QCD and Strongly Coupled Gauge Theories:

Challenges and Perspectives

QCD and strongly coupled gauge theories: challenges and perspectives

N. Brambilla*†,[1] S. Eidelman†,[2,3] P. Foka†‡,[4] S. Gardner†‡,[5] A.S. Kronfeld†,[6]
M.G. Alford‡,[7] R. Alkofer‡,[8] M. Butenschoen‡,[9] T.D. Cohen‡,[10] J. Erdmenger‡,[11]
. Fabbietti‡,[12] M. Faber‡,[13] J.L. Goity‡,[14,15] B. Ketzer‡,[1] H.W. Lin‡,[16] F.J. Llanes-Estrada‡,[17]
H.B. Meyer‡,[18] P. Pakhlov‡,[19,20] E. Pallante‡,[21] M.I. Polikarpov‡,[19,20] H. Sazdjian‡,[22]
A. Schmitt‡,[23] W.M. Snow‡,[24] A. Vairo‡,[1] R. Vogt‡,[25,26] A. Vuorinen‡,[27] H. Wittig‡,[18]
P. Arnold,[28] P. Christakoglou,[29] P. Di Nezza,[30] Z. Fodor,[31,32,33] X. Garcia i Tormo,[34]
Höllwieser,[13] M.A. Janik,[35] A. Kalweit,[36] D. Keane,[37] E. Kiritsis,[38] A. Mischke,[39] R. Mizuk,[19,
G. Odyniec,[41] K. Papadodimas,[21] A. Pich,[42] R. Pittau,[43] J.-W. Qiu,[44,45] G. Ricciardi,[46,47]
C.A. Salgado,[48] K. Schwenzer,[7] N.G. Stefanis,[49] G.M. von Hippel,[18] and V.I. Zakharov[11,19]

in publication on EPJC

QCD and strongly coupled gauge theories: challenges and perspectives

N. Brambilla*†,[1] S. Eidelman†,[2,3] P. Foka†‡,[4] S. Gardner†‡,[5] A.S. Kronfeld†,[6]
M.G. Alford‡,[7] R. Alkofer‡,[8] M. Butenschön‡,[9] T.D. Cohen‡,[10] J. Erdmenger‡,[11] L. Fabbietti‡,[12]
M. Faber‡,[13] J.L. Goity‡,[14,15] B. Ketzer‡§,[1] H.W. Lin‡,[16] F.J. Llanes-Estrada‡,[17]
H.B. Meyer‡,[18] P. Pakhlov‡,[19,20] E. Pallante‡,[21] M.I. Polikarpov‡,[19,20] H. Sazdjian‡,[22]
A. Schmitt‡,[23] W.M. Snow‡,[24] A. Vairo‡,[1] R. Vogt‡,[25,26] A. Vuorinen‡,[27] H. Wittig‡,[18]
P. Arnold,[28] P. Christakoglou,[29] P. Di Nezza,[30] Z. Fodor,[31,32,33] X. Garcia i Tormo,[34] R. Höllwieser,[13]
M.A. Janik,[35] A. Kalweit,[36] D. Keane,[37] E. Kiritsis,[38,39,40] A. Mischke,[41] R. Mizuk,[19,42]
G. Odyniec,[43] K. Papadodimas,[21] A. Pich,[44] R. Pittau,[45] J.-W. Qiu,[46,47] G. Ricciardi,[48,49]
C.A. Salgado,[50] K. Schwenzer,[7] N.G. Stefanis,[51] G.M. von Hippel,[18] and V.I. Zakharov[11,19]

We highlight the progress, current status, and open challenges of QCD-driven physics, in theory and in experiment. We discuss how the strong interaction is intimately connected to a broad sweep of physical problems, in settings ranging from astrophysics and cosmology to strongly-coupled, complex systems in particle and condensed-matter physics, as well as to searches for physics beyond the Standard Model. We also discuss how success in describing the strong interaction impacts other fields, and, in turn, how such subjects can impact studies of the strong interaction. In the course of the work we offer a perspective on the many research streams which flow into and out of QCD, as well as a vision for future developments.

Work for this document started in the preparation of Xconf in Munich in 2012

THE TENTH EDITION IN THE SERIES!

Madrid (Spain) 2010

Mainz (Germany) 2008

Açores (Portugal) 2006

Sardinia (Italy) 2004

Gargnano (Italy) 2002

Vienna (Austria) 2000

TJNAF (USA) 1998

Como (Italy) 1996, 1994

Work for this document started in the preparation of Xconf in Munich in 2012

THE TENTH EDITION IN THE SERIES!

