9th International ”Hiroshima” Symposium on the Development and Application of Semiconductor Tracking Detectors, Hiroshima, Japan

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Book of Abstracts

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Opening address

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This will address the welcome message to the 9th International "Hiroshima" Symposium on the Development and Application of Semiconductor Tracking Detectors (HSTD9)", a brief introduction to the history of the symposium, and the logistics of this year's sympsoium.

Session 1 / 1

Measurements of Low Gain Avalanche Detectors (LGAD) for High Energy Physics applications

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This work introduce a new concept of silicon radiation detector with intrinsic multiplication of the charge called Low Gain Avalanche Detectors (LGAD). These new detectors are based on the standard Avalanche Photo Diodes (APD) normally used for optical and X-ray detection applications. The main difference to standard APD detectors is the low gain requested to detect high energy charged particles and the possibility to have fine segmentation pitches in order to create microstrip or pixel devices which do not suffer from the limitations normally found in avalanche detectors.
The gain implemented in the non-irradiated devices must retain some effect also after irradiation, with a higher multiplication factor with respect to standard structures in order to be used in harsh envairoments such as expected in colliders experiments.
The investigation of these detectors provides important indications on the ability of this modified electrode geometry to control and optimise the charge multiplication effect, in order to fully recover the collection efficiency of heavily irradiated silicon detectors, at reasonable bias voltage compatible with the voltage feed limitation of the CERN HL-LHC experiments.

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Closing Remarks

Author: Hartmut Sadrozinski[1]

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Closing Remarks

Session 1 / 4

Development of Novel On-Chip, Customer-Design Spiral Biasing Adaptor on for Si Drift Detectors And Detector Arrays for X-ray and Nuclear Physics Experiments

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A novel on-chip, customer-design spiral biasing adaptor (SBA) has been developed at BNL. The SBA can be used for biasing a Si drift detector (SDD) and SDD array. The SBA concept has the following novel characteristics and advantages: 1) it is customer-design for any desired geometry of SDD single cell with minimum current and minimum drift time of carriers; 2) it has the spiral shaped ion-implants that define the desired voltage profile according to calculations; 3) the radius dependence of the pitch (pSBA(r)) of the spiral is the same as that of the SDD single cell (pSBA(r))=pSDD(r)), which in general varies with radius; 4) the width of the implanted spiral (WSBA(r)) that varies with radius does not have to equal to that of the SDD single cell (WSBA(r)^{1}WSDD(r)), and can be made small to minimize the current in the SBA; 5) it is processed on the same wafer of SDD and SDD array; 6) only one SBA chip/side is needed for one SDD or SDD array to define the voltage profiles on the front side and backside (two SBA chips for double-side SDD array, one SBA chip for SDD array with uniform backside bias); and 7) the connection of the SBA chip and the SDD array can be either double metal (most convenient, SBA and SDD are attached) or wire bonding (SBA chip can be diced off from the SDD array, no heat on the SDD array). The geometry of a single SDD cell is defined by concentric rings of ion-implants (pSDD(r)=pSBA(r)) with maximum width (WSDD(r))>WSBA(r)) to minimize surface current. The surface potential profiles of the leading single SDD cell are defined by the SBA chips provided by wire bond or second metal interconnections, while those of the rest of single SDD cells in the array are provided by the interconnections (second metal, or in some simple cases, wire bonds) of corresponding rings among the single SDD cells (including the leading one). The interconnections between the SDD single cells in most cases are double-metal ones. For cases with small array and small number of rings (small cells), wire bonding may be doable and desirable for interconnections between single SDD cells. In this new SDD array, minimum or no heat generated by SBA will affect the SDD array, and the power consumption of the new SDD array is reduced by a factor of NxM as compared to the conventional spiral SDD array. The new SDD array with SBA can be used for x-ray and for nuclear physics experiments.

Session 6 / 5

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 is currently under construction and will be installed during the first shutdown of the LHC machine, 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 3.3 cm. The IBL required 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 silicon sensor technologies, planar n-in-n and 3D, will be used, connected with the new generation 130nm IBM CMOS FE-I4 readout chip via solder bump-bonds. 32 FEs with

sensors are glued to a light weight carbon-carbon structure which incorporates a titanium cooling tube for a CO2 cooling system. In total the IBL barrel layer will consist of 14 support structures and will cover 0.2m2 active area with 12 million pixels.
A production quality control test bench was setup in the ATLAS inner detector assembly clean room to verify and rate the performance of the detector elements before integration around the beam pipe. Bias voltage sensor measurements as well as new 130nm IBM CMOS front end chip functionality measurements are complemented with 241Am and 90Sr sources as well as cosmic muon measurements to rate the bump bond quality and charge measurement calibration. During the integration process these measurements are repeated to spot integration issues and optimize the final operation performance. A realistic CO2 cooling plant will allow to perform quick warm and cold tests to verify the electrical functioning integrity of the sensors and readout front-ends.

An overview of the IBL project, of the module design, the qualification for these sensor technologies, the integration quality control setups and recent results in the construction of this full scale new concept detector will be presented and discussed.

Session 6 / 6

Status of the ATLAS Pixel Detector at the LHC and its performance after three years of operation.

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The ATLAS Pixel Detector is the innermost detector of the ATLAS experiment at the Large Hadron Collider at CERN. 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 and its status after three years of operation will be presented, including monitoring, calibration procedures, timing optimization and detector performance. The record breaking instantaneous luminosities of 7.7 x 10ˆ33 cm-2 s-1 recently surpassed at the Large Hadron Collider generate a rapidly increasing particle fluence in the ATLAS Pixel Detector. As the radiation dose accumulates, the first effects of radiation damage are now observable in the silicon sensors. A regular monitoring program has been conducted and reveals an increase in the silicon leakage current, which is found to be correlated with the rising radiation dose recorded by independent sensors within the inner detector volume. In the longer-term crystal defect formation in the silicon bulk is expected to alter the effective doping concentration, producing type-inversion and ultimately an increase of the voltage required to fully deplete the sensor. The fourth pixel layer at the radius of 3.5 cm will be added during the long shutdown 2013-2014 together with the replacement of pixel services. Letter of Intent is in preparation for the completely new pixel detector after 2023, capable to take data with extremely high instantaneous luminosities of 5 x 10ˆ34 cm-2 s-1 at High Luminosity LHC.

Session 4 / 7

3D Sensors and MicroFabricated Systems

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Micro-systems, based on MEMS technology, have been used in miniaturized low power and low mass smart structres in medicine, biology and space applications. Recently similar features found

their way inside high energy physics with applications in vertex detectors for High-Luminosity LHC Upgrades, with 3D sensors, 3D integration and efficient power management using silicon microchannel cooling.
This paper will report on the state of this development.

Poster / 8

Development and Evaluation of an ultra-fast ASIC for future PET scanners using TOF-capable MPPC array 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 4×4 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 16-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.
We first tested a time response of the ASIC by illuminating each channel of a MPPC array device of 3 × 3 mm2 in size with a Pico-second Light Pulsar with light emission peak of 655 nm and pulse duration of 54 ps (FWHM). We obtained 105 ps (FWHM) on the average of each channel for the time jitter measurements. Moreover, we compensated for time lags of each channel with inner delay circuits and succeeded in suppressing about-700ps-lag to 15ps.
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 futureTOF-PET scanners based on the MPPC array.

Session 1 / 9

Qualification of a new supplier for silicon particle detectors

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Most modern particle physics experiments use silicon based sensors for their tracking systems. These sensors are able to detect particles generated in high energy collisions with high spatial resolution and therefore allow the precise reconstruction of particle tracks. So far only a few vendors were capable of producing silicon strip sensors with the quality needed in particle physics experiments. Together with the European-based semiconductor manufacturer Infineon Technologies AG (Infineon) the Institute of High Energy Physics of the Austrian Academy of Sciences (HEPHY) developed planar silicon strip sensors in p-on-n technology.
This talk presents the development, production, electrical characterization, beam tests and gamma-irradiation of the first sensors batches produced by Infineon.

Session 1 / 10

Radiation Hard Sensor Materials for the CMS Tracker Upgrade

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The upgrade of the LHC machine to deliver a significantly higher luminosity of about 5 x 10ˆ34 cmˆ(-2)sˆ(-1) is planned to be operational after 2020. This will significantly increase the radiation dose of the inner detector systems, requiring new radiation hard sensor materials for the CMS Tracker. To identify the appropriate materials which are able to withstand the radiation environment in the middle to outer layers of the CMS Tracker during the full lifetime of the high luminosity LHC, a large irradiation and measurement campaign has been conducted. Several test structures and sensors have been designed and manufactured on 18 different combinations of wafer materials, thicknesses and production technologies. The structures will be electrically characterised before and after irradiation with different doses of neutrons and protons.

The talk will present the close-to-final status and results from this campaign.

Session 3 / 11

Temperature Dependent Measurements of n-in-n Pixel Sensors

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The innermost tracking detector of the ATLAS experiment at CERN-LHC consists of planar n-in-n pixel sensors with FE-I3 front-end electronics as hybrid. The 2013/14 newly to be installed insertable b-layer (IBL) at the ATLAS experiment will consist of pixel sensors with a revised design layout and an improved FE-I4 front-end electronics. The envisaged radiation dose in the forthcoming data taking period of the innermost sensors will be a few 10ˆ{15} Neutrons (1 MeV equivalent) cmˆ{-2}. For future collider and detector upgrades like the high luminosity LHC (HL-LHC) pixel sensors in environments exceeding doses well above 10ˆ{16} n cmˆ{-2} are considered.

In this contribution various aspects of R&D laboratory investigations employing radioactive source scans and electric analogue and digital measurements of unirradiated and irradiated (partly up to IBL fluences and partly up to HL-LHC fluences) n-in-n pixel sensor structures are discussed. Main focus are the dependencies and correlations between the sensor operation temperature and observables including leakage currents and charge collection. Some of the investigations are not only performed on single chip sensor+electronic assemblies using several thousands of pixels but also include smaller pixel clusters down to single pixels.

