Heavy Ion Collisions at the LHC
Last Call for Predictions
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Azimuthal anisotropy of jet quenching

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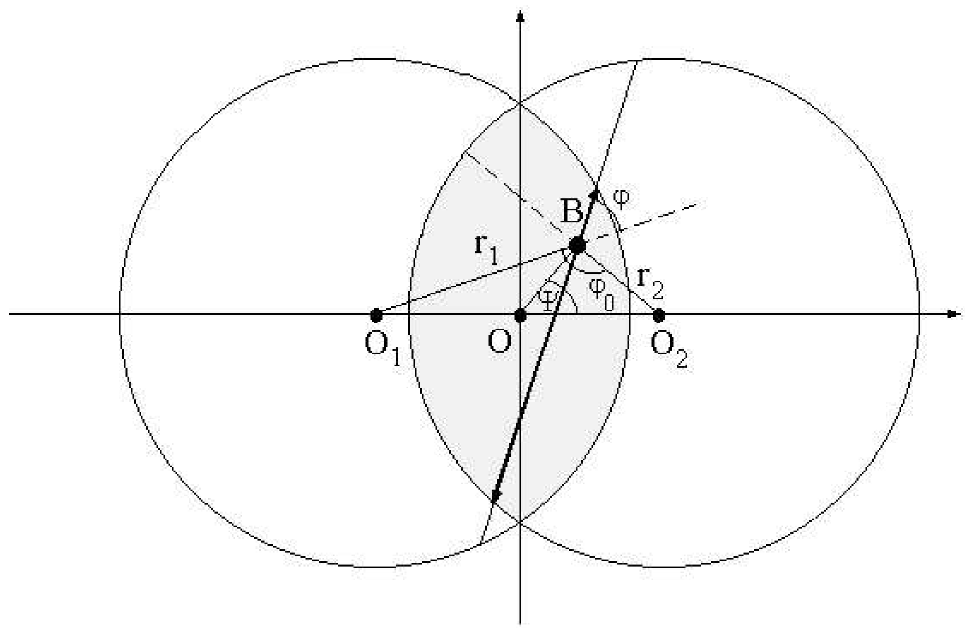
The azimuthal anisotropy of particle spectrum is one of the most important tools to study properties of dense QCD-matter created in heavy ion collisions. It is usually characterized by the second coefficient of the Fourier expansion of particle azimuthal distribution, so called elliptic flow coefficient, v_2.

The momentum dependence of v_2 for high-p_T hadrons, observed in semi-central AuAu collisions at RHIC, strongly supports the presence of rescattering and energy loss of hard partons in the azimuthally asymmetric volume of the nuclear reaction.

A novel observable at the LHC will be the azimuthal anisotropy for a hard jet itself (due to partonic energy loss carried out of jet cone), which can be reconstructed in high multiplicity environment with a good efficiency and low background starting from the energy $E_T^{\rm jet} \sim$ 50-100 GeV

This effect was analyzed in the frame of PYQUEN energy loss model (*Eur. Phys. J. C 45, 211 (2006)*) at $\sqrt{s} = 5.5A$ TeV.

