Pixel 2008 International Workshop

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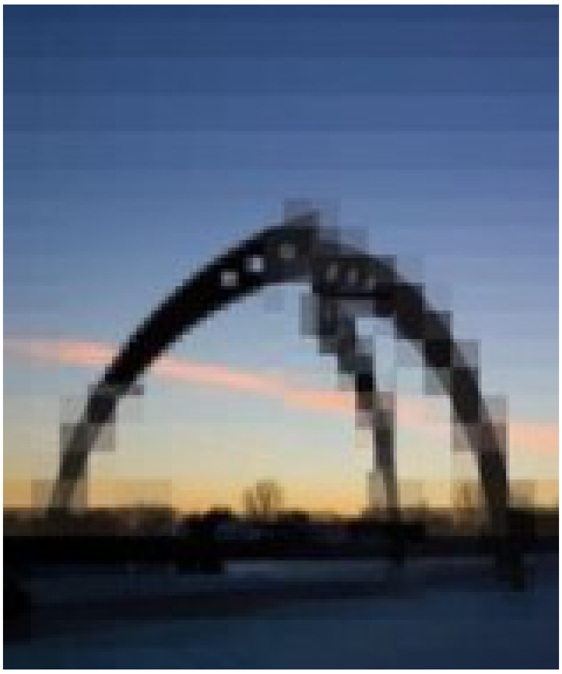

Book of Abstracts

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Status of the ATLAS pixel detector

Corresponding Author: mgarcia-sciveres@lbl.gov

Invited Talks: High Energy Physics / 1

Status of the CMS Pixel Detector

Corresponding Author: danek.kotlinski@psi.ch

Summary:

After 10 years of design and construction the CMS pixel detector has been installed and commissioned. The pixel detector which has two parts, barrel layers and forward disks, consists of 66M pixels of 100um*150um size. The detector installation, commissioning and the results of the detector testing will be presented. We will show the basic electronic parameters of the detector like noise, threshold and signal linearity. The data quality will be illustrated by showing the pixel response uniformity and the number of dead channels.
Some preliminary performance numbers like charge collection and cluster multiplicity will be presented. The technological choices made during the detector design will be reviewed and the problems encountered during the final construction process will be discussed.

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Pixel Support and Cooling Structures Based on Thermally Conducting Carbon Foam

Author: Murdock Gilchriese[1]

Co-authors: Maurice Garcia-Sciveres [1]; William Miller [2]

[1] *Lawrence Berkeley National Laboratory*

[2] *Allcomp, Inc*

Corresponding Author: mggilchriese@lbl.gov

The development of low-mass support structures with integrated cooling for pixel modules based on thermally conducting, carbon foam will be described. The fabrication and test of prototypes will be presented. The conceptual design of structures based on carbon foam for possible application to the ATLAS detector for the Super Large Hadron Collider (SLHC) will be given.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

8

Alignment of the ATLAS Inner Detector tracking system

Author: Heather Gray[1]

Co-author: Jochen Schieck [2]

[1] *Columbia University*

[2] *Max-Planck-Institut fuer Physik Muenchen*

Corresponding Author: heather.gray@cern.ch

The CERN's Large Hadron Collider (LHC) is the world largest particle accelerator. It will make two proton beams to collide to an unprecedented center of mass energy of 14 TeV. It is envisaged that the LHC will start its operations during 2008. ATLAS is a general purpose experiment that will record the products of the LHC proton-proton collision. ATLAS is equipped with a charge particle tracking system built on two technologies: silicon and drift tube based detectors. These compose the ATLAS Inner Detector (ID). The performance of this detectors should be optimized in order to enable ATLAS to achieve its physics goals. The alignment of this tracking system poses a real challenge as one should determine almost 36000 degrees of freedom. Besides, the precision one needs to attain for the alignment of the most sensitive coordinates of the silicon sensors is just few microns. This limit comes from the requirement that the misalignment should not worsen significantly the track parameter determination far beyond the one due the intrinsic sensor resolution. Therefore the alignment of the ATLAS ID requires the application of complex algorithms that demand an extensive CPU and memory usage as large matrix inversion and many iterations algorithms are used. So far, the proposed alignment algorithms have been already exercised on several challenges as: a Combined Test Beam, Cosmic Ray runs and large scale computing simulation of physics samples mimicking the ATLAS operation. For the later samples, the trigger of the experiment has been also simulated and the event filters applied in order to produce an alignment stream. Then the full alignment chain has been tested on that stream and alignment constants have been produced and validated within 24 hours. Therefore it enables a first pass reconstruction of physics events. Besides, one should add that the ATLAS ID commissioning is being currently finalized and that many thousands cosmic ray tracks have already been reconstructed with the final operating system. These cosmic ray data served to produce an early alignment of the real ATLAS Inner Detector even before the LHC start up. Beyond all tracking information, the assembly survey data base contains essential information in order to determine the relative position of one module with respect to its neighbors. Finally a hardware system consisting in measuring an array of grid lines in the modules support structure with a Frequency Scan Interferometer helps in monitoring the system deformations.

Summary:

This talk will concentrate in the alignment of the ATLAS inner detector which is made on three tecnologies. PIXEL, micro strip and drift tubes. Special emphasis will be made in the PIXEL part.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral Presentation

9

Diamond Module Prototypes for the ATLAS SLHC Pixel Detector

Author: William Trischuk[1]

[1] *University of Toronto*

Corresponding Author: william@physics.utoronto.ca

The ATLAS collaboration has recently approved an R&D into the development of diamond pixel modules as an option for the ATLAS pixel detector upgrade for the SLHC. This R&D is possible as a result of significant progress in three areas: the recent reproducible production of high quality diamond material in wafers, the successful completion and test of the first diamond ATLAS pixel module, and the operation of a diamond sensor material that had been exposed to a fluence of 1.8x1016 protons/cm2. This talk will summarise the progress in each of these areas and describe our plans to build and characterize a number of diamond ATLAS pixel modules, test their radiation hardness, explore the cooling advantages made available by the high thermal conductivity of diamond and demonstrate industrial viability of bump-bonding of diamond pixel modules .

submitted on behalf of the the ATLAS Diamond Pixel R&D collaboration (June 2008).

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral Presentation

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Results from the Commissioning of the ATLAS Pixel Detector.

Author: Sara Strandberg[1]

[1] *LBNL*

Corresponding Author: sara.strandberg@cern.ch

The ATLAS Pixel Detector is the innermost detector of the ATLAS experiment at the Large Hadron Collider at CERN. Approximately 80 M electronic channels of the detector, made of silicon, allow to detect particle tracks and secondary vertices with very high precision. After connection of cooling and services and verification of their operation the ATLAS Pixel Detector is now in the final stage of its commissioning phase. Prior to the first beams expected in Summer 2008, a full characterization of the detector is performed. Calibrations of optical connections, verification of the analog performance and special DAQ runs for noise studies are ongoing. Combined operation with other subdetectors in ATLAS will allow to qualify the detector with physics data from cosmic muons and colliding beam interactions. The talk will show all aspects of detector operation, including the monitoring and safety system, the DAQ system and calibration procedures. The summary of calibration tests on the whole detector as well as analysis of physics runs will be presented.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

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FEI4_P1 a prototype pixel readout chip for the ATLAS B-layer upgrade

Author: Abderrezak Mekkaoui[1]

[1] *LBNL*

Corresponding Author: amekkaoui@lbl.gov

A new hybrid pixel readout integrated circuit denominated FE-I4 is being developed for use in ATLAS upgrades. The design goals include 4 times higher rate capability, 4 times the active area (full reticule), and 38% smaller pixels than the presently used FE-I3 IC. The target applications are a possible smaller radius replacement of the present inner layer and/or outer layers or disks of a super-LHC detector. For the innermost layer of a super-LHC detector a further design generation will be needed, and the present effort serves as a stepping stone towards this ultimate goal. Small size analog prototypes have been fabricated in 0.13um feature size bulk CMOS technology. An overview of the full chip design-in-progress is presented, along with status and test results from various test chip prototypes.

Summary:

A new hybrid pixel readout integrated circuit denominated FE-I4 is being developed for use in ATLAS upgrades. FEI4_P1, a prototype chip in 0.13um CMOS, is being developed toward that objective. Test results would be available by the time of the workshop.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

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First Fabrication of full 3D-detectors at SINTEF

Authors: Angela Kok[1]; Thor-Erik Hansen[1]

Co-authors: Christopher Kenney [2]; Cinzia Da Via [3]; Jasmine Hasi [3]; Michael Mielnik [4]; Nicolas Lietaer [1]; Preben Storas [1]; Sherwood Parker [5]; Trond Hansen [1]

[1] *SINTEF Microsystems and Nanotechnology*

[2] *Molecular Biology Consortium*

[3] *University of Manchester*

[4] *SINTEF Microsysyems and Nanotechnology*

[5] *University of Hawaii*

Corresponding Author: thor-erik.hansen@sintef.no

3D-detectors with vertical electrodes penetrating through the substrate has drawn high interest due to unique radiation hardness, ultra-fast response and edgeless capability. In 2008 SINTEF succesfully demonstrated full 3D-detectors with active edge. In this design the electrodes and active edge trenches are filled with polysilicon, and the detectors are sensitive right up to their physical edge. Good pn-junction characteristics were measured with low pixel dark current, good breakdown voltage and high insulation between neighbouring pixels. The process and fabrication issues will be addressed with possible improvements for future production of affordable 3D-detectors. Measurements and characterization of different decies from the first wafar lot will be presented.

Summary:

In 2008 SINTEF succesfully demonstrated full 3D-detectors with active edge. In Good pn-junction characteristics were measured with low pixel dark current, good breakdown voltage and high insulation between neighbouring pixels. The process and fabrication issues will be addressed with possible improvements for future production of affordable 3D-detectors. Measurements and characterization of different decies from the first wafar lot will be presented.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral Presentation

13

Analysis of 3D Stacked, Fully Functional CMOS Active Pixel Sensor Detectors.