Design studies to improve the temperature monitoring of pixel sensors of the IBL design as well as for the foreseen prototyping sensor productions for HL-LHC upgrade studies are presented.

Session 4 / 12

Annihilation of low energy antiprotons in 3D pixel sensor

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The aim of AEgIS is to measure the gravitational acceleration for anti-hydrogen in the Earth's gravitational field, thus testing the Weak Equivalence Principle, which states that all bodies fall with the same acceleration, independent of their mass and composition. AEgIS will make use of a silicon detector in order to measure the deflection of anti-hydrogen from a straight path under the effect of Earth's gravitational field, by detecting the annihilation position on its surface. A position resolution better than 10 µm is required to determine the gravitational acceleration with a precision better than 10%.
The direct annihilation of low energy (˜ 100 keV) anti-protons coming from the CERN antiproton decelerator was detected with a 3D pixel sensor with FE-I4 readout, originally designed for the upgrade of the ATLAS detector at the LHC.

The presented work is part of a study conducted on different silicon sensor technologies for the realization of the silicon anti-hydrogen annihilation detector for the AegIS experiment at CERN.
We show that charged annihilation products (pions and nuclear fragments) can be detected by the silicon sensor. The present study aims at understanding the signature of an annihilation event in a 3D silicon sensor, in order to assess the accuracy that can be achieved by such a sensor in the reconstruction of the position of annihilation, when the same happens directly on the detector surface.
We also present a comparison between experimental data and Geant4 simulations and previous data obtained with a silicon imaging detector. These results are being used to determine the geometrical and process parameters to be adopted by the silicon annihilation detector to be installed in AEgIS.

Session 5 / 13

CBC2: a CMS microstrip readout ASIC with logic for track-trigger modules at HL-LHC

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The CBC2 is the latest version of the CMS Binary Chip ASIC for the readout of the upgraded CMS Tracker at the High Luminosity LHC. It is designed in 130nm CMOS with 254 input channels and will be bump-bonded to a substrate to which sensors will be wire bonded. The CBC2 is designed to instrument double layer modules, consisting of two overlaid silicon microstrip sensors with aligned microstrips, in the outer tracker. It incorporates logic to identify L1 trigger primitives in the form of "stubs": high transverse-momentum candidates which are identified within the low momentum background by selecting correlated hits between two closely separated microstrip sensors. The CBC2 is working well in laboratory tests and the first modules using it have been assembled. The performance of the chip and module characteristics will be reported and the module construction described.

Session 2 / 14

Active edge pixel sensors and development of four-side buttable modules using vertical integration technologies

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We present an R&D activity focused on the development of novel modules for the upgrade of the ATLAS pixel system at the High Luminosity LHC (HL-LHC). They consist of n-in-p pixel sensors, 100 or 200 µm thick, produced at VTT (Finland) with an active edge technology, to considerably reduce the dead area at the periphery of the device. The sensors are interconnected with solder bump bonding to the ATLAS FE-I3 and FE-I4 read-out chips, and characterized by means of scans with radioactive sources and beam tests at the CERN-SPS and DESY. The results of these measurements will be discussed for devices before and after irradiation up to a fluence of 5x10**15 n_eq /cm**2 .
We will also report on the R&D activity to obtain Inter Chip Vias (ICVs) on the ATLAS read-out chip in collaboration with the Fraunhofer Institute EMFT. This step is meant to prove the feasibility of the signal transport to the newly created readout pads on the backside of the chips allowing for four side buttable devices without the presently used cantilever for wire bonding. The read-out chips with ICVs will be interconnected to thin pixel sensors, 75um and 150um thick, with the Solid Liquid Interdiffusion (SLID) technology, which is an alternative to the standard solder bump-bonding.

Session 1 / **15**

Ultra-Fast Silicon Detectors

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We propose to develop a fast, thin silicon sensor with gain capable to concurrently measure with high precision the space (˜10 µm) and time (˜10 ps) coordinates of a particle.
In collaboration with groups within RD50, we have measured charge multiplication with a gain of about 10, allowing to thin pixelated silicon sensors by at least a factor 10 by keeping the performance of thick sensors.
This will open up new application of silicon detector systems in many fields achieve four-dimensional high-precision measurements. We will discuss the basic sensor characteristics and the expected performance, the present status of sensors and readout electronics and discuss the required R&D topics.

Poster / **16**

Wireless Ultra-Wide-Band Transmission Prototype ASICs for Low-Power Space and Radiation Applications

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The paper shows the design of microelectronic circuits composed of an oscillator, a modulator, a transmitter and an integrated antenna. Prototype chips were recently fabricated and tested exploiting commercial 130 and 180 nm CMOS technologies. Preliminary results are summarized along with some measurements of the prototypes behavior. In addition, wireless transmission capabilities have been evaluated. The chips fit a large variety of applications like spot radiation monitoring, punctual measurements of radiation in High-Energy Physics experiments or, since they heve been characterized as low-power components, readout systems for space applications.

Session 6 / 17

Commissioning of the Read-Out Driver (ROD) card for the ATLAS IBL detector and upgrade studies for the Pixel Layers 1 and 2

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During the first shutdown of the LHC collider in 2013/14, the Atlas experiment will be equipped with an innermost silicon layer, called IBL. Read-out electronics have been redesigned in order to accomplish the IBL performances. A new front end ASIC (FE-I4) has been designed as well as new off-detector devices. The latter are two 9U-VME cards called Back-Of-Crate and Read-Out Driver (ROD). The ROD is devoted to data processing, configuration and control of the overall read-out electronics. After the first prototyping samples a pre-production batch has been delivered with a finalized layout. Actual production of the ROD cards is scheduled on summer 2013 and commissioning on 2014. This contribution describes the setup, the tests carried out for the commissioning of the IBL ROD cards and, in general, for the acquisition system. In particular, it will be shown how integration tests have been performed by increasing the level of system complexity: slices of the IBL read-out chain have been instrumented and ROD performances are verified in a test bench mimicking a small-size final setup. This contribution will report also an outlook on the possibile adoption of the IBL ROD for ATLAS Pixel Layer 1 and 2. The higher luminosity that will be expected for LHC after future upgrades will require more performances for the acquisition system, especially in term of throughput. Estimation of future needs for the electronics of Layer 1 and 2 will be shown and it will be discussed whether the adoption of the IBL ROD card or its upgraded version could be a viable solution.

Poster / 18

X-ray Sensor Application for Geometric Calibration and Imaging Acquisition in Cone-Beam Computed Tomography System

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This paper presents how a large area thin film transistor (TFT) x-ray imaging sensor has been applied to calibrate the gantry geometry and acquire x-ray projection images in cone-beam computed tomography (CBCT) system. A cone-beam x-ray tube and TFT imaging sensor could enable imaging of entire organ in one axial acquisition using one rotation of the gantry. The gantry motion could measure, analyze, and calibrate using projection images of five pin-hole phantoms during gantry rotation. The gantry rotation error was calculated by using the difference between reference point and each rotation point after edge detection in the 2D projection image. After gantry calibration, we acquired the projection images from CBCT system for three dimensional (3D) reconstructions. The projection images for the geometric parameters and 3D reconstruction are 361 (30 frame per seconds (fps) × 12 sec per rotation (spr)) with 1o intervals from the same procedures. In this work, amorphous silicon (a-Si) TFT x-ray imaging sensor (PaxScan 4030CB, Varian inc.) having a 397 × 298 mm2 active area with 194 (388) µm pixel pitch and 2048 × 1536 (1024 × 768) pixels in full (2 by 2 binning) mode is applied. 3D reconstruction method for CBCT system uses Feldkamp, Davis, and Kress (FDK) algorithm providing fast reconstructed results.

Session 4 / 19

DEPFET pixels as a vertex detector for the Belle II experiment

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The successful heavy flavor factory KEKB, operating between 1999 and 2010 at KEK, Tsukuba, Japan, is currently being upgraded to SuperKEKB, whichis foreseen to start commissioning in the fall of 2014. SuperKEKB will provide an instantaneous luminosity of 8x1035 cm2/s, 40 times higher than the current world record set by KEKB. For SuperKEKB, a nano-beam scheme is applied to achieve this ultra-high luminosity.
In order to handle the increased event rate and the higher background and to provide high data quality, the Belle detector is upgraded to Belle II. In particular, a new vertex pixel detector with high granularity, surrounding the beampipe of only 20 mm diameter, will be installed, followed by 4 layers of double-sided Si strip detectors.The pixel detector is based on the DEPFET technology and consists of two layers of active pixel sensors. By integrating a field effect transistor into every pixel on top of a fully depleted bulk, the DEPFET technology combines detection as well as in-pixel amplification. This technology allows excellent signal to noise performance, complemented by a very low material budget, which is achieved by thinning down the sensors to 75 microns. The sensors will be operated by a dedicated chain of steering and readout ASICs.

In this presentation the key parameters of the sensor design will be presented, together with the individual ASICs. Furthermore, supplementary systems like cooling, powering, mechanics, etc. will be described. Results of the prototypes tested in various particle beams will be shown as well as the expected performance at SuperKEKB.

