ABSTRACT BOOKLET

ORAL PRESENTATIONS

NDIP 20 – Troyes July 4th -8th , 2022

Plenary Session – Tutorial Lecture #1 - MONDAY

Lecture: Position Sensitive Hybrid Detectors

Speaker: Pr. M. FIORINI
INFN and University of Ferrara, Italy

Massimiliano Fiorini *received his M.Sc. and Ph.D. in physics at the University of Ferrara. He was later employed as fellow at CERN, post-doctoral fellow at the Université Catholique de Louvain and then staff at CERN. He is currently Professor of experimental physics at the Department of Physics and Earth Sciences of the University of Ferrara, and associate researched with INFN. In his career, he worked mainly in the field of high energy physics, with a focus on innovative detector development. Initially, he made substantial contributions to the development and production of a hybrid pixel detector with fast timing for high-rate particle tracking within the NA62 Collaboration. Later he moved to the LHCb Collaboration, where he contributed to the upgrade of the Ring Imaging Cherenkov detectors. He recently joined the Medipix4 Collaboration and is currently developing a hybrid photon detector based on microchannel plates with funding from the European Research Council.*

Plenary Session – Tutorial Lecture #2 - TUESDAY

Lecture: SiPM

Speaker: Pr. Gianmaria Collazuol
University of Padova, Italy

Gianmaria Collazuol *is Associate Professor at the Department of Physics and Astronomy of the University of Padova and Research Associate with INFN. Contributed to the fields of experimental High Energy Particle Physics, Nuclear Physics, Astro-Particle Physics and Medical Physics, working within various international collaborations. His activities include the following: Neutrino Physics and Leptonic CP violation – exp. NOMAD CERN, ENUBET (CERN), T2K and Super-Kamiokande; CP violation with quarks and Flavour Physics – NA48, NA62 and LHCb exp. at CERN; High energy Gamma and Cosmic-ray Physics – CALET exp. on the ISS (JAXA, NASA, ASI); Low energy nuclear cross-sections and neutron physics – exp. at INFN LNL.*

Presently devoting efforts to the T2K, Super-Kamiokande, and CALET: local coordinator of the T2K, Super-Kamiokande and of the CALET research groups in Padova, and co-coordinator of the "Space Weather" analysis in CALET. Project Leader for the development of the new TPCs for the upgrade of the T2K Near Detector.

Broad experience on several experimental techniques. Presently developing TPC gas detectors and innovative silicon pixel detectors for tracking charged particles. Internationally recognized expert in the field of photodetectors. Expert on analogue, digital electronics and TDAQ systems.

Supervisor of several BSc/MSc students and five PhD students. Former member of IAC of NDIP and PhotoDet conference series and of the SNRI INFN School series on advanced detectors. Referee of "JINST" , "Frontiers in Physics" "Nature Sci.Rep.", "NIM A", "IEEE TNS". More than 35 talks at international conferences (several invited) and more than 400 papers on international peer-reviewed journals.

Plenary Session – Tutorial Lecture #3 - WEDNESDAY

Lecture: Electronics for Fast Detectors

Speaker: Dr. David Gascon
University of Barcelona, Spain

***David Gascon** is Associate Professor at the University of Barcelona (UB). He has been working in advanced instrumentation and technologies for astrophysics, particle physics and medical applications since 1998. He received a BSc degree in electronics engineering from University Ramon Llull, Spain in 1998, and a PhD degree in electronics from University of Barcelona, Spain in 2008. Currently he is working in the instrumentation group of the Institute of Cosmos Sciences of the University of Barcelona (ICCUB), Spain. He is Director of the Technology Unit of the Institute of Cosmos Sciences of the UB since 2016 (https://icc.ub.edu/research/technology-unit). His research activity is in the area of mixed signals circuits for high energy physics, astrophysics experiments and medical imaging. Particularly, he is interested in ASIC design for fast photodetector readout and front-end electronics. He has directed 5 PhD Thesis and has co-authored more than 100 refereed publications in scientific instruments technology. He holds 6 patent applications with several industrial licenses.*

This tutorial will cover readout electronics for fast timing photosensors detectors and their application in high energy physics and related fields as medical imaging. First, we will cover signal sensor model and the interplay of sensor and front-end electronics. Then, we will consider preamplifier, shaping and comparator circuits for high-speed response and different aspects determining time resolution: jitter, time-walk, pile-up, baseline-fluctuations, etc. We shall also consider different time pick-up techniques: waveform sampling (ADC and analog memories) versus Time-to-Digital conversion. Finally, we will discuss different examples and future avenues for fast photosensors and associated read-out electronics.

Plenary Session – Tutorial Lecture #4 - THURSDAY

Lecture: Solid State Cathode gaseous detectors

Speaker: Dr. Eugenio Nappi
INFN Sezione di Bari, Italy

Dr. Nappi *is staff at INFN as director of research. He has almost forty years of experience in many areas of high-energy physics projects, from detector design and construction to physics data analyses. In the course of his career, he has gained a large competence in the development of new detectors. Among his achievements, he made substantial contributions to cutting-edge technologies that are of central importance for the sustainable development of particle identification detectors (TOF, Cherenkov and transition radiation detectors). In particular, he produced notable results in the development of innovative imaging Cherenkov counters, which gained him international recognition.*

Development of solid photocathodes for gaseous detectors

The underlying physical process and the operating principle of gas filled devices equipped with solid photocathodes will be outlined together with their feature of detecting single photons with high efficiency and position resolution.

The new trends and developments to overcome the relevant issues and present limitations in the field will also be described in this tutorial.

Plenary Session - S1: SiPM I - MONDAY - 01

Stimulated Fluorescence of Silicon Photomulipiers Devices

Speaker: GALLINA

K. RAYMOND[1], R. FABRICE[2]

[1] TRIUMF/Simon Fraser University|[2] TRIUMF

Arrays of Single Photon Avalanche Diodes (SPADs) are called Silicon PhotoMultipliers (SiPMs). Under the detection of a photon, the produced electron hole pair undergoes an avalanche which increases the gain significantly. This process is also leads to noise and degradation of the signal in detector systems. Secondary photons are emitted from the avalanche and can trigger neighbouring SPADs (cross-talk) or the same SPAD (after pulsing). A careful study of these systematic effects is needed to make improvements to future SiPMs. To satisfy this, we have developed the MIcroscope for Excitation Luminescence characterization (MIEL), which can stimulate individual SPADs and measure the light produced by avalanches in neighbouring SPADs. This will measure the effectiveness of various techniques and features used to limit cross-talk and aid in the development of future SiPM devices. We will introduce the MIEL instrument and present measurements taken of SiPM devices.

Plenary Session - S1: SiPM I - MONDAY - 02

The CMS ECAL upgrade for precision timing measurements at the High-Luminosity LHC

Speaker: AMENDOLA

C. AMENDOLA[1]

[1] *IRFU/CEA Saclay*

The High Luminosity upgrade of the LHC (HL-LHC) at CERN will provide unprecedented instantaneous and integrated luminosities of around 5 x 10^34 cm-2 s-1 and 3000/fb, respectively. An average of 140 to 200 collisions per bunch-crossing (pileup) is expected. In the barrel region of the Compact Muon Solenoid (CMS) electromagnetic calorimeter (ECAL), the lead tungstate crystals and avalanche photodiodes (APDs) will continue to perform well, while the entire readout and trigger electronics will be replaced. The noise increase in the APDs, due to radiation-induced dark current, will be mitigated by reducing the ECAL operating temperature. The trigger decision will be moved off-detector and performed by powerful and flexible FPGA processors.

The upgraded ECAL will greatly improve the time resolution for photons and electrons with energies above 10 GeV. Together with the introduction of a new timing detector designed to perform measurements with a resolution of a few tens of picoseconds for minimum ionizing particles, the CMS detector will be able to precisely reconstruct the primary interaction vertex under the described pileup conditions.

We present the status of the ECAL barrel upgrade, including time resolution results from beam tests conducted during 2018 and 2021 at the CERN SPS.

Plenary Session - S1: SiPM I - MONDAY - 03

Results of QA/QC tests of the Hamamatsu SiPM arrays for the CMS HCAL Phase I upgrade

Speaker: MUSIENKO

CMS. COLLABORATION

The CMS Barrel (HB) and Endcap (HE) Hadron Calorimeters are scintillator sampling calorimeters which use brass as the absorber and plastic scintillator as the active material.Light from the plastic scintillator is wavelength-shifted and captured in WLS fibers for transport to the photo-sensors.The HCAL upgrade is required for the increased luminosity(3x1034 cm-2 s-1) of SLHC Phase I.A key aspect of the HCAL upgrade is to add longitudinal segmentation to improve background rejection,energy resolution and electron isolation at L1 trigger.The increased segmentation is achieved by replacing the HPDs with silicon photomultipliers(SiPMs).High density (15 um cell pitch size,2.8mm and 3.3mm in diameter) SiPMs were developed by Hamamatsu(in cooperation with the CMS SiPM group) for the CMS HCAL Upgrade Phase I project.In this presentation we will show results of QA/QC tests of 1680 Hamamatsu 8-channel SiPM arrays developed for the CMS HB HCAL Phase I upgrade.An overview of our QA results and measurements of the photon detection ef?ciency, spectral response,crosstalk and cell recovery time will be discussed.Results on change of the SiPM parameters after neutron irradiation will be also shown and discussed.The SiPM parameters were measured at the CERN APD Lab: dark current vs bias, noise vs bias,S/N ratio vs bias for constant LED signal.

Plenary Session - S1: SiPM I - MONDAY - 04

Dark noise source characterization in p-on-n SiPM

Speaker: GALLINA

G. GALLINA[1], F. RETIERE[2], B. NOVAKOVIC[3], S. PARENT[4], F. VACHON[4]

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Silicon Photo-Multipliers (SiPMs) are arrays of SPADs widely used to detect scintillation and Cherenkov light. SiPMs measure single photons by amplifying the photo-generated carriers (electrons or holes) via a Geiger-mode avalanche. The latest generation of SiPM is however limited by their high dark count rate at room temperature that prevent their application in an increasing number of ranging and sensing technologies. In this talk, we will introduce a physics motivated parameterization of the dark noise rate of SiPMs. Starting from the extrapolation of the electron and hole avalanche triggering probabilities, we will show a complete experimental and simulation framework in order to predict the voltage and temperature dependence of the SiPM dark noise rate. Furthermore, by a combined fit of the dark noise pulse rate as a function of the over voltage and temperature, we infer the type of carrier and the process which initializes the avalanche in silicon. The new model has been benchmarked against data of 2D SPADs with known doping profile and structure designed at the Institut Interdisciplinaire d'Innovation Technologique, Sherbrooke and fabricated at the Teledyne DALSA Semiconductor Inc. foundry. Moreover, it has been applied to study two p-on-n Vacuum Ultra-Violet sensitive SiPMs, with unknown doping profile.

Plenary Session - S1: SiPM I - MONDAY - 05

Precision Timing with LYSO:Ce Crystals & SiPM Sensors for the CMS MTD Barrel Timing Layer

Speaker: HEERING

CMS. COLLABORATION

The Compact Muon Solenoid (CMS) detector at the CERN Large Hadron Collider (LHC) is undergoing an extensive upgrade program to prepare for the challenging conditions of the High-Luminosity LHC (HL-LHC). A new timing detector in CMS will measure minimum ionizing particles (MIPs) with a time resolution of ~30-40 ps and coverage up to |?|=3. The precision time information from this MIP Timing Detector (MTD) will reduce the effects of the high levels of pileup expected at the HL-LHC and will bring new and unique capabilities to the CMS detector. The central Barrel Timing Layer (BTL) will be based on LYSO:Ce crystals read out with silicon photomultipliers (SiPMs). The BTL will use elongated crystal bars, with double-sided read out, with a SiPM on each end of the crystal, in order to maximize detector performance within the constraints of space, cost, and channel count. We will present an overview of the MTD BTL design, detailed in the recently released technical design report, and will review the extensive R&D studies carried out to optimize the MTD BTL crystal-based technology and the test beam results in which the goal of 30 ps timing resolution has been achieved.

Plenary Session - S2: NOBEL LIQUID - MONDAY - 01

New concept for the Photon Detection System of DUNE FD2 Liquid Argon Experiment

Speaker: CAVANNA

F. CAVANNA[1], W. PELLICO[1], S. SACERDOTI [2]

[1] FERMILAB|[2] AstroParticle and Cosmology (APC) Laboratory -Paris

The photon detector for the DUNE FD2 liquid Argon experiment must be placed on the cathode plane of the TPC at very high voltage.
A new concept in detector technology has been developed for the voltage isolation of sensors and electronics from the power source.
The solution is based on Power-over-Fiber and Signal-over-Fiber technology with transmission of power and signal via non conductive optical fibers.
The main challenge was to customize the PoF and SoF technologies for cryogenics application and to adapt to the specific electrical requirements of the detector.
At the CERN Neutrino Platform facility (Dec.'21) a large area xARAPUCA photon detector module equipped with this innovative cold PoF-SoF technology was tested in experimental conditions, electrically floating on a cathode at 10 kV. Power was distributed via optical fiber immune from noise injection to photo-sensors and electronics, and analog signals, detected down to single photo-electron threshold, were transmitted also via fiber without distortions.

Plenary Session - S2: NOBEL LIQUID - MONDAY - 02

The liquid xenon detector for the MEG II experiment to detect 52.8~MeV γ with large area VUV-sensitive MPPCs

Speaker: IWAMOTO

T. IWAMOTO[1]

[1] *ICEPP, the University of Tokyo*

The MEG II experiment will search for new physics like SUSY-GUT/SUSY-seesaw through the lepton flavor violating mu+ -> e+ gamma decay with ten times better sensitivity than the MEG experiment. The MEG experiment published the result of B(mu+ -> e+ gamma)<4.2x10-13 at 90% CL. in 2016, which was thirty times better result than the previous limit. Because the sensitivity of the MEG experiment is already limited by accidental background, the MEG detector must be upgraded to reach one order of magnitude better sensitivity. The MEG experiment utilized 846 2inch PMTs to detect scintillation light in 900L liquid xenon gamma calorimeter. In the MEG II experiment, 216 2inch PMTs on the gamma incident face are replaced with 4092 MPPCs (SiPMs produced by Hamamatsu) to improve the energy, position resolutions. We started the detector commissioning with the full electronics readout channels for the first time in 2021, and soon after that, we have started the physics data taking. Here the LXe detector status including initial photon sensor calibration and performance will be summarized together with the expected detector performance. The PDE decrease of the SiPM observed in the high rate muon beam environment and our possible solution will also be discussed.

Plenary Session - S2b: SiPM II - MONDAY - 01

Radiation Hardness of a Wide Spectral Range SiPM with Quasi-Spherical Implant

Speaker: RöMER

J. RöMER[1], E. GARUTTI[1], W. SCHMAILZL[2], J. SCHWANDT[1], S. MARTENS[1]

[1] University of Hamburg|[2] Broadcom Inc., Bundeswehr Universität München

Silicon Photomultipliers (SiPM) are the photon detectors of choice for many applications. Development of SiPMs with pixels built around a planar pn-junction reaches a trade-off between photon detection efficiency (PDE) and dynamic range. A challenge in designing efficient red-sensitive SiPMs is the requirement for large depletion depths.
A novel design featuring a quasi-spherical pn-junction called Tip Avalanche Photodiode (TAPD) tackles both problems. For a pixel pitch of 15 ?m, the SiPM prototype reaches a high PDE in a wide spectral range with a peak of 73 % at 600 nm and 22 % at 900 nm. Other promising features are a high dynamic range and a fast pixel recovery. The aim of this study is to characterize this novel type of SiPM. In particular the question of radiation hardness of TAPDs is addressed.
After irradiation with reactor neutrons with fluences up to 10^12 cm^?2 1 MeV neutron equivalent, the sensors are characterised with current-voltage measurements in the dark and under illumination by a LED. The TAPD-SiPMs show no decrease in photo-signal. In comparison with a conventional KETEK SiPM with 15 ?m pixel pitch, the increase in dark count rate (DCR) with irradiation appears to be reduced. This could be promising for the use of TAPD-SiPMs in high radiation applications.

Plenary Session - S2b: SiPM II - MONDAY - 02

A SiPM-based optical readout system for the EIC dual-radiator RICH

Speaker: PREGHENELLA

R. PREGHENELLA[1], P. ANTONIOLI[1], M. CONTALBRIGO[2], M. CHIOSSO[3]

[1] INFN Bologna|[2] INFN Ferrara|[3] INFN Torino

Silicon photomultipliers (SiPM) are candidates selected as the potential photodetector technology for the dual-radiator Ring-Imaging Cherenkov (dRICH) detector at the future Electron-Ion Collider (EIC). They offer several advantages being cheap, highly efficient and insensitive to the high magnetic field expected in the experiment. On the other hand, SiPM are not radiation tolerant and despite the integrated radiation level is expected to be moderate (< 1011 1-MeV neq/cm2) it should be tested whether single photon-counting capabilities and the increase in Dark Count Rate (DCR) can be kept under control across the years.

Several options are available to maintain the DCR to an acceptable rate (below ~100 kHz/mm2), namely by reducing the SiPM operating temperature, using the timing information with high-precision TDC electronics and by recovering the radiation damage with high-temperature annealing cycles.

We present the current status and the first results of studies performed on a large sample of commercial and prototype SiPM sensors. Different subsets of the devices have been irradiated in a campaign with increasing NIEL up to 1011 neq/cm2 and have then undergone high-temperature annealing to recover from radiation damage. The results obtained with a complete readout system based on the first 32-channel prototypes of the ALCOR ASIC chip are also reported.

Plenary Session - S2b: SiPM II - MONDAY - 03

Characterization of Radiation Damage Effects of Protons and X-rays in FBK Silicon Photomultipliers

Speaker: ACERBI

F. ACERBI[1], B. DI RUZZA[2], A.R. ALTAMURA[1], S. MERZI[1], A. GOLA[1]

[1] FBK|[2] TIFPA

SiPMs have been employed in a growing number of applications, like medical imaging, LiDAR, etc. They are quickly replacing photomultiplier tubes and other detector technologies in high-energy physics (HEP) experiments, and for the readout of scintillators in gamma-ray detectors for space experiments. In such applications the SiPMs receive a significant dose of particles (such as protons and neutrons) as well as X and gamma rays. While the effect of radiation in silicon detectors biased below the voltage where avalanche multiplication becomes significant is well studied, the literature is not as much concerning Geiger-mode silicon-detector.
In this work we studied in detail and with a systematic comparison, the effect of radiation on the performance of several SiPM technologies, produced by FBK. In particular we irradiated several chips with 74 MeV protons and with 40 keV X-rays, in two separate experiments. Each time we monitored their dark and light current-voltage curves after every irradiation step. We also studied the annealing after irradiations for few days at room temperature. Finally we characterized functionally the performance of irradiated device after irradiation and annealing, highlighting the differences between p-type silicon devices, n-type ones, and based on layout of the microcells.

Plenary Session - S2b: SiPM II - MONDAY - 04

Design and performance of a scintillating fibre beam monitor read-out with silicon photomultipliers for the secondary particle beams at CERN

Speaker: ORTEGA RUIZ

I. ORTEGA RUIZ[1], A. LIS[1], A. FRASSIER[1], W. DEVAUCHELLE[1], J. KRAL[2], T. SCHNEIDER[1], M. MCLEAN[1], E. BUCHANAN[1]

[1] CERN|[2] Deutsches Elektronen-Synchrotron (DESY)

The Beam Instrumentation group at CERN has developed a new beam profile monitor for secondary particle beams based on scintillating fibres read-out by Silicon Photomultipliers and the CITIROC ASIC. The monitor has a simple design that stands out for its good performance, low cost and ease of production and maintenance. The monitor has been successfully commissioned in two new experimental facilities at CERN, where it has shown an excellent performance as described in the paper.

Plenary Session - S2b: SiPM II - MONDAY - 05

Monte Carlo implementation and experimental validation of a model of SiPM

Speaker: MEHADJI

B. MEHADJI[1], M. DUPONT[2], C. MOREL[2]

[1] Aix Marseille Univ, CNRS/IN2P3, CPPM, Marseille, France|[2] Aix-Marseille Univ, CNRS/IN2P3, CPPM, Marseille, France

The use of SiPMs, instead of PMTs in medical imaging systems has increased these last years since they are cheaper, insensitive to magnetic field and provide a potentially better timing resolution. While an implementation of their behavior has been performed in GEANT4, it remains difficult to model SiPMs for Monte Carlo simulation of a complete imaging system. We have developed a Monte Carlo model of SiPM including all the different sources of noise involved by this type of photodetector and studied their impact on the energy resolution. The model is implemented in GATE, which allows to parametrize the SiPM behaviour. In order to validate our model, results of simulations are crosschecked against experimental measurements.

Plenary Session - S3: NEW SENSING - THURSDAY - 01

Review Talk: Perovskite Photodetectors

Speaker: Pr. Beatrice FRABONI
Department of Physics and Astronomy, University of Bologna, Italy

The demand for large area high-energy radiation detection systems for medical imaging and public security, has pushed the research to develop novel detectors combining high sensitivity and low-cost fabrication processes. Recently, lead-halide perovskites emerged as a very promising novel class of materials for X- and gamma-ray detection. Their success can be attributed to the excellent perovskite optoelectronic properties. The presence of heavy elements like Pb, Br or I coupled to excellent charge transport properties play a crucial role. Moreover, these materials can be deposited at low temperature from solution onto non-conventional substrates, opening the possibility to low-cost, large-area and flexible detectors.

Plenary Session - S3: NEW SENSING - THURSDAY - 02

Trap States Ruling Photoconductive Gain in Tissue-Equivalent, printed Organic X-Ray Detectors

Speaker: FRATELLI

I. FRATELLI[1], L. BASIRICò[1], A. CIAVATTI[1], J. ANTHONY[2], I. KYMISSIS[3], B. FRABONI[1]

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In last decades organic semiconductors have demonstrated to be excellent candidates for the development of a new class of X-Ray detectors able to fulfill important emerging requirements such as the mechanical flexibility, the possibility to cover large surfaces. Moreover, their chemical composition makes them human tissue equivalent in terms of radiation absorption. On one side this is a highly desirable property for the development of a radiation dosimeter to be employed in medical field but on the contrary, it offers poor absorption limiting the detection efficiency. To tackle this issue, one of the most effective strategies is based on the deep comprehension and enhancement of their detection mechanism based on a photoconductive gain effect (PG). Here, the investigation of this amplification mechanism is conducted by a new technique called Photocurrent Spectroscopy Optical Quenching. By these measurements we employed both the X-Rays and visible light to study and identify the electrical traps in organic semiconductors which activate the PG effect under ionizing radiation. For this purpose, we employed flexible organic field effect transistors. We deposited the organic semiconductors from solution by Pneumatic Nozzle Printing, which allowed us to deposit organic thin films in a fully controlled way.

Plenary Session - S3b: MED - MONDAY - 01

Experimental verification of the efficacy of pBCT in terms of physical and biological aspects

Speaker: OKAZAKI

M. HOSOBUCHI[1], H. YOKOKAWA[1], J. KATAOKA[1], Y. OKAZAKI[1], M. UEDA[2], R. HIRAYAMA[3], T. INANIWA[3], A. GLENN[4]

[1] Waseda University | [2] Okayama University | [3] National Institutes for Quantum and Radiological Science and Technology | [4] Lawrence Livermore National Lab

Proton boron capture therapy(pBCT) has recently attracted attention as a method for enhancing the efficacy of proton therapy.
However, the physical origin and biological effects of pBCT are still debatable owing to the lack of experimental data. It is thought that the p+11B->3alpha reaction plays a key role, although the alpha particles are produced in low quantities and cannot fully account for the observed efficacy of pBCT.
In this study, we explored the unknown alpha-particle production reactions that support the effectiveness of pBCT, which are not limited to the 3alpha reaction, through experiments conducted for the first time.
Experiments were performed using a boron-containing scintillator or using an avalanche photodiode and successfully obtained alpha-particle production cross sections.
The results suggested the existence of other alpha-particle production reaction channels, as predicted by theoretical calculations, but these cross sections were not large enough to support the effectiveness of pBCT. Thus, the biological efficacy of pBCT was investigated by measuring the cell viability during proton irradiation. The results indicated that the biological effects were not as effective as previously reported. Further studies on other drugs and cells are ongoing.
These results are systematically discussed herein to examine the unresolved mechanisms of pBCT.

