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GaAs:Cr as an alternative sensor material for hybrid pixel detectors in high-energy electron microscopy

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The introduction of direct electron detectors over the past fifteen years has opened up new possibilities in all branches of electron microscopy. In particular, monolithic detectors with thin Si sensors have been used to great effect for imaging in the life sciences. However, they typically have slower readout and are insufficiently robust for routine exposure to the intense central spot of a diffraction pattern. This makes them unsuitable for use in electron crystallographic experiments in materials and life sciences. The thick sensors of hybrid pixel detectors (HPDs) mean they can record full diffraction patterns, whilst their sophisticated pixel architecture means they are generally capable of fast, noiseless operation. They are therefore well suited for use in a variety of applications for which monolithic detectors are not usable.

Counting HPDs with Si sensors have been shown to offer excellent performance when using low-energy electrons. For example, the Medipix3RX detector [1] bonded to a 300µm Si sensor is able to match the performance of an ideal imaging detector when using electrons with an initial energy $E_0 \leq$ 80keV. Using a counting threshold equal to $E_0/2$, electrons are counted only in the pixel in which they enter the sensor [2]. However, the performance of HPDs deteriorates when using higher-energy electrons ($E_0 \geq$ 200keV). Although it is still the case that only a single pixel records the incident electron when using a threshold equal to $E_0/2$, the pixel registering the hit is usually the pixel at the end of the electron's trajectory [3]. This is because the rate at which an electron deposits energy increases as it slows down, and a high-energy electron will scatter over many pixels in a Si sensor sufficiently thick to protect the ASIC underneath. Using high-Z materials, such as GaAs:Cr, should mean the signal produced by a high-energy electron is more localised, resulting in an improved PSF. However, such materials also have higher backscattering coefficients for primary beam electrons, which may have a negative impact on DQE.

We have compared the performance of the Medipix3RX bonded to a 500µm Si sensor and a 500µm GaAs:Cr sensor using energies from 60keV to 300keV. Our comparison of the two detectors has included analysis of how pixel clusters due to individual electrons change as a function of increasing energy deposition threshold. This has been done with the detectors operating in Single Pixel Mode (SPM), in which each pixel counts independently, and in Charge Summing Mode (CSM), where an arbitration circuit attempts to assign incident electrons to a single pixel. Our results indicate that the spread in signal due to high-energy electrons is significantly reduced in a GaAs:Cr sensor.

When using 200keV electrons with the detectors operating in SPM, the average area of the clusters recorded by the GaAs:Cr sensor is ˜2/3 the average cluster area recorded by the Si sensor at the lowest threshold used with the GaAs:Cr sensor. The lowest threshold of the GaAs:Cr sensor (˜16keV) is higher than that of the Si sensor (˜9keV) due to the GaAs:Cr sensor's higher leackage current. Using their respective lowest threshold settings, average cluster area recorded by the Si sensor was 4.5 pixels, whilst that recorded by the GaAs:Cr sensor was 2.3 pixels. The decrease in the GaAs:Cr sensor's average cluster area with increasing threshold is also more gradual than that of the Si sensor, likely due to the electrons' energy being distributed over fewer pixels. We will present MTF and DQE measurements, currently in progress, which will confirm the extent to which the GaAs:Cr sensor offers enhanced performance relative to the Si sensor and provide further insight into how electrons interact with thick sensors.

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Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 2

Development and characterization of CMOS Sensors for Electron Microscopy

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In this work, we show the design and characterization of an image sensor with 64x64 pixels and its associated hardware and software needed to use the chip. The aim of the chip is to be used as a sensor for TEM electron microscopy. First measurements were done using X-Rays to characterize the chip and to test the whole system (ASIC, Software, and Hardware).
The here described sensor was developed in 180nm AMS HV-technology [1]. Pixel sensors are based on deep n-well in p-substrate diodes. Signals generated by particles are collected by the deep n-wells. Pixel electronics is placed inside the n-wells. The pixel electronics contains a charge sensitive amplifier and a correlated double sampling circuit. Pixel matrix is readout in rolling shutter mode. The signals are passed to 128 readout channels at the chip periphery. Each channel contains an amplifier and an 8-bit digital-to-analog converter (D/A converter). The digital values of the pixels' signals are sent outside the chip, in serial mode, via 8 Low Voltage Differential Signals (LVDS). The output of the chip is received by a Nexys Video FPGA, which is the link between the Chip and the PC. This FPGA allows the user to configure the Chip using the Qt interface designed for this purpose. The interface also allows the user to store the incoming data and watch online the chip readout.
The chip has been illuminated by X-Ray source for 30 minutes. A Seyfert ISO-DEBYEFLEX 3003 X-Ray tube was used, with seven different targets in order to have an X-Ray of specific energy on the range $6,4KeV$ to $25,3KeV$.
Depending on the energy of the X-Ray, the peak of the Gaussian (on the histogram) moves to higher bin output values. Plotting the mean value of each Gaussian vs. the energy shows a linear behavior in the energy range used, with a conversion factor of $253.82\frac{eV}{bit}$ (where "bit" is the 8-bit value of the output).
The chip was tested for radiation tolerance, reaching $50Mrad$ without showing signs of malfunctioning but with an increase of noise (from $82e^-$ to $239e^-$), and a change in the conversion factor, from $250.28\frac{eV}{bit}$ to $328.18\frac{eV}{bit}$.

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Evaluation of UO2 for Solid-State Direct-Conversion Neutron Detection

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The objective of this work was to evaluate UO2 as a solid-state direct-conversion neutron detector material by utilizing single crystal and thin films of UO2. Initial investigations indicated the material properties were unsuitable and efforts were made to enhance grain size and increase electrical resistivity by using dopant materials. Samples of arc-fused single crystal UO2 included that were doped by ion implanted were made into Schottky diode devices. Chemical solution deposition (CSD) utilized to produce higher resistivity UO2 thin films. CeO2 was also used as a nonradioactive simulant. 252Ca source irradiation was performed on UO2 single crystal samples. A testing apparatus suitable for these samples was. Pulse height spectra data was collected and analyzed. MCNP and GEANT4 calculations were then made by a collaborator evaluating these samples. Co-doped samples of UO2 were made to enhance this materials desirability in detection applications. Higher electrical resistivities and larger grain sizes are reported. CeO2 samples are used as a non-radioactive simulant.

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CHROMIE: a new High-rate telescope. Detector simulation and commissioning

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The upgrade of the LHC to the High-Luminosity LHC (HL-LHC) is expected to increase the current instantaneous luminosity by a factor of 5 to 7, providing the opportunity to study rare processes and precision measurement of the standard model parameters. To cope with the increase in pile-up (up to 200), particle density and radiation, CMS will build new silicon tracking devices with higher granularity (to reduce occupancy) and improved radiation hardness. During the R&D period, tests performed under beam are a powerful way to develop and examine the behavior of silicon sensors in realistic conditions. The telescopes used up to now have a slow readout (< 10 kHz) for the needs of the CMS experiment, since the new outer-tracker modules have an effective return-to-zero time of 25 ns (corresponding to a 40 MHz frequency) and a trigger rate of 750 kHz. In order to test the CMS Tracker modules under the LHC nominal rate, a new pixel telescope named CHROMIE (CMS High Rate telescOpe MachInE) was designed, built and commissioned at CERN for beam tests with prototype modules for the CMS Phase-II Tracker upgrade. It is based on 16 CMS Phase-I Barrel Pixel modules of the same type as the ones used in the current CMS pixel detector. In this talk, the design of CHROMIE, the calibration of its modules, and its timing and synchronization aspects are presented, along with the first beam test results. In addition, the tracking algorithm developed for CHROMIE and a preliminary simulation study for the estimation of energy loss of primary particles, cluster multiplicity and spatial resolution are discussed.

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Spatial resolution improvement of gamma camera with diverging collimator using tapered crystal array

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Diverging collimators are used to obtain reduced images of an object, or to detect a wide field-of-view (FOV) using a small gamma camera. In the gamma camera using the diverging collimators, the block scintillator, and the pixel scintillator array, gamma rays are obliquely incident on the scintillator surface when the source is located the periphery of the FOV. Therefore, the spatial resolution is reduced because it is obliquely detected in the depth direction [1]. In this study, we designed a novel system to improve the spatial resolution in the periphery of the FOV. Using a tapered crystal array to configure the scintillation pixels to coincide with the angle of the collimator's hole allows imaging to one scintillation pixel location, even if events occur at different depths. That is, even if is detected at various points in the diagonal direction, the gamma rays interact with one crystal pixel, so resolution does not degrade. The resolution of the block scintillator and the tapered crystal array were compared and evaluated through Geant4 Application for Tomographic Emission (GATE) simulation. Figure 1 shows the scintillator and collimator designed for the simulation and shows the acquired image and profile when the source is generated at the periphery of the FOV. The spatial resolution of the obtained image was 4.05 mm in the block scintillator and 2.97 mm in the tapered crystal array. There was a 26.67% spatial resolution improvement in the tapered crystal array compared to the block scintillation.

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Gamma photons energy measurement in Laser Produced Plasmas: a novel approach using a Timepix3 detector and Geant4-based simulations

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The plasma's X-ray monitoring in Laser Produced Plasmas (LPPs) experiments is troublesome since the X-ray emissions impinge the detector in a too short time window (from a few tens of ps to few ns,) depending on the power and pulse time width of the laser. Hence the measure of the non-integrated photon flux is a problem hard to handle. To this end, we have used the Timepix3 (TPX3) chip, in a side-on configuration, in order to get a quick estimate of the gamma photons energy. TPX3 is a single chip detector, Silicon based, 256 x 256 pixels bump-bonded with 300 µm thick silicon layer and a long side of 14 mm. Using the long side for the interaction of gammas, it is possible to obtain some characteristic tracks or pixels clusters mainly due to Compton electrons. Thanks to many different parameters that can be defined as Cluster Size (CS), Time over Threshold (ToT), Linearity, Roundness, etc. the detector response was studied and compared with some known gamma sources and some Geant4 simulations in the energy range of interest. This new approach, through a Landau distribution comparison between simulations and experimental data, allows discriminating the various energy bands for the gamma photons (also with a single experimental run provided it produces enough statistics).

CMOS, ASIC, chair: George Fanourakis / 8

Predicting the radiation damage in a space-qualified high performance CMOS image sensor

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The CIS115 is a Teledyne-e2v CMOS image sensor with 1504 x 2000 pixels of 7 μm pitch. It has a high optical quantum efficiency owing to a multi-layer anti-reflective coating and its back-side illuminated construction, and low dark current due to its pinned photodiode 4T pixel architecture. The sensor operates in rolling shutter mode with a frame rate of up to 7.5 fps (if using the whole array), and has a low readout noise of ˜5 electrons rms.

The CIS115 has been selected for use within the JANUS instrument, which is a high resolution camera due to launch on board ESA's JUpiter Icy moons Explorer (JUICE) spacecraft in 2022. After an interplanetary transit time of over 7 years, JUICE will spend just under 4 years touring the Jovian system, studying three of the Galilean moons in particular: Ganymede, Callisto and Europa. During this latter part of the mission, the spacecraft and hence the CIS115 sensor will be subjected to the significant levels of trapped radiation surrounding Jupiter.

Proton and gamma irradiation campaigns have therefore been undertaken in order to evaluate both non ionising and ionising dose effects on the CIS115's performance, up to 200 krad(Si). Characterisations were carried out at expected mission operating temperatures (35±10 ℃) both prior to and post-irradiation. The degradation in imager characteristics, particularly the dark current and image lag, will be discussed relative to the mechanisms of radiation damage. Models of these mechanisms are then tuned with the experimental data to present the expected performance of the CIS115 during the JUICE mission lifetime.

Hardware, Applications, chair: Christer Frojdh / 9

"Low Electronic Noise" Detector Technology in Computed Tomography

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Image noise in computed tomography, is mainly caused by the statistical noise, system noise reconstruction algorithm filters. Since last few years, low dose x-ray imaging became more and more desired and looked as a technical differentiating technology among CT manufacturers. In order to achieve this goal, several technologies and techniques are being investigated, including both hardware (integrated electronics and photon counting) and software (artificial intelligence and machine learning) based solutions. From hardware point of view, electronic noise could indeed be a potential driver for low and ultra-low dose imaging, especially if one could tailor and optimize it for specific applications. We have demonstrated that the reduction or elimination of this term could lead to a reduction of dose without affecting image quality. Also, in this study, we will show that we can achieve this goal using conventional electronics (low cost and affordable technology), designed carefully and optimized for maximum detective quantum efficiency. We have conducted the tests using large imaging objects such as 30 cm water and 43 cm polyethylene phantoms (fig.1). We compared the image quality with conventional imaging protocols with radiation as low as 10 mAs (« 1 mGy). Clinical validation of such results has been performed as well and some findings based of noise power spectra will be discussed concerning of the source of the noise [1,2].

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Design of a novel column-parallel ADC in the MAPS for full-image beam monitoring

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To handle the increasing number of cancer patients, China has built its own carbon ion therapy facility. The beam monitoring system in the therapy facility ensures the beam energy deposition can accurately cover the dedicated tumor region. The full image of the beam energy deposition is needed for accurate beam calibration, thus a Monolithic Active Pixel Sensor (MAPS), which can provide the energy deposition in each pixel, is being designed in a 130nm CMOS process. As the key part in realizing this MAPS with full-image output, a 5-bit column-parallel ADC with a novel architecture has been designed to serve the pixels in each column. To respond to the restrict constraints of power dissipation, size, working speed and accuracy for the MAPS, the column-parallel ADC combines the dedicated sample phase and the signal conversion phase into a single phase. Moreover, the column-parallel ADC has a high tolerance to the offset of the comparators in the ADC by generating 1.5-bit in every stage. Each column-parallel ADC covers a small area of 100 μm × 200 μm, consumes low power at 3.3 V supply and provides the sampling rate of 10 MS/s with the dynamic range of 1000 mV. Its DNL and INL are 0.04 LSB and 0.256 LSB, respectively. This paper concerns the design, optimization and performance of the column-parallel ADC.

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Test Beam Measurements of the CMS High Granularity Calorimeter for HL-LHC

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As part of the HL-LHC detector upgrade programme, the CMS experiment is developing a High Granularity Calorimeter (HGCAL) to replace the existing endcap calorimeters. The HGCAL will be realised as a sampling calorimeter, including 36 layers of silicon pads and 14 layers combining both silicon and scintillator detectors interspersed with metal absorber plates. Prototype modules based on 6-inch hexagonal silicon pad sensors with pad areas of 1.0 cm2 have been constructed. Beam tests of different sampling configurations made from these modules have been conducted at the CERN SPS using beams of charged hadrons and electrons with momenta ranging from 20 to 350 GeV/c. The setup was complemented with a CALICE AHCAL prototype, a scintillator-based sampling calorimeter, mimicking the proposed design of the HGCAL scintillator part. This talk summarises the test beam measurements at CERN in 2018, including measurements of pedestal and noise, gain characterisation, calibration with single charged particles and energy reconstruction performance of electron and hadron induced showers. We also show measurements of the timing capabilities of this prototype system and the steps being taken towards electron and hadron identification.

Software, chair: Daniele Passeri / 13

Minimizing CPU Utilization Requirements to Monitor an ATLAS Data Transfer System

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ATLAS[1] experiment at LHC will use a PC-based read-out component called FELIX[2] to connect its Front-End Electronics to the Data Acquisition System. FELIX translates proprietary Front-End protocols to Ethernet and vice versa. Currently, FELIX makes use of parallel multi-threading to achieve the data rate requirements. Being a non-redundant component of the critical infrastructure necessitates its monitoring. This includes, but is not limited to, package statistics, memory utilization, and data rate statistics. However, for these statistics to be of practical use, the parallel threads are required to intercommunicate. The FELIX monitoring implementation prior to this research utilized thread-safe queues to which data was pushed from the parallel threads. A central thread would extract and combine the queue contents. Enabling statistics would deteriorate the throughput rate by more than 500%.
To minimize this performance hit to the greatest extent, we took advantage of the CPU's micro-architecture. The focus was on hardware supported atomic operations. They are usually implemented with a load-link - store-conditional pair of instructions. These instructions guarantee that a value is only modified if no updates have occurred on that value since reading it. They are used to complement and/or replace parallel computing lock mechanisms. The aforementioned queue system was replaced with sets of C/C++ atomic variables and corresponding atomic functions, hereinafter referred to as atomics. Three implementations were measured. Implementation A had one set of atomic variables being accessed from all the parallel threads. Implementation B had a set of atomic variables for every thread. These sets were accumulated by a central thread. Implementation C was the same as implementation B but appropriate measures were taken to eliminate any cache invalidation implications. The compiler used during the measurements was GCC which partially supports the hardware (micro-architecture) optimizations for atomics.
Implementations A and B resulted in negligible differences compared to the initial one. The gains were not consistent and less than 5%. Some benchmarks even showed deterioration of the performance. Implementation C (cache-optimized) yielded results with a performance improvement of up to 625% compared to the initial implementation.
The data rate target was reached. Implementations similar to C in our research could benefit similar environments. The results presented exhibits the power of programming based on atomics. However, from the results, it is clear that the system architecture and cache hierarchy needs to be taken into account in this programming model. The paper details the challenges of atomics and how they were overcome in the implementation of the FELIX monitoring system.

KEYWORDS: Data compression, transfer and storage

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Tomography, chair: Christer Frojdh / 14

Image accuracy improvement of interior region of interest (ROI) reconstruction using field modulation CT acquisition

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Region-of-interest (ROI) imaging is considered an effective method to reduce the exposure dose [1]. We propose ROI-based field modulation acquisition (figure 1) to improve image accuracy of inside ROI and restore the information outside of the ROI. In this study, we compared interior image quality of field modulation CT image with conventional interior ROI reconstruction method. A prototype of the CT system (TVX-IL1500H, GERI, Korea), which has a 1016×760 pixel size flat panel detector, was used. The source-to-detector and the source-to-center of rotation distance were 1178 and 905 mm, respectively. Scout view reconstruction method [2] were used as recently presented comparative interior ROI reconstruction. A total of 720 projection data were obtained, from which full view CT reconstructed images were obtained as a reference image using a filtered back projection (FBP). Interior ROI CT images were reconstructed using the 720 truncated projection data. Scout view reconstruction was also conducted with 720 truncated projection data and we corrected the truncation using 6 scout view which were full-size projection data from the previous scan. Proposed field modulation CT image was reconstructed using 714 truncated and 6 full-size projection data at the same time scan. Using field modulation CT imaging, it is possible to obtain exact interior reconstructed image compared with scout view reconstruction [2]. As an additional effect, proposed method can restore the ROI external information of the reconstructed image to be similar to the reference image, when we obtained with using 648 truncated and 72 full-size projection in field modulation CT acquisition system. In conclusion, we have verified the possibility of applying the field modulation acquisition in CT imaging system. In addition, we performed a quantitative evaluation of the proposed field modulation CT image and the image of scout view reconstruction.

Hardware, Applications, chair: Christer Frojdh / 15

An experimental performance comparison of glass RPC detector with HARDOC based readout electronics and custom electronics

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The proposed 50 kton magnetized Iron Calorimeter (ICAL) detector at India-based Neutrino Observatory (INO) aims to investigate atmospheric neutrino oscillations. The ICAL will employ about 29000 glass Resistive Plate Chambers (RPCs) as the active detector elements and requires millions of electronic channels to be read out. Therefore, a multi-channel readout application specific integrated circuit (ASIC) named as HARDROC is under consideration as a possible option. The ASIC is a 64 channel analog-digital front-end chip which can read negative fast and short input signals with each channel featuring a current sensitive pre-amplifier coupled to triple-branch shaper stage followed by 3 low offset discriminators. A comparative performance study of RPC detector with HARDROC based readout electronics and with custom electronics, based on CAEN modules and HMC pre-amplifiers, was conducted. Measurements were made on a 30cm X 30cm glass RPC detector, using the cosmic rays. The purpose of this work was to compare detector performance in terms of their strip detective efficiency, count rate, and cluster size.

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Performance of silicon photomultipliers from different manufacturers at low temperature

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Abstract

Silicon photomultipliers (SiPMs) are one of the modern instruments for nuclear physics detectors. Due to their excellent parameters near room temperature, these devices the best candidate to be used in the neutrino experiments such as nEXO, NEXT and DUNA, where the SiPMs should operate at sufficiently low temperature. This paper presents the results obtained with SiPMs from different manufacturers. The ambient temperature was varied from room environments up to liquid nitrogen. The influence of temperature variation on key parameters of SiPMs such as photon detection efficiency, gain, dark count rates was studied.

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PULSE SHAPE ANALYZING SYSTEM FOR A GRIDDED IONIZATION CHAMBER

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A high-performance charged particle spectrometer was developed for investigation of reactions induced by fast neutrons. The charge particle detector is a twin-gridded ionization chamber and its structure can be found in Ref. [1]. In this article, we describe experimental methods for detecting alpha particles using a twin-gridded ionization chamber developed at FLNP JINR using the PXI system, which consists of chassis (NI PXI-1031 from NI, USA), the embedded controller (NI PXI-8820 from NI, USA) and one high-speed digitizer (Pixie-4 from XIA, USA). The Pixie-4 is a PCI/PXI 4-channel all-digital waveform acquisition and data card. It combines spectroscopy with waveform capture and on-line pulse shape analysis. Incoming signals are digitized by 14-bit 75 MSPS ADCs. Also as examples are some of our test measurements obtained on 6Li, 10B nuclei. Experiments were performed with a 239Pu-Be radioisotope neutron source.

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Module Development for the Phase-2 ATLAS ITk Pixel Upgrade

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For the high luminosity era of the Large Hadron Collider (HL-LHC) it is foreseen to replace the current inner tracker of the ATLAS experiment with a new, all-silicon detector to cope with the occurring increase in occupancy, bandwidth and radiation damage. It will consist of an inner pixel and outer strip detector aiming to provide tracking coverage up to $|\eta|=4$. The layout of the pixel detector is foreseen to have five layers of pixel silicon sensor modules in the central region and several ring-shaped layers in the forward region. This results in up to 14 m² of silicon depending on the selected layout.

Detector requirements in terms of radiation hardness and occupancy, as well as thermal performance depend strongly on the distance from the interaction region. Therefore, the innermost layer will feature 3D silicon sensors, due to their inherent radiation hardness and low power consumption, while the remaining layers will employ planar silicon sensors with thickness ranging from 100µm to 150µm. All hybrid detector modules will be read out by novel ASICs, implemented in 65nm CMOS technology and thinned to 150µm, which will be connected to the silicon sensors using bump bonding. With about 4 104 pixels per cm² the bump bond density is a much higher than in previous hybrid detectors.

With the recent availability of the first prototype readout chip, the RD53A, module development for the ITk Pixel Detector is entering a new phase. Numerous modules will be assembled to test the performance of bump bonding of objects of realistic area, very small

thickness and high bump bond density, as well as to finalize studies of the module performance with pixel pitches of 50x50µm² and 25x100µm² on the sensors. The stack-up of these hybrid pixel modules can be seen in Fig. 1. Flex circuits are glued on top of the modules for connection and routing of services which have to be qualified too. Moreover, tests of the new serial powering scheme for low voltage supply of the modules will be done as part of the prototyping program. The quality assurance criteria for the production of the final detector modules are verified, including mechanical properties like module flatness as well as electrical tests of the functionality of the modules and the bump bond quality.
We will present the latest results from the assembly and characterization of the prototype modules. Important qualification steps of the module design will be discussed.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 19

The new physical model to study the performance of avalanche photodiodes with single photoelectron detection.

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A new physical model of avalanche process with single photon detection capabilities is presented in this work. The new model describes development of avalanche process in time, taking into account the space charge resistance as well as the change of electric field in the avalanche region caused by internal discharge and external recharge currents. Results of simulations are compared with experimental data received with Geiger mode photodiodes from different suppliers. It was found that at fixed over-voltage the signal gain is reduced significantly depending on the space charge resistance and it reaches its maximum value (2 × Cp ×ΔUp) when resistance of space charge is zero. The relative value of the reduction in signal gain depends on the pixel capacitance and over-voltage. The timing performance of avalanche photodiodes dependence on over-voltage, capacitance of pixel, parasitic capacitance and the space charge resistance are discussed widely in this work

Tomography, chair: Christer Frojdh / 20

Development of CT ring artifact removal technology based on Fuzzy system and radial basis function neural

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Ring artifacts are common phenomena in computer tomography (CT), which can result in the degradation of CT images' diagnostic quality and therefore should be reduced or removed. In the post-processing domain, ring artifacts are transformed into line artifacts through coordinate transformation. Many methods are based on post-processing. However, the results are not obvious in the case of complicated artifacts.
In this study, we first detected the positions of artifacts by proposed specific morphological and enhancement processing. Then we proposed a new fuzzy radial basis function neural network (Fuzzy-RBFNN), as shown in Fig. 1. For an artifact pixel we used six adjacent normal pixels as the input of the neural network, subsequently get the repaired pixels. For training NN, we introduced the gravitational search algorithm (GSA) [1] to train the neural network system. We adopted signal-to-noise ratio (SNR) to evaluate.
Experiments demonstrated that the proposed method removes the artifacts more effectively compared with the other conventional methods [2]. In addition, we trained the system by the well-known error back propagation algorithm (EBPA) to evaluate the performance of GSA. The final experimental results also proved the superiority and effectiveness of GSA.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 21

X-ray Imaging of Metal Whiskers Using Large Area Photon Counting Detectors Timepix

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Metal Whiskering is a phenomenon occurring in electrical devices when whisker-like extrusions are forming from metal during the time, they look like small metal hairs or tendrils. This phenomenon was noticed in a vacuum tube for tin, and for other metals like zinc, cadmium and even

lead. Whiskers growing between metal solder pads causing short circuits.
Investigation of the metal whiskering occurring on small electric samples by the X-ray imaging and tomography utilizing large area Timepix detector will be presented within this work. Large area detector installed in the institute of experimental and Applied Physics consists of 25 Timepix chips with silicon sensor and 500µm thickness.
The detector is a useful tool for small samples like whiskers which have a diameter around 5 m and longitude in the range 10-1000 m, therefore spatial resolution around 1 m is required.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 23

Resolution Limits of a single crystal scintillator based X-ray Microradiography Camera

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Recently, high resolution micrography became of great interest. Very thin scintillator layers of about 5-20 micrometers are used to achieve spatial resolution below one micrometer in application for low energy X-ray micro-radiography. Such thin screens are mainly used in micro-CT and nano-CT systems with either micro-focus X-ray tubes or with synchrotron sources.
This work deals with a high resolution CCD camera together with different optical systems and different single crystal scintillators in application for low energy X-ray micro-radiography. The light distribution on the screen is transferred by an optical system to a high-resolution CCD or CMOS chip. A theoretical modeling and practical comparison of several set-ups has been done to investigate the system resolution limits. Thin screens used were prepared from different scintillators. The resolution is presented on test patterns.

SiPM, High -Z, chair: Roelof de Vries / 24

The Light-Trap: A novel concept for a large SiPM-based pixel

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Several applications in particle physics, high-energy astrophysics or medical imaging require the detection of nanosecond pulses, typically performed with photomultiplier tubes or silicon photomultipliers (SiPMs). SiPMs offer several benefits, such as compactness, low voltage operation and

potentially better detection efficiency and time resolution. Their limited physical area (they are rarely commercially available in sizes larger than 6×6 mm^2) remains however as the main limitation to produce large pixels for large detectors. We propose to solve this issue by building a Light-Trap[[1]], a low-cost pixel consisting on a SiPM attached to a PMMA disk doped with a wavelength shifter (WLS). Light in a given wavelength band is absorbed by the WLS, re-emitted isotropically and trapped inside the disk volume until it reaches the SiPM. Light outside the WLS absorbing band is rejected. As a result, the pixel collects photons over a much larger area than standard SiPMs, while being sensitive only in a desired wavelength range. The cost of building a large pixel is significantly reduced, at the expense of losing some efficiency. We introduce the Light-trap principles and present results from laboratory measurements performed with a proof-of-concept (PoC) pixel. The PoC pixel uses a 3×3 mm^2 SiPM collecting light only in the 300-400 nm band, covering an area ∼20 times larger than that of the same SiPM itself. Its measured trapping efficiency for 375 nm is ∼30\%, i. e., collects the same amount of light than 6 SiPMs like the one used to build the PoC pixel. We will also discuss results from Monte Carlo simulations and potential improvements that could significantly boost the trapping efficiency of the Light-Trap.

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Software, chair: Daniele Passeri / 25

Signal to Noise Ratio optimization for extended sources with a new kind of MURA masks

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Coded aperture imaging is a well known technique for localization of radioactive hot-spots. Its advantages are high detection efficiency and under certain configurations wide Field of View (FOV). We have used a simple assembly technique which results in coded masks with high transparency, low weight and which can be restructured easily. We present the study of the reduction of the intrinsic noise of these coded apertures, when they localize spatially extended γ-emitters. Specifically, the Modified-Uniformly-Redundant-Array (MURA) 1 coded apertures are structured by lead spheres arranged on a transparent medium such as acrylic glass. This configuration induces a systematic, element-wise, noise on the Point-Spread-Function (PSF) of the correlation matrix. In imaging of extended hot-spots with these apertures [2], a penumbra phenomenon occurs which reduces this intrinsic noise in the same way as a kernel filter does. Fast-Fourier-Transform (FFT) is used herein to analyze the effect of this phenomenon on the correlation matrix and to explain the dependence of its Signal-to-Noise Ratio (SNR) on the dimensions of the hot spot. The SNR maximization is achieved for certain combinations of geometrical characteristics of the source and of the coded aperture camera. Simulations have been used for the detailed study of the SNR as a function of the dimensions of the hot-spot, while experiments with two 99mTc cylindrical sources with 11mm and 24mm diameter, respectively and 1.5 MBq activity each, confirm the reduction of the intrinsic noise. The results define the way of optimization of the imaging setup for the detection of extended hot-spots. Such an optimization could be useful for example in the case of lymph nodes imaging in nuclear medicine. Finally, we propose a kernel filter, derived by the Auto-Correlation-Function (ACF) 1, to be applied on PSFs with high intrinsic noise, in order to eliminate it.

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Tomography, chair: Christer Frojdh / **26**

Detection of benign or malignant microcalcifications based on score using dual-energy imaging

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In breast cancer studies, to discriminate between malignant and benign lesions, computer-aided diagnosis (CAD) system has been used to diagnose breast cancer based on morphological characteristics. We propose a method to non-invasively distinguish malignant or benign microcalcifications using only mammographic image based on dual-energy method [1, 2]. In this study, a photon-counting spectral mammography system was simulated using Geant4 Application for Tomographic Emission (GATE) simulation tools. The dual-energy images were acquired using two energy bins. Microcalcifications were used as type I (calcium oxalate) and type II (calcium hydroxyapatite). For statistical analysis, the microcalcifications were classified as calcium hydroxyapatite or calcium oxalate based on a score calculation using the dual-energy images. The score values were calculated using the ratio values at high energy to low energy because there is less attenuation difference in the high energy region and a large attenuation difference in the low energy region. We confirmed that the contrast and noise were influenced because the classification method used in this study was based on the pixel values of the images. Therefore, we also calculated the score as the difference between the two types of microcalcifications using the dual-energy subtraction method [3]. Because of the improved contrast of microcalcifications, the classification performance was better in the dual-energy subtracted images. In addition, this study suggested the ability to automatically classify microcalcifications using segmentation methods and minimum and maximum threshold of score values. These results demonstrated the possibility of classifying microcalcifications based on spectral mammography to improve the diagnostic accuracy of breast lesions.

LHC / **27**

Study of noisy pixel appearance and thermal neutron fluxes with Timepix3 in ATLAS

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Abstract: Medipix (2010 - 2012) and Timepix (from 2013) pixel detector networks installed in ATLAS have proven valuable for the characterization of the radiation fields, determination of the induced radioactivity and dose rates at different places in ATLAS, as well as the measurement of luminosity 1[2]. In January 2018, four hybrid pixel detectors of Timepix3 technology (with 500 μm thick silicon layers, 256 x 256 pixels, 55 μm pixel pitch) arranged in 2-layer stacks were added to the ATLAS-TPX network [3]. One layer of the device closer to the interaction point (X = -3580 mm, Z = 970 mm, Z = 2830 mm) was equipped with neutron converters for detection of thermal (^{6}LiF) and fast neutrons (low density polyethylene) [3].
In this contribution, we present data analysis methods used for the noisy pixel identification and removal as a crucial first step of cleaning the data set for luminosity analysis and present a study of the thermal neutron fluxes measured with the Timepix3 device.
Data are taken in 3-hour long runs. Noisy pixel identification was done separately for each run. On average 0.1 % of pixels became corrupted within one run. After resetting the matrix configuration, pixels identified as noisy were fully recovered (soft errors). It is shown, how the noisy pixel appearance depends on delivered luminosity and how noisy pixel removal increases the precision and stability of the luminosity determination through counting individual particle tracks.
The thermal neutron fluxes were determined through the ^{6}Li(n,α)^{3}H-reaction (940 barns, detection efficiency ˜1 %). Measured thermal neutron fluxes are given as a function of luminosity (see the attached figure). The number of thermal neutrons created per unit luminosity was measured to be 1029.64 ± 0.14 cm^{-2} / nb^{-1}. Similar to the cluster rate, the measured thermal neutron fluxes can be used to determine the ATLAS luminosity. Since the thermal neutron signature allows for reliable separation of neutrons from gamma and x-ray interactions, luminosity measurements using thermal neutron detection are less affected by systematic effects such as the activation of surrounding material.

Figure: Scatter plot of the thermal neutron fluxes as a function of luminosity. Each point corresponds to a single ATLAS fill within the time period from April 27 to June 8, 2019.

