Fragmentation function and partonic k_T at 200 GeV

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Abstract. The high-p_T π^0 trigger associated distributions in $p+p$ collisions at $\sqrt{s}$=200 GeV are analyzed. It is shown that, despite an expectation, the associated distributions as a function of 'scaled' variables $x_{\rm E}$ or $p_{T{\rm a}}/p_{T{\rm t}}$ have almost no sensitivity to the shape of the fragmentation function. It is discussed that the slope of $x_{\rm E}$ and/or $p_{T{\rm a}}/p_{T{\rm t}}$ distributions reflects rather the final state parton spectra.

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The sQGP interpretation of the observed phenomena at RHIC is supported by an excellent, and to some extent, unexpected agreement between a pQCD based calculations of the parton interaction with exited nuclear medium via 'induced gluon radiation' [1]. There are, however, experimental evidences which do not support the 'induced gluon radiation' scenario as a leading mechanism responsible for the observed quenching of high p_T particles. The most striking one is an observation of similar suppression pattern of high p_T electrons from semi-leptonic D and B mesons decays [2]. According to theory of heavy quark propagation in the nuclear medium [3] there should be a 'dead cone' which constrain the available phase space for the induced gluon radiation. Furthermore, the energy loss calculation which reproduces the heavy quark suppression underpredicts the light hadrons yield at high p_T [4].

Another controversy is related to the width of the away side correlation peak associated with high p_T trigger particle. It is expected that the parton energy loss should be associated with significant broadening of the away-side hadron azimuthal distribution [5]. However, the data [6] shows little, if any, modification of the away side peak width as compared to measurements in $p+p$ collisions or when comparing different collisional centralities. Similarly, an analysis of the scaling properties of inclusive hadron production in heavy ion collisions [7] concludes that the induced gluon radiation would strongly violate the x_T scaling ($x_T \equiv 2p_T/\sqrt{s}$) in contrast to what is seen in the data [8].

It was suggested that the parton interactions with nuclear medium should be accompanied by the modification of the fragmentation function [9]. We have studied the associated particle distributions to high p_T π^0 in $p+p$ collisions as a function of the fractional momentum

$$x_{\rm E} \equiv \frac{-\vec{p}_{T{\rm a}} \cdot \vec{p}_{T{\rm t}}}{p_{T{\rm t}}^2} = \frac{p_{T{\rm a}}}{p_{T{\rm t}}} \cos\Delta\phi = \frac{z_{\rm a} \cdot \hat{p}_{T{\rm a}}}{z_{\rm t} \cdot \hat{p}_{T{\rm t}}} \tag{1}$$

suggested in [10], where $p_{T{\rm t}}$, $p_{T{\rm a}}$, $\hat{p}_{T{\rm t}}$ and $\hat{p}_{T{\rm a}}$ are transverse momenta of the trigger and associated particle and partons, and as a function $p_{T{\rm a}}/p_{T{\rm t}}$ according to [9]. These two variables, x_E and $p_{T\mathrm{a}}/p_{T\mathrm{t}}$ differ only by a factor of $\cos\Delta\phi$ (ϕ is the azimuth) and they do not differ at all at high p_T where $\Delta\phi$ is small.

