EDIT 2011 **Excellence in Detectors and Instrumentation Technologies**

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Silicon Strips and Pixel Technologies

Conveners: Paula Collins, Michael Moll, Petra Riedler

Abstracts of Lectures and Hands-on activities

Silicon Detectors - Part I

<u>Lecture</u>: Introduction to Silicon Detectors (45 min, every second day)

Frank Hartmann and Manfred Krammer

The lecture covers the basics to understand the functionality of silicon detectors in high energy physics. We discuss the material properties of silicon, the doping of silicon and the formation of a pn-junction. In the second part of the lecture the basic structures and operation of silicon micro-strip detectors and hybrid pixel detectors are explained. After an explanation of important performance parameters, the lecture finishes with an overview of the state of the art silicon detectors at the LHC experiments.

<u>Hands-on</u>: Silicon Diodes (90 min, 4 groups of 3 students)

Lars Eklund, Irena Dolenc, Doris Eckstein, Jose Garcia, Gregor Kramberger, Marco Milovanovic, Nicola Pacifico

The majority of silicon detectors in particle physics uses a reverse biased pn-junction as the signal generating element. This lab aims to give an understanding of the basic operation of a pn-junction as a sensor for ionising particles. The students will study how the depletion region grows in a reverse biased silicon detector and how this affects the generated signal. First they will measure the Capacitance/Voltage characteristics of the device. Secondly the sensor will be illuminated from the front and the back and the generated signal will be studied as a function of bias voltage.

<u>Hands-on</u>: Wire bonding and Reliability testing (90 min, 2 groups of 6 students)

Alan Honma; Ian McGill; Adam Drozd ; Florentina Manolescu

This lab involves learning about a vital interconnect technology used in silicon detectors known as wire bonding. It also will give a brief overview of the quality assurance and reliability testing (QART) laboratory and focus on one example of reliability testing. The course will start with an introductory presentation to the CERN Wire Bonding and QART laboratories. The purpose of the QART laboratory and its fairly unique testing equipment will be presented. Then the students will split into two groups. One group will work with Ian and Alan to learn about the technology, techniques, testing and inspection of wire bonding for HEP detectors. The students will then get a chance to make wire bonds with the lab's bonding machine and then test them with the pull-testing machine. Then, there will be a demonstration of identifying the structures on a silicon strip module, including sensors, pitch adapter, read-out chip, and the wire bonding that connects them together. The second group will go with Adam and Florentina to learn about an interesting failure mode of bond wires in a powerful magnetic field. This will use one of the lab's unique pieces of equipment, a small bore 2T dipole electromagnet. This part of the course will finish with the students manipulating bond wires under stereo microscopes to get direct experience of the scale and strength of these interconnections. After about 30 minutes the groups will trade places to learn about the other activity.

<u>Lecture</u>: Radiation Tolerant Silicon Detectors (45 min)

Mara Bruzzi; Gianluigi Casse

Silicon detectors are the preferred choice for Tracker and Vertex detectors in High Energy Physics experiments due to their high resolution, low mass and relatively low cost. The present LHC and especially its upgrade (sLHC) are though imposing a very hard challenge to these sensors in term of the required radiation tolerance. We will discuss the radiation levels expected in the future experiments, the damage that the radiation environment causes to the silicon crystal degrading the electrical properties of the sensors, the methods that have been envisaged to produce detectors able to operate efficiently after extremely high hadron radiation doses.

<u>Hands-on:</u> Silicon Strip Detectors (90 min, 3 groups of 4 students)

Richard Bates, Irena Dolenc Kittelmann, Marco Milovanovic, Jose Garcia

This part of the laboratory course illustrates the operation of a silicon strip detector with LHC readout electronics. The first measurement demonstrates the change in the noise of the system with detector bias voltage. The second measurement shows the response of the detector to high energy electrons from a Strontium-90 source. Three sets of apparatus will be available. Two equipped with non-irradiated silicon strip sensors; one with p-type strip implants and a near intrinsic n-type bulk, the other with n-type strip implants and a near intrinsic p-type bulk. The third has an irradiated sensor with n-type strip implants and a p-type bulk. The irradiated sensor must be operated cold to reduce the reverse current of the device to a manageable level, while the others are operated at room temperature.

<u>Hands-on (A):</u> Laser induced signals (90 min, 1 group of 6 students)

Nicola Pacifico, Gregor Kramberger

To study the field profile within the detector, we can use laser generated carriers to “probe” the detector volume and to give us information about the field they have encountered within the detector. Of course, we are looking for local information so we are also going to need a “localized” probe. Laser pulses provide an easy mean to produce localized charge clouds inside the detector bulk, which then drift under the action of the applied electric field. Reading out the signal shape can provide information about many detector parameters, such as the depth and localization of the active region as well as the bulk efficiency and the influence of trapping on the signal development. Two techniques are going to be overviewed during the lab activity: standard red laser-TCT and infrared Edge-TCT. Their potentials are going to be exploited for studying both unirradiated and irradiated detectors, finally drawing conclusions about what the main effects of radiation damage in silicon are.

