Karlsruhe School of Elementary Particle and Astroparticle Physics: Science and Technology (KSETA)

KSETA is the graduate school associated with the KIT Center Elementary Particle and Astroparticle Physics KCETA, which bundles experimental and theoretical research and education at the interface between astronomy, astrophysics, elementary particle physics and cosmology.

We hereby certify that the doctoral researcher

Simon Kast

has attended the following courses during his/her time in the graduate school KSETA.

Scientific writing

May 24 – 31 2017 *William Uber Personalentwicklung und Berufliche Ausbildung KIT*

This course helps participants to gain confidence in their scientific writing and editing skills and provides them with feedback and tips that will help them improve their current and future writing projects. Researchers increasingly need to publish their work in English in order to reach a wider audience and improve their academic standing. Sometimes their level of English leads reviewers to reject the papers or to misunderstand the contents. The course comprises a two-day interactive session that take participants step-by-step through the writing and revision of one of their papers at the conceptual, organisational and writing levels. First, participants learn how to ensure that the paper's content fits to their message and audience. Then, they learn how to organize a paper and structure a logical argument in English. Finally, participants learn how to revise their texts at the section, paragraph and sentence level. At each level we explore the main differences between papers in English and German. Participants apply the theory to their own texts. They also receive feedback and suggestions for improvement of their texts from the workshop leader. By the end of the course each participant will have polished one paper and will be able to approach the next one confidently.

Solid State Physics for Elementary Particle Physicists

Mar 20 – 21 2017 *Wulf Wulfhekel*

In this intensive course, I will give an overview on the theory and experiments of condensed matter physics. Essentially, I will focus on phenomena that deal with periodic structures, many electron systems and their excitations and will highlight the connections to particle physics. Necessary prerequisites for the course are basic knowledge auf quantum mechanics and statistical mechanics. The course will include the special symmetries of the solid state, the lattice and its dynamics, Fermi liquid theory, thermodynamics of the lattice and electron gas, electron transport and superconductivity.

Doctoral workshop 2017

July 10 – 12 2017 *Simon Kast*

The KSETA Doctoral Workshop allows interested KSETA fellows to learn more about methods and tools that might support their research. Doctoral students of all KSETA research fields, from theoretical or experimental particle and astro-particle physics to software or cryogenic engineering, are invited to spend three interesting and inspiring days together and to benefit from the other participants' experience.
One key aspect of the workshop are the tutorials given by all participating doctoral students. In groups, the participants prepare their tutorial "from doctoral fellows for doctoral fellows" on a topic that could be useful to others concentrating on other fields of research. This tutorial may cover introductions to useful tools, basic technologies for non-engineers, basics in physics for non-physicists, or applicable methods for research. Every tutorial lasts one hour and the presenter is free to use any didactic method like PowerPoint, whiteboard, or interactive methods such as exercises on programs installed on the students' laptops.
The workshop program is complemented by invited talks and discussions.

After a short reminder about fundamental notions in statistics, we focus on Bayes' Theorem. We present both the basic definition and derivation, as well as a hands-on example. In the second part we focus on the basic tasks in statistics related to data analysis in physics. Terms, such as p-value, confidence interval, goodness of fit, chi-squared test, maximum likelihood and many more, are defined, explained and classified in the context of fundamental talks in experimental analyses.

Axionic and WISPy Cold Dark Matter

Apr 06 – 07 2017 *Joerg Jaeckel (Uni Heidelberg)*

The axion solving the strong CP problem is one of the best motivated dark matter candidates. In these lectures we will introduce the axion and look at some of its most important features. As it turns out the axion as well as a number of more general very light bosons are an intriguing possibility for the cold dark matter of the Universe. We will consider the production mechanism that makes such light bosons good candidates for the cold dark matter and discuss some of its features. Finding such very light dark matter candidates requires different techniques than employed in the hunt for WIMPs. We will discuss some existing experiments as well as future opportunities.