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X-Ray, Timepix, chair Seppo Nenonen / 28

Detector response and performance of a 500 μm thick GaAs attached to Timepix3 in relativistic particle beams

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Abstract: Timepix3 1 detectors are hybrid pixel detectors developed within the Medipix3 collaboration. Their sensitive layer is divided into a square matrix of 256 x 256 pixel at a pixel pitch of 55 µm. They offer a data-driven readout scheme and can simultaneously measure the Time-of-Arrival (1.5625 ns binning) and the Time-over-Threshold in each pixel. Silicon is the most commonly used sensor material for typical Timepix particle tracking systems. Studies of Medipix and Timepix detectors with high-Z compound semiconductor materials (e.g. CdTe or GaAs) are mainly focusing on x- or γ-ray detection [2,3]. Despite disadvantages of the high-Z semiconductor materials compared to silicon (worse thermal stability, higher leakage currents, sensor inhomogeneities or charge carrier losses), particle tracking devices based on GaAs could profit from the higher electron mobility, the expected higher radiation tolerance and the higher stopping power.
In this contribution, we present a study of the performance of a Timepix3 assembly with a 500 µm thick chromium compensated GaAs sensor (ohmic contact) in particle beams at the Super-Proton-Synchrotron (SPS) at CERN.
In a first experiment, the device was irradiated at 60 degrees with 40 GeV/c pions. The acquired data were used to study the depth dependence of the drift time(s) and charge collection efficiencies (CCE) at bias voltages in the range from -25 V to -500 V (electrons were collected at the pixelated contact) (see the attached figure). A linear behavior of the drift time was found. At a bias of -25 V, drift times were below 22 ns, at -500 V drift times are below 4 ns. By comparing the drift time and CCE curves to theoretical expectations and taking the small pixel effect into account, an attempt is made to determine the charge carrier mobility μ_e and the mobility-lifetime product $\mu\tau_e$.
In a second experiment, a mixed radiation field was created by Pb beam (˜330 GeV/c) impact on target. The Timepix3 assembly was exposed to the mixed ion beam at different angles (0 – 75 degrees wrt the sensor normal). Detector responses were studied in the form of the cluster size distributions, the energy spectra and energetic and temporal projections of single particles. Significant features of the heavy ions signature are presented and discussed. Peaks in the energy spectra are fitted by a linear combination of Landau distributions and the capability of separating different ion species as a function of impact angle is evaluated.

Figure: Measured drift times and charge collection efficiencies as a function of the interaction depth. For the study a Timepix3 with a 500 µm thick GaAs:Cr sensor was irradiated with 40 GeV/c pions at an angle of 60 degrees.

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Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 29

Characteristics of Organic Photodetector with Conjugated Donor and Non-fullerene Acceptor

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In this study, an organic polymer-based photodetector with a conjugated polymer PBDB-T1) and a non-fullerene ITIC2) was investigated to improve the sensitivity and frequency response for the indirect X-ray detection. The PBDB-T has more alkyl-chains and quinoids, so it can show better carrier transport than P3HT3) (commonly used donor). The chosen ITIC instead of PC70BM4) (commonly used acceptor) has the advantage of low voltage loss because its HOMO and LUMO levels are well balanced with those levels of PBDB-T (Fig. 1a). The absorption spectra (Fig. 1b) of the PBDB-T:ITIC thin films showed higher absorbance than the P3HT:PC70BM film. Since the PBDB-T:ITIC absorption spectra tended to shift to the red visible region, two different scintillators, such as the CsI(Tl) with emission peak at 550 nm and the ZnSe(Te) with emission peak at 640 nm, were coupled with the photodetectors for measuring radiation parameters. The detector with the PBDB-T:ITIC = 1:1 blended film and ZnSe(Te) scintillator showed the highest sensitivity of 1.91 mA/Gy*cm2 (Fig. 1c). This is 205% increase of sensitivity over that of the common P3HT:PC70BM detector with the CsI(Tl) scintillator. In order to measure the frequency response, pulsed-light from a green LED with frequencies from 1 Hz to 100 kHz was applied to the photodetectors. The detector with the PBDB-T:ITIC = 1:1 film showed the cut-off frequency of 31.5 kHz, which was higher than that of the P3HT:PC70BM = 1:1 detector

Timepix,Micromegas, chair: Bernd Schmitt / 30

Micromegas detectors for muography: Applications and recent developments in detection systems and data analysis

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The use of muons produced in the atmosphere for the scanning of the internal structure of big objects is known as muon tomography or muography. Being a non-invasive technique, it has enlarge their possible applications in the last years mainly due to the performance achieved in particle detectors. Nowadays this technique is used in such a different fields as archaeology, volcanology, nuclear safety or civil engineering. In particular, CEA group possesses large experience in the operation of gaseous Micromegas detectors and has already successfully used this technique to perform muography measurements for these applications.

However, the variety of applications and the proposal of new ones leads to the conception of new detection systems as well as to the development of new analysis tools. Thus CEA group is currently working in the development of a new concept muon telescope. It is based in a compact TPC equipped with a 2D pixelated Micromegas detector with multiplexed readout. This detector will overcome some of the limitations of the instruments currently used as they limited acceptance keeping other features required for muography as stability, robustness or portability.

In parallel, a dedicated simulation and analysis framework based on Geant4 and ROOT has been implemented. It allows the performance of preliminary feasibility studies for each measurement as well as the data analysis and interpretation. It has been conceived in a versatile and modular mode to be used for any of the potential muography applications as well as for and any muon telescope used. One of its main features is its capability to manage the geometry of the studied objects importing them directly from 3D-CAD models, increasing the simulations accuracy.

In this presentation, main features of Micromegas-based telescopes used for tomography will be presented together with their main applications, paying special attention to the recently developed TPC concept. In addition, a brief explanation of the simulation framework and some of the obtained results will also be showed.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 31

Improvement of Sensitivity of Indirect-type Organic X-ray Detector Using Amorphous IGZO Interfacial Layer

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In this paper, we examined the role of amorphous indium-gallium-zinc-oxide (a-IGZO) interfacial layer between PBDB-T1):PC70BM2) active layer and LiF/Al cathode to improve the sensitivity of indirect-type organic X-ray detector. According to the energy band diagram described in Fig 1a, the a-IGZO layer can block hole transport and also enhance electron transport from the active layer. Using a RF magnetron sputter deposition method, a-IGZO of different thicknesses were grown on the active layer and then current density-voltage (J-V) characteristics (Fig 1b) of fabricated detectors without a CsI(Tl) scintillator were measured under illumination of an AM 1.5 G filtered Xe lamp close to the solar spectrum. The highest power conversion efficiency (PCE) was 7.4% obtained from the detector with the a-IGZO layer grown for 6 min. Compared with the detector without the a-IGZO layer, the PCE value increased by 37%. When the a-IGZO was grown on the active layer, the transmittance was noticeably increased in the range of 450 nm and 650 nm (Fig 1c). At 560 nm, the emission peak of the CsI (Tl) scintillator, the transmittance increased by 27.9% compared to the absence of the a-IGZO layer. Carrier mobility of the detector was calculated following Mott-Curney space charge-limited current model (Fig 1d). Due to improved conductivity and reduced interfacial traps, the detector with the a-IGZO layer grown for 6 min showed the highest mobility of 5.44×10-4 cm2/V•s. The detector with the same a-IGZO layer showed the highest sensitivity of 2.11 mA/Gy•cm2, which was 22% higher sensitivity than the detector without the a-IGZO layer.

Timepix,Micromegas, chair: Bernd Schmitt / 32

A Micromegas neutron detector as Beam Loss Monitor for the ESS Linac

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The high beam intensity of linear accelerators such as the ESS linac implies that even a loss of a small fraction of the beam could result in significant irradiation and destruction of accelerator equipment. The Beam Loss Monitor (BLM) systems must be capable of detecting the smallest possible fraction of beam loss, approaching 0.01 W/m loss, preventing activation of machine components and allowing hands-on maintenance. The monitoring of a loss is usually done by detecting the secondary radiation that is produced by the impact of the lost particles on the accelerator materials. However, especially at the first stages of the accelerators (proton energies <100 MeV), typical BLMs based on charged particle detection (i.e. Ionization Chambers) are not appropriate because the expected particle fields will be dominated by neutrons and photons. Another issue is the photon background due to the RF cavities, which is mainly due to field emission from the electrons from the cavity walls, resulting in bremsstrahlung photons.

The idea for the new BLM system (ESS-nBLM) is to use Micromegas detectors specially designed to be sensitive to fast neutrons and insensitive to low energy photons (X and gammas). In addition, the detectors will be insensitive to thermal neutrons, since part of them will not be directly correlated to beam losses. The appropriate configuration of the Micromegas operating conditions will allow excellent timing, intrinsic photon background suppression and individual neutron counting, extending thus the dynamic range to very low particle fluxes. The performance of several prototypes have been studied over the last year in several irradiation facilities, while one detector was tested with real beam losses at CERN Linac4. The concept of the nBLM system, as well as the performance of the detectors, will be presented here.

Dosimeters, Neutrons, chair: Ulrich Parzefall / 33

FIVE TRANSVERSAL BEAM PROFILE MONITORS FOR THE ESS COLD LINAC

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The European Spallation Source, presently under construction at Lund (Sweden), will consist of a 537 m long linear proton accelerator delivering a 2 GeV proton beam with a 5MW power to a tungsten target, equipped with a highly optimised neutron moderator capable of providing a bi-spectral (thermal and cold) neutron beam to 42 beam ports, 22 of which are followed by a flight path leading to far away measuring stations.
A perfect knowledge of the proton beam is critical to maximize the number of protons on target and minimize beam losses. Transversal beam profile monitors are therefore essential for a good operation of the facility.

Due to the high power, all beam profilers to be used at nominal operating conditions will be of non-interceptive type. In the frame of the in-kind contribution agreement signed with ESS, CEA is going to deliver to the European Spallation Source five Non-invasive Profile Monitors (NPMs) to be installed in the Cold Linac section: one in the Spoke section, 3 in the Medium β section and one in the High β section. A single NPM has two units supporting profile measurements in both horizontal and vertical axis. Each unit is based on the detection of ions generated by the interaction of the proton beam with the vacuum residual gas and is called Ionisation Profile Monitor (IPM). It is composed by a cubic cell of 10 cm side and a read-out. A uniform electric field in one of the directions orthogonal to the beam propagation vector is set in each IPM to drive the ionisation charges towards the read-out. These transversal beam profile monitors will cover proton energies ranging between 90 MeV and 600 MeV and are conceived to deliver one profile/pulse at a residual gas pressure of 10ˆ-9 mbar and with an uncertainty on the beam width of less than 10% of its dimension.

The high density of the proton bunches, typically 10ˆ9 proton in a few mmˆ3 may lead to space charge effect distorting the profile measurements. Studies to contain the space charge effects have been performed. Two different read-outs (current reading from metallic strips and optical) were proposed and tested in two measurement campaigns at the IPHI accelerator at CEA Saclay. After careful analysis, the final choice fell on the read-out composed by a micro channel plate equipped with a phosphorous screen and followed by a camera. The detectors are now in construction at CEA.

A summary of all main steps of the project, with special focus on the space charge simulations and the experimental campaigns, will be presented.

Timepix,Micromegas, chair: Bernd Schmitt / 35

Characterisation of pixelated CdZnTe sensors using Maxipix

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The European Synchrotron Radiation Facility (ESRF) is being subjected to the second phase of its upgrade, the so-called EBS (Extremely Brilliant Source) upgrade. The new storage ring will be able to deliver X-ray beams with up a factor 100 increase in brilliance. In order to exploit these extended source capabilities ESRF has launched an ambitious instrumentation programme, focusing on high performance detector systems.

Within this effort, we develop hybrid pixel detectors based on high-Z sensors for photon-counting in order to overcome limitations set to the detection efficiency by existing silicon sensors in the 20-100 keV energy range. In the past, pixelated sensors made of Cadmium Telluride (CdTe) and chromium-compensated Gallium Arsenide (GaAs:Cr) have been used successfully, as sensitive medium. Despite the improvement on the crystal quality over the years, limitations such as time-dependent polarisation effects in CdTe and spatial distortions of the effective pixel shape in GaAs:Cr are impelling the search for alternatives such as Cadmium Zinc Telluride (CdZnTe).

At ESRF we have developed several test modules implementing high-flux CdZnTe pixel sensors provided by Redlen. Each module, consisting of a CdZnTe sensor bonded to a single Timepix chip, is coupled to the MAXIPIX readout system. I will report on results obtained from tests using high energy X-ray sources and monochromatic synchrotron beams.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 36

Design of a novel centroid finder in the MAPS for heavy-ion experiments

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The heavy-ion experiments at the Heavy Ion Research Facility in Lanzhou (HIRFL) and the future High Intensity Heavy-Ion Accelerator Facility (HIAF) in China drives the development of high-performance particle imaging detectors. Due to the high spatial resolution, fast timing response and low noise level, a Monolithic Active Pixel Sensor (MAPS) is being developed with 130nm CMOS process for the prototype detectors. To reduce the data volume from the MAPS based detectors, a centroid finder that is able to calculate the geometric centroid of the region of the energy deposition in a quick manner has been designed. The centroid calculation is realized by distance screening among the coordinates of the pixels in the fired region. With the fast-stop scheme in the algorithm, the centroid can be figured out without screening the whole region, which reduces the iterations in the calculation process. Performance study with the data from heavy-ion experiments in HIRFL proves that the centroid finder is able to accurately find the centroid of the fired region. In addition, it reduces the data volume from the MAPS by approximately one order of magnitude. This paper will discuss the design, implementation and performance study of the centroid finder.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 37

Effects of energy weighted dual-energy subtraction images with indirect photon-counting detector in mammography

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Abstract
Contrast-enhanced dual-energy mammography (CEDM) is a promising approach for early breast cancer detection. In CEDM, two images could be acquired by using both double exposure with energy integration system or single exposure with energy resolved photon-counting (PC) system 1. The PC systems are commonly consists of direct conversion X-ray sensors connected to application specific integrated circuits (ASICs). However, the direct conversion PC detector has some limitations such as charge-sharing loss and count rate saturation. In this work, we designed an indirect PC system to overcome these limitations. Using a Gd3Al2Ga3O12 (GAGG) crystal array to configure the scintillation pixels connected to silicon photomultipliers (SiPM), breast phantom images are obtained at single exposure scan. The pixelated scintillator array, X-ray source, and the breast phantom were simulated through Geant4 Application for Tomographic Emission (GATE) toolkit. The dimension of the GAGG scintillator is 100.0 mm x 100.0 mm x 2.0 mm, and the SiPM array has the dimensions of 100.0 mm x 100.0 mm. The 200 x 200 element GAGG array is used and the pixel size is 0.5 mm x 0.5 mm x 2.0 mm. The shape of the breast phantom is a semicylinder and it has a diameter of 80 mm, a radius of 40 mm, and a thickness of 40 mm. The breast phantom includes both the calcium disk and the iodine disk. The X-ray spectrum was generated by the SRS-78 code for the specifications of a rhodium (Rh) target, 30 kV tube voltages, and a Rh filter and was then simulated using GATE code. The performance of the PC system is tested by conventional energy subtraction and energy-weighting based energy subtraction. Figure 1 shows the dual-energy subtraction images for conventional energy subtraction, calcium weighted image, and iodine weighted image. Figure 2 is plotted for conventional energy subtraction, calcium weighted image, and iodine weighted image. The contrast-to-noise ratio (CNR) of the energy-weighted energy subtraction images was 2.84 and 2.39. There was a CNR improvement of 1.42% and 18.91% in the energy subtraction images based on energy-weighting.

Reference
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Tomography, chair: Christer Frojdh / 40

Investigation of model and human observer performance of a prototype digital breast tomosynthesis

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Quantitative imaging performance analysis has recently been the focus in medical imaging, which provides objective information and it could aid a patient diagnosis by giving optimized system parameters for various imaging tasks 1. In recent years, task-driven approach has been adopted in which NEQ is combined with the imaging task and model observers to form the detectability index (d') [2]. In this study, we investigated mass detectability performance with different angular range settings between human and model observers. The purpose of this study is to validate our model observer performance on the newly developed prototype digital breast tomosynthesis (DBT).
The images of mass with different sizes of 3.9, 4.7 and 6.3 mm in the target slab of CIRS breast phantom were acquired with four different total angular range of ±10.5°, ±14°, ±21°, ±24.5°, with equal 15 projection views. Each DBT acquisition was repeated as twenty times in a same condition in order to yield the local ensemble of noise power spectrum (NPS). The human and the model observers were four-alternative forced choice (4AFC) and non-prewhitening with an eye filter (NPWE) in Fourier domain. For NPWE model observer, the ideal local modulation transfer function (MTF) was estimated by injecting a point signal in a simulation of the system. All human observers had a training session for each angular range dataset prior to 4AFC test. A percentage of correct responses (PC) was measured at the end of each human observer test [3].
As results, the local MTFs were same for each angular ranges, whereas the local NPS provided reasonable predication of increased noise with the increase of angular range distribution. The performance of the theoretical model observer values resulted in similar trend to the human observers' PC results. The d' results with different sizes of masses decreased with increasing angular distribution from 0.55 to 0.18, 1.01 to 0.45 and 1.51 to 0.74 with mass sizes of 3.9, 4.7 and 6.3 mm, respectively. In the human observer study, the average PC from seven observers were 0.87, ranging PC values from 0.71 to 0.92. The resulted patterns of PC decreased with increasing the angular ranges from ±10.5° to ±24.5° with different size of tasks.
Our results showed that the NPWE model could reasonably predict mass detectability from small to large sizes for different angular ranges. The correlation between theoretical and measured performance is necessary for better description of task-based model observer performance for future study.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 41

Development of a pixel readout ASIC for CZT detectors for spectral X-ray photon-counting imaging applications

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This paper presents the development of a prototype pixel readout ASIC for CZT detectors fabricated in a 180 nm CMOS process. It consists of a 32×32 array of pixels in 100 um pitch and the EOC (end-of column) circuit for control and data readout. Each pixel integrates a charge sensitive preamplifier, a CR-RC shaper, two discriminators, two 12-bit counters and registers, allowing us to acquire and readout images simultaneously. A local 6-bit register has also been integrated for each pixel for calibration enable and threshold fine tuning, which can be programmed through a SPI slow control interface.
A dedicated chip evaluation system was developed and the initial test results showed the chip worked well. The power consumption was measured to be 38.9uW per pixel, which could be adjusted by a master bias unit. The gain of the analog front-end was approximately 79mV/fC and the ENC was less than 100 electrons for different shaping times and the input capacitance of about 100 fF. The results were in good agreement with our design specifications. More detailed design and test results will be discussed in this paper.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 42

Development and Evaluation of Large area Flexible Dosimeter for

Surface Dose Measurement in Radiotherapy

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Radiotherapy has the possibility of adverse reactions due to overlapping dose at skin surface binding parts. Exposure of the skin to 2 Gy or higher doses can cause adverse reactions such as erythema, desquamation, and necrosis. To prevent them, the skin dose is predicted through a treatment planning system, but its accuracy is only 50 ± 25%. Thus, we need dosimeters that can accurately measure the skin dose from computed tomography images and calculated treatment plans in clinical practice. The existing skin dosimeters such as glass rod dosimeter and optically stimulated luminescent dosimeter check the point dose. However, analog-type integrated solid state dosimeters are difficult to analyze the dose of body surface and have low positioning accuracy because the attachment site is decided with naked eye.ˆ1 Meanwhile, to overcome morphological limitations, materials based on flexible polymer-based thin film technology have been actively researched.ˆ[2] On the other hands, a photoconductor PbI_2 may show a mechanical softness as the silicon rubber binder is bound. Such PbI_2 represents the high atomic number and has a property of low leakage current when produced so that studies have been actively performed as a detection substance to measure high-energy X-rays.ˆ[3] As a basic study on a patch-type skin dosimeter, this study produced a PbI_2 dosimeter based on silicon rubber for the human skin using the particle in binder (PIB) method. To evaluate the performance of this dosimeter, reproducibility and linearity were evaluated by 1, 10, 100, 1000 and 10000 bending counts at 6 MV and 15 MV. The reproducibility was examined by irradiating a 1 Gy dose at the dose rate of 4 Gy/min 10 times repeatedly. The linearity was tested by irradiating 0.01 to 10 Gy doses at the dose rate of 4 Gy/min. Consequently, when the relative standard deviation(R-SD) as the evaluation criterion for reproducibility was set to 1.5% or lower, the S-RD of the 1000 bending count was 1.74% at 6 MV and the S-RD of the 10000 bending count at 15 MV was 2.2%. Thus, these results were higher than the criterion. When the coefficient of determination (R-Sq) as the evaluation criterion for linearity was set at 0.9900 or higher, the R-Sq of the 10000 bending count was 0.9730 at 6 MV and 0.9812 at 15 MV. Thus, these results were lower than the criterion. When the bending count increased to more than 10000, the performance showed fine variations. This study introduces a new type of flexible functional material and the problem of performance variations can be improved through further research using various electrodes.

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Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 44

A numerical approach to estimate the absorbed dose distribution in cone-beam computed tomography

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Dedicated dental cone-beam computed tomography (CBCT) examinations are being greatly increased for not only therapeutic but also cosmetic purposes. While, therefore, patient-specific dose management will be a great concern, the average dose measurement with a cylindrical phantom is the only method for the dose estimation in CT. However this standard CT dose index method is aimed at quality control of the CT scanners and is not suitable for patient-specific dose estimations 1. Other alternative to estimate patient doses is the Monte Carlo method, but it requires extremely high computational cost, although it provides accurate estimates.
In this study, we develop a numerical approach to estimate the patient-specific dose distributions in the CBCT. The algorithm is fundamentally based on the ray-tracing technique and the dose distributions are estimated in a two-step process: the absorbed dose due to the primary photons first and then that due to the scattered photons, as demonstrated in Fig. 1. The validation of the algorithm is performed by the experimental measurements. The detailed description of the algorithm will be given, including the effects of parameters used for calculations, such as the number of projections, the number of spectral bins, the number of voxels, and the size of scattering kernel, on the performance. The parameter optimization is crucial for the acceleration of the proposed method.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 45

Soft-tissue radiography using multi-scale convolutional neural networks

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The conventional chest x-ray radiography suffers from a less conspicuity of soft tissue lesions (e.g. lung nodules) because of overlapping bone tissues. Digital tomosynthesis (DTS) or dual-energy imaging (DEI) may enhance the soft-tissue conspicuity by discriminating depth information or suppressing the bone tissues, respectively. However, DTS requires additional equipment and DEI would be vulnerable to the motion artifact. Single-shot DEI using a multilayer detector may be free from the motion artifact, but it is known to be low contrast and high noise because of less energy separation 1.
Neural networks can be an alternative to the DEI [2]. We have previously shown the possibility of soft-tissue-enhanced radiography by using a shallow neural network [3], as shown in Fig.1. In this study, we extend the previous work to use a convolutional neural network (CNN) and expect better performance. The CNN consists of several convolution layers, pooling layers, and unpooling layers. The novelty of the network is that it is designed to be able to train multiple images with different spatial scales by assigning them into different layer channels. For the improvement of the network performance, the layout and hyper-parameters are being optimized. The network performance will be quantitatively addressed in comparison with DEI.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 46

X-ray interaction characteristic functions in semiconductor detectors

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The Compton scattering (CS) and the photoelectric effect (PE) accompanying fluorescence (FL) in semiconductor detectors can cause confused information about interaction locations. This implies signal spreading and increased correlation noise in resultant images. Escapes and reabsorptions of those secondary photons can further increase image noise. When the detector is operated in a photon-counting mode, those effects can also degrade energy resolution.
Using the Monte Carlo technique, we investigate x-ray interaction-induced signal spreading in cadmium telluride, which is typical sensor material used for photo-counting detectors, for various imaging applications such as mammography, radiography, and computed tomography. History of a single photon can be diverse: for example, PE with the production of FL and termination of FL by PE; remote PE plus FL interaction of a scattered photon and termination of FL by PE, etc. Novelty of this study can be found that we distinguish single-photon histories and determine their corresponding signal spreading characteristic functions, as shown in Fig. 1. We discuss energy-dependent characteristic functions for a wide range of energy. We expect this study will be helpful to the design of photon-counting detectors.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 47

Zooming radiography with less artifacts using convolutional neural networks

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In non-destructive x-ray inspection of a printed circuit board (PCB), the field of view (FOV) is usually small because of the application of high magnification into radiographs, which can help find micro-sized defects in ball-grid arrays or wire bonding parts. Without loss of FOV digital zooming can be applied, but which results in check-board artifacts at some extents of zooming level. Digital zooming with an interpolation may avoid the artifact but image sharpness will be degraded.
We develop a zooming filter or a super-resolution filter using a deep convolutional neural network (CNN). The network consists of several convolution layers, deconvolution layers, and element-wise summation layers. For training the network, the input images are obtained by down-sampling x-ray PCB images while the label images are obtained by applying the Gaussian de-blur kernel to the original images. From the total of 52 images, about 30k patches are extracted for training and validation, and separate 8 PCB images are used to test the network. The preliminary results are shown in Fig. 1. Although the network output image is blurrier than the label image, it is almost free from the check-board artifact and outperforms the bi-cubic interpolation method. We are optimizing the network for various hyper parameters, such as the number of layers and channels in each layer. With the optimized network, the performance will be investigated more quantitatively.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 48

High-resolution industrial radiography using convolutional neural networks

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For the quality control of electronic products with high-density electronic packaging and corresponding multilayer printed circuit boards, x-ray inspection is not optional anymore. A combination of micro-focus x-ray source and fine-pixel high-resolution imaging detector is typical in industrial x-ray inspection systems for detecting micro-sized defects. This combination can further enhance image resolution by applying magnification during imaging while sacrificing the size of field of view to be inspected. The maximum magnification factor is however limited by the focal-spot size and the resolving power of the detector because of the well-known penumbra effect.
For a high-resolution radiography, we develop a de-blur filter using a convolutional neural network (CNN). We adopt the super-resolution CNN 1 and modify it for our purpose. For training the network, we use blurred images using the bi-cubic interpolation as the input images while the original images as the label images. Figure 1 shows the preliminary results, and the performance of the network is promising. Detailed description of the network design and its optimization will be given including the quantitative performance of the network.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 49

Task-based detectability-combined cascaded-systems model for the design of sandwich detectors for single-shot dual-energy imaging

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Single-shot dual-energy imaging (DEI) using a sandwich-like multilayer detector is promising because it is immune to motion artifacts and it can relatively emphasize high-frequency contents 1. Since the sandwich detector uses the beam-hardening difference between two detector layers for energy separation, the imaging performance is largely dependent on the detector design (i.e. scintillators and interlayer filter) for given imaging tasks. In addition, the DE reconstruction parameter (i.e. tissue-cancellation factor) and imaging technique (i.e. energy) should be determined as a function of imaging task. We previously introduced a cascaded-systems model for the design of sandwich detectors [2]. However, the model is limited to the detector design in terms of signal-and-noise performance but not the imaging task.
We extend the previous model to incorporate the detectability functioning for several imaging tasks. The model also includes simple observer models such as prewhitening and non-prewhitening matched filters, including human eye filter and internal noise. As a result, the model can be used to optimize the sandwich detector designs, including the DE reconstruction parameter and imaging technique, with respect to simple imaging tasks. Figure 1 shows an example result for the optimization procedure of DE reconstruction parameter and imaging technique. We describe the developed model in detail and present the optimization results of sandwich detector designs appropriate to different imaging applications.

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Simulation study on SOI based electron tracking Compton camera using deep learning method

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SOI(Silicon On Insulator) based pixel detectors are promising as an scatterer in Compton imaging because of its thick sensitive area(˜500 μm) and small pixel size up to less than 10 μm. SOI based electron tracking Compton camera are fabricated and tested in the previous study1[2]. Electron tracking could improve the signal to noise ratio in the reconstructed image.One of the issues in electron tracking Compton camera is the complexity in estimation of ejected direction of Compton recoil electrons. In this study the capability of direction estimation using deep learning method are simulated and validated with Geant4 Monte Carlo simulation for different pixel sizes of 10 μm and 30 μm. The thick silicon detector up to 80 mm is assumed and irradiated by the source of Cs-137 with the energy of 662 keV. The Compton image is reconstructed with and without electron tracking information.The initial direction angles of alpha along the detection surface and beta with the detection surface are estimated by this method. The alpha and beta are divided into 8 classes and 80000 data and 40000 data are used for teaching and testing. The accuracies with the pixel size of 10 μm and 30μm are 61% and 47% for alpha angles and 48% and 49% for beta angles. The calculated FWHM of SPD (Scatter Plane Deviation) is approximately 68 degree in 10 μm by 10μm pixel and 81.2 degree for 30μm by 30μm and 10μm pixel detector show a slightly better resolution of SPD. The SNR of reconstructed image with and without electron tracking estimation is 3.99 and 4.83 and electron tracking shows a better SNR in the reconstructed image. The estimation method could be used for fast determination of ejected angle of Compton electron in the Compton imaging system.

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Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 51

Response of HR-GaAs:Cr sensors to subnanosecond γ- and β-ray pulses

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Currently, semiconductors with high atomic number Z arouse strong interest in construction of sensors with X-ray spectrum. The most prospective materials are presented by elements from the group AIIIBV. Gallium arsenide compensated with chromium (HR-GaAs:Cr) is one of these materials and exhibits unique characteristics. Sensors based on HR-GaAs:Cr demonstrate high efficiency. The

response of HR-GaAs:Cr sensors to subnanosecond γ - and β - ray pulses of 25÷45 keV from accelerator of runaway electrons are described in this research. The samples have symmetric structure metal-semiconductor-metal. The active area of the samples was 6.25÷9 mm2 and the thickness of sensitive layer was 150÷500 μm. Experimental characteristics of pulses were compared with theoretical estimations. An optimal thickness of sensitive layer of HR-GaAs:Cr sensors was determined. This helps to obtain the highest possible value of speed-of-response ≤ 1ns.
The work was financially supported with grants of RSF # 18-44-06001 (TSU, Russia) and HRSF-0004 (DESY, Germany).

LHC / **52**

The CMS Muon System: performance during the LHC Run-2

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A highly performing muon system has been fundamental to achieve many of the physics results obtained by CMS during the LHC Run-2. The CMS muon spectrometer presently consists of three detector technologies covering different regions of pseudorapidity. Drift Tube chambers (DT) equip the CMS muon system barrel, whereas Cathode Strip Chambers (CSC) are installed the CMS end-caps; both are used for offline tracking and provide trigger capabilities. In addition, Resistive Plate Chambers (RPC) complement DT and CSC in both barrel and end-caps, and are mostly used in the trigger. Finally, at different stages of the CMS upgrade programme, the end-caps of the muon spectrometer will be equipped with multiple layers Gas Electron Multiplier (GEM) chambers. A slice test consisting of 10 GEM chambers was successfully operated in 2018, in parallel to the rest of the muon system, to gain experience in view of the installation of the first complete layer of GEM, planned to happen during the second LHC long shutdown (LS2). In this report, the performance of the different detectors comprising the CMS muon system, evaluated using data collected at a centre-of-mass energy of 13 TeV during the LHC Run2, will be presented, together with the one of the muon trigger. The experience from the integration and commissioning of the GEM slice tests will also be discussed, and the status and plans toward the installation of the first complete layer of GEM detector, happening over LS2, will be highlighted.

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Background in the CMS muon detectors: simulation and measure with pp collision data

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The CMS muon system is built of different detector technologies: Drift Tube chambers (DT) and Cathode Strip Chambers (CSC) serve as tracking and triggering detectors respectively in the barrel and the end-caps of the spectrometer, whereas Resistive Plate Chambers (RPC) complement DT and CSC and are mostly used in the trigger. In addition, multiple layers of Gas Electron Multiplier (GEM) chambers are being installed in the muon system end-caps at different stages of the CMS upgrade programme. A measure of the background hit rates and currents drained by the different muon detectors during the LHC Run-2 is of prime importance for an assessment of the longevity of the chambers and their on-board electronics, which are critical for the projection of the expected performance of the system at HL-LHC. Moreover, an accurate modelling of the backgrounds using simulations is also critical. In fact, an estimation of the change in backgrounds as a consequence of the evolution of the CMS detector geometry expected for the Phase-2 upgrade, can only be performed

rely on Montecarlo-based predictions. The state of the art of the understanding of the backgrounds measured with data collected during the LHC Run-2, as well as at CERN high-intensity gamma irradiation facility, (GIF++), will be discussed. Additionally, the work made to improve the accuracy of the background modelling in Fluka and GEANT4 simulations will be also presented.

