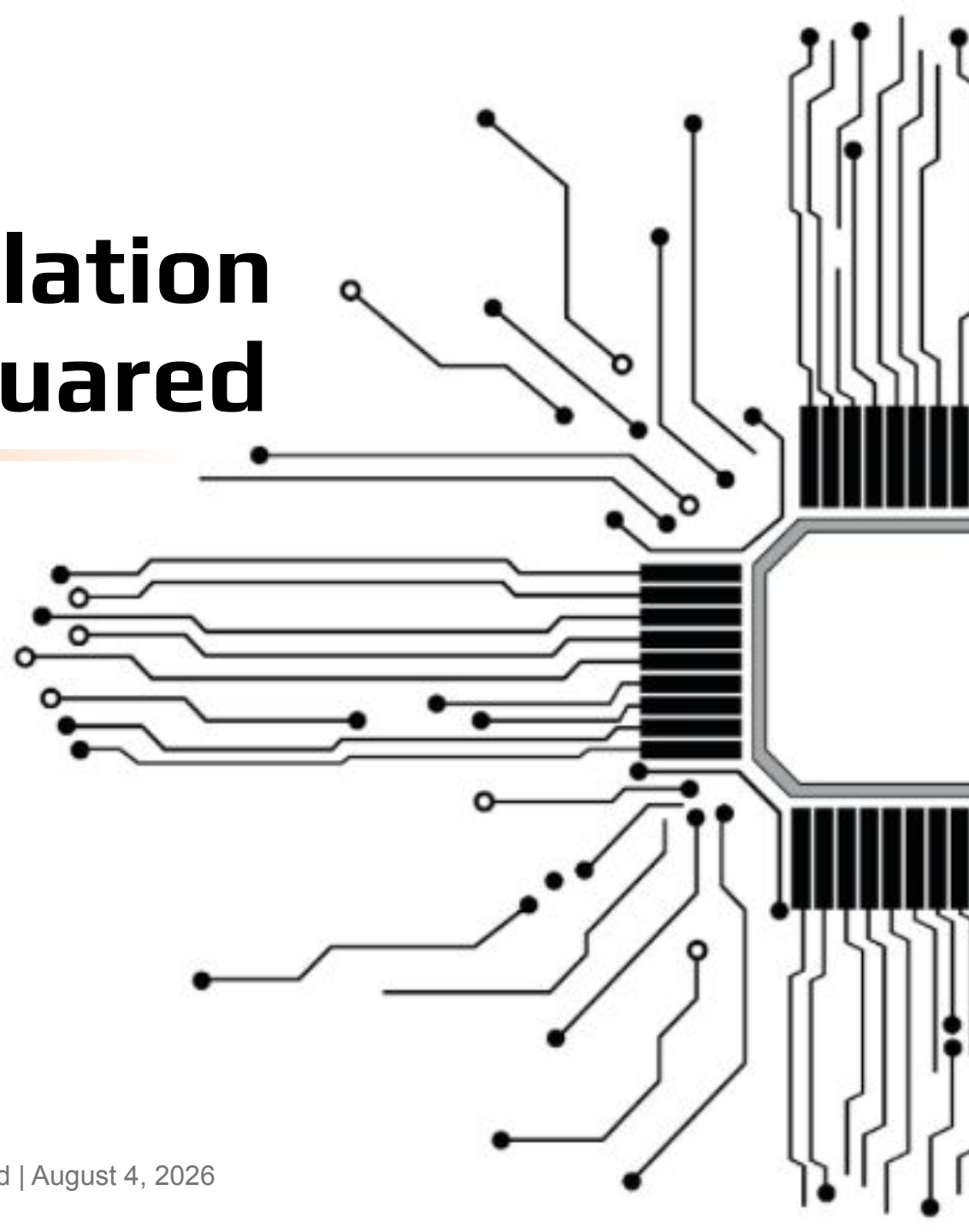
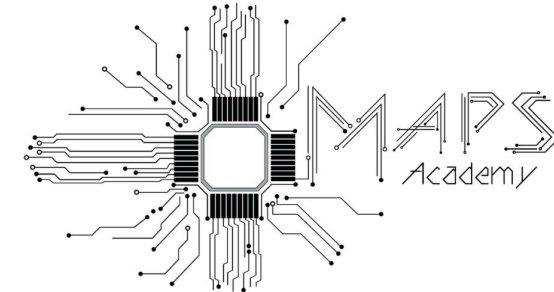


Physical Sensor Simulation with TCAD / Allpix Squared

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Theresa Heinz, ETH Zurich, Switzerland
Tianqi Gao, University of Cambridge, United Kingdom





Tianqi
Postdoc

ETH zürich

Theresa
PhD Student



**UNIVERSITY
OF TRENTO**

Jixing
Postdoc



MAPS Academy 2026 | SLAC, Stanford |
August 4, 2026

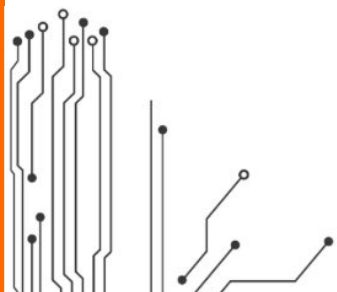
Motivation

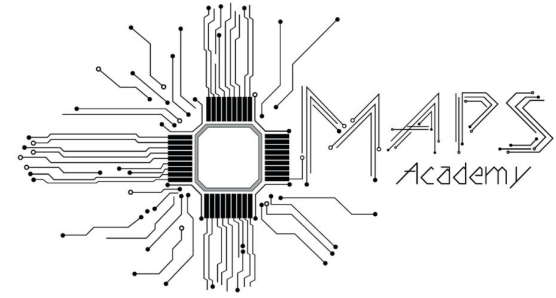
- **Demanding sensor requirements** for HEP experiments in terms of pixel pitch, spatial granularity, particle rates, radiation hardness, fast-timing etc.
- Sensor fabrication cycles are **time consuming** and **expensive**
- Design parameters must be evaluated and optimized prior to fabrication
- **TCAD** provides underlying device physics
- **Allpix²** uses this information to produce detector-like output

<https://indico.global/event/5677/contributions/46838/attachments/23160/39053/2021-09-17-PSD12-APSQ.pdf>

Target

- Understand the physical quantities TCAD computes and their dependence on the sensor geometry and doping
- Set up and run a TCAD simulation for a basic sensor and extract relevant parameters
- Run a complete Allpix² simulation from event generation to the digitization of hits
- By the end: be able to apply the full workflow ✓





Recap TCAD

TCAD

- Device-level simulation tool
- Solves semiconductor equations (Poisson, drift-diffusion) on the actual sensor geometry
- Inputs: material properties, doping profiles, geometry, bias voltage, etc.
- Outputs: electric field, depletion depth/voltage, weighting field, charge transport properties, etc.
- Used for: characterization and optimization of sensor designs

**Sentaurus
TCAD**

SYNOPSYS

https://indico.cern.ch/event/1600786/sessions/638813/attachments/3228097/5753426/TCAD_handson.pdf

Recap Allpix Squared

Allpix Squared

- C++ simulation framework for semiconductor detectors
- Combines Geant4, TCAD and detector electronics
- Outputs is comparable to real detector / testbeam data
- **Models full detector response**



