22nd International Workshop on Radiation Imaging Detectors

Report of Contributions

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Contribution ID: **133** Type: **Poster presentation only**

Large-Area SiPM Pixels (LASiPs) in SPECT

We developed a Large-Area SiPM Pixels (LASiP) to use it in Single Photon Emission Computed Tomography (SPECT).
We present our results of a proof-of concept camera made of 4 LaSiPs prototypes, as well as simulations of the system to study the contribution of different types of LaSiP noise on the energy resolution and the impact of the pixel size, the pixel geometry and the noise on the performance of the camera.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **134** Type: **Poster presentation only**

Analysis of deflection angle for muon energy categorization in muon scattering tomography by means of GEANT4 simulations

In muon scattering tomography, the target materials are distinguished in accordance with the scattering angle through the process chain followed by the incoming muons within the investigated volume, and this scattering angle mainly depends on the atomic number, the density, and the thickness of the medium at a given energy value. The distinct values obtained for the scattering angle at different initial energies also provide the opportunity to classify the incoming muons into a number of energy groups. In this study, we employ the Monte Carlo simulations by using the GEANT4 code and we register the hit locations at the detector layers in order to determine as well as to analyse the deflection angles due to the detector layers present in the studied hodoscope and the possible muon tomography systems. We start with our current hodoscope setup that consists of three top and three bottom plastic scintillators made of polyvinyltoluene with the thickness of 0.4 cm. We show that the deflection angle exponentially declines with respect to the energy increase, and the numerical values for the current configuration are below the detector accuracy except the initial energy bins owing to the low-Z, low density, and low thickness of the current plastic scintillators. This indicates the requirement of auxiliary components that induce the muon scattering. Therefore, we insert stainless steel surfaces into the top and bottom sections in order to augment the deflection angle as well as to diminish the uncertainty, thereby ameliorating the detector performance.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **135** Type: **Poster presentation only**

HEXITEC 2x2: Tiled Hard X-Ray Spectroscopic Imaging Detector System

HEXITEC is a spectroscopic imaging x-ray detector technology developed at STFC Rutherford Appleton Laboratory for high energy x-ray and gamma ray applications. Each module has 80x80 pixels on a 250µm pixel pitch, and has been implemented successfully in a number of applications [1]. This paper presents the HEXITEC 2x2 detector system, a tiled array of 4 HEXITEC modules in a 2x2 formation, which achieves an active area of 16cm2 read out simultaneously. The system has been developed with 1mm thick Cadmium Telluride (CdTe) and 2mm thick Cadmium Zinc Telluride (CZT) detector materials. Here the system [2,3] and data processing methods are presented, and the performance of the first completed systems evaluated.

The detectors were calibrated, and three types of charge sharing correction were applied to the data - charge share addition (CSA), charge share discrimination (CSD), and energy curve correction (ECC) which compensates for energy lost to the inter-pixel region. ECC adds 20.77% to the 59.5keV peak height in CdTe, improving the detector's performance in photon-starved applications. Due to the high frame rate (6300fps) end of frame (EOF) corrections were applied to 5.6% of all events.

The energy resolution of the detector system was measured on the 59.5keV peak of an Am-241 sealed source. Both detector materials were found to have excellent spectroscopic performance with mean energy resolution (FWHM) of 1.05keV in CdTe and 1.20keV in CZT.

This paper demonstrates the potential to tile larger arrays of HEXITEC modules to be read-out simultaneously in order to achieve larger area imaging.

[1] Veale et al., Synchrotron Radiation News 31 (2018), pg.28—32
[2] Zannoni et al., Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 981 (2020), pg. 164531
[3] Van Assche et al., Sensors 21 (2021), pg. 563

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **137** Type: **Poster presentation only**

Plant root PET: visualization of photosynthate translocation to roots in rice plant

Photosynthate translocation from source leaves to sink organs directly affects dry matter accumulation there and promotes auxetic growth of the sink tissues. In particular, the photosynthate translocation to root tissue is an important physiological function that affects growth of roots and determines plant growth, yield and quality. It is essential to evaluate the dynamics of photosynthate translocation to roots in crop cultivation. However, only a few studies have investigated the dynamics of translocation to roots because of the difficulty in measuring translocation to roots with three-dimensional and complex structure in the underground. Although positron emission tomography (PET) offers three-dimensional images of radioactive tracers and applied to plant root imaging [1], the spatial resolution of conventional PET scanners is degraded in the peripheral area of the field of view (FOV) due to parallax error. Because of the root structure, uniform spatial resolution is required. Four-layer depth-of-interaction detectors were developed to overcome the problem and applied to a small OpenPET prototype [2]. Recently, Kurita, et al. have improved the prototype for plant studies and imaged a piece of strawberry fruit at the center of the FOV [3]. In this study, we performed an imaging experiment of rice roots using the prototype and demonstrated the imaging capability of the prototype over the whole FOV.

Figures 1(a) and (b) show the material plant and the experimental setup. A rice plant three weeks after sowing was planted in a plastic pot (diameter of 97 mm, length of 140 mm). The PET was placed vertically in this study. About 34.8 MBq of 11CO2 gas was fed to all source leaves, and 30 min after the injection of 11CO2, the plastic pot was set in the center of the FOV (diameter of 110 mm, length of 145 mm) so as to position the source leaves outside the FOV. Then, the measurement was started and the 11C distribution images were acquired for 120 min. Above the PET, a light-emitting diode lamp was set to promote the photosynthesis of source leaves. The PET data were reconstructed using the ordered subset expectation maximization method. The matrix size and voxel size of the reconstructed images were 76 × 76 × 84 and 1.5 mm × 1.5 mm × 1.5 mm, respectively.

Figure 2 shows the integrated PET images viewed from different planes. From these images, the 11C-photosynthate accumulation in roots which developed in three dimensions from the base to the peripheral area of the FOV in the underground were confirmed. We demonstrated the imaging capability of the prototype over the whole FOV successfully.

[1] S Jahnke et al., Plant J. 59 (2009), 634-644
[2] E Yoshida et al., Radiol. Phys. Technol. 5 (2012), 92-97
[3] K Kurita et al., Nucl. Instrum. Methods Phys. Res. Sect. A 954 (2020), 161843

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **138** Type: **Poster presentation only**

Assessments on alpha imaging detector with energy and efficiency calibration using a single standard source

For the acquisition of the alpha particle distribution, two-dimensional photodetectors combined with a scintillator plate have been developed over the past years. The individual energies of the alpha-emitting radionuclides should be identified for the quantitative analysis. This can be done by the spectrometric method after energy and efficiency calibrations. In order to calibrate energy and efficiency, multi-peak calibration methods using a number of standard sources are widely used in alpha spectroscopy. In this study, we proposed an energy and efficiency calibration method with a single standard source and characterized an alpha imaging detector. We obtained fitting coefficients for the energy calibration curve using each channel of the peak from the real measurements and each energy of the peak from the results of Monte Carlo simulation. The energy resolutions and the values of the efficiency were also evaluated. From the measurement, the alpha imaging detector showed an energy resolution of 16.7% at 5.5 MeV and an efficiency of 27.9%. The tests of resolution and efficiency demonstrate that the alpha imaging detector is correctly calibrated using a single standard source. Further study will include evaluating the effectiveness of the proposed method and the application of the alpha imaging detector for quantitative analysis.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **139** Type: **Poster presentation only**

Compatibility test of selected materials in liquid scintillator towards SABRE South detector design and fabrication to detect dark matter

Abstract:

The Sodium Iodide with Active Background REjection (SABRE South) detector experiment (Figure 1) in Australia aims to direct dark matter detection, and its detector design includes numerous materials that will be in contact with the liquid scintillator over the uninterrupted multi-year operation for around 5 years [1, 2]. The light yield of the liquid scintillator is easily degraded by the presence of contaminates, so compatibility testing was needed to ensure that liquid scintillator was not degraded by the materials used in the construction of the SABRE South detector design and fabrication and the light yield remains above an acceptable limit over the course of the experiment [2].

SABRE South particle detector's component compatibility tests in terms of scintillation light yield and optical absorbance analysis of liquid scintillator over ˜560 days are reported here. A key outcome of the compatibility test is that tested rubbers (MelbRub, NBR, EPDM and Neoprene) and bellows (BellowsWD, BellowsCL, BellowsWS and BellowsAct) materials are totally incompatible with liquid scintillator, which should not use in contact with liquid scintillator at any condition. In addition, Jubilee clip, polyolefin tube and potting compound degraded significant amount (more than 10 %) of light yield and optical absorbance of liquid scintillator over 560 days, which can ultimately reduce the SABRE South detector's energy resolution and detection efficiency. On the other hand, stainless steel, steel coated materials, Viton O-ring, BlackCable (coaxial cable), epoxy sealant, LuMirror, nylon made cable ties, nylon nuts, fluorinated ethylene propylene (FEP) cable, polytetrafluoroethylene (PTFE) tape, aluminium alloy (Al6060) and copper alloy (CuCF) gasket are fully compatible with liquid scintillator. Based on the carried out experimental study, if any liquid scintillator degradation scales as the surface area to volume ratio and scales linearly with time in contact with the material, then the lack of observable changes (at the 1 % level) over 560 days with the used test geometry, translates to a stability at the level of 0.6 % over the 5-year detector operation.

The obtained results from this study can be used to understand the effect of different materials on the light yield and optical absorbance properties of the liquid scintillator over the course of 3 to 5 years uninterrupted operation, and it can aid to design large scale scintillation detectors for nuclear science and particle physics applications.

[1] Rahman, M.S. et al., Investigation of Viton O-Ring Performance for the SABRE Dark Matter Experiment. J. of Materi Eng and Perform 29, 8359–8369 (2020). https://doi.org/10.1007/s11665-020-05259-x .
[2] Bignell et al., SABRE and the Stawell Underground Physics Laboratory Dark Matter Research at the Australian National University, EPJ Web Conf., 2020, 232, p 01002.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **140** Type: **Poster presentation + pitch**

Performance of the ALICE upgraded Inner Tracking System

Major upgrades of the ALICE experiment are under way and will be completed during the LHC Long Shutdown 2 to start operation in 2022 for LHC Run 3. One key part of this upgrade is the new Inner Tracking System (ITS2), a full silicon-pixel detector constructed entirely with CMOS monolithic active pixel sensors. The upgraded ITS2 detector consists of three inner layers (50 μm thick sensors) and four outer layers (100 μm thick sensors) covering 10 m^2 and containing 12.5 billion pixels with a pixel pitch of 27 μm x 29 μm. Compared with the silicon tracking system used during the LHC Run 1 and Run 2, the increased granularity, the very low material budget (0.35% X_0/layer in the inner barrel) as well as a smaller beam pipe radius, will result in a significant improvement of impact-parameter resolution and tracking efficiency.

The assembly of the full detector and services finished in December 2019. A comprehensive commissioning phase (on surface) was completed in December 2020, including fake-hit rate and cosmic-ray data taking, detector calibration, etc. The detector is currently being installed in the ALICE experiment, which will be followed by on-site commissioning. In this talk, the performance of the upgraded ALICE ITS2 detector, as well as the experience gained from its commissioning at the surface will be discussed in detail. Further plans for the commissioning following the detector installation at the ALICE experiment will also be outlined.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **141** Type: **Poster presentation only**

Data acquisition and slow control interface for the Mu2e experiment

The muon campus program at Fermilab includes the Mu2e experiment that will search for a charged-lepton flavor violating processes where a negative muon converts into an electron in the field of an aluminum nucleus, improving by four orders of magnitude the search sensitivity reached so far.
Mu2e's Trigger and Data Acquisition System (TDAQ) uses {\it otsdaq} as its solution. Developed at Fermilab, {\it otsdaq} uses the {\it artdaq} DAQ framework and {\it art} analysis framework, under-the-hood, for event transfer, filtering, and processing.
{\it otsdaq} is an online DAQ software suite with a focus on flexibility and scalability, while providing a multi-user, web-based, interface accessible through a web browser.
The detector Read Out Controller (ROC), from the tracker and calorimeter, stream out zero-suppressed data continuously to the Data Transfer Controller (DTC). Data is then read by a software filter algorithm that selects events considering data flux that comes from a Cosmic Ray Veto System (CRV).
A Detector Control System (DCS) for monitoring, controlling, alarming, and archiving has been developed using the Experimental Physics and Industrial Control System (EPICS) open source Platform. The DCS System has also been integrated into {\it otsdaq}.
A prototype of the TDAQ and the DCS systems has been built at Fermilab's Feynman Computing Center. We report the developments and achievements of the integration of Mu2e's DCS system into the online {\it otsdaq} software.

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **142** Type: **Poster presentation only**

Time-Resolved X-ray Spectroscopy of RE3+-codoped YAG:Ce Scintillator with a Picosecond Resolution

The Ce³⁺ activated Y₃Al₅O₁₂ (YAG:Ce) is a fast and efficient inorganic scintillator widely used in electron and X-ray detection systems. The single crystals of YAG:Ce achieve 90-120 ns decay constant of the scintillation pulse and light yield up to 30 000 photons/MeV. In previous studies, we have shown that RE³⁺ codoping of YAG:Ce and the associated resonant energy transfer from Ce³⁺ to RE³⁺ codopant enables acceleration of the Ce³⁺ photoluminescence decay [1,2].

In this work, the application of the time-resolved X-ray spectroscopy on the measurement of fast processes of the scintillation phenomena will be presented. The setup, consisting of a laser-driven picosecond X-ray excitation source (Hamamatsu) and a fast detection system (Horiba), was used for the current study. The X-ray pulses are generated by the laser with a variable repetition rate and delivered to the sample located near the exit window of the X-ray tube. The luminescence produced by the sample is guided directly to the entrance window of the hybrid PMT through a collecting lens. The acquisition of the data is performed by the time-correlated single photon counting technique. The temporal resolution is defined by the instrumental response function of the setup and the corresponding full width at half maximum which is about 66 ps, see Fig. 1.

In the current study, we exploit the ultrahigh temporal resolution of the described setup for the measurement of the scintillation decay curves of the RE³⁺ codoped YAG:Ce. Specifically, we focus on the initial part of the decay where the RE³⁺ codoping induces a shortening of the rise time of the scintillation pulse, see Fig. 1.

[1] M. Pokorný et al., Opt. Mater., 86 (2018) 338.
[2] J. Páterek et al., J. Lumin., 213 (2019) 469

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Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **143** Type: **Oral presentation**

Studies of high-field QED with the LUXE experiment at the European XFEL

Wednesday, June 30, 2021 2:40 PM (20 minutes)

The LUXE experiment aims at studying high-field QED in electron-laser and photonlaser interactions, with the 16.5 GeV electron beam of the European XFEL and a laser beam with power of up to 350 TW. The experiment will measure the spectra of electrons and photons in non-linear Compton scattering where production rates in excess of 10ˆ9 are expected per 1 Hz bunch crossing. At the same time positrons from pair creation in either the two-step trident process or the Breit-Wheeler process will be measured, where the expected rates range from 10ˆ-3 to 10ˆ3 per bunch crossing, depending on the laser power and focus. These measurements have to be performed in the presence of low-energy high radiation-background. To meet these challenges, for high-rate electron and photon fluxes, the experiment will use Cherenkov radiation detectors, scintillator screens, sapphire sensors as well as lead-glass monitors for back-scattering off the beam-dump. A four-layer silicon-pixel tracker and a compact electromagnetic tungsten calorimeter with GaAs sensors will be used to measure the positron spectra. The layout of the experiment and the expected performance under the harsh radiation conditions will be presented.

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Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **144** Type: **Poster presentation only**

Characterization of FBK 3D pixel sensor modules based on RD53A readout chip for the ATLAS ITk

3D pixel sensors are the technology of choice for the innermost layer (L0) of the ATLAS ITk detector at High Luminosity LHC. The considered sensors have pixel size of either 25 μm ⊠ 100 μm (25⊠100) or 50 μm ⊠ 50 μm (50⊠50), with one read-out electrode at the centre of a pixel and four bias electrodes at the corners. The former geometry has been chosen for the central part of L0 (barrel), the latter for the lateral rings (endcap). A new generation of 3D pixels featuring these small-pitch dimensions and reduced active thickness (˜150 μm) has been developed to this purpose within a collaboration of INFN and FBK since 2014 [1]. The most recent R&D batches at FBK have been oriented to sensors compatible with the RD53A chip, also taking benefit from using an improved lithographical system [2]. Several sensors of different geometries were bump bonded to RD53A read-out chips at Leonardo (Rome, Italy) and tested in laboratory and at beam lines.
In this paper, we report on the module characterization results, including threshold tuning and noise measurements, and results from beam tests performed at DESY facility on both 25×100 and 50× 50 sensors, irradiated with 70 MeV protons up to a fluence of 1×1016 1 MeV neq cm-2. As an example, Fig. 1 shows the hit efficiency in two modules as a function of the bias voltage. It can be seen that both the 25×100 and 50× 50 modules reach the target efficiency of 97% below 100 V, although the 25×100 initially exhibited an anomalous trend. Moreover, we discuss about the electrical characteristics at wafer level and at module level before and after irradiation, also in comparison with other modules from previous fabrication batches [3].

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **145** Type: **Oral presentation**

Imaging of Biomacromolecules in Mass Spectrometry Using Timepix Detectors

Wednesday, June 30, 2021 2:20 PM (20 minutes)

The Timepix (TPX) is a micropixelated imaging detector capable of recording both the arrival time and position of individual ions. In this study, we have integrated TPX detectors to three different mass spectrometers (MS) for the spatially resolved detection and structural analysis of macromolecular assemblies (MMAs). First, a dual microchannel plate (MCP) stack-TPX quad detection assembly has been coupled to a nano-electrospray ionization(nanoESI)-orthogonal time-of-flight(TOF)-MS for the analysis of multiply charged non-covalent protein complexes of molecular weight in excess of 800 kDa. Using this experimental setup, we demonstrate the ability of the TPX to unambiguously detect and image individual macromolecular ion events, providing the first report of single-ion imaging of protein complexes. The single ion imaging capability has been further exploited to gain a better understanding on the effect of ion and voltage parameters on the MCP response for the detection of a broad mass range of 192 to 800,000 Da. Moreover, we have used both the impact position and arrival time information of the ions at the detector to visualize the effects of various ion optical parameters on the flight path of ions. This led to the identification of the origin of an unexpected TOF signal that could easily be mistaken as a fragment of the protein complex as the secondary electron signal arising from ion-surface collisions inside the TOF housing. The TPX detector used for this work is limited by a moderate time resolution (20 ns here, at best 10 ns) and single-stop detection for each pixel that can bias the detection of ions with a low TOF at high count rates. Our second work has been benefited from the implementation of the next generation Timepix3 (TPX3) detector that offers 1.56 ns time resolution, per-pixel multi-hit functionality and kHz readout rates. In this experimental set up, a TPX3CAM (optically coupled to MCP via a fast scintillator) has been added to a MALDI (matrix-assisted laser desorption/ionization)-linear TOF MS, which allowed the detection and ion imaging of singly and doubly charged intact protein ions of mass to charge (m/z) ratio up to 1,150,000 Da. We also demonstrate the spatial and temporal separation of metastable neutrals produced in MALDI MS, and the effect of the matrix structure and laser power on the metastable decay rate for various proteins. Additionally, TPX and TPX3 assemblies used in the first two experimental studies have been added to an in-house developed nanoESI-Orbitrap-linear/orthogonal-TOF MS platform. This innovative imaging approach targets the structural determination of MMAs by analyzing the relative positions of the fragment ions produced from the precursor MMA ion via ultraviolet photo dissociation (UVPD).

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Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **147** Type: **Poster presentation only**

Radioactive source localization using a Data Driven MVA method

In the new era of homeland security there is a growing concern regarding the possession and the potential use of radiological materials by terrorist groups usually in the form of a radiological dispersion device (RDD), also known as "dirty bomb". Since the defended areas from such a threat may not have specific entrance and exit points, the problem of how to localize a radioactive source in an open area should be investigated.
We present a small form factor (0.5cm3) CZT sensor network consisted of a number of five (5) Non-Directional Detectors (NDD) in a planar cruciform topology capable to localize a stationary radiation source in 3D. The localization was performed with fusion algorithms based on MVA techniques. The algorithms make use of Multilayer Perseptron Neural Network (MLP) and Gradient Boosted Decision Trees (BDTG). The training of the MVA methods has been done using a set of experimental data (defined as the response of the sensors in different 3D radiation source positions) collected with the sensor network and exploiting the symmetry of its topology. The initial small set of experimental data points was increased to a few thousand points by utilizing both the symmetry of the network topology and the fact that the response of the sensors is proportional to Ae-μr/r2, where A represents the source activity and the sensor efficiency and r is the distance in 3D between each sensor and the radiation source and the term e-μr corresponds to the absorption term.
Using the above data driven method thousands of data points have been generated and subsequently used for the training of the MVA algorithms. The benefit of this approach is that without any significant computational cost the effects of both the radiation absorption and scattering can be taken into account, which in other circumstances would require a detailed description of the surrounding materials in order to produce reliable simulated data of the experimental setup. When the effect of the radiation absorption and scattering is not taken into account the source localization especially in the depth direction (source transverse distance from the sensor plain) could be biased towards higher values[1].
The localization efficiency of the algorithms has been estimated using a set of experimental data that was not used during the training phase. The data have been gathered in our laboratory using a 137Cs source of 180μCi. A localization resolution (standard deviation of the accuracy distribution, where accuracy is defined as the difference between the estimated and the true coordinate) of the order of 10cm and 12cm has been archived for the Horizontal (Figure 1) and Vertical (Figure 2) directions respectively. In addition a resolution of the order of 15cm has been obtained for the depth (Figure 3) direction without significant bias in the position estimation when the radiation source was located in a monitored volume of 5m x 2.8m x 2m.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **148** Type: **Oral presentation**

Development, construction and tests of the Mu2e electromagnetic calorimeter mechanical structures

Monday, June 28, 2021 4:30 PM (20 minutes)

The "muon-to-electron conversion"(Mu2e) experiment at Fermilab will search for the Charged Lepton Flavour Violating neutrino-less coherent conversion ⊠-N(A,Z) ⊠ e-N(A,Z) of a negative muon into an electron in the field of an aluminum nucleus. The observation of this process would be the unambiguous evidence of physics beyond the Standard Model. Mu2e detectors comprise a straw-tracker, an electromagnetic calorimeter and an external veto for cosmic rays. The electromagnetic calorimeter provides excellent electron identification, complementary information to aid pattern recognition and track reconstruction, and a fast online trigger. The detector has been designed as a state-of-the-art crystal calorimeter and employs 1340 pure Cesium Iodide (CsI) crystals readout by UV-extended silicon photosensors and fast front-end and digitisation electronics. A design consisting of two annular disks positioned at the relative distance of 70 cm downstream of the aluminum target along the muon beamline satisfies Mu2e physics requirements.

The hostile Mu2e operational conditions, in terms of radiation levels, 1 tesla magnetic field and 10ˆ-4 Torr vacuum have posed tight constraints on the design of the detector mechanical structures and materials choice. The support structure of the two 670 crystals matrices employs two aluminum hollow rings and parts made of open-cell vacuum-compatible carbon fibre. The photosensors and front-end electronics associated to each crystal are assembled in a unique mechanical unit inserted in a machined copper holder. The 670 units are supported by a machined plate made of vacuum-compatible plastic material. The plate also integrates the cooling system made of a network of copper lines flowing a low temperature radiation-hard fluid and placed in thermal contact with the copper holders to constitute a low resistance thermal bridge. The digitisation electronics is hosted in aluminum crates positioned on the external surfaces of the two disks. The crates also integrate the digitisation electronics cooling system as lines running in parallel to the front-end system.

In this talk we will review the constraints on the calorimeter mechanical structures, the mechanical and thermal simulations that have determined the design technological choices, and the status of mechanical components production, tests and assembly.

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Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **149** Type: **Poster presentation + pitch**

Absolute primary scintillation yield in Xe for electrons and alpha particles

Xenon scintillation has been widely used in recent particle physics experiments [1-3]. However, information on primary scintillation yield in the absence of recombination is still scarce and dispersed. The mean energy required to produce a VUV scintillation photon (Wsc) in gaseous Xe has been measured in the range of 30-120 eV [4-7]. Lower Wsc-values are often reported for alpha particles compared to electrons produced by gamma or x-rays, being this difference still not fully understood.
We carried out a systematic study of the absolute primary scintillation yield in Xe at 1.2 bar, using a Gas Proportional Scintillation Counter. The simulation model of the detector's geometric efficiency was benchmarked through the primary and secondary scintillation produced at different distances from the photosensor. Wsc-values were obtained for gamma and x-rays with energies in the range 5.9-60 keV, and for 2-MeV alpha particles. No significant differences were found between alpha particles and electrons.

[1] E. Aprile et al. (XENON), The XENON1T Dark Matter Experiment, Eur. Phys. J. C 77 (2017), 881
[2] D. S. Akerib et al. (LUX-ZEPLIN), Projected WIMP sensitivity of the LUX-ZEPLIN dark matter experiment, Phys. Rev. D 101 (2020), 052002
[3] P. Ferrario et al. (NEXT), Demonstration of the event identification capabilities of the NEXT-White detector, JHEP 10 (2019), 052
[4] M. Mimura et al., Average Numbers of Scintillation Photons and Electrons Produced by an Alpha Particle in High-Density Xenon Gas, Japan. J. Appl. Phys. 48 (2009), 076501
[5] S. J. C. do Carmo et al., Absolute primary scintillation yield of gaseous xenon under low drift electric fields for 5.9 keV X-rays, J. Instrum. 3 (2008), P07004.
[6] L. M. P. Fernandes et al., Primary and secondary scintillation measurements in a Xenon Gas Proportional Scintillation Counter, J. Instrum. 5 (2010), P09006.
[7] L. Serra et al. (NEXT), An improved measurement of electron-ion recombination in high-pressure xenon gas, J. Instrum. 10 (2015), P03025.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **150** Type: **Poster presentation only**

Performance improvement of Compton imaging of astatine-211 by optimizing coincidence time window

Introduction
Astatine-211 is a promising radionuclide for targeted α-particle radiotherapy of cancers. It is required to image the distribution of targeted radiotherapeutic agents in a patient's body before or during treatment for optimization of treatment strategies and determination of the suitability of a given agent for a particular patient [1]. Because the biodistribution of astatine-211 is different from that of iodine-131, it is important to image astatine-211 directly.

The astatine-211 and its daughter radionuclide polonium-211 emit gamma rays (570 keV, 687 keV, and 898 keV) at the total intensity of 0.9%. Recently, we have proposed to image astatine-211 with the gamma rays using a Compton camera and demonstrated the imaging capability of the camera in the experiments of a point-like astatine-211 source with a relatively wide coincidence time window of 160 ns [2]. Since random coincidence events by polonium K-shell x rays were dominant and seemed to cause saturation of counts in the experiments, optimization of the coincidence time window is important to reduce the random coincidence events. In this study, we optimized the coincidence time window and evaluated the performance of the camera.

Materials and methods
A. Imaging system
The Compton camera has two detectors: a scatterer and an absorber. The scintillator material of both the detectors is cerium-doped gadolinium aluminum gallium garnet (GAGG; Ce:Gd3Al2Ga3O12; Furukawa Co., Ltd.). The scatterer is a 20.8-mm x 20.8-mm x 5-mm GAGG array block coupled to a silicon photomultiplier S11064-050P (Hamamatsu Photonics K. K.). The size of a single GAGG element of the scatterer is 0.85 mm x 0.85 mm x 5 mm. The absorber is a 41-7-mm x 41.7-mm x 10-mm GAGG array block coupled to a flat-panel-type multianode photomultiplier tube H12700MOD (Hamamatsu Photonics K. K.). The size of a single GAGG element of the absorber is 0.85 mm x 0.85 mm x 10 mm. The distance between the front ends of the two GAGG array blocks is 15 mm. A commercially available data acquisition (DAQ) system [3] was diverted to the DAQ system of the Compton camera. It consists of weighted-summing amplifiers, 100-MHz free-running analog-to-digital converters, and a field-programmable gate array (FPGA). The FPGA detects coincidences of the two detector signals in a variable time window of 10 ns–160 ns. Detailed specifications for the camera can be found in Ref. [4].

B. Optimization of coincidence time window
A 0.6-MBq point source of barium-133 was placed at 6 cm in front of the camera and measured for 100 s each with changing the coincidence time window. We used barium-133 instead of astatine-211 to measure under the condition that there were few random coincidence events. The coincidence count rate was 120 cps when the coincidence time window was 160 ns for both the scatterer and absorber. The coincidence time window was optimized as narrow as the coincidence count rate didn't decrease apparently and preserved more than 85% of the maximum count rate. The optimized coincidence time window was 40 ns for the scatterer and 80 ns for the absorber, where the coincidence count rate was 108 cps.

C. Performance evaluation
A point-like source of an astatine-211 solution occupying a volume of 0.125 mL in a 0.5-mL conical vial was placed at 3 cm in front of the camera. First, the source (17.9 MBq at the measurement start) was measured for 600 s with the coincidence time window of 160 ns. Second, the source (14.5 MBq at the measurement start) was measured for 600 s with the optimized coincidence time window.

The measured coincidence events were filtered by the energy window of 687 keV ± 64 keV. The filtered events were imaged by list-mode maximum-likelihood expectation maximization algorithm.

A detailed description of the implementation of the image reconstruction algorithm can be found in Ref. [4].

Results
The coincidence count rates in the energy window before and after the optimization of the coincidence time window normalized by the activity and measurement time were 21.2 cpm/MBq and 28.8 cpm/MBq, respectively. This means the sensitivity was improved by a factor of 1.4 due to reduction of the random coincidence events by the optimization of the coincidence time window. The spatial resolution of the x-profile was improved from 13.8 mm to 11.8 mm in full width at half maximum by the optimization of the coincidence time window.

Conclusions
We have optimized the coincidence time window of the Compton camera and improved the sensitivity and spatial resolution. Future research plans include the evaluation of image quality.

[1] G Vaidyanathan and M R Zalutsky, Phys. Med. Biol. 41 (1996), 1915-1931
[2] Y Nagao et al., Appl. Radiat. Isotopes 139 (2018), 238-243
[3] H Mashino and S Yamamoto, IFMBE Proc. 14 (2007), 1722-1725
[4] Y Nagao et al., Nucl. Instrum. Methods Phys. Res. Sect. A 912 (2018), 20-23

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **151** Type: **Poster presentation only**

Medical and industrial applications of region-of-interest (ROI) digital tomosynthesis using deep convolutional neural network

Digital tomosynthesis (DTS) based on filtered-backprojection (FBP) reconstruction requires a full field-of-view (FOV) scan and relatively dense projections, which results in high dose for medical imaging purposes. To overcome these difficulties, we investigated region-of-interest (ROI) DTS or interior DTS reconstruction where the x-ray beam span covers only a small ROI containing a target area. In some situations of medical diagnosis, for example, in chest imaging, dental imaging, cardiac imaging, etc., physicians are interested in a local area containing suspicious lesions from the examined structure. This leads to imaging benefits such as decreasing scatters and system cost as well as reducing dose. To put this new DTS examination to practical use, an advanced reconstruction algorithm is needed because ROI-DTS measures incomplete (i.e., truncated, limited-angle) projection data where conventional FBP-based algorithms are unsuccessful in producing clinically feasible images. In common ROI-DTS, the FBP reconstructed images are often contaminated by the bright-band artifacts around the truncation edge and limited-angle artifacts due to the incomplete projection data. Several techniques have been proposed to circumvent the interior and limited angle tomography problem, including sinogram extension technique, compressed-sensing (CS)-aided, etc. However, most of the techniques are typically unstable in case of completely interior truncation and limited-angle. In this work, we propose an artifact reduction method in corrected FBP-based ROI-DTS using U-Net which is a deep convolutional neural network (DCNN) proposed for low-dose and sparse view computed tomography (CT). First, in the FBP-based algorithm, an apodizing function was applied to the original projection data before Fourier transform to smooth the truncated edges of the projection data. Second, we implemented DCNN method to extract limited-angle artifacts through mapping the DTS images and CT images. The reconstruction quality in proposed ROI-DTS images did not suffer from the problem of background-level shift due to the truncated and limited-angle projection data. We successfully reconstructed ROI-DTS images of substantially high accuracy and no truncation artifacts by using the proposed DCNN method, preserving superior image homogeneity, edge sharpening, and in-plane spatial resolution, and reducing imaging doses compared to typical full-FOV DTS images.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **153** Type: **Poster presentation only**

Synthetic dual-energy chest radiography with explicit structural constrained adversarial learning

Dual-energy (DE) chest x-rays (CXRs) provide the ability to selectively imaging two relevant materials, soft tissue and bone structures, to better characterize various chest pathologies and potentially improve diagnosis of CXRs. Recently deep-learning-based image synthesis techniques have attracted much attention as another approach to replace exist DE methods (i.e., dual-exposure based, sandwich-detector based, etc) because of their superior ability for image mapping. Cycle-consistent generative adversarial network (Cycle-GAN) is the central issue in the synthesizing medical images. In this study, we propose a method to utilize Cycle-GAN for image-to-image translation between the conventional and selective images of two relevant materials. In addition, to avoid anatomical structural errors in synthesized results, we use the correlation coefficient loss to directly enforce the structural similarity between the input selective image of two relevant materials and the synthesized image, and to combine the shape consistency information for improving the synthesized DE image. Our results indicate that the proposed network method effectively showed superior ability of synthetic imaging of two relevant materials. Its effectiveness was validated by comparing image performance to those from other network methods such as U-Net, multi-level wavelet CNN (MWCNN) for DE synthetic CXRs.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **154** Type: **Poster presentation only**

Comparing different bulk radiation damage models in TCAD simulations of small-pitch 3D Si sensors

Small-pitch, thin 3D Si sensors have been developed for the ATLAS and CMS experiment upgrades at the High-Luminosity (HL) LHC. The pixel sizes are 50×50 μm^2 with 1 readout column, and 25×100 μm^2 with 1 or 2 readout columns (1E and 2E). Owing to the small inter-electrode distance, ranging from ˜28 μm to ˜51 μm in the considered layouts, these devices are extremely radiation hard. Beam test results for pixel modules based on the new RD53A readout chip have shown a very good hit efficiency of almost 99% at less than 150 V bias after an irradiation fluence of 1×10^{16} n$_{eq}$ cm^{-2}, and further tests are under way to assess the performance up to the ˜2× larger fluences of interest for the experiments.

TCAD simulations by Synopsys Sentaurus, incorporating advanced radiation damage models, have been used for the design/optimization of new 3D pixel sensors. In this study we have compared the accuracy of different bulk damage models in predicting the leakage current, capacitance, and charge collection efficiency (CCE) of small-pitch 3D sensors irradiated at different fluences in the range of interest for HL-LHC. Selected simulation results will be reported in comparison to experimental data. As an example, Figure 1 shows the experimental and simulated CCE of 3D diodes of different geometries irradiated with reactor neutrons at 2×10^{16} n$_{eq}$ cm^{-2} and measured with a position sensitive IR laser setup [1]. Simulations shown in Fig. 1 are based on the bulk radiation damage model proposed in [2], and yield a good agreement with experimental data, correctly predicting also the onset of charge multiplication effects observed in the measurements of sensors with the smaller inter-electrode distances (25×100.2E and 50×50) at high voltage.

[1] R. Mendicino et al., JINST 14 (2019) C01005
[2] Å. Folkestad et al., Nuclear Instrum. Methods A 874 (2017) 94-102

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **155** Type: **Poster presentation + pitch**

End-to-end simulations of the MUon RAdiography of VESuvius experiment

Muon radiography is an imaging technique used to study the interior of large scale natural and man-made objects with the naturally occurring muons from cosmic showers. This technique exploits the penetration capability of muons and the imaging is performed from the measurements of the absorption profiles of muons as they pass through matter. The MUon RAdiography of VESuvius (MURAVES) project [1] aims at the study of the summital cone of Mt. Vesuvius, an active volcano near Naples, Italy. This muographic profile combined with the data from gravimetric and seismic measurement campaigns will be used for better defining the volcanic plug at the bottom of the crater. Figure 1 shows the Digital Terrain Model (DTM) of the Vesuvius crater, from [2]. The detection setup of MURAVES consists of three identical and independent tracking hodoscopes, constituted of scintillator bars coupled to SiPM, which are already installed on Mt. Vesuvius and fully operational. Each hodoscope includes four tracking stations, with a thick lead wall between the 3rd and the 4th that acts as a passive filter for low-momentum muons.

We report on a series of simulation studies that are being conducted to investigate the effects of the experimental constraints and to perform comparisons with the actual observations. The detector simulation setup is developed using Geant4 [3] and for the generation of cosmic showers, a study of particle generators (including CORSIKA [4] and CRY [5]) has been conducted to identify the most suitable one for our simulation framework. Figure 2 shows the interaction of a 1 GeV muon in the simulated geometry. To mimic the real data, Geant4 raw hits are converted to clusters through a simulated digitization: energy deposits are first summed per scintillator bar, and then converted to number of photoelectrons with a data-driven procedure. This is followed by the same clustering algorithm and thresholds as in real data. After application of the same tracking code as in real data, we quantify tracking inefficiencies, the effect of dark noise and other nuisances, and the effect of the lead wall in terms of absorption and scattering as a function of momentum. We also report on the examination of muon transport through the mountain using PUMAS [6] and Geant4. A brief summary of the simulation workflow is shown in Figure 3.

We will elaborate on the rationale for our technical choices, including trade-off between speed and accuracy, and on the lessons learned, which are of general interest for similar use cases in muon radiography.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **156** Type: **Poster presentation only**

A recoil-proton track imaging detector for fast neutrons

Neutron detectors are an essential tool for the development of many research fields, as nuclear, particle and astroparticle physics as well as radiotherapy and radiation protection. Since neutrons cannot directly ionize, their detection is only possible via nuclear reactions with nuclei constituting the matter. In particular, the study of fast neutrons is often based on the neutron-proton elastic scattering reaction. In this two-body reaction, the ionization caused by recoil protons in a hydrogenous material constitutes the basic information for the design and development of neutron detectors. So far, proposed recoil-proton imaging systems detectors using n-p elastic scattering show clear limits in terms of detection efficiency, complexity, cost, and final implementation [1,2]. To address this deficiency, we propose a novel recol-proton track imaging detector (RIPTIDE) in which the light output of a fast scintillation signal is used to perform a complete reconstruction in space and time of the event. It is worth mentioning that the challenging aspects of the proposed technique related to the dE/dx track analysis, could enable the reconstruction of the neutron momentum as well as straightforward background rejection capability.
In this contribution, Geant4 Monte Carlo simulations of the RIPTIDE demonstrator will be presented. In particular, the demonstrator consists of a cubic active volume of BC-408/EJ-200 plastic scintillator, which has been widely characterized in the literature [3] in terms of detection efficiency and interactions with neutrons (see for instance Fig. 1, where the measured and simulated neutron attenuation lengths are reported as function of neutron energy).
In addition, several options for imaging devices and electronic readout of the signal will be discussed.