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Study of the effects of radiation on the CMS Drift Tubes Muon Detector for the HL-LHC

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The CMS drift tubes (DT) muon detector, built for standing up the LHC expected integrated and instantaneous luminosities, will be used also in the High Luminosity LHC (HL-LHC) at a 5 times larger instantaneous luminosity and, consequently, much higher levels of radiation, reaching about 10 times the LHC integrated luminosity. Initial irradiation tests of a spare DT chamber at the CERN gamma irradiation facility (GIF++), at large (˜O(100)) acceleration factor, showed aging effects resulting in a degradation of the DT cell performance 1; however, full CMS simulations have shown almost no impact in the muon reconstruction efficiency over the full barrel acceptance and for the full integrated luminosity. A second spare DT chamber was moved inside the GIF++ bunker in October 2017. The chamber was being irradiated at lower acceleration factors, and only 2 out of the 12 layers of the chamber are switched at working voltage when the radioactive source is active, being the other layers in standby. In this way the other non-aged layers are used as reference and as a precise and unbiased telescope of muon tracks for the efficiency computation of the aged layers of the chamber, when set at working voltage for measurements. An integrated dose equivalent to two times the expected integrated luminosity of the HL-LHC run has been absorbed by this second spare DT chamber and the final impact on the muon reconstruction efficiency is under study. Direct inspection of some extracted aged anode wires presented a melted resistive deposition of materials. Investigation on the outgassing of cell materials and of the gas components used at the GIF++ are underway. Strategies to mitigate the aging effects are also being developed. From the long irradiation measurements of the second spare DT chamber, the effects of radiation in the performance of the DTs expected during the HL-LHC run will be presented.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 55

Design of partially pixelated scintillators for high-resolution imaging with less aliasing effect

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Direct- and indirect-conversion detectors, which use a photoconductor and a scintillator, respectively, for detection of x-ray photons, compete to each other in diverse x-ray imaging fields. The spatial-resolution performance of the direct-conversion detector is generally known to be superior to that of the indirect-conversion detector. Structurization of the scintillator into pixel geometry, which is also matched to the underlying readout pixel array, may revolutionize the concept of indirect-conversion detectors because it may result in the pixel deign-limited spatial resolution as well as the high detection efficiency using high-Z material 1. This pixel-structured scintillator can be realized by packing scintillation material into a pixel-structured well-like grid array. However,

it is very important to notify that the grid array to the x-ray incidence plays a role as the sampling process in signal formation, and it can significantly reduce the signal level over the whole spatial frequency 1.
To avoid or reduce the x-ray sampling loss in signal, we suggest a partially pixelated scintillator design. In other words, we suggest an additional continuous scintillation layer over the pixel-structured scintillator. Although the spatial resolution of this design would be inferior to that of the complete pixel-structured design, the x-ray sensitivity will be higher. We investigate imaging performance of pixel-structured scintillators using Monte Carlo x-ray and optical photon simulations, as shown in Fig. 1. The performance includes x-ray sensitivity, spatial spreading of signal, and aliasing artifact. We determine the optimal design of pixel-structured scintillators for specific x-ray imaging applications or suggest a guideline for design optimization.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 56

Improvement of a Spectrum-to-Dose Conversion Function for Electronic Personal Dosimeters

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The electronic personal dosimeter (EPD) based on a 3×3 mm2 PIN diode coupled to a 3×3×3 mm3 CsI(Tl) scintillator was designed for measuring an ambient dose equivalent (**H*(10)**). The designed EPD was capable of measuring **H*(10)** within the energy range of 40 keV to 2 MeV from the gamma spectroscopy. However, since the inorganic scintillator differs from human tissue, the energy response to 137Cs has a large error, when applying the count-to-dose conversion method which is the conventional method used in a GM counter or ionization chamber 1. Therefore, it is necessary to apply an appropriate dose conversion method to correct this problem.
The G(E) function is a common method for spectra-to-dose conversion that has been developed and published [2]. It is necessary to find the A(K) parameters in the G(E) function. In general, A(K) parameters are obtained by the least-square method (LSM) using the spectrum data and dose data from Monte Carlo simulation or radio-isotope sources. In this manuscript, we apply a gradient-descent method (GDM) and an adaptive moment estimation (ADAM) [3], which are widely used in neural networks, to accurately estimate A(K) in G(E) function. The gamma spectrum data and **H*(10)** data that correspond to 5000 mono-energies from 40 keV to 2000 keV with the random number of particle histories randomly were acquired by Monte Carlo simulation using MCNP6. The newly G(E) functions were found and these conversion methods were verified by using 241Am, 57Co, 137Cs, 22Na, 54Mn, and 60Co radioisotopes.
The relative difference of **H*(10)** from single radioisotopes were in the range of ±16.11%, 12.6% and 9.92% in LSM, GDM, and ADAM, respectively. Furthermore, the energy response to 137Cs was laid in between the values 0.86 and 1, between 0.87 and 1.02, and between 0.9 and 1.03 in LSM, GDM, and ADAM, respectively. Thus, this clearly demonstrates that the obtained G(E) functions can correct the energy response of the designed EPD very well in comparison to the conventional counting method. In addition, it can be confirmed that **H*(10)** is estimated more accurately than the LSM and GDM when the ADAM is used.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 57

Scintillation read out with MAPD array for gamma spectrometer

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Abstract.
Nowdays, silicon photomultipliers are widely used as scintillation light readout in many scientific and commercial applications which one of interesting field is gamma spectroscopy. There are various types of SiPMs offered by different vendors. Among these SiPMs, a micropixel avalanche photodiode (MAPD) characterizes its high photon detection efficiency (PDE). It is known that photon detection efficiency of MAPD decreases significantly with increasing pixel density (PD). However, gamma spectrometers require maximum PD/PDE relation. In this study, we present scintillation light detection performance of MAPD with the best PD/PDE, which were developed for gamma spectrometers. Total area of the 16-channel MAPD array was 12×12 mm2. The MAPD array was used as a light readout device with CaF2(Eu), BGO, LYSO, LaBr3, and YSO(Ce) scintillators. The following measurements were carried out in the experiment: measurements of the breakdown voltage for each channel of the MAPD array, finding the optimal operating voltage, determination of the linearity range of MAPD response for each of the used crystals, and calculation of the energy resolution for 661.6 keV γ-rays from 137Cs. Single MAPD with area 3*3 mm2 was also studied using the scintillators coupled a light guide and with tapered head. The results of the energy resolution and linearity obtained with the MAPD array coupled to scintillators were compared to those obtained for the same scintillators with single MAPD.

X-Ray, Timepix, chair Seppo Nenonen / 58

Boosting direct X-ray detection in organic thin films by small molecules tailoring

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The attention on the application of organic electronics for the detection of ionizing radiation is rapidly growing among the international scientific community, due to the great potential of the organic technology to envisage the need of large-area conformable sensor flat panels.
In recent years, our group reported about the employment of solution-grown organic devices as reliable direct X-ray detectors, operating at room temperature 1, opening the way to the development

of a new class of flexible organic direct X-ray detectors based on TIPS-pentacene thin films, with sensitivity values up to hundreds of nC/Gy at ultra-low bias of 0.2 V [2]. However, high-energy photon absorption is challenging as organic materials are constituted of atoms with low atomic numbers.
The blending into the organic matrix of high-Z nanoparticles, carbon nanotubes and inorganic micrometer-sized scintillating particles has been explored as a possible solution. However, although improvement in the detecting performance has been shown, for all of the above solutions, the presence of even small fractions of the "dopant" (i.e. nanoparticles, carbon nanotubes or scintillating particles) strongly degrade the electrical performance and the stability of the organic film. Moreover, the employment of thick films or bulky single crystals to increase the absorption, results in an increase of the operating voltage and limits the bendability of the device, thus sacrificing the potential advantages.
Here it is reported how, by synthesizing new solution-processable organic molecules derived from 6,13-bis(triisopropylsilylethynyl)pentacene (TIPS-pentacene) and 2,8-Difluoro-5,11-bis(triethylsilylethynyl)anthradith (diF-TES-ADT), with Ge-substitution in place of the Si atoms to increase the material atomic number, it is possible to boost the X-ray detection performance of organic thin films on flexible plastic substrates [3]. TIPGe-pentacene based flexible OTFTs show high electrical performance with higher mobility (0.4 cm2 V-1 s-1) and enhanced X-ray sensitivity, up to 9.0 x 105 μC Gy-1 cm-3, with respect to TIPS-pentacene based detectors. Moreover, similar results are obtained for diF-TEG-ADT devices, confirming that the proposed strategy, i.e. increasing the atomic number of organic molecules by chemical tailoring to improve X-ray sensitivity, can be generalized to organic thin film detectors, combining high X-ray absorption, mechanical flexibility and large area processing.

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Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 59

Thermal vacuum testing of Timepix family based detectors

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We present results of the thermal vacuum testing of Timepix family based detectors with respect to the effects on their properties, sensitivity and behaviour under non-standard conditions. Readout ASIC chip bump-bonded with semiconductor detector was thermally coupled to a small aluminium block. This block was thermally stabilised using a PID controller and a three-stage Peltier element. This arrangement, located in the vacuum chamber, allows the detector to be tested under defined temperature settings ranging from -30 ℃ (resp. -40 ℃) to +80 ℃. Results of this testing help to strengthen the knowledge regarding the behaviour of the base part of the detector under extreme conditions. They can be used to improve results and minimise external influences, for example in space applications like VZLUSAT, LUCID or SATRAM, but also in other fields where temperature stabilisation of the detector is very difficult or energy-consuming. In these cases, thermal cycling of the detectors occurs, for example, due to the orbit and thus distortion of the measurement results either by changing the noise edge (threshold) but also the energy spectra can emerge. Based on detector behaviour knowledge, a procedure (an algorithm) can be designed to minimise this effect of distortion while maintaining the reduced requirement for temperature stabilisation and cooling. The experiments were performed on a detector chip equipped with a 300 μm thick Si sensor.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 60

New digital algorithms for achieving sub-pixel resolution in hybrid pixel detectors working in single photon counting mode.

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Hybrid pixel detectors are segmented devices used for particles detection, consisting of a sensor and readout electronics. To improve the resolution of the detector and allow operation with high-intensity photon fluxes, a pixel size is reduced. However, with decreasing pixel size, a charge sharing effect is more significant. To detect a photon irrespectively of charge sharing effect, the total photon energy should be reconstructed from fractional signals. Therefore, the algorithms dealing with charge sharing are developed 1. The resolution of such detectors is limited by the pixel size, which must be large enough to fit all the functionality required by the complex algorithms.

However, there are known methods applied for high energy physics [2] or integrating X-ray detectors that can improve the spatial resolution of a detector [3]. An alternative digital solution that can be implemented on-chip dedicated to hybrid pixel detectors working in a single photon counting mode is presented in this work. In this approach, charge sharing becomes the desired effect, since the information on the proportions of charge collected by the pixels can be used to estimate the photon interaction position with subpixel resolution.

In the work analytical approach towards detector and readout channel modeling is used to state the requirements for the algorithm. The concept of the algorithm, as well as the simulations results of the new digital on-chip algorithm, are presented.

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Hardware, Applications, chair: Christer Frojdh / 61

Advanced FPGA-Based Readout Electronics for Strip Detectors

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In this article we aim to investigate the performance of strip detectors as spectroscopes by measuring typical sources of ionizing particles, such as photons or alpha-particles, having a well-defined energy. To this end a 128-strip low noise FPGA-based readout system was fabricated alongside a corresponding dedicated software tool and connected to a Si strip sensor.
In addition, adequate equalization and calibration methods were developed in order to get a more uniform response from the channels and hence better energy resolution. In order to read all 128 channels of the sensor employed, 4 independent readout ASICs, featuring 32 channels each, had to be used.
In the current investigation a sigma of 1.6 keV was obtained for the mean of all channels within the

energy range of 15-60 keV, outperforming comparable Si hybrid-pixel detectors typically having a sigma of 2.3 keV. Using a 6-sigma distance to the electronic noise level it was still obtained a system threshold level of 3 keV.
This research provides valuable information for multiple applications in which strip detectors could be used efficiently to replace hybrid-pixel detectors.

LHC / 62

The CMS Outer Tracker for the High-Luminosity LHC

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The HL-LHC upgrade planned to the LHC will reach peak luminosities of 5-7*10^{34} cm^{-2} s^{-1}. The total integrated luminosity will reach 3000 fb^{-1} by the end of 2037. This poses new challenges on the LHC detectors. The current CMS Tracker is already running beyond design specifications and will not be able to cope the HL-LHC radiation conditions. CMS will need a completely new Tracker in order to fully exploit the highly demanding operating conditions and the delivered luminosity. The new Outer Tracker system is designed to provide robust tracking as well as Level-1 trigger capabilities using closely spaced modules composed of silicon macro-pixel and/or strip sensors. Research & Development activities are ongoing to explore options and develop module components and designs for the HL-LHC environment. The design choices for the CMS Outer Tracker Upgrade are discussed, together with some highlights of research and development activities.

Dosimeters, Neutrons, chair: Ulrich Parzefall / 63

Miniature Neutron Spectrometer for Space

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Radiation doses received by astronauts outside of the geomagnetic field are a main risk factor for human space exploration. The radiation sources of concern are Galactic Cosmic Rays and Solar Particle Events. The charged particles interact with spaceship materials and even with the astronaut body and produce neutrons. Inside the geomagnetic field Galactic Cosmic Rays interacting with atoms in the upper part of the atmosphere produce neutrons. The relative biological effectiveness of neutrons is high and the weighting factors for the calculation of dose equivalent are between 5 and 21 in the energy region between 100 keV and 100 MeV 1. We develop a miniature personal active detector (the MIDAS active dosimeter) capable to give information on particle fluence spectra and composition and thus provide information for determining dose equivalent. The detector contains a plastic scintillator (Ej299-33 for the 1st version and EJ276 for the 2nd version). The scintillator has dimensions 7mm x 7mm x 7mm and it is connected to a SensL 60035 Silicon Photomultiplier. The scintillator is covered by a Titanium box and the five faces of this box are covered by two layers of High Voltage CMOS active pixel sensors. The Titanium box prevents recoil protons with energies up to 18 MeV

to escape and hit the surrounding pixel sensors. The signal from the Silicon Photomultiplier is integrated in an analogue fashion and its total and tail parts are digitized by an ultra low power ADC in order to distinguish between neutrons and gammas. The device behaviour has been studied with the aid of GEANT4 based simulations. Calibrations with gamma sources and measurements with a 252Cf source and in quasi-monoenergetic neutron beams have been performed. The 252Cf spectrum has been reconstructed using the experimental data, thus verifying the correct operation of the neutron monitor subsystem. It has become clear that as the neutron energy increases and subsequently the number of photons created by higher energy recoil protons increases, the saturation effect of the Silicon Photomultiplier affects the shape of the response functions. This effect has to be taken into account for the correct reconstruction of the neutron energy. Furthermore we study ways to extend the range of neutron energy reconstruction to the low limit of 100 KeV.

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Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 64

Proton tracking UFXC32k Hybrid Pixel Detector

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We report on the design and measurement results of proton tracking system built with the use of single photon counting hybrid pixel array detector (HPAD). The detector used is Ultra Fast X-Ray Chip (UFXC32k) which is a matrix of 128 x 256 pixels, each 75 um pitch, characterized by very high 50 kfps frame rate. Such features allow it to be used in proton tracking system where high spatial resolution as well as capability to separate single proton events is required.

The proton tracking system was tested in November 2018 at Fermilab Test Beam Facility (FTBF) with 120 GeV proton beam generated by linear accelerator. The detection setup consisted of three layers of different detectors: Low Gain Avalanche Diode (LGAD), UFXC32k-based single layer detection system, and current FTBF proton tracker. The first layer, LGAD, is 4-channel high-time resolution detector that produces a trigger to both remaining setups. The trigger signal is used by UFXC32k-based detector to pick up a frame from 50 kfps data stream. The exemplary result of collective image of acquired frames is shown in the figure below. The visible shape of LGAD channels as well as good separation between them proves that the system successfully isolates protons indicated by LGAD detector.

For additional verification, proton transition points registered by UFXC32-based system were compared to the ones returned by the current FTBF tracker. The results of the data analysis will be presented, together with the description of the hardware and software architecture of the proton tracking system.

X-Ray, Timepix, chair Seppo Nenonen / 65

Single Layer Timepix3 Compton Camera

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The Compton camera concept is based on reconstruction of recorded Compton scattering events of incoming gamma rays. Usually, two or more detectors (layers) are used for constructing the Compton camera. The scattering of primary gamma ray occurs in the first detector (called scattering detector – usually thin) recording position and energy of recoiled electron. The scattered gamma quantum continues towards the second detector (called absorption detector - usually thick) where it is absorbed. The second detector records the energy and position of this scattered gamma. Then, using Compton scattering equation it is possible to determine the scattering angle and estimate possible directions of the original gamma ray as a surface of the cone. When the Compton camera records number of such events the location and shape of the gamma source can be reconstructed.

The Compton scattering of primary gamma and absorption of both recoiled electron and scattered gamma can often occur only within a single detector. By knowing the position and energy of both recoiled electron and scattered gamma within the detector, the same reconstruction principles as in the case of two detector can be applied and location of the gamma source determined.

Timepix3, a hybrid single photon counting pixel detector, is perfect device for creation of a compact Compton camera. Timepix3 is an event based readout chip (every hit pixel is immediately sent to a readout) and can record time-of-arrival (ToA) and energy of incident gamma simultaneously in each pixel. The chip offers high energy resolution (1 keV at 60 keV, 7 keV at 356 keV) as well as time resolution (1.6ns). The Timepix3 readout chip can be combined with different sensor materials (Si, CdTe, CZT).

In this contribution we present a very compact single detector system for imaging with gamma-rays using Compton camera principle. The system consists only of a single layer of hybrid pixel detector Timepix3 with a thick 2 mm CdTe sensor optimized for gamma-ray tracking. Thanks to the high precision ToA measurement of Timepix3, it is possible to measure the time of charge transport within the sensor. Based on this measurement, the relative depth (vertical position) of the interaction within the sensor can be determined. This relative depth of two coincidence events in the detector can be used for calculation of their vertical distance. The knowledge of position and energy of two coincidence events allow us to estimate the possible direction of the original gamma. The angular resolution of the presented Compton camera depends on the detected energy and reaches units of degrees.

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Design of a fast neutron activation analysis system with a gamma-ray detector for the detection of explosives

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We designed a fast neutron activation analysis system with a gamma-ray detector for the detection of explosives. By measuring the prompt gamma-rays emitted from the object upon neutron interrogation, the elements of the material can be identified. This is because the gamma-ray energies emitted by inelastic scattering or capture of fast neutrons present a unique signature for each element of interest to detect explosives. To design and optimize a fast neutron activation analysis system for the detection of explosives, we used the Monte Carlo N-Particle code. As a neutron source, a deuteron-tritium pulsed neutron generator emitting 14.1 MeV neutrons was defined for the fast neutron activation analysis. In order to reduce collateral radiation exposed to the gamma-ray

detector directly, the neutron collimator and shielding materials with polyethylene, lead, and steel were designed after considering 14 MeV neutrons and the shape of the neutron generator and the gamma-ray detector. TNT, RDX, PETN and Nitroglycerine were simulated as an explosive. Also, in order to optimize the position of the gammaray detector and the detector material, we simulated and measured the flux and the spectrum of gamma-rays by changing the position of the gamma-ray detector surround the object and by changing the gamma-ray detector materials, NaI:Tl, LaBr3:Ce, and Cadmium Zinc Telluride. To compare the detector materials, GEB option in the Monte Carlo N-Particle code was used for Gaussian broadening effect. As a result, pulse height spectrum of gamma-ray acquired and analyzed to identify the pure elements and the explosives. Main peaks at 4.43, 5.11, 6.13, 6.91 and 10.8 MeV for carbon, nitrogen, and oxygen elements were observed. The results of energy spectrum at each position of the detector surround the object for each detector material were acquired. To increase the signal to noise ratio, time selection and background spectrum reduction techniques were applied. The results showed that a detector composed of Cadmium Zinc Telluride located on the same side of the neutron generator has better energy resolution than a detector composed of other materials at different positions, which enables distinguish the peaks emitted from carbon, nitrogen, oxygen elements. To identify the explosives, the major gamma peaks of carbon, nitrogen, and oxygen were labeled and the experimentally calculated O/C and N/C ratios were analyzed. The results matched well with theoretical data.

CMOS, ASIC, chair: George Fanourakis / 67

High data-rate readout logic design for 1024*512 CMOS pixel array dedicated for CEPC experiment

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CMOS Pixel Sensors (CPS) are attractive for CEPC vertex detector construction due to its high granularity, high speed, low material budgets, low power and potential high radiation tolerance. For the innermost layer of CEPC vertex detector, the expected resolution is 3 to 5 μm; the bunch spacing of CEPC vertex detector is 680 ns for Higgs, 210 ns for W and 25 ns for Z; the hit density is 2.5/bunch/cm2 for Higgs and W, and 0.2/bunch/cm2 for Z. As a result, the maximal hit rate is about 40 MHz in case of W for a pixel array of 1024×512 with 25 μm pitch. Suppose the average cluster size is 3 pixels, the data rate is near 120 MHz. In addition, in order to achieve a detection efficiency of 99%, the dead time for the pixel readout is about 500 ns assuming the pixel occupancy of 0.05%. The existing CMOS sensors such as ALPIDE, ATLAS-MAPS, MIMOSA and so on can not fully satisfied the requirements. Therefore, the CEPC MOST2 vertex detector design group propose a new readout architecture for CPS chip 1. In the new architecture, the hit pixel addresses in a double column are read out based on the data-driven scheme such as FEI3 [2] and ALPIDE [3], and all the double columns of pixel array are read out parallel. In order to reduce the output data rate of the chip, the timestamp is recorded at the end of the double column, and the data with matched timestamp are buffered for output in case of trigger mode. Considering the chip test, the triggerless mode is also supported. This paper will focus on the peripheral readout logic design of the CPS chip with such high data rate for CEPC.

The overall architecture of the peripheral readout includes two level FIFOs. The first level FIFO is used to store the pixel addresses temporally for each double column and the FIFO depth is 12 to 16 considering the data rate and the deadtime. The second level FIFO is used to match the readout speed of chip interface and there are four FIFOs with depth of 256. In the periphery logic design, we adopt three strategies to fulfill the readout requirements. Firstly, 32 double columns are organized as a group for address priority readout and a special token readout method is proposed between these blocks for realizing the data-driven in the group and avoiding some groups are blocked for a long time. Secondly, both the trigger and the triggerless readout modes are supported in order to suppress the data with unmatched timestamps in trigger mode and to read out all the data in triggerless mode. Thirdly, advance data compression is realized before being written into FIFO1 in order to increase the design capability and reduce the power consumption.

The readout logic of 1024×512 pixel array has been realized in 0.18 μm Tower Jazz process. The area is 25.68 mm×1.13 mm. The simulation results indicate the readout logic work well with an input data rate of 120 MHz in case of disabling the advance data compression. When the data compression is enabled, higher data rate can be supported. A reduced scale chip with 192×64 pixel array is planned to be submitted on May 2019 for evaluation the chip architecture and block circuits.

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Helpful discussions with Ping Yang and Xiangming Sun from Central China Normal University, China and with Yue Zhao and Christine Hu from IPHC, France are greatly acknowledged. The authors would like to thank the financial support in part by supported by National Key Research and Development Program of China under Grant No. 2018YFA0404302, National Natural Science Foundation of China under Grant, No. 11575144, No. 11835007, No. 11705148, and No. 11835008, in part by Natural Science Foundation of Shaanxi province under Grant No. 2017JM6084, and in part by the Fundamental Research Funds for the Central Universities under Grant No. 3102017ZY028.

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Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 68

Instrument efficiency variations with different probe areal phoswich detectors for simultaneous alpha/beta detection

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In decommissioning, the radiological characterization of potentially contaminated sites is required to estimate the residual activity. Prior to actual samplings for the analysis, scanning survey with a movable radiation detector enables to measure the contaminated sites quickly and find local areas with elevated activity. For the scanning survey, minimum detectable concentration (MDC) of a field survey instrument is an important factor to reliably measure radiation particles and verify whether the contaminated sites exceed residual radioactivity criteria. The MDC is mainly calculated by parameters such as probe area, background count rate, instrument efficiency influenced by source-to-detector distance and source-to-detector geometry, surface efficiency, and dwell time. The probe area is highly correlated with the variables of instrument efficiency and background count rate. In this research, as an initial step of calculating the MDC depending on probe areas, phosphor sandwich

(Phoswich) detectors for simultaneous alpha and beta detection were manufactured to identify the variations of instrument efficiency and background count rate with the probe areas of 10×10 cmˆ2, 15×15 cmˆ2, and 20×20 cmˆ2. Instrument calibration for each probe area was conducted with the calibrated radioactive sources of 15×10 cmˆ2 areal Am-241 for alpha measurements; and 10×10 cmˆ2 areal SrY-90, Tc-99, and C-14 for beta measurements. Since the dimensions of a contaminated area can not be known a priori, it was assumed that instrument efficiencies calibrated from distributed sources are used for all surface activity measurements during scanning survey. In this principle, the same probe areal radioactive sources are ideally required for instrument calibration. To demonstrate the source-to-detector geometry of the same probe areal radioactive sources by using a limited size of the sources, new calibration approach was proposed based on Monte Carlo N-Particle Transport Code (MCNP) 6.2 simulation results. To enhance light collection efficiency and consequently increase instrument efficiency by coupling an optimal light guide, commercially available optical design software lighttools was used for light transport simulation. Experimental data showed that instrument efficiency decreased when probe area increased. On the contrary, background count rate tended to increase, especially for beta measurements. In the case of alpha measurements, background count rate did not exceed 2 cpm.

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The ATLAS ITk Strip Detector System for the Phase-II LHC Upgrade

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The ATLAS experiment at the Large Hadron Collider is currently preparing for a major upgrade of the Inner Tracking for the Phase-II LHC operation (known as HL-LHC), scheduled to start in 2026. In order to achieve the integrated luminosity of 4000 fb^{-1}, the instantaneous luminosity is expected to reach unprecedented values, resulting in about 200 proton-proton interactions in a typical bunch crossing. The radiation damage at the full integrated luminosity implies integrated hadron fluencies over $2{\times}10^{16}$ n_{eq}/cm^2 requiring a completed replacement of the existing Inner Detector. An all-silicon Inner Tracker (ITk) is under development with a pixel detector surrounded by a strip detector, aiming to provide increased tracking coverage up to |η|=4.

The current prototyping, targeting an ITk Strip Detector system consisting of four barrel layers in the centre and forward regions composed of six disks at each end, is described in the ATLAS Inner Tracker Strip Detector Technical Design Report (TDR). With the recent final approval of the ITk strip TDR by the CERN Research Board, the prototyping phase is coming to an end and the pre-production readiness phase has started at the institutes involved.

In this contribution we present the design of the ITk Strip Detector. We will give an extended summary of the R&D results achieved, including a wide set of measurements with detectors for several vendors, and irradiated with a range of fluencies and reaching up to to HL-LHC doses, demonstrating the excellent radiation hardness achieved. In addition, we will outline the current status of prototyping on various detector components, with a particular emphasis on the radiation-hard sensors, ASICs and front-end electronics under development. We will also discuss the status of preparations and the plans for the forth-coming pre-production and production phase.

Silicon, Pixel, chair: Val O'Shea / 70

Silicon Detectors for the LHC Phase-II Upgrade and Beyond – RD50 Status Report

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It is foreseen to significantly increase the luminosity of the LHC by upgrading towards the HL-LHC (High Luminosity LHC). Especially the Phase-II-Upgrade foreseen for installation in 2023 will mean unprecedented radiation levels, significantly beyond the limits of the silicon trackers currently employed at the LHC experiments. As a consequence, all-silicon central trackers are being studied in ATLAS, CMS and LHCb, with extremely radiation hard silicon sensors required especially in the innermost layers. Within the RD50 Collaboration, a large R&D program is underway across experimental boundaries to develop silicon sensors with sufficient radiation tolerance. Key areas of recent RD50 research include new sensor fabrication technologies such as High-Voltage (HV) CMOS, exploiting the wide availability of the CMOS process in the semiconductor industry. We also seek for a deeper understanding of the connection between the macroscopic sensor properties such as radiation-induced increase of leakage current, doping concentration and trapping, and the microscopic properties at the defect level. Another strong activity is the development of advanced sensor types like 3D silicon detectors, designed for the extreme radiation levels expected for the vertexing layers at the HL-LHC.
A separate line of RD50 activities is the development of dedicated methods for sensor characterization, such as the laser-based Two-Photon-Absorption (TPA) technique for highly localized measurements of the signal and gain in a sensor as a function of depth, or the system for edge-Transient-Current-Technique (TCT) to study the field profile inside the sensors.
One particular focus area with increasing importance in both ATLAS and CMS is the field of Low Gain Avalanche Detectors (LGADs). In these sensors, a very thin dedicated multiplication layer, designed to create a high field region is built into the sensor. As a result of this thin gain layer, LGADs are characterized by a very high signal compared to traditional Silicon detectors, and in addition a very fast signal with rise times in the order of 50ps. This fast timing makes them ideal candidates for ATLAS and CMS timing layers in the HL-LHC, with the ability to differentiate between multiple vertices in the same event using timing information in addition to space coordinates.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 71

Time-Performance Design and Study of Ultra-Wideband Amplifiers for SiPM

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The recent advances in SiPM technology and the high demanding performance required by the current applications, especially in the field of time-of-flight estimation, calls for a new approach in the design of the front-end amplifier to preserve the correct timing of the signals. SiPM manufacturers are offering devices with dedicated pins for fast-time outputs and recommending front-end amplifiers based on commercial devices for microwave and radio-frequency. We present in this paper our experience in designing customized wide-band amplifier front-ends for SiPM signals in high-resolution timing applications.
The design consists of two stages, the first based on a low noise device (typically a JFET/MOSFET, but we have tried etherojunction transistors as well) to achieve the minimum noise figure and the second based on a MMIC used as a gain stage to boost the signal and maximize the power transfer to the output. The design procedure is a combination of the traditional approach of circuit simulation integrated with techniques involving the use of S-parameters, typical of RF applications. Two versions of the amplifier have been laid out and assembled and are currently under test. Together with the preliminary results we show the advantages of our proposal in achieving very good time resolution performance and point out some possible future improvements.

Timepix,Micromegas, chair: Bernd Schmitt / 72

Precise timing of charged particles with the PICOSEC Micromegas detector: status and prospects

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Fast-timing particle detection in the sub-nanosecond region is a challenge in high energy physics, space science and nuclear physics, as well as in bio-medical imaging instrumentation. The use of fast timing detectors (~10 ps resolution) is crucial for the successful exploitation of the full potential of the future LHC operation at the high luminosity, and will facilitate the search for physics beyond the standard model. Besides the timing properties, these detectors owe to be robust enough to withstand the high particle fluxes in such environments.

In order to achieve such a performance, we have developed in the frame of the RD51 Collaboration the PICOSEC concept: a Micromegas detector is coupled with a Cerenkov radiator (MgF2 crystal), equipped with a CsI photocathode. The conversion (drift) region between photocathode and micromesh is reduced to 200 μm to suppress direct gas ionization, while enabling pre-amplification. Using small, unsegmented prototypes, we have observed a time resolution of 24ps for 150 GeV muons at CERN SPS, and 75 ps for single photoelectrons, produced by 100 fs pulses from a UV laser.
The timing characteristics of the detector have been fully understood in terms of detailed simulations and phenomenological models.

In order to evolve to a large-scale detector, we are currently concentrating our efforts on two directions: the development of larger detectors with resistive and segmented anodes, and the investigation of alternative, robust photocathodes, pure metallic or based on carbon (DLC, diamond). The current status, recent results and the prospects of the project will be presented here.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 73

Study of neutron-rich isotopes near the neutron N=152 shell closure using Timepix type detectors integrated in the MASHA experiment

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The MASHA setup was developed as a high precision mass-spectrometer for heavy and super heavy elements with masses up to 450 a.m.u. The setup uses ISOL (Isotope Separation On-Line) method. The unique property of MASHA opens also great perspectives for the investigation of neutron rich nuclei produced in multinucleon transfer reactions. Mainly nuclei near the neutron N = 126 and N = 152 shell closures are of great interest. This region of nuclei is not enough investigated so far and in addition its research has direct relation to the synthesis of superheavy elements. As is known the island of stability close to super heavy elements (Z=112-118) exists due to shell effects in the nucleus. The more detailed investigation of these shell effects can greatly help in the synthesis of the next super heavy elements.
Heavy neutron rich radon isotopes were produced in multinucleon transfer reaction 40Ar + 232Th at Flerov Laboratory of Nuclear Reactions, Dubna. Radon isotopes with given mass were detected using two types of detectors: the multi-strip detector of well type (made in CANBERRA) and position-sensitive quantum counting hybrid pixel detector of the Timepix type. The position-sensitive quantum counting hybrid pixel detectors of the TIMEPIX type have an array of 256x256 square pixels of pitch size 55m for full sensitive area 14x14 mm2. Radon isotopes implanted into detector then emit alpha and beta particles reaching the long lived isotopes. The position of radon isotopes, the tracks, time and energy of beta particles were measured and analyzed. A new software for the particle recognition and data analysis of obtained results from the experiment was developed and used. It was proved that MASHA + TIMEPIX setup is a powerful instrument for investigation of neutron-rich isotopes far from stability limits.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 74

Spectroscopic characterization of GaAs/AlGaAs avalanche photodiodes with separate absorption and multiplication regions

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Owing to its high atomic number GaAs is an attractive material to realize hard-X-ray single-photon detectors. In fact, its bandgap of 1.42 eV is on the one hand sufficiently wide to operate it at room temperature and on the other hand small enough to provide reasonable spectroscopic performances for high-energy photons. Therefore, III-V semiconductors avalanche photodiodes have been developed to be utilized as X-ray spectroscopic devices. These have been grown by molecular beam epitaxy and comprise of separate absorption and multiplication regions, which are divided by a nanoscale carbon layer. Utilizing a low-noise charge-sensitive preamplifier and sources of characteristic fluorescence lines, several X-ray spectra have been collected at room temperature.
In this work we present some devices featuring different concentrations and thicknesses of the aforementioned carbon layer. These devices have been characterized in dark and under illumination conditions. The results are reported here together with a thorough noise analysis and the acquired X-ray spectra will be discussed.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / 75

3-D visualization of radioactive substances by integrating gamma-ray imaging technology and Structure from Motion

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The Fukushima Daiichi Nuclear Power Station (FDNPS), operated by Tokyo Electric Power Company Holdings, Inc., went into meltdown after the large tsunami caused by the Great East Japan Earthquake of March 11, 2011. Radiation distribution measurements inside the buildings of the FDNPS are indispensable to execute the decommission tasks because the information would be important to predict risk to workers and to decrease the amount of radiation exposure.
We have developed a method for integrating a three-dimensional (3-D) image of radioactive substances obtained by measuring with a Compton camera into a 3-D photo model of the experimental space created using photogrammetry. By measuring a radioactive substance from a plurality of viewpoints using the Compton camera, an image of the radioactive substance can be three-dimensionally reconstructed. Here, information on the self-position and posture of the Compton camera is required for image reconstruction. In this work, we developed a method to automatically acquire the information using Structure from Motion (SfM) and integrate the image of radioactive substances into the constructed 3-D photo model. This method will be effective for remote visualization of radioactive substances using a robot equipped with a gamma-ray imager such as the Compton camera inside the buildings of the FDNPS.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / **76**

Bone surface-based volume stitching in dental computed tomography with improved image quality

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This study presents an effective volume stitching method in dental computed tomography (DCT) using a bone surface-based registration with improved image quality. It consists of four main steps: (1) acquisition of two separate DCT datasets of a small field-of-view (FOV), (2) computation of a three-dimensional transformation for volumetric registration, (3) image registration, and (4) alpha blending. During acquisition of DCT datasets, the focal spot of the x-ray tube was aligned to the bottom of the detector, and one dataset to be registered was obtained with the upper part of a skull phantom in a tilted position to avoid bright shading artifacts around the sinus in the reconstructed DCT image. We performed an experiment using a commercially available dental DCT system to investigate the image quality and evaluate the effectiveness of the proposed method in DCT. The system consisted of an x-ray tube (70 kVp and 5 mA) and a CMOS flat-panel detector with an active area of 13.5 cm × 12.7 cm, and it was operated in a half-beam scan mode to increase the FOV to 160 mm (in diameter) × 90 mm (in height). Our experimental results indicate that the proposed volume stitching method was effective for obtaining homogeneous and seamless stitched images of a larger FOV in DCT.

Poster Exhibition 1: Posters ID 1 - 80, chair: Christer Frojdh / **77**

Designing a first Mexican SiPM Data Acquisition System - MexSiC

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Silicon Photomultipliers (SiPMs) 1 are currently an excellent option to replace the traditional photomultiplier tubes (PMTs) in several fields ranging from astrophysics to medical applications. Having photon detection efficiencies (PDE) higher than 40% at peak wavelengths (in the blue-green visible part of the spectra), much lower operational voltages (ranging between 27 and 70 volts, depending on the manufacturer) than the PMTs (with biasing voltages between 1 and 2 kV), and high immunity to magnetic fields, SiPMs are reliable photodetectors enabling near single-photon counting capability alongside nanosecond time resolutions. One disadvantage of SiPMs, if used in applications where huge detection areas are required, is their respectively small photoactive area (of few square millimeters). Arrays of SiPMs are normally used in such cases.