<https://indico.global/event/5677/contributions/46838/attachments/23160/39053/2021-09-17-PSD12-APSQ.pdf>

Recap Allpix Squared

Inputs

- Detector configuration
- TCAD Field Configurations
- Particle Source

Allpix²

- Energy Deposition
- Charge Propagation
- Signal Formation
- Digitization

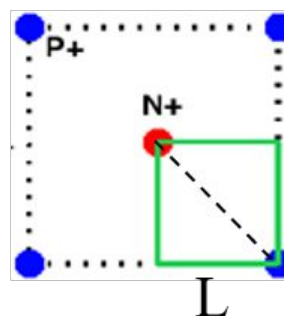
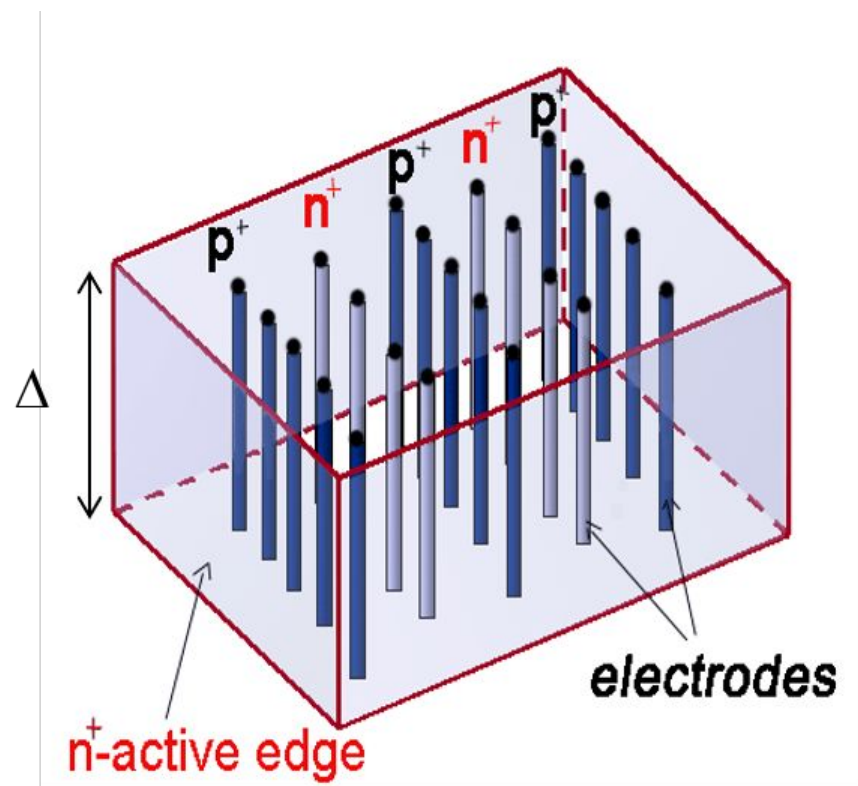
Outputs

- Hits
 - Clusters
 - Timing
 - ...
- ROOT Files



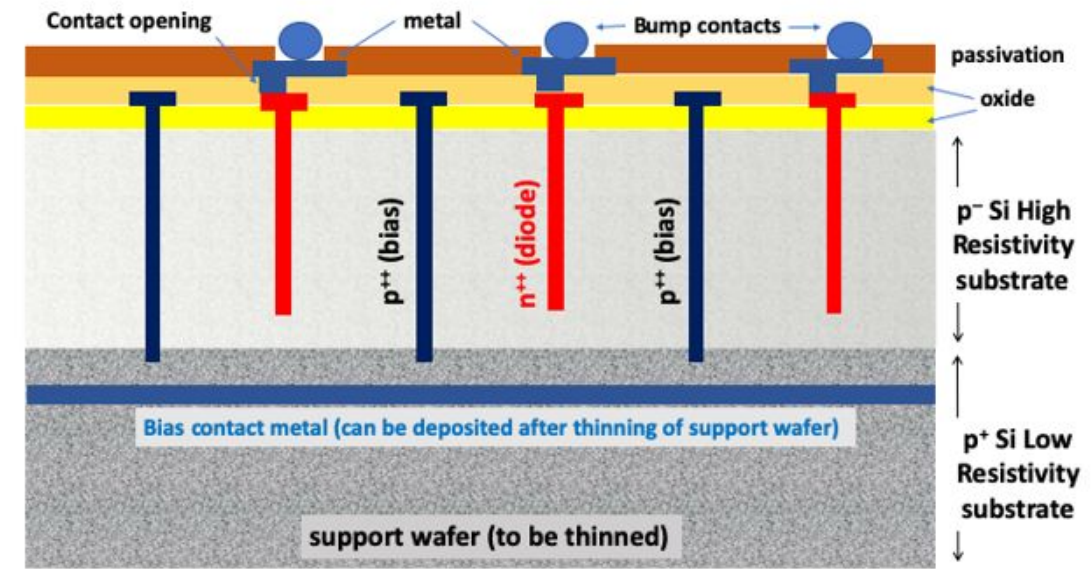
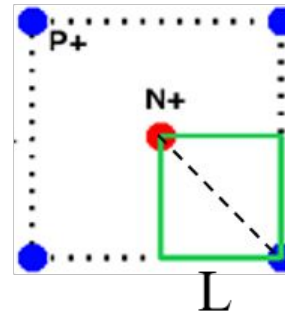
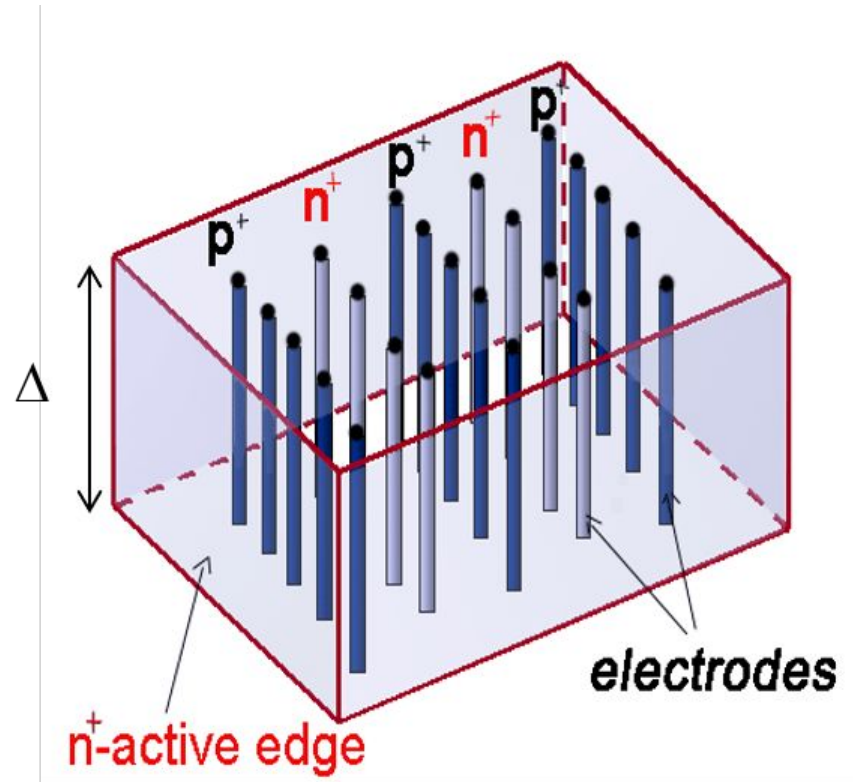
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Simulation Results



