

**Carleton University Department of Physics**  
**PHYS 6602 – Advanced Topics in Particle Physics Phenomenology**  
**Course Outline (Winter 2023)**

**Instructors:**

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**Course web page:**

The webpage for this course will be hosted in Brightspace, at <https://brightspace.carleton.ca/> (you may be redirected to log in using your MyCarletonOne name and password).

**Lecture times:**

Tuesdays and Thursdays, 10:05–11:25 a.m., in room 309 Southam Hall. The first lecture is on Tuesday January 10 and the last one is on Tuesday April 11. There are no lectures on February 21 or 23 because that week is Winter Break.

**Office hours:**

By appointment with each of the instructors, to be arranged by email.

**Lecture format:**

This course consists of four series of lectures, each of three weeks duration, by four different instructors (plus one bonus lecture). Lectures will be fully in-person (modulo future pandemic restrictions) unless otherwise arranged. To reduce the spread of COVID-19, Carleton continues to strongly encourage wearing a mask when indoors; please wear a mask in class. If you get sick, please stay home and notify that week's lecturer, who will provide you with notes to help you make up the missed material.

**Homework assignments (4 × 20% of course mark):**

A homework assignment will be distributed toward the end of each of the four lecture series. It should be completed and handed in within two weeks of the end of the corresponding lecture series. Each instructor will provide instructions for how you should submit their assignment.

**Final seminar (20% of course mark):**

There are no exams in this course. Instead, each student will prepare and deliver a 20-minute<sup>1</sup> final seminar, using slides, on a particle physics topic of your choice (subject to approval by the course coordinator). Please finalize your choice of topic, in discussion with me, before the week of Winter Break. Your talk must be new and cannot be a resubmission or modification of a talk previously prepared for another course, conference, group meeting, etc. You should take this opportunity to learn about a particle physics topic that is not directly related to your thesis research. The talks will be delivered during an in-person mini-symposium to be arranged during the April exam period in consultation with the class. Physics Department faculty will be invited to attend and contribute to the evaluation of the talks.

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<sup>1</sup>15 minutes of prepared talk plus 5 minutes for questions.

## Course description

**PHYS 6602** [0.5 credit] (PHY 8166)

### **Advanced Topics in Particle Physics Phenomenology**

This course will consist of a variety of seminars and short lecture courses, and will cover topics of immediate interest to the research program of the department.

Includes: Experiential Learning Activity

Prerequisite(s): PHYS 6601 or permission of the Department.

## Lecture series and their content

**Prof. Alain Bellerive: Collider physics** (January 10, 12, 17, 19, 24, & 26)

Topics covered will include experimental evidence for the particle constituents of the Standard Model, flavour physics, CP violation and CKM mixing matrix in the quark sector, and precision electroweak tests from electron-positron colliders, and results from hadrons machines. The lectures will provide a connection between theory and experimental results, including particle discoveries and the link to results from modern particle physics experiments.

**Prof. Yue Zhang: Dark matter** (January 31, February 2, 7, 9, 14, & 16)

I will first give a brief introduction to cosmology and review the dark matter puzzle. Afterwards, I will discuss a few dark matter candidates and the corresponding motivations for them to interact with the known particles via forces other than gravity. I will highlight the ongoing experimental searches for these candidates and future prospects.

**Prof. Razvan Gornea: Neutrino physics** (February 28, March 2, 7, 9, 14, & 16)

We will cover the physics of massive neutrinos. We start with a review of weak interactions and neutrino properties. We will introduce the Dirac and Majorana neutrinos as well as a description of neutrino masses. Then we will discuss neutrino oscillations and the double beta decay. We conclude with an extensive review of the experimental techniques used to probe the physics of massive neutrinos.

