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Book of Abstracts

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Complete suppression of reverse annealing of neutron radiation damage during active gamma irradiation in MCZ Si detectors

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For the development of radiation-hard Si detectors for the SiD BeamCal program for International Linear Collider (ILC), n-type Magnetic Czochralski Si detectors have been irradiated first by fast neutrons to fluences of 1.5x1014 and 3x1014 neq/cm2, and then by gamma up to 500 Mrad. The motivation of this mixed radiation project is to develop a radiation-hard Si detector that can utilize the gamma/electron radiation to compensate the negative effects caused by neutron irradiation, all of which exists in the ICL radiation environment. By using the positive space charge created by gamma radiation in MCZ Si detectors, one can cancel the negative space charge created by neutrons, thus reducing the overall/net space charge density and therefore the full depletion voltage of the detector. It has been found that gamma radiation has suppressed the room temperature reverse annealing in neutron-irradiated detectors during the 5.5 month of time needed for the 500 Mrad radiation dose. The reverse annealing in control detectors (detectors having the same neutron fluences, but going through this 5.5 month room temperature annealing (RTA) without gamma radiation) was clearly taking place. This suppression is in agreement with our previous predictions, since negative space charge is generated during the reverse annealing, any suppression of that would mean creation of positive space charge by gamma radiation. The impressive effect is that regardless of the fluence the reverse annealing is totally suppressed by the same dose of gamma (500 Mrad): the full depletion voltage for the two detectors irradiated to two very different fluences stay the same before and after gamma radiation. Meanwhile, for the control detectors, the full depletion voltages have gone up in amounts proportional to the neutron fluence. This would imply that concentrations of positive space charge created in these two samples are different at the same gamma dose, and gamma irradiation effectively "switched off", or "freeze"the RT reverse annealing of neutron irradiation. It has also been found that as soon as the gamma irradiation stops, the RT reverse annealing of neutron irradiation resumes (or "turned on"or "un-freeze") with same rate as that of the control detectors. This behavior would suggest some nonlinear effect, or interaction of radiation induced acceptor-type and donor-type defects.

Applications in High Energy Physics / 5

Operational experience with the ATLAS Pixel Detector at the LHC.

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The ATLAS Pixel Detector is the innermost detector of the ATLAS experiment at the Large Hadron Collider at CERN, providing high-resolution measurements of charged particle tracks in the high radiation environment close to the collision region. This capability is vital for the identification and measurement of proper decay times of long-lived particles such as b-hadrons, and thus vital for the ATLAS physics program.

The detector provides hermetic coverage with three cylindrical layers and three layers of forward and backward pixel detectors.
It consists of approximately 80 million pixels that are individually read out via chips bump-bonded to 1744 n-in-n silicon substrates.

In this talk, results from the successful operation of the Pixel Detector at the LHC will be presented, including monitoring, calibration procedures, timing optimization and detector performance. The detector performance is excellent: 97,5% of the pixels are operational, noise occupancy and hit efficiency exceed the design specification, and a good alignment allows high quality track resolution.

Pixels (including CCD's) / 6

Overview of the ATLAS Insertable B-Layer (IBL) Project

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The upgrades for the ATLAS Pixel Detector will be staged in preparation for high luminosity LHC. The first upgrade for the Pixel Detector will be the construction of a new pixel layer which will be installed during the first shutdown of the LHC machine, foreseen in 2013-14. The new detector, called the Insertable B-layer (IBL), will be installed between the existing Pixel Detector and a new, smaller radius beam-pipe at a radius of 3.2 cm. The IBL will require the development of several new technologies to cope with increased radiation and pixel occupancy and also to improve the physics performance through reduction of the pixel size and a more stringent material budget. Two different and promising silicon sensor technologies, planar n-in-n and 3D, are currently under investigation for the IBL. An overview of the IBL project, of the module design and the qualification for these sensor technologies with particular emphasis on irradiation and beam tests will be presented.

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Observation of Radiation Damage in the ATLAS Pixel System Using the High Voltage Delivery System

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We describe the implementation of radiation damage monitoring using
measurement of leakage current in the silicon pixel sensors provided by the circuits of the ATLAS Pixel Detector high voltage delivery system. The dependence of the leakage current upon the integrated luminosity for several temperature scenarios is presented. Based on the analysis we have determined the sensitivity specifications for a Current Measurement System. The status of the system and the first measurement of the radiation damage corresponding to 1.5 fb^{-1} of integrated luminosity
are presented, as well as the comparison with the theoretical model.

Paging and Bottom Toolbar

Simulations and Manufacturing / 8

Silicon Sensors for High-Radiation Tracking Detectors –RD50 Status Report

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It is foreseen to significantly increase the luminosity of CERN's Large Hadron Collider (LHC) by upgrading the LHC towards the HL-LHC (High Luminosity LHC) in order to harvest the maximum physics potential of the machine. Especially the final upgrade (Phase-II Upgrade) foreseen for 2021 will mean unprecedented radiation levels, exceeding the LHC fluences by roughly an order of magnitude. Due to the radiation damage limitations of the silicon sensors presently used, the physics experiments will require new tracking detectors for HL-LHC operation. All-silicon central trackers are being studied in ATLAS, CMS and LHCb, with extremely radiation hard silicon sensors to be employed on the innermost layers.

Within the CERN RD50 Collaboration, a massive R&D programme is underway across experimental boundaries to develop silicon sensors with sufficient radiation tolerance. One research topic is to gain a deeper understanding of the connection between the macroscopic sensor properties such as radiation-induced increase of leakage current, doping concentration and trapping, and the microscopic properties at the defect level. We also study sensors made from p-type silicon bulk, which have a superior radiation hardness as they collect electrons instead of holes, exploiting the lower trapping probability of the electrons due to their higher mobility. Another sensor option under investigation is to use silicon produced with the Czochralski-process. The high oxygen content in the Czochralski-Silicon has been shown to have a beneficial influence on some of the effects of radiation damage. A further area of activity is the development of advanced sensor types like 3D silicon detectors designed for the extreme radiation levels expected for the vertexing layers at the HL-LHC. These detectors in general have electrodes in the form of columns etched into the silicon bulk, which provide a shorter distance for charge collection and depletion, which reduces trapping and full depletion voltage. We will present results of several detector technologies and silicon materials at radiation levels corresponding to HL-LHC fluences. Based on these results, we will give recommendations for the silicon detectors to be used at the different radii of tracking systems in the LHC detector upgrades.

Simulations and Manufacturing / 9

3D slim edge silicon sensors: processing, yield and QA for the ATLAS IBL production

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3D silicon sensors with double side etched electrodes and dimensions compatible to the ˜4cm2 FE-I4 ATLAS pixel front-end chips, started their production for one of the LHC experiment's upgrades in 2013. The Insertable b-Layer (IBL) is a single additional pixel layer which will be inserted within the existing pixel detectors in the ATLAS experiment. This paper will describe the strategy which allowed the transition of 3D technology from R&D to industrialization, will present the sensors technical specifications, selection criteria, QA and yield in the current production and discuss performance after bump-bonding with front-end chips and irradiation up to 5x1015 ncm-2.

Strips / 10

Silicon Strip Detectors for the ATLAS Tracker Upgrade

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While the Large Hadron Collider (LHC) at CERN is continuing to deliver an ever-increasing luminosity to the experiments, plans for an upgraded machine called High-Luminosity-LHC (HL-LHC) are progressing. The upgrade is foreseen to increase the LHC design luminosity by a factor ten. The ATLAS experiment will need to build a new tracker for HL-LHC operation, which needs to be suited to the harsh HL-LHC conditions in terms of particle rates. In order to cope with the increase in pile-up backgrounds at the higher luminosity, an all silicon detector is being designed. To successfully face the increased radiation dose, a new generation of extremely radiation hard silicon detectors is being designed.
Silicon sensors with sufficient radiation hardness are the subject of an international R&D programme, working on pixel and strip sensors. The efforts presented here concentrate on the innermost strip layers. We have developed a large number of prototype planar detectors produced on p-type wafers in a number of different designs. These prototype detectors were then irradiated to a set of fluences matched to HL-LHC expectations. The irradiated sensors were subsequently tested with prototype HL-LHC readout electronics in order to study the radiation-induced degradation, and determine their performance after serious hadron irradiation of up to a few 10ˆ15 1-MeV neutron-equivalent per cmˆ2.
We will give an overview of the ATLAS tracker upgrade project, in particular focusing on the crucial innermost silicon strip layers. Results from a wide range of irradiated silicon detectors will be presented. We will draw conclusions on what type and design of strip detectors to employ for the upgrades of the tracking layers in the HL-LHC upgrades of LHC experiments.

Poster session / 11

Development of Wide Range Charge integration Application Specified Integrated Circuit for Photo-sensor

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A front-end application specified integrated circuit (ASIC) is developed with a wide dynamic range to read out the signals from a photo-sensor like a photodiode.
The ASIC consists of a charge sensitive preamplifier, four wave-shaping circuits with different amplification
factors and an analog to digital converter(ADC) of Wilkinson-type.
To realize a wider range, the beed back capacitor of integral circuit in preamplifier can be changed from 4pF to 16pF
by two switched.
The output of a preamplifier is supplied to the four wave-shaping circuits with four gains of 1,4,16,64 to
adapt input range of ADC.
The dynamic range of four orders of magnitude is achieved with the maximum range over 10pC.
A 0.25m CMOS process (of UMC electronic CO.,LTD) is used to fabricate an ASIC with four-channels.
In this presentation, the design and the basic performance of ASIC will be reported.

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On-chip power conversion in the FE-I4 pixel chip

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FE-I4 is a 130nm feature size CMOS readout IC designed for the next-generation of hybrid pixel detectors. The first version FE-I4A contains multiple powering options in order to evaluate the performance for future applications. The first optimization is being done for the ATLAS Insertable B-Layer (IBL) upgrade. FE-I4A contains two stand-alone linear-shunt voltage regulators(ShuLDO) and a divide-by-two charge pump DC-DC converter. The design and test results of these on-chip power converters will be presented in this report.