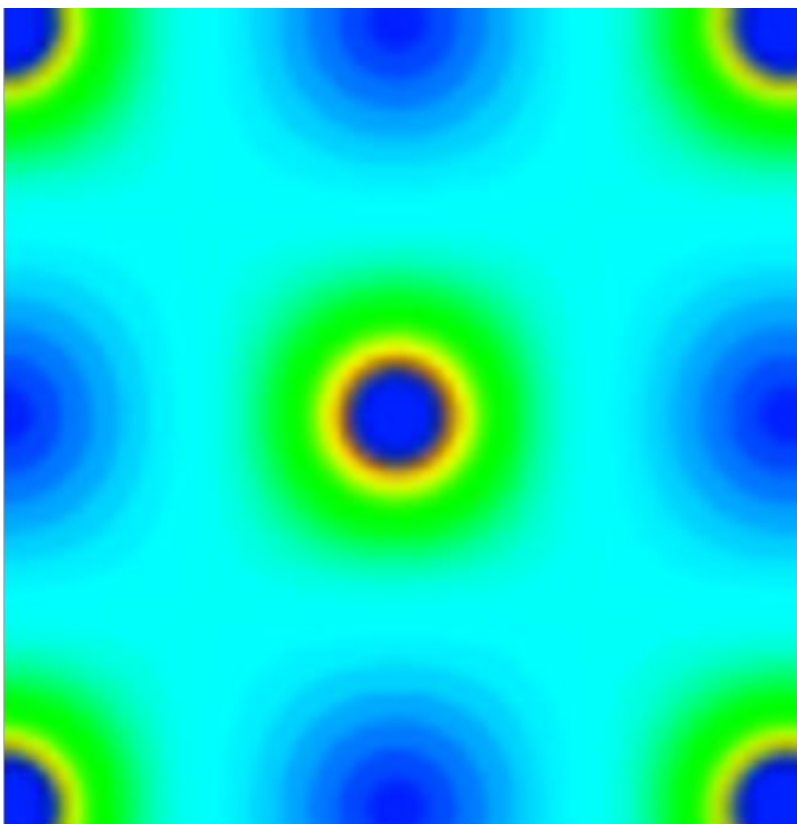
S. Parker et. al. NIMA 395 (1997) 328

Simulation Results

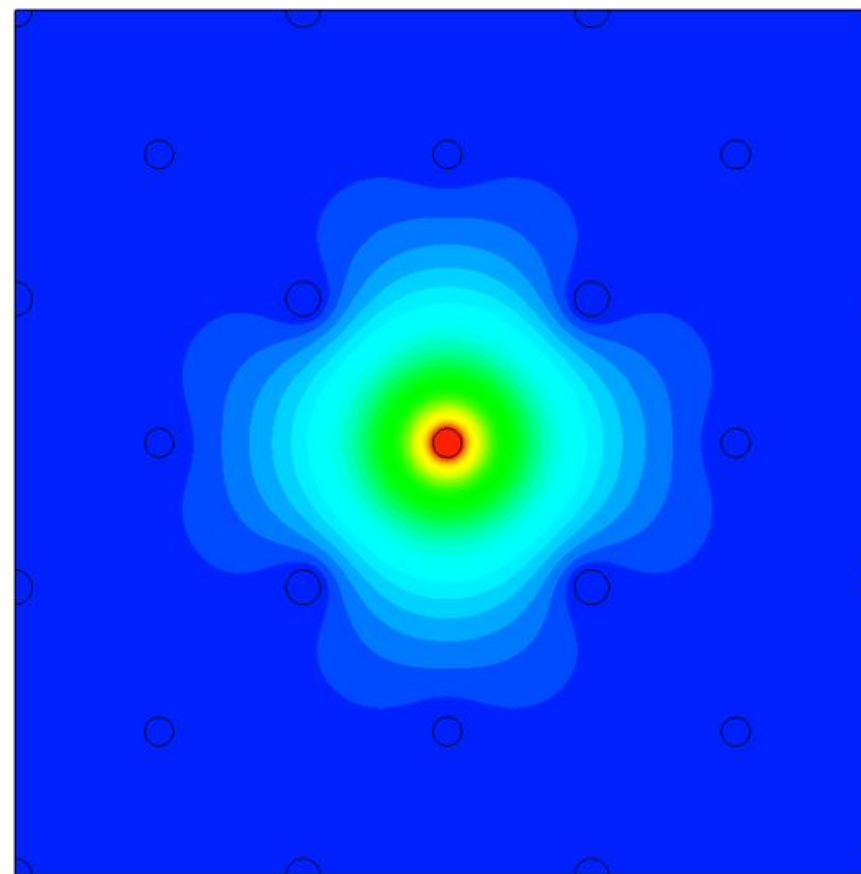


S. Parker et. al. NIMA 395 (1997) 328

