# 6th Allpix Squared User Workshop

Wednesday 7 May 2025 - Friday 9 May 2025

Nikhef

# Book of Abstracts

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**New features and developments / 1**

# Integrating Microelectronics Simulation into the Allpix Squared Framework

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To meet the increasingly demanding performance requirements of future High Energy Physics experiments, ongoing and future Monolithic Active Pixel Sensor (MAPS) developments focus on enhancing key characteristics (such as spatial resolution, timing precision, and energy resolution). Achieving these improvements requires advanced and accurate simulation tools.

For the electrical modeling of pixel sensor front-end circuits (such as Charge Sensitive Amplifiers (CSAs) and discriminators), simulation tools like Spectre and SPICE are commonly used. By integrating Allpix Squared with those tools, we combine detailed physics-based sensor modeling with high-precision microelectronics simulations. To facilitate this integration, we have developed a new Allpix Squared module, [NetlistWriter], which complements the existing digitizer modules [DefaultDigitizer] and [CSADigitizer].

This module generates simulation-ready netlists and creates input signals required for the electrical simulation of pixel sensor front-ends. Specifically, it dynamically modifies the front-end netlist for each simulated event by adding input current sources for every triggered pixel. The timing and amplitude of these sources are taken from the Allpix Squared event data. Additionally, the [NetlistWriter] module can launch the electrical simulation within each event.

This contribution will present the key features of the [NetlistWriter] module and demonstrate its capability by comparing simulation results with experimental data obtained from MAPS prototypes.

**Will the talk be given in person or remotely?**:

In person

**New features and developments / 2**

# Optimizing Charge Transport Simulation for Hybrid Pixel Detectors

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MÖNCH is a charge-integrating hybrid pixel detector with a 25 µm pitch. The charge information collected by individual pixel makes is possible to enhance the detector's spatial resolution under low flux condiftions, either using conventional interpolation or novel machine learning approaches. For this a thorough understanding of the charge transport is essential, especially for machine learning where training samples can be easily obtained using simulation. However, discrepancies between simulation and experimental measurements—particularly in the spectral response of individual pixels—were observed, posing challenges for simulation optimizations.
To address these issues, new simulation methods have been developed based on charge carrier dynamics including charge repulsion. We implemented both a simplified spherical model and a GPU-accelerated model simulating individual charge carriers. Significant improvements were obtained by comparing these simulations with carefully calibrated X-ray measurements. We also present a parameterization of the model, potentially suitable for integration in Allpix Squared.

**Will the talk be given in person or remotely?**:

In person

**Applications and studies / 3**

## Optimization of a 3D neutron imaging sensor through combined simulation approaches

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Neutron imaging provides complementary information to X-ray imaging due to the different interactions of these radiation types with matter. This technique is valuable in various fields, including nuclear engineering and non-destructive industrial diagnostics.

Building on advancements in 3D sensor technology, a novel device based on a 3D micro-structured design has been developed for thermal neutron detection and imaging. This device, studied within the INFN HYDE2 project, is fabricated using a streamlined process with planar n-on-p pixels on the front side. On the back side, Deep Reactive Ion Etching (DRIE) creates deep (˜25 µm) and narrow cavities, which are then to be filled with neutron-converting materials such as $^{6}$LiF or $^{10}$B.

The sensor consists of a 256×256 pixel array, with each pixel measuring 55×55 µm², and is integrated with a Timepix readout chip for data acquisition.

A key objective of this work is to optimize the geometry of the cavities (i.e., their width and distance) to maximize the neutron detection efficiency. This requires careful consideration of neutron capture, the detection of the resulting charged particles, and the collection of the generated charge necessary to produce an electrical signal—a challenging problem to solve.

To address this, the study is divided into multiple tasks. First, the energy deposition map of charged particles generated by neutron capture is determined using GEANT4 simulations. Then, TCAD Sentaurus is used to calculate the electrical properties of the silicon device. While TCAD can also be used to determine charge collection efficiency (CCE), evaluating multiple geometries with this approach is computationally intensive.