Applications in High Energy Physics / 13

ATLAS Silicon Microstrip Tracker Operation and Performance

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The Semi-Conductor Tracker (SCT), is a silicon strip detector and one of the key precision tracking devices in the Inner Detector of the ATLAS experiment at CERN LHC.
The SCT is constructed of 4088 silicon detector modules for a total of 6.3 million strips. Each module is designed, constructed and tested to operate as a stand-alone unit, mechanically, electrically, optically and thermally. The modules are mounted into two macro-structures: one barrel and two end-cap.
The SCT silicon micro-strip sensors are processed in the planar p-in-n technology. The signals from the strips are processed in the front-end ASICS ABCD3TA, working in the binary readout mode. Data is transferred to the off-detector readout electronics via optical fibers.
The completed SCT has been installed inside the ATLAS experimental cavern since 2007 and has been operational since then. Calibration data has been taken regularly and analyzed to determine the noise performance of the system. Extensive commissioning with cosmic ray events has been performed both with and without magnetic field. The sensor behavior in the 2 Tesla solenoidal magnetic field was studied by measurements of the Lorentz angle. We find 99.3% of the SCT modules are operational, noise occupancy and hit efficiency exceed the design specifications, the alignment is very close to the ideal to allow on-line track reconstruction and invariant mass determination.
In the talk the current status of the SCT will be reviewed, including results from the latest data-taking periods in 2009 and 2010, and from the detector alignment. We will report on the operation of the detector including overviews on services, connectivity and observed problems. The main emphasis will be given to the performance of the SCT with the LHC in collision mode and to the performance of individual electronic components. The SCT commissioning and running experience will then be used to extract valuable lessons for future silicon strip detector projects.

Applications in Space, Medical, Biology, Material Sciences / 14

Radiation effects on the silicon semicondoctor detectors for the ASTRO-H mission

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Hard X-ray Imager (HXI) and Soft Gamma-ray Detector (SGD) onboard the 6th Japanese X-ray satellite, ASTRO-H, which is scheduled to be launched in 2014, utilize the double-sided silicon strip detector (DSSD) and the pixel array type silicon sensor (Si-pad), respectively. DSSD with a strip pitch of 250 um in a 3.4 cm x 3.4 cm area has imaging capability in 5-30 keV with an energy resolution of 1–2 keV (FWHM) in both the P and N sides. Si-pad consists of 16 x 16 pixels with the pixel size of 3.2 mm x 3.2 mm is utilized to determine the photon direction by the Compton kinematics in 10-600 keV. Since the ASTRO-H will be operated in the low earth orbit, these detectors are damaged by the irradiation of cosmic-ray protons mainly in the South Atlantic Anomaly. The total radiation level in the orbit is about 1 krad per one year, and the leakage current increases gradually by the produced damage in the sensor. In order to evaluate the damage of the sensor by the irradiation, we have carried out 60Co gamma-ray radiation tests with a total dose of 1, 3, 5 and 10 krad, and a 150 MeV proton beam bombardment with the total dose of 10 years irradiation level. In the both experiments, the leakage current level became larger by a factor of 2-3, resulted in the effect on the noise level is small if we continue the mission for 10 years, and it is found that the radiation effects are not significant under the operation temperature of -15C for the ASTRO-H. In this presentation, we report the summary of the basic performance of the detectors, and the radiation effects on the sensors by the irradiation tests.

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Alumina and silicon oxide side wall passivations for p- and n-type sensors

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We report on a low-cost and flexible implementation of so-called "slim-edges" useful in many applications in high-radiation instrumentation with possible extension into large-scale application of semiconductor sensors in other fields. Post-production treatment affords flexibility and optimization in the sensor application. Future industrialization will be easy since these methods have been developed and proven in the photovoltaic industry.
The method combines preparing a high-quality edge produced by laser scribing followed by cleaving, minimizing the edge current. This low damage surface is then coated with a suitable dielectric having the appropriate interface charge in a low-temperature ALD process. This interface charge will shape the field at the edge. We will show results on the cleaving process with distances to the active area of 14 µm; on the deposition of Si-oxide for n-type sensors; and on the deposition of alumina for p-type sensors. The silicon oxides are deposited by PECVD (plasma enhanced chemical vapor deposition), and we used ALD (atomic layer deposition) for the alumina films. We will discuss

details of the treatment process, the influence of the deposition temperatures, the use of commercial cleaving methods, and the effects of elevated temperature annealing after deposition. Irradiations with ionizing and displacing radiation have been performed and their effects will be shown.

Poster session / 16

Triggering on hadronic tau decays in ATLAS: semiconductor tracking detectors in action

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Hadronic tau decays play a crucial role in taking Standard Model measurements as well as in the search for physics beyond the Standard Model. However, hadronic tau decays are difficult to identify and trigger on due to their resemblance to QCD jets. Given the large production cross section of QCD processes, designing and operating a trigger system with the capability to efficiently select hadronic tau decays, while maintaining the rate within the bandwidth limits, is a difficult challenge.

This contribution will summarize the status and performance of the ATLAS tau trigger system during the 2011 data taking period, emphasizing the key role of semiconductor tracking detectors for tracking and vertexing. Different methods that have been explored to obtain the trigger efficiency curves from data will be shown. Finally, in light of the vast statistics collected in 2011, future prospects for triggering on hadronic tau decays in this exciting new period of increased instantaneous luminosity will be presented.

Poster session / 18

Development of SiTCP based DAQ System of Double-sided Silicon Strip Super-module

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The inner tracker of the ATLAS detector will be replaced at the future upgrade to keep the performance at high luminosity operation. We have been developing super-module concept for the upgrade, based on double-sided silicon strip modules. In the super-module concept, one super-module consists of 12 double-sided modules and one double-sided module has 80 readout ASICs which read 128 strips per one ASIC. Then, we have 122,880 readout strips for one super-module. Since the number of the readout strips becomes large to keep hit occupancy at an acceptable level, the data readout is one of the key issues. We developed readout system by using a "Seabas"DAQ boards. Seabas processes the data from the super modules with an FPGA (User-FPGA) and transfers data to a computer via Ether-net with SiTCP protocol. SiTCP is a technology to realize direct access and transfer of the data in the memory of User-FPGA from the PC by utilizing TCP/IP and UDP communication with a dedicated FPGA. We developed firmware and software for Seabas, together with readout hardware chain, and established basic functionality for reading out the super-module.

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ASIC development for high speed serial data transmission from detector front-end to the back-end

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A 5 Gb/s 16:1 serializer ASIC has been developed using a commercial 0.25 um thin-film silicon-on-sapphire CMOS technology. This prototype has been evaluated against operational conditions in detector front-end environments of the proposed HL-LHC upgrade. A novel two channel array serializer ASIC is being designed to meet challenges in ultra-high data transmission in the range of 100 Gb/s for each front-end board. We will report the prototype measurement results and the array serializer ASIC design status.

Poster session / 20

Development of an optical link system for applications in deep cryogenic environments

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Large volume Liquid Argon TPC is the choice for future neutrino physics. We present studies on front-end electronics and an optical link system, including lasers and passive components such as fiber and connectors. Results from both functional and reliability tests will be presented, providing a methodology we developed for identify components for applications in deep cryogenic environments. Component level reliability results of a few particular digital (FPGA, repeater) and opto-electronics parts will be provided.

Poster session / 21

Design and verification of an FPGA based bit error rate tester

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In characterizing a serial data transmission link, Bit Error Rate (BER) test provides the most stringent measurement. We will present a BER tester implementation using the Altera Stratix GX/GT signal integrity development kits. The Stratix II GX tester operates up to 6.5 Gbps and the Stratix IV GT tester operates up to 10Gbps, both in 4 duplex channels, with information of each single bit flip stored for off-line analysis. The BER testers are used in irradiation and in-lab characterization of ASICs and other components. Results from those tests will be presented as demonstration to the functionality of these BER testers.

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Status of 3D double sided detector fabrications and their applications at CNM-IMB

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Silicon detectors cylindrical electrodes (so called 3D detectors) offer advantages over standard planar photodiodes as more radiation hard radiation sensors. 3D detectors with the double sided geometry have been fabricated at CNM clean room facilities. Different geometries including pixel detectors for high energy physics experiment and synchrotron imaging , short strip detectors with the same inter-column spacing as proposed for the ATLAS pixel detector upgrade and standard pad for radiation hardness studies

The detectors have been irradiated to a fluence of 2 x 1016 cm−2 1 MeV equivalent neutrons, which is twice the expected dose of the inner pixel layer of the ATLAS detector for super-LHC operation. Charge collection studies have been performed with analogue readout with 25ns shaping time, as required for (super)LHC experiments. The response of the detectors to Sr-90 electrons and laser scanning are shown and compared with planar devices.

The 3D detector is shown to have superior charge collection characteristics even at the highest fluences even when compared to planar devices operating at 1000V, which is in excess of that presently possible in the ATLAS experiment. Annealing studies of the collection efficiency and the main electrical characteristics of the detectors are also investigated. The experimental results are compared to the simulation of charge transport in the devices.

Pixels (including CCD's) / 23

Irradiation and beam tests qualification for ATLAS IBL Pixel Modules

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The upgrade for the ATLAS detector will undergo different phases towards HL-LHC. The first upgrade for the Pixel Detector will consist in the construction of a new pixel layer which will be installed during the first shutdown of the LHC machine (foreseen for 2013-14). The new detector, called Insertable B-Layer (IBL), will be inserted between the existing pixel detector and a new (smaller radius) beam-pipe at a radius of 3.2 cm. The IBL will require the development of several new technologies to cope with increase of radiation or pixel occupancy and also to improve the physics performance which will be achieved by reduction of the pixel size and of the material budget. Two different promising Silicon sensor technologies (Planar n-in-n and 3D) are currently under investigation for

the pixel detector.
An overview of the sensor technologies qualification with particular emphasis on irradiation and beam tests will be presented.