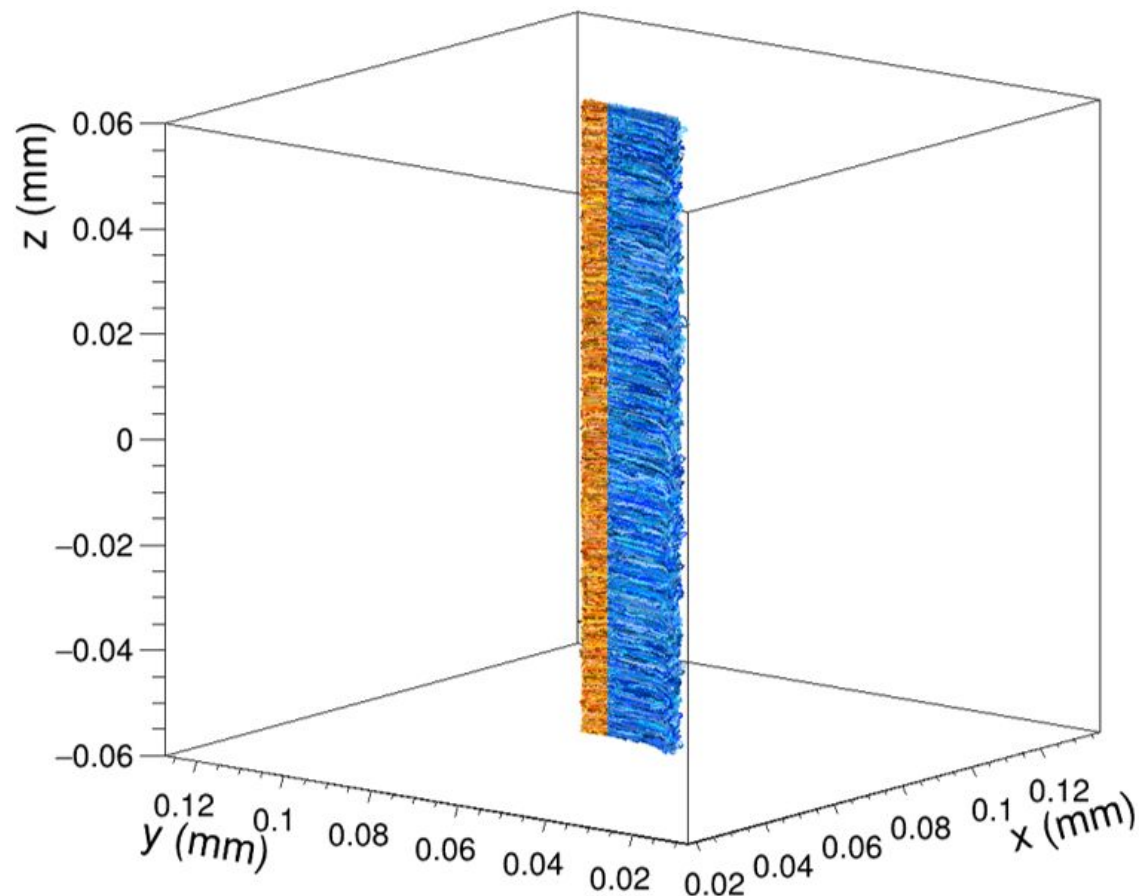
Simulation Results



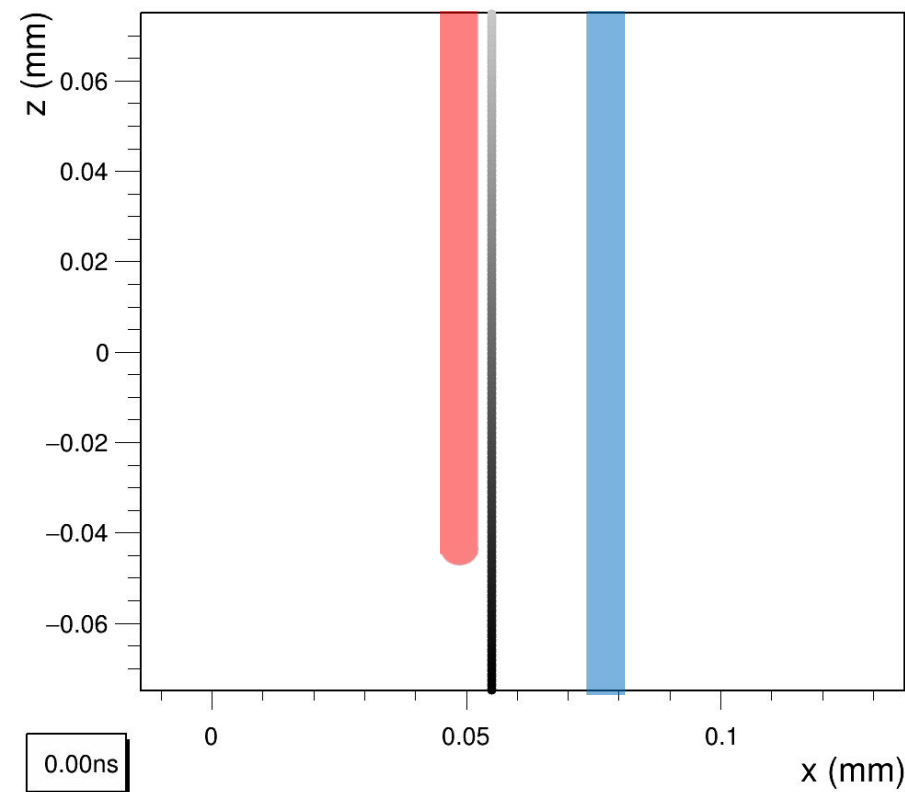
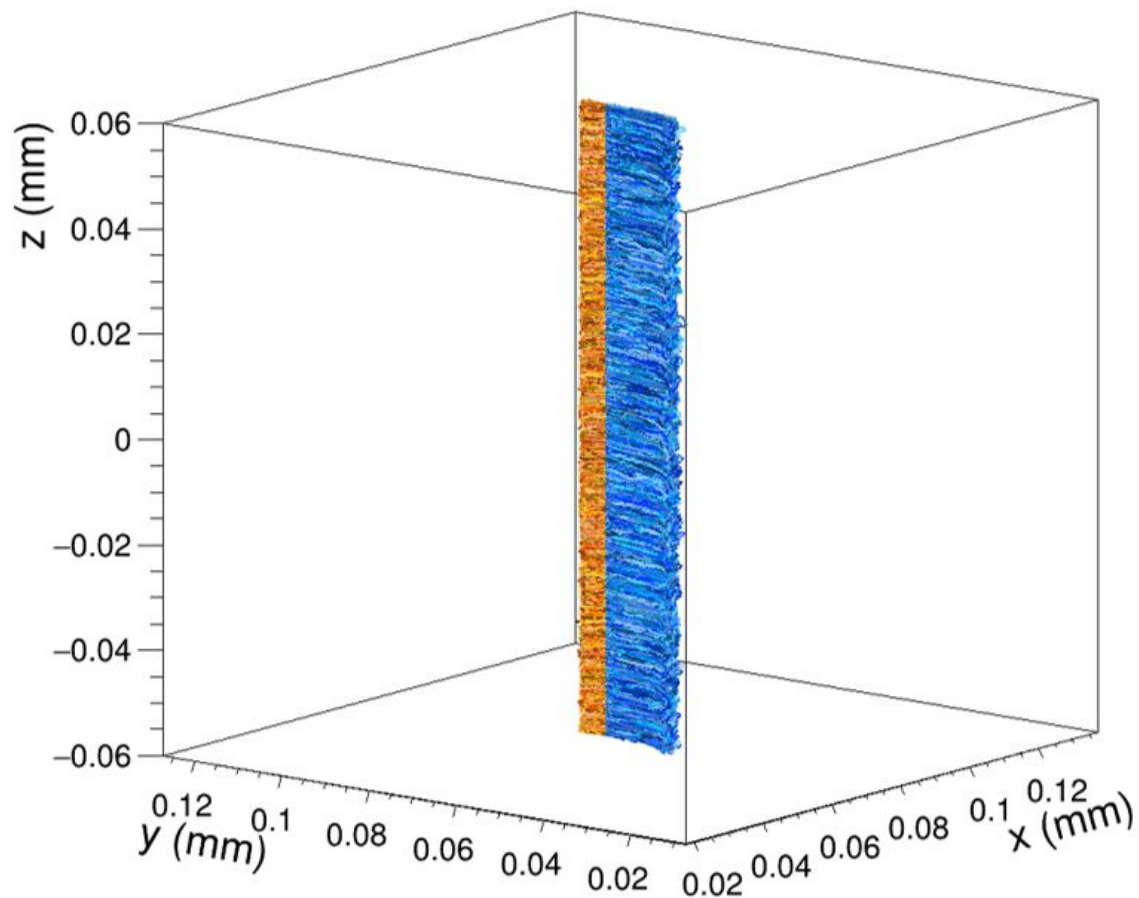
Electric field @ 100 V