To overcome this limitation, the energy deposition map and static TCAD simulation results are incorporated into an Allpix2 simulation. Within Allpix2, the Weighting Potential, Electric Field, and Doping Profile—obtained from TCAD—are imported. Next, the DepositionPointCharge module is employed to inject charge into the device according to the energy distribution derived from GEANT4. To account for the specific geometry of the HYDE2 device, a modified version of the TransientPropagation module is implemented, for the transportation of the charge.

Finally, the total CCE is computed for different geometries, and a comparison with transient TCAD simulations in selected geometries is performed to validate the accuracy of the Allpix2 results.

**Will the talk be given in person or remotely?**:

In person

**Applications and studies / 4**

## Exploring the capability of different 3D-trench electrode sensors for 4D tracking

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Future colliders will produce unrivaled levels of luminosity, generating extreme radiation fluences. These environments call for sensors capable of 4D tracking while withstanding extreme radiation damages. 3D-trench electrode sensors developed under the TimeSPOT project show outstanding timing resolution even after fluences up to $\sim 10^{17}$ 1-Mev $n_{eq}cm^{-2}$. However, the not yet mature fabrication technology limits the yield of large-area sensors. To address this issue in view of sensor layout design, a variant has been proposed that introduces a gap in the continuous p$^{+}$ electrodes. New batch of sensors containing both the standard and dashed sensors have been fabricated at FBK, with preliminary on-wafer electrical test results exhibiting high breakdown voltages and low leakage currents for the majority of sensors. Moreover, the yield of large sensors for the new variant is higher than that of the standard design, proving the effectiveness of the concept. Functional tests and dedicated irradiation campaigns are scheduled to assess the timing performance of these sensors. In the meantime, it is imperative to evaluate the performance of these sensors for future upgrades by utilizing available simulation platforms.
Monte Carlo simulations within the framework of Allpix$^2$ are performed to examine the charge collection efficiency and timing resolution before and after radiation damage. Results show that both designs have high charge collection efficiency even after server bulk damage. Dashed 3D-trench electrode sensors achieve a timing resolution of 10.29 ps before irradiation. Further simulations confirm that the dashed sensors exhibit performance comparable to the standard sensors after fluences up to $2 \times 10^{16}$ 1-Mev $n_{eq}cm^{-2}$. Though the timing performance slight degrades after bulk damage, it can be recovered by increasing the reverse bias.

**Will the talk be given in person or remotely?**:

In person

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## Simulations of the Monolithic Active Pixel Sensors for the Octopus Project

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The OCTOPUS (Optimized CMOS Technology for Precision in Ultra-thin Silicon) project, part of the DRD3 collaboration, aims to simulate, develop, and evaluate fine-pixel monolithic sensors using the 65 nm TPSCo process. The project targets a spatial resolution of 3 μm, a temporal resolution below 10 ns, a material budget of 50 μm silicon, and an average power consumption below 50 mW/cm² to meet the needs of vertex detectors in future lepton colliders.
The OCTOPUS project places significant emphasis on the extensive simulation effort under Work Package 1, which aims to improve sensor layouts and dimensions. This includes simulations of standard sensor designs with different readout options and n-gap designs with small pitch and binary readout. Building on past studies of n-blanket and n-gap designs, current research also explores ways to improve deep n-implant geometry. The simulation strategy combines TCAD static simulations and high-statistics Monte Carlo simulations, both essential for refining sensor designs and improving performance.
The contribution includes the simulation results for the different pitch standard layout designs and n-gap layout designs results with varying gap sizes, as well as the optimization of the n-gap shape.

**Will the talk be given in person or remotely?**:

In person

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## Charge collection studies of 65 nm CMOS MAPS for ALICE ITS3

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In the context of the ALICE Inner Tracking System upgrade (ITS3) project and the CERN EP R&D, a new large area Monolithic Active Pixel Sensor (MAPS), based on stitching, is being developed in the Tower Partner Semiconductor (TPS) Co. 65 nm CMOS Image Sensor (ISC) process.
Different pixel test structures (TS) were designed to validate the sensor technology through an extensive characterization both with laboratory and in-beam measurements.
This work will focus on the Analogue Pixel Test Structure equipped with a fast OPAMP buffer to explore the sensor timing performance and the signal formation process. Every TS has three different sensor versions: standard, modified and modified with gap, respectively with an increased charge collection speed.
Lab measurements with a monochromatic X-ray source were made to characterize the test structures which led to the conclusion that the modified with gap sensors presented a slower charge collection tail when compared to the modified design. In order to understand these experimental data, a model of the charge collection process using a combination of TCAD and AllPix2 was developed.
This contribution will present the simulation approach and the results obtained regarding the charge

collection mechanism that explain the presence of the slower tail in the modified with gap sensor design.