Strips / **24**

Electrical Performance of a Silicon Microstrip Super-Module Prototype for the High-Luminosity LHC Collider

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The Large Hadron Collider (LHC) at CERN is currently providing proton-proton collisions with continous increase in the luminosity delivered to the experiments. ATLAS is a general purpose detector designed to fully exploit the physics potential of the LHC at a nominal luminosity of 1034 cm-2 s-1. It is planned to extend the LHC physics programme by increasing the instantaneous peak luminosity by one order of magnitude in the so-called High-Luminosity LHC (HL-LHC). For ATLAS, an upgrade scenario will require the complete replacement of its internal tracker, since the current detector will start to be inefficient due to cumulated radiation damage and the huge increase in the channel occupancy. A new all-silicon based tracker is currently being designed. Several international R&D programmes are investigating all aspects required for a successful new tracker, like radiation hardness of the silicon sensors and front-end electronics and novel power distribution schemes for the reduction of services.

The super-module concept is presented as the integration solution for the barrel strip region of the future ATLAS tracker. The minimal detecting unit is a double-sided silicon micro-strip module. It consists of two n-on-p silicon micro-strip sensors glued back to back to a central Thermo-Pyrolitical-Graphite (TPG) baseboard. The TPG provides mechanical stability and ensures excellent thermal contact for optimum heat dissipation. Two aluminum-nitride facing plates located at each far-end of the baseboard and four hybrids, two per module side, are bridged on top of the facings so that the hybrids are not only thermally decoupled from the silicon detectors but also any electro-mechanical damages to the sensors are being minimized. Each hybrid contains 20 readout ABCN25 ASICs. The heat generated from the front-end electronics and the detector is transfered to the cooling pipes located in the lateral sides of a light-weight carbon-carbon support structure in which the modules are mounted.

Several double-sided silicon micro-strip module prototypes have been integrated into a common support-structure, so called Super-Module. The digital voltage for the readout ASICs is provided by prototype SM01C DC-DC converters. For each hybrid, a Buffer-Control-Chip (BCC) multiplexes the data-signals from the two columns of ABCN25 chips into a single data-stream running up to 160 Mbps. Three different services buses have been produced at CERN and are used in the Super-Module. The Data-bus is used to drive the common LVDS signals to control both the BCCs and the ABCN25 ASICs, and to receive each multiplexed data-stream coming from up to 16 BCCs. A high-voltage bus is used to bias each sensor individually and a Low-voltage bus for powering the DC-DC converters. A Super-Module Board (SMB) interfaces all signals to the external DAQ.

In this talk, the latest electrical results obtained with the super-mdule prototype are presented.

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Future Silicon Sensors for the CMS Tracker Upgrade

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For the high-luminosity phase of LHC a campaign within CMS started to investigate different technologies. Therefore 6" silicon wafers were ordered at HPK to answer question e.g. radiation tolerance and annealing behavior of different sensor material. The testing variety concern sensor versions n-in-p and p-in-n in thicknesses from 50µm to 300µm. In terms of sensor material the difference between floatzone, magnetic Czochralski and epitaxial grown silicon is investigated. For the n-in-p sensors also different isolation technology p-stop and p-spray are tested. The wafer consists of test- structures, diodes, mini-sensors, long and very short strip sensors, real pixel sensors and double metal routing. The irradiation is done with mixed fluences of protons and neutrons which represents the hadrons that are expected in the CMS tracker after the LHC upgrade. This contribution presents an overview of the different technologies of non-irradiated test structures and also the results after irradiation.

Applications in Space, Medical, Biology, Material Sciences / 26

Performance of the AMS-02 silicon Tracker in the ISS mission

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Since the successful launch of space shuttle, STS-134 on 16/May/2011,
the Alpha Magnetic Spectrometer (AMS-02) has been continuously taking cosmic
data for several months.
As well as the other AMS detector components, the AMS silicon Tracker is working as expected.
The tracker is composed of 2264 double sided silicon microstrip sensors with
total active area of 6.75 mˆ2. In this paper performance of the Tracker, such as noise stability, signal efficiency and resolution, evaluated with the data taken in the first few months of the ISS mission will be presented.

Applications in High Energy Physics / 28

Performance of the LHCb Silicon Tracker

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The LHCb detector has been optimized for the search for New Physics in CP violating observables and rare heavy-quark decays at the Large Hadron Collider (LHC). The detector is a single arm forward spectrometer with excellent tracking and particle identification capabilities. The LHCb Silicon Tracker is constructed from silicon micro-strip detectors with long readout strips. It consists of one four-layer tracking station upstream of the LHCb spectrometer magnet and three stations downstream of the magnet. The detectors have performed extremely well right from the start of LHC operation, permitting the experiment to collect data at instantaneous

luminosities well exceeding the design value. In this presentation, an overview of the operational experience from the first two years of data taking at the LHC will be given, with special emphasis on problems encountered. Calibration procedures will be discussed as well as studies of the intrinsic detector efficiency and resolution. First measurements of the observed radiation damage will also be shown.

Simulations and Manufacturing / 29

Impact of the layout on the electrical characteristics of double-sided silicon 3D sensors fabricated at FBK

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In the past few years important progress has been made in the development of 3D silicon radiation detectors due to the anticipated installation schedule of the ATLAS Insertable B Layer during the first long shut down of the LHC in 2013-2014. Three competing technologies have been evaluated for the IBL sensor production, namely silicon planar and 3D sensors, and diamond sensors. Within the ATLAS 3D Sensor Collaboration, the double-sided 3D technologies from FBK-Trento and CNM-Barcelona have been chosen for the IBL Sensor Qualification. Very good results have been achieved both in terms of tracking performance, radiation hardness and fabrication yield and the evaluation from the IBL Review Panel was positive, so that, although planar sensors were chosen as the lowest risk option, the production of 3D sensors is continuing in order to investigate a possible mixed planar-3D IBL scenario.
Double-sided 3D sensors are indeed offering some advantages in terms of process complexity with respect to the original Full 3D sensor technology proposed by Parker and Kenney and currently available at Stanford and SINTEF. In particular, there is no need for bonding and finally removing a support wafer, a fact that, besides reducing the number of process steps, also makes the wafer back-side fully accessible to apply the substrate bias, thus easing the assembly. A side disadvantage of double-sided detectors is that they do not have an active edge. Nevertheless, using a properly designed termination, the dead area at the edge can be reduced to about 100 µm.
The peculiar structure of 3D sensors with columnar electrodes penetrating all the way through the substrate enables to decouple the active thickness from the electrode distance, offering important advantages in terms of low operation voltage and high charge collection efficiency in irradiated devices. Most of the electrical properties of these sensors are indeed found to be dependent on the distance between the electrodes only, but it should be noted that surface effects are not completely negligible and can significantly affect the sensor capacitance and the breakdown voltage. This is mainly due to the surface implantations (p-spray and/or p-stop) that are used to provide an effective insulation between n+ columns. Additionally, for FBK 3D sensors, since the columnar electrodes are not filled with poly-Si, the metal contacts must be made at the sensor surface, thus requiring an extension of the doped regions around the columns, that is also found to affect the electrical characteristics.
During the R&D phase for IBL, several batches of 3D sensors have been fabricated at FBK and different options for the surface isolation implant (p-spray) and for the layout of the surface layers could be evaluated. In this paper, we will focus on the influence of the layout on the electrical characteristics of these detectors. The main design and technological issues will be reviewed, and experimental results from different sensor batches will be discussed and compared to TCAD simulations.

New materials / 31

Performance of p-Bulk Silicon Microstrip Sensor under Co gamma

Irradiated at Rates Expected at the HL-LHC

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The Large Hadron Collider (LHC) is planned to be upgraded to High Luminosity LHC (HL-LHC) in ten years. The upgrade aims at increasing the luminosity up to 5.0 × 10ˆ34 cmˆ-2 sˆ-1 where the strip sensors will receive about 20 Gy/h of radiation. We are designing n-strip on p-bulk microstrip sensors for the ATLAS experiment at the HL-LHC. The sensors have been shown to be radiation tolerant up to the fluence of 1.0 × 10ˆ15 n/cmˆ2, which is maximum fluence expected at the HL-LHC, from the irradiation studies using protons, neutrons and other particles.
We carried out series of Co gamma irradiation studies to investigate the stability of their IV and isolation properties under irradiation at the expected rates. Non-irradiated sensors tend to lose the IV stability within receiving about 20Gy, which is more evident at higher biases and higher irradiation rates. After they survive at a minimum required bias, they recover the stability as they accumulate the dosage and become sufficient to be operated in the HL-LHC radiation environment. These results indicate that early unstable surface condition is stabilized by radiation. The strip isolation is degraded by irradiation but stays stable within a usable level.

Pixels (including CCD's) / 32

A 4096-pixel MAPS detector used to investigate the single electron distribution in a Young-Feynman two-slits interference experiment

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The Young-Feynman two-slit experiment for single electrons has been carried out by inserting in a conventional transmission electron microscope (TEM) two nanometric slits and a fast recording system able to measure the electron arrival-time. The detector, designed for experiments in future colliders such as those foreseen for the SuperB project, is based on a custom CMOS chip of 4096 monolithic active pixels equipped with a fast readout chain able to manage up to 10ˆ6 low-occupancy frames per second. In particular, the chip was designed using a 130 nm CMOS technology via ST silicon foundry. Moreover, the chip has been tested with protons in a beam-test at CERN in fall 2008 and the results will be summarized. However, here, the chip has been used to detect the elecrons accelerated up to some tens of keV (<120 keV) inside a TEM.
Using this detector and its fast readout chain in this way, high statistic samples of single electron events can be collected within a time interval short enough to guarantee the stability of the system and coherence conditions of the illumination. For the first time in a single electron two-slit experiment, the time distribution of electron arrivals has been measured.