Introduction to statistical methods in particle and astroparticle physics

Apr 05 – 07 2017 *Thomas Schwetz-Mangold*

In this course I will give an introduction to basic methods in probability and statistics from the point of view of an phenomenologist in particle and astroparticle physics. The course will cover frequentist and Bayesian methods and we discuss the problems of parameter estimation, goodness-of-fit and model comparison, as well as sensitivity estimates for future experiments. We will introduce concepts such as the likelihood and chi-squared statistics, discuss global analyses of several data sets, the problem of systematic uncertainties and nuisance parameters.

Introduction to string theory

Sep 21 + 22 2016 *Dr. Timo Weigand (Uni Heidelberg)*

String theory replaces the notion of pointlike fundamental objects in nature by one-dimensional fundamental strings. Combined with the usual axioms of quantization and general covariance, this results in a perturbative interacting quantum theory free of ultra-violet divergences. Its low-energy limit includes massless spin-one and spin-two states, thereby unifying gauge and gravitational interactions in a consistent framework. Compactification of this necessarily higher-dimensional theory makes contact with modern concepts of geometry and provides links to particles physics, quantum field theory, quantum gravity, and mathematics. The first part of these lectures will introduce the basic concepts of perturbative string theory, starting from the quantization of the classical string worldsheet action, including configurations with D-branes, and deriving the Hilbert space of states. In the second part we will discuss aspects of the low-energy effective action and introduce some notions of compactification, time permitting with applications to particle physics.

Scientific programming with Mathematica

Sep 15 + 16 2016 *Dr. Thomas Hahn (MPI Munich)*

I will give an introduction to scientific programming in high-energy physics, with both symbolic and numeric methods. The focus will be not so much on how to use existing packages, but rather to show with concrete examples how to solve typical problems in high-energy physics. For example, a color trace is computed using different methods. Languages used are Mathematica, FORM, C, Fortran, and a little bit of shell scripting. The lectures are self-contained, e.g. familiarity with Mathematica is not assumed; the selection of topics/examples is somewhat theory-biased, however.

Physik jenseits des Standardmodells

Oct 01 – Dec 31 2016 *Prof. Ulrich Nierste*

Qualifikationsziele:
a) Verständnis der Methodik der Suche nach neuer Physik b) Überblick der wichtigsten Erweiterungen des Standardmodells der Elementarteilchen Inhalt:
1. Wiederholung des Standardmodells 2. Symmetrien und Anomalien 3. zusätzliche Higgs-Sektoren 4. erweiterte Eichsymmetrien 5. zusätzliche Dimensionen

New Physics on Trial at LHC Run II
Jul 24 - Aug 5 2016 *MITP Summer School*
The Mainz Institute for Theoretical Physics hosts a summer school for Ph.D. students in theoretical physics. The theme for the first summer school is New Physics on Trial at LHC Run II, which will focus on beyond the Standard Model physics at the LHC.

The school is primarily focused on phenomenology at the Large Hadron Collider, especially in the context of physics beyond the Standard Model. The main theme of the school is the interplay between theory and experiment as told via the relationship between New Physics models and LHC signatures.

Sally Dawson (Brookhaven National Laboratory) - Higgs Physics
Bogdan Dobrescu (Fermi National Accelerator Laboratory) - Exotics Phenomenology
Tobias Golling (University of Geneva / CERN) - LHC - Experimental Perspective
Yuval Grossman (Cornell University) - Flavor Physics
Roni Harnik (Fermi National Accelerator Laboratory) - Dark Matter
Maxim Perelstein (Cornell University) - Collider Physics
Tilman Plehn (University of Heidelberg) - Supersymmetry Phenomenology
Jesse Thaler (Massachusetts Institute of Technology) - Jet Physics

With special lectures by
Nima Arkani-Hamed (Institute for Advanced Study) - Collider Physics From The Bottom-Up

Slavnov-Taylor-Identities and SUSY breaking in Dimensional Reduction
Apr 7 - 8 2016 *Prof. Dominik Stoeckinger*
Slavnov-Taylor-Identities and SUSY breaking in Dimensional Reduction

Introduction to Flavour Physics
Apr 18 - Jul 17 2016 *Prof. U. Nierste*
Contents:
Flavour in the Standard Model, Quantum chromodynamics in electroweak processes, Leptonic and semileptonic meson decays, Effective theories, weak hamiltonian, Meson-antimeson mixing and CP violation.