**Will the talk be given in person or remotely?**:

In person

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## electronCT Simulations with Allpix Squared

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electronCT explores the use of multiple Coulomb scattering of electrons in matter for tomographic imaging, particularly in the context of radiation therapy with electron beams in the 100–250 MeV energy range. This technique has the potential to provide high-precision imaging of tumors immediately before treatment, utilizing the same accelerator as the therapy itself. The proof of concept for electronCT has been investigated at the ARES accelerator at DESY and the MAMI accelerator in Mainz.

Accurate beam simulations play a crucial role in refining image reconstruction techniques and estimating key parameters such as the absorbed dose in patients. In this contribution, we present how Allpix Squared is employed for these simulations. We will also compare the different approaches used by different simulation tools that contributes to the ongoing development of electronCT technology.

**Will the talk be given in person or remotely?**:

In person

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## Investigating the Timing Performance of Silicon Carbide Particle Detectors using Simulations

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Silicon Carbide (SiC) features a ten times higher breakdown field and nearly twice the charge carrier saturation velocity than silicon, theoretically enabling faster signal formation and improved timing resolution. The current road towards designing SiC-LGADs has the potential of unlocking ultra-fast timing detectors, with potentially improved radiation hardness over silicon-based LGADs. However, past research on the timing performance of SiC detectors is scarce, as planar sensors without internal gain struggle to detect minimum ionizing particles with a sufficient signal-to-noise ratio. We report our recent advancements in probing SiC timing performance and designing fast SiC timing detectors using AllPix² simulations.

We employed AllPix² to investigate the theoretical limits of the timing resolution of planar SiC detectors due to Landau fluctuations. By comparing the results to simulations with silicon and diamond, we found that at their respective saturation velocities, SiC exhibits the highest signal power density above 1 GHz, theoretically enabling the best time resolution among the three materials.
However, to access the full spectrum, fast readout electronics are needed. We developed a high-bandwidth readout board based on a monolithic microwave integrated circuit with an intrinsic bandwidth of 10 GHz and 50 Ω input impedance. Coupled with a planar SiC diode with 1 pF capacitance, we achieved a signal bandwidth of 5.5 GHz, which allows us to resolve the charge carrier drift at reverse biases up to 1100 V. To verify our measurement results, we developed an end-to-end simulation workflow integrating TCAD device simulations into AllPix² for accurate current signal modeling, followed by electronics simulations in QUCS-S.
We plan to apply this workflow to evaluate the timing performance of SiC LGADs. Ongoing work focuses on benchmarking SiC-LGAD gain simulations within AllPix² and comparing the results to TCAD for validation.

**Will the talk be given in person or remotely?**:

In person

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## Simulation of MAPS in a 65 nm CMOS Imaging Technology

**Authors:** Adriana Simancas[1]; Anastasiia Velyka[1]; Finn King[1]; Gianpiero Vignola[1]; Håkan Wennlöf[2]; Jona Dilg[1]; Larissa Mendes[None]; Lennart Huth[1]; Manuel Alejandro Del Rio Viera[1]; Sara Ruiz Daza[1]; Simon Spannagel[1]; Yajun He[3]

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Future lepton and electron-ion collider concepts rely heavily on silicon sensors as primary tracking devices. The Tangerine Project at DESY is actively investigating monolithic active pixel sensors (MAPS) developed using 65 nm CMOS imaging technology for future experiments.

This project provides a comprehensive overview of the research and development of these sensors, covering their design, simulation, and testing. It includes the characterization of chip prototypes and simulations of sensor behavior using a genetic algorithm approach. The simulation strategy integrates Monte Carlo methods with electrostatic field simulations via Technology Computer-Aided Design (TCAD) and is validated against test beam data.