Poster session / 33

Characterization of indirect X-ray imaging detector based on nanocrystalline gadolinium oxide scintillators for high-resolution imaging application

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In the last decade, indirect digital X-ray imaging detectors have widely been used for medical imaging and industrial applications. Indirect-detection method is usually cosisted of a scintillation screen (or an X-ray converter) and 2D electronic image devices. A variety of scintillation materials such as terbium-doped gadolinium oxysulfide (Gd2O2S:Tb) and europium-doped gadolinium oxide(Gd2O3:Eu) and thallium-doped Cesium iodide(CsI:Tl) with columnar structure are commonly used because of their high luminescence efficiency and emission wavelength(500-600nm region) well matching to silicon sensors such as a-Si:H based TFT panel detector, CCD and CMOS based imaging devices. However, many researches on scintillation materials are still ongoing for high spatial X-ray imaging application.
In this work, nanocrystalline Gd2O3(Eu) material as a scintillator for high spatial X-ray imaging were fabricated through co-precipitation synthesis method. This synthesis process was carried out using Eu(NO3)3·6H2O and Gd(NO3)3·6H2O as well as a 0.25mol DEA precipitant. The precipitate solution was vigorously stirred at room temperature (RT). And then complete precipitation was done by adding small amount of DI water and maintaining for a few hours. After centrifugation by DI water and ethanol, the bright white powder was dried at 60℃ for 12 hours. The as-synthesized powder was calcinated at various temperatures with 600-1400℃ in the electric furnace. And also, the synthesized Gd2O3 powders with Eu3+ concentration of 3, 5, 7, 10mol% were calcinated at different heat-treatment time with 3, 5, 7, 10 hour. For evaluation of X-ray imaging characterization, uniform nanocrystalline Gd2O3(Eu) scintillation films with both 145 and 200μm thickness were fabricated by screen printing method.
X-ray diffraction(XRD) and scanning electron microscopy(SEM) were measured in order to investigate the characterization such as the crystal structures and microstructures of nanocrystalline Gd2O3(Eu) scintillator according to various calcination time and Eu3+ concentration. The phase transformation from cubic to monoclinic structure was discovered at 1300℃ calcination temperature. The highest light output by X-ray excitation was showed at 1100℃ calcinations temperature and 5 hour. As calcination time and doped-Eu3+ concentration of synthesized Gd2O3(Eu) scintillator increase, particle size and crystal structure were little not changed. X-ray imaging performance in terms of the light response to X-ray exposure dose, signal-to-noise-ratio (SNR) and modulation transfer function(MTF) were measured by combining the fabricated nanocrystalline Gd2O3(Eu) screens with a lens coupled-CCD camera under radiographic conditions.

Applications in Space, Medical, Biology, Material Sciences / 34

Development of a Head Scanner for Proton CT

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The UC Santa Cruz-Loma Linda U. pCT Collaboration is developing a new head scanner for proton CT, based on the experience of the existing prototype being used in the beam to optimize data reduction and reconstruction algorithms.

The system consists of s two silicon telescopes which track the proton before and after the phantom/patient, and an energy detector which measures the residual energy
We will show some of the data taken with the prototype scanner, and the describe the ongoing work on a scanner which will permit a 2 MHz proton rate.

Poster session / 35

Application of the Punch-through effect to safeguard silicon sensors against damage due to beam loss

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The punch-through effect is being developed as a way to safeguard against damage to silicon detectors, when a beam loss collapses the field in the sensors and brings the readout implants close to the bias voltage.
We evaluate the efficiency of the punch-through protection (PTP) by flooding the sensors with IR radiation, and measure the voltages on the strips on the readout side, which are supposed to be at ground.
The voltages are measured as a function of PTP geometry, irradiation levels, temperature, and the external biasing.
Since the efficiency depends on the relative value of 3 resistors (PTP, bulk, implant) we discuss practical applications and limitations.

Pixels (including CCD's) / 36

Development of novel n^+-in-p Silicon Planar Pixel Sensors for HL-LHC

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We have been developing silicon planar pixel sensors for very high radiation environments, based on n^+ pixels in p silicon-bulk, the n^+-in-p technology.
Recent development of the n^+-in-p silicon strip sensor has shown potentiality being radiation tolerant and low cost in fabrication.
An application of the n^+-in-p technology to the pixel sensor in the inner-most tracking detector at the high luminosity upgrade of the large hadron collider (HL-LHC) is a challenge for the technology, where the particle fluence becomes as high as 1-3$\times10^{16}$ 1-MeV neutron equivalent (n_{eq})/cm^2.
The issues in the development are:
(1) the high voltage operation up to 1000 V to achieve a reasonable charge collection in heavily radiation-damaged silicon sensors;
(2) the biasing structure with the least inefficient area, that are required for testing the sensors before bump-bonding the readout ASIC's;
(3) the isolation of the n^+pixels;
(4) the least dead area in the edge of the sensors;
(5) the thin sensors;
and (6) the bump-bonding of the pixel sensors and the readout ASIC's.

In finding the best solutions, we have fabricated pixel sensors and test diodes with punch-thru (PT) and Polysilicon biasing structures, p-spray and p-stop isolation structures, varied edge spaces, varied number of guard rings, and thinning the fabricated wafers.
A number of issues in the bump-bonding with lead-free (SnAg) solders have been revealed and solved.
The sensors and diodes are irradiated up to 1×10^{16} n_{eq}/cm^2.
The non-irradiated and irradiated pixel sensor flip-chip modules were put in testbeams.
The design features of the pixel sensors and the test structures are reviewed and the effects of the radiation damage in the pixel sensors and to the features are summarized.

Strips / **37**

Development of the silicon-microstrip super-module prototype for the HL-LHC

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The current ATLAS Inner Detector (ID) was designed to survive a luminosity of 2x1034 cm-2s-1 at the CERN LHC. Following the phase 2 of the LHC machine upgrade, called High Luminosity LHC (HL-LHC), the peak luminosity will reach 5x1034 cm-2s-1 and the delivered integrated luminosity will increase by a factor of 10. To maintain the tracking performance in a severe radiation environment (up to 1015 1MeV neutron equivalent at 38cm radius) and increased track occupancy, a new ID will be constructed, using silicon pixel and micro-strip technology.
Important micro-strip specifications include the sensor granularity, and a small material budget. Short strips of ˜2.4 cm length are considered for the three innermost layers while longer strip of about ˜9.6 cm is considered for the two outermost layers. The higher granularity requires investigating new powering and data transmission schemes to limit the material budget in the tracking volume.
A module granularity of about 10x10 cm2 is defined by the six-inch wafer sensor diameter and allows the construction of a "super-module"of up to 16 double-sided modules. This promising concept allows full Z-coverage while keeping high modularity and rework ability up to the last integration step during construction.
Prototype double-sided modules have been fabricated that meet the required performance specifications of signal gain and noise, as well as reasonable specifications of thermal management, material budget and mechanical stability.
A super-module concept has been investigated with demonstrators to prove the feasibility of a stiff but low material local support together with the end-insertion and locking mechanism to a barrel structure allowing a flexible integration.
This presentation will cover the super-module program R&D description, the key features, recent progress and future proposed developments towards the construction of a new ID for the ATLAS experiments.

New materials / **38**

Diamond Pixel Detectors in High Radiation Environments

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The performance of diamond pixel detectors (single- and poly-crystalline) in high radiation environments is compared to silicon. Estimation of Signal-to-Noise Ratio (SNR) and measurements on real devices with the ATLAS FE-I4 pixel readout chips are presented.
Diamond is an attractive sensor material for vertex detectors because of its strong radiation-resistance. Also, its tiny leakage current after irradiation and smaller capacitance result in low noise. However, silicon can generate larger signals, because its band gap is smaller than for diamond, while its noise level is similar to diamond before irradiation. This situation changes in high radiation environments, e.g. super Large Hadron Collider, at where a particle fluence 10^{16} n_{eq}/cm^{2} is expected. Hence, the SNR of diamond and silicon pixel detectors after strong radiation damage should be compared. For the signals, the decreasing drift distance of charge carriers versus increasing irradiation is measured using diamond pad detectors, and the results are applied to predict the signal deterioration in pixel detectors. For the noise, analytical calculations and simulations using chip design software are used with the leakage current and capacitance to the amplifier of the pixel readout as key parameters. To know the input capacitance, which has never been clearly identified in pixel detectors, a capacitance measuring chip (PixCap) has been developed, so the input capacitance is directly measured. With all the ingredients mentioned above, the SNR of diamond and silicon pixel detectors with respect to increasing radiation damage by neutral and charged particles can be estimated up to 10^{16} particles/cm^{2} fluence. Finally, we present the measurements of diamond and silicon pixel detectors with the ATLAS FE-I4 pixel readout chip. The devices are characterized before and after irradiation, and the measured SNR is compared to the estimation.

Poster session / 39

Evaluation of novel n-in-p pixel sensors for ATLAS Upgrade with testbeam

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A new type of pixel sensors, n-in-p type, is being developed in order to cope with the particle fluence of 1-3x10^16 1-MeV neutron-equivalent particles/cm^2 in the LHC upgrade (HL-LHC). The n-in-p pixel sensors are ones for the present front-end chip (FE-I3) of the ATLAS detector and the others for the new front-end chip (FE-I4) for the higher occupancy in the HL-LHC. They are made in a p-bulk silicon wafer, planar in geometry, with biasing structures with polysilicon or punch-thru resistance, with isolation structures with p-stops, and a thickness of 320 or 150 µm. The charge collection efficiencies and the performance of the structures before and after irradiation were evaluated by using pion beam of 120 GeV at CERN super proton synchrotron (SPS).

Applications in Space, Medical, Biology, Material Sciences / 40

Development of an ultra-fast ASIC for future PET scanners using TOF-capable MPPC detectors

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We developed a front-end ASIC for future PET scanners with time-of-flight (TOF) capability to be coupled with Multi Pixel Photon Counter (MPPC) arrays. The ASIC is designed based on the open-IP project proposed by JAXA and realized in TSMC 0.35 μm CMOS technology. The circuit comprises 32-channel, low impedance current conveyers to effectively acquire fast MPPC signals. For precise measurement of coincidence timing of 511 keV gamma-rays, the leading-edge method was used to discriminate the signal, and compared with a conventional zero-crossing measurement. We first tested a time response of the ASIC by illuminating a single MPPC device of 3 × 3 mm^2 in size with a Pico-second Light Pulsar with light emission peak of 655 nm and pulse duration of 54 ps (FWHM). We obtained 67 ps (FWHM) and 98 ps (FWHM) for the time jitter and walk measurements, respectively. Excellent energy resolution of 10.5 % (FWHM) was also obtained for 511 keV gamma-rays, when the MPPC and ASIC were coupled with a LYSO pixel scintillator of 3 × 3 ×10 mm^3 in size. We will also report on the TOF measurements using back-to-back 511 keV signals, and suggest that the ASIC can be a promising device for future TOF-PET scanners based on the MPPC array.

Applications in Space, Medical, Biology, Material Sciences / 41

A novel gamma-ray detector with sub-nanosecond and sub-millimeter resolutions using a monolithic MPPC array with pixelized Ce:LYSO crystals

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We have developed a large-area monolithic Multi-Pixel Photon Counter (MPPC) array consisting of 4×4 channels and flexible printed circuit (FPC) cables. Each channel has a photosensitive area of 3×3mmˆ2 and 3600 Geiger mode avalanche photodiodes (APDs). For a typical operational gain of 7.5×10ˆ5 at +20 deg, gain fluctuation is only ±5.8% (RSD) over the MPPC device, and dark count rates (as measured at 1˜p.e. level) amount to ˜400kcps/channel, as averaged over the ten MPPC arrays developed in this paper. We first fabricated a gamma-ray camera consisting of the MPPC array with one to one coupling to a Ce-doped (Lu, Y)2(SiO4)O (Ce:LYSO) crystal array (4×4 array of 3×3×10mmˆ3 crystals). Energy and time resolutions of 11.5±0.5% (FWHM at 662keV) and 493±22ps were obtained, respectively. When using the charge division resistor network, which compiles signals into four position-encoded analog outputs, energy and time resolution of 10.2±0.4% (FWHM) and 837±94ps were obtained, respectively. Finally, we fabricated submillimeter Ce:LYSO scintillator matrices of 1.0 and 0.5mmˆ2 each, to further improve the spatial resolution. In both types of Ce:LYSO matrices, each of the crystals was clearly resolved in a position histogram, as an irradiated 137Cs source. The energy resolutions for the 662keV gamma-rays were 11.5±0.9 and 14.3±1.8% (FWHM), and the time resolutions were 872±84 and 996±149ps among all Ce:LYSO pixels for 1.0 and 0.5mmˆ2 Ce:LYSO matrices, respectively. These results suggest excellent potential for its

use as a high spatial and time resolution medical imaging device, particularly in positron emission tomography (PET).

Pixels (including CCD's) / 42

The DEPFET pixel detector for the BELLE II project

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The upgrade of the KEKB accelerator towards a luminosity of 8*10^35 1/cm2s poses several challenges for the BELLE II detector. Especially detectors close to the interaction point will be faced with a significant radiation of several Mrad per year as well with a high hit density. To cope with this a silicon pixel detector will be used for the innermost layers of the silicon tracker.

The pixel detector (PXD) consists of two layers DEPFET active pixel sensors. The DEPFET technology has an unique set of advantages like good intrinsic signal to noise ratio, low power dissipation in the active area, flexible device size, radiation hardness and a thinning technology allowing to adjust the thickness of the device over a wide range. The layers placed at a radius of 14mm and 22mm and the material budget of approximately 0.16%X0 will improve the IP resolution significantly compared to the previous installed silicon detector.

The PXD detector system consists of the full silicon DEPFET modules with integrated readout ASICS, the data handling hybrid receiving the data and sending them the compute nodes where online pattern recognition is performed. Moreover the powers supply system providing the supply voltages for the DEPFET modules. The power distribution provides low output impedance over all frequencies and a transient response with appropriate overshoots in case of fast varying loads. The power supply system involves several challenges –more than 800 voltages, tight requirements on regulation and noise.

In my talk I will give an overview on the status of the detector R&D with focus on the power supply system.

Applications in High Energy Physics / 43

The ALICE Inner Tracking System: present and future

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The ALICE (A Large Ion Collider Experiment) is general purpose experiment optimized for the study of heavy-ion collisions at the CERN LHC. The physics programme includes proton-proton collisions for reference data and also for genuine physics topics for which ALICE is complementary to the other LHC experiments.
The ALICE Inner Tracking System (ITS) is the innermost tracking detector of ALICE and therefore it plays a key role in tracking and vertexing capabilities. The ITS consists of three coaxial subsystems, surrounding the beam pipe, each one comprising two layers based on different silicon technologies: the Silicon Pixel Detector (SPD), the Silicon Drift Detector (SDD) and the double-sided Silicon Strip Detector (SSD), innermost to outermost respectively. The number, position, granularity and technologies of the layers were optimized for efficient track finding and high impact-parameter resolution in the severe high-multiplicity environment expected for the central Pb-Pb collisions at LHC

energy.
After two years of operation with p-p and Pb-Pb collisions, the ITS has demonstrated its tracking and vertexing capabilities, which are in excellent agreement with the design values. Since the ITS project was frozen, almost 10 years ago, the frontier silicon detector technologies have made a substantial progress and therefore nowadays a detector upgrade based on the currently ongoing developments may allow a substantial enhancement of the ALICE physics capabilities. In particular, the ITS upgrade will improve the tracking performance for heavy-ion detection, where the impact parameter resolution to the primary vertex position plays a crucial role.
This contribution will provide a review of the present ITS performance and the status of the ongoing upgrade studies.

Poster session / 44

Influence of CdTe material ageing on relaxation time and noise

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Because direct band gap and high atom number, Cadmium Telluride based detectors are promissing for next generation of radiodiagnostic devices. In present manufacturing technology, the compensation of deep levels is not satisfactory solid. Presence of deep levels leeds to charge tramping in detectors bulk. The effect of charge tramping is inferior charge collection in contacts area and deteriorated spectral resolution of detector. Impacts of the all mentioned phenomena on detector properties increase with detector age. To describe this, the analysis of detector relaxation time, together with noise spectral density evaluation, is used in this paper.
For this purpose, we analyzed high-ohmic indium doped P type sample with gold contacts, prepared by chemical deposition of aqueous solution of AuCl3. The simulation of ageing process was carried by storing analyzed sample at temperature 100℃. After application of this process, the relaxation time of detector increased from order of hundreds seconds to 10ˆ4 seconds. During the relaxation process, low frequency noise was observed. We found two stages of noise behaviour. Immediately after biasing, Noise spectrum has monotonous 1/fm behaviour with parameter m = 1.3 among the whole frequency range. At time 300 seconds after biasing, the decrease of detector resistivity became less abrupt. Another shape of ospectrum was observed. At low frequencies bellow 3Hz, the m parameter was 0.3 that is close to thermal noise behaviour. The rest of noise spectrum remained the same value of m = 1.3. During abrubt chage of detector current, after biasing, the magnitude of noise pectral density was 10ˆ-7 Vˆ2s. In time region more than 300 s after biasing, the magnitude of noise pectral density dropped to 10ˆ-8 Vˆ2s and remained constant for the rest of relaxation process that lasted for 10 000 seconds. From our measurements, we found that in first 300 seconds after biasing of aged sample, deep level filling by charge carriers takes important role in transport mechanism.

Poster session / 45

Evaluation of slim-edge, multi-guard, and punch-through-protection structures of Hamamatsu p-bulk sensors before and after irradiation to the HL-LHC fluence

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The silicon pixel and strip sensors are required to work up to the fluences of ¥*geq*1¥*times*10^{16} n/cm2 and ¥*geq*1¥*times*10^{15}n/cm2, respectively, for the high luminosity upgrade of the LHC (HL-LHC). This requires a high sensor bias voltage of 1000 V applicable to cope with the radiation damage in the silicon bulk. For planar sensors, the distance to the edge and multiple guard rings are important parameters to withstand such high voltage while a minimum inactive space in the edge is also important. The protection of the sensor, especially the AC coupling insulator, against an accident of beam splash is also to be considered to operate the sensors in the high luminosity machine. We evaluate this with a punch-through-protection (PTP) structures.

We have fabricated test diodes using p-bulk with various edge distances (slim-edge diodes), with single to triple guard structures(multi-guard diodes), and with variousPTP structures. Thesesamples were irradiated with 70 MeV protons to the fluences of 5¥*times*10^{12} up to 1¥*times*10^{16} n/cm2.Through this fundamental study we have determined the required edge space, evaluated the relevance ofthe multiple guard to suppress the microdischargeonset and the effectiveness of the PTP structures.

Pixels (including CCD’s) / 46

SOI Pixel Technology

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Silicon-On-Insulator(SOI) technology was developed in semiconductor industry to realize high-performance and low-power devices, and now it is widely used in many companies. We have been collaborating with Lapis Semiconductor Co. Ltd. (former OKI Semiconductor) to apply this technology for radiation imaging sensor.

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The SOI chip has a layer of integrated-circuit which is separated from the chip's substrate by a thin layer
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To develop the SOI pixel technology was not so easy task, but to keep this kind of technology for long time
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Therefore we have been performing Multi-Project Wafer (MPW) run service to the people in universities and laboratories of all over the world. By doing this, we can maintain some amount of volume to keep the process.

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Details of the technology and recent results will be presented.
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Poster session / 48

A Versatile Link for high-speed, radiation resistant optical transmission in LHC upgrades

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The Versatile Link project is launched to develop a physical layer general purpose optical link with high bandwidth; radiation and magnetic resistance that meets the requirements of LHC upgrade experiments. On behalf of the Versatile Link collaboration we will present the latest results on system specifications, front-end transceiver prototypes, passive components studies and commercial back-end transceiver tests.

Applications in Space, Medical, Biology, Material Sciences / 49

Development of High Performance Avalanche Photodiodes and Dedicated Analog Systems for HXI/SGD Detectors onboard the Astro-H mission

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Hard X-ray Imager and Soft Gamma-ray Detector are being developed as on-board instruments for the Astro-H mission, which is scheduled for launch in 2014. In both detectors, BGO scintillators play key roles in achieving high sensitivity in low earth orbit, by generating active veto signals to reject cosmic-ray events and gamma-ray backgrounds from the radio-activated detector materials. Furthermore, in order to maximize background rejection power, it is important to minimize the energy threshold of this shield. As a readout sensor of weak scintillation light from a number of BGO crystals in a complicated detector system, high performance, reverse-type Avalanche Photodiodes (APDs), with effective area of 10 × 10 mm2 are being employed, instead of bulky photo-multiplier tubes (PMTs). Another advantage of using APDs is their low power consumption, although the relatively low gain of APDs (compared to conventional PMTs) requires dedicated analog circuits for noise suppression.
In this paper, we report on the development and performance of APD detectors specifically designed for the Astro-H mission. In addition to the APD performance itself, various environmental tests, including radiation hardness and qualification thermal cycling, will be described in detail. Moreover, a dedicated charge sensitive amplifier and analog filters are newly developed and tested here to optimize the performance of APDs to activate fast veto signals within a few μs from the BGO trigger. We will also report on the performance test throughout a prototype BGO detector system as a whole that mimics the data acquisition system onboard Astro-H.

