12th ”Trento” Workshop on Advanced Silicon Radiation Detectors

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Book of Abstracts

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Session 10: Technology and Applications (1) / 1

Development of the SHiP Timing Detector Based on Scintillating Bars Readout by SiPMs

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The SHiP experiment (Search for Hidden Particles) is a new general purpose fixed target experiment proposed at the CERN SPS accelerator. A dedicated beam line in the North Area will be aimed at a fixed target station, followed by a magnetic shield to reduce beam induced background. The facility will comprise a compact tau neutrino detector and a detector to search for hidden particles. Background rejection is ensured by use of background taggers and a dedicated timing detector. The timing detector is used to reduce combinatorial di-muon background by requiring incoming particles to be coincident in time within 100 ps. One option for the timing detector consists of columns of horizontal scintillating bars read-out on each end by Silicon Photomultiplier (SiPM) arrays. This study includes characterization of SiPMs from different manufacturers to be used in the timing detector as well as results of time resolution measurements of EJ-200 and EJ-230 plastic scintillating bars read-out on both ends by SiPMs.

TRACK:

Applications

Session 3: Planar Sensors (2) / 3

FBK-INFN-LPNHE thin n-on-p pixel detectors: beamtest results

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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 hard and cost effectiveness.
The paper reports on the performance of 100 μm n-in-p planar pixel sensors produced by FBK-CMM. After discussing the sensor technology an overview of CERN 2016 testbeam results of the produced devices will be given, before and after irradiation, including hit and charge collection efficiency and space resolution.
The plans for new thin and edgeless productions at FBK-CMM will be also presented.

TRACK:

Planar Sensors

Session 10: Technology and Applications (1) / 4

Silicon monolithic pixel detectors in a SiGe Bi-CMOS process for sub-100ps time resolution.

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The TT-PET Collaboration is developing a fast, low power consumption monolithic silicon detector in SiGe Bi-CMOS VLSI process to realize a Time-Of-Flight PET scanner. The development of picosecond-time-resolution silicon pixel detectors is a challenge that requires a detailed study of the sensor geometry and an accurate choice of the Front-End electronics technology.
A time resolution of 100ps was obtained with planar silicon sensors with minimum-ionizing particles using SiGe HBT technology for the pre-amplification stage of the Front-End. The same amplifier, coupled to an LGAD detector, achieved 30ps time resolution with a pulse rise time of 600ps and a signal to noise ratio of 100.
The preliminary results of the tests of a monolithic chip realised with the SG13s IHP process will also be presented.

TRACK:

Planar Sensors

Session 2: Planar Sensors (1) / 5

Simulation of the depletion voltage evolution of the ATLAS Pixel Detector

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The ATLAS Pixel detector has been operating since 2010 and consists of hybrid pixel modules where the sensitive elements are planar n-in-n sensors.
In order to investigate and predict the evolution of the depletion voltage and of the leakage current

in the different layers, a fully analytical implementation of the Hamburg model was derived. The parameters of the model, describing the dependence of the depletion voltage (U_depl) on fluence, temperature and time were tuned with a fit to the available measurements of Udepl in the last years of operation.
A particular emphasis is put on the B-Layer, where the highest fluence has been accumulated up to now. A precise input of temperature and radiation dose is generated from the on-module temperature monitoring and the luminosity data. The analysis is then also extended to the Insertable B-Layer (IBL), installed at the end of Run-1, where we expect the fastest evolution of the radiation damage with luminosity, due to its closer position to the interaction point. Different detector temperatures and luminosity scenarios are simulated to investigate the impact of maintenance periods at room temperature and of the accumulated fluence for the future data taking in Run-2.

TRACK:

Simulations

Session 2: Planar Sensors (1) / 6

Thin planar pixel sensor productions at MPP for the ATLAS ITk

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The ATLAS experiment will undergo around the year 2025 a replacement of the tracker system in view of the high luminosity phase of the LHC (HL-LHC) with a new 5-layer pixel system.
Thin n-in-p planar pixel sensors are promising candidates to instrument the new pixel system, thanks to the reduced contribution to the material budget and their high charge collection efficiency after irradiation. Different possible production processes for this kind of sensors will be presented. The performance of 100-150 μm thick sensors interconnected to FE-I4 chips will be compared up to a fluence of 10^{16} 1 MeV n_{eq}/cm^2 in terms of charge collection and power dissipation.
The design of new sensor productions, compatible with the RD53A chip, with a 50x50 or 25x100 μm^2 pixel cell size will be shown together with possible techniques to improve the electrical isolation between sensor and chip. A first insight of the performance of pixels with these cell sizes is obtained with FE-I4 compatible sensors with a modified geometry.

TRACK:

Planar Sensors

Session 7: LGAD / 7

Timing Measurements on Ultra-fast Silicon Detectors

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I will present measurements of the timing resolution using the UCSC beta source of several thin LGADs (UFSD):
1. irradiated 50um LGAD with 3 different doping concentrations from CNM;
2. pre-rad 50 and 80 LGAD with 4 different doping concentrations from HPK

TRACK:

UFSD, LGAD

Session 1: Introduction / 8

Diamond detector technology; status and perspectives

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At present most experiments at the CERN Large Hadron Collider (LHC) are planning upgrades in the next 5-10 years for their innermost tracking layers as well as luminosity monitors to be able to take data as the luminosity increases and CERN moves toward the High Luminosity-LHC (HL-LHC). These upgrades will require radiation tolerant technologies up to a total fluence of ~2x10^{16} particles/cm^2. As a result all LHC experiments are undergoing intense research programs on radiation tolerant technologies and geometries. Chemical Vapor Deposition (CVD) diamond has been used extensively and successfully in beam conditions/beam loss monitors as the innermost detectors in the highest radiation areas of essentially all LHC experiments. The startup of the LHC in 2015 brought a new milestone where the first diamond pixel modules were installed in an LHC experiment (ATLAS) and successfully began taking data. As a result, this material is now being discussed as a possible sensor material for tracking very close to the interaction region and for pixelated beam conditions/beam loss monitors of the LHC/HL-LHC upgrades where the most extreme radiation conditions will exist.

The RD42 collaboration at CERN is leading the effort to use CVD diamond as a material for tracking detectors operating in extreme radiation environments. During the last three years the RD42 group has succeeded in producing and measuring a number of devices to address specfic issues related to use at the HL-LHC. We will present status of the RD42 project with emphasis on recent beam test results. In particular we present the latest results on material development, the most recent results on the independence of signal size on incident particle rate in poly-crystalline CVD diamond pad and pixel detectors over a range of particle fluxes up to 20 MHz/cm^2 measured, and results from first 3D diamond detectors which produce an extremely radiation tolerant device and collect nearly all of the charge deposited in the material. In addition we will present the plans for future use of the most recent devices.