One of the sensors under study is the DESY Chip V2 (also known as DESY ER1), a four-pixel analog test structure with direct access to the analog amplifier output. Simulation studies of a sensor with the same dimensions as DESY Chip V2 have been conducted to analyze sensor behavior and guide test beam campaigns.

Additionally, a hexagonal pixel grid is explored as an alternative to traditional square or rectangular layouts, with performance assessed for various pixel sizes. Hexagonal pixels are particularly interesting as they may enable shorter drift paths while maintaining sufficient area for circuitry in the p-well, as well as reducing the number of neighboring pixels. While results for a thin epitaxial layer of 10 um show limited improvements in efficiency, cluster size, and spatial resolution, further simulations are discussed to address design limitations and explore potential advantages, such as enhanced timing performance.

The investigations in this work analyze the performance of the hexagonal pixel grid in MAPS for high-energy physics experiments. Moreover, simulations of the DESY Chip V2 explore both the advantages and challenges when comparing simulated results with real data.

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In person

**New features and developments / 10**

## PixESL: a Virtual Prototyping Framework for Pixel Detector Electronics in High Energy Physics.

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This contribution outlines the development of PixESL[1], a virtual prototyping framework for pixel detectors based on C++/SystemC. It offers a platform for describing detector ASICs designed for High Energy Physics experiments at a high level of abstraction, with the capability to simulate an electronics system from the output of a framework for semiconductor particle interaction, such as AllPix2, to the readout of a digital data packet to the experiment back-end. The framework supports modelling analog/digital front-end, readout networks, data processing, and formatting. This presentation details the implementation of the PixESL framework and its use in a pixel detector being developed for the LHCb experiment at CERN. The framework serves as an effective and rapid prototyping method, as well as a reference model for verification.

[1] https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10832570

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In person

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## Monte Carlo Simulation of Low-Gain Avalanche Detectors Using Allpix$^2$

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Low-Gain Avalanche Detectors (LGADs) are silicon sensors designed to deliver excellent time resolution, with a precision better than 20 ps. This exceptional time resolution makes them highly suitable for applications demanding precise timing measurements, such as high-energy physics experiments and medical imaging. The performance of LGADs is influenced by various factors, including charge deposition, charge collection efficiency, electric field distribution, and radiation-induced degradation, highlighting the necessity for detailed simulation studies to accurately characterize and optimize these sensors.

While TCAD simulations are commonly used for detector design, particularly for modeling doping profiles and electric field distributions, Monte Carlo simulations can complement this approach by providing a more detailed and accurate modeling of the complex physical processes involved in charge deposition and transport in semiconductor detectors. In this work, we take advantage of Allpix² by combining both TCAD and Monte Carlo simulation approaches to provide a comprehensive evaluation of LGAD performance under different operating conditions. The doping profiles and electric field distributions, extracted from TCAD simulations, are integrated into the Allpix² framework, enabling a detailed analysis of the sensor's response. The simulation investigates key aspects such as charge collection and the radiation-induced effects on the overall performance of the detector, providing valuable insights into the sensor's behavior in high-radiation environments.

**Will the talk be given in person or remotely?**:

Remotely

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## Validation of Results of 2S Modules in Test Beam

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In this work, we present a toolkit, wrapped around Allpix, that can be used to study the performance of the HL-LHC CMS Outer Tracker 2S modules. The toolkit generates events with tracking particles targeted at a slice of the user defined geometry of 2S modules and then forwards the resulting Allpix output to a front-end emulator that performs the full hit digitization chain. This presentation will review the present status and capabilities of the framework, along with a validation study to beam test data. Future use cases in both beam tests and standalone Phase 2 CMS setups like the Cosmic Rack will also be outlined.

**Will the talk be given in person or remotely?**:

Remotely

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## Simulation of Enhanced Lateral Drift Sensors for Future Lepton Colliders

**Authors:** Anastasiia Velyka[None]; Gianpiero Vignola[1]; Hendrik Jansen[2]; Simon Spannagel[1]

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Key requirements for future vertex detectors at lepton colliders include spatial resolutions on the order of 3 μm and nanosecond time resolution. Several R&D activities are currently underway to meet these demands, exploring various approaches and technologies. Enhanced Lateral Drift (ELAD) silicon sensors leverage charge-sharing mechanisms to improve spatial resolution through a non-homogeneous electric field, created by buried doping implants within the sensor. This allows to

achieve the spatial resolution targhet with larger pixel pitch, reducing the number of readout channels and increasing the space available for the pixel front-end. This allows achieving the spatial resolution target with a larger pixel pitch, reducing the number of readout channels and increasing the space available for the pixel front-end.

