

# **Springer Proceedings in Physics**

Volume 174

More information about this series at <http://www.springer.com/series/361>

Bipul Bhuyan  
Editor

# XXI DAE-BRNS High Energy Physics Symposium

Proceedings, Guwahati, India,  
December 8–12, 2014

 Springer

*Editor*  
Bipul Bhuyan  
Department of Physics  
Indian Institute of Technology Guwahati  
Guwahati, Assam  
India

ISSN 0930-8989  
Springer Proceedings in Physics  
ISBN 978-3-319-25617-7  
DOI 10.1007/978-3-319-25619-1

ISSN 1867-4941 (electronic)  
ISBN 978-3-319-25619-1 (eBook)

Library of Congress Control Number: 2015952533

Springer Cham Heidelberg New York Dordrecht London  
© Springer International Publishing Switzerland 2016

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media  
([www.springer.com](http://www.springer.com))

*Dedicated to my father whom I miss dearly...*

# Preface

The need for publishing the proceedings for the XXI edition of the DAE-BRNS High Energy Physics (HEP) Symposium was felt much earlier than the commencement of the symposium. Dissemination of scientific ideas and knowledge through the publication of the proceedings constitutes a significant component of any conference and the XXI DAE-BRNS High Energy Physics Symposium is no exception.

DAE-BRNS HEP symposium is held every other year in India, supported by the Board of Research in Nuclear Sciences, Department of Atomic Energy, Government of India and is considered as one of the premiere conferences organized in India in the field of elementary particle physics. Around 250 physicists and researchers participated in the symposium to discuss the latest advancements in the fields of particle physics, astro-particle physics, cosmology, and development of new detector technology and accelerator, which was held at Indian Institute of Technology Guwahati during December 8–12, 2014.

This volume includes manuscripts from both invited and contributed talks from most of the active areas of research in particle physics, namely electroweak physics, QCD, heavy ion physics, heavy flavor physics, CP violation, neutrino physics, astro-particle physics, cosmology, formal theory, future colliders, new machines, and BSM Physics such as SUSY, extra dimensions, composites, etc.

The book is intended for both young as well as advanced researchers of the field who are actively following the exciting time that we are all in after the discovery of the Higgs boson at CERN and the recent results from the intensity and the cosmic frontier experiments.

Guwahati, India

Bipul Bhuyan

# Acknowledgments

Organizing a conference and bringing out the proceedings of the conference is a daunting task, and I must confess, it would not have been possible without the support and active participation of my colleagues and students in the Department of Physics, IIT Guwahati. The cooperation that I received from the National Organizing Committee during the organization of the symposium and the editorial board during the preparation of this volume is unparalleled. I must also take this opportunity to thank my co-conveners of the symposium, Dr. Arunansu Sil of IIT Guwahati, Dr. Gobinda Majumdar of TIFR, Mumbai, and all my colleagues in the High Energy Physics group at the Department of Physics, IIT Guwahati. It was indeed a pleasure to work with you all!

I was lucky to have a large pool of student volunteers who worked relentlessly during the conference. It would have been a herculean task to organize this event without the support of Satendra Kumar, Deepanwita Dutta, Biswajit Karmakar, Biswaranjan Das, Kamal Dutta, Kamal Joyti Nath, Nitin Yadav, Deepanjali Goswami, Abhijit Kumar Saha, Shibbananda Sahoo, Pulak Talukdar, Pankaj Saha, Srimoy Bhattacharya, Subhasish Behera, Soumya Ranjan Das, Purusottam Ghosh, Ghanashyam Meher, Nivedita Ghosh, Wadbor Wahlang, Robin T. George, Maitrayee Mandal, and Ayan Biswas. Thank you.

I must also thank the Director, IIT Guwahati for his constant support and encouragement and the entire staff of the institute for providing the assistance whenever necessary. Needless to say, the symposium would not have been possible without the financial support from the Board of Research in Nuclear Sciences, Department of Atomic Energy, Government of India and the European Physical Journal (EPJ).

I would like to thank Sabine Lehr, Associate Editor, Springer-Verlag, GmbH for constantly working with me from the beginning to bring out this volume. Above all, this acknowledgment will not be complete if I do not say thank you to my wife, Pahi for her constant support and company in the journey that we have made together so far. I am lucky to have you by my side. Thank you.

Guwahati, India

Bipul Bhuyan



# Contents

## Part I QCD and Heavy Ion Physics

<b>1</b>	<b>Physics in the Light Flavoured Sector</b> . . . . .	<b>3</b>
	B. Ananthanarayan	
<b>2</b>	<b>Double Parton Scattering Studies via Di-boson Processes Using the CMS Detector at LHC.</b> . . . . .	<b>11</b>
	A. Mehta, R. Kumar, V. Bhatnagar, K. Mazumdar and J.B. Singh	
<b>3</b>	<b>Three-Loop HTLpt Thermodynamics at Finite Temperature and Chemical Potential.</b> . . . . .	<b>17</b>
	Aritra Bandyopadhyay, Najmul Haque, Munshi G. Mustafa, Michael Strickland and Nan Su	
<b>4</b>	<b>Charting the Evolution of the Strong Interaction's Degrees of Freedom</b> . . . . .	<b>23</b>
	Arjun Trivedi, Ralf Gothe and Evan Phelps	
<b>5</b>	<b>Vector Meson Spectral Function and Dilepton Rate in an Effective Mean Field Model</b> . . . . .	<b>31</b>
	Chowdhury Aminul Islam, Sarbani Majumder, Najmul Haque and Munshi G. Mustafa	
<b>6</b>	<b>Axial-Vector Form Factors in the Chiral Quark Constituent Model</b> . . . . .	<b>37</b>
	Harleen Dahiya and Monika Randhawa	
<b>7</b>	<b>Nucleon Structure in AdS/QCD</b> . . . . .	<b>43</b>
	Dipankar Chakrabarti and Chandan Mondal	
<b>8</b>	<b>Dual QCD Formulation and Quark-Antiquark Static Potential.</b> . . . . .	<b>49</b>
	Garima Punetha and H.C. Chandola	