Simulations and Manufacturing / 50

Monolithic and hybrid pixel sensors in vertically integrated CMOS technology for vertexing applications

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Experiments at the future high luminosity colliders (like ILC, SuperB and SLHC) will set severe requirements on each of the parts making up the silicon vertex tracker (SVT), including the detector (i.e., the sensitive silicon volume) and the readout electronics. In order to separate the very dense particle jets emerging from the interaction region, the first detector layer will be placed very close to the pipeline axis and will have to provide remarkably high spatial resolution, with a pitch of a few tens of microns. Thin detectors, with overall thickness in the order of a few hundred microns or less, will be required for the purpose of minimizing the amount of material in the sensitive region of the tracker, therefore reducing multiple scattering and improving momentum measurement accuracy. While not being the only possible solution, vertical integration, or 3D, technologies may satisfy many (if not all) of the above requirements at the cost of some increase in process complexity. Use of a 3D technology, besides increasing the functional density in the front-end electronics, also is expected to improve the charge collection properties of the collecting electrode in the case of the so called deep N-well monolithic active pixel sensors (DNW MAPS). The first vertically integrated DNW monolithic sensors have been fabricated in the framework of the 3D-IC consortium, led by the ASIC design group at Fermilab and involving several European research teams. Single pixel elements, small matrices with simple analog output and large matrices (including up to 65 kpixels) with sparsified digital readout and time stamping have been integrated in a 130 nm, double tier 3D CMOS technology provided by Tezzaron Semiconductor and Globalfoundries. This work, besides describing the main design features of 3D front-end electronics for hybrid pixels and of 3D DNW MAPS, will present the first experimental results from the characterization of the 3D DNW MAPS prototypes.

New materials / 51

Diamond for high energy radiation and particle detection

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Progress in experimental particle physics in the coming decade depends
crucially upon the ability to carry out experiments at high energies and high luminosities. These two conditions imply that future experiments will take place in very high radiation areas. In order to perform these complex and perhaps expensive experiments new radiation hard technologies will have to be developed. Chemical Vapor Deposition (CVD) diamond is being developed as a radiation tolerant material for use very close to the interaction region where detectors may have to operate in extreme radiation conditions. During the past few years many CVD diamond devices have been manufactured and tested. As a detector for high radiation environments CVD diamond benefits substantially from its radiation hardness, very low leakage current, low dielectric constant, fast signal collection and ability to operate at room temperature. As a result CVD diamond now has been used extensively in beam conditions monitors as the innermost detectors in the highest radiation areas of e+e- colliders (BaBar and Belle experiments) and hadron colliders (CDF and every experiment at the recently commissioned CERN Large Hadron Collider). In addition, CVD diamond is now being considered as a sensor material for the particle tracking detectors closest to the interaction region where the most extreme radiation conditions exist. We will present the present state-of-the-art of polycrystalline CVD diamond and the latest results on the radiation tolerance of the highest quality material for a range of proton energies, pions and neutrons obtained from strip detectors

constructed with this material. Recently single crystal CVD diamond material has been developed which resolves many of the issues associated with polycrystalline material. We will also present recent results on radiation tolerance obtained from strip detectors constructed from this new diamond material. Finally, we will discuss the use of diamond detectors in present and future experiments and their survivability in the highest radiation environments.

New materials / 52

The Diamond Beam Monitor for Luminosity Upgrade of ATLAS

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Luminosity monitors, beam monitors and tracking detectors of the experiments at the Large Hadron Collider and their upgrades must be able to operate in radiation environments several orders of magnitude harsher than those of any current detector. We have observed in ATLAS that as the environment becomes harsher detectors not segmented, either spatially or in time, have difficulty handling the separation of signal from background. Once the charged particle multiplicity reaches the point where all segments of these detectors have a high probability of having a hit in every bunch crossing their sensitivity quickly vanishes. This is already happening in ATLAS to the MBTS luminosity counters that will be removed in the 2011 year-end shutdown and LUCID luminosity counters. Chemical Vapour Deposition (CVD) diamond has a number of properties that make it an attractive alternative for high energy physics detector applications. Its large band-gap (5.5 eV) and large displacement energy (42 eV/atom) make it a material that is inherently radiation tolerant with very low leakage currents and high thermal conductivity. CVD diamond is being investigated by the RD42 Collaboration for use very close to LHC interaction regions, where the most extreme radiation conditions are found. The ATLAS Diamond Beam Monitor project (DBM) is a highly spatially segmented diamond-based luminosity monitor to measure bunch-by-bunch luminosity in ATLAS. The DBM will complement the highly time-segmented ATLAS BCM so that when the other ATLAS luminosity monitors (MTBS and LUCID) have difficulty functioning the ATLAS luminosity measurement which is a key to most precision measurement is not compromised. The DBM will provide three orders of magnitude higher spatial segmentation (relative to the single BCM pads) at the
expense of lower (25 ns vs 2 ns) time resolution. However these two systems will complement one another in our characterisation of the beam backgrounds. The BCM will still use its exquisite timing resolution to localise beam background sources up (or down) stream of ATLAS, while the DBM will provide additional spatial information about the source(s) of background. To accomplish these goals, the DBM architecture is
four 3-layer telescopes on each side of the interaction point with each layer having the size of one FE-I4 module, namely 20mm x 16.8mm active area. The first and last layers of the telescope are offset so that particles from both the ATLAS interaction point and beam halo background can be tracked. The results from protoype detectors and status of the project will be presented.

Poster session / 53

Beam Conditions Monitoring in ATLAS

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Beam conditions and the potential detector damage resulting from their anomalies have pushed the LHC experiments to build their own beam monitoring devices. The ATLAS Experiment decided to build two independent systems based on Chemical Vapor Deposition (CVD) diamond material.

The ATLAS Beam Conditions Monitor (BCM) consists of two stations (forward and backward) of detectors each with four modules. The sensors are required to tolerate doses up to 500 kGy and in excess of 10ˆ15 charged particles per cmˆ2 over the lifetime of the experiment. Each module includes two diamond sensors read out in parallel. The stations are located symmetrically around the interaction point, positioning the diamond sensors at z = ±184 cm and r = 55 mm (a pseudorapidity of about 4.2). Equipped with fast electronics (2 ns rise time) these stations measure time-of-flight and pulse height to distinguish events resulting from lost beam particles from those normally occurring in proton-proton interactions. The BCM also provides a measurement of bunch-by-bunch luminosities in ATLAS by counting in-time and out-of-time events. Eleven detector modules have been fully assembled and tested and the best eight installed in ATLAS. Testbeam results from the CERN SPS show a module median-signal to noise of 11:1 for minimum ionising particles incident at a 45-degree angle. The BCM has operated reliably in ATLAS for the last 24 months, has provided feedback on every beam dump during that time and is required to show a clean abort before ATLAS returns the LHC injection permit. In addition the BCM provides collision rate and background measurements that have been instrumental in ATLAS achieving a luminosity precision of better than 4%. As luminosity reached unprecedented levels in 2011 and other luminosity monitors in ATLAS reached saturation, ATLAS reported luminosity comes from BCM measurements.

For the ATLAS Beam Loss Monitor (BLM) a simpler detector was installed and connected to LHC beam abort system. The readout electronics is based on LHC BLM systems, with a few modifications to adopt to CVD diamond sensors. There are 12 sensors of 8x8 mmˆ2 area and 0.5mm thickness attached to the ATLAS Inner Detector end plate at z = ±3450mm, r= 65mm, six on each side of interaction point. ATLAS BLM justifiably aborted the LHC beams twice in Summer 2011 and thus prevented possible damage to the Inner Detector.

The performance of the BCM and BLM detectors and their contributions to ATLAS physics will be presented.

Electronics / **54**

Development of Digital Signal Processing System of Avalanche Photodio des for Space Observations by Astro-H

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Astro-H is 6th Japanese X-ray space observatory which will be launched in 2014. Two of onboard instruments of Astro-H, Hard X-ray Imager and Soft Gamma-ray Detector are surrounded by many number of large Bithmuth Germanate (Bi4Ge3O12; BGO) scintillators. Optimum readout system of scintillation lights from these BGOs are essential to reduce the background signals and achieve high performance for main detectors because most of gamma-rays from out of field of view of main detectors or radio-activated materials can be eliminated by anti-coincidence technique. We apply Avalanche Photo Diode (APD) for light sensor of these BGO detectors since their compactness and high quantum efficiency make it easy to design such complicate BGO detector system. For signal processing from APDs, digital filter and other trigger logics on the Field-Programmable Gate Array (FPGA) is used after dedicated minimal analog circuits due to limitation of circuit implementation area on spacecraft. For efficient observations, we have to achieve as low threshold of anti-coincidence signal as possible. In addition, these signals should be sent to the main detector within 5 us to make it in time to stop AD conversion. Considering these requirements, we adopt two types filter to realize both quick generation of anti-coincidence signals in orbit and detail analysis after the data is down-linked.
We are now in the phase of performance test by implementing such filter and trigger logics into FPGA on the Bread Board Model (BBM) of APD signal processing unit, and we also use other BBM or engineering model components, such as APD sensors and preamplifiers. In this paper, we will review our APD signal processing system and report current result of performance test.

Pixels (including CCD's) / 55

Recent Progress of the ATLAS Planar Pixel Sensor R&D Project

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To extend the physics reach of the LHC, upgrades to the accelerator are planned which will increase the peak luminosity by a factor 5 to 10. To cope with the increased occupancy and radiation damage, the ATLAS experiment plans to introduce an all-silicon inner tracker with the HL-LHC upgrade. For radiation damage reasons, only electron-collecting sensor designs are considered (n-in-p and n-in-n).

