# Advanced Topics In Physics I

# 2018-2019

This curricular unit is composed of several modules described below. All students are expected to take module 1 and choose 5 other modules. To complete this unit they must be approved in three modules.
Timetables will be arranged after students choices are known. Modules take usually 5/6 weeks with 3/4 contact hours per week.

## Modules

1. Communicating Science, Ana Salgado U. Minho.
2. Advanced Materials Preparation and Characterization (AMPC), Bernardo Almeida, U Minho.
3. The Physics of Electronic Materials and Devices (PEMD), Pedro Alpuim,. U. Minho
4. Clean Room and Micro-fabrication (CRMF), Paulo Marques, João Oliveira Ventura, U. Porto.
5. Nanomagnetism (NM), J E Araújo, U. Porto, Vitor Amaral, U. Aveiro.[To be confirmed]
6. Energy Harvesting (EH) : André Pereira, João Ventura, U. Porto
7. Graphene plasmonics (GP), Yuli Bludov ( U. Minho)
8. Group Theory and applications to Condensed Matter Physics (GTACMP), Joaquim Agostinho Moreira, U. Porto
9. Dark Energy, Dark Matter & Gravity (DEDMG), Orfeu Bertolami, U. Porto.
10. Introduction to Topological Matter(ITM), Eduardo Castro, U. Porto
11. Lasers, optics and photonics (LOP), Mario Ferreira, U. Aveiro.
12. Spectroscopic techniques for the characterization of materials (STCM), Luis Carlos, Rute André e N. Sobolev, and Luis Cadillon, U. Aveiro.
13. Scanning Microscopy Techniques and Electronic Microscopy (SMT), Andrei Kholkine and Augusto Barros Lopes (U. Aveiro)[To be confirmed]
14. Computational Physics (CP), Antonio Luis Ferreira, U. Aveiro.
15. Data Analysis in Particle Physics (DAPP), Nuno Castro ( U Minho)
16. Introduction to Little Higgs Models (ILHM) , Nuno Castro(U. Minho) , José Santiago

## Jury Panels

1. CS: Ana Salgado
2. AMTC: Bernardo Almeida, João Ventura, Florinda Costa.
3. PEMD: Pedro Alpuim, Bernardo Almeida, Joaquim Leitão
4. CRMF: João Oliveira Ventura; Paulo Marques, Bernardo Almeida
5. NM: João Pedro Araújo, Vitor Amaral, João Ventura
6. EH: André Miguel Trindade Pereira, João Oliveira Ventura
7. GP: Nuno Peres, Yuliy Bludov, João Lopes dos Santos
8. GTACMP: Joaquim Agostinho Moreira, João Lopes dos Santos, José Carmelo
9. DEDMG: Orfeu Bertolami, João Rosa, Filipe Mena
10. ITM: Eduardo Castro, João Lopes dos Santos
11. LOP: Mário Ferreira, Manuel Marques, Helder Crespo
12. STCM: Luís Carlos, Luis Cadillon
13. SMTEM: Andrei Kholkine and Augusto Barros Lopes,
14. CP: António Luís Ferreira, J V Lopes , Manuel Barroso
15. DAPP: Nuno Castro, Antonio Morais
16. ILHM; Nuno Castro, José Santiago

## 1. Curricular Unit

Advanced Physics Topics I

## Module

Communicating Science

## Type

Lecture Course

## Contact hours

20h contact + 10 online

## Professors/Researchers in charge

Ana Isabel Salgado

## Summary of Contents

By the end of this course students will be able to:

Demonstrate the ability to reflect critically about the impact of communication in interpersonal relationships (potentialialities and constraints of communication);

Identify and apply the necessary tools (knowledge, attitudes and behaviors) that support the development of public speaking skills;

Communicate effectively in an oral presentation;

Formulate a well-organized argument supported by evidence, strengthening the researcher's role in the scientific community and in the society in general;

Achieve higher rates of satisfaction and lower levels of anxiety associated with public speaking.

**Contents**

Communicating Science;

Target your talk;

Organize your presentation;

Visual aids;

Voice and language;

Body language and gestures;

Take control of the situation;

When the unexpected happens;

Handling question and answer sessions;

Inspire your audience.

## Evaluation

Active participation in training sessions (minimum passing requirement: 75% total hours)
Individual talk (minimum passing grade: 9,5): comment with a reflexive/critical analysis and a theoretical foundation
Final grade = 0,4 active participation + 0,6 individual talk

## Jury

Ana Isabel Salgado

## 2. Curricular Unit

Advanced Physics Topics 1

## Module

Advanced materials preparation and characterization (AMPC)

## Type

Lecture course

## Contact hours

18

## Professor/Researcher in charge

Bernardo Almeida, U. Minho

## Summary of Contents

Thin film preparation. Sputtering. Magnetron sputtering. Applications.
Laser Ablation deposition of thin films and nanostructures. Applications.
Structure and microstructure. X-ray diffraction. Low angle X-ray scattering, reflectometry, grazing incidence. Scanning electron microscopy (SEM). Transmission electron microscopy (TEM)
Infrared and Raman Spectroscopies. Lattice dynamics. Experimental setups. Applications.
Electrical properties. Dielectric relaxation. Impedance spectroscopy. Time and frequency domains. Experimental setups. Electrical resistivity. Magnetoresistance.
Magnetic properties. Magnetic interactions and magnetization. Magnetometry. Measurement techniques.
Optical properties. Reflectance and transmittance. Absorption. Photoluminescence. Ellipsometry.

## Evaluation

Final exam

## Jury

Bernardo Almeida, João Ventura, Florinda Costa

## 3. Curricular Unit

Advanced Physics Topics 1

### Module

The Physics of Electronic Materials and Devices (PEMD)

### Type

Lecture course

### Contact hours

18

### Professor/Researcher in charge

João Pedro Alpuim; palpuim@fisica.uminho.pt

### Summary of Contents

Continued miniaturization of silicon devices paved the way for a host of electronic appliances that revolutionized our day-to-day life during the last half century. Nanotechnology is currently introducing a new level of complexity into very small objects that in turn will allow this dizzying pace of miniaturization not only to keep up but possibly to accelerate.

This module is designed to provide a broad view of electronic materials and devices and their fabrication techniques, going from the well-established Si-based technology, through magnetic devices for data storage, up to sensors based on new 2D materials and their applications. The module includes a session hosted by INL in Braga, where students will be introduced to the state-of-the-art facilities that are available at the institute.

Electrons in solids (5 hours)
Electrons in a periodic field of a crystal
Energy bands in metal and semiconductor crystalline solids
Band structures in 3D, 2D and 1D
Electrons in nanostructures: Landauer resistance, Coulomb blockade and resonant tunneling

Micro/nanoelectronic semiconductor devices (5 hours)
The p-n junction and the bipolar transistor
The LED and the LASER
The field-effect transistor: NMOS, CMOS and 2D materials FETs

Macroelectronic devices (2 hours)
Solar cells
MEMS and NEMS devices
Displays

Sensors and data storage (3 hours)
Biosensors
Magnetic devices
Top down fabrication of micro and nanostructures (3 hours)

**Bibliography:**


Solid State Physics, N. W. Ashcroft, N. D. Mermin, Saunders College Publishing. Harcourt College Publishers. Fort Worth Philadelphia (1976).

Physics of Semiconductor Devices, S.M. Sze, K.K. Ng, J. Wiley & Sons Inc., New York, 3rd Edition (2006).

Introduction to Nanoelectronics, by V.V. Mitin, V.A. Kochelap and M.A. Stroscio, Cambridge University Press, Cambridge (2008).

Introduction to Nanoscience, S.M. Lindsay, Oxford University Press, Oxford (2010).

Fundamentals of microfabrication: the science of miniaturization, Marc J. Madou, Taylor & Francis, Inc., 2nd Edition, New York (2002).


## Evaluation

Student grading will be based on a final individual exam containing conceptual questions and problems to be solved by the student. Grading will be based on a 0-20 scale and to get approval the student must obtain at least grade 10.

Students can also adhere voluntarily to a scheme of periodic evaluation of their work, based on the weekly resolution of a problem chosen by the professor and to be returned the following class. Students can seek information of any sort in order to solve the proposed problem but they compromise to do it individually. In every class, 20 minutes of lecture time will be devoted to the discussion of the solution of that week's problem and the methods used to obtain it. Any of the students having returned the problem solved in a particular week can be asked by the professor to introduce that discussion orally, based on the solution and the way he/she obtained it. In case he or she fails to do so, the problem will not be considered for evaluation. There will be a series of 8 weekly problems, each valued 2.5 points, and totalizing 20 points. Each student can enter/leave this evaluation program freely. The student will be approved in this scheme when he/she accumulates at least 10 points. In this case he/she can decide not to present himself/herself to the final exam in which case his/her final grade will be the sum of the points accumulated in the periodic evaluation of his/her work.

## Jury

Pedro Alpuim, Bernardo Almeida, Joaquim Leitão

## 4. Curricular Unit

Advanced Physics Topics 1

## Module

Clean Room and Micro-fabrication (CRMF)

## Type

Practical instruction

## Contact hours

18

## Professor/Researcher in charge

Paulo Vicente Marques

## Summary of Contents

This course will introduce, in a hands-on approach, the main microfabrication and deposition techniques used to produce functional devices in a Clean Room environment. Basic training in the use of a Clean Room, including basic facility description, operating procedures and safety instructions, will be provided. Ion beam deposition, resistive and electron-beam evaporation will be used to grow metallic and insulating thin films. The resolution and minimum feature size attainable by optical lithography will be studied using Direct Write Laser and Mask Alignment systems. Pattern transfer techniques (dry and wet etching and lift-off) will allow the comparison of their selectivity, anisotropy and etching rate. Basic characterization of the produced structures will be performed using optical microscopy and perfilometry, to extract relevant parameters (thin film roughness, thickness, deposition rates and uniformity; feature sizes, distributions, etching profiles). This module will take place in the recently installed Clean Room of the Porto University, CEMUP MNTEC.

## Evaluation

Essay and oral presentation

## Jury

João Oliveira Ventura; Paulo Marques, Bernardo Almeida

## 5. Curricular Unit

Advanced Physics Topics 1

## Module

Nanomagnetism (NM)

## Type

Lecture course

## Contact hours

18

## Professor/Researcher in charge

João Pedro Araújo, U. Porto, Vitor Amaral (U. Aveiro)

## Summary of Contents

Magnetism: basic macroscopic concepts. Magnetic moment, diamagnetism, paramagnetism. Macroscopic description: field and temperature dependence of a spin ½ paramagnetic system.

Spin, orbital and magnetic momentum. Electronic configurations, Hund rules, 3d and 4f atoms/ions

Brillouin function, Curie law, Pauli paramagnetism. Perturbation theory and Van Vleck paramagnetism. Magnetic interactions, microscopic description, ferromagnetism, ferrimagnetism, antiferromagnetism. Electronic correlations. Mean field models. Curie-Weiss law

The Landau theory of phase transitions: order parameters, equation of state, critical temperature and exponents, Arrott-Belov plots, coupled magneto-volume phase transitions, the magnetocaloric effect.

The Bean-Rodbell model, scaling plots, critical phenomena, the Ising and Heisenberg models, the Arrott-Noakes equation of state.

Magnetic domains. Magnetostatic energy, anisotropy energy. Domain walls.

Magnetic nanoparticles, Stoner-Wolfhart model.

Superparamagnetism, relaxation, Néel and Brown mechanisms. Energy distributions, dipolar interactions, surface effects. Exchange bias. Applications: recording, hyperthermia and magnetic resonance imaging.

## Evaluation

Written essay on selected topics. Oral presentation (15’) followed by discussion (10’).

## Jury

João Pedro Araújo, Vitor Amaral, João Ventura

## 6. Curricular Unit

Advanced Physics Topics I

## Module

New Trends of Energy Harvesting towards innovative and efficient Nanogenerators

## Type

Lecture Course

## Contact hours

18h

## Professors/Researchers in charge

André Miguel Trindade Pereira/João Oliveira Ventura

## Summary of Contents

Internet-of-Things (IoT) has become a growing concept with a potential to affect how we live and how we communicate with the “Livings” and the “Things” around us. IoT is a concept of connecting all the daily use devices into the internet such as mobile phones, refrigerator, computers, doors, gadgets, and cars. Although this is an emerging area, there has been an increase in activities to find solutions for extending the lifetime operation for wearables. Energy harvesting is an emerging topic that can be utilized to recharge/replace batteries in low power application. Although, energy harvesting has been known for decades, however, it is becoming possible to harvest since the power consumption of electronic circuits has become low enough to be powered by energy harvesting sources. Further, recent researches in circuit design have pushed the power consumption of electronic circuit as low as possible. In addition, state-of-the-art harvesters have become small, efficient, flexible which allow these harvesters to be integrated into small form factor. This will be the main topic of the present course.

The course has the following contents:

Introduction to Energy Harvesting

NanoPiezoeletric Generators

NanoTriboelectric Generators

NanoThermoelectric Generators

RF Harvesting

Fuel Cells

Hybridization of energy harvesters

Trends, challenges and opportunities in Energy Harvesting

**Bibliography:**

[1] Mohammad Alhawari Baker Mohammad Hani Saleh Mohammed Ismail "Energy Harvesting forSelf-Powered Wearable Devices" Springer 2017. [2] Cátia R.S. Rodrigues, Carla A.S. Alves, Joel Puga, André M. Pereira, João O. Ventura "Triboelectric driven turbine to generate electricity from the motion of water" NanoEnergy **30** 379-386 (2017)

## Evaluation

Written essay on selected topics. Oral presentation (15') followed by discussion (10')

## Jury

André Miguel Trindade Pereira, João Oliveira Ventura

## 7. Curricular Unit

Advanced Physics Topics 1

## Module

Graphene plasmonics (GP)

## Type

Lecture course

## Contact hours

18

## Professor/Researcher in charge

Yuliy Bludov

## Summary of Contents

This module exposes the students to basic concepts of the rapidly emerging area of graphene plasmonics. The practical interest of this area is determined by the small wavelength of the surface polaritons, when compared to that of bulk electromagnetic waves, which allows the miniaturization of photonic components. Furthermore, this gives rise to a higher localization of the surface polaritons, which are characterized by lower damping, in comparison with noble metals. The possibility to dynamically tune graphene's conductivity through the variation of a gate voltage introduces and extra degree of freedom into the problem. In this module students contact with basic knowledge on the optical properties of graphene and on the properties of surface polaritons (a special kind of electromagnetic waves, propagating along surfaces and interfaces) both in noble metals and in graphene (a 2D carbon material). The theory of surface polaritons in graphene, dispersion relations and methods for exciting these type of waves, is explained. Finally the description of experimental works as well as the corresponding operational principles will be detailed. Detailed program:

1.) electronic properties of graphene and its optical conductivity;
2.) Drude model for metals and for graphene;
3.) Surface plasmon-polaritons in noble metals;
4.) Surface plasmon-polaritons in graphene;
4.) Methods for exciting surface plasmon-polaritons;
5.) Some experiments using the excitation of surface plasmon-polaritons;
6.) Localized plasmons in graphene based nano-structures.

## Evaluation

1.) For new comers to the subject: One written report and one introductory computational project.

2.) For experts on the topic: One research project, which must be presented in the end of the semester in front of the class.

Note: Any student can opt for one or the other type of evaluation

## Jury

Nuno Peres, Yuliy Bludov, João Lopes do Santos

## 8. Curricular Unit

Advanced Physics Topics 1

## Module

Group Theory and Applications to Condensed Matter Physics

## Type

Tutorial: Reading and Study assignment

## Contact hours

18

## Professor/Researcher in charge

Joaquim Agostinho Moreira , U. Porto

## Summary of Contents

Representations theory and basic theorems. Character of a representation and basis functions.
Direct product and its representations. Application to selection rules and splitting of atomic levels in a crystal field.
Space groups in real space and in the reciprocal space. Symmetry of the k vectors and the group of the wave vector. Representations of a space group. Little group and stars. Factor group analysis and the Γ point. Points for k≠0. Compatibility relations.
Applications to lattice vibrations and electronic energy levels. Energy band models based on symmetry. Spin-orbit coupling in solids and double groups and application to energy bands with spin.
Time reversal symmetry. The Magnetic Groups and their Corepresentations. Properties of the magnetic point groups.

**References**

Group Theory. M. S. Dresselhaus, G. Dresselhaus, and A. Jorio. Springer. 2008
The Mathematical Theory of Symmetry in Solids. Representation Theory for Point Groups and Space Groups.  C. Bradley and A. Cracknell. Oxford Classic Texts in the Physical Sciences. 2010.
J. L. Ribeiro. Phys. Rev. B 76, 144417 (2007).
J. L. Ribeiro and L. G. Vieira. Phys. Rev. B 82, 064410 (2010)
I. Urcelay-Olabarria, J. M. Perez-Mato, J. L. Ribeiro, J. L. García-Muñoz, E. Ressouche, V. Skumryev, and A. A. Mukhin. Phys. Rev. B 87, 014419 (2013).

## Jury

Joaquim Agostinho Moreira, João Lopes dos Santos, José Carmelo

## 9. Curricular Unit

Advanced Physics Topics 1

## Module

Dark Energy, Dark Matter & Gravity (DEDMG)

## Type

Tutorial

## Contact hours

18

## Professor/Researcher in charge

Orfeu Bertolami

## Summary of Contents

Recent observational evidence arising from the cosmic microwave background radiation (CMB), from type Ia supernovae (SNe-Ia), from baryon acoustic oscillations (BAO), etc, indicate that the expansion of the Universe is accelerating, and that matter that can be observed through the electromagnetic radiation cannot account for the formation of galaxies, cluster and superclusters of galaxies. These observations suggest that, on large scales, the dynamics of the Universe is dominated by a smooth uniformly distributed form of energy, dark energy, and that structure formation requires a substantial amount of a new form of matter, dark matter. The nature and the characterization of these dark components are central issues in contemporary cosmology. Of course, a relevant related question is whether the observations can be accounted by alternative theories of gravity. Thus, in these lectures, observational and theoretical ideas and proposals to unravel these open questions will be discussed.

## References

*Dynamics of dark energy* , E. Copeland, M. Sami, S. Tsujikawa. Mar 2006 - 84 pages Int.J.Mod.Phys. D15 (2006) 1753-1936 DOI: 10.1142/S021827180600942X , e-Print: hep-th/0603057

*Astrophysical and cosmological probes of dark matter,* M. Roos. Aug 2012. 39 pp. e-Print: arXiv:1208.3662 [astro-ph.CO]

*Dark Matter: The evidence from astronomy, astrophysics and cosmology Matts Roos. Jan 2010. 25 pp. e-Print: arXiv:1001.0316 [astro-ph.CO]*

## Jury

Orfeu Bertolami, João Rosa, Filipe Mena

## 10. Curricular Unit

Advanced Physics Topics 1

## Module

Introduction to Topological Matter

## Type

Tutorial

## Contact hours

18

## Professor/Researcher in charge

Eduardo Castro, UPorto

## Summary of Contents

Berry phase in electronic systems; the Chern number as a topological invariant; the quantum Hall effect, Chern insulators and bulk edge correspondence; quantum spin Hall systems; 3D topological insulators; topological superconductors and Majorana modes; topological classification; gapless topological systems (Weyl and Dirac semimetals).

## References


"Berry phase effects on electronic properties", D. Xiao, M.-C. Chang, Q. Niu, Rev. Mod. Phys. **82**, 1959 (2010)

"Topological insulators", M. Hasan and C. Kane, Rev. Mod. Phys. **82**, 3045 (2010)

"Topological insulators and superconductors", X. Qi and S.-C. Zhang, Rev. Mod. Phys. **83**, 1057 (2011)

"Topological Insulators and Topological Superconductors", B. A. Bernevig, Princeton University Press, 2013

"Topological Insulators", S. Shen, Springer, 2012

"Weyl and Dirac semimetals in three-dimensional solids", N. P. Armitage, E. J. Mele, A. Vishwanath, Rev. Mod. Phys. **90**, 15001 (2018)

"A Passage to Topological Matter", K. Park, Journal of the Korean Physical Society **73**, 817 (2018)

## Evaluation

Written Report with oral presentation

or

Written Report

## Jury

Eduardo Castro, João Lopes dos Santos

## 11. Curricular Unit

Advanced Physics Topics 1

## Module

Lasers, optics and photonics (LOP)

## Type

Lecture course

## Contact hours

18

## Professor/Researcher in charge

Mario Ferreira, U. Aveiro

## Summary of Contents

This module will cover several topics that illustrate the revolution in optical area during the last decades, following the invention of the LASER. Special attention will be paid to some latest developments within optical communications and nonlinear optics.

## Evaluation

?????

## Jury

Mário Ferreira, Manuel Marques, Helder Crespo

## 12. Curricular Unit

Advanced Physics Topics 1

## Module

Spectroscopic techniques for the characterization of materials (STCM)

## Type

Lecture course

## Contact hours

18

## Professor/Researcher in charge

Luis Carlos, U. Aveiro

## Summary of Contents

Optical properties;
Photoluminescence in steady state and time resolved (emission spectra and emission decay curves) modes.
Quantification of the emission features (Absolute quantum yield, photometric and radiometric parameters, colour coordinates)
Ellipsometry. Fundamentals and applications. Structural modelling.
Electric properties; EPR

## Evaluation

Written Test (3h).

## Jury

Luís Carlos, Florinda Costa; João Pedro Araújo

## 13. Curricular Unit

Advanced Physics Topics 1

## Module

Scanning Microscopy Techniques and Electronic Microscopy (SMTEM)

## Type

Lecture course

## Contact hours

18

## Professor/Researcher in charge

Andrei Kholkine and Augusto Barros Lopes (U. Aveiro)

## Summary of Contents

This module is designed to provide a broad view of the principles and fundamentals of different microscopy techniques, namely scanning microscopy and electron microscopy.

**Scanning microscopy**
Survey of STM and SPM methods and their comparison with other microscopic techniques
STM and AFM instrumentation
Scanning Tunnelling Microscopy and applications
Forces at the nanoscale and contact AFM
Contact vs. non-contact and tapping AFM.
Electrostatic and Magnetic Force Microscopy
Kelvin Force Probe Microscopy
Piezoresponse Force Microscopy and nanoscale characterization of ferroelectrics.
Scanning Near-field Optical Microscopy
Nanoindentation
Scanning Spreading Resistance Microscopy
AFM demonstration and practical classes

**2. Electronic microscopy**
The electron microscopy as a materials characterization technique

The depth of field and the resolution limit of the optical microscope

Advantages of using electrons

The basic constitution and working principles of the scanning electron microscope (SEM), the transmission electron microscope (TEM) and the scanning transmission electron microscope

(STEM).

Sample preparation for SEM and TEM

The Energy Dispersive Spectroscopy (EDS).

SEM and EDS practical demonstration

The interaction volume. Influence of the atomic number, thickness, electron beam energy and sample tilting.

SEM observation modes. Secondary and backscattered electron image modes.

TEM Image and diffraction modes

TEM Contrast. Mass-Thickness contrast, diffraction contrast (bright and dark field image modes) and phase contrast

TEM practical demonstration

## Evaluation

Written essay on selected topics. Oral presentation (15’) followed by discussion (10’).

## Jury

Andrei Kholkine  and Augusto Barros Lopes, João Ventura

# 14. Curricular Unit

Advanced Physics Topics 1

## Module

Computational Physics (CP)

## Type

Lecture course

## Contact hours

18

## Professor/Researcher in charge

Antonio Luis Ferreira, U. Aveiro, J Pedro Coutinho , U. Aveiro

## Summary of Contents

**Part 1 (9 hours)** Introduction to Monte Carlo Methods

Monte Carlo Methods in Statistical Physics. Markov Chains: Chapman-Kolmogorov equation; Transient and stationary regimes; Detailed balance.

Monte Carlo Integration: Hit or Miss Monte Carlo; integration as an average calculation; random Sampling; importance sampling; Markov Chain Monte-Carlo; Metropolis algorithm

Applications to Statistical Physics: ergodicity; detailed balance; equilibration; estimating errors.