Session 1 / 20

A Systematic 3D Simulation Study Comparing 3D-Trench Electrode Detectors with 3D Column Electrode Detectors

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With the need for very radiation hard semiconductor devices for the High Luminosity upgrade at the Large Hadron Collider, new types of silicon pixel detectors have been proposed. Since 3D Si pixel detectors have been shown to be more radiation hard than the planar ones, scientists at Brookhaven National Laboratory have chosen to design a novel type of 3D Si pixel detectors. Systematic full 3D simulations using Silvaco's TCAD programs have been done to compare the characteristics of this novel 3D pixel design which features at least one trench electrode in a single pixel cell (3D-Trench Electrode pixel) with the 3D pixel with all column electrodes in a single pixel cell. Each cell of the 3D-Trench Electrode pixel detector has a concentric trench electrode surrounding the central collecting column electrode. The detector is an array of these individual cells. The 3D simulations show a much lower depletion voltage and a more uniform electric field in the new 3D-Trench Electrode pixel detectors as compared to the 3D Column Electrode detectors. We've created two sizes of this pixel, a small one (short electrode spacing in a single cell) for High Energy physics applications in high radiation environments and a much larger one for Photon Science applications at the National Synchrotron Light Source II at Brookhaven National Laboratory. The first prototype 3D-Trench Electrode pixel detectors have been manufactured at the National Microelectronics Centre, and are currently being tested. The electrical measurements have been done and the charge collection efficiency measurements will be made and presented.

Session 2 / **21**

Scribe-Cleave-Passivate (SCP) Slim Edge Technology

Author: Vitaliy Fadeyev[1]

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We are pursuing a "slim edge"technology which allows a drastic reduction of inactive region along the perimeter of silicon detectors. Such reduction would benefit construction of large-area tracker and imaging systems. Key components of this method are surface scribing, cleaving, and passivation of the resulting sidewall. We will give a short overview of the project and describe recent progress. A particular emphasis will be given to device performance physics: charge collection near the edge and studies of radiation hardness of the slim edge technology.

Poster / **22**

Silicon Sensors Irradiation Study for ILC Extreme Forward Calorimetry

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We are working on the proposed "BeamCal" project. Its goal is to detect scattered incoming beams at ILC at small angles, to prevent the background from two-photon processes to mimic signatures of new discoveries. The detector, which is envisioned as a tungsten sandwich calorimeter, will be subject to high fluences EM radiation that will shower in the tungsten radiator. We are exploring the effects of radiation damage on candidate sensors at shower-max within the induced shower. As well as electrons, positrons and photons, these showers will contain a flux of neutrons from the de-excitation of the giant dipole resonance that may significantly contribute to radiation damage. The anticipated fluence of the order of 100 MRad/year instigated studies of exotic sensor materials, such as GaAs. Instead, we are studying conventional silicon sensors as an alternative.

A major part of our efforts is test beam at SLAC electron beam facility in June of 2013. The beam setup features tungsten pre- and post-radiators for the purposes of modeling the shower maximum, spreading the beam and capturing neutron component of the radiation. Silicon strip sensors of different types will be irradiated. Sensor handling is designed for a quick connection to the charge measuring station to avoid annealing effects during wirebonding. This will allow us to study the same sensors repeatedly during the dose accumulation over up to four weeks of running time. We will run with the radiator both surrounding and remote from the sensor sample, in order to separate the effects of the ballistic EM shower from those of the isotropic neutron flux. We will describe the test run and show first results.

Poster / **23**

Optical Link in the CDF Run II Silicon Tracking System

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The byte-wide optical link in the CDF Run II silicon tracking system has endured a decade of operation and delivered an integrated luminosity of 12 fb-1. The modules consist of a transmitter converting detector signals to optical pulses, connected with 22 m fiber ribbon cables carrying signals to receiver modules out of the detector. The data transmission is conducted with edge-emitting type laser diode arrays at a wavelength of 1550 nm operating at 53 Mbytes/sec. We report on the design feature and reliability in radiation damage that exceed it original design tolerance of up to 200 kRad after 3 fb-1.

Session 5 / **24**

"Stereo Compton cameras" for 3-D localization of radioactive isotopes

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The Compton camera is a viable and convenient tool used to visualize the distribution of radioactive isotopes that emit gamma rays. After the nuclear disaster at the Fukushima Daiichi power plant in 2011, a large amount of radioactive isotopes (e.g. 134Cs, 137Cs) was released and widely dispersed, thus making the removal thereof is still an urgent task. In response, we are proposing a portable Compton camera weighing only 1.9 kg and measuring just 15 cm3 in size. The camera consists of Ce:GAGG scintillators coupled with large-area MPPC arrays. In this report, we present the detailed optimization of the detector design as based on Geant4 simulation. We show that the detection efficiency for 662 keV gamma rays can be as high as 0.54%, or more than 10 times higher than that of other cameras being tested in Fukushima, along with a moderate angular resolution of 8.1° (FWHM). We also propose a new concept of the "stereo"measurement of gamma rays by using two Compton cameras, thus enabling the 3-D positional measurement of radioactive isotopes for the first time. We will present a brief simulation of this innovative approach and discuss expected performance and applications in the near future.

Session 7 / 25

Two-dimensional Diced Scintillator Array for Innovative, Fine-resolution Gamma Camera

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We are developing a technique to fabricate fine spatial resolution (FWHM < 0.5mm) and cost-effective photon counting detectors, by using silicon photomultipliers (SiPMs) coupled with finely pixelated scintillator plate. Unlike traditional X-ray imagers that use a micro-columnar CsI(Tl) plate, we can pixelate various scintillation crystal plates more than 1mm thick, and easily develop large-area, fine-pitch scintillator arrays with high precision. Coupling a fine pitch scintillator array with a SiPM array results in a compact, fast-response detector that is ideal for X-ray, gamma-ray, and charged particle detection as used in autoradiography, gamma cameras, and photon counting CTs. As the first step, we fabricated a two-dimensional, cerium-doped Gd3Al2Ga3O12(Ce:GAGG) scintillator array of 0.25mm pitch, by using a dicing saw to cut micro-grooves 50μm wide into a 1.0mm thick Ce:GAGG plate. The scintillator plate is optically coupled with a 3.0 x 3.0mm pixel 4 x 4 SiPM array and read-out via the resistive charge-division network. Even when using this simple system as a gamma camera, we obtained excellent spatial resolution of 0.45mm(FWHM) for 122-keV gamma-rays. We will present our plans to further improve signal-to-noise in the image, and also discuss a variety of possible applications in the near future.

Session 6 / 26

Performance of the Latest MPPCs with Reduced Dark Counts and Improved Photon Detection Efficiency

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We have tested the performance of two types of the latest Multi-Pixel Photon Counters (MPPCs; measuring 3 x 3 mm^2 in size) developed by Hamamatsu Photonics K.K. The new S12572-050C is a successor to the S10362-33-050C (i.e., conventional 3 x 3-mm^2 pixel MPPC of 50-µm pitch), comprises 3,600 Geiger mode avalanche photodiodes (APDs), and also features high gain (~ 1.25 x 10^6), a low dark count (~ 10^6 cps), and improved photon detection efficiency (PDE) of ~35%. The S12572-015C is a new type of fine-pitch (15 µm) MPPC featuring a wide dynamic range and fast timing response. This paper first presents the detailed performance of these latest MPPCs as photon counting devices. It then describes our fabrication of a prototype detector consisting of a MPPC optically coupled with a Ce:GAGG scintillator. We obtained average FWHM energy resolutions of 9.0% (S12572-015C) and 10.9% (S12572-050C), as compared to 11.7% (S10362-33-050) for 662-keV gamma rays from the 137Cs source, as measured at 20℃. Moreover, the number of fired pixels for 662-keV gamma rays increased by 14.2% for S12572-050C (as compared to S10362-33-050), thus indicating more than a 10% improvement in PDE around the light emission peak of Ce:GAGG at 480 nm. We also confirmed that the low energy threshold improved from 10 keV to 4 keV, when using the latest MPPC device (S12572-050C). The results thus confirm that these new types of MPPCs are promising for various applications as scintillation detectors.

Session 7 / 27

Qualification Test of a MPPC-based PET Module for Future MRI-PET Scanners

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We have developed a high-resolution, compact Positron Emission Tomography (PET) module for future use in MRI-PET scanners. The module consists of large-area, 4 x 4 ch MPPC arrays (Hamamatsu S11827-3344MG) optically coupled with Ce:LYSO scintillators fabricated into 12 x 12 matrices of 1 x 1 mm^2 pixels. At this stage, a pair of module and coincidence circuits was assembled into an experimental prototype gantry arranged in a ring 90 mm in diameter to form the MPPC-based PET system. The PET detector ring was then positioned around the RF coil of the 4.7 T MRI system. We took an image of a point 22Na source under fast spin echo (FSE) and gradient echo (GE), in order to measure interference between the MPPC-based PET and MRI. We only found a slight degradation in the spatial resolution of the PET image from 1.5 to 1.6 mm (FWHM; x-direction), or 1.6 to 1.8 mm (FHWM; y-direction) when operating with the MRI, while the signal-to-noise ratio (SNR) of the MRI image was only degraded by 5%. These results encouraged us to develop a more advanced version of the MRI-PET gantry with eight MPPC-based PET modules, whose detailed design and first qualification test are also presented in this paper.

