



Massive Neutrinos in
Physics and
Astrophysics
Third Edition

Rabindra N. Mohapatra • Palash B. Pal

Majorive Neutrinos In Physics And Astrophysics

Arnold S. Lavro



Massive Neutrinos In Physics And Astrophysics:

Massive Neutrinos in Physics and Astrophysics Rabindra Nath Mohapatra, Palash B. Pal, 2004 An introduction to various issues related to the theory and phenomenology of massive neutrinos for the nonexpert also providing a discussion of results in the field for the active researcher All the necessary techniques and logics are included and topics such as supersymmetry are covered Massive Neutrinos In Physics And Astrophysics (Third Edition) Rabindra N

Mohapatra, Palash B Pal, 2004-03-09 The recent groundbreaking discovery of nonzero neutrino masses and oscillations has put the spotlight on massive neutrinos as one of the key windows on physics beyond the standard model as well as into the early universe This third edition of the invaluable book Massive Neutrinos in Physics and Astrophysics is an introduction to the various issues related to the theory and phenomenology of massive neutrinos for the nonexpert providing at the same time a complete and up to date discussion on the latest results in the field for the active researcher It is designed not merely to be a guide but also as a self contained tool for research with all the necessary techniques and logics included Specially emphasized are the various implications of neutrino discoveries for the nature of new forces Elementary discussions on topics such as grand unification left right symmetry and supersymmetry are presented The most recent cosmological and astrophysical implications of massive neutrinos are also dealt with Fundamentals of Neutrino Physics and Astrophysics

Carlo Giunti, Chung W. Kim, 2007-03-15 Our Universe is made of a dozen fundamental building blocks Among these neutrinos are the most mysterious but they are the second most abundant particles in the Universe This book provides detailed discussions of how to describe neutrinos their basic properties and the roles they play in nature The Neutrino Story: One Tiny Particle's Grand Role in the Cosmos Rabindra N. Mohapatra, 2020-11-05 Every second of every day we are exposed to billions of neutrinos emitted by the Sun and yet they seem to pass straight through us with no apparent effect at all Tiny and weakly interacting this subatomic particle may be but this book will show you just how crucial a role it has played in the evolution of the elements in the universe and eventually ourselves We first start with an introduction to the basics of subatomic physics including brief backgrounds on the discoveries that set the stage for major 20th century advances The author a distinguished theoretical physicist who has researched neutrinos for over thirty years next explains in nontechnical language how and why the neutrino fits into the wider story of elementary particles Finally the reader will learn about the latest discoveries in the past half century of neutrino studies This semi popular science book will appeal to any physics students or non specialist physicists who wish to know more about the neutrino and its role in the evolution of our universe

Physics of Neutrinos Masataka Fukugita, Tsutomu Yanagida, 2013-06-29 This book aims to provide a survey of the current state of research in the physics of neutrinos which has undergone dramatic development during the last decade in a form accessible to the nonspecialist and the graduate student The major issue during the last two decades has been the neutrino mass whereas the interaction of neutrinos was well understood within the framework of the standard theory which

was established in the 1970s In 1994 we published a textbook format review article *Physics 01 Neutrinos in Physics and Astrophysics 01 Neutrinos* in anticipation that the mass of the neutrino would be found in the near future It was indeed found thanks to the Super Kamiokande experiment four years after that book was written and a flurry of activity followed in the phenomenology of the neutrino mass From the theoretical point of view the importance of this discovery stems from the fact that it probably indicates the presence of a new energy scale beyond the standard theory At the same time the formalism for massive neutrinos and the techniques to find the neutrino mass have now realistic importance and have become the subject of standard physics On the other hand experiment revealed that the pattern of the neutrino mass and mixing among generations appears in a way different from what has been speculated on the basis of existing theoretical models *Massive Neutrinos in Astrophysics and in Particle Physics* J. Thanh Van Tran, 1984

Neutrinos in Particle Physics, Astronomy and Cosmology Zhizhong Xing, Shun Zhou, 2011-06-08 Neutrinos in Particle Physics Astronomy and Cosmology provides a comprehensive and up to date introduction to neutrino physics neutrino astronomy and neutrino cosmology The intrinsic properties and fundamental interactions of neutrinos are described as is the phenomenology of lepton flavor mixing seesaw mechanisms and neutrino oscillations The cosmic neutrino background stellar neutrinos supernova neutrinos and ultrahigh energy cosmic neutrinos together with the cosmological matter antimatter asymmetry and other roles of massive neutrinos in cosmology are discussed in detail This book is intended for researchers and graduate students in the fields of particle physics particle astrophysics and cosmology Dr Zhizhong Xing is a professor at the Institute of High Energy Physics Chinese Academy of Sciences China Dr Shun Zhou is currently a postdoctoral fellow at the Max Planck Institute for Physics Germany

