Effect of heavy-quark energy loss on the muon differential production cross section in Pb-Pb collisions at 5.5A TeV

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Le facteur de modification nucléaire des muons dans les collisions centrales Pb+Pb à 5.5A TeV a été évalué. Pour le domaine en impulsion transverse de muons inférieur 25 GeV, une suppression importante de la production des muons est attendue. Ces muons sont issus principalement de la décroissance semi-leptonique des saveurs lourds, et ces derniers devraient interagir fortement avec le plasma des quarks et des gluons formé dans les collisions centrales Pb+Pb. Pour des impulsions supérieures à 25 GeV, les bosons électrofaibles deviennent la source principale des muons via leur désintégration leptonique. Les bosons électrofaibles n'interagissent pas avec le plasma et en conséquence le facteur de modification nucléaire devra être seulement sensible aux effets froids.

Heavy quarks are regarded as effective probes of the strongly-interacting medium produced in ultra-relativistic heavy-ion collisions, since they are produced in the initial hard-scattering processes and they may subsequently interact with the medium. Heavy-quark medium-induced energy loss will be one of the most captivating topics to be addressed at LHC. In hadron–hadron collisions at LHC energies, muons are predominantly produced in semi-leptonic decays of heavy-flavoured hadrons, mostly beauty for muon pt 4 GeV/c. Thus, in heavy-ion collisions, the muon pt distribution is sensitive to b-quark energy loss effects. The muon pt distributions in pp and Pb–Pb collisions at LHC energies are calculated considering the semi-muonic decays of heavy-flavoured hadrons and the muonic decay of W and Z bosons. The pt and rapidity distributions of W/Z and of their decay muons are obtained from the PYTHIA event generator. The resulting pt distributions are normalized to the NNLO cross sections that is a cross section per nucleon–nucleon collision of 6.56 (7.34) nb for the W and 0.63 (0.68) nb for the Z in Pb–Pb (pp) collisions at 5.5 TeV, including the muonic branching ratios (10.6% for W and 3.4% for Z). We use the NLO pQCD calculation implemented in the HVQMNR program to obtain the heavy-quark pt–y double-differential cross sections, with the following parameters values: for charm, m_c = 1.2 GeV and factorization and renormalization scales μ_F = μ_R = $2\mu_0$. For beauty, m_b = 4.75 GeV and μ_F = μ_R = μ_0. Finally, we decay the hadron into a muon according to the spectator model.

The muon production cross sections per nucleon–nucleon collision from charm (beauty) at $\sqrt{s_{NN}}$ = 5.5 TeV that we obtain are 0.415 mb (20 μb) in Pb–Pb collisions and 0.637 mb (23 μb) in pp collisions. A charm (beauty) semi-muonic branching ratio of 9.6% (11.0%) has been considered.

We compute the muon pt distribution taking into account the heavy quark energy loss in the strongly-interacting medium that is expected to be formed in central Pb–Pb collisions at LHC energies. For modelling the energy loss of heavy quarks by medium-induced gluon radiation, we used the quenching weights in the multiple soft scattering approximation.

We start by presenting, in Fig. 1, the muon production cross-section as a function of transverse momentum in the 10% most central Pb–Pb collisions, when only nuclear shadowing is included. The contributions from charm, beauty and weak gauge bosons are shown separately. Due to their large masses, W and Z bosons are mainly produced with small transverse momentum, pt $m_{W,Z}$. Therefore, the decay muons have typically pt $m_{W,Z}/2$. In the range 4–30 GeV/c beauty decays prevail, and at larger pt the W decays represent the largest contribution to the muon spectra.

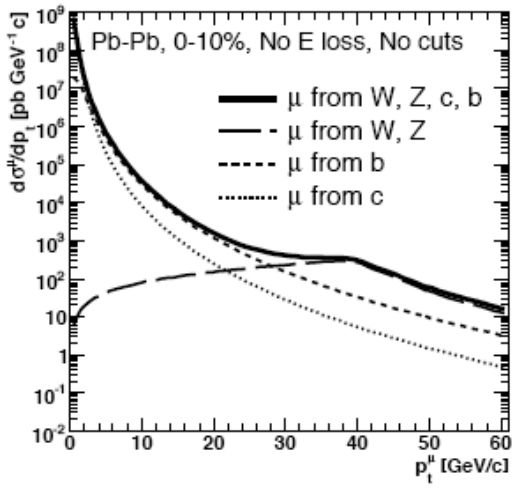

Fig. 1. Muons in central (0–10%) Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.5 TeV. Heavy-quark pt-differential cross section normalized to one binary nucleon–nucleon collision.

We now include in the calculation the in-medium energy loss for heavy quarks. Besides the Pb–Pb-to-pp nuclear modification factor R_{AA}, also the central-to-peripheral nuclear modification factor R_{CP} will provide information on the medium-induced suppression of b quarks. The central (0–10%) to peripheral (40–70%) ratios are shown in Fig. 2. In central (0–10%) collisions the yield might be reduced with respect to peripheral collisions (40–70%) by a factor 2–3 in the pt range from about 2 GeV/c to about 13 GeV/c, where the b-quark contribution dominates. When going to larger pt, the RCP of muons increases fast and then flattens at around 1.0 at forward rapidity.

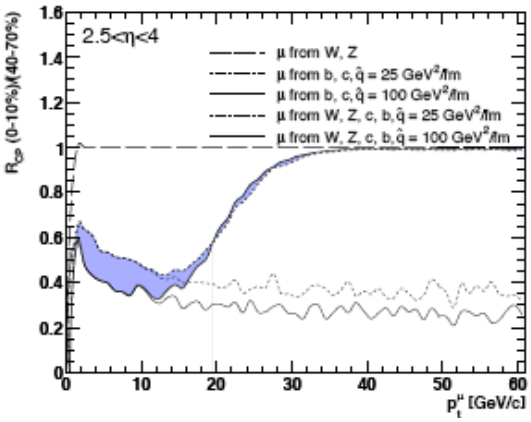

Fig. 2. Central (0–10%) to peripheral (40–70%) nuclear modification factors of muons from W, Z, c and b decays in Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.5 TeV.

These muon nuclear modification factors could provide the first experimental observation of the b quark medium-induced suppression in Pb–Pb collisions at the LHC. The presence of a medium-blind component (muons from W and Z decays) that dominates the high-pt muon yield. will allow an intrinsic calibration of the medium-sensitive probe (heavy quarks), because it will provide a handle on the strength of the initial-state effects that may alter the hard-scattering cross sections in nucleus–nucleus collisions at the unprecedented energies of the LHC.

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La distribution en impulsion transverse des muons produits dans les collisions centrales PbPb à 5.5A TeV a été calculé en tenant compte des effets induits par la formation du plasma des quarks et des gluons (PQG) dans les collisions centrales Pb+Pb à 5.5A TeV. Nous constatons que la décroissance semi-leptonique des quarks de saveurs lourdes est la source principale de muons pour les impulsions inférieures à 25 GeV. Au delà de 25 GeV, la source principale des muons est la décroissance leptonique des boson électro-faibles. Les quarks lourds devraient interagir fortement avec le PQG et, en conséquence ils perdront une part importante de leur énergie. Pour cette raison, une suppression importante du facteur de modification nucléaire de muons est prédite pour les impulsions inférieures à 25 GeV. Au contraire, les bosons électro-faibles W et Z n'interagissent pas avec le PQG et le facteur de modification nucléaire devrait atteindre l'unité pour les impulsions supérieures à 25 GeV. Ce travail a été publie dans la revue internationale *Physics Letters* B, volume 663, page 202.

References

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