Geant4 Simulation Science

Instructor: Haruo Ikeda (ikeda@awa.tohoku.ac.jp, RCNS Annex I 03 room 122)
GPPU Experimental Point (GEP): 3

Goal of Study
Geant4 is a toolkit for the simulation of the passage of particles through matter. Its areas of application include high energy, nuclear and accelerator physics, and low energy, neutrino and dark matter physics. This course will cover the toolkit from basic coding through advanced topics. The goal of this study is students will make their own Monte Carlo simulation for their physics detectors.

Contents
This class will give a basic overview on the main characteristics of the Geant4 Monte Carlo toolkit. Theoretical lessons will be coupled to practical exercises that will give the possibility to the student to move the first steps with the code, from the installation, to the run of a simple application. GPPU prepares a laptop linux PC with geant4 installation. Students will learn basic geant4 coding method (running geant4, geometry construction, primary particles definition, physics lists definition and scoring results) with lectures, write simple example codes by themselves, and analyzing the Monte Carlo results. Finally, students will make simple Monte Carlo simulation and present their simulation results. This class will help students to make and analyze their own Monte Carlo simulations.
**Textbook and References**

Handout is provided.


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**Progress Schedule**

- **Day 1**
  - Introduction to Geant4 (Lecture)
  - Geometry and Material (Lecture and Hands-on)
- **Day 2**
  - Primary Particle (Lecture and Hands-on)
  - Physics (Lecture and Hands-on)
- **Days 3 ( - 4 )**
  - Scoring (Lecture and Hands-on)
  - Simple detector and analysis (Hands-on)

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**Other Details**

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<th>2017 Winter</th>
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**In Addition**

A linux computer with geant4 installation is prepared for this class. Please contact Ikeda in advance if the following requirements apply.

1. You want to use your own laptop PC.
2. You have never used C++ or Linux.
Basic of Signal Processing for Sensors (ASIC)

Instructors: Akimasa Ishikawa (akimasa@epx.phys.tohoku.ac.jp, room:H-34 104), Manobu Tanaka, Tetsuichi Kishishita, Assistants: Kazuya Tauchi, Yoichi Fujita, Shoichi Shimazaki, Masayoshi Shoji
GPPU Experimental Point (GEP): 3

Goal of Study
A lab-intensive introduction to basics of sensors and their analog signal processing design skills through design exercises, discussion using Computer Aided Design (CAD) tools for detection system development (e.g. imaging sensor system etc).

Contents
Learning outcome and objectives
1. Understanding of transistor and building blocks for signal processing
2. Design skill of basic amplifier and understanding the function by simulation
3. Understanding of signal processing circuit by simulation
4. Quantitative evaluation of signal to noise ratio by simulation
5. Understanding of the transistor structure and the semiconductor LSI process

Textbook and References
[1] To be uploaded to web site.
Progress Schedule

- **Day 1**
  1. ASICs for accelerator experiments (Lecture)
  2. Signal processing technology (Lecture)
  3. Semiconductor process overview (Lecture)
  4. Simulation tools (Lecture/Training)
  5. Common source circuit (Lecture/Training)
  6. Current source and Mirror circuit (Lecture/Training)
  7. Source follower (Lecture/Training)

- **Day 2**
  8. Single-end amplifier (Lecture/Training)
  9. Differential amplifier (Lecture/Training)
  10. Signal Processing (Lecture/Training)
  11. Signal processing for sensor and noise (Lecture/Training)

- **Days 3**
  12. Layout 1 (Training)
  13. Layout 2 (Training)

Other Details

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In Addition

One laptop PC (Windows, Mac, Linux, etc.) should be prepared.

Requirements: X-server, ssh client, Ethernet port (RJ45)

X-server and its fonts on Windows : Xming


terminal including ssh client on Windows : putty

http://hp.vector.co.jp/authors/VA024651/download/file/putty–0.63–jp20130916.zip
Superconducting detector

Instructor: Koji Ishidoshiro (koji@awa.tohoku.ac.jp, RCNS Annex 221)
GPPU Experimental Point (GEP): 4

**Goal of Study**

The students will understand superconducting detectors and their wide application to particle and nuclear physics and astrophysics. The students will also learn basics of superconductor, electronics, cryocooler, digital signal processing, data acquisition system and data analysis from detector characterization and response measurements of cosmic rays and/or gamma rays.

**Contents**

Superconducting detectors are extremely sensitive and have a wide variety of application from particle and nuclear physics to quantum measurement and biology. However, it is difficult to integrate into large arrays like a CCD camera. Kinetic Inductance Detectors (KIDs) provide a promising solution to produce the large array. Several KID arrays have been constructed for astronomical observations and TeraHertz imaging. Research Center for Neutrino Science in Tohoku University is developing KID arrays for next generation dark matter and double-beta decay experiments. Using that facility, students will learn superconducting detectors, especially KID detectors, and their wide application. We hope that the students will propose in future the new experiments using superconducting detectors based on this experience.

KID detector used in the course

KID detector and 3He cryocooler
Textbook and References


Progress Schedule

✧ Day 1
   Lecture on superconducting detector, microwave, and cryocooler.
   Lecture on readout and setup of DAQ.
   Preparation of cooling.
✧ Day 2
   Lecture on application of superconducting detector to particle physics.
   Detector characterization at 0.3 K.
✧ Days 3—4
   Lecture on application of superconducting detector to astrophysics.
   Measurement of detector response with cosmic-ray and/or gamma-ray source.
   Data analysis

Other Details

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In Addition

Cooling (300K to 0.3K) takes about 24 hours. Tentative plan: 1st day is Monday, 2nd—4th days are Wednesday – Friday.
Scintillation detector development

Instructor: Itaru Shimizu (shimizu@awa.tohoku.ac.jp, Research Center for Neutrino Science, room 205, 022-795-6724)
GPPU Experimental Point (GEP): 4

Goal of Study
This course aims to provide broad knowledge and experience of the scintillation detection with fundamental techniques necessary for advanced experiments in particle and nuclear physics research through your work on the liquid scintillator measurement and data analysis.

Contents
The scintillation detection is a widely-used technique in foremost large-scale experiments in the world, relatively cost-effective and multipurpose, so there has been made ongoing efforts on various developments to improve the experimental sensitivities. Actually, a large liquid scintillator detector (KamLAND) has established a new world record in the neutrino mass sensitivity utilizing a unique low-background technique developed in Tohoku University. In this experiment, you will learn the principal and the device design of the scintillation detection in lectures and experiments, and master the practical technique adaptable to the particle and nuclear physics experiments in the future. This course consists of lectures and experiments in 4 days, containing the following items, understanding of light-output and transfer mechanism, particle identification, measurement of neutron capture time, data acquisition and analysis.
**Textbook and References**


**Progress Schedule**

- **Day 1**
  - Principle of scintillation measurement (lecture)
  - Production of liquid scintillator (experiment)
- **Day 2**
  - Design of liquid scintillator detectors (lecture)
  - Measurement of light output, light collection efficiency (experiment)
- **Days 3—4**
  - Particle identification, Measurement of neutron capture time (experiment)
  - Presentation (measurement results and discussion) and oral test

**Other Details**

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**In Addition**

Some homework for data analysis and consideration will be required on off-duty days.
FPGA training course

Instructor: Koji Ishidoshiro (koji@awa.tohoku.ac.jp, RCNS Annex 221) and Koji Miwa (miwa9@lambda.phys.tohoku.ac.jp) GPPU Experimental Point (GEP): 3

Goal of Study
The students will learn basic of Field-Programmable Gate Array (FPGA) and Hardware Description Language (HDL) and obtain the methods to develop FPGA circuits using Xilinx Vivado. After this course, the students can start to develop FPGA circuits.

Contents
Field-Programmable Gate Array (FPGA) is one of key components for digital signal processing in the experiments of particle and nuclear physics. For the development of FPGA circuits, knowledge of digital circuits and implementation methods to FPGA is required. This course focus to introduce the latter experience.

In this course, we will use Xilinx Artix-7 FPGA with Vivado. The students are expected to install Vivado on their computers before the course. We do not recommend to use virtual machine.
Textbook and References
The latest version will be announced.

Progress Schedule
✧ Day 1
  - Lecture on digital circuit
  - Lecture on combinational circuit
✧ Day 2
  - Lecture on FPGA
  - Lecture on sequential circuit
✧ Day 3
  - Exercises

Other Details
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In Addition
KEK Open-It is the co-host of this course. This course is also open for external students, technical staff, postdocs, and so on. Language used in this course is only Japanese.
Scintillator hodoscope array read by multi-pixel photon sensor (MPPC)

Instructor: Koji Miwa (miwa9@lambda.phys.tohoku.ac.jp)
GPPU Experimental Point (GEP): 4

Goal of Study
In this lecture, we aim to obtain the knowledge and the experience of a pixelated photon detector (MPPC is one of the pixelated photon detector produced by Hamamatsu photonics) which becomes very popular in the particle and nuclear experimental fields. By operating MPPCs for a scintillator hodoscope readout, we expect that students understand the basic features of MPPC and also learn how to operate multi MPPCs.

Contents
The new photon sensor, MPPC, has many pixels of avalanche photo diode (APD) in the sensitive area and the MPPC signal is the sum of all fired APD. By operating each APD in the Geiger mode, MPPC can have an enough large gain to detect a single photon. The sensitive area of MPPC is rather small (typical size is 1 x 1 mm²). However, MPPC can be operated in the magnetic field and its cost is rather low. Therefore MPPC is one of the best photon sensors to read out fine segmented scintillation detectors such as scintillation fiber detector.

In this lecture, we obtain the skill to operate multi MPPCs by using the EASIROC board which was developed for this purpose. At first, we evaluate the basic performance and features of MPPC such as the relation between the operation voltage and signal gain. Then, we move to the readout of the scintillator hodoscope array with MPPC. In this detector, a wave length shifting (WLS) fiber is embedded in the hole made on the surface of the scintillator. The scintillator hodoscope array consists of 128 scintillators with WLS fibers and has a layer configuration of 8 segments for X direction and 8 segments for Y direction. We try to read out the 128 channels of MPPCs with EASIROC board. As an advanced course, by making the special trigger with FPGA module, we try to measure the angular distribution of cosmic ray or the life time of the cosmic ray muon.
Textbook and References


Progress Schedule

- **Day 1**
  - Basics of MPPC and its readout (lecture)
  - Readout of a single MPPC with EASIROC board (experiment)
- **Day 2**
  - Readout of a single MPPC (check of MPPC feature) (experiment)
  - Readout of a multi MPPC (gain adjustment, DAQ) (experiment)
- **Days 3**
  - Analysis of data (photon yield, detection efficiency, etc.) (experiment)
  - Make special trigger with FPGA module and accumulated data (experiment)
- **Days 4**
  - Analysis of the accumulated date and summarize this course

Other Details

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In Addition

Between Days 3 and Day 4, we set data accumulation period of one day.
Basic of Data Acquisition, Detector Technique, and Data Analysis

Instructor: Masashi Kaneta (kaneta@lambda.phys.tohoku.ac.jp, Science Complex A, 6F, Rm. 642)
GPPU Experimental Point (GEP): 6

Goal of Study

In this course, we would like you to acquire the following knowledge and techniques.
(a) Construction of a test bench using NIM and VME modules
(b) Control of VME modules and reading/writing data from/to modules (VME access).
(c) Detector construction and data analysis