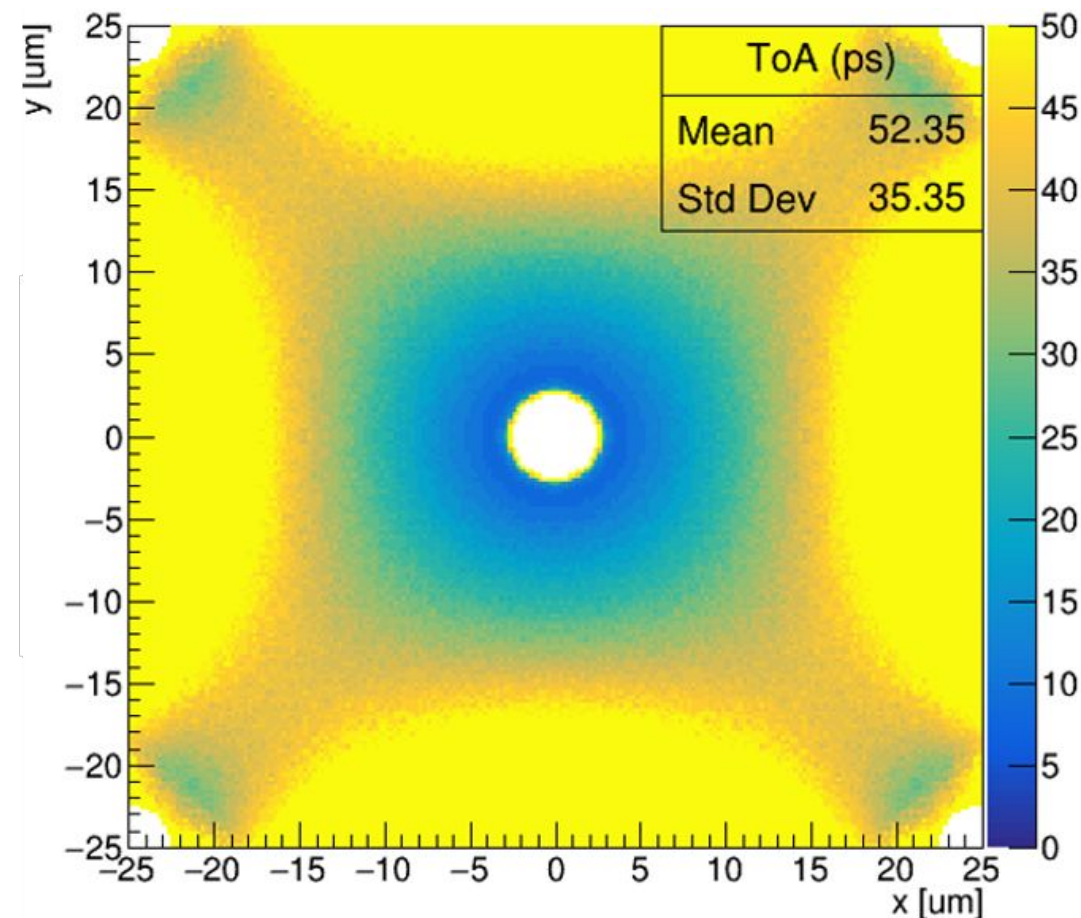
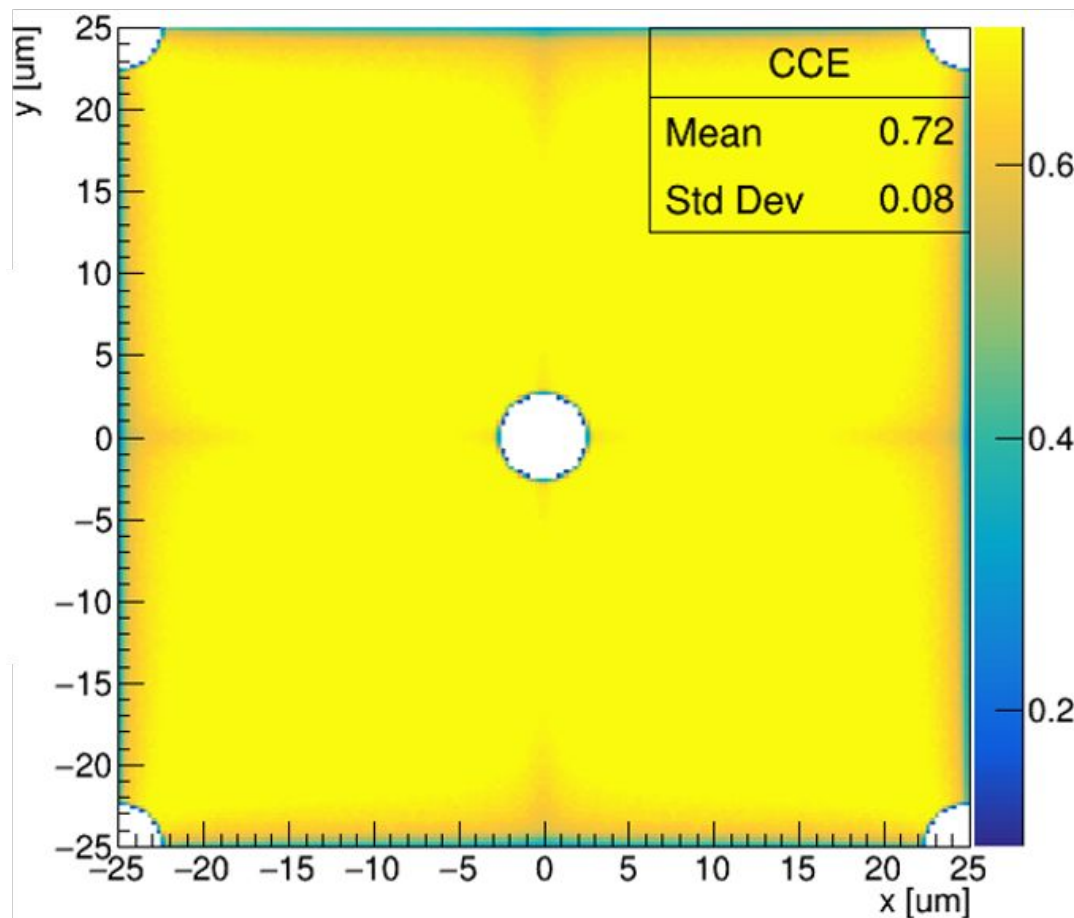
Simulation Results



