Available online at www.sciencedirect.com
ScienceDirect
Nuclear Physics B (Proc. Suppl.) 214 (2011) 3–36
NUCLEAR PHYSICS B
PROCEEDINGS SUPPLEMENTS
www.elsevier.com/locate/npbps

Quarkonium production in high energy proton-proton and proton-nucleus collisions

Z. Conesa del Valle[a,b], G. Corcella[c], F. Fleuret[d], E.G. Ferreiro[e], V. Kartvelishvili[f], B. Kopeliovich[g], J.P. Lansberg[h], C. Lourenço[b], G. Martinez[i], V. Papadimitriou[j], H. Satz[k], E. Scomparin[l], T. Ullrich[m], O. Teryaev[n], R. Vogt[o,p], J.X. Wang[q]

[a] Institut Pluridisciplinaire Hubert Curien (IPHC), Université de Strasbourg, CNRS-IN2P3, Strasbourg, France
[b] European Organization for Nuclear Research (CERN), Geneva, Switzerland
[c] INFN, Laboratori Nazionali di Frascati, Via E.Fermi 40, I-00044, Frascati, Italy
[d] LLR, École polytechnique, CNRS/IN2P3, Palaiseau, France
[e] Departamento de Física de Partículas and IGFAE, Universidad de Santiago de Compostela, Santiago de Compostela, Spain
[f] Lancaster University, Lancaster LA1 4YB,United Kingdom
[g] Departamento de Física Universidad Técnica Federico Santa María, Instituto de Estudios Avanzados en Ciencias e Ingeniería and Centro Científico-Tecnológico de Valparaíso, Casilla 110-V, Valparaíso, Chile
[h] IPNO, Université Paris-Sud 11, CNRS/IN2P3, F-91406 Orsay, France
[i] SUBATECH, Ecole des Mines de Nantes, Université de Nantes, CNRS-IN2P3, Nantes, France
[j] Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, Illinois, 60510, U.S.A
[k] Fakultät für Physik, Universität Bielefeld, Germany
[l] INFN Torino, Via P. Giuria 1, Torino, I-10125, Italy
[m] Brookhaven National Laboratory, Upton, New York 11973, USA
[n] Bogoliubov Laboratory of Theoretical Physics, JINR, Dubna 141980, Russia
[o] Physics Divsion, Lawrence Livermore National Laboratory, Livermore, CA 94551
[p] Physics Department, University of California at Davis, Davis, CA 95616
[q] Institute of High Energy Physics, Chinese Academy of Sciences, P.O. Box 918(4), Beijing, 100049, China

Abstract

We present a brief overview of the most relevant current issues related to quarkonium production in high energy proton-proton and proton-nucleus collisions along with some perspectives. After reviewing recent experimental and theoretical results on quarkonium production in pp and pA collisions, we discuss the emerging field of polarisation studies. Afterwards, we report on issues related to heavy-quark production, both in pp and pA collisions, complemented by AA collisions. To put the work in broader perpectives, we emphasize the need for new observables to investigate the quarkonium production mechanisms and reiterate the qualities that make quarkonia a unique tool for many investigations in particle and nuclear physics.

Keywords: Quarkonium, production, proton, nucleus

Contents

doi:10.1016/j.nuclphysbps.2011.03.053

1. Introduction

The attention devoted to heavy quarkonium states started with the discovery of the J/ψ charmonium meson in 1974 followed by the Υ bottomonium meson in 1977. From the theoretical point of view, quarkonium bound states offer a solid ground to probe Quantum Chromodynamics (QCD), due to the high scale provided by the large mass of the heavy quarks.

The application of perturbative techniques together with the factorization principle gave birth to the Color-Singlet Model. Since then, the appearance of puzzling measurements has never stopped and has led to new challenges for theorists. These puzzles required the introduction of new ideas providing new probes for the understanding of QCD. Fifteen years ago, the observation of an excess in charmonium production reported by the CDF Collaboration, by orders of magnitude over the theoretical predictions available at that time, gave rise to the theory of Non-Relativistic QCD.

Data collected at the Tevatron, at HERA, and at low energy e^+e^- colliders has never ceased to challenge the existing theoretical models: the apparent violation of universality arising when comparing data from the hadron-hadron and the lepton-hadron colliders, the disagreement between the predictions for the polarization of the J/ψ produced in hadronic collisions and the current data, as well as the excess of double charmonium production first observed by Belle. The solution to these puzzles requires new theoretical developments on the underlying production mechanism(s), as the computation of higher-order corrections for characteristic processes and the study of new production processes, in addition to investigations of new observables not analyzed so far.

The interest in this field and its developments are not limited to the issue of the production mechanisms. The progress in lattice calculations and effective field theories have converted quarkonium physics into a powerful tool to measure the mass of the heavy quarks and the strength of the QCD coupling. The properties of production and absorption of quarkonium in a nuclear medium provide quantitative inputs for the study of QCD at high density and temperature. In fact, charmonium production off nuclei is one of the most promising probes for studying properties of matter created in ultrarelativistic heavy-ion collisions. Since quarkonium is heavy, it can be used as a probe of the properties of the medium created in these collisions, such as the intensity of interactions and possible thermalization.

Lattice QCD calculations predict that, at sufficiently large energy densities, hadronic matter undergoes a phase transition to a plasma of deconfined quarks and gluons. Since 1986, substantial efforts have been dedicated to the research of high-energy heavy-ion collisions in order to reveal the existence of this phase transition and to analyze the properties of strongly interacting matter in the new phase. The study of quarkonium production and suppression is among the most interesting investigations in this field since calculations indicate that the QCD binding potential is screened in the QGP phase. The level of screening increases with the energy density/temperature of the system. Given the existence of several quarkonium states, each of them with different binding energies, it is expected that they will sequentially melt into open charm or bottom mesons above succesive energy density thresholds. Moreover, the SPS and RHIC data on charmonium physics have brought to light further interesting results, among them puzzling features in proton-nucleus data, which highlighted new aspects of charmonium physics in nuclear reactions, namely the role of cold nuclear matter effects.

The startup of the LHC and the opening of the new energy frontier will offer new and challenging possibilities for the study of quarkonia.

All the above reasons have motivated the organization of the Quarkonium 2010 workshop held at the Ecole Polytechnique (Palaiseau, France) from July 29 to July 31, 2010. This workshop, gathering both experimentalists and theorists, was devoted to finding answers to the numerous quarkonium-hadroproduction puzzles at the dawn of the LHC era and the concurrent apogee of the Tevatron and RHIC. Introductory and review talks focusing upon recent theoretical and experimental results were presented, in addition to six topical Working Group (WG) discussion sessions, each one devoted to a specific issue: