PHYS7360-001, the Spring Semester of 2018.

Course Description, Prerequisites and Instructors

This course, Elementary Particle Physics I, is for students who plan to be particle physicists, especially experimental particle physicists. It may also be useful for anyone who needs to understand basic physics and techniques in particle detection. It follows PHYS5380, Concepts of Experimental Particle Physics. The focus will be on interactions of particles with matter (the physics of detection) and particle detectors for momentum and energy measurements. Other topics in particle detection, such as particle identification and readout electronics will also be discussed.

Elementary particles are detected through their interactions with matter. There are two interactions that are used in measuring a particle's momentum or energy: the electromagnetic and strong (hadronic) interactions. A particle's type is usually identified with information of the particle obtained through a combination of two or three detectors. Particles have to live long enough so that they can pass through the measuring detector. These are photon (treated as a particle, not a wave), electron, muon, pion, keon, proton and neutron. As neutrinos only interact with matter through weak interaction, they need specially designed detector with huge amount of mass in order to have enough interactions in the detecting volume. We will not discuss these types of detectors. Instead, any specific detector systems may be assigned as a research project as mentioned below in the grading policy part. Particles that have very short lifetime, such as Z, $W^{\pm}$, or τ, for example, are measured through their decay products. We reconstruct back the characteristics of the original particles.

Prerequisites: the knowledge of a graduate student in physics with adequate math and basic coding skills in C++, together with PHYS5380.

This course will be guided by Drs Xiandong Zhao, Datao Gong and Andy Liu, and myself. Most of the coding and simulation work will be helped by Xiandong and Datao. Andy and myself will guide discussions on detector related topics.

Learning objectives and textbook

Learning outcomes	The course aims to develop the following abilities: (1) to understand the physics for particle detection, the basic types of detectors for momentum and energy measurements, the basic knowledge of detector readout; (2) the design and layout of a generic detector for collider physics experiment, and how a particle is detected, identified and sometimes reconstructed through such a detector system; (3) the use of GEANT4 (geant4.cern.ch), the simulation tool in particle detection and detector designs.
Textbook	We will follow mostly this textbook: Particle Detectors, Second Edition by Claus Grupen and Boris Shwartz. ISBN-13**:** 978-0-511-38866-8 or

978-0-521-84006-4. You may also want to consult review articles in PDG: http://pdg.lbl.gov/2017/reviews/contents_sports.html, especially these review articles: Passage of particles through matter, Particle detectors at accelerators, Particle detectors for non-accelerator physics, Probability, Statistics, Monte Carlo techniques and Kinematics.

Course Format and Information

As this is a high level graduate course, it will be mostly based on guided reading, classroom discussions and presentations. Reading materials will be assigned a week ahead of time together with simulation work in GEANT4. Students are required to have an account at SMU's computing facilty where the CERN programing environment is established. If you have questions about GEANT4, or any computing related issues, please contact Xiandong (xiandongz@mail.smu.edu) for help. The class meets Tuesday and Thursday from 9:50 AM to 10:50 AM in room 155 of Fondren Science Building.

Class attendance is required as classroom discussions together with in-class presentations of your work are an important part of the learning process.

Grading policy: Final grades will be computed as 40% from the in-class presentations, and 3 research projects through the semester with each carrying a 20% weight. Numerical grade and letter grade conversion is based on:

Letter	A		A-		B+		B		B-		C+		C		C-		D+		D		D-		F
Numerical (%)		90.0		85.0		80.0		75.0		70.0		66.6		63.3		60.0		56.6		53.3		50.0	

Other policies:

Disability Accommodations

Students needing academic accommodations for a disability must first register with Disability Accommodations & Success Strategies (DASS). Students can call 214-768-1470 or visit http://www.smu.edu/Provost/ALEC/DASS to begin the process. Once registered, students should then schedule an appointment with the professor as early in the semester as possible, present a DASS Accommodation Letter, and make appropriate arrangements. Please note that accommodations are not retroactive and require advance notice to implement.

Religious Observance

Religiously observant students wishing to be absent on holidays that require missing class should notify their professors in writing at the beginning of the semester, and should discuss with them, in advance, acceptable ways of making up any work missed because of the absence. (See University Policy No. 1.9.)

