Electroweak Interactions : Experimental Facts and Theoretical Foundation
(Landolt-Börnstein Numerical Data and Functional Relationships in Science and Technology, Group 1, Vol 10)

edited by H Schopper

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The Standard Model Confronts Experimental Data

"(In 1968) representatives of 7 university groups met in Milano to discuss the programme of neutrino physics at CERN.....12 topics were arranged in priority order, and in this list, the search for neutral currents – the unique prediction of the Salam-Weinberg model came at number 10 !"/1/. In spite of this "somewhat inauspicious birth /1/" the Glashow-Salam-Weinberg (GSW) model /2/ of unified electroweak interactions has successfully confronted a whole host of gruelling experimental tests involving wide spectrum of energies* since 1973 when the neutral current was actually discovered. Together with quantum chromodynamics (QCD), the asymptotically free field theory of strong interactions /3/ the GSW model now constitutes the standard model which is accepted by the overwhelming majority of high energy physicists as the theory of interactions between quarks and leptons. It is true that the Higgs boson and the top quark, two important ingredients of the standard model, have not yet been found experimentally. So, for example, the possibility that the Higgs boson sector of the GSW model responsible for spontaneous symmetry breaking will be replaced by some form of dynamical symmetry breaking scheme is still open. It is, however, inconceivable that future developments will lead to a complete overthrow of the standard model.

The standard model contains too many free parameters (at least four coupling constants, the quark and lepton masses etc.) and hence, is unlikely to be the fundamental theory – many people argue. Thus more "complete" theories like left-right symmetric models, grand unified theories etc. /4/ have been proposed. In all such constructions, however, the standard model is an indispensable part of the larger theory which takes care of the currently available experimental data.

The purpose of the book 'Electroweak Interactions : Experimental Facts and Theoretical Foundation' by D Haidt and H Pietschmann belonging to the New Series (Ed H Schopper, Springer-Verlag, 1988), is to cover "all our knowledge about the so-called electroweak interactions, a knowledge, which in the last fifteen years, has coalesced into a consistent framework". Some of the extensions of

*Low energy non-accelerator processes like parity violation in atomic physics on the one hand and very high energy processes like deep inelastic scattering and e^+e^- annihilation on the other.

the GSW model have also been briefly reviewed. It must be admitted that the authors have largely been successful in their ambitious attempt. This book will serve every active researcher in particle physics as an important reference book containing many useful formulas (without derivation) along with brief sketches of the theoretical concepts involved and experimental facts, with references to the more detailed literature. Admittedly, part of the experimental information may also be found elsewhere (e.g. in the particle data book). However, throughout this work the emphasis is on confronting the theory with the data which makes the scope of this volume much wider than that of a mere source of information. The book also contains, in appropriate chapters, concise accounts of many classic experiments like the discoveries of the weak neutral current, the J/ψ particle, the τ lepton, the W boson, the Z boson etc., which are not readily available in typical high energy physics text books. The presentation throughout is lucid and the organisation well-planned.

The book begins with a brief historical introduction in Chapter one. Chapter two contains a well-organised summary of the theoretical framework and many useful formulas with Feynman rules in quantum electrodynamics (QCD), spontaneously broken gauge theories (mainly the standard $SU(2)_L \otimes U(1)$ model) and quantum chromodynamics (QCD). Even very technical topics like infrared and ultraviolet divergences, renormalisation, different renormalisation schemes for electroweak theories etc., have been included. However, a small section on dimensional regularisation with the basic formulas and some applications (e.g., expressions for QED renormalisation constants (Table 2.22) in this scheme) would have made this chapter more complete. Brief comments on the treatment of infrared divergence to all orders in perturbation theory and the infrared problem in QCD should have been included. The discussion on quark and lepton masses (Table 2.31) should include the limits on m_t from colliders with comments on the uncertainties in these limits. In view of the recent CDF, SLC, TRISTAN and LEP results, m_t, m_W and m_Z presented in Tables 2.30 and 2.31 and latter in Chapters three and four already require updating.