Session 4 / 28

Radiation hardness tests of double-sided 3D strip sensors with passing-through columns

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An improved technology for double-sided 3D sensors with passing-through columns has been developed at FBK in collaboration with the University of Trento and INFN for the fabrication of 3D pixels for the ATLAS IBL [1]. The IBL production was successfully completed in 2012, with good results in terms of electrical characteristics and yield. On the same production wafers (p-type, 230±20 µm thick), different sets of 3D test diodes were included, as well as 3D strip sensors (1 cm2 area, 80 µm pitch). The latter are very useful, since they allow for functional testing with LHC-compatible read-out without need of bump bonding. Moreover, radiation hardness tests can be carried out up to very large fluences, since the sensors can be irradiated separately from the read-out electronics.
We have previously reported on the characterization of non-irradiated 3D strip sensors coupled to the ALIBAVA system [2]. All tested sensors have shown to be fully efficient already at low voltage (˜10V), with noise values (from 1 to 1.5 ke- rms) compatible with the relatively high strip capacitance (˜10pF). Measurements have been carried both on sensors with integrated coupling capacitors and biased by punch-through, and on DC-coupled sensors by using external R-C chips. Results are qualitatively similar, but, due to non-optimized coupling capacitors, higher S/N values are obtained with R-C chips.
Later, nine of these strip sensors were irradiated with protons at the Karlsruhe cyclotron at four different fluences (2E15, 5E15, 1E16, and 2E16 neq/cm2), and are currently being tested at the University of Freiburg. The measurement plan includes functional tests with a position resolved laser and a 37 MBq 90Sr beta source system, as well as electrical tests to assess the operation of the punch-through bias after irradiation. Initial results from the beta source tests are encouraging: the noise is not significantly affected by radiation, provided that the sensors are properly cooled to reduce leakage current, and the charge signal can be clearly distinguished from the noise already at ˜25 V bias. The maximum values of the collected charge are in good agreement with previous tests carried out in Freiburg with the same setup on 3D strip sensors from CNM irradiated at the same fluences [3]. As an example, a sensor irradiated at 2E15 neq/cm2 collects 13.3±0.7 ke- at 120 V, and a sensor irradiated at 2E16 neq/cm2 collects 6.5±0.4 ke- at 200 V. However, it should be noticed that a sharp, surface-related breakdown prevents FBK sensors to be operated at higher voltages which would lead to charge multiplication effects.
At the conference we will report selected results from the characterization of all irradiated sensors, in comparison to pre-irradiation results. The charge collection efficiency will also be compared to that measured on irradiated 3D pixel sensors belonging to the same FBK production [4] and to TCAD simulation predictions.

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Poster / 29

Radiation-Hard Silicon Detectors for HL-LHC Tracking - RD50 Status Report

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It is foreseen to significantly increase the luminosity of the LHC by upgrading towards the HL-LHC (High Luminosity LHC) in order to harvest the maximum physics potential. Especially the Phase-II-Upgrade foreseen for 2021 will mean unprecedented radiation levels. 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 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 study sensors made from p-type silicon bulk, which have a superior radiation hardness as they collect electrons instead of holes. 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 inner layers. We will present results of several detector technologies and silicon materials at radiation levels corresponding to HL-LHC fluences. Observations of charge multiplication effects at very high bias voltages in a number of detectors will be reported. In this context, we will show first measurements from a set of dedicated detectors designed in order to better understand the charge multiplication mechanism. Based on our results, we will give recommendations for the silicon detectors to be used for LHC detector upgrades.

Session 6 / **30**

Simulation on silicon tracker for the TAC-PF Detector

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The proposed Turkish Accelerator Center (TAC) Particle Factory is a super charm factory based on colliding a 1-GeV electron beam against a 3.5 GeV positron beam. The Particle Factory (TAC-PF) detector will be constructed for the detection of the producing particles from this collision. The main components of the preliminary design of TAC-PF detector are: tracker (SiT), time of flight (ToF), calorimetry (ECAL), and muon system (MUON). The initial design of TAC-PF tracking detector is composed of five individual modules with 3 cm distances between them. Each module has two parallel silicon strip detector planes. (carbon+ silicon + 1.5cm gap + carbon + silicon). In this work, simulation results using with FLUKA code will be presented for this structure.

Poster / **31**

Low-Resistance Strip Sensors for Beam-Loss Event Protection

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AC-coupled silicon strip sensors can get damaged in case of a beam loss due to the possibility of a large charge accumulation in the bulk, developing very high voltages across the coupling capacitors which can destroy them [1]. Punch-through protection (PTP) structures are currently used to avoid this problem helping to evacuate the accumulated charge as large voltages are developing [2]. Nevertheless, previous experiments, performed with laser pulses, have shown that these structures can become ineffective in relatively long strips. The large value of the implant resistance can effectively isolate the "far"end of the strip from the PT structure leading to large voltages [3, 4].

In order to overcome this problem we propose to reduce the strip resistance so that the PTP structures can be effective even when the big amount of charge is deposited far from the PTP side of the strip. We have fabricated one batch of "low-resistance strip sensors" by means of the deposition of an Aluminium layer in contact with the strip implants, reducing drastically the strip resistance. One of the technological challenges of this proposal is the creation of the coupling capacitor after the deposition of this aluminium layer, as thermal processes would destroy the Aluminium over about 400 ºC. Several experiments have been performed to optimize the low temperature deposition of the isolation, resulting in a tri-layer made of a sandwich of two Plasma-Enhanced CVD (PECVD) silicon oxide layers with a silicon nitride layer in between [5].

In the conference, results will be presented on these experiments and optimization of the MIM coupling capacitors. Also general performance results from the first Low-R sensors fabricated at the clean room of CNM-Barcelona will be shown (technological parameters, IV, CV). First tests on the PTP structures behaviour will be shown, which indicate that some technological issues should still be solved in order to have a full PTP performance [6]. Results on the tests on other important sensor parameters for this experiment will be presented, like strip resistance, inter-strip isolation, and pulse shape. Initial laser tests emulating the event of a beam loss will also be presented. Finally, the optimization and solutions proposed for the second batch, already in production, will be detailed, together with some new technological proposals to be implemented.

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Poster / **32**

Recent Results of the 3D-Stripixel Si Detectors

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First prototype of the new 3D-Stripixel Detectors has been fabricated by CNM of Spain. TCT test results using lasers of various wavelengths (660 to 1.06um) have shown good 2D-position sensitivity with one-sided processing. CCE test by ALIBAVA using the laser with um-beam size have shown sub-pixel (80 um)2D position resolution. Recent BNL ALIBAVA tests using a 1.06 um laser with mm-beam size have shown clear 2D-position sensitivity as well. The 2D-position sensitivity has been measured as a function of detector bias voltages and laser intensity.

Session 4 / 33

High-Voltage Pixel Sensors for ATLAS Upgrade

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The high-voltage (HV) CMOS pixel sensors offer several good properties: a fast charge collection by drift, the possibility to implement relatively complex CMOS in-pixel electronics and the compatibility with the commercial processes. The sensor element is a deep-n-well diode in a p-type substrate. The n-well contains CMOS pixel electronics.

The main charge collection mechanism is drift in a shallow-, high field region, which leads to a fast charge collection and a high radiation tolerance.

We are currently evaluating the use of the high-voltage detectors implemented in 180nm HV CMOS technology for the high-luminosity ATLAS upgrade. Our approach is replacing the existing pixel- and strip-sensors with the "intelligent"CMOS sensors while keeping the presently used readout ASICs. In this way we could benefit from the advantages of the HV sensor-technology such as lower cost, lower mass, lower operating voltage, smaller pitch, smaller clusters at high incidence angles all with comparable radiation hardness, without the need to develop new readout electronics.

In order to test the concept, we have designed two HV CMOS prototypes that can be readout in two ways: using pixel- and strip-readout chips. In the case of the pixel readout, the connection between HV CMOS-sensor and the readout ASIC can be established capacitively.

We will present measurement results performed on both prototypes, that include irradiations up to the fluence of 10ˆ(16) neq/cmˆ2.

Session 4 / 35

Design and characterization of Explorer0 monolithic pixel sensor in 180 nm CMOS process

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Within the R&D activities for the upgrade of the ALICE Inner Tracking System (ITS), Monolithic Active Pixel Sensors (MAPS) are being developed and studied, due to their lower mass (˜0.3% X/X0 for the inner layers) and higher granularity (˜20 μm x 20 μm pixels) with respect to the present pixel detector.
This paper presents the design and characterization results of the Explorer0 chip, manufactured in the TowerJazz 180 nm CMOS Imaging Sensor process, based on a wafer with high-resistivity (ρ > 1 kΩ cm) and 18 μm thick epitaxial layer.
The chip is organized in two sub-matrices with different pixel pitches (20 μm and 30 μm), each of them containing several pixel designs. The collection electrode size and shape, as well as the distance between the electrode and the surrounding electronics, are varied; the chip also has the possibility of decoupling the charge integration time from the readout time, and of changing the sensor bias.
The charge collection properties of the different pixel variants implemented in Explorer0 have been studied using a 55Fe X-ray source and Minimum Ionizing Particles (5 GeV/c π-). The sensor capacitance has been estimated, and the effect of the sensor bias has also been examined in detail, including a reverse bias option.
Following these results, a second version of the Explorer0 chip has been submitted for production in March 2013, together with a novel circuit with in-pixel discrimination and a sparsified readout.

Session 5 / 36

Fast Front-End ELectronics for Semiconductor Tracking Detectors: Trends and Perspectives

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Deep submicron CMOS technologies of the 130 nm generation are now the baseline choice to implement front-end electronics for tracking detectors, while the R&D in the 65 nm node is starting. In such technologies, new analogue to digital converters achieving 8-10 bit resolution, 50-100 MHz sampling frequency and 1mW of power have been demonstrated both by the industry and in the academia. This makes it possible to design front-end ASICs in which a prompt digitization of the amplifier output is followed by digital signal processing within the tight power budget allowable in high granularity tracking systems. At the same time, the interest is growing around tracking detectors embedding also high resolution timing capabilities These applications require high performance discriminators and low power Time to Digital Converters. In the presentation, the developments in these areas will be discussed, emphasizing in particular the challenges and perspectives of high resolution timing systems.

Session 2 / 37

High-speed Light Peak optical link for high energy applications

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The Light Peak technology aims for high speed optical cables of 10 Gb/s that overcome the limits of electrical cables in speed and length. Cables that comply with the USB 3 specification of 4.8 Gb/s are already delivered in market. The low-mass compact design of light coupling to opto-electronic is an advantage to high energy applications in tracking system. The high speed capacity provide a significant reduction in readout links.

