3rd Allpix Squared User Workshop

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Book of Abstracts

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New Features & Developments / 1

Status update of Allpix Squared simulations for Multi-element Germanium Detectors for Synchrotron Applications

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Synchrotron experiments using X-ray fluorescence (XRF) techniques are currently limited by the sensitivity of fluorescence detectors, where the maximum counting rate, the energy resolution and the signal-to-background ratio are key performance features. The two last features are highly affected by charge sharing events, i.e., events where photon energy is shared between pixels. This undesirable effect is avoided in current commercial detectors using a collimator in front of the detector sensor, at a cost of a significant reduction of the detector active area, which is undesirable in detectors where smaller pixels will be required. The impact of charge sharing in detector sensitivity is being studied in the conception of a new generation of multi-element germanium detectors, developed by the LEAPS-INNOV project, using Allpix Squared framework.

This talk presents a fully operational simulation based on Allpix Squared framework, developed by the Detector group of Synchrotron SOLEIL, customized to multi-element germanium detectors, and combined with three-dimensional simulation of the electric field and the weighting potential, based on COMSOL Multiphysics®. Ongoing changes in the simulation chain will be also presented: 1) the implementation of beamline environment and detector components in GDML format, 2) non-standard pixel shapes (hexagonal and trapezoidal) at the germanium sensor and 3) the use of electrostatic simulations generated by Solid State Detectors code. A first estimation of detector sensitivity in XRF experiments will be also presented.

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Simulation of HR GaAs:Cr Timepix3 detectors with Allpix2

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Recent advantages in crystal growth have facilitated the production of high resistivity (HR) chromium compensated gallium arsenide (GaAs:Cr), which has become an alternative to silicon, especially in X- and gammas-ray detection and imaging, where such sensors profit from their higher absorption efficiency.

To explore charge transport properties of the HR GaAs:Cr material we measured the dependence of the electrons and holes drift velocity on the electric field and the dependence of the diffusion coefficient on the electric field. It became possible by analyzing the HR GaAs:Cr-Timepix3 detector response to charged particles entering the detector at a grazing angle. The holes lifetime and their mobility were measured using the drift time information for the first time for HR GaAs:Cr material to be τ_h = 4.5±0.5 ns, μ_h = 320±10 cm^2/V/s at 300 V.

The measured dependencies were introduced into the Allpix^2 simulation framework. Simulated Timepix3 detector response was validated by comparison of the measured and the simulated data for various X- and gammas-ray sources in the energy range of 6 –60 keV, protons of 125 MeV, and pions of 120 GeV/c.

The talk will be divided into two parts: firstly I will tell about the performed experiments and following data analysis and then I will continue with a short tutorial on how to perform the simulation of HR GaAs:Cr Timepix3 detectors with Allpix^2.

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Simulating the 100µPET scanner

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The 100µPET project, a SNSF SINERGIA between UNIGE, EPFL and HUG, aims at producing a small-animal PET scanner with unprecedented volumetric spatial resolution by using multi-layer monolithic silicon pixel detectors.
The Allpix^2 framework is central for the detector's parameters optimization. Different detector geometries and electrical parameters are studied in order to optimize the scanner parameters and performance.
In this contribution we will present the scanner, the results of the simulations and how these were analyzed.

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Cosmic Strips Telescope Simulation with Allpix

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We are simulating the performance of the ATLAS ITk Strips EC System Test as a Cosmic Muon Telescope with the Allpix Squared framework. A couple of modifications to the Allpix (and Corryvreckan) frameworks have been made to deal with the particularities of the cosmic particle flux.

Planned contents of the talk:

- The ATLAS ITk Strips System Test
- ITk Strips Endcap Modules (with a reference to Radek's work)
- Cosmic Muon Flux (Energy, distribution, east-west-effect)
- The CRY-framework and the DepositionCosmics module (thanks Simon)
- The AnalysisParticleFlux module in Corryvreckan
- Results we have until the talk
- Outlook

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Development and simulation of a new preshower detector for the FASER experiment at the LHC

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The design of a new high-granularity pre-shower detector for the FASER experiment at LHC is in progress, with the purpose of measuring and discriminating electromagnetic showers generated by photons with O(TeV) energies and separation down to 200 μm. The new pre-shower will comprise six planes of monolithic silicon pixel detectors with hexagonal pixels of 65 μm side.
The detector simulation was implemented in Allpix Squared to drive the design of the pre-shower layout and the production of the shower reconstruction algorithms. New modules were developed for the integration of the hexagonal pixel matrix and the simulation of the ASIC charge measurement and digitization circuit.