[1] J. Hu, J. Liu, Z. Zhang, et al., Sci. Rep. 8, 13363 (2018)
[2] S.M. Valle, et al., Nucl. Instrum. & Methods A 845, 556 (2017)
[3] W.F. Rogers, et al., Nucl. Instrum. & Methods A 943, 162436 (2019)

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **157** Type: **Poster presentation only**

A 25 Gbps VCSEL Driving ASIC for Applications in High-Energy Physics Experiments

Due to the advantages in density, bandwidth and radiation performance of VCSEL-based array optical transmission system, it has been prevailingly researched and used for the front-end data acquisition in high-energy physics experiments [1]. This paper presents the design and the test results of a 25 Gbps VCSEL driving ASIC fabricated in 55 nm CMOS technology as a continuous development of the previous 14 Gbps/ch driver [2].
The whole ASIC consists of four independent channels, and each channel has the fixed channel height of 250 μm to keep the whole ASIC as the array form fitting with a four channel VCSEL array. The 25 Gbps VCSEL driver is implemented as one of the four channels. The 25 Gbps VCSEL driver is composed of an input equalizer stage, a limiting amplifier stage and an output driver stage with multiple novel peaking and pre-emphasis techniques. The input equalizer stage adopts a 5-step continuous-time linear equalizer (CTLE) structure [3] to compensate the high frequency losses from the system level including PCB traces, bonding wires and pads. The CTLE boosts maximum up to 5.8 dB at 18 GHz while providing a DC gain of 4.7 dB. To obtain sufficient swing and high bandwidth, the limiting amplifier uses the passive shared inductor structure and active feedback circuit [4]. The output driver stage consists of a main driver stage and an emphasis driver stage. A passive inductor peaking technique is integrated with the traditional structure in the main driver stage. Besides, the feedforward capacitor compensation [5] and T-coil technique [6] are both used in main driver to further enhance the bandwidth. The emphasis driver stage uses the programmable delay unit to acquire the desired pre-emphasis components with adjustable timings to be added with the main signal. The 25 Gbps VCSEL driver can be controlled by the SPI module with the Triple Modular Redundancy (TMR) structure.
The whole ASIC features a size of 2 mm x 2 mm with 52 pads. The 25 Gbps VCSEL driver has a size of 2 mm x 0.25 mm. Widely-open 25 Gbps eye has been observed at the typical settings of 2 mA bias current and 5 mA modulation current in the post layout simulation, and the power consumption is 130 mW when working at 25 Gbps. The chip has been taped out and the tests are planned to be conducted in this April. The driver ASIC will use chip on board (COB) measurement setup, and is wire bonded to an 850 nm VCSEL. The optical test, electrical test and total ionizing dose (TID) test will be performed. The test results will be reported in the meeting.

[1] D. Guo et al., Developments of two 4 × 10 Gb/s VCSEL array drivers in 65 nm CMOS for HEP experiments, 2017 JINST 12 C02065.
[2] D. Guo et al., A 4 × 14-Gbps/ch VCSEL array driving ASIC in 65 nm CMOS for high energy physics experiments, 2019 JINST 14 C05016.
[3] S. Gondi et al., A 10 Gb/s CMOS Adaptive Equalizer for Backplane Applications, IEEE ISSCC 2005 (2005) 328-329.
[4] T.-C. Huang et al., A 28 Gb/s 1pJ/b shared-inductor optical receiver with 56% chip-area reduction in 28 nm CMOS, IEEE ISSCC 2014 (2014) 144-145.
[5] Daniel Kucharski et al., A 20Gb/s VCSEL Driver with Pre-Emphasis and Regulated Output Impedance in 0.13μm CMOS, IEEE ISSCC 2005 (2005) 222-223.
[6] Mohammad Mahdi Khafaji et al., A 4 x 45 Gbps/s Two-Tap FFE VCSEL Driver in 14-nm FinFET CMOS Suitable for Burst Mode Operation. JSCC 2018.

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **158** Type: **Poster presentation only**

LDLA14: a 14 Gbps optical transceiver ASIC in 55nm for High-Energy Physics Experiments

High speed and radiation tolerant optical link has been prevailing used between the front-end detector and the back-end data acquisition in the high-energy physics experiments. The optical transceiver (driver/receiver) ASIC is the key component within the optical data transceiver systems. This paper presents the design and test results of an optical transceiver ASIC fabricated in 55 nm CMOS technology. The chip is designed to be a part of the optical link ASICs in the Nuclotron-based Ion Collider fAcility (NICA) [1] front-end readout electronics. NICA is a new accelerator complex designed at the Joint Institute for Nuclear Research (Dubna, Russia) to study properties of dense baryonic matter.
This ASIC (LDLA14) consists of a laser driver module (LD) and a limiting amplifier module (LA) both operating at 14 Gbps. The LD would drive the external TOSA (Transmitter Optical Subassembly) to generate optical signal for the transmitting side. The LA receives the signal from ROSA (Receiver Optical Subassembly) to provide standard electrical signal for the receiving side.
Both the LD and LA are composed of input stage, four-stages limiting amplifiers with feedback circuit and output stage with pre-emphasis. The same designs of input stage and limiting amplifiers are used in LD and LA. The input stage adopts the CTLE (Continuous Time Linear Equalizer) equalizer structure to compensate for the high frequency signal attenuation caused by the transmission lines on PCB, the bonding wires and input pads. The four-stage limiting amplifiers aims at amplifying a wide range of the signals output from equalizer to the saturation level. In order to improve the bandwidth of four-stage limiting amplifiers and minimize the chip area, an inductor is shared between adjacent amplifier stages. To accommodate the Process, Voltage and Temperatures (PVT) variations, an adjustable active feedback circuit is also used within the limiting amplifiers. The strength of the active feedback can be configured via SPI module.
For the output stage in LD, a novel structure of capacitive coupling pre-emphasis is proposed to compensate the nonlinear characteristics of VCSEL [2] in TOSA and improve the quality of output eye diagram. Compared with the traditional pre-emphasis structures [3][4], the proposed design would not sacrifice the modulation current swing to obtain the same bandwidth boost effect. The output stage in LA uses two-stage cascaded differential circuits to drive off-chip loads. Besides, a R-C degenerated pre-emphasis is combined within the shared inductor structure into the output stage to further optimize the eye diagram.
The dimension of the LDLA14 is 1.5 mm x 1.3 mm, including 32 PADs. The post-layout simulation results show that both the LD and LA output widely-open eye diagrams at data rate of 14 Gbps with total power consumption of 190 mW. The ISI (Inter symbol Interference) jitters of LD and LA of eye diagrams are 11 ps and 8 ps, respectively. This chip has been taped out and the tests are planned to be conducted in this April. The plan includes optical eye diagram test of LD, electrical eye diagram test of LA, the bit error ratio (BER) link test of LALD14 and total ionizing dose (TID) irradiation test of the whole chip. The test results will be reported in the meeting.

[1] https://nica.jinr.ru/
[2] Yazaki, Toru et al., 25-Gbps×4 optical transmitter with adjustable asymmetric pre-emphasis in 65-nm CMOS. 2692-2695. 10.1109/ISCAS.2014.6865728.
[3] W. Zhou et al., "LOCld65, a Dual-Channel VCSEL Driver ASIC for Detector FrontEnd Readout," in IEEE Transactions on Nuclear Science, vol. 66, no.7, pp.1115-1122, July 2019.
[4] Chen, Y., Gong, J., Yao, J. and Tian, L. (2015), 4-channel 35 Gbit/s parallel CMOS LDD. Electron. Lett., 51: 1178-1180. https://doi.org/10.1049/el.2015.0885

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **159** Type: **Poster presentation only**

Selection of Photodetectors in Nuclear Medical Imaging Using Multi-Criteria Decision-Making Methods

Photodetectors used in nuclear medical imaging such as single photon emission computed tomography (SPECT) and positron emission tomography (PET) are an important element of radiation detection systems. Selecting the photodetector depends on many physical criteria including quantum efficiency (QE) and gain. The aim of this study is to apply multi-criteria decision-making (MCDM) methods to determine the optimum photodetector based on the evaluation and comparison of complex and multiple criteria. The photodetectors investigated in this study are photomultiplier tube (PMT), avalanche photodiode (APD) and silicon photomultiplier (SiPM). The bias voltage, gain, rise time, and QE were selected since they are considered as the key criteria for the photodetectors. Then, the corresponding values of each criteria were defined (Table 1) and preferred weights were assigned to each criteria based on the desired outcome (Table 2 and 3). The fuzzy preference ranking organization method for enrichment of evaluations (f-PROMETHEE) and fuzzy technique for order of preference by similarity to ideal solution (f-TOPSIS) methods were used to evaluate the alternatives. The results showed that conventional PMT came first in the ranking, followed by SiPM, while APD was the least desirable photodetector according to the f-PROMETHEE and f-TOPSIS methods based on the selected criteria and assigned weights (Table 4 and 5). MCDM methods were used to select photodetectors used in PET and SPECT systems. One can incorporate as many alternatives and criteria as needed and assign the weights accordingly.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **160** Type: **Poster presentation only**

Advanced plastic scintillation detectors for low-background experiments

Many international low-background experiments are showing increasing interest in the use of different plastic scintillation detectors. Based on our experience in the field of quality improvement of the polystyrene (PS) based plastic scintillation detectors [1,2], this work is focusing on a further enhancement of the scintillator light output and the associated energy resolution crucial for the detection of a very rare processes. To produce PS scintillators from liquid styrene various stabilization additives and conditions of polymerization process are commonly used. These factors, i.e. stabilization additives and atmospheric oxygen, have a negative impact on above mentioned optical properties of the scintillation detectors. Within this study, several samples under different conditions, e.g. concentration of luminescent and stabilization additives; air and inert atmosphere, were prepared and tested using a unique tunable electron spectrometer providing a monoenergetic electron beam ranging from 200 keV to 1.4 MeV [3].

[1] R. Hodák et al., AIP Conference Proceedings 1672 (2015) 130003
[2] A.S. Barabash et al., Nuclear Inst. and Methods in Physics Research, A 868 (2017) 98–108
[3] C. Marquet et al., Journal of Instrumentation 10 (2015) P09008

This work was supported by the Ministry of Industry and Trade of the Czech Republic under the Contract Number FV30231.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **161** Type: **Poster presentation only**

Beam Test Results of Silicon Sensor Module Prototypes for the Phase-2 Upgrade of the CMS Outer Tracker

The start of the High-Luminosity LHC (HL-LHC) in 2027 requires upgrades to the Compact Muon Solenoid (CMS) Experiment. In the scope of the upgrade program the complete silicon tracking detector will be replaced until 2026. The new CMS tracker will be equipped with silicon pixel detectors in the inner layers closest to the interaction point and silicon strip detectors in the outer layers further away. The new CMS Outer Tracker will consist of two different kinds of modules called PS and 2S modules. Each module will be made of two parallel silicon sensors (a macro-pixel sensor and a strip sensor for the PS modules and two strip sensors for the 2S modules). Combining the hit information of both sensor layers it is possible to measure the transverse momentum of particle tracks in the magnetic field of 3.8 T at the full bunch-crossing rate of 40 MHz directly on the module. This information will be used as an input for the first trigger stage of CMS.

It is necessary to validate the Outer Tracker module functionality before installing the modules in the CMS experiment. Besides laboratory-based tests several 2S module prototypes have been studied at Test Beam Facilities at CERN, DESY and FNAL. This talk will concentrate on the beam tests at DESY during which the functionality of the module concept was investigated using for the first time the final readout chain. Additionally the performance of a 2S module assembled with irradiated sensors at different annealing states was studied. Thus, it is possible to investigate the particle detection efficiency of the module at the beginning and end of runtime of the CMS experiment. This talk will summarize the results of the 2S module beam test measurements and compare the module performance before and after irradiation.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **162** Type: **Poster presentation only**

Development of a compact test board for silicon sensors IV/CV characterization

To build a new CMS Phase II tracker system [1] in the framework of High Luminosity LHC (HL-LHC), more than ten thousand silicon strip modules have to be produced and tested. The Belgium production center at the IIHE, contributing to this collective task, has decided to build about 2000 dual silicon strip modules for one endcap of the outer silicon tracker. Integration centers in UCL (Belgium) and Lyon (France) will assemble those modules to form one endcap that will be later installed in the CMS detector at CERN. The modules in the new tracker will have to reliably work during 10 years under harsh irradiation conditions, as it will be impossible to replace a failing module once installed inside CMS. It means that reliable and rigorous testing of strip modules and its components becomes necessary. There are numerous tests to be done for the quality control (QC) of them: hybrid functional tests, sensor test including visual inspection and IV/CV measurements, module functional tests, etc. To sustain the production throughput we should be able to test several modules in parallel. For this reason a fast, reliable, scalable and cost effective production QC test bench has to be designed and implemented. For the CV and IV measurements of sensors and modules we are developing a low-cost (less than 500€) integrated electronic board which will be scaled up to ten channels to measure DUTs (device under test) in parallel to provide the following features:
• generation of high reverse bias voltage up to 1 kV to deplete the silicon sensors;
• provide 250 mV, 1 kHz sine wave and adequate biasing for CV measurements;
• measure of the reverse-bias leakage current and the junction capacitance;
• low voltage supplies for front-end electronics found on modules;
• monitoring environmental data (temperature and humidity);
• overcurrent protection on High voltage channels with hardware and firmware sequences to safely handle faults.
In the current work the design of the IV/CV board and the calibration procedure to increase the accuracy of the current and capacitance measurements, for which a special calibration dipole board based on tight tolerance capacitors and resistors has been designed, as well as future development plans are described.

[1] CMS Collaboration. "The Phase-2 Upgrade of the CMS Tracker Technical Design Report", CERN-LHCC-2017-009, CMS-TDR-014, 2017.
[2] Ali Safa. "Characterisation of the new tracker sensors for the CMS experiment at CERN". Master thesis (2019).

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **163** Type: **Poster presentation only**

Simulated detector characterization in x-ray breast imaging virtual clinical trials

Virtual clinical trials in x-ray breast imaging permit to compare different technical solutions and imaging modalities (2D vs 3D) at reduced costs related to apparatus management and involved personnel, and at reduced times and radiation risks to patients [1,2]. For a fair in-silico reproduction of clinical images, the patient models [3] and the simulated physics assume great importance. In addition, also the replication of the detector characteristics (spatial resolution, noise level and efficiency) is of primary importance. The project AGATA proposes to simulate the detectors with a layer of defined materials. The simulated images are then computed calculating the absorbed dose within the detector layer, and post-processed in order to present characteristics similar to the real ones. The manipulation of the simulated images relies on the knowledge of the intrinsic characteristics of real and simulated detector. With this scope, we evaluated the presampled modulation transfer function (MTF), the detector-response function and the noise power spectrum (NPS) of the simulated detector, as first step for the post-processing manipulations. Two detectors were simulated: 1) the adopted one in the Hologic Selenia Dimension digital breast tomosynthesis (DBT) (0.20 mm-thick a-Se direct flat panel with 70 μm pixel pitch) and 2) the one used in the GE Senographe DS DBT (CsI(Tl) indirect flat panel with 100 μm pixel pitch and scintillator layer 0.25 mm thick). In addition, the impact of simulating the de-excitation processes (Auger emission and fluorescence) were explored. Simulations were performed with a validated code based on Geant4 toolkit vers. 6 and the Option4 physics list. Figure 1 shows the MTF of the simulated a-Se detector. It was evaluated via a 12.5 μm wire, put on the support paddle of the simulated mammographic apparatus. Here, the impact of the simulation of the de-excitation processes (Auger electrons and fluorescence) was evaluated. The simulation of this effects permits a more accurate simulated physics with an increase of the simulation time of about 2 times. Figure 2 compares the presampled MTF of the a-Se detector respect to the CsI simulated detector at 26 kV. The MTF curve falls down its 10% at 12.5 mm-1 in the former case and at 8.8 mm-1 in the latter. As example, figure 3 reports the NPS for the simulated a-Se detector. No postprocessing was applied.

[1] F di Franco et al., Phys. Med. 74 (2020), 133-142.
[2] A Sarno et al., IWBI2020. Vol. 11513, 2020
[3] A Sarno et al., Med Phys (2021).

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **164** Type: **Poster presentation + pitch**

SPECTRUM 1k –Integrated Circuit for Medical Imaging Designed in CMOS 40 nm

We present a multichannel integrated circuit of pixel architecture designed in CMOS 40nm technology. The chip is composed of 40 × 24 pixels of 75 μm pitch working in the SPC mode, each built of Charge Sensitive Amplifier (CSA), Peak Detector (PDH), 6-bit Analog to Digital Converter (ADC), and memory composed of 64 × 12-bit counters. Thanks to the proposed functionality it is possible to store in each pixel separately information of incoming particles energy spectrum. The chip is dedicated to operate with both electrons and holes of 2.2 ke- –32 ke- energy. The IC occupies an area of 2 x 4.5 mm2, is back from fabrication, and being prepared for measurements.

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **166** Type: **Oral presentation**

Three years of muography at Mount Etna: results and future perspectives

Tuesday, June 29, 2021 10:10 AM (20 minutes)

Mount Etna Volcano is characterized by the Summit Craters system which represents the crucial point of its persistent tectonic activity. The Muography of Etna Volcano project started in 2016 and the first muon-tracking telescope prototype has been installed on the slope of North-East Crater from August 2017 to October 2019 (Figure 1). The aim of the project was to find anomalies in the density of volcanic edifice and monitor their time evolution. In this work, the major results achieved by the project are presented, including the detection of an expanding underground cavity months before the collapse of the crater floor, but we also want to focus on our strategy and plans to realize a muography application at Mount Etna.
In designing the first telescope prototype of the MEV project, built at the Department of Physics and Astronomy (DFA) "E. Majorana" of the University of Catania, all common characteristics among detectors for an out-of-laboratory muography application were included: ruggedness and water-tightness to face every climatic condition at high altitude, power network independence (by means of solar panels and a battery pack) and low consumption, connection to the internet in order to remotely access and operate the telescope. The telescope is designed to work horizontally oriented with three X-Y position-sensitive tracking planes (TP) vertically placed and spaced in the horizontal direction. The distance D between the two external planes is 97 cm . The third TP is located in the middle between the two external planes. Particle detection and tracking are based on scintillating plastic bars technology, with two wavelength-shifting optical fibers (WLS) embedded in to transport the scintillation light to the sensor.
At the base of this design choice, there is the intention to measure at the same time the muon flux coming from the front and back sides of the detector. In this way, it is possible to measure the flux through the object of interest and the flux directly coming from the sky (not attenuated), or "open sky"flux. By comparing these two quantities, we have direct access to the spatial distribution of the absorption coefficient through the target object, which is a quantity related to its opacity, i.e. density integrated over the particle path along the direction of sight of the telescope.
Each TP is completed by a 64 channels Multi-Anode Photomultiplier (MAPMT, mod. Hamamatsu H8500) that allows us to read-out the scintillation light signal. Counting both WLS for each scintillating bars, there are 4 ⊠ N = 396 optical channels for each TP, but only 64 channels on the sensor. The coupling is made possible by a proper routing of the WLS that allows us to minimize the number of corresponding front-end channels by a factor 1/sqrt(N). The choice to develop custom electronic boards allowed to remove all the redundant components that can be found in an evaluation board and to keep only the ones required for the specific purpose. At the end of summer 2018, before the interruption of the second year of the data acquisition campaign, a module to measure particle time-of-flight (TOF) between the external tracking planes was installed. The purpose of this measurement is the correct discrimination of near-horizontal tracks.
The MEV telescope was installed and remained at the measurement site at the base of NE crater from 1st August 2017 till the end of September 2019, thus for more than two years. However, in 2017 and 2018, the whole detector, including solar panels, was buried under a huge snow coverage with the incoming winter. With solar panels covered, the detector went off after a short time and remained quiet during both winters. Only at the beginning of the summer, when the snow melted down, and the measurement site was again reachable by a car, it was possible to restore the power

supply and start a new acquisition. However, the detector's design has demonstrated to be able to overcome exceptional weather conditions during winters at high altitudes without detriments to electronics and tracking modules. Only the components outside of the box were partially damaged, i.e., solar panels and antennas for data transmission over the LTE network, and required to be repaired or substituted.

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Session Classification: Oral presentations

Track Classification: Highlighted sessions

Contribution ID: **167** Type: **Poster presentation + pitch**

Hexagonal Pixel Multi-element Germanium Detector For Synchrotron Applications: Simulation of Detector Performance

One of the major limitations of the X-ray Absorption Spectroscopy (XAS) experiment at synchrotron facilities is the performance of the detectors. In order to be able to measure more challenging samples and to cope with the very high photon flux and input count rate of the current and future light sources, technological developments to enhance the performance of various detectors are necessary. In this paper, a performance study of potential configurations of a monolithic multi-element germanium detector is presented.

In this context, the signal-to-background ratio and energy resolution are two key detector features that characterize the detector performance, especially for complex targets and at high throughput where a weak fluorescence peak from an element trace must be discriminated from the elastic peak or other more intense element lines. One of the options to increase the throughput of photons is to reduce the pixel size and therefore increase the number of photons per unit area. Hence, monolithic multi-element detectors with hexagonal pixels have been proposed for XAS applications mainly to maximize the compactness and granularity of the traditional multi-element germanium detectors. One of these proposals is a demonstrator composed of a monolithic Ge sensor with the backside electrode segmented in 19 hexagonal pixels of 2 mm inner diameter. [1]

In this work, the detector response for different configurations is simulated. A simulation chain combining both Allpix2 Simulation [2] with 3D electrostatic field simulation performed with COMSOL Multiphysics® has been used in this study. The previously mentioned simulation chain has been validated with experimental data [3]. In addition, new features in the Allpix2 framework have been implemented to model hexagonal pixel shape.

Several configurations of a new generation of multi-element germanium detectors have been studied. The results present a comparison of the detector response in these different cases in terms of signal-to-background ratio, signal and background efficiency as well as the charge sharing effect in these configurations for direct X-ray beam in the energy range (0-80 keV). In addition, these simulations help to build a trusted simulation model to be used in studying variant hexagonal shaped germanium detector for future applications.

Keywords: Charge sharing, hexagonal pixel, HPGe, semiconductor radiation detectors, X-ray detectors, X-ray spectroscopy.

References:
[1] N. Tartoni et al., "Hexagonal Pad Multichannel Ge X-ray Spectroscopy Detector Demonstrator: Comprehensive Characterization", IEEE Transaction on Nuclear Science, vol. 67, NO. 8, (2020)
[2] S. Spannagel et al., "Allpix2: A modular simulation for silicon detectors", Nucl. Instr. Meth. A 910, 165-172 (2018
[3] T. Saleem et al., "Simulation of Multi-element Germanium Sensors for Synchrotron Radiation XAFS experiments using Allpix2 framework", in progress to be submitted to JINST Journal.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **168** Type: **Poster presentation only**

Material decomposition in low-energy micro-CT using a dual-threshold photon counting x-ray detector

Material decomposition in computed tomography is a method for differentiation and quantification of materials in a sample and utilises the energy dependence of the linear attenuation coefficient [1]. While in clinical applications, the x-ray spectrum is manipulated by changing the acceleration voltage between acquisitions [1], a photon-counting detector directly utilise the polychromatic spectrum of an x-ray tube [2]. Via multiple energy-discriminating thresholds, specific energy windows can be created containing only photons within a specific energy range. Acquiring an energy window on each side of an absorption edge of a material allows to decompose a sample into specific materials [3].
In this study, a micro-CT system with a dual-threshold photon-counting detector is used to construct a post-reconstruction material decomposition method [2] utilising K-edges in the range 4-11 keV. This energy range allows to identify naturally occurring elements in organic tissue ($Z \leq 36$). In comparison, clinical applications often utilise iodine- or gadolinium-based contrast agents with absorption edges at around 33 keV and 50 keV respectively, which have to be introduced into the sample.
The implemented method was verified with a phantom made of copper and aluminium and then applied to paraffin embedded human atherosclerotic plaques containing calcifications and areas with haemorrhages and were therefore decomposed into iron, calcium and paraffin. Using two energy windows, the samples could be decomposed into three base materials using manually selected regions to obtain attenuation values for the specific materials. While the method suffers from strong ring and beam hardening artefacts due to significant absorption in air in the low energy range and limited number of photons due to the required small size of the energy windows, the decompositions show distinct distributions of the expected materials within the samples without the need for staining.

[1] R. E. Alvarez and A. Macovski, Physics in Medicine and Biology 21 (1976), 733–744
[2] C. T. Badea et al., Am. J. Physiol. Cell. Mol. Physiol. 302, L1088–L1097 (2012).
[3] P. M. Shikhaliev and S. G. Fritz, Physics in Medicine and Biology 56 (2011), 1905–193

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **169** Type: **Poster presentation only**

Characteristic Evaluation of Intrinsic Radiation of 176Lu in Scintillation Crystal

Inorganic scintillators contain lutetium such as lutetium oxyorthosilicate (LSO), lutetium yttrium oxyorthosilicate (LYSO) widely used today in nuclear medicine and other fields because of their convenient physical properties of high detection efficiency, fast decay time, and high light yield. Despite its advantages, lutetium-based scintillators issue in single transmission measurement, low sensitivity imaging, or wide energy windows scanning due to natural occurring radioisotope 176Lu contained in natural lutetium. 176Lu undergoes decay and emits a beta particle with mean and maximum energy of 182 keV and 593 keV and a cascade of gamma rays of energies 307 keV, 202 keV, and 88 keV.
Those radiations from 176Lu are an annoyance that makes a background noise of apparatus as a uniformly distributed radiation source in scintillation crystal. Furthermore, its noise signal is not easy to define in a spectrum as independent radiation because it is complicated that the designation of degree which radiations from 176Lu attribute to spectrum signal when the performance of spectroscopy is not guaranteed for a wide energy range. On the other hand, it is possible to quantitatively evaluate the attribution degree of each radiation to the spectrum even the performance of spectroscopy is not fully satisfying on a wide energy range, 176Lu will be of sufficient value as it suggests the possibility to conduct the energy calibration of the detector or evaluate the characteristics of the detector structure without external radiation sources.
In order to quantitatively evaluate the performance of the spectroscopy system, experiments using a detector consisting of silicon photomultiplier (SiPM) and LYSO were conducted with a data acquisition system of PETSYS Inc. With this experiment, we define the performance according to the energy as the full-width half maximum (FWHM) and reflect it in the Monte Carlo simulation code as Gaussian Energy Broadening (GEB) function. Based on the above code setting, simulations were conducted with 7 interaction cases that can occur from the cascade of gamma rays, and the results were used for making base spectrums by convolving with the beta spectrum. Through the linear combination of base spectrums and optimization algorithm, simulation data will be optimized with the experimental data. This study may serve as useful data to assess detector performance and calibrate spectrum.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **170** Type: **Oral presentation**

Study of charge carrier transport properties and lifetimes in HR GaAs:Cr with Timepix3

Wednesday, June 30, 2021 11:00 AM (20 minutes)

The response of a Timepix3 [1] (256 x 256 pixels, pixel pitch 55 μm) detector with a 500 μm thick HR GaAs:Cr [2] sensor was studied with proton beams at the Danish Centre for Particle Therapy in Aarhus, Denmark. The detector was irradiated at different angles with protons of 125, 171 and 219 MeV. The readout chip was configured to operate in electron or hole collection modes.

Measurements at grazing angles allow to see elongated tracks with well-defined impact and exit points, so that charge carrier production depths can be determined in each pixel. We extracted the charge collection efficiencies (Figure 1) and the charge carrier drift times (Figure 2) as a function of the distance to the pixel matrix plane.
It was found that measured proton tracks are shorter in hole collection than in the case of electron collection, which is explained by the shorter lifetime of holes. At the angle of 60 degrees with respect to the sensor normal, the average track length in hole collection is ˜600 μm, while it is 880 μm in electron collection mode.

To understand the experimental findings, models describing the properties of HR GaAs:Cr were implemented into the Allpix^2 simulation framework [3]. We added previously presented experimental results describing the dependence of the electron drift velocity on the electric field [4] and validated the response by comparing measurement and simulation or various X- and gamma-ray sources in the energy range from 5 –60 keV.

Results presented in Figure 1 and Figure 2 were reproduced in the simulation using the hole mobility μ_h = (300 ± 45) cm^2/V/s and the lifetime of holes as τ_h = (6 ± 2) ns. Further studies will include results seen for measurements at different proton energies and bias voltages.

[1] T. Poikela et al., 2014 JINST 9 C05013
[2] A.V. Tyazhev et al., 2003 NIM A 509 34.
[3] S. Spannagel et al., 2018 NIM A 901 164
[4] B. Bergmann et al., 2020 JINST 15 C03013

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Session Classification: Oral presentations

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **171** Type: **Poster presentation only**

Trigger primitive generation algorihtm in the CMS barrel muon chambers during HL-LHC

This contribution presents an update on the Analytical Method (AM) algorithm for trigger primitive (TP) generation in the CMS Drift Tube (DT) chambers during the High Luminosity LHC operation (HL-LHC or LHC Phase 2). The algorithm has been developed and validated both in software with an emulation approach, and through hardware implementation tests. The algorithm is mainly divided in the following steps: a grouping (pattern recognition) step that finds the path of a given muon, a fitting step to extract the track parameters (position and bending angle), a correlation step that matches the information from the different super-layers and with signal from the Resistive Plate Chambers. Agreement between the software emulation and the firmware implementation, has been verified using different data samples, including a sample of real muons collected during 2016 data taking. In this contribution, an update of the grouping step using a pseudo-bayes classifier will be discussed.

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **173** Type: **Poster presentation only**

Muography system combined with Cherenkov detector to reduce measurement time

An abstract is attached.

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Session Classification: Poster session 1

Track Classification: Imaging theory

Contribution ID: **174** Type: **Poster presentation only**

High-rate readout with precise time resolution of a high-granularity calorimeter: the case of the CMS Electromagnetic calorimeter upgrade

The Electromagnetic Calorimeter (ECAL) of the CMS detector has played an important role in the physics program of the experiment, delivering outstanding performance throughout data taking. The High-Luminosity LHC will pose new challenges. The four to five-fold increase of the number of interactions per bunch crossing will require superior time resolution and noise rejection capabilities. For these reasons the electronics readout has been completely redesigned. A dual gain trans-impedance amplifier and an ASIC providing two 160 MHz ADC channels, gain selection, and data compression will be used in the new readout electronics. The trigger decision will be moved off-detector and will be performed by powerful and flexible FPGA processors, allowing for more sophisticated trigger algorithms to be applied. The upgraded ECAL will be capable of high-precision energy measurements throughout HL-LHC and will greatly improve the time resolution for photons and electrons above 10 GeV.

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **175** Type: **Oral presentation**

Experimental study of the adaptive gain feature for improved position sensitive ion spectroscopy with Timepix2

Monday, June 28, 2021 12:00 PM (20 minutes)

Timepix2 [1] is a hybrid pixel detector developed in the Medipix2 collaboration as the successor of Timepix. It separates the sensor attached to the ASIC into a square matrix of 256 x 256 pixels at a pixel pitch of 55 µm. Similar to Timepix [2], it relies on a frame-based readout scheme. However, it comes with valuable additional features such as an occupancy trigger allowing to force the frame termination if a preset number of columns received entries. Moreover, it prevents the frame shutter from cutting ToT signals at the end of the frames and allows to reduce power consumption by reducing the sensitive area (pixel masking).

While the aforementioned improvements have already been studied [3,4], in this contribution, we investigate the behaviour of the per-pixel energy measurement with the adaptive gain mode, which was implemented to allow for an extended per pixel energy range.
A Timepix2 detector with a 300 µm thick silicon sensor was calibrated using x- and gamma-rays in the energy range up to 60 keV. An energy resolution of 1.62 keV (FWHM: 3.8 keV) is achieved for 59.5 keV gamma-rays. To study the high energy response, the device was further irradiated with alpha particles from a 241Am source, whereby the per-pixel energy depositions were varied by changing the applied reverse bias and the distance from the source to the sensor top (utilizing the alphas particle energy loss in air). For completeness, measurements were done in vacuum.
For each measurement, the energies measured in the alpha tracks are compared with the expected energy calculated by SRIM. While at greater distances (where the maximal per pixel energy is below 650 keV) the expectation and measurement are in good agreement, an underestimation of the alpha energy is found at shorter distances. Assuming correct per-pixel energy measurement up to 650 keV and using the topology of the alpha particle tracks, we can relate the energy measured in the central pixels of the track (Emeas) to the energy required to obtain the predicted alpha particle energy (Eexpected). The scatter plot of Emeas vs Eexp is shown in Figure 1. The observed behaviour is modelled with a bilinear function and used to correct the per-pixel energy calibration curve. Energy spectra at different distances to the alpha-source are shown in Figure 2 after applying the correction function. The energy resolution was determined by fitting Gaussian distributions. We find ˜110 keV (FWHM: 260 keV) at 0.9 MeV and ˜300 keV (FWHM: 706 keV) at 5.5 MeV. It will be shown that energies up to ˜850 ke- (i.e. 3.2 MeV in silicon) can be measured in a single pixel, outperforming the other chip of the Timepix family currently used.
References:
[1] W.S. Wong et al., Radiation Measurements, Vol. 131, 106230 (2020).
[2] X. Llopart et al., NIM A, Vol. 581, Issues 1–2, 485-494 (2007).
[3] P. Burian et al., JINST 15, C01037 (2020).
[4] S. George et al., NIM A, Vol. 958, 162725 (2020).

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Session Classification: Oral presentations

Track Classification: Front end electronics and readout

Contribution ID: **177** Type: **Poster presentation + pitch**

Development and performance of a fast timing micro-pattern gaseous detector for future collider experiments and medical diagnostics

The fast timing MPGD (FTM) is a result of an ongoing effort for developing an MPGD with a time resolution under one nanosecond, while maintaining the excellent rate capability (tens of MHz/cm2) and the good space resolution (150 µm) of the present-generation micro-pattern gaseous detectors, whose reliability has been demonstrated at present colliders and ongoing upgrades of LHC experiments. The natural scope of application of the FTM would be in the instrumentation of areas in high-pileup environments at future collider experiments, such as in muon systems or as calorimeter readout. In medical imaging, the FTM is being studied as a possible affordable detector for PET using time-of-flight methods.
This presentation starts by formulating the working principle of the FTM, whose geometry is made of a stack of decoupled ionization layers, each with its own amplification structure; the improved time resolution is guaranteed by the competition in the arrival times of the signals due to the different ionization clusters created by an incident charged particle in each layer. Maintaining good signal transparency across the entire detector requires a fully resistive structure; the latest advancements in the manufacturing of GEM foils with DLC coating have been implemented, and additional techniques are being explored. The development of the FTM will be described with focus on the most recent results of the latest FTM prototype assembled, summarizing the laboratory measurements on gain, choice of operating gas mixture, efficiency and time resolution; an overview on the most challenging aspects of the FTM R&D will also be given, including the requirements of a fast, low-noise readout electronics, the setup of a high-precision test stand for gain and signal transparency measurements and the necessity for new methods for the simulation of signal formation in resistive detectors.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **178** Type: **Oral presentation**

18k Pixel Readout IC for CdTe Detectors Operating in Single Photon Counting Mode with Interpixel Communication

Tuesday, June 29, 2021 1:50 PM (20 minutes)

This paper presents a readout integrated circuit (IC) of pixel architecture called MPIX (Multithreshold Pixels), designed for CdTe pixel detectors used in X-ray imaging applications. The MPIX IC of the area of 9.6 mm x 20.3 mm is designed in a CMOS 130 nm process. The IC core is a matrix of 96 x 192 square-shaped pixels of 100 µm pitch. Each pixel contains a fast analog front-end followed by four independently working discriminators and four 12-bit ripple counters. Such pixel architecture allows photon processing one by one and selecting the X-ray photons according to their energy (X-ray color imaging). To fit the different range of applications the MPIX IC has 8 possible different gain settings, and the IC can process the X-ray photons of energy up to 154 keV. The MPIX chip is bump-bonded to the CdTe 1.5mm-thick pixel sensor with a pixel pitch of 100 um (see Fig.1) To deal with charge sharing effect coming from a thick semiconductor pixel sensor, Multithreshold Pattern Recognition Algorithm is implemented in the readout IC [1]. The implemented algorithm operates both in the analog domain (to recover the total charge spread between neighboring pixels, when a single X-ray photon hits the pixels border) and in the digital domain (to allocate a hit position to a single pixel). The example of the measured integral spectra with three different X-ray energies is shown in Fig. 2.

[1] P. Otfinowski, et al., 2019 JINST 14 C01017

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Session Classification: Oral presentations

Track Classification: Front end electronics and readout

Contribution ID: **179** Type: **Poster presentation only**

Snow water equivalent measurement using Muon Radiography

Muons reach the surface of the earth with an approximately constant flux and deviate their trajectory when crossing matter. These deviations can be measured in order to obtain information or density maps about the inner state of preferably dense and big objects. Previous work done by the company Muon Systems, presenting the capacity of Muon Radiography to help in industrial problems can be consulted in [1]. Here we present a new application of Muon Radiography, the non-destructive measurement of snow water equivalent (SWE), that is, the water content of a snowpack. In this case study, the measurement target is a column of snow with a base of approximately 1 m2 and a height varying from 0 to 2 m, suitable for the available detection system. On the other hand, the density of the snow is low compared to other materials measured in traditional Muon Radiography applications, which makes this challenge more demanding in terms of angular resolution.

Despite its hydrological importance, real time SWE monitoring remains challenging for hydrometeorological networks. This new application of Muon Radiography would contribute to enhance the SWE monitoring capabilities of the water agencies and land managers, improving the estimation of the mountainous water resources and the river discharge forecast. Nowadays, other technologies are employed to carry out measurements of SWE, but difficulties and uncertainty sources have been noticed [2].

To analyse this problem by Muon Radiography, firstly the snow has been simulated. We have used the energy and mass balance snow model Snowpack, forced by means of the global ERA5-Land surface reanalysis in the Spanish Pyrenees, in a location at 2041 meters above sea level in the Monte Perdido massif. The simulations cover five years with a changing number of snow layers, containing information including the density, height and the ice, liquid water and air content of each layer (Figure. 1).

Secondly, Geant4 simulations have been performed to propagate and measure muons passing through the snow layers previously simulated. The approach of the Muon Radiography analysis is to interpret the physics behind the muon measurements and characterise them in an optimal way. Preliminary results for a constant snowpack height of 1 m, show a coefficient of determination of R2=0.94 between mean absolute muon deviation of one-hour measurements and snowpack bulk density. The goal is to detect density changes in a time frame that would allow a successful monitoring of SWE, improving the performance of other technologies and reducing uncertainty sources like natural variability at small scales, instrumental bias and errors induced by observers.

To conclude, more sophisticated algorithms based in Machine Learning and advanced statistics will be presented and discussed. The development of those algorithms can lead to more accurate results regarding the layer density determination and the automation of field applications.