Plenary Session - S3b: MED - MONDAY - 02

A portable gamma camera for the optimization of the patient dosimetry in radioiodine therapy of thyroid diseases

Speaker: BOSSIS

T. BOSSIS, M. VERDIER[1], L. MéNARD[1], L. PINOT[2], F. BOUVET[3], T. BEAUMONT[4], D. BROGGIO[5], S. LAMART[6], O. CASELLES[7], S. ZERDOUD[7]

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Molecular radiotherapy is an efficient treatment modality of benign and malign thyroid diseases. However, there is still a need to better assess the dose delivered to target tissues and organs-at-risk in order to optimize for each patient the activity to be administered according to the objectives of disease control (destruction of tumor residues or thyroid function) while maintaining the risk of toxicity at justifiable levels. In that context, our objective is to develop a high-resolution mobile gamma camera specifically designed to accurately measure the radiotracer biokinetics at the patient� s bedside during treatment planning and therapeutic dose verification. A first feasibility prototype of the mobile camera with a 5x5 cm2 field

Initial results of in vivo CT imaging of contrast agents using MPPC-based photon-counting CT

Speaker: SATO

D. SATO[1], M. ARIMOTO[1], K. YOSHIURA[1], T. MIZUNO[1], K. AIGA[1], H. KAWASHIMA[1], S. KOBAYASHI[1], J. KATAOKA[2], T. TOYODA[2], M. SAGISAKA[2], S. TERAZAWA[3], K. MURAKAMI[1], S. SHIOTA[3]

[1] Kanazawa University|[2] Waseda University|[3] Hitachi Metals Ltd

X-ray computed tomography (CT) is an essential technology in the modern medical field, as it enables three-dimensional non-destructive observation of the inside of the body. Contrast-enhanced CT scanning is widely performed for lesion-enhanced imaging. However, conventional X-ray CT systems integrate incident X-ray signals leading to the acquisition of monochromatic energy information, preventing material identification and quantitative evaluation of the concentration of contrast agents. Recently, photon counting CT (PC-CT) has been attracting attention as a new system to solve these problems. PC-CT utilizes energy information of individual X-ray photons enabling identification of target materials. Its future application in drug-delivery systems is expected; accordingly, we have been conducting demonstrations of our developed PC-CT system combined with fast scintillators and multi-pixel photon counters. We previously performed a static phantom study with contrast agents. In this study, we report on the initial results of in-vivo X-ray CT imaging with our developed PC-CT system. We injected contrast agents into a mouse and visualized the concentrations. The obtained concentration images showed successful three-dimensional enhancement of the kidney and bladder in the mouse, indicating great potential for the clinical application of silicon photomultiplier-based PC-CT.

Plenary Session - S3b: MED - MONDAY - 04

Activation imaging: A new concept of visualizing drug distribution using the wide-band X-ray and gamma-ray imager

Speaker: KOSHIKAWA

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Visualization of drug distribution in the body is a key aspect of cancer diagnosis and therapy. Although there are various ways to visualize drugs, a versatile method to visualize all types of drugs have not yet been established. In this study, we propose a novel method, “activation imaging”, which is applicable to various types of drugs. The concept of activation imaging involves the visualization of X-rays and gamma rays emitted from activated samples. The visualization device is a hybrid Compton camera (HCC) that can perform the imaging of X-rays and gamma rays ranging from a few tens of keV to more than 1 MeV, enabling the visualization of various X-rays and gamma rays emitted from activated medicines. As a proof-of-concept study, we activated drugs with thermal neutrons and conducted spectroscopy and imaging of activated drugs. We used gold and platinum nanoparticles as drug carriers; cisplatin as an anticancer drug; and ferucarbotran, gadoteridol, and iohexol as contrast agents. Consequently, gold nanoparticles and iohexol were successfully visualized using an HCC, and several gamma rays that can potentially be used for visualization were observed in the spectra.

Plenary Session - S4: HYBRID - TUESDAY - 01

CYGNO: directional dark matter search using a TPC with optical readout

Speaker: D'IMPERIO

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Gas detectors are interesting candidates for direct dark matter (DM) search.
The goal of the CYGNO project is to construct and operate a gaseous TPC of O(1)m3 at atmospheric pressure for DM search with directionality.
CYGNO uses an innovative optical readout, detecting the light produced by the de-excitation of gas molecules during the primary electrons multiplication in triple GEM stacks.

The light is detected simultaneously by low-noise sCMOS cameras and fast-response photomultiplier tubes. The cameras provide a high-granularity 2D-track reconstruction, while the third coordinate is obtained using the time profile of light measured by the PMTs.
The combined readout provides a full 3D reconstruction, allowing to infer the direction of the incoming particle.
The detailed reconstruction of the event topology gives also a powerful tool to discriminate DM signal from radioactivity background.
A prototype of about 50-liters (LIME) was successfully operated in Frascati National Laboratories and will be commissioned in Gran Sasso Underground Laboratories in 2022. With CYGNO prototypes we demonstrated the detector stability and characterized the tracking performances down to energies of O(keV). LIME underground data will be essential to characterize the background in the real environment for DM search and to demonstrate the feasibility of the CYGNO project.

Plenary Session - S4: HYBRID - TUESDAY - 02

Hybrid single-photon imaging detector with embedded CMOS pixelated anode

Speaker: BOLZONELLA

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The development of a single-photon detector based on a vacuum tube, transmission photocathode, microchannel plate and CMOS pixelated read-out anode is presented. This imager will be capable of detecting up to 1 billion photons per second over an area of 7 cm^2, with simultaneous measurement of position and time with resolutions of about 5 microns and few tens of picosecond, respectively. The detector has embedded pulse processing electronics with data-driven architecture, producing up to 160 Gb/s data that will be handled by a high-throughput FPGA-based external electronics with flexible design. These performances will enable significant advances in particle physics, life sciences, quantum optics or other emerging fields where the detection of single photons with excellent timing and position resolutions are simultaneously required.

Plenary Session - S4: HYBRID - TUESDAY - 03

Operation of 144-channel HAPDs and Belle II Aerogel RICH Counter

Speaker: SANTEJL

S. NISHIDA[1]

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Belle II experiment at SuperKEKB is a B factory experiment aiming at collecting 50 times more data than Belle.
One of the key components in such an flavor physics experiment is the particle ID (PID), especially the separation of kaons and pions.
In the Belle II spectrometer, a proximity focusing ring imaging Cherenkov detector using aerogel as a radiator (ARICH) is equipped for the PID at the forward endcap.
In this counter, a total of 420 of hybrid avalanche photo-detectors (HAPDs) with 144 channels are used as position-sensitive photon detectors that work inside the 1.5 T magnetic field.
Belle II started the physics run with full detectors from 2019, and accumulated more than 250 /fb of collision data.
In the presentation, we explain the overview of ARICH counter, and briefly mention about the installation and commissioning of this detector.
We then report about the operation and performance of the HAPDs in ARICH.
We also report the initial performance of ARICH, estimated from the initial data.

Plenary Session - S5 : SEMINCONDUCTOR I - TUESDAY - 01

Caliste-SO detectors: performance in flight on board STIX/Solar Orbiter

Speaker: LIMOUSIN

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The Spectrometer Telescope for Imaging X-rays (STIX) has been successfully launched on 9 February 2020 from Cape Canaveral on board the Solar Orbiter satellite. The first mission of the Cosmic Vision scientific program of the European Space Agency is now orbiting the Sun and started its scientific program. STIX is a compact, low power, low telemetry and autonomous hard X-ray imaging spectrometer covering the energy range from 4 to 150 keV. Its imaging technique is based on an indirect bigrid Fourier technique using a set of tungsten grids placed in front of 32 CdTe coarsely pixelated detectors, namely Caliste-SO. Solar Flare hyperspectral images can be obtained with 7 arcsec angular resolution and 1 keV fwhm energy resolution at 6 keV. The detectors perform well in flight. In this paper, we will present the instrument concept, Caliste-SO properties and performance in flight after two years of successful operations. Examples of solar eruption time resolved imaging spectrometry will be presented.

In memory of our colleagues R. Schwartz (NASA) and R.P. Lin (SSL/UC Berkeley).

Plenary Session - S5 : SEMINCONDUCTOR I - TUESDAY - 02

Imaging and Spectral Performance of Wide-gap CdTe Double-Sided Strip Detectors

Speaker: NAGASAWA

S. NAGASAWA[1], T. MINAMI[1], W. SHIN[2], T. TAKAHASHI[3]

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We develop a new configuration CdTe double-sided strip detector as "Wide-gap CdTe-DSD", in which a gap between strips is much wider than strips. The detector has 128 strip electrodes on both cathode and anode sides varied from 60 um strip pitch (30 um strip and 30 um gap width) to 100 um strip pitch (30 um strip and 70 um gap width). By widening the gap between the strips, the percentage of charge sharing events between adjacent strips is enhanced, and a sub-strip position resolution could be achieved by utilizing the information on the sharing energies. To confirm this concept, we conducted an evaluation test by uniformly irradiated X-rays using Am-241. By developing a new energy reconstruction method to compensate for the charge loss of wider gaps and the depth of interaction effects, an energy resolution of 0.9 keV is obtained using all single and double strip events. We also conducted fine beam scanning experiments at SPring-8 to study the spatial dependence of the response. The beam size is collimated to 10 um squared, and the beam energy is changed from 7 to 35 keV. From these experiments, the sub-strip position resolution has been demonstrated, especially for the anode side with a precision of 10 um in the gap region.

Plenary Session - S5 : SEMINCONDUCTOR I - TUESDAY - 03

GeSn: a newcomer for the group IV infrared optoelectronics; Light emission and photo detection prospects

Speaker: PAUC

N. PAUC[1], L. CASIEZ[2], C. CARDOUX[2], G. LE RHUN[2], J.M. HARTMANN[2], A. TCHELNOKOV[2], V. REBOUD[2], V. CALVO[1]

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Ge1-xSnx alloys are a new family of direct band gap compounds belonging to the group IV semiconductors with an infrared band gap in the 2-4 microns range. The field of GeSn photonics is rapidly growing, with many recent breakthroughs such an all group IV Si compatible laser source operating at room temperature or photodetection in the mid infrared. In this contribution, we will focus on strategies of strain management in the active zone of GeSn materials, with on demand induction of strains in the % range for tunable light emitters or detection purposes.

Plenary Session - S5: SEMICONDUCTOR I - TUESDAY - 04

A CZT 3D Imaging Spectrometer with Digital Readout prototype for High Energy Astronomy

Speaker: CAROLI

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The scientific challenges still open in hard X/soft-ray astronomy, require the development of new instrumentation able to overcome the sensitivity limits of the present one. Among the technologies currently under study to cover the energy range between several tens of keV and one MeV, the development of telescopes equipped by broad band Laue lens associated to focal planes with high spectroscopic and imaging performance represent an extremely promising solution. With this perspective, we report on both the development and the first characterisation results of a detection system (10-1000 keV) based on CZT spectrometers with spatial resolution in three dimensions (3D) and a digital electronics acquisition chain suitable to build high performance focal planes. The prototype is made by packing four sensor units. Each sensor is realized using a single spectroscopic graded CZT crystal with dimensions of ~20x20x5 mm3. For each sensor unit, we adopted an electrode for the anode side a structure consisting of 12 collecting anodes with a pitch of 1.6 mm and 3 drift strips between each pair of anodes for 48 strips, while the cathode side is segmented in 10 strips with a pitch of 2 mm that are orthogonal to anode side strips. The detector readout front-is based on custom designed low noise charge sensitive preamplifiers which supply the signals to a system capable of digitizing and processing them continuously.

Plenary Session - S5: SEMICONDUCTOR I - TUESDAY - 05

Development of a high-sensitivity CdTe semiconductor imager with a parallel-hole collimator

Speaker: KATSURAGAWA

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Hard X-ray imaging is increasingly recognized as a valuable method in various fields of medical research such as in-vivo small animal imaging. CdTe semiconductor is a promising device for this purpose thanks to its high efficiency for hard X-ray. We have started to develop a camera which covers a large area by means of a parallel hole collimator and a Cadmium Telluride double-sided strip detector (CdTe-DSD) which has a high energy resolution of 1—2 keV at 60 keV (FWHM) and fine position resolution of 250 um. The collimator is configured as a honeycomb with tungsten septa whose thickness is 0.16 mm by using the technology of metal 3D printing. In order to evaluate the imager, we performed experiments using a radiative point source and some phantoms (flat and Derenzo) at the National Cancer Center in Japan. Because of the high position resolution of the CdTe-DSD, an artifact caused by the space between the collimator and the detector appears in the image. By using a low pass filter in image processing, we succeeded in getting a clear image and a spatial resolution of 1.2 mm. In this presentation, we describe performance of the imager.

Plenary Session - S6: SiPM III - TUESDAY - 01

Development of a Compton telescope calorimeter module for MeV–range gamma–ray astronomy

Speaker: HAMADACHE

C. HAMADACHE[1], A. LAVIRON[1], C. HIVER[1], J. KIENER[1], A. MEYER[1], J. PEYRE[1], V. TATISCHEFF[1]

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Gamma-ray astronomy in the MeV energy range shows a lack of sensitivity compared to other gamma-ray energy bands. To fill this gap, several space observatory projects are proposed to space agencies. The COMCUBE CubeSat project will focus on the measurement of the polarization of the prompt emission of GRBs which can provide an understanding of the physics of ultra-relativistic jets. Furthermore, the linear polarization of distant gamma ray sources could be a probe to study the fundamental physics related to the Lorentz invariance violation.

The best instrument is thought to be a Compton telescope. We develop an instrument including double-sided silicon strip detectors and scintillation crystals coupled to a pixelated photodetector. The incoming photon undergoes an inelastic scattering in one or several layers of position–sensitive silicon strip detector before being absorbed in a position–sensitive calorimeter based on inorganic scintillators. The measurement of both positions and energy deposits enables the determination of the photon’s source direction. It also enables measurement of the linear polarization of the incident gamma rays. In this contribution, we will present the results of the extensive work we have carried out for the development of the calorimeter and its integration into a Compton telescope prototype.

Plenary Session - S6: SiPM III - TUESDAY - 02

Neutron/gamma discrimination and localization with pixelated plastic scintillator and SiPM dedicated multiplexing readout

Speaker: LYNDE

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The development of instruments for measuring radioactivity and more particularly systems for characterizing and locating particles is an important issue in many fields, such as nuclear industry (gamma-neutron imaging and radiography) and medicine (scintigraphy, SPECT and PET), high-energy physics (tracking and calorimetry) and astrophysics (space observatory). These areas are not exempt from the need of technologies to reduce size and energy consumption along with the increase of durability. In this context, the use of silicon photomultipliers (SiPM), instead of a photomultiplier tube, addresses to these issues thanks to its compactness, modularity, low cost and robustness. Moreover, their assembly in a matrix form allows the position of interactions to be measured.

The aim of this work is to develop a compact, scalable and position-sensitive neutron detector with high sensitivity based on a pixelated plastic scintillator (PS) and a SiPM array coupled with a multiplexing readout. The chemical composition of manufactured PS was chosen for its gamma/neutron discrimination abilities. The SiPM array used in these experiments is from SensL, the ArrayC-30035-16P. In order to minimize the number of channels to be digitized, we employed the multiplexing readout from AiT. Preliminary performances of this new kind of detectors were evaluated on this basis.

Plenary Session - S6: SiPM III - TUESDAY - 03

VUV-SiPMs applied to cross-luminescence detection in BaF2 for ultrafast timing applications

Speaker: GOLA

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Inorganic scintillators are widely used for fast timing applications in high energy physics experiments, time-of-flight positron emission tomography (TOF-PET), and time tagging of soft and hard X-ray photons. As the best coincidence time resolution (CTR) achievable is proportional to the square root of the scintillation decay time it
is worth to study fast cross-luminescence e.g. in BaF2 , with an intrinsic light yield of 8500 photons/MeV. However, emission bands in BaF2 are located in the deep-UV at 195nm and 220nm, which sets severe constraints on the photodetector selection. Recent developments for dark matter search yielded silicon photomultipliers
(SiPMs) with photon detection efficiencies (PDEs) of 20-25% at wavelengths of 200nm. We tested state-of-the-art devices from FBK and measured a best CTR of 51±5ps FWHM, when coupling 2x2x3mm3 BaF2 crystals excited by 511keV electron-positron annihilation gammas. Using these VUV-SiPMs we measured the scintillation kinetics of samples from Proteus and Epic-crystals, confirming a fast decay time of 855ps with 12.3% relative light yield and 806ns with 83.8% abundance, together with a rise time of almost 0ps. We also found a till now overlooked faster component with 136ps decay time and 3.9% relative light yield, extremely interesting for fastest timing applications, which will be discussed further alongside new VUV-SiPM developments.

Plenary Session - S6b: Vac Det I - TUESDAY - 01

Invited Talk: High Performance Cross Strip Imaging Readout Planacon Sealed Tubes

Speaker: SIEGMUND

O. SIEGMUND[1], J. MCPHATE[2], T. CURTIS[2]

[1] University of California, Berkeley|[2] University of California

Sealed tube MCP detectors have provided a valuable platform for high time resolution photon counting detectors. Specifically, electronic readout microchannel plate (MCP) based sensors have been used as photon counting, imaging, event time tagging detectors for astronomy, time resolved biological imaging, imaging LIDAR, Cherenkov (RICH), scintillation detection, and neutron imaging. For future initiatives we have been developing novel atomic layer deposited MCPs, UV optimized photocathodes and high resolution cross strip readouts for sealed tube detectors. The Photonis Planacon is a useful sealed detector format (~50 mm active area) to employ and demonstrate these novel technologies. The Planacon standard geometry has been used, but the pad anode is replaced with a cross strip anode that demonstrates ~20 micron FWHM spatial resolution for single photon events at electron gains of the order 106 with tight pulse amplitude distributions. Atomic layer deposited MCPs with 10um pores replace the standard MCPs, providing enhanced gain stability and reduced (/3) gamma ray sensitivity. The entrance window (Sapphire or MgF2) permits high UV sensitivity bialkali photocathodes (>30% @180nm) or alkali halides (60% @ 115nm) to be used. Encoding electronics also provides the high resolution imaging at event rates of up to 5 MHz.

Plenary Session - S6b: Vac Det I - TUESDAY - 02

Optimization of High Count Rate MCP/Timepix Photon Counting Detectors for Synchrotron Applications

Speaker: TREMSIN

A. TREMSIN[1], J. VALLERGA[1], T. CURTIS[2], J. MCPHATE[2], O. SIEGMUND[2], R. RAFFANTI[3], S. ROY [4], Y. CHUANG[4], A. US SALEHEEN[4], S. MORLEY[4], X. FENG [4]

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Detectors with Microchannel Plates have found niche applications in soft X-ray detection where event counting with high spatial and timing resolution is needed. The Timepix placed directly below MCP in the vacuum is one of the readout options. The capability of these readouts to detect many simultaneous events substantially increased the count rate capabilities of these devices to GHz levels. In this paper, we present the results obtained with an MCP detector coupled to a quad Timepix readout. The spatial resolution of this detector is shown here to be <6 µm. This resolution is achieved in real time through the event cenrtoiding. Optimization of detector characteristics are performed in order to achieve such a high spatial resolution. A couple of application examples of these detectors at Resonance Inelastic X-ray Scattering (RIXS) and X-ray Photon Correlation Spectroscopy demonstrate the unique capabilities of such devices for certain synchrotron-based experimental studies. Same MCP/Timepix detectors can be very attractive for the applications where the photon/electron/ion/neutron counting with high spatial and temporal resolution is required, such as Time of Flight experiments in energy-resolving neutron imaging at spallation neutron sources, fluorescence lifetime imaging and, if adapted for the electron detection, experiments on photoelectron spectroscopy

Plenary Session - S7: VACUUM DETECTORS II - WEDNESDAY - 01

Development of hybrid and portable field detectors for absorption and scattering muography applications

Speaker: AVGITAS

T. AVGITAS[1], J. MARTEAU[1]

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We developed an innovative Cerenkov prototype in the IP2I-Lyon (CNRS-IN2P3, University Lyon-1) within the MEGAMu project funded by the ANR. The current prototype consists of a PVC cylinder filled with de-ionized water and with internal walls covered with reflective material (TYVEK). The light collection is performed by a fibers bundle readout by the same opto-electronics chain as in the surrounding scintillator tracker planes (MaPMT + stand-alone electronics distributed on Ethernet). An interesting feature is the uniqueness of the readout chain for tracker and Cerenkov detectors, making it perfectly suited for field experiments with simple trigger and synchronization schemes. We present results on the detector's performance (detection and light collection efficiency, acceptance, particle energy response and particle discrimination) and the comparison with a full set of dedicated simulations based on GEANT4 implementing the exact experimental geometry and taking a muon distribution analytical model as input.

Plenary Session - S7: VACUUM DETECTORS II - WEDNESDAY - 02

Observations of gamma-ray bursts during thunderstorms using a newly developed high-speed DAQ system

Speaker: MASUBUSHI

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Gamma-ray bursts initiated by lightning discharges and thunderclouds have been observed since the 1980s. However, mechanisms underlying these emissions remains to be elucidated. The observed gamma rays are classified into two categories based on their duration: long bursts and short bursts. Observation of short bursts is challenging because of their extremely short duration and high counting rate, which necessitate detectors having time resolution better than milliseconds and counting rates over 1 Mcps. Therefore, we developed a novel high-speed data acquisition (DAQ) system specialized for detection at count rates over 1 Mcps in a few milliseconds. The system primarily employs scintillation detectors, which consist of a photomultiplier tube and scintillator (e.g., BGO, CsI, GAGG and LYSO). The signals from the detectors are obtained using a high-time resolution analog-to-digital converter, with time and energy information as outputs. The high-speed DAQ system enables the detection of the arrived photons at high count rates (>1 Mcps) in short durations (a few milliseconds). The system was placed in a mountain area near the Japan Sea during the winter of 2019–2022. We detected two types of remarkable gamma-ray bursts associated with lightning discharge. The results indicate the applicability of the proposed system in elucidating gamma-ray burst mechanisms related to thunderclouds.

Plenary Session - S8 : SEMINCONDUCTOR II - WEDNESDAY - 01

Design and performance of the camera of the SVOM Micro-channel X-ray Telescope

Speaker: MEURIS

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The Microchannel X-Ray Telescope (MXT) will be implemented on board the SVOM Sino-French space mission to observe the early afterglow of gamma-ray bursts in the 0.2-10 keV energy range and localize them within 2 arcmin. For a total mass of 42 kg and a total power of 60 W, this instrument is composed of an optics system, a telescope tube in carbon fiber, a radiator, a camera and a data processing unit. The 9 kg camera consists of a focal plane assembly with a detector assembly and thermoelectrical coolers, a front-end electronics assembly, a calibration wheel assembly and a support structure assembly. Spectral characterization tests of the focal plane assembly based on a 256 x 256 pixel pn-CCD spectroscopic imager were performed in the laboratory, in the Metrology beamline of the SOLEIL synchrotron and in the PANTER X-ray facility. Energy resolution of 79 eV FWHM at 1.5 keV were demonstrated in the nominal flight configuration (-65°C, event selection by the camera). The paper will present the design, the realization and the performance of the flight camera of MXT. It will focus on the technical challenges, the original implemented solutions and the custom-made setups for the validation and performance tests.