<b>9</b>	<b>Infrared Abelian Dominance in a Special Gauge</b> . . . . .	55
	Haresh Raval and Urjit A. Yajnik	
<b>10</b>	<b>Multiplicity Characteristics of Forward-Backward Emitted Particles in Heavy-Ion Interactions at SPS Energies.</b> . . . . .	61
	Mir Hashim Rasool, M. Ayaz Ahmad, Muzamil Bhat, Om Veer Singh and Shafiq Ahmad	
<b>11</b>	<b>NICA Project at JINR</b> . . . . .	67
	Vladimir D. Kekelidze, Richard Lednicky, Viktor A. Matveev, Igor N. Meshkov, Alexander S. Sorin and Grigory V. Trubnikov	
<b>12</b>	<b>Quark ACM with Massive Gluon</b> . . . . .	75
	Ishita Dutta Choudhury and Amitabha Lahiri	
<b>13</b>	<b>Flavor-Singlet Axial Coupling Constant in the QCD Sum Rule.</b> . . . . .	81
	Janardan P. Singh	
<b>14</b>	<b>Do the <math>pp</math> Collisions at LHC Energies Form a Collective Medium?</b> . . . . .	87
	Jajati K. Nayak	
<b>15</b>	<b>Chiral Symmetry Breaking in the Lattice Gross-Neveu Model with the Borici-Creutz Fermion</b> . . . . .	93
	J. Goswami, D. Chakrabarti and S. Basak	
<b>16</b>	<b>Freeze-Out Conditions in High-Energy Heavy-Ion Experiments.</b> . . . . .	99
	L. Kumar, S. Chatterjee, S. Das, D. Mishra, B. Mohanty, R. Sahoo and N. Sharma	
<b>17</b>	<b>Exploring the Proton Spin Structure</b> . . . . .	105
	Cédric Lorcé	
<b>18</b>	<b>Bottomonium Suppression at LHC Energy Based on the Temperature Dependent Formation Time</b> . . . . .	115
	S. Ganesh and M. Mishra	
<b>19</b>	<b>Higher Harmonic Flow of <math>\phi</math> Meson in STAR at RHIC.</b> . . . . .	123
	Mukesh K. Sharma	
<b>20</b>	<b>A Study of Multiplicity Scaling in Nucleus-Nucleus Collisions.</b> . . . .	129
	N. Ahmad, A. Kamal and M.M. Khan	
<b>21</b>	<b>Disintegration of Quarkonia in QGP Due to Time Dependent Potential</b> . . . . .	135
	Partha Bagchi and Ajit M. Srivastava	
<b>22</b>	<b>Strange Hyperon Productions at LHC Energies.</b> . . . . .	141
	Purabi Ghosh, Santosh Kumar Agarwalla and Jajati K. Nayak	

<b>23</b>	<b>Study of the Double Parton Scattering via <math>W + 2\text{-Jet}</math> Process Using the CMS Detector at LHC</b> . . . . .	147
	R. Kumar, S. Bansal, M. Bansal, V. Bhatnagar, K. Mazumdar and J.B. Singh	
<b>24</b>	<b>Transverse Momentum Distribution of Identified Hadrons in Pb–Pb Collisions at <math>\sqrt{s_{NN}} = 2.76</math> TeV Within Multiple Freeze-Out Scenario</b> . . . . .	153
	Ranbir Singh, Bedangadas Mohanty and Sandeep Chatterjee	
<b>25</b>	<b>Centrality and Energy Dependence of Elliptic Flow of Light Nuclei in STAR.</b> . . . . .	159
	Md. Rihan Haque	
<b>26</b>	<b>Nuclei Production and Two Chemical Freeze-Out Model of High Energy Heavy Ion Collisions.</b> . . . . .	165
	Sandeep Chatterjee and Bedangadas Mohanty	
<b>27</b>	<b>Wigner Distributions of the Quark and Gluon in the Light-Front Dressed Quark Model.</b> . . . . .	171
	A. Mukherjee, S. Nair and V.K. Ohja	
<b>28</b>	<b>Strangeness Production in U+U Collisions at RHIC</b> . . . . .	177
	Srikanta Kumar Tripathy	
<b>29</b>	<b>Two Particle Correlation at Intermediate <math>p_T</math> with Identified Leading Hadron at LHC Energy Using AMPT Model</b> . . . . .	183
	Subikash Choudhury, Debojit Sarkar and Subhasis Chattopadhyay	
<b>30</b>	<b>Temperature and Multiplicity Fluctuations as a New Tool of Characterization for Heavy Ion Collisions at LHC Energy</b> . . . . .	189
	Sumit Basu, Rupa Chatterjee, Basanta K. Nandi and Tapan K. Nayak	
<b>Part II Heavy Flavor Physics, CP Violation</b>		
<b>31</b>	<b>Testing Violations of CP, CPT and Bose Symmetries via Dalitz Plots and Dalitz Prisms</b> . . . . .	197
	Dibyakrupa Sahoo	
<b>32</b>	<b>Search for the Decay <math>B_s^0 \rightarrow \eta\eta</math> at <math>\Upsilon(5S)</math> Resonance</b> . . . . .	203
	Kamal Jyoti Nath and Bipul Bhuyan	
<b>33</b>	<b>Exact Test of Standard Model in <math>B \rightarrow K^* \ell^+ \ell^-</math></b> . . . . .	209
	Rusa Mandal	
<b>34</b>	<b>Minimal Set of Texture Specific Quark Mass Matrices.</b> . . . . .	215
	Samandeep Sharma and Gulsheen Ahuja	

<b>35</b>	<b>Scalar Leptoquarks and the Rare B Meson Decays</b> . . . . .	221
	Suchismita Sahoo and Rukmani Mohanta	
<b>36</b>	<b>Exotic Charmonium-Like States from Belle</b> . . . . .	227
	Vishal Bhardwaj	
<b>Part III Neutrino Physics</b>		
<b>37</b>	<b>Study of Muonless Events at the INO ICAL Detector</b> . . . . .	239
	Ali Ajmi and S. Uma Sankar	
<b>38</b>	<b>TeV-Scale Leptogenesis</b> . . . . .	245
	P.S. Bhupal Dev	
<b>39</b>	<b>Neutrino Masses, Mixing and Leptogenesis in Type-I Seesaw with <math>A_4</math> Symmetry</b> . . . . .	255
	Biswajit Karmakar and Arunansu Sil	
<b>40</b>	<b>Large <math>\theta_{13}</math> and <math>S_3</math> Perturbation with Neutrino Mass Matrix</b> . . . . .	261
	Ch. Upender, Biswaranjan Behera and A. Giri	
<b>41</b>	<b>Determination of <math>\theta_{23}</math> Octant and Precision Measurement of Atmospheric Neutrino Oscillation Parameters @ INO-ICAL</b> . . . . .	267
	Daljeet Kaur, Md. Naimuddin and Sanjeev Kumar	
<b>42</b>	<b>CP Violation Study at LBNE in Conjunction with Reactors</b> . . . . .	273
	Debajyoti Dutta and Kalpana Bora	
<b>43</b>	<b>Phenomenological Analysis of Two Texture Zeros/Vanishing Cofactors of Neutrino Mass Matrices</b> . . . . .	279
	S. Dev, Lal Singh and Desh Raj	
<b>44</b>	<b>Resolving Entanglement of CPV Phase with Octant of <math>\theta_{23}</math>, and Leptogenesis</b> . . . . .	287
	Gayatri Ghosh and Kalpana Bora	
<b>45</b>	<b>RPC Electrode Characterisation and Performance Studies with Different Gas Compositions</b> . . . . .	293
	Md. Hasbuddin, A. Gaur, D. Kaur, P. Kumar, S. Mishra, P. Kumar, A. Kumar and Md. Naimuddin	
<b>46</b>	<b>Oscillation Studies with Upward-Going Muons Using INO-ICAL</b> . . . . .	299
	R. Kanishka, Vipin Bhatnagar and D. Indumathi	
<b>47</b>	<b>R&amp;D on Sub-keV Ge-Detectors for Studies on Electromagnetic Properties of Neutrino</b> . . . . .	305
	Lakhwinder Singh, G. Kiran Kumar and H.T. Wong	

