PSD9: The 9th International Conference on Position Sensitive Detectors

Monday 12 September 2011 - Friday 16 September 2011

PSD9
9th International Conference on
POSITION SENSITIVE DETECTORS

Book of Abstracts

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ATLAS Silicon Microstrip Tracker Operation and Performance

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The SemiConductor Tracker (SCT), comprising of silicon micro-strip detectors is one of the key precision tracking devices in the ATLAS Inner Detector. ATLAS is one of the experiments at CERN LHC.
The completed SCT is in very good shapes with 99.3% of the SCT's 4088 modules (a total of 6.3 million strips) are operational. The noise occupancy and hit efficiency exceed the design specifications. In the talk the current status of the SCT will be reviewed. We will report on the operation of the detector, its performance and observed problems, with stress on the sensor and electronics performance.
In December 2009 the ATLAS experiment at the CERN Large Hadron Collider (LHC) recorded the first proton-proton collisions at a centre-of-mass energy of 900 GeV and this was followed by the unprecedented energy of 7 TeV in March 2010. The Semi-Conductor Tracker (SCT) is the key precision tracking device in ATLAS, made from silicon micro-strip detectors processed in the planar p-in-n technology. The signals from the strips are processed in the front-end ASICS ABCD3TA, working in the binary readout mode. Data is transferred to the off-detector readout electronics via optical fibers.
The completed SCT has been installed inside the ATLAS experimental hall since 2007 and has been operational since then. Calibration data has been taken and analyzed to determine the noise performance of the system. In addition, extensive commissioning with cosmic ray events has been performed both with and without magnetic field. The sensor behavior in the 2 Tesla solonoidal magnetic field was studied by measurements of the Lorentz angle. After this commissioning phase, the SCT was ready for the first LHC pp collision run. We find 99.3% of the SCT modules are operational, noise occupancy and hit efficiency exceed the design specifications, the alignment is already close enough to the ideal to allow on-line track reconstruction and invariant mass determination.
In the talk the current status of the SCT will be reviewed, including results from the latest data-taking periods in 2009 and 2010, and from the detector alignment. We will report on the operation of the detector including overviews on services, connectivity and observed problems. The main emphasis will be given to the performance of the SCT with the LHC in collision mode and to the performance of individual electronic components. The SCT commissioning and running experience will then be used to extract valuable lessons for future silicon strip detector projects.

Preferred medium (Oral/poster):

Oral

Detectors for high radiation environments / 3

Silicon Strip Detectors for the ATLAS sLHC Upgrade

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While the Large Hadron Collider (LHC) at CERN is continuing to deliver an ever-increasing luminosity to the experiments, plans for an upgraded machine called Super-LHC (sLHC) are progressing. The upgrade is foreseen to increase the LHC design luminosity by a factor ten. The ATLAS experiment will need to build a new tracker for sLHC operation, which needs to be suited to the harsh sLHC

conditions in terms of particle rates and radiation doses. In order to cope with the increase in pile-up backgrounds at the higher luminosity, an all silicon detector is being designed. To successfully face the increased radiation dose, a new generation of extremely radiation hard silicon detectors is being designed.
Silicon sensors with sufficient radiation hardness are the subject of an international R&D programme, working on pixel and strip sensors. The efforts presented here concentrate on the innermost strip layers. We have developed a large number of prototype planar detectors produced on p-type wafers in a number of different designs. These prototype detectors were then irradiated to a set of fluences matched to sLHC expectations. The irradiated sensors were subsequently tested with prototype sLHC readout electronics in order to study the radiation-induced degradation, and determine their performance after serious hadron irradiation of up to a few 1015 1-MeV neutron-equivalent per cm2.
One key figure of merit is the signal that can still be measured with a silicon detector after irradiation to increasing radiation doses representative of the severe sLHC conditions. Due to radiation-damage effects such as carrier trapping and growing depletion voltage of the detectors, the measurable signal is degraded as a function of irradiation. We measure a signal of roughly 25,000 electrons for an unirradiated sensor, which reduces to about 17,500 electrons after 2·1015 1-MeV neutron-equivalent per cm2 . We have also measured signals around 9,500 electrons for radiation doses expected for the pixel detectors in the ATLAS tracker upgrade.
From these data, it is evident that sufficient charge can still be recorded even at the highest fluence.
In our presentation, we will give an overview of the ATLAS tracker upgrade project, in particular focusing on the crucial innermost silicon strip layers. Results from a wide range of irradiated silicon detectors will be presented, and layout concepts for lightweight yet mechanically very rigid detector modules with high service integration will be shown.
We will draw conclusions on what type and design of strip detectors to employ for the upgrades of the tracking layers in the sLHC upgrades of LHC experiments.

Preferred medium (Oral/poster):

Oral

Detectors for Particle Physics / 5

Performance of the LHCb Vertex Locator

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LHCb is a dedicated experiment to study new physics in the decays of beauty and charm hadrons at the Large Hadron Collider (LHC) at CERN. The beauty and charm hadrons are identified through their flight distance in the Vertex Locator (VELO), and hence the detector is critical for both the trigger and offline physics analyses. The VELO is the highest resolution vertex detector at the LHC.

The VELO is the silicon detector surrounding the LHCb interaction point, and is located only 7 mm from the LHC beam during normal operation. The VELO is moved into position for each fill of the LHC, once stable beams are obtained. The detector is centred around the LHC beam during the insertion by the online reconstruction of the primary vertex position. The detector operates in an extreme and highly non-uniform radiation environment, and the effects of surface and bulk radiation damage have already been measured.

The VELO consists of two retractable detector halves with 21 silicon micro-strip tracking modules each. A module is composed of two n+-on-n 300 micron thick half disc sensors with R-measuring and Phi-measuring micro-strip geometry, mounted on a carbon fibre support paddle. The minimum pitch is approximately 40 µm. The detector is also equipped with one n-on-p module. The detectors are operated in vacuum and a bi-phase C02 cooling system used. The detectors are readout with an analogue front-end chip and the signals processed by a set of algorithms in FPGA processing boards.

The performance of the algorithms is tuned for each individual strip using a bit-perfect emulation of the FPGA code run in the full software framework of the experiment.

The VELO has been successfully operated for the first LHC physics run. Operational results show a signal to noise ratio of around 20:1 and a cluster finding efficiency relative to the design of 99.5 %. The small pitch and analogue readout, result in a best single hit precision of 4 μm having been achieved at the optimal track angle.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 34 / **6**

Snapshot Electron Spectroscopy using a Linear Array

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A one dimensional electron counting detector array for electron spectroscopy applications is presented. The array uses a microchannel plate in conjunction with a custom ASIC.

The detector assembly is fitted at the focal plane of the CLAM4 hemispherical energy analyser and enables imaging across the width of the focal plane. The electron energy analyser is built into a system specifically designed for in-situ real-time electron spectroscopy. The detector system is controlled by means of a stand alone controller based on a National Instruments cRIO embedded computer. Results are presented showing key aspects of the detector, including the linearity of the device and maximum readout speed and count rate.

Preferred medium (Oral/poster):

Oral

Detectors for Particle Physics / **7**

The Belle II DEPFET vertex detector: current status and future plans

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An upgrade of the existing Flavour Factory KEKB (Tsukuba, Japan) is under construction, and is foreseen for commissioning by the end of 2014. This new e+e- machine (”SuperKEKB”) will deliver an instantaneous luminosity of 8x1035 cm-2s-1, which is 40 times higher than the the world record set by KEKB.

In order to be able to fully exploit the increased number of events and provide high precision measurements of the decay vertex of the B meson systems in such a harsh environment, the Belle detector

will be upgraded ("Belle II") and a new silicon vertex detector, based on the DEPFET technology, will be designed and constructed. The new pixel detector, close to the interaction point, will consist of two layers of DEPFET active pixel sensors. This technology combines the detection together with the in-pixel amplification by the integration, on every pixel, of a field effect transistor into a fully depleted silicon bulk. In Belle II, DEPFET sensors thinned down to 75 um with low power consumption and low intrinsic noise will be used.

In the talk, though the full system will be described, an introduction to the sensor technology together with the electronics chain and the expected performance will be presented.

Preferred medium (Oral/poster):

Oral

Detectors for high radiation environments / 8

Characterisation of microstrip and pixel silicon detectors before and after hadron irradiation

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The use of segmented silicon detectors for tracking and vertexing in particles physics has grown substantially since their introduction in 1980. It is now anticipated that not less than 50,000 six inch wafers of high resistivity silicon will need to be processed into sensors to be deployed in the upgraded experiments in the future high luminosity LHC at CERN.
These detectors will also face an extremely severe radiation environment, varying with distance from the interaction point. The volume of required sensors is large and their delivery is required during a relatively short time, demanding a high throughput from the chosen suppliers. The current situation internationally, in this highly specialist market, means that security of supply for large orders can therefore be an issue and bringing additional potential vendors into the field can only be an advantage.
Semiconductor companies that could include planar sensors suitable for particle physics in their product lines will, however, need though to prove their products meet all the stringent technical requirements. A semiconductor company with very widespread experience of producing science grade CCDs (including deep depletion devices) has adapted their CCD process to fabricate for the first time several wafers of pixel and micro-strip radiation hard sensors, suitable for future high energy physics experiments.
The results of the pre-irradiation characterisation of devices fabricated with different processing parameters and the measurements of charge collection properties after different hadron irradiation doses up to those anticipated for the pixel layers at the high-luminosity LHC (HL-LHC) are presented.

Preferred medium (Oral/poster):

Oral

X-Ray and Gamma detectors / 9

Pixellated CZT high-energy X-ray instrument

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Co-authors: Caroline Reid [2]; Christiana Christodoulou [2]; James Scuffham [3]; Matthew Veale [1]; Matthew Wilson [1]; Paul Sellin [4]; Robert Cernik [5]; Robert Speller [2]; Silvia Pani [4]; Simon Jacques [5]; Steven Bell [1]

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We have developed a pixellated high-energy X-ray detector instrument to be used in a variety of imaging applications. The instrument consists of a Cadmium Zinc Telluride based detector bump-bonded to a large area ASIC and packaged with a high performance data acquisition system. The 80 by 80 pixels each of 250um by 250um give 1-1.5kev energy resolution at the same time providing a high speed imaging performance. This system uses a relatively simple wire-bonded interconnection scheme but this is being upgraded to allow multiple modules to be used with very small dead space. The readout system and the novel interconnect technology is described and how the system is performing in several target applications.

Preferred medium (Oral/poster):

Oral

Detectors for Particle Physics / 10

Operational experience with the ATLAS Pixel Detector at the LHC.

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The ATLAS Pixel Detector is the innermost detector of the ATLAS experiment at the Large Hadron Collider at CERN, providing high-resolution measurements of charged particle tracks in the high radiation environment close to the collision region. This capability is vital for the identification and measurement of proper decay times of long-lived particles such as b-hadrons, and thus vital for the ATLAS physics program.
The detector provides hermetic coverage with three cylindrical layers and three layers of forward and backward pixel detectors.
It consists of approximately 80 million pixels that are individually read out via chips bump-bonded to 1744 n-in-n silicon substrates.

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

Preferred medium (Oral/poster):

Oral

Photon Detectors for Synchrotron Radiation and other applications / 11

Improving the resolution in soft X-ray emission spectrometers through photon-counting using an Electron Multiplying CCD

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Co-authors: Andrew Holland [1]; Bernd Schmitt [2]; James Tutt [1]; Matthew Soman [1]; Thorsten Schmitt [2]

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Four years ago, a study of back-illuminated Charge-Coupled Devices (CCDs) for soft X-ray photon detection demonstrated the improvements that could be brought over more traditional micro-channel plate detectors for X-ray spectrometers based on diffraction gratings and position sensitive detectors [1]. Whilst the spatial resolution was reported to be improved dramatically, an intrinsic limit of approximately 25 micrometers was found due to the spreading of the charge cloud generated in the CCD across several pixels. To overcome this resolution limit, it is necessary to move away from the current integrated imaging methods and consider a photon-counting approach, recording the photon interaction locations to the sub-pixel level.

To make use of photon-counting techniques it is important that the individual events are separable. To maintain the throughput of the beamline for high intensity lines, higher frame rates and therefore higher readout speeds are required. With CCD based systems, the increased noise at high readout speeds can limit the photon-counting performance.

The Electron-Multiplying CCD shares a similar architecture with the standard CCD but incorporates a "gain register". This novel addition allows controllable gain to be applied to the signal before the read noise is added, therefore allowing individual events to be resolved above the noise even at much higher readout rates.

In the past, the EM-CCD has only been available with imaging areas too small to be practical in soft X-ray emission spectrometers. The current drive for large area Electron-Multiplying CCDs is opening this technology to new photon-counting applications, requiring in-depth analysis of the processes and techniques involved. Early results indicate that through the introduction of photon-counting techniques the resolution in such systems can be dramatically improved.

[1] Dinardo et al., Nucl. Instrum. Meth. A 570 (2007) 176-181

Preferred medium (Oral/poster):

Oral

X-Ray and Gamma detectors / 12

Development of high temperature AlGaAs soft X-ray photon counting detectors

Author: John Lees[1]

Co-authors: Anna Barnett [1]; Chee Hing Tan [2]; David Bassford [1]; Donna Boe [3]; Jo Shien Ng [2]; Nasser Babazadeh [2]; Peter Vines [2]; Rajiv Gomes [2]; Robert McKeag [3]

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New types of detectors based on the wide band gap material AlGaAs have been developed for soft X-ray spectroscopy applications. We report on the spectroscopic performance of simple p-i-n diodes and avalanche photodiodes (APDs). A number of diode types with different layer thicknesses have also been characterised. X-ray spectra from a 55Fe radioactive source show these diodes can be used for spectroscopy with promising energy resolution (0.9–2.5keV) over a −30 to +90 C temperature range .The temperature dependence of the avalanche multiplication process at soft X-ray energies in Al0.8Ga0.2As APDs was investigated at temperatures from +80 ℃ to -20 ℃. The temperature dependence of the pure electron initiated multiplication factor (Me) and the mixed carrier initiated avalanche multiplication factor (Mmix) were experimentally measured. The experimental results are compared with a spectroscopic Monte Carlo model for Al0.8Ga0.2As diodes from which the temperature dependence of the pure hole initiated multiplication factor (Mh) is determined.

Monte Carlo simulations for the avalanche gain of absorbed X-ray photons have also been developed to study the relationship between avalanche gain and energy resolution for semiconductor X-ray avalanche photodiodes. The model showed that the distribution of gains, which directly affects the energy resolution, depends on the number of injected electron hole-pairs (and hence the photon energy), the relationship between ionization coefficients and the overall mean gain. Our model showed that the conventional notion of APD gains degrading energy resolution significantly is incomplete.

We compare the Monte Carlo simulations with experimental data from a number of different Al0.8Ga0.2As diodes.

Preferred medium (Oral/poster):

Oral

Advances in Gas Based Detectors / 13

Development of spark-protected micropattern gaseous detectors with resistive electrodes

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Nowadays, micropattern gaseous detectors (MPDGs) challenge traditional gaseous detectors (such as MWPCs, RPCs and parallel-plate avalanche chambers) in practically all the applications. The main advantage of the MPGDS is that they are manufactured by means of a microelectronics technology, which offers a high granularity and, consequently an excellent position resolution. However, the

fine structure of their electrodes and the small gap between them make MPGDs electrically "weak" In fact, their maximum achievable gains are usually not very high and they can be easily destroyed by sparks, which may occur during their operation.
A few years ago, we have developed the first GEM-type micropattern detectors featuring resistive electrodes instead of metallic ones. The resistive electrodes limit the current during the sparks and make the detector spark-protected. This work triggered a sequence of similar developments, which are nowadays performed not only by our group, but by several other groups. We will review the latest achievements in this direction, for example the successful development and tests of large-area MICROMEGAS with resistive electrodes will be described. Finally we will present a new family of spark-protected MPGDS recently developed by us: the resistive microstrip and microdot detectors and the resistive WELL/CAT- type detectors. These innovative detectors are produce on standard PCB boards by a simple technology. We will present the results of exhaustive studies performed on these detectors: their rate and gain characteristics, position and energy resolutions, stability with time and so on . As follows from our tests, these detector are very promising and thus may have a great future.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 21 / **14**

Centroiding Methods for Split Events in a Charge Coupled Device used for Resonant Inelastic X-ray Scattering

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When X-rays interact in the 'field free'region of a back illuminated Charge Coupled Device (CCD) they form clouds of electrons that diffuse outwards in a stochastic fashion. These electrons can diffuse into neighbouring pixels before being contained in the potential wells beneath the electrodes. This process leads to signal electrons from a single interaction event being spread across multiple pixels –a 'split event'.

At the Swiss Light Source (SLS), PolLux is a microscopy beamline capable of producing photons with energies from 200 eV to 1400 eV with a beam width down to 20 nm [1]. The beam can be scanned across back illuminated CCD pixels (˜15 µm square) to take images of split events where the position of interaction is known. This allows the dependence of position of interaction in a pixel on charge spreading and split event profiles to be studied. Centroiding algorithms can be applied to the split event profiles, inviting the comparison of the known and calculated positions to compare the accuracy of the methods to be investigated.

The Super Advanced X-ray Emission Spectrometer (SAXES), used for Resonant Inelastic X-ray Scattering on the ADRESS beamline at the SLS, has a resolution that is reported to be limited by the charge spreading in the CCD. By applying the centroiding techniques to these split events we aim to improve the spatial resolution of the CCD down to sub-pixel levels (<13.5 µm) from the currently reported 24 µm FWHM [2]. However, understanding the formation of split events and the errors associated with the centroiding algorithms is essential before these techniques can be fully applied to improve the resolution of SAXES.

[1] J. Raabe, et al., Rev. Sci. Instrum., vol. 79, 113704, 2008.
[2] G. Ghiringhelli, et al., Rev. Sci. Instrum., vol. 77, 113108, 2006.