Introduction to neutrino physics

Apr 14+15 2016 *Prof. Michael Wurm*

Since the 1930s when Pauli postulated the neutrino, a long series of experiments has steadily increased our knowledge on the properties of these ghost-like particles. This series of lectures aims to review the past, present and likely future experimental milestones along this path: Starting from the discovery of the free neutrino at the Savannah River reactor, we will proceed to the early experiments that established basic properties of the neutrinos, e.g. neutrino left-handedness in the Goldhaber experiment and the existence of different neutrino flavors at AGS and LEP accelerators. From there, we will turn to the first experiments searching for neutrinos from the Sun, the resulting solar neutrino deficit, and the eventual discovery of neutrino flavor oscillations by Super-Kamiokande, SNO and KAMLAND. Following the subsequent experiments using accelerators (MINOS, T2K) and reactor neutrinos (Double-Chooz, Daya Bay, RENO) that measured the neutrino mixing angles and mass squared differences, we will arrive at present-day experimental approaches for determining the neutrino mass hierarchy (DUNE, PINGU/ORCA, JUNO), leptonic CP violation and additional sterile neutrino flavors (SOX, STEREO). From here, we will turn to experiments measuring the neutrino mass in low-endpoint nuclear beta-decays (MAINZ, KATRIN, PROJECT-8) or electron captures (ECHO), and contrast these with neutrino-less double-beta decay searches (GERDA, EXO, KamLAND-ZEN) that have the potential to determine not only the neutrino mass but also its origin in a Dirac or Majorana mechanism. Time permitting, we will also review the possibility to investigate astrophysical sources by observing their neutrino emission over a wide energy range, from MeV-energy neutrino observations of solar and geoneutrinos in BOREXINO to the first evidence of PeV cosmic neutrinos in ICECUBE.

The Philosophy of Physics

Apr 04+05 2016 *PD Dr. Dr. Norman Sieroka*

The course provides a systematic introduction to philosophical questions in and about physics and to their historical development. After introducing important stages in the history of physics, starting with antiquity and the early modern period, the course focuses on the last two centuries. We will explore the development of electromagnetism, relativity theory, and quantum physics, and will examine the character of the knowledge that these theories provide. Particular attention is paid to typical explanatory strategies, to the role of experiments and predictions, to the formation and development of theories and concepts (such as causation), and to the significance and prominence of mathematics in modern physics. The course is intended for graduate students who desire to learn more about the philosophical (especially epistemological) implications of physics theories they have studied or heard about. The references to the history of physics are born of a conviction that a deeper understanding of systematic questions can only be gained through an awareness of the origin and background of these questions.
The content of the course is based on the following two books:
- Norman Sieroka. Philosophie der Physik – Eine Einführung. Beck-Verlag, München 2014.
- James T. Cushing. Philosophical Concepts in Physics. Cambridge University Press, 1998.

Effective Field Theory

Oct 12 – 13 2015 *Prof. Dr. Thomas Becher*

Effective Field Theories are an important tool in quantum field theory. They allow one to separate physics at disparate energy scales, expand in small scale ratios and resum logarithmically enhanced contributions to all orders. Traditionally, effective field theories are obtained by integrating out the heavy particles in a given theory and their degrees of freedom are the light particles. Modern effective theories (such as HQET, NRQCD, SCET) describe more complicated situations, in which the fields do not directly correspond to particles, but to different low-energy momentum regions which are relevant in a given process. In these lectures, we will first cover the basic concepts of effective field theory. Then, after discussing the momentum regions arising in low-energy expansions of Feynman diagrams, we turn to modern effective field theories and their applications.
The course assumes basic knowledge of quantum field theory and perturbation theory.