TRACK:

Technology

Session 6: Electronics / 9

Silicon Drift Detectors and readout ASICs for High-Resolution and High-Count Rate X-ray Spectroscopy

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This work presents the progress done in the development of multichannel X-Ray detectors based on Silicon Drift Detectors matrices and related readout ASICs.
SDDs allow to achieve state of the art performances for high-resolution and high-count rate spectroscopy. CUBE preamplifier [1] allows to reach optimal resolution performances even at high count rate i.e. at short pulse processing times.
SIDDHARTA experiment [2] uses SDDs array for spectroscopy measurements of kaonic hydrogen atoms. Detectors have to be cooled down below 100 K to reduce detector drift time i.e. time uncertainty due to random position of the interaction in the SDD. SIDDHARTA detector is based on a matrix of 2x4 squared SDDs, each of them with $64\,\mathrm{mm}^2$ area, produced by FBK with low leakage technology. The detector is mounted on a ceramic that minimizes dead areas between modules. 8 single channel CUBE preamplifiers are used for SDDs matrix readout. ARDESIA project [3] targets the development of a detector optimized for X-ray fluorescence and X-ray absorption fine structure measurements with synchrotron light. Detector should be able to cover a solid angle large enough to collect high fluorescence signal while minimizing collected background. A good energy resolution is mandatory to increase signal to noise ratio and high count rate capability is needed to reduce measurement time. ARDESIA detection module is based on a matrix of 2x2 SDDs, whose area is $12\mathrm{x}12\,\mathrm{mm}^2$. ARDESIA detector has been produced into two different shapes: squared pixel of $25\,\mathrm{mm}^2$ area, to minimize dead areas and circular pixels of $\simeq 20\,\mathrm{mm}^2$, to minimize drift time at temperatures close to room one. Detector is read out by a 4-channels, monolithic CUBE preamplifier, placed in the middle of the ceramic board. The whole detection module is very compact, as its area is $16\mathrm{x}16\,\mathrm{mm}^2$. It is possible to juxtapose together several detection modules to achieve bigger active area if this is needed. The SFERA ASIC for analog processing of the mentioned SDD detectors is also presented in this work.

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1. L. Bombelli, C. Fiorini, T. Frizzi, R. Alberti, R. Quaglia, *High rate X-ray spectroscopy with "CUBE" preamplifier coupled with silicon drift detector*, IEEE 2012 NSS/MIC Conference Record.

2. R.Quaglia, et al., *Development of arrays of Silicon Drift Detectors and readout ASIC for the SIDDHARTA experiment*, in Nuclear Instruments and Methods in Physics Research A, Volume 824, Pages 449-451, July 2016.

3. R.Quaglia, et al., *New Silicon Drift Detectors and CMOS Readout Electronics for X-ray Spectroscopy from Room Temperature to Cryogenic Operations*, in proceedings of the IEEE NSS-MIC conference, San Diego, 2015.

TRACK:

Electronics

Session 10: Technology and Applications (1) / 10

Development of Ultra-High-Density (UHD) Silicon Photomultipliers with improved Detection Efficiency

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Silicon Photomultiplier (SiPM) is an arrays of many Single-photon avalanche diodes (SPADs), all connected in parallel. Each SPAD is sensitive to single photons and the SiPM gives an output proportional to the number of detected photons. It is becoming more and more popular in different applications, from high-energy physics to spectroscopy, and it has been significantly improved over last years, decreasing the noise, increasing the cell fill-factor (FF), thus reaching very high photon-detection efficiency (PDE).
Fondazione Bruno Kessler (FBK, Trento) developed, during last years, "high-density" (HD) Silicon photomultipliers (SiPM) technologies. They features narrow trenches to separate the SiPM microcells, obtaining small cells with high fill-factor (FF) and thus high Photon Detection Efficiency (PDE). Moreover, we pushed this technology further and developed the ultra-high density RGB SiPM (RGB-UHD), with extremely low cell size. The cell pitch is between 7.5µm and 12.5µm, arranged in a honeycomb configuration, corresponding to a cell density between 20500 and 7400 cells/mm2, respectively. The main issue of such small cells was the active area border effect which dramatically reduces the effective FF. Therefore, we recently developed a new version of UHD SiPM, with a "new guard ring" (NGR) structure with engineered doping profiles leading to a reduction of the border transition region. Thanks to this technology we were able to have functioning SiPM with 5µm-size pitch. This device features a cell density of 46190 cells/mm2 with a FF of ~40%, and a PDE reaching 15%. Moreover, also the cell recharge time constant is in the order of few nanosecond, further improving the dynamic range in photon detection.
This new UHD SiPM is very interesting in applications that require high dynamic range, like detection of high energy gamma rays, or applications requiring a good resistance to radiation damage. Indeed, the smaller the cell size the smaller is the effect of a damaged cell on the overall SiPM performance, thus the detector is able to operate up to a higher level of radiation damage.

TRACK:

Planar Sensors

Session 11: Technology and Applications (2) / 11

Hybrid pixel detectors for soft X-ray applications

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Hybrid pixel detectors with silicon sensors are a well established technology for X-ray detection in the 5 keV – 20 keV range. With the commissioning of the JUNGFRAU (75 μm cell pitch) and of the first prototypes of the MÖNCH (25 μm cell pitch), the noise performance has been significantly improved, reaching the value of 55 e- ENC for JUNGFRAU and 36 e- ENC for MÖNCH, and therefore opening the soft X-ray range (below 1 keV) for hybrid pixel detector technology.
In the last years the prototypes underwent an exhaustive characterization and a series of tests have been conducted at various beam lines at Paul Scherrer Institut with energies ranging from 300 eV to 3 keV, to verify the compliance of the prototypes with the requirements of realistic soft X-ray experiments in a vacuum environment. The detector requirements for the experiments performed so far will be discussed, together with the technological challenges and the solutions adopted to make the prototypes vacuum-compatible. First results will be shown.
Finally, the plans for improvements and future prototypes commissioning will be discussed, including the commissioning of prototypes with thin entrance window sensors to increase the soft X-ray detection efficiency, or the possibility to employ Low Gain Avalanche Detectors (LGADs) to improve the signal to noise ratio.

TRACK:

Applications

Session 3: Planar Sensors (2) / 13

Determination of doping profiles using pad diodes and MOSFETs

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Capacitance-Voltage (C-V) measurements of pad diodes are a standard tool to determine doping profiles and study radiation damage in silicon. Using C-V measurements on pad diodes with different areas we show that guard rings significantly influence the determination of the doping profile and the active diode thickness. Different methods of extracting the doping profile are compared. Correcting for the influence of guard rings is also important, when measurements on radiation-damaged pad diodes are compared to 1-dimensional TCAD simulations. We recommend pad diodes with different areas as test structures for a precise determination of doping profiles and for the study of radiation damage.

Current-Gate Voltage (I_{ds}-V_{ds}) measurements for different back-side voltages (V_{bs}) on n-MOSFETs with and without p-spray implant are used to determine the doping profile, the oxide-charge density and the dependence of the electron mobility on the electric-field at the Si-SiO_2interface. Standard methods from electronics are adapted to the high-ohmic silicon used for sensors, and the difficulties of extracting precise doping profiles are discussed. We use TCAD simulations to verify the analysis methods. The results are relevant for understanding and optimising the p-implants used to isolate the n^+-implants of n^+-p pixel and strip sensors.

TRACK:

Technology

Session 10: Technology and Applications (1) / 14

3D detectors for personalised particle therapy

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In particle therapy and in particular in scanning beam proton therapy, fast, accurate, and efficient characterization of intensity and energy-modulated beams and patient-specific quality assurance of such beams is a considerable challenge.
Each Intensity Modulates Proton Therapy (IMPT) beam in a treatment may employ thousands of individual pencil beams or "spots" of variable intensities, energies, and positions to produce highly inhomogeneous dose distributions within the target. The sum of contributions of all such beams is the desired dose distribution in the target.
For IMPT continuous profile scanning with a conventional 2D detectors (ion chamber or diode) is not feasible because the pencil beam sweeps continuously over a certain line in a given time, and any profile acquired with a moving detector would not be a representative of a true dose profile.

Complex systems combining several layers of 2D detectors have been used with good results but low spatial resolutions in the z direction (1cm)
A conformal 3D printed system using liquid scintillators with a patient specific segmented 3D reproduction of the target might solve some of the above questions – one could even include gold nano particles and assess their contribution to the treatment.
Furthermore the simultaneous use of Geant4 could complete the full understanding of the full dosimetry and specifically define target and surrounding healthy tissue regions with high precision helping the preparation of a personalised treatment planning.