**Prof. Heather Logan: Topics in Higgs physics** (March 21, 23, 28, 30, April 4, & 6)

An introduction to perturbative unitarity in Higgs physics. I'll show how this technical feature of the Standard Model leads to the famous upper bound on the Higgs boson mass. Then I'll consider models with extended Higgs sectors and show how the same physics constrains the decoupling behaviour of the new particles, how this plays out in explicit models, and what it implies for searches for additional Higgs bosons. If time allows, I'll also discuss flavour violation in two-Higgs-doublet models.

*Bonus lecture:* **Prof. Thomas Koffas** (April 11)

### **Development of Radiation Hard Semiconductor Sensor Devices for Particle Physics Experiments**

Experimental conditions at particle colliders are harsh and radiation levels can become comparable to those in the core of a nuclear reactor. This constitutes a major challenge for the design and construction of particle detectors, especially tracking detectors which are located closest to the interaction point. Physicists have been able to meet this challenge and develop radiation-hard technologies for the construction of such detectors. In this lecture the motivation and the current technology status for the High-Luminosity LHC will be presented. It will then move on to review developments in detector technologies for the envisioned future colliders such as CERN's flagship development program for the Future Circular Collider.

## Academic accommodations and human rights

Carleton University is committed to promoting academic accessibility for all individuals.

*Academic accommodation* refers to educational practices, systems, and support mechanisms designed to accommodate diversity and difference. The purpose of accommodation is to enable students to perform the essential requirements of their academic programs. At no time does academic accommodation undermine or compromise the learning objectives that are established by the academic authorities of the University. More information can be found at:

<https://students.carleton.ca/course-outline/>

University rules regarding registration, withdrawal, appealing marks, and most anything else you might need to know can be found on the university's website, here:

<https://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/>

### **Human rights and non-discrimination:**

Carleton University and all members of the Carleton community share responsibility for ensuring that the University's educational, work, and living environments are free from discrimination and harassment. Should you have concerns about harassment or discrimination relating to your age, ancestry, citizenship, colour, creed (religion), disability, ethnic origin, family status, gender expression, gender identity, marital status, place of origin, race, sex, pregnancy, or sexual orientation, please contact the Department of Equity and Inclusive Communities (<https://carleton.ca/equity>) at [equity@carleton.ca](mailto:equity@carleton.ca).

If you feel comfortable doing so, you can also contact me to address any concerns related to the course or classroom environment.

### **Academic accommodations for students with disabilities/Disabled students:**

If you have a documented disability requiring academic accommodations in this course, please consult the Paul Menton Centre for Students with Disabilities (PMC)'s new centralized accommodation-handling web portal called Ventus at <https://ventus.carleton.ca/student/>. PMC can also be reached at 613-520-6608 or [pmc@carleton.ca](mailto:pmc@carleton.ca). You must make arrangements with the PMC no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, get in touch with me as soon as possible to ensure accommodation arrangements are made. For more details, visit the Paul Menton Centre website (<https://carleton.ca/pmc>).

Regardless of documentation, if your learning experience could be improved by me adjusting the way I do things in this course, please don't hesitate to let me know and I will do what I can to address it.

### **Religious obligations:**

Please contact me during the first two weeks of class with any requests for religious accommodations, or as soon as possible after the need for accommodation is known to exist. For more details, please review the Student Guide to Academic Accommodation (<https://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf> (2.1 MB pdf)).

### **For survivors of sexual violence:**

Carleton is committed to maintaining a positive learning, working, and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations in accordance with Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: <https://carleton.ca/sexual-violence-support/>

### **If you miss academic work due to illness (in place of doctor's notes):**

Carleton recognizes that the COVID-19 pandemic has placed unprecedented strain on the health-care system and that health-care resources should not be diverted to produce doctor's notes for missed academic work. For this reason, Carleton is currently using a self-declaration form for students to self-declare illness, self-isolation, or other emergencies that cause you to miss course-work or exams. The form can be found at: <https://carleton.ca/registrar/wp-content/uploads/self-declaration.pdf>

As soon as you know that you may miss a homework deadline or the final seminar, please send an email, with the self-declaration form attached, to the lecturer whose assignment it is with a "carbon copy" (cc) to the course coordinator letting us know roughly when you expect to be able to submit the assignment or deliver your final seminar. This will allow us to plan for the delayed activity. Points will not be deducted for work submitted late due to illness or other emergencies.

