8th ”Trento” Workshop on Advanced Silicon Radiation Detectors (3D and p-type)

Monday, 18 February 2013 - Wednesday, 20 February 2013

FBK, Trento

Book of Abstracts

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Upgrade Planning for the ATLAS Tracker

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A series of upgrades leading to those required for the HL-LHC phase of ATLAS is described with emphasis on those relating to the tracking part of the experiment. Aspects of the proposed ATLAS HL-LHC tracker layout and recent results on prototyping performance are presented. The wider context of ATLAS Upgrade planning is also briefly discussed along with current understanding of scheduling. The expected performance of the upgraded tracker in the presence of high pile-up is shown to motivate the baseline detector choices although possible alternative layouts are also mentioned.

Summary:

The proposed talk is intended to have the nature of an overview but can enter into more detail on technologies, depending on the topics dealt with in other ATLAS presentations.

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Diamond Sensors for HE Frontier Experiments

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With the first three years of the LHC running well underway, 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 present the issues which arose in the ATLAS Beam Conditions Monitor (BCM) and Diamond Beam Monitor (DBM) projects both of which are based on CVD diamond with the goal of elucidating the issues that should be addressed for future diamond based detector systems. The talk will also present the first beam test results of prototypes of a new diamond detector geometry which should further enhance the radiation tolerance of diamond.

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Performance and radiation hardness of the LHCb Velo

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LHCb is a dedicated experiment to study New Physics in the decays of heavy hadrons at the Large Hadron Collider (LHC). Heavy hadrons are identified through their flight distance in the VELO, the retractable silicon-strip vertex detector surrounding the LHCb interaction point at only 7 mm from the beam during normal LHC operation.
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- and φ-measuring 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 module operating at the LHC.
The performance of the VELO in its three years of successful operation during the LHC physics runs will be presented. Highlights will include alignment, cluster finding efficiency, single hit resolution, and impact parameter and vertex resolutions.
The VELO module sensors receive a large and non-uniform radiation dose having inner and outer radii of only 7 and 42 mm, respectively. In this extreme and highly non-uniform radiation environment type-inversion of the inner part of the n-on-n sensors has already been measured.
Radiation damage is monitored and studied in three ways: (1) dependence of sensor currents on voltage and temperature; (2) noise versus voltage behaviour; and (3) cluster finding efficiency. Results will be presented in all three areas with updates based on recent results from the 2012 LHC running.

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

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The ATLAS experiment will upgrade its Pixel Detector with the installation of a new pixel layer in 2013-14. The new sub-detector, named 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.
To cope with the high radiation and pixel occupancy due to the proximity to the interaction point, a new read-out chip and two different silicon sensor technologies (planar and 3D) have been developed. Furthermore, the physics performance should be improved through the reduction of pixel size while targeting for a low material budget should be imposed, pushing for a new mechanical support using lightweight staves and a CO2 based cooling system.
An overview of the IBL project and the status of the two pre-series staves made before going into production in order to qualify the assembly procedure, the loaded module electrical integrity and the read-out chain will be presented.

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3D modules production for the IBL detector

Author: Andrea Gaudiello[1]

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The first upgrade of the ATLAS Pixel Detector will consist in the installation of a new pixel layer during the shutdown of
the LHC machine in 2013. The new detector, called Insertable B-Layer (IBL), will be inserted between the existing Pixel Detector and a new (smaller radius) beam-pipe, at an average sensor radius of 3.4 cm. The IBL requires the development of several new technologies to cope with the increase of radiation and pixel occupancy at such a reduced radius. In particular 3D sensors will be installed in the
outermost part of the new detector.
An overview of the 3D sensor production for IBL done at CNM and FBK will be given, together with first results after module integration with FE-I4 and full assembly.

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Characterization of 3D CNM prototypes for the ATLAS forward detector

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Due to the successful performance of the IBL 3D sensors, the technology was selected for the ATLAS Forward Physics (AFP) project. The AFP presents a new challenge due to the need for a reduced dead area with respect to IBL, and the in-homogeneous nature of the radiation dose distribution in the sensor. Electrical characterization of the first CNM AFP prototypes and beam test studies of 3D pixel devices irradiated non-uniformly will be presented.

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

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To extend the physics reach of the LHC, upgrades to the accelerator are planned which will increase the peak luminosity by a factor 5 to 10. To cope with the increased occupancy and radiation damage of the inner trackers, 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 Planar Pixel Sensors R&D Project was established comprising 17 institutes and more than 80 scientists.

The presentation will give an overview of the recent accomplishments of the R&D project. Among these are beam test results obtained with pixel sensors irradiated to HL-LHC fluences at realistic b-layer inclination angles and with unirradiated read-out electronics bumped to irradiated sensors, thus eliminating the uncertainty of FE-chip related effects. In addition, first results obtained with heavily irradiated modules using the new ATLAS FE-I4 readout will be shown.

On the topic of edge efficiencies, significant progress has been made with respect to the application of the SCP (scribe-cleave-passivate) post-processing technology which enables the creation of almost active edges even for originally non-slim-edge sensors. New results will be shown for both n-in-n and n-in-p sensors and will be compared to initial TCAD simulations. In addition, first results of planar active edge projects using DRIE trench etching will be presented.

Summary:

The high-luminosity upgrades of the LHC will lead to increased occupancy and radiation damage of the inner trackers, approaching fluences of a few 10**16 neq/cm2 at the innermost layer and still some 10**15 neq/cm2 at the outer pixel layers.

The ATLAS experiment plans to introduce an all-silicon inner tracker with the HL-LHC upgrade to cope with the elevated occupancy. With silicon, the occupancy can be adjusted by using the unit size (pixel, strip or short strip sensors) appropriate for the radiation environment. For radiation damage reasons, only electron-collecting sensors designs are considered (n-in-p and n-in-n): Beyond a fluence of about 1015 neq/cm2, trapping becomes the dominant radiation effect and electrons are trapped significantly less than holes.

To investigate the suitability of pixel sensors using the proven planar technology for the upgraded tracker, the ATLAS Planar Pixel Sensor R&D Project was established comprising 17 institutes and more than 80 scientists. Main areas of research are
* performance assessment and improvement of planar pixel sensors at HL-LHC fluences
* the achievement of slim or active edges to provide low geometric inefficiencies without the need for shingling of modules
* establishment of reliable device simulations for severely radiation-damaged pixel detectors
* the exploration of possibilities for cost reduction to enable the instrumentation of large areas with pixel detectors

Recently, it has been demonstrated with sensors from different vendors that planar pixel sensors can be operated and still yield more than 5000 electrons of signal charge even above 10**16 neq/cm2; hit efficiencies of well above 97% were obtained.
Special slim-edge designs have been implemented and tested and show a reduction of the inactive edges from 1100 µm in the current ATLAS Pixel Detector to only about ~200 µm. Further improvements towards fully active edges by SCP (scribe-cleave-passivate) and DRIE etching techniques are being investigated.

The presentation will give an overview of the recent achievements of the R&D project, among them
* beam test results with planar sensors irradiated up to 2*1016 neq/cm2 at different eta angles providing new insight into efficiencies and cluster sizes under realistic b-layer conditions*
** results obtained with n-in-n pixel assemblies with sensors irradiated up to 1.4*10**16 neq/cm2 while read-out chips (FE-I3) remained unirradiated to disentangle sensor and FE-related effects**
*** first results from pixel assemblies based on the new ATLAS pixel readout chip FE-I4 irradiated to beyond 1*10**16 neq/cm2
* systematic studies of the SCP technique to obtain almost active edges by post-processing already existing sensors based on scribing, cleaving and edge passivation
* comparisons of these experimental findings with initial TCAD device simulations
* first results towards fully active edges by means of anisotropic trench etching with planar technology
* experience with recent large-scale planar sensor productions in terms of yield and QA and status of future plans for sensor productions on 6"substrates

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Characterization of thin n-in-p planar pixel sensors with active edges before and after irradiation

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We report about the characterization of silicon pixel modules employing n-in-p planar sensors with an active thickness of 150µm, produced at MPI/HLL, and 100µm with active edges, produced at VTT in Finland.
The thinned sensors are designed to reduce the signal degradation and ensure radiation hardness even after high fluences. Moreover the n-in-p technology only requires a single side processing and is a cost-effective alternative to the n-in-n pixel technology presently employed in LHC experiments. High precision beam test measurements of the hit efficiency have been performed with high energy pions at the SpS CERN with different bias voltages and beam incidences.
Results obtained on 150µm thick sensors, assembled with the new ATLAS FE-I4 chip and irradiated up to a fluence of 4e15 n_eq cmˆ-2, show that they are excellent candidates for larger radii of the silicon pixel tracker in the ATLAS Phase II. In addition, the active edge technology maximises the active area of the sensor and therefore suits the requirements for the innermost layers.
The edge pixel perfomance of VTT modules has been compared to the central region and a first analysis of the charge collection of these devices after irradiation was performed in the laboratory using radioactive sources.