Preferred medium (Oral/poster):

Poster

X-Ray and Gamma detectors / **15**

The Silicon Strip Tracker of the Fermi Large Area Telescope

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The Large Area Telescope (LAT) is the primary instrument onboard the Fermi Gamma-ray Space Telescope (Fermi),
an observatory on a low earth orbit that was launched on 11 June 2008 to monitor the high energy gamma-ray sky. The LAT tracker is a solid-state instrument :
tungsten foils converts the gamma rays into electron-positron pairs which are then tracked in silicon planes in order to reconstruct the incoming gamma-ray direction.
The tracker comprises 36 planes of single-sided silicon strip detectors, for a total of 73 square meters of silicon, read out by nearly 900,000 amplifier-discriminator channels. The system operates on only 160 W of conditioned power while achieving > 99% single-plane efficiency within its active area and better than 1 channel per million noise occupancy. We describe the tracker design and performance, and discuss in particular the excellent stability of the hardware response during the first three years of operation on orbit.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 1 / **16**

Planar slim edge ATLAS pixel sensors for the IBL and high-lumi-LHC upgrades

Author: Tobias Wittig[1]

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The pixel detector is the innermost tracking detector of ATLAS which requires hermeticity to achieve superb track reconstruction performance. The current planar n-type sensors feature an active pixel matrix of n+ implantation and, so called, guard rings on the opposite p-side to reduce the high voltage stepwise. Because of the inactive safety margin around the active area, the sensor modules have been shingled on top of each other's edge which limits the thermal performance and adds complexity in the present detector.
For the insertable b-layer (IBL) and the high-lumi-LHC upgrade of ATLAS, a flat arrangement of sensors is foreseen. If the inactive edge is reduced from 1100 um down to about 250um (slim edge) the required level of hermeticity can be achieved.

In this presentation it will be shown that the essential reduction of the inactive edge is feasible by still fulfilling the IBL quality criteria concerning electrical specifications and breakdown behaviour. This is firstly achieved by monitored dicing into the safety margin, secondly by the reduction of number of guard rings and thirdly by shifting them beneath the active pixel area.

Dedicated designed and produced pixel sensors were studied in test beams to investigate the efficiency performance in the edge region of unirradiated sensors and those ones irradiated up to IBL fluences.

On the basis of these results we designed and produced planar n-type sensors adapted to the new read-out chip (FE-I4) with different bulk thicknesses. These sensors are designated candidates for IBL as well as one option for high-lumi-LHC. First unirradiated and irradiated sensor-chip-assemblies have already proven their performance during test beams.

Preferred medium (Oral/poster):

Oral

Advances in Pixel Detectors / 17

Irradiation and beam tests qualification for ATLAS IBL Pixel Modules

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

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

Preferred medium (Oral/poster):

Oral

Knowledge Transfer and Commercial Opportunities for PSDs / 18

Detection of explosive materials with Gamma Resonant Nuclear Absorption and Argon-Nitrogen TPC

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Detection of explosives in large cargo containers is an important preventive measure to counteract terrorism. The element-sensitive radiography with gamma-rays is one promising method, allowing to selectively detect Nitrogen content in various materials, which is a reliable signature of most of commercial explosives.
A novel high-resolution tracking detector sensitive to 9.17 MeV Nitrogen nuclear resonant absorption-line is being developed at the University of Bern.
The detector is based on a Time Projection Chamber (TPC) filled with a mixture of liquefied Argon and Nitrogen. The facility to generate gamma-rays of the required energy is based on a 2 MeV proton LINAC. First promising results of the performance of the detector and of the gamma-source facility are presented.

Preferred medium (Oral/poster):

Oral

Detectors for Astrophysics / **19**

Performance results from the ZEPLIN-III second science run

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The ZEPLIN-III direct dark matter experiment uses a 3D position-sensitive two-phase xenon time projection chamber. It is located in a deep underground laboratory at Boulby in North Yorkshire (UK) and searches for weakly interacting massive particles (WIPMs). Since June 2010 ZEPLIN-III is collecting the data in the second science run. The talk will give an overview over the detector performance and will describe in details the energy and position reconstruction.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 25 / **20**

Improvement of energy thresholds for scintillation detectors using a monolithic 2x2 MPPC array with a coincidence technique

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The performance of a large-area, monolithic Hamamatsu Multi-Pixel Photon Counter(MPPC) was tested consisting of a 2x2 array of 3x3 mm2 pixels. MPPC is a novel type of semiconductor photodetector comprising multiple avalanche photodiode (APD) pixels operated in Geiger mode. Despite its great advantage of signal multiplication comparable to that achieved with the photomultiplier tube (PMT), the detection of weak scintillation light signals is quite difficult due to the severe ontamination of dark counts, which typically amounts to ' 1 Mcps/3x3mm2 at room temperature. In this study, a coincidence technique was applied for scintillation detectors to improve the detection efficiency for low energy gamma-rays. The detector consisted of a 10x10x10 mm3 crystals of GSO, BGO and Pr:LuAG optically coupled with the 2x2 MPPCarray. With this technique, we demonstrated that the contamination of dark counts was reduced with a rejection efficiency of more than 99.8 %. As a result, 22.2 keV gamma-rays were successfully detected with a GSO scintillator as measured at +20 ◦C.

Preferred medium (Oral/poster):

poster

Poster Session - Board: 19 / **21**

A wavelength-shifting-fibre-based scintillator neutron detector implemented with a median point calculating method

Author: Takuro Kawasaki[1]

Co-authors: Atsushi Birumachi [2]; Kaoru Sakasai [3]; Kazuhiko Soyama [1]; Kentaro Toh [1]; Masaki Katagiri [4]; Masumi Ebine [2]; Takaaki Hosoya [5]

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A median point calculating method was introduced to the wavelength-shifting-fibre based neutron image detector to increase the spatial resolution. The detector was originally developed for the neutron diffraction instrument, SENJU, at the Japan Proton Accelerator Research Complex J-PARC. The detector head was comprised of 64x2 of wavelength shifting fibres placed in x, and y directions each in a 4-mm pitch. The fibres were sandwiched with the ZnS/10B2O3 scintillator sheets at the up and downstream of the fibres. The neutron-induced scintillation light was collected in each WLS fibre in a photon counting mode to ensure high detector efficiency. The original method of position determination for a detected neutron was with a coincidence between fibres in x and y that counted more than a threshold number of photoelectrons. The conventional method intrinsically determined the pixel size of the detector to the fibre pitch. By implementing the median point calculating method the detector reproduced neutron images with a finer effective pixel size and position information than the fibre pitch. This result clearly demonstrated the effectiveness of this interpolation method even to the detector working based on a photon counting mode. This kind of position determination method is especially useful in diffraction measurements in which the finer position information than the fibre pitch is often required for data analysis. Moreover the implementation of the method does not require any change on detector hardware settings, simply changing the calculation program to the FPGA-based signal processing electronics. In the presentation the spatial responses of the detector measured with a collimated neutron beam are compared both with the conventional and median point calculating method.

Preferred medium (Oral/poster):

poster

Poster Session - Board: 23 / **22**

Electron Multiplying CCDs for future Soft X-ray Spectrometers

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EM-CCDs are commonly used for the detection of optical light, but seldom for X-ray detection partially due to the high energy and large charge packets that are generated at these energies. Through the analysis of high energy X-ray events it has been possible to show that the noise generated by the stochastic nature of the gain multiplication process in EM-CCDs can be minimised by operating at modest levels of gain (<10x). This paper will aim to take this work further by attempting to verify this reduction in the noise generated at low levels of gain for 'soft'X-rays (200 –2,000 eV).
Due to their low energy, the photon interaction of a 'soft'X-ray will occur close to the devices back surface; therefore, the charge packet will have a large thickness of silicon to travel through before it is collected in the buried channel. This will lead to charge splitting between pixels in the EM-CCD making complete charge collection difficult, thus degrading the devices energy resolution.
Using the e2v CCD220 it is possible to fully deplete the silicon, causing the charge packet to be collected in the buried channel faster than in a standard device. This should reduce the amount of charge splitting seen, leading to a better energy resolution. With this improved charge collection it should then be possible to verify the effect of gain in the multiplication register on the noise generated by the amplification process allowing predictions to be made about EM-CCDs performance at 'soft'energies with the view to use them on future space missions such as IXO (OP-XGS) and WHIMEX.
In this paper we discuss the practical limitations when using EM-CCDs for X-ray spectrometers, together with modelling of the excess noise introduced by the avalanche gain and measurements confirming the predictions taken at the BESSY synchrotron.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 5 / **23**

Silicon Sensor Developments for the CMS Tracker Upgrade

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CMS started a campaign to identify the future silicon sensor technology baseline for a new Tracker for the high-luminosity phase of LHC. We ordered a large variety of 6"wafers in different thicknesses and technologies at HPK. Thicknesses ranging from 50μm to 300μm are explored on floatzone, magnetic Czochralski and epitaxial material both in n-in-p and p-in-n versions. P-stop and p-spray are

explored as isolation technology for the n-in-p type sensors as well as the feasibility of double metal routing on 6”wafers. Each wafer contains different structures to answer different questions, e.g. geometry, Lorentz angle, radiation tolerance, annealing behavior, read-out schemes. Dedicated process test-structures, as well as diodes, mini-sensors, long and very short strip sensors and real pixel sensors have been designed for this evaluation.
The structures will be exposed to mixed fluences composed of protons and neutrons representing the mixture of charged hadrons and neutrons as expected in the CMS Tracker after an integrated luminosity of 3000fb-1 at several radii.
This contribution provides an overview of the individual structures and their characteristics and summarizes interesting measurements performed so far.

Preferred medium (Oral/poster):

Oral

Detectors for Astrophysics / 24

Modelling Charge Packet Storage within Euclid CCD Structures.

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The primary aim of ESAs’Euclid mission is to map the distribution of galaxies and galaxy clusters, with an aim to mapping the ‘dark’architecture of the universe. This requires a highly accurate CCD, which is also designed to endure a harsh radiation environment.
The e2v CCD204 image sensor was redesigned for use on the Euclid mission; the resulting e2v CCD273 device has, among other changes, a smaller register electrode causing a reduction in the size of charge packets stored, this reduces the number of traps encountered by the signal electrons and therefore improves the serial CTI under irradiation.
The Euclid CCD device structure has been modelled using the Silvaco TCAD software to test preliminary calculations for the full-well capacity (FWC) of the device and provide indications of the volume occupied by varying signal sizes. These results are useful for realising mission objectives and for radiation damage studies.
The FWC of a buried channel (BC) CCD is the total amount of charge which can be stored before ‘blooming’occurs (i.e. the spreading of charge along the transfer columns into adjacent pixels) or before charge comes into contact with the Si-SiO2 surface interface, causing a reduction of CTE. Devices are preferentially operated at voltages where charge would spill across the transfer columns before contact is made with the surface.
The Silvaco simulations have been tested against actual devices to compare experimental measurements to those predicted in the models. Using these results, the implications of this study on the Euclid mission can be investigated in more detail.

Preferred medium (Oral/poster):

Oral

Knowledge Transfer and Commercial Opportunities for PSDs / 25

Tracking of moving fiducial markers during radiotherapy using a CMOS active pixel sensor.

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Co-authors: Emma Harris [1]; Giovanni Lupica [2]; Hafiz Zin [1]; Nigel Allinson [3]; Phil Evans [1]

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In order to minimise the dose delivered to healthy tissue during radiotherapy treatment of a moving tumour, it is first necessary to accurately measure tumour position as a function of time. For example, a portal imager can be used to detect surrogate markers implanted around the tumour in order to track the tumour with a moving collimator. Lung tumours can move at up to ˜20 mm/s, requiring a sampling rate of 20 Hz to achieve mm accuracy. However the passive a-Si flat panel imagers (FPIs) available with current linear accelerators operate at ˜2-10 frame/s, significantly slower than the required rate. Furthermore a-Si FPIs provide low image quality at their fastest frame-rates and are susceptible to damage by the treatment beam, requiring replacement every 1-2 years. Emerging CMOS active pixel sensors use an addressable and partial read-out architecture to achieve significantly improved frame rates relative to their passive counterparts. They are also capable of superior resolution, image quality and radiation-hardness. This study investigates the feasibility of using a CMOS portal imager to quickly and accurately track radio-opaque markers during radiotherapy. A custom CMOS imaging system was designed and constructed in collaboration with the MI3 consortium. The performance of this system was characterised and compared with an a-Si FPI. Four cylindrical gold markers of diameter 0.8 to 2 mm and length 8 mm were positioned on a motion-platform and moved according to the Lujan approximation to respiratory motion. Images were acquired using the megavoltage treatment beam at a range of frame and dose rates. The success rate of an automatic detection routine, mean-error from the expected position and contrast-to-noise ratio of the marker imager were then evaluated as a function of marker size, marker speed and integration time. The CMOS imager was found to offer improved resolution and signal-to-noise over the standard a-Si FPI at comparable dose. The long integration time of the FPI resulted in marker images being too blurred to detect. The CMOS was able to detect all four markers >90% of the time and estimate their position to within 0.04 mm at 150 MU/min and 20 frame/s. However success rate declined with decreasing dose and increasing integration time. In conclusion a CMOS megavoltage imaging system was found to offer superior signal-noise and resolution than the standard a-Si FPI. Furthermore the high speed of CMOS provided sub mm tracking of moving markers at a clinically acceptable dose rate and marker size.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 11 / **26**

Novel methods for identifying the cause of inherent ageing in Electron Multiplying Charge Coupled Devices

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The pre-amplifier, multi-stage, charge multiplication process used in the Electron Multiplying CCD (EMCCD) is subject to an ageing effect in which the gain achieved at particular avalanche potentials,

decreases during operation. To utilise these devices for both space and terrestrial applications where recalibration of the gain is not feasible a comprehensive understanding of the ageing process is required.
The Automated Test Equipment (ATE) is a fully automated testing environment and has been used to develop advanced techniques to investigate the ageing process. In a novel experiment changes in the potential of the DC phase are observed. These shifts are caused by hole build up at the Si/SiO2 interface below the gate and give rise to a lower avalanche potential. The results detailed in this work may provide a greater understanding of the Electron Multiplying ageing process.

Preferred medium (Oral/poster):

Poster

Poster Session - Board: 18 / **28**

Investigations with Gaseous Electron Multipliers for use on the ISIS spallation neutron source

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Over the last few years several investigations have been undertaken to ascertain the suitability of gaseous electron multipliers (GEMs) for use as a neutron detector on the ISIS spallation neutron source. Our initial investigations focussed purely on whether these devices could be operated at the elevated pressure of 3He and CF4 necessary for 1mm position location (2.6 bars of CF4). In fact we were able to operate the GEMs at suitable gains with 3.5 bars of CF4. However encouraging these results were, we found that the GEM charged up over time, which we postulated was due to the kapton substrate. A similar problem was seen at the early stages of the development of the microstrip gas chamber (MSGC), a solution of which was to use the semiconducting glass Schott S8900 as the substrate. We then focussed our attention to the manufacture of a GEM structure on an S8900 substrate. Our first devices were manufactured from 1mm thick glass and exhibit gains in excess of 10000 for a single GEM stage in an argon isobutane gas mixture, when illuminated with 55Fe x-rays. A stable gain has been measured in a flowing gas mixture with the device simply tracking ambient conditions. Further measurements in a 3He:CF4 atmosphere will show how suited these devices are to the needs of ISIS.

Preferred medium (Oral/poster):

poster

X-Ray and Gamma detectors / **29**

One dimensional detector for X-Ray diffraction with superior energy resolution based on silicon strip detector technology

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1-D position sensitive X-ray detectors based on silicon strip detector technology have become a standard for x-ray diffraction instrumentation. They are widely used with laboratory equipment but also at powder XRD beam lines. As these devices have been proven to be very useful due to their measurement speed and angular resolution, the implementation of further improvements of their performance obviously needs to be investigated. The silicon strip detectors as applied in X-ray diffraction are primarily used as counting devices and the requirements concerning the spatial resolution, dynamic range, and count rate capability are of primary importance. However, there are several experimental conditions in which a good energy resolution is a highly demanded feature.
The energy resolution of silicon strip detectors is limited by the charge sharing effects in the sensor, by the noise of the front-end electronics, and as well as by base line fluctuations. All these effects have been analysed in detail and have resulted in the development of a new readout design. A front-end ASIC with a novel scheme of baseline restoration and novel interstrip logic circuitry has been designed. The interstrip logic is used to reject the events resulting in significant charge sharing between neighbouring strips. In expense of rejecting small fraction of photons entering the detector one can obtain single strip energy spectra mostly free of charge sharing effects.
In the paper we present the design consideration and measured performance of the detector being developed. The electronic noise of the system at room temperature is typically of 70 el rms for 18 mm long silicon strips and a peaking time of 1 microsec. The energy resolution including non-reducible charge sharing effects and electronic noise of 800 eV FWHM has been achieved. It will be shown that this energy resolution is sufficient to electronically suppress the Fe-fluorescence which commonly is a problem in X-ray diffraction on iron containing samples irradiated by the most generally used Cu-K radiation.

Preferred medium (Oral/poster):

Oral

Detectors for FELs and other light sources / 30

Optimization of Silicon Pixel Sensors for the high X-ray Doses of the European XFEL

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The European X-ray Free Electron Laser (XFEL) will deliver 30,000 fully coherent, high brilliance X-ray pulses per second with a duration below 100 fs. This will allow to record diffraction patterns of single molecules and study ultra-fast processes.
One of the detectors under development for the XFEL is the Adaptive Gain Integrating Pixel Detector (AGIPD), which consists of a classical hybrid pixel array with readout ASICs bump-bonded to a silicon sensor with pixels of $200 \times 200\ \mu m^2$.
The particular requirements for the detector are a high dynamic range (0, 1 up to 10^5 12 keV photons/XFEL-pulse), a distance between XFEL-pulses of 200 ns, and doses up to 1 GGy of 12 keV X-rays for 3 years of operation. At these X-ray energies no bulk damage in silicon is expected. However fixed oxide charges in the SiO_2 layer and interface traps at the Si-SiO_2 interface will build-up.
We have investigated as function of the 12 keV X-ray dose the microscopic defects in test structures and the macroscopic electric properties of segmented sensors. From the test structures we have determined as function of dose the oxide charge density, the density of interface traps and their properties. We find that both saturate (and even decrease) for doses above a few MGy. For segmented sensors the defects introduced by the X-rays increase the full depletion voltage, the surface

leakage current and the inter-pixel capacitance. In addition an electron accumulation layer forms at the Si-SiO_2 interface which increases with dose and decreases with applied voltage.
Using TCAD simulations with the dose dependent parameters obtained from the test structures, we are able to reproduce the results of the measurements. This allows us to optimize the sensor design for the XFEL requirements.