Chapter three deals with the properties of quarks and leptons with emphasis on the τ lepton, c and b quarks. Sections on some modern experimental techniques (e.g., the B meson reconstruction) are well written. Unfortunately, the section on the very important topic of top quark search is rather brief. The basic techniques for top searches, at e^+e^- and $\bar{p}p$ colliders, the uncertainties in the mass limits etc. should have been included.

Chapter four is on the properties of the gauge bosons W and Z, the mediators of weak interactions. Analyses of the UA1 and the UA2 experiments on the properties of these bosons are reviewed nicely. However, in view of more recent results from CDF, LEP, and SLC parts of this chapter already require updating. The measurements of the Z width and neutrino counting at LEP from the invisible

width of the Z should be added at the earliest opportunity. The section on neutrino counting, as it stands now, is not sufficiently critical. For example, the uncertainties in the production cross sections of the W and the Z due to those in the quark distribution functions and their effects on neutrino counting have not been mentioned.

Chapter five is on the Higgs sector. The discussion includes decay properties and experimental mass limits. Among the possible process for Higgs boson search only the Wilczek mechanism ($r \to Hr^0$) has been discussed. This discussion on this very important topic is, however, somewhat inadequate. According to the present state of the art in this subject the search strategies for the light Higgs ($m_H < m_W$), the intermediate-mass Higgs ($m_W \leqslant m_H \leqslant 2m_W$) and the heavy Higgs bosons ($m_H > 2m_W$), where m_W and m_H are the masses of the W boson and the Higgs boson respectively, are separately discussed /5/. A brief section along these lines is needed for the completeness of this chapter. The naturalness or the gauge heirarchy problem and the nonminimal Higgs sector should have been included either in this chapter or in Chapter 7. The last line of p 89 contains a misprint (4 GeV instead of 4 meV).

Chapter six, by far the largest in this volume, deals with the properties of the electromagnetic current, the weak neutral current and the weak charged current. The review of the "clean" tests of pure QED at high energy e^+e^- colliders in processes involving only leptons and photons in the final state is fairly comprehensive. Surprisingly the deep inelastic ep scattering and two photon induced deep inelastic processes ($e^+e^- \to e^+e^-x$) have been omitted. The section on weak neutral current is divided into two subsections involving purely leptonic and semileptonic processes. The elastic neutrino (antineutrino)-lepton scattering, the observed forward-backward asymmetry in $e^+e^- \to l^+l^-$ or $q\bar{q}$, where l and q stand for leptons and quarks respectively and the extraction of $\sin^2\theta_W$ from the data are presented carefully. The discussion on higher order electroweak correction are rather back dated. For example the values of these corrections for the top quark mass as low as 20 GeV have been presented in some tables. However, as was noted by the authors the sensitivity of the data presented in this book, is not sufficient to test the effect of higher order corrections. With the advent of LEP, this situation is likely to change and hence an updating of the discussion on higher order effects is called for. The extraction of $\sin^2\theta_W$ and the ρ parameter from neutrino-nucleon deep inelastic scattering data has been handled reasonably well. In this section, the parton model has been introduced. In view of the nature of this book, a section on the (QCD improved) quark parton model in Chapter 2 would have been very appropriate. The section on the weak charged current is fairly comprehensive. Low energy processes (such as heavy flavour decays, meson-antimeson mixing, CP violation etc.) as well as high energy processes (such as neutrino nucleon deep inelastic scattering) have been reviewed systematically. Some sections nevertheless, require immediate updating. For

example, V_{ub} (the *ub* element of the Kobayashi-Maskawa matrix) is now certainly known to be non zero whereas only a upper limit (and the preliminary results of the ARGUS group which later turned out to be wrong) have been presented in this book (p 245). Search for CP violation in the B system which has received much attention – theoretical as well as experimental – in recent times has not been paid the due attention.

