}{p_{T\gamma}}$ spectrum is mostly unchanged, except for a small difference between the medium and vacuum spectra at low p_T caused by the fact that certain events in the medium have a lower $p_{T,Q}$ and cannot pass the experimental cuts any more. However since we have a two-particle final state we can investigate the correlations of the two final

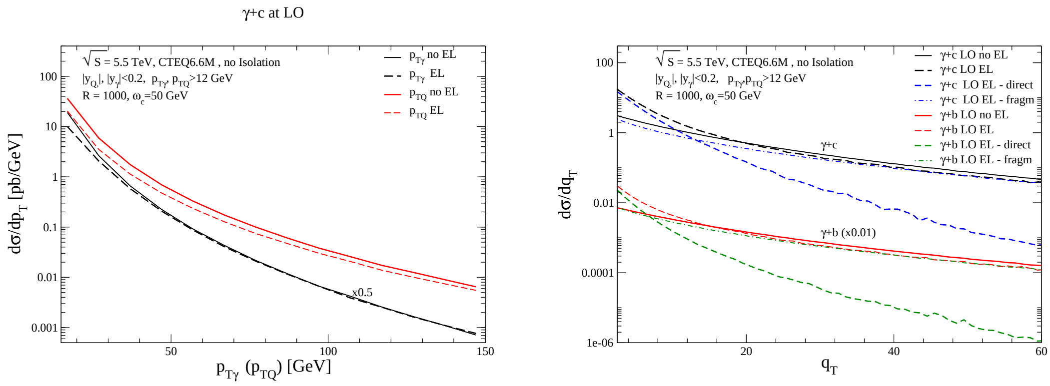

Figure 2: a) The LO $\frac{d\sigma^{\gamma+c}}{dp_{T\gamma}}$ in vacuum (solid line) and in medium (dotted line); $\frac{d\sigma^{\gamma+c}}{dp_{TQ}}$ in vacuum (dashed line) and in medium (dashed-dotted line). b) The LO differential cross-section versus q_T for $\gamma + c$ and $\gamma + b$, showing the fragmentation and direct contributions in vacuum and in medium.

state particles, since this provides a much better handle on the amount of energy loss. The photon-jet pair momentum, $q_T = |\vec{p}_{T\gamma} + \vec{p}_{TQ}|$, for example, is a good probe of ε_Q, as $q_T \simeq \varepsilon_Q$, (at direct order LO accuracy in the medium $q_T = \varepsilon_Q$). Unfortunately when one investigates two-particle observables for this process at LO, only the fragmentation contributions in medium and in vacuum can be compared, as due to the kinematic constraints the direct component in vacuum is non-zero only when $q_T = 0$. In Fig.2b) we show the different contributions to the differential cross-section as a function of the photon-jet pair momentum, in medium and in vacuum. As we only have a distribution for the fragmentation contributions for this observable in vacuum (solid black line $\gamma + c$, solid red line $\gamma + b$), we can only compare them against the corresponding fragmentation contributions in the medium (dash-dotted blue line $\gamma + c$, dash-dotted green line $\gamma + b$). The differences in the fragmentation contribution represented by the shift in the q_T spectrum in vacuum versus the one in medium, are proportional to $< \varepsilon_Q >$. In Fig.3 the fragmentation contributions in medium to $\gamma + c$ and $\gamma + b$ normalized to the $p - p$ case are shown. Clearly $\Delta E_c > \Delta E_b$ at small q_T, while as q_T grows the difference disappears, as the quenching weight depends on m/E, which becomes similar for charm and bottom quarks at large q_T. However, definite conclusions can only be drawn after a study at NLO accuracy [15].

References

[1] Schienbein I *et al.* 2008 *Phys. Rev.* **D77** 054013 (*Preprint* `arXiv:0710.4897 [hep-ph]`)

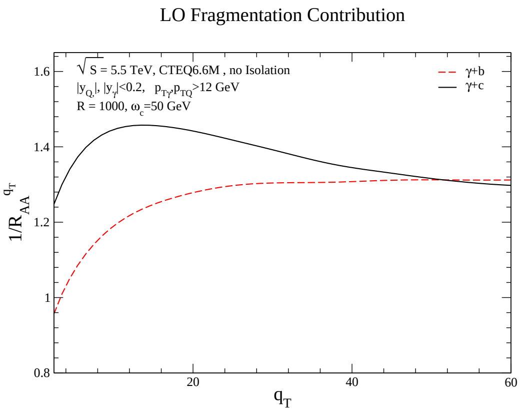

Figure 3: The ratio of the LO vacuum fragmentation contribution to the medium fragmentation contribution for $\gamma + c$ (solid line) and $\gamma + b$ (dashed line).

[2] Schienbein I *et al.* 2009 *Phys. Rev.* **D80** 094004 (*Preprint* `arXiv:0907.2357 [hep-ph]`)

[3] Kovarik K *et al.* 2011 *Phys. Rev. Lett.* **106** 122301 (*Preprint* `arXiv:1012.0286 [hep-ph]`)

[4] Hirai M *et al.* 2007 *Phys. Rev.* **C76** 065207 (*Preprint* `arXiv:0709.3038 [hep-ph]`)

[5] Eskola K J *et al.* 2009 *JHEP* **04** 065 (*Preprint* `arXiv:0902.4154 [hep-ph]`)

[6] Stavreva T *et al.* 2011 *JHEP* **01** 152 (*Preprint* `arXiv:1012.1178 [hep-ph]`)

[7] Adcox K *et al.* 2005 *Nucl.Phys.* **A757** 184 (*Preprint* `arXiv:nucl-ex/0410003`)

[8] Adams J *et al.* 2005 *Nucl.Phys.* **A757** 102 (*Preprint* `arXiv:nucl-ex/0501009`)

[9] Adcox K *et al.* 2002 *Phys.Rev.Lett.* **88** 022301 (*Preprint* `arXiv:nucl-ex/0109003`)

[10] Aad G *et al.* 2010 *Phys.Rev.Lett.* **105** 252303 (*Preprint* `arXiv:1011.6182 [hep-ex]`)

[11] Wang X-N *et al.* 1996 *Phys. Rev. Lett.* **77** 231 (*Preprint* `arXiv:hep-ph/9605213`)

[12] Arleo F *et al.* 2004 *JHEP* **11** 009 (*Preprint* `arXiv:hep-ph/0410088`)

[13] Dokshitzer Y L and Kharzeev D E 2001 *Phys. Lett.* **B519** 199 (*Preprint* `arXiv:hep-ph/0106202`)

[14] Armesto N *et al.* 2005 *Phys. Rev* **D71** 054027 (*Preprint* `arXiv:hep-ph/0501225`)

[15] Arleo F, Schienbein I, and Stavreva T *Work in Progress*