Author: Daniele Passeri[1]

Co-authors: Leonello Servoli [2]; Stefano Meroli [2]

[1] *University of Perugia, Italy*

[2] *I.N.F.N. Perugia, Italy*

Corresponding Author: daniele.passeri@diei.unipg.it

The future generation of High-Energy Physics experiments will demand for stringent requirements to the tracking systems, in particular in terms of low material budget and read-out speed. The progress of the microelectronics technology already fostered the adoption of monolithic detection systems based on CMOS Active Pixel Sensors (APS) structures.

In this work, we will focus on the capabilities of the state-of-the–art vertical scale integration technologies, allowing for the fabrication of very compact, fully functional, multiple layers CMOS APS detectors. The main idea is to exploit the features of the 3D technologies for the fabrication of a "stack" of very thin and precisely aligned CMOS APS layers, leading to a single, integrated, multi-layers pixel sensor.

The primary goal of this approach is to improve the spatial/angular ionizing particle trajectory resolution, and to measure the particle momentum, reducing multiple scattering and material related problems (especially in high magnetic field regions).

Actually, the adoption of multiple-layers single detectors can dramatically reduce the mass of conventional, separate multi-layer detectors, at the same time allowing for very precise measurements of a particle trajectory/momentum (e.g. by using a couple of multiple-layer single detectors spatially separated). Moreover, the adoption of the vertical scale integration technology allows for the integration of a dedicated layer for the on-chip elaboration electronics to be coupled to multiple sensing layers. A significant bandwidth reduction can be therefore obtained, by simultaneously on-chip elaborating the output signals of multiple layers.

As a proof of concept, an extensive simulation activity has been carried out, starting from a simple 2D section of a 7-pixels sub-array. Mixed-mode (namely device-circuit) simulations have been carried out: each pixel sensitive element (photodiode) has been coupled to the 3T transistors circuit APS scheme. A Minimum Ionizing Particle stimuli response has been therefore simulated, considering the distribution of the charge for an impinging particle. The combinations of different incidence points ranging from -15 micrometers to +15 micrometers with respect to the central pixel and incidence angle (ranging from -45° to +45° with respect to the normal incidence) have been considered. The voltage response as a function of both position and angle have been calculated. Multiple layer responses (up to 4 layers) have been subsequently combined.

The main effects of having multiple, spatially closed measuring layers are: i) improving the accuracy on the position measurement and ii) obtaining the local curvature (with at least three points) without assumptions on the primary vertex position. Actually, assuming a simple weighted average of the voltage responses of each pixel, the particle hit position can be reconstructed. All the results were obtained considering both charge drift and diffusion components, for a typical CMOS epitaxial substrate doping concentration and biasing conditions. Moreover, a 1.2mV equivalent noise (as obtained from previously fabricated APS in a bulk CMOS 0.18 micrometers technology) has been considered. The standard deviation of the reconstructed hit position as a function of the incidence angle and the hit position has been calculated. A significant accuracy improvement can be obtained with

more than two layers, even with very closely located layers (e.g. 10 micrometers of vertical pitch). A similar behaviour can be appreciated for the incidence angle reconstruction. Such a kind of results can be very useful when trying to set the lower resolution limits of the particle position/angle measurement, as a function of technological parameters.

As a conclusion of this preliminary study, the fabrication of a very compact (i.e. with very low mass) all-in-one position/momentum pixel sensor for tracking applications (in high magnetic fields regions) seems to be very suitable, by exploiting the capabilities of vertical scale integrated circuit technology.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral Presentation

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CMS pixel detector upgrade

Author: Hans-Christian Kaestli[1]

[1] *PSI*

Corresponding Author: hans-christian.kaestli@psi.ch

After a few years of operation, the LHC machine will increase the luminosity delivered to the CMS experiment. This will happen in two steps. In a first phase the luminosity will increase by a factor 2 by pushing the existing accelerator complex to its ultimate. In a second phase the luminosity might increase by a factor 10 to 10^35 cm-2 s-1 where new magnets will have to be installed. This has far reaching implications for the CMS detector, especially for the inner tracking device.
In phase I only the pixel tracker will be replaced. The focus of this upgrade will be a substantial reduction in material budget. Based on the experience with the present pixel detector we aim for a lighter support structure with CO2 cooling and a simplified module design, both mechanically and electronically. Phase II requires a completely new pixel architecture and parts of the present strip tracker beeing replaced by short strips or 'strixels'. A strawman design and possible module designs are just evolving.
This presentation will address these challenges for an upgrade of the CMS inner tracker and show the status of the R&D activities.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral Presentation

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Status and performance of the CMS pixel detector

Author: danek kotlinski[1]

[1] *PSI*

Corresponding Author: danek.kotlinski@psi.ch

After 10 years of design and construction the CMS pixel detector has been installed and commissioned. The pixel detector which has two parts, barrel layers and forward disks, consists of 66M pixels of 100um*150um size.
The detector installation, commissioning and the results of the detector testing will be presented.

We will show the basic electronic parameters of the detector like noise, threshold and signal linearity.
The data quality will be illustrated by showing the pixel response uniformity and the number of dead channels. Some preliminary performance numbers like charge collection and cluster multiplicity will be presented.
The technological choices made during the detector design will be reviewed and the problems encountered during the final construction process will be discussed.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

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Building the CMS Pixel Barrel Detector: assembling, testing and integration

Authors: Andrey Starodumov[1]; Lea Caminada[2]

[1] *PSI, Villigen, CH*

[2] *PSI*

Corresponding Authors: lea.michaela.caminada@cern.ch, andrey.starodumov@cern.ch

The CMS pixel detector is designed to measure tracks close to the interaction point with high resolution and to reconstruct decay vertices of short-lived particles. The detector is divided into three cylindrical barrel layers and two end disk on each side. The barrel of the pixel detector consists of 768 segmented silicon sensors modules with a total of about 48 million readout channels connected to it.
This talk is intended to present an overview of the assembly and the early commissionig and testing of the CMS pixel barrel detector. The sophisticated technique for mounting the modules on the support structure will be reviewed. In addition, the integration of the detector control and readout electronics in the supply tube will be explained and the methods and results of the first testing period will be discussed.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral Presentation

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Commissioning of the CMS pixel barrel detector

Author: Valeria Radicci[1]

[1] *Kansas University*

Corresponding Author: valeria.radicci@psi.ch

The CMS pixel barrel detector is a complicated system that consists of 768 modules, 1104 optical link channels connected to the 32 Front End Drivers (FEDs). In this talk the strategy and results from the commissioning of the complete readout chain will be presented. The general experience gained by operating the pixel barrel system, first at PSI and then after the connection to the final CMS data acquisition system, will be described. This includes hardware aspects, acquisition software, calibration tests and data analysis completed to ensure that pixel detector performs according to specifications.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral Presentation

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A New Technique for the Reconstruction, Validation, and Simulation of Hybrid Pixel Hits

Author: Morris Swartz[1]

Co-authors: David Fehling [1]; Gavril Giurgiu [1]; Petar Maksimovic [1]; Vincenzo Chiochia [2]

[1] *Johns Hopkins University*

[2] *University of Zurich*

Corresponding Author: morris@jhu.edu

We present a new technique for the reconstruction, validation, and simulation of hybrid pixel hits. The technique is based upon the fitting of the cluster projections to pre-computed shapes or "templates". A detailed simulation called Pixelav that has successfully described the profiles of clusters measured in beam tests of radiation-damaged sensors is used to generate the cluster shapes. Although the technique was originally developed to optimally estimate the coordinates of hits after the detector became radiation damaged, it also has superior performance before irradiation. The technique requires a priori knowledge of the track angle which makes it suitable for the subsequent passes in a multi-pass reconstruction algorithm. However, the same angle sensitivity allows the algorithm to determine if the sizes and shapes of the cluster projections are consistent with the input angles. This information may be useful in suppressing spurious hits caused by secondary particles and in validating seeds used in track finding. In combination, the improved reconstruction and seeding significantly reduce the resolution tails of reconstructed track parameters and reduce the light quark background of tagged b-quarks by a factor of 2-3. Finally, a new procedure that uses the templates to re-weight clusters generated by the CMSSW simulation is described. This technique permits the fast simulation of pixel hits that have the characteristics of the much more CPU-intensive Pixelav hits and may be the only practical way to simulate radiation-damaged detectors in the full detector simulations of the LHC experiments.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral Presentation

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Status and perspectives of Deep N-Well 130 nm CMOS MAPS

Author: Valerio Re[1]

[1] *Università di Bergamo*

Corresponding Author: valerio.re@unibg.it

Deep N-Well (DNW) MAPS were developed in two different flavors to approach the specifications of vertex detectors in dissimilar experimental environments such the Super B-Factory and the ILC. The first generation of MAPS with on-pixel data sparsification and time stamping capabilities is now available and is going to be tested in a beam for the first time in September 2008. These devices are fabricated in a commercial 130 nm CMOS process, and the triple well structure available in such an ultra-deep submicron technology is exploited by using the deep N-well as the charge-collecting

electrode and by locating inside it the NMOSFETs of the analog section. PMOSFETs can also be used with considerable performance advantages, without degrading charge collection efficiency, if the area of the deep N-well electrode is much larger than the area of the N-well where PMOSFETs are located. Instead of the standard MAPS source follower readout, signal amplification is based on a charge-sensitive preamplifier which has the advantages of decoupling the gain from the electrode capacitance (allowing for a larger deep N-well) and of not needing correlated double sampling techniques to separate signals from the pedestal. The high integration density of the 130 nm CMOS process is exploited to add digital functions associated to the single pixel, which are used for the sparsified readout of the pixel matrix.
This paper reviews the features of the "ILC class" and "SuperB class" MAPS devices, discussing their different design in terms of pixel pitch, analog signal processing, and digital readout architecture. For SuperB, a data-driven, continuously operating readout scheme was adopted along with a macropixel matrix arrangement, whereas for the ILC the matrix is read out in the long intertrain period. In both versions, the address of hit pixels is transmitted off-chip along with the time stamp. The experimental performance of the chips provides an assessment of the Deep N-Well MAPS potential in view of future applications.
The paper also discusses the way forward in the development of these devices, outlining the issues that have to be tackled to design full size Deep N-Well MAPS for actual experiments. These sensors could take advantage from technological advances in microelectronic industry, such as vertical integration. The impact of these new technologies on the design and performance of DNW pixel sensors could be large, with potential benefit for various device features, from the charge collection properties to the digital readout architecture.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral Presentation