TRACK:

Applications

Session 5: CMOS / 15

Measurements of passive structures on irradiated HV-CMOS detectors

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Results of an irradiation study on full scale HV-CMOS demonstrator chips will be presented. Samples were characterised using Edge-TCT and Sr90 measurement methods. With Edge-TCT the depleted depth was estimated for different substrate resistivities and neutron fluences. The study was complemented with measurements of charge deposited by MIPs from a Sr90 source. All measurements were performed on passive test structures using an external amplifier.

TRACK:

CMOS Sensors

Session 3: Planar Sensors (2) / **16**

Latest results from development of n^+-in-p planar pixel sensors and LGAD devices by KEK/HPK

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In this report, we present two topics: one is on the n^+-in-p planar pixels sensors with 50x50 or 25x100 um^2 pixels, and the other on the first trial of low-gain avalanche device (LGAD). The 50x50 or 25x100 um^2 pixels are laid out in a pattern of (50x50 or 25x100) + 50x450 um^2 pixels for the 2x (50x250) um^2 pixels of the FE-I4 ASIC. A number of patterns of biasing networks, including without, are implemented. The bias resistor with Polysilicon is made into a shape of vortex in an area of 50x50 um^2. These pixel sensors were flip-chipped and were gone through irradiation with protons of a fluence of 3x10^15 neq/cm^2 and test beams at CERN. The detection efficiency for the passing charged particles are evaluated and reported. LGAD devices (diodes and miniature strip sensors) were fabricated. The LGAD diodes were gone through the irradiation of gammas or neutrons. The responses were measured with LED lights. The first results are presented.

Work done by ATLAS-Japan Silicon Collaboration.

TRACK:

Planar Sensors

Session 1: Introduction / **17**

Radiation hardness of thin LGAD detectors

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Thin Low Gain Avalanche Detectors suitable for timing applications at LHC were produced along the control samples by CNM and FBK. The effects of radiation on gain were studied after reactor neutron and 200 MeV pion irradiations. A significant decrease of charge was observed after irradiation in line with previous measurements pointing to the decrease of electric field in the multiplication region. Unlike for sensors of standard thickness operation at very high voltages (>600 V) leads to gain also at equivalent fluences beyond 1e15 cm-2, a consequence of very high average electric field in the sensor. At fluences beyond few times 1e15 cm-2 there is no difference between standard and LGAD detectors in terms of gain at very high voltages.

TRACK:

UFSD, LGAD

Session 6: Electronics / 18

ATLAS ITK strips ASIC: design and radiation hardness

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The 130nm CMOS node is the technology of choice for the design of ASICs for many current state-of-the art vertex detectors and for future trackers at high luminosity experiments. This technology is chosen among other reasons for its radiation hardness. Experience with 130nm ASICs in ongoing experiments shows however that leakage current of NMOS transistors at low doses can lead to a substantial increase of the chip current with potentially severe consequences on the entire detector system.

The ATLAS ITK strip detector for the HL-LHC employs this technology for the design of on-stave readout and control chips. The 130nm chip set is made of the strips readout chip, the so-called ATLAS Binary Chip (ABCStar), the Hybrid Controller Chip (HCCStar) to interface the ABC chips to the service bus, and the Autonomous Monitor and Control Chip (AMAC) providing both monitoring and interrupt functionality. A thorough characterisation of the total ionising dose (TID) effects on the parameters of the chips needs to be carried out to estimate the current increase as a function of dose and temperature. This allows the development of models to predict the electronics power consumption during operation and to design a detector system able to cope with the change in current over the experiment lifetime.

The talk will introduce the ABCStar, HCCStar and AMAC chips, and review the effects of TID on 130nm CMOS technologies. Results of irradiations with gamma rays and protons of the ASICs prototypes will be presented, and the model of power increase as function of temperature and dose will be discussed.

TRACK:

Electronics

Session 2: Planar Sensors (1) / 19

A Long-Term Annealing Study of Irradiated P-Type Sensors

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The silicon-based tracking detector systems in the HL-LHC upgrade will be exposed to highly adverse radiation conditions for more than a decade, without access options for service or repair. It is therefore imperative to understand and predict the long-term evolution of sensor properties, including the signal collection efficiency and the leakage current. In this context, we present a summary of long term annealing studies performed on miniature p-type strip sensors from a leading manufacturer, irradiated up to a fluence of 2e15 n_eq/cm^2. Sensors were subjected to annealing at two temperature scales, room temperature and 60℃, and comparative measurements were undertaken. The measurements include the charge collection and leakage current behaviour.

Based on these measurements, we find that the charge multiplication effect at high bias voltages decreases with time, indicating that we should not blindly rely on charge multiplication as a means to achieve a higher signal level. We also estimate the scaling factor between the two temperatures and the behaviour of the effective doping concentration. The scaling factor commonly used does very significantly exceed the one we measure in this study. This indicates that the results from the accelerated annealing studies commonly undertaken give a far too optimistic picture of the long-term evolution of silicon detectors in HL-LHC conditions.

TRACK:

Planar Sensors

Session 5: CMOS / 21

HV-CMOS developments for the CLIC vertex detector

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Advancements in CMOS fabrication over the past decade have led to a proliferation of new silicon detector concepts in recent years, leading beyond current hybrid pixel detectors with passive diode sensors. Each technology offers both advantages and drawbacks, and must be matched to the application in hand. One of those currently under consideration for the CLIC vertex detector is a commercial 180 nm High Voltage (HV-) CMOS process, where on-pixel circuitry is implemented in a deep n-well which shields it from the substrate. This scheme allows significant bias voltages to be applied to the device, facilitating fast charge collection and a depletion depth of up to several tens of microns. The readout scheme envisaged by CLIC is for capacitive coupling to a dedicated 65 nm CMOS readout ASIC, with the HV-CMOS acting as an "active" sensor. This presents challenges beyond the exploration of the CMOS technology: coupling between the chips must be controlled, necessitating further study on the device glueing and cross-capacitancies between neighbouring pixels. The chip planarity will directly affect the transmitted signal, in addition to the precision with which the devices are bonded. An overview of current R&D towards the reliable production of capacitive assemblies for CLIC will be presented, along with the next-generation ASICs which have recently been submitted for fabrication.

TRACK:

CMOS Sensors

Session 5: CMOS / 22

Technologies for the CLIC tracker

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The vertex- and tracking detectors at the proposed high-energy CLIC electron-positron collider will be based on small-pitch silicon pixel- or strip detectors. The requirements for these detectors include single-point position resolutions of a few microns and time stamping with an accuracy of approximately 10 ns. For the outer tracking region, fully integrated CMOS sensors are under consideration. Test beam measurements performed on an analog 180nm CMOS demonstrator pixel chip on a high resistive substrate show good spatial and timing resolution in line with the CLIC requirements. In addition, test beam characterization of an integrated prototype pixel-chip fabricated on Silicon-on-Insulator material will be presented.

TRACK:

CMOS Sensors

Session 8: 3D Sensors (1) / 23

Development of Thin, Narrow-Pitch 3D Pixel Sensors for HL-LHC

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We report on the development of new 3D pixel sensors oriented to the Phase 2 Upgrades at the High-Luminosity LHC (HL-LHC), carried out within the framework of the INFN-FBK "Phase 2" R&D program.
These sensors have increased pixel granularity (e.g., 50×50 or 25×100 µm2 pixel size), thinner active layer (~100 µm) with columnar electrodes having narrower size (~ 5 µm) and reduced spacing (~ 30 µm), as required for high radiation hardness (up to a fluence of 2×1016 neq cm-2).
The talk will cover experimental results and simulations relevant to the sensors and test structures from the first batch fabricated at FBK on 6" SiSi DWB wafers, and technological and design aspects relevant to the fabrication of the second batch, funded by the AIDA2020 project, that is being launched.