**48 Neutrino Flux at NO $\nu$ A: Empirical Constraint and Sytematics Errors** . . . . . 311  
 Kuldeep K. Maan, H. Duyang, Sanjib R. Mishra and Vipin Bhatnagar

**49 Neutrino Mass Matrices with Two Texture Zeros and Near Maximal Atmospheric Neutrino Mixing** . . . . . 317  
 S. Dev, Radha Raman Gautam, Lal Singh and M.M. Gupta

**50 Exploring Texture Two-Zero Majorana Neutrino Mass Matrices with the Latest Neutrino Oscillation Data** . . . . . 323  
 Madan Singh and R.R. Gautam

**51 Atmospheric Neutrino Flux.** . . . . . 329  
 M. Sajjad Athar and M. Honda

**52 Can the Hint of  $\delta_{CP}$  from T2K Also Indicate the Hierarchy and Octant?** . . . . . 339  
 Monojit Ghosh, Srubabati Goswami and Sushant K. Raut

**53 Neutrino-Nucleon Cross Section in Ultra High Energy Regime.** . . . . . 345  
 Kalpana Bora and Neelakshi Sarma

**54 Cosmic Muon Induced EM Showers in NO $\nu$ A** . . . . . 353  
 Nitin Yadav, Hongue Duyang, Sanjib Mishra, Bipul Bhuyan and Peter Shanahan

**55 Constrained Analytical Interrelations in Neutrino Mixing.** . . . . . 363  
 Biswajoy Brahmachari and Probir Roy

**56 High Scale Unification of CKM and PMNS Mixing Matrices** . . . . . 369  
 Rahul Srivastava

**57 Glass RPC and Its Electrode Characterization.** . . . . . 377  
 K. Raveendrababu, P.K. Behera and B. Satyanarayana

**58 Non-vanishing  $\theta_{13}$  and CP-Violation in Inverse Neutrino Mass Matrix** . . . . . 383  
 Surender Verma and Shankita Bhardwaj

**59 Particle Production Measurements Using the MIPP Detector at Fermilab** . . . . . 389  
 Sonam Mahajan, Vipin Bhatnagar, Brajesh C. Choudhary and Rajendran Raja

**60 Is It All in a Perturbation?** . . . . . 395  
 Soumita Pramanick and Amitava Raychaudhuri

<b>61</b>	<b>Predicting Leptonic CP Phase by Considering Deviations in Charged Lepton and Neutrino Sectors. . . . .</b>	<b>401</b>
	M. Sruthilaya, C. Soumya, K.N. Deepthi and R. Mohanta	
<b>Part IV Astro-Particle Physics and Cosmology</b>		
<b>62</b>	<b>Primordial Generation of Magnetic Fields . . . . .</b>	<b>409</b>
	Jitesh R. Bhatt and Arun Kumar Pandey	
<b>63</b>	<b>Probing Dynamics of Phase Transitions Occurring Inside a Pulsar . . . . .</b>	<b>415</b>
	Partha Bagchi, Arpan Das, Biswanath Layek and Ajit M. Srivastava	
<b>64</b>	<b>Analysis of Lateral Distribution of Cherenkov Photons Associated with an EAS . . . . .</b>	<b>421</b>
	D. Kalita and K. Boruah	
<b>65</b>	<b>Explaining Muon Magnetic Moment and AMS-02 Positron Excess in a Gauged Horizontal Symmetric Model . . . . .</b>	<b>427</b>
	Gaurav Tomar	
<b>66</b>	<b>Angular Distributions of Cherenkov Photons in Extensive Air Showers of Gamma and Proton Primaries. . . . .</b>	<b>433</b>
	G.S. Das, P. Hazarika and U.D. Goswami	
<b>67</b>	<b>Design of a Small Cosmic Ray Air Shower Array to Study Atmospheric Effects . . . . .</b>	<b>439</b>
	K. Boruah, S. Zamal, M. Rahman, B. Tiru, U. Sarma and P.K. Boruah	
<b>68</b>	<b>P Type Point Contact Germanium Detector for Dark Matter Search . . . . .</b>	<b>447</b>
	M.K. Singh and H.T. Wong	
<b>69</b>	<b>Inflation After Planck and BICEP2. . . . .</b>	<b>453</b>
	Raghavan Rangarajan	
<b>70</b>	<b>Resonant Gravitino Production in the Early Universe . . . . .</b>	<b>463</b>
	Raghavan Rangarajan	
<b>71</b>	<b>Dark Matter in SM4 and Its Implications in LFV Decays . . . . .</b>	<b>467</b>
	Shivaramakrishna Singirala and Rukmani Mohanta	
<b>72</b>	<b>Synchrotron Radiation from Instabilities in the Early Universe . . . . .</b>	<b>473</b>
	Soma Sanyal	

**73 Muon Tomography for Carbon Storage and Monitoring . . . . . 479**  
 S. Pal, S.J. Clark, M. Coleman, J.G. Gluyas, V.A. Kudryavtsev,  
 J. Klinger, S.M. Paling, N.J.C. Spooner, S. Telfer, L.F. Thompson  
 and D. Woodward

**74 Consequences of Holographic Scalar Field Dark Energy  
 Models in Chameleon Brans-Dicke Cosmology. . . . . 487**  
 Surajit Chattopadhyay and Antonio Pasqua

**75 Galactic Center Gamma-Ray Excess and Higgs-Portal  
 Dark Matter . . . . . 493**  
 Tanmoy Mondal and Tanushree Basak

**Part V Formal Theory**

**76 Spectral Dimension of Kappa Space-Time . . . . . 501**  
 V. Anjana and E. Harikumar

**77 Torsion Geometries in U(1) Gauge Theory on  $D_5$ -brane. . . . . 507**  
 Deobrat Singh, Richa Kapoor and Supriya Kar