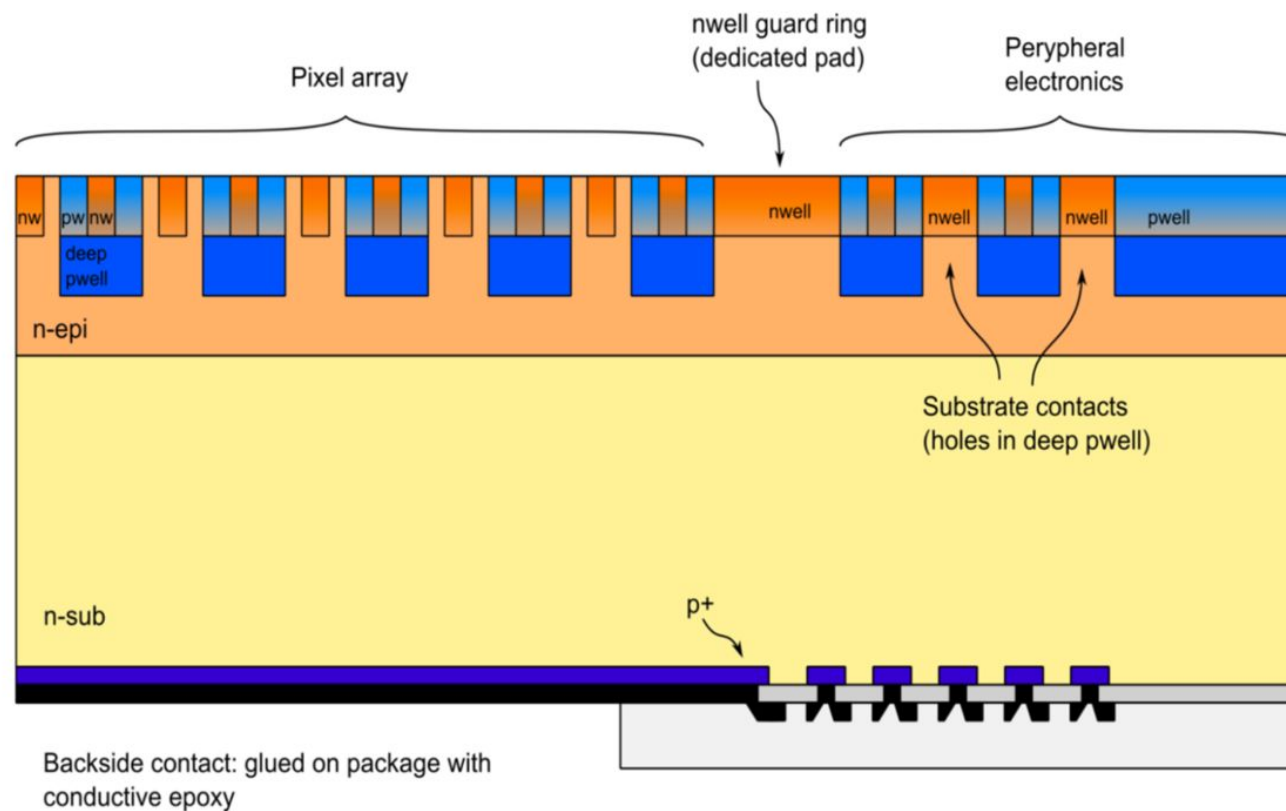
Simulation Results



Simulation Results



Simulation Results



Simulation Results

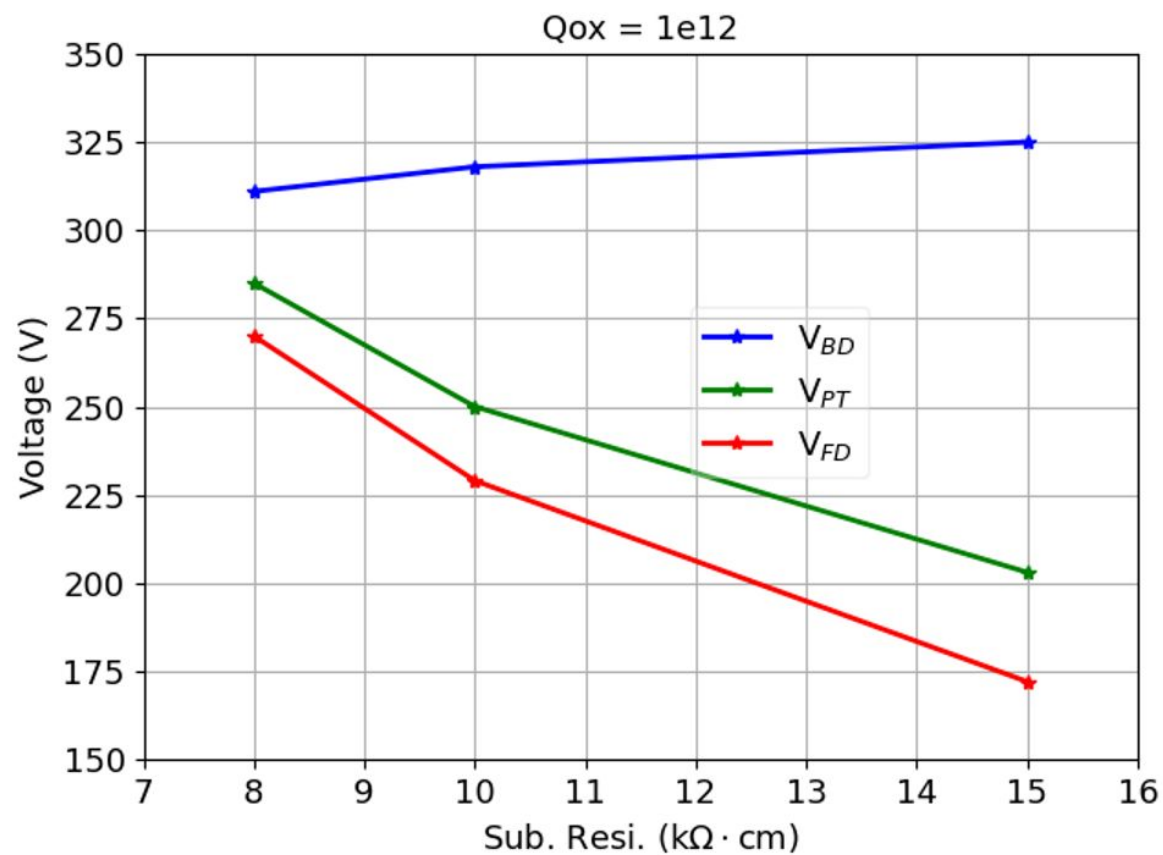
European
Innovation
Council



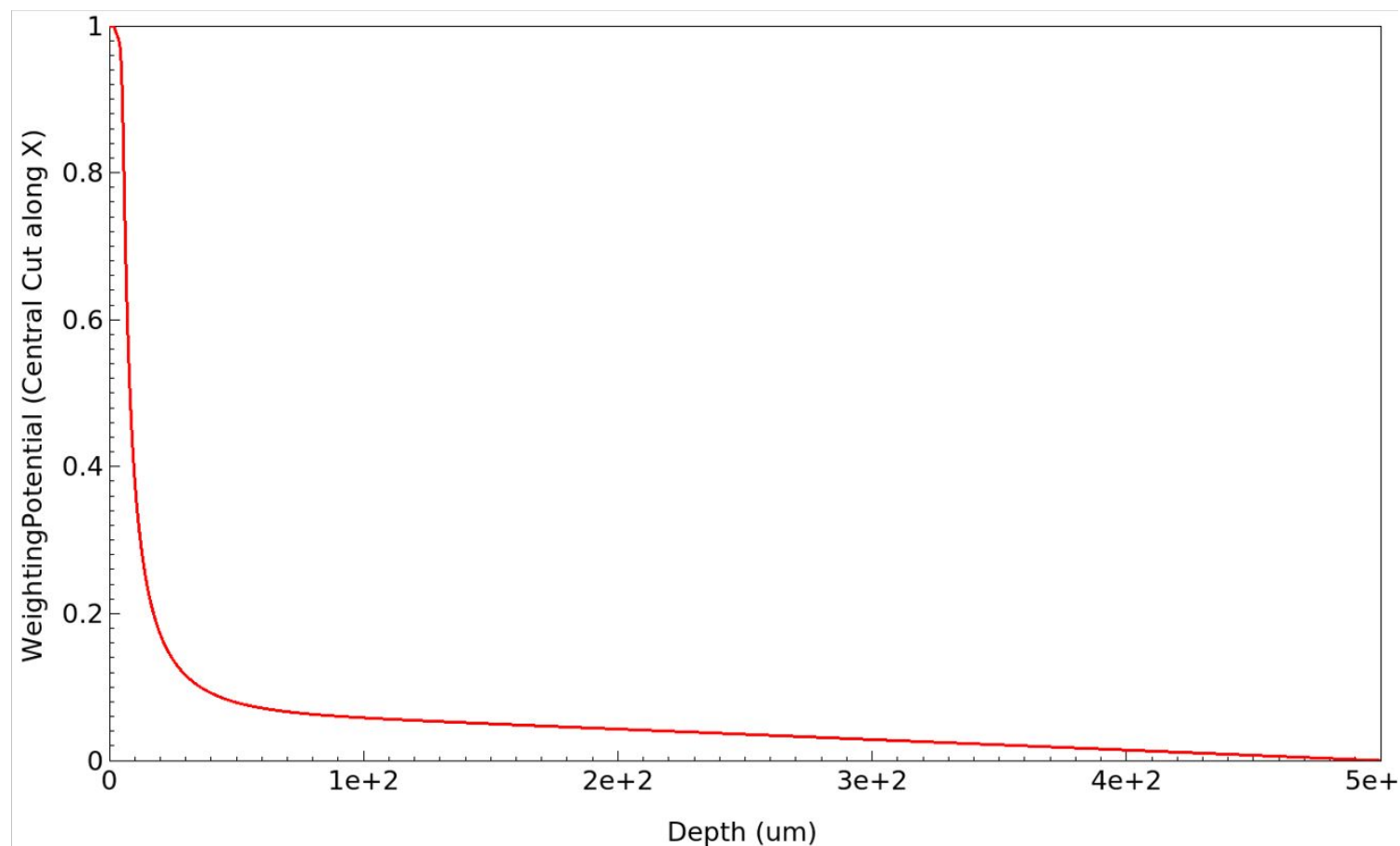
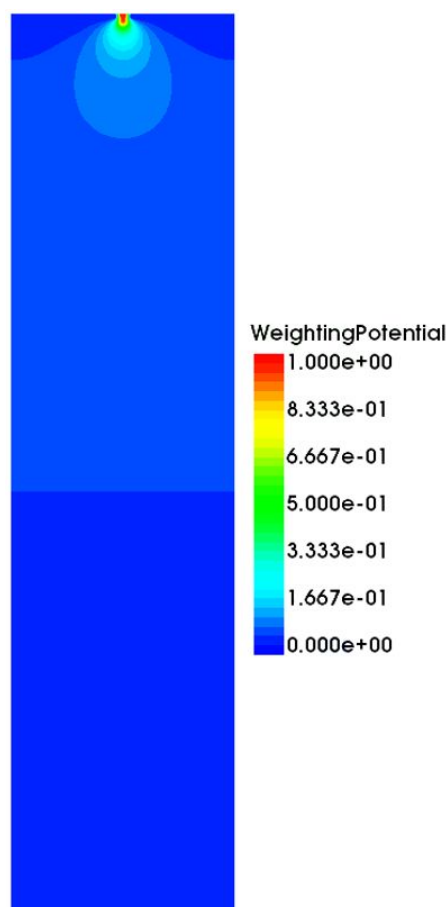
**Funded by
the European Union**