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Session Classification: Poster session 1

Track Classification: Highlighted sessions

Contribution ID: **180** Type: **Poster presentation only**

Electroluminescence yield in noble gases in uniform electric fields

Dual phase and high-pressure gaseous optical-TPCs are used in many modern day experiments to detect rare events, e.g., in experiments that search for the neutrinoless double beta decay [1,2] and WIMP dark matter [3-5]. These experiments use the electroluminescence processes in the gas to amplify the primary ionization signals produced by radiation interaction inside the detector active volume. Pure noble gases are an obvious choice for this kind of experiments. In order to decide what gas to use in a certain experiment, it is of utmost importance to determine the electroluminescence yield for each candidate. Using a gas proportional scintillation counter, coupled to a large area avalanche photodiode (LAAPD), we have done experimental studies on the electroluminescence yield for argon, krypton and xenon. With our setup it is possible to compare the pulse amplitudes generated by the VUV photons and the 5.9-keV X-rays interacting directly in the LAAPD. Thus, one can calculate the number of charge carriers produced by the scintillation pulse and, hence, the number of photons impinging the LAAPD. The value of the scintillation amplification parameter obtained, defined as the number of photons produced per drifting electron per kilovolt, was 81 photons/kV for argon, 113 photons/kV for krypton and 140 photons/kV for xenon. The energy resolution and the scintillation and ionization thresholds were also studied. Best energy resolution values for 5.9 keV x-rays of 12.5%, 9.5% and 7.8% were obtained for argon, krypton and xenon, respectively. The scintillation and ionization thresholds obtained were 0.55 and 3.0 kV cm^{-1} bar^{-1} for argon, 0.7 and 3.3 kV cm^{-1} bar^{-1} for krypton and 0.8 and 4.5 kV cm^{-1} bar^{-1} for xenon.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **181** Type: **Oral presentation**

The timing detectors of the FOOT experiment: the charge changing cross sections measured using 16O beams of 400 MeV/u energy

Monday, June 28, 2021 2:40 PM (20 minutes)

In Particle Therapy (PT), nuclear interactions of the beam with the patient's body causes fragmentation of both the projectile and target nuclei. In treatments with protons, target fragmentation generates short range secondary particles along the beam path, that may deposit a non-negligible dose especially in the entry channel. On the other hand, in treatments with heavy ions, such as C or other potential ions of interest, like He or O, the main concern is long range fragments produced by projectile fragmentation, that release the dose in the healthy tissues downstream of the tumor volume. Fragmentation processes need to be carefully taken into account when planning a treatment, in order to keep the dose accuracy within the recommended 3% of tolerance level. The assessment of the impact that these processes have on the released dose is currently limited from the lack of experimental data, especially for the relevant fragmentation cross sections. For this reason, treatment plans are not yet able to include the fragmentation contribution to the dose map with the required accuracy. The FOOT (FragmentatiOn Of Target) collaboration, funded by INFN (Istituto Nazionale di Fisica Nucleare, Italy) , designed an experiment to fill this gap in experimental data, aiming the measurement of the differential cross sections of interest with an accuracy better than 10%. The apparatus, shown in figure 1, is composed of several detectors that allow fragment identification in terms of charge, mass, energy and direction. Starting from the incident beam direction, the particles cross a plastic scintillator (Start Counter) and a drift chamber to measure the start for the Time Of flight and to monitor the primary beam respectively. Then the beam interacts with the magnetic spectrometer composed by two pixel detectors, a microstrip detector and a permanent magnet system that provides the required magnetic field in order to measure the fragments momentum. The last part of the FOOT electronic setup is composed by a plastic scintillator wall (ΔE-TOF detector) and a calorimeter that provide the fragments energy loss (ΔE) and the stop of the TOF measurements.The TOF system composed by the SC and after ˜ 2 m the ΔE-TOF detector, plays a crucial role as the charge Z of fragments reaching the ΔE-TOF detector can be identified from the energy loss ΔE and the TOF information. The two detectors have been optimized in order to achieve a TOF resolution lower than 100 ps and an energy loss resolution σ(ΔE)/ΔE ˜ 5%. For this reason the SC thickness was carefully optimized looking for a good compromise between the out of target fragmentation probability, that called for the smallest possible thickness, and the time resolution, that is directly linked to the light yield requiring a thick detector. The final SC detector layout, that was optimized using MC simulations, foresees a squared EJ –228 plastic scintillator (5 × 5 cm2 active area) arranged in a set of four different thickness (ranging from 250 µm to 1 mm) used depending on the beam projectile and energy range. According to this geometrical proprieties the expected beam fragmentation inside the SC is about 5% of the incident ions. The plastic scintillator readout is performed by means of 48 3 × 3 mm2 SiPMs, 12 per side, bundled in eight electronic channels, each reading a chain of 6 SiPMs. The ΔE-TOF detector consists of a matrix of EJ-200 bars, 3mm thick, orthogonally arranged in two subsequent layers. The thickness of the bars is chosen as a trade-off between the amount of scintillation light produced in the bar (resulting in a better timing and energy resolution), which increases with the deposited energy and therefore with the bar thickness, and the systematic uncertainty induced on the ΔE- TOF measurement by secondary fragmentation in the bars that would worsen the particle identification and tracking. Each layer is composed of 20 bars that are 2 cm wide and 44 cm long, resulting into a 40 × 40 cm2 active area. The light produced in each bar is collected at both the extremities using to 4 SiPMs per side (3 × 3 mm2 active area) biased and read-out by a single electronic channel. The two detectors share the SiPM read-out system: the 88 output signals of the ΔE- ToF and the SC are digitized and recorded by using the WaveDAQ system, capable of a 0.5–5 GS/s sampling speeds.The FOOT TOF system has been tested with 12C and 16O ion beams with energies ranging from 115 MeV/u to 400 MeV/u in March 2019 at the CNAO (Centro Nazionale di Adroterapia Oncologica) experimental room. The measured TOF resolution has matched the expectations (the average resolution σ(ToF) ranges between 55 ps and 80 ps as a function of the beam kinetic energy) and fulfilled the requirements needed for the fragment atomic mass discrimination level needed by the cross section measurement program of the FOOT experiment. In April 2019 a first data taking was done at GSI Laboratory using a 400 MeV 16O beam impinging on a graphite target with a partial FOOT experiment setup including the SC, the Beam Monitor and the ΔE-TOF detectors. In this contribution the two timing detectors and their performance tested at GSI are explained in detail. In addition, preliminary results of the charge changing cross sections for the production of fragments with Z between 2 and 7 for the case of 400 MeV/u 16O beam integrated in the ΔE-TOF detector acceptance will be presented.

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Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **183** Type: **Poster presentation + pitch**

The upgrade of CMS Resistive Plate Chambers for HL-LHC

The High Luminosity phase of the Large Hadron Collider (HL-LHC) that will follow the 3rd Long Shutdown of the accelerator opens the window to a very rich and ambitious physics program, exploiting an integrated luminosity of 3000 fb^{-1}. During the HL-LHC operation, the instantaneous luminosity will be increased to $5\times10^{34}cm^{-2}s^{-1}$, i.e. five times the machine's original design value, and the ultimate performance of the HL-LHC would enable the collection of 400 to 450 fb^{-1} of integrated luminosity per year. The expected experimental conditions in that period in terms of background rates, event pileup and the probable ageing of the present detectors present a challenge for the entire CMS detection system. In particular, to ensure a highly performing muon system under HL-LHC conditions, different upgrades are required and currently implemented. This includes the upgrade of the Resistive Plate Chambers (RPC), which covers both barrel and endcap regions, contributing to the trigger, reconstruction and identification of muons. To extend the RPC coverage from $|\eta|$=1.9 up to 2.4, an improved version of the already existing RPCs (iRPCs) will be installed in the forward region of the 3rd and 4th endcap disks. Figure 1 shows the region where new RPCs will be placed to extend the coverage (inside the red box) [1]. This will lead to an increase in the efficiency for both muon trigger and offline reconstruction in a region where the background is the highest and the magnetic field is the lowest. New front-end electronics will fully exploit the intrinsic time resolution of iRPCs, improved it by about a factor just two compared to the current system, which will enhance the background hit rejection, and identification as well as the reconstruction of slowly moving Heavy Stable Charged Particles (HSCP). The iRPCs will also offer a better spatial resolution of the order of a few cm along the strip direction (non-bending projection), by measuring the time difference between the signals at both ends of the readout strips. The performance of the proposed iRPCs has been studied with gamma radiation at Gamma Irradiation Facility (GIF++), CERN. A longevity study is ongoing and main detectors parameters (currents, rate, resistivity) are regularly monitored as a function of the integrated charge. Prototype chambers were built and studied for validating the chamber mechanics. The present overall status of the CMS iRPC project, including also results of the ongoing studies at GIF++ will be presented.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **184** Type: **Poster presentation only**

Thermo-mechanical design for ALPIDE pixel sensor chip in a High-Energy Particle Detector space module

The Limadou collaboration includes all Italian scientists working on the project CSES (China Seismo-Electromagnetic Satellite), a constellation of satellites equipped with the most advanced technologies for correlating ionosphere perturbations with the occurrence of seismic events. For the launch of CSES-02, scheduled for mid-2022, the collaboration is realizing the High-Energy Particle Detector, aimed at detecting electrons and protons trapped in Earth's Magnetosphere, with energies 5 MeV-100 MeV and 30 MeV-300 MeV respectively. This payload consists of a particle tracker, a trigger system and a calorimeter, which work in time-coincidence to accurately identify particles and measure their energy and trajectory. The tracker is based on monolithic active pixel sensors ALPIDE [1], an innovative platform with superior performances in the field of pixel detectors, developed for the upgrade of the ALICE experiment at the LHC, at Cern.
The challenge in the construction of the tracker has been to adapt the ALPIDE technology to the space environment and to the specifications of the space register. Lightness and stiffness, essential features for structures in a tracker module, needed to balance with the need for withstanding structural and vibrational stress in the extended range of temperature occurring in the launch phase. Proper material choice with high thermal conductivity for the heat dissipation, innovative design of thermal paths and structural test results guided the project of mechanics. The modular particle tracker consists of 5 turrets, each one made of 3 stacked staves, with 150 pixel sensors in total. For readout and control purposes, ALPIDE sensors are wire-bonded to Flexible Printed Circuits, which enhances the fragility of the system and makes handling critical. Sensor supports in Carbon Fiber reinforced Plastic and an external aluminum frame preserve the mechanical integrity and provide the essential thermal bridges for heat dissipation.
We provide results from the intense campaign of structural, thermal and vibrational qualification tests that has been performed in compliance with the procedures required by the space register. It regards structure, module and turret elements. The envisaged solution is a novelty in the field of space applications and paves the way for important developments for particle and astroparticle physics experiments.

[1] NIMA, Volume 824, 11 July 2016, Pages 434-438

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **185** Type: **Oral presentation**

Pioneering use of Monolithic Active Pixel Sensors in space: the HEPD tracker on the CSES-02 satellite

Thursday, July 1, 2021 10:10 AM (20 minutes)

The most advanced particle trackers for space experiments all rely on micro-strip silicon sensors, readout with custom ASICs including amplification and shaping stages. This technology proved to be efficient, robust and fully compliant with space requirements. Both in its single- and the double-sided versions, microstrips allowed for important experiments like Pamela, AGILE, Fermi, AMS-02 and Dampe. They are still the baseline option for near future enterprises like HERD. Nonetheless, microstrips have become a niche application for silicon foundries, with profound consequences on the pace of their development, the cost of their fabrication and the complexity of their implementation.
This work reports on what the authors consider to be a breakthrough in the field, i.e. the first space application ever of Monolithic Active Pixel Sensors. The CMOS-fabricated ALPIDE sensor [1], designed and constructed for the ALICE experiment at the Large Hadron Collider, has been used as the building block of a particle tracker to be operated within the HEPD payload, onboard the CSES-02 satellite. The process of spatialisation had mostly to cope with those characteristics that mark the difference between ground-based laboratory applications and space devices, i.e. reduction of the power consumption, implementation of redundant control and readout solutions, design of mechanics suitable to withstand launch stresses and guarantee heat dissipation.
The project resulted in a three-layer particle tracker, as large as 250 cm2, made of 150 ALPIDE sensors, controlled and readout with a Hybrid Integrated Circuit and supported by Carbon Fiber Reinforced Plastics staves, housed in an aluminium case. The system is going to be in operation in space by mid-2022 and it will possibly change the paradigm of tracking particles in space.
We describe in detail the HEPD-02 tracker project, demonstrating the advantages of using MAPS in space and manifesting the pioneering nature of the project for next-future larger size space missions.
Figure 1. A "turret"of the HEPD tracker, made of three layers of ALPIDE sensors.

[1] NIMA, Volume 824, 11 July 2016, Pages 434-438

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Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **186** Type: **Poster presentation only**

The DAQ system for the HEPD-02 tracker: a clock-on-demand approach for using Monolithic Active Pixel Sensors in space

To adopt monolithic active pixel sensors for space-based applications requires to lower their power consumption and to optimize the heat dissipation, to fulfill the constraints imposed by satellite power and cooling capacity. MAPS will be used for the first time in space within the High Energy Particle Detector, onboard the CSES-02 satellite. Space-register requirements are met with a parallel sparsified readout architecture, implemented on a single low-power FPGA chip, which manages 150 ALPIDE sensors [1], arranged on three sensitive planes. Two devices mainly contribute to reduce the average power consumption, i.e. using the control line instead of the high speed data link to readout the ALPIDE sensors and locally distributing the clock only to when the detector is crossed by a particle. The last concept is scalable to larger and more complex detectors and represents an important step towards the future of particle trackers in space.

[1] NIMA, Volume 824, 11 July 2016, Pages 434-438

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **187** Type: **Oral presentation**

Method for system-independent material classification through basis material decomposition from spectral X-ray CT

We present a method for material classifications in spectral X-ray Computed Tomography (SCT) using energy-resolved, photon-counting detectors (PCD), with which one can simultaneously measure the energy dependence of a linear attenuation coefficient (LAC) of a material. The method uses a basis material decomposition taking advantage of the spectral LACs to estimate effective atomic number (Z_{eff}) of a material independently from the system or specifics of the scanner, such as the X-ray spectrum. In this decomposition we represent the LAC of a material as the sum of two basis materials with equivalent thicknesses [1, 2]. The measured spectra in photon-counting detectors working under high flux is distorted by a range of detector effects, such as charge sharing and weighting potential cross-talk, fluorescence radiation, Compton scattering, pulse pile up and incomplete charge collection. These physical effects lead to distortions of the measured LAC curves and our classification method uses a spectral correction algorithm to correct the distorted attenuation curve [3]. Using the correction algorithm the measured LACs of a material directly corresponds to the theoretical formulation in the basis material decomposition. Therefore, the method in this work gives a system-independent solution to classify materials. Brambilla et al. presented a basis material decomposition method estimating Z_{eff} of a material with a PCD, which directly uses the distorted LACs and therefore requires a calibration of the detector's spectral response for various combinations of basis materials of equivalent thicknesses [4]. However, this result in a system-dependent solution due to the dependence on the source spectrum.
In this work, we use sparse-view reconstructions from few projections which is important to achieve fast scanning in security screening. To improve reconstruction performance we employ the joint reconstruction regularization with the vectorial total variation method called L_∞-VTV [5]. L_∞-VTV correlates the image gradients using a L_∞ norm over multi energy bins and results in strong coupling between energy bins. The classification performance is estimated over a set of weighting parameters, λ defining the strength of the spectral regularization term of L_∞-VTV. We use 33 different materials in the range of $6 \leq Z_{\text{eff}} \leq 15$ for experimental validation of the method, scanned with a MultiX ME-100 v2 line array PCD. We show that using the spectral correction algorithm with the material decomposition classification method decrease the relative deviation in Z_{eff} to 2.4$\%$ from 5.2% when spectral correction is not used.

[1] R. Alvarez and E. Seppi. A comparison of noise and dose in conventional and energy selective computed tomography, IEEE Transactions on Nuclear Science 26(1979) 2853.
[2] S. J. Riederer and C. Mistretta. Selective iodine imaging using K-edge energies in computerized x-ray tomography, Medical Physics 4(1977) 474.
[3] Dreier ES, Kehres J, Khalil M, Busi M, Gu Y, Feidenhans R, et al. Spectral correction algorithm for multispectral CdTe x-ray detectors. Opt Eng 2018; 57(5):16. http://dx.doi.org/10.1117/12.2272935.
[4] A. Brambilla, A. Gorecki, A. Potop, C. Paulus, Verger L. Basis material decomposition method for material discrimination with a new spectrometric X-ray imaging detector. J Instrum 2017; 12(8):P08014. http://dx.doi.org/10.1088/1748-0221/12/08/P08014.
[5] Jumanazarov, D., Koo, J., Poulsen, H. F., Olsen, U. L., and Iovea, M., Material classification from sparse spectral X-ray CT using vectorial total variation based on L infinity norm. Submitted to NDT & E International (2021).

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **188** Type: **Poster presentation + pitch**

Nuclear waste monitoring and hazard detection software for Timepix3 detector network

Nuclear waste monitoring and hazard detection software for Timepix3 detector network

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Increased decommissioning of nuclear power plants brought new challenges regarding the storage and monitoring of radioactive waste. Complex networks of hybrid pixel detectors have shown promising results in long-term monitoring and characterization of large particle fluxes inside the caverns of ATLAS and MoEDAL experiments at CERN [1].

As members of the Horizon 2020 project Measurement and Instrumentation for Cleaning and Decommissioning Operations (MICADO) [2] we proposed monitoring system based on a network of the Timepix3 detectors with various sensor types (Si with thicknesses of 100, 300 and 500 μm, and CdTe with a thickness of 1 mm; Si detectors are equipped with neutron convertors).

The radiation field in nuclear waste sites is predominantly constituted of γ-rays and neutrons. Timepix3 with its precise time and energy resolution (1.56 ns and 2 keV for 300 μm Si at 60 keV [3]) and continuous operational (data-driven) mode offers great capabilities in waste radiation field characterization. With improved Katherine readouts [4] a novel long-term measurement detector network was developed.

A newly developed MM Track Lab control and acquisition software with specifically designed plugins for the presented network, permits not only to control and acquire measurement data from all detectors simultaneously, but also displays current particle fluxes in real time. With such capabilities, the system can offer a near instant nuclear waste hazard warning with detailed characteristics of the ongoing accident.

Following previous results in particle classification with Timepix3 [5,6,7], we plan to build on the developed techniques and present classification of electrons, alpha particles, γ-rays and other particles. A variety of artificial-intelligence-based classifiers (e.g. neural networks, decision trees) will be developed and tested to correctly identify the mentioned particle classes. These methods will be based on the data directly measured by Timepix3 as well as on morphological features of the clusters (e.g. skeletonization) and the classification algorithms will operate in real-time.

Training data from neutron fluxes for classifiers will be measured at the Czech Metrology Institute and for complex nuclear waste radiation field measurement, it is planned to use a phantom (testing) nuclear waste drum. A comparison of the methods used will be presented (including their accuracy).

Figure 1. User interface of the network monitoring system. Cells of top two rows represent a matrix of individual Timepix3 chips. The bottom row shows the statistics of different classes in a timeline (blue color chart represents gamma rays, green alfa particles and yellow electrons). Displayed data do not represent actual radiation field around nuclear waste.

Figure 2. Detail of one device with highlighted types of events. The electron is marked in yellow, the alpha particle (visible below the ⁶LiF foil after a ⁶Li(n,α)³H reaction) in green and the γ-ray in blue.

[1] B. Bergmann, T. Billoud, C. Leroy and S. Pospisil, "Characterization of the Radiation Field in the ATLAS Experiment With Timepix Detectors," in IEEE Transactions on Nuclear Science, vol. 66, no. 7, pp. 1861-1869, July 2019, doi: 10.1109/TNS.2019.2918365.
[2] https://www.micado-project.eu
[3] Poikela, T., et al. "Timepix3: a 65K channel hybrid pixel readout chip with simultaneous ToA/ToT and sparse readout." Journal of instrumentation 9.05 (2014): C05013.
[4] P. Burian, P. Broulím, M. Jára, V. Georgiev and B. Bergmann, "Katherine: Ethernet Embedded Readout Interface for Timepix3", Journal of Instrumentation, Volume 12, no. 11, pp. C11001–C11001, November 2017
[5] L. Meduna, B. Bergmann, P. Burian, P. Mánek, S. Pospíšil and M. Suk, "Real-time Timepix3 data clustering, visualization and classification with a new Clusterer framework", arXiv preprint arXiv: 1910.13356 (2019)
[6] P. Mánek, "Machine learning approach to ionizing particle recognition using hybrid active pixel detectors", Master Thesis, 2018.
[7] L. Meduna, "Detecting elementary particles with Timepix3 detector", Master Thesis, 2019.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **189** Type: **Poster presentation + pitch**

X-ray imaging of moving objects using on-chip TDI and MDX methods with single photon counting CdTe hybrid pixel detector

Tuesday, June 29, 2021 4:00 PM (20 minutes)

X-ray imaging of moving objects by using line detectors stays the most popular method of object content and structure examination with a typical resolution limited to 0.4 -1 mm. Higher resolutions are difficult to obtain as for the detector in the form of a single pixel row, the narrower the detector is, the lower the image Signal to Noise Ratio (SNR). This is because, for smaller pixel sizes, fewer photons hit the pixel in each time unit for given radiation intensity.
To overcome the trade-off between SNR and position resolution, a two-dimensional sensor, i.e., pixel matrix can be used. Imaging of moving objects with pixel matrix requires time-domain integration (TDI). Straight forward TDI implementation is based on the proper accumulation of images acquired during consecutive phases of object movement. Unfortunately, this method is much more demanding concerning data transfer and processing. Data from the whole pixel matrix instead of a single pixel row must be transferred out of the chip and then processed.
The alternative approach is on-chip TDI implementation. It takes advantage of photons acquired by multiple rows (higher SNR) but generates the same data amount as a single pixel row and does not require data processing out of the chip.
In this paper on-chip TDI is described and verified by using single photon counting two-dimensional (matrix of 128 x 192 pixels) CdTe hybrid X-ray detector with 100 um x 100 um pixel size with up to four energy thresholds per pixel. The spatial resolution verification is combined with Material Discrimination X-ray (MDX) imaging method.

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Session Classification: Oral presentations

Track Classification: Front end electronics and readout

Contribution ID: **190** Type: **Poster presentation only**

A 5-Gbps Serializer ASIC in 130 nm for Radiation Readout Environment

The serializer ASIC is used to convert parallel data into a higher bit rate serial data stream, which is widely used in high-speed serial communication systems and becomes one of the key functional modules in the serial data transmission system.This paper presents the design and the test results of a low-power 5Gbps 10:1serializer chip based on standard 130nm CMOS technology.

The chip receives ten channels of 500Mbps parallel data and output one channel of 5Gbps serial data. It is mainly composed of clock Rx, clock divider, parallel data Rx, 5:1module, 2:1module, serial data Tx. The 5:1 module adopts a multiphase structure to convert five channels of 500Mbps parallel data into one channel of 2.5Gbps serial data. The 2:1 module, which follows the two 5:1 modules, receives two channels of 2.5 Gbps data and adopts a tree structure to convert two 2.5Gbps data into one 5Gbps data. The 2:1module has the most restrict requirements on the timing issues of the data and the clock due to its highest data rate within the chip. In order to ensure the timing margin between the data and the clock, a customized multistage LATCH structure is adopted in the 2:1 module. The first stage of the 2:1 module uses a two-path multiple LATCH structure, while the second stage adopts a tree-shaped structure to implement 2:1 serializing. The first path in the front stage is composed of 2 LATCHs, and the second path is composed of 3 LATCHs. Therefore, the phase difference between the two paths (outputs of the first stage)is solely determined by the edge of the clock, instead of any process/temperature dependent buffers. The second stage of the 2:1 module receives two outputs of first stage with fixed phase difference, thus implement the 2:1 serializing safely using tree-shaped structure. An internal parallel PRBS7 source is also added within the chip, and the chip is capable of self-check without external parallel inputs.

The whole serializer ASIC features a size of 1.5mm*1.2mm with 37 pads.The chip has been taped out and a complete logic test has been done. In the self-check mode, a 5 Gbps PRBS 7 serial data has been observed and checked at the output of the ASIC, and the clear widely-open 5 Gbps eye has also been captured on the scope. Both the logic function and analog performance of the ASIC have been verified, and the TID (Total Ionizing Radiation) X-ray radiation test is also planned to be conducted in May. All related test results will be included in the report.

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **191** Type: **Poster presentation only**

Quality assessment of Cadmium Telluride as a detector material for multispectral medical imaging

The MPMIB project (*Multispectral photon-counting for medical imaging and beam characterization*), funded via the Academy of Finland RADDESS programme, focuses on the development of a next generation radiation detection system operating in a photon-counting (PC) mode [1]. The extraction of spectrum per pixel data will lead to higher efficiency and image quality, as well as the possibility to identify different materials and tissue types. Our approach is to construct direct-conversion semiconductor detectors hybridized with read-out chips (ROC) capable of operating in PC mode. Currently, we focus on Cadmium Telluride (CdTe) as a detector material candidate, which is a high-Z material with excellent photon radiation absorption properties.
However, CdTe is a fragile material that can include large concentrations of extended crystallographic defects, such as grain boundaries and tellurium (Te) inclusions, necessitating material assessment prior to the complex procedure of detector processing [2]. As CdTe is nearly transparent in the near-infrared we employ infrared microscopy (IRM) to make Te inclusions inside the crystal visible. Employing a neural network [3], we identify and classify the defects in the obtained IRM images and visualise the defect distribution in 3D-maps (Fig.1). We are currently comparing the defect distributions to measurement results with transient current technique (TCT) to study the relation between areas of higher defect densities and the charge collection effiency of the detector.
We will give an update on the MPMIB project, discuss IRM results showing defect distributions of CdTe crystals and the possible implications on the performance of the processed detector, as well as present first experimental data obtained with one of our prototype PC detectors in a small tomographic setup. Further analysis and advanced image reconstruction will give us a clearer picture of how our detectors are performing in respect to multispectral imaging.

[1] E. Brücken et al., Journal of Instrumentation 15 (2020), doi:10.1088/1748-0221/15/02/C02024
[2] A. Gäddä et al., Journal of Instrumentation 12 (2017), doi:10.1088/1748-0221/12/12/C12031
[3] Ohtu neural networks. https://github.com/Ohtu-project/Ohtu-neural-networks

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **192** Type: **Oral presentation**

From muography to muon tomography of large structures

Tuesday, June 29, 2021 9:50 AM (20 minutes)

Muography is a penetrating imaging technique making use of the natural cosmic muons to probe the inside density distributions of objects. Since the pioneering work from Luis Alvarez in the 1960s, different imaging modes have been implemented depending on the size of these objects. The most common and only usable one for very large structures is the so-called transmission muography, where the image is obtained from muons which passed through the structure. This image is by nature a 2D density distribution, the density along the direction of observation being integrated. This situation is very similar to medical imaging, and a 3D picture can be accessed by combining different projections. In this case, however, the size of the objects as well as the modest number of available projections impose several challenges to this inverse problem. Following a previous work on absorption muography, a SART algorithm was successfully applied on simulated transmission data. This talk will review the various challenges of this inversion and how they were addressed. By the time of the conference, new results should be released from the ScanPyramids collaboration, and the application of the SART algorithm to the CEA data will then be shown.

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Session Classification: Oral presentations

Track Classification: Highlighted sessions

Contribution ID: **193** Type: **Poster presentation only**

AC-coupled pixel detectors for high luminosity environments

We report on manufacturing and testing of AC-coupled n-in-p pixel sensors for the usage in high luminosity environments. The detectors are produced at Micronova, Finland's national research infrastructure for micro- and nanotechnology, on magnetic Czochralski (MCz) p-type silicon wafers. High leakage current caused by radiation damage in silicon is a significant source of noise in the readout electronics and limits their dynamic range. The AC- coupled design will substantially reduce the leakage current through the readout when compared to DC- coupled detectors, especially after heavy irradiation. With this design and by using MCz p-type silicon, we expect the detectors to show good radiation hardness.
To avoid complex p-stop/p-spray structures usually used for sensors with segmented n+ electrodes, we employ thin Al2O3 and HfO2 films as field insulation layer grown by Atomic Layer Deposition (ALD). Due to the presumably negative oxide charge of the thin film(s), we expect it to prevent accumulation of electrons between the pixels and thus to provide excellent surface passivation and inter-pixel insulation. Biasing is realized via thin film titanium nitride (TiN) resistors. Details can be found in references [1,2].
The pixel pattern of our sensor matches the layout of the PSI46dig readout ASIC, which is currently used in the inner tracking detector of the CMS experiment at the LHC [3]. In addition to standard characterization techniques performed on the sensors, such as IV, CV and TCT measurements, we also tested fully assembled detectors, which were flip-chip bonded to the PSI46digV2.1-r readout chips. The tests were performed using various X- and gamma-ray calibration sources and the results will be presented here in detail. The impact of bias line design, bias voltage, and threshold settings of the readout chip on detector performance will be discussed. To evaluate the radiation hardness of our sensors, we are performing irradiations with high proton fluences (> 1015 protons/cm2) using a 10 MeV proton beam, followed by a comparative study of non-irradiated and irradiated sensors.

References

[1] J. Ott et al., Processing of AC-coupled n-in-p pixel detectors on MCz silicon using atomic layer deposited aluminium oxide, Nucl. Instrum. Meth. A 958 (2020), 162547, doi:10.1016/j.nima.2019.162547.
[2] J. Härkönen et al., Processing and Interconnections of Finely Segmented Semiconductor Pixel Detectors for Applications in Particle Physics and Photon Detection, Front. in Phys. 9 (2021) 32, doi:10.3389/fphy.2021.601730.
[3] H. C. Kaestli, Frontend electronics development for the CMS pixel detector upgrade, Nucl. Instrum. Meth. A 731 (2013), 88, doi:10.1016/j.nima.2013.05.056.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **194** Type: **Poster presentation only**

Medipix3 proton and carbon ion measurements across full energy ranges and at clinical flux rates in MedAustron IR1

The Medipix3, a hybrid pixel detector with a silicon sensor, has been evaluated as a beam instrumentation device with proton and carbon ion measurements at EBG GmbH MedAustron IR1 (Irradiation Room 1), Marie-Curie-Straße 5, 2700 Wiener Neustadt, Austria. Protons energies are varied from 62.4 to 800 MeV with 10ˆ4 to 10ˆ8 protons per second impinging on the detector surface. For carbon ions, energies are varied from 120 to 400 MeV/A with 10ˆ7 to 10ˆ8 carbon ions per second. Measurements include simultaneous high resolution, beam profile and beam intensity with various beam parameters at up to 1000 FPS (frames per second), count rate linearity and an assessment of radiation damage after the measurement day using a X-ray tube to provide a homogeneous radiation measurement. The count rate linearity is found to be linear within the uncertainties (dominated by accelerator related sources) for the measurements without degraders. Various frequency components are identified within the beam intensity over time firstly including 49.98 Hz with standard deviation, $\sigma = 0.29$, secondly 30.55 Hz $\sigma = 0.55$ and thirdly 252.51 Hz $\sigma = 0.83$. A direct correlation between the number of zero counting and noisy pixels is observed in the measurements with the highest flux. No conclusive evidence of long term radiation damage was found as a result of these measurements over one day.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **195** Type: **Poster presentation only**

Semi-insulating GaAs detectors degraded by 8 MeV electrons up to 1500 kGy

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We have dealt with SI (semi-insulating) GaAs detectors for two decades and successfully developed GaAs detectors for gamma and alfa spectrometry as well as for neutron detection [1, 2]. We have also fabricated GaAs sensor chips which were successfully applied to a TIMEPIX readout chip for radiation imaging [3]. Our radiation hardness studies included the resistance of GaAs detectors against gamma rays, fast neutrons or electrons [4]. Results of these studies suggest that the degradation is manifested by the generation of defects in GaAs lattice (e.g. vacancies and interstitials) acting as traps for charge carriers, which shortens their lifetime and decreases their mobility. The shorter carrier lifetime will lead to higher detector resistivity shifting the breakdown voltage higher. On the other hand, the charge collection efficiency will be degraded due to trapping. These processes were observed in our previous experiments [5].

In this paper, we have involved positron annihilation spectroscopy (PAS) aimed at characterization of the vacancy-type defect production in the GaAs-substrate irradiated by 8 MeV electron up to doses of 1500 kGy. Radiation-induced mono-vacancies were clearly identified in the irradiated materials, and their concentration was estimated by the standard trapping model [6]. The results show an onset of radiation degradation below 500 kGy, followed by a linear increase in the concentration of vacancies. The effect of these vacancies on the detector quality was studied by galvano-magnetic measurements utilized to determine the electron Hall mobility and the resistivity of the SI GaAs substrate. An increase of the material resistivity and decrease of charge mobility were observed with increasing applied dose. On the contrary to our previous studies, the detector material was degraded before contact evaporation, which ensured separation of radiation degradation solely to the bulk material, excluding the contact degradation. After the evaporation of Schottky contacts, the current-voltage characteristics of the structures were measured (Figure 1). With an increasing dose, one could observe an increase of the reverse current in the voltage range up to 450 V, the reduction of the barrier height of the Schottky contact almost totally disappearing at a dose of 1 MGy (the current almost linearly increases with the reverse bias without any saturation) as well as vanishing of the breakdown behaviour beneath 500 V with all doses applied. The 241-Am gamma and alfa spectra were analysed to determine the spectrometric quality of the detector after degradation. A gradual decrease of charge collection efficiency was observed with increasing dose.

[1] F. Dubecky et al., Nucl. Instr. & Meth. in Phys. Res. A576(2007), 87-89.
[2] A. Sagatova et al., JINST 11(2016), C12002.
[3] A. Sagatova et al., Applied Surface Science 461(2018), 3-9.
[4] A. Sagatova et al., Applied Surface Science 395(2017), 66-71.
[5] A. Sagatova et al., JINST 15(2020), C01024.
[6] A. Vehanen, et al., Phys. Rev. B 25(1982), 762.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **196** Type: **Oral presentation**

The LHCb Vertex Locator Upgrade

Wednesday, June 30, 2021 9:50 AM (20 minutes)

The Large Hadron Collider Beauty detector is a flavour physics detector, designed to detect decays of b- and c-hadrons for the study of CP violation and rare decays. At the end of Run-II, many of the LHCb measurements will remain statistically dominated. In order to increase the trigger yield for purely hadronic channels, the hardware trigger will be removed and the detector will be read out at 40 MHz. This, in combination with the five-fold increase in luminosity requires radical changes to LHCb's electronics, and, in some cases, the replacement of entire sub-detectors with state-of-the-art detector technologies.

The Vertex Locator (VELO) surrounding the interaction region is used to reconstruct the collision points (primary vertices) and decay vertices of long-lived particles (secondary vertices). The upgraded VELO will be composed of 52 modules placed along the beam axis divided into two retractable halves. The modules will each be equipped with 4 silicon hybrid pixel tiles, each read out with by 3 VeloPix ASICs. The silicon sensors must withstand an integrated fluence of up to 8×10^{15} 1 MeV n_{eq}/cm^2, a roughly equivalent dose of 400 MRad. The highest occupancy ASICs will have pixel hit rates of 900 Mhit/s and produce an output data rate of over 15 Gbit/s, with a total rate of 1.6 Tbit/s anticipated for the whole detector.

The VELO upgrade modules are composed of the detector assemblies and electronics hybrid circuits mounted onto a cooling substrate, which is composed of thin silicon plates with embedded micro-channels that allow the circulation of liquid CO_2. This technique was selected due to the excellent thermal efficiency, the absence of thermal expansion mismatch with silicon ASICs and sensors, radiation hardness of CO2, and very low contribution to the material budget. The front-end hybrid hosts the VeloPix ASICs and a GBTx ASIC for control and communication. The hybrid is linked to the opto-and-power board (OPB) by 60 cm electrical data tapes running at 5 Gb/s. The tapes must be vacuum compatible and radiation hard and are required to have enough flexibility to allow the VELO to retract during LHC beam injection. The OPB is situated immediately outside the VELO vacuum tank and performs the opto-electrical conversion of control signals going to the front-end and of serial data going off-detector. The board is designed around the Versatile Link components developed for high-luminosity LHC applications.

The design of the complete VELO upgrade system will be presented with the results from the latest R\&D. The LHCb upgrade detector will be the first detector to read out at the full LHC rate of 40 MHz. The VELO upgrade will utilise the latest detector technologies to read out at this rate while maintaining the required radiation hard profile and minimising the detector material.

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Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **197** Type: **Poster presentation only**

4D tracking and vertexing for LHCb Upgrade II

LHCb has recently submitted a physics case for a an Upgrade II detector to begin operation in 2031. The upcoming upgrade stage is designed to run at instantaneous luminosities of $2 \times 10^{34} cm^{-2} s^{-1}$, an order of magnitude above Upgrade I, and accumulate a sample of more than 300 fb^{-1}. At this intensity, the mean number of interactions per crossing would be 56, producing around 2500 charged particles within the LHCb acceptance. To meet this challenge it is foreseen to modify the existing spectrometer to exploit the use of precision timing.

In particular, the LHCb upgrade physics programme is reliant on an efficient and precise vertex detector (VELO). The higher luminosity poses significant challenges which need the construction of a new VELO with enhanced capabilities. Compared to Upgrade I there will be a further order of magnitude increase in data output rates accompanied by corresponding increases in radiation levels and occupancies. To cope with the large increase in pile-up, new techniques to assign correctly each b hadron to the primary vertex from which it originates, and to perform the real time pattern recognition, are needed. To solve these problems a new 4D hybrid pixel detector with enhanced rate and timing capabilities in the ASIC and sensor will be developed. Improvements in the mechanical design of the Upgrade II VELO will also be needed to allow for periodic module replacement. The design will be further optimised to minimise the material before the first measured point on a track (which is dominated by the RF foil) and to achieve a more fully integrated module design with thinned sensors and ASICs combined with a lightweight cooling solution. As well as improving the VELO performance, quantified by the impact parameter resolution and vertex reconstruction efficiencies, these changes will also be beneficial both in improving the momentum resolution of the spectrometer and reducing the impact of secondary interactions on the downstream detectors.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **198** Type: **Poster presentation only**

Multi-threshold Window Discriminator Based on SAR Logic

The new class of X-ray imaging detectors allows us to capture an image in various energy ranges in one shot [1]. This technique is called X-ray color imaging, and it is becoming a promising method in many applications such as medical imaging, computed tomography, and material testing [2]. To measure the energy spectrum in one shot, discriminant circuits need to be integrated into the pixel front-end electronics. Several solutions of in-pixel discriminators exist. However, current designs suffer from a low number of discrimination bins and need to adjust each discrimination threshold separately, leading to relatively complicated calibration procedures [3].

This work will introduce a novel design of a multi-threshold window discriminator based on successive approximation register logic. This circuit realizes in-pixel binning to ten equidistant windows. Two variables are used for tuning the multi-threshold window discriminator: offset of first window and width of windows. Setting these parameters allows the user to fulfill the need for the target application. The results will be presented.

[1] M. C. Veale, et al., Synchrotron Radiat. News, 31 (2018), 28–32

[2] J. P. Ronaldson, et al., IEEE Nuclear Science Symposium Conference Record, (2011)

[3] R. Ballabriga, et al., Journal of Instrumentation, 8 (2013), no. 2,

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **199** Type: **Poster presentation + pitch**

The radiation hardness comparision of Si, SiC, GaAs and CdTe detectors under high-energy electron irradiation

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We have fabricated and studied semiconductor detectors of ionizing radiation for more than two decades. In preference, we have investigated detector structures based on bulk semi-insulating GaAs and 4H-SiC high-quality epitaxial layer. The electrical and detection performance of fabricated detector structures were researched [1, 2]. Also, the radiation hardness or lifetime in radiation harsh environment is very important parameter of detectors. We have comprehensively studied the radiation hardness of semi-insulating GaAs detectors [3, 4].

In this paper, the radiation hardness of various detector types was investigated. In our study, we used four types of typical radiation detectors based on Si (silicon), 4H-SiC, semi-insulating GaAs and CdTe. Detectors based on Si have the thickness of 300 um and active area of 6×6 mm2. The high-quality epitaxial layer with doping concentration about 7×10E13 cm-3 and 70 um thickness was used for 4H-SiC detectors fabrication. The diameter of Ni Schottky contact was 2 mm. In case of semi-insulating GaAs detectors, we utilized 220 um thick base material with 1 mm circular Pt Schottky contact. The CdTe Schottky detectors have 4×4 mm2 size and 1 mm thickness. Studied detectors were irradiated with 5 MeV electrons by using several steps. After each irradiation step the spectrometric performance of all detector samples was investigated and then the total dose was increased. The detection and spectrometric parameters of detectors were measured with the same read-out chain based on Amptek charge sensitive preamplifier and digital pulse processor. As a source of testing radiation, we used 241-Am radioisotope which generates X-rays and gamma-rays peak up to about 60 keV. Fig. 1 shows selected measured spectra of Si and 4H-SiC detectors. Left chart shows the spectrometric performance of Si detector after 0.5 kGy and 1.0 kGy dose of high-energy electron irradiation. Due to better visibility of 60 keV peak we inset also magnified spectra. It can be seen that after only 1 kGy of radiation dose the Si detector completely loses its ability to resolve X-rays peaks. On the contrary 4H-SiC detectors is still able to resolve X-ray peaks even after 30 kGy of irradiation dose. Our study indicates that Si detectors work only up to 4.1 kGy or irradiation dose which totally damage the samples, which means that detectors were not able to detect any radiation. On the contrary 4H-SiC detectors were irradiated up to 2.5 MGy and were still able to detect radiation with very limiting resolution. Regarding semi-insulating GaAs detectors, most of results we published in our previous works and detectors were able to operate up to 1 MGy of radiation dose. Detectors still can detect radiation but due to very small charge collection efficiency about 10% the detection of 60 keV peak of 241-Am radioisotope was not possible. The CdTe detectors show similar radiation hardness like Si samples. But the major limitation is polarization effect which tested samples demonstrated. The unirradiated CdTe samples were able to work about 90 minutes without peaks shifting to lower channels but after only a radiation dose of about 2 kGy the operational time was shortened to only 1 minute after that detectors loses their spectrometric performance and should be switched off.