<u>**Hands-on (B):**</u> **The Medipix System** (90 min, 1 group of 6 students)

R.Plackett, K.Akiba, G.Blaj, J.Buytaert

The Medipix Lab at EDIT will demonstrate the flexibility of hybrid pixel detectors. There will be a demonstration of the Timepix chip being used to perform X-ray imaging as well as two short hands on experiments with the chip involving radioactive sources and cosmic ray detection. Students will gain a familiarity with the differing ways particles interact with a silicon sensor and how different measurements can be made by varying chip parameters. They will also be encouraged to consider the chips use in tracking applications

Silicon Detectors - Part II

<u>**Lecture**</u>**: Application of Silicon in Trackers** (45 min, every second day)

Andrei Nomerotski, William Trischuk

This lecture will describe the use of silicon sensors (strips or pixels) in high energy physics experiments. We will describe the issues faced when these sensors are used to measure charged particle tracks and secondary vertices in high energy collisions. In particular we will address the limitations on the resolution of the systems and how hit uncertainties are determined. This will include a discussion of the alignment of both HEP trackers, but also simplified testbeam setups that are used to study silicon detector prototypes. After discussing issues surrounding track pattern recognition we'll give some examples from current LHC trackers. Finally we conclude with a few examples of how the precision in silicon trackers has found application outside HEP.

<u>**Lecture**</u>**: Hybrid Silicon Pixel Detectors** (30 min)

Markus Keil

Hybrid pixel detectors are nowadays state-of-the-art for tracking and vertexing in a high-multiplicity environment. With spatial resolutions in the order of 10 micrometers they can cope with the high track densities and radiation doses of the LHC experiments. Even though technologically challenging, currently several large hybrid pixel detector systems are successfully being operated. The lecture describes the operating principle of hybrid pixel detectors and the different steps involved in the construction of the detector modules.

Hands-on: Hybrid Pixel Detectors (45 min)

Markus Keil, Simon Kwan, Mauro Dinardo

This hands-on session will familiarise you with the construction of hybrid pixel detectors. Samples from all production steps, from the silicon ingot to a slice of an LHC pixel tracker, will be shown. Furthermore, Pixel Detectors based on new technologies (3d, diamond) will be shown.

Lecture: CMOS Pixel Sensors (30 min)

Marc Winter, Jerome Baudot

The lecture will introduce the audience to CMOS pixel sensors. It will expose their main features, describe the signal sensing and processing principles and architecture variants. It will summarise the detection performances obtained so far and provide an overview of the technology state of the art. It will next go through a couple of applications of the sensors. Finally, it will give an outlook highlighting the trends followed today to improve the technology performances.

Hands-on: The MIMOSA detector (60 min)

Marc Winter; Jerome Baudot; Constanza Cavicchol i

The activity will be based on a test bench allowing to tune the steering and read-out parametres of a sensor. By illuminating the latter with a radioactive source emitting at a well-defined energy, a charge-to-voltage calibration can be performed.

Lecture: Pixel Detectors in High Energy Physics Experiments (30 min)

Vito Manzari

This lecture aims to illustrate how the features of a silicon pixel detector can be exploited in high energy physics experiments at fixed target as well as collider. Since the first test of a hybrid silicon pixel detector was carried out in a fixed target experiment environment at the CERN SPS in 1993, it became clear that this kind of detector would have played a key role for accurate tracking in high energy physics experiments, even in challenging conditions of very high track multiplicity and density. Following the successful results of this first test, pixel detectors were adopted by several experiments. In particular, hybrid pixel detectors were used to build the tracking telescope of the NA57 heavy ion experiment, allowing the study of the multi-strange hyperons yields in lead-lead collisions. In the collider age, the great majority of vertex detectors are based on pixel detectors: the design optimization and the physics capabilities of the innermost vertex detector of the ALICE experiment at LHC will be described.

<u>Hands-on</u>: Operate a Mini HEP Experiment (90 min)

Vito Manzari, Annalisa Mastroserio, Marian Krivda, Constanza Caviccholi, Romualdo Santoro, Gianluca Aglieri Rinella

The aim of this hands-on session is to estimate the rate of cosmic rays by an array of ALICE pixel detector modules. The students will have the possibility to experience the real life of operating a pixel detector: after a quick description of the detector and the auxiliary services, they will set up and run an array of ALICE pixel modules. After a preliminary rough evaluation of the detection efficiency, a sample of cosmic rays events will be collected exploiting the self-triggering capability of the detector.

<u>Lecture</u>: Present and future Pixel systems at the LHC (30 min)

Alessandro La Rosa, Christian Gallrapp, Daniel Dobos, Heinz Pernegger

The lecture gives an introduction to the LHC Pixel systems of the ALICE, ATLAS and CMS experiments. This includes also future developments as 3D silicon and diamond sensors. Basic principles of the detector readout as well as the quality, tuning and calibration procedures are discussed in order to get the theoretical understanding for the following hand-on session.

<u>Hands-on</u>: Pixel systems at the LHC (30 min)

Alessandro La Rosa, Christian Gallrapp, Daniel Dobos, Heinz Pernegger

The Hand-On session will get you familiar with the general pixel detector design by comparing exhibited modules from different experiments. You will understand the handling of pixel detectors on the example of the current ATLAS n-in-n pixel detector by performing the main front-end tuning steps as well as source measurements with radioactive ^{241}Am.

<u>Lecture</u>: Future Developments and Challenges (30 min)

Heinz Graafsma, Michael Campbell, Simon Kwan

Hybrid pixel detectors are used extensively as High Energy Physics vertex detectors as they provide fast and practically noise-free 2D hit information making them ideal for pattern recognition in a high multiplicity environment. These properties have also led to their deployment in other fields of particle detection, notably in photon science. The development of hybrid pixels has been based on the availability and access to the latest CMOS processes as well as to high density interconnect processes. Future challenges include reducing material budget in inner vertex layers, providing triggerless time stamped data at optimal power consumption and covering large areas seamlessly at a reasonable cost.