KTH Fysik

SH2201 - Experimental particle physics - 6 credits (h.p.)

Course plan - 'kurs-PM'

Version 2009-1.0

Introduction

Particle physics probes the fundamental structure and interaction of matter at the smallest possible distance scales. The aim of this course is to give a predominantly non-mathematical but none-the-less complete introduction to particle physics. The course begins with a survey of the theoretical models used to describe the subatomic world. This is followed by a discussion of the experimental techniques used to test these theories.

Some of the teaching methods used in this course are quite different from those you usually meet. The methods used may seem foreign and even uncomfortable to you at first. However, these methods have been adopted to promote deep understanding and to avoid superficial learning. This is reflected in both the course activities and examination methods.

Course goals

After completing this course, you should be able to:

- Classify the fundamental subatomic particles by their possible interactions.
- Use Feynman diagrams to analyse subatomic interactions qualitatively.
- Identify the key features of the interactions and synthesise these to describe the Standard Model of particle physics.
- Explain how particles can be detected and their properties determined by exploiting their interactions with matter. Demonstrate the limitations of different particle detection techniques.
- Develop particle detection systems by combining detection methods.
- Combine your theoretical knowledge of particle interactions with your more practical knowledge of detection techniques to understand the construction of contemporary experiments.
- Perform dimensional analysis to investigate physical relationships in particle physics
- Interpret data from figures published in the scientific literature and use this to perform calculations and develop conclusions.

- Reflect on the current ‘open questions’ in particle physics and the experiments planned to address these issues.

- Select and critically research a particle physics sub-topic of your choice and present your work to other members of the class during the student seminar day.

Course level and prerequisites

There are no mandatory prerequisites for this course. The course is primarily designed for:

- students in the final year of physics studies and, in particular, those following the ‘subatomic physics’ specialisation within ‘F4’.
- students following the Modern Physics Master’s Programme

It is therefore assumed that you have followed introductory courses in quantum mechanics, particle physics and nuclear physics (to a level corresponding to the ‘subatomic physics’ course given in ‘F3’). It is recommended that you follow this course (SH2201) if you are also planning to follow SH2200 Astroparticle Physics which is given in the spring term (January – March) of the following year. Note that while the course is predominantly non-mathematical, you should feel comfortable manipulating equations and performing elementary calculus.

Course literature

The basic concepts and theoretical ideas of the course are covered in the recommended textbook:

- B.R. Martin and G. Shaw, ‘Particle Physics, 2nd edition’, J. Wiley & Sons, ISBN 0 471 97285 1

Earlier this year a new edition was released. For this year’s course the 2nd edition is sufficient and formula and page references in lectures will refer to the 2nd edition.

- B.R. Martin and G. Shaw, ‘Particle Physics, 3rd edition’, J. Wiley & Sons,

An additional textbook which covers similar material, but with a more rigorous treatment of the theoretical side of the subject is:

- D. Perkins, ’Introduction to High Energy Physics, 4th edition’, Cambridge University Press, ISBN 0 521 62196 8

You are recommended to have continuous access to either of the two editions of the Martin and Shaw book during the course. You are expected to study the course book as well as attending lectures. At several instances during the course, it will be very useful to also consult the Perkins book (which can be found in the library).

In additional to these ‘traditional’ academic texts, there are a large number of more popularised texts (books, articles and web pages) which describe our understanding of the subatomic world and the key scientific breakthroughs in the subject area. As the course progresses, there will be frequent references to such sources of further reading.

Lecture structure

The course is based around six lecture topics and each topic is assigned a different number of lecture periods, as detailed in the following section. Each lecture session consists of a standard 2 x 45 minutes timetabled period.

Lecture topics

The following six lecture topics form the basis of the course. The number of 45 minute lecture sessions tentatively assigned to each topic is indicated. The relevant parts of the course textbooks are indicated (MS = Martin and Shaw and P = Perkins); MS 1 means Martin and Shaw: chapter 1, for example). Additional material will be provided in the form of hand-outs (HO) during the course.

1. **Introduction (2 x 45 mins)**
    a. Practical information
    b. Overview of course content
    c. Information sources
    d. Teaching methods
    e. The basic concepts of particle physics [MS 1, 2, P 1, 2]

2. **Particle interactions (8 x 45 mins)**
    a. The electromagnetic interaction [MS 1]
    b. The strong interaction [MS 5, 7]
    c. The weak interactions (charged [MS 8.2] and neutral current [MS 9])

3. **Particle acceleration (2 x 45 mins) [MS 3.1, P 11.1]**
    a. Particle production
    b. An overview of accelerator techniques

4. **Particle detection techniques (8 x 45 mins)**
    a. Particle interactions with matter [MS 3.2, P 11.5]
    b. Single particle detectors [MS 3.3, P 11.6]
    c. Particle shower detectors [MS 3.3, P 11.7]

5. **Case studies (4 x 45 mins)**
    a. Electron-positron collisions [HO]
    b. Proton-(anti-)proton collisions [MS 8.1, 8.3]
    c. Proton-electron collisions [MS 7.3, HO]

6. **Odds and ends (2 x 45 mins) [MS 11, P 9, HO]**
    a. Particle physics without accelerators
    b. Probing particle physics beyond the Standard Model

Lecture notes

At the start of each lecture topic, copies of the slides to be shown will be distributed. These are available free of charge and are provided in order to minimise the amount of time you spend taking notes. Use the time to absorb the material presented and formulate questions instead!