Chapter seven discusses rare processes some of which are forbidden in the standard model but is predicted by some extensions of it. The authors have restricted their attention to the experimental limits on neutrino masses and mixing angles, half-lives of neutrinoless double β-decays and branching ratios of some rare weak decays. Since no positive signature of the so-called "new physics" has been seen so far there is no unique theoretical model. This perhaps is the reason of restricting the references to the theoretical scenarios to a few brief comments. This, however, is not compatible with the spirit of the rest of the book. Brief but comprehensive accounts of a few promising theoretical scenarios like supersymmetry (SUSY), the left-right symmetric model, models with extra neutral gauge bosons could have been included. The results of heavy new particle searches at different colliders also deserve brief mentioning.

As has already been pointed out several times, this book, like many other attempted encyclopaedic works in rapidly developing fields, suffers from partial impcompleteness. A few of the noticeable omissions are of course due to oversight. But must of them are to some extent inevitable since the frontiers of experimental high energy physics are changing continuously, yielding new results and limits and this state of affairs is likely to persist thanks to the on line and upcoming experiments at HERA, LEP, SLC, TEVATRON. TRISTAN etc. A possible way of ameliorating this is to publish (once in every two years – say) a booklet updating – where necessary – the material already presented. A completely revised version after a reasonable interval of time should also be kept in mind.

References

1. D H Perkins, *in Proceedings of the XXIV International Conference on High Energy Physics*, Ed. R Kolthaus and J Kuhn, Springer-Verlag : Berlin-Heidelberg (1989).
2. S L Glashow, *Nucl. Phys.* **B22**,579 (1961) ; A Salam in *"Elementary Particle theory"* ed N Svartholm, Stockholm : Almquist and Wiksell 1968, p. 367 ; S Weinberg, *Phys. Rev. Letters* **19**, 1264 (1967).
3. See, for example, *'Foundations of Quantum Chromodynamics'*, T Muta (World Scientific, Singapore, 1987).
4. For a review see, for example, R N Mohapatra, *"Unification and Supersymmetry"*, Springer-Verlag, 1986.
5. See, for example, *"Phenomenology of the Standard Model and beyond"*, Proceedings of the Workshop on High Energy Physics Phenomenology, Bombay, India Eds. D P Roy and P. Roy, World Scientific, Singapore, 1989.

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Dynamics of Disordered Materials (Springer Proceedings in Physics, Vol 37)
(Proceedings of the ILL Workshop, Grenoble, France, September 26-28, 1988)
edited by D Richter, A J Dianoux, W Petry and J Teixeira
Springer-Verlag : Berlin-Heidelberg-New York-London-Paris-Toyko, 1989
x+323 pages, 202 figures ; price : DM 85 (Hard cover) ISBN 3-540-50942-9

In ten review articles and about forty contributed papers the book surveys the recent developments on certain aspects of disordered materials particularly glasses in both theory and experiment. It is divided in following five parts : Introduction to neutron scattering, Dynamics around glass transition, Low frequency excitation, Spin glasses and orientational glasses and Fractal dynamics.

The physical properties near the glass transition have been studied by using different types of experimental probes like dielectric relaxation, NMR, light scattering and the well known neutron scattering techniques. Since the dynamics of interest spans a very large range in time scales, varied techniques are essential. However, majority of data have been acquired by neutron scattering method as described in the first two sections. Simultaneously the mode coupling theory as well as the more conventional free volume model and the Vogel-Fulcher law and others have been invoked to interpret experiment near the transition. The relaxation of density-density correlation functions studied by computer simulation is a significant preliminary attempt to capture atomic level description. Certain studies clearly indicate the existence of a critical temperature above the glass transition temperature but whose precise significance is still somewhat unclear. Another interesting area has been covered about the glass dynamics in absence of the diffusive motion commonly known as β-relaxation. Although significant advance has been achieved, the present models are yet to incorporate intramolecular degrees of freedom in polymers and molecular liquids which comprise a large class undergoing glass transition.

Another important area of disordered materials has been covered in part III. Evidence has been gradually increasing over the years that there exists a common feature namely an excess vibrational density of states at very low temperature for various types of disordered materials. Phenomenologically, these excitations which co-exist with sound waves have been broadly grouped in three categories, two level tunneling states, structural relaxation and additional harmonic vibrations. Although the validity of models based on them is well established the understanding of them on the basis of a microscopic picture is still marginal. A significant step forward has been to analyse the density of states as revealed by low energy neutron scattering in terms of atomic motions at least for some situations.