**78 Exact Background Solution for Matter Coupled Higher  
 Derivative Gravity . . . . . 513**  
 Lata Kh. Joshi

**79  $\kappa$ -Deformed Bohlin-Sundman Transformation . . . . . 519**  
 P. Guha, E. Harikumar and N.S. Zuhair

**Part VI Future Machines**

**80 Effect of Geometrical Artifacts on the Response  
 of INO-ICAL RPC. . . . . 527**  
 Abhik Jash, Nayana Majumdar, Supratik Mukhopadhyay  
 and Subhasis Chattopadhyay

**81 Building of a Bakelite Resistive Plate Chamber Prototype . . . . . 535**  
 Himangshu Neog, Sharmili Rudra, M.R. Bhuyan, S. Biswas,  
 B. Mohanty, Rudranarayan Mohanty, P.K. Sahu and S. Sahu

**82 Development of Silicon Pad and Strip Detectors  
 in High Energy Physics . . . . . 541**  
 Manoj Jadhav and Raghava Varma

**83 Study of Performance of Bakelite Resistive Pate  
 Chamber (RPC). . . . . 547**  
 R. Ganai, K. Agarwal, A. Roy, B. Muduli, S. Chattopadhyay,  
 Z. Ahammed, G. Das and S. Ramnarayan

<b>84</b>	<b>Assembly and Characterization of Resistive Plate Chambers in India for the CMS Detector . . . . .</b>	<b>553</b>
	R. Kumar, A. Mehta, V. Bhatnagar, J.B. Singh, R. Chudasama, A.K. Mohanty, L.M. Pant, R. Sehgal, S.T. Sehgal and R.G. Thomas	
<b>85</b>	<b>Delay and Offset Calibration Schemes for the INO ICAL Electronics . . . . .</b>	<b>559</b>
	P.K. Kaur, N.K. Mondal, Pathaleswar, M.N. Saraf, B. Satyanarayana, D. Sil and S.S. Upadhya	
<b>86</b>	<b>Soft-Core Processor Based Data Acquisition Module for ICAL RPCs with Network Interface . . . . .</b>	<b>565</b>
	M.N. Saraf, U. Gokhale, A. Lokapure, N.K. Mondal, P. Nagaraj, Pathaleswar, B. Satyanarayana, S.S. Upadhya and E. Yuvaraj	
<b>87</b>	<b>Study of the Spin-Parity of a Resonance via the Gold-Plated Decay Mode . . . . .</b>	<b>571</b>
	Tanmoy Modak	
<b>88</b>	<b>Study of Photon Detection Efficiency and Position Resolution of BESIII Electromagnetic Calorimeter . . . . .</b>	<b>577</b>
	Vindhyawasini Prasad, Chunxiu Liu, Xiaobin Ji, Weidong Li, Huaimin Liu and Xinchou Lou	
<b>Part VII Electroweak Physics</b>		
<b>89</b>	<b>Tau Reconstruction and Identification with Upgraded CMS Detector at LHC . . . . .</b>	<b>585</b>
	A.K. Kalsi, N. Dhingra, J.B. Singh, V. Bhatnagar and K. Mazumdar	
<b>90</b>	<b>Measurement of <math>\phi^*</math> Variable in Drell-Yan Events in p-p Collisions Using CMS Detector at LHC . . . . .</b>	<b>591</b>
	G. Walia, M. Kaur, K. Mazumdar, M. Guchait and R. Chatterjee	
<b>Part VIII Beyond Standard Model: SUSY, ExtraDimensions</b>		
<b>91</b>	<b>Mass Determination and Event Reconstruction at Large Hadron Collider . . . . .</b>	<b>599</b>
	Abhaya Kumar Swain and Partha Konar	
<b>92</b>	<b>Masses of Physical Scalars in Two Higgs Doublet Models . . . . .</b>	<b>605</b>
	Ambalika Biswas and Amitabha Lahiri	
<b>93</b>	<b>Identification of Type-III Seesaw Fermionic Triplet at the International Linear Collider . . . . .</b>	<b>611</b>
	Deepanjali Goswami and Poullose Poullose	



**94 Higgs Sector of NMSSM in the Light of Higgs Discovery . . . . . 619**  
 Jacky Kumar

**95 Search for Higgs→Invisible Decays at the LHC . . . . . 627**  
 Prolay Kumar Mal

**96 Neutral MSSM Higgs Bosons Searches in  $\tau\tau$  Channel  
 at CMS . . . . . 633**  
 Ram Krishna Dewanjee

**97 Study of Hadronic Event-Shape Variables in Multijet  
 Final States in  $pp$  Collisions at  $\sqrt{s} = 7$  TeV . . . . . 639**  
 Sandeep Bhowmik

**98 Influence of Anomalous  $VVh$  and  $VVhh$  on Determination  
 of Higgs Self-coupling . . . . . 645**  
 Satendra Kumar and P. Poullose

**99 Beyond Standard Model Higgs Boson Physics  
 at the CMS Experiment . . . . . 653**  
 Somnath Choudhury

**100 Electroweak Symmetry Breaking via Strong Dynamics  
 in the Precision Higgs Era: Extra Dimension  
 and Composite Higgs . . . . . 661**  
 Tirtha Sankar Ray

**101 What Do the New LHC Results on  $W_R$  Hint About Grand  
 Unified Theories? . . . . . 671**  
 Triparno Bandyopadhyay, Biswajoy Brahmachari  
 and Amitava Raychaudhuri

**Index . . . . . 677**

# **Editorial Board**

## **Chief-Editor**

Dr. Bipul Bhuyan  
Department of Physics,  
Indian Institute of Technology Guwahati  
Guwahati, Assam 781039, India

## **Editorial Board Members**

Prof. Kajari Mazumdar  
Department of High Energy Physics  
Tata Institute of Fundamental Research  
Homi Bhabha Road  
Mumbai 400005, India.

Prof. B. Ananthanarayan  
Centre for High Energy Physics  
Indian Institute of Science  
Bengaluru 560 012, India

Prof. Rahul Sinha  
Institute of Mathematical Sciences  
IV Cross Road, CIT Campus  
Taramani, Chennai 600 113  
Tamil Nadu, India.

Prof. L. Sriramkumar  
Department of Physics,  
IIT Madras, Chennai 600 036  
Tamil Nadu, India.