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New Allpix Squared Documentation & Website

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Allpix Squared has been using LaTeX to create its documentation. While this results in an excellent looking PDF, the documentation on the website has issues with displaying certain math and code blocks nicely. Thus it was decided to change the documentation format, using Markdown for the source and Docsy for the website.

This talk will present the new website and goes into some of the technical details of the process. A brief introduction in Markdown is given as well to get the audience familiar with the new format. At the end the missing steps for deployment are given.

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Developing new detector model geometries in Allpix-Squared

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Recent efforts in the Allpix-Squared development have been focused on implementing non-typical detector model geometries, such as radial strip detectors with trapezoidal sensors or detectors with hexagonal pixels.
The Geant4 library, the underlying simulation core handling (among else) model geometry in Allpix-Squared, can create a variety of detector shapes. However, creating the model geometry is only the beginning and many more issues have to be tackled, including choosing suitable coordinate systems or defining the segmentation of a sensor.
In this contribution, an overview of the development process of a new detector model is presented and illustrated on the example of the radial strip detector model.

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Radial strip detectors in Allpix-Squared

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The Allpix-Squared simulation toolkit has long been used by the ATLAS ITk Collaboration to perform simulations of pixel and strip silicon detectors.
In this contribution, a new functionality added into the toolkit is presented, enabling simulations of ATLAS ITk strip end-cap detectors featuring a trapezoidal sensor shape with detection strips fanning out radially from a common focal point.
The implementation has been tested by comparing obtained simulation outputs with available test beam measurement data obtained at the DESY-II test beam facility in 2018. Further simulation studies based on this implementation, such as the ATLAS ITk Strips End-Cap System Test, are already ongoing.

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Simulation of hybrid pixels using precise TCAD simulations

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In view of the High Luminosity LHC phase the ATLAS collaboration is preparing a new all silicon tracking detector - the Inner Tracker (ITk).
At the core of the new tracker there will be 5 barrel layers instrumented with hybrid pixel detectors with fine pitch (50x50 or 25x100 um).
The new detector will have to sustain radiation damage levels up to 10 times larger than the actual tracker.
It is important to make predictions on performance after such a large accumulated radiation damage fluence.
For this allpix-squared is used, in combination with inputs from TCAD tools, like the electric field and the weighting potential.

In this contribution we will show the possibility to read in TCAD files from Silvaco tools and some studies for 100 um thick n-on-p sensors.

The plan is to use these predictions to correct cluster shapes and charges of the ATLAS MC pixel simulated events.

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Allpix2 Simulations of Particle Interactions in Cell Phone Camera Image Sensors for DECO

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The Distributed Electronic Cosmic-ray Observatory (DECO) is a cell phone app which uses the cell phone camera image sensor (CMOS) to record images of ionizing radiation from cosmic rays or radioactivity. A convolutional neural network (CNN) is used to classify these images according to their morphology, which indicates particle identity and energy. In this project, we use Allpix^2 to simulate the CMOS sensor and images produced by ionizing radiation. After classification by the CNN, these simulated events are compared against DECO collected real events both individually and collectively. The simulation parameters are adjusted according to the comparison result to improve data - Monte Carlo agreement.

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Beam telescope simulations in Allpix Squared

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Beam telescopes are used to investigate future particle detector prototypes, and to do this efficiently they must provide excellent position and time resolution at the device under test location. One of the goals of the Tangerine Project is to develop a beam telescope based on sensors created in a 65 nm CMOS imaging process. In order to study the tracking performance and choose the best geometry configuration, simulations are needed. This talk will cover all the steps needed for the simulation of a beam telescope in Allpix Squared, with a particular focus given to the Allpix Squared integration with Corryvreckan, which is a framework dedicated to reconstructing and analyzing test beam data. Finally, the first simulation results of the Tangerine telescope will be discussed.