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Update on CCE results with very thin (50µm) Si detectors

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The effect of thickness on the CCE performances after irradiation is here investigated with measurements taken with a 50µm thick microstrip detectors irradiated at about 2.2 Neq cm-2.

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PTP and the inter-strip capacitance and resistance for irradiated ATLAS07 mini-sensors.

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PTP against beam splashes together with the inter-strip capacitance and resistance have been measured on the heavily irradiated (4e14, 2e15 and 1e16neq/cmˆ2) and non-irradiated samples of n-on-p HPK ATLAS07 mini-sensors. Each sample consists of four mini-sensors with special PTP structures A, B, C and D and with three different ion concentrations of p-stop and p-stop with p-spray n-strip isolation: 2e12, 4e12 and 1e13 ion/cmˆ2. There were found no onsets of micro-discharges below of -600 V of reverse bias. Punch through voltage is increasing with growing fluency and reaches its valuable maximum at fluency 2e15 neq/cmˆ2 for sample of 1e13 ion/cmˆ2. PTV is smallest at 1e16neq/cmˆ2 from all tested fluencies including zero one. Inter-strip capacitance does not depend on fluency up to 1e16 neq/cmˆ2 and on the p-stop ion concentration. Inter-strip resistance is decreasing with fluency. Study is continuing.

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Study of Behaviour of n-in-p Silicon Sensor Structures Before and After Irradiation

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Radiation-tolerant n-in-p silicon sensors were developed for use in very high radiation environments. Novel n-in-p silicon strip and pixel sensors and test structures were fabricated, tested and evaluated, in order to understand the designs implemented. The resistance between the n-implants (interstrip resistance), the electric potential of the p-stop, and the punch-through-protection (PTP) onset voltage, leakage current breakdown at n-implant at very high voltage were measured before and as a function of fluence after irradiation. The technology computer-aided design (TCAD) simulations were used to understand the radiation damage and fluence dependence of the behavior of structures.

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Fabrication of new p-type pixel detectors with enhanced multiplication effect in the n-type electrodes.

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In the framework of the RD50 collaboration New p-type pixel detectors with small gain will soon be fabricated in the clean room at the CNM. Our new design will allow for thinner structures with moderate multiplication factors and ultra short collection times. The mask of the new structures will be presented and the results of some electrical simulations on these new devices will be discussed.

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Charge collection studies on special diodes from RD50 multiplication run

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Silicon diodes with special design of the implant - so called “spaghetti diodes” - were used to study the impact of implantation process on charge multiplication after irradiations to very large equivalent fluences of 8e16 cm-2. The samples were found to work even at this unprecedented levels of irradiation. Different implantation processes were implemented on samples for studying the impact of implantation on charge multiplication. The spaghetti diodes of different thicknesses were also compared to conventional
strip detectors and normal pad detectors in order to determine the impact of different weighting field on the collected charge.

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Ultra-Fast Silicon Sensors

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Ultra-fast silicon sensors will combine short collection time with internal gain. I will present motivation, principle of operation, implementation and first results for ultra-fast silicon sensors.

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3D Sensors 1 / 22

Production of 3D silicon pixel sensors at FBK for the ATLAS IBL

Author: Maurizio Boscardin[1]

Co-authors: Alvise Bagolini [1]; FRANCESCA MATTEDI [1]; Gabriele Giacomini [1]; Gian-Franco Dalla Betta [2]; Marco Povoli [2]; Maurizio Boscardin [1]; Nicola Zorzi [1]

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We report on the results from the production of the 3D silicon pixel sensors for the ATLAS IBL.
We present the fabrication process and some selected results from the electrical characterization of detectors and test structures.
The main technological aspects related to the production yield optimization will also be addressed.

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Characterization results of recent CNM 3D productions

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The results of the CNM 3D sensor development and productions, including sensors for the ATLAS IBL detector, will be briefly reviewed. Testbeam results of irradiated and non-irradaited sensors and recent burn-in tests of 3D prototypes will be presented.

