Energy loss of heavy quarks at forward rapidities at LHC

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Heavy quarks produced at the early stage of relativistic heavy-ion collisions are believed to be an efficient probe for the study of Quark Gluon Plasma (QGP). A charm quark/antiquark produced at the initial time of interaction will pass through the QGP, colliding with quarks and gluons and radiating gluons. It will later combine with a light antiquark/quark to produce a D meson whose subsequent semi-leptonic decay will carry information about the initial hot and dense stage of the collision. The large rapidity window which opens at LHC provides an environment varying with the rapidity. Thus in one single experiment, dependence on initial temperature etc. of the energy loss mechanisms can be put to a rigorous test.

For the medium-induced radiative energy loss of a charm quark, a number of formalisms have been proposed in the literature [1–3]. In this work we make a comparison of the results obtained using these mechansims. We estimate the radiative energy loss of a charm quark considering DGLV formulation [1] where the radiation pattern from the finite number of Feynman diagrams are computed, XDZR formulation [2] where light path integral approach is used and ASW formulation [3] where multiple elastic scattering in a spatially extended color field is computed. Similarly, for the collisional energy loss of a charm quark, a number of formalisms have been proposed [4–6]. We estimate the collisional energy loss of a charm quark considering Peigne and Peshier (PP) formulation [4] where a fixed coupling approximation is used, Braaten and Thoma (BT) formulation [5] where a quantum field theoretic formalism is used and Bjorken formulation [6] where the energy loss of quarks is estimated in light of the ionization of charged particles in ordinary matter. The formalism of Bjorken is extended by BT [5] for heavy quark energy loss through QGP matter. A comparison of the results for energy loss at central rapidity, using these different mechanisms is given in an accompanying paper. In this work we discuss the results for more forward rapidities.

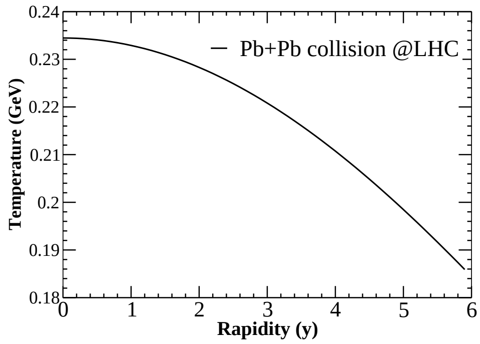

FIG. 1: Variation of Temperature of QGP with rapidity y for $(\frac{dN_g}{dy})_0 \approx$ 2550 at τ=L/2 and L=4 fm.

The rapidity dependence of the temperature of the plasma is as shown in FIG.1. All the results are obtained with number of flavours N_f = 3, $C_f = 4/3$, mass of charm quark $m_c = 1.6$ GeV, α_s=0.3, average path length L = 4 fm, particle density $\frac{dN_g}{dy} = (\frac{dN_g}{dy})_0 e^{\frac{-y^2}{2\sigma^2}}$, $(\frac{dN_g}{dy})_0 \approx$ 2550 and $\sigma = 5$.

ΔE at forward rapidities

We perform the calculations in the frame in which the rapidity of the charm quark is same as the fluid rapidity.

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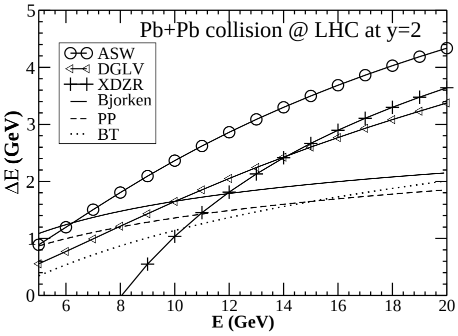

FIG. 2: Collisional(lines without symbol) and radiative(lines with symbol) energy loss of a charm quark at y=2.

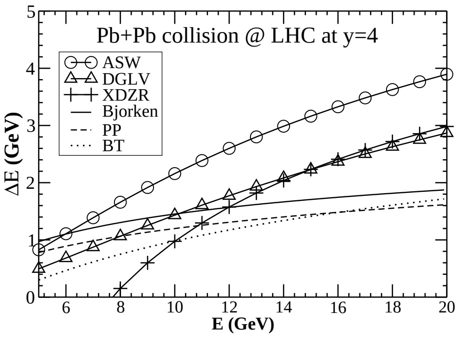

FIG. 3: Collisional(lines without symbol) and radiative(lines with symbol) energy loss of a charm quark at y=4.

The heavy quark cross section for pp collisions is calculated using NLO QCD treatment [7]. The factorization and renormalization scales μ_F=μ_R=1.5 GeV are used and the value of mean intrinsic transverse momentum $< k_T >$ is calculated from the Gaussian broadening of intrinsic transverse momentum at LHC as 1 GeV [8]. We have obtained an accurate parametrization for dN_c/d^2p_Tdy at LHC energy:

$$\frac{dN_c}{d^2p_Tdy} = \frac{a}{(b+p_T)^c} \qquad (1)$$

TABLE I: Parameters for the charm quark distribution dN_c/d^2p_Tdy for Pb+Pb at 5.5A TeV (Eq. 1). We have used CTEQ4M PDF data set for nucleon. The range of validity of the parameters is $p_T = 5-20$ GeV

	$y=0$	$y=2$	$y=4$
a	5.58×10^2	2.48×10^3	4.62×10^4
LHC b	1.786	2.347	3.21
c	5.56	6.176	7.6

In FIGs.2 and 3, we show the energy loss due to the collisions and radiations at y=2 and 4. We see that once p_T is of the order of 10 GeV or more the radiative energy dominates over the collisional energy loss. The collisional energy loss is also found to be only marginally dependent on p_T while the radiative energy loss is seen to rise rapidly with increase in p_T. The consequences of reduced energy loss at more forward rapidities on various observables like the nuclear modification factor R_{AA} and co-related charm decay is underway. We expect these results to constrain the models under study. The formalism will also be extended to the study of energy loss of bottom quarks.

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