European Summer School 2014

Ateliers de recherche franco-allemands pour jeunes chercheurs

From the Mystery of Mass to Nobel Prizes

The Physics of the Higgs Boson

(An introductory school to modern particle physics)

Strasbourg, 7/07/2014 – 12/07/2014

Structure of the Scientific Programme

The scientific programme of the Workshop in the format of a Summer School is being built out of lectures, which span over several days and Workshops, where students can work in small groups under the guidance of a researcher.

Lectures (4-6h long):

- Introduction: Spontaneous symmetry breaking,
  F. Englert (Nobel prize 2013, video transmission from ICHEP, Valencia)
- The Standard model (SM) and the Higgs mechanism
  Margarete Mühlleitner, KIT, 6h,
  Electro-weak unification and spontaneous Symmetry Breaking, the Higgs mechanism
  Stability of the Higgs mass, the hierarchy problem,
  Extensions of the SM to very high energies; example SUSY and others
- Experimental challenges I:
  - The conception of the LHC and CMS and ATLAS detectors,
    Jean-Marie Brom, IPHC, 2h
  - Future developments: the upgrades to even higher luminosity at the LHC.
    Ulrich Husemann, KIT, 2h
    CERN pursues a long-term plan to fully exploit the vast physics potential of the Large Hadron Collider (LHC) within the next two decades. The CERN accelerator complex will be upgraded in several steps to increase the collision energy and the luminosity delivered by the LHC and thus to maximize the amount of data delivered to the LHC experiments. The increase in luminosity comes at a price: the experiments will have to cope with very high detector occupancies and operate in the harsh radiation environment caused by the thousands of elementary particles produced at each beam crossing.

    In parallel to the accelerator upgrades the LHC experiments are preparing various upgrades to their detector, trigger, and data acquisition (DAQ) systems. The general goal of the upgrades is to achieve comparable or better physics performance than with the current setup in the increasingly challenging LHC environment. The LHC experiments are planning to move to new technology standards, to replace aging components by more radiation-hard parts, or to implement entirely new detector, trigger, and DAQ concepts in order to meet this goal. The upgrades can be roughly divided in two phases. The Phase-1 upgrade started after LHC Run 1 in 2013. In Phase 2 of the upgrade the experiments will prepare for the high-luminosity era of the LHC (HL-LHC) after 2024. In my lecture I will discuss the plans of the LHC experiments for the Phase-1 and the Phase-2 upgrades, focusing on the interplay between physics program, detectors, trigger, and DAQ.

    The particle physics community is also planning the next generation of electron-positron colliders, such as the International Linear Collider (ILC). In many respects, the ILC will be complementary to the LHC, including the challenges for detector design. In my lecture I will contrast detector requirements and designs for the ILC with those for the LHC upgrades.
- Experimental challenges II:

Data analysis: Discovery and characterization of the Higgs Boson, new analysis strategies for high luminosity and future discoveries at LHC and future colliders
Michalis Bachtis, CERN, 6h
The discovery of a Higgs boson in ATLAS and CMS was one of the greatest achievements in particle physics. These lectures will describe all the experimental steps towards the discovery and beyond.
Starting from the detector design of ATLAS and CMS, we will review all the performance requirementsto be sensitive to the Higgs boson and describe all the experimental techniques implemented to improve the sensitivity to the search. Then we will study how the several analyses ar performed and how the Higgs signal is extracted reviewing also the latest results from the experiments from Run I data taking.
The last part of the lecture will describe future prospects of Higgs physics in the LHC and in future e+e- and pp colliders.

- Relation to cosmology: The early Universe: Inflation and symmetry breaking,
  Lorenzo Sorbo, University of Massachusetts Amherst, 2 h
  Cosmological observations strongly support the existence of a primordial epoch of accelerated expansion of the Universe, known as inflation.
  After a very brief review of the fundamentals of cosmology, I will review the main motivations that led to the theory of inflation. Since inflation is characterized by one or more fields taking a large, time-dependent expectation value, we will see that it generally leads to the breaking of symmetries, and to the generation of large, time-dependent masses for otherwise light particles.
  In the second part of the course we will see how inhomogeneities are generated by quantum effects in the inflating Universe and how such inhomogeneities evolved into the structure (planets, solar systems, galaxies and clusters of galaxies) we inhabit today.
- Lepton mixing and Neutrino Mass, Werner Rodejohann MPI-Heidelberg. (2h)
  The Standard Model predicts neutrinos to be massless, which contradicts observation. Therefore the study of neutrinos is the only directly testable physics beyond the Standard Model.
  We will deal with the description of lepton mixing and the formalism for neutrino oscillations, a phenomenon only possible if neutrinos are massive. Our current understanding of the lepton mixing matrix is presented.
  Then we turn to the question of how neutrino mass is actually generated, and why it is so small. A mechanism in analogy to the one that generates quark and charged fermion masses is unlikely. The seesaw mechanism is the favoured explanation to generate tiny neutrino masses, and has a number of phenomenological consequences, the main one being that neutrinos are so-called Majorana particles. Lepton-number violating processes are then possible, and the implications of the most interesting one, neutrinoless double beta decay, are discussed.

Working groups (2 half days):

- Exercises and details to the lectures :
  - Higgs theory
  - Higgs experimental strategies
  - Neutrinos
  - Cosmology and inflation
- Higgs studies at a linear e^+e^- collider (A. Besson and J. Baudot)
  - Precision on the determination of the Higgs mass with the recoil-mass method,
  - Benefit of the beam polarization for specific cross-sections,
  - Precision on the Higgs coupling to charm.
- Statistical tools in Higgs searches (tbc)
- Examples of analysis at the LHC, exchange of experiences,
  (participating PhD students)

Visit of Laboratories (Campus Nord KIT-KCETA)

Time	Event	Location
8:45	Bus arrives at KIT Campus North Campus North, South Gate, Hermann-von-Helmholtz-Platz	
8:50	Welcome, students guided to lecture hall	in front of FTU
9:00	Welcome to KIT, Overview of KCETA	FTU, Room 162
9:15	Lecture: The Higgs Mechanism 3	FTU, Room 162
10:30	Coffee break	FTU
11:00	Lecture: LHC Upgrade Program	FTU, Room 162
12:30	Lunch break	Campus North Canteen
13:30	Enter KIT Campus North through South Gate, split in 2 groups Campus North, South Gate, Hermann-von-Helmholtz-Platz	

Group 1

13:45	Introduction to KATRIN	Building 425, Room 206 (IKP)
14:30	KATRIN visit	Campus North, Building 460
15:15	Coffee break	Building 425, Room 206 (IKP)
15:45	Introduction to Silicon Detectors	Building 242, Room 114 (IPE)
16:30	Laboratory visits at IPE and EKP	Campus North, Buildings 230 and 401

Group 2

13:45	Introduction to Silicon Detectors	Building 242, Room 114 (IPE)
14:30	Laboratory visits at IPE and EKP	Campus North, Buildings 230 and 401
15:15	Coffee break	Building 425, Room 206 (IKP)
15:45	Introduction to KATRIN	Building 425, Room 206 (IKP)
16:30	KATRIN visit	Campus North, Building 460

17:30 Bus leaves from KIT Campus North
Campus North, South Gate, Hermann-von-Helmholtz-Platz

Poster session: All students are supposed to present a poster with their work of research or a topic related to the subject of the school