In order to use SiPM arrays, data acquisition (DAQ) systems capable of reading multiple channels in parallel synchronizing their time of arrival, processing the input electric signals, discriminate between events, and generate resulting digital output signals that can be stored on an external memory unit are required. This work describes a DAQ system currently being developed for an array of nine SensL J-Series 30035 SiPMs [2]. The aim of the system is to be as flexible as possible so it could be applied in the Cherenkov light detection or together with any array of scintillation based detectors using SiPMs. An application specific integrated circuit (MexSIC) to be fabricated in the 180 nm CMOS technology has been designed as a core unit of this DAQ system. It contains a transimpedance amplifier (TIA) as its input stage, used to amplify and convert the SiPM output current pulses into voltage signals, a triggering logic unit (TLU) used to discriminate the input signals and generate a master readout triggering signal in case a desirable event has been detected, a phase locked loop (PLL) used to generate a clock reference for the time-to-digital converter (TDC), and an additional charge-to-digital converter (QDC) to be able to determine the amount of charge generated within each individual SiPM. An additional field-programmable gate array (FPGA) -the Xilinx Kintex 7- is used for signal processing and system controlling. With this approach, the end-user will obtain the information regarding the charge generated in each SiPM, the exact time in which a valid event has been identified accompanied by the exact single SiPM that triggered it first, as well as the time duration of the event (using the time-over-threshold TOT approach) for all the individual SiPM channels, additionally considering all the time delays present in the signals of all the SiPMs triggered for coincidence analysis.

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Digital tomosynthesis (DTS) reconstruction using deep learning with convolutional neural network

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Digital tomosynthesis (DTS) is a geometric tomography technique by limited-angle scan that has popularly been used in both medical and industrial x-ray imaging applications. It provides the tomographic benefits of computed tomography (CT) with reduced dose and time. However, conventional DTS reconstruction based on computationally-cheap filtered-backprojection (FBP) method typically produces poor image quality due to limited angular samplings. To overcome these difficulties, iterative reconstruction methods are often used in DTS reconstruction owing to the potential to

provide multiplanar images of superior image quality to conventional FBP-based methods. Further, the compressed-sensing (CS), the development of three-dimensional reconstruction algorithms from sparse-view and/or limited angle-view data, as in DTS, has received growing attention during the last decade. However, they require enormous computational cost in the iterative process, which has still been an obstacle to put them to practical use. In this work, we propose a method for reducing limited angle artifacts effectively in conventional FBP reconstruction using a state-of-the-art deep learning with convolutional neural network. Recently, deep learning technique, which makes major advances in medical imaging processing, has been used image classification, denoising, and segmentation. Our results indicate that the proposed DTS reconstruction method effectively minimized limited angle artifacts, and its effectiveness was validated by comparing to other reconstruction methods such as FBP, CS for the DTS datasets.

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Effective design of the noise reduction collimator for high dose environments

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Radioactive contamination of nuclear power plants must be precisely identified for safe decommissioning. Especially, hot spots should be evaluated for the safety of workers in high dose environments. Gamma cameras are widely used to investigate the hot spots of the radioactive materials. The output signals of the gamma cameras are saturated in high dose regions. Pinhole collimator is widely used to reduce the number of the gamma rays incidents in the detector to solve the problems. However, the noise is generated by interaction of the gamma rays with the collimator. Three major types play an important role in radiation measurements: photoelectric absorption, compton scattering, and pair production 1. The characteristic X-ryas, the scattered gamma rays, and the annihilation gamma rays caused by these types should be minimized to reduce the noise. These noise are related to the components of the collimator. The purpose of this study was to design the noise reduction collimator for high dose environments. The Monte Carlo N-Particle Transport Code (version 6) was performed to investigate the characteristics of the noise of the collimator with various materials and the radioactive sources. The collimator consisted of an aperture and septa for shielding background radiation. The acceptance angle and source-to-collimator distance were around 37° and 100 cm, respectively. The diameter of hole of the aperture was 1 mm. The Signal-to-Noise Ratio (SNR) of the collimator was evaluated using aluminum, iron, copper, bismuth, lead, and tungsten. It also was evaluated with ²⁴¹Am, ¹³⁷Cs, ⁶⁰Co, ²²Na, and ¹⁵²Eu sources. The experimental measurements were performed to verify the results of the simulations and the SNR also was investigated to evaluate the performances of the noise reduction collimator.

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Study on Availability of Monte-Carlo Simulation for Attenuation Correction of Brain-Dedicated PET

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Brain-dedicated positron emission tomography (B-PET) aimed at diagnosing Alzheimer disease is being developed. Unlike the existing PET used in combination with MRI or CT, B-PET will be operated independently without additional equipment. Therefore, a study is needed for PET-based correction method, which replaces a CT-based method for quantitative assessment as well as improved quality of an image. This study was conducted with focusing on attenuation mapping in a series of processes for that purpose. The B-PET system is a ring shape with 36 two-line blocks, each containing 8x8 array silicon photomultipliers (SiPM) and the ring has a diameter about 300 mm. Lutetium-yttrium oxyorthosilicate, known as LYSO, is used for a crystal of detector. In the simulated B-PET system like the aforementioned environment, the PET-based attenuation correction method was performed on MCNPX 2.7 using water-based cylinder phantom and ICRP phantom. An experiment with tissue equivalent brain phantom was conducted with B-PET as a control group of simulations to verify the availability of Monte-Carlo simulations. As a result of this study, we will show the application of the attenuation correction method and discuss the availability of simulation by comparing images reconstructed by simulation data and experimental value. The electronics of front-end module and readout system are manufactured by PETSYS electronics, and the SiPM (Mo. PA3325-WB-0808) which manufactured by KETEK GmbH was used for PET detector.

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 81

Improving spatial resolution by predicting the initial position of charge sharing effect in photon counting detectors

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X-ray Photon counting detectors are known as next generation x-ray detectors because they have advantages over general energy-integrating detectors. Since X-ray photons are counted, energy information can be obtained. In addition, because of the direct measurement without scintillation, the contrast-to-noise ratio is higher than the general charge integration detector. The photon counting detector measures the electrons generated by the photon incident in the CdTe / CdZnTe. When an incident X-ray photon interacts with an atom of the detector material, a photoelectron or a Compton scattered electron is created as a primary process. The electrons generated by this primary process affect the other pixels due to the phenomenon of spreading in the process of moving to the anode. Also a characteristic x-ray generated by a photoelectric effect forms an electron cloud at another pixel. Due to these two phenomena, distortion occurs in the position information and the energy information. In this work, we use the time-over-threshold (ToT) and projection method to compensate the position information of the pixel sharing charge sharing. We project the charge sharing value of 8 neighboring pixels to the middle pixel, and find the point where the photon has the highest probability of entering the middle pixel. We divided the middle pixel into 3x3 sections and found the location where the x-ray photon was first incident through the projection. Using a timepix chip with CdTe pixels, 50,000 images were acquired for 1.5 seconds at intervals of 30 us with the ToT method. At this time, x-rays were irradiated to various materials at 80 kVp and 5 uA.

X-Ray, chair : Heinz Graafsma / 82

Performance Improvement of the Event-Driven SOI Pixel Detectors for X-ray Astronomy

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Future X-ray astronomical satellite missions will require a new type of a detector that can distinguish X-rays and charged particle tracks, so as to reduce the background level. In order to realize these demands, we have been developing monolithic active pixel detectors, named “XRPIX,” based on the silicon-on-insulator (SOI) CMOS technology. XRPIX offers high coincidence time resolution (~50 ns), superior hit-position readout time (~10 μs), wide bandpass (1–40 keV), and comparable performances in imaging spectroscopy. XRPIX contains a comparator circuit in each pixel to detect particles; it offers an intra-pixel hit trigger (timing) and two-dimensional hit-pattern (position) outputs. Therefore, XRPIX can directly access the selected pixels to readout the signal amplitude. One of our key development items is the improvement of the energy resolution for the event-driven readout mode. We have observed that the logic inversion of the intra-pixel comparator circuit affects the analog signal at the time of event detection and causes the degradation of the energy resolution. This phenomenon can be attributed to the capacitive coupling between the CMOS circuit and the sensor layer. Recently, two sensor structures have been introduced to reduce capacitive coupling. One is a Double-SOI (D-SOI) structure which contains a middle-silicon layer within the buried oxide (BOX) layer. The other is a pinned depleted diode (PDD) structure which contains a fixed potential layer at the interface between the BOX layer and the sensor layer. We succeeded in improving the spectral performance of the event-driven readout mode for both the D-SOI and PDD structures. In case of the D-SOI structure, we achieved an energy resolution of 410 eV in full width at half maximum for the 6.4-keV X-rays. Furthermore, the peripheral digital circuit of the hit-pattern processing was improved to enhance the functionality of the event-driven readout mode. In this presentation, we report the recent status and evaluation results of our developed XRPIXs.

SiPM, High -Z, chair: Roelof de Vries / 83

Development of SiPM using SOI technology

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INTRODUCTION
Silicon Photomultiplier (SiPM) is an array of Single Photon Avalanche Diodes (SPADs), avalanche photodiodes operating in Geiger mode followed by quenching resistors, connected in parallel. Since SiPMs have short recovery time and superior time resolution with high energy resolution and are insusceptible to magnetic field, they are used as radiation detectors for diagnostic imaging equipment using nuclear medicine such as PET and SPECT in combination with a scintillator in substitution for photomultiplier tubes (PMTs). In recent years, with a background of improvement in time resolution and simplification of complex signal processing circuit, the integration of SiPM and readout circuit onto a single chip, such as digital-SiPM and Complementary Metal Oxide Semiconductor-Single Photon Avalanche Diode (CMOS-SPAD), have recently started getting attention 1. The objective of this study is to develop SOI (Silicon on Insulator)-SiPM using SOI-CMOS process that enables the three-dimensional integration of sensors into circuits and also high-speed performance of transistors without mechanical bump bonding [2]. This time, focusing on the performance improvement of the sensor part, we designed and fabricated SiPM using SOI technologies, and evaluated the basic performance of both the sensor and readout circuit.

METHOD
The 36-channel SiPM array was designed using a 0.2 μm 5-metal SOI-CMOS process technology provided by LAPIS Semiconductor Co., Ltd. One 250 μm2 SiPM channel is constituted by 9×9 microcells, which are arranged in a 27.52 μm pitch.
SiPM amplifies and detects free carriers generated due to thermal processes, band-to-band tunneling, and diffusion in the absence of incident photons. This pulse is a dark count pulse, which causes a detection error. Also, its photon detection efficiency (PDE) depends on sensor's active area, wavelength dependent quantum efficiency, and avalanche probability. In previous research, high dark count rate (DCR) and low PDE remain issues to be improved. As one of the causes, we considered that the inhomogeneous electric field derived from the shape of the edge of the microcell influenced the breakdown characteristics, dark count rate, and PDE of SiPM. Thus, we fabricated the circular cathode and anode to eliminate the edge.
A readout circuit consists of charge-sensitive preamplifier, shaping preamplifier, buffers, discriminators, and several bias circuits. The input signals, which are outputs of SPADs, are sensed and amplified by preamplifier, and finally digital output signal is generated. Each circuit part is followed by individual output pins; therefore, one can selectively look at the output of each circuit.

RESULTS
In order to evaluate sensor characteristics, IV characteristics are obtained by using the semiconductor parameter analyzer, and the peak histogram of incident photons by using laser pulses with a wavelength of 510 nm. As a result of modification, the breakdown voltage increases from 48.2 V to 50.7 V, the operating voltage range, which reflects the characteristics of gain and dark count rage, increases from 3.3 V to 3.8 V, DCR decreases from 245 MHz/mm2 to 218.8 MHz/mm2, and PDE increases from 0.47 % to 2.74 %. In circuit part, we measured analog circuit outputs of preamplifier and shaper by voltage pulse input from test terminal. The peaks of output waveforms linearly increase as test input voltage increases, from 0.25 V to 1.5 V with a step size of 0.25 V. Finally, we confirmed that the sensor and readout circuit properly operate as one system.

CONCLUSION and FUTURE PLAN
In this study, to develop a photodetector with the monolithic integration of sensor and readout circuit that can be applied to PET and SPECT, we designed and fabricated SiPM using SOI process. Measured results, such as reduction of DCR and increase of PDE, indicate that the structural change of the sensor from square to circle is effective. However, comparing to performances of commercially available SiPM, SOI-SiPM's DCR and PDE still need improvement. Also, a method of the integration of SOI-SiPMs and scintillators will be investigated further.

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Performance evaluation of total variation noise reduction algorithm with self-produced AAPM computed tomography phantom by using 3D printer

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Recently, many studies for development of the algorithm using image processing have been conducted to reduce the noise in medical image 1. In this study, we proposed total variation (TV) noise reduction algorithm and confirmed application feasibility in the self-produced phantom by 3D printer. For that purpose, we designed the TV noise reduction algorithm using L1-norm gradient operator that can maintain a stable signal than L2-norm. In addition, a self-produced phantom was designed based on AAPM computed tomography (CT) performance phantom, and manufactured using a 3D printer of the fused filament fabrication technique with polylactic acid filament. To quantitatively evaluate image performance, we calculated the coefficient of variation (COV) and contrast to noise ratio (CNR) of the proposed TV noise reduction algorithm and conventional noise reduction algorithm (median filter and Wiener filter). Fig. 1 shows the result images, COV, and CNR results in this study. According to the results, the COV and CNR values of the TV noise reduction algorithm applied images show improvement values more than conventional noise reduction algorithms. Especially, COV and CNR values were improved averagely about 3.89 and 3.12 times, compared to original image. In conclusion, our results demonstrated that the suggested TV noise reduction algorithm can efficiently remove noise and improve the image quality in CT image.

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Prompt gamma imaging with gamma electron vertex imaging system for proton beam range monitoring

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Thanks to the dose characteristic so-called Bragg peak, proton therapy can deliver a very conformal dose to the target volume while minimizing the dose to adjacent normal tissues and critical organs. However, the proton dose distribution in the patient, especially the beam range might deviate from the planned one due to dose calculation errors, organ motions or patient setup errors. To overcome this limitation and fully utilize advantages of proton therapy, the real-time monitoring technique based on the prompt gamma (PG) imaging was suggested 1.

To measure the two-dimensional PG distribution with the high detection efficiency, we proposed a new imaging method, gamma electron vertex imaging (GEVI), and demonstrated the possibility of the imaging method [2]. To determine the emission position, an incident PG is converted to an electron by Compton scattering, and then the trajectory and energy of the converted electron are measured by two hodoscopes and a calorimeter, respectively. To reconstruct image, the effective events are determined from triple coincidence events by applying the optimal energy window and then, the line back-projection algorithm is employed on interaction positions in the first and second hodoscope detectors.

Based on the previous results, in the present study, we improved the GEVI imaging system for clinical applications, and tested its performance for therapeutic proton beams. To increase the field of view

in the beam direction, the active area of hodoscope detector (= DSSD array) was increased to 10 cm × 5 cm. The EJ200 plastic scintillation detector of 16 cm × 8 cm × 5 cm was used to cover the extended active area. With this expansion, it was expected that the FOV and the imaging sensitivity will be increased by two times. To improve the data acquisition speed of the imaging system, we had developed a FPGA-based DAQ system.
To estimate the performance of the imaging system, a proton pencil beam extracted from the 230-MeV cyclotron at Samsung Medical Center in Korea was used. In this study, 82, 120 and 150 MeV proton beams were used and 6.24× 10ˆ9 protons (corresponding to 1 s measurement for 1 nA proton beam) were used for each measurement case. By changing the proton beam energy and irradiation locations, the PG images were measured and then, the beam ranges were determined within 3 mm error. We expects that the imaging system can be used to proton therapy monitoring by measuring the PG distribution.

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Timepix,Micromegas, chair: Bernd Schmitt / 88

Neutron tomography of two different internal structures in cask storage

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Dry storage facilities necessitate a reliable safeguards technique which is able to detect any undeclared activities such as diversion, misuse, or theft of spent nuclear fuel assemblies in a cask. Many techniques based on gamma, neutron, or muon have been applied but suffered from low accuracy caused by shields of a cask. Therefore, the present authors developed a new tomography system employing new He-4 gas scintillation detectors, designed to simultaneously measure both thermal and fast neutrons without any moderators.
To demonstrate the availability of the experimental system, Monte Carlo simulation has been first carried out regarding the actual cask dimension(HI-STAR) and material information of spent nuclear fuel. 19 detectors were linearly arrayed and positioned at the middle of a cask. 36 image profiles were obtained at every 10 degrees and aligned in single frame image called a sonogram. The cross-sectional image was then fabricated by the inverse radon transform algorithm.
In this study, two cases of the spent-fuel diversion were considered. The first case is that the spent fuel is removed from the cask and then the lid is closed. The second case is the same as the first case but empty spaces are filled with the dummy fuels composed of high-Z number non-radioactive materials (dummy fuel). As shown in figure, five different diversion scenarios were considered for each case in order to check the change of spatial resolution of the cross-sectional image.
It was resulted that the new tomography system can detect a possible partial or gross defect of assemblies for both cases, but also pointed out that it depends on the position where diverted assemblies were previously located. Defining diversion of some central assemblies is notoriously difficult with neutron tomography since the quality of cross-sectional images is dominated by neutron information mostly emitted by the close spent fuel assembly.
This study showed that the new neutron tomographic system has considerable potential to detect some nuclear fuel diversion. Future steps will be to experimentally demonstrate the actual system with some nuclear materials and conduct various parametric studies to enhance the image quality.

Software, chair: Daniele Passeri / 89

Mass measurement and study of decay properties of super heavy elements by using the pixel detectors

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The discovery of the Super Heavy Elements (SHE) with atomic number Z=113-118 as well as new neutron excess isotopes of the elements with Z=104-112 was one of the outstanding scientific results of the last decades. These high priority experiments were carried out on the cyclotron U400 of the FLNR (JINR, Dubna, Russia). The synthesis of the new super heavy elements stimulated works on the development of methods of their identification by means of the technique called Isotope Production On-Line (ISOL). Thereto, in the FLNR there was designed and put into commissioning the mass separator MASHA - Mass Analyzer of Super Heavy Atoms. The uniqueness of this mass spectrometer consists in ability to measure "on line" the masses of the synthesized isotopes of the super heavy elements simultaneously with detection of their alpha decays and spontaneous fission.
Another progress in the investigation of superheavy elements is the registration of other particles than alphas and fission fragments in the decay chain of superheavy elements such as beta particles and X-rays, which increase the reliability of their identification. The position-sensitive quantum counting hybrid pixel detectors of the TIMEPIX type satisfy the requirements while providing high spatial resolution and single-quantum detection. Two main characteristics of TIMEPIX are the most important for experimental studies of synthesis of super heavy elements. The first one is the position sensitivity and tracking detection of single particles; the second one is the capability of detection of alpha particles and fission fragments in wide energy range. So far the signature of identification of superheavy elements was mainly based on the lifetime and the alpha energy of nuclei in the decay chain. The mass separator MASHA adds the mass measuring with high accuracy and TIMEPIX adds the position sensitivity and tracking detection. Although the superheavy elements decay predominately by alpha emission the beta emission is not excluded and has never measured before. These capabilities of TIMEPIX increase the reliability of identification of superheavy elements which is quite important in such rare processes.
A few experiments with heavy ion beams were carried out to test the isotope identification method with the help of tracks in pixel detectors. The mercury and radon isotopes were produced in complete fusion and multinucleon transfer reactions. A new software, based on the neural network approach and principal component analysis, for the particle recognition and data analysis of experimental results was developed and used.
The next experiments at the modernized mass separator MASHA with "Cryogenic Gas Stopping Cell" and gas-filled magnetic separator placed at the accelerator DC280 ("Factory of Superheavy Elements", JINR, Dubna) are discussed. The "Cryogenic Gas Stopping Cell" uses IGISOL technique (Ion-Guide Isotope-Separator On-Line) and can extract the produced isotopes with life time up to 10 ms. The main goal of MASHA setup will be the mass measurement and study of decay properties of super heavy elements (Z = 112 - 118) in complete fusion reactions induced by heavy ion beams.

XFEL, chair: Ralf Menk / 90

Commissioning and operation of the JUNGFRAU detector at the European XFEL: status and prospects

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The JUNGFRAU detector is a now established hybrid pixel detector developed at Paul ScherrerInstitute (PSI), featuring 75 µm pixel pitch with a charge integrating architecture1 designed for FELapplications2. Thanks to its dynamic gain switching mechanism it provides an extensive dynamicrange up to ˜ 104 photons/pixel at 12 keV3. With an average noise of ˜80 ENC rms for 10 µsintegration time, it offers single photon resolution above ˜ 1 keV. An array of 16 memory cells perpixel makes it possible to store images at a repetition rate greater than 200 kfps, which allows thedetector to partially exploit the EuXFEL time structure. The combination of these features makesthe JUNGFRAU detector a promising candidate for several scientific instruments at the EuXFELfacility.The small pixel pitch grants enhanced spatial resolution in comparison to other high speed imagingdetectors available at EuXEL, which is of great advantage for Small Angle X-ray Scattering(SAXS) experiments like the ones performed at the High Energy Density (HED) instrument or forall spectroscopy applications. The Femtosecond X-ray Experiment (FXE) instrument exploits thisfeature, together with the compact dimensions of a single JUNGFRAU module, to setup a versatilesingle shot spectrometer mounted on a robotic arm.The combination of a large dynamic range and modular structure of the detector is fundamental fora large area camera for diffraction experiments, like the ones performed at the Single Particles,Clusters, and Biomolecules & Serial Femtosecond Crystallography (SPB/SFX) instrument. On theother hand, the excellent signal-to-noise ratio in the 3 – 16 keV range is fundamental forexperiments performed in the single-photon regime, like the X-ray Photon Correlation Spectroscopy(XPCS) and Coherent X-ray Diffraction Imaging (CXDI) which are the goals of the MaterialsImaging and Dynamics (MID) instrument. We will present the status of commissioning of the JUNGFRAU detector at the EuXFEL in generalterms and with focus on details specific for individual scientific experiments at EuXFEL. Eventhough the full implementation of the 16-memory cell operation mode of the detector currently is atan advanced experimental stage, particular focus will be given to the status of its implementation,its integration at the facility and results of the first tests.

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Software, chair: Daniele Passeri / 91

Multispectral Photon-Counting for Medical Imaging and Beam Characterization

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Next generation detection systems operating in multispectral mode have the potential to revolutionize diagnostic capabilities in medical imaging in terms of efficiency, image quality and lower patient dose.

We present our approach that utilizes direct conversion radiation detectors operating in Photon Counting (PC) mode.
Our strategy is to use several different detector technologies including thick silicon, high-Z semiconductor materials (CdTe/CdZnTe) and silicon enhanced by scintillator (SiS) material together with pixel Read-Out Chips (ROC) running in PC mode. Due to our involvement in high energy physics, in particular in the CMS Tracker at CERN, we have access to existing solutions of ROCs that are capable of working in the PC mode.

The main focus lies on the utilization of CdTe. Due to its high quantum efficiency it outperforms silicon in terms of photon radiation absorption. Additionally, due to the large energy band gap, devices based on CdTe can be well operated at room temperature. However, CdTe crystals are, at present times, difficult to grow and are only available in small form-factors containing a variety of defects. Therefore, we apply a thorough quality assurance that enables us to choose the best crystals for detector fabrication.

After manufacturing first successful prototypes for the proof-of-concept, we are now focusing on the processing of the CdTe crystals and thick Si wafers at Micronova Nanofabrication Centre in Espoo. Processed sensors will then be flip-chip bonded with the ROCs, which is a critical step in the detector production. Due to the intrinsic material properties of CdTe, bump bonding has to be done at lower temperatures compared to silicon sensors, thus usual materials cannot be used. A feasible approach is to employ indium based bumps that allow bonding at low temperatures.

In addition to detector development, other crucial tasks related to this project are: the evolution from single module to detector arrays and its electronic readout; the advanced data analysis and image reconstruction; and prototype testing to guarantee repeatability and long term stability.

This work is conducted within a consortium of Finnish research groups from Helsinki Institute of Physics, Aalto University, Lappeenranta-Lahti University of Technology LUT and Radiation and Nuclear Safety Authority (STUK) under the RADDESS program of Academy of Finland.

Figure 1. Photograph of processed CdTe crystal matching the pixel structures of the ROC (left) and rendering of the High Definition Interconnect PCB holding the detector array (right).

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S3 - detector of reactor antineutrinos

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Neutrino research is relatively new and still not well-known part of physics. Therefore, many neutrino detectors have been developed to investigate neutrino properties. This paper describes present status of highly-segmented scintillating detector S3, which was developed as a common effort of IEAP CTU in Prague and JINR, Dubna. Since detector material meets strict safety rules of nuclear

power plant, it can be installed in the close vicinity from the reactor, which is the most intense man-controlled source of antineutrinos.

In order to test the proposed detector design, a simplified 2-channel version of S3 prototype was constructed. Numerous measurements were performed using the prototype, such as background characterization, verification of proposed shielding and investigation of neutrino-like events. Based on these measurements, 80-channel S3 detector was designed and constructed. While classical PMTs were used in the prototype, new progressive photoelements were utilized in the detector for signal collection. Readout electronics for 80-channel detector is based on multichannel system (100 MS/s, 15 bits), which was developed by IEAP CTU in Prague. First measurements were carried out using the simplifier version of multichannel system (24 channels). Another option of DAQ system is based on VME module (62.5 MS/s, 12 bits).

Since detector can be installed near the reactor (˜ 10 m), it can be used for study of neutrino properties with higher efficiency, investigation of neutrino oscillations on short baselines, verification of sterile neutrino hypothesis and online measurement of the reactor power and fuel composition. Therefore, detector can be of great importance to fundamental and applied research.

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 93

A new method for assessing radioactive contamination of human body using an artificial neural network

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Human body receives an external and internal exposure from radioactive materials. The effective dose can be derived as the sum of the personal dose equivalent (Hp (10)) from external exposure and the committed effective dose (E (50)) from internal exposure 1. The International Commission on Radiological Protection (ICRP) recommends that the dose limit should be expressed as an effective dose of 20 mSv per year, averaged over defined 5 years periods, with the further provision that the effective dose should not exceed 50 mSv in any single year 1. Whole body counters (WBC) are used to evaluate the radioactive contamination of workers at domestic nuclear power plants and it is often possible to estimate external contamination as internal contamination [2]. A method to identify the location of the radioactive contamination using WBC has been developed to solve this problem [2]. However, this method has a critical problem that can not discrimination between external and internal contamination if the inside and the outside of the human body are contaminated simultaneously. The purpose of this study was to develop a method for assessing the location of the radioactive contamination of human body using an Artificial Neural Network (ANN). A humanoid ATOM phantom recommended by ICRP was used for this study. Various spectra were obtained for three cases to get a training set of the ANN: (1) 137Cs and 60Co sources were attached to the surface of the phantom, (2) The sources were inserted between slices of the phantom, (3) The sources were attached and inserted of the phantom at the same time. The hyper parameter including the number of layers, the number of neurons in each layer, the learning rate of the optimizer, and the neuron dropout rate were optimized to improve accuracy of the ANN. The accuracy of the ANN was evaluated using a test set.

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 94

Contrast resolution limits of Timepix detector based on semi-insulating GaAs material sensor

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Semi–insulating (SI) GaAs is one of the perspective candidates for fabrication of semiconductor X– and gamma–ray detectors applicable in digital radiology instrumentations. Advantage of the bulk SI GaAs is the possibility of fabrication of a monolithic strip or matrix detectors in one substrate due to the creation of the space charge region under each blocking contact. We fabricated pixelated sensor using undoped SI GaAs substrate with thickness of 350 um. The detection area has a size of 14.1 × 14.1 mm2 with 256 × 256 pixels and was connected to Timepix readout chip 1.
In our previous work we compare imaging performance of GaAs-based Timepix detector with Si-based sensor, concentrate on detection efficiency, energy resolution and imaging performance [2]. Overall, prototype GaAs sensor shows very good and promising results in all aspects. In this work we concentrate on contrast resolution limits. For experiments we used various type of testing objects. Using nanomachining we fabricated steps from aluminium board. The height of steps is variable and changed from 2 um up to 100 um. The X-ray source with micro-focal spot size (about 8 um) was used in testing contrast resolution. GaAs sensor can operate at positive and also negative polarity. All our presented results were done at positive polarity. Now we study also the imaging performance at negative polarity of GaAs sensor. The advantage is that the space charge region is spreading from further part of GaAs material to Timepix readout chip surface. We have no dead layer if the sensor is not fully depleted. The drawback is higher reverse current (about three times) and worse energy resolution but the detection efficiency is much better especially for energy of X-rays below 20 keV. The silicon based Timepix detector was also used for comparison discussion of obtained results.

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Dosimeters, Neutrons, chair: Ulrich Parzefall / 95

Study of small scale position-sensitive scintillator detector for gamma-ray spectroscopy

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Precision measurement of the energy and the direction of gamma-rays plays a key role in many fields such as medical imaging, nuclear spectroscopy, and astrophysics. Present space gamma-ray telescopes are mainly based on large arrays of detectors which are expensive, necessarily complex, and take long time to build. A different approach is the use of detector with similar energy and

direction resolution, but small enough to be deployed on a nanosatellite.
We research[1] a solution based on a monolithic scintillator and a multipixel photon sensor. The first stage of our study is focused on characterising inorganic scintillators of $CeBr_3$ and 256 channel multianode PMT. The response of $CeBr_3$ was obtained with a single anode PMT. The energy resolution for different material thickness was obtained and compared. A prototype of a single layer detector with $CeBr_3$ scintillator and a 256 channel multianode PMT was constructed exploiting 3D printing technology. The individual channel responses of the multipixel photon detector coupled to the $CeBr_3$ scintillator are being studied. The current results and challenges will be discussed.

[1]The activities are performed at the University of Sofia and supported by the Bulgarian National Science Fund under contract DN18/17, project NDeGRA "Novel Detectors for Gamma-Ray Astronomy".

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 96

Development and imaging optimization of X-ray intraoral imaging sensor for dental tomosynthesis applications

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In recent years, digital indirect X-ray imaging sensors have been widely used in many dental imaging applications such as intraoral, panorama and dental CT. These digital indirect detectors are based on the utilization of a complementary metal-oxide semiconductor (CMOS) array with different scintillating screens such as CsI, Gadox. Currently, a CMOS-based indirect X-ray imaging sensor with high spatial resolution has been widely utilized for dental intraoral-imaging applications. Diagnostic accuracy in standard intraoral imaging is very low for many routine clinical tasks due to overlapping structures of teeth, bone, restorative materials in 2D images. Digital multi-projection imaging techniques such as digital tomosynthesis with several projections and full-rotation tomography with hundreds of projection have been developed for 3D image display in dental application.
In this work, we have designed and developed the high-resolution and high-sensitive CMOS imaging sensor for intra-oral imaging tasks with low-dose and high-speed. The sensor consists of CMOS array with a 10um x 10um pixel size and a 24mm x 33mm active area, and 10fps readout rate in high-definition mode and with a 20um x 20um pixel size and a 24mm x 33mm active area, and 20fps readout rate in binning mode respectively. Different scintillation materials such as FOS(fiber optic plate with CsI scintillator) and Gadox were used. The fiber-optic plate is a highly X-ray absorption material that minimizes the X-ray induced noise. Their design parameters were optimized for high X-ray imaging performance at low radiation dose condition.
For evaluation and optimization of the X-ray imaging characterization, a thallium-doped CsI(CsI:Tl) scintillator with 100-200um thickness and Gadox screen with 50-70 um thickness were directly coupled on the CMOS photodiode array. The X-ray imaging performance such as the light response to X-ray exposure dose, signal-to-noise-ratio (SNR) and modulation transfer function (MTF), image lag etc. were measured under practical dental imaging systems with 70kVp tube voltage and 2mA tube current.

CMOS, ASIC, chair: George Fanourakis / 97

Prototype single-ended and differential charge processing circuits for micro-strip silicon and gaseous sensors read-out

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Read-out electronics for High-Energy Physics Experiments as for example Compressed Baryonic Batter experiment at FAIR, Darmstadt, Germany, should meet tight requirements concerning noise (ENC < 1000 e- rms to guarantee proper measurements of charge), power consumption (< 10 mW/channel) and high average input hit frequency (250 kHit/s/channel) 1. The ICs design should take into account not only the charge processing parameters but also the impact of the environment like radiation, noisy power supply and temperature to ensure reliable and stable operation during experiment in a system built with tens of thousands of devices.
The operation with gaseous detectors require protection of the inputs against electrostatic discharge. The ESD protection circuit together with the sensor itself or decoupling capacitors (after irradiation) can be however a source of additional leakage current flowing into the first stage of charge processing chain and contributing to the overall system noise [2]. The read-out electronics (in particular first stage – charge sensitive amplifier, CSA) and detector related noise can be mitigated using proper filtration and signal shaping. However, noise introduced by external sources, like power supply interference can not be limited only via proper shaping and filtration. When no LC filtering is possible (due to high magnetic fields) it may be beneficial to use differential or pseudo-differential signal processing [3].
The purpose of this work was to test several ideas to improve noise performance and to make the architecture of charge processing chain configurable to better adapt to varying target radiation imaging applications. The ASIC comprises four single-ended and four pseudo-differential signal processing channels. In both types of channel configurable slow shaper configuration is used – it is switchable CR-RC2 type shaper and complex conjugate poles 3rd order shaper. CSA feedback in single-ended architecture can be selected between MOS transistor working in linear region and double-polarity Krummenacher circuit for leakage current compensation capability.
The chip was designed and fabricated in Q3 2018 using 180 nm process. Front-end single-ended and differential channels occupy area from 950 x 60 um2 up to 1150 x 125 um2 and consume 4.5 up to 10.5 mW of power respectively. The work presents design and measurements results.

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Dosimeters, Neutrons, chair: Ulrich Parzefall / 99

Detailed analysis of quasi-ohmic contacts to high resistive GaAs:Cr structures

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Proper choice of contact material leads to reduction of leakage current, increase of X-ray penetration coefficient, when so-called transparent contacts are used, and increase of noise to signal ratio 1.