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Simulations of 65 nm silicon sensors using Allpix Squared

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The Tangerine project's goal is to develop the next generation of small collection electrode monolithic silicon pixel detectors using the 65nm CMOS imaging process which offers a higher logic density and overall lower power consumption compared to previously used processes.
A combination of TCAD and Monte Carlo (MC) simulations are used in order to understand the processes and parameters that are involved in the developments in the new 65 nm technology.
Allpix Squared utilizes the realistic electric field and doping profiles provided by the TCAD simulations and by the use of MC methods, obtains important quantities that characterize the performance of the sensors. These results can later be compared to results from test beam experiments.
In this presentation, a discussion on the procedure, setup, and importance of these simulations will be presented, as well as the results obtained from various detectors layouts and configurations.

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Allpix Squared - An Overview

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The silicon detector simulation framework Allpix Squared is under constant development. In the past year, the framework has seen two feature releases, versions 2.1 and 2.2, and several patch releases. These add one new module as well as several new functionalities for the existing modules. Above that, the next feature release is already in preparation, among others opening the framework for other semiconductor materials.

In this presentation we will give an introduction to Allpix Squared and present the features recently added to the framework. In addition, an overview over current developments will be presented.

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Ongoing & Future Developments

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This contribution provides an overview of ongoing developments and planned features of the Allpix Squared framework, such as the extended geometry options for sensors, 3D front- and backside implants, impact ionization and a change in how detector fields are applied in the simulation.

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Combining COMSOL and Monte Carlo Methods to Simulate SiC Sensors using the Allpix2 Framework

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Accurate simulation of nuclear-voltaic battery performance can provide valuable insight into optimal power generation through novel nuclear-voltaic designs. Rigorous models require the use of Monte Carlo methods along with electrostatic field simulations, detailed charge generation, and correct treatment of the charge propagation. This paper presents simulations for a silicon carbide (SiC) planar Schottky detector that was configured as an alpha-voltaic power cell using 241Am electrodeposited on its Schottky metal contact. The model integrates a detailed electric field model

from finite element software COMSOL Multiphysics into a Monte Carlo based simulation using the Allpix2 framework. The approach is applicable to the study of complex semiconductor devices when exposed to various radioactive sources or environments.

The use of Monte Carlo based software such as Geant4 and Allpix2 in combination with COMSOL or TCAD is a relatively recent development, but not entirely new. However, this paper details an approach that accurately models the charge propagation in SiC using a SiC specific mobility model in a relatively novel detector configuration. The results can be used as a baseline validation of the approach, lending credibility to the simulation approach when applied to more complex device geometries of more intricate electric field distributions

In this study, the alpha spectrum are simulated from a custom SiC detector having 241Am electrodeposited onto its surface, as well as simulations of other SiC detectors where the 241Am source is located some distance from the SiC detector. The simulated alpha spectra are compared to experimental data recorded from the custom SiC detectors. The charge propagation details such as charge collection time and propagation paths of the SiC detectors are quantified and illustrated. The comparisons show good agreement between the modeled and experimental data.

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Using Allpix Squared for proton computed tomography

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Proton therapy is, due to its higher precision of energy deposition, an effective alternative to conventional x-ray therapy. Occurring uncertainties due to the use of x-ray computed tomography in treatment planning can be reduced through the use of proton computed tomography. To accurately predict the range of the protons in tissue, it is necessary to reconstruct the tracks of the protons through the body with the help of detectors.
A new track reconstruction software, Corryvreckan, was published in 2017 with the intention of equally good track reconstruction capability with respect to EUTelescope, while reducing external dependencies. It bears great similarity in its modular structure with the simulation software Allpix2, creating a good compatibility between the two frameworks.
The different implemented modules in Corryvreckan ensure its usability for track reconstruction and analysis in complex environments.
Applications of track reconstruction with pixel sensors are investigated at TU Dortmund with regard to proton computed tomography.
The use of Allpix2 in the context of proton computed tomogrophy is presented in this talk, for its utility of creating valid simulations, which can be further processed with Corryvreckan

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Welcome from the Workshop Organisers

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Frequently asked questions and frequently encountered problems

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Describing freqeuntly asked questions about Allpix Squared simulations, as well as frequently encountered problems and their solutions. The talk will outline important things to think about when setting up and running an Allpix Squared simulation, and describe possible pitfalls and their workarounds.