Poster / **39**

X-ray imaging performance comparison between CMOS and TFT sensors for a high speed fluoroscopy and CBCT system

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The physical performance characteristics of complementary metal oxide semiconductor (CMOS) and thin film transistor (TFT) x-ray imaging sensors are compared for the fluoroscopy and cone-beam computed tomography (CBCT) medical imaging application. In this paper, our developing CMOS x-ray imaging sensor has been designed with the 14.3 bit extended counting analog to digital converter (ADC) and fabricated by using a 0.35 μm 1Poly 4Meta CMOS process. CMOS sensor has a 100 μm pixel pitch, and provided a 120 × 120 mm2 (1200 × 1200 pixels) field of view (FOV). Thallium-doped cesium iodide (CsI:T1) scintillator screens are used as converters for incident x-ray to visible light photons. The compared amorphous silicon (a-Si) based TFT x-ray imaging sensor (PaxScan 4030CB, Varian inc.) having a 397 × 298 mm2 active area with 194 μm pixel pitch and 2048 × 1536 pixels is used. The most important factors that affect the image quality are contrast, spatial resolution and noise. The evaluation is made in terms of the modulation transfer function (MTF), the normalized noise power spectrum (NNPS), and the resultant detective quantum efficiency (DQE) in full and 2 × 2 binning modes.

Session 3 / **40**

The silicon strip vertex detector of the Belle II experiment

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The CP violation in the quark sector had been observed in 2001 by two B-factories, the Belle and BaBar experiments. The Belle II, upgrade of the Belle experiment, searching for the physics beyond the Standard model is under construction toward the physics run scheduled for the end of 2016. The vertex detector of the Belle II consists of two types of silicon detectors, of a pixel detector (PXD) and a strip detector (SVD) using double-sided silicon detectors(DSSDs). One of the most characteristic features of SVD is adapting unique chip-on-sensor scheme which ensures good S/N ratio while

keeping the material budget as low as possible. In this talk, I'll report on the implementation of the scheme, the status and future prospect of the Belle II-SVD.

Session 3 / **41**

Development of HPK n-in-p Pixel Sensors for HL-LHC

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We, Hamamatsu Photonics K.K have been developing high raditation-tolerant n-in-p planar pixel sensors which can be used for HL-LHC.
N-in-p planar pixel sensor is one of candidate for HL-LHC, and has advantages of high radiation-tolerance with reasonable price (compared with 3D sensor or diamond sensor).
On the other hand, n-in-p planar pixel sensors also have some issues to be solved such as "slim egde/protection for edge HV sparking/decrease of efficiency after irradiation". We are now trying to solve these issues by wafer level process, which is important for mass production.
In this symposium, we show our progress of development, mainly about slim edge.

Poster / **42**

Design and initial X-ray characterization of active-pixel CMOS imaging detectors using different scintillators for digital mammography and breast tomosynthesis

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In recent years, digital mammography with advantages of high sensitivity to low-contrast masses, wider dynamic range and lower radiation dose has been introduced as a new alternative to conventional X-ray film-screen mammography. At the present time, both indirect X-ray conversion approach using a combination of a-Si:H with thin film transistors(TFT), CCD(Charge coupled device) and suitable scintillators and direct X-ray conversion approach using amorphous selenium(a-Se)/TFT-based detector are widely used for clinical digital mammography. However, expensive manufacture process and bulky reduction optics, special cooling systems are required in a-Si based flat panel detector and CCD technology respectively. Recently, CMOS (complementary metal oxide semiconductor)-based X-ray imagers with low power consumption and compactness have been used for high resolution and real-time X-ray imaging such as mammography, fluoroscopy and CBCT application. The CIS has many benefits such as the higher readout speed, low noise, smaller pixel size and high system integration for superior spatial resolution.In this work, the small CMOS detector with 94x24 pixel array of 100um x100um pixel size was fabricated using a 0.35um 1poly/4metal standard CIS process. The 14-bit extended counting ADC and different frame rates with 30/60fps mode were used to reduce the area and simultaneously improve the image resolution. We used a thallium-doped CsI(CsI:Tl) scintillation film of 150µm thickness and Gd2O2S:Tb scintillation screen with different thickness for the X-ray imaging characterization and comparison. Additionally, the

fiber optic plate (FOP) with 6m diameter and 2mm thickness was used in order to improve the signal to noise ratio by minimizing direct X-ray induced noise from photodiode surface and its effect was investigated in terms of X-ray imaging quality. Furthermore, we investigated the initial X-ray imaging performance of our small-field CMOS-based detector such as the signal response to X-ray exposure dose, modulation transfer function (MTF), signal-to-noise-ratio (SNR) and image lag for mammographic and tomosyntheis systems.

Poster / 43

Investigation of CdCl2 treatment effect on polycrystalline CdTe films for large area medical X-ray imaging detectors

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In recent years, direct detection X-ray imaging detectors using a photoconductor and an array of storage capacitors (TFT) have been researched and used in various medical applications such as chest radiography, mammography and fluoroscopy imaging. As an alternative to amorphous selenium (a-Se) material with low atomic number and high ionization energy, the various heavy photoconductor materials such as lead iodide (PbI2), mercury iodide (HgI2), lead oxide (PbO) and cadmium telluride (CdTe) or cadmium zinc telluride (CdZnTe) have been researched for the possible medical application. Among many photoconductors, CdTe/CZT direct-conversion material has been considered and developed as an attractive candidate for high energy X-ray imaging application requirements. In this work, a large effort has been implanted in order to improve the previous experimental result and performances. Different polycrystalline CdTe films on ITO/glass substrate were fabricated by physical vapor deposition (PVD), closed space sublimation (CSS) method and vapor transport deposition (VTD). The various polycrystalline CdTe films were grown by using optimal process conditions such as deposition rate, substrate temperature and post heat-treatment. Physical properties such as microstructures, surface morphology and crystal structure of the polycrystalline samples were characterized by SEM, AFM and XRD pattern respectively. In addition, CdCl2 post-treatment was in order to investigate the effects of structural and electrical properties of polycrystalline CdTe films. The polycrystalline CdTe films were immersed in a saturated solution of CdCl2 and then treated at 400℃ for 30 minute in the furnace under ambient N2 condition. The morphology of surface and grain boundary of the CdTe films with and without post CdCl2 heat-treatment were characterized. Furthermore, the electrical properties such as the dark current as a function of applied voltage, X-ray sensitivity were measured and investigated through practical X-ray exposure. The physical and electrical results of the fabricated CdTe films will be presented in detail.

Session 5 / 44

The Si/CdTe semiconductor Compton camera of the ASTRO-H Soft Gamma-ray Detector

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The Soft Gamma-ray Detector (SGD) is one of the ASTRO-H instruments and will feature wide energy band (60–600 keV) at a background level 10 times better than instruments currently in orbit. The SGD achieves low background by combining a Compton camera scheme with a narrow field-of-view active shield. The Compton camera in the SGD is realized as a hybrid semiconductor detector system which consists of silicon and CdTe (cadmium telluride) sensors. The Compton camera has an overall size of 12 cm x 12 cm x 12 cm, and consists of 32 layers of Si pixel sensors and 8 layers of CdTe pixel sensors surrounded by 2 layers of CdTe pixel sensors. The total volumes of sensitive Si and CdTe in one Compton camera are 50 cm3 and 40 cm3, respectively. The detection efficiency of the Compton camera reaches about 15% and 3% for 100 keV and 511 keV gamma rays, respectively. The pixel pitch of the Si and CdTe sensors is 3.2 mm, and the signals from 13312 pixels in total are processed by 208 ASICs developed for the SGD (and HXI of ASTRO-H). Good energy resolution is afforded by semiconductor sensors and low noise ASICs, and the obtained energy resolutions with the prototype Si and CdTe pixel sensors are 1.0–1.6 keV (FWHM) at 60 keV and 1.6–2.5 keV (FWHM) at 122 keV, respectively. It results in good background rejection capability due to better constraints on Compton kinematics. Utilization of Compton kinematics also makes the SGD sensitive to gamma-ray polarization, opening up a new window to study properties of emission processes.
In this paper, we will present the details of the detector configuration and the data acquisition system of the SGD Compton camera. We will also present the performance evaluated in the final prototype, which is equivalent to the flight model.

Session 4 / 45

Development of a full depleted back illumination sensor based on SOI CMOS technology for future X-ray astronomy satellites

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We have been developing monolithic active pixel sensors based on the Silicon-On-Insulator (SOI) CMOS technology, called XRPIX, for next-generation X-ray astronomy satellites. Compared to CCDs, which are currently used as standard sensors for X-ray astronomy, our devices have much better time resolution of ˜ microsecond since they can issue triggers to determine X-ray arriving time. Therefore, we can employ active shields to reduce non-X-ray background (NXB), and can extend the energy range coverage beyond 10 keV, where NXB becomes dominant. We successfully demonstrated the trigger function with our previous prototypes.

We aim to cover the energy range of 0.5–40 keV with XRPIX. For higher energy range, a key is to have thick depletion layers. By using float zone wafer with a resistivity of ˜ 7 kOhm cm, we developed a prototype called XRPIX1b-FZ which has a 500-micron thick sensor layer. We found the device is fully

depleted with a bias voltage of 120 V and demonstrated its high detection efficiency by irradiating it with various line X-rays. A back illumination (BI) configuration is essential to make the devices sensitive to soft X-rays below 1 keV. We are now fabricating BI sensors based on XRPIX1b-FZ and will test them soon. In this talk, we will present details of our development and will show our recent results.

Session 5 / 46

Development of a High Counting Rate ASIC for Heavy-ion Beam Monitoring

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Recently, we have developed a series of analog front-end ASICs for readout of semiconductor detectors such as CdTe, Si, and APD. While the main objective is to develop instruments for astrophysical observations, the same technology can be used in other fields. In this paper, we describe development of a 40 channel high counting rate ASIC, and its application to heavy-ion beam monitoring in the medical field. The heavy-ion radiotherapy is one of the most front-line therapy for cancer. The heavy ion beam is created by a synchrotron acceleration facility and targeted on a patient. The beam intensity reaches 10ˆ5-9 particles/sec. A realtime monitoring system of the beam position/shape is a key issue to realize efficient cancer treatments. The ASIC includes a current conveyer circuit to receive detector signals, window comparators for energy discrimination, and scalers. The ASIC delivers 21-bit digital counter values for each channel to back-end electronics. Using test pulse injection, two sequential pulses with 24 ns separation were successfully distinguished, which corresponds to 40 Mcps per channel. A Si strip detector with 300 um pitch was connected to the ASIC. A performance test in this configuration is planted to be performed.