To investigate the suitability of pixel sensors using the proven planar technology for the upgraded tracker, the ATLAS Upgrade Planar Pixel Sensor R&D Project (PPS) was established comprising 17 institutes and more than 80 scientists. Main areas of research are the performance of planar pixel sensors at highest fluences, the exploration of possibilities for cost reduction to enable the instrumentation of large areas, the achievement of slim or active edges to provide low geometric inefficiencies without the need for shingling of modules and the investigation of the operation of highly irradiated sensors at low thresholds to increase the efficiency.

The presentation will give an overview of the recent accomplishments of the R&D project. Among these are in particular testbeam results obtained with irradiated FE-I3 and FE-I4 pixel detectors and developments in the field of slim and active edges.

Poster session / 56

CMS Silicon Strips alignment and monitoring with the Laser Alignment System

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The alignment of the CMS Silicon Strips detector can be monitored using its built in Laser Alignment System. The 32 Laser beams in each endcap and the 8 Laser beams connecting the barrel and the endcap regions make it possible to monitor the alignment changes to a precision better than 10 μm and the measurement of the absolute alignment parameters better than 100 μm.

For this, 434 of the Silicon Strips modules (3%) are illuminated by the laser beams, assuring a continuous surveillance during the collisions and cosmics data taking. In this contribution the status and the preliminary results of monitoring and alignment parameters during the 2011 LHC data taking period are presented.

Poster session / **57**

Alignment of the CMS Preshower Detector

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The Preshower detector, as part of the CMS endcap electromagnetic calorimeter, is designed to have good spatial resolution to identify the position of incoming photons/electrons in the endcaps. It is based on 4288 silicon sensors, each with active area 61x61 mmˆ2 segmented into 32 strips with 1.9mm pitch. Its spatial resolution relies upon excellent alignment with the neighbouring detectors, especially the Tracker. This is based on the extrapolation of tracks from the Tracker to the Preshower and gives an alignment precision of a few millimeters for translation and a few milliradians for rotation. The method for Preshower alignment will be discussed and the results of the alignment with respect to the Tracker will be presented.

Poster session / **58**

Evolution of Silicon Sensors Characteristics of the Current CMS Tracker

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The CMS silicon strip tracker is the largest detector of its kind. It is expected to operate at the LHC for more than 10 years. In order to quantify aging effects, it is important to keep track of the evolution of fundamental detector properties under radiation and thermal fluctuations. In the this talk we present our methods measuring the evolution of our sensors full depletion voltage and leakage current. We will also present a comparison between the change in detector properties as seen so far with the theoretical predictions. As an outlook we introduce our simulations of the evolution of the detector properties in the next ten years.

Pixels (including CCD’s) / 59

CMS Pixel detector phase 1 upgrade project

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Along the line of successful operation of LHC, it is expected to have the performance surpassing the design luminosity of 10ˆ34 cm-1s-1 before 2020. CMS has planed the so-called phase I upgrade between the two LHC long shutdowns to replace the current silicon pixel detector. The upgrade detector will be capable to fully exploit the luminosity.

The upgrade detector will decrease the material budget significantly. The newly designed Readout chip will improve the deadtime during high rate and high luminosity data taking. In this paper, we present the design of the upgrade detector with the improvement and application on data taking and physics performance.

Simulations and Manufacturing / 60

New results of charge multiplication in irradiated segmented silicon detectors with special strip processing

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The charge multiplication in severely irradiated silicon detectors is now a well proven effect that enhances the charge collection of silicon sensors making them able to operate up to at the doses anticipated for future super-colliders (like the high luminosity LHC at CERN). The effect is well documented but not completely understood. The multiplication is caused by impact ionisation due to hot electrons moving in the high electric field that develops near the junction in the irradiated sensors. The details of the electric field profile in the silicon bulk are not available due to the unknown spatial distribution of the inhomogeneous effective space charge in the hadron irradiated silicon bulk. The gradient of the effective space charge distribution is crucial to the formation of high electric field regions where the multiplication takes place. The electric field might be influenced by the implant forming the n-p junction. Deep n+ implant with different gradients could enhance or reduce the multiplication effect. A possible way to influence the multiplication process in microstrip detectors is to shape the junction implanting through a trench etched in the silicon bulk to create a much larger surface for the n+ implant. We report here the result obtained with this method before and after various doses of neutron irradiation.

Applications in High Energy Physics / 61

CMS tracker performance

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The CMS tracker is the largest of its kind built to date. It has an active area in excess of 200m2 of silicon, which provides high precision measurement points for track reconstruction. In order to use the data from the silicon strip and pixel systems to reconstruct charged particle trajectories as well as primary and secondary vertices, multi-step calibration procedures including module alignment are required. Results from operating the CMS tracker during the first two years of 7 TeV LHC collisions will be presented. These include aspects such as the data acquisition, detector slow control, and data quality monitoring. Projections for the evolution of the CMS tracker performance with increasing irradiation will be given.

Applications in Space, Medical, Biology, Material Sciences / 62

X-Ray Polarimetry with Gas Pixel Detectors

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The Gas Pixel Detector, recently developed and continuously improved by Pisa INFN in collaboration with IASF-Roma of INAF, can visualize the tracks produced within a low Z gas by photoelectrons of few keV. By reconstructing the impact point and the original direction of the photoelectrons, the GPD can measure the linear polarization of X-rays, while preserving the information on the absorption point, the energy and the time of arrival of individual photons. Applied to X-ray Astrophysics, in the focus of grazing incidence telescopes, it can perform angular resolved polarimetry with a huge improvement of sensitivity, when compared with the conventional techniques of Bragg diffraction at 45 degrees and Compton scattering around 90 degrees. This configuration has been the basis of POLARIX and HXMT, two pathfinder missions, and was included in the baseline design of IXO, the very large X-ray telescope under study by NASA, ESA and JAXA.

Special session in honour of Prof. Ohsugi / 63

The construction of the Fermi silicon tracker

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The Fermi Gamma-Ray Large Area Space Telescope (previously known as GLAST) is an international and multi-agency space mission that is studying the cosmos in the energy range 20 MeV - 1 TeV. Fermi is a gamma-ray observatory much more capable than instruments flown previously. The main instrument on board of the spacecraft is the Large Area Telescope (LAT), a high energy pair conversion telescope consisting of three major subsystems: a precision silicon tracker/converter, a CsI electromagnetic calorimeter and a segmented anti-coincidence system. In this presentation, we describe the construction and tests of the silicon tracker and how this enterprise was made possible by the superb quality of the silicon sensors developed at the Hiroshima University within the the Oshugi's group

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The Silicon Strip Tracker of the Fermi Large Area Telescope: performance after three years of operation in space

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Title: The Silicon Strip Tracker of the Fermi Large Area Telescope: performance after three years of operation in space
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The Large Area Telescope (LAT) is the main instrument onboard the Fermi Gamma-ray Space Telescope, an orbital observatory launched in low-Earth orbit on June 11 2008 to survey the high-energy gamma-ray sky. The LAT tracker/converter serves the twofold purpose of converting the incoming gamma-ray into an electron-positron pair and tracking the latter in order to measure the original photon direction. With its 73 square meters of single-sided silicon-strip detectors, read out by some 900,000 independent electronics channel, it is the largest solid-state tracker ever built for a space application. The tracker system operates on 160 W of conditioned power while achieving a single-plane hit efficiency in excess of 99% and a noise occupancy at the level of 1 channel per million.
We describe the basic tracker design and the performance throughout the first three years of operation in orbit.

Poster session / 66

P-in-n and n-in-p sensor performance study of SOI monolithic pixel detectors

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We are developing monolithic pixel detectors
with a 0.2 um Fully-Depleted (FD) silicon-on-insulator
(SOI) CMOS technology. The substrate layer
is high-resistivity silicon, and works
as a radiation sensor having p-n junctions.
The SOI layer is 40-nm silicon, where
readout electronics is implemented.
There is a buried oxide layer between these silicon layers.
This structure is ideal for a monolithic pixel detector.
We developed p-in-n and n-in-p SOI pixel sensors
with Czochralski (CZ) or Float Zone (FZ) silicon substrate.
We operated the 500-um-thick, FZ SOI pixel detectors
under full depletion voltage.
In this presentation we show resent test results
of the SOI pixel detectors
about the characteristics
such as sensitivity, spatial resolution,
energy resolution and radiation tolerance.

Poster session / 67

Misaligned 2D projection geometry based calibration method for cone-beam computed tomography

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Recently X-ray based Computed Tomography (CT) technology has a revolution impact on medical diagnosis and also has been successfully used in industrial non-destructive testing of advanced materials. Such a technique takes advantage of the cone-beam CT (CBCT) geometry, to increase the resolution and reduce the acquisition time. CBCT system relies extremely on geometric precision and measurement quality. In CBCT system, it is generally considered that instrumentation effects (misalignment and noise, etc) and physical effects (beam hardening, scattering, etc) produce artifacts and blurring which limit the spatial resolution.
In this work, we have approached to the two-step process for misaligned geometry of CBCT system. In the first step, the center of the detector was forcibly aligned in order to adjust X-ray focal spot by using metal-hole phantom and physical center of the detector. After setting the focal spot, in the second step, the projection data were acquired at intervals of one degree by putting five pin-hole phantoms on detector for geometric alignment between source part and detector part. The misalignment of gantry was measured by using the difference between reference point (start point) and each rotation point based on the 2D projection. The geometric alignment of CBCT system was implemented through their measured difference.
In this experiment, the X-ray tube (A-132, Varian inc.) having rhenium-tungsten molybdenum target and flat panel amorphous silicon X-ray image sensor (PaxScan 4030CB, Varian inc.) having a 397mm x 298mm active area with 194μm pixel pitch and 2048 x 1536 pixels was used for geometric alignment in our CBCT system. The focal spot alignment was repeatedly carried out by acquiring the X-ray image of 14 x 14 metal-hole phantom. 360 projections with five pin-hole phantoms were used for geometric alignment. The X-ray image results of before and after alignment of CBCT system will be analyzed and compared through the proposed method.