This work is dedicated to investigation of quasi-ohmic contacts behavior in the system "Me-GaAs:Cr-Me". AuGe metallization was made by means of electron-beam deposition. Chromium compensated GaAs samples of different thicknesses in the range of 250-1000 μm were tested. Investigation was carried out under various temperature conditions. The results of current-voltage dependence measurement give an overview of the current transport model in such structures and allow to calculate concentration of deep level impurities.
The work was financially supported with grants of RSF # 18-44-06001 (TSU, Russia) and HRSF-0004 (DESY, Germany).

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X-Ray, Timepix, chair Seppo Nenonen / 100

Gamma and X-ray imaging with Timepix3 pixel detectors: Spectrum and image reconstruction using subpixel hit mapping and depth of interaction determination

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The gamma or hard X-ray imaging systems are often used in various application fields such as: medical imaging (radiography, tomography, scintigraphy, SPECT, PET), non-destructive testing, environment protection (nuclear waste storage, radiation monitoring), back-scatter imaging etc. The common effort in all these applications is oriented towards a maximal reduction of radiation dose preserving good quality of images. The key property in this direction is sensitivity of detection system and its ability to record maximal information for each detected radiation quantum (e.g. gamma photon). In this sense the Timepix3 type detectors are nearly optimal.
The state-ot-the-art particle tracking hybrid detectors of Timepix3 type have excellent properties: High granularity (256 x 256 pixels with pitch of 55 μm), spectral and temporal sensitivity. These detectors can be coupled with high-Z sensors such as CdTe, CZT or GaAs for imaging applications with gamma or hard X-rays where the scintillator based imagers have dominated so far.
Very small pixels of Timepix3 detector of 55 μm connected to relatively thick CdTe or CZT sensor (2 mm) present very interesting combination: The ionization charge created by interacting gamma photon expands significantly during the charge collection process causing so called charge-sharing effect when multiple pixels (cluster) react to single photon. This effect is considered as negative in most cases since it causes image blurring and degradation of spectrum quality. If properly understood and modelled the charge-sharing effect can be used in positive way: The hit position with subpixel precision including depth of interaction can be determined, the influence of incomplete charge collection can be reduced as well as charge loses due to nonzero threshold energy in border pixels of the cluster. This way the image and energy spectrum are reconstructed. The reconstruction method is based on comparison of measured data to theoretical model.
The proper function of image and spectrum reconstruction method will be illustrated using several practical examples.

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MÖNCH 04, a tool for the development of a fine pitch, low energy hybrid pixel detector for applications at the SwissFEL

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MÖNCH 1 is a hybrid silicon pixel detector based on charge integration and with analog readout, featuring a pixel size of 25x25 μm2. The latest working prototype (MÖNCH 03 [2]) consists of an array of 400×400 identical pixels for a total active area of 1×1 cm2. Its design is optimized for the single photon regime. The chip has an ENC in the order of 35 electrons RMS and a dynamic range of ˜4×12 keV photons in high gain mode, which increases to ˜100×12 keV photons with the lowest gain setting.
Thanks to its low noise, MÖNCH can be used for soft X-ray detection below 1 keV [3]. In particular, we want to develop a detector for the ATHOS beamline, in construction at present at the Swiss Free Electron Laser (SwissFEL), with a minimum operating energy of 250eV with an extremely high photon flux. However, the architecture implemented in MÖNCH03 does not provide enough dynamic range for applications at the SwissFEL and a lower noise would be desirable to achieve single photon resolution at lower energies. For this reason, a new large area prototype (MÖNCH 04) was designed and is at present in production, to be able to test different approaches to get to the required specifications: energy sensitivity down to at least 500eV, single photon resolution down to 800eV and a dynamic range of at least 10000 x 800eV photons.
The chip has the same size and periphery of MÖNCH03 but contains 19 different test variations, each one spanning 1 or 2 supercolumns (i.e. 1 or 2 times 25x200 pixels). These include different gain combinations of the preamplifier and the correlated double sampling (CDS) circuitry, different type and dimensions of the storage capacitors, additional signal filtering, plus special pixels without CDS but more storage capacitors to perform off-pixel correlated multi sampling. Most importantly, several architectures contain different implementations of dynamic gain switching circuitry, where the pixel is able to dynamically change its gain to a lower value if the input charge is exceeding a given threshold.
The most important test variations will be described, including the possible benefits that they could bring when employed in the final full size chip (˜2x3 cm2) planned for 2021.
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Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 103

SiC based charged particle strip spectrometer with neutron detection capability

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Silicon carbide (SiC) devices have gained much attention owing to their superior characteristics that make them high-temperature, and radiation-hard applications. The advantage of SiC arises from its unique combination of electronic and physical properties such as wide band-gap, high breakdown electric field strength, high saturated electron velocity, and high thermal conductivity. The wide

band-gap results in low intrinsic concentration and radiation hardness. The low intrinsic concentration determines low device leakages at high temperature. The high breakdown strength allows SiC devices to operate at much higher voltages.
Aim of this publication is to present current status of charged particle spectrometer based on SiC strip detector. The sensor is made of 4H−SiC (α-SiC) hexagonal crystalline structure material which manifests good spectroscopic characteristics for charged particle detection similar to standard silicon diode (20 keV FWHM with 5,4857 MeV 241Am alpha particle). To obtain sensors for charged particle detection out of SiC bulk material we created Schottky contacts on top and Ohmic contact on the bottom. Preparation of the contacts will be discussed alongside electric characterization of the sensor material. Moreover, results of charged particle detection, photon detection and detection of thermal neutron detection (after neutron converter deposition) and fast neutron detection will be presented. Particle detection capabilities were tested using standard NIM spectroscopic chain (sensors, preamp, spectroscopic amp and ADC). Moreover, the SiC sensor material was attached to VATA GP8 based 128 strip readout to form handheld spectrometer which will be demonstrated.

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PERCIVAL: possible applications in X-ray micro-tomography

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X-ray computed micro-tomography (μ-CT) is one of the most advanced and common non-destructive techniques in the field of medical imaging and material science. It allows recreating virtual models (3D models), without destroying the original objects, by measuring three-dimensional (3D) X-ray attenuation coefficient maps of samples on the (sub) μm scale. The quality of the images obtained using μ-CT is strongly dependent on the performance of the associated X-ray detector i.e. to the acquisition of information of the X-ray beam traversing the patient/sample being precise and accurate. Detectors for μ-CT have to meet the requirements of the specific tomography procedure in which they are going to be used. In general, the key parameters are high spatial resolution, high dynamic range, uniformity of response, high contrast sensitivity, fast acquisition readout and support

of high frame rates. At present the detection devices in commercial μ-CT scanners are dominated by charge-coupled devices (CCD), photodiode arrays, CMOS acquisition circuits and more recently by hybrid pixel detectors. Monolithic CMOS imaging sensors, which offer reduced pixel sizes and low electronic noise, are certainly excellent candidates for μ-CT and may be used for the development of novel high-resolution imaging applications. The uses of monolithic CMOS based detectors such as the PERCIVAL detector1 are being recently explored for synchrotron and FEL applications. PERCIVAL was developed to operate in synchrotron and FEL facilities in the soft X-ray regime from 250 eV to 1 keV. Despite its low quantum efficiency, PERCIVAL could offer all the aforementioned technical requirements needed in μ-CT experiments. In order to adapt the system for a typical tomography application, a scintillator is required, to convert incoming X-ray radiation into visible light which may be detected with high efficiency. Such taper-based scintillator was developed and mounted in front of the sensitive area of the PERCIVAL imager.
In this presentation the setup of the detector system and preliminary results of first μ-CTs of reference objects, which were performed in the Tomolab at Elettra, will be reported.

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Timepix,Micromegas, chair: Bernd Schmitt / 106

Miniaturized Fully Spectroscopic Radiation Camera based on Timepix3 chip for tracking of radioactive sources and monitoring of space weather

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The excellent features of the state-of-the-art particle tracking hybrid detectors Timepix3 have been already shown. They are namely: High granularity (256 x 256 pixels with a pitch of 55 μm), spectral and temporal sensitivity. These detectors can be coupled with high-Z sensors such as CdTe, CZT or GaAs. The Timepix3 properties allow for suppression of secondary radiation generated inside of high-Z sensors (CdTe) such as internal XRF or Compton effect.

The new simplified, miniaturized and networkable version of Timepix3 based detector was developed under the name MiniPIX TPX3. The main parameters are: low power consumption, low weight, the possibility of local data processing of every detected particle (integrated ARM CPU and FPGA), all in a size of a bit larger USB flash drive.

Thanks to its flexibility and small size, it perfectly fits for the monitoring of tight and/or complicated radiation environment. Extended with suitable collimator makes it a perfect small-sized gamma camera. These are all reasons why this solution was chosen for ongoing projects (observation of migration of the radioactive sources in the soil or particle tracker for the monitoring of the space weather).
The features of MiniPIX TPX3 with various sensor materials and thicknesses were tested and evaluated in terms of spectral sensitivity, long term stability, and imaging performance. Special effort was spent to test gamma camera with various kinds of pinhole/multi-pinhole collimators

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 107

Analogue and digital approach of gas gain in Ne – CO2 mixtures.

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CO2 is widely used as the quenching agent in detectors used in high-energy physics due to its good features of stabilizing the electrons avalanche development. Also, the life time is two orders of magnitude higher than for mixtures with an organic quenching agent. In detectors used for precise measurements of particle tracks (i.e. vertex detectors)with an accuracy of less than 50 μm, CO2 is increasingly used. This gas is characterized by a large active cross-section to inelastic electron scattering, which causes that the characteristic energy of electrons and their drift velocity are small, which improves the spatial detector resolution. Other important features of CO2, especially important in large particle detection systems is its non-flammability and low price. This mixture was and still is intensively examined to fully understand the physical processes occurring in them. In previous works a model of physical phenomena in detector was created. On the basic of this model an analytical formulae describing the gas amplification were obtained. These formulae contained two or three constants characteristic for the mixture to be determined experimentally. Nowadays, we use Monte Carlo algorithms to study the phenomena occurring in gas detectors. In this work we want to use both analytical formulae for gas amplification as well as the Monte Carlo methods for the analysis of the measured data.

X-Ray, chair : Heinz Graafsma / 108

Digital Integration: a novel readout concept for XIDER, an X-ray detector for the next generation of synchrotron radiation sources

Authors: Pablo Fajardo[1]; Paolo Busca[1]; Florian Erdinger[2]; Peter Fischer[2]; Marie Ruat[1]; David Schimansky[2]

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The core of this contribution is the *digital integration* concept, a novel readout scheme for the front-end of 2D pixelated detectors. By using this concept, the XIDER project, an ongoing collaboration between the ESRF and Heidelberg University, aims at implementing a fast high dynamic range detector optimised for high energy scattering and diffraction applications at the upcoming generation of diffraction limited synchrotron radiation facilities.

The digital integration readout includes features found in both current photon-counting and charge-integrating devices and is particularly suitable for X-ray detectors that need to operate with very high photon flux, under strong pileup conditions, and have to provide high sensitivity with noise-free effective operation. One of the advantages of this concept relies on the ability of continuous cancellation of the dark current contributions even if they are not stable or fluctuate in time. This opens the possibility of building integrating detectors able to operate at high duty cycles, including continuous beam, with high-Z compound semiconductor sensors, a major challenge for future detectors for the upcoming synchrotron sources.

In the first phase of the XIDER project different implementations of the new readout scheme are being evaluated and compared. The first prototypes have been designed with CdTe sensors and readout electronics based on TSMC 65nm technology. The ongoing work is not only a proof of the new concept but also a necessary step towards the development of the full XIDER system, one of the main strategic instrumentation developments for EBS, the ESRF Extremely Brilliant Source. This new storage ring, currently under advanced construction, will be the first high-energy fourth-generation synchrotron facility worldwide. If exploited with high-performance and tailored instrumentation, the highly brilliant and coherent beams produced by ESRF-EBS will make possible new research opportunities in many different fields of research.

SiPM, High -Z, chair: Roelof de Vries / 110

Latest Developments in KETEK's Silicon Photomultiplier Solutions

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KETEK provides silicon photomultiplier (SiPM) detectors for many years now. Besides single channel SiPM sensors, KETEK has developed several customized, easy-to-use and integrated products for many applications.

The new WB-series of Silicon Photomultiplier features a cost efficient, robust and reliable package, which is also MR compatible. Noise parameters have been minimized and the detection efficiency has been improved. In addition to WB-series SiPM with a 3x3 mm² active area, the SiPM WB-series is now also available with a 1x1 mm² active area. This compact SiPM is ideal for high resolution arrays and features the same robust chip package.

KETEK developed and improved highly competitive multi-channel array solutions with optimized fill factor. Besides SiPM arrays consisting of 64 channels with 3x3 mm² each, we show a high-resolution array of 64 SiPM with 1x1 mm² per channel. Furthermore, custom array solutions can be integrated in this concept as well.

Based on the SiPM technology we established integrated modules. For detection with ultra-low noise effects KETEK shows a SiPM module in TO8 housing with integrated TEC cooling and NTC sensor.

Besides the easy-to-use evaluation kits with preamplifier and bias source we present an integrated module as a cost-effective replacement of photomultiplier tubes. It includes a transimpedance amplifier and a bias voltage controlling function. Moreover, it offers a high dynamic range, single photon detection capability and is compatible to standard optics mounts. The output signal can be fed directly into the DAQ without further pre-processing.

KETEK is constantly developing new solutions and improving the current detectors. We will give an outlook on our research and development activities and on future products.

SiPM, High -Z, chair: Roelof de Vries / 111

Preliminary characterization of a pixelated CZT gamma ray spectrometer

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The SRE3020 is a camera module for X-ray and gamma spectroscopy which can be used in a variety of applications, such as radiation hot-spot location, isotope identification, nuclear power plant monitoring, or compton scatter collimation. The module is mounted with a single cadmium zinc telluride

(CZT) sensor with the dimensions of 20×20×15 mm^3. The sensor readout is pixelated, and it consists of array of 11×11 pixels (121 pixels in total). We present basic characterization of this assembly: (1) characterization of the readout electronics; (2) calibration procedure; (3) spectral response to various radionuclide and calibrated X-ray sources, and (4) fluence rate response of the camera. We also discuss the possibilities of using the setup as a Compton camera.

Acknowledgement:
The research leading to these results has received funding from the Ministry of Education, Youth and Sports of the Czech Republic and the Research Council of Norway within subprogram Eurostars-2 under Project Contract no. MSMT-8179/2017-1.

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 113

Characterization of Sintef 3D diodes with trenches geometry before and after neutron irradiation

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Detectors with high radiation tolerance and high time resolution are required for charged particle in high physics and space applications.
3D detectors were introduced by S. Parker 1 in the middle 90' and they represented a starting point for evolved device able to work at fluency up to $2 \times 10^{16}\ n_{eq}/cm^2$. A limit to 3D detector is the not uniformity of electrical field that translates in a not uniform charge collection efficiency after high radiation doses and an uneven timing for the signal.
Different solution has been proposed in the last decade (eg. Hexagonal geometry of the electrodes) but many TCAD device simulations suggest parallel trenches as best solution [2]. Two different geometries have been taken into consideration both with parallel trenches. The distance between trenches of opposite sign is 25 μm in both case and the distance between trenches with equal sign is fixed to 50 μm. The main difference is trenches length that is respectively of 100 μm and 50 μm. They have been designed and fabricated by SINTEF MiNaLab, Oslo, Norway on SI-SI, high resistivity, float zone substrates (6–12 kΩ cm) with an active thickness of 100 µm.
The neutron irradiation of the sensors has been carried out at the TRIGA Mark II reactor at JSI (Ljubljana, Slovenia) in May 2018 and the characterization was performed afterwards.
The functional characterization has been performed by using a position resolved laser and by using a setup designed for this type of measurements.
The radiation source is a pulsed laser with a wavelength of 1064 nm that allow a quasi-uniform release of charge in the silicon substrate and a nominal pulse of 40ps. The laser source is integrated in a microscope optics that can be moved in the 3 axes with a precision on the micrometer range. In additional, the detectors are located in a vacuum chamber that avoid problems related to the humidity/hoarfrost when the detectors works at low temperature. The detector is connected by using two tungsten micro-needles connected to the readout circuits.
The results are two-dimensional maps of the signal across the 3D single basic cell. The measure has been repeated for different voltages and temperature.
The data are then normalized to the signals acquired on non-irradiated samples.
At the conference we will report on the device design and technology, as well as on selected results from the electrical and functional characterization.

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XFEL, chair: Ralf Menk / 114

The first DSSC 1-Megapixel Camera for the European XFEL

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The DSSC 1-Megapixel Camera was developed for photon science applications in the energy range between 0.25 keV and 6 keV at the European XFEL in the Hamburg area in Germany. The first complete 1 Megapixel DSSC camera 1 is now available (see Figure 1), fully tested and installed at the Spectroscopy and Coherent Scattering (SCS) instrument. The detector system is at the moment the fastest existing 2D camera for soft X-rays.
The recently assembled camera operates at a maximum frame rate of 4.5 MHz and allows one to cope with the very demanding pulse time structure of the European XFEL: bursts with 2700 pulses spaced by 220 ns at a rate of 10 Hz.
The DSSC detector is based on Si-sensors and is composed of 1024 x 1024 hexagonal pixels for a total active area of 210 x 210 mmˆ². The pixel arrays are subdivided into 16 ladders with 128 × 512 pixels each. Every detector ladder is bump-bonded to mixed signal readout ASICs [2]. The ASICs, comprising 64 x 64 channels, are designed in 130 nm CMOS technology and provide full parallel readout of the sensor pixels. Each ASIC channel is composed of an analog trapezoidal filter, a 8-bit ADC and an SRAM able to store up to 800 frames per bunch train. The detector is able to overwrite selected images stored in the memory in real-time, in case an event is tagged as non-valid by a veto signal provided by the XFEL machine.
The camera head electronics has to cope with a total data transfer of 144 Gbit/s for the 1-mega-pixel device.
This first mega-pixel camera is equipped with linear MiniSDD pixel arrays. Even if this sensor technology can provide only limited dynamic range, it has a very low noise level of around 70 el. rms at the full speed of 4.5 mega-frames/second. This performance has been demonstrated on the complete camera using a lab pulsed X-ray source and will be shown for the first time during this talk.
The challenge of having high-dynamic range (up to ˜ 10ˆ⁴ photons/pixel/pulse) and single photon detection simultaneously requires a non-linear response of the system front-end. This will be implemented in the second version of the DSSC camera. In fact, the entire DSSC system is designed in order to be compatible with both types of pixelated sensors, MiniSDD and DEPFET.
The ultimate performance is expected operating the DSSC camera with the DEPFET [3] pixel arrays that provide lower noise figures and signal compression at the sensor level. This allows one to achieve a dynamic range of several thousand photons at 1 keV, keeping at the same time single photon sensitivity.
At this stage of the project the complete camera has been tested, calibrated and is being installed at the SCS photon beamline. The first users' experiment of X-ray holography using ˜700 eV photons is foreseen by the end of May and it will be completed by the time of the talk.
We will give an overview of the DSSC system with its main components with special focus to the first results obtained with the first full Megapixel camera.
We will shortly discuss the realization of the second DEPFET-based DSSC camera. Results on DEPFET devices produced for the first time in a CMOS foundry will be shown together with the performance of the newly designed DEPFET version of the improved readout ASIC.

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Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 115

Topography and Angular Dependence on synchrotron soft XRF imaging

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Synchrotron based Low Energy X-ray Fluorescence (XRF) spectroscopy is one of the most widely used non-destructive techniques for elemental analysis in many fields; from biomedical to electrochemical. Even if XRF emission is an isotropic phenomenon, the specimen inhomogeneities may exhibit angular dependence. Despite the modern understanding of the technique, angular dependence artifacts remain an issue especially when using micro- or nano-X-ray beams and detectors located at small angles with respect to the sample surface. The more perpendicular the incident beam is with respect to the sample surface, the deeper the incident photons will penetrate inside the specimen. The higher the angle of incidence, the more the analysis will be limited to the sample surface. This is due to the progressive absorption of incident photons when traveling inside the sample. Although the angular dependence may be an advantage in some cases, when analyzing inhomogeneous samples with non-flat surfaces such as biological specimens with micro- or nano-beams, the sample topography and surface roughness play an important role and may cause misleading interpretations if not carefully taken into account.
This work presents certain relevant findings from a series of beamtime experiments in the spectromicroscopy synchrotron beamline TwinMic 1 in Elettra Sinctrotrone Trieste, Italy. The latest of these experiments use a novel SDD detector system [2] with a multi-element detection layout suitable for the topographical methods we have developed [3].

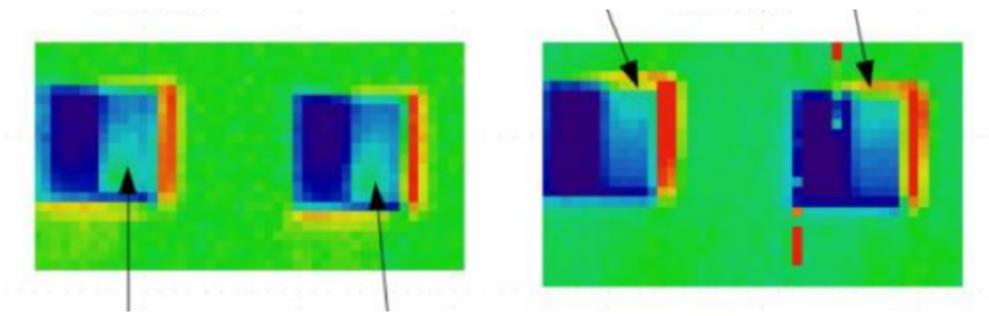

Figure 1: alt text

Figure 1. XRF maps showing Aluminum acquired from diametrically opposed detectors exhibiting angular detection artifacts and shadowing.

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LHC / 116

Operational Experience and Performance with the ATLAS Pixel detector at the Large Hadron Collider at CERN

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ATLAS is one of the four major experiments at the Large Hadron Collider (LHC) at CERN. It is a general-purpose particle physics experiment run by an international collaboration and is designed to exploit the full discovery potential and the huge range of physics opportunities that the LHC provides.
The tracking performance of the ATLAS detector relies critically on its 4-layer Pixel Detector, located at the core the ATLAS tracker. The ATLAS pixel detector consists of four barrel layers and a total of six disk layers, three at each end of the barrel region. The four barrel layers are composed of n+-in-n planar oxygenated silicon sensors at 33, 50.5, 88.5, and 122.5 mm from the geometric center of the ATLAS detector. The sensors on the innermost barrel layer (the insertable B-layer or IBL) are 200 µm thick, while the sensors in the other layers are 250 µm thick. At both ends of the innermost barrel layer, there are n+-in-p 3D sensors that are 230 µm thick. The innermost barrel layer pixels pitch is 50 × 250 µm2; everywhere else the pixels pitch is 50 × 400 µm2.
It has undergone significant hardware and readout upgrades to meet the challenges imposed by the higher collision energy, pileup and luminosity that are delivered by the Large Hadron Collider (LHC), with record breaking instantaneous luminosities of 2 x 1034 cm-2 s-1 recently surpassed.
The key status and performance metrics of the ATLAS Pixel Detector are summarised, and the operational experience and requirements to ensure optimum data quality and data taking efficiency will be described, with special emphasis to radiation damage experience.
By the end of the proton-proton collision runs in 2018, the IBL had received an integrated fluence of approximately Φ = 9 × 1014 1 MeV neq/cm2. The innermost of the three outer layers (B-layer) has been exposed to about half the fluence of the IBL, and lower fluences for other layers.
The ATLAS collaboration is continually evaluating the impact of radiation on the Pixel Detector. In particular, signs of degradation are visible but are not impacting yet the tracking performance (but will): a trend of decreasing charge collection, dE/dX, occupancy reduction with integrated luminosity, under-depletion effects with IBL, effects of annealing that are significant for the inner-most layers.
A quantitative analysis of all these effects will be presented and discussed, as well as the operational issues and mitigation techniques adopted during the LHC run and the ones foreseen during the LHC Long Shutdown 2.
In addition, the strategy to contain the readout bandwidth limitation will be discussed, required by the LHC over-performing.

Software, chair: Daniele Passeri / 117

Molecular Breast Imaging system with dual asymmetric detection heads for early breast cancer diagnosis

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ABSTRACT
Introduction: Breast cancer is the most common cancer in women. Early detection of breast cancer is a crucial aspect for an effective therapy. Mammography (MMG) is the most used technique for screening, able to identify small-size tumours at the early stage; nevertheless MMG showed reduced performance in case of dense breast. Magnetic Resonance Imaging, Ultrasound and Molecular Breast Imaging (MBI) techniques have been proposed as complementary to MMG. MBI, based on the use of radionuclides and gamma camera, provides functional, specific informations, particularly appropriate to dense breast 1. It may represent a promising support to mammographic screening, thanks to its potential better sensitivity and specificity.
Materials & Methods: In order to maximize the Signal to Noise Ratio (SNR) and spatial resolution in a MBI image, a new compact system (figure 1), consisting of a two asymmetric (different geometries and collimations) detectors, has been developed [2]. The two detector heads face each other in anti-parallel viewing direction, either mildly compressing the breast between them and allowing spot compression, to increase efficiency and SNR, or performing Limited-Angle Tomography (LAT).
Figure 1. The MBI prototype. Spot-compression (A): PMMA breast-phantom (C, inside tumoral lesions) is resting on the big detectors (LH) and the small one (SH) points the lesion moving on the phantom. LAT (B): MBI system is vertically arranged, the LH and phantom are fixed and the SH rotates around them over an arc.
A full scale prototype based on matrices of Position Sensitive Photo-Multiplier Tube (PSPMT), coupled to segmented NaI(Tl) scintillators with parallel and pin holes optics has been constructed to test different design solutions, and evaluate the expected performances. Monte Carlo (MC) simulations using the GATE (Geant4 based) framework have been performed to evaluate the best detector configuration, in terms of sensitivity and spatial resolution, and to evaluate data and image processing solutions; the detectors provide somehow complementary planar images that shall be properly combined (fused) to get enhanced, diagnostic information with high specificity and sensitivity. A dedicated breast-phantom (figure 1.C) simulating a woman breast, with up to four, moveable, spherical tumours of different sizes, was used.
Results and Outlook: Preliminary outcomes on lesion detectability shows approximative 5 mm diameter as lower limit, confirmed by MC. Good correspondence of reconstructed and real tumor depth was found in LAT modality: trade off between larger span and number of view, clinical session time and complexity need to be evaluated. The analysis of simulated and real data is ongoing with the aim to optimally exploit the MBI images in the different procedures and eventually combine them to the mammographic/tomographic outcomes. In parallel, the migration from PSPMTs to segmented Silicon PhotoMultiplier has recently started. After a description of the system, we will present the results of the performed measurements, in different modalities, including comparison with MC simulations and the LAT, at different lesions positions and with a diagnostic range of uptakes. Status of the analysis of the optimal MBI and mammographic image fusion as well migration to SiPM will be also reported.
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Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 118

Development of a characterization set-up for testing position sensitive silicon micro-strip sensors at the University of Delhi

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The silicon strip sensors are heavily employed in the high energy physics experiments owing to their excellent performance in tracking and vertexing of incoming particles in the radiation environment. However, as these sensors have to be operated in intense radiation environment with unprecedented luminosity, they would undergo both surface and bulk radiation damage. The requirement of operation of these sensors in such radiation environment imposes stringent constraints on the design parameters and so the production of a large quantity of sensors demands for a quality assurance scheme. The quality assurance scheme, in general, consists of measuring various sensor design parameters, viz. total sensor leakage current, backplane capacitance, strip leakage current, poly-silicon resistance, interstrip resistance, coupling capacitance, interstrip capacitance, and dielectric current in temperature and humidity controlled environment. The sensors are then accepted or rejected based on the constraints offered by a specific experiment.
Our Group at the University of Delhi is in the process of establishing a characterization system, for the first time in India, for testing a large array of silicon micro-strip sensors. A set of electrical characterization units, capable of providing 3000 V and measuring pico-Ampere currents and pico-Farad capacitances, are installed in the facility. Among other features, the probe station has a capability to translate in three directions, with a step size of 2 micro-meter over the range of 20 cm in XY directions. The entire system is interfaced through the Automated Characterization Suite (ACS) software and can be programmed in such a way that one does not need to intervene manually as it switches from one silicon strip to another. Several measurements involving currents, capacitances and resistances can be performed for the total, strip and inter-strip parameters. It is primarily envisioned to utilize the setup for the qualification of position-sensitive micro-strip silicon sensors for the CMS outer tracker in the high-luminosity LHC upgrade. In this work, we present the details of this characterization system and measurements performed on some silicon strip sensors.

SiPM, High -Z, chair: Roelof de Vries / 119

Timing Resolution of SiPM technologies before and after neutron irradiation

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Timing Resolution of SiPM technologies before and after neutron irradiation
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ABSTRACT
In recent years, silicon photomultiplier (SiPM) technology is getting attention from various applications due to its low cost, immunity to magnetic field, compactness and ruggedness. However, its applicability in experiments with harsh radiation environments is still limited due to lack of corresponding radiation damage studies. A typical 10-year lifetime operation in a typical Small Angle Neutron Scattering experiment 1 with an acceptable PDE degradation [2] has already been reported, and in this study, the timing resolutions of SiPMs before and after exposure with cold neutrons (5 Å) were compared. For this purpose, two analog SiPMs, developed by SensL and Hamamatsu, and a digital SiPM manufactured by Philips Digital Photon Counting were irradiated up to a dose of

6E12n/cm2 at the KWS-1 instrument of the Heinz Maier-Leibnitz Zentrum (MLZ) in Garching.
The used measurement system consists of a 403 nm Laser with a pulse width of 45 ps FWHM, and an oscilloscope (40 GS/s, 14 GHz) for data acquisition. During the characterization campaign, a time resolutions has been measured using ˜500 photon pulses impinging on the SiPMs, which were kept under constant temperature of 21 ℃. The first result of SensL SiPM show no significant difference in jitter values before and after irradiation up to a dose of 1.9E12 n/cm2. The performed tests provide an insight into feasibility of implementing SiPM based fast and efficient scintillation light detectors for applications such as neutron time-of-flight scattering experiments.

CMOS, ASIC, chair: George Fanourakis / 120

Characterization of the IBEX ASIC for Electron Detection

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Hybrid Photon Counting (HPC) detectors revolutionized measurement methods and data collection strategies at synchrotron facilities and laboratories over the last 10 years thanks to key features such as the absence of readout noise, high photon flux capability, high dynamic range and high framerate. Similar advantages are expected to be directly transposed to the field of electron detection, e.g. in the context of Transmission Electron Microscopy (TEM). The high dynamic range and the fast read-out are of great advantages for in-situ Electron Microscopy and Materials Science techniques where the typical solid-state sample or nanostructure can tolerate high electron flux. In electron diffraction experiments is then possible to get an accurate count rate from both the un-scattered beam and the weaker Bragg spots without damaging the detector. Low noise and single electron counting capability, on the other hand, are extremely beneficial in the field of life science where sample damage requires the accurate detection of weak signals.
In order to assess the electron detection performance of a hybrid pixel counting detector, we characterize an EIGER 1M detector in a TEM microscope. The detector is based on the IBEX ASIC and the sensor material is silicon, 450 µm thick, with a pixel size of 75 µm. The calibration is performed with X-rays in the range 8-75 keV and the explored electron energies are in the range 20-300 keV
Images taken with a high statistic flat-field illumination show a high count homogeneity with sigma of about one percent. The electron energy spectra show one main peak at the electron energy down to energies of 30 keV. The average cluster size (event multiplicity) increases for higher energies and for lower threshold energies. The measured multiplicity reaches a value of 3.5 at 300 keV at a threshold energy of 20 keV.
The imaging properties are evaluated at different beam energies and thresholds through the Modulation Transfer Function (MTF) and Detective Quantum Efficiency (DQE) and compared with simulations.
The IBEX retrigger technology, originally developed to cope with the very intense X-ray beams available at modern synchrotrons, also allows for very high count rates (up to 10 Mcts/pixel/s) in the case of electron counting. Moreover, long-term exposure at high fluxes up to $2.6 \cdot 10^6$ electrons/pixel/s over a spot of about 8000 pixels has a stable behavior. A very high level of radiation tolerance is measured with 300keV electron beam: no count variation on a flat-field image is observed after 10min of irradiation at fluxes of about $250 \cdot 10^6$ electrons/pixel/s.
For the correct interpretation of our first experimental results, experimental data are complemented by Monte Carlo simulations based on FLUKA – a multi-particle transport simulation tool developed at CERN. In the contribution, we present the simulation workflow and illustrate how the comparison between measurements and simulations yields a very high degree of consistency.
Based on these first encouraging results, we prove the suitability of the IBEX (Bochenek et al., 2018) Hybrid Pixel Counting technology for electron detection and we believe that it has the potential to be the next successful paradigm for many applications in the field of electron microscopy, such as small molecule electron crystallography (Grüne et al., 2018; Heidler et al., 2019).

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GaAs, Diamond, TPC, chair : Nicola Guerrini / 121

Time response of avalanche photodiode based on GaAs/AlGaAs with separated absorption and multiplication region

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In order to tackle current and future challenges in photon science it requires novel concepts of ultra fast photon counters. Especially for photon pulses with ultra-short durations at short wavelengths as delivered currently by synchrotrons and free electron lasers his leads to a demand for hard X-ray detectors providing sufficient time resolution to exploit the potential of such ultra-short pulses in time-resolved investigations.
Although silicon avalanche photodiodes and silicon photomultipliers represent the cutting edge of detection in some ultrafast experiments their main drawback is their low detection efficiency for high- energy radiation. Therefore, we have fabricated an avalanche photodiode based on GaAs/AlGaAs providing increased absorbance when compared to their silicon based counter parts due to their higher atomic number. As a consequence a much thinner absorption layer is sufficient to obtain the same or higher quantum efficiency as in silicon, resulting in an improved time resolution.
The devices presented in this work have been grown by MBE and they comprise an absorption region separated from a multiplication region by a p-doped layer of C atoms.
Here we report on the timing performances together with the signal-to-noise characterization of two devices featuring different concentrations and thicknesses of the carbon layer, a δ layer of 2.5·1012 cm -2 and a 50-nm-layer of 6·1012 cm-2 of C atoms, respectively. In particular, these devices have been tested with the 10-ps pulses delivered by a 510-nm laser with a repetition rate of 40 MHz at room temperature, achieving response rise-times as short as few tens of ps .