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Tests of small X-ray Active Matrix Pixel Sensor prototypes at the National Synchrotron Light Source

Author: Gabriella Carini[1]

Co-authors: Anthony Kuczweski [2]; Jack Fried [2]; Pavel Rehak [2]; Peter Siddons [2]; Richard Michta [2]; Wei Chen [2]; Zheng Li [2]

[1] *Brookhaven National Laboratory*

[2] *BNL*

Corresponding Author: carini@bnl.gov

X-ray Active Matrix Pixel Sensor (XAMPS) were designed and fabricated at Brookhaven National Laboratory. Devices based on J-FET technology were produced on 100 mm high-resistivity silicon, typically 400 µm-thick. The prototypes are square matrices with n rows and n columns with n=16, 32, 64, 128, 256, 512. Each pixel of the matrix is 90 x 90 µm2 and contains a JFET switch to control the charge readout.
The XAMPS is a position sensitive ionization detector made on high resistivity silicon. It consists of a pixel array detector with integrated switches. Pixels are isolated from each other by a potential barrier and the device is fully depleted by applying a high voltage bias to the junction on the entrance window of the sensor. When the photon is absorbed, the generated electron charge drifts to the exit side of the device and is stored on a capacitor which occupies most of the pixel area. The switches are opened during this phase (data accumulation) and then closed (data readout phase) to allow the charge to flow to the drain, connected to readout lines.
This sensor is highly efficient in the energy range between 8 and 12 keV. It has ~100% fill factor, low noise, millisecond readout, single photon sensitivity and a dynamic range of more than 104 photons per frame. It can be tiled to form bigger area detectors.
The small features of the design presented some technological challenges fully addressed during this production. The first prototypes were tested at the National Synchrotron Light Source (NSLS) with a monochromatic beam of 8 keV and millisecond readout and exhibit good performances at room temperature. Experimental results will be presented and discussed.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Either Poster or Oral Presentation

22

Commissioning of CMS Forward Pixel Detector

Author: Ashish Kumar[1]

[1] *State University of New York at Buffalo*

Corresponding Author: ashishk@fnal.gov

The Compact Muon Solenoid (CMS) detector is getting ready to start taking data with the first ultra high energy proton-proton collisions at Large Hadron Collider (LHC) this year. At the core of the CMS all-silicon tracker is the silicon pixel detector comprising of three barrel layers and two pixel disks on each side of the interaction point accounting for 66 million channels The pixel detector will be crucial to achieve a good vertex resolution and will play a key role in pattern recognition and track reconstruction while being embedded in hostile radiation environment. The end disks of the pixel detector, known as the Forward Pixel detector, has been assembled and tested at Fermilab, USA. It has 18 million pixel cells with dimension 100 × 150 µm2. The complete forward subdetector was transported to CERN from Fermilab in December 2007 and has undergone extensive system tests at the Tracker Integration Facility for commissioning. The barrel subdetector is also complete and is currently being commissioned at PSI. The pixel system is scheduled for insertion into CMS following the installation and bake out of the LHC beam pipe in mid July 2008. This report will cover the present status of CMS pixels and results from commissioning of CMS forward pixel detector at CERN.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

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The DEPFET Active Pixel Sensor for future e+e- colliders

Author: Stefan Rummel[1]

[1] *MPI für Physik / Halbleiterlabor*

Corresponding Author: stefan.rummel79@gmx.de

The DEPleted Field Effect Transistor (DEPFET) is a concept for a fully depleted detector with in pixel amplification.

The low input capacitance, which allows low noise operation, and the large sensitive volume make the DEPFET attractive for position resolved spectroscopic applications as well as vertexing in high energy physics.

The signal is determined by the internal amplification, the so called gq, of the DEPFET. The main parameters which affect the gq are on the one hand the geometry of the FET and on the other hand the biasing conditions under which the detector is operated. This talk will focus on the dependence on these parameters and shows that a gq of more than 1nA/e- is within reach of the current technology.

The DEPFET intrinsic noise contribution was directly measured with a fast amplifier, showing that the inherent noise of the DEPFET is around 50e at a bandwidth of 50MHz.

Due to the low noise and a thinning technology compatible with the DEPFET technology it is possible to build thin detectors down to 50 micron thickness, with a SNR which still allows the detection of particles with high efficiency.

Another important property is the radiation hardness of the device. As every MOS device the DEPFET is susceptible to damage due to ionizing radiation. The radiation hardness has been studied up to 8MRad an overview of the results will be given here.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral Presentation

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The DEPFET prototype for the ILC: Test Beam Measurements

Author: Lars Reuen[1]

[1] *University of Bonn*

Corresponding Author: reuen@physik.uni-bonn.de

By incorporating a field effect transistor into a fully depleted sensor substrate the DEPFET sensor combines radiation detection and amplification allowing for low noise measurements and high spatial resolution. This makes DEPFET sensors an auspicious technology for the vertex detector of the planned International Linear Collider (ILC). The demands on the vertex detector are high, including small pixels (20-30 µm) and fast readout of almost a giga pixel in 50µs.
Aiming to meet these high demands a prototype system with fast steering chips, a current based readout chip and a 64x128 pixel matrix has been build and successfully tested in recent years, including a DEPFET based pixel telescope with a spatial resolution close to one micron. Based on these experiences a new generation of DEPFET pixels has been produced. Their performance is studied in an ongoing test beam at the SPS at CERN. In this talk the first results of these test beam studies are presented.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral Presentation

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SOI Pixel development at KEK

Author: Yasuo Arai[1]

[1] *KEK*

Corresponding Author: yasuo.arai@kek.jp

We are developing monolithic pixel detectors in a 0.15/0.2 um CMOS, fully-depleted SOI (Silicon-On-Insulator) technology developed by Oki semiconductor CO., Ltd.
The substrate is Cz high-resistivity silicon, and works as a radiation sensor having p-n junctions. The SOI layer is 40nm thick Si, where CMOS readout electronics is implemented.

There is no mechanical bonding in the SOI pixel detector between the sensor and the readout electronics, so higher sensitivity and lower noise are expected compared with hybrid detectors.
We are now hosting MPW (Multi Project Wafer) runs of this SOI process in these years.
In last two MPW runs, we have received more than 30 designs from Japan and US universities/laboratories.
Experience from this MPW run and test results obtained from the SOI pixel chips will be reported.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

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Silicon Pixel Detector for the PHENIX experiment at the BNL RHIC

Author: Ryo Ichimiya[1]

Co-authors: Atsushi Taketani [1]; Charles Pancake [2]; Eric Mannel [3]; Ermias Atomssa [4]; Eugene Shafto [2]; Franck Gastaldi [4]; Hideto E'nyo [1]; Hiroaki Ohnishi [1]; Kohei Fujiwara [1]; Maki Kurosawa [1]; Olivier Drapier [4]; Raphael Granier de Cassagnac [4]; Simon Chollet [4]; Yasuyuki Akiba [1]

[1] *RIKEN*

[2] *Stony Brook University*

[3] *Columbia University, Nevis Laboratories*

[4] *Ecole Polytechnique, CNRS-IN2P3*

Corresponding Author: ryo@riken.jp

The PHENIX detector in BNL RHIC, which has been exploring both heavy ion physics and spin physics, is being upgraded with a silicon vertex tracker (VTX) to get precise information near the collision point.
The VTX detector has four barrel layers. For the inner two layers we will use a silicon pixel device with 50x425um pixels that have been developed for the ALICE/LHCb experiments at the CERN LHC. Each half ladder module, which is the minimum unit in the readout configuration, includes 8 readout chips.
Each chip has a 32-bit wide data bus. Four chips are readout simultaneously.
Compared with ALICE/LHCb experiments, the PHENIX experiment requires fast trigger rates (up to 20kHz).
Thus four 32-bits wide data buses are required. This scheme gives us the benefit that the detector front-end becomes simple, but the readout bus needs to have high signal density.
In addition, the readout bus needs to be lower material budget to minimize the multiple scattering and photon conversion in the detector layers.
We have developed: 1) high signal density (188 wires in 13.9mm width) and low material budget (28% of radiation length) data bus PC board (PHENIX pixel bus), and 2) double bus width interface ASIC (digital Pilot ASIC) using the same design rules and radiation tolerant technology as the original ALICE/LHCb digital pilot ASIC. For the high signal density and low material budget, Flexible Printed Circuit Board with polyimide-Cu-Al was chosen as the readout bus.
The signal line is made from 3um thick Cu and the minimum line/spacing is 30/30 um. 50um thick Al is used as the conductors for power layer.
The bus behaves as a distributed-parameter circuit from the signal point of view. We have optimized termination resistance using realistic HSPICE simulations.
In this presentation, current status of the PHENIX pixel detector system, technical difficulties in high-signal-density low material budget readout bus development and the digital pilot ASIC for the PHENIX pixel detector.