[1] Zaťko, B., Hrubčín, L., Šagátová, et al., Applied Surface Sci 536 (2021) 147801.
[2[Dubecký, F., Zaťko, B., Kolesár, V. et al., Applied Surface Sci 467-468 (2019) 1219.
[3] Šagátová, A., Zaťko, B., Nečas, V., and Fülöp, M., J. Instrument. 15 (2020) C01024.
[4] Šagátová, A., Zaťko, B., Nečas, V. et al, J. Instrument. 13 (2018) C01006.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **200** Type: **Poster presentation only**

Monte Carlo Simulations for XIDER, a Novel Digital Integration X-ray Detector for the Next Generation of Synchrotron Radiation Sources

This work presents the first simulation results of the incremental digital integration readout, a charge-integrating front-end scheme with in-pixel digitisation and accumulation. This novel readout concept [1] is at the core of the XIDER project, which aims at building 2D pixelated X-ray detectors optimised for high energy scattering and diffraction applications for the next generation of synchrotron radiation storage rings. These new photon sources such as the ESRF Extremely Brilliant Source (EBS), the first fourth-generation high-energy synchrotron facility worldwide, will provide new research opportunities but at the same time, will require very demanding new X-ray instrumentation. For this purpose, the digital integration readout and the XIDER detector will open the possibility of high-duty-cycle operation under very high photon fluxes enabling fast frame-rate and high dynamic range with single-photon sensitivity in the 40 100 keV energy range. The readout method will allow for noise-free effective X-ray detection, but also a high level of versatility to suit a wide range of synchrotron radiation experiments.
The digital integration concept is currently under thorough investigation to evaluate the impact of main critical design parameters in order to identify the weaknesses and strengths of the readout scheme and consequently to propose refinements in the final implementation. Simulations are performed with a dedicated Monte Carlo simulation tool, DECIMO [2], a modular Python package designed to recreate in an easy-to-use way the complete detection chain of X-ray detectors for synchrotron radiation experiments, including the XIDER project.
In addition to presenting simulation results for this novel readout scheme, this work underlines the potential of the approach and some of its limitations.

[1] P. Fajardo et al., 2020 JINST 15 C01040
[2] T. Johng-ay et al., 2016 IEEE Nuclear Science Symposium (NSS/MIC/RTSD), pp. 1-7

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **202** Type: **Poster presentation only**

Study of enhancement of luminescence with addition of phosphor materials in plastic scintillators.

A novel method of loading phosphor materials in plastic scintillators (here on PS) is demonstrated in this work. ZnS(Ag) and ZnO phosphor materials are integrated into thin PS medium to exploit high Z and phosphor characteristics of these materials in radiation detection. These PS are prepared using polystyrene as base, xylene as solvent, PPO and POPOP as primary and secondary flours and phosphor as an additional luminescent material to 250±30μm thickness. The synthesized composite PS are studied for characterization of photoluminescence, radioluminescence, energy transfer phenomenon in composite PS and their detection efficiencies for common alpha, beta, gamma and neutron sources. The results obtained showed there is a notable increase in the performance of the phosphor loaded PS compared to that of bare PS. The performance for gamma radiation detection in these PS has been enhanced without degrading actual light yield. The results obtained are also compared with that of commercially available PS.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **203** Type: **Poster presentation only**

High rate capability studies of triple-GEM detectors for the ME0 upgrade of the CMS Muon Spectrometer

The high-luminosity LHC (HL-LHC) upgrade is setting a new challenge for particle detector technologies. In the CMS Muon System gaseous detectors, the increase in luminosity will produce a particle background ten times higher than at the LHC. To cope with the high rate environment and maintain performance, triple Gas Electron Multiplier technology is a promising candidate for high-rate capable detectors for the CMS-ME0 upgrade project in the innermost region of the forward Muon Spectrometer of the CMS experiment. An intense R&D and prototype phase is ongoing in order to prove that such technology meets the stringent performance requirements of highly efficient particle detection in the harsh background environment expected in the innermost ME0 region. The authors will describe the recent rate capability studies on triple-GEM detectors operated with an Ar/CO_2 $(70/30)$ gas mixture at an effective gas gain of 2×10^4 by using a high intensity $22keV$ X-ray generator. Moreover, we will present the novel foils design based on double-sided segmented GEM-foils, high voltage distribution powering and filtering and their impact on the performance of the detector in light of new rate capability studies, with a summary of the ongoing R&D activities.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **204** Type: **Poster presentation only**

Effects and image evaluation of high-resolution scintillators on digital X-ray detector for intra-oral radiography

In recent years, digital X-ray imaging sensors with indirect detection method have been widely used in many dental imaging applications such as intra-oral, panorama and dental CT. These indirect X-ray imaging detectors are based on the combination of a complementary metal-oxide semiconductor (CMOS) array with different scintillating materials such as CsI, GOS. Currently, a CMOS-based indirect X-ray imaging sensor with low dose and high spatial resolution has been widely utilized for dental intra-oral radiography.
In this work, we have designed and developed the CMOS APS image sensor with high-resolution and high-sensitivity for dental imaging tasks. A prototype sensor consists of CMOS array with a 24mm x 33mm active area with high-definition mode (10um pixel pitch) and normal-definition mode (20um pixel pitch) respectively. Different high-resolution scintillation materials such as FOS (fiber optic scintillator) with columnar CsI:Tl and Gd2O2S:Tb(GOS) with various thickness were used to investigate the imaging performance. The used FOS screen is a highly X-ray absorption material that minimizes the X-ray induced noise. The used scintillator's design parameters were optimized for excellent image quality at low X-ray exposure condition.
For evaluation and optimization of the X-ray image sensor characterization, different scintillating screen materials were directly coupled on the prototype CMOS photodiode array. The typical imaging performance such as the light response to X-ray exposure dose, signal-to-noise-ratio (SNR) and modulation transfer function (MTF), low-contrast detail resolution was measured under practical dental imaging systems with 60-70kVp tube voltage and 2-5mA tube current. The experimental results with CMOS image sensor using FOS scintillators, about 16.6lp/mm spatial frequency could be seen.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **205** Type: **Oral presentation**

Impact of X-ray induced radiation damage on FD-MAPS of the ARCADIA project

Thursday, July 1, 2021 11:20 AM (20 minutes)

The ARCADIA collaboration is developing Fully-Depleted Monolithic Active Pixel Sensors (FD-MAPS) with an innovative sensor design in a 110nm CMOS process. This technology provides efficient charge collection and fast timing over a wide range of operational and environmental conditions [1]. The design targets very low power consumption, of the order of 20mWcm at 100MHzcm hit flux, to enable air-cooled operation.
In November 2020, the collaboration finalized the first design of a prototype with 1.31.3cm active area, consisting of 512512 pixels with 25m pitch. This prototype is currently being produced in a first engineering run together with additional test structures of pixel and strip arrays with different pitches and sensor geometries and will be available for testing in May 2021.
In this contribution, we will present the current status of the project and discuss the methodology, based on TCAD simulations, that has been used for the selection of the different pixel geometries included in the first engineering run. An emphasis will be set on the modelling of X-ray induced radiation damage at the Si-SiO interface and the impact on the in-pixel sensor capacitance. The so-called new Perugia model [2] has been used in the simulations to predict the sensor performance after total ionising doses of up to 10Mrad. Figure 1 shows the cross-section of the ARCADIA pixel with 25m pitch and 50m thickness in TCAD simulations at a backside bias voltage of -10V and a sensor bias voltage of 0.8V, with (b) and without (a) introduced surface damage. As visible in Figure 1; the effect of radiation damage at the Si-SiO interface changes the depletion region around the collection electrode, and gives rise to an accumulation of electrons in the gap between the p-, and n-wells. This accumulation originates from the introduced positive oxide charges in the SiO and effectively enlarges the collection nwell. The increase of the pixels'capacitance, in the given example from 1.9fF to 3.3fF at the depletion voltage of -7V, requires an optimisation of the gap and well sizes to minimise the capacitance after irradiation.
The simulated sensor characteristics will be related to characterisation results of active (MATISSE chip [3]) and passive pixel matrices produced in ARCADIA sensor technology.

[1] L. Pancheri et al.: FD-MAPS in 110-nm CMOS process with 100–300-μm active substrate, doi:10.1109/TED.2020.2985639
[2] A. Morozzi et al., TCAD advanced radiation damage modeling in silicon detectors, PoS(Vertex2019)050
[3] E. J. Olave et al., MATISSE: A Low power front-end electronics for MAPS characterization, PoS(TWEPP-17)016

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Session Classification: Oral presentations

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **206** Type: **Oral presentation**

8b 10MS/s Differential SAR ADC in 28 nm CMOS for Precise Energy Measurement

Wednesday, June 30, 2021 3:30 PM (20 minutes)

In this article we present an 8-bit differential Successive Approximation Register (SAR) Analog-to-Digital Converter (ADC), designed and manufactured in 28 nm CMOS process.

Radiation imaging is an essential part of medical diagnostics. Although integrating detectors are still widely used, more and more medical institutes have already switched to single photon counting (SPC) devices. The next step is colorful imaging, where each color represents the energy of the acquired photon, and the intensity –the number of hits in the pixel in the given time [1]. This could break new ground in medical imaging, reducing the number of exposures and thus the total irradiation dose. In the literature, there are examples of well-characterized detectors with two levels of energy discrimination [2]. However, in older technologies it was difficult to combine high spatial and energy resolution, maintaining a high count rate and low power consumption. Our aim is to enable fast imaging with the resolution of 256 energy levels, placing an ADC in each of the thousands of 100 μm × 100 μm pixels.

The SAR ADC presented in this article allows to distinguish 256 levels of energy and is capable of converting 10 MS/s. The Integrated Circuit (IC) (Fig. 1.) is currently under measurement and preliminary results show the INL and DNL of about ±0.5 LSB and ±0.6 LSB, respectively. Importantly, the proposed ADC's comparator input offset voltage correction in the time domain allows to effectively compensate mismatches without affecting the conversion rate as reported in [3-4]. Here, by changing the delay buffer voltage, the transfer characteristic can be shifted within the range of about 45 mV (Fig. 2.).

The whole IC area is 400 μm × 450 μm, while the core of the ADC occupies only 30 μm × 60 μm, and this can still be decreased by reducing the unit capacitance (here 0.5 fF), or by applying another switching scheme and changing the capacitor array. Nevertheless, such an ADC is able to fit into a considered pixel and to enable fast imaging with high energy resolution, while maintaining the spatial one at a fine level.

[1] K. Taguchi and J. S. Iwanczyk, Med. Phys. 40 (2013), 100901
[2] P. Gryboś et al., IEEE Trans. Nucl. Sci. 63 (2016), 1155–1161
[3] X. Yang et al., ESSCIRC 2019, 305-308
[4] P. Kaczmarczyk and P. Kmon, Przegląd Elektrotechniczny 96 (2020), 119-122

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Session Classification: Oral presentations

Track Classification: Front end electronics and readout

Contribution ID: **207** Type: **Poster presentation only**

Study of the spatiotemporal structure of extensive air showers at high energies

High-mountain scientific researches in the field of high energies are being carried out at the Tien Shan High Altitude Scientific Station (TSHASS) in collaboration with al-Farabi Kazakh National University. The interest in these studies is mainly connected with two insufficiently studied directions, which can significantly change the interpretation of the spectrum of cosmic rays not only in the high-energy region, but also in the ultra-high-energy region. These studies of the penetrating component of cosmic rays in the region of the so-called knee in the spectrum of cosmic rays are the HADRON experiment and the study of the extended air showers (EAS) with several fronts separated by hundreds of nanoseconds from the leading front —the Horizon-T experiment

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **208** Type: **Poster presentation only**

Improved algorithms for determination of particle directions in space with Timepix3

Timepix3 pixel detectors [1] have shown potential to contribute to a variety of fields. In particle tracking, their improved time and energy resolution, (1.56 ns and 2 keV at 60 keV, respectively) permits precise vertex determination and particle identification via stopping power [2]. Following previous studies of their 3D reconstruction capabilities [3,4], the presented work provides a comprehensive comparison of regression methods for estimation of spatial directions from tracks, which are produced by clustering hits recorded in the detector. Developed methodology is evaluated on simulated data, where ground truth information is available (shown in Fig. 1), and later applied to real-world data acquired in test beam campaigns, in the LHC tunnel (shown in Fig. 2), and the Monopole and Exotics Detector at LHC (MoEDAL), CERN [5]. Assessment of the particle dE/dx and the impact angle allows the characterization of the complex radiation field on a track-by-track basis.

The selection of evaluated regressors comprises a broad range of commonly available methods with varying degree of sophistication and runtime complexity. This includes direct trigonometric calculations, methods that exploit per-pixel Time-of-Arrival as well as Time-over-Threshold information and expensive numerical fitters that rely on iterative convex optimization. Due to morphological selection of input clusters, it is possible to investigate advantages of data preprocessing with operators such as skeletonization. Finally, presented approaches are contrasted with cheap surrogate models (e.g. random forests [6]) that were previously trained in supervised scheme.

Evaluated regressors are compared by means of computing resources and accuracy, which is measured as FWHM in two spherical angles (azimuth φ and zenith θ). The best overall resolution in simulated data FWHM(φ) = 1.3° and FWHM(θ) = 1.2° was achieved with random forest regression.

References:

1 Poikela, T., *et al.*, JINST **9.05** (2014): C05013.

2 Bergmann, B., *et al.*, NIM A **978** (2020): 164401.

3 Bergmann, B., *et al.*, EPJ C **79.2** (2019): 1-12.

4 Mánek, P., *et al.*, CDT/WIT 2018 (2019), arXiv: 1911.02367.

5 MoEDAL Collaboration, ICHEP 2020 (2021). DOI 10.22323/1.390.0720.

6 Mánek, P., *et al.*, JNF pending review (2021), arXiv: 2104.04026.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **209** Type: **Oral presentation**

The new GEM station GE1/1 of the CMS muon detector: status, commissioning and early performance studies

Monday, June 28, 2021 3:50 PM (20 minutes)

During Run 3 the LHC will deliver instantaneous luminosities of 5*10ˆ34 cmˆ-2 sˆ-1 or even 7*10ˆ34 cmˆ-2 sˆ-1. To cope with the high background rates and to improve the trigger capabilities in the forward region, the muon system of the CMS experiment has been upgraded with a new station of detectors based on triple-GEM technology, named GE1/1. The station, which has been installed in 2020, consists of 72 ten-degree chambers, each made up of two layers of triple-GEM detectors. GE1/1 provides two additional muon hit measurements which will improve muon tracking and triggering performance. This contribution will describe the status of the ongoing commissioning phase of the detector together with the preliminary results obtained from cosmic-ray events. Detector and readout electronics operation, stability and performance will be discussed, as well as the preparation for Run 3 of the LHC.

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Session Classification: Oral presentations

Track Classification: Front end electronics and readout

Contribution ID: **210** Type: **Poster presentation + pitch**

Portable Muon Telescope for multidisciplinary applications

Muon tomography or "Muography"is an emerging imaging technique that uses cosmogenic muons as the radiation source. Due to its diverse range of applications and the use of natural radiation, muography is being applied across many fields such as geology, archaeology, civil engineering, nuclear reactor monitoring, nuclear waste characterization, underground surveys, etc. [1]. Muons can be detected using various detector technologies, among which, resistive plate chambers (RPC) are a very cost effective choice [2]. RPCs are planar detectors which use ionization in a thin gas gap to detect cosmic muons, already used since years in major particle accelerator experiments.

In this project, we have developed a muon telescope (or "muoscope") composed of small scale RPCs. The design goal for our muoscope is to be portable and autonomous, in order to take data in places that are not easily accessible. The whole setup is light and compact, such to be easily packed in a car trunk. Individual RPCs are hosted in aluminium that are gas tight. There is no need for gas bottles, once the chambers are filled. The muoscope can be controlled from a reasonable distance using wireless connection. The usage goals of our device are very broad and include, for example, 3D imaging of cultural heritage, such as monumental statues and building decorations. For this kind of application, more established methods based on other forms of radiation (X rays, neutrons) are often infeasible as these objects are very large and in many cases they can not be transported to a properly equipped laboratory.

The current muoscope prototype consists of four identical RPCs and the data acquisition system (DAQ) comprising a computer integrated with high voltage supply to the RPCs. The first and third RPCs are oriented orthogonally to the second and fourth, in order to provide a bi-dimensional information (x and y orientation). Each RPC consists of 2 glass plates with the size of 20 cm x 20 cm, with semi-resistive coating of 18 cm x 18 cm active area, separated with spacers to create a gap of 1.1 mm between them, and a readout board with 16 copper strips. Each strip is 16 cm long and 0.9 cm wide, with a 0.1 cm distance between strip edges. Our RPCs are filled with a specific mixture of 3 gases: Freon (95.2%), ISO-Butane (4.5%) and SF6 (0.3%). The DAQ has two front end PRC boards from the CMS experiment, and each board can handle 32 analog inputs. Each channel is connected to the System on Chip (SoC) module, which is installed in a carrier board with wireless connection. We are using different simulation frameworks like Geant4, COMSOL/Elmer (to calculate the electric field), Garfield++ (to simulate the signal formation) to compare with actual data.

At iWoRID 2021, we are going to present recent development of the current prototype with respect to [3] and [4] and the development that we are planning to do in the near future. We introduced an external trigger system, and the RPCs are upgraded with new semi-resistive glass plates and gas mixture. The resistive coating of these glass plates is laid with a serigraphy method, achieving a much better uniformity with respect to the manual procedure described in [3]. We report on performance and simulation studies and on the resistivity variation of these plates with time.

[1] Atmospheric muons as an imaging tool / L. Bonechi, R. D'Alessandro, A. Giammanco; arXiv:1906.03934 [physics.ins-det]; Reviews in Physics 5 (2020) 100038.
[2] Resistive Plate Chambers in Muography, S. Andringa, E. Cortina Gil, A. Giammanco, M. Tytgat. 22 pages. Peer-reviewed contribution (status: accepted) to the book "Muography: Exploring Earth's Subsurface with Elementary Particles", edited by L. Olah, H. Tanaka and D. Varga. To be published in 2021 by the American Geophysical Union / Wiley.
[3] Towards portable muography with small-area, gas-tight glass Resistive Plate Chambers / S. Basnet, E. Cortina Gil, P. Demin, R.M.I.D. Gamage, A. Giammanco, M. Moussawi, M. Tytgat, S. Wuyckens; arXiv:2005.09589 [physics.ins-det]; JINST 15 (2020) C10032
[4] A portable muon telescope based on small and gas-tight Resistive Plate Chambers / S. Wuyck-

ens, A. Giammanco, P. Demin, E. Cortina Gil; arXiv:1806.06602 [physics.ins-det], Phil. Trans. R. Soc. A 377 (2018) 20180139

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **211** Type: **Poster presentation + pitch**

The GEM Gas Monitoring system: using a gaseous detector as a gas detector for CMS Triple-GEM safe operation

The CMS experiment will exploit the Gas Electron Multiplier (GEM) technology for the first time during the next LHC run. These detectors will work with Ar/CO2 (70/30) gas mixture at an effective gas gain of around 2×104. Maintain the gas mixture quality and concentration is fundamental for the safe and correct operation of such gaseous detectors. An Ar concentration 1% higher or lower will respectively increase or decrease the detector gain of almost 15%. A lower gain will reduce the detection efficiency (>97% at 2×104 gain) decreasing the physics potential, on the other hand, a higher gain will increase the probability to develop streamers and sparks during the electron multiplication. The latter potentially could damage the GEM foils and/or the readout electronics.

The CMS GEM Group decided to develop a monitoring system of the gas concentration by exploiting a small Triple-GEM detector. The gain measurement of this test chamber, fed by the gas mixture derived from the CMS GEM gas system, allows retrieving information about the Ar/CO2 ratio. The accurate removal of the gain fluctuations due to environmental changes, gas flow etc. have been implemented. Detection of wrong gas concentrations in the test chamber will allow to trigger warnings or alarms before sending the gas to the GEM detectors and eventually to real-time tune the working point.

This contribution will describe the GEM Gas Monitoring system from the design to the commissioning foreseen for end 2021. It will report about the calibration procedure, illustrating all the necessary steps to detect gain changes of around 5% corresponding to a systematic variation of Argon (or CO2) concentration of 0.33 %.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **212** Type: **Poster presentation only**

Detection of patient anatomical changes during carbon-ion radiotherapy using secondary ion tracking

Introduction: Carbon-ion radiation therapy offers several advantages to treat deep-seated tumors compared to other radiation therapy with photons or protons. The focused depth dose deposition of carbon ions allows to cover with high doses the full tumor volume while minimizing the dose deposited in surrounding healthy tissues. However, this also leads to a higher sensitivity to anatomical changes during the treatment delivery. This can then lead to an overdosage in the healthy region or underdosage in the tumor region and impair the treatment outcome. It is, thus, of great importance to monitor these anatomical changes during and between patient irradiations.

Aim: In our research we develop and investigate a non-invasive carbon-ion treatment monitoring method based on secondary-ion detection. Secondary ions are nuclear fragments from the interactions of the therapeutic carbon ions with the patient nuclei and can emerge from the treated patient as a by-product of the treatment. Our research focuses on exploiting measured secondary ion tracks around the patient for a non-invasive monitoring of the radiation field in the patient and the anatomical changes influencing it. In this contribution, we present the capability of the method to detect and localize a 2-mm-thick air cavity, which might appear within patients during their treatment.

Methods: A typical clinical carbon-ion irradiation of a head tumor was performed on a head model (PMMA cylinder) at the Heidelberg Ion-Beam Therapy Centre (HIT), Germany. The emerging nuclear fragments were measured by a mini-tracker composed of a two small 1.4 x 1.4 cm^2 pixelated 300-µm-thick silicon semiconductor detectors Timepix3 (AdvapPIX TPX3), developed at CERN and commercialized by ADVACAM s.r.o. (Prague). They offered data-driven, dead-time free, and simultaneous per-pixel information of fragment's ToA, deposited energy and impact position. Measured secondary ion tracks were analyzed and their origin distribution along the beam axis was compared for different internal geometries of the head model (with or without 2-mm-thick air cavity). The precision of the localization of this cavity along the beam axis was studied for different positions of the mini-tracker (at 10°, 20°, 30°, 40°, 50°) and different position of the cavity.

Results: The measured fragments carry information about geometrical changes in the head model (cf Figure.1). In particular, the presence of the 2-mm-thick air cavity can be detected, and even located. In this contribution, we will present in detail how the performance of the method changes with changing the mini-tracker position.

Conclusion: Overall, this work shows that the developed carbon-ion beam monitoring method based on secondary-ion detection with small Timepix3 detectors placed around an irradiated head model allows the detection of even minor anatomical changes within a patient head model.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **213** Type: **Poster presentation only**

GBTX emulator for development and special versions of GBT-based readout chains

The GBTX ASIC is a standard solution for providing fast control and data readout for radiation detectors used in HEP experiments [1,2]. However, it is subject to export control restrictions due to the usage of radiation-hard technology. To enable the development of GBT-based readout chains in countries, where the original GBTX can't be imported, an FPGA-based GBTX emulator (GBTxEMU) has been developed. Thanks to utilization of slightly modified GBT-FGPA core [3] it maintains basic compatibility with standard GBT-based systems.
The emulator may be implemented in a relatively cheap Artix 7 FPGA chip. It provides the basic functionality of the original GBTX - time-deterministic transport of downlink messages, allowing synchronization and fast control of front-end, and high-speed transmission of hit data in the uplink direction. The GBTxEMU supports limited modes of E-Link operation with a clock frequency of 40 or 80 MHz. The downlink operates with SDR (40 or 80 Mbps) and the uplink with DDR (80 or 160 Mbps). The number of supported E-Links depends on the E-Link clock frequency and is equal to 28 for 80 MHz and 56 for 40 MHz.
The emulator may also be used in special versions of the GBT-based readout chain, where radiation hardness is not essential, but the overall price of the system may be important. Currently, its usage in DAQ systems for BM@N and MPD experiments is planned [4]. The original hardware implementation is based on a commercial Artix-7 module and a dedicated baseboard providing jitter cleaner and communication interfaces. The development version was created at GSI, and the final BM@N version in Eurocard format was designed at JINR. In the applications where the maximum throughput of the GBTxEMU is not needed, the board may be placed at some distance from the on-detector electronics, outside of high magnetic field and radiation enviroment. The 10-meter length copper cable connection between the front-end electronics and GBTxEMU was proven to be stable in the BM@N STS project.
Thanks to the FPGA-based architecture, the GBTxEMU is highly flexible. The end-user may connect his own IP blocks to the internal bus, creating additional control interfaces. A special address space management system [5] facilitates their easy integration with the control software. The internal registers are accessible either via the GBT link or via IPbus (using 100Mbps or 1Gbps Ethernet). The embedded Forth-based CPU may perform complex initialization procedures during power-up, and be used for interactive diagnostics.
The GBTxEMU may be an interesting solution for the development of GBT-based readout chains and for less demanding experiments.

[1] J.Mitra et al., "Trigger and timing distributions using the TTC-PON and GBT bridge connection in ALICE for the LHC Run 3 Upgrade", doi: 10.1016/j.nima.2018.12.076
[2] J. Lehnert et al.,"GBT based readout in the CBM experiment",doi:10.1088/1748-0221/12/02/C02061
[3] M. Barros Marin, "The GBT-FPGA core: features and challenges", doi:10.1088/1748-0221/10/03/C03021
[4] W.M.Zabolotny et al., "GBTx emulation for BM@N/MPD data acquisition systems", NICA Days 2019, http://cern.ch/go/J8TL
[5] W.M.Zabolotny et al., "Automatic management of local bus address space in complex FPGA-implemented hierarchical systems", doi: 10.1117/12.2536259

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **214** Type: **Poster presentation only**

Monte-Carlo study of PET scanners for imaging at low and high activity sources using different crystals

PET (Positron Emission Tomography) is an advanced imaging technique that uses radiotracers to target a specific biological or pathological process. This process produces radiotracers because the active/targeting compound labeled with the radioisotope is present at trace levels. These radiotracers are used to study biochemical processes in humans and animals. Performing PET on certain oncologic cases such as paediatric applications pose certain unique challenges. Children have an increased risk of harm when exposed to radiation, hence the study of low activity sources was proposed to identify the most effective geometry of the PET scanner for paediatric applications. This study aims to investigate a set of scintillation crystals including BGO, LSO, LYSO and GAG, and explore their ability to detect the most amount of counts at low activity in order to construct an image with a good resolution and compare the results with high activity for validation purposes. Extensive simulation has been conducted and results will be shown and discussed. This study is significant for paediatric oncologic patients who repeatedly go for check-up sessions.

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Track Classification: Applications

Contribution ID: **215** Type: **Poster presentation only**

Measurement of Angular Correlation Changes in Double-Photon Emission Nuclides Using Ultrasound irradiation

Our group has been developing DPECT (Double Photon Emission CT) to enhance nuclear medicine diagnostics using cascade nuclides that emit multiple gamma rays simultaneously. It is possible to detect the local environment around the nuclide by examining the angular correlation of the emitted gamma rays. In this study, we investigated the effect of ultrasound to cascade gamma-ray emission and found that the angle correlation could be changed by inducing a small electric field in 111In aqueous solution by ultrasound irradiation.
Key word Nuclear Medicine, Angular Correlation, Double Photon

1. Introduction
   Our group has been developing DPECT (Double Photon Emission CT), which enhances nuclear medicine diagnosis by using cascade nuclides that emit multiple gamma rays simultaneously [1]. While it can provide highly accurate nuclear medicine diagnosis, it uses a collimator for imaging and the increase in radiation dose and degradation of image quality due to low detection efficiency are important problems. So, it is necessary to develop a method of DPECT imaging without using collimator. In this study, we focused on the angular correlation between two gamma rays emitted from cascading nuclides (Figure 1). The emission angles of multiple gamma rays from a cascade of nuclides are not random, but have a spin-dependent correlation, and this correlation depends on the local environment of the nuclide. By irradiating ultrasound from the outside and measuring the change in the angular correlation that appears due to the interaction with the nuclear spins of 111In, a two-photon coincidence emitter, we explored the possibility of a new imaging method that combines ultrasound and nuclear medicine.

2. experimental method
   As a cascade nuclide, 111InCl3, which is a SPECT tracer, was used as a point source. 8 × 8 GAGG scintillators and 8 × 8 MPPC (Hamamatsu Photonics SiPM) was used as detectors, and a dToT (dynamic time-over-threshold) circuit board was used to read out the time and energy information for all channels simultaneously and independently. The ultrasound is irradiated by a convergent ultrasound instrument with a fixed frequency of 1MHz, and the sound pressure can be adjusted by changing the input voltage value from 0 to 0.2 V. The intensity of the irradiated ultrasound, the intensity of 111In, and the experiment time are shown in Table 1. To obtain sufficient coincidence events, the experiment time was 2 hours each.

3. Analysis method
   For all channels from GAGG scintillator, we extracted the gamma-ray energies of 171 keV and 245 keV from the acquired energy spectra from 111In, and obtained the emission time difference spectra of these two gamma-rays (Figure 3). From this time difference spectrum, the coincidence time windows are set from -50 to 200 [ns], and only the events with time differences within this time window are extracted.

4. Result
   Figures 4 show the results of the experiment. Figure 4 is the result of how the angular distribution changes when ultrasound is irradiated. For the irradiated sound pressure of 0.2V, 0.15V, and 0.1V, the coincidence events around 0 degrees and 180 degrees increased about 5%, while the coincidence events around 90 degrees decreased about 2%. This phenomenon is thought to be by the induction of a small electric field by ultrasonic irradiation to the liquid [2].We derived an index of angular correlation change A_2 G_2 from the ratio of the number of counts in the 90° and 180° directions for events with a time difference

of -50˜200 [ns] (time window), and calculated ω_e from this result. The frequency of this change thought to show the quadrupole interaction due to the micro-electric field induced by the ultrasound. And from this value we also calculated the micro-electric field gradient imparted to the 111In nucleus (Table 2). This value of ω_e and V_z was consistent with the magnitude of the change in the angular distribution of the emission as previous literature focusing on small electric fields [3].

5. Summary
We found that ultrasound irradiation can change the angular correlation of 111In gamma-ray emission. This result is thought to be due to the induction of micro-electric field gradient in the aqueous solution by electroacoustic effect from ultrasonic irradiation.
As future experiments, we plan to conduct one-dimensional positioning experiments using the properties of convergent ultrasound and angular correlation changes.

Reference

[1] K. Shimazoe et al., "Double Photon Emission Coincidence Imaging using GAGG-SiPM pixel detectors", JINST 12 (1997) C12055.
[2] G. A. Gist and M.D. Wilson, J. Acoust, Soc. Am., 93, May 1993.
[3] Akihiko Yokoyama, "Ultrafine electric field measurement at the active site in metalloproteins" , FY2005 Grant-in-Aid for Scientific Research (C), Research Report, March 2006.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **216** Type: **Poster presentation only**

Prototype design and performance test of a cosmic ray tracker

The High energy cosmic-Radiation Detection(HERD)[1,2] facility has been proposed as one of several space astronomy payloads onboard the future China's Space Station(CSS), which is planned for operation starting around 2026 for about 10 years. A cosmic ray tracker with position resolution of better than 1mm and effective detection area of 1m*1m is designed to do detector performance study.*

*The cosmic ray tracker will consist of two tracking stations each with two detection planes. Each detection plane will have 10 SciFi modules, placed in parallel next to each other constituting a 1m*1m detection surface. The modules contain 1m long scintillating fibers with a diameter of 1mm which are arranged 10cm wide and 1m long fiber-mats of 3 staggered layers of fibers. The fibers will be read out by arrays of SiPMs with a channel widths of 1mm and a channel height of 3mm. An epoxy loaded with TiO_2 is used to glue fibers together and block inter-fiber crosstalk. To increase the number of scintillation photons detected by the SiPMs the fiber end of the detector is covered with ESR reflector to reflect the light towards the readout ends. The readout board mounted with SiPMs are precisely positioned with respect to the fiber ends. The precise SiPMs mounting on the fiber matrix will provide the position of the through-going cosmic ray.

The performance of a small prototype module was tested with cosmic ray and radioactive source 90-Sr. The measured light output of the 3-layer fiber module is around 10 p.e. per MIP events.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **217** Type: **Oral presentation**

Multi-bin energy-sensitive Micro-CT using large area photon-counting detectors Timepix

Tuesday, June 29, 2021 2:10 PM (20 minutes)

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X-ray micro-CT has become a popular widely used tool for purposes of scientific research. Although the current state-of-the-art micro-CT technology is on a high technology level it still has some known limitations. One of relevant issues is an inability to clearly identify and quantify certain materials [1].
The mentioned drawback can be solved by energy-sensitive CT approaches. The dual-energy CT (DECT), which is already frequently used in human medicine, offers identification of two different materials –i. e. to differentiate an intravenous contrast agent from bones or to analyze composition of urinary stones [2].
Resolving of a higher number of constituents within a single object requires also a higher number of energy measurements and, therefore, DECT is not applicable for such measurement. A possible solution for multi-bin –or so-called spectral-CT –is the application of technology of photon-counting detectors (PCD). PCD technology is equipped with an integrated circuitry capable of resolving the energy of incoming photons in each pixel. Therefore, it is possible to collect data in user-defined energy widows [3].
This contribution evaluates the applicability of large-area photon-counting detectors Timepix for multi-bin energy-sensitive micro-CT [4]. It presents a phantom-study focused on simultaneous K-edge-based identification and quantification of multiple contrast agents within a single object. It is based on a set of simulations searching for optimal settings of the energy bins considering their mean energy, width and achievable signal-to-noise ratio. The experimental part of the contribution presents a series of multi-bin energy-sensitive micro-CT scans of a phantom object and results of its material decomposition carried-out using an in-house implemented decomposition algorithm.

[1] M. Willemink et al: "Photon-counting CT: Technical Principles and Clinical Prospects", Radiology, vol. 289, no. 2, pp. 293-312, 2018.
[2] A. C. Silva et al: "Dual-Energy (Spectral)" CT: Applications in Abdominal-Imaging", Radiographics, vol 31, pp. 1031-1046, 2011.
[3] C. McCollough et al: "Dual- and Multi-Energy CT: Principles, Technical Approaches, and Clinical Applications", Radiology, vol. 276, no. 3, pp. 637-653, 2015.
[4] J. Jakubek et al: "Large area pixel detector WIDEPIX with full area sensitivity composed of 100 Timepix assemblies with edgeless sensors", Journal of Instrumentation, vol. 9, no. 04, pp. C04018, 2014.

The work was done in the frame of Medipix Collaboration and was financially supported from European Regional Development Fund-Project "Engineering applications of microworld physics" (No. CZ.02.1.01/0.0/0.0/16_019/0000766).

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Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **218** Type: **Poster presentation + pitch**

Module development for the ATLAS ITk Pixel Detector

In HL-LHC operation the instantaneous luminosity will reach unprecedented values, resulting in about 200 proton-proton interactions in a typical bunch crossing. The current ATLAS Inner Detector will be replaced by an all-silicon system, the Inner Tracker (ITk). The innermost part of ITk will consist of a state-of-the-art pixel detector.
The individual modules of the ITk Pixel Detector comprise silicon sensors using various different technologies, with the sensors read out using the new ITKpix ASIC.
In this talk we will present results from first prototype modules using the new ASIC.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **219** Type: **Oral presentation**

System Tests for the ATLAS ITk Pixel Detector

Wednesday, June 30, 2021 10:10 AM (20 minutes)

The ATLAS tracking system will be replaced by an all-silicon detector for the HL-LHC upgrade around 2025. The innermost five layers of the detector system will be pixel detector layers which will be most challenging in terms of radiation hardness, data rate and readout speed. A serial power scheme will be used for to reduce the radiation length and power consumption in cables. To handle the expected data output of about 11 Tb/s, a high-speed transmission chain with many parallel lines running at 1.28 Gb/s will transmit data from the detector to an opto-electrical conversion system. This Optosystem features custom-designed radiation-hard electronics devoted to signal equalisation, aggregation (to 10.24 Gb/s) and optical-electrical conversion.
Operation of the optical system together with FELIX readout hardware, which is also used to trasmit DCS data, is currently being tested using RD53 prototype ASICs and will soon be included in the larger scale Demonstrator setups. In this talk we will present the current status of the system tests exercising these systems.

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Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **220** Type: **Oral presentation**

TCAD numerical simulation of irradiated thin Low-Gain Avalanche Diodes

Thursday, July 1, 2021 11:40 AM (20 minutes)

In this work the results of Technology-CAD (TCAD) device-level simulations of non-irradiated and irradiated Low-Gain Avalanche Diode (LGAD) detectors will be presented, aiming at evaluating the effects of layout and technological parameters on the device performance. LGADs are becoming one of the most promising devices for high performance in harsh operating environment thanks to the compensation of the radiation damage effects by exploiting the controlled charge multiplication in silicon after heavy irradiation. State-of-the-art Synopsys Sentaurus TCAD tools have been adopted to have a predictive insight into the electrical behavior and the charge collection properties of the LGAD detectors up to the highest particle fluences expected in the future HEP experiments. To this purpose, the updated "University of Perugia TCAD radiation damage model" has been adopted [1]. By coupling this numerical model, which allows to consider the comprehensive bulk and surface damage effects, with an analytical model that describes the mechanism of acceptor removal in the multiplication layer [2], it has been possible to reproduce experimental data [3] with high accuracy, demonstrating the reliability of the simulation framework. The good agreement obtained between simulation results and measurement data allows us to apply the new developed model not only for the prediction of the behavior, but also for the optimization of the new thin LGAD detectors fabrication run at the Fondazione Bruno Kessler (FBK) facility.

[1] D. Passeri, A. Morozzi, "TCAD radiation damage model", AIDA-2020-D7.4 report (2019)
[2] M. Ferrero et al., "Radiation resistant LGAD design", Nucl. Inst. and Meth. in Phys. Res. A (2019)
[3] V. Sola et al., "First FBK production of 50 µm ultra-fast silicon detectors", Nucl. Inst. and Meth. In Phys. Res. A (2019)

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Session Classification: Oral presentations

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **221** Type: **Poster presentation only**

Negative Capacitance effects in ferroelectric devices: a TCAD numerical simulation approach

In this work the potentiality of Negative Capacitance Transistors (NC-FET) will be explored thanks to advanced TCAD (Technology Computer Aided Design) modelling. The goal is to investigate the suitability of innovative negative capacitance devices to be used in High Energy Physics experiments detection systems, featuring self-amplificated segmented, high granularity detectors. This fosters the fabrication of tracking devices featuring high spatial resolution and extremely thin layers, with very low parasitic capacitance (intrinsic and extrinsic).
Within this framework, MFM (Metal-Ferroelectric Material-Metal) and MFIM (Metal-Ferroelectric-Insulator-Metal) capacitors have been deeply investigated within the TCAD environment, by comparing simulation findings with experimental measurements. The strength of this approach is to exploit the behavior of a simple capacitor to accurately ad-hoc customize the TCAD library aiming at realistic simulation of ferroelectric materials. Fig.1 shows the Polarization and Electric Field within a MFM capacitor with a ferroelectric layer of 7.7 nm [1].
The comparison between simulations and measurements in terms of Polarization as a function of the applied bias voltage for both MFM and MFIM devices (Fig.2) has been used for model and methodologies validation purposes. The P-V hysteresis is typical for MFM devices. The analysis and results obtained for MFIM capacitors can be straightforwardly extended to the study of NC-FETs. Their optimization leads to a non-hysteretic behavior, due to the negative capacitance stabilization on the wider operation voltage range by achieving a matched design of the ferroelectric layer and the MOS capacitors [2-5]. The Ginzburg-Landau-Khalatnikov equation, which provides a reliable description of ferroelectric material properties in terms of a free energy F expanded as a power series in the ferroelectric polarization P can be accounted for within the TCAD environment.
This work would support the use of the TCAD modelling approach as a predictive tool to optimize the design and the operation of the new generation NC-FET devices for the future High Energy Physics experiments in the HL-LHC scenario.