Session 1 / 47

Long-range Plans for HEP experiments and facilities

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On May 30, 2013 CERN Council approved the Update of the European Strategy for Particle Physics. This was the final step of a process involving the whole European particle physics community as well as many colleagues from outside Europe. The presentation gives an overview of the numerous facilities and projects proposed to the strategy group before explaining the decisions and the rational behind the agreed European strategy.

Poster / 48

Development of ASIC for Si/CdTe detectors in radioactive substance visualizing system

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We report on the recent development of a 64-channel analog front-end ASIC for a new gamma-ray imaging system to visualize radioactive substances. The imaging system employs a novel Compton camera which consists of silicon and cadmium telluride (CdTe) detectors. The ASIC aims for the readout of pixel /pad detectors utilizing Si/CdTe as detector materials, and the dynamic range from 100 keV to a few MeV. The readout chip consists of 64 identical signal channels and was implemented with the X-FAB 0.35 um CMOS technology. Each channel contains a charge-sensitive amplifier, pole-zero cancellation circuit, low-pass filter, comparator, and sample-hold circuit together with a Wilkinson-type A-to-D converter. We observed an equivalent noise charge of ˜ 500 e- and a noise slope of ˜5 e-/pF. We also report on the performance test when connected to Schottky CdTe diodes.

Session 7 / 49

Performance Verification and Calibration of the Soft X-ray Imager aboard ASTRO-H

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We are developing the Soft X-ray Imager (SXI) on-board the ASTRO-H satellite, which is planned to be launched in 2015. The SXI consists of four CCDs arranged in a 2 by 2 mosaic and covers a wide field-of-view 38' by 38'. Since the CCDs are P-channel back-illuminated type and have the depletion layers of ˜200 micrometers, the SXI has high quantum efficiency for X-rays in the wide range of 0.4-12 keV. In order to restore degradation of charge transfer efficiency (CTE), which results from charge traps generated by cosmic rays in orbit, artificial charges are injected into given pixels from the serial registers attached to the top of each column (CI). The CCDs are operated at low temperature of -120 degrees Celsius, which also suppresses the CTE degradation.

We carried out a performance verification by using the engineering model (EM) system developed before the flight model (FM). For the CI technique, uniform charges of ˜10ˆ5 e- were injected into rows at regular intervals. The measured readout noise and energy resolution are 7 e (rms) and 150 eV (FWHM) at 6 keV, respectively. Charge transfer efficiency is about 10ˆ-6 per transfer.

We are constructing the FM system and will perform calibrations of response, gain, uniformity of the quantum efficiency. We will present the results on the experiments of the SXI EM and FM systems.

Session 6 / 50

Fast Beam Conditions Monitor for CMS: performance and upgrade

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The CMS beam and radiation monitoring subsystem BCM1F (Fast Beam Conditions Monitor) consists of 8 individual diamond sensors situated around the beam pipe within the pixel detector volume, for the purpose of fast bunch-by-bunch monitoring of beam background and collision products. In addition, effort is ongoing to use BCM1F as an online luminosity monitor. BCM1F will be running whenever there is beam in LHC, and its data acquisition is independent from the data acquisition of the CMS detector, hence it delivers luminosity even when CMS is not taking data. A report will be given on the performance of BCM1F during LHC run I, including results of the van der Meer scan and on-line luminosity monitoring done in 2012. In order to match the requirements due to higher luminosity and 25 ns bunch spacing, several changes to the system must be implemented during the upcoming shutdown, including upgraded electronics and precise gain monitoring. First results from Run II preparation will be shown.

Session 7 / 51

Highlights from the Fermi Large Area Telescope after 5 years of operations

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The Fermi Large Area Telescope (LAT) has been exploring the high-energy gamma-ray sky since its launch on June 11, 2008.
After 5 years of essentially flawless operations, the LAT collected more than 800 million gamma rays from 20 MeV to more than 300 GeV.
With its uniform coverage of the sky, the LAT allowed the first high statistics observations of gamma-ray sources of known classes as well as a discovery of new emitters.
The LAT allowed also a detailed study of the diffuse gamma-ray emission, which constitutes roughly 90% of the LAT photons, and constrains cosmic-ray production and propagation in our own Galaxy.
In this talk I will review the status and the performance of the LAT and describe the some of the most important scientific results.

Poster / 52

Evaluation of KEK n-in-p planar pixel sensor structures for very high radiation environments with testbeam

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Various structures for n-in-p planar pixel sensors have been developed at KEK in order to cope with the huge particle fluence in the upcoming LHC upgrades.
Performances of the sensors with the different structures have been evaluated with testbeam.
The n-in-p devices were connected by bump-bonding to the ATLAS Pixel front-end chip (FE-I4A) and characterized before and after the irradiation to 1×10^{16} 1 MeV equivalent neutrons per square centimeter (n_{eq}/cm^2).
Results of measurements with 120 GeV/c momentum pion beam at the CERN Super Proton Synchrotron (SPS) in September 2012 are presented.

Session 3 / **53**

Development of n-in-p large-area silicon microstrip sensors for very high radiation environments

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We have developed a novel and radiation-tolerant n-in-p silicon microstrip sensors for very high radiation environments such as high-luminosity LHC. The sensors are designed to be operable to the end-of-life fluence of ≥1×10ˆ15 1-MeV neutron-equivalent/cmˆ2. The sensors are fabricated in p-type, float-zone, 6 in. wafers where we lay out two designs of large-area, 9.75 cm × 9.75 cm, strip sensors, together with a number of miniature sensors. The large-area sensors have four blocks of short strips, 2.4 cm long each. One design is made with all "axial"segments (ATLAS12A) and the other with two "axial"and two "stereo"strip segments (ATLAS12M). Each design has (1) two edge-widths: standard (˜900 µm) and slim (˜450 µm), and (2) punch-through protection (PTP) structures at the end of each strips. The miniature sensors are implemented with variations of the PTP structure, and the "wedge"designs for the endcap sensors with stereo strips or the "skewed"layout. A "ganging" of stray stereo strips to the readout strips is designed in a stereo-strip segment of the ATLAS12M sensor and in the "wedge"miniature sensors. We report the design and the initial performance of the large area and the miniature sensors with the standard or the slim edge dicing.

Poster / **54**

Location of bias voltage breakdown in n-in-p silicon segmented sensors with p-stop structure before and after irradiation

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We have fabricated n-in-p miniature silicon microstrip sensors and small test structures. A p-stop structure is implemented in order to isolate the n-implant against the inversion layer of electrons in the interface of silicon bulk and the oxide surface passivation. Along irradiation the strongest electric field is said to move from the edge of the n-implant to the edge of the p-stop due to the

resulting electron inversion layer in the silicon surface with the build-up of positive charges in the interface; the breakdown may occur at the p-stop edges. We have irradiated the samples for protons or gamma's and evaluated the location of the breakdown. In all samples, we have observed the breakdown at the n-implant edges. With the help of TCAD simulations, we have understood the observation that is explained by the diminishing of the electron inversion layer by increasing the bias voltage.

Session 3 / 55

Achievements of the ATLAS Upgrade Planar Pixel Sensors R&D Project

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To extend the physics reach of the LHC, accelerator upgrades are planned which will increase the integrated luminosity from 730 to beyond 3000 fb-1 and the pile-up per bunch-crossing 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.

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 19 institutes and more than 80 scientists. Main areas of research are the performance assessment of planar pixel sensors with different designs and substrate thicknesses up to HL-LHC fluences, the achievement of slim or active edges to provide low geometric inefficiencies without the need for shingling of modules and the exploration of possibilities for cost reduction to enable the instrumentation of large areas.

The presentation will give an overview of recent accomplishments and ongoing work of the R&D project, in particular testbeam results obtained with highly irradiated sensors, developments in the field of slim and active edges and first steps towards prototypes of future pixel modules.

Session 2 / 56

Diamond Sensors for HE Frontier Experiments

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With the first three years of the LHC running complete, ATLAS and CMS are planning to upgrade their innermost tracking layers with more radiation hard technologies. Chemical Vapor Deposition (CVD) diamond is one such technology. CVD diamond has been used extensively in beam condition monitors as the innermost detectors in the highest radiation areas of BaBar, Belle, CDF and all LHC experiments. This talk will describe the lessons learned in constructing the ATLAS Beam Conditions Monitor (BCM) and ATLAS Diamond Beam Monitor (DBM) both of which are based on CVD diamond with the goal of elucidating the issues that should be addressed for future diamond based detectors. The talk will also present the first beam test results of prototypes of the 3D detector geometry in diamond which should further enhance the radiation tolerance of this material.

Session 2 / 57

Recent results of diamond radiation tolerance

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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 and hadron colliders. 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 and single-crystal 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. We will also discuss the use of diamond detectors and their survivability in the highest radiation environments.

Session 4 / **58**

Development of Silicon-On-Insulator Monolithic Pixel Detectors

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We are developing monolithic pixel detectors using a Silicon-on-Insulator (SOI) technology for X-ray and charged particle applications. It is based on a 0.2 um CMOS fully-depleted (FD-)SOI process of Lapis Semiconductor Co. Ltd. The SOI wafer consists of a thick, high-resistivity substrate for the sensing part and a thin Si layer for CMOS circuits.
To overcome back-gate effect affected by higher back bias voltages, we have successfully introduced buried-well structures. Furthermore, to reduce crosstalk between the sensing node and the pixel circuit, we have developed a double-SOI wafer process. Newly introduced middle Si layer also works as a compensation electrode to the electric field generated by oxide trapped holes created by radiations.
Here we present recent progress and test results of the SOI monolithic pixel detectors.