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Investigation of the electrical characteristics of double-sided silicon 3D sensors after irradiation with different particles

Author: Roberto Mendicino[1]

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We have previously reported on the impact of layout on the electrical characteristics of double-sided silicon 3D sensors fabricated at FBK. In the past year, our study has been continued to account for radiation damage effects. To this purpose, different irradiation campaigns have been conducted in collaboration with some external groups. Several sets of 3D diodes with different layout and test structures have been irradiated with 800-MeV protons and reactor neutrons up to 5e15 neq/cmˆ2, i.e., the fluence of interest for the ATLAS IBL. Moreover, additional irradiations have been performed with X-rays, in order to focus on surface damage alone.
The characterization of parameters such as leakage current, breakdown voltage and capacitance, performed through measurements at different temperatures, has shown a good correspondence with theoretical model for radiation damage. TCAD simulations incorporating radiation damage models have also been performed in order to better understand the device behavior in view of future layout and technology optimization. Selected results will be presented at the workshop.

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Charge Collection Measurements of Irradiated 3D Sensors

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In collaboration with the University of Trento we have measured the charge collection response of three different FBK 3D sensor designs. The sensors have been irradiated with 800 MeV protons to various fluences exceeding 1x10ˆ16 neq/cmˆ2, and the relative CCE has been characterised with source and laser stimulus.

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Characterization of 3D-DDTC strip sensors with passing-through columns

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We report on the characterization of newly developed Double-sided Double Type Column (DDTC) 3D detectors produced by FBK in Trento. Pre-irradiation measurements on these sensors include charge collection measurements using a Beta source to test the sensors performance in terms of absolute charge deposited, as well as laser can measurements in order to investigate the spatial uniformity of the sensors response. Current-voltage and capacitance-voltage measurements as well as simulation of the punch-through biasing of the sensors were also carried out.

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Testbeam and laboratory characterization of 3D CMS pixel sensors

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The pixel detector at the heart of the CMS experiment at the CERN LHC will be exposed to unprecedented radiation fluences, i.e. 1x1016 neq/cm2, at the high-luminosity LHC upgrade in 2020. Standard planar technology was shown to be unable to meet the CMS physics requirements at this high fluence regime. Ultra radiation-hard 3D technology is one of the most promising candidates for replacement due to its superior features. The CMS 3D pixel sensors, fabricated at FBK, have been tested thoroughly both in laboratory and beam tests before and after irradiation. Characterization measurements were carried out for the CMS 3D sensors, diode, and test structures from different batches. We will report on our 3D test results obtained so far.

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3D Diamond Detectors

Author: Iain Haughton[1]

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I shall present on the fabrication and characterization of the first prototype 3D diamond detector for particle physics applications. A femto-second laser was used to create arrays of graphitic columns in single crystal and polycrystalline diamond samples, these conductive columns are a few microns in diameter and create a 3D readout similar to that produced in silicon. Creating a 3D structure within diamond has two main objectives; firstly, to increase the radiation hardness compared to that of planar diamond detectors and secondly, to increase the signal response from polycrystalline diamond. Polycrystalline diamond has crystal boundaries within its bulk which act as charge traps reducing the un-irradiated drift path to ˜ 250μm compared to >1000μm in single-crystal, however, as a material it is much cheaper than single-crystal diamond. Both prototype single-crystal and polycrystalline detectors were tested in particle beams at CERN (proton/pion) using a charge integrating readout. Other laboratory tests are currently being conducted to fully understand the detector characteristics.

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Latest developments for the improvement of double-sided 3D detectors fabrication at FBK

Author: Nicola Zorzi[1]

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Double-side 3D sensor technology developed at FBK (Trento, Italy) in collaboration with INFN turned out successful not only in the performance demonstration of prototypes but also to supply good quality detectors for the ATLAS-IBL with a good fabrication yield.
Although obtained results are satisfactory, the performance of these devices can be further improved and a simplification of the fabrication technology will be desirable to reduce the time required for a medium volume production.
This paper reports on the modifications at the layout and fabrication levels aimed at improving the sensor breakdown voltage, both before and after irradiation, while reducing the number of lithographic steps required during fabrication. The new adopted layout solutions will be shown together with TCAD simulations supporting them. A modified 3D technology with full passing ohmic columns and junction columns stopping at about 25 microns from the opposite surface will be introduced. Preliminary results will be reported from the electrical characterization of a new 3D detector batch fabricated at FBK and implementing the proposed improvements.