Plenary Session - S8 : SEMINCONDUCTOR II - WEDNESDAY - 02

First light of MC2-1K, a 250 µm pixel pitch CdTe imaging spectrometer for hard X-ray astronomy

Speaker: ALLAIRE

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To understand the physical processes behind the most violent events in our Universe, a new generation of space telescopes evolving in the hard X-ray domain is required with enhanced performances in detection sensitivity and angular resolution. Emerging super mirror techniques allow the development of improved resolution and high-energy efficiency spectro-imagers, leading to large focal plane detectors with high pixel density. We present MC^2-1K, a new generation of hybrid pixelated detectors, with a 32 x 32 pixels array comprised of a 250 \textmu m pitched pixelated CdTe semiconductor detector point-to-point connected to the spectroscopic channels of a full-custom ASIC. The ASIC named D^{2}R$_2$ was produced in 2019 in the XFAB 0.18 \textmu m and we demonstrated a median equivalent charge noise of 54 e- RMS, equivalent to 654 eV at 31 keV for a CdTe detector. We developed an acquisition system where the D2R2 ASIC data of 32 rows are encoded in parallel by the 32-channel ADC OWB-1 ASIC. The daughter board with the hybrid detector is placed in a thermally controlled vacuum chamber for a moderate cooling. The paper will present the characterization tests of the ASIC, the dedicated test set-up and the first spectroscopic tests of the MC^2-1K hybrid detector.

Plenary Session - S8 : SEMINCONDUCTOR II - WEDNESDAY - 03

Application of a Si/CdTe Compton camera for the polarization measurement of radiative recombination x-rays

Speaker: TSUZUKI

Y. TSUZUKI

Recent research shows the polarization degree of dielectronic recombination x-rays is strongly affected by the Breit interaction, an interaction between electrons. However, more advanced examination of the Breit interaction requires a polarimeter with higher accuracy and sensitivity than we have ever achieved. We develop a novel x-ray polarimeter composed of silicon (Si) and cadmium telluride (CdTe) semiconductor layers, which is based on Si/CdTe Compton cameras developed for observations of astronomical objects, such as the Crab nebula. The gain of the polarimeter was adjusted to concentrate on the x-ray energy (75 keV) and the detector was calibrated using test pulses. A series of Monte Carlo simulations was performed to evaluate the detector response. To demonstrate the polarimetric capability of the polarimeter, we observed radiative recombination x-rays emitted from highly charged krypton (Kr) ions and calculated the polarization degree. The modulation curve for the radiative recombination x-rays was successfully obtained. Subtracting the contribution of background on the polarization degree, we confirm 100 % linear polarization, which is theoretically estimated. In this presentation, we present its polarimetric capability and observations of highly charged heavy ions generated by an electron beam ion trap (EBIT).

Plenary Session - S8 : SEMINCONDUCTOR II - WEDNESDAY - 04

Development of an ultra-high resolution multi-probe CdTe SPECT

Speaker: TAKEDA

S. TAKEDA

A new 3D imaging system for in-vivo small animal SPECT (Single Photon Emission Computed Tomography) was developed. This allows us to simultaneously visualize multiple radioactive probes in a living mouse with an ultra-high resolution of better than 500 µm. The high energy resolution, typically 1.5 keV (FWHM) at 27.5 keV, double-sided CdTe strip detectors (CdTe-DSD) play a key role in our instrumentation, which is originally developed by ISAS/JAXA and Kavli IPMU for space science missions. Its excellent capability of energy measurement is definitely effective for not only astrophysics but also biomedical SPECT because that enables us to clearly separate gamma-rays from different isotopes, therefore low-noise images of individual isotopes with less contamination become available. The system is composed of 8 CdTe-DSDs and a Tungsten collimator with 168 pinholes with diameters of 200 µm. The image reconstruction is a critical issue, because the pinholes and the detectors are not exactly located to designed positions, the sizes of pinholes are not exactly 200 µm, and also the shapes of the pinholes are not exactly circles. In NDIP2020, we will present our imaging system, calibration, image reconstruction algorithm, and verification with phantoms and small animals.

Plenary Session - S8 : SEMINCONDUCTOR II - WEDNESDAY - 05

The New DePFET Sensor for the ATHENA Wide Field Imager

Speaker: BÄHR

P. LECHNER[1]

[1] *MPG HLL*

DePFET (DEpleted P-channel Field Effect Transistor) Active Pixel Sensors have been selected as focal plane instrument of ESA's ATHENA X-ray observatory. Prototypes of representative formats have been produced and characterised. A new device topology with the linear arrangement of source, gate and drain allows for a reduction of the gate dimension and therefore an improved signal-to-noise ratio as well as a faster signal processing. The new devices' superior performance both in energy resolution and in readout speed are demonstrated by experimental data. A next generation of devices in the final format has been finished, test results of flight-like devices will be presented.

Plenary Session - S9: DATA SCIENCE - WED - 01

Optimized Reconstruction of the Position of Interaction in High-Performances gamma-Cameras

Speaker: VERDIER

M. VERDIER[1], T. BEAUMONT[2], T. BOSSIS[1], F. BOUVET[3], D. BROGGIO[2], O. CASELLES[4], S. LAMART[2], L. PINOT[3], S. ZERDOUD[4], L. MéNARD[1]

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Targeted radionuclide therapy is one of the most widespread treatment modality for benign and malignant thyroid diseases. In order to maximize the therapeutic effects on the target tissues while minimizing the toxicity for organs-at-risk with adapted dose defined for each patient, dedicated gamma-imaging devices are required. They must be optimized for high energy gamma-rays, high photon fluences and avalaible for repeated measurements at specific times before and after treatment administration. Our objective is to develop a portable high-resolution gamma camera specifically optimized for dose quantification at the patient's bedside during the treatment of thyroid diseases with 131I. We are currently developing a fully operational clinical version of the mobile gamma camera with a 10x10 cm2 FoV suited to the size of the thyroid, based on a monolithic 10x10x1 cm3 CeBr3 scintillator coupled to a 256 channels, sillicon-photmultiplier array of 6x6 mm2. We present here the intrinsic spatial performances of the photodetection module of the camera and compare two methods for reconstruction of the position of interaction of the gamma-raysusing experimental data, one is a fitting-based method relying, the other use a Deep Residual Convolutionnal neural network. Both methods give millimetric spatial resolution (FWHM) on the central field of view at 356 keV.

Plenary Session - S9: DATA SCIENCE - WED - 02

Utilising machine learning algorithms for high speed data processing of a single photon counting 256 channel PMT with a timing resolution of 60 ps.

Speaker: MARKFORT

A. MARKFORT, A. BARANOV[1], A. MUDROV, I. TYUKIN[1], J. LAPINGTON[1], T. CONNEELY[2], A. DURAN[2], J. MILNES[2]

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Development of a 256 channel photomultiplier tube to increase the spatial resolution while maintaining the temporal resolution of 60 ps using charge sharing techniques would enable a novel commercial camera system. This is designed so that each channel is an independent photon detector allowing for single photon counting possibilities which would advance fields such as LiDAR, particle physics and quantum information systems.
Increasing photon rates due to charge sharing and application demands are progressively highlighting the bottleneck of utilising current algorithmic software to perform real time data processing.
This research explores a potential solution of a machine learning (ML) algorithm for performing the data processing and imaging, with the objective of reconstructing the photon event in both spatial and temporal coordinates with a time constraint 10 mu s per single photon event. In this paper optimisation of the model is detailed with discussion on various hyper-parameters of the model architecture. Results detailed demonstrate the ML model's success in reconstructing photon events from real detector data with a training set consisting of simulated data. Furthermore this work aims to assess the variance in performance of the ML model when trained with a hybrid training set containing both simulated data and data from the MCP-PMT.

Plenary Session - S9: DATA SCIENCE - WED - 03

In-situ visualization system of 3D dose distribution for precision proton therapy

Speaker: SAGISAKA

S. SATO[1], M. HOSOBUCHI[2], H. YOKOKAWA[2], J. KATAOKA[2]

[1] Waseda Univ.|[2] Waseda University

In proton therapy, a PET system is widely used to verify the irradiated region by measuring 511 keV annihilation gamma rays after irradiation. However, the positron distribution does not precisely reflect the proton dose distribution. Therefore, we propose a precise and cost-effective proton dose visualization system by measuring scattered protons. In this system, we placed tens of scintillation detectors on the body surface, and then monitored the integration of energy deposits by scattered particles, mainly protons. The 3D dose distribution in the human body is estimated from the detector positions and energy deposits using deep learning algorithms. As an initial demonstration, the polystyrene phantom was irradiated by a 70 MeV proton beam, and the proton dose distribution was estimated by recording the output current of the detectors placed at different positions on the phantom surface. Consequently, we have succeeded in estimating the peak position in depth approximately within a 5 mm error. In the future perspective, for the realization of our proposed system, we intend to perform the estimation in more complex geometries.

Plenary Session - S9: DATA SCIENCE - WED - 04

Deep Learning approach for ORA (Optimized Random Pattern) Coded aperture in gamma ray image reconstruction

Speaker: FERNANDES DE OLIVEIRA

G. DANIEL[1], O. LIMOUSIN[2], D. MAIER[2]

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X-ray and gamma ray sources localisation is challenging and necessary in many fields, such as astronomy or nuclear safety and security. One main method for X and gamma imaging relies on the use of a coded mask associated to a high-energy photon detector. The shadow of the mask, projected on the detector, must be analysed by an operation called deconvolution in order to recover the position(s) of the source(s). In the present paper, we introduce a new method based on a deep learning approach to perform this deconvolution. By means of a Convolutional Neural Network (CNN), trained on a synthetic database, we are able to localize radioactive hotspots observed with a gamma camera composed by an ORA (Optimized Random Pattern) mask and a Caliste, a CdTe semi-conductor detector for high-energy photons of 16x16 pixels with 625 µm pitch. We show that this method has similar performances in terms of localisation than MLEM (Maximum Likelihood Expectation Maximization), a classic algorithm to process this deconvolution, while our CNN outperforms in terms of computation time by a factor of 100. We also highlight the expected capabilities of CNN to image extended radioactive sources, which is still challenging for coded mask imaging.

Plenary Session - S10: SPAD - MONDAY - 01

Review Talk : Large-format SPAD image sensors for biomedical and HEP applications

Speaker: Pr. E. CHARBON

E. CHARBON[1], C. BRUSCHINI[1]

[1] *École polytechnique fédérale de Lausanne (EPFL)*

CMOS SPADs have initially appeared in 2003 and they have soon gone deep-submicron. SPAD image sensors have been growing over the past two decades to reach 1Mpixel and beyond. One of their peculiarities is an excellent timing resolution, which is at the core of the success of SPAD sensors in time-resolved imaging. New and old applications literally exploded in recent years. Examples include particle sensing in HEP experiments, FLIM/FRET, and various super-resolution microscopy styles. SPAD based sensors are today in almost every smartphone and the promise is that they will soon be in every car. 3D-stacked SPADs have appeared in 2015, pushing the potential even further. The inherently digital nature of SPADs and the increased density of computation over multiple silicon layers enable deep-learning processors, thus enabling complex processing in situ, hence reducing power consumption. Another recent trend is the use of SPADs in quantum imaging and quanta burst photography, applications that are notoriously computationally intensive, which will certainly take advantage of massively parallel processing. SPAD technology has been a technical success, but also an economic one, representing a versatile solution for products that became better and faster but also much cheaper thanks to the economy of scale enabled by CMOS technology.

