Top quark production with proton tagging at the CERN LHC

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We propose to study top quark pair diffractive production ($pp \to pt\bar{t}X$ or $pp \to pt\bar{t}Xp$, where X represents additional hadrons produced in the collision) in proton-proton collision as a new probe to constrain the diffractive structure function of the proton, which is still ill understood. The diffractive exchange can be thought of as two-gluon exchange at leading order in QCD. Thus, hard diffraction gives us information on the parton content of the proton complementary to that obtained in the standard inclusive probes. Diffractive top quark pair production provides additional constraints on diffractive PDFs (dPDFs) given the hard energy scale given by the top quark mass and its direct sensitivity to the gluonic content of the pomeron. Single- or double-diffractive single top quark production ($pp \to ptWX$ or $pp \to ptWXp^{(*)}$) allows the possibility to unambiguously constrain the intrinsic bottom quark content of the diffractive structure function. The intrinsic b-quark densities of the pomeron are assumed to be zero in standard dPDFs fits. The latter would also enable us to challenge one of the underlying assumptions adopted by the H1 and ZEUS experiments in the extraction of dPDFs, namely quark flavor symmetry of parton densities, which might be important at higher $\sqrt{s}$.

In diffractive reactions where the protons remain intact, we can use so-called Roman Pot (RP) detectors to tag the forward scattered protons. The ATLAS and CMS experiments are equipped with such a set of RP detectors, known as ATLAS Forward Proton (AFP) [1] and CMS Precision Proton Spectrometer (PPS) [2], respectively. The top quark decay daughters can be reconstructed using the standard techniques used at the Tevatron and LHC experiments. The expected cross section rates for diffractive top quark production is on the order of 1 pb for pp collisions at $\sqrt{s} = 14$ TeV, including the screening effects encoded in the so-called survival probability. Studies could be done to address the constraint potential of this new probe of hard diffraction based on the Forward Physics Monte Carlo (FPMC) event generator, and the Pythia 8 event generator. Given that the diffractive structure function of the proton is an important piece in the global picture of parton structure of the proton, it is instrumental to test possible ways of better understanding it at the LHC and future colliders.

High-mass central exclusive production of top quark pairs is also sensitive to the electromagnetic process $\gamma\gamma \to t\bar{t}$, which has so far not been studied experimentally. Indeed, in very peripheral proton-proton collisions, the electromagnetic field generated by the protons can be treated as a source of quasi-real photons which can then interact to produce the top quark pair system. The coherent photon emission off the proton is under control theoretically. Photoproduction of top quark pairs is directly sensitive to the electric charge of the top quark, which so far in the SM is assumed to be the same as that of the up and strange quarks, but which is rather difficult to be directly measured. The cross section for top quark photoproduction is of the order of 0.1 fb at 13 TeV [3, 4]. We could probe this process at the High Luminosity LHC, possibly reaching the level of observation of the process. The central exclusive production channel may give us a unique access to spin-correlation effects between the vector gauge bosons and the top quark, since there is no underlying event, proton remnants and initial-state radiation effects like in inclusive top quark production. These effects may dilute these spin-correlation effects in the data. Deviations from the QED $\gamma\gamma \to t\bar{t}$ process are parametrized in terms of effective field theory operators. Sensitivities on the strength coupling parameters associated to these effective operators will be extracted, similar as in Refs. [5, 6, 7, 8].

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