Summary:

This presentation gives overview and technical topics on
the PHENIX Pixel detector system at the BNL RHIC, which will be installed
in 2010, including high-density and low material budget data bus
and front-end ASIC.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral Presentation

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First Performance Results of the PHENIX Silicon Stripixel Detector at RHIC

Author: Nouicer Rachid[1]

Co-author: . PHENIX Collaboration [2]

[1] *Brookhaven National Laboratory*

[2] .

Corresponding Author: rachid.nouicer@bnl.gov

Rachid Nouicer for the PHENIX Collaboration

Abstract:

Recently, a novel design consisting of "spirals" of silicon stripixel sensors was
invented at the Instrumentation Division, Brookhaven National Laboratory [1]. The silicon sensor is a single-sided, DC-coupled, two-dimensional detector. This design is simpler in terms of fabrication and signal processing than the conventional double-sided strip sensor. Hamamatsu, Japan, produced 400 silicon sensors for PHENIX experiment at the Relativistic Heavy Ion Collider (RHIC). The silicon detector is now under construction and stripixels form the two outer barrels of the central silicon vertex tracker (VTX) and are part of a comprehensive upgrade
program for the PHENIX detector. The VTX will substantially enhance the physics capabilities of the PHENIX central arm spectrometer and will enable precision measurements of heavy-quark production (charm and beauty) in A + A, p(d) + A, and polarized p + p collisions. These are key measurements that are required for the future RHIC program, both for the study of high-density partonic matter created in heavy ion collisions and for the exploration of the nucleon spin structure function.

In this talk, I will present the physics capabilities of the new silicon vertex tracker in PHENIX, the status of the project, including technology choices used in the design, performance of individual silicon stripixel sensor and detector prototype, including the challenges faced and their solutions. Latest performance results of stripixel detector prototypes using beta source Sr-90 and cosmic-rays will
be presented and discussed. Finally, the ladder and barrel configurations will be illustrated

Reference:

[1] Z. Li, Nucl. Instr. and Meth., A 518, 738 (2004).

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral Presentation

28

Laser Annealing of Thinned Detectors

Author: Ronald Lipton Lipton[1]

[1] *Fermilab*

Corresponding Author: lipton@fnal.gov

Detector thinning can be used to reduce mass and improve radiation hardness in silicon detectors. Detectors which are thinned after topside processing need additional processing to form the backside ohmic contact. High temperature annealing of the backside contact will typically destroy topside metallization. As a part our our program to study SOI and 3D detectors we have explored a laser annealing process for formation of the backside ohmic contact. This process preserves topside circuitry while annealing the backside implantation by local melting of the silicon. The process consists of mounting the wafer on a pyrex handle, backgrinding and CMP, ion implantation, and laser annealing. We will present results on laser annealing studies of thinned silicon strip detectors, and diodes designed to study the annealing process as well as diode structures thinned to 50 microns using the full process.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

29

CCDs for the Dark Energy Camera

Author: Juan Estrada[1]

[1] *FNAL*

Corresponding Author: estrada@fnal.gov

The Dark Energy Camera (DECam) being currently built for the Dark Energy Survey will consists of an array of ~600 Mpix of fully depleted 250um CCDs. These thick detectors developed by LBNL have been selected by several future astronomical instruments for their higher efficiency in the near infrared. The detectors performance will be discussed and compared with the technical requirements for DECam. The prospects of using these CCDs in a low threshold dark matter search will also be presented.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

30

Characterization of prototype LSST CCDs

Author: Ivan Kotov[1]

[1] *BNL*

Corresponding Author: kotov@bnl.gov

Characterization methods and results are presented on a number of new devices produced specifically to address LSST's performance goals, including flatness, QE, PSF, dark current, read noise, CTE,

cosmetics, and crosstalk. The results indicate that commercially produced, thick n-channel over-depleted CCDs with excellent red response can achieve tight PSF at moderate applied substrate bias with no evidence of persistent image artifacts. Also ongoing studies of mosaic assembly techniques to achieve chip-to-chip co-planarity, high fill factor, and thermal stability are discussed.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

oral

33

X-Ray Tests of a Pixel Array Detector Designed for Coherent X-ray Imaging at the Linac Coherent Light Source

Author: Lucas J Koerner[1]

Co-authors: Hugh T Philipp [1]; Marianne S. Hromalik [1]; Mark W. Tate [1]; Sol M. Gruner [1]

[1] *Cornell University*

Corresponding Author: ljk29@cornell.edu

Test results of a pixel array detector (PAD) being developed for x-ray imaging at the Stanford Linear Coherent Light Source (LCLS) are presented. The basic module of the PAD consists of a 185x194 pixel silicon reverse-biased diode coupled by bump-bonds to a charge integrating ASIC with in-pixel digitization. The LCLS experiment requires a high signal-to-noise ratio for detection of single 8 keV x-rays, a pixel full-well exceeding 1000 8 keV x-rays, a frame-rate of 120 Hz and the ability to handle the arrival of thousands of x-rays per pixel in 10s of femtoseconds. Measurements have verified a pixel full-well value of 2500 8 keV x-rays. Single 8 keV photon detection has been shown with a SNR > 6. Line-spread response measurements confirmed charge spreading to be limited to nearest neighbor pixels. Modules still functioned after dosages up to 75 MRad(Si) at the detector face. Work is proceeding to incorporate an array of modules into a full large-area detector.

Summary:

Summary:

1. Introduction An experiment is being developed to collect scattered radiation from single biological particles inserted into the LCLS x-ray beam. Since the time for particle explosion due to radiation is momen- tum limited the short temporal width of the LCLS x-ray beam, approximately 100 fs, ensures the scattered radi- ation measures the pre-exploded particle. This experiment provides the opportunity to determine the atomic level structure of biological particles without crystallization. The scattering intensity profile will drop strongly with scattering angle, with 1000s of x-rays per pixel at the central region and an average of less than one photon per pixel in the wide-angle regions. A new particle will be injected into the beam every 8.3 ms. The experiment demands a large signal-to-noise ratio at low illumination levels, a pixel full-well greater than 1000 x-ray photons and a frame rate of 120 Hz from the detector. To meet the requirements of the experiment a pixel array detector (PAD) is being developed. PADs couple the low conversion noise and excellent spatial response of direct con- version in silicon with the flexibility and speed of a readout ASIC designed in standard CMOS. The de- tector layer is fabricated by SINTEF (Trondheim, Norway) using high-resistivity 500 μm thick silicon. P+ pixel implants are formed on the bump-bonded side and the x-ray incident side is an aluminized N+ ohmic contact for the application of an approximately 200 V bias. The readout ASIC is fabricated in TSMC 0.25 μm feature-size CMOS mixed-mode process. The pixel circuity consists of a low-noise charge integrating front-end with per-pixel configurable two-level gain followed by an in-pixel single-slope

14-bit analog-to-digital conversion. Detector
and ASIC chips were bump-bonded using tin-lead

solder by RTI (Research Triangle Park, NC, USA). Bump-bonded modules were wire-bonded to a support card and mounted in a vacuum cryostat with a thermally regulated cold-finger and a light-tight, x-ray transparent window. Detector control and data acquisition was accomplished with a Xilinx Virtex4 FPGA on a PCI-SYS development board from PLDA (San Jose, CA).

1. Measurement Results

Single-photon sensitivity was confirmed using monochromatic copper K-alpha radiation incident on the detector through 25 µm pin-holes in a tungsten mask. Figure 1 shows a histogram of single-pixel values acquired using four exposure times. Pixel linearity was confirmed and full-well measured by illuminating with an 1 mm x 1 mm x-ray spot while varying the exposure time. Full-well values are reported in Table 1. Raster scans of 25 µm spots showed charge spread at a distance of 70 µm to fall to 0.1%. Bump-bonded modules were spot-irradiated while electrically biased using copper K-alpha radiation up to 75 MRad(Si) at the detector face. Detector layer leakage currents increased by about a factor of three, but functionality remained, as evidenced by the acquisition of a spectrum similar to Figure 1. Bare-ASICs were irradiated up to 400 kRad(Si). Pixel functionality was lost around 120 kRad(Si), but any indication of damage vanished for all dose levels following an un-biased room-temperature anneal and a 20 hr 56 C biased warming cycle.

1. Conclusions Prototype PADs have been tested with x-rays and show satisfactory noise, spatial response, full-well and radiation robustness. The next step is to incor- porate single chips into modules that can be abutted side-by-side, upgrade support electronics and design and fabricate housing to build a large-area (758x758 pixels, 83.8 mm x 83.8 mm) detector.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

34

Charge Transfer Inefficiency in DECam CCDs

Author: Derek Thompson[1]

Co-authors: Brenna Flaugher [2]; Joshua Frieman [1]; Juan Estrada [2]

[1] *University of Chicago*

[2] *Fermi National Accelerator Laboratory*

Corresponding Author: dthom@fnal.gov

We present the measurement of charge transfer inefficiency in 250 um thick, fully depleted, back illuminated CCD detectors that will be installed in the ~600 Mpix Dark Energy Camera (DECam)

currently being developed for the Dark Energy Survey (DES). For some detectors we measure a trend in charge transfer inefficiency (CTI) as a function of light level. Using these results, we perform simulations to study how CTI distorts objects detected by CCD images.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral Presentation

35

Low-mass support structures for pixel detectors

Author: William Cooper[1]

[1] *Fermilab*

Corresponding Author: cooper@fnal.gov

Pixel detector support strctures intended to limit material to 0.1% of a radiation length per detector layer will be described, along with implications of dry gas or more active cooling for the number of radiation lengths represented by sensors and their support. Structures developed for vertex detectors of linear collider experiments have typically assumed average power could be liimited by power cycling. In experiments requiring that power be provided continuously, heat removal will be a more serious issue. Material increases associated with removing that higher power will be described.