Extensive simulations have been performed using a combination of TCAD and Allpix$^2$ frameworks to optimize the electric field and spatial performance. The results indicate the feasibility of achieving an almost linear charge-sharing behavior between two readout electrodes, reaching O(5 µm) spatial resolution using a 150 µm thick ELAD sensor with 55 µm pitch.

This contribution will present the ELAD technology, detailing the simulation setup and discussing results obtained for different geometric and doping configurations. The findings from this study have guided the design of the first ELAD prototypes, currently in production, and will serve as a benchmark for future laboratory and test beam measurements.

**Will the talk be given in person or remotely?**:

In person

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## Implementation of Charge Carrier Mobility and Radiation Damage Models for Diamond Sensors in Allpix Squared

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We present the implementation of various charge carrier mobility models for diamond sensors in the Allpix Squared simulation framework. These models account for the electric field, temperature, and impurity concentration dependence of mobility to accurately simulate charge carrier propagation in diamond sensors. Furthermore, we implement "radiation damage model"parameters for polycrystalline structure and radiation damage in diamond sensors. Together with an appropriate mobility model, these parameters enable accurate simulation of signal loss resulting from reduced charge collection efficiency. Our simulation results show good agreement with existing literature data.

**Will the talk be given in person or remotely?**:

In person

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## Simulation of CMOS Strip Sensors

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In high-energy physics, there is a need to investigate silicon sensor concepts that offer large-area coverage and cost-efficiency for particle tracking detectors. Sensors based on CMOS imaging technology present a promising alternative silicon sensor concept.
As this technology follows a standardised industry process, it can provide lower sensor production costs and enable fast and large-scale production from various vendors.

The CMOS Strips project is investigating passive CMOS strip sensors fabricated by LFoundry in a 150nm technology.
The stitching technique was employed to develop two different strip sensor formats.
The strip implant layout varies in doping concentration and width, allowing the study of various electric field configurations.

The performance of irradiated and unirradiated samples was evaluated based on several test beam campaigns conducted at the DESY II test beam facility. The detector response was also simulated using Monte Carlo methods combined with TCAD Device simulations.

This contribution demonstrates how performance differences of the various strip sensor layouts can be investigated using Allpix$^2$ simulations.
In particular, the simulated detector response is presented and compared to test beam data.

**Will the talk be given in person or remotely?**:

In person

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# Ongoing Developments

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**Will the talk be given in person or remotely?**:

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# Recent Developments & New Features

**Authors:** Håkan Wennlöf[1]; Paul Schütze[2]; Simon Spannagel[2]

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**Will the talk be given in person or remotely?**:

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# Fast Lookup Tables for Parametrizing Charge Digitization in HL-LHC ATLAS ITk detectors

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The ATLAS ITk-Pixel and ITk-Strip detectors are planned tracker upgrades for the High-Luminosity LHC utilizing n+-in-p silicon sensors. They must withstand severe irradiation over their operational lifetimes, corresponding to fluences of up to 9x10^15 1-MeV neq/cm, with consequences on charge collection efficiencies. To achieve a precise understanding of the expected performance and to produce Monte Carlo simulations with realistic tracking performance, TCAD models of irradiation effects on internal electric fields are developed and coupled with AllPix2 simulations of ionization-charge propagation through the sensors. To bypass computational bottlenecks in simulating the busy HL-LHC environment, various fast Lookup Table strategies are explored and integrated into the AllPix2 ecosystem.

