



UNIVERSITAT DE  
BARCELONA

# Master on Astrophysics, Particle Physics and Cosmology

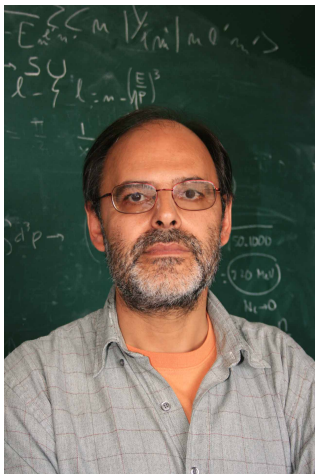
## Elementary Particles

Joan Soto    Ricardo Vázquez

Mon-Thu; 10:30-11:30; V12M

# Lecturers

Joan Soto



~ 2/3

Ricardo Vázquez



~ 1/3

# Aim

- Learning the main characteristics of elementary particles
- Learning the main features of fundamental interactions
- Calculating tree level observables in the QFTs relevant to nature
- Learning the basics of current detectors
- Learning the main features of key HEP experiments
  
- **Skills**
  - Critical assessment
  - Problem solving
  - Team work

# Previous Knowledge

- **Needed:**

- Quantum Mechanics
- Special Relativity

- **It will help:**

- Introduction to Particle and Nuclear Physics
- Introduction to High Energy and Collider Physics

# Syllabus

## 1. **Overview of particle physics**

Elementary particles and interactions; Baryons and mesons; Weak interactions; More generations.

## 2. **Fields for Free Particles. Discrete symmetries**

Scalar fields; Dirac Fermions; Vectors fields; C, P and T symmetries; Propagators.

## 3. **Continuum symmetries in Particle Physics**

Symmetry groups and conservation laws; Rotations and angular momentum conservation; Lie groups and Lie algebras; Representations of  $SU(2)$  and  $SU(3)$ .

## 4. **The quark model and effective theories of hadrons**

Internal symmetries and classification of hadrons; Non-relativistic quark model; The linear sigma model; The non-linear sigma model.

## 5. QED for leptons

Electromagnetic interaction as a U(1) (Abelian) gauge theory (QED); Calculation of scattering amplitudes and cross sections at tree level for several processes in QED ( $e^- \mu^- \rightarrow e^- \mu^-$ ,  $e^+ e^- \rightarrow \mu^+ \mu^-$ ,  $e^- e^- \rightarrow e^- e^-$ ,  $e^- \gamma \rightarrow e^- \gamma$ ). Mandelstam variables. Helicity conservation at high energies.

## 6. QED and the structure of hadrons

Concept of form factors;  $e^- p \rightarrow e^- p$  elastic scattering: proton form factors;  $e^- p \rightarrow e^- X$  inelastic scattering; Bjorken scaling and quarks; quark distribution functions; the gluons; the QCD Lagrangian.

## 7. Weak Interactions

Weak decays and parity violation: V-A weak charged currents; W boson as mediator of weak charged currents; Low energy tests: muon decay, nuclear beta decay, neutrino decay, neutrino-electron scattering; fermion mixing matrix; Weak neutral currents:  $Z^0$  and the GIM mechanism; CP violation.

## 8. **Electroweak Unification**

Weinberg-Salam Model of Electroweak Interactions; Spontaneous symmetry breaking: Higgs mechanism; Masses of the Gauge Bosons and of the Fermions.

## 9. **Experimental Techniques in Particle Physics**

Interaction of particles with matter. Types of sub detectors: calorimeters, tracking and Cherenkov. Accelerators. Measurement of luminosity. Trigger, event reconstruction and data analysis

## 10. **Example of a HEP experiment: ALEPH**

The Aleph detector. Measurement of the number of light neutrinos. Jets physics. Search for new physics.

## 11. **Heavy flavour experiments**

The LHCb and BaBar experiments.  $e^+e^-$  vs  $pp$  machines. Flavor tagging. Secondary vertex reconstruction. Lifetime measurements. Rare decays. CP violation. T violation.

# Bibliography

- *Quarks and leptons : an introductory course in modern particle physics*, Francis Halzen, Alan D. Martin
- *Introduction to high energy physics*, Perkins, Donald H. (e-book)
- *Introduction to elementary particles*, Griffiths, David J. (e-book)
- *Concepts of Elementary Particle Physics*, Peskin, Michael E. (e-book)
- *An Introduction to quantum field theory*, Peskin, Michael E.; Schroeder, Daniel V.
- *Lie algebras in particle physics : from isospin to unified theories*, Georgi, Howard



# Evaluation

- 70%, in groups of two
  - Weekly exercises
  - Problem sheet
  - Summary of a research article
- 30%, individual
  - Final Exam

Thank you