Poster / **59**

Development of Edgeless Silicon Pixel Sensors on p-type substrate for the ATLAS High-Luminosity Upgrade

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In view of the LHC upgrade phases towards the High Luminosity LHC (HL-LHC), the ATLAS experiment plans to upgrade the Inner Detector with an all-silicon system. Because of its radiation hardness and cost effectiveness, the n-on-p silicon technology is a promising candidate for a large area pixel detector.

The talk reports on the joint development, by LPNHE and FBK of novel n-on-p edgeless planar pixel sensors, making use of the active trench concept for the reduction of the dead area at the periphery of the device. After discussing the sensor technology, a complete overview of the electrical characterization of the produced devices will be given. Measurements on irradiated devices will be presented too, together with results on the charge collection efficiency in the edge region.

The results will be compared to device simulations we run and to other current edgeless planar productions aimed at the ATLAS tracker upgrade for the HL-LHC.

Eventually results from beam test measurements on these edgeless sensors, such as hit-efficiency, space-point resolution and charge collection efficiency - in particular at the sensor periphery - with minimum ionizing particles will be discussed.

Poster / **60**

ALIBAVA: A compact readout system for silicon microstrip detectors

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The Alibava system has been developed in the framework of the CERN RD50 collaboration to test silicon microstrip detectors. The Alibava System is conceived to characterize strip radiation detectors,

providing high sensitivity to small signals, high position resolution and high speed. The system is able to measure the collected charge in one or two microstrip silicon sensors by reading up to 256 channels in analog mode. Characteristics of detectors before and after irradiation, as a function of bias voltage or other variables (temperature, influence of magnetic field, etc.) can be studied in real operation conditions. The frontend electronics is based on the beetle chip and is a low noise ASIC with 128 input channels and a clock speed of 40MHz. The beetle chip has been designed by the ASIC laboratory of the University of Heidelberg and the Max-Planck-Institute for Nuclear physics in Heidelberg for the LHCb experiment. It is used by the LHCb Vertex Detector (VELO), the Silicon Tracker and the RICH. The mother board (MB) arbitrates the communication between the PC and the DB. The core of the MB is a FPGA block that is composed of a FPGA (Spartan 3, Xilinx) that controls hardware and commands and synchronises the readout. The board includes line driver amplifiers, 2 ADCs (10 bits) clocked at 40 MHz, a TDC for signal shape reconstruction, comparators and coincidence for login handling of the trigger. The data passing to and from the computer is performed through a USB controller. The DC power needed by the MB and the DB are generated by DC-DC converters and LDO regulator.
In this work we will present new results obtained with the Alibava system on heavy irradiated detectors and the future developments implemented to create a sophisticated scientific instruments to be used as particle telescope.

Session 2 / 66

Radiation-Hard/High-Speed Parallel Optical Engine

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Abstract
We will present the results from three R&D projects on high-speed/radiation-hard opto-links for the LHC upgrades. The goal is to develop a 12-channel high-speed driver to operate a 12-channel VCSEL array. The array allows the deployment of a compact 120 Gb/s parallel optical engines at a high-radiation location close to the interaction region where space is at a premium. We will briefly summarize the latest results on the 5 Gb/s array driver fabricated using a 130 nm process. This will be followed with the results from the design for 10 Gb/s transmission. We conclude with the preliminary results of the design using the 65 nm process.

Summary
The LHC at CERN is now the highest energy and luminosity collider in the world. Upgrades to the accelerator are currently being planned to further increase the energy and luminosity. The detectors must be upgraded to take advantage of the planned accelerator upgrades. This requires the optical links to transmit data at much higher speed to handle the much increased luminosity. We will present the results from three R&D projects. The goal of the R&D is to develop an ASIC that contains an array of 12 high-speed drivers to operate an array of 12 VCSELs (Vertical Cavity Surface Emitting Lasers). With the spacing of 250 μm between two VCSELs, the width of an optical array is only 3 mm. High speed VCSEL arrays operating at 10 Gb/s are now readily available and have been proven to be radiation-hard in our previous studies. This allows the deployment of a compact 120 Gb/s parallel optical engines at a high radiation location close to the interaction region where space is at a premium.
We incorporate the experience gained from the fabrication and operation of the optical link system of the current ATLAS pixel detector into the design of the new ASICs. For the first R&D project, the ASIC is a 12-channel VCSEL array driver operating at 5 Gb/s per channel. Each channel has an LVDS receiver, an 8-bit DAC, and a VCSEL driver. The 8-bit DAC is used to set the VCSEL modulation current. There is also a single 8-bit DAC to set the bias currents of all channels simultaneously. A scheme for redundancy has also been implemented to allow bypassing of a broken VCSEL. To enable operation in case of a failure in the communication link to the ASIC, we have included a power on reset circuit that will set the ASICs to a default configuration with no signal steering and the VCSEL modulation current to 10 mA. The ASIC was designed using a 130 nm CMOS process to enhance the

radiation-hardness. The performance of the fabricated ASIC at 5 Gb/s is satisfactory. We are able to program the bias and modulation currents and to bypass a broken VCSEL channel. The power-on reset circuits have been successfully implemented.

For the second R&D project, we modify the design of the ASIC to operate at 10 Gb/s. The 5 Gb/s VCSEL driver uses thick oxide transistors in order to provide sufficient voltage to drive the VCSEL. This is not practical for the high speed operation. We therefore modify the architecture to use thin oxide transistors and add a negative VCSEL bias voltage. We simulate the extracted layout with parasitic capacitance, inductance, and resistance from the VCSEL itself and the wire bonds and pads used for connecting the VCSEL to the ASIC. The simulated eye diagram is open, indicating that it is possible to design an ASIC to operate at 10 Gb/s using a 130 nm CMOS process.

For the third R&D project, we plan to export the design to a 65 nm CMOS process to further increase the operating margin at 10 Gb/s. This will allow us to compare this design to the 130 nm design which is not as expensive. We will present the preliminary results from this design.

Session 3 / 67

Development of planar pixel modules for the ATLAS high-luminosity LHC tracker upgrade

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The high-luminosity LHC will present significant challenges for tracking systems. ATLAS is proposing to replace the entire tracking system, including a significantly larger pixel detector. This paper reports on the development of large area planar detectors for the outer pixel layers and the pixel end-caps. Large area sensors have been fabricated and mounted onto 4 FE-I4 readout ASICs, so called quad-modules, and their performance evaluated in the laboratory and testbeam. Results from characterisation of sensors prior to assembly, experience with module assembly, including bump-bonding and results from laboratory and testbeam studies will be presented.

Session 5 / 68

Qualification of the CMS pixel readout chip for the phase 1 upgrade

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For the phase 1 upgrade of the CMS experiment the front end electronics of the pixel detector will be replaced to improve the readout efficiency at high luminosity. The redesign of the readout chip that is bump-bonded to the silicon sensor is an essential part of this upgrade. The first prototype

versions of the new readout chip have been designed and produced. The results of the complete qualification and calibration of the new chip similar to the one done prior to the installation of the current detector will be presented. The results of the high rate tests performed with an intense x-ray source specific to the upgraded chip will be shown as well.

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A double-sided super-module development for the HL-LHC

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As part of the High Luminosity LHC upgrade (HL-LHC), a new Inner Tracking Detector (ITK) will be constructed for the ATLAS experiment, using silicon pixel and micro-strip technology.
A back-up prototype development for the micro-strip barrel detector of the ITK envisages double-sided modules of typically 10x10 cm2 assembled on a stiff but low material local support to form a 'super-module'of up to 16 modules.
Following the successful completion of component demonstrators and prototype elements, the feasibility of the super-module concept has been largely demonstrated and the project using ABC250 front-end chips is now being concluded.
In this summary, the major design specifications are confronted with the principal electrical and mechanical prototype results.

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Synchronized analysis of testbeam data with the Judith software

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The Judith software performs pixel detector analysis tasks utilizing two different data streams such those produced by the reference and tested devices typically found in a testbeam. This software addresses and fixes problems arising from the desynchronization of the two simultaneously triggered data streams by detecting missed triggers in either of the streams. The software can perform all tasks required to generate particle tracks using multiple detector planes: it can align the planes, cluster hits and generate tracks from these clusters. This information can then be used to measure the properties of a particle detector with very fine spatial resolution. It was tested at DESY in a KarTel telescope with an ATLAS Diamond Beam Monitor module as a DUT.

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Development of pixel sensors with 25x500 um2 pitch for the ATLAS HL-LHC upgrade

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Upgrade of the ATLAS tracker detector for high-luminosity LHC conditions requires novel approaches to the pixel sensor design. Tests of different pitch layouts represent significant part of the ATLAS upgrade program. Better momentum resolution and multiple track reconstruction in the r-phi plane could be achieved with finer phi-segmentation. The new proposed geometry adapts to the floorplan of the baseline readout ASIC geometry (50x250) but modifies the area of the sensing element. It is relevant to outer layers and high eta regions of the barrel pixel detector. Requirements to the eta resolution in these regions are not as strict as in other parts of the pixel detector. Changing the pitch from 50x250 um2 to 25x500 um2 in the outer pixel modules would improve the tracking performance of the upgraded ATLAS detector. The pixel sensors with 25x500 um2 readout by FE-I4 chips have been designed at The University of Liverpool. The sensors were measured in the laboratory and testbeam. Results of these tests will be presented. Also, OTHER novel pixel layouts compatible with the FE-I4 floorplan have been designed and produced. Their geometry characteristics will be presented.