Part IV is concerned with the critical dynamics of the spin glass transition and the characteristics of orientational glasses which exhibit a freezing of the orientational degrees of freedom analogous to spin glasses and show low temperature thermodynamic behaviour peculiar to amorphous solids. The coupling of random

strain fields and dynamic modes is capable of describing qualitatively some broad features of orientational glasses at high temperature and low concentration of impurity ions. Another important feature is the non-ergodic instability and the onset of a quadrupolar glass for which definite experimental evidence exists. However, comparison of Potts glass model and axial quadrupolar model with experiments, is still an open question.

In part V a distinctly different and novel approach to the dynamics of a type of disordered materials has been adopted by introducing the fractal concept. Several works concentrate on evaluation of density of states of self similar fractal structure. The main feature of a fracton model is a cross over in the excitation spectrum at a critical frequency from extended to strongly localised modes seems to have been experimentally confirmed. Still alternative interpretations exist. Further experiments may resolve the point in near future.

The present compilation brings out in clear relief the diverse nature of problems associated with the dynamics of disorder that extends over about fifteen orders of magnitude in time. Again despite their complexity and dynamic range, different types of glasses display some common features which we want to understand in terms of a few simple ideas – a goal from which we are still far off. Highlighting and pinpointing the precise problems, the present book has served a very important purpose which the reviewer feels, will stimulate works for further clarification of our understanding of this difficult and interesting subject.

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Particle Physics and Astrophysics : Current Viewpoints

(Proceedings of the XXVII Int. Universitätswochen für Kernphysik Schladming, Austria, February 1988)

edited by H Mitter and F Widder

Springer-Verlag : Berlin-Heidelberg-New York-London-Paris-Tokyo-Hong Kong, 1989
x+309 pages, 100 figures ; price : DM 89 (Hard cover) ; ISBN 3-540-50699-8

The book constitutes the proceedings of the 27th Schladming Winter School, Austria, February 1988, dedicated to astrophysics and cosmology and their interface with particle physics and the theory of gravitation.

The first two chapters are intended as introduction to the current status in particle physics and in astrophysics and cosmology. Rapid surveys are made of the prevailing popular concepts, and physical entities with their theoretical backings are presented in capsules.

The third chapter presents a review of the state of the art in the studies of Type II supernova and constitutes a good introduction to the subject for non-experts. There is a balance in the exposition of observational aspects and theoretical models of core collapse supernovas. The SN 1987A neutrino events have been discussed, with special emphasis on neutrino transport and neutrino masses.

Black holes, though elusive, is a fascinating topic in astrophysics. Observational aspects and criteria of black holes along with the status of the three black hole candidates are discussed in chapter 4. Chapter 5, on the other hand is devoted to black hole energetics. The rather recent positive energy theorems are explained and the Hawking effect is discussed here.

The last chapter presents a fascinating account of the large-scale structure of universe suggested by recent observations. It starts with a review of the formation of large-scale structures through gravitational growth of primordial perturbations and then discusses how these perturbations could be produced by symmetry breaking phase transitions in the early universe.

Chapters six and seven provide a diversion from the general tenor of the proceedings. Chapter 6 discusses computer simulations as a tool to investigate models of quantum gravity while chapter 7 presents a short and elegant discussion of neutrino oscillations, a topic which may have important bearing on astrophysical problems such as the solar neutrino problem.

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Fermi Surface Effects (Springer Series in Solid State Sciences, Vol 77)
(Proceedings of the Tsukuba Institute, Tsukuba Science City, Japan, August 27-29, 1987)
edited by J Kondo and A Yoshimori
Springer-Verlag : Berlin-Heidelberg-New York-London-Paris-Tokyo-Hong Kong, 1988
ix+141 pages, 76 figures ; price : DM 85 (Hard cover) ; ISBN 3-540-19104-6

Any meaningful theory of electrons in metals started at the turn of this century by Drude and Lorentz. Later development by Sommerfield yielded that the electrons form a degengate Fermi-Dirac gas inside the metal. These electrons obey the Fermi-Dirac distribution which has a discontinuty at the Fermi energy. This discontinuty, although does not affect the ordinary conductivity, gives rise to singularities at low frequencies, which in effect become responsible for a number of effects in different physical processes which are known as Fermi surface effects.

The above description has an alternate intuitive picture where the electrons are assumed to constitute a sea known as Fermi Sea. The surface of this sea is

known as the Fermi Surface. The sea was initially assumed to be calm having only some ripples which could be easily treated by purturbation. But later on it was found that this sea is dangerous, it reacts violently to external perturbation giving rise to a number of tantalising physical effects known as the Fermi Surface effects. These developments have taken place in the last few decades and these are promises of new effects coming up. To take stock of the recent situation an workshop was held from August 27-29, 1987 at the Tsukuba Institute, Tsukuba Science City, Japan. The present book, under review, is the proceedings of this workshop.

The book contains only 5 articles containing the different aspects of the Fermi Surface effects. These articles are written by J Kondo, G D Mahen, A Okiji, D M Newns and C M Verma. The initial article by Kondo mainly deals with the effect of magnetic impurities in metals. He also surveys various models which are used to explain the various Fermi Surface effects. The articles by G D Maham deals with the singularities of X-ray spectra of metals. This effect was discovered around the end of sixties by the author and has become a powerful tool, since then, to study X-ray physics. The book ends with an article by C M Verma on the 'Heavy Fermion Superconductors' which is a very good example of a Fermi Surface effects. The presence of rare earth elements such as Ce in some compounds creates a situation where the valence of the rare earth become either mixed or fluctuating. If such compound becomes a superconductors some new tantalising interactions come into force and the superconductors shows some peculier behaviour. Prof Verma gives a lucid description of the phenomenon with a theoretical Hamiltonian containing the magnetic interaction term. As the book is a proceeding of an workshop which was mainly concerned with very highly shophisticated research topic, it is only suitable for research workers on this field. However the articles in the book contain many valuable informations which may be of interest to research workers in general.

Elemental and Molecular Clusters (Springer Series in Materials Science, Vol 6)
(Proceeding of the 13-th International School, Erice, Italy, July 1-15, 1987)
edited by G Benedek, T P Martin, G Pacchioni and J P Toennies
Springer-Verlag : Berlin-Heidelberg-New York-London-Paris-Tokyo-Hong Kong, 1988
viii+377 pages, 218 figures ; price : DM 105 (Hard cover) ; ISBN 3-540-19048-1

The study of the physical properties of states intermediate between the atom and the solid is called the cluster physics. This is an interesting branch of Solid State Physics since one can understand how the macroscopic properties of solid evolve by aggregating the atoms to form the ultimate extended solid structure. A Cluster is a stable group of a few or a few hundred identical atoms or molecules. A cluster builds up by adding successively single atom to the originally starting

atom. As the atom adds to the assembly of atoms then it reconstructs itself. After a cluster reaches a critical size, it is no longer free to reconstruct each time when a new atom is added. The book under review deals with electronic properties and structure of both metal and molecular cluster. This book, in fact, is the proceedings of the 13-th International School on this subject held from July 1-15, 1989.

In the introduction, T P Martin explained schematically how the various properties of solid such as Crystal growth, energy band and absorption spectrum are understood from the cluster. In part II, electric, optical and dynamic properties are discussed in details. How the nature of bonding changes progressively when one goes through clusters of increasing size are studied theoretically by considering the electron-electron interaction starting from H_2 molecule. Dynamical and optical properties of metal clusters are described experimentally by means of molecular beam techniques combined with mass spectroscopy.

In part III, the structure of clusters are studied by the different theoretical models. E Blaisten-Barojas extensively described the various properties such as total energy and coordination number and also the instantaneous structure of different cluster by computer simulation. In this part, the structure and energetics of doped clusters have been explored using the quantum path intergral molecular dynamics method. W Andreoni studied the electronic, structural and thermal properties of microclusters from the car-parrinello method which includes both molecular dynamics and density functional theory formalism.

In part IV, details experimental observations on fragmentation, reaction and dissociation of clusters are described. O Echt fully described the metastable decay, dissociation and electron attachment to Van der Waals clusters. In Part V, the chemical interaction in clusters are described. In this part, the electronic structure has also been studied by molecular orbital and constrained space orbital variation methods.

Thus the book contains both experimental and theoretical observations of metal and molecular clusters. It is very simple to understand from this book how the macroscopic properties of solids are evolved from the elemental constituents like atoms. In all the book is very helpful to both beginners and advanced research workers in cluster physics.

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Electronic Structure and Optical Properties of Semiconductors (Springer Series in Solid State Sciences, Vol 75)

by M L Cohen and J R Chelikowsky

Springer-Verlag : Berlin-Heidelberg-New York-London-Paris-Tokyo-Hong Kong, 1989, (2nd edn)
xii+264 pages, 161 figures ; price : DM 69 (Soft cover) ; ISBN 3-540-51391-4

In recent times, we have seen a surge of investigations on semiconducting materials due to the rapid advancements made in the device technologies based on compound semiconductors. New information regarding physical properties and preparative techniques poured-in in an exceedingly rapid fashion. This situation rightly demanded the publication of a book, like the one under review, documenting the progress in semiconducting materials alongwith a brief and refreshing presentation of basic theories related to semiconductor physics. The reviewer strongly beleives that this book will serve the basic need of an experimentalist in form of a quick reference book.

The basic concepts and theoretical methods are presented in a very lucid and concise way without losing the indepth meaning. The chapters on pseudo-potential and density of states demand special mentioning. The pseudo-potential method was elaborated systematically to explore the advances in pseudo-potential theory : self-consistent and *ab initio* pseudo-potentials. The authors havs also briefly discussed the connection of the above with surface and interface studies.

Chapters 8-10 deal with the band structures of elemental and compound semiconductors. They were classified in three groups : diamond (and zinc blende), wurtzite and chalcopyrite. Most of the semiconducting materials of current interest are covered in these chapters. Adequate theoretical results presented here added to the advantage of the experimental physicist.

However, the reviewer felt that the chapter 6 could have been presented a bit elaborately to include more detailed discussions on the data interpretation of some of the semiconductors. This would have been very helpful to the experimentalists, in general. The bibliography is quite updated and arranged in a neat way. The reviewer feels that the book will surely "serve both as a coherent source for the underlying ideas relating electronic structures and optical properties and as a source of factual information about semiconductors".

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Consistent Classical Supergravity Theories (Lecture Notes in Physics, Vol 336)

by Martin Müller

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vi+125 pages ; price : DM 39 (Hard cover) ; ISBN 3-540-51427-9

The volume is a compact lecture note in Physics, which represents an advanced level classification of the Classical Supergravity Theories in four dimension. The book consists of three parts. The part I deals with conformal Supergravity, the part II with Poincare Supergravity and the last part as a conclusion. The detail of part I contains the Superspace Geometry, the Bianchi Identities, the Linear and Non-linear Ricci Identities and the Invariant Chiral Superfield and Actions. All these are in detail and elaborate, although an introductory knowledge of supergravity, is necessary to understand the whole part.

In part II, an elaborate analysis of One and Two Form Gauge Potentials and On-shell and Off-shell Supergravity makes the book rich and profound. The conclusion part is very much helpful to the reader. As it gives a good summary and it also points towards the trend in present and future researches in this subject. The inclusion of appendices, which represent the mathematical detail of the calculations, is a nice facility and an extra advantage for the researchers in this field. The part of many calculations in the book may be used as a starting point for further calculations and further researches in many Extended Supergravity Theories.

Every physics library should have this book. I would like to recommend the book for the M.Phil, and Ph D students of Indian and Foreign Universities and to the researchers in Supergravity Theories.

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