[1] M. Hoffmann et al., 2018 IEEE International Electron Devices Meeting IEDM, 18-727 (2018).
[2] Íñiguez, J., et al., Nat Rev Mater 4 (2019), 243–256.
[3] M. Kao et al., IEEE Electron Device Letters, vol. 40, no. 5 (2019), 822-825.
[4] J. Jo et al., 2016 IEEE Silicon Nanoelectronics Workshop (2016), 174-175.
[5] H. Agarwal et al., IEEE Electron Device Letters, vol. 40, no. 3 (2019), 463-466.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **222** Type: **Poster presentation only**

Optimization of fast neutron and gamma ray pulse shape discrimination (PSD) at high neutron to gamma ray ratio

Organic crystalline, liquid and plastic scintillators with low Z number materials are commonly used to detect fast neutrons. These detectors are also sensitive to gamma rays by Compton scattering while measuring fast neutrons. Pulse shape discrimination (PSD) is used to distinguish between neutrons and gamma rays. To perform PSD, Charge Comparison method (or called Charge Integration method) comparing the total charge (Qbody) and the delayed charge (Qtail) at peak was used in this study. Most studies have been conducted under laboratory conditions such as 252Cf or 241Am-Be sources. In our case, we will perform PSD in 15 MeV electron accelerator, where the total flux is 6.72E+14 #/sec and the ratio of neutron to gamma ray is up to 1:4071. Since PSD is difficult to perform due to the pile up effect under these conditions, PSD was optimized by changing the size of the silicon photomultiplier (SiPM) pixel pitch and thickness of the plastic scintillator before measuring high flux conditions. Optimization was performed in terms of count per second (CPS) and PSD performance. Although CPS is not related to PSD performance and PSD performance is evaluated as a figure of merit (FoM) index, it is important to conduct PSD within a limited time because our PSD system will be applied to the industry field. To distinguish neutrons from gamma rays under these conditions, it is necessary to use lead shielding to reduce neutron to gamma ray ratio. We are performing Monte Carlo N-Particle Transport Code (MCNP6) simulation to find optimized shielding thickness. In general, lead is known as a gamma ray shielding material. Fast neutrons also interact with lead due to its high density, but lead has a high Z number, which results in less neutron energy loss and changes direction by scattering. This may cause noise signals to other pixels. To verify the effect of noise, reconstruction will be performed to obtain neutron images under lead shielding conditions.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **223** Type: **Poster presentation only**

Design and image quality evaluation of DSLR (digital single-lens reflex) based X-ray imaging detector with different scintillators

In nowadays, digital X-ray imaging sensors with indirect detection type have been widely used in many medical imaging applications. These conventional indirect X-ray imaging detectors are based on the combination of a thin-film transistor (TFT) panel with different scintillating screens such as CsI, GOS materials. However, the digital radiography system using TFT-based X-ray imaging detectors are expensive and very limited to access in less developed countries.
In this work, we have designed and developed the inexpensive and compact X-ray imaging system with scintillating screens and a consumer-grade digital camera for medical X-ray imaging tasks. A latest digital single-lens reflex camera (DSLR) such as EOS 90D (Canon) consists of CMOS array with a 22.3mm x 14.8mm active area with 6960 x 4640 pixels and 14bit depth. Different high-resolution commercial scintillation materials such as columnar CsI:Tl and powder Gd2O2S:Tb(GOS) were used to evaluate the preliminary imaging quality. The various design parameters such as scintillator type, the f-number of lens and ISO setting number were optimized for excellent image quality at low X-ray exposure condition.
For preliminary evaluation and optimization of the X-ray image device characterization, different design parameters are selected and tested. The typical imaging performance such as the light response to X-ray dose (Sensitivity), signal-to-noise-ratio (SNR) and modulation transfer function (MTF), phantom imaging was measured and investigated under practical X-ray equipment with 60-90kVp tube voltage and various tube current. The experimental results with a commercial DSLR image camera using scintillating screens showed the potential possibilities to robust high-quality image at lower cost.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **224** Type: **Poster presentation only**

Scalable Control Systems for Vertex Detector utilizing Single Photon Counting Readout

I report the design and operation verification of two control systems for vertex detector dedicated for beam particle trajectory tracking. Both of the presented systems are designed to control and perform acquisition from the detector made of two layers of single photon counting hybrid pixel detectors (called later sensors). The alignment and synchronization of two sensors allows for particle transition registration and further calculation of the angle of incidence based on the timestamp and transition points.

The sensor chosen for the application is UFXC32k [1], designed at the AGH-UST in Cracow, made of 256 x 128 matrix of 75 um side square-shape pixels. The sensor is capable to operate in so-called zero dead-time mode enabling continuous streaming of sequential images. Using FPGA as the heart of the controller, the systems provide high speed data streaming allowing for up to 50 kfps data acquisition.

The two presented systems are build based on:
1st case: two NI sbRIO 9651 system on modules from National Instruments –the low-cost devices that enables building small and embedded detectors
2nd case: two NI FlexRIO Controllers with NI 7972R FPGA cards from National Instruments – powerful Kintex FPGA cards that allow achieving higher throughput

Due to compact nature of the devices and the fact that they are fully programmable in the same LabVIEW environment (both FPGA, RTOS and Host) the systems are highly scalable in terms of adding additional layers in the vertex detector as well as adding new functionality to the acquisition or data analysis process.

Both systems has been proved to work synchronously and are capable of registering ionizing beam particles [2].

[1] P. Grybos, P. Kmon, P. Maj, and R. Szczygiel, "32k Channel Readout IC for Single Photon Counting Pixel Detectors with 75 μm Pitch, Dead Time of 85 ns, 9 e- rms Offset Spread and 2% rms Gain Spread,"IEEE Trans. Nucl. Sci., vol. 63, no. 2, pp. 1155–1161, 2016, doi: 10.1109/TNS.2016.2523260.
[2] A. Koziol et al., "High rate proton detection with single photon counting hybrid pixel detector," Nucl. Instruments Methods Phys. Res. Sect. A Accel. Spectrometers, Detect. Assoc. Equip., vol. 956, 2020, doi: 10.1016/j.nima.2019.163333.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **225** Type: **Poster presentation + pitch**

The Annular Anode Gas Proportional Scintillation Counter

Gas Proportional Scintillation Counters (GPSC) exploit the photon emission from the de-excitation of noble gas atoms as a detection mechanism. The size of the detector radiation window relative to the photosensor active area has always been a limitation in this type of detectors, since the amount of light collected by the photosensor may vary according to the axial distance of the incident x-ray interaction due to solid angle effects. An annular geometry for the detector anode defines a scintillation region for which the solid angle subtended by the photosensor remains constant, independent from the radiation interaction position, thus enabling to obtain a GPSC design with a large radiation window. Along with this advantage, the simplicity and robustness of this novel geometry could provide a step forward into the design of a portable GPSC, coupled to low power electronics, e.g. using SiPM or Large Area APDs instead of PMTs. We report on the simulation studies of the electric field in the detector volume for several parameters, like anode diameter, shape and applied voltage in order to maximize the annular anode GPSC detection efficiency. Simulation results also show the expected scintillation yield and energy resolution for 5.9 keV x-rays. Preliminary experimental studies for 5.9 keV x-rays are presented for an annular anode GPSC with a radiation window area of 50 cm^2 and a photosensor sensitive area of 18 cm^2. This type of portable, room-temperature detector, with large-detection-area and/ large-detection-volume can be an interesting choice for x-ray astronomy, competing with solid-state detectors.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **226** Type: **Oral presentation**

A Miniaturized Radiation Monitor for Continuous Dosimetry and Particle Identification in Space

Thursday, July 1, 2021 9:50 AM (20 minutes)

Space radiation poses a threat not only to human space flight missions, but also to the electronic equipment of any space mission. Some dramatic space system failures and disturbances in recent years have been assumed to be radiation-induced malfunction of critical electronics parts. The space radiation environment consist of a variety of particle species, including electrons, protons and heavy ions, which may pose threats at different levels to different electronic devices. Therefore, the presence of a radiation monitor on-board of any mission is highly desirable to provide the capability to take protective measures in-flight and to contribute with flight-data to the improvement of existing radiation environment models. This contribution describes the development of a novel Miniaturized Radiation Monitor (MIRAM) for this purpose. Compared to the currently used devices, it is cheaper, has lower weight and power consumption. It is capable of providing a continuous measurement of dose as well as an estimation of the particle species composition of the radiation environment.

MIRAM has the dimensions 80 x 60 x 30 mm. It's nominal power consumption is 1.2 W with a peak consumption of 1.8 W. The device features four single pad diodes and a Timepix3 pixel detector with 256 x 256 pixels in a 55 μm pixel pitch. The diodes and the Timepix3 are separated by a 4 mm thick copper shield to separate electrons. Sensor material of diodes and the Timepix3 are made of Si and each is 300 μm thick. The electronic parts are low-power consuming and radiation tolerant commercial off-the-shelf components. The device further features a high-voltage power supply, 4 MB data storage M-RAM with an optional 16 MB DRAM and a CAN interface. MIRAM is capable of on-board real-time self-diagnostic. The device can be seen in Figure 1 with the box opened.

The MIRAM device supports on-board analysis of the measured data to be able to work autonomously. The dose rate is calculated continuously based on the energy deposition in the Timepix3 detector. For the estimation of the particle species composition of the radiation environment, two methods are applied depending on the current flux. At lower fluxes ($< 10^4$ particles per cm^2 per s), a more thorough analysis will be utilized. Particles are selected and determined based on the pixels temporal coincidence. The pixels are then sorted into three categories: low, medium and high energy, and the deposited energy is summed up. This data set is then compared with a data base, where typical values for electrons and protons are stored. The particle is classified according the closest similarity or, if there is no similarity, as heavier ion. At higher fluxes, the deposited energy is measured over a fixed time window. Then the average energy per pixel is calculated. The average energy per pixel varies very little around a constant value for a certain composition of different particle species. Towards lower fluxes, the variation around that value increases, so that different compositions cannot be resolved anymore. At this point, a track-by-track analyses is utilized.

Both methods have been developed with the help of reference measurements of monoenergetic electrons, protons and heavier ions of different energies on the ground in conjunction with measurement of the Space Application of Timepix Radiation Monitor (SATRAM), which measures the space radiation environment in a Low Earth Orbit (LEO) on-board the Proba-V satellite since 2013, in space. The measurements were supported by a Monte Carlo simulation of the MIRAM device.

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Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **227** Type: **Poster presentation only**

First experimental test of a photon counting detector

This paper presents the first experimental test results of the X-ray photon counting detectors based on our pixel readout ASIC [1]. The chip integrates 64x128 array of pixels in the size of 150 µm x 150 µm and each pixel consists of four 12-bit energy windows. Two types of CdTe and one type CZT detectors have been bump bonded to the ASICs and have been tested.

The electronic characteristics of the readout chip were evaluated first by injecting charge through the calibration capacitor. The power consumption, the noise and the gain of the analog front-end were measured. The non-uniformity of the energy thresholds among pixels were measured and then were compensated by tuning the local DACs.

The detector performance were then characterized using both gamma radioactive sources and X-ray tubes. The energy responses of the detectors were measured using the characteristic X-ray of the target material. The global and local thresholds were then calibrated with these specific energies of photons. Polarization effects under different photon fluxes were also studied for different detector bias voltages. Preliminary imaging test was conducted. The detector response under uniform irradiation was investigated. The spatial uniformity of the detectors was analyzed and the flat field correction was then conducted to improve image quality. The test results show that most of the readout channels work well thus our photon counting detector can be used for imaging applications. Detailed test results will be discussed in this paper.

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **228** Type: **not specified**

Commissioning of the new small-diameter Monitored Drift Tube detectors for the phase-1 upgrade of the ATLAS muon spectrometer

The Muon Drift Tube (MDT) chambers provide very precise and reliable muon tracking and momentum measurement in the ATLAS muon spectrometer. Already in Run 2 of the LHC they have to cope with very high background counting rates up to $500Hz/cm^2$ in the inner endcap layers. At High-Luminosity LHC (HL-LHC), the background rates are expected to increase by almost a factor of 10. New small (15 mm)-diameter Muon Drift Tube (so-called sMDT) detectors have been developed for upgrades of the muon spectrometer. They provide about an order of magnitude higher rate capability and allow for the installation of additional new triple-RPC trigger chambers in the barrel inner layer of the muon detector for HL-LHC. They have been designed for mass production at the Max Planck Institute (MPI) for Physics in Munich and achieve a sense of wire positioning accuracy of $5\mu m$. A pilot project for the barrel inner layer upgrade is underway during the 2019/20 LHC shutdown. Several sMDT chambers have already been installed and operated in the ATLAS detector. The detailed studies of the muon detection efficiency and muon track resolution have been carried out after the assembling of the sMDT detectors in MPI and repeated at CERN after the integration with the new RPC detectors. The author will describe the detector design, the quality assurance and certification path, as well as will present the status of the installation and commissioning, worth its preliminary results and an overview for the complete integration of the sMDT project in the ATLAS experiment.

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Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **229** Type: **Poster presentation only**

3D TSV Hybrid Pixel Detector Modules with ATLAS FE-I4 Readout Electronic Chip

The through silicon via (TSV) technology has been introduced in a wide range of electronic packaging applications. Hybrid pixel detectors for x-ray imaging and for high-energy physics (HEP) can benefit from this technology as well [1], [2]. A 3D TSV prototype using the ATLAS FE-I4 readout electronic chip is presented in this paper. This type of readout chip is already prepared for the TSV backside process providing a TSV landing pad in Metal1 of the backend-of-line (BEOL) layer stack. Based on this precondition a TSV backside via-last process is developed on ATLAS FE-I4 readout chip wafer.

The readout chip wafer is thinned to 100µm and 80µm final thickness using a temporary carrier wafer bonded onto the wafer CMOS side. Using the established BOSCH-process, straight sidewall vias with 60µm in diameter are etched into the silicon from wafer backside. An electroplated Cu-redistribution layer (RDL) forms the electrical interconnection to the Metal1-BEOL-layer. The deposition process includes the filling of the TSVs and the formation of the wafer backside interconnection to the next substrate level. A nickel-gold pad finish enables the electrical chip connection by wire bonding as well as by soldering. In addition to the backside chip RDL, TSV capacity test structures and daisy chain test structures are implemented in the TSV chip design and are characterized after the wafer TSV processing.

Fully processed ATLAS FE-I4 readout chips are successfully tested and tuned. In addition, hybrid pixel detector modules are flip chip bonded using ATLAS FE-I4 TSV readout chips and planar sensor chips. After mounting the bare modules onto a support PCB, the complete setup is characterized in a source scan and is showing very promising results.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **230** Type: **Poster presentation + pitch**

BLEMAB European project: muon imaging technique applied to blast furnaces

The BLEMAB project (BLast furnace stack density Estimation through on-line Muon ABsorption measurements) [1], evolution of the previous Mu-Blast project [2], will investigate in detail the capability of muon radiography techniques, applied to the imaging a blast furnace inner zone. In particular, the geometry and size of the so called "cohesive zone", i.e. the spatial zone where the slowly downward moving material begins to soften and melt, that plays such an important role in the performance of the blast furnace itself. Thanks to the high penetration power of natural cosmic ray muon radiation, muon transmission radiography could be an appropriate non invasive methodology for the imaging of large high-density structures such as a blast furnace, whose linear dimensions can be up to a few tens of meters. A state of the art muon tracking system, derived from our previous experience with the MIMA and MURAVES detector (references [3,4]), is currently in development, and will be installed at a blast furnace on the ArcelorMittal site in Bremen (Germany), where it will take data for many months. The sketch on the left side in figure 1, not to scale, shows one of the two BLEMAB muon trackers placed a few meters far from the blast furnace wall, pointed along the direction where the cohesive zone is expected to be. The plot on the right side in the same figure shows the two dimensional muon flux angular distribution that is expected within the BLEMAB detector geometrical acceptance after one day data taking. Hundreds of muons are expected each day, for each angular bin with a size of 2 deg in azimuth and 2 deg in elevation, thus allowing a continuos measurement of the average density distribution keeping statistical fluctuations at less than ten percent. Muon radiography results will also be compared with measurements obtained through an enhanced multipoint probe and standard blast furnace models.
We will present the project, its development status and the expectations based on preliminary simulations.

[1] BLEMAB - EU project, RFCS 2019, G.A. n. 899263
[2] Mu-Blast –EU project, RFCS 2014, RFSR-CT-2014-00027
[3] G. Baccani et al., 2018 JINST 13 P11001
[4] G. Saracino et al., Ann.Geophys.Italy 60 (2017) 1, S0103

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **231** Type: **Poster presentation only**

Investigation of the physical parameters of new MAPD-3NM silicon photomultipliers and its applications

In the presented work, the parameters of the new MAPD-3NM-II photodiode with the buried pixel structure manufactured by Zecotek Ph. were investigated. The following physical and electrical parameters were studied; current-voltage and capacitance-voltage characteristics, dark count rate, photon detection efficiency, gain, the temperature coefficient of breakdown voltage, breakdown voltage, and gamma-ray detection performance of photodiodes. A specialized designed readout and electronic module SPECTRIG MAPD was used to measure the parameters of the MAPD-3NM-II and a scintillation detector was based on it. The obtained results prove that the newly developed MAPD-3NM-II photodiode outperforms the former MAPD-3NM-II photodiode in most of the parameters and it can be successfully applied in space application, medicine, high-energy physicist and security. New improvements were discussed and proposed for further parameter enhancement of the MAPD photodiodes to be produced in the coming years.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **232** Type: **Poster presentation + pitch**

Characterization of primary and stray radiation produced in FLASH electron beams with Flex chip-assembly TimePIX3 pixel detectors

Characterization of primary and stray radiation produced in FLASH electron beams with Flex chip-assembly TimePIX3 pixel detectors

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New dosimetric challenges are imposed by the emerging modern cancer techniques, such as FLASH treatments [1]. Suitable detectors and dosimetry protocols need to be developed when dealing with ultra-high dose rate pulses (UHDpulse) such as ultra-short pulses of MeV-level electrons.

This work aims to characterize UHDpulse electron beams using the hybrid semiconductor pixel detector. The TimePIX3 ASIC chip [2] was used to measure the composition, spatial, time and spectral characteristics of the primary and secondary radiation fields at the Microtron electron Accelerator of the Nuclear Physics Institute CAS (UJF CAS), Prague, Czech Republic. The research' s central idea is the desire to develop one detector that could extract spectrometric and dosimetric information on such high flux short-pulsed fields.

For secondary beam measurements, a PMMA plate of 8 cm thickness was placed in front of the electron beam, with a pulse duration of 3.5 µs. The TimePIX3 detectors (with silicon sensors of 100 and 500 µm) were placed on a shifting stage allowing for data acquisition at various angles and lateral positions to the beam core.

For primary beam measurements, a TimePIX3 ASIC chip-sensor assembly was mounted on a customized detachable Flex architecture (see Figure 1). Two types of detectors (with a GaAs sensor and a naked chip without sensor) were tested with pulsed electron fields in the range 5-23 MeV and dose rates exceeding 80 Gy/s (Figure 2) in order to study their suitability for the characterization of primary UHDpulse beams.

The results highlight the technique and the detector's ability to measure individual UHDpulses of electron beams in very short time, as well as the particles deposited energy and to estimate the particle types in mixed radiation fields.

References:

[1] M. McManus et al., Scientific Report, 10 (2020)
[2] T. Poikela, et al., Timepix3: a 65K channel hybrid pixel readout chip with simultaneous ToA/ToT and sparse readout, J. of Instrum. JINST 9 (2014) C05013

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **233** Type: **Poster presentation + pitch**

Pragmatic method for fast programming of Hybrid Photon Counting Detectors

It is now been over 15 years since Hybrid Photon Counting Detectors (HPCD) became one of the standard position-sensitive detectors for synchrotron light sources and X-ray detection applications [1]. This is mainly due to their single-photon sensitivity over a high dynamic energy range and electronic noise suppression thanks to energy thresholding [2]. To reach those performances, all HPCD pixels must feature the same electrical response against same photon energy. From the analysis of a monochromatic beam, in case of an ideal HPCD detector, it would be sufficient to apply a fixed voltage threshold, positioned at a fraction of the mean pulse amplitude, and the counting of each photon above the threshold, for each pixel. However, in practical cases, it must be considered that noise baselines from all pixels are not always strictly located at the same voltage level but can be spread over some voltage ranges. To address this kind of issue, most of all HPCDs apply a conventional offset correction, also called threshold equalization [3], that mainly relies on three steps; the setting of a global threshold at an arbitrary value, the identification of pixels noise baseline around that global threshold through an in-pixel threshold trimmer, and the computation of the required threshold offsets for setting all pixels at their own noise baseline at the same time. In case of a first-time use of an HPCD, the offset correction might be biased by a wrong choice of parameters for certain pixels. Those biases can sometimes be characterized by the inability to localize some pixel noise baselines, which could be outside the voltage range of the threshold trimmer. By referring to the 'classical'offset correction, the recovery of those biased pixels could be performed by changing the position of the global threshold, or by increasing the voltage range of the threshold trimmer. Unfortunately, both solutions could be very time consuming; on one hand because changing blindly the position of the global threshold do not ensure the direct recovering of missing noise baselines, on the other hand because increasing the voltage range of the threshold trimmer has the effect of increasing the voltage steps of the threshold trimmer, leading to a reduced accuracy of noise baselines localization. In order to overcome this issue in a reasonable time, this work introduces a pragmatic method that can be applied to HPCDs for an early and effective identification of appropriate pixels'parameters, avoiding the need to test a high number of pixels configurations. The application of this method, at the early stage of the HPCD calibration, may drastically reduce the investigation time for finding the best operating point of HPCDs (Figure 1).

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **235** Type: **Poster presentation only**

Characterization of Time-of-Flight Compton double photon Imaging System by Monte Carlo Simulation

We propose the use of double photon coincidence events resulting from cascade decay of certain radioactive nuclides to increase the signal to background ratio and its spatial resolution in a 3-D Compton imaging system. The Time-of-flight (TOF) technique could be applied to ensure a better image quality on the third direction with utilization of photon arrival time. Geant4 simulation is performed to evaluate the design of TOF double photon Compton imaging. The result shows that the TOF technique can greatly improve the image quality. The FWHM value has decreased by more than 60% in the reconstructed 3D image on the depth direction.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **236** Type: **Poster presentation only**

A Geant4 tool for Edge-Illumination X-ray Phase-Contrast imaging

The number of applications and technical implementations of X-ray phase-contrast imaging (XPCi) has continuously increased over the last two decades. As imaging detectors are insensitive to the phase of X-ray waves, various techniques were developed to transform sample-induced phase modulations into intensity modulations on the detector. For all these XPCi techniques the image formation process can be described with rigorous wave models stemming from the Maxwell' s equations, each containing suitable approximations (e.g., paraxial wave field, projection approximation) [1]. On the other hand, when the spatial coherence of the experimental setup is limited, i.e., when the X-ray source distribution and/or the detector's point spread function are broad, the image formation process can be effectively approximated with ray tracing/geometrical optics models [2]. In particular, the local distortion of the X-ray wavefront due to the phase-shift induced by a sample can be described through the refraction effect governed by the Snell's law. This approximation allows to integrate phase effects into sophisticated Monte Carlo toolkits, such as Geant4, where the interactions between radiation (including X-rays) and matter are inherently treated as a ray tracing problem [3]. In this context, a novel Geant4 simulation tool that adds ad-hoc X-ray refraction physics processes has been implemented within a (virtual) edge illumination (EI) setup [4]. EI is a XPCi technique widely implemented within compact laboratory-based setups where two absorbing masks featuring periodic apertures, referred to as sample and detector masks, are positioned upstream from the sample and detector, respectively. The sample mask serves to structure the incoming radiation into a series of independent beamlets. Each beamlet interacts with the sample being attenuated, refracted, and scattered, and it is subsequently analyzed by the detector mask which features the same periodicity apart from the geometry-dependent magnification factor. By acquiring two or more images at different relative positions of the two masks, attenuation, refraction and (optionally) scattering effects can be separated, yielding independent maps of different properties of the sample.
Specifically, in this study, an EI setup featuring an overall dimension of 1 m (source to sample distance 70 cm, sample to detector distance 30 cm), a polychromatic spectrum from a 40 kV tungsten anode X-ray tube, a circular focal spot of 20 µm, and a photon-counting detector with 62 µm pitch are simulated (Figure 1). These parameters mimic the ones of a new EI facility under construction at INFN laboratories in Trieste (Italy), which will make use of a spectral photon-counting detector (Pixirad1-PixieIII) to investigate novel EI imaging geometries and spectral phase-contrast applications (project PEPI –Photon-counting Edge-illumination Phase-contrast Imaging). The simulation allows the user to choose the relative displacement between the two masks (stepping) and the position of the sample with respect to the masks (dithering), closely replicating the experimental data acquisition process.
The results of the simulation (Figure 2) demonstrate that the developed tool accurately reproduces attenuation and refraction effects in an EI setup. Remarkably, the possibility of simulating phase-effects within Geant4 paves the way for the use of this tool in the optimization of XPCi setups, including many realistic details which are often difficult to account for in analytical simulations, and being appealing for other non-interferometric XPCi techniques (e.g., analyzer-based imaging). In this context, the developed simulator will be used to design the final PEPI's experimental setup, exploring many parameters such as geometry, mask thickness, pitch and aperture, source spectrum and size, and detector response.

Figure 1 Graphical interface visualization of the simulated setup.
Figure 2 Refraction image of a PMMA wire with a diameter of 1 mm (left) and its respective profile, measured within the dashed blue rectangle, compared with the theoretical prediction (right).]

[1] D Paganin, Coherent X-Ray Optics, Oxford University Press, (2006).
[2] L Brombal et al., Phys. Rev. Applied 11, 034004 (2019).
[3] M Langer et al., Opt. Express 28, 14522-14535 (2020).

[4] A Olivo and R Speller, Phys. Med. Biol. 52, 6555 (2007).

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **237** Type: **Poster presentation only**

Characterization of a hybrid pixel silicon detector Timepix in particle identification measurements

Hybrid pixel detectors- Timepix are multi-parameter detectors that gives simultaneously information about the position, energy, and time of arrival of a particle hitting the detector. These types of multi-parameter detectors can be effectively used to study and/or reinvestigate some fission processes such as the rare fission modes (ternary, quaternary, quinary), which are planned. In the rare fission mode processes, light charged particles (LCP) are emitted as third and fourth fission products. For these purposes, it is necessary to investigate the response of the Timepix detector to LCPs. The aim of this work is to study the response of the Timepix hybrid pixel silicon detector to light particle isotopes. A spontaneous fission source 252Cf was used as a light particle isotope source, since LCPs (mainly alpha particles) are formed along with the heavy fragments in ternary fission. Timepix response was investigated registering LCPs (1H, 3H, 4He, 7Li, and 8Be) using tailor-made ΔE-E particle telescopes consisting of transmission type ΔE detectors and the Timepix detector. The particles (isotopes of interest) were identified by the method ΔE-E, since the (ΔE/Δx)×E value is unique to the type of particle. The specific energy loss (ΔE/Δx) was measured using the transmission type ΔE detector (15 or 150 um thicknesses) purchased from the company Micron Semiconductors, while the residual energy (E) measured by a Timepix detector with thicknesses of 600 um. The Timepix was used simultaneously as a common single-pad silicon detector (processing back-side-pulse signal) and as a pixel detector working in Time over Threshold mode. In addition to ΔE-E method individual cluster analysis from the pixel part was performed to identify the charge particles, the related energy, and isotopes using the pattern recognition method. These results were compared to the results obtained from the ΔE-E method. The comparison of the experimental activities of the radioactive source with its expected activity allowed the test of the detector efficiency.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **238** Type: **Oral presentation**

Pixel chamber: a solid-state active-target for 3D imaging of charm and beauty

Monday, June 28, 2021 4:10 PM (20 minutes)

Modern vertex detectors are based on cylindrical or planar layers of silicon sensors, generally immersed in a magnetic field. These detectors are used for precision measurements of the particles produced in the interactions and, in particular, of the dacay products of those with a long mean life, such as open charm and beauty. Since the tracking layers are always few to tens of cm from the interaction point, this poses an ultimate limitation in the achievable resolution of the vertex position.

A silicon-based active target detector capable to image particles produced inside the detector volume in 3D, similarly to a bubble chamber, does not exist. Ideas for a silicon active target providing continuous tracking were put forward already 40 years ago but the required technology just did not exist until recently (1).

In this talk, I will describe the idea for the first silicon active target based on silicon pixel sensors, called Pixel Chamber (2), capable to perform continuous, high resolution (O(μm)) 3D tracking, including open charm and beauty particles.
The aim is to create a bubble chamber-like high-granularity stack of hundreds of very thin monolithic active pixel sensors (MAPS) glued together. To do this, the ALPIDE sensor chip, designed for the ALICE experiment at the CERN LHC, will be used (3). This sensor is a matrix of 1024x512 monolithic active pixels (size $\sim$ 29x27 μm^2) with an area of $\sim$1.5x3 cm^2 and thickness $\sim$ 50 μm. Pixel Chamber is conceived as a stack of 216 ALPIDE chips, having a volume of $\sim$1x1.5x3 cm^3 and forming a 3D matrix of almost 10^8 pixels.

Figure 1 shows a comparison between a bubble chamber image for the strange barion Ω^- (4) and a Geant4 simulation of a D^+ meson decaying to $K\pi\pi$ in a proton-silicon interaction with Pixel Chamber.

A tracking and vertexing algorithm developed specifically for reconstructing the interactions inside Pixel Chamber will be discussed. Monte Carlo simulations of proton-silicon interactions at 400 GeV, based on Geant4, were used to test tracking and vertexing performances. According to those simulations, it is possible to obtain a high efficiency for the reconstruction of hadronic tracks, and for the primary interaction vertex and secondary decay vertices inside the detector. The vertex resolution can be up to one order of magnitude better than state-of-the-art detectors like those of LHC experiments.

(1) G. Bellini et al., Miniaturization of High-Energy Physics Detectors, pp41-55, Springer, 1983
(2) G.Usai et. al, "Pixel Chamber: A universal silicon heavy-avor imager for fixed-target measurements of charm and beauty with unprecedented precision", R&D project funded by the Regional Government of Sardinia - Italy
(3) Gianluca Aglieri Rinella, on behalf of the ALICE Collaboration, Nucl. Instrum. Meth. A, volume 845 (2017)
(4) V. E. Barnes et al., Observation of a Hyperon with Strangeness Minus Three, Phys. Rev. Lett. 12, 204, 24 February 1964

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Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **239** Type: **Poster presentation + pitch**

Poisson noise analysis of the Pixirad-2/PIXIE-III photon-counting detector

X-ray photon-counting detectors (XPCD) have gained substantial interest for biomedical and materials science applications due to their low-electronic noise, high-detection efficiency and energy-discrimination capabilities, compared to charge-integrating devices. The Pixirad-2/PIXIE-III is a hybrid XPCD with a 650 μm CdTe Schottky type diode with electron collection at pixel, bonded to the PIXIE-III CMOS ASIC. The readout system is organized in two blocks of a 512 x 402 matrix of 62 μm pitch square pixels, giving a global active area of 63.6 x 25 mm2. It implements two independent discriminators with a programmable threshold per pixel, allowing the acquisition of two spectral images in a single exposure 1.

Due to their capability to set a threshold above the electronics noise of each channel, XPCD are often approximated to an ideal detector in which each pixel's output signal is only limited by the Poisson noise inherent to the quantized nature of light [2]. However, because of the charge sharing effect characteristic of small pixel sizes and thick sensor materials, XPCD data is often spatially and energetically correlated [3]. The Poisson nature of noise in XPCD has been previously studied with the Pixirad [4] and Medipix [5] technologies. This has been done by comparing theoretical and experimental standard deviation as a function of mean counts for different energies [4] or assessing the ratio between observed and expected standard deviation for different sensor materials [5].

In this work, the noise in the Pixirad-2/PIXIE-III detector is studied with a χ2 hypothesis test for the Poisson distribution. The analysis is done locally, initially on a pixel-by-pixel basis with 512x1s frames, then on a 20x20 pixels sliding window in a single frame after pixel-wise equalisation. The effect of low-energy threshold, ROI window size and number of frames in the flat field image is also considered. The experiments were conducted with a W-anode microfocus Hamamatsu source at 40 kVp and 250 μA. The detector was cooled to −20℃ and the CdTe crystal was polarised with a 400 V voltage.

Figure 1 shows results of the pixel-wise hypothesis test with significance level of α=0.05. It was observed that nearly 80% of pixels follow Poisson distribution. Non-Poisson noise was found at the detector edges, the gap between the two tiles and a few cold spots in the Flat Field image. These agree with previous studies that showed higher sensitivity in sensor edges due to manufacturing imperfections, and lower sensitivity in the dark regions due to charge trapping [5]. In addition, almost an entire column of pixels on the left tile showed non-Poisson behaviour, which is not observed in the flat field images, and could be related to defects in the readout system, adding electronic noise.

The effect of flat field correction was also studied as shown in Figure 2. It was found that increasing the number of frames in the Flat Field image improves the Poisson behaviour (from 36% to 82% of the studied windows when 4 and 32 frames are used, respectively). However, when more than 64 frames are used in the Flat Field, the correction becomes less effective, especially in the gap between tiles. This is likely due to sensor instabilities over time and/or polarisation caused by the Schottky type diode. Ongoing work is focused on establishing reliable rules of thumb for optimising the system in long acquisitions. Optimal exposure and bias cycle trade-offs are being identified based on the required statistics, the intensity of the radiation reaching the detector and the required exposure time.

The methodology of the hypothesis test, along with the effect of low-energy threshold and sliding window size will be presented with further detail. This work in progress is aiming to better understand noise in the Pixirad-2/PIXIE-III for more accurate X-ray system modelling and optimization, and more robust image post-processing.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **240** Type: **Poster presentation only**

Development of a synchrotron-based wide-band high-energy resolution spectral K-Edge Subtraction imaging setup

K-Edge Subtraction (KES) imaging allows to quantify the presence of one or more contrast agents embedded within a matrix material, and it can be applied both in planar and tomographic configurations. KES signal derives from the sharp rise in the attenuation coefficient corresponding to the binding energy of the contrast element K-shell electrons. In its simplest formulation, KES consists in subtracting images obtained at energies above and below the K-edge. For this reason, any KES imaging setup must provide spectral information, either by using spectral detectors 1 or by tuning/shaping the X-ray spectrum [2].
Many Synchrotron Radiation (SR) applications of KES fall in the latter category and make use of bent Laue monochromators, selecting an energy bandwidth including the contrast agent's K-edge. Cylindrically bent Laue crystals allow to focus the laminar SR X-ray beam and to diffract a relatively wide energetic bandwidth (few keV), which is (at first approximation) inversely proportional to the bending radius. The resulting beam is energetically dispersed in the diffraction plane, so that different positions in space correspond to different energies. In a typical KES setup, the sample is positioned and scanned through the focal spot while a bi-dimensional detector is placed downstream. In this way, one image axis (x) shows the sample spatial distribution while the other (y) encodes its spectral decomposition (Fig. (a)). If the contrast medium's K-edge lies within the selected bandwidth, the recorded image shows a strong intensity variation along the energy axis. The sharpness of this transition defines the energy resolution of the system. So far, most of the SR-based KES systems have shown poor energy resolution meaning that a large fraction of the beam (typically about 1/3) is involved in "edge crossing"and must be filtered out [3]. This brings to a focal spot blurring, to the need of beam splitter devices to remove crossover energies, hence to a reduction in the X-ray flux, and a-priori excludes the implementation of techniques requiring fine energy resolution as, e.g., X-ray Absorption Spectroscopy (XAS).
In this context, the INFN-funded KISS (K-edge Imaging with Spectral Systems) project aims to develop a wide-band high-energy resolution KES setup at the SYRMEP beamline at the Elettra synchrotron facility (Trieste, Italy). In fact, energy resolution can be maximized if the Laue crystal is asymmetrically cut, and the asymmetry angle is such that the geometrical focus corresponds to the single-ray focus [3]. This "magic condition"[3], is primarily determined by the selected energy while it has a shallow dependence on the crystal bending radius. For this reason, by using small bending radii, a system featuring both a wide-energy bandwidth and high-energy resolution can be pursued. Allegedly, the most critical part of the KES experimental setup is the frame required to bend and hold the crystal avoiding its breaking. Our frame (Fig. (b)) is manufactured, via a numerical control machine, from a single aluminum block and it includes a curved nylon coated surface, where the crystal is strained, defining the final bending radius. To bend the crystal a smaller frame featuring two plastic rods is positioned on top of the silicon wafer and, by using two fine screws, it is pushed against the crystal to make it adhere to the larger frame. Thanks to this design the mechanical stress is more uniformly distributed, allowing to bend a rather thick (0.77 mm) silicon crystal to a small bending radius of 0.5 m without any rupture: this value is smaller than bending radii reported in literature so far (≥ 1 m) [3,4]. Such small bending radius allows the use of multiple contrast agents with K-edges within some keV energy range. Additionally, using thick crystals increases diffraction efficiency, hence the flux. The first experimental planar images obtained with the novel setup have been acquired with a 4-inches Si wafer by using the (111) reflection and the Pixirad1-PixieIII photon-counting detector, featuring a pixel size of 62 μm [5]. The sample was composed by two plastic cuvettes filled with an iodine-based solution (25 mg/ml, K-edge at 33.2 keV) and Xenon gas at atmospheric pressure (K-edge at 34.5 keV).
Energy resolution analysis, performed by fitting the K-edge transitions with an erf, shows a resolution around 100 eV (FWHM) for both elements with a wide energy bandwidth of about 5 keV

(Fig. (c)). By applying a suitable spectral KES decomposition algorithm, based on least squares minimization, a quantitative material decomposition has been performed, singling out the iodine and xenon signals (Fig.(d)). In addition to the reported measurements, the first tomographic images of biological samples containing iodine-based and barium-based (K-edge at 37.4 keV) contrast agents have been performed.
The results obtained with the novel KES setup demonstrate the feasibility of multiple K-edge applications making use, for instance, of iodine, barium, and xenon-based contrast agents, that is appealing for simultaneous pulmonary, cardiac, and gastrointestinal imaging. Additionally, the achieved energy resolution suggests further investigations at lower X-ray energies to perform wide field of view XAS.

Figure Sketch of the experimental setup (a), crystal bending frame (b), K-edges imaging results (c), spectral decomposition (d).

1 F Brun et al., Phys. Med. Biol. 65 (2020), 055016.
[2] W Thomlinson et al., Physica Medica 49 (2018), 58-76
[3] N Samadi et al., AIP Conference Proceedings. 1741 1 (2016)
[4] Y Zhu et al., Phys. Med. Biol. 59 (2014), 2485
[5] R Bellazzini et al., JINST 10.01 (2015), C01032.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **241** Type: **Poster presentation only**

A proton computed tomography demonstrator for stopping power measurements

Particle therapy is an established method to treat deep-seated tumours using accelerator-produced ion beams. For treatment planning, the precise knowledge of the stopping power (SP) within the patient is vital. Currently, SP values are extrapolated from X-ray CT, thus introducing conversion errors, eventually leading to uncertainties in the applied dose distribution. Using a proton computed tomography (pCT) system for direct measurement of the SP has the potential to increase the accuracy of treatment planning.