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Numerical simulation of thin 3D detectors with built-in charge multiplication

Author: Marco Povoli[1]

Co-authors: Ching-Hung Lai [2]; Cinzia Da Via [3]; Gian-Franco Dalla Betta [4]; Lucio Pancheri [1]; Stephen Watts

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One of the required features of tracking devices for the futures upgrades of LHC experiments will be a reduced thickness, in order to decrease the material budget and to achieve lower multiple scattering. The main drawback related to a reduced sensor thickness is a decrease in the total sensing volume, which translates in a large reduction of the signal available for particle detection. To counteract this effect, charge multiplication can be exploited to increase the sensor signal without significantly affecting the noise figure of the system.

We present a numerical simulation study aimed at defining an innovative thin 3D sensor topology with built-in charge multiplication, able to obtain moderate gains at relatively low voltages.
After proving that the simulator accurately reproduces charge multiplication effects recently observed in 3D detectors, the new sensor concept is presented. The effects of the sensor geometry on the electrical characteristics and the charge multiplication properties are studied both before and after heavy irradiation. The excess noise factor of the proposed sensors is also estimated by using an analytical model, and a preliminary layout and process sketch are proposed.

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3D Double-Sided sensors for the CMS phase-2 vertex detector

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By 2020 a two stage upgrade of the accelerator complex, the High Luminosity-LHC (HL-LHC), will increase the instantaneous luminosities up to a factor of ten compared to the current design. The particle fluxes at CMS experiment will increment substantially with special impact on the inner tracking detector which will be subjected to large occupancies and radiation damage. In order to cope with the higher instantaneous luminosities CMS will upgrade its current vertex detector. The so-called 3D sensors are a very promising technology as they offer efficient operation at moderate bias voltages after fluences above 1x1015cm-2 1 MeV neutron equivalent.

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Modelling of 3D detectors and comparison with data

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Modelling of charge collection in 3D silicon detectors is described. The modelling is extended to irradiated devices using the deep acceptor model and combined with avalanche multiplication. Modelling of charge transport in the electrodes for full-3D devices is described. The results are compared to data from test beams and also x-ray scans at the Diamond synchrotron at the Rutherford Appleton Laboratory. Conclusions are made on defect modelling at high fluences, avalanche effects, and charge transport in electrodes.

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Discussion

CMOS Sensors and Electronics / 18

First experience with radiation-hard active sensors in 180 nm HV CMOS technology

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CMOS processes are cost-efficient and commercially available. We explore the concept of using a deep-submicron HV CMOS process to produce a drop-in replacement for traditional radiation hard silicon sensors. Unlike fully integrated monolithic active pixel sensors (MAPS), such active sensors still require a traditional (pixel or strip) readout chip to receive and organize the data from the active sensor and handle high level functionality such as trigger management. In contrast to standard radiation-hard silicon pixel sensors, however, active sensors contain simple circuits to amplify and either discriminate or condition the basic pulses created by charged particles which yields many advantages such as improved resolution, reduced cost, capacitive coupling and very thin devices leading to an improved material budget.

After outlining the design of the HV2FEI4 test ASIC, characterization results and first experience obtained with pixel and strip readout will be shown before discussing future prospects of active sensors.

Summary:

Future detectors at colliders will contain enlarged pixel detectors to cope with the large density of particle tracks near the interaction point. For radiation damage reasons, mostly hybrid detectors were used up to now which comprise a silicon pixel sensor fabricated on high-resistivity FZ silicon and a bump-bonded readout chip in deep sub-micron technology. The requirement for bump-bonding and mechanical demands constrained the pixel pitch/size to larger than ˜50-100um and also led to elevated costs which prevented the instrumentation of larger areas with pixel detectors.

Deep-submicron HV CMOS processes feature moderate bulk resistivity and HV capability and are therefore good candidates for drift-based radiation-hard monolithic active pixel sensors (MAPS). It is possible to apply up to 100V of bias voltage leading to a depletion depth of ˜10-20 um. Thanks to the high electric field, charge collection is fast and nearly insensitive to radiation-induced trapping. Due to the still rather high dopant concentration, almost no radiation effect is expected to the depletion voltage.