Introduction to flavour physics

Mar 26 + 27 2015 *Prof. Ulrich Nierste*

In this lecture I will give an introduction to flavour physics. First, the Standard Model of particle physics (SM) is reviewed especially its gauge structure and particle content with focus on the electroweak interactions. I will present the flavour structure of the SM in detail and derive quark– and lepton-mixing which is encoded in the CKM– and PMNS-matrix. Furthermore the Unitarity Triangle, the origin of CP violation and the three different types of CP violation are discussed. With this basic knowledge about flavour physics concrete flavour observables, like meson mixing and various flavour violating decay modes are presented and compared with the current experimental status. Despite the great success of the SM there are substantive hints (both theoretical and experimental) for physics beyond the SM. Since flavour physics is not only a very powerful tool to test the SM but also to search for new physics (NP), open questions of the SM and possible extensions are sketched. I will then illustrate with some concrete examples the potential to find NP with the help of flavour physics. It can probe very short distance scales that are beyond the direct reach of the LHC without directly producing new heavy particles. With its rich phenomenology the flavour sector can help us to disentangle different models beyond the SM.

Astroparticle physics: 13 billion years of evolution reviewed in a one-day-course

Mar 25 2015 *Dr. Klaus Eitel, Dr. Markus Roth, Dr. Kathrin Valerius*

Astroparticle physics is the field at the intersection of particle physics, astronomy and cosmology. It combines our knowledge about the largest structures in the Universe with our understanding of the smallest particles and the forces between them. The research programme at KIT addresses fundamental questions in this context: Where is the origin of cosmic rays, and how do these charged particles propagate in the Milky Way? What are the highest-energy particles and how do they obtain their incredibly high energies? Why do we need Dark Matter? Can we detect Dark Matter particles directly or indirectly via their annihilation products? What is the mass of neutrinos and how did they shape the structure of the early Universe? In this introductory course we will explain how to tackle these questions, how they are linked and how they are addressed by experiments.

Scientific writing – A quick–start guide

Mar 20 2015 *Dr. Sebastian Fischer*

The doctoral thesis is the most important thesis a physicist has to prepare. It contains the results of his/her research and is the proof of his/her qualification as a scientist. The thesis should be prepared in form and content in a way that it fulfils the common scientific requirements. The seminar will deal, among others, with the following topics: “Why is the message so important and how do we find it?”, “How does a meaningful table of contents looks like?”, “What do we have to take into account while writing the introduction?”

Instantons and Supersymmetry

Jun 23 – Jul 10 2015 *Prof. Dr. Arkady Vainshtein (University of Minnesota, Minneapolis, USA)*

In these lectures I will introduce the notion of instanton an related calculus in non-abelian gauge theories. Starting with quantum mechanical examples, we move then to QCD, and then to supersymmetric gauge theories. Application to perturbative and nonperturbative quantum effects will be reviewed.

Karlsruhe School of Elementary Particle and Astroparticle Physics: Science and Technology (KSETA)

KSETA-Doktorandenworkshop

Jul 6 – 8 2015 *R. Derco, R. Podskubka, S. Richter, Mrs. C. Assmus, Mr. Ritter*

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A basic introduction to Mathematica is given. The talk will start at the very beginning, addressing people, who have never worked with Mathematica before. Basic algebraic calculation, definition of functions, solving equations and simplification and expansion of expressions will be covered. The special strength of Mathematica to operate on symbolic expressions will be emphasised. In addition the generation of many different kinds of plots will be explained. Simultaneously to the presentation a glimpse on the internal structure of Mathematica's special way of organisation will be provided. A rudimental introduction to working with the useful Wolfram Documentation Center will help people to continue working with and studying more of Mathematica on their own. If time, further glimpses on more advanced topics will be given.

Karlsruhe, November 22, 2017

Dr. Irmgard Langbein
Managing Director