A pCT demonstrator, consisting of double-sided silicon strip detectors (DSSD) as tracker and an upgraded version of the TERA range telescope comprised of plastic scintillator slabs coupled to silicon photomultipliers (SiPM) was developed. This system was used to image a 3D tomogram of an aluminium stair phantom at the accelerator facility MedAustron, Austria.

For image reconstruction, the GPU-based open source software framework TIGRE was used. Imaging results as well as technical and physical limitations of this pCT demonstrator will be discussed. Finally, a novel ion computed tomography (iCT) system based on 4D tracking detectors for particle path estimation as well as time-of-flight residual energy measurement will be proposed and first design study results for this iCT system will be presented.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **242** Type: **Poster presentation + pitch**

Testing of planar hydrogenated amorphous silicon sensors with charge selective contacts for the construction of 3D- detectors.

The presentation will describe the performances of planar hydrogenated amorphous silicon (a-Si:H) sensors with charge selective contacts developed in the framework of the fabrication of a 3D a-Si:H sensor. These devices were developped as an intermediate technological step towards the final detector but they have interseting flux/dose measuring capabilities by themselves.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **243** Type: **Poster presentation + pitch**

Measurements of charge sharing in a hybrid pixel photon counting CdTe detector.

Hybrid pixel radiation detectors working in single-photon counting mode have gained increasing attention due to their noiseless imaging and high dynamic range. Due to the fact that sensors of different materials can be attached to the readout circuit, they allow operation with a wide range of photon energies. The performance of the single photon counting detectors is limited by pile-up. To allow a detector to work under the high flux conditions, the pixel size is reduced, which minimizes detector dead time. However, with smaller pixel size the charge sharing effect - a phenomenon that deteriorates both spatial resolution and the detection efficiency is more profound 1. The influence of charge sharing on the detector performance can be quantified using parametrization of the s-curve obtained in the spectral response measurements as well as calculation of the Edge Spread Function (ESF) and Modulation Transfer Function (MTF).

The article presents the measurements of the ESF and the response function of a hybrid pixelated photon counting detector for certain primary energy, which corresponds to the probability for detecting a photon as a function of its energy deposition. The measurements were carried out using an X-ray tube by performing a threshold scan during illumination with x-ray photons of a 1.5mm thick CdTe detector. The charge size cloud depends on the sensor material, the bias voltage, and the sensor thickness. Therefore, the experimental data from a sensor biased with different bias voltage are compared to the theoretical results based on a cascaded model of a single-photon counting segmented silicon detector.

The study of the charge sharing influence on the spatial resolution of the CdTe detector will serve for a further study of the possible implementations of the algorithms achieving subpixel resolution, in which the charge sharing becomes the desired effect, since the charge division in the pixels is used to interpolate the photon interaction position [2].

1 J. Marchal, "Theoretical analysis of the effect of charge-sharing on the Detective Quantum Efficiency of single-photon counting segmented silicon detectors,"J. Instrum., vol. 5, no. 01, p. , 2010.
[2] A. Krzyzanowska, A. Niedzielska, and R. Szczygieł, "Charge sharing simulations for new digital algorithms achieving subpixel resolution in hybrid pixel detectors,"J. Instrum., vol. 15, no. 2, 2020.

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **244** Type: **Poster presentation only**

Energy-Resolved Neutron Imaging with Glass Gas Electron Multiplier and Dynamic Time-over-Threshold Signal Processing

Recent micro pattern gaseous detectors (MPGDs) have many readout channels for high-resolution imaging and large-area sensitivity. Reducing the circuit complexity while maintaining its performance is important for the readouts of large-scaled and high-resolution detectors.

The time-over-threshold (ToT) is a pulse processing technique which converts an analogue pulse height into a digital pulse width. Its advantages over ADC-based pulse-height measurement are less circuit complexity, lower power consumption, and pin-saving digital output interface. However, the conventional ToT suffers from the non-linearity between input pulse height and output time width. To overcome this problem, the dynamic time-over-threshold (dToT) has been proposed1. In dToT, the threshold is dynamically changed over time to improve the conversion linearity. We have demonstrated X-ray imaging with a glass gas electron multiplier (G-GEM) and a dToT-based readout system [2].

In this research, we demonstrated energy-resolved neutron imaging with a G-GEM and a dToT-based readout system. The measurement was conducted in J-PARC MLF beam line 10. The experimental setup of detector and readout is shown in Figure.1. We demonstrated energy-resolved neutron imaging by performing charge-division imaging simultaneously with neutron time-of-flight (TOF) measurement. The result is shown in Figure. 2. We obtained different images for different neutron energy regions. In conclusion, we have successfully performed energy resolved neutron imaging with a G-GEM and a dToT-based readout system.

1 T. Orita, K. Shimazoe and H. Takahashi, The dynamic time-over-threshold method for multi-channel APD based gamma-ray detectors, Nucl. Instrum. Meth. A 775 (2015) 154
[2] Y. Mitsuya, T. Fujiwara, H. Takahashi, M. Uesaka, "X-ray imaging demonstration of glass GEM detector with dynamic time-over-threshold-based readout,"Journal of Instrumentation, 13, P12023 (2018)

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **245** Type: **Oral presentation**

Intercalibration and comparative tests of 3D diamond and diamond on iridium detectors for medical dosimetry

Wednesday, June 30, 2021 11:40 AM (20 minutes)

Thanks to a new emerging technology, diamond devices with 3-dimensional structures are produced using laser pulses to create graphitic paths in the diamond bulk. The fabrication of very narrow and close by columnar electrodes perpendicular to the detector surface allows the employment of a lower bias voltage at which the saturation charge velocity is reached and faster detector response, due to the decreased distance between the polarizing electrodes, compared to a planar geometry detector. Also due to the much shorter electrodes distance, the 3D diamond detector charge collection efficiency is less deteriorated by the radiation damage of the diamond material.
On the other hand, diamond tissue-equivalence, high radiation sensitivity and high resistance to radiation damage make it a good candidate for high precision measurement of the doses released during medical radiation therapy.
In medical radiation dosimetry, the use of small photon fields is almost a prerequisite for high precision localized dose delivery to delineated target volume. However, such fields have inherent characteristics of charge particle disequilibrium and high-dose gradient, making dosimetric measurements challenging. The accurate measurement of standard dosimetric quantities in such situations strongly depends on the size of the detector with respect to the field dimensions.
3D diamond detectors with small dimensions compared to the field size, have been tested under photon irradiation and evaluated for medical radiation dosimetry referring particularly to the problem of small fields dosimetry and/or of high spatial gradient fields dosimetry.
We will present results obtained with two new 3D finely segmented detectors made of a 500 um polycrystalline diamond substrate and a 500 um diamond on iridium substrate where multiple 3D cells are read in parallel when irradiated by a medical linear accelerator with the aim of understanding which substrate is the best solution for a more linear, stable and repeatable dose rate response in order to measure small field profiles in one measurement session, reducing the uncertainty of the delivered dose.

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Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **246** Type: **Poster presentation only**

Metascintillators: a new approcah in radiation imaging

In the last years, new solutions in both hardware and software have resulted in significant improvements in effective sensitivity in Positron Emission Tomography (PET). This improvement is mainly achieved by increasing the thickness of the gamma detectors (reducing time and spatial resolution), increasing the number of detector rings (increasing the economic cost) or developing gamma detectors based on faster scintillators with improved electronics. The third option
is related to the potential of adding TimeOf-Flight (TOF) information on the event characterization.
TOF is the time necessary for the electron-positron annihilation produced gammas to be detected. Without TOF information, it is not possible to know the position along the Line of Response (LOR) where the e +-e- annihilation process took place. However, when this information is available, it is possible to narrow down this position more precisely, being able to better model the annihilation photon emission probability distribution. The reduction through TOF improves the statistical properties of the PET image and leads to an improvement of the signal-to-noise ratio (SNR). Currently, the best TOF values are close to 205 ps in commercial devices.
This work aims to carry out a study based on simulations in order to achieve better TOF values through metascintillators. We define as meta-scintillators the composite topologies of scintillating and lightguiding materials, arranged to produce a synergistic effect at some step of the scintillation process, from gamma absorption to light detection, combining thus the favorable physical characteristics of their constituting components. One way is to place two scintillators with different properties in close enough proximity, so that the recoil electron resulting from the photoelectric conversion of a gamma ray in one material can reach the second one and deposit part of its energy in it.
Hence, it is possible to use a highZ material benefiting from its stopping power and design a geometrical topology that brings fast optical photon emitters close enough, resulting in a substantial probability of recoil electrons crossing through them. Thus, some optical photons will be produced according to the fast kinetics of the second material. The role of prompt photons and ways to produce them have been first described.
Based on this concept, we simulated a first generation of composite metastructures including a high-Z host and a fast emitter, cut in layers with thicknesses significantly less than the recoil electron range and arranged in geometrically periodic alternating positions. In this context we performed simulations building a metascintillator consisting of LYSO as dense scintillator and EJ232 plastic
scintillator (Eljen technologies) as a fast scintillator with GATE 8.2. We simulated a planar source emitting 1Million of 511 keV gammas impacting perpendicular or parallel to the layers of the metamaterial.
The recoil electron resulting of the gamma interaction with the material has been studied, as well as the energy sharing between materials. Several thicknesses of both materials have been simulated in order to optimize the energy deposit in both. The results for efficiency and energy distribution for different thicknesses in the perpendicular configuration are presented.
In a future work, different options as fast scintillators will be tested, such as CdSe/CSe nanoplatelets and perovskites. The simulation tool developed here is being further adapted to include electromagnetic interactions, for the adaptation to systems including photonic crystal slabs and high quality nano-machined reflectors to improve the light collection efficiency of the prompt photons.

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Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **247** Type: **Poster presentation only**

Standing Equine Leg CT (slCT)

All horse ridden disciplines result in stresses to both bony and soft tissue structures, with many breeds, in particular Western performance horses,experiencing extreme forces on the structures of the lower limb whilst executing transitions such as a tight turn or rapid acceleration. Lameness subsequent to distal limb injury is common to both the performance and pleasure horse, resulting in time out of ridden work at best or career ending at worst.
In this context, Hallmarq Veterinary Imaging Ltd (a company dedicated to veterinary imaging) and the Institute of Instrumentation for Molecular Imaging (i3M) established a collaboration in order to develop a CT prototype device for the examination of horse limbs. The Standing Equine Leg CT (slCT) is an additional tool for equine veterinarians to fully evaluate and diagnose lameness, fracture and disease in the equine distal limb.
The system consists of a novel dual- concentric ring design which enables the detector plate to remain very close to the region of interest to maximize the field of view, while the X-ray source rotates simultaneously with the detector about a common axis. Each acquisition lasts 60 seconds with the horse remaining in a standing position. In order to avoid overprojection of the contralateral limb, the acquisition may be made covering an angle of 270 degrees rather than 360º. The limited angle reconstruction is performed with a filtered backprojection algorithm. The device incorporates a unique motion correction technique to compensate for possible patient movement during the study.
This work presents the evolution from prototype to product of the slCT system, its measurement protocols, and an image gallery of patients.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **248** Type: **Poster presentation only**

Artificial intelligence explainability framework for the optimization of PET detectors

PET detectors based on monolithic crystals show better performance with respect to the ones based on pixellated crystals in terms of 2-D spatial resolution and depth-of-interaction estimation capabilities.
However, they need a long and complex calibration procedure to reach optimal performance and the best event positioning algorithms are too complex for a real-time implementation in a clinical PET scanner. Artificial intelligence (AI) and in particular neural networks seem to be a solution to this problem, achieving the best performance with relatively low computational complexity. However, these algorithms do not have solid theoretical foundations and are prone to severe overfitting.
We present an explainability framework for AI algorithms to use in the optimization of PET detectors based on monolithic crystals. The framework is able to show the internal working of the network, allowing to build trust in it and to improve its performance.

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Session Classification: Poster session 1

Track Classification: Imaging theory

Contribution ID: **249** Type: **Oral presentation**

Development of Data Correction Techniques for the 1M Large Pixel Detector at FXE

Tuesday, June 29, 2021 11:20 AM (20 minutes)

STFC's developed 1M Large Pixel Detector (LPD) 1 is now in operation on the femtosecond experiment (FXE) instrument [2] at the EuXFEL. LPD consists of more than 1 million pixels split across 2048 ASICs, with each ASIC having dimensions 32 × 16 pixels and a pixel pitch of 500µm. LPD's three parallel gain stages provide a large dynamic range, capable of detecting 105 photon/pixel/12keV x-ray pulse. When adding in the fact that each image is captured using 1 of the 512 available memory cells, more than 1.5 billion sets of individual pixel gain correction coefficients are required. This paper reviews recent progress in finalising these values. One method for calculating these coefficients is through comparison of LPD signals to an independent reference signal. In these measurements a combination of Si photodiodes and Si Avalanche Photodiodes (APD) were used. Through utilising these correlations the entire 1M of individual pixel outputs can be aligned on a common axis and their relative gains extracted, with correction to a common axis the first step towards a unified energy calibration per pixel. This technique is expanded across a range of memory cells as well as the detector gain stages. Finally a validation of the correction will be presented, including examples applied to liquid scatter data acquired at FXE.

1 M. Hart et al., "Development of the LPD, a high dynamic range pixel detector for the European XFEL," 2012 IEEE Nuclear Science Symposium and Medical Imaging Conference Record (NSS/MIC), pp. 534-537, doi: https://doi.org/10.1109/NSSMIC.2012.6551165
[2] D. Khakhulin et al., "Ultrafast X-ray Photochemistry at European XFEL: Capabilities of the Femtosecond X-ray Experiments (FXE) Instrument", 2020, Applied Sciences, 10(3), 995. https://doi.org/10.3390/app10030995

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Session Classification: Oral presentations

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **250** Type: **Poster presentation + pitch**

MiniPIX Timepix3 –a miniaturized radiation camera with onboard data processing for the online measurement of particle fluxes and dose rates in mixed radiation fields

The MiniPIX TPX3 is a miniaturized, low-power radiation camera (see Fig. 1) based on the Timepix3 64k active pixel sensor, providing imaging, spectral and tracking information of individual particles in mixed-radiation fields. Timepix3 1 is a high-granularity 256 × 256 pixel array of pitch 55 µm, with two per-pixel signal chain electronics. The hybrid architecture supports the use of different sensor materials (e.g., Si, CdTe, GaAs) of varying thickness (typically in the 100 µm –2000 µm range).

The high data rate performance makes use of the USB 2.0 readout port and operation by a PC/laptop computer. It utilises the PIXET software tool [2] which provides control, data acquisition and online visualization of single particle tracks. The maximum data and frame rate is 2.3 M hit pixels per second and 16 fps, respectively. The power consumption is in the range 1–2 W depending on the radiation field, intensity and resulting data rate. Raw data is readout and stored on an external PC/laptop where pre-processing can be performed by extended plug-in tools in the PIXET package. Steps performed include identification of single events registered in the form of pixelated cluster tracks (clustering) and application of the per-pixel energy calibration. Extensive data processing is performed offline for high-resolution, wide-range data evaluation and precise data products; such as selective particle fluxes, dose rates, LET spectra, deposited energy spectra, angular distributions, spatial- and time-distributions and charged-particle radiographs. High-resolution particle tracking coupled with advanced pattern recognition analysis of the single particle tracks provides enhanced resolving power of particle-type composition [3] for detailed analysis of radiation fields. A heuristic empirical approach, based on wide-range of calibrations of the Timepix detector in well-defined radiation fields, provides particle-type discrimination of up to 8 classes [3].

Onboard processing operation is enabled by firmware reconfiguration and the embedded microcontroller in the readout electronics. Control and communication is via the SPI port. A low power (0.5–1.5 W) mode is intended for space applications such as ESA's MIRAM payload intended for LEO and GEO orbit deployment [4]. Data processing can be performed to a limited extent for an online response. A detailed event-by-event mode provides position, timing, dose, deposited energy and LET data of single events for radiation field fluxes up to 105 cm-2s-1. An integrated summed mode suitable for high intensity radiation fields (up to 107 events cm-2s-1) provides integrated limited information of total particle flux and total dose rate. Both modes provide basic particle-type discrimination (3 main classes are resolved –see Fig. 2).

1 T. Poikela et al., Timepix3: a 65k channel hybrid pixel readout chip with simultaneous ToA/ToT and sparse readout, J. of Instrum. JINST 9 (2014) C05013
[2] D.Turecek et al, USB 3.0 readout and time-walk correction method for Timepix3 detector, J. of Instrum. JINST 11 (2016) C12065
[3] C. Granja et al., Resolving power of pixel detector Timepix for wide-range electron, proton and ion detection, Nucl. Instrum. Meth. A 908 (2018) 60-71.
[4] S. Gohl et al., A miniaturized radiation monitor for continuous dosimetry and particle identification in space, contribution to this conference.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **251** Type: **Oral presentation**

Radiation Damage Study of the ePix100 Detector at the European XFEL

Thursday, July 1, 2021 11:00 AM (20 minutes)

Operation of detectors at free-electron laser (FEL) facilities with sources providing high brilliance, high repetition rate and ultra-short X-ray pulses poses high risk of radiation damage to detector components exposed to X-ray radiation, e.g. the sensor and the readout Application Specific Integrated Circuit (ASIC). Knowledge about radiation-induced damage is important for understanding its influence on the quality of scientific data and the detector's lifetime.

The ePix100 detector 1 is a hybrid pixel detector designed for low noise spectroscopy applications and is a member of the ePix detector family providing hybrid pixel detectors to support a wide range of applications at FEL facilities. At the European XFEL (EuXFEL) the ePix100 is used at two scientific instruments, namely High Energy Density Matter (HED) [2] and Material Imaging and Dynamics (MID) [3].

The aim of our study was to evaluate influence of radiation induced damage by the EuXFEL beam on the performance and lifetime of the ePix100 detector. The detector was irradiated under controlled conditions by a direct attenuated beam with a photon energy of 9 keV and a beam energy of 1 μJ. An area of $20\,\mathrm{pixels} \times 20\,\mathrm{pixels}$ was irradiated to a dose of approximately 760 kGy at the location of the $\mathrm{Si/SiO_2}$ interface in the sensor. The performance changes of the ePix100 detector induced by radiation damage were evaluated in terms of offset, noise, energy resolution and gain. We have observed a dose dependent increase in both offset and noise and the results suggest the main cause being the increase of the sensor leakage current. Energy resolution given as Full Width at Half Maximum (FWHM) was increasing by $\approx$ 115 eV/kGy and can also be attributed to an increase of the noise. Changes in gain were evaluated one and a half hours and 240 days post irradiation. The observed gain changes suggest damage to occur also in the ASIC. Based on the obtained results, we have assessed limits for the long term operation of the ePix100a at EuXFEL and other light sources in terms of its scientific performance. The detector can be used without significant degradation of its operation performance for several years if the incident photon beam intensities do not outperform the detector's dynamic range by several orders of magnitude.

1 G. Blaj, P. Caragiulo, G. Carini, S: Carron, A. Dragone, D. Freytag, G. Haller, P. Hart, J. Hasi, R. Herbst, S. Herrmann, C. Kenney, B. Markovic, K. Nishimura, S. Osier, J. Pines, B: Reese, J. Segal, A. Tomada, and M. Weaver. X-ray detectors at the Linac Coherent Light Source. Journal of Synchrotron Radiation, 22(3):577–583, May 2015.
[2] HED. Scientific Instrument HED. EuXFEL Webpage, 2021. Status March 2021.
[3] A. Madsen, J. Hallmann, G. Ansaldi, T. Roth, W. Lu, C. Kim, U. Boesenberg, A. Zozulya, J. M¨oller, R. Shayduk, M. Scholz, A. Bartmann, A. Schmidt, I. Lobato, K. Sukharnikov, M. Reiser, K. Kazarian, and I. Petrov. Materials Imaging and Dy- namics (MID) instrument at the European X-ray Free-Electron Laser Facility. Journal of Synchrotron Radiation, 28(2):637–649, Mar 2021.

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Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **252** Type: **Poster presentation only**

Design optimization of silicon photomultipliers using performance parameter modeling for scintillation detector applications

In this work, we present models to simulate two performance parameters for silicon photomultipliers (SiPMs) in Complementary Metal-Oxide Semiconductor (CMOS) technology: Photon Detection Probability (PDP) and Dark Count Rate (DCR). These models were developed to comply with the specifications of SiPM which is applicable to scintillation detectors. These two characteristics are important parameters that affect the photon number resolving capability of the scintillation detector, and are in a trade-off relationship with each other 1. It is essential to predict the values of these parameters at the design stage. The PDP and DCR models were devised on the basis of Technology Computer-Aided Design (TCAD) simulations and Matlab routines. The doping profile for the n-on-p structure was determined through case analyses by employing these models. The simulation results will be compared with the experimental results performed for the 350 nm to 850 nm wavelength range and four different over-voltages. Our work provides an effective way to optimize the SiPM design by considering the trade-off relationship appropriately.

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Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **253** Type: **Oral presentation**

Timepix4, a large area pixel detector readout chip which can be tiled on 4 sides providing sub-200ps timestamp binning

Wednesday, June 30, 2021 3:50 PM (20 minutes)

The Timepix4 chip is designed to read out a large area pixel detector comprised of 448 x 512 pixels of 55 micron square. The chip is the first large area pixel detector which can be tiled on all 4 sides when Through Silicon Vias are used to access the chip IO. There are two operating modes: data driven and photon counting. In data driven mode each pixel which is hit will produce a 64-bit word containing the hit pixel address, the Time over Threshold (with a precision of ˜ 120 e- rms) and the arrival time stamped to within a 200ps bin over a total time of up to ˜80 days. The maximum flux which can be read out correctly is ˜ 7Mhits/mm2/s when all 16 serial links running at 10 Gbps are used. In photon counting mode the chip can operate at up to 44kfps in 16-bit mode and 89 kfps in 8-bit mode. This paper will describe the requirements, the chip architecture and show first measurements

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Session Classification: Oral presentations

Track Classification: Front end electronics and readout

Contribution ID: **254** Type: **Poster presentation only**

Double photon coincidence crosstalk reduction method for multi-nuclide Compton imaging

Compton imaging is one of promising imaging methods in nuclear medicine. This method is based on Compton kinematics 1 and can visualize a wide range of gamma-ray energy. Therefore, the multi-nuclide imaging capability of Compton imaging was reported in previous research [2]-[4]. A problem in multi-nuclide imaging is crosstalk artifacts on the reconstructed images of low-energy gamma-rays [5]. Sakai et al. demonstrated a crosstalk reduction method using a dual energy window (DEW) scatter correction in Compton imaging, and the artifacts could be eliminated by the DEW method [5]. In this research, we demonstrated the double photon coincidence method as another crosstalk reduction method. In the previous research, we have applied the double photon coincidence method to Compton imaging and Pb-collimation-based imaging [6]-[8]. Some nuclides emit two or more gamma-rays through metastable intermediate levels. By detecting the coincidence of Compton events, the position of a nuclide can be determined at an intersection of Compton cones. Herein, we utilized the coincidence method to reduce crosstalk caused by gamma-rays from other nuclides. By detecting coincidence between photo-absorption events and Compton events (Figure 1), the crosstalk can be reduced although the position of a nuclide cannot be determined.

We have developed a ring-type Compton imaging system, which consists of eight Compton cameras (Figure 2 (a)). A Compton camera comprises a scatterer and an absorber, which are 8×8 array of high-resolution type GAGG scintillators coupled with 8×8 array of silicon photomultipliers. The pixel sizes of a scatterer and an absorber are 2.5 mm × 2.5 mm × 1.5 mm and 2.5 mm × 2.5 mm × 9 mm, respectively. Charge signals from SiPMs were processed by the dynamic Time over Threshold (dToT) method in parallel and converted from analog signals to digital signals of the time width [9]. These digital signals were acquired by a field-programmable gate array (FPGA, Xilinx Artix7) based data acquisition (DAQ) system with 1.0-ns accuracy as list-mode data. The intrinsic time resolution of this system is approximately 50 ns. For the demonstration, approximately 0.2 mL of 111InCl3 (0.73 MBq) and 177LuCl3 (7.3 MBq) were dispensed into 0.5 mL micro tubes, individually (Figure 2 (b)). Both nuclides are double photon emitters and used in nuclear medicine. 111In emits cascade gamma-rays with energies of 171 keV and 245 keV with 84.5 ns time constant. 177Lu emits cascade gamma-rays with energies of 208 keV and 113 keV with 0.5 ns time constant. The measurement time was approximately 12 hours. In analysis, coincidence events between a scatterer and an absorber were extracted as Compton events used for Compton imaging. Moreover, coincidence events of a Compton event and a photoelectric effect event (171 keV gamma-ray events for 111In, 113 keV gamma-ray events for 177Lu) were extracted to reduce crosstalk. Time windows were ±100 ns for 177Lu and from -50 ns to 250 ns for 111In.

Figure 3 shows energy spectra of sum of deposited energies in the scatterer and the absorber. By taking double photon coincidence, the background Compton events were reduced and peaks of 245 keV or 208 keV Compton events can be clearly seen. The signal-to-background ratio (SBR) and absolute detection efficiencies were shown in Table 1. SBRs were calculated as the ratio of the number of Compton events that are used for reconstruction with energy selection in Compton events that are not used for reconstruction. SBRs were approximately 1.4 ˜ 1.8 times increased although the detection efficiencies of double photon coincidence method were ˜10ˆ2 smaller than those of single photon method.

In this research, we demonstrated the double photon coincidence method to reduce crosstalk by taking coincidence of a photoelectric absorption event and a Compton event. Background events were reduced in the spectra of sum of deposited energies in the scatterer and the absorber and SBRs were increased. This coincidence method is useful to reduce the crosstalk. We will report the detail including imaging results in conference.

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Session Classification: Poster session 1

Track Classification: Imaging theory

Contribution ID: **255** Type: **Poster presentation + pitch**

Optimization of pixel size and propagation distance in X-ray phase-contrast virtual histology

The use of Computed Tomography at the micrometre scale (μCT) is becoming a viable solution in the field of virtual histology [1-2]. In principle, μCT can provide a complete three-dimensional visualization of histological specimens which can be virtually sliced at any point and in any direction. This, if not a diagnostic tool per se, can enable guided sectioning of tissues in histological analysis for selecting the most suitable cutting plane when dissecting specimens in order to obtain, e.g., the largest cross-section of the pathological area of interest. One of the challenges of virtual histology is related to the poor X-ray attenuation contrast that exists between the soft tissues commonly encountered in biopsy specimens. In this context, the high sensitivity offered by X-ray phase-contrast imaging techniques, such as propagation based (PB) imaging, can overcome this limitation. To be suitable for clinical evaluation, virtual histology images should have a spatial resolution high enough to distinguish small structures but, at the same time, cover a sufficiently large volume to enable the inspection of biopsy specimens, usually having sizes of 4-5 cm3, in a single or very few μCT acquisitions. Considering the standard dimensions of commercial detectors (4-8 MP), the aforementioned requests translate in acquisitions with pixel size of few microns (1-5 μm). To provide adequate visibility of soft-tissue structures in the virtual slices, such high spatial resolutions must be combined with high signal-to-noise ratio (SNR).
In conventional attenuation-based CT the image noise is strongly dependent on the detector pixel size and the geometrical magnification. Recently published theoretical models [3-4] showed that PB phase-contrast tomography, with the application of phase-retrieval (PhR) in the near field regime, mitigates the dependence of noise on the pixel size bringing to a major SNR gain at small pixel sizes. Similarly, the model predicts a steep increase in the SNR for increasing propagation distances. In two recent papers [5,6] this model was quantitatively compared with experimental results obtained with monochromatic synchrotron radiation and employing a photon-counting detector having a quasi-ideal (box-like) response function. The measured SNR gain due to the PhR application showed a good agreement with the theoretical prediction by varying both the pixel size and the propagation distance. This quantitatively demonstrated that a careful optimization in terms of pixel size and propagation distance is required to fully exploit the advantages of PB and PhR. On the other hand, considering current limitations in the manufacturing process, the level of spatial resolution required by virtual histology cannot be achieved with photon counting detectors. Another limitation in their use comes from the extremely high X-ray fluxes which are needed to provide high SNR at high resolution, that is commonly achieved at synchrotrons by employing white (i.e. polychromatic) beams. These features require the use of small-pixel indirect-conversion detectors, such as CCD or sCMOS, usually coupled with magnifying optical elements, leading to a detector's response function that is far from being a 1-pixel wide function. Both polychromaticity and wide response function represent deviations from the model validated in [6].
In this context, we present a preliminary experimental optimization of propagation distance and pixel size obtained in virtual histology imaging experiments performed at the SYRMEP beamline of the Italian Synchrotron facility Elettra (Trieste, Italy). Experiments were carried out by using a white beam from a bending magnet source with an added filtration of 1 mm of Si, resulting in an average energy of 24 keV. Samples were surgical specimens of pathologic breast tissues embedded in paraffin. The imaging system was a Hamamatsu sCMOS camera (2048×2048 pixels) coupled with a GGG:Eu scintillator and a high numerical aperture optic enabling to adjust the pixel size between 0.9 and 6.5 μm. In the study we used three different pixel sizes: 1, 2.5 and 4 μm. For each pixel size we performed CT scans, collecting 1800 projections over 180o, at 5 sample-detector distance: 4.5, 150, 250, 500 and 1000 mm. For each image, noise and SNR were measured within homogeneous regions of the sample and optimal combinations of pixel size and propagation distance were identified. Experimental results were compared to the theoretical model which has been adapted to the imaging system-specific point-spread function. This preliminary optimization will serve as guideline in the choice of the best experimental parameters for a future larger virtual histology

study, aiming to assess the invasiveness of malignant diseases in various anatomical districts.

Figure 1 Detail of a slice of the breast specimen acquired with pixel size of 4 μm and three different propagation distances: 45 mm (a), 150 mm (b) and 500 mm (c). The slice at largest propagation distance shows a much higher signal to noise ratio with slightly worse sharpness. Scalebar in (a) is equal to 0.5 mm.

Figure 2 Comparison between X-ray phase-contrast image obtained with 4 μm pixel size (a) and the corresponding histological image obtained with a D-Sight F 2.0 slide scanner (b) of a breast tissue specimen with an intraductal papilloma. Scalebar in (a) is equal to 1 mm.

1 J Albers et al., Molecular Imaging and Biology 20.5 (2018), 732-741.
[2] P Baran et al. IEEE transactions on medical imaging 37.12 (2018), 2642-2650.
[3] Y I Nesterets et al., Journal of Physics D: Applied Physics 51.11 (2018), 115402.
[4] T E Gureyev et al., JOSA A 34.12 (2017), 2251-2260.
[5] L Brombal et al., Physics in Medicine & Biology 63.24 (2018), 24NT03.
[6] L Brombal, JINST 15 (2020), C01005.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **256** Type: **Oral presentation**

FASTpix - small collection electrode CMOS sensors for precise time-stamping capabilities, high efficiency in thin sensors and high radiation tolerance

Monday, June 28, 2021 10:30 AM (20 minutes)

In the framework of the ATTRACT FASTpix project monolithic small collection electrode CMOS technologies for fast signal collection, high radiation tolerance and precise timing in the sub-nanosecond range are investigated.
Deep sub-micron CMOS technologies give access to very small, sub-femtofarad collection electrodes and large signal-to-noise ratios, essential for very precise timing in monolithic sensors. However, the small collection electrode design results in highly non-uniform electric and weighting fields in the sensor, that introduce variations of the charge collection times in dependence of the particle incident position, a key limitation for precise timing and radiation tolerance.
Within the FASTpix project sensor design modifications have been developed to mitigate these variations. Special implant structures have been designed that shape the electric field to uniformize the drift path within a pixel cell. In particular, reduced charge collection times in the pixel edges have been achieved, that reduce the charge sharing, increase the efficiency before and after irradiation and improve the time stamping capabilities. Additionally, a hexagonal arrangement of the collection electrodes has been found to mitigate slow charge collection at the pixel edges. Moreover, the hexagonal pixel geometry is also favorable for timing and efficiency measurements due to the reduced number of neighboring pixels, minimizing the charge sharing and therefore increasing the single pixel signal-to-noise ratios.
The FASTpix chip contains several mini-matrices with digital and analogue pixels and different sensor designs and geometries. Pixel pitches down to about 8.7 micrometer between collection electrodes are implemented in a 180 nm technology by placing only a minimum amount of circuitry inside the pixel matrix. The optimized well structures are implemented on a high resistivity epitaxial layer.
At present, the FASTpix has been investigated in laboratory measurements, showing the improved performance of the optimized designs even at small pixel pitches below 10 micrometer. This talk presents the concepts and results of 3D TCAD based sensor design optimizations as well as measurement results comparing different sensor designs.

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Session Classification: Oral presentations

Track Classification: Front end electronics and readout

Contribution ID: **257** Type: **Poster presentation + pitch**

A 144-channel Gamma-Ray Spectrometer with High Dynamic Range and Embedded Machine Learning Algorithms for Position Sensitivity in Thick Scintillators

This work presents an innovative gamma-ray spectroscopic module that is based on a cylindrical 3”×3”codoped lanthanum bromide scintillator crystal (25 [ns] decay time, 73 [ph/keV]), optically coupled to a large array of 144 NUV-HD SiPMs, produced by Fondazione Bruno Kessler (FBK, Italy) 1. The array is made up of 9 tiles, each one counting 4×4 SiPMs. A 16-channel front-end Gain Amplitude Modulation Multichannel ASIC (GAMMA, [2]) is connected to each tile, allowing an individual, low-noise readout of the SiPMs charge up to 30 MeV incoming gamma photons.
The ASIC is specifically designed for the module; each channel provides 84 dB dynamic range, thanks to the innovative Adaptive Gain Control circuit. Moreover, thanks to the positive-feedback architecture of the input current buffer, each channel could be loaded with more than 50 nF allowing, in different applications, to connect more than 20 individual 6×6 mm² SiPM to a single channel.
In nuclear physics experiments, detected gamma rays might be subject to apparent energy shifts generated by the relativistic Doppler effect. Position sensitivity of the interaction position in the scintillation crystal with spatial resolution smaller than 2 cm on a single axis has to be met to counteract this effect [3]. Since we are dealing with a thick scintillator crystal, there is currently no suitable physical model of the system that enables position sensitivity.
To address this problem, we explored multiple machine-learning-based embeddable solutions. A training dataset was built acquiring the signals generated in 45 positions on a grid (Fig.1) from a ¹³⁷Cs collimated source (Fig.2). The acquired data were used to train and test classifiers (Decision Tree, Neural Network, Support Vector Machine), which are able to correctly identify the interaction position of new gamma photons. Comparative results of the different solutions will be presented at the conference.
Thanks to low latency and reduced area occupation on FPGA, Decision Trees are perfect candidates for an embedded solution (Fig.3). The performance of Decision Tree classifiers is described using confusion matrixes in Fig.4 and Fig.5. The rms error of this solution on the x-axis is 1.52 cm. We will also present a machine-learning-based event filter designed with the objective to discard those events whose position of interaction is more often wrongly classified; this is mainly associated with multiple scatterings or with scintillation light from events interacting far from the SiPMs. Applying the filter, the Decision Tree classifier error for x-axis position sensitivity scales down to 1.08 cm. Results for position sensitivity on the xy-plane, obtained before and after the application of the filter, are shown in Fig.5. The Decision Tree classifier was embedded in an Artix-7 FPGA-based DAQ in order to achieve real-time classification and relax constraints on data transmission for applications in nuclear physics experiments, nuclear safety, and homeland security, which otherwise often represent a bottleneck for count-rate.
The module is capable of spectroscopy measurements between 20 keV and 30 MeV, showing state-of-the-art resolution spanning from 2.6% at 662 keV down to 1.0% at 8.9 MeV, with a 35 kcps count rate. The embedded classifier in the Artix-7 presents a latency of 400 ns and an area occupation lower than 10%, allowing real-time position sensitivity and reducing data communication rate by a factor of 100.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **258** Type: **Poster presentation only**

Multi-channel front-end ASIC for a 3D position-sensitive detector

Arrays of 3D position-sensitive detectors (3DPSD) operating at room temperature and using cadmium zinc telluride (CZT) and thallium bromide (TIBr) sensors are suitable for gamma-ray spectrometry in many applications [1,2,3]. One detector configuration, the 3D position-sensitive virtual Frisch-grid detector (VFG), is particularly advantageous for integrating into large area arrays. The signals generated inside each detector of the array are captured with the anode, cathode and four pads that enable the reconstruction of the position and energy of the ionizing interaction by measurements of amplitude and timing of the signals.
For these applications, a low-noise front-end ASIC, capable of processing bipolar signals (due to the AC-coupling of some electrodes), is needed. The ASIC can be coupled to a fast ADC in order to form a compound waveform "digitizer"capable of post-processing the analog signals and determining amplitude and timing information.
This paper describes a 32-channel front-end ASIC that is suitable for reading out a 3 x 3 or 4 x 4 element matrix in the VFG configuration [4,5]. Each channel is composed of a low-noise charge amplifier with an adaptive continuous reset [6] feedback circuit suitable for both positive and negative charge, a first order shaper and a single-to-differential converter output stage. Voltage and current references are all internally generated by 10-bit DACs and the chip is fully controllable with the I2C communication protocol. The readout channel response has been verified using the implemented injection circuit, demonstrating linear behavior up to ˜100 ke-/+ with gain of ˜80 mV/fC, and up to ˜200 ke-/+ with gain of ˜40 mV/fC. This paper reports the first test results using radioactive sources (241Am, 137Cs, Tb(kα,kβ)), where inputs have been connected to a small PIN Si diode (size = 2 x 2 mm2, thickness = 50 um, C = ˜8 pf) emulating the typical detector capacitance of the elements (5 –10 pF) used in 3DPSD.

1 K.S. Shah et al, IEEE Trans. Nucl. Sci., vol. 36, no. 1, pp. 19 –202, 1989.
[2] K. Hitomi et al, Nucl. Instr. and Meth. A 458, no. 1, pp. 365–369, 2001.
[3] A. Owens and A. Peacock, Nucl. Instrum. Methods, vol. A531, pp. 18–37, 2004.
[4] E. Vernon et al, Nucl. Instr. and Meth. A 940, pp. 1–11, 2019.
[5] A.E. Bolotnikov et al, Nucl. Instr. and Meth. A 954, 161036, 2020.
[6] D. De Geronimo et al, IEEE Trans Nucl. Sci., vol. 47, no. 6, pp. 1857-1867

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **259** Type: **Oral presentation**

A new AGIPD detector generation

Monday, June 28, 2021 10:10 AM (20 minutes)

The Adaptive Gain Integrating Pixel Detector (AGIPD), a megahertz frame-rate, high-dynamic range integrating pixel detector, was developed for photon science experiments at the European X-Ray Free Electron Laser (European XFEL) and tailored to its unique specifications. Two 1-Megapixel AGIPD detector systems have been installed at the European XFEL and are producing numerous scientific publications. In order to further improve the existing systems, and to provide dedicated systems for two user consortia, we have been developing the next generation of hardware. These developments will also reach out into entirely new areas.

Two new generation of ASICs have been developed. AGIPD1.2 corrects a problem with the gain encoding in AGIPD1.1, which made it difficult or impossible to distinguish whether a pixel was in medium or low gain, effectively reducing the useful dynamic range of the system. The improved gain bit encoding was tested and verified in a test beam experiment at the HED scientific instrument at the European XFEL in November 2020. The other generation, AGIPD1.3, is an electron collecting version of the ASIC, needed for readout of high-Z sensor materials such as Gallium-Arsenide (GaAs), Cadmium-Telluride (CdTe), or Cadmium-Zinc-Telluride (CdZnTe). Such sensors are needed to provide higher absorption efficiencies for photon energies in the range from 15-30 keV, which are demanded by a number of user communities.