Plenary Session - S10: SPAD - MONDAY - 02

Detecting photons and MIPs with ultra fast Geiger mode APDs

Speaker: RIPICCINI

E. RIPICCINI[1], F. GRAMUGLIA[1], C.A. FENOGLIO[1], M. WU[1], L. PAOLOZZI[2], C. BRUSCHINI[1], E. CHARBON[1]

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Major advances in silicon pixel detectors, with outstanding timing performance, have recently attracted significant attention in the community. In this work we present and discuss the use of state-of-the-art Geiger-mode APDs, also known as single-photon avalanche diodes (SPADs), for the detection of minimum ionizing particles (MIPs) and for optical photons with best-in-class timing resolution. The SPADs were implemented in standard CMOS technology and integrated with on-chip quenching and recharge circuitry. By using a femtosecond laser a SPAD in coincidence with a fast photodiode showed a timing resolution of 12 ps FWHM . For the MIPs two SPADs in coincidence allowed to measure the time-of-flight of 180 GeV/c momentum pions with a coincidence time resolution of 22 ps FWHM (9.5 ps Gaussian sigma). This measurement paves the road to a new generation of low cost beam trackers with extremely high timing and spatial resolution. Radiation hardness measurements are also presented here, highlighting the suitability of this family of devices for a wide range of high energy physics (HEP) applications.

Plenary Session - S11: GAZEOUS - THURSDAY - 01

Sub-25 ps timing measurements with 10x10 cm2 PICOSEC Micromegas detectors

Speaker: LISOWSKA

M. LISOWSKA, S. AUNE[1], I. GIOMATARIS[1], J. BORTFELDT[2], F.M. BRUNBAUER[3], G. FANOURAKIS[4], F.I. GARCIA FUENTES[5], K. KORDAS[6], C. LAMPOUDIS[6], J. LIU[7], I.M. MANIATIS[6], H. MULLER[8], E. OLIVERI[3], K. PARASCHOU[6], B. QI[9], F. RESNATI[3], L. ROPELEWSKI[3], D. JANSSENS[10], D. SAMPSONIDIS[6], L. SCHARENBERG[11], T. SCHNEIDER[3], L. SOHL[12], M. VAN STENIS[3], A. TSIAMIS[6], Y. TSIPOLITIS[13], S. TZAMARIAS[6], R. VEENHOF[14], X. WANG[9], S. WHITE[15], Z. ZHANG[16], Y. ZHOU[9], T. GUSTAVSSON[17], M. KEBBIRI[17], M. POMORSKI[17], D. DESFORGE[17], M. LUPBERGER [8], M. GALLINARO[18]

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The PICOSEC Micromegas detector is a precise timing gaseous detector based on a Cherenkov radiator coupled to a semi-transparent photocathode and a Micromegas amplifying structure. First single-pad prototypes demonstrated a time resolution below 25 ps, however, to make the concept appropriate to physics applications, several developments are required. An objective of the PICOSEC Micromegas project is to build multi-channel modules for large area coverage. To achieve uniform timing response, new 100-channel 10x10 cm2 prototypes with precise mechanics to preserve uniform thickness (< 10 ?m) of the preamplification gap were produced. The detectors were tested in the laboratory and successfully operated with 80 GeV muon beams. Preliminary results for the 10x10 cm2 prototype with CsI photocathode show a time resolution below 25 ps for all measured pads, transferring the excellent timing performance of the single-pad PICOSEC detector's proof of concept to the new 100-channel prototype. Additionally, alternative photocathodes including DLC and B4C were investigated to find a robust solution against ion bombardment. Measurements on the 10x10 cm2 prototype with DLC photocathode resulted in a time resolution below 45 ps. Finally, a single-pad detector with a reduced preamplification gap of 120 ?m displayed time resolution below 20 ps.

Plenary Session - S11: GAZEOUS - THURSDAY - 02

X-ray detectors for the BabyIAXO solar axion search

Speaker: KONRAD ALTENMUELLER

E. FERRER RIBAS[1]

[1]*CEA/IRFU*

IAXO is a largescale axion helioscope that will look for axions and axion-like particles produced in the Sun with unprecedented sensitivity. The near term goal of the collaboration is the construction and operation of BabyIAXO, an intermediate experimental stage that will be hosted at DESY. BabyIAXO is conceived to test all IAXO subsystems at a relevant scale for the final system and thus serve as prototype for IAXO, but at the same time as a fully-fledged helioscope with relevant physics reach in itself, and with potential for discovery.
One of the crucial components of the project is the ultra-low background X-ray detectors that will image the X-ray photons produced by axion conversion in the experiment. The baseline detection technology for this purpose are small Time Projection Chambers with pixelated Micromegas readouts. We will show the quest and the strategy to attain the very challenging levels of background targeted for BabyIAXO that need a multi-approach strategy coming from ground measurements, screening campaigns of components of the detector, underground measurements, background models, in-situ background measurements as well as powerful rejection algorithms. Results from the IAXO-D0 prototype will be shown.

Plenary Session - S11: GAZEOUS - THURSDAY - 03

Nanodiamond photocathode for MPGD-based single photon detectors at the future EIC

Speaker: PANDIT

C. CHATTERJEE[1]

[1] *INFN*

The construction of a Ring Imaging CHerenkov (RICH) detector for the particle identification in the high momenta range at the future Electron Ion Collider (EIC) is a challenging task. A compact collider setup imposes to design a RICH with a short radiator length, hence limiting the number of produced photons. The last can be increased by detecting photons in the far UV region. Fused-silica windows are opaque below 165 nm; therefore, a windowless RICH approach is considered.

CsI is a widely used UV photo-cathode (PC), even if fragile. Novel, less delicate PC with sensitivity in the far UV region are needed. Layers of hydrogenated nanodiamond grains have recently been proposed as alternative PC material and shown to have promising characteristics. The performance of nanodiamond PC coupled to MPGDs is the objects of our ongoing R&D.

The first phase of these studies includes the characterization of THGEMs coated with nanodiamond PC, the comparison of the effective QE in vacuum and in gaseous atmospheres, the hardness respect to the PC bombardment by ions.
The approach is described in detail as well as all the results obtained so far with this exploratory studies.

Plenary Session - S11: GAZEOUS - THURSDAY - 04

MPGD-based photon detectors for the upgrade of COMPASS RICH-1 and beyond

Speaker: FULVIO TESSAROTTO

S. DALLA TORRE[1]

[1] *INFN - TRIESTE*

After the realization of the MWPCs with CsI PC for the RICH detector of the COMPASS experiment at CERN SPS, we have upgraded COMPASS RICH by four novel gaseous Photon Detectors (PD) based on MPGD technology, never used before in RICHes, covering a total active area of 1.5 m2. The new PDs consist of two layers of THGEMs, the first also acting as a reflective PC thanks to CsI coating, and a bulk Micromegas on a pad-segmented anode; the signals are read-out by analog APV-25-based F-E.
Presently, we are further developing the MPGD-based PDs for operation at the future EIC. A compact collider setup imposes to construct a RICH with a short radiator length, hence limiting the number of photons. The last can be increased by detecting the photons in the far UV region. Another challenge is the need of improved space resolution, related to the shorter lever arm.
All aspects of the COMPASS RICH-1 PDs upgrade are presented, as well as the on-going development for collider application.

Plenary Session - S12: SiPM IV - THURSDAY - 01

NUV-HD SiPMs with Metal-filled Trenches

Speaker: MERZI

S. MERZI[1], A. GOLA[1], A. MAZZI[1], G. PATERNOSTER[1], M. RUZZARIN[1], C. PIEMONTE[2], A. INGLESE[2], S. BRUNNER[2]

[1] Fondazione Bruno Kessler|[2] Broadcom Inc.

In this contribution we would like to present a breakthrough improvement of the optical crosstalk between SPADs in SiPMs. In the framework of a collaboration between FBK and Broadcom we developed narrow metal-filled trenches that greatly suppress the optical crosstalk while maintaining a high fill factor and, in turn, photon detection efficiency. In particular, the new metal in trench detector (NUV-HD-MT) features an internal crosstalk almost 10 times lower than previous NUV-HD FBK SiPMs and can operate up to 17 V of excess bias voltages without any divergence of the correlated noise. The higher operating bias compensates the small loss in fill factor due to the insertion of the metal layer in the trenches and allows the NUV-HD-MT to reach PDE in excess of 60% with 40 µm cells. Together with a SiPM layout optimized for timing, the extended bias range allows to operate the detector with higher gain and low level of correlated noise, improving the CTR performance below 90 ps using 4x4 mm2 detectors coupled to 3x3x5 mm3 LYSO:Ce crystals and readout by a conventional front-end. The characteristics described above allow this detector to be considered as a good candidate for the upgrade of ToF-PET machines.

Plenary Session - S12: SiPM IV - THURSDAY - 02

Silicon Photomultipliers technologies for 3D integration

Speaker: PARELLADA MONREAL

L. PARELLADA MONREAL[1], L. FERRARIO[1], F. ACERBI[1], A. FRANZIO[1], A.G. GOLA[1], S. MERZI[1], A. NAWAZ[1], M. RUZZARIN[1], G. PATERNOSTER[1]

[1] Fondazione Bruno Kessler

Progress in 3D interconnecting technologies paved the way to a new generation of Silicon Photomultipliers (SiPM) by combining the integrated functionalities of the digital SiPM with the high performance, in terms of noise and efficiency, of the analog SiPM. Recently, FBK has been developing new 3D integration technologies, specifically designed for SiPMs, to improve performances and functionalities by using backside-illuminated (BSI) devices and Through Silicon Vias (TSV) interconnections.
Two different technology platforms have been identified: a BSI design for NIR and TSV interconnections for NUV/VUV SiPMs. Two R&D batches are under development to demonstrate the feasibility as well as robustness and reliability of both the technologies.
For NIR applications, electrical characterization of ultra-thin SiPM wafers with a metal reflector on the front side has shown an improved photon detection efficiency when operated in BSI configuration compared with thinned front-side illuminated (FSI) devices, allowing at the same time high-segmentation access to the SiPM output from the front-side.
Instead, for NUV/VUV applications, a FSI stacked approach is more suitable since the junction depth needs to be shallower to absorb short wavelengths. In this case, TSV interconnections have been implemented allowing to place the contacts on the backside of the wafer.

Plenary Session - S12: SiPM IV - THURSDAY - 03

Studies of GaN-based avalanche diodes as a primary cell for a solid-state photomultiplier

Speaker: OTTE

N. OTTE, D. RUSSEL[1], S. SHEN[1], H. JEONG[1], D. THEERADETCH[1], E. GAZDA[1]

[1] *Georgia Institute of Technology*

Silicon photomultipliers (SiPMs) are now widely used in high-energy physics. They are popular because of their small size, their capability to detect single-photons, their insensitivity to magnetic fields, and their low radioactivity. It is, however, challenging to achieve high photon detection efficiencies in the UV and VUV. A feature very much desired in liquid Argon and Xenon detectors. Achieving good UV sensitivity is an inherent problem with any silicon-based photon detector. Compound III-V semiconductors like GaN or AlGaN, on the other hand, exhibit good UV sensitivity. Also, their spectral response can be tuned to meet the needs of a specific application. Is it thus feasible to build a GaN or AlGaN photon detector that uses the SiPM concept?
To find out, we develop GaN and AlGaN photodiodes and test the electrical and optical characteristics of single cells operated in Geigermode. In this talk, I present our structures and their Geigermode characteristics.

Plenary Session - S12: SiPM IV - THURSDAY - 04

Studies of propagation mechanism of optical crosstalk in silicon photomultipliers

Speaker: TAJIMA

H. TAJIMA[1], A. OKUMURA[1], K. FURUTA[1]

[1] *Nagoya University*

Silicon photomultipliers (SiPMs) are now replacing photomultiplier tubes where low voltage operations, compactness, and cost per channel are important. However, optical crosstalk (OCT) is still one of the major disadvantages of SiPMs since it increases accidental triggers and degrades the accuracy of photon counting.

In NDIP 2017, we reported that the OCT can be suppressed by either thicker or no protection resin coating. Without the resin coating, an optical photon is reflected back to the original cell where the avalanche is already there. With thicker resin coating, the optical photon often escapes out of the device with a reflection at the resin surface, which reduces the apparent OCT rate.