TRACK:

3D Sensors

Session 10: Technology and Applications (1) / 24

Novel MCz-Silicon Material and Applications for the Radiation Detection Community

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Magnetic Czochralski (MCz) silicon wafers have been successfully employed in sensor applications for high-energy physics, space and medical applications. It is known to have a superior radiation tolerance and robustness compared to Float-Zone (FZ) silicon and better availability. On the other hand, the higher oxygen concentration of the material can lead to the generation of Thermal Donors (TD's) in the sensor processing steps under certain conditions. Those TD's change the resistivity of high-resistivity material and can only be dissolved by high-temperature annealing steps.

Okmetic Oyj has a long tradition in the fabrication process of MCz wafers and is dedicated to developing new crystal pulling techniques in order to offer ideally suited materials for respective applications.
We have developed a new Advanced-MCz material with resistivities above 5 kΩ cm and an oxygen concentration ranging from 1×10^{17} cm^{-3} to 2.5×10^{17} cm^{-3}. This material still offers the beneficial properties of oxygen-rich MCz but has a reduced probability of generating TD's. The material will be very robust for thermal cycles in the sensor processing steps but still feature the positive properties of MCz.
In this overview, we will present the simulated generation of TD's for different temperatures, material properties like IR-absorption spectra in comparison to other Si-materials and wrap up some applications which might be interesting for the detector community.

TRACK:

Technology

Session 7: LGAD / 25

Progress report on the characterization of LGAD microstrip sensors (n-in-p and p-in-p) and their readout tests using a dedicated high dynamic-range Charge-Sensitive Amplifier-Shaper front-end developed on the AMS 180nm technology.

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We will present here the most recent results from the laser and test-beam based characterization of fully functional s-LGADs (n-in-p strip LGAD) and i-LGAD (p-in-p strip LGAD) sensors. Measured current transient shapes were compared against TCAD simulations for a better understanding of the signal formation process, sensor response uniformity, signal amplification and timing features; tracking performance of a i-LGAD device was assessed at the SPS particle's beam using off-the-shelf Alibava readout electronics; finally, it will be shown a preliminary study of an assembly consisting of s-LGAD sensors read out with of dedicated analog front-end which implements a charge amplifier-shaper manufactured on the AMS 180nm technology

TRACK:

UFSD, LGAD

Session 2: Planar Sensors (1) / 26

Ongoing activities at CiS

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The CiS research institute is engaged in developments of radiation detector technologies on several different fields. Current projects are dealing e.g. with large area thinned sensors, active edge sensors, sensor-chip packaging technologies and defect engineering.
For large area sensors, the need for smaller thicknesses can be approached by etching cavities to the sensors back side while guaranteeing stability on wafer level by thick frames at the edges. A first n-in-p pixel run with membranes up to 4x4cm² and target thicknesses of 100 and 150µm is finished and shows promising results. The technology is currently transferred to 6" wafer size. First results of etching trials with dummy wafers with larger thinned areas will be shown as well.
We are now focused on development of large area thinned double sided detectors and very thin dead layers.
An active edge sensor run is finished. Three side wall doping methods have been tested in combination with two wafer thicknesses as well as with n- and p-substrates. Electrical measurements show the functionality of sensors with inactive edge widths down to 50µm.
CiS is currently focusing on developing additional technologies for custom respectively application specific hybrid and multifunctional module solutions which match to each other detector technology, for instance multifunctional large area silicon submounts.

TRACK:

Planar Sensors

Session 7: LGAD / 27

STUDY AND CHARACTERIZATION OF LOW GAIN AVALANCHE DIODES

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Low Gain Avalanche Diode, a novel concept of silicon sensors, are detectors with intrinsic gain due to a thin gain layer implanted underneath the n electrode. In this contribution we will Illustrate several measurements performed in laboratory to understand the characteristic of the gain layer.

Measurements will be showed (leakage current, breakdown voltage, capacitance and doping profile of the gain layer) and a comparison between gain layers with different dose implant will be discussed.

We will also present group of measurements on the same LGAD pad type, to verify reproducibility.

TRACK:

UFSD, LGAD

Session 4: Poster Session / 28

Charged particles detector based on a two-tier avalanche pixelated sensor

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In this work, carried out in the framework of APiX2 project funded by Istituto Nazionale di Fisica Nucleare (INFN), a pixelated device for the direct detection of charged particles is described and characterization measurements are reported. The working principle of the device is the discrimination between particle-triggered detections and dark counts, obtained with a coincidence circuit embedded at pixel level.
The device is composed of two arrays of Geiger-mode avalanche detectors vertically-aligned and bump bonded. Each array, fabricated in a 150nm CMOS process, is formed of 48 x 16 pixels with a pitch of 50 µm x 75 µm; four different active areas were included from a minimum of 30 x 30 µm2 to a maximum of 43 x 45 µm2. Pixel electronics consists of a quenching transistor, a programmable-length monostable, a coincidence circuit and a memory to store the coincidence events.
A preliminary campaign of measurements was performed to electrically characterize the functionality of the device. The DCR of each layer was measured together with the coincidence rate with different lengths of the monostable pulse. A validation of the sensor was performed with a 90Sr β source.

TRACK:

CMOS Sensors

Session 9: 3D Sensors (2) / 29

Simulation and testing of thin silicon microdosimeters realized with 3D technology

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Modern cancer treatments have become increasingly more sophisticated in the past years and therefore require a real-time, reliable radiation dose monitoring system in treatment planning and monitoring, with high spatial resolution. Silicon microdosimeters are excellent candidates as they are small in size and have high spatial resolution. The ease of coupling them to readout electronics makes them the first choice for a real time on-line system.

The devices in this study were realized with 3D technology on SOI wafers with active sensor thickness of 10 μm. This technique allows the formation of cylindrical sensitive cells with diameters of between 15 and 30 μm. The sensor design and configuration were based on information from previous microdosimeters developed by SINTEF MiNaLab in collaboration with the Centre for Medical Radiation Physics at the University of Wollongong, Australia. Numerical simulation was an important design tool and some results will here be shown.

Electrical and functional testing of the completed microdosimeters will be presented and discussed. The charge collection tests were performed at beam line ID21 at the ESRF, Grenoble, France and at ANSTO microprobe, using a sub-micron X-ray and He ion beams respectively demonstrating high definition of the sensitive volume. Testing on C-12 ion therapeutic beam at HIMAC, Japan demonstrated the ability of the MicroPlus probe with new sensors to derive RBE in a field and dose equivalent in out of field with submillimeter spatial resolution.

Finally, the latest results from a fabrication technique aiming at integrating tissue-equivalent materials for embedding of SVs directly onto the sensor will be presented. The final scope of this process is to achieve the generation of secondaries by gamma and neutron radiation exactly like in human tissue, allowing the application of these microdosimeters for dose equivalent measurements for personal radiation protection in mixed radiation fields.

TRACK:

3D Sensors

Session 6: Electronics / 30

TOFFEE a fully custom readout ASIC for timing applications with UFSD

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Time tagging is becoming a fundamental tool for the future of High Energy Physics, where the high luminosity will introduce hundreds of overlapping events (pile-up) making really tricky to take and analyse data. This is the case of the high luminosity LHC, where the expected number of events per bunch crossing is ~150-200. A possible strategy for pile-up mitigation consists in exploit time tagging to distinguish events overlapping in space but separated in time by few tens of picoseconds. For this reason, the so called Ultra Fast Silicon Detectors (UFSD) and a fully custom readout ASIC have been developed. The ASIC is called TOFFEE and is designed in a standard 0.11 μm CMOS technology. The chip has been optimized for the readout of signals produced by UFSD 50 μm thick sensors to cope with the CMS-TOTEM Precision Proton Spectrometer (CT-PPS) time resolution requirement of 30 ps per detector plane. TOFFEE consists of 8 independent channels, each with a charge sensitive amplifier (CSA), a single threshold discriminator, a stretcher and a LVDS driver. The readout chain has been designed to work with the High Precision TDC (HPTDC) which requires a minimum pulse width of 5 ns. This talk reports the design and the first measurement results of TOFFEE.

