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## Prospective for A Fixed-Target Experiment at the LHC: AFTER@LHC

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We outline the physics opportunities [Brodsky:2012vg] which are offered by a next generation and multi-purpose fixed-target experiment exploiting the LHC beams extracted by a bent crystal. This mature extraction technique offers an ideal way to obtain a clean and very collimated high-energy beam, without altering the performance of the LHC [Uggerhoj:2005xz, Scandale:2011zz, LUA9]. The multi-TeV LHC beams grant the most energetic fixed-target experiment ever performed, to study  $pp$ ,  $pd$  and  $pA$  collisions at  $\sqrt{s_{NN}} \simeq 115$  GeV and  $PbA$  collisions at  $\sqrt{s_{NN}} \simeq 72$  GeV. AFTER – for A Fixed-Target Experiment – gives access to new domains of particle and nuclear physics complementing that of collider experiments, in particular RHIC and the projects of electron-ion colliders. The typical instantaneous luminosity achievable with AFTER in  $pp$  and  $pA$  mode [Brodsky:2012vg] surpasses that of RHIC by more than 3 orders of magnitude and is comparable to that of the LHC collider mode. This provides a quarkonium and heavy-flavour observatory in  $pp$  and  $pA$  collisions where, by instrumenting the target-rapidity region, gluon and heavy-quark distributions of the proton, the neutron and the nuclei can be accessed at large  $x$  and even at  $x$  larger than unity in the nuclear case.

The nuclear target-species versatility provides a unique opportunity to study cold nuclear matter versus the features of the hot and dense matter formed in heavy-ion collisions, including the formation of the quark-gluon plasma. During the one-month lead runs,  $PbA$  collisions can be studied at a luminosity comparable to that of RHIC and the LHC over the full range of target-rapidity domain. Modern detection technology should allow for the study of quarkonium excited states, in particular the  $\chi_c$  and  $\chi_b$  resonances, even in the challenging high-multiplicity environment of  $pA$  and  $PbA$  collisions, magnified by the boost of the fixed-target mode.

Precise data from  $pp$ ,  $pA$  and  $PbA$  should help to greatly improve our understanding of heavy-quark and quarkonium production, to clear the way to use them for gluon and heavy-quark PDF extraction in free and bound nucleons, to unravel cold from hot nuclear effects and to restore the status of heavy quarkonia as a golden test of lattice QCD in terms of dissociation temperature predictions at  $\sqrt{s_{NN}}$  where the recombination process is expected to have a small impact. The fixed-target mode also has the advantage to allow for spin measurements with polarized targets. We will discuss a tentative design for AFTER, and report the projected detector performances from the first preliminary simulations.

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