Silicon, Pixel, chair: Val O'Shea / 124

Test beam characterization of irradiated 3D pixel sensors

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Due to its large instantaneous luminosity, the future HL-LHC upgrade is going to set strong requirements on the radiation hardness of the CMS detector inner tracker. The 3D pixel technology, with its superior radiation hardness, complies with these extreme conditions.

A full study and characterization of pixelated 3D sensors fabricated by CNM and FBK is presented here. The sensors were bump bonded to the RD53A and ROC4SENS readout chips and measured at several LHC SPS and DESY test beams. Results on hit efficiency, cluster size and hit position residuals for fresh and irradiated samples are presented. The response against bias voltage and temperature is also considered.

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 125

Super-resolution X-ray imaging with a hybrid pixel detector

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With increasing demand for high-resolution X-ray images, the super-resolution method allows to estimate a single high-resolution image from several low-resolution images. Hybrid pixel detectors provide high-quality and low-resolution images, which makes them particularly well suited for super-resolution. However, such detectors consist of a limited number of pixels at high cost.

Applying super-resolution with hybrid pixel detectors shows that it is a viable method to achieve high-resolution images. Since hybrid pixel detectors have a square point-spread function of 1 pixel, the estimated super-resolution image shows almost no blur making such detectors the ideal choice for the application of super-resolution X-ray imaging.

Utilising an X-ray source, which allows magnetic stepping of the X-ray spot, several slightly shifted images can be obtained without requiring mechanical movements. Registering the shifts between individual images with sub-pixel precision allows to estimate a high-resolution image. With repeatable and equally spaced X-ray spot position patterns, sufficient information can be obtained with only a few images. In this paper, we present the application of super-resolution for X-ray imaging and single-shot phase-contrast imaging using a Pilatus 100K hybrid pixel detector from Dectris Ltd. and a prototype microfocus X-ray Source from Excillum AB. Moreover, we analyse the image quality and discuss the required pre- and post-processing for applications in X-ray radiography and tomography.

Using a sufficient number of low-resolution images allows us to achieve an increase in resolution, without introducing significant blur or artefacts into the image. However, different methods of image interpolation and pre-processing of the low-resolution images will affect the super-resolution image. Further, the quality of the estimated high-resolution image and thus the required post-processing also depends on the relative image translation on the detector, the number of images.

Dosimeters, Neutrons, chair: Ulrich Parzefall / 126

Performance Evaluation of Multi-Array Plastic Scintillation Detector using Static and Dynamic Source Conditions

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Radiation portal monitor systems have been deployed to monitor the inflow or outflow of illegal radionuclides at border crossings world widely. Large-sized plastic scintillation detector has been commonly used for RPM system, but due to the components of the plastic scintillator are carbon and hydrogen, which are low Z-number material, it has poor energy resolution that shows the broad Compton edge area from Compton scattering rather than a clear peak from photo-electric effect in the measured energy spectrum, identifying the illegal radionuclides from numerous cargos is very challengeable. Therefore, we proposed a minimized and multiply arranged plastic scintillation detector to improve the detection efficiency of the plastic scintillation detector and evaluated the

performance of the detector using radionuclides sources.
The detector consists of a total of 14 hexagonal pillar plastic scintillators with a diameter of 24 cm and a thickness of 15 cm, and each scintillator has a PMT attached to the back center. The energy spectra were measured to evaluate the performance of the detector. And radiation sources used for evaluation were 137Cs (8.6, 74.6 μCi) and 60Co (6.6, 13.2 μCi) with activities corresponding to international spectroscopy criteria for the RPM system for both static and dynamic conditions. Sources were individually measured under static condition 20 times repetition for one to ten seconds 2.5 m from the center of the detector for static condition. 137Cs and 60Co were measured individually with 10 times repetitions in 10, 20, and 30 km/h using a vehicle to measure the energy spectra under dynamic condition criteria.
The energy spectra measured with static sources showed narrower half-width at half maximum (HWHM) Compton edge area by 26.32% and 29.85% from the energy spectra measured with large-sizes plastic scintillation detector for 137Cs and 60Co. Compared to the large-sized plastic scintillation detector, the shape and size of individual scintillators of the multi-array system was changed and the number of the PMT was increased to 14. By this reason, the probability of generated light reaches the PMT increases, resulting in the improvement of energy resolution of the detector. Even though the measured energy spectra showed increased statistical fluctuation as the measurement time was shortened from ten to one second, the location of the maximum Compton edge energy was within the short range of 0.5% (0.002 MeV) and 3.5% (0.037 MeV) of the theoretical Compton edge energy for 137Cs (0.478 MeV) and 60Co (1.041 MeV), respectively. It is estimated that the Compton edge area of the spectra measured with this system shows a value almost equal to the theoretical Compton edge energy. In case of the energy spectra with dynamic sources, considering that the direction of the radiation incident to the detector changes continuously as the source moves, lower counts were measured compared to the spectra of the static condition measured during the time it takes for the sources to move.
In this study, the improved performance of multiply arranged plastic scintillation detector was evaluated using radionuclides with static and dynamic conditions. In addition, since the energy spectra from multi-array system showed emphasized Compton edge area than conventional system, the development of classification algorithm between artificial radionuclides and naturally occurred radioactive materials which have similar theoretical Compton edge energies (137Cs: 0.478 MeV – 226Ra: 0.412 MeV and 60Co: 1.041 MeV – 40K: 1.243 MeV) is expected with high accuracy using the multi-array plastic scintillation detector.

Software, chair: Daniele Passeri / 128

Accurate event localisation for pixelated direct electron detection using a convolutional neural network

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Modern pixelated electron counting detectors provided a giant leap in the use of cryogenic electron microscopy (cryo-EM) by structural biologists to study the structures of macromolecules and complexes thereof. Ideally, a detector for cryo-EM would give a list of position, time and energy of each individual electron that arrives at the detector surface with infinite accuracy. The ultimate direct-electron detector will have an ideal curve for both the detective quantum efficiency (DQE) and modulation transfer function (MTF), a large field of view, a large dynamic range and will be fast enough to record data at time scales during which stage drift is not an issue. The current range of commercially available direct electron detectors, while being a huge improvement over traditional film based or CCD solutions have a limited dynamic range, require long exposure times and do not reach ideal DQE and MTF figures. Moreover, their best results have only been obtained at 300 kV

and require exposure times up to a minute. There is a need for detectors that can be operated at a broader range of energies and at higher throughput.
The Timepix3 ASIC, in quad configuration, has a maximum output of 120 Mhit/s in a noise-less, data-driven readout mode and provides position, time and energy data for each hit with a time resolution down to 1.6 ns. In the past, Medipix ASICs were reported to be unsuitable for electron imaging at energies above 80 kV as those electrons would affect too many pixels. Here we show that the Timepix3 ASIC using a 300-500 µm silicon sensor layer can be used for EM applications both at low and at higher energies. Detectors have been mounted under a 200 kV FEI Tecnai Arctica microscope and 300 kV FEI Tecnai G2 Polara microscope. A per-pixel response calibration method was developed to correct for per-pixel differences in both the Time-over-Threshold and Time-of-Arrival output. Using the simulation package GEANT4Medipix the output of the Timepix3 ASIC was simulated for individual electron events. Global statistical characteristics of the simulated detector response are shown to be in good agreement with experimental results. Series of simulated digitised pixel output have been used to train a convolutional neural network (CNN) to predict the incident position of the electron within a pixel cluster. A second series has been used to evaluate the performance of the CNN: it is able to predict the point of impact of individual electrons with, on average, 0.39 pixel and 0.42 pixel accuracy for 200 keV and 300 keV electrons respectively.
By applying the CNN on experimental data the MTF of the detector at half Nyquist is improved from 0.30 and 0.05 to 0.65 and 0.70 for 200 kV and 300 kV respectively. We show that the entire dose-lifetime of a protein can be measured within a 1 second exposure. Preliminary data will be shown on how the Timepix3 can be used for cryo-EM single particle data acquisition.

Hardware, Applications, chair: Christer Frojdh / 129

Stratigraphy of the wooden painting utilizing back scattered photons

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Aim of the presented work is investigation of the wooden paintings (and medieval sculptures decorations) which is based on so-called polychromy. Polychromy consists of several layers in a variety of colors and elemental composition. It is also common that such artifacts have been renovated several times. Therefore, it is highly desirable to investigate the current status of existing polychromy.

It will be presented that x-ray back-scatter imaging can be utilized for exploration of the 3D depth profile of surface layers. Such technique can be applied regardless of volume of the object behind the investigated structures, as it was shown in 1 during investigation the honeycomb structure.

Experimental work was done with sheet shape beam with thickness 0.1 mm irradiating sample under low angle (6 Deg). Pinhole camera with single photon counting detector observing signal from the side (detector parallel with X-ray beam), see figure left for whole setup and top right for camera arrangement. Registered signal depends on scattered and XRF photons and drop down of the signal intensity is related with layer thickness, see figure right bottom. It was analysed in that color layer laying on the 10 mm thick wooden plate has thickness 25 micrometers in accordance with the technology of the sample preparation.

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 130

Quick turn-around ultrathin entrance window postprocessing of wafers and single dies …. a dream?

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Advances in pixellated Silicon sensors - be they hybrids or monolithic - are ubiquitous and rapid. More and more complex systems often take several development iterations before they reach maturity in the context of their often specialized applications. For some applications, namely measurements of UV or soft X-ray photons, or imaging of low- energy charged particles, an added challenge makes sensor development and fabrication more complex: absorption lengths or ranges well below a micrometer prevent sensors from even being tested, much less efficiently used, with the actual target radiation without complex additional "Post"-processing.

Methods to fabricate such ultrathin entrance windows have been established over the past decades, one of the most prominent examples is the MBE-based "delta doping" developed by NASA/JPL.
Community needs, in our perception, include quick turn-around access to processes such as this, allowing high-quality entrance window processing of wafers that can achieve single-nanometer passive layers - embedded in a process flow that can guarantee wafer thinning and lithography (e.g. for pad access) as needed.
Looking to the future, an easily accessible solution with a capability to post-process MPW-obtained single dies for rapid evaluation of prototype sensors in realistic environments would also assist sensor development.

We will present these ideas and needs, together with an overview of available options today insofar as we are aware of them (and will be only too happy if there are points where we have to stand corrected), and invite the community as well as exhibitors to a hopefully lively discussion.

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 131

Multi-energy X-ray imaging for high-Z elements identification

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Material decomposition of sample components can be performed using multi-energy or multi-threshold X-ray imaging. The hybrid semiconductor photon counting pixel detectors of the Medipix family are highly convenient for this application as they enable dual- or multi-threshold imaging (Medipix3) or fully spectral imaging (Timepix3). We have proven that various types of materials can be identified based on their material response extracted from two or more images measured with different thresholds.
The K-edge imaging method gives even more analytic approach to identification of a specific element within the unknown sample matter. It is based on the fact that there is a sudden increase of the X-ray absorption at certain energy (absorption edge), which is characteristic for given element. The exact implementation of this method depends on the type of sample and number of elements to be identified. Especially for high-Z elements, where also high-Z sensor material is required for efficient detection (e.g. CdTe), the K-edge imaging becomes difficult to implement due to high absorption combined with Compton scattering in both the sample and the detector as well as the X-ray fluorescence within the sensor material. The Medipix- and Timepix-based detectors take advantage of the possibility of suppressing the unwanted effects by suitable multi-thresholding or original spectra reconstruction.
We demonstrate the K-edge based identification of selected high-Z element within a material mixture. The sample is decomposed into components and the content of the selected element is calcu-

lated. The K-edge based approach can be used in many practical applications including inspection of element concentration within ore in the mining industry.

LHC / 132

Total ionising dose radiation damage studies of the RD53A chip for the ATLAS and CMS upgrades

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The planned upgrade to the LHC at CERN, known as the HL-LHC (High Luminosity Large Hadron Collider) is designed to maximise the physics potential through a sizable increase in luminosity. Consequently, with the increase in expected radiation damage, readout rates and granularity, a complete re-design of the current inner detectors at ATLAS and CMS are being developed.

The RD53 collaboration was set up jointly by the ATLAS and CMS communities to focus on the development of the next generation hybrid pixel chips to replace the innermost layers of the particle trackers using 65 nm CMOS technology. The collaboration has produced a prototype RD53A chip, evaluating three approaches to the front end implementation, which address challenges in expected hit rate, data output bandwidth, power consumption and radiation tolerance.

This presentation will focus on the Total Ionising Dose (TID) radiation damage studies performed on bare chips at the environmental conditions expected during normal operation at the LHC. To date, six RD53A chips have been irradiated to the TID fluencies between 100 and 1000 MRads, with the simulated levels in the innermost layers of the ATLAS and CMS pixel detectors at the end of their life time being up to 500 MRads. The study will show the details of the TID irradiation effects of the periphery electronics and all three front end designs implemented on the prototype chip, both at room temperature and at -25 ℃. The results from the study show promising performance beyond end-of-life ionising radiation doses with no severe degradation of the prototype chips. No significant changes in power consumption was observed up to 600 MRads. Noise increase was shown to be insignificant up to 500 MRads in all three front ends. The behaviour of the ring oscillators was also demonstrated to be consistent with simulations.

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Development of a high resolution Compton imaging system using position-sensitive solid-state gamma ray detectors

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The Compton imaging system, which is based on electric collimation, has been of great interest for nuclear medicine and molecular imaging applications [1, 2]. However, the performance of the imaging system is limited by the intrinsic spatial resolution based on the geometric size. To solve this

limitation, various methods have been suggested such as the pulse shape analysis and the digital signal processing.
In this work we developed a high resolution Compton imaging system and evaluated the performance of the system. The system is based on a Double–sided Silicon Strip detector (DSSD) with dimensions of 50 mm x 50 mm x 1.5 mm which consists of 16x16 orthogonal strips and a pixelated Cadmium Zinc Telluride (CZT) detector with dimensions of 5.9 mm x 5.9 mm x 5mm which has an array of 4 x 4 pixels. The system performance is simulated from the Monte Carlo method using a GEANT4 simulation toolkit and the list-mode maximum likelihood expectation maximization (MLEM) algorithm is used for the image reconstruction. In order to determine the interaction depth in the detector, pulse shapes of two detectors were digitally recorded with a 64-channel 62.5 MS/s digitizer (v1740B) manufactured by CAEN. By using coincidence data obtained for gamma rays emitted from a 22Na standard source, the energy spectrum and the reconstructed image were obtained and the efficiency of the system was estimated.

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GaAs, Diamond, TPC, chair : Nicola Guerrini / 134

Fabrication characterisation of 3D diamond detectors with a femto-second laser: Canceled

Authors: Ivan Lopez Paz[1]; Olivier Allegre[2]; Zhaoqing Li[2]; Alexander Oh[1]; Alice Laura Porter[1]; David Whitehead[2]

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3D diamond detectors constitute a promising design to improve the radiation hardness of the already radiation hard diamond detectors. This geometry is achieved by graphitising column-like electrodes inside the diamond bulk. The fabrication process is performed using a femto-second laser. In this work we show a systematic study of the characteristics of the electrodes fabricated in two CVD diamond samples (single and poly-crystalline), such as cross-section, graphitic content from Raman spectroscopy and resistivity, as a function of laser pulse energy, processing speed and beam polarisation.
Finally, the recent results of the development of a sensor characterisation set-up for diamond detectors via multi-photon absorption transient current technique is discussed.

X-Ray, chair : Heinz Graafsma / 135

Application of a general-purpose data acquisition and processing toolkit for hyperspectral X-ray detectors in spectral ptychography

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The framework for control and data processing of hyperspectral cameras, presented at iWoRiD 2018 1 has been further developed into a flexible general-purpose toolkit for multiple hyperspectral X-ray detector types. We now demonstrate the result of this continued development through a practical application in synchrotron-based nano-imaging, enabled by the toolkit.

The methods originally developed for use with the SLcam [2] at Ghent University have been generalised to work with any hyperspectral detector by exploiting the modular build-up. A small detector-specific software module extracts raw frames and publishes them in a network stream. This stream serves as input for the spectral processing framework, which converts the raw frames into a stream of photon events by applying the detector calibration files and performing charge-sharing corrections if required.
A comprehensive set of analysis and diagnostic tools is available to monitor detector and experiment performance, guarantee operation safety and generate the detector-specific calibration files required by the toolkit. The processing chain provides plug-in functionality for hardware- or detector-specific pre-processing of raw frames and post-processing or filtering of the photon event stream.
All functionality of the toolkit is split up into separate functional modules, which can be distributed over a large processing cluster if required for easy scalability, though a single contemporary workstation PC should suffice for data rates up to 4 Gbit/s. Additionally, all control and monitoring is also network-enabled for ease of operation and use by multiple simultaneous operators.

This toolkit has been applied during multiple recent beamtimes using two cameras: the pnCCD-based SLcam [2] and the higher-energy CdTe CMOS-based HEXITEC system [3]. During these beamtimes, both systems were used to perform single-shot hyperspectral ptychography at the I13-1 branchline at Diamond Light Source using a broadband pink beam. The performance, control and reliability of the toolkit proved to be instrumental in enabling this novel application of hyperspectral X-ray cameras.
The toolkit has further been tested using the HEXITEC Quad, a 2x2 tiled variant of the HEXITEC system, with additional detector systems being included in the near future.

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Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 136

Overview of the CMS BCML system and the potential of pCVD diamond detectors surface modification

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Beam luminosity increasing leads to the fact that undesirable deviations from the trajectory can lead to catastrophic consequences for any deflecting and measuring systems. To prevent such incidents, the BRIL team has developed the BCML system, which allows to dump the beam in a short time if a certain dangerous level of luminosity is exceeded. To this system the many requirements applying such as high radiation resistance, reaction speed and stability over time. In this poster, we examine the behavior of the BCML system during 2017 and perform a comparative analysis of various types of detectors, including experimental R&D samples.

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 137

Radiation hardness limits for semi-insulating GaAs detectors irradiated by 5MeV electrons

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Recent progress in the field of high energy physics and in space applications brings detector utilization in a radiation harsh environment where also high-energy electrons play an important role, like radiation belts of planets or the electron-positron collider foreseen as the ILC. We have been studying the radiation hardness of developed Schottky barrier semi-insulating (SI) GaAs detectors against 5 MeV electrons for a couple of years. The influence of cumulative dose up to 200 kGy on detection and electrical properties of detectors was published in [1, 2], were degradation of charge collection efficiency (CCE), energy resolution (FWHM) with decrease of breakdown voltage and reverse current were observed. However, the ability of SI GaAs detectors to measure spectra and distinguish energies was preserved. The investigated detectors were irradiated in 25 steps by now and a limit of their functionality was reviled to be 1000 kGy. The influence of cumulative absorbed dose on detection properties (CCE, FWHM, peak to valley ratio and detection efficiency) was analysed, with relation to detector applied voltage. The CCE has dropped down to 20%, the peak to valley ratio reached almost 1 and the FWHM increased to 40% at maximum applied dose. The spectrometric properties of detectors were determined from gamma ray spectra of 241-Am and 133-Ba depending on the detector reverse voltage. The electrical properties, the breakdown voltage and the reverse current were obtained from measured current-voltage characteristics of detectors. The breakdown voltage of detectors decreased to 60% of its original value and the reverse current was slightly lower also with decreased value of dynamic resistance. The investigated detectors were made of a bulk VGF (Vertical Gradient Freeze) SI GaAs grade of 230 μm thickness with the circular Schottky electrode made of Ti/Pt/Au (10/35/90 nm) multilayer on the top and a whole area quasi-ohmic metal electrode from Ni/AuGe/Au (30/50/90 nm) multilayer on the back side of the substrate.

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Hardware, Applications, chair: Christer Frojdh / 139

Characterization of active-edge detectors fabricated without support wafer

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Silicon radiation sensors typically have an inactive volume at the device periphery necessary to accommodate multiple guard-rings and current terminating structures necessary to deliver increased breakdown voltage and stability and to shield the active area from the defects induced by the dicing procedure.
The extension of the dead region can be as wide as a few mm, depending on the thickness and resistivity of the wafer as well as on the performance requirements for the sensor. There is a demand in both industrial and scientific communities for "edgeless" silicon radiation sensors where the insensitive edge area is reduced to a minimum. This would allow for the reduction of geometrical inefficiencies and for the seamless tiling of multiple sensors into matrices, to ensure large area coverage without distortions or missing data.
The need for "edgeless" detectors has initiated the efforts to engineer the state-of-the-art silicon radiation sensors in order to drastically reduce the dead periphery of the devices 1. The fabrication of edgeless radiation detector has so far been demonstrated at SINTEF, VTT, and FBK. The "edgeless" feature is realized by etching deep trenches around the active area of the sensor using deep reactive ion etching (DRIE) and by doping the trenches heavily to prevent the depletion region from reaching the damages induced by the etching procedure. In order to maintain the wafer integrity during and after the DRIE process, the device wafer is fusion bonded to a support wafer prior to DRIE, which, for most applications, must be removed after the sensor processing has been completed. The removal of the support wafer is very challenging, making this traditional approach far from ideal for productions with high yield and low cost.
At SINTEF we have recently developed a simplified method to fabricate edgeless sensors without the need for a support wafer. This method was conceptualized [2]. Instead of a continuous trench surrounding the active area of the sensor, a segmented trench is created, leaving enough silicon in place to ensure mechanical integrity without the use of a support wafer. We call this approach "perforated" edge (Fig.1). After doping of the trench segments, the unetched material between segments is doped by deep drive-in, thereby effectively forming a fully doped "wall" throughout the entire thickness of sensor. Once the wafer processing is completed, the edgeless sensors can be safely singulated using conventional saw dicing methods.
The sensors presented here, were fabricated on 300 μm thick, FZ high resistivity n-type wafers. The electrical characterization was performed using a manual probe station before and after dicing, on 5x5 mm2 edgeless diodes. The full depletion voltage as extracted from C-V measurements is ˜45 V. The leakage current at full depletion is < 100 pA, comparable to the leakage current of their counterparts with traditional guard ring edge termination. The breakdown voltage is still above 300 V even after dicing through the center of the trench segments, demonstrating that this novel edge termination can prevent edge-related early discharge. After dicing 10 μm inwards from the center of trench segments, the leakage current dramatically increases at 135 V as the depletion region is not shielded from the dicing region anymore.
We have successfully demonstrated a method for the fabrication of edgeless silicon radiation sensors with edge insensitivity of < 10 μm, without using a support wafer. This method is simpler, more cost effective, and delivers a higher throughput when compared to the traditional edgeless detector fabrication methods that have been previously demonstrated. At the conference we will present details on design, fabrication, electrical and functional characterization with focus on the signal efficiency and response uniformity of the edge termination of these newly developed edgeless detectors.
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X-Ray, Timepix, chair Seppo Nenonen / 140

ePixM: a fully-depleted active pixel sensor for soft X-ray experiments at high-repetition rates FELs

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Modern Free Electron Laser (FEL) facilities produce X-ray light pulses at MHz repetition rates. The LCLS-II accelerator, which is currently under commissioning, will operate at a continuous rate of 1 MHz with X-ray energies between 250 eV and 5 keV. Experiments conducted at LCLS-II will require detectors with a unique set of features, such as high-spatial resolution, low-noise performance (single photon resolution at X-ray energies down to 250 eV), high-dynamic range (up to 10ˆ3 photons) and high-frame rates (from 5 kHz up to 1 MHz).

We present the design of ePixM, a charge-integrating imaging detector developed for soft X-rays applications. It consists of 384 x 192 active pixel sensors, with a pixel size of 50x50 um and a total sensitive area of 2 x 1 cm. ePixM has been designed in LFoundry 150 nm CMOS technology on high-resistivity substrate to enable full depletion of the substrate: This results in a lower detector capacitance (˜ 50 fF) and a charge-collection time on-the-order of a few ns.

Each pixel includes a Charge Sensitive Amplifier (CSA) with gain auto-ranging capability and a noise-shaper performing Correlated Double Sampling (CDS). The performance in terms of Equivalent Noise Charge (ENC) has been evaluated through post-layout simulations and meets the experimental requirements of 15 electrons, thus allowing single-photon resolution at X-ray energies down to 250 eV. Moreover, the dynamic range exceeds 10ˆ3 photons at 500 eV thanks to the auto-ranging circuitry. We present the architecture of the front-end electronics and report the first preliminary results.

Timepix,Micromegas, chair: Bernd Schmitt / 141

Capillary Collimated XRF-imaging with Timepix 3

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X-ray fluorescence (XRF) imaging have been published addressing the non-destructive investigation of the elemental distribution in heterogeneous media in many microscopy imaging applications, especially when the separation of different elements are crucial. Usually, single pad detectors of high spectroscopic quality are used for the precise elemental analysis. By scanning the sample surface with a focused X-ray beam, information about the spatial distribution of a given element in the sample can be obtained 1. However, this scanning process is tedious and time-consuming. One single shot setups based on a pinhole camera configuration has been proven successful for some applications, as shown in Fig. 1 (Left) [2]. In this work, a single shot setup based on a capillary collimator instead of a pinhole collimator is evaluated.

In this paper, we determine the suitability of the Timepix 3, a hybrid pixel readout chip, for one single shot XRF imaging. In order to acquire an XRF image of the sample in one single shot, a detector capillary collimator is required in front of the detector. The setup consists of an X-ray tube with silver cathode, a capillary collimator made of 1 mm thick lead glass with 10 µm pinholes and a USB 3.0 readout system for Timepix3 detectors [3], as shown in Fig.1 (Right). If imaging lead (Pb), X-ray fluorescence signals from the Pb (L-line 10.55 keV and 12.61 keV) in the coating of the sample will pass through the monolithic capillary channels and a material resolving image is achieved. With a precise per pixel calibration, this technique allows to obtain the spatial distribution of a specific element. One shot XRF imaging could be achieved using a high pitch energy resolving imaging system with a capillary collimator.

Fig.1 Pinhole camera setup (Left) and capillary collimated setup (Right) for X-ray fluorescence imaging.

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X-Ray, chair : Heinz Graafsma / 142

Development of the Gotthard-II Detector for the European X-ray Free-Electron Laser

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Gotthard-II is a charge-integrating microstrip detector developed for the European X-ray Free-Electron Laser (EuXFEL) for experiments using hard X-rays of 5 keV – 20 keV. Thanks to its excellent single photon sensitivity, large dynamic range as well as high frame rate of 4.5 MHz in burst mode, its potential scientific applications at the EuXFEL include X-ray absorption/emission spectroscopy, hard X-ray high resolution single-shot spectrometry (HiREX), energy dispersive experiments, beam diagnostics, as well as veto signal generation for large area pixel detectors currently being operated at the EuXFEL, $e.g.$ the Adaptive Gain Integrating Pixel Detector (AGIPD), the Large Pixel Detector (LPD) and others. In addition to its target applications at the EuXFEL, the Gotthard-II detector can also be operated at a frame rate of > 660 kHz in continuous mode for extended usage at synchrotron radiation sources and for the future EuXFEL upgrade to CW mode. Gotthard-II uses a silicon microstrip sensor with a pitch of 50 µm or 25 µm and with 1280 or 2560 channels wire-bonded to readout chips (ROCs). In the ROC, the full signal chain consisting of a dynamic gain switching preamplifier (PRE), a fully differential Correlated-Double-Sampling (CDS) stage, an Analog-to-Digital Converter (ADC) with a sampling/conversion rate of >20 MS/s as well as a Static Random-Access Memory (SRAM) capable of storing all the 2700 images in an EuXFEL bunch train has been implemented. The Gotthard-II ROC is designed based on the independent characterization results from the analogue front-end (PRE and CDS) and ADC test structures. Each ROC, which reads out 128 strips, has dimensions of 6.12x6.64 mm^2 and 61 pads to the readout PCB, for a total of more than 30 million transistors. The Gotthard-II ROC is currently being fabricated using UMC-110nm technology and is expected to be available in mid May 2019. The performance of the final ROC in terms of noise, linearity, dynamic range, coupling between channels and speed will be investigated according to the specifications and discussed in this talk.

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 143

Runaway Electron Diagnostics Using Silicon Strip Detector

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We present an application of the PH32 strip radiation detector 1 for a study of runaway electrons [2] in the GOLEM tokamak at the FNSPE CTU in Prague [3]. GOLEM has a chamber 0.8 m in diameter and operates in the magnetic field $B_t < 0.5$ T and the discharge duration is $t \approx 13$ ms. The detector used for diagnostics is composed of the PH32 silicon readout chip and a high-resistivity silicon strip sensor. It was primarily designed for measurement of X-rays, electrons and charged ions including alpha particles.

The main goal of this measurement is to study the spatial and temporal distribution of the runaway electrons directly and compare the results to the indirectly obtained results from already existing diagnostic method implementing an HXR scintillator. The strip detector was placed in vacuum inside the tokamak vacuum chamber on swivel head in order to directly detect the generated runaway electrons in all directions with respect to the direction of plasma. The performed experiment illustrates the development of a new plasma diagnostic method and acquired results are promising.

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Silicon, Pixel, chair: Val O'Shea / 144

Development of the MYTHEN III microstrip detector

Authors: Aldo Mozzanica[1]; Anna Bergamaschi[2]; Antonio Cervellino[3]; Bernd Schmitt[3]; Carlos Lopez-Cuenca[3]; Christian Ruder[3]; Davide Mezza[3]; Dhanya Thattil[3]; Dominic Greiffenberg[4]; Gemma Tinti[None]; Jiaguo Zhang[3]; Marie Andrä[1]; Markus Jürgen Meyer[1]; Martin Brückner[1]; Nicola Casati[3]; Rebecca Barten[3]; Roberto Dinapoli[3]; Sabina Chiriotti Alvarez[1]; Seraphin Vetter[3]; Sophie Redford[1]; Xintian Shi[5]

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The MYTHEN detector is a single photon counting microstrip detector with 50 μm pitch developed at the Swiss Light Source for powder diffraction experiments 1. After more than ten years of operation of MYTHEN II, a new readout chip MYTHEN III was designed in 110 nm UMC technology to upgrade the current detector. It is designed to improve all aspects, specifically noise performance, count rate capability, threshold dispersion and frame rate.
Each strip in the MYTHEN III chip features a dual polarity front end consisting of a charge sensitive amplifier and a shaper with variable gain and shaping time, as well as three comparators and gateable 24-bit counters. The internal counting logic allows for different modes of operation: energy-windowing, charge sharing suppression, count rate improvement and pump-probe with multiple time slots.
The first two prototypes have been tested in the lab and at the synchrotron. The noise is reduced to 175 electrons (-24% compared to MYTHEN II) and the untrimmed threshold dispersion was measured as 476 eV (-70% compared to MYTHEN II) [2].
Thanks to the three thresholds in the chip, we can exploit pile-up of the analog signal in the shaper at high photon flux and thereby reach a count rate of 25 MHz.
Based on these results, a full scale chip with 128 channels was developed and sent to production.
The architectures of the chips and characterisation results will be presented.

X-Ray, chair : Heinz Graafsma / 145

Characterization MÖNCH0.3 for soft X-ray applications

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Detectors for applications in the soft X-ray energy range (250−2000 eV) face several challenges like providing a high signal-to-noise ratio, single photon resolution capability, a large dynamic range, fast readout and a high quantum efficiency as well as the requirement for vacuum mechanical setups.

MÖNCH 1 is a low-noise charge-integrating hybrid pixel detector under development at PSI targeting soft X-ray applications at synchrotron sources and X-ray free electron lasers. The current prototype MÖNCH0.3 [2] has pixels of 25 μm pitch and an active area of 1 x 1 cm^2 with a noise of 35 electrons ENC (rms). Due to its low noise, MÖNCH0.3 has been successfully used at several pilot experiments at different beamlines of the Swiss Light Source (SLS) down to 700 eV photon energies[3]. Nevertheless, some optimizations of both the chip design and the sensor side are still necessary before building a large area charge-integrating detector operative for the soft X-ray ATHOS beamline at the Swiss Free Electron Laser (SwissFEL).

Several doping technologies were used to reduce the thickness of the inactive layer of the sensor entrance window in order to improve the quantum efficiency below 1 keV. In this contribution, we will show the characterization of these silicon sensors in terms of quantum efficiency and noise

fabricated by FBK with different entrance window technology and bump-bonded to a MÖNCH0.3 readout chip.
Moreover, we will present the performance of MÖNCH0.3 in a new soft X-ray spectromicroscope based on ptychography at the SIM beamline of the SLS highlighting its advantages compared to monolithic detectors and we will discuss the main challenges at low energies like reducing the noise and obtaining single photon resolution. Finally, we will give an outlook for the development of the large area detector for SwissFEL.

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[3] A. Bergamaschi et al. (2018) Synch. Rad. News 31, 11.

XFEL, chair: Ralf Menk / 146

JUNGFRAU for SwissFEL: operation, characterisation and future improvements

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JUNGFRAU is the charge integrating hybrid photon detector designed for SwissFEL, the free electron laser at the Paul Scherrer Institut. Three independently and automatically switching gains per pixel ensure both a low readout noise of 55 electrons and a large dynamic range of 10^4 12.4 keV photons 1. During the last year, two 16 megapixel JUNGFRAU detectors were constructed at PSI and installed as the principal detector systems at SwissFEL. Several smaller JUNGFRAU detector systems act as additional detectors and monitors. These systems have already been integrated and used successfully in the pilot and first SwissFEL experiments [2].

For successful operation, the JUNGFRAU requires an in-depth characterisation and energy calibration. This has required a campaign of dedicated laboratory and testbeam based measurements, to fully probe the behaviour of the 1.0 ASIC. Lessons from these measurements are crucial to ensure the optimal operation of the existing systems [3]. Moreover, a good understanding of the shortcomings of the current ASIC has allowed the redesign of an improved, pin compatible JUNGFRAU 1.1 ASIC, where the non critical shortcomings are addressed. In addition, the new readout chip is expected to improve the noise and linearity performance.

In this contribution the JUNGFRAU photon detector will be introduced and described. First operational and experimental experiences from SwissFEL will be shared. Test beam and laboratory measurements crucial to understanding the system will be presented. Depending on the delivery date of the new ASIC, preliminary results from its electrical characterisation will be shown.