We explore the concept of using such a HV CMOS process to produce a drop-in replacement for traditional radiation hard silicon sensors. Such active sensors contain only simple circuits to amplify and either discriminate or condition the basic pulses created by charged particles. A traditional readout chip is still needed to receive and organize the data from the active sensor and handle high level functionality such as trigger management. The devices are tested with the ATLAS FE-I4 pixel readout chip and the the ATLAS ABCN and the LHCb Beetle strip readout chips. Either strip-like or pixel-like readout can be selected on the same device.

While a readout chip is still needed (unlike the case of an ideal MAPS device that contains all sensing and processing functionality in one), the active sensor approach offers many advantages: such sensors can be fabricated in a fully commercial CMOS process without need for special substrates or processing and will therefore cost less than traditional diode sensors, they can be thinned to the limit of the collection layer resulting in much lower mass, they require relatively low bias voltage, and they can operate at room temperature or with only moderate cooling after irradiation. In addition, they can contain sub-pixels with smaller pitch than the readout chip and improve the spatial resolution compared to standard sensors by encoding the hit sub-pixels in the signal sent to the readout chip. From a practical perspective, maintaining the traditional separation between sensing and processing functions lowers development cost and makes use of existing infrastructure. Active sensors can also be seen as a first step towards 3D-integrated electronics in which the analogue tier contains the sensor.

To explore the performance and radiation hardness of active sensors, the HV2FEI4 ASIC was produced in the AMS H18 process. It is compatible with the pixel and strip readout chips mentioned above and features a matrix of 60 by 24 pixels with a pixel cell size of 33 by 125 um. Thanks to relying on active circuits, capacitive coupling to the pixel readout chip is feasible and is explored with HV2FEI4 chips glued to FE-I4s. The option to replace the expensive and time-consuming bump-bonding by gluing would significantly lower the cost of future large-scale Pixel Detector upgrades and enable the instrumentation of larger areas with pixel detectors. For comparison, bump-bonding the HV2FEI4 with gold stud-bumps is still possible.

The HV2FEI4 pixels are combined to match the readout multiplicity of the respective chips: for the pixel readout, three HV-CMOS pixels are multiplexed onto one FE-I4 pixel such that the hit pixels are encoded by the pulse height. In this way, the position resolution of the HV-CMOS sensor can be significantly better than the granularity of the readout chip suggests. For the strip readout, the pixel cells are combined to form virtual strips. Here, the z-position of the hit is encoded via the discriminator's pulse height and can be evaluated by analogue strip readout electronics like the Beetle chip.

The presentation will give an overview of the characterization results of the HV2FEI4 chip and highlight first experience with both pixel and strip readout. In addition, the status of the irradiation programme will be summarized and future prospects will be discussed.

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A thin and fully depleted monolithic pixel sensor in SOI technology

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The Silicon On Insulator (SOI) technology is one of the leading technologies for the realization of monolithic pixel sensors on high resistivity wafers. A commercial, deep-submicron SOI process by LAPIS, coupled with high-resistivity silicon substrates, is made available through KEK. In this process, a full CMOS circuitry is integrated in a 40 nm thick layer on top of each pixel. Thanks to the realization of vias through the 200 nm thick Buried Oxide (BOX), pixel implants can be created and the 260 µm thick substrate can be reverse-biased and depleted to improve charge collection.
In the framework of an international collaboration between INFN and University of Padova, LBNL and UC Santa Cruz, we have realized monolithic and depleted pixel sensors in SOI technology, both for charged particle detection and for imaging applications. In this contribution we will review the latest chip produced, the so called SOImager3, a matrix of 256×256 pixels of 13.75 µm of pitch. This chip has been thinned down to 70 µm, back-processed and successfully tested with soft X-ray photons in back-illumination at the Advanced Light Source (ALS) of LBNL and with 300GeV pion-at the CERN SPS. These results show that a thin, fully-depleted SOI pixel provides charged particle detection capability with large signal-to-noise ratio and detection efficiency and achieves a single point resolution of the order of 1 µm.