Prof. Anshuman Maharana  
Harish-Chandra Research Institute,  
Jhansi, Allahabad 21109, UP, India

Prof. Sanjay Kumar Swain  
School of Physics Sciences,  
NISER, Bhubaneswar, Orissa 751 021, India

Prof. Monoranjan Gurchait  
Department of Theoretical High Energy Physics  
Tata Institute of Fundamental Research  
Homi Bhabha Road  
Mumbai 400005  
India

# Contributors

- K. Agarwal** Birla Institute of Technology and Science, Pilani, Rajasthan, India
- Santosh Kumar Agarwalla** F. M. University, Odisha, India
- Z. Ahammed** Variable Energy Cyclotron Centre, Kolkata, India
- M. Ayaz Ahmad** Physics Department, Faculty of Science, University of Tabuk, Tabuk, Saudi Arabia
- N. Ahmad** Department of Physics, Aligarh Muslim University, Aligarh, India
- Shafiq Ahmad** Department of Physics, Aligarh Muslim University, Aligarh, India
- Gulsheen Ahuja** Department of Physics, Panjab University, Chandigarh, India
- Ali Ajmi** Homi Bhabha National Institute, Mumbai, India
- B. Ananthanarayan** Centre for High Energy Physics, Indian Institute of Science, Bengaluru, India
- V. Anjana** University of Hyderabad, Hyderabad, India
- Partha Bagchi** Institute of Physics, Bhubaneswar, India
- Aritra Bandyopadhyay** Theory Division, Saha Institute of Nuclear Physics, Kolkata, India
- Triparno Bandyopadhyay** Department of Physics, University of Calcutta, Kolkata, India
- M. Bansal** Panjab University, Chandigarh, India
- S. Bansal** Panjab University, Chandigarh, India
- S. Basak** NISER, Bhubhenswar, India
- Tanushree Basak** Department of Physics, Indian Institute of Technology, Ahmedabad, India

**Sumit Basu** Variable Energy Cyclotron Centre, Kolkata, India

**Biswaranjan Behera** Physics Department, IIT Hyderabad, Hyderabad, India

**P.K. Behera** Physics Department, Indian Institute of Technology Madras, Chennai, Tamil Nadu, India

**Shankita Bhardwaj** Central University of Himachal Pradesh, Dharamshala, India

**Vishal Bhardwaj** Department of Physics and Astronomy, University of South Carolina, Columbia, SC, USA

**Muzamil Bhat** Department of Physics, Aligarh Muslim University, Aligarh, India

**Vipin Bhatnagar** Department of Physics, Panjab University, Chandigarh, India

**Jitesh R. Bhatt** Theoretical Physics Division, Physical Research Laboratory, Ahmedabad, India

**Sandeep Bhowmik** Visva-Bharati University, Santiniketan, India

**Bipul Bhuyan** Indian Institute of Technology Guwahati, Guwahati, Assam, India

**M.R. Bhuyan** School of Physical Sciences, NISER, Jatni, India

**Ambalika Biswas** SNBNCBS, Kolkata, India

**S. Biswas** School of Physical Sciences, NISER, Jatni, India

**Kalpana Bora** Department of Physics, Gauhati University, Guwahati, Assam, India

**P.K. Boruah** Department of Instrumentation and USIC, Gauhati University, Guwahati, India

**Biswajoy Brahmachari** Department of Physics, Vidyasagar Evening College, Kolkata, India

**Dipankar Chakrabarti** Department of Physics, Indian Institute of Technology Kanpur, Kanpur, India

**H.C. Chandola** Centre of Advanced Study, Department of Physics, Kumaun University Nainital, Nainital, India

**Rupa Chatterjee** Variable Energy Cyclotron Center, Kolkata, India

**R. Chatterjee** Tata Institute of Fundamental Research, Mumbai, India

**Sandeep Chatterjee** Theoretical Physics Division, Variable Energy Cyclotron Centre, Kolkata, India

**Subhasis Chattopadhyay** Variable Energy Cyclotron Centre, Kolkata, India

**Surajit Chattopadhyay** Department of Computer Application (Mathematics Division), Pailan College of Management and Technology, Kolkata, India

**Brajesh C. Choudhary** Department of Physics and Astrophysics, University of Delhi, Delhi, India

**Ishita Dutta Choudhury** S. N. Bose National Centre for Basic Sciences, Kolkata, India

**Somnath Choudhury** Indian Institute of Science Education and Research, Bhopal, India

**Subikash Choudhury** Variable Energy Cyclotron Centre, Kolkata, India

**R. Chudasama** Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai, India

**S.J. Clark** Department of Earth Sciences, Durham University, Durham, UK

**M. Coleman** NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

**Harleen Dahiya** Department of Physics, Dr. B.R. Ambedkar National Institute of Technology, Jalandhar, India

**Arpan Das** Institute of Physics, Bhubaneswar, India

**G. Das** Variable Energy Cyclotron Centre, Kolkata, India

**G.S. Das** Department of Physics, Dibrugarh University, Dibrugarh, Assam, India

**S. Das** Institute of Physics, Bhubaneswar, India

**K.N. Deepthi** University of Hyderabad, Hyderabad, India

**P.S. Bhupal Dev** Consortium for Fundamental Physics, School of Physics and Astronomy, University of Manchester, Manchester, UK

**S. Dev** Department of Physics, School of Sciences, HNBG Central University, Srinagar, Uttarakhand, India

**Ram Krishna Dewanjee** Department of High Energy Physics, T.I.F.R, Mumbai, India

**N. Dhingra** Brown University, Providence, RI, USA

**Debajyoti Dutta** Department of Physics, Gauhati University, Guwahati, Assam, India

**H. Duyang** Department of Physics and Astronomy, University of South Carolina, Columbia, USA

**R. Ganai** Variable Energy Cyclotron Centre, Kolkata, India

**S. Ganesh** Department of Physics, Birla Institute of Technology and Science, Pilani, Rajasthan, India

**A. Gaur** Department of Physics and Astrophysics, University of Delhi, Delhi, India

**Radha Raman Gautam** Department of Physics, Panjab University, Chandigarh, India

**Purabi Ghosh** F. M. University, Odisha, India

**Gayatri Ghosh** Physics Department, Gauhati University, Guwahati, Assam, India

**Monojit Ghosh** Physical Research Laboratory, Ahmedabad, India

**A. Giri** Physics Department, IIT Hyderabad, Hyderabad, India

**J.G. Gluyas** Durham Energy Institute, Durham University, Durham, UK

**U. Gokhale** Department of High Energy Physics, Tata Institute of Fundamental Research, Mumbai, India

**Deepanjali Goswami** Indian Institute of Technology Guwahati, Assam, India

**J. Goswami** IIT, Kanpur, India

**Srubabati Goswami** Physical Research Laboratory, Ahmedabad, India

**U.D. Goswami** Department of Physics, Dibrugarh University, Dibrugarh, Assam, India

**Ralf Gothe** Department of Physics and Astronomy, University of South Carolina, Columbia, SC, USA

**M. Guchait** Tata Institute of Fundamental Research, Mumbai, India

**P. Guha** S. N. Bose Center for Basic Sciences, Kolkata, India

**M.M. Gupta** Department of Physics, Panjab University, Chandigarh, India; Department of Physics, Himachal Pradesh University, Shimla, India