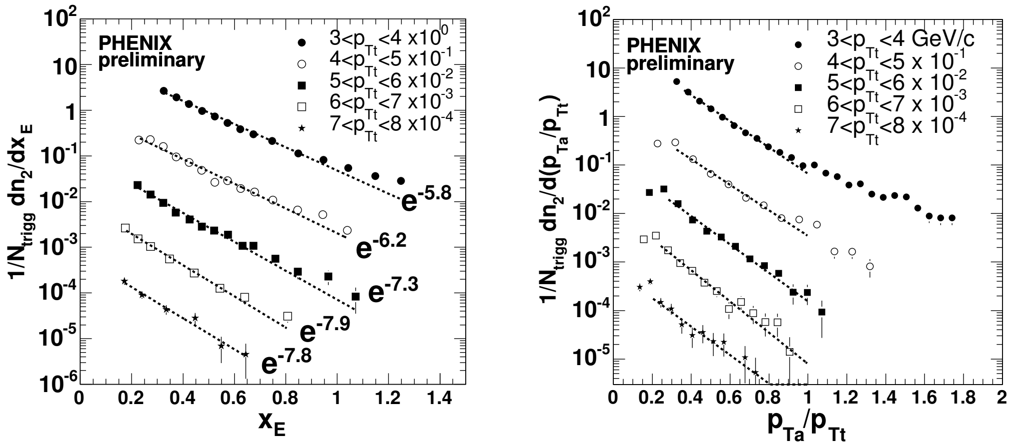

FIGURE 1. The x_E (left) and $p_{T\mathrm{a}}/p_{T\mathrm{t}}$ (right) distributions of charged hadrons associated with high p_T trigger π^0 for different trigger transverse momenta $p_{T\mathrm{t}}$ extracted from $p+p$ data. The dashed lines correspond to the exponential fits.

The x_E and $p_{T\mathrm{a}}/p_{T\mathrm{t}}$ distributions of charged hadrons associated with high p_T trigger π^0 for different trigger transverse momenta $p_{T\mathrm{t}}$ are shown on Fig. 1. As expected, the local exponential slopes of x_E and $p_{T\mathrm{a}}/p_{T\mathrm{t}}$ do not differ, the slopes themselves are getting steeper with $p_{T\mathrm{t}}$ and both distributions reveal non-exponential tails. This can be attributed to the trigger bias and to the fact that the shape of associated distribution is determined by final state parton spectrum, as it is in the case of the single inclusive particle distribution, rather then by fragmentation function. This become more transparent when we express, inspired by pQCD factorization theorem, the single inclusive invariant cross section for particle production as

$$\frac{1}{p_T}\frac{d\sigma_\pi}{dp_T} \approx \int_{x_T}^{1} D_\pi^q(z)\cdot\Sigma(\frac{p_T}{z})\frac{dz}{z^2} \approx p_T^{-n}\int_{x_T}^{1} D_\pi^q(z)\cdot z^{n-2}dz \tag{2}$$

where D_π^q(z), the fragmentation function, is convoluted with final state parton spectrum $\Sigma(\hat{p}_T) \propto \hat{p}_T^{-n}$ of the power law shape. The last integral is a constant factor (up to the weak dependence on p_T due to the lower limit) and hence one can conclude that the shape of the single inclusive p_T distribution is given dominantly by final state parton spectrum and it is almost insensitive to the shape of D_π^q(z).

A similar line of thoughts can be used when exploring the trigger associated distribution which can be written as

$$\frac{d\sigma}{dp_{T\mathrm{t}}dx_\mathrm{E}} = \frac{dp_{T\mathrm{a}}}{dx_\mathrm{E}} \times \frac{d\sigma}{dp_{T\mathrm{t}}dp_{T\mathrm{a}}} \simeq \frac{1}{\hat{x}_\mathrm{h}p_{T\mathrm{t}}}\int_{x_{T\mathrm{t}}}^{\hat{x}_\mathrm{h}\frac{p_{T\mathrm{t}}}{p_{T\mathrm{a}}}} D_\pi^q(z_\mathrm{t})D_\pi^q(\frac{z_\mathrm{t}p_{T\mathrm{a}}}{\hat{x}_\mathrm{h}p_{T\mathrm{t}}})\Sigma'(\frac{p_{T\mathrm{t}}}{z})z_\mathrm{t}^{-1}\,dz_\mathrm{t} \tag{3}$$

where $\hat{x}_\mathrm{h} = \hat{x}_\mathrm{h}(p_{T\mathrm{t}}, p_{T\mathrm{a}}k_T) \equiv \langle\hat{p}_{T\mathrm{a}}\rangle\,/\,\langle\hat{p}_{T\mathrm{t}}\rangle$, $x_{T\mathrm{t}}$=$2p_{T\mathrm{t}}/\sqrt{s}$ and z_t=$p_{T\mathrm{t}}/\hat{p}_{T\mathrm{t}}$ is a momentum fraction of the trigger particle and k_T is a parton intrinsic transverse momentum. The parton distribution function on the opposite side of the trigger particle Σ' is smeared by $\vec{k}_T$ and can be approximated by a folding of a power law parton distribution with a Gaussian function.