Contents

Recent high energy particle physics, like Large Hadron Collider (LHC) experiment at CERN, has a few hundred to a few thousand people in the collaboration. The tasks are separated to specialist and it is difficult to understand whole system (detectors, data acquisition, trigger, and analysis frame work) by one person.
On the other hand, the experimental physicist in elementary particle/nuclear physics filed should have an experience of construction of test bench for detector test. The knowledge will be requisite to design an experiment and to be a group leader.
You will learn the following items in this course.
   (1) Construction of a test bench for detector test using cosmic-ray.
   (2) Assembling of Multi-gap Resistive Plate Chamber (MRPC) and performance study by cosmic-ray and electron/positron beam.
We plant to use plastic scintillation counters and to analyze data to evaluate timing resolution.
The data on VME module is a binary data and need to know how to treat those data on memory. Using a simple program written by C/C++, you will learn how to access VME memory. ROOT which is a framework for data processing and born at CERN will be used for analyses.
MRPC is a kind of gaseous ionization detector and developed as a Time-Of-Flight (TOF) detector. It consists of print circuit boards, glass plates, and fishing line as a spacer. You will make MRPC by yourself and investigate its timing resolution and efficiency by cosmic-ray and electron/positron beam.
Textbook and References
The recent references are proceedings of “3th Workshop on Resistive Plate Chambers and Related Detectors (RPC2016)” http://iopscience.iop.org/journal/1748-0221/page/extraproc54. The basic information of MRPC can be found the web page of ALICE experiments: http://aliceinfo.cern.ch/Public/en/Chapter2/Chap2_TOF.html. Also you can find a link to “Technical Design report” in that web page to know detailed information of ALICE-MRPC, https://edms.cern.ch/document/460192/1

Progress Schedule
✧ Day 1
  Basic of data acquisition system (Lecture and Experiment)
  How to access and control memory on VME modules (Lecture and Experiment)
✧ Day 2
  Construction of test bench using plastic scintillation counters and NIM/VME modules (Experiment).
✧ Days 3
  How to get intrinsic timing resolution from TOF information (Lecture).
✧ Day 4
  Assembly of MRPC (Experiment)
✧ Day 5
  Construction of test bench using MRPC and plastic scintillation counters. Performance test by cosmic-ray (Experiment).
✧ Day 6
  Performance test of MRPC by electron/positron beam (Experiment).

Other Details
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In Addition
After construction of the test bench, you need one day to a few days for data taking.
Data analysis will be homework.
Date and time of the course will be decided by discussion with attendants
Nucleus-nucleus scattering experiment

using a cyclotron accelerator

Instructors: Masatoshi Itoh (itoh@cyric.tohoku.ac.jp, CYRIC 2nd floor),
Yohei Matsuda (matsuda@cyric.tohoku.ac.jp, CYRIC 2nd floor)
GPPU Experimental Point (GEP): 6

Goal of Study

The aim of this course is to acquire basic knowledge and skills for scattering experiments in accelerator facilities. In experimental particle and nuclear physics, recent projects become large and complex. Therefore, a student hardly understand and handle all experimental apparatuses. This course offers you the opportunity. The experience will help you to draw up a specific project in future.

Contents

Tohoku University has a good environment to study experimental nuclear physics because there are various accelerators (cyclotron, dynamitron, and electron linac) in the campus. Taking advantage of the environment, you learn the whole technique of the experimental nuclear physics, particle acceleration, construction of the detection system, data analysis, and so on, using K=110 MeV AVF cyclotron in CYRIC (Fig.1).

In this course, after taking some lectures to learn principles of the accelerator, the beam transport, detectors, and data acquisition system, the experiment will be performed by the following steps.

1. Operation of the ECR ion source which supplies ions to the accelerator (Fig.2).
2. Acceleration of the ions up to several hundred MeV using AVF cyclotron.
3. Measurement of the angular distribution of the nucleus-nucleus elastic scattering (Fig.3).

In the measurement, you will use various kind of detectors, such as semiconductor, scintillation, and gas detectors. In addition, you are required to construct the data acquisition system by yourself. Finally, you can master how to obtain the absolute value of the cross sections.

Fig. 1: AVF cyclotron. Fig. 2: ECR ion source. Fig. 3: Experimental setup.
Textbook and References

Progress Schedule
✧ Day 1
   Principle of Cyclotron (lecture)
   Principle of beam transport (lecture)
   Detection method of charged particles (lecture)
✧ Day 2-4
   Principle of semiconductor, scintillation, and gas detectors (lecture)
   Readout of semiconductor, scintillation, and gas detectors (practice)
✧ Day 5
   Basic techniques of data acquisition and data analysis (practice)
✧ Days 6-8
   Acceleration and transport (practice)
   Scattering experiment (practice)

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In Addition
Each student is responsible for one equipment in the experiment, and reports the result in the presentation. The presentation will be scheduled one month after the experiment. There is no need to submit any reports.
Measurements on optical aberrations in an optical observation system

Instructor: Masayuki Akiyama (akiyama@astr.tohoku.ac.jp, Science Complex C, 5F, S514)
GPPU Experimental Point (GEP): 4

Goal of Study

(1) understand the relation between aberrations in an image and distortions in the optical wavefront through Fourier optics.
(2) understand the setup for optical experiment, and measure the distortions in the optical wavefront.
(3) master methods to handle imaging data through your own C programs.