After NDIP 2017, we measured the OCT rate across devices in SiPM arrays and confirmed that the OCT rate in adjacent SiPMs increases with a thicker protection layer, and the total OCT rate is more or less conserved when the resin coating is present.

In this talk, we report measurements of the total rate of delayed OCT and the contribution to the remaining OCT for SiPMs with no resin coating, which indicates the delayed OCT dominates the remaining OCT for no resin coating.

Plenary Session - S12b: PET - THRUSDAY - 01

Invited Talk: Developments in Molecular Imaging: from Photosensors to System Implementation

Speaker: GONZALEZ

A.J. GONZALEZ[1]

[1] Institute for Instrumentation in Molecular Imaging, i3M-CSIC

Molecular Imaging provides images of a radio-tracer distribution inside the patient body, allowing to track physiological and biochemical processes in vivo. These techniques are typically based on single or multiple detectors. Detector blocks, in most of the cases, are made of a scintillation crystal, a photosensor array and associated electronic. In this contribution we aim to deeply show these different components, their geometries and types, as well as their performance.

The accuracy of the molecular images is directly affected by the quality of the detector blocks. There are mainly two types of crystal types pixelated or monolithic. Regarding photosensors, nowadays new commercially available whole-body PET systems already use SiPM. The third element of a detector block regards to the electronic. ASIC based readout are good candidates for TOF applications.
This contribution covers the systems implementation. We will describe past and current state-of-the-art in PET, including what whole-body PET systems can do better than organ-dedicated, and what are their limitations.

There are two directions improving the image quality (especially in PET). The total-body PET approach, but also the idea of reaching near 10 ps FWHM timing resolution. Both lines improve the image SNR and, therefore, patient diagnostic or therapy assessment.

Plenary Session - S12b: PET - THRUSDAY - 02

Limited angular coverage TOF PET imager

Speaker: PESTOTNIK

R. PESTOTNIK[1], G. EL FAKHRI[2], S. MAJEWSKI[3], R. DOLENEC[4], S. KORPAR [5], G. RAZDEVšEK[4], M. OREHAR[4], A. STUDEN[4], P. KRIžAN[4]

[1] Jožef Stefan Institute| [2] MGH Boston| [3] University of California, Davis| [4] University of Ljubljana| [5] University of Maribor

PET, the leading diagnostic functional medical imaging modality, is based on detection of two annihilation gamma rays originating from beta+ radio-labelled agent. In Time-Of-Flight PET arrival time of both rays is measured in addition to their position. The coincidence timing resolution (CTR) of state-of-the art scanners is around 200 ps FWHM, which can already significantly improve the contrast in imaging large objects. To increase the sensitivity of the next-generation imagers timing accuracy should be substantially increased. By using latest advances multichannel system with improved CTR is becoming technologically possible. Images from limited angle PET scanners are distorted and have artefacts; with improving timing resolution, artefact-free images can be obtained even by a very simplified detector. We were studying a panel PET detector consisting of gamma detectors with 50 ps CTR. With this new concept, the price of PET scanners for imaging single or multiple organs can be drastically decreased. We evaluated different panel detector arrangements by imaging different phantoms. The reconstructed images were compared with the image obtained with the Siemens Biograph Vision PET scanner. We found comparable image quality of both systems when the CTR approaches 50ps FWHM and also that good CTR can partially compensate for smaller gamma detection efficiency.

Plenary Session - S12b: PET - THRUSDAY - 03

Precise time estimation with Cherenkov photons and analog SiPMs for TOF-PET

Speaker: KRATOCHWIL

N. KRATOCHWIL[1], S. GOMEZ[2], G. TERRAGNI[3], G. ARINO-ESTRADA[4], S. GUNDACKER[5], E. AUFFRAY[1]

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TOF-PET can strongly benefit from an accurate time estimator, e.g. prompt Cherenkov photon emission. Recent SiPM improvements and the use of high-frequency electronics make it possible to fully exploit the faint Cherenkov signal. However, event to event fluctuation in the number of detected photons causes fluctuations in the leading edge, which introduces an additional time bias. A double threshold system allows to determine the photon time density, enabling classification of the events based on their timing performance as well as correction of the time bias. For 20mm long BGO crystals, CTR values as good as 200ps FWHM are possible for a fraction of events. Harvesting solely Cherenkov photons in PbF2 , this quantity is improved to 142ps for small crystals and all events after correction. The combination of semiconductor detectors like TlBr with the utilizing of Cherenkov photons can lead to an outstanding detector performance with superior sensitivity, challenging the figure of merit of lutetium-based materials.

In this contribution, we examine the benefits of a double threshold system and present measured and simulated CTR results for various Cherenkov radiators coupled to analog SiPMs. System integration aspects as well as limits and paths for future detector improvements toward 100ps CTR are discussed.

Plenary Session - S12b: PET - THRUSDAY - 04

Design considerations for a PET system with 100 picoseconds coincidence time resolution

Speaker: GONZALEZ-MONTORO

A. GONZALEZ-MONTORO[1], S. POURASHRAF[1], M.S. LEE[1], J. CATES[2], C.S. LEVIN[3]

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PET reconstructed image SNR can be improved by including the 511keV photon time-of-flight (TOF) information. This improvement depends on the PET system's coincidence time resolution (CTR). The CTR of state-of-the-art clinical PET/CT systems ranges from 225-450ps. Our goal is to enhance PET image SNR by achieving 100ps CTR. This boost could be employed for better lesion detection/quantification, lower radiation dose or scanning duration. Key to achieving our goal of 100ps CTR with a small footprint electronic readout is a high-performance integrated circuit (IC) that extracts precise timing information. For our design, we have tested a high-performance IC in combination with a PET detector based on LGSO scintillation crystal coupled to SiPM. The "standard-output" of the SiPM was used for the energy analysis and the "fast-output" was connected to the IC and used for timing measurements. Data were acquired for a wide range of SiPM bias voltages and IC thresholds. The best CRT value of 92.8±0.9ps that was achieved for a 3x3x3mm3 LGSO crystal using the IC is comparable to 89.6±0.8ps achieved for the same experimental configuration except using high-performance discrete components. We also report preliminary CTR results obtained using 10mm long crystals, which are more suitable for clinically-relevant detectors.

Plenary Session - S12b: PET - THRUSDAY - 05

Clear Mind : Development of a “scintronic” crystal for very fast timing gamma ray imaging

Speaker: YVON

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The ClearMind project develops a monolithic gamma ray detector (0.5 MeV to few MeV) with a large area (25 cm2), high efficiency, high spatial accuracy (< 4 mm3 FWHM) and high timing accuracy. We use PbWO4 scintillating crystals on which are directly deposited photoelectric layers.

The crystal is encapsulated with a micro-channel plate multiplier tube (MCP-PMT) with a densely pixelated anode plane. The MCP-PMT is read out using transmission lines and a SAMPIC waveform recorder. Our detector assets consist in:

- Improving the efficiency of light collection in a high-density, and high-effective atomic number crystal.
- Using the Cherenkov light emission for detection. The gain in optical coupling optimizes the detection efficienvy of Cherenkov photons, inherently very fast.
- The scintillation photons provide a measurement of the energy deposited in the crystal, and an accurate positioning of the gamma ray interaction.
- Using the SAMPIC waveform recorder and transmission lines, provide excellent timing and spatial resolution

We will present the detector concept and first results.

Plenary Session - S14: FEE - FRIDAY - 01

MONOLITH - picosecond time stamping capabilities in fully monolithic highly granular silicon pixel detectors

Speaker: IACOBUCCI

M. MUNKER[1], A. PICARDI[1], C. MAGLIOCCA[2], D. FERRERE[1], F. MARTINELLI[1], G. IACOBUCCI[1], H. RUECKER[3], J. SAIDI[1], L. PAOLOZZI[1], M. NESSI[4], M. VICENTE[1], P. VALERIO[1], R. KOTITSA[1], R. CARDELLA[1], S. GONZALEZ SEVILLA[1], T. MORETTI[1], Y. GURIMSKAYA[1], R. CARDARELLI [1], M. MILANESIO[1]

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The MONOLITH ERC Advanced project aims at producing a monolithic silicon pixel ASIC with picosecond-level time stamping by using fast SiGe BiCMOS electronics and a novel sensor concept, the Picosecond Avalanche Detector (PicoAD).
The PicoAD uses a multi-PN junction to engineer the electric field and produce a continuous gain layer deep in the sensor volume. The result is an ultra-fast current signal with low intrinsic jitter in a full fill factor highly granular monolithic detector.
A proof-of-concept ASIC prototype confirms that the PicoAD principle works according to simulations. Testbeam measurements show that the prototype is fully efficient and achieves time resolutions down to 24ps.

Plenary Session - S14: FEE - FRIDAY - 02

Invited Talk: Evaluation of the FastIC ASIC with sub-100 ps Coincidence Time Resolution

Speaker: GóMEZ FERNáNDEZ

G. SERGIO[1], A. MARISCAL[1], J.M. FERNANDEZ-TENLLADO[1], J. MAURICIO[1], N. KRATOCHWIL[2], J. ALOZY[2], G. ARINO-ESTRADA[3], G. BORGHI[4], A. GOLA[4], S. MAJEWSKI,[3], R. MANERA[1], R. PESTOTNIK[5], M. PILLER[2], A. SANMUKH[1], A. SANUY[1], E. AUFFRAY[2], R. BALLABRIGA[2], M. CAMPBELL[2], G. EL FAKHRI[6], D. GASCON[1], S. MERZI[4], G. PATERNOSTER [4]

[1] University of Barcelona| [2] CERN| [3] Department of Biomedical Engineering, University of California Davis| [4] Fondazione Bruno Kessler| [5] Jozef Stefan Institute| [6] Gordon Center for Medical Imaging and Harvard Medical School

Molecular imaging, High Energy Physics and applications requiring a precise timestamp demand efficient photo-detectors coupled to fast readout electronics. The 8-channel FastIC ASIC developed in CMOS 65 nm technology provides an accurate time-stamping of the detected particles and a linear energy measurement. Power consumption is 12 mW/Ch with default settings. The ASIC features a double input stage capable of processing positive and negative polarity detectors with intrinsic amplification. Readout channels can be processed individually or they can be summed in clusters of 4 channels prior extracting the time and energy information. Single photon time resolution (including laser, sensor and electronics contribution) using a blue-light laser source and a HPK SiPM S13360-3050CS was measured to be 176±3 ps FWHM at 10.6 V of over-voltage compared to 202±3 ps of previous HRFlexToT ASIC. When the FastIC is connected to new technology FBK HD-NUV Low-Field SiPM (3.2x3.12 mm2 pixel, 40?m cell) the SPTR decreased to 151±3 ps. Using 511 keV gamma excitation and a pair of identical LSO:Ce:Ca0.2% measuring 2x2x3 mm3 coupled to HPK and FBK devices, coincidence time resolution values of 94±2 and 76±2 ps FWHM were obtained. First measurements of the chip confirmed its ability to detect scintillating light (LSO and BGO) and prompt light emitters (using Cherenkov radiators like TlCl and PbF2).

Plenary Session - S14: FEE - FRIDAY - 03

Performances of Radioroc: a Front-End ASIC for SiPM readout

Speaker: MORENAS

J. CIZEL[1]

[1] *Weeroc*

RADIOROC is a 64-channel front-end ASIC designed to readout silicon photo-multipliers (SiPM). Radioroc allows triggering down to 1/3 p.e. and provides dual-gain energy measurement with excellent Signal-to-noise ratio on the high gain (SNR over 10 for single p.e.) and large dynamic range on the low gain.
Moreover, RADIOROC can output the 64-channel triggers with jitter as low as 55 ps FWHM on a single p.e. (160 fC, Cinj = 100pF). Photo-counting has been measured to be over 200 MHz and Time Over Threshold (TOT) charge measurement is possible on the full input swing with excellent energy resolution and single photons separation.
An adjustment of the SiPM high-voltage is possible using a channel-by-channel 8-bit DAC connected to the ASIC inputs to homogenize SiPM gains.
Timing resolution better than 55 ps FWHM is possible along with 1% linearity energy measurement up to 2000 p.e. Outputted signals can be selected via I2C channel wise with 2 direct outputs per channel and the possibility to output single-ended/differential triggers or analog signals.
Testbench measurements will be presented including LASER test.