**Md. Rihan Haque** National Institute of Science Education and Research, Bhubaneswar, Odisha, India

**Najmul Haque** Department of Physics, Kent State University, Kent, OH, USA

**E. Harikumar** University of Hyderabad, Hyderabad, India

**Md. Hasbuddin** Department of Physics and Astrophysics, University of Delhi, Delhi, India

**P. Hazarika** Department of Physics, Dibrugarh University, Dibrugarh, Assam, India

**M. Honda** Institute for Cosmic Ray Research, the University of Tokyo, Kashiwa, Chiba, Japan

**D. Indumathi** The Institute of Mathematical Sciences, CIT Campus, Chennai, India

**Chowdhury Aminul Islam** Saha Institute of Nuclear Physics, Kolkata, India

**Manoj Jadhav** Department of Physics, Indian Institute of Technology Bombay, Mumbai, India

**Abhik Jash** Saha Institute of Nuclear Physics, Kolkata, India

**Xiaobin Ji** Experimental Physics Division, Institute of High Energy Physics, Beijing, China

**Lata Kh. Joshi** Indian Institute of Technology Bombay, Mumbai, India

**D. Kalita** Department of Physics, A.D.P College, Nagaon, Assam, India

**A.K. Kalsi** Panjab University, Chandigarh, India

**A. Kamal** Department of Basic Science, Umme Al-Qura University, Makkah, Saudi Arabia

**R. Kanishka** Physics Department, Panjab University, Chandigarh, India

**Supriya Kar** Department of Physics and Astrophysics University of Delhi, New Delhi, India

**Biswajit Karmakar** IIT Guwahati, Guwahati, Assam, India

**Richa Kapoor** Department of Physics and Astrophysics University of Delhi, New Delhi, India

**Daljeet Kaur** Department of Physics and Astrophysics, University of Delhi, Delhi, India

**M. Kaur** Panjab University, Chandigarh, India

**P.K. Kaur** Department of High Energy Physics, Tata Institute of Fundamental Research, Mumbai, India

**Vladimir D. Kekelidze** Veksler-Baldin Laboratory for High Energy Physics, Joint Institute for Nuclear Research, Dubna, Russia

**M.M. Khan** Department of Applied Physics, Aligarh Muslim University, Aligarh, India

**G. Kiran Kumar** Physics Department, KL University, Guntur, India

**J. Klinger** Department of Physics and Astronomy, University of Sheffield, Sheffield, UK

**Partha Konar** Theoretical Physics Division, Physical Research Laboratory, Ahmedabad, India



**V.A. Kudryavtsev** Department of Physics and Astronomy, University of Sheffield, Sheffield, UK

**A. Kumar** Department of Physics and Astrophysics, University of Delhi, Delhi, India

**Jacky Kumar** Tata Institute of Fundamental Research, Mumbai, India

**L. Kumar** Department of Physics, Panjab University, Chandigarh, India

**P. Kumar** Department of Physics and Astrophysics, University of Delhi, Delhi, India

**R. Kumar** Department of Physics, Panjab University, Chandigarh, India

**Sanjeev Kumar** Department of Physics and Astrophysics, University of Delhi, Delhi, India

**Satendra Kumar** Department of Physics, Indian Institute of Technology Guwahati, Guwahati, India

**Amitabha Lahiri** S. N. Bose National Centre for Basic Sciences, Kolkata, India

**Biswanath Layek** Department of Physics, Birla Institute of Technology and Science-Pilani, Pilani, India

**Richard Lednicky** JINR Director, Joint Institute for Nuclear Research, Dubna, Russia

**Weidong Li** Experimental Physics Division, Institute of High Energy Physics, Beijing, China

**Chunxiu Liu** Experimental Physics Division, Institute of High Energy Physics, Beijing, China

**Huaimin Liu** Experimental Physics Division, Institute of High Energy Physics, Beijing, China

**A. Lokapure** Department of High Energy Physics, Tata Institute of Fundamental Research, Mumbai, India

**Cédric Lorcé** SLAC National Accelerator Laboratory, Stanford University, Menlo Park, CA, USA; IFPA, AGO Department, Université de Liège, Liège, Belgium