Electronics / 69

Experiences with constructing and operating the world's largest silicon-based electromagnetic calorimeter - the CMS Preshower

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The Preshower detector, part of the CMS Endcap Electromagnetic Calorimeter, is designed to have good spatial
resolution to distinguish between different types of incoming particles. The Preshower is a sampling detector
with two layers of lead absorber, each followed by 1.9mm pitch silicon strip sensors. Each of the 4288 DC-coupled sensors
has an active area of 61x61mmˆ2, making a total surface of around 16mˆ2.
The Preshower was installed and commissioned in CMS in 2009 and has been used in data taking ever since.
The design, construction, commissioning and operational experience will be described, including the observation and mitigation of
radiation-induced bulk and surface effects. The calibration strategy will also be discussed.

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XFEL Detector Developments at SACLA

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The SPring-8 Angstrom Compact Free Electron Laser (SACLA) facility has observed the X-ray lasing on June 7th, 2011. SACLA is the second laser of its type in operation, following LCLS at the U.S. Department of Energy's SLAC National Accelerator Laboratory. It has produced X-ray laser with 0.08 nm wavelength, which is the world's shortest X-ray laser light. SACLA offers scientists a new tool for studying and understanding the arrangement of atoms moving extremely rapidly in various materials. To meet various the scientific demands at SACLA, we have two X-ray 2D detector projects, namely, multi-port CCD (MPCCD) detector, and multi-via (MVIA) detector by using SOI sensor technology. The MPCCD sensor has 1024 x 512 pixels with 50 um square 2 phase pixels, and 8 output ports at 5.3 MHz to enable 60 frames/sec readout. We have demonstrated the performance of 4.5 Me- peak signal with < 300 e- noise, and over 30 Mrad X-ray radiation hardness. 3 types of detector systems with 1, 2, and 8 sensor arrays have been developed. The latter MVIA detector has multi charge collection nodes inside a pixel to transfer the signal charge disproportionally to the dual gain amplifiers, which enables smaller pixel with larger dynamic range. The goal of the MVIA sensor is to improve the peak signal and noise performances to 7.5 Me- and 100 e-, respectively, while shrinking the pixel size down to 30 um. A large area sensor of this design has been submitted to produce 65.5 mm x 30.0 mm sensor by a CMOS integrated circuit lithography stitching technique.

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The Radiation Qualification of the Taiwanese CMOS Image Sensor for the Remote Sensing Satellite

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FORMOSAT-5 is the first space program that National Space Organization (NSPO) takes full responsibility for the complete satellite systems engineering designs including payload(s). FORMOSAT-5 will operate in a sun synchronous orbit at 720-km altitude. The satellite has the optical Remote Sensing Instrument (RSI), which provides 2-m resolution panchromatic (PAN) and 4-m resolution multi-spectral (MS) images. This made-in-Taiwan optical payload will be the first commercial remote sensing instrument using the CMOS image sensor and this sensor IC is design, manufacturing, and verification by the Taiwanese teams.

This paper presents the CMOS image sensor chip radiation qualification analysis as well as the test result for FORMOSAT-5 remote sensing satellite. A total of 100Krad cobalt -60 radiation dose tests of the CMOS image sensor chip have been successful performed and evaluated its test results. This test result has proven that the CMOS image sensor developed by domestic manufacture in Taiwan meets the five years mission radiation requirement for the FORMOSAT-5. The CMOS image sensor

chip has also successful proven that it will be able to perform its functional design goal in the outer space environment.

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Fermi-LAT: A Retrospective on Design, Construction, and Operation and a Look Towards the Future

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GLAST (now Fermi-LAT) was conceived in 1992 and first presented at the 3rd Hiroshima Conference in 1993. The LAT was launched in 2008 and is now beginning its 4th year on orbit. The silicon strip technology was immediately identified as the technology of choice for a space-based detector: stability, no consumables, radiation hard, and high precision. What was not immediately realized were the numerous other benefits derived from efficiencies near 100% and fine segmentation. The process of optimizing the design, how construction challenges were met, and the now 3+ years of operational experience will be summarized.

Special session in honour of Prof. Ohsugi / 74

Silicon devices for scientific applications

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Silicon devices for scientific applications

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The early years-SSC

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The early years-SSC

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LHC Upgrade

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LHC Upgrade

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Applications in Medical and Material Sciences

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Applications in Medical and Material Sciences

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CDF

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CDF

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SCT

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SCT

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Astrophysics

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IC designer behind the BTeV Fpix chip and more recently the ATLAS FE-I4

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Meeting the challenges in ASIC design

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Measuring the radiation environment in ATLAS or elsewhere: see it on your PC with Medipix

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Measuring the radiation environment in ATLAS or elsewhere: see it on your PC with Medipix

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LHC instrumentation

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LHC instrumentation

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Silicon as an Unconventional Detector in Positron Emission Tomography

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studying small animal models of human disease. In the conventional approach, the 511 keV annihilation photons emitted from a patient or small animal are detected by a ring of scintillators such as LYSO read out by arrays of photodetectors. Although this has been successful in achieving ˜5mm FWHM spatial resolution in human studies and ˜1mm resolution in dedicated small animal instruments, there is interest in significantly improving these figures. Silicon, although its stopping power is modest for 511 keV photons, offers a number of potential advantages over more conventional approaches. Foremost is its high spatial resolution in 3D: our past studies show that there is little difficulty in localizing 511 keV photon interactions to ˜0.3mm. Since spatial resolution and reconstructed image noise trade off in a highly non-linear manner that depends on the PET instrument response, if high spatial resolution is the goal, silicon may outperform standard PET detectors even though it has lower sensitivity to 511 keV photons. To evaluate performance in a variety of PET "magnifying glass"configurations, an instrument has been constructed that consists of an outer partial-ring of PET scintillation detectors into which various arrangements of silicon detectors can be inserted to emulate dualring or imaging probe geometries. Recent results have demonstrated 0.7 mm FWHM resolution using pad detectors having 16x32 arrays of 1.4mm square pads and setups have shown promising results in both small animal and PET imaging probe configurations. Performance using detectors having 1mm square pads is currently being tested. Although, there remain many challenges, silicon has potential to become the PET detector of choice when spatial resolution is the primary consideration.

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Commissioning of a Strip x-ray Detector for the RIXS Spectrometer at BL12XU

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The Inelastic X-ray Scattering (IXS) spectrometer at the Taiwan beamline BL12XU at SPring-8 is a powerful instrument designed for a wide range of IXS experiments on electronic excitations of a variety of systems. It features two major setups, one for non-resonant IXS (NIXS) and the other for resonant IXS (RIXS) experiments. In the RIXS setup uses a horizontal dispersion plane for the analyzer. The energy scan of the scattered photons is done by scanning the analyzer and the detector simultaneously within the Rowland circle of the analyzer to maintain the focusing condition. In a typical spectrometer, a perfect crystal is bent to a curvature radius of twice the radius of Rowland circle in order to focus the radiation on a detector. To bent the crystal, however, causes elastic deformations which broaden the bandwidth of the reflection. For high-resolution application, another type analyzer is developed so called diced analyzer crystal, which are built by fixing a large number of small flat single crystals on a spherical substrate. In this way practically all elastic deformations are avoided, but it is still not useful in applications because the finite size of a single flat dice causes a contribution to the resolution [1, 2]. The dispersion relation between the energy and the dispersive position within the focus is dE/dx = E/2R*cotθB. At this commission (E=8986 eV, R=1000 mm, θB=87.08o), the dispersion is 0.229 eV/mm. The accuracy of the energy measurement is directly related to the accuracy in the measurement of the position of the x-rays. One could use a position insensitive point detector with a selected size slit to match the needed resolution but result in relatively poor efficiency. Using a position sensitive strips detector has the advantages that with a large sensitive area and the resolution only limited by the pixel-size effect. For this proposal, a 32 strips position sensitive x-ray detector is designed and fabricated for RIXS system. The energy resolution is limited only geometrically by the strip size of the detector, and by the focusing quality of the analyzer. At this commission, a Ge(337) analyzer was chosen to realize the performance of the whole RIXS setup under Cu absorption edge. From the experimental results, each strip (0.125 mm width) corresponds to 29 to 35 meV depends on the RIXS setup as a function as the incident x-ray energy. The energy resolution of the whole RIXS setup achieved here were 80, 110, 110 meV as the incident x-ray energy were 8986, 8990, 8995 eV individuality, which was approached to the limitation of the

whole energy broadening convoluted by the incident beam bandwidth, beam size contribution and the resolution the backscattering analyzer.

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The LHCb VELO and the LHCb VELO upgrade

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LHCb is a dedicated experiment to study new physics in the decays of beauty and charm hadrons at the Large Hadron Collider (LHC) at CERN. The beauty and charm hadrons are identified through their flight distance in the Vertex Locator (VELO), and hence the detector is critical for both the trigger and offline physics analyses. The VELO is the highest resolution vertex detector at the LHC. The VELO is the silicon detector surrounding the LHCb interaction point. The sensors have an inner radius of 7mm from the LHC beam and an outer radius of 42 mm. Consequently the sensors receive a large and non-uniform radiation dose. A dose of 0.7 x 1013 1 MeV neutron equivalents /cm2 per fb-1 of data is predicted at the tip of the sensors. The sensors are fabricated from oxygenated n-on-n silicon with one module made from n-on-p silicon (as proposed for several of the sLHC upgrades).

The radiation damage is monitored by three studies: 1) the currents drawn as a function of temperature and voltage 2) studying the noise versus voltage behaviour and 3) charge collection efficiency, studied with tracks from proton-proton collisions, as a function of voltage. The results of all three studies are presented, clear signs of radiation damage being observed in each technique. Clear differences in behaviour, as expected, are observed between n-on-n and n-on-p sensors. Type inversion is observed in the tips of the n-on-n sensors.

The detector so far shows no significant performance degradation, however many interesting effects have been observed in the sensors. Effects that will be reported include a coupling of charge to the second metal routing line layer after irradiation, and the evolution of the depletion voltage of n-in-p sensors is compared to that in the n-on-n sensors.

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LHCb Vertex Locator

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LHCb VELO Tracking Resolutions

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