TRACK:

Electronics

Session 8: 3D Sensors (1) / 31

Beam test measurements of irradiated 3D pixel sensors with 50x50 μm² pixel size

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The ATLAS experiment will replace the entire inner tracking detector with a completely new silicon-only system. 3D silicon pixel sensors are promising candidates for the innermost layers of the Pixel detector due to their excellent radiation hardness and low power dissipation. 3D pixel sensors with 50x50 and 25x100 μm² pixel pitches have been produced at CNM Barcelona and studied by IFAE. The smaller pixel size will allow to cope with the increased particle rate at HL-LHC and in addition the reduced electrode distance is expected to increase the radiation hardness. A chip with pixel size of 50x50 μm² (RD53 - compatible with both small pixels) is still under development and the initial studies of the small-pitch 3D pixel sensor prototypes were made using the FEI4 readout chip (pixel size 50x250 μm²), presently used on the current innermost layer of ATLAS (IBL).
The hit efficiency of 50x50 μm2 sensors was measured in beam tests at CERN SPS after uniform (at KIT to 5e15 neq/cm2) and non uniform irradiations (at CERN PS up to 1.4e16 neq/cm2). The 5e15 neq/cm2 irradiation point is ideal to compare to IBL qualification devices due to the same fluence and irradiation facility. The non uniform irradiation allows to study a range of different fluences within the same device. The operation voltage of the new irradiated small-pixel sensors will be compared with the IBL-type 3D sensors.

TRACK:

3D Sensors

Session 9: 3D Sensors (2) / 32

Recent beam test results of 3D detectors constructed with poly-crystalline diamond

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We have measured the pulse height and spatial resolution in 3D detectors constructed with single-crystal and poly-crystalline CVD diamond. The work using single-crystal diamond was performed in 2014 and published in 2015[1]. Since our first results we have constructed 3D detectors using poly-crystalline diamond. Our results indicate that the 3D geometry allowed us for the first time to collect essentially all the deposited charge in a poly-crystalline diamond detector. This result indicates that the grain boundaries in poly-crystalline material may not be fundamental impediments to charge collection in diamond. The electrical properties and beam test results from 2015 and 2016 of the recent single-crystal and poly-crystalline 3D devices we have constructed will be presented and compared.

[1] F. Bachmair, et al.,
"A 3D diamond detector for particle tracking,"
Nucl. Instr. and Meth. A 786, 97 (2015).

TRACK:

3D Sensors

Session 8: 3D Sensors (1) / 34

Pixel detector development for CMS Phase-II upgrade

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The talk will report on the INFN ATLAS-CMS joint research activity in collaboration with FBK, which is aiming at the development of new pixel detectors for the LHC Phase-2 upgrades. The talk will cover the main aspects of the research program, starting from the sensor design and fabrication technology, with an outlook on the future steps using both Silicon On Insulator (SOI) and Direct Wafer Bonded (DWB) wafers. The RD covers both planar and 3D, made with columnar technology, pixel devices. All sensors are low thickness n-in-p type, as this is the mainstream foreseen for the HL-LHC pixel upgrades. Results from device characterization measurements will be shown. Hybrid modules, with 100µm and 130µm active thickness, connected to the PSI46dig readout chip, have been tested on beam test experiments. Preliminary results from the test beam will be presented.

TRACK:

3D Sensors

Session 4: Poster Session / 35

Edgeless planar pixel sensors with ATLAS and CMS designs produced by FBK-CMM

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In view of the LHC roadmap towards the High Luminosity LHC (HL-LHC), n-on-p silicon technology is a promising candidate to achieve a large area equipped with pixel sensors, since it is radiation hard and cost effective.
The talk reports on the first batch of n-on-p edgeless planar pixel sensors produced by FBK-CMM using an Active Edge technology where the detector edge is made by staggered trenches. The process was performed both on Si-Si and SOI wafers. Several kinds of pixel detectors, e.g., compatible with read-out chips such as FE-I4, PSI46, and RD53A, have been realized on wafers.
In the talk we will present the sensor technology and offer an overview of the first electrical characterization of the devices we have produced.

TRACK:

Planar Sensors

Session 9: 3D Sensors (2) / 36

The CT-PPS tracking system with 3D pixel detectors

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The CMS-TOTEM Precision Proton Spectrometer (CT-PPS) project will add in the next months tracking and timing detectors in Roman pots (RP) positioned on either side of CMS, at about 210 m from the interaction point. CT-PPS allows the measurement of forward leading protons, opening the possibility of detailed studies of diffractive physics and central exclusive production in standard LHC running conditions. The tracking system of the CT-PPS apparatus will consists of two detector stations per arm equipped with six 3D silicon pixel-sensor modules, each read out by six PSI46dig chips. 3D sensors have been chosen for their high radiation hardness and the possibility of a reduced inefficient area at the edge of the sensor toward the beam. Sensors have been designed and manufactured by CNM in double-sided technology, with not-completely passing-through columns and 200 um slim edges. The front-end electronics has been designed to fulfill the mechanical constrains of the RP and to be compatible as much as possible with the readout chain of the CMS pixel detector. The tracking system is currently under construction and testing. In this contribution the final design

and the expected performance of the CT-PPS tracking system will be presented. A summary of the studies performed, before and after irradiation, on the 3D detectors produced for CT-PPS will be given.

TRACK:

3D Sensors

Session 5: CMOS / 37

Development of HV-MAPS detectors at the University of Liverpool

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The industry standard High Voltage-CMOS (HV-CMOS) technology is emerging as a very attractive option to track particles in planned future high energy physics experiments. Tracker detectors in HV-CMOS technologies combine in the same substrate material a high bias voltage to create a large depleted sensing volume, which enables fast charge collection by drift and high radiation tolerance, and high integration density of CMOS electronics. Novel developments have shown the feasibility of fully monolithic HV-CMOS detectors, the so-called High Voltage-Monolithic Active Pixel Sensors (HV-MAPS), which integrate analog and also digital processing front-end electronics in the same sensor chip either at the sensor matrix periphery or inside the pixel area, thus suppressing the need for bump bonded or glued readout chips.

In this talk, I will report on recent submission plans and results from HV-MAPS detectors developed by a collaboration of institutes that includes the University of Liverpool.

TRACK:

CMOS Sensors

Session 3: Planar Sensors (2) / 39

Proton-induced bulk damage in silicon pad-diodes

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It has been previously observed that silicon radiation damage depends on the type and energy of the radiation, even after scaling with the hardness factor derived from NIEL (Non-Ionising-Energy-Loss)

hypotheses. Nowadays, little is known about the energy dependence of proton-induced bulk defects in silicon sensors.

In this work, 200 μm silicon pad-diodes were irradiated with protons (with kinetic energies of 23 MeV, 188 MeV and 23 GeV), up to a ϕ_{neq} (1 MeV neutron-equivalent fluence) of
$3 \cdot 10^{14}$ cm^{-2}. The investigated samples were fabricated on n- and p-type MCz (Magnetic Czochralski), FZ (Float Zone) and dd-FZ (Float Zone with deep diffusion) silicon crystals.
Current-Voltage (IV), Capacitance-Voltage-frequency (CVf) and Thermally Stimulated Current (TSC) measurements were performed at subsequent annealing steps at 80°C, for annealing times between 0 and 60 minutes.

A new TSC analysis method is presented, which implements the SRH (Shockley-Read-Hall) statistics for radiation-induced point-like and cluster defects. Several challenges posed by measurement and analysis of TSC spectra are discussed.
From the TSC spectra, the properties and introduction rates of the different defect states are derived. A strong correlation between the leakage current (from IV characteristics) and the concentration of defect clusters (from TSC spectra) is found. In addition, the impact of specific defects on the space charge will be presented by comparing the results from CVf and TSC measurements.