Plenary Session - S14: FEE - FRIDAY - 04

The new monolithic ASIC of the preshower detector for di-photon measurements in the FASER experiment at CERN

Speaker: ZAMBITO

S. ZAMBITO[1], G. IACOBUCCI[1], L. PAOLOZZI[1]

[1] University of Geneva, Geneva, Switzerland

The FASER experiment at the LHC is designed to look for new, long-lived fundamental particles. To extend its discovery potential, a W-Si preshower detector is currently under construction, with the objective of enabling the discrimination of photon pairs with O(TeV) energies and separation down to 200 µm. The detector will be based on a new monolithic silicon pixel sensor in 130nm SiGe BiCMOS technology, featuring a matrix of N-on-P hexagonal pixels of 65 µm sides. The ASIC will integrate SiGe HBT-based fast front-end electronics with O(100) ps time resolution, and will feature an extended dynamic range for the charge measurement. Analog memories inside the pixel area will provide the capability of storing charge information for thousands of pixels per event, allowing for a frame-based event readout with minimum dead area. After a short description of the preshower detector and its expected performance, the design of the monolithic ASIC and the test results on the ASIC prototypes will be presented.

Plenary Session - S14: FEE - FRIDAY - 05

Evaluation of the BETA ASIC for the FIT and PSD detectors at the HERD facility

Speaker: GASCON

S. GóMEZ FERNáNDEZ[1], A. COMERMA[2], A. SANMUKH[3], J. MAURICIO[4], R. MANERA[5], A. SANUY[4], X. WU[6], P. AZZARELLO[6], C. PERRINA[6], F. GARGANO[7], D. GASCON[8]

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The 16-channel BETA ASIC implemented in a 130~nm technology has been developed as the readout electronics for the Scintillating Fiber Tracker (FIT) and the Plastic Scintillator Detector (PSD) at the High Energy Cosmic-Radiation Detection (HERD) facility. The main objective of this ASIC is to track the minimum ionizing particles (MIPs) and perform a charge measurement of the detected events. The ASIC includes a dual-gain scheme automatically configured depending on the incoming signal that provides. The signal processing has a nominal power consumption of 1 mW/ch and a high dynamic range from 3800 pe to 0.1 pe. Signal to noise ratio at single photon level is about $\approx$13. The ASIC also contains 2 discriminators to provide a trigger signal. A linearity error of the charge measurement of 3\% for a dynamic range as large as 15 bits. Finally, on-chip digital back-end circuitry controls the acquisition, and data serialization to a single output link. The second version of the chip will provide a discriminator output signal channel for the trigger system and eventually for backsplash discrimination by time-of-flight measurement.

Plenary Session - S14: FEE - FRIDAY - 06

Ultra-Fast Readout Through Transmission Lines for TOF PET detectors

Speaker: SHARYY

V. SHARYY[1], D. YVON[1], M. FOLLIN[1], E. DELAGNES[1], D. BRETON[2], J. MAALMI[2], R. CHYZH[3], A. GALINDO-TELLEZ[3]

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We discuss the development of an innovative PET detection technologies with the enhanced time-of-flight performances for two projects: BOLD-PET and ClearMind. In both projects the signal from optical photons are multiplied with micro-channel-plate PMT with a pixelized anode. In order to optimize the time resolution and limit the number of electronics channels, we readout anode signals through the transmission lines PCB. The signal from both ends of 32 lines are amplified by the dedicated amplification boards (2 x 20 dB, 700 MHz) and signal shape is digitized by a SAMPIC module with the frequency 6.4 GS/s.
In this presentation we discuss the test results of such readout scheme using commercial Planacon MCP-PMT and a pulsed laser PILAS with beam duration of 20 ps. In particular, we measure the time difference for signals from both ends of the line with a precision of 20 ps (FWHM) resulting in a spatial resolution along lines down to 1.6 mm and 0.9 mm across lines. We measured a single-photon time resolution corresponding of 70 ps (FWHM). We study the possibility and limitation of multi-photon reconstruction in such ultra-fast readout.

Plenary Session - S15: Vac Det III - FRIDAY - 01

Characterization of Amorphous Silicon Based Microchannel Plates with High Aspect Ratio

Speaker: FREY

S. FREY[1], M. BEYGI[1], C. BALLIF[1], N. WYRSCH[1]

[1] *École polytechnique fédérale de Lausanne (EPFL)*

Microchannel plates fabricated using hydrogenated amorphous silicon (AMCP) offer unique advantages over conventional MCPs. In the newest generation of AMCPs, a large multiplication gain of 1485 was measured for an aspect ratio 25, significantly improving on the previous generation's maximum gain of only 100 at aspect ratio 13.6. Based on our simulations, gains of up to 10'000 are achievable with a further increase of the aspect ratio to 30, and by coating the channel walls with a high secondary emission material. Additionally, we report on preliminary findings with the first detectors to be fabricated with a funnel shaped opening to increase the active area.

Plenary Session - S15: Vac Det III - FRIDAY - 02

New results from the TORCH R&D Project

Speaker: JONES

T. JONES[1]

[1] *University of Warwick*

TORCH is a large-area and high-precision time-of-flight detector, designed to provide chargedparticle identification over a 2-20 GeV/c momentum range. The TORCH detector comprises a 10 mm
thick quartz radiator, instrumented with photon detectors, which precisely time and measure the spatial positions of the Cherenkov photons emitted by the traversing particles. The photon detectors are micro-channel plate photo-multiplier tubes (MCP-PMTs) comprising a finely segmented anode of 64 x 64 pixels over a 53 mm2 area, an excellent intrinsic time resolution of ~30 ps, and a long lifetime of up to ~ 5-10 C/cm2. These MCP-PMTs have been developed with an industrial partner, Photek Ltd, to satisfy the stringent requirements of the TORCH detector. The TORCH R&D programme has demonstrated the concept through extensive laboratory and beam tests. Two TORCH prototypes have been constructed and have yielded encouraging results when exposed to low momentum charged hadrons. Characteristic patterns of Cherenkov photons have been recorded, illustrating the required spatial accuracy and timing resolution of 70 ps per photon. Both laboratory and beam test results are in line with the design goal of TORCH and will be presented, alongside future TORCH R&D
plans.

Plenary Session - S15: Vac Det III - FRIDAY - 03

New Advances of Microchannel-Plate PMTs

Speaker: MIEHLING

D. MIEHLING[1], M. BöHM[1], S. KRAUSS[1], M. PFAFFINGER[1], S. STELTER[1], F. UHLIG[1]

[1] *Friedrich-Alexander-Universität Erlangen-Nürnberg*

The PANDA experiment at the FAIR facility at GSI will study hadron physics using a high intensity antiproton beam of up to 15 GeV/c momentum to perform high precision spectroscopy. Two DIRC detectors with their image planes residing in an ~1 T magnetic field will be used in the experiment. The only suitable photon detectors for both DIRCs were identified to be Microchannel-Plate Photomultipliers (MCP-PMTs). Now that the aging problems of MCP-PMTs were solved recently by coating the MCPs with the so-called ALD-technique (atomic layer depostion) we are investigating devices which are significantly improved with respect to other parameters, as, e.g., the collection efficiency (CE) and the quantum efficiency (QE). The latest generation of MCP-PMTs can reach a detective quantum efficiency DQE=QE*CE of ~30%. This talk will present the performance of the most advanced 2x2 inch^2 ALD-coated MCP-PMTs from PHOTONIS (8x8 and 3x100 anodes) and Photek (8x8 anodes), also inside the magnetic field. With a picosecond laser and a multi-hit capable DAQ system which allows to read out up to 300 pixels simultaneously, parameters like darkcount rate, afterpulse probability and time resolution as well as the temporal and spatial distributions of recoil electrons can be investigated as a function of incident photon position.

Plenary Session - S16: SiPM V - FRIDAY - 01

Tip Avalanche Photodiode – a new spherical-junction-based SiPM

Speaker: VINOGRADOV

S. VINOGRADOV[1]

[1] *Lebedev Physical Institute*

An avalanche region of APD cells in the modern SiPMs is formed by a planar p-n junction where an edge breakdown is suppressed by area-consuming measures. Performance of the planar SiPMs is limited due to an inherent trade-off between photon detection efficiency (PDE) affected by an inactive cell area and dynamic range dependent on the cell pitch and capacitance.

To overcome the limitations of the planar SiPM design, a spherical-junction-based SiPM – Tip Avalanche Photodiode (TAPD) – has recently been developed. Its quasi-spherical tips turn the edge breakdown problem into benefits of highly efficient collection and multiplication of photoelectrons in focusing electric field, low breakdown voltage, low cell capacitance, and eliminate needs in the separation borders between the APD cells.

TAPD samples of 15 um pitch outperform the state-of-the-art SiPMs in the record PDE of 73% at the peak sensitivity wavelength of 608 nm. Moreover, the PDE is above 45% in a range from 400 nm to 800 nm and 22% at 905nm. The high PDE is accompanied by the fast single electron response and cell recovery time of about 4 ns due to the low capacitance of the tips. The report presents an overview of the spherical-junction-based APD and SiPM features.

Plenary Session - S16: SiPM V - FRIDAY - 02

Cryogenic Characterisation of Silicon Photomultipliers for future Dark Matter Detectors

Speaker: KACHRU

P. KACHRU[1], C. GALBIATI[2]

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SiPMs are the baseline photo-sensor solution for the Darkside-20k detector and thanks to their high timing resolution and photon detection efficiency will allow to achieve an excellent pulse shape discrimination discriminating electron recoil from nuclear recoil events. The SiPMs by FBK produced in LFoundry are being characterised at LNGS, Italy have timing resolution of 200-300 ps with Dark Count rate of 0.1 cps/cm2-0.3 cps/cm2 with afterpulse probability upto 10%. The internal CrossTalk (iCT) increases significantly with over-voltage that spoils the resolution. Also, PDE needs to be characterised at cryogenic temperatures due to its temperature based inconsistency. A strategy to calculate the triggering efficiency in SiPMs under test is used to model the absolute PDE at 77 K. Modelling of depletion region and absorption length in the SiPM lattice structure, will enhance PDE upto 60% at 77 K. Additionally, external CrossTalk (eCT) phenomenon is also characterised. This phenomena can account for noises that mimic the SiPM signals similar to internal Crosstalk, but the only distinction being the source and timing. Through careful implementation of Poisson statistics between the SiPMs in such a setup, we were able to quantify the contribution of eCT in SiPMs which will valuable for disentangling noises for future dark matter detectors.

Plenary Session - S16: SiPM V - FRIDAY - 03

Direct Comparison of the Performance of the SiPM-Based and PMT-Based Detector Modules Operating in the Imaging Camera of the MAGIC-I Telescope

Speaker: HAHN

A. HAHN[1], A. DETTLAFF[1], D. FINK[1], D. MAZIN[2], R. MIRZOYAN[1], M. TESHIMA[3]

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MAGIC consists of two 17m diameter imaging atmospheric Cherenkov telescopes (IACTs) located at the Canary island of La Palma. The imaging cameras of the telescopes are based on 1039 photomultiplier tubes (PMTs). We developed three mechanically and electronically compatiple prototype detector modules based on silicon photomultipliers (SiPM) from different manufacturers. We installed these modules in the corners of the hexagonal-shape PMT-based camera of the MAGIC-I telescope and since few years are operating them in parallel with PMTs. We combined seven to nine SiPM chips to produce composite pixels of a comparable area as the used PMT input windows. We present a direct comparison of the performances of the SiPM- and PMT-based pixels during real telescope operations.