Massive Neutrinos: Flavor Mixing Of Leptons And Neutrino Oscillations Harald Fritzsch, 2015-08-28 Since the discovery of neutrino oscillations neutrino physics has become an interesting field of research in physics They imply that neutrino must have a small mass and that the neutrinos coupled to the charged leptons are mixtures of the mass eigenstates analogous to the flavor mixing of the quarks The mixing angles for the quarks are small but for the leptons two of the mixing angles are large The masses of the three neutrinos must be very small less than 1 eV but from the oscillation experiments we only know the mass differences the absolute masses are still unknown Also we do not know if the masses of the neutrinos are Dirac masses as the masses of the charged leptons and of the quarks or whether they are Majorana masses In this volume an overview of the present state of research in neutrino physics is given by well known experimentalists and theorists The contents originated from talks and discussions at a recent conference addressing some of the most pressing open questions in neutrino physics range from the oscillation experiments to CP violation for leptons to texture zero mass matrices and to the role of neutrinos in astrophysics and cosmology

Massive Neutrinos in Particle Physics and Astrophysics, 1986 The concepts of Majorana and Dirac neutrinos are reviewed from an operational point of view and survey the experimental search for neutrino mass Also reviewed are the work of Mikheyev and Smirnov on the enhancement of neutrino oscillations

via the mechanism of Wolfenstein matter oscillations Results of an extensive computation of MSW effects in the sun are described 41 refs 6 figs *Physics of Massive Neutrinos* Felix Boehm,Petr Vogel,1992-06-26 Neutrinos play a decisive part in nuclear and elementary particle physics as well as in astrophysics and cosmology Some of their most basic properties such as their mass and charge conjugation symmetry are largely unknown This book focuses on what we know and may hope to know about the mass of the neutrino and its particle antiparticle symmetry Topics include neutrino mixing neutrino decay neutrino oscillations double beta decay solar neutrinos supernova neutrinos and related issues The authors stress the physical concepts and discuss both theoretical and experimental techniques This updated second edition differs from the first in that it contains an expanded coverage of experimental results and theoretical advances Since publication of the first edition many issues that were at that time unresolved such as tritium beta decay and reactor neutrino oscillations have been clarified and are discussed here Also included is an expanded coverage of solar and supernova neutrinos This book deals with one of the most intriguing issues in modern physics and will be of value to researchers graduate students and advanced undergraduates specializing in experimental and theoretical particle physics and nuclear physics *Physics of Massive Neutrinos* Felix Boehm,Petr Vogel,1992-06-26 Neutrinos play a decisive part in nuclear and elementary particle physics as well as in astrophysics and cosmology Because they interact so weakly with matter some of their basic properties such as mass charge conjugation symmetry are largely unknown These subjects are considered in detail by authors who also discuss such topics as neutrino mixing neutrino decay neutrino oscillations double beta decay and related ideas Physical concepts are stressed and both theoretical methods and experimental techniques are presented This second edition contains an expanded coverage of new experimental results and recent theoretical advances In the intervening years since the first edition many then unresolved problems such as tritium beta decay and reactor neutrino oscillations have been clarified This edition also gives expanded coverage of solar and supernova neutrinos **The Physics of Massive Neutrinos** Boris Kayser,Françoise Gibrat-Debu,1989 This book explains the physics and phenomenology of massive neutrinos The authors argue that neutrino mass is not unlikely and consider briefly the search for evidence of this mass in decay processes before they examine the physics and phenomenology of neutrino oscillation The physics of Majorana neutrinos neutrinos which are their own antiparticles is then discussed This volume requires of the reader only a knowledge of quantum mechanics and of very elementary quantum field theory **Introduction to the Physics of Massive and Mixed Neutrinos** Samoil Bilenky,2018-04-02 Small neutrino masses are the first signs of new physics beyond the Standard Model of particle physics Since the first edition of this textbook appeared in 2010 the Nobel Prize has been awarded for the discovery of neutrino oscillations which shows that neutrinos have mass The measurement of the small neutrino mixing angle θ_{13} in 2012 launched the precision stage of the investigation of neutrino oscillations This measurement now allows such fundamental problems as the three neutrino mass spectrum is it normal or inverted and the CP violation in the lepton sector to be tackled

In order to understand the origin of small neutrino masses it remains crucial to reveal the nature of neutrinos with definite masses are they Dirac neutrinos possessing a conserved lepton number which distinguishes neutrinos and antineutrinos or are they Majorana neutrinos with identical neutrinos and antineutrinos Experiments searching for the neutrinoless double beta decay are presently under way to answer this fundamental question The second edition of this book comprehensively discusses all these important recent developments Based on numerous lectures given by the author a pioneer of modern neutrino physics recipient of the Bruno Pontecorvo Prize 2002 at different institutions and schools it offers a gentle yet detailed introduction to the physics of massive and mixed neutrinos that prepares graduate students and young researchers entering the field for the exciting years ahead in neutrino physics

'86 *Massive Neutrinos in Astrophysics and in Particle Physics* Orrin Fackler, J. Thanh Van Tran, 1986 **Introduction to the Physics of Massive and Mixed Neutrinos** Samoil Bilenky, 2010-09-14