TRACK:

Planar Sensors

Session 1: Introduction / **40**

From pixel module to larger detector structures

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For the High-Luminosity upgrade of the LHC, a new pixel detector is foreseen for the ATLAS experiment. Currently, the prototyping phase is ongoing to build various detector components. The standard hybrid pixel modules consisting of a silicon pixel sensor and front-end electronics connected via bump-bonging are widely used. Prototypes with p-type sensors are built and tested. In a second step the modules are assembled and tested on larger structures so-called staves. This includes various new challenges. In the talk the challenges, the prototyping status and plans for a larger structure are presented.
In addition, as an alternative module assembly step, the concept deploying through-silicon-vias and laser soldering will be shown. Using modified components of standard modules first trials of TSV modules are discussed.

TRACK:

Systems Issues

Session 7: LGAD / **41**

Gain and time resolution of 50 um thin LGAD before and after irradiation

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Silicon Low-Gain Avalanche Detectors (LGAD) are a promising technology for high energy physics experiments where high precision segmented timing sensors are required. This can be used for example in the ATLAS High Granularity Timing Detector (HGTD) or forward experiments like the ATLAS Forward Proton (AFP) and CMS-TOTEM Precision Proton Spectrometer (CT-PPS) for pileup removal. LGAD from a recent CNM production on a 50 um thin substrate were tested before and after neutron irradiation at Ljbuljana to 3e14 and 1e15 neq/cm2. The gain was measured with Sr90 beta particles, showing the expected gain degradation after irradiation, supposedly due to acceptor removal. The time resolution was studied at AFP beam tests in July and September 2016 at CERN SPS. A time resolution of <30 ps was achieved before irradiation, as well as after a fluence of 3e14 neq/cm2. At 1e15 neq/cm2, a time resolution of ~55 ps was measured at the maximum applied voltage of 620 V. It is found that the time resolution before and after irradiation follow a similar behaviour as a function of the gain achieved.

TRACK:

UFSD, LGAD

Session 6: Electronics / 42

Results from CHIPIX65 prototype of a New Generation Pixel Read-out ASIC in 65nm CMOS for HL-LHC experiments

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A first prototype of a readout ASIC in CMOS 65 nm for a pixel detector at High Luminosity LHC is described. The pixel cell area is of 50x50 um2 and the matrix consists of 64x64 pixels. The chip was designed to guarantee high efficiency at extreme data rates for very low signals and with low power consumption. Two different analogue very-front-end designs, one synchronous and one asynchronous, were implemented, both occupying an area of 35x35 um2. ENC value is below 100 e- or an input capacitance of 50 fF and in-time threshold below 1000 e-. Leakage current compensation up to 50 nA with power consumption below 5 uW. A ToT technique is used to perform charge sampling with 5-bit precision using either a 40 MHz clock or a local Fast Oscillator (up to few hundred MHz). Internal 10-bit DAC's are used for biasing, while monitoring is provided by a 12-bit ADC. A novel digital architecture has been developed which maintains high efficiency (above 99.5%) at pixel hit rates up to 3 GHz/cm2, trigger rates up to 1 MHz and trigger latency of 12.5 us. The total power consumption per pixel is below 5 uW. Analogue dead-time is below 1%. Data are sent via a serializer connected to a CMOS-to-SLVS transmitter working at 320 MHz. All IP-blocks and very-front-ends used are silicon proven and tested after high irradiation doses of 500-800 Mrad. The chip was designed as part of the Italian INFN CHIPIX65 project and in close synergy with the international CERN RD53 collaboration on 65 nm CMOS and was submitted in July 2016 for production. Test results of the prototype will be described. All ASIC functionalities are fully working, with a complex digital design working while the analog very front end works at 250e- threshold, confirming the fast, low noise and low power performances

TRACK:

Electronics

Session 7: LGAD / 43

Last measurements and developments on LGAD detectors

Authors: Maria del Mar Carulla Areste[1]; David Flores Gual[2]; Giulio Pellegrini[3]; Salvador Hidalgo Villena[4]; David Quirion[5]; Angel Merlos[None]

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Last measurements of LGAD devices on 50 µm and 70 µm epitaxial wafers will be presented, as well as the effect of neutron irradiation on Gallium diodes.

TRACK:

UFSD, LGAD

Session 8: 3D Sensors (1) / 45

3D sensors measurements with FEi4 read-out chips

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During the 2023-2024 shutdown, the Large Hadron Collider (LHC) will be upgraded to reach an instantaneous luminosity up to 7×10 cm-2 s-1. This upgrade of the accelerator is called High-Luminosity LHC (HL-LHC). The ATLAS and CMS detectors will be replaced to meet the challenges of HL-LHC: an average of 200 pile-up events in every bunch crossing and an integrated luminosity of 3000 fb-1 over ten years.

In order to have high resolution tracking performance, in such a challenging and dense environment, pixel cell size needs to be minimized. A new 65 nm Front-End is being developed by the RD53 collaboration with a readout cell size of 50 × 50 μm2 . The new front-end chip will be compatible with 50 × 50 μm2 or 25 × 100 μm2 pixel size sensors.
Italian groups are involved in the R&D effort on the design and production of new 3Ds sensors with thicknesses of 100 to 200 μm, 5 μm diameter columns and smaller pixel cells. A first batch of sensors have been produced by FBK Trento. As the new read-out chip with small pixel size is not available yet, sensors have been bump-bonded by Leonardo to FE-I4 chips, the read-out electronics used in the Pixel layer inserted in ATLAS in 2014. Although the read-out size is 50x250 μm2 , measurements of the new smaller size sensor pixel have been done.
In this talk we present an overview of these results including laboratory measurements such as IV curves, noise and charge collection using sources and laser setup and also preliminary measurements of efficiency and charge collection from a test beam at the Cern SPS.

TRACK:

3D Sensors

Session 4: Poster Session / 46

Laboratory measurements of 3D devices assembled with FEi4 read-out electronics

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During the 2023-2024 shutdown, the Large Hadron Collider (LHC) will be upgraded to reach an instantaneous luminosity up to 7×10 cm-2 s-1. This upgrade of the accelerator is called High-Luminosity LHC (HL-LHC). The ATLAS and CMS detectors will be replaced to meet the challenges of HL-LHC: an average of 200 pile-up events in every bunch crossing and an integrated luminosity of 3000 fb-1 over ten years.

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This short contribution is meant to be a poster detailing the measurements done in the laboratory on all the 3D devices. So it will report the full statistics of the assembled devices, their IV curves, noise as a function of the pixel size,
charge collection using sources and laser setup.

TRACK:

3D Sensors

Session 4: Poster Session / 48

Simulation of 3D Diamond Detectors

Author: Giulio Tiziano Forcolin[1]

Co-authors: Alexander Oh [1]; Iain Haughton [1]; Steven Alexander Murphy [1]

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The development of 3D Diamond detectors is raising interesting prospects for future Particle Physics experiments due to the increased radiation hardness resulting from a combination of a 3D geometry and the use of an inherently radiation hard material. As well as for medical applications due to the tissue equivalence of diamond.

Test beams have been performed on various 3D Diamond devices to study their performance using 4.5MeV and 120GeV protons. To understand the observed measurements, simulations have been carried out using Sentaurus TCAD and good agreement has been found between simulation and experimental data. Simulations have also been used to make predictions on what fabrication parameters and geometries would improve the performance of the devices.

TRACK:

3D Sensors

Session 11: Technology and Applications (2) / 49

Micro-channel cooling for silicon detectors: status and perspectives at AIDA-2020 mid-term

Authors: Paolo Petagna[1]; Alessandro Mapelli[1]

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With a dedicated Work Package to ultra-light and highly efficient integration of thermal management and support elements for the future silicon detectors, AIDA-2020 has provided the ideal framework for sensible progresses on micro-channel cooling. Through the creation of new synergies and the optimisation of complementary activities, the last 20 months have seen substantial advances in all identified fields of activity:

- micro-fluidic connection and interconnections
- alternative production processes for micro-channel devices
- thermo-fluid dynamics models applicable at the micro-scale
- measurement methods and set-ups

The presentation will report about the status of the work ongoing and will provide perspectives projected on the time-scale of the completion of the AIDA-2020 project.