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Optimization of timing performance of large-area FBK SiPMs in the scintillation light readout

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In this work we describe the work that we have carried out at FBK, aimed at the optimization of the timing performance of large-area SiPMs coupled to LYSO crystals, in the detection of 511 keV gamma photons. We focus on the role of the detector noise, namely its Dark Count Rate (DCR), and on possible baseline compensation techniques for the reduction of its effects on the Coincidence Resolving Time (CRT) of the detector. Once the effects of the DCR are strongly attenuated, it is possible to observe an additional limit to the timing performance due to the optical crosstalk (OC) of the device, which is increased by the presence of the scintillator. We report on the experimental evidence of the phenomenon and we discuss possible solutions.

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Integrated Circuit Design for Time-of-Flight PET with Silicon Photomultiplier

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The high gain and fast rise time of compact Silicon Photomultiplier matrices paved the way for the development of instrumentation with very stringent timing requirements, such as Time-of-Flight PET. Fast, low-noise and low-power integrated front-end electronics is a key factor to achieve the envisaged time resolution. We discuss methods and circuit topologies that target this performance, implemented in customized ASICs for SiPM readout.

Non HEP Projects / 16

HYDE Project: the combination of 3D detectors with polysiloxane based scintillators.

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The aim of HYDE (HYbrid DEtectors for neutrons) project, financed by INFN V commission, is the realization of detectors for neutrons made by 3D systems coupled to polysiloxane based scintillators suitable to convert the energy of fast and slow neutrons both in scintillation light and in reaction products detectable by the patterned silicon detector.
Polysiloxane scintillators are cheap, stable and resistant systems reaching up to 70% of scintillation yield with respect to the best plastic scintillators. In particular, it has been demonstrated that polysiloxane scintillators retain their scintillation yield after 50 kGy of absorbed dose.
By dispersing different dye molecules and boron rich compounds, the detection of both fast and thermal neutrons can be achieved. Recently, red emitting scintillators have been produced by combining three different dyes for promoting the wavelength shift in the red part of the spectrum, in order to match the responsivity curve of 3D photodetectors.
Further research has been carried on for studying the possibility of obtaining the pulse shape discrimination between gamma rays and neutrons.
Finally the first coupling tests between polysiloxane scintillators and 3D systems will be presented, evidencing a good matching of the organic resin into the silicon wells and the first results about the detection by silicon 3D detectors of recoil protons produced by 2 MeV neutrons in the polysiloxane will be presented.

Non HEP Projects / 1

X-ray detectors development at the Swiss Light Source

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An overview of the microstrip and pixel detectors developed at the SLS is presented together with example applications.
Parallel to the successful development of large area single photon counting systems for synchrotron radiation experiments (MYTHEN, EIGER), charge integrating detectors with extended dynamic range and single photon resolution are being developed to satisfy the strict requirements of X-Ray Free Electron Lasers (GOTTHARD, AGIPD, JUNGFRAU).
These detectors present interesting performances also for synchrotron
applications, e.g. the analog low noise information provided by GOTTHARD allowed to exploit the charge sharing between 20um pitch strips to achieve almost micron spatial resolution by means of interstrip interpolation.
Open issues concerning the sensors design will also be addressed, including the absorption efficiency for low and high energy X-rays and the radiation hardness.

Non HEP Projects / 28

Wide Area Radiation Surveillance with Semiconductor Detectors

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The Real Time Wide Area Radiation Surveillance System (REWARD) is a novel mobile system for radiation detection and monitoring based on the integration of new miniaturized solid-state radiation sensors: a CdZnTe detector for gamma radiation and a neutron detector based on novel silicon technologies. The sensing unit also includes a wireless communication interface to send the data remotely to a monitoring base station as well as a GPS unit.
This presentation will introduce the REWARD project, funded within the 7th Framework Progamme of the EU. Particular emphasis will be placed on the semiconductor sensors at the core of the system.

Non HEP Projects / **46**

Discussion

Microfabrication / **9**

Studies on enhanced silicon detector cooling and integration through microfabrication techniques at CERN

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Ultra-thin liquid micro-fluidic silicon devices have been recently selected for the active thermal management of the GigaTracker detector in the NA62 experiment at CERN. Following this first successful application, further studies have been launched on two-phase flow devices for the upgrades of the ALICE Inner Tracker System (room temperature and low pressure) and LHCb Vertex Locator (low temperature and high pressure) detectors. Recent developments at CERN on this subject will be discussed, including thermal performance, material budget impact, structural reliability and hydraulic connector issues.
In the frame of a collaboration agreement with CSEM (Centre Suisse d'Electronique et Microelectronique), studies are also on-going towards the fabrication of a demonstrator gathering micro-channels for cooling and fine-pitch TSV for interconnectivity in the same device. The status of this R&D aiming to an active silicon interposer will be presented.