**Will the talk be given in person or remotely?**:

Remotely

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# Detector Response Simulation of a Hardpix Detector for Neutron Measurements on the Moon

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Interest in subsurface lunar water has grown due to plans for a permanent Moon base. A common approach involves sending a rover to drill and analyze soil samples, but site selection is largely

random. To improve this, a feasibility study is exploring albedo neutron spectrum measurements, which vary in the presence of water. Hardpix detectors are specifically designed for space radiation environments featuring a Timepix3 chip. To convert a Timepix3 chip into a neutron detector, it is covered with a converter material that has high neutron cross section. A simulation was set up using the Allpix Squared framework with four sensors, each covered by LiF, Cd + LiF, and polyethylene, with one bare detector for reference. LiF enriched with $^{6}$Li has a high cross section for thermal and epithermal neutrons, while polyethylene is used for detecting fast neutrons. The simulation was validated with several measurements. The detector efficiency for neutrons in the range of 10 meV to 10 GeV has been simulated, along with the expected measured neutron spectrum for this four-detector configuration.

**Will the talk be given in person or remotely?**:

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## Simulation of 3D Pixel Sensors in a Test Beam Setup Using Allpix$^2$

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As part of my master's thesis, I have performed a simulation study of 3D silicon pixel sensors developed by SINTEF, for use in the ATLAS ITk upgrade at CERN. The aim of this work is to reproduce the conditions of a real test beam experiment, where sensors were exposed to a 120 GeV pion beam. The simulation setup replicates the EUTelescope beamline configuration and has been implemented using the Allpix$^2$ framework.

The study focuses on evaluating the detection efficiency and charge transport in the 3D sensor geometry. The simulated data has been analyzed and compared to real test beam measurements obtained under similar conditions.
Results so far show promising similarities between the simulation and experimental data, indicating that Allpix$^2$ can effectively model complex sensor behavior in a realistic beam environment. This comparison not only validates the simulation framework but also supports the continued development and testing of 3D pixel sensor technologies for future high-luminosity environments

**Will the talk be given in person or remotely?**:

In person

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## A Repulsive Effect: Modelling Coulomb Interactions in a 1 Micron X-ray CT Sensor

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Our research group is developing a novel, ultra-high resolution, Xray sensor for use in medical imaging CT. The sensor is an edge-on deep-silicon sensor and achieves the resolution by performing charge-fitting on the signal from adjacent pixels for single interactions.
In previous comparisons between measurements and simulations it has been noted that the amount of charge sharing is less in the simulations than in the measurements. It is hypothesized that one source of this discrepancy is the lack of coulomb repulsion in the simulations, whose effect would cause the cloud charge-carrier to spread out further.
To investigate the effect of the coulomb repulsion on the charge cloud diffusion, our research group have added the coulomb repulsion functionality in a new propagation module based on the Transient Propagation module.
Different interaction energies are simulated at different distances from the collection electrodes, and the effects of the coulomb repulsion on the induced current and the charge cloud size will be presented together with the effects of the coulomb repulsion using the novel sensor.

**Will the talk be given in person or remotely?**:

In person

**Applications and studies / 23**

## The 100μPET project: Simulation of the next generation PET scanner with monolithic silicon pixel sensors

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**Co-authors:** Aleix Boquet-Pujadas [2]; Giuseppe Iacobucci [1]; Lorenzo Paolozzi [1]; Mateus Vicente Barreto Pinto [1]

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The 100μPET project, led by the University of Geneva, the University of Luzern, and the École Polytechnique Fédérale de Lausanne, aims at the development of a small-animal positron emission tomography (PET) scanner with ultra-high-resolution molecular imaging capabilities.

This is achieved with compact and modular stacks of multiple thin monolithic pixel detectors bonded to flexible printed circuits (FPC) via flip-chip, thus resulting in unprecedented scanner depth-of-interaction and volumetric granularity.

Monte Carlo simulations performed with the Allpix2 framework allowed both the optimisation of the scanner design and the generation of realistic scanner data for imaging reconstruction. Very large datasets with billions of events were produced with different source phantoms to characterize its performance.
The scanner is predicted to have a point-spread-function of 0.2 mm, no parallax effect, and display a volumetric spatial resolution of ~0.015 $mm^3$ - one order of magnitude better than modern scanners.

The work developed within the $Allpix^2$ framework, including all simulation results, will be presented in this contribution.