TRACK:

Systems Issues

Session 9: 3D Sensors (2) / 50

3D diamond detectors for tracking and dosimetry

Authors: Alex Oh[None]; Iain Haughton[None]; Francisca Munoz Sanchez[None]; Giulio Forcolin[None]; Steven Murphy[None]

Advances in the laser assisted transformation of diamond into amorphous-carbon has enabled the production of a new type of particle detector - 3D diamond.

When compared to conventional planar technologies, previous work has proven a 3D geometry to improve the radiation tolerance of detectors fabricated in silicon.
This work demonstrates the same principle in diamond, with the aim of producing an accurate particle detector tolerant to extreme radiation fields.

We present the latest fabrication methods, including the use of a spatial light modulator to produce a 3D array of ~1um diameter low resistivity electrodes, and discuss the fabrication of several devices in both single-crystal and polycrystalline CVD diamond.
In order to optimise the 3D geometry, devices were fabricated with various cell geometries, and measurements obtained from various beams, all of which shall be presented.

Outside the field of high energy particle physics, a potential application for this technology includes medical dosimetry; where the high resilience to radiation damage, operation at low bias voltage with well defined active volume, in addition to high compatibility to human tissue, makes their use desirable. We shall present results obtained with 3D diamond detectors for dosimetry applications.

TRACK:

3D Sensors

Session 8: 3D Sensors (1) / 51

Characterization of small pitch 3D sensors from CNM

Author: Gervasio Gomez[1]

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Silicon pixels of area 25x100 and 50x50 square microns, fabricated at CNM using double sided 3D technology on 230 um thick wafers, are characterized using a Sr90 radioactive source and in a pion/proton test beam at the CERN SPS. Results are shown both for non-irradiated sensors and for sensors irradiated with protons at the CERN PS.

TRACK:

3D Sensors

Session 7: LGAD / 52

New Developments of Ultra Fast Silicon Detectors at FBK

Author: Giovanni Paternoster[1]

Co-authors: Francesca Cenna [2]; Gian Franco Dalla Betta [3]; Lucio Pancheri [3]; Marco Ferrero [2]; Marco Mandurrino [4]; Maria Margherita Obertino [2]; Maurizio Boscardin [5]; Nicolo Cartiglia [2]; Roberta Arcidiacono [2]; Roberto Mulargia [2]; Valentina Sola [2]

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UFSD are silicon sensors based on the Low-Gain Avalanche Diodes (LGAD) design and, due to internal gain, exhibit a signal which is a factor of ~ 10 larger than standard silicon detectors.
In this contribution we report on the design, fabrication and performances of the first fully double-sided production of segmented UFSD. The production was carried out at the FBK facility in Trento (Italy), in collaboration with the Trento University and INFN, Torino. This production houses two main type of devices: one type where a segmented gain layer is on the same side of the read-out electrodes, the other type where a uniform gain layer is on the side opposite to the pixelated electrodes (reverse-LGAD). In the latter case, we have also explored the possibility of obtaining position information via AC coupling with a segmented metal electrode.
We report an exhaustive characterization of the first samples in terms of internal gain and time resolution performance. In addition, a characterization of both reverse-LGAD and AC coupled devices will be reported.
Starting from the analysis of the first produced samples results, a new production of UFSD, based on 50um thick FZ silicon, has been designed and it is currently ongoing at FBK. This production implements different technological solutions aimed at increasing the timing performance and the radiation hardness of the detectors. Fabrication technology and numerical simulations of these new 50um thick devices will be presented and discussed.

TRACK:

UFSD, LGAD

Session 5: CMOS / 53

An overview of recent HV-CMOS results

Author: Thomas Weston[1]

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In accordance with the High-Luminosity upgrade of the LHC (HL-LHC), the current Inner Tracker (ID) of the ATLAS detector will be replaced with an all-silicon sub-detector (ITk upgrade) comprising of pixel and micro-strip silicon sensors. A candidate technology for the outer pixel layers of the ITk is a new radiation hard monolithic pixel silicon sensor, based on High Voltage CMOS technology, allowing for the pixel electronics to be embedded in the silicon sensor itself. Results of the characterisation of a full demonstrator sensor produced in the 350nm process are presented, as part of an overview of recent results of HV-CMOS sensor technologies.

TRACK:

CMOS Sensors

Session 1: Introduction / 54

The role of detectors in nuclear physics measurements for radiotherapy and space applications

Author: Chiara La Tessa[1]

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Many challenges in radiotherapy with ions and in space radioprotection are related to the investigation of the same nuclear processes and require similar experimental setups to be tackled. The Theoretical Institute for Fundamental Physics Applications (TIFPA) in Trento, Italy, focuses its research on these two fields and can take advantage of the Trento protontherapy center, where it coordinates and runs the activities at the experimental room in operation since 2016. An overview of the scientific program conducted by TIFPA and the applied detection methodologies are presented here.

TRACK:

Applications

Session 4: Poster Session / 55

TCAD simulations of breakdown voltage and isolation properties of 3D sensors

Authors: Gilberto Giugliarelli[1]; Gian-Franco Dalla Betta[2]; Daniele Passeri[3]; Francesco Moscatelli[4]; Arianna Morozzi[5]; Roberto Mendicino[6]

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We report on the initial results from a TCAD simulation study aimed at investigating the breakdown voltage and read-out electrode isolation properties of 3D sensors. Both these features can vary significantly with sensor geometry and process details; moreover, after irradiation, they strongly depend on both bulk damage and surface damage, making any prediction based on analytical models unreliable. TCAD simulations can effectively address all the involved aspects and their mutual interplay in a quantitative way, so they can aid in the interpretation of experimental results from existing samples and in the design and optimization of new sensors oriented to the HL LHC upgrades. However, in order to yield accurate results, comprehensive radiation damage models, incorporating both bulk damage and surface damage (in particular for the interface state parameters), must be adopted, that are currently being developed by several groups.
In this study, we have used the new combined bulk/surface model from the University of Perugia. As a first step, simulations have been performed with reference to the double-sided 3D sensors from FBK used in the ATLAS IBL, for which a wide set of experimental results are available for validation purpose. In particular, the sensitivity of the breakdown voltage to several parameters of the radiation damage model has been analysed, also studying the corresponding impact on the surface isolation properties. We will report on selected results from simulations, in comparison to experimental measurements.

TRACK:

Simulations

Session 1: Introduction / 56

HVCMOS Sensors for high rate particle tracking

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HVCMOS sensors employ depleted diodes as sensor elements. HVCMOS sensors have a high time resolution and a good radiation tolerance. Several large area prototypes have been designed and tested recently. The application of these sensors are particle physics experiments such as Mu3e and ATLAS. Novel electronic blocks such as fast data transmitters, waveform sampling circuits, data reduction methods have been implemented. Design details and experimental results will be presented.

TRACK:

Session 4: Poster Session / 57

Study of Irradiation Effect on Active Doping Profile in Silicon Detectors

Authors: Tasneem Rashid[1]; Abdenour Lounis[2]; Dmytro Hohov[1]

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We used to measure total doping profile using Secondary Ion Mass Spectrometer (SIMS). But to study the effects of irradiation on the pixel silicon we need to know how is the doping profile is changing after the irradiation. This talk addresses the study of the irradiation effects on active doping profile by
developing new promising method call Transfer Linear Method (TLM). The TLM method enables us to see the variation of electrically active dopant after the irradiation and to compare the active doping profiles before and after irradiation. For this test structures of four different wafers have been
manufactured specially to characterize the active dopant concentration. In this talk I will show the first results of TLM method will be shown and discussed.