Excused Absences for University Extracurricular Activities	Students participating in an officially sanctioned, scheduled University extracurricular activity should be given the opportunity to make up class assignments or other graded assignments missed as a result of their participation. It is the responsibility of the student to make arrangements with the instructor prior to any missed scheduled examination or other missed assignment for making up the work. (University Undergraduate Catalogue)

Schedule:

Dates	Reading and class discussions	Notes
1/23	a) Introduction to the course and the class. b) GEANT4 basics 1. c) reading assignment: section 1.1	The reading is outside of class
1/25	a) GEANT4 basics 2 b) reading assignment: read section 1.1	
1/30	a) Class presentation on 1.1.1, 1.1.4, 1.1.5, 1.1.8, 1.1.10. b) In class show one example (the dE/dx plot) from GEANT4. c) HW1: Follow this example to run on other particles (photon, electron, muon, pion, proton, alpha) d) reading assignment: section 1.2	
2/1	a) Help with GEANT simulation and compare results. b) reading assignment: Read section 1.2	
2/6	a) C and C++ basics b) reading assignment: section 1.3, 1.4	
2/8	a) C and C++ basics b) reading assignment: section 2.1 – 2.5	
2/13	a) Class presentation of HW1, with calculations using the empirical formula. b) In class show one example with one particle in HW2. c) Introduction/example about ROOT d) HW2: simulate photon, electron, muon pion and proton at the five energy points: 100 KeV, 1 MeV, 100 MeV, 1 GeV, 10 GeV, and in BGO (a 50 cm cube), with 1000 particles in each job. Record interaction types, display particle trajectory or the shower shape (one particle, typical case). e) reading assignment: chapter 3	
2/15	a) Class presentation of HW2, discussion about the results. b) More on ROOT c) reading assignment: chapter 4	

2/20	a) In class show one example about how to include magnetic fields in GEANT4. b) Class presentations that briefly summarize chapter 2, 3, and 4. c) reading assignment: sections 5.1, 5.2 and 5.3	
2/22	a) Research project 1: simulation of electron microscope's electromagnetic lens. b) reading assignment: sections 5.4, 5.5, 5.6 and 5.7	
2/27	a) Class presentations on chapter 5, with prepared questions b) reading assignment: chapter 6	
3/1	a) Class presentation on research project 1, and selected topics from chapters 6. b) Introduction to Garfield (simulation of gaseous detectors) and related programs c) reading assignment: section 7.1 and 7.2	
3/6	a) Using Garfield to calculate a pulse shape of a straw detector. b) Understand about GEM, Gas Electron Multiplier (http://mice.iit.edu/detectors/sauli_32002.pdf) c) reading assignment: section 7.3.1 and 7.3.3 (if you can manage, read sections 7.3.2, 7.4, 7.5 and 7.6)	
3/8	a) Class presentation on sections 7.1, 7.2 7.3.1, 7.3.3 and 7.5 b) HW3: simulate electron, pion at 1, 10 and 50 GeV in a dummy EM + sampling HCal, record energy deposition. Run 10 events each case. c) reading assignment: section 8.1	
3/13, 15	Spring break	
3/20	a) Class presentation on HW3, and discuss about the energy deposition in the cases of electron and pion. b) HW4: use the above dummy detector, alter the absorber/sampling ratio, find the best achievable energy resolution of pions in the ranges 1 – 50 GeV c) reading assignment: sections 8.2 and 8.3 (time permits 8.4).	
3/22	a) Class presentation/discussion about HW4 b) reading assignment: chapter 9	
3/27	a) Research project 2: simulation of a ThickGEM (follow the paper *A concise review on THGEM detectors* by A. Breskin et al, NIMA, 598 (2009) 107-111 b) reading assignment: chapter 9	
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	b) reading assignment: chapter 10
4/3	a) Class presentation on research project 1, and selected topics from chapters 9. b) reading assignment: chapter 11
4/5	a) Study of the ATLAS detector, an example of a general-purpose detector in collider physics b) reading assignment: chapter 13
4/10	a) Class presentation of detectors in ATLAS (inner tracker and LAr) b) reading assignment: chapter 14
4/12	a) Class presentation of detectors in ATLAS (HCAL and Muon) b) reading assignment: chapter 14
4/17	a) Class presentation of detectors in ATLAS (Triggering system) b) reading assignment: sections 15.1, 15.2 and 15.3
4/19	a) Research project 3: construction of a MWC with delay line readout. b) Or Conducting the alpha scattering experiment and data analysis c) reading assignment: section 15.2
4/24	a) Research project 3: construction of a MWC with delay line readout. b) Or Conducting the alpha scattering experiment and data analysis c) reading assignment: section 15.4
4/26	a) Research project 3: construction of a MWC with delay line readout. b) Or Conducting the alpha scattering experiment and data analysis c) reading assignment: section 15.5
5/1	a) Class presentation on research projects b) Reading assignment: chapter 16
5/3	a) Class presentation on research projects b) Reading assignment: chapter 16

Final Exam: there will be no in-class final exam of this course.