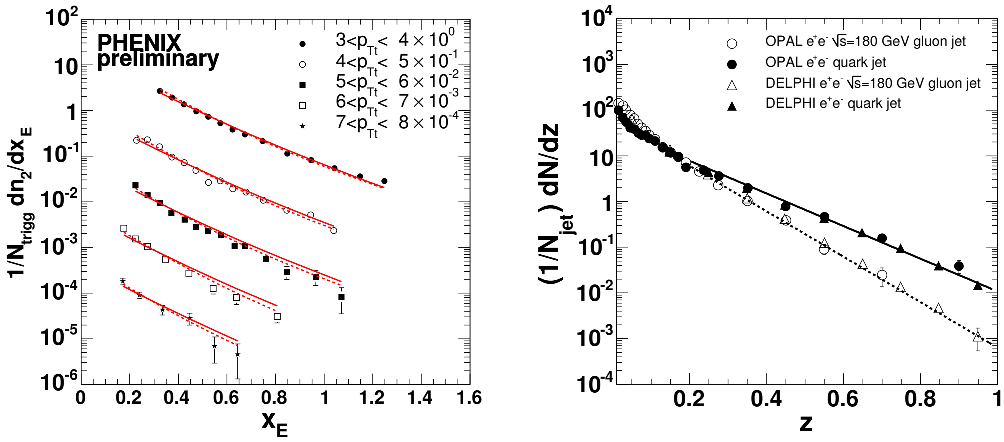

FIGURE 2. Left: the same x_E distributions as on Fig. 1 shown with calculations according Eq. (3) for quark (solid lines) and for gluon (dashed lines) $D(z)$. An exponential approximation was used and the slopes for quark and gluon fragmentation function were obtained by fitting to LEP data [11] (right).

Calculated distributions according Eq. (3) for two sets of the fragmentation function, corresponding to the quark and gluon jet fragmentation, are shown on Fig. 2. Simple exponential parameterization was used and the slopes were obtained from the fit to the LEP data [11] (right panel of Fig. 2). For the quark and gluon jet we found $D_q(z) \approx \exp(-8.2 \cdot z)$ and $D_g(z) \approx \exp(-11.4 \cdot z)$ respectively. The parton final state spectrum we used $\Sigma' \approx \hat{p}_T^{-8}$. It is evident that the x_E distribution calculated for quite different quark and gluon fragmentation functions do not differ almost at all (the difference between solid and dashed lines on the left panel of Fig. 2).

We concluded that the high p_T trigger associated distributions have surprisingly small sensitivity to the shape of the fragmentation function.

REFERENCES

1. I. Vitev and M. Gyulassy, Phys. Rev. Lett. **89**, 252301 (2002); Q. Wang and X.-n. Wang, Phys. Rev. **C71**, 014903 (2005).
2. S. S. Adler *et al.*, (2005); J. Adams *et al.*, Phys. Rev. Lett. **91**, 172302 (2003).
3. Y. L. Dokshitzer and D. E. Kharzeev, Phys. Lett. **B519**, 199 (2001).
4. M. Djordjevic, M. Gyulassy, and S. Wicks, Phys. Rev. Lett. **94**, 112301 (2005); N. Armesto, A. Dainese, C. A. Salgado, and U. A. Wiedemann, Phys. Rev. **D71**, 054027 (2005).
5. I. Vitev, Phys. Lett. **B630**, 78 (2005).
6. D. Magestro, nucl-ex/0510002.
7. S. J. Brodsky, H. J. Pirner, and J. Raufeisen, (2005).
8. S. S. Adler *et al.*, Phys. Rev. **C69**, 034910 (2004).
9. X.-N. Wang, Nucl. Phys. **A702**, 238 (2002); X.-N. Wang, Phys. Lett. **B595**, 165 (2004).
10. A. L. S. Angelis *et al.*, Physica Sripta **19**, 116 (1979).
11. P. Abreu *et al.*, Eur. Phys. J. **C13**, 573 (2000); G. Alexander *et al.*, Z. Phys. **C69**, 543 (1996).