This work was supported by the European Union's Horizon Europe research and innovation programme under the 1MICRON project – “New Technology for 1 MICRON Resolution Biomedical Imaging” (grant agreement No. 101186826).”

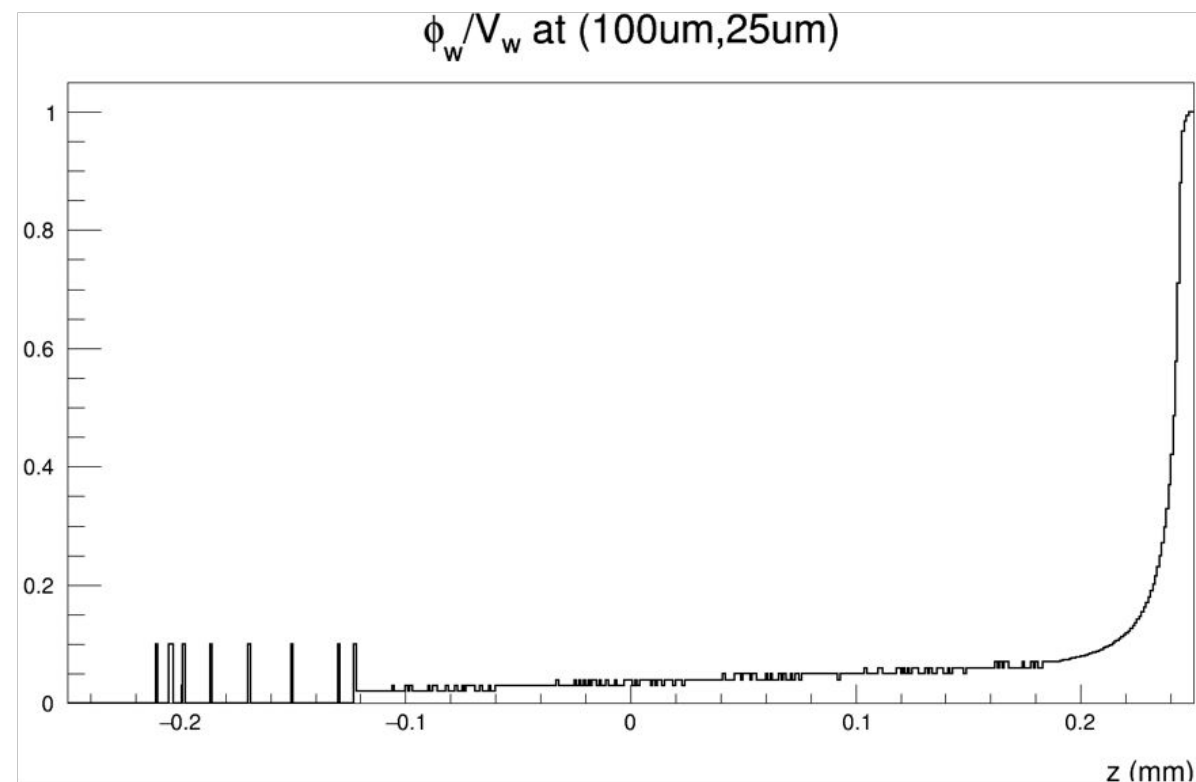
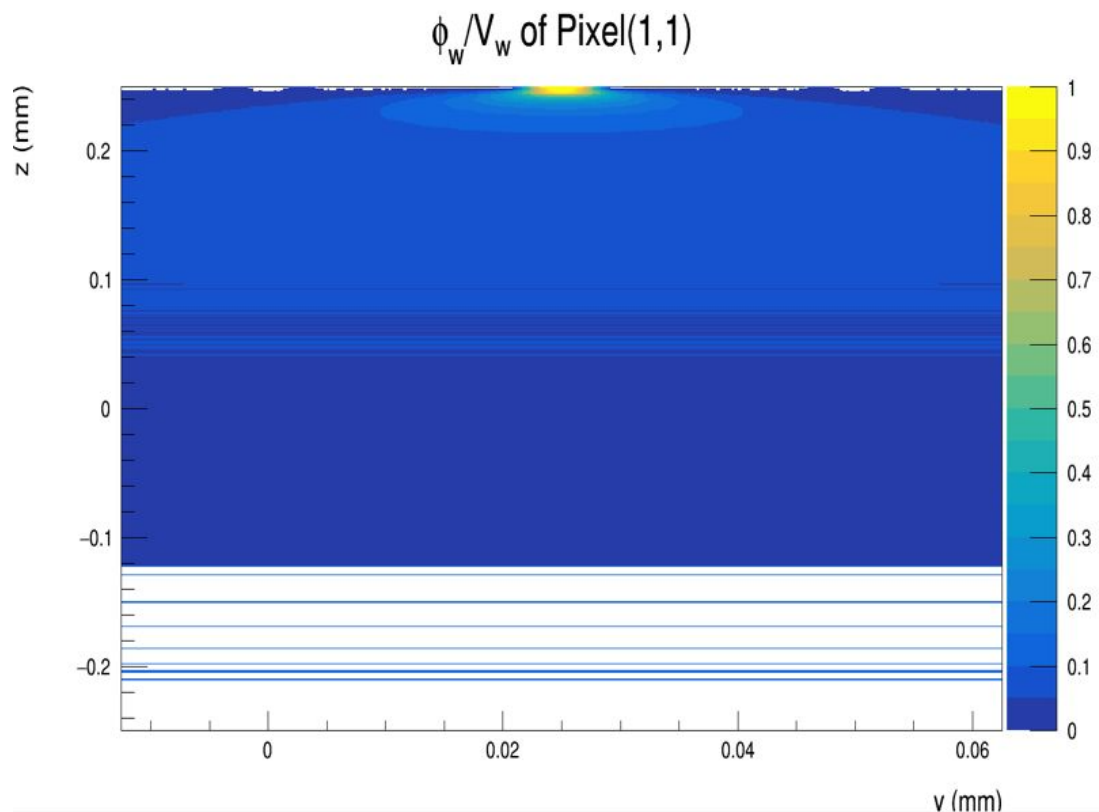
Simulation Results



