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Editorial

Physics at a Fixed-Target Experiment Using the LHC Beams

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The collisions of the high-energy LHC beams with fixed targets, including polarized and nuclei targets, can greatly expand the range of fundamental physics phenomena accessible at CERN. The fixed-target mode allows for an intensive study of rare processes, novel spin-correlations, high x_F dynamics, diffractive physics, and nuclear phenomena as well as the novel spectroscopy of hadrons carrying multiple heavy quarks.

The extraordinary energy of the LHC beams would make such a LHC fixed-target physics program, referred to as AFTER@LHC thereafter, unique. We believe that such a facility is of much interest to a wide range of hadron, nuclear, and particle physicists and we are glad that this volume gathers fifteen state-of-the-art contributions supporting such an endeavour.

The contributions to this volume are of different kinds, ranging from theoretical articles reviewing the theory of some effects to be studied with such a facility to experimental contributions detailing the techniques and the performances of specific targets and feasibility studies of key measurements. We briefly outline them below topic by topic.

On the theory side, the volume gathers two very important reviews. The first one entitled "A Review of the Intrinsic Heavy Quark Content of the Nucleon" by S. J. Brodsky et al. summarizes the current knowledge on the charm content in the proton. This is a hot topic which has direct implications, for instance, with neutrino astrophysics. The second theory review by D. Boer et al. entitled "The Gluon Sivers Distribution: Status and Future Prospects" focuses on the gluon Sivers effect which encapsulates the connection between the gluon angular momentum and the proton spin.

The nucleon-spin-structure topic is complemented by two theoretical predictions for the transverse single-spin asymmetries for pions, jets, and photons, one by M. Anselmino et al. entitled "Transverse Single-Spin Asymmetries in Proton-Proton Collisions at the AFTER@LHC Experiment in a TMD Factorisation Scheme" and the other by K. Kanazawa et al. entitled "Transverse Single-Spin Asymmetries in Proton-Proton Collisions at the AFTER@LHC Experiment."

This sets the context for measurements using polarised gas targets which is precisely the scope of the contribution of C. Barschel et al. entitled "A Gas Target Internal to the LHC for the Study of pp Single-Spin Asymmetries and Heavy Ion Collisions" which paves the way for a polarised internal gas target in the LHC complex. Such a proposal follows from the successful target system of the HERMES experiment at DESY. In this contribution, the luminosities expected for unpolarised and polarised hydrogen and nuclear gas targets are estimated.

Continuing with contributions dealing with the hadron structure and the perturbative regime of Quantum Chromodynamics, the contribution by F. A. Ceccopieri entitled "Studies of Backward Particle Production with a Fixed-Target

Experiment Using the LHC Beams" explores the possibility of studying in hadronic collisions with AFTER@LHC the *fracture* functions using the production of a hard dilepton, just as in the Drell-Yan process, but in association with an observed final-state hadron.

Quarkonium production is also known to be an ideal probe of Quantum Chromodynamics at the interface between its perturbative and nonperturbative domain. The contribution of Y. Feng and J.-X. Wang entitled "Next-to-Leading Order Differential Cross Sections for J/ψ, $\psi(2S)$, and Υ Production in Proton-Proton Collisions at a Fixed-Target Experiment Using the LHC Beams" presents a next-to-leading order analysis of the quarkonium yields at the energies reached by AFTER@LHC and demonstrates how such measurements in a new energy domain would constrain the long-distance physics parameters needed to predict the quarkonium yields even at collider energies.

The use of nuclear targets with the LHC lead beam provides a new window to study nuclear phenomena, such as the quark-gluon plasma in the target rest frame (or over a large rapidity range). The contribution of K. Zhou et al. entitled "Antishadowing Effect on Charmonium Production at a Fixed-Target Experiment Using LHC Beams" analyses the impact of the antishadowing of gluons in heavy nuclei on the production of charmonia at AFTER@LHC. This work clearly demonstrates that the study of heavy-ion collisions in an energy domain between SPS and RHIC, never explored before with high luminosities, can perfectly complement the RHIC and LHC heavy-ion program and provide measurements of phenomena inaccessible otherwise.

Along these lines, one of the superior advantages of the fixed-target mode is to provide extremely precise analyses of proton-nucleus collisions. These are mandatory baselines to interpret nucleus-nucleus results and are extremely useful to learn more about the nuclear phenomena in the subfemtometer domain. The contribution of F. Arleo and S. Peigné entitled "Quarkonium Suppression from Coherent Energy Loss in Fixed-Target Experiments Using LHC Beams" studies the impact of a coherent energy loss on charmonium production in proton-lead collisions whereas the contribution of R. Vogt entitled "Gluon Shadowing Effects on J/ψ and Υ Production in $p+Pb$ Collisions at $\sqrt{s_{NN}} = 115$ GeV and $Pb+p$ Collisions at $\sqrt{s_{NN}} = 72$ GeV at AFTER@LHC" studies in detail the impact of the nuclear modification of the gluon densities on the quarkonium yields.

These studies are nicely complemented by a paper entitled "Feasibility Studies for Quarkonium Production at a Fixed-Target Experiment Using the LHC Proton and Lead Beams (AFTER@LHC)" by L. Massacrier et al. which is the first of its kind and which paves the way for the elaboration of a number of figures-of-merit which would support a forthcoming *Expression of Interest* for AFTER@LHC. In addition to these detailed feasibility studies, D. Kikoła in his contribution entitled "Prospects for Open Heavy Flavor Measurements in Heavy Ion and $p + A$ Collisions in a Fixed-Target Experiment at the LHC" looks at the feasibility to perform state-of-the-art studies of open charm and beauty production in proton-nucleus and nucleus-nucleus collisions at AFTER@LHC. Finally, A. B. Kurepin and N. S. Topilskaya review in their contribution entitled "Quarkonium Production and Proposal of the New Experiments on Fixed Target at the LHC" the current knowledge of quarkonium studies in heavy-ion collisions and discuss the opportunities offered by an internal solid target at the ALICE experiment interaction point.

The list of studies linked to heavy-ion collisions is completed by the contribution of R. E. Mikkelsen et al. entitled "Bremsstrahlung from Relativistic Heavy Ions in a Fixed Target Experiment at the LHC" which focuses on the emission process of high-energy photon in ultraperipheral heavy-nucleus collisions. Such measurements would enable us to extract the charge distributions of nuclei with a lifetime down to femtoseconds.

The last contribution by J. P. Lansberg et al. entitled "Near-Threshold Production of $W^{\pm}$, Z^0, and H^0 at a Fixed-Target Experiment at the Future Ultrahigh-Energy Proton Colliders" is to our knowledge the first work ever dealing with the possibility offered by a possible fixed-target experiment at the future ultrahigh-energy hadron facilities such as HE–LHC, FCC–hh, and SppC.

Overall, we are very hopeful that the contributions gathered in the present volume will give a new impetus to initiatives in favour of a fixed-target program at the LHC. In particular, they will certainly serve as a solid background for the writing of a forthcoming *Expression of Interest* for such a facility.

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