**Xinchou Lou** Experimental Physics Division, Institute of High Energy Physics, Beijing, China

**Kuldeep K. Maan** Department of Physics, Panjab University, Chandigarh, India

**Sonam Mahajan** Department of Physics, Panjab University, Chandigarh, India

**Sarbani Majumder** Saha Institute of Nuclear Physics, Kolkata, India

**Prolay Kumar Mal** National Institute of Science Education and Research, Bhubaneswar, Orissa, India

**Rusa Mandal** The Institute of Mathematical Sciences, Chennai, India

**Viktor A. Matveev** JINR Director, Joint Institute for Nuclear Research, Dubna, Russia

**K. Mazumdar** Tata Institute of Fundamental Research, Mumbai, India

**A. Mehta** Department of Physics, Panjab University, Chandigarh, India

**Igor N. Meshkov** Dzhelapov Laboratory of Nuclear Physics, Joint Institute for Nuclear Research, Dubna, Russia

**D. Mishra** National Institute of Science Education and Research, Bhubaneswar, India

**M. Mishra** Department of Physics, Birla Institute of Technology and Science, Pilani, Rajasthan, India

**S. Mishra** Department of Physics and Astrophysics, University of Delhi, Delhi, India

**Sanjib R. Mishra** Department of Physics and Astronomy, University of South Carolina, Columbia, USA

**Tanmoy Modak** The Institute of Mathematical Sciences, Chennai, India

**Rukmani Mohanta** School of Physics, University of Hyderabad, Hyderabad, India

**A.K. Mohanty** Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai, India

**Bedangadas Mohanty** School of Physical Sciences, National Institute of Science Education and Research, Jatni, India

**Rudranarayan Mohanty** School of Physical Sciences, NISER, Jatni, India

**Chandan Mondal** Department of Physics, Indian Institute of Technology Kanpur, Kanpur, India

**N.K. Mondal** Department of High Energy Physics, Tata Institute of Fundamental Research, Mumbai, India

**Tanmoy Mondal** Theoretical Physics Division, Physical Research Laboratory, Ahmedabad, India

**B. Muduli** Variable Energy Cyclotron Centre, Kolkata, India

**A. Mukherjee** Indian Institute of Technology Bombay, Mumbai, India

**Supratik Mukhopadhyay** Saha Institute of Nuclear Physics, Kolkata, India

**Munshi G. Mustafa** Theory Division, Saha Institute of Nuclear Physics, Kolkata, India

**Basanta K. Nandi** IIT Mumbai, Mumbai, India

**P. Nagaraj** Department of High Energy Physics, Tata Institute of Fundamental Research, Mumbai, India

**Md. Naimuddin** Department of Physics and Astrophysics, University of Delhi, Delhi, India

**S. Nair** Indian Institute of Technology Bombay, Mumbai, India

**Kamal Jyoti Nath** Indian Institute of Technology Guwahati, Guwahati, Assam, India

**Jajati K. Nayak** Variable Energy Cyclotron Centre, Kolkata, India

**Tapan K. Nayak** Variable Energy Cyclotron Centre, Kolkata, India

**Himangshu Neog** School of Physical Sciences, NISER, Jatni, India

**V.K. Ohja** Indian Institute of Technology Bombay, Mumbai, India

**S. Pal** Department of Physics and Astronomy, University of Sheffield, Sheffield, UK

**S.M. Paling** STFC Boulby Underground Science Facility, Boulby Mine, Cleveland, UK

**Arun Kumar Pandey** Theoretical Physics Division, Physical Research Laboratory, Ahmedabad, India; Department of Physics, Indian Institute of Technology, Gandhinagar, Ahmedabad, India

**L.M. Pant** Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai, India

**Antonio Pasqua** Department of Physics, University of Trieste, Trieste, Italy

**Pathaleshwar** Department of High Energy Physics, Tata Institute of Fundamental Research, Mumbai, India

**Evan Phelps** Department of Physics and Astronomy, University of South Carolina, Columbia, SC, USA

**P. Poulouse** Department of Physics, Indian Institute of Technology Guwahati, Guwahati, India

**Soumita Pramanick** Department of Physics, University of Calcutta, Kolkata, India

**Vindhyawasini Prasad** Experimental Physics Division, Institute of High Energy Physics, Beijing, China

**Garima Punetha** Centre of Advanced Study, Department of Physics, D.S.B. Campus, Kumaun University Nainital, Nainital, India

**M. Rahman** Physics Department, Gauhati University, Guwahati, India

**Desh Raj** Department of Physics, Himachal Pradesh University, Shimla, India

**Rajendran Raja** Fermi National Accelerator Laboratory, Batavia, IL, USA

**S. Ramnarayan** Variable Energy Cyclotron Centre, Kolkata, India

**Monika Randhawa** University Institute of Engineering and Technology, Panjab University, Chandigarh, India

**Raghavan Rangarajan** Theoretical Physics Division, Physical Research Laboratory, Navrangpura, Ahmedabad

**Mir Hashim Rasool** Department of Physics, Aligarh Muslim University, Aligarh, India

**Amitava Raychaudhuri** Department of Physics, University of Calcutta, Kolkata, India

**Sushant K. Raut** Department of Theoretical Physics, School of Engineering Sciences, KTH Royal Institute of Technology - AlbaNova University Center, Stockholm, Sweden

**Haresh Raval** Department of Physics, Indian Institute of Technology Bombay, Mumbai, India

**K. Raveendrababu** Physics Department, Indian Institute of Technology Madras, Chennai, Tamil Nadu, India

**Tirtha Sankar Ray** Department of Physics, Indian Institute of Technology Kharagpur, Kharagpur, India

**A. Roy** Variable Energy Cyclotron Centre, Kolkata, India

**Probir Roy** Saha Institute of Nuclear Physics, Kolkata, India; Bose Institute, Kolkata, India

**Sharmili Rudra** Department of Applied Physics, CU, Kolkata, India

**Dibyakrupa Sahoo** The Institute of Mathematical Sciences, Taramani, Chennai, India

**R. Sahoo** Indian Institute of Technology, Indore, India

**S. Sahoo** Institute of Physics, Bhubaneswar, India

**Suchismita Sahoo** University of Hyderabad, Hyderabad, India

**P.K. Sahu** IOP, Sachivalaya Marg, Bhubaneswar, India

**S. Sahu** IOP, Sachivalaya Marg, Bhubaneswar, India

**M. Sajjad Athar** Department of Physics, Aligarh Muslim University, Aligarh, India

**Soma Sanyal** University of Hyderabad, Prof. C.R. Rao Road, Hyderabad, India

**M.N. Saraf** Department of High Energy Physics, Tata Institute of Fundamental Research, Mumbai, India

**Debojit Sarkar** Variable Energy Cyclotron Centre, Kolkata, India

**Neelakshi Sarma** Department of Physics, Gauhati University, Guwahati, Assam, India

**U. Sarma** Department of Instrumentation and USIC, Gauhati University, Guwahati, India

**B. Satyanarayana** Department of High Energy Physics, Tata Institute of Fundamental Research, Mumbai, India

**R. Sehgal** Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai, India

**S.T. Sehgal** Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai, India

**Peter Shanahan** Fermilab, Batavia, IL, USA

**Mukesh K. Sharma** University of Jammu, Jammu, India

**N. Sharma** University of Tennessee, Knoxville, TN, USA

**Samandeep Sharma** Department of Physics, GGSDS College, Chandigarh, India

**Arunansu Sil** IIT Guwahati, Guwahati, Assam, India

**D. Sil** Department of High Energy Physics, Tata Institute of Fundamental Research, Mumbai, India

**Deobrat Singh** Department of Physics and Astrophysics University of Delhi, New Delhi, India

**J.B. Singh** Department of Physics, Panjab University, Chandigarh, India

**Janardan P. Singh** Physics Department, Faculty of Science, The M. S. University of Baroda, Vadodara, India

**Lakhwinder Singh** Department of Physics, Banaras Hindu University, Varanasi, India; Institute of Physics, Academia Sinica, Taipei, Taiwan

**Lal Singh** Department of Physics, Himachal Pradesh University, Shimla, India

**M.K. Singh** Institute of Physics, Academia Sinica, Taipei, Taiwan

**Madan Singh** Department of Physics, Panjab University, Chandigarh, India

**Om Veer Singh** Department of Physics, Aligarh Muslim University, Aligarh, India

**Ranbir Singh** School of Physical Sciences, National Institute of Science Education and Research, Jatni, India

**Shivaramakrishna Singirala** School of Physics, University of Hyderabad, Hyderabad, India

**Alexander S. Sorin** Bogoliubov Laboratory for Theoretical Physics, Joint Institute for Nuclear Research, Dubna, Russia