Summary:

Pixel detector support strctures intended to limit material to 0.1% of a radiation length per detector layer will be described, along with implications of dry gas or more actve cooling for the number of radiation lengths represented by sensors and their support.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral presentation

36

Characteristics of a prototype matrix of Silicon PhotoMultipliers (SiPMs)

Author: Nicoleta Dinu[1]

Co-authors: A. Tarolli [2]; Alberto Del Guerra [3]; Christophe De La Taille [1]; Claudio Piemonte [2]; Cyril Bazin [1]; Gabriela Llosa [4]; Gianmaria Collazuol [5]; Giusepina Bisogni [3]; Jean-Francois Vagnucci [1]; Maurizio Boscardin [2]; Mirco Melchiori [2]; Nicola Belcari [4]; Nicola Zorzi [2]; Pierre Barrillon [1]; Sara Marcatili [3]; Sylvie Bondil-Blin [1]; Veronique Puill [1]; Vincent Chaumat [1]

[1] *LAL*

[2] *FBK-irst*

[3] *Universita' di Pisa, Dipartimento di Fisica "E. Fermi", INFN Sesione di Pisa*

[4] *Universita' di Pisa, Dipartimento di Fisica "E. Fermi"*

[5] *Scuola Normale Superiore, Pisa, INFN Sezione di Pisa*

Corresponding Author: dinu@lal.in2p3.fr

This contribution reports on the electrical (static and dynamic) as well as on the optical characteristics of a prototype matrix of Silicon Photomultipliers (SiPM).
The prototype matrix consists of 4x4 SiPM's on the same substrat fabricated at FBK-irst (Trento, Italy). Each SiPM of the matrix has an area of 1x1mm^2 and it is composed of 625 pixels connected in parallel. Each pixel of the SiPM has an area of 40x40µm^2 and it is represented by a GM-APD (n+/p junction on p+ substrate) connected in series with its integrated polysilicon quenching resistance.
The static characteristics as breakdown voltage, quenching resistance, post-breakdown dark current as well as the dynamic characteristics as gain and dark count rate (e.g. thermal generated carriers, afterpulses, cross-talk) have been analysed. The photon detection efficiency as a function of wavelength and operation voltage has been also estimated.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

oral

38

Simulation of guard ring influence on the performance of ATLAS pixel detectors

Author: Mathieu Benoit[1]

[1] *LAL*

Corresponding Author: benoit@lal.in2p3.fr

Electric field magnitude and depletion in the bulk of silicon pixel detectors, which influence its breakdown behaviour, was studied using finite-element method to solve the drift-diffusion equation coupled to Poisson's equation in a simplified two dimensional model of the ATLAS pixel sensor. Based on this model, the number of guard rings, dead edges width and detector's thickness were modified to investigate their influence on the detector's depletion at the edge and on its internal electrical field distribution. Finally, the 3 level model was implemented into the simulation to study the behaviour of such detector under different level of irradiation.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

39

High Resolution Digital Imaging X-ray Detectors

Author: Bill Cardoso[1]

[1] *Aguila Technologies*

Corresponding Author: bcardoso@aguilatech.com

In this paper we will describe the work done at Aguila Technologies to develop a high resolution, high contrast detector for digital x-ray imaging systems. The target
detector has a Detective Quantum Efficiency much greater than 80%, a limiting resolution of at least 10 lp/mm, ultra-low noise, linear response and a dynamic range of more than 14 bits. We are building such device using CdZnTe crystals. The detector crystal is hybridized to a readout integrated circuit

device that allows the signal to be collected efficiently, digitized and stored in a computer as an image matrix. The planned individual detector unit, designed for use in a slot scan system, has 192 stages in the scan direction and 384 columns in the non-scan direction. The detectors are planned to be mounted in a staggered array with overlap at the ends up to the full breast x-ray image width (~25 cm) in the non-scan direction. The detector pixel pitch will be 50 microns with 100% fill factor. Compared to the present film systems, a reduction of patient dose by a factor of six can be achieved without loss of image quality. To achieve these objectives, in this paper we present the development of: a high quality and high spatial resolution bump bonding technique; an optimized readout IC for the CZT crystals; and a reliable, low cost, high throughput technique to test and select high quality, high uniformity CZT crystals.

Summary:

In this paper we will describe the work done at Aguila Technologies to develop a high resolution, high contrast x-ray detector for digital x-ray imaging, such as mammography systems. The target detector has a Detective Quantum Efficiency (DQE) greater than 80%, a limiting resolution of at least 10 lp/mm, ultra-low noise, linear response and a dynamic range of more than 14 bits. We are building such a detector by using a high Z, high density photoconductive solid state detector crystal that provides high x-ray quantum detection efficiency. Unlike scintillation detectors, such materials directly and precisely convert the absorbed x-ray energy into an electric signal. The detector crystal is hybridized to a readout integrated circuit device that allows the signal to be collected efficiently, digitized and stored in a computer as an image matrix. Our work has shown that single crystal CdZnTe (CZT) has the potential to meet the requirements for producing such a detector.

The full potential of detection by CZT will only be realized by obtaining crystals with a uniform crystalline structure and a high electrical resistivity. A high quality bump bonding technique to the readout IC is also essential to achieving the high resolution, low pixel loss and low noise. Design of a readout IC with electrical
characteristics tailored to the CZT crystals is also necessary. To achieve these objectives, in this paper we will present:

• A high quality and high spatial resolution bump bonding technique
• An optimized readout IC for the CZT crystals
• A reliable, low-cost, high throughput technique to test and select high quality, high uniformity CZT crystals

Reliable bump bonding at 50 μm pitch at a reasonable cost will be a significant challenge. The dominant method today for bonding at this pitch is indium bump bonding. Only flip chip solder bumping holds the promise of achieving both low cost and consistent high yield. Our aim is to advance the low temperature solder bumping method developed at Aguila Technologies to produce bumped assemblies at this pitch. The company's finest bump pitch detector assembly to date is at 100 μm pitch using solder paste bumping. To achieve 50 μm we developed an entirely new method of applying bumps. In this method we adapt the current low temperature solder bumping method to photolithographic plating of copper bumps rather than the current solder paste bump printing method. Plating of copper
or gold bumps has been employed by flip chip manufacturers to produce bumps as small as 30 μm pitch. This paper represents a high-risk/high payoff plan to develop a reliable source of CZT detectors for x-ray and gamma ray imaging.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

oral

40

A Data Acquisition Architecture for Integrated Control and Analysis for Pixel Detector Development

Author: Marcos Turqueti[1]

Co-author: Ryan Rivera [1]

[1] *Fermi National Accelerator Laboratory*

Corresponding Author: turqueti@fnal.gov

Semiconductor tracking detectors for high energy physics are frequently implemented using pixel or silicon strip sensors coupled with readout electronic integrated circuits. These detector and readout IC systems are evaluated and developed in laboratory test setups as well as particle test-beam environments. The Electronic Systems Engineering department at Fermilab is developing a hardware architecture (called CAPTAN) for data acquisition suitable for supporting these activities in an integrated environment. This architecture is based on an expandable stack of hardware components which share communication and control resources. These hardware components provide the interfaces which couple the front end detector electronics with the data acquisition and analysis firmware and software components including offline computing resources and file servers. This paper will describe the details of this architecture with specific examples of support for existing pixel and strips detector components. Test results obtained with hardware and software designed to this architecture will be presented for the Vertically Integrated Pixels (VIP) device.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

41

Application of Pixel Array Detectors at X-ray Synchrotrons

Author: Antonino Miceli[1]

[1] *Argonne National Laboratory*

Corresponding Author: antonino.m@gmail.com

Pixel Array Detector have only recently been seriously used at x-ray synchrotrons.
In this talk, we describe the application of a digital pixel array detector (Pilatus100K) to a variety of synchrotron experiments at the Advanced Photon Source at Argonne. The Pilatus100K was developed at the Paul Scherrer Institut (PSI). It has been commercialized by a PSI spinoff (Dectrics Ltd.) This is the first commercially available pixel array detector for x-ray synchrotron applications. The APS synchrotron provides tunable x-ray pulses with a duration of ~80 ps and a repetition period of 153 ns (24-bunch mode). The Pilatus100K is direct x-ray detector where each 172-micron pixel counts individual x-ray pulses above a lower threshold. It consists of ~100K pixels each of which is capable single-photon counting (> 3 keV) at count rates up to ~ 1 MHz. In addition, the Pilatus100K is an electronically gateable detector. We present data showing that the Pilatus100K is capable of isolating a single x-ray bunch at the APS in 24 bunch mode. We will also present a variety of different experiments exploiting the unique capabilities of the Pilatus100K.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

42

CCD Charge Transfer Efficiency with the new DES Clock Board

Author: Julia Campa[1]

[1] *CIEMAT*

Corresponding Author: julia_campa@yahoo.es

The Dark Energy Camera will be comprised of 74 CCDs with high efficiency out to a wavelength of 1 micron.
The CCDs will be read out by a Monsoon-based system consisting of three boards: Master Control, CCD
Acquisition, and Clock boards. The charge transfer efficiency (CTE) is closely related to the clock waveforms
provided by the Clock Board (CB). The CB has been redesigned to meet the stringent requirements of the Dark
Energy Survey. The number of signals provided by the clock board has been extended from 32 (the number required for 2 CCDs) up to 135 signals (the number required for 9 CCDs). This modification is required to fit
the electronics into the limited space available on the imager vessel. In addition, the drivers have been changed to provide more current. The resultant rise times of the clock signals directly influence how fast we can readout the CCD. In order to improve and study these it is important to model the CCD as accurately as possible. The first test result with the new clock board shows a clear improvement in the CTE response when reading out at the higher frequencies required for the guide CCDs"

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Poster

43

Development of an automated system to test and select CCDs for the Dark Energy Survey Camera (DECam)

Author: Donna Kubik Kubik[1]

[1] *Fermilab*

Corresponding Author: kubik@fnal.gov

The Dark Energy Survey Camera will be comprised of a mosaic of 74 CCDs. The goal of the Dark Energy Survey (DES) is to measure the dark energy equation of state parameter, ω, to a statistical precision of 5% with four complementary methods. This goal sets stringent technical requirements for the CCDs.

Testing a large number of CCDs to determine which best meet the DES requirements would be a very time-consuming manual task. We have developed a system to automatically collect and analyze CCD test data. The test results are entered into an online SQL database which facilitates selection of those CCDs that best meet the technical specifications for charge transfer efficiency, linearity, full well, quantum efficiency, noise, dark current, cross talk, diffusion, and cosmetics.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

poster

44

STAR Pixel Detector, Mechanical Design

Author: Howard Wieman[1]

[1] *Lawrence Berkeley National Lab*

Corresponding Author: hhwieman@lbl.gov

A high resolution pixel detector is being designed for the STAR experiment at RHIC. This device will use MAPS as the detector element and will have a pointing accuracy of ~25 microns. We will be reporting on the mechanical design required to support this resolution. The radiation length of the first layer (~0.3% X0) and its distance from the interaction point (2.5 cm) determines the resolution. The design makes use of air cooling and thin carbon composite structures to limit the radiation length. The mechanics are being developed to achieve spatial calibrations and stability to 20 microns and to permit rapid detector replacement in event of radiation damage or other potential failures from operation near the beam.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

45

Sensor and Readout Development for the HFT Pixel Vertex Detector at STAR

Author: Leo Greiner[1]

[1] *LBL*

Corresponding Author: lcgreiner@lbl.gov

The STAR experiment at the Relativistic Heavy Ion Collider (RHIC) is designing a new vertex detector. The purpose of this upgrade detector is to provide high resolution pointing to allow for the direct topological reconstruction of heavy flavor decays such as the D0 with by finding vertices displaced from the collision vertex by greater than 60 microns. We are using Monolithic Active Pixel Sensor (MAPS) as the sensor technology and have a coupled sensor development and readout system plan that leads us to a final detector with a <200 us integration time, 400 M pixels and a coverage of -1<eta<1. We will present our coupled sensor and readout development plan and the status of the prototyping work that has been accomplished.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

46

Measurements of the Quantum Efficiency of 250 Micron, Fully-Depleted CCDs for the Dark Energy Survey

Author: Vic Scarpine[1]

[1] *Fermilab*

Corresponding Author: scarpine@fnal.gov

Presented for the DES collaboration.

The Dark Energy Survey (DES) Project will optically image 5000 square degrees of the southern sky to measure the dark energy equation of state parameter, w. The survey will use a new wide-field mosaic camera (DECam) mounted at the prime focus of the Blanco 4m telescope at the Cerro-Tololo International Observatory (CTIO). DECam will acquire images in four filter bands (g,r,i,z) and utilize back-illuminated, 2K x 4K, 250 micron thick, fully-depleted CCDs, developed at the Lawrence Berkeley National Laboratory (LBNL), to provide improved quantum efficiency in the near infrared. We present here the laboratory measurements of the quantum efficiency of these CCDs over the wavelengths of 400 nm to 1060 nm. Also presented are proposed techniques to calibrate these CCDs in-situ on the Blanco telescope.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Poster

Invited Talks: High Energy Physics / 47

Non Atlas/CMS Pixel Detectors for HEP Experiments

Corresponding Author: michael.campbell@cern.ch

Mechanical Aspects of Pixel Detectors and Upgrades / 48

Building the CMS Pixel Barrel Detector: assembling, testing and integration

Corresponding Author: andrey.starodumov@cern.ch

High Energy Physics Detectors / 49

Commissioning of the CMS pixel barrel detector

Author: Lea Caminada[1]

[1] *CMS*

Corresponding Author: lea.michaela.caminada@cern.ch

Summary:

The CMS pixel barrel detector is a complicated system that consists of 768 modules, 1104 optical link channels connected to the 32 Front End Drivers (FEDs). In this talk the strategy and results from the commissioning of the complete readout chain will be presented. The general experience gained by operating the pixel barrel system, first at PSI and then after the connection to the final CMS data acquisition system, will be described. This includes hardware aspects, acquisition software, calibration tests and data analysis completed to ensure that pixel detector performs according to specifications.

High Energy Physics Detectors / 50

Results from the Commissioning of the ATLAS Pixel Detector

Corresponding Author: sara.strandberg@cern.ch

Mechanical Aspects of Pixel Detectors and Upgrades / 51

Alignment of the ATLAS Inner Detector tracking system

Corresponding Author: heather.gray@cern.ch

Invited Talk: Radiation Hardness / 52

Silicon Radiation Hardness

Corresponding Author: zhengl@bnl.gov

High Energy Physics Detectors / 53

Silicon Pixel Detector for the PHENIX experiment at the BNL RHIC

Corresponding Author: ryo@riken.jp

High Energy Physics Detectors II / 54

First Performance Results of the PHENIX Silicon Stripixel Detector at RHIC

Corresponding Author: rachid.nouicer@bnl.gov

High Energy Physics Detectors II / 55

Commissioning of CMS Forward Pixel Detector

Corresponding Author: ashishk@fnal.gov

High Energy Physics Detectors II / 56

The control and readout systems of the CMS Pixel detector

Corresponding Author: veelken@fnal.gov

Mechanical Aspects of Pixel Detectors and Upgrades / 57

Pixel Support and Cooling Structures Based on Thermally Conducting Carbon Foam

Corresponding Author: mggilchriese@lbl.gov

Mechanical Aspects of Pixel Detectors and Upgrades / 58

STAR Pixel Detector, Mechanical Design

Corresponding Author: hhwieman@lbl.gov

Mechanical Aspects of Pixel Detectors and Upgrades / 59

Diamond Module Prototypes for the ATLAS SLHC Pixel Detector

Co-author: William Trischuk [1]

[1] *University of Toronto*

Corresponding Author: marko.mikuz@cern.ch

Summary:

The ATLAS collaboration has recently approved an R&D into the development of diamond pixel modules as an option for the ATLAS pixel detector upgrade for the SLHC. This R&D is possible as a result of significant progress in three areas: the recent reproducible production of high quality diamond material in wafers, the successful completion and test of the first diamond ATLAS pixel module, and the operation of a diamond sensor material that had been exposed to a fluence of 1.8x1016 protons/cm2. This talk will summarize the progress in each of these areas and describe our plans to build and characterize a number of diamond ATLAS pixel modules, test their radiation hardness, explore the cooling advantages made available by the high thermal conductivity of diamond and demonstrate industrial viability of bump-bonding of diamond pixel modules .

Invited Talks: Light Sources and Space Applications / 60

Impact of pixellated detectors on synchrotron radiation experiments

Corresponding Author: siddons@bnl.gov

Summary:

The availability of pixellated x-ray detectors for synchrotron radiation is still in its infancy compared to high-energy physics experiments, but their impact is already powerful. The talk will address some of the benefits and issues associated with the unique requirements of these experiments.

Invited Talks: Light Sources and Space Applications / 61

Pixel detectors for x-ray imaging spectroscopy in space

Imagers / 62

Tests of small X-ray Active Matrix Pixel Sensor prototypes at the National Synchrotron Light Source

Corresponding Author: carini@bnl.gov

Imagers / 63

Characterization of prototype LSST CCDs

Corresponding Author: kotov@bnl.gov

Imagers / 64

Application of Pixel Array Detectors at X-ray Synchrotrons

Corresponding Author: antonino.m@gmail.com

Imagers / 65

CCDs for the Dark Energy Camera

Corresponding Author: estrada@fnal.gov

Imagers / 66

The DEPFET Active Pixel Sensor for future e+e- colliders

Corresponding Author: stefan.rummel79@gmx.de

Imagers / 67

High Resolution Digital Imaging X-ray Detectors

Corresponding Author: bcardoso@aguilatech.com

Imagers / 68

CMOS pixel sensor development: a fast readout architecture with integrated zero suppression

Imagers / 69

Sensor and Readout Development for the HFT Pixel Vertex Detector at STAR

Corresponding Author: lcgreiner@lbl.gov

Imagers / 70

The DEPFET prototype for the ILC: Test Beam Measurements

Corresponding Author: reuen@physik.uni-bonn.de

Imagers / 71

X-Ray Tests of a Pixel Array Detector Designed for Coherent X-ray Imaging at the Linac Coherent Light Source

Corresponding Author: ljk29@cornell.edu

Colloquium / 72

Solid State Imagers in Space and Scientific Applications - DALSA Technology Review

Summary:

DALSA is an imaging company with unique positioning on the market as a leading provider of high end imaging solutions for any application; these solutions are based on propriatery to DALSA technologies, which include: semiconductor processing foundry, CCD and CMOS image sensor desing and manufacturing capability, MEMS foundry, camera and vision systems design capability, imaging software design. From the first sensors in early 80s DALSA is actively growing custom design business to provide the most demanding customers with optimized imaging technologies. Starting from basics of solid-state imaging this presentation will expand on different options for applications in space and scientific experiment; examplesof relevant DALSA products and technologies will be provided.

Upgrades and Associated Readout / 73

CMS pixel detector upgrade

Corresponding Author: valeria.radicci@psi.ch

Upgrades and Associated Readout / 74

FEI4_P1 a prototype pixel readout chip for the ATLAS B-layer upgrade

Multi-Pixel Photon Detectors Readout / 75

Integrated Electronics for SiPM and MPPCs

Corresponding Author: fleury@lal.in2p3.fr

Invited Talks: 3D Bonding Technology / 76

3D Bonding at Tezzaron

Invited Talks: 3D Bonding Technology / 77

3D-LSI technology for Image Sensors

Summary:

Recently the development of three-dimensional large-scale integration (3D-LSI) has been accelerated and its stage has changed from the research level or limited production level to the investigation level with a view to mass production. The 3D-LSI using Through-Silicon Via (TSV) has simplest structure and it is expected to realize high-performance, high-functionality and high density LSI cube. This presentation covers the current 3D technology for chip size package of image sensor devices and next generation 3D-LSI technologies.

3D Bonding / 78

Test Results from the VIP Chip

Corresponding Author: deptuch@fnal.gov

3D Bonding / 79

Fabrication, Assembly, and Evaluation of Cu-Sn and Cu-Cu Bump Bonding arrays for Ultra-Fine Pitch Hybridization and 3D Integration

Summary:

The use of collapsible (solder) bump interconnects in pixel detector hybridization has been shown to be very successful. However, as pixel sizes decrease, the use of non-collapsible metal-to-metal bump bonding methods is needed to push the interconnect dimensions smaller. Furthermore, these interconnects are compatible with 3D intgration technologies which are being considered to increase overall pixel and system performance. These metal-to-metal bonding structures provide robust mechanical and electrical connections and allow for a dramatic increase in pixel density. Of particular interest are Cu-Cu thermocompression bonding and Cu/Sn-Cu solid-liquid diffusion bonding processes.

Working with Fermilab, RTI undertook a demonstration to show that these bump structures could be reliably used to interconnect devices designed with 20 micron I/O pitch. Cu and Cu-Sn bump fabrication processes were developed to provide a well-controlled surface topography necessary for the formation of low resistance, high yielding, and reliable interconnects. The electrical resistance and yield has been quantified based on electrical measurements of daisy chain test structures and the mechanical strength of the bonding has been quantified through die shear testing. The reliability has been characterized through studies of the impact of thermal exposure on the mechanical performance of the bonds. Cross-section SEM analysis, coupled with high resolution energy dispersive spectroscopy, has provided insight into the physical and chemical nature of the bonding interfaces and aided in the evaluation of the long-term stability of the bonds.

3D Bonding / 80

Status and perspectives of Deep N-Well 130 nm CMOS MAPS

Corresponding Author: valerio.re@unibg.it

3D Bonding / 81

Analysis of 3D Stacked, Fully Functional CMOS Active Pixel Sensor Detectors

Corresponding Author: daniele.passeri@diei.unipg.it

Invited Talk: Multi-Pixel Photon Detectors / 82

Multi-Pixel Photon Detectors

Corresponding Author: nakaya@scphys.kyoto-u.ac.jp

Multi-Pixel Photon Detectors / 83

Characteristics of a prototype matrix of Silicon PhotoMultipliers (SiPMs)

Corresponding Author: dinu@lal.in2p3.fr

Multi-Pixel Photon Detectors / 84

Characterization of MPPCs detectors in Japan

Corresponding Author: tohru@shinshu-u.ac.jp

Multi-Pixel Photon Detectors / 85

Studies of time resolution of the SiPM

Multi-Pixel Photon Detectors Readout / 86

ASIC development for the SiPM readout

Corresponding Author: corsi@poliba.it

Inivted Talks: Simulation and Future Direction / 87

The van Roosbroeck system, its mathematical properties and use in device simulation tools

Corresponding Author: gaertner@wias-berlin.de

Inivted Talks: Simulation and Future Direction / 88

Future Directions of Pixel Detectors and their Applications in Life Sciences

Author: Jan Jakubek[1]

[1] *Institute of Experimental And Applied Physics, Czech Technical University*

Corresponding Author: jan.jakubek@utef.cvut.cz

Summary:

Recent advances in semiconductor technology allow to construct highly efficient and low noise pixel detectors of ionizing radiation. Steadily improving quality of front end electronics enables fast digital signal processing in each pixel which offers recording of more complete information about each detected quantum (energy, time, number of particles). All these features improve an extend applicability of pixel technology in different fields. Some applications of pixel technology especially for imaging in

life sciences and astronomy will be shown (energy and phase sensitive X-ray radiography and tomography, SPECT, neutron radiography, electron microscopy, etc).
On the other hand a number of obstacles can limit the detector performance if not handled. The pixel detector is in fact an array of individual detectors (pixels), each of them has its own efficiency, energy calibration and also noise. The common effort is to make all these parameters uniform for all pixels. However an ideal uniformity can be never reached. Moreover it is often seen that the signal in one pixel can affect the neighbouring pixels due to various reasons (charge sharing, crosstalk). All such effects have to be taken into account during data processing to avoid false data interpretation.
A brief view into the future of pixel detectors and their applications including also spectroscopy, tracking and dosimetry will be given too. Special attention will be paid to the problem of detector segmentation in context of the charge sharing effect.

Simulation and Future Direction / 89

A New Technique for the Reconstruction, Validation, and Simulation of Hybrid Pixel Hits

Corresponding Author: petar@pha.jhu.edu

Summary:

We present a new technique for the reconstruction, validation, and simulation of hybrid pixel hits. The technique is based upon the fitting of the cluster projections to pre-computed shapes or "templates". A detailed simulation called Pixelav that has successfully described the profiles of clusters measured in beam tests of radiation-damaged sensors is used to generate the cluster shapes. Although the technique was originally developed to optimally estimate the coordinates of hits after the detector became radiation damaged, it also has superior performance before irradiation. The technique requires a priori knowledge of the track angle which makes it suitable for the subsequent passes in a multi-pass reconstruction algorithm. However, the same angle sensitivity allows the algorithm to determine if the sizes and shapes of the cluster projections are consistent with the input angles. This information may be useful in suppressing spurious hits caused by secondary particles and in validating seeds used in track finding. In combination, the improved reconstruction and seeding significantly reduce the resolution tails of reconstructed track parameters and reduce the light quark background of tagged b-quarks by a factor of 2-3. Finally, a new procedure that uses the templates to re-weight clusters generated by the CMSSW simulation is described. This technique permits the fast simulation of pixel hits that have the characteristics of the much more CPU-intensive Pixelav hits and may be the only practical way to simulate radiation-damaged detectors in the full detector simulations of the LHC experiments.

Simulation and Future Direction / 90

First Fabrication of full 3D-detectors at SINTEF

Corresponding Author: thor-erik.hansen@sintef.no

Simulation and Future Direction / 91

Simulation of guard ring influence on the performance of ATLAS pixel detectors

Corresponding Author: benoit@lal.in2p3.fr

Simulation and Future Direction / 92

Monolithic Pixel Sensors in deep-submicron SOI technology

Corresponding Author: dcontarato@lbl.gov

Simulation and Future Direction / 93

SOI Pixel development at KEK

Corresponding Author: yasuo.arai@kek.jp

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Integrated Electronics for SiPM and MPPCs

Author: Julien Fleury[1]

[1] *OMEGA / IN2P3 / CNRS*

Corresponding Author: fleury@lal.in2p3.fr

Expectations on front-end electronics have deeply changed with the strong increase of channels in physics experiments and medical imaging. Integration has become a key issue to achieve low-cost and efficient readout of new photo-detectors generation.
The Orsay Microelectronics group Associated (OMEGA) has developed an expertise in front-end chip to read out such photodetectors with a high level of integration.
A first version of SiPM readout chip has been designed and produced to read out the 8,000-channel Iron-Scintillator hadronic calorimeter prototype currently in test beam at CERN. An input DAC allows a channel by channel 5V adjustment on the SiPM bias ensuring a trimless tuning of the signal to noise ratio of every channel. The read-out chain embeds an AC-coupled charge preamplifier followed by a $CRRC^2$ shaper and a track and hold.
A new generation of System-on-Chip ASICs called SPIROC (standing for SiPM Integrated Read-Out Chip) is being designed embedding high-voltage fine adjustment, gain correction, amplification, filtering, analogue memory, analogue to digital conversion, digital memory, time measurement, self-triggering capability. This new stand-alone device will allow going further in the integration of high numbers of channels at low cost.
Several chip designed at the microelectronic pole will be presented and some example of integration will be developed.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral Presentation

95

A full 3-dimensional simulation study of a pixel sensor

Author: Eunil Won[1]

Co-author: Ron Lipton [2]

[1] *Korea University*

[2] *Fermilab*

Corresponding Author: eunil@hep.korea.ac.kr

We present a full 3-dimensional simulation study of a pixel sensor based on SOI technology. The doping concentration and its spatial distribution of the sensor are optimized to the target fabrication technology through process simulation. A 3-dimensional device simulation is carried out in order to extract electrical properties of the sensor. A detailed study on the effect of pinning layers and pad geometry on sensor biasing and charge collection is reported in our presentation.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

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The van Roosbroeck system, its mathematical properties and their use in device simulation tools

Author: Klaus Gaertner[1]

[1] *WIAS*

Corresponding Author: gaertner@wias-berlin.de

K. G"artner, Weierstrass Institute for Applied Analysis and Stochastics, Mohrenstr. 39, 10117 Berlin, Germany, gaertner@wias-berlin.de, phone +49 30 20372 475

Abstract. The classical van Roosbroeck system, describing the carrier transport in semiconductors, is analytically well understood with assumptions on data and domains, covering practical applications.
Properties, like the existence of a Ljapunov functional (the free energy), or bounded steady state solutions etc. can be carried over to the discrete version for 'boundary conforming Delaunay grids', the classical Scharfetter-Gummel and the implicit Euler scheme.
Hence the basic stability properties can be guaranteed for any spatial or time step size. Proving these discrete properties is of practical value, too, because averaging schemes for coefficients preserving these properties can be identified. A 3d device simulator, based strictly on theory, is used at WIAS to push the limits in some directions. Having solved the discretization problem to some extent, the remaining challenges are grid generation and solving the linear systems, arising from Newton's method or from fixed point iteration schemes. The linear systems complexity issues together with the huge condition numbers limit the present code to roughly 1 000 000 grid points. The dream is a factor ten in size based on algorithmic improvements only.
The semiconductor sensor design community, especially HLL Munich, was collaborating over years by creating inherently 3d, large volume and complex simulation tasks. Insight into device operation - not numbers - was the main, helpful goal. Hence an X-ray CCD and the charge handling capacitance computations will be discussed in detail to illustrate the status. The mathematics motivated goals differ from those driving the development of commercial tools, but methods will diffuse into the commercial simulators.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

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The control and readout systems of the CMS Pixel detector

Author: Christian Veelken[1]

[1] *UC Davis*

Corresponding Author: veelken@fnal.gov

The CMS Pixel detector measures the direction and momentum of charged
particles close to the nominal interaction point of the CMS experiment
at CERN, Switzerland.
It is a rather complex device, consisting of 1444 detector modules,
in total providing about 66 million pixels of size 100 x 150 μm and
an active area of about 1~m^2 for the measurement of charged particles
traversing its fiducial volume.
The hardware and software components of the control and the read–out systems of the CMS Pixel detector will be described in this document.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral Presentation

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3D-LSI technology for Image Sensors

Author: Makoto Motoyoshi[1]

[1] *ZyCube Co., Ltd and Tohoku University*

Summary:

Recently the development of three-dimensional large-scale integration (3D-LSI) has been accelerated and its stage has changed from the research level or limited production level to the investigation level with a view to mass production. The 3D-LSI using Through-Silicon Via (TSV) has simplest structure and it is expected to realize high-performance, high-functionality and high density LSI cube. This presentation covers the current 3D technology for chip size package of image sensor devices and next generation 3D-LSI technologies.