Preferred medium (Oral/poster):

Oral

Detectors for Particle Physics / **31**

Developement of a novel 2D position-sensitive microstrip detector concept.

Author: Daniela Bassignana[1]

Co-authors: David Quirion [1]; Francisca Munoz [2]; Giulio Pellegrini [1]; Iván Vila [2]; Manuel Lozano [1]; Marcos Fernández [2]; Richard Jaramillo [2]

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We have developed a novel 2D position-sensitive semiconductor detector manufactured using the conventional planar technology used in the production of single-side AC-coupled microstrips sensors. In the new device the coupling electrode
is made of a slightly resistive material being read out at both ends. The balance between the recorded charges at both electrode ends is used to define an estimate of the position along the strip where the charge was created. A proof-of-concept sensor has been manufactured using strongly doped polycrystalline silicon as resistive material. The sensor response was characterized using a microspot infrared laser and a radioactive 90Sr source. Experimental results were compared against an electronic simulation of the sensor equivalent circuit. The spatial resolution achieved with these first sensors is of about 30 um (laser test-stand) and a Signal-to-noise ratio of around fifteen was determined using the radioactive source. We have demonstrated for the first time, the feasibility of this technological implementation of the charge-division concept in a real microstrip detector. New prototypes have been produced and tested and different test beams have been carried out in the 120 GeV/c pion line at the SPS testbeam area. The new experimental results will be presented as well as the results of the last simulation study for the production of a new generation of sensors.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 24 / **33**

Fast, low-noise, and low-power, electronics for the analog readout of non-linear DEPFET pixels

Author: Stefano Facchinetti[1]

Co-authors: Andrea Castoldi [1]; Carlo Fiorini [1]; Chiara Guazzoni [1]; Davide Mezza [1]; Florian Erdinger [2]; Giulio De Vita [3]; Luca Bombelli [1]; Matteo Porro [3]

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We present the analog front-end for the readout of non-linear DEPFET pixels designed in the framework of the European X-ray Free Electron Laser (XFEL). The facility is under construction in Hamburg (Germany). The proposed electronics is developed to be implemented in a 1-Megapixel X-ray detector system with single photon resolution at 1keV operating at a maximum frame-rate of 4.5MHz. Due to the high intensity of the laser pulses, it is fundamental that the system has a huge dynamic-range since up to 104 1KeV-photons con be delivered per pixel. The project of a new type of DEPFET Sensor with Signal Compression (DSSC) is under development to obtain a manageable signal range at the input of the front end electronics.
In this presentation the requirements for the readout electronics and the implementation in a 130-nm CMOS technology will be discussed. Due to the very high frame rate, full parallel readout is a must; this imposed severe limitations in power budget and in space occupancy of the 1 million electronic channels. The proposed architecture is based on the Flip Capacitor Filter (FCF), which implements the DEPFET drain-current readout and filtering with only one amplifying stage. The readout process consists in measuring the current at the output of the pixel before and after the signal arrival. The difference of the two measurements give the information on the charge collected in the pixel and therefore on the number of absorbed photons.
Spectroscopic performance of the implemented FCF connected to a single pixel linear detector will be presented. Measurements with a 55Fe calibration source show an equivalent noise charge (ENC) of 48 electrons at 4.5MHz, which is adequate for single photon identification and counting. Moreover, measurement with a highly focused infrared laser will be presented as well.

Preferred medium (Oral/poster):

oral

Poster Session - Board: 31 / **34**

Synthesis and scintillation characterization of nanocrystalline Lu2O3(Eu) powder for high-resolution X-ray imaging detectors

Author: Bo Kyung Cha[1]

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In the last decade, digital X-ray imaging detectors using CCD arrays, CMOS and amorphous silicon flat panel (a-Si:H) in combination with various scintillation screens have been widely used for medical and industrial applications. The conventional scintillators such as thallium-doped cesium iodide (CsI:Tl) and terbium-doped gadolinium oxysulphide(Gd2O2S:Tb) and europium-doped gadolinium oxide(Gd2O3:Eu) were used for conversion of X-rays into visible light. However, new scintillators with excellent X-ray stopping power and high X-ray to light conversion efficiency are still researched and developed for low radiation dose and high spatial resolution applications. The scintillation screen based on nanocrystalline powders compared to commercially available scintillation screen with large particle size shows improved spatial resolution and higher detection efficiency. In this work, Eu-doped Lu2O3 was synthesized via a homogeneous precipitation method using diethylamine (DEA) as a precipitant. First, the Lu(NO3)3·xH2O was dissolved in 50 ml of ethanol with continuous stirring to form a clear homogeneous solution. To the clear solution above, DEA was added drop-wise with vigorous continuous stirring. The solution immediately turned in to thick whitish slurry, which was further stirred in the same vigorous manner and precipitated. A small

mound of DI water was added to the precipitate and allowed to stand for a few hours to ensure completed precipitation. After the reaction, the final products were systematically washed with DI water and ethanol by centrifugation. The powder obtained was subsequently dried at 60oC for 12 h and calcined from 700 to 1300 oC for different calcinations time in electrical furnace. Eu(NO3)3·6H2O was dissolved in the ethanol to form the homogeneous Eu-doped Lu2O3 powder. To the above solution, (100-x) mol% of calcined Lu2O3 powder was dispersed under sonication for 2 h. And then DEA was added to form a Eu-doped Lu2O3 in accordance with above procedures. By the reaction, round-shaped and homogenously dispersed Lu2O3(Eu) with 20˜30nm particle size was obtained. And then, X-ray diffraction (XRD) and scanning electron microscopy (SEM) were used in order to investigate the structural properties and microstructure of synthesized Lu2O3(Eu) powder. The scintillation properties, such as light emission spectrum, light intensity and decay time of the nanocrystalline Lu2O3(Eu) powder were measured by photo-luminescence (PL) and X-ray luminescence.

Preferred medium (Oral/poster):

poster

Poster Session - Board: 10 / **35**

Simulating the effect of interface recombination velocity and fixed oxide charge on the responsivity of arsenic and phosphorus doped n+p PSDs

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There is an ever growing need for highly effective electron detectors with high responsivity. One of the parameters that has been shown to have a negative influence on the responsivity of a radiation detector is the surface recombination velocities of minority carriers at the Si-SiO2 interface. With the n+p detector discovered to possess better responsivity than a p+n detector at any given interface recombination velocity or fixed oxide charge Qf, there is a need to further investigate the n+p detectors.

In order to identify the effects of the parameters in question, an n+p detector with doping profile (1e15 atoms/cm2) and low sheet resistance was processed. The doping profile for various n+ doping with sheet resistance of 500 Ohms/sq and the resultant electric field are shown in the figure 1 below.

Before the processing of the device, Monte Carlo (MC) simulation methods were used to model the interaction between the electrons and the detector after the processing steps described above. This was employed to track the passage of bombarding electron particles through the detector taking into account possible interactions and decay processes. The simulations made use of "Standard" electromagnetic processes which Geant4 provides. With the aid of the program, we were able to investigate the energy deposit of electrons at different radiation energy per slice of 1 mm thick of the detectors at a given depth as well as compute a Linear Energy Transfer data (LET) that was then used in Taurus Medici to further analyze the detectors.

To analyze the silicon bulk and the Si-SiO2 interface, we used some simple mobility models such as parallel field mobility model to account for carrier heating and velocity saturation effects. This was done by using analytic expressions for the drift velocity vd as a function of the electric field in the direction of current flow, E||, and defining μ(E||) = vd(E||)/E||. Other models used included Auger recombination model, Shockley-Read-Hall recombination model with fixed lifetimes as well as a concentration-dependent mobility model which involves the use of mobility tables to model the dependence of carrier mobility on impurity concentration.

Preferred medium (Oral/poster):

Poster

Photon Detectors for Synchrotron Radiation and other applications / 36

EIGER a new single photon counting detector for X Ray applications: performance of the chip.

Author: Valeria Radicci[1]

Co-authors: Anna Bergamaschi [2]; Beat Henrich [2]; Dominic Greiffenberg [2]; Roberto Dinapoli [2]; Xintian Shi [3]; aldo mozzanica [3]; bernd Schmitt [2]; ian Johnson [2]

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EIGER is the next generation of single photon counting detector for synchrotron radiation designed by the PSI-SLS detector group. It features a pixel size of 75x75 µm2 and frame rates up to 22kHz. An array of 256x256 pixels fits on a 2cm x 2cm chip. The chip provides 4, 8 and 12 bit counting modes and practically an infinite dynamic range (32 bits) due to the continuous read/write and the summation of frames on the fly in firmware.
Along with the first X Ray absorption images, the characterization and performance of the chip will be presented. The most important parameters i.e. energy calibration, noise, minimum energy threshold and rate capability were measured on a single chip system with an X Ray tube and at the SLS-PSI synchrotron. Trimming and irradiation studies will be discussed. Tests so far have shown that the EIGER system meets its specifications. A report on the status and plan for a full module (2x4 chips) and 4M pixel EIGER detector will also be given.

Preferred medium (Oral/poster):

Oral

Europlanet Workshop on Detectors for Astronomy and Planetary Science / 37

The use of swept-charge devices in planetary analogue X-ray fluorescence studies

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The Chandrayaan-1 X-ray Spectrometer (C1XS) was launched onboard the Indian Space Research Organisation (ISRO) Chandrayaan-1 lunar mission in October 2008. The instrument consisted of 24 swept-charge device (SCD) silicon X-ray detectors providing a total collecting area of ˜24 cm2, corresponding to a 14° field of view (FWHM), with the ability to measure X-rays from 0.8 - 10 keV. One algorithm used to analyse C1XS flight data has been developed at Rutherford Appleton Laboratory (RAL) to convert the raw X-ray flux data into elemental ratios and abundances to make geological interpretations about the lunar surface. Laboratory X-ray fluorescence (XRF) data were used to validate the RAL algorithm, with previous studies investigating how the measured XRF flux varies with target surface characteristics including grain size and roughness. Evidence for a grain-size effect was observed in the data, the XRF line intensity generally decreasing with increasing sample grain size, dependent on the relative abundance of elemental components, as well as physical sample characteristics. This paper presents a subsequent study using more homogeneous samples made from mixtures of MgO, Al2O3, SiO2 and Fe2O3 powders, all of grain size <75 m, across a broader range of mixture ratios and at a higher level of X-ray flux data in order to further validate the RAL algorithm. For the majority of the C1XS data analysed so far with the RAL algorithm, the corresponding lunar ground tracks have been generally basaltic, laboratory verification of the algorithm having been conducted using basaltic lunar regolith simulant (JSC-1A) data. This paper also presents results from tests on a terrestrial anorthosite sample, more relevant to the anorthositic lunar highlands, from where the remaining C1XS dataset derives. The operation of the SCD, the XRF test facility, sample preparation and collected XRF spectra are discussed in this paper.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 30 / **38**

Spatial and temporal beam profile monitor with nanosecond resolution for CERN's Linac4

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The Linac4, now being constructed at CERN, will provide 160-MeV H- beams of high intensity of 2x10ˆ14 ions/s. Some sequences of 500-ps-long micro-bunches must be removed from the beam using a chopper before the H- ions can be further accelerated in the Proton Synchrotron. We developed a monitor to measure the time structure and spatial profile of this high-intensity chopped beam, with respective resolutions 1 ns and 2mm. The ion beam first struck a carbon foil, and secondary electrons emerging from the foil were accelerated by a series of parallel grid electrodes. These electrons struck a phosphor screen, and the resulting image of the scintillation light was guided to a CCD camera. The time resolution was attained by applying high-voltage pulses of sub-nanosecond rise and fall times to the grids. The monitor has been tested with 700-ps-long UV laser pulses, and a 3-MeV proton beam.

Preferred medium (Oral/poster):

Poster

Applications in Medicine, Life Sciences and Biology / **39**

DynAMITe: A Wafer Scale Sensor for Biomedical Applications

Author: Michela Esposito[1]

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Wafer scale detector technology represents an alternative approach for biomedical imaging where currently Flat Panel Imagers (FPIs) are the most common option. However, FPIs possess several key drawbacks such as large pixels, high noise, low frame rates, and excessive image artifacts. Recently Active Pixel Sensors have gained popularity overcoming such issues and are now scalable up to wafer size by appropriate reticule stitching. Detectors for biomedical imaging applications require high spatial resolution, low noise and high dynamic range. These figures of merit are related to pixel size and as the pixel size is fixed at the time of the design, spatial resolution, noise and dynamic range cannot be further optimized. The authors report on a new rad-hard monolithic APS, named DynAMITe (Dynamic range Adjustable for Medical Imaging Technology), developed by the UK MI-3 Plus consortium. This large area detector (12.8 x 12.8 cm2) is based on the use of two different diode geometries within the same pixel array with different size pixels (50 um and100 um). Hence the resulting camera can possess two inherently different resolutions each with different noise and saturation performance. The small pixels and the large pixels can be reset at different voltages, resulting in different depletion widths. The larger depletion width for the small pixels allows the initial generated photo-charge to be collected by the small pixels, which ensures an intrinsically lower noise and higher spatial resolution. After these pixels reach near saturation, the larger pixels start collecting so offering a higher dynamic range whereas the higher noise floor is not important as at higher signal levels performance is set by Poisson noise. Further different reset voltage can selectively choose the operating resolution of the detector leading to a true pixel binning.
The overall architecture and detailed characterization of DynAMITe will be presented in this paper.

Preferred medium (Oral/poster):

Oral

Advances in Pixel Detectors / 40

Imaging and spectroscopic performance studies of pixellated CdTe Timepix detector with synchrotron radiation

Author: Dima Maneuski[1]

Co-authors: Christer Fröjdh [2]; Erik Fröjdh [2]; Eva Gimenez-Navarro [3]; Graeme Stewart [1]; Heribert Wilhelm [3]; Julien Marchal [3]; O'Shea Val [1]; Rasif Modh Zain [1]; Tartoni Nicola [3]; Wraight Kenneth [1]

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In this work the results on imaging and spectroscopic performances of 1 mm thick 110x110 and 55x55 um pixellated CdTe detectors bump-bonded to a Timepix single photon counting chip are presented. The performance of the 110x110 um pixel detector was evaluated at the extreme conditions beam-line I15 of the Diamond Light Source. The energy of X-rays was set between 25 and 77 keV. The beam was collimated through the edge slits to 10 um FWHM. The spatial response of the detector was recorded for horizontal and vertical positions along several pixels at various energies below and above the K-edges of Cd and Te. This allowed measurement of the point spread function (PSF) of the detector with a resolution better than the pixel pitch. Quantitative analysis of variation of spatial resolution is performed for various energies. The detector was operated in the time-over-threshold mode, allowing direct energy measurement. This was used to calculate energy resolution of the detector for energies between 25 and 77 keV. Charge sharing effects were also quantified. Comparative imaging and energy resolution studies were also carried out between 55x55 and 110x110 um pixel detectors with fluorescence target X-ray tube. Energy as well as spatial resolutions were compared between two pixel pitches and quantitative and qualitative analysis was given.

Preferred medium (Oral/poster):

Oral

Detectors for FELs and other light sources / 41

Investigation of pixel detector designs for X-ray Photon Correlation Spectroscopy by computer simulations

Author: Julian Becker[1]

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The European XFEL, currently under construction at DESY in Hamburg, will produce coherent X-ray pulses every 222 ns in a bunch train of up to 2700 pulses. In conjuction with the fast 2D area detectors currently under development, it will be possible to perform X-ray photon correlation spectroscopy (XPCS) on microsecond timescales.

In XPCS experiments using pixel detectors usually the intensity autocorrelation function is calculated on a per pixel basis yielding information about the underlying interactions in the sample. The large number of individual pixels allows for acquisition of multiple q vectors at once while simultaneously enabling ensemble averaging, which allows to study non-ergodic systems (i.e. systems where time and spatial average differ). In this way equilibrium fluctuations in e.g. colloid suspensions can be directly studied or non-equilibrium processes using a pump-probe approach.

A case study for the AGIPD detector at the European XFEL employing the intensity autocorrelation technique was performed using computer simulations. The study compares the AGIPD (pixel size of 200 um) to a possible apertured version of the detector and to a hypothetical system with 100 um pixel size.

Simulations have been performed within the IDL framework using the detector simulation tool HORUS. Computer simulations are presented showing the impact of an excessively large pixel size, as well the influence of aperturing the pixels to a smaller effective size. It is shown under which circumstances aperturing is beneficial and what the limitations of the aperturing technique are.

Preferred medium (Oral/poster):

Oral

Detectors for FELs and other light sources / 42

AGIPD, the Adaptive Gain Integrating Pixel Detector: A 4.5 MHz camera for the European XFEL

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One of the main advantages of the European XFEL is its fast bunch repetition frequency of 4.5 MHz. The XFEL will provide bunch trains of up to 2700 bunches every 222 ns, followed by an idle time of 99.4 ms, resulting in a supercycle of 10 Hz and 27000 bunches per second. Correspondingly fast 2D detectors such as AGIPD are being developed. Thiswill allow investigations with various techniques on timescales that have not been accessible with 2D detectors before.

The AGIPD is one of three detector development projects approved by the European XFEL project team. The development is done in a collaboration between DESY, the University of Hamburg and the University of Bonn in Germany, and the Paul Scherrer Institute (PSI) in Switzerland.

AGIPD is based on the hybrid pixel technology. A newly developed ASIC will feature in each pixel a dynamic gain switching amplifier (to cope with the high dynamic range) and an analogue pipeline capable of storing the pictures at the desired 4.5 MHz speed.

The AGIPD will feature a pixel size of 200 x 200 umˆ2 and a sensor thickness of 500 um. The ASIC will be able to store more than 300 images inside the pixel area during the bunch train. The image data will be read out and digitized in the gap between two bunch trains.

The current results of the 16 x 16 pixel prototype will be presented, showing for example the linearity, noise and high pulse tolerance of the ASIC.

Preferred medium (Oral/poster):

oral

Positron Emission Tomography / 43

Development of a gamma-ray imager using a large area monolithic 4x4 MPPC array for a future PET scanner

Author: Takeshi Nakamori[1]

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We have developed a new type of large-area monolithic Multi-Pixel Photon Counter (MPPC) array consisting of a 4x4 matrix of 3x3 mmˆ2 pixels. Each pixel comprises 3600 Geiger mode avalanche photodiodes that achieve an average gain up to 10ˆ6 with variations of only +/- 7% over 4x4 pixels. Excellent uniformity was also obtained for photon detection efficiencies (PDE) of +/-6%. We fabricated a prototype gamma-ray camera consisting of an MPPC array optically coupled with a scintillator matrix, namely a 4x4 array of 3x3x10 mmˆ3 crystals. Then we tested the performance with Ce-doped LYSO, Pr-doped LuAG and surface coated Pr:LuAG matrices whereby the emission peak of Pr:LuAG was shifted from 310 to 420 nm via a wavelength shifter. An average FWHM energy resolution of ˜10% were obtained for 662 keV gamma-rays, as measured at 0 degree with each scintillator matrix. Besides, in order to reduce the number of readout channels, we employed a chargedivision readout technique with a resistors' matrix. We present that reconstructed gamma-ray events were nicely resolved in each pixels without deterioration in energy resolutions. These results suggest that a large-area monolithic MPPC array developed here could be promising detector especially for positron emission tomography.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 9 / **44**

Inaccuracy of coordinate determined by several detectors'signals

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In order to locate particle position, it is necessary to have several signals of spaced detectors, since the amplitudes of these signals depend on the particle interaction point. For all position sensitive detectors the crucial characteristic for using as tracking or imaging detector is the accuracy of coordinate determination. The position resolution is closely connected not only with the energy resolutions of detectors but also with the correlations between the signals'fluctuations. In this paper, general relation between position and energy resolutions that accounts for the correlation between the signals' fluctuations of detectors was derived. This general relation was used for the special cases of two and three detectors'outputs. Using these formulae and experimental calibration data allows, without any technical improvements of detectors, significantly improve position resolution by rather simple procedure of experimental data handling.

Preferred medium (Oral/poster):

Poster

Poster Session - Board: 6 / **45**

A Combined Energy and Angular Dispersive X-ray Diffraction System Using a Novel Pixellated X-ray Detector for Material Identification.

Author: Christiana Christodoulou[1]

Co-authors: Caroline Reid [1]; Matthew Veale [2]; Matthew Wilson [2]; Paul Seller [2]; Robert Speller [1]

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[2] *Rutherford Appleton Laboratory*

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A novel pixellated energy resolving x-ray detector is used in a combined energy dispersive and angular dispersive x-ray diffraction set-up enabling the acquisition of multiple scatter angles without the use of multi-collimation between the sample and the detector, using narrow beam geometry. A

system with 20x20 pixels of 250x250μm pitch and Cadmium Telluride detector material is used to acquire numerous samples of pseudo-crystalline materials and others including plastics The detection configuration makes full use of the ability to acquire both energy and angular information simultaneously. The technique's ability in enhanced offline material identification is evaluated through the use of multivariate analysis software and energy-angle maps.

Preferred medium (Oral/poster):

Poster

Advances in Pixel Detectors / 46

SLID-ICV Vertical Integration Technology with Thin Pixel Sensors for the ATLAS Pixel Upgrades

Author: Philipp Weigell[1]

Co-authors: Anna Macchiolo [1]; Hans-Günther Moser [2]; Ladislav Andricek [2]; Michael Beimforde [1]; Richard Nisius [1]; Richter Rainer [2]

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A new pixel module concept for future ATLAS pixel detector upgrades is presented, where thin n-in-p sensors are connected to the front-end chip exploiting the novel Solid Liquid Interdiffusion technique (SLID) and the signals are read out via Inter Chip Vias (ICV) etched through the front-end. This should serve as a proof of principle for future four-side buttable pixel assemblies for the ATLAS upgrades, without the cantilever presently needed in the chip for the wire bonding.

N-in-p pixel sensors with active thicknesses of 75\,μm and 150\,μm have been produced from wafers of standard thickness using a thinning process developed at the Max-Planck-Institut Halbleiterlabor. The pre-irradiation characterization of these sensors shows a very good device yield and high break down voltages. After irradiations up to a fluence of 10^{16}\,n_{eq}cm^{-2} Charge Collection Efficiency measurements yield higher values than expected from the present radiation damage models.

The SLID interconnection, developed by the Fraunhofer EMFT, serves as a possible alternative to the standard bump-bonding. It is characterized by a very thin eutectic Cu-Sn alloy and allows for stacking of different layers of chips on top of the first one, without destroying the pre-existing bonds. This paves the way for vertical integration technologies.

We will present the results of the characterization of the first pixel modules interconnected through SLID, performed with the ATLAS pixel read-out system USBPix. Besides the electrical properties and the connection efficiency also the mechanical strength of the interconnection was investigated.

Additionally, the etching of ICV into the front-end wafers was started and the progress will be reported. ICVs will be used to route the signals vertically through the front-end chip, to newly created pads on the backside. In the EMFT approach the chip wafer is thinned to 50\,μm.

Preferred medium (Oral/poster):

Oral

Europlanet Workshop on Detectors for Astronomy and Planetary Science / 47

Development of the Balloon-Borne sub-MeV Gamma-ray Compton Camera Using an Electron-Tracking Gaseous TPC and a Scintillation Camera

Author: Tetsuya Mizumoto[1]

Co-authors: Atsushi Takada [1]; Hidetoshi Kubo [1]; Joseph Parker [1]; Kazuki Ueno [2]; Kentaro Miuchi [1]; Kiseki Nakamura [1]; Satoru Iwaki [1]; Shigeto Kabuki [3]; Shotaro Komura [1]; Shunsuke Kurosawa [4]; Tatsuya Sawano [1]; Toru Tanimori [1]; Yasushi Sato [1]; Yoshihiro Matsuoka [1]; Yuji Kishimoto [5]

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We have developed a Compton camera that can determine the arrival directions of sub-MeV/MeV gamma rays for gamma-ray astronomy observations. This is a hybrid detector consisting of a gaseous TPC, which has a two-dimensional position sensitive gaseous detector with pixel anode electrodes at a pitch of 400 micrometers, and a position-sensitive scintillation camera enclosing the TPC. Some incident MeV gamma rays produce recoil electrons within the TPC whose tracks can be measured in three dimensions. Additionally, scattered gamma rays are absorbed in the scintillation camera where we measure their absorption points and energies. From these data, we can reconstruct the arrival direction of every incident MeV photon to about 1 degree from the kinematical analysis, so we can reject a large fraction of background events. This detector has a large field of view (about 3str). In 2006, in the first measurement of SMILE (Sub-MeV gamma ray Imaging Loaded-on-balloon Experiment), we observed diffuse cosmic and atmospheric gamma rays at balloon altitudes with a 10-cubic-centimeter Compton camera as the first step toward a future all sky survey with high sensitivity. As the next step, we are planning to test the gamma ray imaging performance of a 30-cubic-centimeter Compton camera, which has a larger effective area and higher angular resolution than the Compton camera used for SMILE-I, by observing the Crab Nebula from balloon altitudes starting from 2012 (SMILE-II). For the SMILE-II balloon measurement, a reduction in size and energy consumption of the electronics along with a performance survey of the experimental devices and experimental simulations are necessary. In this conference, we will present an overview of the Compton camera and the status of SMILE-II.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 28 / **48**

Radiation hardness studies of n+-in-n planar pixel sensors irradiated to 5E15 n_eq cm^-2 and beyond for HLLHC

Authors: André Rummler[1]; Claus Goessling[1]; Daniel Muenstermann[2]; Georg Troska[1]; Jennifer Jentzsch[1]; Reiner Klingenberg[1]; Silke Altenheiner[1]; Tobias Lapsien[1]; Tobias Wittig[1]

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ATLAS plans two major upgrades of its pixel detector on the path to HLLHC: First, the insertion of a 4th pixel layer (Insertable B-Layer, IBL) is currently being prepared for 2013. This will enable the ATLAS tracker to cope with an increase of LHC's peak luminosity to about 3E34 cm^-2 s^-1 which

requires a radiation hardness of the sensors of up to 5E15 n_eq cmˆ-2. Towards the end of this decade, a full replacement of the inner tracker is foreseen to cope with luminosities of up to 10E35 cmˆ-2 sˆ-1 at HLLHC. Here, the innermost pixel layer will have to withstand a radiation damage of 2E16 n_eq cmˆ-2.

We have irradiated n+-in-n sensor assemblies based on the current ATLAS pixel read-out chip FE-I3 to IBL as well as HLLHC fluences using thermal neutrons in Ljubljana as well as protons in Karlsruhe and at CERN PS and will present the charge collection efficiency results of lab measurements with a Sr-90 source after irradiation.

Space resolved analysis results such as hit efficiencies from data taken in dedicated CERN SPS and DESY testbeams are going to be shown as well.

Furthermore first results realised with irradiated sensor assemblies based on the new read-out chip FE-I4 will be shown thus enabling a cross-check of results obtained with the FE-I3 system. Data from testbeam measurements with steep angle insertion might be helpful for an improved understanding of charge multiplication.

Preferred medium (Oral/poster):

oral

Poster Session - Board: 20 / **49**

Improved micro-pixel detector element for neutron measurement under high pressure

Author: Kentaro Toh[1]

Co-authors: Hideshi Yamagishi [1]; Kaoru Sakasai [1]; Kazuhiko Soyama [1]; Tatsuya Nakamura [1]

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Some neutron scattering experiments performed at high-intensity pulsed neutron facilities located in Japan, the United States, and the United Kingdom require advanced two-dimensional neutron detectors that have features such as a short response time, good spatial resolution, and high detection efficiency. To this end, we are currently developing a two-dimensional position-sensitive neutron detection system that can read out individual signal lines and consists of a micro-pixel detector element. By increasing the gas pressure, the spatial resolution and detection efficiency of a two-dimensional gas-based detector are improved but the output signal strength is decreased. Therefore, the supply voltage must be increased to obtain output signals under high pressure. In the present study, we have developed a micro-pixel detector element with a high-voltage resistance by an improved fabrication process, and then, we have conducted neutron irradiation experiments using this detector element. A detection system capable of individual line readout and consisting of the developed detector element, a pressure vessel, amplifier-shaper-discriminator boards, an optical signal transmission device, and a fast data acquisition device was constructed for the experiment. The voltage resistance of the developed element was improved, and the element could operate up to 750 V at a total pressure of 5 atm (4.1 atm of He for the neutron converter and 0.9 atm of CF4 for the stopping gas). The measured gas gain was found to be approximately 100, and the thermal neutron detection efficiency was estimated to be 70% at the gas pressure of 5 atm. A flat-field image was obtained to confirm the spatial homogeneity of the detector element. The image showed good homogeneity, and the average pixel count was 290 with a standard deviation of σ = 25.4, corresponding to an average gain spread of about 8.7%.

Preferred medium (Oral/poster):

poster

Poster Session - Board: 29 / **50**

Simulation program for multiwire-type two-dimensional neutron detector with individual readout

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Two-dimensional gas-based neutron detectors having a fast response time and high spatial resolution are required for some neutron scattering experiments performed using a high-intensity spallation neutron source at the Materials and Life Science Experimental Facility at J-PARC. We are currently developing a multiwire-type two-dimensional neutron detector system for use in such scattering experiments. This system can attain high response time and high spatial resolution by using the individual line readout method. The performance parameters of a gas-based two-dimensional neutron detector, such as spatial resolution and detection efficiency, strongly depend on the mixture gas condition of the neutron converter, stopping gas, and quenching gas, and this condition must be determined before the system is installed in the actual irradiation facility. Therefore, we developed a simulation program for our multiwire-type two-dimensional neutron detector system to determine the gas condition. Further, a small test system was fabricated to evaluate the simulation program. The simulation program involves the following calculations in each gas condition: the reaction probability between neutron and He-3, ranges of secondary particles generated by the nuclear reaction, ejection angle of the particles, wall effect of the conversion gap, and pitch of the multiwire element. The simulation results showed that the spatial resolution was 1.79 and 1.19 mm full width at half maximum (FWHM), and the detection efficiency was 53% and 59% at a total pressure of 5 atm (including 30% of CF_4) and 7 atm (including 40% of CF_4), respectively. Experimental results obtained using the small test system agreed well with the simulation results, and the measured spatial resolution was 1.80 and 1.12 mm FWHM. Thus, it was confirmed that the simulation program can be effectively used to determine the gas condition when the required spatial resolution and detection efficiency are known.

Preferred medium (Oral/poster):

poster

X-Ray and Gamma detectors / **52**

Planar Semiconductor Compton Imaging using Pulse Shape Analysis

Author: Anthony Sweeney[1]

Co-authors: Amandeep Thandi [2]; Andrew Boston [1]; Daniel Judson [1]; David Oxley [1]; David Scraggs [1]; Helen Boston [1]; Jamie Dormand [1]; John Cresswell [1]; Laura Harkness [1]; Mark Ellis [2]; Martin Jones [1]; Mike Slee [1]; Paul Nolan [1]

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Homeland security agencies have a requirement to be able to locate and identify radionuclides which decay via gamma ray emission. One possible solution is the use of a Compton camera [1,2]. A prototype planar semiconductor Compton imaging device is under development at the University of Liverpool in partnership with the Atomic Weapons Establishment (AWE). Compton cameras offer

higher detection efficiency in comparison with conventionally collimated devices currently in use such as gamma cameras or coded aperture systems.
State of the art digital data acquisition electronics are being used to undertake measurements with the prototype development system, allowing pulse shapes to be stored for every event. Compton cameras are limited by their ability to locate the gamma ray interaction points within the detector crystals used. Pulse shape analysis [3] can then be utilised to determine the interaction positions within the detector more accurately than via detector segmentation. This enhanced knowledge of the interaction position within the detectors results in an improved Compton image resolution. A comparison of Compton images generated with and without pulse shape analysis techniques will be presented, highlighting the impact of this approach on image quality. The full potential of this system shall be quantified in terms of position resolution in the detector and the resulting image resolution in the reconstructed image. The ability of these technologies to identify radioactive sources in the field will be discussed.
Data has been collected using the double sided high purity germanium strip detectors used in the SmartPET project [4]. New detectors (a thinner planar germanium detector and a planar silicon lithium detector) are also being introduced as part of the prototype system, data from these will also be presented.
[1] Todd, R.W., Nature, Volume 251,Issue 5471, Pages 132-134, 1974
[2] Mihailescu, L., NIM Volume 570 Issue 1, Pages 89-100, 2007
[3] Kroll, T., NIM Volume 463 Issue 1, Pages 227-249, 2001
[4] Boston, H., NIM Volume 579 Issue 1, Pages 104-107, 2007

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 8 / **53**

Development of Beam Profile Monitor for Antiproton Annihilation Cross Section Measurements by the ASACUSA Collaboration

Author: Koichi Todoroki[1]

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ASACUSA will attempt to measure the A-dependence of the antiproton-nucleus annihilation cross sections for the first time in the energy region where it is expected to deviate significantly from the Aˆ(2/3)-law established at higher energies, using CERN's Antiproton Decelerator and ASACUSA' s radio-frequency quadrupole decelerator, the combination of which provides 100-ns-long pulses each containing ˜10ˆ7 antiprotons. The instantaneous flux of antiprotons is too high to distinguish individual particles, which makes the controlled rejection of backgrounds difficult. One way to avoid this problem is to assure all antiprotons to strike only the target, not the surrounding target frame or vacuum pipe.
In order to satisfy this requirement, we developed a beam profile monitor based on the secondary electron emission, and measured destructively 30-mm-diameter spatial profiles of pulses containing > 6*10ˆ4 antiprotons with an active area of 40*40 mmˆ2 and a resolution of 4 mm at the target position. One can determine where charged particles strike by measuring the positive charge induced by electrons which they release. Features of this method are that it can be directly placed in the high vacuum unlike gas detectors, the structure can be simple, and it can be lightweight and low cost. This monitor consisted of cathode micro wires of 20-μm diameter, and 20*20 segmented anode pads arranged in a checker-board pattern on a four-layered electric board of thickness t = 2 mm made of an FR4-type glass epoxy.

Preferred medium (Oral/poster):

poster

Poster Session - Board: 7 / **54**

Characterization of new hybrid pixel module concepts for the ATLAS Insertable B-layer upgrade

Author: Malte Backhaus[1]

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on behalf of ATLAS IBL collaboration

For the ATLAS pixel detector, a fourth hybrid pixel detector layer known as Insertable B-Layer (IBL) is developed, which will be slid into the present pixel detector. Due to the very small distance to the interaction point of about 3.4 cm, the IBL will improve the track reconstruction and vertexing of the pixel detector. In order to handle the extreme particle flux and radiation damage close to the interaction point, new sensor concepts as well as a new readout chip, FE-I4, are currently developed. To reduce the pixel occupancy, the pixel size in FE-I4 is reduced from the 50 x 400 μm^2 of the readout chip of the current ATLAS pixel detector (FE-I3) to 50 x 250 μm^2. The FE-I4 active area will cover ˜ 2 x 1.7 cm^2, resulting in 26.880 pixels, nearly a ten-fold increase in pixel number with respect to FE-I3. This translates into an increased active over inactive area ratio from less than 75% in FE-I3 to 90% in FE-I4. This enables a better, more integrated module concept, with a smaller periphery to achieve a good material budget for IBL, while simplifying the mechanical placement of the modules. FE-I4 was designed to fit the requirements of various new radiation hard sensor concepts using planar silicon, 3D silicon or diamond sensor technologies that are currently being evaluated. These sensor prototypes are available for the new readout chip generation FE-I4 and characterization of all the eligible module concepts in laboratory and test beam environment is ongoing, in order to achieve a fair comparison. A detailed introduction to the FE-4 architecture and results from bare IC testing will be provided. Focus will be brought on the operation and test results of the unirradiated and irradiated modules.

Preferred medium (Oral/poster):

Oral

Knowledge Transfer and Commercial Opportunities for PSDs / **55**

A High Purity Germanium detector for Compton imaging in nuclear medicine

Author: Laura Harkness[1]

Co-authors: Andrew Boston [1]; Daniel Judson [1]; David Scraggs [1]; Graham Kemp [2]; Helen Boston [1]; Ian Burrows [3]; Ian Lazarus [3]; Janet Groves [3]; Janet Sampson [1]; John Cresswell [1]; John Simpson [3]; Jon Headspith [3]; Mike Cordwell [3]; Paul Nolan [1]; William Bimson [4]

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Single Photon Emission Computed Tomography (SPECT) systems employ a gamma camera to locate a radioactive tracer which has been administered to a patient to study specifically targeted physiological processes. A typical system is composed of scintillation detectors coupled to a mechanical collimator which allows the distribution of the radiation to be inferred. However, use of the collimator results in only a small fraction of the patient dose being used to generate an image.
The ProSPECTus project aims to improve image quality, provide shorter data acquisition times and lower patient doses by replacing the gamma camera with a high-sensitivity Compton camera. The ProSPECTus system is composed of a Si(Li) detector and HPGe detector, a configuration deemed optimum using a validated Geant4 simulation package. The Si(Li) and HPGe detectors are (60x60x9) mm and (60x60x20) mm, electronically segmented with orthogonal strips of 4 mm pitch and 5 mm pitch, respectively. The typical energy resolution at 122 keV is 2.0 keV for the Si(Li) detector and 1.4 keV for the HPGe detector. Utilising position and energy sensitive detectors is essential as Compton kinematics are employed to reconstruct the paths of incident gamma rays using the interaction positions and energy depositions within the two detectors, to identify the location of the radiation source.
Characterising the response of the detectors to gamma irradiation is essential in maximising the sensitivity and image resolution of the Compton imaging system. To this end, the performance of the HPGe detector has been measured at the University of Liverpool. Results show that the detector performs well at the energy of interest, 122 keV. However, poorer spectroscopic performance is observed at higher energies, such as 662 keV. An investigation of this degradation of performance is underway and will be presented alongside the characterisation measurements.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 14 / **56**

Development of X-ray/Gamma-ray Imaging Spectrometer with Reach-through APD Arrays

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Co-authors: Jun Kataoka [1]; Nobuyuki Kawai [2]; Takahiro Eonomoto [2]; Takahiro Toizumi [2]; Yoichi Yatsu [2]; Yoshitaka Ishikawa [3]; Yusuke Matsunaga [3]

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It is important to obtain wide band X-ray/gamma-ray spectra at the same time in order to probe efficiently the emission processes or the structures of transient object such as gamma-ray bursts. We have developed, for future missions, an X-ray/gamma-ray detector utilizing reach-trough type avalanche photodiode (APD) array (8- and 16-segments) with the area of 1.6x1.8 cmˆ2. Excellent uniformity over the segments was achieved both in gain and energy resolution, where the deviations are less than 1.5 and 2%, respectively. We optically coupled the APD arrays with segmented CsI(Tl) scintillators fabricated to fit the APD pixel sizes. We irradiated gamma-ray source from the side of the APD. With this configuration X-rays are directly absorbed with the APD while gamma-rays are stopped by the CsI(Tl) where the APD works as a scintillation detector. These two events are discriminated by the differences in signal rise time using shaping amplifier with a time constant of 50 nano and 2 micro-seconds.We demonstrated that the two components were clearly separated and energy coverage was from about 1 keV to 1 MeV. Typical energy resolution for 662 keV and 32 keV was 8% and 9% (detected directly by the APD). These results shows that our detector can be used as a nice 1-dimentional imaging spectrometer. We propose to employ two sets of this detector for X- and Y- axis together with coded aperture masks for imaging the sky.

Preferred medium (Oral/poster):

poster

Poster Session - Board: 17 / **57**

Position sensitive detectors with SiPM readout for measuring antiproton annihilations

Author: Anna Soter[1]

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The ASACUSA experiment at CERN is now constructing 530-channel position-sensitive scintillation detectors and its FPGA-based readout electronics to measure and track high rates of charged pions emerging from antiproton annihilations in a future radiofrequency Paul trap for antiprotons. Each channel is read out by a wavelength shifting (WLS) fiber and 1600-pixel silicon photomultiplier (MPPC). We first optimized the light yields of five types of extruded and cast scintillator bars with various cross sections. Double-clad WLS fibers were embedded in grooves or holes fabricated within the scintillators, and they were read out by multichannel hybrid or ASIC monolithic charge-sensitive preamplifiers. The first assembled detectors were tested against the 100-keV pulsed $\overline{p}$ beam at the Antiproton Decelerator (AD) of CERN, where we found that the pixel saturation at high antiproton rates were an issue.

Preferred medium (Oral/poster):

poster

Nuclear Physics / **58**

AGATA Detector Characterisation using the Liverpool Scanning Table

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The Advanced Gamma Tracking Array (AGATA) project is a pan-European collaboration whose aim is the construction of a next-generation gamma-ray spectrometer for use in nuclear structure studies. The final array will consist of 180 (coaxial) HPGe crystals arranged in a spherical honeycomb geometry. Utilising the technique of gamma-ray tracking, the array will significantly improve upon the performance of large, Compton-suppressed HPGe arrays currently in use in laboratories around the world (e.g. Gammasphere).

A fundamental requirement of gamma-ray tracking is accurate Pulse Shape Analysis (PSA). This technique allows identification of the spatial locations of gamma-ray interactions within each detector volume, which itself is divided into 36 segments. The 36 segment output signals (along with the coaxial core output signal) require precise analysis in order to accurately assess the aforementioned gamma-ray interaction position, and computations must be performed rapidly for the technique to be of use in real-time experimental scenarios.

The most practicable method here is to pre-simulate a database of signal bases for each detector, which maps the detector response for interactions at all spatial coordinates within its volume. This is then compared, in real-time, with signals received from the detector in order to isolate the gamma-ray interaction position. It is thus imperative that confidence in the accuracy of such simulations is assured.

In addition to the standard 'coincidence scan'method used at Liverpool, other experimental techniques via which simulated detector bases may be validated are desirable. One example under development involves assessing the experimental and simulated responses of the detector whilst set below its recommended operating voltage, allowing study of depletion region evolution as a function of applied voltage. Another focuses on the implementation of a novel pulse shape analysis technique to determine gamma-ray interaction position within the detector volume. Current work will be presented.

Preferred medium (Oral/poster):

Oral

Applications in Medicine, Life Sciences and Biology / 59

The application of Large Area Active Pixel Sensor to high resolution Nuclear Medicine imaging

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A large area CMOS active pixel sensor(LAS)has been investigated to study its potential application to Nuclear Medicine imaging. LAS consisted of 1350 x 1350 40 micron pixels with noise levels of ˜40e. The sensor was coupled directly to both segmented and unsegmented 2mm thick CsI(Tl) crystals. The segmented crystal contained 400 micron x 400 micron pixels seperated by ˜100 microns of reflective material. The quantum efficiency at these wavelengths is only ˜20%. The system was interfaced to a PC via an FPGA-based DAQ and optical link enabling imaging rates of of up to 20 frames per sec.

Imaging tests were performed using 99mTc sources emitting 140 keV gamma rays together with various lead collimators. The majority of the system noise was found to be fixed pattern in nature caused largely by the reset signals. Importantly this means that much of the noise can be accurately removed if the sensors are held under consistent environmental conditions

The intrinsic spatial resolution of the sensor coupled to the segmented scintillator was measured as ˜80 microns. Results show that the signals in the sensor pixels from 140 keV gamma rays are small as the light from the scintillator is spread over a large number of pixels. In spite of this the sensor can be used to produce images with 140keV gamma rays when coupled to both types of scintillators. Measurements of the MTF made using the unsegmented crystal show values of 0.68, 0.55, 0.43 and 0.26 and spatial frequencies of 0.1, 0.17, 0.25 and 0.5 lp/mm. The system can easily resolve objects 1-2mm in diameter and with a segmented crystal sub-mm resolution is possible. A new much larger sensor is presently being manufactured.

Preferred medium (Oral/poster):

Oral

Detectors for Astrophysics / 60

Assessment of proton radiation-induced charge transfer inefficiency in the CCD204 detector for the Euclid dark energy mission

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Euclid is a medium class mission candidate for launch in 2017 with a primary goal to study the dark universe using the weak lensing and baryonic acoustic oscillations techniques. Weak lensing depends on accurate shape measurements of distant galaxies. Therefore it is beneficial that the effects of radiation-induced charge transfer inefficiency (CTI) in the Euclid CCDs over the course of the 5 year mission at L2 are understood. This will allow, through experimental analysis and modelling techniques, the effects of radiation induced CTI on shape to be decoupled from those of mass inhomogeneities along the line-of-sight. This paper discusses a selection of work from the study that has been undertaken using the e2v CCD204 as part of the initial proton radiation damage assessment for Euclid. The experimental arrangement and procedure are described followed by the results obtained, thereby allowing recommendations to be made on the CCD operating temperature, to provide an insight into CTI effects under different levels of optical background and integration time, to asses the benefits of using charge injection on CTI recovery and the effect of the use of two different methods of serial clocking on serial CTI. This work will form the basis of a comparison with a p-channel CCD204 fabricated using the same mask set as the n-channel equivalent. A custom CCD has been designed, based on this work and discussions between e2v technologies plc. and the Euclid consortium, and designated the CCD273.

Preferred medium (Oral/poster):

Oral

Detectors for high radiation environments / 61

Signal propagation and spark mitigation in resistive strips readouts

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MicroPattern Gaseous Detectors (MPGD) made of resistive strips have rised as a promising technology for the protection against spark processes having place in the gaseous chamber. The reproduction of the signals and its propagation through the resistive foil is mandatory to better understand its behaviour and optimise the key parameters which might depend on the application requirements. In this work it will be presented a resistive-strip model and the charge diffusion through the resistive strip for different model parameters, such as the strip resistivity, together with the advantages and/or disadvantages of this type of technology.

Preferred medium (Oral/poster):

oral

Poster Session - Board: 22 / **62**

Characterisation of AGATA HPGe detectors for Pulse Shape Analysis.

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Co-authors: Andrew Boston [1]; Carl Unsworth [1]; Fay Filmer [1]; Helen Boston [1]; Ian Lazurus [2]; John Cresswell [1]; John Simpson [2]; Mike Slee [1]; Paul Nolan [1]; Steven Moon [1]

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The Advanced GAmma Tracking Array, AGATA, is part of a new generation of highly segmented hyper-pure germanium (HPGe) gamma-ray detection arrays that are currently being developed for use at low-yield, high background radioactive ion beam facilities. AGATA aims to utilize gamma-ray tracking in order to add-back scattered gamma-rays that would be vetoed in arrays with a Compton suppression shield. Key to the GRT process is pulse shape analysis, (PSA), which is used to identify interactions within the germanium diodes to within a few milimetres.
An electric field simulation of the detector can also be utilized to calculate charge responses for the detector. In order to validate and test the accuracy of the pulse shapes produced by the simulation, coincident data taken with ancillary scintillation detectors is compared with a simulated database. With these techniques we aim to fully characterize the AGATA HPGe crystals.
Characterization of the charge response of the AGATA HPGe detectors is vital to build a database of pulse shapes corresponding to spatial locations within the detector. The results of characterization as well as a comparison of performance of two AGATA asymmetric detectors will be presented.

Preferred medium (Oral/poster):

Oral

Detectors for high radiation environments / **63**

Performance of the CMS Pixel detector for the Phase I upgrade at HL-LHC

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The luminosity upgrade of the Large Hadron Collider is foreseen to proceed in two phases. An eventual factor-of-ten increase in LHC statistics will have a major impact in the LHC Physics program. However, the HL-LHC as well as offering the possibility to increase the physics potential will create an extreme operating environment for the detectors, particularly the tracking devices and the trigger system. An increase in the number of minimum-bias events beyond the levels envisioned for design luminosity creates the need to handle much higher occupancies and for the innermost layers unprecedented levels of radiation. This can degrade the performance of the current detector. In order to recover and improve the current level of seeding, tracking, and b-tagging performance an upgrade of the CMS pixel detector system has been proposed for the Phase I of the HL-LHC. Results of Monte Carlo simulation studies for the new pixel detector will be presented and compared to that of the current CMS detector. The upgraded pixel system will provide improved b-tagging, pixel track seeding and stand-alone tracking capabilities, which will be key elements of many CMS physics analyses at the HL-LHC. In particular the upgrades will enhance CMS physics reach in exploring the Higgs sector where b-jets and tau-leptons are often produced in association with the Higgs boson or in its decays.

Preferred medium (Oral/poster):

oral

Detectors for Particle Physics / 64

Track based alignment of the ATLAS Inner Detector tracking system

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ATLAS is a multipurpose experiment that records the LHC collisions. In order to reconstruct trajectories of charged particle, ATLAS is equipped with a tracking system built using different technologies, silicon planar sensors (pixel and microstrips) and drift-tube detectors. In order to achieve its scientific goals, the ATLAS tracking system requires to determine accurately its almost 700,000 degrees of freedom. The demanded precision for the alignment of the silicon sensors is below 10 micrometers. This implies to use a large sample of high momentum and isolated tracks. The high level trigger selects and stores those tracks in a calibration stream. Tracks from cosmic trigger during empty LHC bunches are also used as input for the alignment.

The implementation of the track based alignment within the ATLAS software unifies different alignment approaches and allows the alignment of all tracking subsystems together. Primary vertexing and beam spot constraints have been implemented, as well as constraints on the particle momentum as measured by the Muon System. As alignment algorithms minimize the track-hit residuals, one needs to solve a linear system with thousands of DoF. The alignment jobs are executed at the CERN Analysis Facility. The event processing runs parallel jobs. The output matrices from all jobs are added before solving.

We will present the results of the alignment of the ATLAS tracker using data recorded during 2010 and 2011 using the LHC proton-proton collision runs at 7 TeV. Validation of the alignment was performed by measuring the alignment observables as well as many other physics observables, notably resonance invariant masses in a wide mass range (K0s, J/ψ and Z decays in to μ+μ-) and the effect of detector systematic distortions on their invariant mass and μ momentum. Also the E/p for electrons has been studied. The results of the alignment with real data reveal that the precision of the alignment constants is approximately 5 microns.

Preferred medium (Oral/poster):

oral

Poster Session - Board: 12 / **65**

Application of a high-speed CMOS image sensor for geometric calibration of cone-beam computed tomography system

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The Cone-Beam Computed Tomography (CBCT) system has been widely used for medical diagnostic and surgical application. However, the 3D reconstructed images in CBCT are significantly affected by a variety of vibrations of the operating gantry system.
In this work, the geometric calibration in our developing CBCT was performed and analyzed in order to solve these problems by using a high-speed CMOS camera and infrared reflecting mark. The images for a geometric calibration were acquired by putting a high-speed camera with 120 fps (frame per second) on an X-ray source position and a reflection mark on flat panel detector position in our developing CBCT system. The geometric calibration during rotation of gantry system from 0 degree (reference point) to 360 degree (stop point) was done. Also, its gantry system with 5rpm (rotation per minute) and still images at a regular interval of 10 degree were applied. The calibration parameters through the Euclidean distance were calculated using the difference between reference point and each rotation point. The experimental results were used for geometric calibration of u-coordinate (forward-backward) and v-coordinate (left-right) in CBCT gantry system
The CMOS camera (MV-D640, photon focus) having a 6.34mm x 4.75mm active optical area with 9.9μm pixel pitch and 640 x 480 pixels was used for geometric measurement and analysis in our CBCT system. The 1440 (120fps x 12s) moving images were used for precise analysis of gantry system with 5rpm. Because a lot of images than commercial X-ray CBCT images with maximum 30 fps were acquired through our proposed method, the geometric measurement of gantry system as a function of each phase were significantly improved. After we solved the geometric problems from the first experiment results, gantry vibration of u and v-coordinates of CBCT system from secondary measurement was largely improved to 94.4% and 25%, respectively.

Preferred medium (Oral/poster):

poster

Advances in Pixel Detectors / **68**

Application of a HEPE-oriented 4096-MAPS to time analysis of single electron distributoin in a two-slits interference experiment

Authors: Alessandro Gabrielli[1]; Antonio Zoccoli[1]; Filippo Maria Giorgi[1]; Gian Carlo Gazzadi[2]; Giorgio Matteucci[3]; Giulio Pozzi[3]; Mauro Villa[1]; Nicola Semprini Cesari[1]; Stefano Frabboni[4]

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Up to now, the superposition of electron waves has been demonstrated in a variety of arrangements, among which the electron biprism has been the most successful. Nevertheless, the most striking part of the experiment, i.e. the build-up of two-beam interference pattern by the single electrons arriving on the final screen, has been observed only by means of limited statistic samples and never with a two slit set-up. The reason of this fact relies on one hand on the rate limitation of the available recording systems, able to collect a relatively low number of pictures within a time interval compatible with a stable operation of the electron microscope and on the other on the difficulty of preparing well defined slits in the submicron range.
Both such restrictions have been overcome by the results presented in this paper, where the build-up of high statistics single electron interference pattern and the time distribution of electron arrivals have been measured for the first time. Nano slits are prepared by using modern nanotechnology tools, a conventional transmission electron microscope is used as a versatile optical bench, and a fast recording system, sensitive to single electrons, replaces the final viewing screen of the microscope. The detector is based on a custom CMOS chip of 4096 monolithic active pixels (MAPS), designed by the SLIM5 collaboration as vertex detector for experiments at future colliders, and equipped with a fast read-out chain able to manage up to 10exp6 frames per second (fps). This capability allows us to collect high statistic samples of single electron events within a time interval where the stable operation and the coherence conditions of the microscope are guaranteed. Moreover the large fraction of empty events makes possible to get the first measurement of the distribution of electron arrival times.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 3 / **69**

DETECTORS FOR DISTANT DIAGNOSTICS OF NUCLEAR-ENERGETIC INSTALLATION

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The complex of distant noncontact diagnostic devices for the correlated measurements of key parameters and characteristics of fast electro-nuclear and transmutational processes (t = 1 mksec) in nuclear-energetic installation is presented.
Complex contains the detectors of the gamma-, X-ray- and infrared-radiations, which work in a real-time mode in the line from a computer.

Preferred medium (Oral/poster):

Oral

Detectors for high radiation environments / **70**

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

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To extend the physics reach of the LHC, upgrades to the accelerator are planned which will increase the peak luminosity by a factor 5 to 10. This will lead to increased occupancy and radiation damage of the inner trackers.

To cope with the elevated occupancy, the ATLAS experiment plans to introduce an all-silicon inner tracker with the HL-LHC upgrade. With silicon, the occupancy can be adjusted by using the appropriate unit size (pixel, strip or short strip sensors). For radiation damage reasons, only electron-collecting sensors designs are considered (n-in-p and n-in-n).

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

The presentation will give an overview of the recent accomplishments of the R&D project. Among these are testbeam results obtained with n-in-n pixel sensors irradiated up to 2 10**16 neq/cm**2, investigations of the edge efficiency of dedicated slim-edge sensors and comparisons of these experimental findings with TCAD device simulations taking into account the radiation damage.

Updates will be given on the status of several efforts towards fully active edges with planar technology and on n-in-p and n-in-n productions with substrate thicknesses down to 150 um.

Finally, first laboratory and testbeam measurements of sensors using the new ATLAS readout chip FE-I4 will be shown including the exploration of the low-threshold behaviour of highly irradiated assemblies.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 16 / **71**

Performance Comparison of CMOS-based Photodiodes for High Resolution and High Sensitivity Digital Mammography

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Recently, CMOS Image Sensors (CIS's) are becoming candidate solution for digital mammography (DM) systems due to relatively low cost, high speed and possibility to integrate signal processing electronics. Therefore, it is very important to optimize the performance of the CMOS-based photodiode combined with the scintillator for DM. In this research, we compared the performance of four different photodiodes fabricated using 0.18 μm CMOS process which is specialized in image sensor

technology. All photodiodes have 50 μm pitch and the same pixel structure, 3-transistor active pixel. Moreover, the same readout architectures are connected to each photodiode so that the comparison can be focused only on the photodiode itself. The four photodiodes are n-well/p-epi, p+/n-well/p-epi, n+/p-epi and n-/p-epi. The flexibility of the process to fabricate photodiodes allows a lightly doped (n-) implant layer and shallow trench isolation (STI) blocked n-well region, as well as an epitaxial wafer necessary for widely depleted photodiodes. The active pixel for each photodiode was designed in the form of a 40 x 40 array for statistical analysis of noise, dark current rate, charge-to-voltage conversion gain and uniformity. In addition, thallium doped cesium iodide (CsI:Tl) scintillator, which is usually used in the DM system, was directly deposited on the test chip so as to investigate the photodiode's sensitivity to X-rays.

Preferred medium (Oral/poster):

poster

Poster Session - Board: 32 / **72**

Study and Optimization of Positioning Algorithms for Monolithic PET Detector Blocks

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We are developing a PET insert for existing MRI equipment to be used in clinical PET/MR studies of the human brain. The proposed scanner is based on annihilation gamma detection with monolithic blocks of cerium-doped lutetium yttrium orthosilicate (LYSO:Ce) coupled to magnetically-compatible APD matrices. The light distribution generated on the LYSO:Ce block provides the impinging position of the 511 keV photons by means of a positioning algorithm. Several positioning methods, from the simplest Anger Logic to more sophisticate supervised learning Neural Networks (NN), can be implemented to extract the incidence position of gammas directly from the APD signals. Finally, an optimal method based on a two step Feed Forward Neural Network has been selected. It allows us to reach a resolution at detector level of 2 mm, and acquire images of point sources using a first BrainPET prototype consisting of two monolithic blocks working in coincidence [1].
In order to obtain an efficient positioning method for the complete scanner, an optimization process has been carried out. Neural networks provide a straightforward positioning of the acquired data once they have been trained. Therefore the critical work was finding a training procedure that reduces the data acquisition and processing time without introducing a noticeable degradation of the spatial resolution.
A grouping process and posterior selection of the training data has been done regarding to similitude of the light distribution of the events which have one common incident coordinate (transversal or longitudinal). This way the amount of training data can be reduced to about 5% of the initial number with a degradation of spatial resolution of less than 10%.

[1] I. Sarasola et al. "Coincidence Imaging with Monolithic Detector Blocks for a Human Brain PET Scanner,"2009 IEEE Nuclear Science Symp. Conf. Rec., 2009, pp. 2669-2673.

Preferred medium (Oral/poster):

Poster

Poster Session - Board: 33 / **73**

Zero Ion Backflow detector operating in pure xenon

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One of the challenges of modern Time Projection Chambers (TPC) is to prevent the re-injection of the secondary ions produced on the gas amplification layer into the sensitive volume of the detector. Particularly in high multiplicity TPC the presence of positive ions has the potential to affect the tracking properties of the detector due to space charge effects.
The use of the secondary scintillation emitted by noble gases and CF4 is an alternative to the readout of TPC since no secondary ionization occurs and hence the ion feedback is naturally reduced to the level of primary ionization.
The Zero Ion Back Flow (Zero IBF) detector is the combination of a gaseous scintillation proportional counter (GSPC) with a gaseous photomultiplier (GPM) and presents full ion backflow suppression. The GSPC is composed by 3 parallel grids that define the conversion and the scintillation regions of the detector. The primary electrons produced in the conversion region are transferred to the scintillation region were they are accelerated by an electric field with an intensity above the threshold for scintillation but below the one for ionization. A fraction of the secondary scintillation emitted by the atoms of the gas is collected by the GPM that in the current setup is composed by a CsI photocathode coupled to a double GEM detector, although other gaseous electron multipliers, e.g. THGEM and MHSP, are considered.
The number of photo-electrons extracted from the CsI photocathode per each primary electron, defined in previous works as the optical gain, is of critical relevance for the efficient operation of the Zero IBF detector. In this work we present the results achieved with the Zero IBF detector operating in pure Xenon.

Preferred medium (Oral/poster):

poster

Photon Detectors for Synchrotron Radiation and other applications / **74**

Application of time-tagged photon imaging for trace gas measurement using cavity enhanced absorption spectroscopy

Authors: Jon Lapington[1]; Jonathan Hallam[2]; Stephen Ball[2]

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Optical spectroscopy is a powerful tool for the measurement of atmospheric gases and changes to atmospheric composition. For example, global measurements of ozone (and other species) are updated daily from satellite observations using essentially the same spectroscopic principles. The strength of spectroscopic methods at visible, UV or IR wavelengths lies in (i) their selectivity, which makes it possible to target individual compounds unambiguously, and (ii) their sensitivity, which makes them is capable of accurately determining mixing ratios in the range 10e-9 to 10e-12.

We describe the application of a microchannel plate-based time-tagged photon imaging detector to broadband cavity enhanced absorption spectroscopy (BBCEAS). BBCEAS is technique which utilizes a high finesse cavity with a broad band light source for determination of atmospheric absorption over a range of wavelengths, to provide very high accuracy trace gas measurements. The detector tags each detected photon with a three-dimensional x,y,t coordinate which is used to identify the wavelength of each photon along the spectrometer dispersion axis (x coordinate) and simultaneously record its source, either from the cavity or reference signal from the light source (y co-ordinate). The time coordinate, t, identifies the photon arrival time. Phase shift and attenuation as a function of wavelength, for both cavity output and the light source, are determined by time-histogramming the imaged spectra.

Time-tagged photon imaging offers a unique advantage for a multi-wavelength frequency domain BBCEAS since it provides direct access to mirror reflectivity and thus photon path length, a key quantity that cannot be measured directly by conventional BBCEAS instruments. This combination of technologies provides an instrument whose calibration is a simple procedure not requiring technical input or specialist gases, and capable of automation.

We present data which demonstrate the applicability of time-tagged photon imaging to BBCEAS and preliminary results illustrating trace gas measurement accuracy.

Preferred medium (Oral/poster):

Oral

Nuclear Physics / **75**

Preliminary Compton imaging results of the AGATA A006 detector

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Co-authors: Andrew Boston [1]; Carl Unsworth [1]; Daniel Judson [1]; David Scraggs [1]; Fay Filmer [1]; Helen Boston [1]; Laura Harkness [1]; Moon Steven [1]; Samantha Colosimo [1]

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By comparing the pulse shapes, using pulse shape analysis (PSA), the interaction positions within a position sensitive HPGe crystal can be accurately located. Compton Image Reconstruction can be used to create an image testing the accuracy of the ability to locate the positions of scatter and absorption events, through PSA. The more accurately the points of interaction are known the better the image will be, thus the PSA algorithms are. An interesting use for this is for imaging applications, most commercial Compton imagers use scintillators but the energy resolution from these systems is poor. One suggested method would be to utilize two planer Ge strip detectors but despite the high energy resolution the efficiency is poor due the detector being operated in coincidence. To achieve increased efficiency and high resolution, a large volume HPGe position sensitive crystal, such as the AGATA A006 detector, can be utilized to detect full energy events that Compton scatter within the detector. Results of Compton Imaging from the AGATA A006 detector will be discussed.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 26 / **76**

Operational voltage of silicon heavily irradiated strip detectors utilizing avalanche multiplication effect

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Recent results on the collected charge Qc in heavily irradiated Si detectors developed by RD50 collaboration for SuperLHC showed a significant Qc enhancement if detectors were operated at the bias voltage beyond 1000 V. Our investigations showed that this enhancement arises from a fundamental effect of carrier avalanche multiplication in high electric field of n+-p junction. The goal of the study is estimation of the minimal bias which initiates the avalanche process and is important for maintaining an appropriate power dissipation. Simulations of the collected charge vs. bias voltage and fluence demonstrated that:
• double peak electric field distribution is still the main feature for heavily irradiated detectors operated in the avalanche multiplication mode;
• the electric field near the n+ strips is stabilized via voltage drop redistribution and electric field extension towards the p+ contact;
• this redistribution depends on the concentration ratio of radiation defects with deep levels, Ndd/Nda (Ndd and Nda are deep donors and deep acceptors concentrations, respectively).

The other factors which are sensitive for enhancement of avalanche multiplication at lower bias voltage are strip detector geometry which affects the electric field focusing near the strips, and the temperature of detector operation. The concentration ratio is the impact parameter for the E(x) distribution and bias voltage minimal for charge enhancement. The ratio depends on the radiation type and affects E(x) asymmetry due to potential redistribution over the detector caused by carrier trapping. Predictions on the position sensitivity and detector behavior under mixed irradiation of the real experimental environment are made. In the case of neutron radiation prevailing introduction of deep acceptors leads to a severely asymmetric profile which may reduce the bias specific for avalanche multiplication in strip detectors. This effect is translated on the detector performance at different temperature and radiation environment.

Preferred medium (Oral/poster):

oral

Nuclear Physics / 77

Spectra distortion by the interstrip gap in spectrometric silicon strip detectors

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The NUSTAR experiments in program FAIR (Facility for Antiproton and Ion Research) that are developed now in GSI require unique spectrometers for heavy ions which energy is ranged starting

from hundred keV up to hundreds MeV. The spectrometers are constructed on the basis of silicon double sided detectors which must provide the energy and the hit point position.
The double sided detectors for simultaneous high resolution ions spectroscopy and tracking were developed within the framework of PTI and RIMST collaboration. The scaled reduced sizes samples of the detectors were studied with 241Am source in terms of their spectrometric performance at different specific points of the detector. The best energy resolution of 14.7 keV was measured at the crossing point of the p+ and n+ strips. It was shown that the spectrum for the particles hit to the inerterstrip gap is much broader and has two maxima at the high and low energy edges.
In this study the shape of the short range particle spectra is explained in terms of the potential distribution at the surface of the passivated interstrip gap which has a saddle point at the center of the gap underneath the surface. Thus the effective entrance window thickness in the interstrip gap is modulated by the potential distribution that produces a specific shape of the detector spectral response. It is shown that this effect can be minimized by the interstrip gap construction however it is still important for the detection of low energy ions even at high bias voltage The position of potential saddle point depends on the electric field at the neighboring strips. The results should be considered in the spectra treatment and can be used in the future developments of spectrometric detectors for nuclear physics.

Preferred medium (Oral/poster):

oral

Detectors for Particle Physics / 78

Results from the NA62 Gigatracker prototype: a lowmass and sub-ns time resolution silicon pixel detector

Author: Riccardo Fantechi[1]

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The Gigatracker (GTK) is a hybrid silicon pixel detector developed for NA62, the experiment studying ultra-rare kaon decays at the CERN SPS. Three GTK stations will provide precise momentum and angular measurements on every track of the high intensity NA62 hadron beam with a time-tagging resolution of 150ps. Multiple scattering and hadronic interactions of beam particles in the GTK has to be minimized to keep background events at acceptable levels, hence the total material budget is fixed to 0.5% X0 per station. In addition the calculated fluence for 100 days of running is 2 × 10ˆ14 1 MeV neq/cm2, comparable to the one expected for the inner trackers of LHC detectors in 10 years of operation. These requirements pose challenges for the development of an efficient and low-mass cooling system, to be operated in vacuum, and on the thinning of read-out chips to 100 µm or less.
The most challenging requirement is represented by the time resolution, which can be achieved by carefully compensating for the discriminator time-walk. For this purpose, two complementary readout architectures have been designed and produced as small-scale prototypes: the first is based on the use of a Time-over-Threshold circuit followed by a TDC shared by a group of pixels, while the other uses a constant-fraction discriminator followed by an on-pixel TDC. The readout pixel ASICs are produced in 130 nm IBM CMOS technology and bump-bonded to 200 µm thick silicon sensors.
The Gigatracker detector system is described with particular emphasis on recent experimental results obtained from laboratory and beam tests of prototype bump-bonded assemblies, which show a time resolution of less than 200 ps for single hits.

Preferred medium (Oral/poster):

oral

Nuclear Physics / 79

Methodology development for analysis of in-beam AGATA data

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Co-authors: Andrew Boston [1]; Andrew Robinson [2]; Carl Unsworth [1]; Daniel Judson [1]; David Cullen [2]; Helen Boston [1]; John Cresswell [1]; John Simpson [3]; Michael Slee [1]; Paul Nolan [1]; Samantha Colosimo [1]; Steven Moon [1]

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The AGATA (Advanced Gamma Ray Tracking Array) physics campaign commenced in February 2010 and there is an emphasis on effective methodologies for the analysis of in-beam data. In order to realise the AGATA demonstrator a number of commissioning experiments have been performed. Analysis of a commissioning experiment using two AGATA triple clusters coupled to ancillary detectors will be presented here. The experiment was performed at LNL, Legnaro, in September 2009, the reaction was 110Pd (32S,4n) 138Sm at 135MeV. During the commissioning phase the user can extract raw pulse-shape data, pulse processed data or tracked data. This is required to fully calibrate the processing, essential for a successful AGATA physics campaign. Here preliminary analysis of the in-beam data will be presented, along with an overview of the methodology involved. As the ultimate aim of the work is to investigate the linear polarisation sensitivity of the AGATA device, the methodology involved here will also be discussed.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 27 / **80**

Picosecond imaging using a capacitive charge division readout

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The requirements of high energy, high luminosity particle accelerators, particularly the Large Hadron Collider at CERN, has driven the development of a range of Application Specific Integrated Circuits (ASICs) able to cope with extremely high event rates and data throughput, while maintaining picosecond timing resolution in the region of 10-100 ps incorporated in a high channel density design. The University of Leicester and Photek Ltd. have been collaborating on using two of these CERN developed ASICs, the NINO amplifier/discriminator and High Performance Time to Digital Convertor (HPTDC), for readout of multi-channel and imaging MCP detectors.

We present results from a photon-counting microchannel plate (MCP) imaging detector using the Capacitive Division Image Readout (C-DIR), designed to provide moderate position resolution (of the order of 100x100 pixelˆ2), with timing resolution of the order 25 ps and a maximum event rate of 10 MHz, limited by microchannel plate count rate saturation. The NINO and HPTDC combination simultaneously provide picosecond event timing and time-over-threshold determination of charge

amplitude required for position determination by the centroiding C-DIR readout. Measurements of the detector's performance will be presented, with a discussion of our experience with utilising ASICs designed for high energy physics for alternative applications.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 2 / **81**

Basis Pulse Shape Analysis using planar HPGe semiconductor detectors

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Co-authors: Andy Boston [1]; Anthony Sweeney [1]; Daniel Judson [1]; David Oxley [2]; David Scraggs [1]; Helen Boston [1]; Jason Ralph [1]; Laura Harkness [1]; Paul Nolan [1]; Richard Taylor [3]; Yannis Goulermas [1]

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We present an approach of applying Pulse Shape Analysis to preamplifier charge pulses from a planar High Purity Germanium (HPGe) semiconductor γ-ray detector to improve interaction position resolution through depth. This leads to an improvement in the quality of images reconstructed by Compton camera systems that are comprised of such detectors. Algorithms that achieve this and recent experimental data is discussed.

Digital ADCs allow charge pulses to be stored for each γ-ray interaction in the detector. By scanning the detector using a collimated source a database of reference pulses can be built corresponding to specific interaction sites. Experimental pulses can be compared to this database using a chi-squared minimisation method to extract position information beyond the raw granularity of the detector.

This method was tested using a planar HPGe semiconductor
detector with an active volume of 60mm x 60mm x 20mm, electronically segmented to give raw position resolution of 5mm x 5mm x 20mm. Database pulses were recorded at 1mm intervals both across the face of the detector (x) and through depth (y) with FWHM values of $\leq$ 2.5mm for y positions at all given x positions. This was compared to datasets from a Compton camera experiment using the same detector and CAEN V1724 digital ADCs where Cs-137 and Na-22 measurements were taken in various positions and configurations. Experimental pulses were digitized and compared to the database to form a histogram of interaction depths. By comparing this to the expected exponential attenuation of γ-rays as predicted by theory this concept can be validated. Results from this investigation will be presented in the context of a γ-ray Compton imaging device being developed for a nuclear decommissioning application.

Preferred medium (Oral/poster):

Oral

Advances in Pixel Detectors / **82**

PImMS, a fast event-triggered pixel detector with storage of multiple timestamps

Author: Jaya John John[1]

Co-authors: Alex Johnsen [2]; Andrei Nomerotski [1]; Andy Clark [3]; Claire Vallance [2]; Craig Slater [2]; Edward Wilman [2]; Ewen Campbell [2]; Iris Friedli [1]; Jamie Crooks [3]; Jason Lee [2]; Laura Hill [1]; Mark Brouard [2]; Renato Turchetta [3]; Weihao Yuen [2]

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PImMS, or Pixel Imaging Mass Spectrometry, is a novel high-speed CMOS imaging sensor tailored to mass spectrometry requirements, also suitable for other dark-field applications. In its application to mass spectrometry, the sensor permits Time of Flight information to be combined with 2D imaging, gaining additional information about the initial position or velocity of ions under study. PImMS1, the first generation sensor in this family, has an array of 72 by 72 pixels on a 70μm by 70μm pitch. Pixels independently record digital timestamps when events over an adjustable threshold occur. Each pixel contains 4 memories to record timestamps at a resolution of better than 50ns. The sensor was designed and manufactured in the INMAPS 0.18μm process. This allows the inclusion of significant amounts of circuitry (over 600 transistors) within each pixel while maintaining good detection efficiency. We will present an overview of the pixel and sensor architecture, explain its functioning and present test results, ranging from characterisation of the analogue front end of the pixel, to verification of its digital functions, to images captured on mass spectrometers.

Preferred medium (Oral/poster):

Oral

Applications in Medicine, Life Sciences and Biology / 83

Performance of a high throughput multichannel detector for life science applications

Author: Jon Lapington[1]

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We describe a 256 channel microchannel plate-based multi-anode photomultiplier camera system with integrated electronics designed for picosecond photon timing applications at very high throughput. The system was designed primarily for high content applications in life sciences, such as high throughput fluorescence lifetime microscopy, fluorescence correlation spectroscopy, and other time-resolved spectroscopies.

The 40 mm detector utilizes a small pore microchannel plate stack operating at a gain of 1e6 and optimized for high count rate. The multi-anode readout comprises a multilayer ceramic which provides detector body vacuum integrity and electrical feed-throughs for the integrated discrete pixel readout. The compact, modular electronics comprise: (i) a detector board which mates directly with the detector, (ii) 4 sets of in-line 64 channel preamplifier/discriminator and time-to-digital converter boards using CERN-developed ASIC technology, and (iii) a backplane and processor card with programmable digital processing capability and USB interface.

In the current system each of the 256 independent electronics channels addresses 2x2 pixel2 of the detector multi-anode 32 x 32 pixel2 format readout. The modular electronics design is specifically organized for expansion of the channel count to 1024 to eventually allow independent readout of single detector pixels.

We present measurements of component and system performance including event time resolution, channel crosstalk, detector and electronic count rate capabilities, and projected detector lifetime, and discuss possible detector modifications to enhance local count rate limitations and extend lifetime.

Preferred medium (Oral/poster):

oral

Poster Session - Board: 15 / **84**

Investigation of the secondary electron emission characteristics of alternative dynode materials for imaging photomultipliers

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The requirement to accurately detect and image very high speed photon events is crucial for many applications across a range of disciplines. Photon imaging detectors often make use of the planar geometry of MCP's for high resolution imaging. However, the inherent rate limitations of MCP's provide opportunities for discrete dynode devices where rapid recharge times and high throughput are required. Non-conventional dynode materials and designs offer the possibility to further improve event time resolution and pulse height distribution.

Significant performance advantages can be achieved by increasing the gain of each dynode stage by utilizing less conventional materials such as CVD diamond. Secondary electron emission (SEE) coefficients for polycrystalline CVD diamond have been reported as 45 for Hydrogen terminated surfaces [1] and >80 for Cs terminated surfaces [2]. These values are far in excess of currently used materials such as AgMgO(Cs) and CuBeO(Cs) which have SEE coefficients <15 [3].

Polycrystalline diamond is a widely available, relatively inexpensive material that can be deposited over large areas on appropriate substrates, making the manufacture of large format imaging detectors a practical possibility.

The application of new dynode designs for imaging photomultipliers requires knowledge of the secondary electron emission characteristics of the material. We describe a facility to measure the relevant characteristics of novel dynode materials and designs with 2D imaging capability, and discuss the significant challenges, intricacies and complexities involved with SEE coefficient measurements. We present secondary electron emission measurements for a variety of dynode materials and designs and discus their application in imaging photon-counting devices.

[1] Lapington et al. Nucl Instrum Meth A 610 (2009) 253-257
[2] Yater et al. J Vac Sci Tech A 16(1998) 913
[3] Photonis PMT handbook

Preferred medium (Oral/poster):

Poster

Positron Emission Tomography / 85

A modular positron camera for positron emission particle tracking in harsh environments

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By detecting the back-to-back gamma ray emissions from a positron emitting tracer particle high speed and accurate tracking can be achieved as it moves throughout the field of view of a positron camera; this forms the basis of the technique Positron Emission Particle Tracking (PEPT), developed at Birmingham for over 25 years. The ability to track either particles or neutrally buoyant flow followers (in the case of liquid systems) enables the use of the PEPT technique for studying a wide range of particulate systems, granular dynamics and multiphase flows. We have previously described the development of a modular positron camera used for PEPT which has proven to have considerable benefit as the field of view and hence the sensitivity can be custom tailored to the application in question. Further, the camera is transportable and can be operated in remote or industrial environments.

One of the recent successes for the modular camera has been in the study of liquid metal casting at the foundry on the University campus. This has proved challenging as the camera is operated in a harsh high temperature environment with a significant amount of gamma ray scattering and attenuating material present. Tracer particles which are used for PEPT have been developed which can survive the conditions found in liquid aluminium. Investigations into the camera performance for PEPT experiments involved in the study of liquid metals, including measurements of sensitivity and location precision, gamma ray attenuation and scattering properties of the materials involved, are reported in this paper. Example particle trajectories from these experiments will be given to illustrate the applicability of PEPT to an increasing range of applications.

Preferred medium (Oral/poster):

Oral

Poster Session - Board: 13 / **86**

Development of High Spatial Resolution Camera for Characterization of X-ray Optics

Author: Haris Kudrolli[1]

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Technological innovations in grazing incidence X-ray optics have been crucial to the advancement of the field of X-ray astronomy. These X-ray focusing optics are capable of improving the sensitivity of X-ray telescopes operating in the energy range above 10 keV by orders of magnitude. Full characterization of the X-ray optics includes measurement of the point spread function, scattering, and

reflectivity properties of substrate coatings. This requires a very high spatial resolution, high sensitivity, photon counting and energy discriminating, large area detector. In this paper we describe the construction of a camera using EMCCD that is well suited to meeting these requirements.

Back thinned EMCCD cameras have very high quantum efficiency, high spatial resolution and ability to detect very low light levels because of very low read noise. They can be coupled via a lens to a bright scintillator but this configuration has very low efficiency for detection of the scintillation light and limits the performance of the camera. We overcome this limitation by optically bonding a 3:1 fiber optic taper to the EMCCD chip. This improves the light coupling efficiency and increases the detector active area to 25.2 mm x 25.2 mm with effective pixel size of 49 microns. Furthermore, the sensitivity of the detector is increased without degrading spatial resolution by coupling the detector to micro-columnar CsI(Tl) scintillator that was tailor-made to thickness than can efficiently absorb 10 to 100 keV X-rays with high efficiency. Methods to improve light transport from scintillator to EMCCD were devised by direct deposition on to the fiber optic taper. Characterization of the scintillator performance in terms of its light transport properties and spatial resolution, and the performance of the X-ray camera as a whole will be described.

A prototype version of this camera was used to help characterize the performance of the X-ray focusing optics for the Nuclear Spectroscopic Telescope Array (NuSTAR) mission. Data obtained during the ground calibration of the NuSTAR telescopes demonstrate the advantages of the detector.

Preferred medium (Oral/poster):

Poster

Applications in Medicine, Life Sciences and Biology / 87

Development of a camera for imaging of prompt gamma rays in measurements of proton beam range

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Particle therapy plays nowadays an important role in cancer treatment and growing research efforts are directed in this direction. In particular, strength of proton therapy, is related to the possibility to release the maximum of the dose in the target site destroying tumoral cells and limiting otherwise the dose to normal tissue. For this purpose, the measurement of the proton beam range in the target is very important and one method to reach this goal is based on the measurement of prompt gamma rays emitted by excited nuclei during proton irradiation.
This work deals with the application of the recently developed HICAM (HIgh resolution CAMera) camera for the measurements of prompt gamma rays. The camera is composed by 25 Silicon Drift Detectors of 1cm2 active area each, 5x5 format, characterized by a high quantum efficiency (>80%) and low electronic noise. The HICAM camera is characterized by a very high intrinsic resolution (˜1mm) and has recently shown good performances both in clinical and pre-clinical measurements. The photodetectors are coupled with a LYSO crystal of 1cm thickness, and a first measurement session was made to assess the imaging capability of the system with a 60Co source.
The second part of the trials is foreseen in radiotherapy facility with the cooperation of IBA and

ULB which are involved in the development of a practical concept of a prompt gamma camera which would allow checking in real-time the range of a single pencil beam with accuracy of millimeters. The experimental set up consists in a proton beam impinging on a PMMA target of 20 cm length. HICAM camera is used with a slit collimator to detect prompt gammas emitted in a perpendicular direction with respect the beam one.
The results of these preliminary tests and some possible future perspectives are here presented.

Preferred medium (Oral/poster):

oral

Europlanet Workshop on Detectors for Astronomy and Planetary Science / 88

A Radiation-Hard Silicon Drift Detector Array for Extraterrestrial Element Mapping

Author: Brian Ramsey[1]

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We are developing a sensitive spectrometer for measuring abundances of light elements fluoresced by ambient radiation. Based on a Silicon Drift Detector (SDD) with custom readout electronics, the instrument offers high energy resolution and large-area coverage, yet with modest power and cooling requirements. The goal of the development program is to build a detector array that can be scaled to any desired area and used in a wide variety of applications from the moon to the extremely harsh environment of the Jupiter system.

The basic systems consist of 16 and 64-channel SDD arrays read out by one and four 16-channel high-speed custom ASICS (application specific integrated circuits) respectively. Once the basic geometry was fixed, we iterated the design to achieve low-energy response, down to the Carbon line at 0.28 keV, using a thin entrance window produced through a double implantation of Boron and Phosphorus ions through the silicon dioxide. We also experimented with the silicon base material resistivity and thickness, to improve radiation hardness in anticipation of operation in challenging environments. In parallel with these efforts we fine tuned the ASIC design for high rate capability and radiation tolerance.

We have investigated the spectroscopic (and rate) performance of our arrays and have recently begun a series of radiation-hardness tests at the Indiana University Cyclotron Facility. To date, we have irradiated two of our early SDD arrays with doses to 0.25 Mrad (as well as relevant Si diodes to 5 Mrad) and our current-iteration ASIC to 12 Mrad. In the near future, we will radiation-test the newly-produced thin-window, radiation-hard, SDD arrays, which we are currently characterizing prior to irradiation.
Full details of our program and our results will be given in this presentation.

Preferred medium (Oral/poster):

Oral

Detectors for Particle Physics / 89

Performance of the present ALICE Inner Tracking System and studies for the upgrade

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The Inner Tracking System (ITS) of the ALICE experiment is made out of six layers of silicon detectors exploiting three different technologies (pixel, drift and strip). It covers the central pseudorapidity range of $|\eta| < 0.9$ and its distance from the beam line ranges from r = 3.9 cm for the innermost pixel layer up to r = 43 cm for the outermost strip layer. The main tasks of the ITS are to reconstruct the primary and secondary vertices, to track and identify charged particles with a low pt cutoff and to improve the momentum resolution at high pt.
In this talk I will present the performance of the ITS in p-p and Pb-Pb collisions in 2010, both from the
hardware point of view, with a brief overview of the features of the system, and the physics achievements for what concerns the vertexing, the tracking and the particle identification.
Furthermore, I will give also an outlook on a possible upgrade of the ALICE ITS which is presently being studied, in order to extend its physics performance by improving the measurements of charmed hadrons and accessing new physics items like the measurement of the beauty hadrons.

Preferred medium (Oral/poster):

Oral

Detectors for FELs and other light sources / 90

Active Pixel Sensors for direct detection of Soft X-rays

Author: Richard Bates[1]

Co-authors: Andrew Blue [1]; Andy Clark [2]; Dima Maneuski [1]; Graeme Stewart [1]; Julien Marchal [3]; Nicola Tartoni [3]; Renato Turchetta [2]

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The imaging of soft X-ray images is typically performed with CCDs. However, these have limited readout speed, dynamic range and also require significant cooling to obtain the required signal to noise ratio.

Active pixel sensors (APS) are able to combine faster readout speeds and higher dynamic range with in-pixel intelligence to allow region of interest readout and adaptive gain. To obtain high detection efficiency and 100% pixel fill factor the sensor is back thinned and illuminated from the backside.

We report on the characterization of a back-thinned APS, (Vanilla); an array of 512 x 512 pixels of size 25 x 25 microns. The sensor has a 12 bit digital output for full frame mode, as well as being able to be readout in a fully programmable Region-Of-Interest (ROI) analogue mode. In full frame, the sensor can operate at a readout rate of more than 100 frames per second.

Characterization of the detector was carried out through the analysis of photon transfer curves to yield measurements of the full well capacity, noise levels, gain constants and device linearity.

A typical synchrotron experiment was performed at the Diamond Light Source (DLS) using Soft X-rays (˜700 eV) to produce a diffraction pattern from a permalloy sample. The pattern was imaged at a range of integration times, down to 0.05s, and a range of temperatures for both a back-thinned Vanilla and a Princeton PIXIS-XO: 2048B Charge Coupled Device. The results of which are compared.

The detection efficiency of the APS is shown to be the same as that of the CCD and its response is shown to be linear, with no charge blooming effects at the longest integration times. We conclude that the back-thinned Vanilla APS is a suitable starting point to design an APS for direct detection of soft X-rays for synchrotron applications.

Preferred medium (Oral/poster):

Oral

Europlanet Workshop on Detectors for Astronomy and Planetary Science / 91

Using a CCD for the direct detection of electrons in a low energy space plasma spectrometer

Author: Robert Bedington[1]

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Low energy plasma spectrometers for space science typically use micro channel plates (MCPs) with position sensitive anodes as detectors behind their analyser heads (electrostatic optic energy selecting filters). MCPs however require high vacuums and high voltages which can add challenges and complications for the design and implementation of an instrument.

As an alternative at MSSL we have been using an E2V CCD64 back illuminated, full frame, scientific x-ray CCD as an imaging electron detector for testing and calibrating a highly miniaturised prototype plasma spectrometer analyser head. The small size of the analyser head makes it well matched to the size of the CCD which has a much smaller detecting area than that of the MCP detectors that most traditional plasma spectrometers demand. Simulations, the experimental setup and results will be discussed and the application of CCD detectors to such calibrations evaluated.

The CCD is being considered as a possible detector for use with the prototype analyser head for a proposal for a low altitude sounding rocket flight. Although it cannot detect the lowest energy particles an MCP can detect, and it is more sensitive to stray light, the low voltages required and the lack of vacuum requirements make it an attractive candidate. Further trade-offs of the CCD with the different detector technologies available for the proposal will be discussed.

Preferred medium (Oral/poster):

oral

Detectors for Particle Physics / 92

Performance of the Resistive Plate Chambers in the CMS experiment

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Resistive Plate Chambers (RPCs) are used in the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider (LHC) as a dedicated trigger detector. Moreover, they contribute to the muon identification and reconstruction alongside Drift Tubes and Cathode Strip Chambers.
The operational experience after more than one year of LHC collisions and the performance of the RPC detector during 2010 and 2011 will be reported.

Preferred medium (Oral/poster):

Oral

Applications in Medicine, Life Sciences and Biology / 93

Recent Developments in Molecular Imaging

Author: Dewi Lewis[1]

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During the last decade there have been numerous advances within industry in developing imaging systems for nuclear medicine and molecular imaging but in general these improvements in clinical systems tend to lag behind the ground breaking research and improvements that are made at academic laboratories. In this paper we will describe the present day industrial environment for imaging instrumentation and radionuclides and also highlighting the medical areas where this technology is most effective. We will describe the leading developments in the field and how they have benefited routine medical practice. We will also analyse how these developments were initially 'brought to market'and comment on the possible impact for the diagnosis of disease.

Preferred medium (Oral/poster):

Oral

Positron Emission Tomography / 94

Position-sensitive Solid-state Photomultiplier Devices

Author: Christopher Stapels[1]

Co-authors: Chad M. Whitney [1]; Erik B. Johnson [1]; Frank L. Augustine [2]; James Christian [1]; Kanai Shah [1]; Michael R. Squillante [1]; Mickel McClish [1]; Purushottam Dokhale [1]; Xiao Jie Chen [1]

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Nuclear imaging applications, such as PET, often use position-sensitive photodetectors coupled to scintillation detectors, to determine the location and energy of the event in a scintillation detector.