TRACK:

Session 5: CMOS / 59

First tests of a novel radiation hard CMOS sensor process for Depleted Monolithic Active Pixel Sensors

Author: Heinz Pernegger[1]

[1] *CERN*

Corresponding Author: heinz.pernegger@cern.ch

The upgrade of the ATLAS tracking detector for the High-Luminosity Large Hadron Collider at CERN requires the development of novel radiation hard silicon sensor technologies. Latest developments in CMOS sensor processing offer the possibility of combining high-resitivity substrates with on-chip high-voltage biasing to achieve large depleted active sensor volume. We characterized depleted monolithic active pixel sensors (DMAPS), which were produced in a novel modified imaging process implemented in the TowerJazz 180nm CMOS process (manufactured by Tower Semiconductor Ltd, Israel) in the framework of the monolithic sensor development for the ALICE experiment. The novel process modification implemented in this technology allows full depletion of the epi layer even after substantial irradiation. The designed sensor aims to minimise the capacitive load on the amplifier and enable fast signal collection, in time for the LHC 25ns bunch spacing. Separating the collection well from digital area allows to decouple analog and digital electronics to further minimize capacitance and prevent cross-talk. The radiation hardness of the charge collection to Non Ionizing Energy Loss (NIEL) has been characterized for the different pixel sensor cell designs. The talk focuses on the charge collection properties measured in the laboratory using radioactive sources, focused X-ray beam tests and in test beams. The talk summarises results on charge collection efficiency and charge collection time measured in the lab and beam tests, local efficiency distribution in the pixel as determined in beam tests with comparisons before and after irradiation. Finally an outlook the design of a full-reticle size CMOS sensors towards ATLAS specifications will be given.

TRACK:

CMOS Sensors

Session 11: Technology and Applications (2) / 60

Precision timing at CMS for HL-LHC

Author: Artur Apresyan[1]

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High energy particle colliders experiments are facing ever more challenging conditions, operating at todays accelerators capable of providing instantaneous luminosities of 1034 cm-2s-1 and above. The high center of mass energy, the large number of simultaneous collision of beam particles in the experiments and the very high repetition rates of the collision events pose huge challenges. They result in extremely high particle fluxes, causing very high occupancies in the particle physics detectors operating at these machines. A precise timing information with a precision of around 10 ps and below is seen as a major aid in the reconstruction of the physics events under such challenging conditions. I will present the recent progress in enabling such technologies for collider experiments, and the expected improvements to the event reconstruction from high precision timing detectors.

TRACK:

Applications

61

Welcome

TRACK:

62

Registration

Session 1: Introduction / 63

Microscopic observation of individual neutron interactions in Silicon

Authors: Stanislav Pospisil[1]; Benedikt Ludwig Bergmann[2]

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The first part of the contribution will be devoted to description of the family of Medipix/ Timepix semiconductor pixel detectors including the corresponding R/O electronics. A short demonstration of capabilities of the devices for high resolution (micrometric and nearly nanometric) radiography and 3D imaging by means of X-rays and neutrons will follow. Also the ability of Timepix pixel detectors to visualize individual particle tracks in the semiconductor sensor (solid state) similarly to nuclear emulsions, cloud chambers, bubble chamber and micro-pattern gaseous detectors will be documented. Advantages of this "particle tracking" capability will be evidenced by examples of use of the Timepix detectors for measurements of composition and spectral characteristics of mixed radiation fields around physics experiments, hadron therapy facilities, and in space research. The main part of the presentation will be dedicated to results of measurement of single neutron interactions in silicon, namely to ionizing energy depositions in a 300 µm thick silicon layer after fast neutron impact. With the Time-of-Flight (ToF) technique, the ionizing energy deposition spectra of recoiled silicon nuclei and of secondary charged particles were measured and assigned to (quasi-) monoenergetic neutron energies in the range from 180 keV to hundreds of MeV. Representative spectra will be shown and interpreted. By separating the ionizing energy losses of elastically and inelastically recoiled silicon nuclei from their energies expected from kinematics of the scattering at given neutron energy, the ratio between ionizing (IEL) and non-ionizing energy losses (NIEL) of the nuclei within the silicon lattice was determined. The data give supplementary information to the results of a previous measurement and are compared with different theoretical predictions.

TRACK:

Applications

Session 3: Planar Sensors (2) / 64

Industrial Production of Large-Area Si-Detectors

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HEPHY Vienna and Infineon Technologies are working on the establishment of industrial processes for both AC-coupled and DC-coupled large-area n-in-p Si sensors for high energy physics and medical applications. In the talk the present status and the outlook will be presented.

TRACK:

Technology

Session 2: Planar Sensors (1) / 65

Hybrid pixel modules and R&D on compact modules

Authors: Susanne Kuehn[1]; Richard Bates[2]; Heinz Pernegger[1]; Fabian Huegging[3]

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For the High-Luminosity upgrade of the LHC, a new pixel detector is foreseen for the ATLAS experiment. Currently, the prototyping phase is ongoing to build various detector components. The standard hybrid pixel modules consisting of a silicon pixel sensor and front-end electronics connected via bump-bonging are widely used. Prototypes with p-type sensors are built and tested.
In addition, the R&D activity deploying an alternative module assembly step, the concept using through-silicon-vias and laser soldering will be shown. Using modified components of standard modules first trials of TSV modules are discussed.

TRACK:

Planar Sensors

66

Conference Photograph

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Tour and Dinner

Bus Tour to Casa Depero Museum (http://www.mart.trento.it/context.jsp?ID_LINK=683&area=137)

Dinner at Locanda D&D (http://www.locandaded.it/en/)

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Conference Closing

Session 11: Technology and Applications (2) / 69

The pixel module for the Inner Tracking System upgrade of ALICE at LHC

Author: Benedetto (On behalf of the ALICE Collaboration) Di Ruzza[1]

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The ALICE (A Large Ion Collider Experiment) detector at the CERN LHC collider was designed to address the physics of strongly interacting matter, and in particular the properties of the Quark-Gluon Plasma (QGP) using proton-proton, proton-nucleus, and nucleus-nucleus collisions. Even if with this physics goal a lot of important results were already reached, there are still several fundamental measurements to be finalized, like high precision measurements of rare probes (D, B mesons and Lambda barions decays) over a broad range of transverse momenta. In order to achieve these new results, a wide upgrade plan was approved that combined with a significant increase of luminosity will enhance the ALICE physics capabilities enormously.
The ALICE Inner Tracking System (ITS) upgrade is one of the major improvements of the experimental set-up that will take place in 2019-2020 where the whole ITS sub-detector will be replaced with a new one realized using a innovative CMOS Monolithic Active Pixel silicon Sensor (MAPS), called ALPIDE. This new upgraded ITS will be realized using more than twenty-four thousand ALPIDE chips organized in seven different cylindrical layers surrounding the ALICE interaction point along the beam-line, for a total surface of about ten square meters. The main features of the future ALICE ITS are a low material budget, high granularity and low power consumption. All these peculiar capabilities will allow for full reconstruction of rare heavy flavor decays and the achievement of the physics goals.
In this talk after a description of new ALIPIDE pixel chip and the whole ITS upgrade project, will be presented the construction procedure of the basic building block of the detector, namely the module, and the laboratory characterization of this element.

TRACK:

Applications

Session 7: LGAD / 70

Properties of LGAD sensors

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In this presentation I will review the results on the gain behaviour of LGAD sensors as a function of several key parameters such as Vbias, Temperature, doping of the gain layer, and irradiation dose. This review will include results from LGAD manufactured by different foundries using different productions techniques and production parameters.

The experimental results are compared to simulation results obtained using the Weightfield2 program.

TRACK: