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Future physics opportunities with W and Z bosons and top quarks for high-density QCD at LHC

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Droplets of quark-gluon plasma (QGP), a state of strongly interacting quantum chromodynamics matter, are produced in high-energy collisions between heavy nuclei. Recent theoretical studies suggest using the top quark, the heaviest elementary particle known to date, as a novel time-delayed probe of the QGP. The top quark is a colored particle that decays almost always into a W boson plus a bottom quark, hence by "triggering" on the top quark transverse momentum we can select W bosons produced at different QGP timescales. At variance with most of the experimental signatures considered in the literature so far, where a limiting factor is that they are the integrated result of a fast-evolving and extended medium, top quark thus offers the opportunity to perform a full tomographic analysis of the QGP time evolution.

Using the largest data sample of lead-lead collisions recorded by the Compact Muon Solenoid (CMS) experiment at the unprecedented nucleon-nucleon center-of-mass energy of 5.02 TeV achieved at the Large Hadron Collider (LHC), evidence of top quark pair production is reported. Therefore, for the first time, the feasibility of reconstructing top quark decay products is demonstrated, irrespective of whether interacting with the medium (bottom quarks) or not (leptonically decaying W bosons). This measurement paves the way for more detailed investigations of top quark production in nuclear interactions with increased colliding energies and/or luminosities at current or future higher-energy colliders. In particular, it establishes a new tool for probing nuclear parton distribution functions as well as the properties of the produced QGP.

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