Coupling nuclear imaging techniques to magnetic-resonance imaging, for morphological images, introduces a strong magnetic field that constrains the choice of photodetector. Solid-state photomultipliers (SSPMs) are high-gain photodetectors that are suitable for scintillation-based applications and are insensitive to magnetic fields. In general, SSPM detectors provide the energy of the scintillation event, but not its location.
Charge dividing networks require a small number of readout channels and are used to provide position information in photomultiplier tubes and avalanche photodiode detectors. In this work, we describe the design, modeling, and performance of position-sensitive SSPM detectors using charge dividing networks. The performance of devices that divide the charge between segments of SSPM detectors is compared to that of devices that divide the charge between each Geiger photodiode element of the SSPM detector. The performance of prototypes is compared, including position resolution and timing as a function of detector area and size of the resistors in the resistor network. The signals produced by GPD elements in a simple resistor network were modeled in SPICE to determine the best value for the network resistor. Simple simulation results will be presented.

Preferred medium (Oral/poster):

Oral

Knowledge Transfer and Commercial Opportunities for PSDs / 95

KE towards High k dielectrics, CMOS and solar cells

Author: Simon Rushworth[1]

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The FORME strategic research cluster is a Science Foundation of Ireland supported project with 15 funded academic investigators and 5 industry partners. The focus of the work plan is to develop functional oxides and materials for the semiconductor industry however in the later stages of the project applying the results obtained to different industry applications is a key exploitation target.
In particular the deposition of high-k metal oxide thin films for CMOS logic and memory devices along with improved performance MOSFET devices is being investigated. Due to scaling limitations of Si based materials the integration of new materials into standard production technologies is required to ensure Moores Law is complied with in future technology generations. However thin, highly conformal metal oxide films possess a wide number of potential applications outside the semiconductor field ie solar cells, photocatlytic glazing, antimicrobial coatings, biocompatible medical coatings, gas sensors etc.
In this talk the motivation for the project and the different partner objectives will be discussed. In addition some recent results will be presented on Atomic Layer Deposition technology development and examples of its potential in alternative industries provided. The mechanism for Knowledge Transfer to ensure successful roll out of the cluster results will also be described.

Preferred medium (Oral/poster):

Oral

Knowledge Transfer and Commercial Opportunities for PSDs / 96

Opportunities for the community towards a Sensors - Technology Innovation Centre (TIC)

Author: Carlos Huggins[1]

[1] *Systems Technology Innovation Centre*

After a degree in Natural Sciences (especially Physics and Maths), and an MSc in Semiconductor Science, Carlos Huggins went into industrial R&D and technology management,. Over 22 years he has had contributed as a Gallium Arsenide epitaxial grower and device designer for defence imaging and space power applications; worked on fibre optic devices and pump laser structures for telecommunications; acted as a project Technical Authority for space imager programmes; been engineering team leader for a gas sensors group; taken a corporate seat in a strategic Technology and Market group, building bridges and consortia with external collaborators and funding bodies both academic and commercial; and performed Technology Due Diligence in corporate Mergers and Acquisition. Now he is a Technology Translator for the Sensors and Instrumentation Knowledge Centre (SIKC) of the Electronics Sensors and Photonics Knowledge Transfer Network (ESP-KTN), with a particular focus (today) on the Sensor Systems Technology Innovation Centres (TIC) consultation process in which the SIKC is engaged, alongside exploring opportunities for sensors for the built environment, and KT from the "big science" base.

The Technology Strategy Board (TSB) has launched a long-term strategy involving the development of industry-led, business-focussed TICs, to act as a focus and accelerator of technology commercialisation and impact in the UK. Sensor Systems is one of the ten candidate areas for the next tranche of three to be selected, and the SIKC is supporting the consultation process on behalf of TSB. The status of the process to date, the key messages, and the next stages will be discussed, as will the general activities of the ESP-KTN in Knowledge Exchange.

Preferred medium (Oral/poster):

Oral

Photon Detectors for Synchrotron Radiation and other applications / 100

Position sensitive photon detectors for Nuclear Physics, Particle Physics and Healthcare Applications

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Modern experiments in hadronic physics require detector systems capable of identifying and reconstructing all final-state particles and their momentum vectors. Imaging Cherenkov counters (RICH and DIRC) are frequently employed in nuclear and particle physics experiments, These detectors require high-rate, single-photon capable light detection system with sufficient granularity and position resolution. Several candidate systems are available, ranging from multi-anode photomultiplier tubes to micro-channel plate systems to silicon photomultipliers. Each of these detection solutions has particular advantages and disadvantages. We present detailed studies of rate dependence, cross-talk, time-resolution and position resolution for a range of available photon detection solutions: Hamamatsu MAPMTs, MCP-PMTs from Photonis and Hamamatsu. These properties make these photon detection systems ideal for radionuclide imaging applications as well and we will put their properties into a healthcare context.
Cherenkov radiation can also be used for medical imaging applications. We will review two different applications using the Cherenkov effect for radionuclide imaging.

Preferred medium (Oral/poster):

oral

Detectors for FELs and other light sources / 101

The Detector Development Program for the European X-ray Free Electron Laser

Author: Markus Kuster[None]

The European X-ray Free Electron Laser (XFEL) will provide as-yet-unrivaled peak brilliance and ultra-short pulses of spatially coherent X-rays with a pulse length of less than 100 fs in the energy range between 0.25 and 25 keV. The high radiation intensity and ultra-short pulse duration will open a window for novel scientific techniques and will allow to explore new phenomena in biology, chemistry, material science, of matter at high energy density, in atomic, ion and molecular physics. The European XFEL will provide six different user accessible experiment stations which will be optimized for different scientific applications.

The variety of scientific applications and especially the unique XFEL time structure will required adequate instrumentation to be developed to exploit the full potential of the light source. In 2007 the European XFEL GmbH started three independent multi-national detector development programs, with the primary goal to overcome the technological challenges for imaging detectors given by the XFEL burst mode frame rate and the required high dynamic range. I will present a summary of requirements for detectors at the European XFEL and the status of the European XFEL detector development projects, which includes large area ultra-fast 2D imaging detectors and 1D and 2D detectors for, e.g., spectroscopy applications. I will provide an overview and outlook over the forthcoming 4 years long implementation phase of the project with respect to detector R&D, detector performance optimization, integration, and commissioning.

Preferred medium (Oral/poster):

oral

Detectors for Astrophysics / 102

The AMS-02 spectrometer: first data and detector performance

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The Alpha Magnetic Spectrometer (AMS-02) is a high-energy physics experiment designed to operate in space on board the International Space Station (ISS), where it has been installed on May 16th 2011, taking data continuously since then. Thanks to the very large acceptance (˜ 0.5 m2 sr) and an exposure time that will match the ISS lifetime, AMS-02 will measure a wealth of data to study with unprecedented accuracy the composition and the energy spectrum of charged CRs and gammas up to the TeV energy scale. AMS-02 is able to measure the energy spectrum of the most rare cosmic ray components (antideuteron, antiproton, positron, ⋯) allowing for the search of primordial anti-matter and dark matter annihilation products.
The magnetic spectrometer consists of 7 layers of Silicon sensors in the permanent magnet bore (B field ˜ 0.15T) complemented by 2 layers at both ends of the detector. The measurement of the curvature radius of the charged particles bent trajectories - through the precise location (resolution of 10 m) of the particle impact points on the Si Tracker planes - allows for the computation of the particle rigidity and charge sign. With an effective sensible area of 6.2m2 the AMS-02 Silicon Tracker is among the largest tracker built for space application. It is composed by 2264 double-sided Silicon sensors (72x41mm2, 300µm thick) assembled in 192 read-out units, for a total of 200.000 read-out channels.
At the end of July 2010 the AMS-02 Silicon Tracker has been successfully integrated and installed within the AMS-02 detector. Then an extensive period of muon data acquisition on ground, a beam

test, and the first months of data taking in space, allowed for the study of the spectrometer performances.
The design and construction of the AMS-02 Silicon Tracker are reviewed, as well as the operation in space. The main characteristics in terms of spatial resolution, charge distinction and alignment strategy, both from beam test and cosmic-rays data taking results will be presented.

Preferred medium (Oral/poster):

Oral

Advances in Pixel Detectors / 103

Imaging Based on Tracking of Individual Particles with the Timepix Pixel Detector

Author: Jan Jakubek[1]

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In radiation imaging applications the pixel detectors are so far mostly operated in single particle counting mode. In this mode the signal generated by the particle is compared with a certain preselected energy threshold to remove noise and, if higher, it is counted in a digital counter. Such approach provides low noise, energy discrimination and absolutely linear image accumulation. Resulting images have extremely high dynamic range and virtually unlimited contrast which play an essential role in imaging of low contrast objects such as soft tissue structures.
Pixel detectors operated in tracking mode with reduced exposure time having only few particle traces in each frame can offer even more complete information about each detected quantum. The pixels can be then operated in Time-over-Threshold mode providing information about energy deposited in each pixel. The shapes of recorded traces are often characteristic for different particle types. Analyzing these shapes it is possible for instance to suppress undesired background, to improve spatial and energy resolution, to estimate particle type and its mass. Using coincident techniques based on time stamping in each pixel it is possible to derive also other radiation properties such as polarization for X-rays, identification of secondary particles of nuclear reactions or decay products.
Radiation imaging methods can be significantly enhanced by particle tracking principles. A few examples will be given such as fully spectroscopic X-ray transmission imaging, neutron and proton radiography with very high spatial resolution and imaging based on ion scattering.
A brief glance into the future of pixel detectors and their applications including 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.
This work is carried out in frame of the Medipix Collaboration.

Knowledge Transfer and Commercial Opportunities for PSDs / 105

The development of x-ray imaging for aiport security, defence and medical markets

Author: John McGrath[1]

[1] *Kromek*

The application of current x-ray inspections systems to the identification of foreign objects in complex environments is limited by a number of factors. At best the systems are a compromise between conflicting performance requirements. The challenge facing x-ray system manufacturers is that many materials will show the same output characteristics using traditional X-ray absorption techniques. Coupled with the commercial drivers of the products'end users the technical challenges

require a step change in the methods and science applied. Airport security provides a useful exemplar for the difficulty of the problem. In detecting the presence of liquid explosives in carry-on baggage we require a high level of analytical specificity with low false alarm rates in a wide range of sealed containers and a minimal impact on the passengers'experience.
Multi-spectral x-ray detectors using CdTe/CZT are becoming increasingly important for detection of x-rays and gamma rays in these applications. One key feature is their ability to detect and separate out the entire energy spectrum emitted by an x-ray source into many different electronically configurable bands. Analysing the intensity of the x-rays across the whole spectrum after they have passed through an object provides a unique fingerprint of the object's composition.
Although the benefits of CdTe/CZT have long been known, the material has not been widely used since it is difficult to manufacture in commercially interesting volumes. Kromek has solved this through its patented MTPVT vapour-phase growth process, which has the ability to grow defect-free crystals larger than any other suppliers. We have supplemented this foundation technology with the development of detector technologies and the acquisition of Nova, a US subsidiary with a range of ASIC technologies for CdTe and CZT signal conditioning electronics. We are also active in algorithm development for end user applications such as threat detection and medical imaging.
Kromek's technology is vital to a wide range of market sectors, pioneering digital colour imaging for x-rays and advanced 3D imaging for the security, industrial inspection, defence and medical markets. Most recently Kromek has developed a family of products for the global aviation and border security markets to combat threats posed by liquid based explosives and precursors, and the smuggling of narcotics dissolved in alcohol. In this presentation we will give an overview of Kromek's technologies and their applications.

Preferred medium (Oral/poster):

oral

Poster Session - Board: 4 / **106**

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

Authors: Igor Gorelov[1]; Konstantin Toms[1]; Martin Hoeferkamp[1]; Sally Seidel[2]

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

Preferred medium (Oral/poster):

Oral

Advances in Pixel Detectors / **107**

Planar Fourier Capture Arrays: Tiny Optical Sensors Built Entirely in Unmodified CMOS

Author: Patrick Gill[1]

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In 2008 at Cornell, we developed a new class of optical sensor made in standard CMOS: the angle sensitive pixel (ASP). ASPs have allowed us to develop several optical innovations including the Planar Fourier Capture Array (PFCA) in 2011: the first camera without lenses, mirrors or moving parts. PFCAs capture the Fourier transform of the far-away scene directly without external optics. The first prototype PFCA is 100 000 times smaller by volume than the smallest focusing cameras and can image with an effective resolution of 400 pixels, making it an interesting intermediate between single photodiodes and miniaturized focusing cameras.

Nuclear Physics / 108

Position Sensitive Detectors for Nuclear Structure Physics and their Applications

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The nucleus is a unique, strongly interacting many-body system. There are many techniques and reactions to study different features of the nucleus which all rely on the detection of charged particles or gamma-rays. Each major technical advance in detection devices has resulted in significant new insights into nuclear science. As the systems evolve more exotic features of the nucleus can be measured and some key questions can be investigated such as how are elements and isotopes found in the Universe formed?
A number of these position sensitive semiconductor arrays will be covered in this talk along with the physics they are investigating and results they have produced.
The TRIUMF ISAC Gamma Ray Escape Suppressed Spectrometer (TIGRESS) array at TRIUMF, Canada, uses 12 32–fold segmented Germanium detectors in the shape of clovers for use with accelerated radioactive ion beams. Coulomb excitation and nucleon transfer reactions of interest have been studied with this array. The gamma rays emitted in these reactions are measured using this spectrometer and insight into the internal structure of the nucleus can be gathered and reconstructed.
The next major global step is to remove the suppression shields producing a 4 pi highly segmented high purity Germanium array constructed from 180 36-fold tapered hexagonal detectors resulting in 6660 channels . A gamma-ray tracking system measures the position and energy of gamma rays that Compton scatter through the crystals so that the path and sequential energy loss of a single gamma-ray can be deduced. The full energy of the event can then be reconstructed using gamma ray tracking (GRT) methods. The Advanced GAmma Tracking Array (AGATA) represents a major advance in gamma-ray spectrometer design. Using gamma-ray tracking a much higher efficiency and much lower Doppler broadening is achieved.
The Advanced Implantation Detector Array (AIDA) will be assembled from wafers of double sided silicon strip detectors and will be used in decay spectroscopy experiments of exotic nuclei on the Facility for Anti proton and Ion Research (FAIR) accelerator at GSI, Germany.
The development of these position sensitive detectors has the potential to be used in the medical, security, decommissioning and environmental imaging fields. Their applications will be discussed.

Detectors for Particle Physics / 110

LHC detectors overview with emphasis on ATLAS

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The talk will overview the big variety of detectors deployed by the experiments at LHC, their performance and few example of physics results obtained so far, with emphasis on techniques and results in ATLAS. An analysis and a comparison will be done to show the reasons of the choices made. Finally a roadmap of the foreseen improvements and upgrades will be covered.

Advances in Gas Based Detectors / 111

The ARGONTUBE, a R&D liquid Argon Time Projection Chamber

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For future neutrino oscillation experiments new large mass scale detectors are needed. One possible type of such detectors could be the liquid Argon Time Projection Chamber (LAr TPC). Therefore, some technical challenges have to be met: purity of the LAr, high voltage supply, calibration etc. To face these challenges, a R&D LAr TPC is now under development at the LHEP of the University of Bern. The goal is to reach a drift length of 5m in liquid Argon and prove the feasibility of large volume TPCs.
In this talk, different aspects of the technology will be reviewed and recent achievements presented.

Europlanet Workshop on Detectors for Astronomy and Planetary Science / 112

Life Marker Chip and its Detection Technologies

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The Life Marker Chip (LMC) instrument aims to detect organic molecules on Mars as part of the 2018 planned ESA/NASA rover mission. The LMC is based around use of immuno-assay technology from bio-technology where a molecular receptor binds to a target molecule. This binding is detected using fluorophores attached to the molecular receptor. High sensitivity (ppm to ppb) can in principle be achieved using immuno-assays and antibody based molecular receptors. The fluorescence excited by light from a laser is detected using a cooled position sensitive CCD detector with an image of the assay region relayed to the detector using coherent fibre optics and relay lens systems. The assay takes place on a silicon nitride waveguide which is used to direct the laser light to the assay and excite the fluorophores using evanescent excitation. The LMC consortium, science objectives, detector technologies, overall design and current status will be described.

Europlanet Workshop on Detectors for Astronomy and Planetary Science / 113

Silicon Detectors in Space

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Europlanet Workshop on Detectors for Astronomy and Planetary Science / 114

Introduction to Europlanet Workshop

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Europlanet Workshop on Detectors for Astronomy and Planetary Science / 115

Europlanet Workshop Summary and Discussion

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Detectors for Particle Physics / 116

Silicon detector in the ALPHA –experiment for antihydrogen detection

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The aim of the ALPHA experiment at CERN is to trap cold atomic antihydrogen and study it's properties, and ultimately, perform a comparison between hydrogen and antihydrogen atomic spectra. Recently, ALPHA has reached important milestones by demonstrating the ability to trap neutral cold antihydrogen and keep the antiatoms confined over a period of 1000 s. [1,2].

The main diagnostic tool for detecting antihydrogen is a silicon tracking device. The device consists of 120 double sided 128x256 silicon strip detectors and has been constructed at the University of Liverpool. The detector is placed to surround the antihydrogen trap of the ALPHA-experiment at CERN. The detector monitors the annihilation events of antihydrogen or antiproton plasmas and enables the detection of single annihilation events. Description and characteristics of this detector and an overview of the ALPHA experiment will be given.

[1] Nature (2010), doi:10.1038/nature09610
[2] Nature Physics 7, 558–564 (2011), doi:10.1038/nphys2025

Opening speeches and Welcome / 118

A Brief History of PSD

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Opening speeches and Welcome / 119

Welcome To Aberystwyth

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Knowledge Transfer and Commercial Opportunities for PSDs / 120

High resolution SFOV gamma camera systems

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