1 Mozzanica et al., Characterization results of the JUNGFRAU full scale readout ASIC (2016)
[2] Mozzanica et al., The JUNGFRAU Detector for Applications at Synchrotron Light Sources and XFELs (2018)
[3] Redford et al., Operation and performance of the JUNGFRAU photon detector during first FEL and synchrotron experiments (2018)

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 147

Performance evaluation of dual energy cargo container inspection system

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Cargo container inspection system uses megavoltage x-rays to detect illicit objects. We developed dual energy cargo container inspection system to decompose materials with different atomic numbers. The cargo container inspection system developed in this study generates MeV dual energy, 9 MeV and 6 MeV x-rays using a linear accelerator. Also, empirical dual energy calibration algorithm and a real-time dual energy calibration device were developed to discriminate organic and inorganic materials which represent low and high density objects. 1 In order to evaluate the performance of the developed cargo container inspection system, tests including penetration, wire detection, and material decomposition, were performed according to ANSI N42.46 standards. [2] Penetration testing is based on the ability to identify rhombus specimens made of steel placed behind 40 sheets of 600 mm by 600 mm with 10 mm thick steel plates, total thickness 400 mm. According to the ANSI N42.46 standards, the thickness of the rhombus specimen should be set to 20% contrast. Since the thickness of the steel plate was 400 mm, it should be 80 mm or less. As a result, we observed the shape of rhombus specimens behind the steel plate with 400mm of thickness from the x-ray images. Wire detection measures the diameter of the minimum identifiable copper wire. In order to perform the wire detection test, a steel plate of various thickness was placed in front of the copper wire, and a ring-shaped copper wire was identified from the X-ray image. Wire detection measurements were made for copper wires with various diameters, varying the thickness of the steel plate from 0 mm (in air) to 400 mm. As a result, it was possible to identify copper rings with diameters of 2, 2.5, 4, 6, and 15 mm for steel sheet thicknesses of 100, 150, 200, 250 and 300 mm respectively. The contrast within 5 % was calculated. In order to evaluate the material decomposition, the containers were filled with organic and inorganic materials such as tire, water, wheat flour, agricultural products, bolts, nuts and steel plates to determine whether the organic substances or inorganic substances were separated. As a result, the organic materials including tire, water, wheat flour, and agricultural products, were represented by the orange color and the inorganic based materials including klystron, bolts, nuts, and steel plate were represented by the blue color by applying pseudo-coloring scheme according to the calculation result of material selective coefficients.

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SiPM, High -Z, chair: Roelof de Vries / 148

Characterization of SiPM radiation hardness for application in hadron calorimeters at FAIR, CERN and NICA

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Silicon Photomultipliers (SiPMs) are an excellent choice for the scintillator light readout at modern hadron calorimeters due to their insensitivity to magnetic fields, low operating voltages, low cost, compactness and mechanical endurance. They are already successfully utilized in Projectile Spectator Detector (PSD) of NA61@CERN, and will be utilized soon in PSD of CBM@FAIR, Forward Hadron CALorimeters (FHCALs) of NICA and BM@N heavy-ion collision experiments. All of those are compensating lead-scintillator calorimeters designed to measure the energy distribution of the forward going projectile nucleons and nuclei fragments (spectators) produced close to the beam rapidity. The main issue of SiPM application at such facilities is degradation of their characteristics within high neutron fluence that can reach up to 2E11 n_{eq}/cm^2 per year of the experiment operation. Multiple irradiation tests of SiPMs produced by Ketek, Zecotek, Hamamatsu and Sensl manufacturers were conducted at the cyclotron of NPI Rez with a "white" (from thermal up to 34 MeV) neutron spectrum and total fluences in the wide range of 6E10 - 9E12 n_{eq}/cm^2. Detailed SiPM characterisation was performed based on dependencies of capacitance on voltage, capacitance on frequency, dark current on voltage and signal/noise on voltage. Results of these measurements before and after SiPMs' irradiation as well as main parameters variability and self-annealing after irradiation will be discussed. Performance of the PSD calorimeter module equipped with irradiated SiPMs in CERN during the beam scan with 2–10 GeV/c protons will be overviewed.

Dosimeters, Neutrons, chair: Ulrich Parzefall / 149

Development of Depleted Monolithic Active Pixel Sensors (DMAPS) for Dosimetry in Space

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The ability to protect astronauts from harmful radiation particles is critical for future human exploration missions beyond ISS. Active dosimeters with demanding specifications concerning mass, power consumption and local intelligence are required to support crew autonomy for operational decisions related to radiation hazards. Important progress in the direction of active dosimetry is being made by the EuCPAD detector and by the timepix based dosimeters. We leverage on the research and development made by the high energy physics community on the HVCMOS particle tracking detectors in order to investigate the possibility to use this kind of detectors for measuring the energy deposition in Si and the track of protons and heavy ions which are constituents of the Galactic Cosmic Rays and of the Solar Energetic Particle (SEP) events. Based on this technology we proposed a device whose data can be used for inferring the flux spectra and discriminate between particle species. Consequently the device can determine the dose equivalent, while its data can be used to calculate dosimetric quantities apart from the point where it is placed. DMAPS sensors in high energy physics experiments are measuring energy deposition by minimum ionizing particles impinging on them with high rate. In the space environment outside the geomagnetic field they have to detect energy depositions which vary by many orders of magnitude as they can be caused by minimum ionizing particles or by completely ionized heavy nuclei. The rate is very low except in the cases of SEP events. However mass and power reduction, radiation hardness, simplicity and even cost reduction are common concerns in both applications. We target these specifications by developing a CMOS pixel sensor in the LF15 technology. The first demonstrator chip has been manufactured and characterized. It contains 32 x32 pixels with 105 um pitch. The detecting p-n diode is

formed by the fully depleted 2500 Ohm*cm p type substrate and the deep nwell. The deep nwell cathode is connected to an error amplifier. The amplifier through negative feedback maintains the reset voltage at the cathode, when there is no hit. When a hit occurs, the amplifier triggers a comparator which closes a switch connecting the diode to a lateral overflow integration circuit for some tens of nanoseconds. In this way the charge of the pulse is stored. The dynamic range is limited at the low side by the diode capacitance and at the high side by the dimensions of the necessary lateral overflow capacitor. Only hit pixels are readout and the two voltage readings for each pixel are converted to digital words by an embedded successive approximation analog to digital converter.

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 150

Calibration and characterization software framework for the high data rate soft X-rays PERCIVAL imager

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The PERCIVAL detector is a large Monolithic Active Pixel Sensor (MAPS) dedicated to soft X-ray experiments, in the primary energy range of 250 eV to 1 keV, for synchrotron and FEL facilities. A first 2 million pixels system is being developed. Its sensitive area is $\sim 4 \times 4\ cm^2$ with a pixel pitch of 27 μm. Due to the absorption lengths of photons in the soft X-ray region, the sensor must be Back-Side Illuminated (BSI) and a specific process applied for the thin back-entrance window to enable use with soft X-rays. To cope with a large dynamic photon flux range detection (1 to 5×10^4 photons at 250 eV), the 3T pixel architecture is enhanced by a smart gain system able to adapt its photo-detection sensitivity.

A software framework is being developed for calibrating and characterising the sensors. It will be able to manipulate data containing the 12 (+3) bits digitised signal, which are stored as HDF5 files utilizing the virtual dataset architecture. The calibration constants will be calculated from raw data and will be applied during the acquisition - prior to writing disk - or during the off-line analysis. The modularity of the code, written in Python-3, will ensure that developers and/or users can plug and play with different analysis methods to perform a calibration or a characterization of the sensor, or to analyze corrected data acquired with the imager.

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 151

Characterization of a back-illuminated CMOS camera on the METROLOGIE beamline at synchrotron SOLEIL

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A commercial scientific camera has been bought by the SOLEIL Synchrotron for improving the acquisition capabilities of the soft X-ray coherent scattering experimental station at SEXTANTS beamline. The device is equipped with a commercial Back-Side-Illuminated scientific CMOS (BSI-sCMOS) developed by Gpixel Inc. It has a sensitive area of $\sim 2 \times 2\ \mathrm{cm}^2$ for a pixel pitch of $11\ \mu\mathrm{m}$ and a frame rate of 48 Hz for a low noise image. The sensor has different working modes, which provides a low read-out noise (1.6 e^- R.M.S in High Gain mode) and a large full-well capacity ($\sim 80\ \mathrm{ke}^-$ in Low Gain mode).
For being able to work in vacuum conditions, the camera has been adapted and tests results obtained in laboratory will be presented.Moreover, an overview of beam-time campaigns at the soft X-ray branch of the METROLOGIE beamline will be given. The radiation hardness of the chip has been quantify, as well as its Line-Spread-Function (LSF) and Modulation Transfer Function (MTF). Further tests are foreseen with this imager on SEXTANTS or HERMES beamline.

CMOS, ASIC, chair: George Fanourakis / 152

FRIC - A 50 µm pixel-pitch single photon counting ASIC with Pattern Recognition algorithm in 40 nm CMOS technology

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This work presents the design and implementation details of a 64 × 64 pixel readout circuit designed at AGH UST. The analog front-end 1 is based on an inverter amplifier and uses a novel feedback topology, which allows for very short pulse-shaping times, while maintaining good gain linearity. Fine pixel pitch of 50 µm requires certain measures for charge sharing compensation. For that purpose, the presented circuit uses signal summing together with the Pattern Recognition algorithm [2-3]. The digital back-end composes of two independent 16-bit counters. Additionally, it supports a high-speed burst mode, which allows for sub-microsecond frame times.
The presented ASIC has been manufactured and is currently under tests. Preliminary measurement results will be presented on the conference.

Fig. 1. Layout of the designed ASIC, 64 × 64 pixels, 3.24 × 5.12 mm2.

1. X. Llopart, et al., "Study of low power front-ends for hybrid pixel detectors with sub-ns time tagging," JINST 14 C01024

2. Piotr Otfinowski "Spatial resolution and detection efficiency of algorithms for charge sharing compensation in single photon counting hybrid pixel detectors," Nuclear Instruments and Methods in Physics Research Section A, Volume 882, 21 February 2018, Pages 91-95

3. P. Otfinowski, G. W. Deptuch, P. Maj "Asynchronous Approximation of a Center of Gravity for Pixel Detectors' Readout Circuits," IEEE Journal of Solid-State Circuits, Volume 53, Issue 5, May 2018

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 153

Single Photon Counting Integrated Circuit with multiple energy thresholds and charge sharing compensation

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Single photon counting systems offer good position resolution and operation with high X-ray flux, so making a pixel size smaller is a general tendency in such systems. Thanks to the detector technology development based on high Z materials (GaAs, CdTe, CZT, etc.), the hybrid pixel detectors with direct photon−to−charge conversion become more and more popular, even in medical applications. Nowadays, the usual requirement for the pixel size is the range from 50 µm to 200 µm. However, for small pixel size the charge sharing effect can significantly distort measured energy spectrum of incoming photons 1.

We propose the new algorithm for charge sharing compensation – the Multithreshold Pattern Recognition algorithm, being an extension of the PR algorithm which allows for simultaneous allocation and energy measurement of a photon in the presence of charge sharing [2-3]. It uses multiple energy thresholds to determine the energies of individual photons and to increase the allocation accuracy at the same time. The algorithm was implemented in a readout circuit of a pixel architecture in the CMOS 130 nm technology. The circuit is designed for operation with wide energy-range X-ray radiation and it has four energy thresholds. The implementation details and preliminary measurement results will be presented on the conference.

Fig. 1. A concept of Multithreshold Pattern Recognition implementation in a pixel.

1. V. Di Trapani et al., "Characterization of noise and efficiency of the Pixirad-1/Pixie-III CdTe X-ray imaging detector," 2018 JINST 13 C12008
2. P. Otfinowski, A. Krzyżanowska, P. Gryboś and R. Szczygieł "Pattern Recognition algorithm for charge sharing compensation in single photon counting pixel detectors," 2019 JINST 14 C01017.
3. A. Krzyżanowska, P. Otfinowski, P. Gryboś, "Simulations of High Count Rate Performance of Hybrid Pixel Detectors with Algorithms Dealing with Charge Sharing," 2018 International Conference on Signals and Electronic Systems (ICSES).

XFEL, chair: Ralf Menk / 154

Megapixels @ Megahertz - AGIPD Detectors for the European XFEL and beyond

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The Adaptive Gain Integrating Pixel Detector (AGIPD) are hybrid multi-megapixel detectors developed by DESY, PSI, and the Universities of Bonn and Hamburg for use at the European XFEL.
The European XFEL is an extremely brilliant Hard X-ray Free Electron Laser Source with a unique non-uniform pulse structure, in which bursts of up to 2,700 X-ray pulses are emitted at a rate of up to 4.5 MHz on a 10 Hz overall cycle. The individual photon pulses are of extremely high brilliance, i.e. containing up to 10ˆ12 12 keV photons/pulse (depending on photon energy) and extremely short (≤100 fs) in duration. For diffraction experiments of various kinds the dynamic range covered can span orders of magnitude: it is mandatory to deal with diffracted intensities of up to 10ˆ4 12-keV photons/pulse/pixel while providing reliable single photon detection and single pulse temporal resolution.

Thus the readout ASIC has to provide not only single photon sensitivity and a dynamic range up to >10ˆ4 photons/pixel in the same image, but also a memory to store as many images of a pulse train as possible for delayed readout in the gap between two bursts. The AGIPD 1.1 ASIC uses a 130 nm CMOS technology and radiation tolerant techniques to withstand the radiation damage incurred by the high impinging photon flux.
Two 1M pixel AGIPD detector systems have been installed at the European XFEL, one (SPB) at the SPB/SFX beamline and one at the MID scientific instrument. The SPB AGIPD has been successfully utilized for the first user run of European XFEL in late 2017, already having resulted in high-ranked publications from those experiments. Meanwhile, the AGIPD at MID together with instrument have been commissioned and already had a first successful experimental user run in 2019.

There are two 2nd generation AGIPD detectors for the European XFEL currently under construction: One for the SFX (Serial Femtosecond Crystallography) user consortium at the SPB/SFX instrument and one for the HIBEF (Helmholtz International Beamline for Extreme Fields) user consortium. Both detectors incorporate the same readout ASIC, but are built around a new readout board incorporating advanced concepts such as on-board power supplies, a new interlock and timing architecture based on commercial multimedia SER/DES ICs, a new calibration mechanism and fully optical communications and data transmission. Furthermore, the mechanical setup of these detectors with large motion ranges in a vacuum setup made the development of a new cooling concept mandatory.

The SFX detector is mainly used for diffraction from biological samples and with photon energies of around 12 keV, hence Si sensors are utilized. For the HIBEF setup, the typical photon energies employed are in the range of 20-30 keV; while the HIBEF AGIPD detector will initially be delivered with Si sensors as well. Those will later be exchanged for High-Z material sensors currently under development. These sensors are read out with an electron collecting version of the AGIPD ASIC, called ecAGIPD, of which a prototype is currently under test. Some improvements of the in-pixel memory for ecAGIPD were also implemented in the hole-collecting AGIPD 1.2 ASIC, which is used for the remaining production of detector modules based on hole-collecting silicon sensors.
Besides results from the first user beam time at the European XFEL, we will show the concept of the 2nd generation AGIPD detectors for HIBEF and SFX. In addition the AGIPD 1.2 and ecAGIPD readout ASICs together with supporting results will be presented.

Silicon, Pixel, chair: Val O'Shea / 155

Characterization of irradiated p-type silicon detectors for TCAD surface radiation damage model validation

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The HL-LHC upgrade will impose very stringent constraints in terms of radiation resistance of solid-state detectors. In this work we address the effects of surface damage on detectors fabricated on high-resistivity p-type FZ <100> substrates by Hamamatsu Photonics (HPK) and Infineon Technologies (IFX).The devices underwent a wide set of measurements before and after X-ray irradiation with doses up to 100 Mrad(SiO2) to extract the integrated interface trap density (NIT) and the oxide charge (QOX) peculiar to different vendors, processes and technology options 1[2]. NIT and QOX can be then used as inputs to TCAD simulation tools aiming at validating the model itself. On the basis of the new experimental evidences at these high doses, the TCAD model has been updated with two main bands of defects, one acceptor and one donor, extended to the whole silicon bandgap accounting for the net effect of the radiation-induced acceptor- and donor-like defects. Updated measured cross-sections render the new modeling scheme more robust.
The comparison between simulations and measurements, e.g. in terms of C-V curves of IFX/HPK MOS capacitors, is illustrated in Fig.1 and has been used as cross-check for surface radiation damage validation purposes. With the same modeling scheme it is possible to reproduce the I-V of gated-diodes and the interstrip resistance as a function of the dose up to 100Mrad(SiO2) for the wide range of technology and design options investigated. The good agreement between simulations and measurements would support the use of the TCAD model as a predictive tool to optimize the design and the operation of the new generation of silicon detectors for the future High Energy Physics experiments in the HL-LHC scenario.

ATTACHED FIGURE

Figure 1. Simulated and measured C-V of MOS capacitors manufactured by HPK (pstop/pspray) and by IFX (6"/8'' wafers) after X-ray irradiation doses of 0.05, 10 and 100 Mrad(SiO2).
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GaAs, Diamond, TPC, chair : Nicola Guerrini / 156

Investigation of 3D Diamond Tracking Detectors for Timing application with TCAD tools

Authors: Arianna Morozzi[1]; Daniele Passeri[2]; Leonello Servoli[3]; Silvio Sciortino[4]; Lucio Anderlini[4]; Stefano Lagomarsino[5]

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In view of the HL-LHC upgrade the use of Chemical Vapor Deposited (CVD) diamond has been proposed as an efficient alternative to conventional silicon-based devices 1. Diamond detectors are more

robust to radiation damage, the high carriers mobility allows faster signal collection when compared to silicon, while retaining extremely low leakage currents. This could be of particular interest in particle detection applications where stringent timing and radiation tolerance requirements need to be fulfilled. A suitable implementation of such a class of detector is that of 3D pixelated CVD diamond with graphitic parallel columns/trenches contact scheme, fabricated through a focused laser beam technology [2]. TCAD simulations can be exploited to assess the effect of different electrode configurations and/or biasing scheme on the electric field profiles, aiming at minimizing the effects of inefficient field regions in terms of charge collection. For timing application purposes, the effects of a single particle hit have been accounted for by means of realistic time and space descriptions of the energy deposition along its path. Figure 1 shows the simulated transient response of 3D diamond detectors taking into account different particle impact positions.
The transport effects along the graphitic columns can be accounted for, aiming at evaluating the performance and limitations of such a class of detectors. The equivalent "load" effect of graphitic columns of different size/resistivity can be taken into account by means of device-circuit-level simulations including measured resistances and capacitances.
This work is being carried out within the framework of the Italian INFN experiment TIME and Space real-time Operating Tracker (TIMESPOT).

ATTACHED FIGURE

Figure 1. 3D diamond detector time-response comparison for different particle impact positions.
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SiPM, High -Z, chair: Roelof de Vries / **157**

Advancements of high-Z sensor materials evaluated by the low noise, charge-integrating pixel detector JUNGFRAU

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The most common sensor material for detectors at synchrotron sources and free electron lasers is silicon due to its outstanding material quality in terms of homogeneity and charge carrier transport properties. However, silicon (Z = 14) based sensors suffer from relatively low absorption efficiency at energies above 20 keV. Sensors manufactured from high atomic number material, so-called high-Z sensors, provide absorption efficiencies that are significantly higher but typically suffer from downsides in comparison to silicon, including crystal inhomogeneities, fluorescence emission, dislocation lines and charge-trapping. The usability and progress of different high-Z sensor materials (GaAs, CdTe, CZT) at synchrotron sources has been evaluated using the JUNGFRAU readout chip as a possibility to widen the usable energy range of the detector systems. JUNGFRAU is a low noise, charge-integrating pixel detector with a pixel pitch of 75 x 75 μm^2 and 256 x 256 pixels per single chip.
Charge-integrating detectors provide a suitable environment to reveal the properties of sensors as each pixel provides a direct measure of the charge collected in a defined area. In addition, each pixel is sensitive to temporal as well as spatial sensor effects, which affect the charge collection and help

to understand those aforementioned shortcomings of high-Z sensors.
We will evaluate and present an overview of the typical sensor material characteristics like charge transport properties (μτ), resistivity (ρ) and I-V characteristics including temperature dependency studies for various high-Z materials. Moreover, system characteristics like stability, noise and spectroscopy performance (FWHM) will be shown. The findings will be interpreted in the context of the actual sensor performance and usability to highlight key variables and potential improvements for the future. Furthermore, first imaging results with a CdTe quad sensor (active area: 3.92 x 3.92 cm^2) will be presented.

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 158

Time-lapse micro-CT Analysis of Fatigue Microcrack Propagation in Cortical Bone

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A bone microcrack under physiological condition can be defined as a fissure in the hydroxyapatite matrix caused by damage accumulation over the limit of remodeling process 1. Microdamage accumulation accelerated by process of aging and metabolic diseases decreases bone strength and finally leads to loose of primal stability and bearing capacity of the bone. Understanding the fatigue cracking mechanism of the bone and identification of the relevant mechanical properties is a key element for the further improvements in design of bone scaffolds and replacements. In this paper, time-lapse micro-tomography (micro-CT) analysis is used as a method for the identification of the fatigue microcracks in human cortical bone. Custom design table-top loading device with a bioreactor chamber [2] was employed for in-situ fatigue loading directly in the X-ray scanner. The specimen of the human cortical bone was submerged in the circulating simulated body fluid with controlled temperature approx. 37°C to represent real conditions of the human body. Initial defects in the bone were induced by the first loading step with peak force sufficient for the crack initiation. After the first loading step, thin (approx. 5-10 micrometers) longitudinal microcracks formed in the bone microstructure. Then, in-situ fatigue loading was performed to induce propagation of the microcracks. Loading increments of several thousand load cycles with period of approx. 2 seconds were used to investigate crack propagation phenomena. The fatigue testing was ended after approx. 20 thousand cycles. During the overall experimental process, the in-situ loading device was mounted on the rotary stage of the X-ray scanner and the tested specimen was scanned using high-resolution micro-CT in the representative loading steps (before initiation of the microcracks, directly after the initiation and each time after a defined increment of fatigue cycles was reached). The micro-CT scans were performed using the modular X-ray imaging device TORATOM. In this study, a XWT-160-THCR transmission type X-ray tube with maximum tube voltage 160 kV, target power 25 W and minimum focal spot size 1 micrometer was used together with a flat panel X-ray detector Dexela 1512NDT for the acquisition of the X-ray images. The detector is based on CMOS (Complementary Metal–Oxide–Semiconductor) semiconductor technology and is equipped with an oriented CsI scintillator. The active area of the detector is 145.4 mm x 114.9 mm with pixel matrix of 1944 x 1536 pixels with pixel pitch of 74.8 micrometers and maximum frame-rate of 26 fps. The X-ray energy range of the detector is 12 - 160 keV making it suitable for imaging of bone samples. The individual micro-CT reconstructions of the specimen were processed using a differential tomography algorithm for identification of the individual microcracks in the microstructure and for investigation of the crack propagation phenomena. The micro-tomography results were compared with the results from the in-situ loading device recorded during the fatigue testing and the overview of the fatigue damage mechanism was introduced.

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Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 159

The SEU and TID characterization of a novel X-CHIP-03 monolithic pixel detector

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The presented study concerns the effects of cumulative and transient ionizing radiation damage on the novel monolithic pixel detector, X-CHIP-03 1, manufactured in a 180 nm SoI technology. The X-CHIP-03 contains analog and digital parts, where the latter includes a long shift register useful for SEE measurements. Its predecessor X-CHIP-2 [2], manufactured in the same SoI technology, contains transistor testing matrices for TID measurements.

A high-flux Co-60 medical radiation source was used for the TID measurement. The samples under irradiation were placed in a Pb/Al enclosure, which provides an approximate electron equilibrium. This study compares the effects of two different dose rates of 16 Gy/min and 460 Gy/min on the threshold voltage shifts of the CMOS transistors of different geometries as well as the effects on the off-state and maximal current. Moreover, the effects of placement in HV P-wells are studied. In addition, integral current consumption of the device was measured and it was found to be correlated to the increase of the off-state transistor current. The test structures were irradiated up to a dose of 38 kGy (low dose rate measurement) and 100 kGy (high dose rate measurement). The measurement showed that the radiation effects are negligible up to a threshold TID of 1.6 kGy. A consistent annealing behavior was observed in both transistor test structures and ASIC circuits.

The SEE study was performed using heavy charged particles produced at Tandetron (NPI Rez, Czech Republic) and U400M (JINR, Dubna, Russia) accelerator complexes. While the Tandetron accelerator was used as a source of He-4 and Li-7 ions, the isochronous cyclotron U400M was the source of accelerated Ne-22, Ar-40, Xe-136 and Kr-84 ions. The measurements were performed in vacuum for different detector – beamline angular configurations to increase the extent of available LET ranges. During irradiation, a checkerboard test pattern was written into the shift register and the data were read-out periodically and analyzed off-line. A bit-flip cross section as a function of particle LET was measured for the D-flip flops, which make up the shift register in the X-CHIP-03 ASIC.

1 Havranek, M., et al., X-CHIP-03: SOI MAPS Radiation Sensor with hit-counting and ADC mode, submitted for publication to the Conference Record for the 2018 IEEE NSS/MIC/RTSD.
[2] Havranek, M. et al., MAPS sensor for radiation imaging designed in 180 nm SOI CMOS technology, 2018 JINST 13 C06004.

GaAs, Diamond, TPC, chair : Nicola Guerrini / 160

A high pressure gas TPC detector for reactor neutrino : Canceled

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A high pressure gas TPC detector has been developed in IHEP, in China, which aims to measure the reactor neutrino energy spectrum by elastic scattering with an energy resolution of less 3%@1 MeV. The whole detector with a 200-kg target will installed nearby reactor of about 20 m. On the one hand, the energy spectrum can provide an input with a model-independent nuclear database for Jiangmen Underground Neutrino Observatory (JUNO). Additionally, the gas TPC detector has other physics potentials, such as measurement of the neutrino magnetic moment, the weak mixing angle and the search for sterile neutrino.

At present, we have finished the pre-study of physics potential and simulation based on the 200-kg conceptual detector. To achieve good performance target materials with high event rate, high spatial resolution, and high energy resolution, we select the working gas with high density of free electrons, and small drift diffusion and attachment. Using the simulation tools of Garfield and Geant4, we simulated the drift properties of various gases and reconstructed the electron tacks. We found that the doping of polyatomic gases (such as TMA or iC4H10) in Ar and Ne gases is effective to decrease the electron drift diffusion, increase the drift velocity, and reduce the fluctuation of the original ionized electron. In addition, pure CF4 gas with good properties and high electron density, is also selected as the candidate working gases. To verify the selection of target material and the detector design, we developed a prototype detector with an effective volume of about 4.5 L. Some measurement results have been also achieved of the prototype detector. These results also provide more references for the large detector.

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 161

R&D of a high pressure gas TPC detector for reactor neutrino spectrum

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Recently, reactor neutrino experiments have found that the measured reactor antineutrino spectrum disagrees with the reactor flux model prediction. In the energy range of 4-6 MeV, an excess of 10% found in the measured spectrum suggests the prediction of the reactor antineutrino spectrum is incorrect. The reactor antineutrino spectrum and the origins of the disagreement with prediction becomes a hot topic in the neutrino and nuclear physics. We plan to construct a high-pressure gas TPC detector nearby a reactor to precisely measure the reactor antineutrino spectrum utilizing the features of high spatial resolution and high energy resolution. The antineutrino energy can be determined using the reaction of antineutrino-electron scattering with precise measurement of the electron scattering angle and the kinetic energy. The expected energy resolution of the reconstructed antineutrino energy is better than 3% at 1 MeV. The precise antineutrino energy spectrum provides model-independent inputs for other reactor neutrino experiments, such as JUNO which aims to determining the neutrino mass hierarchy. Additionally, the gas TPC experiment has other physics potentials, such as measurement of the neutrino magnetic moment, the weak mixing angle and the search for sterile neutrino.

The poster focuses on the R&D of a prototype detector with an effective volume of about 4.5 L for the high pressure gas TPC detector. This prototype detector will be used to verify the selection of target material and the detector design. And the detector is equipped with a gas circulation and purification system that can withstand a working pressure of 10 atm. The spatial resolution of the prototype

detector reaches a level of 100 um with the 600 strips readout. At present, we have finished the detector assembly and preliminary measurement, such as drift velocity, attachment and so on. And the preliminary measurement results of the 600-channels readout will be also introduced.

CMOS, ASIC, chair: George Fanourakis / 162

Single Event Upsets in the ATLAS IBL Frontend ASICs at the Large Hadron Collider at CERN

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ATLAS is one of the four major experiments at the Large Hadron Collider (LHC) at CERN. The tracking performance of the ATLAS detector relies critically on its 4-layer Pixel Detector, located at the core the ATLAS tracker.
During operation at instantaneous luminosities of up to 2 10ˆ34/cmˆ2/s the frontend chips of the ATLAS innermost pixel layer (IBL) experienced single event upsets affecting its global registers as well as the settings for the individual pixels, causing, amongst other things loss of occupancy, noisy pixels, and silent pixels. A quantitative analysis of the single event upsets as well as the operational issues and mitigation techniques will be presented.

LHC / 163

First Annealing Studies of Irradiated Silicon Sensors with Modified ATLAS Pixel Implantations

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In Dortmund, planar silicon pixel sensors were designed with modified n+ -implantations and produced in n+ -in-n sensor technology. Baseline for these new designs was the layout of the IBL planar silicon pixel sensor with a 250 µm × 50 µm pitch.
The different implantation shapes are intended to cause electrical field strength maxima to increase charge collection after irradiation and thus increase particle detection efficiency.
To test and compare the different pixel designs, the modified pixel designs and the standard IBL design are placed on one sensor which can be read out by a FE-I4.
At the IWORD 2018, the measurements of sensors irradiated with neutrons at different research reactors were presented and showed different results. Unintended annealing during irradiation was considered as an explanation for the observed differences in hit detection efficiency.
In this talk, the results of first annealing studies of a neutron irradiated sensor in Ljubljana will be presented which are now in agreement with the results of a sensor irradiated at Sandia. The results

of neutron irradiated sensors will be compared to measurements of proton irradiated sensors before and after annealing.

Timepix,Micromegas, chair: Bernd Schmitt / **164**

Measurement of energy loss of secondary charged particles in carbon-ion beam therapy range monitoring using TPX3 Detectors

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Compared to other radiotherapy modalities for cancer treatment, carbon-ion radiotherapy permits a higher dose concentration in targeted tumor volumes while better sparing patient's healthy tissues. However, this benefit comes with the price of a higher sensitivity to any changes of the patient internal geometry due to movements, or tumor swelling and shrinkage. Monitoring methods of the patient radio-treatment are therefore of great importance to visualize carbon-ion beam range in-vivo and, thus, to detect possible under- or over-dosage in the patient.

In this contribution, we focus on a carbon-ion beam monitoring method based on secondary-ions detection. This method uses the fact that when a carbon-ion beam enters a patient during radiotherapy, the carbon ions undergo nuclear reactions (also called "fragmentation") with the targeted patient tissue 's nuclei. These nuclear reactions produce detectable secondary-ion fragments along the path of the carbon-ion beam. In this work, we investigate a possible application of pixelated silicon detectors for carbon-ion beam range monitoring, by developing a monitoring method based on the detection of secondary charged nuclear-fragments emerging from an irradiated target. A correlation between the measured depth of the fragments' origin (i.e. where primary carbon-ion beam fragmentation occurs) and the planned primary carbon-ion-beam range in the target was studied. Moreover, we also explore additional benefits of the knowledge of both fragments' position and energy-loss information on the precision of our method.

In order to mimic a clinical treatment, a typical 12Carbon-ion treatment plan fraction of a head tumor was applied on an anthropomorphic head model at the Heidelberg Ion-Beam Therapy Center (HIT), Germany. Several carbon ion beam energies ranging from 165,09 MeV/n to 246,57 MeV/n were used to treat the whole volume of the targeted tumor. The directions and energy deposition of the emerging secondary-ions were measured by a pair of parallel pixelated silicon detectors Timepix3 (TPX3), developed at CERN and commercialized by ADVACAM s.r.o. (Prague) placed behind the targeted head. Each of the detectors we used in this work contains a 300 µm thick sensor, with a sensitive area of 1,4 x 1,4 cm^2 divided into 256 x 256 pixels (55 µm pitch). Compared to Timepix detectors, the new generation of Timepix3 used in this contribution offers the advantage of a data-driven dead-time free flow of pixel information containing simultaneously: (1) a precise time of arrival (TOA with time resolution of 1,56 ns) and (2) deposited energy in sensitive layer for each detected secondary-ion. To reconstruct a secondary-ion-track, detected clusters in both our detectors are matched based on coincident ToA information. This measured track is then extrapolated back in space to the carbon-ion beam axis, allowing us to estimate the carbon-ion fragmentation position.

We have shown, that the deducted fragmentation position in the targeted head varies in depth for different incident carbon-ion beam energies, which could be related to the carbon-ion beam range in the patient head (cf. Figure 1.a). Moreover, we have found that there are significant differences in the ions' track origins position for different energy depositing ions (cf. Figure 1.b). Indeed, detected secondary-ions with high a deposited energy dE in our detector are related to tracks that originated more deeply in the head phantom (cf. light blue distribution in Figure 1.b). In the end, we have shown that the energy deposition of single detected secondary ions in TPX3 detectors is linked to the secondary ion's velocity. This enables us to identify slower secondary ions increasingly suffering from scattering in the patient. Therefore, this additional deposited energy information, together with the almost dead-time-free secondary-ions' time-of-arrival given by Timepix3 detectors, can be used in the future to improve the precision of the carbon-ion beam range monitoring method based on secondary charged ions.

Ion Beam, chair: Valeria Rosso / 165

Non-invasive visualization of the pencil beam scanning movement in an irradiated object during a carbon-ion beam therapy delivery

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In comparison to conventional tumor treatments with x-rays, the usage of carbon-ion beams in radiotherapy has shown better sparing of the healthy tissue that surrounds the tumor. This is possible due to the small lateral scattering and finite range of the ions within the tumor. As ions penetrate the tissue, nuclear fragmentation reactions occur between the incoming ions and the nuclei of the targeted tissue. This produces secondary ions which can emerge from the patient. These secondary ions are a candidate to be used to monitor the beam in the patient during the treatment application. The present work focuses at the assessment of an independent non-invasive monitoring method to evaluate the lateral beam positions in a clinic-like 12C treatment irradiation. The aim is to reach an uncertainty of 1 mm, which is the standard uncertainty at the clinic. This method is based on tracking of secondary ions outgoing from an irradiated object.

To evaluate the performance of this method, a treatment plan with carbon ions was designed to irradiate a typical target region within an anthropomorphic head model. To cover this target region with the desired dose of 3 GyE, several ion beam energies were used. Thus, the treatment plan contains 22 carbon-ion beam energies ranged from 163.09 MeV/n to 246.57 MeV/n. The dose was delivered using narrow pencil-like beams scanning laterally over the target cross-section. The irradiations were carried out at the Heidelberg Ion-Beam Therapy Center (HIT) in Germany.