For many years neutrino was considered a massless particle The theory of a two component neutrino which played a crucial role in the creation of the theory of the weak interaction

is based on the assumption that the neutrino mass is equal to zero We now know that neutrinos have nonzero small masses In numerous experiments with solar atmospheric reactor and accelerator neutrinos a new phenomenon neutrino oscillations was observed Neutrino oscillations periodic transitions between different flavor neutrinos are possible only if neutrino mass squared differences are different from zero and small and flavor neutrinos are mixed The discovery of neutrino oscillations opened a new era in neutrino physics an era of investigation of neutrino masses mixing magnetic moments and other neutrino properties After the establishment of the Standard Model of the electroweak interaction at the end of the seventies the discovery of neutrino masses was the most important discovery in particle physics Small neutrino masses cannot be explained by the standard Higgs mechanism of mass generation For their explanation a new mechanism is needed Thus small neutrino masses is the first signature in particle physics of a new beyond the Standard Model physics It took many years of heroic efforts by many physicists to discover neutrino oscillations After the first period of investigation of neutrino oscillations many challenging problems remained unsolved One of the most important is the problem of the nature of neutrinos with definite masses Are they Dirac neutrinos possessing a conserved lepton number which distinguish neutrinos and antineutrinos or Majorana neutrinos with identical neutrinos and antineutrinos Many experiments of the next generation and new neutrino facilities are now under preparation and investigation There is no doubt that exciting results are ahead **Massive**

Neutrinos Orrin Fackler, Gérard Fontaine, J. Thanh Van Tran, 1991 *Current Aspects of Neutrino Physics* David O.

Caldwell, 2013-11-11 This is a particularly exciting time for neutrino physics Now providing the first experimental evidence for new physics beyond the Standard Model of particle physics neutrino studies are leading that larger field in new directions As a probe for discovery neutrinos are unique among particles Being leptons neutrinos are as far as one knows true elementary particles but in addition they are unencumbered by charge and of course they do not have complicating strong

interactions Their unusually small mass also points to their novelty and possibly to their providing a window onto very high energy scales The emphasis for neutrino physics at this time is on their masses and mixing with each other as well as on their basic nature and their role in the Universe While they have been important tools for studying particle properties such as structure functions and the nature of the weak interaction at present this is not the thrust of most research and hence is not covered in this book Rather the topics are those currently of most interest at the frontier of particle physics

Neutrinos In Physics And Astrophysics Esteban Roulet, Francesco Vissani, 2022-09-20 This book covers the field of neutrino physics and astrophysics providing an up to date presentation of the different research topics on the frontier of the field It starts with a historical description to understand how the different aspects of our knowledge about the neutrinos evolved up to the present state The main required elements of the Standard Model of electroweak interactions are introduced and the different neutrino interactions and detection techniques are presented We introduce the various ways to give neutrinos a mass and the phenomenon of neutrino oscillations which provides the main evidence for non vanishing neutrino masses We then consider the neutrinos produced in the Sun what we have learned from them and how they can also be useful to study our star The geoneutrinos produced by the radioactivity in the Earth are discussed and the status of their detection is presented We survey the neutrino production in the supernova explosions at the end of the life of very massive stars what has been observed in SN1987A and what could be learned from a future supernova or from the observation of the diffuse supernova neutrino background We describe in detail the neutrino production by cosmic rays interacting in the atmosphere the evidence for their flavor oscillations and the oscillograms to describe their flavor change in terrestrial matter The different mechanisms of production of high energy astrophysical neutrinos and the observations achieved with the IceCube detector are presented also discussing their flavor content by means of the flavor triangle We then examine the cosmological neutrino background its impact on Big Bang nucleosynthesis and on the CMB observations with the associated bound on their masses and effective number Finally we review the basics of the leptogenesis scenarios which provide an attractive explanation for the observed baryon asymmetry of the Universe

[A Modern Introduction to Neutrino Physics](#) Frank F Deppisch, 2019-11-07 A deeper understanding of neutrinos with the goal to reveal their nature and exact role within particle physics is at the frontier of current research This book reviews the field in a concise fashion and highlights the most pressing issues and areas of strongest topical interest It provides a clear self contained and logical treatment of the fundamental physics aspects appropriate for graduate students Starting with the relevant basics of the SM neutrinos are introduced and the quantum mechanical effect of oscillations is explained in detail A strong focus is then set on the phenomenon of lepton number violation especially in $0\nu\beta\beta$ decay as the crucial probe to understand the nature of neutrinos The role of neutrinos in astrophysics expected to be of increasing importance for future research is then described Finally models to explain the neutrino properties are outlined The central theme of the book is the nature of neutrino masses and the above topics will

revolve around this issue *Neutrinos* Arnold S. Lavro, 2002 Neutrinos are one of the most abundant particles in the universe Because they have very little interaction with matter however they are incredibly difficult to detect Neutrinos are similar to the more familiar electron with one crucial difference neutrinos do not carry electric charge Because neutrinos are electrically neutral they are not affected by the electromagnetic forces which act on electrons Three types of neutrinos are known Each type or flavour of neutrino is related to a charged particle which gives the corresponding neutrino its name Hence the electron neutrino is associated with the electron and two other neutrinos are associated with heavier versions of the electron called the muon and the tau The book presents citations from the literature for the last three years from the journal literature and the existent book literature Access is provided by subject author and title indexes

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