**Will the talk be given in person or remotely?**:

In person

**Applications and studies / 24**

## Si3: Simulation-Driven Design of a Next-Generation Semiconductor Detector for PET and SPECT Imaging

**Author:** Luca Terenzi[1]

**Co-authors:** Mats Danielsson [1]; Per Lundhammar [1]

[1] *Royal Institute of Technology Stockholm (KTH)*

The Si3 project aims at the development of a novel radiation detector for medical imaging applications such as Positron Emission Tomography (PET) and Single Photon Emission Computed Tomography (SPECT). The aim is to significantly enhance detector efficiency as well as improve resolution compared to current state-of-the-art.

The detector consists of compact, modular layers of semiconductor sensors with monolithic pixels. Unlike conventional SPECT systems, it operates without a collimator and unlike standard PET systems, it does not rely solely on fully absorbed photon events. Instead, it is designed to collect all interactions within the detector volume and reconstruct the causality of each interaction sequence in order to reconstruct the incident direction of the incoming photon.

This contribution presents an overview of the Si3 project along with some of the latest results and characterizations enabled by Allpix-Squared. Simulations within the Allpix-Squared framework are being used to investigate requirements and assess the best trade offs in terms of detector spatial resolution, time coincident events, charge collection time and more.

Finally, some remarks will be made concerning the next steps of the simulation set-up and the improvements needed to fully simulate the whole detector set-up.

**Will the talk be given in person or remotely?**:

Remotely

**Welcome and Allpix Squared overview / 25**

## Welcome from the workshop organisers

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**Will the talk be given in person or remotely?**:

**26**

## Open Discussion and close-out

**Will the talk be given in person or remotely?**:

**New features and developments / 27**

## Charge Carrier Propagation based on pre-calculated Lookup-Tables

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In the past few months CERN EP-R&D WP1.2 in collaboration with ALICE ITS3 adapted its Monte Carlo simulation methodology to support a lookup based propagation technique : In a first step the pixel is meshed and a fixed amount of electrons are injected in each node and propagated in the 'standard'way using TCAD generated electric field, the final state of these electrons is saved. In a second step, more realistic charge deposition is generated, and the previously generated look-up is used to simulate propagation. This leads to extremely fast simulation (for the moment giving access only to the amplitude of the signal without timing, a coarse timing information is under consideration).
Using this method in Garfield++ gave excellent matching with measurements for the iron spectrum of MAPS in a 65nm technology. A similar method is currently under development in Allpix-Squared via the modules MappedPropagation and PropagationMapWriter.
Garfield++ also allows loading mobility and lifetime directly from a file (e.g. generated by TCAD). This feature is also in development in Allpix-Squared. Ultimately, loading lifetime from TCAD also allows to include the effect of irradiation in the lifetime, enabling more complex models.

As a summary this contribution presents one of the MAPS simulation frameworks used at CERN and how part of it is currently implemented by Allpix-Squared developers.

**Will the talk be given in person or remotely?**:

In person

**Applications and studies / 28**

## SImulations of LGAD test structures

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**Will the talk be given in person or remotely?**:

**Applications and studies / 29**

## Placeholder

This is a placeholder for a nice contribution.

**Nikhef colloquium / 30**

## Allpix Squared: Eight Years of Advancing Microscopic Monte Carlo Simulations for Semiconductor Detectors

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Accurate simulations of signal formation in semiconductor detectors with high statistical precision are crucial across all phases of detector development, from initial design through to final qualification. Allpix Squared is a powerful, open-source simulation framework tailored for semiconductor detectors, enabling detailed end-to-end simulations that span from the initial interaction of ionizing radiation with the sensor to the output of digitized detector data.

Originally developed for silicon pixel detectors in high-energy physics, Allpix Squared has evolved into a versatile tool capable of simulating a wide range of detector types, semiconductor materials, and geometries. It supports applications in diverse fields, including space-based experiments, photon science, and medical imaging. A key strength of the framework lies in its modular architecture, which allows users to implement various algorithms for different stages of the simulation pipeline, interface with external tools like Geant4, TCAD, or SPICE simulators, and customize simulations by selecting the most appropriate modules.

Since its initial release eight years ago, Allpix Squared has undergone continuous development, expanding its capabilities and applications. This colloquium will provide an overview of the framework, highlight notable developments and applications across various domains, and present an outlook on future advancements.