The nuclear overlap region



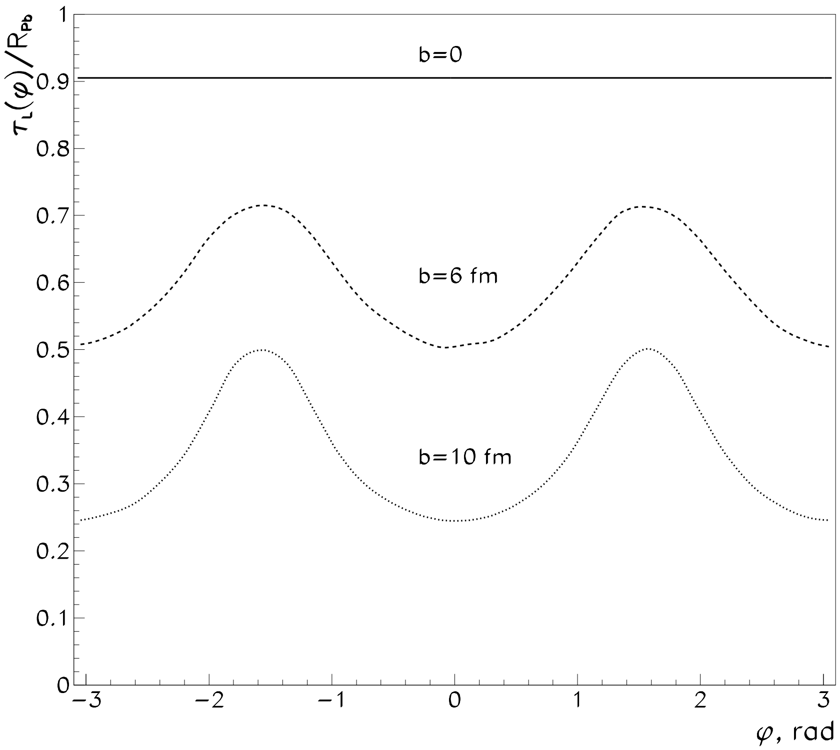
Jet production in high energy symmetric nucleus-nucleus collision in the plane of impact parameter $\vec{b}$. O_1 and O_2 are nucleus centers, $OO_2 = -O_1O = b/2$. B is the dijet production vertex; r is the distance from the beam axis to B; r_1, r_2 are distances between nucleus centers and B.

It is straightforward to evaluate the time $\tau_L = L$ it takes for the jet to traverse the dense zone:

$$\boldsymbol{\tau_L = min\{\sqrt{R_A^2 - r_1^2 \sin^2\phi} - r_1 \cos\phi,}$$

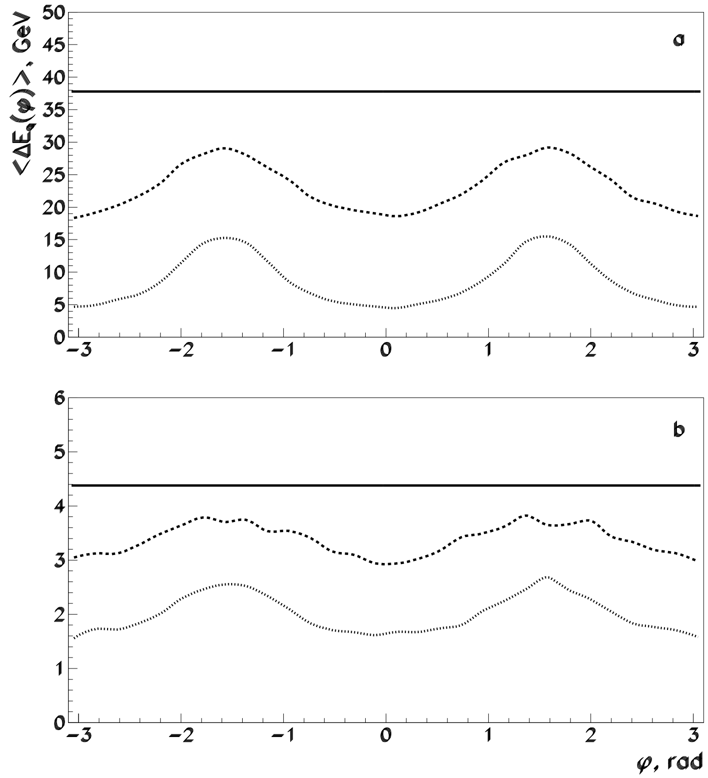
$$\boldsymbol{\sqrt{R_A^2 - r_2^2 \sin^2(\phi - \varphi_0)} - r_2 \cos(\phi - \varphi_0)\},}$$