Microfabrication / **27**

Silicon Buried Channels for Pixel Detector Cooling

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This talk reports the development of an integrated microchannels cooling into silicon devices. The microchannels are formed in silicon using isotropic SF6 plasma etching in a DRIE (deep reactive ion etcher), after the DRIE process the channels are sealed by depositing a PECVD silicon oxide. We have realized on a silicon wafer microchannels with different geometries and hydraulic diameters. We describe the main fabrication steps of microchannels with focus on the channel definition and we report some selected results on the thermal characterization of several prototypes.

Microfabrication / **11**

Microfluidic scintillation detectors for hadron therapy and high energy physics

Authors: Alessandro Mapelli[1]; Pietro Maoddi[1]

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Within the microScint project in the CERN Physics Department a new generation of microfabricated particle detectors based on liquid scintillators is being developed.
These novel devices consist of dense arrays of microfluidic channels acting as optical waveguides and feature high spatial resolution and increased radiation resistance, while minimizing the material budget. Experimental measurements on prototype detectors yielded light output efficiencies comparable to state of the art scintillating fiber trackers.
Several technological solutions for the fabrication of the microchannels, such as SU-8 photolithography and silicon DRIE, are being investigated within the cleanroom facilities at the EPFL Center for Micronanotechnology (CMi) with the Microsystems Laboratory 4 (LMIS4).
Potential applications include single particle tracking in high energy physics experiments and beam monitoring for hadron therapy applications. A collaboration with INFN Rome has just started to develop a common approach to the potential applications considered. A common system is foreseen, with custom parts dedicated to beam monitoring applications, based on silicon photodiodes, while silicon photomultipliers (SiPM) are being considered for single particle tracking.

Microfabrication / **14**

3D-S: A fast, high resolution, low-mass, detector with embedded cooling and internal charge multiplication capability

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3D silicon sensors have completed the key milestones set by the 3DATLAS R&D collaboration and are now industrially fabricated. A new challenge is now being faced for the HL-LHC which will require a totally new approach in sensor fabrication. 3DS is an innovative fast, low mass modular system where all components, including cooling and active edges, are fabricated and are vertically integrated using microfabrication techniques. The talk will present some of the highlights of the current 3D sensors production and discuss the developement status of 3DS.

Microfabrication / **26**

A new 3D PIN diode structure for neutron detection

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A new hybrid structure of a 3D silicon sensor coupled to a scintillator for the detection of fast and thermal neutrons is presented. The device is based on a PIN diode with DRIE-etched cavities filled with polysiloxane acting as a scintillator, while the signal is transferred to the other side by means of TSV. The structure increases the active interaction volume for neutron, with respect to a planar device, giving higher detection efficiencies. We present the fabrication process and some selected results from the electrical characterization of devices and test structures.

Active/Slim Edges / **36**

Thin Edgeless Silicon Pixel Sensors on Epitaxial Wafers

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The demand for minimizing the material budget of tracking detectors, especially those closer to the interaction region, has been addressed by fabricating pixel sensors on 100 µm thin epitaxial material. After processing, the thick, heavily doped substrate can be thinned down, leaving only a very thin layer, necessary for properly terminating the depletion region. In order to reduce the insensitive (dead) area at the sensor periphery, the 'active edge'technique has been exploited, surrounding the devices by deep, heavily doped DRIE-etched trenches. An overview of the key technological steps and of the first electrical characterization of the fabricated devices will be given.

Active/Slim Edges / 15

Novel edgeless n-on-p planar pixel sensors for the ATLAS tracker 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. The n-on-p silicon technology is a promising candidate to achieve a large area instrumented with pixel sensors, since it is radiation hardness and cost effectiveness.
The talk reports on the development of novel n-on-p edgeless planar pixel sensors produced by FBK-CMM, making use of the active trench concept for the reduction of the dead area at the periphery of the device.
Electrical characterization of the sensors will be presented, after outlining the project and commenting the sensors simulation studies.

Active/Slim Edges / 39

Progress onslim edges with Scribe-Cleave-Passivate

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We will report on recent results on slim edges using the Scribe-Cleave-Passivate SCP method

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Conference Closing

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Conference Photograph