On the backend, new, more compact, read-out electronics have been developed most notably including a new FPGA, firmware, and all-optical communication with new multifibre Gbit tranceivers.
A 0.5-Megapixel prototype system, using the new readout electronics, firmware and AGIPD1.2 ASIC has been built, commissioned and operated in user experiments at the HED instrument in 2020 (see figure). This system provided the first Megahertz diffraction capabilities for HED science at the European XFEL.

This new generation of AGIPD will be used to build two new detector systems. A 4-Megapixel system for the SFX user consortium at the SPB/SFX station, and a 1-Megapixel system with high-Z sensors for the HED instrument at the European XFEL. In addition, also the existing AGIPD detectors at SPB and MID will be equipped with new front-end modules containing AGIPD1.2.

In this talk we will present and discuss the current status of all AGIPD developments on the front-end and read-out electronics and show results from the data of the Second Generation prototype AGIPD system at HED.

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Session Classification: Oral presentations

Track Classification: Front end electronics and readout

Contribution ID: **260** Type: **Poster presentation only**

An 8-bit low-power and small-area column-parallel ADC in the MAPS for beam imaging

To handle the increasing number of cancer patients, China has built its carbon ion therapy facility, in which the beam monitoring system 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 full-image output, an 8-bit column-parallel ADC has been designed to serve the pixels in every four adjacent columns.

To satisfy the restricted constraints on power, size and speed, a novel structure has been designed. The sub-ADC generates 1.5-bit in each conversion step, which simplifies the circuits of the comparators and improves the tolerance to the offset of the reference voltage. The multiplying digital-to-analog converter (MDAC) is realized by only one amplifier and six capacitors. The amplifier is shared by the multiply-by-two circuit and sample-and-hold circuit. These actions significantly reduce the power consumption and chip area. Also, the MDAC reduces the conversion duration by combining the conversion phase and reset phase. The well-optimized timing for the switches also decreases the charge injection effect and eliminates the influence of charge left from the last conversion, which benefits the resolution.

Each column-parallel ADC covers a small area of 100μ m x 300 μm and consumes a low power of ˜5mW at 3.3V supply. Lab tests have been performed on the taped out column-parallel ADC array, the DNL and INL are measured to be 0.16/-0.18 LSB and 0.11/-0.10 LSB, respectively. The ENOB is measured to be 8.07bit at the sampling rate of 1MSPS and 6.63bit at the sampling rate of 5MSPS.

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **261** Type: **Oral presentation**

On the possibility to utilize a PCO Edge 4.2 bi scientific CMOS imager for extended ultra violet and soft X-ray photon detection

Tuesday, June 29, 2021 1:30 PM (20 minutes)

Photon science with extended ultra violet (EUV) to soft X-ray photons generated by state of the art synchrotrons and FEL sources imposes an urgent need for suitable photon imaging detectors. Besides a high quantum efficiency, requirements on such EUV detectors include high frame rates, very large dynamic range, single-photon sensitivity with low probability of false positives, small pixel pitch and (multi)- megapixels. Owing to their unique features back illuminated scientific CMOS (sCMOS) imagers can be tailored to these particular needs 1. In general application driven detector development is a sensible, albeit time consuming approach allowing to take full advantage of the luminosity improvements that FELs and diffraction-limited synchrotron rings (SRs) can provide. Conversely such characteristics can be found in few state of the art commercial detectors based on sCMOS, which have been recently developed for other applications mainly in the visible light regime. In particular back thinned sCMOS are suited for experiments exploiting the water window (between 282 eV and 533 eV) and transition metal L-edges, a target photon energy range which implies vacuum operations. Applying some modifications, in particular UHV compatibleness, these commercial devices can be disposed for EUV and soft X-ray applications as demonstrated by [2].
In this contribution we describe the adaption of the PCO edge 4.2 bi for soft X-ray imaging in the energy range from 35 eV –2000 eV. The PCO edge is build around the GSENSE2020BSI-APM-NUN PulSar back thinned sCMOS sensor, which has been designed by Gpixel (https://www.gpixel.com) and has been processed by Tower Semiconductor (https://towersemi.com). The sensor comprises 2048 x 2048 pixels with a pixel size of 6.5 µm x 6.5 µm, which translates into an active area of 13.3 mm x 13.3 mm. The sensor exhibits a full well capacity of 48 000 e- and a readout noise of 1.9 e- (rms) with a typical dynamic range of 88 dB. The integration time can be adjusted between 10 µs –2 seconds. Using its USB 3.1 data interface the maximum frame rate is given by 40 fps for the full frame while it can reach for instance 520 fps for a region of interest of 2048 x 128 pixels. In addition, a total of 4 trigger signals are provided to synchronize image acquisitions. Vacuum compatibility has been obtained by sealing the carrier board of the sensor, which constitutes the barrier between vacuum and normal atmosphere. In this fashion it is possible to keep the entire readout and trigger electronics in air. At the moment a KF flange based interface plate is utilized to attach the camera and subsequently sensor to the experimental vacuum chamber (Figure 1). Here we present the first measurements carried out at the CiPo beamline at Elettra Sincrotrone Trieste with a modified soft X-ray PCO Edge 4.2 bi showing a very high quantum efficiency greater than 60% in the energy range between 30 eV and 100 eV and greater than 80% for energies between 100 eV and 1000 eV. Soft X-ray imaging capabilities have been assessed by means of slanted edges and generation of Airy patterns through a pin hole (Figure 1). Moreover, spectral X-ray imaging with this single photon processing detector can be accomplished.

1 A. Marras, J. Correa, S. Lange, et al., J. Synchrotron Radiat. 2021, 28, 131.
[2] Desjardins, K., Medjoubi, K., Sacchi, M., Popescu, H., Gaudemer, R., Belkhou, R., et al. (2020). research papers. J. Synchrotron Rad (2020). 27, 1–13.

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Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **262** Type: **Oral presentation**

A Low-Noise Pixelated ASIC for the Readout of Micro-Channel Plates

Tuesday, June 29, 2021 11:40 AM (20 minutes)

In the field of astronomy, photon counting detectors based on micro-channel plates (MCP) are commonly used for UV detection and their characteristics often limit the overall instrument performance. In particular, UV spectroscopy is adopted in solar physics and for the investigation of planetary exospheres. The PLUS (PLanet extreme Ultraviolet Spectrometer) Project aims at developing a spectrometer in the 55-200 nm range leveraging a dual channel (VUV/EUV) architecture and high-efficiency optical components individually optimized for each channel. Within this context, we present the first version of a new ASIC custom-designed for MCP readout. The ASIC will be able to detect the electrons cloud generated by each photon interacting with the MCP, sustaining high local and global count rates to fully exploit the MCP intrinsic dynamic range with low dead time The main rationale that guided the electronics design is the reduction of the input equivalent noise charge (ENC) in order to reduce the gain of the MCP, thus, enlarging its lifetime, crucial for long missions.
The readout chain (Fig. 1) is composed of the low-noise charge sensitive amplifier (CSA), a filtering stage with selectable analog processing time (125 or 250 ns, Fig. 2), a discriminator with a 5-bit selectable threshold, a charge-sharing compensation logic (CSCL) offering two arbitration modes and, finally, two 17-bit counters alternating in parallel and, thus, granting zero dead time in the serial digital readout. The frame rate is 1 Hz and the maximum count rate per pixel is 100 kcps. The maximum collectable charge at the anode is 6000 e- with an ENC of only 25 e-. This value can be compared with 72 e- of MEDIPIX 3 (55 μm pixel 1) and 84 e- of CHASE Jr. (100 μm pixel [2]).
The charge cloud on the array of collecting anodes is expected to spread at maximum among 4 adjacent pixels. In the basic arbitration mode, the event is assigned to the pixel with the highest detected charge. Instead, to address conditions of equally partitioned charge, in the advanced mode (an evolution of the MEDIPIX 3 approach), the cluster that received the highest charge is identified by the summing nodes between pixels and then the winning pixel is identified by vertical and horizontal comparisons.
A scaled 65-nm CMOS technology has been selected in order to achieve a compact pixel size (35 ×35 μm2 with an anode size of 20 ×20 μm2 for a 32% fill factor), providing high spatial resolution which is a key characteristic for the spectrometer under study, but which also makes the device suitable for different photon-counting (spectroscopic or imaging) applications. The first prototype of the ASIC contains an array of 32 × 32 pixels for a total chip area of 2 ×2 mm2, including several pads for diagnostics and characterization. Analog and digital block are carefully separated in a super-pixel configuration (Fig. 4).

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Session Classification: Oral presentations

Track Classification: Front end electronics and readout

Contribution ID: **263** Type: **Poster presentation + pitch**

High-contrast proton radiography of thin samples with the pixel detector Timepix3

We examined the application of proton imaging 1 on thin samples at the proton and light-ion Tandetron accelerator [2] of the NPI-CAS in Rez near Prague. We make use of high-sensitivity hybrid semiconductor pixel detectors Medipix/Timepix equipped with integrated per-pixel signal processing electronics. We use the Timepix3 ASIC chip [3] equipped with a 500 µm Si sensor operated with the fast data rate AdvaPix readout electronics interface.

Measurements were performed in air with a 2.9 MeV proton microbeam on thin samples (< 100 µm thick). Mylar and aluminium foils were stacked into closely packed assemblies of varying well-defined thickness. The samples were placed in front of the detector in orthogonal geometry (beam axis perpendicular to the sensor plane –see Fig. 1). Radiographies were collected with standard (few mm size) and a focused microbeam (few µm size).

The imaging principle is based on high-resolution spectrometry of single transmitted particles. Contrast is obtained by registration of small changes in the deposited energy of the proton after passing through the sample [4]. These changes can be measured in wide-range by detailed spectral-tracking analysis of the pixelated clusters in the detector [5]. The track parameters we utilize for imaging contrast are deposited energy, cluster area (number of pixels) and cluster height (maximum energy value of the pixels in the cluster) [5]. The position of interaction in the detector is registered in sub-pixel resolution [4] down to few µm scale for the particles and geometry used [6]. Radiographies are reconstructed based on these individual parameters imaged in image bins of adjustable size (few µm up to few tens of µm). The radiography of a sample assembled from several aluminium foils stacked in stairs geometry is shown in Fig. 2. No post-processing was applied in the image. The technique developed with different cluster parameters will be presented together with evaluation of image contrast sensitivity on various types of samples and beam energies.

1 Koehler, A.M. Proton radiography Sci. 160 (1968), 3825
[2] Romanenko, O., et al. Performance and application of heavy ion nuclear microbeam facility at the Nuclear Physics Institute in Rez Rev. Sci. Inst. 90 (2019), 013701
[3] Poikela, T., et al. Timepix3: a 65K channel hybrid pixel readout chip with simultaneous ToA/ToT and sparse readout, J. of Instrum. JINST 9 (2014) C05013
[4] Jakubek, J. Semiconductor pixel detectors and their applications in life sciences, J. of Instrum. JINST 4 (2009), P03013
[5] Granja, C., et al. Resolving power of pixel detector Timepix for wide-range electron, proton and ion detection Nuc. Inst. Met. A 908 (2018) 60-71
[6] Granja, C., et al. Directional detection of charged particles and cosmic rays with the miniaturized radiation camera MiniPix Timepix Nuc. Inst. Met. A 911 (2018) 142-152

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **265** Type: **Oral presentation**

Quantum Entangled PET Imaging

Monday, June 28, 2021 2:20 PM (20 minutes)

The effect of quantum entanglement was first discussed more than 80 years ago [1,2]. Particles that are quantum entangled are described by a common wavefunction which leads to enhanced correlations between the particle interactions, even when separated over macroscopic distances. The two photons resulting from positron annihilation are predicted to be in such an entangled state. Their entanglement in linear polarisation modifies the double-Compton scattering cross-section as a function of the relative azimuthal scattering angle of the photons ($\Delta\phi$), resulting in a $\cos(2\Delta\phi)$ modulation having an amplitude far in excess of that expected for non-entangled photons. Previous experimental measurements have shown enhancement consistent with the entangled predictions, albeit for restricted scattering kinematics and using conventional detectors (e.g. NaI [3]). The recent advances in CZT detector technology allowed us to overcome many of the past difficulties and obtain experimental demonstration of quantum entanglement in MeV range with large acceptance. One of the most exciting applications of quantum entanglement is in Positron Emission Tomography (PET), a technique widely used for medical research and clinical diagnosis. It utilises the back-to-back emission of annihilation photons to image metabolic processes inside of the body. PET images are obtained with significant in-patient scattering and random backgrounds, which reduce image resolution and contrast. Both of those problems are mitigated using scintillator detectors with timing resolution of a few hundreds of nanoseconds, thus making solid state detectors largely impractical for such purpose. Using quantum entanglement principles could open new ways to use CZT detectors in PET.
To investigate the potential benefits of quantum entanglement, it was incorporated into the GEANT4 code using polarized Klein-Nishina formula [4,5]. The simulation was verified against experimental data from a CZT PET demonstrator developed by Kromek, shown in Figure 1. The detector system is comprised of a pair of 10 mm thick 800 μm pixel pitch CZT detectors connected to the main controlling unit. Events with two interactions in each detector were selected and analysed, Using the excellent energy and 3D position resolution which are among the strongest advantages of CZT detectors allowed reconstruction of photon trajectories along with their scattering angles. In Figure 2 we show the experimental data from the CZT system (black data points) exhibiting the clear modulations predicted by quantum mechanics. The prediction from the QE-GEANT4 simulation including entanglement (blue line) is clearly essential to reproduce the experimental data.
In addition to the experimental demonstration of quantum entanglement, we present simulated GEANT4 imaging studies of the efficacy of exploiting the implicit quantum entanglement between true PET photon coincidences. PET images of a NEMA_NU4 phantom using a simulated array of CZT detectors were obtained. 2D PET images were reconstructed from the data using simple filtered back projection (FBP) methods. A simple procedure to use the new information from the entanglement enabled spatially resolved determination of the contribution of both scatter and random coincidences to the image. The ability to extract such information purely from the data offers new opportunities for PET imaging methodologies.

The results indicate that use of CZT detector systems would allow access to previously inaccessible quantum entanglement information in PET. This offers independent, new information to quantify random and scatter backgrounds. In future work, we plan to incorporate this information into more advanced image reconstruction techniques and optimise the design of new imaging systems. The work presented has been accepted for publication at Nature Communications [6].

1 D Bohm, Y Aharonov, Phys. Rev. 108, 1070–1076 (1957).

[2] H S Snyder, S Pasternack, J Hornbostel, J. Phys. Rev. 73, 440 (1948).

[3] P Caradonna, D Reutens, T Takahashi, S Takeda, V Vegh, J. Phys. Commun. 3 (2019).

[4] M H L Pryce, J C Ward, Nature 160, 435 (1947).

[5] M A Stroscio, Phys. Rev. A 29, 1691 (1984).

[6] arXiv: 2012.04939.

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Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **266** Type: **Poster presentation only**

The CDAU - a common data acquisition unit for the radiation imaging detectors at HIRFL-CSR

The Cooling Storage Ring of the Heavy Ion Research Facility in Lanzhou (HIRFL-CSR) is constructed to study nuclear physics, atomic physics, interdisciplinary science, and relative applications. There are many different kinds of detectors for radiation imaging in the experiments at HIRFL-CSR. To reduce the development time, production cost, and maintenance difficulties of the readout electronics for the detectors, a Common Data Acquisition Unit (CDAU) has been designed as a common interface between the detector-specific electronics and the common computing system.

The geometry of the CDAU is designed according to the PCIe specification, which allows several CDAUs to be installed into adjacent PCIe slots. The central component on the board is Xilinx Kintex Ultrascale FPGA, which has 20 GTH Transceivers. The CDAU exchanges data from the detector front-end electronics with 4 serial full-duplex optical links, which are four SFP modules. The serial links are directly connected to the front-end boards with detectors by fibers, achieving a speed of up to around 16.5 Gbps. The CDAU connects with the online data computer with the PCIe interface, which is realized with the PCIe hard block in the Kintex Ultrascale FPGA for up to eight-lane PCIe Gen3 (8.0 Gbps per lane). The CDAU hosts four DDR4 SRAMs with a total size of 16 GBytes and a maximum data rate of 2400 Mbps. The CDAU also hosts a 300Mhz differential oscillator for the main FPGA. On the other hand, a configurable reference clock oscillator for the PCIe, GTH, and the DRR4 memories, which allows the interface to run at any speed within the supported range. This paper will discuss the design and performance of the CDAU.

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **267** Type: **Poster presentation + pitch**

Vernier Time-to-Digital Converter with Ring Oscillators for in-Pixel Time-of-Arrival and Time-over-Threshold measurement in 28 nm CMOS

Hybrid pixel detectors for radiation imaging suitable for 3-D particle tracking and reconstruction offer the capability of high-resolution measurement of Time-of-Arrival (ToA) parameter. ToA is the amount of time between the discriminator first edge and the moment when the shutter closes. Possible applications include electron microscopy and antimatter research 1. For example, 1.58 ns ToA accuracy of Timepix3 chip allowed for determining the parameters of antiproton annihilations [2]. Its precursors, GOSSIPO-3 and GOSSIPO-4 chips, offered TDC resolution on the order of 1.7 ns, and its successor, Timepix4 chip is planned to have 200 ps ToA resolution [3-5]. Timepix chips also include the possibility to measure Time-over-Threshold (ToT), which allows for indirect measurement of particle energy without the need to implement a separate ADC.

Our aim is to improve the ToA resolution further in nanometer technologies. This is a continuation of previous work on the development of readout integrated circuits for hybrid pixel detectors [6-8]. Vernier TDC architecture with two ring oscillators may offer resolution even on the order of 5.1 ps and should be suitable for this project [9,10]. Its operating principle is like the one of a caliper. Using two oscillators, slow and fast, whose frequencies slightly differ, a time resolution equal to the difference of their oscillation periods may be achieved. Figure 1 shows how two oscillators can be configured to measure ToA using Vernier method and ToT, gating the signal from the slow oscillator.

We are developing a chip prototype without an analog front-end that consists of Vernier TDC for in-pixel integration. Simplified schematic is shown in Figure 2. External Stop and StopToT signals represent the rising and falling edge of a discriminator, respectively. In normal mode, the slow oscillator (OSC1) is started by the Start signal, and the fast oscillator (OSC2) is started by the Stop signal. Global and local DACs and capacitance banks are used to calibrate the oscillators' frequencies. Oscillators consist of three stages built from current-starved gates (NAND gate for enable signal and two inverters). Signals for the counters (whose resolutions are given in the figure) are generated in the coincidence and counter control block. Additionally, two correction signals are generated to compensate the uncertainty of the moment when the coarse counter increments with respect to the fine counter. Figure 3 summarizes the exemplary configurations of oscillators' frequencies and counters'depths and the resulting range and resolution of ToA and ToT. Moreover, the maximum ToA conversion time TConv is estimated for each case. Currently, layout of the chip is under development. IC will be fabricated in 28 nm CMOS technology in the following months. Figure 4 presents the layout of one of the two ring oscillators with the capacitance bank.

1 R Ballabriga et al., Nucl. Instruments Methods A 878 (2018), 10-23
[2] N Pacifico et al., Nucl. Instruments Methods A 831 (2016), 12-17
[3] A Kruth et al., J. Instrum. 5 (2010), C12005
[4] F Zappon et al., J. Instrum. 7 (2012), C01081
[5] R Ballabriga et al., Radiation Measurements 136 (2020), 106271
[6] P Kmon et al., J. Instrum. 13 (2018), P01018
[7] G A Carini et al., Nucl. Instruments Methods A 935 (2019), 232-238
[8] L A Kadlubowski et al., Przegląd Elektrotechniczny 12 (2020), 115-118
[9] N Roy et al., IEEE Trans. Radiation Plasma Medical Sci. 1 (2017), 486-494
[10] F Nolet et al., Electronics Letters 56 (2020), 424-426

Figure. 1. Concept of ToA/ToT measurement using two ring oscillators.
Figure. 2. Simplified system schematic.
Figure. 3. Measurement parameters for several configurations of oscillator frequencies.
Figure. 4. Ring oscillator layout: (1) oscillator core with current starving, (2) capacitance bank, (3)

enable signal buffer, (4) output buffers. Dimensions are given for three variants including transistor structures, supply wiring and separate N-well.

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **268** Type: **Oral presentation**

Electron detection with CdTe and GaAs sensors using the charge integrating hybrid pixel detector JUNGFRAU

Monday, June 28, 2021 11:40 AM (20 minutes)

JUNGFRAU is a charge integrating hybrid pixel detector developed for use at X-ray free electron lasers. With in pixel gain switching it provides single photon sensitivity down to 2 keV while maintaining a dynamic range of 120 MeV. The pixel size is 75 x 75 μm^2 and the largest detector currently in use has 16M pixels. The characteristics of Jungfrau makes it an interesting detector for electron detection, capable of both providing information about the energy deposition of single electrons, in the low flux regime as well as measuring very high fluxes, for example in diffraction experiments, due to the charge integrating architecture. Exploiting the possibility to acquire per pixel information on energy deposition and leakage current it also is a useful tool for sensor characterization.

While Silicon sensors coupled to hybrid pixel detectors show good results up to ˜100 keV [1, 2], at higher electron energies multiple scattering in the sensor layer reduces the spatial resolution. One strategy to mitigate this is to use a high Z sensor material which gives a shorter track of the primary electron. In this work we compare Si, GaAs and CdTe sensors bump bonded to JUNGFRAU and present results on energy resolution, cluster size and modular transfer function. The measurements were carried out using a 300 keV FEI Tecnai G2 Polara microscope at 100, 200 and 300 keV. We also compare the results to simulations done in Geant4.

1 J. Mir, R. Clough, R. MacInnes, C. Gough, R. Plackett, I. Shipsey, H. Sawada, I. MacLaren, R. Ballabriga, D. Maneuski, V. O'Shea, D. McGrouther, A. Kirkland, Characterisation of the Medipix3 detector for 60 and 80 keV electrons, Ultramicroscopy 182 (2017) 44–53.

[2] G. Tinti, E. Fröjdh, E. van Genderen, T. Gruene, B. Schmitt, D. A. M. de Winter, B. M. Weckhuysen, J. P. Abrahams, Electron crystallography with the EIGER detector, IUCrJ 5 (2) (2018) 190–199.

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Session Classification: Oral presentations

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **269** Type: **Poster presentation only**

Neutral Bremsstrahlung scintillation emission in xenon optical TPCs

Xenon TPCs with optical readout are being increasingly applied to rare event detection, in the important fields of cosmology and particle physics, e.g. dark matter search or neutrino physics studies such as double-beta decay, double electron capture and neutrino detection.
Through the years, it was assumed that secondary scintillation in noble gases was solely due to VUV emission from excimers, created in a three-body collision of two neutral atoms and one excited atom produced by electron impact, being the Neutral Bremsstrahlung (NBrS) emission ignored. Recent studies have shown the presence of NBrS in argon.
We have measured, for the first time in pure xenon, non-excimer-based secondary scintillation, Neutral Bremsstrahlung, in a dedicated setup based on a Gas Proportional Scintillation Counter. We present an unambiguous identification of NBrS emission in xenon TPCs, and provide a quantitative assessment of the NBrS emission yield as a function of reduced electric field, sup-ported by a predictive theoretical model of this light-emission process. We have implemented a robust theoretical model describing the experimental data with accuracy. The relevance of xenon NBrS emission in the context of rare event experiments will be discussed.
The emission of NBrS by drifting electrons occurs even for electric field values below the gas excitation threshold. We have shown the presence of NBrS in the NEXT-White TPC, at present the largest optical HPXe-TPC in operation (~ 5 kg of xenon at 10 bar).
Moreover, for field values above 1 kV/cm/bar, as typically employed for electroluminescence (EL), there is consistent evidence that NBrS is present with an intensity about two orders of magnitude lower than conventional, excimer-based, EL.
Despite fainter than EL, in pure xenon, this "new"source of emission has to be accounted for in xenon optical TPCs and may play an important role in future single-phase LXe TPCs.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **270** Type: **Oral presentation**

WiggleCam: a method to cope with inter-sensor gaps for high-framerate tiled sensor arrays

Tuesday, June 29, 2021 11:00 AM (20 minutes)

In order to keep down costs and control yields, large area hybrid detectors are commonly implemented using multiple sensor tiles in various geometries. Due to the presence of guard rings, readout connections and other design considerations it is practically impossible to make tiled sensor arrays where the tiles meet up exactly. Even in the case of four side buttable sensors, arrays will still have some measure of dead space between the tiles. A variety of hardware and software techniques currently exist to fill in the inactive space, such as roof tile arrangements of sensor tiles, software interpolation to fill in gaps, and stitching together multiple overlapping but shifted exposures. All of these techniques present their own drawbacks, from greatly increasing hardware complexity, introducing undesirable artefacts in certain applications, or increasing measurement times and experimental overhead.

The authors propose a novel technique, called WiggleCam, for mitigating inactive regions and malfunctioning pixels in X-ray cameras which use very high frame rates (often exceeding 1 kHz). This is commonly the case in hyperspectral imagers, which provide raw ADC output frames at very high time resolution for energy dispersive single photon detection. In this work we present the results of a proof-of-concept implementation of the method using a HEXITEC 2x2 camera1 mounted on an XY-stage, with all data processing done using SpeXIDAQ, the in-house developed framework for hyperspectral imagers[2]. A practical implementation requires access to the raw high-framerate camera output before it is integrated into the final exposure. By moving the detector such that every section of the region of interest is imaged at least part of the desired exposure time, and shifting the individual photon events using the coincident detector position in the lab frame before integration, any inactive areas are fully covered. By then compensating for the non-uniform exposure time no deterministic motion path is required, and a final image output is obtained free from gaps, without temporal overhead, and with no further post-processing required by the end-user.

The method is shown to accurately compensate for the inter-tile gaps without compromising the spatial and spectral resolution. It also provides a way to increase the effective spatial resolution without physically reducing the pixel pitch. This presentation will conclude by demonstrating a new camera device under development using multiple HEXITEC sensors, designed to include the Wigglecam method in the camera construction itself for a more compact and useful implementation.

1 Wilson, Matthew D., et al. "Multiple module pixelated CdTe spectroscopic X-ray detector"IEEE Transactions on nuclear science 60.2 (2013): 1197-1200
[2] Van Assche, Frederic, et al. "The Spectral X-ray Imaging Data Acquisition (SpeXIDAQ) Framework"Sensors 21(2) (2021): 563

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Session Classification: Oral presentations

Track Classification: Front end electronics and readout

Contribution ID: **271** Type: **Poster presentation only**

A new six-sensor HEXITEC readout incorporating the WiggleCam technique

Larger field of view hybrid photon counting detectors are commonly constructed using multiple distinct sensor tiles, keeping costs and process yields within reasonable parameters. It is however practically impossible to make these multiple tiles form one gapless active detection surface, especially if uniformly sized pixels are desired. While multiple existing techniques and technologies aim at either reducing the size of these gaps or filling in missing information using various algorithms, some tiling artefacts are hard to avoid without other drawbacks or high device costs.

A novel technique, WiggleCam, has been developed by the authors to fill any inactive regions (due to tiles or faulty pixels) with real measured photons using precise movement of the sensors. This technique completely removes tiling artefacts with no overhead placed on the user. While this technique has been successfully demonstrated using a HEXITEC 2x2 camera1 mounted on an external movement stage, further refinement and mechanical miniaturisation is required for applied use.

In parallel to this, the SpeXIDAQ[2] software framework for hyperspectral X-ray cameras has been developed at Ghent University. In order to benefit maximally from both the WiggleCam technique and the SpeXIDAQ framework, a custom designed readout platform is being designed, incorporating six HEXITEC ASICs in a 2x3 tiled array setup. By opting for a 10 Gbps fibre connection, the full 9kHz design framerate can be transferred and processed simultaneously for all six ASICs, an improvement over the 6.3kHz limit of the USB3 connection used in the existing HEXITEC 2x2 readout. Moving the WiggleCam motion system into the camera itself reduces the amount of mass that needs to be moved, and increases the precision of the system as a whole. It also makes for a much more compact camera system, able to be mounted at beamlines and lab facilities the same way a conventional photon counting camera would be.

Additionally, this readout platform serves as a testbed for on-FPGA processing and compression techniques to be developed in tandem with the SpeXIDAQ framework. This hardware-assisted processing of hyperspectral X-ray camera data will greatly benefit the implementation of readout systems for future much higher bandwidth hyperspectral ASICs, which will see single sensor output rates approaching 100 Gbps. Any reduction of the required output bandwidth and off-camera processing power would be favourable for applications of these next-generation ASICs, if cheaper data transfer technologies and processing hardware can be considered without loss of performance.

1 Wilson, Matthew D., et al. "Multiple module pixelated CdTe spectroscopic X-ray detector"IEEE Transactions on nuclear science 60.2 (2013): 1197-1200
[2] Van Assche, Frederic, et al. "The Spectral X-ray Imaging Data Acquisition (SpeXIDAQ) Framework"Sensors 21(2) (2021): 563

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **272** Type: **Poster presentation only**

Radiation Background Simulation and Comparison with data for the GE1/1 Triple-GEM detector

The CMS experiment has planned to upgrade its muon system with GEM technology referred to as GE1/1, GE2/1 and ME0 for enhancing physics output. The GE1/1 chambers have already been installed in 2020 and are currently being commissioned. A zero-bias data set was taken to measure the radiation background from the GE1/1 demonstrator known as the "Slice Test". It is known that the background radiation field is mainly composed of low energy neutrons, photons, electrons/positrons and charged hadrons, namely kaons, pions, and protons. Accurate modelling of the backgrounds using simulations is critical, as an estimation of the expected radiation background for the Phase-2 upgrade can only rely on Monte Carlo-based simulation. In this study, the prediction of radiation background using FLUKA and GEANT4 simulation for the "Slice Test" configuration of the GE1/1 detector is compared with the data.

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Presenter: Mr KUMAR, Sunil (Panjab University (IN))

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **274** Type: **Poster presentation only**

Performance of high-density indium bump-bonding.

About half of the ATLAS pixel modules have been produced with the Indium bonding technology [1,2].

The building blocks are modules made of a silicon sensor tile (pixel size of 400x50 µm2, with a sensitive area 16,4 x 60,8 mm2) and 16 front-end (FE-I3, 200 µm thick and 7,6 x 10,8 mm2 area) integrated circuits, each serving 18 x 160 pixels. Bumps are at the same time the electrical and the mechanical connection between sensor and electronics and they are a crucial component of the detector assembly. The general ATLAS requirements for bump deposition are:
• a bump pitch of 50 µm with a defect rate < 10-4;
• a density of 5000 contacts/cm2, or 2880 bumps per readout IC
The new ITk ATLAS silicon detector has more stringent requirements for the read-out chip: the new front-end has been developed with a pixel size of 50 x 50 µm2, to cope with high hit rates, in a 65 nm feature size bulk CMOS process, in view of future ATLAS high luminosity pixel applications. In order to reduce the detector material, thinning the sensors down to 100 µm and 150 µm and the FE to 150 µm is foreseen.
From the bumping point of view, the higher density requirement of 40000 contacts/cm2, with the same minimum bump pitch, is achievable. The critical parameters for the bonding process are the larger size of the bonding area, about 20x20 mm2 per front-end chip, together with the requirement of a thinned devices. Handling of such a thin and large chip, planarity with respect to the sensor during flip-chip, deformations coming from internal stress of the chip and/or working temperature during the bonding step, are possible origin of problems for the hybridization step.
The Indium bump bonding technique is an appealing candidate for coping with these problems because it requires just one Under-Bump Metallization (UBM) step and a low (90 ˚C) maximum working temperature of the process. Therefore, a research and development collaboration has been arranged between INFN and Leonardo to develop this process up to the point to produce assemblies with sensors thinned down to 100 µm.

To qualify that the process is coping with these requirements, the ATLAS collaboration tested several prototypes assembled with half size, double chip modules (two 11.6x20 mm2 FEs bonded to a 10.9x41.05 mm2 sensor): results from these prototypes will be presented and discussed.

1 G.Alimonti et al., Analysis of the production of ATLAS indium bonded pixel modules, Nucl. Instr. and Meth. A 565 (2006) 296
[2] G. Aad et al., ATLAS pixel detector electronics and sensors. JINST 3(07):P07007, 2008.

Authors: ALIMONTI, Gianluca (Università degli Studi e INFN Milano (IT)); Prof. ANDREAZZA, Attilio (Università degli Studi e INFN Milano (IT)); Dr ANTONELLO, Massimiliano (Universität Hamburg); CARBONE, Antonio (Università degli Studi e INFN Milano (IT)); DAAS, Michael (University of Bonn (DE)); Dr HÜGGING, Fabian (University of Bonn); MONZANI, Simone (Universita degli Studi di Udine (IT)); SABATINI, Fabrizio (Università degli Studi e INFN Milano (IT)); CERVATO, Beatrice (Università degli Studi e INFN Milano (IT))

Presenter: CERVATO, Beatrice (Università degli Studi e INFN Milano (IT))

Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **276** Type: **Poster presentation + pitch**

Characterisation of a double-sized Timepix3 mini-tracker for nuclear fragment detection in carbon-ion radiotherapy

Carbon-ion therapy is a form of external-beam radiotherapy used for highly precise cancer treatment. The characteristic depth-dose deposition curve of carbon ions exhibits a large dose gradient at the end of the beam range, the so-called Bragg peak. The position of the Bragg peak in the tumour is sensitive to anatomical changes such as tumour shrinkage or cavity filling. Therefore, the measurement of the beam range in the patient during treatment would allow improving the accuracy of carbon-ion radiotherapy. This real-time treatment verification could potentially be achieved by detecting charged fragments produced in nuclear interactions of the carbon ions with the patient. A fraction of those fragments emerges from the patient as secondary radiation. The quality of the conclusions drawn for an individual patient increases with increasing number of detected fragments, thus motivating the development of detectors with a large sensitive area.

In this work, a novel mini-tracker made of a pair of double-sized Timepix3 detectors (AdvaPIX TPX3 1x2x2 Stack, ADVACAM s.r.o., Prague, Czech Republic) is investigated for its suitability for measuring nuclear fragments that emerge from an irradiated head model. Each of the two detectors has a sensitive area of 2.8x1.4 cm2 divided into 512x256 pixels with a pixel size of 55x55 um2. The thickness of the silicon layer is 500 um. The two detectors are arranged one behind another at a distance of 20.3 mm, enabling the reconstruction of fragment tracks via cluster matching. The measurements were performed at the Heidelberg Ion Beam Therapy Centre (HIT, Heidelberg, Germany). The head model was irradiated with different clinical carbon-ion beams in order to generate a realistic fragment field (carbon-ion pencil beam energies range from 168 to 239 MeV/u). The experimental method has previously been described in Felix-Bautista et al. (2019) 1.

The pixel detector performance was characterised in the mixed fragment field. Cluster size, detector synchronisation as well as precision and accuracy of the track reconstruction were analysed. This analysis allowed finding the optimum working point in terms of bias voltage, energy threshold, detection angle with respect to the beam axis and detector distance to the head model. Moreover, the detector performance at high fragment intensity is of particular interest due to the large number of fragments generated in certain anatomies. The results help to inform the design of a detection system that will be used in an upcoming clinical trial.

1 R Felix-Bautista et al 2019 Phys. Med. Biol. 64 175019

Authors: Dr KELLETER, Laurent (German Cancer Research Center DKFZ); SUBRAMANIAN, Meera (DKFZ); GHESQUIERE-DIERICKX, Laura (DKFZ); GEHRKE, Tim (German Cancer Research Center (DKFZ)); FÉLIX-BAUTISTA, Renato (DKFZ); ECHNER, Gernot (DKFZ); GRANJA, Carlos (Advacam); JAKUBEK, Jan (ADVACAM s.r.o.); JAKUBEK, Martin (Advacam); MAREK, Lukas (Czech Technical University (CZ)); SOUKUP, Pavel (Department of Research and Development, ADVACAM s.r.o., Czech Republic); TURECEK, Daniel (ADVACAM); Dr MARTIŠÍKOVÁ, Mária (German Cancer Research Center (DKFZ))

Presenter: Dr KELLETER, Laurent (German Cancer Research Center DKFZ)

Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **277** Type: **Poster presentation only**

4H-Silicon carbide as particle detector for high-intensity ion beams

In ion cancer therapy high intensity ion beams are used to treat tumors by taking advantage of the Bragg-Peak 1. Typical ion therapy centers use particle rates up to 10ˆ10 ions/second for treatment [2]. On the other hand, such intensities are often too high when using these beamlines for particle physic experiments or as a test-beam environment in general. The project presented here aims to develop a beam position and intensity monitor, to cover the full intensity spectrum from a few kHz up to GHz rates as used in clinical settings.

Silicon carbide has been chosen as detector material because it combines not only a high radiation hardness with a high bandgap [3], but also for its affordability. Additionally, the fast charge collection can help to mitigate pile-ups in the high-rate regime.

The readout electronics is developed completely from scratch, starting in discrete electronics for one channel. This will be expanded to multiple channels in discrete electronics first and later integrated into an ASIC. The electronics comprises a transimpedance and a voltage amplifier, a comparator, and an FPGA, which uses time over threshold measurements for robust pile-up detection.

In this presentation, the first measurements on a single channel SiC sample are shown in comparison to other common sensor materials like silicon and diamond. All these sensors were tested in the laboratory using radioactive sources and a readout prototype for a one channel sensor. Moreover, the prototype, which was successfully tested in MedAustron with a proton beam in a wide intensity range (kHz –GHz) and with different energies (60 –800 MeV), is presented (Figure 1, Figure 2).

1 O. Jäkel, Br. J. Radiol., vol. 93, no. 1107, p. 20190428, Mar. 2020
[2] F. Ulrich-Pur et al., Feb. 2021, Accessed: Mar. 02, 2021. [Online]. Available: http://arxiv.org/abs/2102.06240.
[3] F. H. Ruddy, A. R. Dulloo, J. G. Seidel, J. W. Palmour, and R. Singh, in Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Jun. 2003, vol. 505, no. 1–2, pp. 159–162

This project received funding from the Austrian Research Promotion Agency FFG under the Bridge framework (project number 883652)

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Presenter: CHRISTANELL, Manuel

Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **278** Type: **Poster presentation only**

Therapeutic Carbon-Ion effects on Monolithic Active Pixel Sensor with 130nm High-Resistivity Process

The Wuwei radiotherapy centre is the first carbon ion therapy facility in China .It can deliver 12C6+ beam with the energy up to ˜410 MeV/A. The beam delivery system in the therapy facility ensures the beam energy deposition can cover the dedicated region in the body. It has been shown that Monolithic Active Pixel Sensors (MAPS) are very promising tools for direct online beam monitoring. Thus, a Monolithic Active Pixel Sensor (MAPS) with 25μm pitch is currently being designed in a novel 130nm High-Resistivity (>1kΩ·cm) CMOS process with the bulk depth of ˜500μm.

Charge deposited by the carbon ions that pass through the MAPS is collected by the charge sensing node, which is formed by an n- well–p- substrate junction. The charge goes into the shaper and the amplifier insides each pixel and then read out by the in-chip scan circuitry. To improve the capability of charge collection, a reverse bias voltage is supplied to the p- substrate to increase the depletion region. Aiming for a comprehensive understanding of the carbon-ion induced process in the MAPS, a 3-dimensional TCAD model has been established. The thickness of the depletion layer, charge collection efficiency, charge collection time and characteristics of NMOS devices with different bias voltages and carbon-ion hitting locations have been deeply studied. This paper will discuss the simulation and analysis of the effects of the carbon ion on the MAPS.