### **For pregnancy:**

Please contact me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, please review the Student Guide to Academic Accommodation (<https://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf> (2.1 MB pdf)).

### **For extracurricular student activities:**

Carleton recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation must be provided to students who compete or perform at the national or international level (this also includes things like CUPC). Please contact me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, see the Senate Policy on Accommodation for Student Activities (<https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf> (25 kB pdf)).

### **Note about COVID-19 and mental health:**

The global pandemic has led to extra stress and uncertainty for everyone, but this affects each person in a unique way. If you need extra help with course material or have missed something, don't panic—email me and we can set a time to talk. If you're freaking out about stuff in general, I'm here to listen and will try to help to the extent that I'm able. Carleton also offers an array of mental health and well-being resources, which can be found at <https://carleton.ca/wellness/>.

## **Carleton's letter grade scheme**

In accordance with the Carleton University Undergraduate Calendar Regulations, the letter grades assigned in this course will have the following percentage equivalents:

A+ = 90–100    B+ = 77–79.99    C+ = 67–69.99    D+ = 57–59.99    F = below 50

A = 85–89.99    B = 73–76.99    C = 63–66.99    D = 53–56.99

A– = 80–84.99    B– = 70–72.99    C– = 60–62.99    D– = 50–52.99

WDN = Withdrawn from the course (deadline to withdraw from Winter 2023 courses is March 15)

ABS = Student absent from final exam

DEF = Deferred

FND = (Failed, no Deferred) = student could not pass even with 100% on final exam

## Academic integrity and how to avoid cheating

Examples of actions that violate Carleton's Academic Integrity Policy include:

- Plagiarism (e.g., passing off another person's words, equations, problem-solving strategies, or thoughts as your own, without citing the source);
- Accessing unauthorized sites for assignments or tests (e.g., posting the assigned questions on Chegg or searching the internet for solutions to similar problems);
- Unauthorized collaboration on assignments or exams (e.g., communicating with another student during an exam).

For details of what constitutes plagiarism, please see the Faculty of Science Academic Integrity website (<https://science.carleton.ca/academic-integrity/>). Students are expected to familiarize themselves with and follow the Carleton University Student Academic Integrity Policy (<https://carleton.ca/registrar/academic-integrity/>). The Policy is strictly enforced and is binding on all students. To further understand Academic Integrity, consider attending the Learning Support Academic Integrity Workshop (<https://carleton.ca/csas/learning-support-2/learning-support-workshops/>).

### Standard penalties for violating Carleton's Academic Integrity Policy:

- **First offence, first-year students (< 4.0 credits completed):** No credit for assessment(s) in question, or a final grade reduction of one full letter grade (e.g., A- becomes B-), whichever is a greater reduction.
- **First offence (anyone else):** Grade of F in the course.
- **Second offence (anyone):** Grade of F in the course and a one-term suspension from studies.
- **Third offence:** Expulsion from the University.

While these are the standard penalties, more severe penalties may be applied when warranted.

### Process of an Academic Misconduct Investigation:

Step 1: The instructor believes misconduct has occurred and submits documentation to the Dean of the Faculty of Science.

Step 2: The Dean reviews documentation and can proceed with or dismiss the allegation.

Step 3: If sufficient evidence, the student receives an allegation statement by email. Ombuds services is copied on the email.

Step 4: The student provides a written response to the evidence provided.

Step 5: Either party may request a meeting between student, Dean, and the ombudsperson.

Step 6: Dean informs the student of the decision.

Appeal: Student has the right to appeal the decision.

Additional details about this process can be found on the Faculty of Science Academic Integrity website (<https://science.carleton.ca/academic-integrity/>).