Madrid (Spain) 2010

Mainz (Germany) 2008

Açores (Portugal) 2006

Sardinia (Italy) 2004

Gargnano (Italy) 2002

Vienna (Austria) 2000

TJNAF (USA) 1998

Como (Italy) 1996, 1994

The conference has become
an important discussion forum
for strong interactions: use the discussion
at the meeting to formulate "visions
for strong theories" at a particular
important time for particle physics
after the discovery of the Higgs.

Conference Sections

Section A: *Vacuum Structure and Confinement*

Conveners: M. Faber (TU Vienna), M. Polikarpov (ITEP, Moscow)

Section B: *Light Quarks*

Conveners: R. Alkofer (Univerität Graz), B. Ketzer (TU München), J. Goity (JLAB, Newport News), H. Sazdjian (IPN Orsay), H. Wittig (JGU Mainz)

Section C: *Heavy Quarks*

Conveners: G. Bodwin (Argonne National Lab), P. Pakhlov (ITEP, Moscow), J. Soto (University of Barcelona), A. Vairo (TU München)

Section D: *Deconfinement*

Conveners: P. Arnold (Univerity of Virginia), Y. Foka (GSI, Darmstadt), H. Meyer (JGU Mainz), J. Rafelski (University of Arizona)

Section E: *QCD and New Physics*

Conveners: S. Gardner (University of Kentucky), H. W. Lin (University of Washington), F. Llanes Estrada (UC Madrid), M. Snow (Indiana University)

Section F: *Nuclear and Astroparticle Physics*

Conveners: M. Alford (Washington University in St. Louis), T. Cohen (University of Maryland), L. Fabbietti (TU München), A. Schmitt (TU Vienna)

Section G: *Strongly Coupled Theories*

Conveners: J. Erdmenger (MPP Munich), E. Katz (Boston University), E. Pallante (University of Groningen), A. Szczepaniak (Indiana University)

AFTER TWO YEARS of WORK:

QCD and strongly coupled gauge theories: challenges and perspectives

This document highlights the status and challenges of strong-interaction physics at the beginning of a new era initiated by the discovery of the Higgs particle at Cern

AFTER TWO YEARS of WORK:

QCD and strongly coupled gauge theories: challenges and perspectives

This document highlights the status and challenges of strong-interaction physics at the beginning of a new era initiated by the discovery of the Higgs particle at Cern

effort. Together, we have sought to address a common set of questions: What are the latest achievements and highlights related to the strong interaction? What important open problems remain? What are the most promising avenues for further investigation? What do experiments need from theory? What does theory need from experiments? In addressing these questions, we aim to cast the challenges in quantum chromodynamics (QCD) and other strongly-coupled physics in a way that spurs future developments.

Contents

243

[2759] P. A. R. Ade et al. (Planck Collaboration) (2013), 1303.5076.

2759 references!

Acknowledgements

We dedicate this document to the memory of Mikhail Polikarpov, who passed away in July 2013. Misha worked with us for decades as a convener of the "Confinement" section of the Quark Confinement and Hadron Spectrum Series. He guided and expanded the scientific discussion of that topic, inspiring and undertaking new research avenues. From its initial conception, he supported the enterprise of this document and organized Chapter 8, writing the part on confinement himself. He attracted the XI$^{\text{th}}$ Conference on Quark Confinement and the Hadron Spectrum to St. Petersburg (September 8-12, 2014; see `http://phys.spbu.ru/confxi.html`). His warm and kind personality, his high sense of humor, his ideas in physics and his special energy in imagining and realizing new projects will be always a loss and an example for us. We also miss four other physicists who made lasting contributions to the field of strong interactions: Dmitri Diakonov, Nikolai Uraltsev, Pierre van Baal, and Kenneth Wilson. We remember Misha, Dima, Ken, Kolya, and Pierre with fondness and gratitude.

We expect that this work will attract a broad readership, ranging from practitioners in one or more subfields of QCD, to particle or nuclear physicists working in fields other than QCD and the SM, to students starting research in QCD or elsewhere.

but also for funds agencies, projects applications ...

We expect that this work will attract a broad readership, ranging from practitioners in one or more subfields of QCD, to particle or nuclear physicists working in fields other than QCD and the SM, to students starting research in QCD or elsewhere.

but also for funds agencies, projects applications ...

So we hope that you will find useful and you will use this work!