where $\varphi = \phi - (\psi/|\psi|) \arccos\{(r \cos\psi + b/2)/r_1)\}$ is the isotropically distributed angle which determines the direction of a jet relative to vector $\vec{r_1}$, φ is the azimuthal angle between the direction of a jet and $\vec{b}$, $\varphi_0 = (\psi/|\psi|) \arccos \frac{r^2 - b^2/4}{r_1 r_2}$ is the angle between vectors $\vec{r_1}, \vec{r_2}$. One can see that for noncentral collisions value τ_L depends on φ: it is maximum at $\varphi = \pm\pi/2$ and minimum at $\varphi = 0$.



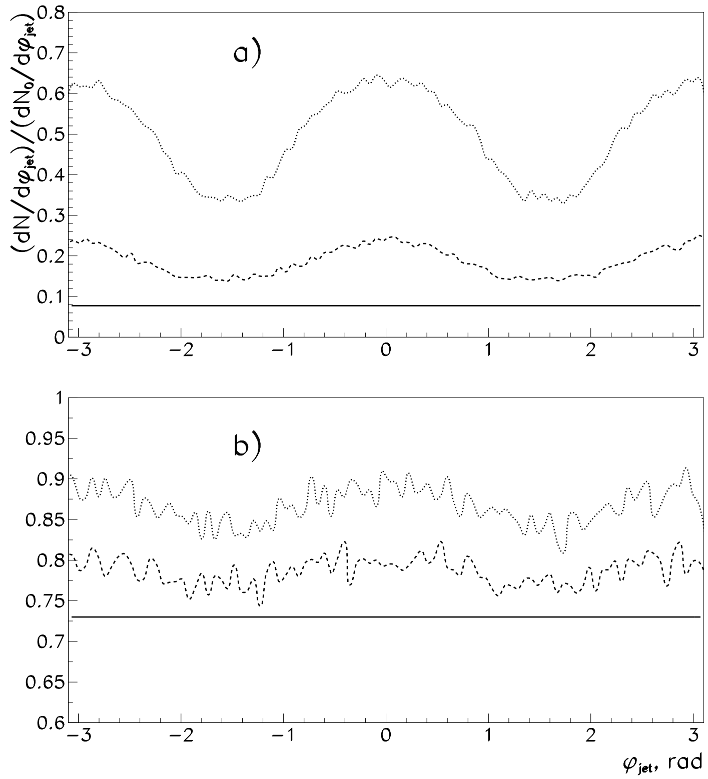
Mean proper time $\tau_L(\varphi)/R_{Pb}$ of the escape of a hard parton from dense matter as a function of the parton azimuthal angle with respect to the reaction plane for PbPb collisions at the impact parameter values of $b = \mathbf{0}$ (solid curve), $\mathbf{6}$ (dashed curve), and $\mathbf{10}$ fm (dotted curve).

The anisotropy of medium-induced partonic energy loss goes up with increasing collision impact parameter b, because the azimuthal asymmetry of the interaction volume gets stronger. However, the absolute value of the energy loss goes down with increasing b due to the reduced mean path length and the initial energy density.

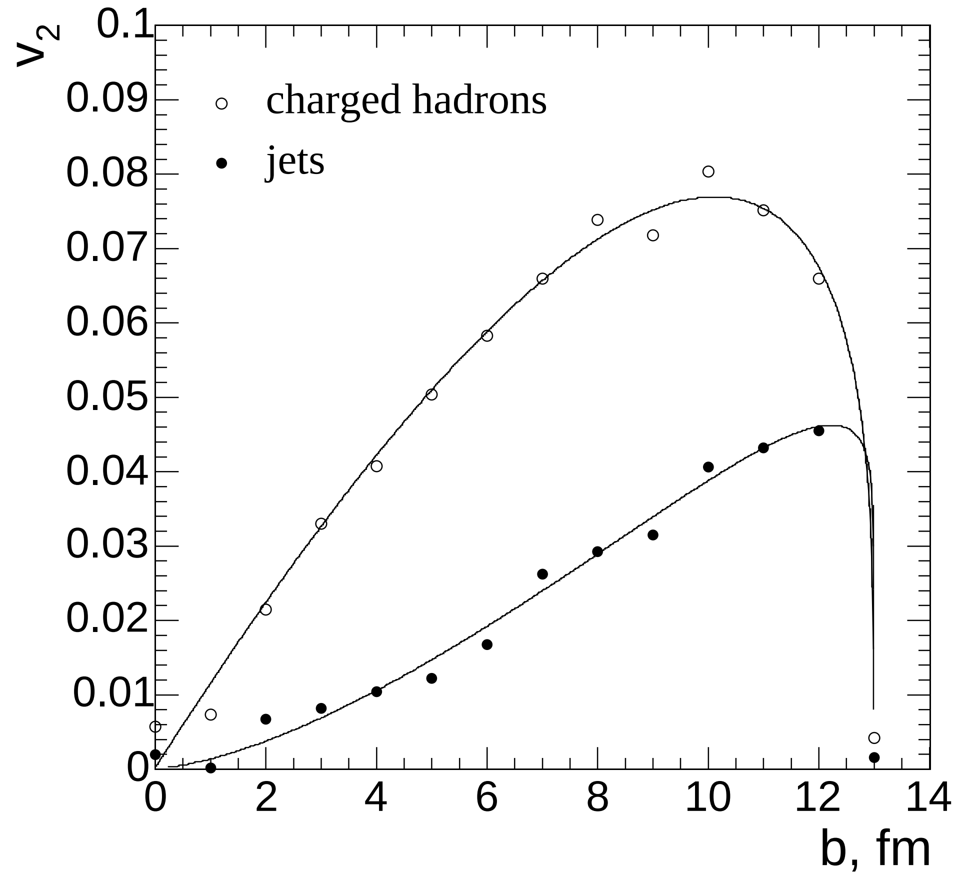


Mean radiative (a) and collision (b) energy loss of a hard quark with initial energy of $E_T^q = 100$ GeV versus the quark azimuthal angle for PbPb collisions at the impact parameter values of $b = 0$ (solid curve), 6 (dashed curve), and 10 fm (dotted curve).

The non-uniform dependence of the loss on the parton azimuthal angle φ (with respect to the reaction plane) is then mapped onto the final parton spectra in semi-central collisions which are approximated well by the elliptic form. It results in the elliptic anisotropy of observed high-p_T hadrons and hard jets



The jet distribution over azimuthal angle for the cases with collisional and radiative loss (a) and collisional loss only (b). The histograms (from bottom to top) correspond to the impact parameter values $b =$ 0,6 and 10 fm.



The impact parameter dependence of elliptic flow coefficients $v_2^{\rm jet}$ for jets with $E_T^{\rm jet} > 100$ GeV (black circles) and $v_2^{\rm h}$ for inclusive charged hadrons with $p_T > 20$ GeV$/c$ (open circles) in PbPb events triggered on jets, $|\eta^{\rm h}| < 2.5$ and $|\eta^{\rm jet}| < 3$.

The absolute values of v_2 for high-p_T hadrons is larger that one's for jets by a factor of $\sim 2-3$.

However, the shape of b-dependence of v_2^{h} and v_2^{jet} is quite similar: it increases almost linearly with the growth of the impact parameter b and becomes a maximum at $b \sim 1.6 R_A$ (where R_A is the nucleus radius).

After that, the v_2 coefficients drop rapidly with increasing b: this is the domain of impact parameter values, where the effect of decreasing energy loss due to a reducing effective transverse size of the dense zone and initial energy density of the medium is crucial and not compensated anymore by the stronger non-symmetry of the volume.