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Pixel Luminosity Telescope for CMS

Author: Robert Stone[1]

[1] *Rutgers University*

Corresponding Author: stone@physics.rutgers.edu

The Pixel Luminosity Telescope (PLT) is an innovative luminosity monitor which is planned as an upgrade for the CMS detector at LHC. It uses pixelated single crystal diamonds as the active sensor material bumpbonded to standard CMS pixel readout electronics. The PLT makes use of a presently unused feature of the pixel readout chip which was designed to provide an input to a hardware trigger processor. This feature will produce a bunch crossing (25ns) 'hit' signal that can form the basis of luminosity information at the hardware level. I will report on the first successful use of this fast signal to self-trigger on beta particles from a source using a diamond pixel detector.

Preferred Presentation Type (Choose either Oral Presentation or Poster Presentation):

Oral

High Energy Physics Detectors / 103

Pixel Luminosity Telescope for CMS

Corresponding Author: stone@physics.rutgers.edu

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Future Directions of Pixel Detectors and their Applications in Life Sciences

Author: Jan Jakubek[1]

[1] *Institute of Experimental and Applied Physics, Czech Technical University in Prague*

Corresponding Author: jan.jakubek@utef.cvut.cz

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SiPM

Author: Gianmaria Collazuol[None]

Summary:

The silicon photo-multiplier (SiPM) is semiconductor device consisting in a matrix
of tiny avalanche photo-diode pixels (~103 3 /mm2) grown on a common silicon substrate and connected in parallel via integrated resistors. The diodes are operated in Geiger mode so that any single carrier, generated either by photons or thermally in the depletion region, might trigger a self-sustaining avalanche which is quenched by the integrated resistors. All SiPM pixels work on a common load and the output signal is the sum of the signals from all fired pixels. While each pixel is an independent binary photon counter (with a dead-time of ~30ns), the SiPM as a whole works as an analog detector with negligible dead-time.
High gain (~106) and high efficiency (up to 80%) in detecting low optical photon

fluxes with unprecedented charge resolution, extreme single photon timing resolution, low voltage operation, insensitivity to magnetic fields, RF and EM pickup, and high rate capabilities make SiPM suitable for many applications, as an alternative to vacuum photo-multiplier tubes.

In this talk, after an introduction to the relevant device physics we'll shortly report about our most recent measurements of SiPM basic characteristics as a function of temperature on a wide range (down to cryogenic temperatures). We found that break-down voltage is decreasing with decreasing T in fair agreement with the Baraff model. Dark current is also decreasing at low T, being dominated by generation-recombination noise above 200K and by tunnel noise at lower temperatures.

The main part of the talk will follow, focusing on the timing properties of SiPM. In particular our measurement of single photon timing resolution of devices from various manufacturers will be discussed. The timing resolution was studied by illuminating a single SiPM with ultra-short (70fs) low intensity laser pulses with fixed repetition period (sub-picosecond jitter) and measuring the time difference between next pulses. Low noise and ultra-fast electronics was used to amplify the SiPM signal and to sample its waveform at high rate. Optimum timing digital filtering was adopted in order to minimize the effects of the noise. Intrinsic resolutions of a some tens ps was measured for typical operating conditions, under illumination with l~400nm light. The dependencies of single photon timing resolution as a function of l and of the bias voltage are also discussed. The measurements are in fair agreement with numerical simulations of the devices.
Results about timing of systems consisting in (organic / inorganic) scintillators readout by SiPM will be also reported.

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Fabrication, Assembly, and Evaluation of Cu-Sn and Cu-Cu Bump Bonding arrays for Ultra-Fine Pitch Hybridization and 3D Integration

Author: Alan Huffman[1]

[1] *RTI*

Summary:

The use of collapsible (solder) bump interconnects in pixel detector hybridization has been shown to be very successful. However, as pixel sizes decrease, the use of non-collapsible metal-to-metal bump bonding methods is needed to push the interconnect dimensions smaller. Furthermore, these interconnects are compatible with 3D integration technologies which are being considered to increase overall pixel and system performance. These metal-to-metal bonding structures provide robust mechanical and electrical connections and allow for a dramatic increase in pixel density. Of particular interest are Cu-Cu thermo-compression bonding and Cu/Sn-Cu solid-liquid diffusion bonding processes.

Working with Fermilab, RTI undertook a demonstration to show that these bump structures could be reliably used to interconnect devices designed with 20 micron I/O pitch. Cu and Cu-Sn bump fabrication processes were developed to provide a well-controlled surface topography necessary for the formation of low resistance, high yielding, and reliable interconnects. The electrical resistance and yield has been quantified based on electrical measurements of daisy chain test structures and the mechanical strength of the bonding has been quantified through die shear testing. The reliability has been characterized through studies of the impact of thermal exposure on the mechanical performance of the bonds. Cross-section SEM analysis, coupled with high resolution energy dispersive spectroscopy, has provided insight into the physical and chemical nature of the bonding interfaces and aided in the evaluation of the long-term stability of the bonds.

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Pixel detectors for x-ray imaging spectroscopy in space

Author: Johannes Treis[1]

[1] *MPI HLL*

Summary:

Pixelated semiconductor detectors for X-ray imaging spectroscopy have become key components of a large variety of space missions exploring the x-ray sky, and instruments using such devices as radiation sensitive elements are included in the payload of a large number of future missions.
Located on the platform of the new Spectrum-Roentgen-Gamma3 satellite, the eROSITA (extended Roentgen Survey with an Imaging Telescope Array) instrument will perform an imaging all-sky survey up to an X-ray energy of 10 keV with unprece-dented spectral and angular resolution and investigate of the nature of dark energy and dark matter. The instrument will consist of seven parallel oriented mirror modules each having its own pnCCD camera in the focus.
The satellite born X-ray observatory SIMBOL-X will be the first mission to use formation-flying techniques. Mirror system and scientific instrumentation are located on individual, independent spacecrafts. In this way, an X-ray telescope with an unprecedented focal length of around 20 m can be built with an energy range between 0.5 to 80 keV. The detector instrumentation consists of separate high- and low energy detectors, HED and LED. The LED is a monolithic 128 x 128 DEPFET macropixel array, while the HED consists of an array of 3D-integrated CdTe pixels. SIMBOL-X will study the physics of black holes and the mechanisms of cosmic particle acceleration. A similar concept is proposed for the next generation X-ray observatory XEUS/IXO.
Finally, the MIXS (Mercury Imaging X-ray Spectrometer) instrument on the European Mercury exploration mission BepiColombo will use DEPFET macropixel arrays together with a small X-ray telescope to perform a planetary XRF analysis of Mercury's crust with high spatial resolution to study the composition, the generation and evolution of the planetary surface. A similar instrument is considered for the Jupiter exploration probe Laplace.
The talk will introduce the mission concepts and their scientific targets, the requirements on the detector devices and the strategies chosen to fulfill the requirements.

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Impact of pixellated detectors on synchrotron radiation experiments

Author: Peter Siddons[1]

[1] *BNL*

Summary:

The availability of pixellated x-ray detectors for synchrotron radiation is still in its infancy compared to high-energy physics experiments, but their impact is already powerful. The talk will address some of the benefits and issues associated with the unique requirements of these experiments.

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Solid State Imagers in Space and Scientific Applications - DALSA Technology Review

Author: Andrey Lomako[1]

[1] *DALSA Corporation*

Summary:

DALSA is an imaging company with unique positioning on the market as a leading provider of high end imaging solutions for any application; these solutions are based on propriatery to DALSA technologies, which include: semiconductor processing foundry, CCD and CMOS image sensor desing and manufacturing capability, MEMS foundry, camera and vision systems design capability, imaging software design. From the first sensors in early 80s DALSA is actively growing custom design business to provide the most demanding customers with optimized imaging technologies. Starting from basics of solid-state imaging this presentation will expand on different options for applications in space and scientific experiment; examplesof relevant DALSA products and technologies will be provided.

Upgrades and Associated Readout / 110

Commissioning of the ALICE Silicon Pixel Detector

Corresponding Author: romualdo.santoro@ba.infn.it

Conference Social Event and Banquet / 111

Conference Social at the Fermilab User's Center

Conference Social Event and Banquet / 112

Conference Dinner at Chez Leon

Discussion Session on Fermilab sponsored 3D MPW Run / 113

3D Technology Plans at Fermilab

Corresponding Author: yarema@fnal.gov

Discussion Session on Fermilab sponsored 3D MPW Run / 114

Round Table Discussion on 3D Technology