Authors: Prof. ZHAO, Chengxin (Institute of Modern Physics, CAS); Ms DUAN, Jinhong (Harbin Institute of Technology)

Presenter: Prof. ZHAO, Chengxin (Institute of Modern Physics, CAS)

Session Classification: Poster session 2

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **279** Type: **Poster presentation only**

The commissioning of PIMEGA-540D: a Medipix3RX based Large Area Detector

PiTec is designing and producing, in collaboration with the Brazilian Synchrotron Light Laboratory (LNLS) at CNPEM, the PIMEGA large area X-ray detectors to supply the experimental demands of Sirius, the new 4th generation storage ring. The detectors are based on hybrid pixel technology, consisting of semiconductor silicon pixeled sensors assembled over arrays of the Medipix3RX (ASIC). The PIMEGA-135D modules are 2.4 Mpx detectors with 36 ASICs arranged in a 6x6 in either coplanar or overlapped configuration, with sensor thicknesses of 300 µm or 675 µm, depending on the target application. These modules can be easily stacked up to produce large detection areas.

The PIMEGA-540D (Figure 1) is a 9.4 Mpx detector composed of four PIMEGA-135D modules, assembled in a 2x2 configuration, each module is rotated by 90 degrees and positioned with an adjustable gap at the center for the direct beam.

The CATERETÊ beamline (Coherent and Time-Resolved Experiments) is the first beamline of Sirius to receive one fully mounted module of PIMEGA-540D This experimental station is under commissioning and is dedicated to coherent x-ray scattering applications, such as Coherent X-ray Diffractive Imaging (CXDI) and X-ray Photon Correlation Spectroscopy. During the commissioning of the PIMEGA 540D at the beamline, experiments involving the pixels' matrix equalization, full depletion analysis, energy calibration, and flat-field correction have been performed to test and calibrate the detector. This poster will present these experimental results and the main characteristics and scientific potentialities of these detectors.

The Sirius project is funded by the Brazilian Ministry of Science, Technology, and Innovation.

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Presenter: MENDES, Larissa Helena (PiTec)

Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **280** Type: **Poster presentation + pitch**

Waveform Analysis Using Machine Learning Algorithms on the Front-end Electronics

In a multi-channel radiation detector readout system, waveform sampling, digitization and transmitting bits to the data acquisition system constitutes a conventional processing chain. The quantities, such as time-of-arrival and signal magnitude, i.e. deposited energy is estimated by fitting analytical models over the acquired digital data extracting starting times of signals, peak amplitudes, or areas under pulse envelopes. However, such a data processing could be carried out through machine learning algorithms on the front-end ASICs often termed as edge computing. Edge computation offers enormous benefits, especially when the analytical forms are not fully known, or the registered waveforms suffer from imperfections of practical implementations. Also, experimental findings early in the data processing chain often reduces bandwidth of the data throughput, thereby reducing overall cables in any of the experiment.
Our study has focused on investigation of various neural networks and their implementation, training them with sensor signals of single peak from a single-channel typical from a silicon sensor for predicting peak amplitude. The sampling rate has been reduced, resulting 3 to 4 sample points on the signal peak. We have investigated two types of neural network: MultiLayer Perceptron (MLP) and 1D-Convolutional Neural Network (CNN) till date. Both are popular choices for common machine learning tasks and offer different characteristics of computation complexity and parameter efficiency. These neural networks are optimized in terms of hidden layers, neurons and weights through pruning while still maintaining an acceptable inference accuracy. In this workshop, we would like to present the overall performance and hardware requirements for the Multi-Layer perceptron (MLP) and the Convolutional Neural Networks (CNN) in predicting the peak amplitude of a single channel sensor response.

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **281** Type: **Oral presentation**

Development of an intensified neutron camera system for high sensitivity white-beam imaging

Monday, June 28, 2021 3:30 PM (20 minutes)

Thermal Neutron Imaging is a steadily expanding area of imaging technology and techniques with increasing interest from applications such as cultural heritage, palaeontology, and metallurgy [1,2]. Increased demand for access combined with a limited number of suitable beamlines requires efficient use of available beamtime [3,4]. N-Cam is a new experimental neutron camera system designed with increased sensitivity, thus able to capture detailed images with reduced exposure time as compared to most neutron cameras. N-Cam utilizes a 20μm thick Gadox scintillator applied directly onto the input window of an image intensifier. In experiments performed at the Rutherford Appleton Laboratory ISIS-IMAT facility, N-Cam demonstrated high contrast imaging with 10 lp/mm spatial resolution in 5 second exposures over a 75mm field of view. The Modular Transfer Function was calculated at multiple positions to assess the direction dependence of spatial resolution as seen in Figure 1. The fractional standard deviation of a 24 mm × 24 mm region is given as a function of binned pixel size in Figure 2, where T = 5 seconds and Fn = 2 × 107 n/(s·cm2). The data are well fit with the given equation, resulting in an estimated DQE = 16%. Additional data on contrast-to-noise and tomography will also be presented.

1 B. Schillinger et al, J. Imaging, 4(1) (2018), 22
[2] E. Lehmann et al, Physics Procedia, 88 (2017), 5 –12
[3] W. Kockelmann et al, J. Imaging, 4(3) (2018), 47
[4] E. Lehmann et al, Physics Procedia, 88 (2017), 140 –147

Authors acknowledge the support of the UK government and STFC Rutherford Appleton Laboratory

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Presenter: Dr HINK, Paul (Photek USA LLC)

Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **282** Type: **Oral presentation**

High-angular resolution tracking of energetic charged particles in wide field-of-view with compact tracker telescope MiniPIX Timepix3 1×2 Stack

Monday, June 28, 2021 11:20 AM (20 minutes)

We developed a highly integrated particle telescope assembled from two Timepix3 ASIC chip detectors 1 operated and readout in sync with highly integrated MiniPIX readout interfaces. The pixel detectors are used as particle trackers stacked on top of each other (see Fig. 1a) being accommodated in close geometry. The small distance gap (about 10 mm) between the pixel detectors provides a wide field-of-view (FoV) of about 1/3 of the full 2π with high angular resolution (sub-degree). The remaining FoV, about 2/3 of full 2π, which corresponds to particles incident at large angles (>35°) to the plane of the sensors, can be covered by each of the detectors separate. The angular resolution in this remaining region is few degrees [2] and, in a narrow range, also sub-degree (for very large incident directions and grazing angles). This configuration also enables to register all energetic charged particles in full tracking mode i.e. with tracks having elongated morphology which allows performing high-resolution tracking. This enables to derive precise wide-range spectrometric and tracking information of individual particles e.g. precise LET and also provide enhanced particle-type resolving power of up to 8 event classes [3]. The device is controlled, operated and readout via two USB 2.0 connectors (each tracker detector is connected to a separate USB port). Communication and fast clock timing synchronization between both trackers is realized by the SPI ports. The coincidence timing window between both trackers is in the range 50 −100 ns. Control, operation and data readout is performed on standard PC/laptop and the software package PIXET. Test measurements were performed with energetic i.e., penetrating charged particles, 5–25 MeV electrons (at the Microtron MT-25 electron accelerator) and 8–36 MeV protons –see Fig. 1, (at the cyclotron U–120M proton/light ion accelerator) both at the NPI-CAS in Rez near Prague. Future measurements and novel applications include space radiation studies in outer space, nuclear and cosmic ray physics and particle radiotherapy research.

1 T. Poikela et al., Timepix3: a 65k channel hybrid pixel readout chip with simultaneous ToA/ToT and sparse readout, J. of Instrum. JINST 9 (2014) C05013
[2] C. Granja et al, Directional detection of charged particles and cosmic rays with the miniaturized radiation camera MiniPIX Timepix, Nucl. Instrum. and Meth. A 911 (2018) 142-152
[3] C. Granja et al., Resolving power of pixel detector Timepix for wide-range electron, proton and ion detection, Nucl. Instrum. Meth. A 908 (2018) 60-71

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Presenter: Dr GRANJA, Carlos (Advacam)

Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **283** Type: **Oral presentation**

Characterization of the ePixM monolithic CMOS sensor for soft X-rays

Tuesday, June 29, 2021 3:40 PM (20 minutes)

ePixM is a charge-integrating pixel detector which is being developed for soft X-rays experiments at LCLS-II. To enable single-photon detection with photon energies down to 250 eV, a monolithic active pixel sensor has been designed on a CMOS 150 nm process with a high-resistivity substrate 1. The sensor is fully depleted, so charges are collected by drift. The back-side of the wafers has been post-processed at SLAC to form a thin entrance window [2]. Small-scale devices, consisting of 48x48 pixels, have been mounted on a dedicated carrier board, as shown in Figure 1. The response of the pixel circuitry has been measured with a calibration signal injected at the pixel input, as shown in Figure 2, as well as with an Fe55 source. Both the automatic gain-switching capability and the correlated pre-charging technique are functional. A readout noise of 16 electrons has been measured with the devices operated at room temperature. The performance of the sensor and of the readout electronics will be presented.

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Presenter: ROTA, lorenzo (Stanford University)

Session Classification: Oral presentations

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **284** Type: **Poster presentation only**

Application of MPX3 camera with monolithic sensor for phase contrast imaging and computed tomography

New WidePIX camera assembled form 2x5 Medipix 3 chips is equipped with common monolithic 500 um thick silicon sensor. This monolithic sensor ensures uniform response of the camera thanks to the homogenous electric field, higher possible operation voltage which enables thicker sensor comparing with edgeless chips, which are used for large area detectors assembled from single chips 1. Besides of good image response, camera allows arbitrary selected energy channel as single photon counting Medipix 3 detector has 2 energy thresholds. Read-out of the camera is realized with two independent read out channels based on USB3 protocol, each one operates subassembly 1x5 chips, therefore maximal frame rate 400 fps is available for the whole camera.

It was already demonstrated in the past that pixelated detector Timepix with one energy threshold may be very useful for high resolution and material sensitive tomographic imaging of the fibre composites [2] (although images were distorted by the edges of the sensors). Concurrently, energy threshold may help to identify delamination thanks to the phase contrast effect occurring on the crack faces [3]. Improvement of the image quality and delamination detectability will be demonstrated on the same carbon fibre sample. Newly, fusion of the X-ray computed tomography reconstruction with 3D shape of the delamination reconstructed from phase contrast images taken from certain number of angles will be presented.

It was also already shown, that 2Hz tomography is possible in laboratory conditions [4], however only single chip detector Timepix was used there. Such fast tomography with higher spatial resolution will be demonstrated as other case study.

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Presenter: VAVRIK, Daniel

Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **285** Type: **Oral presentation**

SparkPix-ED: a readout ASIC with 1 MHz frame-rate for rare event experiments at LCLS-II

Tuesday, June 29, 2021 3:20 PM (20 minutes)

The LCLS-II accelerator will provide pulses with a repetition rate of up to 1 MHz. To cope with the increase in repetition rate, a new family of detectors named SparkPix is being developed at SLAC. SparkPix-ED is the first detector based on the Event-Driven information extraction engine, which combines high-frame rates and a triggering capability. Coarse X-ray images are streamed out at 1 MHz in a "Continuous Wave"(CW) mode. These images will be processed by an external computing layer to detect rare events and generate a "trigger"signal when one is found. While the low-resolution images are streamed out, the ASIC records high-resolution images on a pulse-by-pulse basis at 1 MHz repetition rate. The high-resolution images are stored in a local memory implemented as a circular buffer with depth N (in the first prototype, N=4). In this manner, when a rare event is detected, N high-resolution images taken around the event can be read-out.

The ASIC can also be operated as stand-alone in high-resolution mode, trading off frame-rate for spatial resolution and noise performance. In this case, the frame-rate scales down to 100 kHz with continuous readout.

The first prototype has been designed with a CMOS 130 nm technology. Due to the high level of parallelism required to achieve 1 MHz operation, analog-to-digital converters and control logic has been distributed in the pixel matrix. The first prototype has been received and characterized with a dedicated carrier board, as shown in Figure 1. At the time of writing, the functionality of all blocks has been demonstrated, as shown in Figure 2. Detailed results about the performance will be presented at the conference.

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Presenter: ROTA, lorenzo (Stanford University)

Session Classification: Oral presentations

Track Classification: Front end electronics and readout

Contribution ID: **286** Type: **Poster presentation + pitch**

An improved method to assess the incident angle and LET of protons using a compact Timepix-based detector

High-sensitivity hybrid semiconductor pixel detectors can provide precise and wide-range spectrometric and directional information of energetic charged particles in mixed radiation fields. The high-granularity, small pixel size and integrated signal processing at the pixel level allow performing single-particle tracking with high-spatial resolution and spectral response. Through detailed pattern recognition analysis of the pixelated clusters created by single particles, an enhanced resolving power of particle-event type can be achieved. The miniaturized radiation camera MiniPIX-Timepix proves to be particularly useful for characterizing primary and secondary radiation in particle therapy. Wide-range data can be obtained such as deposited energy, linear energy transfer (LET) spectra and angular distribution of particles in a wide-field of view 1. LET is mainly crucial for particle therapy and is an important parameter in assessing the biological effectiveness of the treatment. Using Timepix detectors, the calculation of LET is based on the deposited energy and the particle's track length which depends on the elevation angle. However, the existing methodology for the assessment of the elevation angle and thus the path length and the LET using a single Timepix chip is limited to particles with incident angles greater than 20º and with a limited angular resolution for incident angles smaller than 28º [2].

In this work, we present a new model to derive the proton's incident angle based on a morphological analysis of the cluster track parameters, namely, track path length, roundness and linearity. Using this method, we have extended the angular sensitivity of the detector down to an elevation angle of 0º (normal incidence) for Timepix detectors equipped with 300 and 500 μm thick silicon sensors. This enables the reconstruction of the particle's incident angle with an improved angular resolution of a few degrees over the full solid angle (2). As a result, the calculation of the track length across the sensor is extended and further improved, which is an essential parameter for estimating the LET. The model is applicable to protons with sufficient energy to cross the sensitive layer of the detector. By using this method, the LET spectra of a wide-range of proton energies (10 MeV to 200 MeV) were measured and compared with Monte Carlo simulations using TOPAS. A very good agreement was found between measurements, simulations and the electronic stopping power based on PSTAR (see figure 1). At low energies, approaching the Bragg peak region, variations in the measured LET values arise due to a greater difference in the energy loss registered along the single tracks especially for low-energy particles incident at large angles –e.g. 12 MeV protons at 60°. Our method shows that precise LET calculation and directional response with accurate angular resolution in extended range can already be obtained with a single layer Timepix detector reducing the need for a stacked telescope array. In future work, we will investigate how a similar approach can be applied to ions heavier than protons.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **287** Type: **Oral presentation**

High-spatial resolution measurements with GaAs sensor with the charge integrating MÖNCH detector

Wednesday, June 30, 2021 11:20 AM (20 minutes)

In contrast to silicon-based sensors, high-Z sensors materials like GaAs or Cd(Zn)Te provide a good quantum efficiency for the detection of hard X-rays above 15 keV. However, high-Z sensors require a careful characterization to better understand their performance since they typically suffer from crystal inhomogeneities, charge-trapping (leading to the so-called polarization effect) and high energetic fluorescence photons which are not present in silicon. Extensive studies performed with GaAs:Cr sensors bump-bonded to the charge integrating detector JUNGFRAU have proved that JUNGFRAU with GaAs:Cr is a promising X-ray detector for imaging applications at synchrotron facilities for high energies 1[2].
In this work we present a GaAs:Cr sensor bump-bonded to a MÖNCH readout chip. The MÖNCH0.3 detector [3] is a low-noise charge-integrating hybrid pixel detector which has 160k, 25 µm pitch pixels covering an active area of 1 x 1 cm2 with a noise of 35 electrons ENC (rms) with Si sensors.

Recently we have characterized a GaAs:Cr sensor bump-bonded to MÖNCH03 and we measured a low noise of ˜80 e- ENC in high gain mode and at 6 µs exposure time.Recent imaging measurements acquired with a GaAs:Cr sensor mounted to a MÖNCH readout chip have shown that it is possible to use subpixel interpolation algorithms and thus enhance the spatial resolution beyond the actual pixel size. In this contribution, first imaging results of a Siemens Star with GaAs and Silicon based sensors acquired at the TOMCAT beamline of the Swiss Light Source at energies from 10 keV to 30 keV will be presented. We will show the preliminary results on the quantum efficiency as a function of the energy for both sensor materials, the energy dependent spatial resolution (affected by fluorescence / charge sharing), including energy-binned imaging achievements as well as a quantitative evaluation of the spatial resolution by means of determining the MTF.

These preliminary results are very promising since they open new possibilities to apply interpolation algorithms for micrometre resolution for colour imaging with MÖNCH at high energies. Further measurements with an X-ray microfocus tube are under way to exploit the energy-resolving power of colour imaging.

1 D. Greiffenberg et al. JINST (2019) 14 P05020

[2] D. Greiffenberg, et al. Sensors (2021),21, 1550

[3] R. Dinapoli et al, J. Instrum. 9 (2014) p. C050115.

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Session Classification: Oral presentations

Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **288** Type: **Poster presentation + pitch**

Three-dimensional visualization of a beta-emitting nuclide by combining a directional Geiger-Mueller counter and Structure from Motion

At the Fukushima Daiichi Nuclear Power Station (FDNPS) where the accident occurred due to large tsunami caused by the Great East Japan Earthquake of 11 March 2011, it is important to understand and visualize the distribution of radioactive substances in order to reduce exposure dose of workers and to establish decontamination plans.
We focused on the importance of visualizing beta-emitting nuclides in addition to gamma-emitting ones to reduce the exposure dose of workers at the FDNPS, and proposed a method for three-dimensional (3-D) visualizing the position of beta-emitting ones. It is also important in discussing the effective dose of the crystalline lens of the eye.
We prepared a directional detector to beta rays by equipping the Geiger-Mueller (G-M) counter with a resin collimator. By combining the counter with Structure from Motion (SfM) technology using a digital camera, the self-position and posture information of the measurement system on the movement trajectory can be estimated one by one. Since the counter has directivity, it is possible to estimate the position of the beta-emitting nuclide on the 3-D model reconstructed with SfM from each position on the movement trajectory. In the demonstration test, the 90Sr- source position was visualized in three dimensions. In the presentation, detailed visualization techniques will be reported.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **289** Type: **Oral presentation**

First user experiments of the PERCIVAL soft X-ray imager

Tuesday, June 29, 2021 2:30 PM (20 minutes)

The PERCIVAL detector is a CMOS imager specifically designed for the soft X-ray regime. In 2020, although still in a development phase, it served its two first user experiments, at a Storage Ring (SR) and also at a Free Electron Laser (FEL). We will report some preliminary results and sketch future plans.
With its 2 Megapixels, 27 µm pixel size, and 4 x 4 cm2 active area (extendable to 8 x 8 cm2 in clover-leaf like configurations), PERCIVAL can provide images with high spatial resolution. Moreover, its fast readout was designed to reach speeds up to 300 frames per second. In fully optimised mode, the sensor's dynamic range is expected to cover a range from 16e- to 3.5 Me-. The development, jointly carried by 5 light sources (Deutsches Elektronen Synchrotron (DESY), Pohang Accelerator Laboratory (PAL), Elettra Synchrotron, Diamond Light Source (DLS) and SOLEIL Synchrotron), and the Rutherford Appleton Lab (RAL/STFC), will enable increased science yielded from today's FEL and SR sources in the soft X-ray regime.
In collaboration with groups at the Helmhotz Zentrum Berlin (HZB) and Max-Born Institute (MBI), we used the P04 XUV beamline at PETRA-III to perform holographic imaging of topological materials (in particular skyrmions) at an energy of 780eV. Together with colleagues from FLASH, we used the beamline FL24 at the FLASH2 FEL to perform ptychographic imaging of plasma treated surfaces in an energy range between 92 and 462eV. Both experiments benefited from the very large dynamic range provided by the PERCIVAL detector.
The development will go on in order to reach the nominal specification parameters. In the meantime, new user experiments with a high impact factor will be scheduled and will help us to speed up the process.

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Session Classification: Oral presentations

Track Classification: Applications

Contribution ID: **290** Type: **Poster presentation only**

CVD Diamond Detectors and Performance for Neutron Detecting: Design and Development

This study describes the design and construction of a Chemical Vapor Deposit (CVD) diamond detector used to detect neutron radiations. The use of a neutron detector in a thin CVD diamond film has many benefits, including radiation hardening, fissile-material free, low gamma susceptibility, compact and solid state, spectroscopic, both thermal and quick neutron detection, especially when external "blankets" are used to turn neutrons into visible charge particles. As Gd and Ag neutron detectors, thermal and fast neutron detectors have been developed. In addition, a simultaneous detector capable of detecting both thermal and rapid neutron radiations was built. The thin film deposition of Gd and Ag electrodes was calculated to be 4 m and 150 nm, respectively, based on the geometry and measurement.The performance testing to characterize the response of CVD diamond detectors has been carried out at the KIGAMS MC-50 Cyclotron having a 30 MeV proton energy and 10 µA current, which is an accelerator based neutron sources with the high neutron flux about $1x10^4$ ~$1x10^6$ n.cm^{-2}.s^{-1}. The detector counting efficiency and energy resolution were accordingly derived as a function of the thickness of the ^{6}LiF and CVD diamond layers, both for thermal and fast neutrons, thus allowing us to choose the optimum detector design for any particular application. Comparison with experimental results is also reported.

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Track Classification: Sensor Materials, Device Processing & Technologies

Contribution ID: **291** Type: **Poster presentation only**

Development of an On-Chip Data Transmission Link for Monolithic Active Pixel Sensor

The development of CMOS pixel detector technology provides an unprecedented signal-to-noise ratio, spatial resolution, material budget, and readout speed for vertex and tracking detectors in particle experiments 1. The commonly used CMOS pixel detector is the Monolithic Active Pixel Sensor (MAPS), which collects the charge deposited by the particles that pass through the detector.

The data transmission link is a key part of the MAPS. Thus a 5Gbps on-chip data transmission link has been designed for Monolithic Active Pixel Sensor (MAPS). The link converts the parallel data from the column ADCs into high-speed serial data and accomplishes the data transmission. The serial link is designed in a commercial 130nm CMOS technology with the power supply of 1.2 V. The architecture of the whole data transmission link is shown in Fig.1. It consists of a 16b/20b encoder, a 20:1 serializer, a Feed Forward Equalization (FFE) driver, and a high-speed receiver to deal with the external clock. Aiming to reduce the working frequency, the 16b/20b encoder has been designed in a parallel coding structure. The customized multi-level structure in the serializer core guarantees the timing margin between the data and the clock. The FFE driver is designed to drive the serial transmission via low mass cables. The data link is also compatible with MAPS with the data rate lower than 5Gbps. The power consumption of the whole data transmission link is 51 mW. This paper will discuss the design and performance of the data transmission link.

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **292** Type: **Poster presentation only**

Development of an On-Chip configurable DAC array for Monolithic Active Pixel Sensor

As the leading research platform of heavy-ion science in China, the heavy-ion physics and heavy-ion applications at the Heavy Ion Research Facility in Lanzhou (HIRFL) drives the development of new detector technology. Thus, a Monolith Active Pixel Sensor (MAPS) is has been designed in a 130nm CMOS process.

The pixels can record the energy, time, and position of the hit particles. To be tuned and characterized for different applications, the pixels have been designed in a configurable method. This is done by providing the current and voltage to the pixel with a configurable DAC array, which consists of four 10bit voltage DACs, seven 8bit current DACs, a Bandgap, and an I2C interface. The voltage DAC is implemented with an R-2R resistor ladder network and each LSB corresponds to 2.4mV. The current DAC is in current-Steering type with thermometer Code. Each LSB of the current DAC corresponds to 10nA. The Bandgap provides a stable, temperature-independent reference current of 10uA and voltage of 600mV to the DACs. All the DACs can be accessed and configured with the I2C interface. The DAC array covers 3074*400um2 and the power consumption is 46.2mW. This paper will discuss the design, integration and performance the DAC array with the pixels in the MAPS.

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **293** Type: **Poster presentation only**

Multidetector Embedded Readout Interface for Timepix3

Timepix3 1 was developed within the Medipix3 Collaboration at CERN as the successor of the widely used Timepix detector. The chip showed good performance in various domains –3D track reconstruction [2, 3], radiation monitoring in particle physics experiments such as ATLAS or MoEDAL [4, 5]. Readout electronic systems were designed, e.g. SPIDR [6], ADVADAQ[7] and Katherine[8] with interfaces based on Gigabit Ethernet, 10G Ethernet or USB 3.0.

The Katherine readout was used in a lot of applications and projects. However, after several years of using, new demands on such device arose. Therefore, the new generation (designation "Ultimate Edition") of Katherine readout has been developed. It is introduced in this contribution.

A key feature of the upgraded version is the native support for more Timepix3 detectors. The device implements a pair of VHDCI connectors that allows to connect two standard CERN chipboards immediately (see Fig.1). However, the input data lines of the device could work independently, it means that through a reduction board up to 8 detectors can be connected. For example, one of aim application is the support of a quad detector geometry (four Timepix3 detectors with common sensor).
The new device offers wider possibilities of connectivity: Besides the Gigabit Ethernet used in the older device, a USB 3.0 interface was implemented as well. In case of USB, the user can use this fast interface for data rate around 40 Mhit/s at shorter distances between computer and readout device. On the other hand, the Gigabit Ethernet makes it possible to use remote control and several devices in the local area network (LAN). In this case the speed is limited to 14 Mhit/s.

Another upgrade is related to the bias voltage supply for the sensors. Thick silicon sensors, CdTe, CZT, or GaAs sensors require higher reverse bias voltage. Two independent high voltage power supplies are on the board. Each of them can provide a voltage in range from -1kV to +1kV additionally providing a leakage current measurement.

The experience obtained by using the previous version of the device, mainly in more complex measurement chain, showed us that one of the most important features of the readout device is the possibility of easy integration into bigger experimental readout chains. Therefore, advanced readout devices should offer an easy way of synchronization using one or more external trigger signals or feeding an external clock. The new Katherine device implements one input for external clock (also can be used as general input) and other three I/O signals for triggering or other purposes. The SMA connectors are used for these I/O signals with optional 50ohm termination (controlled by software). The device synchronization (demonstration –time differences between two layers of Timepix3 are shown in Fig.2) is solved in several layers. Firstly, clocks for detectors are synchronized and phase matched. The device implements a coarse soft Time-to-digital convertor (TDC) with a resolution of 4 ns for the measurement of delays. Then, there is a set of hardware TDCs with a precision of 50 ps used to get accurate synchronization. Lastly, the RAM memory of the device was extended to 2GB, in line with the dual ARM A9 processor it gives user good chance to implement enhanced data pre-processing directly in the hardware.

1 Poikela, T., et al. Timepix3: a 65K channel hybrid pixel readout chip with simultaneous ToA/ToT and sparse readout. Journal of instrumentation, 2014, 9.05: C05013.B.
[2] Bergmann, B., et al. 3D track reconstruction capability of a silicon hybrid active pixel detector. The European Physical Journal C, 2017, 77.6: 1-9.
[3] Bergmann, B., et al. 3D reconstruction of particle tracks in a 2 mm thick CdTe hybrid pixel detector. The European Physical Journal C, 2019, 79.2: 1-12.
[4] Burian, P., et al. Timepix3 detector network at ATLAS experiment. Journal of Instrumentation, 2018, 13.11: C11024.
[5] Bergmann, B., et al. Relative luminosity measurement with Timepix3 in ATLAS. Journal of

Instrumentation, 2020, 15.01: C01039.
[6] Van der Heijden, B., et al. SPIDR, a general-purpose readout system for pixel ASICs. Journal of Instrumentation, 2017, 12.02: C02040. Visser, J., et al. SPIDR: a read-out system for Medipix3 & Timepix3. Journal of Instrumentation, 2015, 10.12: C12028.
[7] Turecek, D.; Jakubek, J.; Soukup, P. USB 3.0 readout and time-walk correction method for Timepix3 detector. Journal of Instrumentation, 2016, 11.12: C12065.
[8] Burian, P., et al. Katherine: Ethernet embedded readout interface for timepix3. Journal of Instrumentation, 2017, 12.11: C11001.

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Session Classification: Poster session 2

Track Classification: Front end electronics and readout

Contribution ID: **294** Type: **Poster presentation only**

Partially sampled digital tomosynthesis reconstruction using deep learning technique : Dynamic collimation and multislit collimation

Digital tomosynthesis (DTS) is a well-established multiplanar imaging technique that uses limited angular scanning to produce cross-sectional images of the scanned object with a moderate cross-plane resolution. DTS images are typically reconstructed by using the computationally-cheap analytic filtered-backprojection (FBP) algorithm. This popular technique has been used in a variety of clinical applications such as chest imaging, mammographic imaging, and dental imaging owing to the fact that it provides tomography benefits at reduced radiation dose and scan time. DTS reconstruction methods at low radiation dose are an important field of research. Several methods for radiation dose reduction have been studied including sparse-view DTS, region-of-interest (ROI) DTS, and low-dose DTS. In a previous study 1, we investigated low-dose DTS reconstruction in partial sampling using a multislit collimation technique where a multislit collimator placed between the x-ray tube and the patient oscillates during projection data acquisition, partially blocking the x-ray beam to the patient thereby reducing radiation dose. Partially sampled DTS images reconstructed using the analytic FBP algorithm usually suffer from severe bright-band artifacts around multislit edges of the collimator due to incomplete spatial sampling. Thus, we revisited the FBP algorithm with a new prior sinogram interpolation method in an attempt to obtain a reasonable image quality in partially sampled DTS reconstruction. In this study, we propose the U-Net architecture for partially sampled DTS reconstruction to match the original image (multislit collimation) and fully-sampled image (no collimation). Figure 1 shows the FBP-reconstructed CT images using the fully-sampled projections, FBP-reconstructed DTS images using the original and the recovered projections for C(4/4) collimator, and the proposed DTS images using the XCAT phantom. Here C(n/n) denotes a collimator layout that blocks the x-ray beam over n detector pixels vertically with a n-pixel interval. As shown in Fig. 1, the reconstruction quality in the proposed DTS images was close to the CT images. Furthermore, the proposed DTS reconstruction more closely recovered the phantom structure in under-sampling situation (i.e., truncated and partially sampled imaging) compared to the FBP-based reconstruction. In this study, we investigated an effective method for using a deep learning scheme with convolutional neural network to reduce bright-band artifacts in partial sampled DTS.

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **295** Type: **Poster presentation only**

Design of a PET System with Axially Arranged Scintillators Increasing the Field of View

A new detector concept has been developed for a positron emission tomography (PET). This concept is similar to the one used for JPET 1, but there are some conceptual differences. The design of the gantry and the Monte Carlo Simulations are in progress. The basic idea is the axial orientation of the scintillators which are widely used in PET; namely LYSO (Lutetium–yttrium oxyorthosilicate). 64 scintillators of size 3 mm x 5 mm x 100 mm are to be coupled to SiPMs (Silicon photomultipliers) on both sides. The measurement of the time difference and the analysis of the energy spectrum enable the determination of the location where the photon hits the scintillator.
FreeCAD for the 3D design, KiCAD for the electronics circuit design, Geant4 for Monte Carlo Simulations and Root for the data analysis have been used in this project. The work for the imaging of the PET phantoms using pharmaceuticals has also started. In order to be able to obtain a necessary founding for the prototype production, a national project application has been submitted. The system is expected to reduce the amount of radioactive dose almost by 50%, to improve the resolution below 5 mm with less SiPM usage and to process more than two photons which are emitted from positronium [2].

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Session Classification: Poster session 1

Track Classification: Applications

Contribution ID: **296** Type: **Oral presentation**

The MYTHEN III single photon counting detector for powder diffraction

Wednesday, June 30, 2021 4:10 PM (20 minutes)

After more than 12 years of users operation, the MYTHEN II single photon counting microstrip detector has been upgraded in order to cope with progresses in the detector and data acquisition technology. MYTHEN III presents the same geometry as its predecessor (50 µm pitch 8 mm long strips, 6.4 mm wide modules), but it provides an enhanced performance.
In particular, a new readout chip has been developed by the SLS detector group in 110nm UMC technology.
Every readout channel features a double polarity preamplifier and shaper with variable gain and shaping time. The shaper output is fed to three independent discriminators, each one having a dedicated threshold, trim bit set and enable signal. The outputs of the three discriminators are processed by a counting logic that, according to the selected mode of operation, generates the increment signals for the three following 24-bit counters. The new readout chip features an improved noise of 115 e- ENC and a threshold dispersion of about 20 eV RMS 1. The maximum frame rate is up to 300 kHz with no dead time between frames, and the count rate capability can reach up to 3.5 MHz per strip with 90% counting efficiency. Moreover, it is possible to exploit the three counters per strip with independent thresholds and gates not only for energy binning and time resolved pump-probe applications, but also to push the count rate capability to above 20 MHz per strip with 90% efficiency, thanks to the possibility of counting piled-up photons [2]. Finally, we implemented an innovative digital communication logic between channels, which allows charge sharing suppression and improves the spatial resolution beyond the strip pitch, as a first demonstration of on-chip interpolation in a single photon counter detector.
A 48 modules MYTHEN III detector is under commissioning and the first 14 modules recently started users operation at the powder diffraction end station of the Swiss Light Source.
We will present the architecture of the new detector, starting from the readout chip, as well as the first results of its performance characterization.
1 Andrä M, The MYTHEN III Detector System - A single photon-counting microstrip detector for powder diffraction experiments, DISS. ETH NO. 27290, doi: 10.3929/ethz-b-000462676.
[2] Andrä M, et al. Journal of Instrumentation. 2019, 14(11): C11028. doi: 10.1088/1748-0221/14/11/C11028

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Session Classification: Oral presentations

Track Classification: Front end electronics and readout

Contribution ID: **297** Type: **Invited presentation**

Towards Physics-Informed Cameras (PhI-Cam)

Tuesday, June 29, 2021 4:40 PM (50 minutes)

Recent advances in artificial intelligence, compact computing hardware, and CMOS imaging sensors motivate physics-informed cameras (PhI-Cam). Here different physics-driven information can come from device-specific sensor materials, sensor architecture, electronics and noise, environmental parameters including illumination, and degradation of the hardware performance over time. Given enough data, for example, from calibration, device modeling, and accumulative use, all such information may be captured or 'learnt'through a machine learning framework such as a neural-networkbased deep learning, and implemented through either onboard or off-line hardware schemes. In this talk, we give an overview about recent advances in high-speed imaging, experimental needs at the Argonne Advanced Photon Source (APS) synchrotron and its near future upgrades, and highlight some progress towards PhI-Cam for high-speed Xray applications. This work is supported in part by LANL C2, C3 and LDRD programs.

Authors: WANG, Zhehui (Los Alamos National Laboratory); DATTELBAUM, Dana; UBERUAGA, Blas; ERIC, Fossum; PILANIA, Ghanshyam

Presenter: WANG, Zhehui (Los Alamos National Laboratory)

Session Classification: Invited lectures

Track Classification: Imaging theory

Contribution ID: **298** Type: **Invited presentation**

X-ray Edge Illumination phase contrast imaging techniques, principles and applications

Monday, June 28, 2021 1:30 PM (50 minutes)

X-ray Edge Illumination X-ray phase contrast imaging techniques are presented with an overview of the basic principles and applications. A more in-depth discussion is dedicated to two examples where these techniques were tested outside of the laboratory to provide solution in security and in the medical field.

Author: ENDRIZZI, Marco (University College London)

Presenter: ENDRIZZI, Marco (University College London)

Session Classification: Invited lectures

Track Classification: Applications

Contribution ID: **299** Type: **Invited presentation**

X-Ray Spectroscopy @ MHz Frame Rates

Monday, June 28, 2021 9:20 AM (50 minutes)

In 2006 the STFC Rutherford Appleton Laboratory began the development of the High Energy X-ray Imaging Technology (HEXITEC) detector system. Over the subsequent decade the system has delivered exceptional spectroscopic performance of < 1 keV for hard X-ray energies (2 - 200 keV) using Cd(Zn)Te sensors. With a frame rate of 10 kHz the current system is able to deliver this spectroscopic performance up to photon fluxes of 10^4 ph s^{-1} mm^2.

As light sources across the world undergo upgrades, gains in source brightness of the order of $\times 100$ and an increase in the number of high energy beam lines (>10 keV) mean that many of today's detector technologies, like HEXITEC, will be unable to support future science programmes. To meet these needs will require a new generation of detector technologies running at higher frame rates and making use of high-Z sensor materials.

In 2018 we began work on an upgrade of the HEXITEC detector system with the aim of delivering a spectroscopic imaging capability at future light sources. The HEXITEC$_{MHz}$ system aims to deliver the same high resolution spectroscopy but at a continuous frame rate of 1 MHz. At these rates spectroscopic imaging will be possible for hard X-rays at fluxes in excess of 10^6 ph s^{-1} mm^2.

In this lecture I will review the current status of the HEXITEC technology, provide an update on the development of the HEXITEC$_{MHz}$ system as well as the work we have been doing to characterise the sensor materials that will be at the heart of these new imaging systems.

Authors: CLINE, Ben (STFC); VEALE, Matthew (STFC Rutherford Appleton Laboratory); JONES, Lawrence (Science and Technology Facilities Council); JOWITT, Lydia (Science and Technology Facilities Council (UKRI)); FRENCH, Marcus Julian (Science and Technology Facilities Council STFC (GB)); PRYDDERCH, Mark Lyndon (Science and Technology Facilities Council STFC (GB)); HART, Matthew (STFC); WILSON, Matthew (STFC); SELLER, Paul (RAL); WHEATER, Rhian (STFC); GARDINER, Thomas (STFC)

Presenter: VEALE, Matthew (STFC Rutherford Appleton Laboratory)

Session Classification: Invited lectures

Track Classification: Front end electronics and readout

Contribution ID: **300** Type: **Invited presentation**

X-ray ptychography using a lab source

Wednesday, June 30, 2021 1:30 PM (50 minutes)

X-ray ptychography is a scanning coherent diffraction imaging technique that is capable of obtaining quantitative electron density maps at the nanoscale. The technique has been proven to achieve resolutions beyond the limitations of conventional x-ray optics and has been applied to a wide range of scientific fields: from life science to environmental science, and magnetism. Until now the technique has been available only at large synchrotron facilities due to the levels of coherent beam required, with limited and competitive access.
Here we present the first X-ray ptychography images obtained using a laboratory X-ray source. The experiment was performed at the Soft Matter Analytical Laboratory in Sheffield with a Ga liquid metal-jet source. The hyperspectral detector used for recording the diffraction patterns in the far field, allowed characterising the spectral properties of the source. The sample was scanned in a 20 x 20 raster grid at 1 um step using a 5 um illumination size.
The results prove the robustness of the ptychographic imaging technique in low coherent flux and low stability conditions. This is the first step toward unlocking a powerful technique to the laboratory environment for serving a broader scientific community and enlarging the range of applications.

Authors: Dr PARNELL, Andrew J. (University of Sheffield); Dr BATEY, Darren (Diamond Light Source); Prof. RAU, Christoph (Diamond Light Source); VAN ASSCHE, Frederic (Ghent University); BOONE, Matthieu (Universiteit Gent); Dr MYKHAYLYK, Oleksandr O. (University of Sheffield); VANHEULE, Sander; CIPICCIA, silvia (University College London)

Presenter: Dr BATEY, Darren (Diamond Light Source)

Session Classification: Invited lectures

Track Classification: Applications

Contribution ID: **302** Type: **Invited presentation**

Invited lecture: A. Sharma

Wednesday, June 30, 2021 9:00 AM (50 minutes)

Presenter: SHARMA, Archana (CERN)

Session Classification: Invited lectures

Contribution ID: **303** Type: **Invited presentation**

Invited lecture: C. Carloganu

Tuesday, June 29, 2021 9:00 AM (50 minutes)

Presenters: CARLOGANU, Cristina (LPC/IN2P3/CNRS); CARLOGANU, Cristina (Univ. Blaise Pascal Clermont-Fe. II (FR))

Session Classification: Invited lectures

Contribution ID: **304** Type: **not specified**

Pi-Tec industrial lecture

Wednesday, June 30, 2021 3:00 PM (10 minutes)

Session Classification: Industrial lectures