Contents

Optical systems for observations of the universe are always affected by aberrations caused by various origins in the systems. Moreover, ground-based observations are affected by aberrations caused by fluctuation and turbulence in the atmosphere. Due to the aberrations, object images on a detector will be distorted from the ideal diffraction-limited pattern. Because observations of the universe are moving toward higher spatial resolution with larger lens/mirror/dish, understanding of the aberrations becomes more critical in the observations not only in the optical/visible wavelength, but also in the UV, IR, and mm wavelengths. In this course, at first the relation between aberrations in an image and distortions in the optical wavefront is explained through Fourier optics, then participants will conduct an optical experiment to measure the distorted optical wavefront. Obtained images are analyzed through your own C programs, and the distortion in the measured wavefront will be evaluated.

Examples of wavefront sensor images (left) and estimated optical wavefronts from the images (right). The sensor images are analyzed with your own code to estimate the distorted wavefront.
Textbook and References


Progress Schedule

✧ Day 1
  Fourier optics (Lecture)
  Relation between aberration and distortion in the optical wavefront (Lecture)
  Method to measure the distorted optical wavefront (Lecture)
  Optical experiment setup (Experiment)
✧ Day 2
  Measuring the optical wavefront (Experiment)
  Image data acquisition (Experiment)
✧ Days 3—4
  Image data handling with C programs (Lecture)
  Image data analysis with C programs (Experiment)
  Final summary and report (Presentation)

Other Details

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In Addition

Presentation session will be made on the afternoon of the final day. Each participant is requested to make his/her own presentation based on the 4+ day experiments.
mm–Wave spectroscopy

with Fourier Transform spectrometer

Instructor: Makoto Hattori (hattori@astr.tohoku.ac.jp)
GPPU Experimental Point (GEP): 4

Goal of Study

Frequency dependence of the emissivity of metal plates are measured with Martin–Puplett type Fourier Transform Spectrometer (FTS)[2] using mm–submm bolometric detector operated at 1.5K[1]. Through the course, students are expected to obtain skills for treating and operating low temperature detector and absolute spectroscopy with FTS.

Contents

FTS is a broad band absolute spectrometer with has played important role in wide field of astronomy and cosmology in the wave bands longer than far infrared wave band. The FIRAS instrument mounted on COBE satellite[3] is one of the most famous application of FTS. It measured spectrum of the cosmic microwave background (CMB) radiation and showed that it follows the perfect black body spectrum with temperature of 2.725K. This results confirmed that our universe has been evolved following the description of the standard big band theory. Application of the FTS to space born CMB B–mode polarization experiment as an ultimate instrument has been also proposed [4]. Extension to the 3 dimensional fourier transform instrument (2D in sky position and 1D in time axis) has been also studied [5]. Application and fundamental studies of FTS have been still active field. In this course, the Martin–Puplett type FTS which is the same type as FIRAS, is used to measure the frequency dependence of the emissivity of metals. Students are expected to study how and why the absolute spectroscopy are possible with the Martin–Puplett type FTS. Final day, we have a time for discussion on future application to the CMB B–mode experiment.
Textbook and References


Progress Schedule

✧ Day 1
  Lecture on fundamental and operation of the Semiconductor bolometer
  Start cooling the detector.
  Lecture on the Martin–Puplett type FTS.
  Lecture on the measurement.
✧ Day 2
  Operate detector by pouring liquid He and pumping by He.
  Emissivity measurement.
✧ Days 3—4
  Data analysis.
  Presentation of the results.
  Study and discuss on future application of FTS to the CMB B-mode experiment.

Other Details

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In Addition