The secondary ions emerging from the head phantom were measured by means of two silicon pixel detector layers, based on the Timepix3 technology developed at CERN by the Medipix3 Collaboration. Timepix3 detectors allow a simultaneous acquisition of time of arrival and energy deposition of the impinging ion in a dead-time-free data-driven readout. The Timepix3 detectors used in this investigation had a sensitive area of around 2 cm2. We developed a method to derive the pencil beam position from the measured secondary ion tracks. This enabled us to visualize the pencil beam scanning in the irradiated object as a function of time.

To quantitatively assess the precision of the presented method, we evaluated the distances of the measured pencil beam positions with respect to the information from the accelerator (see Figure 1). The mean value of the distance distribution of each beam energy was calculated. Most of these mean values were found to be within ±0.5 mm. The standard deviations of the distance distribution for each beam energy were also calculated, and they ranged from 0.98 mm to 3.39 mm. Moreover, we quantitatively evaluate the reproducibility of the presented method, which was found to be below 2 mm for beam energies greater than 197.58 MeV/n.

In conclusion, the visualization of the pencil beam scanning movement in the irradiated object was possible using this non-invasive secondary-ion based monitoring method. Furthermore, we have demonstrated the potential of the Timepix3 detector for this application. We quantitatively showed that the mean distances of the measured lateral beam positions with respect to those from the beam-record files were within ±0.5 mm. The precision of this method was found to be below 2 mm for higher energy layers. By having larger areas of detection, with this method uncertainties of about 1 mm could be reached.

Tomography, chair: Christer Frojdh / 166

Evaluation of scan strategies for small animal in-vivo micro-CT

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The aim of the presented work is the evaluation of possible adaptation options for in-vivo CT scans of small animals with Timepix based micro-CT scanner. Until now the system has been used only for post mortem high-resolution imaging and dose delivered to the sample was not a crucial parameter. Pilot measurements with thermoluminescent dosimeters (TLD) were performed and the dose rate for small rodent was estimated. This dose rate limits the maximal irradiation time for live specimens to tens of seconds to avoid immunosuppression or other irreversible biological damage.
Series of measurements were performed with PlastiMouse phantom using different acquisition parameters to evaluate best data acquisition strategy for given dose limits. The presented data refers to the relationship between exposure time recorded by the detector and reconstructed micro-CT slices

quality. CNR was evaluated for 96 selected combinations of acquisition times and angular sampling. This covers a range of sample doses from 50 to 500 mGy delivered just during the recorded exposure time.
However, total scan time, therefore total accumulated dose, is prolonged by undesirable processes such as detector readout time or gantry movement. Both hardware and software options for decreasing the sample dose in used micro-CT scanner will be presented in the contribution.

Software, chair: Daniele Passeri / 167

Enhanced volume resolution by inline spot-convolution in iterative volume reconstruction : Canceled

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In the classic understanding the achievable volume resolution in computed tomography depends on a number of system parameters, i.e. detector pitch, focal spot size and geometric magnification.
However, at second glance, this fundamental assumption turns out to be rather inaccurate. Given, for example, a detector with a box-like point function (PSF), with an edge response much narrower than its pixel pitch, such as some hybrid-pixel detectors 1, the target resolution can be enhanced dramatically by spatial sub-sampling [2]. This is inherently the case when performing tomography with dense angular sampling.
A different limitation of the target resolution arises from the smearing by the finite size of the X-ray source's focal spot. Opposite to smearing by a broad detector PSF, this effect cannot be efficiently counteracted by application of a projection based deconvolution. This is particularly true in case of large variation of the effective magnification within the sample, which is the case when large geometrical magnification is employed.
A possible remedy of this effect is the accurate implementation of the smearing process into the forward model of an iterative volume reconstruction algorithm.
The current contribution demonstrates that significant improvement of the volume resolution can be achieved by combination of such a routine with direct converting hybrid-pixel detectors. The implementation of the reconstruction routine allows for arbitrary shape of the focal spot, entailing interesting application fields for example where modern high performance metal-jet micro-focus X-ray tubes with asymmetric focal spot are employed.

1 D. Maneuski et al, 2015 JINST 10 P03018
[2] J. Dudak et al, 2017 JINST12 C01060

Timepix,Micromegas, chair: Bernd Schmitt / 168

Ethernet Embedded Readout Interface for Timepix2 - Katherine readout for Timepix2

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Timepix2 1 is an improved version of the Timepix with advanced features and functionalities developed by the Medipix2 Collaboration at CERN. It is a frame-based readout chip featuring a 256x256 pixel grid with 55 µm pitch. The chip implements eight modes of operation, of which two allow simultaneous and six continuous measurements. In continuous modes, two sets of pixel counters are available. While the first set is used for measurement, the second one is used data readout. Thus, the dead time is practically absolutely eliminated.
Simultaneous modes enable a measurement of energy (Time-over-Threshold) and time-stamping (Time-of-Arrival) simultaneously. In addition, Timepix2 supports matrix occupation checking (which could be valuable for a reduction of overlapping clusters). Special digital pixels outside the matrix enable a connection of external signals (e.g. from single pad diodes, triggers). While the high power consumption of Timepix and Timepix3 are rather high, Timepix2 allows to switch off parts of the matrix absolutely so that power consumption can be reduced. This could make Timepix2 a good candidate for space projects or wearable electronic systems.
The presented readout/acquisition device for Timepix2 is the next generation of the Katherine readout [2]. Katherine is an embedded computer, supporting a connection with the CERN chip board. It manages all communication with the Timepix2 readout chip. The readout device is based on the Gigabit Ethernet interface and profits from all its advantages: cheap and reliable cabling, good bandwidth and operation at long distances (up to 100m) from a computer or server. Thus, the readout system is an ideal solution for places with difficult access.
The introduced system supports all detector modes, including Zero Columns Suppression (ZCS; suppression of zero columns within a readout process). The device implements decoding of pixel data to an easily readable format and zero-pixel suppression directly in hardware. This reduces demands on control/acquisition software. There is also high voltage power supply offering both polarities of bias voltage (up to ±300V) and GPIO ports for triggering or integration of the detector to an existing measurement chain. Since it has enough computational power (dual-core ARM A9 processor + FPGA + DDR3 memory), this platform is suitable and ready for on-line data pre/processing (cluster analysis).
The presented work describes the functionalities and performance of the readout system in detail and also presents a control software with functionalities such as the sensor equalization, DACs dependency scan, Threshold calibration, etc. developed for this system.

Figure 1. Katherine readout for Timepix2 with CERN's chipboard.

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Ion Beam, chair: Valeria Rosso / 170

Measurement of heavy ions with the charge integrating hybrid pixel detector Jungfrau

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While originally developed for photon science at free electron lasers the Jungfrau hybrid pixel detector is also suitable for charged particle detection due to its high dynamic range and fast frame rate. In this work we present measurements performed at the HIMAC accelerator at the National Institute of Radiological Sciences in Chiba, Japan. Four different ion species were measured, ranging from He at 230 MeV/A to Fe at 290 MeV/A. We compare the results to Geant4 simulations to verify the detector response. The dynamic range of Jungfrau extends from single particle detection at 2 keV up to 120 MeV/pixel/frame. With the three linear gains we can employ a lab based calibration using X-rays for absolute calibration of the highest gain, and subsequently cross calibrate medium and low gains without the need for an accelerator as part of the calibration procedure. We are able to correctly measure the energy of all four ion species at 0, 45 and 75 degrees, including Fe 290 MeV/A impinging perpendicularly to the sensor which deposits 142 MeV.

SiPM, High -Z, chair: Roelof de Vries / **172**

Quantitative analysis on electric field distribution in SiPMs for scintillator detection applications

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In this work, we report on the quantitative analysis on the effect of electric field on SiPM characteristics in scintillator detection applications. In particular, we demonstrate the SiPM performance with respect to the electric field distribution in terms of the number of incident photons (Nph) and wavelengths (λ) to highlight the importance of well structure in SiPMs. SiPMs investigated in this work were based on an n-on-p structure and all samples were fabricated on a 200 mm n-type epitaxial-layer wafer with a pixel size of 2.95×2.95 mm2 and a microcell size of 65 µm. Maintaining the wafer, fabrication conditions, and device layout identical, we produced SiPMs with three different electric field distributions across the depletion region by applying three boron implantation doses (Φp-well) in descending order during the p-well formation: 5.0×1012 (Device #1), 4.0×1012 (Device #2), and 3.0×1012 (Device #3) atoms/cm2. Measurements on the dark count rate (DCR) and photon detection efficiency (PDE) were obtained as a function of excess voltage (Vex) for three samples. Based on the measured device parameters, the photon number resolution 1 of each sample was calculated as a function of Nph ranging from 5.0×102 to 10.0×104 and λ 375 to 700 nm to account for as many scintillators as possible. The results show that SiPMs with reduced electric field could be a reasonable approach for scintillator detection applications with a very high photon flux (e.g., CsI(Tl) and LaBr3), whereas SiPMs with enhanced electric field could be a better choice for moderate or low photon flux (e.g., LYSO and plastic).

Tomography, chair: Christer Frojdh / **173**

A novel Approach to separate Absorption, Refraction and Scattering in Analyzer Based Lung Imaging

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One of the advantages of phase contrast x-ray imaging with respect to conventional x-ray attenuation is its capability of extracting complementary and useful physical properties of the sample under investigation. Different phase contrast methods have been developed and extensively applied at synchrotron radiation sources, one of them being Analyzer Based x-ray Imaging (ABI) 1 which utilizes perfect crystals exploring the x-ray deviation by their interaction with the sample. Owing to the narrow angular acceptance of the analyzer crystals, ABI is an excellent tool for highlighting x-ray scattering.

A single image acquisition is sufficient to obtain qualitative and high signal to background radiographs, however, it requires multiple image acquisition schemes to assess quantitative metrics.

ABI may yield three parametric output images [2,3], which assess different physical properties namely absorption, refraction and scattering linked to dark field images, when a minimum of three input images are acquired and dedicated image processing on a pixel basis is applied. These modalities can be extended from planar images to computed tomography and allow quantitatively retrieving of scattering even for wide scattering distribution. Linking the (sub) micro-structure to morphological changes in soft tissues at biocompatible radiation doses is a yet challenging problem due to the lack of quantitative characterization tools possessing sufficient structural sensitivity at this length scale. In this view dark field or scattering based images yielded by ABI possess additional valuable information on the microscopic range without necessarily employing a high-resolution imaging detector. ABI enables to qualitatively assess such scattering in a wide angular validity range.

For biological samples this in turn might yield information on biological function in micrometer sized particulate systems as found for instance in lungs. Scattering can be efficiently separated from refraction and absorption effects acquiring only three images of the sample with the associated dose reduction with respect to multiple images approaches. While the potential benefits of dark field and scattering images in lung imaging yielded with different phase contrast modalities are generally acknowledged, it is still in question for ABI, which image (single shot images, a linear combination of those or parametric images (i.e. the scatter image)) would provide the highest diagnostic value and what are the role of the x-ray energy and the spatial resolution of the image receptor.

For this purpose contrast and signal to noise ratio have been evaluated in post mortem AB images of mice lungs, acquired at the SYRMEP beamline of the ELETTRA synchrotron in Trieste (Italy), for different x-ray energies and pixel sizes in several regions of interest. In this presentation some of the aforementioned image processing algorithms will be presented and the yielded parametric images, which have been analyzed in terms of contrast and signal-to-noise ratio will be discussed.

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Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 174

Implementation of the interpolator for signal peak detection in read-out ASIC

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One of the trends in the development of front-end electronics is a digitization of analog signals at the earliest stage, followed by their application specific processing in digital domain. Digital processing allows to filter data, remove uninformative or spoiled data, detect overlays and calculate of peak signal. The processing functions are usually assigned to the remote data acquisition system. The stream of digital data coming from read-out ASIC can easily reach a few Gb/s. To reduce the output data flow, it is required the selective digital signal processing, being built-in the ASIC.
For peak detection inside read-out ASIC with high resolution (e.g. 10 bit) for fast signal (e.g. one coming from shaper with peaking time 100 ns), sampling rate must be very high – at least 100 Msps. In this case high-speed ADC will have high power consumption, which is usually inappropriate for low-power read-out channel.
To determine the signal maximum (peak) with the required accuracy (amplitude resolution), it is proposed to use an interpolation. The interpolation allows to find the fit function of a curve that passes through a given set of points. Knowing the equation of the curve, it is possible to calculate the values of the function at intermediate points in the area of the desired maximum of the signal. This will allow to find peak with necessary accuracy, reduce the required sampling rate of the ADC and finally minimize the output data volume.
Comparison of various interpolation methods has shown that interpolation of polynomials in the Lagrange form is most appropriate. This type of interpolation gives high accuracy and is not resource-intensive in its implementation.
The accuracy of the coincidence of the obtained curve with the desired one (the output response of the shaper) is determined by the set of points (the location of the points relative to the signal peak and their number), as well as the accuracy calculating of the coefficients for polynomial.
The behavioral modeling of the interpolator was carried out with variation of the design parameters such as shaper peaking time, ADC sampling rate, upsampling coefficient (count of intermediate points). Method of choosing the optimal parameters for required peak amplitude error is described. Simulation results showed that interpolator usage allows to achieve the accuracy of peak determination < 1 LSB for 10 bit ADC with 30 MHz sampling rate at shaper peaking time 200 ns. The implemented interpolator has polynomial of 6-th degree and uses 3 upsampling points, that is equivalent to 120 MHz ADC using. The interpolator is described as a building block for the read-out ASIC in UMC 180 nm MMRF CMOS process.

Ion Beam, chair: Valeria Rosso / 175

Ion-beam imaging as a tool in ion-beam therapy – based on the technology of silicon pixel detectors

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Ion-beam radiotherapy has the capacity to improve cancer treatments by highly conformal doses to the tumor. This results in a better sparing of healthy tissue in comparison to the standard radiotherapy with photons. On the other hand, the dose concentration–with steep gradients– increases the sensitivity of ion-beam radiotherapy to potential uncertainties during the treatment process like deviations between the predicted and the actual ion stopping power of the patient's tissue or anatomical changes of the patient geometry. Therefore, an accurate measurement of the actual stopping power distribution (relative to water, abbreviated: RSP) is of great interest. In this respect, performing an ion-beam radiography (iRAD) of the patient, who is already positioned on the treatment couch, right before the application of the treatment could be a valuable tool. iRAD could provide direct measurements of the RSP integrated along the beam direction, also called water-equivalent thickness (WET) of the object to be imaged. The WET based on iRAD measurements could then be used to verify that the actual RSP distribution and the one planned on are in agreement. Furthermore, iRAD can in principle provide a higher soft-tissue contrast at the same dose compared to imaging with x-rays. However, the lack of suitable detection systems for clinical application and a limited spatial resolution due to multiple Coulomb scattering (MCS) of the ions are challenges to be met.
To experimentally investigate the capabilities of iRAD, we built a small prototype detection system that solely consists of thin silicon pixel detectors. Here, the image contrast is obtained by precise energy deposition measurements of single ions in a 300 µm thick silicon sensor downstream of the imaged object. Measurements with protons (resulting in proton-beam radiographs: pRADs) and helium ions (αRADs) were performed at the Heidelberg Ion-Beam Therapy Center (HIT). The experiments have shown that a method of ion identification (especially in the case of αRADs) for an efficient suppression of background signals and a system for ion tracking upstream and downstream of the imaged object are substantial to reach clinically-relevant image qualities. The ion identification and ion tracking led to improvements with respect to the contrast-to-noise ratio (CNR) and the spatial resolution, respectively, such that WET differences of 0.6 % in head-sized phantoms could be resolved, and spatial resolutions with σ_LineSpreadFunction < 1.1 mm were achieved.
In this contribution, a fair comparison—using the same detection system—between pRAD and αRAD considering CNR, spatial resolution, and imaging dose is presented. Furthermore, future steps, which are required to bring the prototype detection system closer to an envisaged clinical application, are discussed.
Figure 1 shows a measured helium-beam radiography (αRAD) of a cherry. It exemplarily demonstrates the image quality that can be achieved with this ion-imaging modality.

Poster Exhibition 2, Posters ID 81 - 182, chair: Christer Frojdh / 176

A 2-D localization of a lightly shielded radiation source using a network of small form factor CZT sensors

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Detection of radioactive sources in unconstrained environment with no specific entrance and exit points remains a challenge for nuclear security. The problem is more difficult when it comes to shielded radiation sources. In this work we present an approach of a sensor network that is composed of small form factor CZT radiation sensors which uses both an analytical algorithm and MVA techniques to localize a light shielded radiation source in 2D. The system is capable to combine the fast response time and the large Field Of View (FOV) of the CZT sensors to target spatially confined radioactive sources. Localizing a 137Cs (˜7MBq) with the CZT network yields to a precision better than 20cm in planar coordinates when covering a FOV of 500×280×200cm3 for acquiring time greater than 40sec. Both analytical and Machine learning localization algorithms have been simulated and verified by a series of experiments.

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1.2 Mfps standalone X-ray detector for Time Resolved Experiments

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We present first, standalone and autonomous X-ray camera capable of operation 1.2 Mfps. The camera utilizes UFXC32k hybrid pixel detectors for sensing X-rays, FPGA for sensor data acquisition and compression, Real-Time operating system for FPGA control and data streaming to the higher-level system over 1Gbps Ethernet connection. 1.2 M frames per second is achieved in so-called burst mode of operation while in zero-dead time mode 50 kfps is possible. Due to efficient data compression in FPGA there's no need of using high-speed transceivers and a Frame-Grabber cards on the data server side and the detector can stream the data infinitely over standard 1 Gbps network connection. The camera was prepared for autonomous operation at Advanced Photon Source Synchrotron for X-ray Photon Correlation Spectroscopy experiment and shows excellent performance. Details of camera construction both discrete electronics and software structure will be shown together with APS synchronization methods and meaningful results of measurements of dynamic behavior of biological samples. Comparison to other commercially available detectors will be provided.

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A UV photodetector based on ordered free standing MWCNT

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Multiple wall carbon nanotubes (MWCNT) present advantages for optoelectronic applications such as the large effective photo-collector surface as well as the possibility to tune their band gap and absorbance through the growth parameters.The use of ordered free-standing MWCNTs for photodevices1 presents advantages, since they have a tunable absorbance depending on their height while their dense ordering results in a large effective area sensor. Additionally the bandgap depends on their thickness, thus it is tunable by changing the formation conditions.In this work we demonstrate a hybrid MWCNT/Si3N4/n-Si photodetector based on ordered MWCNTs and evaluate its performance in the UV, visual and near IR spectrum (200-1000nm). Depending on the application the absorbing nanotube layer can be made thick enough (e.g. several millimetres) to enhance radiation absorption and electron-hole pair generation. The best result obtained so far as a UV detector is a 90% Equivalent Quantum Efficiency @ 275nm[2] for a 20μm CNT layer thickness.

X-Ray, chair : Heinz Graafsma / 179

Effectiveness of x-ray phase-contrast tomography: effects of pixel size and magnification on image noise

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Noise magnitude in absorption x-ray tomographic (CT) images is strongly dependent on the detector pixel size and/or the geometrical magnification. For this reason, when constraints in terms of radiation dose or scan time are present, as in clinical or animal studies, high resolution CT imaging at acceptable noise levels is not feasible. In this context, the use of propagation-based phase-contrast technique (PhC) coupled with the application of a suitable phase-retrieval filter (PhR), is a valuable tool to overcome this limitation. In fact, at fixed radiation dose, the noise dependence on the (effective) pixel size when the PhR filter is applied is much shallower with respect to conventional absorption CT images.
This has been quantitatively modelled by Nesterets and co-workers 1, who demonstrated that the image noise is proportional to the inverse of the square of the effective pixel size in case of absorption imaging (i.e., no PhR), while the application of PhR introduces an additional term, mitigating the dependence of noise on the pixel size. In particular, within the validity conditions of the ray-optical approach (i.e., Fresnel number larger than 1), smaller effective pixel sizes correspond to a larger noise reduction due to the PhR, thus amplifying the difference between images reconstructed with or without phase retrieval. Moreover, it has been shown that, when coupled to propagation-based PhC imaging, the only effect of PhR is to reduce image noise while preserving the same spatial resolution that would be observed in conventional absorption images [2, 3].
Along with phase effects, in-vivo imaging can take advantage of high-Z direct-conversion photon-counting detectors, ensuring both high efficiency and spatial resolution, that is mainly limited by the pixel dimension.
In this presentation, experimental results, based on a large (˜10 cm) surgical breast specimen, are compared with the described theoretical model. The measurements have been performed at the Italian synchrotron radiation facility Elettra (Trieste, Italy), by using a large-area CdTe photon-counting detector (Pixirad-8), featuring a 60 µm pixel pitch and ensuring a nearly total absorption efficiency at the selected beam energy (30 keV). In addition to the native pixel spacing, the acquired projections have been rebinned to simulate pixel pitches of 120, 180 and 240 µm (see figure) and the sample has been imaged at three magnifications (1.05, 1.1 and 1.4). The results, expressed in terms of signal-to-noise ratio (SNR) gain due to the PhR application, show a good agreement between theoretical predictions and experimental data at all pixel pitches, quantitatively demonstrating the importance of going towards detectors featuring smaller pixels (or higher spatial resolution) to fully exploit the advantages of PhC and PhR. SNR gain up to a factor of 20 is observed at the smallest pixel pitch and largest magnification. At the same time, as predicted theoretically, larger magnifications correspond to a lower image noise (or higher SNR) due to the effect of the PhR algorithm: this trend is unparalleled in absorption CT imaging where larger magnification (i.e., smaller effective pixel sizes) leads to a higher noise.
![Detail of a breast specimen at different pixel sizes without (top row) and with (bottom row) PhR]figure

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Synchrotron Soft XRF and Ptychography with related Applications

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Soft X-ray Microscopy has rapidly developed into an important spectro-imaging technique for several application fields, from life and environmental science, cultural heritage to material science. It is mostly deployed in synchrotron facilities taking advantage of their tunability and high brilliance characteristics.
Soft X-ray Microscopy coupled with spectroscopy can provide insightful simultaneous morphological and chemical information that help in the understanding of biochemical processes taking place at sub-micron scales. In the last few years the TwinMic soft X-ray microscopy station 1 (400-2200 eV) installed at the Elettra synchrotron has been attracting the interests of the several scientific communities thanks to its complementary imaging capabilities (brightfield and phase contrast) combined with low energy X-ray Fluorescence and X-ray absorption spectroscopy. The developed low energy XRF system [2] enables to correlate the specimen morphology with the elemental distribution of light elements (from B till P) and of transition metals with characteristic emission lines in the 180-2100 eV energy range.
The implementation of novel TwinMic imaging modes is in progress and has been demonstrated by ptychography with randomly phased illumination acquiring scans across the L absorption edge of iron on fibroblast cells exposed to cobalt ferrite nanoparticles [10] and with Phase-diverse Fresnel coherent diffractive imaging of malaria parasite-infected red blood cells.
Representative applications and latest research projects in different research fields will be presented through selected results.

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Synchrotron XRF imaging and XANES spectroscopy at the new PUMA beamline at SOLEIL

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Archaeometry is a scientific discipline which aims at characterizing, studying, preserving and/or dating archeological materials by applying scientific analytical techniques. Such analyses allow to retrieve historical and artistic information about the past and can be performed with standard instrumentation, devoted to a specific technique, or with dedicated instrumentation built to better satisfy the requirement of archeological/artistic artefacts. This is the case of PUMA, standing for French for "Photons Utilisés pour les Matériaux Anciens", a hard X-ray imaging beamline at SOLEIL synchrotron optimized for the scientific communities of the heritage sciences. It is equipped with a 2d imaging end-station which offers a resolution of several microns with elemental (XRF), chemical (XANES) and structural (XANES and XRD) contrast.
In the this work, we present the first analyses performed at the newly opened-to-users PUMA beamline on three set of samples, namely decorated ceramics 1, painted architectural terracottas [2] and natural stones treated with conservation products [3]. The first and recent results obtained on the analyzed samples are here presented to highlight the potential offered by this new beamline in characterizing different kind of archaeological materials, highlighting possible research outcomes and new challenges in cultural heritage studies.

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Opening and Welcome: George Fanourakis, Christer Frojdh

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TBA

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Total ionising dose radiation damage studies of the RD53A chip for the ATLAS and CMS upgrades

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Invited Talk 1, Tracker design for future colliders: CMS Tracker for HL-LHC (and beyond)

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Invited Talk 5: X-ray imaging with photon-counting detectors

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XFEL, chair: Ralf Menk / 189

Megapixels @ Megahertz - AGIPD Detectors for the European XFEL and beyond

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Invited Talk 4: Design of CMOS detectors for electrons and X-rays

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Invited Talk 3 : Thin CMOS Pixel Sensors : State-of-the-art and prospects in subatomic physics and connected domains

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Invited Talk 2: X-ray Phase Contrast with synchrotron radiation for biomedical applications and breast imaging

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Phase contrast x-ray imaging methods have yielded a substantial improvement in image quality compared to conventional radiology, which is based on absorption properties and possesses only little soft tissue differentiation. The majority of phase techniques has been developed for synchrotron radiation x-ray sources.
Free space propagation phase contrast is the simplest method, which relies on x-rays sources featuring a high degree of spatial coherence and no additional optics is required. Phase sensitive methods capable of exploiting deviation of the x-ray path in the order of microradiants are analyzer based imaging and grating based imaging.
These special imaging tools offer the possibility to visualize different length scales from micrometric details in the size of cell aggregates up to the patient level for the diagnosis of different diseases such as breast cancer.
Depending on the specific applications, these techniques have been implemented at the medical imaging beamline of the synchrotron facility ELETTRA in Trieste (Italy).
On the patient level, synchrotron radiation phase contrast mammography has been successfully applied in a clinical trial with uncertain diagnosis of breast cancer. The monochromatic laminar X-ray beam and the selection of optimal energy for the given breast thickness and composition allow acquiring high quality images with reduction of scattering and delivered dose. Moreover, the high spatial coherence of the source with large propagation distance permits to exploit the free space propagation phase-contrast effect enhancing soft tissue contrast.
Besides planar mammography X-ray breast computed tomography (breast CT) is an emerging and challenging technique for increasing the diagnostic power of mammography that aims to overcome the superposition of the structures inherent in conventional planar mammography improving breast

cancer diagnosis. Synchrotron radiation provides again ideal X-ray imaging conditions for this purpose. Starting from the previous successful experience in the clinical phase contrast mammography with synchrotron radiation, a breast CT project is in advanced development stage at ELETTRA.

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New photosensor readout for noble gas electroluminescence

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The current generation of noble liquid dark matter detectors is limited by the radioactivity coming from detector materials, mostly from the specially radio-clean PMTs.Alternative large area avalanche photodiodes (LAAPDs), e.g. EXO, have low gain, small area, insensitiveness to low scintillation levels and high cost per unit of area. Large area hybrid vacuum PMTs, such as SIGHT, may be used as an alternative to PMTs. However, problems related with vacuum sealing and high voltages are limiting factors, adding up to the low interest shown by Hamamatsu in developing such devices. In addition, the large dimensions that are sought to be developed for SIGHT, for competitiveness, limit the spatial resolution that could be obtained for the event interaction position.An alternative to PMTs will be, indeed, SiPMs. The NEXT Collaboration has proven the potential of aSiPM 2D-readout plane for Xe EL. A 2D pattern of SiPM, 1mmˆ2 active area and 10 mm pitch, coated with PTB for wavelength shifting, was used to readout the EL in a 10-bar HPXe TPC. The 10% photosensor area coverage was shown to be sufficient, but a compromise has to be made with the energy resolution and position resolution that could be achieved with such a readout plane of small area coverage lowSiPM density. For Xe-EL readout, an alternative to PMTs and to large area-coverage highSiPMdensity, can be a GPM. Standard GPM uses a CsI photocathode coating the "front" surface of a THGEM, which is the first photoelectron multiplier element; photoelectrons are focused into the holes and forwarded to subsequent amplification stages, a cascade of 2 or 3 THGEMsthat is used for photoelectron signal amplification through electron avalanche.The final signal is collected in the pixelated anode readout. GPMs allow for large-area coverage with high detection efficiency and high filling factor. In GPMs, the use of THGEMs and of total voltages that can reach few kV are needed to attain maximum gains above 10ˆ5, which are required for efficient single photoelectron detection. In addition, the use of FR4 in THGEMs, with high intrinsic radioactivity, and the need for having the "hot" electronics close to the anode electrodes for the charge readout,hampers its use in dark matter searches. These critical issues still need to be solved in GPMs.

The GPM to be developedsubstitutesfor the electron multiplier cascade used for photoelectron signal amplification. Instead, a 2D SiPM plane, will be used to readout the scintillation produced in the photoelectron avalanches in the first element. This allows a much simpler device with only one micropattern element, instead of a cascade of a few elements. A Micro-Hole and Strip Plate, etched on kapton for radiopurity's sake, will be used substituting for the THGEM, since the former achieves higher photon output than the latter. The additional gainreached with the SiPMs provides signals with large amplitude and large signal to noise ratio. The large photon output of the charge avalanches and the small distances from the SIPMs to the scintillation region allow the use of a low coverage area, i.e. low SiPM density, with signals well above the dark current noise in several neighbor SiPMs and, thus, an easy measurement of both the signal amplitude its 2D-position.

The kapton foils, the SIPMs, the GPM fused silica window and the GPM metal case can be obtained with reduced radioactivity levels.Also important, is the feasibility of the deployment of remote "hot" electronics, since the large gains achieved in the SiPMs allow for signal transmission over large distances without significant degradation. In addition, the GPM will allow for an area coverage similar toor better than that of PMTs.On the other hand, the quantum efficiency of CsI is ˜25% (in vacuum) and, with a photoelectron extraction & collection efficiency into the holes of 60%-80%, the photon detection efficiency may be lower than that achieved withPMTs.

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Evolution of scintillation and electrical characteristics of AlGaN during hadron irradiation

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The wide direct-bandgap AlGaN is one of the most promising materials for fabrication of radiation hard, double response particle detectors for future collider facilities. However, formation of defects during growth and fabrication of AlGaN based devices is unavoidable. Furthermore, radiation defects are formed in detector structures during operation at extreme conditions.
Study of defect evolution in-situ during hadron irradiation has been performed in this work. GaN and AlGaN (with various Al concentrations) epi-layers grown by metalorganic chemical vapour deposition technique on sapphire substrate have been examined. Electrical signals were registered (using the barrier evaluation by linearly increasing voltage method) simultaneously with the hadron induced luminescence spectra, recorded using signal integration regime. To evaluate the parameters of thermal emission in Schottky barrier structures and cross-sections of the photon-electron coupling, ascribed to technological and radiation defects in the AlGaN crystals, the complementary ex-situ measurements were performed by deep level transient and pulsed photo-ionization spectroscopy techniques.
It has been shown that these combined methods of the in situ-and ex-situ measurements enable ones to trace evolution of the electrical and scintillation characteristics of AlGaN layers with fluence of hadron irradiations. Variations of spectral and electrical parameters could be applied for remote dosimetry of large hadron fluences.

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Processing of Gallium Arsenide VGF Wafers for Radiation Imaging Pixel Detectors

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GaAs was extensively studied for the last 70 years, but still remains the material of choice only in certain areas (like production of commercial semiconductor lasers). Noticeable advantages of GaAs over Si
for radiation detector manufacturing, such as higher electron mobility (8000 vs 1400 cm2/(V·s)), higher
average atomic number (31.5 vs 14) and wider bandgap (1.43 vs 1.12 eV) 1 result in better charge
collection, higher radiation absorption efficiency, superior radiation hardness and lower noise. Silicon is
preferable in this area mainly due to low cost and well-established technology for electronic device
production. However, with the last developments in vertical gradient freeze (VGF) growth of bulk GaAs
crystals, this material came very close to silicon in terms production feasibility. High-quality 4” and 6“
wafers of semi-insulating GaAs material available on market make possible adaptation of Si processing
technology for large-scale production of GaAs hybrid radiation detectors.
As part of the European H2020 funded X-MINE [2] project Advacam has studied possibilities to produce
radiation detectors using VGF semi-insulating GaAs material available in the market. We used 3”, 4” and 6”
<100> VGF GaAs wafers with resistivity in range of 1-7*108 Ohm-cm with thickness of 575-625 um. We
have demonstrated a wafer-level processing of the wafers using sensor designs compatible with Timepix
readout ASIC [3]. Figure 1 (left) shows a 3” and 4” GaAs wafers

The presentation summarises the GaAs wafer-level processing and micro packaging. Comparison of the
electrical, X-ray imaging and spectroscopic performance of the GaAs sensors manufactured from different
sizes of semi-insulating wafers will be given. The presented properties include leakage current, measured
point-spread-function, material homogeneity, stability and energy resolution. We have concluded that the
electron collection modality is superior over the hole collection and that the VGF GaAs shows imaging
quality comparably to silicon but worse energy resolution.
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Neutron transmission imaging with single pixel spectroscopic resolution

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High resolution energy resolved neutron imaging at pulsed neutron sources enables simultaneous measurement
of transmission spectra in a wide range of energies spanning from meV to tens of keV. The key enabling
technologies needed for this high resolution spectroscopic imaging are bright spallation neutron sources and
novel neutron counting detectors capable of measuring both position and time of each neutron and capable of
operation at very high input rates exceeding 107 n/cm2/s. Analysis of these neutron transmission spectra allows
non-destructive investigation of various sample characteristics such as microstructure (distribution of phase,
variation of texture and strain), elemental and isotopic composition (for the elements with relatively high
resonance absorption cross section), distribution of temperature, and many others. The recent development of
high resolution neutron counting detectors with Microchannel Plates (MCPs) and Timepix readout provided
new opportunities in energy-resolved imaging due to their unique capability to register many nearly
simultaneous neutrons with relatively high detection efficiency (˜50% for the thermal neutrons).
In this paper, we demonstrate the unique capabilities of energy-resolved neutron imaging and show results of
our recent studies in fields as diverse as materials science, structural and aerospace engineering, studies of
cultural heritage objects, geophysics, and others. The limitations of present detection technology for this
applications and possible solutions foreseen in the near future will be discussed

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A Polarized Infrared Calibration Bench for the B-BOP Bolometric Camera working at 50mK

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Development of a characterization set-up for testing position sensitive silicon micro-strip sensors at the University of Delhi

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