Session 2 / 72

Status and perspectives of the development of pixel sensors based on 3D vertical integration

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The development of 3D vertical integration in the microelectronic industry brings along significant advantages for pixelated semiconductor radiation sensors in cutting-edge scientific experiments at high luminosity particle accelerators and advanced X-ray sources. These applications set very demanding requirements on the performance of sensors and their readout electronics, in terms of pixel pitch, radiation tolerance, signal-to-noise ratio and capability of handling very high data rates. 3D vertical integration of two or more layers with sensors and CMOS devices naturally leads the designer towards extending pixel-level processing functionalities and achieving novel structures where each layer is optimized for a specific function. For front-end electronics, 3D integration could be a way to avoid using CMOS technologies with a feature size of a few tens of nm, nevertheless achieving a very high functional density for the integration of complex analog and digital circuits inside a small pixel cell. This talk reviews current efforts in the high energy physics community towards the development of novel vertically integrated pixel sensors and discusses the challenges that are being tackled to qualify these devices for actual applications.

Session 6 / 73

The Silicon Vertex Locator for the LHCb Upgrade

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The upgrade of the LHCb experiment, planned for 2018, will transform the entire readout to a triggerless system operating at 40 MHz. All data reduction algorithms will be executed in a high level software farm, with access to all event information. This will enable the detector to run at luminosities of 1-2 x10ˆ33 /cmˆ2 /s and explore New Physics effects in the beauty and charm sector with unprecedented precision.

The upgraded silicon vertex detector (VELO) must be light weight, radiation hard, and compatible with LHC vacuum requirements. It must be capable of fast pattern recognition and track reconstruction and will be required to drive data to the outside world at speeds of up to 3 TB/s.

This challenge is being met with a new VELO design based on hybrid pixel detectors positioned to within 5 mm of the LHC colliding beams. The sensors have 55 x 55 square pixels and the VELOPix ASIC which is being developed for the readout is based on the Timepix/Medipix family of chips. The ASIC will operate in data driven mode, time stamp the hits and will operate with a fast front end in order to eliminate timewalk at 40 MHz trigger rate. The hottest ASIC will have to cope with pixel hit rates of up to 900 MHz. Work is in progress to optimise the sensor guard ring design to cope with the irradiation levels, which are highly non uniform and reach 8 x 10ˆ15 at the innermost regions.

The material budget will be optimised with the use of evaporative CO2 coolant circulating in microchannels within a thin silicon substrate. Microchannel cooling brings many advantages: very efficient heat transfer with almost no temperature gradients across the module, no CTE mismatch with silicon components, and low material contribution. This is a breakthrough technology being developed for LHCb, and work is in progress to demonstrate the robustness of the substrate and connector against the high pressures which may be developed in a CO2 cooled system.

LHCb is also focussing effort on the construction of a lightweight foil to separate the primary and secondary LHC vacuua, the development of high speed cables, and the metallisation and radiation qualification of the module.

The 40 MHz readout will also bring significant conceptual changes to the way in which the upgrade trigger is operated. Work is in progress to incorporate momentum and impact parameter information into the trigger at the earliest possible stage, using the fast pattern recognition capabilities of the upgraded detector.

The current status of the VELO Upgrade will be described together with a presentation of recent test results, and a discussion of the R&D on alternative solutions which has been carried out within the LHCb VELO upgrade programme.

Session 2 / 74

LHCb VELO detector: Performance and Radiation Damage

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The LHCb experiment is dedicated to the study of New Physics in the decays of heavy hadrons at the Large Hadron Collider (LHC) at CERN.
Heavy 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 retractable silicon-strip detector surrounding the LHCb interaction point. It's innermost radius is located only 7 mm from the LHC beam during normal LHC operation, once moved into its closed position for each LHC fill when stable beams are obtained. During insertion the detector is centred around the LHC beam by the online reconstruction of the primary vertex position.

Both VELO halves comprise 21 silicon micro-strip modules each. A module is made of two n+-on-n 300 µm thick half-disc sensors with R-measuring and phi-measuring micro-strip geometry, mounted on a carbon fibre support paddle. The minimum pitch is approximately 40 µm. The detector is also equipped with the only n-on-p sensors operating at the LHC. The detectors are operated in vacuum and a bi-phase C02 cooling system is used. The signals read out with analogue front-end chips are subsequently processed by a set of algorithms in FPGA processing boards.

The VELO has been performing very successfully. Operational results show a signal to noise ratio of around 20:1 and a cluster finding efficiency >99 % excluding dead channels. The small pitch and analogue read-out result in a best single hit precision of 4 µm having been achieved at the optimal track angle. The performance of the VELO during its three years of operation during the LHC physics runs will be presented, focussing on the latest studies. This will include highlights such as alignment, cluster finding efficiency, single hit resolution, impact parameter resolution and vertex resolution.

The VELO module sensors receive a large and non-uniform radiation dose having inner and outer radii of only 7 and 42 mm, respectively. A maximum dose of 1.2 x 1014 1 MeV neutron equivalent /cm2 was received in the innermost region of the sensors for the combined 2010-12 run (3.4 fb-1 of delivered data). Type-inversion of the inner part of the n-on-n sensors has already been measured. The radiation damage in the detector is monitored and studied in three dedicated ways: (1) dependence of sensor currents on voltage and temperature; (2) measurement of the effective depletion voltage of the sensors from the charge collection efficiency and from studying the noise versus voltage behaviour; and (3) cluster finding efficiency. In addition, the noise and charge collection is directly monitored over time. Results will be presented in all areas with updates based on recent results from the LHC running in 2012. The primary results presented are the first observation of type-inversion at the LHC; a comparison of n-type and p-type silicon in operation; system-wide measurement of the silicon effective band gap after irradiation; and the observation of a radiation-induced charge loss effect due to the presence of a second metal layer.

Session 6 / 75

Performance and operation experience of the Atlas Semiconductor Tracker

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We report on the operation and performance of the ATLAS Semi-Conductor Tracker (SCT), which has been functioning for 3 years in the high luminosity, high radiation environment of the Large Hadron Collider at CERN. The SCT is constructed of 4088 silicon detector modules, for a total of 6.3 million strips. Each module operates as a stand-alone unit, mechanically, electrically, optically and thermally. The modules are mounted into two types of structures: one barrel, made of 4 cylinders, and two end-cap systems made of 9 disks. The SCT silicon micro-strip sensors are processed in the planar p-in-n technology. The signals are processed in the front-end ABCD3TA ASICs, which use a binary readout architecture. Data is transferred to the off-detector readout electronics via optical fibres. We find 99.3% of the SCT modules are operational, the 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. We will report on the operation and performance of the detector including an overview of the issues encountered. We observe a significant increase in leakage currents from bulk damage due to non-ionizing radiation and make comparisons with the predictions.
We will also cover the time evolution of the key parameters of the strip tracker, including the evolution of noise and gain, the measurement of the Lorentz angle and the tracking efficiency in the harsh LHC environment. Valuable lessons for future silicon strip detector projects will be presented.

Session 2 / 76

Sensors for very high fluences

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Rising the electric field so as to provoke charge multiplication of electrons has enabled silicon to provide measurable signals from sensors irradiated to unprecedented radiation levels up to 1.6x10ˆ17

n_eq/cmˆ2. A simple scaling of collected charge vs. applied bias has been established experimentally for fluences above 10ˆ15 n_eq/cmˆ2 for planar strip sensors. Departure from linear scaling of leakage current vs. fluence has been observed. Despite these successes, operation of silicon sensor based detectors at extreme fluences is not to be taken for granted, as issues of the signal to noise ratio depend both on details of the readout as well as on the environmental conditions, dictated by engineering constrains. Special applications thus might favour alternative materials such as diamond.

Session 5 / 77

To uncover hotspots of radiation with a Si/CdTe Compton Camera

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Dust containing radioactive materials dispersed following the Fukushima nuclear power plant accident in March 2011. Gamma-rays are emitted in the process when unstable nuclei in the materials decay. Based on the technology of Si/CdTe Compton Camera, we have manufactured a quick prototype model for the use in the field. The camera, now called an "Ultra-Wide-Angle Compton Camera" was successfully applied to visualize the distribution of radio-active substances in the Fukushima area. In this talk, we will summarize the design and performance of the ultra-wide angle Compton Camera. Commercial models currently developed by our groups will be also described.

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Logistics

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Briefing the schedule and useful hints

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Next symposium

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Announcement of the next symposium, date, site, and briefing the site.

Session 4 / 80

CMOS Monolithic Active Pixel Sensors for High Energy Physics

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Monolithic detectors integrate sensor and readout in one piece of silicon and therefore favorably compare with hybrid detectors in terms of detector assembly, production cost and detector capacitance. Several functional devices on high resistivity silicon have been developed but often require fabrication steps incompatible with high volume manufacturing in standard semiconductor foundries. Recently more standard CMOS technologies have received significant attention to implement monolithic detectors, which now are starting to be deployed in high energy physics experiments.
An overview will be presented of different approaches to realize of monolithic detectors in CMOS technologies for high energy physics, which include in reality a variety of developments. Device, circuit and architecture mutually influence each other. Design tradeoffs and their impact on performance, power consumption and radiation tolerance will be presented, including the challenge to integrate more complex circuitry within the pixel for alternate architectures and the role of reverse substrate bias. An effort will be made to point out perspectives and challenges to be overcome for CMOS monolithic sensors to be adopted more widely in high energy physics.

Poster / 81

Turkish Accelerator Center Particle Factory Facility

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In this presentation, general specification of Turkish Accelerator Center (TAC) Particle Factory (PF) facility will be given. TAC PF is a super charm factory with the asymmetric beam energy setup consisting of an electron beam with 1 GeV from a linac and a positron beam with 3.56 GeV from a ring, proposed as a linac-ring type collider and a dedicated detector. The main components of the preliminary design of TAC-PF detector are: tracker, time of flight, calorimetry, and muon system. A super charm factory with luminosity L=1035 cm-2 s-1 will give opportunity to investigate charm physics well further than B factories, benefiting from a boost parameter (βγ=0.68) for some processes.

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Registration

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