Laboratory session

The aim of the laboratory is to give you experience in applying the theoretical aspects of particle physics and experimental techniques to a real-life problem. The laboratory is computer-based and you will study data from electron-positron collisions recorded with the LEP particle accelerator at CERN (The European Particle Physics Laboratory in Geneva). The laboratory forms part of one of the home assignments.

Examination method

Successful completion of the course will lead to grades A – Fx, F being awarded. There are three components to the examination, as detailed below:

1. Three home assignments, each containing 2 extended questions
2. Student seminar day
3. Oral examination (if grade A is sought)

Each component is described in more detail below, along with the grading scheme. To achieve grade B - Fx, only the first two components need be completely satisfactorily. To be considered for grade A, the oral examination is also mandatory.

Home assignments

The six lecture topics are covered by three home assignments, each containing 2 extended questions. The home assignments will be handed out periodically during the course and must be completed within the allotted time (approximately one week). The distribution and collection scheme will be provided at the start of the course. Note that while you are welcome (encouraged!) to discuss the problems with others, the answer script you submit must be your own work. Identical scripts will be treated as plagiarism ('plagiat'). During grading (see section below), attention will be paid to the explanation and presentation of solutions – and this should represent your own work.

Student seminar day

You will be asked to identify a topic covered during the lectures which you found particularly interesting, or select a topic from a list posted on the course homepage. You will search for additional scientific information (i.e.: not simply repeat what has already been discussed in class) about this topic and deliver a 15-20 minutes (TBD) presentation to the rest of the class during the student seminar day. You will grade each others presentations according to the scheme detailed in the next section. These grades will be averaged to form each student's final grade for the seminar day. The course responsible will independently grade the presentations and ensure marking standards are upheld. Each presentation will be followed by a time for questions, and active participation is expected.

Oral examination

Students wishing to be considered for grade A must take an oral examination. This examination will be administered in small groups. During the oral examination, the group will be asked to develop ideas and concepts developed during the lectures. Each student will be asked to contribute in turn to the discussion and will be graded individually. Each oral examination will last for approximately 45 minutes. It is not possible to repeat the oral examination.

Grading scheme

Successful completion of this course will lead to grades A -Fx being awarded. Each element of the examination is weighted as specified in the following table:

Examination type	**Points**	**Point breakdown**
Home assignment 1	2 x 5	• Identification of correct physical principles **(2 points)** • Creation of the correct mathematical framework to solve the problem **(2 points)** • Numerically correct answer **(1 point)**
Home assignment 2	2 x 5	
Home assignment 3	2 x 5	
Student seminar day	20	• Organisation and coherence of presentation material **(5 points)** • Quality of presentation materials **(3 points)**

		• Identification and explanation of the key physical principles **(5 points)** • Personal conclusions and analysis of the topic presented **(5 points)** • Keeping time **(2 points)**
Oral examination	Pass or fail	You will be judged according to the following criteria: 1. Being able to coherently describe concepts introduced during the course. 2. Being able to interpret information (a figure, perhaps) based on concepts introduced during the course. 3. Being able to combine concepts developed during the course to hypothesise and defend new material. Note that the criteria are ranked from 1 (superficial understanding) to 3 (deep understanding). A pass will only be awarded to students judged to surpass level 1.

The final grade is assigned as follows:

Grade	**Overall percentage**
A	90% + oral pass
B	80%
C	70%
D	60%
E	50%
Fx	40-49%
F	< 40%

A grade Fx can be ‘upgraded’ to grade E. The course responsible will define the extra work which must be completed for the upgrade. This work must be successfully completed within 6 weeks of the issue of the course results. After this time the grade will be automatically, and irreversibly, converted to ‘F’.

A note on the use of web materials

There is a large amount of very useful material related to particle physics on the web (you should also be aware that some sites promote theories that are not widely accepted!). Useful pages can be easily located with your favourite search engine. For example, searching for “Feynman Diagram” with *Google* yields over 14 000 hits! You are encouraged to make use of this information to increase your understanding of the topics covered in the course. Verbatim copying from web sources is strictly forbidden when completing home assignments and will be considered as plagiarism (‘plagiat’) and appropriate disciplinary measures taken. All sources used in the preparation of talks for the student seminar day should be clearly stated.

Appeals

Appeals against grades awarded must be communicated to the course responsible in writing within three weeks of the distribution of the final grades for the course.

Course language

This course is given in English.

Timetable and location

The course runs in the autumn term (October - December). The exact course timetable is available from 'KTH schema' (http://www.kth.se/student/schema). The time for the student seminar day will be fixed at the start of the course.

Course evaluation

You are encouraged to complete a web-based course evaluation at the end of the course. Further instructions will be given nearer the time. The evaluation is anonymous and consists of approximately 15 'multiple choice' questions with space for written comments. The feedback received will be used to monitor and improve the course. Your opinions are very valuable!

Course homepage

The course homepage can be found at: http://www.particle.kth.se/SH2201

Course updates

Any important information, changes of lecture times, latest news etc. will be sent to course participants primarily by e-mail and may also be registered on the course homepage. It is therefore very important that you provide a valid and **legible** e-mail address when registering for the course.

Course responsible

The course responsible / examiner is Professor Bengt Lund-Jensen, lund@particle.kth.se, 08-55378179.

He can be found in AlbaNova University Centre on the 5th floor (A5:1017). Enter the main AlbaNova building on the Ruddammen side through the main entrance and ask the receptionist to direct you to his office. It's usually best to book a time in advance by e-mail or phone, but you are also very welcome to drop by with questions.