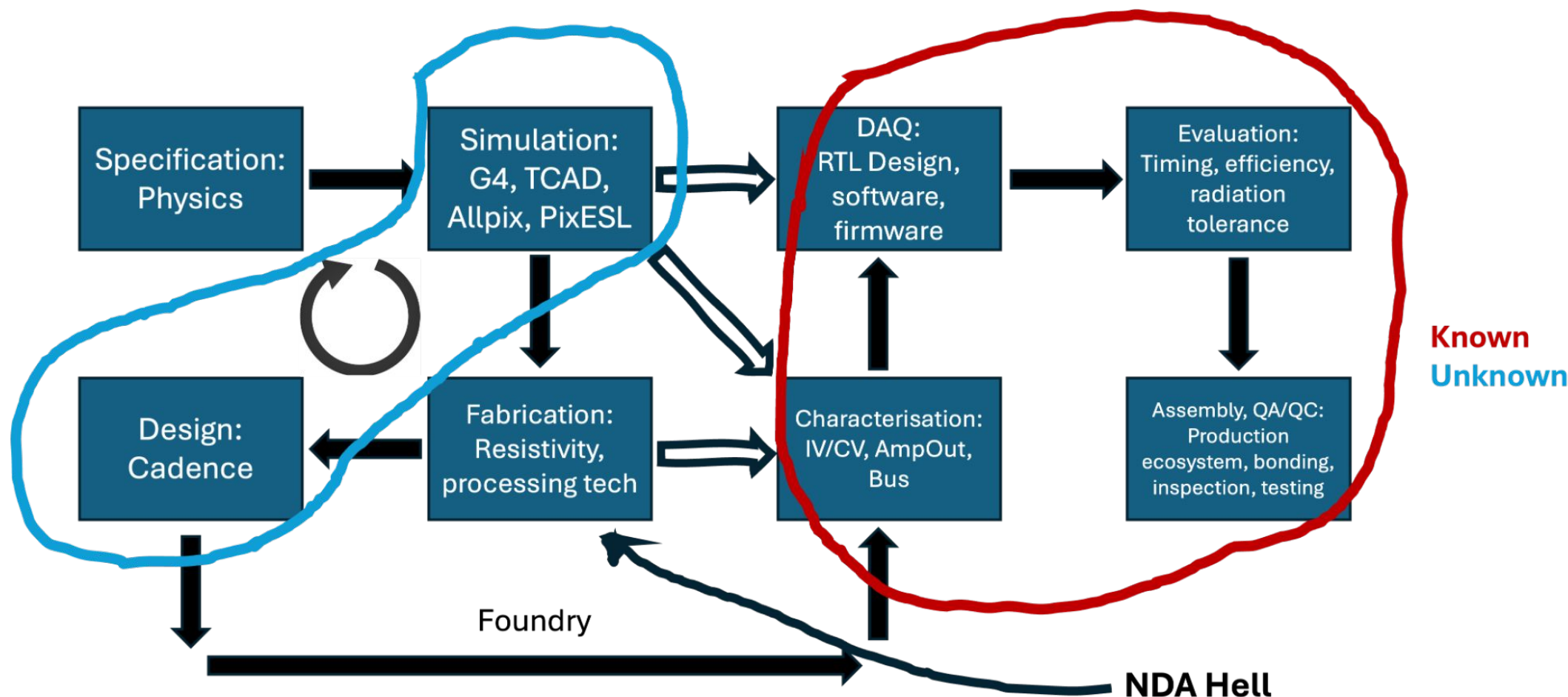
Simulation Results

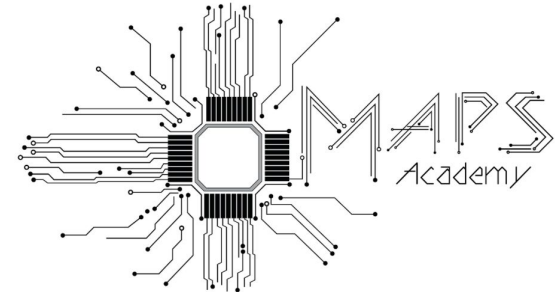


Simulation Results



The academy filled exactly the gap I had





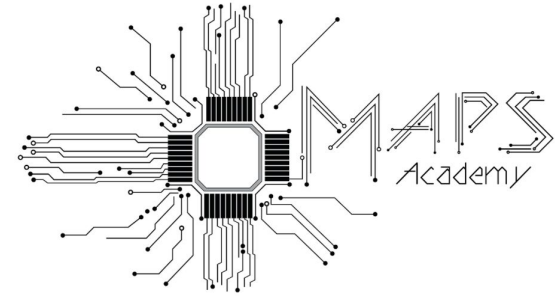
A big jump-start for me

Before the academy, I was:

- Already working with MAPS, mainly DAQ, characterisation and evaluation
- But starting with zero hands on experience in simulation or chip design
- Often finding design discussions difficult to follow

The academy gave me:

- A great jump-start through hands on work and small-group teaching
- Enough tools and confidence to explore what previously felt daunting
- A much clearer understanding of past and future pixel and readout-ASIC design meetings



Comments for future schools

- Allow students early access to tutorials and environment setup
 - a. Get the computer related problems out of the way
 - b. background research in one's own time
 - c. students can take advantage of the small class to ask questions related to MAPS design and simulation
- Same class size but work in groups of size 2 or 3
- Allow two full days per topic; 1–1.5 days can feel rushed, especially for first-time users
- Keep a full two-day weekend, perhaps with an optional excursion or lab visit