Advanced Monte Carlo methods

**Part 2:** Density Functional Theory: Modeling Solids, Surfaces and Molecules

Introduction to Density Functional Theory; The many-body Hamiltonian and the exchange-correlation functional; Pseudo-potentials; Valence states and basis functions; Brillouin zone sampling methods; Numerical implementation.

Applications to solid-state problems, surfaces and molecules

Hands-on session: “Pick a problem for your classmate”

## References


Understanding Molecular Simulations, Daan Frenkel and Berend Smit

Computer Simulation of Liquids, M P Allen and D J Tildesley

Monte Carlo Methods in Statistical Physics, by Mark Newman, G T Barkema

Density functional theory: An introduction, Nathan Argaman and Guy Makov, American Journal of Physics 68, 69-79, (2000); doi:10.1119/1.19375; arXiv:physics/9806013

The ABC of DFT, Kieron Burke, https://dft.uci.edu/doc/g1.pdf

## Evaluation

Exam with computational exercises (part1); Exam with computational exercises (part2).

## Jury

António Luís Ferreira, J Pedro Coutinho

# 15. Curricular Unit

Advanced Physics Topics I

## Module

Data Analysis in Particle Physics

## Type

Tutorial

## Contact hours

18h

## Professors/Researchers in charge

Nuno Castro

## Summary of Contents

The ability to fully explore the physics potential of the Large Hadron Collider (LHC) data relies on the ability to efficiently analyze the available dataset, maximizing the sensitivity to subtle signals hidden in a huge amount of background events. In the present tutorial will allow the students to acquire, in a supervised way, competences on advanced data analysis techniques, as well as expertise on some advanced tools commonly used in the high energy physics community.

During the tutorial, the following topics will be covered:

1) Monte Carlo Simulation
    1.1) Event generation and the use of Madgraph
2) Analysis tools
    2.1) Data analysis at the LHC
        2.1.1) Basic concepts
        2.1.2) C++ and ROOT
        2.1.3) Madanalysis
        2.1.4) Multivariate analysis techniques and the use of TMVA
3) Limit setting in searches for new physics phenomena

The tutorial will consist on a set of different exercises, designed to illustrate in an hands-on way, the use of the different tools and techniques, with the final goal being the development of a data analysis project by each student.

## Evaluation

The evaluation will be done based on the discussions held during the contact hours, as well as on the final project, according to the following weights:

Discussions during the contact hours: 10%

Quality of the developed project: 50%

Defense and presentation of the developed project: 40%

## Jury

Nuno Castro, António Morais

# 16. Curricular Unit

Advanced Physics Topics I

## Module

Introduction to Little Higgs Models

## Type

Tutorial

## Contact hours

18h

## Professors/Researchers in charge

Nuno Castro and José Santiago

## Summary of Contents

Recently there has been renewed interest in the possibility that the Higgs particle of the Standard Model is a pseudo-Nambu-Goldstone boson. This development was spurred by the observation that if certain global symmetries are broken only by the interplay between two or more coupling constants, then the Higgs mass-squared is free from quadratic divergences at one loop. This "collective symmetry" breaking is the essential ingredient in little Higgs theories, which are weakly coupled extensions of the Standard Model with little or no fine tuning, describing physics up to an energy scale ~10 TeV. In the current tutorial the structure and phenomenology of Little Higgs Models will be reviewed. Furthermore, the phenomenology of Little Higgs models will be discussed from different but complementary prespectives.

References:


[1] M. Schmaltz and D. Tucker-Smith, Little Higgs review, Ann. Rev. Nucl Part Sci. 55, 229 (2005), hep-ph/0502182.

[2] D. Dercks, G.Moortgat-Pick, J. Reuter and S. Y. Shim, The fate of the Littlest Higgs Model with T-parity under 13 TeV LHC Data, JHEP 1805, 049 (2018), arXiv:1801.06499 [hep-ph]; and the following recent update: arXiv:1811.02268 [hep-ph].

## Evaluation

The evaluation of the tutorial will be done in continuous way, with different exercises related to the content of the tutorial being proposed to the students. The final grade will be obtained by averaging the grades of exercices solved during the tutorial.

## Jury

Nuno Castro, José Santiago