**C. Soumya** University of Hyderabad, Hyderabad, India

**N.J.C. Spooner** Department of Physics and Astronomy, University of Sheffield, Sheffield, UK

**Ajit M. Srivastava** Institute of Physics, Bhubaneswar, India

**Rahul Srivastava** The Institute of Mathematical Science, Chennai, India

**M. Sruthilaya** University of Hyderabad, Hyderabad, India

**Michael Strickland** Department of Physics, Kent State University, Kent, OH, USA

**Nan Su** Institut Für Theoretische Physik, Goethe-Universität Frankfurt am Main, Frankfurt, Germany

**Abhaya Kumar Swain** Theoretical Physics Division, Physical Research Laboratory, Ahmedabad, India

**S. Telfer** Department of Physics and Astronomy, University of Sheffield, Sheffield, UK

**R.G. Thomas** Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai, India

**L.F. Thompson** Department of Physics and Astronomy, University of Sheffield, Sheffield, UK

**B. Tiru** Physics Department, Gauhati University, Guwahati, India

**Gaurav Tomar** Physical Research Laboratory, Ahmedabad, India; Indian Institute of Technology, Gandhinagar, India

**Srikanta Kumar Tripathy** Institute of Physics, Bhubaneswar, Odisha, India

**Arjun Trivedi** Department of Physics and Astronomy, University of South Carolina, Columbia, SC, USA

**Grigory V. Trubnikov** JINR Director, Joint Institute for Nuclear Research, Dubna, Russia

- S. Uma Sankar** Indian Institute of Technology Bombay, Mumbai, India
- S.S. Upadhya** Department of High Energy Physics, Tata Institute of Fundamental Research, Mumbai, India
- Ch. Upender** Physics Department, IIT Hyderabad, Hyderabad, India
- Raghava Varma** Department of Physics, Indian Institute of Technology Bombay, Mumbai, India
- Surender Verma** Central University of Himachal Pradesh, Dharamshala, India
- G. Walia** Panjab University, Chandigarh, India
- H.T. Wong** Institute of Physics, Academia Sinica, Taipei, Taiwan
- D. Woodward** Department of Physics and Astronomy, University of Sheffield, Sheffield, UK
- Nitin Yadav** Indian Institute of Technology, Guwahati, Assam, India
- Urjit A. Yajnik** Department of Physics, Indian Institute of Technology Bombay, Mumbai, India
- E. Yuvaraj** Department of High Energy Physics, Tata Institute of Fundamental Research, Mumbai, India
- S. Zamal** Physics Department, Gauhati University, Guwahati, India
- N.S. Zuhair** University of Hyderabad, Hyderabad, India

# Acronyms

$\chi$ CQM	Chiral Constituent Quark Model
2HDMs	Two Higgs Doublet Models
ACM	Anomalous Chromomagnetic moment
ACT	Atmospheric Cherenkov Technique
AMPT	A MultiPhase Transport model
ATLAS	A Toroidal LHC ApparatuS
BAU	Baryon Asymmetry of the Universe
BEM	Boundary Element Method
BICEP	Background Imaging of Cosmic Extragalactic Polarization
BLKT	Brane-Localized Kinetic Terms
BNL	Brookhaven National Laboratory
BNS	Baryon Number Susceptibility
BSM	Beyond Standard Model
CERN	European Organization for Nuclear Research
CF	Correlation Function
CFO	Chemical Freeze-Out
CKM	Cabibbo–Kobayashi–Maskawa
CMBR	Cosmic Microwave Background Radiation
CMS	Compact Muon Solenoid
CNM	Cold Nuclear Matter
CORSIKA	COsmic Ray SIMulation for KAscade
DARE	Dark Ages Radio Explorer
DIS	Deep Inelastic Scattering
DM	Dark Matter
DPR	Dilepton Production Rate
DPS	Double Parton Scattering
DUNE	Deep Underground Neutrino Experiment
EAS	Extensive Air Shower
EDM	Electric Dipole Moments
EDXS	Energy Dispersive X-ray Spectroscopy
EMC	Electromagnetic Calorimeter



ESM	Extended Survival Hypothesis
EWPT	ElectroWeak Phase Transition
FADC	Flash Analog-to-Digital Converter
FAIR	Facility for Antiproton and Ion Research
FCNC	Flavor Changing Neutral Current
FEM	Finite Element Method
Fermilab	Fermi National Accelerator Laboratory
FF	Form Factor
FLAG	Flavor Lattice Averaging Group
GB	Goldstone Boson
GEM	Gas Electron Multiplier
GPD	Generalized Parton Distribution
GSI	Gesellschaft für Schwerionenforschung
GTM	Global Trigger Module
GTMD	Generalized Transverse-Momentum dependent Distribution
GUT	Grand Unified Theory
HMC	Hybrid Monte Carlo
HPTDC	High Performance Time to Digital Converter
HSMU	High Scale Mixing Unification
HTLpt	Hard Thermal Loop perturbation theory
ICAL	Iron CALorimeter
INO	India-based Neutrino Observatory
ISR	Initial State Radiation
IVI	Isoscalar Vector Interaction
JINR	Joint Institute for Nuclear Research
JLab	Jefferson Laboratory
KFO	Kinetic Freeze-Out
KNO	Koba–Nielsen–Olesen
KSNL	Kuo-Sheng Neutrino Laboratory
LBNE	Long Baseline Neutrino Experiment
LDF	Lateral Distribution Function
LFCQM	Light-Front Constituent Quark Model
LFV	Lepton Flavor Violation
LHC	Large Hadron Collider
LNV	Lepton Number Violation
LQCD	Lattice QCD
MCHM	Minimal Composite Higgs Model
MCU	Micro Controller Unit
MIP	Minimum Ionizing Particle
MIPP	Main Injector Particle Production
MPD	MultiPurpose Detector
MPI	Multiple Parton Interactions
MSSM	Minimal Supersymmetric Standard Model
NICA	Nuclotron-based Ion Collider fAcility
NJL	Nambu–Jona–Lasinio

NMSSM	Next-to-Minimal SUSY Model
NNLO	Next-to-Next-Leading-Order
NOvA	NuMI Off-axis $\nu_e$ Appearance
OAM	Orbital Angular Momentum
PDG	Particle Data Group
PL	Polyakov Loop
PMNS	Pontecorvo–Maki–Nakagawa–Sakata
PQCD	Perturbative QCD
QCD	Quantum Chromodynamics
QED	Quantum Electrodynamics
QGP	Quark–Gluon Plasma
QNS	Quark Number Susceptibilities
QPM	QuasiParticle Model
RHIC	Relativistic Heavy Ion Collider
RPC	Resistive Plate Chamber
SEM	Scanning Electron Microscope
SiPM	Silicon Photomultiplier
SM	Standard Model
SPS	Single Parton Scattering
TBM	TriBiMaximal
TDC	Time-to-Digital Converter
TEXONO	Taiwan Experiment on Neutrino
TMD	Transverse Momentum dependent Distribution
TOF	Time-of-Flight
TPC	Time Projection Chamber
UHE	Ultra High Energy
VMSF	Vector Meson Spectral Function
WIMP	Weakly Interacting Massive Particle