

## Fractional energy loss of heavy mesons at the LHC energies

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### Introduction

One of the main goal of relativistic heavy-ion collider experiments is to study the bulk properties of the strongly-interacting matter, usually referred as the Quark-Gluon Plasma (QGP). Heavy quarks, i.e. charm and beauty quarks, are excellent probes of the QGP as they are produced in the early stage of the collisions and witness the entire space-time evolution of the system. Heavy quarks lose their energy in the hot and dense QCD medium through collision and radiation and ultimately fragments to heavy (D or B) mesons. Medium effects are quantified through the measurement of nuclear modification factor ( $R_{AA}$ ) of particles is defined as the ratio of invariant transverse momentum yield of particles in heavy-ion collisions with respect to the corresponding cross section in pp collisions scaled by the nuclear overlap function. In recent PHENIX collaboration has discussed an alternative way to measure the in-medium energy loss which is effective shift ( $\Delta p_T$ ) in  $p_T$  spectra of light hadrons recorded in nucleus-nucleus and proton-proton collisions [1]. It has been shown that the fractional energy loss of partons,  $\Delta E/E$ , is indeed significantly different at RHIC and LHC kinematic conditions even though the  $R_{AA}$  is similar [2]

The facts motivate us to carry out an emperical study of fractional energy loss of heavy-quarks at RHIC and LHC energies. For this purpose, we have parameterized the invariant momentum yield of heavy mesons by Hagedorn function [3]. The fitt parameters are then utilised to find a relation between fractional energy loss parameter  $\Delta m_T$  and  $R_{AA}$

of heavy mesons measured at the LHC experiment.

### Formalism

The nuclear modification factor ( $R_{AA}$ ) of produced particles is described as the ratio of the cross section of produced particles in heavy-ion collisions and the same in pp collisions, scaled to per nucleon-nucleon collisions:

$$R_{AA}(p_T, b) = \frac{d\sigma^{AA}/d^2p_T dy(b)}{d\sigma^{pp}/d^2p_T dy(b)}. \quad (1)$$

Inspired of Hagedron function, we parameterise the production cross-section of heavy mesons produced in pp collisions as:

$$d\sigma/d^2p_T dy = A \left(1 + \frac{m_T}{p_0}\right)^{-n}, \quad (2)$$

where  $A$ ,  $n$ ,  $p_0$  are constants and  $m_T = \sqrt{p_T^2 + m^2}$ .  $A$  has dimension  $GeV^{-2}$ ,  $p_0$  is in  $GeV$  and  $n$  is dimensionless, can be related to the nature of parton scatterings involved in the collisions. We have chosen  $m_T$  instead of  $p_T$  as it is the relevant hard momentum scale for heavy quark production [4].

In the same spirit, we write the invariant transverse momentum distribution of hadrons in AA collisions as:

$$d\sigma^{AA}/d^2p_T dy = A \left(1 + \frac{m_T + \Delta m_T}{p_0}\right)^{-n}, \quad (3)$$

The resoning behind writing Eq. 3 lies in the assumption that particle yield at a given  $p_T$  in AA collisions would be similar to the yield of particles in pp collisions at  $p_T + \Delta p_T$ . The shift  $\Delta p_T$  (or  $\Delta m_T$ ) includes the medium effect, chiefly energy loss of parent quark inside the plasma. Using Eq. 1, 2 and 3, we shall obtain the expression for energy shift  $\Delta m_T$ :

$$\Delta m_T = \left( (R_{AA}(p_T))^{-1/n} - 1 \right) (p_0 + m_T). \quad (4)$$

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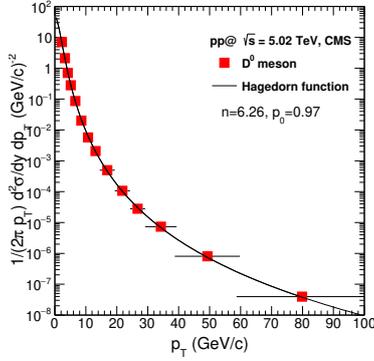


FIG. 1: The invariant yield of  $D^0$  mesons in p + p collisions at  $\sqrt{s} = 5.02$  TeV measured by CMS Collaboration.

## Results and Discussions

In order to study the fractional energy loss suffered by heavy quarks in QGP, we have parameterized the invariant yield of  $D^0$  mesons for p+p collisions at the LHC energies with Eq. 2 and obtained the parameters  $n$  and  $p_0$ . Figure displays the fitted invariant yield of  $D^0$  mesons in pp collisions at  $\sqrt{s} = 5.02$  TeV measured by CMS Collaboration [5]. Similar exercise have been performed for different center of mass energies. Next we have calculated the  $\Delta m_T$  using the extracted parameters  $n$  and  $p_0$ , and the data of  $R_{AA}$  for a given centrality. The variation of  $\Delta m_T$  vs  $m_T$  is depicted in Figure 2 for Pb+Pb collisions at  $\sqrt{s_{NN}} = 2.76$  and 5.02 TeV. Now we are looking for an empirical relation between  $\Delta m_T$  and  $m_T$ , thus we have fitted the graph as:

$$\Delta m_T = a(m_T + c)^\alpha \quad (5)$$

where  $a$  is normalization constant,  $\alpha$  is the exponent.  $c$  is the offset transverse mass, is so adjusted that  $\Delta m_T$  is positive always. We have found the value of exponent  $\alpha$  is about 0.5 at both collision energies. The observation may imply that heavy quark energy loss mechanism does not significantly change while the centre of mass energy increases almost by double. The parent heavy quark lose

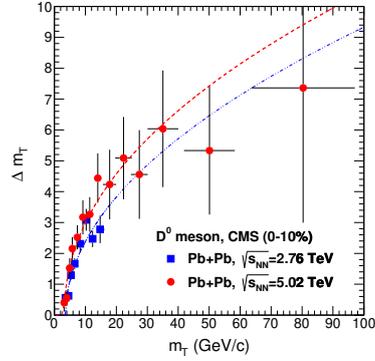


FIG. 2: The fractional energy loss  $\Delta m_T$  vs  $m_T$  of  $D^0$  mesons in Pb + Pb collisions at  $\sqrt{s_{NN}} = 2.76, 5.02$  TeV. The data of  $R_{AA}$  of  $D^0$  mesons are adopted from CMS [5]

energy via multiple collisions and radiation while traversing the QGP, results in deficit of yield at a given  $p_T$  bin. The effect has been also imprinted on the momenta of  $D^0$  meson, fragmenting from the heavy quark. In addition, our finding suggests that parent heavy quark may lose energy through coherent gluon emission. In this LPM regime, the energy loss per collision ( $\Delta E$ ) is proportional to the square root of energy ( $E$ ) of the parton [6]. A comparison of  $\Delta E$  vs  $E$  of heavy quarks at the LHC kinematic conditions for different energy loss models is underway.

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## References

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